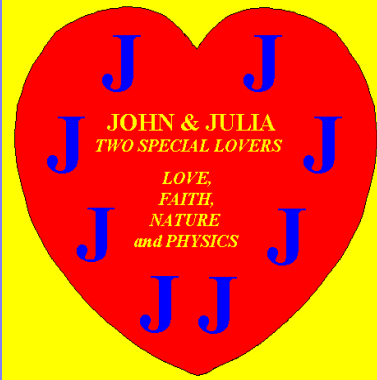
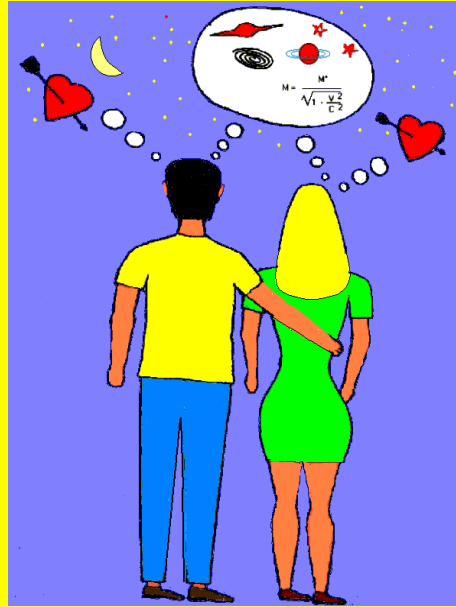
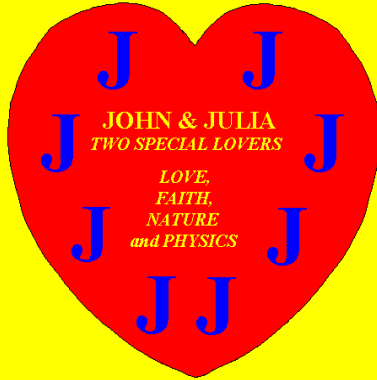


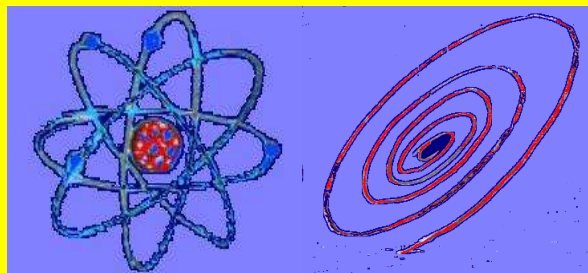
ANTONINO CUCINOTTA



JOHN AND JULIA TWO SPECIAL LOVERS

**CHARMED BY THE MYSTERIES OF THE UNIVERSE,
HELP US UNDERSTAND
HOW THE PHYSICAL WORLD IS MADE
AND HOW IT OPERATES**

plus the text version of PEOPLEPHYSICS.COM WEBSITE



RERUM NATURAM AMBULANDO DISCERE

**MESSINA - COPYRIGHT 2004-2009
ALL RIGHTS RESERVED**

**THE ITALIAN VERSION CAN BE PAY-DOWNLOADED FROM
THE WEBSITE www.librishop.it (the price is 10 Euro)**

INDEX

Page

8PREFACE

9..... I

THE UNIVERSE IS EXPANDING.

WILL IT GO ON TO EXPAND OR TO IMplode ?

14.... II

BIRTH, EVOLUTION AND COLLAPSE OF A STAR

21.... III

STARS, PLANETS AND LIVING BEINGS.

THE MATTER OF WHICH THEY ARE MADE CONTAINS THE SAME FUNDAMENTAL COMPONENTS:

QUARK AND ELECTRONS

27.... IV

THE "FLAVORS" AND "COLORS" OF THE MICROCOSM

36.... V

THE MYSTERY OF THE DOUBLE BEHAVIOUR OF MATTER AND OF THE ELECTROMAGNETIC RADIATION

WAVES OR PARTICLES ?

44....VI

BOSONS AND FERMIONS

OUR LIVE IS POSSIBLE BECAUSE WE ARE MADE OF FERMIONS

47....VII

THE LONG-DISTANCE CORRELATION BETWEEN IDENTICAL PARTICLES MAKES POSSIBLE TELETRANSPORTING ATOMIC AND PHOTONIC QUANTUM STATES

53...VIII

***THE FOUR FUNDAMENTAL FORCES OF THE NATURE:
THE GRAVITATIONAL, ELECTROMAGNETIC, SUBNUCLEAR
STRONG AND SUBNUCLEAR WEAK ONES***

57...IX

***THE MYSTERY OF GRAVITY, A SUI GENERIS FORCE.
IT BENDS SPACE AND SLACKENS TIME***

64...X

***THE MISTERY OF ANTIMATTER
THE UNIVERSE MADE OF MATTER EXISTS OWING TO AN
INITIAL ASYMMETRY BETWEEN MATTER AND ANTIMATTER***

70...XI

***THE MECHANICAL, ELECTROMAGNETIC AND
GRAVITATIONAL WAVES
PERTURB THE MEDIA ACROSS WHICH THEY PROPAGATE
TRANSMITTING ENERGY***

