Extreme-Energy Space Particles

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Exploding stars lit the way for our understanding of the universe, but researchers are still in the dark about many of their features. [12]

A team of scientists from Russia and China has developed a model explaining the nature of high-energy cosmic rays (CRs) in our galaxy. These CRs have energies exceeding those produced by supernova explosions by one or two orders of magnitude. [11]

On August 14, 2017, a groundbreaking University of Maryland-designed cosmic ray detector will travel to the International Space Station (ISS) aboard the SpaceX-12 Commercial Resupply Service mission. [10]

It was because of these characteristics that it was proposed to give this new class of variable stars the acronym BLAPS, i.e. Blue Large-Amplitude Pulsators. [9]

Researchers at the University of Southampton have cast doubt over established explanations for certain behaviours in pulsars - highly magnetised rotating neutron stars, formed from the remains of supernovae. [8]

Installed on the International Space Station, by mid-July it will commence its scientific work – to study the exotic astrophysical objects known as neutron stars and examine whether they could be used as deep-space navigation beacons for future generations of spacecraft. [7]

NASA's Chandra X-ray Observatory has discovered the first direct evidence for a superfluid, a bizarre, friction-free state of matter, at the core of a neutron star. Superfluids created in laboratories on Earth exhibit remarkable properties, such as the ability to climb upward and escape airtight containers. The finding has important implications for understanding nuclear interactions in matter at the highest known densities. [6]

This paper explains the Accelerating Universe, the Special and General Relativity from the observed effects of the accelerating electrons, causing naturally the experienced changes of the electric field potential along the moving electric charges. The accelerating electrons explain not only the Maxwell Equations and the Special Relativity, but the Heisenberg Uncertainty Relation, the wave particle duality and the electron's spin also, building the bridge between the Classical and Relativistic Quantum Theories.

The Big Bang caused acceleration created the radial currents of the matter and since the matter composed of negative and positive charges, these currents are creating magnetic field and attracting forces between the parallel moving electric currents. This is the gravitational force experienced by the matter, and also the mass is result of the electromagnetic forces between the charged particles. The positive and negative charged currents attracts each other or by the magnetic forces or by the much stronger electrostatic forces. The gravitational force attracting the matter, causing concentration of the matter in a small space and leaving much space with low matter concentration: dark matter and energy.

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New for three types of extreme-energy space particles: Theory shows unified origin

New model connects the origins of very high-energy neutrinos, ultrahigh-energy cosmic rays, and high-energy gamma rays with black-hole jets embedded in their environments.

One of the biggest mysteries in astroparticle physics has been the origins of ultrahigh-energy cosmic rays, very high-energy neutrinos, and high-energy gamma rays. Now, a new theoretical model reveals that they all could be shot out into space after cosmic rays are accelerated by powerful jets from supermassive black holes.

The model explains the natural origins of all three types of "cosmic messenger" particles simultaneously, and is the first astrophysical model of its kind based on detailed numerical computations. A scientific paper that describes this model, produced by Penn State and University of Maryland scientists, will be published as an Advance Online Publication on the website of the journal *Nature Physics* on January 22, 2018.

"Our model shows a way to understand why these three types of cosmic messenger particles have a surprisingly similar amount of power input into the universe, despite the fact that they are observed by space-based and ground-based detectors over ten orders of magnitude in individual particle energy," said Kohta Murase, assistant professor of physics and astronomy and astrophysics at Penn State. "The fact that the measured intensities of very high-energy neutrinos, ultrahigh-energy cosmic rays, and high-energy gamma rays are roughly comparable tempted us to wonder if these extremely energetic particles have some physical connections. The new model suggests that very high-energy neutrinos and high-energy gamma rays are naturally produced via particle collisions as daughter particles of cosmic rays, and thus can inherit the comparable energy budget of their parent particles. It demonstrates that the similar energetics of the three cosmic messengers may not be a mere coincidence."

Ultrahigh-energy cosmic rays are the most energetic particles in the universe—each of them carries an energy that is too high to be produced even by the Large Hadron Collider, the most powerful particle accelerator in the world. Neutrinos are mysterious and ghostly particles that hardly ever interact with matter. Very high-energy neutrinos, with energy more than one million mega-electronvolts, have been detected in the IceCube neutrino observatory in Antarctica. Gamma rays have the highest-known electromagnetic energy—those with energies more than a billion times higher than a photon of visible light have been observed by the Fermi Gamma-ray Space Telescope and other ground-based observatories. "Combining all information on these three types of cosmic messengers is complementary and relevant, and such a multi-messenger approach has become extremely powerful in the recent years," Murase said.

Murase and the first author of this new paper, Ke Fang, a postdoctoral associate at the University of Maryland, attempt to explain the latest multi-messenger data from very high-energy neutrinos, ultrahigh-energy cosmic rays, and high-energy gamma rays, based on a single but realistic astrophysical setup. They found that the multi-messenger data can be explained well by using numerical simulations to analyze the fate of these charged particles.

"In our model, cosmic rays accelerated by powerful jets of active galactic nuclei escape through the radio lobes that are often found at the end of the jets," Fang said. "Then we compute the cosmic-ray propagation and interaction inside galaxy clusters and groups in the presence of their environmental magnetic field. We further simulate the cosmic-ray propagation and interaction in the intergalactic magnetic fields between the source and the Earth. Finally we integrate the contributions from all sources in the universe."

The leading suspects in the half-century old mystery of the origin of the highest-energy cosmic particles in the universe were in galaxies called "active galactic nuclei," which have a super-radiating core region around the central supermassive black hole. Some active galactic nuclei are accompanied by powerful relativistic jets. High-energy cosmic particles that are generated by the jets or their environments are shot out into space almost as fast as the speed of light.

"Our work demonstrates that the ultrahigh-energy cosmic rays escaping from active galactic nuclei and their environments such as galaxy clusters and groups can explain the ultrahigh-energy cosmic-ray spectrum and composition. It also can account for some of the unexplained phenomena discovered by ground-based experiments," Fang said. "Simultaneously, the very high-energy neutrino spectrum above one hundred million mega-electronvolts can be explained by particle collisions between cosmic rays and the gas in galaxy clusters and groups. Also, the associated gamma-ray emission coming from the galaxy clusters and intergalactic space matches the unexplained part of the diffuse high-energy gamma-ray background that is not associated with one particular type of active galactic nucleus."

"This model paves a way to further attempts to establish a grand-unified model of how all three of these cosmic messengers are physically connected to each other by the same class of astrophysical sources and the common mechanisms of high-energy neutrino and gamma-ray production," Murase said. "However, there also are other possibilities, and several new mysteries need to be explained, including the neutrino data in the ten-million mega-electronvolt range recorded by the IceCube neutrino observatory in Antarctica. Therefore, further investigations based on multi-messenger approaches—combining theory with all three messenger data—are crucial to test our model."

The new model is expected to motivate studies of galaxy clusters and groups, as well as the development of other unified models of high-energy cosmic particles. It is expected to be tested rigorously when observations begin to be made with next-generation neutrino detectors such as IceCube-Gen2 and KM3Net, and the next-generation gamma-ray telescope, Cherenkov Telescope Array.

