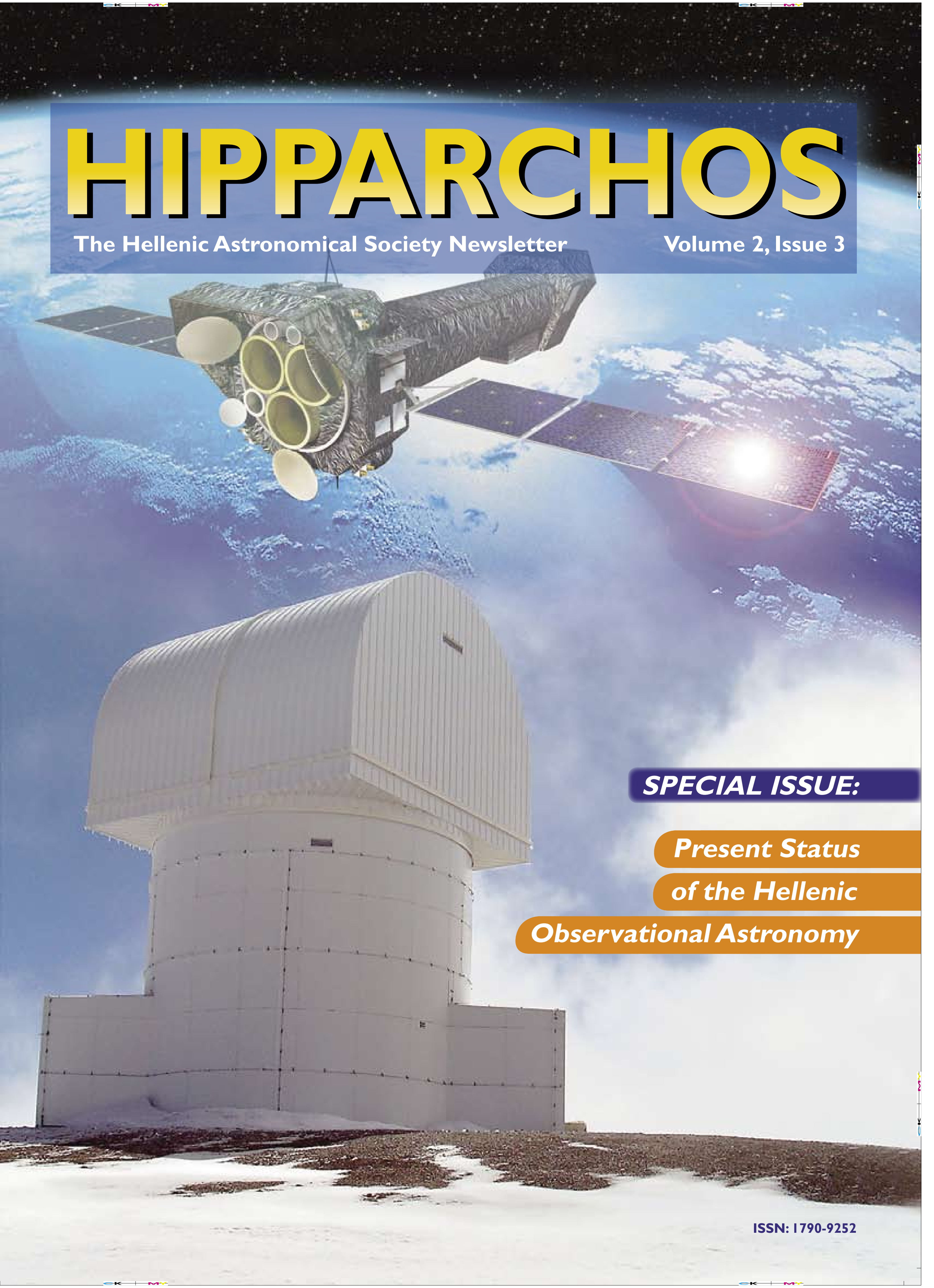
HIPPARCHOS

The Hellenic Astronomical Society Newsletter

Volume 2, Issue 3



SPECIAL ISSUE:

Present Status of the Hellenic Observational Astronomy

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Contents

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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:
A space probe and the ARISTARCHOS telescope.

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Special Issue: Present Status of the Hellenic Observational Astronomy
Editor: Manolis Plionis

Message from the President

Dear Hel.A.S. members,

This is a special issue of Hipparchos devoted to Hellenic Observational Astronomy: from the smaller University telescopes and the historical Kryonerion telescope, to the new 2.3m "Aristarchos", now at the final stages of commissioning, to the giant, state of the art, ESO telescopes and to the great space observatories. The issue provides the reader with the satisfaction that in all those steps of the ladder to the sky and the Universe there is a vibrant Hellenic involvement, of one form or another.

Thus, C. Goudis et al. introduce us to the Helmos Astronomical Station which houses the most awaited new Hellenic astronomical instrument, the "Aristarchos" 2.3m telescope. In addition to providing the structure, optics, performance and instrumentation of the telescope the article shows some of its "first light" images. The telescope will soon be fully operational, providing excellent observations with image quality <0.35". It is important to note it will be automated and remotely controlled through the network. M. Plionis & I. Georganto-

Message from the President *(continued)*

poulos outline the technical details and the science of the new wide-field (10.1' x 10.1') Vernikou-Eugenides CCD imaging camera (VEC) to be installed on the "Aristarchos" telescope. VEC will provide unique opportunities to undertake a relatively high spatial resolution, deep, broad band imaging surveys of selected areas of the sky, searching for extrasolar planets and various transient objects, studying the physics of star formation in our galaxy and other ones, stellar populations, galaxy formation and evolution, large scale structure, etc. E. Kontizas, among the key people who made Aristarchos a reality, describes the first steps in the long process of building the telescope focussing on the details original proposal to the Greek government in 1996 which was officially approved by the General Secretariat of Research & Technology in November 1997.

Next, C. Goudis, et al. describe the 1.2 m telescope of the National Observatory of Athens situated at 22 km SW from Kiato Corinthias, near the village of Kryonerion at a height of 930 m. This historical, for the Hellenic Astronomy, telescope, which is equipped with several instruments, used in the past to perform mainly photometric and spectrographic observations, seems to also have a modern future: an agreement recently has been reached with members of the Cork Institute of Technology, Ireland, to fund, upgrade and robotize the telescope. Then there are two articles on the image quality of the 1.2m Kryonerion telescope by Sue Worswick et al and D. Mislis, et al, test-studies of the "seeing" at the Kryonerion Station during July and October 2002, wherein they find a median "seeing" of 0.68 arcseconds and 1.42 arcseconds, respectively.

