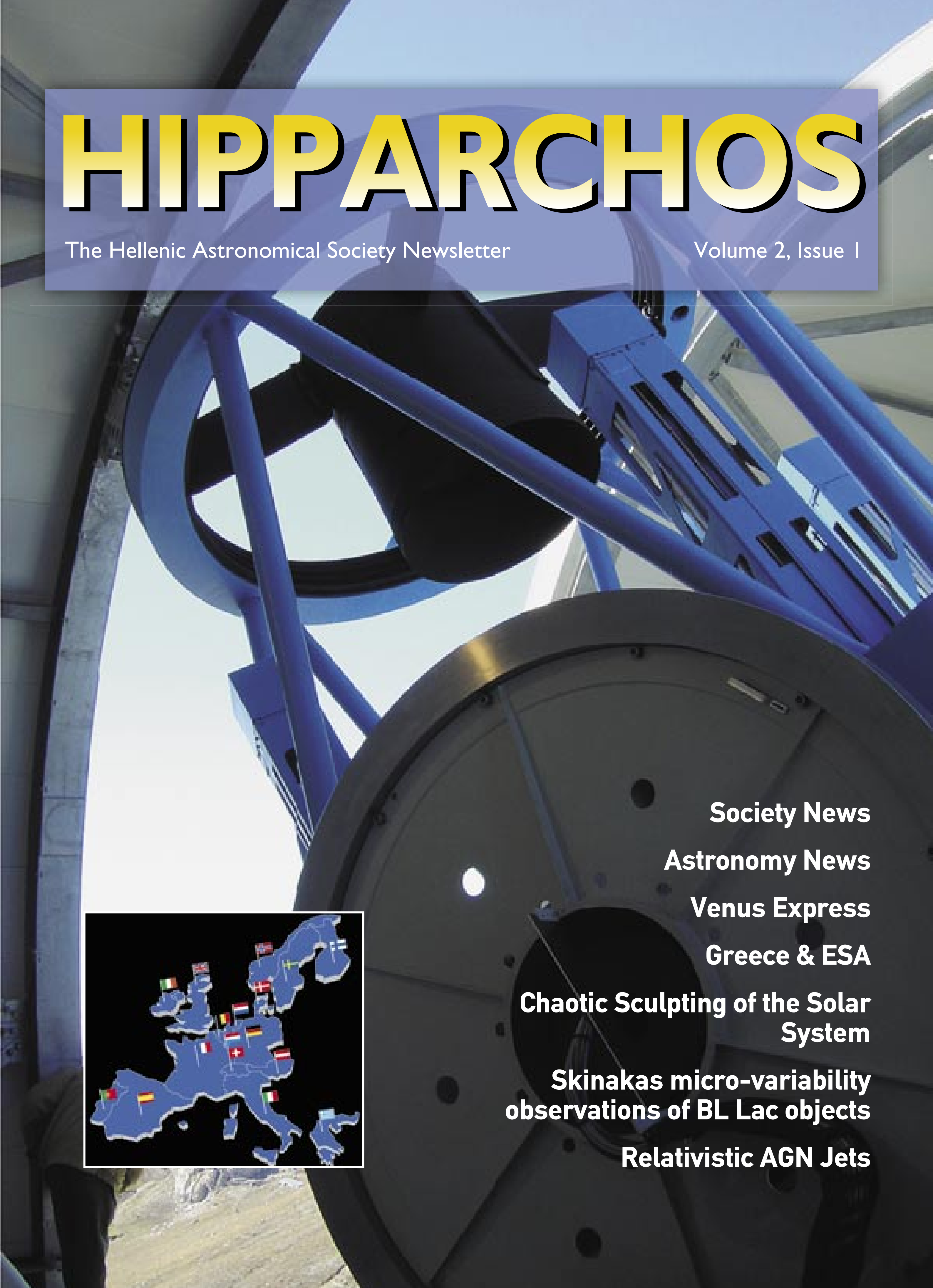
HIPPARCHOS

The Hellenic Astronomical Society Newsletter

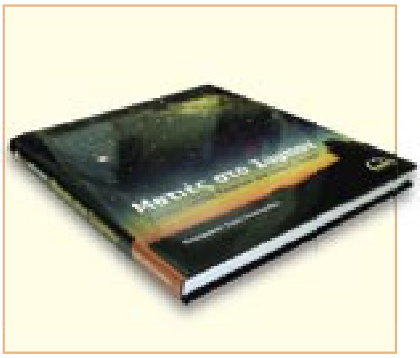
Volume 2, Issue 1



Ματιές στο Σύμπαν

των Carolyn Collins Petersen και John C. Brandt

Μόλις κυκλοφόρησε!



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"Αυτό που είναι ακατάληπτο σχετικά με το σύμπαν είναι ότι θα έπρεπε να είναι πέρα για πέρα καταληπτό"
Albert Einstein

Μόλις κυκλοφόρησε από τις εκδόσεις «ΠΛΑΝΗΤΑΡΙΟ Θεσσαλονίκης» το φημισμένο βιβλίο "VISIONS OF THE COSMOS" (Cambridge University Press), μεταφρασμένο στα ελληνικά, με τίτλο «ΜΑΤΙΕΣ ΣΤΟ ΣΥΜΠΑΝ». Αυτό το εντυπωσιακά εικονογραφημένο βιβλίο είναι ένας κατανοητός οδηγός για την αστρονομική εξερεύνηση, μέσα από τα μάτια των τηλεσκοπίων. Περιλαμβάνοντας τις πιο εκπληκτικές εικόνες που ελήφθησαν από τα μεγαλύτερα αστεροσκοπεία και από διαστημικές αποστολές, παρουσιάζει ένα θαυμάσιο πορτρέτο της ομορφιάς του σύμπαντος. Το συνοδευτικό κείμενο είναι ένας προσιτός οδηγός στην επιστήμη που κρύβεται πίσω από τις εικόνες, με σαφείς επεξηγήσεις όλων των κύριων αστρονομικών θεμάτων.

Απαραίτητο για όσους επιθυμούν να κατανοήσουν και να εκτιμήσουν το σύμπαν, αυτό το βιβλίο συμπληρώνει την επιτυχία του προηγούμενου έργου των συγγραφέων, "Hubble Vision", που έγινε διεθνές best seller και κέρδισε επαίνους από όλο τον κόσμο.

Περιεχόμενα: 1. Μάτια στραμμένα στον ουρανό, 2. Τηλεσκόπια: Χρονομηχανές πολλαπλών συχνοτήτων, 3. Πλανήτες σε ένα pixel, 4. Οι ζωές των αστέρων, 5. Γαλαξίες: Ιστορίες αστρικών πόλεων, 6. Το σύμπαν στο παρελθόν και στο μέλλον, 7. Αστρονομική παρατήρηση: Η επόμενη γενιά.

Μια πολυτελής έκδοση, μια άριστη επιλογή δώρου!

*Στις τιμές περιλαμβάνεται Φ.Π.Α. Δεν περιλαμβάνονται έξοδα αποστολής.

Contents

HIPPARCHOS

Hipparchos publishes review papers, news and comments on topics of interest to astronomers, including matters concerning members of the Hellenic Astronomical Society

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Cover Story: Since March 2005 Greece is the16th full ESA Member State. This new development provides unique opportunities to Greek Astronomers to participate in the exploration of space (page 10).

Contents

Message from the President

It is really a long time since we communicated through this column and many historical events for Hel.A.S. and the Hellenic Astronomy in general happened in this interval.

In relation to this journal of our Society, it is already known to you that Konstantinos Kokkotas, Associate Professor of the Aristotelian University of Thessaloniki and a member of the Council of Hel.A.S. since the 2004 election, succeeded Dr. Manolis Plionis as the Editor of “Hipparchos”. The first issue is now in your hands. As you can see, Kostas decided and passed through the Council the change of the format of our journal, as well as the increase of the number of pages to thirty two, some of them in color. So, Manolis got the journal from eight pages to sixteen and now Kostas from sixteen to thirty two! This is a great progress just in the time interval of a very few years only. It is tempting to imagine that one or two more editor’s changes will lead “Hipparchos” to a full fledged astronomical journal!. Kostas went also forward by adding some pages with ads in order to cover some of the cost the extra pages will bring.

At this point I take the opportunity to express our sincere thanks to Manolis Plionis, who was instrumental in elevating the “Hipparchos” status, adding color pages for the first time and publishing his inspiring (and sometimes controversial) editorials. Also, we thank him for not

Message from the President *(continued)*

dropping everything in Kostas lap, but staying and helping him with the details during the transition time.

As for Hel.A.S. the great event of the past semester was the 7^{th} Meeting of our Society in Lixouri, Kefallinia from September 8^{th} to 11^{th}, 2005. It was really a superb meeting in a marvellous island. The head of the Local Organizing Committee was Dr. Nikos Solomos, who did an excellent job and made us in the Council of Hel.A.S. feel proud for our meeting. There is an item in this issue by Prof. Despina Hatzidimitriou with more details of this meeting. Meanwhile, as you have probably heard via our e-newsletter, which is sent to all of you by our Secretary Dr. K. Tsinganos, Fr. George Anagnostopoulos, Associate Professor at the Demokritos' University of Thrace, has accepted the proposition of the Council to be the head of the Local Organizing Committee for the next (8^{th}), Conference of our Society, which is to be held somewhere in Thrace. We all feel very pleased, since the places of our Panhellenic Meetings keep spreading all over Greece.

The big event in this year for Hellenic Astronomy was Greece's official participation in the European Space Agency (ESA). Although cooperation between ESA and the Hellenic National Space Committee began in the early 1990s, it was only the 16^{th} of March 2005 when the official announcement was made to the ESA Council by the chairman of the ESA Council that Greece became the 16^{th} ESA member state. Prof. K. Tsinganos, the national delegate to the ESA's Science Programme Committee gives us a detailed account of the workings of ESA, its science programs and opportunities for Hellenic scientists, in a detailed article in this issue. Now the Hellenic delegates in the various boards and councils of ESA work full time to assure as many advantages for Greece as possible and to inform their colleagues in Greece of the opportunities ESA offers to Greek space science, astronomy and related industry. This was the reason that we included a special session with prominent invited speakers during our 7^{th} Astronomical Meeting in Kefallinia, And, also for the organization of two special workshops in Athens (October 31^{st}) and Thessaloniki (November 7^{th}) with the Secretary of the Special ESA-Greece Task Force, J. Pedro V. Poiares Baptista. On the other hand we all have to try hard in order to persuade the Greek Government to allocate some funds for the ESA PRODEX program, which can be of great importance for the participation of our community to nationally funded payloads on space missions. For this purpose, a letter composed by the Councils of the previous GNCA and Hel.A.S. in a special joint meeting, has been addressed to the General Secretary of Research and Technology, Prof. J. Tsoukalas. At the moment, however, the financial situation of the Ministry does not allow the Secretary to put even the minimum amount required. Another direction we should pay attention is training of young Greek scientists in space science. In that direction, ESA has the Young Graduate Trainee allowing young men and women to obtain valuable experience at various ESA establishments (see the article on Greece/ESA). At the same time, Prof. K. Tsinganos has been trying hard to persuade the Foundation of Hellenic State Fellowships IKY to add new space-science oriented fellowships in their predoctoral program in 2006 and also start a new program for training at ESA.

Finally, in the beginning of November, Prof. I. Tsoukalas, named the new National Greek Committee for Astronomy, the official body that advises the Greek Government on issues of Astronomy. The Chairman of the previous Committee, the term of which expired on September 8^{th}, 2005, Prof. J. Seiradakis, asked the General Secretary not to be named again Chairman, but he accepted to be a member in the new Committee. The good thing for our Society is that the elected Chairman of the Hellenic Astronomical Society is the new Chairman of this Committee. This is a great achievement for our Society and we all hope that this is not a simple coincidence and that in the future our Chairman will be always present in this Committee. The other members, except me and John, are the eminent Academician, Dr. Stamatis Krimigis (as Vice-Chairman), Prof. N. Kylafis of the University of Crete and Dr. J. Daglis, recently elected Director of the Institute of Space and Applications and Remote Sensing of the National Observatory of Athens. Substitute members are also Prof. J. Papamastorakis (University of Crete), Dr. Helen Dara (Research Center for Astronomy and Applied Mathematics of the Academy of Athens), Prof. S. Avgoloupis (University of Thessaloniki), Prof. M. Kafatos (George Mason University, U.S.A.), and Prof. A. Nindos (University of Ioannina). There is a two year term for this Committee and we all hope that our presence will benefit the Greek astronomy.

The new GNCA, in its first meeting, named Prof. J. Seiradakis and Prof. N. Kylafis the official representatives in the OPTICON network and Dr. Nikos Prantzos, as the new Greek representative to the Board of Astronomy and Astrophysics, since Prof. J. Ventura did not want to continue the fine job he did in this Board.

Meanwhile, January is almost here and, as you know, in this month we shall start looking for candidates for President and members of the Council of our Society. I hope that we shall have enough candidates of men and women wanted to work harder than we did.

With my sincere wishes for a Happy and Productive New Year

Paul G. Laskarides

...and the Descartes Prize goes to Pulse and J.H.Seiradakis

John H. Seiradakis is one of the main researchers of the PULSE collaboration which has been awarded the Descartes Prize in Research.

The Descartes Prizes have been created by the European Commission with the aim to encourage and reward excellence in Scientific and Technological collaborative research and Communication in any field of science.

On December 2 , 2005 the winners received the prestigious Prize from the EU Commissioner for Science and Research, Janez Potocnik at a high level ceremony in London. This year the 1,000,000 Euros Descartes Research Prize was shared between five pan-European teams who achieved major scientific breakthroughs in key European research areas. Among them was Professor **John Seiradakis** from the **Aristotle University of Thessaloniki.** The PULSE collaboration, awarded the Descartes Prize for demonstrating the impact of European pulsar science on modern physics.

Members of the PULSE collaboration are between the pulsar groups at the University of Manchester's Jodrell Bank Observatory, the Max Planck Institute for Radioastronomy in Germany, ASTRON in the Netherlands, the INAF Astronomical Observatory of Cagliari in Italy and the **Aristotle University of Thessaloniki in Greece**.

The success of PULSE was possible because of the unique position of Europe having the largest number of 100m-class radiotelescopes required to observe the weak signals from pulsars. The collaboration used the telescopes at Jodrell Bank, Effelsberg, Westerbork and Bologna.

The pulsar network was initiated in 1995 with a grant from the European Union with the aim of creating a team who could undertake large scale research projects that were otherwise too big to be undertaken by the individual groups on their own. It was led by Prof. R.Wielebinski of the MPIfR in Bonn. The work of the Manchester group, the largest in the collaboration, is largely funded by the United Kingdom's Particle Physics and Astronomy Research Council.

The group's crowning achievement has been the discovery and follow-up observations, made in collaboration with Australian astronomers, of the first known double pulsar. Studies of the double pulsar have enabled them to make the most accurate confirmation yet of Albert Einstein's general theory of relativity - the theory of gravity which supplemented that of Isaac Newton. *"Rarely does a single class of object lend itself to high-precision experiments in so many domains of modern and fundamental physics"*, enthuses Dr Michael Kramer of the University of Manchester.

The importance of the collaboration was emphasized by Professor **John Seiradakis** of the Aristotle University of Thessaloniki: *"The bringing together of groups across Europe has enabled us to benefit from collaborative instrumentation and software effort, the sharing of expertise and training opportunities and the co-ordination of observing programmes."*

PULSE has enabled the setting up of a unified data format for the easy exchange of pulsar data and has designed and performed unique experiments to understand pulsars. Ten years on, the teams are world leaders and their research achievements cover a wide field, not only in studying the extreme physics of the pulsars themselves, but also in using them as probes of the interstellar medium through which their signals pass.

Professor Lyne underlines the importance of the collaboration: *"Our work increases mankind's knowledge of some of the fundamental laws that govern the universe. These results are not only of interest to today's scientific professionals. They also help to interest young people in astronomy, physics and basic research, forming an important foundation for a society increasingly based on science and technology."*

Congratulations John

Members in new positions

Dr. Ioannis A. Daglis was recently selected by a special committee as the new Director of the Institute for Space Applications & Remote Sensing of the National Observatory of Athens. The Director position has a 5-years term.

Dr. Ioannis A. Daglis has been invited to become a member of ESA's Solar System Working Group (SSWG) for a period of three years (2006 to 2008). SSWG is one of the three scientific advisory groups for ESA's Science Programme (the other two being the Astronomy Working Group (AWG) and the Fundamental Physics Advisory Group (FPAG)). These advisory groups act as mediators between the scientific community and ESA. The three advisory groups are each composed of ten to fifteen scientists with expertise in the specific discipline covered by the group. The groups meet at the request of the Director of the Scientific Programme and issue recommendations on the matters submitted to them.

Dr. Vassilios Chamandaris has been recently appointed as the new Editor of the European Astronomical Society Newsletter. Vasilis is replacing Dr. Mary Kontizas who served for many years as the Editor of the Newsletter.

Prof. Stamatis Krimitzis has recently become member of the Academy of Athens.

Venus Express

en route to probe the planet's hidden mysteries

On the 9th of November 2005, the European spacecraft Venus Express lift-off from the Baikonur Cosmodrome in Kazahkstan and was successfully placed into a trajectory that will take it on its journey from Earth towards its destination of the planet Venus, which it will reach next April. An initial Fregat upper-stage ignition took place nine minutes into the flight, manoeuvring the spacecraft into a low-earth parking orbit. A second firing, one hour and 22 minutes later, boosted the spacecraft to pursue its interplanetary trajectory. The 1240 kg mass spacecraft Venus Express is currently distancing itself from Earth at full speed, heading on its five-month, 350 million kilometre journey inside our Solar System. Contact with Venus Express was established by ESA's European Space Operations Centre (ESOC) at Darmstadt, Germany approximately two hours after lift-off. The spacecraft has correctly oriented itself in relation to the sun and has deployed its solar arrays. All on-board systems are operating perfectly and the orbiter is communicating with the Earth via its low-gain antenna while in a few days, it will establish communications using its high-gain antenna.

Venus Express will eventually manoeuvre itself into orbit around Venus in order to perform a detailed study of the structure, chemistry and dynamics of the planet's atmosphere, which is characterised by extremely high temperatures, very high atmospheric pressure, a huge 'greenhouse effect' and as-yet inexplicable 'super-rotation' which means that it speeds around the planet in just four days.

The European spacecraft will also be the first orbiter to probe the planet's surface while exploiting the 'visibility windows' recently discovered in the infrared waveband.

The Venus Express spacecraft

Full speed ahead for Venus

When making its closest approach, Venus Express will face far tougher conditions than those encountered by Mars Express on nearing the Red Planet. For while Venus's size is indeed similar to that of Earth, its mass is 7.6 times that of Mars, with gravitational attraction to match.

To resist this greater gravitational pull, the spacecraft will have to ignite its main engine for 53 minutes in order to achieve 1.3 km/second deceleration and place itself into a highly elliptical orbit around the planet. Most of its 570 kg of propellant will be used for this manoeuvre.

A second engine firing will be necessary in order to reach final operational orbit: a polar elliptical orbit with 12-hour crossings. This will enable the probe to make approaches to within 250 km of the planet's surface and withdraw to distances of up to 66 000 km, so as to carry out close-up observations and also get an overall perspective.

Twin sister of Mars Express

Venus Express largely re-uses the architecture developed for Mars Express. This has reduced manufacturing cycles and halved the mission cost, while still targeting the same scientific goals. Finally approved in late 2002, Venus Express was thereby developed fast, indeed in record time, to be ready for its 2005 launch window.

However, Venusian environmental conditions are very different to those encountered around Mars. Solar flux is four times higher and it has been necessary to adapt the spacecraft design to this hotter environment, notably by entirely redesigning the thermal insulation.

Whereas Mars Express sought to retain heat to enable its electronics to function properly, Venus Express will in contrast be aiming for maximum heat dissipation in order to stay cool.

The solar arrays on Venus Express have been completely redesigned. They are shorter and are interspersed with aluminium strips to help reject some solar flux to protect the spacecraft from temperatures topping 250 °C.

It has even been necessary to protect the rear of the solar arrays – which normally remain in shadow – in order to counter heat from solar radiation reflected by the planet's atmosphere.

An atmosphere of mystery

Following on from the twenty or so American and Soviet missions to the planet carried out since 1962, Venus Express will endeavour to answer many of the questions raised by previous missions but so far left unanswered.

It will focus on the characteristics of the atmosphere, its circulation, structure and composition in relation to altitude, and its interactions with the planet's surface and with the solar wind at altitude.

To perform these studies, it has seven

Continued in page 33

Worlds without End

Not one but three new large bodies have been recently discovered beyond Neptune. Together they are changing the way that astronomers understand the earlier and present solar system.

This three bodies were discovered using the 48-inch Samuel Oschin Telescope at the Palomar Observatory by a team of astronomers from California Institute of Technology, the Gemini Observatory and Yale University lead by Mike Brown of Caltech.

