A fractal model of particles

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Sommaire

1 Foreword

Since the years around 1920, many experiences have confirmed the existence of elementary particles as the electron, the photon, etc…. In the specialized literature, the nature and their interactions are described starting from abstract principles such as symmetries in « internal » spaces attached to each point of space-time. Rotations in those abstract spaces allow passing from one particle type to another, under the effect of an interaction. These purely mathematical creations seem to satisfy a great number of physicists. Even if they furnish equations that correctly reproduce experimental facts, their explicative power appears to me as rather weak, in particular regarding the very nature of particles which is often not even addressed. For my part, since the beginning of my studies in the seventies, I was firmly convinced that particles have a spatial structure and that the symmetries of these structures (called real or external symmetries) will permit their classification and the description of their interaction. In other words, it is the real external symmetries which should explain the abstract internal symmetries of the interactions.

I thought that I could visualize those particle structures, which was considered anathema in those times, because the particles were seen as points without dimensions, qualified by « quantum numbers » which defined their qualities, like the electric charge, the mass, the spin….

My second intuition concerned the spin ½, a completely mysterious property of some particles like the electron, the proton, …, characterised by the fact that these particles require two full turns on themselves (720°) to come back to their original state ! I was convinced that if one could explain

the spin ½, it would be the key to understand the nature of particles.

My goal in this essay is to present a model which could explain, at least qualitatively the true nature of the electron, the positron (the antiparticle of the electron) and the photon (the particle of light). This model should also suggest plausible structures for all other elementary particles.

2 Introduction

This model is addressed to a large public and it is thus limited to qualitative explanations. But should it also limit itself, as it is the case for most vulgarisation books, to the current consensus ? I do not think so, because science is far from consensual. Intense battles are fought in the background, behind a smooth and tranquil facade. Large divergences have appeared, and intense debates take place. An impressive number of questions remain unanswered and this has been so for many decades. Having much reflected about these questions, I will propose new suggestions whenever no current explanation appears to be convincing. Too many books are content to vulgarise the consensus without criticising it and hide the remaining difficulties.

In a scientific approach, one must wonder whether creating a model before establishing the theory has any value according to the criteria of modern science. The great majority of professional physicists will answer by the negative without any hesitation. And one cannot criticise them entirely, because it is so true that the model can be contrived to provide any answer. By its nature it is too vague, and it allows using imprecise arguments to counter anything that would put him into danger. To confront the hard reality

of facts nothing surpasses a rigorous mathematical demonstration.

However, at least one case of fruitful model exists in the history of science : Maxwell, and his disciples Fitzgerald, Heaviside and Lodge have used various models to help them formulate the equations of the electromagnetic field. It cannot be denied that they were of use, in spite of the fact that their mechanical nature provided little hope that they could represent more than simple analogies. With the test of time, these models have disappeared with little traces, except in a few science history books. Only equations remained. In the mind of many physicists they have acquired a proper existence. Some, and not the least, do even pretend that one should not try to understand the EM field in terms of a geometrical or mechanical or hydrodynamical explanation, that they embody the physical reality itself. For my part, I am terribly shocked by this attitude. It seems to reflect so much the position of a mathematician, content and entirely satisfied of himself when he has found an equation. As a physicist, this affirmation troubles me as much as the idea of a vibration of the EM field without any material support, or an action at a distance in the vacuum. These statements result so obviously from mathematical idealisations that they lead me to think that the direction of physics is too much guided by the mathematical achievements of an Heisenberg, Hawking, or a Witten and not enough by the research of an underlying reality by Einstein, de Broglie, Böhm, Vigier or Arp.

Before any argumentation in a sense or another, it is important to note that the scientific method has never been revealed as fire letters in the sky. It has been shaped across the centuries by men for men. It is thus imperfect and in need of improvement. Moreover it is not clear whether it should

apply the same way in case of « normal » science or in a change of paradigm. In a normal period, the current method is astonishingly effective. Remember that when the orientation of quantum mechanics was understood, it took only three years (from 1924 to 1927) to establish its basis. But I am much more doubtful concerning the capacity of normal science in a change of paradigm.

So the question arises : are we in a period of normal science or in a change of paradigm ? For my part the answer is clear. We are without doubt in the second situation. But to be able to appreciate my arguments you will have to familiarise yourself with particles and some associated concepts of modern science.

3 Introduction to elementary particles

It is easy to get lost in the maze of particles, because they are so numerous and varied: more than 100 types are known. In reality, many are simply composite of others. The true elementary ones (which are not assemblies of smaller particles) are much less numerous. The essential of basis particles are found while exploring the atom structure as understood after Rutherford's experiments in 1911.

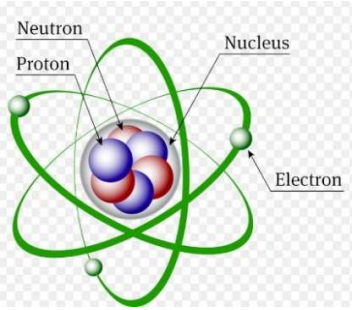


Figure 1: La structure de l'atome selon Rutherford.

From a long distance the atoms appear to be neutral. This is because it is composed of particles of equal but opposite charges. The envelope is constituted of a kind of electron cloud. Those are light particles of negative charge. The atomic centre is occupied by a much heavier nucleus, composed of neutrons and protons. Protons and neutrons are designated by a common name: the nucleon. A proton weights about 1836 times more than an electron, which is considerable, and which explains why the electron move furiously around a quasi-static nucleus. The charge of the proton is exactly equal to the electron charge, but of opposite sign. It is already a mystery this charge which is in absolute value rigorously identical for two particles of such different masses. Neutrons have a zero charge and their mass is nearly identical to that of the proton. Since there are as many protons in the nucleus as electrons in the cloud, the ensemble appears to be neutral at large distances.

Now let us examine for which reason this complex atomic structure has cohesion. If anything remains of your electrical courses in the secondary school, it is that charges of same sign repel why charges of different sign attract. In fact, it is because attractions and repulsions have been noted experimentally that one has introduced this notion of charges of opposite sign.
The interaction responsible for these phenomena has been called electromagnetism after the splendid unification performed by Maxwell between electricity and magnetism. In the years 50 and 60 it has been shown in a very convincing manner that the electromagnetic interaction is due to the exchange of photons between electrically charged particles. So protons for example emit photons that are captured by an electron. The photon takes away some energy and momentum and transmits it to the electron. It is in this way

that the electromagnetic interaction can be understood, and one represents it by appropriate Feynman's graphs.

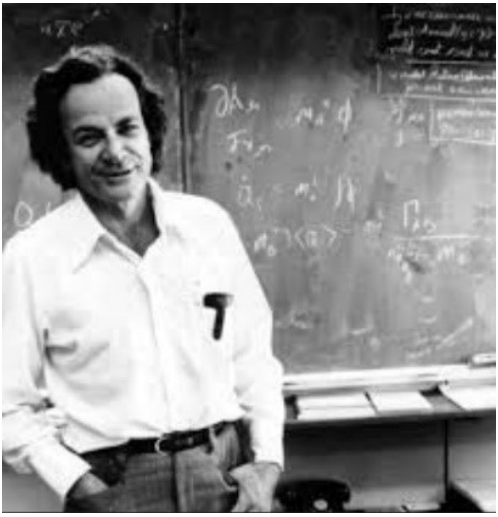


Figure 2: Richard Feynman.

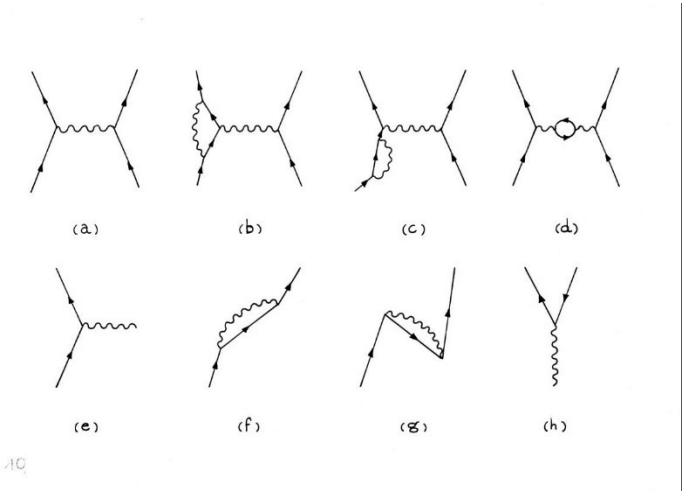


Figure 3: Basic Feynman's graphs for the electron-electron interaction.

The space axis is vertical and the time axis horizontal. An arrow represents the space-time line of a charged particle (for example an electron). A wavy line is the space-time line of a photon.

The figure (a) on top shows the direct interaction of two electrons with the exchange of one photon. In the process (b) one photon is emitted before the exchange of another photon and then it is recaptured after the exchange. In (c), the photon is emitted and recaptured before the exchange. In (d) the exchanged photon materialise itself temporarily in a electron-positron pair.

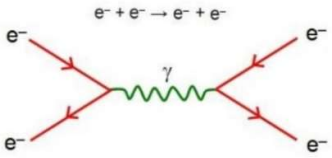


Figure 4: Basic graph for the electron-electron interaction.

One interaction decomposes itself into a sum of diagrams more and more complex. Each diagram is associated to a transition probability which becomes smaller and smaller with the complexity of the graph.

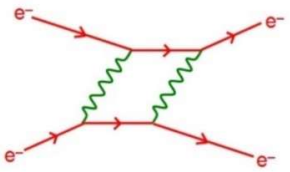


Figure 5: Graph of superior order with the exchange of two photons.

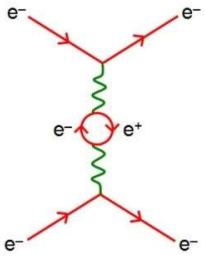


Figure 6: Graph of superior order for the electron-electron interaction. The photon exchanged materialises itself temporarily into an electron and a positron.

Let us come back to the atomic structure. Electrons are strongly attracted by the positive nucleus, and it is why they stay more or less confined in a restricted space around it. The electrons, being of same charge, repel themselves violently but this poses not too big a problem because the space that they occupy around the nucleus is large compared to the size of it. On the contrary, the protons of the nucleus are very close to each other and it is thus surprising that the nucleus does not explodes under the effect of the intense and repulsive electromagnetic force. This is because there exists another force always attractive and much more intense. It exerts itself indifferently between nucleons (protons and neutrons) and does not seem to depend on the electric charge. In view of its intensity, it has been called the “strong interaction”. It is able to overcompensate the electrical repulsion of protons and is thus responsible for the stability of the nucleus. Since neutrons do not participate to the electromagnetic repulsion, they contribute greatly to the cohesion of the nucleus by bringing only attractive supplementary forces. There is thus a bit more neutrons than protons in the stable nuclei.

The strong interaction results from the exchange of mesons between nucleons. Mesons are new kind of particles and are of three types: the neutral meson π^0 and the charged mesons π^+ and π^-.

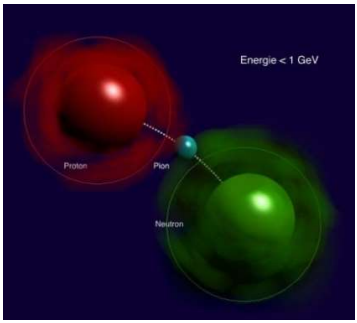
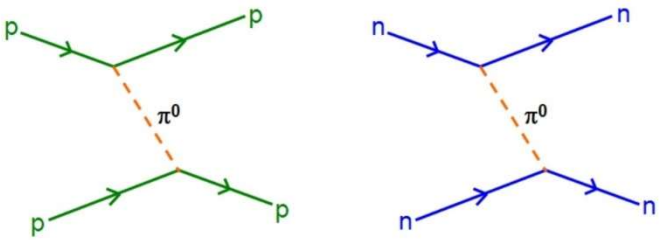


Figure 7: Strong interaction proton – neutron by exchange of pi mesons.

The Feynman graphs corresponding to the exchanges are represented below.



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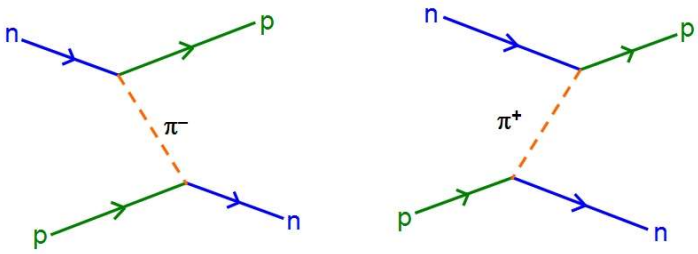
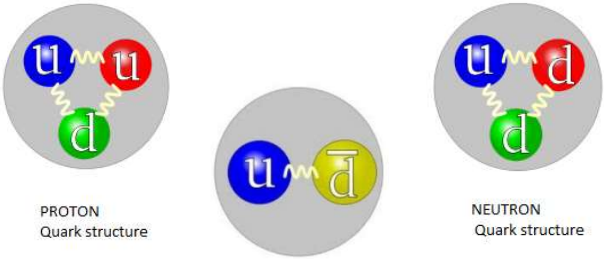


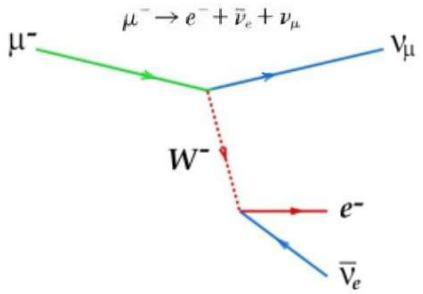
Figure 8: Feynman graphs for the proton-neutron interaction by exchange of pi mesons (pions).

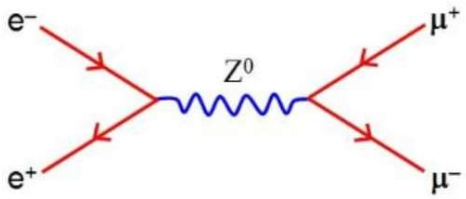
Electrons seem to be truly elementary in the sense that no one has been able to break them in smaller components. The same is true for the photon, the particle of light. But the nucleons are composed of smaller entities called quarks. Quarks interact by the exchange of gluons. Similarly, mesons represent a bound state of a quark and an antiquark.



Amongst other particles, let us cite also the muon μ^- which is a kind of heavy electron and the neutrinos which are neutral particles of very small mass. Three kinds exist: the electronic, the muonic and the tauic neutrinos. The muon disintegration happens because of another interaction: the

weak interaction. It is due to the exchange of heavy particles like the Z^0 and the $W^{\pm}$.





Particles can be arranged in families or generations with similar properties.

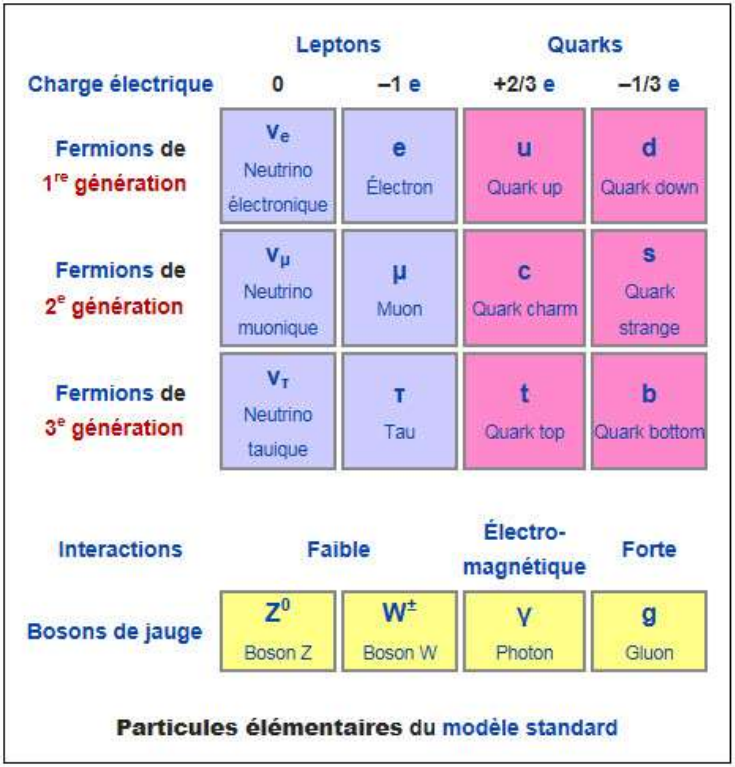


Figure 9: The three generations of elementary particles.

In the present model we will not try to describe the different quark varieties nor the neutrino types. We will present precise models only for some of the best known particles, that is; the **electron**, the **positron** and the **photon**, which is in fact sufficient to get a visual image of electrodynamics. For the quarks, neutrinos, etc… we will only furnish general indication on the way they could be distinguished. Indeed, it would not help to push the model too far at this point. As we pointed out already, the goal of this model is simply to give an idea of the direction to take in developing the theory.

Then, starting from the theory and seeking the possible solutions we will be able to describe in a precise and rigorous fashion the structure of each particle.

4 Particle physics is in crisis

But why do we search for a particle model before the theory ? Is it a scientific process ? First let us note that the scientific method I not revealed truth. It can evolve and it depends on the advancement of science: normal science or change of paradigm (Thomas Kuhn, 1962). The accepted method is very efficient for normal science but much less so to lead a change of paradigm.

Now a change of paradigm is in order. Indeed, despite some successes like the discovery of the mediating bosons, particle physics is in a dire state. Since the end of the seventies, except for the Brout-Englert-Higgs boson discovery, almost no prediction of the theories have been confirmed by experiment.

- The vacuum energy density predicted by Quantum Electrodynamics is 10^{120} times larger than the observed one !
- The grand unified theories (GUT) predict the disintegration of the proton which is not observed.
- Magnetic monopoles predicted by GUT have not been observed.
- Supersymmetric partners of known particles, invoked to solve the hierarchy problem have not been observed in the Large Hadron Collider at CERN.
- String theory has not yet been able to yield observables predictions.

- Unification of gravitation and quantum theory has not been achieved yet.

In astrophysics, the results are not more encouraging :

- The rotation speeds of the galaxies are not explained by general relativity.
- The excess redshift of some objects is not explained.
- Super massive black holes have not had time to form.
- We have no satisfying explanation for dark matter and dark energy.

We will try to explore in more details each of these points to understand which are the blocking features of current theories.

4.1 Vacuum energy

One tends to forget it too often, but quantum electrodynamics already contains one crippling defect. Even after subtracting all infinities by the renormalisation procedure there remains an enormous problem which is far from solved. I want to speak of the vacuum energy also called the cosmological constant problem. Let us examine first the problem from the point of view of general relativity (GR). The equations of this theory are written:

$$G_{\mu\nu} = -\kappa T_{\mu\nu}$$

where $G_{\mu\nu} = R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R$ is the Einstein tensor and $R_{\mu\nu}$ is the curvature tensor. In the right-hand side, $T_{\mu\nu}$ is the energy-momentum tensor. The proportionality constant is $\kappa = 8\pi G/c^4$ where G is the gravitational constant and c is the speed of light. Those equations express the fact that the

curvature of space-time is everywhere proportional to the energy-momentum density.

By remembering that the divergence of the Einstein tensor is zero $\nabla_\mu G^{\mu\nu} = \kappa \nabla_\mu T^{\mu\nu} = 0$ and that the covariant derivative of the metric is also supposed to vanish ($\nabla_\mu g^{\mu\nu} = 0$), one can add a multiple of $g_{\mu\nu}$ in the left-hand side of Einstein's equation, so that it becomes

$$G_{\mu\nu} + \Lambda g_{\mu\nu} = -\kappa T_{\mu\nu}$$

where Λ is a new universal constant called the cosmological constant. By writing this one has not modified a very important property of the equation which says that that the divergence of the two members vanishes:

$$\nabla_\mu G^{\mu\nu} + \nabla_\mu g^{\mu\nu} = \kappa \nabla_\mu T^{\mu\nu} = 0$$

Notice that the term in $g_{\mu\nu}$ can be transferred in the right-hand side where it can be seen as a peculiar energy-momentum tensor :

$$\begin{aligned} G_{\mu\nu} &= -\kappa T_{\mu\nu} - \kappa \left(\frac{\Lambda}{\kappa}\right) g_{\mu\nu} \\ &= -\kappa \left[T_{\mu\nu} + \left(\frac{\Lambda c^4}{8\pi G}\right) g_{\mu\nu} \right] \end{aligned}$$

Let us understand how this tensor can be considered as the energy-momentum of the vacuum. The energy-momentum tensor of a perfect fluid is

$$T^{\mu\nu} = (\rho + p/c^2) u^\mu u^\nu - p g^{\mu\nu}$$

where ρ and p are respectively the density and pressure of the fluid. Let us imagine that a strange substance has an equation of sate such that $\rho + p/c^2 = 0$, which implies a negative pressure $p = -\rho c^2$. Its energy-momentum tensor would become

$$T^{\mu\nu} = -pg^{\mu\nu} = \rho c^2 g^{\mu\nu}$$

This term corresponds to a repulsive gravitational energy. In contrast to the terms of $T^{\mu\nu}$ related to galaxy matter or to the fossilised photon gas which diminish in a given volume with time, it remains constant despite the universe expansion. Since the term depends only on $g^{\mu\nu}$, it is a property of the vacuum itself and one can call ρc^2 the density of the vacuum energy. If one rewrite this term as a function of the cosmological constant, one finds :

$$\rho^{vac} c^2 = \frac{\Lambda c^4}{8\pi G}$$

Let us call $T^{\mu\nu} = \rho c^2 g^{\mu\nu}$ the energy-momentum of the vacuum

$$T_{\mu\nu}^{vac} = \rho^{vac} c^2 g_{\mu\nu}$$

The modified equations can then be written

$$G_{\mu\nu} = -\kappa\left[T_{\mu\nu} + T_{\mu\nu}^{vac}\right]$$

The vacuum energy density is not fixed by the standard cosmological model. But one can obtain a superior limit. Indeed, energy creates curvature and the measured curvature of space-time can provide us with a maximal cosmological constant compatible with observations. More and more constrained limits have been obtained by considering the

solar system, the galaxy and even the large scale structure of the universe. Carroll and his collaborators have found (Carroll et al (1992)) :

$$|\Lambda| < 10^{-56} cm^2$$

This limit is usually given in terms of the vacuum energy density

$$|\rho^{vac}| < 10^{-29} \frac{g}{cm^3} \sim 10^{-9} \frac{erg}{cm^3}$$

Let us examine now what quantum electrodynamics (QED) has to say about the vacuum energy.

The classical energy density of the electromagnetic field is

$$E = \frac{1}{2}(\boldsymbol{E}^2 + \boldsymbol{B}^2)$$

In field theory, the electric field $\boldsymbol{E}$ and the magnetic field $\boldsymbol{B}$ become operators $\widehat{\boldsymbol{E}}$ and $\widehat{\boldsymbol{B}}$. The hamiltonian density $\widehat{\mathcal{H}}$ Is built on the same function as in the classical theory and the energy of the vacuum state $|0\rangle$ becomes

$$\begin{aligned} E = \langle 0|\widehat{\mathcal{H}}|0\rangle &= \frac{1}{2}\langle 0| \int d^3x \left(\widehat{\boldsymbol{E}}^2 + \widehat{\boldsymbol{B}}^2\right)|0\rangle \\ &= \delta^3(0) \int d^3k \frac{1}{2}\hbar\omega_k \end{aligned}$$

The last result doubly diverges. First there is the function $\delta^3(\mathbf{0})$ which has a peak at $\boldsymbol{k} = \mathbf{0}$. Then there is the integral on all oscillation modes. This integral can be made finite by introducing a cutt-off at the maximum frequency that this theory can describe $\omega_{max} = c|\boldsymbol{k}_{max}|$. To reduce the δ

function, one supposes that the field is contained in a finite volume V and one has :

$$\delta^3(\boldsymbol{k}) = \frac{1}{(2\pi)^3}\int d^3x\ e^{ikx}$$

$$\delta^3(\boldsymbol{k}\to\mathbf{0}) \ \ \to \ \ \frac{V}{8\pi^3}$$

$$\rho^{vac} = \frac{E}{V} = \frac{1}{V}\sum_{\boldsymbol{k}}\frac{1}{2}\hbar\omega_k \approx \frac{\hbar}{2\pi^2c^3}\int_0^{\omega_{max}}\omega^3 d\omega$$
$$= \frac{\hbar}{8\pi^2c^3}\omega_{max}^4$$

The sum is performed on the normal modes of the field that are compatibles with the limit conditions imposed on the surface of the box of volume V. Then the final result is obtained by taking the limit $V \to \infty$.

The difficulty comes from the evaluation of the maximal energy to consider $E_{max} = \hbar\omega_{max}$. If one takes $E_{max} \sim 100GeV$ as the energy at which weak interaction becomes as intense as the electromagnetic interaction, one finds

$$\rho^{vac} \sim 10^{46}\, erg/cm^3$$

By comparison with the maximal value of $10^{-9}\frac{erg}{cm^3}$ allowed by the astrophysical experiments it gives an error of the order of 55 powers of ten ! But if one estimates that the correct cut-off in energy is even bigger and extends to the unification energy of Planck, $E_{max} \sim 10^{19}GeV$, the problem is even more acute. Indeed, one has in this case

$$\rho^{vac} \sim 10^{114}\, erg/cm^3$$

which is about 120 order of magnitudes larger than the experimental limit.

4.2 The proton disintegration

The years sixties and seventies have been very fruitful in theoretical and experimental successes. After the invention of quantum electrodynamics Steven Weinberg and Abdus Salam have shown in 1967 how the weak and electromagnetic interactions could be unified in one single electroweak interaction. It predicted the existence of three massive mediators of weak interaction, the W^+ , the W^- and the Z^0. These three particles have been observed and they are effectively extremely massive. The electroweak theory is a gauge theory and the trick used to explain how the mediators can be massive is the spontaneous breakdown of symmetry.