74...XII

***IN THE UNIVERSE TOTAL ENERGY, MOMENTUM, ANGULAR
MOMENTUM AND ELECTRIC CHARGE KEEP UNCHANGED,
REVEALING TO US THAT THE SPACE-TIME IS HOMOGENEOUS
AND ISOTROPIC***

83...XIII

***THE ENTROPY OF THE UNIVERSE IS ALWAYS INCREASING,
SHOWING TO US THE DIRECTION OF THE TIME ARROW***

86...APPENDIX - JOHN'S NOTES

THE MOST IMPORTANT FORMULAE OF PHYSICS

107... PEOPLEPHYSICS

SCIENTIFIC CULTURE WEBSITE (TEXT VERSION)

108... INTRODUCTION

110... FREQUENTLY ASKED QUESTIONS ON THE PHYSICAL WORLD

121... SCIENCE AND BELIEF

124.... THE PIONEERS OF PHYSICS
FROM ARCHIMEDES TO CARLO RUBBIA

- 124.... ARCHIMEDES
- 124.... GALILEO GALILEI
- 125.... ISAAC NEWTON
- 126.... ALESSANDRO VOLTA
- 126.... MICHAEL FARADAY
- 127.... ANDRE'-MARIE AMPERE
- 127.... GEORG SIMON OHM
- 127.... GUSTAV ROBERT KIRCHHOFF
- 127.... JAMES CLERK MAXWELL
- 128.... WILLIAM THOMSON (LORD KELVIN)
- 128.... HEINRICH RUDOLPH HERTZ
- 129.... WILHELM CONRAD ROENTGEN
- 129.... ANTOINE HENRI BECQUEREL
- 129.... PIERRE CURIE
- 129.... MARIE SKLODOWSKA CURIE
- 129.... MAX PLANCK
- 130.... ALBERT EINSTEIN
- 131.... LORD ERNEST RUTHERFORD
- 131.... NIELS BOHR
- 132.... LOUIS-VICTOR PIERRE RAYMOND DE BROGLIE
- 132.... WERNER HEISENBERG
- 132.... ERWIN SCHROEDINGER
- 133.... PAUL ANDRIEN MAURICE DIRAC
- 133.... ENRICO FERMI
- 133.... WOLFGANG PAULI
- 134.... EUGENE PAUL WIGNER
- 135.... SIN-ITIRO TOMONAGA
- 135.... JULIEN SCHWINGER
- 135.... RICHARD FEYNMAN
- 135.... MURRAY GELL-MANN
- 136.... SHELDON LEE GLASHOW
- 136.... ALVIN WEINBERG
- 136.... ABDUS SALAM
- 136.... CARLO RUBBIA
- 136.... SIMON VAN DER MEER

138.... THE EXPLORATION OF MICROCOSM IN XX CENTURY
FROM THE RESEARCHES ON THE CATHODE RAYS TO THE STANDARD MODEL

- 138.... THE EXPERIMENTS ON CATHODE RAYS
- 138.... THE DISCOVERY OF X-RAYS (1895)
- 138.... THE DISCOVERY OF THE NATURAL RADIOACTIVITY (1896)
- 139.... THE DISCOVERY OF ELECTRON (1897)
- 139.... THE MAX PLANCK QUANTIZATION HYPOTHESIS OF THE RADIANT

ENERGY EMITTED BY A BLACK BODY (1900)
140.... THE SPECIAL RELATIVITY THEORY OF ALBERT EINSTEIN
141.....EINSTEIN'S HYPOTHESIS OF PHOTONS CONSENTS TO EXPLAIN THE PHOTOELECTRIC EFFECT (1905)
141.....THE DISCOVERY OF THE ATOMIC NUCLEUS (1911)
142.....THE X-RAYS DIFFRACTION EXPERIMENTS AND THE STUDIES ON THE CRYSTAL LATTICES (1912-13)
142.... THE BOHR-RUTHERFORD ATOMIC MODEL (1913)
142.....DE BROGLIE'S WAVE-LIKE HYPOTHESIS OF THE MICRO-WORLD PARTICLES (1924)
143... SCHROEDINGER'S NON-RELATIVISTIC QUANTUM MECHANICS (1925)
HEISENBERG'S UNCERTAINTY PRINCIPLE (1926)
143.... THE DISCOVERY OF THE ELECTRON SPIN (1927)
144.... THE ELECTRON DIFFRACTION EXPERIMENTS (1927)
144.... THE DIRAC RELATIVISTIC QUANTUM MECHANICS AND THE ANTIMATTER HYPOTHESIS (1928)
145.... PAULI'S NEUTRINO HYPOTHESIS(1930)
145.... THE DISCOVERY OF NEUTRON (1932)
145.... ENRICO FERMI'S RESEARCHES ON NEUTRONS (1934-1938)
146.... THE DISCOVERY OF THE URANIUM FISSION (1939)
146.... FROM THE RESEARCHES ON THE COSMIC RAYS TO THE HIGH ENERGY PHYSICS
147.... THE FUNDAMENTAL PARTICLES OF MATTER: QUARKS AND LEPTONS
148.... THE THREE GENERATIONS OF QUARKS AND LEPTONS IN THE STANDARD MODEL
149.... THE FUNDAMENTAL FORCES OF NATURE AND THE STANDARD MODEL FORCE VECTORS
153....FROM THE STANDARD MODEL TO THE GREAT UNIFICATION THEORIES

