HIPPARCHOS

The Hellenic Astronomical Society Newsletter

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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 photo:
The Antikythera Mechanism.
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Message from the President

Dear Hel.A.S. fellows,

Formally the Governing Council of Hel.A.S. is elected every two years but the officers can serve a maximum of two consecutive 2-year terms, i.e., up to a total of 4 continuous years. Last summer (2006) the fourth 4-year period of the Governing Council (GC) of Hel. A.S. started since the first council was elected in 1994. The three previous 4-year terms (Presidents: G. Contopoulos, J. Seiradakis, P. Laskaridis) made an enormous contribution to solidify the Hellenic Astronomical Society and inherit us a strong, well organized and peaceful Society. The obligation of the present 4th term is to take Hel.A.S. a further step forward adding new elements in this already established good tradition. As a matter of fact, in the 2006 elections the GC of the Hel.A.S. was considerably rejuvenated with younger members rich with fresh ideas.

Among the first measures taken by this new GC is the external appearance of the Society. The webpage has been conveniently named

www.helas.gr

while its content is also drastically reformed: the layout has a professional and very useful structure, its style is more pleasant and youthful, the new logo of the Society is artistic, etc, all conveying to the reader the appropriate astronomical excitement which a Hel.A.S. webpage should do. Our thanks go to

Message from the President *(continued)*

Vassilis Charmandaris for coordinating all this effort. Next, we are waiting for the second surprise, which has to do with the new appearance and format of another popular contribution of the Hel.A.S. to our members –but at this point I should rather cut it short ... Finally, as you can also witness by yourselves, the present second issue of the second volume of HIPPARCHOS is also the second one with the new more professional and better style, a result that has to be credited to Kostas Kokkotas.

This summer, the aided Hellenic Astronomical eye will be considerably upgraded too. Aristarchos, the 2.3 meters new telescope will be fully in operation atop Mt Helmos, at 2350 m. More than 90% of the tests have been performed and they are to the satisfaction of the NoA telescope committee. At the same time, at a common meeting of the National Astronomical Committee and the GC of Hel.A.S. a strong supportive letter for ARISTARCHOS was signed and handed to Christos Goudis, the IAA/NoA Director for facilitating his meetings with the government and other involved officials in taking care of the last necessary actions for the operation of the telescope this summer. Christos manages well the effort to bring the telescope project to completion and so we are indeed looking forward to this in the coming summer.

The previous seven Hel.A.S. Panhellenic Astronomical conferences have become already a tradition on their own and the forthcoming 8th Hellenic Astronomical conference will be no exception. They combine reporting the latest in research in astronomy, meeting other Greek and foreign colleagues and also exploring other regions of Greece and diffusing to them the astronomical experience. This summer, the 8th Hellenic Astronomical conference will take place in the beautiful northern Aegean island of Thassos, between September 13th to 15th, 2007. Fr George Anagnostopoulos is chairing the local organising committee and promises a memorable local organisation. At the same time the conveners of the scientific organizing committee are already preparing their sessions and the Hel.A.S. GC has already invited several distinguished plenary speakers. It will be a good opportunity for all of us to be there and exchange views about the latest astronomical news, etc.

2009 has been declared by UNESCO and the International Astronomical Union the International Year of Astronomy (IYA):

http://www.astronomy2009.org/

The IYA2009 will be a global celebration of astronomy and its contributions to society and culture, stimulating worldwide interest not only in astronomy, but in science in general. The vast majority of IYA2009 activities will take place on several levels: locally, regionally and nationally. Several countries have already formed National Nodes to prepare activities for 2009. Paul Laskaridis is coordinating the Hellenic node together with V. Charmandaris, I. Daglis, J.H. Seiradakis, E. Theodossiou and myself as members. In particular, the conference entitled "Communicating Astronomy with the Public 2007" will take place in Athens, Greece, from 8 -11 October 2007: http://www.communicatingastronomy.org/cap2007.

Another direction we can move in the years ahead is to expand the Directory of Hel.A.S. by including in it every Greek astrophysicist working anywhere in the world, regardless of being a member of the Society. I would thus ask anyone who knows such scientists to notify them to contact the Secretary, or vice versa, in order that their name and affiliation details are included in the Society Directory. Our aim is to make Hel.A.S. really the Astronomical Society of everyone of Hellenic origin, or, everyone who shares the Hellenic cultural and historical values.

Thus, till 2009, there are many astronomical events expecting all of us to participate. Till then, I wish to all and everyone of you good health, good skies and good ideas.

Kanaris Tsinganos

8th Hellenic Astronomical Conference

13th – 15th September 2007, Thassos, Greece http://www.ee.duth.gr/hac/index.htm

The Conference will take place at the Hotel "Makryammos bungalows" located in the island of Thassos, Greece. Makryammos is the most picturesque beach in the Limenas area, in beautiful surroundings with forest all around. Set in a pretty bay with shallow water and fine sand. Very well organized.

Conference Sessions will cover most areas of Astronomy and Astrophysics:

- Sun, Planets and Interplanetary Medium
- Our Galaxy: Stars, exo-Planets and Interstellar Medium
- Extragalactic Astrophysics
- Dynamical Astronomy, Relativity and Cosmology
- Instrumentation and Methods in Space and Astronomical Observations
- History and Education in Astronomy

General assembly and elections of Hel.A.S.

During the 24th General Assembly of Hel.A.S. which took place on September 22, 2006 the President of the Society Prof. P. Laskarides presented a summary of the activities of HelAS during the last two years, the Treasurer Assoc. Prof. E. Theodossiou a detailed account of the finances. The Secretary Prof. K. Tsinganos presented an update on the HelAS membership status over the past year.

In the elections that followed the 24th General Assembly of September 22, 2006, the members of Hel.A.S. voted for a President, as well as a new Council and Auditors. The total number of eligible to vote members was 82 and an equal number of ballots were collected.

The results were:

President: Tsinganos Kanaris *(73 votes)*

Council:

1. Kokkotas Kostas *(39 votes)*
2. Plionis Manolis *(37 votes)*
3. Charmandaris Vassilis *(32 votes)*
4. Mastichiadis Apostolos *(28 votes)*
5. Daglis Ioannis *(25 votes)*
6. Papadakis Iosif *(20 votes)*
7. Anagnostopoulos Georgios *(19 votes)*
8. Efthymiopoulos Christos *(19 votes)*

Auditors:

1. Xilouris Emmanuel *(53 votes)*
2. Vlahakis Nektarios *(45 votes)*
3. Nindos Alexandros *(23 votes)*

Following the constitution of Hel.A.S. the new Governing Council for the 2006-2008 term is:

President: K. Tsinganos

Council:

1. K. Kokkotas (vice-President & Hipparchos' Editor)
2. V. Charmandaris (Secretary)
3. A. Mastichiadis (Treasurer)
4. M. Plionis (member)
5. I. Daglis (member)
6. I. Papadakis (member)

Members in new positions

- We would like to congratulate Prof. **Christos Goudis,** who was recently unanimously reelected as the director of the Institute of Astronomy and Astrophysics of the National Observatory of Athens.
- Dr. **Panayotis Hantzios** was recently appointed to the level of Researcher-C (Associate Researcher) at the Institute of Astronomy & Astrophysics of the National Observatory of Athens.
- Dr. **Ioannis Bellas-Velidis** was recently appointed to the level of Researcher-C (Associate Researcher) at the Institute of Astronomy & Astrophysics of the National Observatory of Athens.
- We would like to congratulate Dr. **Kleomenis Tsiganis**, who recently commenced his appointment as Lecturer in the Dept. of Physics of the University of Thessaloniki.
- We would like to congratulate Dr. **Nektaria Gizani** who recently commenced her appointment as Lecturer in the Section of Astroparticle Physics of the Hellenic Open University.
- We would like to congratulate Dr. **Christos Efthymiopoulos**, for his recent promotion to the position of Main Researcher (Researcher B′) in the Research Center for Astronomy of the Academy of Athens.
- We would like to congratulate Dr. **P. Patsis**, for his recent promotion to the position of Director of Research (Researcher A′) in the Research Center for Astronomy of the Academy of Athens.
- We would like to congratulate Dr. **Manolis Plionis** who was recently promoted to the position of Director of Research (Researcher A′) at the Institute of Astronomy and Astrophysics of the National Observatory of Athens.
- We would like to congratulate Prof. **Harry Varvoglis** who was recently promoted to the position of Full Professor at the Department of Physics of the University of Thessaloniki.
- We would like to congratulate Dr. **Manolis Xilouris** who was recently promoted to the position of Researcher C′ at the Institute of Astronomy and Astrophysics of the National Observatory of Athens.

New members of Hel.A.S.

Members of Hel.A.S. moving from Junior to Ordinary status:

1. Dr Olga Bitzaraki *(PhD 2003, University of Athens)*
2. Dr Alceste Bonanos *(PhD 2005, Harvard University, USA)*
3. Dr Dimitris Giannios *(PhD 2005, University of Crete)*
4. Dr Ioannis Gonidakis *(PhD 2005, University of Manchester, UK)*
5. Dr Paschalis Paschos *(PhD 2005, University of Illinois Urbana-Champaign, USA)*
6. Dr Emmanouel Rovilos *(PhD 2004, University of Manchester, UK)*

Newly elected Ordinary members:

1. Dr Zacharias Ioannou *(PhD University of Keele, UK)*
2. Dr Styliani Kafka *(PhD 2005, University of Indiana, USA)*
3. Dr Maria Kroustalloudi-Flerianou *(PhD 2006, Nat. Tech. Un. of Athens)*
4. Dr Athena Meli *(PhD 2002, Imperial College, Univ. of London, UK)*
5. Dr Polychronis Papaderos *(PhD 1998, University Gottingen, Germany)*
6. Dr Spiros Patsourakos *(PhD 2000, In. of Paris XI, Orsay, France)*
7. Dr Jason Spyromilio *(PhD 1989, Imperial College, Un. of London, UK)*
8. Dr Christos Tzanavaris *(PhD 2003, Cambridge, Institute of Astronomy, UK)*

Newly elected Junior members:

1. Panagiotis Gavras *(Graduate student, University of Athens)*
2. Eva Lefa *(Graduate student, University of Athens)*
3. Maria Magkanari *(Graduate student, University of Athens)*
4. Kostas Moraitis *(Graduate student, University of Athens)*
5. Periklis Rammos *(Graduate student, University of Athens)*

Newly elected Associate members:

1. Alexandros Liakos
2. Kostantinos Markakis
3. Kostantinos Stamou

Human Resources in Astronomy, Astrophysics & Space Physics in Greece

by Vassilis Charmandaris
Department of Physics, University of Crete, Greece

In this article we present a brief statistical analysis of the distribution of astronomers among the various institutions in Greece[1]. As one would expect, since more than half of the population in Greece is concentrated in the Athens and Thessaloniki metro areas, most of the astronomers in Greece are also associated with institutes located in these two cities. This is depicted in Figure 1 where the fraction of tenured and tenure track astronomy faculty in the major AA&SP institutions in Greece is presented.

An additional issue, which affects the current state and has direct implications to the future of Greek astronomy, is related to the age distribution of Greek professional astronomers. In Figure 2, a histogram of 135 astronomers working in Greece is presented, using the database of the members of the Hellenic Astronomical Society, as well as ancillary information collected by the author. The study was limited to individuals over the age of 30, since this is typically the age when one is competitive for tenure track or long term research associate positions. Some individuals over the retirement age of 67, who are on an emeritus-type position and/or still active, were included in the analysis. The error on a single 5-year bin is of the order of 5% but it is very likely that the values of bins at ages greater than 55 are somewhat underestimated. This is due to the fact that there are a number of individuals who formally have a tenured astronomy positions but as they are no longer active they were not included in the database of Hel.A.S, on which analysis was based.

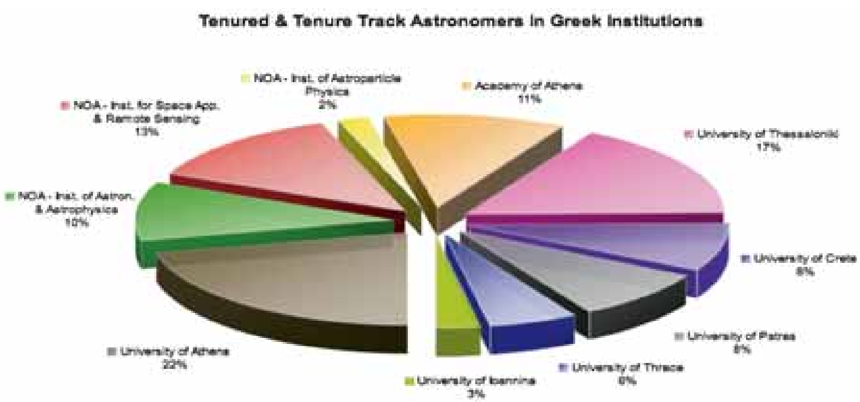

Figure 1: Distribution of tenured and tenure track astronomers in the major research institutes in Greece. The total number of astronomers included in this study is 107 and it is restricted to individuals on tenure or tenure track positions.

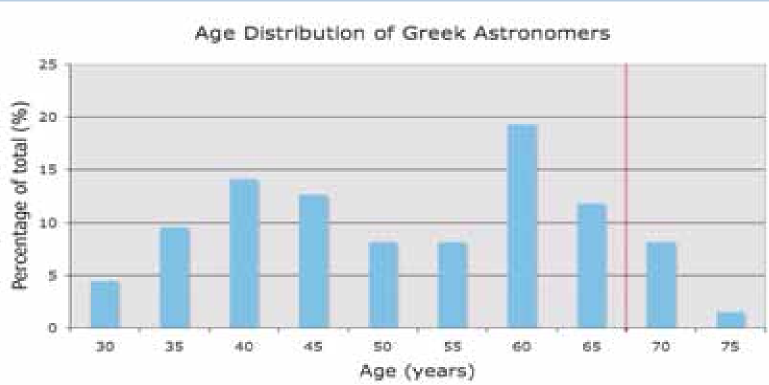

Figure 2: A histogram of the age distribution of astronomers in Greece in 2006. The vertical line indicates the 67th year of age which is the current compulsory retirement age for civil servants.

Inspection of Figure 2 clearly reveals that almost 30% of Greek astronomers are near or over the age of 60. Furthermore, statistics over the last 10 years indicate that on average there were less than 3 new tenure track astronomy position openings per year in the country, including both universities and research institutions. The fraction of astronomers near the age of retirement is even larger if we were to consider only the two older universities of Athens and Thessaloniki. This implies that within the next 3 to 10 years a large number of their current faculty members will retire and they will have to be replaced in a very short time scale. This will be an interesting challenge for Greek astronomy. Will it be possible for these institutions to find enough, well qualified, candidates from the available pool of post-docs and research associates for their needs? If necessary, will changes in the legislation make it possible for the institutions to hire with a lower pace, being selective and identifying the key scientific research areas they should be investing in, without loosing any position in the process?

Finally, another topic worth touching upon is the gender diversity in Greek astronomy. At the time of writing this report 14% of the permanent or tenure track astronomy positions in Greece were held by women. This percentage is less than in France[2], which leads the way with ~26%, or in Italy, Russia and Spain, all above 15%, but higher than the fraction of female astronomers in the United States which is ~10%. We should note though, that only recently one female astronomer in Greece reached for the first time the highest possible academic rank (Full Professor or Researcher A).

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1. This article is an exerpt from a report entitled "Astronomy, Astrophysics & Space Phyiscs in Greece" prepared by the author available at: http://arxiv.org/abs/physics/0604144
2. The percentages for the other countries mentioned are based on the 2003 report by Dr. Florence Durret (Institute d'Astrophysique de Paris, France) available at: http://www2.iap.fr/sf2a/courrier.html

The prospects of employment for young astronomers in Greece

by S. Kitsionas, *Astrophysikalisches Institut Potsdam, An der Sternwarte 16, D-14482 Potsdam, Germany*

Abstract: Based on my recent Hipparchos article [1], I review the existing legislation and employment opportunities (including PhD positions) for young astronomers in Greece. Several points of concern are raised, referring mainly to funding and employment status, that need to be addressed in order to improve the prospects of employment for young astronomers in Greece.

The funding of temporary positions in Astronomy Departments in Greece

We first review the short-term positions available for early stage researchers (e.g. PhD students) and experienced researchers (e.g. post-docs) in Greek astronomy departments/groups (referred to in the sequel as Greek astronomy institutes; GAIs).

1. **Astronomy Groups in Universities** are funded by the **Ministry of Education**.

a) Over the last few years there have been two calls for funding research projects including personnel expenses (EPEAEK), based mostly on EU funds for the promotion of education and addressed mainly to early stage researchers. This programme offers rather generous financial terms to its beneficiaries (including funding for travel and publication expenses), but the fact that it is highly competitive and open to all disciplines makes the number of fellowships available to astronomy rather limited. A major problem with this sort of funding is that it is based on funds that will not be available from the EU indefinitely.

b) There are only a few **"407" teaching positions** (temporary teaching assistantships) available to experienced researchers (at the postdoctoral level), only in provincial universities. These positions provide comfortable salaries but they last for an average of one year only. Due to the nature of these positions, the researchers employed are expected to spend considerable time in teaching.

c) The number of **IKY state fellowships** for astronomy is limited and the postdoctoral fellowships only last for a maximum of 18 months. These fellowships can be awarded for research undertaken even at non-university research institutes. However, their financial coverage is minimal and they include no contributions towards social security and pension (even at the post-doctoral level).