I. Papadakis & Y. Papamastorakis provide a short description of the Skinakas observatory, operating in central Crete at an altitude of 1750 m and on a site with excellent seeing conditions (the median seeing has been measured to be sub-arc second) and providing impressive results since 1986 (a more detailed article on Skinakas can be found in the previous issue of Hipparchos). P.G. Niarchos and P.G. Laskarides present the 40 cm telescope atop the building of the Department of Physics of the University of Athens. This small but well equipped telescope not only has been playing a catalytic role in the astronomical education offered at the University of Athens at the undergraduate and postgraduate level, but the telescope's modern instrumentation enables it to carry out some specialized research programs and participate in international networks for the observation of variable stars, as shown in the article.

I. Daglis et al present the wide research activities of the Institute for Space Applications and Remote Sensing of NOA, in particular in this new era that the country has joined ESA, while G. Tsiropoula and K. Tziotziou present solar observations at ISARS/NOA. I. Georgantopoulos, I. Papadakis and M. Plionis summarize the Observational X-ray Astronomy activities in Greece and finally E. M. Xilouris the upcoming Herschel Space Observatory in which there is also a Hellenic participation.

I. Spyromilios, provides a panoramic view of the impressive state of the art ESO telescopes and equipments, the product of the European active collaboration on La Silla (the 3.6-m telescope, the NTT and the 2.2-m telescope, etc), Cerro Paranal (the four very well equipped 8.2-m Unit Telescopes known as the VLT), APEX and the under-construction Atacama Large Millimetre Array (ALMA). It is also noted that recently the ESO Council decided to go ahead with the construction of the European Extremely Large Telescope (EELT) which will have unprecedented discovery capabilities. The exciting science from ESO telescopes is also reviewed, for example, finding planetary systems to the most exciting limits with the recent discovery of Gliese 581c, the first almost earth-like planet in the habitable zone. The quoted statistics is remarkable: refereed publications from ESO telescopes exceed 600 per year, with the VLT alone producing more than one paper per day!

In particular, focusing for a moment to the more sophisticated means of astronomical observations and the ladder to the Universe involving some form of Hellenic participation, i.e., Aristarchos, the space observatories and ESO one may feel the satisfaction that the nation has finally built one of the greatest telescopes in continental Europe (Aristarchos) and also has recently joined ESA. At the same time however, one may wonder why Greece is not yet a member of the great ESO astronomical organization, despite the unanimous call of an international experts committee that joining ESO should be the top astronomy priority for the nation (Terzian report,

http://www.astro.noa.gr/gnca/NEWS/ca-report2000.htm,

the cost is a one-time entrance fee of about 10 million €, i.e., similar to the ESA annual membership fee, and an annual membership fee of about 1 million €). Clearly the benefits of joining the European Southern Observatory, the major astronomical organization of Europe, are multiple and there is no doubt that it is a worthwhile investment. The GC of the Hel.A.S. firmly believes, that this should be the next goal for the Greek astronomy.

Due to lack of space in this special issue we mainly concentrated to the larger Hellenic telescopes. That by no means should be interpreted that we do not appreciate the role of the smaller ones, in particular, in Astronomy education *(Michalitsianos, Ioannina, Stephanion)*, or, public outreach *(NOA, Penteli)*. All have their place and contribution in the present status of Hellenic Observational Astronomy.

It should be mentioned that the first articles, submitted for this special issue quite some years ago, were co-authored by the late Emilios Harlaftis, one of the most aspiring members of the Hellenic Observational Astronomy family, who passed away tragically on the 13 February 2005. For this reason the governing board of Hel.A.S. decided to devote this issue to Emilios memory.

In addition to the authors of the articles for their contributions, I would like to also thank Manolis Plionis who did all the editing and excellent coordination making this issue a reality.

Kanaris Tsinganos

The Helmos Observatory

by C. Goudis, P. Boumis, P. Hantzios, E. Xilouris, A. Dapergolas
Institute of Astronomy & Astrophysics, National Observatory of Athens

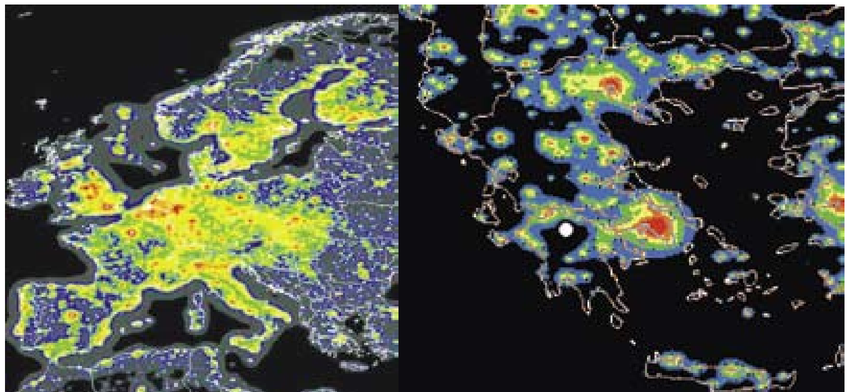

Figure 1. The maps of light pollution in Europe (left panel) and in Greece (right panel) taken from Cinzano et al 2001. The white circle in North-Central Peloponnese indicates the location of the telescope site.

1. The Site

The National Observatory of Athens completed the construction of the new astronomical station on the top of mount Helmos (Longitude = 22° 13' E, Latitude = 37° 59' N) at an altitude of 2340 m (nearby the city of Kalavryta). Road access, infrastructure, meteorological conditions, darkness of the night sky (see Fig. 1) and image quality were the criteria for the selection of the Helmos mountaintop.

The astronomical station consists of two main compartments: the telescope tower and the control building, with a distance of 35 meters between them (see Fig. 2). This way, human activity and the heat radiated from engines, computers, etc will not affect the performance of the telescope and particularly the image quality.

The Helmos Astronomical Station disposes the necessary infrastructure for the support of the observing activities and operation. The site (250 km from Athens) is accessible by a four-wheel-drive car. The road is asphalt paved except the last 8 km which are through a mountain road which was vastly improved in 2005 (see Fig. 3).

The telescope is, for the moment, running on electrical power from two generators (of 75 kVA and 12 kVA). Connection with the Public Electric Company network is anticipated by the end of summer 2007. The connection of the astronomical station with the headquarters of our Institute in Athens will be effected through a microwave link. The capacity of the link is 11 Mb/s. Finally, the astronomical station is equipped with a computer network (server, work stations, PCs and related items), which will support the operation of the telescope, the astronomical instruments, communications, etc.