"The golden era of multi-messenger particle astrophysics started very recently," Murase said. "Now, all information we can learn from all different types of cosmic messengers is important for revealing new knowledge about the physics of extreme-energy cosmic particles and a deeper understanding about our universe." [15]

How we created a mini 'gamma ray burst' in the lab for the first time

Gamma ray bursts, intense explosions of light, are the brightest events ever observed in the universe – lasting no longer than seconds or minutes. Some are so luminous that they can be observed with the naked eye, such as the burst "GRB 080319B" discovered by NASA's Swift GRB Explorer mission on March 19, 2008.

But despite the fact that they are so intense, scientists don't really know what causes gamma ray bursts. There are even people who believe some of them might be messages sent from advanced alien civilisations. Now we have for the first time managed to recreate a mini version of a gamma ray burst in the laboratory – opening up a whole new way to investigate their properties. Our research is published in *Physical Review Letters*.

One idea for the origin of gamma ray bursts is that they are somehow emitted during the emission of jets of particles released by massive astrophysical objects, such as black holes. This makes gamma ray bursts extremely interesting to astrophysicists – their detailed study can unveil some key properties of the black holes they originate from.

The beams released by the black holes would be mostly composed of electrons and their "antimatter" companions, the positrons – all particle have antimatter counterparts that are exactly identical to themselves, only with opposite charge. These beams must have strong, self-generated magnetic fields. The rotation of these particles around the fields give off powerful bursts of gamma ray radiation. Or, at least, this is what our theories predict. But we don't actually know how the fields would be generated.

Unfortunately, there are a couple of problems in studying these bursts. Not only do they last for short periods of time but, most problematically, they are originated in distant galaxies, sometimes even billion light years from Earth (imagine a one followed by 25 zeroes – this is basically what one billion light years is in metres).

That means you rely on looking at something unbelievably far away that happens at random, and lasts only for few seconds. It is a bit like understanding what a candle is made of, by only having glimpses of candles being lit up from time to time thousands of kilometres from you.

Artist impression of gamma ray burst. Credit: NASA

World's most powerful laser

It has been recently proposed that the best way to work out how gamma ray bursts are produced would be by mimicking them in small-scale reproductions in the laboratory – reproducing a little source of these electron-positron beams and look at how they evolve when left on their own. Our group and our collaborators from the US, France, UK, and Sweden, recently succeeded in creating the first small-scale replica of this phenomenon by using one of the most intense lasers on Earth, the Gemini laser, hosted by the Rutherford Appleton Laboratory in the UK.

How intense is the most intense laser on Earth? Take all the solar power that hits the whole Earth and squeeze it into a few microns (basically the thickness of a human hair) and you have got the intensity of a typical laser shot in Gemini. Shooting this laser onto a complex target, we were able to release ultra-fast and dense copies of these astrophysical jets and make ultra-fast movies of how they behave. The scaling down of these experiments is dramatic: take a real jet that extends even for thousands of light years and compress it down to a few millimetres.

In our experiment, we were able to observe, for the first time, some of the key phenomena that play a major role in the generation of gamma ray bursts, such as the self-generation of magnetic fields that lasted for a long time. These were able to confirm some major theoretical predictions of the strength and distribution of these fields. In short, our experiment independently confirms that the models currently used to understand gamma ray bursts are on the right track.

The experiment is not only important for studying gamma ray bursts. Matter made only of electrons and positrons is an extremely peculiar state of matter. Normal matter on Earth is predominantly made of atoms: a heavy positive nucleus surrounded by clouds of light and negative electrons.

Due to the incredible difference in weight between these two components (the lightest nucleus weighs 1836 times the electron) almost all the phenomena we experience in our everyday life comes from the dynamics of electrons, which are much quicker in responding to any external input (light, other particles, magnetic fields, you name it) than nuclei. But in an electron-positron beam, both particles have exactly the same mass, meaning that this disparity in reaction times is completely obliterated. This brings to a quantity of fascinating consequences. For example, sound would not exist in an electron-positron world.

So far so good, but why should we care so much about events that are so distant? There are multiple reasons indeed. First, understanding how gamma ray bursts are formed will allow us to understand a lot more about black holes and thus open a big window on how our universe was born and how it will evolve.

But there is a more subtle reason. SETI – Search for Extra-Terrestrial Intelligence – looks for messages from alien civilisations by trying to capture electromagnetic signals from space that cannot be explained naturally (it focuses mainly on radio waves, but gamma ray bursts are associated with such radiation too).

Of course, if you put your detector to look for emissions from space, you do get an awful lot of different signals. If you really want to isolate intelligent transmissions, you first need to make sure all the natural emissions are perfectly known so that they can excluded. Our study helps towards understanding black hole and pulsar emissions, so that, whenever we detect anything similar, we know that it is not coming from an alien civilisation. [14]

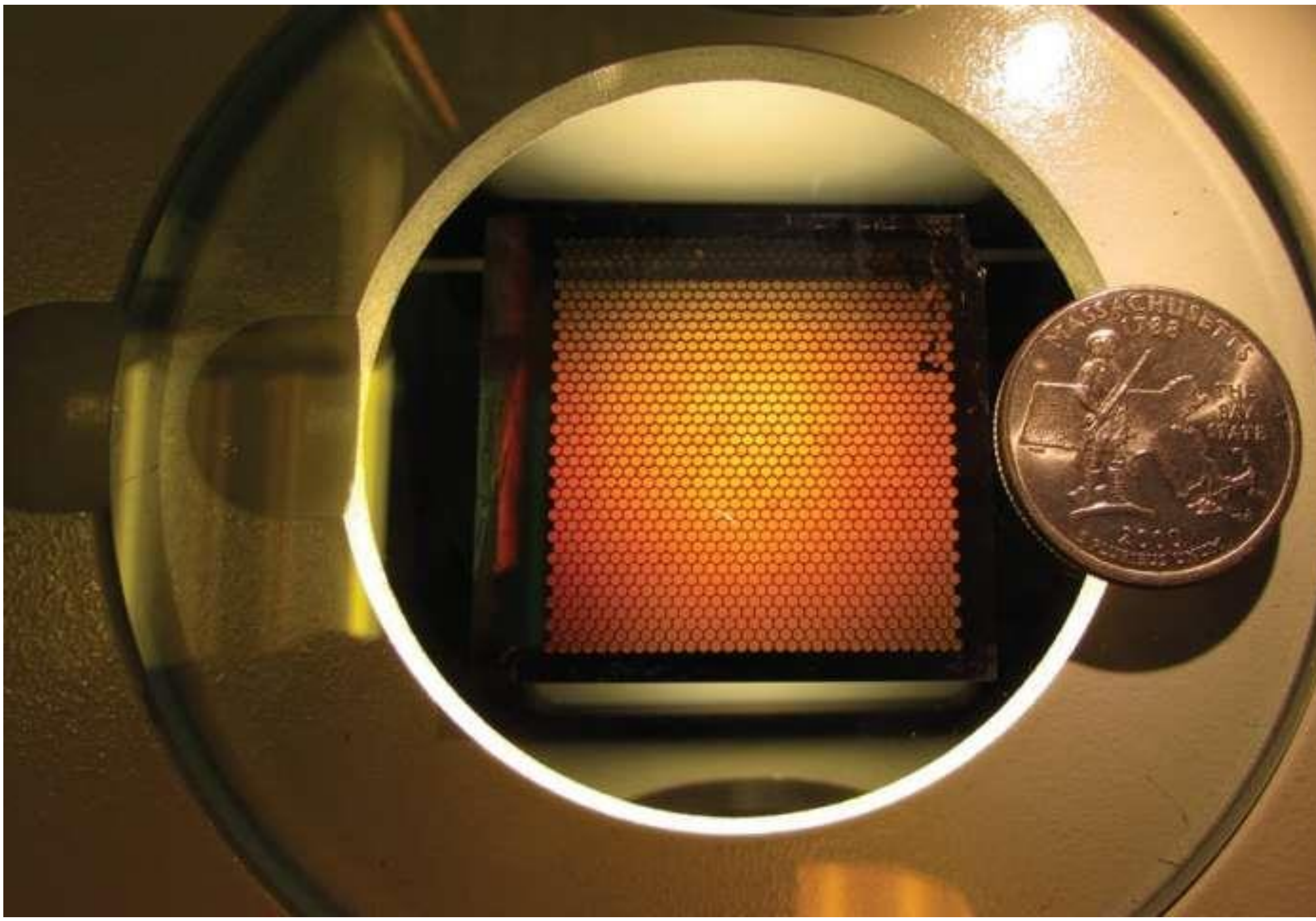
High-resolution X-ray gratings enable state-of-the-art spectrometer