2. **Astronomy groups of Research Institutes** (e.g. NOA, FORTH etc.) get funded from the **Ministry of Development (GSRT)**.

a) The recent initiative for funding "centers of excellence" included generous personnel expenses for both early stage and experienced researchers (through the "Competitiveness" programme of the 3rd EU Support Framework Programme, a programme that will, thus, also not be available indefinitely). The GSRT also provides funding to promote collaboration with international organisations (e.g. ESO, ESA etc.) that includes salaries for temporary research personnel. Moreover, the GSRT announces regular binational funding initiatives, but usually these do not include salaries (as they mainly cover needs of permanent staff in travel and infrastructure). In general the GSRT is technology oriented, leaving not too much room for pure research funding.

b) The PENED programmes, funded by the GSRT and addressed mainly to early stage researchers from research groups at the universities, mostly concentrate on technological projects. They thus require a commercial partner, making the selection of pure research projects rather problematic. Moreover, the salary provided is not really generous.

In summary, there are regularly a limited number of jobs opening in projects, which receive funding that includes personnel expenses, but these are not enough to employ many young researchers at the same time. Employment is mainly at the post-doctoral level, or at least funds are not available for most PhD students. Most full post-doc positions come with the relatively comfortable net amount of 1000 euros. However, salaries for early stage researchers can be considerably lower than this. Most of the above mentioned grants usually also include contributions towards travel and computing support.

Non-permanent personnel status

We now discuss the legislation on employment of non-permanent research staff. Funding for non-permanent positions is channeled through each institute's "special account for research", the operating mechanism of which is totally outdated, e.g. personnel payments can only be made to external collaborators, i.e. temporary staff status is not recognised. Therefore, researchers can formally be hired only as free-lance!!! This increases considerably the amount of bureaucracy (e.g. opening of small personal business for taxation purposes, subscription to the health-insurance fund of self-employed professionals (TEBE), receiving salaries only through bank cheques –and not bank transfer– on irregular intervals etc.).

Temporary research staff are accommodated along the gaps of the employment system (e.g. they do not have to receive, and then return to the state, VAT for the provided services since they are employed under one contract only and/or if their programme is supported by the EU) and usually have to face ignorance of state agencies on their individual needs (e.g. for researchers employed by the same programme, different bureaucratic procedures could be followed depending on the interpretation of the regulations by local officers of the corresponding taxation/health-insurance state agencies [1]). **This should better change soon!**

The operating mechanism of the "special accounts for research" should be restructured in order for research groups to be able to hire non-permanent employees directly and not as free-lance external collaborators. The new Presidential decree for short-term positions (the "Pavlopoulos law" that has been introduced to apply in the Greek legislation a long lasting corresponding EU directive) allows for this. It also includes a reasonable exception for the maximum position duration, allowing research positions to last for 3 years instead of the 2 years that it permits in general.

Possibility for rolling grants

In the previous section, I have argued for the reform of the legislation on the employment of non-permanent research staff in Greece. In the first section, I have listed a number of funds available in recent years for such positions in Greece. In this section, I propose altering the mechanism with which such funding is awarded. In particular, I believe that for the number and size of GAIs a system of rolling grants would be ideal. This way, all such funds currently available for astronomy will be put together and get distributed to the different departments/groups according to criteria, such as their size, their scientific impact etc. For example, in the existing EPEAK scheme, the Ministry of Education funds the different universities and not directly projects. It is the universities that then distribute the grants to their research groups with internal evaluation procedures. What I propose is similar, in the sense that all funding for astronomy will be distributed to the different departments/groups (e.g. in the form of a (few?) new position(s) each year, each position lasting for 2-3 years) and then the allocation of the positions to the various research teams of that department will be decided on a local departmental level. The way with which the first stage allocation to the different departments/groups will be implemented remains open to discussion/negotiation. A national research council is just an example of a body that could be responsible for the funding allocation.

Essentially this will provide a constant number of post-doc and PhD positions per department/group and each permanent researcher of that department/group could be assigned one such position at relatively regular intervals. Then decisions will be made at a local level and more importantly by the real experts.

This will require senior staff to get involved in negotiations with the government and/or the political parties for the implementation of the rolling grant system. What would be the benefit of the state out of such an exercise (since it will anyway allocate the same total funds under the proposed scheme)? Decreased bureaucracy is what one can guarantee! New procedures will have to be implemented at a local level but these will be dealt with mainly by senior research staff and not bureaucrats.

Ideally of course, but also according to the recently voted European Charter for Researchers[2], all available PhD positions should get full funding and PhD students should be primarily considered as early stage research employees. However, the Greek research employment system is not probably capable of handling such a big change immediately and any improvement on the number of funded PhD positions should be gradual.

Other means of funding

The funding of positions is of course the most important issue both financially and in terms of the required legislation. However, there is funding on other issues that is also necessary for making both permanent and short-term positions in astronomy in Greece competitive with respect to corresponding positions abroad.

The advanced needs for computing networks as well as computing techniques and methods for both theoretical and observational astronomical projects makes the opening of new computer manager positions really necessary in every GAI. Of particular importance in this respect is the maintenance of local high-speed networks connecting departments/groups with each other and abroad. The continuous effort that needs to be invested for the setup and maintenance of such networks makes it impossible for the network managers to be short-term or part-time employees. Moreover, their support on astronomical software will be beneficial to all members of staff (permanent or not) of the corresponding department/group. It would worth trying to establish funding for the opening and maintenance (at least for the first few years) of such positions through big EU IT initiatives, such as "Information Society".

As far as travel support is concerned, I have already proposed [1] the introduction of a new student fund that will award travel grants to every PhD student in Greece (that is not funded by other projects) to attend at least 2 international conferences during his/her studies. The fund could be established at a local level and for students of all disciplines (e.g. for each university), or at a national level for all astronomy students under the auspices of the Hellenic Astronomical Society (HEL.A.S.) or the Greek National Committee for Astronomy (or a National Research Council if/when this is introduced). The option of the central management of such a fund has the benefit of being more flexible to handle a larger total sum.

In [1] I also proposed the award of travel support to researchers from GAIs that have interesting results to communicate to the rest of the astronomical community in Greece in the time between the Hellenic Astronomical Conferences. Such funding could be awarded by the HEL.A.S. and would be beneficial to researchers of all employment status, as it could essentially support the establishment of regular seminar series in most GAIs.

In summary, I believe that the existing funding for computing and travel support is more or less sufficient to provide a better service to the astronomical community in Greece if it is managed centrally.

Summary and conclusions

Based on my previous Hipparchos article [1], I review the existing legislation and employment opportunities (including PhD positions) for young astronomers in Greece. Several points of concern are raised, referring mainly to funding and employment status, that need to be addressed in order to improve the prospects of employment for young astronomers in Greece.

In particular, in the recent years there have been a few short-term positions (mostly at the post-doctoral level) that definitely need to increase in numbers. I argue that the establishment of rolling grants awarded to each GAI will greatly increase the efficiency with which such grants are awarded within the astronomical community. However, the existing employment legislation for non-permanent staff at state run institutes is totally outdated and needs reform urgently. Moreover, the employment system should soon start moving towards providing funding for all research students in Greece.

Finally, I have proposed the establishment of centrally managed funds for the award of computing and travel support to young researchers in astronomy in Greece.

The new legal frameworks for research and higher education in Greece, which are still in their drafting stage, should in principle discuss such issues. It is still unknown to the author to which degree the proposals made in this article are in line with the new legislations.

References

1. Kitsionas, S., 2003, ``Important basic necessities for the development of astrophysical research in Greece'' in *Hipparchos, the Hellenic Astronomical Society Newsletter*, Plionis, M., ed., **13**, pp. 10-11
2. http://ec.europa.eu/eracareers/pdf/am509774CEE_EN_E4.pdf

Decoding the Antikythera Mechanism

by John H. Seiradakis
Department of Physics, University of Thessaloniki

The *Antikythera Mechanism* is as important for the development of Technology as the Acropolis for the development of Architecture. Using a set of gears (at least 30), it put into practice the astronomical knowledge of ancient Greeks about the motion of the Sun, the Moon and (most probably) the planets among the stars. The diurnal and annual motion of these objects was calculated with astonishing accuracy, including eccentric gearing for the anomalous orbit of the Moon (first lunar anomaly). It could also predict eclipses of the Sun and the Moon from the Saros period, which has been found in one of its scales. Taking into account the theoretical and technological knowledge required for the construction of the *Mechanism*, it can easily be ranked among the *Wonders of the Ancient World*.

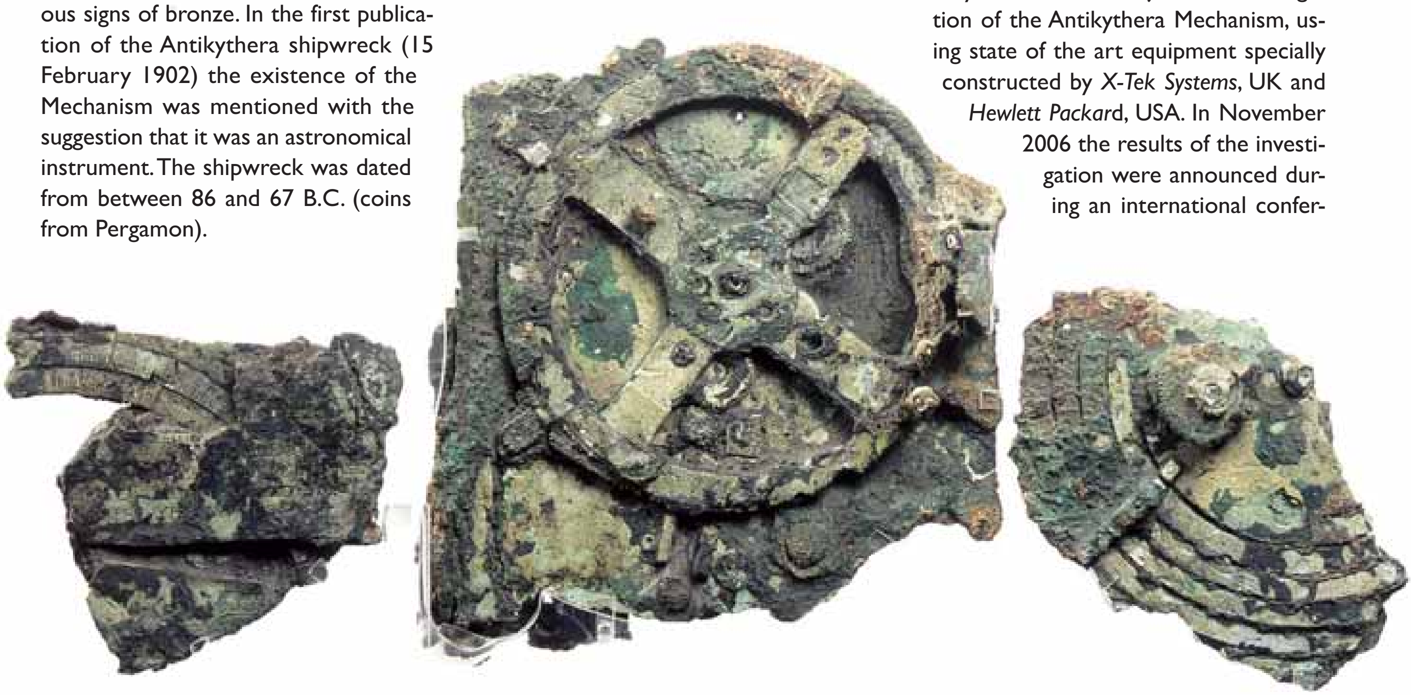
The Antikythera Mechanism was found by chance close to the small island of Antikythera (between Crete and Peloponnese) in April 1900 by sponge divers, who were stranded there, due to bad weather. A wealth of statues, statuettes, household goods and amphorae were brought to the surface during marine excavations between November 1900 and September 1901. Among the recovered artifacts was a strange bulk of material, broken, worn and calcified, with obvious signs of bronze. In the first publication of the Antikythera shipwreck (15 February 1902) the existence of the Mechanism was mentioned with the suggestion that it was an astronomical instrument. The shipwreck was dated from between 86 and 67 B.C. (coins from Pergamon).

The Antikythera Mechanism was portable. Its size was not much larger than a present-day Laptop (probably 30×20×10 cm). The main feature on the front side was a bronze dial with two concentric annuli. The outer annulus was not fixed and bore the names of the twelve months. It was divided into 365 (or 360) days. The inner annulus was fixed and bore the names of the 12 zodiac constellations. It had 360 divisions (360 degrees). In order to take into account leap years, every 4 years, the user could rotate the outer annulus by one day. The back of the Mechanism had two independent spirals (upper and lower). It was probably built in Rhodes and has been dated, by epigraphologists, around the second half of the 2nd century B.C. (100 – 150 B.C.). About this time the great Greek astronomer Hipparchos lived in Rhodes. He died there in 120 B.C.

The first scholar, who studied the Mechanism extensively, was Derek de Solla-Price, with the help of Charalambos Karakalos from the Research Centre *Demokritos* in Athens. He worked for over 30 years and eventually published an extensive account, "Gears from the Greeks". He declared that "the Antikythera Mechanism is the oldest proof of scientific technology, that survives today and completely changes our view of ancient Greek Technology"

The baton was taken by Michael Wright and Alan Bromley. Michael Wright published a series of papers, where he correctly postulated that the back dials of the Mechanism were spiral and that the upper dial was built to follow the Draconic lunar month. He made large strides toward the reconstruction of the *Mechanism* and produced superb bronze replicas.

In 2001, Mike Edmunds and Tony Freeth (Cardiff University), Xenophon Moussas and Yanis Bitsakis (University of Athens) and John Seiradakis (University of Thessaloniki) created the "*Antikythera Mechanism Research Group*". They received a grant from the Leverhulme Foundation, U.K. and the permission to undertake a new investigation from the Ministry of Culture of Greece. After the permission was granted, Eleni Magkou and Mary Zafeiropoulou (National Archaeological Museum) and Agamemnon Tselikas (Cultural Foundation of the National Bank of Greece) joined the team, which was soon supported by an international team of astronomers, archaeologists, mathematicians, physicists, chemists, computer engineers epigraphologists and papyrologists. In September and October 2005 they undertook a major new investigation of the Antikythera Mechanism, using state of the art equipment specially constructed by *X-Tek Systems*, UK and *Hewlett Packard*, USA. In November 2006 the results of the investigation were announced during an international confer-



ence in Athens and published in the international journal Nature.

The results of the new investigation were surprising and stunning! New inscriptions, that had not been read for more than 2000 years were revealed with high energy X-ray tomography (more than 2160 letters were unveiled) and a very careful analysis of the gears' co-action unfolded their use in calculating (a) the 235-month Metonic lunar cycle and (b) the lunar Saros cycle. The Metonic cycle included a pin-and-slot mechanism that reconstructed the *first anomaly* of the Moon's motion (due to its elliptical orbit around the Earth). The final gear was driving a pointer that showed the position of the Moon among the constellations and its phase, with the help of a black and white coloured spherule. The 224-month Saros cycle was marked with the dates (month, day, hour) when a possible solar or lunar eclipse would occur. The markings (they were dubbed "*glyphs*") were engraved with symbols ("*H*" –ΗΛΙΟΣ– for the Sun and "*Σ*" –ΣΕΛΗΝΗ– for the Moon, etc). The fact that both letters, "H" and "Σ", appear simultaneously in some glyphs, means that the glyphs represent **predictions** of future eclipses and not records of past eclipses.

Using a crank-driven pointer, the user of the Mechanism could manually select a date of the year in the front dial. As he was doing this, a set of other pointers were driven by the gears of the Mechanism to show a variety of astronomical phenomena. In the front dial the position and the phase of the Moon was shown. In the back dials, the user could read the position of the Moon within the Metonic cycle (upper dial).

The Antikythera Mechanism was a complicated instrument. Therefore it is not curious that it was accompanied by an extensive *User's Manual*. As mentioned before, at least 2160 characters have been deciphered up to now. They all fall into three broad categories: astronomical inscriptions, geographical inscriptions and technical inscriptions. The word "ΣΤΗΡΙΓΜΟΣ" (stationary point) is mentioned several times, obviously referring to planetary stationary points. We were delighted to discover the word "ΙΣΠΑΝΙΑ" (Spain). According to the

Spanish archaeoastronomer Juan Antonio Belmonte, it is probably the first written evidence of the word "ΙΣΠΑΝΙΑ", which was adopted and established by the Romans during the 1st century B.C. Before then, the name "ΕΣΠΕΡΙΑ" (Hesperia) was used, indicating the location of Spain toward the West, where the Sun was setting in the evening (ΕΣΠΕΡΑ).

