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The new faces of the Universe, p.2

A World of SCIENCE

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IN THIS ISSUE

EDITORIAL

The sky's the limit

On 3 November, NASA and the European Space Agency announced that the Hubble Space Telescope had captured the first visible-light snapshot of a planet orbiting another star. This provides us with the first real image of a planet situated 25 light years from Earth. Not that Fomalhaut b, as the new planet is known, seems much more than a speck in the sky. Yet scientists are already speculating that this planet may be of a similar size to Jupiter and have its own ring system.

Above all, this prowess may help us to understand a little more about the Universe in which we live and of which we are such a tiny part. Our own galaxy, which seems so immense, is just one among 100 billion galaxies. No wonder we ask ourselves: are we alone? A discovery like Fomalhaut b only serves to revive our curiosity. If Fomalhaut b bears similarities to Jupiter in our own Solar System, we muse, could that mean that Jupiter is not unique? And if Jupiter is not unique, what about Earth? In these pages, we put this question to exobiologist André Brack, one of the speakers at the launch of the International Year of Astronomy on 15 January.

Like André Brack, the other authors of the story overleaf on *The new faces of the Universe* are members of the International Astronomical Union, UNESCO's partner in the Year. In these pages, Roland Lehoucq and Jean-Marc Bonnet-Bidaud remind us that, even as our gaze turns heavenwards, our feet remain firmly planted on a celestial body. Which is why scientists have decided to look no farther than the Earth itself for elusive particles which are thought to be as old as the Universe and endowed with the ability to traverse solid matter: neutrinos.

Which is why, after a comet struck Jupiter in 1994, NASA decided to launch a research programme into Near-Earth Objects. After all, if it could happen to Jupiter, it could happen to us. In these pages, astronomer Giovanni Valsecchi explains why it is so important to patrol the skies for cosmic hazards, particularly now that we have the technology to do something about it, should an asteroid ever start on a collision course with Earth. The question is, how do we co-ordinate an asteroid early warning system at the global level?

The theme of the International Year of Astronomy is *The Universe: Yours to Discover*. We hope you will enjoy this 12-month journey into the unknown – and little known. Information on forthcoming events will be conveyed throughout the year via this journal. The adventure begins on 15 January at UNESCO here in Paris, with presentations on different aspects of astronomy, followed by a concert the next day by the Kronos string Quartet; it will be performing *Sun Rings*, a movement based on radio waves gathered from the far reaches of the Solar System by various spacecraft, including the two Voyagers, Galileo and Cassini. Collected over 40 years by American physicist Don Gurnett, these sounds have recently been arranged by composer Terry Riley into what may be the very first space concerto.

W. Erdelen
Assistant Director-General for Natural Sciences

The **new faces** of the Universe

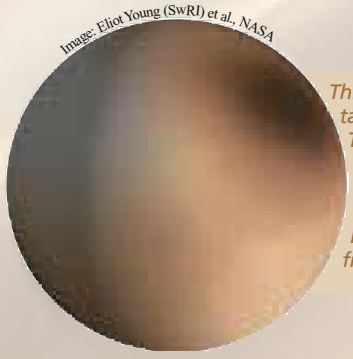
Artist's impression of the eight largest known transneptunian objects, drawn to scale. The four largest are Plutoids. If Pluto had not been stripped of its planet status, the Solar System would now include a good dozen planets!

We kick off the International Year of Astronomy with a brief inventory of the latest discoveries. This journey will take us to the confines of our Solar System; we may already know quite a lot about our neighbours but that doesn't stop them from springing surprises on us, such as the presence of a lake filled with methane on Titan as vast as Lake Superior in North America. From here, we shall go in search of other planet Earths and signs of extraterrestrial life, in the hope of answering a question which has always intrigued us: are we alone in the Universe? Our journey will then take us from the giant black hole in our own galaxy to the most distant galaxies. We shall rediscover dark matter and dark energy, the two invisible components of the Universe which are strangest of all. Our tour will end with a return to Earth, around Earth and even under the Earth, where groundbreaking experiments are tackling one of the great mysteries of modern astrophysics, the composition of the Universe that surrounds us.

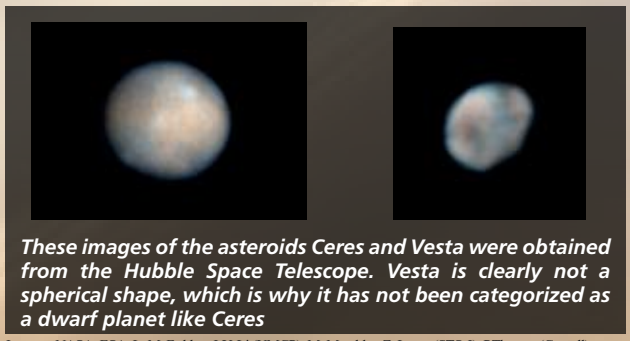
How many planets are there in the Solar System? No, not nine as we have been taught up until now but eight. The International Astronomical Union (IAU) declassified Pluto in August 2006, remember[1], placing it in a new category of 'dwarf planets' established especially for the occasion. Stripped of its planetary status, Pluto is now seen as the archetype of a new category, that of transneptunian objects situated beyond Neptune's orbit.

The new Solar System

Studying the outer limits of the Solar System has transformed our understanding of this region. Modern telescopes have discovered numerous icy objects beyond Neptune's orbit in a region known as the Kuiper Belt, in honour of the Dutch astronomer who posited its existence in 1951. The first transneptunian object was discovered in 1992. It was followed by hundreds of others, confirming that the belt posited by Kuiper did in fact exist. A vast number of icy bodies, possibly as many as several billion, are now thought to lie beyond Neptune's orbit. They are particularly difficult to observe because, being small – some are just 10–50 km in diameter or less – and extremely distant from the Sun, they emit very little light. Also, since they need several centuries to complete an orbit of the Sun, their movement appears very slow and scarcely perceptible. These objects are probably debris left over from the formation of planets which have been flung out into this remote region by interactions with the giant planets.



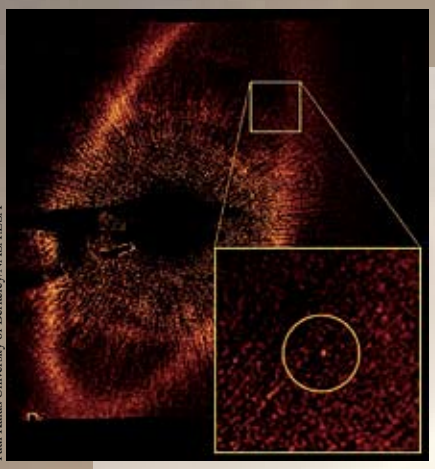
This image of Pluto was obtained from the Hubble Space Telescope. The weak resolution should not overshadow the feat of obtaining images of the surface of a planet located almost 6 billion km from Earth!



These images of the asteroids Ceres and Vesta were obtained from the Hubble Space Telescope. Vesta is clearly not a spherical shape, which is why it has not been categorized as a dwarf planet like Ceres

Images : NASA, ESA, L. McFadden, J. Y. Li (UMCP), M. Mutchler, Z. Levay (STScI), P.Thomas (Cornell), J. Parker, E. Young (SwRI), C. Russell, B. Schmidt (UCLA).

For some time, Pluto was the largest known object in the Kuiper Belt. Then, in 2005, it was confirmed that an object catalogued as number 2003 UB313, located well beyond Neptune, was larger than Pluto. This posed the question of whether the Solar System had 10 planets. Later renamed Eris, the new object was the most distant in the Solar System: twice as far from the Sun as Pluto at



Paul Kalas/University of Berkeley/NASA-ESA

The first visible-light snapshot of a planet orbiting another star, captured by the Hubble Space Telescope. 'Just' 25 light years from Earth, the planet is probably close to the mass of Jupiter. It takes about 872 years to orbit its sun, at a distance about four times that separating Neptune from our Sun. Known as Fomalhaut b, the planet could have a ring system about the dimension of Jupiter's early rings, before the dust and debris coalesced into the four Galilean moons. Fomalhaut is a sun about 200 million years old which will burn out in a billion years. This makes it a short-lived star compared to our Sun, now about 4.5 billion years old and expected to burn another 5 billion years. Fomalhaut's short life is a result of being 16 times brighter than our Sun. Other planets may lie in the wide belt between Fomalhaut b and its sun

the time of its discovery. What is more, its very inclined orbit, like that of Pluto, set it apart from the first eight bodies in the Solar System. It was also discovered that Eris had a satellite, which was named Dysnomia.

The IAU settled the matter by establishing the new category of dwarf planet for Solar System bodies other than the eight classical planets whose mass is nonetheless sufficient for their own gravity to give them a quasi-spherical shape. Currently, five bodies are classified as dwarf planets: the asteroid Ceres, located between Mars and Jupiter, and four trans-neptunian objects which make up the new category of Plutoids: Pluto, Eris, Makemake and Haumea (*see image*).

The Kuiper Belt has yet to be explored by a space probe. However, NASA's New Horizons mission, launched from Cape Canaveral on 19 January 2006, should fly past Pluto and its satellite Charon on 14 July 2015 to obtain high-resolution images of them. This mission will also deepen our knowledge of Pluto's two new satellites, Hydra and Nix, which were first detected by the Hubble Space Telescope. Subsequently, circumstances permitting, New Horizons might study another object in the Kuiper Belt but that remains to be decided.

The new Earths

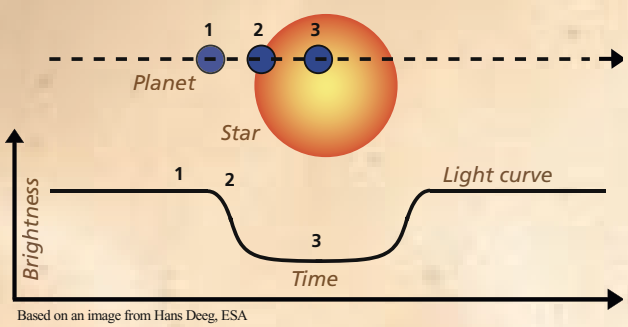
Are there any Solar Systems like ours in the Universe? This question long remained theoretical, even though the chances of finding one seemed quite good in view of the daunting number of stars in the sky: the number of galaxies within range of our telescopes is estimated at 100 billion, each of which contains a good 100 billion stars! Since the discovery in 1995 of the first extrasolar planet, the problem has been resolved: other Solar Systems do indeed exist and there are even quite a few of them (*see box overleaf*).

How do astronomers 'spot' these? Essentially, using two methods. The first is known as the transit method. It is based on the idea that a planet passing in front of the disk of its star produces a mini-eclipse which temporarily dims the star's luminosity by a percentage equal to the relationship between the apparent surfaces of the star and the planet, a value ranging from 1% for a planet like Jupiter passing in front of the sun, to 0.01% in the case of Earth. Continuous observation of the luminosity of a star enables us to identify the period and intensity of this drop in luminosity. This, combined with a measurement of the radial speed – the speed with which the object approaches or moves away from the observer –, makes it possible to deduce the planet's characteristics (*see image*).

The second method is based on the fact that a massive body orbiting a star affects the latter's own movement: rather than moving across the sky in a straight line, the star follows an undulating curve. This situation is similar to that of a hammer-thrower who gravitates from right to left when spinning his hammer in the starting circle. This undulating movement can be detected by the effect it produces on the light from the planet's star: when the star moves towards us, the light takes on a bluish hue

Image : ESA, NASA, G. Tinetti

An artist's impression of the extrasolar planet HD 189733b, the atmosphere of which is known to contain methane and water. This discovery was made by using the Hubble Space Telescope to observe the light of the star filtered through the planet's atmosphere



Based on an image from Hans Deeg, ESA

How can we see exoplanets thousands of light years from Earth, when no telescope can see that far? The presence of a planet orbiting a star can be detected by photometry or spectroscopy. With the transit method, as here, you calculate the drop in luminosity of the star when the exoplanet passes in front of it

Are we alone?

Are we alone? This question has always fired the human imagination. But how we do turn myth into reality? What should we look for? And where? Scientists are essentially looking for a life form that develops in water and is based on carbon chemistry. They are not simply mimicking life on Earth: these two factors are universal and possess exceptional qualities. This is why the quest for a second genesis will benefit enormously from work done on the origin of life on Earth.

The emergence of life on Earth

Four billion years ago, a number of molecules organized themselves in water, the true cradle of life. Here, they formed chemical groups capable of generating true copies of themselves (self-reproduction). As a result of minor errors of assembly, more effective groups appeared and became dominant species (evolution). The two properties of self-reproduction and evolution are the minimal requirements for the transition from matter to life.

It is generally thought that these primitive groups were already made of carbonaceous molecules, some of which may have been created in the atmosphere. For instance, Stanley Miller produced five amino-acids, the building blocks of proteins, by submitting an atmosphere of methane, hydrogen, ammonium and water to electrical charges replicating lightning. Underwater warm springs along the ocean ridges may also have provided some of the carbonaceous molecules that were involved in the emergence of life. Furthermore, an analysis of carbonaceous meteorites, and especially of micrometeorites collected in the ice of Greenland and Antarctica indicates that the quantity of extraterrestrial carbonaceous matter delivered to Earth at the start of its history amounted to 25 000 times the quantity of biological carbon currently recycled on the Earth's surface. Experiments in the laboratory and in space have confirmed the extraterrestrial link.

Signs of extraterrestrial life

Where else might conditions be found that are approximate to those which supported the transition from matter to life on Earth? Using large radio-telescopes, astronomers have identified more than 100 carbonaceous molecules in the interstellar nebulae, proving that carbon chemistry is universal. But where might liquid water be found?

