Astrophysics wants its physics back.

Introduction

A new method for studying astrophysics is now yielding fascinating results. Instead of mindlessly accepting existing constructs that are untestable *by definition* (e.g., dark matter, dark energy, etc.), this new method is based entirely on laboratory physics. It solves problems that have defied previous efforts by integrating all of the provable forces into non-linear systems, where competing forces cause instabilities that resolve into the distinctive forms that we observe. Existing theories acknowledge only inertia and gravity, and if those forces can't fully explain something, the theorists account for the discrepancies with untestable inventions. The new method acknowledges inertia, gravity, electromagnetism, and nuclear forces, and demonstrates that the resulting combinatorial complexity can plausibly resolve into a wide variety of forms. When two or more configurations of forces appear to match the explanandum, additional data are tested against the expectations of each configuration. In the end, this method settles on the most probable combination of known forces, given the available data. And nothing within the problem domain has been found to necessitate the invention of anything new.

As straight-forward as this sounds, it begs the question of how this can be considered a "new" method — why isn't this the conventional approach?

In other disciplines, it would be. But modern astrophysics is dominated by concepts developed by Einstein and Eddington in the early 1900s, *before* the discovery of nuclear forces, and before the emergence of an atomic model that integrates Newtonian, electromagnetic, and nuclear forces into a unified framework. At the macroscopic level, this model is now performing famously, and is universally accepted in the disciplines of chemistry, biology, mechanical engineering, etc. In its mature form, it just hasn't been applied back to astrophysics.

So why is astrophysics lagging behind terrestrial disciplines?

The main reason is simply that its hypotheses are so much harder to test. Most of what we study in astrophysics can only be observed, because of the vast distances separating us and the explanandum. More significantly, it is easy to test phenomena that can occur in terrestrial conditions, but hard to test the extremes of temperature and pressure found elsewhere in the Universe. Most of space contains cryogenic plasma in a near-perfect vacuum, while stars are comprised of highly supercritical fluids. Only very recently have scientists begun to investigate such conditions, and the data that can be applied directly to astrophysics are sparse when compared to terrestrial fields of focus, resulting in uneven progress in the physical sciences. And in a slowly moving discipline, the existing paradigm can become deeply entrenched. Then the full implications of new laboratory findings might be overlooked, especially if a shift in paradigm is required. Such is the case in astrophysics.

Nevertheless, the laboratory evidence continues to accumulate, and the implications for astrophysics are startling. Black holes and neutron stars, as described in existing literature, are certainly not allowed by atomic theory. The application of recent research shows how the existing constructs can be replaced by powerful force feedback loops, using stuff we have here on Earth, taken to extreme limits by the scale of the phenomena. The result is a fundamentally new conception of the heavens.

The most striking aspect of this approach is that it yields tangibility. Those are known particles and forces out there — we just didn't know that they were capable of such dramatic manifestations. So this approach has an immediacy that just isn't present in the existing literature. It's hard to relate to astrophysics when the prerequisite is acceptance of counter-intuitive contortions of general relativity. But when conceived as the products of terrestrial factors, just at astronomical scales, we know that in a laboratory big enough, we could make these things ourselves, and it all becomes powerfully real.

Enjoy!

Accretion

We should start at the beginning, which means that we need to understand how celestial bodies condensed from dusty plasmas in the first place. The standard model is just heuristic math. If we want to understand it in physical terms, we have to start over from the beginning. Gravity only accounts for 1/5 of the force necessary to cause a dusty plasma to collapse into a star. There are 3 fundamental forces operative at the macroscopic level: gravity, the electric force, and the magnetic force. If gravity provides 1/5 of the force, the other 4/5 can only come from the electric and/or magnetic forces. There is no known configuration of magnetism that could create a body force on a dusty plasma. But there is very definitely a way that the electric force could do the job.

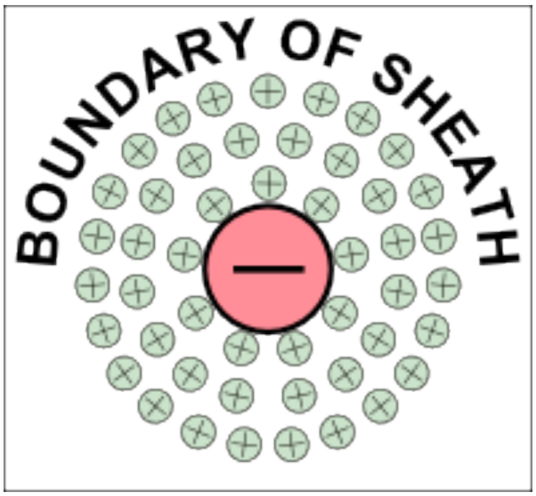

Figure 1. Debye sheath.

Dusty plasmas do not have a net charge, but they do have local charge separations. (That's why we call them "plasmas" and not "gases.") There are a couple of charging mechanisms. The less common is high speeds in the presence of an external magnetic field, which sends positive & negative charges in different directions.[1] But particles can become charged even at rest. Any dust particle with more than a couple million atoms is capable of hosting a net negative charge, while the surrounding plasma has a net positive charge. This plasma is known as a Debye sheath. The charge separation occurs because at any given temperature, the velocity of free electrons is at least an order of magnitude greater than that of atomic nuclei, since the electrons are so much lighter. Consequently, the surface of a nearby dust particle is impacted by many more electrons than atoms. The electrons are absorbed into the electron cloud of the dust particle, which distributes the charge, and covalent bonding holds the electrons in place. The net result is that the dust particle develops a negative charge, leaving the surrounding atoms positively charged. Once the charges have been separated, the Debye sheath is attracted to the dust particle by the electric force. When a positive ion impacts the dust particle, it might just grab its missing electron and bounce off, or if the ion is moving slow enough, it might get attached to the dust particle and held in place by covalent bonding, in which case the dust particle has just gained another atom.[2]

Note that the consolidation of matter into growing dust particles does not increase the gravitational body force on the entire cloud. When we calculate the force of gravity between two objects, it's convenient that we can compress the masses into their centroids, and then treat the centroids as point sources, because the results are the same as if we had calculated the force from each atom to each other atom. Physical aggregation does the same thing, and with the same result: no change in the overall body force.

Since the negative dust particle and its positive Debye sheath are net neutral, we might just think that they form a self-satisfying plasma cell that does not interact electrically with its environment. It would certainly be true that they won't interact *much*. But we are looking for something that is 5 times more powerful than gravity, which is 39 orders of magnitude weaker than the electric force. So we are looking for a near-infinitesimal electric interaction between net neutral plasma cells.

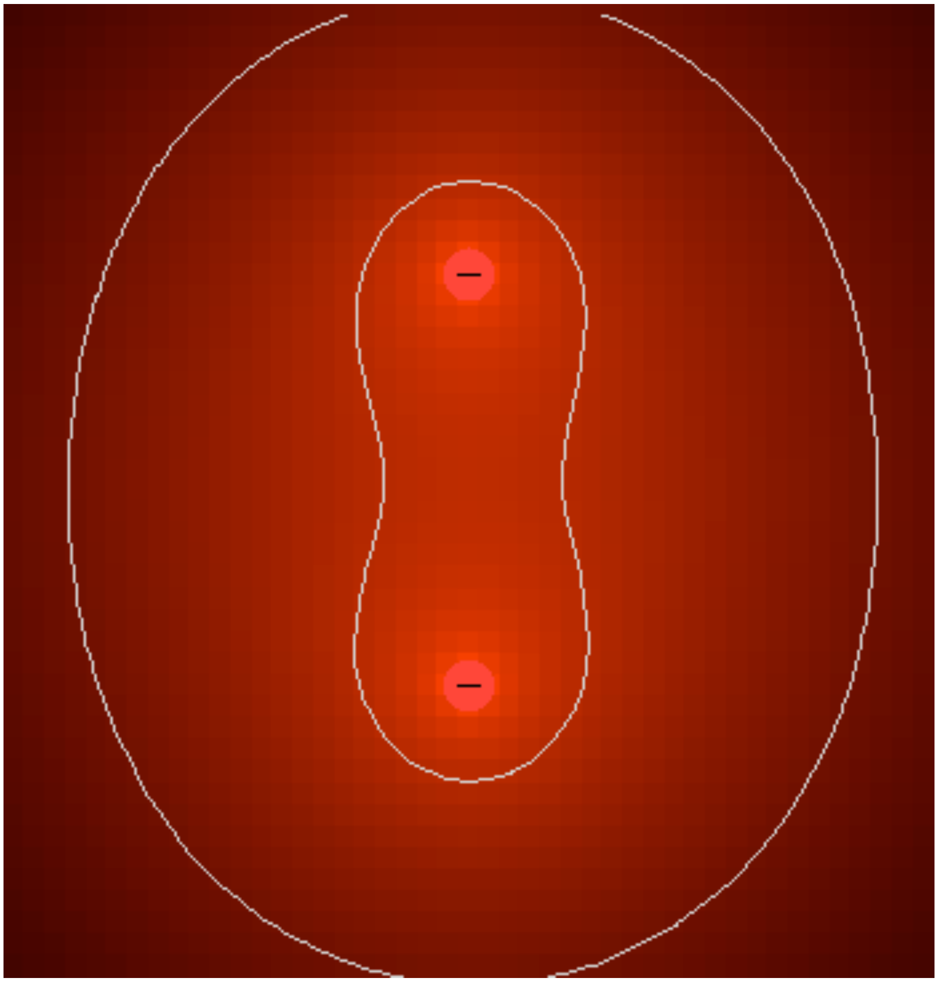

Figure 2. The concentration of positive plasma between two negative bodies creates an attractive force.

If we take a second look at how two plasma cells interact, we find the missing body force. It is simply one of the implications of the inverse square law as it applies to the electric force. Since we have both positive and negative charges, we have both attractive and repulsive forces. Each dust grain, along with its Debye sheath, is net neutral. The grains themselves are negative, so they repel each other, while they are attracted to their positively charged Debye sheaths. Yet between two negative dust grains, there will be a concentration of positive plasma, attracted to the combined negative field. The implication is that the attraction of the negative dust grains to their Debye sheaths is no longer omnidirectional — it's now toward that concentration of positive charge — and that's in the direction of the other dust particle. Since the positive ions are closer, the net force is attractive. In other words, if the negative and positive charges were compressed into point sources in the centers of the plasma cells, everything would cancel out, and there would be no body force on the entire cloud. But the Debye sheaths are space charges, not point sources, and they exist in the medium between the dust grains, where they pull both negative charges toward each other.

This is a manifestation of what Feynman called the "like-likes-like" phenomenon, and it's the same principle as covalent bonding in a molecule (just on the macroscopic level).[3:ch2:pg2,4,5,6] Atoms repel each other, but they are attracted to electrons, and there are more electrons between the atoms than beyond. So the like-charged atoms are pulled together, as if they were attracted to each other (when really they are attracted to the shared opposite charge). Remove the electrons and the molecule falls apart. Hence we can think of Debye sheaths surrounding dust grains as if they were electron clouds surrounding atoms in a molecule (except that the polarities are reversed).

How powerful is this body force? Since the electric force is 39 orders of magnitude more powerful than gravity,[7] 1 charged particle per thousand-trillion-trillion-trillion would generate an equivalent electric force, and 5 charged particles would supply the force necessary to cause the collapse of a dusty plasma. Interestingly, Debye sheaths typically have at least 1 charged particle per billion. So at first, it looks like we have 30 orders of magnitude too much force! But the positive charges in the Debye sheaths are concentrated near the negatively charged dust grains. So we are just concerned with the difference in distances between one dust grain and the positive charges just outside of the neighboring grains, versus the repulsion from those grains. That cuts the force back, from 1×10^{9} down to 5×10^{39}.

The "like-likes-like" principle accounts for the missing force in every respect. It is easily 5 times more powerful than gravity. It varies directly with the amount of normal matter present, and there is no "cuspy halo" problem, since it's an electric force between charged particles, not CDM exerting gravitational force. It can even explain dynamic changes in body force. In the standard model, a dusty plasma collapses into a star when the force of gravity is too strong and/or the hydrostatic pressure is too weak. Yet we also know that dusty plasmas are famous for collapsing when there has been a supernova nearby, and this is tough to explain just in terms of gravity and pressure. Ejecta from the explosion will add mass to the cloud, increasing the force of gravity. But the thermalization of their relativistic velocities will add *a lot more* hydrostatic pressure, and the net effect should be the expansion of the cloud. To cling to the standard model, we'd have to conclude that supernovae increase the amount of CDM. But there is a much simpler explanation that obeys well-known physical laws. We know that UV radiation from the supernova ionizes the dust cloud. More ionization means more powerful Debye sheaths, increasing the "like-likes-like" force.

This model passes the next test as well. Recent research has shown that a spherical dusty plasma first resolves into filaments, and then the filaments collapse into a star.[8,9,10] In the more general sense, the Universe is full of filaments of various sizes and shapes.[11,12] Both gravity and gas pressure object to this form, so this is a prime candidate for EM treatment.

Figure 3. Filament in the Cygnus Loop.

Some EM theorists have generalized the concept of Birkeland currents to explain the prevalence of filaments, but without establishing the electromotive forces at play, and without demonstrating that the currents would require material filaments. So we'll neglect electrodynamics, and focus instead on electrostatics.

Figure 4 shows a random distribution of charges, where the connecting lines show electrostatic attraction between opposite charges. That is the source of the "like-likes-like" force. But notice that there is repulsion in that configuration, between like-charged dust grains, and between like-charged +ion clouds, where lines of force from like charges collide with each other. Now look what happens if the spherical dusty plasma is stretched into a filament, as in Figure 5. There is no repulsion anywhere in that configuration! All of the electric lines of force close on the nearest neighbor, which is oppositely charged. So it's all attraction and no repulsion. From this we can conclude that the net attractive force in the linear configuration is much greater, and thus the chances of accretion are much greater. So it makes sense that spherical dusty plasmas don't tend to collapse, but if the plasma resolves into filaments, the chance of collapse is much greater.

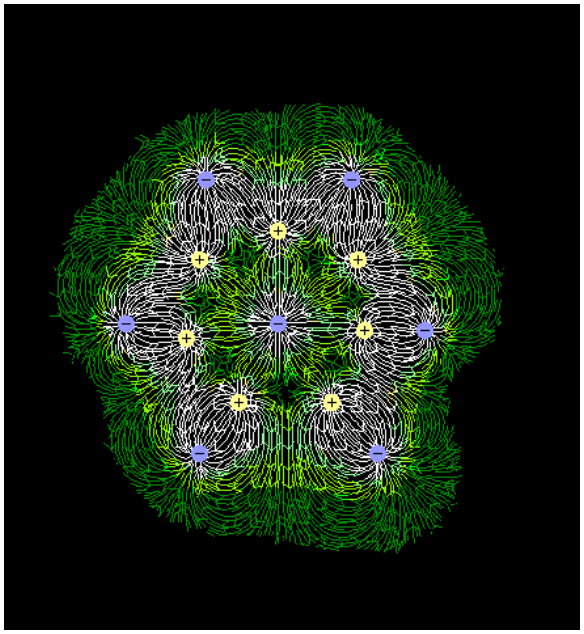

Figure 4. Attraction & repulsion in a random distribution of charges.

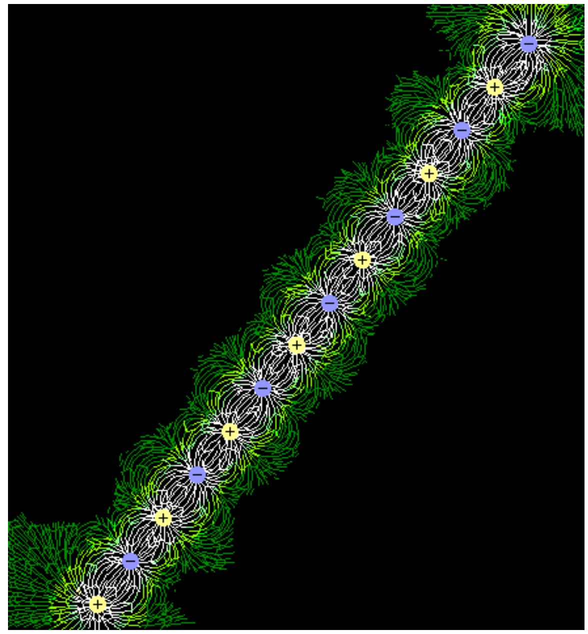

Figure 5. Purely attractive forces in a linear configuration.

So then we just have to look for things that would encourage filaments to form, and then the rest happens automatically. We have already recognized that supernovae are important triggers for star births, and we acknowledged that the UV radiation increases the degree of ionization, which increases the "like-likes-like" body force. Now we should consider another implication. It's possible that irregular jets from the supernovae are creating turbulence in the dusty plasmas, and the velocity differences are stretching the plasma into filaments. Once formed, they'll snap together. In other words, it's like grabbing a balloon and stretching it into an oval. Eventually, the balloon bursts, and then the rubber is pulled violently toward the fingers that stretched it.

Galaxies

Figure 6. NGC 1427A

So we have an electric force in a "like-likes-like" configuration causing the condensation of dusty plasmas into asteroids, planets, & stars. A big enough cluster of stars makes a galaxy. But with just these factors taken into account, we have no reason to expect the star clusters to show any larger organizational structure. We can easily understand the so-called peculiar galaxies, such as in Figure 6, which are random assemblies of stars in no particular form. But there are three other major galactic types that are much more organized: the ellipticals, the lenticulars, and the spirals. What is the organizing principle responsible for those forms?

The first thing that we observe about organized galaxies is their rounded form, whether it is nearly spherical, or a perfectly flat disc. Assuming that all of these galaxies were once peculiars, the rounding suggests that one or more times in their past, they have imploded and exploded. The implosions would have occurred simply due to the "like-likes-like" force, followed by inevitable explosions after the implosions developed excess hydrostatic pressure in the center. The reason for the spherical form is that explosions accelerate matter outward in a radial pattern. This is true whether all of the matter implodes simultaneously, or one clump at a time — whatever goes in will come out in a form that is centered on the explosion. It might take several cycles to completely change a peculiar shape into a perfect sphere, but this will happen eventually. So we will suspect that organized galaxies are in implosion/explosion cycles.

Figure 7. ESO 325-G004

Roughly 4% of all galaxies are classified as ellipticals (as in Figure 7). These are actually *ellipsoids* (i.e., 3D ellipses), and are believed to get their shape from two galaxies merging. How exactly this happens has not been identified. Ellipticals do not have bimodal cores, and the density drops off smoothly from the center, producing an indistinct boundary. The motion of stars within the galaxy appears to be more radial than rotational, though the rotational component appears to vary with the aspect ratio (i.e., major axis over minor axis). Hence nearly spherical galaxies have no detectable average rotation, and the stars move in random directions. The greater the aspect ratio, the more consistently all of the stars rotate in the same direction.

The stars in elliptical galaxies appear to be much older than in spiral galaxies, implying that the galaxies are stable in this configuration. Nevertheless, ellipticals (such as NGC 4486 and NGC 383) sometimes shoot out relativistic jets from their active galactic nuclei, and ellipticals are the only galaxies that emit bipolar radio source jets. When active, these jets clearly reveal powerful energy sources in the galactic nuclei, and this can only be evidence of matter converging on the center. The implosion will reforge old stars into new ones. (See Star Types for more info on the stellar life cycle.)

Figure 8. NGC 5866

Roughly 14% of all galaxies are classified as lenticulars, such as in Figure 8. These are similar to ellipticals in many ways.

- They have elliptical forms.
- The galactic boundaries are indistinct.
- They are comprised mainly of old stars.
- There is very little interstellar plasma.
- The consistency of rotation varies with the aspect ratio.

For these reasons, many scientists consider lenticulars to be related to ellipticals, just with a higher aspect ratio. The main difference is that lenticulars have a distinct disc made of dust. This makes them similar to spiral galaxies, except that the dust is not organized into discrete lanes.

Far and away the *most* organized galaxies, and the most numerous (at 72% of the total), are the spirals (such as our own Milky Way, and NGC 4565 in Figure 9). These typically have a central, elliptical bulge, which has many properties in common with elliptical galaxies (i.e., old stars on semi-random orbits around the center, and without much interstellar plasma).

Figure 9. NGC 4565

The distinguishing characteristic of spirals is the dominance of their accretion discs. And these are the least-understood of all. Except for the central bulge, all of the matter has achieved a consistent rotation around the center, all on the same plane. There is some sort of progression, from sphericals, to ellipticals, lenticulars, and then spirals, where the random orbits get coerced into unison. In spirals, the progression is nearly complete. This is clear evidence of an organizing principle. It takes *force* to alter the motions of stars and planets. Anything that can alter the paths of most of the matter in a galaxy is a force of galactic proportions. So what is the nature of that force?

First, we should acknowledge that there is a time scale on which this force is acting. A recent study revealed that in the early Universe, there were far more peculiar galaxies, and now, there are far more spirals.[13] (See Figure 10.) This means that peculiars are evolving into spirals. It seems likely that the peculiars first got organized into ellipticals. Then, the mystery force continued to exaggerate the aspect ratios into lenticulars, and then finally into spirals. The fact that the number of ellipticals and lenticulars has stayed roughly the same further suggests that those are evolutionary stages in a process.

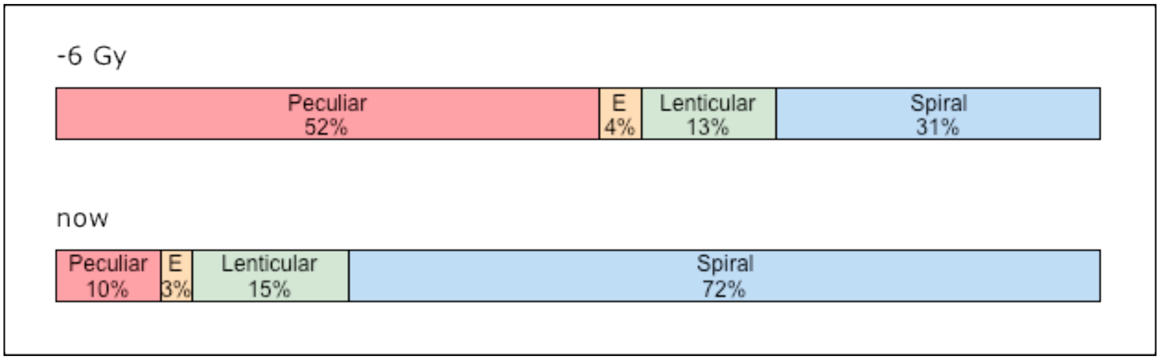

Figure 10. Distribution of galaxy types, 6 billion years ago versus now.

All other factors being the same, if gravity combined with the "like-likes-like" principle can get a galaxy to implode, we will then expect for there to be an explosion, and this will send everything outward, one day to get drawn back in by the same forces in the next cycle. And we would expect no net rotation in these implosions and explosions. On a galactic scale, the random orbits of billions of stars should average out. Whatever it happens to be, during the implosion the net angular momentum is distributed throughout all of the matter involved. Once the sum has been calculated, this should be the total angular momentum of that galaxy, forever. In other words, if we were to generously think that .1% of the net momentum in a peculiar galaxy is rotational as opposed to radial, successive implosions and explosions will never result in more than .1% rotational momentum. Yet in spirals we're seeing that the majority of the momentum is rotational, which shouldn't be possible, starting with a random distribution of billions of stars. (And here we have to remind ourselves that whatever *does* happen, *can* happen. In other words, it's a mistake to discount observations because they don't make sense.) In rigorous physics, observations that cannot be explained by the existing framework constitute proof of the presence of one or more other forces, *by definition*.

The standard answer is that the angular momentum comes from galactic near-misses. As two galaxies pass close to each other, their outer reaches come under the influence of the gravitational and EM fields of the other galaxy, possibly drawing the matter into wispy tails. Because it was a near miss, the matter will not move toward the galactic center in a radial pattern, but will rather approach with angular momentum. This will induce rotation on a plane that bisects the vectors of both galaxies.

Figure 11. A near-miss between two spiral galaxies, NGC 3808A and NGC 3808B (Arp 87).

All by itself, this would not get everything in the entire galaxy rotating on the same plane. The chance of two stars colliding anywhere in there is one in several billion. So the new spiral should rotate on its own plane forever. If the galaxy implodes, the angular momentum will get distributed, and the ejecta from the explosion will all rotate at the same rate. Yet we have to remember that the matter contributed by the collision is small compared to what was already there. We know that the existing galaxy already had a lot of mass — otherwise, it wouldn't have stripped matter from the other galaxy. And the existing mass has its existing momentum. If there was no rotation, now it has some. If it was already rotating in the same direction, now it will rotate faster. If it was already rotating in the opposite direction, it will be slowed down or stopped. But the net effect should be slight.

Furthermore, even with angular momentum, we have no reason to expect planar ejecta that would become a disc. Rather, we expect spherical ejecta, while nearer the equator the angular momentum will elongate the major axis. But that won't create a *disc*.

Further still, it's hard to believe that galactic near-misses turned 72% of all galaxies into spirals.

So we need to take a closer look at what actually goes on in implosion/explosion cycles, which might convert the momentum from radial to angular, all on the same plane. And we need to consider EM forces, since Newtonian mechanics cannot account for the induced rotation.

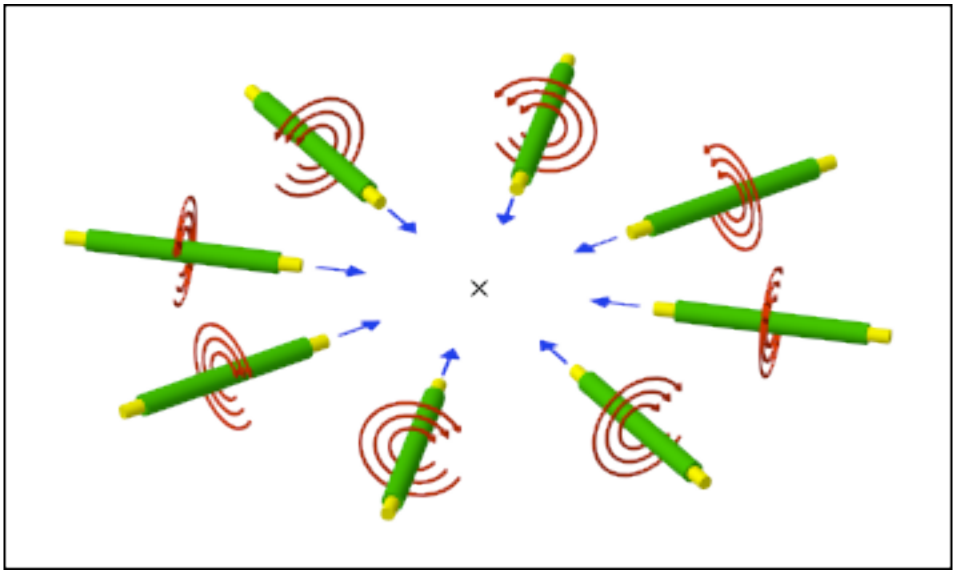

Figure 12. Radial inflow generates clashing magnetic fields.

Matter being drawn inward achieves relativistic speeds. This means that the moving electric charges will generate extremely powerful magnetic fields. The significance of *that* is that in a more-or-less radial inflow, the magnetic fields will clash. (See Figure 12.) With some randomness, the various clumps of matter won't hit the center of gravity — they'll miss to the left or to the right, and then fall into elliptical orbits. While this arrangement satisfies the gravitational and inertial forces, the magnetic pressure between the converging particle streams encourages them to merge, such that everything is moving in the same direction.

The product of all of the forces is a spiraling inflow. If the matter could fall into a circular orbit around the center of gravity, the magnetic pressure would be zero, since all of the matter would be traveling in the same direction. Yet the gravitational force will be unsatisfied. If the matter moves inward in a radial pattern, the force of gravity is satisfied, but there will be magnetic pressure. Splitting the difference between the opposing forces yields spiraling accretion.

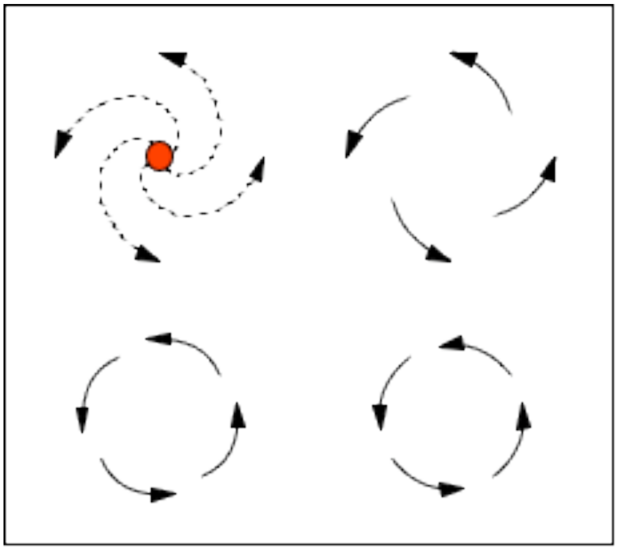

Figure 13. Effects of magnetic pressure on ejecta.

And this is also true for the ejecta from an explosion, if the matter has angular momentum. As it spirals outward, it maintains its velocity, though the revolutions take longer, since it has more distance to traverse. But in this configuration, neighboring clumps of matter travel at an angle to each other, with magnetic pressure between them. This again nudges radial lines of motion into spirals, and spirals into circles. (See Figure 13.)

Then we just have to consider what would happen after many repetitions of this cycle. As the lines of motion get more and more consolidated in top view, everything is also getting squashed down into a solitary plane of rotation. In other words, it becomes a *disc*.

It's possible that the most mature galactic form is the ring galaxy, in which all of the radial motion has been converted to angular momentum in a rotation around the center. In Figure 14 we can clearly see the old, yellow galactic nucleus, surrounded by the young, blue stars in the ring, which would have condensed from the ejecta in the last explosion. It's possible that once this stage has been achieved, there will be no more implosions or explosions, unless something disrupts it, such as a collision with another galaxy.

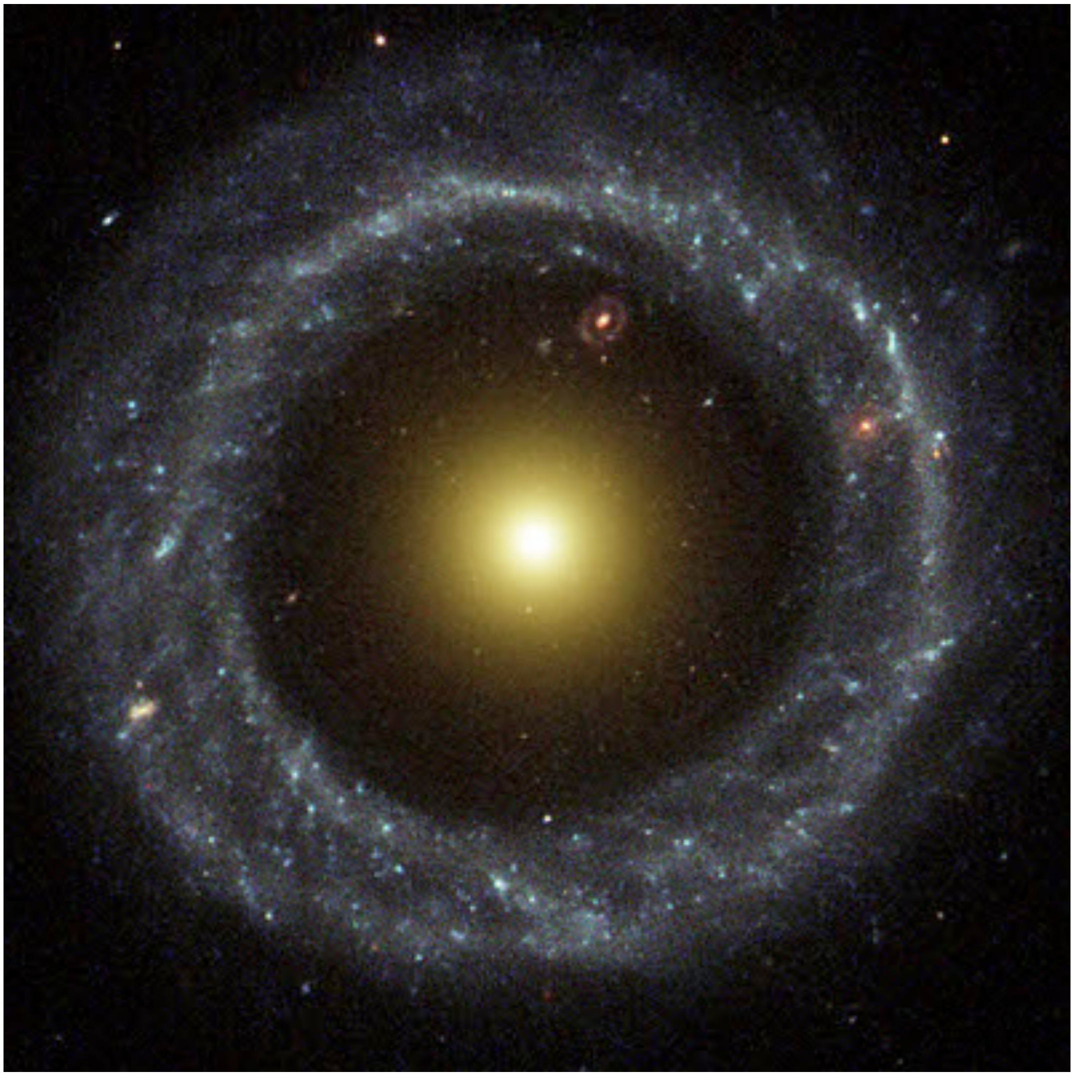

Figure 14. PRC D-51 (Hoag's Object), an example of a ring galaxy.

We can also see a twist in the ring, which makes sense only in EM terms. As the galaxy will have an overall magnetic field, charges moving within that field develop a spin due to the Lorentz force.

Now we should consider what could possibly produce a disc as flat as that in Figure 9. The lay literature frequently likens this to the flattening of pizza dough when twirled in the air. This is actually a good metaphor, as the centrifugal force will, indeed, stretch the shape. But in a critical analysis, we realize that there also has to be some sort of tensile strength, or it will fly apart. If we cut the dough into pieces and try to twirl it, we'll just make a mess of the place. So where do we get the tensile strength to hold together a galaxy?

It isn't gravity, and that's by definition. Gravity is a function of mass, and so is the centrifugal force, and these two forces cancel each other out — they don't fight each other, and yield tensile strength as a by-product. Additional gravity from CDM doesn't help, at least not if it's conventional matter (albeit surprisingly cold and dark), whose mass would also have its own centrifugal force. (Heavier chunks of dough still fly apart if they are twirled at the same speed.) We have to find a fundamental physical force that operates at the macroscopic level (ruling out the strong & weak nuclear forces), that isn't a direct function of mass (ruling out gravity), and that can exert an attractive force. The only remaining candidate is electromagnetism. If EM can be attractive, we have our answer. And sure enough, in a "like-likes-like" configuration, the electric force is attractive, so this is what provides the tensile strength that allows a galaxy to be twirled into a flat disc without falling apart.

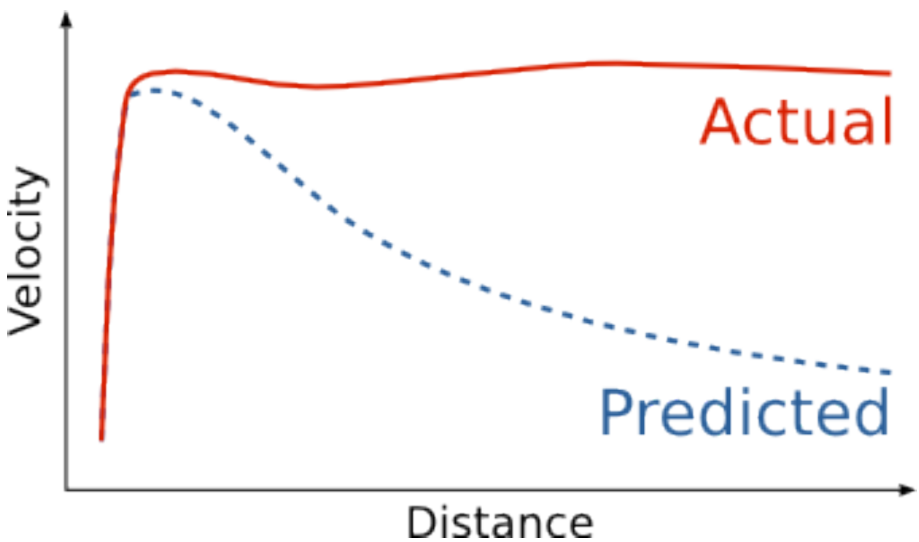

Figure 15. Rotation curve of a typical spiral galaxy. The distance is from the galactic center of gravity.

To be more specific, the outer reaches of spiral galaxies rotate 5 times faster than what is predicted by the laws of gravity, as shown in Figure 15. For objects to remain in orbit around the center of gravity, the centrifugal force developed by their orbital speeds has to match the force of gravity exactly. If the centrifugal force is greater, the objects fly away. If it is less, the objects fall inward. Since the spiral arms are stable, this can only be evidence of a non-Newtonian force, 5 times more powerful than gravity. We know that the planets are negatively charged, surrounded by positively charged ionospheres, and we know that the interplanetary medium is plasma with a slight positive charge. Subsequent sections will demonstrate that stars have a net negative charge. So the "like-likes-like" force is definitely present, and could easily be 5 times greater than gravity.

And lastly, we would like to know what causes the filamentary arms in spiral galaxies. When we see the cyclonic pattern as in Figure 11, we immediately think of a whirlpool that is pulling matter inward. But we should distinguish between observation and explanation. These are not lines of motion — they're *filaments*. An inward force would create a cyclonic inflow, but what causes the filamentary nature of the inflow (if it *is* inflow)?

Some EM theorists have attributed this to the magnetic pinch effect, wherein the matter is flowing inward at such a rapid rate that enclosing magnetic fields consolidate the matter into filaments. But the magnetic field lines in spiral arms tend to run parallel to the arms, and are not wrapping around the arms, pinching them into filaments.

Figure 16. "Snap the Whip" (Winslow Homer, 1872).

So it's not gravity, and it's not the magnetic force. That leaves the electric force. The most plausible answer is simply that this is yet another manifestation of the "like-likes-like" force, which gets stronger when the matter is drawn into filaments (as presented in the Accretion section). So the same centrifugal force that flattens the disc also stretches the matter into strands that have the tensile force necessary to keep them from flying off. In other words, spiral arms are like the so-called "whipper snappers" who play a child's game in an open field. (See Figure 16.) They start by holding hands and running around in a circle, with the heaviest kid anchoring the center. The centrifugal force stretches the line tight, so they try to hold on as tightly as they can, while the angular velocity at the outer end of the line eventually exceeds the rate at which the child can pedal his/her feet, resulting in a child somersaulting across the field. The contention about spiral galaxies is that the tensile force is supplied by the "like-likes-like" configuration, while the centrifugal force stretches the matter into filaments, and anything rotating too fast has already been released.

It's even possible that the "like-likes-like" principle is responsible for the bars that connect many spiral arms to the elliptical bulges in the centers of the galaxies. (See Figure 17.) The arms themselves are in centrifugal-centripetal equilibrium, given the inertial, gravitational, and electric forces at play. And so are the stars in the elliptical bulges. But where the bulge and the arms are nearest to each other, we see a mutual attraction, creating a central bar. This is an expected property if there is a charge separation between solids and their atmospheres, even if there is no net charge separation in each stellar system, much less any EM fields between the arms and the bulges.

Figure 17. NGC 1300, a barred spiral galaxy.

With this framework we can solve the "winding" problem. Essentially, the inner aspects of the arms should be traveling faster, so that they will have more centrifugal force, and will not fall into the center. But if they are traveling faster, they should wrap around the galactic nucleus. So why don't spiral arms typically do this?

The answer might be that this isn't a simple cyclonic inflow, and it might not even be an *inflow*. The spiral arms are skater's whips, and the ends are traveling much faster than they should, while the tensile strength within the arms keeps them from flying away.

But that begs another question. If it was just a skater's whip, then eventually, the extra centrifugal force out at the end should get the arm fully outstretched, with the arm pointing straight at the galactic nucleus. Only if the arm encountered friction would it curl backwards, despite the centrifugal force. So is there any reason to think that there is any friction?

Actually, there is. The interstellar medium is not a pure vacuum — it has something like 0.35 atoms/cm^3. What if we're swinging an arm through this medium? We'll generate particle collisions (i.e., friction) that will slow down the arm, and the effect will be proportional to the speed and the density of the interstellar plasma. Now look closely at the lower arm of NGC 1300. The leading edge of the arm sports young, blue-white stars, while the trailing edge has old, yellow stars. This has led some researchers to conclude that there is some sort of shock wave rotating around the galaxy, and where the pressure is higher, stars are condensing, and when the shock wave moves on, the stars fall apart again.[14] But that's gibberish, and we have a better answer. This is a skater's whip plowing through plasma, and new stars are forming on the leading edge, with the build-up of matter due to compression. The trailing edge is shielded from all of this, and has only the old stars that were there when the filament first formed.

In summary, galaxies condense due to the "like-likes-like" principle. The resulting galactical explosions transform peculiar galaxies in spherical forms. Magnetic pressure induces rotation, which transforms sphericals ultimately into spirals. There doesn't appear to be a limit to the size of galaxies, and small galaxies can eventually merge into large ones. The nature of galactic clusters, and larger cosmological discontinuities, were not investigated.

Black Holes

Supernovae sometimes leave a remnant behind in the center, such as a black hole. Scientists now believe that a supermassive black hole is at the center of every galaxy. (It's possible that *those* black holes are not the remnants of stellar explosions, but rather, of galactic explosions.)

What do we know about black holes? We know that they have a strong gravitational field, and that they don't produce any light, not even infrared radiation, which simply has to be present as matter gets compacted by the force of gravity.

Scientists then conclude that black holes have *so much* gravity that even light cannot escape. But no one has ever actually proved that gravity can deflect photons.[15] The so-called "gravitational lensing" effect is often cited as proof, but for that to work, somebody would have to prove that gravity is deflecting the photons, and not something else.

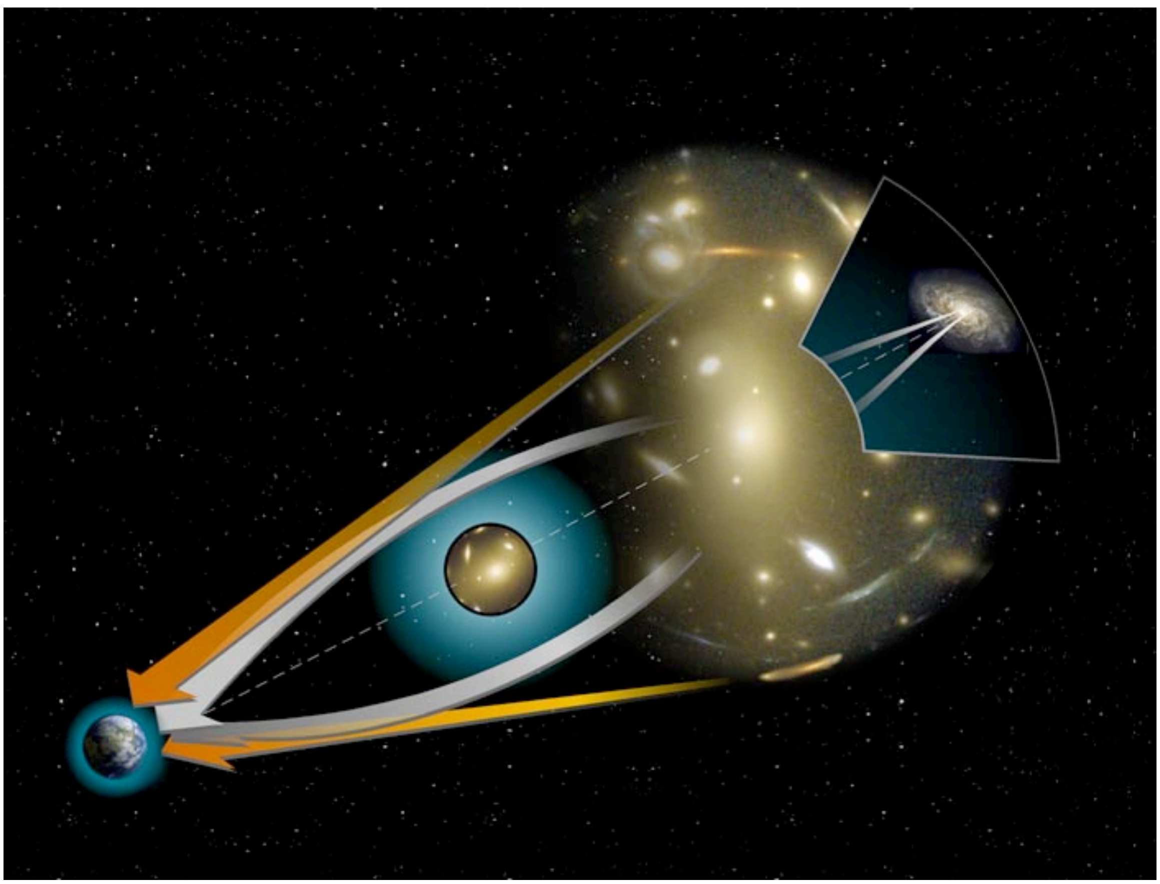

Figure 18. An illustration of the (supposed) gravitational lensing effect.

Figure 19. A mirage.

There is actually a far simpler explanation for the lensing effect. When light passes through a density gradient in a gas, it is deflected in the direction of the greater density, producing a mirage. For example, on a sunny day in the desert, hot air near the ground is less dense, and light can get bent upwards, toward the denser air above, creating the illusion of a blue lake on top of the sand. (See Figure 19.) If this is true on Earth, it should also be true out in space. All substantial gravity sources have atmospheres with density gradients, so they bend light toward themselves, *as if gravity is bending the light*.[16,17,18] But it isn't gravity itself — it's the density gradient, which in this case is caused by gravity.

This, of course, is not a new idea — it goes all of the way back to Sir Arthur Eddington, who in 1920 claimed that gravitational lensing had been instrumentally confirmed, while noting that the effect is exactly the same as a mirage.[18] He went on to say that mirages provide a useful analogy for those having difficulty understanding gravitational lensing. This cleverly builds the problem into the solution, making it look like it's not a problem anymore. Had Sir Arthur been doing rigorous science, he would have acknowledged that the instruments were not (and still are not) accurate enough to detect any deviation from the simple expectations of the mirage effect, leaving no anomaly for gravitational lensing to explain. And this means that the so-called "event horizon" in a black hole cannot reasonably be attributed to relativity, and we'll look elsewhere for an explanation.

Is it a mirage? No. A back-lit galaxy might bend light toward itself, and in a steep enough density gradient with a large enough radius, light could theoretically get bent into a circular path. But the light propagating outward from a black hole is perpendicular to the density gradient in the surrounding gas, and therefore will not get deflected. So what actually causes the opacity of black holes?

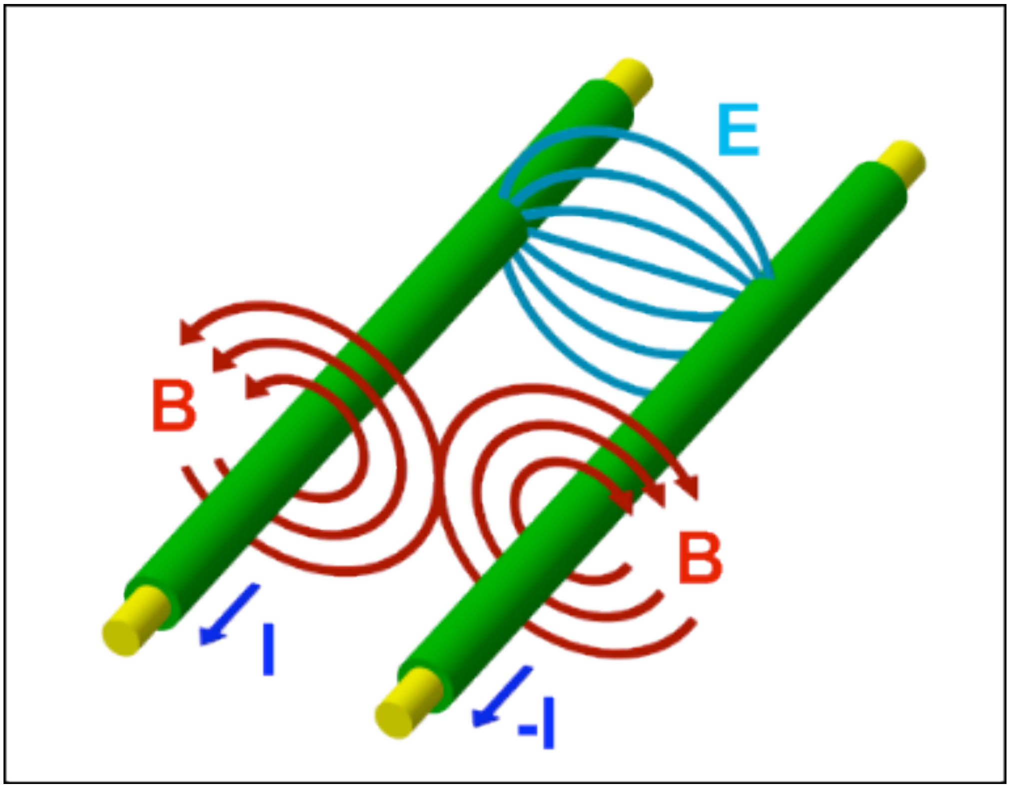

Figure 20. Opposite charges (I) traveling in the same direction generate opposing magnetic fields (B). At relativistic speeds, these approach the strength of the electric field (E) that attracts the opposite charges.

Near black holes, we know that matter being pulled in has been accelerated to relativistic speeds. At relativistic speeds, the moving electric charges will generate powerful magnetic fields. Protons generate fields by the right hand rule, while for electrons, it's the left hand rule. Since magnetic lines of force repel each other, opposing fields generate magnetic pressure. (See this for a demonstration.) Near the speed of light, these opposing magnetic fields become almost as powerful as the electric fields holding opposite charges together. But all other factors being the same, the electric force should still dominate. (See Figure 20.)

Yet there is an interesting difference between electric and magnetic fields. While the electric force that binds electrons to atomic nuclei falls off with the inverse of the square of the distance, the magnetic force generated by moving electric charges only falls off with the distance. Because of this, the electric force might be more powerful at short range, but with a little more distance between the charged particles, at sufficient speeds the magnetic force is stronger.

The significance is that if photo-ionization liberates an electron from an atom, the distance between the charged particles is greatly increased, and the magnetic force might be strong enough to prevent recombination. And the significance of *that* is that the photon that got absorbed doesn't get re-released on electron uptake. Photons getting absorbed, and not re-released, equals opacity.

So when we see a gravitational source with an accretion disc, and there just has to be photons getting emitted, but we don't see any, and we know that the matter has been accelerated to relativistic speeds, we can attribute the opacity to no electron uptake, in spite of the electric force, and because of the magnetic force.

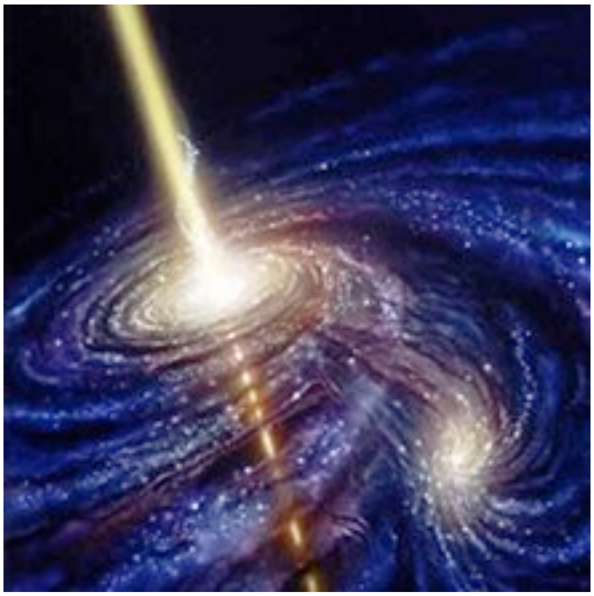

Figure 21. Black hole with an accretion disc jet.

Then things get really interesting. Some black holes produce beams of gamma rays shooting out along the axis of rotation. Scientists attribute the gamma rays to nuclear fusion outside of the event horizon. But fusion takes an enormous amount of pressure. So what supplies the pressure?

One possibility is gravity. But the force of gravity is cumulative, and only achieves the pressure for fusion deep inside a large body. The problem there is that gamma rays are absorbed by even the thinnest of gas clouds, and there shouldn't be any visible gamma ray sources from gravity-induced fusion.

The other possibility is sudden impacts, but there again, no gamma rays should escape. The necessary pressure is supplied by inertial forces, but like gravity, these are cumulative, and only underneath a large volume of matter will fusion occur. The overlying material, which contributes force but does not have enough itself for fusion, will absorb all of the gamma rays.

So how does fusion occur when at least in one direction (toward us), there is no matter to contain the pressure? The answer is that it is not gravity, or momentum, but rather, magnetic pressure developed by the relativistic speeds of matter spiraling inward. In other words, there's a natural tokamak at the center of the accretion disc.[19]

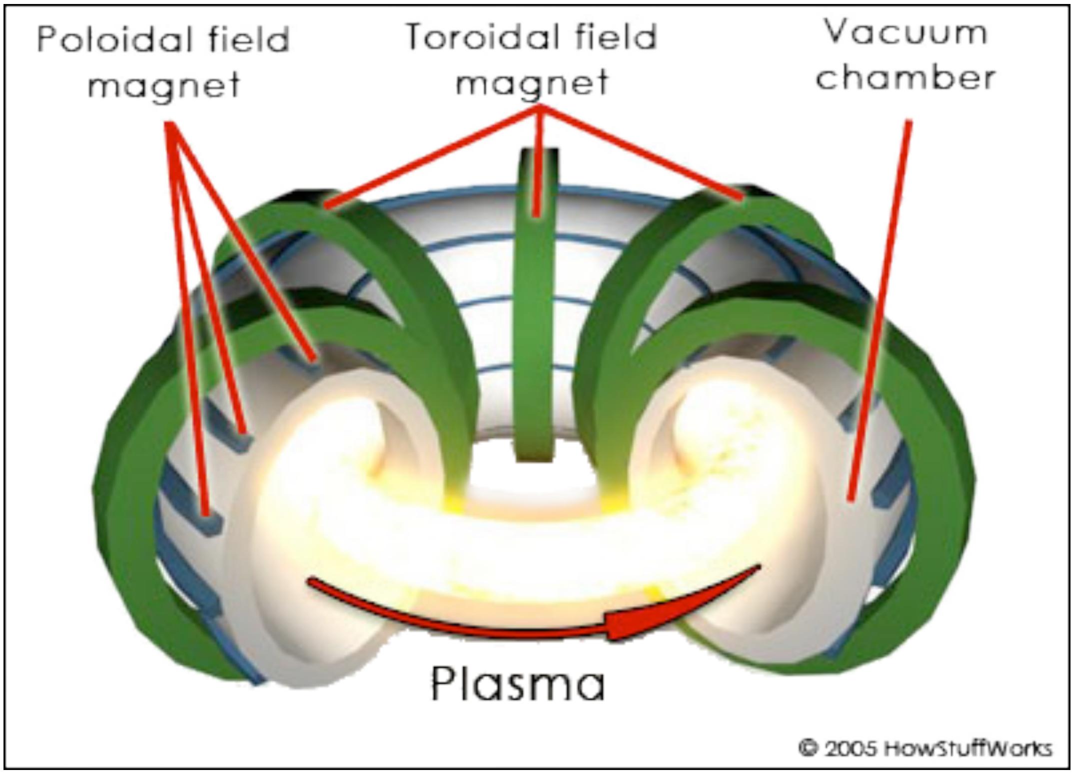

Figure 22. Tokamak, courtesy HowStuffWorks.

There is, of course, a fundamental difference between this and a human-made tokamak. To get sustained fusion in the laboratory, plasma is accelerated with applied poloidal magnetic fields, and then compressed with applied toroidal magnetic fields. (See Figure 22.) In nature, there will be no poloidal fields, and the toroidal fields will come just from the relativistic velocities of the plasma itself.

So how are such extreme angular velocities achieved, capable of the magnetic confinement necessary for nuclear fusion?

One possibility is the so-called magnetorotational instability. Differential rotation in an accretion disc from the Rankine increase in velocity nearer the axis would otherwise just produce a laminar flow with no other implications, but if charged particles are involved, the relative motion generates a force between neighboring parcels. This has two effects: the inner layer is slowed down, and the outer layer is sped up.[20] This has been cited as an important mechanism in the gravitational collapse of accretion discs that should have had too much centrifugal force for it. The other implication is that outer layers will gain velocity not possible in a simple Newton regime.

Another possibility results from collisions near the center. As matter has been accelerated inward by the "like-likes-like" principle, and rotation has been induced by magnetic pressure in the radial momenta, eventually there will be a significant number of collisions near the center, and some of these will be explosive. The ejecta from these explosions will spiral outward with the same angular momenta they already had. As they move away from the center, they will collide with matter spiraling inward. On collision, the net result will be the vector product of the two motions. So when matter spiraling outward collides with matter spiraling inward, the result is matter rotating around the center — *even faster*. As there is no theoretical limit to the amount of energy that can be stored in the momentum of an accretion disc, we can expect a sufficiently large one to develop relativistic angular velocities near the center. (See Figure 23.) If it does, nuclear fusion will begin. And gamma rays will not be blocked by the surrounding high-pressure plasma, because there *is* none — the fusion will be sustained by magnetic pressure instead.