The new investigation of the *Antikythera Mechanism* has created word-wide interest both among the scientific community and the public. Responding to the demand for updated and authoritative information, the *Antikythera Mechanism Research Group* has created a web site:

http://www.antikythera-mechanism.gr

where new results are posted, including answers to basic questions, articles, pictures, videos and other relevant information.

It is evident that the Antikythera Mechanism is a very important record of the ability of ancient Greeks to work with advanced technological problems, offering innovative solutions that, even with present day standards, we cannot fail to admire and respect.

The Astronomy top stories of 2006

Among the top physics stories selected by AIP for the year 2006, five were related to astronomy. These top stories include:

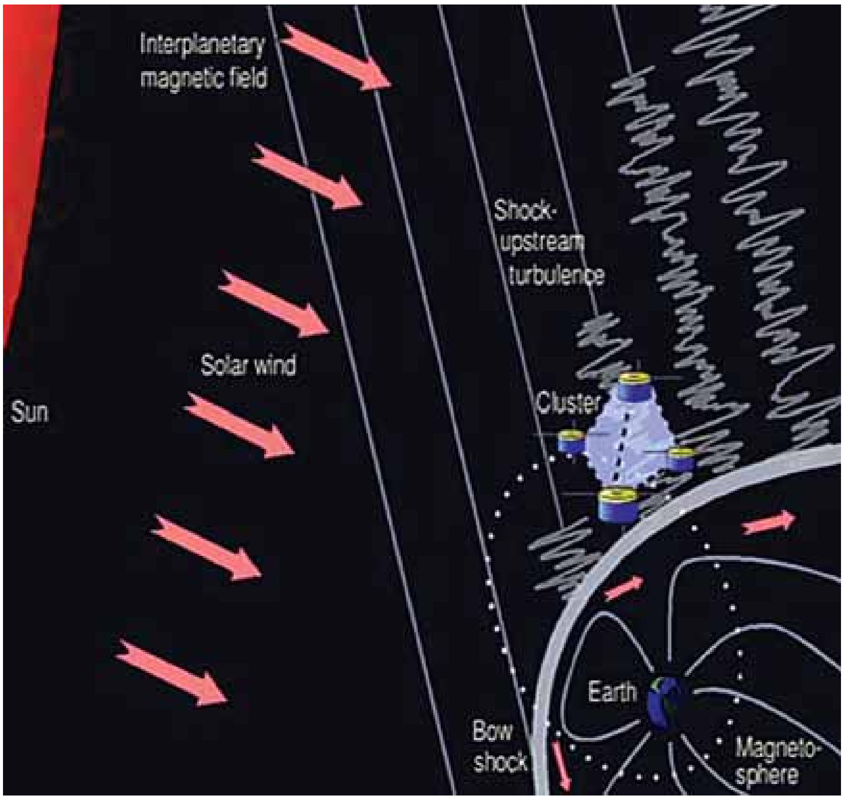
1.

The observation of many more supernovas at redshifts of z=1. See next article by V. Charmandaris.

2.

The first direct measurement of turbulence in space. Turbulence can be studied on Earth easily by mapping such things as the density or velocity of fluids in a tank. In space, however, where we expect turbulence to occur in such settings as solar wind, interstellar space, and the accretion disks around black holes, it's not so easy to measure fluids in time and space. Now, a suite of four plasma-watching satellites, referred to as Cluster, has provided the first definitive study of turbulence in space. The satellites are positioned just outside the bow shock ahead of Earth's magnetosphere and measure rapid variations in the magnetic field as solar wind particles arrive in Earth's vicinity. The fluid in question is the wind of particles streaming toward the Earth from the sun, while the location in question is the region just upstream of Earth's bow shock, the place where the solar wind gets disturbed and passes by the Earth's magnetosphere. The waves in the shock-upstream plasma, pushed around by complex magnetic fields, are observed to behave a lot like fluid turbulence on Earth. The data is primarily in accord with the leading theory of fluid turbulence, the so called Kolmogorov's model.

(http://www.aip.org/pnu/2006/split/802-2.html)



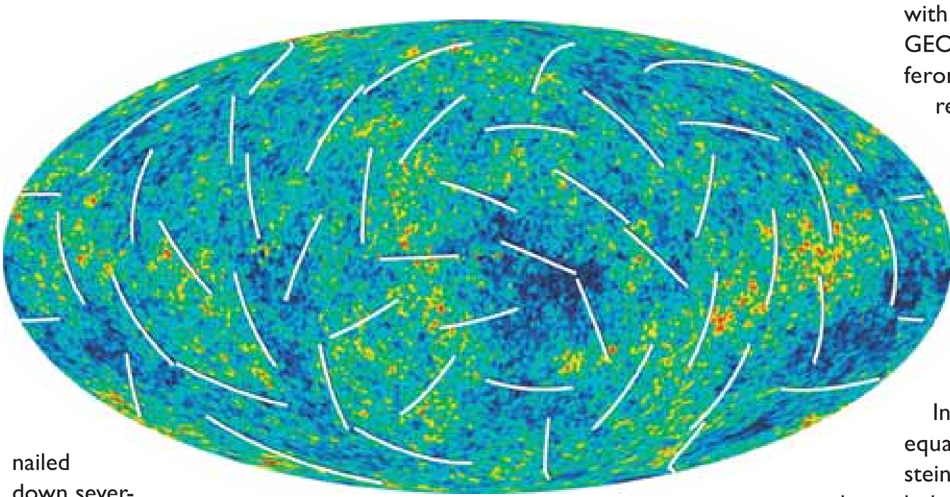
3.

The best direct test of Einstein's $E=mc^2$ formula Albert Einstein's formulation of how matter and energy are equivalent is an important enunciation of the principle of conserved energy. As far as we know, it is at work at the moment an atom bomb explodes, when the fissioning of uranium is exploited for making commercial electricity, or when an electron and positron annihilate inside a PET scanner. A new experiment –conducted by scientists from MIT, Université Laval in Quebec City, Canada, Florida State University, Oxford University, the National Institute of Standards and Technology, and the Institut Laue-Langevin in Grenoble, France– keeps careful account of both matter mass and electromagnetic energy for a process in which ions of sulphur and silicon absorb neutrons, transforming them into new isotopes as they emit gamma rays. In this transaction Einstein's equation is shown experimentally to be true at a level of 0.00004 percent, a factor of 55 better than the previous best test.

(http://www.aip.org/pnu/2006/split/761-1.html)

4.

A New Triumph for Inflation New WMAP measurements of the cosmic microwave background, including polarization information, help to sharpen cosmological numbers such as the age or the flatness of the universe. The inflationary big bang model has passed a crucial test as scientists working on the Wilkinson Microwave Anisotropy Probe (WMAP) released a long-awaited second set of data at a press conference held March 17, 2006. WMAP was launched in 2001 to map the anisotropies in the cosmic microwave background (CMB) with far greater precision than the Cosmic Background Explorer, the predecessor that first discovered the anisotropies in 1990s. The earlier release of WMAP data 3 years ago



nailed down several grand features of the universe that had previously been known only very roughly, including: the time of recombination (380,000 years after the big bang, when the first atoms were formed); the age of the universe; and the makeup of the universe. Since that 2003 announcement, WMAP researchers have painstakingly worked to reduce the uncertainties in their results. The big new thing in this announcement, based on three years of data, was the release of a map of the sky containing information about the microwaves' polarization. The microwaves are partly polarized, or oriented, from the time of their origin (emerging from the so called sphere of last scattering) and partly polarized by scattering, on their journey to Earth, from the pervasive plasma of mostly ionized hydrogen created when ultraviolet radiation from the first generation of stars struck surrounding interstellar gas. WMAP now estimates that this reionization, effectively denoting the era of the first stars, occurred 400 million years after the big bang, instead of 200 million years as had been previously thought. The main step forward is that smaller error bars, courtesy of the polarization map and the much better temperature map across the sky –with an uncertainty of only 200 billionth of a degree Kelvin– provide a new estimate for the inhomogeneities in the CMB's temperature. The simplest model, called Harrison-Zeldovich, posits that the spectrum of inhomogeneities should be flat; that is, the inhomogeneities should have the same variation at all scales. Inflation, on the other hand, predicts a slight deviation from this flatness. The new WMAP data for the first time measures the spectrum with enough precision to show a preference for inflation rather than the Harrison-Zeldovic spectrum –a test that was long-awaited as inflation's smoking gun.

(http://www.aip.org/pnu/2006/split/769-1.html)

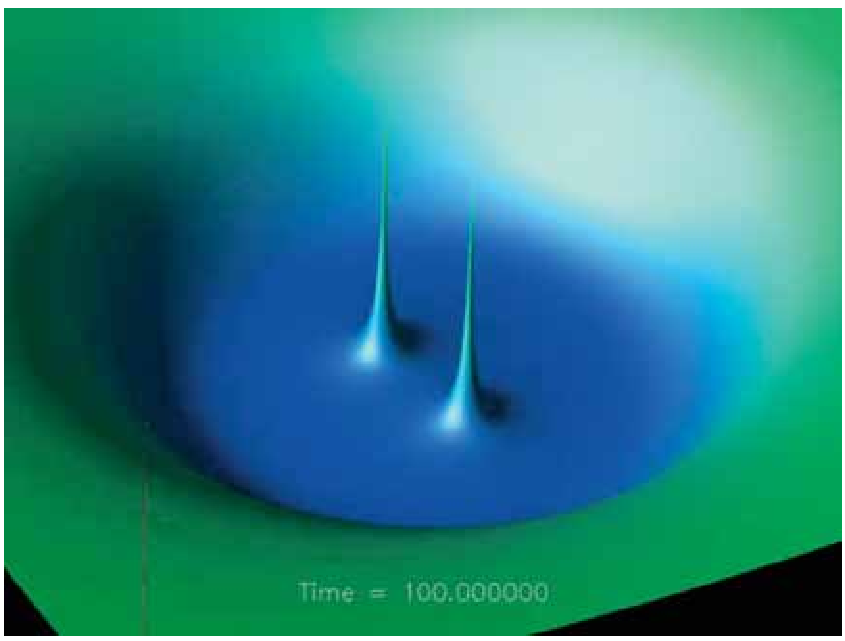
5.

Modeling gravity wave emissions from black hole mergers, the kinds of events that LIGO or LISA would possibly detect. Accurate calculations of the gravitational waveforms emitted during the collision of black holes can now be made. A new computer study of how a pair of black holes, circling each other, disturbs the surrounding space and sends huge gusts of gravitational waves outwards, should greatly benefit the experimental search for those waves with detectors such as the LIGO, Virgo, GEO600 and the planned Laser Interferometer Space Antenna (LISA). The relative difficulty of computer modeling of complicated physical behavior depends partly on the system in question and on the equations that describe the forces at work. To describe the complicated configuration of charges and currents, one uses Maxwell's equations to determine the forces at work.

In the case of black-hole binaries, the equations are those from Albert Einstein's theory of general relativity. Black holes encapsulate the ultimate in gravitational forces, and this presents difficulties for computations attempting to model behavior nearby. Nevertheless, physicists from various groups (Albert Einstein Institute, University of Jena, Penn-State University, University of Texas at Brownsville, Goddard Space Flight Center, Caltech) have now derived algorithms that not only produce accurate estimates of the gravitational waves of the inspiraling black holes, even over the short time intervals leading up to the final merger, but also is easily implemented on computers.

(http://www.aip.org/pnu/2006/split/771-1.html)

K.K.



Dark Energy at Redshift z=1[1]

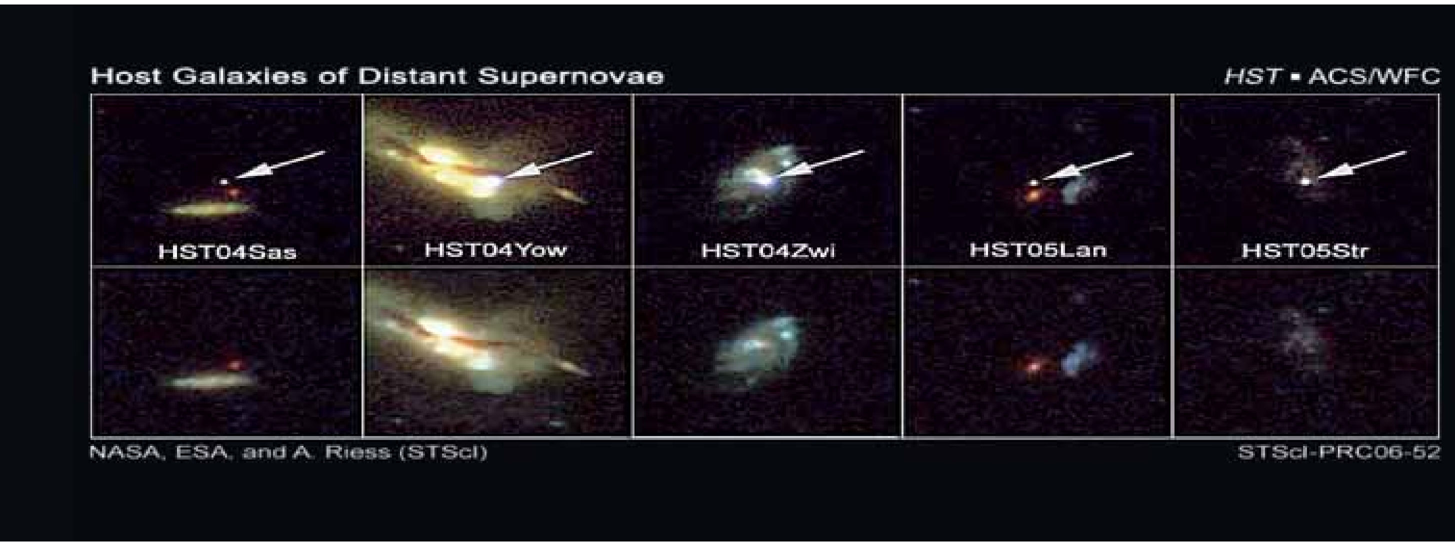
Dark energy, the unidentified force that's pushing the universe to expand at ever faster rates, was already at work as early as z=1, nine billion years ago, scientists reported during a NASA press conference on November 16, 2006. New Hubble Space Telescope sightings of distant supernova explosions support the explanation of dark energy as energy of the vacuum whose density has stayed constant throughout the universe's history. This cosmic acceleration was first revealed in 1998 by two separate teams of astrophysicists. By measuring the brightness of supernova explosions from up to seven billion light years ago, the scientists discovered an unexpected discrepancy. The supernovae appeared dimmer, and thus farther, than expected from their measured redshifts, that is supernovae at a given distance were less red shifted than expected. Because red shift measures how much light waves stretch as the universe expands, the lower red shift meant that, early on, the light from these distant supernovae had traveled in a universe that was expanding at a slower rate than the current universe (whose rate of expansion is known by other means). The then-widely accepted model of cosmology required instead that the universe be slowing down in its expansion, owing to the mutual gravitational tug of all of the matter and energy contained in it.

Using the Hubble, a team led by Adam Riess, an astrophysicist at the Space Telescope Science Institute and at Johns Hopkins University has now observed 23 new supernovae dating back to 8 to 10 billion years ago. That was an era of intense star formation, when galaxies were three times as bright as they are today. Until now, astronomers had only seen seven supernovae from that period, Riess said, too few to measure the properties of dark energy. The data, which will be publisned in the Astrophysical Journal on February 2007) show that the repulsive action of dark energy was already active at that time, and are consistent with a constant energy density –in other words, with an energy of the vacuum that does not dilute itself as the universe expands, eventually fueling an exponential growth of the universe. More complicated models with non-constant energy density –including a class known as quintessence models– are not completely ruled out, Riess said during the press conference: the new data still allows for variations of up to 45 percent from constant density. "It's still pretty crude," Riess said. For more recent ages, dark energy is known to have been constant up to a 10 percent variation. Lawrence Berkeley Lab astrophysicists Saul Perlmutter, who leads another supernova search, says that this is a step in the right direction, but that only a new, dedicated space telescope will be able to constrain the variation enough to convince scientists that dark energy is constant. Perlmutter says his team is also looking at supernovae from the distant past, focusing on ones from dust-free regions of the universe, in order to estimate the statistical and systematic uncertainties of the measurements.

The new data also confirm the reliability of supernovae as signposts of the universe's expansion. The particular kind of supernova used for this kind of measurement, called type Ia, takes place when a white dwarf star becomes heavier by accreting matter from a companion star, until –at a critical mass of about 1.4 times the mass of our sun– it undergoes a thermonuclear explosion. Virtually all type Ia supernovae have very standard characteristics –they all follow the same cycle, have roughly the same brightness and relative abundances of elements, as seen from their spectra. This makes astrophysicists believe that type Ia's have a predictable intrinsic brightness, making their distances easy to estimate. It now appears that the same is true for the oldest supernovae, even though the elemental composition of the universe as a whole was different back then.

V.Ch.