X-ray-optics technology has progressed such that future astrophysics X-ray observatories will have orders-of magnitude better performance than existing observatories such as NASA's Chandra X-ray Observatory. High-resolution soft X-ray spectroscopy offers particularly useful observations that can provide information about the evolution of large-scale structure in the universe, conditions near black holes, stellar atmospheres, and more.

Spectrometers employing novel critical-angle transmission (CAT) X-ray gratings promise spectral resolving power, R, as high as 5000—at least 5-10 times that of present instruments. In 2016, an

SMD-sponsored team produced and successfully demonstrated this new technology. A high-resolvingpower, soft X-ray objective grating spectrometer for deployment in space requires a lightweight focusing optic with very good angular resolution and gratings that can disperse X-rays to the largest possible angles with high efficiency and minimal aberrations. Realizing the challenging CAT grating design required almost a decade of development and breakthroughs in advanced nanofabrication technology including patterning, etch and atomic level deposition. Demonstrating this capability in the lab was challenging, however, and required a combination of unique state-of-the art nanofabrication processes and test hardware such as a long X-ray beamline and a spectrally narrow source.

Future X-ray missions employing this technology will provide vastly improved absorption- and emissionline spectroscopy of high-energy astrophysical sources such as black hole winds and hot gas in the cosmic web. Additional potential applications for CAT gratings include spectrographs for observations of the heliosphere, optics for high-power X-ray facilities, and filters for neutral-particle measurements in Earth's magnetosphere.



Recent large-area CAT grating next to a U.S. quarter coin. Credit: R. Heilmann, MIT, and A. Bruccoleri, Izentis, LLC

In 2016, three institutions collaborated to produce and demonstrate this new technology. The Space Nanotechnology Lab at the Massachusetts Institute of Technology (MIT) Kavli Institute provided state-of-the-art 200-nm-period ultrahigh- aspect-ratio silicon CAT gratings coated with a thin layer of platinum that enabled diffraction to angles up to 18 times larger than those supported by Chandra spectrometers. The 100-m-long Marshall Space Flight Center Stray Light Facility served as the beam line, and the X-ray optics group at Goddard Space Flight Center provided a lightweight high-resolution focusing optic. Preliminary analysis from this demonstration showed R much higher than 10,000—believed to be a world record for grating spectroscopy in the X-ray band. CAT grating technology continues to be refined to achieve higher efficiency and larger gratings. This technology is currently being proposed for use on an Explorer satellite mission named Arcus and studied for potential use in the Lynx mission concept, a potential successor to Chandra in the next decade. [13]

Scientists detect first X-rays from mystery supernovas

Exploding stars lit the way for our understanding of the universe, but researchers are still in the dark about many of their features.

A team of scientists, including scholars from the University of Chicago, appear to have found the first X-rays coming from type Ia supernovae. Their findings are published online Aug. 23 in the Monthly Notices of the Royal Astronomical Society.

Astronomers are fond of type Ia supernovas, created when a white dwarf star in a two-star system undergoes a thermonuclear explosion, because they burn at a specific brightness. This allows scientists to calculate how far away they are from Earth, and thus to map distances in the universe. But a few years ago, scientists began to find type Ia supernovas with a strange optical signature that suggested they carried a very dense cloak of circumstellar material surrounding them.

Such dense material is normally only seen from a different type of supernova called type II, and is created when massive stars start to lose mass. The ejected mass collects around the star; then, when the star collapses, the explosion sends a shockwave hurtling at supersonic speeds into this dense material, producing a shower of X-rays. Thus we regularly see X-rays from type II supernovas, but they have never been seen from type Ia supernovas.

When the UChicago-led team studied the supernova 2012ca, recorded by the Chandra X-ray Observatory, however, they detected X-ray photons coming from the scene.

"Although other type Ia's with circumstellar material were thought to have similarly high densities based on their optical spectra, we have never before detected them with X-rays," said study coauthor Vikram Dwarkadas, research associate professor in the Department of Astronomy and Astrophysics.

The amounts of X-rays they found were small—they counted 33 photons in the first observation a year and a half after the supernova exploded, and ten in another about 200 days later—but present.

"This certainly appears to be a Ia supernova with substantial circumstellar material, and it looks as though it's very dense," he said. "What we saw suggests a density about a million times higher what we thought was the maximum around Ia's."

It's thought that white dwarfs don't lose mass before they explode. The usual explanation for the circumstellar material is that it would have come from a companion star in the system, but the amount of mass suggested by this measurement was very large, Dwarkadas said—far larger than one could expect from most companion stars. "Even the most massive stars do not have such high mass-loss rates on a regular basis," he said. "This once again raises the question of how exactly these strange supernovas form."

"If it's truly a Ia, that's a very interesting development because we have no idea why it would have so much circumstellar material around it," he said.

"It is surprising what you can learn from so few photons," said lead author and Caltech graduate student Chris Bochenek; his work on the study formed his undergraduate thesis at UChicago. "With only tens of them, we were able to infer that the dense gas around the supernova is likely clumpy or in a disk."

More studies to look for X-rays, and even radio waves coming off these anomalies, could open a new window to understanding such supernovas and how they form, the authors said. [12]

Astrophysicists explain the mysterious behavior of cosmic rays

A team of scientists from Russia and China has developed a model explaining the nature of highenergy cosmic rays (CRs) in our galaxy. These CRs have energies exceeding those produced by supernova explosions by one or two orders of magnitude. The model focuses mainly on the recent discovery of giant structures called Fermi bubbles.

