STILL CURRENT NEWTONIAN PROBLEMS

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This paper wishes to point out that the work of Newton gave rise to a series of physical researches over three hundred years, which is the time that has passed since the publication of the first edition of the "Principia". We divide the whole research into seven main chapters.

1. The Epistemological Problem

Cotes and Newton discussed the nature of an action at a distance in empty space and, more generally, the problem of scientific methodology in its possibility to penetrate into the nature of reality. This problem is still in discussion, after the development of classical and relativistic physics and of quantistic mechanics.

2. The Problem of Space, Time and Reference system

The criticism of Leibnitz and Berkley of Newtonian absolute space became concrete with Mach in his principle which states that if really we eliminate every object in the universe except a test body, it is not possible to speak of motion of this body and therefore of inertial reaction to acceleration, so that the mass must be considered as deriving from a relation connecting in some way the test body to all the other cosmic objects. After the formulation of the Einsteinian principle stating that light velocity is a limit to velocities, it appears still problematic to conciliate Mach's principle with instantaneity of inertial reaction and with the distribution of cosmic masses at such different distances and perhaps it induces one to think of a kind of interaction in some way similar (but not yet singled out) to that proposed in 1945 by Wheeler and Feynman for the problem of electromagnetic interaction. The theory of relativity does not include Mach's principle as a necessity to its own structure even though Einstein was deeply interested in it.

Naturally the principle does not allow the possibility of cosmic rotation so that if we could discover a phenomenon interpretable only as cosmic rotation Mach's principle would be incorrect. Such an experimental possibility could be offered by the examination of cosmic 3°K radiation; its isotropy denies an angular velocity $\omega > 10^{-8}$ s y^{-1} so that at least within this limit Mach's principle appears valid; nevertheless, Birch, in 1982, on examining radiogalaxies which are very distant one from another, noticed some characteristics that seem to be interpreted only if a rotating universe is considered with $\omega \simeq 10^{-8}$ s y^{-1}. This effect has been questioned by some authors and confirmed by others.

In 1983 Ellis and Olive remarked that inside the inflationistic theory of big bang a cosmic rotation is possible, but inflation reduces it drastically so that Mach's principle could be redundant and weakly false. Barrow examines the problem theoretically and finds that in an open universe $\omega < 10^{-9}$ s y^{-1} while in parabolic or closed universes the limit should be much less than this value so that if Birch's results are correct it is not possible to interpret them as cosmic rotation inside the big bang theory.

3. The Problem of Equality of Inertial and Gravitational Mass

Newton expounded clearly the problem of the independence of bodies from the kind of material used and carried out an experiment (with pendula) from which he obtained that such independence is correct up to $1/10^3$. Among other experiments made afterwards those of Eötvös who reached a precision of $1/10^9$ and of Braginski with $1/10^{12}$.

The equivalence principle, so important for the theoretical foundation of relativity, needs to be examined again after the formulation of the theory of great unification of fundamental interactions of nature because the gravitational phenomenology has been considered mediated, in addition to the so-called graviton, by two particles called graviphoton and graviscalar which, though in a range of a few kilometers, should modify the gravitational phenomenon changing the ratio $Mass_{iner}/Mass_{grav}$ and so discriminating the two masses. Graviphoton and graviscalar in fact should act on the inertial mass, considered as energy, and on the other quantities of atomic nuclea (for instance bound energy or bosonic number) and hence differently on different materials. Nevertheless, recent studies appear to exclude it.

4. The Problem of Validity of the Fundamental Law of Gravitation $F = Gr^{-2}$

The general theory of relativity in a first approximation is equivalent to a potential which in addition to the term r^{-1} (Newtonian) has a term r^{-2} which contributes to the motion of perihelion of planetarian orbits (seen in Mercury's orbit).

If the problem presented in the previous no. 3 were resolved affirmatively the gravitational phenomenon could be practically interpreted either as a deviation of F from simply depending on r^{-2} or as a variation of G for short distances not more than some kilometers.

5. The Problem of Validity of the Dynamic Fundamental Law F = ma.

Newton states this law and from the knowledge of the acceleration in planetary motion (and of Keplerian laws) deduces the well-known law of gravitation from which it follows that in the empty space exterior to the gravitating body the rotation velocity v of the satellites depends on the distance r as $r^{-\frac{1}{2}}$. In the case of galaxies the observations show on the contrary: v = constant. Many astronomers think they understand this fact in the Newtonian framework if the region in which this happens instead of being empty contains a significant quantity of matter; they think that since this matter is not visible it must be constituted of particles whose existence is foreseen by physical theory of high energies applied to the initial phase of the big bang theory. In 1983 Milgrom proposed on the contrary that when the accelerations are very small as are gravitational ones at great distances from the central part of the galactic mass m the fundamental law of mechanics must be

$$F = ma^2/a_o \quad (a_o = \text{constant}).$$

The observations may be justified without introducing "black masses".

The problem of black matter is present also in other astronomical cases and represents one of the most important problems of modern research.

6. The Problem of the Value of G

Newton tries, but without success, to determine G. Nowadays G is a precision that is not enough for certain research works. A theory has been given which states that G is variable with time. Dirac proposes $G \simeq t^{-1}$ but Teller and Pochoda-Schwarzschild point out that probably G does not depend on t. The problem is still open.

7. The Cosmological Problem

Newton's gravitational law raises the problem of a finite or infinite universe; he considered the universe infinite because otherwise gravity would lead to the collecting of all cosmic matter in a small region, stating in this way the first cosmological model conditioned by a cosmic law. Nevertheless this model is in contrast with the problem of darkness at night (already slightly indicated by Kepler and Halley and improperly known as Olbers paradox).

The cosmological problem is still open since it is difficult to choose among theoretical models deriving from laws which are thought to be fundamental, and to assign a clear cosmological meaning to certain observational data.

Even though most modern astronomers are sure of the general validity of the big bang theory, there are authoritative cosmologists who deny it. So the cosmological problem is still open.

Conclusion

Newton's work opened up an immense panorama to the future of research. In the 300 years from the publication of the first edition of the Principia enormous progress has been made in the directions shown by Newton.

We have mentioned the principal lines of Newton's work in order to pay homage to this representative genius of the human race and to show that subsequent researches, not yet definitely worked out, have been so deeply elaborated that we are sure that soon the Newtonian program will be concluded and presented to human reflection.

In the Middle Ages men following the Christian theological doctrines had solved every problem pertaining both to cosmological as well as to physical reality and personal and moral behaviour; in practice these doctrines were accepted by the majority of the Western world.

THe majestic theological and philosophical theory of Saint Thomas d'Aquino and its poetic exposition by Dante in the Divina Commedia are the finest and most complete of its achievements.

Yet around 1300 signs of a breach in social life and literature (humanism and the Renaissance) at first and then in philosophy rose together with the necessity of describing nature with autonomy, looking for simplicity and unity in revealing the effective structure of reality.

It gave birth to the problem of envisaging the validity of such a process which destitutes philosophy and religion of a relevant part in the domain of knowledge and then the still realistic problems started to match scientific theory to the real world and to correlate science, philosophy and religion.

We arrive in this way at 1500, when Copernicus worked out the heliocentric theory of the planetary system so that the scientific world had to choose between the new or the secular Ptolomaic vision of the world: the former very simple and the latter more elaborated but deeply rooted in traditional culture: both of them however equally satisfying the purpose of describing celestial phenomenology.

At this time the attitude began for which science does not see the reality of things but science only describes formally nature so that its authority relies merely on the fact that it allows a computation conforming to observations. This point of view is very well exposed by the Lutheran theologist A. Osiander in the foreward to the "De Revolutionibus Orbium Coelestium" by N. Copernicus when first published in 1543 in Nuremberg: "...It is not necessary for these hypotheses to be true and even not verisimilar but it is enough that they consent a calculus congruent to observations unless someone is so unaware of geometry and optics as to think realistic the Venusian epicycle and to think it to be the cause why Venus sometimes comes before the Sun and sometimes follows it. Who could not see that in this case the diameter of Venus at perigee should appear more than four times bigger (and its body more than sixteen) but secular experience says that it is not true.

"...It is clear enough that this art ignores completely why the apparent motions are unequal. It invents some causes and surely many causes are invented, not to persuade someone but to state correctly the calculus.

"Since sometimes many hypotheses are proposed for a given motion (as for the Sun's motion, for epicycle, for eccentricity) the astronomer will prefer the easiest one. The philosopher will require the verisimility. However nobody will be able to understand or teach anything sure if not what God revealed to him."

