Chapter 6:

The engendering of a chimera.

Back in 1916. In the previous pages, the excellent understanding of Schwarzschild's papers published by the young Ludwig Flamm and Schwarzschild's observation of the existence of physical criticality when a mass is confined to a certain volume were mentioned.

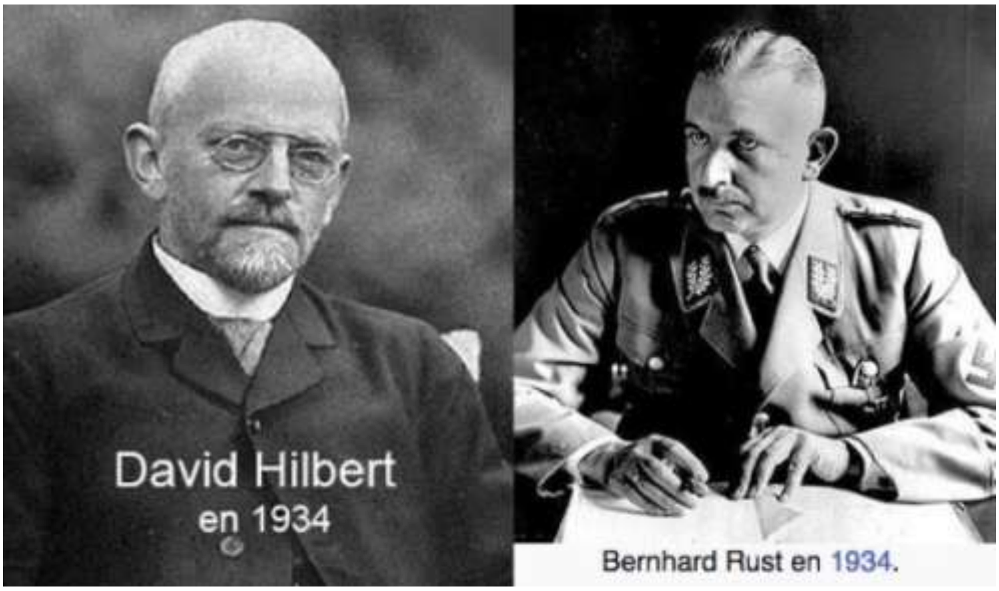
It is known that Albert Einstein had difficulties with mathematics. But above all he was an extraordinary physicist. So, when you put together Einstein, Schwarzschild, Flamm and a few others, you get what happens when you introduce into physics tools freshly constructed by mathematicians.

Conversely, Hilbert's writings reflect the opposite approach, when a mathematician ventures into the jungle of physics.

It is known that it was following numerous exchanges with Einstein that the mathematical genius that was David Hilbert understood that it could prove interesting to put some order into certain theoretical developments concerning physics. Hilbert collaborated for many years with the mathematician Richard Courant. The two of them joined forces to write a 1000-page treatise, published in 1924, entitled "Mathematical Methods of Physics", which was a landmark in its time. In this book they show how variational methods are ubiquitous in physics. But this collaboration ended with the departure of Courant for the United States who, of course, was Jewish.

About this diaspora of mathematicians and physicists, most often to the United States, let us quote an anecdote which is not without flavour.

When the University of Göttingen, where he held the prestigious chair of mathematics, was emptied of all its Jews, Hilbert could only observe what he soon saw as a real catastrophe. One day he is visited by Bernhardt Rust, Minister of Science. A fanatical Nazi who committed suicide in 1945. The following dialogue is reported:



Rust: Professor Hilbert, did your university suffer a lot from the departure of the Jews?

Hilbert: Nein, nein ...

Rust: Really! Didn't she suffer?

Hilbert: No, it doesn't exist anymore, that's all...

What happened to this new cosmology?

Einstein emigrated to the United States in 1933. He tried until his death, without success, to integrate electromagnetism into his cosmological model, dreaming of a "unified field theory".

As Schwarzschild died in 1916, what remains of his work? Hermann Weyl, like Flamm and others, envisaged that the external solution could be related to a topological view of the masses, if one decided to consider it as a kind of bridge bringing two space-time structures into communication.

Mathematical solutions of this kind [1] have the property of being able to be expressed a priori in multiple coordinate choices. But as these are solutions that we want to be linked to physics, they are subject to some constraints. One of them refers to boundary conditions, to infinity. The Schwarzschild outer solution reflects the structuring of the field around a mass. This gravitational field does not propagate to infinity At long distances, it can be considered as zero. The geometry must then correspond to that of a relativistic vacuum. It is then described by the Lorentz metric ;

$$ds^2 = c^2\,dt^2 - dx^2 - dy^2 - dz^2$$

A change of coordinates allows its expression in polar coordinates:

$$ds^2 = c^2\,dt^2 - dr^2 - r^2\,(\,d\theta^2 + \sin^2\theta d\varphi^2\,)$$

If an "outer solution" is expressed in a set of coordinates that appear close to these polar coordinates, then this expression (metric) will be asked to tend towards the Lorentz metric at infinity.

In 1934 Albert Einstein and Nathan Rosen [2] also venture into this attempt to describe particles through topology.

An article that can be downloaded at :

http://www.jp-petit.org/papers/cosmo/1935-Einstein-Rosen.pdf

[1] Qu'o appelle « des métriques »
[2] Cosignataire de l'article sur « le paradoxe d'Einstein, Podowlski-Rosen. » Maus ceci est une autre histoire.

JULY 1, 1935 PHYSICAL REVIEW VOLUME 48

The Particle Problem in the General Theory of Relativity

A. EINSTEIN AND N. ROSEN, *Institute for Advanced Study, Princeton*

(Received May 8, 1935)

The writers investigate the possibility of an atomistic theory of matter and electricity which, while excluding singularities of the field, makes use of no other variables than the $g_{\mu\nu}$ of the general relativity theory and the φ_μ of the Maxwell theory. By the consideration of a simple example they are led to modify slightly the gravitational equations which then admit regular solutions for the static spherically symmetric case. These solutions involve the mathematical representation of physical space by a space of two identical sheets, a particle being represented by a "bridge" connecting these sheets. One is able to understand why no neutral particles of negative mass are to be found. The combined system of gravitational and electromagnetic equations are treated similarly and lead to a similar interpretation. The most natural elementary charged particle is found to be one of zero mass. The many-particle system is expected to be represented by a regular solution of the field equations corresponding to a space of two identical sheets joined by many bridges. In this case, because of the absence of singularities, the field equations determine both the field and the motion of the particles. The many-particle problem, which would decide the value of the theory, has not yet been treated.

Reading the summary one immediately understands the origin of the motivation of all those who try to model particles in a topological way. A mass generates a gravitational field. An electric charge generates an electric field. Both are Newtonian, in 1/r2. If the particles are assimilated to points these fields become infinite. By giving these particles a different topology, these infinities disappear.

Einstein and Rosen use a very simple change of variable [3] :

$$(t , r , \theta , \varphi) \rightarrow (r , u , \theta , \varphi)$$

$$r = R_s + u^2$$

Note that this change of variable materializes the constraint

$$r > R_s$$

In the abstract, we find the sentences:

"These solutions imply a mathematical representation of the space of physics as a space consisting of two identical sheets, with a particle constituting a kind of bridge connecting these two sheets".

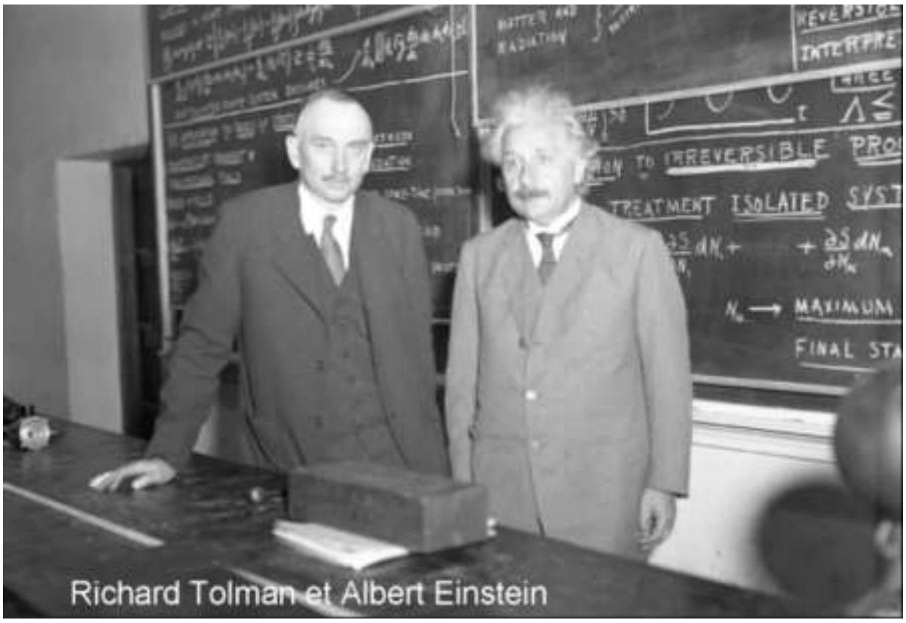
How are the essays of different scientists passed on? These are first published in specialist journals. Today English is the common language, but in Schwarzschild's time the Germans published their work in German, in German-speaking journals, whose readership was limited to the German-speaking world.

---

[3] Mais en transformant ainsi la solution de Schwarzschild on notera que son expression ne s'identifie plus avec la métrique de Lorentz à l'infini.

The authors of these articles then had "offprints", i.e. a certain number, usually limited to a dozen, of sets of printed sheets representing their article. They could then send these copies of their article to correspondents by post.[4]

When Einstein arrived in the United States in the early 1930s, he was a carrier, so American scientists who read German could read his work.[5] Among these readers, two characters will play an essential role. First, there is the mathematician Richard Tolman, who will get this information directly from Einstein himself.



Richard Tolman et Albert Einstein

When Einstein moved to the United States, accepting a position at the prestigious Princeton Institute of Advanced Science, he was 54. Tolman is 52 years old.

So Tolman already has a large part of his scientific career behind him. In the 1930s he completed a book on thermodynamics. He then decided to add these aspects of cosmology to his manuscript. The book was published in 1934:

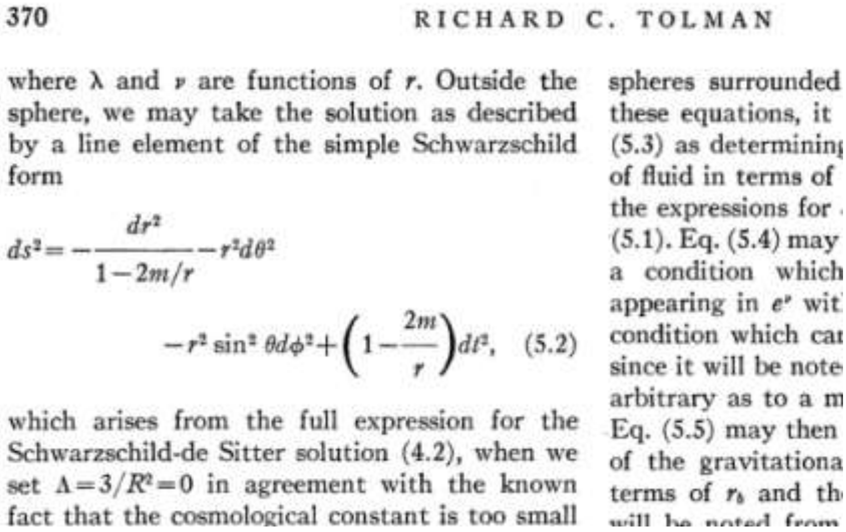
In this book Tolman only mentions the first Schwarzschild solution, the one that describes the geometry outside the masses He then replaces the letter a , denoting the Schwarzschild length, with 2m, remembering that the letter m this time denotes length, not mass. In fact this way of writing this quantity amounts to replacing the gravitational constant G and the speed of light c by the unit.

$$R_s = \frac{2Gm}{c^2} \longrightarrow 2m$$

[4] Un système qui a été la règle, tant que le système de messagerie électronique ne lui a pas été substitué.

[5] Rappelez-vous que la traduction anglaise du premier article de Schwarzschild n'a été disponible, dans des ouvrages publiés par une maison d'édition, qu'en 1975. Pour le second article, celui de février 1916, il faudra attendre 1999.

He then makes a mistake that will not be without consequences. Not only does he replace Schwarzschild's "intermediate quantity" R with the letter r, but he fails to indicate the constraint that accompanies this change in notation.



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where λ and ν are functions of r. Outside the sphere, we may take the solution as described by a line element of the simple Schwarzschild form

$$ds^2 = -\frac{dr^2}{1-2m/r} - r^2 d\theta^2 - r^2 \sin^2\theta d\phi^2 + \left(1-\frac{2m}{r}\right)dt^2, \quad (5.2)$$

which arises from the full expression for the Schwarzschild-de Sitter solution (4.2), when we set $\Lambda = 3/R^2 = 0$ in agreement with the known fact that the cosmological constant is too small

spheres surrounded
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Tolman's mistake

It is indeed missing the mention :

An oversight that will have incalculable consequences for almost a century.

The second person to become familiar with these German writings is the young Robert Oppenheimer. In the early thirties he was not yet thirty years old. Born into a wealthy family, after brilliant studies in the United States, he stayed in Germany, precisely in the heart of theoretical physics at the time, at the University of Göttingen [6] where he acquires additional theoretical knowledge. Like Tolman, he reads and speaks fluent German. In Germany he completed his doctoral thesis under the supervision of the physicist Max Born (who was the same age as him). Then he returned to the United States.