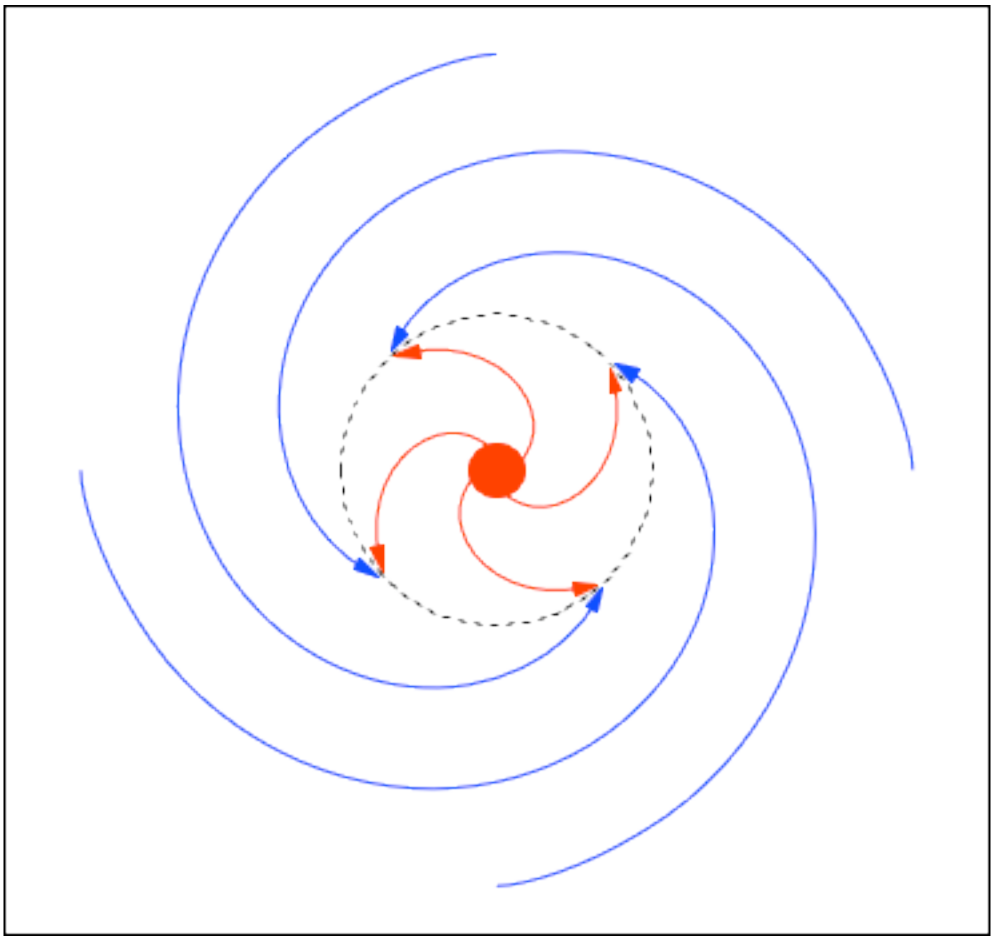

Figure 23. Collisions between inward and outward spirals produce accelerated rotation.

Then a variety of things become possible. If the accretion disc is composed of mainly lighter elements, most of the matter will be ejected from the tokamak as it fuses. Then again, heavier elements might accumulate within the toroid, confined by magnetic pressure, but not sufficient to fuse them into even heavier elements. In this case, the mass of the tokamak will continue to increase, and there's no theoretical limit to the amount of matter that could be packed into one of these things. Whatever was in the accretion disc that was still being forced inward, and which doesn't get ejected by fusion events, will contribute mass. But black holes do not represent a loss of matter, nor is there any reason to say that the very fabric of space and time is being broken down. Black holes convert gravitational potential into angular momentum. In free space, with no friction to impede the rotation, the magnetic fields will persist, and the energy might stay locked inside forever. Then again, the continued accretion of matter, and the ever-accelerating rotation, might achieve the threshold for the next stage of nuclear fusion, in which case a supernova will result. Another possibility is that two black holes might collide, which would produce a supernova also. Either way, the toroidal structure gets destroyed, and all of the internal potential is released.

Black holes also produce X-rays. Scientists were surprised to find distinct peaks in the X-ray band from iron near black holes, and even more surprised to find that the amount of iron in black holes that are 11 billion light-years away seems to match the amount that they're seeing in much closer black holes.[21] Existing stellar theory asserts that iron is produced in supernovae, so we would expect the amount of iron to increase with time, not stay the same. It's interesting to note the model that scientists have developed for explaining the X-rays.

> The distinctive X-ray spectral peaks are produced by the fluorescence of iron atoms in a doughnut-shaped torus orbiting a supermassive black hole. In this process, high-energy X-rays from hot gas very near the black hole excite the iron atoms to a higher energy state, and they almost immediately return to their lower energy state with the emission of a lower-energy, fluorescent X-ray.

So how does "hot gas" produce X-rays? And why would there be an iron toroid orbiting the black hole? And why would the amount of iron be consistent in a wide sampling of black holes, old and young?

This makes a lot more sense if we consider that the toroid *is* the black hole, and that the emissions are coming from nuclear fusion. In other words, black holes are manufacturing heavy elements.

To conclude this section, the biggest problem with the "natural tokamak" construct is that it would seem impossible to develop relativistic speeds without the centrifugal force becoming too great. We might say that a large enough object would have a powerful gravitational field, but both gravity and centrifugal force stem from mass, so these should balance out.

One possible solution is that the electric force helps keep the toroidal plasmoid consolidated. At relativistic speeds, positive and negative charges will get separated and then pinched into distinct charge streams. Because the positive charges have more mass, their centrifugal force will get them to take the outside track. Negative charges will then congregate in the interior of the toroid, attracted to the concentration of positive field there. This means that there will be a centripetal force of electric origins that might help offset the centrifugal force of the positive ions traveling at relativistic speeds.

Pulsars

As new matter flows into the tokamak, random clumps will produce episodic fusion events and/or flare-ups. It's also possible that the fusion rate will begin to oscillate. A random surge in fuel might create an explosion. The increased heat will cause the plasma to expand, reducing the fusion rate. If there is a great surrounding pressure, there will be a corresponding implosion shortly thereafter. The implosion will generate higher pressures than were present before the explosion, so there is the chance of another explosion. The only limiting factor is just that the pressure will implode upon the centerline of the tokamak, where all the fuel has already been used up. All other factors being the same, we wouldn't expect a secondary explosion. But since more matter is pressing in from the outside, there is the chance that enough fuel will be close enough to the high-pressure center of the implosion to create a secondary reaction.

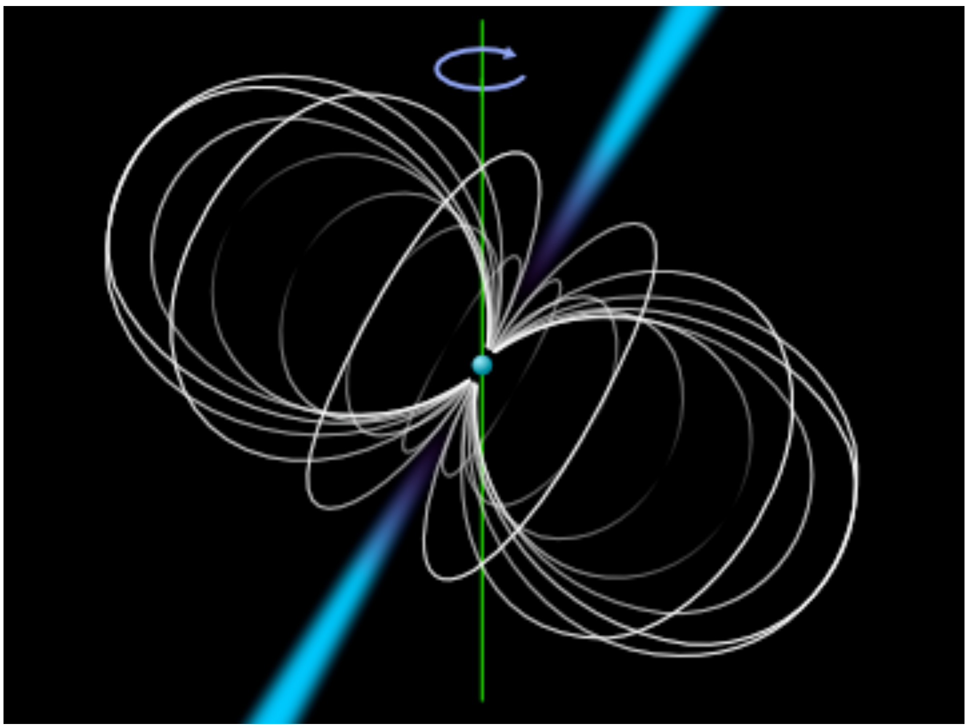

Figure 24. Schematic view of a pulsar. The sphere in the middle represents the neutron star; the curves indicate the magnetic field lines; and the protruding cones represent the emission beams.

This might be a more reasonable explanation for pulsars. Consider the following description from the Wikipedia article, with the associated image at right:

Pulsars are highly magnetized, rotating neutron stars that emit a beam of electromagnetic radiation. The radiation can only be observed when the beam of emission is pointing towards the Earth. This is called the lighthouse effect and gives rise to the pulsed nature that gives pulsars their name. Because neutron stars are very dense objects, the rotation period and thus the interval between observed pulses is very regular.

For some pulsars, the regularity of pulsation is as precise as an atomic clock. The observed periods of their pulses range from 1.4 milliseconds to 8.5 seconds. A few pulsars are known to have planets orbiting them, such as PSR B1257+12. Werner Becker of the Max Planck Institute for Extraterrestrial Physics said in 2006, "The theory of how pulsars emit their radiation is still in its infancy, even after nearly forty years of work."

But that "model" doesn't exactly connect all of the dots. Five significant disconnects have been identified.

First, a star made out of neutrons isn't possible, as neutrons outside of the nucleus of an atom undergo beta decay (producing a proton, an electron, and an electron antineutrino). So how did scientists come up with the concept of a "neutron star" in the first place? The answer is that they think that the frequency of events sets a limit on how big the object can be, outside of which it wouldn't be capable of acting as a single unit. With the size set, and knowing the mass (by the orbits of neighboring stars of known mass), they can then calculate the density. When they do that, they get an impossible number. Rather than re-thinking the size limits for an organized structure, they postulate densities beyond the limits of atomic theory. So we get *so much gravity* that protons and electrons are rammed together into neutrons. Lacking electrostatic repulsion in atomic nuclei, these can then be packed together to make a "neutron star" of the estimated density. In other words, it's (supposedly) an object with the density of an atomic nucleus, but the atom is a lot larger than anything you'll find on the periodic table. But gravity cannot over-ride the weak nuclear force and prevent beta decay, as both increase at the same rate, given the number of neutrons present, and the weak nuclear force is far more powerful.

Second, if the period of oscillation was tied to the rotation, then *every* pulsar would have a perfectly regular cycle, not just a roughly regular cycle. The variances in period have never been explained.

Third, there is no given energy source for the beams of light. These are said to emanate from the poles of the solenoidal magnetic fields. But magnetic fields do not emit photons, nor can they bend or otherwise focus photons. So we have a spherical star made of neutrons that generates bipolar beams of light. How?

Fourth, neutrons are neutrally charged, so rotation isn't going to generate a magnetic field.

Fifth, to think that the star is rotating on its axis, *and* the axis is rotating (so that the lighthouse beacon intermittently points in our direction), is ignorant of Newtonian physics. A rotating object has a powerful force that keeps the axis stationary — it's called the gyroscope effect.

So for the star's axis to rotate several hundred times a second, so that it can flash a beam of photons in our direction, generated by magnetic fields resulting from extremely fast rotation (of neutrally charged particles) *around* the axis, is supermassive naïveté.

It is more reasonable to think that a pulsar is not a sphere but a toroid, and that it's actually a natural tokamak that has fallen into an explosion/implosion cycle.

But it will take more than that to actually explain the tight beams of light emitted by pulsars. It is undeniable that the light that we see is focused. If the light radiated in all directions (as it would from a nuclear explosion), we would be seeing just that portion that happened to be pointed in our direction, which would be a very small fraction of the total. If we multiply the intensity of the light that we see by the inverse of that fraction, the total amount of energy at the source would be way beyond theoretical limits. And well below those limits, the explosion would disperse the matter, producing a supernova, and without there being an immediate repetition of the same process. So there is definitely a beam-concentration mechanism.

The nuclear reactions will radiate EM energy in all directions. The energy aimed back into the accretion disc will, of course, get absorbed by it, or reflected off of it. Any light that travels away from the plane of rotation can escape, and eventually land on our telescopes. But that includes a wide angle, and even if we're only talking about light in a 45° cone perpendicular to the plane of rotation, we're still talking about way, way too much energy. We need to find something capable of producing a beam of perfectly focused EM waves, that can travel halfway across the Universe without losing much energy.

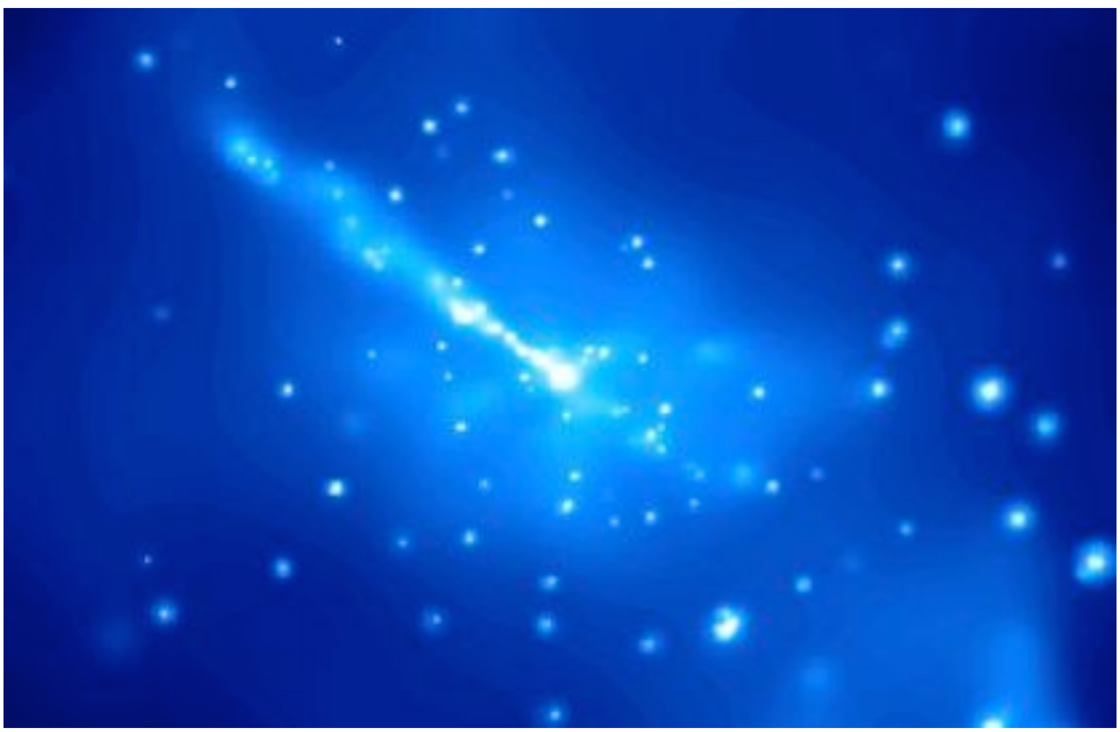

Figure 25. NGC 5128 (Centaurus A) in the x-ray band. The source of the axial jet is in the center of the image, which is the center of the galaxy.

To find the answer, we shall take a closer look at the output from our natural tokamak. With a ring of confined plasma exploding, we get helium (or heavier elements) accelerated to relativistic speeds out of the tokamak. Stuff that flies outward on the plane of rotation slams into the accretion disc, while everything else gets to escape. We can expect a radial pattern of ejecta, but along the axis of rotation, we can expect a concentration. This is because the inner 180° slams into stuff ejected from the opposite side of the tokamak, and the vector product of the collision is along the axis of rotation.

Note that the "axial" jet has nothing to do with the rotation itself, and the standard explanation of axial jets (i.e., that gravitational pressure overloads the core) is gibberish. Here Einstein was right — the centrifugal force should prevent the collapse of matter at the center of the accretion disc, and nothing should be able to cause an axial jet. Only if there is an explosion can we get relativistic ejecta, and only if it occurs in a ring configuration can 50% of the ejecta get consolidated into jets. (See Figure 26.)

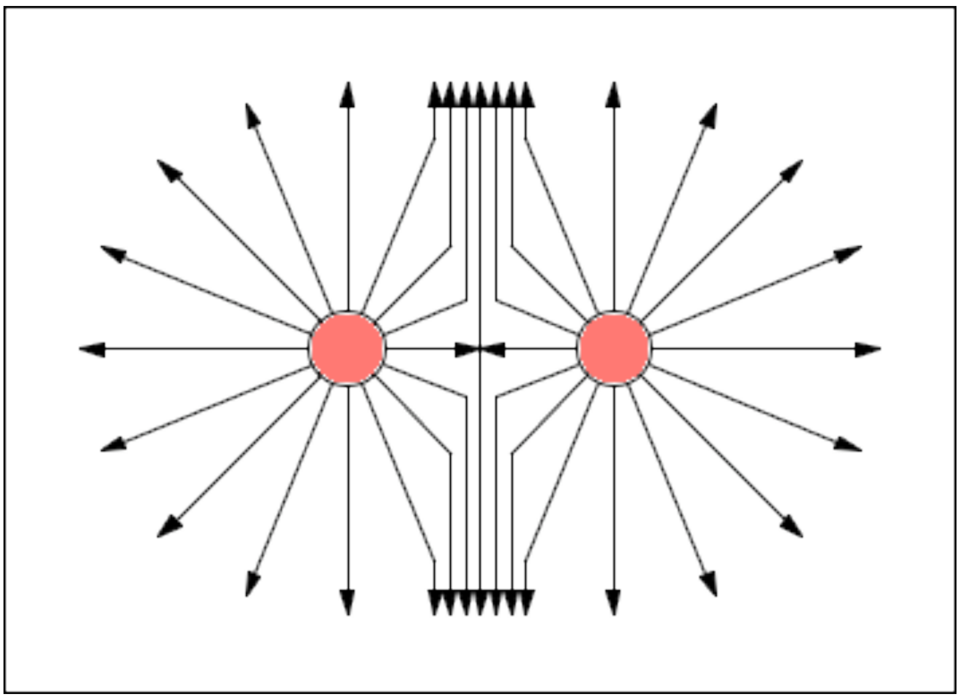

Figure 26. Section of a toroidal explosion, showing that 50% of the ejecta merge into "axial" jets (25% each way).

Once the axial jet gets organized, we can then expect it to stay organized as it streams away from the tokamak. The relativistic speeds of the plasma will generate magnetic fields capable of pinching the charge stream, and until/if/when it gets slowed down by collisions with other plasma, it will stay organized.[22]

Axial jets are, of course, particle streams, not photons. So what focuses the photons? These should radiate outward in all directions, and they're not going to "collide" and merge together due to the incident angle in the collision.

Yet the axial jets can focus photons. They are particle streams, with density gradients that fall off with distance from the axes. And what do we know about density gradients? They can bend light! So if we shine a light into an axial jet, the light will be bent toward the centerline of the jet, due to the mirage effect. At first we might expect the light to just start bouncing off the outer walls of the gradient, not really getting "focused." But as the jet eventually disperses, the density gradient relaxes. So each time light bounces off the density gradient back toward the centerline, the angle of reflection will not be quite as great as the angle of incidence, relative to the axis. This means that eventually, all of the light will be traveling in the same direction.

Hence we can, with conventional physics, explain a pulsar as a natural tokamak in an explosion/implosion cycle, producing axial jets, and where the jets focus light along their axes. And here again we should remember that even though experiments with sustained nuclear fusion have failed to yield a net power output, it doesn't mean that tokamaks don't work, and that this is a flawed analogy. It just means that tokamaks are not economical (and never will be). Yet the principles are sound, and with the input of the condensed angular momentum of an entire stellar system, sustained and/or oscillating nuclear fusion is certainly possible. (Somebody needs to tell the particle physicists at Stanford that if they just feed a couple of large asteroids into their tokamak every day, traveling at relativistic speeds, they should be able to keep the thing going.)

So how do the bipolar jets ever fail, once accelerated to relativistic speeds, and fully collimated by the magnetic pinch effect? One answer is that even in the extremely thin plasma of interstellar space, there is still a little bit of friction, hence the particle streams will slow down. As they do, the organizing principle (i.e., the B-field) relaxes, and then hydrostatic and electrostatic pressures will blow the stream apart. But there might be a more powerful reason, which would explain another observation about these streams: they are radio sources. It's possible that these streams develop bi-directional flows of nucleons and electrons. The particle collisions reduce the velocity, and cause the emissions. (See Figure 27.)

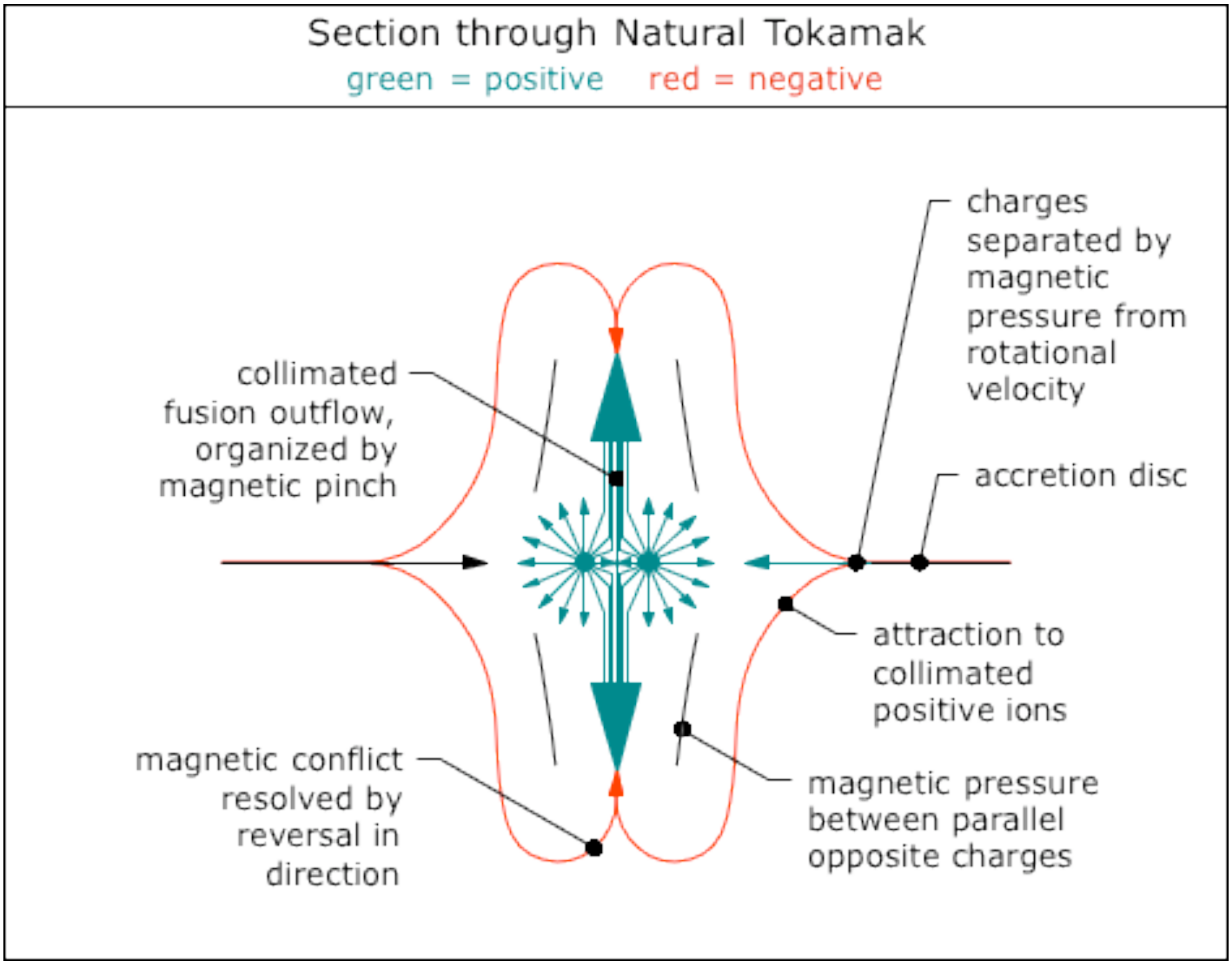

Figure 27. Possible configuration of charge recombination in bipolar jets, after reversal in direction of electrons to resolve magnetic conflict.

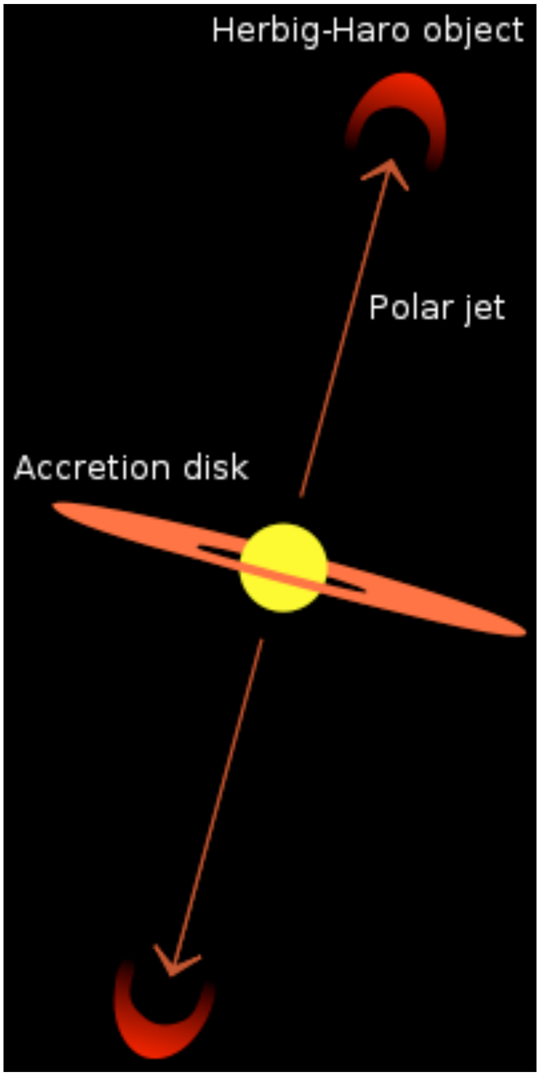

Figure 28. Flare-ups at ends of bipolar jets.

It is significant to note that bipolar jets terminate in so-called Herbig-Haro objects, which are flare-ups that are thought to be caused by the collision of the jets with interstellar plasma. (See Figure 28.) But that doesn't explain flare-ups that only last a couple thousand years, but which are larger than the distance traveled by the particles at their known speeds (i.e., ~300 km/s). Analogously, if somebody driving a car at 30 m/s steps on the brakes, a skid mark 10 m long, formed in 3 s, makes sense. But a skid mark 1 km long formed in 3 s does not, because the car wasn't going fast enough to travel that distance, much less with the brakes on. So a Newtonian collision is not a plausible answer, but relativistic velocities in an EM flare-up are easily possible. So it's far more likely that the transient flare-ups are wafts of electrons streaming in to recombine with the positive ions inside the jets (as shown in Figure 27).

Newtonian mechanics also cannot explain why jets traveling in both directions, sometimes for many light-years, would run into something that distinct, both at the same time. The symmetry strongly suggests coupling, which would make sense if both ends are part of a singular EM system. Charge recombination in the jets causes their failure by eliminating the magnetic pinch effect. And electron drag supplies hydrostatic pressure that induces turbulence in the jets at the failure points.

Quasars

One type of object *seems* to outshine all of the rest in the night sky. Its spectrum is like that of a star, so it is called a "quasi-stellar object" (QSO, or quasar). But there is a quasar (i.e., 3C 273) that has an estimated absolute luminosity of 2×10^{12} times that of our Sun, which is greater than the average *giant galaxy*. Since that kind of luminosity is quite impossible for a single star, and since that kind of spectrum is quite impossible for a galactic collection of them, there has to be a false assumption somewhere in the mix here. There is no question that a quasar's spectrum and periodic oscillations can only be caused by a single object. So the only thing left to double-check is the method by which the absolute luminosity is estimated. This is the apparent luminosity, times the rate at which the luminosity falls off with distance, times the distance. Hence the two things to check will be the fall-off rate, and the way distances are estimated.

First, we can observe that quasars have bipolar jets. The Pulsars section described how the density gradient within the jets can focus light into tight beams. So it's possible that we only know the quasars whose jets are pointed at us, and if estimate the absolute luminosity by the inverse square law, we'll be way off, because the luminosity in a beam doesn't fall off like that.

Second, and perhaps more significantly, we can challenge the way distance is estimated. This is done by the redshift. But one quasar (i.e., ULAS J1120+0641) has a redshift of 7.085, which works out to 28.85 billion light-years away. In Big Bang cosmology, the Universe is only 13.77 billion years old, so something is definitely wrong with that. Furthermore, there is apparent evidence of quasars with high redshifts associated with galaxies of a much lower redshift.[23:5] If this is true, the greater redshift of the quasar compared to the parent galaxy is due to something about the quasar itself. *Some* of the difference can be attributed to relative motion of the quasar within the galaxy (i.e., a particularly fast orbit). But that adds up to less than a difference of +/− 0.01 (depending on whether it's coming toward us, or going away), and we're looking for a difference of +2 or more (i.e., always greater, and substantially so).

If quasars are "exotic" stars, they are open-air tokamaks, making them gamma ray sources. But the spectra of quasars are much more complex than that. So what is the source of the other radiation?

In the Pulsars section, Figure 27 shows +ions and electrons meeting in the Herbig-Haro objects. Electron drag in those arc discharges will accelerate some of the plasma against the flow. (See Figure 29.) If the polar jet is pointing toward us, such that we're seeing the focused beam, it's possible that the primary source of photons is charge recombination within the jet (and not nuclear fusion in the "natural tokamak"). Such photons will have a Doppler redshift due to the relativistic velocities of the electrons and the counter-streaming +ions accelerated away from us by the electron drag.

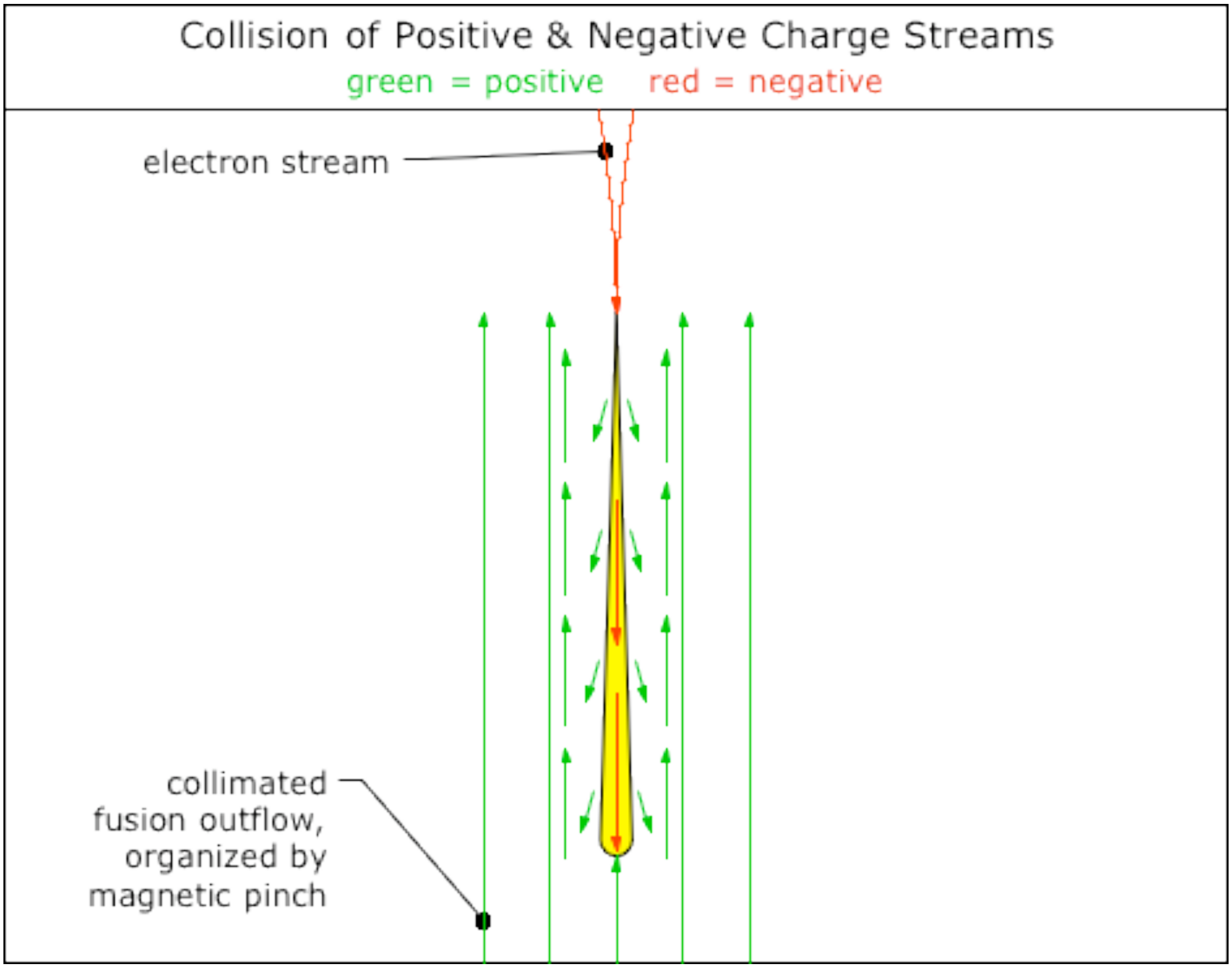

Figure 29. The counter-streaming electrons will accelerate nucleons in the same direction. Collisions and electron uptake in the yellow region are responsible for the photons we observe.

Hence the quasar's redshift might not be due to Big Bang recession, nor to relative motion of the quasar itself, but rather, just due to relative motion in one part of the quasar system: the counter-streaming charge recombination in the bipolar jets. The significance is that quasars might be much closer, and *that* means that their absolute luminosity is much less.

Due to their (incorrectly) estimated luminosity, quasars were originally classified as galaxies. When improved telescopes detected other stars in the vicinity, quasars were demoted to active galactic nuclei. Now some researchers believe that if there aren't any other stars in the vicinity that *should* be there, given the resolution of the imagery, we're seeing a galaxy in the making. In other words, they think that quasars are, at the very least, galactic seeds. But no mechanism is proposed for a galaxy growing out of a quasar, and this looks suspiciously like a strained attempt to preserve the earlier galactic classification. If the energy is actually just in the stellar range, these quasi-stellar objects are really just stars.

Nevertheless, there *do* appear to be relationships between quasars and nearby (on the sky) galactic nuclei.

First, quasars appear to be on or near the minor axis of elliptical galaxies. This suggests that they form in the bipolar jets of the AGNs. But the highly ionized particles and violent collisions in the jets would seem to preclude star formation. The alternate interpretation is that quasars are in elliptical orbits with extremely high aspect ratios. (See Figure 30.)

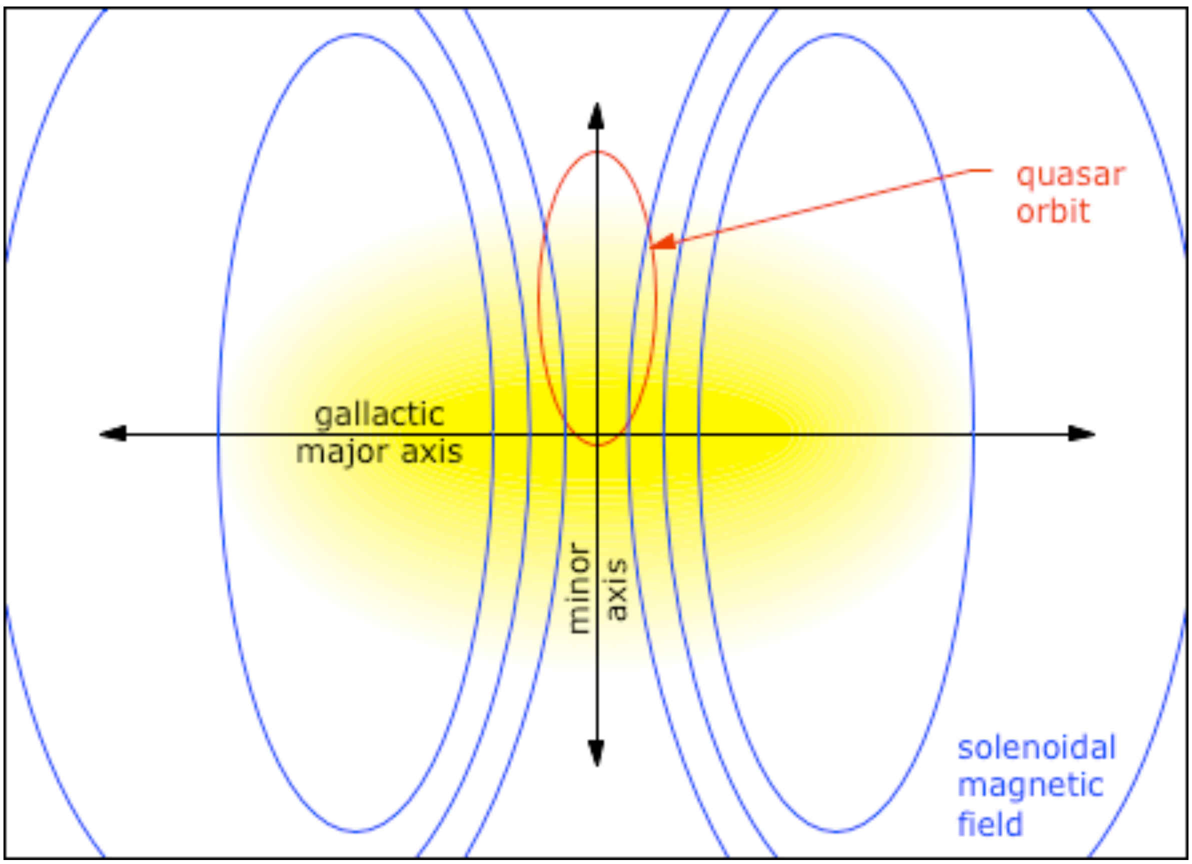

Figure 30. Quasar orbit on minor axis of elliptical galaxy.

This has an interesting implication. If they are actually just stellar systems, but moving roughly along the minor axis of the galaxy, they are moving parallel the magnetic lines of force of the AGN.[24] As such, they will pick up an induced spin from the Lorentz force. That additional force might be an important contributor to the angular momentum necessary to establish an exotic star. This leads to a fundamentally new conception of quasars, wherein they are made, not born. Of all of the stellar systems in orbit around the AGN, ones on the major axis generate the galactic magnetic field, but remain normal stars, while ones on the minor axis develop extreme angular momenta, and transition into exotic stars (i.e., "natural tokamaks"). We then observe more quasars along the axis of the AGNs, and think that the quasars formed in the bipolar jets, when it's actually another aspect of the AGNs that is responsible. And the magnetic fields didn't assist in the accretion of matter into the quasar, but rather, simply transformed the existing star into an exotic.

The second quasar/AGN relationship is that there appear to be equal quantities of quasars ejected in both directions from the AGNs, with one half showing greater redshifts, and the other half showing lesser.[23:5] This suggests that something in the AGN is manufacturing quasars in pairs. But this might presume a degree of sophistication in the AGN that simply isn't necessary. The "core" of an elliptical galaxy is populated by stars and clusters in elliptical orbits around the center of gravity. It's possible that during a pass near the center, a star accretes a lot more matter, the assimilation of which sends the natural tokamak into overdrive. The "ejected" quasars are simply those stars that are still in their highly elliptical orbits, but are past the periapsis and are headed back out. Roughly equal quantities of quasars headed both toward and away from us might simply be evidence of a large population of stars in these highly elliptical orbits.

Third, the difference in redshift between the quasar and the AGN decreases with distance from the AGN. More interestingly, it does so in distinct steps, known as the Karlsson periodicity, wherein the differences favor specific values (i.e., 0.60, 0.91, 1.41, and especially 1.96).[25] Attempts to assimilate these data led to a radical new idea, that redshift (or at least one component of it) is an intrinsic property of matter, and has little or nothing to do with relative velocity. This "intrinsic property" was proposed to be the age of the matter.[26] The idea was that AGNs manufacture matter, which initially has a different redshift, but as it ages, it comes to resemble the rest of the matter in the galaxy, and the redshift difference diminishes. (Apparently the matter ages rapidly at first, such that it can "catch up" to the age of the surrounding matter.) The idea continued on to say that when matter is first created, it has zero mass, and that it gains mass with age. The redshift was then tied to the mass (somehow), and the Karlsson periodicity was attributed to the quantized nature of elementary particles. In other words, the particles gain mass in distinct steps, "because" everything else about particles is quantized.

The study in question noted roughly equal quantities of quasars with higher and lower redshifts than the parent galaxy, while the unsigned difference corresponded directly with apparent distance from the AGN. But if matter is being "manfactured" at zero mass, and if redshift is a function of mass, it makes no sense that quasars shooting out in one direction would have more redshift, while in the other direction they would have less. In other words, quasars are being manufactured at zero mass in pairs *of different masses*, with the heavy one going one way, and the light one going the other? If any of that was possible, part of it would sound odd.

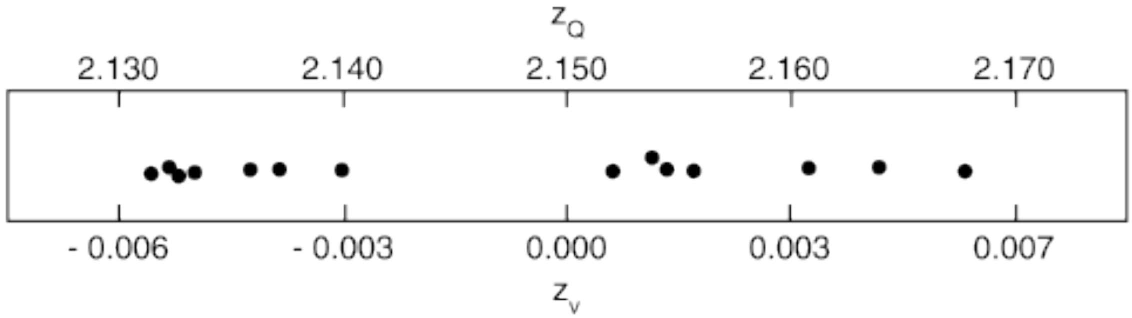

Figure 31. The absolute redshifts (Z_Q) of the 14 QSOs within 70' of AM 2230-284, and the shifts compared to the parent galaxy (Z_v), courtesy Arp et al. (2013).

In the present model, there is another interpretation. The masses are stable; redshift is an accurate indicator of relative motion; and redshift is coming from counter-streaming particles in the bipolar jets. That turns the question posed by the Karlsson periodicity into a search for quantization in electron uptake. And that would appear to be easy to answer, as it would be a function of the degree of ionization, which is definitely quantized. Greater charge will allow electron uptake at greater opposing speeds, while weakly charged ions require that the electron be traveling at nearly the same speed as the ion.[1] Then the rest of it falls neatly into place. The highest Karlsson number (i.e., 1.96) exhibited by quasars nearest the AGN is an indication that the quasars are burning brightly due to matter they scavenged passing through the densest part of the AGN, and they are vigorously expelling +ions in their bipolar jets, with powerful counter-streaming arc discharges, and photons with a high redshift. Further from the AGN, the quasars cool back down, and the weaker bipolar jets support slower counter-streaming arc discharges.

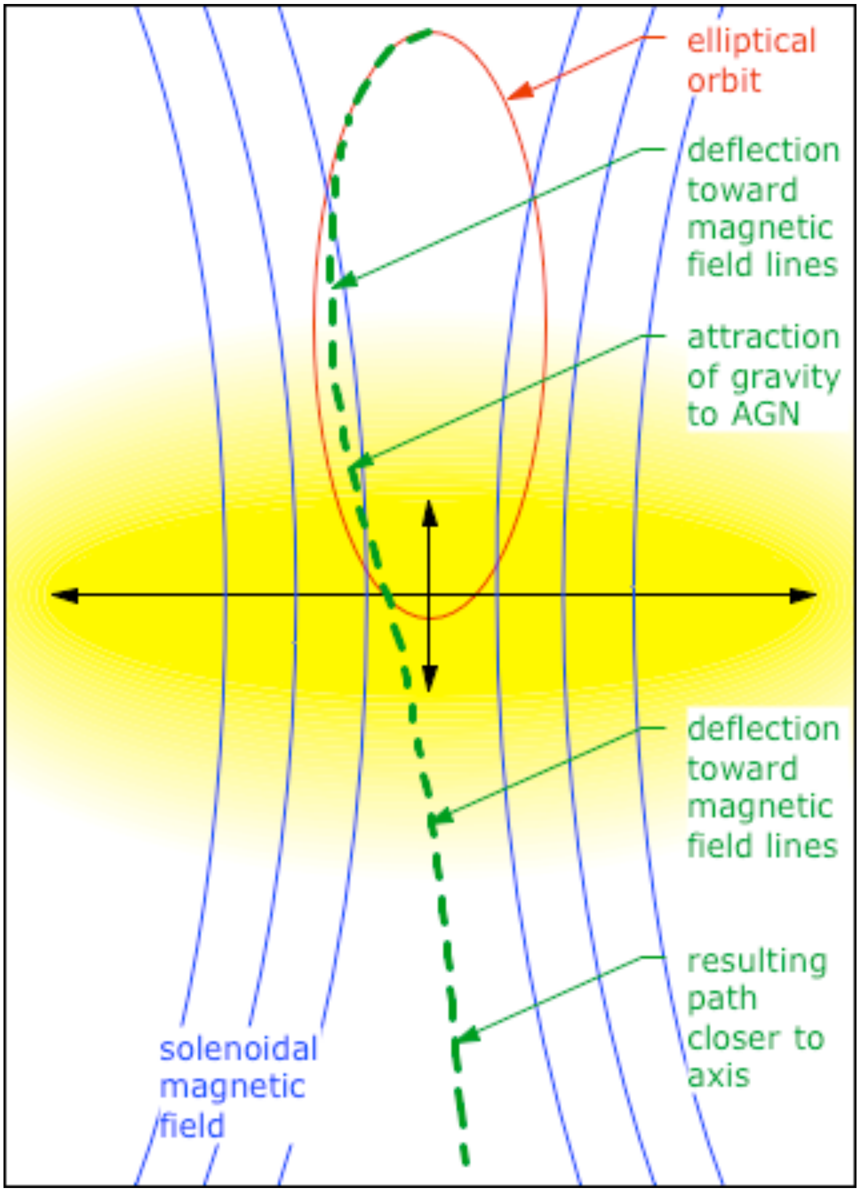

Figure 32. Elliptical orbit is converted into linear motion by magnetic forces.

Note that if this is correct, the elliptical orbit of the quasar might not stay elliptical. (See Figure 32.) Normally, the combination of gravity and inertial forces resolve into a perfect ellipse. But now we have two more forces to take into account: the angular momentum of the quasar, and the AGN's magnetic field. The quasar falling through that field picks up spin, like an autorotating helicopter falling through the air. Nearing the periapsis, gravity urges the quasar to stay in an elliptical orbit. But past the peak of its velocity on the minor axis, the transfer of energy from the Lorentz force flips. While it had been converting linear motion through a magnetic field into angular momentum, now it converts angular momentum into linear thrust. Due to the gyroscopic force, the quasar's rotational axis will not change, so the thrust cannot abide by the elliptical regime — it can only remain parallel to the external magnetic field. This force might be sufficient to break the quasar out of its elliptical orbit, steering the quasar straight through the AGN and out the other side.

It's also possible that at the far end, the quasar won't even fall back toward the AGN. In addition to spin picked up from the Lorentz force, as the quasar moves through the galactic nucleus, it might also pick up spin from the other mechanisms mentioned in the Black Holes section (e.g., the magnetorotational instability, and the vector product of collisions between incoming and outflowing particles). If so, the magnetic force will propel the quasar further out — perhaps escaping the gravitational attraction of the galaxy.

To summarize,

- Quasars are exotic stars (i.e., natural tokamaks).
    - They have collimated bipolar jets, and highly focused EM radiation.
    - Compensated for focusing, the power output is in the stellar range, not the galactic. So quasars are stars, not galaxies, AGNs, or galactic seeds.
    - The radiation is generated by counter-streaming charges in the bipolar jets.
    - The high redshift is not from the relative motion of the entire quasar, but rather, from the relative motion of the photon emitters in the bipolar jets, which have been accelerated away from us by electron drag.
    - The redshifts are quantized by the degree of ionization in the plasma jet.
- They are in elliptical orbits around AGNs.
    - The velocity in an elliptical orbit is the greatest near the AGN, producing greater differences in redshift, compared to the redshift of the AGN. If the quasar is moving away from us, the redshift will be greater, while a quasar moving toward us will have a lower redshift. The orbital velocity is trivial compared to the redshift in the counter-streaming discharge channels (i.e., maximum of 1.96 relative redshift, compared to a maximum absolute redshift of 7.085).
    - The high aspect ratio of the elliptical orbit gives the impression that the quasars are ejected from the AGNs.
    - Quasars actually began as normal stars, but with orbits aligned to the minor axis of the AGN, the Lorentz force increased the spin, transforming it into an exotic star.

Nebulae

There are numerous examples of "bipolar outflow" in which stars produce two masses of ejecta that are functionally identical. (See Figure 33.)

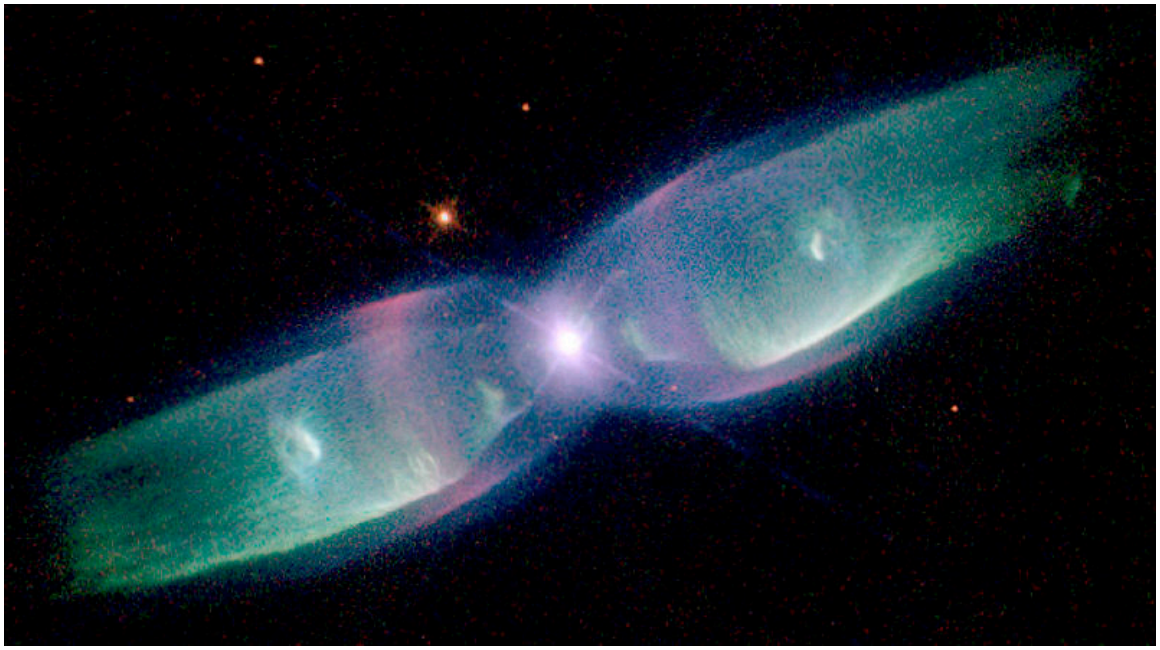

Figure 33. M2-9 (the Butterfly Wings Nebula), is an example of bipolar outflow.

Wikipedia defines "bipolar outflow" like this:

> The presence of a bipolar outflow shows that the central star is still accumulating material from the surrounding cloud via an accretion disk. The outflow relieves the build-up of angular momentum as material spirals down onto the central star through the accretion disk. Indeed, without the outflow, disk accretion would not be possible and the star would never form.
>
> Bipolar outflows from evolved stars probably start out as spherically-symmetric winds (called post-AGB winds), ejected from the surface of a red giant star as it cools and fades. These are focused into cones of gas by magnetic fields or a binary companion in a process that is not yet well understood. The bipolar outflows from post-AGB stars eventually grow to form a planetary nebula.

In other words, scientists don't understand what causes these things. The two paragraphs actually represent two different schools of thought, the first being a more generic concept of accretion discs, while the second is a more specific contention about expulsion from a red giant that gets focused into cones. Yet neither of these "models" is founded in physics.

That outflow could "relieve the build-up of angular momentum" is just an observation presented as an explanation, but it also deliberately skirts a major theoretical problem. As Einstein pointed out, the center of an accretion disc should be like the eye of a hurricane — the centrifugal force should keep it clear of all activity. This left Einstein without an explanation for bipolar outflows. When the next generation of astronomers was pressed for some progress on the issue, it explained that the outflow *relieves* the worrisome angular momentum. This builds the problem into the solution, meaning that it isn't a problem anymore, for all who would believe it. So now, outflow is an intrinsic property of accretion discs, without which the inflow would not be possible? That's gibberish. To test our theories, we have to forget about the observations we are trying to explain, and focus just on the forces that we have identified. If we were given a brand new, empty Universe in which to test our assumptions, and we specified that these forces, and *only* these forces, shall be present, what is going to happen? If an accretion disc always produces bipolar outflow because of overloaded angular momentum, then orthogonal outflow is an intrinsic property of angular momentum. But in reality, it is not, and Newtonian physics is not ambiguous on such issues. In the end, those who understand the problem understand that it's a tough problem, so they accept the quick-n-dirty answer, and those who do not understand the problem simply accept the answer, not knowing that it's a deception.

The second explanation isn't any better. A red giant accelerates huge volumes of material to relativistic speeds after its fuel is depleted, in a process that is not yet well understood, and in the case of a bipolar nebula, the spherical outflow is focused into bimodal cones in a process that is not yet well understood. This is how scientists talk when nothing is making sense.

First things first. In the lay literature, the glow of a nebula is sometimes described as the smoldering remains of a super-hot explosion. But there is no way to preserve such temperatures for long distances out into space. Rather, we're seeing high-velocity collisions between particles in the ejecta and in the interstellar space. In the near-perfect vacuum, such collisions are rare, but they are extremely high-energy events, and they produce photons.

Second, thinking of a nebula as the result of an explosion is not correct. It's clearly a steady stream. The Butterfly Wings Nebula in Figure 33 took about 1200 years achieve this size.[27] So it was a continuous *process* that produced the ejecta, not an explosion. This is where things get tough. Only nuclear fusion can accelerate particles above the gravitational escape velocity. So this is the exhaust from a nuclear reactor. But nuclear fusion requires extreme pressures (i.e., *plasma confinement*), and here we're seeing that the axes are wide open, as the ejecta flow freely outward. So in spite of the centrifugal force that should eliminate inward pressure, and with the axes wide open, we're seeing sustained nuclear fusion creating relativistic outflow.

This can only be evidence of a natural tokamak that compresses matter by magnetic confinement. Newly fused atoms are then expelled at relativistic speeds.

The perfect symmetry of the ejecta cannot possibly be the result of random chunks of matter spiraling in — it can only mean a perfectly regulated inflow, which only a natural tokamak could accomplish. The extreme angular velocities will generate sufficient magnetic fields to separate protons from electrons. The protons are consolidated by the magnetic force, but distributed by the electric force, with a particle density set by the angular velocity, which is the same all of the way around the tokamak. In other words, the reactor meters its own fuel.

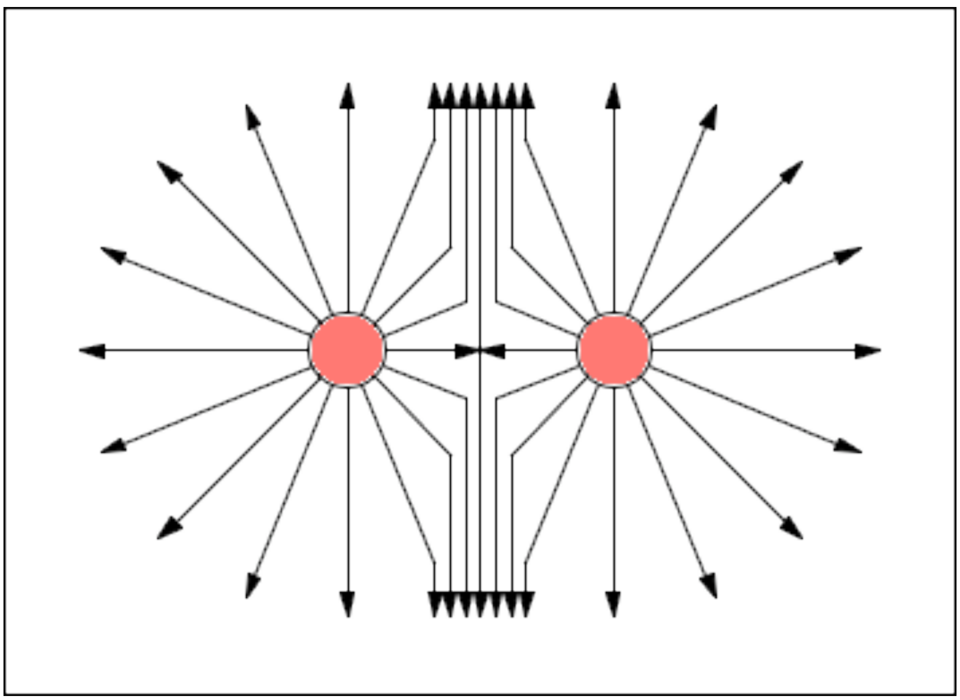

Figure 34. Section of a toroidal explosion, showing that 50% of the ejecta merge into "axial" jets (25% each way).

What makes the difference between bipolar jets and bipolar nebulae? Figure 34 describes the geometry of the polar outflow from a natural tokamak. Initially, 50% of the ejecta are fully collimated. In bipolar jets, they stay collimated, where the organizing force would be the magnetic pinch effect. In bipolar nebulae, we see conical ejecta. It's possible that these smaller streams are not moving as fast, and therefore are not pinched to the same degree, and the extreme temperature in the ejecta creates pressure that disperses the plasma. So a supermassive black hole creates polar jets that stay tightly bound as they stream off into interstellar space, while intermediate-mass stars (1~8 times the mass of the Sun) create bipolar planetary nebulae.

In some cases (e.g., the Boomerang and Butterfly nebulae), the ejecta continue on in their conical form. In other cases (e.g., the Butterfly Wings, Calabash, Hourglass, and Southern Crab nebulae), the ejecta morph into a cylindrical form. Sometimes (e.g., the Ant and Homunculus nebulae) the outflow is even spherical, with the matter converging back on itself some distance from the center. And then there are cases in which there appear to be ejecta from two stars (e.g., the Egg and Red Rectangle nebulae). The forces responsible for the differences in these forms are not yet well understood.

Figure 35. Herbig-Haro 46/47 in the Vela constellation, courtesy ALMA.

Figure 35 shows a rare, recently discovered nebula, which is not symmetrical.

One final note is worthy of mention. In a recent study of the radio emissions from supernova remnants (SNRs), it was found that almost all of the bipolar jets were aligned with their respective galactic planes, while the probability of this distribution occurring by chance is only 0.0007.[28,29,30,31] This is clear evidence of a force. Gravity isn't it, so it has to be electromagnetic. The galactic magnetic field is parallel to its plane of rotation. The prevailing opinion is that this field is not strong enough to have dynamical effects on the SNR itself, so it must be that the field steers the polar jets into alignment after ejection from the SNR. Yet in none of the cases is there any evidence of course changes moving away from the SNR, meaning that all of the "steering" would have to occur very near the SNR, when the ejecta are at their peak speeds. This is highly unlikely.