Image : NASA

In July 2005, the space probe Cassini–Huygens flew within 175 km of Enceladus, capturing the first images of the plume of icy material streaming from the moon's south pole: possible evidence of geysers fed by an underground reservoir of liquid water. It also spotted ice boulders the size of a house on the surface of Enceladus, which reflects so much sunlight (almost 100%) that the surface temperature is only -201° C. Thanks to this space probe, which has been orbiting Saturn since 2004 after a six-year journey from Earth, we now know that the planet has more than 60 small moons, 40 of which have been discovered since 2000

On Mars, of course. Photographs taken by Mars missions from Mariner 9 in 1971 to the present day clearly show that large quantities of water formerly covered part of the surface of Mars. It is therefore tempting to think that an elementary form of life like that on Earth could have appeared and developed on the red planet. The American Mars Science Laboratory mission and the European ExoMars mission will be tasked with searching for traces of possible life on Mars, in 2011 and 2016 respectively.

Image: ESA/DLR/FU Berlin (G. Neukum)

A dried-out river in the Nepenthes Mensae delta on Mars, an image dating from January 2008

Europa, the smallest of Jupiter's four moons observed by Galileo, is covered with a shield of ice which could be from 10 to 100 km thick. Under the ice, Europa very probably has an ocean of liquid water. Any hydrothermal sources in that ocean could provide the carbonaceous matter needed for a form of life to emerge on Europa.

Titan, Saturn's largest satellite, resembles Earth with its dense atmosphere. The Cassini-Huygens probe has shown that Titan's atmosphere contains methane and dense clouds of complex carbonaceous molecules. Blocks of ice litter the surface but there can be no liquid water there because the temperature is around -180°C. Enceladus, another of Saturn's satellites, is covered in ice but the Cassini probe observed jets of water vapour on its surface that might come from an underground reservoir of liquid water.

Life beyond the Solar System

Beyond the Solar System, the search for water can only be carried out by remote sensing. For there to be water on the surface of an exoplanet, the planet must be the right size and distance from its star. Since September 1995, when two Swiss astronomers discovered the first exoplanet, more than 300 have been detected.

About 25 star systems comprising several planets have been identified. However, it was only in early 2008 that a star was discovered via gravitational microlensing* which had two planets similar in size and position to a small-scale model of the Jupiter–Saturn couple in our Solar System. This discovery demonstrates that star systems resembling our Solar System may well be common in the Universe. What about small inhabitable exoplanets the size of Earth? Our instruments are not yet accurate enough to detect these but this prowess might yet be possible using the Corot space telescope launched in December 2006.

André Brack**

See essays by A. Brack and other authors in English and French: http://astro.u-strasbg.fr/goutelas/g2005

* *For this observation method by telescope, the field of gravity of a planet located between an observer and a distant source of starlight will bend the light rays passing close to it and amplify the light received, thereby betraying the planet's presence*

** *Centre for Molecular Biophysics at the Centre national de recherche scientifique (CNRS), France*

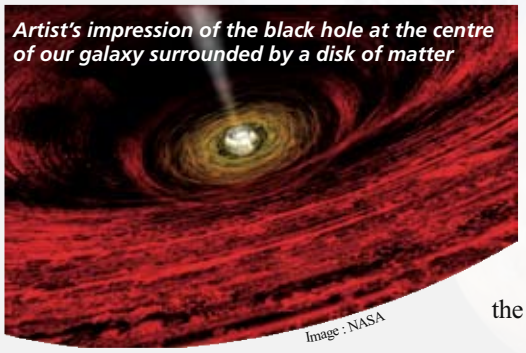
(blueshift); when it moves away, the light reddens slightly (redshift). By measuring simultaneously both this periodic shift in colour and the period of movement, the lower limit to the planet's mass can be calculated and its orbital path estimated.

The difficulty with this method lies in the subtlety of the colour change, expressed in speed. For a giant planet comparable to Jupiter orbiting a sun-like star, the speed is 12 m per second. For a planet of a similar mass to Earth, however, it is less than 0.1 m per second. Most exoplanets have been discovered with this method using extremely sensitive specialist spectrometers.

Most of the exoplanets detected to date are at least as large as Jupiter. We have only discovered about 15 'super-Earths' – planets with a mass 5–20 times greater than our own planet. Those discovered to date are essentially hot objects which have the particularity of orbiting very close to their star where temperatures are high. Only two super-Earths have been detected near the habitable zone of a low-luminosity red star. We still have no true twin for the Earth. Once such a planet is detected, the next step will be to analyse its atmosphere to detect any traces of life. That will have to await the launch of special space missions or the advent of ground telescopes of a very large diameter.

Portrait of a giant black hole

The centre of our galaxy, the Milky Way, conceals a most exotic star, a giant black hole several million times bigger than the Sun. For a long time, astronomers doubted that such a star could exist inside our own galaxy but they are now certain that this is the case.



Artist's impression of the black hole at the centre of our galaxy surrounded by a disk of matter

Image : NASA

A black hole is an object with such intense gravity that it can retain all forms of matter and light: that is why it is not directly visible. Our galaxy is a vast disk containing more than 100 billion stars. For a long time, its central core was inaccessible. It is particularly difficult to observe because of the distance – over 20 000 light-years away –, the dust and the large number of stars in the centre.

For many years, the only clearly detected emission from the centre of the Milky Way was a compact radio wave source discovered in 1974 and named SgrA* because of its location in the constellation of Sagittarius. Better techniques for observing infrared light have since made it possible to penetrate the dust screen and locate the stars closest to the centre. After more than 10 years observation, we now know that these stars, which appear to move at random, actually follow regular orbits around the centre. An analysis of these orbits based on the laws of gravity has made it possible to calculate the mass at the centre for the first time:

The central image results from the assembly of 800 photographs taken by the Hubble Space Telescope with a total imaging time in excess of 11 days. This deep probe of our Universe was undertaken in order to observe the most distant galaxies. The field of view is very small: in the sky, it represents an area 50 times smaller than that occupied by the full Moon, equivalent to the eye of a needle held at arm's length. Consequently, the image only shows three stars in our galaxy, although we can count almost 10 000 galaxies! By extending this count to the entire sky, we can deduce that the Universe contains over 100 billion galaxies. This image represents a breakthrough in our knowledge of the distant Universe. Formerly, astrophysicists could only study a few very bright galaxies called quasars, very different from ordinary galaxies. The dimmest objects in this image (circled in green and enlarged on the left) are among the very first galaxies to have formed, when the Universe was only about 800 million years old. This category of very young galaxies is comprised exclusively of dwarf galaxies from which the current large galaxies were formed through successive collisions. These first galaxies are difficult to observe, not only because their great distance from us considerably weakens their luminosity but also because the expansion of the Universe redshifts the light, the wavelength of the light being stretched during its journey through space. This reddening of the sources reduces the intensity of the light reaching us and obliges astrophysicists to use infrared-sensitive sensors like those installed on the Spitzer satellite. On the right, we can see the enlargement, in visible and infrared light, of the part of the central image marked by a blue rectangle. A galaxy can be clearly seen in infrared light (blue circle) that is almost invisible in visible light

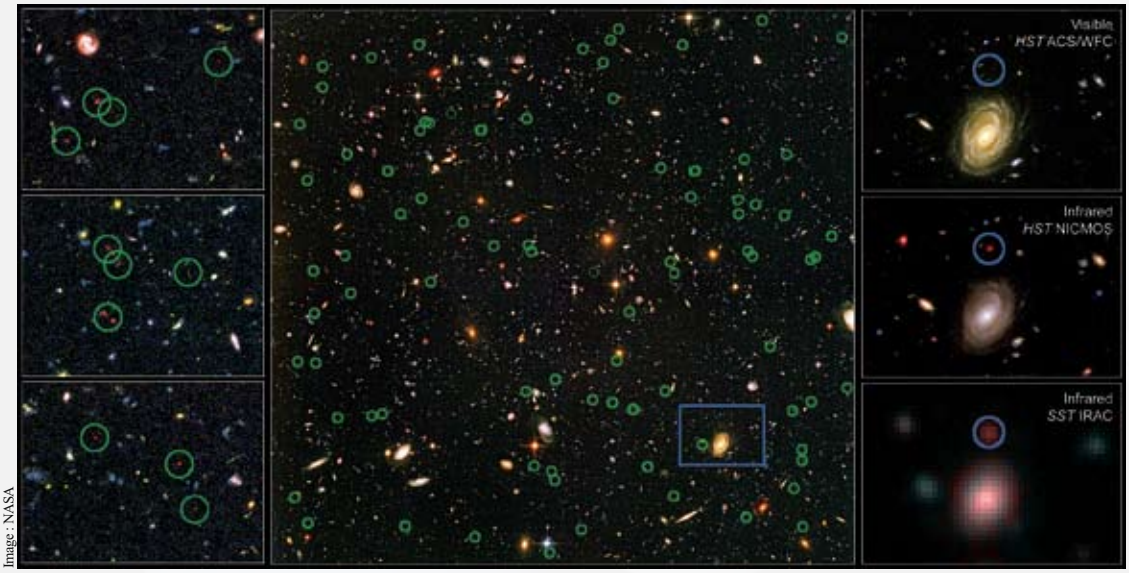
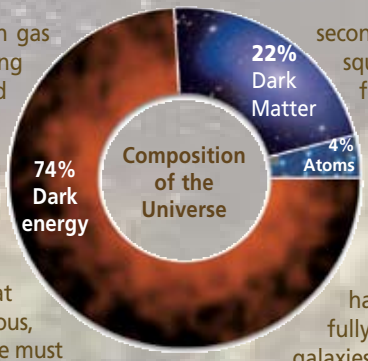


Image : NASA

What if dark matter didn't exist?



The galaxies are a vast collection of stars mingled with gas and dust within which new stars are constantly being formed. Most galaxies are spirals, shaped like a flattened disk, within which the stars form spiral arms. Visible matter – stars and gases – rotates around the central axis, like a rotating disk. By measuring the speed of rotation as a function of distance, the total mass of the galaxy can be calculated. The faster the matter rotates, the larger the mass.

One of the greatest mysteries of galactic physics is that the mass calculated from the speed of rotation is enormous, far greater than the galaxy's visible mass. Therefore, there must be an invisible mass, or 'dark matter', which accounts for these high rotation speeds. But of what is that dark matter made? Despite the fact that invisible matter was discovered over 60 years ago, we still cannot answer this question.

The galaxies formed shortly after the birth of the Universe with the Big Bang 13.7 billion years ago. The Universe was expanding rapidly and, in an environment in which all elements of matter were moving apart from each other, it would have been very difficult for matter to collapse and form galaxies. Calculations show that, if only the currently visible matter had been available at the time, it would have been insufficient to produce the collapse: here again, to explain the formation of galaxies, we have to fall back on large quantities of dark matter helping the galaxies to form. But the nature of dark matter remains a great mystery. Today, we are certain that it cannot be composed of ordinary atoms like all the ordinary matter that surrounds us. This enormous mass must be made up of exotic particles which we have not yet succeeded in revealing in large particle accelerators.

Newton's law may need some tweaking

What if dark matter didn't exist, after all? Rather than adding an unknown mass, an alternative solution to the problem would be to modify very slightly Newton's law of gravity in regions where that gravity is very weak: on the edges of galaxies. Such regions do not exist on Earth, which is why we have not yet been able to detect the effects of this change to Newton's law.

Detailed observations of the rotational speed of galaxies tell us how Newton's law should be revised. Whenever acceleration becomes smaller than a universal constant equal to one Ångström (10^{-10} m) per square second, then the force of gravity decreases not as the square of the distance but as the actual distance; and the force of attraction is proportionate not to the mass of the body attracting it but to its square root. In these circumstances, the force of gravity is more intense than predicted by Newton's law. If we interpret the observations according to Newton's law, we are led to believe that there is more mass than is really the case.

Were the laws of gravity to be modified, this would have many consequences. The repercussions are not yet fully understood, be it with regard to large-scale clusters of galaxies or the beginning of the Universe. This line of research is now being actively explored, to ensure we do not overlook a possible solution to a problem that has haunted astronomers for decades!

Françoise Combes*

** Paris Observatory*

Image : European Southern Observatory (ESO)

The spiral galaxy NGC 1232

How an apple changed the course of history

English physicist and astronomer Isaac Newton (1643—1727) liked to tell the story of how watching an apple fall from a tree inspired his theory of gravitation. Why did the apple fall straight to the ground, he wondered? Moreover, if gravity — the force responsible for gravitation — could extend to the highest tree, did that mean it could extend far enough to explain why the moon did not fall out of its orbit? This questioning led to:

Newton's First Law of Motion
Every object in a state of uniform motion tends to remain in that state of motion unless an external force is applied to it (also termed the Law of Inertia)

Newton's Second Law of Motion
The relationship between an object's mass m, its acceleration a, and the applied force F is F = ma. In other words, an object with a certain velocity maintains that velocity unless a force acts on it to cause an acceleration.

Newton's Third Law of Motion
For every action, there is an equal and opposite reaction. This law is exemplified by what happens if we step off a boat onto the bank of a lake: as we move in the direction of the shore, the boat tends to move in the opposite direction.

Adapted from: Web Syllabus of the Department of Physics and Astronomy at the University of Tennessee (USA): http://csep10.phys.utk.edu/astr161/lect/index.htm

more than three million times the mass of the Sun, concentrated in a volume scarcely bigger than the Solar System! There can be only one explanation: a super-massive black hole is lurking at the centre of our galaxy.

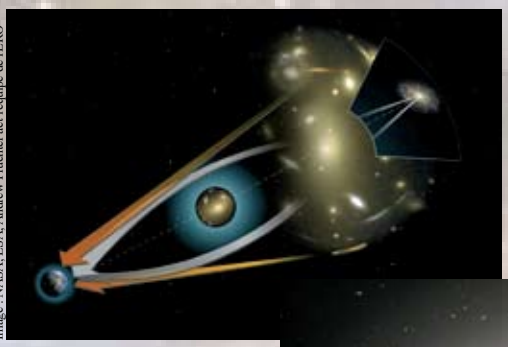


Image : NASA, ESA, Andrew Fruchter aet l'équipe de l'ERO

A gravitational mirage results from light being deviated in a space distorted by the presence of a large mass

Its presence was predicted as long ago as 1971 by British astrophysicists Donald Lynden-Bell and Martin Rees. They posited that matter on the point of being swallowed up by a black hole formed a disc girdling the black hole, inside which violent friction phenomena were produced. Thus, in some very active galaxies, known as quasars, powerful jets of accelerated particles may be observed escaping from the compact core. The considerable heat that results gives rise to a powerful source of radiation, not only in the radio spectrum but also in the X-ray and gamma spectra.