154.... THE STANDARD MODEL

155.... LEPTONS

161.... QUARKS

167.... THE QUANTUM FIELDS

167.... GLUONS: THE VECTOR BOSONS OF THE STRONG SUBNUCLEAR FORCE BETWEEN QUARKS

168.... THE LAWS OF CHROMATIC SYNTHESIS FOR THE GLUON FIELD

170.... PIONS: THE SCALAR BOSONS OF THE RESIDUAL STRONG INTERACTION BETWEEN NUCLEONS (PROTONS AND NEUTRONS)

173.... PHOTON : THE VECTOR BOSON OF THE ELECTROMAGNETIC FORCE BETWEEN ELECTRICALLY CHARGED PARTICLES

176.... THE HEAVY INTERMEDIATE VECTOR BOSONS OF THE ELECTRO-WEAK QUANTUM FIELD

180.... THE MAIN HADRONIC COMBINATIONS OF THE STANDARD MODEL

181.... THE MAIN MESONS

187.... THE MAIN BARYONS

191....MEMORANDUM

194.... THE LAWS OF THE PHYSICAL WORLD

LET'S THINK ABOUT SOME DAILY EXPERIENCES TO EXPLAIN WITH SIMPLE WORDS AND SOME FORMULAE THE LAWS WRITTEN BY GOD IN THE STRUCTURE OF THE PHYSICAL WORLD

- 194....THE FIRST LAW OF DYNAMICS (GALILEO-NEWTON'S INERTIA PRINCIPLE)**
- 195....THE IMPULSE OF A FORCE AND THE LINEAR MOMENTUM OF A BODY**
- 195....THE SECOND LAW OF DYNAMICS (GALILEO-NEWTON'S LAW)**
- 197....THE THIRD LAW OF DYNAMICS (NEWTON'S ACTION-REACTION PRINCIPLE)**
- 198....NEWTON'S UNIVERSAL GRAVITATION LAW**
- 199....THE GALILEAN LAW OF FALLING BODIES**
- 201....EINSTEIN'S EQUIVALENCE PRINCIPLE (AMONG ACCELERATED MOTIONS OF THE REFERENCE FRAME AND GRAVITATIONAL FIELDS)**
- 202....THE GALILEO RELATIVITY PRINCIPLE**
- 203....THE THEOREM OF "LIVE FORCES" (THE WORK-ENERGY THEOREM)**
- 204....THE CONSERVATION PRINCIPLE OF LINEAR MOMENTUM**
- 206....THE SECOND LAW OF THE ROTATING-BODY DYNAMICS**
- 209....THE CONSERVATION PRINCIPLE OF ANGULAR MOMENTUM**
- 212....THE FRICTION**
- 213....THE HYDRODYNAMIC RESISTANCE**
- 213....THE AERODYNAMIC RESISTANCE**
- 214....PASCAL'S PRINCIPLE**
- 216....ARCHIMEDE AND STEVINO'S PRINCIPLES**
- 217....THE MASS CONSERVATION PRINCIPLE**
- 217....THE HEAT PROPAGATION (BY CONDUCTION, CONVECTION OR IRRADIATION)**
- 219....THE ENERGY CONSERVATION PRINCIPLE AND THE THERMODYNAMICS PRINCIPLES**
- 223....TRANSFORMATIONS OF HEAT INTO MECHANICAL WORK**
- 225....ELECTRIC FIELDS**
- 228....THE WORK OF THE ELECTRIC FORCES**
- 230....OHM'S LAW AND JOULE EFFECT**
- 231....THE MAGNETIC FIELDS**
- 234.... AMPERE'S LAW (THE LAW OF THE MAGNETIC CONCATENATION)**
- 235....FARADAY-NEUMANN'S LAW (ELECTROMAGNETIC INDUCTION LAW)**
- 237....THE ELECTROMAGNETIC (LORENTZ'S) FORCE BETWEEN AN ELECTRIC CHARGE AND A MAGNETIC FIELD**
- 239....THE ELECTROMAGNETIC FORCES ACTING ON AN ELECTRIC CIRCUIT IN A MAGNETIC FIELD**
- 241....THE ELECTROMAGNETIC FORCES (ELECTRODYNAMIC FORCES) ACTING AMONG ELECTRIC CIRCUITS**
- 241....MAXWELL'S ELECTROMAGNETISM**
- 243....THE ELECTROMAGNETIC FIELDS AND THE PROPAGATION OF THE ELECTROMAGNETIC WAVES**