At the beginning of the seventies, the gauge principle has been able to explain the strong interaction by a theory called *Quantum Chromodynamics* or QCD. This theory has been submitted to rigorous experimental testing which has confirmed it. What has been called the "standard model" of particles is built from electroweak unification and QCD.

Three forces could now be described in terms of gauge theories. The weak force and the electromagnetic force were already unified. It seemed thus clear that they could be integrated with the strong force in a single formalism. But the idea of this great unification was to find a new symmetry which would include the quarks and the leptons in the same super-multiplets. Only one type of particle would remain with a single type of gauge field.

The gauge group of the electroweak theory was SU(2) x U(1), and the one of QCD was SU(3). One thus had to find a larger group which could include all particles and cover the group SU(3) x SU(2) x U(1). The first "grand unified theory" or GUT used the group SU(5) depending on 5 complex variables. 3 variables came from QCD and 2 variables from the electroweak symmetry. Not only did GUT SU(5) justify all predictions of the standard model but it also produced its ownn prediction. In SU(5), quarks, electrons and neutrinos are different manifestations of the same type of particle. There exists thus a process which converts a quark into electrons plus neutrinos. It is a kind of disintegration. A proton which would contain this quark would not be stable. The disintegration rate was predicted to be of 10^{-33} per year.

Expensive experiments were conducted to verify the proton instability, but none gave a positive response in more than 30 years. The proton does not disintegrate. Or at least it does not disintegrate at the predicted rate.

4.3 Magnetic monopoles

Another prediction results from the fact that Maxwell's equations

$$\nabla \cdot E = \rho/\varepsilon_0$$
$$\nabla \cdot B = 0$$
$$\nabla \times E = -\frac{\partial B}{\partial t}$$
$$\nabla \times B = \mu_0 \epsilon_0 \frac{\partial E}{\partial t} + \mu_0 j$$

are not perfectly symmetrical. Indeed, the equation $\nabla \cdot B = 0$ indicates that there is no magnetic charge analogous to the electric charge ρ. Similarly, there is no magnetic current analogous to the electric current j.

A magnet is in effect a dipole which is due to the circulation of closed microscopic circuits. These currents define a surface which has two sides. One side is called the north pole and the other one the south pole. If one breaks a magnet to try to isolate a pole, a dipole forms itself again automatically at the position of the break.

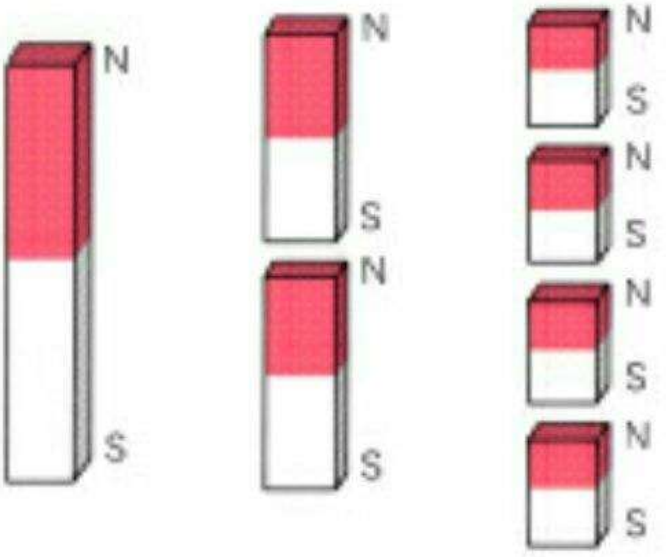


Figure 10: When a magnet is broken (magnetic dipole), there appears a north and a south pole on both sides of the break. And this happens whatever the number of breaks. This implies that one cannot isolate a north or a south pole (no monopole can be formed).

It is Paul Dirac who in 1931 showed that the introduction of elementary magnetic charges in the quantised version of Maxwell's equations was not only possible but that it implied automatically the quantisation of the electric charge. If a magnetic monopole exists then its magnetic charge must be a multiple of a quantity determined by the unit of electric charge (the electron charge).

The new extended Maxwell's equations then would become

$$\nabla \cdot E = \rho_e/\varepsilon_0$$
$$\nabla \cdot B = \rho_m \mu_0$$
$$\nabla \times E = -\frac{\partial B}{\partial t} - \mu_0 j_m$$
$$\nabla \times B = \mu_0 \epsilon_0 \frac{\partial E}{\partial t} + \mu_0 j_e$$

Where ρ_m is the density of magnetic charge and j_m is the magnetic current.

Many experiments were devised to try to create monopoles in particle accelerators or to detect them in the cosmic rays and they all failed. At the beginning of the seventies, 't Hooft and Polyakov were able to prove that the equivalent of the Dirac monopole should appear in the yang-Mills theories using the principle of spontaneous symmetry breakdown, and then notably in GUT. Monopoles of 't Hooft and Polyakov have such an enormous mass, of the order of 10^{16} times of the proton mass, that they cannot be created in the accelerators. Nonetheless they could have been produced during the Big Bang and relics have been searched in lunar rocks. Several scientists have tried to estimate the production rate of magnetic monopoles. To the great surprise of theoreticians, the calculated abundances were extremely large. One of this calculation showed that they could be as

numerous as the atoms in the universe ! But there can only be one monopole per 10^{16} atoms. The standard response to this question is that the inflationist period of the big-bang by increasing enormously the dimensions of space has automatically decreased the volume density of primordial monopoles. And finally, the detection experiments have always proved negative.

4.4 Supersymmetry

At the beginning of the seventies another direction of research called supersymmetry was taking form in the works of Russian physicists Likhtman and Golfand in 1971 and Akulov and Volkov in 1972. An independent version was conceived by Wess and Zumino in 1973. This idea also concerned the search for a symmetry which could assemble the parts of the standard model that seemed disparate. After the electroweak unification and QCD particle physics was separated into two entities: on one side the particles and on the other side the forces. In each case the forces were mediated by one or several particles, called intermediary bosons. Why bosons, because the carry a spin with integer value. Other particles, with half integer spin, are called fermions (so, the photon de spin 1 is the mediator of the electromagnetic interaction between electrons which have spin ½). With the idea of relating particles and forces, supersymmetry proposed to link fermions and bosons.

Consequently, if a quantum field theory is super-symmetric then for each boson there must exist a fermion whose spin must differ by ½ with respect to the spin of the boson. These particles related by supersymmetry are called super-partners.

In its original form, super-partners have the same mass. So the super-partner of the electron, the super-electron or selectron, must be a boson of the same mass as the electron, and it should have been seen in accelerators.

It can be supposed that supersymmetry is spontaneously broken. In this case the selectron can become much more massive than the electron. So massive that it would not yet have been observed. But it must be understood that the supersymmetric hypothesis entails the existence of a great number of particles, none of which having yet been seen.

After years of intense work, it appeared that the theory could not be quantised. Numerous quantities remained infinite. The theory was not renormalisable.

4.5 String theory is not verifiable

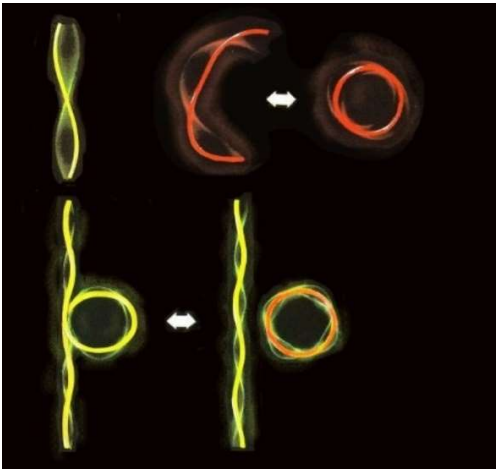
About the end of the sixties, when QCD had not yet been developed, many questions remained about the strong interaction between quarks which had been explored experimentally. Let us consider in particular the system with three quarks which constitutes the proton. If one pulls two quarks apart a restoring force appears, and what is truly special is that the force increases with the distance, as if the gluon system between quarks behaved like a spring. On the contrary, when the three quarks are close to each other they nearly move as free particles. Moreover, it is impossible to extract an isolated quark.

In 1968 the young physicist Gabriele Veneziano worked at CERN on strong interaction. For several years he reflected on peculiarities of these interactions and he searched for a formula to describe the probability that two particles collide and diffuse at different angles. Suddenly he realised that the beta function

of Euler allowed to represent the characteristics of the interaction in a very compact way.

But one had to wait 1970 for Yoichiro Nambu of Chicago university, Holger Nielsen of the Niels Bohr institute and Leonard Susskind of Stanford university to discover independently the physical meaning of the Veneziano formula. Their interpretation was that particles had to be seen as little unidimensional vibrating which exchanged energy by collision. The various vibration states of the string correspond to different particles. So started string theory.

In the string model particles are extended objects. They are little string moving in a vacuum of ten dimensions. Each particle is characterised by the vibration mode of the string. Strings can be open or closed. A closed string can be exchanged by two open string.



But string theory presents many inconveniences which have been discussed in the books of Peter Woit (2006) and Lee Smolin (2006). In addition to being excessively complex mathematically speaking it is based on a rather naïve physical model.

It is not clear how to compactify some dimensions to go from 10 dimensions (or 11) to 4. Moreover, there are still no verifiable experimental predictions.

As a theory of the strong interaction, string theory was soon supplanted by QCD of the standard model. But that does not mean that it was wrong. In some circumstances it gave a correct view of the strong interaction. The force between two quarks increases with distance as we have already seen, then it attains a stage where it remains constant whatever the distance. The vision in terms of string is correct in the region of increase with distance.

In the years that followed two very reasonable principles were imposed on string theory: that it should be compatible with relativity and quantum theory. It was found that it could happen only in a world with 25 dimensions of space. In addition, it was found that it should have a tachyon – a particle that goes faster than light. Finally the theory was not able to describe fermions, only bosons. And this was a fundamental problem for quarks which are fermions. Three of the four problems were solved by Pierre Ramond who proposed a new symmetry between bosons and fermions. He invented supersymmetry.

The new super-symmetric theory (superstring) included the fermions. It did not have a tachyon and it reduced to 9 spatial dimensions (and one dimension of time). In addition, it was compatible with quantum theory and relativity.

In the mean time, André Neveu and John Schwarz had invented their own version of the theory which lived in a space of 10 dimensions and which had no tachyons.

There remained the problem of particles without mass. First there was the photon, the mediator of the electromagnetic force. Many physicists also postulate the existence of the graviton, a particle of zero mass and spin 2 supposed to propagate the gravitational force, but never observed until now.

Figure 11: Michael Green and John Schwarz, founders of string theory.

Joel Scherk and John Schwarz showed that one of the particle predicted by string theory could be the graviton. They thus proposed to view superstring theory as much more than a theory of strong interaction, but as a grand unification theory able to encompass the three forces plus gravitation.

In 1984 a calculation by John Schwarz and Michael Green seemed to imply that superstring theory was at the same time finite and consistent. More precisely they showed that it did not present what was called an anomaly, at least in a space of 10 dimensions.

This feat was called the “first string revolution” because it opened the possibility that string theory was effectively the

searched for unified theory. From this day an army of physicists started searching in this direction. The superstring theory seemed to be the quantum gravity theory expected.

During the 4 or 5 following years advances were numerous and the interest for the theory increased until it attained levels of confidence that were inconceivable for scientists. For example some did not hesit to declare that « string theory is the only game in town ».

But the situation was not as good as expected. One discovered soon that there were in fact 5 consistent string theories at 10 dimensions. For a theory that presented itself as a unified theory, this did not augur well. On another side, one could have hoped that the values of the 19 constants of the standard model could be fixed by the only constant of string theory. But it was not the case. In order to hide the six extra dimensions, one must fold them (a process called compactification) so that they become so small that they are no more measurable. The problem is that there exist many ways to do that, which led to too many solutions. It entailed also instability problems, with dimensions that exploded while others collapsed into a singularity.

The second string revolution happened in 1995 when Edward Witten published a paper proving that the 5 string theories were related by duality relations.

Figure 12: Edward Witten

In the most favourable case, it could be that the 5 theories are different versions of a single theory.

But if the duality relations are not exact, one would have 5 different theories. Even in the most favourable case, the number of possible solutions remains enormous. As a consequence, it is impossible to make precise predictions about the numerical values of the standard model constants for example. String theory cannot thus be tested and it produces no verifiable experimental predictions.

5 Astrophysics is in crisis

Astrophysics is in a dire state too. Many questions remain without answer despite a great number of experimental and theoretical works.

5.1 Dark matter

When studying the galaxies of the Coma cluster, Fred Zwicky had noticed, as soon as 1913 that galaxies had too much average speed with respect to their masses. This could indicate either a defect of the Newtonian theory or a mass effect in the cluster. Zwicky called this the « dark matter ». All possible sources of this dark matter have been evoked, without success.

During his thesis on spiral galaxies Vera Rubin studied their rotation courses. Naively she expected to observe Keplerian trajectories of stars, with the corresponding rotation speed. But it was not the case. After a rapid increment starting from the centre, the rotation curves remained constants as far as they could be measured and the keplerian decrease is not observed. Again this could indicate either an error in the Newtonian gravitation or a mass defect in galaxies.
This last approach has been tried by considering a spherical halo of dark matter around the galaxies. The combination with the disk mass and the core mass must reproduce the rotation speed curve. The problem was that each galaxy was a particular case necessitating different values to realise the best fit. For each galaxy one must add a variable quantity of halo mass and the radial distribution must be adapted to fit the profile of the rotation curve.

Alternatively, it is maybe a modification of gravity that must be envisaged. A proposal has been produced by Mordecai Milgrom in 1983 under the name MOND (Modified Newtonian Dynamics). It postulates that the dynamics changes below a peculiar value of the acceleration $\boldsymbol{a}_0$. The regime where the rotation speed becomes constant happens when acceleration passes below $\boldsymbol{a}_0$. The agreement with experiment is excellent and it is realised with a single

parameter $\boldsymbol{a}_0$, even though the visible mass distribution differs sometimes a lot from one galaxy to the other.

In 2004, Jacob Bekenstein managed to put MOND in lagrangian form. It is an extension of Einstein general relativity with a tensorial and a scalar field.

However, the MOND approach has difficulties when applied to clusters of galaxies. Indeed, in galaxies, the missing mass problem is more acute for large values of the radius, that is; at the periphery of galaxies. In contrast, for clusters, it is where the density of galaxies is the largest, at the centre of clusters, that the mass default is most felt. If one supposes that part of the dark matter is composed of neutrinos, it is possible to completely explain the dynamics of galaxies.

5.2 The excess redshift

Let us consider a light source of wavelength λ_0 at point *P*. Let us move this source at speed *v* in a given direction. The light appears to take a wavelength λ different from λ_0 . It is the Doppler effect. When the source moves away at speed *v*, the observed wavelength increases and the light appears to be shifted to the red (redshifted). This shift is measured by :

$$z = \frac{\lambda - \lambda_0}{\lambda_0}$$

A source that would approach would have a blue shift.

One could show that $\lambda = \left(1 + \frac{v}{c}\right)\lambda_0$, where c is the speed of light and *v* the source speed. It follows that

$$\lambda - \lambda_0 = \frac{v}{c}\lambda_0$$

and

$$z = \frac{v}{c}$$

The redshift is the source speed expressed in unit of c.

More complex calculations allow to relate the redshift with the current distance of the source l : one finds

$$z = H_0 l + \frac{1}{2}(1 + q_0)(H_0 l)^2$$

Where H_0 is the Hubble constant which measures the expansion rate of the Universe. The best current value is $H_0 = 72{,}5\ kms^{-1}(Mpc)^{-1}$. The parameter q_0 measures the expansion acceleration. For $q_0 = -1$ one falls back on Hubble's law

$$z \cong H_0 l$$

This law is one pillar of modern science. It shows that all galaxies fly away from us with a speed proportional to distance. The distance is also proportional to the redshift as the law above shows. Nearly all measures of distance are currently based on this principle. However, in the sixties a few physicists were opposed to this dogma.

In 1962 a new class of astronomical objects was discovered. They were called quasars (quasi stars) because they resemble stars on photographic plates. But their spectrum was much closer to that of highly excited galaxies, and it was strongly redshifted.

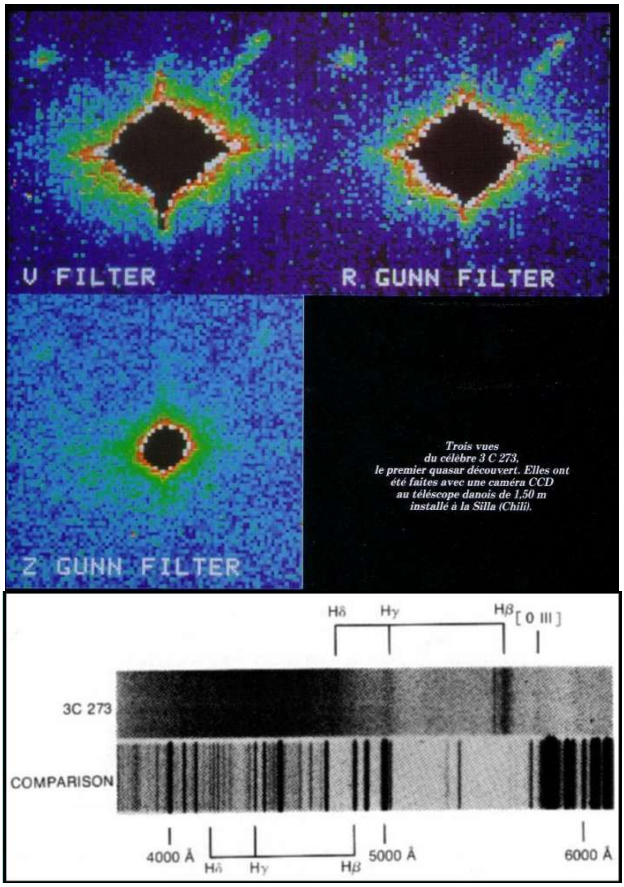


Figure 13: Above one finds the spectrum of 3C 273 together with a reference spectrum. One notices for example that all the hydrogen lines are strongly shifted towards the red, by the same quantity.

Following the cosmological credo, the distance of a luminous source is always proportional to its redshift, as Hubble's law shows. Quasars being highly redshifted must be very distant, and thus they must be very large and

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extremely luminous so that they can be seen as brightly at these colossal distances.

However, as soon as 1963, a few dissidents criticise the cosmological interpretation: James Terrel and the gang of 4 (Halton Arp, Geoffrey Burbidge, Fred Hoyle and Jyant Narlikar) claim that quasars are closer than their redshift seem to indicate and that they are emitted by the nuclei of galaxies. The excess redshift (non cosmological) would be due to an unknown mechanism.

Figure 14: Halton Arp

Following these allegations, Arp has been destroyed by the establishment. He was revoked from two well known observatories where he worked: Palomar in 1983 and Las

Campanas in 1984. Today, nobody can observe the objects that he discovered ! Luckily, he had enough time to accumulate many evidences in favour of the ejection hypothesis.

In his book (Arp, 1987), he notes several cases of galaxies having in their close neighbourhood 1, or2, or even 3 quasars. The proponents of the cosmological hypothesis claim that these quasars are in fact far behind the galaxies. Considering the scarcity of quasars, the probability for that to happen by chance is extremely weak.

Figure 15: From top to bottom, Jayant Narlikar, Sir Fred Hoyle, Geoffrey Burbidge.

Then he indicates cases of galaxies visibly connected to objects of very different redshift. It is the case of NGC 4319 with MK205 and the quasar Parkes 1327-206 linked to a galaxy which possesses a jet.

Finally, he cites the case of two galaxies NGC 1097 and NGC 520 which are surrounded by quasars in a distribution which evokes an ejection cone.

For the majority of astronomers the redshift controversy has been definitively decided when Todd Boroson and John Beverly Oke showed at the beginning of the eighties that the halo enveloping some quasars is in effect coming from the light of stars pertaining to the host galaxy of the quasar, and that these host galaxies have the redshift of the quasar.

But finally, it is the following object that gives the undeniable proof that galaxies have non cosmological components.

It is the galaxy NGC 7603 discovered by Arp and connected by a luminous filament to another galaxy. The two galaxies have different redshift. But what is even more surprising are two compact objects that lie in the filament. These two also have very different redshifts.

We thus have 4 objects of very different redshift linked by a luminous bridge. I do not think that there could exist a better proof that the redshift can have a non cosmological component. Yet, nothing changed. The great majority of astronomers refuse to face this reality.

The most plausible explanation is that there are two classes of objects. In the first class one has large galaxies whose nucleus is highly excited and that are called quasars. A good

part of their redshift is probably cosmological, which places them at large distances. In the second class, the objects have spectra very similar to those of quasars. But they are small and compact and they are ejected by the nuclei of galaxies and quasars. A great part of their redshift is of non cosmological origin, what we will call the excess redshift. I propose to name these objects the CERO's for Compact Excess Redshift Objects. In particular, the two objects in the luminous filament of NGC 7603 are good candidates for CERO's.

5.3 Formation of supermassive black holes

A truly exceptional quasar has been discovered in the Bouvier constellation, at a distance of about 13,1 billion light years, at the enormous redshift of 7,54. Named ULAS J1342+0928, its gigantic mass is of 800 million times that of our sun. But this quasar is observed completely constituted at no more than 690 million years after the Big Bang.

Such a monster is not unique. The previous quasar which held the record of the most distant quasar was ULAS J1120+0641, discovered in 2011 in the Leo constellation. With a redshift slightly above 7 the quasar appears as it was 770 million years after the big bang.

How can we explain the formation of such monsters in such a small time ? Some researchers believe that these supermassive black holes were smaller in the first days of the universe. With time they accreted gas and dust and merged to give the monsters that we observe today. But the details of this model remain rather vague.

A minority of astronomers think that these black holes are evidence that the universe has known a Big Bounce in place of a Big Bang, with black hole already formed before the Big Bounce.

It is believed that there are no more than 20 or 100 quasars as bright in the visible universe. They are actively searched to try and solve the mystery of their rapid growth.

5.4 Dark energy

An important question of experimental cosmology is to determine if the universe expansion is accelerated or decelerated. In other terms, one would like to fix the q_0 constant presented above.

Saul Perlmutter and Adam Riess, have studied the luminosity curve emitted by the supernovae explosions of type SN1A in close galaxies.

These supernovae have an absolute luminosity which is nearly constant. Let L_0 be this luminosity, and L the apparent luminosity as seen from the earth.

One has $L = L_0/l^2$, where l is the distance from the earth to the source. As L_0 is not a perfect constant these supernovae are not really standard candles. But they nevertheless constitute rather good distance indicators. And there is no need to know their redshifts to be able to determine their distance. Indeed, knowing L_0 and measuring L, one deducts l. Measuring next z and introducing it in the formula

$$z = H_0 l + \frac{1}{2}(1 + q_0)(H_0 l)^2$$

one can compute q_0.

In 1998, experiments were sufficiently precise and numerous to be able that our universe was in accelerated expansion, which suggested to reintroduce the cosmological constant term in the Einstein's equations.

Today, this cosmological constant dominates the observable universe by representing about 73% of the energy density, for a volume of space whose size is of the order of several million light years.

Because it manifests itself under the form of a repulsive force between clusters, this mysterious energy has been dubbed "dark energy".

Nobody knows what is the nature of this energy even if the accelerated expansion seem to be a well established fact. Several theoretical explanations have been proposed. One has even tried to get rid of it. The accelerated expansion poses formidable problems such as the vacuum energy and it constitutes a major challenge for theoreticians. Moreover it could be an open window on the physics beyond the standard model, such as supergravity.

6 A new model is necessary

Regarding the number of unsolved problems, we are presumably at the border of a change of paradigm. And the method used to pass it, standard science, is inefficient in these circumstances.

Let us consider the way to proceed of academical physics. The standard method gives a very small weight to intuition.

Typically, the standard physicist starts from known equations such as general relativity or quantum field theory. He systematically investigates all the possible extensions of the formalism such as adding supplementary dimensions, additional symmetries or other geometrical degrees of freedom. He will so explore the whole space of possible mathematical formulations. This method can eventually converge but the process of searching solutions and comparison with experiments will take decades, maybe centuries.

I had no more a priori concerning the method or the physical principles to conserve. I was ready to put everything into question, including the research process itself because it seemed to me that the one in vogue at the moment did not merit an excessive respect. For me, a good method is a method that works. I do not care if it does not respect the established guidelines as long as it furnishes results rapidly. I estimated then that I should not hesitate to explore variants of the current method. In fact, one can judge the quality of the process only as its capacity to produce a sensible theory.

I agree that the ultimate goal of physics is to produce a mathematical theory in accordance with the experimental facts. But I simply wonder what is the most efficient way to achieve this.

My reasoning is issued from the principle that it is much easier to find the solution of a problem when some information is known about the solution.

I was convinced that if a model could be found, even an imprecise one, that would furnish at least a qualitative explanation of experimental facts it would provide a precious guide about the type of theory which could describe

it. It is not much considering the effort to furnish but in this domain any help is precious considering the difficulty of the enterprise. Once started the process meets then very naturally the standard method: a theory is formulated on this basis. All possible solutions are searched and one verifies that they all correspond to known particles. In addition, it must be checked that there are no more solutions without correspondence to known particles. So long as the adequation between predictions of the theory and physical reality is not perfect, one modifies either the model or the theory or both until they correspond to each other.

Before formulating our model we will review the most important models that have been presented in the past.