1. Reprinted from the NASA HQ Press office (http://www.nasa.gov/hubble) and the Physics News Update.



Skinakas observatory – Crete, Greece
A General Description of Infrastructure and Activities

by Yiannis Papamastorakis,
Department of Physics, University of Crete, Greece
www.skinakas.org.gr

1. Location
2. Founding Institutions
3. Seeing Characteristics
4. Telescopes and Instruments
5. Research Activities
6. Educational & Training Activities

1. Location

Skinakas Observatory (Longitude 24° 53' 57" East, Latitude 35° 12' 43" North) is located on the Ida mountain in Central Crete at an altitude of 1750 m, 25 km line-of-sight distance and 60 km by road from the city of Heraklion. On the road, 20 km before Skinakas, one finds the traditional town of Anoghia, which is well known for its significant role in the recent Cretan history. About 6 km line-of-sight west of the Observatory, lies Ideon Andron, the famous cave where, according to Myth, the infant Zeus was raised. At the western outskirts of Heraklion, on the way to Skinakas Observatory, are located the Physics Department of the University of Crete (UoC), with the Astronomy Laboratory, and the Foundation for Research and Technology – Hellas (FORTH). From there the driving time to Skinakas Observatory is about 1.5 hours.

Fig. 1: Aerial photograph of Skinakas Observatory

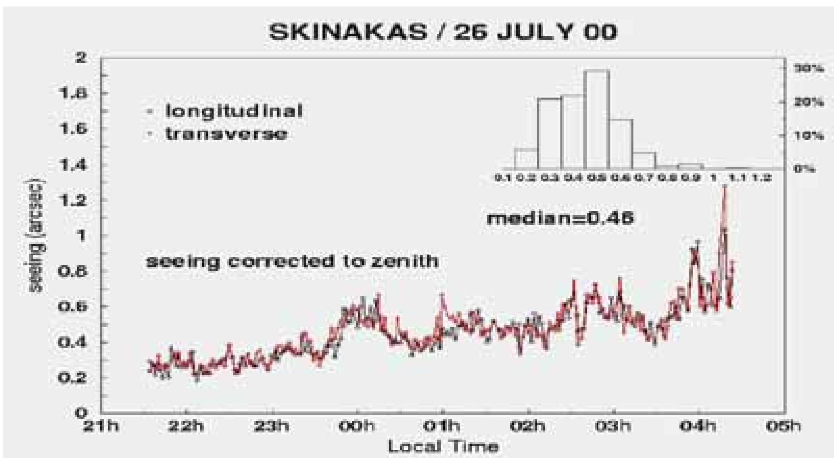


Fig. 2: Seeing measurement using DIMM method

2. Founding Institutions

Skinakas Observatory was jointly founded by the UoC, FORTH and the Max-Planck Institut für Extraterrestrische Physik (MPE, Garching) in 1984 as a research and educational facility.

3. Seeing Characteristics

Using a two-aperture Differential Image Motion Monitor (DIMM), the seeing over Skinakas was measured during two campaigns in 2000 and 2001. For a total of 45 nights the median seeing was found to be less than 0.7 arcsec. Seeing values as low as 0.25 arcsec have been observed, indicating that Skinakas is an excellent site for astronomical observations.

4. Telescopes and Instruments

On the summit of Skinakas mountain there are three telescopes:

- A **1.3 m modified Ritchey-Chretien** telescope, which has been in working order since 1995. It has an f/8 focal ratio with a corresponding scale of 0.02 arcsec/μm in normal mode. With the use of a Focal Reducer, the scale is multiplied by a factor of 1.87. The telescope works together with an off-axis guiding unit, which provides tracking with an accuracy of 0.2 arcsec.
- A **wide field Schmidt-Cassegrain 30 cm** telescope, which was installed on Skinakas in 1986 as the first tel-

Fig.3: 1.3m Ritchey-Chretien telescope *(left)*, 30cm Scmidt-Cassegrain telescope *(top right)*, 60cm Cassegrain telescope *(lower right)*

escope there. It is of f/3.2 focal ratio, computer controlled with an autoguiding unit.

- In the summer of 2006, a **60 cm Cassegrain telescope** was installed in collaboration with Tübingen University. It is of f/8.2 focal ratio and will operate in robotic mode with a Peltier cooled, 4006 x 2672, 9 μm pixel, CCD camera.

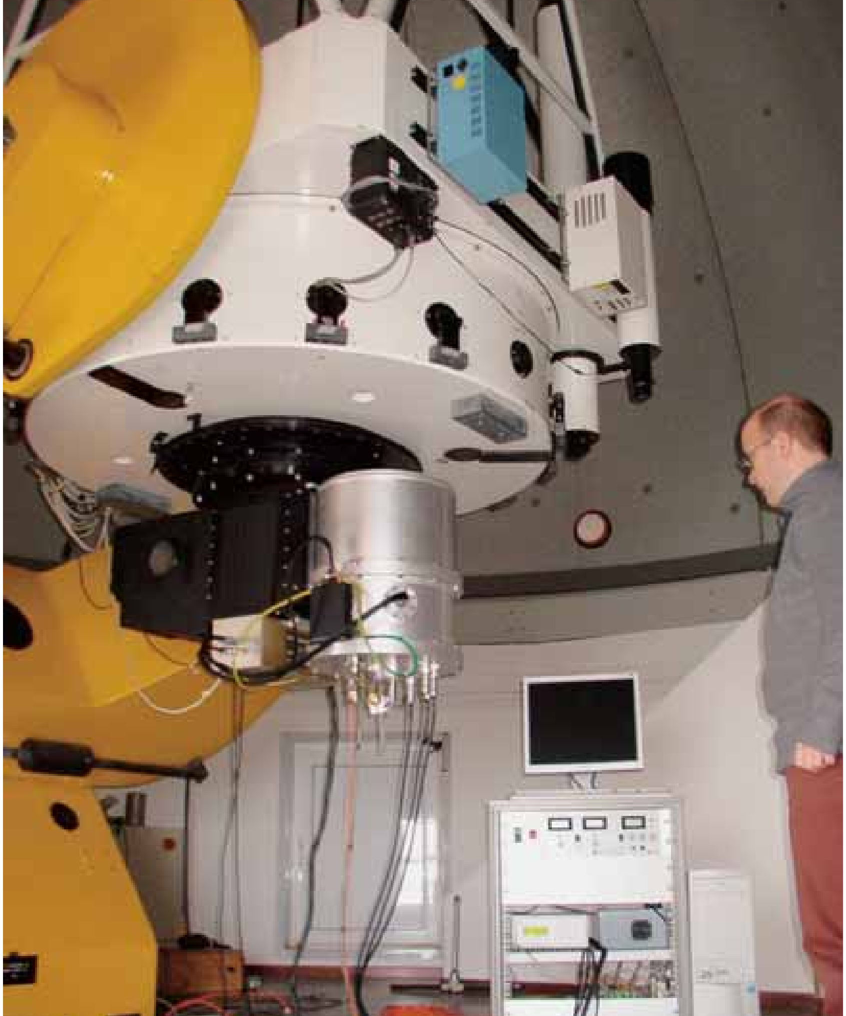
Several **CCD cameras** are used for imaging or spectroscopy. These are three LN2 cooled cameras, a Photometrics front illuminated Thomson chip 1024 x 1024, with 19 μm pixel size, a Photometrics back illuminated SITe chip 1024 x 1024, with 24 μm pixel size, an ISA back illuminated SITe chip 2000 x 800, with 15 μm pixel size, and a newly gained deep Peltier cooled Andor camera back illuminated E2V chip 2048 x 2048, with 13.5 μm pixel size.

For photometric observations with the 1.3 m telescope (in normal mode or with the Focal Reducer) the standard **U, B, V, R, I broadband filters** are available together with a set of **Strömgren filters (u, v, b, y, H_β)**. Also, **16 narrowband interference filters** are available covering the most important emission lines in the optical region. Several of these filters can also be used with the 30 cm telescope for wide field imaging.

For spectroscopic observations, the Focal Reducer installed on the 1.3 m telescope is used as a **slit spectrograph** with slit widths 80, 160, 320 and 640 μm. Using one of the 10 blazed gratings results in dispersions ranging from 530 Å/mm down to 25 Å/mm.

A high resolution **fiber-fed Echelle Spectrograph** with dispersion 3 Å/mm was commissioned in the Summer of 2006 as an instrument of the 1.3 m telescope. It is a bench mounted spectrograph in white pupil arrangement using an Echelle R2.14, 31.6 grooves/mm grating with two prisms as cross dispersion elements. The spectrograph is currently working with a 100 μm diameter fiber achieving a resolution of R~19000. With a microlens coupled 50 μm fiber –to be installed in the Spring of 2007– it is expected to achieve a resolution of up to 38,000.

Fig.4: The Echelle Spectrograph



▲ *Fig.5:* Near Infrared Camera mounted on the 1.3m Skinakas telescope

▼ *Fig. 6:* OPTIMA-Burst mounted on the 1.3m telescope

Another significant addition to the infrastructure at Skinakas is a **Near-Infrared camera** (NIR), manufactured by Fraunhofer IOF, Jena and commissioned in the Summer of 2006 on the 1.3 m telescope. It is a f/7.7 Offner design with a Rockwell Hawaii Array of 1024 x 1024, with 18.5 μm pixel size. It covers the spectral range between 1 and 2.4 μm and includes two sets of filters, 5 narrowband (FeII/1644 nm, H2/2122 nm, H2/2144 nm, BrG/2166 nm, CO/2295 nm) and the broadband J, H, and K.

Another instrument provided and operated by the researchers of the MPE (G. Kanbach's group) on the 1.3 m Skinakas telescope is **OPTIMA (Optical Pulsar TIMing Analyzer)**, a fiber-fed high speed photo-counter. It utilizes sensitive avalanche photo-diodes detecting the fast intensity variability of objects with time resolution of μsec. The improved version of the instrument, OPTIMA-Burst, run on a three month campaign in the Summer of 2006 on the 1.3 m telescope, to observe gamma-ray bursts immediately after detection by the SWIFT satellite.

There is a **Microwave link** connecting Skinakas Observatory with the UoC and FORTH with a 2 Mbit/sec line.

The telescopes and the basic instruments (Autoguiders, Filter-wheel, CCD cameras) can be controlled **remotely** or run in **robotic mode**. Live demonstrations of the remotely controlled use of the 1.3 m telescope were carried out from Bulgaria, CERN-Geneva, FORTH-Heraklion and Bremen-Germany in 2006.

5. Research Activities

The current research projects, conducted by the members of the Astrophysics Group in Crete, that involve the acquisition and use of optical data from Skinakas Observatory include:

- Deep narrow band observations (performed with both the 0.3 m and 1.3 m telescopes at Skinakas) complemented by deep long slit spectra at selected positions of the target objects, are used to study the morphology and the energy distribution of Planetary Nebulae and Supernova Remnants.
- Photometry and spectroscopy of Be/X-ray binaries with a compact star companion, using data from the 1.3 m telescope. The main objective is

to characterize the optical/IR variability time scales of these objects by monitoring the evolution of the disc over many years.

- Photometry and spectroscopy of field stars in order to optically identify newly discovered X-ray sources by satellites like SWIFT and INTEGRAL.
- Fast photometry of BL Lac objects, on time scales of ~minutes, with the use of different optical band filters. The main aim is to characterize the intra-night flux and spectral variations of these objects. Members of the group also participate in many of the World Earth Blazar Telescope campaigns.
- Photometry of time-scales of minutes/days is also performed to radio-quiet AGN, with central engines of small black-hole mass.
- Photometry and spectroscopy of X-ray sources in the Local Group Galaxies M33 and M31 is being performed with the aim of identifying them. Furthermore, R-band and Hα nightly monitoring of the central part of M31 is also conducted for the detection of new novae.

Previous research programs included among others:

- Structure of Spiral Galaxies
- Photometry of Star Clusters
- RR Lyrae Variables
- Interaction of Cometary Tails with the Solar Wind

Fig. 7: Supernova Remnant CTB1 (Hα+N[II] filter)

The total number of refereed publications based (partly or solely) on Skinakas Observations exceeds 80.

6. Educational & Training Activities

A large number of Astrophysics courses are offered to under- and post-graduate students in the Physics Department as part of the teaching responsibilities of the faculty members. At Skinakas Observatory, students have the possibility to do their Diploma Thesis on Observational Astrophysics participating in the research projects highlighted above. This involves analysis and interpretation of data in the various fields of interest. There are currently 3 undergraduate, 2 master's-level and 1 PhD students, working on an Astrophysics related Thesis project in the Physics Department of the UoC.

On a European level, undergraduate students from the International University of Bremen come for regular summer visits to Skinakas Observatory in order to be introduced in Observational Astronomy.

In the framework of two recent research projects (one sponsored by the Greek Ministry of Transport & Communication and the other by the EU as part of the eTEN programme), the 1.3 m Skinakas telescope has been remotely operated from Secondary School classes as part of their Astronomy education.

Fig. 8: Comet Hale-Bopp

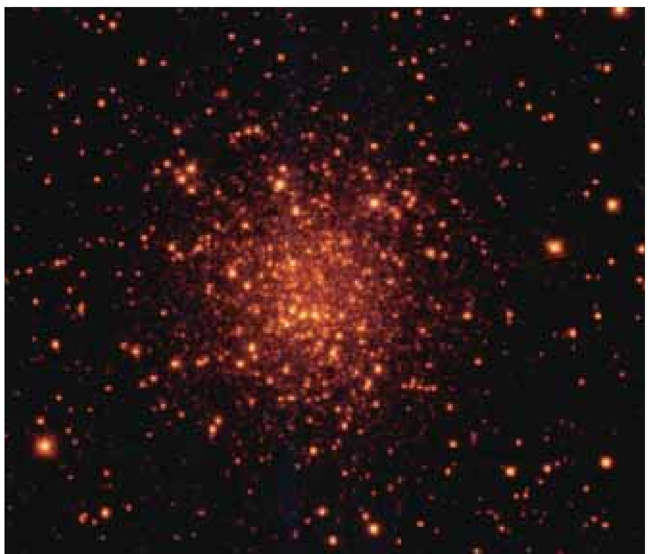


Fig. 9: Globular star cluster NGC 6426

Eclipsing Binaries: Tools for Calibrating the Extragalactic Distance Scale

by Alceste Bonanos
Department of Terrestial Magnetism, Carnegie Institute of Washington, USA

Abstract

In the last decade, over 7000 eclipsing binaries have been discovered in the Local Group through various variability surveys. Measuring fundamental parameters of these eclipsing binaries has become feasible with 8 m class telescopes, making it possible to use eclipsing binaries as distance indicators. Distances obtained using eclipsing binaries provide an independent method for calibrating the extragalactic distance scale and thus determining the Hubble constant. This method has been used for determining distances to eclipsing binaries in the Magellanic Clouds and the Andromeda Galaxy and most recently to a detached eclipsing binary in the Triangulum Galaxy by the DIRECT Project. The increasing number of eclipsing binaries found by microlensing and variability surveys also provide a rich database for advancing our understanding of star formation and evolution.

1. Introduction

The last decade has seen a dramatic increase in the number of extragalactic eclipsing binaries discovered. Most of these have been found as a side product of the microlensing surveys towards the Large and Small Magellanic Clouds (LMC and SMC). Starting in the early 1990s the EROS Experiment, the MACHO Project, the Microlensing Observations in Astrophysics (MOA) and the OGLE Project began monitoring the Magellanic Clouds with 1 meter telescopes in a search for dark matter in the form of massive compact halo objects. As a side product they have discovered thousands of variable stars, including many eclipsing binaries. The 75 EROS binaries in the LMC published by Grison et al. (1995) doubled the known binaries in the galaxy at the time. Soon after, the MOA group released a catalog of 167 eclipsing binaries in the SMC (Bayne et al. 2002), followed by the extensive catalogs of the OGLE-II Project which comprise of 2580 eclipsing binaries in the LMC (Wyrzykowski et al. 2003) and 1350 in the SMC (Wyrzykowski et al. 2004). A catalog of the eclipsing binaries found by the MACHO project with ~4500 binaries in the LMC and 1500 in the SMC is underway. Note that some of these binaries are foreground or galactic. The SuperMACHO project, using the CTIO Blanco 4 meter telescope, has surveyed the Magellanic Clouds down to VR~23 mag (Huber et al. 2005), extending the sample to include solar type stars, some of which will be W UMa variables. The first detection of an extragalactic W UMa was recently made by (Kaluzny et al. 2006), with photometry from the 6.5 meter Magellan telescopes at Las Campanas, Chile.

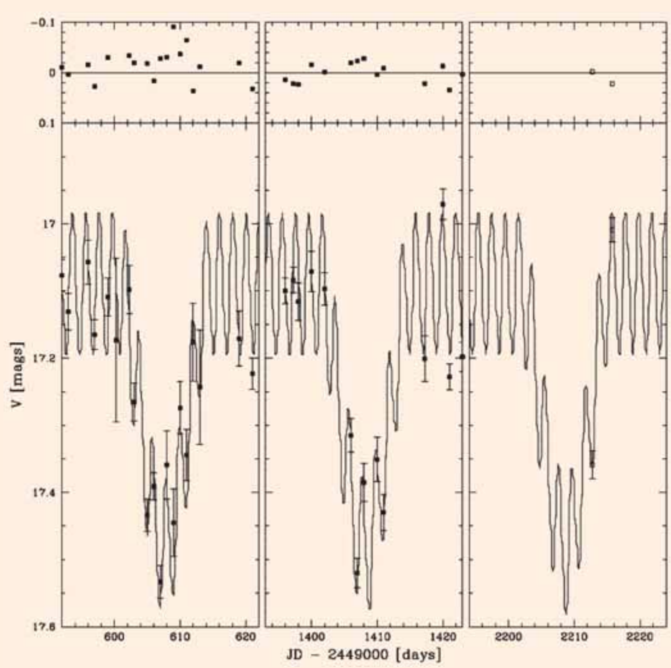


Figure 1: Primary eclipses of SC16 in V with curve of best fit. Upper panels show residuals in magnitudes. Filled boxes indicate observations from the MACHO project, open boxes observations from the OGLE project (from Alcock et al. 2002).