2. The Aristarchos 2.3m Telescope

The 2.3m ARISTARCHOS telescope (Fig. 4) utilizes new technologies and techniques arising mainly as a spin-off from the development of the new generation of 8-metre optical/IR telescopes. The modern design of the telescope makes it unique in this class of telescopes, since technologies developed for the new, largest 8-10 m telescopes are now applied to medium-size telescopes (2.3 m ARISTARCHOS, 2 m Liverpool telescope, 2.5 m VST/ESO). A back-illuminated 1024 x 1024 pixel CCD camera (with a pixel size of 24 μm and a field-of-view of 5 arcminutes), as well as a filter-wheel, are already attached to the telescope (see Fig. 5).

Mechanical Structure

The alt-azimuth design makes the telescope lighter and easier to construct, whereas at the same time offers a number of instrument positions which are easily accessible by a simple movement of a small flat mirror. It has four cassegrain side ports able to bear instruments up to a total of 300 kgr, while the weight of one instrument can be up to

Figure 2. The Helmos observing site (left panel) and the enclosure with the telescope (right panel).

Figure 3. Part of the road through the woods (left panel) and the mountaintop (right panel).

100 kgr, and one main cassegrain port sustaining an instrument up to 300 kgr (by distance of the center of gravity of the instrument less or equal to 300 mm from the instrument flange). The total weight of the moving parts is 29.000 kgr rising up to 34.000 kgr if the rest of the infrastructure is included.

Optics

The 2.3 m ARISTARCHOS telescope is a Ritchey Chretien telescope, consisting of a Sitall primary mirror of 2.3 meters in diameter with a focal ratio f/2.4, and a Sitall secondary mirror of 74 cm in diameter with focal ratio f/3.1. The final focal ratio of the telescope is f/8.
The optical design is such as to offer an uncorrected field of view of ~10 arcmin (in the four side ports) and a corrected field of view of ~1 degree (in the main cassegrain port) with an image scale of 1.17 arcsec/mm. The telescope has been designed to provide image quality of less than 0.35 arcsec spreading for 80% of the encircled energy.

Performance

Some useful parameters characterizing the performance of the telescope are:

Range of movement in azimuth	: +/- 200 degrees
Range of movement in altitude	: +/- 90 degrees
Rate of movement in azimuth	: max 2 degrees per second
Rate of movement in altitude	: max 2 degrees per second
Accuracy of pointing	: < 4 arcsec up to zenith distances of 70 degrees
Accuracy of tracking in open loop	: < 0.5 arcsec in 10 minutes
	< 2 arcsec in 1 hour
Accuracy of tracking in closed loop	: < 0.25 arcsec in 10 minutes
	< 0.5 arcsec in 1 hour
Accuracy of rotator tracking	: 0.25 arcsec in 10 minutes
	0.5 arcsec in 1 hour
Radius of Zenith blind spot	: 2 degrees
Operating temperature range	: from – 10 C to + 35 C
Operating humidity range	: up to 80% relative humidity
Wind tolerance	: up to 15 m/s (in operation)
	>15 m/s (parked)
Earthquake resistance	: accelerations up to 2m/ square sec in any direction

Figure 4. The ARISTARCHOS telescope.

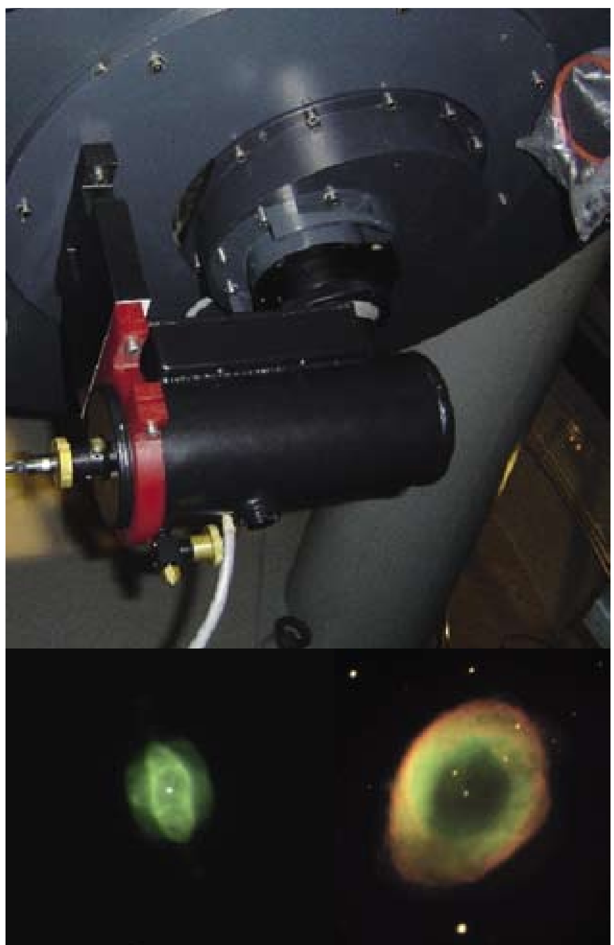

Figure 5. The CCD camera attached to the telescope's main port (top) and the "First light" images, of the Ring and the Saturn planetary nebulae, taken with this camera (bottom).

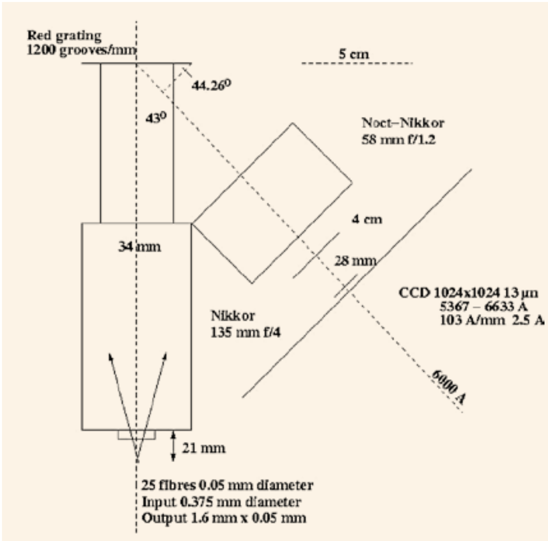

Figure 6. The optical layout of the Aristarchos Transient Spectrometer (designed by J. Meaburn)

Figure 7. The mechanical layout of the Aristarchos Transient Spectrometer

As has already pointed out, the telescope building design is such as to minimize any heat trapped within the structure which could degrade the ambient 'seeing' (control room outside telescope building, oil cooling system, heat extractor, advanced ventilation of building, advanced shielding and insulation of building). The control system is designed to support remote-control operation of the telescope.