These new bodies are all part of the Kuiper Belt, orbiting beyond Neptune, and are around the size of Pluto or larger. So far, the names Santa, Easterbunny and Xena are as informal as they sound, the IAU knows them as 2003EL61, "005FY9 and 2003UB313 respectively.

The sizes of these bodies are not yet well known, but estimates based on their orbits and reflectivity suggest objects that are possibly bigger than Pluto, Xena is probably similar to Pluto with a surface covered in methane ice, leading to suggestions that it should be considered the tenth planet.

Santa is a cigar-shaped body, about the diameter of Pluto along its longer axis, and rotating with a four hour period — astonishingly fast. It even has a moon, inevitably known as Rudolph.

The third new object, named because it was discovered in the spring of this year, appears to have a methane surface making it the such Kuiper Belt object.

The team hopes to get better estimates of their size by compatring their optical appearences, which gives a lower limit on size, with the infrared signature obtained from Spitzer Space Telescope to set an upper limit (Astronomy & Geophysics, October 2005)

Large Binocular Telescope (LBT): First Light

The Large Binocular Telescope (LBT) partners in USA, Italy and Germany announced that they achieved "First Light" on Oct. 12, 2005. Exceptional images were obtained with one of the telescope's two primary mirrors in place and are being released on ***http://www.lbto.org***.

This milestone marks the dawn of a new era in observing the Universe. Upon completion the LBT will peer deeper into space than ever before, and with ten times the clarity of the Hubble Space Telescope. With unparalleled observational capability, astronomers will be able to view planets in distant solar systems, and detect and measure objects dating back to the beginning of time.

Located on Mount Graham in southeastern Arizona, the $120 million (USD) LBT is a marvel of modern technology. It uses two massive 8.4m diameter primary mirrors mounted side-by-side to produce a collecting area equivalent to an 11.8m circular aperture. Furthermore, the interferometric combination of the light paths of the two primary mirrors will provide a resolution of a 22.8m telescope.

The "honeycomb" structured primary mirrors are unique in that they are lighter in weight than conventional solid-glass mirrors. The second primary mirror was recently transported from the University of Arizona to Mount Graham and has been installed. By fall 2006, the LBT will be fully operational with both of its enormous eyes wide open.

The LBT's first light images were taken on 12 October 2005. The target was an edge-on spiral galaxy (type Sb) in the constellation of Andromeda known as NGC891. This galaxy lies at a distance of 24 million lys. NGC891 is of particular interest because the galaxy-wide burst of star formation inferred from X-ray emission is stirring up the gas and dust in its disk, resulting in filaments of obscuring dust extending vertically for hundreds of light years.

The images were captured through a state-of-the-art camera known as the Large Binocular Camera (LBC), which is mounted high above the primary mirror at the telescope's prime focus. Designed by the Italian partners in the project, the LBC acts like a superb digital camera. Its large array of CCD detectors is fed by a sophisticated six-lens optical system. Scientists can obtain very deep images over a large field of view, which is important since the processes of star formation and faint galaxy evolution can be observed with unmatched efficiency.

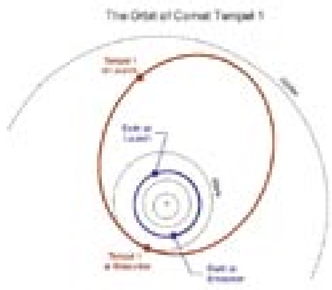
The "First Light" image at LBT was obtained on the night of 12 October 2005 (UT). The target was the NGC891 edge-on spiral galaxy (type Sb) in the constellation of Andromeda.

Comet Dusty Bunny:
Tempel 1 proves to be a ball of fluff

In the course of the Space Age, planets have gone from astronomical objects—wandering specks in the night sky—to geological ones: full-fledged worlds you could imagine yourself walking on. In the 1990s asteroids made the same transition. And now it is comets' turn, as exemplified by July's (deliberate) crash of the Deep Impact probe into the nucleus of Comet Tempel 1. In September researchers announced a batch of findings at an American Astronomical Society meeting in Cambridge, England.

The impact threw up a cone of dusty debris some 500 meters high; it extended right from the surface, indicating that the cometary material put up no significant resistance to the projectile. The flight path of debris particles revealed the strength of the comet's gravity, hence its density—on average, about half of water. The body must be riddled with voids. So much fine dust flew out that it could not have been created by the impact itself but rather must have already been sitting on the surface. A lack of big pieces suggest that the comet has no outer crust. Along with other data, these results indicate that Tempel 1 is not a compacted snowball, as many had conjectured, but a loose, powdery fluff ball—an agglomerate of primordial dust that came together at low speeds and gently clung like dust bunnies under a bed. If other comets are like this, landing on one – as ESA's Rosetta mission plans to do in 2014—could be tricky.

Despite its flimsiness, Tempel 1 has an almost planetlike surface, covered with what appear to be impact craters (the first ever observed on a comet), cliffs, and distinct layers. The composition hints at an unexpectedly complex history of chemical reactions. Humans have always found comets mysterious, and seeing them up close has done nothing to change that. (Scientific American, November 2005)

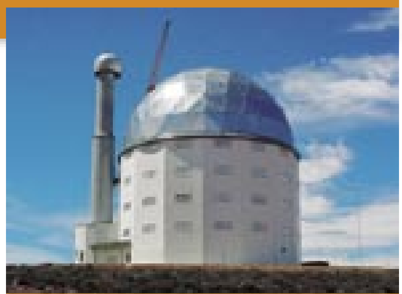


Comet 9P/Tempel 1 was discovered on April 3, 1867 by E.W.L. Tempel of Marseille, France. The comet was then 9th magnitude and calculations revealed that has an orbital period of 5.5 years and a perihelion distance of roughly 1.5 AUs.

First light for SALT

Africa's giant eye on the sky - the South African Large Telescope - released its first light images on September 1st .

The largest telescope in the southern hemisphere, SALT, is now at commissioning stage in its superb dark skies skies location on the edge of the Kalahari desert. The telescope has a mirror 10m by 11m made up of 91 hexagonal segments. Instruments, including the Prime Focus Imaging Spectrograph, will be installed and tested over the coming weeks of commissioning, building up the capabilities of this new and powerful observatory. It is hoped that access to such an instrument in Africa will boost astronomical research among local scientists. Its global position between comparable telescopes in Chile and Australia will allow continuous observation of objects such as supernovae in the southern hemisphere. The project has already fulfilled one of its aims, however. It was intended as a showcase for South African scientists and engineers, and has been completed on time and to the original $20million budget.

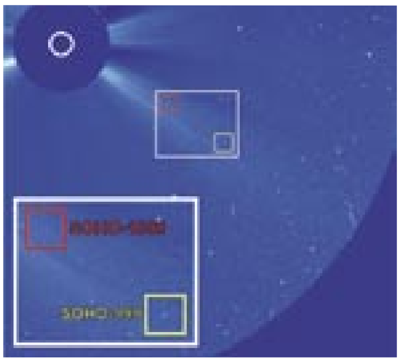


The South African Large Telescope (SALT), near Sutherland, South Africa. The calibration tower (left) contains an interferometer for alignment of 91 panels of the 10-meter-wide segmented mirror. The dome roof rotates for viewing, and has an 11-meter hexagonal openable panel.

SOHO's 1000th comet found by a high-school teacher

The 999th and 1000th comet discovered from SOHO (Solar and Heliospheric Observatory) data, Tony Sacramento, a high-school teacher from San Costantino di Briatico, Calabria, Italy, found two comets in the same SOHO image. He is an astrophysics graduate of Bologna University, and said : *"I am very happy for this special experience that is possible thanks to the SOHO satellite and NASA-ESA collaboration. I want to dedicate the SOHO 1000th comet to my wife Rosy and my son Kevin to compensate for the time that I have taken from them to search for SOHO comets"* Many comet discoveries have been by amateurs using SOHO images on the internet, and SOHO comet hunters come from all over the world.

SOHO spacecraft is history's greatest comet hunter, it has accounted for approximately one-half of all comet discoveries with computed orbits in the history of astronomy.



WORLD YEAR OF PHYSICS 2005

in Thessaloniki

The *General Assembly of the United Nations, the Unesco* and the *International Union of Pure and Applied Physics* have declared the year 2005 as the **World Year of Physics**. The international celebration coincides with the 100th anniversary of the *"miraculous year"* 1905, when Albert Einstein initiated on the the greatest scientific revolutions by publishing five papers containing three ground braking discoveries. He proved the **particle nature of light,** he calculated the **true dimensions of molecules** and explained their **random walk** and he formulated the **special theory of relativity**, which lead to the most famous equation of all times, $\mathbf{E=mc^2}$. For this reason, the year 2005 is also celebrated as the Einstein Year 2005.

The Department of Physics of the Aristotle University of Thessaloniki (AUTh) participated in the international celebration of the World Year of Physics and Einstein Year by organizing a large number of events, which aimed at making more accessible to the academic community and the general public the important discoveries of the 20th century, which was characterized as the century of Physics. These discoveries did not only change our view of the Universe, but also brought significant improvements to the quality of everyday life.

The events organized by the Department of Physics included:

- Seminar "Neutrino and Astrophysics", Prof. G. Gounaris (AUTh), 30/3/05.
- Public Lecture: "The Life and Death of Stars", Prof. N. Kylafis (U. of Crete), 19/4/05
- "Open Doors" two-day event, 30/9-1/10/2005, during which dozens of school classes and the general public visited all of the research and teaching laboratories of the Department of Physics. In parallel, an open discussion about "Physics Jobs in the 21st Century" was organized, during which a one-hour movie with this theme was shown (an internal production of the Department of Physics made specially for the World Year of Physics).
- Main Celebration Event of the World Year of Physics, in which Prof. Gerard `t Hooft (U. of Utrecht), Nobel Prize Winner of 1999, presented a public lecture on "Spacetime, Particles and Forces, 100 Years After Einstein". The lecture was attended by more than 800 people in the main lecture hall of the Aristotle University of Thessaloniki on 11/10/05.
- Seminar: "The Historic Voyager 1 and 2 Missions and the Crossing of the Heliosphere's Termination Shock" , Prof. S. Krimigis (Academy of Athens, Johns Hopkins University), 11/11/05.
- Seminar: "Quantum Mechanis is… Here", S. Trachanas (Fundation of Research and Technology - Hellas), 29/11/05.
- Two-day Workshop: "Research in the Physics Department" with presentations by all research groups in the Department, 6-7/12/05.
- Workshop: "Physics and the Other Sciences: AUTh 2005-2015", with participation of the Heads and members of several other Departments of AUTh and of CERTH, 8/12/05.
- Workshop: "Physics and Technology: Greece 2005-2015", with participation of Heads of other Physics Departments in Greece, of the research center "Democritus", of the National Observatory in Athens, representatives of GSRT and of the National Council on Research and Technology, representatives of the Union of Hellenic Physicists and representatives of private enterprises, 9/12/05.
- Public Lecture: "The Constancy of the Speed of Light and Curved Spacetimes", Prof. G. Schaefer (U. of Jena), co-organized with the Goethe Institute of Thessaloniki, 15/12/2005
- Workshop: "Cosmology and Gravitational Physics", international scientific workshop on new developments in Relativistic Cosmology and Gravity, with participation of invited speakers and speakers from AUTh, 15-16/12/05.

More information on the above events can be found on the web page of the Physics Department:

http://www.physics.auth.gr/

Nick Stergioulas

Professor Gerard `t Hooft lecturing in the main lecture hall of the Aristotle University of Thessaloniki

The Hellenic participation in the European Space Agency (ESA)

by Kanaris Tsinganos,
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1. Greece and ESA

ESA was formed in 1975 and has currently 17 Member States: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom. Canada, Hungary and the Czech Republic also participate in some projects under cooperation agreements. As it can be seen from this list, not all member countries of the European Union are members of ESA and not all ESA Member States are members of the EU. ESA is an entirely independent organization although it maintains close ties with the EU through an ESA/EU Framework Agreement. The two organizations share a joint European strategy for space and together are developing a European space policy.

Cooperation between ESA and the Hellenic National Space Committee began in the early 1990s and in 1994 Greece signed its first cooperation agreement with ESA. This led to regular exchange of information, the award of fellowships, joint symposia, mutual access to databases and laboratories, and studies on joint projects in fields of mutual interest. In September 2003 Greece formally applied to join ESA. Subsequent negotiations were followed in the summer of 2004 by the signing of an agreement on accession to the ESA Convention by Jean-Jacques Dordain, ESA Director General on behalf of ESA, and by D. Sioufas, the Greek Minister for Development and the Secretary General for Research and Technology Prof. I. Tsoukalas, on behalf of the Greek Government. Greece already participates in ESA's telecommunication and technology activities, and the Global Monitoring for Environment and Security Initiative. Following the ratification of the ESA Convention by the Greek Parliament, Greece has now become ESA's 16th Member State. The official announcement was made to the ESA Council on the 16th of March 2005 by the chairman of the ESA Council. Now, with the deposition of its instrument of ratification of the Convention for the establishment of ESA with the French Government on 9 March 2005, Greece become the 16th full ESA Member State.

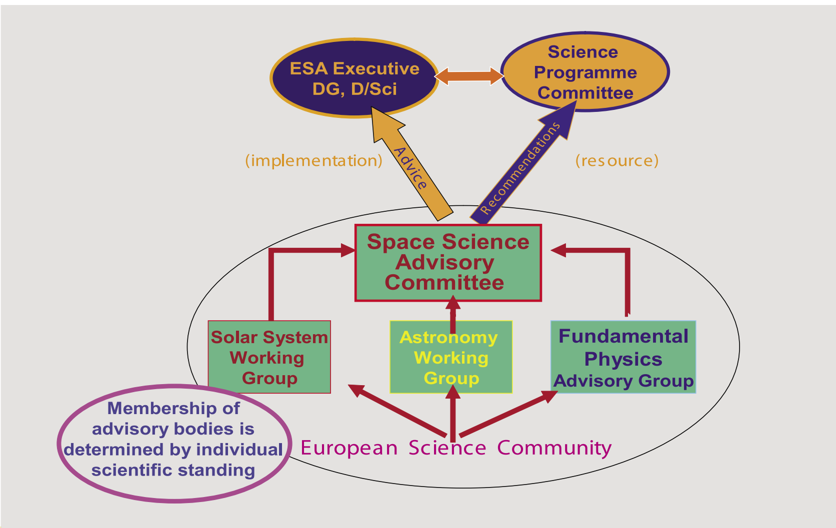
ESA's job is to draw up the European space programme and carry it through. The Agency's projects are designed to find out more about the Earth, its immediate space environment, the solar system and the Universe, as well as to

develop satellite-based technologies and services, and to promote European industries. ESA also works closely with space organizations outside Europe to share the benefits of space with the whole of mankind.

ESA's headquarters are in Paris where policies and programmes are decided upon. In addition, ESA also has several centers in a number of European countries, each of which has different responsibilities.

- **ESTEC**, the European Space Research and Technology Centre, the design hub for most ESA spacecraft and technology development, situated in Noordwijk, the Netherlands.
- **ESOC**, the European Space Operations Centre, responsible for controlling ESA satellites in orbit situated in Darmstadt, Germany.
- **EAC,** the European Astronauts Centre, training astronauts for future missions situated in Cologne, Germany.
- **ESRIN**, the ESA Centre for Earth Observation, based in Frascati, near Rome in Italy. Its responsibilities include collecting, storing and distributing Earth Observation satellite data to ESA's partners, and acting as the Agency's information technology centre

In addition, ESA has liaison offices in Belgium, the United States and Russia; a launch base in French Guiana; and ground and tracking stations in various areas of the world. In February 2005 the total number of staff working for ESA numbered approximately 1907. These highly qualified people come from all Member States and include scientists,



The "First Light" image at LBT was obtained on the night of 12 October 2005 (UT). The target was the NGC891 edge-on spiral galaxy (type Sb) in the constellation of Andromeda.

engineers, information technology specialists and administrative personnel. Presently there are only a very few staff members of Greek origin working in ESA.

ESA's mandatory activities (space science programmes and the general budget) are funded by a financial contribution from all the Agency's Member States, calculated in accordance with each country's gross national product. The Greek contribution without adjustments is presently 1.57%. In addition, ESA conducts a number of optional programmes. Individual countries decide in which optional programme they wish to participate and the amount they wish to contribute.

ESA's total budget for 2005 is 2977 million EURO. The agency operates on the basis of geographical return, i.e. it invests in each Member State, through industrial contracts for space programmes, an amount more or less equivalent to each country's contribution. The mandatory contribution from all member states is 371 million Euros, i.e., every citizen of an ESA Member State pays about one Euro per year. Thus the total European per capita investment in space is rather small. On average, every citizen of an ESA Member State pays, in taxes for a total expenditure on space, about the same as the price of a cinema ticket. In the United States, investment in civilian space activities is almost four times as much.

The ESA Council is the Agency's governing body and provides the basic policy guidelines within which the Agency develops the European space programme. Each Member State is represented on the Council and has one vote, regardless of its size or financial contribution. The Agency is headed by a Director General who is elected by the Council every four years. The present Director General of ESA is Jean-Jacques Dordain.

Each individual research sector has its own Directorate that reports to the Director General. Thus, ESA's activities are divided into nine Directorates, each headed by a Director who reports directly to the Director General. These are:

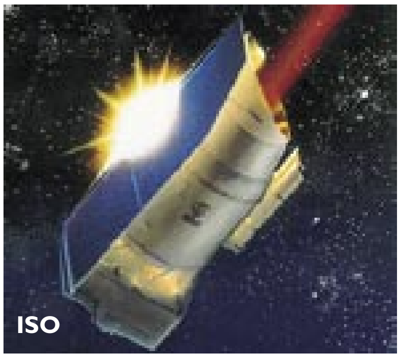
- **Science Programmes**
- **Earth Observation Programmes**
- **Technical and Quality Management**
- **Launcher Programmes**
- **Human Spaceflight, Microgravity and Exploration Programmes**
- **Resources Management**
- **External Relations**
- **EU and Industrial Programmes**
- **Operations and Infrastructure**

2. The Science Programme of ESA

The Science Programme is the only mandatory element of the ESA programme, and is therefore both a flagship and a symbol for the Agency. It enhances European capability in space science and applications, builds European industrial technical capacity, and brings together European national space programmes. ESA staff and contractors assemble and test new ESA scientific spacecraft at the European Space Research and Technology Centre (ESTEC), Noordwijk (The Netherlands). These will then be operated from ESA's European Space Operations Centre (ESOC) at Darmstadt in Germany. At ESA headquarters, the Director of Science oversees policy and the overall shape of the science programme. ESA Science staff are also deployed elsewhere, for example in Spain, Germany, and the United States.

The present Director of Science (Programmes) is Prof. David Southwood. The scientific community is represented by three working groups :The Solar System Working Group, the Astronomy Working Group and the Fundamental Physics Advisory Group. Recently Dr. I. Daglis was invited to become a member of ESA's Solar System Working Group for a period of three years (2006 to 2008). The recommendations of these three groups are finalized by the Space Science Advisory Committee, currently chaired by Prof. G. Bignami, which submits the scientific proposals for their final approval

to the Science Programme Committee (SPC). Each Member State is also represented on the SPC with one vote, regardless of its size or financial contribution. The Hellenic Delegate in the SPC is the author of this article with Advisers Dr. V. Tritakis and Prof. Th. Karakostas.

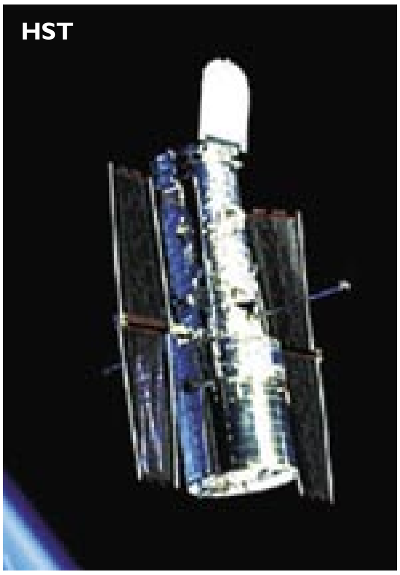


(a) Early ESA missions

In the early period of ESA, 1968-1985, some 15 European spacecraft were launched on scientific missions to study a vast array of disciplines:

- Cosmic rays and solar X-rays (ESRO 1B & 2B) - 1 Oct 1969 and 17 May 1968
- Ionosphere and aurora (ESRO 1A) - 3 Oct 1968
- Solar wind (HEOS-1) - 5 Dec 1968
- Polar magnetosphere (HEOS-2) - 31 Jan 1972
- UV astronomy (TD-1) - 11 March 1972
- Ionosphere and solar particles (ESRO-4) - Nov 1972
- Gamma ray astronomy (COS-B) - 9 Aug 1975
- Magnetosphere (GEOS-1 & 2) - 20 Aug 1977 and 14 Jul 1978
- Magnetosphere and sun-Earth relations (ISEE-2) - 23 Oct 1977
- Ultraviolet astronomy (IUE) - 26 Jan 1978
- Cosmic x-rays (Exosat) - 26 May 1983

More recently, the ESA Giotto probe (launched in 1985) became the first spacecraft ever to meet two comets,


HST

Halley (1986) and Grigg-Skjellerup, (1992). Between 1989 (when it was launched) and 1993 the Hipparcos satellite collected data on the positions and movements of a million stars with the respective catalogues published in 1997. The infrared space observatory (ISO) was launched in 1995 and concluded its operation in 1998, giving the first detailed view and spectra of infrared celestial objects.