6.1 The Greeks

Our first step will be to visit the Greek presocratic philosophers. The development of Greek physics was lightning swift, by contrast with the 3000 years of very slow progression with Mesopotamians and Egyptians. In less than 500 years immense progresses were accomplished by philosophers like Thales, Anaximander, Anaximenes, Anaxagoras, Leucippus, Democritus, Pythagoras ...

It seems that the large difference between these performances can be explained by the fact that the Greeks tried to understand the phenomena in a natural way (not related to the existence of an hypothetical god) when the previous civilisations were content to calculate some physical effects with a religious goal, or administrative or commercial. Already the presocratic Greeks ask the good questions about the nature of the vacuum, of matter, …

Thales (624-546 BCE) founded the Milet school, on the west coast of Anatolia. He sustained that water was the source of all things. Then came Anaximander (610-546 BCE), second director of the school. He had Anaximenes and maybe Pythagoras as pupil. Anaximander notice that water, first principle of Thales, cannot describe all oppositions in nature (water cannot describe dry objects), and thus cannot serve as primitive substance to all things existing. No other candidates are satisfying. He postulates the existence of an "apeiron", a limitless substance, which is at the origin of all things, and which although not directly sensitive to us, could explain oppositions like warm and cold, dry and wet, … Would it be the ancestor of the aether of the 19th century.

Finally, his young contemporary Anaximenes (585-525 BCE), considered air as first principle, with density variations giving birth to fire, wind, clouds, water and earth.

Figure 16: Position de Miletus sur la carte de Grèce.

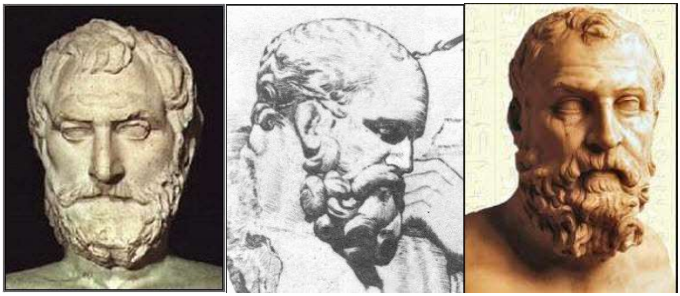

Figure 17: from left to right, Thales, Anaximander and Anaximenes.

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So the Milet school conceives matter as coming from a first principle filling all the vacuum (a plenum) and whose density variations produce the observed states.

An opposite school developed later with Leucippus and his pupil Democritus of Abdera (460-370 BC). It saw matter as composed of atoms, small indivisible and imperishable objects, distinguishable by their forms. They move in the infinite void, collide and amalgamate to give other objects differing by their variety, their number, their size and the forms of the atoms which compose them.

These two visions of a plenum with variable density and of a vacuum in which atoms move will constantly oppose in the following centuries. Today, the atomistic vision seems to have definitively won, but nevertheless the idea of isolated particles in a perfect void poses many problems.

Firstly, how to imagine that a wave such as the electromagnetic wave, which is now well established, could propagate in the vacuum without any support ?

How to explain that passing from the vacuum to the particle, the void density goes suddenly from zero to infinity ? If the particle cannot be divided it has no parts. It should then be infinitely rigid ? And if it is like a point, what permits one to distinguish a particle from another ? This vision of rigid particles separated by a perfect vacuum cannot be something else than a mathematical idealisation.

These questions existed already in antiquity and still exist today. In the course of history the various particle models will oscillate between these two extreme visions: the plenum filled with a fluid or the vacuum in which material particles move. When one model imposes itself, the other one

declines. It would be maybe more judicious to attempt a synthesis. It is what we will try in the present work.

6.2 The vortex models

Some fragments of the Greek literature seem to indicate that Anaximander had built a cosmology based on an analogy with vertices. This idea had been developed by Anaxagoras who thought that the world had been created by the rotative moment of a spiral. The idea of vortices is persistent and it will reappear several times in the various model that we will examine.

The idea of vertices is persistent and it will reappear several times in the various models that we will study. These objects fascinate because they are stable structures in fluids. They thus realise in some way the synthesis between two world visions : relatively stable structures can exist in a fluid medium which fills all space.

Besides, vortex structures can interact. Let us consider a vortex 1. It is characterised by a constant circulation Γ_1 . The circulation is the integral of the fluid speed around a closed contour which turns one time around the axis. Let us take as contour a circle of radius r. One finds $\Gamma_1 = 2\pi r v$. Conversely, vortex 1 at distance r of the centre of vortex 2, Induces on it a speed $v_2 = \Gamma_1/2\pi r$. Similarly, the vortex 2 of circulation Γ_2 induces a speed $v_1 = \Gamma_2/2\pi r$ on vortex 1. If the vertices turn in the same sense, the induced speeds tend to move the vertices around each other on a common circle.

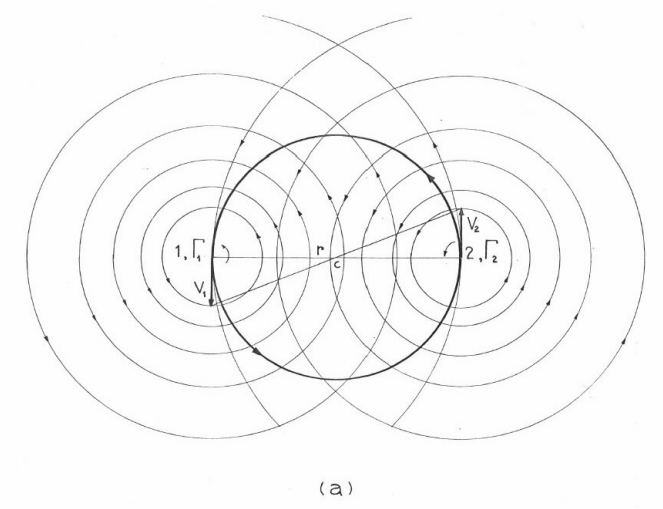

Figure 18: Induced speeds by vertices of the same sense. The vertices move around each other on the bold circle.

For vertices of opposite sense, the result of the interaction is a translation in a common direction.

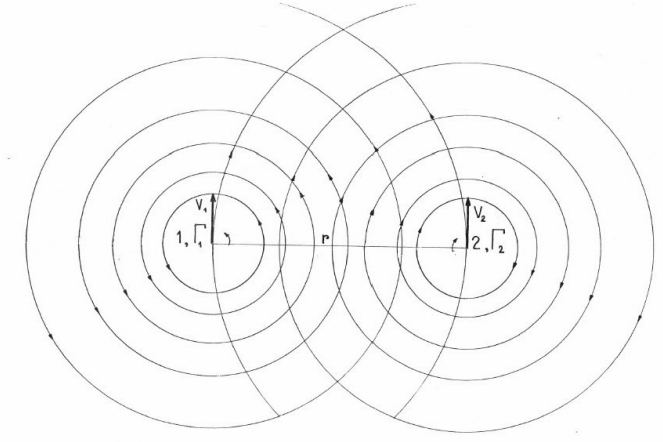

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Figure 19: Induced speeds of opposite sense vertices. The vertices move parallelly.

A vortex possesses at least one vortex line: it is the symmetry axis around which the fluid particle move. These lines can exist in great number. In the neighbourhood of a vortex line, the fluid particles possess some rotational: they are rotating on themselves and around the vortex line. The fluid wraps itself as a helix around the vortex line. The latter can accumulate to form a surface with axial symmetry. One speaks then of a vortex tube. The tube can close up to form a vortex ring. The latter has an absolutely remarkable property. Each section perpendicular at the symmetry axis induces a speed on all other sections. It is called a self-interaction. The result is that the vortex ring propagates by this self-interaction at constant speed V in a direction parallel to the big axis.

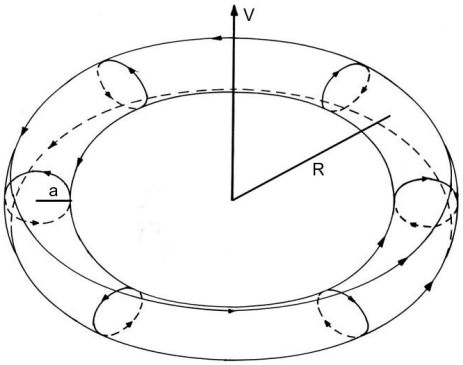

Figure 20: The vortex ring moves by self-interaction at speed V perpendicular to the plane of the ring.

This extraordinary property will be exploited later in our model. We can see below a splendid example o vortex ring above Etna.

Others are produced in water by deep see swimmers.

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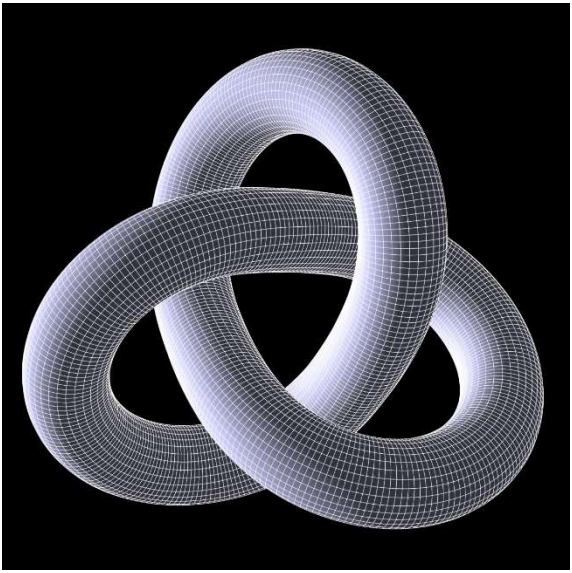
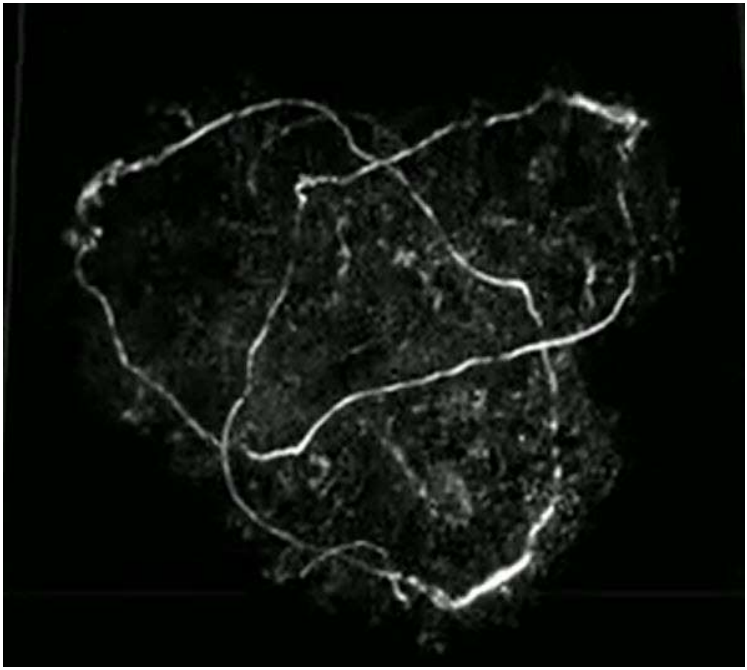
For a long time, one has been convinced, but without proof, that vortex tubes more complex than simple rings can exist in nature.

This has been finally demonstrated by Kleckner and Irvine (2013). The structure immediately after the vortex ring in complexity is the trefoil represented below.



The ingenious apparatus of Kleckner and Irvine is represented below.

The following figure shows a trefoil generated by the apparatus.



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Another very important property is reconnection. When crossing the vortex lines can cut themselves and recombine with a change in the topology. So complex structures can give way to new structures by simple contact and reconnection.

Finally, vortex structures move with the fluid itself. In other words, vortex structures always contain the same fluid elements.

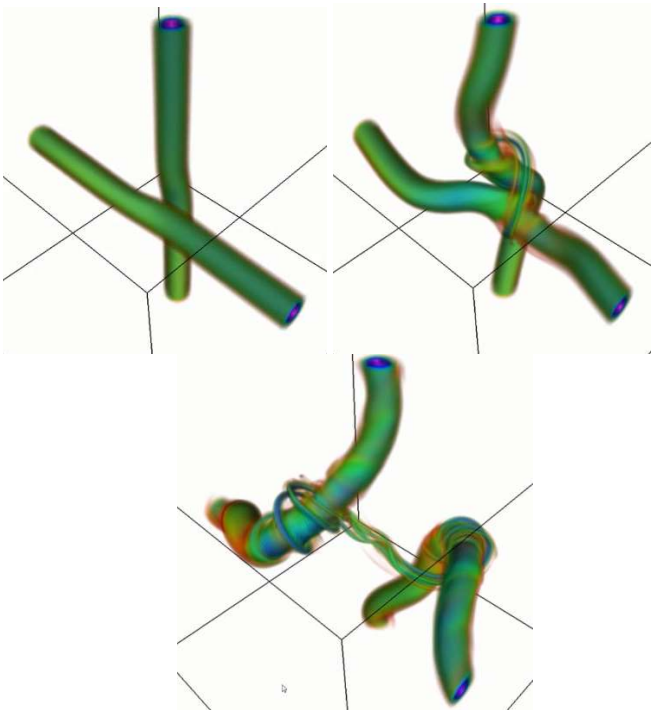


Figure 21: Crossing and reconnection for two vortex tubes.

René Descartes elaborated a celestial mechanic entirely based on vertices. For him, the planetary motions are due to large aether vertices (subtle matter composed of small

transparent globules) filling space and which carry the planets out and maintain them on their trajectories.

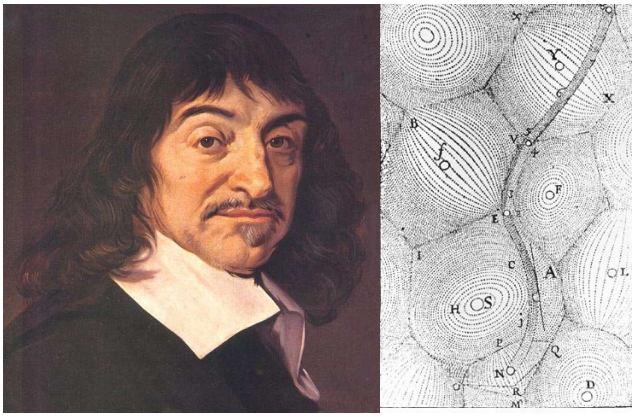


Figure 22: Descartes and vertices in aether.

This qualitative physics was able to justify the motion of planets in a mechanistic way, by altogether refuting the void existence. This same aether was supposed to transmit light in the form of pressions.

Newton destroyed this vortex theory by calculations. In his own theory planets move in the vacuum under the effect of a gravitational force.

Forces act at a distance, across the vacuum. No medium is supposed to exist for transmitting gravitation.

Although he was glad of the mathematical efficiency of his theory, Newton was not satisfied about this situation. In a letter to Richard Bentley in 1692 he wrote :

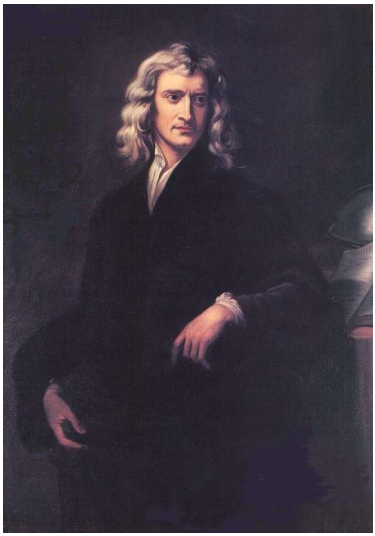


Figure 23: Isaac Newton

« That gravity be innate, inherent and essential to matter, in such a way that a body could act on another at a distance across the vacuum, without mediation of anything else, by which and through which their action and force could be communicated from one to the other is for me an absurdity which I believe nobody, having the capacity to reason in a competent way in philosophical matter, could profess »

So, in the scholium general of book III of Principia, he reintroduces a dose of aether sideways. He conceives a kind of subtle spirit which penetrates all solid bodies, adding that it is by the force and the action of this spirit that particles of these bodies attract mutually: a mechanical aether filling space and justifying the transmission of the gravitational force.

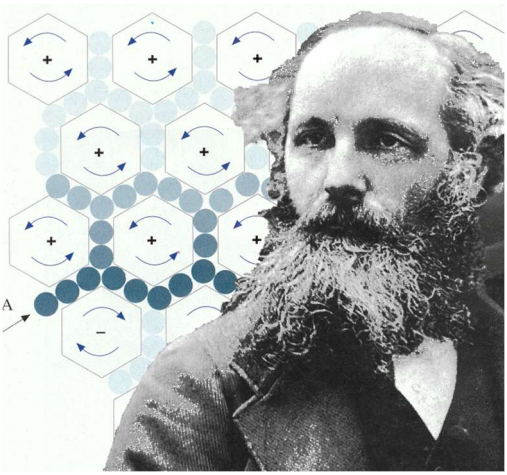
This aether mediates the gravitational force but is not submitted to it, and it seems abstracted from the principles enunciated in the Principia. Newton sustained this point of view starting from theological considerations, saying that space is the sensorium dei, a kind of god's sensorial organ, which allows him to transmit influences from one body to another. This aether always remained an underlying hypothesis, not intervening in the calculations, but with the status of a reassuring hypothesis for the coherence of this theory. For Newton, this aether was the same that transmitted light, considered as composed of corpuscles of different sizes, transmitting oscillations to the aether and so creating colours.

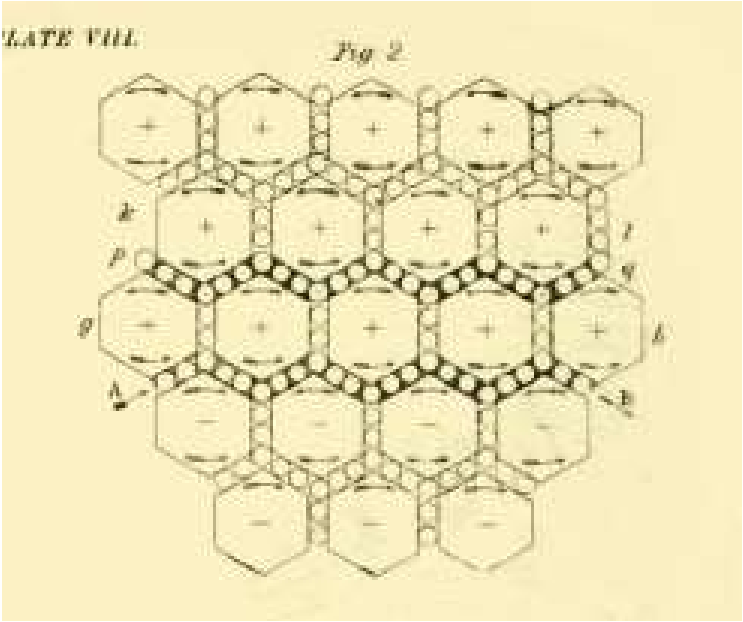
This corpuscular theory of light will be criticised by Huygens who proposed in 1678 a wave theory of light. For a long time it was rejected because of Newton's stature, until Augustin Fresnel adopted the principle of Huygen's secondary wave fronts in 1818, with which he was able to explain much easier the effects of linear propagation in the vacuum and the reflection and diffraction on solid obstacles. This resurgence of the wave theory in place of the corpuscular theory marked an important come back towards aether theories, a material medium necessary to transport luminous waves.

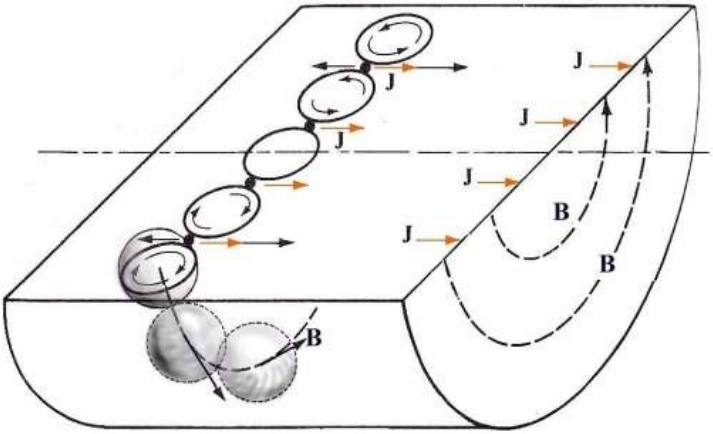
Amongst other effects, Faraday had discovered that the polarisation plane of a linearly polarised light can be set in rotation by the application of an external magnetic field aligned with the direction of light. Sir W. Thomson thought that this implied the existence of a rotational motion in the magnetised medium. However, it is clear that this rotation cannot affect the whole medium. It must be a common rotation which affects small portions of the medium, each

around its own axis. In other words, the medium must split in a number of “molecular vertices”.

Consequently, in his remarkable unification of electricity and magnetism James Clerk-Maxwell used a model of vortex in the aether, neither hydrodynamical mor mechanical.







For a conducting wire traversed by an electrical current he visualised a sea of small aether vertices rotating around the axis perpendicular to the wire section.

-

The rotation speed of the vertices increased linearly with the distance to the central axis, which reproduced the current density observed in a wire. The magnetic field was proportional to the rotation speed of vertices and directed along their rotation axis, passing from a zero value on the wire axis to a value B at the periphery. Between vertices moved beads (idle wheels ») creating an electrical current. These beads allowed adjacent vertices to roll in the same sense. In a non conducting material, the beads cannot move. All motion of them result in a deformation of the vortex cells. These distortions represent an electrical field.

Adjacent molecular vertices press against each other, due to the centrifugal force. This allowed to explain the repulsion of magnetic field lines. Maxwell identified the force exerted on a wire traversed by a current by the differential pressure in the sea of vertices.

It must be noticed however that although the molecular vortex model helped Maxwell to establish his theory, almost nothing of it remains except an historical curiosity. The whole import of Maxwell and Faraday is concentrated in the notions of electrical and magnetic field and in the equations that govern them. But I would not be surprised if below the mathematics the premises of a new model to come would hide. A much more precise and appropriate model that could not be denied so easily.

The apex of the vortex model happened in the 19th century when physicists speculated about atoms and the aether nature. Lord Kelvin, then professor in Glasgow university, proposed in 1867 a model of atom which seemed to explain several features of chemical elements.

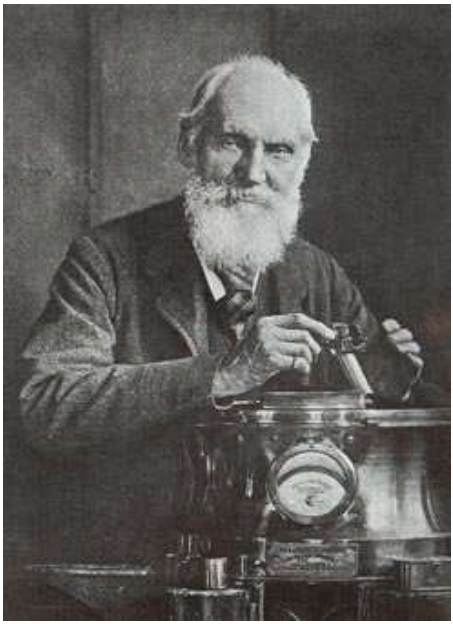


Figure 24: Lord Kelvin

He viewed atoms as vortex rings in aether. Because vortex lines are bound to the fluid, their arrangement should be stable and should thus enable the classification of atoms (elementary particles were unknown at this time). A knot in 3 dimensions is any closed ring which does not cut itself. Possible topologies of atoms should thus be all possible topologies of knots. The Scottish physicist Peter Tait attempted the classification of knots. Topologically two knots are identical if one can be continuously deformed into the other, without crossing nor tearing. The figure below shows Tait's classification.

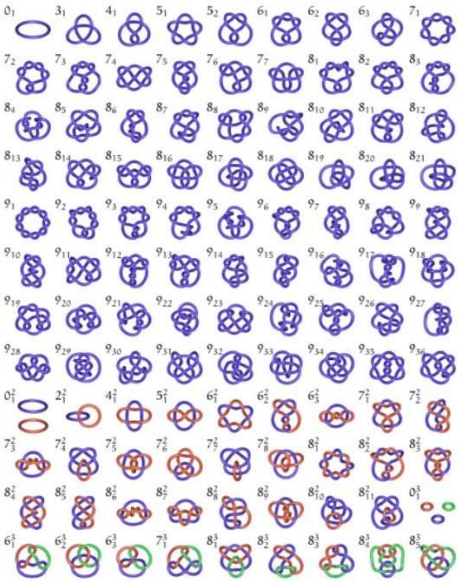
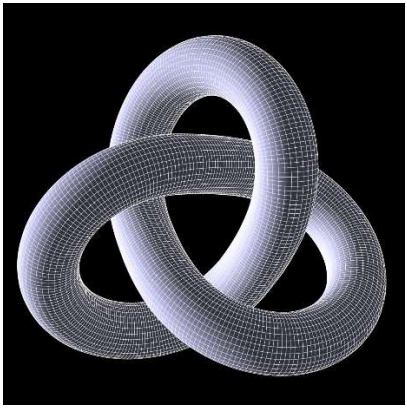


Figure 25: Classification of knots by Tait.

Directly after the simple ring comes the trefoil represented below.



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The topological stability and the variety of knots were two essential qualities which it was hoped would enable to reproduce the stability and variety of atoms.

This model knew a real success during about two decades, until it was found that only the simplest rings are stable. Today, what we know of atoms completely rules the model out. Notably, the possibility to create excited states and the emission of photons during deexcitation.

But could it be that this model still applies to particles rather than to atoms ? In his favour one can say that it contains some explanative features which are very difficult to reproduce in other models :

- Only some elementary particles are stable, in the same way that only some rings are stable.
- The spin angular momentum of particles is quantized. Similarly, it is well known that the circulation of vortex tubes is quantised, in some circumstances.
- The non inertial displacement of photons can be explained if photons are similar to a vortex ring. Indeed, a vortex ring can exist only if it moves at constant velocity due to vortex self-interaction.
- The strong interaction between quarks may be due to the restoring force in a stretched vortex tube.