One of the key problems in the theory of the origin of cosmic rays, which consist of high-energy protons and atomic nuclei, is their acceleration mechanism. The issue was addressed by Vitaly Ginzburg and Sergei Syrovatsky in the 1960s when they suggested that CRs are generated during supernova (SN) explosions in the galaxy. A specific mechanism of charged particle acceleration by SN shock waves was proposed by Germogen Krymsky and others in 1977. Due to the limited lifetime of the shocks, it is estimated that the maximum energy of the accelerated particles cannot exceed 1014-1015 eV.

Explaining the nature of particles with energies above 1015 eV is key. A major breakthrough in researching the acceleration processes of such particles came when the Fermi Gamma Ray Space Telescope detected two gigantic structures emitting radiation in the gamma-ray band in the central area of the galaxy in November 2010. The structures are elongated and symmetrically located in the galactic plane perpendicular to its center, extending 50,000 light-years, or roughly half of the diameter of the Milky Way disk. These structures became known as Fermi bubbles. Later, the Planck telescope team discovered their emission in the microwave band.

The nature of Fermi bubbles is still unclear, but the location of these objects indicates their connection to past or present activity in the center of the galaxy, where a central black hole of 106 solar masses is believed to be located. Modern models relate the bubbles to star formation and/or an energy release in the galactic center as a result of tidal disruption of stars during their accretion onto a central black hole. Similar structures can be detected in other galactic systems with active nuclei.

Dmitry Chernyshov (MIPT graduate), Vladimir Dogiel (MIPT staff member) and their colleagues from Hong Kong and Taiwan have published a series of papers on the nature of Fermi bubbles. They have shown that X-ray and gamma-ray emission in these areas is due to processes involving relativistic electrons accelerated by shock waves resulting from stellar matter falling into a black hole. In this case, the shock waves should accelerate both protons and nuclei. However, in contrast to electrons, relativistic protons with bigger masses lose hardly any energy in the galactic halo and can fill the entire volume of the galaxy. The authors of the paper suggest that giant Fermi bubble shock fronts can re-accelerate protons emitted by SN to energies greatly exceeding 1015 eV.

Analysis of cosmic ray re-acceleration showed that Fermi bubbles may be responsible for the formation of the CR spectrum above the "knee" of the observed spectrum, i.e., at energies greater than 3×1015 eV (energy range "B" in Fig. 2). To put this into perspective, the energy of accelerated particles in the Large Hadron Collider is also ~1015 eV.

"The proposed model explains the spectral distribution of the observed CR flux. It can be said that the processes we described are capable of re-accelerating galactic cosmic rays generated in supernova explosions. Unlike electrons, protons have a significantly greater lifetime, so when accelerated in Fermi bubbles, they can fill up the volume of the galaxy and be observed near the Earth. Our model suggests that the cosmic rays containing high-energy protons and nuclei with energy lower than 1015 eV (below the energy range of the observed spectrum's "knee"), were generated in supernova explosions in the galactic disk. Such CRs are re-accelerated in Fermi bubbles to energies over 1015 eV (above the "knee"). The final cosmic ray distribution is shown on the spectral diagram," says Vladimir Dogiel.

The researchers have proposed an explanation for the peculiarities in the CR spectrum in the energy range from 3×1015 to 1018 eV (energy range "B" in Fig. 2). The scientists proved that particles produced during the SN explosions and which have energies lower than 3×1015 eV experience reacceleration in Fermi bubbles when they move from the galactic disk to the halo. Reasonable parameters of the model describing the particles' acceleration in Fermi bubbles can explain the nature of the spectrum of cosmic rays above 3×1015 eV. The spectrum below this range remains undisturbed. Thus, the model is able to produce spectral distribution of cosmic rays that is identical to the one observed. [11]

Space-based experiment will tackle the mysteries of cosmic rays

On August 14, 2017, a groundbreaking University of Maryland-designed cosmic ray detector will travel to the International Space Station (ISS) aboard the SpaceX-12 Commercial Resupply Service mission. The instrument, named ISS Cosmic Ray Energetics and Mass (ISS-CREAM), is roughly the size of a refrigerator and will remain installed on the ISS's Japanese Experiment Module for at least three years. The massive amounts of data ISS-CREAM will collect could reveal new details about the origin and diversity of cosmic rays.

Cosmic rays are not rays at all, but highly energetic particles that zoom through space at nearly the speed of light. The particles range in size, from subatomic protons to the atomic nuclei of elements such as carbon and boron. Scientists suspect that the particles are bits of subatomic shrapnel produced by supernovae, but could also be signatures of other cataclysmic phenomena.

Regardless of their origin, "cosmic rays are direct samples of matter from outside our solar system— possibly from the most distant reaches of the universe," said Eun-Suk Seo, a professor of physics at UMD and lead investigator for ISS-CREAM. Seo leads UMD's Cosmic Ray Physics Group and has a joint appointment in the UMD Institute for Physical Science and Technology.

ISS-CREAM builds on more than a decade of work by Seo's research group, which includes seven Long-Duration Balloon (LDB) missions in Antarctica dedicated to studying the nature of cosmic rays. Each of these LDB missions was facilitated by NASA with additional support from the National Science Foundation.

The first, known as Cosmic Ray Energetics and Mass I (CREAM I), launched in December 2004. CREAM I carried instruments to measure the energy, charge, mass and direction of incoming cosmic ray particles. The following five missions, also named CREAM and numbered II-VI, carried the same basic suite of instruments. The seventh and most recent mission took on a different name: Boron and Carbon Cosmic rays in the Upper Stratosphere (BACCUS). The flight set a record for the earliest seasonal launch in the history of NASA's LDB program on November 28, 2016, and concluded 30 days later.

ISS-CREAM will carry a suite of instruments very similar to its balloon-borne cousins. But unlike the balloon experiments, ISS-CREAM's detectors will have direct, unimpeded access to incoming cosmic rays—with no atmospheric interference. Back on Earth, Seo's team will monitor operations around the clock, taking shifts to ensure the instruments are properly calibrated and collecting the maximum amount of data.

When a cosmic ray particle reaches Earth's atmosphere, it soon collides with another particle— most likely an atom of nitrogen or oxygen. This sets off a cascade of secondary particles that carry less energy than the original particle. The atmosphere serves as a protective filter, slowing down dangerous cosmic rays before they have a chance to damage life and property here on Earth's surface.

This also means that Earth-bound cosmic ray detectors can only see secondary particles. By orbiting above the atmosphere, ISS-CREAM addresses this challenge and offers several other benefits compared with balloon experiments.

"To see primary particles we have to fly an instrument in space. This removes atmospheric background," Seo explained. "Prior experiments were also limited to lower energies because of the payload size and flight duration. ISS-CREAM will extend our measurements to the highest energies possible and will allow us to increase our exposure by an order of magnitude."

ISS-CREAM also has to withstand harsh conditions far beyond those experienced during a balloon mission.

"ISS-CREAM has to survive a violent rocket launch. A balloon launch is very gentle by comparison," Seo said. "ISS-CREAM also has to continue working without repairs for years, while a balloon instrument only needs to last a month or two. And any space-based experiment has to be shielded from radiation, which makes everything more expensive and the design processes more exacting."