(b) ESA missions in operation.

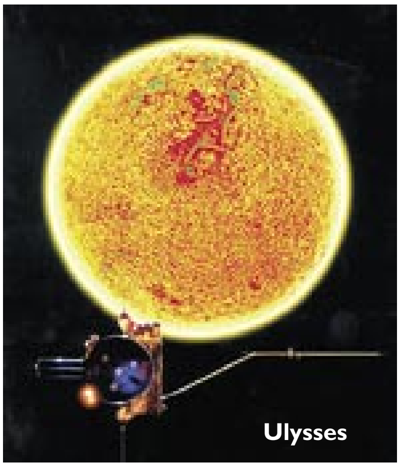
There are 15 ESA missions in operation today. The Hubble Space Telescope (1990), a long-term, space-based observatory whose observations are carried out in visible, infrared and ultraviolet light. In many ways Hubble has revolutionised modern astronomy, not only by being an efficient tool for making new discoveries, but also by driving astronomical research in general.

Ulysses(1990) developed in collaboration with NASA is the first mission to study the environment of space above and below the poles of the Sun. Its data have given scientists their first look at the variable effect that the Sun has on the space around it.

The solar observatory **SoHO** (1995) stationed 1.5 million kilometres away from the Earth, constantly watches the Sun, returning spectacular pictures and data of the storms that rage across its surface. SOHO's studies range from the Sun's hot interior, through its visible surface and stormy atmosphere, and out to distant regions where the wind from the Sun battles with a breeze of atoms coming from among the stars. The SOHO mission is a joint ESA/NASA project.

Cassini/Huygens (1997) also in collaboration with NASA is already in the Saturnian system. It will orbit Saturn for four years, making an extensive survey of the ringed planet and its moons. The ESA Huygens probe landed in January 2005 on the surface of Titan, Saturn's largest moon. Data from Cassini and Huygens are offering us clues about how life began on Earth.

XMM-Newton (1999), the biggest science satellite ever built in Europe


Ulysses

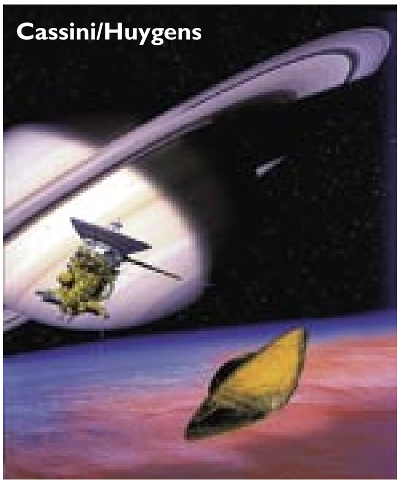
with its telescope mirrors are the most sensitive ever developed in the world, is detecting more X-ray sources than any previous satellite and is helping to solve many cosmic mysteries of the violent Universe, from what happens in and around black holes to the formation of galaxies in the early Universe. It is designed and built to return data for at least a decade.

The second high-energy observatory is **Integral** (2002), observing a cosmos,


SoHO

full of violent phenomena and extreme energy in the γ-rays.

The **mission Cluster** (2000) is a collection of four spacecrafts flying in formation around Earth. They, in combination with the Double – Star (2003/2004) developed in collaboration with China, give us a stereoscopic view of the terrestrial magnetosphere and its interaction with the solar wind and relay the most detailed ever information about how the


Cassini/Huygens

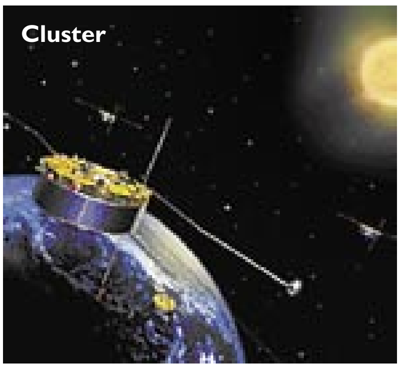
solar wind affects our planet in three dimensions. The solar wind can damage communications satellites and power stations on Earth. The original operation life-time of the Cluster mission ran from February 2001 to December 2005. However, in February 2005, ESA approved a mission extension from December 2005 to December 2009.

Mars Express (2003), Venus Express (2005) and **SMART-1**, (2003) are the


Newton XMM

first missions to our neighbouring planets and the moon. The SMART-1 mission in orbit around the Moon has had its scientific lifetime extended by ingenious use of its solar-electric propulsion system (or 'ion engine').

Finally, Rosetta, (2004) is the first mission ever to land on a comet and follow it in its orbit around the Sun. ESA's Rosetta spacecraft will be the first to undertake the long-term exploration of a comet at close quarters. It comprises a


Cluster

large orbiter, which is designed to operate for a decade at large distances from the Sun, and a small lander. Each of these carries a large complement of scientific experiments designed to complete the most detailed study of a comet ever attempted. After entering orbit around Comet 67P/Churyumov-Gerasimenko

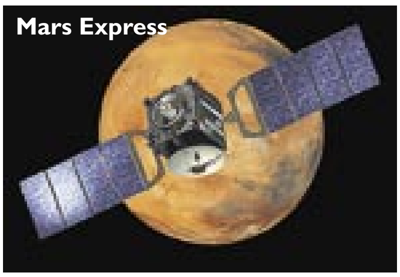

Integral

in 2014, the spacecraft will release a small lander onto the icy nucleus, then spend the next two years orbiting the comet as it heads towards the Sun. On the way to Comet Churyumov-Gerasimenko, Rosetta will receive gravity assists from Earth and Mars, and fly past main belt asteroids.

(c) ESA Missions under development

Today, several ESA missions are under development. They are going to further explore our Solar System, observe several interesting astrophysical objects and also test fundamental physical laws. Thus, Venus Express (2005) is already heading towards Venus. BepiColombo (2015) will explore the closer to the Sun planet Mercury, while the similar Solar Orbiter (2015) will approach our Sun several solar radii to get a close up view of its hot corona.

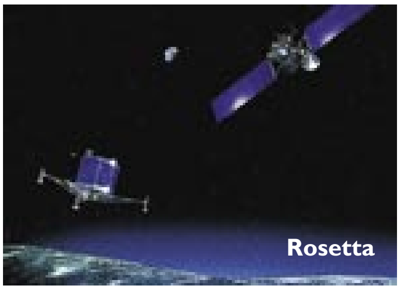
In Astrophysics, Herschel (2007) is a grand infrared observatory following the successful infrared space observatory ISO while its twin Planck (2007)


Mars Express

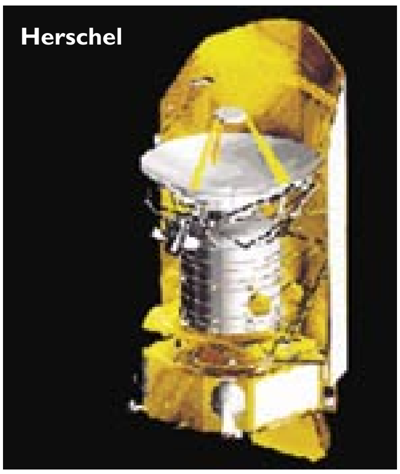
has been planned to study the cosmic background radiation following the successful WMAP. GAIA (2012) is powerful astrometric satellite able to map one billion of stars in six dimensions and decipher the history of the entire Galaxy. Finally, in cooperation with NASA the James Webb Space Telescope (2014) will follow the legacy of the Hubble Space Telescope. In fundamental physics, LISA Pathfinder (2009) will test the technology of the following three LISA (2014) satellites which will be aiming at the detection of the much awaited gravitational waves.

3. The future science program of ESA: Cosmic Vision (2015-25)

Space science is playing a prominent role in Europe's space programme. It has been the core of European co-operation and success in space since the early 1960s. As ESA turns thirty years old, it continues a tradition of innovative thinking and long-term perspectives that

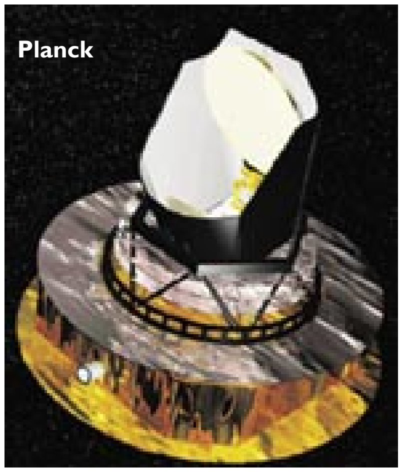

Rosetta

form the basis for ESA's scientific programme. The Horizon 2000 long-term plan for space science, formulated 20 years ago (1984), is almost completed. Its successor, Horizon 2000+, approved ten years ago, comes now to fruition with a wealth of scientific satellites and space telescopes in orbit producing great results. In the first years of this new millennium, ESA is building its future in space science based on a 'Cosmic Vision'. This is a way of looking ahead, building on a solid past, and working today to overcome the scientific, intellectual and technological challenges of tomorrow.


Herschel

For this new Cosmic Vision programme, the scientific community was called upon to express its new ideas in April 2004 and did so by submitting more than 150 such novel ideas. ESA's scientific advisory committees and working groups made a preliminary selection of themes, which were discussed in a open Workshop in Paris in September 2004 attended by about 400 members of the scientific and industrial communities. After an iteration with the Science Programme Committee (SPC) and its national delegations, the finally selected themes are addressing the following 4 questions:

(a) What are the conditions for planet formation and the emergence of life?


Planck

From gas and dust to stars and planets: Map the birth of stars and planets by peering into the highly obscured cocoons where they form.

From exo-planets to biomarkers: Search for planets around stars other than the Sun, looking for biomarkers in their atmospheres, and image them.

Life and habitability in the Solar system: Explore in situ the surface and subsurface of the solid bodies in the solar Systems most likely to host-or have hosted-life. Explore the environmental conditions that makes life possible.

Candidate Projects are a Near – In-


LISA Pathfinder

First colour view of Titan's surface (Credits: ESA).

frared Nulling Interferometer, Mars Landers and Mars Sample Return, Far-Infrared Observatory, Solar Polar Orbiter, Terrestrial Planet Astrometric Surveyor, Europa Landers, Large Optical Interferometer.

(b) How does the Solar System work?

From the Sun to the edge of the Solar System: Study the plasma and magnetic field environment around the Earth and around Jupiter, over the Sun's poles, and out to the Heliopause where the solar wind meets the interstellar medium.

The giant planets and their environments: In situ studies of Jupiter, its atmosphere, internal structure and satellites

Asteroids and other small bodies: Obtain direct laboratory information by analysing samples from a Near-Earth Object.

Candidate Projects are an Earth Magnetospheric Swarm, Solar Polar Orbiter, Jupiter Exploration Programme, Europa Lander, Orbiter and Jupiter probes, Near – Earth Object Sample Return, Interstellar Heliopause Probe.

(c) What are the fundamental physical laws of the Universe?

Explore the limits of contemporary physics: Use the stable and weightless environment of space to search for tiny deviations from the standard model of fundamental interactions.

The gravitational wave Universe: Make a key step toward detecting the gravitational radiation background generated at the Big Bang.

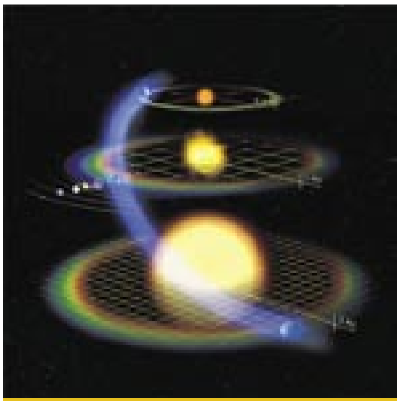
Matter under extreme conditions: Probe gravity theory in the very strong field environment of black holes and other compact objects, and the state of matter at supra-nuclear energies in neutron stars.

Candidate Projects are a Fundamental Physics Explorer Series, Large-Aperture X-ray Observatory, Deep Space Gravity Probe, Gravitational Wave Cosmic Surveyor, Space Detector for Ultra-High–Energy Cosmic Rays.

(d) How did the Universe originate and what is it made of?

The early Universe: Define the physical processes that led to the inflationary phase in the early Universe, during which a drastic expansion supposedly took place. Investigate the nature and origin of the Dark Energy that is accelerating the expansion of the Universe.

The Universe taking shape: Find

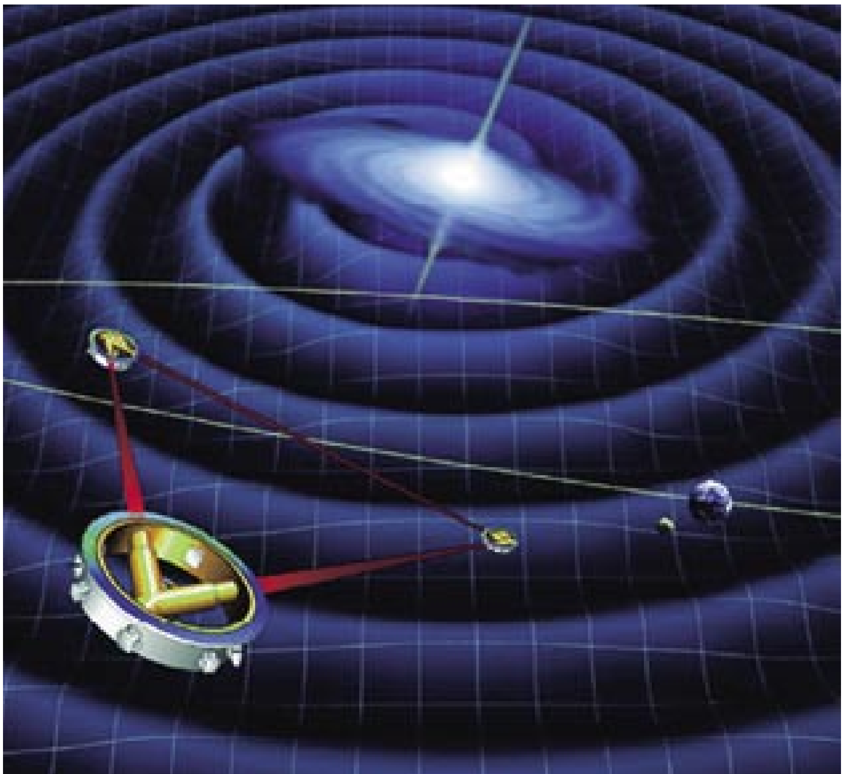


ESA is designing missions to detect habitable planets across a wide range of stellar types (Credits: ESA).

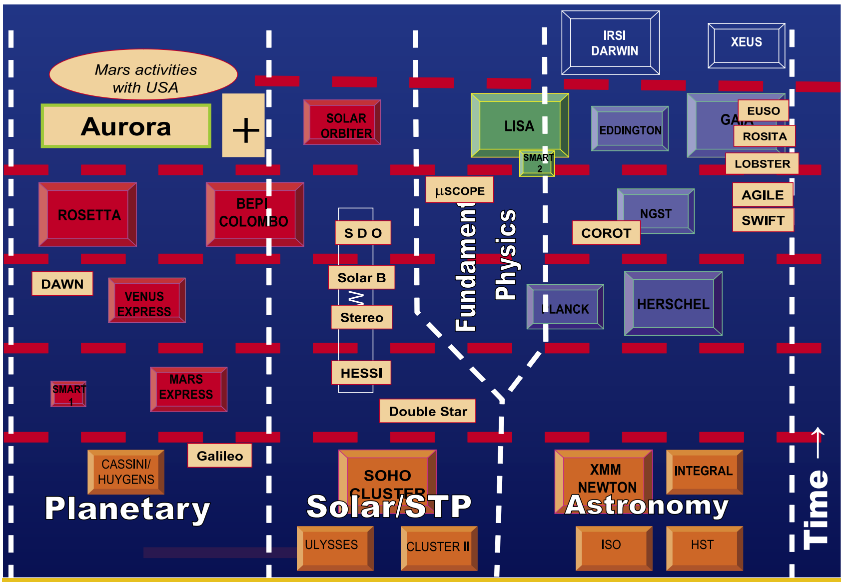
the very first gravitationally-bound structures that were assembled in the Universe-precursors to today's galaxies, groups and clusters of galaxies-and trace their evolution to the current epoch.

The evolving violent Universe: Trace the formation and evolution of the supermassive black holes at galaxy centres - in relation to galaxy and star formation – and the life cycles in matter in the Universe along its history.

Candidate Projects are a Large-Aperture X-ray Observatory, Wide-Field Optical-Infrared Imager, All-sky Cosmic Microwave Background Polarisation



LISA will be the first space-based mission to attempt the detection of gravitational waves. These are ripples in space that are emitted by exotic objects such as black holes (Credits: ESA).



The science program of ESA (Credits: ESA).

Mapper, Far-Infrared Observatory, Gravitational Wave Cosmic Surveyor, Gamma-Ray Imaging Observatory .

4. Opportunities for ESA related science/technology work for Hellenic researchers

(a) The first *Call for Ideas* for Hellenic participation to ESA programmes.

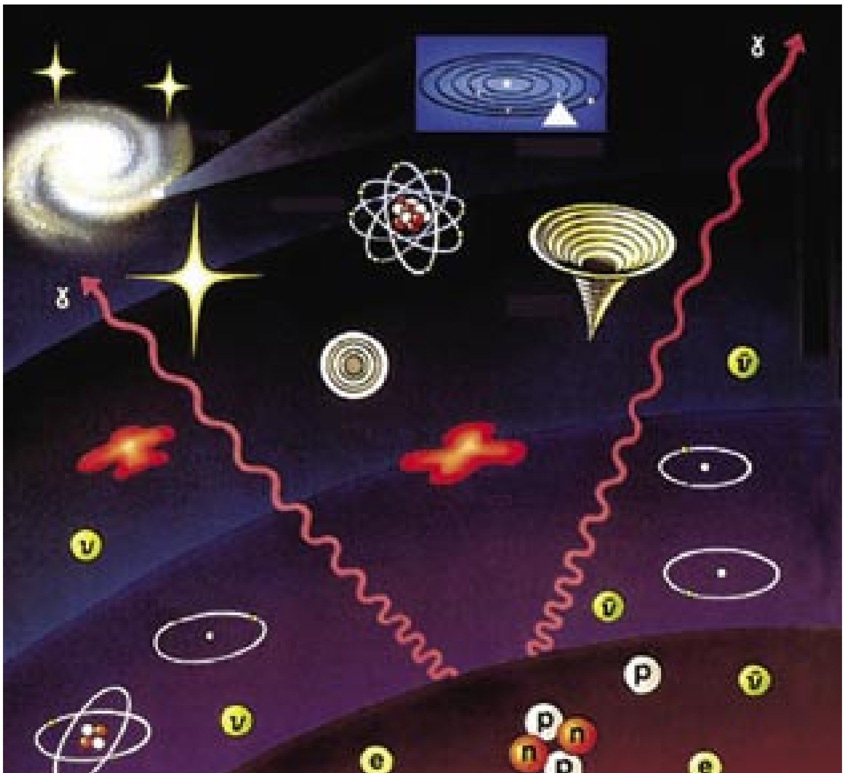
The Accession Agreement of Greece and ESA specifies transitional measures that will apply during a period of six years, starting from the date of accession (i.e., from 2005 to 2010). The transitional measures aim at adapting Greece's industry to the Agency requirements. An ESA-Greece Task Force was set-up in September 2005 which has a programmatic role and advises the Director General of ESA on the implementation of the transitional measures. Representatives from both ESA and the Hellenic Republic compose this Task Force. In the frame of these transitional measures contracts will be placed with Greek firms, institutions and universities. For this purpose the ESA-Greece Task Force has issued a first Call for Ideas [1]. The proposal which the Greek community is invited to submit is a relatively simple one with a suggested overall maximum length of only 2-3 pages. The submitted ideas should cover activities that have a future potential in the frame of ESA activities or programmes (no "single-shot" activities will be considered), address specific niche markets (no competitive products available elsewhere in Europe or when a second source would be an asset), provide the resources to enable Greek industry/institutes to enter normal ESA procurement and finally foster the establishment of strong and long-term relations between Greek companies and well-established European space firms. The deadline for the submission is 06/01/2006.