It's significant to note that accretion discs associated with SNRs are always perpendicular to the polar jets. Hence it's possible that the steering mechanism is not acting on the jets, but rather, on the discs. Then, the jets emerge perpendicular to the discs, as described previously. (See Figure 34.) This just happens to accelerate the jets in a direction that is parallel to the external magnetic field. Once parallel, the jets will then tend to stay parallel, as B-field-aligned electric currents.[32] (Note that these are poleless currents, not responding to electric fields, but which nevertheless exhibit electrodynamic properties simply because they are moving charged particles.) The synchrotron emissions from within the jets then make sense as the products of the helical motion of charged particles in a field-aligned current.

The essential question is then, "What gets the accretion disc rotating on a plane that is perpendicular to the magnetic lines of force?"

The present model maintains that the relativistic speeds of matter in the accretion disc are generating extremely powerful magnetic fields. Outside of the star, this field forms a solenoid, with the greatest field density along the axis. All other factors being the same, we would expect this axis to be aligned with an external magnetic field (if present). We must acknowledge that the galactic field is weak, and its force is small compared to the inertial and gravitational forces in the accretion disc. Hence the proposed mechanism is really only tenable as a weak force that gently nudges the angular momentum in the disc into alignment. It's possible that alignment is only achieved after a long period of time, possibly even spanning multiple implosion/explosion cycles, wherein the angular momentum is preserved, and the galactic field continues to nudge the rotation into alignment. It's also possible that the galactic field helped induce the rotation in the first place. Purely radial accretion in the presence of an external magnetic field will be subject to a Lorentz force accelerating matter in a circular motion on a plane perpendicular to the lines of magnetic force.

Along the same lines, it has been noted that galaxies at the edge of galactic clusters tend to rotate on a plane facing away from the center of the cluster.[33] It's also interesting to note that high redshift galaxies ($z > .5$) do not show this orientation, implying that the galaxies are *getting* aligned over time by the application of a force.[34] If the magnetic lines of force in the cluster face inward toward the center, the alignment of the solenoidal field from the galactic rotation with the "external" field of the cluster would make sense for the same set of reasons.

It's also possible that the orbits of planets within our own solar system are getting aligned perpendicular to the plane of the Milky Way for the same reason. Currently, the axis of our solar system is aligned with the direction of the nearest spiral arm (the Orion–Cygnus Arm), but is 30° from the galactic plane. (See this graphic.) This would be consistent with the other rotations considered.

The Sun

Motivation

On 1859-09-01, at 11:18 GMT, an English astronomer named Richard Carrington made the first recorded observation of a solar flare. 17 hours later, the largest geomagnetic storm in history occurred. Incredibly, the aurora was visible directly overhead as far south as the Caribbean.

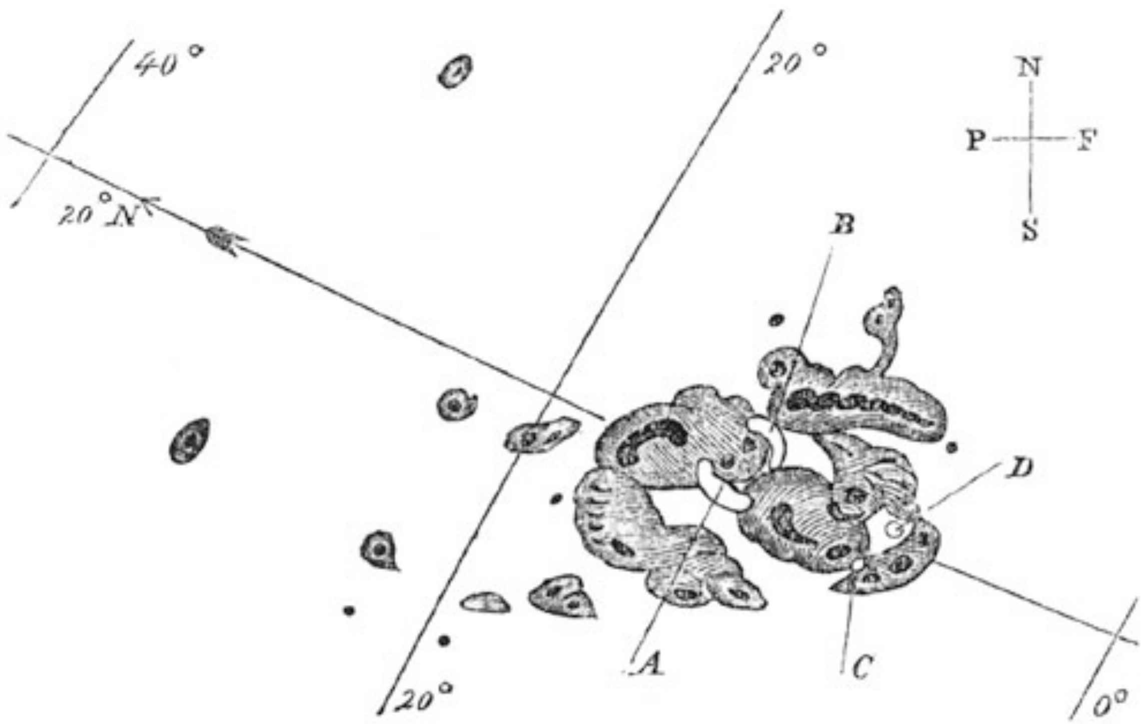

Figure 36. Carrington's drawing of the sunspots on 1859-09-01, with letters showing the locations of the flares.

At the time, the event was little more than an idle curiosity. Consider the tone of following report from the Baltimore American and Commercial Advertiser.[35]

> "Those who happened to be out late on Thursday [1859-09-01] night had an opportunity of witnessing another magnificent display of the auroral lights. The phenomenon was very similar to the display on Sunday [1859-08-28] night, though at times the light was, if possible, more brilliant, and the prismatic hues more varied and gorgeous. The light appeared to cover the whole firmament, apparently like a luminous cloud, through which the stars of the larger magnitude indistinctly shone. The light was greater than

> that of the moon at its full, but had an indescribable softness and delicacy that seemed to envelop everything upon which it rested. Between 12 and 1 o'clock, when the display was at its full brilliancy, the quiet streets of the city resting under this strange light, presented a beautiful as well as singular appearance."

Aside from the pretty lights in the sky, there was one other effect: telegraph lines were overloaded with geomagnetically induced currents (GICs). Some of the lines burned out, while others continued to function, though the telegraph operators had to wait until the storm had passed, if they didn't want to get shocked while keying messages.

The next time a storm like this hits us, it won't be just a curiosity. Rather, it will be a major catastrophe. Power lines will get knocked out, but not like in a normal power outage. We are all accustomed to going without power, sometimes for several days, usually because of extreme weather. The damage might be relatively local, or an entire region might be affected. Either way, repair crews from neighboring areas swarm in, and power is restored relatively quickly. But a geomagnetic storm isn't a regional event — it's global. What if power gets knocked out all over the world?

The obvious problem is that there aren't enough repair crews to fix everything at once. The less obvious (but far more sobering) fact is that replacement parts will be in short supply, first because of the huge demand, and second because of the power outages at the manufacturing plants. So how do we replace blown-out line transformers, without the electricity necessary to manufacture new ones? In essence, our power grid has become like an organism. If one organ is injured, resources are diverted from other organs to repair the damage. But if too many organs are damaged, there aren't the resources to divert. This is when organisms die. So too could our power grid die. And without electricity, we'll be in deep trouble. In 1859, people had no problem surviving without any new telegrams for a few days. But today, we will be hard-pressed to survive without electricity. If we all had fireplaces in our homes, we could all learn to chop wood to keep from freezing to death in the winter. But we have become so reliant on electricity that few people have fireplaces. Now what are we going to do?

The good news is that a lot of the damage can be avoided if we shut down the power grid prior to the storm. The strength of a GIC is a function of the length of the wires. The grid in its entirety makes one huge antenna. But with all of the switches open, it's just a bunch of little antennas, and the currents won't be as strong.

The bad news is that we don't know how to predict geomagnetic storms with sufficient confidence to order a global power-down, just in case it's another Carrington Event. Nor are we going to get that kind of capability with existing scientific strategies. The abstract and heuristic math that characterizes modern solar science is fine for after-the-fact rationalizations. But heuristics are bad at making accurate predictions, especially outside the range of what has already been recorded with modern instrumentation.

To know a Carrington Event in near real time, with confidence, just on the basis of solar imagery, we need a *mechanistic* understanding of solar flares and CMEs, such that we can derive accurate predictions from the fundamental principles, instead of just quantifying past observations. And we need this as soon as possible — *before* the next event. Hence there is a great sense of urgency amongst astronomers to gain such a capability, since few things could be as devastating as a world-wide power outage.

Surface

So now we turn our attention to the star about which we have the most information: our own Sun. Previous sections (Black Holes, Pulsars, and Nebulae) explained exotic stars as "natural tokamaks." But while the Sun is of far more interest to us, it is not what astronomers would call exotic. And it's not a tokamak. The Sun's average magnetic field is about 1 Gauss, which is merely twice the strength of the Earth's magnetic field. For an object with 333,000 times more mass, proportionally speaking that's 1/166,500 the field. So the organizing principle is not magnetism, nor electrodynamics. But being less exotic doesn't make it any simpler. We have far more information about the Sun than we do for distant stars, and in the fine grain detail, there are many things that don't make sense.

For example, Figure 37 shows the surface of the Sun "on the limb" (i.e., the horizon). Notice that the edge of the photosphere is very distinct, topped by the tenuous plasma in the chromosphere and transition region.[36] At the surface, there is a marked change in the fluidity of the plasma, from the liquid-like surface, to the gas-like atmosphere.

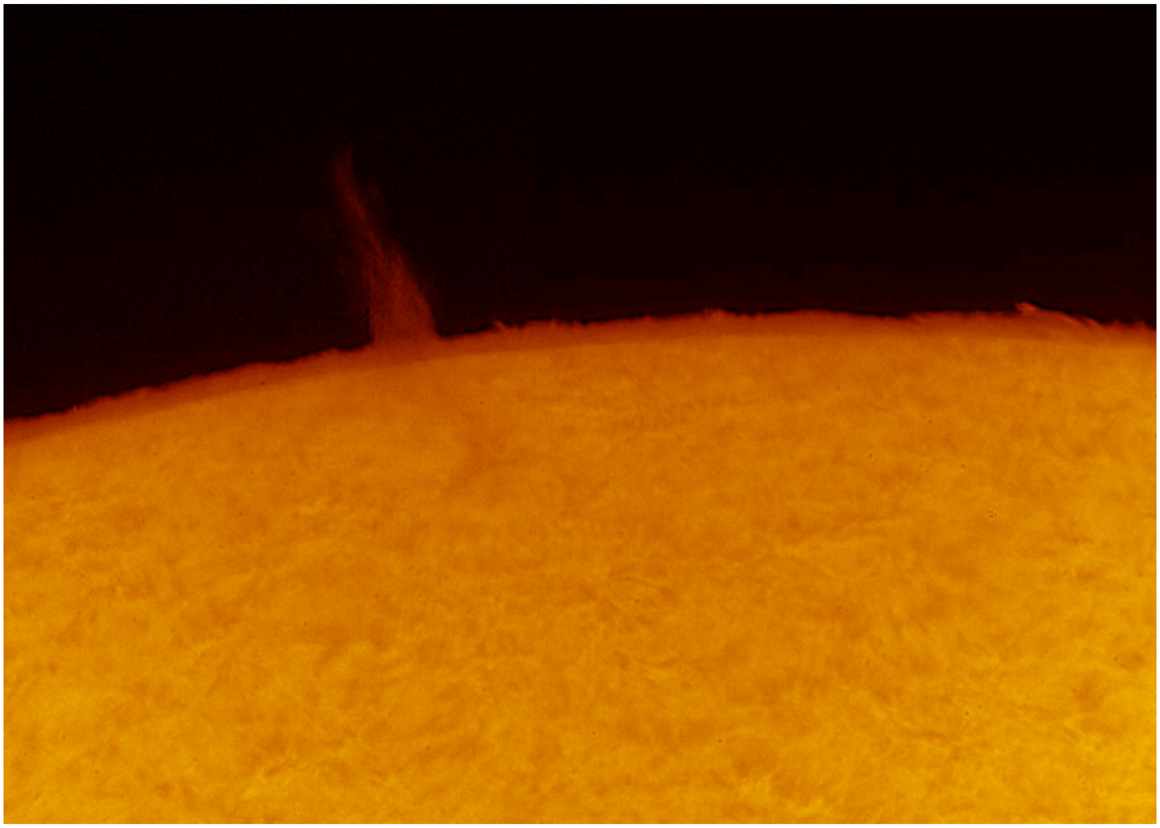

Figure 37. The solar limb seen in H-α (6563 Å), 2007-05-27, courtesy Fred Bruenjes.

The liquid-like behavior of the surface becomes more obvious when we take a closer look. After the explosive release of energy in a solar flare, surface waves have been observed.[37] This type of wave can only occur at the boundary between layers of dramatically different densities.[38:73] (See Figure 38.)

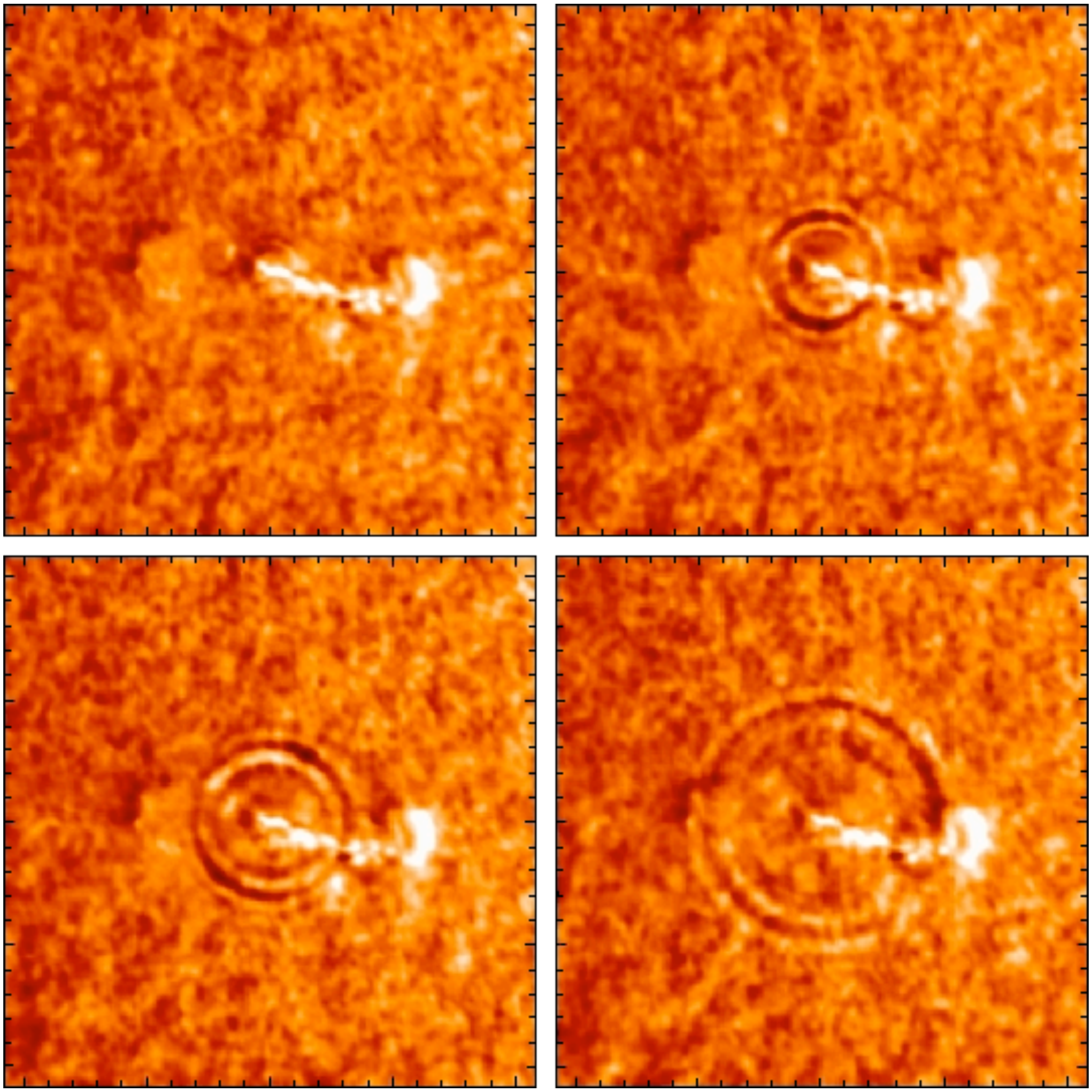

Figure 38. Waves propagating after a solar flare, 1996-07-09, courtesy [SOHO](). The images show an area 200 Mm across.

Yet in the standard model, a distinct surface just isn't possible. If the organizing principle is gravity, balanced only by hydrostatic pressure, the density gradient should be set deterministically by the ideal gas laws. (See Figure 39.)

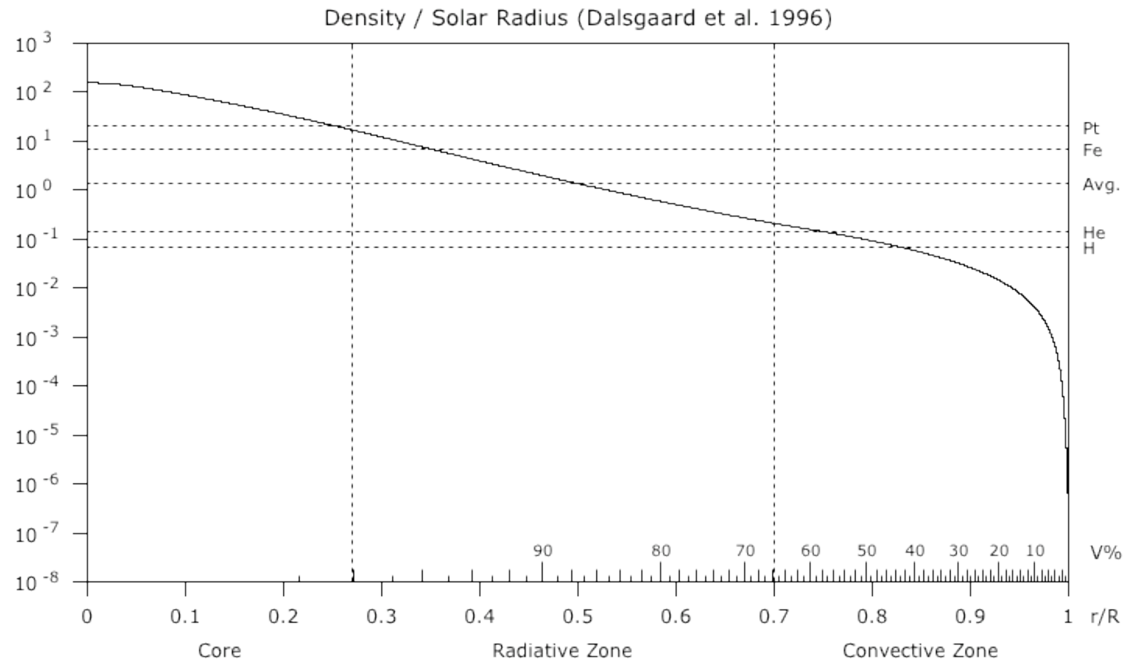

Figure 39. The density gradient of the Sun in the [Dalsgaard](#) model, based on the ideal gas laws, with gravity supplying the pressure, and with nuclear fusion in the core supplying the heat. The X axis shows the decimal of the solar radius starting from the center, and the percentage of the solar volume, starting from the surface. The Y axis shows g/cm^3. The densities of liquid platinum, iron, helium, and hydrogen are shown for reference. The average density of the Sun is $10^{0.15}$ = 1.408 g/cm^3 = 1408 kg/m^3.

The model density at 1.0 $R_\odot$ (i.e., at the surface) is 2×10^{-4} kg/m^3 (i.e., a good laboratory *vacuum*), increasing steadily to the density of STP air at a depth of 13.22 Mm. In such a smooth gradient, there is no distinct surface. Analogously, the Earth's atmosphere traverses the same gradient from the top of the mesosphere (i.e., the dashed red line in Figure 40) down to sea level.[39] In this traversal, there are changes in composition that can become visible under the right conditions.

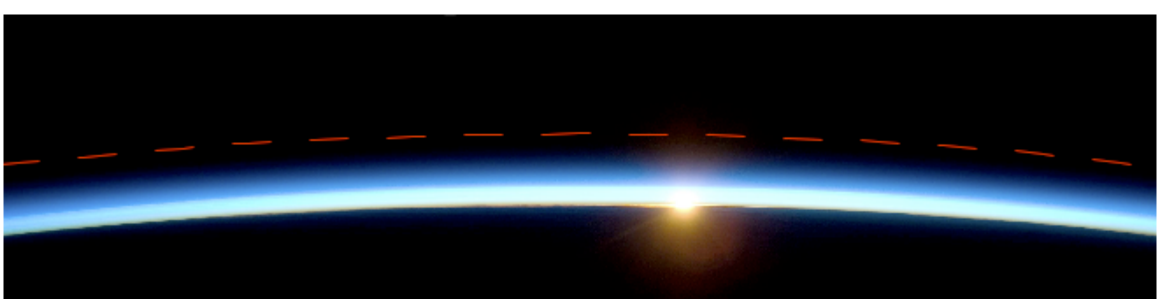

Figure 40. Earth's atmosphere back-lit at sunrise, courtesy NASA. The pale blue-green color is from water vapor in the troposphere. The dark blue is from nitrogen and oxygen in the stratosphere. The dashed red line shows the top of the transparent mesosphere.

And in the right conditions, waves in the Earth's atmosphere can form. (See Figure 41.)

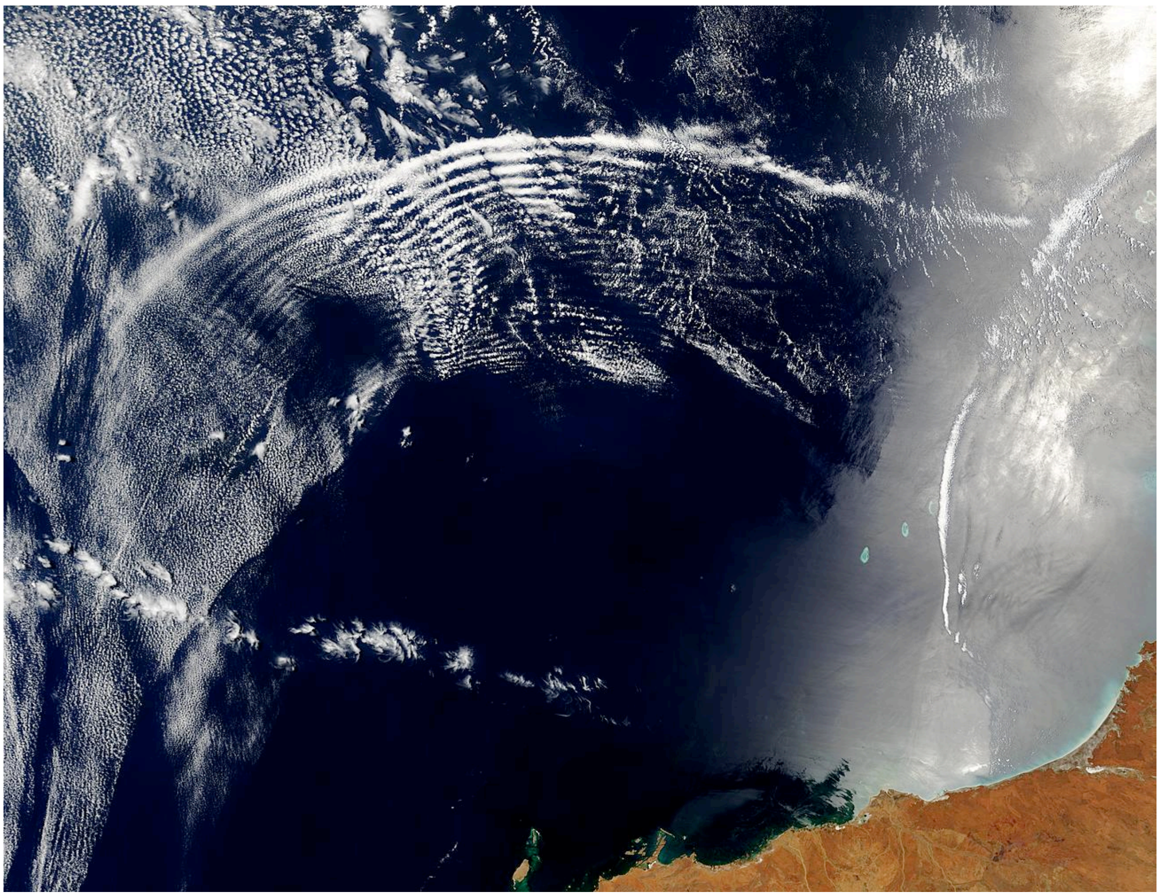

Figure 41. Gravity waves in the Earth's atmosphere off the coast of Australia, 2003-11-11, courtesy NASA.

But these are not surface waves, because the atmosphere has no distinct surface. Rather, these are "gravity waves" that move very slowly (typically at something like 10 m/s[40]). The solar surface waves begin at a supersonic speed, *and then increase*, which is characteristic of a fundamentally different type of wave.

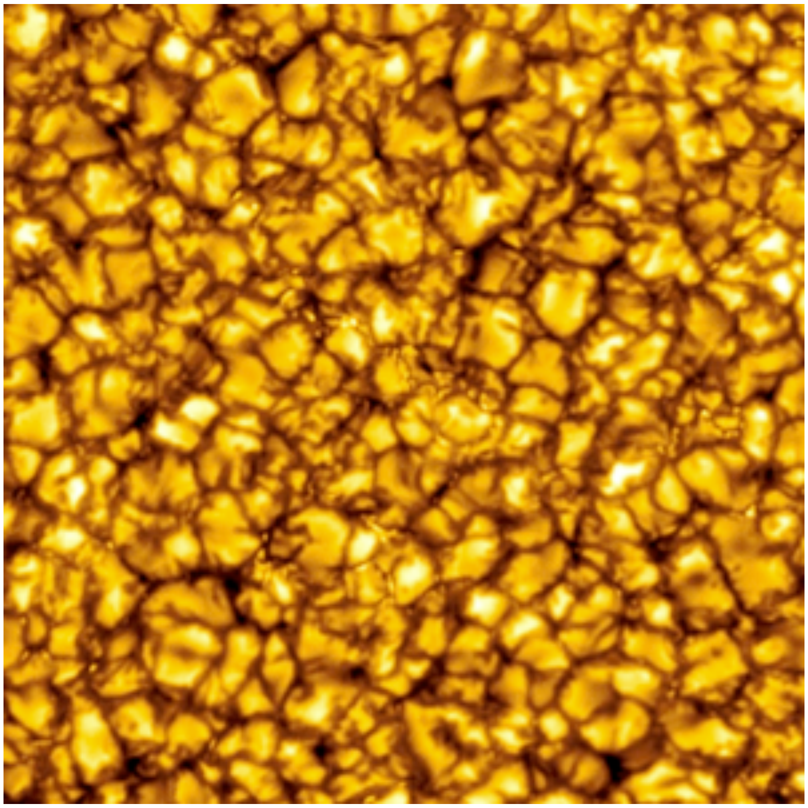

Figure 42. Granules observed at 4364 Å by the [Swedish 1-m Solar Telescope](), 2004-08-22.

While surface waves are rare, another form of hydrodynamics at the solar surface occurs all of the time (except when disrupted by sunspots): solar granules. (See Figure 42.) These have the appearance of thermal bubbles erupting onto the surface, as if an internal heat source was causing the matter to boil. While the granules are typically about 1 Mm across, the altitudes of the tops are very consistent, typically being within .1 Mm of each other. Such precision is not expected when matter boils in a smooth density gradient. We would rather expect that the larger bubbles would achieve a height above the norm in direct proportion to their size. Only a sharp drop-off in density at a surface can produce large and small bubbles that terminate at precisely the same elevation.

More telling is that the hydrodynamics in such granules have been simulated, but it took a steep drop-off in density to get the dynamics right.[41] (See Figure 43.) Clearly there are forces at work other than just gravity and hydrostatic pressure, or the density and pressure gradients would be straight lines on a log scale. So what are those forces?

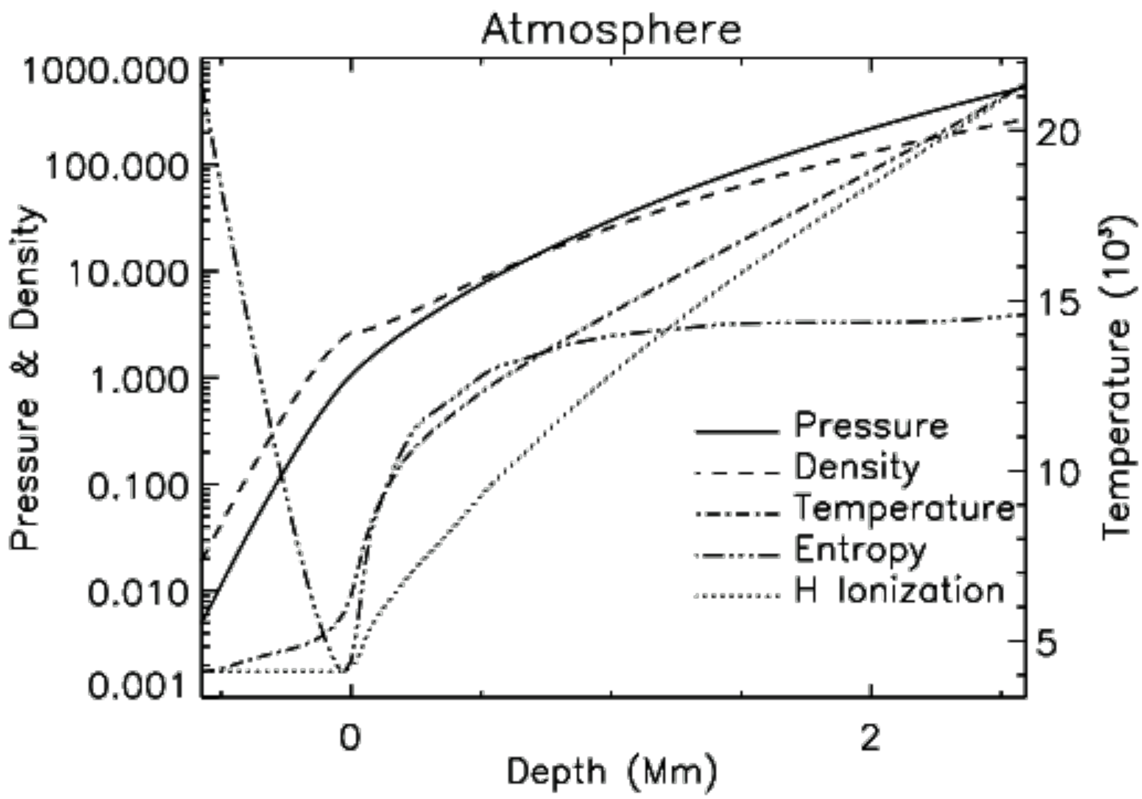

Figure 43. Density gradient necessary for simulating granules, courtesy Stein & Nordlund.

Since the ideal gas laws leave no room for reinterpretation, the only possible conclusion is that non-Newtonian forces are responsible for the density drop-off going from the photosphere out into the chromosphere. At the macroscopic level, there are two candidates: the electric force, and the magnetic force.

We can rule out the magnetic force by several lines of reasoning. First, the Sun's magnetic field averages 1 Gauss, which is merely twice the strength of the Earth's average field, and there is no distinct density drop-off in the Earth's atmosphere due to the magnetic force. Second, hydrogen plasma doesn't have much of a magnetic dipole, so it wouldn't respond much, even to a strong field. Third, if it did, the surface of the Sun would vary with the strength and polarity of the magnetic field, which it does not.

That leaves only the electric force. Since it's the only candidate, its presence need not be proved any other way. The next section will determine the configuration of the electric force responsible for such a distinct edge.

Interior

We know that for the electric force to have the influence described in the previous section, the top layer has to be charged.

We can also deduce with confidence that there has to be a strong field between it and an underlying layer. If the Sun only had one charge (positive or negative), the Coulomb force would simply add to the hydrostatic pressure, somewhat more vigorously, and the density would thin out over a much greater distance. The only way to get densely packed plasma that suddenly stops at its outer extent is with an opposite charge below that is pulling it down forcefully. Hence there have to be "current-free double-layers" (CFDLs), where opposite charges cling to each other, but something is preventing recombination.

CFDLs wouldn't seem possible in 6,000 K hydrogen, due to its excellent conductivity. But there are two known forces that can keep electric charges separate in the absence of electrical resistance. They are (obviously) the two other forces present at the macroscopic level: the magnetic force, and gravity. We already ruled out magnetism, so we'll investigate the effects of gravity.

It is well-known that at high pressures, plasma is ionized.[42] This is because of the Pauli Exclusion Principle, whereby no two identical fermions (i.e., particles with a half-integer spin, such as electrons) may occupy the same quantum state simultaneously. When the atoms are pushed too close together, and the electron shells of neighboring atoms overlap, the conflict forces the liberation of one of the electrons. The extra force required to do this accounts for the incompressibility of liquids.

Electron Degeneracy Pressure

$$P = \frac{\hbar^2}{20 m_e m_p^{5/3}} \left(\frac{3}{\pi}\right)^{2/3} \left(\frac{\rho}{\mu_e}\right)^{5/3}$$

where:

P	=	pressure
h	=	Planck's constant
m_e	=	mass of electron
m_p	=	mass of proton
ϱ	=	density
μ_e	=	electron/proton ratio

Under moderate pressures, the electrons so liberated don't go far. They are still attracted to the atoms by the electric force, and as soon as they can find adequate space between two atoms without shell conflicts, they come to rest. This space is provided by the random motions of atoms in a hot, high pressure plasma. But under extreme pressures, even the widest gaps afforded by random motions do not provide sufficient space for the electrons. As a consequence, there is more pressure on the electrons than on the +ions.

This is known as electron degeneracy pressure (EDP), and it causes the electrons to bubble up to a higher altitude, where the lesser density affords room for them.

The implication not typically considered in astrophysics is that a charge separation has occurred, creating current-free double-layers (CFDLs), where a powerful electric field attracts the layers to each other, but EDP prevents recombination. So we need to work out the implications of CFDLs inside the Sun.

The inner layer is positive, due to the expulsion of electrons under extreme pressure. The liberated electrons congregate at a higher altitude. But that isn't the end of it. The negative layer so produced might go on to induce a positive charge in the layer above it, which will likewise be a CFDL, still in the presence of excellent conductivity. The positive double-layer will be attracted to the negative layer, but repelled by the positive layer below that (i.e., the one created by EDP), and all three will be stable in a positive-negative-positive (PNP) configuration. Such layers created simply by induction can continue *ad infinitum*, though in spherical layers, the charge density relaxes with each inversion. At some point away from the primary charge separation, the next induced double-layer will not be bound firmly enough to stay organized.

So we have deduced with confidence the following facts.

- The electric force is responsible for the extreme density of the photosphere compared to the chromosphere.
- The photosphere is electrically charged.
- There is at least one other layer below it, with the opposite charge, supplying the force necessary to compress the photosphere far beyond the expectations of the ideal gas laws.
- The primary charge separation mechanism is electron degeneracy pressure (EDP), setting up the first two current-free double-layers (CFDLs). Additional layers might also be caused by induction.

We can also deduce the sign of the photosphere's charge, and the relative strength of its charge compared to the underlying layer. There are six possible configurations. There are two possible stacking orders (positive over negative, or negative over positive). Then there are three variations for the relative strengths of the charges (top layer is stronger, underlying layer is stronger, or the charges are perfectly matched).

We can dismiss the possibility that the top layer has more charge, since the excess charge would simply drift away.

We can also dismiss the possibility that the charges are evenly matched. In CFDLs, the electric field between the layers is greatest at the boundary between them. Moving away from the boundary, the field density diminishes, because of the increased distance from the opposite charge, and because of repulsion from like charges in the same layer. (See Figure 44.) Analogously, in a heavy element, the outer electrons are loosely bound, because of distance from the nucleus, and because of repulsion from electrons in inner shells. The same is true of plasma double-layers. The significance is that with equally matched charges in the solar double-layers, the density of the top layer would still relax gradually to nothing at some distance away. So the distinct limb proves that the underlying charge has to be more powerful, and the top layer has only its densest component. (See Figure 45.)

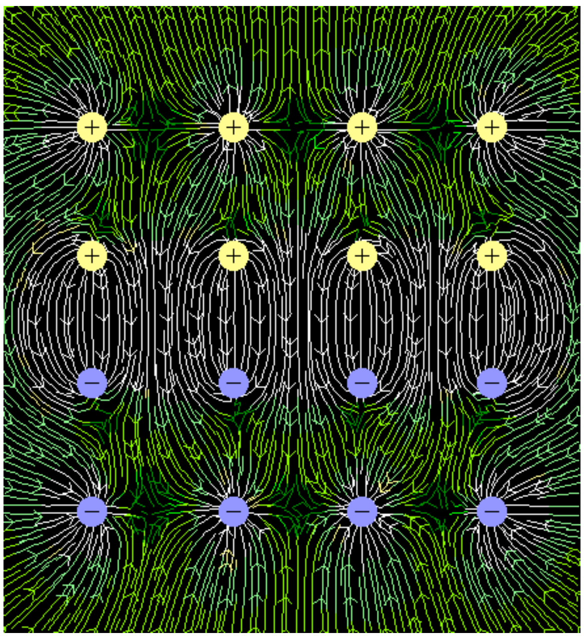

Figure 44. Evenly matched charges.

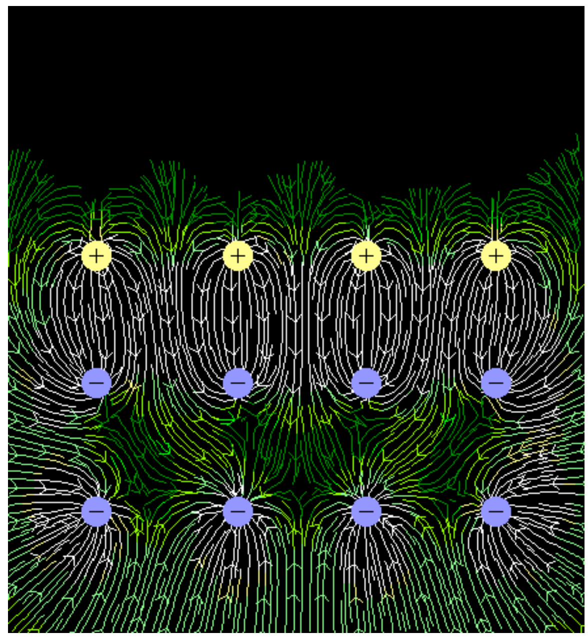

Figure 45. Lower layer more powerful than upper.

This leaves only two possible configurations, depending on the stacking order (positive over negative, or negative over positive).

First we'll consider that the underlying layer is positive. If so, it would easily strip all of the excess electrons from the overlying layer, since they would all be unbound at 6,000 K. Neutral atoms left behind would form a gravitational gradient, tapering off to nothing at infinity. So the underlying layer cannot be positive.

The only remaining possibility is that the underlying layer is negative. As such, it will attract positive ions, and ionize neutral atoms to pull in the positive charges that it wants. Excess electrons above such a layer will be repelled by the net negative charge, and thus will not obstruct our view. Hence the distinct limb reveals the extent of a positive double-layer being held down tightly to a far stronger negative layer. The heavy +ions then support hydrodynamic behaviors, where momentum is a considerable factor, and which wouldn't be if the surface was negatively charged.

If the surface is positive, held down to an underlying negative layer, and if the driving charge separation mechanism is EDP (which produces a positive layer with an overlying negative layer), there have to be at least three layers. EDP creates a lower body of positive ions, with the expelled electrons forming a negative layer above that, and then there is a positive double-layer around the outside, whose charges were simply induced by the proximity to a negative layer.

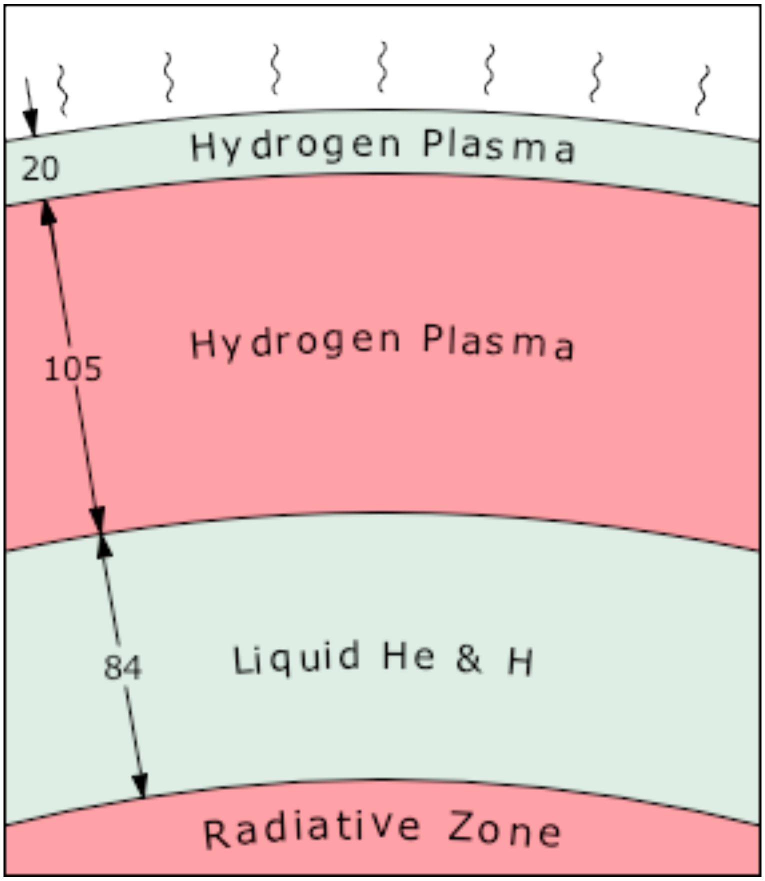

Figure 46. Convective zone layers. Red = negative; green = positive. Dimensions are in Mm.

Figure 46 depicts this charge configuration. For reasons presented in the next section, these three layers occur entirely within the convective zone, with the degenerate layer being the lower 84 Mm, topped by an electron-rich 105 Mm layer in the middle, and with a 20 Mm induced positive layer at the top.

Note that the extra force coming from EDP, and the resultant charge separation, provides an explanation for recent high-precision measurements that revealed that the Sun is not as oblate as it should be.[43] The equatorial velocity (~2 km/s) should produce a centrifugal bulge, but it doesn't. There is no possible solution to this using Newtonian mechanics. If we asserted that the plasma near the surface was heavier than in the standard model, it would be held down more forcefully by gravity, but it would also have more inertial force, meaning a corresponding increase in centrifugal force, and the bulge would still be there. Somehow, the centripetal force is being increased, *without an increase in centrifugal force*. This can only be proof of a force that does not vary with mass, and which can only be the electric force. This only makes sense in a model based on CFDLs.

Hence by fully processing a few simple facts, we gain a lot of information about the structure of the Sun, at least near the surface. This begs the obvious question of why such reasoning has not been considered before. If it *has*, it was surely rejected because of the implications. The principles of degenerate matter don't just modify the density gradient at the surface — they deterministically dictate different densities throughout the Sun, especially in the core. Full consideration of *those* implications leads to a totally new model of the solar interior, with a radically different energy source. This is a bit much for established scientists who have already made a name for themselves within the existing paradigm. But if the data mandate it, this is the road that we must choose, because all other roads will eventually end in impasses.

Elements

The previous section established that electron degeneracy pressure (EDP) has to be taken into account if we are to understand the solar surface, since it is the only way that current-free double-layers (CFDLs) can be established in the excellent conductivity of 6,000 K hydrogen plasma. Since the primary charge created by EDP is positive, with a negative layer above that, and since the surface is positive, there have to be at least three layers in the Sun: positive at the bottom (caused by EDP), negative in the middle (from the expelled electrons), and an induced positive layer at the top. The previous section showed a PNP configuration all within the convective zone. (See Figure 46.) The reasons for this will be presented later in this section. But for now, we have to consider the implications of the simple fact *that* there is another source of pressure, other than just hydrostatics.

In Figure 39, which predicts the density of the Sun by the ideal gas laws, given the model temperatures, which assume that the heat source is nuclear fusion in the core, we see that at roughly 0.5 $R_\odot$ the plasma has been compressed to the density at which the K shells of hydrogen atoms overlap (i.e., 1408 kg/m^3).[44§8] Further compression would, of course, require the ionization of the hydrogen.[42] And of course, at the model temperatures, the hydrogen is already ionized, so it isn't compression that is forcing the ionization (if the model temperatures are correct). But further compression *will* invoke EDP, since the wave functions of the electrons will be in conflict, and thus the supercritical fluid will become electron-poor. The resulting Coulomb force between the atoms produces a repulsion. The problem for the standard model is that this repulsion is not taken into account, and in Figure 39, all of the density above $10^{0.15}$ g/cm^3 shouldn't be there. And the problem with *that* is that it reduces the overall mass of the Sun, leaving no way to account for the 1.99×10^{30} kg as measured. So something is wrong with the standard model.

There's really only one possibility here — to get more mass packed into a tighter space, without any additional force, we have to go with matter that has already been compacted beyond the Coulomb barrier and fused into heavier elements, which no longer need additional pressure to stay at that density.[38:76]

How much heavier?

Simple calculations show that if the average density of the convective zone is that of liquid hydrogen, the average density of the core and radiative zone combined has to be 52 times greater.[45] Iron's atomic mass is 55 times greater than hydrogen's, so at first blush, we might think that everything below the convective zone is just liquid iron. But there are two reasons for thinking that it isn't that simple.

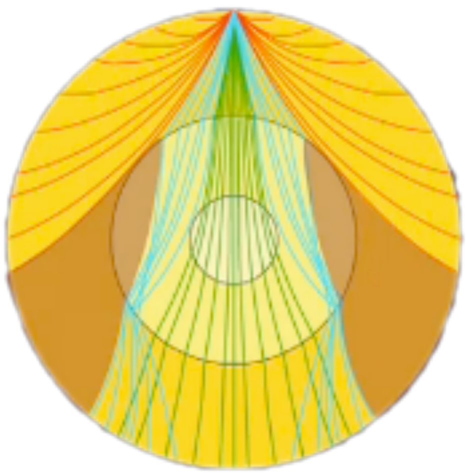

Figure 47. Seismic shadows due to differences in density.

First, helioseismology reveals a distinct boundary at .27 $R_{\odot}$ that wouldn't be there if it was just one element below the convective zone. (See Figure 47.) So there must be an even heavier element in the core.

Second, we can see in Figure 39 that most of the radiative zone is above the density of liquid iron, which means that it's plasma, lighter than liquid. This makes sense if the temperature inside the Sun is at least 6000 K, because iron is only liquid below 4000 K at that pressure. And if most of the iron is plasma, lighter than liquid, something much heavier than iron has to be in the core to make up the total mass of the Sun.

So with hydrogen & helium in the convective zone, there are at least two other elements in the Sun (i.e., something heavier in the radiative zone, and something much heavier in the core).

Which elements?

We can guess at combinations of elements that might make up the mass of the Sun, but there is another type of data that can be taken into account that produces interesting results. In 1989, Anders & Grevesse did an excellent study of the spectrum of the Sun, detecting 92 elements.[46] On the basis of the intensity of the spectral lines, they estimated the abundances of each element. (See Figure 48.)

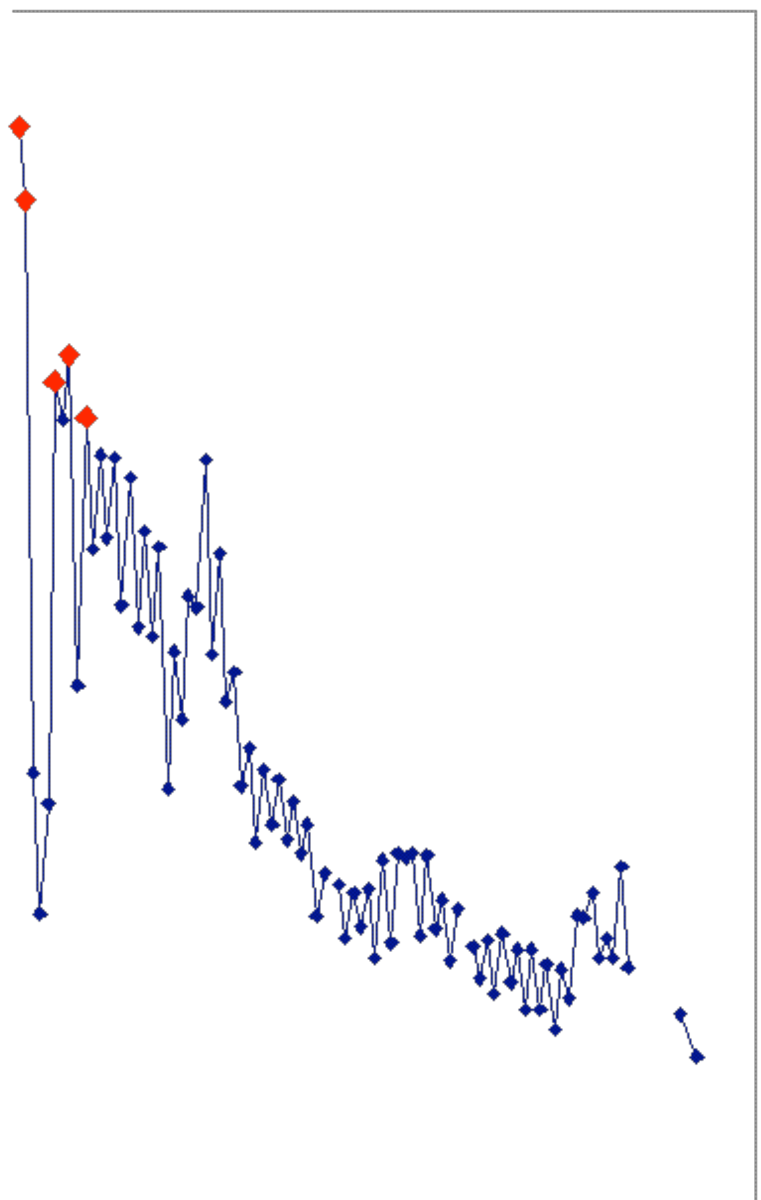

Figure 48. Abundance of elements in the photosphere, dominated by hydrogen ($10^{10.45}$) and helium ($10^{9.46}$), based on the intensity of spectral lines.

This only tells us the abundances in the photosphere. But if there are traces of heavier elements in the photosphere, there are probably much larger quantities of those elements deeper in the Sun, assuming that most of the heavier atoms settled to the bottom.[47,48] In other words, if we were to estimate the composition of the Earth, and all we had was information about the troposphere, how would we go about it? The raw numbers tell us that the troposphere is 78% nitrogen, 21% oxygen, and 1% trace elements. But even if compressed by gravity into liquids, nitrogen and oxygen would still be too light to make up the total mass of the Earth. So there must be heavier elements in the Earth. Which elements? Having no other information, we can only look at the 1% trace elements, and assume that there are a lot more where those came from. Hence our best guess will be to re-scale the abundances, making up the missing mass by increasing the estimates of the heavier elements.

Figure 49 shows the Anders & Grevesse abundances, resorted by liquid density, and with the heaviest on the left. (All of the labels are clearly legible in the 11x17 PDF.) The dashes represent a new baseline that would greatly increase the abundances of heavier elements to get up to the target density of 1408 kg/m^3. Hydrogen and helium still dominate, but there are also large quantities of iron and nickel. (Note that these calculations assume that all of the elements have been compressed to their liquid densities, which will be justified in the next section.) The resulting plot of density per solar radius is shown in the lower panel.

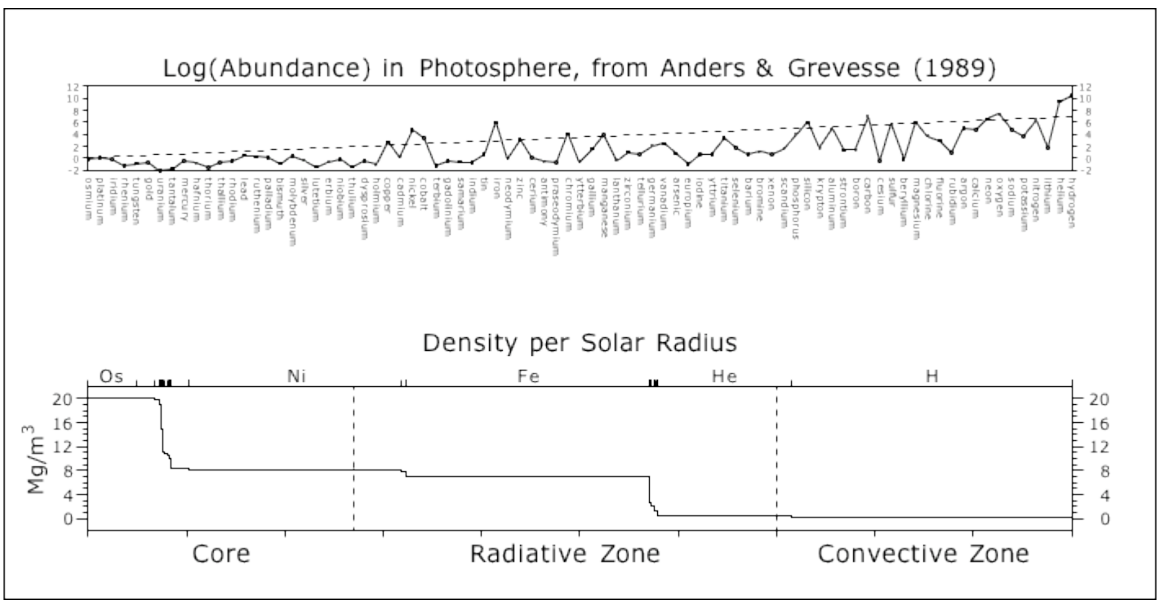

Figure 49. Abundances with linear correction for mass separation. (See the [11x17 PDF version](#).)

In the lower plot we can clearly see two large steps in density, from 1st period elements (hydrogen & helium) at the top, to 4th period elements (iron & nickel) in the middle, to 6th period elements (platinum & osmium) at the bottom. This is interesting because helioseismology tells us that there are 3 distinct densities in the Sun: the convective zone, the radiative zone, and the core (as in Figure 47). But the steps in Figure 49 don't match up with the helioseismic boundaries. This suggests that we have the right idea, but we just need to fine-tune it a little bit. We have no reason to believe that the effects of mass separation have to be precisely linear. In order to know exactly how gravity stratifies elements in the Sun, we'd also have to know what is stirring up the mix, and this is information that we do not have. So it's possible that the correction factor should be some sort of curve.

With heuristics it was determined that the simplest curve that gets the density steps to fall at the right places is a cubic Bezier with 2 control points. (See Figure 50.)

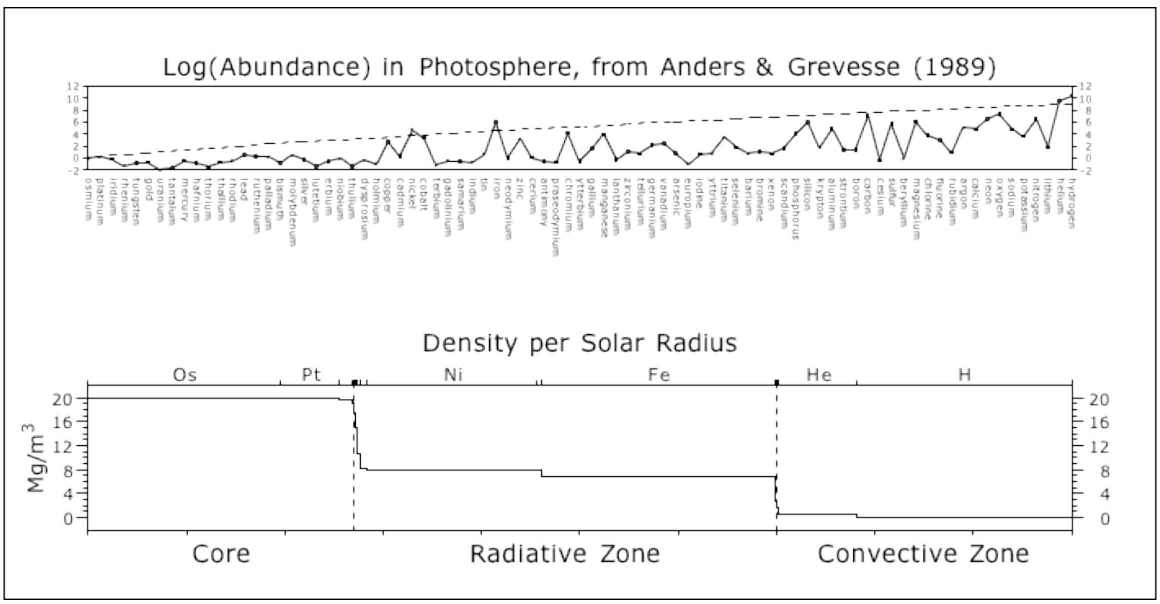

Figure 50. Abundances with a Bezier correction for mass separation. (See the 11x17 PDF version.)

The slight degree of curvature in the new baseline is barely visible in Figure 50, but can be more clearly seen in Figure 51. (Note that the figure shows the curve inverted, as it was used to subtract from the raw log values, as opposed to the baseline in Figure 50. The tick marks on the X axis are for the same element list, sorted by liquid density, with the heaviest on the left.)