Fewer eclipsing binaries are known in more distant galaxies, partly due to their faintness and the necessity of large amounts of time on medium size telescopes (2-4 meters) to obtain good quality light curves. Two microlensing surveys are underway for M31. The Wendelstein Calar Alto Pixellensing Project (Fliri et al. 2006) discovered 31 eclipsing binaries in the bulge of M31. The variable star catalog released by the POINT-AGAPE Survey (An et al. 2004) has not been searched systematically for eclipsing binaries, but is bound to contain some among the 35000 variables.

The DIRECT Project (see Stanek et al. 1998; Bonanos et al. 2003) began monitoring M31 and M33 in 1996, specifically for Cepheids and detached eclipsing binaries (DEBs) with the 1.2 m telescope on Mount Hopkins, Arizona. In M31, a total of 89 eclipsing binaries were found in the 6 fields surveyed. A variability survey using the 2.5 m Isaac Newton telescope by Vilardell et al. 2006 has found 437 eclipsing binaries in M31, bringing the total to over 550 eclipsing binaries. In M33, the DIRECT Project has found 148 eclipsing binaries (see Mochejska et al. 2001, and references therein). Eclipsing binaries have also been discovered by the Araucaria Project in NGC 6822, a dwarf irregular galaxy in the Local Group (Mennickent et al. 2006).

It is worth mentioning the eclipsing binaries discovered beyond the Local

Group. The first such discovery was made back in 1968 by Tammann & Sandage, who presented the light curve of a 6 day period binary in NGC 2403 (M81 group) with B~22 mag. More recently, the Araucaria Project has discovered a binary in NGC 300 (Sculptor group). Mennickent et al. (2004) present the light curve of the B~21.5 mag detached eclipsing binary in this galaxy.

Finally, the discovery of 3 Cepheid binaries in the LMC by Udalski et al. (1999) and Alcock et al. (2002) provides a new way of calibrating the Cepheid period-luminosity relation and the extragalactic distance scale. The light curve of one of these (SC16) is shown in Figure 1.

2. Eclipsing Binaries as Distance Indicators

Eclipsing binaries provide an accurate method of measuring distances to nearby galaxies with an unprecedented accuracy of 5% —a major step towards a very accurate and independent determination of the Hubble constant. Reviews and history of the method are presented by Andersen (1991) and Paczynski (1997). The method requires both photometry and spectroscopy of an eclipsing binary. From the light and radial velocity curve the fundamental parameters of the stars can be determined accurately. The light curve yields the fractional radii of the stars, which are then combined with the radial velocity curves to yield the physical radii and effective temperatures. The velocity semi-amplitudes determine both the mass ratio and the sum of the masses, thus the individual masses can be solved for. Furthermore, by fitting synthetic spectra to the observed ones, one can infer the effective temperature, surface gravity and luminosity. Comparison of the luminosity of the stars and their observed brightness yields the reddening of the system and distance.

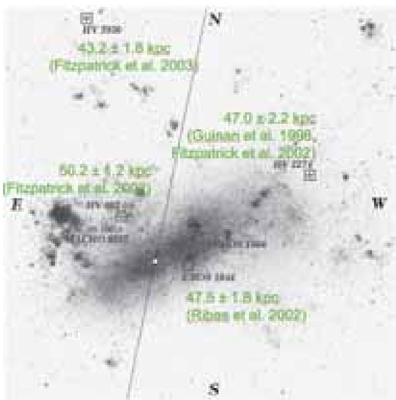


Figure 2: Photo of the LMC (from Fitzpatrick et al. 2003), indicating the locations of eclipsing binaries with distance determinations and of two future targets, EROS 1066 and MACHO 0537. The optical center of the LMC's bar is indicated by the open box, and the LMC's line of nodes is shown by the line. The "near side" of the LMC is to the east of the line of nodes. The location of SN 1987A is also indicated.

Measuring distances with eclipsing binaries is an essentially geometric method and thus accurate and independent of any intermediate calibration steps. With the advent of 8 m class telescopes, eclipsing binaries have been used to obtain accurate distance estimates to the LMC, SMC, M31 and M33; these results are presented below.

3. Eclipsing Binary Distances to the Magellanic Clouds and M31

The first extragalactic distance measurement using a detached eclipsing binary system was published by Guinan et al. (1998) and demonstrated the great potential and usefulness of EBs as distance indicators. The detached 14^{th} mag system HV 2274 was observed with the Faint Object Spectrograph (FOS) on-board the *Hubble Space Telescope*. The UV/optical spectrophotometry was used to derive the radial velocity curve and reddening. The distance to HV 2274 was determined to be 47.0±2.2 kpc (Guinan et al. 1998, Fitzpatrick et al. 2002). Distances to 3 more systems in the LMC have been determined: the detached 15^{th} magnitude system HV 982 (Fitzpatrick et al. 2002) at a distance of 50.2±1.2 kpc, the 15^{th} magnitude detached EROS 1044 (Ribas et al. 2002) at 47.5±1.8 kpc and the 14^{th} magnitude semi-detached system HV 5936 at 43.2±1.8 kpc (Fitzpatrick et al. 2003). These support a "short" distance scale to the LMC, in contrast to the LMC distance of 50 kpc adopted by the Key Project (Freedman et al. 2001). The spread in the distances is most likely an indication of the intrinsic extent of the LMC along the line of sight.

Harries et al. (2003) and Hilditch et al. (2005) have conducted a systematic spectroscopic survey of eclipsing binaries in the SMC, obtaining fundamental parameters and distances to 50 eclipsing binary systems. Their sample was selected from the OGLE-II database of SMC eclipsing binaries as the brightest systems (B<16 mag) with short periods (P_{orb}<5 days) to increase the efficiency of multi-fiber spectroscopy over a typical observing run. The mean true distance modulus from the whole sample is 18.91±0.03 (random) ±0.1 (systematic) and the implied LMC distance is 18.41±0.04 (random) ±0.1 (systematic), again in support of the "short" distance scale.

M31 and M33, being the nearest spiral galaxies, are crucial stepping-stones in the extragalactic distance ladder. Ribas et al. (2005) have determined the first distance to a spiral galaxy, specifically to a semi-detached system (V=19.3 mag) in M31. Note that, at such distances, the location of the binary within the galaxy has an insignificant effect on the distance (<1%). Light curves for the system in M31 were obtained from the survey of Vilardell et al. (2006) with the 2.5 m Isaac Newton telescope and spectroscopy with the 8 m Gemini telescope using GMOS. Such stars are at the limit of current spectroscopic capabilities. The resulting distance is 772±44 kpc and distance modulus is 24.44±0.12 mag, in agreement with previous distance determinations to M31.

4. DIRECT Distance to a Detached Eclipsing Binary in M33

(a) Motivation

The DIRECT Project (see Stanek et al. 1998; Bonanos et al. 2003) aims to measure distances to the nearby Andromeda (M31) and Triangulum (M33) galaxies with eclipsing binaries and the Baade-Wesselink method for Cepheids. It began surveying these galaxies in 1996 with 1 m class telescopes. The goal of the DIRECT Project is to replace the current anchor galaxy of the extragalactic distance scale, the LMC, with the more suitable spiral galaxies in the Local Group, M31 and M33. These are the nearest spiral galaxies to ours, yet more than ten times more distant than the LMC and therefore more difficult to observe stars in them. The Cepheid period-luminosity relation is used to measure distances to a few tens of Mpc, while Type Ia supernovae are used to probe distances out to a few hundred Mpc. Galaxies hosting both Cepheids and Type Ia supernovae become calibrators of the luminosities of supernovae, which are used to determine the Hubble constant, H_0.

How is the Cepheid period-luminosity calibrated? Figure 3 shows 84 recent measurements of the distance modulus of the LMC using 21 methods (Figure is taken from Benedict et al. 2002). The large spread in the different measurements is quite disturbing. There are several problems with using the LMC as the anchor of the distance scale, which demand its replacement. The zero point of the period-luminosity relation is not well determined and the dependence on metallicity remains controversial. There is increasing evidence for elongation of the LMC along the line of sight that complicates a distance measurement. One has to additionally include a model of the LMC when measuring distances, which introduces systematic errors. Finally, the reddening across the LMC has been shown to be variable (Nikolaev et al. 2004), which has to be carefully accounted for. These effects add up to a 10-15% error in the distance to the LMC, which in the era of precision cosmology is unacceptable. The replacement of the current anchor galaxy of the distance scale with a more suitable galaxy or galaxies is long overdue. Furthermore, the *Hubble Space Telescope* Key Project (Freedman et al. 2001) has measured the value of H_0 by calibrating Cepheids measured in spiral galaxies and calibrating secondary indicators and found $H_0=72\pm8$ km s^{-1} Mpc^{-1}. This result is heavily dependent on the distance modulus to the LMC they adopt (18.50 mag or 50 kpc).

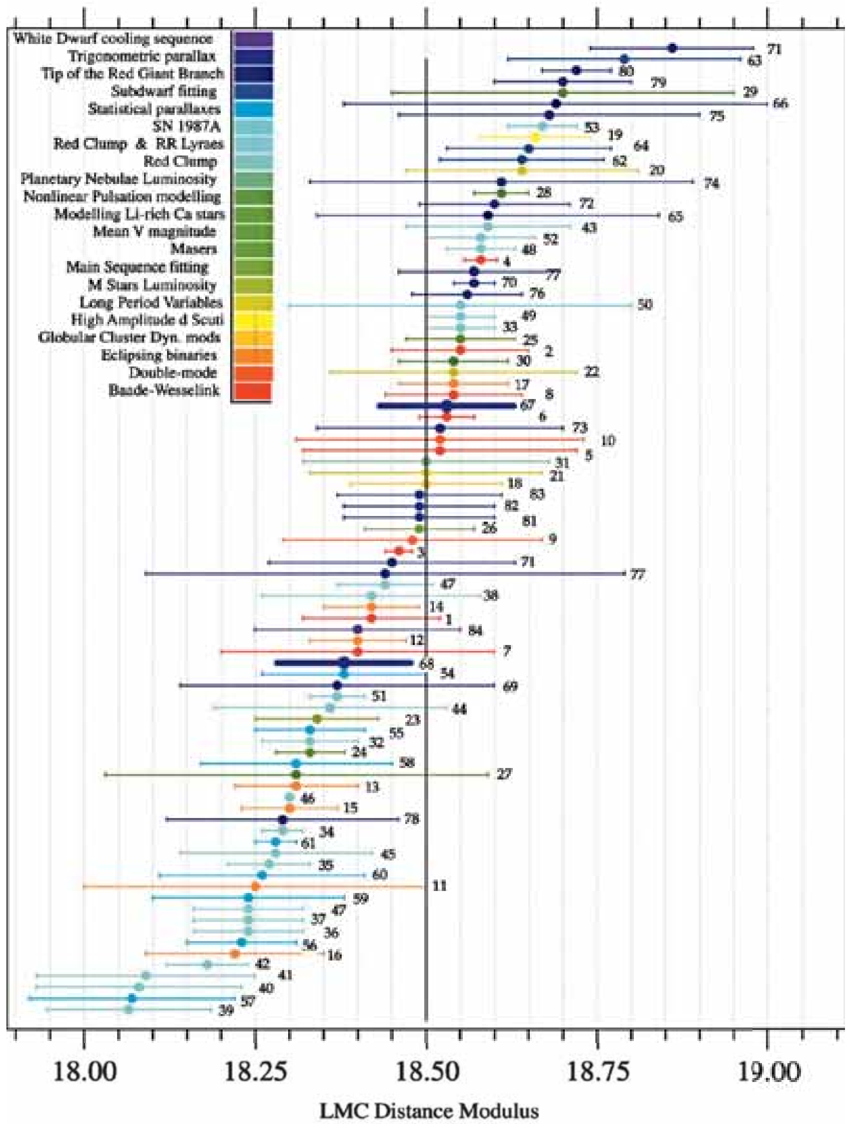


Figure 3: Recent determinations of the distance modulus of the LMC. Colors represent the various methods, while the numbers refer to the individual investigations (from Benedict et al. 2002, see paper for details). The thick vertical line denotes the distance modulus adopted by the HST Distance Scale Key Project (Freedman et al. 2001).

(b) DIRECT Observations

The DIRECT project involves three stages: surveying M31 and M33 in order to find detached eclipsing binaries and Cepheids; once discovered selecting and following up the best targets with medium size telescopes (2-4 m class) to obtain more accurate light curves and lastly, obtaining spectroscopy which requires 8-10 m class telescopes. DIRECT completed the survey stage in 1996-1999 with 200 full/partial nights on 1 m class telescopes in Arizona. Follow up observations of the 2 best eclipsing binaries were obtained in 1999 and 2001 using the Kitt Peak 2.1 m telescope in Arizona. The total number of eclipsing binaries found in M33 were 237, however only 4 are bright enough ($V_{max}<20$ mag) for distance determination with currently available telescopes. The criteria for selection include a detached configuration (stars are well within their Roche lobes) and deep eclipses, which remove degeneracies in the modeling and a short period (<10 days) that makes follow up observations feasible.

Bonanos et al. (2006) presented the first distance determination to a detached eclipsing binary (DEB) in M33 that was found by Macri et al. (2001). D33J013346.2+304439.9 is located in the OB 66 association shown in Figure 4. Follow up optical data were obtained in order to improve the quality of the light curve and additional infrared observations were made using the 8 m Gemini telescope in order to better constrain the extinction to the system. Spectra of the DEB were obtained in 2002-2004 with the 10-meter Keck-II telescope and 8 m Gemini telescope on Mauna Kea. Note that ~4 hours of observations per epoch were required for radial velocity measurements, a large investment of 8-10 m class telescope time. Absorption lines from both stars are clearly resolved in the spectrum, making it a double lined spectroscopic binary.

Careful modeling with non-local thermodynamic equilibrium model spectra yielded effective temperatures $T_{eff1}=37000\pm1500K$ and $T_{eff2}=35600\pm1500K$. The primary star is defined as the hotter star eclipsed at phase zero. We measured radial velocities from the spectra and from the light and radial velocity curves derived the parameters of the DEB components. The V-band light curve model fit for the DEB is shown in Figure 5. Note that the deviation of the secondary eclipse from phase 0.5 is due to the eccentricity of the system. The radial velocity curve is presented in Figure 6. The rms residuals are 26.0 km s^{-1} for the primary and 28.0 km s^{-1} for the secondary star. We find the DEB components to be O7 type stars with masses: M_1=33.4±3.5 Mo, M_2=30.0±3.3 Mo and radii R_1=12.3±0.4 Ro, R_2=8.8±0.3 Ro.

(c) Distance Determination

Having measured the temperatures of the stars from the spectra, we computed fluxes and simultaneously fit the optical and near-infrared BVRJHK_s photometry. The best fit that minimized the photometric error over the 6 photometric bands yielded a distance modulus to the DEB and thus M33 of 24.92±0.12 mag (964±54 kpc). The fit of the reddened model spectrum to the photometry is shown in Figure 7. Thus the first DIRECT result is a 6% distance to M33, which is very accurate considering the faintness of the system and limited spectroscopy.

There are several avenues for improving the distance to M33 and M31 using eclipsing binaries. Wyithe & Wilson (2002) propose the use of semi-detached eclipsing binaries to be just as good or better distance indicators as detached eclipsing binaries, which have been traditionally considered to be ideal. Semi-detached binaries provide other benefits: their orbits are tidally circularized and their Roche lobe filling configurations provide an extra constraint in the parameter space, especially for complete eclipses. Bright semi-detached binaries in M33 or M31 are not as rare as DEBs, and are easier to follow-up spectroscopically, as demonstrated by Ribas et al. (2005) in M31. Thus, for the determination of the distances to M33 and M31 to better than 5% we suggest both determining distances to other bright DEBs and to semi-detached systems found by DIRECT and other variability surveys. Additional spectroscopy of the DEB would also improve the current distance determination to M33, since the errors are dominated by the uncertainty in the radius or velocity semi-amplitude.