Image : Télescope spatial Hubble

The Sombrero Galaxy. The rotational curve of the galaxies suggests that they contain a large quantity of dark matter

However, observations in the X-ray spectrum done in 2000 and 2001 by the European XMM-Newton observatory and NASA's Chandra satellite revealed very low emissions from the black hole in the Milky Way, much lower than expected for such a mass. Why is the efficiency of energy conversion of matter falling on to the black hole so low? Is the bulk of the emission radiated at higher energy? That is the enigma still posed by what seems to be an anaemic giant black hole.

The centre of the Milky Way remains a highly complex region. Recently, the European INTEGRAL (INTErnational Gamma-Ray Astrophysics Laboratory) satellite even discovered antimatter there, the twin sister of matter which is destroyed on contact with matter to produce gamma rays. This antimatter exists in the form of anti-electrons, or positrons, which can be produced when particles are accelerated at a very high speed.

New matter

The visible matter of the Universe is organized hierarchically. The stars and gas collect in galaxies which can include hundreds of billions of stars and the galaxies themselves are grouped in their tens or hundreds into clusters. Studying the movements of these stars, galaxies and clusters has unveiled a mystery which continues to puzzle astronomers. There is a hidden mass in the Universe!

The first indication that there was a mass our instruments could not detect, since the mass was not luminous, came from studying the movement of galaxies in a cluster.

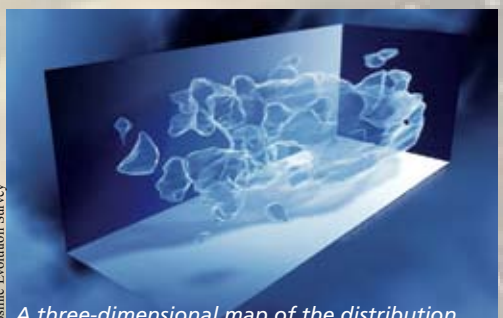


Image : Cosmic Evolution Survey

A three-dimensional map of the distribution of dark matter in a region of the Universe. The distance to Earth increases from left to right

In the 1930s, Swiss astronomer Fritz Zwicky studied the dynamics of the two closest clusters, located towards the Coma Berenices and Virgo constellations. He showed that the gravitational pull of the visible content of the cluster was insufficient to hold the galaxies together; unless there was a supplementary invisible mass, the clusters should disintegrate. Subsequent study of spiral galaxies, in which the stars rotate regularly around a common centre, has confirmed this initial observation. By measuring the orbital speed of thousands of stars and interstellar clouds around the centre of the galaxy, astrophysicists can draw a curve representing the speed of the stars as a function of their distance from the centre. Initially ascending, the curve becomes remarkably consistent as the distance from the centre increases. The luminous matter alone, the stars and gases, cannot account for this observation. To explain the curve, we have to factor in the gravitational pull of an invisible mass some 10 times greater than that of the visible galaxy and suppose that this mass affects the galaxy uniformly.

Astrophysicists settled the matter in the 1990s using a new method of analysing the sky. According to Albert Einstein's theory of gravity, every distribution of matter causes a deformation of space and thereby a deviation of the rays of light passing nearby. Consequently, the image of a luminous source located towards the rear of a galaxy cluster is deformed and even weakened in what is known as the gravitational lens effect. Studying these distortions in some parts of the sky has made it possible to reconstruct the distribution of mass in the deflecting cluster. The result has confirmed that a great deal of invisible matter is present.

What is this dark matter made of? Not of ordinary matter (protons and neutrons), since that would already have revealed its presence, such as through its involvement in the nuclear fusion reactions at the origin of the first atoms. However, the quantities of helium, deuterium and lithium produced in this way show beyond question that ordinary matter is wholly insufficient to constitute the entire mass of the Universe.

In an attempt to understand the nature of this dark matter, particle physics has joined forces with astrophysics to track down dark matter on Earth. Two experiments are underway: the American Cryogenic Dark Matter Search in a mine in Minnesota (USA) and its Franco-German rival Edelweiss, located beneath the Mont Fréjus tunnel in the underground laboratory at Modane in France. No new particle has been detected but the sensitivity of the experiments should be multiplied 100-fold in coming years. If these reveal nothing, we shall have to design a new model and different experiments. The discovery of a new exotic particle would resolve one of the greatest mysteries in modern astrophysics. It would be the start of a fantastic scientific adventure.

The flight of the galaxies

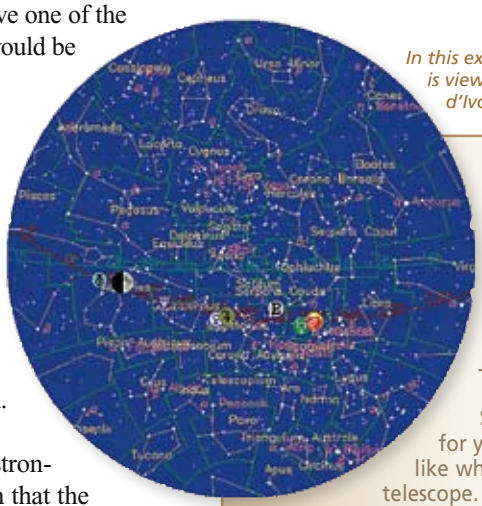
Our understanding of the evolution of the Universe is changing rapidly. By studying supernovae, explosions of stars that are visible over very great distances, astrophysicists have discovered a new fundamental component of the Universe, an energy of still unknown origin that accelerates its expansion.

Ever since the observations by American astronomer Edwin Hubble in 1920, we have known that the galaxies are moving away from each other. This flight of the galaxies is the effect of the expansion of the Universe: year after year, century after century, the Universe is expanding and the distance between two distant galaxies is increasing. Until very recently, it was thought that this expansion would inevitably slow down because the effect of gravity tends to pull the galaxies towards each other. But observations have yielded the opposite result.

In 1998, several teams of scientists chose to measure the expansion of the Universe using a number of supernovae which were seen as 'standard candles', that is, whose intrinsic luminosity was thought to be identical. Thus, a reduction in their visible brightness could only be due to their growing remoteness. In this way, their distance could be estimated, in much the same way surveyors calculate distance by measuring the apparent size of a stick of known length. It turned out that the most remote supernovae were much dimmer than expected and thus seemed to be further away.

The only possible conclusion is that, rather than being constant, the Universe has expanded more quickly than expected. It is as if an invisible energy, which astrophysicists have baptised 'dark energy', is overcoming the pull of gravity on a very large scale. This dark energy alone seems to represent three-quarters of the total energy in the Universe.

This component of the Universe cannot be explained by any theory of physics. For the moment, physicists are searching for its origin in the properties of the vacuum and in new theories of the infinitely small which could change our understanding of gravity. Some of these theories, such as string theory, suggest for instance that space might have more than three dimensions. Major particle accelerators like the Large Hadron Collider, which has just gone into service at the European Organization for Nuclear Research (CERN) in Switzerland, are one hope for confirming these new paths in physics. Meanwhile, astronomers are also dreaming up new space missions like Euclid, which would measure very accurately the effects of dark energy in the Universe.



In this example taken from Your Sky, the night sky is viewed from above the city of Abidjan in Côte d'Ivoire, on 5 December 2008

Your own home planetarium

A number of websites propose a free service which enables Internauts to see the night sky above their head from their computer. The following are a few examples.

Stellarium is a free open source planetarium for your computer. It shows a realistic sky in 3D, just like what you see with the naked eye, binoculars or a telescope. It is being used in planetarium projectors. Just set your coordinates and go: *www.stellarium.org/*

Your Sky is an interactive planetarium. You can produce maps in the forms described below for any time and date, viewpoint, and observing location. If you enter the orbital elements of an asteroid or comet, Your Sky will compute its current position and plot it on the map: *www.fourmilab.ch/yoursky/*

Celestia lets you explore the Universe in three dimensions. It runs on Windows, Linux and Mac OS. It comes with a large catalogue of stars, galaxies, planets, moons, asteroids, spacecraft, etc: *www.shatters.net/celestia/*

The frontiers of observation

Since Galileo first used a telescope to observe the sky, observation techniques have progressed to the point where a considerable size of the Universe is now accessible to our instruments. When we observe the most distant galaxy known today, we are looking almost 12.9 billion years into the past because of the time it takes for light to travel; the estimated age of the Universe is 13.7 billion years. The new generation of very large telescopes offers the titillating hope that we might be able to observe galaxies at the very moment they formed.


Image : ESO

The Extremely Large Telescope will have a mirror 40 m in diameter. It should be completed by 2013 at a site yet to be identified

Large ground-based observatories, such as the Very Large Telescope in Chile or the Keck Telescope in Hawaii, now use mirrors 8–10 m in diameter and innovative techniques such as active and adaptive optics which provide an image quality previously unattainable from the ground. With active optics, you can adjust the shape of the mirror surface; with adaptive optics, you can remove the atmospheric distorsions of an image in real time.

A range of future instruments is under study: the Thirty Meter Telescope (TMT) or the European Extremely Large Telescope (E-ELT) with a segmented mirror more than 40 m in diameter! The radio wave spectrum is also covered from the ground. The giant radio-telescope Atacama Large Millimeter Array (ALMA) will comprise at least 54 antennae of 12 m-diameter operating in the millimetre wave band. The signals captured by these antennae will be combined to give resolution equivalent to a single antenna 14 km in diameter! Construction of this instrument will be completed in 2013. The future Square Kilometre Array, which should be completed by 2020 in South Africa or Australia, will cover a million square metres with several hundred antennae.

Space devices are increasingly important for capturing light from space that cannot reach the ground because of atmospheric absorption. The successor to the Hubble Space Telescope, launched in 1990, will be the James Webb Space Telescope, jointly developed by NASA, the European Space Agency (ESA) and the Canadian Space Agency. This should enter service in 2013. It will have a mirror 6 m in diameter optimised for great sensitivity to infrared radiation in order to observe the most distant objects, light from which is heavily red-shifted by the expansion of the Universe. It will be preceded in this field by the Herschel satellite, with a more modest 3.5 m mirror but operating over a wider spectrum of infrared radiation. Herschel will be placed in orbit in 2009 to observe the formation of stars and the evolution of galaxies. It will be launched together with the Planck satellite, which will study the cosmic background radiation, the light emitted when matter became transparent in the earliest times of the Universe.

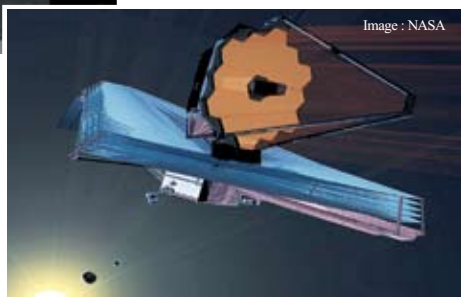


Image : NASA

The James Webb Telescope will be launched in 2013. The successor to the Hubble Space Telescope, it has a deployable mirror 6 m in diameter

A fleet of astronomical satellites is currently orbiting Earth to observe the various radiations that will enable us to understand better how stars work: the Spitzer space telescope for infrared radiation, the Chandra satellite and the XMM-Newton observatory for X-rays, the INTEGRAL laboratory and Fermi satellites for gamma radiation.

Astronomers are no longer satisfied with capturing light; they are also detecting cosmic vibrations and seeking to trap cosmic particles. They hope to observe the gravitational waves predicted by Einstein's theory of gravity for the first time. These are minute deformations of space time created by the explosion of a star or the merger of compact bodies like neutron stars which spread through space like ripples on water. On the ground, the American LIGO and European VIRGO instruments have begun listening for these vibrations with a truly challenging objective: to measure changes in distance of the order of $1/1000^{th}$ the size of an atomic nucleus over distances of several kilometres! From space, the LISA experiment planned for 2020 should then be able to make far more accurate measurements over distances of 5 million kilometres.

There are also plans to capture particles circulating in the Universe. The most powerful of these are now being analysed by the Pierre Auger Observatory, a huge network of 1600 sensors distributed over 3000 km^2 in Argentina. The most plentiful of space particles, the elusive neutrino which interacts very little with matter, is also being actively sought. Neutrinos can pass through the Earth undisturbed. Produced in abundance in the very dense Universe at the dawn of time, even before there was light, they are a unique messenger from the most distant past. In the hope of capturing them, various 'neutrino telescopes' have had to be located in the most unusual places: ICE CUBE is located under 2000 m of ice in the Antarctic and ANTARES at a depth of 2500 m in the Mediterranean.

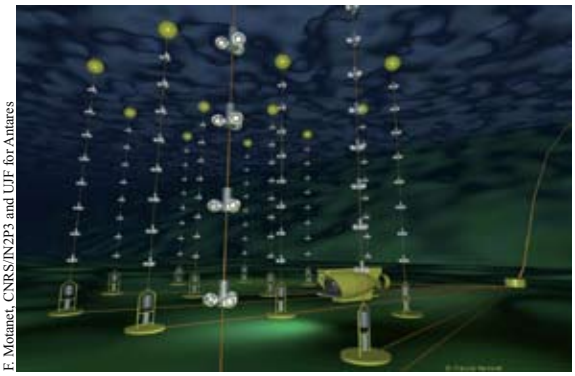

F. Motanet, CNRS/IN2P3 and UJF for Antares

Diagram of the undersea neutrino observatory, ANTARES, operating at a depth of 2500 m off the coast of Toulon in France

Jean-Marc Bonnet-Bidaud and Roland Lehoucq[2]

1. *See* A World of Science, *January 2007*
2. *Both of the French Commissariat à l'Énergie Atomique (CEA) : bonnetbidaud@cea.fr and lehoucq@cea.fr*

Forum urges **new approach to health research**

The ministers and representatives of ministries of health, science and technology, education, foreign affairs and international cooperation from 59 countries have adopted a *Call to Action* in Bamako (Mali) which fixes ambitious targets for increasing investment in research for health.