Even if probably this was not the opinion of Copernicus himself (as we deduce from the letter in which the author dedicates his work to Pope Paul III) the question is that the Catholic Church kept it in its mind during the following decades when they had to face the logic with which the effective reality of the Copernican system was sustained and it became unavoidable to assume a clear position: after the meeting of the Inquisition on February 23rd 1616 when the Copernican theory was declared false and heretical, Cardinal Bellarmino accepted the possibility of referring to it on the condition of considering it merely a hypothesis only in order to simplify the calculus: the "monster" himself (this was the nickname of the Master of the Holy Palaces because of his fatness) gave the nulla osta for the publication of Galileo's Dialoghi dei Massimi Sistemi on the condition that the Copernican system be presented as a "hypothesis", "ingenious fantasy", "mathematical caprice", but not as a reality.

In the same period in France, Cartesius based his physics on geometric criteria, which were the most convenient for his fundamental theory (clear and distinct) for extension as a prime property of being and he proposed (as a fabula) a mechanical reconstruction of cosmic formation from a primeval chaos. Following the thought by which God keeps the world in being, Cartesius sought, in phenomenology, a sign of something constant even in its apparent modification: from this point of view Cartesius sees the inertial concept as a cosmic law and as the essay to look (in the seven cases of the shock phenomenon) the constancy of motion quality, i.e., the product of mass by velocity.

We have to notice that Cartesius sometimes named "vis" what we call "work" (the same vis is necessary to lift 100 pounds by a foot, or 50 pounds by 2 feet) but all this clarifies that the mechanical concepts proceed and become clear after some time.

Cartesius accepted the Copernican thesis of the structure of the planetarian solar system and completed it with the hypothesis of ethereal matter vortices to justify the planetarian motions which are so different from the rectilinear uniform motion of inertial law but after the condemnation of Galileo (1633) he went through a crisis and tried to overcome the obstacle with scarcely convincing expressions.

It is interesting to remember that at the same time in Germany Leibnitz saw more clearly than Cartesius (and Cartesians) the idea of cinetic energy which he called "vis viva" and he thought that this quantity, and not motion's quantity, was the one that remained constant in the mechanical phenomena. Going over the Cartesian observation that the same force (nowadays called work) is necessary to raise weight P to a given height h when the product Ph is the same, he made a step forward and he thought that this force had to be present in the moving body when it falls from height h. With reference to the Galilean law for which a falling body has velocity growing as $h^{\frac{1}{2}}$, he points out that in the mechanical expressions of conservation the velocity does not appear as v as Cartesians erroneously thought, but as v^2, so that what is conserved is mv^2, i.e., the vis viva.

Contemporary with Leibnitz there was Newton in England where the Copernican theory was accepted as reality not only for the Galilean contribution but also for the Keplerian one specifying the peculiarities of the planetarian orbits around the Sun.

About 1665 Newton began his studies on gravity and his problem was if terrestrial gravity is still active up to the Moon and it is, even if weakened by distance, what compells our satellite to orbit around Earth, transforming the natural rectilinear trajectory into a circular one.

Examining the case of the motion of a body compelled to follow a circular path, Newton computed the total force (motion's quantity variation) acting on it for a complete circle which is given by $2\pi mv$ (v = velocity, m = mass)(1) so that the force is $2\pi mv \div T$ ($T = 2\pi R \div v$ = period of circular movement, R = radius of circular path) and therefore $mv^2 \div R$ or, which is the same, $4\pi^2 mR \div T^2$.

We shall use this formula soon. Newton found this formula in other ways as well, and computed the acceleration of the orbital motion of the Moon assuming (correctly) as the Earth-Moon distance 60 terrestrial radiuses (= R). He compared the result obtained with gravity on the Earth's surface and found that the first was about 4000 times smaller than the second. He was not quite satisfied with this result because Kepler's third law for planets states $R^3 \div T^2$ = constant so that $R \div T^2 = \text{const.} \div R^2$; for the former result it means that the centripetal force due to the attraction of the Sun is inversely proportional to the square of distance.

If an analogous law exists for terrestrial gravity the lunar acceleration should be $60^2 = 3600$ times smaller than the terrestrial one and not 4000 times as obtained before.

The disagreement was really very small even considering the approximations used by Newton, but it is said that Newton was really concerned with the results obtained and that he felt compelled to admit that for the Moon some other effects acts of the same kind as the Cartesian vortices.

Around 1671 the French astronomer Jean Picard measured with care the length of a degree of terrestrial meridian and from it a better value of the terrestrial radius was obtained; on the basis of this new datum Newton made his computations again and obtained that gravity's acceleration at the lunar distance is really 3600 times less than that at the terrestrial surface.

In 1640 the English astronomer William Gascoigne discovered by chance an instrument to be applied to the telescope, the micrometer, which has been fundamental to astronomical research: it allowed very precise measurements of angular distances. In 1660 Huygens and others emphasized this instrument which was applied to evaluate the diameter of planets and the distance of satellites from Jupiter and Saturn and their motion: it appeared that the planet's satellites also follow the Keplerian laws.

It appeared that comets also follow these laws so that around 1680 Newton had elements enough to affirm and demonstrate that the space in which celestial bodies move is empty, that the theory of space filled with ether and Cartesian vortices is impossible; the celestial bodies confirm the mechanical laws based on the existence of absolute space and time and they show that an attraction among bodies exists which follows the law of inverse proportion to the square of distance and that the phenomenon of gravity on the terrestrial surface is of the same nature as cosmic universal attraction.

In 1686 the Philosophiæ Naturalis Principia Mathematica was presented in three volumes to the Royal Society and was published in 1687. The Principia affirm the objective existence of absolute space and time and define the quantity of matter as the product of density by volume. This definition contains a vicious circle because density is defined as the quotient between quantity of matter and volume, nevertheless it has the merit of distinguishing the quantity of matter from the weight which is the phenomenon of the gravitational interaction between Earth and the body even though Newton associated the quantity of matter to the weight (in the comment to the definition given by Newton as product of density by volume); but he associated it also to inertia in the third definition in which the quantity of matter is explicitly considered as proportional to the "vis insita", i.e., to the attitude to maintain the motion or to the necessity of an applied force to change it.

These concepts are repeated in the formulation of the first law of motion in which he stated what today is called the first law of inertia and in the formulation of the second law of motion (in which the force induces a variation of quantity of motion, i.e., the product of quantity of matter by velocity).

It was E. Mach who gave a clear definition of mass (better, of the ratio between the masses of two bodies) as the inverse ratio of the accelerations of the two bodies when they interact.

Apart from the poor definition of quantity of matter, Newton performed very accurate experiments which allowed the confirmation of the proportionality of gravitational force (weight) to the quantity of matter independently from the kind of mass itself.

C. Huygens had studied the phenomenon of shock in which he had recognized the conservation of vis viva and the phenomenon of circular motion in which he had pointed up the centrifugal force as $mv^2 \div R$, pendular motions and he had singled out the elements by which the period P of oscillation depends: $P = 2\pi\sqrt{e \div g}$. This period does not depend on the quantity of matter of pendulum because gravity is independent of it and of the kind of substance constituting that quantity of matter.

Newton understood that the confrontation of equal pendula made of different materials allows a very accurate verification of the independence of g because, even though very small, eventual connections should imply a phase difference between the oscillations which progressively should amplify themselves and become sensible. Newton understood that such an experience verifies very precisely the phenomenon of free fall itself, which Galileo had shown to occur independently from the mass.

Newton observed then the relative motion of two pendula with the same length (3 meters) carrying geometrically equal spheres, but containing different substances: wood, water, gold, silver, lead, glass, sand, salt, wheat). He did not notice any sensible phase difference during all the time of experimentation and as for the precision obtained he said only that the different substances were equivalent for the motion by one over one thousand. He confirmed with this accuracy that bodies of different substances fall from the same height in equal time.

Newton in this way had made an experiment belonging to the series of those carried out to convalidate experimentally with better and better precision the so-called "equivalence principle".

Newton naturally did not see things from this point of view and accepted the results of his experiment as a proof that for gravity, the quantity of matter is concerned in its materiality in the most general meaning and he had no more doubts about the validity of his celestial mechanics. He faced the problem of computing the difference in weight of a certain quantity of matter situated at the same distance from the Sun, Jupiter, Saturn and Earth, i.e., from the celestial bodies known, at that time, to have satellites and for which therefore were known the ratios $R^3 \div T^2$ (= GM ÷ $4\pi 2$ from which $R \div T^2 = GM \div 4\pi^2 R^2 = g \div 4\pi^2 = F \div 4\pi^2 m$).

Then it was possible to calculate T at a given distance from each of the above-mentioned celestial bodies and therefore the ratio of weights (F) that a body (m) should have if it were situated at a given distance from each of them: given 1, the weight with regard to the Sun, the weights turned out to be 1/1067, 1/3021, 1/169282 with regard to Jupiter, Saturn and Earth. Knowing by precise measurements obtained by Gascoigne and Huygens with the micrometer, the angular distance of planets and their distance, Newton also computed the weights of the same body on the surface of each of the aforementioned celestial bodies and obtained that they are as 1000, 997, 791 and 109; and at last, since the ratio of weights of a same body to the same distance from the above-mentioned celestial bodies depends only on the difference in quantity of matter of these, Newton concluded that the masses of Sun, Jupiter, Saturn and Earth are as 1, 1/1067, 1/3021, 1/169282 respectively.