(b) Involvement in future Space missions within Horizon 2000+

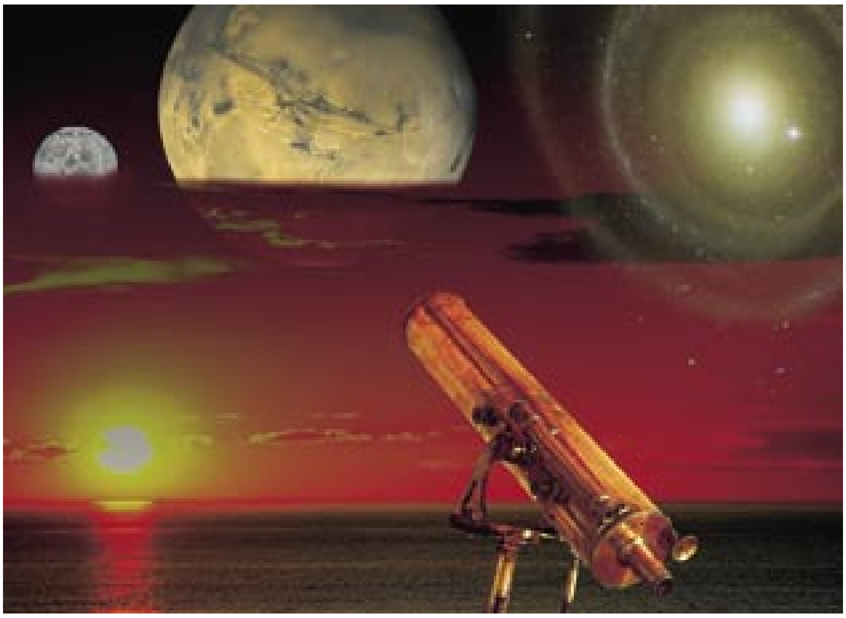
Within the Horizon 2000+ programme there is still time for Hellenic scientists to participate in the preparation of several space missions. Such examples are the Herschel/Planck Observatory (launch in 2007, with involvement in the data analysis from one of its three instruments SPIRE, HIFI, PACS, for more information contact V. Charmandaris, Un. of Crete). The mission BepiColombo to the planet Mercury (launch in 2015, for more information contact I. Daglis NOA/ISARS), the astrometric satellite GAIA (launch 2011, for more information contact P. Niarchos or M. Kontizas, Un. of Athens), the mission Solar Orbiter (launch in 2015, for more information contact K. Tsinganos, Un. of Athens) and also the gravitational waves space interferometer LISA (launch 2014, for more information contact K. Kokkotas, AUTH).

(c) Predoctoral ESA young graduate trainees (YGT)

ESA's Young Graduate Trainee (YGT) programme[2] offers recently graduated men and women, a one-year non-renewable training contract designed to give valuable working experience and to prepare them for future employment in the space industry and/or research. Applicants should have just completed, or be in their final year, of a higher edu-



Overall view of the history of the Universe according to the Big Bang model (Credits: ESA).



cation course typically at Masters level and probably in a technical or scientific discipline at a university or equivalent institute. They should be fluent in either English or French. Contracts are for one year and non-renewable. ESA will provide a monthly salary. In 2003 the basic net salary for a single YGT ranged from 1930 to 2333 Euros per month, depending on the establishment, including expatriation allowance. Also, a monthly expatriation allowance for those not resident in the country to which they are assigned, plus an installation allowance upon arrival, travel expenses at the beginning and end of the contract and health cover under ESA's Social Security scheme. Towards the end of the training period, trainees are asked to submit a report on their activities and accomplishments achieved during the year.

(d) Postdoctoral ESA research fellowships

ESA's postdoctoral research fellowship programmes(1) aim to offer young scientists the possibility of carrying out research in a variety of disciplines related to space science, space applications or space technology. The Agency has an internal and an external fellowship programme, both for two years, with no possibility of an extension. ESA hosts approximately 20 external and 30 internal fellowships at any given time. Applicants must have recently attained their doctorate or be close to successfully completing studies in space science, space applications or techniques, or other fields closely connected to space activities. In the internal fellowship programme, fellows carry out their research topic under the supervision of one or more experienced scientists or engineers, in one of ESA's establishments. Interested candidates should submit the *application form* that is available online. There is no specific closing date and applications may be submitted at any time during the year. In the external fellowship programme, the fellows work in a university, research institute or laboratory on a research topic related to the research activities of the Agency. The application should be sent directly to the relevant national delegation, who will forward it to ESA, by 31 March for the June selection and by 30 September for the December selection.

(e) IKY fellowships for Space Physics

IKY will start in the year 2006 new predoctoral fellowships for studies in the area of Space Physics, within the known frame of fellowships in Astronomy, Astrophysics, Relativity, Physics, etc.

5. Epilogue

We hope that our scientific community will be mobilized to take soon advantage of the Hellenic participation to the Science programmes of ESA. The first indication of such a mobilization will be our response to the Call for Ideas. Secondly, we need to pursue a direct involvement in several ESA missions under development (Herschel/Planck, JWST, GAIA, BepiColombo, Solar Orbiter and LISA). As an example, we succeeded to convince ESA to issue an announcement for the employment of Greek software engineers in the upcoming (2007) ESA "cornerstone" Herschel/Planck observatory (see Dec. 2005 issue of the HelAS electronic newsletter). Similarly, Hellenic participation is needed at the level of PI or Co-I in specific mission instruments, or in the direct involvement for the analysis of related observations, in the upcoming ESA programmes. Finally, we should encourage Hellenic young researchers to apply for the various ESA related fellowships in order to get training and serve as links between ESA and the academic, research, industrial and technological sectors of Greece. All in all, it remains to be seen if the adventure of the Hellenic scientific and technological community in European space activities - something dated back thousands of years in mythology with the story of Daedalus and Icarus - will be fruitful and worth of our expectations.

(1) http://www.astro.auth.gr/elaset/esa/
(2) http://www.esa.int/SPECIALS/Careers_at_ESA/
(3) http://www.esa.int/SPECIALS/Careers_at_ESA/SEM19DXO4HD

The chaotic “sculpting” of the Solar System

by Kleomenis Tsiganis,

Depertment of Physics, University of Thessaloniki

ABSTRACT

The orbits of the large celestial bodies in our Solar System are stable for very long times, as can be shown by numerical simulation. This gives the erroneous impression of perpetual stability of the system. It is only when we study the orbital distribution of the numerous minor bodies in the Solar System that we discover the rich variety of complex dynamical processes that have in fact shaped our system. During the last decade, enormous progress has been made, in understanding the evolution of the system over the last ~3.9 Gy. However, it also became clear that, in order to unveil its behaviour during the first ~700 million years of its lifetime, we have to find convincing explanations for observations that appear as details of its dynamical architecture. In the following we are going to show how the two best-known – and up to now unexplained – observations in the Solar System, namely (i) the heavily cratered surface of the Moon and (ii) the elliptic (and not circular) motion of the planets, lead us to the discovery of the chaotic sculpting of the Solar System [1]-[3].

1. Early stages of evolution

The newly-born Sun was surrounded by a disc of (mainly) gas and dust. The sedimentation of dust grains in the mid-plane of the disc marked the beginning of planetary formation. A review of planet formation theories is beyond the scopes of this paper. Hence, we will only briefly present the currently accepted scenario for the formation of our Solar System. In chronological order, the different formation stages are:

(a) Dust grains started to accumulate, forming ~1 km-sized bodies, known as planetesimals[4].

(b) Planetesimals accumulated to form lunar-sized objects, called planetary embryos, which in turn collided with each other to form the solid cores (~3-15 Earth masses, M_E) of the Giant planets (Jupiter, Saturn, Uranus and Neptune) [4]-[5].

(c) Jupiter and Saturn evolved to gas giants, by accreting gas envelopes that later on collapsed on the cores. Uranus and Neptune have a gas-poor composition; this is why we usually refer to them as *ice giants* (see [6]).

According to the theory described above, giant planets form on circular and co-planar orbits in the mid-plane of the disc, within 1-10 My (the typical lifetime of a circumstellar gas disc). However, our Giant planets follow orbits with eccentricities e~5-10% and mutual inclinations i~2-3 degrees. These values, although small compared to extra-solar planets[7], are by no means negligible. It has been shown that, during the gas-dominated phase, the eccentricity of a Jupiter-sized planet cannot grow beyond a few times 10^{-3}, unless very “well-tuned” conditions are met [8]-[9]. Thus, the current values of the planetary orbital elements are most likely the result of some physical process that took place after the gas was gone, when the system consisted of the Sun, the giant planets and a *debris disc* of planetesimals, embryos and dust, possibly extending up to >50 AU away from the Sun.

(d) Terrestrial planets begun to form close to the Sun, by the process described in (b) (see [5],[10]).

According to the minimum mass solar nebula model (see [10]), the asteroid belt (2-4 AU) was ~1,000 times more massive, at the epoch of terrestrial planet formation, than at present (~5×10^{-3} M_E). Numerical simulations indeed show that strong perturbations, exerted by the giant planets on embryos at ~2-4 AU, prohibited the formation of large bodies in this region [11]. Moreover, embryos were scattering away planetesimals so efficiently that the primordial asteroid belt was depleted by a factor of ~200. (keep in mind that we are a factor of ~5-10 short!).

In the meantime, a dynamically “cold” and massive disc of planetesimals (~30-50 M_E within a ~20-30 AU-wide ring) existed beyond the orbits of the ice giants; the progenitor of the Kuiper belt. Today’s Kuiper belt is estimated to be nearly as massive as the asteroid belt. Moreover, it has a two-component dynamical structure (see [12]): (i) the classical belt, with bodies on nearly co-planar and circular orbits, and (ii) the scattered disc, with bodies on highly eccentric and inclined (w.r.t. the mid-plane of the system) orbits. Several models have been proposed to explain the depletion of this external disc, mostly related to collisional grinding (see [12] and references therein). However, if we assume that, at those times, the giant planets had already settled on their final orbits (with orbital radii at 5.2, 9.5, 19.2 and 30.1 AU), then the mass depletion and dynamical structure of the Kuiper belt cannot be explained.

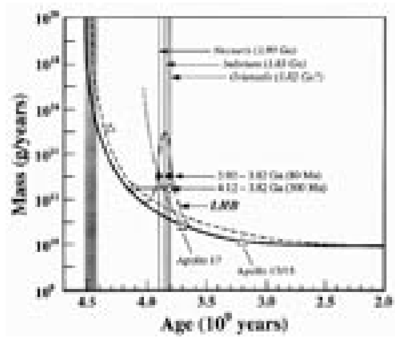


***Figure 1**: Compiled lunar data, showing the inferred rate of bombardment of the Moon vs. time (from C. Koeberl’s web-site).*

It was already suggested in the late 60’s [4] that Uranus and Neptune must have formed much closer to the Sun than are currently observed, in order for their formation time to be shorter than the lifetime of the gas disc, and subsequently (somehow) moved outwards. In the following we are going to show how the interaction of the giant planets with the external disc forces the former to migrate.

Let us now describe an observational “detail”, whose origin dates back to the early phases of Solar System evolution. As can be seen during most nights of the year, the surface of the Moon is covered with large lava-filled basins and numerous small craters, which are the result of an intense bombardment of the Moon by small bodies. When the first lunar samples were analyzed, things became more complex. The values of the sample ages of the large basins formed a tight clustering around 3.9 Gy, suggesting a heavy bombardment of the Moon ~600 My af-

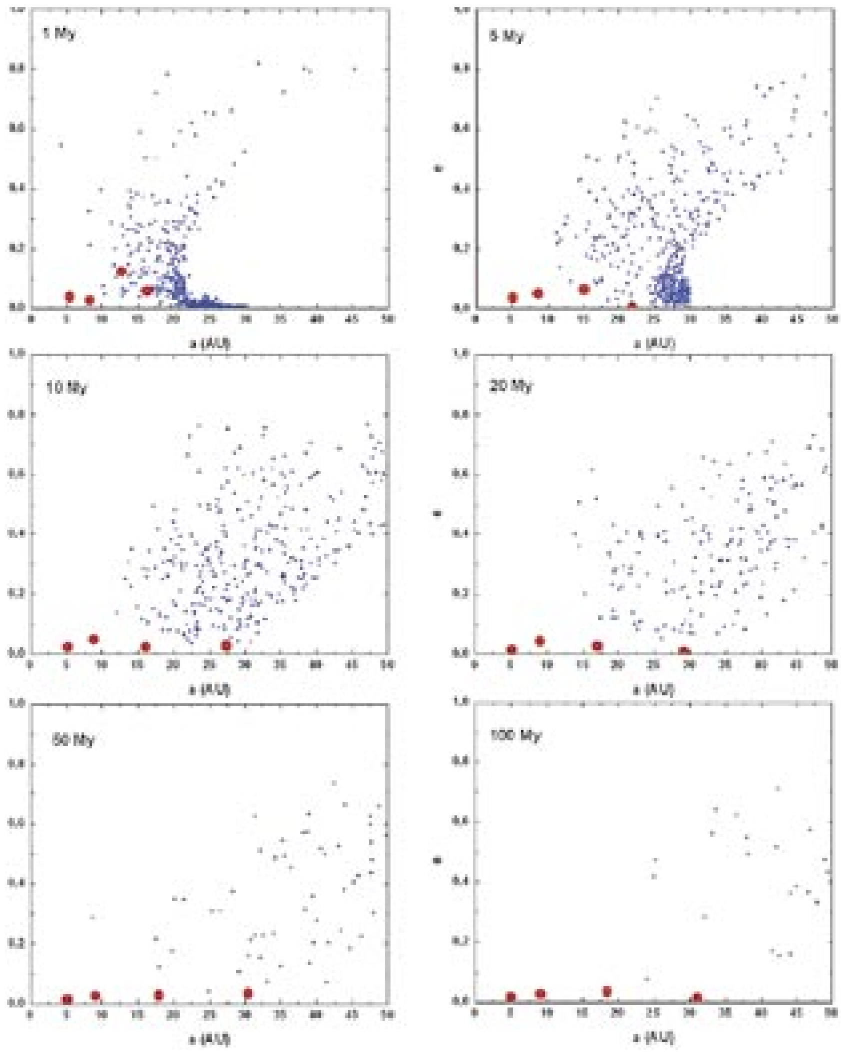


***Figure 2:** Snapshots from an N-body simulation of the migration of the outer planets. All bodies are projected on the (a,e) plane, where a is the semi-major axis and e the eccentricity of the orbit.*

ter its formation, with a duration of only a few tens of Mys: the *Late Heavy Bombardment* (LHB [13]-[15], see Fig. 1). We note that an alternative scenario supports the continuous heavy bombardment of the Moon. Several theoretical models were proposed to explain the LHB, but all of them turned out to violate some important observational constraint (see related references in [3]).

From the dynamical point of view, the "continuous bombardment" theory, although easier to understand, does not seem probable. If we take into account the depletion of the asteroid belt during terrestrial planet formation, we find that there are not enough projectiles to sustain the necessary mass flux on the Moon for 600 My. This in turn means that we need to find (i) the source and (ii) the dynamical mechanisms responsible for the delay, onset and short duration of a "cataclysmic" LHB. From the above discussion it is evident that the solution to this problem must be related to interaction of the giant planets with the external, massive, planetesimals disc.

2. Planitesimal – driven migration

Let us go back to the beginning of the gas-free era and assume that Uranus and Neptune were formed closer to the Sun than they are today (say, within 20-25 AU) and the external disc extended up to 40-50 AU. Fernandez & Ip [16] were the first to point out that the exchange of angular momentum between the planets and the disc particles would force the planets to migrate. Roughly speaking, when a disc particle approaches the outermost planet, it receives a "kick" that decreases (or increases) the semi-major axis of its orbit. Consequently, the planet must move outwards (or inwards) by a very small amount. Repeated encounters between the two bodies give zero net displacement, unless (i) the kick is so strong that the particle is ejected from the system on a hyperbolic orbit, in which case the planet moves inwards, or (ii) the particle encounters one of the inner planets. In the latter case, the particle escapes the influence of the outer planet, whose orbital radius is slightly increased.

The above scheme can be generalized for the four giant planets of the Solar System. In this chain, the innermost planet (Jupiter) is far more massive than the outermost one. Numerical simulations [17] show that most disc particles approach Jupiter, after being "kicked" by Neptune, Uranus and Saturn. Thus, after wandering around the inner Solar System for some time, and provided that they don't hit a planet (or the Moon), they are ejected on hyperbolic orbits by Jupiter. Consequently, Neptune, Uranus and Saturn move outwards, while Jupiter moves inwards. Of course, the more massive planets (Jupiter and Saturn) are displaced much less than the ice giants; the orbital radii of the first two change by a few tenths of an AU, while the ones of the ice giants may change by several AU.

A simulation of this process is shown in Fig. (2). Six snapshots of the evolution of the system are shown, in which the red points denote the four giant planets and the blue dots are disc particles. In this simulation a disc of 35 M_E was used, extending up to 30 AU. The planets were started within 20 AU from the Sun. As shown in the plots, the planets deplete the disc within 100 My and reach stable orbits with approximately the same values of semi-major axis as observed today. The remnants of the disc have an orbital distribution that is similar to the one of the current trans-neptunian population. Indeed, as was first shown in [18], planetesimal-driven migration can explain the final semi-major axes of the planetary orbits and the orbits of the *plutinos* – Pluto and ~7% of Kuiper belt objects – which are trapped in a 2:3 orbital resonance with Neptune.

There are, however, two major problems with this "smooth" migration model. First, migration ends too soon (~100 My from the formation of the planets) to explain the LHB. Second, the final values of eccentricity and mutual inclination of the planets are almost zero. Note that, in the experiment shown in Fig. (2), we even "cheated", by initially setting the planets on eccentric orbits. Their eccentricities were in fact damped during migration, due to a well-known phenomenon in galactic dynamics: the small particles exert *dynamical friction* on the planets, circularising their orbits (see also [10]). Thus, some excitation mechanism, not present in this model, must have acted during planetary migration; otherwise the planets would end up on circular and co-planar orbits.

3. Planetary excitation and the late heavy bombardment

There are several unknown parameters that enter a simulation of planet migration. The most important ones are (i) the initial conditions for the planets, and (ii) the total mass, surface density profile, and outer edge of the disc. Recent results suggest that the mass of the disc was between 35 and 50 M_E, and its outer edge was located at ~30-35 AU. For a more extended and more massive disc, Neptune would not stop at 30 AU (see [19])!

There are no constraints a priori for the initial orbital radii of the giant planets. Up to now, the usual assumption was a well-spread planetary system, with Jupiter starting at ~5.5 AU and Neptune at ~23 AU. It is true that, if we assume the initial planetary orbits to be as eccentric as today, a more "compact" system would tend to be strongly unstable. However, for initially circular orbits, the system could be stable for billions of years, even if the planets were packed within 15 AU from the Sun. We tested this hypothesis by numerical integrations, in which we found that compact systems are indeed stable, provided that the interplanetary distances are not smaller than ~3 AU.

An initially compact configuration of the planets evolves in a qualitatively different way, with respect to an initially well-spread one. During migration, a pair of planets will have to pass temporarily through a first-order (i.e. the strongest possible) resonance, where the ratio of their orbital frequencies is nearly constant and equal to a fraction of small integers, say 1:2 or 2:3. Repeated resonant conjunctions increase the eccentricity of both orbits. In a well-spread system the planets are far enough from each other to avoid the relevant resonances. For example, if Jupiter is at 5.5 AU, its 1:2 resonance with Saturn is at 8.73 AU, as given by Kepler's 3rd law. Thus, given their relative migration, the planets can never be in a 1:2 resonance, if Saturn starts at a>8.73 AU.

We did several numerical experiments, changing the initial configuration of the planets, in order to study all possible resonance crossings. Indeed we found that this mechanism always excites the eccentricities of the respective pair of planets. However, we found that the 1:2 resonance between Jupiter and Saturn also has a dramatic effect on the whole system. Thus, we focused our study on compact systems, in which Saturn was initially placed closer to Jupiter than their 1:2 resonance.