Adopted on 19 November, the final day of the Global Ministerial Forum on Research for Health hosted by Mali, the *Call to Action* urges national governments to allocate at least 2% of budgets of ministries of health to research. In parallel, funders of research and innovation, together with international development agencies, are urged to invest at least 5% of development assistance funds earmarked for the health sector in research, according to country-led research strategies. The reference to 'country-led research strategies' is significant, as donors have up until now been tempted to impose their own research agenda on recipient countries.

The *Call to Action* stresses that 'the global research for health agenda should be determined by national and regional agendas and priorities'. President Amadou Toumani Touré recalled at the Forum opening on 17 November that Mali was not only confronted with malaria, HIV, tuberculosis and emerging diseases like haemorrhagic fevers and avian flu but also, increasingly, by chronic diseases like diabetes and cardiovascular problems. Despite this trend being seen across Africa, countries still struggle to interest donors in new priorities for health research.

The signatories appeal to all partners and stakeholders to implement the recommendations of the WHO Commission on the Social Determinants of Health. Launched last August, the Commission's report, *Closing the Gap in a Generation*, asserts that health inequities are avoidable and that there is sufficient scientific evidence available today for policy-makers to act to reduce these inequities, even if more research is still needed.

Social determinants of health include the level of education, nutrition and access to safe drinking water and sanitation. The *Call to Action* reflects a shift to a broader-based, intersectoral approach to research for health, linking it more closely with research on education, food, water and agriculture.

The signatories urge governments to stress, at the secondary and tertiary levels of education, the importance of scientific research. They also call upon national governments to 'strengthen research capacity and build a critical mass of young researchers by developing and including curricula on research methods and research ethics, especially but not exclusively for students of health sciences.' Regional bodies are encouraged to strengthen the harmonization of regulation and ethical conduct.

In light of its broad mandate, UNESCO is invited to promote research for health as an important intersectoral issue in its own capacity-building projects and as part and parcel of the policy advice it provides to governments.

Conscious that 'only a small proportion of spending on research addresses the health challenges that disproportionately affect the poor', the signatories urge countries, ministries, international agencies and the private sector to work together more effectively through 'equitable partnerships' to direct research at improving the health of poor people around the world.

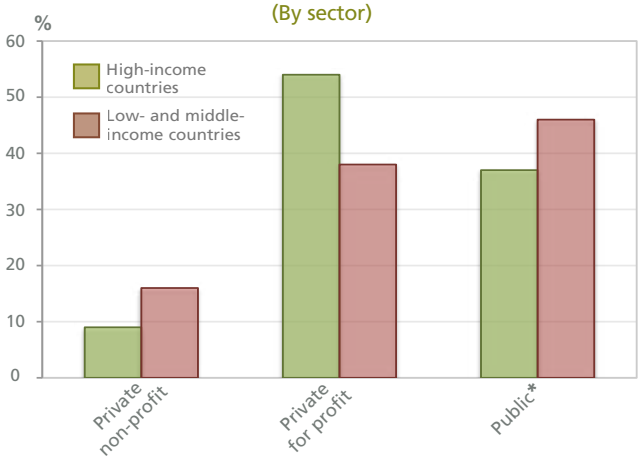
Global spending on health R&D doubled between 1998 and 2005 to US$160.3 billion. The G7 countries alone make up 88% of the total, well above their share of the world economy (61%). 'Low- and medium-income countries (LMIC) may represent just 3% of global health R&D spending', comments Charles Gardner of the Global Forum for Health Research, 'but these countries are investing at least US$2.3 billion a year of their own domestic public funds in health research.' He remarks that 'lower labour and infrastructure costs in many of these countries imply an even higher purchasing power for this investment. In 2005, Goldman-Sachs estimated that bio-pharma R&D in India cost only 12.5% of the cost of comparable research carried out in "wealthy countries"'.

Gardner believes development partners need to pay 'far greater attention to building the capacity of public research institutions in LMICs to enter into equitable local public–private R&D partnerships, including public-interest intellectual property management practices to encourage access'.

With more than half of global health research being financed by the private sector, the collaboration of the pharmaceutical industry and other private stakeholders has become essential. In high-income countries, private spending on health research is expanding faster than public spending (*see graphic*). During a session in Bamako devoted to research leaders, the British Wellcome Trust described how its Malaria Genetic Epidemiology Network was studying resistance to malaria in populations of 11 African and three Asian

Relative increase in health R&D funding, 1998–2005

(By sector)



** in LMICs, nearly one-quarter of this increase concerns overseas development assistance*

Source: Global Forum for Health Research (2008) Monitoring Financial Flows for Health Research

countries. Multinational Merck & Co. then described how it had donated drugs to the onchocerciasis programme fighting river blindness in West Africa.

The question of ownership of research was a central concern in Bamako. National governments are urged to 'give priority to the development of policies for research and innovation for health, especially related to primary health care, in order to secure ownership and control of their research for health agendas.' Moreover, all partners and stakeholders are urged to 'promote and share the discovery and development of, and access to, products and technologies addressing neglected and emerging diseases which disproportionately affect low- and middle-income countries'.

WHO is expected to lead by example by ensuring that its strategy on research for health and its global strategy and plan of action on public health, innovation and intellectual property are implemented in unison.

Meanwhile, the World Bank Group and regional development banks are urged 'to deepen and expand their research for health, with particular emphasis on health systems research and innovation, and national science and technology capacity-building'.

The *Call to Action* also invites multilateral agencies to explore with Member States and partners the feasibility of establishing 18 November as World Day of Research for Health.

The Forum was organized by the Government of Mali, WHO, the World Bank, UNESCO and two Geneva-based NGOs, the Council on Health Research for Development and the Global Forum on Research for Health.

For details: www.bamako2008.org; http://www.tropika.net/svc/home/bamako2008

Reform of Tanzanian science system gets under way

The reform of Tanzania's science, technology and innovation (STI) system got under way on 15–16 December with the first consultation of stakeholders at a workshop in Bagamoyo (Tanzania). UNESCO is heading a team of United Nations (UN) agencies and development partners which are accompanying Tanzania in this endeavour, within the One UN initiative. Under this umbrella, UNESCO and government departments and agencies have formulated a series of proposals for a total budget of US$10 million, to be financed from the One UN fund and other sources.

Tanzania is one of the eight pilot countries[3] for the One UN initiative launched in 2007 within a broader reform to improve coordination among UN agencies. The programme is inspired by a report submitted to the UN by a high-level task force on *Delivering as One*.

Within the One UN initiative, several UN agencies work together to formulate joint programmes for each pilot country, with funding from mainly the One UN Fund. UNESCO's participation in the One UN Programme for Tanzania came in response to the request made by the President, Jakaya Mrisho Kikwete, for UNESCO's assistance in conducting a comprehensive review and in repositioning the Tanzanian STI system, in a letter to UNESCO's Director-General in June 2007.

Photo UNESCO/Jasmina Sopova

View of the old Stone Town on the island of Zanzibar, popular with tourists. UNESCO plans to help Tanzania use innovation to develop ecotourism

In August 2007, the heads of UN agencies agreed to UNESCO's proposal for science components to be included in the One UN programme for Tanzania, in support of the government's Vision 2025 objective of 'transform[ing] the economy into a strong, resilient and competitive one, buttressed by science and technology'. In the words of Peter Msolla, Tanzanian Minister of Communications, Science and Technology, 'without a dose of innovation [in Tanzania], the macro-economic gains achieved over the years through the implementation of sound economic policies would be wiped out.'

Within the One UN proramme for Tanzania, UNESCO heads the Innovation and Technology Thematic Area, also involving the World Bank and Finland, whose activities are spread across three joint programmes. Under the Joint Programme on Wealth Creation, Employment and Economic Empowerment, UNESCO coordinates the section on policies and plans of action for the explicit integration of STI into the economy. Under the Joint Programme on Capacity Strengthening for Development Management, UNESCO coordinates the section on improving management and governance of the STI system. Under the Joint Programme on Education, UNESCO coordinates the section on strengthening STI capacities in higher education by 2010.

During the preparatory phase, UNESCO collaborated with the Swedish International Development Agency and its Department for Research Cooperation (SAREC), as well as with South Africa's Department of Science and Technology. Tanzanian senior officials travelled to both Sweden and South Africa on study visits.

As head of the Innovation and Technology Thematic Area, UNESCO was responsible for coordinating the formulation

3. *The others are Albania, Cape Verde, Mozambique, Pakistan, Rwanda, Uruguay and Vietnam*

of proposals for initial funding. It will now supervise implementation and decide upon the division of labour between UN agencies, according to whichever are best-placed to implement the various components of the programme elaborated by UNESCO. The programme will be implemented via the Joint Steering Committee on One UN, co-chaired by the Permanent Secretary for Finance and Economic Affairs and the UN Resident Coordinator in Tanzania.

UNESCO itself will be providing regular programme funding in support of the science reform, particularly through its internal platform on strengthening national research systems. The Organization will mobilise additional donor support from other countries, including Sweden and Japan.

One of the first projects implemented by UNESCO will harness innovation to developing Tanzania's tourism industry. Another will establish a UNESCO Chair in a leading Tanzanian university, yet to be identified, for the training of science policy experts.

Based on similar science reforms implemented in developing countries, it is estimated that the full reform in Tanzania will require an investment of US$500 million over the next 10 years.

For details: f.osotimehin@unesco.org; a.maduekwe@unesco.org; www.unesco.org/science/psd

Corrosive seas may prove **costly for fisheries**

The acidification of the world's oceans is accelerating at an unprecedented rate, threatening marine ecosystems and the livelihoods of tens of millions of people. So concluded the 250 marine scientists from 32 countries attending the Second International Symposium[4] on the Ocean in a High CO_2 World, in Monaco on 6–9 October.

The meeting was organized by UNESCO's Intergovernmental Oceanographic Commission (IOC), the Scientific Committee on Oceanic Research, the International Atomic Energy Agency (IAEA) and the International Geosphere Biosphere Programme, under the High Patronage of Prince Albert II.

Currently, the ocean absorbs about eight billion tonnes of CO_2 annually that would otherwise stay in the atmosphere. It thus plays an important role in mitigating global warming. But at what price?

'Our oceans are sick. We don't quite know how sick but there is enough evidence now for us to say that ocean chemistry in changing, that as a result some marine organisms will be affected and that decision-makers need to sit up and take notice,' said James Orr of the IAEA's Marine Environmental Laboratory, who chaired the meeting. 'Since the industrial revolution, the acidity of ocean surface waters has increased by 30%. This change is greater and happening about 100 times faster than for previous acidification events experienced in many millions of years,' added Dr Orr.

'Published research indicates that, by 2030, the Southern Ocean will start to become corrosive to the shells of some marine snails that swim in surface waters,' he observed. These snails provide a major source of food for Pacific Salmon. If they decline or disappear in some regions, such as the North Pacific, what will happen to the salmon – and the salmon fishing industry? And what will happen as ocean acidification increasingly affects coral reefs, which are home to one-quarter of the world's fish during at least part of their lifetime and which support a multibillion dollar tourist industry?'

'Previous acidification events provide a clue,' commented Carole Turley from the Plymouth Marine Laboratory (UK). The evidence indicates mass extermination of shell-bearing organisms around 55 million years ago, for example. This bears out studies of the ocean floor around existing natural CO_2 vents today, where the sea water is already highly acidified. These studies show a steep decline in biodiversity and the appearance of invasive species.'

Projections of the saturation levels of aragonite, a form of calcium carbonate used by many marine organisms to build their skeletons or shells, predict that calcification rates in the tropics may decrease by 30% over the next century.

Some coastal regions, such as the west coast of the USA, are already experiencing seasonal undersaturation, a process whereby corrosive waters are upwelled seasonally onto the continental shelf. Approximately 70% of the world's known deep cold-water corals that serve as a nursery for many commercial fish stocks will be bathed in corrosive waters by 2100.

What can be done? The participants agreed that much more research was needed to understand the implications and impact of the acidification occurring today. Hermann Held of the Potsdam Institute for Climate Impact Research (Germany) stressed that reducing carbon emissions would be the only effective way of stabilizing or reversing

A pteropod. These small 'winged snails' form the basis of the food chain for many commercial fish species. A recent study has observed that the shell of living pteropods dissolves when exposed to the carbonate content of the ocean expected in the next 50 years in the high latitudes. Corals, calcareous phytoplankton, mussels, snails, sea urchins and other marine organisms all use calcium (Ca) and carbonate (CO_3) in seawater to construct their shells or skeletons. As the pH decreases and the oceans become more acidic, carbonate will become more scarce, making it difficult for organisms to secrete $CaCO_3$ to form their skeletal material. This will have dire consequences for industry: mollusc aquaculture produces 12 million tonnes per year, for a market value of over US$10.5 billion

Photo: US Geological Survey

4. On the first symposium, see A World of Science, *October 2004*

the acidification process. He argued that, despite the reticence of many governments, this was both achievable and affordable. He estimated that the cost of achieving zero carbon emissions over the next century could be less than 1.5% of global GDP.

'Over the past four years, we have moved from an issue with little understanding or awareness to one that is now more certain, detectable and increasingly in the public eye', commented Maria Hood, Coordinator of the International Ocean Carbon Coordination Network at the UNESCO-IOC, after the meeting. 'For the second symposium, we thought it was important to start making the link between the science and both economics and policy. Scientists formulate scientific questions, which are often poorly linked to policy needs.'

'A new trend we are promoting', she added, 'is the inclusion of reference user groups in the development of research programmes. These groups include experts from industry, government and the conservation sector. They advise on the types of product that would be most useful to managers and decision-makers. They also facilitate the dissemination of results beyond the research community. It's a win–win situation and a critical link to making the science useful for wise management decisions.'