Knowing the quantity of matter and radius of each of these bodies, Newton obtained the ratio of their mean density: given 100 the density of the Sun, he found 94.5, 67, 400 as densities of the other bodies.

In this way Newton underscored his discovery of the law of universal gravitation that had been pursued also by many other scientists.

Many years before, following the magnetic phenomenon, the one W. Gilbert had been interested in, Kepler himself thought that the planets were moved and attracted by a solar magnetic force and, on the basis of the second planetary law, where rv is constant, he supposed v≃ 1/r including the force of which v supposed a consequence.

Hooke, a contemporary of Newton's, was convinced he had been plaigerized by Newton when the Principia was published. Truly Hooke in 1674 published his lessons to the Royal Society in which the natural motion of celestial bodies was said to be uniformly rectilinear so that the elliptical planetarian and satellites' motions had to be due to a force (such that the natural motion was deviated); Hooke said also that this force was attractive (gravitational) towards every celestial body and is the bigger the smaller the distance from the attractive body is. He even thought of the law of inverse proportion to the square of distance, but his argumentation was incorrect.

The brilliant Newtonian theory with the cosmic law dominating different phenomena as the planetary, satellites', comets' motions, the weight on Earth and terrestrial tides, showed a fundamentally unitary cosmic structure, but was this theory true in every respect? In effect, the gravitational force had not been discovered directly, but because the fundamental dynamic laws had been formulated in a peculiar way which says that acceleration is caused by a force: the gravitational force had been deduced by studying the acceleration observed. A force acting in a void was surprising, at a distance such that the attractive bodies do not touch each other in any case.

Even the idea of void space was not understandable: the void that Newton thought absolutely necessary to explain celestial motion is incompatible with Cartesian ethereal space and vortices.

It was an important problem that Newton overcame in different ways: first of all with the famous expression of "general scholiam" at the end of Principia: "Hypotheses non fingo", and also: "everything that is not deduced from phenomena must be said hypothesis and physical or metaphysical hypotheses have no place in experimental philosophy.

Nevertheless, in a letter written to Bentley in 1693 he showed some perplexity:

> "Tis unconceivable that inanimate brute matter should (without ye mediation of something else wch is not material) operate upon and affect other matter without mutual contact; as it must if gravitation in the sense of Epicurus be essential and inherent in it. And this is one reason why I desired you would not ascribe innate gravity to me. That gravity should be innate inherent and essential to matter so yt one body may act upon another at a distance through a vacuum without the mediation of anything else by and through wch their action or force may be conveyed from one to another is to me so great an absurdity that I believe no man who has in philosophical matters any competent faculty of thinking can ever fall into it. Gravity must be caused by an agent acting constantly according to certain laws, but whether this agent be material or immaterial is a question I have left to ye consideration of my readers."

The problem was very important and was deepened by R. Cotes (certainly Newton consented) when he wrote in the foreward to the second edition of Principia (1713):

"Since then, all bodies, whether upon earth or in the heavens, are heavy, so far as we can make any experiments or observations concerning them, we must certainly allow that gravity is found in all bodies universally. And in like manner as we ought not to suppose that any bodies can be otherwise than extended, movable, or impenetrable, so we ought not to conceive that any bodies can be otherwise than heavy. The extension, mobility, and impenetrability of bodies become known to us only by experiments; and in the very same manner their gravity becomes known to us. All bodies upon which we can make any observations, are extended, movable and impenetrable; and thence we conclude all bodies, and those concerning which we have no observations, are extended and movable and impenetrable. So all bodies on which we can make observations, we find to be heavy; and thence we conclude all bodies, and those we have no observations of, to be heavy also. If anyone should say that the bodies of the fixed stars are not heavy because their gravity is not yet observed, they may say for the same reason that they are neither extended nor movable nor impenetrable, because these properties of the fixed stars are not yet observed. In short, either gravity must have a place among the primary qualities of all bodies, or extension, mobility, and impenetrability must not. And if the nature of things is not rightly explained by the gravity of bodies, it will not be rightly explained by their extension, mobility, and impenetrability.

"Some I know disapprove this conclusion, and mutter something about occult qualities. They continually are cavilling with us, that gravity is an occult property, and occult causes are to be quite banished from philosophy. But to this the answer is easy: that those are indeed occult causes whose existence is occult, and imagined but not proved; but not those whose real existence is clearly demonstrated by observations. Therefore gravity can by no means be called an occult cause of the celestial motions, because it is plain from the phenomena that such a power does really exist. Those rather have recourse to occult causes, who set imaginary vortices of a matter entirely fictitious and imperceptible by our senses, to direct those motions.

"But shall gravity be therefore called an occult cause, and thrown out of philosophy, because the cause of gravity is occult and not yet discovered? Those who affirm this, should be careful not to fall into an absurdity that may overturn the foundations of all philosophy. For causes usually proceed in a continued chain from those that are more compounded to those that are more simple; when we are arrived at the most simple cause we can go no further. Therefore no mechanical account or explanation of the most simple cause is to be expected or given; for if it could be given, the cause were not the most simple. These most simple causes will you then call occult, and reject them? Then you must reject those that immediately depend upon them, and those which depend upon these last, till philosophy is quite cleared and disencumbered of all causes.

"Some there are who say that gravity is preternatural, and call it a perpetual miracle. Therefore they would have it rejected, because preternatural causes have no place in physics. It is hardly worth while to spend time in answering this ridiculous objection which overturns all philosophy. For either they will deny gravity to be in bodies, which cannot be said, or else, they will call it preternatural because it is not produced by the other properties in bodies, and therefore not by mechanical causes. But certainly there are primary properties of bodies, and these, because they are primary, have no dependence on the others."

As a matter of fact the question raised by Newton was very difficult, and the former defence of Cotes (and Newton) caused more methodological problems than he believed to resolve.

R. G. Boscovich accepted the concept of action at a distance and supported examining the shock of two bodies (considered rigid in absolute) that at very small distances repulsive forces should be started, whose intensity is bigger the smaller the distance is and so one can never speak of action at contact.

G. Berkeley analytically criticized the general concept of force (not only gravitational force); from a philosophical point of view he sustained that the concept of force is a useful hypothesis in order to set up the mathematical calculus not to be objectivated and not to be considered a "real cause" because it is not possible to distinguish the agent from the movement. The object of science is to search for regularity and uniformity for natural phenomena and to bring to general laws the particular appearances.

The problematic connected to the nature of gravitational force, with its not yet explained aspect of action at a distance through an empty space, had different reasons to leave doubtful many researchers: Newton had committed to this space two more thaumaturgical properties: the existence in itself, absolutely and the permission to show the inertia of matter. By the experience of the bucket of water hanging from a twisted rope Newton believed he had shown without doubt that the inertial effects of matter (water) become evident every time we are in the presence of an accelerated motion with respect to the absolute space and that vice-versa the real and effective existence of such a space was clearly demonstrated by these effects. Such a vision implies an effective action of interference between the body and the absolute space which action does not show up when the motion is uniform and rectilinear, but it appears immediately with accelerated motions.

Among the opposers to the introduction of such an absolute space, considered not only not proved operatively by Newton but impossible to be proved since the motion will always be referred to a materialistic system of reference, we mention Leibnitz and Berkeley (the Cartesians referred to ether). The first stated that there is no space if there is no matter; the second stated that absolute Newtonian space has to be replaced by a space defined by fixed stars so that all the motions, the rotational accelerated ones included, have to be related to fixed stars and not to the space in itself: a space imagined without matter is empty of any concrete reference and with an only present body it is not possible to speak of acceleration or rotation: it has no meaning to speak of any kind of motion and so it is not possible to have any dynamic effect on that body.

The analysis of methodological aspects and of the relation: scientific description-reality has not been deeply examined by Newton´s continuers who have been attracted by the possibility of discovering more and more general principles, the more abstract the more mathematically formulated, from which they obtained a full description of mechanical phenomenology and, as a special case, the Newtonian formulation.

So we had D´Alembert´s formulation and Lagrange´s equations included soon after in the principle of least action of Maupertius, Euler, Hamilton and the general formulation of Laplace´s celestial mechanics.

In this formulation the Newtonian action at a distance was not so important but it appeared any time the potential function (in the so-called Lagrangian) had to be referred to the gravitational phenomenon, so that it is possible to say that the whole mechanics of the 18th and 19th centuries was a triumph for Newton's mechanics in which the action to astronomical distances was a peculiarity even though no progress was made in the comprehension of its cause: it was considered very satisfying the formal fact from which all the mechanical, cosmic and terrestrial phenomenology was derived.