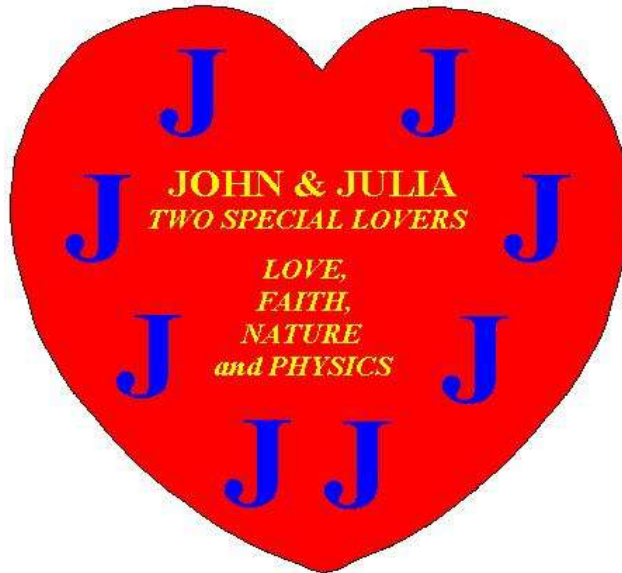
245....THE REFLECTION AND REFRACTION LAWS OF THE ELECTROMAGNETIC WAVES

247....THE POLARIZATION OF THE ELECTROMAGNETIC WAVES

247....THE INTERFERENCE OF THE ELECTROMAGNETIC WAVES

249....THE DIFFRACTION OF THE ELECTROMAGNETIC WAVES

250....THE DOPPLER EFFECT



PREFACE

I have written this book, being inspired by the Virgilian maxim "omnia vincit amor", with the intent to experiment a new approach, perhaps pleasant, I hope so, to the knowledge of the laws governing the physical reality, from the microcosm of quarks, photons, gluons and electrons, to the macrocosm of stars, black holes and of galaxies.

The laws of physics, that normally are expressed by a rigid and at same time elegant mathematical formalism, that makes us catch only some glimpses, although passed a few more than four centuries since Galileo founded the modern science, of the logic written by God in the space-time of the universe, often are able to generate mental closing, or even immediate refusal in anyone wants to study for the first time the phenomena of nature.

This is one of the principal reasons of division, which isn't irremediable as I think, between the so called "two cultures ", the humanistic one and the scientific one, that are nothing but faces of the same medal, the culture with no adjective, that takes us back to the classical Greece, *alma mater* of the universal knowledge.

Then, why don't we exploit love to overcome the barrier of incommunicability between the world of science and the one of the daily live in this early years of the third millennium, that are pregnant with several advanced technologies, that aren't science, but derive from its innumerable applications, whichever they are, good or bad ?

The fundamental scientific research, that has to be constantly and however developed, whichever may be its technological applications, is, unlike the technology, a human gasping that cannot be repressed, the vital force of Ulysses who would awake in everyone of us, mainly in the young people, if we want the cultural, technological, economic and social regression to be avoided.

I hope the paths of love, science and faith of John and Julia, two special lovers, fascinated by the mysteries of the universe, who while walking, take as a starting point the observation of the nature to speak in a simple mode about the laws and the mysteries of the creation and to feel everything deriving from the boundless love of God for the humanity, are able to communicate to the reader many little but meaningful stimuli that may be useful to broaden his horizon of scientific knowledges.

I

THE UNIVERSE IS EXPANDING. *WILL IT GO ON TO EXPAND OR TO IMplode ?*

John and Julia were going out together for a few months. They had met at the university restaurant and at once felt to stay well together. They were attending the courses of the fourth year of physics and of the second year of natural sciences, respectively, and met often during the breaks among the lessons, because they had soon discovered to have both a special curiosity for the natural phenomena.



A June evening, under a marvellous starry heaven, John and Julia were sitting on the beach and cradling by the rhythm of the backwash, while the long blonde hairs of Julia, ruffled from a pimpling breeze carrying bitter scents, were grazing John's face, predisposing him to more intense feelings.

Their looks often were turned to the stars, that made still more magic the meeting of the two boys, isolating them from the rest of the world. "Look", said Julia, "that bright point ploughing fast the heaven".

"It is a meteorite", said John, "you can express a wish" .

Julia, charmed after seeing that meteorite and thinking about the immensity of the universe, started to ask John any questions about that:

"John, what are you feeling while looking at this marvellous heaven?"

"I think about the immensity of the space", answered John.

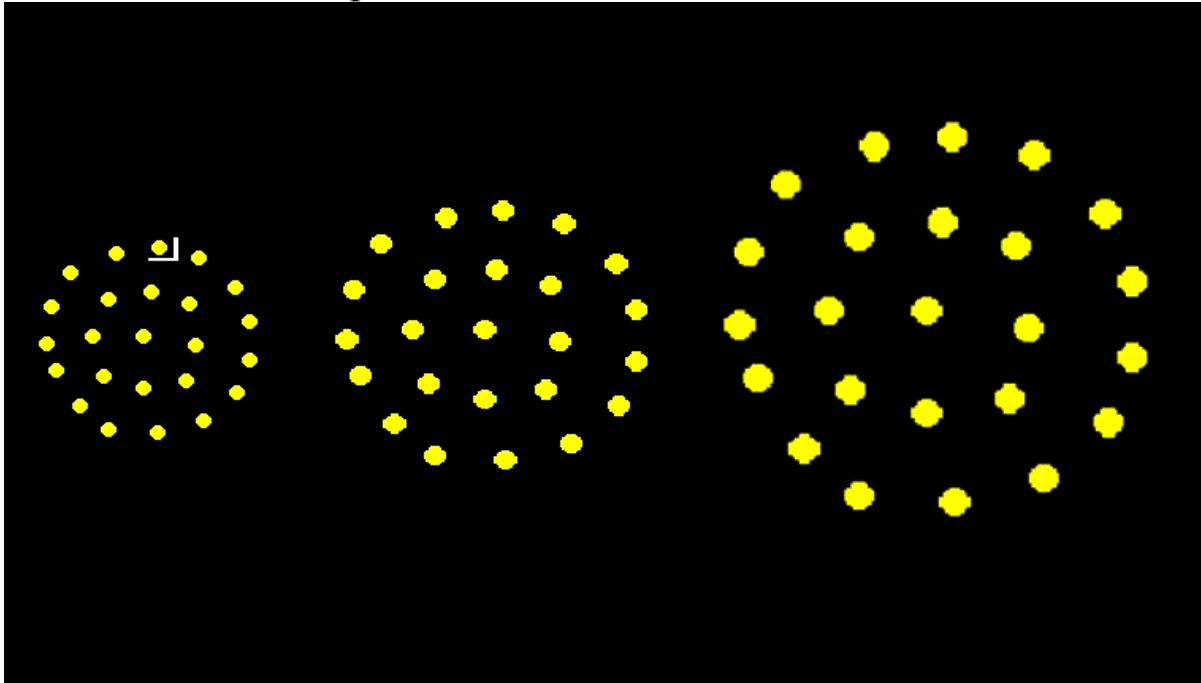
"Don't you feel anything else ?", said Julia, "don't you think about the Creator of this marvellous, eternal natural view that makes us feel to be so tiny and so lost in the boundless universe?"