For details: m.hood@unesco.org; www.ocean-acidification.net/

SESAME team takes up residence

Better known by its acronym of SESAME, the centre for Synchrotron-light for Experimental Science and Applications in the Middle East was officially handed over to staff on 3 November, five years after the first stone was laid.

The ceremony took place in Allan (Jordan), in the presence of UNESCO Director-General Koïchiro Matsuura and under the auspices of H.M. King Abdullah II Ben Al-Hussein of the Hashemite Kingdom of Jordan.

The SESAME building was completed early last year. Over the past few months, the secretariat has been progressively taking up residence, after operating from the premises of UNESCO's Amman office since 2004. In that time, the technical team at SESAME, headed by a member of the team responsible for the construction of the SOLEIL synchrotron in France, has been upgrading the microtron and booster[5] donated to the project by Germany. In parallel, the scientific team has been running training sessions for potential users. The November ceremony also marked the installation of the microtron and the main part of the booster, the injector of SESAME.

Once fully operational at the end of 2011, the SESAME centre will offer the Middle East a world-class laboratory for basic research and numerous applications in archaeology, biology, medical sciences, physics, high technology and industry. A synchrotron source provides an indispensable tool for research and the creation of new materials. Hundreds of scientists from the region and beyond will be able to work at a centre of excellence equipped with a modern 'third generation' synchrotron equal to any in the world.

Photos: UNESCO/Maciej Nalecz

Guests arriving for the soft inauguration and (right) inspecting the newly installed microtron in the experimental hall

The 'soft' inauguration was immediately followed by the SESAME Council's 13th meeting on 3 and 4 November. After nearly 10 years of leading a project close to his heart, Professor Herwig Schopper, former Director-General of the European Organization for Nuclear Research (CERN), handed over the presidency of the Council at the meeting to Professor Sir Chris Llewellyn-Smith, currently Chair of the ITER Council[6] and the Consultative Committee for Euratom on Fusion.

The members of SESAME are Bahrain, Cyprus, Egypt, Iran, Israel, Jordan, Pakistan, Palestinian Authority and Turkey.

For details: c.formosa-gauci@unesco.org; www.unesco.org/science/bes

5. *The electrons are injected from a 22 MeV microtron into a 800 MeV booster synchrotron, with a repetition rate of 1 Hz. The 800 MeV beam is transported through the transfer line to the main storage ring and, after accumulation, accelerated to 2.5 GeV. As magnets force the electrons to bend, they emit synchrotron light, the wavelength of which ranges from infrared to hard X-rays*

6. *The International Thermonuclear Experimental Reactor (ITER) project is building an experimental reactor powered by nuclear fusion in Cadarache (France) which should be operational by 2038. Unlike nuclear fission, which current nuclear plants practice and which produces radioactive waste, nuclear fusion is environmentally friendly. However, the technology is yet to be fully mastered. This is because nuclei strongly resist being brought too close together, as all nuclei have a positive charge due to their protons and like charges repel. Accelarating the nuclei to high speeds can overcome this electromagnetic repulsion until the nuclei get close enough to achieve fusion. ITER is funded by the European Union, India, Japan, China, Rep. of Korea, Russian Federation and USA*

Towards a **law of transboundary aquifers**

In a groundbreaking decision, the UN General Assembly adopted a resolution on the Law of Transboundary Aquifers on 11 December that includes 19 articles prepared jointly by the UN International Law Commission and UNESCO's International Hydrological Programme (IHP).

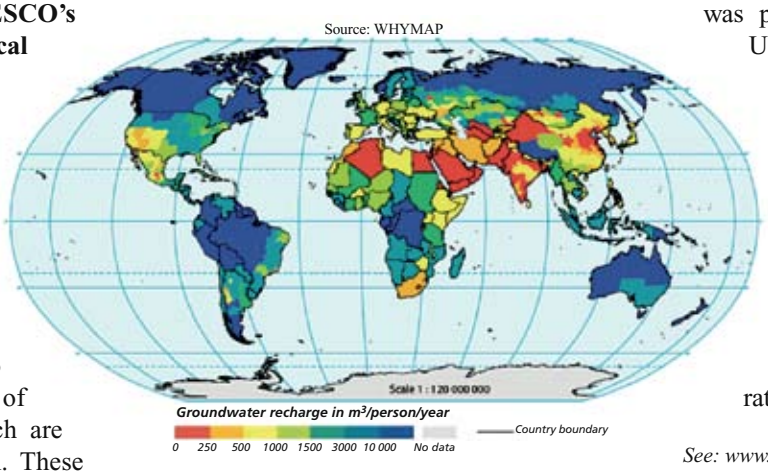
The resolution encourages the States concerned 'to make appropriate bilateral or regional arrangements for the proper management of their transboundary aquifers, taking into account the provisions of these draft articles', which are annexed to the resolution. These provisions include cooperation among States to prevent, reduce and control pollution of shared aquifers. In view of the importance of these 'invisible resources', States are invited to consider these draft articles as a basis for the elaboration of a convention.

Aquifers contain almost 96% of the planet's freshwater. Globally, 65% of groundwater is devoted to irrigation, 25% to the supply of drinking water and 10% to industry. Aquifers account for more than 70% of the water used in the European Union and are often one of the only sources – if not the only one – in arid and semi-arid zones: 100% in Saudi Arabia and Malta, 95% in Tunisia and 75% in Morocco. Irrigation systems in many countries depend heavily on groundwater resources: 90% in the Libyan Arab Jamahiriya, 89% in India, 84% in South Africa and 80% in Spain.

Since 2002, the IHP's Internationally Shared Aquifer Resources Management (ISARM) project has been compiling an inventory and evaluating the world's transboundary aquifer systems. The project is also itemizing the legal systems of each country as they relate to aquifer management. ISARM has so far inventoried 273 transboundary aquifers: 68 on the American continent, 38 in Africa, 65 in eastern Europe, 90 in western Europe – and 12 in Asia where the inventory is still in progress.

Some of the biggest transboundary aquifers in the world are located in South America and North Africa, such as the Guarani and Nubian Sandstone aquifers. Those in Africa remain largely unexploited. Since aquifers generally extend across several State boundaries, exploiting these presupposes agreements for managing them jointly, in order to prevent pollution or over-exploitation by particular States. Mechanisms of this kind have begun to emerge. For example, in the 1990s, Chad, Egypt, the Libyan Arab Jamahiriya and Sudan established a joint authority to manage the Nubian Sandstone aquifer system in a concerted manner.

The UNESCO-IHP *World Map of Transboundary Aquifers* served as background for the preparation of the first set of international legal articles. The map was published in October by UNESCO's Worldwide Hydrological Mapping and Assessment Programme (WHYMAP), which has been establishing a groundwater database since 2000. The map also assesses the characteristics of the main aquifer systems and their rate of replenishment.



Groundwater recharge from 1961 to 1990
Per capita (2000)

See: www.isarm.net/ and www.un.org/ga/63/resolutions.shtml; Download world map: http://typo38.unesco.org/en/about-ihp/associated-programmes/whymap.html

Inequities in Latin America affect schoolwork

UNESCO's Regional Bureau for Education in Latin America and the Caribbean has published the findings of the most ambitious evaluation of student performance ever launched' in the region. The *Second Regional Comparative and Explanatory Study on Student Achievement in Latin America and the Caribbean* reveals that the Cuban primary education system distances that of its neighbours; it also highlights the strong learning inequities within the region and within countries.

The four-year survey was conducted in 3065 schools in 16 countries by the Laboratorio Latinamericano de Evaluación de la Calidad de la Educación. It evaluated the performance of 196 000 pupils in their third and sixth years of schooling in mathematics, natural science, reading and writing. Each pupil sat a series of tests based on curricular elements common to the region, fashioned after the life-skills approach propounded by UNESCO.

The survey classifies pupils' achievements into four levels of performance. Cuba stands out in science, with 35% of sixth grade pupils attaining the highest level (four) and 31% level three, compared to a regional total of 2% and 11% of pupils

respectively. In Colombia, Uruguay and the Mexican State of Nuevo Leon, practically half of pupils perform at level two. In Argentina, the Dominican Republic, El Salvador, Panama, Paraguay and Peru, over 40% of sixth grade pupils perform at level one or below.

Cuba also stands out in mathematics, with 51% of sixth grade pupils attaining level four and 26% level three, but the differences are less glaring than for science. At the regional level, 11% of pupils attain level four and 32% level three. Uruguay trails Cuba, with 32% of pupils attaining level four and 40% level three. One-third of pupils or more attain level three in Argentina, Chile, Colombia, Costa Rica and Mexico. However, in Ecuador, El Salvador, Guatemala, Nicaragua, Panama, Paraguay and Peru, more than 20% of pupils perform at level one or below and even 47% in the Dominican Republic.

Gender-based comparisons reveal that boys enjoy a marked advantage over girls in science in some countries. The difference is greatest in Colombia, El Salvador, Peru and the Mexican State of Nueva Leon. No statistically significant differences between girls and boys in sixth grade have been detected however in Argentina, Cuba, the Dominican Republic, Panama, Paraguay or Uruguay.

The survey reveals that pupils attending urban schools tend to outperform their rural counterparts in science, with the notable exception of Cuba and a minimal difference in the Dominican Republic. Peru exhibits the greatest difference in performance, followed by El Salvador and Panama.

The survey concludes that national per capita income is strongly associated with student performance in mathematics, reading and science. The greater the inequality in any one country, the lower its average performance.[7]

Read an Executive Summary of the study (in English): http://unesdoc.unesco.org/images/0016/001610/161045e.pdf

7. *Cuba and the Mexican State of Nueva Leon were not involved in this part of the survey for lack of available data*

40 winners for **photo contest**

UNESCO's photo contest on The Changing Face of the Earth has been won by 15 year-old Muatez Nasser Al-Adwan from Jordan and, in the adult category, by Anil Risal Singh from India. The contest was organized within the International Year of Planet Earth, which set out to highlight the utility of geosciences for society.

Each first-prize winner receives a digital camera, in addition to the two UNESCO titles which will be distributed to all 40 winners: The *Changing Face of the Earth* – demonstrating continental drift over the past 250 million years – and *Explaining the Earth*.

In the 15–20-year category, an honorable mention goes to: Min Htike Aung (Myanmar), Marta Castro (Portugal), Magda Kotas (Poland), Desislava Kusheva (Bulgaria), Marcos Lajciak (Slovakia), Justyna Malgorzata (Poland), Pedro Matos (Puerto Rico), Kosar Miri (Iran), Ugne Palcukaite (Lithuania), Klara Simic (Croatia), Marieta Stefanova (Bulgaria), Reuben Todd (New Zealand), Silvia Toledo (Argentina) and Milan Vujisic (Serbia).

Muatez Nasser captured the spectacular sight of salt accumulating as the Dead Sea in the Middle East gradually evaporates

In the 21 years and over category, an honorable mention goes to: T. R. Bandre (India), Plinio Barraza (Colombia), George Cabig (Philippines), Ivaldo Cavalcante (Brazil), Abhijit Dey (India), Ali Zourkaleini Djibrilla (Niger), Gilbert Gamolo (Philippines), Reza Golchin (Iran), Khaled Hasan (Bangladesh), Juana María López Rojo (Spain), Edilberto Magpayo (Philippines), Mihail Mancas (Moldova), Samarendranath Mandal (India), Joydeep Mukherjee (India), Emma Marks (New Zealand), Somenath Mukhopadhyay (India), Mohammed Rakibul Hasan (Bangladesh), Pinaki Ranjan Majumdar (India), Milagros Vico Ríos (Spain), Reza Salarian (Iran), Luciano Sarote (Brazil), Ankit S. Sharma (India), Fernando Zapata (Philippines) and Zulkarnain (Indonesia).

Contestants were asked to portray one of the ten themes of the International Year of Planet Earth: soil; groundwater; hazards; Earth and health; climate change; resource issues; megacities; the deep Earth; the Ocean; and Earth and life. More winning photos will be published in future issues of *A World of Science*.

A boatman cleaning plastic and other rubbish out of the Gomthi River in Lucknow, photographed by Anil Risal Singh

Consult the winning photos online: www.unesco.org/science

Giovanni Valsecchi

Preparing for a cosmic disaster

Asteroids are space rubble left over from the formation of the Solar System about 4.6 billion years ago. Most of these rocky fragments orbit the Sun between Mars and Jupiter. This Asteroid Belt could contain millions of asteroids, ranging from about one-quarter the size of our Moon to less than 100 m wide. More than 200 000 have been officially numbered so far by astronomers around the world. One of these asteroids, Apophis, will pass less than 40 000 km from Earth in 2029, where gravitational forces could place it on a trajectory that would send it slamming into Earth seven years later. The consequences would be devastating. An asteroid thought to have been just 45 m wide destroyed 2000 km^2 of Siberian forest in 1908. Apophis is about 300 m wide. Perhaps the most famous asteroid disaster on Earth is that which dug an immense crater 65 million years ago near the Yucatan peninsula in Mexico; it is thought to have wiped out up to 70% of biodiversity, including the dinosaurs.

Image: Galileo Project, NASA

Asteroid 951 Gaspra, as observed by the Galileo spacecraft in 1991 in the Asteroid Belt. Gaspra is about 20 km long, twice the size of that which killed the dinosaurs

Today, both asteroids and comets are being tracked by astronomers but there is no official channel for warning governments of an impending impact. This state of affairs has motivated a group of astronauts and cosmonauts to prepare a Near-Earth Object (NEO) Deflection Decision Protocol which it hopes to present to the UN's Committee on the Peaceful Uses of Outer Space later this year. Giovanni Valsecchi, an astronomer working on impact monitoring at the Istituto Astrofisica Spaziale e Fisica Cosmica in Rome (Italy), explains here that we do have the technology to prevent an asteroid impact. Prevention is costly, however, and there is little likelihood of an asteroid impact this century. Whether or not we invest in this technology will depend on whether governments consider preparations a priority.

What are the chances of Apophis colliding with Earth in 2036?