It was around 1800 when the study of electric and magnetic phenomena started and very soon the concept of field was born. It appeared that an action at a distance could be interpreted as something similar to action at contact and such a concept showed all its fertility with the introduction of flux lines by M. Faraday, and mainly with the magnificent construction of the electromagnetic theory by J. C. Maxwell by which the propagation of electromagnetic fields is explained.

It was particularly important the fact that the equation of propagation was of the same kind as that found by D'Alembert for the propagation of waves in a mechanical medium so that also light was thought of as propagating in waves.

In this explosion of physical research both in mechanics and electromagnetism (as well as thermodynamics) there was little space left for a methodological analysis so that only a few scientists tried to critically deepen the fundamenta of physics: the majesty of results appeared to be a valuable proof and a justification of the validity, as an objective correspondence to reality, of the principles among which force was predominant.

Nevertheless a few scientists felt the necessity of such a deepening: we name for all E. Mach who set up the concept of force and mass in strictly operative ways as the only ones with which science (and knowledge) had to be concerned with, relying on positivistic rules. Any reference to an autonomous objectivation of those concepts has to be taken away and they are considered in their essential mathematical and relational nature.

So the mass ratio of two bodies is defined as the ratio of the accelerations reciprocally introduced along the joining line, seen as experimental fact and the product of mass[1] by acceleration is defined as motive force. So that the definition of mass and force are reconducted only to the measure of space and time and they have a relational and mathematical meaning. In this way Mach could banish from science the concept of force, mass and cause as autonomous concepts.

Besides this, Mach observed, starting from the Berkeleian critics, that there cannot be any phenomenological difference between a rotating body with respect to the fixed stars and a resting body and rotating stars (supposing that speaking of it has a physical meaning): in both cases centrifugal forces should appear on the body. In other words, the distinction, between inertial and non inertial systems of reference, so important in describing mechanical phenomena, keeps its basis in singling out the principal inertial reference constituted by all the matter scattered in the universe which substitutes materially Newtonian absolute space.

In this way such a fundamental reference had to be considered, after Mach, not as passive and inert but as something active and present in all the mechanical phenomenology showing at the same time the unity and totality of nature: in particular the pendulum of Foucault was a witness of it, since its plane of oscillation remains constantly fixed in the reference system of stars in spite of terrestrial rotation so that it can can be seen even in a closed laboratory; this fact implies a strict correlation between pendulum and the whole universe.

The inertial mass of objects had to be considered as the result of some peculiar interaction with all the matter of the universe.

It is the so-called "Mach's principle" which, while transferring to the stars the representation of the fundamental reference system (Newton had believed it in absolute space) raises a question, analogous to the one posed by Newton, of specifying the cause provoking inertia.

Naturally Mach was not able to indicate it and at first his methodological procedures, still not accepted by everyone, did not bring any practical contribution to the development of mechanics, thermodynamics asnd classical electromagnetism whose development has been carried on the basis of the concept of field as real and autonomous vehicle of force: most scientists accepted the reality of ether as material support to the field. This fact explains the disappointment after the result of Michelson-Morley's famous experience in which the motion of the Earth with respect to ether was not revealed.

The idea of an electromagnetic field seemed to resist even after 1905 when Einstein eliminated from the physical reality the existence of ether.

Machian critics, nevertheless, appeared again in the work of Einstein who, even though he did not explicitly introduce Mach's principle, took inspiration from it, as he said in public, when he formulated the so-called "Einsteinian equivalence principle", which is a fundament to the general theory of relativity (1915).

According to this principle inertial and gravitational phenomena are equivalent in every experimental effect and so they have to be described with a unitary formalism. In dealing with inertial and gravitational phenomenology Einstein changed the Newtonian concept of space into the "quadrimensional metric" which characterizes the space around the mass m, and he avoided the introduction of Newtonian gravitational force.

The new inertial law had to be: "a body near another body has a natural motion (i.e., non subject to forces) following the "geodetic of quadridimensional metric" characteristic of the field, where quadridimensional metric and geodetic are peculiar mathematical expressions which now we do not explain but they describe with better details the motion of celestial bodies and they also show up some unexpected peculiarities of luminous propagation soon after confirmed by experience.

Everything turned into a new formalism which Einstein thought was correlated with physical reality and characterizing the gravitational field.

Therefore it was a mathematical construction where expressions appeared as a "curvature", which probably disconcerted those who tried to find an intuitive representation.

It was necessary to set up the mind to the fact that in the metric field the fundamental relations of Euclideian geometry were replaced by the relations of the geometry of curved surfaces.

The general theory of relativity was a formal non intuitive theory of the gravitational phenomenon which could include the whole phenomenology of classical mechanics and other aspects that this mechanics could not interpret: I am speaking of the secular advance of the perihelium of Mercury, of the curvature of a rayon of light in a gravitational field, of the reddening of light when it passes through a gravitational field.

The new theory, while confirming the old one, stated its limits: the normal phenomenology usually respected these limits which had to be overcome in particular cases, which could be explained by the new theory only.

We were faced with a theory, even though abstract, which had a generality and unitarity bigger than the Newtonian one and therefore more fitting to natural phenomenology.

A subsequent extension showed the possibility of comprehending the universal cosmic structure and soon after it was understood that by introducing some general hypotheses not very dissimilar from those of general relativity, even the Newtonian theory itself could be adjusted to include the cosmic universal structure.

Among these hypotheses, isotropy, homogeneity of space and the limit velocity of light had a very particular function: especially the latter, which in practice says that any event B caused by an event A situated at whatever distance A-B cannot happen in a time t, from the moment when the event A happened, shorter than the time taken by light to go from A to B.

So that in nature the ratio cause/effect cannot be instantaneous and it is realized in a time interval proportional to the distance between cause and effect.

Physical science showed in this way all its possibilities for showing up the cosmic structure, although it had chosen a mathematical formalism whose individual symbology had lost contact with intuition so that it was difficult to see their correspondence with the immediate objectivity of reality. But this aspect practically did not affect physical science because its schemes were more than sufficient in the majority of cases so that the correspondence between the theoretical symbol and real objectivity appeared in all its practical validity.

At the beginning of this century it appeared that sometimes these concepts were not appropriate: the problem of black body radiation and the photoelectric phenomenon induced the removal of the typical physiognomy of field from electromagnetism and its attribution to the aspect of particles (photons - Plank, Einstein).

Soon after, it appeared that some concepts elaborated by classical physics and relativity as energy, quantity of motion, position, velocity, time interval, etc., could be used but were conditioned by some limits and indeterminations which became essential when the particles to which these concepts are applied are sufficiently small (see the famous relation of indetermination of Heisemberg); the same concept of particle loses its precise and autonomous meaning because of the above-mentioned indeterminations and also because with respect to some measures it was inadequate and had to be replaced by that of wave and therefore of field. Consequently it appeared that the so-called particles acquired the physiognomy of corpuscle or of field depending on the instrument used for measuring, so that it, from instrument for measuring an objective reality, became an active element of a reality together with what had to be measured; in addition it was not possible to speak of the instrument itself because it was necessary to consider it as a completing part in every respect of the reality of what had to be measured.

From this point of view someone has generalized that man himself, as an observer, has to be considered a whole with the observed phenomenon. The question was whether it was necessary to give up, in describing the atomic world, those concepts that macroscopic physics had so usefully elaborated and that not even the theoretical critical analysis had put in doubt. Some of these concepts were particularly elementary and intuitive, for instance the particles, the trajectory of particles, etc.; on the other hand, many classical concepts, although defined more precisely and with formal innovation, were still present in the new description of quantistic formalism.

It is known that many physicists (Bohr, Heisemberg) answered affirmatively the above question and that they considered the new quantistic mechanics as reflecting completely the essential reality of nature, while others (Einstein) thought that the quantistic formalism, even though correct and valuable in its results, had to be considered temporary since reality is well specified in itself, constituted by really autonomous elements, independent from the instruments of measurement (and also from man as observer and experimenter) so that it must be possible to build a more complete new theory containing symbols objectively corresponding to reality.

For those who reasoned in this way it was necessary to prove, at least at the beginning, that quantistic mechanics had to face insuperable difficulties of interpretation if it is considered in its present form.

In 1935, a famous note by A. Einstein, B. Podolski, N. Rosen (E.P.R.) they thought they had reached the goal. They started from the two following assumptions that can be considered a definition of physical reality and completeness of a theory:

a) if a system is not perturbed (i.e., no instrument of measure is used) and it is possible to affirm with certitude that such a system is in possession of a given physical quantity with a definite value, then an element exists in physical reality corresponding to that physical quantity;

b) a physical theory is complete if for every element of physical reality there are in the theory elements corresponding to them.

Before going on we recall what the quantistic theory affirms about the measurement of the spin component of an electron along the x axis (S_x) and the z axis (S_z): each one can be +h/2 or -h/2 but it is not possible to take simultaneous measurements because if we measure, for instance, S_x then S_z appears completely indeterminate and vi-ce-versa; following the interpretation of quantistic theory it is not possible to speak of S_z, S_z has no value; vice-versa if we had measured S_z we should have found with the same probability +h/2 or -h/2 but we then should have concluded that S_x has no value.