How does the M33 DIRECT distance compare to previous determinations? Table 1 presents a compilation of 13 re-

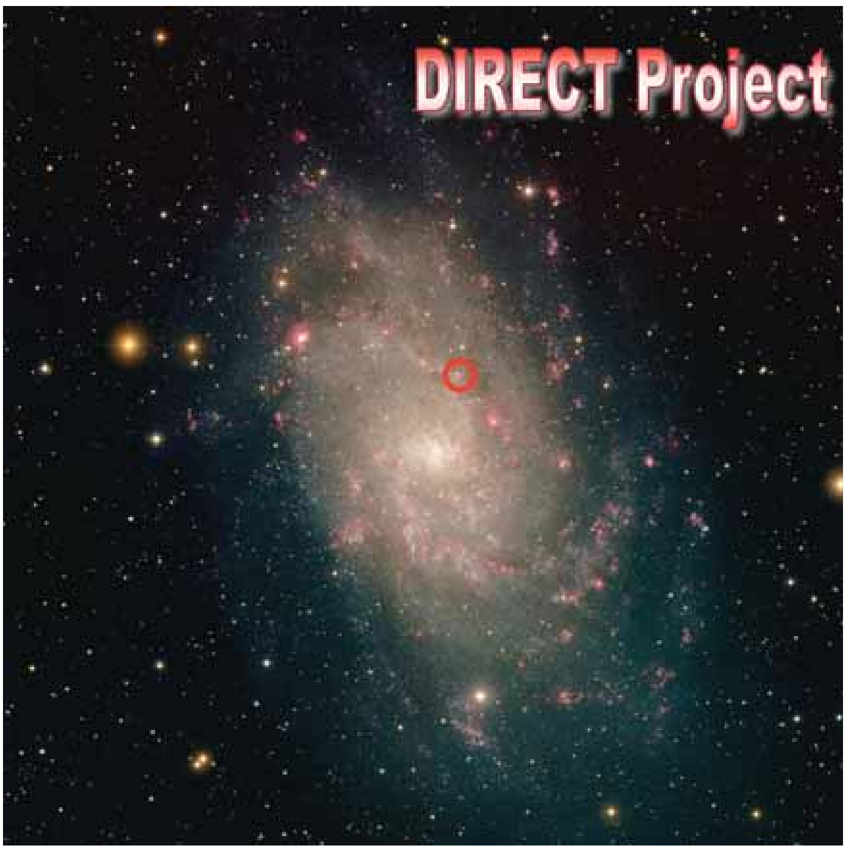


Figure 4: Color image of M33 (B,V, I and Hα) indicating the location of the OB 66 association that hosts the DEB. Credit: T.A.Rector (NRAO/AUI/NSF and NOAO/AURA/NSF) and M.Hanna (NOAO/AURA/NSF).

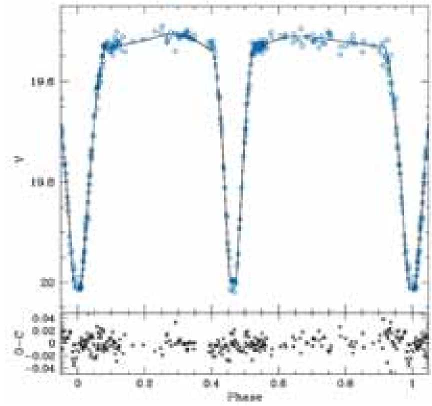


Figure 5: V-band phased light curve of the DEB with model fit from the Wilson-Devinney program. The blue circles correspond to the 278 V-band observations and the solid line to the model; the rms is 0.01 mag (from Bonanos et al. 2006).

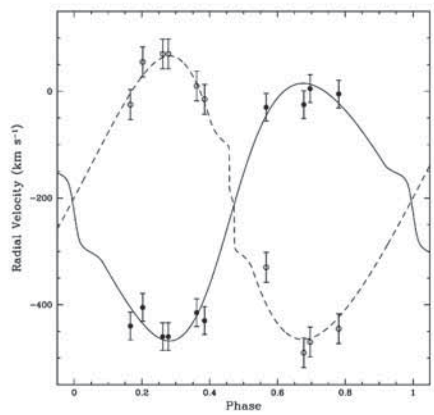


Figure 6: Radial velocities for the DEB measured by two-dimensional cross correlation with synthetic spectra. Model fit is from Wilson-Devinney program. Error bars correspond to the rms of the fit: 26.0 km s^{-1} for the primary (filled circles) and 28.0 km s^{-1} for the secondary (open circles) (from Bonanos et al. 2006).

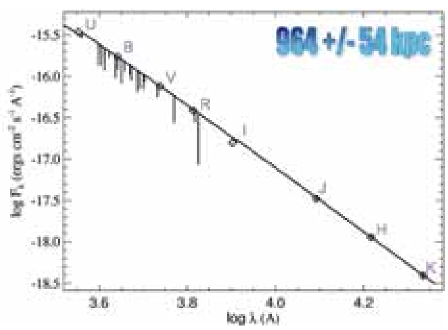


Figure 7: Fit of the reddened DEB model spectrum to the BVRJHKs ground-based photometry. Overplotted is the U and I photometry from Massey et al. (2006). The distance modulus to the DEB and thus M33 is found to be 24.92±0.12 mag (964±54 kpc) (from Bonanos et al. 2006).

cent distance determinations to M33 ranging from 24.32 to 24.92 mag, including the reddening values used. Our measurement although completely independent yields the largest distance with a small 6% error, thus is not consistent with some of the previous determinations. This possibly indicates unaccounted sources of

systematic error in the calibration of certain distance indicators. Note the Freedman et al. (2001) distance to M33 is *not* consistent with the DIRECT measurement. This could be due to their ground based photometry which is likely affected by blending, but highlights the importance of securing the anchor of the extragalactic distance scale. The eclipsing binary distances to the LMC presented above indicate a shorter distance to the LMC. Combined with eclipsing binary distances to M31 and M33, we should soon be able to reduce the errors in the distance scale and thus the Hubble constant to 5% or better.

Study	Method[a]	Distance Modulus	Reddening
Bonanos et al. (2006)	DEB	24.92 ± 0.12	$E(B-V) = 0.09 \pm 0.01$
Sarajedini et al. (2006)	RR Lyrae	24.67 ± 0.08	$\sigma_{E(V-I)} = 0.30$
Brunthaler et al. (2005)	Water Masers	24.32 ± 0.45	—
Ciardullo et al. (2004)	PNe	$24.86^{+0.07}_{-0.11}$	$E(B-V) = 0.04$
Galleti et al. (2004)	TRGB	24.64 ± 0.15	$E(B-V) = 0.04$
McConnachie et al. (2004)	TRGB	24.50 ± 0.06	$E(B-V) = 0.042$
Tiede et al. (2004)	TRGB	24.69 ± 0.07	$E(B-V) = 0.06 \pm 0.02$
Kim et al. (2002)	TRGB	$24.81 \pm 0.04(r)^{+0.15}_{-0.11}(s)$	$E(B-V) = 0.04$
Kim et al. (2002)	RC	$24.80 \pm 0.04(r) \pm 0.05(s)$	$E(B-V) = 0.04$
Lee et al. (2002)	Cepheids	$24.52 \pm 0.14(r) \pm 0.13(s)$	$E(B-V) = 0.20 \pm 0.04$
Freedman et al. (2001)	Cepheids	24.62 ± 0.15	$E(V-I) = 0.27$
Pierce et al. (2000)	LPVs	24.85 ± 0.13	$E(B-V) = 0.10$
Sarajedini et al. (2000)	HB	24.84 ± 0.16	$< E(V-I) > = 0.06 \pm 0.02$

[a]DEB: detached eclipsing binary; TRGB: tip of the red giant branch; PNe: planetary nebulae; RC: the red clump; LPVs: long period variables; HB: horizontal branch stars.

Table 1: Recent Distance Determinations to M33 (from Bonanos et al. 2006).

5. Epilogue

The accelerating rate of discovery of eclipsing binaries provides immense opportunities. With current spectroscopic capabilities it has become possible to measure distances to Local Group galaxies out to 1 Mpc, thus providing distances independent of the controversial LMC distance and the calibration of Cepheids, which most methods rely on. An independent calibration of the extragalactic distance scale has become possible. The recent distance determinations to the LMC, SMC, M31 and M33 are providing 6% distances to these galaxies that will improve over the next few years. Combined with geometric distances to the maser galaxy NGC 4258, the extragalactic distance scale will soon be anchored to several spiral galaxies (M31, M33, NGC 4258).

In addition to their use as distance indicators, eclipsing binaries provide many more opportunities to advance our understanding of star formation and evolution. In particular, they provide direct means of measuring masses, radii and luminosities of stars. For example, applications to the extremes of stellar mass ranges are underway in order to provide constraints to theoretical models of stellar atmospheres and evolution, such as for M-dwarfs and at the other extreme for very massive (>50 Mo) O-stars and Wolf-Rayet stars. Future projects such as the wide field imaging surveys Pan-STARRS and the Large Synoptic Survey Telescope (LSST) will survey the sky down to 24th mag and yield thousands of binaries in the Galaxy, the Local Group and beyond.

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Mid-Infrared Spectroscopic Diagnostics of Galactic Nuclei

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Abstract

In this paper I summarize the science motivations, as well as a few mid-infrared spectroscopic methods used to identify the principal mechanisms of energy production in dust enshrouded galactic nuclei. The development of the various techniques is briefly discussed. Emphasis is given to the use of the data that are becoming available with the infrared spectrograph (IRS) on Spitzer as well as some of the results which have been obtained by over the past three years.

1. Introduction

One of the open issues in extragalactic astronomy is how to quantify the physical mechanisms that contribute to the energy production in galactic nuclei. The most luminous galaxies often display strong evidence of massive star formation taking place in their nucleus. This is typically due to the large quantities of atomic and molecular gas driven in their center as a result of instabilities on their disk such as bars, which often form during tidal interactions. It is also widely accepted that most galactic nuclei likely harbor a super-massive black hole (SMBH) (see review of Ferrarese & Ford 2005). Due to the high densities found in the nuclei the SMBH may accrete matter at a variable rate, even though this accretion does not always result in emission of radiation (Narayan et al. 1998) which would characterize the galaxy as harboring an active nucleus (AGN). A prime example of such "non-AGN" is our own Galactic Center, which does contain a ~10^6 $M_\odot$ SMBH and accretes material, but does not display any visible AGN activity (Genzel & Townes 1987; Ghez et al. 1998). However, in the cases where AGN activity is present, hard electromagnetic radiation, mostly in form of UV and X-rays, is emitted from the nucleus. This is typically observed either directly, in the form of X-rays and radio emission, which are less affected by obscuration, and/or indirectly as high energy photons are absorbed by the gas and dust and subsequently re-emitted at longer wavelengths. So the original question naturally translates to what fraction of the bolometric energy observed from a galaxy originates from an accretion disk (AGN) compared to usual star formation activity. This issue is of particular interest in cases where most of the energy of a galaxy originates from the nuclear regions rather than the outer regions/disk.

Historically, our knowledge on the physics of the nuclear activity of galaxies is mostly based on optical and near-IR spectroscopy, obtained in major ground based telescope facilities. A wealth of diagnostic methods to classify and quantify the AGN activity has been developed over the years (ie Veilleux & Osterbroc 1987; Armus et al. 1989; Kennicutt 1998; Kewley et al. 2001). A presentation of these methods is well beyond the scope of this review but it is only fair to state that they have been extremely successful in providing insight into the properties of galactic nuclei, in particular in cases where a direct line of sight to the nucleus is available. Polarization measurements have also been very useful in identifying evidence of AGN activity, in cases where the nucleus is indirectly probed via scattered light (Heisler et al. 1997).

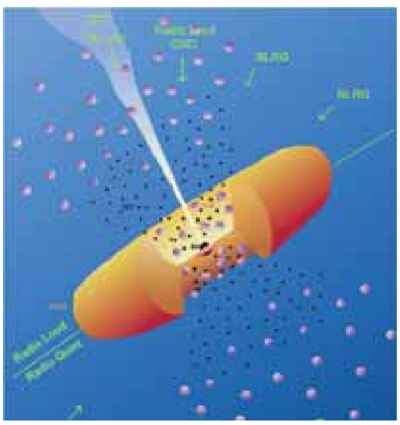

Figure 1. An artist conception (not in scale) of the "Unified Model" (Urry & Padovani 1995, Antonucci 1993) according to which the obscuring torus which, depending on its orientation, may block the line of sight of the observer to the central engine, determines the observational characteristics of an AGN.

According to the so-called "Unified Model" for AGN (see Figure 1) the putative accretion disk near the event horizon of the SMBH is surrounded by a torus that blocks the light to the observer if he/she happens to be close to the plane of the torus. Only for inclinations sufficiently high above this plane the observer has a direct view to the broad line region, to observe it either directly or via its polarized light emission. This model, with various corrections related to the structure of the obscuring medium (whether it consists of are clumpy optically thick clouds or a rather uniform distribution of molecular gas and dust), has been tested extensively in the optical and the near-IR. Recently the last puzzle of this unification was resolved with the observation of silicate in emission from the inner torus of quasars, has recently been verified in the mid-IR (Siebenmorgen et al. 2005, Hao et al. 2005)

The effects of this dust absorption are very strong, vary substantially as a function of wavelength, and historically are the principal reasons complicating the interpretation of the optical data. It is useful to be reminded that a 10eV optical photon can penetrate ~0.5mag of dust, while a 1keV X-ray photon can pass through a hydrogen column of ~10^{22} cm^{-2}. If we were to consider the case of our Galactic Center where the A_V ~30mag, only ~1 in 10^{12} optical photons emitted in the nucleus of the Milky Way can reach our Sun. However, if we were to observe in K-band (2.2μm) the $A_{2.2\mu m}$ ~2.5mag, and one can detect 10% of the near-IR photons emitted from the source. Based on the arguments above, X-rays are clearly the best diagnostic of an AGN especially for higher redshift systems, as the slope of the X-ray spectrum and the sensitivity of the detectors result in relatively flat sensitivity out to z~4–5 (Brandt & Hasinger 2005). However, the energy emitted in X-rays from the majority of luminous extragalactic sources is ~ 10^{42}ergs^{-1}, several orders of magnitude bellow their bolometric luminosity. This, in addition to the fact that X-ray observations need to be performed from space, and most extragalactic sources are intrinsically faint in X-rays, makes estimates of the contribution of an AGN to their bolometric luminosity rather challenging (see Mushotzky 2004). Radio waves are an appealing alternative, in particular given the latest improvements in VLBA (Lonsdale et al. 1993, 2003). Even in this case though, there are difficulties in detecting higher redshift systems, as well as in disentangling issues related to non-thermal emission and self-absorption from embedded nuclei (see Condon 1992). The use of the infrared part of the spectrum 3μm<λ<1000μm in order to develop AGN diagnostics is an avenue which has been explored for the past twenty years for two main reasons: a) most luminous galaxies, QSOs being a "bright" exception, emit a sizeable fraction their energy (>30% in the infrared and b) the infrared is considerably less affected by dust absorption than the optical. The all sky survey by IRAS provided the first opportunity to classify a large number of galaxies based on the shape of their global spectral energy distribution (SED), de Grijp et al. (1987) showed that a ratio of S60/S25>0.26 2 could result in a 70% success rate in identifying previously unknown Seyferts.

2. Mid-IR Emission Line Diagnostics

The advent of mid-IR spectroscopy with the Infrared Space Observatory (ISO) opened a new window in the study of active and starburst galaxies (see Verma et al. 2005, for a review). Emission lines from relatively high excitation ions which are not produced by O stars can be used as a direct probe of AGN activity. In the infrared such lines are the [NeV]λ14.3μm and [NeV]λ24.3μm with an ionization potential of 97.1eV, and the [OIV] λ25.9μm with 54.9eV. The neon lines were detected by ISO in Seyferts, though their detection in ULIRGs was challenging due to the limitations in the sensitivity of the ISO spectrographs (Genzel et al. 1998; Sturm et al. 2000). Another indicator is the strength of the emission bands from polycyclic aromatic hydrocarbons (PAH) at 3.3, 6.2, 7.7, 8.6, 11.3, 12.7, 16.3 and 17.1μm, which are suppressed in AGN since the hard radiation field photo-dissociates the PAH molecules (Lutz et al. 1998). The improved sensitivity of the infrared spectrograph (IRS) on Spitzer (Houck et al. 2004; Werner et al. 2004), a factor of ~100 compared to ISO, enables us to extend these diagnostics. More detections based on the [NeV] lines were secured for a large sample of galaxies and an in depth study of PAH emission has become possible (see Figure 2). Moreover, techniques employing correlations based on the strength of other lines such as [SIV]λ10.5μm and [SIII]λ18.7/33.5μm or principal component analysis are also being explored (see Weedman et al. 2005; Armus et al. 2006; Brandl et al. 2006; Dale et al. 2006; Buchanan et al. 2006, for details). More specifically the use of the 6.2μm PAH is now readily used instead of the 7.7μm PAH which is more affected by uncertainties in the extinction due to the absorption by the 9.7μm silicate feature.

In addition to the mid-IR high-ionization lines and the 6–18μm PAH emission features, the strength of the 3.3μm PAH has also been proven a useful AGN tracer. This feature, which can be probed from the ground for relatively bright sources, has an EW of ~0.1μm in starburst systems but is also suppressed in AGN (see Imanishi 2006).