The impact probability for 2036 is about 1 in 45 000, so it would be premature to say the least to worry about where Apophis might strike Earth at this stage. Supposing that Apophis did slam into Earth, it could generate a 500 megaton explosion or, if it landed at sea, a massive tsunami.

Apophis will come relatively close to Earth in 2013 and 2021, making it possible to observe by telescope. This should enable us to eliminate even the slight probability of Apophis hitting the Earth.

How does the impact monitoring system work?

The chain of reaction is as follows. When astronomers detect a comet or asteroid through their telescopes, including NEOs, they send their observations to the Minor Planet Center (MPC) of the International Astronomical Union, which is the clearing house for these data; the MPC uses these data to identify whether the observations correspond to known objects or new discoveries. The MPC publishes all the provisional orbits of newly discovered NEOs daily, as well as all the new observations relating to known NEOs.

Two computing centres, NEODyS at the University of Pisa (Italy), which is duplicated at the University of Valladolid (Spain), and the Jet Propulsion Laboratory in Pasadena (USA), use the new observations to refine calculations of the orbit of each NEO. Those objects which might pass uncomfortably close to Earth are processed by specialized software robots to calculate the probability of a collision with our planet over the coming century. The results are then published online on these centres' specialized risk pages. Astronomers around the world try especially to observe the objects listed on these risk pages. Once our knowledge of these orbits improves to the point where we can exclude the possibility that the object might be on a collision course with Earth, the object is taken off the risk pages.

This monitoring procedure is now almost a decade old. At any one time, we can confidently exclude collisions with Earth over the next century for almost all the NEOs that could cause substantial damage. For the remainder, we know which objects necessitate further scrutiny before they can be declared 'safe'. Of course, there is a further possibility, namely that someday we shall discover that an object capable of causing considerable damage has a high probability of impacting Earth. Should that happen, we would have decades of advance warning, time enough to take preventive measures.

But once you have discovered, tracked, examined and declared safe for 100 years all the dangerous NEOs, will we be done with impact monitoring?

No, monitoring will have to go on forever essentially, exactly as with monitoring for other natural disasters, such as

volcanic eruptions, tsunamis or earthquakes. The reason is that, due to slow, systematic changes in the orbits of NEOs caused by the gravitational action of the planets, the orbits of objects due to pass close to Earth in this and the next century will become harmless in the coming millennia, while others will take their place in the 'to be watched' category.

We are currently studying ways of extending the validity of impact monitoring from one century into the future to several centuries. There are some technical problems but initial results are encouraging and we think it can be done. The obvious benefit would be that we could spot dangerous Earth approaches or even predict hits a lot earlier than at present.

Is it possible to deflect an asteroid?

In theory, yes, but it has never been done. That hasn't stopped people from coming up with some very inventive techniques. One idea concerns getting a spacecraft to hover in front or behind the asteroid to use the spacecraft's tiny gravitational force to accelerate or slow down the asteroid slightly, thereby manoeuvring it away from its original trajectory. Another idea proposes sprinkling the asteroid with material that would change the amount of sunlight it reflects or absorbs, since this would slowly but continuously change its energy balance and thus its trajectory!

Courtesy of William Hartmann: www.psi.edu/hartmann/index.html

Artist's depiction of the scene minutes after an asteroid exploded in the atmosphere in 1908 in Russia's Tunguska region. Although it didn't dig a crater, the 3–5 megaton blast still devastated 2000 km^2 of Siberian forest. It is estimated that an event like Tunguska occurs two to three times every 1000 years. Far fewer comets than asteroids make a close approach to Earth

The most thoroughly studied initiative so far is the European Space Agency's Don Quijote mission[8]. Even this is no more than a study for the moment, though, as there is no funding for it yet. The mission would consist of two components, Sancho, an orbiter spacecraft, and Hidalgo, an impactor spacecraft. Sancho would be inserted into an orbit around a target asteroid about 500 m wide, from where it would measure the asteroid's position, shape, mass and gravity field for several months before and after Hidalgo impacted the asteroid, in order to determine to what extent the impact had deflected the asteroid.

If an asteroid were spotted too late for deflection to be an option, it could be rammed by a missile or spacecraft – or even nuked!

Smaller asteroids burn up upon entering the Earth's atmosphere: in such circumstances, an asteroid 30 m across would probably liberate an energy corresponding to that of a small atomic bomb.

The bigger the asteroid, the harder it will be to deflect or destroy. On the other hand, asteroids smaller than 1 km across are more difficult to spot from Earth and much more numerous than the larger variety.

A deflection mission would have to leave Earth many years in advance to rendez-vous with the asteroid at the appropriate place. In the case of Apophis, the mission would have to leave Earth less than a decade before 2029.

Who would pay to deflect or destroy an asteroid?

Good question! I'm afraid nobody has the answer yet...

What do you know of the NEO Deflection Decision Protocol?

The Association of Space Explorers (ASE) based in Texas (USA) has prepared a report[9] on the need to develop an international decision-making programme for a global response to NEO threats.

The ASE argues that, within 10–15 years, the United Nations will be faced with a decision on whether and how to act to prevent the threat of a comet or asteroid impact. On 1 December, it handed *Asteroid Threats: a Call for Global Response* to national delegates from the Permanent Missions to the United Nations in Vienna (Austria). Similar briefings on the report have been given to officials of several space agencies[10].

What does the report advocate?

The report calls for a three-pronged programme co-ordinated by the United Nations. The first function would be to establish an information gathering, analysis and warning network. This network would also establish criteria for issuing impact warnings.

Secondly, a mission planning and operations group would identify required technologies and survey the NEO-related capabilities of interested space agencies. The group would use these mission plans to prepare for a deflection campaign in the event of a specific warning.

Thirdly, an intergovernmental mission mandated by the United Nations would be responsible for authorization and oversight; it is this group which would establish impact risk thresholds and criteria to determine when to execute an NEO deflection campaign. Il would also submit recommendations to the UN Security Council for appropriate action.

Interview by Susan Schneegans

8. *see www.esa.int/SPECIALS/NEO/SEMZRZNVGJE_0.html*
9. *www.space-explorers.org/committees/NEO/docs/ATACGR.pdf*
10. *Indian Space Research Organization, Canadian Space Agency and NASA. The ASE says it is negotiating future briefings with the European Space Agency, China, Japan and Russia*

Ageing **youthfully**


Photo Alastair Nisbet

Human beings are living longer. By 2100, life expectancy could vary across countries from 66 to 97 years. Much of the credit for this longer lifespan will go to better hygiene and medical progress. But scientists are also exploring another avenue: the possible existence of a longevity gene. They suspect that there may not be one gene in fact but several which influence all the other genes in our body and thus our capacity to reach an advanced age. But living longer is not necessarily synonymous with enjoying those extra years. How can we age youthfully? This was the question put to a panel of 14 experts at a public forum on Longevity and Quality of Life: the Latest Advances for Staying Young Longer, organized by UNESCO and the French weekly magazine *Paris Match* at UNESCO headquarters on 16 September.

The world is ageing in what appears to be an irreversible phenomenon. According to a UN report published in 2007[11], the median age could climb from 28 to 38 years by 2050, with a strong acceleration in developing countries. Today, the median age varies considerably, from 39 years in Europe and 36 in North America to about 28 years in Latin America and less than 20 in Africa. With a median age of 43 years, Japan's population is the oldest in the world, a combination of high development and a falling birthrate: those over 60 are expected to represent 31% of the population by 2020.

Globally, life expectancy is currently 67 years, compared to just 46 years in 1950. There were 30 000 centenarians in the world in 1985, compared to 226 000 today and an estimated 4 million by 2050. In France alone, the number of centenarians will climb from nearly 20 000 to nearly 300 000 by 2050. This inversion of the age pyramid will place a heavy burden on retirement pensions, taxes, health care, the labour force and so on. But a longer life expectancy will also be good news… as long as we are able to enjoy these extra years. As we age, we become vulnerable to a wide spectrum of chronic illnesses which attack our mental, physical and sensorial faculties. The three things people fear most are the loss of sight, the loss of brain function and the loss of autonomy.

The September forum[12] focused on some of the most common diseases related to ageing: the neurodegenerative diseases of Alzheimer's and Parkinson's, eye diseases like the cataract, glaucoma and age-related degeneration of the macula, the central part of the retina; and bone-thinning diseases like osteoporosis and arthritis. The message from the panel was reassuring: we are beginning to understand the mechanisms behind ageing and even to influence some of these mechanisms.

Taking the fear out of the 'g' word

In the case of the common cataract, the eye surgeon can replace the cloudy lens of the eye with a supple implant, in a totally painless operation under local anaesthetic which enjoys a high success rate. 'The same technique can be used to correct other anomalies of the eye,' Prof. Christophe Baudouin from the Hôpital des Quinze-Vingts in Paris explains, 'such as short- or long-sightedness and astigmatism'.

The word 'glaucoma' strikes fear into the heart of patients, for glaucoma can lead to blindness due to the gradual destruction of the optic nerve. Glaucoma is caused by a blockage which causes pressure to build up within the eyeball. The earlier the condition is treated, the better the prognosis, as optic nerve damage is irreversible. For the closed angle glaucoma (20% of cases), a product injected into the eye can lower the tension in the eye by irrigating it, in what is known as the Yag laser technique. The open-angle glaucoma can be treated with a daily rinsing of the eye with eye-drops. It is now possible to stabilize the open-angle glaucoma in 80% of cases.

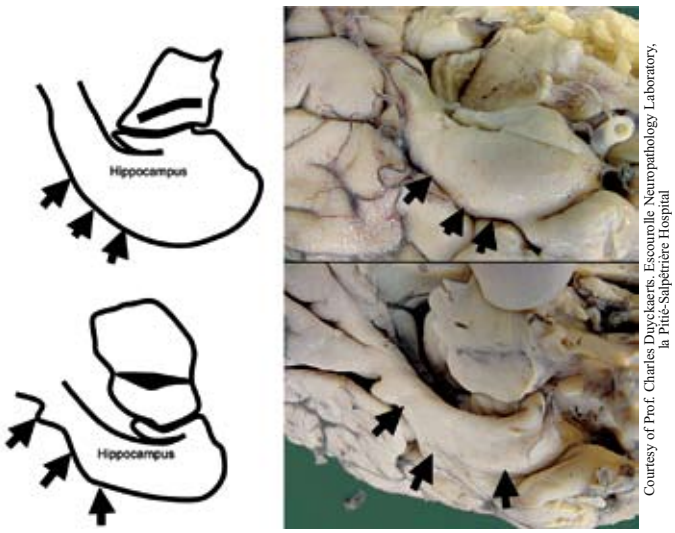
Faces from Kazakhstan, Ethiopia, Peru, Morocco, Jamaïca and India

For the remainder, a recent laser technique can stabilize the condition in about 10% of patients. If all else fails, an operation can clean up the evacuation canal to unblock the eye, effective in 80% of cases.

The brain: a complex machine

'The human brain is made up of 100 billion neurons and other nervous cells, each of which sends 1000 signals per second to its neighbours,' explains Prof. Yves Agid, Head of Neurology at the Pitié-Salpêtrière Hospital and Scientific Director of the Institut du Cerveau et de la Moelle Epinière in Paris. The brain's sheer complexity means that it drains 20% of the body's energy, despite representing only about 2% (1.350 kg) of the weight of an adult human body.

Neurons do not die in the normal ageing process. Rather, as we age, we begin to lose the nerve endings which enable neurons to communicate with one another. But no two individuals will age in the same way. 'Two-thirds of those over 65 years of age complain of memory loss,' observes neurologist Prof. Bruno Dubois, also from Pitié-Salpêtrière. 'In fact, it is more a case of inattention, as in the case of the man who cannot remember where he has left his reading glasses.'



Courtesy of Prof. Charles Duyckaerts, Escourolle Neuropathology Laboratory, la Pitié-Salpêtrière Hospital

Cross-section of a healthy brain (top) and of a brain affected by Alzheimer's disease. The black arrows point to the hippocampus, which is clearly atrophied in the lower image

Slowing the progression of Alzheimer's disease

The difference with Alzheimer's disease is that the person *does* lose neurons, leading to memory loss. Someone who is interested in politics, for example, will be unable to recall the name of the prime minister. We don't know what causes Alzheimer's but we do know the sequence of events. To a certain extent, we can even 'predict' these events: a brain scan can detect an atrophy of the hippocampus, the part of the brain where information is stored, even before the first symptoms of Alzheimer's appear.

Photo courtesy of S. Tabakov

A magnetic resonance scanner. A brain scan can detect an atrophy of the hippocampus even before the first symptoms of Alzheimer's appear. The scanner can also pick up lesions in the hippocampus. In France, Alzheimer's disease affects 860 000 people out of a population of about 60 million

Research is attempting to intervene at different stages of the development of the disease. In one encouraging study, a transgenic mouse suffering from Alzheimer's was created, as animals do not develop the disease spontaneously. A therapeutic vaccine in the form of a protein was injected into the mouse's brain. The mouse subsequently developed antibodies which cured it of Alzheimer's. Subsequent trials with human patients were intrrupted because of side effects but have since resumed. 'I don't think we are far from developing a medicine which can slow down the progression of Alzheimer's,' observes Prof. Dubois.

A 'pacemaker' for Parkinson's patients

With Parkinson's disease, the patient develops a trembling of the hand when it is in a resting position and there is a stiffening of the muscles which slows movement. About 10% of cases are due to the mutation of a gene. Some 15% of cases are benign and a further 15% extremely severe.

L-DOPA is a naturally occurring amino acid found in food and normally made from L-Tyrosine in the human body. L-DOPA is converted into dopamine in the brain and body; in the USA, it is even sold as a dietary supplement. One of the functions dopamine controls in the brain is motor activity. Parkinson's disease results from a deterioration in the group of neurons which produce dopamine. Dopamine can be administered as a medication but, because it is unable to cross the blood–brain barrier, it does not directly affect the central nervous system. A drug derived from L-DOPA, Levodopa, is able to cross the blood–brain barrier to metabolize to dopamine and thereby relieve symptoms. However, Levodopa has been known to produce severe side effects in some patients, such as excessive movements, hallucinations or hypotension.