After this, E.P.R. examined an example which, following Bhom, says: let us consider two electrons a and b coupled so that the total spin $S_T = 0$ if $S_x(a)$ is measured and we find +h/2 (or -h/2), $S_x(b)$ must be -h/2 (or +h/2) because $S_T = 0$; on the other hand, if we measure $S_z(a)$ and we find + (or -) h/2, $S_z(b)$ has to be -(+)h/2. Now in this case quantistic mechanics admits the possibility of measuring S_T and S_x or S_T and S_z. Let us measure $S_T(=0)$ when the two electrons interact mutually and let us suppose that afterwards they get apart one from the other up to immense distances so that they cannot anymore affect each other, for example, to a distance of many light years. If now we measure $Sbx^{(a)}$ and we find +h/2 we have to say that $S_x(b)$ is -h/2 (since $S_T = 0$). In this way without any influence of instruments of measurement on electron b we are sure that it must have spin sx(b) = -h/2; for the given definition of reality we say that electron b "has really" spin $S_x(b) = -h/2$ (in the same way if we had found S(a) = -h/2.

Not only, but we could have decided to measure $S_z(a)$ so as to deduce the value of $S_z(b)$ and we could say that b "has really" an exact value $S_z(b)$: therefore without any influence on electron b we could say that b has the exact values of $S_x(b)$ and $S_z(b)$ in opposition to what quantistic mechanics affirms. If we then take measurements also on b we should not have expected values. But there is more: if, as given by Bohr's interpretation of quantistic mechanics, the value of $S_x(a)$ or of $S_z(a)$ has a given value (+h/2 or -h/2) at the moment the measurement is taken, how can electron b instantaneously assume the complementary value (as an observer situated near b could measure in the same moment of the observer near a) given that it is many light years away? We should admit that the two electrons influence each other with some signals instantaneously propagating, that is, with infinite velocity. Evidently E.P.R. could not admit such an event so they thought they had shown that quantistic mechanics is not complete since it does not comprehend some variables which have to be present in reality and which rule the behaviour of two electrons in a realistically correlated way.

For such conclusions many researchers remained doubtful but Bohr did not modify his interpretation of quantistic mechanics and did not accept the criterion of reality of E.P.R. just because it is not possible to speak of definite properties of a particle without any reference to a measuring instrument; the ideal experiment of E.P.R. is to be seen in its globality together with the whole revelation system.

The physical world turned out to be divided on the interpretation of the deepest meaning of quantistic mechanics: everybody (E.P.R. included) agreed on the practical validity in dealing with the phenomenology of the atomic world but while some (the majority) consider it complete and definitive since fully adequate to reality (which therefore has not the objectivity of the elements of classical physics), others consider it as a non definitive theory waiting for a new theory capable of containing all the elements corresponding to the physical quantities that objectively have to exist in the real world and therefore it will get over the indeterminism and the consequent probabilism to which present-day quantistic theory is obliged to be bound.

In effect the discussion about these aspects of physical methodology faded rapidly both because one could not see a way of solving it with a clarifying experiment and because minds were too busy in developing the new theory which as for results was a strong and adequate formalism for the research.

In 1964 the physicist J. S. Bell observed that it is possible to tackle the problem experimentally because if E.P.R. is correct and some characteristics exist in reality corresponding to physical quantities existing objectively (and therefore independent from measuring instruments), then it is possible to make experiences whose results, suitably handled, must respect some precise restrictions; if these limitations are violated the existence of such characteristics should be denied and the interpretation of Bohr should be convalidated.

In this way the problem took on new interest and some physicists realized suitable experiences: but these experiences were very delicate and the results did not come quickly and were not inequivocable.

It was only in 1981 that in France A. Aspect, P. Grangier and G. Roger at the Orsey Institute of Optics, could clearly prove that the experience transgresses the limitations of Bell. We have then to conclude that a future theory must not be expected to replace quantistic mechanics, i.e., a theory which has some variables corresponding to elements of objective reality as supposed by Einstein, because since present-day mechanics has to be thought complete there is no sense in speaking of these; therefore we have to conclude that they do not exist in reality and that reality itself behaves unitarily and globally as interpreted by Bohr.

It is relevant to notice that these conclusions must not be interpreted as the philosophic movement named positivism sees the relation science-reality. The positivists think that the task of science is not to interpret the reality whose essence is hidden from us; its task is to make previsions relative to the results of measurements, to state correlations between phenomena without introducing elements not connected to the phenomena themselves.

Bohr's interpretation is different: the quantistic mechanics describes and explains reality; if it does not introduce elements it is because these elements have not an objective reality; reality behaves in a unitarian and global way as shown up by quantistic mechanics. Bohr always denied being a positivist.

As we have seen, the problem science-reality passed through different phases: from the interpretation of Osiander and Bellarmino, which assigns to theory a mathematically useful task for the calculus of phenomena, scientists had passed to other theories which interpreted objectively the reality but which introduced elements not objectively existent according to a rigorous formal critica (see the Newtonian force, the electromagnetic field). In this way giving up to these elements as real beings implies that classic physics clarifies the global and unitary behaviour of nature. This appeared even more evident in 1945 when J. A. Weeler and R. P. Feynman showed that in the possibility of electromagnetic emission the source and the absorber are present in equal measure so that without them both the electromagnetic phenomenon could not be possible.

The two authors developed this point of view strictly adherent to classic formalism (but without considering the electromagnetic field as objectively real); as an introduction they report an idea given in 1922 by the physicist Tetrode: "the Sun does not irradiate if it were alone in space and not a body could absorb its radiation". In other words, the Sun can irradiate since the universe has the characteristic of absorber due evidently to its far matter. After having thanked Einstein for remembering this note, the authors referred another important idea of G. N. Lewis (1926) which attributes to an atom the possibility of radiating only towards another absorbing atom since it is absurd an emission independent of an absorption; following this idea we have to speak of "transmission", i.e., a process of exchange of energy between two definite atoms or molecules, both identically necessary instead of emission by an atom.

In this way the concept was stated of spatial and temporary unity of natural phenomenology: the authors technically developed these ideas and they showed that in this way some fundamental difficulties of classical electrodynamics are overcome.

A similar point of view is found in the study of elementary interaction considered as exchange of particles.

In the case of strong or weak interaction there are no particular difficulties in the understanding since the range of these forces is of nuclear dimensions $r_0(10^{-13}$cm), involved times r_0/c 10^{-23} s and the indetermination principle acts completely.

The problem becomes more delicate in electromagnetic interaction because of a very long range and of the finite limit of the velocity of light, so that the corresponding time may be very long.

The mathematical description given by Wheeler and Feynman satisfies the requirement of logic but it puts our intuition, based on a normal concept of space and time, face to face with serious difficulties well exemplified by Tetrode: "If, for example, I observed through my telescope yesterday evening that star which, let us say, is 100 light years away, then not only did I know that the light which it allowed to reach my eye was emitted 100 years ago, but also the star or individual atoms of it knew already 100 years ago that I, who then did not even exist, would view it yesterday at such and such time".

Wheeler and Feynman dealt with the phenomenology of emission-absorption without considering cosmic expansion; it has been pointed out that in a universe like ours difficulties arise and things have to be dealt with in a different way. At the moment we do not yet have a satisfying description of this phenomenology but it is likely that the path followed by the two authors indicates the epistemological formulation of the problem.

The gravitational interaction is now the object of many studies in particular to describe it in the most unitary way with the other fundamental interactions but, after what we have learnt from Newton up to now, the concept will not be denied that the emittent and the absorber are equally present even if in this moment the concept of presence is rather indeterminate: for inertia and gravity it has to involve the whole universe.

The problem of the relationship science-reality does not end up with that of quantistic mechanics and relativity, as said before; other aspects need to be clarified and research is in course to examine them because even if scientific methodology shelters more and more in a strict formal aspect, not for that can it elude the philosophical task of understanding the structure of reality: if it gives up to "the thing in itself" it does not give up to "how it appears" and to the task of putting this "how" in a scheme mostly unitarian and especially coherent as a warranty of a genuine general interpretation.

Just the necessity of coherence claims to be clarified as for the interpretation of inertial and gravitational phenomenon.

It is necessary to confront this interpretation with the finite value of light velocity as a limit to velocities of whichever physical propagation and with the concept that states that the fundamental interactions of nature have to be interpreted unitarily.

Whatever is the nature of gravitational interaction, if, according to Mach's principle, the inertial phenomenon has to be attributed to some interaction with the cosmic matter as a whole (and so prevalently with the distant matter both because of its prevalent quantity and because experimentally no anisotropy is seen in the appearance of inertial mass, how can we understand the fact that inertial reaction happens to be contemporary with acceleration (with respect to cosmic matter)?