Cosmic ray particles could help solve one of today's most elusive scientific puzzles: determining the nature of dark matter. According to Seo, theory suggests that dark matter particles might collide and annihilate one another, resulting in energetic particles of conventional matter that we recognize as cosmic rays. If this theory is correct, studying cosmic rays could result in promising leads in the search for dark matter.

"The mysterious nature of cosmic rays serves as a reminder of just how little we know about our universe. The discovery of cosmic rays gave birth to the field of particle physics in the early 20th century. But no human-made particle accelerator can reach the energy levels we see in cosmic rays," Seo added. "Our team has been anxiously awaiting this launch for years. This is a very exciting time for us as well as others in the field of high-energy particle astrophysics." [10]

The mystery of the pulsating blue stars

In the middle of the large Chilean Atacama desert, a team of Polish astronomers are patiently monitoring millions of celestial bodies night after night with the help of a modern robotic telescope. In 2013, the team was surprised when they discovered, in the course of their survey, stars that pulsated much faster than expected. In the following years, the team that included Dr. Marilyn Latour, an astronomer from the Dr. Remeis-Sternwarte Bamberg, the astronomical institute of Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), studied these stars in more detail and concluded that they had stumbled upon a new class of variable star.

Many classes of star exhibit variations in brightness. Unlike our Sun, these stars are not stable; their surface oscillates, meaning that the surface expands and shrinks by a few percent. This is what happens in the case of the more familiar Cepheids and RR Lyrae stars, which have oscillation periods that extend over a few hours to hundreds of days.

The researchers discovered a dozen stars that seemed at first sight to show variations that were very similar to those of the Cepheids and RR Lyrae stars but have much shorter (20-40 minutes) oscillation periods and, at the same time, are much bluer in colour. This indicates that the newly identified stars are hotter and more compact. It was because of these characteristics that it was proposed to give this new class of variable stars the acronym BLAPS, i.e. Blue Large-Amplitude Pulsators. What kind of stars these were, however, remained an enigma.

The nature of the newly discovered stars

For the astronomers, these new stars posed a riddle. At first, they assumed that BLAPs could be hot dwarf stars since they have similar oscillation periods. Hot dwarf stars are old stars approaching the end of their lives. They generate their energy by means of the thermonuclear fusion of helium to form carbon. The Sun, being in an earlier phase of its life, is currently converting hydrogen to helium.

In order to find out whether BLAPs are actually hot dwarfs, the astronomers used two of their largest telescopes to make observations. They were able to capture suitable spectra of some BLAPs using the large Gemini and Magellan telescopes, both located in the Chilean Atacama desert. Latour analysed these spectra using sophisticated physical-numerical models. She was able to show that the variations in luminosity are attributable to temperature changes on the surface of the stars. The temperature of the BLAPs turned out to be five times greater than that of the Sun - something that is characteristic of hot dwarfs.

However, the BLAPs are significantly bigger than hot dwarfs, meaning that they form a new class of stars that are similar to hot dwarfs but have a more bloated envelope than the latter. Why BLAPs oscillate like Cepheids and why they are bloated remain puzzles, as does their origin. Further investigations need to be undertaken to solve the mystery of how BLAPs come into being. [9]

Study calls into question theories on pulsar phenomena

Researchers at the University of Southampton have cast doubt over established explanations for certain behaviours in pulsars - highly magnetised rotating neutron stars, formed from the remains of supernovae.

Mathematicians have used complex modelling to examine data for one particular pulsar which exhibits both 'glitching' and 'wobbling'. They found accepted theories which explain these phenomena conflict with one another - meaning they can't fit together to explain what is happening in the star.

Findings are published in the journal Physical Review Letters.

A pulsar emits a rotating beam of electromagnetic radiation, which can be detected by powerful telescopes as it sweeps past the Earth, rather like observing the beam of a lighthouse from a ship at sea. They rotate at extremely stable speeds, but occasionally they suddenly speed up in brief events described as 'glitches'. Pulsars can also spin at a slight angle so that their axis traces a cone shape, rather like the movement of a rugby ball which has been thrown slightly off balance - 'wobbling' at each end as it moves through the air.

Lead researcher Dr Ian Jones commented: "There are a number of different theories around what causes pulsars to glitch and wobble. Some centre on the interaction between superfluid in a star's core and its crust - others suggest gravity from an orbiting planet is pulling the star back and forth.

"By studying this unusual pulsar, which glitches and wobbles, we have found that current theories contradict each other and therefore can't explain how both anomalies are occurring in the same star. As such, our results imply we are not seeing the whole picture and that there are errors in our current theories - suggesting a need to rethink what causes the anomalies."

The researchers from Mathematical Sciences at the University of Southampton, UK and the Max Planck Institute for Gravitational Physics, Hannover, Germany, studied data on the pulsar PSR B182811. The star was discovered by Jodrell Bank in the UK in the in early 1990s and lies around 10,000 light-years from Earth in the constellation of Scutum. [8]

Neutron stars could be our GPS for deep space travel

NASA's Neutron Star Interior Composition Explorer, or NICER, is an X-ray telescope launched on a SpaceX Falcon 9 rocket in early June 2017. Installed on the International Space Station, by mid-July it will commence its scientific work – to study the exotic astrophysical objects known as neutron stars and examine whether they could be used as deep-space navigation beacons for future generations of spacecraft.

What are neutron stars? When stars at least eight times more massive than the Sun exhaust all the fuel in their core through thermonuclear fusion reactions, the pressure of gravity causes them to collapse. The supernova explosion that results ejects most of the star's material into the far reaches of space. What remains forms either a neutron star or a black hole.

I study neutron stars because of their rich range of astrophysical phenomena and the many areas of physics to which they are connected. What makes neutron stars extremely interesting is that each star is about 1.5 times the mass of the Sun, but only about 25km in diameter – the size of a single city. When you cram that much mass into such a small volume, the matter is more densely packed than that of an atomic nucleus. So, for example, while the nucleus of a helium atom has just two neutrons and two protons, a neutron star is essentially a single nucleus made up of 1057 neutrons and 1056 protons.

Exotic physics impossible on Earth

We can use neutron stars to probe properties of nuclear physics that cannot be investigated in laboratories on Earth. For example, some current theories predict that exotic particles of matter, such as hyperons and deconfined quarks, can appear at the high densities that are present in neutron stars. Theories also indicate that at temperatures of a billion degrees Celsius, protons in the neutron star become superconducting and neutrons, without charge, become superfluid.

The magnetic field of neutron stars is extreme as well, possibly the strongest in the universe, and billions of times stronger than anything created in laboratories. While the gravity at the surface of a neutron star may not be as strong as that near a black hole, neutron stars still create major distortions in spacetime and can be sources of gravitational waves, which were inferred from research into neutron stars in the 1970s, and confirmed from black holes by the LIGO experiments recently.