In the seventies, Herbert Jehle (1971, 1972, 1975) has proposed a new version to the Kelvin vortex model, but this time applied to particles. He views particles as small magnetic flux tubes. The particle types correspond to the different topologies of the flux tubes. The classification is that of closed knots. This reconversion towards a magnetic field is probably due to the spirit of the time: in the seventies it was not allowed to speak of the aether. Yet what

approaches most closely vortex tubes in a fluid are magnetic flux tubes. This is what probably explains Jehle's choice.

However, this entails a scaling problem which renders Jehle's position inacceptable. A magnetic field is generated by a large photon ensemble which are themselves elementary particles. How could it be then that elementary particles be constituted of a macroscopic field which itself is generated by a large ensemble of elementary particles. This signals a fundamental reasoning error. Fortunately, it is possible to remediate that rather easily.

In that respect, let us note the very strong analogy between vorticity and magnetism.

Vorticity is defined by

$$\omega = \nabla \times v$$

The magnetic field is given by

$$B = \nabla \times A$$

The transport equation for vorticity is :

$$\frac{\partial \omega}{\partial t} + \nabla \times (\omega \times v) = \nu \nabla^2 \omega$$

where ν is the viscosity coefficient and $\omega = \nabla \times v$.

The transport equation for the magnetic field is :

$$\frac{\partial B}{\partial t} + \nabla \times (B \times v) = \lambda \nabla^2 B$$

Where λ is called the coefficient of magnetic diffusion.

We note the remarkable similarity between the two cases. $B = \nabla \times A$ suggest that B is the rotational of a speed, the aether speed, and then that A be that speed.

Jehle should have better considered vortex tubes in the aether, rather than magnetic flux tubes, but then he would probably not have been published. But for us particles definitely are vortex tubes in the aether. Yet we will have to explain what the aether is constituted of.

6.3 Special Relativity Theory

By several aspects the vortex model seems to oppose itself to the special relativity of Einstein.

Firstly, it postulates the existence of a medium, the aether, supporting at the same time particle structures and electromagnetic waves. But the notion of aether poses serious problems :

- Entrainment of particles by an aether wind has not been observed in the famous Michelson-Morley experiments (1881-1887).
- There is a priori no privileged referential in a relativistic universe while in a model with aether the referential in which the aether is at rest is peculiar.
- No mechanical interaction with the aether has ever been observed. In this case is it not a superfluous notion ?
- The aether should possess a very high rigidity to explain the very large propagation speed of electromagnetic waves.

- Luminous vibrations are transverse. It is not compatible with a fluid medium. In such a medium the waves should be longitudinal.

If we persevere with a hydrodynamical aether model we will have to answer all these questions very convincingly.

By establishing Special Relativity, Einstein proposes to get rid of the aether notion, with the postulate that light speed is a constant in any referential. Einstein's proposition marks a pendulum back swing towards an atomists theory of unbreakable particles in a perfect vacuum. But it is too simplistic and contains its own contradictions. For example, by postulating $c = cste$, he abandons all hope to explain the value of light speed and the photons propagation mode by an ab initio theory.

6.4 General Relativity

After the establishment of the General Relativity equations , Einstein and Rosen point out that there exists a solution of the equations for the vacuum with a curvature and a non

trivial topology. This solution establishes a bridge between two universe sheets of 3 dimensions denoted the Einstein-Rosen (ER) bridge. Einstein and Rosen (1935) propose this for a particle model as a kind of hole in the vacuum.

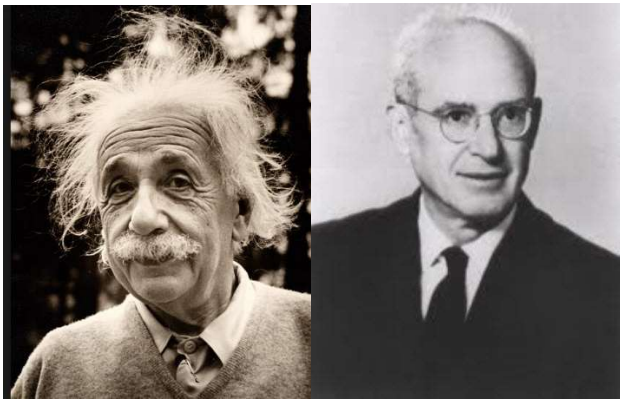
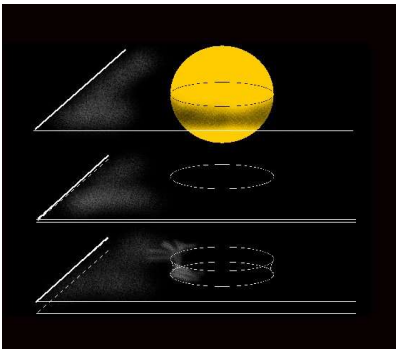
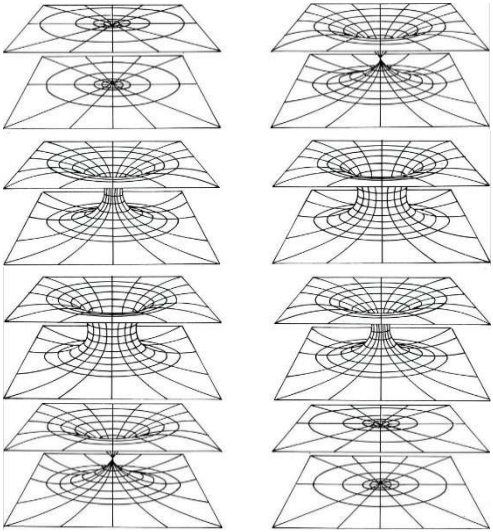


Figure 26: Albert Einstein and Nathan Rosen

To represent correctly the ER bridge, let us consider a sphere and let us imagine that each point of it belongs at the same time to the 2 universe sheets with 3 dimensions. The points of the sphere are the points of contact of the two universes. Let us then perform a cut in the sphere by a plane which passes through the sphere centre. Finally, let us part lightly the two universe sheets so obtained by adding a supplementary z dimension. One recovers so the section in the ER bridge.



Unfortunately the ER model is not stable ! It starts from an infinite curvature point at $t = -\infty$. It opens maximally at $t = 0$. And it closes up on an infinite curvature point at $t = +\infty$.



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What are the problems at the origin of the ER model ? Many physicists now estimate that Einstein's General Relativity is incomplete.

- Firstly, it presents true singularities (zones where the curvature tensor becomes infinite) which are not due to a peculiar choice of the coordinate system.
- Then it is not able to describe spin 1/2. Whence the impossibility to use it to represent the electron for example.
- It cannot reproduce rotation curves of galaxies.

Today, many physicists believe that General Relativity should incorporate new degrees of freedom (new tensorial objects) such as torsion, a tensor that describes proper rotation and thus associated with spin and vorticity, and non-metricity, a tensor related to shearing and expansion stresses.

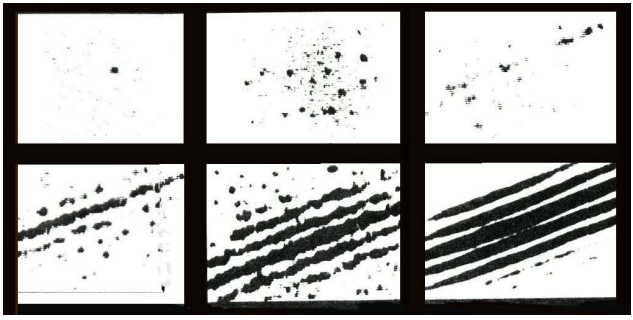
It is not unreasonable to think that the spin rotation (and so the torsion) could stabilise the black hole into a traversable "wormhole" and prevent the apparition of singularities. In other words, vorticity could forbid the closing up of the ER bridge and transform it into a traversable wormhole.

In this new theory to be built, it is possible to conceive more precisely what a particle will be mathematically. But first we need to introduce the notion of a Killing vector. It is a vector such that in a displacement along it the geometry does not change. Killing vectors thus characterise the space-time symmetries. We believe that a particle must be determined by two Killing vectors. The first one is time-like, and it expresses that fact that the particle structure is stationary. The second one is space-like and describes the particle axial symmetry.

6.5 Quantum Mechanics

The emergence of Quantum Mechanics will not simplify the task of establishing a model. A great number of more or less mysterious effects will have to be taken into account and explained by the model. In particular, it will have to explain the wave-corpuscle duality.

Could it be that particles sometimes exist as delocalised waves ? At least two experiments go against the conception. Firstly, in the Compton effect, in the collision of an electron and a photon, everything happens as if the particles were small billiard balls, extremely well localised. Secondly, in a diffraction experiment the diffraction figure is composed of individual impacts. On the figure below one shows the accumulation of impacts which progressively reveal the diffraction figure.



It must then be supposed that the corpuscular aspect predominates. Wave effects are secondary and generated by the vibration of the particle in the medium. One supposes that the de Broglie waves are produced in the aether and are transmitted via the aether.

About the structures of particles themselves the quantum field theory brings no precision. Particles are supposed to be points without dimensions in the vacuum. They differ only by the quantum numbers (spin, charge, isospin, strangeness, …) which are attached to them.

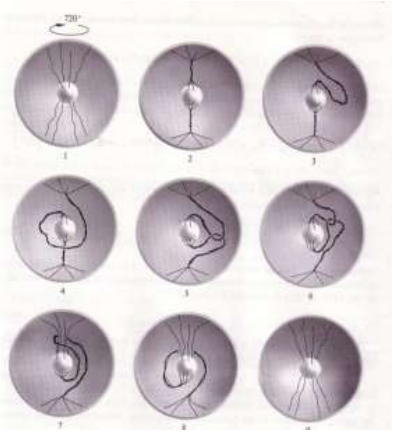
What is new in quantum field theory is that the vacuum contains fluctuations like the creation-destruction of pairs particles-antiparticles. It is thus a false vacuum and more like an aether able to generate pairs.

6.6 Spin ½ of the electron

One fundamental mystery of particle nature is to dispose of a good model for spin ½ . Not simply a purely mathematical description such as the ½ representation of the rotation group, but a truly explicative model. What is the mystery of spin ½ of the electron for example ? Let us take any object of 3 dimensional space. After one complete 360° turn around an axis, it comes back to its initial state. But this is not true for the electron: after one turn, the electron change state because the wavefunction is multiplied by -1. After two turns (720°), it comes back to the initial state. This is supposed to be a purely quantum effect, whatever that means. In any case, this is a very important effect, probably one of the keys of comprehension of particles.

In his conferences Dirac used to present the following model. Let us consider a sphere inside another sphere. The small sphere symbolises the electron. It is bound to the large sphere by at least three elastic threads. The large sphere represents the external medium. After one complete turn of the small sphere around an axis the threads are tied. However after a second turn in the same sense and axis, the threads can be untied by operating as shown on the figure

below. After two turns the situation is thus topologically equivalent to the initial situation.



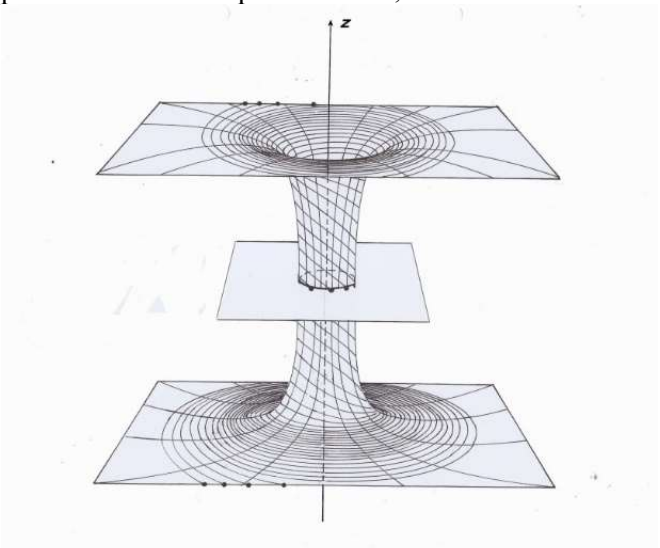
We need to understand the signification of the sphere and of the elastic threads for an electron. What do they represent in reality ?

The difficulty is to merge in one single plausible model three partial models which each have their quality but also their big defects:

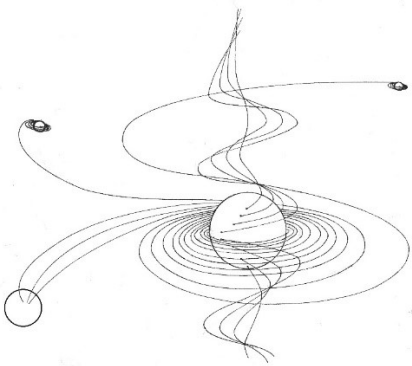
- The Einstein-Rosen model (wormhole),
- The models of Kelvin and Jehle,
- The spin 1/2 model (sphere in the box).

Let us start from a 3D representation of the electron based on an Einstein-Rosen model. This structure appears originally as a non traversable wormhole in space-time. The difference with the standard model is that in our model the wormhole is supposed to be stabilised by its vorticity. It remains open at all time and so becomes traversable. As

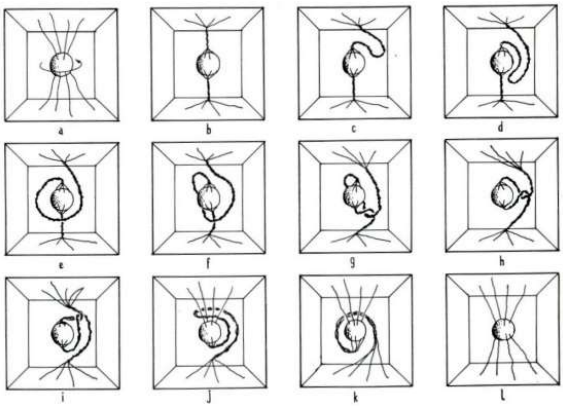
usual we have kept only 2 dimensions for the visual representation of the spatial section, which should count 3.



The space-like section represented here can be seen as a universe membrane of finite thickness and the electron as a hole in it. The vortex lines *a,b,c,...* come from infinity and wind up around the axis. These lines are extensible but cannot be cut by virtue to a theorem due to Helmoltz . Their intersections *A,B,C,...* with the throat of the wormhole defines a ring which rotates with the fluid because vortex lines are frozen in the fluid and move with it. If one adds the third dimension of space this ring becomes a spherical surface to which the vortex lines are attached. Besides one can imagine that vortex lines are attached in the same way to the cores of neighbouring particles, so that the situation becomes that represented below.



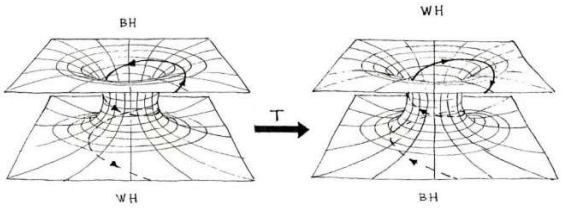
From the point of view of topology the model is in all points equivalent to a central sphere (the wormhole throat) attached by elastic threads to distant particles (the box sides).



This model synthesises the three models presented above and takes account of spin ½ of the electron. Before extending the model to other particles, how can we understand the positron, the electron antiparticle.

Predicted in 1931 by the Dirac theory it was discovered experimentally by Anderson in 1932. Stückelberg (1934, 1941, 1948), then Feynman (1948, 1951) have shown that the positron could be interpreted as an electron that goes backward in time.

What is the time reversal of our electron model ? Let us consider an electron in the form of a wormhole with a counter-clockwise spin. Suppose that it has a “black head” for the superior sheet of the universe, meaning that the aether flows inward into this head. The time reversal transform of this structure is a wormhole with a white head on the superior sheet and a clockwise spin.



6.7 Intrication

Let us note in passing the implications that this model could have for the curious phenomenon of intrication. We have established that each particle is bound to its neighbours by vortex lines. Let us consider first two particles A and B. The number of vortex lines binding them together is large but finite. Indeed, each vortex line is in fact a quantised and very thin vortex tube. Each tube has a small but well determined section.

The set of intersections with a sphere form an hexagonal network. So the number of vortex tubes attached to a particle core is large but finite. When all sites of A are occupied by vortex lines coming from B, one can say that A is intricated at a 100 percent with B. No other particle can then intricate with A. If A possesses free sites it can bind partially with C, D, … One could then define percentages of intrication.

6.8 The spin-spin interaction

In the present model particles have a spin which is directly related to their property of rotation on themselves. If two particles come close together, each one with its spin, a spin-spin interaction arises about which we have already spoken for the cases of parallel or antiparallel spins. In any case, for a particle model in terms of vortex structures, it is clear that a spin-spin interaction must exist. If it was not observed it would be a falsification proof of the model.

From a theoretical point of view, the spin is an essential dynamical variable, on the same footing as mass, since the two are necessary to classify the irreducible representations of the Lorentz-Poincare group. This group contains translations, rotations and “boosts”.

One can then speculate that the spin will appear in the Lagrangian. The latter is a function which contains all fields of the system considered. By varying it with respect to these fields and by expressing that the variation is zero, one obtains the field equations.

To gauge a theory with respect to a group of transformations consists in finding a Lagrangian formulation which remains invariant with respect to the operations of this group. In

practice a large part of the work consists in replacing the derivatives which appear in the theory by a covariant derivative :

$$\partial \rightarrow \nabla = \partial + \Gamma$$

So that this derivation becomes itself invariant under the group. The compensating field Γ is called a gauge field.

When one tries to gage the relativity theory of Einstein-Cartan-Sciama-Kibble (ECSK) with the Lorentz-Poincaré group, the compensating gauge field for rotations of the fields which appears is called the « torsion ». The existence of torsion implies that space-time itself is endowed of vorticity. In the ECSK theory, torsion is attached to matter and does not propagate as a wave. A weak spin-spin interaction exists but it is purely of the type "contact interaction" (no propagation). However it seems reasonable to think that in a more satisfying theory of gravitation torsion would propagate et would thus be able to mediate a stronger spin-spin interaction between the sources, that is; between two spinning particles (or between two galaxies).

Already in 1948 Stueckelberg had suggested the existence of such an interaction (Stueckelberg, 1948). In the seventies, one observed that two polarised laser beams placed in a polarisable medium interact. The beams repel each other when the beam polarisation are opposed and attract when the polarisations are identical (Happer and Tam, 1977 ; Tam and Happer, 1977). To try and explain this a theory of the long range spin-spin interaction was formulated (Naik et Pradhan, 1981). It contained a gauge field vectorial, axial and without mass, responsible for the interaction. In this scheme the interaction is thus seen as due to the exchange of an axial-vector- massless particle.

Several extensions of the standard model of particles also predict the existence of a spin-spin interaction due to the exchange of diverse weakly interacting particles (Moody and Wilczek, 1984).

In the nineties, various experiments were performed to detect the spin-spin interaction, beginning with the work of Ritter and his collaborators (Ritter et al., 1990) using a torsion pendulum built with the material Dy_6Fe_{23} . The latter possesses a net intrinsic spin but a weak magnetic moment. The difficulty is indeed to distinguish the spin-spin interaction from the well known interaction between magnetic moments. All results were negative.

Other trials are described in review papers (Adelberger et al. 1991, W-T. Ni, 2010, 2015). One of the most recent has tried to use the whole earth as a source of polarised electrons and to study its influence on electrons and nucleons in the laboratory, when all their spins are also polarised. None of these experiments was able to detect the interaction.

It is particularly frustrating that all those so well motivated experiments have failed. We will propose an explanation of this fact and we will suggest a new method of measurement which should give a positive result.

It must be noticed that in our model it is not an interaction in the proper sense because it does not represent an acceleration due to a force. The model shows that it is a speed generated by vorticity induction. It shows also that the effect is clearly not due to particle exchange. All the calculations based on the exchange paradigm (for example Naik and Pradhan, 1981) are thus probably wrong. Quite the contrary, the speed is induced in the space-time fabric in a plane perpendicular to the particle spin.

The effect being concentrated in a plane, that must be taken into account during the experiment conception. The spins must be parallel to reinforce the induction effect.

One understands why Goldberg's experiment with the torsion pendulum has given nothing. It is based on the idea of an exchange interaction which applies in all directions in an uniform way.

The problem is thus to create an electron set, all located in the same plane, with parallel spins. In this way the speed induction effects will reinforce each other considerably in the plane considered.

FIGURE

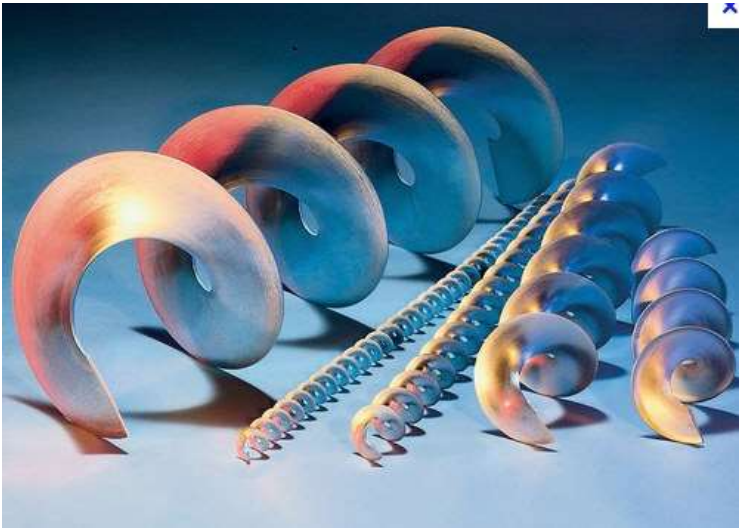
Solving this problem is nothing but simple. In an electron gas at low density the potential energy of electrons dominates the kinetical energy. So, if one lets the gas organise itself in a neutral and inert medium, it will crystallise and form a face centred cubical network in three dimensions, and a triangular network at two dimensions. It is the famous Wigner's crystal predicted by Wigner (Wigner, 1934). The potential energy will be lowest if the spins are alternatively « up » and « down ». But in this case the induction effects have a tendency to destroy each other.

What we need is a planar repartition of electrons were the spins are all « up » or all « down ». This repartition is rare because in a neutral medium it is not stable. One must thus find a new medium were it is possible.

In a supraconducting material, the electrons congregate by pair. Unfortunately, they usually they combine in a spin-up,

spin-down arrangement (spin singlet). There exists nevertheless at least a supraconductor which supports a spin Triplet pairing (were the two electrons in a pair have parallel spins). It is Sr_2RuO_4. As other cuprates supraconductor it has a planar structure and one can expect that supraconductivity happens in the plane Ru-O. From our point of view it is excellent news since part of our problem was to concentrate as much as possible active electrons in the same plane.

The idea is to build a crystal of Sr_2RuO_4 under the form of an helix folded on itself such as to constitute a torus. One must take care that the Ru-O plane coincides with the tangent plane to the helix.



Two electrons of a pair propagate in the plane of the helix and possess parallel spins perpendicular to this plane. The

electrons must then induce speeds in the plane so that their effects add up as shown below :

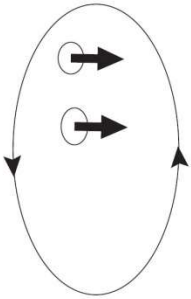
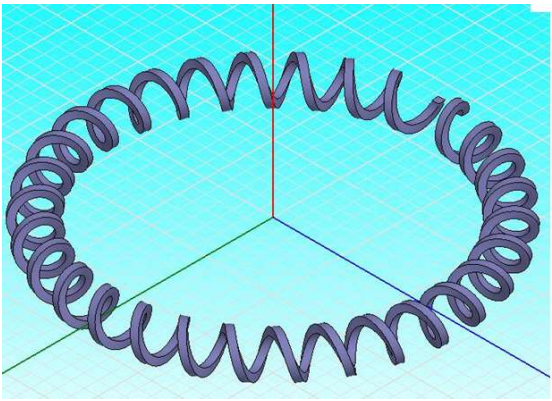


Figure 27: Circulation induced by an electron pair in the spin-triplet state, and with the spins perpendicular to the supraconductor main plane.

If one curves the helix to obtain a torus, one arrives at the following geometry:

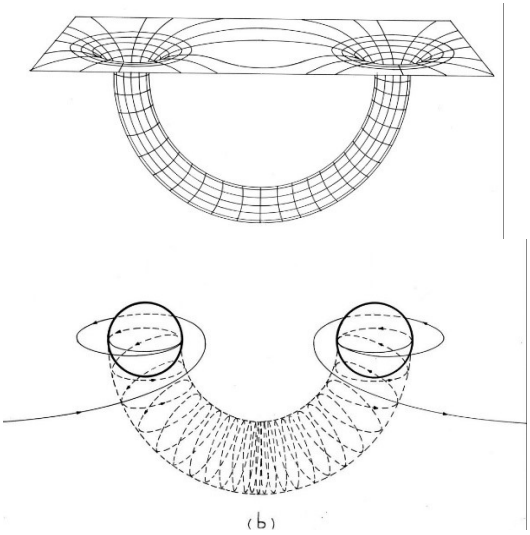


All sections of the ring induce a speed in the plenum, in particular along the main torus axis. By sending a flux of

neutral particles along this axis it should be possible to measure the induced velocity by the ring on the neutral particles.

6.9 The photon model

Let us consider anew the wormhole model of the electron; When the two heads of the wormhole are open in the same universe sheet, as on the figure below, then one obtain a new structure which cannot be generated starting from the electron structure by a simple deformation. It must then represent another particle.