[6] A cette époque, celui qui veut se plonger dans les travaux de physique et de cosmologie doit impérativement maîtriser la langue allemande.

Oppenheimer and Einstein.

Tolman's book will have a considerable impact in the United States. Acquired by all university libraries, it immediately becomes the Bible for those who undertake to study cosmology.

Tolman and Oppenheimer then published articles in the same Physical Review magazine, in the same issue of 15 February 1939, in which they took up the inner solution developed by Karl Schwarzschild. In fact, they know each other and rather than publish an article together, and rather than compete with each other, they decide to publish their own article, in the same journal, on the same date.

Here is Tolman's article first:

FEBRUARY 15, 1939 PHYSICAL REVIEW VOLUME 55

Static Solutions of Einstein's Field Equations for Spheres of Fluid

Richard C. Tolman
Norman Bridge Laboratory of Physics, California Institute of Technology, Pasadena, California
(Received January 3, 1939)

A method is developed for treating Einstein's field equations, applied to static spheres of fluid, in such a manner as to provide explicit solutions in terms of known analytic functions. A number of new solutions are thus obtained, and the properties of three of the new solutions are examined in detail. It is hoped that the investigation may be of some help in connection with studies of stellar structure. (See the accompanying article by Professor Oppenheimer and Mr. Volkoff.)

§1. Introduction

It is difficult to obtain explicit solutions of Einstein's gravitational field equations, in terms of known analytic functions, on account of their complicated and nonlinear character. Even in the physically simple case of static gravitational equilibrium for a spherical distribution of perfect fluid, there are only two explicit solutions which are at present well known. These are Einstein's original cosmological solution for a uniform distribution of fluid with constant density ρ and constant pressure p throughout the whole of space, and Schwarzschild's so-called interior solution for a sphere of incompressible fluid of constant density ρ and a pressure p which drops from its central value to zero at the boundary.[1] To these, by regarding empty space as the limiting case of a fluid having zero density and pressure, we can also add de Sitter's cosmological solution for a completely empty universe, and Schwarzschild's so-called exterior solution for the field in the empty space surrounding a spherically symmetrical body, thus giving four solutions in all.

The present paper has a twofold purpose. In the first place, a method will be given for treating

[1] In addition to these explicit solutions for a spherical distribution of fluid, we also have Lemaitre's interesting explicit solution for a spherical distribution of solid, each concentric layer of which supports its own weight by purely transverse stresses. See Eq. (5.11), Ann. de la Soc. Scient. de Bruxelles **A53**, 51 (1933).

http://www.jp-petit.org/papers/cosmo/1939-Tolman/pdf

Then Oppenheimer's, published with George Volkoff.

FEBRUARY 15, 1939 PHYSICAL REVIEW VOLUME 55

On Massive Neutron Cores

J. R. Oppenheimer and G. M. Volkoff
Department of Physics, University of California, Berkeley, California
(Received January 3, 1939)

It has been suggested that, when the pressure within stellar matter becomes high enough, a new phase consisting of neutrons will be formed. In this paper we study the gravitational equilibrium of masses of neutrons, using the equation of state for a cold Fermi gas, and general relativity. For masses under $\frac{1}{3}\odot$ only one equilibrium solution exists, which is approximately described by the nonrelativistic Fermi equation of state and Newtonian gravitational theory. For masses $\frac{1}{3}\odot < m < \frac{3}{4}\odot$ two solutions exist, one stable and quasi-Newtonian, one more condensed, and unstable. For masses greater than $\frac{3}{4}\odot$ there are no static equilibrium solutions. These results are qualitatively confirmed by comparison with suitably chosen special cases of the analytic solutions recently discovered by Tolman. A discussion of the probable effect of deviations from the Fermi equation of state suggests that actual stellar matter after the exhaustion of thermonuclear sources of energy will, if massive enough, contract indefinitely, although more and more slowly, never reaching true equilibrium.

I. Introduction

For the application of the methods commonly used in attacking the problem of stellar structure[1] the distribution of energy sources and their dependence on the physical conditions within the star must be known. Since at the time investigation would afford some insight into the more general situation where the generation of energy is taken into account. Although such a model gives a good description of a white dwarf star in which most of the material is supposed to be in a degenerate state with a zero point energy

http://www.jp-petit.org/papers/cosmo/1939-Oppenheimer-Volkoff.pdf

Tolman's paper focuses on the mathematical aspect of the solution. In the chosen form of the metric, both the outer and the inner metric, Tolman reduces the problem to the determination of two unknown functions of the variable r :

λ (r) et ν (r)

These two functions are the exponents of two exponential functions present in the solution:

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In the first place, since the condition of gravitational equilibrium for a fluid will on physical grounds be a static and spherically symmetrical distribution of matter, we can begin by choosing space-like coordinates r, θ and ϕ, and a time-l coordinate t such that th lution will be descr d by the simple form of e element

$$ds^2 = -e^{\lambda}dr^2 - r^2 d\theta^2 - r^2 \sin^2\theta d\phi^2 + e^{\nu}dt^2, \quad (2.2)$$

with λ and ν functions of r alone, as is known to be possible in the case of any static and spherically symmetrical distribution of matter. With the simple expressions for the gravitational potentials appearing in (2.2), the application of the field equations (2.1) then leads to the following expressions for the only surviving components of

The same approach is taken by Oppenheimer and Volkoff:

II. Relativistic Treatment of Equilibrium

It is known[5] that the most general static line element exhibiting spherical symmetry may be expressed in the form

$$ds^2 = -e^{\lambda}dr^2 - r^2 d\theta^2 - r^2 \sin^2\theta d\phi^2 + e^{\nu}dt^2, \quad \lambda = \lambda(r), \quad \nu = \nu(r). \quad (1)$$

If the matter supports no transverse stresses and has no mass motion, then its energy momentum tensor is given by[6]

Exponential functions are strictly positive. Thus Tolman, Oppenheimer and Volkoff implicitly express the invariance of the signature of the solution (the sequence of signs of its component terms). The solution therefore shows the equation of state, the evolution of the pressure inside the star, as a differential equation [7].

The year is 1939. The neutron was discovered in 1932. It was soon imagined that massive stars could evolve into neutron stars. In their article Oppenheimer and Volkoff question the stability of such objects. This led Robert Oppenheimer to publish a second article with Hartland Snyder a few months later, in September 1939:

http://www.jp-petit.org/papers/cosmo/1939-Oppenheimer-Snyder.pdf

SEPTEMBER 1, 1939 PHYSICAL REVIEW VOLUME 56

On Continued Gravitational Contraction

J. R. OPPENHEIMER AND H. SNYDER
University of California, Berkeley, California

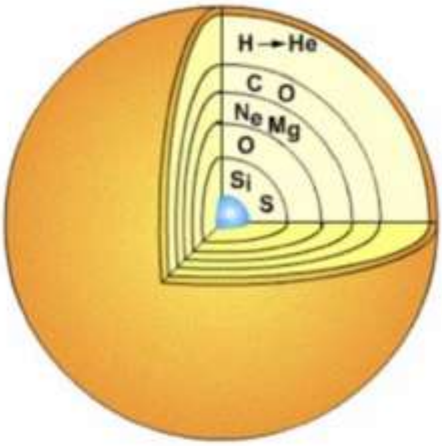
(Received July 10, 1939)

When all thermonuclear sources of energy are exhausted a sufficiently heavy star will collapse. Unless fission due to rotation, the radiation of mass, or the blowing off of mass by radiation, reduce the star's mass to the order of that of the sun, this contraction will continue indefinitely. In the present paper we study the solutions of the gravitational field equations which describe this process. In I, general and qualitative arguments are given on the behavior of the metrical tensor as the contraction progresses: the radius of the star approaches asymptotically its gravitational radius; light from the surface of the star is progressively reddened, and can escape over a progressively narrower range of angles. In II, an analytic solution of the field equations confirming these general arguments is obtained for the case that the pressure within the star can be neglected. The total time of collapse for an observer comoving with the stellar matter is finite, and for this idealized case and typical stellar masses, of the order of a day; an external observer sees the star asymptotically shrinking to its gravitational radius.

This paper is considered to be the founder of the black hole theory.

We have considered above the fate of a neutron star progressing, slowly but surely, towards physical criticality. Oppenheimer and Volkoff envisage a scenario seen from a more catastrophic and brutal angle. Let's take the scenario of the end of view of a massive star. During its lifetime it has synthesised heavier and heavier atoms, far beyond helium and carbon. . These heavier reaction products accumulated at depths depending on their masses. The star has thus acquired an onion-like structure.

[7] A laquelle on donnera le nom d'équation TOV (pour « Tolman-Oppenheimer-Volkoff »).



Internal structure of a massive star. In blue, its iron core.

As we go deeper into the star we first find helium, then oxygen and carbon. Then successively Neon, Magnesium, Sulphur and Silicon. The reactions leading to iron are the last to release energy. This iron behaves as an "ash" in fusion reactions.

Suddenly the star runs out of 'fusion fuel'. This shortage is extremely sudden. The system then behaves like a soufflé in an oven, whose heating has been abruptly interrupted by the cook, also by opening the oven door. Like a soufflé, the star collapses on itself, at a very high speed. All this matter will therefore hit the central iron core very hard.

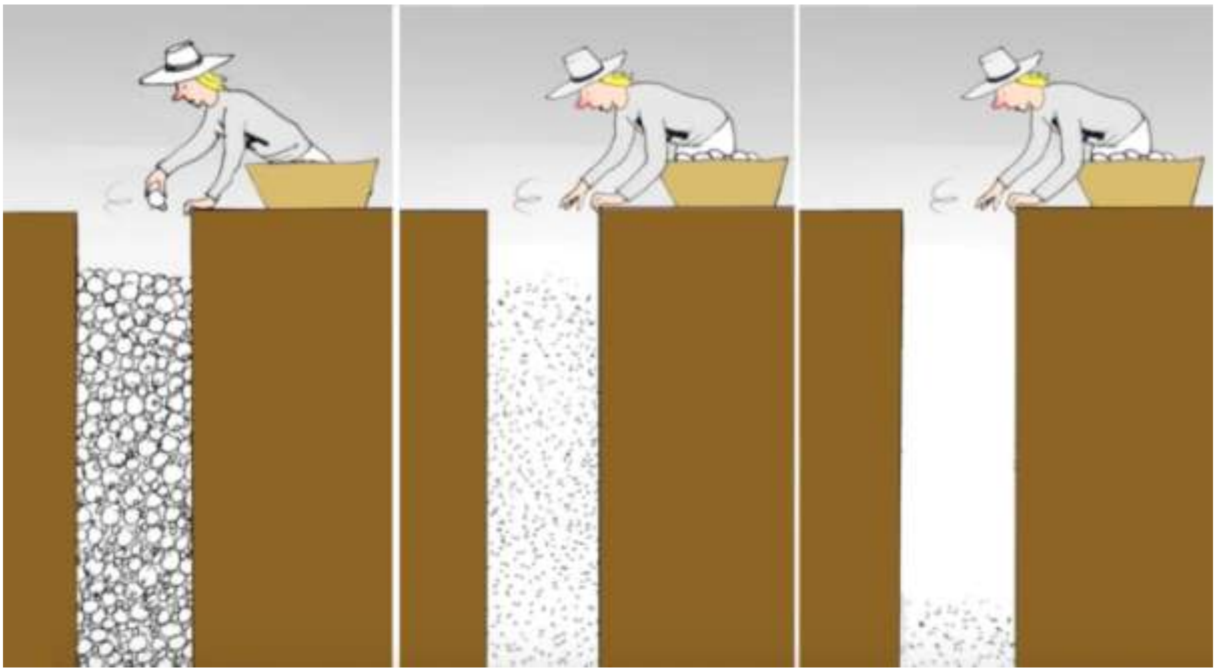
The shock is such that the iron atoms are immediately broken up into neutrons, protons and electrons. As the compression occurs, the electrons and protons disappear in the central part of the object.

But why isn't there a rebound?

Imagine tapping an iron block with a powerful hammer. This iron block will react. After experiencing the force of the impact it will react by giving your hammer a certain impulse, which will cause it to bounce. Blacksmiths witness this when they strike a piece of iron that has not yet acquired plasticity through heating.

But if you hit a block of clay, the hammer does not react. The kinetic energy of the hammer has been used to deform the block of clay. We are faced with inelastic compression. It will be the same with the compression of the iron core at the centre of the massive star. The kinetic energy corresponding to the almost free fall of the star's mass will not lead to a rebound, because the object formed in this way gets rid of the energy, which is then carried away by the neutrinos from the reaction. The latter, interacting very weakly with matter, can thus disperse this energy outside the star.

The neutron star forms when the neutrons exert sufficient back pressure on each other to prevent collapse. The didactic image is of a pile of light bulbs in a mine.



It is understandable that objects cannot be piled up against each other indefinitely. There will inevitably come a time when the glass of the bulbs can no longer withstand the pressure they exert on each other.

The situation envisaged by Oppenheimer and Snyder is therefore one in which a massive star undergoes a complete collapse, with no matter, even if it is reduced to neutrons, being able to oppose this movement of convergence towards the star's geometric centre. The model to which they refer is that of the collapse of a ball made of dust (where the particles are immobile in relation to each other, which amounts to neglecting the absolute temperature of this "gas" and therefore its pressure. The collapse is therefore tending to accelerate. The authors then assume that the geometry outside this collapsing star can be described by the Schwarzschild outer solution. Indeed, this solution will remain the same regardless of the degree of concentration of this mass M. It is this constant value of the mass that gives the characteristic quantity, the Schwarzschild length.