3. Instrumentation

The modern design of the 2.3 m ARISTARCHOS telescope, similar to that of the design of 8-10 m class telescopes, along with the excellent dark-sky site on mount Helmos that this telescope is installed at, makes it a very unique telescope in its class with which a plethora of research projects can be performed. Several instruments have already been developed and are ready to be tested and installed to the telescope [the "ARISTARCHOS Transient Spectrometer" (ATS) and the "Manchester Echelle Spectrometer-ARISTARCHOS Telescope" (MES-AT)] and others are currently being developed [the "Vernikos-Eugenedis Camera" (VEC)].

1kx1k LN_2 CCD

A 1024x1024, 24 micron pixel size (0.28") CCD camera giving a field of view of ~5 minutes of arc has already been installed on the telescope and several first light images have been taken (figure 5).

ARISTARCHOS TRANSIENT SPECTROMETER (ATS)

The Aristarchos Transient Spectrometer (ATS – Meaburn, Boumis & Goudis 2004), whose optical and mechanical layouts are shown in Figs 6 and 7 respectively, is a low/medium dispersion spectrometer which has been designed and manufactured specifically to obtain spectra of relatively bright (brighter than 18 mag) but transient phenomena. These can include gamma-ray bursts as soon after the events as possible, the variable spectra of Symbiotic stars, Cataclysmic variables, nuclei of nearby Seyfert galaxies, nearby nova events etc. This spectrometer sponsored by the Universities of Patras and Manchester and it is constructed by the University of Manchester.

To achieve these aims any of three gratings can be driven into the beam with present angles. These are:

- a Red 1200 groove/mm grating centered on 6400 Å to give 2.5 Å resolution and 103 Å/mm
- a Green 1200 groove/mm grating centered on 5000 Å to give 2.5 Å resolution and 95 Å /mm
- a 600 g/mm grating centered on 5750 Å but at 245 Å/mm to give 6 Å resolution.

The detector is a thermo-cooled AP47p CCD with 1024x1024 13 micron pixels. Ease of operation and rapid serendipitous response are traded for some loss in ultimate sensitivity i.e. the spectra will be dark-current limited rather than read-out noise limited as with a liquid nitrogen cooled CCD. The AP47p CCD can be driven using the parallel port of any Windows PC. The spectrometer's long slit input is fed by 50 fibers (each 50 micron diameter) in a 10 arcsec diameter bundle in the telescope's focal plane. Again, ease and rapid target acquisition are traded for some fiber losses when compared to a traditional long-slit spectrometer.

This spectrometer has been designed and manufactured that can be left running permanently for opportunist override observations of transient events. Survey programmes of relatively bright but transient phenomena can also be carried out. It is not intended for use as a traditional low-dispersion spectrometer found on most telescopes.

The performance of ATS shown in Figs. 6 and 7 is summarized in Table 1 when combined with the Aristarchos 2.3-m telescope (Boumis, Meaburn 2007).

The calibration process of the three different gratings has been performed in the optical laboratory of I.A.A. in Penteli (Athens), using a CuAr arc lamp. An example of CuAr arc lamp spectra can be seen in Fig. 8 where, the X-axis shows the total pixel size of the CCD camera and the Y-axis the intensity of the emission lines. The identification of the latter has been performed hence these spectra are ready to be used for the wavelength calibration of the upcoming data.

The CCD software MAXIM DL is also needed in order to use the CCD camera.

MANCHESTER ECHELLE SPECTROMETER (MES-AT)

The Manchester Echelle Spectrometer (MES - Meaburn et al 1984; Meaburn et al 2003) whose optical layout is shown in Fig. 11, is a very simple spectrometer dedicated to a narrow range of astrophysical problems where it performs better than more generalized designs with similar dimensions.

Two identical spectrometers have been made in the past: the first for use on the 3.9 m Anglo-Australian telescope (AAT) after 1983 and the second after 1987 for the 2.5 m Isaac Newton (INT) and 4.2 m William Herschel (WHT) telescopes on La Palma (Canaries). The first of these spectrometers has been brought to Greece in 2006 for use on the 2.3 m Aristarchos telescope after upgrading its control system and the second was taken to Mexico in 1996 for use on the 2.1 m San Pedro Martir (SPM) telescope where it continues to be a successful common-user device.

In its primary mode MES has a single order of its echelle grating (nominally $\delta = 63.54°$ with 31.6 grooves mm^{-1} isolated by a broad, efficient, three-period (top-hat profile) interference filter eliminating the need for cross-dispersion. Consequently, its primary use, at Cassegrain or Ritchey-Chretien (RC) foci, is to obtain spatially-resolved profiles of individual emission lines from *faint* extended sources emitting in the range 3900-8000 Å with spectral resolving power around $\lambda/\Delta\lambda = 10^5$. Below 3900 Å the flint glass of the lenses starts to absorb light, the anti-reflection cease to function (the air/glass surfaces revert back to their usual reflectivities) and CCDs tend to have lower sensitivities. Above around 8000 Å the anti-reflection coating become enhanced reflectors and hence not only is transmission lost but unwanted ghosts are enhanced.

The MES lens is not an achromat for it is designed to give good imagery for small wavelength ranges. When obtaining spectra, particularly with narrow slit widths, each wavelength domain requires a separate lens focus.

Several secondary modes are available in practice for their inclusion does not impinge on its primary performance. For instance, a direct image of the field can be obtained by both the insertion of a clear area to replace the slit and of a mirror before the grating. For one thing, precise slit positions against images of extended sources can be obtained using this facility.

Also, insertion of a grism along with the plane mirror permits longslit, low-dispersion (76.3 Å mm^{-1}) spectra to be obtained.

Table 1. Parameters at the Aristarchos f/8 focus (f.l. = 17714 mm)

ATS SPECTROMETER			
gratings	**option 1 (RED)**	**option 2 (BLUE)**	**option 3**
(grooves/mm)	1200	1200	600
(arcsec)	≡ 10	≡ 10	≡ 10
spectral range	5780-7070 Å	4400-5780 Å	4200-7300 Å
resolution	2.5 Å	2.5 Å	6 Å
dispersion	103 Å mm^{-1}	95 Å mm^{-1}	245 Å mm^{-1}
centered wavelength	6400 Å	5000 Å	5750 Å