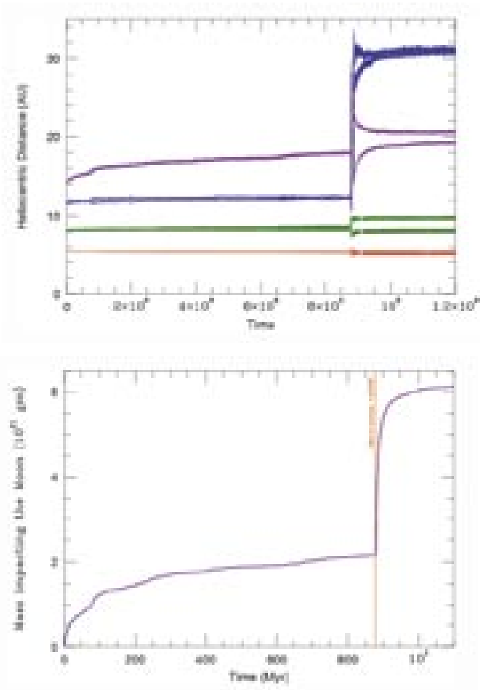


***Figure 4:** (a) Evolution of the planetary orbits in a 1.2 Gy simulation. At ~880 My Jupiter and Saturn cross the 1:2 resonance and develop eccentric orbits. The planets engage in a short phase (~2 My) of mutual encounters, during which their eccentricities and mutual inclinations grow. Disc-particles are ejected throughout the Solar System and 9x10^{21} g of comet material hit the Moon within 50 My. Asteroids contribute to the LHB by almost the same amount (~3-8 x10^{21} g). The system slowly relaxes, due to dynamical friction, and the planets achieve their final orbits.*

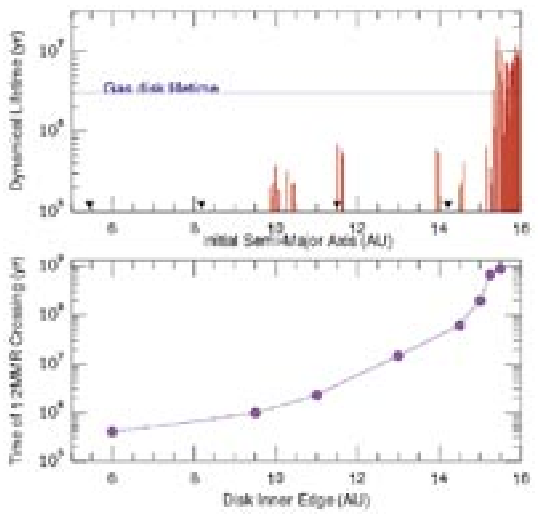


***Figure 3:** (a) Dynamical lifetime of disc particles, in a typical compact system of planets (triangles). Only particles starting ~2 AU away from Neptune remain in the system until the beginning of the gas-free era. (b) The time of resonance crossing for Jupiter and Saturn, as a function of the inner edge of the disc. For an external disc of particles, as suggested in panel (a), the onset of instability is delayed by hundreds of My.*

Before proceeding with these numerical experiments, we had to consider another important dynamical process. A compact planetary system strongly modifies the surface density profile of the disc. As shown in Fig. 3(a), the dynamical lifetime of disc particles in the interplanetary zone is smaller than the lifetime of the gas disc. Thus, at the beginning of the gas-free era, the compact system of the four giant planets had already gravitationally eroded the inner part of the massive disc. This implies a very low flux of disc particles, driving planet migration. Hence, for a realistic planets-disc configuration, as suggested by the results shown in Fig. 3(a), planetary migration would have been so slow that the crossing of the 1:2 Jupiter-Saturn resonance would have been *delayed* by several hundreds of My (Fig. 3b). Then, curiously enough, the resonance-crossing epoch could coincide with the LHB epoch!

After producing these encouraging results, we performed a series of ~50 N-body simulations, in which we monitored the evolution of the system, until the depletion of the disc and the end of planetary migration (typically ~1 Gy). In each simulation the initial positions of the planets were varied, with Saturn being always set interior to the 1:2 resonance with Jupiter and the initial interplanetary distances being set between 2.5 and 6 AU. The disc was represented by 1,000-10,000 equal-mass particles, its total mass was varied between 35 and 50 M_E, and its inner edge was set 1.5-2.5 AU away from the orbit of Neptune. In these runs, the resonance-crossing time varied from ~100 My to 1.2 Gy.

The typical evolution of the planetary system in our runs is shown in Fig. 4(a), where the perihelion (q) and aphelion distances (Q) of each planet are given as functions of time. The difference Q-q is proportional to the eccentricity of the orbit. Figure 4(b) shows the cumulative mass flux of disc particles that hit the Moon, during the same time interval. As shown in the plot, planet migration is very slow for ~880 My, as a result of the small amount of disc particles on planet-crossing orbits. At this point Jupiter and Saturn cross their 1:2 resonance and their orbits become eccentric. The orbits of Uranus and Neptune are then strongly perturbed, due to the small interplanetary distances. In fact their eccentricities grow so much that the orbits of the planets begin to cross, and the planets suffer close encounters with each other. The system is thus lead to a short period (~2 My) of chaotic frenzy, during which repeated two- or even three-body encounters increase the eccentricities and mutual inclinations of the planetary orbits.

In 1/3 of our runs, the instability grew so strong that one of the ice giants was ejected from the system, by encountering Jupiter. However, in 2/3 of our runs (let us call them "successful runs"), the planetary system eventually became stable, due to the action of the massive disc; Uranus and Neptune were forced to penetrate the outer parts of the disc, where dynamical friction reduced their eccentricities and put an end to this planetary billiards. At the same time, disc particles were forced to "fly" all over the Solar System. As shown in Fig. 4(b), the amount of comets hitting the Moon increased abruptly at the resonance crossing epoch, and ~8.4x10^{21} g of mass accreted on the Moon within 50 My.

The above numbers agree well with the time-delay, intensity (estimates give ~6 x10^{21} g of projectile mass [20]) and duration of the LHB. We emphasize that the same series of events occurred in *all* our successful simulations, since the mechanisms responsible for the onset and suppression of the instability are both deterministic and generic to the system.

At the end of each successful run, the four giant planets were found to follow orbits, very similar to the ones currently observed. Our runs can be divided in two classes: (i) runs in which only two-body encounters among the ice giants were recorded (class-A), and (ii) runs in which triple encounters between Saturn, Uranus and Neptune took place (class-B). For each class we computed the mean and standard deviation of the final values of (a,e,i) for all planets. As shown in Fig. (5), both types of evolution produce systems, which are very similar to the Solar System. However, the triple-encounters scenario seems to provide a much better match to Solar System data: the currently observed values of (a,e,i) of all Giant planets fall within one standard deviation from the mean values of class-B runs.

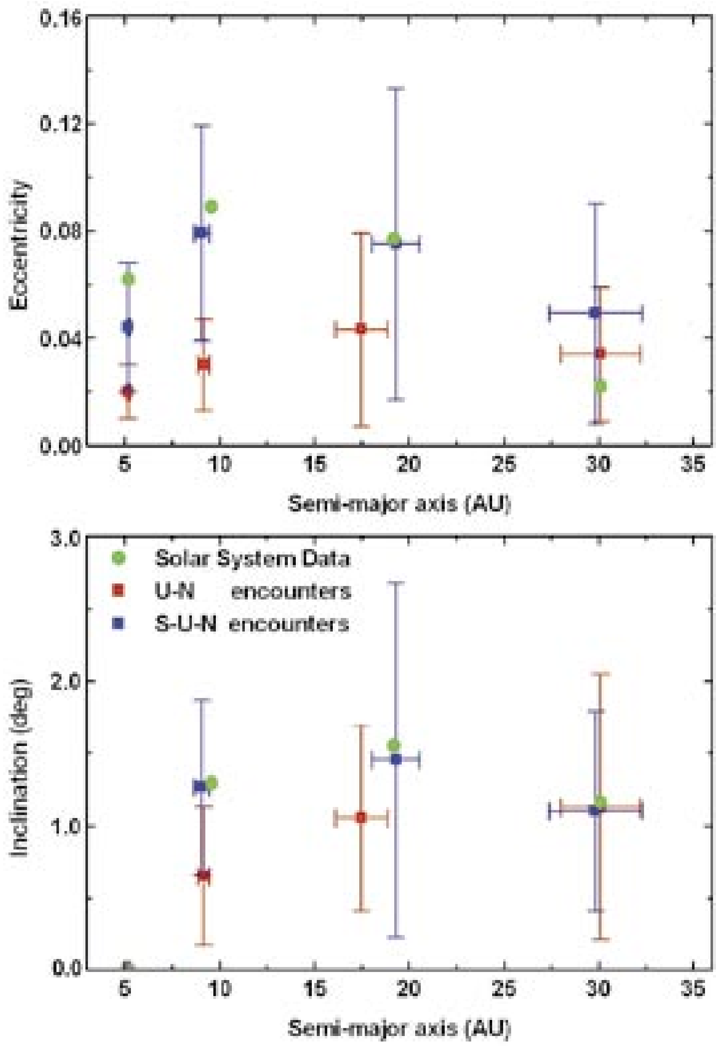


***Figure 5**: Comparison between our "synthetic" final planetary systems and the real Solar System data. The red symbols refer class-A runs, while the blue symbols refer to class-B runs. All final planetary systems are similar to the Solar System, but class-B runs match amazingly well.*

Let us not forget that, in the beginning of the LHB, the inner Solar System contained an asteroid belt ~10 times more massive than today. We simulated the effect of our chaotic migration model on the asteroid belt, by including in some reference simulations 1,000 massless asteroids, with an initial orbital distribution as predicted in [11]. We found that their orbits became unstable, due to resonance sweeping: the continuous displacement of resonances throughout the belt, as a result of the migration of Jupiter and Saturn. In fact, our asteroid belt lost ~90% of its mass; we seem to have found the missing depletion factor, discussed in the introduction. This process supplies another 3-8 x10^{21} g of asteroid-type "bombs" on the Moon. This result is consistent with recent geochemical evidence, concerning the composition of projectiles that formed the large lunar basins (see [14]-[15]).

4. Conclusions – Discussion

Our chaotic migration model naturally predicts a cataclysmic bombardment of the Moon, reproducing quite well current estimates of the *time-delay, duration, intensity* and *projectile composition* of the bombardment. However, what is most important is that this model explains, for the first time, the orbital architecture of the outer Solar System.

Although our model is certainly physically plausible, there is of course no guarantee that these events actually took place. However, there are a number of points that strongly favour our model. To begin with, this model does not involve "exotic" perturbations (e.g. passing stars or rogue planets), of the system. All mechanisms involved are generic to planetary systems. The only critical assumption of our model is that Saturn was formed interior to the location of its 1:2 resonance with Jupiter (i.e. ~0.5 AU closer to the Sun than usually assumed).

We find no contradiction between our model and observations. In fact we seem to explain more than we asked for. In particular:

(a) At the LHB epoch, collisions among asteroids must have been so frequent that a great number of fragment clusters (called "families") must have been formed. Yet, there are no families known, with ages greater than 3.8 Gy [21]. Our model takes care of this problem, since the "shaking" of the asteroid belt during the chaotic phase is so strong, that no compact family would survive.

(b) According to our simulations, the amount of water accreted by the Earth during the LHB (i.e. comets) is ~8 x10^{22} g, i.e. 6% of the ocean mass. Measurements of the heavy-to-normal (D/H) ratio of ocean water indeed suggest a 5% upper bound for the cometary contribution to the Earth's water budget [22].

(c) An important test for our model was the existence of Trojan asteroids; a group of bodies that nearly share the same orbit as Jupiter, but lead or trail the planet by ~60 degrees in longitude. Up to now there was no model explaining the orbital distribution of Trojans, in particular their nearly homogeneous distribution of orbital inclinations between 0 and 40 degrees. We performed a series of simulations, in which we found that primordial Trojans were driven away from Jupiter's co-orbital zones, during the chaotic evolution phase of the system. However, at the same time, outer-disc particles were constantly flying through the co-orbital regions, temporarily replenishing them. As the planets were moving towards a stable configuration, some of these particles got permanently trapped in the Trojan region. We found a total mass of trapped particles between 4×10^{-6} and 3×10^{-5} M_E. Recent observations estimate the total mass of Trojans to be $\sim10^{-5}$ M_E. Moreover, the orbital distribution of our trapped Trojans was very similar to the observed one. Hence, our model is the first to explain the origin and orbital distribution of Jupiter Trojans.

Recent results seem to provide solid back-up to our model. Marchis et al. [23] calculated the density of the binary Trojan Patroclus, finding an average bulk density of 0.8, a number much smaller than any known asteroid and similar only to the ones found for distant Kuiper-belt objects. This astonishing result supports our claim that Trojans and Kuiper-belt objects have, in fact, a common origin. Finally, analyzing the size distributions of projectiles responsible for both 'LHB' and 'younger' (age < 3.8 Gy) craters, Strom et al. [24] found that the latter ones correspond to Near Earth Asteroids, while the former ones to Main-belt asteroids. Thus large 'LHB' craters were formed by asteroids who where ejected from all over the main belt, by a size-independent mechanism. The most likely mechanism (at that epoch) is resonance sweeping, due to the late migration of the outer planets, as Strom et al. concluded.

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Dr. Tsiganis has been recently elected Lecturer in the Department of Physics at the Aristotle U. of Thessaloniki.

ISHEPAC 2005

The 2nd International School of High Energy Physics and Cosmology was organized in Heraklion, from the 4th of September to the 27th of October 2005. The school was attended by a total of 25 postgraduate students, 7 of which were from Greek Universities. The school program included lectures in Quantum Field Theory, General Relativity and Gravitation, Particle Phenomenology, String Theory and Cosmology. A total of 13 lectures contributes, 7 of them Greek (K. Kokkotas, A. Lahanas, A. Petkou, K. Skenderis, M.Spiropulu, K. Tamvakis, N. Tsamis) and 6 foreign scientist (R. Woodard, P. West, V. Mukhanov, J. Peacock, K. Narain, C. Angelantonj). The last two weeks of the school, the students have had the opportunity to attend the pedagogical lectures and research seminars of the 1st Young Researchers Workshop of the Research and Training Network (RTN) "SUPERSTRINGS", which was also organized by the University of Crete.

The aim of ISHEPAC is to cover the teaching needs of Greek postgraduate student in the areas of High Energy Physics and Cosmology, in particular those who are in their first years of their Ph.D. studies. At the same time, the wide program of the school together with the high level profile of the lectures attracts the interest of many postgraduate students from outside Greece. The Department of Physics at the University of Crete intents to organize ISHEPAC on a yearly basis, and to broaden its scope to include, together with High Energy Physics and Cosmology, also Astroparticle physics and related matters.

Tassos Petkou
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Skinakas micro-variability observations of BL Lac objects

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1. Introduction

BL Lac objects (BL Lacs) constitute a class of Active Galactic Nuclei whose optical spectra usually do not exhibit strong emission or absorption lines. They show high polarization, continuum variability at all wavelengths at which they have been observed, from X-rays to radio, and superluminal motion of radio components. Together with the flat-spectrum radio quasars are known as "blazars".

Although the details of their emission mechanism are still under debate, the commonly accepted paradigm assumes the presence of a central black hole fed by an accretion disc, and that of a plasma jet which is responsible for the non-thermal emission. In order to explain several observational pieces of evidence, the emitted radiation from the jet is assumed to be relativistically beamed toward us.

Their overall spectral energy distribution shows two distinct components in the ν-νF_ν representation. The "low"-energy emission, from the radio band to X-rays, peaking usually between mm and the UV band, is believed to be synchrotron radiation produced by ultra-relativistic electrons in the jet. The higher energy emission, up to γ-rays, usually peaks between GeV-TeV, respectively. Its origin is less clearly established. The most widely accepted scenario regards these high energy photons as inversely Comptonized soft photons off the energetic electrons. The source of the soft source radiation is unclear. The seed photons could be those produced by the synchrotron process itself, or could be produced out of the jet, either in the accretion disc or in the broad line region.

2. Optical variability of BL Lacs

Large amplitude, fast optical variations of a few BL Lac objects were detected from the early days of their discovery, when they were still classified as "variable stars". For example, DuPuy et al. (1969) detected optical variations of the order of 0.3 mag day^{-1} in BL Lac itself (i.e. the prototype for this class of active galaxies), while Racine (1970) reported "optical fluctuations by 0.1 mag over a few hours" from the same "strange" object.

The intense, long term (i.e. on time scales of days/months/years) optical variations of BL Lacs is well established, documented and studied in the last thirty years (see for example the work of Carini et al. 1992, Maesano et al. 1997, Webb et al. 1998, and Fan et al. 2001 in the case of BL Lac). During the last few years, blazar optical variability studies have resulted in excellent quality light curves (both in terms of length and dense sampling) as optical observers set up collaborations to make their observational effort more efficient. One of those collaborations is the "Whole Earth Blazar Telescope" (WEBT), an international organization that includes about 30 observatories all over the world (Skinakas observatory is one of them). The main aim of this organization is to obtain accurate and continuous optical monitoring of a source during time-limited campaigns (lasting from a few days to several weeks), often simultaneously with satellite observations in X- and γ-rays, and ground-based observations in the radio band and at TeV energies. The results from the few campaigns that have already been organized are very encouraging (see e.g. http://www.to.astro.it/blazars/webt/).

One of the most impressive properties of blazars is the detection of the so called "intra-night optical variations" or "optical micro-variability" (i.e. brightness changes by 10-20% on time scales as short as a fraction of an hour) in a large number of these sources. The systematic study of these variations started in the late eighties by Miller and coworkers (Miller et al. 1989, Carini et al. 1991). Since then, micro-variability studies have been performed by many groups. As an example we mention the work of Heidt & Wagner (1996, 1998), Romero et al. (2002), and Stalin et al. (2005), who have studied the micro-variability properties of radio and X-ray selected BL Lacs, EGRET and radio-core dominated blazars, respectively.

The observed flux variations in blazars have been explained in a variety of ways: shocks traveling down the jet (e.g. Marscher 1996), changes in the Doppler factor due to geometrical reasons (e.g. Dreissigacker & Camenzind 1996), and gravitational microlensing (e.g. Schneider & Weiss 1987). Variability studies are a powerful tool to investigate blazar emission and to discriminate among the various theoretical interpretations that have been proposed so far, especially if the observations are done in a continuous way and simultaneously at different wave bands. At the very least, micro-variability studies raise the question of what is the smallest variability time scale, and hence, of how small the size of the emitting region is.

3. Skinakas observations of BL Lacs

The Skinakas Observatory is located in the Ida mountain in Central Crete at an altitude of 1750m. It is a collaborative project of the University of Crete, the Foundation for Research and Technology-Hellas, and the Max-Planck-Institut für Extraterestrische Physik, in Garching, Germany. It hosts a 0.3 m, Flat-Field, telescope, and a 1.3 m, Ritchey-Cretien, telescope.

The 1.3 m telescope is ideal for micro-variability studies of BL Lacs. Since most of them are usually quite bright (~ 13-15 mag in the optical band), it is possible to obtain accurate measurements (i.e. with an accuracy as good as ~ 0.01 mag) within 1-5 minutes. In this way, one can obtain light curves which are dense (i.e. with a typical point separation of no more than ~ 10-15 minutes, depending on the number of filters used). In the period between the years 2001-2004, systematic observations of a few BL Lacs, over a large number of nights, and in various filters, took place in the Observatory. In total, we observed 9 BL Lac objects over more than 50 nights using various optical filters (mainly B and I, but also V and R in some cases as well).

All the objects are radio-selected BL Lacs chosen from the 1 Jy sample using the following criteria: a) average R-band magnitude > 16.5 mag b) variability amplitude > 15% (as estimated by Heidt & Wagner, 1996) and c) declination > 0. The first criterion was imposed so that the peak of the emitted power in all objects is at mm/infrared (IR)/optical wavelengths. As a result, the optical emission corresponds to the emission from the most energetic, synchrotron emitting electrons in the jet. The second criterion was chosen in order to maximize the probability of detecting micro-variations during the observations, while the restriction in studying objects in the northern hemisphere was necessary for the acquisition of the longest possible light curves each night.

4. Data reduction and the resulting light curves

Up to date we have studied the light curves of 4 BL Lac objects, namely BL Lac itself, S5 0954+658, S5 2007+777 and 3C 371 (Papadakis et al. 2003, Papadakis et al. 2004, and Xilouris et al. 2006). In all cases, the observations were carried out with a CCD camera using a 1024x1024 SITe chip with a 24 μm^2 pixel size (corresponding to 0.5" on the sky). The exposure time varied between 30 sec for the I-band observations of BL Lac and 9 min for the B-band observations of S5 2007+777. The total number of frames we have obtained is 899, 914 and 217 in the B, I and R-bands, respectively, over 33 nights. During the observations, the seeing varied between ~1"-1.5".

Standard image processing (bias subtraction and flat fielding using twilight-sky exposures) was applied to all frames using the standard IRAF routines. In all cases, aperture photometry by integrating counts within a circular aperture (of various radii, depending on the seeing) centered on the objects. Instrumental magnitudes were transformed to the standard system using published comparison star sequences in the field of BL Lac and S4 0954+658, or by providing a comparison star catalogue ourselves (in the case of S5 2007+777 and 3C 371). In all cases, the derived magnitudes were corrected for Galactic reddening, transformed to fluxes, and then corrected for the contribution of the host galaxy as well.