This raises the problem of conveying information to an external, distant observer. Let us consider this Schwarzschild solution as used for example by Tolman:

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where λ and ν are functions of r. Outside the sphere, we may take the solution as described by a line element of the simple Schwarzschild form

$$ds^2 = -\frac{dr^2}{1-2m/r} - r^2 d\theta^2 - r^2 \sin^2\theta d\phi^2 + \left(1-\frac{2m}{r}\right)dt^2, \quad (5.2)$$

which arises from the full expression for the Schwarzschild-de Sitter solution (4.2), when we set $\Lambda = 3/R^2 = 0$ in agreement with the known fact that the cosmological constant is too small

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Let's consider radial trajectories and let the speed of light reappear:

$$ds^2 = \left(1-\frac{2m}{r}\right) c^2 dt^2$$

$$\tau = \sqrt{1-\frac{2m}{r}}\; t$$

The same thing, at the same time t for an observer located at a great distance (r infinite):

$$\tau_o = t$$

Oppenheimer deduced that t is the proper time of a distant observer. However, in differential geometry, only the proper time is relevant, the coordinates being only means of locating the points in the hypersurface.

Here we discover the phenomenon of gravitational redshift. Time does not flow at the same rate in the vicinity of the masses: it flows more slowly. This is one aspect of general relativity that we can trust. Indeed, it has been experimentally verified for two points located at different distances from the centre of mass of the Earth [8] .

A distant observer, receiving a light beam emitted at distance r from a mass, with a wavelength , will perceive a signal of wavelength :

[8] Expérience menée à bien en 1960 par Pound et Rebka.

$$\lambda_o = \frac{\lambda_e}{\sqrt{1 - \frac{2m}{r}}}$$

If the signal is emitted at a point corresponding to the value r = 2m (from the Schwarzchild sphere, then the gravitational redshift effect is infinite. The object will appear to emit no light and appear "black".

Taking this reasoning further, Oppenheimer and Snyder say:

- No matter what happens inside this sphere, we cannot have any information about what happens inside, for example the collapse of a mass, totally destabilised.
-
- This Schwarzschild sphere is thus renamed "event horizon". They thus manage to use the external, stationary solution to describe a phenomenon that is in fact highly unsteady. Their calculation of the complete collapse of a star with a stellar mass in days. Going further they rely on the free fall time of a control mass to this Schwarzschild sphere. If this time, counted as proper time (a time attached to this witness mass) is finite, it becomes infinite if measured with the time coordinate t, which is then supposed to correspond to the proper time experienced by a distant observer.
-
- It will be shown much later that this measurement of time using the t-coordinate in this expression of the solution is based on an assumption that may have seemed natural: the absence of a drdt cross-term in the solution form. As shown by the French mathematician Pascal Koiran, this time becomes finite if we introduce this form of solution. We will postpone this discussion until later.
-
- During the Second World War Robert Oppenheimer turned away from these considerations of the end of life of massive stars to experimental verifications of quantum mechanics in spectacular outdoor experiments.


During this period Richard Toman was scientific advisor to General Leslie Groves, who was in charge of the Manhattan Project.

After the war Oppenheimer had little opportunity to return to these cosmological considerations. Indeed, given his reticence about the switch from the A-bomb to the H-bomb, he had a run-in with the American authorities. As for Tolman, he was ill and died in 1948 at the age of 67.

This is the time when scientists are taking up these questions of becoming massive neutron stars. At the centre of this revival is John Archibald Wheeler.

Wheeler was also an active participant in the Manhattan Project as a young theoretician familiar with quantum mechanics. Unlike Oppenheimer, he participated in the development of the thermonuclear weapon without qualms. At the time of the Vietnam War, which lasted until 1975, a Jason Committee was set up, in which scientists were asked to use their creativity to bring the conflict to a successful conclusion. Wheeler will take an active part in this committee, as will theoretical physicist Murray Gell-Man [9]. At the same time, Wheeler is involved in the development of future nuclear reactors for civilian applications.

Wheeler has held a professorship at the Princeton Institute for Advanced Study and has supervised 48 doctoral dissertations, including that of his student Kip THorne. His imagination knows no bounds, and he is active in many areas of science. A great communicator, he never forgets to put his ideas into words. In quantum mechanics, he invented the concept of "quantum foam". In geometry, he decided to give a name to the space of metric solutions, which became "geometrodynamics". But as soon as he became

[9] A qui l'on doit le modèle des quarks.

interested in the writings on general relativity, he renamed the Einstein-Rosen bridge "wormhole".

His attention then turned to the article published by Oppenheimer in 1939. His predecessors had coined the names "Schwarzschild body" or "collapsar". Wheeler immediately gave this theory the name "black hole" and it became a worldwide success.

At that time, and to this day, nobody pays attention to Schwarzschild's second article [10]. All of them got their start in the book published in 1934 by Richard Tolman. As a result, the formulation is written in all articles and books:

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where λ and ν are functions of r. Outside the sphere, we may take the solution as described by a line element of the simple Schwarzschild form

$$ds^2 = -\frac{dr^2}{1-2m/r} - r^2 d\theta^2 - r^2 \sin^2\theta d\phi^2 + \left(1-\frac{2m}{r}\right)dt^2, \quad (5.2)$$

which arises from the full expression for the Schwarzschild-de Sitter solution (4.2), when we set $\Lambda = 3/R^2 = 0$ in agreement with the known fact that the cosmological constant is too small

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arbitrary as to a m
Eq. (5.5) may then
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One question is on everyone's lips: Even today, very few 'black hole specialists' know of the existence of this second paper, even fewer who have had access to its contents, and none whose attention has been drawn to the variation in the speed of light discovered by Schwarzschild in 1916.

This collective madness affects all those who are interested in this new field, which is totally beyond observation.

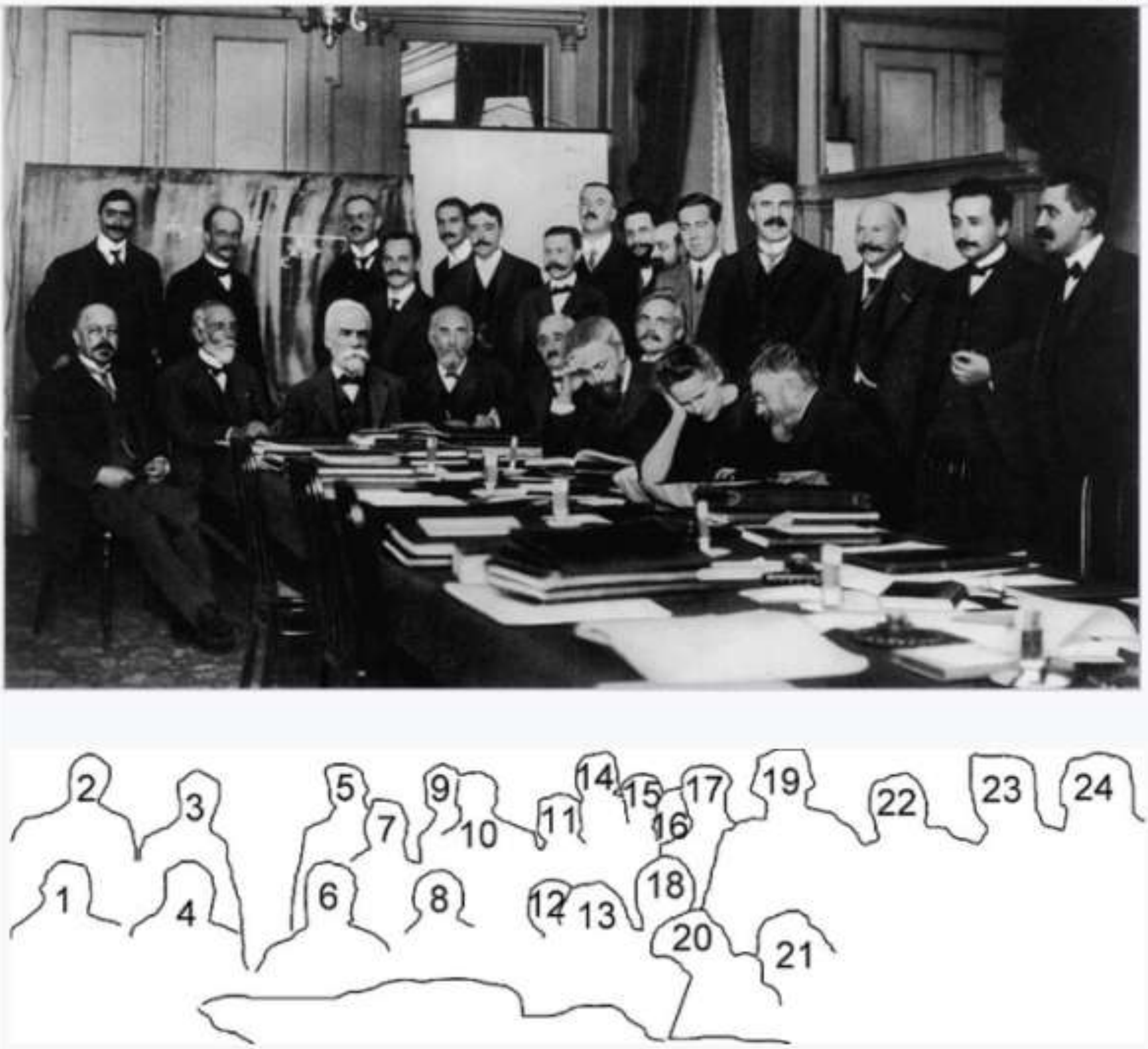
Before listing the aberrations that gave rise to the black hole model, which is a real chimera, it is worth mentioning the general situation of world theoretical research after the 1970s.

We are facing a global, widespread crisis.

To realise this, we need only ask ourselves which theorist of the present era will leave a name in the history of science?

[10] Lequel, rappelons-le, ne sera traduit en anglais qu’en 1999 !

Another important fact. In the previous period, a Solvay conference had been held since 1911. . The following are the participants of this first, historic congress:



1 Walther Nernst 2 Robert Goldschmidt 3 Max Planck 4 Marcel Brillouin 5 Heinrich Rubens 6 Ernest Solvay 7 Arnold Sommerfeld 8 Hendrik Antoon Lorentz 9 Frederick Lindemann 10 Maurice de Broglie 11 Martin Knudsen 12 Emil Warburg 13 Jean-Baptiste Perrin 14 Friedrich Hasenöhrl 15 Georges Hostelet 16 Édouard Herzen 17 James Hopwood Jeans 18 Wilhelm Wien 19 Ernest Rutherford 20 Marie Curie 21 Henri Poincaré 22 Heike Kamerlingh Onnes 23 Albert Einstein 24 Paul Langevin

Here is the 1927 congress, 16 years later:

Solvay Conference 1927

In this picture :

In the front row: Planck, Marie Curie, Lorentz, Einstein, Langevin.

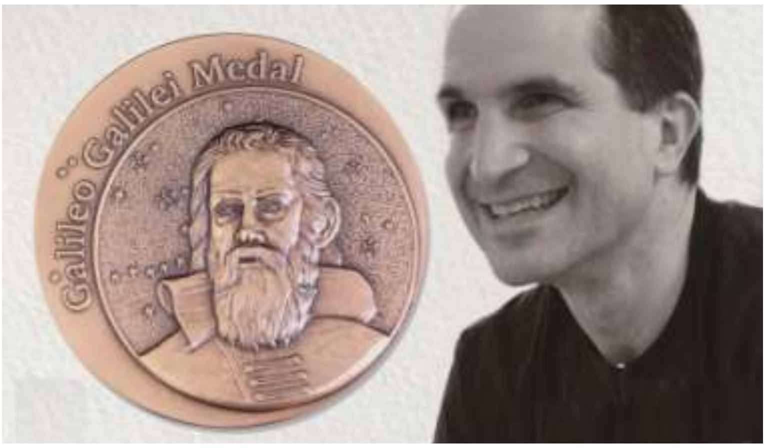
In the second row: Niels Bohr, Max Born de Broglie Compton, Dirac

In third place : Heisenberg, Pauli.

In the post-war period, a few more Solvay colloquia were held, of which no one had any memory, one of the last being on the theme of "the great problems of cosmology and astrophysics".

Today, these conferences have simply disappeared from the scientific scene.

Another sign: Look for the physicists at the Institute for Advanced Science in Princeton. You will find only a handful of string theory specialists. For cosmology: Juan Maldacena, a pioneer in this new discipline: the thermodynamics of black holes.