Evidently we cannot think that as soon as a body is accelerated a signal starts, whose nature is still not identified precisely but in any case surely of a physical nature, which reaches the distant cosmic matter, situated in deep space at different distances which reacts so as to produce the inertial response of the body to the acceleration: the idea of light velocity as an insurmountable limit and the instantaneous inertial reaction prevent it.

It is a problem with many analogies with that, already seen, of Wheeler and Feynman for the emission-absorption of light phenomenon and could be understood in the same way.

Undoubtedly this aspect of the phenomenology is against our common sense which is based on the concept of cause and time, but it is difficult to accept the thought that the phenomenology can be understood on the basis of concepts for which any single body appears autonomously without considering the conditioning "presence", for its existence as a single body and for the appearance of its phenomenology, of everything that is around and therefore of the whole universe.

Naturally the reference to the above-mentioned "presence" is very vague and indefinite and for the moment a further specification is not possible.

The equivalence principle has many formulations: the gravitational phenomenon is formally indistinguishable, being inside the reference system, from the inertial one, or that bodies of different qualities and of different mass fall with equal acceleration in a gravitational field.

The second formulation was experimented by Newton with the experience of pendular oscillations already described. In this form it is inherent both to the Newtonian theory and to the Einsteinian one for gravitation.

Some doubts on its general validity arose when the existence of antimatter was discovered, but the doubt disappeared when it was specified that "anti" refers only to some properties of matter (for example to the sign of electric charge) while the inertial mass con be considered the same for material and antimaterial particles; on the other hand, relativity bases the concept of matter on that of energy, strengthening the concept that the equivalence principle remains unchanged also for the other kind of matter. Soon after physicists elaborated the C.P.T. theorem which affirms perfect symmetry, for the validity of physical laws, between the material and antimaterial world even if it did not specify its validity in particular situations: two bodies of matter attract each other exactly as two bodies of antimatter (of the same mass), but the same thing cannot be said between two bodies one of matter and the other of antimatter.

Besides that, quantistic physics introduced particular potential functions into the problem of fundamental interaction of nature (for the first time proposed by Yukawa); these functions use some quantities understandable as discrete unities or as exchanging particles between those which interact and so mediating the interaction itself, with radiuses of action inversely proportional to the rest of the mass.

So for instance the photon, the particle mediating the electromagnetic interaction, having an infinite action radius has a null rest mass and it also explains the decrease of interaction by the inverse square of distance. In the same way we introduce other particular particles mediating the weak and strong interaction.

A characteristic of particles mediating fundamental interaction is to have an integer spin, and they are called bosons while others with half integer spin are called fermions.

The quantistic way to consider the phenomenon of interaction is quite different from that presented by the general theory of relativity which interprets very well the gravitational interaction by introducing quantities like "space-time curvature" around a mass of reference while the trajectory of the particle in the gravitational field (in the space-time curve) of the mass is perfectly defined by its complete initial state of motion (position and velocity) and by the condition of geodecity of the consequent motion, independently from every structural attribute of the particle itself except mass, i.e., attitude to perturbate with its own field the curvature of space time of the other mass.

As is well known, quantistic mechanics denies the possibility of assigning complete initial conditions, as in classic physics (relativistic physics included), and to speak of well defined trajectories; it substitutes the initial conditions by limitative ones (the indetermination relation) and the defined trajectories with the probability of finding the particle moving in a given place at a given time.

These two such different ways of interpreting the phenomenology (each one of them has been confirmed by a wide series of distinct and specific observations and experiments) induced the theoretical physicists to investigate the possibility of seeing the two theories in a more unitary way; it has been possible by introducing a peculiar particle in gravitational interaction, the graviton, in a quantistic version of relativistic theory.

It has been necessary to overcome many and various difficulties and recent studies show that theory assumes a more coherent and unitary form if, together with the graviton, two other bosonic particles are introduced to mediate gravitational interaction in addition to the first one and modifying its action.

We have to remember that the concept of "particle", for the critical analysis we have referred to before and that will be confirmed afterwards in its fundamental aspects, is to be taken not as an autonomous reality, but as ways to simplify the description of a reality in which emittent and absorber are equally necessary to the appearing of the phenomenon so that in every aspect of it the "presence" of the whole universe is shown in the phenomenon. So when we speak of particles and even of their peculiar quantities (mass, charge, spin, etc.) we have to refer to precise operations made or that could be made at least theoretically and to the consequent quantitative results.

Now we can say that the two mentioned bosonic particles are the graviphoton and the graviscalar which should have spin 1 (the former) and spin 0 (the latter) together with a rather high mass.

The correspondent interactive effects affect for instance the bandage energy of the atomic nuclea and they depend also on the structure of the atomic nuclea constituting matter and are to be added to the normal gravitational effect by means of the graviton (spin 2, mass 0). Because of their high mass not only their effect does not lower as the inverse square of distance, but it is sensible to rather short distances so that only in such conditions is it possible to have an eventual deviation from the Newtonian law, besides the fact that the graviphoton should imply a repulsive gravitational effect between matter and matter (and between antimatter and antimatter), between matter and antimatter the effect is attractive.

So if graviphoton and graviscalar effectively exist the equivalence principle should be incorrect. Nevertheless, today these points of view have lost some reliance because of theoretical and experimental results. As for what concerns the experimental results we recall those that Newton himself obtained: by means of pendula he compared the equivalence between m_i (inertial mass and m_g (gravitational mass) obtaining a precision of $1/10^3$; in 1832 Bessel repeated the same experiment and in 1929 Potter made it again with the same technique of pendula obtaining a better precision of $1/10^5$. Using as tortion scale situated so that it could measure horizontal effects Eötvös obtained higher precision, around $1/10^9$ and at last in 1970 Braginsky with a technique similar to that of Eötvös obtained a precision of $1/10^{12}$.

Other experiments have been made by other scientists, but we do not insist on them both for brevity and because no one gave results in contrast with the above-mentioned ones. So everybody is confident that the equivalence principle will not have experimental disproval and since the distances implied in the experiences were rather short the theory of graviphoton and graviscalar appeared not to have had an experimental confirmation.

Nevertheless in 1982 Fishbach, Sudarsky, Szafer, Talmadge and Aronson made a critical review of the results of Eötvös' experience and they found that these results indicate a small effect that changes the ratio m_i/m_g when the kind of matter changes and so the equivalence principle is put into discussion.

Naturally other experiences have been made and the results have not been matching since, while Niebauer, McHugh, Faller denied it, Boynton, Crosby, Ekstrom, Szumilo confirmed it (1987). Wm. R. Bennet Jr. (1989) made a precise experience but he did not find evidence for a fifth force and he says that he will continue the research to reach a better precision (at least one order of magnitude).

We must say that if we affirm the existence of that effect and if we think that it is due to the theoretically foreseen existence of graviphoton and graviscalar, such an effect must be very small because the one due to the graviphoton is repulsive while the other due to the graviscalar is attractive and since they are almost equal, their effect is almost null so that the measure's results are justified. But as already said this happens when the gravitational effect is experienced between matter and matter; differently it should happen if the experience should be made between matter and antimatter since in this case the graviscalar's and graviphoton's effect acts in the same attractive way which adds to the normal graviton's attraction. Experiences are to be conducted and soon probably we shall obtain some clarifications.

As for the theoretical aspect, recent research (R. Barbieri, 1986) shows that the possibility of introducing gravitational couplings which are different in masses of different nuclear structure is possible at the price of forcing theory in some way not easily acceptable.

Naturally experimental and theoretical studies are going on showing all the importance of the problem both in itself and for the consequences that it could have on the validity of the equivalence principle on which general relativity is based; for this question we mention also the recent paper by M. J. Longo (1988) which interprets the nearly simultaneous arrival of neutrinos and photons emitted by supernova SM 1987 A after a journey of some 160 000 y as a new test of validity of the Einstein equivalence principle.

Another important question promoted by Newton and still outstanding is the existence of absolute space as fundamental reference system since it can explain some fundamental aspects of phenomenology independently from the distribution of matter in space. For Newton the inertial phenomenon is caused by an interaction between the accelerated object and space, with a mechanism not yet understood. It raised objections from those who considered absurd any interaction between an object and "nothing": in no other way was it possible to define something so immaterial as space.

Furthermore, such an interpretation put a hard division between inertial uniform motion which we cannot realize if not with a connection with the outside (in this case the velocity is relative to the particular reference chosen) and the non uniform motion typically absolute which we realize by the inside without any exterior reference.

We have already referred to the experience of the bucket of water written by Newton in the Principia and of the observations of Leibnitz and Berkeley. We have already said also that the system of distant cosmic matter became even more concretely important with Mach since (according to the positivistic philosophy) we have to eliminate any conceptual reference that is not observable as Newtonian space: the centrifugal effects rise when we see stars rotating and they are stronger the stronger the angular velocity of rotation: they vanish when angular velocity vanishes; the centrifugal effect and more generally the inertia of a body can be ascribed only to the accelerated motion with respect to the far matter. But what is the process?