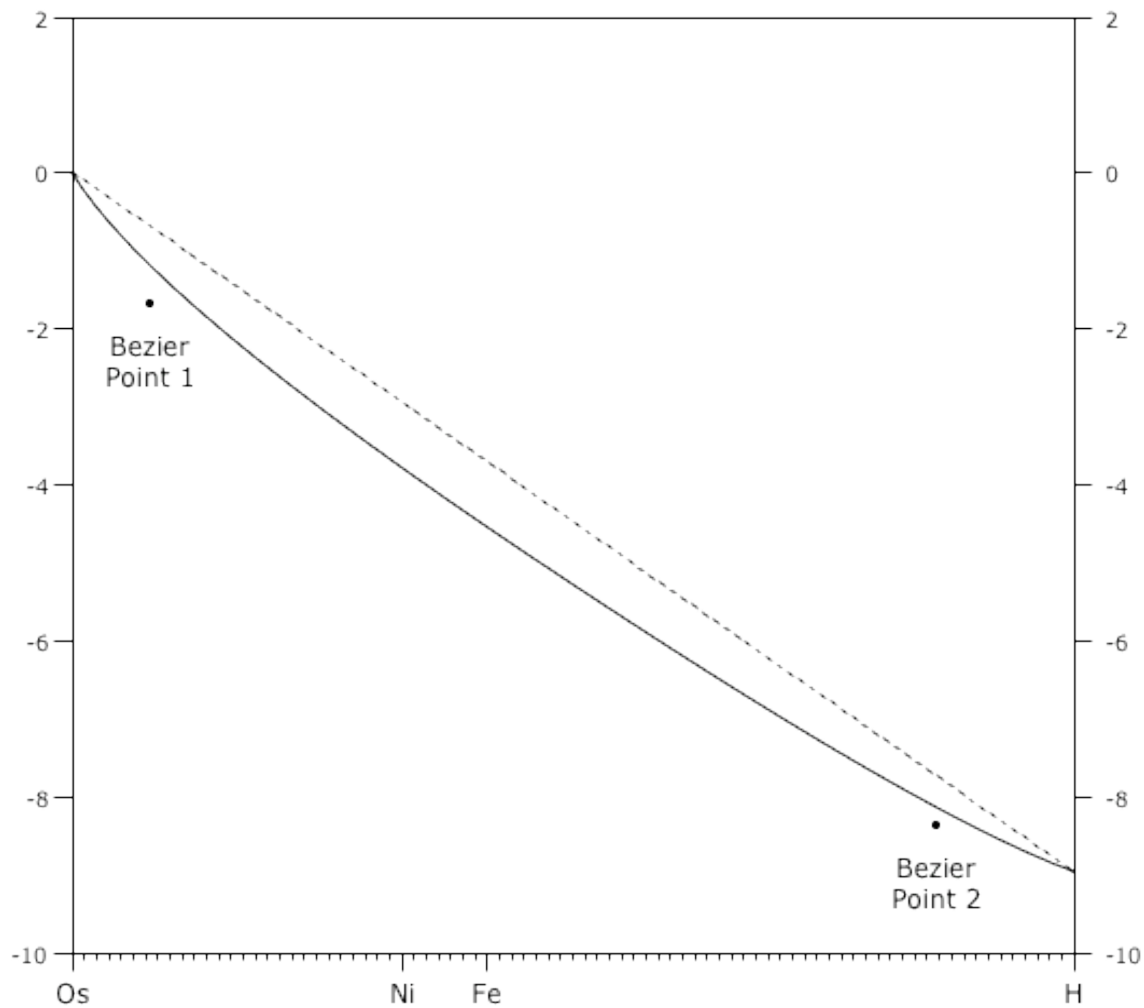

Figure 51. Bezier curve used to re-weight the Anders & Grevesse abundances.

Figure 52 shows these densities plotted on a log scale, compared to the Dalsgaard model densities.

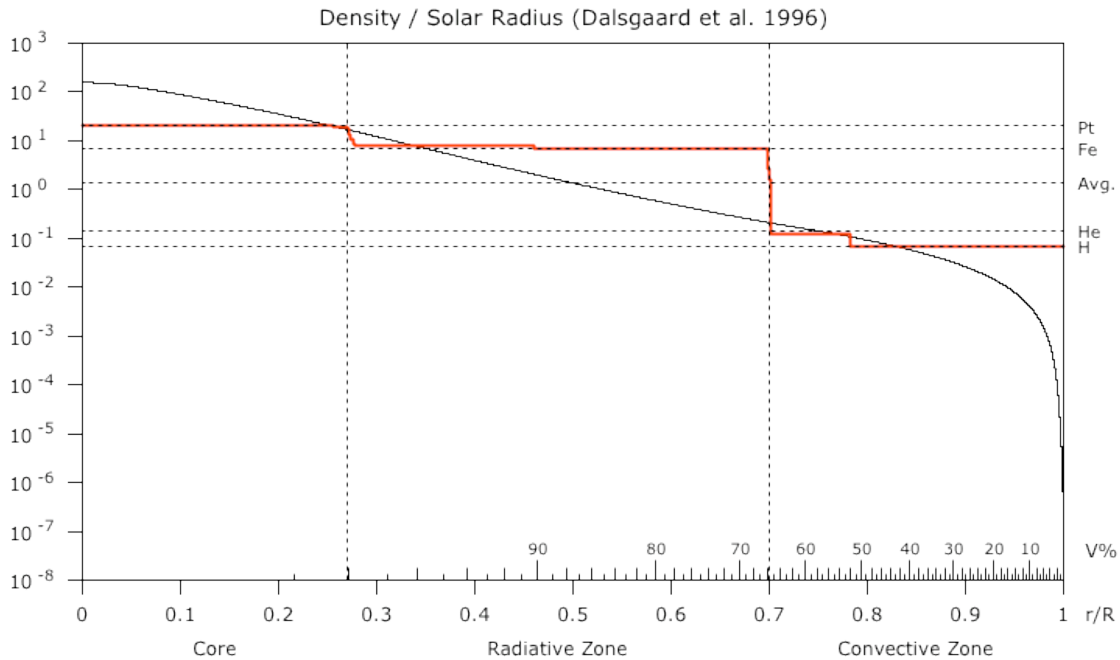

Figure 52. Comparison of density of heavy elements (thick colored line) to the Dalsgaard model densities.

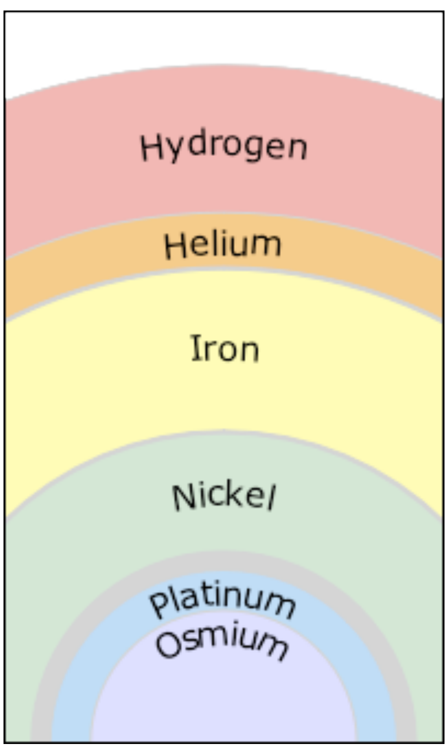

Figure 53. Solar elements.

As mentioned above, these calculations assumed that all of the elements have been compressed into liquids. This actually produces *too much* mass. Yet only in the core, and in the bottom of the convective zone, is the pressure sufficient to liquify the elements there. So the flat-line densities of iron and hydrogen above their liquid lines in Figure 52 should actually have about a 2° slope.

The net result is a fundamentally new conception of the solar constitution, which yields the correct overall density, with gravity supplying the centripetal force and without requiring additional force to fight EDP, and which produces helioseismic shadows at the correct solar radii. (See Figure 53.) We can then test this model, to see if the expected properties match up with the observations.

Potentials

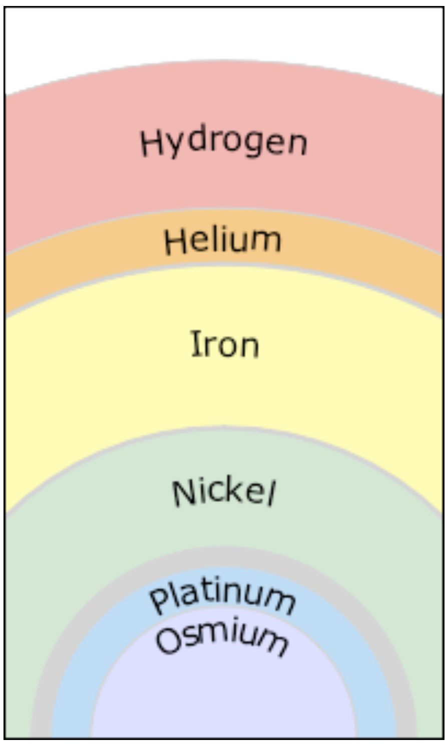

Figure 54. Solar elements.

The previous section established that when electron degeneracy pressure (EDP) is taken into account, the overall mass of the Sun can only be achieved if there are heavier elements below the convective zone. (See Figure 54.) This is problematic for the energy budget in the standard model, which asserts that nuclear fusion in the core is responsible for the 3.86×10^{26} watts of EM radiation that continually stream out of the Sun.[49] The model pressure (i.e., 2.35×10^{16} N/m^2) and temperature (i.e., 15 MK) would certainly cause *hydrogen* fusion. But what if that isn't hydrogen in the core — what if it's *osmium*? The fusion of elements heavier than iron consumes more energy than it releases. So if the core and the radiative zones are made up of iron or something heavier, and if fusion is occurring in the core, it isn't an energy source — it's an energy *sink*. So the standard energy budget is gone and then some. But realistically speaking, if this is correct, we need not include such a sink in the new energy budget, because core fusion in not likely anyway. The force necessary for nuclear fusion goes up exponentially with the atomic number, hence the temperature would have to be exponentially higher. But that presents two more impossibilities.

1. The gravitational force to maintain the density at that temperature isn't present.
2. If there *were* temperatures up to the task in the core, thermal conduction would transport even more heat to the surface, and the net output of 3.86×10^{26} watts would be too low.

So the present model rules out core fusion. This, of course, does not mean that *no* fusion is occurring. Judging by the solar neutrino flux, fusion is responsible for 1/3 of the Sun's power.[50] It just means that fusion isn't occurring in the core.

Note that researchers committed to the "fusion furnace" model consider the low neutrino count to be proof that neutrinos spontaneously change flavor, such that in the time it takes them to reach the Earth, 2/3 of the electron neutrinos have changed into muon or tau neutrinos, which are not detectable.[51] But modifying a theory to absorb an anomaly, and then calling the anomaly proof of the theory, is circular reasoning. *Independent* proof has not been established, and without it, that's just an unverified hypothesis. If we take the data at face value, we are still in search of something that can cause 2/3 of the solar output.

This leaves us with two questions.

1. What is the source of the other 2/3 of the energy?
2. What are the conditions responsible for fusion, if not core pressure?

If we revisit the density gradient shown in Figure 39, we find another form of potential energy that needs to be investigated. Any hydrogen below the midpoint in the convective zone has been compressed into liquid, and most of the helium is similarly in liquid form. The iron and nickel in the radiative zone are above their liquid densities, but the platinum and osmium in the core are both below their liquid densities. If electron degeneracy begins at the liquid density, the core and the lower half of the convective zone are positively charged (green in Figure 55). Outside of these layers, the electrons expelled from the liquids will congregate, attracted to the positive charges, but not able to neutralize them because the density won't allow it (red in Figure 55). At the top of the convective zone, there is a layer of induced positive charge (blue in Figure 55). Hence there are 5 layers of alternating positive and negative charges.

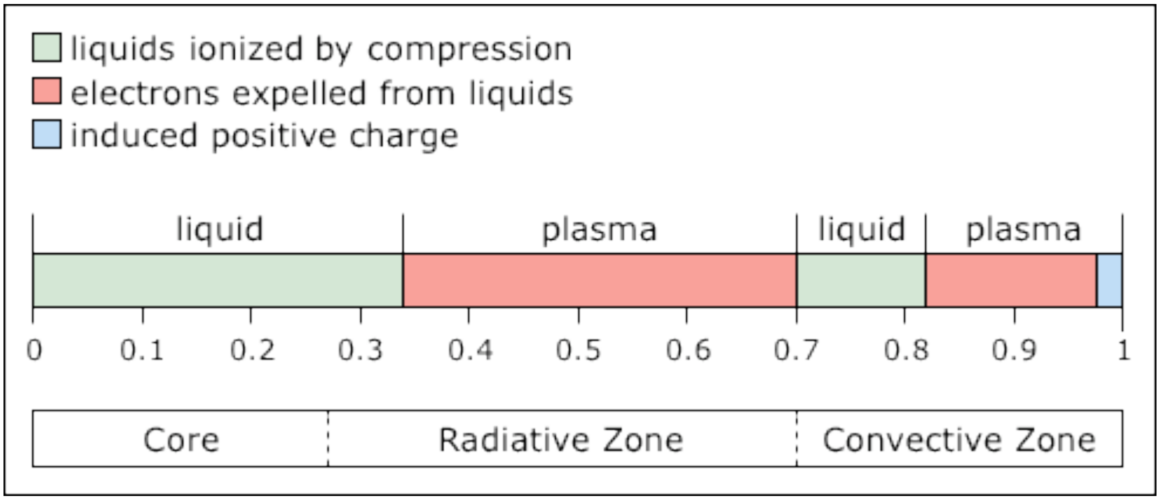

Figure 55. Layers of charge in the Sun, due to compressive ionization and induction.

The significance is that the electrostatic potentials between these layers will be enormous. In the excellent conductivity of supercritical fluids, we'd think that the charges would spontaneously recombine. But the prime mover is gravity, which invokes electron degeneracy pressure (EDP). Since the force of gravity is constant, the potentials should be stable, as long as nothing disrupts the layering. Yet the Sun is a very dynamic thing indeed, and we can expect constant disruptions. These will enable electric currents that will release heat and light. So we'll investigate the possibility that the primary energy source is gravitational potential that has been converted to electrostatic potential, and which is getting released by electric currents as the layers are disrupted.

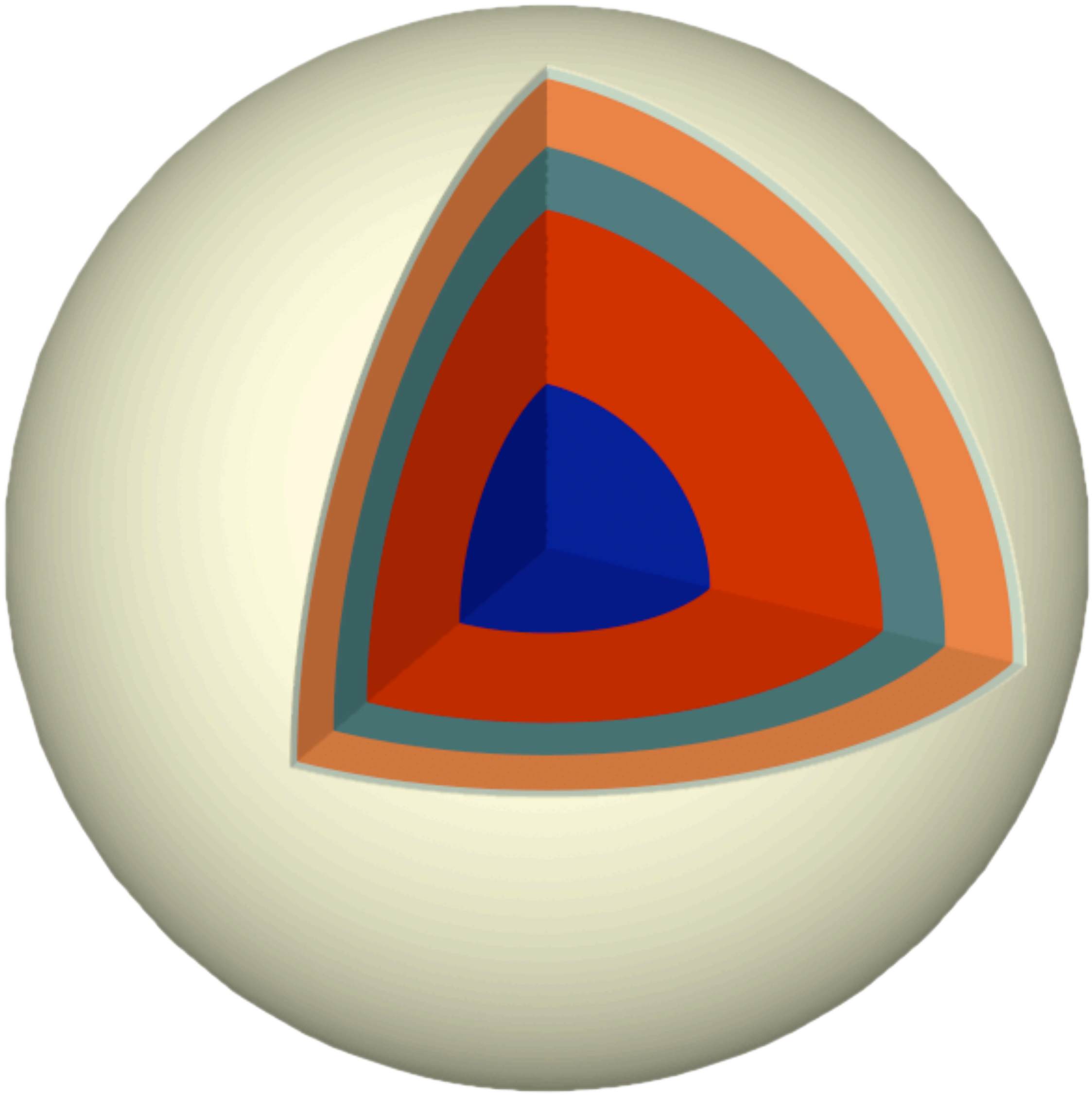

Figure 56. The proposed 5 layers of charge that are created by electron degeneracy pressure, given the proposed abundances that have been mass-separated, and the hydrostatic pressure from gravity. The electric force between oppositely charged layers further compresses them into the final equilibrium.

Blue	*= positive osmium, platinum, & nickel*
Red	*= negative nickel & iron*
Green	*= positive helium & hydrogen*
Orange	*= negative hydrogen*
Yellow	*= positive hydrogen*

If attributing the solar output to electrostatic discharges provides a more accurate description of the observable characteristics of the Sun, the "fusion furnace" model is displaced, and we are left with a new question: what are the internal temperatures, if they are not dictated by the fusion energy budget? We would have no reason to suspect that the core temperature would be any higher than the temperatures in the layers much nearer the surface that are hosting the discharges. They might even be lower, since the electric force in charge-separated matter removes degrees of freedom.[52] So in essense, thermal potential has been converted to electrostatic potential, and all of the energy gets converted back to heat when the charges recombine.

The implication of this is that the heavy elements might not be hot enough to be highly ionized just because of the temperature. If so, we can expect them to behave as incompressible liquids. This is why the elements in the solar interior were based on liquid densities.

And note that with this, we can now account for the acceleration of the surface waves in Figure 38. If the surface is positively charged, the electrostatic repulsion between positive ions constitutes a resting force that is always there. If a wave is induced, these ions will not wait until they actually collide before transferring force. In fact, the electric force is so powerful that the ions never even collide. Rather, they exert force on each other as soon as the distance between them changes. So the waves are not limited to the speed of sound, but rather, the speed of light, minus the inertial forces in the ions themselves. This is why the waves accelerate instead of instantly reaching peak velocity.

Conversions

The next step is to identify where, exactly, the electrostatic potentials in the Sun are getting discharged. Then we'll estimate the power in those discharges, and see if it matches the known 3.86×10^{26} watts of output from the Sun.

The first observable evidence of a solar heat source that we'll consider is the supergranules. These are thermal bubbles that rise at ~.4 km/s, and are typically 30 Mm across. Their nature is poorly understood, but we can get a rough idea of their origins just by their dimensions. The width of a thermal bubble is a function of the depth from which it originates, because during its ascent, smaller bubbles merge into larger ones that rise with less friction. Typically a bubble traverses a depth that is 4 times its width. So if the supergranules are 30 Mm wide, we can guess that they originate from 120 Mm below the surface. And what is going on at that depth?

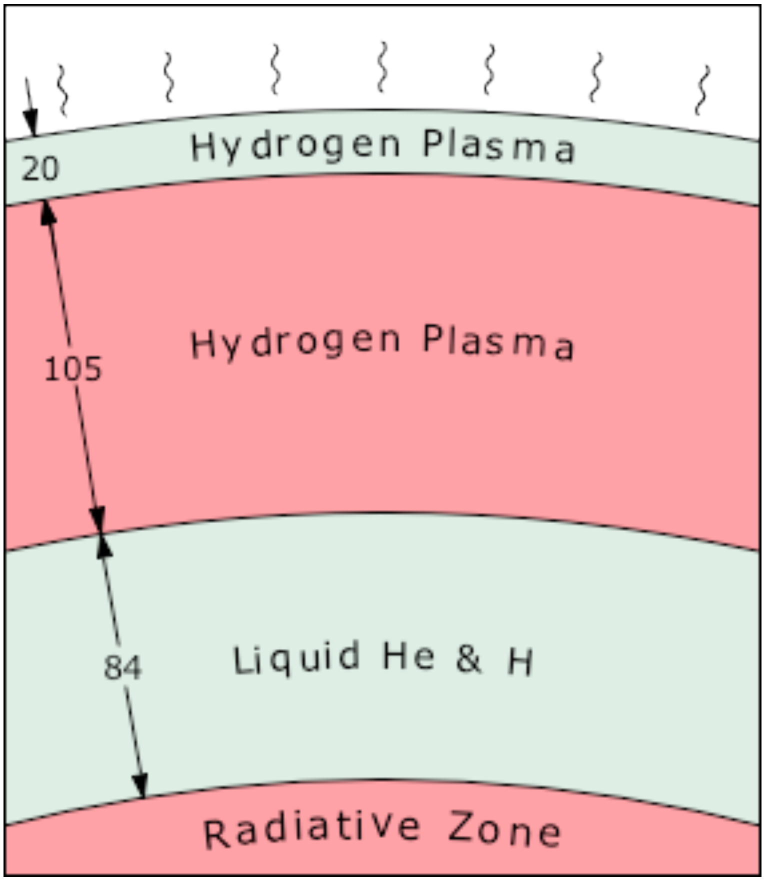

Figure 57. Convective zone layers. Red = negative; green = positive. Dimensions are in Mm.

In the Elements section we observed that at roughly .83 $R_\odot$ the pressure becomes sufficient to compress hydrogen into a liquid. (See Figure 57.) This is 125 Mm below the surface, so the liquid hydrogen threshold appears to be the origin of the supergranules.

Why would there be a heat source at the transition between plasma and liquid?

In the Potentials section we noted that whenever an element is compressed beyond its liquid density, electron degeneracy pressure (EDP) begins to separate the charges. So in addition to the state change at the liquid threshold, there is also a difference in electric charge. Below the threshold, the supercritical fluid is positively charged. Above it, the plasma is negatively charged, as that is where the expelled electrons accumulate. Across this threshold, the electrostatic potential will be enormous. So the release of that potential could be the supergranular heat source.[53,54§5.3]

All other factors being the same, this gravitational charge separation should be stable, and none of the potential will be discharged. The electrons were expelled from the supercritical fluid because there wasn't the room for them between the atoms. If the pressure doesn't change, the charge separation will not change.

The corollary is that electrostatic discharges under these conditions will be triggered if the pressure *does* change. Since supergranules are evidence of a heat source at roughly the depth of the plasma~liquid boundary, it appears that something is, in fact, altering the pressure. It certainly isn't fluctuations in the gravitational field. But waves (G, P, or S) inside the Sun cyclically alter the pressure. Such alterations occurring precisely at the threshold for EDP will alternately ionize and de-ionize matter. The de-ionization (i.e., electrostatic discharges) will produce heat.

Of the types of waves that could make the pressure fluctuate, s-waves are the most interesting, as only they can explain the full complement of characteristics associated with supergranules. First, they have the ability to generate electrostatic discharges, because the crests and troughs of the waves repeatedly cross the threshold for EDP. Above the line, charges can recombine. Below the line, charges are separated again. This generates an alternating current, where ohmic heating initiates thermal bubbles.

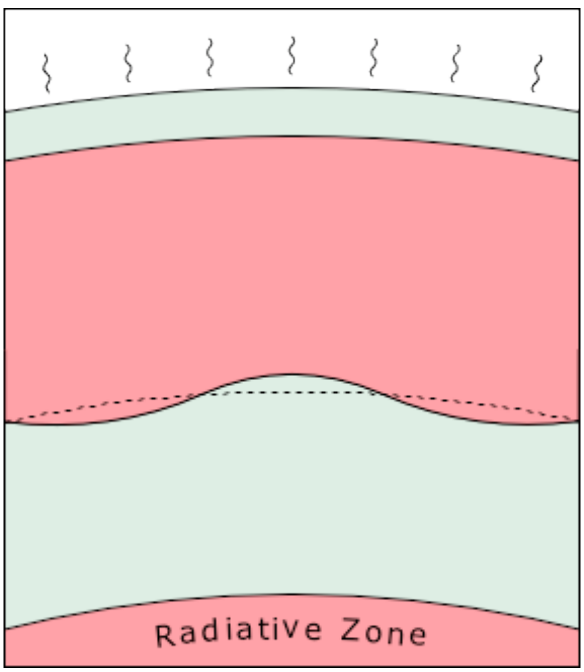

Figure 58. S-waves at the liquid line elevate the supercritical fluid above the threshold for plasma.

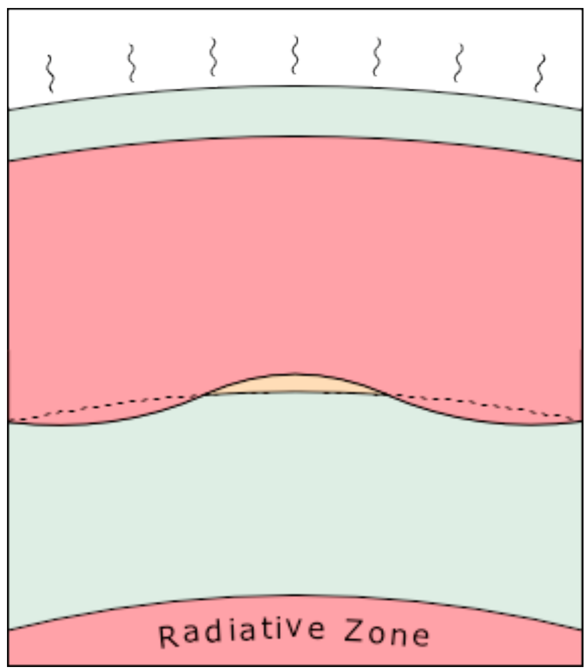

Figure 59. The reduction in pressure allows electron uptake, generating heat.

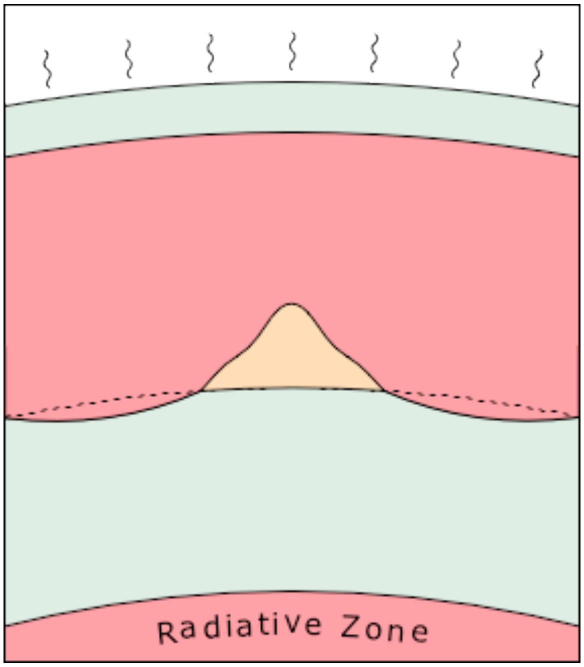

Figure 60. The heated plasma forms into a thermal bubble.

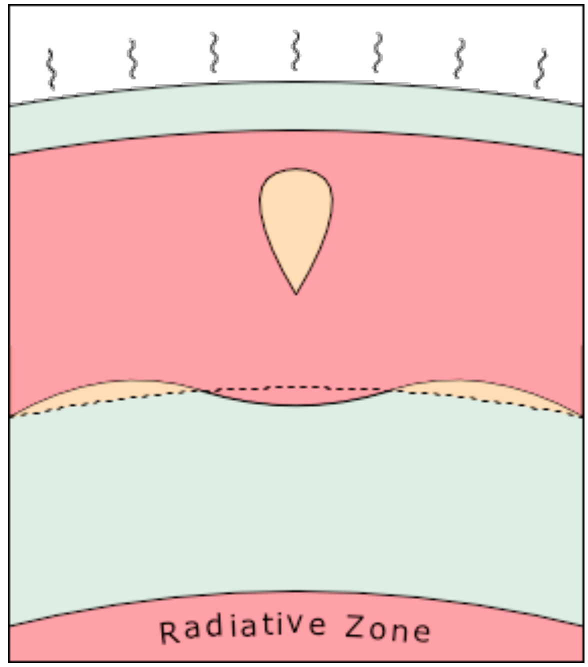

Figure 61. The thermal bubble rises to the top as a supergranule.

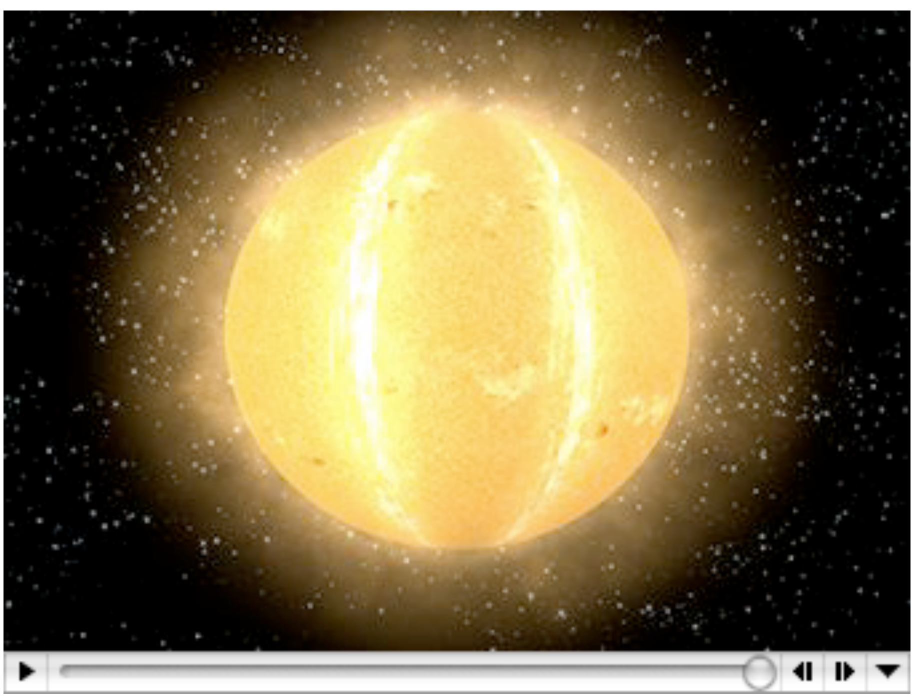

Figure 62. Artist's conception of the pattern of supergranules moving across the Sun, courtesy NASA.

Second, s-waves are the only type of wave that can produce the distinctive pattern in which supergranules occur. Rather than popping up randomly across the surface, a line of them progresses across the surface of the Sun.[55,56] The pattern is the most pronounced at the equator.[57] (See Figure 62.) If the origin of the supergranules is the liquid line (at a depth of 125 Mm), and if they occur in a wave-like pattern, there have to be transverse waves (i.e., s-waves) at the liquid-plasma boundary. Gravity and pressure waves would not produce this pattern. S-waves also explain differential rotation (detailed in the Cycles section), which cannot be explained any other way.

So how much heat is brought to the surface by supergranules?

Recent research has found that convection transports less than 1/20 of the Sun's total thermal energy to the surface.[58] So the supergranules themselves are relatively insignificant. It's possible that some of the heat generated at the liquid line is conducted, rather than convected, to the surface. The two transport mechanisms combined *might* be responsible for as much as 1/6 of the total. But this leaves us still in search of the *primary* electrostatic discharges.

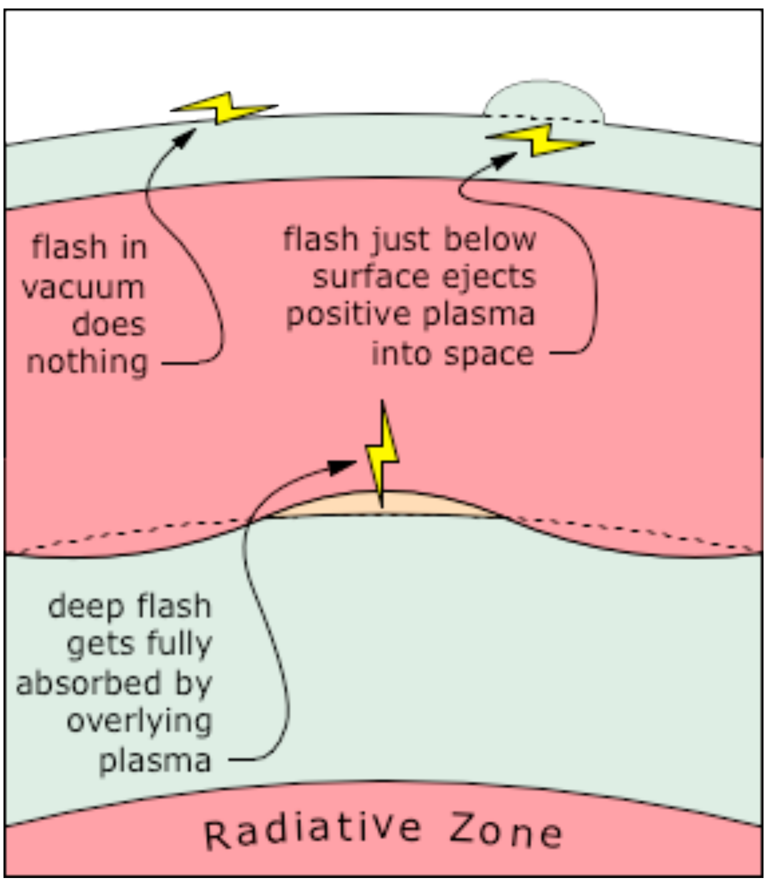

Figure 63. Results of flashes at different depths.

At the surface, we can see arc discharges directly, in the form of solar flares. The heat generated by these discharges is insignificant, but flares can have an interesting side-effect. A flare that occurs above the surface is just a big spark that flashes through a near-perfect vacuum. A flare deep within the Sun, such as one at the liquid line, creates a p-wave, but the impact is fully absorbed by the overlying plasma. But a flare just below the surface creates a p-wave that accelerates the overlying plasma out into space in what is known as a coronal mass ejection (CME). (See Figure 63.) The entire process is complex, and is treated in greater detail in the CMEs section. The amount of power in the flare itself is trivial compared to the overall energy budget, but there is a hidden significance to CMEs within this EM framework.

At the bottom of the convective zone, the hydrogen and helium has been compressed into a liquid, and ionized, so it is positively charged. Above the liquid threshold, electrons expelled from the supercritical fluid will congregate, making the plasma negatively charged. Both of those charges should be equally matched, with a powerful electric force pulling them together. Then, on the outside of the negative layer, there will be a positive double-layer. This is because positive ions in the vicinity will be attracted to the negative layer, though repelled by the underlying positive layer, yet the negative layer is closer. Since the electric force obeys the inverse square law, the net force will attract positive ions and repel electrons, and a layer of positive charge will build up on the outside of the negative layer. For reasons presented later, the depth of this layer is estimated at 20 Mm.

The significance is that CMEs near the surface are occurring in a positive double-layer, and the ejections affect a net loss of positive charge. This leaves the Sun with a net negative charge, and creates an electrostatic potential between the Sun and the heliosphere.[59,60] This solar~heliospheric electric field is not powerful enough to create arc discharges in the atmosphere. But it can still motivate an electric current, and therefore generate ohmic heating. (See Figure 64.)

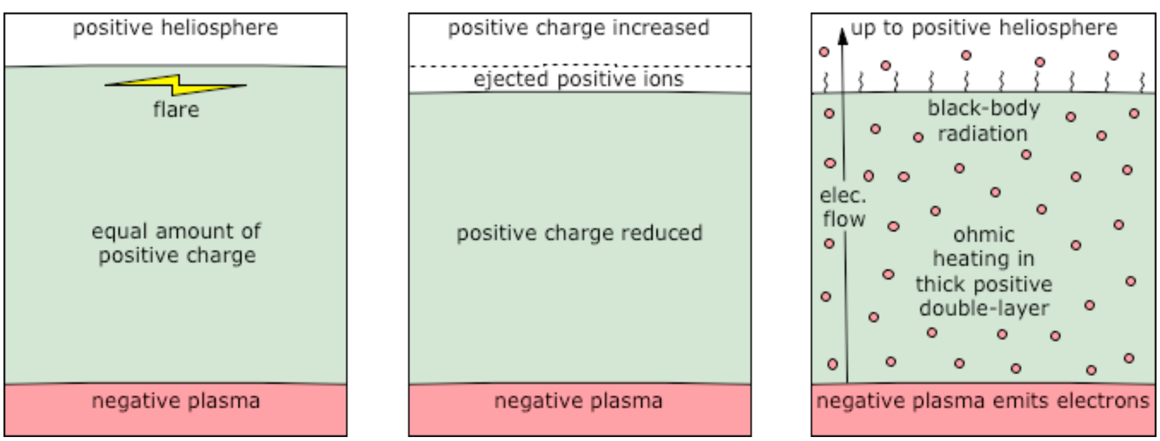

Figure 64. The depletion of the positive double-layer by a flare motivates a flow of electrons, from the negative layer out into the heliosphere. The depletion is greatly exaggerated in the images. One CME reduces the overall radius of the Sun by a mere 10^{-10} m.

How much ohmic heating?

We know the average mass of a CME, and the rate at which they occur. All we have to do is assign a positive charge to all of that mass, and find the net loss of positive charge. The equal-but-opposite reaction will be a subsequent electron drift *through the positive layer*. Knowing the voltage,[61:6] we can calculate the watts from ohmic heating, and compare that to the known power output of the Sun.

- The number of CMEs per day ranges from .2 at the minimum to 3.5 at the maximum, for an average of 1.85 per day.
- The average mass per CME is 1.6×10^{12} kg.
- The mass loss to CMEs is:
  - (1.85 CME/day) × (1.6×10^{12} kg/CME) = 2.96×10^{12} kg/day = 3.43×10^{7} kg/s.
- Assuming that this is all hydrogen, and given that a kg of hydrogen contains 5.35×10^{26} atoms, the number of expelled hydrogen atoms is:
  - (3.43×10^{7} kg/s) × (5.35×10^{26} atoms/kg) = 1.83×10^{34} atoms/second.
- The charge of a proton is 1.6×10^{-19} Coulombs.
- The "current" (in positive ions) due to CMEs is:
  - (1.83×10^{34} atoms/second) × (1.6×10^{-19} Coulombs/atom) = 2.93×10^{15} Coulombs/second.
  - Since an amp equals 1 Coulomb per second, that's 2.93×10^{15} A.
- Volts = 1.7×10^{9}.
- Watts = Amps × Volts = (2.93×10^{15} A) × (1.7×10^{9} V) = 4.99×10^{24} W.

The known power output of the Sun is 3.8×10^{26} W.[62:980-985,63] Assuming that 1/3 of the power is coming from nuclear fusion, and that 1/6 is coming from arc discharges at the liquid line, that leaves 1/2 of the power unattributed, or 2.35×10^{25} W. Ohmic heating, as just calculated, accounts for 4.99×10^{24} W, so we're less than an order of magnitude off, out of 25. If we then acknowledge that the CME counts are conservative, as they do not include events on the opposite side of the Sun, we can conclude that these numbers are within range. This means that the solar energy budget has been balanced, and without having to alter subatomic theory to make the "neutrino problem" go away.

So what causes the nuclear fusion that provides 1/3 of the power? If there isn't any fusion in the core, there isn't any fusion at all just due to extreme pressures from gravity. So what else could cause nuclear fusion?

The answer is arc discharges. Precursors for fusion have been found in lightning strikes here on Earth.[64] This is believed to occur at the ends of the discharge channels, where relativistic electrons slam into the STP gas, instantaneously creating the necessary temperatures and pressures. Note that the only "plasma confinement" mechanism is the inertial forces of the gas itself, but as the channel advances in stepped leaders, the hard x-rays (and sometimes even gamma rays) are distinctive, and lingering free neutrons have been detected. (So this is a type of "inertial confinement fusion," though it is very different from nuclear energy research.) On Earth, the discharge channels are only ~5 km long, with stepped leaders 100 m long. The discharges in the Sun can be over 100 Mm long, and the electrons are accelerated to nearly the speed of light. Evidence of fusion directly associated with solar flares has been confirmed.[65,66] Since the pressure in the convective zone is nothing compared to the requirements for fusion, this is the only possible set of conditions that could produce it.

With this in mind, it makes sense that fusion accounts for 1/3 of the total energy, and charge recombination accounts for the other 2/3. If it takes an arc discharge to cause fusion, the discharge itself produces *some* energy, and if this didn't show up in the budget, something would be wrong.

So in the most fundamental sense, the prime mover is the electric force. The "like-likes-like" principle (as described in the Accretion section) pulled matter together to create the Sun out of a dusty plasma. EDP created alternating layers of positive and negative charges, adding the force necessary to keep the final aggregate organized. The electrostatic potentials between these layers are being slowly converted to kinetic energy as arc discharges expel material, and as the resulting electrostatic imbalance causes a steady electric current. The discharges also produce the conditions for fusion. Without the electric force, none of this would have happened.

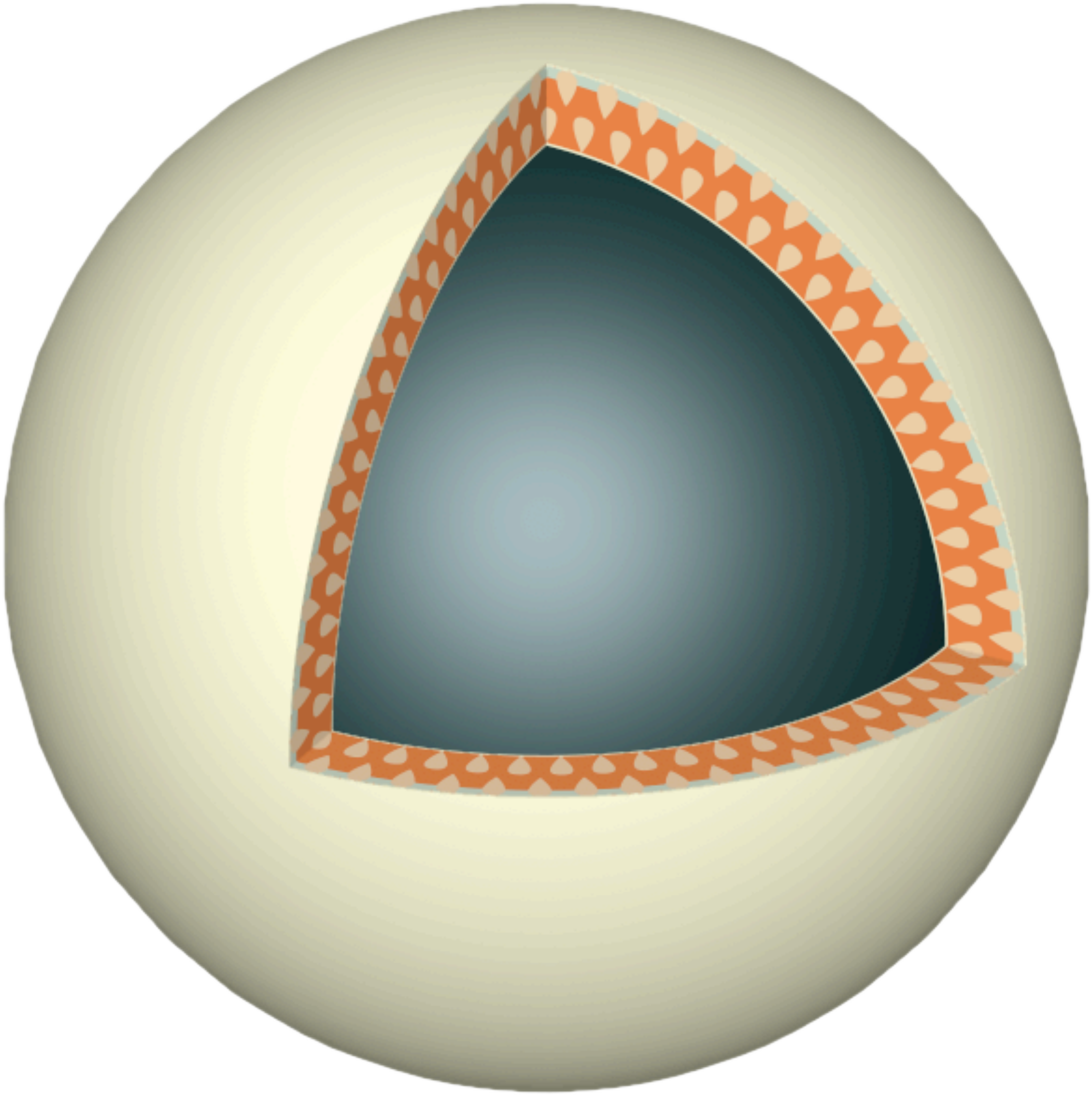

Figure 65. The layers responsible for the heat & light released by the Sun. Positively charged liquid hydrogen (green) is topped by negatively charged plasma (dark orange), with a positive double-layer (yellow) at the very top. S-waves in the liquid hydrogen generate supergranules (light orange). The solar~heliospheric current through the positive double-layer generates the ohmic heating that is responsible for 1/2 of the black-body radiation.

To summarize, there are no energy sources below 125 Mm. Nuclear fusion in the core is not possible, and there is no evidence of electrostatic discharges below the liquid line. Hence the "radiative zone" doesn't radiate anything. (Where the term is used herein, it only designates the mid-region of the Sun's interior, which we know to be there from helioseismology. It gets its name from the role that it plays in the "fusion furnace" model, while in the present model, the name is a misnomer.) For that matter, only the upper half of the "convective zone" actually convects, and even then, convection is responsible for less than 1/20 of the heat transported to the surface.[58] In the present model, as much as 1/2 of the total heat is generated at the liquid line (1/6 by arc discharges and 1/3 by nuclear fusion). Most of this heat is transported to the surface by conduction in the supercritical plasma. The remaining 1/2 of the heat is generated in the topmost 20 Mm by ohmic heating.

Radiation

To further increase the specificity of the present model, we can scrutinize the solar power output, and ask if the model would produce power in precisely that form.

All of the power from the Sun is in the form of electromagnetic radiation (i.e., photons), and the intensity per wavelength is a close match to a 5525 K black-body curve.

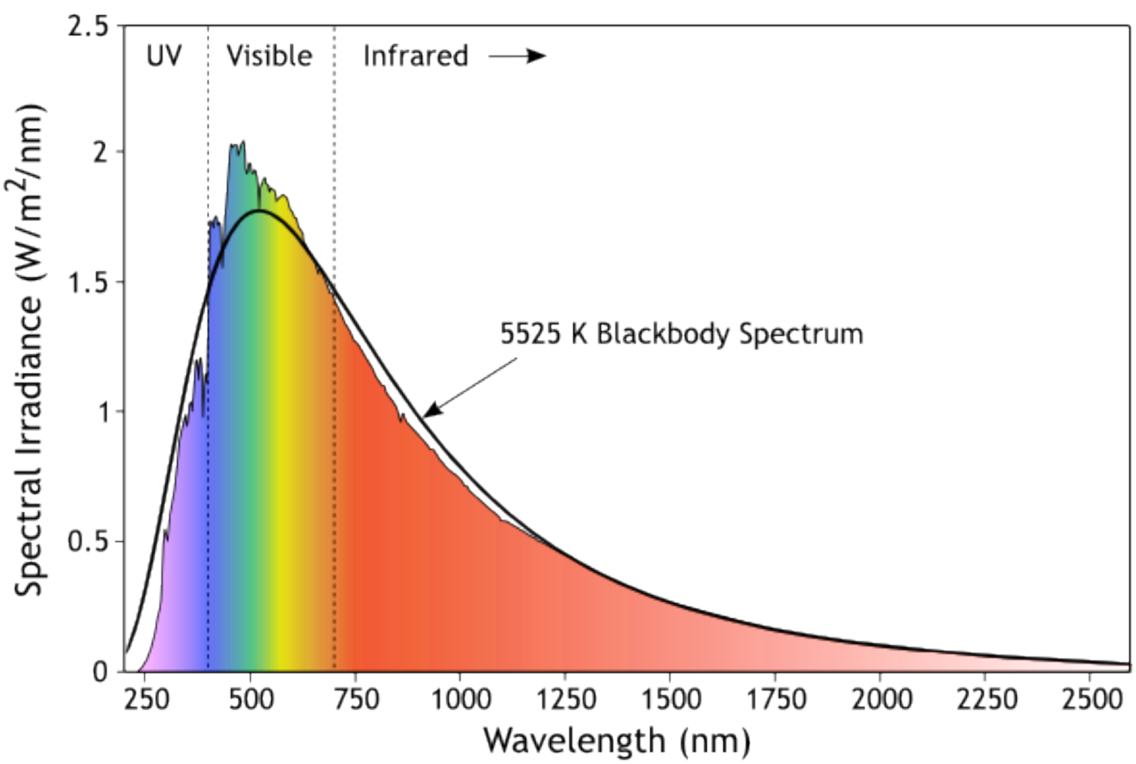

Figure 66. Solar spectrum.

So what is a black-body spectrum? Following in Balfour Stewart's footsteps, Gustav Kirchhoff canonized the essential characteristics of different types of EM radiation in his three laws of spectroscopy.[67,68]

1. A hot solid object produces light with a continuous spectrum (i.e., black-body radiation). (Wilhelm Wien went on to say that the power distribution has a bell curve that depends on the temperature, as in Figure 66.[69])
2. A hot tenuous gas produces light with spectral lines at discrete frequencies, and in combinations that depend in a more complex way on the temperature. (Niels Bohr later developed the concept of electron shells, and traced the spectral lines down to the degrees of ionization in the gas, which are a function of temperature.[70])
3. A hot solid object surrounded by a cool tenuous gas produces black-body radiation, but with gaps at discrete frequencies (which are the same as the emission frequencies of the gas, and likewise depend on the degree of ionization).

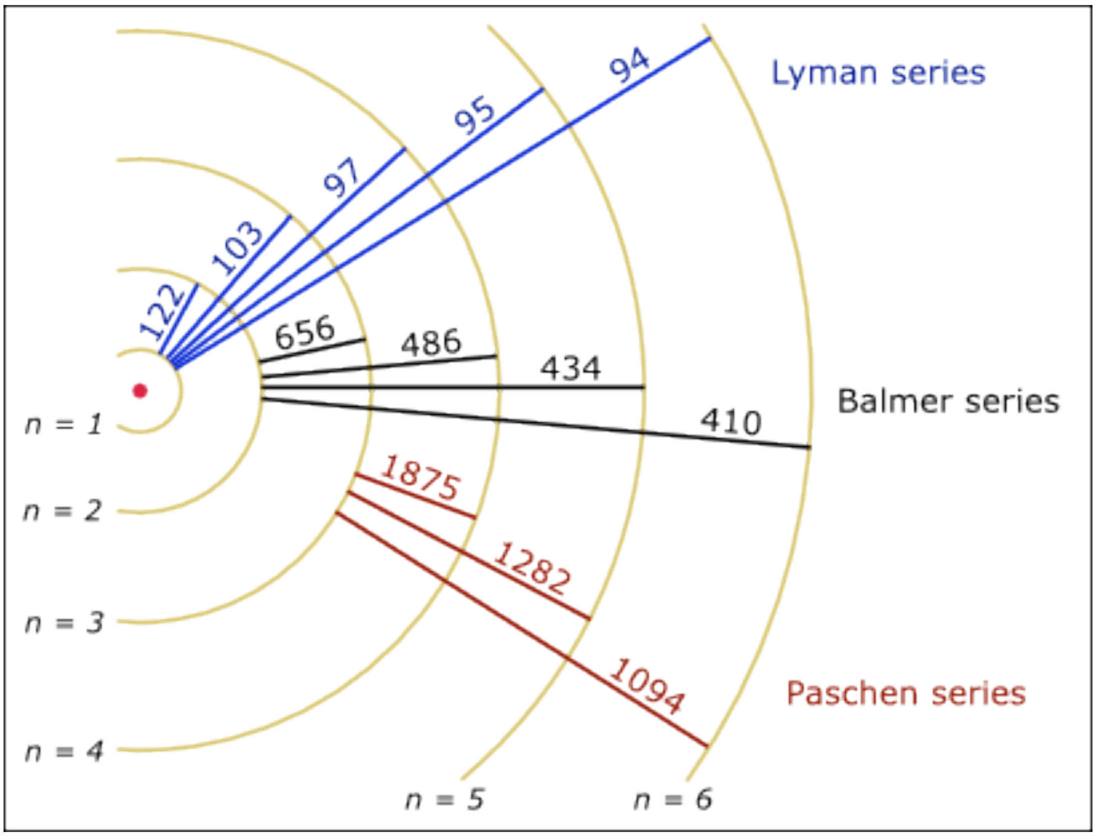

Figure 67. Hydrogen emission wavelengths (in nm), given the energy levels traversed.

To fully understand this, we should focus first on the Bohr model of the atom (which explains the 2nd law, and part of the 3rd). Emission and absorption of specific frequencies in gases are the consequence of electrons changing states. (See Figure 67.) Electrons entering lower energy levels emit photons. This could be electron uptake by a positive ion, or it could be an electron in an outer shell settling into an inner shell. Either way, the sudden movement of the charged particle creates a disruption in the surrounding electric and magnetic fields, producing an EM wave that propagates outward at the speed of light. Since electron shells occur at specific radii, the waves are generated at specific frequencies, producing distinctive spectral lines. Different elements have a different number of protons in their nuclei, so the electron shells occur at different radii. Thus the frequency of photons can be used to determine the elements (and the degrees of ionization) that produced them. The reciprocal process is photon absorption. Any electron bound to an atom is capable of being photo-ionized, where the frequency of the photon that gets absorbed is the same as the photon that will be re-emitted when that electron settles back into its original state. But when it does, the direction of the new photon is random. Hence a cool tenuous gas "scatters" photons from a light source, producing absorption bands, even though it emits as many photons as it absorbs.

Black-body radiation (as described in the 1st law) is obviously generated by a fundamentally different mechanism, since it is a smooth continuum of frequencies, not spectral lines. The standard explanation for BB radiation is abstract and complex. Before the Bohr model became accepted, scientists struggling to understand the nature of light, and disillusioned by the failure of classical thermodynamics to predict BB curves, concluded that there was no suitable mechanistic framework, and that the problem could only be solved with heuristic math.[71,72,73] Yet we are in the pursuit of a mechanistic model of the Sun, and such constructs are not useful to us, as their structural members will never rest squarely on any solid foundation.[38:73] To integrate BB radiation into our physical model of the Sun (so we can double-check the energy sources), we first need a physical model of BB radiation. Since there isn't one currently under consideration in mainstream science,[74:36] we are free to explore possibilities that have only recently appeared in the literature.

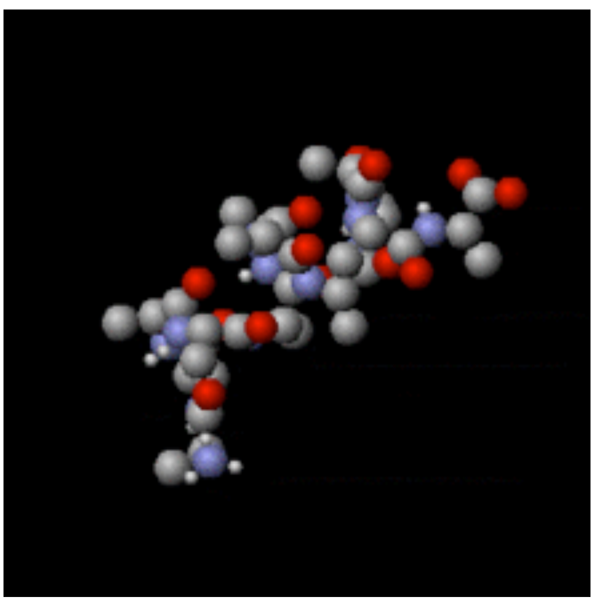

Figure 68. Atomic vibrations due to heat.

Some work has been done on a new conception of BB radiation at the quantum level.[75] But we need not introduce such complexity into the present problem domain, which is already sufficiently broad. At the next level up there is a possible explanation for BB radiation based on simple atomic theory. Atoms in a molecule above absolute zero are in constant vibration, within the limits of their covalent bonds. (See Figure 68.) This movement of positively charged nuclei generates EM waves.[76] The frequency is a direct function of the speed of the atoms, as they bounce back and forth within the lattice. We might think that the regularity of the lattice would determine a single frequency of oscillation, but the atomic motions in a solid are semi-random. So there will be a center frequency, predictable by the dimensions of the lattice and by the temperature, but all frequencies will be present, producing a continuous spectrum instead of individual lines.

Note that this BB model will not suffer the same fate as the Rayleigh-Jeans law, which naïvely predicted that the power distribution should vary with the temperature over the wavelength. Thus decreasing wavelengths should have resulted in power that hyperbolically approached infinity, but what we actually see is a bell curve, and in the UV band, the power drops back down to nothing. So T/λ just isn't going to work. But the present contention is that the waves are caused by oscillating particles, and their physical characteristics need to be taken into account. Specifically, the particles have mass, and their kinetic energy varies with the square of the velocity ($E_k = ½ \cdot m \cdot v^2$). Hence it takes exponentially more thermal energy to generate higher frequencies, and this attenuates the power in the UV band. So simple atomic oscillators remain a reasonable model for black-body radiation from solids.[68,77:98]

But what about gases and plasmas?

Outside of the complexities in a crystal lattice, discrete gas molecules vibrate only at characteristic frequencies, producing well-known emission/absorption lines in the infrared band. (Other gaseous degrees of freedom, such as translation and rotation, do not produce EM waves, as the protons and electrons translate and rotate together, and the field perturbations cancel out.) So gases don't produce continuous spectra like black-body solids. Rather, they only emit photons of specific wavelengths.

Plasmas do not have molecular vibrations or rotations, but the translation of an ion *should* generate a wave. Theoretically it does, but the mean free path between atoms is typically so long that the black-body radiation is in the ELF band, and the power is extremely weak, due to the low density. The emission lines from electron uptake in plasmas are far more powerful.

Hence gases and plasmas are known by their distinct emission/absorption frequencies, and their lack of black-body radiation.

Yet we know that the Sun issues BB radiation, and that the temperature is roughly 5525 K. The only elements that are still solid at 5525 K are tantalum, tungsten, and rhenium, but these are not present in sufficient quantities to dominate the spectrum. So what produces the BB radiation?

Black-body Frequency

$$f = \frac{v}{d \times m}$$

where:

f = frequency

v = atomic velocity

d = mean free path

m = atomic mass

More recent research has demonstrated that supercritical fluids, well above their boiling points but under sufficient pressure to still be at or near their liquid densities, produce BB radiation.[78] Instead of covalent bonds constraining the motion of atoms, Coulomb forces between closely packed ions do the same thing. So instead of a crystal lattice, it's a Coulomb lattice, so to say. The greater the pressure, the closer the atoms, and the higher the frequency of vibration, even with the same atomic speeds. So Kirchhoff's "4th law" should have been that a supercritical fluid does not produce spectral lines (because of a lack of bound electrons), but it does produce BB radiation (from the oscillations of atomic nuclei with short mean free paths).