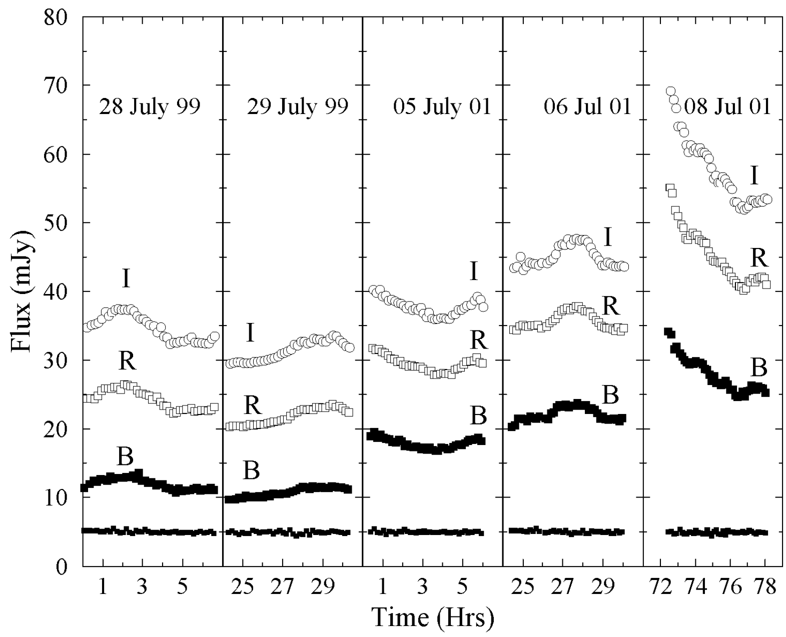

***Figure 1:** The B, R and I-band light curves of BL Lac during the 1999 and 2001 Skinakas observations. Errors are also plotted but are smaller than the size of the light curve points. Time is measured in hours from 20:00 UT on July 5, 2001, for the 2001 observations, and from 19:00 UT on July 28, 1999 for the 1999 observations. The small filled squares at the bottom of the figure show the B band light curve of the comparison star B (for clarity reasons, the light curve is shifted from a mean of ~ 7 mJy to 5 mJy).*

We observe significant intra-night variations during almost all nights. Two examples are shown in Figures 1 and 2. In the first Figure, we show the light curves of BL Lac (a bright and highly variable object) while in Figure 2 we show the light curves resulted from the 2004 observations of S5 2007+777 (a less variable object). In both cases, we also plot the B-band light curves of a comparison star. While these are virtually "flat", significant variations can be observed in the light curves of the two objects. In the case of BL Lac, we observe smooth variations which last for a few hours, while in the case S5 2007+777, similar amplitude smooth variations are observed on time scales of ~a day.

A useful measure of the amplitude of the observed variations is the so-called "fractional variability amplitude", f_{rms}, which is defined as:

$$f_{rms} = (\sigma^2 - \sigma^2_N)^{1/2} / <x>,$$

where σ^2 is the sample variance of the light curve, σ^2_N is the variance introduced by the instrumental noise process, and $<x>$ is the light curve mean. The fractional variability amplitude represents the average amplitude of the observed variations as a percentage of the light curve mean. We find that the f_{rms} values, within each night, are ~ 5-6.5%, 2-5%, 2-3% and 1% in the case of BL Lac, S4 0954+658, S5 2007+777 and 3C 371, respectively.

5. Data analysis and results

Compared to most of the previous micro-variability blazer studies, the big advantage of the Skinakas observations is the availability of simultaneous light curves in more than one optical bands. This is a crucial factor, necessary to understand the basic characteristics of the intra-night variations in these objects. The main results from our analysis so far are as follows: In all four objects, the variability amplitude increases toward higher frequencies, i.e. from the I to the B-band light curves. For example, in the case of BL Lac, f_{rms} decreases from ~6.5% in the B, to ~5.5% and ~5% in the R and I-band light curves, respectively. By fitting the light curves with simple linear or exponential functions, we were able to measure flux-rising and flux-decaying time scales. In the case of BL Lac, these time scales are comparable, within each band, but shorter in the B than the I-band light curves. In S4 0954+658, we observe a flare-like event where the flux rises faster than the rate with which the flux decays. In S5 2007+77 and 3C 371 we find the flux decaying and rising time scales are not equal, neither within nor between the

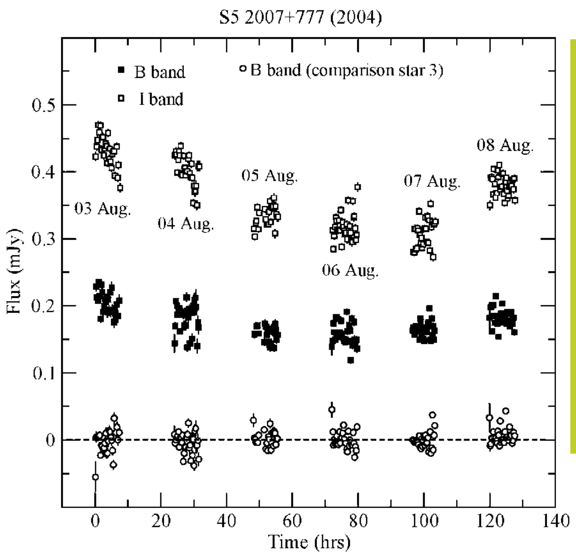

***Figure 2:** B and I band light curves for the S5 2007+777 during the 2004 Skinakas observations. Time is measured in hours from 18:12 UT on August 03, 2004. The empty circles at the bottom of the plot show the B-band light curve of the comparison star 3. For clarity reasons, the standard star light curve is shifted to the mean flux level of zero mJy.*

B and I-band light curves. We find spectral variations associated with the observed flux variations. In general, we observe the usual "harder when brighter/softer when fainter" behaviour. However, the relation between flux and spectral index is not linear in most cases. Instead, we have detected loop like patterns in the "spectral slope vs flux" plane which evolve in the clockwise or anti-clockwise direction. In all cases, the observed variations in the different bands are well correlated, with no detectable delays.

As an example of the spectral variations that we have detected and the different variability rates in the flux decaying/rising parts of the light curves, in Figure 3 we present our results during the 2004 observations of 3C 371. In the upper panel we show the B and I-band light curves normalized to their mean (filled and open squares, respectively). It is obvious that the min/max variability amplitude is larger in the B-band. In the same panel, the solid and dashed lines correspond to best-fitting model curves which describe rather well the flux evolution in the two bands. The model fitting results show that the B-band flux decays and rises faster than the I-band flux. Furthermore, there seems to be a ~ 10-12 hrs delay between the B and I light curves at minimum (with the B-band leading). The middle panel in the same Figure shows the B/I flux ratio light curve (which is representative of the spectral slope in the optical band). As a result of the differences between the B and I- band flux rise/decay time scales, this ratio is variable, implying significant spectral variations during the observations. These variations are correlated with the associated flux variations, but in a rather complicated way, as the bottom panel in the same Figure demonstrates. In this panel, we plot the B/I ratio as a function of the total (i.e. B+I) source flux. In the first part of the observations, as the flux decays, the B/I ratio decreases (since the flux is decaying faster in the B than the I-band). As the flux subsequently rises again, the flux ratio increases as well (because B is rising faster than I). Only during the last night of the observations the flux ratio appears to decrease again, because the B light curve may have started to decay while I is still rising. Note that the "B/I vs B+I" plot cannot be fitted well by a simple linear function. Instead, a loop-like structure, which evolves in the clockwise direction, appears.

As an example of how well the variations in the different bands are correlated, in Figure 4 we show the cross-correlation function (CCF) between the B and I-band light curves during the 1999 and 2001 observations of BL Lac (shown in Figure 1). In these plots, a positive lag means that the B leads the I-band variations. The CCFs show large maxima (~1) at around zero lag. These results imply that the B and I-band light curves are highly correlated, as expected from their good visual agreement (see Figure 1), and the delay between them is less than ~5 minutes. The only case where we do find evidence for a delay between the variations in the two bands is during the July 5, 2001 observations, where the I-band is delayed by ~ 15 min, with respect to the B-band light curve (this result is significant at the 95% level). In any case, most of the CCFs appear to by asymmetric, in the sense that, on time scales longer than ~0.5 hours, the correlation at positive lags is larger than that at negative lags. This result suggests that

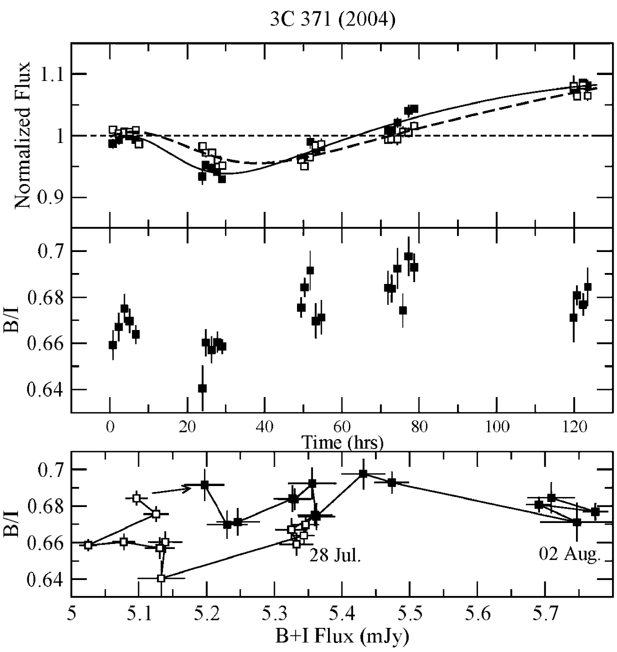

***Figure 3:** (I) B and I-band light curves of 3C 371 in 2004 (filled and open squares, respectively). They are binned using bins of size 1.5 hrs, and are normalized to their average flux level. (II) In the middle panel we plot their ratio B/I. (III) The B/I vs the B+I flux plot. The open and filled squares in this panel indicate the periods when the source flux decreases and increases, respectively. The data of the first day of observations (28 July 2004) are market with the respective date. The solid line which connects the points aims at indicating the spectral evolution during the following nights until August the 2nd (last day of observations).*

the variability components with periods longer than 0.5 hours in the B-band lead the respective components in the I-band light curves.

6. Discussion

The results from the analysis of the Skinakas BL Lac observations demonstrate that one can constrain the mechanism that causes the observed variations in these objects, provided that the light curves at hand are long, dense and cover more than one bands. To this end, we briefly investigate below some consequences of our results.

The continuum emission in blazers is believed to arise from a relativistic jet oriented close to the observer, i.e. the emitted radiation is highly beamed in the forward direction. One possible mechanism that can explain the observed variations is if the optical emission is produced in discrete blobs moving along magnetic fields and the viewing angle (i.e. the angle between the blob velocity vector and the line of sight) varies with time. In this case the beaming or Doppler factor should vary accordingly and, since the observed flux depends on this, viewing angle variations can result in flux variations. For example, a change of less than 0.5 degrees can explain variations of the order of 20% (Ghisellini et al. 1997). In this case, we would expect the variations to be "achromatic". The same holds true in the case when the observed variations are caused by gravitational microlensing. Since in most cases we observe significant spectral variations, correlated with the associated flux variations, we conclude that caused by microlensing effects.

The only notable exception is the variability behaviour of S4 0954+658 during two nights in April 2001 when we observed a flare-like event which was symmetric (i.e. equal rise and decay time scales) and evolved with no spectral variations (i.e. same variability amplitude in all bands). Raiteri et al. (1999) have found that the long term optical variations in this source are also achromatic. Obviously, changes of the jet orientation with respect to the observer's line of sight is a major cause for the observed long and short term variations in this source.

However, this was an isolated event. Most of the observed flux and spectral optical intra-night variations that we have observed are similar to the X-ray variability properties of well studied objects like Mkn 421 (e.g. Brinkmann et al, 2005; 2003) and PKS 2155-30 (e.g Zhang et al. 2002). The peak of the synchrotron emission in these objects is located in the UV/X-ray band. Therefore, the X-ray band corresponds to frequencies that are located around/above the peak of their spectral energy distribution, just like the optical band for the four radio-selected BL Lacs observed from Skinakas. The fast X-ray variations in Mkn 421 and PKS 2155-30 are thought to be a direct result of the acceleration/cooling mechanism of relativistic electrons which represent the highest tail of the synchrotron component. It is natural then to assume that the observed optical micro-variations in the 4 BL Lac objects that we have studied are also caused by a perturbation which

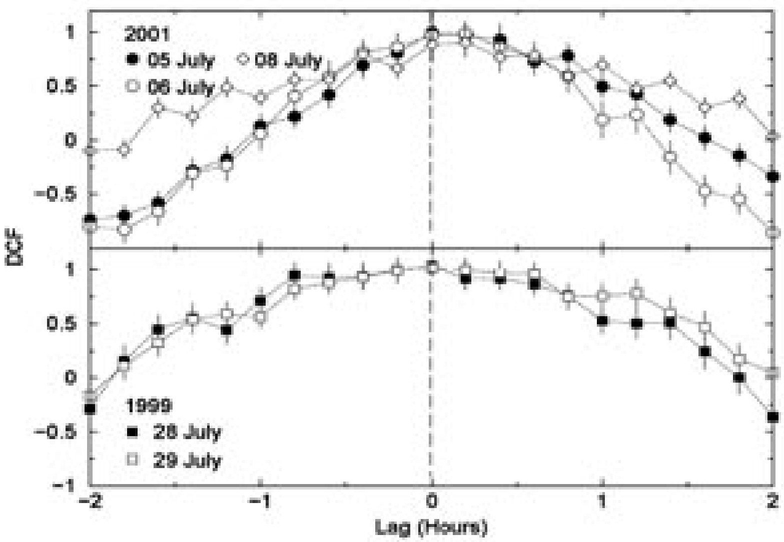

Figure 4: Cross-correlation functions between the B and I band light curves during the 1999 and 2001 BL Lac observations shown in Figure 1.

synchrotron radiation. In this case, the important time scales which govern the spectral evolution of the flaring events are the acceleration, cooling, escape and light travel time scales.

The fact that we observe flaring events which last for different periods, even for the same object, suggests that different regions/parts of the jet contribute to the optical emission in BL Lac objects (assuming that the difference in time scales reflects differences in the size of the emitting region). In other words, there does not seem to exist a "smallest" characteristic time scale, which could be used to determine the typical size of the optical emitting region in these objects. Furthermore, the rich phenomenology that we observe regarding the differences in the flux rising/decaying time scales between different bands and the loop-like structures in the "spectral slope vs flux" plots, suggests that the assumed perturbations do not affect the particles in the jet in the same way. However, the quality of the light curves we have obtained allow us to identify possible physical mechanisms which operate each time.

For example, the fact that the B-band decays faster than the I-band flux during the first part of the 3C 371 2004 observations that we show in Figure 4 could be explained by the cooling of the emitting particles due to synchrotron and self-Compton radiative losses. For a particle of energy γmc^2, emitting at an observed frequency of $\nu_0 \sim \gamma^2$, the cooling time is $\sim \nu_0^{-0.5}$. The ratio of the B and I-band median frequencies is ~1.8, implying that $t_{cool,B}/t_{tcool,I} \sim (\nu_B/\nu_I)^{-0.5} \sim 0.7$. This value is close to the ratio of the decaying B and I-band time scales that we have estimated from the light curves. During the subsequent flux rising parts of the light curves, we observe the flux increasing first in the B and then in the I-band. This is expected in the case when the source is injected with particles at high energies for a period longer than the light crossing time of the source. In this case, the emission starts increasing at high energies for as long the injection continues and the emitting volume increases accordingly. The particles start emitting at lower frequencies only after some time equal to the cooling time scale, hence the delay in the increase of the flux in the I-band.

Our results demonstrate that well sampled, intra-night, multi-band optical observations of BL Lac objects, whose peak of the emitted power is at IR/

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Relativistic AGN Jets

by Nectarios Vlahakis

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ABSTRACT

Jets in active galactic nuclei are collimated, relativistic flows that emanate from accretion disks around supermassive black holes. Electromagnetic stresses are the most plausible candidate for extracting energy from the source and converting it into outflow kinetic energy. Questions that need to be answered in order for these processes to be well understood are: Can we explain parsec-scale accelerations that the observations infer? How the conditions near the disk are related to the terminal Lorentz factor of the jet and what is the asymptotic value of the Poynting-to-matter energy flux ratio? Can we model the apparent kinematics of the observed jet components? I present solutions of the ideal magnetohydrodynamic equations that help to shed light on these questions.

1. Introduction

The commonly accepted interpretation of AGN jets is that they represent relativistic flows ejected from the vicinity of supermassive black holes and powered by energy released by accretion in an underlying disk. These jets consist of various components that follow curved apparent trajectories and exhibit apparent superluminal motions, a manifestation of their relativistic velocities (see figure 1 for the jet in the quasar 3C345). There is growing evidence that these components undergo extended (parsec-scale) acceleration. For example Unwin et al (1997) deduced a change in the bulk Lorentz factor of the C7 component in 3C345, from $\gamma \sim 5$ to $\gamma \sim 10$ over a deprojected distance range of ~3-20 pc (they also infer a decrease in the Doppler factor from 12 to 4 and an increase in the angle between the velocity of the component and the line of sight from 2 to 10° during the same period). Sikora et al (2005) give a more general argument related to the extended acceleration: If the bulk flow near the disk is sufficiently fast ($\gamma \geq 5$) it would Comptonize photons coming from the disk, producing bulk-Compton features. The absence of such features indicate that acceleration up to $\gamma \geq 10$ must take at least 10^3 Schwarzschild radii. They also argue that the electron/positron kinetic energy (estimated from the emissivity of blazar events), is too small to support the energetics of blazars and of radio lobes in quasars. Thus, the dynamics of AGN jets is likely dominated by protons rather than leptons.

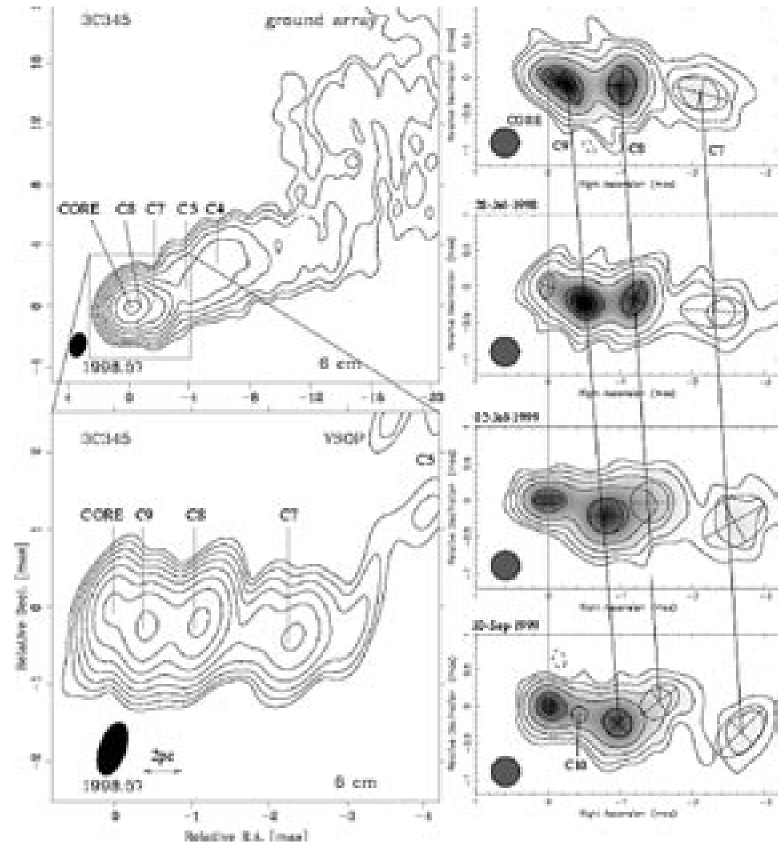

***Figure 1:** Total intensity images of 3C345 - Top left: VSOP observations at 6cm resolve the nuclear region into several components. Right: VSOP observations trace the evolution of the inner jet components at a resolution of 350μas. The ellipses are the modelfit components. Bottom left: 3mm image of 3C345 with a resolution of 70μas along jet direction. From Klare et al (2001).*

Extended acceleration is unlikely to be driven hydrodynamically in a proton-electron outflow. If T_i is the initial temperature, energy conservation implies that pure-hydrodynamic driving gives Lorentz factors $\gamma_\infty \sim k_B T_i / m_p c^2$, which is of order unity even if the temperature is as high as 10^{12}K.

In addition, the distance on which the Lorentz factor attains its terminal value is of the order of the sonic distance, certainly much smaller than pc-scales where the acceleration is inferred from the observations, since the sonic surface is located close to the event horizon of the central black-hole. Alternatively, a possible heating source makes $\gamma_\infty >> 1$ possible (e.g., Meliani et al 2004). It is, however, unclear how such a heating source would be established in a natural way on pc-scales.

The most likely alternative is magnetic driving, which is considered in the following.