"Julia, you wouldn't say the universe is eternal, because it is only fifteen year billions old, since the big bang, the so called big explosion from which the Creation arised."

"And before God created the universe, what was there ?", asked Julia.

"Einstein would have said you that before the big bang neither space nor time existed, then didn't exist also the so called time-space , as he called the space-time continuous that is the background for the galaxy billion hundreds that today the astronomers see keep at a distance from us and from the Milky Way, our galaxy, with extraordinary speeds, rather a lot of thousand tens of kilometres per second."

" Who discovered this phenomenon ?", asked Julia.



THE EXPANSION SPEED OF THE UNIVERSE IS DIRECTLY PROPORTIONAL TO THE DISTANCE AMONG THE GALAXIES ($V = H D$ – HUBBLE'S LAW)

"This phenomenon", which is known as the expansion of the universe, was discovered by the USA astronomer Hubble in 1929, and gave the cue for the formulation of "big bang" theory, that was confirmed experimentally in 1965, when Penzias and Wilson detected the existence of the fossil cosmic

radiation, that is a residual thermal radiation relating to a temperature of about -270°C .

This radiation is present in the actual universe for effect of its continuous cooling since the big bang, when the temperature, esteemed by the cosmologists, was about 100000 billion billions of degrees".

" Then the universe will go on to expand and get cold more and more", said Julia. "

"Yes, you' re right", answered John, "till the galaxies,going away from each other with speeds that are the higher, the greater are their mutual distances, will make the universe less and less luminous and dense".

Such a magic silence was interrupted by some cackling boys, that were about mode to turn on a bonfire."

John, taking tenderly Julia by hand, proposed her to walk along the beach, attempting to regenerate the magic atmosphere that pushed them to speak about the galaxies and the "big bang".

"John",asked Julia,"when will the expansion of the universe come to a stop ?"

"Well, Julia ! When you throw a stone up, you can see that, owing to the force of gravity, its speed will be gradually decreasing while it will be going up , till to stop for one instant, and next will be gradually increasing, till it will fall to the ground.

If instead the stone were thrown up with a speed equal to the one of escape out of the Earth gravity field ($40000\text{ Km/h} \sim 11,11\text{ Km/s}$ is a speed so high that it would be used a special gun), its speed wouldn't ever annihilate and therefore it would escape forever out of the Earth attraction.

In the same way, after the "big bang" the bubble of mass-energy forming the universe began to expand, the gravitational attraction, by compressing the matter, slowed down the expansion of the most inner layers in comparison with the external ones, so that the escape speed of matter was directly proportional to the distance from the point of the "big bang" point (Hubble's law). According to the actual theoretical estimates, the final state of the universe would depend entirely on the total quantity of matter inside it: if were enough matter to stop the expansion speed, it would happen a phase of contraction determining the collapse of the universe till the so called "big crunch" (the great implosion) , after which another "big bang" would follow , and then another "big crunch", and so on.

If instead the amount of matter weren't enough, that is, if the total mass of the universe were smaller than the critical value needing to make the universe implode, this would be expanding continually, becoming always

less and less dense and luminous. Unfortunately, at present, the measures of the density of matter in the universe don't allow to make reliable estimates, and therefore it isn't possible to say, on the basis of the actual cosmological knowledges, which kind of evolution will happen, continuous expansion or alternations among "big bangs" and "big crunchs", that is among explosions and implosions."

"Well, then how many chances have the scientists", said Julia, "to perform more reliable measures of the total amount of matter in the universe?"

"Here", Julia, "is the problem. Recent observations of the rotation speed of the more external regions of the galaxies, have pushed the scientists to do the hypothesis that only the 5% of matter of the universe is visible or however noticeable across the emission of waves, X or gamma rays ; the rest of the cosmic matter, the so called dark matter, don't emit any electromagnetic radiation, because it has no electric charges, perhaps because it is made of neutrinos or of much heavy, still unknown and exotic particles (WIMP: Weak Interacting Massive Particles), as they are called by the physicists. This is the mystery of the dark matter.