As the Sun is comprised of hot, high-pressure plasma, this emerging "4th law" explains solar BB radiation.

But this causes more problems than it solves for the standard model. Most astronomers set the optical depth of the Sun in the range of 300~700 km, and all photons from deeper than that should be scattered by the overlying gases.[79] This leaves them with no choice but to assert that the 5525 K BB radiation comes from within 700 km of the surface. But the same model also states that plasma above that depth is thinner than a laboratory vacuum, and laboratory studies show that such extremely tenuous plasmas produce only spectral lines. Any BB radiation should be extremely weak, and in the ELF band, signifying extremely low temperatures. This, of course, is not at all the nature of the radiation from the Sun.

In the standard model, these problems cannot be solved. Only considering gravity and hydrostatic pressure, the density gradient is dictated by the ideal gas laws, with no room for reinterpretation. Then, the optical depth is set by the requirements of the "fusion furnace" model. Various species of different elements are tasked with absorbing gamma rays from the solar interior, and emitting a variety of lower frequencies that, when taken together, just happen to add up to a 5525 K BB curve. But this presents several impossibilities.[77]

- If the standard model is correct, the Sun is composed of 75% hydrogen and 25% helium. This means that
  - there is no way of accounting for the overall mass of the Sun, given the electron degeneracy pressure, and
  - the wide variety of elemental species necessary to convert gamma rays to BB radiation shouldn't be present.
- If a wide variety of species (including heavier elements) *were* present,

- the chance of many non-BB processes adding up to a smooth BB curve is effectively nil, and
- the heavier elements would settle into the core, where the pressure is insufficient for fusion, meaning that there shouldn't be any gamma rays.

Clearly, the standard model just doesn't work, and cannot be made to work. So the model constraints need to be removed, and we need to look directly at the data and the physical properties of the plasma. We know that the solar BB radiation can only be coming from high-pressure plasma, so the optical depth can be set by the pressure gradient. This creates another impossibility for the standard model, where supercritical hydrogen occurs only at depths greater than 100 Mm. All photons having to travel through 100 Mm will surely be scattered. But the standard model assumes that it is only gravity that compresses the plasma. When electrostatic potentials between charged double-layers are taken into account, the forces are much greater, and supercritical hydrogen occurs much closer to the surface.

Granules

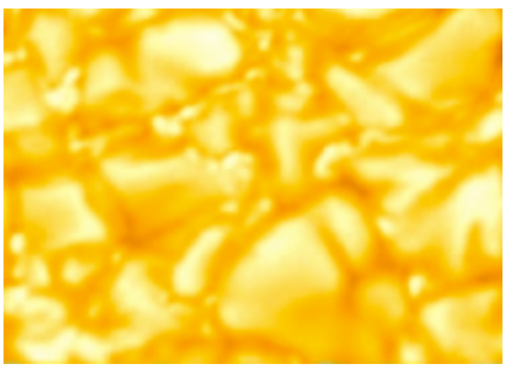

Figure 69. Granules

The Surface section identified some of the visible characteristics of the Sun, which necessitated current-free double-layers (CFDLs), which themselves required elaboration. Now that this model has been fleshed out, we can go back and make a more detailed analysis of the surface.

As mentioned earlier, the surface of the Sun is covered in granules. (See Figure 69 or Figure 42.) These have the appearance of convective cells erupting onto the surface. The updrafts in the center average 2 km/s, and the downdrafts around the outsides can exceed 7 km/s.[80] But these are supersonic speeds for the 6,000 K hydrogen,[81] and while we don't know for sure the depth at which the updrafts began, and thus we don't know how long they had to accelerate, we *do* know that at the top, the plasma splays out and is accelerated to 7 km/s in the downdrafts, and this is in the plasma that is still visible (i.e., very near the surface). It's hard to image how negative buoyancy could accomplish this instantaneous acceleration. But then, if we take a closer look, the question gets even harder to answer. The intergranular lanes, with the (supposedly) cooler plasma that is falling at 7 km/s due to negative buoyancy, has streaks of even hotter plasma, called faculae. (See Figure 70 or Figure 71.) Hotter plasma is not negatively buoyant, much less hypersonically so.

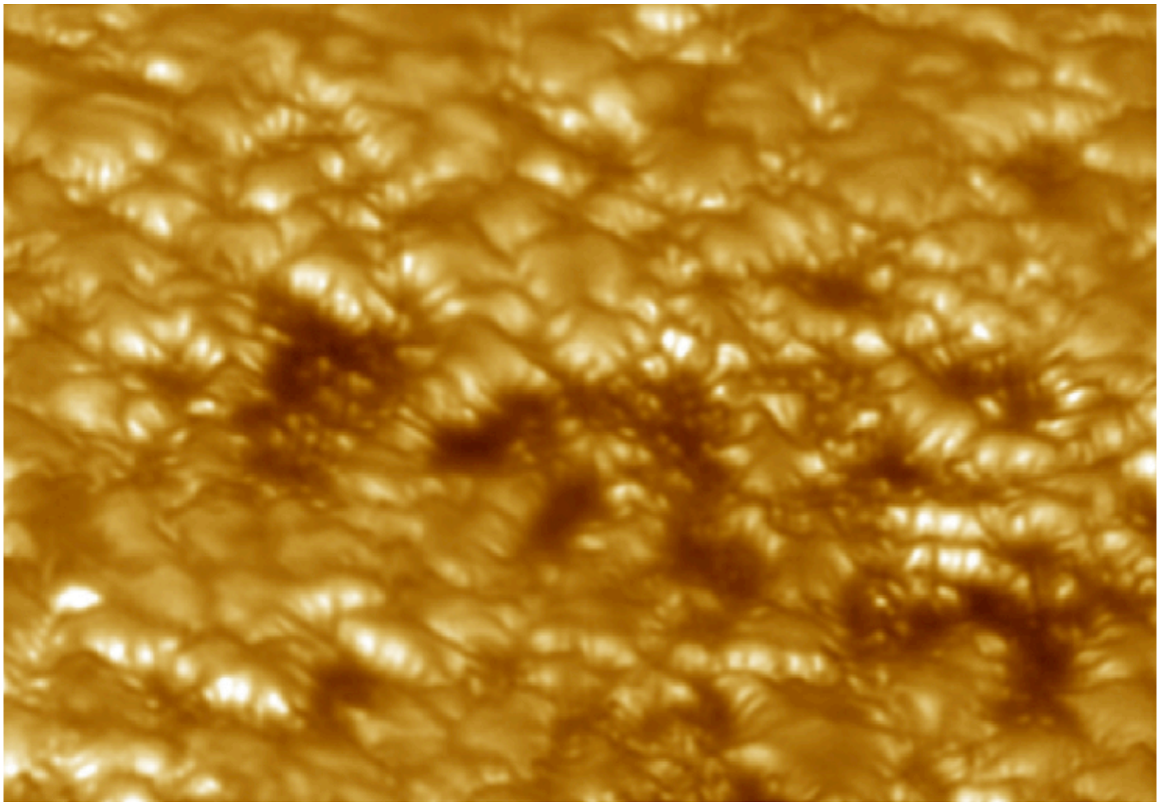

Figure 70. Close-up of the solar surface, 2002-07-24, showing faculae on the near edge of many of the granules.

Clearly, forces other than just buoyancy are at work here. So we'll examine granules in the context of the EM model, to see if they don't make more sense that way. To start, we should make what inferences we can about the 3D structure.

The granules are typically 1 Mm across. If they originate from a depth that is 4 times greater than their width, the granular layer is 4 Mm deep. This dimension can be confirmed, at least indirectly, in two ways. First, near-surface helioseismology of sunspots (covered in more detail in the Sunspots section) shows updrafts in the sunspot shafts that end at about 4 Mm below the surface. (See Figure 72.) The granular recirculation was thus shown to be a totally different type of flow that occurs only in the topmost 4 Mm.

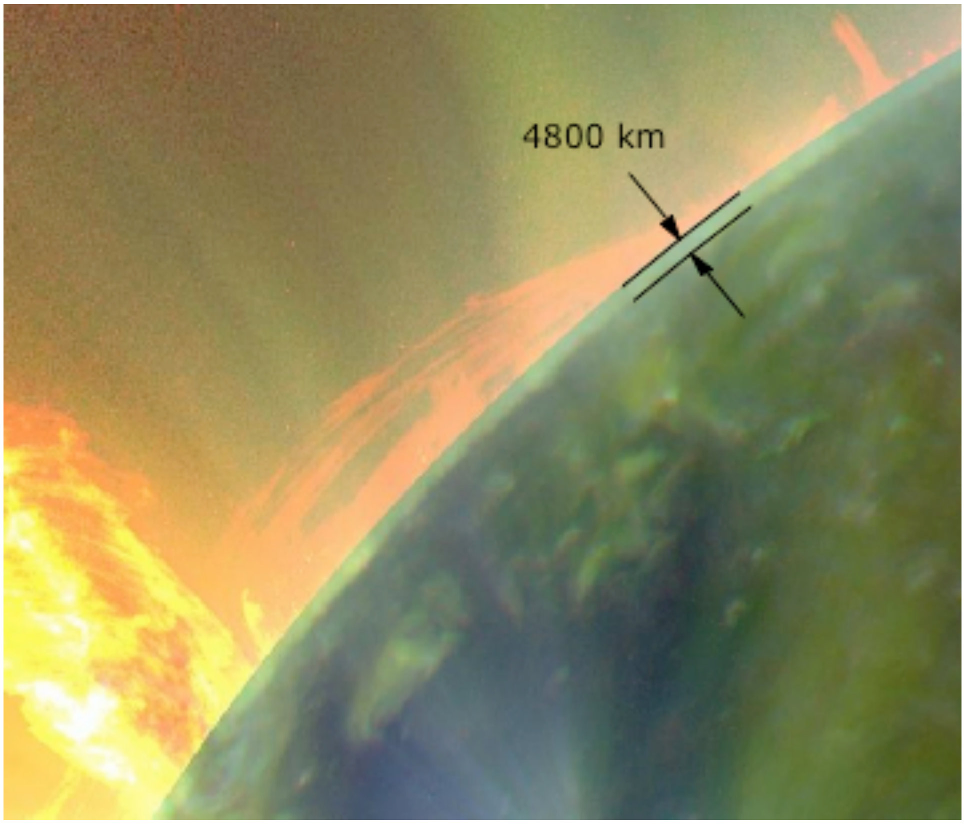

Figure 73. The Sun in a composite of different wavelengths, 2010-03-30, courtesy [SDO](). Iron is shown in green.

Second, we should consider Figure 73, and one of the possible interpretations. This was the first image taken by SDO. The scientists were so excited to have caught a CME in the first shot that they released the image without any post-processing. On closer scrutiny, we see a curious thin layer at the top, 4.8 Mm deep, that has no business being there in the standard model. Trusting their model and not the initial calibration of the filters based on the known dimensions of the Sun, the filters have since been adjusted to not show a saturation drop-off at depth. But a 4.8 Mm error, on an object with a 696 Mm radius, is nearly 1% off. It's a bit hard to believe that the engineers who lined up the filters for the first shot would have been that sloppy. It's possible that the initial calibration was correct, that the standard model is wrong, and that there is, in fact, a ~4 Mm layer at the top that is much thinner than the underlying plasma.

Note that none of these forms of data are terribly conclusive. But they are the only data we have, they all say the same thing, and there are three sets: the aspect ratio of thermal bubbles, the sub-surface flows under sunspots, and the imagery taken with geometrically calibrated filters. Until data are collected that can invalidate these, in a theory-independent way, these are the data that will be used. So the tentative conclusion is that the granules occur in a layer that is ~4 Mm deep, and that the underlying plasma is much thicker.

The standard model is even harder-pressed to explain this double drop-off (i.e., one at a depth of 4 Mm, and the other at the surface). It was originally thought that convection was the primary heat transport mechanism in the topmost 210 Mm of the Sun, hence it was named the "convective" zone. But recent research has shown that deep convection can only account for less than 1/20 of the power emanating from the surface.[58] Thus radiation and conduction are the primary transport mechanisms in the "convective" zone. Then, looking at Figure 74, we can see that from the core, the temperature decreases more or less steadily to near the surface, while above .9 $R_\odot$ (70 Mm below the surface) the fall-off accelerates, as a consequence of heat loss at the surface. So the convection should begin at a depth of 70 Mm, not 210 Mm, and not 4 Mm.

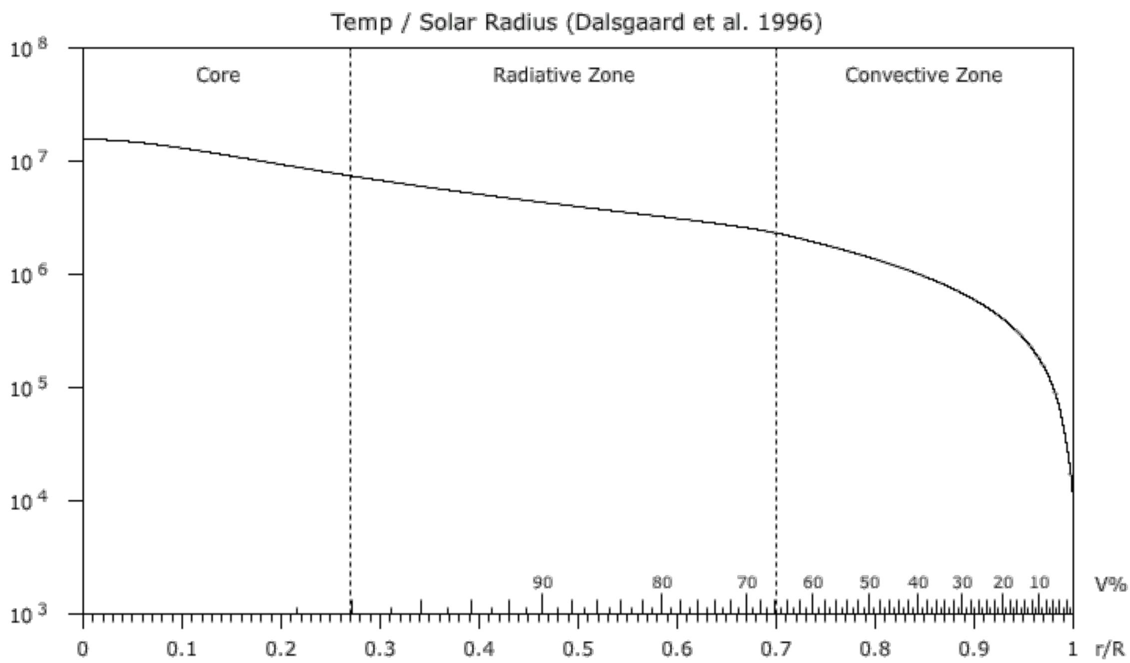

Figure 74. Temperatures in the Dalsgaard model.

This all makes a lot more sense if we use the density gradient in the present model. (See Figure 52.) The density of the hydrogen layer is maintained to very near the surface, since it is a positive double-layer being held down forcefully by an underlying negative layer. Then we just have to come to understand the eruption of convection in the topmost 4 Mm.

This is explained by the action of the electric current. There is a flow of electrons from the negative layer up through the topmost 20 Mm of positive plasma. These electrons start out moving slowly, and accelerate as they go. The reason is that they begin at a current divider where there is an ambiguous electric field. Below, there is a strong positive charge in the liquid helium & hydrogen layer. This holds down the bulk of the electrons. At the top of the negative layer, the downward force is weak, as electrons are shielded from the underlying positive charge by the negative charge in their own layer. In the other direction, there is the positively charged heliosphere. Somewhere in the negative layer the net force is nothing, and the electrons are stationary. Above that level, electrons are free to flow outward toward the heliosphere, but the electric field is weak at first. The further they get from the current divider, the less ambiguous the electric field, and the greater the acceleration.

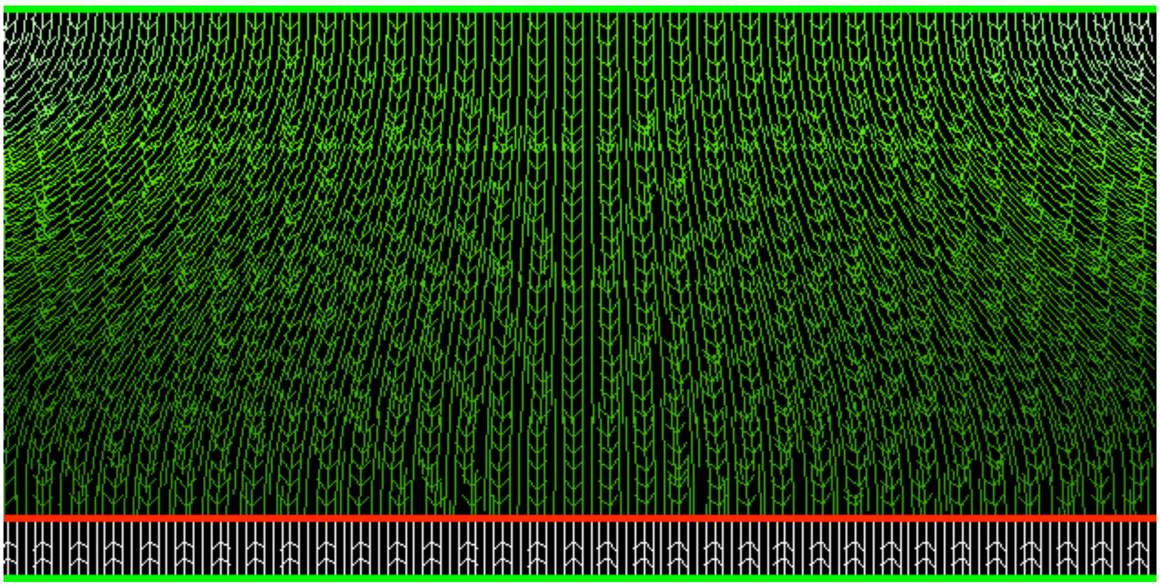

Figure 75. Lines of force in a tripolar field. Green = positive; red = negative. The arrows show direction of force on a positive charge. Brightness of lines indicates field density.

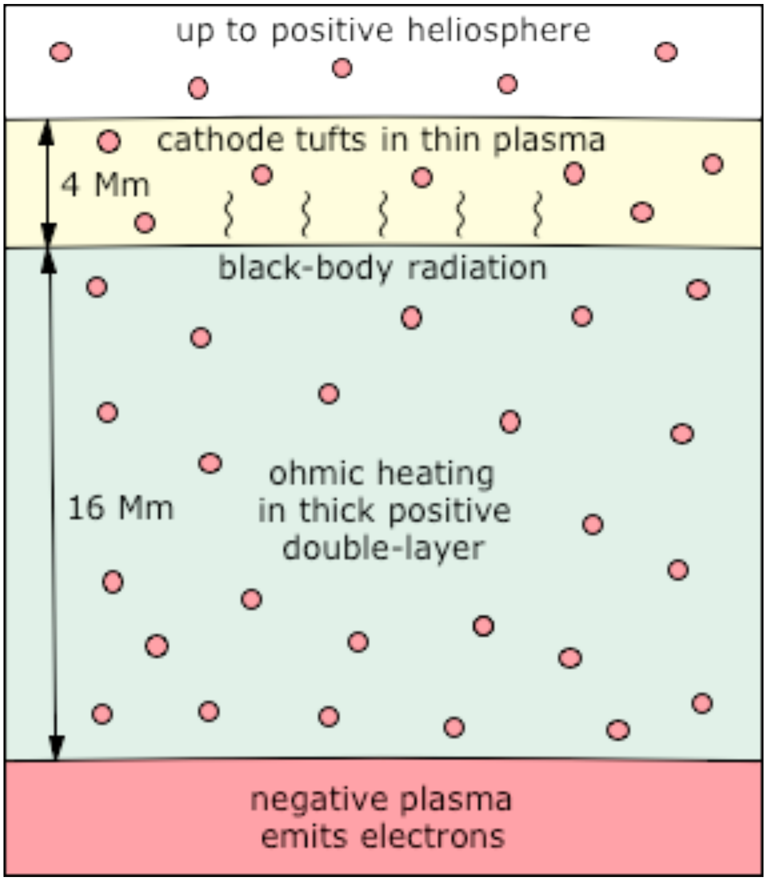

Figure 76. The topmost 20 Mm of the Sun, with 16 Mm of dense plasma, and 4 Mm of thin plasma at the very top.

Due to the acceleration, the ohmic heating in the topmost 20 Mm increases in the direction of the flow of electrons. The density of the plasma also decreases. At some point, the increasing heat and decreasing pressure result in the eruption of thermal bubbles. As mentioned above, their 1 Mm width suggests that this transition occurs at a depth of ~4 Mm. (See Figure 76.) Below that depth, densely packed plasma generates black-body radiation. In the topmost 4 Mm, the loosely packed plasma in the granules is cooler, and is responsible for the absorption lines in the solar spectrum (per Kirchhoff's 3rd law).

And in this context, we can understand supersonic updrafts and downdrafts. All matter has at least some degree of electrical resistance. Normally we only care about the effects of this resistance on the flow of electrons through the resistor, but the equal-but-opposite effect is that the resistor itself has a force applied to it. As concerns electric currents flowing through wires, *the wire itself is pulled in the direction of the current*, with a force equal to the electrical resistance. In a decent conductor that is well-fastened at both ends, the force is negligible, and never mentioned. In a plasma, it's not really electrical resistance *per se*, but more a matter of the Newtonian forces of high-speed electrons bombarding atoms in their way. The effect on the atoms is called "electron drag," and it accelerates the atoms in the direction of the electrons.[82:806] Normally the effect is small, and in the present model, the current density is weak. With a total of 2.93×10^{15} A, divided by the surface area of the Sun (i.e., 6.09×10^{18} m^2), that comes out to 5.4×10^{-4} A/m^2. But this current acts on the plasma through the entire depth of the granular layer (~4 Mm), and the ionized plasma is virtually frictionless. So electron drag really only has to overcome the inertial forces in the plasma to accelerate it to supersonic speeds. Yet ultimately, the more powerful force operating on the positive ions is their electrostatic attraction to the negative electrode. So when the bubbles hit the surface, the electrons are free to stream out into space, and the positive ions are pulled back into the Sun at up to 7 km/s. In engineering terms, this "convection" is called cathode tufting.[83,84]

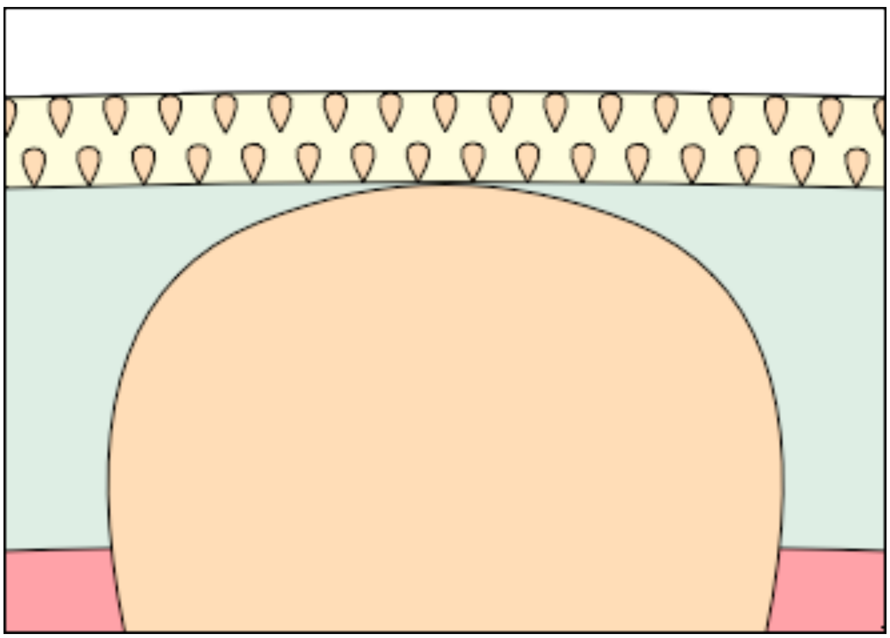

Figure 77. A comparison of granules, 1 Mm wide, to supergranules, 30 Mm wide.

Figure 77 compares granules in the topmost 4 Mm to supergranules that originate from a depth of 125 Mm. The supergranules stop at the 4 Mm depth, since the granular layer is a surface condition that has nothing to do with convection in the underlying plasma. It's useful to think of the supercritical fluid below 4 Mm as a liquid that we can't see, but with a thin layer of flames on top that we can. A bubble in the liquid will elevate the surface condition, even without otherwise affecting it.

Note that this model offers a fundamentally new conception of the photosphere (i.e., the sphere from which all photons emanate). In the standard model, the topmost .3~.7 Mm is responsible for all of the solar photons, because that's the optical depth of hydrogen gas. In the present model, the tenuous plasma in the granular layer is too thin for BB radiation, and is responsible only for absorption lines in the solar spectrum. So the "photosphere" isn't the topmost layer at all — it's 4+ Mm down, and slightly obscured by the features of the granular layer.

And this enables the assimilation of even more data. If we take a closer look at the actual black-body curve, we see an anomalous overshoot in the blue band. (See Figure 66.)

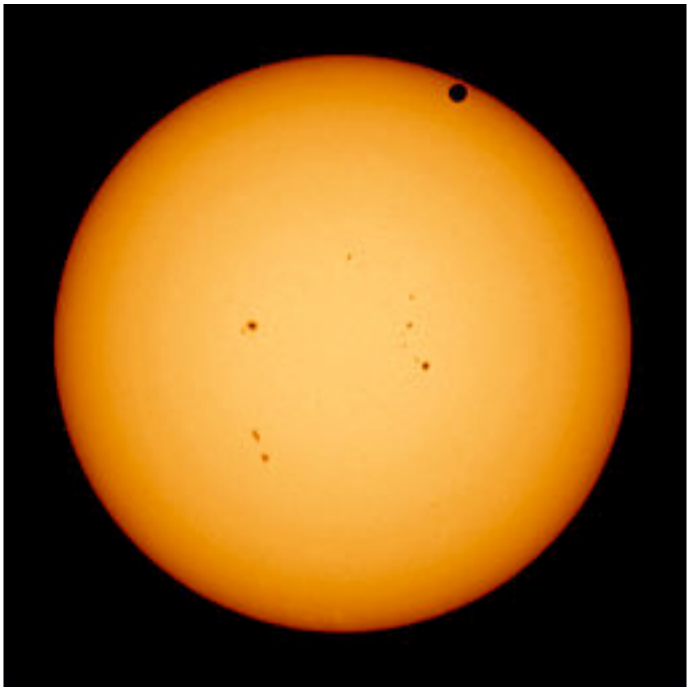

Figure 78. The Sun with Venus in transit, courtesy [Solar Dynamics Observatory](#).

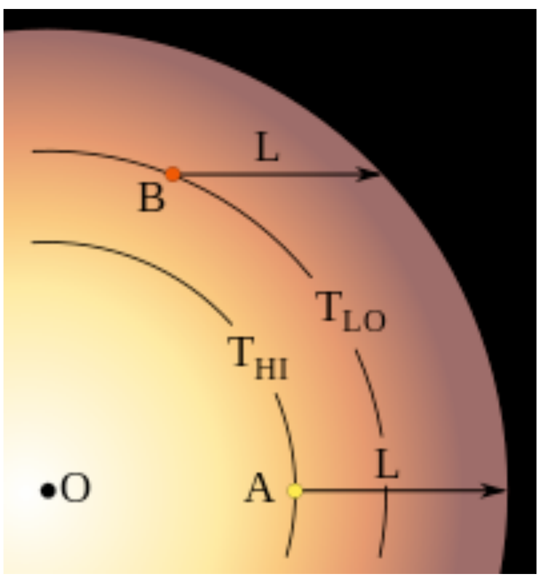

Figure 79. The selective suppression of light from deeper in the Sun.

The reason for this is that the spectrum is actually a blend of BB curves from plasma at different temperatures. The light that we receive from the edge of the Sun is 4600 K, while normal to the surface it's 6400 K.[85,86] (See Figure 78.) Hence the 5525 K fit is actually just an average of temperatures that vary from 4600 to 6400 K.

This so-called "limb darkening" proves that hotter light has to be coming from deeper in the Sun, and that nearer the surface, the temperature is cooler. The reason is that photons from deeper in the Sun have to traverse a lot more plasma when coming from the limb, and more of the light gets scattered. (See Figure 79.) Cooler light from nearer the surface still makes it through, because it doesn't have to pass through as much plasma to get above the surface.

But the Dalsgaard model can't make sense of these temperatures. It has 4600 K occurring at .224 Mm *above* the surface, and 6400 K at .048 Mm below, meaning an optical depth of just .273 Mm. But the same model has the density where 6400 K is achieved at just 2.52×10^{-4} kg/m^3, which is four orders of magnitude thinner than STP air (i.e., 1.29 kg/m^3), and which is far too tenuous to absorb/emit black-body radiation.

In the present model, the 4600 K BB radiation is coming from a depth of 4 Mm, and the 6400 K radiation is coming from deeper than that. And the difference in BB "temperature" is actually an index of pressure, not temperature. Compressing plasma shortens the distance between ions, and with the same atomic speeds, they'll vibrate faster, because they have less distance to travel. Hence "hotter" plasma does not have more thermal energy. This is significant in that the supercritical fluid should conduct heat quite nicely, and we wouldn't expect sharp temperature gradients.

It's also significant to note that in this model of black-body radiation, "hotter" light can shine through thinner plasma. The high-frequency photons from high-pressure plasma will not get absorbed by low-pressure plasma, which cannot resonate at such high frequencies. So the source of the 6400 K radiation can be much deeper than just ~4 Mm + .273 Mm. Nevertheless, atomic vibrations are random, so there is still *some* absorption, and limb darkening is still possible in this model.

Sunspots

Aside from granules, the other distinctive pattern in the solar surface is sunspots. In classic form, these have a roughly circular interior, called the umbra, surrounded by filaments that arc up, out, and then back down into the granular layer. The filaments are known collectively as the penumbra. (See Figure 71.)

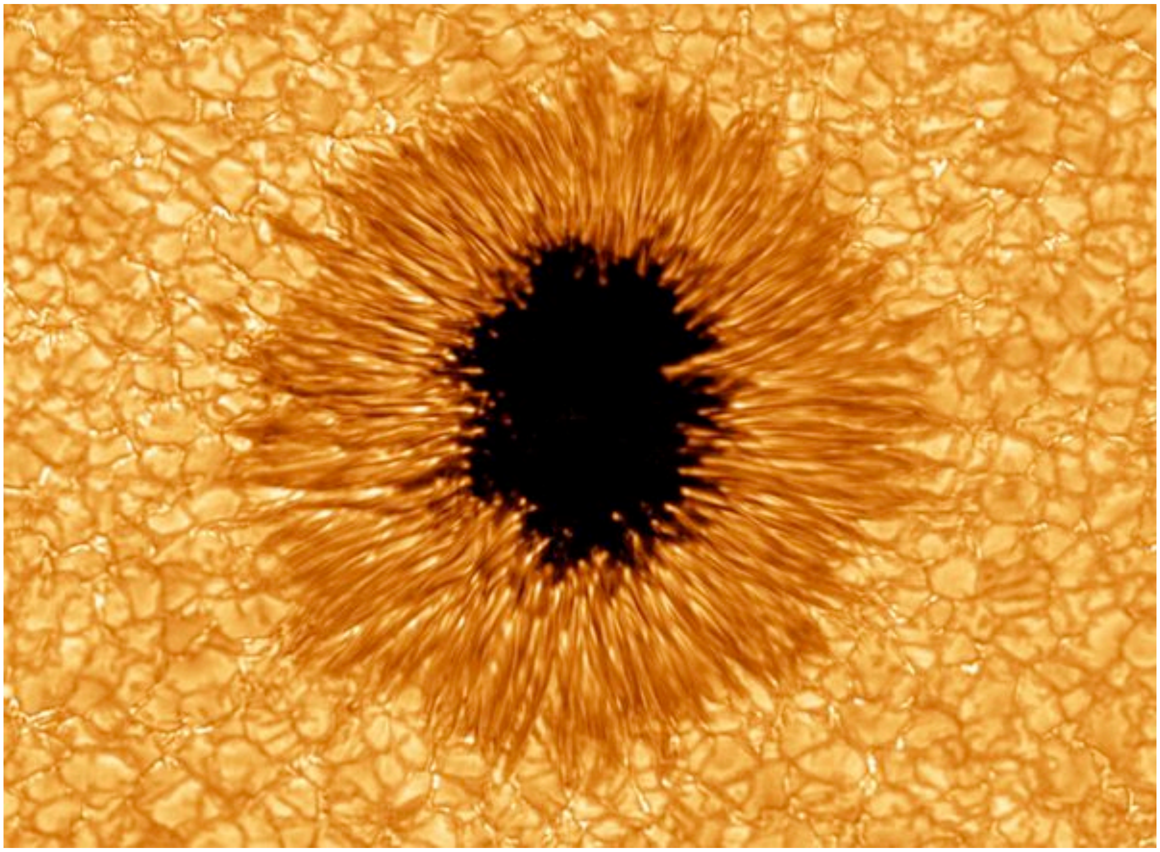

Figure 71. Sunspot, courtesy New Jersey Institute of Technology's New Solar Telescope.

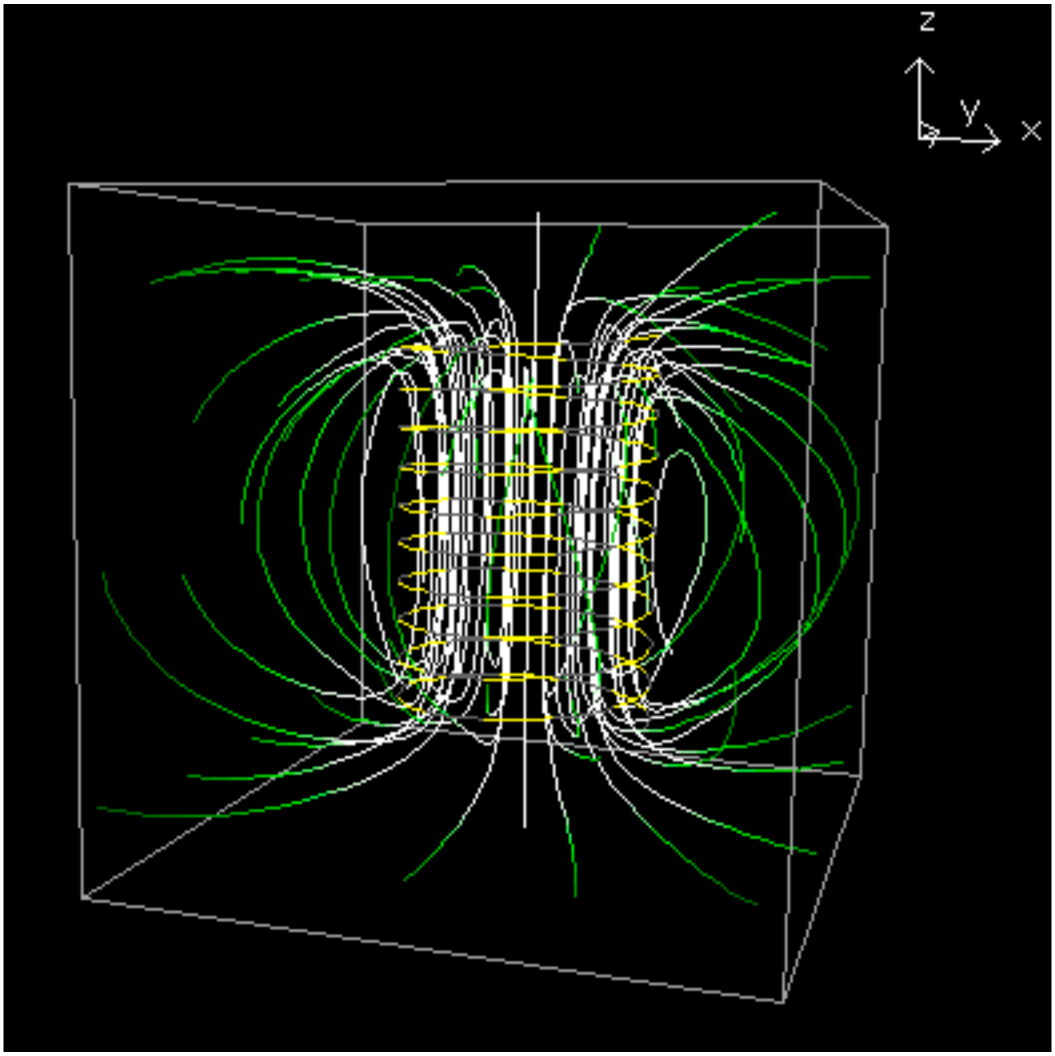

Figure 80. In a solenoid, a rotating electric current generates axial lines of magnetic force.

The key to understanding sunspots is their magnetic fields.[87] The lines of force rise up through the center of the sunspot, and then splay outward above the surface. So what is the magnetomotive force?

As the convective zone is comprised of 75% hydrogen and 25% helium (neither of which have strong magnetic dipoles, especially in the plasma state), the particles in question are not magnetized, and the field cannot be coming from frozen-in dipoles.

The only other way to generate a powerful magnetic field is with an electric current. When we see the greatest field density along the axis of a roughly circular form, we know that it's a solenoid generated by a rotating current. (See Figure 80.) Since there is no evidence of the plasma itself rotating fast enough to generate the field densities in question, the solenoid can only be evidence of a flow of electrons through the excellent conductivity of the plasma, where the positive ions remain relatively stationary.

Indirect evidence of the rotating electric current includes the migration of granules away from sunspots (indicating a submerged heat source, such as ohmic heating under the penumbra, as in Figure 72), and the Wilson depression in the center of the umbra (where less ohmic heating leaves the plasma cooler, and thus heavier, so it settles).

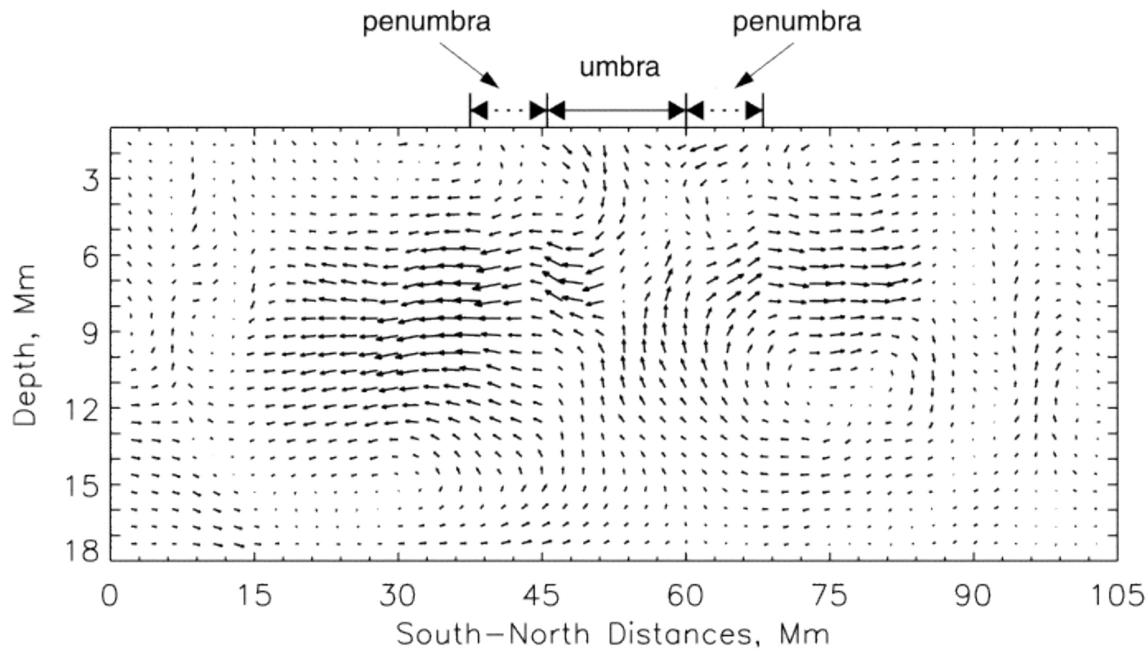

Figure 72. Plasma flows under a sunspot, indicating a heat source from roughly 18 Mm to 4 Mm below the surface.

Note that the updrafts in Figure 72 level off at about 4 Mm from the top, and then splay outward. This is one of the lines of evidence that there is a layer of thick plasma below 4 Mm, topped by a very thin layer of granules — otherwise, the updrafts wouldn't mushroom at a depth of 4 Mm.[88] Some of the literature refers to this density ledge as the difference between the actual "surface" of the Sun, versus its "atmosphere." In the present model, there is definitely a distinct change at 4 Mm, from high-density plasma issuing black-body radiation, to low-density granules that absorb specific frequencies in that radiation. The depth of the granular layer is estimated at 4 Mm by the typical dynamics of thermal bubbles (i.e., depth = width × 4), which the helioseismic data confirms. But the thick plasma below 4 Mm is still above its liquid density, so calling it a "surface" isn't substantially more accurate.

Measurements of the sub-surface speed of sound confirm that the cooler umbra is roughly 4 Mm deep, and that the sunspot shaft below that is hotter than the surrounding plasma.[89]

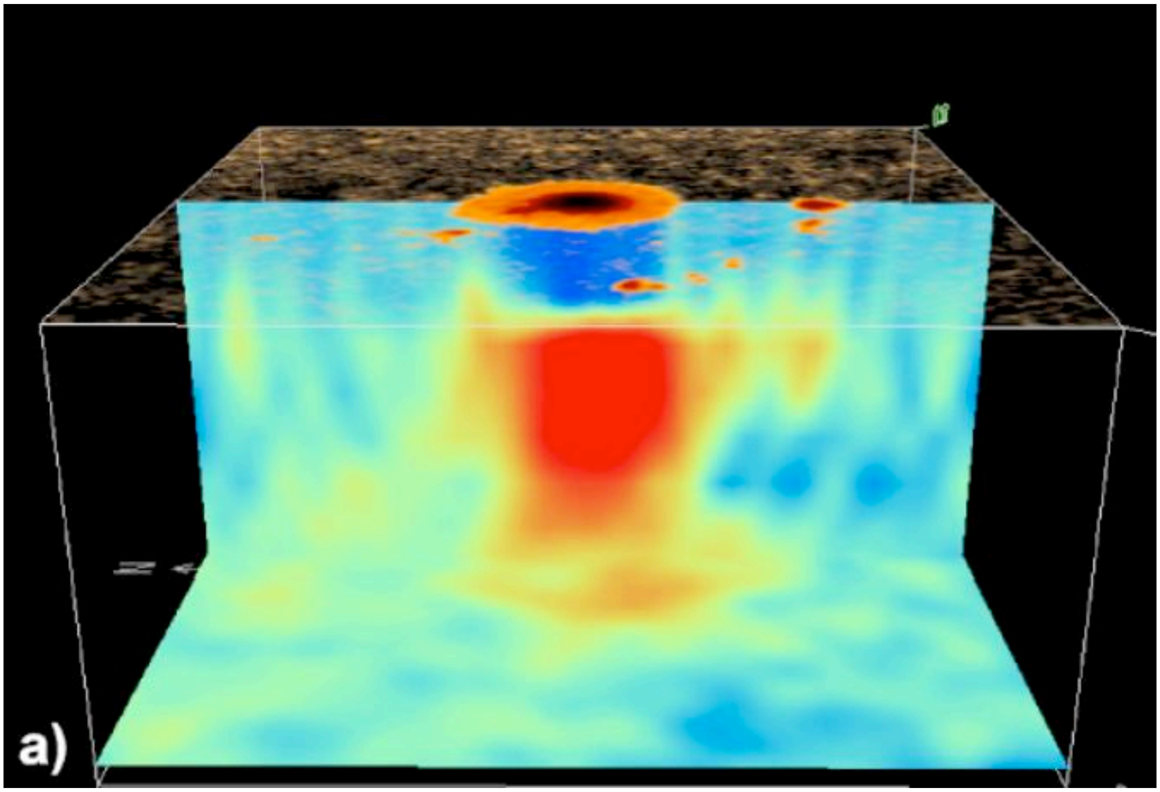

Figure 81. View of the 3-D structures and sound speeds of the flows below a sunspot, courtesy Kosovichev et al.

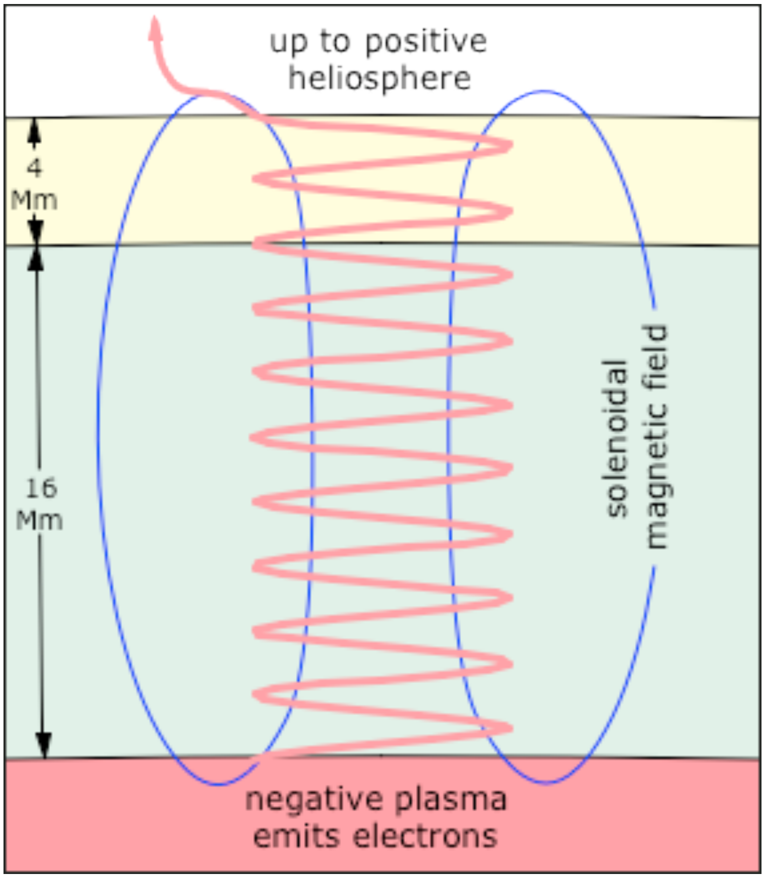

Figure 82. Schematic diagram of a sunspot.

The other significance of these helioseismic data is that they set a depth of ~20 Mm for the sunspot shaft. So in the present model, that's where the electric current starts, defining the upper limits of the negative layer. (See Figure 82.)

What's the electromotive force?

In the Granules section, a steady flow of electrons was identified, from the negative layer in the convective zone, up through the 20 Mm positive double-layer on top of it. (See Figure 76.) It was noted that this current starts slowly, accelerating as it moves away from the current divider. Because of the slow speeds, we don't typically see electrodynamic effects. Due to electrostatic repulsion, the electrons are well distributed, and they just drift slowly toward the surface and then on out into space. But in sunspots, electrodynamics are present and distinctive. Hence the electric current in a sunspot is the same electron drift that emanates from all points on the Sun, but the current density is greater, and an organized form emerges.

The next question is, "What induces the rotation in the electrons as they rise up through the sunspot, resulting in a solenoidal field?" They certainly aren't following the wraps in a coil of wire.

The most plausible answer is that it's the Lorentz force. Where sunspots occur, the Sun's magnetic field is perpendicular to the surface. Electrons shooting straight up through a sunspot will generate magnetic fields in conflict with that pre-existing field. If the electrons spin as they go, the fields come into agreement. (In other words, it forms a Birkeland current.) Due to magnetic pressure *within* the spiral, the spin is flattened, resulting in more turns to achieve the same vertical motion. The result is a solenoidal field that is actually far stronger in its axis than the external field — up to 4000 times stronger!

Still, the general sense of the electric current is from the negative layer outward into space, and this explains a curious fact about the sunspot's magnetic field. The central lines of force are "open," meaning that instead of closing within the solenoid, they project out into space. (See Figure 83.) This shouldn't be possible, but if that's the overall direction of the current, solenoidal lines that should have closed locally can get distorted into axial fields in Birkeland currents, which never "close" in the same way.

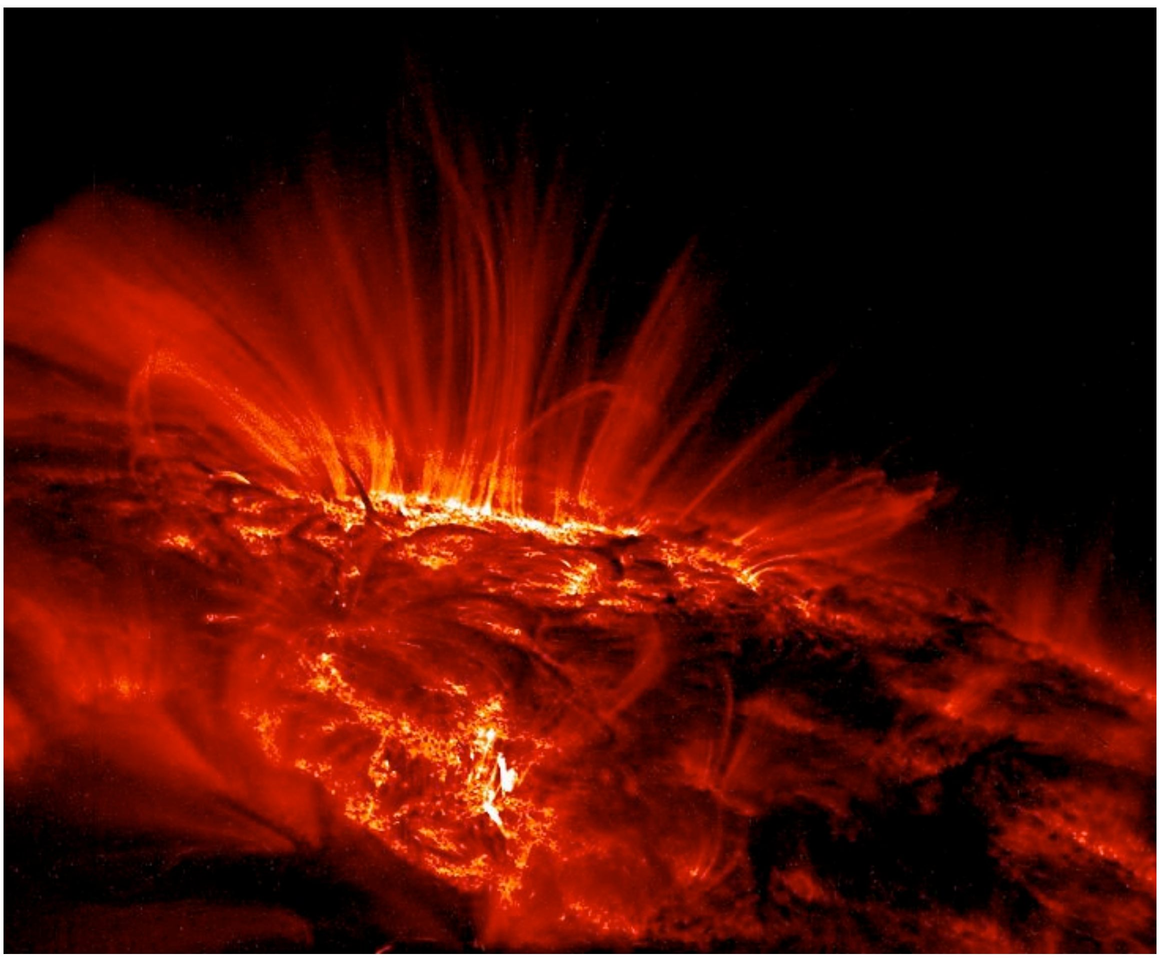

Figure 84. AR 9169, 2006-06-11, seen in 171 Å, courtesy TRACE.

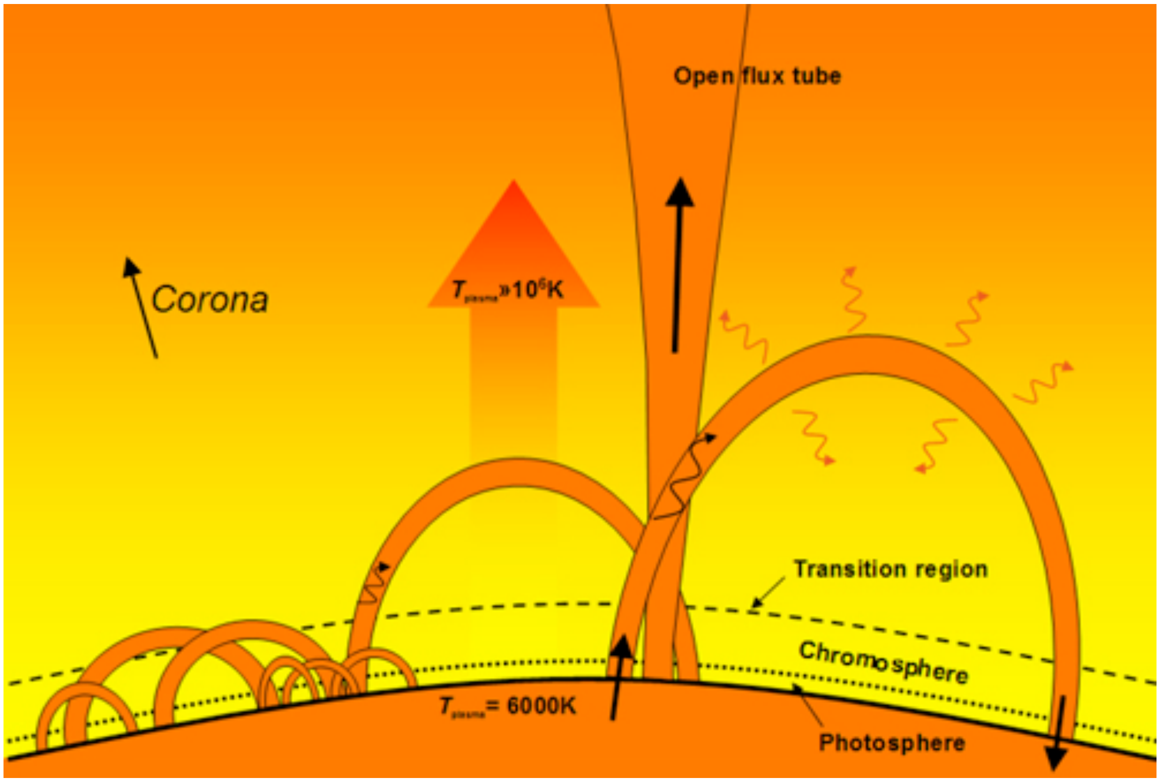

Figure 83. Coronal loops and open flux tubes.

Yet we also see electric currents that ignore the overall electric field, and prefer to flow through the penumbral filaments toward the surrounding granular layer (as in Figure 71). The evidence of these currents is that on one side of each filament, the solenoidal field is deflected downward, and on the other side it's upward. Hence there is a circular Ampèrian field generated by a current through the filament.[90]

These penumbral electric currents don't make sense until the entire context is considered. The dominant electric field is between the negative layer below and the positive heliosphere above. Not considering electrodynamics, the electron drift should be straight up. But once the solenoidal configuration is instantiated, electrons moving outward toward space have to cross their own magnetic field lines to get there. This introduces a new Lorentz force that deflects the electrons into spirals around the solenoidal lines. (See the deflected path at the top of Figure 82.)

Now if we look carefully at Figure 71, we see that the penumbral filaments have no footpoints at the outer ends. The granules outside of the sunspot seem relatively unaffected, even by filaments that arc across their tops. So where do the penumbral currents go? To answer this, we have to remember that the electric field is between the Sun and the heliosphere. With an added Lorentz force, the current can be deflected. But the solenoidal lines close within the Sun, and if the current kept following them, it would be taken back down, into the Sun. This would have the current flowing *against the electric field*. So once the current gets to the top of a filament, the electric field starts *decelerating* the current. With decreasing velocity, the current's Ampèrian field diminishes, leaving it less subject to the Lorentz force. Then the electrons are dispersed by their own Coulomb force, and are free to respond simply to the solar~heliospheric electric field. Hence the tapering filaments are evidence of their relaxing current density, and they do not discharge into the granules at all.

The deflection of the current also answers the obvious question of why we don't see evidence of an increased current density in the chromosphere above a sunspot. Once the current gets past the resistance inside the Sun, its velocity should increase dramatically, and the current should get pinched into a discrete discharge channel. In other words, there should be a spicule on top of every sunspot, but this is not what happens. Yet a *decreasing* current density, and an absence of spicules, is expected in the presence of a solenoidal field, whose lines splay outward. Currents following those lines will get less dense, not more.

Hidden in this is a more interesting question. If the magnetomotive force is a solar~heliospheric current, why do the lines of force close in such small loops? The axis of the solenoid should stay organized, and in fact, it should get stronger, as the current accelerates out into space. This shouldn't form a solenoid just within the Sun — the magnetic field should be as big as the current itself.

Yet the current has to pass through the granular layer, which is cooler. Electron uptake in this layer represents an increase in resistance to the current. So the electron drift velocity is reduced. The result is that the magnetic field density relaxes. This allows the stronger field lines already generated to close locally. When they do, the current out of the top is further decelerated by the braking effect of the penumbral Lorentz forces, further reducing the field in and above the granular layer. So the whole thing resolves into a local solenoid, instead of an interplanetary one.

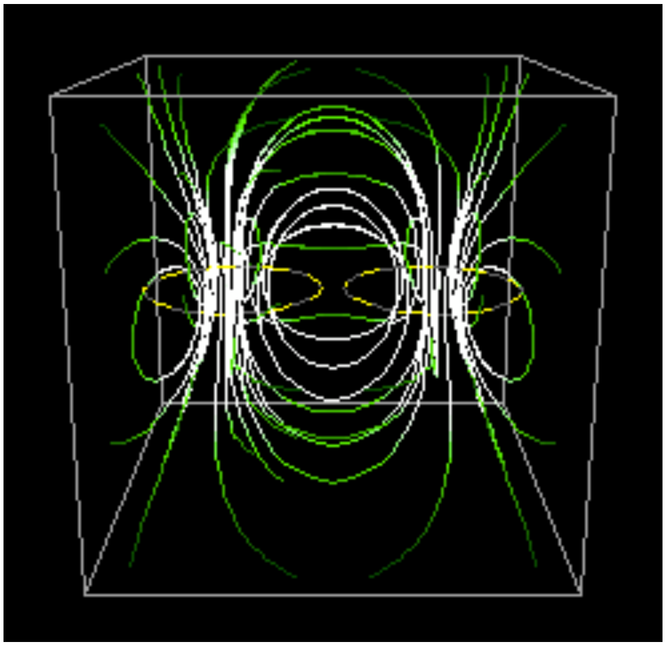

Figure 85. Closing field lines in reversed solenoids.