Juan Maldacena, Galileo Medal 2019

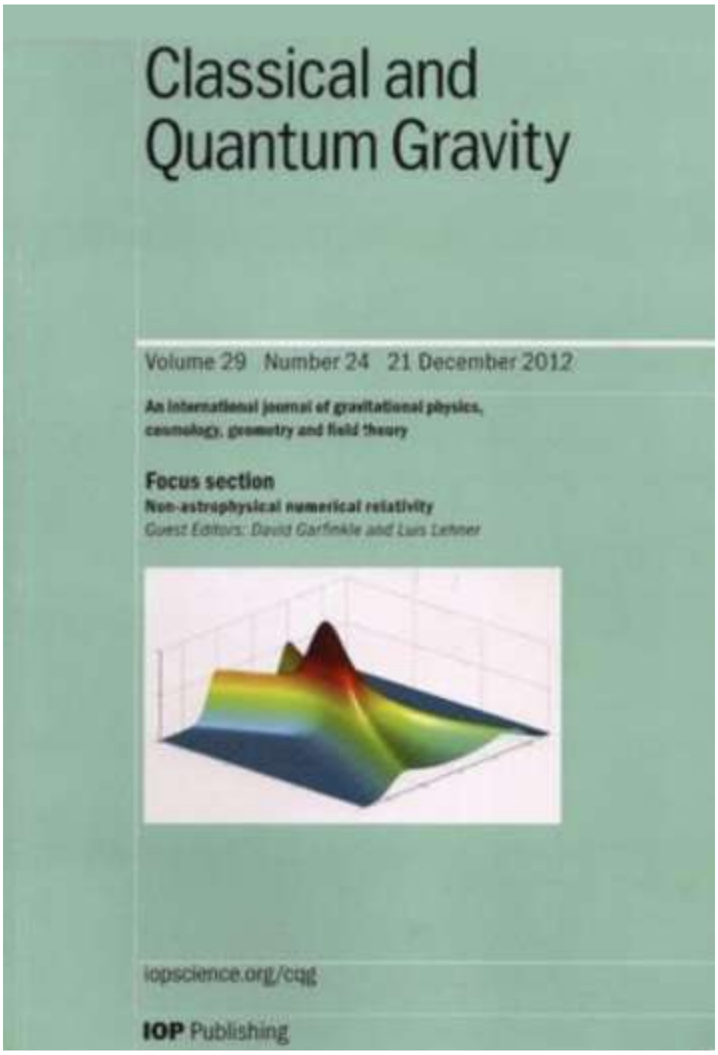
An institute that was headed from 2012 to 2022 by a Dutchman:

RobbertDijkgraaf, who headed the Princeton Institute for Advanced Science
Princeton's Advanced Science Institute from 2012 to 2022. Spinoza Prize 2003.

Author of 70 articles on string theory, back to his home country, at 62 he is Minister of Education and Culture.

The Princeton Institute of Advanced Science.
A sanctuary of science that God seems to have given up visiting.

Many theorists say they are working in a new field: quantum gravitation. A journal has even been created to publish advances in this field:



What is this new discipline? Let's find out. It has one goal: to unify gravitation and quantum mechanics. But this is only a project. Indeed, no one to date has managed to quantify gravitation [11] . In this sense this publication could be described as a ... journal project. But no. The articles are filtered by the new quantum gravitation specialists. Anything that does not meet the journal's strict selection criteria is immediately rejected.

What have the specialists in this new discipline produced in concrete terms? Nothing. It is reminiscent of the Hans Christian Andersen short story where a tailor creates clothes for the king that are so beautiful that only people of quality can see them. All the courtiers of the court comment on their incomparable beauty. They lack the words to describe what they claim to see No one wants to remain silent in the face of this spectacle, for fear of being labelled a second-rate character. Until a child cried out:

- The king is naked!

[11] Dans la suite du livre je présenterai les arguments en faveur de ce qui pourrait permettre de dénouer cette situation et enfin quantifié le champ gravitationnel : Introduire des masses négatives dans le modèle cosmologique.

But the "theoretical physics, cosmology, theoretical astrophysics" machine must continue to function. There is teaching to be done, chairs to be filled, doctoral dissertations to be presented. Journals publishing articles in these disciplines must be able to fill the pages of their issues. Significant advances should also be rewarded with prizes. There is also a need to justify funding for salaries, research and participation in scientific conferences.

In addition, an image of excellence must be maintained with the public. This will be the task of popular science journals. Today, they are strongly supported by scientists who promote a true virtual science, thanks to the computer-generated images they create with the help of increasingly powerful computers. The precision of such images has become such that not only do the public confuse them with reality, but scientists themselves, seduced by their achievements, also end up confusing reality with illusion.

In short:

- In the kingdom of the blind, the one-eyed man is king.

It is a dizzying realisation. The first to refuse to consider such a failure are the scientists themselves. And that makes sense: If the reality is so depressing, then they have something to do with it. Their status, their entire career and their work are being called into question. What scientist would accept this?

In this question of the conformity of theoretical models with realities, we have three interlocutors:

There are those who are in favour. There are those who are against. Finally, there is a third interlocutor who always ends up having the last word:

Nature

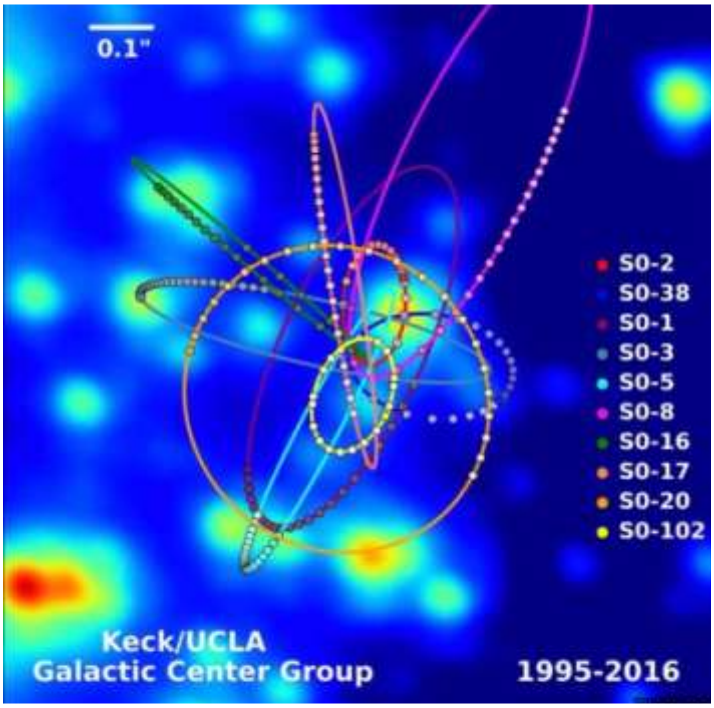
This is expressed through observations and experiences. However, for half a century, the latter has obviously been sulking. It stubbornly refuses to confirm the predictions of particle physics theorists. See the total failure of the supersymmetry theory. On the observational side it has simply collapsed all the theoretical constructs painstakingly built over the previous decades. Attempts had to be made to patch up the models by invoking new concepts, new ingredients from the 'cosmic soup':

- Influence field
- Dark matter
- Dark energy

Words that, instead of referring to tangible and identifiable elements, are more of an exorcism than anything else. This is to the point where the theoretical model presented as "standard" seems to have been created, not by theorists, but by cooks.

There remained the model of black holes, stellar, mini, giant, of all sizes.

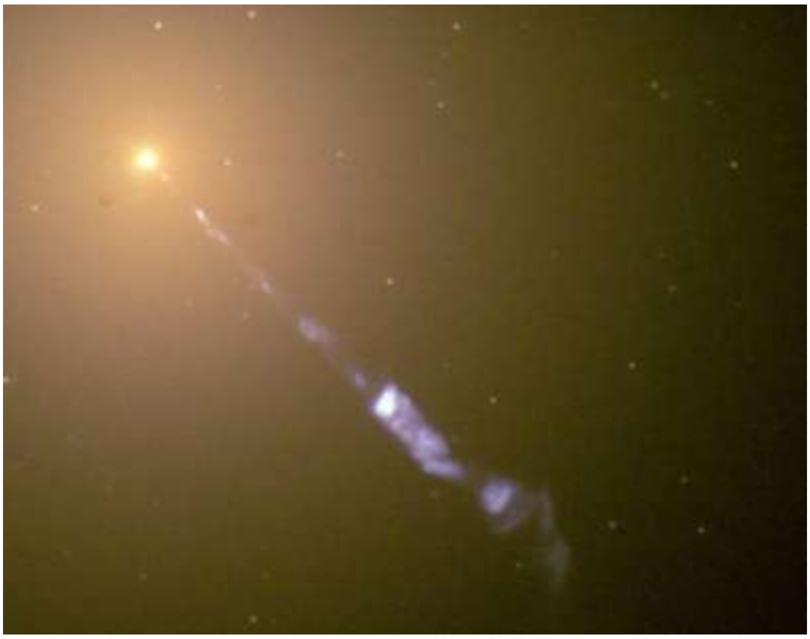
Suddenly, in 2021, a team presents, in a voice altered by emotion, what is presented as the first image of a giant black hole. Indeed, measurements of the velocities of stars circulating at the centre of galaxies have shown that their very high speeds could only be explained if they were orbiting objects with considerable masses.



Measurements of the position and velocity of the ten or so stars circulating around a centre of our galaxy, the Milky Way.

The coloured dots indicate the times when the data were collected, over a period of more than 20 years, and the curves show the Keplerian trajectories that were deduced from these observations. We deduce that these trajectories reflect the presence of an extremely compact supermassive object, located 26,000 light-years from Earth, with an estimated mass of 4 million solar masses.

Similar measurements indicate the presence of supermassive objects at the centre of many galaxies. The galaxy M87 is located in the Virgo Cluster, 50 million light years away. It is an elliptical galaxy with an estimated mass 200 times that of your galaxy. This is what we call "an active galaxy "[12] . This means that there is a quasar at its centre· [13] . These quasars emit very fine jets of plasma, usually in two diametrically opposite directions and perpendicular to the plane of symmetry of the galaxies. The image below shows one of the jets emanating from the quasar at the centre of the M87 galaxy.



The quasar at the heart of the elliptical galaxy M87.

Only one of the two jets can be imaged in the same wavelength range. The second shifts into the infrared due to the Doppler effect. The material that is emitted in this jet moves away from us.

[12] Ou « galaxie de Seyfert ».
[13] Dont il n'existe à ce jour aucun modèle théorique crédible.

Artist's image of an active galaxy and its quasar.

The light emitted by the jets being strongly polarised, this betrays the presence of a very strong magnetic field, dipolar, which orients the direction of the jets along its magnetic lines and ensures their collimation.
What are these mysterious quasars? The answer given by theorists is only in the form of an opinion. When this is shared by many of them it takes the form of a new entity, now part of the scientific world:

the consensus

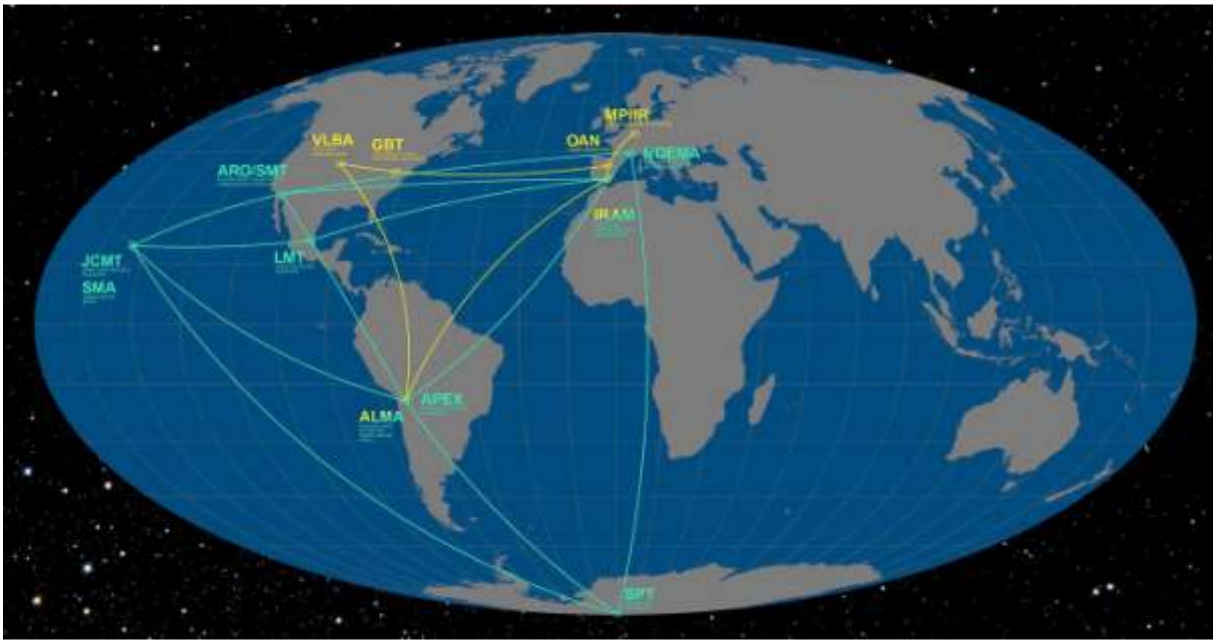
In the case of quasars, this means that the quasar phenomenon is "the ejection of matter collected by a giant black hole. This is "what the specialists think".

In addition, the measurement of the high velocities of objects at the centre of galaxy M87 has made it possible to estimate the mass of the hypermassive object located at its centre: 6.5 billion solar masses. It should be noted in passing that the latter is more than a thousand times smaller than the one located at the centre of the Milky Way, while the galaxy that hosts it is two hundred times more massive. One more mystery.