On the other hand, by some more precise measures of the escape speed of the galaxies, it would result that the expansion speed of the universe is greater of the one calculated by holding account only of the decelerating effect owing to the total cosmic matter (that is, the visible matter and the dark one), as if in the universe were acting a mysterious repulsive force, that is a force of antigravity accelerating the expansion and the evolution of the universe toward a final state less and less dense and luminous of the one corresponding to an expansion with a constant speed."

"Then, John, the temperature of the universe will be decreasing still more because of the acceleration of the expansion ?"

"You're right, Julia, till the moment when, after a lot of year billions, the cosmos will become entirely dark and the background thermal radiation won't be noticeable, because the average temperature in all the points of the space-time will have assumed values near the absolute zero, that corresponds to the least possible energy (the zero-point energy)."

"I think is very strange the presence of the dark energy. How is it possible to justify it physically?"

"You' re right, Julia. In effects the problem of the dark energy may be led back to the cosmological constant that Einstein added to the his equations of the gravitational field, before Hubble in 1929 discovered the expansion of the universe.

The artificial introduction of the cosmological constant, that is equivalent in effect to a repulsive force opposing to the attractive gravity force, was

invoked by Einstein to explain the stability of the universe, that otherwise would evolve toward the gravitational collapse.

After the discovery of Hubble, that implicated the existence of a speed expansion deriving from the "big bang", Einstein was repented much bitterly of his introducing the cosmological constant, that he judged the greatest error made in his life. Today, after many years, the repulsive cosmological term, expelled from the gate, is going back across the window as dark energy, that physically is like an energy connected with all the pairs of virtual particles and antiparticles that incessantly are produced and destroyed in the empty of the space-time, respecting Heisenberg's uncertainty principle.

The dark energy produces a further, very slow expansion of the space-time, that is added to the one derived from the "big bang" ,and is caused by the quantum fluctuations of the void; it is tending to balance, with a very slight prevalence of the repulsion, the contraction of the space-time produced by gravity.

The small value of the acceleration of the universe expansion agrees with this interpretation."

While Julia was absorbed in listening to John speaking and caressing tenderly her hairs, heard her cellular telephone ringing.

It was her parents who were very anxious and urged her to return home. They were right to be anxious, because it was four in the morning and they had been wide-awake all through the night waiting her. Julia reassured them saying he would soon return home.

John and Julia agreed to meet on the next day in the afternoon at the library of the university.

Then, they kissed ... passionately and said goodbye each other.

II BIRTH, EVOLUTION AND COLLAPSE OF A STAR

John and Julia met at the university library at five in the afternoon. It was an hour to the closing time and they both had to consult the database of the scientific magazines. While Julia was able to find at once the references that serve her, John's search was more hard-working, since he had to read quite a lot of abstracts and select the most recent articles, to be used as bibliographical references for the development of his thesis, a very exacting work concerning the most advanced theories about the formation, evolution and death of stars. Because it was already too late, John decided to resume his search the next day and then proposed to Julia to go to visit some friends of theirs, Robert, Anthony and Danielle, who were very fond of astronomy and often were used to gather in a small, isolated villa, in a hilly zone, calm and far from the bright town lights, to look comfortably at the heavenly bodies.

Anthony and Danielle, who were both over thirty and work as experts for an advertising computer-graphics agency, would have to marry after some months, while Robert, the owner of the small country-house, was an established over forty architect, living alone and being more prone to organize amusing evenings with his friends than to establish lasting and binding relationships with women; in fact, his love stories didn't last more than five months, on average. John and Julia contacted their friends in good time, that they might succeed to improvise a pleasant dinner.

After a brief exchange of various jokes and wisecracks about work, taxes, traffic problems and so on, they went to the terrace, where had been installed a beautiful computerized, reflector telescope, with a one-meter focal length.

Robert and Danielle invited John and Julia to approach in turn their eyes near the ocular to observe the bigger planets and some constellations.

Julia, slightly myopic, met some difficulty in focusing Saturn's rings, but with the help of John she succeeded to distinguish them and even recognize easily any constellations.

But Julia, coming back to sit down, heard the necklace and the small medal her maternal aunt had given to hers for the confirmation, falling to the ground.

"Here I am, Julia, I have recovered your fragments of stars", said John,

lifting from the floor on which he has bent."



"Thank you, John, but... excuse me, I don't understand the sense of your sentence!"

"It is simple, Julia, if you think that gold, silver and copper of which your jewels are made, were formed in stars that concluded their evolution by collapsing in *supernovae*, a long time before that were formed the Sun, the Earth and the planets."

"John, this history is very interesting", says Robert, "do you want to explain how this phenomenon happened ? "

"If you listen carefully to what I am saying, I will explain to you in brief how a star originates ,evolves and collapses.