The main focus of NICER is to accurately measure the mass and radius of several neutron stars – and, although the telescope will observe other types of astronomical objects, those of us studying neutron stars hope NICER will provide us with unique insights into these fascinating objects and their physics. NICER will measure how the brightness of a neutron star changes according to its energy, and how it changes as the star rotates, revealing different parts of the surface. These observations will be compared to theoretical models based on properties of the star such as mass and radius. Accurate determinations of mass and radius will provide a vital test of nuclear theory.

A GPS for deep space

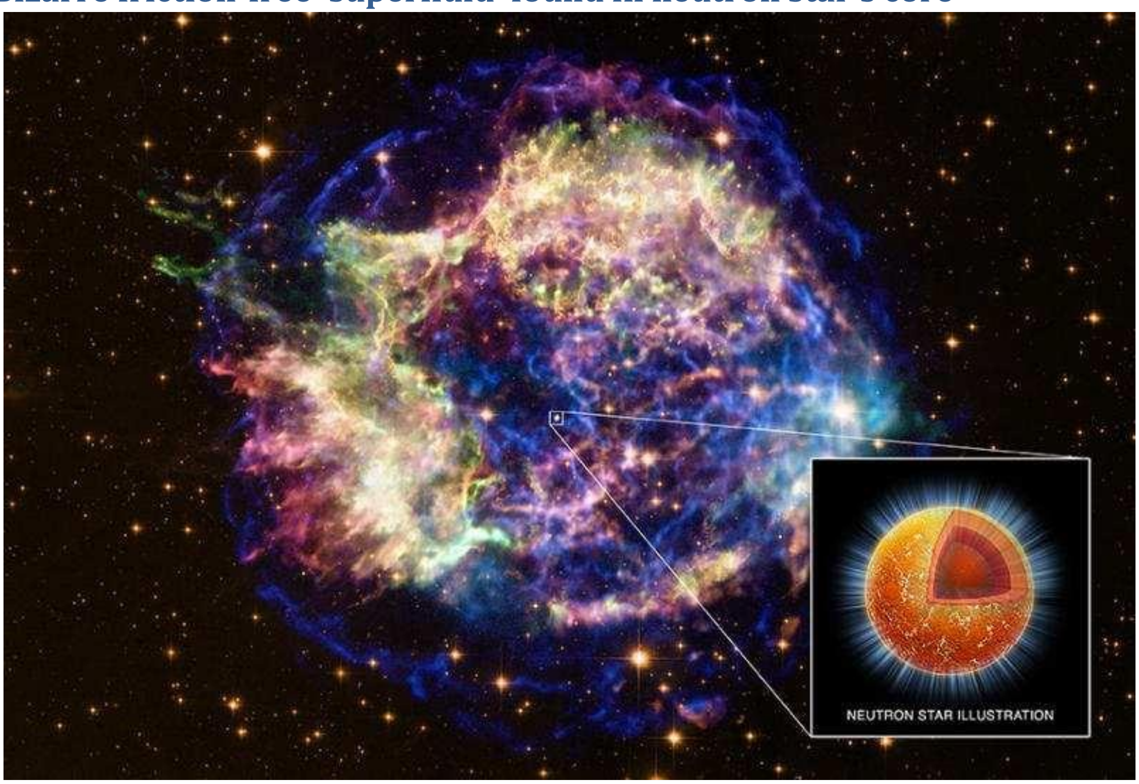
Another aspect of neutron stars that could prove important for future space travel is their rotation– and this will also be tested by NICER. Rotating neutron stars, known as pulsars, emit beams of radiation like a lighthouse and are seen to spin as fast as 716 times per second. This rotation rate in some neutron stars is more stable than the best atomic clocks we have on Earth. In fact, it is this characteristic of neutron stars that led to the discovery of the first planets outside our solar system in 1992 – three Earth-sized planets revolving around a neutron star.

The NICER mission, using a part of the telescope called SEXTANT, will test whether the extraordinary regularity and stability of neutron star rotation could be used as a network of navigation beacons in deep space. Neutron stars could thus serve as natural satellites contributing to a Galactic (rather than Global) Positioning System and could be relied upon by future manned and unmanned spacecraft to navigate among the stars.

NICER will operate for 18 months, but it is hoped that NASA will continue to support its operation afterwards, especially if it can deliver on its ambitious scientific goals. I hope so too, because NICER combines and greatly improves upon the invaluable capabilities of previous X-ray spacecraft – RXTE, Chandra, and XMM-Newton – that are used to uncover neutron stars' mysteries and reveal properties of fundamental physics.

The first neutron star, a pulsar, was discovered in 1967 by Jocelyn Bell Burnell. It would be fitting to obtain a breakthrough on neutron stars in this 50th anniversary year. [7]

Bizarre friction-free 'superfluid' found in neutron star's core



This composite image shows a beautiful X-ray and optical view of Cassiopeia A (Cas A), a supernova remnant located in our Galaxy about 11,000 light years away.
These are the remains of a massive star that exploded about 330 years ago, as measured in Earth's time frame. X-rays from Chandra are shown in red, green and blue along with optical data from Hubble in gold. At the center of the image is a neutron star, an ultra-dense star created by the supernova. The inset shows an artist's impression of the neutron star at the center of Cas A. The

different colored layers in the cutout region show the crust (orange), the core (red), where densities are much higher, and the part of the core where the neutrons are thought to be in a superfluid state (inner red ball). The blue rays emanating from the center of the star represent the copious numbers of neutrinos -- nearly massless, weakly interacting particles -- that are created as the core temperature falls below a critical level and a neutron superfluid is formed, a process that began about 100 years ago as observed from Earth. These neutrinos escape from the star, taking energy with them and causing the star to cool much more rapidly.

Neutron stars contain the densest known matter that is directly observable. One teaspoon of neutron star material weighs six billion tons. The pressure in the star's core is so high that most of the charged particles, electrons and protons, merge resulting in a star composed mostly of uncharged particles called neutrons.

Two independent research teams studied the supernova remnant Cassiopeia A, or Cas A for short, the remains of a massive star 11,000 light years away that would have appeared to explode about 330 years ago as observed from Earth. Chandra data found a rapid decline in the temperature of the ultra-dense neutron star that remained after the supernova, showing that it had cooled by about four percent over a 10-year period.

"This drop in temperature, although it sounds small, was really dramatic and surprising to see," said Dany Page of the National Autonomous University in Mexico, leader of a team with a paper published in the February 25, 2011 issue of the journal Physical Review Letters. "This means that something unusual is happening within this neutron star."

Superfluids containing charged particles are also superconductors, meaning they act as perfect electrical conductors and never lose energy. The new results strongly suggest that the remaining protons in the star's core are in a superfluid state and, because they carry a charge, also form a superconductor.

"The rapid cooling in Cas A's neutron star, seen with Chandra, is the first direct evidence that the cores of these neutron stars are, in fact, made of superfluid and superconducting material," said Peter Shternin of the Ioffe Institute in St Petersburg, Russia, leader of a team with a paper accepted in the journal Monthly Notices of the Royal Astronomical Society.

Both teams show that this rapid cooling is explained by the formation of a neutron superfluid in the core of the neutron star within about the last 100 years as seen from Earth. The rapid cooling is expected to continue for a few decades and then it should slow down.