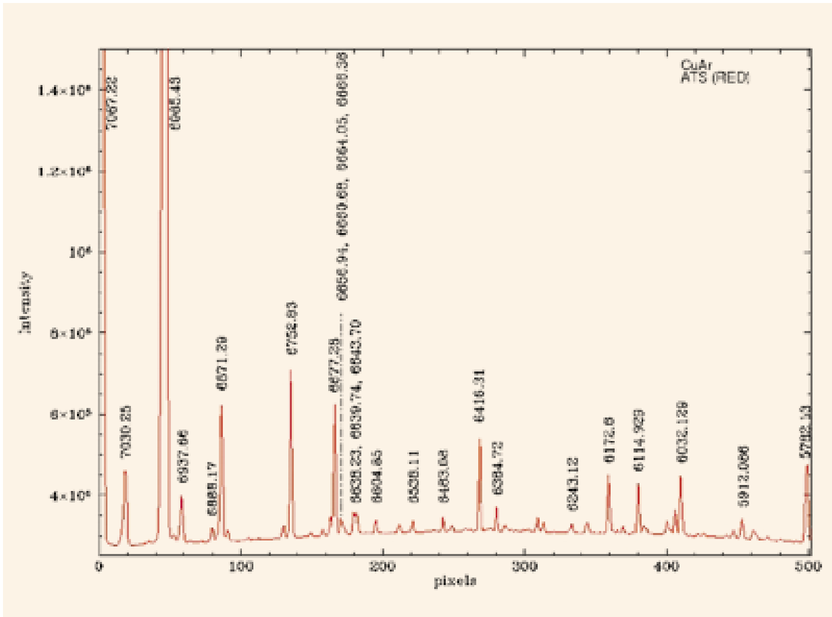

Figure 8. The calibrated arc of CuAr lamp for option 1 grating (table 1)

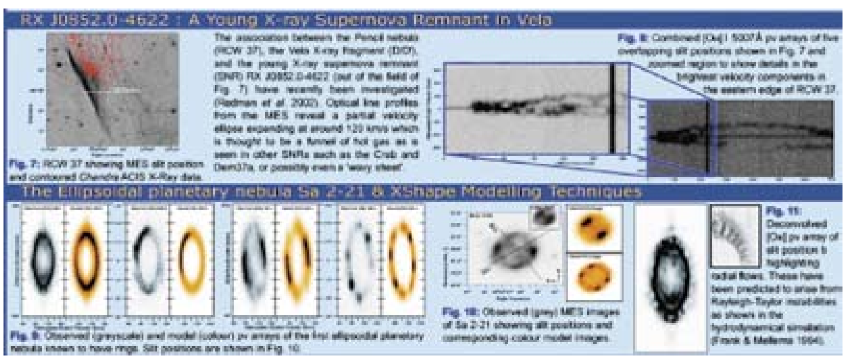

Figure 9. Examples of the MES results.

We present information on the performance of MES on the Aristarchos 2.3-m telescope (MES-AT; Meaburn, Boumis, Goudis 2003) and points out several operational details (Meaburn, Boumis, Harman, Maroussis 2007).

The performance of MES, shown in Figs. 10 and 11, is summarized in Table 2 when combined with the Aristarchos 2.3-m telescope. No mention is given here of the CCD detector that could be used because this can vary with availability (at the moment a liquid-nitrogen cooled 1024x1024 CCD, 24μm pixel size is to be used) .

The best guide to the performances of these two versions of MES are the several hundred papers produced as a consequence of their use at the three observatories. Typical examples of the use of the first MES on the AAT can be found in Meaburn, 1984; Meaburn & Walsh, 1989; Bryce et al, 1997; Redman et al. 2002; Harman et al. 2003; results from the last two can be seen in Fig. 9. An example of the use of the second MES at La Palma is Bryce et al, 1992, and when at San Pedro Martir, Lopez et al, 1997 and Meaburn et al, 2005.

A good use of the low-dispersion grism in the second MES when at La Palma is illustrated by the results in Ivison, Bode & Meaburn, 1994.

The overall electronic system has been upgraded to operate it from a PC.

• A user interface has been developed instead of the previous mechanical console (which is still connected and always available for use in case of computer failure). A calibration device has been designed and manufactured in order to calibrate the spectra. This system is controlled both by the PC and a mechanical console. The wiring of the whole system is shown in Fig. 13.

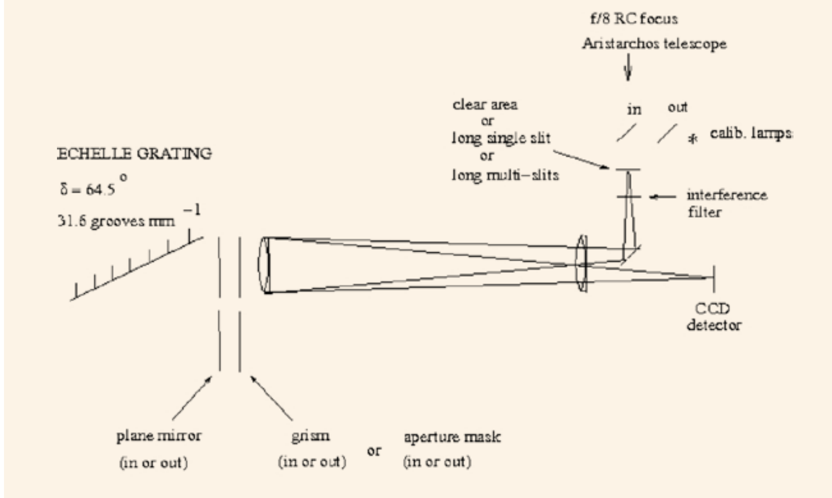

Figure 10. The optical layout of the Manchester Echelle Spectrometer (MES-AT)

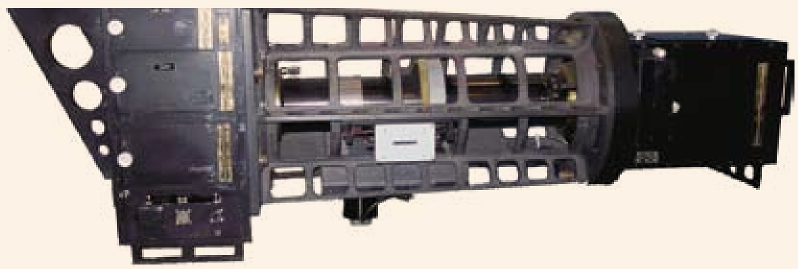

Figure 11. The mechanical layout of the Manchester Echelle Spectrometer (MES-AT)

Table 2. Parameters at the Aristarchos f/8 focus (f.l. = 17714 mm)