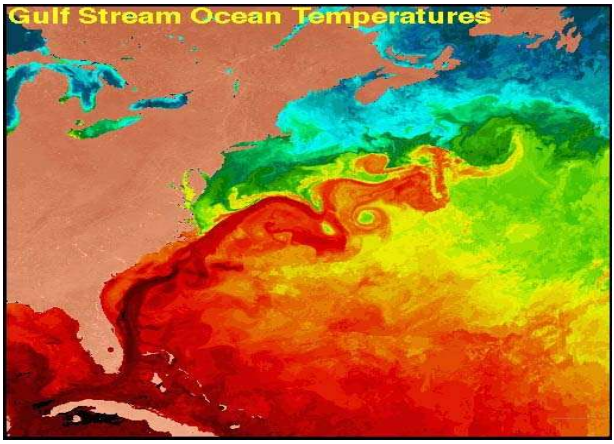


On the upper universe sheet, it presents itself as an electron head connected by a material bridge to a positron head. Globally, at a certain distance, the particle seems to be electrically neutral. By the vortex self-interaction effect, the two heads rotate around the gravity centre, which implies

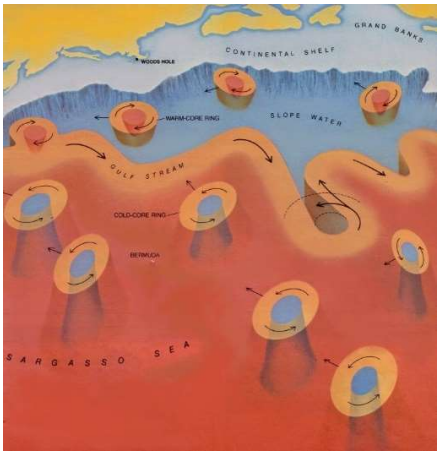
that circular polarisation is the basic polarisation. Each head behaves as a spin ½. The addition of two parallel spin ½ behaves like a particle of spin 1. If one reverses the time sense, the electron head becomes a positron head and vice-versa. This particle is thus its own antiparticle. Still by vortex self-interaction, the half vortex ring confers a constant speed to the ensemble, and it is perpendicular to the line which joins the two heads. The fact that the particle possesses a constant non inertial speed, for its very existence, implies that the inertial mass is zero. One can suppose too that the heads vibrate along the axis joining them. Then the fluid acceleration represents the contribution to the electric field of the isolated particle. The rotational of the fluid is proportional to the magnetic field contribution.

All the above characteristics lead us to think that we have here a model for the photon.

In QED, electrons are always surrounded by a cloud of virtual photons. Virtual photons can be exchanged with another electron. It is the way electrons interact. Richard Feynman has described this process by graphs. Are we able to reproduce the graph processes in our model ? By which process an electron structure could emit a photon structure ? The idea came to me when looking at the gulfstream meanders.



Here is the gulfstream picture in false colour, the red indicating high temperatures and the blue low temperatures. The meanders are sometimes so pronounced that rings can detach from the principal flow. One so obtains cold water rings in hot water and vice-versa.



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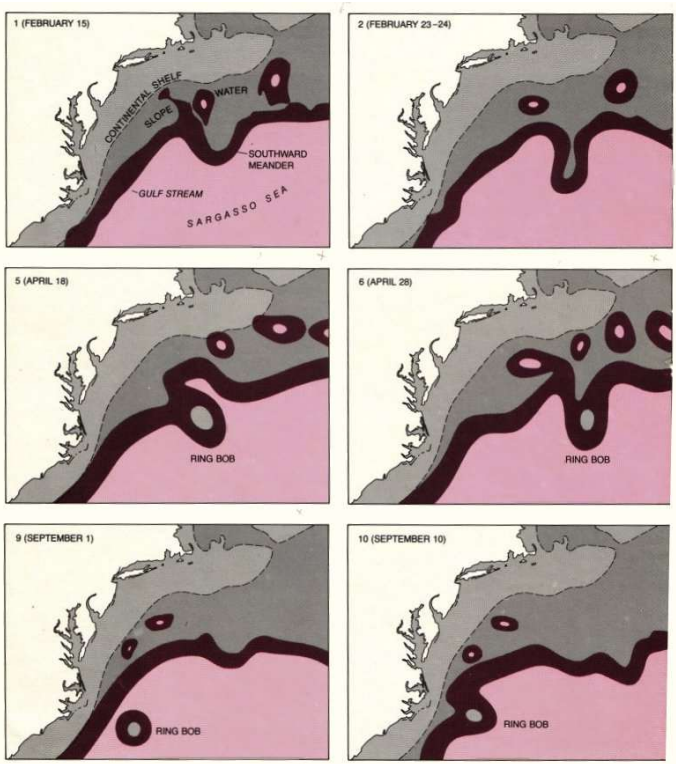
The rings can be recaptured as the history of « Bob » ring shows below.



The same meanders and production of rings are found in geological times for the Missisipi.

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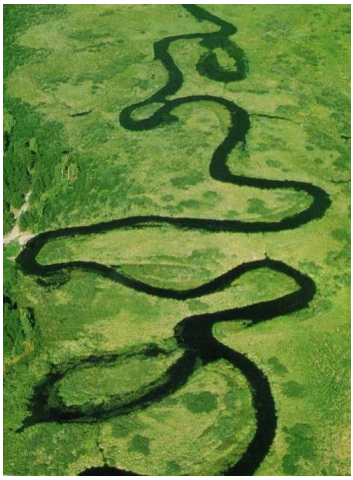
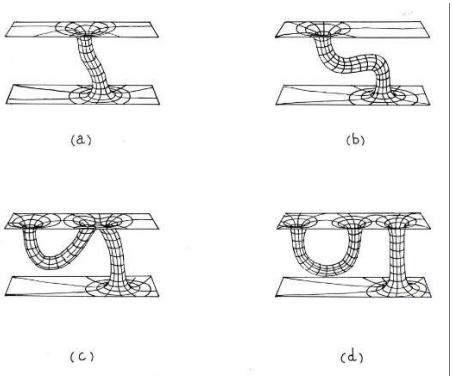


In fact one finds these instabilities at the interface of all flows of more or less viscous fluids, or for a single fluid but with various densities.

This suggests the following evolution for the electron structure :



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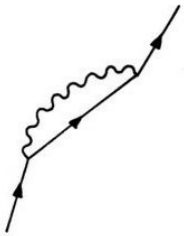
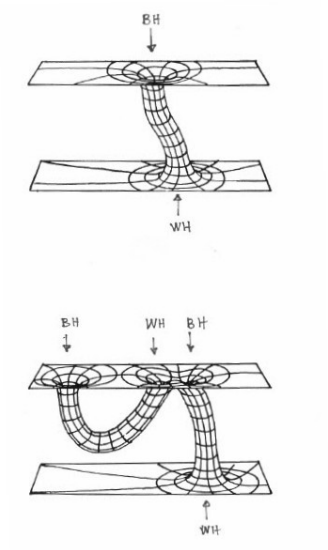
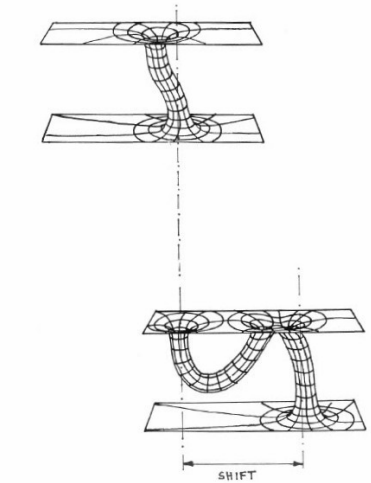
The electron structure in (a) curves due to an instability in the flow (b). The wormhole touches the superior sheet (c), which gives way to the emission of a photon structure (d), eventually followed by a recapture. With the latter, the evolution would correspond to the Feynman graph below.



In the image below, we have represented first an electron , with its « black head (BH) » in the upper sheet and its « white head (WH)» in the lower sheet. When a photon moves away with the process described in the picture, a couple WH-BH appears, that is a new electron shifted some distance away.



Let us note that the shift is of the order of the photon size.



This could explain the translational part of the electron « Zitterbewegung ».

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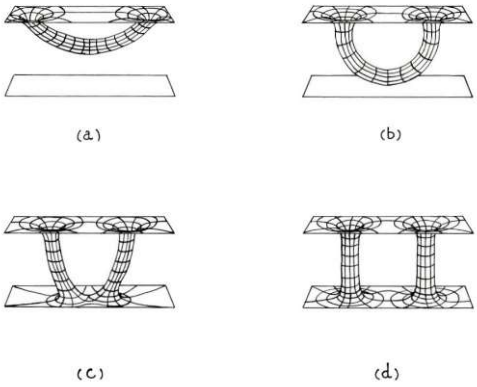
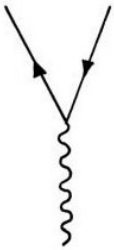
Conversely, the process



describes a photon (a) which touches the lower sheet (c). An electron and a positron structure appear. This corresponds to the following graph.



Hence in our photon model we easily visualise the creation of a pair. We can envisage that the process is due to a local diminution of the distance between the two sheets. In this case, the photon materialisation would be due to a fluctuation of the medium properties. Maybe this would be the cause of the vacuum quantum fluctuations.

6.10 Other particles

Jehle sees the particles as quantised flux tubes of magnetic field. All particles would correspond to all possible topologies of the horizon (the wormhole throat) and the vortex lines that sustain it. Then the classification would be that of knots. We have adopted the same basic idea but we have replaced magnetic lines by vortex lines in a fluid: the aether.

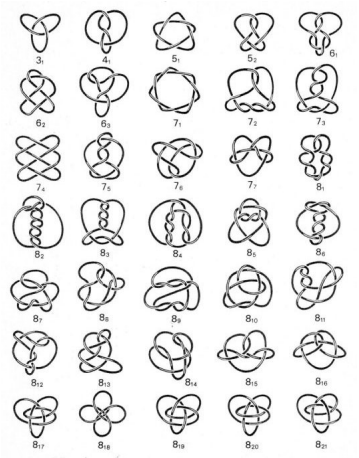


Figure 28: First knots of the classification.

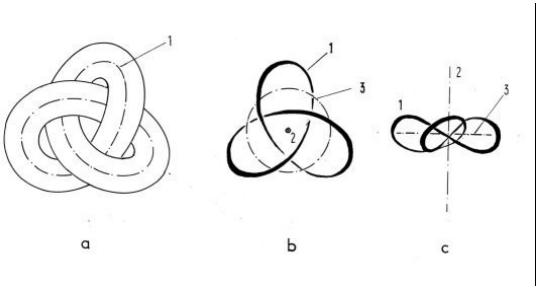


Figure 29: The trefoil. Vortex lines make three turns around the central axis.

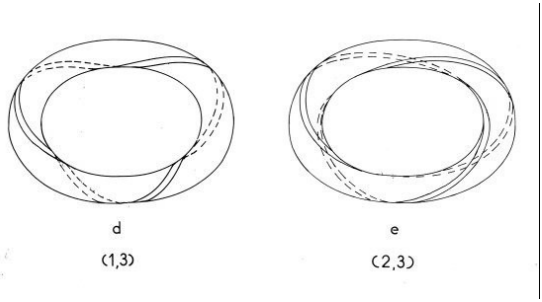


Figure 30: Another way to see the trefoil is to consider vortex lines that make three turns around the central axis by winding themselves on the surface of a simple torus.

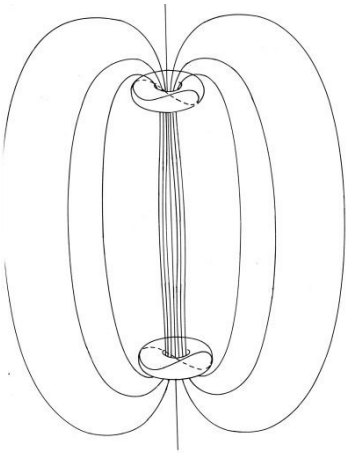


Figure 31: Jehle sees the meson as composed of two linked rings. If one is of the type BH (particle) the other is necessarily of the type WH (antiparticle).

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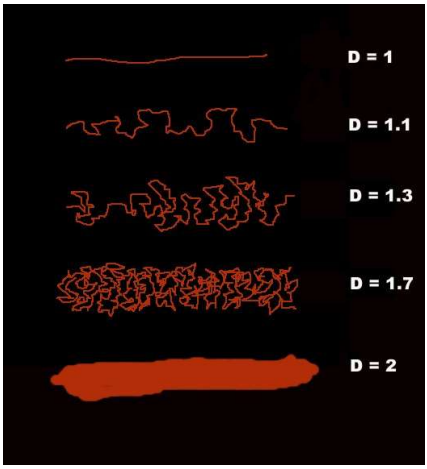
7 The galaxy scale

7.1 The fractal model

Benoit Mandelbrot invented the term “fractal” in 1975 for designating a certain class of objects that reproduce themselves homothetically on different scales. Any part of the fractal is similar to the whole object. It is a geometrical object such as a curve or a surface, whose structure is invariant by change of scale. A fractal has fractional dimensions.

Figure 32: Benoit Mandelbrot

How can we visualise a fractional dimension ? In the example below, the first line possesses a dimension 1. The successive curves are more and more fragmented and they progressively fill the plane. The line dimension is given in each case. It attains 2 when the band is completely filled. These curves are fractals with dimension between 1 and 2.



The next figure shows a very well-known fractal: Mandelbrot's "hypopotamus". By zooming on any part of the fractal one falls back on structures similar to the beginning ones and finally one would find back the hypopotamus structure after a sufficiently long zoom.

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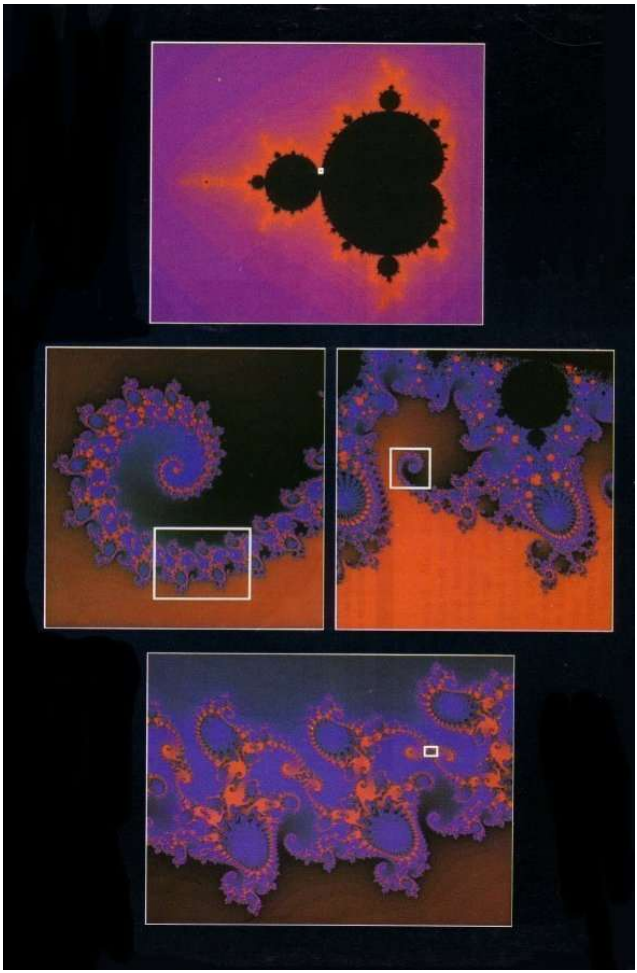

This fractal is generated by computer, but Mandelbrot observes fractal everywhere in nature: a cauliflower, a snow crystal, a leaf, the sun's surface with its convection cells, Jupiter's surface with its turbulences, a coast filled by glaciers, a tree, a lung, …

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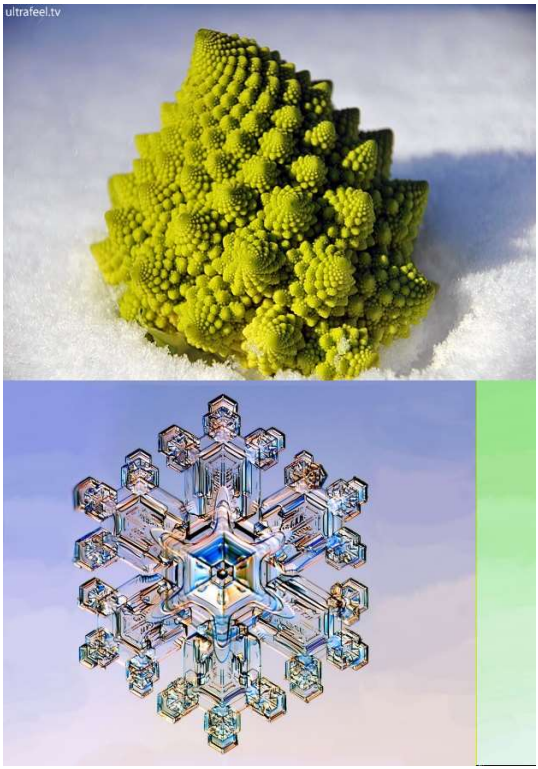

Figure 33: A cauliflower, a snow crystal.

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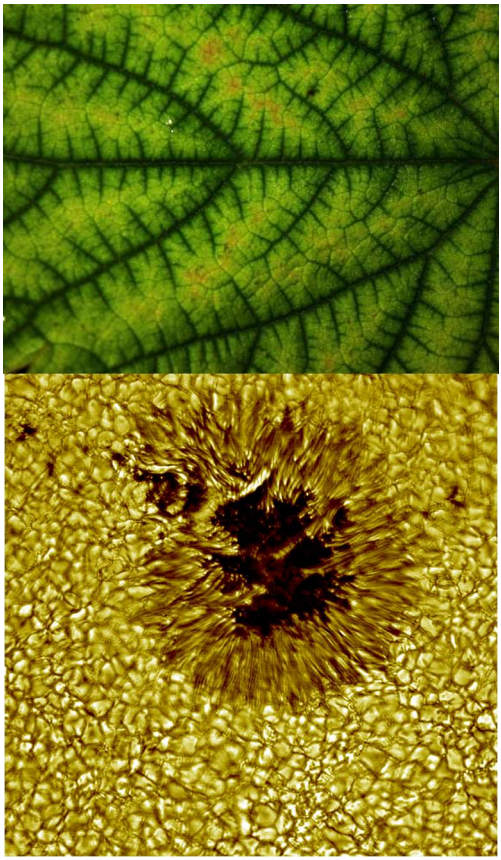

Figure 34: A leaf, a black dot on the sun's surface, surrounded by convection cells.

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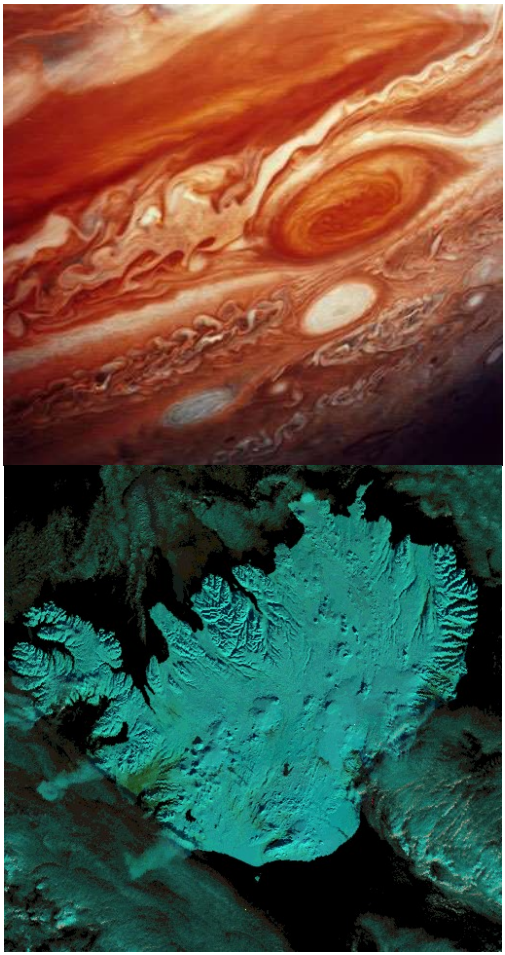

Figure 35: Jupiter’s surface, a snow-covered coast.

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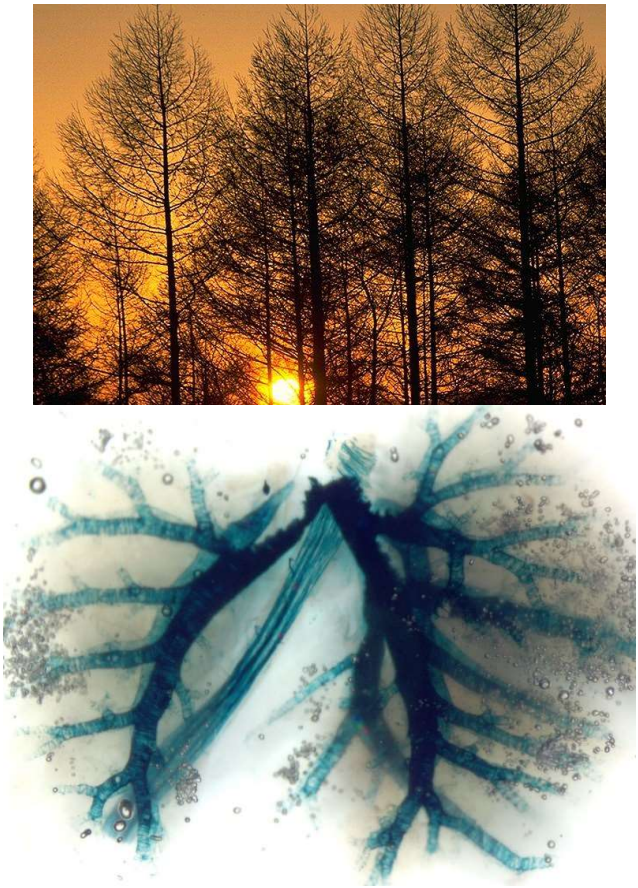

Figure 36: Trees, lungs.

The fact to observe fractals everywhere and at all levels has led me to formulate an hypothesis: the universe itself could be a fractal. This would have very strong consequences.

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In particular, a single physics should be able to describe the homothetical structures at various scales (tha microcosm and the macrocosm which would considerably raise the hope to arrive at a unified theory.

Homothetical structures to particles should reproduce at macroscopic scales. Let us thus seek for an electron model at the upper scales. This structure should:

- Ressemble a vortex structure in a fluid.
- Possess a wormhole in its centre.
- Behave like a spin ½.
- Exchange objects of the photon type.

Let us notice that if an electron possesses a structure, there will be no two identical electrons. They will have a distribution around median values, in size, in mass, etc… We have been used to think in terms of a unique electron with a fixed mass. But we forget that this mass results from a statistic on a considerable number of electrons.

Let us search thus for a candidate to the electron structure amongst vortex structures at larger scales: macroscopic vertices, tornadoes, cyclones, spiral galaxies.

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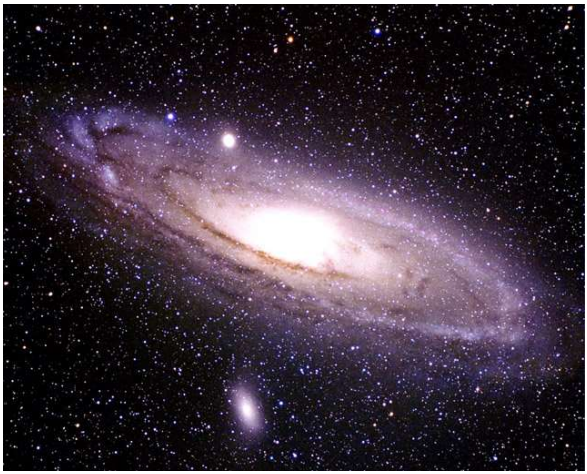

Only the spiral galaxy could eventually satisfy all these criteria. It is what we will try to demonstrate.

Spiral galaxies have a central black hole. Since the galaxy structures are stable, one can suppose that the core is a wormhole rather than a black hole.

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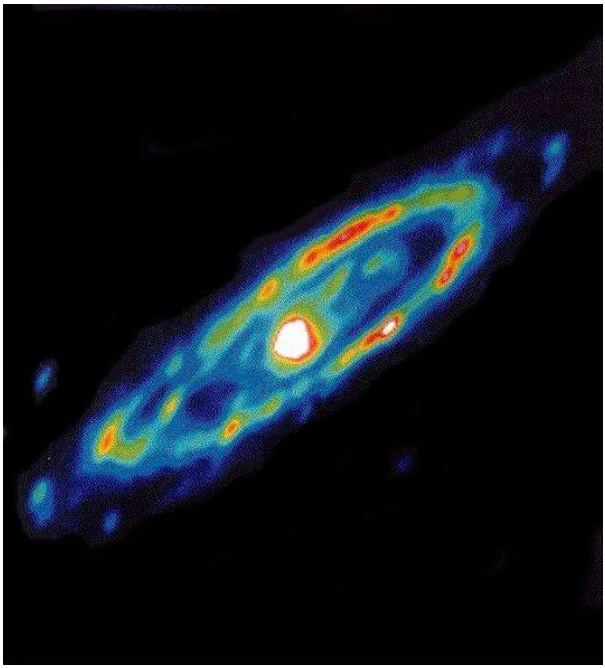

Even the heart of our galaxy possesses a massive body from where three filaments are sticking.

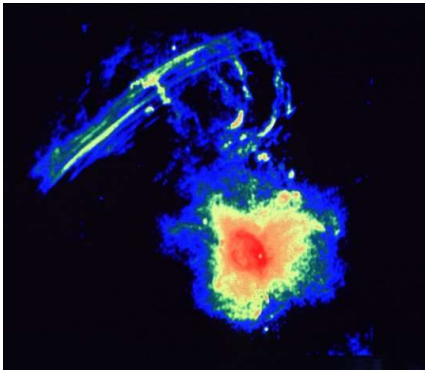

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Figure 37: The centre of our galaxy shows a massive from which a complex filamentary structure emerges.