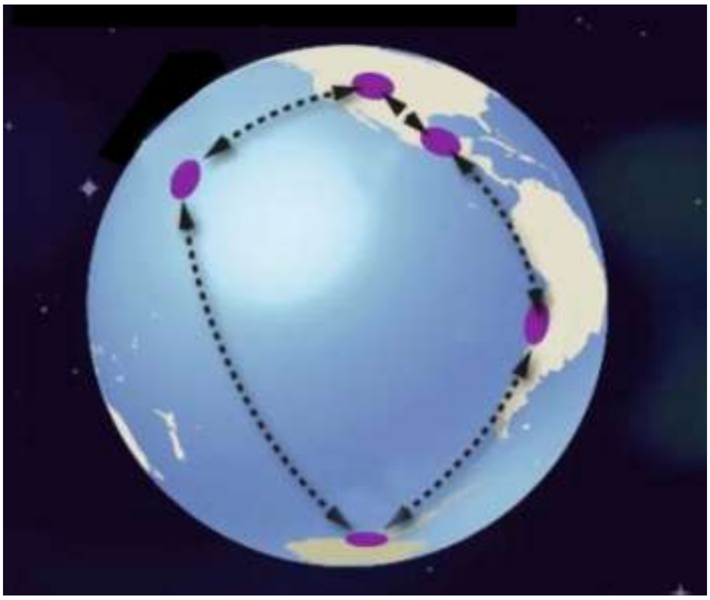
But let's come to this image, presented in 2021. How was it created?

Astronomers have long known that by combining (with the help of computer processing) the images provided by two instruments located at a distance D from each other, they can recreate an image that would then match the one that could have been obtained using a telescope of diameter D. The larger the diameter of the instrument, the greater its 'resolving power'. This refers to the fineness of the angular brush of the sight, the "separating power" of the instrument.

This also applies to radio telescopes. A fantastic project was born. As much as the activities of theorists are pathetic, those of the creators of increasingly effective observation tools deserve all the praise they can get. Data collected by radio telescopes located more than ten thousand kilometres apart were combined. Here are the radio telescopes that make up the EHT network [14] .



But these radio telescopes can only combine their data if they are located on the same hemisphere. For example :



[14] EHT : Event Horizon telecope.

Combining data from 5 instruments
located in Hawaii, USA, Mexico, Chile and South Pole.

Ainsi les données conjuguées de ces cinq instruments permettent de reconstruire une image, telle qu'elle serait produite par un radiotélescope dont les collecter aurait une surface comparable à celle de la Terre. This work involves the processing of a huge amount of data by powerful computers. Here is the result:

Note that the title does not refer to the first image of a supermassive object, but to a supermassive black hole.
In the article you will find the reason for this choice: the authors found no other possible interpretation.

The article can be downloaded at

http://www.jp-petit.org/papers/cosmo/2019-APJ-M87.pdf

maximum likelihood (RML; e.g., Narayan & Nityananda 1986; Wiaux et al. 2009; Thiébaut 2013). RML is a forward-modeling approach that searches for an image that is not only consistent with the observed data but also favors specified image properties (e.g., smoothness or compactness). As with CLEAN, RML methods typically iterate between imaging and self-calibration, although they can also be used to image directly on robust closure quantities immune to station-based calibration errors. RML methods have been extensively developed for the EHT (e.g., Honma et al. 2014; Bouman et al. 2016; Akiyama et al. 2017; Chael et al. 2018b; see also Paper IV).

Every imaging algorithm has a variety of free parameters that can significantly affect the final image. We adopted a two-stage imaging approach to control and evaluate biases in the reconstructions from our choices of these parameters. In the first stage, four teams worked independently to reconstruct the first EHT images of M87* using an early engineering data release. The teams worked without interaction to minimize shared bias, yet each produced an image with a similar prominent feature: a ring of diameter ~38–44 μas with enhanced brightness to the south (see Figure 4 in Paper IV).

In the second imaging stage, we developed three imaging pipelines, each using a different software package and associated methodology. Each pipeline surveyed a range of imaging parameters, producing between $\sim 10^3$ and 10^4 images from different parameter combinations. We determined a "Top-Set" of parameter combinations that both produced images of M87* that were consistent with the observed data and that reconstructed accurate images from synthetic data sets corresponding to four known geometric models (ring, crescent, filled disk, and asymmetric double source). For all pipelines, the Top-Set images showed an asymmetric ring with a diameter of ~40 μas, with differences arising primarily in the effective angular resolutions achieved by different methods.

For each pipeline, we determined the single combination of fiducial imaging parameters out of the Top-Set that performed best across all the synthetic data sets and for each associated imaging methodology (see Figure 11 in Paper IV). Because the angular resolutions of the reconstructed images vary among the pipelines, we blurred each image with a circular Gaussian to a common, conservative angular resolution of 20 μas. The top part of Figure 3 shows an image of M87* on April 11 obtained by averaging the three pipelines' blurred fiducial images. The image is dominated by a ring with an asymmetric azimuthal profile that

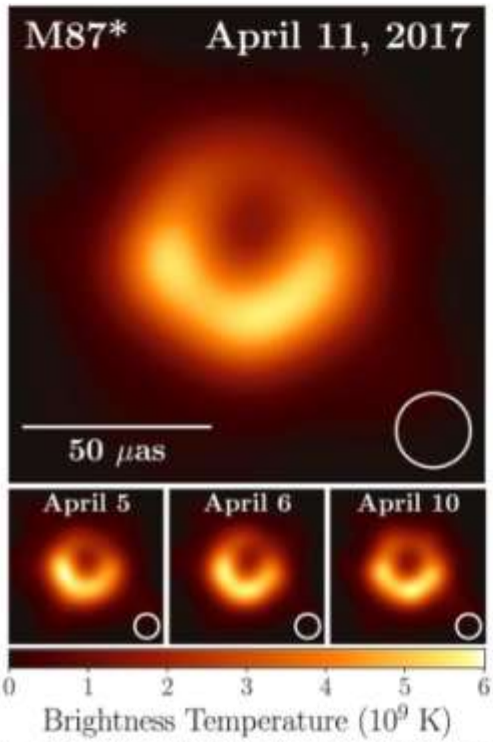


Figure 3. Top: EHT image of M87* from observations on 2017 April 11 as a representative example of the images collected in the 2017 campaign. The image is the average of three different imaging methods after convolving each with a circular Gaussian kernel to give matched resolutions. The largest of the three kernels (20 μas FWHM) is shown in the lower right. The image is shown in units of brightness temperature, $T_b = S\lambda^2/2k_B\Omega$, where S is the flux density, λ is the observing wavelength, k_B is the Boltzmann constant, and Ω is the solid angle of the resolution element. Bottom: similar images taken over different days showing the stability of the basic image structure and the equivalence among different days. North is up and east is to the left.

In 2021 this was complemented by an entirely similar image, presented as "the giant black hole at the centre of the Milky Way".

Without any caution, the entire scientific community, relayed by the media, welcomes this major advance. Robbert Dijgraaf even goes so far as to declare in a video:

- This discovery is the equivalent of the discovery of the atom a century earlier

Let's look back at the genesis of this modern-day chimera.

J.A.Wheeler is certainly an important scientist. But he wants to leave his name in history, having been at the origin of an important discovery. He then focused his interest on the article published in 1939 by Robert Oppenheimer.

I participated in 2017 in the "Schwarzschild Annual Colloquium", which was held in Frankfurt, his hometown. Although having published a paper in 2015 representing an alternative interpretation of the Schwarzschild outer solution:

Modern Physics Letters A
Vol. 30, No. 9 (2015) 1550051 (13 pages)

DOI: 10.1142/S0217732315500510

World Scientific
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Cancellation of the central singularity of the Schwarzschild solution with natural mass inversion process

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We reconsider the classical Schwarzschild solution in the context of a Janus cosmological model. We show that the central singularity can be eliminated through a simple coordinate change and that the subsequent transit from one fold to the other is accompanied by mass inversion. In such scenario matter swallowed by black holes could be ejected as invisible negative mass and dispersed in space.

Downloadable at :

http://www.jp-petit.org/papers/cosmo/2015-MPLA.pdf

where I had found, without knowing that he had done it a century before me, the equation of the meridian of the Flamm surface:

is no longer zero. The metric is well defined for all values of ρ. If we embed the surface in a 3D-Euclidean space we can define the meridians, corresponding to

$$d\Sigma^2 = \frac{dr^2}{1 - \frac{R_s}{r}} + dz^2 \,. \tag{12}$$

And we immediately get the meridians as

$$z = \pm 2R_s\sqrt{\frac{r}{R_s} - 1}\,, \quad r^2 = R_s + \frac{z^2}{4R_s}\,. \tag{13}^*$$

The surface is a *space bridge*, a "2D diabolo" linking two 2D-Euclidean surfaces.

The problem of the signature has disappeared. From Lagrange equations we can calculate the geodesics in the $[\rho, \varphi]$ coordinate system. If embedded, the surface owns a throat circle whose perimeter is $2\pi R_s$. We can shape the surface as a twofold $F^{(+)}$ and $F^{(-)}$ cover of a M_2 manifold with a 1D common circular border, and create induced mapping between adjacent points $M^{(+)}$ and $M^{(-)}$.

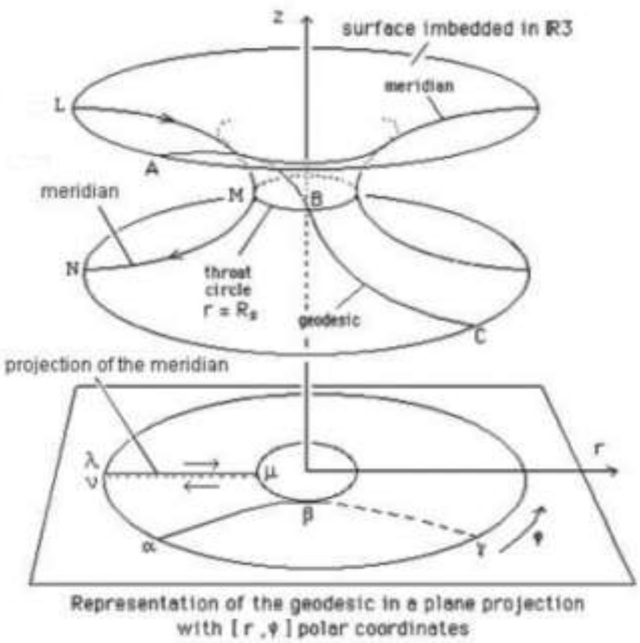


Fig. 2. The 2D diabolo embedded in R^3.

In that paper I presented this geometry, in the same way as Einstein and Rosen did in 1935, as a bridge connecting two four-dimensional spacetimes.

With a difference. Thanks to the change of space variable that I had implemented, unlike Einstein's and Rosen's, the metric-solution became Lorentzian at infinity, on both slices:

Cancellation of the central singularity of the Schwarzschild solution

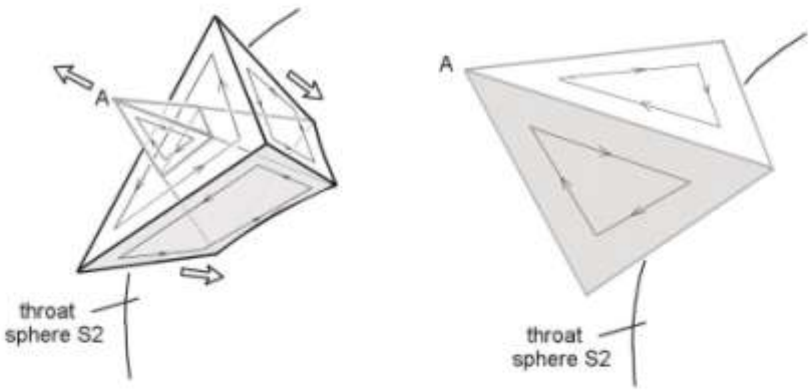


Fig. 8. By crossing the throat sphere, the tetrahedron is inverted.

Now let us go back to (2) and apply (10). We get

$$ds^2 = \frac{\text{Log ch}\,\rho}{1+\text{Log ch}\,\rho}c^2\,dt^2 - R_s^2\left[\frac{(1+\text{Log ch}\,\rho)}{\text{Log ch}\,\rho}\,\text{th}^2\,\rho\,d\rho^2 + (1+\text{Log ch}\,\rho)^2(d\theta^2+\sin^2\theta\,d\varphi^2)\right]. \quad (16)$$

When ρ tends to $\pm\infty$, $\text{Log ch}\,\rho \to \rho$ and $\text{th}\,\rho \to 1$. The metric tends to Lorentz metric. Space is extended to $(\rho > 0;\ \rho < 0)$ domain. The hypersurface becomes a *spacetime bridge*, linking two Lorentz spaces through a throat surface S2. When we calculate the geodesics in the plane $\theta = \frac{\pi}{2}$ in the $\{t, r, \theta, \varphi\}$ representation we find the following (Eq. (6.90) in Ref. 8):

Beyond that I showed that the passage put in communication two PT-symmetrical space-time, i.e. where the coordinates of space and time were reversed.

But I was only allowed to put up a poster at the entrance of the room, as my paper was not considered to be of a high enough standard to be presented to the participants. But the theme of this conference was 'the physics of black holes'.