The formation of a star is beginning from hydrogen, that is the most simple and abundant element in the cosmic space. A great mass of gaseous hydrogen is becoming more and more dense because of the force of gravitational attraction among atoms, forming an enormous sphere toward whose center atoms are falling, giving rise to a nucleus whose density, by means of the weight of the impending layers, goes increasing continually. Then atoms, being accelerated toward the center of this gas sphere by the force of gravity, acquire speed and a kinetic energy more and more high that is continually transforming into heat. In such a mode the temperature of the nucleus increases continually by means of the most frequent collisions among atoms, till it reach the value of 15 millions of °C, enough to trigger the thermonuclear reactions ,that make the mass to be

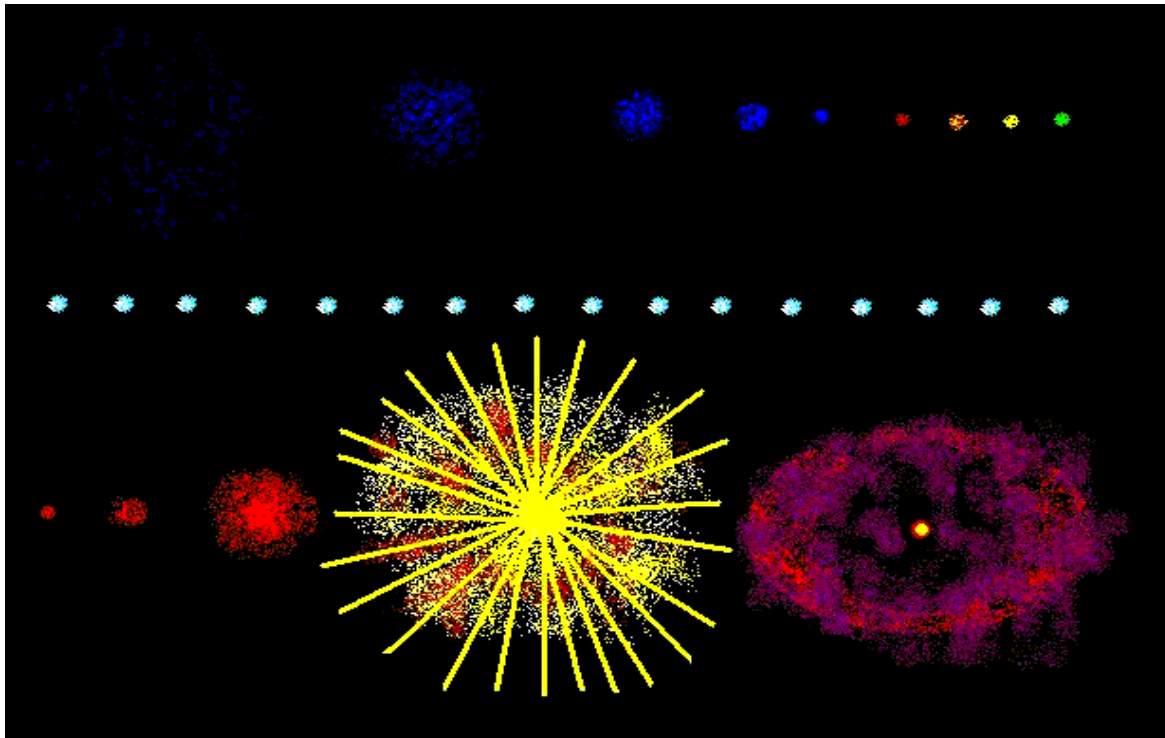
converted into energy, according to the famous Einstein's equation $E = mc^2$, turning on the thermonuclear furnace that makes the star be born and feeds it."

"Excuse me, John, what are the thermonuclear reactions?", asked Anthony. "I mention the example of the hydrogen bomb, the H-bomb, in which take place thermonuclear reactions like that producing energy in stars. The difference consists in the fact that, while in a H-bomb the energy is emitted by means of an explosion, while in stars it is emitted with regularity for year billions. The Sun in fact was formed about 5 billions of years ago and will continue to burn hydrogen for other 5 year billions. Besides, while in the H-bomb the huge temperature (about millions of about tens^o) necessary for the trigger of the thermonuclear reactions is gotten making detonate a conventional atomic bomb, by uranium or plutonium, as the one of Hiroshima, for instance , in the stars instead the reactions are triggered by means of heat generated by the gravitational contraction of an hydrogen cloud. To understand in what does consist the thermonuclear reactions, it is enough to consider that at the huge temperatures at which they happen, matter is in the plasma state, that is electrons, with a negative electric charge, and the nucleus, with a positive electric charge, don't form more neutral atoms, but they are moving freely in all the directions with speeds that are the higher, the higher is the temperature, while colliding continually each other.

Then their displacements are like the ones of the molecules in gases.

When two protons (nuclei of hydrogen) collide with speeds enough to exceed the strong repulsive electric forces which they are subjected to, because of their positive charge, are becoming very strong the attractive nuclear forces, about 100 times more intense than the electromagnetic ones, and the two protons, after being transformed into a proton and a neutron (a particle having no electric charge and a mass nearly equal to the one of the proton), they undergo the thermonuclear fusion, releasing mainly electromagnetic energy (gamma rays). In particular, this first reaction produces a nucleus of deuterium (heavy hydrogen), formed by a proton and a neutron, a neutrino (a neutral particle with a nearly zero mass) and a positive electron (positron).

In the next reaction, from the collisions between two deuterium nuclei originate a neutron, an helium-3 nucleus (made of two protons and a neutron) and gamma rays. Finally, in the last reaction, from the collisions between two helium-3 nuclei originate an helium-4 nucleus (made of two protons and two neutrons) and two neutrons, together with emitting gamma rays. The energy that turns on and feeds the star, is carried away primarily



FORMATION AND EVOLUTION OF A STAR THAT, COLLAPSING IN A SUPERNOVA, EJECTS IN THE SPACE HIGHEST-ENERGY JETS OF MATTER, GIVING RISE TO FORMATION OF NUCLEI OF HEAVY ELEMENTS.

as heat, deriving from the kinetic energy of the neutrons and the helium nuclei . The rest of the energy is carried away by the neutrinos that are emitted by the star."