The next topic is sunspot pairs. The primary sunspot's field has the same polarity as that hemisphere's pole, but the secondary sunspot's polarity is always reversed. This is because the secondary sunspot forms in the presence of an overall field that is opposite. While the Sun's overall magnetic field, at 1 Gauss, sets up the Lorentz force that induces the rotation in the first sunspot, the rotating current generates a 4000 Gauss field. (See Figure 80.) Where its closing lines of force dive back into the Sun, the dominant magnetic field is opposite from the Sun's overall field in that hemisphere. If another sunspot forms in the presence of *that* polarity, its electrons will spiral in the opposite direction, to generate a magnetic field that agrees with *those* lines of force.

The two sunspots then make a pair that is much stronger, as neither has to fight back-pressure in the surrounding granular layer. (See Figure 85.) In both cases, the prime mover is the electric force that induces a flow of electrons upward, and the physical characteristics (i.e., width, Evershed flow, Wilson depression, etc.) are roughly the same for either polarity. The only difference is which way the electrons rotate as they climb up through the convective zone.

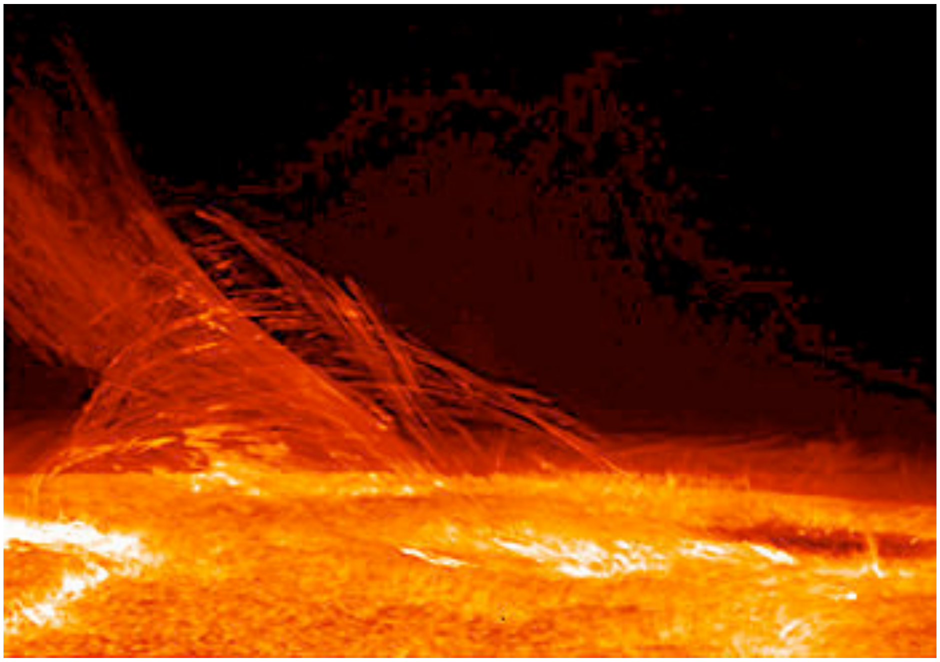

Figure 86. Taken by Hinode's Solar Optical Telescope on 2007-01-12, this image of the Sun reveals the filamentary nature of the plasma connecting regions of different magnetic polarity.

Between sunspots there can be filaments (also called "prominences" when viewed from the side). (See Figure 86.) These filaments definitely match up with the magnetic field lines that have been measured, so there is no doubt that the EM configuration is like that shown in Figure 85.

Typically the filaments are described as magnetized particles in "magnetic flux tubes," like beads sliding down a string, but this is not correct. With weak magnetic dipoles, hydrogen and helium plasma wouldn't be moved much anyway, even in extremely powerful magnetic fields. Furthermore, magnetic fields can only accelerate magnetized particles where the lines of force are converging, and the acceleration is only in the direction of the convergence. Hence there is no way to accelerate magnetized particles out of one pole and into the other, and the ferromagnetic analogy is truly no help here. In superheated hydrogen and helium plasma, all of the magnetic fields come from the flow of charged particles, by Ampère's law. When we see particles flowing along magnetic field lines, we know that it is a B-field-aligned current, wherein the particles spiral to get their magnetic fields lined up with the external field, which in this case is the double-solenoid field. The actual amount of current in these "flux tubes" is substantial compared to the total discharge at the top of the sunspots. (The average solar current density, as the total current divided by the surface area of the Sun, is 2.93×10^{15} A / 6.09×10^{18} m^2 = 5.4×10^{-4} A/m^2, while in the filaments, it's in the range of 1~3 A/m^2.[91:11]) Sunspots are of opposite magnetic polarity, but of *like electric polarity*, so strong currents only flow along these filaments when the charge balance has been disrupted by a solar flare.

Another interesting aspect of sunspot pairs is that the "leading" sunspot always has the magnetic polarity of that hemisphere's pole, while the "trailing" sunspot's polarity is reversed. ("Leading" means ahead, in the direction of the Sun's rotation.) This implies that both sunspots sprang from a hotspot deeper in the convective zone, such as at the liquid hydrogen line. The first upwelling of hotter, more conductive plasma to reach the surface provides a conduit for electrons that rotate in a direction consistent with that hemisphere's overall magnetic field. The second upwelling, arriving later and therefore emerging "behind" the first due to the conservation of angular momentum in the updraft, does so within the closing magnetic lines of force of the first sunspot. Hence the electrons in the trailing sunspot rotate in the opposite direction.

One final detail is worth noting. The umbra of a sunspot is cooler than the surrounding granular layer, issuing black-body radiation in the range of 3000~4500 K, compared to the typical 5525 K radiation from the rest of the Sun. (See Figure 71.)

When combined with the fact that the center of the umbra is typically 700 km below the tops of the granules (i.e., the Wilson depression), the standard model has it that the layer generating the 5525 K radiation is only 700 km thick, and the sunspot somehow parts this layer, revealing the cooler convective zone beneath. In other words, the belief is that the underlying temperature is 3000~4500 K, while in the topmost 700 km, the temperature jumps up to 5525 K. If a sunspot is there, we peer into what we can't see otherwise. This is an odd piece in the standard model, which has all of the energy propagating outward from the core. If we could peel back the outer layer, we should see higher temperatures, not lower.

Then, when combined with "limb darkening" (as presented in the Granules section), the standard model is stretched to the breaking point, because the temperature profile in the topmost 700 km would be 3000~6400~4600 K. It's hard to believe that such a stratification would be possible when also remembering that granules redistribute the heat in this layer every 20 minutes. So all of the energy would have to be converted *within that 700 km layer*. Yet the standard model has heat convecting to the surface. Furthermore, what kind of conversion could be occurring in hydrogen plasma, only when it gets to a density 4 orders of magnitude thinner than STP air?

It's far more reasonable to consider that the optical depth is far greater, and that the 4600~6400 K black-body radiation is coming from a depth of 4+ Mm. As the granular layer is thinner, the temperature should be less, and cooling enables charge recombination. Once neutralized, the atoms become capable of photo-ionization, which explains the absorption lines in the solar spectrum. The net result is that we shouldn't expect a major temperature difference in the Wilson depression just on the basis of heat stratification.

The present construct offers another explanation. The Lorentz force induces a rotation that gets the electrons out of the umbra and into a spiral under the penumbra, meaning less ohmic heating in the umbra. 3000 K is then the temperature of the granular layer with an unusually weak electric current running through it.

CMEs

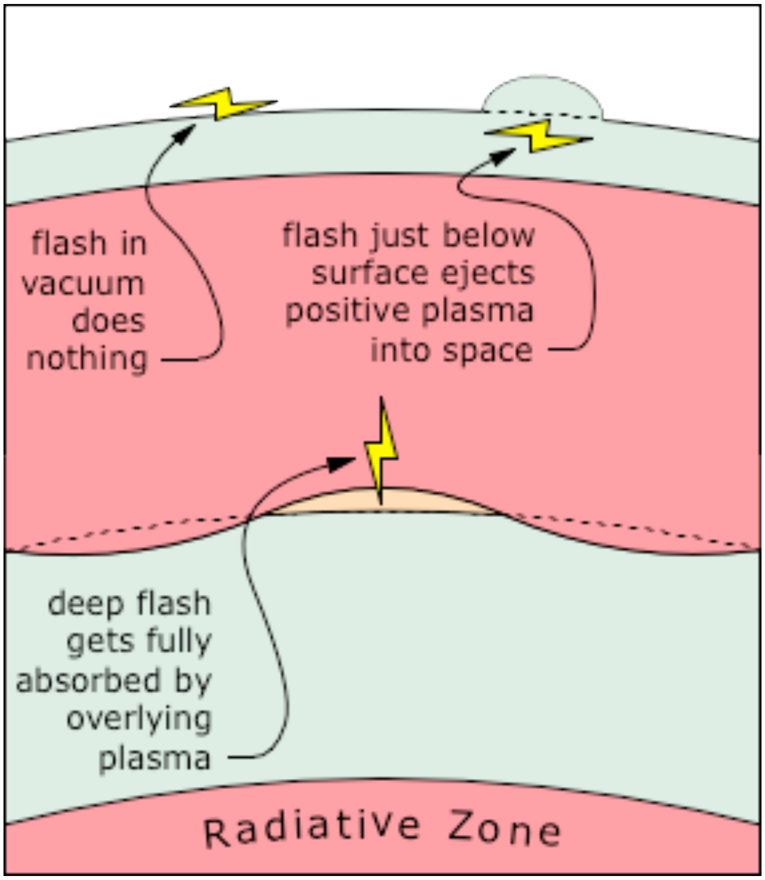

Figure 87. Effects of flashes at different altitudes.

The Potentials section identified CMEs as the critical enabler in the sustained electric current between the Sun and the heliosphere, because they deplete the supply of positive ions on top of the negative layer, so CMEs deserve a more detailed analysis. CMEs are the consequence of flashes below yet near the surface. (See Figure 87.) So we should like to know what causes the flashes. Then we can study the dynamics of the ejections themselves.

Sub-surface flashes are frequently preceded by a sudden disappearance of coronal loops.[92,93,94] Since coronal loops are manifestations of magnetic fields, the standard model explains that the magnetic lines of force "reconnected" below the surface, leading to a huge release of energy. In the words of Wikipedians:

"Scientific research has shown that the phenomenon of magnetic reconnection is responsible for solar flares. Magnetic reconnection is the name given to the rearrangement of magnetic lines of force when two oppositely directed magnetic fields are brought together. This rearrangement is accompanied with a sudden release of energy stored in the original oppositely directed fields."

While that may be the standard answer, here's what the Australian Space Weather Agency said on the topic:

"The bottom line is that at this stage in solar physics we do not really know what produces a flare nor what produces a coronal mass ejection. There are competing theories, but all tend to have deficiencies with respect to matching the observational evidence. We certainly believe that they all depend on the reconfiguration of magnetic fields as their primary energy source, but in the final analysis, we really only believe this because we can conceive of no other solar energy source of sufficient magnitude."

If they can conceive of the magnetic force, why can't they conceive of the electric force? After all, in the absence of magnetized particles, the only thing that can generate magnetic fields is the movement of charged particles (i.e., an electric current), which means that the prime mover is the electric field. Not starting there can only lead to mistakes. Four of these are described below.

First, in the most general sense, the reconnection literature does not identify the magnetomotive force responsible for coronal loops, nor the nature of the explosive release of the energy "stored" in them. The term "reconnection" doesn't even appear in electrical engineering textbooks, and hasn't been demonstrated in any laboratory. In short, the model doesn't have a physical foundation.

Second, it's quite obvious that a flare in the extremely thin corona is not going to produce a CME — a flash in a vacuum is just a flash, but a flash in a dense medium is an explosion. (See Figure 87.) So some of the literature specifies that a CME is the result of reconnection below the surface. But there, the magnetic permeability is much lower. How does energy incapable of flashing in the high-permeability corona become explosive in the lower-permeability plasma below the surface?

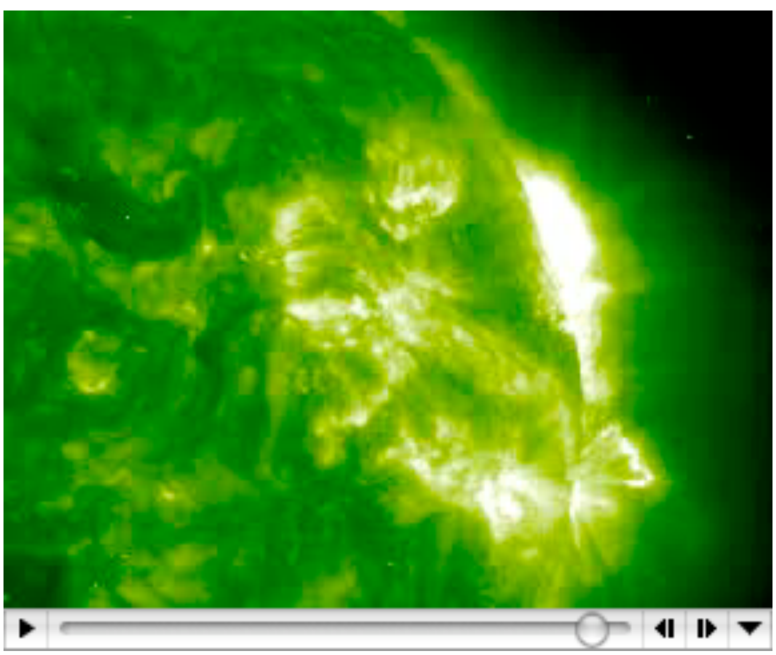

Figure 88. This sequence of flares, from 2003-10-17 to 2003-11-05, included the largest ever recorded, courtesy SOHO. (Click the image to play the movie.)

Third, coronal loops are the most powerful *after the flare*. If the flare is the release of magnetic potential, the post-flare loops should be weaker. (See Figure 88.)

Fourth, by latching onto coronal loops as the central piece, the reconnection model gets everybody thinking of flares and CMEs as the release of potential *between two coupled active regions*. Even models that neglect magnetic fields incorporate this preconception. For example, one theory is that flares are arc discharges that release electrostatic potentials between oppositely charged sunspots (begging the question of what separated the charges in the excellent conductivity of 6000 K plasma). The mistake is in the premise, as there is no evidence of flares connecting two sunspots. Rather, a flare is between an active region and the surrounding positive double-layer. One flare might trigger another, and before the entire event is over, a pair of coupled sunspots might both have discharged into the granules, but never at the same time, never directly from one sunspot to another, and never following the magnetic field lines.

Clearly, the relationships among sunspots, flares, CMEs, and post-flare loops are more complex than they're given credit, and we'll have to pay close attention to the details to work it out.

To start, there *is* direct evidence that solar flares are arc discharges.[65,95,96] This asks many questions.

1. What sort of charge separation mechanism could sustain the potentials for such huge flashes, in the excellent conductivity of 6000 K plasma (as asked just above)?
2. Why, specifically, would the discharge be between the active region and the surrounding quiet areas?
3. And why not toward another active region?

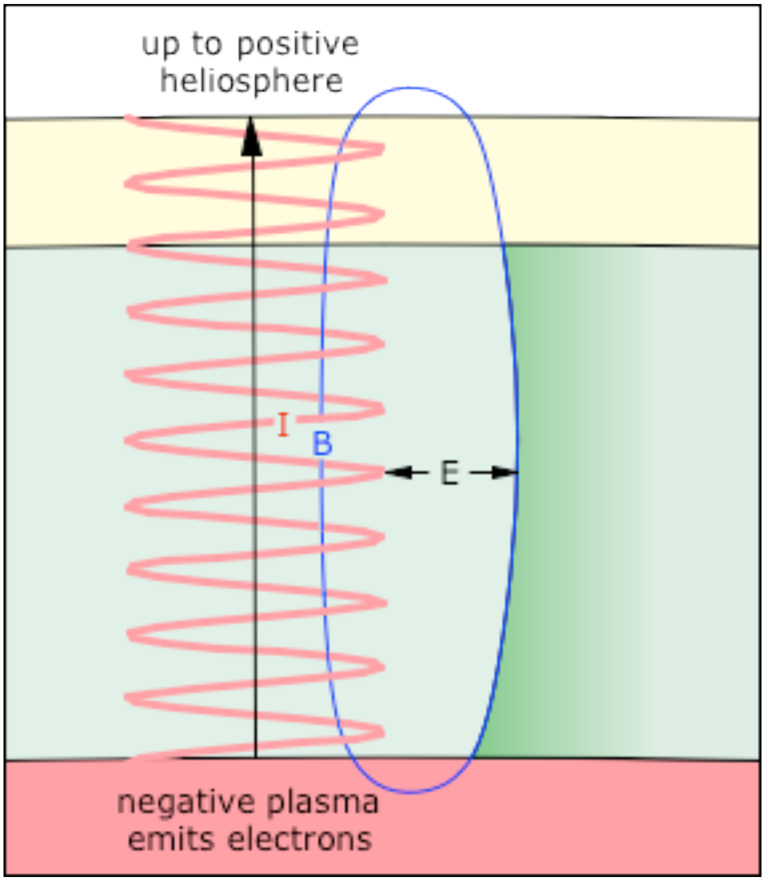

Figure 89. Magnetic pressure maintains charge separation.

The thing that keeps opposite charges from recombining, until extreme potentials have developed, is certainly not any sort of insulator. And the horizontal charge separation mechanism *across the surface* is not compressive ionization, which can only be vertical. There is only one other possibility: magnetic pressure. The electrons spiraling toward the heliosphere are generating powerful B-fields. Once the fields superimpose into an organized form, any electron attracted to the positive double-layer would have to fight the combined magnetic field to get there. (See Figure 89.) As the current density increases, the plasma in the sunspot shaft thins out, due to ohmic heating. Thus there are fewer positive ions, and more electrons, in the spiraling current. The increased charge density inside the current attracts a stronger positive double-layer (shown as darker green in Figure 89). But it also generates more powerful magnetic fields that keep the charges from recombining. So if the current density is steady, or increasing, the horizontal E-field between negative charges inside the sunspot shaft and positive charges outside of it can continue to build.

But what if the current relaxes? Then the magnetic pressure goes away, and the opposite charges are free to recombine. Having built up to extreme charge densities, the recombination might be catastrophic.

In this context, it makes sense that flares are preceded by sudden disappearances of coronal loops. If the current relaxes, the solenoidal B-field that it was generating relaxes as well. So the coronal loops go away, and then there is a flare, and not because of "magnetic reconnection" below the surface, but because of the expiration of the magnetic pressure, enabling "electric reconnection" (if you will).

It also makes sense that after the flare, the coronal loops come back, and far more vigorously. The loops are manifestations of a solenoidal magnetic field, and the magnetomotive force is a vertically oriented electric current responding to the solar~heliospheric E-field. If the B-field is more dense, the electric current must be more robust. This is expected if the flare ejected a large volume of positive plasma, leaving the Sun with even more of a net negative charge, and creating an even higher potential between the Sun and the heliosphere.

In cases where two proximal sunspots are generating opposite-polarity solenoids, the axial lines of force will be coupled. If one of the consequences of the flare is that there is a disparity in charge density between the sunspots, an electric current will flow between them, and it will follow the magnetic field lines.[97,91:9] The density of such currents has been estimated (perhaps conservatively) at 1~3 A/m^2.[91:11] Whatever it is, that's a lot compared to the solar~heliospheric current, which is 5.4×10^{-4} A/m^2. So flares leave major charge disparities between sunspots, and with the magnetic lines of force already there, healthy currents flow from one sunspot to the other.

Now we can consider the properties of the CMEs themselves. The Wikipedia article lays out the basics.

> A typical coronal mass ejection may have any or all of three distinctive features: a cavity of low electron density, a dense core (the prominence, which appears as a bright region on coronagraph images embedded in this cavity), and a bright leading edge.
>
> Coronal mass ejections reach velocities between 20 km/s to 3200 km/s with an average speed of 489 km/s, based on SOHO/LASCO measurements between 1996 and 2003. The average mass is 1.6×10^{12} kg. The values are only lower limits, because coronagraph measurements provide only two-dimensional data analysis. The frequency of ejections depends on the phase of the solar cycle: from about one every fifth day near the solar minimum to 3.5 per day near the solar maximum. These values are also lower limits because ejections propagating away from Earth (backside CMEs) can usually not be detected by coronagraphs.
>
> Current knowledge of coronal mass ejection kinematics indicates that the ejection starts with an initial pre-acceleration phase characterized by a slow rising motion, followed by a period of rapid acceleration away from the Sun until a near-constant velocity is reached. Some *balloon* CMEs, usually the slowest ones, lack this three-stage evolution, instead

accelerating slowly and continuously throughout their flight. Even for CMEs with a well-defined acceleration stage, the pre-acceleration stage is often absent, or perhaps unobservable.

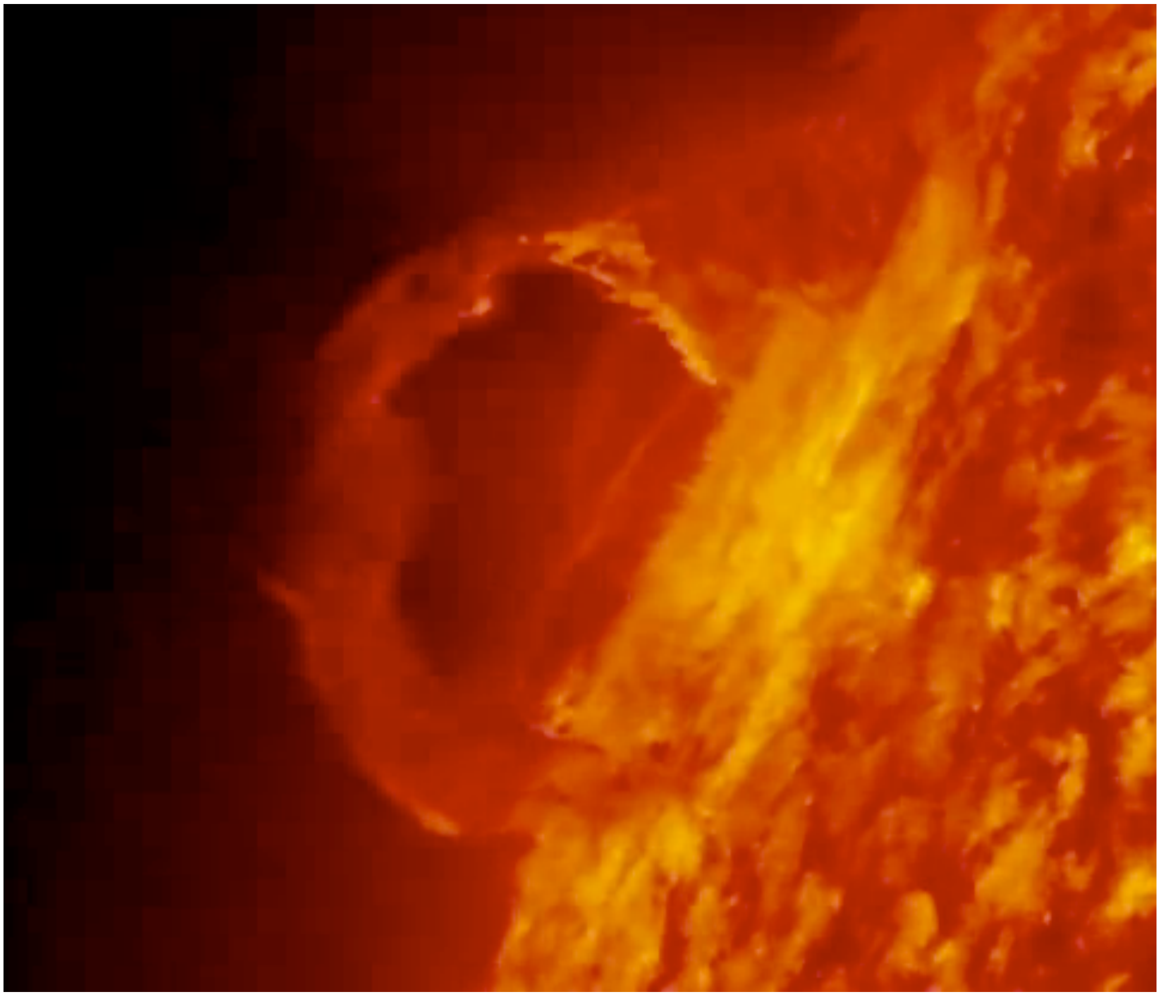

Figure 90. Balloon CME, 2010-03-30, courtesy [SDO](SDO).

The "cavity of low electron density" makes sense if the granular layer is positively charged. But if we think of a CME as an explosive event, the kinematics do not make sense, especially for a "balloon" CME. (See Figure 90. Click the SDO link to watch the movie.) Its physical dimensions are larger than all other types, suggesting that the "explosion" was a lot larger. But instead of instantaneously achieving peak velocity, the plasma starts slowly and constantly accelerates. More interestingly, the interior is clear, while the boundary is opaque, and the plasma around the outside sheds off the bubble and falls back into the Sun, frequently moving at relativistic speeds. All in all, it looks like a balloon bursting (hence the name), but that's a descriptive metaphor, not an explanation.

The movie associated with Figure 91 shows a CME that was well below the surface, as we see expansion before there is evidence of a flare, and a huge volume of plasma is ejected. Yet the "balloon" quickly breaks. Some material continues on out into space, but the majority is pulled back into the Sun. Notice the non-ballistic trajectories of the parcels, and their relativistic velocities. Clearly, a force far more powerful than gravity is pulling the plasma back, and directing it toward specific points of entry back into the Sun. This can only be evidence of EM forces.

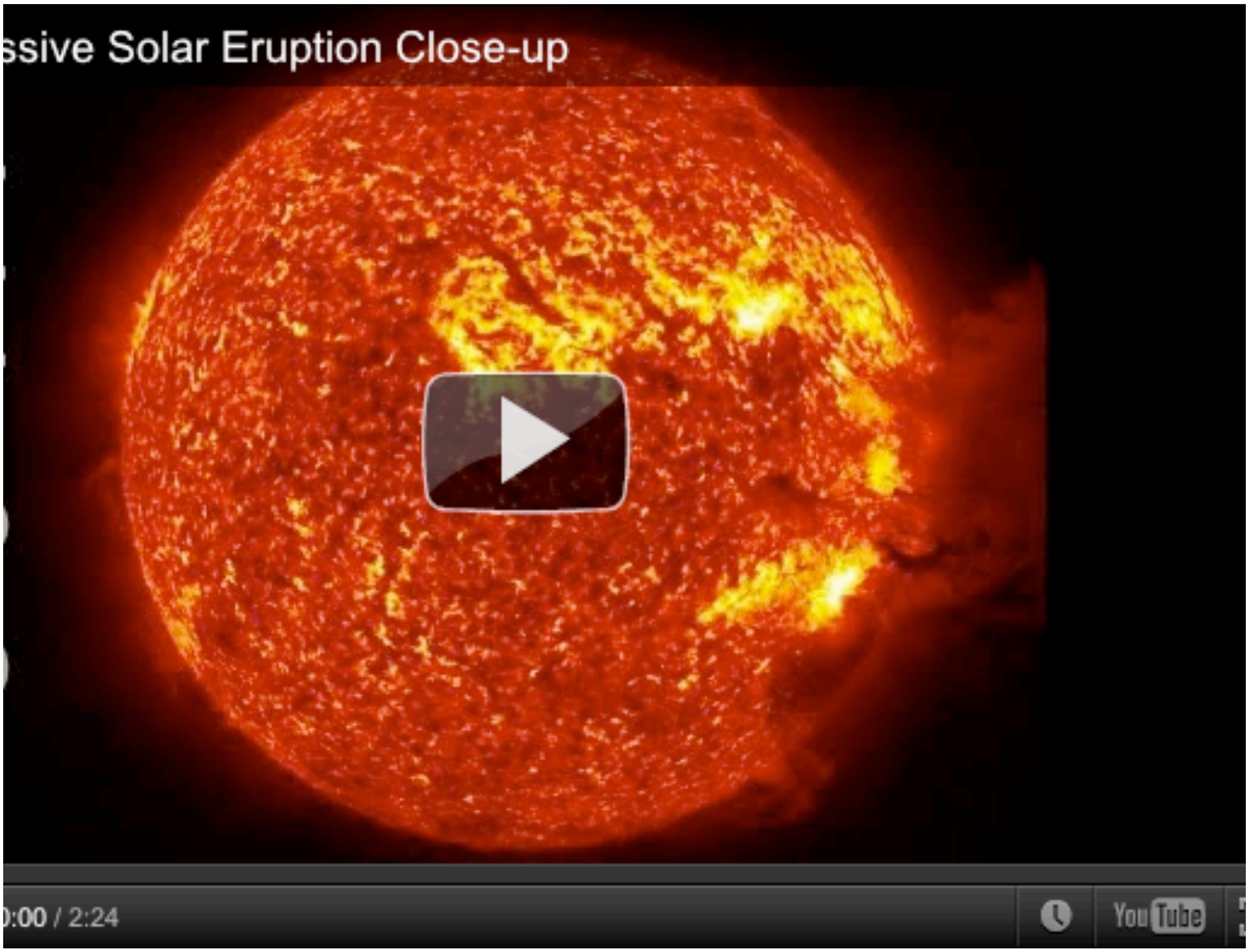

Figure 91. CME on 2011-06-07, courtesy Goddard Space Flight Center.

Sorting this out requires returning to the electrostatic model, which has electrons being accelerated away from the Sun, and positive ions being pulled inward. In this context, we can think of the clear interior as free electrons, and the dark boundary as positive ions. An explosive event below the surface accelerates positive ions outward, initiating the bubble. This draws free electrons out of the underlying negative layer, which fill up the interior of the "balloon." We can expect flashes in the corona due to charge recombination (hence the "bright leading edge"), but opposite charges that do not recombine will be accelerated in opposite directions in the 1.7 GV electric field. Electrons moving away from the current divider will pick up speed in the direction of the heliosphere, while positive ions will be pulled forcefully back into the Sun.

Note that these rare balloon CMEs are not depleting the store of positive ions, and thereby driving the solar~heliospheric current. Rather, they would *seem* to expel more electrons than ions. (At least that's the interpretation within the present model, and which seems to be necessary to explain the bidirectional acceleration.) So in the present model, balloon CMEs are the rare exceptions, where the rule is that CMEs deplete the positive charge in the topmost 20 Mm. The estimate of the solar mass loss due to CMEs (i.e., 3.43×10^7 kg/s) that was used in the Conversions section to calculate the solar~heliospheric current density is of course based on the mass of the nucleons, not the electrons.

One other aspect of the event in Figure 91 is worth mentioning. We can clearly see that the plasma getting pulled back down is opaque at 304 Å. Interestingly, this is a wavelength that hydrogen and helium cannot absorb, so this is primarily iron plasma. Yet solar spectroscopy estimates the surface of the Sun to be 75% hydrogen, 25% helium, and only 1 part in 30,000 of iron.[46] Some researchers believe that this is evidence of much greater quantities of iron in the convective zone, while the present model offers another suggestion. It was noted earlier that the pre-flare solar~heliospheric current in the sunspot shaft attracts a positive double-layer, though the magnetic field prevents charge recombination. Heavier elements are capable of higher degrees of ionization. Hence hydrogen is only capable of losing one electron, but iron is regularly observed in the solar atmosphere missing 14 of them. The much greater ionization will produce a much more vigorous response to an electric field. Thus we can expect the atoms in the positive double-layer around the sunspot shaft to be sorted by degree of ionization, with a concentration of Fe XV way out of proportion to its average abundance in the convective zone. If a flare occurs and there is a CME, the constitution of the ejected plasma will be misrepresentative of the average abundances in the convective zone. Once ejected, weakly ionized hydrogen & helium might continue on out into space. These ions represent a net charge loss, and will therefore drive the subsequent solar~heliospheric current as calculated in the Conversions section. Any highly ionized iron in the ejecta will be far more subject to the electric field, and will get pulled back down.

We should also wonder how arc discharges cause such explosive events. Some think that it's just the rapid expansion of the discharge channel, because of ohmic heating. While the temperature is well into the MK range, the slowest CME speeds (i.e., 20 km/s) are still supersonic for that temperature, ruling out simple thermal expansion.

The first realistic candidate for such an accelerator is relativistic electrons colliding with positive ions. On Earth, the electrons in lightning traveling ~5 km achieve approximately 1/10 the speed of light. Discharges in the Sun can extend more than 100 Mm, and it's possible that the electrons achieve speeds over 9/10 the speed of light. As these electrons evacuate the discharge channel, the collisions will be extremely high-energy events, creating a supersonic shock wave propagating outward.

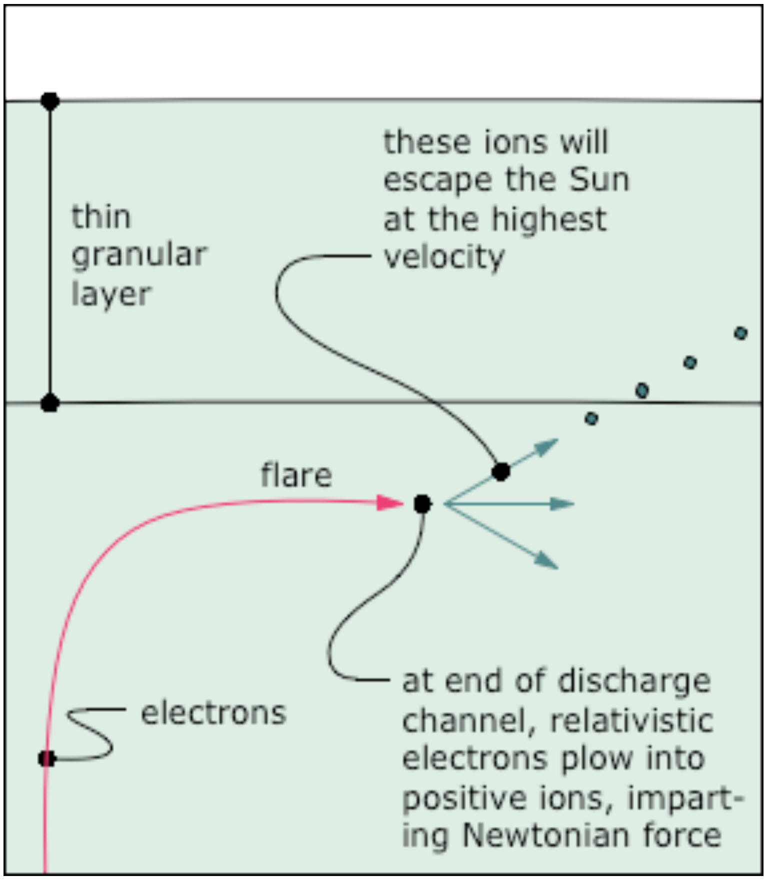

Figure 92. Particle collisions at end of discharge channel.

Evidence of this relativistic electron drag might be the so-called "proton storms" that sometimes hit the Earth at extreme velocities. One of the most vigorous of these on record occurred 2005-01-20, and the protons travelled at 1/3 the speed of light on their way to the Earth.[98] Such proton storms tend to occur when the solar flare is at 60° west longitude.[99] Assuming that the discharge was parallel to the surface of the Sun, and the azimuth of the discharge was pointing in our direction, the highest-velocity particles would be those scattered slightly upward (such as at a 30° angle). (See Figure 92.)

Somewhat more significantly, when the electrons plow into stationary plasma at the end of the channel (perhaps analogous to the "beads" at the ends of stepped leaders in terrestrial lightning), the instantaneous increase in temperature and pressure might create the conditions necessary for nuclear fusion.[65,64,66] If this is the case, CMEs are at least partially thermonuclear explosions, and relativistic ejecta are easy to understand.

The direct data from the explosions themselves also seem to fit nicely into the arc discharge model. (See Figure 93.) The rise in soft X-rays preceding the flare is consistent with an electric arc. The hard X-rays and gamma-rays are indicative of nuclear fusion, and the "impulsive" increases are analogous to stepped leaders in terrestrial lightning.

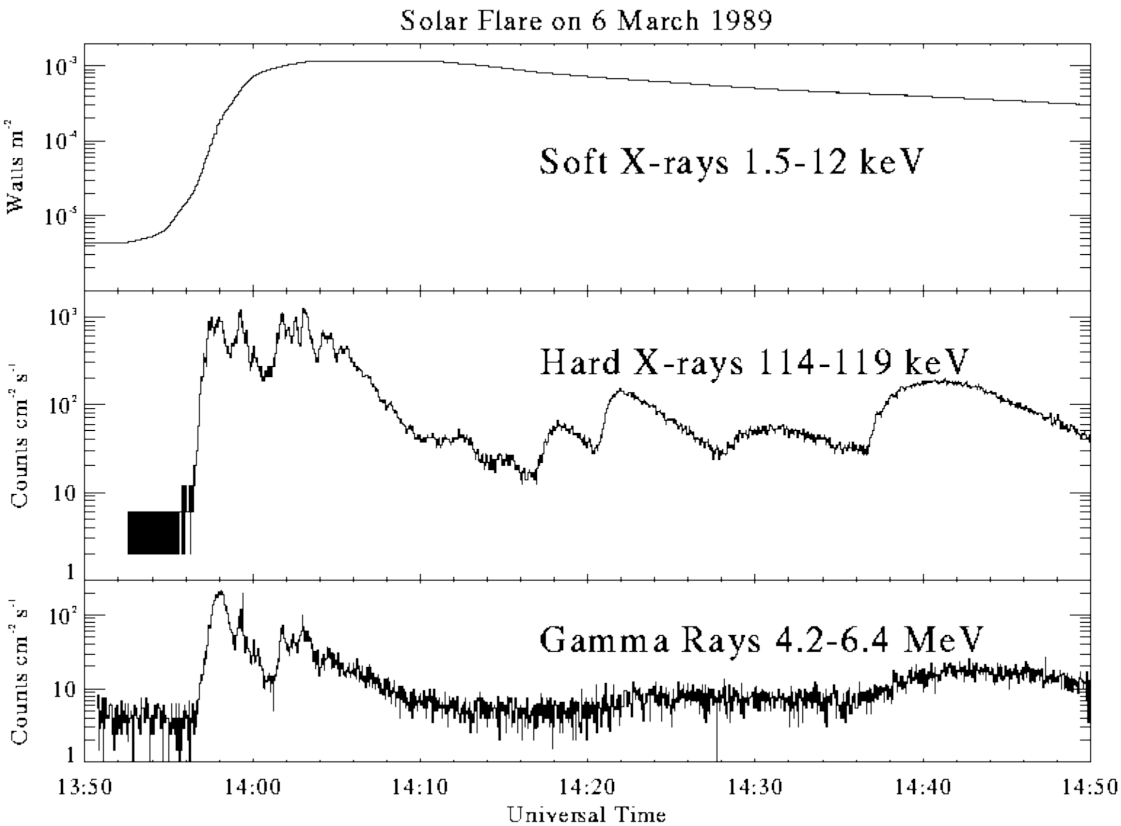

Figure 93. In the preflare stage (13:50 to 13:56 UT), the soft X-ray emission gradually increased, but little if any hard X-rays or gamma rays were detected above the instrumental background level. This was followed by the so-called impulsive phase, in which the hard X-ray and gamma-ray emission rose impulsively, often with many short but intense spikes of emission, each lasting a few seconds to tens of seconds. (Data and description courtesy NASA.)

Arcades

After a solar flare, sunspot pairs frequently become connected by coronal loops, known collectively as arcades. Robust loops are more likely to occur if 10~24 hours before the flare, there is a significant increase in the number of high energy protons ejected by microflares.[91] In the present model, the ejection of protons thins out the positive double-layer clinging to the solar cathode, encouraging the primary current out into space. Greater current densities in the sunspot shafts develop more powerful magnetic fields that keep the currents organized, which prevents discharges into their positively charged sheaths. This allows the electric fields to develop to extreme limits before flares occur, meaning much more powerful CMEs. And the consequence of a CME is that positive ions are ejected into space, creating a charge disparity between the sunspots. Electric currents discharging that potential will follow the magnetic lines of force, producing coronal loops.

Interestingly, the coronal loops show up best in 284 Å emissions from Fe XV, which is iron that is missing 14 electrons. This is interesting because hydrogen is about 30,000 times more abundant than iron in the granular layer and lower corona,[46] meaning that these loops *should* show up far better in H-α emissions, but which aren't present at all.

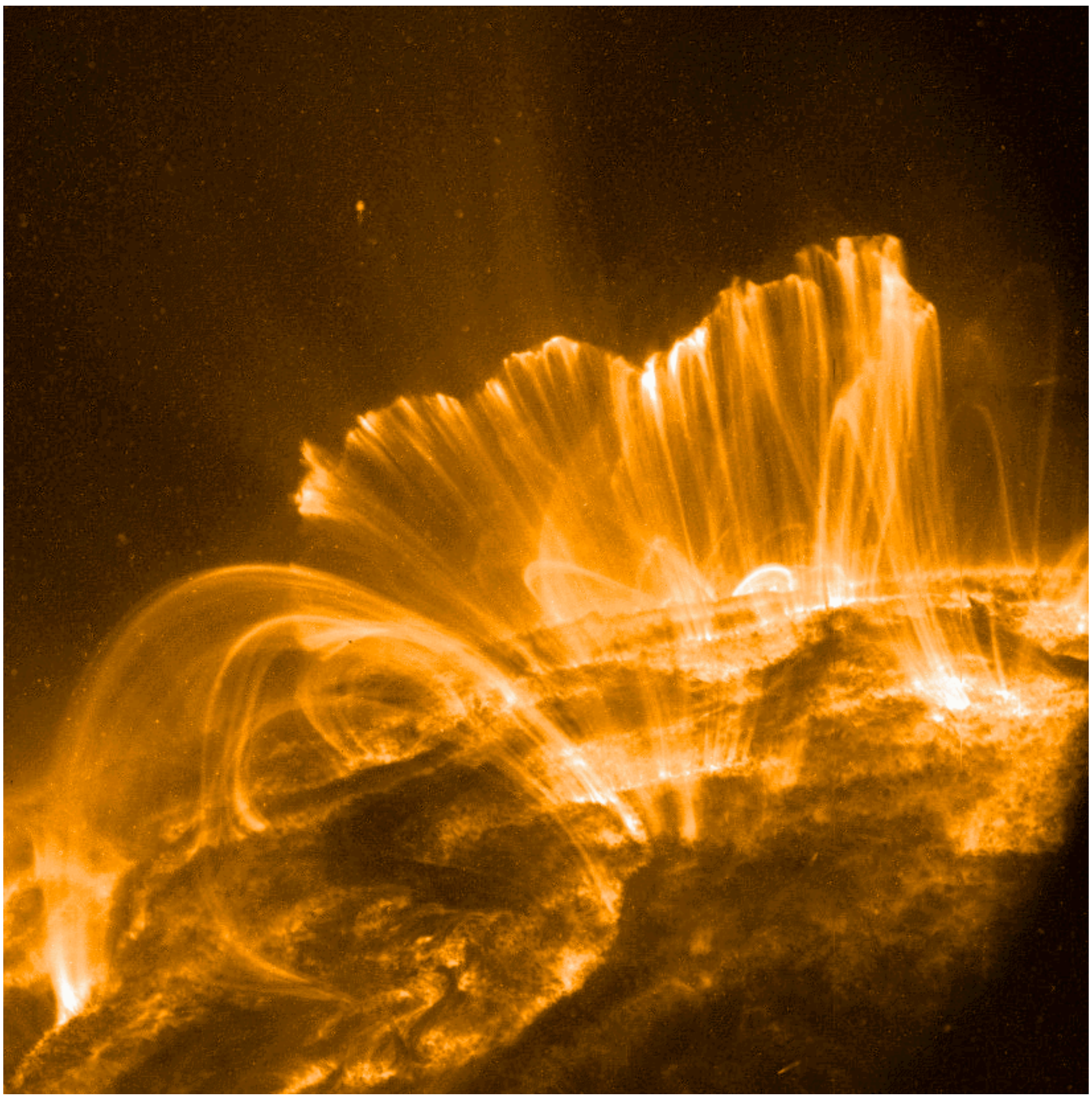

Figure 94. Coronal loops seen in 284 Å emissions, produced by Fe XV, sprouting out of what is sometimes called "solar moss" (i.e., the irregular surface of the Sun seen in iron emissions). Note that in single-frequency imagery, brightness doesn't mean temperature, but rather, just ion density.

We know that these coronal loops match up exactly with magnetic lines of force. We also know that magnetic fields don't produce photons, but electric currents do (assuming that there are atomic nuclei in the way). So these are B-field-aligned electric currents that reconcile charge disparities between sunspots,[97,91:9] usually and most vigorously after the arc discharge in a solar flare, and with a current density of 1~3 A/m^2.[91:11]

We might be tempted to say that the currents prefer concentrations of iron because of its conductivity, but *all* of the plasma in the Sun is a near-perfect conductor. So the conductivity of the far more abundant hydrogen should serve the purpose just fine, and we still have no explanation for the presence of iron emissions, and the absence of hydrogen emissions.

We might also think that iron would be more attracted by the magnetic field, and hence get drawn into the filaments, but ionized iron is not magnetic. Furthermore, even if it was, it would move toward the poles, and it would not form continuous loops. Magnetic fields can only accelerate magnetized particles where the lines of force are converging, and the acceleration is only in the direction of the convergence. Hence the particles aren't going to flow out of one pole and into the other, as we see in these arcades.

The only relevant property of iron plasma is simply that it is capable of higher degrees of ionization than hydrogen. At the end of the CMEs section it was noted that we can expect the positively charged sheath around a sunspot shaft to contain an inordinate amount of highly ionized iron, as it is capable of responding much more vigorously to the electric field. In short, the Fe XV pushes the H^+ out of the way, as it is motivated by 14 times more force. The concentration of iron in the current sheath then explains its inordinate abundance in CMEs. This also means that after the flare and the CME, if coronal loops form, they will connect two regions that are rich in iron. These atoms can then get sucked up into the loops, in one direction by electron drag, and in the other simply by the electric force.

The next question concerns the temperature. Fe XV is typically estimated to be over 2 MK. The assumption there is that the only thing that can knock an electron off of an atom is atomic motion. We can then estimate the atomic motion (i.e., temperature) by the degree of ionization. This is convenient for extremely high temperatures that cannot be measured any other way, and for estimating temperatures of distant objects (such as the Sun). But it may be just a little *too* convenient, and perturbing factors might be getting overlooked. The reality is that temperature isn't the only thing that can ionize plasma. Powerful electric fields do the same thing, and these actually remove degrees of freedom, thereby lowering the temperature instead of raising it.[52] This isn't taken into account because there is no way to measure an electric field from a distance. But when we see things that just don't make sense when temperature is estimated just by the degree of ionization, we have to remember that this might be evidence not of high temperatures, but of powerful electric fields. As concerns coronal loops, it's hard to imagine how filaments can persist, sometimes for hours, at >2 MK, without getting blown apart by the pressure from the extreme temperature, especially considering the fact that they are surrounded by a near-perfect vacuum. It's more likely that the temperature is far less, and that the iron concentrations are maintained by the electric and magnetic forces.

Further to the point, we also have good imagery of 171 Å emissions from Fe IX and Fe X (i.e., iron missing 8 or 9 electrons). (See Figure 95.) We see the same affinity for active regions. But we also see a solid background of iron emissions in the quiet areas. (Note that the 3D effect comes from post-processing, and is not an indication of altitude. The raw data simply registered ion densities. These were made easier to visualize by brightening the gradients facing in one direction, and darkening them in the other, creating the 3D effect.)

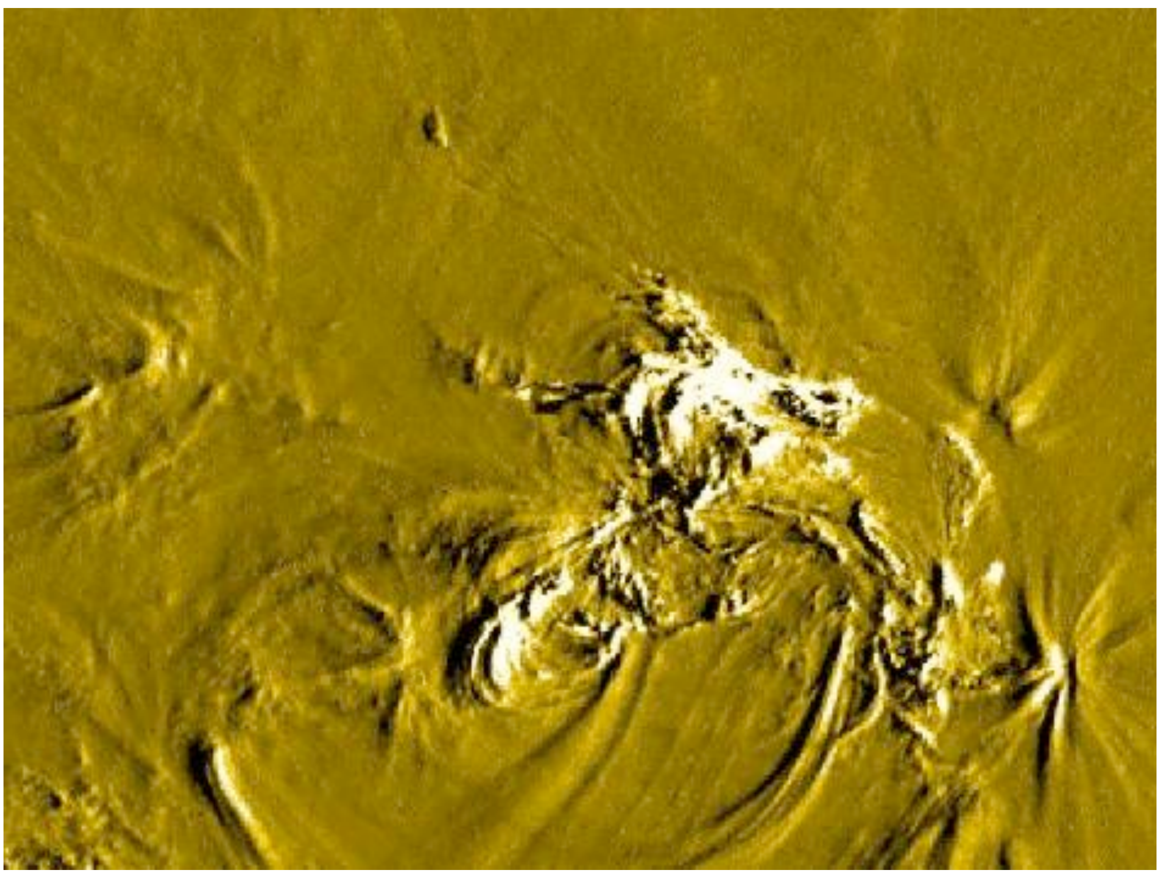

Figure 95. Active region 9143, 2000-08-28, seen in 171 Å emissions, courtesy TRACE.

The ionic temperature of Fe IX/X is about 1.5 MK. But why would the iron be so hot in the quiet areas, when the surrounding hydrogen is only 6000 K? Here we have to remember that hydrogen is 30,000 times more abundant than iron in the granular layer. This means that iron atoms are 30,000 times more likely to bump into hydrogen atoms than other iron atoms, and all of the atomic motions (i.e., temperatures) should be well distributed among all of the elements present. If the ionization cannot be attributed to temperature, it can only be proof of a powerful electric field.

On a much larger scale, we see patterns in 195 Å emissions from Fe XII that sometimes persist for days, or even weeks, in a recognizable form. This is suggestive of physical structures inside the Sun.

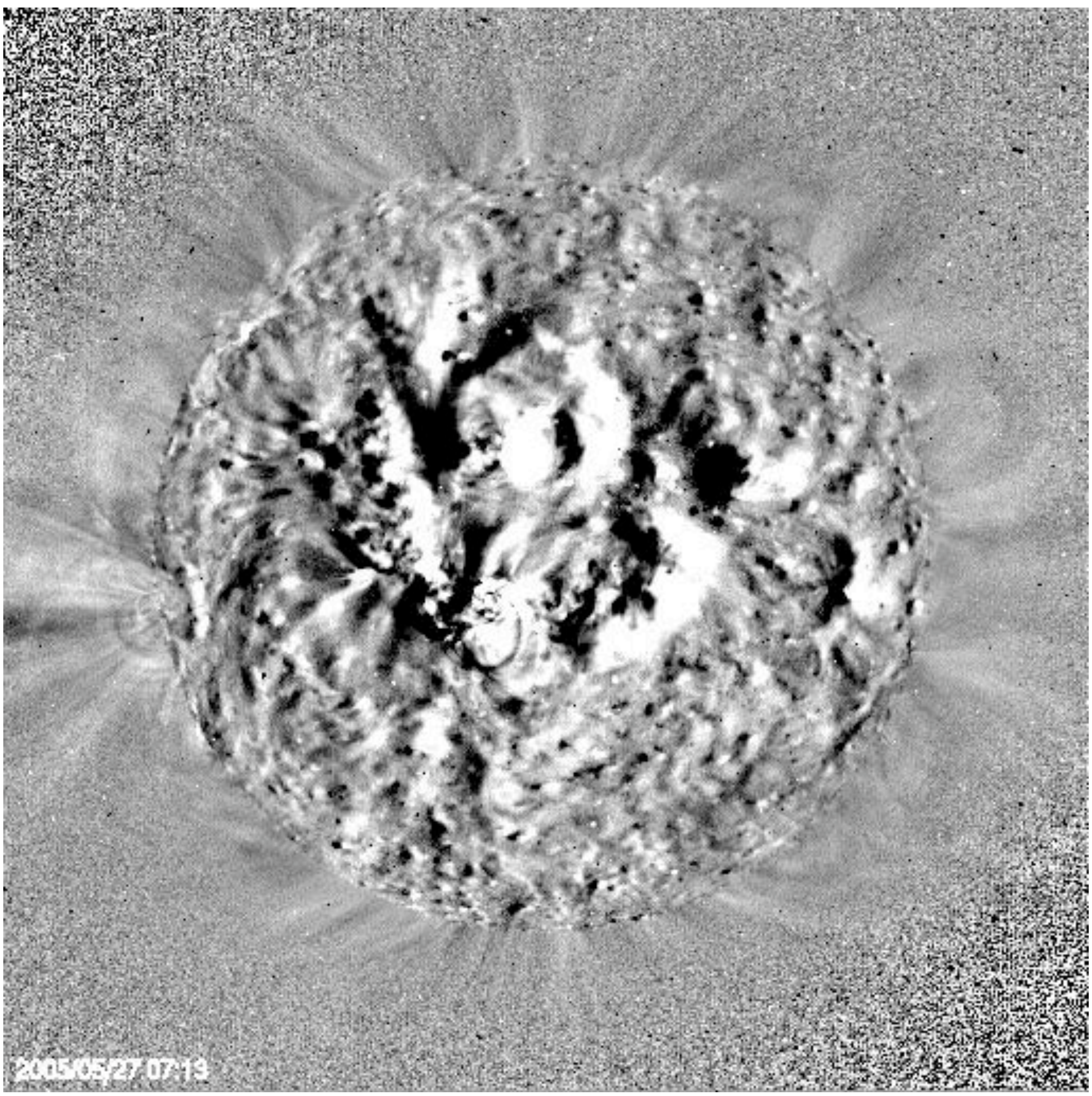

Figure 96. 195 Å emissions, 2005-05-27, courtesy SOHO.

But again, hydrogen is 30,000 times more abundant than iron in the granular layer. Persistent concentrations of iron ions in the Sun do not reveal the topography of structural features any more than clouds in the Earth's atmosphere do. What we're seeing is iron atoms suspended in hydrogen plasma. We see the iron because we're filtering only for iron emissions, which hydrogen cannot block.

Nevertheless, the ion concentrations give us an enormous amount of information. When interpreted as evidence of electric fields, and when correlated with coronagraphs, we get a more complete picture of the electric currents that power the Sun. The ions reveal increases in the local electric field, due to equatorial thinning of the positive double-layer, and due to the depletion of positive ions by CMEs.

Corona

Above the visible edge of the Sun is a ~3 Mm layer known as the chromosphere, and above *that* is the corona, which is visible if the Sun is fully eclipsed, either naturally, or with a human-made obstruction of the right size in front of the camera. (See Figure 97.)

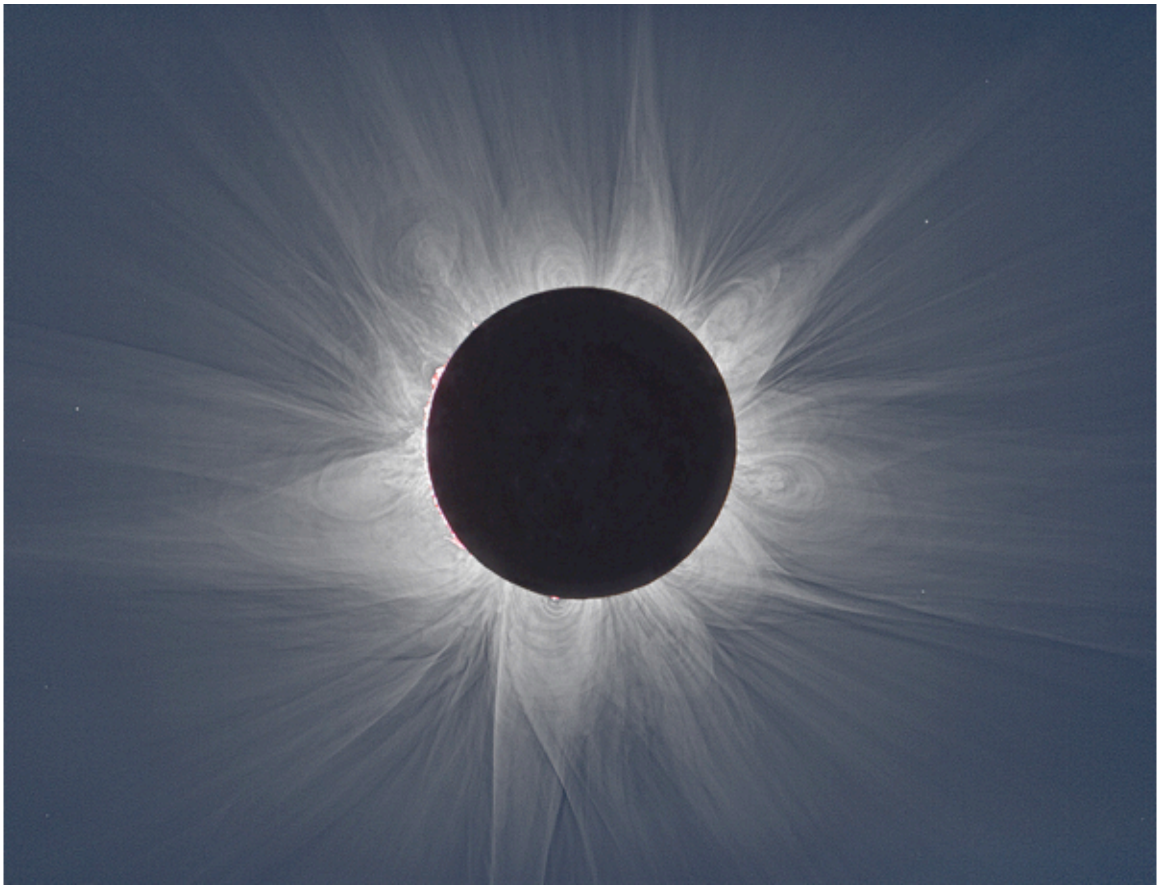

Figure 97. An abundance of helmet streamers in all directions at the sunspot maximum, courtesy Constantine Emmanouilidi.