ECHELLE SPECTROMETER			
slit widths (μm) (km s^{-1}) (arcsec)	**option 1** 70 ≡ 5 ≡ 0.8	**option 2** 150 ≡ 10 ≡ 1.7	**option 3** 300 ≡ 20 ≡ 3.5
multi-slits	**number of slits** 10 slits 5 slits 3 slits	**free spectral range** 1.65 mm separation ≡ 138 km s^{-1} 3.3 mm separation ≡ 277 km s^{-1} 6.6 mm separation ≡ 555 km s^{-1}	**Separation on sky** ≡ 19.2 arcsec ≡ 38.4 arcsec ≡ 76.9 arcsec
slit length	**linear** 30 mm	**on sky** ≡ 5.82 arcmin	**comments** current max.
order isolator filters	**centre (bandwidth)** 6730 (100) Å	**centre (bandwidth)** 6580 (100) Å	**centre (bandwidth)** 5020 (70) Å
echelle grating	**blaze angle** 64.5°	**grooves mm^{-1}** 31.6	**ruled area** 128 x 254 mm^2
GRISM SPECTROMETER			
	dispersion 76.3 Å mm^{-1}	**spectral range** 4500 – 6750 Å	
IMAGING			
field area (max)	**linear** 19 x 30 mm	**on sky** ≡ 3.69 x 5.82 $arcmin^2$	

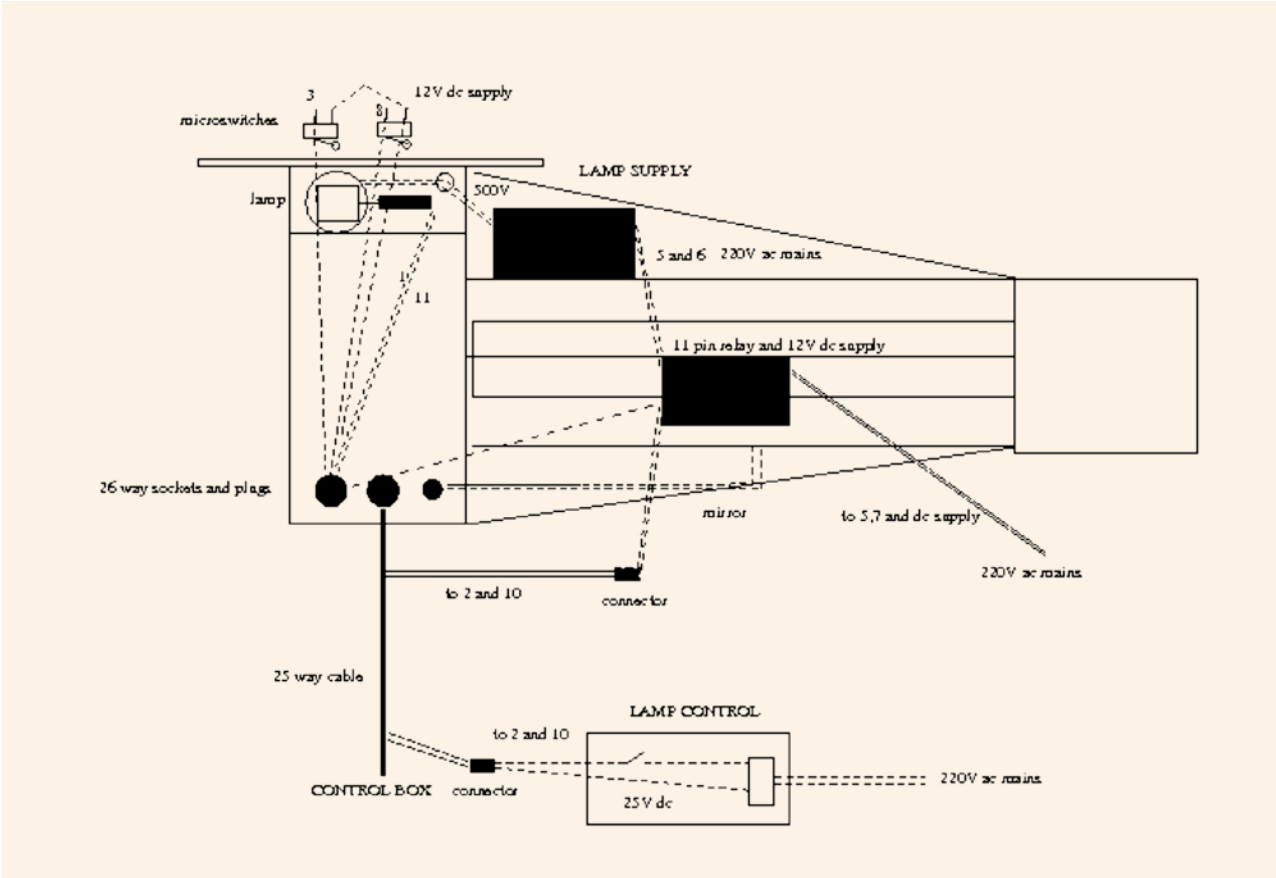

Figure 13. The wiring of the calibration system is shown.

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The *Vernikos-Eugenides* Wide Field CCD Camera of the 2.3m "Aristarchos" telescope

by Manolis Plionis & Ioannis Georgantopoulos
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Abstract

A new wide-field CCD imaging camera is to be installed on the 2.3m "Aristarchos" telescope, now in the final stages of commissioning in Mount Helmos. The excellent specifications of this f/8 Ritchey-Chretien telescope (<4" pointing accuracy down to elevations of to z=70 deg, image quality on axis <0.35", uncorrected FOV 10.1' in diameter, RC-corrected FOV 1.04 deg) in conjunction with the new wide-field imaging camera will provide a very versatile scientific instrument, from which the Greek astronomical community will benefit greatly. The camera is equipped with a single high-quality science 4K x 4K CCD chip, a fact that not only provides an inexpensive Wide Field Camera but also reduces dramatically the difficulty of the data reduction procedures and relevant software development, a known problem with other Wide Field (WF) imaging instruments.

1. Introduction

Within the scopes of the project "*X-ray Astrophysics with ESA's Mission XMM*" that was awarded to the X-ray Astronomy & Cosmology group of the Institute of Astronomy and Astrophysics in 2002, under the program "Promotion of Excellence in Technological Development and Research", was the acquisition of a CCD camera for the new *Aristrachos* 2.3m telescope (see related article of Goudis et al. in this volume).

This new (Vernikos-Eugenides) Wide Field Camera (VEC), covering a relatively wide-field of view (10.1' x 10.1'), will provide the astronomical community of Greece with a unique opportunity to undertake a relatively high spatial resolution, deep, broad band imaging survey of selected areas of sky. Deep optical surveys combined with large area surveys at all wavelengths, are fundamental in searching for rare types of objects, discovering new categories of objects, and doing accurate large volume statistical surveys. The scientific returns from the use of VEC will be enormous: ranging from Solar System studies, such as searches for primordial comets and Near Earth Asteroids out to searches for distant objects in the Universe, such as high redshift quasars and galaxies. The wide field data will be especially powerful when used in conjunction with survey data in other wavebands, e.g. the 2 micron *2MASS* survey, the deep *VLA* radio surveys *FIRST* and NVSS, the forthcoming *ACT* and *LMT* sub-mm surveys, the *XMM* wide area survey, and selected deep *XMM* and *Chandra* X-ray survey fields.