Today, there is an alternative for these patients: stereotaxy, a painless surgical technique which entails placing electrodes in the brain that are connected to a kind of 'pacemaker' to provide electrical stimulation of the patient's muscles and thereby improve movement.

When age starts eating into your bones

As we age, the cartilage in our joints thins, our muscles shrink in volume and our bone mass diminishes. Knee problems affect 30% of people over the age of 70 and osteoarthritis 10% of those over 60. Osteoporosis tends to affect women more than men, as bone mass diminishes more rapidly after oestrogen levels drop at the menopause.

Photo: UNESCO

A woman 115 years old in Grand-Popo, Benin

The development of a new class of drugs called bisphosphonates has reduced bone pain, excessive calcium in the blood and the risk of bone fractures. In the USA, for example, the number of hospital admissions for hip fractures has dropped by 60% since 1990. Bisphosphonate compounds bind to the surface of damaged bone cells, inhibiting the rate of bone breakdown and enabling the bone to recover and heal. Nowadays, bisphosphonates are added to toothpaste, to protect against tooth decay.

You are what you eat

'When the compound resveratrol, one of a group of molecules called polyphenols, was administered to overfed, sedentary mice, their health and fitness improved,' observes geneticist Prof. Axel Kahn from the Institut Cochin in Paris. But that doesn't mean we should look to science for all the answers. People can do a lot to improve their chances of ageing well, simply by sticking to a healthy diet and regular exercise.

If you lead a sedentary lifestyle, are overweight or have suffered physical trauma, this can play havoc with your joints. The best way to prevent joint problems is to exercise at least an hour several times a week. Exercise can even attenuate the debilitating effects of arthritis by maintaining tendons and leg muscles in good condition. Regular exercise also favours the production of a class of neurotropics – molecules produced naturally by the body which are beneficial for the nervous system – which protect the brain and can even generate new neurons, notably in the hippocampus.

Diet can also work wonders. 'Eating fish twice a week halves the risk of cardiovascular disease,' recalls neurobiologist Prof. Jean Mariani from the Pierre and Marie Curie University in Paris. This is because fish oil, rich in Omega 3 fatty acids, stimulates blood circulation. A diet rich in fish and antioxidants has also been shown to reduce the risk of Alzheimer's disease. Examples of antioxidants – which protect the body's cells from the damaging effects of oxidation – are vitamin E, vitamin C and beta carotene, found in carrots. Antioxidants are also thought to protect us from the dry form of age-related degeneration of the macula.

If a healthy lifestyle can preserve neurons and help to avoid high blood pressure, dangerous cholesterol levels or diabetes, an excess consumption of alcohol or chronic stress can have the opposite effect, by stimulating the production of hormones like corticoids which, in excessive quantities, will actually destroy neurons.

Deepening our understanding of ageing

Research into a rare genetic disease may have the added benefit of deepening our understanding of ageing. Progeria syndrome causes stunted growth in children, accompanied by symptoms associated with ageing that include a hardening of the arteries, the apparition of wrinkles, joint stiffness and atherosclerosis. Children suffering from progeria tend to die in their early teens. Researchers in the USA and France have located a gene associated with progeria, Lamin A, which appears to mutate, an anomaly also found in 90-year olds.

Are we genetically programmed to live 100 years?

Human longevity is nothing new. Egyptian Pharaoh Ramses II lived 90 years (1303 BC – 1213 BC). The difference today is that many more of us are living into our 90s and beyond. The average lifespan in Japan is about 82 years. Could we be genetically programmed to live 100 years or more?

'There is no genetic programme for ageing,' explains Prof. Kahn. 'As repairing DNA takes up a lot of the body's energy, there has to be a balance between reproduction and reparation. If our body devoted much of its energy to longevity, there would not be enough energy left over for reproduction. And once a living being has reproduced itself, evolution does not much care what happens to it next.'

There may be no fountain of eternal youth – but that doesn't mean we cannot age youthfully.

Susan Schneegans

Watch a webcast of this forum (in French) on: www.longevitv.com/longevitv/22

For details, contact: r.clair@unesco.org

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11. World Population Ageing*: www.un.org/esa/population/publications/WPA2007/wpp2007.htm*

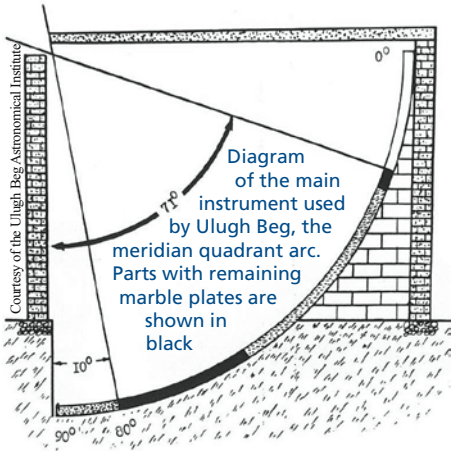
12. This was the fifth annual UNESCO Scientific Forum for the public. The first, in March 2003, tackled research on breast cancer, the second AIDS among women, the third arthritis and osteoporosis and the fourth cancer

Ulugh Beg:
the scholar on the throne

Forensic facial reconstruction of Ulugh Beg by M.Gerasimov

There is only one case in history of an astronomer being the ruler of a mighty state. Ulugh Beg (1394–1449) was born in Sultaniya (Persia), during a campaign of his grandfather, Tamerlane, founder of the vast Timurid Empire (*see overleaf*). At the age of 17, Ulugh Beg became the ruler of Maverannakhr (Transoxiana), the part of his grandfather's empire lying between the Syrdarya and Amudarya rivers and whose capital, Samarkand, is situated in modern-day Uzbekistan.

Ulugh Beg used his princely wealth more for education and scientific development than for military and political gain. In 1420, he built a gigantic observatory in Samarkand. Nothing like the observatories of today, this structure was cylindrical in shape, being approximately 48 m in diameter and 35 m high. Its main instrument consisted of two meridian arcs with a radius of 40 m. The arcs were sunk 11 m into the rock at their lowest point, their peak rising 30 m above the ground. It is important to note that the use of two arcs contributed to the high level of accuracy of observations. Each measurement was made on both arcs, thus cancelling out errors due to deviation of the arcs' directions from the meridian. The arcs were made of fired bricks lined with polished marble plates. These plates are engraved with regularly spaced holes 70 cm apart, each corresponding to 1°. Embedded copper plates contain finer graduations.



Courtesy of the Ulugh Beg Astronomical Institute

This instrument was very probably used to observe the Sun and the Moon, in order to determine basic astronomical constants like the inclination of the ecliptic, the path the Sun traces in the sky during the year to the celestial equator[13]. For instance, the duration of the tropical year was measured to an accuracy of about one minute. The tropical year is the period which falls between the two equinoxes. These occur around 21 March and 23 September when the Sun passes the point where the celestial equator and ecliptic intersect.

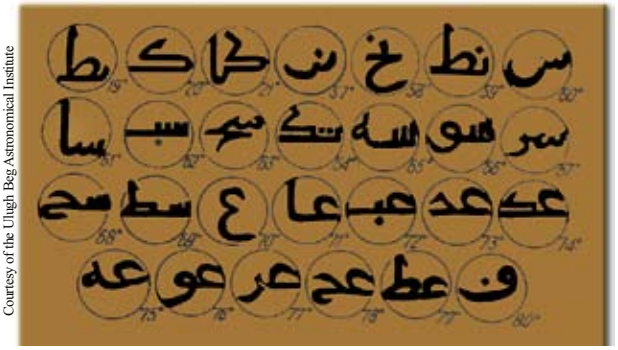
A catalogue of 1000 stars

The many years of activity of Samarkand's observatory resulted in the publication of *Zij Ulugh Beg* in 1437. The main part of the *Zij* is a catalogue of 1018 stars not known in Europe until 200 years later. By the date and number of stars included, this was the first observational catalogue to have been compiled since the 2nd century, when Ptolemy reproduced the Hipparchos catalogue in his *Almagest*.

To perform these measurements, Samarkand's astronomers had to use instruments other than the meridian arc. Alas, no description exists of the tools or methods implemented, so we can only speculate. Undoubtedly, the Samarkand observatory erected by Ulugh Beg and his inspired collaborators was unique. Since its excavation in 1908 by archaeologist V.L.Vyatkin, more then ten versions of its construction have been proposed. These differ not only in shape but also as to whether the observatory was a closed cylindrical building equipped with astronomical instruments on its roof which used the outer wall as a horizontal (azimuth) instrument for measuring celestial objects; or whether it was a hollow construction without a roof. One of the most realistic constructions was recently suggested by architect J. F. Oudet. According to his version, the main instrument was a gigantic *camera obscura*. This may explain how the coordinates of the Sun and Moon could have been

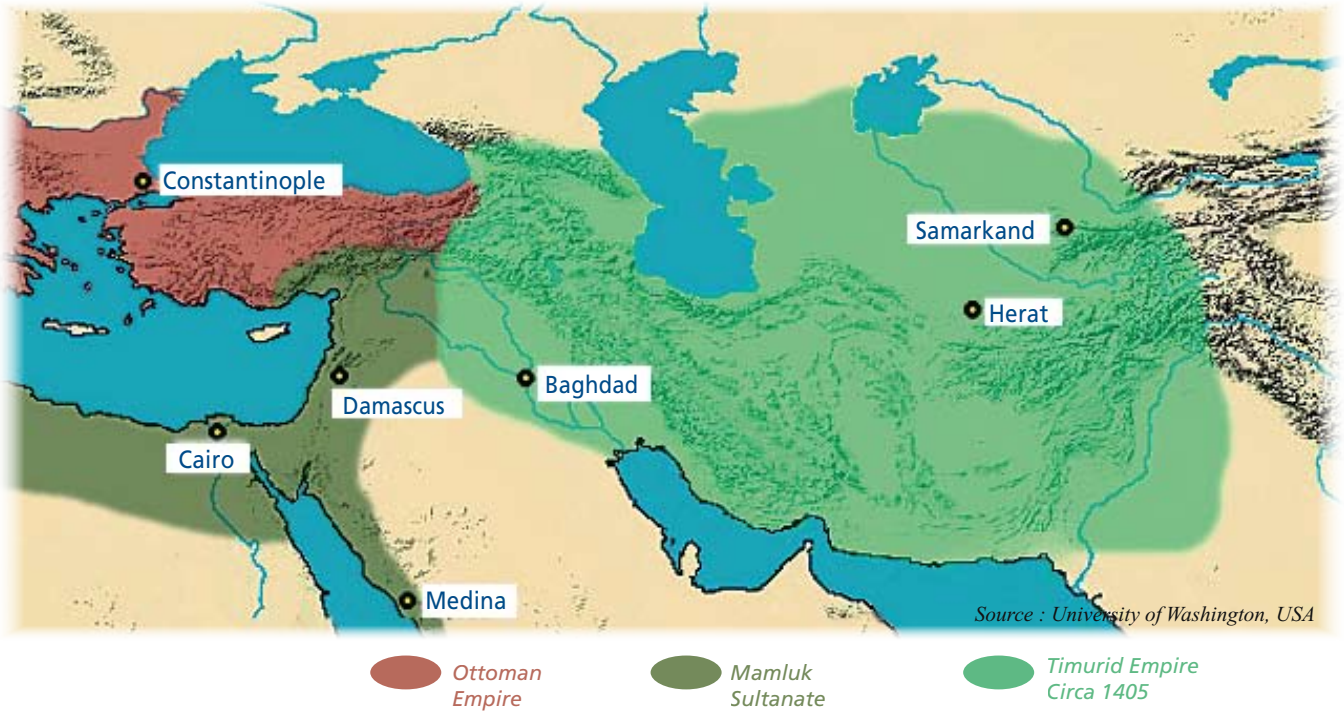
Photo: www.Samarkand.uz

The main instrument of the Ulugh Beg observatory was a meridian quadrant arc with a 40 m radius. Its excavated remains are open to the public



Courtesy of the Ulugh Beg Astronomical Institute

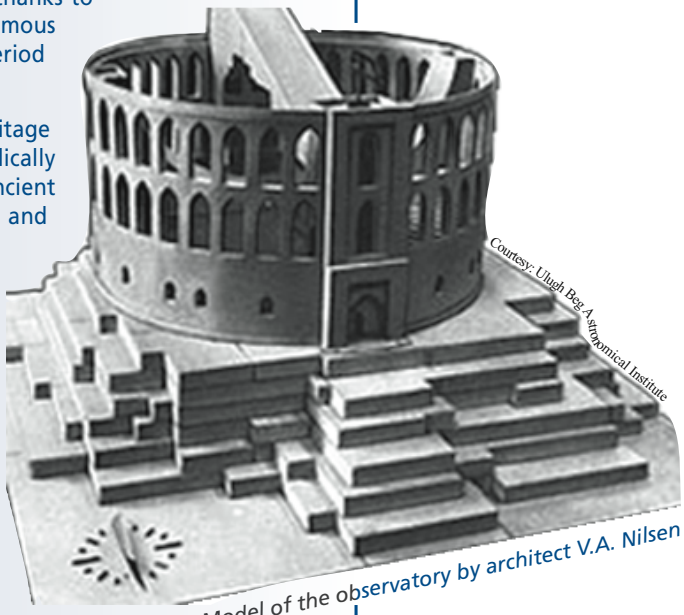
The degrees engraved on the surface of the preserved marble plates lined the meridian arcs



Astronomy and World Heritage

Ulugh Beg's Observatory is part of the World Heritage property Samarkand – Crossroads of Cultures, inscribed on the World Heritage List in 2001. Founded in the 7th century BC as the ancient Afrasiab, Samarkand was a cultural melting pot, thanks to its location on the trade route linking China and Europe, the famous Silk Road. Samarkand's golden age dates back to the Timurid period of the 14th and 15th centuries.