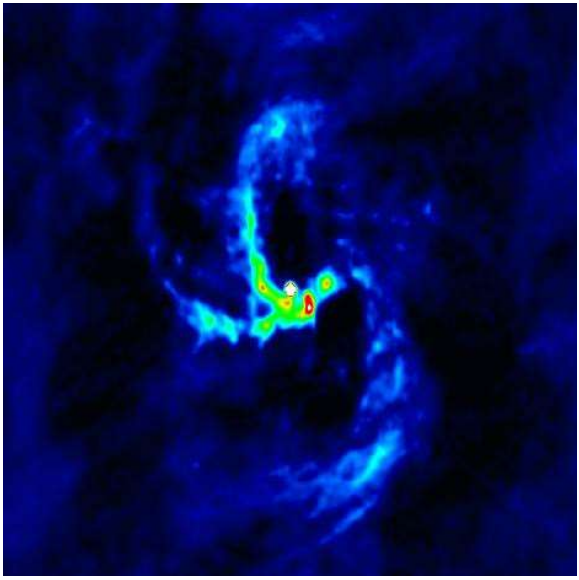


Figure 38: In more details one observes that three filaments stick out from the core of our galaxy.

An extended general theory of relativity should be able to describe the spiral galaxy structure plus the filaments which emerge from it. But it cannot do it actually. What is missing is to consider space-time as a true fluid, a material fluid which has vorticity but also dilation and shear. The space-time fluid is here constituted of stars, planets, gas, … One makes the hypothesis that the galaxy is a vortex structure in that fluid. This includes the filaments. Vortex lines wind up in spirals around the symmetry axis. The rotational speed of the fluid around these lines increases as one comes closer to the galaxy core, until it reaches light speed on that scale. One

can suppose that the set of points were the speed attains this limit defines a light-like 2-surface. The topology of this surface characterises the galaxy type. For the spiral, the simplest structure, it is probably the simplest topology, that of the sphere S^2. On one side, vortex lines are attached to this sphere (frozen into the fluid) and rotate with it around the axis. On the other side, they are attached to the core of neighbouring galaxies. One falls thus back on the model of particle in a box, which implies that spiral galaxies have a spin ½. If it turns out to be possible to create a theory which would admit this kind of behaviour, one would conclude that the spin ½ is a gravitational effect rather than a quantum effect.

Particles can be seen as topological defects. The particle cores are surfaces where torsion and non-metricity is concentrated. Due to the strong non-linearity and to the gravitational collapse which resulted from it, these geometrical quantities are concentrated in a delta function on these defects.

One can thus now precise the fractal hypothesis : particles and galaxies would be homothetical structures of a fractal universe. They would have exactly the same structures, but at different scales. The recurrence would continue in both sense, towards the microcosm and the macrocosm.

A particle at scale n is constituted of particles from the lower scales $n-1, n-2$, ... This recurrent definition cannot be denied logically. The vacuum does not exist. It is everywhere filled with particles of the lower scale. This is why we will call it the “plenum” or aether.

At the scale of galaxies, the existence of a fluid constituted of stars, asteroids and gas, and thus ultimately of particles of the lower scale, cannot be denied. We see it with our own eyes. In our conception, it is this aether which constitutes space-time. There exists thus an infinity of aethers, one for each scale. One for particles, one for galaxies, … At scale n the aether is constituted of particles pertaining to scales *n-1, n-2*, … In the fractal hypothesis, the aether existence cannot be doubted because it forms the basis of all matter on each scale. We must simply understand its nature and we must be able to answer the objections that it poses.

But are we in a position to answer now the objections made against the aether ?

- No dragging of a particle of scale n by an aether wind.

The aether at scale n is constituted of particles of scale $n-1, n-2, \ldots$, so small with respect to scale n, that there is practically no viscosity. When the particle moves with a constant speed with respect to the aether there is no interaction and hence no dragging effect. It must be supposed that sensible interaction effects appear only in case of acceleration.

- There is a priori no preferred referential.

All referentials in motion with constant speed with respect to each other cannot be differentiated because of what we have just said.

- No mechanical interaction effect with the aether is known.

It is possible and even probable that these effects are hidden in QED as exposed actually, or in its failures.

- The aether should have a very large rigidity to explain the very large velocity of wave propagation.

The great propagation speed of photons is due to the self-vortex interaction of their structure. It is not directly related to the aether rigidity.

- Luminous vibrations are transverse. It is not compatible with a fluid medium.

It is the vibration of the photon structure which is transverse (perpendicular to the propagation direction) and it is this vibration which is communicated to the aether. Here is how a transverse vibration can be generated in an aether fluid.

There are good reasons to think that the aether behaves like a superfluid and is practically devoid of viscosity. Indeed, particles and galaxies are, each at its own scale, stable structures. Knowing that viscosity destroys the stability of vortex structures, very little viscosity is allowed. It can exist only close to the core of particles (galaxies) and must be of dynamical origin (due to the gravitational interaction in the fluid).

Another characteristic of superfluids is to support vortex structures whose spin angular momentum is quantised. But it is precisely the case of the electron.

For a particle like the photon, it is the particle structure itself which vibrates. For a particle like the electron, it is the constant emission and absorption of virtual photons which provoke its vibration.

In each case the vibration is transmitted to the aether and propagated by it. Following the interpretation of de Broglie – Böhm (Böhm et Hiley, 1993 ; Holland, 1993), the wave reacts back on the particle to guide it on its trajectory. The fluid being quasi viscous less it can support persistent waves on very large scales.

The quantum hypothesis is thus extended to galaxies : these should experiment quantum effects exactly like particles. For example it must be noticed that the relative rotation velocity of galaxy couples is quantised ! In 1976 Tifft has observed the redshifts in the couple of galaxies. These couples are sufficiently compact to suppose that the galaxies are at the same distance from us. Consequently, a redshift difference must indicate the existence of a relative rotation speed of the galaxies (the galaxies rotate about each other). Yet, when one plots the number of couples which have a given Δz, as a function of Δz, one obtains a diagram which clearly shows the quantisation, with a step $\Delta z = 72 kms^{-1}$ (figure 39) ! The diagram shows peaks for preferential values $\Delta z = -72\ ;\ 72\ ;144\ ;\ 216\ kms^{-1}$….

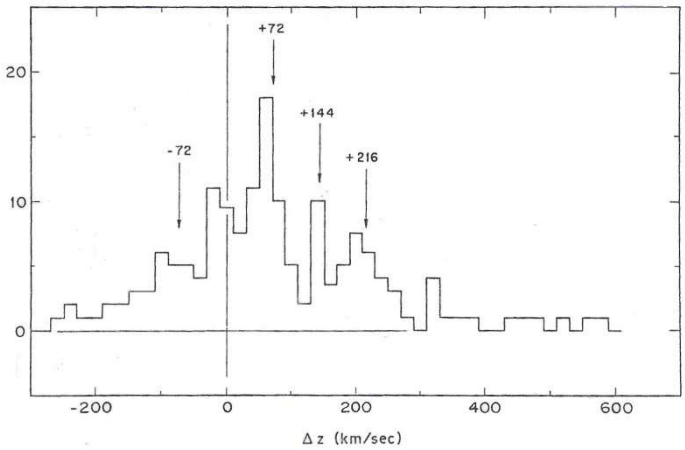


Figure 39: relative redshift of galaxy pairs measuring the relative rotation speed. The redshift is shown horizontaly. Vertically one plots the number of pairs which have a given redshift. The diagram is clearly quantised. Let us note that the redshift is expressed in unit of speed by multiplying it with the speed of light.

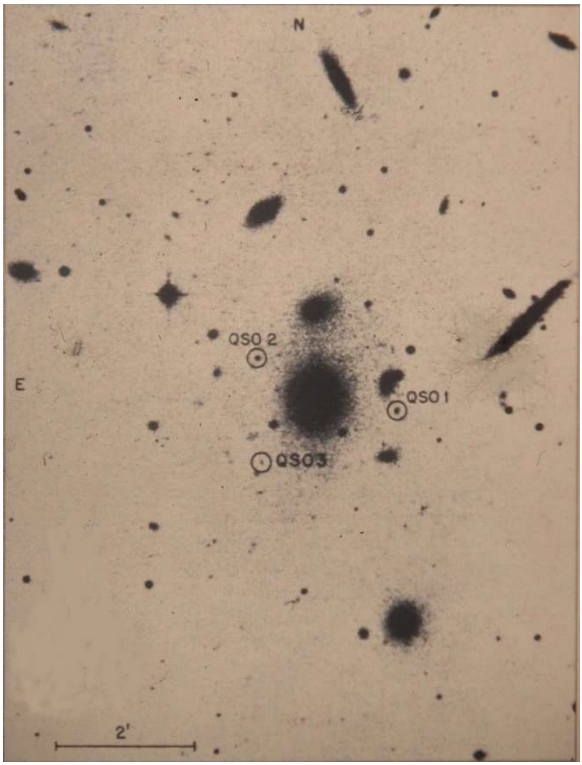
We notice that no known mechanism would be able to create such a quantisation. And yet, it clearly exists. It has been confirmed by several authors.

However, in our optic, if the fractal hypothesis is correct, the relative motion of galaxies must be submitted to the precepts of quantum mechanics and the relative speed must be quantised.

-

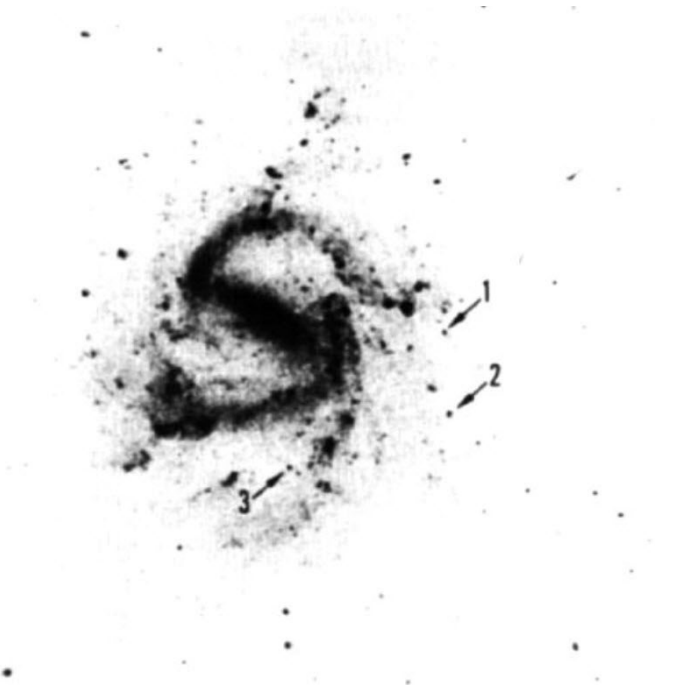
7.2 Quasars

Fortunately, Arp has disposed of enough time to accumulate much evidence in favour of the hypothesis of quasar ejection by galaxies, before encountering serious problems with his hierarchy. We examine here the most impressive cases. The details can be found in his books (Arp, 1987) et (Arp, 1998).

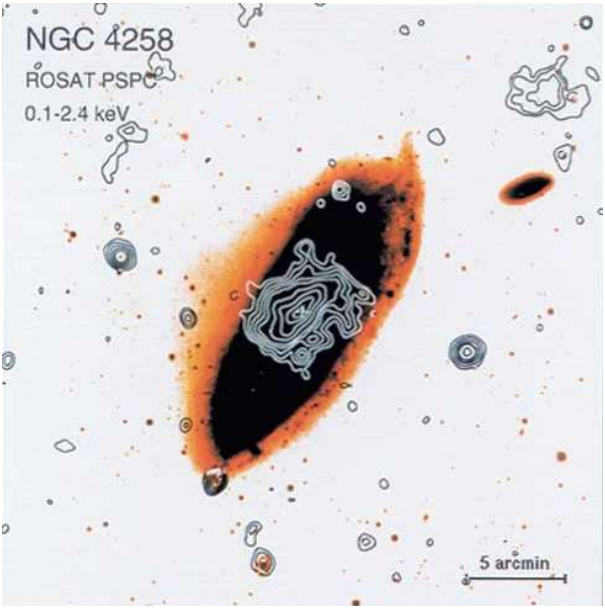


Let us consider for example these three quasars at the edge of galaxy NGC3842. Their redshifts are much higher than those of the galaxies. Proponents of the purely cosmological redshift pretend that these quasars lie far behind the galaxy.

They would thus be found by chance close to the galaxy, in projection on the sky. But considering the scarcity of quasars, it is very improbable to observe three of them so close to a galaxy. Arp has calculated that the probability of association is around 10^{-6}.



For this other galaxy (NGC1073), one counts again three quasars very near the spiral arms. Here the probability that 3 quasars would be seen so close to the galaxy is $2\ 10^{-5}$.



Let us cite again the extraordinary case of galaxy NGC4258. The iso-contours in grey give the X-ray intensity emitted. On both sides of the very active core, one finds two punctual sources which are nearly aligned with the galaxy centre. These two quasars whose redshifts ($z_1 = .653$ et $z_2 = .398$) are very different of the galaxy redshift. This system evokes very strongly an ejection by the core of the galaxy.

On another side, it is clear that most quasars are effectively large excited galaxies a very large distances as defenders of the cosmological redshift hypothesis pretend. How can we reconcile this with the other observations ? It seems that there exists a particular class of objects which I propose to call CERO, for « Compact Excess Redshift Object » which have the following properties :

- They are compact (of the size of a galaxy core).
- They have a quasar spectrum, or at least very similar to those of quasars.
- They are emitted by the cores of galaxies.

7.3 Cause of excess redshift

The precise cause of the CERO excess redshift (and of galaxies in general) is not yet known. But it seems to happen when light moves in a diffuse and excited gas medium. This is suggested by the fact that, when extracting from galaxies, CERO's which have a mass of at least a million solar mass, would tear off a part of the host galaxy gas and would then be surrounded by a cocoon of highly excited gas. When traversing this medium, light would lose some energy which would translate to a redshift of its frequency. As Arp (1990) pointed out, the energy loss cannot be due to simple collisions between phtons and matter. Indeed, in this case one would get a broadening of pictures due to diffusion. The mechanism must be more subtle.

This « tiring of light » could be explained as follows: the particles of excited gas move at high speed through aether and are submitted to collision, that is accelerations in the medium. One can suppose that cause elementary excitations in the medium called photons and rotons. The photons which traverse the medium are vortex rings. They interact with the photons and rotons. The result is an energy loss for the photons. But since they are forced to move at constant speed, due to their ring structures, the only way they can lose energy is by a diminution of their frequency of vibration. Whence the shift to the red.

7.4 Galaxy jets

Some galaxies present material jets which are issued from the core. One finds jets in spirals such as UGC 10214 below.

Figure 40: The galaxy UGC 10214 and its jet.

They are also found in ellipticals such as M87 below.

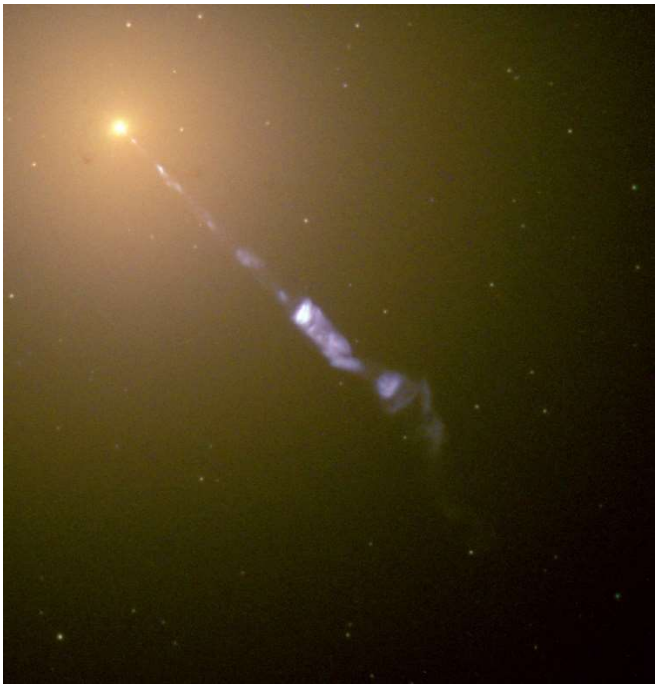


Figure 41: The ellipical galaxy M87 and a jet emerging from the core.

In the case of Cygnus A, the jet, mostly observed in radio waves, is double. It seems to correspond to a dipolar ejection from the galaxy centre. At the end of each jet, there is a rather large lobe of diffuse synchrotron emission, resulting from the gas of electrons-positrons in rotation in the magnetic field. In the lobes there are spots of high emission (hot spots).

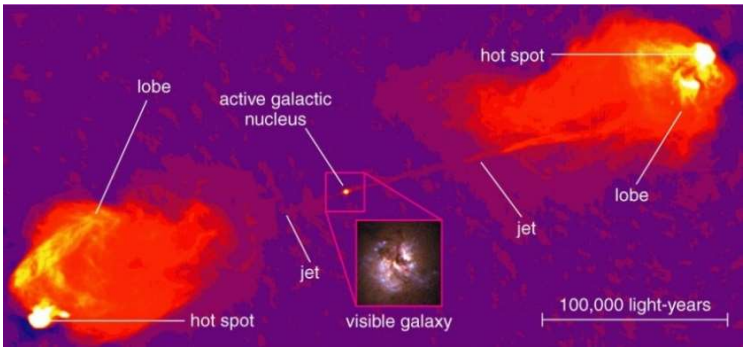
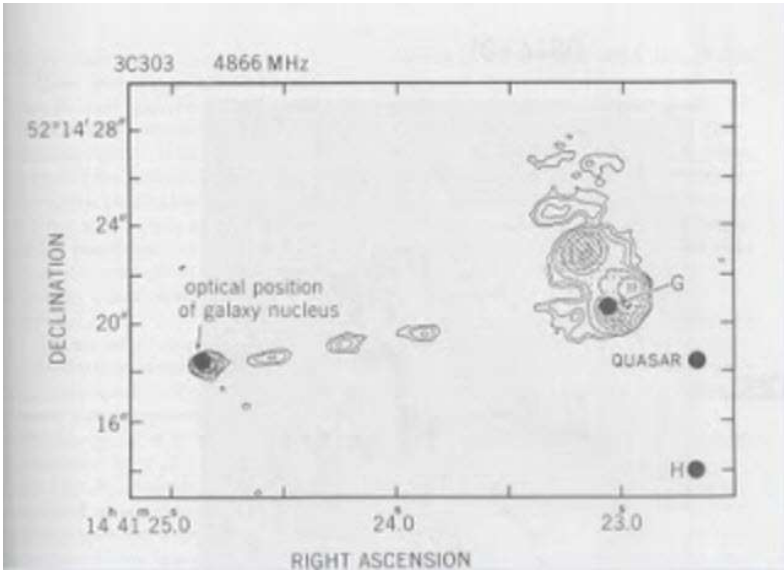


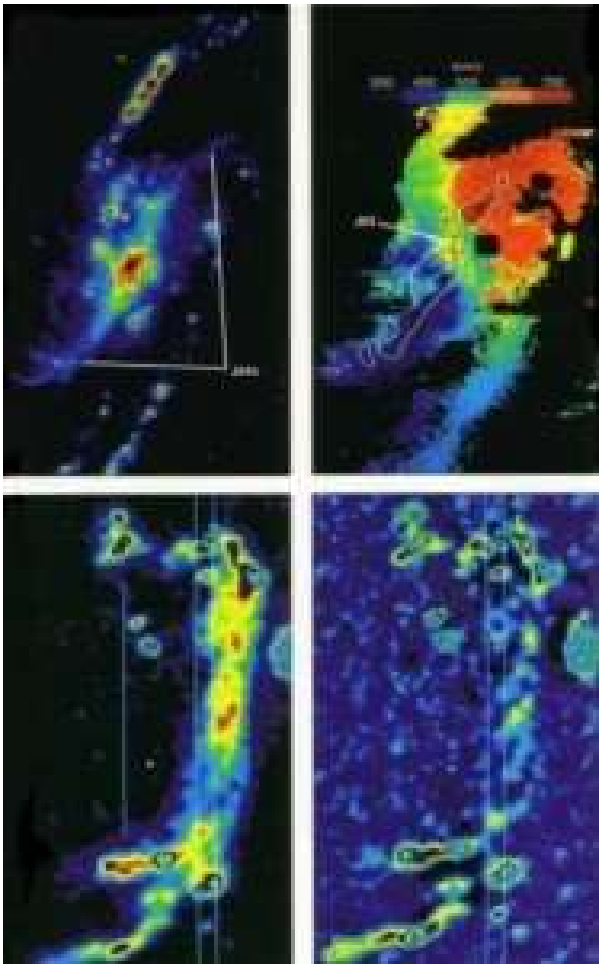
Figure 42: The galaxy Cygnus A at the centre (only the core is visible) and its two jets.

In the current theory hot spots happen where the jet meets the interstellar medium. The problem is that there are often two of them as shown on the picture above. It is not clear at all in this paradigm why the interaction does not happen closer to the galaxy. Arp reinterprets these objects in quite a different way. He suggests that quasars are ejected by the galaxy and lie in the hot spots. I will bring two precisions. What are found in the hot spots are CERO's. If they do not appear clearly is because they are surrounded by a gas cocoon when they are ejected by the galaxy core.

Let us consider the radio galaxy 3C303 which partially illustrates this point of view below. Very close to the lobe, one observes three objects, of which one possesses a quasar spectrum. It was not possible to obtain a spectrum for the other two, but it is nevertheless rather probable that they have quasar spectra too. In our new hypothesis, it is the CERO's which are responsible for the hot spots activities.



In the current theory, galaxy jets are supposed to be highly relativistic and rigid. But the example below shows a galaxy from which three jets are issued and they wind up around each other. This is only compatible with relatively slow and flexible jets.



The configuration of the three jets is pictured below.

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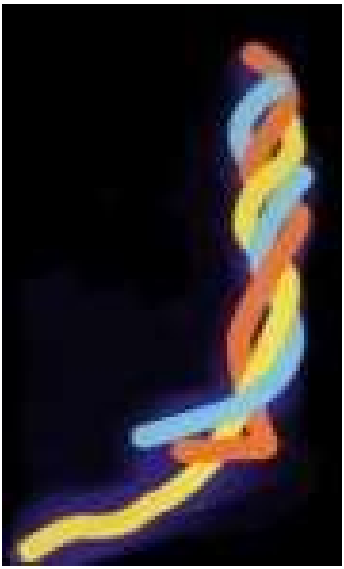
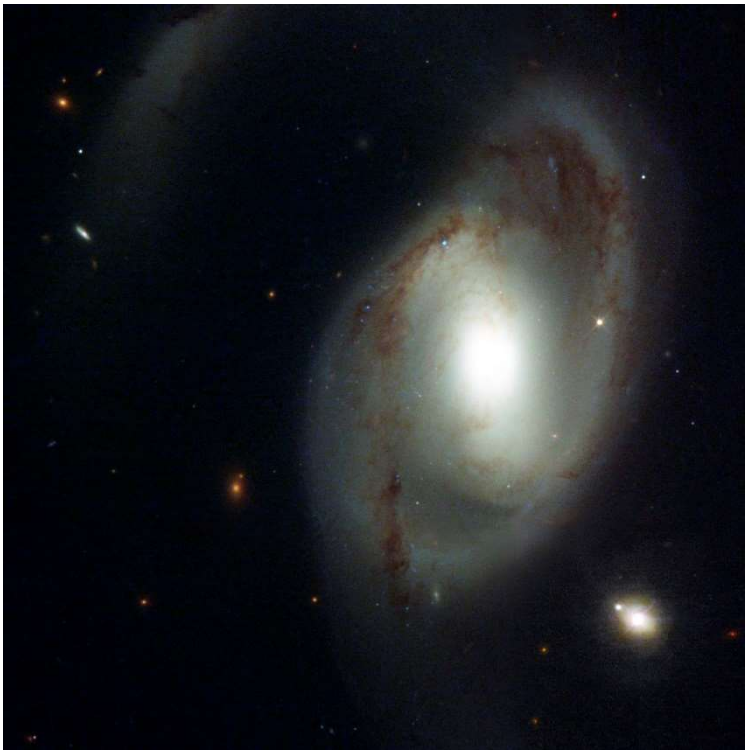


In our model, the jets are vortex tubes, which could explain their flexibility, stability, and also the fact that they roll up around each other by vortex speed induction. But we know that a vortex tube cannot stop in the fluid. We thus formulate the hypothesis that each tube is connected to a CERO which is itself a vortex structure.

7.5 NGC4319 and MK205

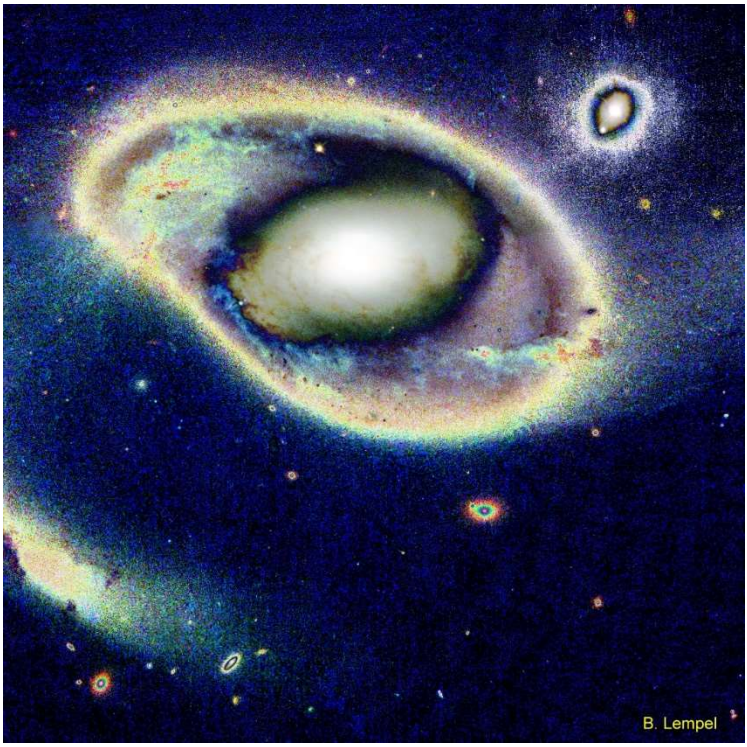
Let us address next the famous case of the galaxy NGC 4319 and of the Seyfert galaxy MK 205.