A variety of studies could be realized with the VEC, among which the search for extrasolar planets and transient phenomena (asteroids, supernovae, AGN variability, etc), star formation activity in nearby galaxies, cosmological evolution of different active and starburst galaxies, galaxy formation and evolution, clusters and groups of galaxies at intermediate and large redshifts, unveiling the cosmic-web and cosmological parameter estimation.

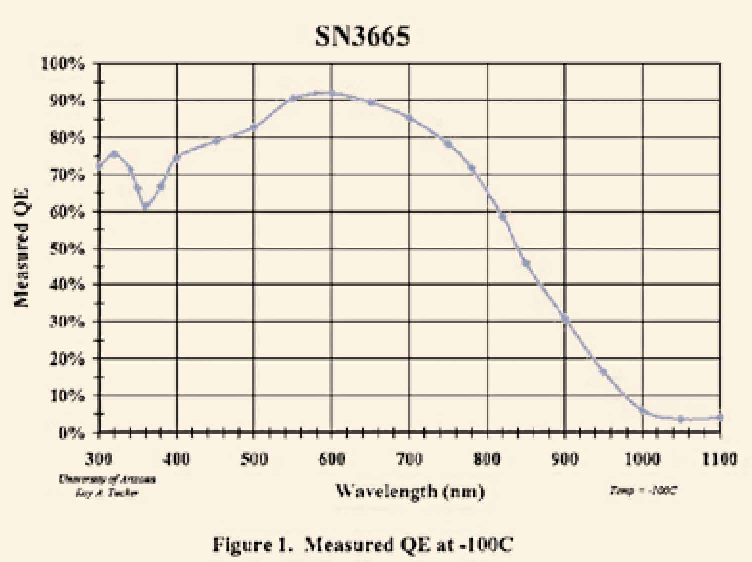

Figure 1. STA0500 A Chip Quantum efficiency.

2. Technical Details of the new CCD Camera

The new wide-field camera uses a back-illuminated 4k x 4K *STA0500 A* CCD chip with a 15 microns pixel-size. The acquisition of the back-illuminated CCD chip became possible due to a collaboration between the Institute of Astronomy & Astrophysics of the National Observatory of Athens and the *Eugenides Foundation,* who provided the extra funds necessary to upgrade the originally planned front-illuminating chip to a back-illuminated chip. This CCD chip has a very high quantum efficiency (as can be seen in Fig.1), peaking at 92% at 600 nm, falling off pretty linearly in both directions from there to 75% at 400nm and 68% at 800 nm. According to the joint decision between the IAA of the NOA and the Eugenides foundation, the new wide-field camera was named ***Vernikou-Eugenides CCD camera (VEC).***

The acquired CCD chip can be cooled well below -100 deg. C, and has multiple outputs. The cooling system is liquid nitrogen in a dewar that has a 3-liter capacity, giving a hold time well in excess of 24 hours. The temperature stability is maintained by a diode temperature sensor and a small resistor, both mounted close to the CCD, regulated by a digital temperature controller that maintains the temperature to 0.2 deg. C. The main camera that hosts the STA0500 A chip has a spectral range between ~300 to ~1100 nanometers and it was build by *Astronomical Research Cameras, Inc., USA*. Regarding the camera operation possibilities given to the user we would like to stress that at any time during the operation of the camera, the user will be able to select:

- software selectable readout from any one of the four readout corners or all at once.
- software selectable binning in both directions
- software selectable readout of sub-images
- software selectable temperature control of the CCD.

In Figure 2 you can see the VEC camera and the CCD chip.

The readout rate of the CCD is determined by software, built in during the system integration. The default total pixel readout time is 3.24 microsec, which can be made shorter (increasing the readout noise) of longer (decreasing the readout noise) in software. This gives a total readout time for the 4K x 4K chip of 52 seconds if reading out the whole image from one quadrant or 13 seconds in simultaneous quadrant readout mode (which is a built in possibility). The photon transfer curves, one for each quadrant of the chip, have been derived and the default average readout noise is found to be ~8 electrons rms.

Note however that installing the VEC camera to the side ports of the "Aristarchos" telescope, where the FoV is 10.1 arcmins, would imply a pixel size that corresponds to 0.15 arcsec's on the sky. Therefore, the camera will be used in a bin x2 mode, which implies a readout time of about 13 seconds for the whole chip (or 4 seconds in simultaneous quadrant readout mode). Only with the acquisition of a focal reducer and moving the camera to the main Cassegrain port would it be possible to exploit the full potential of the camera and sample a much larger field of view (~30 arcmins with a pixel size ~0.45 arcsecs).

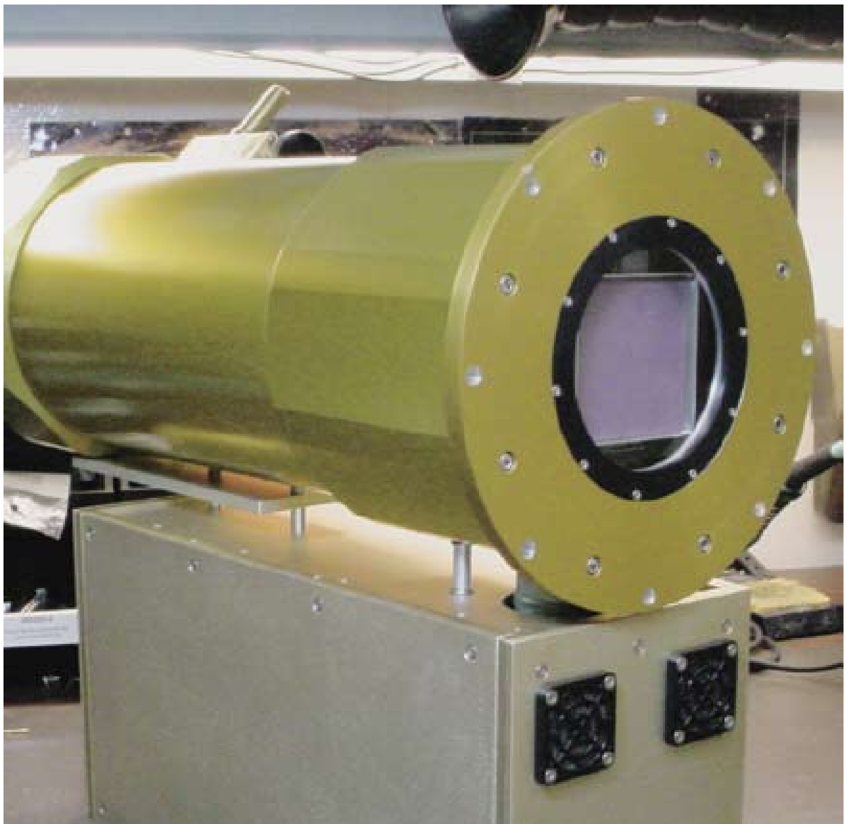

Figure 2. The VEC camera (the STA0500 A Chip can be seen).