AGN jets are also well collimated; e.g., in the galaxy M87, the jet is seen opening widely in its formation region, at an angle of about 60° nearest the black hole, but is squeezed down to only 6° at 100

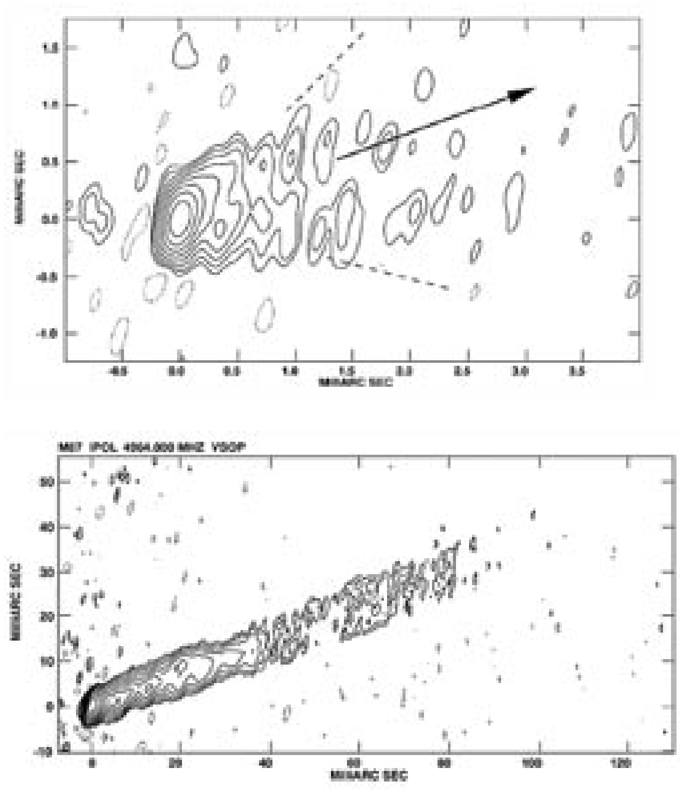

***Figure 2:** The jet in the galaxy M87. The very central region is seen in the top panel, and the jet at larger spatial scales in the bottom. The arrow in the top panel indicates the direction of the 20" jet (kpc-scale jet), while the dashed lines indicate the position angles of the limb-brightened structure within 1 mas (subpc-scale) of the core. The maximum resolution (~0.1mas) corresponds to 0.01pc, or 30 Schwarzschild radii. This is the highest resolution yet obtained on a nucleus of an active galaxy. From Biretta et al (2002).*

Schwarzschild radii (see figure 2). The jet opening angle continues to decrease at larger distances. Magnetic self-collimation has long been thought to be the underlying mechanism for the observed jet shape.

Summarizing, as far as the dynamics of AGN jets are concerned, we need to explain extended (pc-scale) acceleration, collimation and the observed jet kinematics by using MHD modeling.

2. Magnetohydrodynamic (MHD) modeling

The dynamics of astrophysical outflows may be described to zeroth order by the set of steady, ideal magnetohydrodynamic equations. These consist of Maxwell's and Ohm's equations, mass conservation, entropy equation (with possible heating mechanisms included) and the momentum equation. Due to the axisymmetric nature of jets, which means that there is an ignorable coordinate, the above system can be partially integrated to yield several constants of motion (e.g., Tsinganos 1982). The remaining equations are two components of the momentum equation: one along the flow (which gives the velocity for a given shape of the flow) and one in the perpendicular direction with respect to the flow (the so-called transfield equation that determines the shape of the flow and the magnetic field distribution). These two equations are coupled because not only the velocity depends on the shape of the flow and the magnetic field distribution, but also inertial forces that are present in the transfield equation affect the shape of the magnetic fieldlines. Despite the fact that the remaining equations are only two, of which one is algebraic, the system remains highly intractable. The reason is that the problem remains two-dimensional (with independent variables say the z and v cylindrical coordinates which define the so-called poloidal plane) and the resulting partial differential equation is of mixed type, i.e., changes from elliptic to hyperbolic in unknown a-priori surfaces. Due to this fact, it is beyond the capability of existing numerical codes to solve this highly nonlinear problem, and no numerical solution has been obtained so far.

An alternative numerical approach is to solve the time-dependent problem (which is hyperbolic in time) and expect to reach a steady-state. Although there has been significant progress over the last years in doing so for studying nonrelativistic flows, all existing codes fail to simulate relativistic magnetohydrodynamic disk-driven flows for more than a few rotational periods. On top of that, it is not always clear how the issue of the boundary conditions is handled.

Besides fully numerical methods, there have also been suggested semi-analytical ones. These are basically a way to separate the two independent variables in the poloidal plane (z,v), and reduce the system to ordinary differential equations. There are two families of such models: the θ self-similar, appropriate for the description of coronal outflows near the rotation axis, and the r self-similar for outflows associated with disks (see the review article by Tsinganos 2002).

Li et al (1992) and Contopoulos (1994) found independently an r self-similar relativistic model, which was further generalized including thermal effects and applied to γ-ray burst jets by Vlahakis & Königl (2003), and to AGN jets by Vlahakis & Königl (2004).

I'll present in the following a typical solution obtained using this model, showing that many of the observable characteristics of AGN jets can be explained.

2.1 Acceleration

As discussed in the introduction, the most likely acceleration mechanism for AGN outflows is that they are driven magnetically. Thus, we are interested in examining Poynting flux-dominated flows at the neighborhood of the accretion disk, meaning that the electromagnetic part of the total energy-to-mass flux ratio is much larger that the matter part.

In general, there are three acceleration mechanisms.

i) Thermal acceleration: This is due to the expansion of the flow under its own pressure (or enthalpy) gradient. Remembering that the thermal acceleration is a result of a De-Laval nozzle coming from the interplay between gravity (that initially confines the flow) and pressure gradients (that expands the flow) we conclude that thermal acceleration is almost complete at distances where the outflow speed reaches the local sound speed which is of the order of the escape speed from the central gravitational

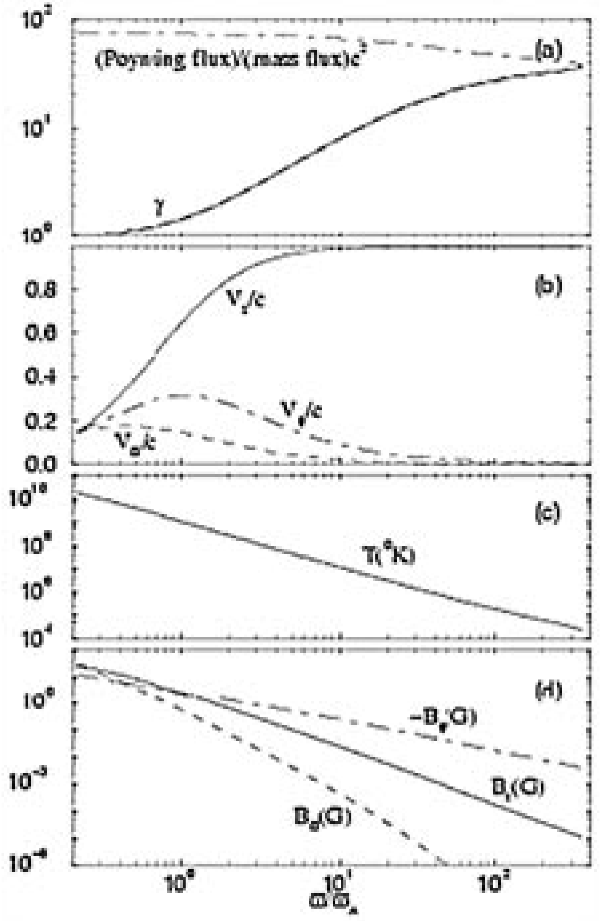

Figure 3: Various quantities as functions of the dimensionless cylindrical distance v from the axis of rotation, in a r self-similar solution. The cylindrical distance is normalized using the Alfvénic distance v_A.

(a): Lorentz factor and Poynting-to-matter energy flux ratio.

(b): Velocity components V_z, V_φ, V_j in cylindrical coordinates. (c)Temperature.

(d) Magnetic field components B_z, B_φ, B_j in cylindrical coordinates. From Vlahakis & Königl (2004).

potential. This happens very close to the black hole and cannot be connected to pc-scale accelerations, unless there is an extended heating distribution.

ii) Magnetocentrifugal acceleration: This is the result of the centrifugal force, and can be interpreted in the «bead on a rotating wire» picture (Blandford & Payne 1982). The magnetic field lines act like rotating rigid wires and the plasma as beads moving along them. If the angle between the wires and the axis of rotation is sufficiently large, the centrifugal force overtakes the gravitational pull causing acceleration. The main ingredient of this mechanism is the rotation of the roots of the wires and the terminal speed that gives is of the order of the Keplerian velocities of the underlying disk. However, in relativistic flows this mechanism cannot play an important role. This is because the non-negligible rotation that would be required in this case would constrain the maximum value of the poloidal speed (since their vector sum cannot exceed the speed of light).

iii). Magnetic acceleration: This is simply the result of the **JxB** Lorentz force; its work describes the transformation from Poynting flux to kinetic energy flux. The maximum Lorentz factor that this mechanism can give is the initial ratio of the Poynting flux over the mass flux (over c^2). However, it is an important question if this mechanism continues to operate until the whole energy initially deposited in the magnetic field is transferred to the matter, or stops at some distance resulting in some finite Poynting-to-matter energy flux ratio. In other words, it is important to know what the efficiency of this acceleration mechanism is, and how the conditions near the disk affect this result.

Figure 4 shows the various forces accelerating the jet. The thermal pressure gradient is negligible even for initial temperatures of the order of 10^{10}K (as in this particular solution; see figure 3c). The magnetocentrifugal mechanism is the dominant one very close to the disk and remains finite as long as the rotation speed is non-negligible. However, the magnetic acceleration rapidly takes over.

The result of the acceleration is shown in figure 3a. It is seen that the Lorentz factor increases monotonically with distance. The upper curve in figure 3a indicates that the Lorentz factor increases due to a decreasing Poynting-to-mass flux ratio: the Poynting flux is converted into matter kinetic-energy flux. Note that the sum of these two quantities is a constant of motion (a result of the total energy-to-mass flux ratio conservation).

If μ is the initial Poynting-to-mass flux ratio (over c^2), and since the flow initially is Poynting-flux-dominated, this number μ gives also the maximum Lorentz factor that the flow can achieve (in the case where the whole Poynting flux is transferred to matter). Asymptotically the Lorentz factor is ~μ/2, or, equivalently, the flow reaches a rough equipartition between Poynting and kinetic energy fluxes. In other words, the efficiency of the magnetic acceleration in this particular solution is ~50%.

2.2 Collimation

In order to examine the collimation process we need to think which are the forces acting on the plasma in the trans-field direction (i.e., perpendicular to the flow). Besides the pressure gradient component (which is not expected to be important for Poynting-dominated flows), there are two forces of electromagnetic nature. The magnetic force (the component of the **JxB** force) is responsible for the well known and understood self-collimation process in nonrelativistic flows. The same force is of course present in

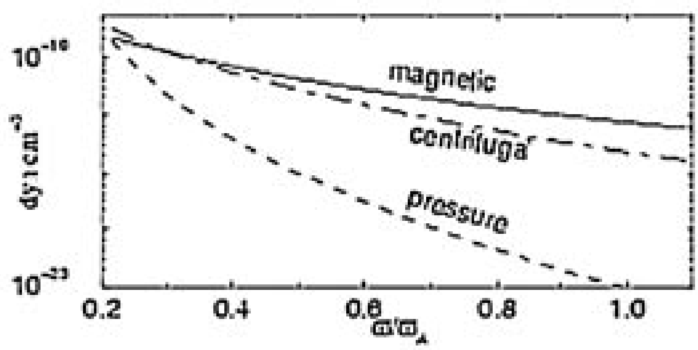

***Figure 4:** Various forces acting on the plasma along its motion, as functions of distance.*

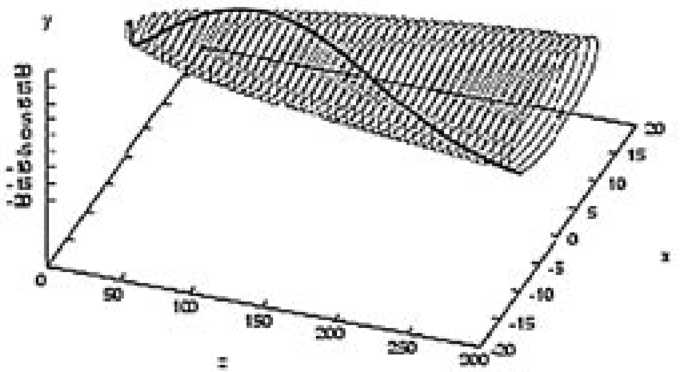

***Figure 5:** The 3D fieldline (thin) and streamline (thick) shape for the presented model. All distances are in units of v_A.*

relativistic flows as well. The important difference between these two categories is the appearance of the electric force. The electric field is comparable with the magnetic field for $V \approx c$, since from Ohm's law $E \approx (V/c)B$. Moreover, it is always acting against the collimating magnetic force. Thus, we expect the collimation to be much more difficult to achieve for extremely relativistic flows (Bogovalov & Tsinganos 1999). The magnetic and electric forces almost cancel each other. Their difference, which is much smaller than each of the two terms, equals the inertia force in the transfield direction. Quantitatively, this can be written as $R=\gamma^2 v$, where R is the curvature radius of the streamlines (e.g., Bogovalov 2001): it is much more difficult to change the shape of a relativistic flow because it has higher inertia.

The above reasoning led Bogovalov & Tsinganos (2002) to suggest that highly relativistic jets could be collimated by an outer nonrelativistic magnetized wind. In this scenario, the self-collimation works in the outer wind, and the wind itself forces the inner highly relativistic flow to collimate (see also Gracia et al 2005 for an application to the jet in M87).

However, if the flow starts with $\gamma \gg 1$ there is a possibility that the main part of the collimation happens at relatively small values of γ. This is seen in the presented solution. Figure 3b shows the velocity components. At the origin of the jet the two poloidal components V_z and V_y are comparable, meaning that the angle between the flow motion and the axis of rotation is 45°. Following the ratio of these two components from figure 3b and looking also the Lorentz factor evolution from figure 3a, we see that the collimation is indeed almost complete for relatively small values of γ.

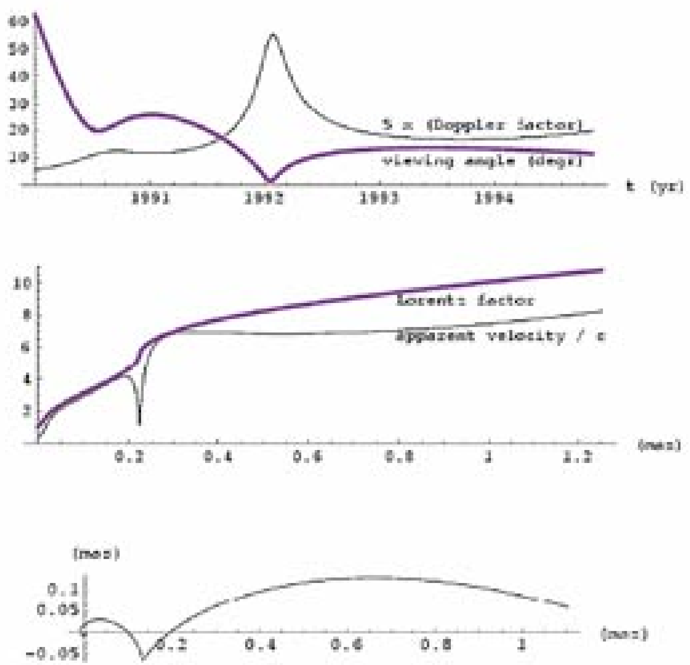

***Figure 5:** The 3D fieldline (thin) and streamline (thick) shape for the presented model. All distances are in units of v_A.*

Note that the collimation and acceleration processes shown in figure 3 are found self-consistently by solving the two coupled components of the momentum equation, along and perpendicular to the flow direction.

2.3 Apparent kinematics

The components of AGN jets follow curved (helical) trajectories over the years. Their apparent velocity, as well as their intensity, depends on two quantities: the Lorentz factor and the angle between the velocity of the component and the line of sight. There have been various efforts to explain the apparent jet kinematics: as Kelvin-Helmholtz instabilities (Hardee & Walker 2005), or due to source precession (Lobanov & Roland 2005). However, since a MHD outflow – being rotating – naturally follows a helical path (see figure 5) it may explain (or at least play some partial role to) the observed kinematics. In order to explore this possibility I used the self-similar solution presented in the previous parts of the article.

Suppose that the angle between the line of sight and the axis of the jet is θ_{obs}. Assuming that each observed plasma component corresponds to ejection from a localized region of the disk (characterized by an angle φ_o on the disk-plane and the distance from the center, or equivalently the Alfvénic distance of the field-line that is rooted at this region), one can easily project the plasma trajectory on the plane perpendicular to the line of sight, as well as to find Doppler factors and apparent speeds.

As a test for the model we tried to fit the trajectory, Doppler factor and angle between velocity and line of sight, as they were inferred from observations by Unwin et al (1997).

For $\theta_{obs}=9°$ and $\varphi_o=180°$ the model successfully explains the Unwin et al (1997) results (Vlahakis, Marin, & Königl to be submitted). Between the years 1992-1993 the Doppler factor decreases from 12 to 4 and the viewing angle increases from 2° to 10° during the same period.

2.4 Polarization maps

Another manifestation of magnetic driving is the observed polarization in radio maps of AGN jets. Fractional polarization of a few tens percent are typical in pc-scale jets, supporting the existence of a dominant large-scale magnetic field component. In addition, the observed

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Research Production of the Hellenic Astronomy, Astrophysics and Space-Science Sector

by Manolis Plionis (IAA, NOA)

Aim: This brief note is intended to inform the members of the Hellenic Astronomy/ Astrophysics and Space Science community of some indices regarding the research productivity of the Astronomy & Astrophysics sector (Departments and Institutes) in Greece. Its intension is to explore, without pretending to exhaust the theme, only the research output and not the overall scientific contribution (being educational, public outreach, services, or other) of the different departments and Institutes. The final and most important aim is to fortify the Hellenic Astronomical community with data and possible arguments in the onset of the difficult struggle to convince the Greek government for the need to participate in the European Southern Observatory (ESO).

Study set-up: I have used the NASA ADS system to retrieve relevant information regarding the research production of Greek Astronomy-Astrophysics Institutions using the Astronomy/ Planetary, Instrumentation and Physics/ Geophysics databases. I have counted all the refereed publications, characterized as such by the ADS, and independent of the journal impact factor by using the corresponding ADS filter for two 3-year periods (1999-2001 and 2002-2004). Furthermore:

• The publications were selected so that at least one of the authors has an academic position (lecturer and above for the universities, researcher D for the research institutes). I have not counted papers of affiliated members or students of the corresponding institutions if they had no staff member as a co-author. The names of the academic staff considered in this study can be found in the appendix.

• I have attempted to avoid double entries and verify that names were correctly used (to avoid counting papers of scientists having the same or similar names but belonging to different institutions). I note a few examples: there are two Anastasiadis, A. (a) Aristotelis – Univ. of Thessaloniki and (b) Anastasios - NOA-Space, which are not distinguished by the ADS, and thus it was necessary to check the corresponding abstracts to verify the affiliation. Also there are two Spyrou, N. (a) of the Univ. of Thessaloniki, section of Astronomy, Astrophysics & Celestial Mechanics and (b) of the University of Surrey, School of Electronics, Computing and Mathematics.

• I have taken into account the specific year in which new staff members have joined the different departments.

• I have excluded from the listed "refereed" articles some erroneous ADS entries (eg. erratums, book reviews by other authors which are attributed to the editor of the book or conference proceedings, etc.)

• In order to take into account the time lag between publication and first citations, I present citations (counted the first week or so of 2005) only for articles published between 1999 and 2001. I caution that the citations listed in ADS for articles published in physics journals are incomplete. Furthermore, I made no attempt to exclude auto-citations.

Table 1

Period	Staff	Refereed Publications	Publications /staff	Citations	Citation /paper
1999-2001	74	288	3.9	2325	8.1
2002-2004	80	337	4.2		

Results: The main results of this analysis can be found in Table 1, where we present the number of refereed publications and the mean publication number per staff member for the two 3-year period over all Institutions (see the appendix). Furthermore, for the 1^{st} period we present also the total number of citations (including self-citations) counted up to the 31/12/2004. It can be seen that there is a small increase of the mean publication per staff member in the second period, a result which is significant at the $\sim 1.4\sigma$ level (assuming Poisson statistics), since the standard deviation of the mean is ~0.22.

The results presented can be appreciated if compared with those of other developed countries with similar GDP per capita (or more appropriately with a similar fraction of the GDP invested in pure research), an analysis which is out of the scope of this brief presentation.

However, we do present here (Table 2) a crude comparison with the scientific production of the Concilio Nacional de le Ricerce (CNR-Italy), of the Centre National de la Recherche Scientifique (CNRS-France), of the Consejo Superior de Investigaciones Cientificas (CSIC-Spain) and finally of the Max-Plank (Germany) for roughly the same period (2001-2002). These data have been borrowed from a similar study of the CNR, published in early 2004.