They have profoundly different redshifts : $1{,}700\ kms^{-1}$ (z=0.0057) for NGC 4319 and $21{,}000\ kms^{-1}$ (z=0.07) for MK205. Following the standard cosmological hypothesis, MK205 should lie far behind NGC4319. But Arp pretends to have demonstrated the existence of a material bridge between the two.

If the two galaxies are at the same distance, it may seem curious that their size are so different. In fact, it is rather frequent to find that sort of couple where one galaxy prevails as much on the other.

We will be capable to propose a mechanism to explain that below.



The association is visible on this more recent picture. Moreover, Arp and Sulentic have proposed a special picture treatment after which the bridge shows very strongly (see below).

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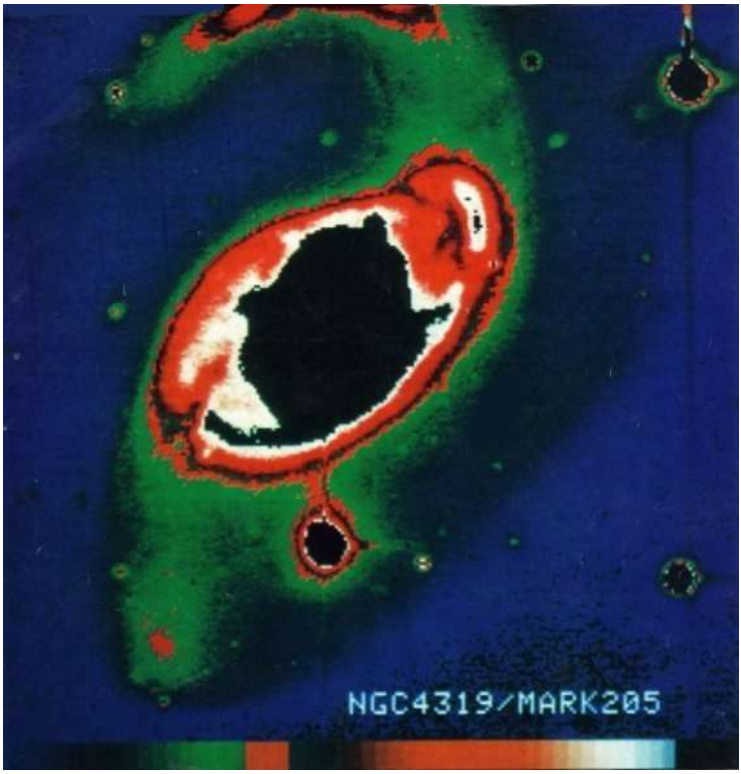


A supplementary work on the figure at the centre of NGC4319 by Sulentic has revealed that the bridge undulates and joins the galaxy centre, and even beyond. The bridge appears thus to join the centres of the two galaxies.

Let us notice also a very red and compact companion close to the core of MK205. In the standard model, it has no real justification and one does not see to what it could correspond.

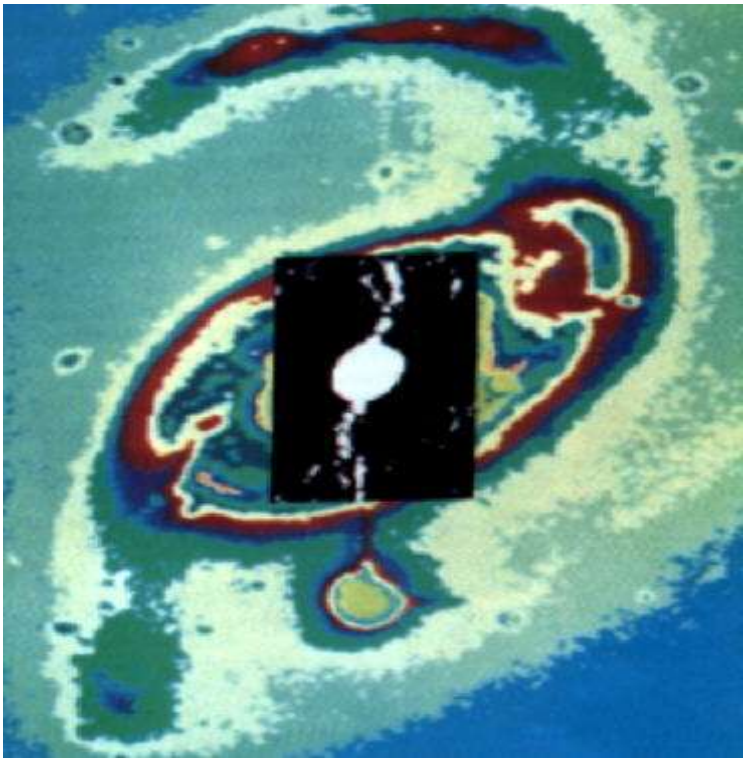


Figure 43: The picture centre has been reworked with a software program. It shows a filament which comes from the galaxy centre and heads for the core of MK205.

7.6 Cosmic photons

If CERO's are ejected by galaxies as many evidences seem to prove, they may be absorbed by other galaxies. In other words, could galaxies interact by CERO exchange ? One would then have a diagram of the type :

-

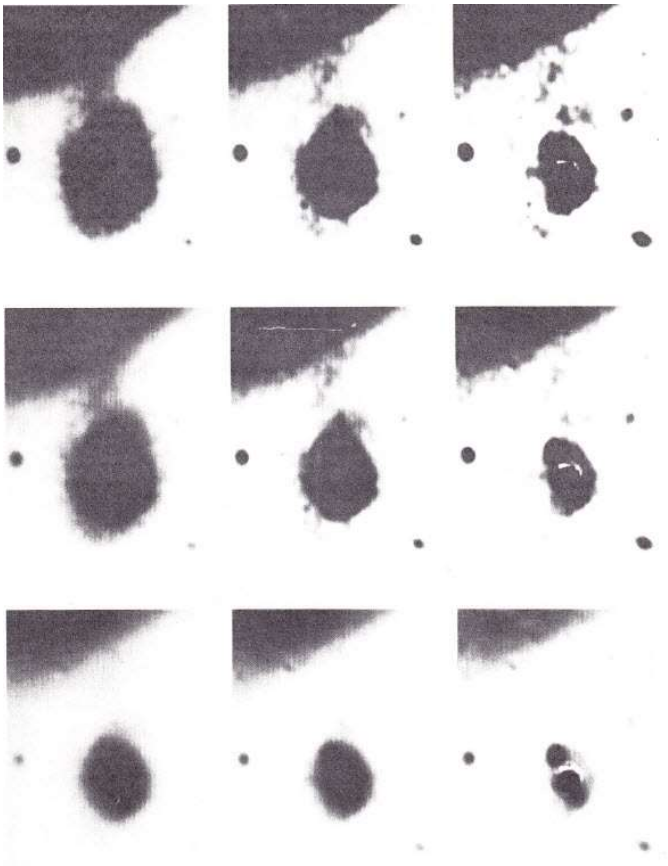
ELECTRON ➔ PHOTONS ➔ ELECTRON

GALAXY ➔ CERO's ➔ GALAXY

CERO's would then be the photons of the galactic scale.

A first confirmation of the exchange notion is furnished by a series of pictures taken by Cecil and Stockton (1985) of the link between NGC4319 and MK205. Stockton was one of the most bitter critic of Arp. Ironically, it is him who obtained the most impressive series of pictures of the link. The pictures are centred on MK205 and relate to the same view but with different exposures. They are classified by order of decreasing exposure, from top to bottom and left to right.

The first pictures confirm the existence of a luminous bridge between the two galaxies.



The last picture is the most interesting one.

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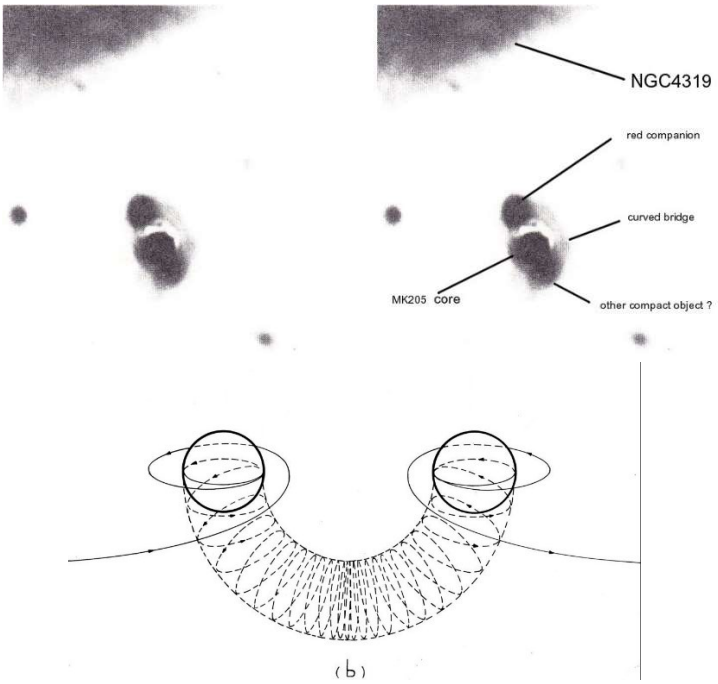
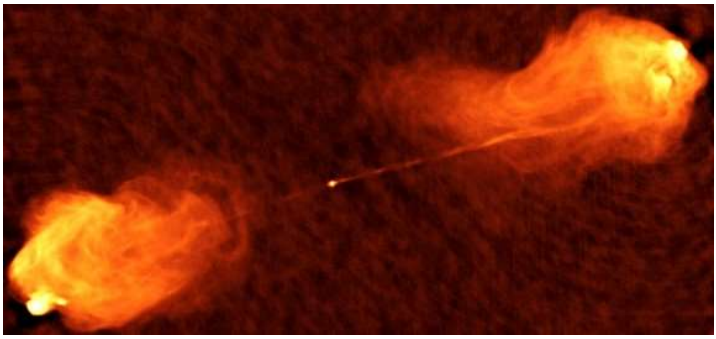


One sees the core of MK205 and a half ring structure which starts from the red companion and joins another unidentified compact object. The half ring structure strongly evokes the structure which we had proposed for the photon.

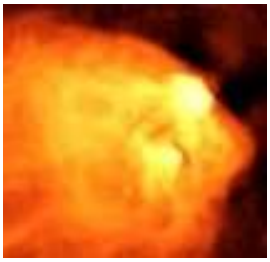
However, the part of the ring which goes in the other dimensions cannot be the one that we are seeing here. This part is well visible in our portion of space-time. It must then be supposed that a visible bridge exists between the two photon heads, in our space.

We would be then in the presence of a CERO which has been ejected by the core of NGC4319 and which is currently being absorbed by the core of MK205.

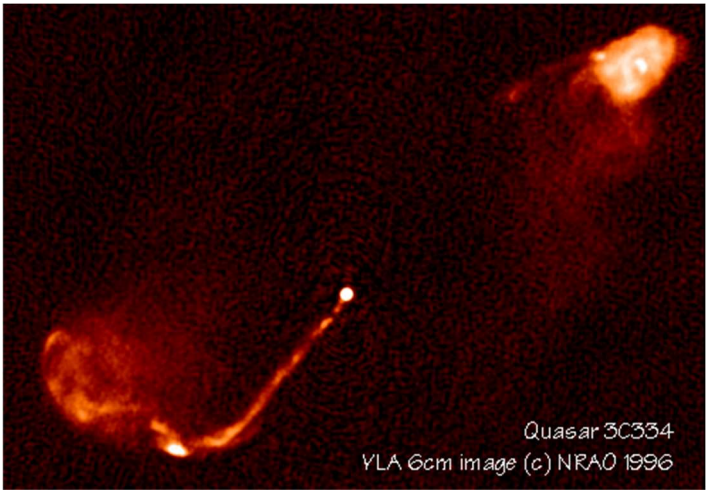
Do all CERO's present a dipolar structure in the form of a half ring joining two compact object, as our photon model requires ? In radio waves we have several examples where the dipolar structure is well marked; Firstly, Cygnus A is the most striking example.



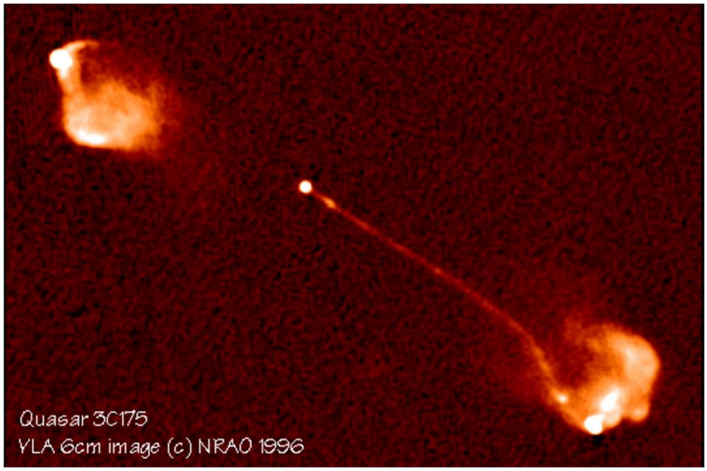
The dipole structure is well visible in the right lobe, as shown below :



Let us cite yet 3C334, where the dipole structure appears again in the right lobe:



In the quasar 3C179 below the structure is a little bit less marked.



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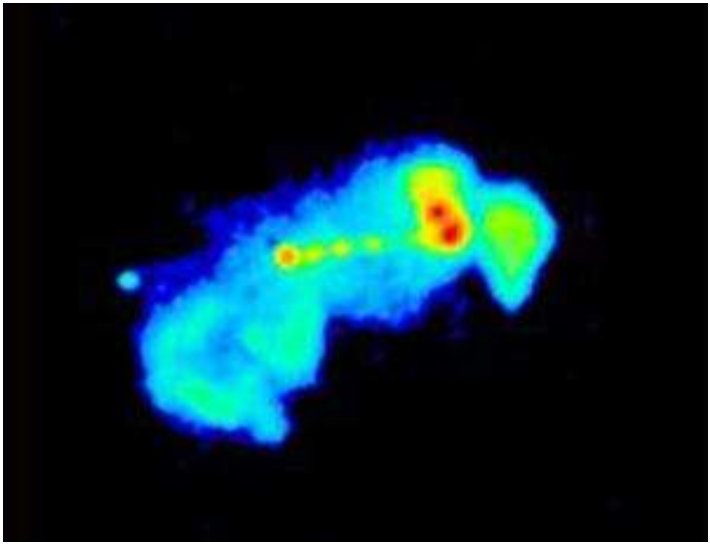
Our last example is 3C 303 :



Here is how we imagine an interaction between two galaxies ;

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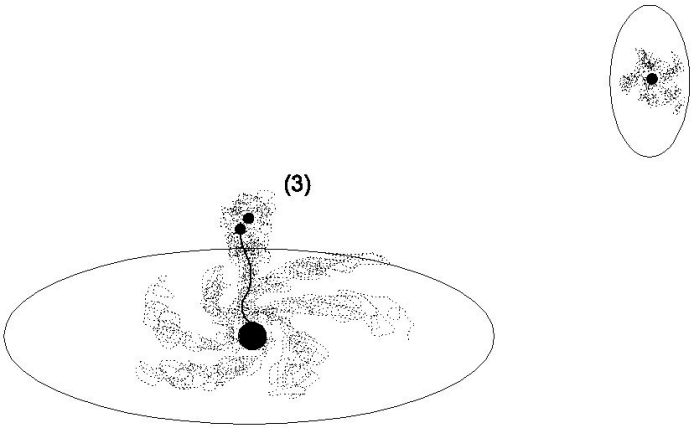
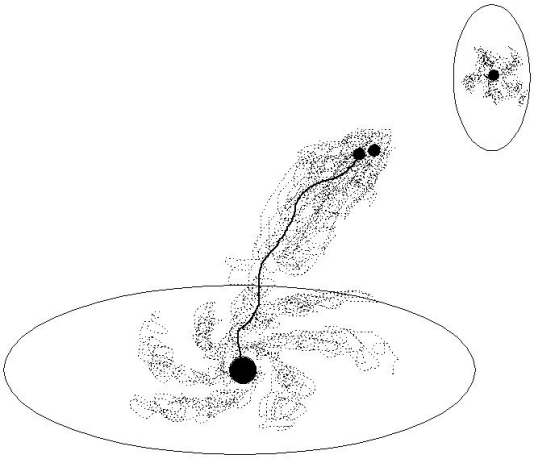
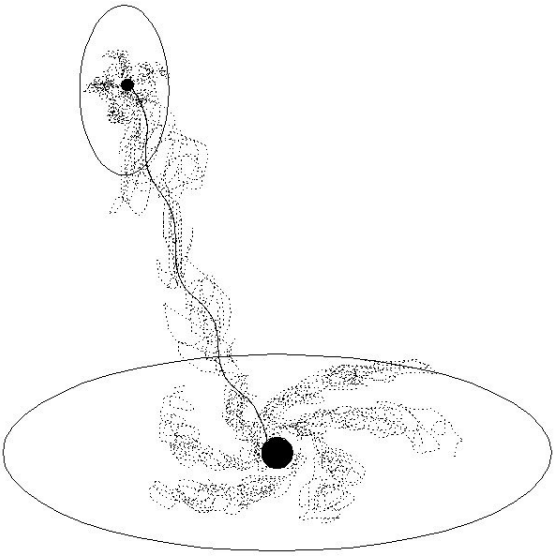


The tidal gravitational effects due to an approaching galaxy provoke an excitation of the galaxy nucleus which emits a CERO. In the first times, the CERO is still attached to the emitting galaxy by a vortex tube.

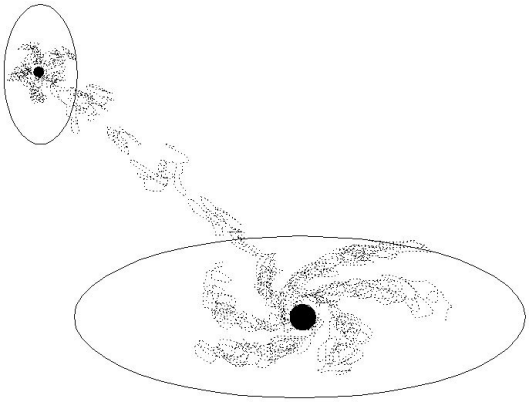


The CERO is gravitationally attracted by the approaching galaxy. As long as the CERO remains attached to the galaxy

it must be considered as a virtual cosmic photon. When the vortex tube stretches in the direction of its axis, it constricts itself in the transversal direction and the rotational speed in the tube increases. The centrifugal force grows too. A restoring force appears along the filament which tends to keep the filament close to the galaxy. Through this process the photon acquires some inertia. It is how the inertia of virtual photons can be explained.



The CERO is captured and absorbed by the nucleus of the second galaxy.



After some time, the vortex tube dissolves under the effect of dynamical viscosity.

One understands now why in galaxy couples it is possible to have large differences in size and mass. During an exchange, a large quantity of gas is transferred from one galaxy to the other. The galaxy which receives becomes more massive and so more attractive. During a second exchange there is a good chance that the mass transfer will proceed in the same sense. So one galaxy will become progressively more massive.

7.7 Confirmation of the exchange model

As an argument in favour of the exchange model, let us examine the galaxy NGC7603 and its companion.

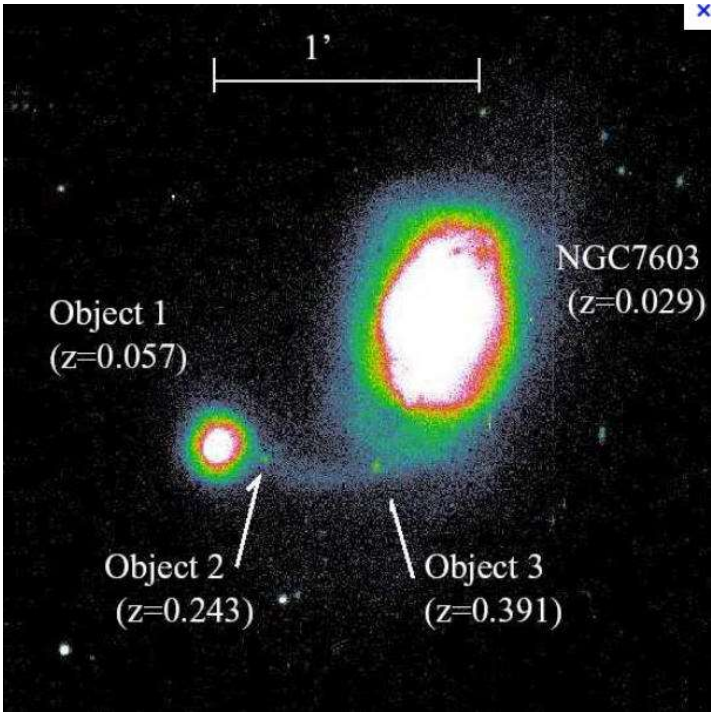
They are two galaxies of rather different redshift linked by a luminous bridge. Moreover, inside the filament one distinguishes two much smaller compact objects.

This group has been studied by Arp in 1973 who was able to give the redshifts of the two galaxies. The one from NGC7603 is $z = 0.029$ and the one from the companion is $z = 0.057$. It is already extraordinary to find two objects of so different redshifts manifestly linked by a material bridge.

In 2002, two Spanish astronomers (Lopez-Corredoira and Gutierrez, 2002) have been allowed to study this system with the NOT telescope of Las Palma. They could take the spectrum and the redshift of the two compact objects located in the luminous bridge.

The spectra are rather similar to those of HII galaxies (containing excited molecular hydrogen). The redshifts are important.

On the picture below, the redshifts of the four objects have been indicated. At this time, it is our best proof that objects with very different redshifts can be connected. This implies obviously that the redshifts have a non-cosmological component. Even if the theory of these discordant redshifts has not yet been established, it must be realised that there is a big problem if one insists to keep the hypothesis of puely cosmological redshifts.



Let us notice that the redshift of the filament has been measured and that it is equal to the one of NGC7603, a further proof that it has been emitted by the galaxy.

The two compact objects are temporarily classified as HII galaxies. But considering that they are at the distance of the galaxies, that they are extremely compact and that they have high redshifts with respect to the galaxies, it is very unlikely that they are ordinary galaxies. In all cases, they are good CERO candidates.

The disposition of these objects indicates the possibility of a CERO exchange by the two galaxies, along the luminous bridge.

A catalogue of peculiar galaxies has been prepared by Arp (Arp, 1966). It contains several pictures strongly suggestive of an exchange along a luminous bridge.

We notice that the very long stretched jets which join these galaxies do not look like spiral arms teared off in a collision. Here the filaments remain extremely well collimated on their whole length, and they go directly from the centre of a galaxy to the centre of the other galaxy. These are jets, not spiral arms.

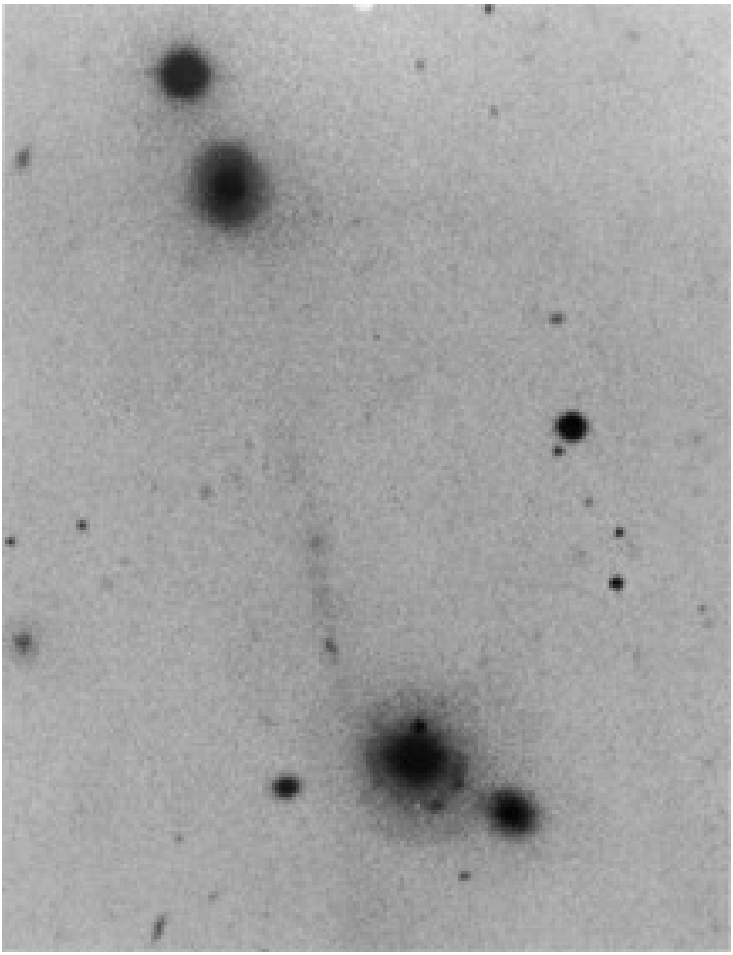


Figure 44: Arp 103 in the catalogue (Arp, 1966). Notice the two compact objects in the filamentt. It would be interesting to get their redshift.