The keynote speaker was of course Juan Maldacena, who presented Schwarzschild's solution on the screen, with his letter r instead of R, stating:

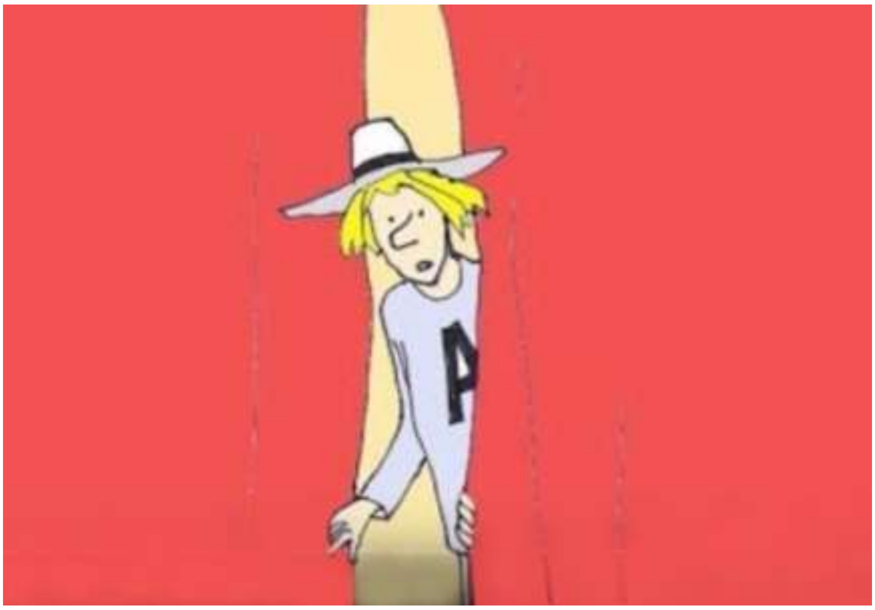
- When Karl Schwarzschild presented this solution to Einstein's equation in 1916, the scientific community had difficulty understanding what it meant. But after years these things are now well understood.

2017 : The Schwarzschild Colloquium, Frankfurt Germany.

Not a word about the second solution, about this second article published by Schwarzschild in February 1916, before his death. I think Maldacena is probably unaware of its existence.

I described my participation in this conference in my video Janus 22/1 :

https://youtu.be/FMtfbUX5q4E



- *Y a-t-il un géomètre dans la salle ?*

-

- *So you see what happened. After the Second World War, scientists became interested in the work of Karl Schwarzschild, based on the way Richard Tolman had presented it in his 1934 book. where the constraint :*

$r > R_s$

disappeared completely.

People like J.A. Wheeler in the United States and Roger Penrose in England therefore sought to interpret this strange and disconcerting geometry. How, for example, does one manage to penetrate the "Schwarzschild sphere", renamed by Oppenheimer "event horizon".

In 1960 Wheeler had dinner in a Princeton restaurant with a young researcher, Martin Kruskal, who described his approach.

Martin Kruskal 1925 - 2006

The latter explains to Wheeler, on the paper tablecloth of the restaurant, his way of proceeding. Enthusiastically, Wheeler immediately supported the publication of a paper, which appeared immediately in Physical Review:

PHYSICAL REVIEW VOLUME 119, NUMBER 5 SEPTEMBER 1, 1960

Maximal Extension of Schwarzschild Metric*

M. D. KRUSKAL†
Project Matterhorn, Princeton University, Princeton, New Jersey
(Received December 21, 1959)

There is presented a particularly simple transformation of the Schwarzschild metric into new coordinates, whereby the "spherical singularity" is removed and the maximal singularity-free extension is clearly exhibited.

THE well-known Schwarzschild expression[1] for the metric around a center of mass $m(g)$ or $m^*=(Gm/c^2)(\mathrm{cm})$ is

$$ds^2=-(1-2m^*/r)dT^2+(1-2m^*/r)^{-1}dr^2+r^2d\omega^2, \quad (1)$$

with

$$d\omega^2=d\theta^2+\sin^2\theta\, d\varphi^2. \quad (2)$$

Kasner, Lemaître, Einstein and Rosen, Robertson, Synge, Ehlers, Finkelstein, and Fronsdal have shown[2] that the singularities at $r=0$ and $r=2m^*$ are very different in character (Table I). Their conclusion—that

The extended space, $\mathcal{S}$, moreover, is the *maximum* singularity-free extension of $\mathcal{L}$ that is at all possible, for the following reason: As may be seen by direct examination of the geodesics (perhaps most simply carried out mainly in the familiar r,T coordinates, with special attention to geodesics on which $r=2m^*$ either isolatedly or everywhere), every geodesic, followed in whichever direction, either runs into the "barrier" of intrinsic singularities at $r=0$ ($v^2-u^2=1$), or is continuable infinitely with respect to its "natural length." (This is measured in terms of the number of parallel transfers of an infinitesimal tangent vector, is determined only

Downloadable at :

http://www.jp-petit.org/papers/cosmo/1960-Kruskal.pdf

The reader will not find any calculation details in this article. As can be seen in the accompanying figure, Kruskal presents a diagram of what Wheeler already calls a 'wormhole'.

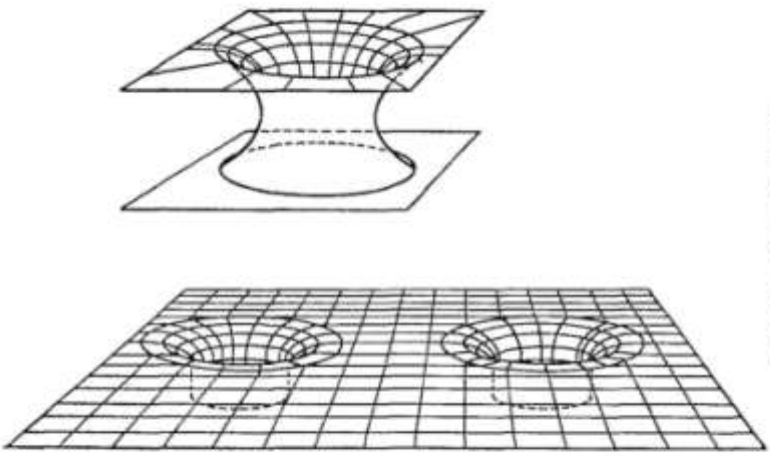
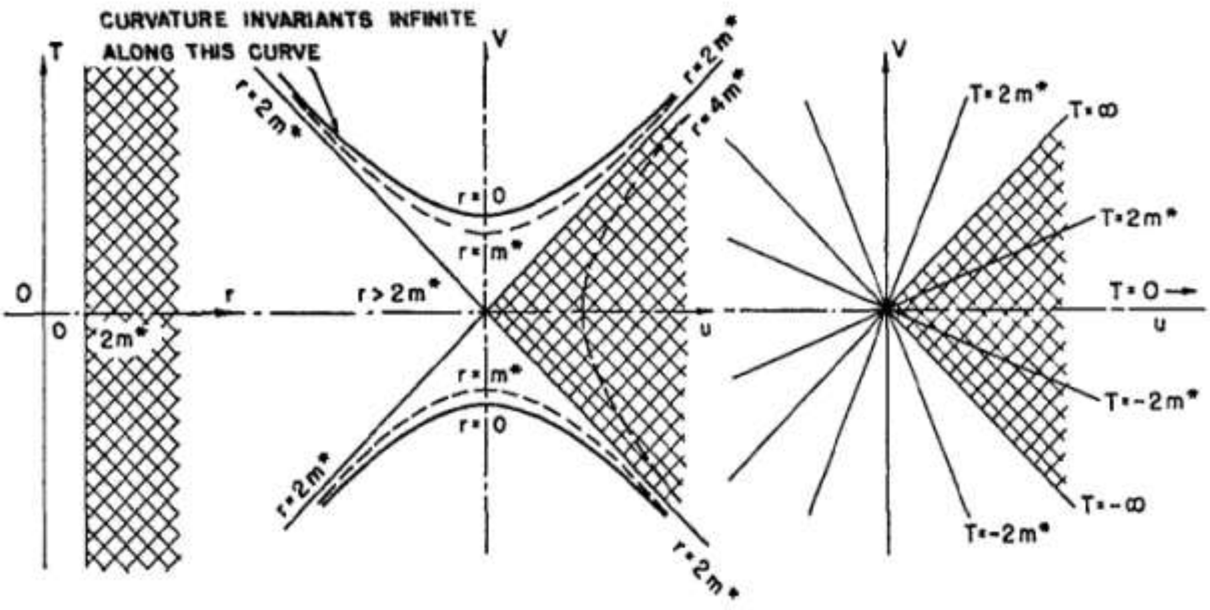


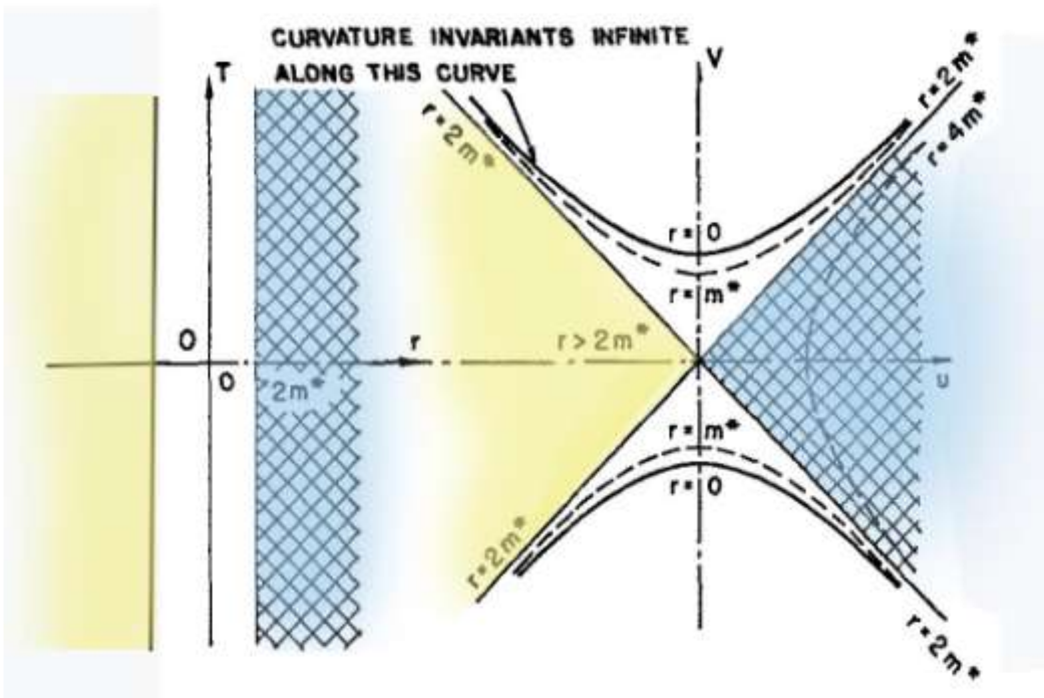
FIG. 1. Two interpretations of the 3-dimensional "maximally extended Schwarzschild metric" at the time $T=0$. Above: A connection or bridge in the sense of Einstein and Rosen between *two* otherwise Euclidean spaces. Below: A wormhole in the sense of Wheeler connecting two regions in *one* Euclidean space, in the limiting case where these regions are extremely far apart compared to the dimensions of the throat of the wormhole.

But it presents what will later be known as the "Kruskal diagram":

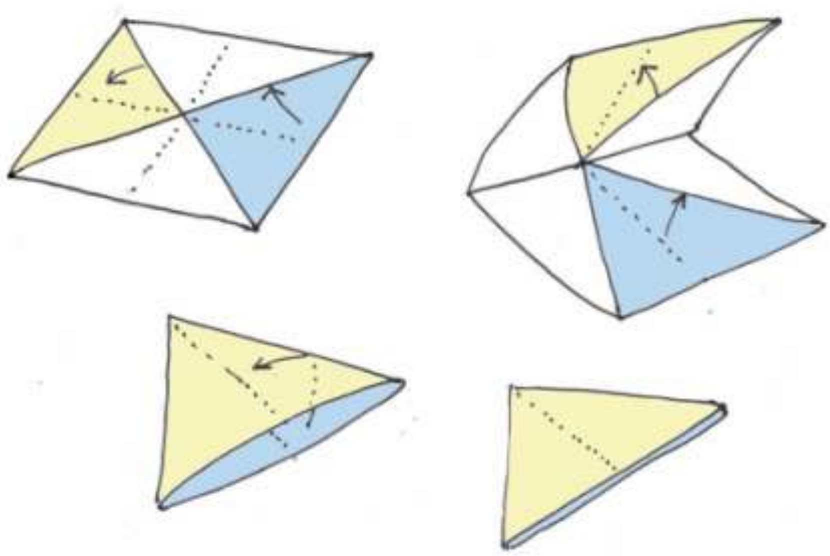


The Kruskal diagram.

The part underlined by Kruskal represents the first layer of the Wormhole. Let's associate it with the colour blue. If we connect the two figures, this sector represents the second layer, represented by the yellow-orange colour:

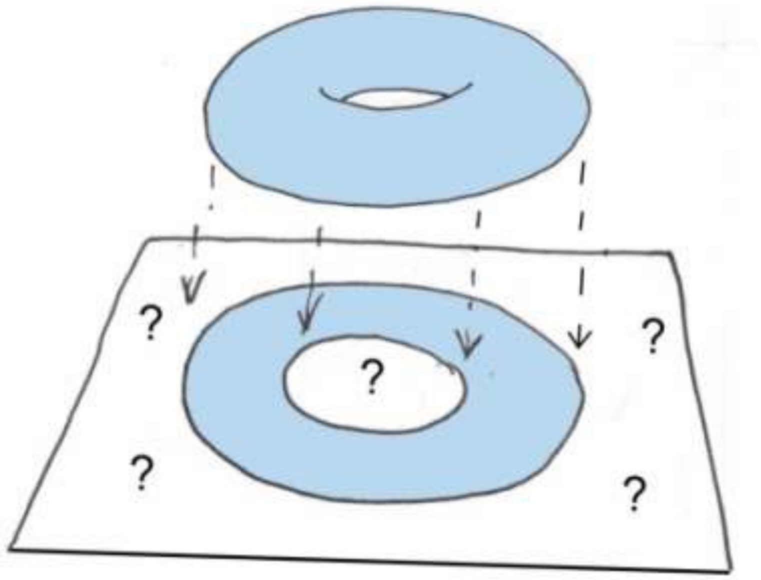


By fitting the drawing of the wormhole presented by Kruskal to the diagram in (u,v) coordinates, this would mean folding the figure according to :



This would have the effect of removing the areas left blank as topological artefacts. There are always many ways to represent geometric objects. By projecting a torus onto a plane, projections appear which ... do not exist:

The only criterion, with respect to these various representations, is to keep in mind the sign of the length element ds2. If it is negative, the length in these portions of the surface becomes purely imaginary. We then leave a geometry based on reals and move to a complex geometry. By losing sight of this criterion, our modern theoretical physicists did not realise that they were de facto placing their cosmology in the world of complexes, whereas the starting point was to consider that the coordinates and length s belonged to the world of real numbers.