Some consider the corona to be the most mysterious aspect of all. Temperatures measured by the degree of ionization exceed 1 MK. This would seem to be a violation of the 2^{nd} law of thermodynamics, which predicts that the temperature should fall off with the square of the distance from the source of the heat. But after a small decrease in the first .25 Mm above the surface, the temperature levels off, and then rises, with sharp increases in the upper chromosphere and in the transition region, ultimately achieving over 1 MK in the corona.[100] (See Figure 98.)

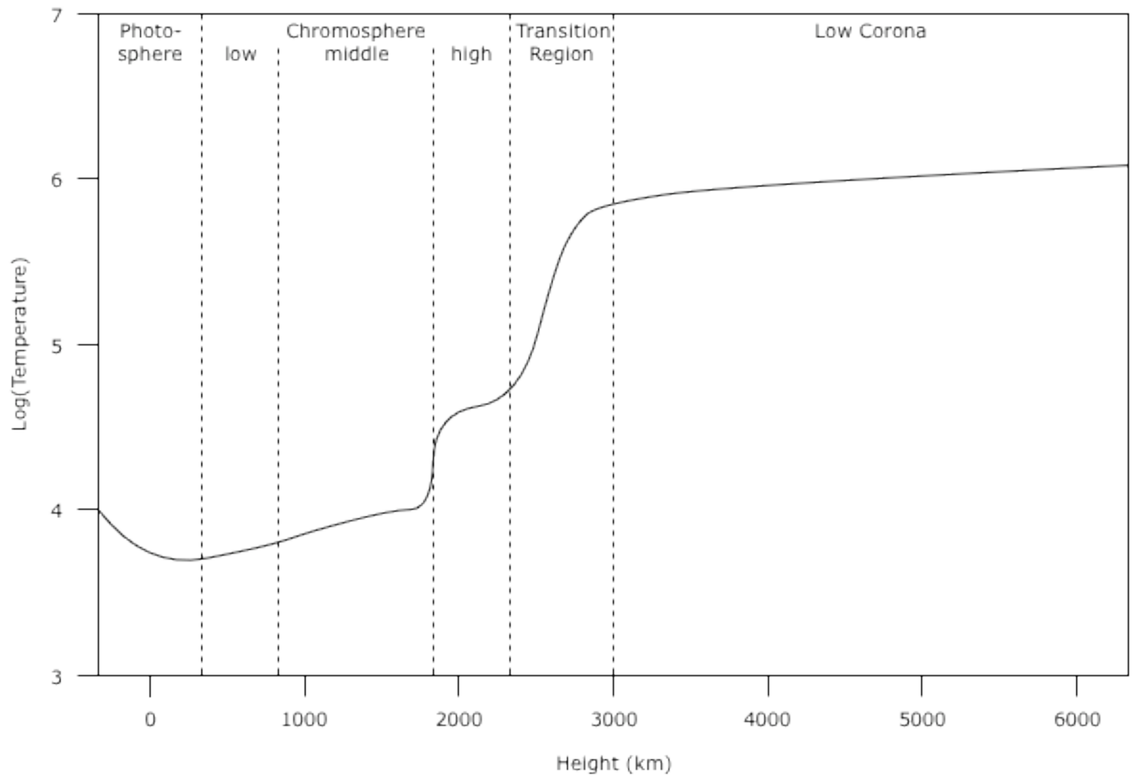

Figure 98. Temperatures at and above the surface, from Erdélyi & Ballai (2011).

At first blush we might think that this is just typical behavior for the atmosphere of a celestial body. The Earth's thermosphere reaches a temperature of 1,700 K without any help from surface heating. (See Figure 99.) In the near perfect vacuum of space, particles achieve extreme speeds, and when drawn in by the Earth's gravity, the initial particle collisions are extremely high-energy events.

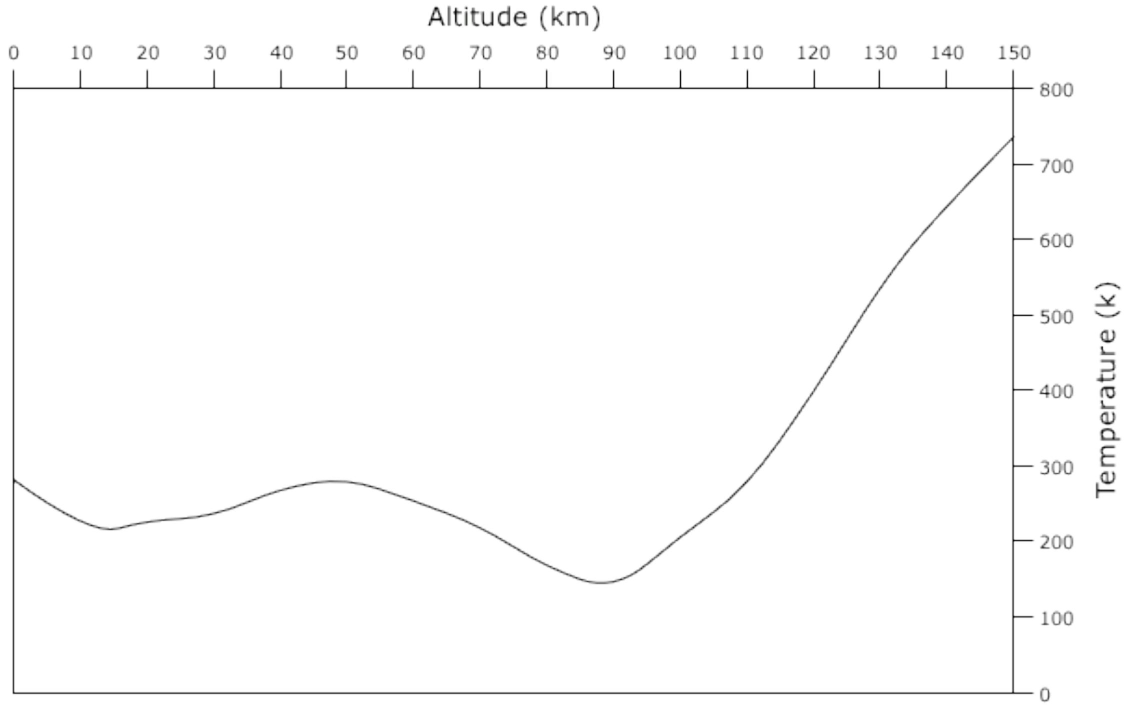

Figure 99. Temperature in the Earth's atmosphere, from Lutgens and Tarbuck, "The Atmosphere."

The Sun's mass is 333,000 times greater than the Earth's. If we scale the temperature by the mass ratio, look at what we get...

1,700 K × 333,000 = 566,100,000 K

So it's possible that the Sun's corona achieves temperatures into the millions of K just on the basis of high-energy collisions from falling particles.[101] And there is actually direct evidence of particles being accelerated inward, by the force of gravity and/or the electric field.[102,103]

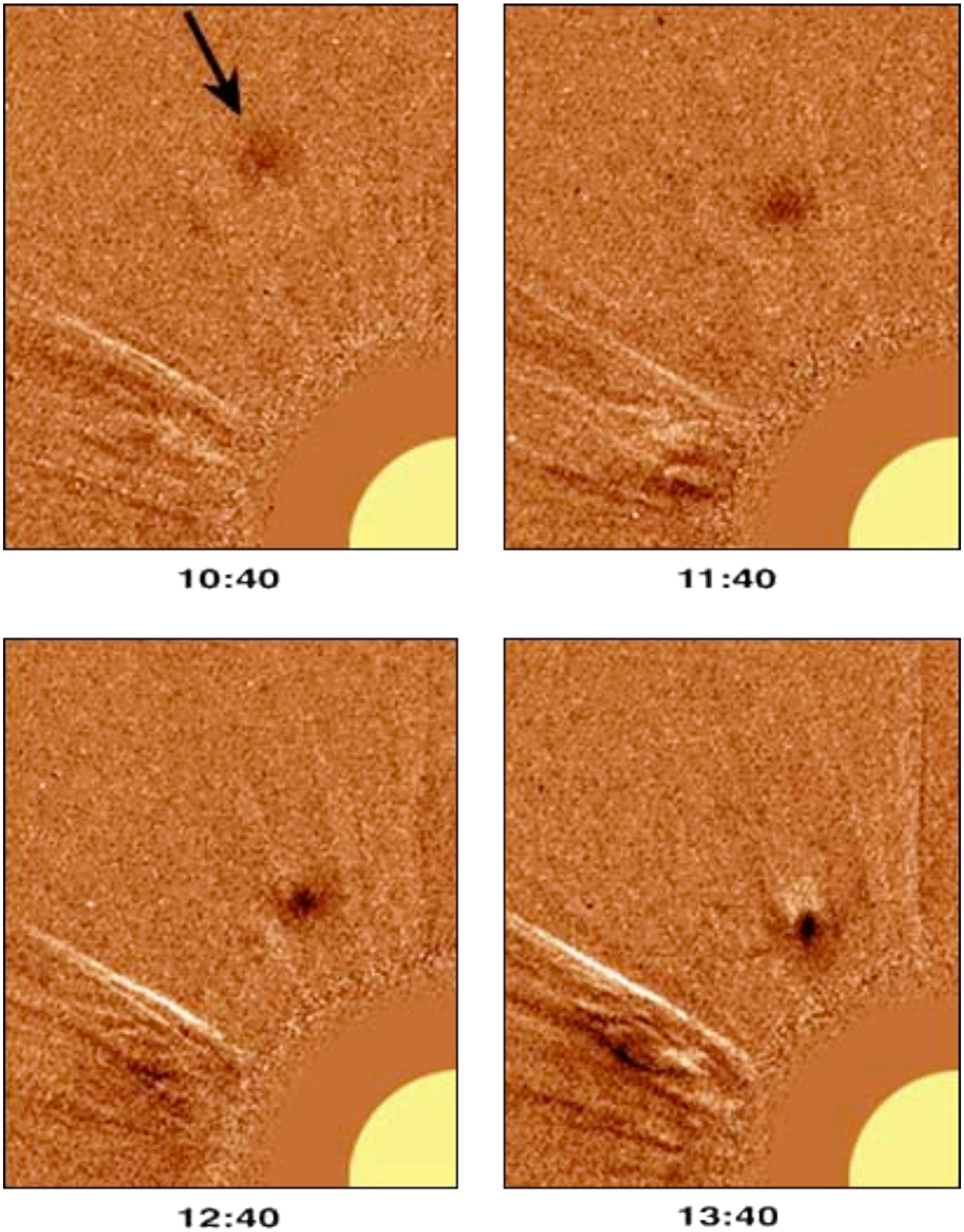

Figure 100. A gas cloud is tracked traveling towards the Sun, courtesy SOHO.

But on closer inspection, it isn't that simple. Videos of the streamers show an apparent *outward* flow. So there are opposing inward and outward forces. Some scientists believe that the outward force is simply hydrostatic pressure in superheated plasma. But there are three major problems with that.

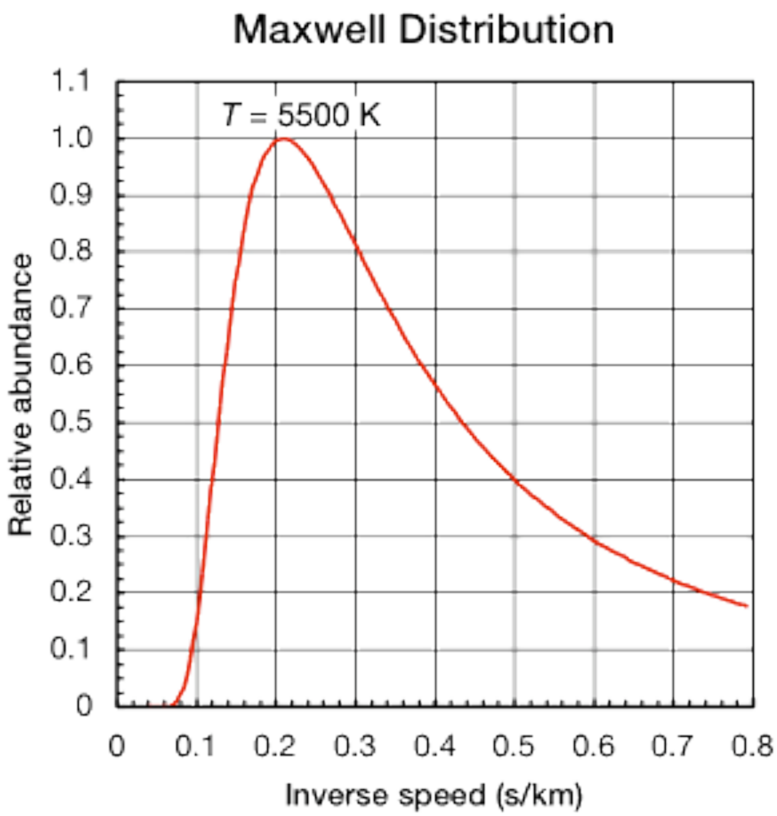

Figure 101. Speed of a helium atom as a function of abundance (which varies with temperature).

First, the speed of the solar wind is in the range of 300~800 km/s near the Sun. More than 10 $R_{\odot}$ away, the speed stabilizes at roughly 400 km/s. Yet the 5525 K black-body temperature is insufficient to accelerate plasma to > 300 km/s. The translational velocity of a helium atom at 5500 K is merely 4.78 km/s (see Figure 101). The rate at which a parcel of plasma can expand is at most .62 of the velocity of the atoms (i.e., the speed of sound). Hence the peak speed just from thermal expansion would be 2.96 km/s, less than 1/100 the speed of the solar wind. This led some researchers to concentrate on the effects of higher temperatures in the corona as the motivating force, where the temperature is nearly 3 orders of magnitude higher. But the peak thermal speed of helium is just 12 km/s. It's twice as high for hydrogen, but that still doesn't get into the solar wind range. Furthermore, if the heat is created by high-energy collisions of falling particles, they will not be accelerated back out. Rather, as the collisions create heat and the hydrostatic pressure increases, the particles will slow down and stop, thereafter remaining in a gravitational-hydrostatic equilibrium.

Second, the solar escape velocity is 618 km/s. This begs the question of how the bulk of the particles get free of the Sun's gravity, moving as slow as 400 km/s.

Third, the velocity of the particles *increases* with distance from the surface of the Sun, up to a peak at about 10 $R_{\odot}$. If the source of the energy was the Sun itself, the velocity would be greatest at the surface, and would decrease with time due to the forces of gravity and friction with in-falling particles.

Hence there is no configuration of gravitational, thermal, and inertial forces that can account for the solar wind.

The only remaining possibility is that another force is at work, which can only be electromagnetism. This force can easily accelerate particles to such velocities. The magnetic fields in the corona are extremely weak, but the electric field between the Sun and the interplanetary medium has been estimated between 600 MV and 1.7 GV.[104,105,61:6,106] So we'll focus on the electric force.

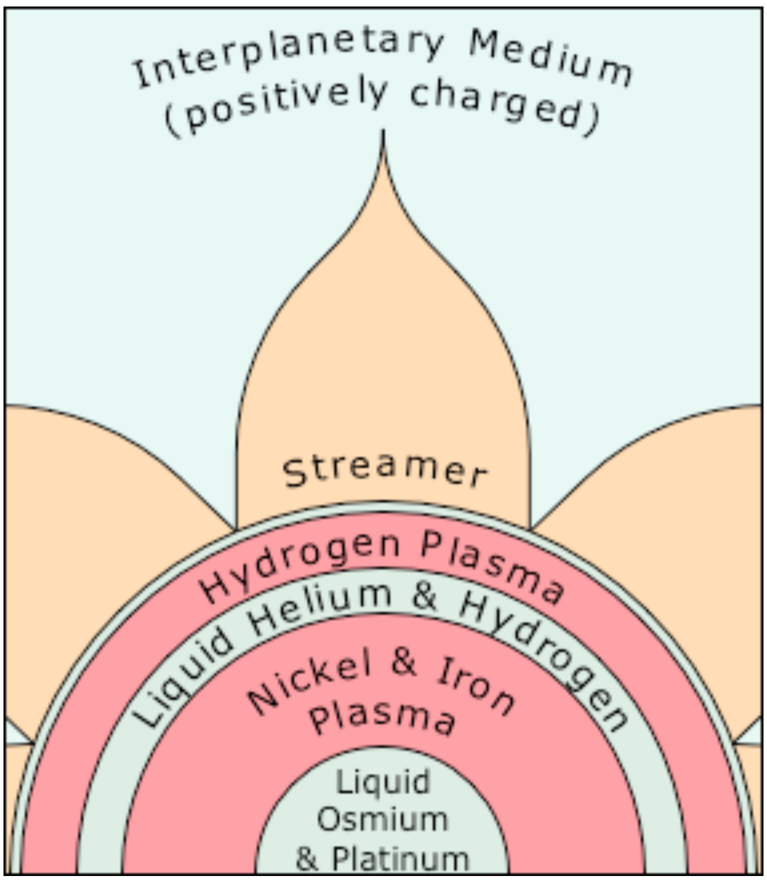

Figure 102. The charged layers of the Sun & the heliosphere (blue = positive, red = negative, and orange = neutral, current conducting plasma).

Studies of the solar wind near the Earth have found roughly equal quantities of positive ions and free electrons, both moving outward from the Sun. From this we get a basic concept of the "wind" as a neutrally charged particle stream starting at the Sun. But if the electric force is responsible, we have to acknowledge that in an electric field, positive ions go one way and electrons go the other. With the dominant charge near the surface of the Sun being negative, and with the plasma in the interplanetary medium being predominantly positive, electrons will be expelled from the Sun, while positive ions will be pulled inward by gravity (to the limits of hydrostatic pressure). The bi-directional motion of particles establishes the energy source in the corona. High-energy collisions between electrons and positive ions moving in different directions generate the extreme temperatures in the corona, as well as the distinctive photons.[107:31] (See Figure 102.)

If the electric force is pulling positive charges toward the Sun, what then causes the wind *away from the Sun* that has been measured near the Earth? The answer might be that ions further from the Sun, and therefore experiencing less attraction, are also being bombarded by high-energy electrons that impart outward Newtonian forces. Once neutralized by the electrons, the electric field is no longer a factor, and at 10 $R_{\odot}$, 400 km/s velocities are well above the escape velocity. In other words, the out-flowing electrons drag the positive ions along with them. The apparent outward flow near the Sun might actually be just wafts of electrons passing through plasma that is only beginning to get accelerated away from the Sun.

Note that the net charge in the corona appears to be zero. Some have concluded that this proves that the electric force cannot be present, as it requires a charge separation. But there is a difference between electrostatics and electrodynamics. If we were to measure the net charge in a current-carrying wire, we'd find it to be zero. It's the electrostatic potential *from one end of the wire to the other* that produces the current through the wire, not a charge separation *in the wire*. If electrons are flowing through plasma in the corona, the net charge of the corona might be zero, while the proof of an electric current is the ohmic heating, the EM radiation, and the observable bi-directional flows in the corona.

Also note that the top of the negative layer inside the Sun is a current divider. Below that level, electrons are pulled down to the ionized hydrogen & helium. Above that level, they are pulled away from the Sun. This accounts for the acceleration that we see in the corona. The further the electrons get from the current divider, the more unambiguous the field, and hence the greater the force acting on them. It also accounts from the broadly distributed flow of current, as in Figure 103. While currents through a low-density medium are easily pinched into discrete channels (e.g., terrestrial lightning), the currents at the solar surface emanate from a wide area. Only slow-moving electrons, dispersed by electrostatic repulsion in the cathode, would emerge from such a broad area, and only get pinched into discrete channels as they move further from the cathode.

Figure 103. Superheated plasma in the chromosphere, 2006-11-22, courtesy Scott McIntosh, Bart De Pontieu, Viggo Hansteen and Karel Schrijver. (Click the image to watch the movie.)

Within this framework, we can now ratchet up the specificity. It was previously stated that the speed of the wind is in the range of 300~800 km/s, but there isn't much of a continuum within that range. There are actually two distinct groups: the slow wind (at ~300 km/s), and the fast wind (at ~800 km/s). The slow wind typically emanates from the equatorial band during the sunspot minimum, or at all latitudes during the sunspot maximum (as in Figure 97). The visible aspect of the slow wind is the helmet streamers. The fast wind averages 800 km/s, and is characteristic of higher latitudes during the sunspot minimum, in the so-called coronal holes.

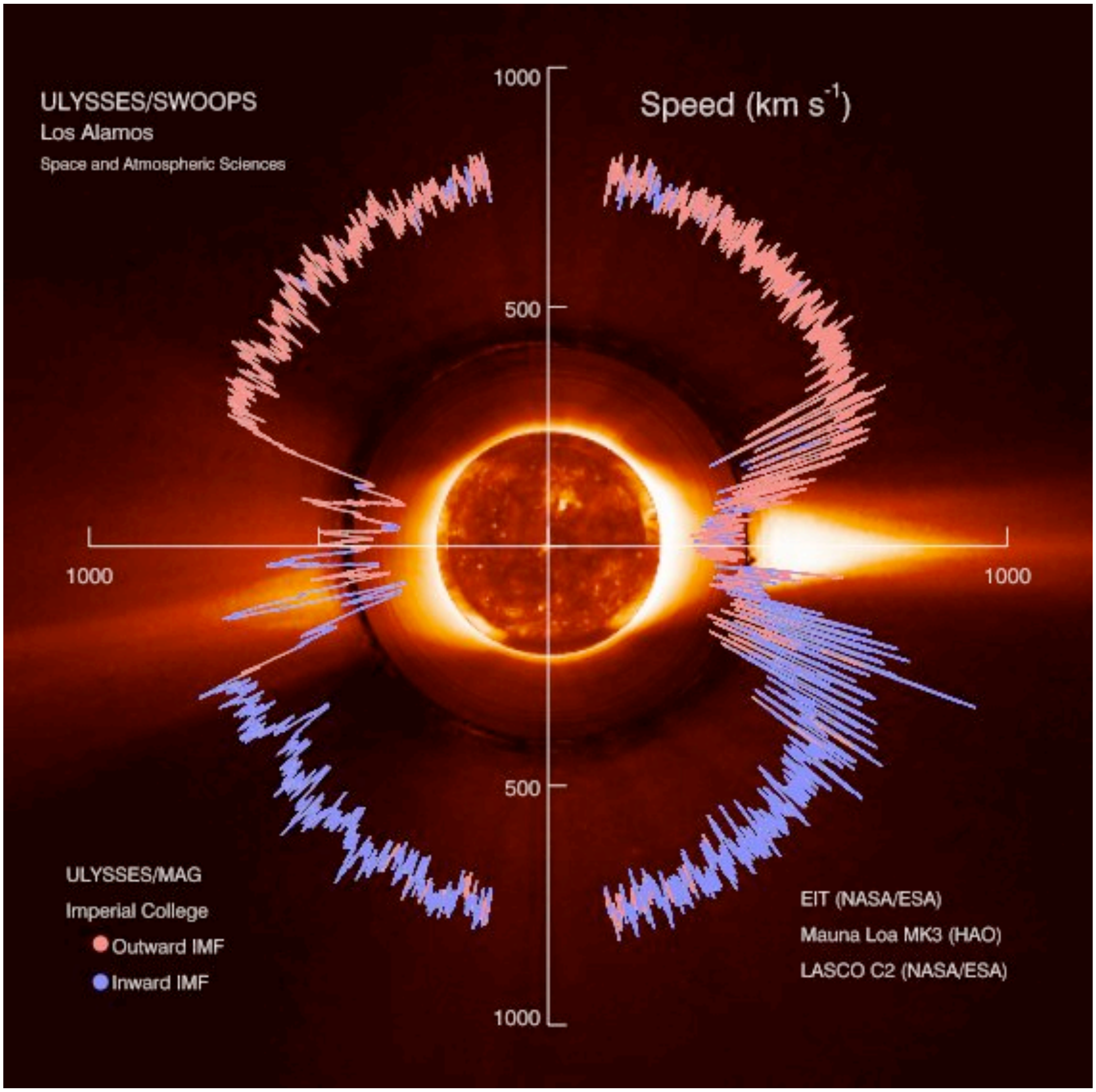

Figure 104. Fast and slow solar winds at the solar minimum, as measured by a variety of means, courtesy NASA.

The reason for the much greater luminosity of the streamers is that the positive ion density is much greater, resulting in more electron uptake and bremsstrahlung radiation. Ion density also modulates the wind speed, since it presents electrical resistance. Thus the wafts of electrons struggle through the streamers at 300 km/s, while they zip through the coronal holes at 800 km/s. The inverse relationship between ion density and wind speed also holds for temporal variations. (See Figure 105.)

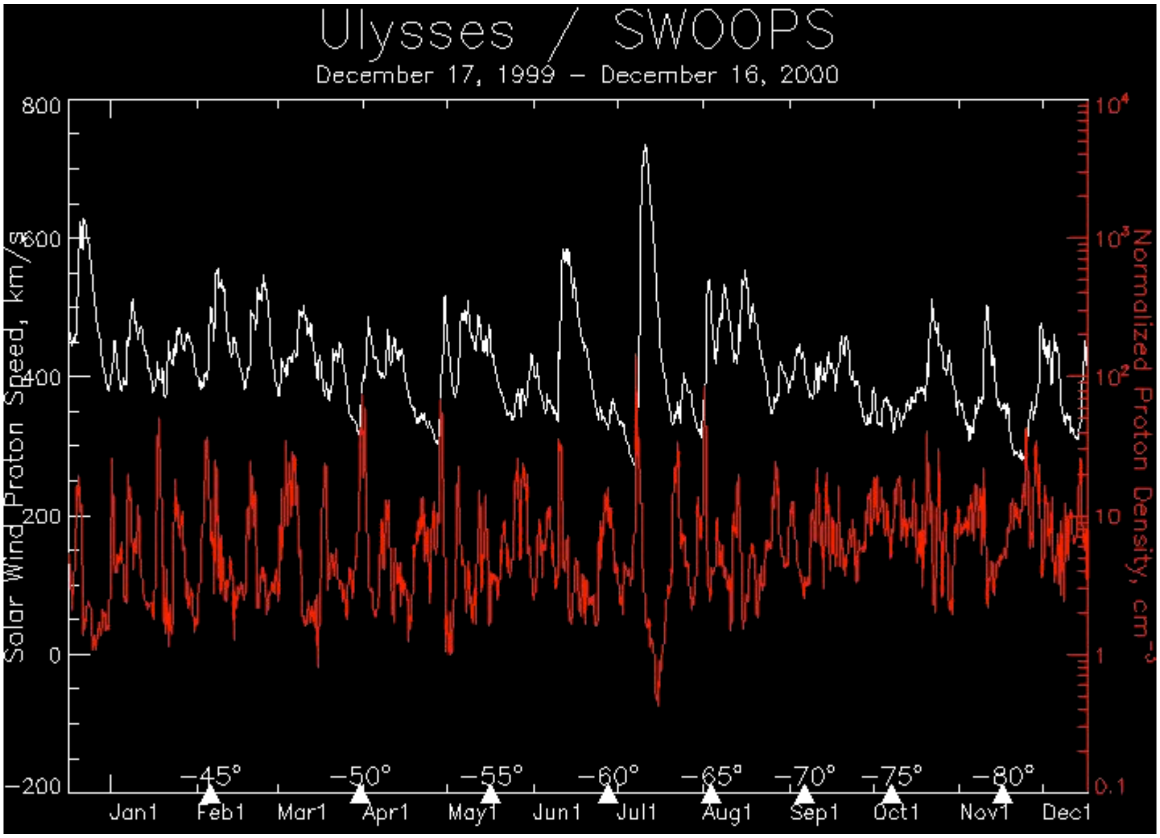

Figure 105. A comparison of the speed of the solar wind (in white) to the density of protons (in red), courtesy LANL.

The last question concerns why the ion density is so variable. The answer might be that the electron drift velocity varies for its own reasons. Where it is fast, electron drag evacuates the ions, and where it is slow, more ions linger. So what could make such a difference in electron drift velocity?

There is no reason to believe that the solar~heliospheric electric field is any different in the equatorial versus the polar direction. The positive charge in the heliosphere should be well distributed by electrostatic pressure, and the same should be true of negative charges inside the Sun, so the field should be radially symmetrical. What else is there?

This is easiest to answer if we simply constrain the choices to forces that originate from inside the Sun, which vary with the solar cycle, and which are operative in the corona. That pretty much narrows it down to the Sun's overall magnetic field. (See Figure 106. See the Cycles section for a description of the magnetomotive forces.)

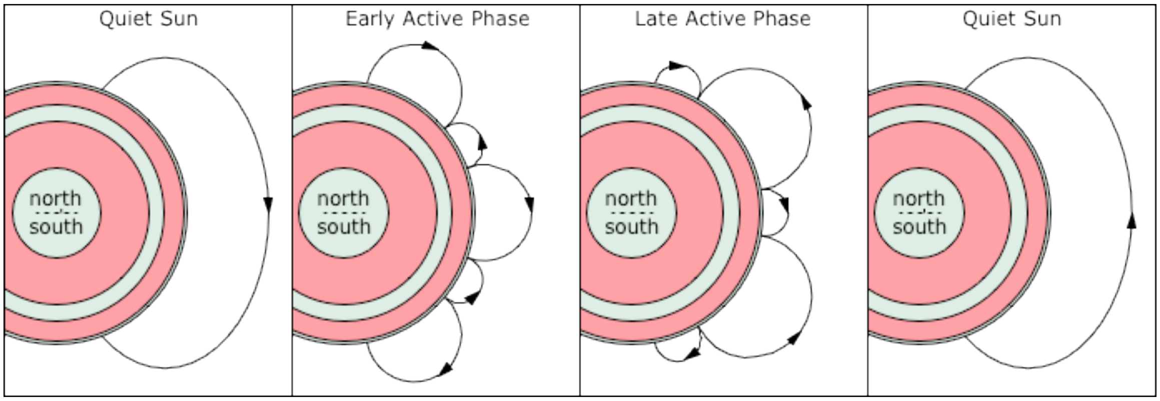

Figure 106. Progression of magnetic fields through 11-year cycle.

During the quite phase, equatorial currents will be damped by the Lorentz force as they attempt to cross perpendicular magnetic lines. Polar currents do not have this problem, as the lines of force are normal to the surface. In other words, the Sun's magnetic field encourages polar currents in the same way that the Earth's magnetic field causes the aurora. So during the quiet phase, the electron velocity is higher at the poles. In the tenuous solar atmosphere, electron drag is sufficient to evacuate the ions, creating coronal holes. The reduced ion density reduces the electrical resistance, further encouraging the currents.

During the active phase, the overall field is more complex. Wherever the magnetic field lines are normal to the surface, the winds will be fast and more transparent. Wherever the lines are parallel to the surface, the winds will be slow and luminous.

Heliosphere

Now we should make a direct examination of the larger environment in which all of this is happening. The entire scope of the Sun's influence is known as the heliosphere, with the Sun at the center (of course), and with a radius of something like 1.5×10^{10} km. The solar wind expands at roughly 450 km/s. When it runs into the interstellar winds (which move at only 23 km/s relative to the Sun), the friction brings the solar winds to a stop, forming a "termination shock" that defines the principle extents of the Sun's influence. The interstellar winds then slowly carry off excess plasma, creating an indistinct coma.

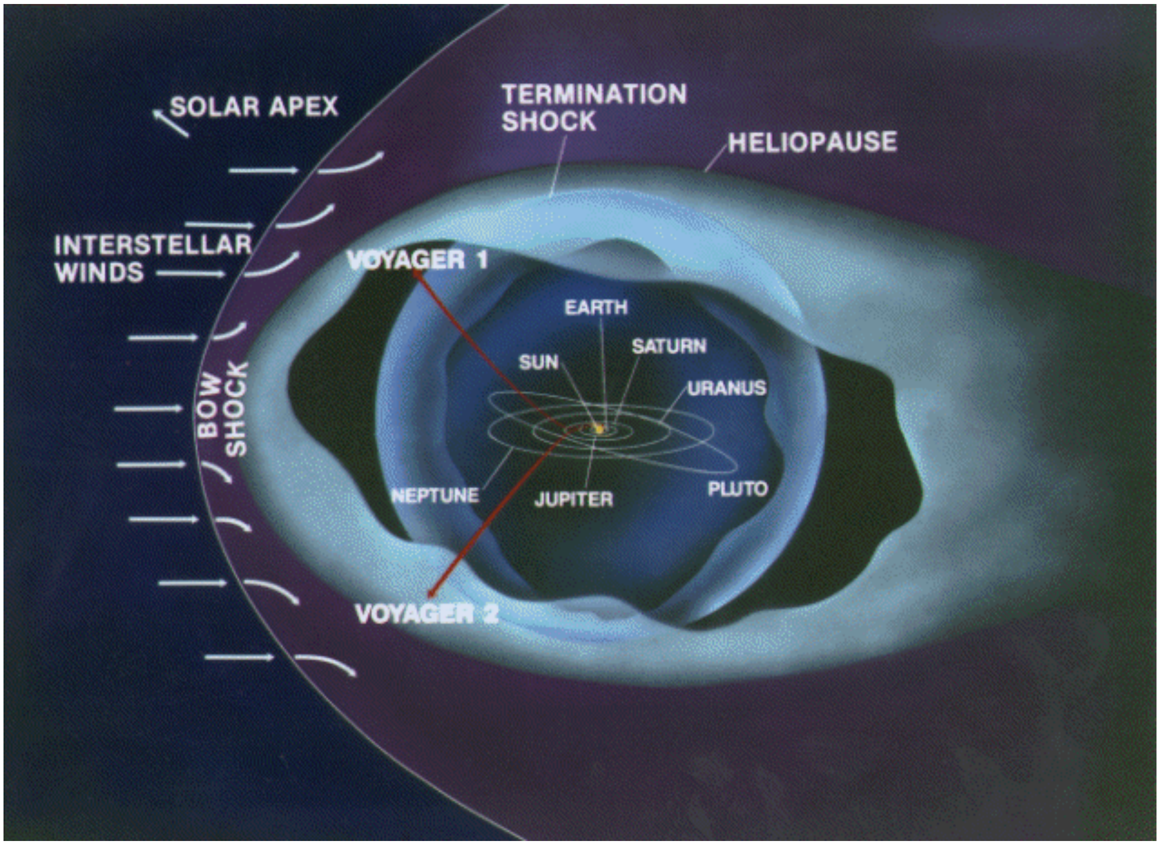

Figure 107. Solar and interstellar winds.

As mentioned in the Corona section, the conventional notion of the solar wind expanding due to simple gas pressure does not account for the acceleration of the winds in the first 10 $R_\odot$, much less to supersonic velocities, both of which are not allowed by the laws of thermodynamics. Nor does it account for the temperature increasing with distance from the Sun, ultimately achieving over 1 MK in the corona. These behaviors can only be evidence of an electric field that accelerates charged particles away from the Sun, where particle collisions generate temperatures that increase with the speed of the particles.

These electric fields are evidence of charge separations, and the CMEs section demonstrated that the ejection of +ions is the electromotive force. The electron drift responding to the electric field does not fluctuate directly with the e.m.f., because the electrons are sitting on a current divider. They are at once attracted to an underlying layer of positive charge, and to the positive charge in the heliosphere, and a shift in that balance creates only a slight (but sustained) increase in voltage. This creates a sustained electron drift, even if the e.m.f. is episodic, analogous to a steady flow through a dam's spillway, even if rainfall in the catchment area isn't steady. Once the solar winds are liberated from the Sun's gravity and accelerated to 450 km/s, there is nothing to stop them until they reach the heliopause, though the density thins by the inverse square law due to the radial expansion. (See Figure 108.)

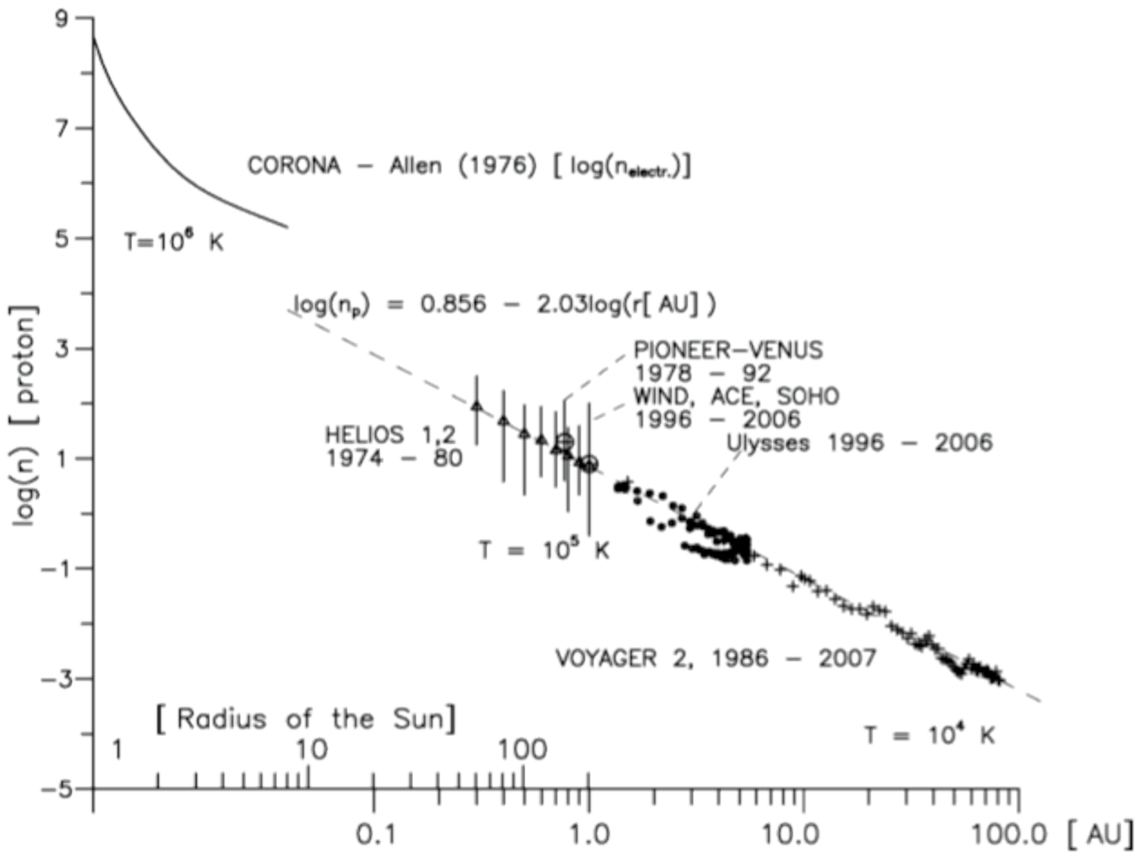

Figure 108. Proton density (i.e., 95% of the constitution of the solar wind) in the interplanetary medium, courtesy Pintéra et al. (2009).

At the heliopause, there appears to be another mechanism that increases the positive charge in the solar wind. Recent research has demonstrated that when neutral interstellar atoms impinge on the heliosphere, the electrons are stripped off in particle collisions, while the +ions continue into the heliosphere due to their greater inertial forces.[60] Electrostatic repulsion within the heliosphere distributes the charges. So when CMEs eject +ions out into the heliosphere, they are simply adding to an existing positive charge there, and the electrons flowing out of the Sun to re-establish charge equilibrium are attracted to the combined positive charge.

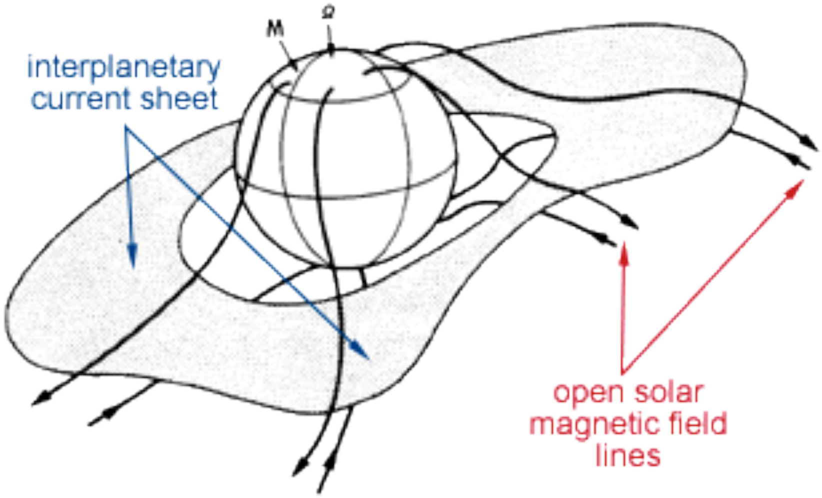

Figure 109. Heliospheric current sheet, courtesy SWRI.

Finally, the heliospheric current sheet should be considered. (See Figure 109.) Here we have a fair amount of data, but the standard interpretation makes little sense. Beginning at roughly 1.5 $R_{\odot}$, there is a thin sheet of electric current propagating outward from the Sun. The total current has been estimated at 3×10^9 A.[108] In the present model, we can easily accept that there is a current, but it's quite low compared to 2.93×10^{15} A estimated in the Conversions section. Yet this doesn't mean that something is wrong. CMEs expel +ions, motivating an outward electron drift. Once away from the Sun, the electrons are also attracted to the net positive charge in the heliosphere. So the electrons are driven by the electric force, and the +ions are driven by CMEs, hydrostatic pressure, and electron drag. At some point away from the Sun, the net force on the electrons drops to zero, and the net current ceases. Closer to the Sun, the electrons are still moving faster, registering as a negative current away from the Sun. Since the solar wind appears to still be accelerating at 1 AU,[109,110,111:9:12] it makes sense that there is still *some* current, while only directly at the surface of the Sun would we expect the full 2.93×10^{15} A.

The current sheet is ridiculously thin, being roughly 10 Mm near the orbit of the Earth, which is thinner than the diameter of the Earth itself. What could keep a current like this organized? The standard model answers this with a riddle. While it is a fundamental law that magnets are always dipoles, astronomers maintain that the Sun has "open magnetic field lines" (or "magnetic flux tubes" as they are sometimes called) that project outward, and the current sheet is sandwiched between "flux tubes" of opposite polarity. (See Figure 109.) So what's a "flux tube"? And what binds them together so that they can exert some sort of force on the current sheet? Opposing magnetic fields normally repel each other, so this is a non-trivial question.

To sort this out, we have to start back at the Sun. Figure 110 shows a progression of interactions that ultimately produce the helmet streamers, the open field lines, and the current sheet.

In the first panel, the electron drift away from the Sun is shown radiating in all directions, along with the typical magnetic field (during the quiet phase).

The second panel shows the effect of the magnetic field on the electron drift — the current is deflected in the direction of the B-field. This gets the current converging on the equatorial plane. But of course *at* the equatorial plane, the solenoidal B-field is perpendicular to the radial E-field, meaning that the electrons are no longer accelerated along the B-field by the electric force. A pile-up of negative charge at the equatorial plane then decelerates the current. Moving more slowly, the current is less susceptible to the B-field, and is free to respond only to the E-field. Hence near the equator, the current breaks out of the solenoidal lines, and resumes its outward flow.

The third panel shows the final result, where the current is not only affected by the B-field, but modulates it as well. As a field-aligned current, the particles develop a spin. In the gradual transition from the solenoidal back to the radial path at the tips of the helmet streamers, the particles retain their angular momenta, and continue to generate their own magnetic fields. While the solenoidal field deflects the particles into field-aligned currents, it is also true that as the particles are pulled more and more away from the solenoidal form, the B-fields are deflected in the direction of the spinning particles. This ultimately resolves into spinning particles streaming out into space, with axial B-fields that have split the solenoid into "open field lines."

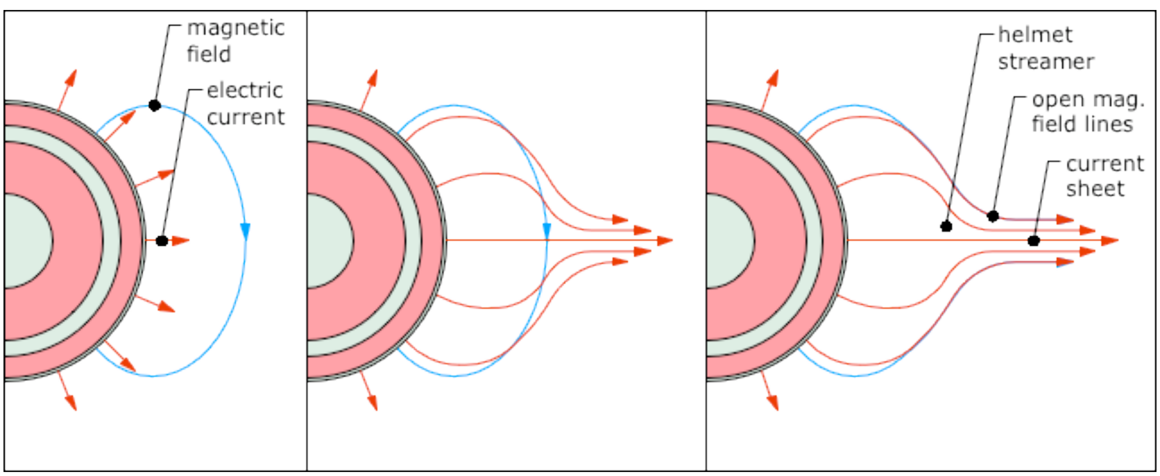

Figure 110. The emergence of helmet streamers and the heliospheric current sheet from a radial current and a toroidal magnetic field.

This explains the broad base of the helmet streamer, the narrow tip, the "open field lines" in the Birkeland currents, and to some extent, the current sheet in the middle of it all. But it also positions us for a new insight into the true nature of the current sheet. In the standard model, the "magnetic flux tubes" do not have associated electric currents, which is odd because only electric currents can generate magnetic fields. Then, there's the current sheet, which strangely doesn't have an associated magnetic field. The two riddles answer each other. The electric current that generates the magnetic fields in the "flux tubes" is the current sheet itself. Figuratively speaking, if we look closely at the "sheet," we find that it is made of threads, and the threads are Birkeland currents. So it's not that the oddly non-magnetic current sheet is sandwiched between the oddly non-electric "flux tubes", but rather, that the current *through* the many "flux tubes" constitutes the sheet.

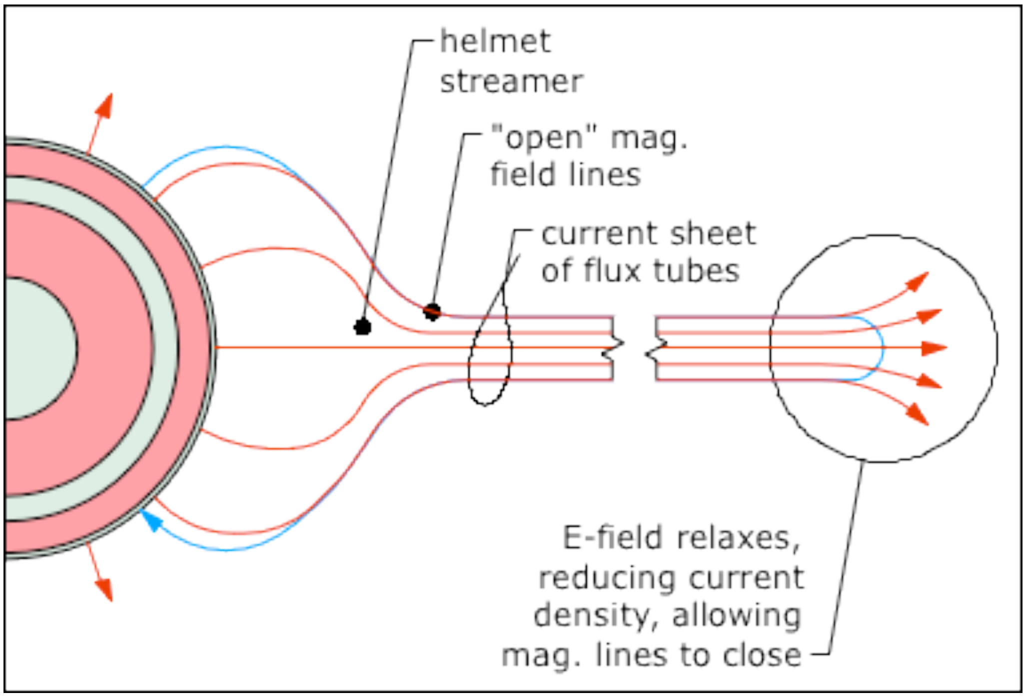

Figure 111. Closing magnetic field lines.

We can also tie up the loose ends of the "open field lines." As noted above, at some point in the heliosphere, the net force on the electrons drops to zero, and the electrons stop moving faster than the atoms, extinguishing the current. This means no more magnetomotive force. At that point, the magnetic field lines are free to close. Since Birkeland currents of both magnetic polarities are projecting outward, the nearest closing point for their magnetic fields will be each other. Hence the magnetic field lines form a continuous loop, starting inside the Sun, following Birkeland currents out into the heliosphere, and returning to the Sun through similar Birkeland currents of the opposite polarity.

Cycles

Lastly we will challenge the present model to explain the solar cycle. There are a lot of data, because the cycle is complex, but there really isn't a standard explanation for all of it to give us some competition. So the challenge is simply to see if the present model can identify mechanisms that would produce the broad range of observations, without violating any fundamental principles of physics.

The first fact is that the total solar power output varies approximately 0.1%, on an 11.2 year cycle.[112] The true significance of those numbers is easy to miss in the solar literature, but the reality is that it's a very slight difference, over a long period of time. Hence we shouldn't be looking for powerful mechanisms that throw the Sun into wild fluctuations. Rather, we should be curious about what keeps the power output so consistent. In that context, the study of the solar cycle is a search for near-perfect power regulator(s) whose nature(s) can be clarified by understanding the minimum and maximum output modes.

The most obvious aspect of the cycle is the number of sunspots. The Sunspots section explained these as electric currents similar to the current flowing through the granules, but with a greater current density, such that electrodynamic effects emerge, including self-stabilizing solenoidal magnetic fields. So why is there a cyclic increase in current density?

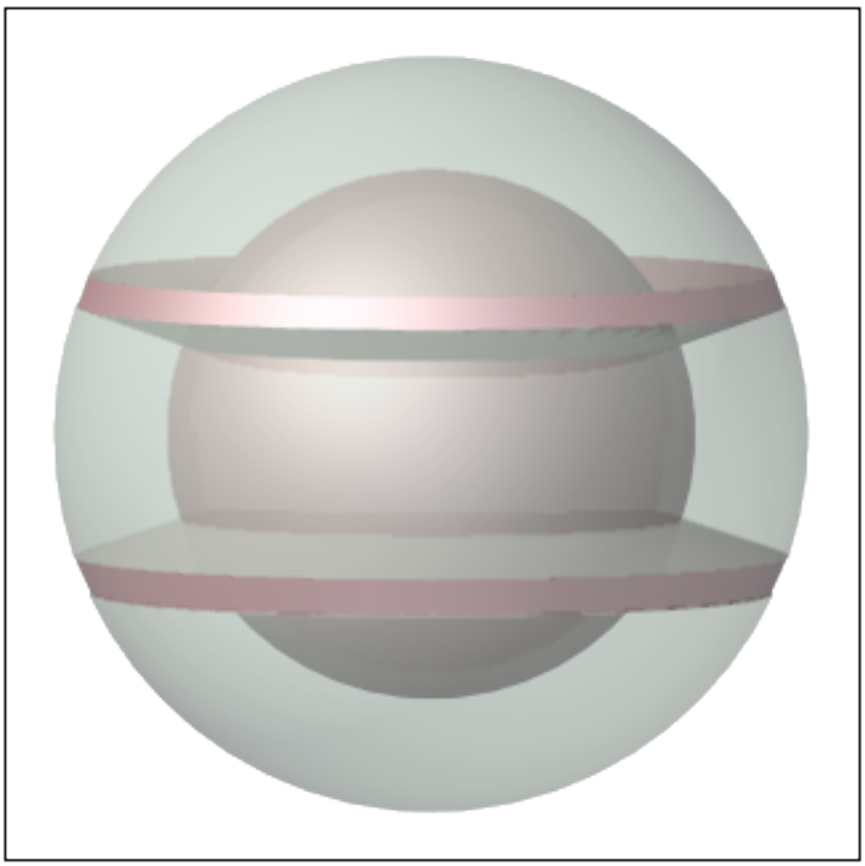

Figure 112. The equatorial band and polar caps in the convective zone.

First we should consider *where* sunspots occur. The convective zone has an equatorial band, spanning 30° N to 30° S, that rotates faster than the polar caps. Sunspots occur in the boundary between these masses. (See Figure 112.) As the sunspot maximum proceeds, the width of this band shrinks, eventually spanning only 5° N to 5° S, bringing the sunspots nearer the equator. So something about differential rotation is definitely conducive to sunspots, and the increased current density then produces 0.1% more power.

Some have suggested that boundary vortexes resulting from differential rotation encourage sunspots.[113] But sunspots rotate extremely slowly, if at all, questioning the significance of vorticity. So we need to make a more detailed analysis, starting with what creates differential rotation in the first place.

The core and the radiative zone rotate as solid bodies. In the absence of convection (because of a lack of a heat source), all relative motion has ceased. But in the convective zone, relative motion *does* exist, and we wouldn't expect solid body rotation. Yet what happens doesn't match the initial expectations.

Given the conservation of angular momentum in an updraft, it *should* rotate slower than the plasma into which it rises, producing an apparent retrograde deflection. Figure 113 depicts an equatorial section looking down from the north pole, where the frame rotates counterclockwise with the Sun over a 3.62 day period. The s-wave at the bottom left generates a supergranule that should appear to move diagonally to the right as it rises. Similarly, downdrafts should rotate faster than the plasma into which they descend. So the upper convective zone *should* rotate slower than the solid body rate.

The deceleration of updrafts and the acceleration of downdrafts certainly happen in the topmost 25 Mm.[114,115,116] (See Figure 114.) This suggests that there are robust convective currents in the topmost positive layer, driven by ohmic heating from the solar~heliospheric current.

Below 25 Mm, simple expectations are not met. In the lower latitudes, we actually see an acceleration, *above the solid body rotation*. And then in higher latitudes, where there is less angular momentum to conserve, there is an even more dramatic *deceleration*.

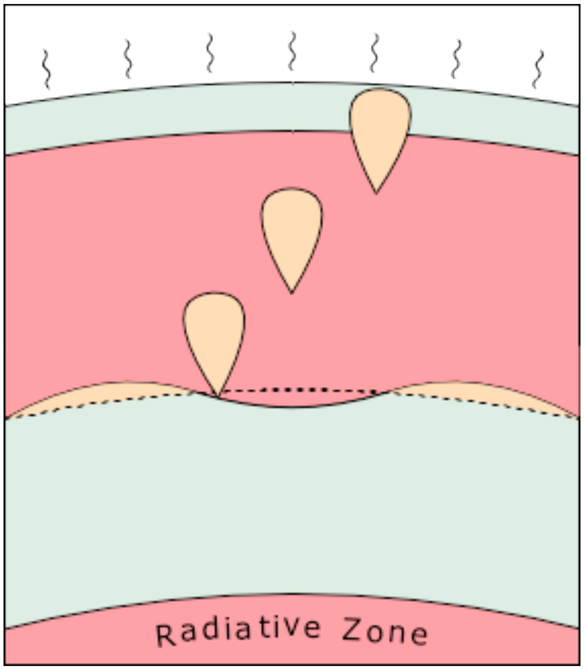

Figure 113. Apparent deflection due to conservation of angular momentum in an updraft.

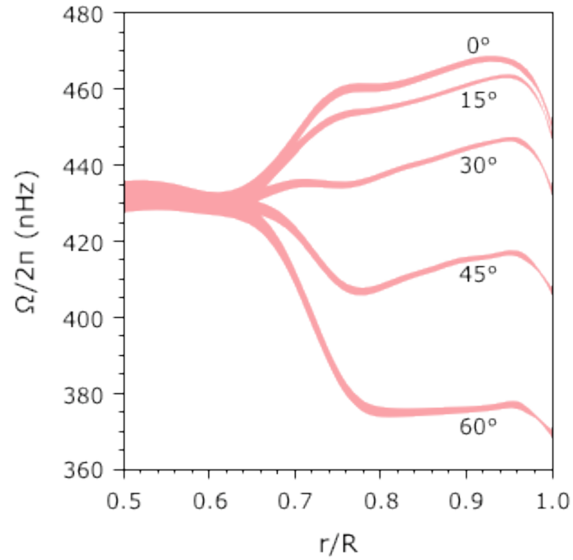

Figure 114. Differential rotation per solar radius and latitude.

Figure 115 shows the data from Figure 114, in 3D. The sphere at the center denotes the core, about which we know little. The flat plane in the radiative zone reveals its solid body rotation. In the convective zone, equatorial plasma is accelerated, while polar plasma is decelerated.

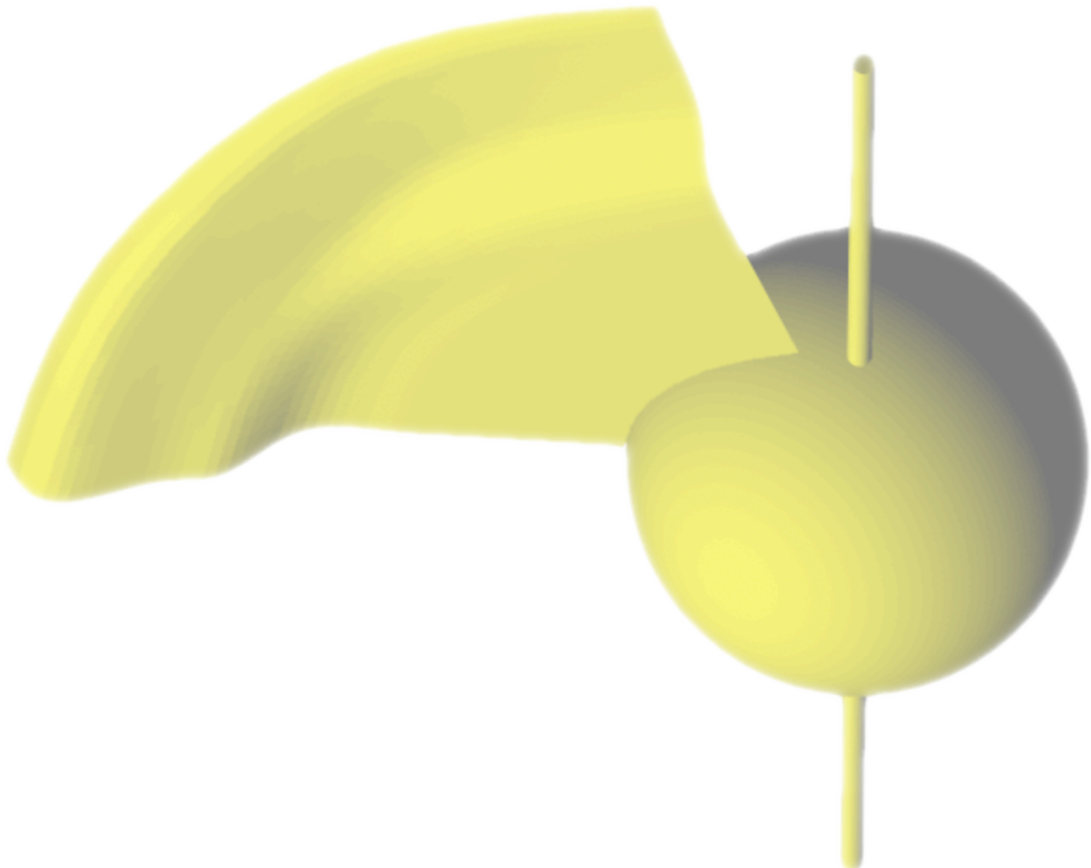

Figure 115. Differential rotation for 0~75° latitude in one quadrant of the Sun.