Table 2

CNR-Italy	CNRS-France	CSIC-Spain	Max-Plank	Greece
4.1	4.2	5.7	6.9	4.2

Note that the above European estimates are derived from all the natural science subjects and not only from Astronomy/Astrophysics and Space Sciences. It is evident that to a first order Greek Astronomy compares quite well with that of at least some European countries.

Appendix

The staff members considered in the above analysis are:

• **Academy of Athens:** Contopoulos, G., Dara, Efthimiopoulos, Patsis, Tritakis, Voglis, Zachariadis, Petropoulos

(Efthimiopoulos in the second period only).

- **University of Athens:** Antonopoulou, Apostolatos, Danezis, Deligiannis, Ioannou, Konstantopoulos, Kontiza, Laskarides, Mastichiadis, Moussas, Niarchos, Papagiannopoulos, Papaelias, Papathanasoglou, Pinotsis, Preka-Papadema, Rovithis-Livaniou, Sakellariadou, Stathopoulou, Theodossiou, Tsamparlis, Tsinganos, Vlachakis (Vlachakis in the second period only).
- **University of Crete:** Hadjidimitriou, Haldoupis, Kylafis, Papamastorakis, Papadakis, Reig, Vardavas, Ventura (Reig in the 2nd period only).
- **University of Ioannina:** Alissandrakis, Krommydas, Nindos, Tsikoudi (Nindos only in the second period)
- **NOA-IAA:** Boumis, Dapergolas, Georgantopoulos, Goudis, Kontizas, Plionis, Sinachopoulos,, Xilouris (Boumis and Xilouris in the 2nd period only)
- **NOA-Space:** Anastasiadis, Belehaki, Daglis, Harlaftis, Tsiropoula
- **University of Patras:** Zafeiropoulos, Flogaiti, Gerogiannis, Antonakopoulos.
- **Aristotle University of Thessaloniki:** Avgoloupis, Caranicolas, Grigorelis, Hadjidemetriou, Ichtiaroglou, Kokkotas, Meletlidou, Papadopoulos, Seiradakis, Spyrou, Stergioulas, Varvoglis, Vlahos, Voyatzis.
- **University of Thrace** (Laboratory of Electromagnetic theory): Anagnostopoulos, Diamantidis, Pavlos, Rigas, Sarafopoulos, Sarris.

It is possible that I have accidentally omitted some colleagues from the above lists (new staff members etc), a possibility that would not change significantly the results presented previously. I repeat that in all of the above statistics I have considered on an equal basis all refereed journals, considered as such by the ADS.

Skinakas micro-variability observations of BL Lac objects

(continued from page 25)

optical wavelengths, can offer us clues on the acceleration and cooling mechanism of the energetic particles in the jet. In order to advance our knowledge in this field we need a much larger number of light curves with a dense sampling pattern (no more than a few minutes) and in more than one bands, for a representative sample of BL Lacs. In this way, we will be able to study, in a statistical way, variability time scales, the cross-correlation between the different bands, and the spectral evolution during flaring events. This will allow us to understand their "typical" or "average" variability properties, and subsequently constrain physical models. Such light curves can result from dedicated, monitoring observations with medium size (i.e. 0.5-1 m) "robotic" telescopes. Since there are quite a few telescopes of this size in Greece, this can be a promising field of research for the Greek observational astronomical community in general.

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Top Astronomy Stories for 2005

According to the Physics News, the Bulletin of the American Institute of Physics, among the top physics stories for 2005, we found five related to astronomy:

- The arrival of the Cassini spacecraft at Saturn and the successful landing of the Huygens probe on the moon Titan (January 2005)
- the biggest burst of light ever recorded from outside the solar system, from a soft gamma repeater (February 2005)
- Detection of infrared radiation directly from an exoplanet (March 2005)
- Geoneutrinos observed (July 2005)
- Short gamma ray bursts identified as coming from in-spiraling neutron stars (October 2005)

Close Binaries in the 21st Century:

New Opportunities and Challenges

The idea to organize a conference on Close Binaries in Greece was conceived a few years ago and the first plans were set up during the VIth Pacific Rim Conference on Stellar Astrophysics held in Xian, China, July 11-17, 2002. After many discussions, the decision to organize the conference in 2005 was made in the summer of 2004 and the four organizers were A. Gimenez, E. Guinan, P. Niarchos and S. Rucinski. Chairman of the LOC was P. Niarchos, who undertook the main responsibility of the organization of the conference. The conference was supported by the Commission 42 ofIAU, the European Space Agency (ESA), the National and Kapodistrian University of Athens, the Ministry of Education and Religion Affairs, the University of Aegean, the Hellenic Astronomical Society, the Municipality of Ermoupolis, the Alpha Bank and the PLAISIO Computers A.E.B.E.

Figure 4: ***Various forces acting on the plasma along its motion, as functions of distance.***

Scientific Rationale: Surveys of stars in the Galaxy consistently show that most stars (>60%) are members of binary and multiple star systems. It is crucial to determine the properties of these binary systems so that we can better understand the galaxies whose luminous matter consists mostly of stars which are members of binary systems. Moreover, the evolution of binary stars is also responsible for a large number of astrophysically diverse and energetic phenomena that include X-ray binaries (with black hole or neutron star components), cataclysmic variables and novae (with white dwarf components), and some types of supernovae (e.g.-SN Ia).

From the vantage point of the observer, a tiny fraction (0.2-0.3%) of all binary stars are favourably aligned in space, allowing the observer to see the mutual eclipses of the component stars; these systems are Eclipsing Binary (EB) stars. The study of EBs over the last century, with increasingly better data and analyses with more sophisticated computer codes, has led to accurate determinations of the basic astrophysical data on stars - such as masses, diameters, luminosities, along with crucial information about stellar atmospheres and internal structure and stellar evolution. In special cases, selected eclipsing binaries in nearby galaxies are being used as "standard candles" to secure accurate distances to clusters and to the Local Group of Galaxies. This results in a better calibration of the extragalactic distance scale and in establishing an accurate zero point of the Hubble constant H_0.

More recently a new class of eclipsing binaries was discovered in which the eclipses are produced by the transit of a giant exosolar planet of a solar-type primary star (e.g. HD 209458). Many more of these eclipsing binary planet/star systems are expected to be discovered within the next several years. These open a new important window of opportunity to study the properties (mass, diameter, albedo, atmosphere, etc.)of planets outside our solar system. These are exciting binary systems with great potential that are just beginning to be explored.

A major revolution in the study of close binaries has taken place over the last decade. Very large surveys (e.g. MACHO, EROS, OGLE and others), which repeatedly photometrically monitor the brightness of stars, can now detect about over 20,000 EBs, mostly in the galactic bulge and in the Large and Small Magellanic Clouds (LMC and SMC). A new survey planned during the next decade will most likely find >5-10 millionadditional EBs. These surveys perform photometry, but not spectroscopy, which provides the radial velocities of the two stars. Surveys of M31 and M33 carried out by three groups (e.g. the DIRECT Program) are discovering many additional EBs and expect > 1 million new EBs over the next decade; radial velocities of a very small subset of these systems (and EBs in the LMC) are being obtained to determine the physical properties of the stars and their distances. The upcoming European COROT mission and the NASA space mission "Kepler", which are both designed to detect transit eclipses of stars by terrestrial-size planets (i.e. eclipsing binary planet/star systems), will also deliver thousands of new galactic EBs with exquisitely precise (micromag) photometry. Later into the future, the enormouslyESA space mission GAIA should deliver ~ 8 million new EBs, an estimated ~100,000 of which will have radial velocities, calibrated colours, and parallaxes. Therefore, in the next decade or so there will be hundreds of thousands new EBs and several hundred eclipsing planet/star binaries.

Programme Topics

- Recent Developments in Close Binary Star Research (Non-Degenerate Stars)
- Formation and Evolution of Close Binaries: Star + Star Systems and Planet + Star Systems
- Binary Stars as Astrophysics Laboratories
- Binaries in Clusters and Nearby Galaxies
- Binary Star - Planet Systems: New Developments and New Things learned
- Recent Developments in Close Binaries with Degenerate Components
- New and Improved Tools for Analyzing Light and Radial Velocity Observations
- Future expectations: Impact of New Instrumentation and Technologies on Close Binary Star/ Exoplanet Research

Conference activities

A total number of 110 participants from 34 countries attended the meeting. There were 9 invited lectures, 37 contributed talks and 65 poster presentations. The conference was very successful with regards to both the scientific part and the organization. Undoubtedly it was an important event for the munity of binary stars astrophysics. the participants were absolutely satisfied from the scientific program, the organization, the hospitality and the beauty of Syros and Greece. Those contributions to the conference which will pass the refereeing process, will be published in the journal Astrophysics and Space Science. The web site of the conference is:

http://www.phys.uoa.gr/CB_Greece05

P. G. Niarchos

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Venus Express... *(continued from page 6)*

instruments on board: three are flight-spare units of instruments already flown on Mars Express, two are from comet-chaser Rosetta and two were designed specifically for this mission.

The PFS high-resolution spectrometer will measure atmospheric temperature and composition at varying altitudes. It will also measure surface temperature and search for signs of current volcanic activity.

The SPICAV/SOIR infrared and ultraviolet spectrometer and the VeRa instrument will also probe the atmosphere, observing stellar occultation and detecting radio signals; the former will in particular seek to detect molecules of water, oxygen and sulphuric compounds thought to be present in the atmosphere.

The VIRTIS spectrometer will map the various layers of the atmosphere and conduct multi-wavelength cloud observation in order to provide images of atmospheric dynamics.

Assisted by a magnetometer, the ASPERA 4 instrument will analyse interaction between the upper atmosphere and the solar wind in the absence of magnetospheric protection such as that surrounding Earth (for Venus had no magnetic field). It will analyse the plasma generated by such interaction, while the magnetometer will study the magnetic field generated by the plasma.

The VMC camera will monitor the planet in four wavelengths, notably exploiting one of the 'infrared windows' revealed in 1990 by the Galileo spacecraft (when flying by Venus en route for Jupiter), making it possible to penetrate cloud cover through to the surface. The camera will also be used to monitor atmospheric dynamics, notably to observe the double atmospheri vortex at the poles, the origin of which still remains a mystery.

Relativistic AGN Jets... *(continued from page 29)*

electric field polarization vectors and the Faraday rotation measure gradients across the jet, support the existence of helical magnetic fields with strong transverse (azimuthal) component (e.g., Gabuzda et al 2004). This is consistent with the MHD picture, since the field is naturally helical (see figure 5) and the azimuthal (B_j) component is dominant beyond the Alfvénic distance (see figure 3d). This is another connection between models and observations that definitely need to be examined more closely (Vlahakis, Marin, & Königl in preparation).

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7th International Conference of the Hellenic Astronomical Society

by D. Xatzidimitriou

The 7th biannual International Conference of the Hellenic Astronomical Society, entitled "Recent Advances in Astronomy & Astrophysics", took place in September, 8-11, 2005, in Lixourion, Kefallinia.

The Scientific Organizing Committee (SOC) of the 7th HelAS conference was chaired by Prof. P.G. Laskarides (University of Athens) and included H. Dara (Academy of Athens), J. G eorgantopoulos (National Observatory of Athens), V. Geroyiannis (University of Patras), E. Harlaftis (National Observatory of Athens), J. Hadjidemetriou (University of Thessaloniki), D. Hatzidimitriou (University of Crete), K.D. Kokkotas (University of Thessaloniki), N. Kylafis (University of Crete), X. Moussas (University of Athens), P. Niarchos (University of Athens), S. Papadakis (University of Crete), J.D. S. Persides (University of Thessaloniki), J.H. Seiradakis (University of Thessaloniki), N. H. Solomos (Hellenic Naval Academy), E. Theodossiou (University of Athens), Ch. Tomboulides (MNE & RA) and K.Tsinganos (University of Athens).

The Local Organizing Committee (LOC) consisted of N. Solomos [Chair] (Hellenic Naval Academy & "EUDOXOS" National Observatory of Education), G. Fanourakis (NRCPS "DEMOKRITOS" & NOE "EUDOXOS"), A. Heilaris (Hellenic Navy & Hellenic Naval Academy), V. Kokalis (NOE "EUDOXOS"), O. Malandraki (National Observatory of Athens), D. Patrikios (NOE "EUDOXOS") and A. Zachariadou (NRCPS "DEMOKRITOS" & NOE "EUDOXOS"). Thanks to the efforts of the LOC, the local organisation of the conference was excellent.

The conference was attended by over 160 participants from Greece and abroad and was deemed to be a great success, both from the point of view of organisation and of the quality of the scientific contributions of the participants.

Opening remarks were addressed by the Hel.A.S. chairman Prof. P. Laskaridis, by the member of the Academy of Athens Prof. G. Contopoulos, by the Mayor of Lixourion and other local representatives.

The scientific agenda of the conference contained, parallel and poster

sessions,well as two special meetings/ moderated discussions, open to all interested participants.

The scientific sessions of the conference were devoted to: (1) Sun, Planets & Interplanetary Medium, (2) Our Galaxy: Stars, Clusters, Interstellar Medium,(3) Extragalactic Astrophysics, (4) Theoretical Insights in Dynamical Astronomy, Relativity and Cosmology,(5) Instrumentation & Methods of Astronomical Observations,and (6) History and Education in Astronomy.

The special meetings were focussed on discussions on the future of astronomy in Greece and on the prospects of the Greek participation to the European Space Agency, with representatives from ESA, NASA and the Greece/ESA Task Force.

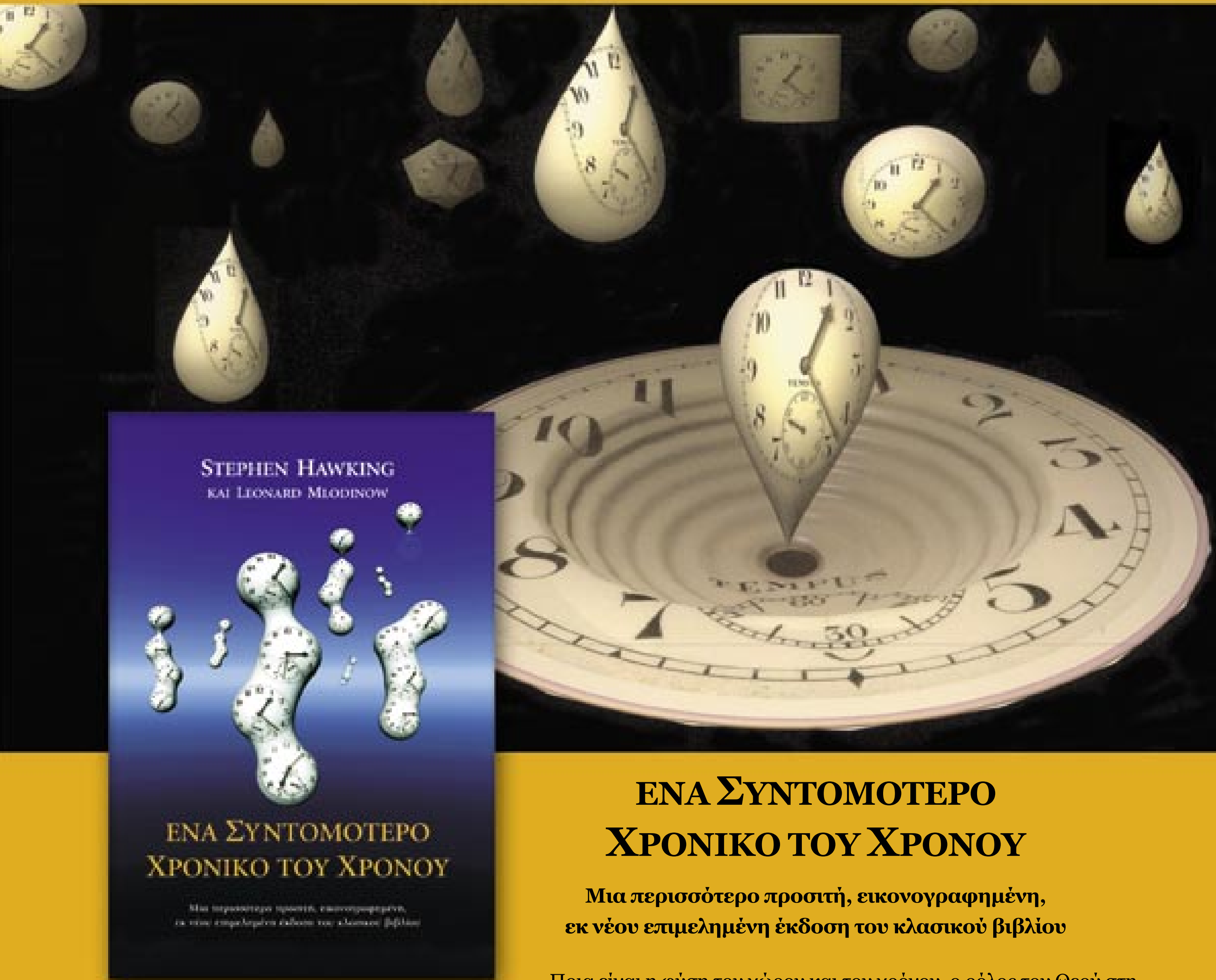
The distinguished invited speakers of the conference presented excellent review talks on a wide range of subjects. (1) Dr Athena Coustenis (LESIA, Observatoire de Paris, Meudon, France) spoke on"The Cassini/Huygensto Saturn/Titan", (2) Prof. Mike Edmunds (Head of School of Physics and Astronomy, University-Wales, UK), on "The Antikythera Mechanism", (3). Attilio Ferrari (Dipartimento diFisica Generale, Universita di Torino, Fisica Spaziale, Italy) on "Astrophysical", (4) Prof. Keith Horne, (Head of Astronomy, School ofPhysics & Astronomy,of St. Andrews, UK) on "ExtraSolar Planets" (Emilios Harlaftis Lecture), (5) Prof. Eric Priest (Fellow of the Royal Society, University of St.Andrews, UK) on "Our Enigmatic Sun", (6) Prof. James Truran Jr., Department of Astronomy & Astrophysics, Universityof Chicago, USA)"Nucleosynthesis, Challenges and New Developments".

The 7th Hel.A.S. conference was sponsored by the "Alexander S. Onassis" Foundation, the Hellenic Astronomical Society, the Municipality of Lixourion-Pali, the Hellenic Tourism Organization, the Hellenic National Committee for Astronomy, the EUDOXOS National Observatory of Education, the Technological Educational Institute of Ionian Islands, the Prefecture of Kefallinia and Ithaki and the Hellenic Naval Academy.

On September 9th, the General Assembly of the HEL.A.S. was held. The Secretary of the Hel.A.S., Prof. K. Tsinganos, summarised the current situation within the Society. Sixteen new members were elected, thus raising to 274 the number of Hel.A.S. members. Progress on the preparation of the new Who-is-who in Greek Astronomy was presented by the Chairman Prof. Laskarides. A small number of amendments to the founding chart of the Society were also approved by the Assembly. Finally, the establishment of the Harlaftis Travel Fund was announced. The aim of the fund is to support young astronomers to visit International Observational Facilities.

More details on the 7th Hel.A.S. conference and its scientific agenda can be found on its web site: **http://comas.interzone.gr/cgi/article.cgi.**

STEPHEN HAWKING
ΚΑΙ LEONARD MLODINOW



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«Σκοπός μας γράφοντας το παρόν βιβλίο ήταν να μοιραστούμε μαζί σας μέρος του ενθουσιασμού που προκαλούν οι πιο πρόσφατες ανακαλύψεις, καθώς και τη νέα εικόνα της πραγματικότητας η οποία αναδύεται ως συνέπειά τους.»
—*Οι συγγραφείς*

ΕΝΑ ΣΥΝΤΟΜΟΤΕΡΟ ΧΡΟΝΙΚΟ ΤΟΥ ΧΡΟΝΟΥ

Μια περισσότερο προσιτή, εικονογραφημένη, εκ νέου επιμελημένη έκδοση του κλασικού βιβλίου

Ποια είναι η φύση του χώρου και του χρόνου, ο ρόλος του Θεού στη Δημιουργία, το παρελθόν και το μέλλον του Σύμπαντος; Κανείς δεν μας εξήγησε τα παραπάνω ερωτήματα καλύτερα από τον ιδιοφυή Stephen Hawking στο μπεστσέλερ του *Το χρονικό του χρόνου*. Από την πρώτη έκδοση, ωστόσο, πολλοί αναγνώστες διεμήνυαν στον καθηγητή ότι δυσκολεύονται να παρακολουθήσουν πολλές από τις σημαντικότερες έννοιες του βιβλίου. Έτσι, με τη συμβολή και του Leonard Mlodinow, η κοσμολογία τού Stephen Hawking παρουσιάζεται αναθεωρημένη στο παρόν βιβλίο —ώστε να είναι περισσότερο κατανοητή στον καθένα— και ταυτόχρονα πλήρως ενημερωμένη με τις πιο πρόσφατες κατακτήσεις της ανθρώπινης γνώσης.

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