The inertia to the accelerated motion with respect to the far matter appears instantaneously and from this point of view Newton's hypothesis (which appeared more understandable by an action at "contact") that Mach's one (more understandable by an action at a "distance") it could be considered more coherent with a general scientific conception when it was stated that infinite velocities do not exist and that the light velocity is the biggest one.

Nevertheless, the Machian hypothesis has been preferred for its better epistemological coherence and because Einstein had drawn his inspiration from it when he formulated the general relativity theory. Since inertia had been seen as strictly bound to gravitation some could think of some interaction between the body and some "gravitational field" wherever present due to the far matter into the "present horizon" following the big bang theory. In such a case the gravitational field should have some physical reality let alone its formal introduction and its direct unobservability: in this way one could agree with an epistemological position (to exclude an absolute space conceptually unobservable and to refer to far matter which is only operatively concrete) and be against one (to exclude the objectivation of conceptually unobservable fields).

Apart from some conceptual difficulties, we have to point out that the reference to far matter could appear as a system of absolute nature similar to that attributed by Newton to absolute space. But things are different: if we had ideally eliminated every material body in the universe, with the exception of the test body, we should have eliminated any reference and it should not make any sense to speak of acceleration and therefore of any inertial effect. So the reference to cosmic matter in its totality has the character of "fundamentality" and not of "Newtonian absoluteness" of space. Besides, it is interesting to notice that conceptually, with respect to this reference system, we can speak of fundamental uniform rectilinear motion and of fundamental rest.

When in the Sixties it was found that the universe is pervaded by an electromagnetic radiation of 3°K, this was interpreted as the present echo of the coupling matter-radiation foreseen by the big bang theory. It shows the far cosmic matter so that it represents the fundamental reference system proposed by Mach and it is very important to have here and now the reference to see the fundamental motion, also the rectilinear and uniform ones.

In this way it was possible to rebuild the fundamental kinematics characterizing the matter inside a very large cosmic radius. These researches are still in course. Furthermore, 3°K radiation, because of its property, is more meaningful than Machian cosmic matter: in fact, in the Newtonian scheme of absolute space it is possible to think that cosmic matter has a general rotational motion (absolute). To such a motion it is possible to think also in the scheme of the relativity theory which does not put expressly the condition of Mach's principle: Einstein was influenced by this principle but he did not put it explicitly in his own theory.

Naturally if it is possible to speak of cosmic rotation, Mach's principle loses its strength; such an eventuality had been rejected up to a few years ago since the 3°K radiation is isotrope with a precision of $1/10^4$: for this reason and eventual angular velocity should be less than 10^{-8} s year^{-1}.

Nevertheless, in 1982 P. Birch, an astronomer working at the University of Manchester, studying the distributions of emission intensity and polarization of radio sources, discovered a very strange and unforeseeable effect: the difference between the position angle of sources elongation (major axis) and the position angle of the magnetic field (found by measurements of polarization) is positive in one half of the sky and negative in the other, independently of red shift or, which is the same, of distance: it shows that the elongation of sources (radio galaxies or quasars) is almost parallel in each half of the sky and antiparallel between the two halves.

Different causes of error and various explicative hypotheses left out the only interpretive possibility left by the author to condition in this way distance up to 30.10^9 light years radiogalaxies is to think that the observed objects rotate relative to the intergalactic medium, the rotation axis being preferentially aligned with a universal vorticity. Considering that slowly rotating radiogalaxies, preferentially aligned, have condensed from the intergalactic medium under constant angular momentum, the appropriate angular velocity of the universe is found to be on the order of 10^{-8} s year^{-1}.

Birch immediately saw the importance of this conclusion:

Mach's principle and the widely held assumption of large-scale isotropy would be violated.

It is natural that such a result has been examined very critically and checked by further observations.

In 1983 S. Phinney and R. Webster of the Instutute of Astronomy of Cambridge (England) on examining the results of Birch said that there is no evidence for an asymmetry in the alignment of an extended radio source, as said in Birch's paper, but Birch answered his critics and confirmed his thesis.

On the other hand, D. Kendall and A. Yong of Cambridge University (England) carried out the analysis once again with a bigger series of observational data and found that the effect discovered by Birch is supported to a high level of significance.

Theoretically using the latest measurements of 3°K radiation, Barrow and others found that the universe can spin no faster than 10-9 arc second year^{-1} if the universe is open, 10^{-13} arc second y^{-1} if the universe is at the limit between open and closed universes and 10^{-19} if the universe is closed. They consider therefore Birch's results practically inconsistent with the big bang theory, especially in its more recent inflationistic formulation for which the universe is dynamically and geometrically classifiable in the second case.

In 1983 J. Ellis and K. A. Olive, of CERN in Geneva, observed that just the theory of an inflationistic universe explains, among other characteristics shown by the universe up to this moment, why the universe does not spin or, if it spins, the angular velocity is very small. It is well known that this theory considers that at cosmic time 10^{-35}s the expansion happens exponentially so that its dimensions grow by many orders of magnitude ($\sim 10^{30}$). Because of the conservation of angular momentum it is clear that even an eventual initial rotation dims drastically to a negligible value, as today observations show. At the end of their paper the authors properly observe that this solution to the rotation problem could make Mach's principle redundant because we no longer need it to understand why distant objects rotate so slowly relative to a bucket of water whose surface is flat, and they add: inflation offers the possibility that Mach's principle might be slightly false. Unfortunately it (the inflation) suggests that distant objects are likely to rotate at an unobservably slow rate relative to a truly flat water bucket.

As far as gravitational force is concerned, it must be noted that if the existence of an interaction due to graviphoton and graviscalar (we spoke of them before) is confirmed, the law of dependence to the inverse square of distance should be very slightly modified for distances on the order of some hundreds of meters.

Relativity theory considers the Newtonian law a valid approximation for a very wide range of cases with very small correction equivalent to the gravitational potential expressed by a first term in R^{-1} (Newtonian) and a second one in R^{-2} which contributes to the perihelium motion of planetary orbits, practically verifiable in the solar system only on that of Mercury, but well observable in particular binary stellar systems; among these the most important is the binary pulsar PSR1913+16 (Taylor, Fowler, McKullogh).

Generally at astronomical distances the Newtonian gravitational law, eventually completed by relativity, interprets very well the phenomenology. According to it in many galaxies' clusters the escape velocity has been computed for each one: the mass is considered equal to the sum of the masses of the "visible" galaxies of the cluster; observations of the velocities said that for many of them the value is higher than that of the escape velocity.

In this case the evaporation time of a cluster should be very short ($<10^9$ years) so that the probability of observing it is very small, even negligible if the cluster was born by chance by a momentary casual assembling of galaxies moving in space independently one from another. The structure of these clusters is regular and it seems that galaxies are subject to a common gravitational field generated by the total present mass.

On the other hand, the total mass of all the visible galaxies appears to be insufficient to keep together all the components (escape velocity is less than the observed one for many of them) so that we have to conclude that either in the cluster there is no visible matter (in addition to that of visible galaxies) or the gravitational theory used (Newtonian) is not applicable.

An analogous situation occurred when we studied the rotational orbital velocity of stars and gases (hydrogen) situated at great distances from the central regions of a galaxy where all the galactic mass appears in practice concentrated. The Newtonian theory affirms that $v^2/r = GM/r^2$ so that if M is constant v varies as $r^{\frac{1}{2}}$. In a great number of cases on the contrary it appears that, at distances greater than the apparent limits of galaxies v = constant, understandable only if M = kr, that is, if mass is present even at distances greater than where matter is visible.

Hence either invisible matter is present at these great distances in a sensible quantity or the Newtonian law of mechanics or that of gravitation is not applicable.

Seeing that many astronomers consider true the first hypothesis and without calling into question the Newtonian theory (whose validity, in these cases, is more than enough and it does not require any reference to general relativity) are studying to understand the specific nature of that "black" matter (they have thought of stars with very low luminosity, of black holes, neutrinos and even of different, not yet experimentally observed particles but foreseen by the theory of high energies applied to the cosmology of the big bang).

Nevertheless, some astronomers have not followed this line and they considered the case where the Newtonian fundamental law ($F = ma$), valid for normal accelerations, has to be modified for very small accelerations as in the cases considered. Then these cases become the evidence of the necessity of altering the law: it seems that there should not be black matter, but the necessity of modifying Newton's dynamic law in the presence of very weak accelerations.

M. Milgrom (Israel) was the first to follow this line in a series of papers in the Ap.J. 1983. In reality he has not received general assent, but surely he gained the attention of many scientists. Milgrom did not modify the gravitational law either for masses or for the inverse square of distance: he would not have had confirming observational results; he proposed to substitute the law $F = ma$ with $F = ma^2/a_o$ dealing with very small acceleration, with a_o constant (of course it has the dimension of an acceleration) to be further on defined.