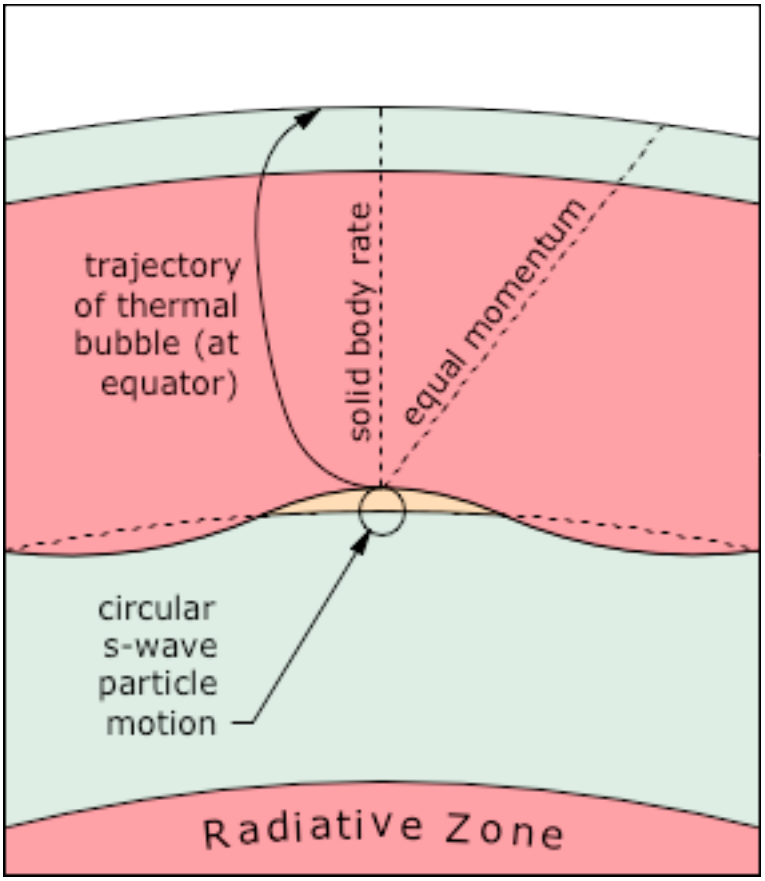

Figure 116. Acceleration of thermal bubble in direction of wave.

The acceleration in the lower latitudes can be attributed to the way supergranules are created by wave crests. (See Figure 116.) While there is no net flow in s-waves, there is a circular particle motion, and at the crest, the motion is in the direction of the wave. A thermal bubble generated by an s-wave inherits the momentum of the crest. Hence the equatorial waves create an equatorial acceleration. The equal-but-opposite deceleration in the higher latitudes is then easiest to explain as an eddy current flowing in the reverse direction.

As an aside, a bit of additional information can be gleaned from Figure 114, and integrated into the present model. Many researchers define the tachocline as being only .04 $R_\odot$ thick, centered at roughly .7 $R_\odot$.[117:3,118] This is because the "fusion furnace" model requires that the transition between heat radiation and convection be abrupt. Yet the only data that we have are helioseismic, and these show that the transition begins at the level at which the solid body rotation of the radiative zone ends (i.e., .66 $R_\odot$), and continues to the point of the stabilization of differential rotation (i.e., .76 $R_\odot$), amounting to a .1 $R_\odot$ thickness. The standard model has no explanation for this, while the present model identifies a liquid helium & hydrogen layer (i.e., .7~.82 $R_\odot$), which is .12 $R_\odot$ thick. The ionized liquid is frictionless, so the shear from differential rotation produces a laminar flow that transitions smoothly from the rotation of the radiative zone to that of the overlying convective zone.

So if s-waves at the liquid line are the prime mover behind the equatorial bands, why are these waves more pronounced at the equator? The Sun is a sphere, and all other factors being the same, it should be capable of sustaining s-waves equally in all directions.

But it's not that simple, because the Sun is rotating. This means that an s-wave crossing the poles encounters a reversal in the direction of the medium through which it travels. On its way toward the pole, conservation of momentum in the particle motions generates a Coriolis effect, with an apparent anterograde deflection, contrary to the actual motion of the medium. After crossing the pole and propagating back toward the equator, any loss of angular momentum results in a retrograde Coriolis effect. This twisting of the waves, which constantly sets them against the rotational "flow" of the medium, refracts the waves, and thereby dissipates their energy. Yet equatorial waves do not have this problem, and can continue in the same "direction" forever. So we can expect equatorial waves to be better organized, and more robust.

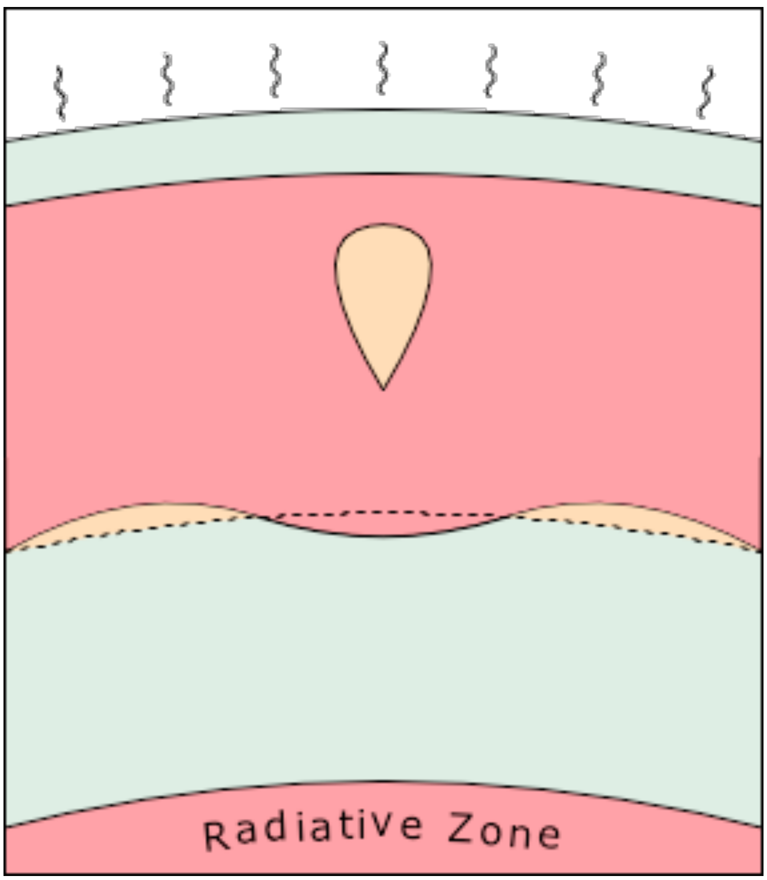

Figure 117. Thermal bubble pushes down the next trough.

One of the implications of this is that equatorial waves will fall into the nearest harmonic frequency, and this might be an important part of the solar power regulator. Here we should note that a wave cresting above the liquid line, and triggering an electrostatic discharge that generates an enormous amount of heat, is a wave that perpetuates itself, as the superheated plasma pushes down the next trough. Hence energy is added back to the mechanism that is releasing energy, establishing a positive feedback loop, which will increase the rate at which energy is released, until the next set of limits are hit. (See Figure 117.)

Those limits are a function of resonance. Larger waves travel at faster speeds, meaning longer wavelengths. Yet the spherical geometry of the Sun guarantees that only harmonic frequencies will resonate. Hence a positive feedback loop that increases the wavelengths will push the waves outside of the resonance frequency, and destructive interference will attenuate the wave heights. A positive feedback loop with a negative boundary condition produces energy at a regular rate, while competition between these opposing forces might also produce regular oscillations. Thus the peak mode starts with a wide equatorial band, where the positive feedback loop has accentuated the wave heights, but destructive interference attenuates them, first at higher latitudes, where the circumference is shorter, and then at progressively lower altitudes, causing the equatorial band to shrink. As such, the s-waves do, indeed, appear to be self-regulating. As noted previously, the energy conversions at the liquid line include electrostatic discharges as well as nuclear fusion in the discharge channels, both of which produce heat that is conducted and convected to the surface. Together these energy sources are responsible 1/2 of the total solar power.

The other 1/2 comes from ohmic heating in the topmost positive double-layer. Is that regulated too?

There the prime mover is CMEs. When these occur, positive ions are ejected, leaving the Sun with a net negative charge, and instantiating an electric field between the negative Sun and the positive heliosphere. The electric current responding to that field then causes the ohmic heating. So the question is, "Are CMEs regulated, and if so, how?"

One possible regulator was introduced in the Sunspots section (though that aspect of it was not mentioned). At the top of a sunspot, the solar~heliospheric current passes through the granular layer, which is cooler. Electron uptake in the cooler plasma increases the electrical resistance, reducing the electron drift velocity. The result is that the magnetic field lines close locally. This increases the density of the closing lines.

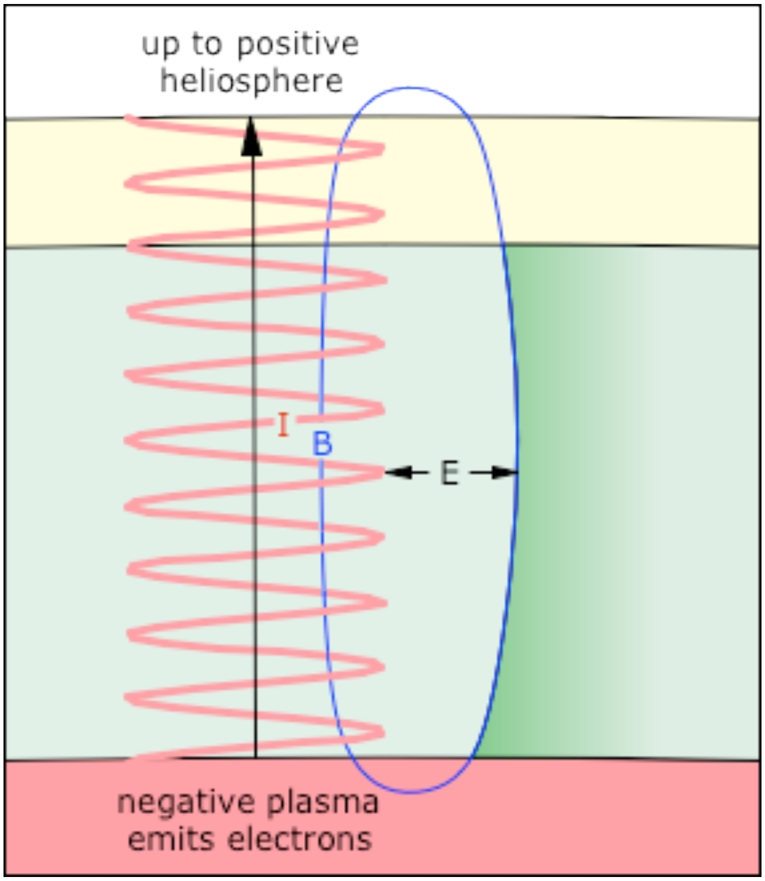

Figure 118. Magnetic pressure maintains charge separation.

The CMEs section described how this local solenoidal field insulates opposite charges from each other (by introducing a Lorentz force perpendicular to the E-field). This creates the potential for a sub-surface flare and the subsequent CME. (See Figure 118.) The CME expels positive ions, creating the solar~heliospheric E-field that causes ohmic heating.

The net effect is that a cool granular layer sets up the conditions for the CMEs that drive the ohmic heating. Thus the temperature is self-regulating.

Now we just have to figure out why sunspots occur at the edges of the equatorial band.

The Sunspots section showed that the solenoidal magnetic fields have to be coming from a rotating current, and that this is expected when electric and magnetic fields line up. So one of the prerequisites for sunspots is that the lines of force from the Sun's overall magnetic field be normal to the surface, to get them parallel to the lines of the solar~heliospheric electric field. Once organized into a Birkeland current, the electrons can stream straight out into space. Where the overall lines of force *are not* normal to the surface, electrons don't have an open conduit to the heliosphere. At the equator, where the overall lines of force are parallel to the surface, the Lorentz force deflects the current toward the poles. So the magnetic and electric forces are in opposition, and the current is discouraged. (The same thing happens here on Earth. Charged particles from the solar wind are deflected by the Earth's magnetic field, and enter the atmosphere at the poles, causing the aurora. A similar current *exiting* the Earth would similarly be deflected.) From this we can infer that there is something about differential rotation that sets up magnetic lines of force normal to the surface at the boundary.

The Sun's magnetic fields are complex, and dynamic. As the Sun rotates, the charged layers generate magnetic fields. The fields from alternating layers cancel each other out, leaving the Sun with a very weak overall field (i.e., ~1 Gauss). The polarity of this field is a function of torsional oscillation, wherein the charged layers speed up and slow down relative to each other from one cycle to the next, and the field from the faster layer dominates.[119] Magnetic pressure between the alternating layers makes it a winner-take-all phenomenon, and the polarity stays the same through the entire 11.2 year cycle.

At a smaller scale, differential rotation in the upper convective zone results in the equatorial band generating a field with the same polarity as the overall field. But this more powerful field has shorter lines of force, some of them closing just across the equator, and the others diving back into the Sun in the 30~60° latitudes. This gets the lines from the polar field to close there, instead of going all of the way around to the other pole. (See Figure 119.)

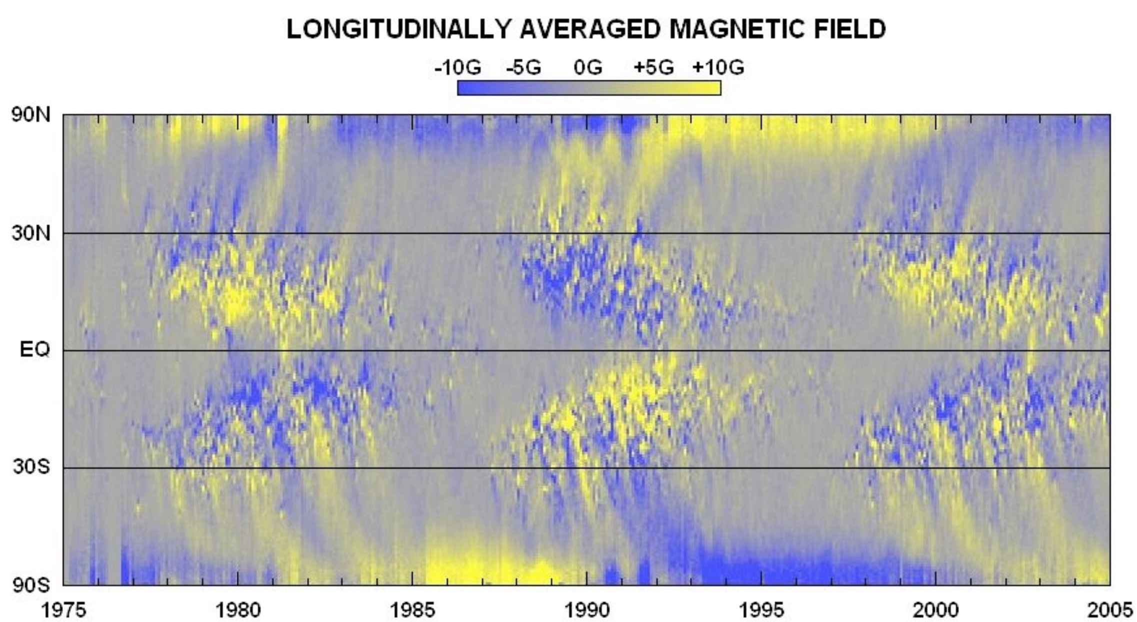

Figure 119. Magnetic fields, courtesy NASA.

Figure 120 shows the fields in schematic form. Note that as the equatorial band shrinks, its poleward lines of force come to dominate, eventually merging into an overall field that is opposite from the previous quiet phase.

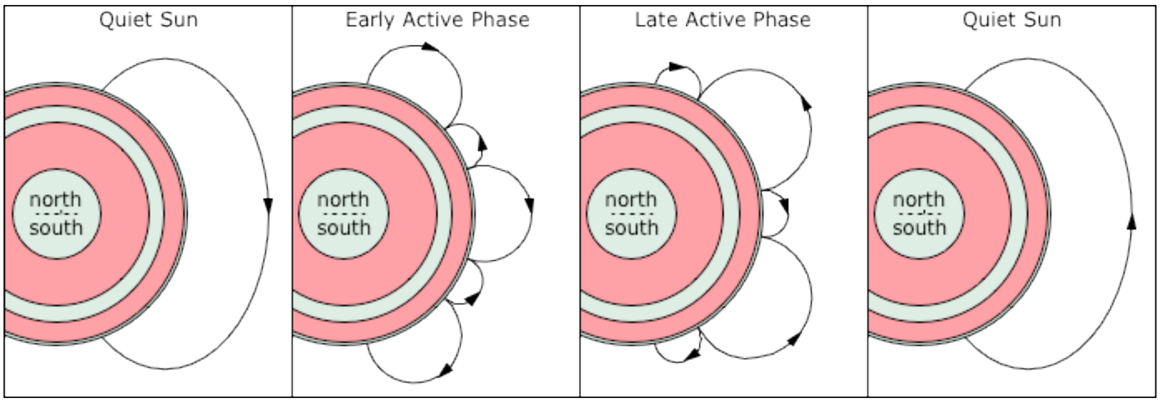

Figure 120. Progression of magnetic fields through 11-year cycle.

During the quiet phase, there is a magnetic shield enveloping the majority of the Sun. And just like the Earth's magnetosphere discourages incoming currents (except at the poles), the quiet Sun's magnetosphere discourages the solar~heliospheric current. In this context, the fast solar wind emanating from the poles during the quiet phase makes sense. But even the polar currents are deflected somewhat, as all of the lines of force close within the Sun.

Now consider the effects of the more complex configuration during the active phase. The longer lines of force (not shown in Figure 120) don't have any obvious re-entry points, as there is no net overall field. Such lines can easily be converted into axial fields in Birkeland currents streaming out into space. So when we see sunspots forming where the magnetic lines of force are normal to the surface, and given that the prime mover is the solar~heliospheric current, and knowing that currents flow the best when the electric and magnetic fields are parallel, we can conclude that it is the magnetic fields of differential rotation that spawn sunspots.

To summarize, s-waves at the liquid line fall into harmonic frequencies around the equator. This produces waves of supergranules transporting heat to the surface. It also produces differential rotation, with an equatorial band rotating faster than the polar caps. At the edge of the equatorial band, the magnetic lines of force are normal to the surface, inviting the solar~heliospheric current to turn these into open lines out to the heliosphere. The increased charge density in the sunspots attracts positive ions, and short-circuit discharges cause CMEs that expel excess positive plasma into space. This regulates the resistance in the positive double-layer, and thereby the ohmic heating.

Conclusion

The original source of the energy that went into the Sun was the momentum of the particles in the collapse of a dusty plasma. The implosion, plus the gravity field from the compressed matter, created hydrostatic pressure sufficient for electron degeneracy pressure, wherein charges are separated, thus converting the energy to electrostatic potentials. The electric force between charged double-layers pulls them together, even if electron degeneracy pressure prohibits recombination. Futher compacting the matter increases the density of the gravity field. Thus the equilibrium that was finally achieved is a very dense by-product of a force feedback loop involving electric and gravity fields.

With the primary energy store being electrostatic potential, 2/3 of the power output of the Sun is the recombination of opposite charges (i.e., electrostatic discharges), while 1/3 of the power output is from nuclear fusion within the discharge channels.

The prime mover in the energy release, and a source of heat in its own right, is charge recombination due to equatorial s-waves 120 Mm below the surface. The output is constrained by positive and negative feedback loops. The release of heat at the crest of the wave pushes down the next trough, and accelerates the wave, but destructive interference attenuates the wave heights, resulting in a steady output, though the feedback loop oscillates in an 11.2 year cycle. The s-waves also create differential rotation. The main implication is that magnetic field lines close just outside the equatorial band, and with the field normal to the surface, Birkeland currents can stream outward with magnetic braking. The current density can become great enough for organized electrodynamic effects such as sunspots.

Hence a wide variety of data have been taken into account, without finding reason to abandon this mechanistic approach. After all, the Sun is a physical object, so somewhere out there, we ought to be able to find a physical description of it. This search has yielded interesting and potentially valuable results.

This is not to ignore the economy of mathematical simplifications. But math should not preclude physics. As our knowledge increases, it becomes possible to make the transition from heuristics to mechanics. In so doing, we gain the ability to anticipate new discoveries. Phenomenology is OK for assimilating existing datasets, and for presenting them in a way that seems to make sense. But when we come to understand the physical forces responsible for the phenomena, we know where to look for new types of data that might be even more valuable.

Credits

Thanks to Horst Dieter Preschel for bringing to my attention the work of Harold Aspden, which was important in establishing the forces necessary to complete the organization of the Sun.

Thanks to Brant Callahan for sharing his extensive knowledge of spectral analysis, including black-body theory.

Thanks to Michael Mozina for many productive discussions on nuclear fusion in arc discharges, and the intricacies of solar analysis using emissions from specific degrees of ionization.

Thanks most of all to Lloyd Kinder, whose patient and insightful questioning prodded this research along, and who specifically encouraged me to take a closer look at bulk solar abundances, which now forms the core of the stellar model.

Star Types

Now we can see if the model that explains the Sun applies to other stars as well.

We had previously examined the "exotic" stars, such as black holes and pulsars, and considered the properties of a "natural tokamak" as the explanation. Then we saw that our Sun is not like that. With low angular velocities, the magnetic fields are weak, and magnetism is not the organizing principle as it is in a tokamak. Rather, charge separations hold the Sun together, sustained by electron degeneracy pressure. In that framework, a highly detailed description of the Sun became possible.

Interestingly, most stars seem not to be tokamaks, as they have weak magnetic fields, and they emit very little x-ray and gamma ray radiation. So we should see if the electrostatic model generalizes to an explanation of the full range of "non-exotic" stars.

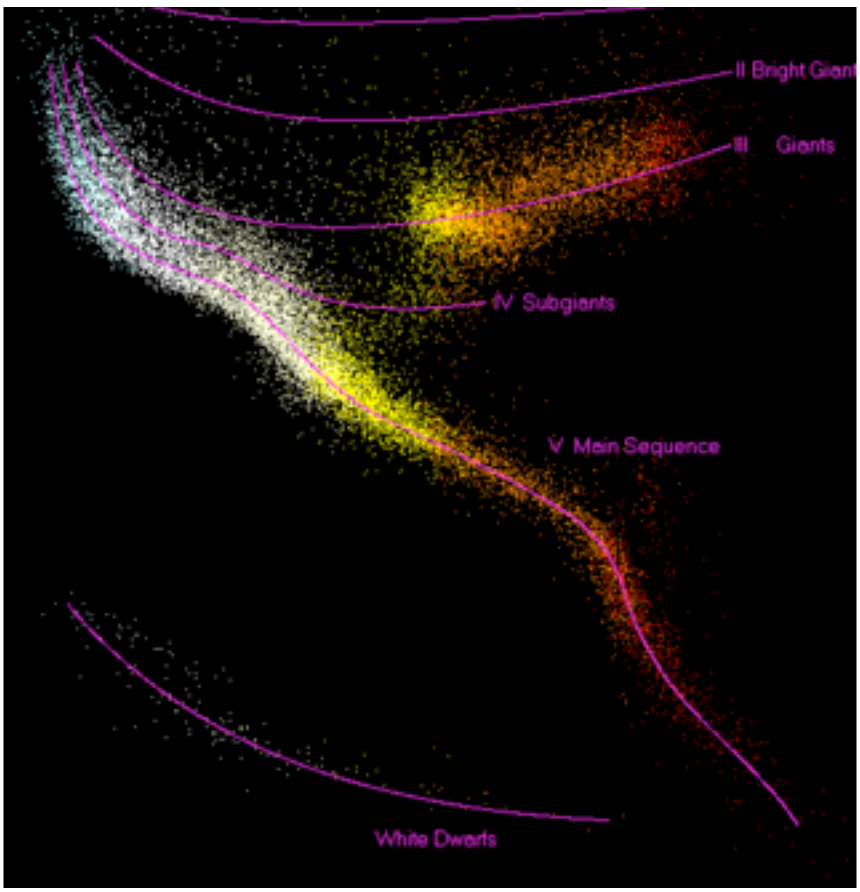

Figure 121. The Hertzsprung-Russell diagram.

The best place to start is with the Hertzsprung-Russell diagram, which sorts out the stars on the basis of luminosity (on the vertical axis) per color (on the horizontal axis).[120] (See Figure 121.) When we do this, we can clearly see some distinctive patterns. 90% of all stars are in the "main sequence," from bright, blue stars at the upper left, to dim, red stars at the lower right. Our yellow Sun is in the middle of this sequence. Other patterns include the cluster in the upper center known as the red giants, and a grouping at the lower left known as the white dwarfs.

(Note that the increased width of the main sequence at the blue end might be just an artifact of discrepancies in redshifts, which are used to estimate distances. We need to know the distances so we can derive the absolute luminosities, given the apparent luminosities. But redshifts seem to lose precision at greater distances, where we can only see the brightest of stars. So the luminosity/color correlation might be quite precise through the whole sequence.)

As is always the case in physics, distinctive patterns are evidence of forces, and the main sequence is definitely distinctive. So what are the forces?

As noted in the Potentials section, the standard stellar model doesn't explain black-body radiation, so it won't be much help in analyzing the luminosity/color relationship. If stars were held together just by gravity, and if their densities were a strict function of hydrostatic equilibrium, the supercritical fluids necessary for BB radiation would only occur deep within the stars, and most of the photons would be scattered. This point becomes more emphatic with increasing temperature. If explaining 5525 K BB radiation from our Sun is problematic, explaining 30,000 K BB radiation from blue giants is catastrophic, and for two reasons. First, the radiation should originate from even deeper, and therefore should be scattered even more. Second, shorter wavelengths can be absorbed by a wider variety of atomic events, and thus they are scattered more easily. This is built into the standard model of the Sun, as the explanation for the absence of UV radiation in the solar spectrum, but the same fact is neglected if the star *does* produce high-frequency radiation.

Furthermore, if gamma rays from deep inside a star are getting converted (somehow) to lower-frequency BB radiation, the BB temperatures from all stars should be the same. Bigger stars should have higher temperatures in their cores, but the radiation should pass through thicker "filters" before reaching the surface.

Further still, it's unlikely enough that the Sun's smooth 5525 K BB curve is the product of gamma rays getting smeared and redshifted by wide variety of non-BB events. It's considerably more difficult to believe that this is the rule for 90% of all stars, regardless of luminosity and color, as this would require that uncanny coincidences of elemental abundances be the norm. Then, thinking that this could hold true even for stars whose luminosity and color varies (e.g., the Cepheids[121]), is simply beyond belief. The conversion of gamma rays to a BB-like curve requires a specific combination of elements, in specific abundances. For this to the rule for the Cepheids, the elements and abundances would have to vary cyclically, and in a period as brief as a couple of days. What could remove and restore elements repetitively, varying continuously between extremes, and adhering so precisely to such intricate recipes? The answer is, of course, nothing at all, and the standard model of BB-like stellar radiation has to be pitched.

The charged double-layer model provides a physical explanation for BB radiation, and doesn't dictate a specific temperature, nor that it be static. "Hotter" BB temperatures are produced by more densely packed matter, which shortens the mean free path of vibrating atoms, which increases the frequency. Gravity is insufficient to exert the force necessary to compact plasma to such densities at the outer edge of a star, so stellar BB radiation can only be evidence of electric fields pulling charged double-layers together. The correlation between luminosity and color comes from the size of the star, which determines the density of the gravitational field, and by extension, the degree of compressive ionization. A heavier star has a higher degree of ionization, and therefore the layers are packed together more tightly, producing "hotter" BB radiation, and more of it. Smaller stars are loosely packed, producing "cooler" light. (The oscillations of the Cepheids are described later in this section.) So compressive ionization passes the first test.

The next test concerns the stellar life cycle. The standard model asserts that stars occur on the main sequence pretty much where they were born, and then eventually decay into either red giants or white dwarfs, but it's interesting to consider the possibility that all stars actually shift down through the main sequence with age. So a blue giant might eventually evolve into a red dwarf. This would be the simple consequence of mass loss to its stellar wind. As the gravitational field diminishes, so does the compressive ionization, and the BB temperature goes from blue to red, while the luminosity of the star relaxes as it gets smaller.

In this context, we can observe that the main sequence has two humps, where the luminosity isn't relaxing as fast as the color is shifting from blue to red. One of these is at the transition from white to yellow stars, and the other is in the red dwarf section. The standard model has no explanation for this, as hydrostatic equilibrium should produce a smooth continuum. But electrostatic layering might provide distinct thresholds. There appear to be 5 charged double-layers in the Sun. Perhaps blue giants have 7, and perhaps red dwarfs have only 3 (which would be the minimum number for electrostatic binding). The white-yellow hump would then represent where a 7-layer star is in the process of losing its two outermost layers, and transitioning to a 5-layer star.

At that hump also occurs another distinctive feature: the Asymptotic Giant Branch (AGB), which leads to the cluster of red giants at the upper center of the HR diagram. Interestingly, the road from the main sequence to the red giants is populated by a series of "variable" stars, which oscillate in luminosity and color over a period of days to months. Here is the conventional explanation, from Wikipedia.

> The accepted explanation for the pulsation of Cepheids is called the Eddington valve, or ϰ-mechanism, where the Greek letter ϰ (kappa) denotes gas opacity. Helium is the gas thought to be most active in the process. Doubly ionized helium (helium whose atoms are missing two electrons) is more opaque than singly ionized helium. The more helium is heated, the more ionized it becomes. At the dimmest part of a Cepheid's cycle, the ionized gas in the outer layers of the star is opaque, and so is heated by the star's radiation, and due to the increased temperature, begins

to expand. As it expands, it cools, and so becomes less ionized and therefore more transparent, allowing the radiation to escape. Then the expansion stops, and reverses due to the star's gravitational attraction. The process then repeats.

But there are 3 fatal flaws in that reasoning.

Heated helium certainly expands. But for it to do so rapidly enough to alter the luminosity of the star in just a couple of days, it would have to expand at a hypersonic speed. Yet the maximum speed at which a gas can expand due to temperature is the speed of sound. Updrafts and downdrafts due to differences in buoyancy move much slower than that. So the ϰ-mechanism is out of range for the faster oscillations.

1. Even if the plasma could do the job just at thermodynamic speeds, Eddington never established how his "valve" would produce global oscillation instead of just a bunch of individual Rayleigh-Bénard cells. Heat getting absorbed near a source, causing the medium to expand, until it radiates its heat and then falls back down, is a well-understood phenomenon that produces simultaneous upward and downward motions throughout the medium. Getting all of the expansion and contraction in individual convective cells organized into a global oscillation would take an additional force that Eddington did not identify.
2. The helium in the tenuous outer layer of the ϰ-mechanism will not produce BB radiation, much less at a BB temperature that varies directly with the luminosity. Rather, tenuous helium has specific emission frequencies, depending on the degree of ionization. If that wasn't true, identification of elements by spectral lines wouldn't work.

How could Eddington have made so many mistakes? The reason is that he had an ulterior motive. He was actually trying to apply Einstein's idea that photons have mass. Thus on collision with atoms, they should impart Newtonian forces (i.e., "photonic pressure"). To wrangle this into a model that seemed to match laboratory physics, he had to neglect some simple facts. As no one dared argue with Eddington, much less Einstein, the ϰ-mechanism was accepted without scrutiny. But "photonic pressure" still hasn't been demonstrated, nor has the mass of photons in any other context. So we are still in search of an explanation for Cepheids.

What if Cepheids have s-waves in the boundary between liquid and plasma layers, as was proposed for the Sun, and what if the variations are produced by competing constructive and destructive interference? Such waves can circumnavigate a star in a matter of hours, meaning that fluctuations in power output could easily occur in as little as a few days.

So why do Cepheids oscillate in such a short period, while stars like the Sun have such a long cycle? It's possible Cepheids represent a transitional phase, from a heavier to a lighter star. When it was heavier, s-waves found a resonance frequency in the long circumference. With time, mass loss to stellar winds whittled the star down, shortening the circumference. This compressed the wavelengths, which produces more dramatic crests and troughs, given the same wave energies. But such waves are not at their natural resonance frequency. So the equilibrium between positive and negative feedback is far less stable, producing more dramatic oscillations. At their peak, the waves enable more charge recombination, resulting in more photons (i.e., greater luminosity), and the higher temperatures emit bluer light. So the luminosity/color relationship holds, but for a totally different set of reasons. This puts the Cepheids off of the main sequence.

We might then wonder why Cepheids seem to be evolving into red giants. First we should consider the standard explanation of red giants, from Wikipedia.

> When a star exhausts the supply of hydrogen by nuclear fusion processes in its core, the core contracts and its temperature increases, causing the outer layers of the star to expand and cool. The star's luminosity increases greatly, and it becomes a red giant, following a track leading into the upper-right hand corner of the HR diagram.

So when the fuel runs out, the core heats up, which causes the outer layers to cool, and the luminosity increases greatly? It's clear that red giants are formed by a process that is "imperfectly understood."

It's possible that the pulsations of the Cepheids generate so much heat that the star expands too much, and the weaker gravitational field can no longer support compressive ionization. If so, the star falls apart. Opposite charges recombine in a brief flare-up, but the low density produces long wavelengths. The red giant phase is thought to last only a few million years,[122] which would make sense if it's the final charge recombination in a star whose compressive ionization is undergoing a catastrophic failure of the gravitation/electrostatic force feedback loop that was holding it together.

Thinking that stars evolve *along* the main sequence (assuming they don't turn off at the AGB), makes sense of another fact, this time concerning galactic evolution. The huge blue-white stars on the leading edges of spiral arms are young, while the yellow-red stars in the elliptical bulges are old. All of these stars are on the main sequence. So why are young stars typically blue giants, and old stars yellow dwarfs? This would be expected if mass loss transitions a large, hot star into a cool, small one.

Table 1. Milky Way Abundances

Element	Percent
Hydrogen	73.97
Helium	24.02
Oxygen	1.04
Carbon	0.46
Neon	0.13
Iron	0.11

Nitrogen	0.10
Silicon	0.07
Magnesium	0.06
Sulfur	0.04

This also answers another troubling question in stellar theory. The Elements section established that only 66% of the Sun's volume is hydrogen and helium, while 34% of it is heavier elements (iron, nickel, platinum, & osmium). This stands in stark contrast to typical abundances elsewhere, such as throughout the Milky Way, as shown in Table 1. So how did the Sun come upon such great abundances of heavier elements?

There are two possibilities. First, the Sun could have condensed from a dusty plasma that was 34% heavier elements. But then we'd expect the heliosphere and the nearby interstellar medium to be 34% heavier elements, which is not the case. Second, the Sun could have once been a much heavier star, capable of fusing heavier elements in its core. In time, mass loss to solar winds whittled it down to a yellow dwarf, but it still has the core of a blue giant, and the concentration of heavy elements is way out of proportion to their average abundance throughout the rest of the Milky Way.

This leaves just one more major star type in the HR diagram to explain: the white dwarfs. And these are strange stars indeed. They are incredibly dense (like a neutron star), where the mass of the Sun could be packed into the volume of the Earth. (That's 333,000 times more dense than the Sun!) And the surface temperatures can exceed 150,000 K.[123] So something has gone seriously wrong with the ideal gas laws, because the hydrostatic pressure shouldn't have allowed condensed matter with such thermal energy (not to mention the fact that atomic theory doesn't allow such densities, even at absolute zero). White dwarfs also have extremely powerful magnetic fields (as high as 300 million Gauss![124]). Needless to say, the angular velocity necessary to generate such fields, combined with the extreme temperatures, and the Coulomb barrier, should have caused the dispersion of the matter, but strangely, it does not.

This would be a tough problem to solve, if it were not for the fact that we already have a construct with precisely these properties: the natural tokamak. The extreme angular velocities generate powerful magnetic fields that confine the plasma, and the high-frequency photons are gamma rays and x-rays from nuclear fusion. But the extreme densities are just not correct. We actually don't know the volume of white dwarfs, since none are close enough to measure the diameter, and the "extreme densities" are just artifacts of the standard model, which needs unbelievable gravitational forces to offset extreme hydrostatic pressures. But the "natural tokamak" model can produce a faint blue light from a small star with enormous magnetic fields. Hence we can consider white dwarfs to be exotic stars, in the same category as black holes, neutron stars, and pulsars. This is consistent with recent research that has found new parallels between the behavior of white dwarfs and black holes,[125] and among black holes, blazars, quasars, and gamma-ray bursters,[126] lending more support to the idea that all of the "exotic" stars have fundamental similarities.

So we really only have two basic constructs for stars: the "natural tokamak" (for the exotics), and compressive charge separation for everything else, such as our Sun. And while conventional astronomy asserts any normal star, such as our Sun, could collapse into an exotic star, wherein the determining factor is simply the amount of mass, the present model asserts that the difference between a normal and an exotic star is relativistic angular velocity.

Conclusion

Future generations will look back and snicker at the fictional presentations of today's astronomers. Gravity can become so powerful that it can warp space and time itself, and break all of the other laws of physics? Sailors used to tell stories of huge sea serpents, and vortexes in the ocean that could swallow ships whole. It made great entertainment, until everybody realized that the active ingredient was their own gullibility. Now it's time that we inform those who explore outer space that fantastic stories are fun for a while, but sooner or later, somebody is going to stand up and say, "That just doesn't make sense. Do you really expect us to believe that?" And with the passage of time, somehow later became sooner, and then sooner became today.

Meanwhile, new data keeps coming in, and people who want answers keep trying to make sense of it all. Now the tireless efforts of rationalists all over the world are beginning to accumulate, and we're starting to get a glimpse of how plausible physics can explain the rich diversity of the heavens.

References

1. Peratt, A. L.; Verschuur, G. L., 2000: Observation of the CIV effect in interstellar clouds: a speculation on the physical mechanism for their existence. *IEEE Transactions on Plasma Science*, 28 (6): 2122-2127

2. Thomas, H. et al., 1994: Plasma Crystal: Coulomb Crystallization in a Dusty Plasma. *Physical Review Letters*, 73: 652-655

3. Feynman, R.; Leighton, R.; Sands, M., 1970: The Feynman Lectures on Physics. *Reading, MA, USA: Addison-Wesley*

4. Nagornyak, E.; Pollack, G. H., 2005: Connecting filament mechanics in the relaxed sarcomere. *Journal of Muscle Research and Cell Motility*, 26 (6-8): 303-306

5. Pollack, G. H.; Figueroa, X.; Zhao, Q., 2009: Molecules, Water, and Radiant Energy: New Clues for the Origin of Life. *International Journal of Molecular Sciences*, 10 (4): 1419

6. Zhao, Q.; Coult, J.; Pollack, G. H., 2010: Long-range attraction in aqueous colloidal suspensions. *Proceedings of the Society of Photo-Optical Instrumentation*, 7376: 73761C1-73761C13

7. Chandler, C., 2013: E/G. *QDL*, 6862

8. Carlqvist, P., 1988: Cosmic electric currents and the generalized Bennett relation. *Astrophysics and Space Science*, 144 (1-2): 73-84

9. Verschuur, G. L., 1995: Interstellar Neutral Hydrogen Filaments at High Galactic Latitudes and the Bennett Pinch. *Astrophysics and Space Science*, 227 (1-2): 187-198

10. Peretto, N. et al., 2012: The Pipe Nebula as seen with Herschel: Formation of filamentary structures by large-scale compression?

11. Lockman, F. J.; Free, N. L.; Shields, J. C., 2012: The Neutral Hydrogen Bridge between M31 and M33. *arXiv*, 1205.5235

12. Bolatto, A. D. et al., 2013: The Starburst-Driven Molecular Wind in NGC 253 and the Suppression of Star Formation. *arxiv*, 1307.6259

13. Delgado-Serrano, R. et al., 2010: How was the Hubble sequence 6 Gyr ago? *Astronomy and Astrophysics*, 509 (A78): 1-11

14. Lin, C. C.; Shu, F. H., 1964: On the Spiral Structure of Disk Galaxies. *The Astrophysical Journal*, 140: 646

15. Dowdye, E. H., Jr., 2007: Time resolved images from the center of the Galaxy appear to counter General Relativity. *Astronomische Nachrichten*, 328: 186

16. Bergman, D. L., 2001: The Universe in Motion. *Common Sense Science*, 4 (3)

17. de Felice, F., 1971: On the gravitational field acting as an optical medium. *General Relativity and Gravitation*, 2: 347-357

18. Eddington, A. S., 1920: Space, time and gravitation: an outline of the general relativity theory. *Cambridge University Press*

19. Rezzolla, L. et al., 2011: The missing link: Merging neutron stars naturally produce jet-like structures and can power short Gamma-Ray Bursts. *arXiv*, 1101.4298

20. Chandrasekhar, S., 1960: The stability of non-dissipative Couette flow in hydromagnetics. *Proceedings of the NAS-USA*, 46 (2): 253-257

21. Brusa, M.; Gilli, R.; Comastri, A., 2005: The Iron Line Background. *The Astrophysical Journal Letters*, 621: L5-L8

22. Kronberg, P. P.; E. Lovelace, R. V.; Lapenta, G.; Colgate, S. A., 2011: Measurement of the Electric Current in a Kpc-Scale Jet. *arXiv*, 1106.1397v3

23. Arp, H.; Fulton, C.; Carosati, D., 2013: Intrinsic Redshifts in Quasars and Galaxies.

24. Shukurov, A.; Moss, D., 1996: Turbulence and magnetic fields in elliptical galaxies. *Monthly Notices of the Royal Astronomical Society*, 279 (1): 229-239

25. Karlsson, K. G., 1971: Possible Discretization of Quasar Redshifts. *Astronomy and Astrophysics*, 13: 333

26. Narlikar, J. V.; Arp, H. C., 1997: Time Dilation in the Supernova Light Curve and the Variable Mass Hypothesis. *The Astrophysical Journal*, 482: L119-L120

27. Livio, M.; Soker, N., 2001: The "Twin Jet" Planetary Nebula M2-9. *The Astrophysical Journal*, 552: 685-691

28. Gaensler, B. M., 1999: Morphological Studies of Extragalactic Supernova Remnants. *Perspectives on Radio Astronomy: Science with Large Antenna Arrays*, 271-274

29. Bhatnagar, S., 2001: Radio Study of Galactic Supernova Remnants and the Interstellar Medium. *Tata Institute of Fundamental Research, Pune, India*

30. Henning, T.; Li, H., 2011: The alignment of molecular cloud magnetic fields with the spiral arms in M33. *Nature*, 479 (7374): 499-501

31. Beck, R., 2000: Magnetic fields in normal galaxies. *Philosophical Transactions of the Royal Society of London. Series A: Mathematical, Physical and Engineering Sciences*, 358 (1767): 777-796

32. Fälthammar, C., 2004: Magnetic-field aligned electric fields in collisionless space plasmas — a brief review. *Geofísica Internacional*, 43 (2): 225-239

33. Trujillo, I.; Carretero, C.; Patiri, S. G., 2006: Detection of the effect of cosmological large-scale structure on the orientation of galaxies. *arxiv*, L111-L114

34. Hung, C.; Ebeling, H., 2012: Galaxy Alignments in Very X-ray Luminous Clusters at z>0.5. *arXiv*, 1201.2727v1

35. Dobbin, R. A.; Fulton, C. C., 1859: The Aurora Borealis. *Baltimore American and Commercial Advertiser*, 120 (19,654): pg. 2, col. 2

36. Robitaille, P., 2011: On the Presence of a Distinct Solar Surface: A Reply to Hervé Faye. *Progress in Physics*, 3: 75-78

37. Kosovichev, A. G.; Zharkova, V. V., 1998: X-ray flare sparks quake inside Sun. *Nature*, 393: 317-318

38. Robitaille, P., 2007: A High Temperature Liquid Plasma Model of the Sun. *Progress in Physics*, 1: 70-81

39. Picone, J. M.; E. Hedin, A.; Drob, D. P.; Aikin, A. C., 2002: NRLMSISE-00 empirical model of the atmosphere: Statistical comparisons and scientific issues. *Journal of Geophysical Research*, 107 (A12): 1468

40. Gossard, E.; Munk, W., 1954: On Gravity Waves in the Atmosphere. *Journal of Meteorology*, 11 (4): 259-269

41. Stein, R. F.; Nordlund, A., 1998: Simulations of Solar Granulation. I. General Properties. *The Astrophysical Journal*, 499: 914-946

42. Saumon, D.; Chabrier, G., 1992: Fluid hydrogen at high density: Pressure ionization. *Physical Review A*, 46 (4): 2084-2100

43. Kuhn, J. R.; Bush, R.; Emilio, M.; Scholl, I. F., 2012: The Precise Solar Shape and Its Variability. *Science*, 337 (6102): 1638-1640

44. Aspden, H., 2003: The Physics of Creation. *Southampton, England: Sabberton Publications*

45. Chandler, C., 2012: Quick Density Calcs. *QDL*, 6744

46. Anders, E.; Grevesse, N., 1989: Abundances of the elements: Meteoritic and solar. *Geochimica et Cosmochimica Acta*, 53 (1): 197-214

47. Michaud, G.; Richard, O.; Richer, J.; VandenBerg, D. A., 2004: Models for Solar Abundance Stars with Gravitational Settling and Radiative Accelerations: Application to M67 and NGC 188. *The Astrophysical Journal*, 606: 452-465

48. Manuel, O.; Kamat, S. A.; Mozina, M., 2006: The Sun is a plasma diffuser that sorts atoms by mass. *Physics of Atomic Nuclei*, 69 (11): 1847-1856

49. Fröhlich, C.; Lean, J., 2004: Solar Radiative Output and its Variability: Evidence and Mechanisms. *Astronomy & Astrophysics Review*, 12: 273-320

50. Koshiba, M., 2003: Nobel Lecture: Birth of neutrino astrophysics. *Reviews of Modern Physics*, 75 (3): 1011-1020

51. McDonald, A. B.; Klein, J. R.; Wark, D. L., 2003: Solving the Solar Neutrino Problem. *Scientific American*, 288 (4): 40-49

52. Caflisch, R. et al., 2008: Accelerated Monte Carlo Methods for Coulomb Collisions. *Bulletin of the American Physical Society*, 53 (14)

53. Simon, G. W.; Leighton, R. B., 1964: Velocity Fields in the Solar Atmosphere. III. Large-Scale Motions, the Chromospheric Network, and Magnetic Fields. *The Astrophysical Journal*, 140: 1120-1149

54. Gizon, L.; Birch, A. C., 2005: Local Helioseismology. *Living Reviews in Solar Physics*

55. Rieutord, M.; Rincon, F., 2010: The Sun's Supergranulation. *Living Reviews in Solar Physics*, 7

56. Gizon, L.; Duvall, T. L., Jr.; Schou, J., 2003: Wave-like properties of solar supergranulation. *Nature*, 421: 43-44

57. Beck, J. G., 2000: A comparison of differential rotation measurements – (Invited Review). *Solar Physics*, 191 (1): 47

58. Hanasoge, S.; Duvall Jr, T. L.; Sreenivasan, K. R., 2012: Anomalously Weak Solar Convection. *arxiv.org*, 1206.3173

59. Foukal, P.; Hinata, S., 1991: Electric fields in the solar atmosphere: A review. *Solar Physics*, 132 (2): 307-334

60. May, H. D., 2008: A Pervasive Electric Field in the Heliosphere. *IEEE Transactions on Plasma Science*, 36 (5): 2876-2879

61. Alfvén, H., 1941: Remarks on the Rotation of a Magnetized Sphere with Application to Solar Radiation. *Arkiv för Matematik, Astronomi och Fysik*, 28A (6): 1-9

62. Cameron, A. G., 1988: The World Book Encyclopedia. *Field Enterprises Educational Corp*.

63. Noerdlinger, P. D., 2008: Solar Mass Loss, the Astronomical Unit, and the Scale of the Solar System. *arxiv*, 0801.3807

64. Gurevich, A. V. et al., 2012: Strong Flux of Low-Energy Neutrons Produced by Thunderstorms. *Physical Review Letters*, 108 (12): 125001

65. Mozina, M.; Ratcliffe, H.; Manuel, O., 2006: Observational confirmation of the Sun's CNO cycle. *Journal of Fusion Energy*, 25: 107-114

66. Watanabe, K. et al., 2010: G-band and Hard X-ray Emissions of the 2006 December 14 flare observed by Hinode/SOT and RHESSI. *arXiv.org*, 1004.4259

67. Kirchhoff, G., 1860: Ueber das Verhältniss zwischen dem Emissionsvermögen und dem Absorptionsvermögen der Körper für Wärme and Licht. *Annalen der Physik und Chemie*, 109: 275-301

68. Robitaille, P. M., 2003: On the validity of Kirchhoff's law of thermal emission. *IEEE Transactions on Plasma Science*, 31 (6): 1263-1267

69. Wien, W.; Lummer, O., 1895: Methode zur Prüfung des Strahlungsgesetzes absolut schwarzer Körper. *Annalen der Physik*, 292 (11): 451-456

70. Bohr, N., 1913: On the Constitution of Atoms and Molecules. *Philosophical Magazine*, 26: 1-25

71. Einstein, A., 1905: Über einen die Erzeugung und Verwandlung des Lichtes betreffenden heuristischen Gesichtspunkt. *Annalen der Physik*, 322 (6): 132-148

72. Planck, M.; Masius, M., 1914: The theory of heat radiation. *Philadelphia: P. Blakiston's Son & Co*

73. Kuhn, T. S., 1987: Black-Body Theory and the Quantum Discontinuity, 1894-1912. *Chicago: University of Chicago Press*

74. Robitaille, P., 2008: Blackbody Radiation and the Carbon Particle. *Progress in Physics*, 3: 36-55

75. Lucas, C. W., 2003: A Physical Model for Atoms and Nuclei, Part 4: Blackbody Radiation and the Photoelectric Effect. *Foundations of Science*, 6 (3)

76. Robitaille, P., 2009: Blackbody Radiation and the Loss of Universality: Implications for Planck's Formulation and Boltzman's Constant. *Progress in Physics*, 4: 14-16

77. Robitaille, P., 2011: Stellar Opacity: The Achilles' Heel of the Gaseous Sun. *Progress in Physics*, 3: 93-99

78. Tsintsadze, L. N.; Callebaut, D. K.; Tsintsadze, N. L., 1996: Black-body radiation in plasmas. *Journal of Plasma Physics*, 55: 407-413

79. Iglesias, C. A.; Rogers, F. J., 1996: Updated Opal Opacities. *The Astrophysical Journal*, 464: 943

80. Hathaway, D. H., 2012: Photospheric Features. *NASA/Marshall Solar Physics*

81. Kennewell, J.; McDonald, A., 2012: The Solar Photosphere. *IPS Radio and Space Services*

82. Hantzsche, E., 2003: Mysteries of the Arc Cathode Spot: A Retrospective Glance. *IEEE Transactions on Plasma Science*, 31 (5): 799-808

83. Compton, K. T.; Langmuir, I., 1930: Electrical Discharges in Gases. Part I. Survey of Fundamental Processes. *Reviews of Modern Physics*, 2 (2): 123-242

84. Langmuir, I.; Compton, K. T., 1931: Electrical Discharges in Gases Part II. Fundamental Phenomena in Electrical Discharges. *Reviews of Modern Physics*, 3 (2): 191-257

85. Freedman, R. A.; Kaufmann, W. J., 2008: Universe, Chapter 16 (8th Edition). *W. H. Freeman & Company*, 414-428

86. Neckel, H.; Labs, D., 1994: Solar limb darkening 1986-1990 (lambda lambda 303 to 1099nm). *Solar Physics*, 153: 91-114

87. Borrero, J. M.; Ichimoto, K., 2011: Magnetic Structure of Sunspots. *Living Reviews in Solar Physics*, 8

88. Kosovichev, A. G., 2002: Subsurface structure of sunspots. *Astronomische Nachrichten*, 323 (3−4): 186-191

89. Kosovichev, A. G. et al., 2011: Local helioseismology of sunspot regions: Comparison of ring-diagram and time-distance results. *Journal of Physics: Conference Series*, 271 (1): 012005

90. Borrero, J. M.; Lites, B. W.; Solanki, S. K., 2008: Evidence of magnetic field wrapping around penumbral filaments. *Astronomy and Astrophysics*, 481 (1): L13-L16

91. Ryutova, M. P.; Frank, Z.; Hagenaar, H.; Berger, T., 2011: Flares Producing Well-organized Post-flare Arcades (Slinkies) Have Early Precursors. *The Astrophysical Journal*, 733 (2): 125

92. Pojoga, S.; Huang, T. S., 2003: On the sudden disappearances of solar filaments and their relationship with coronal mass ejections. *Advances in Space Research*, 32 (12): 2641-2646

93. Soru-Escaut, I.; Mouradian, Z., 1990: Sudden disappearance and reappearance of solar filaments by heating and cooling. *Astronomy and Astrophysics*, 230: 474-478

94. Taliashvili, L.; Mouradian, Z.; Páez, J., 2008: Dynamic disappearance of prominences and their geoeffectiveness. *Geofísica internacional*, 47 (3)

95. Veselovsky, I., 2008: Universal and important physical process in space plasmas: electric charge separation. *37th COSPAR Scientific Assembly*, 37: 3332

96. Lee, T. N., 1974: Solar-flare and laboratory plasma phenomena. *Astrophysical Journal*, 190: 467-479

97. Ryutova, M., 2006: Coupling effects throughout the solar atmosphere: 2. Model of energetically open circuit. *Journal of Geophysical Research*, 111 (A9): A09102

98. Wikipedia, 2011: Solar Flare.

99. Lin, R., 2005: A New Kind of Solar Storm. *NASA*

100. Erdélyi, R.; Ballai, I., 2007: Heating of the solar and stellar coronae: a review. *Astronomische Nachrichten*, 328 (8): 726-733

101. Smid, T., 2010: Gravitational Energy of the Sun explains "Coronal Heating".

102. Sheeley, N. R., Jr.; Wang, Y., 2001: Coronal Inflows and Sector Magnetism. *The Astrophysical Journal Letters*, 562 (1): L107

103. Fleck, B., 2001: SOHO's latest surprise: Gas near the Sun heading the wrong way.

104. Birkeland, K., 1908: The Norwegian aurora polaris expedition, 1902-1903. *H. Aschehoug & Co.*

105. Alfvén, H., 1990: Cosmology in the plasma universe - an introductory exposition. *IEEE Transactions on Plasma Science*, 18: 5-10

106. Neslušan, L., 2001: On the global electrostatic charge of stars. *Astronomy and Astrophysics*, 372: 913-915

107. Swartz, M. et al., 1999: The SERTS–97 Rocket Experiment to Study Activity on the Sun: Flight 36.167–GS on 1997 November 18. *NASA*, 1999-208640

108. Israelevich, P. L. et al., 2001: MHD simulation of the three-dimensional structure of the heliospheric current sheet. *Astronomy & Astrophysics*, 376: 288-291

109. Phillips, J. L. et al., 1995: Ulysses solar wind plasma observations from pole to pole. *Geophysical Research Letters*, 22 (23): 3301-3304

110. Cranmer, S. R., 2009: Testing and Refining Models of Slow Solar Wind Acceleration. *SHINE 2009 Workshop*

111. Johnson, R., 2013: The Nature of the Sun Revisited. *Electric Universe Conference (Albuquerque)*

112. Willson, R. C.; Hudson, H. S., 1991: The Sun's luminosity over a complete solar cycle. *Nature*, 351 (6321): 42-44

113. Zhao, J.; Kosovichev, A. G., 2004: Torsional Oscillation, Meridional Flows, and Vorticity Inferred in the Upper Convection Zone of the Sun by Time-Distance Helioseismology. *The Astrophysical Journal*, 603: 776

114. Vorontsov, S. V. et al., 2002: Helioseismic Measurement of Solar Torsional Oscillations. *Science*, 296 (5565): 101-103

115. Korzennik, S.; Thompson, M. J.; Toomre, J., 1997: Internal rotation and dynamics of the Sun from GONG data. *Proceedings of the 181st Symposium of the International Astronomical Union*

116. Basu, S.; Antia, H. M., 2003: Changes in Solar Dynamics from 1995 to 2002. *The Astrophysical Journal*, 585: 553-565

117. Miesch, M. S., 2005: Large-Scale Dynamics of the Convection Zone and Tachocline. *Living Reviews in Solar Physics*

118. Charbonneau, P. et al., 1999: Helioseismic Constraints on the Structure of the Solar Tachocline. *The Astrophysical Journal*, 527: 445-460

119. Lanza, A. F., 2007: Angular momentum conservation and torsional oscillations in the Sun and solar-like stars. *Astronomy & Astrophysics*, 471 (3): 1011-1022

120. Rosenberg, H., 1910: On the Relation Between Brightness and Spectral Type in the Pleiades. *Astronomische Nachrichten*, 186 (4445): 71

121. Fernie, J. D., 1967: The intrinsic colors of classical Cepheids in the galaxy. *Astronomical Journal*, 72 (3): 422-428

122. Méndez, B., 2000: Stellar Life Cycle: Red Giants. *Berkeley*

123. McCook, G. P.; Sion, E. M., 1999: A Catalog of Spectroscopically Identified White Dwarfs. *The Astrophysical Journal Supplement Series*, 121: 1-130

124. Koester, D.; Chanmugam, G., 1990: Physics of white dwarf stars. *Reports on Progress in Physics*, 53 (7): 837-915

125. Li, K. L. et al., 2012: A Luminous Be+White Dwarf Supersoft Source in the Wing of the SMC: MAXI J0158-744. *arxiv*, 1207.5023

126. Nemmen, R. S. et al., 2012: A Universal Scaling for the Energetics of Relativistic Jets from Black Hole Systems. *Science*, 338 (6113): 1445-1448

Bibliography

Arp, H.; Fulton, C.; Carosati, D., 2013: Intrinsic Redshifts in Quasars and Galaxies.

Pintéra, T.; Dorotoviča, I.; Rybanský, M., 2009: The heliosphere mass variations: 1996–2006. *Proceedings of the International Astronomical Union*, 4 (257): 291-293