"It turns out that Cas A may be a gift from the Universe because we would have to catch a very young neutron star at just the right point in time," said Page's co-author Madappa Prakash, from Ohio University. "Sometimes a little good fortune can go a long way in science."

The onset of superfluidity in materials on Earth occurs at extremely low temperatures near absolute zero, but in neutron stars, it can occur at temperatures near a billion degrees Celsius. Until now there was a very large uncertainty in estimates of this critical temperature. This new research constrains the critical temperature to between one half a billion to just under a billion degrees.

Cas A will allow researchers to test models of how the strong nuclear force, which binds subatomic particles, behaves in ultradense matter. These results are also important for understanding a range of behavior in neutron stars, including "glitches," neutron star precession and pulsation, magnetar outbursts and the evolution of neutron star magnetic fields.

Small sudden changes in the spin rate of rotating neutron stars, called glitches, have previously given evidence for superfluid neutrons in the crust of a neutron star, where densities are much lower than seen in the core of the star. This latest news from Cas A unveils new information about the ultradense inner region of the neutron star. [6]

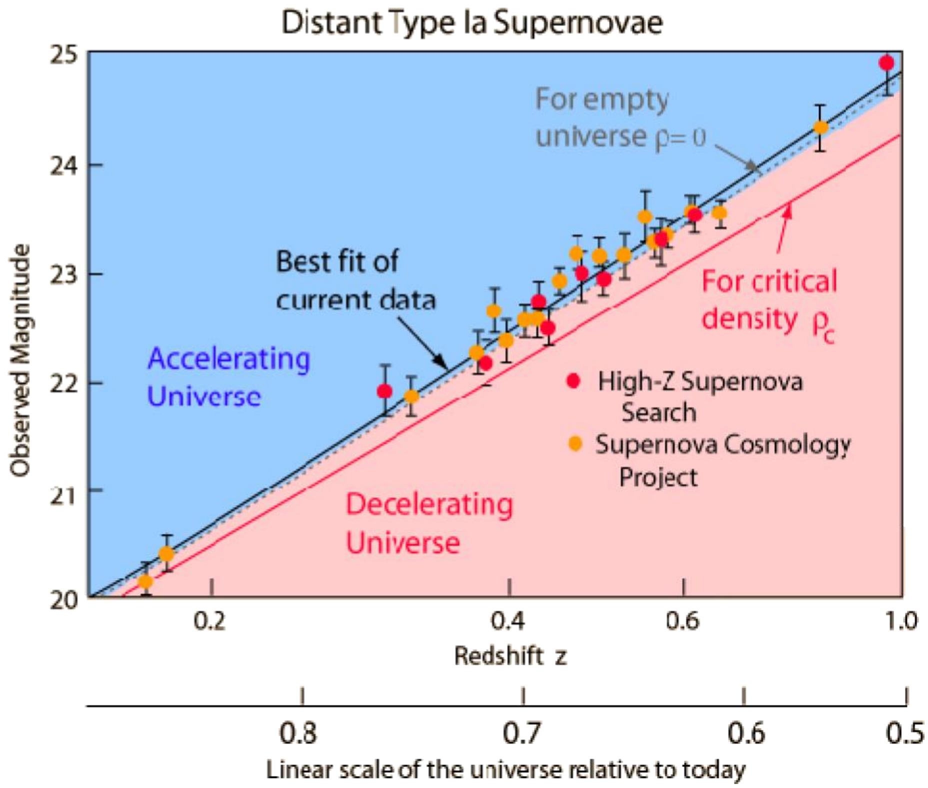
The Big Bang

The Big Bang caused acceleration created radial currents of the matter, and since the matter is composed of negative and positive charges, these currents are creating magnetic field and attracting forces
between the parallel moving electric currents. This is the gravitational force experienced by the matter, and also the mass is result of the electromagnetic forces between the charged particles.
The positive and negative charged currents attracts each other or by the magnetic forces or by the much stronger electrostatic forces!?
The gravitational force attracting the matter, causing concentration of the matter in a small space and leaving much space with low matter concentration: dark matter and energy.
There is an asymmetry between the mass of the electric charges, for example proton and electron, can understood by the asymmetrical Planck Distribution Law. This temperature dependent energy distribution is asymmetric around the maximum intensity, where the annihilation of matter and antimatter is a high probability event. The asymmetric sides are creating different frequencies of electromagnetic radiations being in the same intensity level and compensating each other. One of these compensating ratios is the electron – proton mass ratio. The lower energy side has no compensating intensity level, it is the dark energy and the corresponding matter is the dark matter.

Evidence for an accelerating universe

One of the observational foundations for the big bang model of cosmology was the observed expansion of the universe. [4] Measurement of the expansion rate is a critical part of the study, and it has been found that the expansion rate is very nearly "flat". That is, the universe is very close to the critical density, above which it would slow down and collapse inward toward a future "big crunch". One of the great challenges of astronomy and astrophysics is distance measurement over the vast distances of the universe. Since the 1990s it has become apparent that type Ia supernovae offer a unique opportunity for the consistent measurement of distance out to perhaps 1000 Mpc. Measurement at these great distances provided the first data to suggest that the expansion rate of the universe is actually accelerating. That acceleration implies an energy density that acts in opposition to gravity which would cause the expansion to accelerate. This is an energy density which we have not directly detected observationally and it has been given the name "dark energy".

The type Ia supernova evidence for an accelerated universe has been discussed by Perlmutter and the diagram below follows his illustration in Physics Today.



The data summarized in the illustration above involve the measurement of the redshifts of the distant supernovae. The observed magnitudes are plotted against the redshift parameter z. Note that there are a number of Type 1a supernovae around z=.6, which with a Hubble constant of 71 km/s/mpc is a distance of about 5 billion light years.

Equation

The cosmological constant Λ appears in Einstein's field equation [5] in the form of

$$R_{\mu\nu} - \frac{1}{2} R\, g_{\mu\nu} + \Lambda\, g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}\,,$$

where *R* and *g* describe the structure of spacetime, *T* pertains to matter and energy affecting that structure, and *G* and *c* are conversion factors that arise from using traditional units of measurement. When Λ is zero, this reduces to the original field equation of general relativity. When *T* is zero, the field equation describes empty space (the vacuum).

The cosmological constant has the same effect as an intrinsic energy density of the vacuum, ρ_{vac} (and an associated pressure). In this context it is commonly moved onto the right-hand side of the equation, and defined with a proportionality factor of 8π: $\Lambda = 8\pi\rho_{vac}$, where unit conventions of general relativity are used (otherwise factors of *G* and *c* would also appear). It is common to quote values of energy density directly, though still using the name "cosmological constant".

A positive vacuum energy density resulting from a cosmological constant implies a negative pressure, and vice versa. If the energy density is positive, the associated negative pressure will drive an accelerated expansion of the universe, as observed. (See dark energy and cosmic inflation for details.)

Explanatory models

Models attempting to explain accelerating expansion include some form of dark energy, dark fluid or phantom energy. The most important property of dark energy is that it has negative pressure which is distributed relatively homogeneously in space. The simplest explanation for dark energy is that it is a cosmological constant or vacuum energy; this leads to the LambdaCDM model, which is generally known as the Standard Model of Cosmology as of 20032013, since it is the simplest model in good agreement with a variety of recent observations.