"Why does a star die ?" , asked Danielle.

"Well, Danielle", answered John, "I give you the example of the Sun, that is a star of average size. When in the Sun, among about five year billions, all the nuclear fuel, that is hydrogen, will be exhausted, its nucleus, that has a temperature about 20 millions of °C, will contract releasing, because of the gravitational potential energy, a quantity of heat that will cause initially a noticeable expansion of the surrounding spherical zone, that consequently will be cooled from about 6000 °C to 3000 °C. The Sun in this phase will become a red giant star, with a diameter some hundred times greater than the one at present (1400000 km), becoming so big that it will incorporate almost all the planets.

Meanwhile the nucleus of the Sun will have reached a temperature of about 100 millions of C°, that will trigger the fusion of three nuclei of helium-4 into a carbon-12 nucleus (composed by 6 protons and 6 neutrons). In the terminal phase, when all the helium will have changed into carbon, all the thermonuclear reactions will stop and the Sun will undergo a final gravitational contraction, collapsing, because of its relatively small mass, into a dwarf star (a white dwarf star) with a diameter of about some

tens of thousands of kilometers, formed by a compressed nucleus made of protons and neutrons and having a density about one million of times the one of water, and by an electron superficial layer, extremely condensed (collapsed).

"But I don't still understand", said Julia, "how metals originate inside stars."

"Well, I explain you this at once. From the astrophysical calculations it results that if a star has a mass till 1.4 times the mass of the Sun, at the end of its life it will collapse into a white dwarf star. If instead the mass is in the range between 1.4 and 3 times the solar mass, the star, after it will have burnt all its helium, it will increase subsequently the temperature of its nucleus burning carbon and producing, by means of further thermonuclear fusion reactions, elements more and more heavy till iron will be formed. When the nucleus of a star will be primarily constituted by iron, the star won't have more any element to burn and therefore it will collapse definitely and within a shortest time under the action of the gravity, while releasing its gravitational energy by a huge explosion, during which neutrons inside it will be absorbed by the iron nucleus, giving rise to the synthesis of all the other heavy elements, from gold to uranium. A *supernova* may be observed even for a few days, and appears as a star much more bright than the Sun, as, for example, the *supernova* of the Crab nebula, which was observed in 1054 A.D..

When a star collapses into a *supernova*, assuming temperatures that are able to overcome one billion of degrees, emits into the space high energy jets of matter, containing nuclei of almost all the natural chemical elements, that therefore are part of the cosmic dust which is continually gathering until to form heavenly bodies. After the explosion of a *supernova*, remains a neutron star, that is a pulsar, so denominated because it emits periodic radio pulses, owing to the fact that it is a little star, having a diameter of about ten kilometers and a much strong magnetic field, and spinning rapidly around itself."

"But if a star is heavier than three solar masses, what happens ?", asked Danielle.

"In this case", said John, "the star dies becoming a black hole, as foresees Einstein' theory of the general relativity."

"What is a black hole ?", added Danielle.

"A black hole", answered John, "which is defined as a singular point of the space-time, is an heavenly body with a spherical symmetry and a radius of some kilometers, that generates such a strong gravitational field, that neither the light, that is propagating in the void with a speed of 300000 km/s, can escape from its attraction; then the body cannot be seen, because

it appears black.

The enormous intensity of the gravitational field of a black hole is owing to the fact that a mass, for example, so big as the one of the Sun, is compressed inside a sphere with a diameter of a few kilometers, very little in comparison with the diameter of a star (from about a thousand of kilometers for a dwarf star to a few million hundreds of kilometers for a red giant star). This means that the density of matter inside a black hole is about 19 ton billions per each cubic centimeter.

Therefore all the heavenly bodies, even photons, both the ones of the light and the ones of the X and gamma rays, when propagating near a black hole, they come inevitably swallowed by it . Think that the mass of the Sun, although it is enormous, two billion billions of tons, isn't enough to make it collapse into a black hole, because it is distributed inside a much large volume, equal to the one of a sphere with a diameter of 1400000 km. The Sun could collapse only if its diameter were of only 6 km !

If instead we were considering the Earth, that has a mass of about 6000 billion billions of tons and a diameter of 12800 km,we would able to calculate that, to get the characteristic density of collapsing into a black hole, it would be necessary compressed into a sphere with a diameter of only eighteen millimeters of diameter."

"John, these numbers are so huge, that escape from our immagination", said Danielle.

"Nothing at all", said Robert,"if you imagine the universe is so huge as a sphere with a radius of fifteen light year billions."

"How many kilometers correspond to a light year?", asked Danielle.

"A light year", answered Robert, "is equivalent to about 9500 billions of km".

"Well",said John, "it is already late, above all for Julia. If you aren't sorry, we shall again come to you the next week, even to look at the heaven with your telescope. We shall warn you before coming."

"Please, you will be able to come to us everytime you like", answered the friends."

"Thank you! Goodbye by the next week!"