Samarkand is one of several sites inscribed on the World Heritage List with a link to astronomical observations. Other sites symbolically or directly connected with astronomy include (from most ancient to most recent) the Stone Circles of Senegambia (Gambia and Senegal), Stonehenge (UK), the Nubian temples (Egypt), the Mesopotamian site of Persepolis (Iran), the temple of Apollo Epicurius (Greece), Lines and Geoglyphs of Nasca and Pampas de Jumana (Peru), the Pre-Hispanic City of Teotihuacan (Mexico), the Cliff of Bandiagara – Land of the Dogons (Mali), the Angkor temples (Cambodia), the Mayan site of Tikal (Guatemala), the Sun temple in Konarak (India), the Inca site of Machu Pichu (Peru), Maritime Greenwich (UK) and Pulkovskaya Observatory, one of the components of the Historic Centre of Saint Petersburg (Russian Federation).



Model of the observatory by architect V.A. Nilsen

UNESCO's Astronomy and World Heritage Initiative has been launched in support of the International Year of Astronomy, as an occasion to encourage States Parties to the World Heritage Convention to propose specific sites connected with astronomy for inscription on the World Heritage List.

For details of Astronomy and World Heritage: http://whc.unesco.org/en/activities/19/ (click on Group tools then Astronomy to see a global timeline); a.sidorenko@unesco.org

so precisely measured. As to the other instruments, the question remains open. We need more information from historical manuscripts of the time to get a more realistic understanding of what the observatory looked like and how it operated.

The mathematical methods used in Ulugh Beg's observatory are much better described and discussed in the literature than the instruments. In the Middle Ages, stellar catalogues gave the latitudes and longitudes of stars using the ecliptic as a fundamental plane. It was thus necessary to transform the measured horizon-based coordinates to the ecliptic system using precise trigonometric tables. The sins of a few angles (60°, 45°, 30° and so on) were already precisely known from geometrical methods. But the others had to be calculated using multiple-angle formulae and interpolation. Ulugh Beg used sin(1°) as the starting point.

Image by GlavNPU, Ministry of Culture of Uzbekistan

Artist's reconstruction of the Samarkand observatory

Ulugh Beg calculated sin(1°) by an original iterative method using base-60 arithmetic. His result[14] differs from the value given by modern computers by only 3×10^{-17}! His trigonometric tables are generally accurate to eight or nine decimal places and list the sins and tangents for every arcminute[15] from 0° to 45°. Many other mathematical methods were developed at Samarkand, including the use of decimals well before their use was standardized in Europe by Simon Stevin in the 16th century.

A team effort

It would be naive to think that such exhaustive results could be obtained without an excellent scientific organization. Unlike astronomers before him and the many others who came after, Ulugh Beg was not a solitary observer. He founded an astronomical school which counted numerous employees. Many brilliant scientists worked there. Indeed, the trigonometric tables and the conversion of coordinates into the ecliptic system could not have been completed without the efforts of many qualified people over several years.

In many ways, Ulugh Beg's school was the prototype for modern scientific institutions. During the Middle Ages in Europe, scientific investigation was concentrated primarily in the East, where a developed system for communication allowed relatively fast exchanges between scientific centres. Ulugh Beg's observatory thus operated in a highly educated, scientific atmosphere.

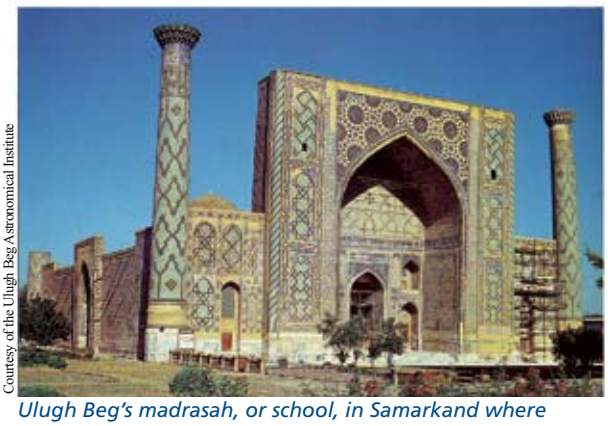
A scientific genius

Some scholars believe that Ulugh Beg was no more than a benefactor and that ideas and methods attributed to him actually originated from other people. Yet many facts substantiate his stature as a scientific genius. A well-known letter from Persian astronomer Jamshid al-Kashi to his father, who lived in Kashan (Iran), tells of the governor's mental calculation – while riding on horseback – of the solar longitude to within about 2 arcminutes.

Another story concerns a scribe who lost a notebook containing a list of every bird killed by Ulugh Beg on hunting expeditions, including the date, species and number of arrows used. The scribe, who expected a heavy punishment, was happy to take Ulugh Beg's dictation from memory to reconstruct the list. Not long afterwards, the notebook was found. To the astonishment of many, there were only a few mistakes in the dictated list and then only as concerned dates.

To sum up, the astronomical observatory in Samarkand epitomizes a brilliant age of astronomical development. Ulugh Beg himself was undoubtedly one of the key players in its success.

Shuhrat Ehgamberdiev[16]



Courtesy of the Ulugh Beg Astronomical Institute

Ulugh Beg's madrasah, or school, in Samarkand where astronomy and mathematics were subjects of intense study

13. The celestial equator is a projection of the terrestrial equator out into space

14. Ulugh Beg derived sin(1°) as: $1/60+2/60^2+49/60^3+43/60^4+11/60^5+14/60^6+44/60^7+16/60^8+26/60^9$

15. $1/60^{th}$ of a degree

16. Ulugh Beg Astronomical Institute of the Uzbek Academy of Sciences: shuhrat@astrin.uzsci.net

Diary

2 January
Entry into force of Convention
On the Protection of Underwater Cultural Heritage (2001). See next issue of *A World of Science* for detailed account (*see 26 March* below). Film available: *www.unesco.org/culture/en/underwater; u.koschtial@unesco.org*

11–13 January
Offshore Arabia
Intl conf. to enhance potential future for oil and gas industry, the global market and global environment. Organized by INDEX. UNESCO co-sponsor. Topics include energy challenges; climate change; sustainability; the global environment and role of governments; offshore and onshore protection. Dubai (UAE): *www.index.ae; offshorearabia@index.ae; b. boer@unesco.org*

15–16 January
International Year of Astronomy
Launch. Speakers will trace history of astronomy and latest developments. Includes exhibition and concert. UNESCO (Paris): *www.unesco.org/iya2009; www.astronomy2009.org/; y.berenguer@unesco.org*

19–23 January
Role of astronomy in society and culture
Symposium with CNRS France. UNESCO (Paris): *y.berenguer@unesco.org; www.astronomy2009.org/*

24–25 January
Wind-up of International Polar Year
With release of State of Polar Research report, joint committee meeting and photo exhibit. Palais des Nations, Geneva (Switzerland): *www.ipy.org ; k.alverson@unesco.org*

12 February
200th anniversary of Charles Darwin's birth
And 150th anniversary of On the Origin of Species. As part of celebrations, UNESCO is sponsoring a seminar in the Galapagos Islands in July: *m.clusener-godt@unesco.org*

3–5 March
The state of the Gulf ecosystem
Gulf II, intl conf. organized by Bahrain Center for Studies and Research and Aquatic Ecosystem Health and Management, with UNESCO Doha and University of Bahrain. Register before 25 January. Bahrain: *www.aehms.org; www.bcsr.gov.bh; b.boer@unesco.org*

3–6 March
The Arctic in the face of global climate change
Intl experts meeting to examine scientific, social, cultural and educational challenges for sustainable development in Arctic. Monaco. UNESCO and Principality of Monaco: *d.nakashima@unesco.org*

16 March
Launch of 3rd world water development report
Entitled *Water in a Changing World*. At 5th World Water Forum, Istanbul (Turkey): *wwap@unesco.org: www.unesco.org/water/wwap/*

31 March – 2 April
Education for sustainable development
World conf. on moving into second half of UN Decade (2005–2014). UNESCO and German Min. of Education and Research. Exhibition on UNESCO's recycling initiative in Arab region; special event on Transmitting Knowledge: Synergies between Intangible Cultural Heritage and ESD - Austrian Commission for UNESCO/Natl Agency for Intangible Cultural Heritage, supported by UNESCO. Bonn, Germany: *esddecade@unesco.org ; eck@unesco.at, (special event): d.nakashima@unesco.org:*

26–27 March
Underwater Cultural Heritage
1st meeting of States Parties to Convention (*see 2 January above*). UNESCO Paris.

New Releases

Madrid Action Plan for Biosphere Reserves (2008–2013)

Produced by UNESCO-MAB, with support of Spanish government. Exists in Arabic, Chinese, English, French, Russian and Spanish, 36 pp.
Approved by 3rd World Congress on Biosphere Reserves and 20th Session of MAB International Coordination Committee, in Madrid in February 2008. Aims to make biosphere reserves the principal internationally designated areas dedicated to sustainable development. The focus will be on developing models for local, national and global sustainability and on turning biosphere reserves into places of learning where policy professionals, decision-makers, research and scientific communities, managers and stakeholder groups can work together. Download: *http://unesdoc.unesco.org/images/0016/001633/163301e.pdf*

Uncertainties in Water Resource Management
Causes, technologies and consequences

Edited by D. Basandorj and D. Oyunbataar. produced by UNESCO's Regional Bureau for Science in Asia (Jakarta) within the IHP Technical Documents in Hydrology Series. English only, 132 pp.
Proceedings of a conference held in Ulaanbaatar (Mongolia) on 29 September – 3 October 2008, to share and disseminate knowledge, information and experiences, and promote cooperative and collaborative work. The conference was organized by the Mongolian National IHP Committee and sponsored by UNESCO.
Download: *http://unesdoc.unesco.org/images/0016/001632/163281E.pdf*

Coastal Basins on the Edge

UNESCO-SCOPE -UNEP Policy Brief n°7, English only, 6pp.
Semi-enclosed coastal seas, bays and gulfs provide critical services for sustaining marine life and human well-being. These need integrated management and governance, involving multiple stakeholders across national boundaries and political jurisdictions. For details: *a.persic@unesco.org*; download: *http://unesdoc.unesco.org/images/0016/001632/163268e.pdf*

Tsunami News

Quarterly newsletter produced by UNESCO-IOC. English only, 3 pp.
Provides up-to-date information on the activities of Members States related to tsunami and other coastal hazards warning systems. Download: *http://ioc.unesco.org/tsunami/newsletter*

Teachers' Guide for Education for Sustainable Development in the Caribbean

Produced by Regional Bureau for Education in Latin America and the Caribbean (Santiago) with UNESCO Kingston Office and specialists from the region, with financial support from Japanese government. ISBN: 978-9568302917, English only, 112 pp.
The experiences of the Caribbean described here are intended to be replicated in the region's classrooms, schools and communities. Request a copy from: *c.jerez@unesco.org*; download: *http://unesdoc.unesco.org/images/0016/001617/161761e.pdf*

Student Achievement in Latin America and the Caribbean

Second Regional Comparative and Explanatory Study, produced by UNESCO's Regional Bureau for Education in Latin America and the Caribbean. Exists in English and Spanish, Executive Summary available: 52 pp. See page 14.

Biocombustível para o MERCOSUL

UNESCO Brasilia, RECyt/Mercosul, MCT, MBC, CNPq, Petrobrás. In Portuguese, 203 pp.
Presents the winning research projects on biofuel, the topic of last year's Mercosur's Science and Technology Award. Each project has the potential to contribute to the development of the Mercosur countries: Argentina, Brazil, Paraguay, Uruguay and Venezuela.
For details: *grupoeditorial@unesco.org.br*

Iraqi Educational TV channel

Launched by UNESCO and Minister of Education of Iraq on 20 October, financed by European Union (USD$ 6.5 million).
Comes in response to the ongoing insecurity in Iraq which is keeping 22% of children away from school, many of them girls. Since 2003, more than 250 educators have been assassinated and hundreds more have disappeared. IRAQI EDU will broadcast programmes based on primary and secondary school curricula 24 hours a day on NILESAT at 10775 hz. For details: *www.unesco.org/education*

UNESCO and Research for Health

Edited by S. Schneegans, coordinated by Division of Basic and Engineering Sciences. English only, 16 pp.
Distributed at Global Ministerial Forum on Research for Health (Bamako, Mali), *see page 10*. The examples of UNESCO projects in this brochure illustrate the broad approach advocated by the Forum. Download: *www.unesco.org/science/bes* or request a copy from: *j.hasler@unesco.org* or *l.hoareau@unesco.org*

Entrepreneur's Guide to Computer Recycling
Basics for starting up a computer recycling business in emerging markets

By Benoit Varin and Pierre-Etienne Roinat. Produced by UNESCO, French Environment and Energy Management Agency (ADEME), Tic Ethic, Emmaüs Solidarité Ouagadougou, Ateliers du Bocage, UNIDO. Open license. Exists in English and French.
Almost 180 million computers were replaced in 2008 and an estimated 35 million computers dumped, despite the toxic substances they contain. This guide helps entrepreneurs develop skills to handle the growing flux of waste generated by the market for new and used computers. Reuse of obsolete computer equipment is preferred to destruction. Equipment and components not fit for reuse should be disassembled and processed to recover raw materials in an environmentally sound manner. Personal computers (PCs) contain valuable ferrous (e.g. iron), non-ferrous (e.g. aluminium and copper) and precious metals, such as gold, palladium, silver, indium and gallium that can be retrieved. The rising value of raw materials makes recycling more economically viable and attractive. There are now almost 4 billion mobile telephones and over 1 billion PCs in use. The digital divide is shrinking: 58% of computers are in developed countries, a share that could drop to 30% by 2014 when there should be 2 billion PCs worldwide, including half a billion in China, up from 55 million in 2007. For details: *r.cluzel@unesco.org*; download: *www.ticethic.com/guide*

International Year of Astronomy: www.unesco.org/iya2009; www.astronomy2009.org

For sales publications: www.unesco.org/publishing A World of Science online: www.unesco.org/en/a-world-of-science

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Cover image: Artist's impression of Fomalhaut b orbiting its sun. Image: NASA