3. Mid-IR Continuum Diagnostics

Even though high ionization line emission is the ideal probe of an active nucleus, despite the IRS sensitivity, the lines are often difficult to detect in highly extinct and faint/distant sources. The presence of an AGN though can also be inferred by detecting the thermal emission from dust surrounding the putative torus heated by the accretion disk to nearly sublimation temperatures (~1000K) and

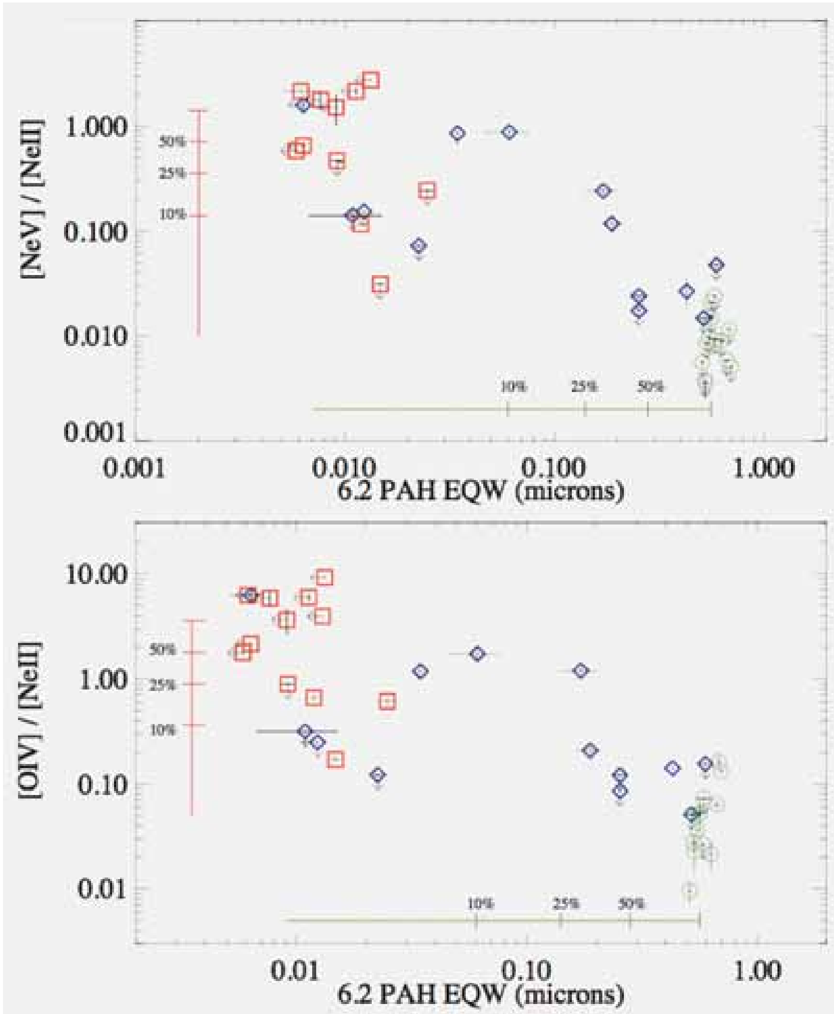

Figure 2. Mid-infrared excitation diagrams for [NeV]λ14.3μm (top) and [OIV]λ25.9μm (bottom) as a function of the 6.2μmPAHEW, for starbursts (green circles – Brandl et al. 2006), AGN (red squares, Weedman et al. 2006) and ULIRGs (in blue diamonds), adapted from Armus et al. (2006). The vertical (red) and horizontal (green) lines in dictate the fraction of AGN and starburst contribution.

radiating in near equilibrium. This emission had been detected in Seyfert galaxies and is now evident in IRS spectra of distant sources (see Alonso-Herrero et al. 2003, and Figure 3).

Unlike extreme starbursts or HII regions which also display a rising slope at λ>10μm, due to the heating of the grains to T~300K by the embedded O/B stars, the presence of this hot continuum at λ~5μm is only seen in AGN. This is due to the fact the very close to an AGN the hard radiation field from the accretion disk can heat the dust to nearly sublimation temperature (either ~1500K for silicate or ~1000 for graphite) which would have a black body peak according to Wien's law at ~3-5μm. Laurent et al. (2000) proposed an AGN diagnostic method –the so called "Laurent Diagram"– which takes advantage of this difference, as well as the destruction of PAHs in both AGN and extreme starbursts. Using three template mid-IR spectra for a "pure" AGN, an HI I region, and a photodissociation region (PDR) they defined an AGN dominated locus in a two parameter phase-space (see Figure 4). The proximity of a galaxy to one of the three corners, i.e. the AGN corner, would suggest the extent by which the mid-IR spectrum displays AGN characteristics. A first application of this method to Spitzer/IRS spectroscopy has been presented in Armus et al. (2007). In Figure 4 we display the principle of the method with the three template spectra used, as well the classification of a number of galaxies based on it. Even though we suggest the reader to review the original paper for a detailed discussion of the method, a few points are worth mentioning here.

- The predictive power of the method depends strongly on the selection of the template spectra used as the three cornerstones. In the original paper of Laurent et al. (2000) Centaurus A was selected as the AGN template, while now the wealth of high quality IRS spectra enabled us to fine tune the selection.

- The actual coordinates of the three templates depend on the corresponding PAH to 5.5μm continuum and 14.5 to 5.5μm continuum ratios. Since the con-

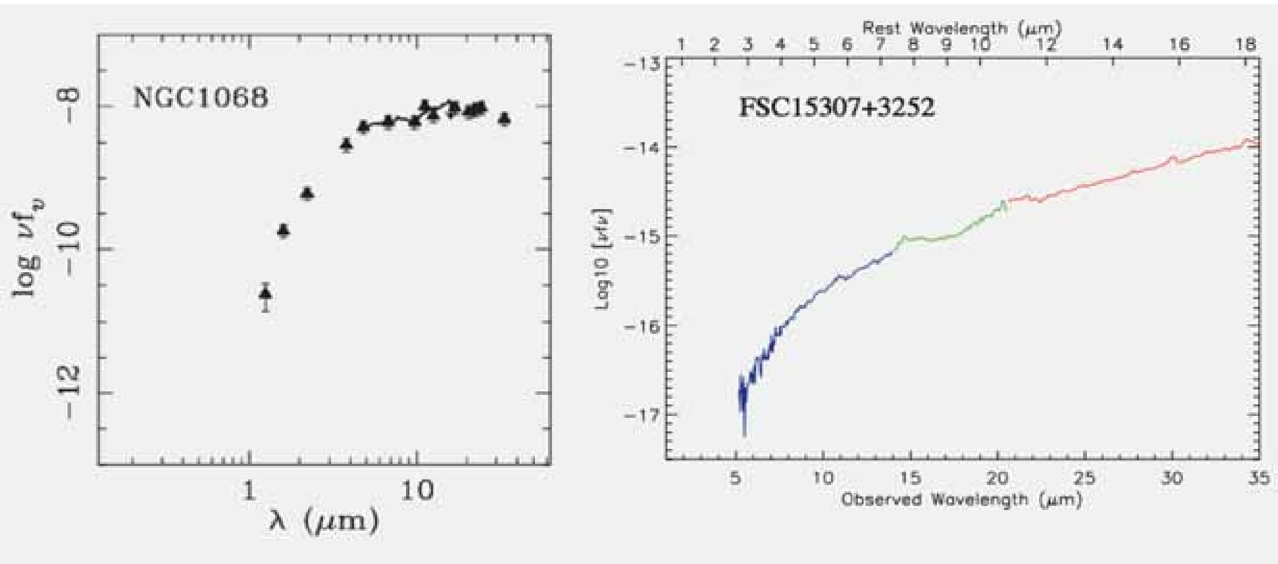

Figure 3. The SED of the nucleus of NGC1068, our nearest Sy-2 at D=14.4Mpc (left), adapted from Alonso-Herrero et al. (2003) compared to the IRS spectrum of FSC15307+3252, a quasar at z=0.92, D=5.8Gpc (see Teplitz et al. 2006). Note the similarity in the thermal emission from the dust near the AGN torus heated to near sublimation temperatures.

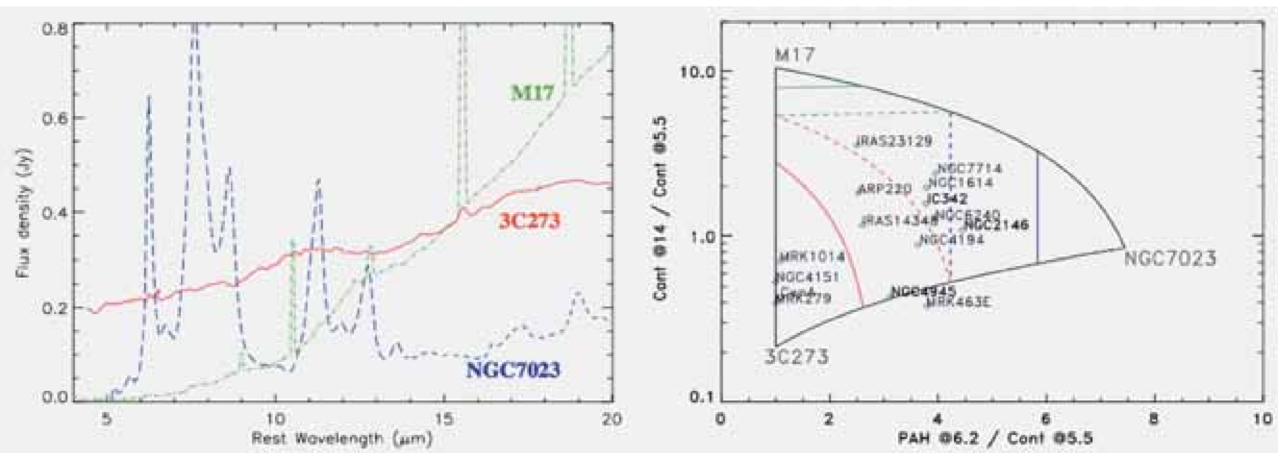

Figure 4. An application of the "Laurent Diagram" based on Spitzer/IRS spectra. On the left we display the three template spectra: M17 (scaled by 10^{-3}) as the HII/extreme starburst, 3C273 as the pure AGN template, and NGC7023 as the pure PDR template. On the right we show the location of a number of starbursts, AGNs and ULIRGs on the diagram. The dotted and solid lines indicate the 50 and 75% contribution of the corresponding template to the integrated spectrum of a source (see also Armus et al. 2007)

tinuum fluxes are calculated by integrating under the spectrum, the wavelength range used for the integration directly affects the value of the ordinate for all points in the diagram. It is not obvious that a flat νf_ν spectrum will result in an ordinate equal to unity. In addition, the exact selection of the limits and underlying continuum in the calculation of the 6.2μm PAH, also affects the value of the abscissa.

▶ None of the templates have been corrected for extinction, so the intrinsic extinction in the observed integrated spectrum of a source may result in placing it outside the parameter space of the diagram. Note that the nucleus of a galaxy, which may contain a strong AGN and/or HI I region component, is often more enshrouded than the PDR regions in its disk. As a result of this variable extinction, there is no one-to-one translation of an extinction vector for all points placed in the Laurent diagram.

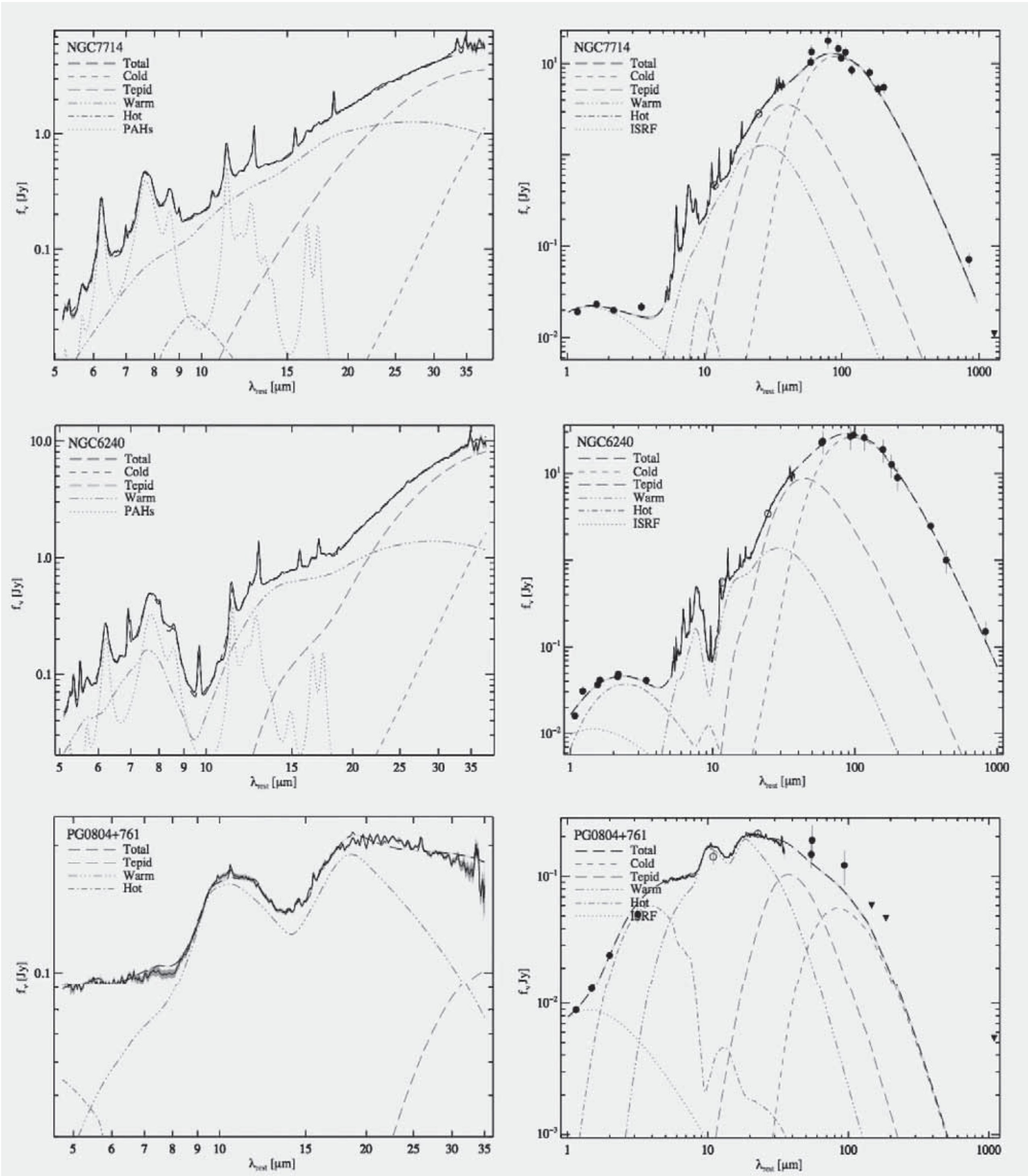

Figure 5. Model fitst to the IRS spectrum and SED of NGC7714, NGC6240, and PG0804+761. The contribution of the various temperature components is indicated by the dotted and dashed lines. Note how well the model fit trace, PAH emission features, as well as the silicate absorption and –in the case of PG0804+76– emission features. The presence of an AGN in PG0804+761 is also revealed by the hot dust component peaking at ~4μm. For more details on the luminosity contribution of eachcomponent see Marshall etal. (2006)

The method provides quantitative means for estimating the AGN contribution to the "integrated mid-IR spectrum" of a galaxy. Even though the ~25–35μm flux traces luminosity it has not yet been demonstrated that the this method can be used to estimate the contribution of an AGN to the infrared luminosity (LIR) of a system.

The "Laurent Diagram" appears to be the most powerful method for AGN classification in the mid-IR for galaxies where no detections or strong limits on high ionization lines are available. More analysis based on Spitzer/IRS spectra will be need to extend its predictive power to the whole IR. Ongoing work indicates that the method can also be applied in Spitzer/IRS low resolution spectroscopic studies of extended star forming regions where variations in the slope of the mid-IR spectrum and the strength of PAHs can be used to quantify the intensity of star formation of the regions (Leboutellier priv. comm.).

4. Theoretical Modeling

Another approach to quantitatively assess the contribution of the various components in the observed IR emission from a source is to fit the IR spectrum using theoretical models. Ideally one could use a full 3D radiative transfer calculation to model the dust properties and match the observed spectrophotometry. A large set of theoretical SEDs are now available for comparison with the observations (i.e. Elitzur & Shlosman 2006; Siebenmorgen & Kruegel 2007, and references therein.). However, limited knowledge of the details in the spatial distribution and geometry of the sources, in particular for systems such as starburst and ULIRGs, which are inherently disturbed, often make this approach rather challenging.

Recently, a new fitting approach relying on the Spitzer/IRS 5–38μm spectra, using constrains from near- and far-IR observations has been developed (Marshall et al. 2006). The method assumes that the SED of a galaxy can be decomposed into dust components at different characteristic temperatures, source emission components, embedded photospheric emission from starburst cores or an active nucleus as well as PAH feature emission. The emission from each component is calculated using a realistic dust model consisting of a distribution of thermally emitting carbonaceous and silicate grains. The model accounts for stochastic emission from very small grains by fitting model PAH templates to the spectra. This method has been applied in a variety of Spitzer/IRS data and most sources are well fit by a maximum of four components referred as cold (~30K), tepid (~100K), warm (~200K), and hot (>300K). The results of the fits are used to calculate the relative bolometric contributions from the different components, providing a method to compare the infrared properties of starburst galaxies and quasars. Sample results of the fitting method on NGC7714 –a starburst galaxy–a ULIRG such as NGC6240 and the quasar PG0804+761 are presented in Figure 5.