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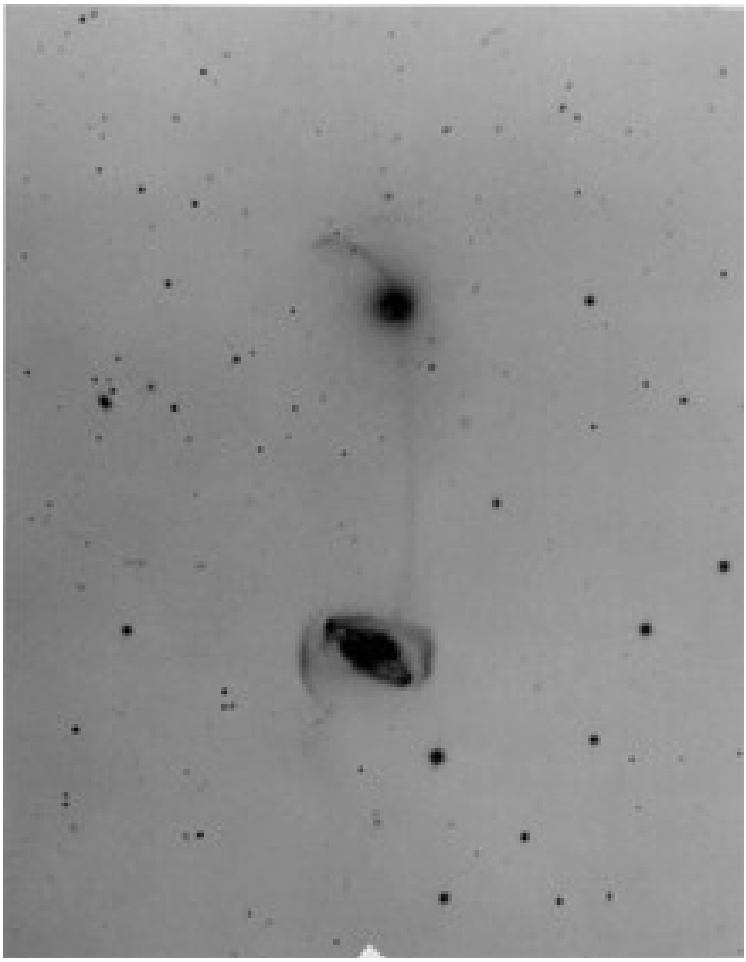

Figure 45: Arp 104 in the catalogue (Arp, 1966). The jet is perpendicular to the spiral arm.

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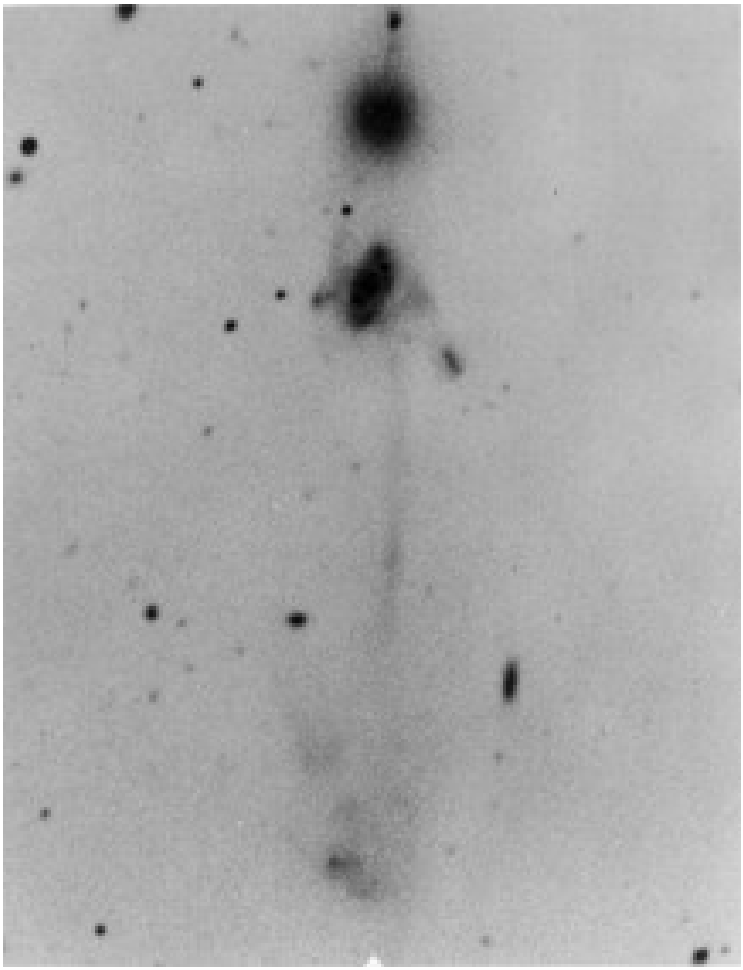

Figure 46: Arp 105 in the catalogue (Arp, 1966). The extraordinary jet below is not manifestly directed towards a particular galaxy. What is interesting here is the small jet between the two galaxies.

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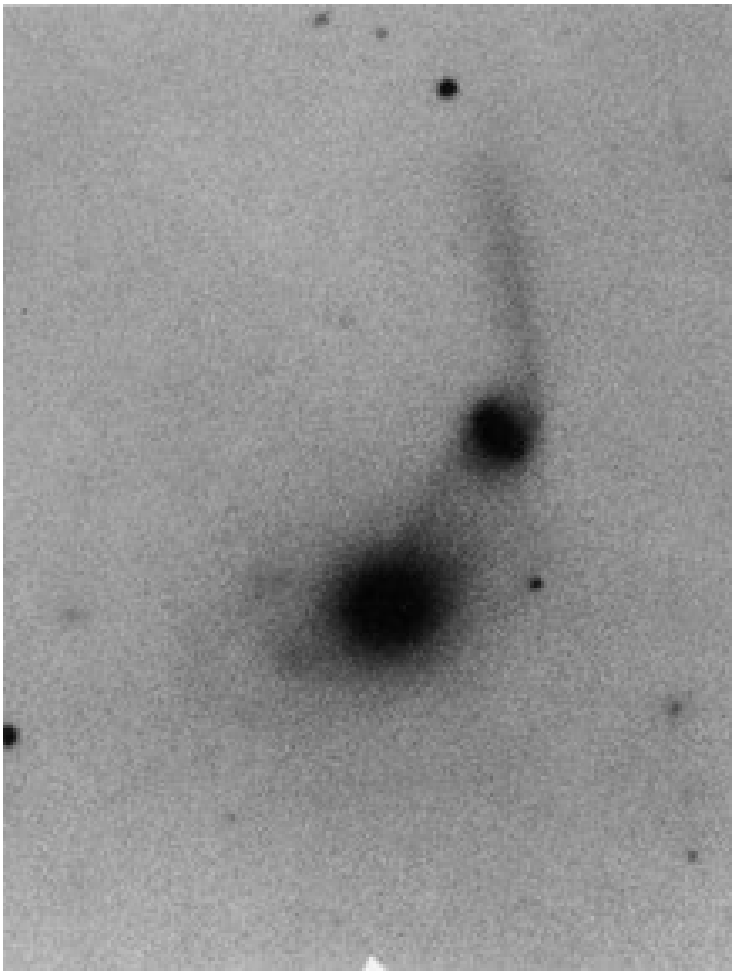

Figure 47: Arp 106 in the catalogue (Arp, 1966)

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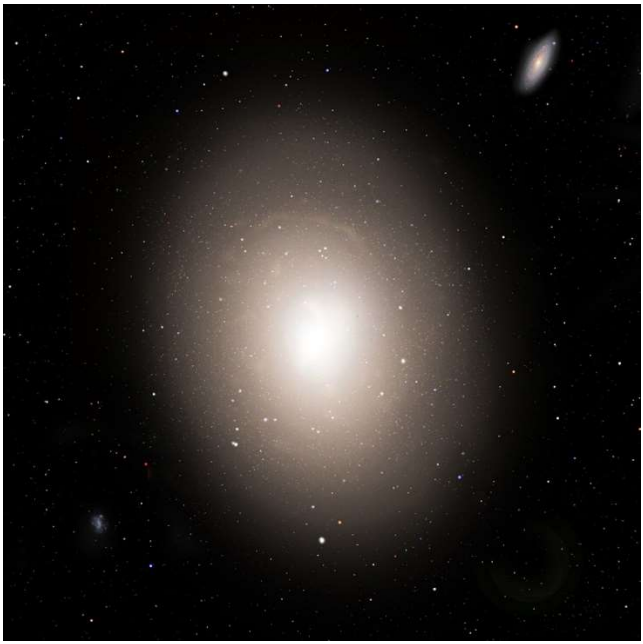
7.8 Cosmic atoms and molecules

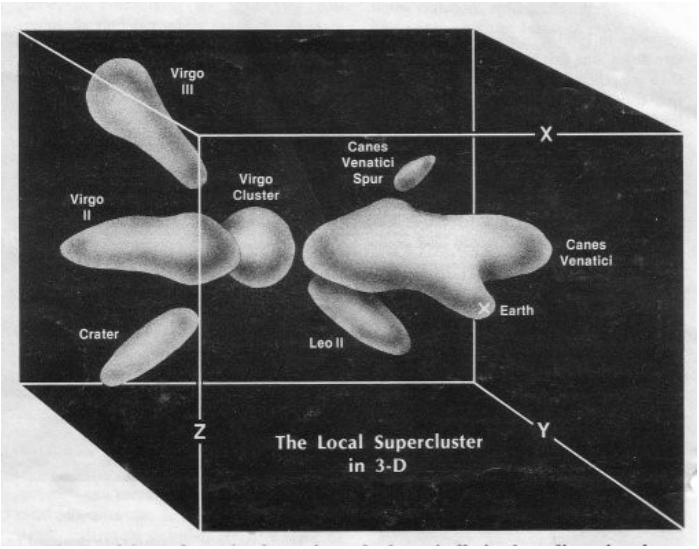
If electrons are represented by spiral galaxies on the cosmic scale, what about neutrons and protons ? Elliptical galaxies appear as excellent candidates.



Logically, there should exist also atoms and molecules on the cosmic scale. Our first example above shows a large elliptical galaxy with a spiral in the vicinity. If we identify the elliptical with a proton and the spiral with an electron, we have an example of a hydrogen atom on the cosmic scale.

As second example, see below the Virgo cluster of galaxies. The central part is occupied by ellipticals and the periphery with spirals.

As third evidence, let us examine the local super cluster. Iso-density curves have been traced by Tully and Fischer and this gave the figure below. The left part suggests a CH_3 group, with the Virgo cluster at the centre, and the extensions Virgo III, Virgo II and Crater for the three C-H bonds.



In this interpretation, the Virgo cluster at the centre must contain a Carbon atom of the cosmic scale, with 6 protons and 6 neutrons. And in fact, the Virgo cluster contains precisely 12 elliptical galaxies (Arp, 1998, p118) of which at least four are active. Following our fractal principle, these four galaxies must represent protons. The 12 galaxies are more or less aligned on a line (Arp, 1987, p.141).

To comfort this hypothesis would require much work. We should dispose for this of a galaxy catalogue with distances independent of redshift.

8 Fudamental constants

8.1 Length, time, mass… scales

We are going to use at the maximum the fractal hypothesis in this chapter, in order to detect what are the true fundamental constants of physics. This is a summary of my paper (Driessen, 1994). Firstly, the scales are established for distances, durations, speeds, masses, … For distances we have found three different methods to determine the scale factor between galaxies and particles: the Bohr orbit radius, the de Broglie wavelength and the compared size of spiral galaxies and electrons. The average of the three measures gives a length scale of :

$$\Lambda_L = 2.4\ 10^{34}\ .$$

This means for example that the galaxy radius is about $2.4\ 10^{34}$ times larger than the electron radius.

For durations, one has found only one evaluation method: the CERO ejection period for spiral galaxies has been compared to the Zitterbewegung period of the electron (this oscillation which is supposed to be due to the flip-flop ejection of virtual photons).

The CERO ejection period has been measured by supposing that each spiral goes through excitation periods (Seyfert phases) during which CERO's are emitted, and by estimating the periodicity of these phases.

After a rapid calculation one obtains $T \sim 6.34\ 10^7$ (Driessen, 1994) years between each Seyfert phase. Comparing with the Zitterbewegung time ($6.44\ 10^{-22} s$), we get

$$\Lambda_T = 3.11\ 10^{36}.$$

It should be noticed that the scale constant for durations differs from that for lengths. There is thus a speed scale which differs from 1. By simple division one obtains this speed scale factor as $\Lambda_V = \Lambda_L / \Lambda_T = 1/127$. This factor determines for example the ratio of light speed between two scales. In that case, Λ_V should logically become one a-dimensional constant of the same importance as the fine structure constant α. But Λ_V is strangely close to $\alpha = \frac{e^2}{\hbar c} \approx \frac{1}{137}$. It would be surprising to get two different universal constants of so close values. It is thus tempting to assume that one has exactly $\Lambda_V = \alpha$. In this case the CERO speed would be :

$$C = \Lambda_V\ c = 2354\ km\ s^{-1}$$

Which would represent lightspeed on the galaxy scale.

For the mass scale, one must compare the typical mass of a large spiral galaxy to the electron mass ($m = 9.109\ 10^{-28} g$). An average calculus on a statistic of about 100 galaxies (Driessen, 1994) leads to the value of $M_g = 1.43\ 10^{12} M_\odot$. One deduces from it

$$\Lambda_M = \frac{1.43\ 10^{12} M_\odot}{9.109\ 10^{-28} g} = 1.1\ 10^{72}$$

Now, let us compare angular momenta. These should be quantised in units of $\Lambda_J\ \hbar/2$. Since angular momenta have dimensions ML^2T^{-1} , one has $\Lambda_J = \Lambda_M{\Lambda_L}^2{\Lambda_T}^{-1} = 2.1\ 10^{104}$, and thus $\mathrm{H}/2 = \Lambda_J\ \hbar/2 = 0.55\ 10^{77} gcm^2s^{-1}$. This is the basic value of the angular momentum of the spiral and the elliptical galaxy. It is a very high value and as for the mass one can say that there is a very high missing angular momentum problem. The whole mass of galaxies is not sufficient to account for the angular momentum.

8.2 The exchange force

The three fundamental constants are e, $\hbar$ and c. They form a complete set in the sense that one single a-dimensional constant can be formed from them, that is; the fine structure constant

$$\alpha = \frac{e^2}{\hbar c}$$

But in the fractal universe, one can define three other constants on the galaxy scale:

- The charge of the CERO exchange force : E
- The basic angular momentum : H
- The CERO speed : C

H and C have already been determined. The galactic charge E which represents the CERO exchange force, can be evaluated starting from the scaling law between E and e :

$$E^2 = \left(\Lambda_M{\Lambda_L}^3{\Lambda_T}^{-2}\right)e^2 = {\Lambda_E}^2 e^2$$

$$\Lambda_E{}^2 = \Lambda_M \Lambda_L{}^3 \Lambda_T{}^{-2} = 1.64\ 10^{102}$$

$$E^2 = 3.79\ 10^{83}\ g\ cm^3\ s^{-2}$$

E,H and C constitute a new set of constants for the galactic scale, linked by the same constraint :

$$\alpha = \frac{E^2}{HC}$$

E gives an absolute measure of the exchange force, but it would be more interesting to be able to compare it to the gravitational force. It is thus time to introduce gravitation in our schema. It is traditionally defined by the constant $G_{(1)} = 6.67\ 10^{-8}\ cm^3 g^{-1} s^{-2}$, well validated on the solar system scale, and which is such that two masses m and M at distance r are submitted to a force (in module):

$$F = G_{(1)} \frac{Mm}{r^2}$$

Let us note that G depends on dimensions [L], [M], and [T]. Moreover, the fact that $G_{(1)}$ may remain constant across a large scale of distance, time and mass, is more and more doubted. We suggest that two new constants of gravitation be defined:

- $G_{(0)} = g$, where gm^2 measures the gravitational interaction intensity between two electrons (situated at unit distance, on the particle scale).

- $G_{(2)} = G$ where GM^2 measures the gravitational interaction intensity between two spiral galaxies (situated at unit distance on the galaxy scale).

A measure of the exchange force is the a-dimensional ratio

$$\gamma = \frac{e^2}{gm^2} = \frac{E^2}{GM^2}$$

The difficulty is that there is no simple way to relate $G_{(1)}$ which is measured on the solar system scale, to $G_{(2)}$ of the galactic scale, and to $G_{(0)}$ on the particle scale.

There exists nevertheless a direct way to surmount this difficulty. In Einstein's theory, one has the relationship:

$$R_{(1)BH} = \frac{2G_{(1)}M_{(1)BH}}{c^2}$$

One can suppose that such relations can exist on the galactic and particle scale

$$R_{(0)BH} = \frac{2gM_{(0)BH}}{c^2}$$
$$R_{(2)BH} = \frac{2GM_{(2)BH}}{C^2}$$

One suspects also that electrons and spiral galaxies have the same structure. In this case, the classical electron and galaxy radius are written:

$$R_{(0)CL} = \frac{e^2}{mc^2} = r_0$$
$$R_{(2)CL} = \frac{E^2}{MC^2} = R_0$$

Let us compute then

$$\frac{R_{(2)G}}{R_{(2)BH}} = \left(\frac{E^2}{MC^2}\right)\left(\frac{C^2}{2GM_{(2)BH}}\right) = 0.5\left(\frac{E^2}{GM^2}\right)\left(\frac{M}{M_{BH}}\right)$$

One obtains

$$\gamma = \frac{E^2}{GM^2} = 2\left(\frac{R_{(2)G}}{R_{(2)BH}}\right)\left(\frac{M_{BH}}{M}\right)$$

The first ratio $R_{(2)G}/R_{(2)BH}$ can be evaluated approximately. Variations of radiation of less than one half hour have never been observed in active galaxies. This implies a limit of about 3.6 astronomical units (au) for the region emitting plasma. And it is generally admitted that the maximum radiation zone issued from the accretion disk comes from a zone at about three Schwarzschild radii from the centre. Thus we will formulate the hypothesis that the black hole radius is of the order of 1 au. For the galaxy radius, we base ourselves on a list of a hundred spiral galaxies for which we have calculated an average radius of $12{,}65\ kpc$. The ratio becomes :

$$\left(\frac{R_{(2)G}}{R_{(2)BH}}\right) = \frac{12{,}65\ kpc}{1\ au} = 2.61\ 10^9$$

For the second ratio (M_{BH}/M), one notes a rather large spread of possible values for M_{BH}, from 10^6 to $10^8 M_\odot$, with a most probable value of $510^6 M_\odot$ and for M an average value of $5.510^{11} M_\odot$. Finally, one finds

$$\gamma = \frac{E^2}{GM^2} = 5.22\ 10^4$$

The interaction by CERO exchange is stronger than the gravitational interaction ! A spiral galaxy gas will thus behave essentially as an electron gas, in agreement with the fractal hypothesis. It should be noted that the exchange force must be repulsive between spiral galaxies, if the analogy with particles is correct. Conversely, the interaction between an elliptical and a spiral galaxy must be attractive, and is responsible for the cluster cohesion. It could eventually explain the missing mass in clusters.

Starting from γ we can determine

$$G = \frac{E^2}{\gamma M^2} = 7.34\ 10^{-12} cm^3 g^{-1} s^{-2}$$

$$g = \frac{e^2}{\gamma m^2} = 5.33\ 10^{30} cm^3 g^{-1} s^{-2}$$

These are the gravitational « constants » at the galactic and the particle scales. It is supposed that on each scale the value remains essentially constant on a large spread of dimensions, and that between the scales, the values evolve much more rapidly so that they can meet.

The existence of g had already been predicted by Oldershaw (1987), with a value of $1.85\ 10^{31} cm^3 g^{-1} s^{-2}$. He has shown that the theories of strong gravity furnish essentially the same result (Sivaram et Sinha, 1979).

The blach-hole radius at the electron centre can now be found

$$R_{(0)BH} = \frac{2gM_{(0)BH}}{c^2} = \frac{2gm}{c^2}\left(\frac{M_{(0)BH}}{M_{(0)}}\right) = 1.08\ 10^{-22} cm$$

where one has supposed that $\frac{M_{(0)BH}}{M_{(0)}} = \frac{M_{(2)BH}}{M_{(2)}} = 10^5$.

8.3 The gravitational constant

One sign of a successful unification is that the theory can contain only one single a-dimensional constant (Georgi and Glashow, 1974; Wesson, 1981). There are indications that $\alpha = e^2/\hbar c$ can play this role.

Natural dimensions have been defined by Planck, as a function of the basic constants $\hbar$, c et $G_{(1)}$:

A mass : $M_{PL} = \left(\hbar c/G_{(1)}\right)^{1/2} = 2.18\ 10^{-5}\ g$

A length : $L_{PL} = \left(\hbar G_{(1)}/c^3\right)^{1/2} = 1.62\ 10^{-33}\ cm$

A time : $T_{PL} = \left(\hbar G_{(1)}/c^5\right)^{1/2} = 5.39\ 10^{-44}\ s$

It is a considerable surprise that they do not correspond to anything known. In particular, the mass of $10^{-5}\ g$ iss ridiculously large with respect to a particle mass. By contrast, the Planck length is incredibly small compared to the characteristic size of a particle. In the same way, the Planck time is 22 orders of magnitudes smaller than the Zitterbewegung time.

Our analysis shows that this is due to a bad value of the gravitational constant. We suggest to redefine two sets of constants :

At the particle level :

A mass : $m^* = (\hbar c/g)^{1/2} = 2.43\ 10^{-24}\ g$
A length : $l^* = (\hbar g/c^3)^{1/2} = 1.44\ 10^{-14}\ cm$
A time : $t^* = (\hbar g/c^5)^{1/2} = 4.82\ 10^{-2}\ \ s$

At the galaxy level :

A mass : $M^* = (HC/G)^{1/2} = 1.34\ 10^{15}\ M_\odot$
A length : $L^* = (HG/C^3)^{1/2} = 114\ pc$
A time : $T^* = (HG/C^5)^{1/2} = 4.74\ 10^4\ an$

Let us consider those new Planck constants at the particle level. The mass m^* falls very close to the proton mass $m_p = 2.43\ 10^{-24}\ g$. So close that it is probably not by chance. A better adjusted model would probably furnish $m^* = m_p$. The length l^* is close to the Compton length $\lambda_p = \hbar/m_p\ c = 2\ 10^{-14}\ cm$. The time t^* is nearly the Zitterbewegung time of the proton $t_p = \hbar/m_p\ c^2 = 7\ 10^{-25}\ s$. The last two results come directly from the hypothesis $m^* = m_p$.

In the same way, on the galactic scale, we find a mass close to the elliptical galaxy mass. For the time we find $T^* = 4.74\ 10^4\ an$, a time close to the CERO emission by the ellipticals (if we suppose that the emission periods are inversely proportional to the masses)

$$\frac{T^*_{ell}}{T^*_{spi}} = \frac{M^*_{spi}}{M^*_{ell}} = \frac{1}{1836}$$

$$T^*_{ell} = 6.34\ 10^7 an/1836 = 34\ 10^4 an$$

It should be noted that the Zitterbewegung time is inversely proportional to the mass, which justifies our hypothesis.

Finaly we obtain a length $L^* = 114\,pc$ which should represent the Compton length on the galactic scale.

It is clearly a good point of the fractal model that the theoretically defined Planck constants are so close to well known physical values.

By inverting the relation of the Planck mass on the particle scale one finds

$$g = \frac{\hbar c}{(m^*)^2} = \frac{\hbar c}{(m_p)^2}$$

If moreover one takes as units $\hbar = c = 1$, one obtains

$$g = \frac{1}{(m_p)^2}$$

g appears as a redefinition of the proton mass. It is the same for G and the average elliptical mass.

There remains then only three fundamental constants e, $\hbar$ and c from which one can define only one a-dimensional constant α.

9 Conclusions

Physics is going through a profound crisis which can only be resolved via the acceptation of decisive experimental observations, what we have been trying to develop here. We have built a particle model starting from well known

observations, rather than beginning from a theoretical prejudice, like in string theory. We so arrived at a rather sophisticated model, but whose mathematization should not pose insurmountable problems. By comparison, string theory starts from a simplistic model of microscopic strings vibrating in the vacuum, but whose mathematization is excessively complex.

The fractal hypothesis has allowed us to establish a link between particles and galaxies. In particular we have shown that there exists an exchange interaction on the galaxy scale. Compact objects with a spectrum close to that of quasars and possessing an excess redshift are ejected by the cores of galaxies and one supposes that they are recaptured by other galaxies. This force which is more intense than the gravitational interaction, must play a major role in the physics of galaxy clusters. It maybe could explain the missing mass at this level.

If the comparison between particles and galaxies can be extended further, what we will know after a time-consuming work, then we will dispose of a double laboratory to explore these levels. On the particle scale, events happen too fast and detailed visualisation is not possible, but in contrast we have large statistics. On the galactic scale, time is like frozen but we can look at interaction with a luxury of details. By combining the two, we should be able to progress fast in the comprehension of particle structures.

But many obstruction remain against such a program. In fact, when physicists will continue to submit to particular interests, they will be forced sooner or later to a denial of reality. So it goes for the redshift. While a single compelling experience such as the analysis of galaxy NGC7603 should suffice to eliminate definitively the purely cosmological

redshift hypothesis, many physicists still hang on to it, at the profit of a few at the summit of the pyramid, which have interest to conserve the s*tatus quo*.

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