Quel sens donner aux parties blanches du plan ?

Signification de cette figure : This is exactly what happens when we go from the metric representation of the torus :

$$ds^2 = \frac{dr^2}{-r^2 + 2\,r R_a + r_g^{\,2} - R_a^{\,2}} + r^2 d\varphi^2$$

to this one:

$ds^2 = r_g^{\,2} dq^{\,2} + (R_a + r_g \cos q)^2 dj^{\,2}$

using the change of variable :

$r = R_a + r_g \cos q$

Alors que la première représentation laissait le ds^2 positif pour toutes les values of q and j , the second one showed some kind of geometrical ghosts, corresponding to values of the new coordinate r for which ds2< 0.

This is explained in detail in the Janus 22-4 video from 28 minutes. It is subtitled in English. See :

https://youtu.be/glepnXSkiyE

This brings us back to the question: "who suddenly introduced a change of sign in the expression of the mathematical solutions of the Einstein equation, by proposing to go from

$$ds^2 = -\frac{dr^2}{1-2m/r} - r^2 d\theta^2 - r^2 \sin^2\theta d\phi^2 + \left(1-\frac{2m}{r}\right)dt^2$$

à ceci :

$$ds^2 = +\frac{dr^2}{1-2m/r} + r^2 d\theta^2 + r^2 \sin^2\theta d\phi^2 - \left(1-\frac{2m}{r}\right)dt^2$$

Nowhere in the literature have I found an article explaining the reason for this post-war change of sign.

Now, let us consider trajectories with constant r, q and j. For r>2m(therefore, outside the "Schwarzschild sphere" ds2 is negative. To obtain a real proper time it is then necessary to define it according to :

$$\tau = \int \sqrt{\left(1 - \frac{2m}{r}\right)}\, dt = \int \sqrt{-g_{tt}}\, dt$$

The proper time, as Hilbert defined it in his 1916 paper, thus appears. In order to arrive at a real proper time, he is obliged to introduce a minus sign in front of the quantity under radical.

quand $G\left(\frac{dx_s}{dp}\right) < 0$

ausfällt, heiße eine *Zeitlinie* und das längs dieses Kurvenstückes
le long de cette portion de courbe
genommene Integral
l'intégrale

$$\tau = \int \sqrt{-G\left(\frac{dx_s}{dp}\right)}\, dp$$

heiße die *Eigenzeit der Zeitlinie*;
est le temps propre de cette ligne de temps

The person responsible for this change of signs is therefore Hilbert. But then, why did he opt for a bilinear form with these signs, since, in order to fall back on a positive proper time, and thus on a positive length, it was then necessary for him to define it by introducing this change of sign!

It seems to me that the explanation lies in Hilbert's conception of space-time, associated with an almost biblical interpretation of Genesis.

For Hilbert, what is primary is space.

Before the advent of general relativity, space was free of curvature. But even with the effect of curvature, translated by this very slight alteration of the Keplerian trajectories, this space is almost Euclidean. One could therefore write :

- So God creates this quasi-Euclidean space [15].

- He then installs the masses in this space (the stars)

- Then he defines the laws to which these stars will have to conform (the field equation [16])

[15] « elliptique », décrit par des coordonnées (x , y , z , l)

- At this stage the four coordinates of this "Hilbert world" are :

$$(x , y , z , l)$$

→In its bilinear form there are only plus signs [17] . The field equation he published in 1915, which had Einstein in a tizzy, is still written with these coordinates.

- Only then does God give the start. Then this coordinate l turns into it . For Hilbert, time is purely imaginary. The fact that his geometry becomes hyperbolic simply reflects the idea of integrating the relativistic aspects identified by Einstein.

When he deals with the question of the solution constructed by Schwarzschild, he formulates it in dimensions (x , y , z , l). It is on the basis of this choice of variables that it carries out all the calculations. At no time does the time t appear. This universe is located "before time appears", "before it manifests", so to speak.

In their projections in (x , y , z) the trajectories of the planets are already traced.

And it is only at the very last moment that Hilbert decides to convert his variable into it, by making time appear:

keine wesentliche Einschränkung bedeutet, so ergibt sich aus (43) für $l = it$ die gesuchte Maßbestimmung in der von Schwarzschild zuerst gefundenen Gestalt

$$(45) \quad G(dr, d\vartheta, d\varphi, dl) = \frac{r}{r-\alpha} dr^2 + r^2 d\vartheta^2 + r^2 \sin^2\vartheta \, d\varphi^2 - \frac{r-\alpha}{r} dt^2 .$$

$l = it$

Translation :

This is the origin of the signature: (+ + + -)

---

[16] Celle-ci est présentée dans le papier de 1915 où le temps n'apparaît pas. Le mot n'y est pas formulé. L'espace quadridimensionnel de Hilbert se décrit à l'aide de coordonnées w_1 , w_2 , w_3 , w_4 et c'est à l'aide de celles-ci que sont exprimées toutes les dérivées, premières et seconde, ainsi, implicitement, que l'équation de champ.

[17] Sa géométrie, avec ses variables (x , y , z , l) est « elliptique ».

... alors pour $l = i\,t$, (43) aboutit à la métrique désirée sous la forme trouvée pour la première fois par Schwarzschild

$$G(dr, d\theta, d\varphi, dl) = \frac{r}{r-\alpha} dr^2 + r^2 d\theta^2 + r^2 sin^2\theta \, d\varphi^2 - \frac{r-\alpha}{r} dt^2 \qquad (45)$$

En fait, Hilbert devrait faire intervenir deux étapes

Emergeant de ses calculs : sa solution géométrique, avec la signature (+ , + , + , +)

$$G(dr, d\theta, d\varphi, dl) = \frac{r}{r-\alpha} dr^2 + r^2 d\theta^2 + r^2 sin^2\theta \, d\varphi^2 + \frac{r-\alpha}{r} dl^2 \qquad (45)$$

et c'est seulement à ce moment-là qu'il fait jouer : $l = i\,t$

Alors sa solution s'exprime avec une signature : (+ , + , + , −)

$$G(dr, d\theta, d\varphi, dt) = \frac{r}{r-\alpha} dr^2 + r^2 d\theta^2 + r^2 sin^2\theta \, d\varphi^2 - \frac{r-\alpha}{r} dt^2 \qquad (45\,\text{bis})$$

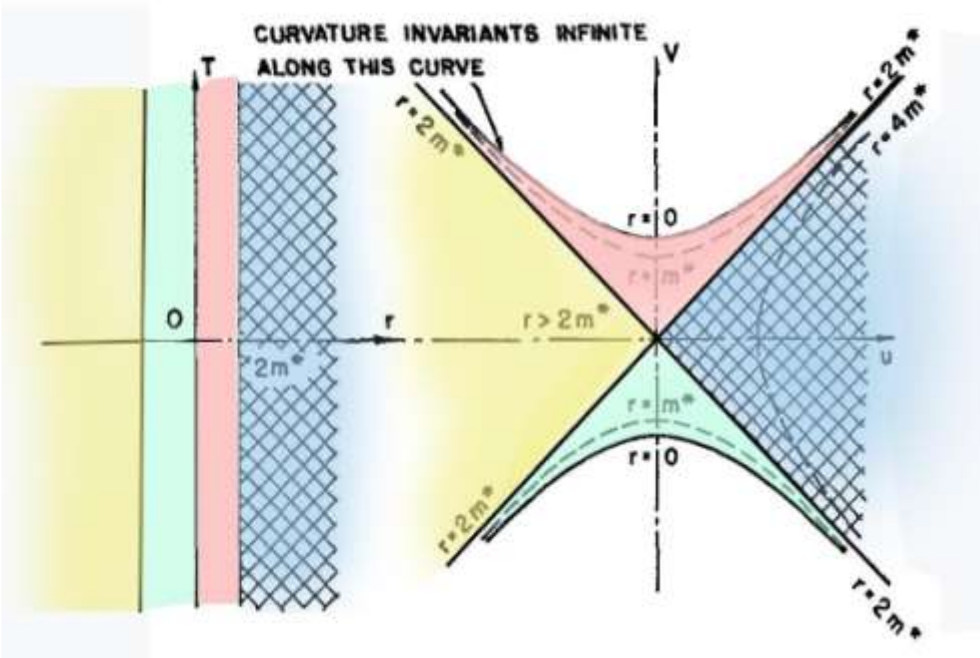
I am sorry for this foray into the world of mathematics, but I did not know where to put this analysis, which is extremely important. Unless some theorist can show me a post-war paper where someone justifies this change of signs (of the signs making up the "signature") I can't think of any reason other than the fact that someone thought, at some point, "Hilbert does it this way. He must have his reasons: we'll do the same".

The consequence is that we have lost the framework of this modern geometry where the guiding principle is precisely to keep a positive ds2, i.e. to remain in the real world.

With Kruskal and Wheeler, cosmology shifts to a form of

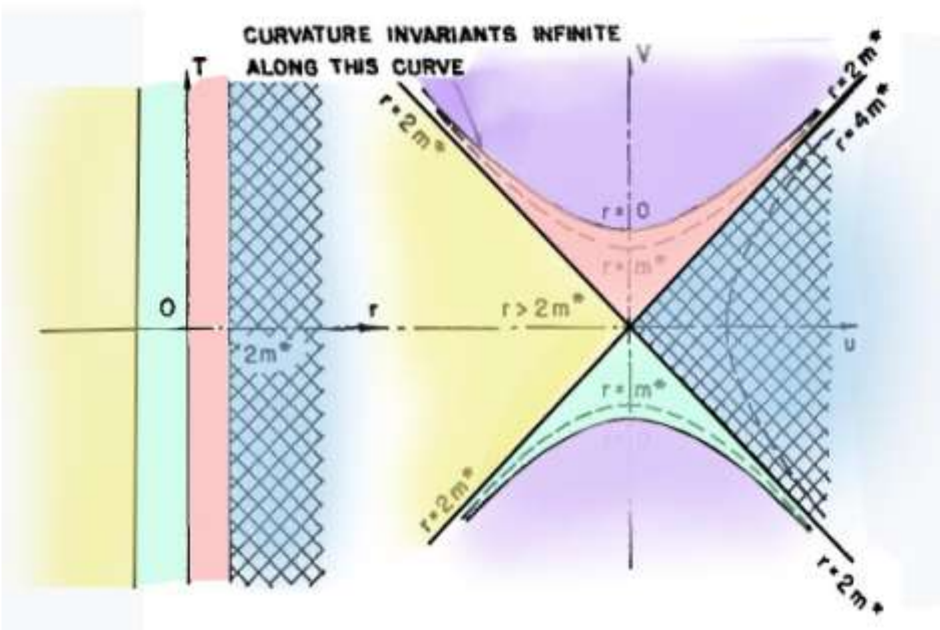
Scientific surrealism.

The Kruskal diagram is a perfect illustration. The two sectors shown in pink and green then represent the 'interior of the black hole', where proper time becomes purely imaginary, but neither Kruskal, Wheeler nor their successors care about this.



This black hole then has a 'centre'. Is that a point? In this Kruskal diagram, the points can be transformed into ... curves. This "centre" thus becomes two hyperbolas along which "the curvature is infinite".

There are still two regions that have not been defined, left blank here. Let us adopt the colour purple:



As the hyperbolas are the image of "the point at the centre of the object", the purple regions then represent "the interior of that point".

In this Kruskalian meta-world the points have an interior!

There is still one point that poses a problem for our extreme geometers. If we opt for these coordinates :

$$ds^2 = +\frac{dr^2}{1-2m/r} + r^2 d\theta^2 + r^2 \sin^2\theta d\phi^2 - \left(1-\frac{2m}{r}\right)dt^2$$

We can focus on radial trajectories. So :

$$ds^2 = +\frac{dr^2}{1-2m/r} - \left(1-\frac{2m}{r}\right)dt^2$$

An immediate constant: when we cross the Schwarzschild sphere, the sign of the two terms is reversed.

But in the black hole, everything is possible, everything is allowed. His new specialists immediately provide the explanation: Inside the black hole, the variables exchange their respective roles: R becomes the time variable and t a space variable.