In our case the gravity acceleration for a very large distance from the central area of a galaxy where most matter is, instead of $g = GM/r^2$ will be $g^2/a_o = GM/r^2$. It is possible to prove that all this can be interpreted also as a change in Newtonian acceleration g to $g' = (a_o GM/r^2)^{\frac{1}{2}} = (a_o g)^{\frac{1}{2}}$.

The best success of this formulation is that it deduces that the rotation velocity, when the distance from the central area is large enough, is independent of distance ($v' = a_o GM$) and it is the same as the observed one when M represents the mass of the "seen" matter without introducing any "black" matter to have convergence with the Newtonian theory.

With it we also explain the empirical relation of Tully-Fisher: there exists a linear relation between rotational velocity and luminosity of galaxies. The relation is explained if we consider that galaxies present proportionality between mass and total luminosity. For this reason it is possible to determine the value of a_o.

We obtain $a_o \simeq 2 \cdot 10^{-8}$ cm s^{-2}, in agreement with other independent proceedings. Since $a_o \tau \simeq 3 \cdot 10^{10}$ cm s^{-1} ($\tau = H_o^{-1} = 10^{17}$ s = the universe's age for the big bang theory), a_o is the necessary acceleration to reach light velocity in a time equal to the age of the universe. The author thinks that it is not casual. Since c is constant while τ evidently grows with time, the author admits the possibility that a_o varies with time as it could happen also to the gravity constant G, as Dirac proposed. The only difficulty that the author meets is that it is not possible to assign to the theory a relativistic formulation but naturally he hopes to reach this purpose in the future.

What appears clearly to Milgrom is that it is not possible to speak of black matter as it is to be done if we refer to Newtonian mechanics.

We add at last that many scientists have a preference for a general non validity of known physical laws for certain particular cosmic phenomenology (very energetic sources, quasars anomalous red shift, early phases of the big bang and similar).

At last we have to consider the problem of the determination of the constant of universal gravitation, G.

It is well known that it is the constant of nature known with the least precision among all the fundamental constants even though many experimental efforts have been made to determine it.

Pignedoli (University of Bologna) asserts that Newton himself obtained $g \sim 6 \cdot 10^{-8}$ (C G S) considering the Earth's mass as the product of mean density by volume and knowing the gravity acceleration g on the Earth's surface. The author does not give the bibliographical reference and I have not been able to find it. The bibliography does not mention this Newtonian result, but it refers only to the essays made by Newton to evaluate G by means of a plumb line situated near a mountain whose attraction causes the deviation from the vertical or setting two masses one near the other and evaluating the time taken by these to move to contact.

Nevertheless, Newton did not obtain significant results. The first measurement obtained in a laboratory was made by Cavendish in 1798 ($G = 6.755 \cdot 10^{-11}$ N m^2 Kg^{-2}) followed by others up to recent times. A survey of these results is in Pignedoli or in Cook. A recent value given by Cook is $G = 6 \cdot 6725\ 10^{-11} \neq 12\ 10^{-15}$ N m^2 Kg^{-2}.

Recently two important aspects have been discussed: 1st: if G, with other fundamental constants, is variable with time; 2nd: if it can be considered different when distances are on the order of hundreds of meters because of the effect of the already mentioned fifth force. In this case it has been tried to determine a defined by the reasltion $G_{lab} = G_{\infty}(1 + a)$ (G_{∞} = G when the masses are at distances bigger than some hundreds of meters).

Even though many authors affirm that a = 0, others affirm that $a \neq 0$. F. D. Stacey, G. J. Tuck, G. I. Moore, S. C. Holding, B. D. Goodwin, R. Zhou think that a = -0.0075 within a range of two hundred meters, according to the repulsive effect required by the theory.

Naturally the problem is still open. As for the question of the eventual variation of G with time we recall that it had been originally foreseen by Dirac when he observed the coincidence of the expression

$$\tau m_e c^3/e^2 \simeq 6\cdot 10^{39} \text{ with } e^2/Gm_p m_e \simeq 9\cdot 10^{39}:$$

the first one depends on time, so that $G \to \tau^{-1}$ if the two values, so enormous, are to be coincident not only with the present value of τ (which from the cosmological point of view does not present any particularity) but always.

These observations raised many discussions and cosmological researches; calculations have been made on the consequences on stellar evolution since it is so sensible to the value of G: $L \to G^7$, (L = stellar luminosity) and in particular of the Sun.

In 1948 E. Teller pointed out that since $L \to G^7$ (for stars in the main sequence), and the radius R of the terrestrial orbit around the Sun: $R \to G^{-1}$ (for the law of conservation of angular momentum) a variation of G with time as τ^{-1} would cause temperature T, which on the Earth's surface depends on t as

$$T \simeq (L \div R^2)^{1/4} \sim G^{9/4} \simeq \tau^{-9/4},$$

to be more than 400°K in recent epoch so that no kind of life would be possible, against all biological evidence.

P. Pochoda and M. Schwarzschild said that for the same reason the Sun (and many stars) should have burnt the hydrogen in their interior part very quickly and now the Sun could no longer be in the main sequence. An eventual more recent temporal origin has to be excluded for many reasons, for instance because of the age of the Earth which has been computed very precisely.

As for the consequences in cosmology, different models have been examined with G depending on t by different functions, but up to now no one can coherently justify the various phenomenology so that we have to conclude that the cosmological theory according to the theory of general relativity (which assumes G constant) and the consequent theory of the big bang, seems to have no competitors.

The gravitational law, already well-established and confirmed by Newton not only in its mathematical formulation but as essential property of matter (Cotes underlined this with particular insistence) clearly implied cosmological consequences: how does it happen that stars, which have to be thought of as constituted of matter, remain distant one from the other even though they are subject to their reciprocal attraction?

To this question Newton replies in two ways: the first one, in the Principia, saying that stars uniformly distributed in the sky cancel their attractive effects because they undergo opposite attraction; the second one, in a letter to R. Bentley, saying that if in the sky matter should be scattered in a finite part of space, surely matter should collect in a big spheric mass in the center of this space, but if matter is scattered homogeneously and isotropically in an infinite space then the formation of a single mass is not possible: there can be only local agglomerates so as to give rise to an infinite number of large masses, separated by great distances, and he says that also the Sun and the stars could have had this origin: in this way Newton indicates an evolutive cosmic process.

At the same time he believes it incomprehensible that matter should be divided into two distinct kinds: bright, to form the Sun and stars and dark to form planets, so he attributes this process to God who creates also the order and the harmony of the system formed by these bodies.

This is the first time that to a step is made forward the need of an evolutive cosmic process due to a physical law even though such a concept does not match the concept (of Newton himself) of absolute and infinite time while it approaches the Christian idea of the creation of the world (4000 years before Christ, as calculated by biblical genealogy).

It is known that soon after science will have faced up to the cosmological problem with its own means only and has tried to choose from among observational data the most meaningful ones for cosmology it will give the problem the characteristic of science.

The fact that in order to attribute to observational data a cosmological meaning we have to refer to a particular theory (so that these data may have different significance according to the theory chosen) is one of the main causes for which the cosmological problem is currently still open.

Most scientists agree with the big bang theory since it interprets the observational data in the framework of the theory, very logically persuasive, of general relativity; other theories (some of which are not very distant from the Newtonian one) either do not recognize a cosmological meaning to some observational data or deny the meaning given by the big bang theory (red shift, 3°K radiation, deuterium and helium abundance, relativistic cosmology, etc.).

At present all the theories meet different difficulties like for instance the above-mentioned ones (equivalence principle, nature of inertia and gravity, "universal presence" in the phenomenology connected with electromagnetic and gravitational interaction, etc.).

Even though many problems raised by the fundamental work of Newton are still outstanding, we must underline that physical science is built up to now very powerfully. It has placed man in front of nature pointing up some fundamental aspects which, in the moment they tune in with human logic, escape human intuition: for all of them we mention the concept of "universal presence" in the phenomenologies appearing as the most independent and automous (in time and space) and the concept of the "birth of the universe" with that of the present age of the universe.

Certainly we cannot share the idea, still widely accepted, that science by its very nature has to change its paradigms frequently so that no theoretical scheme can be said to be stable and definitive even though it cannot be excluded that future studies will improve and make them more exact. It is interesting to notice that at this moment we can say that many cognitions are surely stable and definitive: for instance the concept of cosmic evolution together with all the partial knowledge on stars and stars' agglomerates.

Nevertheless, we are conscious of the remarkable youth of our science (3 - 4 hundred years) and we are sure that many general problems will be solved in the future. What we see to be difficult is the relation between coherence and logic on the one hand and intuitivity and human comprehension on the other. But this is a different problem... and perhaps outside the scientific sphere.

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