Lorentz transformation of the Special Relativity

In the referential frame of the accelerating electrons the charge density lowering linearly because of the linearly growing way they takes every next time period. From the referential frame of the wire there is a parabolic charge density lowering.

The difference between these two referential frames, namely the referential frame of the wire and the referential frame of the moving electrons gives the relativistic effect. Important to say that the moving electrons presenting the time coordinate, since the electrons are taking linearly increasing way every next time period, and the wire presenting the geometric coordinate. The Lorentz transformations are based on moving light sources of the Michelson - Morley experiment giving a practical method to transform time and geometric coordinates without explaining the source of this mystery.

The real mystery is that the accelerating charges are maintaining the accelerating force with their charge distribution locally. The resolution of this mystery that the charges are simply the results of the diffraction patterns, that is the charges and the electric field are two sides of the same thing. Otherwise the charges could exceed the velocity of the electromagnetic field.

The increasing mass of the electric charges the result of the increasing inductive electric force acting against the accelerating force. The decreasing mass of the decreasing acceleration is the result of the inductive electric force acting against the decreasing force. This is the relativistic mass change explanation, especially importantly explaining the mass reduction in case of velocity decrease.

The Classical Relativistic effect

The moving charges are self maintain the electromagnetic field locally, causing their movement and this is the result of their acceleration under the force of this field.

In the classical physics the charges will distributed along the electric current so that the electric potential lowering along the current, by linearly increasing the way they take every next time period because this accelerated motion.

Electromagnetic inertia and Gravitational attraction

Since the magnetic induction creates a negative electric field as a result of the changing acceleration, it works as an electromagnetic inertia, causing an electromagnetic mass.

It looks clear that the growing acceleration results the relativistic growing mass - limited also with the velocity of the electromagnetic wave.

Since $E = hv$ and $E = mc^2$, $m = hv /c^2$ that is the m depends only on the v frequency. It means that the mass of the proton and electron are electromagnetic and the result of the electromagnetic induction, caused by the changing acceleration of the spinning and moving charge! It could be that the m_o inertial mass is the result of the spin, since this is the only accelerating motion of the electric charge. Since the accelerating motion has different frequency for the electron in the atom and the proton, they masses are different, also as the wavelengths on both sides of the diffraction pattern, giving equal intensity of radiation.

If the mass is electromagnetic, then the gravitation is also electromagnetic effect caused by the accelerating Universe! The same charges would attract each other if they are moving parallel by the magnetic effect.

The Planck distribution law explains the different frequencies of the proton and electron, giving equal intensity to different lambda wavelengths! Also since the particles are diffraction patterns they have some closeness to each other – can be seen as a gravitational force.

Electromagnetic inertia and mass

Electromagnetic Induction

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Relativistic change of mass

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The frequency dependence of mass

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Electron – Proton mass rate

The Planck distribution law explains the different frequencies of the proton and electron, giving equal intensity to different lambda wavelengths! Also since the particles are diffraction patterns they have some closeness to each other – can be seen as a gravitational force. [1]

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Gravity from the point of view of quantum physics

The Gravitational force

The gravitational attractive force is basically a magnetic force.

The same electric charges can attract one another by the magnetic force if they are moving parallel in the same direction. Since the electrically neutral matter is composed of negative and positive charges they need 2 photons to mediate this attractive force, one per charges. The Bing Bang caused parallel moving of the matter gives this magnetic force, experienced as gravitational force.

Since graviton is a tensor field, it has spin = 2, could be 2 photons with spin = 1 together.

You can think about photons as virtual electron – positron pairs, obtaining the necessary virtual mass for gravity.

The mass as seen before a result of the diffraction, for example the proton – electron mass rate Mp=1840 Me. In order to move one of these diffraction maximum (electron or proton) we need to intervene into the diffraction pattern with a force appropriate to the intensity of this diffraction maximum, means its intensity or mass.

The Big Bang caused acceleration created radial currents of the matter, and since the matter is composed of negative and positive charges, these currents are creating magnetic field and attracting forces between the parallel moving electric currents. This is the gravitational force experienced by the matter, and also the mass is result of the electromagnetic forces between the charged particles. The positive and negative charged currents attracts each other or by the magnetic forces or by the much stronger electrostatic forces!?

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The Graviton

In physics, the graviton is a hypothetical elementary particle that mediates the force of gravitation in the framework of quantum field theory. If it exists, the graviton is expected to be massless (because the gravitational force appears to have unlimited range) and must be a spin-2 boson. The spin follows from the fact that the source of gravitation is the stress-energy tensor, a second-rank tensor (compared to electromagnetism's spin-1 photon, the source of which is the four-current, a first-rank tensor). Additionally, it can be shown that any massless spin-2 field would give rise to a force indistinguishable from gravitation, because a massless spin-2 field must couple to (interact with) the stress-energy tensor in the same way that the gravitational field does. This result suggests that, if a massless spin-2 particle is discovered, it must be the graviton, so that the only experimental verification needed for the graviton may simply be the discovery of a massless spin-2 particle. [2]

Conclusions

"Previously we had no idea how extended superconductivity of protons was in a neutron star," said Shternin's co-author Dmitry Yakovlev, also from the Ioffe Institute. The cooling in the Cas A neutron star was first discovered by co-author Craig Heinke, from the University of Alberta, Canada, and Wynn Ho from the University of Southampton, UK, in 2010. It was the first time that astronomers have measured the rate of cooling of a young neutron star. [6]

The accelerating Universe fits into the accelerating charges of the electric currents, because the Bing Bang caused radial moving of the matter.

Needless to say that the accelerating electrons of the steady stationary current are a simple demystification of the magnetic field, by creating a decreasing charge distribution along the wire, maintaining the decreasing U potential and creating the **A** vector potential experienced by the electrons moving by **v** velocity relative to the wire. This way it is easier to understand also the time dependent changes of the electric current and the electromagnetic waves as the resulting fields moving by c velocity.

It could be possible something very important law of the nature behind the self maintaining **E** accelerating force by the accelerated electrons. The accelerated electrons created electromagnetic fields are so natural that they occur as electromagnetic waves traveling with velocity c. It shows that the electric charges are the result of the electromagnetic waves diffraction.

One of the most important conclusions is that the electric charges are moving in an accelerated way and even if their velocity is constant, they have an intrinsic acceleration anyway, the so called spin, since they need at least an intrinsic acceleration to make possible they movement .

The bridge between the classical and quantum theory is based on this intrinsic acceleration of the spin, explaining also the Heisenberg Uncertainty Principle. The particle – wave duality of the electric charges and the photon makes certain that they are both sides of the same thing. Basing the gravitational force on the accelerating Universe caused magnetic force and the Planck Distribution Law of the electromagnetic waves caused diffraction gives us the basis to build a Unified Theory of the physical interactions.

The electric currents causing self maintaining electric potential is the source of the special and general relativistic effects. The Higgs Field is the result of the electromagnetic induction. The Graviton is two photons together. [3]

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