Let us quote what is written in Adler Schiffer and Bazin's treatise, page 223:

The Schwarzschild Solution and Its Consequences **223**

When r becomes less than $2m$, the signs of the metric components g_{00} and g_{11} change, g_{11} becoming positive and g_{00} becoming negative. This forces us to reconsider the physical meaning of t and r as time and radial markers inside the Schwarzschild radius. Indeed a world-line along the t axis (r, θ, φ constant) has $ds^2 < 0$ and is a *spacelike* curve, while a world-line along the r axis has $ds^2 > 0$ and is a *timelike* curve. It would thus appear natural to reinterpret r as a time marker and t as a radial marker for events which occur inside the Schwarzschild radius. Since we inter-

Traduction française :

When r becomes less than 2m, the signs of the components g11 and goo of the metric change, g11becoming positive, and goo negative. This forces us to reconsider the physical meaning of t and r as markers of temp and radius, within the Schwarzschild sphere. Thus a universe line along the time axis t (r , q , j constant) is then associated with a negative value of ds2 and is then a space-like line. While a line extending along the r-axis becomes a time line. It therefore seems natural to reinterpret r as a time marker and t as a space marker, for events taking place within the Schwarzschild sphere.

Understand who can.

We recall that Tolman and Oppenheimer posed :

$g_{oo} = g_{tt} = e^{n(r)}$ $g_{11} = g_{rr} = e^{l}$

Bearing in mind that real variable exponentials are strictly positive, this was a way of imposing the constancy of the signature, the signs of the terms in the metric.

Page 187 of the book that serves as a reference for us (but the same thing will be found in all books) reads:

(69) $ds^2 = e^{n(r)} c^2\, dt^2 - e^{l(r)} dr^2 - r^2 \,(\, dq^2 + \sin^2 q\, dj^2 \,)$

But a few pages later, all calculations are made:

$$
(6.47) \qquad
\begin{aligned}
e^{\nu} &= e^{-\lambda} = 1 - \frac{2m}{r} \\
e^{\lambda} &= \frac{1}{1 - 2m/r}
\end{aligned}
$$

When r becomes less than 2m these exponentials become ... negative.

In 1963 a New Zealander, Roy Kerr, succeeded in constructing a stationary solution of the field equation, no longer spherically symmetrical, but axisymmetrical. The specialist community is quick to enthusiastically identify this solution as a 'spinning black hole'.

This solution has a "cross term" in dt dj where two variables are mixed: the time t and the angle j marking the position of the points according to a rotational movement with respect to the axis of symmetry.

$$
\begin{aligned}
ds^2 = &\left(1 - \frac{R_s \rho}{\rho^2 + a^2 \cos^2\theta}\right) c^2 dt^2 - \frac{\rho^2 + a^2\cos^2\theta}{\rho^2 + a^2 - R_s \rho} d\rho^2 - \left(\rho^2 + a^2\cos^2\theta\right) d\theta^2 \\
&- \left[\left(\rho^2 + a^2\right)\sin^2\theta + \frac{R_s \rho\, a^2 \sin^4\theta}{\rho^2 + a^2\cos^2\theta}\right] d\varphi^2 - \frac{2R_s\, \rho\, a \sin^2\theta}{\rho^2 + a^2\cos^2\theta}\, c\,dt\,d\varphi
\end{aligned}
$$

This particularity implies that the speed of light, measured in an azimuthal direction, has two different values, depending on whether the light beam accompanies the rotational movement or is emitted in the opposite direction.

The interpretation is as follows [18] .

- Loosely speaking, we may think of the rotating source as "dragging" space around with it, in a Machian sense the source "competes"with the Lorentzian boundary conditions at infinity in the establishment of a local inertial frame.

Translation :

- This phenomenon can be interpreted by considering a rotating source that, in a way, "drags" space with it. Following Ernst Mach's idea, this source opposes the Lorentzian conditions at infinity by trying to establish its own local inertial system.

We will see later that this idea is in fact very profound, and deserves development.

The chimera was born.

At a time when a divorce has taken place between models and observations, due to the impossibility of the slightest comparison with the latter, which are totally absent in this field, everything becomes permitted, everything becomes possible.

The theory is therefore conditional.

Mathematician Roger Penrose [19] constructs theorems referring to the "central singularity of black holes".

Roger Penrose, Nobel Prize 2020

[18] Ouvrage d'Adler, Schiffer et Bazin, page 258. Téléchargeable à : http://www.jp-petit.org/books/asb.pdf

[19] Bénéficiaire du Prix Nobel 2020 "pour avoir démontrée que les trous noirs étaient une conséquence inéluctable de la relativité générale ».

Others are studying their stability. Steven Hawking shows that "black holes have no hair". In other words, their horizon sphere must be regular.

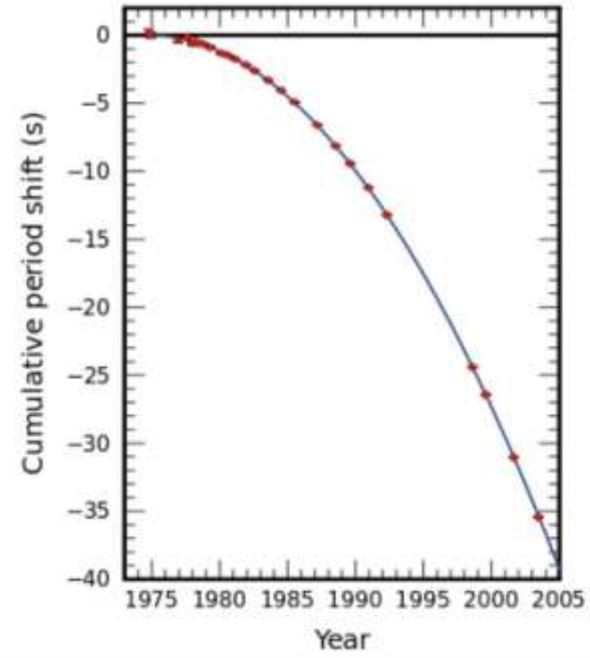
In the case of the "Kerr black hole", a method of extracting energy from it is even being considered.

Hawking is building a beam that will bear his name. With this in mind, since the vacuum is teeming with matter and antimatter, he imagines that the black hole could capture one of the pair, allowing the other to escape. Thus black holes would 'evaporate'. But the phenomenon, for supposed black holes with masses of the order of a few solar masses, would last 1050 years. In other words, it is unobservable.

Finally, a thermodynamics of black holes appears. Indeed, if these objects capture sets of masses with complex structures, what happens to the information? The resolution of such a paradox mobilises armies of researchers. Prizes are awarded to those who make advances in this field.

While no progress has been made in theoretical models over the last fifty years, every effort has been made to test those that emerged in previous decades. Within this range lies what has been done with regard to the existence of gravitational waves.1 This theory predicted that two bodies, orbiting around a common centre of gravity, should emit these waves, reflecting a loss of energy. This would bring the two stars closer together, while reducing their orbital period.

In 1974 Hulse and Taylor discovered a double pulsar, i.e. a set of two neutron stars of similar masses (1.44 and 1.38 solar masses) orbiting around a common centre of gravity in 7 hours. The monitoring of this orbit time shows a decrease of 35 seconds in 28 years, in excellent agreement with the theoretical predictions.



Decay of the orbiting period as a function of time.

v This result therefore represents a confirmation of the existence of gravitational waves. Insofar as this loss of energy by radiation brings the two stars closer together, we can conclude that this process will eventually lead to their merger, accompanied by a fantastic emission of these waves. Researchers then had the crazy idea of creating a device that could detect such signals. This was the beginning of the LIGO and VIRGO projects.

Gravitational waves result in joint changes in length, in the direction in which they propagate, and in a direction perpendicular to it. By installing two arms several kilometres long, a sort of tunnel in which the vacuum is created, it is possible to demonstrate the phenomenon by laser interferometry.

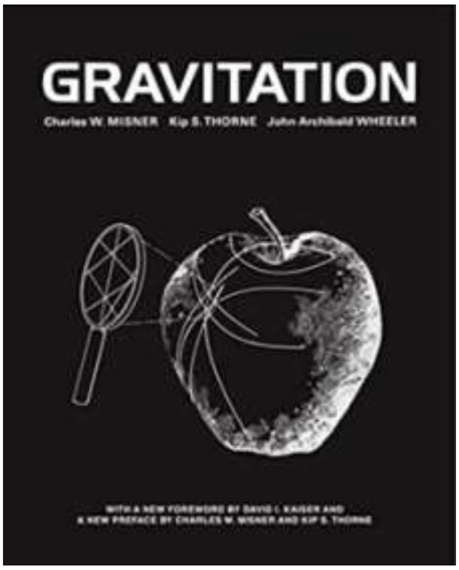
This is a fantastic gamble, since this variation in length corresponds to a fraction of the diameter of an atom. Decades of work have gone into reducing noise levels. In the United States, the LIGO system is made up of two facilities, located at the northwest and southeast ends of the country, as far apart as possible.

One of the two American LIGO facilities [20].

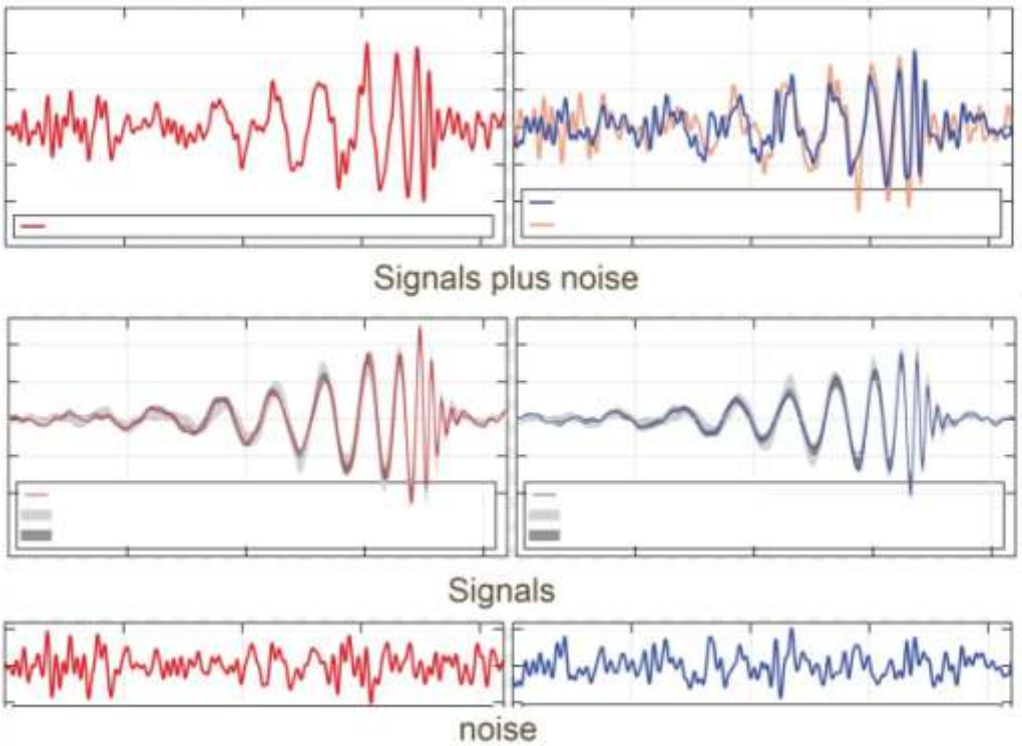
Both facilities are likely to record a signal, disturbed by background noise. This noise is not the same for both installations. Initially it was hoped that this signal could be extracted by combining the two recordings to eliminate the noise. In the end, using their model, the theorists create a range of around a hundred thousand signals, associated with as many possible configurations of the two merging masses. The range of configurations includes pairs of neutron stars and of course pairs of black holes. The theorist at the heart of this interpretive effort is Kip Thorne, a student of J.A. Wheeler.

Thorne is co-author with Wheeler and Misner of what the community considers to be the bible of the subject, their famous book Gravitation

[20] LIGO : Laser Interferometry fGravitational (waves) Observatory



The signal recorded by the two LIGO installations on 14 September 2015 is immediately visible on both records.



Signals recorded by the two LIGO installations on 14 September 2015.

It was a huge success, crowning decades of technical efforts by two people who were awarded the 2017 Nobel Prize two years later: the two designers of the project, Rainer Weiss and Bary Barish.

R.Weiss and B.Barish Nobel Prize 2017

But what is the source of this signal? We then turn to Kip Thorne who is the author of a program called "numerical relativity", where these mergers are modelled. This program then provides an estimate of the two masses involved, selecting the signal closest to the available record.

It is then essential to keep in mind that this decoding
depends entirely on the model considered.

Given the estimated mass values, this is not a neutron star merger, but what is interpreted as a merger of two black holes, with masses of 36 and 29 solar masses respectively, located at a distance of 1.3 billion light years. Thorne says that these mass estimates, obtained using his programme, are given to the nearest 4 solar masses. Specialists unanimously consider that this observation provides proof of the existence of black holes.

This first detection of a gravitational signal was quickly followed by others and the astronomers, who were thus equipped with a new observing instrument, estimated that it recorded an event every fifteen minutes.

Kip Thorne is associated with the 2017 Nobel Prizes.

Here are some results, as of September 2020.

On the ordinate the logarithm of the masses of the objects.

The mass record is held by the GW190 521 event, located 7 billion light years away, where Kip Thorne's numerical relativity programme estimates the masses of merging objects at 66 and 85 solar masses. The residual object then has a mass of 142 solar masses (plus or minus 18). This results in a mass difference of 8 solar masses, converted into energy dissipated by gravitational waves.

The question that emerges is:

- If they are black holes, how did they form?

For information in 2018 the young star R136a1 (300,000 years old) was detected in 2018, 160,000 light years from Earth, with an estimated mass of between 170 and 230 solar masses