5. Conclusions

It has become evident from the numerous contributions presented during this meeting that the high quality of Spitzer/IRS spectroscopy is opening new horizons in the use of the infrared as a tracer of the properties of nearby and high-redshift galaxies. With another 2.5 years of mission to go, we have just glimpsed on the possibilities that lie ahead.

Acknowledgments. I would like to thank Jim Houck for giving me the opportunity to spend 5.5 formative years in Ithaca and participate in the Spitzer/IRS "venture". I would also like to acknowledge all members of the IRS instrument team at Cornell and Caltech for many enlightening and stimulating discussions on spectroscopy and the infrared. I also appreciate the help of Lee Armus and Jason Marshall who provided data and plots for this paper prior to publication.

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The Athens Solar Orbiter Workshop

The Sun has many satellites, the largest of which are the planets and our Earth. *Solar Orbiter*, an ESA satellite planned to be launched in 2015, will be the closest satellite to orbit the Sun: its shortest solar distance will be around 45 solar radii, one fifth of the distance Sun-Earth, where solar radiation is 25 times stronger. Evidently, the technical challenges are immense for a man made object to reach these extreme and hostile conditions. Equally challenging are the unique scientific goals of Solar Orbiter which will:

- Determine the properties, dynamics and interactions of plasma, fields and particles in the near-Sun heliosphere;
- Investigate the links between the solar surface, corona and inner heliosphere;
- Explore, at all latitudes, the energetics, dynamics and fine-scale structure of the Sun's magnetized atmosphere;
- Probe the solar dynamo by observing the Sun's high-latitude field, flows and seismic waves.

The second Workshop devoted to ESA's *Solar Orbiter* mission was held in Athens, Greece, on 16-20 October 2006. The Workshop was attended by more than 200 scientists and agency members from Europe, the USA, Russia and China. Among the participants were the ESA director of Science, prof. D. Southwood along with many other ESA and NASA executives. The participants were welcome by academician, prof. G. Contopoulos and the vice-rector of the Un. of Athens prof. D. Asimakopoulos. The 22-member scientific organizing committee (SOC) which was co-chaired by E. Marsch (Germany), R. Marsden (ESA) and K. Tsinganos (Greece), consisted of scientists from 10 countries, ESA and the USA while the local organizing committee (LOC) consisted of K. Tsinganos (Chair), I. Daglis, E. Dara, C. Gontikakis, X. Moussas, S. Patsourakos, and M. Zoulias. The *Solar Orbiter* satellite was originally selected in October 2000 as an ESA F-mission, with a launch foreseen in the time frame 2008-2013. Six years later, however –despite continued strong support from the international solar and heliospheric science community and a number of industrial feasibility studies– the mission has yet to enter its implementation phase. No technical show-stoppers have been identified; rather the mission has suffered, and continues to suffer, from problems with ESA's science programme funding. It is now hoped to obtain final approval to start *Solar Orbiter* at the end of 2007 with the goal to launch in 2015, before the period covered by the new science programme *Cosmic Vision* 2015-2025. A Call for *Letters of Intent* to propose for the payload of Solar Orbiter was recently issued by ESA, and was answered by many groups in Europe (including several Greek groups) and America, an impressive response that again clearly shows the wide and strong interest of the solar and heliospheric science community in this unique mission. In fact, in the recent Nov. 2006 ESA/SPC, the ESA executives called the Athens meeting the "break-through" towards the process of materialization of the Solar Orbiter mission.

Given that it is the task of this community in Europe and worldwide to exploit the research opportunities offered by *Solar Orbiter* and to define its scientific goals in more depth and detail, the prime motivation for the second *Solar Orbiter* Workshop was to prepare for, and make the best possible use of, *Solar Orbiter* within the context of the network of international solar/heliospheric missions. The top-level objectives of the workshop were to:

- Inform the wider community of the *Solar Orbiter* opportunity and to investigate synergies to enhance this opportunity, including ground-based support and modelling;

- Discuss *Solar Orbiter* operations strategies and scenarios, and outline how the goals of Orbiter will be achieved;
- Strengthen the political and scientific support for the mission, demonstrating the wide international interest in the mission.
- Improve the definition of the payload scientifically and technologically;
- Identify ways of mission optimization and international cooperation.

The workshop was organized around these goals in several sessions addressing the science objectives and the instrumental approaches and observational strategies to achieve them. A specific focus of the meeting was the exploitation of the unique orbit and vantage point of *Solar Orbiter* that are ideal to link remote-sensing with in-situ observations. Invited reviews defined the general state of the field and placed the science to be conducted with *Solar Orbiter* in the context of past, present and future solar and heliospheric physics missions. Together with the contributed oral papers and posters, the invited talks addressed the specific science targets and goals for *Solar Orbiter*. Models and theoretical aspects were discussed in special theory presentations. There was also a session devoted to mission aspects and instrumental and technological issues.

In parallel with the planned scientific program, a good part of the discussion time of the Workshop was spent in numerous community, committee and bilateral meetings. Special attention was given to the synergies of *Solar Orbiter* with contemporary space missions and existing ground-based observatories. In particular, the envisioned collaboration with the NASA Sentinels was strongly supported by the workshop attendees and concluded by the agency representatives to be crucial for the health and survival of the mission in the ESA programme. The planned joint ESA/NASA effort promises great enhancements of the science possible and offers novel and unique perspectives for this new multi-spacecraft approach to solar and heliospheric physics.

The venue and conference hotel was the Divani Palace Acropolis in Athens, just a couple of blocks away from Acropolis. The attendees enjoyed the hospitality of the Greek hosts and their many helpers. The presentations (invited, oral and posters) which will be published by ESA proceedings, were all of very high quality and made the Workshop a great success. Sincere thanks go to all whose contributions and active engagement were essential for the workshop achieving its goals.

Kanaris Tsinganos

X-ray summer school, September 18-20, 2006

The Institute of Astronomy & Astrophysics of the National Observatory of Athens organised the first **X-ray Astronomy** school. This was held between September 18-20 at Penteli. The school was addressed at postgraduate and young postdoctoral scientists. The meeting was a success. Over 20 young astrophysicists from all over Greece but with the majority of them coming from the University of Athens and the National Observatory of Athens. The talks covered both theoretical issues (e.g. radiation mechanisms in X-ray Astronomy) as well as observational topics. More emphasis was given on the extragalactic Universe. Apart from the lectures there was a 'hands-on' session dedicated on the analysis of data from the **XMM** X-ray mission in front of a computer. The lecturers came from both Greek and International Institutes. In particular the program was the following:

- I. Georgantopoulos (National Observatory): Overview of X-ray Astronomy
- A. Mastichiadis (University of Athens): Radiation Processes
- K. Nandra (Imperial College London): Active Galactic Nuclei X-ray Spectroscopy
- A. Akylas (National Observatory): Introduction to XMM Data Analysis
- K. Tsinganos (University of Athens): Jets I
- N. Vlahakis (University of Athens): Jets II
- M. Plionis (National Observatory): X-ray surveys of clusters
- S. Vasilakos (Academy of Athens): Large Scale Structure in the X-ray Universe
- G. Chartas (Penn State University): CCDs in X-ray Astronomy
- A. Georgakakis (Imperial College London): Galaxies at X-ray Wavelengths

All lectures can be downloaded from the school's web page:

www.astro.noa.gr/~ig/xrayschool/index.htm

The meeting was very timely given that in recent years we have seen a golden age in X-ray Astronomy with a wealth of data coming from NASA's **Chandra**, ESA's **XMM** and Japan's **Suzaku** X-ray missions. The meeting was particularly interesting for Greek scientists since Greece joined ESA last year and a large fraction of ESA's activities are devoted on X-ray Astronomy and Space Sciences in general. ESA is planning to launch within the next decade the **XEUS** mission as a replacement to its current **XMM** mission. **XEUS** is expected to revolutionise X-ray Astronomy having a telescope with an area at least 10 times larger than **XMM** reaching an angular resolution of 2 arcsec.

I. Georgantopoulos

Recent Developments in Gravity, NEB XII
Nafplion 29/6 - 2/7/2006

Continuing the 24 year old tradition, one of the Greek relativistic groups, this time the Relativity Group of the Physics Department of the University of Athens, organized the 12th Conference of the series "Recent Developments in Gravity" (NEB XII). This time NEB took place at Nafplio, Greece, from Thursday 29th of June to Sunday 2nd of July, 2006. The Conference was attended by more than 100 participants, more than 50% of whom were relativists from abroad (Greek and foreign nationals). This signals a tendency of the last few Conferences to open up the Greek Relativity Conference to the international scientific community. Actually, many notable members of the relativistic community from all over the globe showed particular interest to come to Nafplio, and spend four relaxed days in a nice sunny and historical place, presenting the results of their more recent work and discussing with colleagues and students from Greece.

The NEB XII Conference covered various aspects of gravitational physics: Relativistic Astrophysics, Mathematical Relativity, Quantum Gravity, and Cosmology. Although the program was rather heavy and for the first time we had parallel sessions running in the afternoons, the wonderful weather (apart from the heavy rain during the last afternoon) and the beauty of Nafplion helped the organizers offer the participants a warm, pleasant, and creative time. According to most attendees' response, their impression was more than good, not only with respect to

the hospitable environment, but with respect to the high level of talks as well. We hope the next Conference that will be organized by the Relativity Group of the Aristotle University of Thessaloniki, in the summer of 2008, will raise the standards of the Conference even higher, thus further establishing our Conference as a notable Conference in the Relativistic community all over the world.

Theocharis Apostolatos

The Schutz Symposium on Gravitational Waves and Relativistic Astrophysics
24 - 26 August 2006, Santorini, Greece

On the occasion of the 60th birthday of Bernard Schutz (Director of the Albert-Einstein-Institute, Max-Planck-Institute for Gravitational Physics, Golm) a very special symposium was organized by his students and collaborators on the island of Santorini. The symposium was attended by more than 50 participants, whose scientific careers were initiated or influenced by Bernard Schutz. At the Bellonio Cultural Center in Fira, where the symposium took place on three consecutive days, several speakers presented the impact that Bernard Schutz had as an advisor, collaborator or student (in the case of his own advisor, Kip Thorne) on their research in a wide range of topics that included Stellar Oscillations and Instabilities, Gravitational Wave Theory, Detection and Data Analysis, Relativistic Astrophysics, Numerical Relativity, Computing and Science Outreach. A memorable highlight of the social programme was the birthday party which was organized with the help of Bernard Schutz's close family and which all participants particularly enjoyed. The symposium ended with a very inspiring presentation

by Bernard Schutz of his path in science, from the days he was a student to the present.

Nikolaos Stergioulas

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• Το *Scientific American* αποτελεί την παλαιότερη περιοδική έκδοση *για την επιστήμη και την τεχνολογία* —κυκλοφορεί στις ΗΠΑ αδιαλείπτως από το 1845.

• Βασικό χαρακτηριστικό του είναι ότι τα περισσότερα άρθρα του γράφονται *από τους ίδιους τους επιστήμονες και τους ειδικούς κάθε τομέα* και όχι από δημοσιογράφους. Από αυτό απορρέει η εγκυρότητα και η αξιοπιστία του. Μέχρι σήμερα στις σελίδες του έχουν αρθρογραφήσει 135 νομπελίστες.

• Σε κάθε τεύχος παρουσιάζονται τεκμηριωμένα οι πιο πρόσφατες εξελίξεις *στους τομείς αιχμής της επιστήμης και της τεχνολογίας* (φυσική, κοσμολογία, πληροφορική, βιοτεχνολογία, περιβάλλον, οικολογία, ιατρική, υγεία, ψυχολογία, νευροεπιστήμες, μαθηματικά, οικονομικά, κ.λπ.) καθώς και οι κρίσιμες αλληλεπιδράσεις τους με επιχειρηματικές δράσεις στο επίπεδο της έρευνας και της ανάπτυξης.

• Διεθνείς εκδόσεις του περιοδικού κυκλοφορούν στη Γαλλία, τη Γερμανία, την Ιταλία, την Ισπανία, το Βέλγιο, την Ολλανδία, την Πολωνία, την Πορτογαλία, την Τσεχία, τη Ρουμανία, τη Φιλανδία, την Κίνα, την Ιαπωνία, τη Ρωσία, το Μεξικό, τη Βραζιλία, την Ταϊβάν, το Κουβέιτ, το Ισραήλ, και βεβαίως στην Ελλάδα. (Για το 2007 προγραμματίζεται η έκδοση του περιοδικού στην Τουρκία.)

• Σήμερα το περιοδικό αποτελεί ένα απαράμιλλο *εργαλείο γνώσης και ενημέρωσης*, και σε αυτό προστρέχουν τόσο το επιστημονικό και επιχειρηματικό δυναμικό του πλανήτη όσο και ένα ευρύτερο αναγνωστικό κοινό με όραμα για το μέλλον βασισμένο στην τεκμηριωμένη γνώση για το παρόν.

• Το 2000, το *Scientific American* τιμήθηκε με το Βραβείο Sagan για την προσπάθειά του να προωθήσει την κατανόηση της Επιστήμης από το ευρύ κοινό. (Το εν λόγω βραβείο απονέμεται ετησίως σε «ερευνητές και/ή εκπαιδευτικούς, των οποίων το έργο αναγνωρίζεται ότι ενισχύει την εμπέδωση της Επιστήμης από το ευρύ κοινό».)

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«Ένα περιοδικό όπως το *Scientific American* αποτελεί πολύτιμο βοήθημα όχι μόνο για τη διεύρυνση των γνώσεων του αναγνώστη του ή για την επέκταση της επιστημονικής του μόρφωσης, αλλά και για τη διαμόρφωση ενός επιστήμονα-πολίτη κοινωνού της επιστημονικής μεθοδολογίας και απαλλαγμένου κατά το δυνατόν από φανατισμούς και προκαταλήψεις. [...] Ιδιαίτερα ο έλληνας φοιτητής, που καλείται συνήθως να απομνημονεύσει παρά να σκεφτεί και να καλλιεργήσει τη φαντασία του, που αναπτύσσεται πνευματικά σε ένα περιβάλλον πτωχό σε ερευνητική παράδοση, ανεπαρκές σε υλικοτεχνική υποδομή, με ορίζοντα που συνήθως δεν ξεπερνά το ένα και μοναδικό πανεπιστημιακό σύγγραμμα (όχι πάντα καλογραμμένο), χρειάζεται περισσότερο από οτιδήποτε άλλο κανάλια επικοινωνίας με την πρωτοπορία της παγκόσμιας επιστημονικής έρευνας· και ένα τέτοιο κανάλι τού προσφέρει το *Scientific American*.

—*Ελευθέριος Οικονόμου, καθηγητής φυσικής στο Πανεπιστήμιο Κρήτης, πρώην πρόεδρος του Ιδρύματος Τεχνολογίας και Έρευνας*

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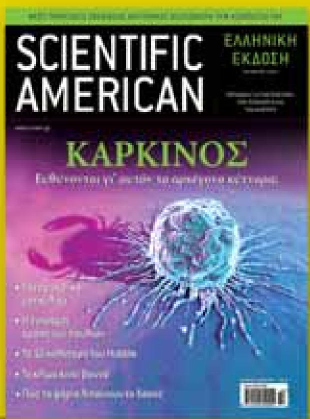

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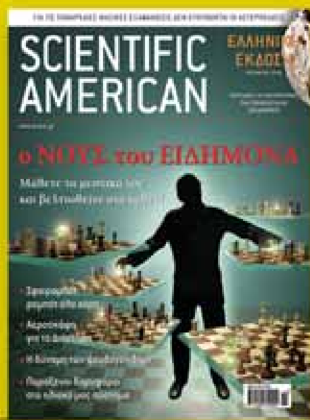

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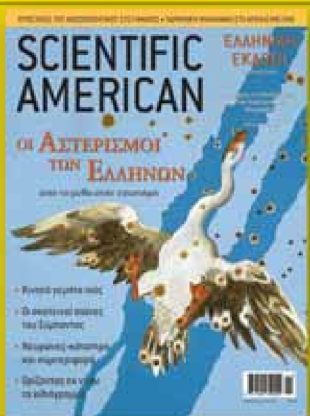

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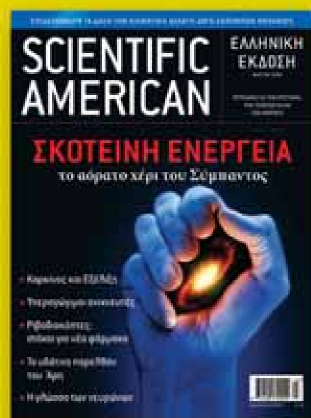

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περιοδικό για την επιστήμη,
την τεχνολογία και τον άνθρωπο

Ένα απαράμιλλο εργαλείο γνώσης και ενημέρωσης