Using some first estimates of the sensitivity of VEC with the *sloan* photometric system, we anticipate that it would require ~6.5 hours to sample one square degree (including some dithering and the overheads) to reach a 5 sigma sensitivity of 23.5 in the sloan i-band filter. This implies that in ~30-32 clear nights we can survey a 6 square degrees area in all 5 colors, providing hundred of thousands of galaxies with available photometric redshifts.

3. Science with the new Vernikou-Eugenides Wide Field Camera (*VEC*)

Below we describe in more detail two example science cases for wide-field surveys that can be conducted with the VEC camera over a reasonable period of a few months.

3.1 Detailed studies of the cluster of galaxies environment, dynamical status and evolution in order to constrain theories of structure formation and star-formation processes.

In the framework of the hierarchical model for the formation of cosmic structures, galaxy clusters are supposed to form by accretion of smaller units (galaxies, groups etc) along the filamentary structure within which they are embedded (cf. Shandarin & Klypin 1984; West 1994), which after the epoch of primary aggregation (which depend on the cosmological model), violent relaxation processes will tend to virialize the clusters producing *regular*, quasi-spherical, with smooth radial density profile clusters. Recent low-z observational indications, based on the relative orientation of substructures and galaxies within clusters (West, Jones & Forman 1995; Plionis et al. 2003) and on the relation between the dynamical state of clusters and their large-scale environment (eg. Plionis & Basilakos 2002; Basilakos, Plionis, Yepes & Gottlober 2006), do support the hierarchical model for cluster formation and show that a considerable number of local clusters are dynamically active (see also Buote & Tsai 1996). Furthermore, hints do exist for a very recent (within the last Gyr) dynamical evolution of the cluster population (Melott et al 2001; Plionis 2002). A related issue, the dynamical evolution of member galaxies and the ICM gas, is also poorly understood (cf. Buote 2000). Intense star formation seems to occur in clusters showing substantial substructure and velocity gradients, as expected if a recent merger has taken place. For example, the fraction of blue galaxies is strongly correlated with cluster ellipticity (Wang & Ulmer 1997), while ellipticity is strongly correlated with the dynamical state of the cluster (cf. Kolokotronis et al. 2001). It appears that the violent merging events trigger star-formation, possibly through a multitude of different mechanisms; for example, the excess number of galaxy-galaxy interactions, the rapid variation of the cluster gravitational field (Bekki 1999), etc. Unveiling these mechanisms and their evolution through time is an important task in order to understand how clusters and galaxies form and evolve.

Such important issues could be studied in detail using VEC 5-band (u,g,r,i,z) observation of a large number of clusters at different evolutionary phases and redshifts. At large redshifts the new sub-mm and mm facilities (*LMT*, *ACT* etc) will provide the means of detecting high-z clusters through the Sunyaev-Zel'dovich (SZ) effect. The *ACT*, a 6-m mm-wavelength telescope funded by NSF is now under construction in Chile above the *ALMA* site on Cerro-Tolo. It is designed specifically to search for, and identify a few hundred clusters and collapsed structures down to a mass limit of M > 3 x 10^{14} Solar Masses in the CMB map region through the S-Z effect. The *LMT*, with its larger aperture and higher resolution (6 - 20 arcsec pixels) has the ability to follow-up these observations at 1.1 - 3.3 mm, and resolve the SZ emission providing important information on the distribution of hot-gas and material within the cluster halo. However, neither of these facilities, traces the stellar content (in galaxies) of the clusters. A major science-goal of the VEC, therefore, would be to exploit its sensitivity, resolution and wide-field capability, and provide multicolor optical confirmation of the galaxy population associated with the cluster potential. These data could be complemented by the spectroscopic capabilities of the *GTC*, and follow-up X-ray observations using *Chandra,* and *XMM*, facilities on which we have regular access and excellent record of being awarded observing time: see

http://www.astro.noa.gr/xray.

Together this impressive multi-wavelength data-set will allow us to determine the local and distant fraction of dynamically active clusters of galaxies, the evolution of cluster virialization and thus investigate structure formation theories and put constraints on the cosmological parameters.

3.2 Investigating the high-energy properties of normal galaxies: Deep surveys with *Chandra* have demonstrated the emergence of 'normal' (ie non AGN dominated) galaxies at faint X-ray fluxes ~10^{-16}cgs.(Hornschemeier et al. 2003). The majority of these systems are found to be star-forming galaxies with X-ray–to–optical flux ratios f_X/f_{opt} ~-2, two orders of magnitude lower than typical AGNs. X-ray selected 'normal' galaxies are detected in increasing numbers with decreasing X-ray flux suggesting that they are likely to dominate the X-ray counts below 10^{-17}cgs.

The studies above however, primarily probe 'normal' galaxies at faint X-ray limits (~10^{-16}cgs – 10^{-15}cgs). At brighter fluxes (>~10^{-15}cgs) the 'normal' galaxy source counts remain ill constrained. The only observational data in this region of the parameter space are from Georgakakis et al. (2006). Their 'normal' galaxy sample however, suffers from limited statistics (only a dozen 'normal' galaxies). The lack of tight observational constraints at bright fluxes is mainly due to the low surface density of 'normal' X-ray selected galaxies requiring wide area surveys to obtain samples large enough for statistical studies. On the X-ray side the *XMM* facility, having 5 times more effective area than *Chandra* and 4 times larger FOV is ideal for such a study while on the optical side the VEC would provide the necessary optical imaging follow-up which beyond the essential determination of the f_{opt} in order to identify the 'normal' galaxies, will provide accurate photometric redshits and thus the three-dimensional distribution of these objects and thus the prerequisites for the determination of their luminosity function and the logN-logS.

However, a major problem with this selection is the presence of obscured and low luminosity AGNs in the log f_X/f_{opt} <–1 regime contaminating our 'normal' galaxy sample. In order to address these issues we will use the photometric redshift estimates provided by the VEC camera to provide a large bona-fide sample of normal galaxies which will then allow (i) the identification of obscured or low-luminosity AGNs contaminating our 'normal' galaxy sample. (ii) constrain the 'normal' galaxy X-ray logN -log S in the flux range ~10^{-15}cgs – 10^{-13}cgs using our bona fide 'normal' galaxy sample which will be complementary to the galaxy counts from the deep *Chandra* surveys (Hornschemeier et al. 2003). (iii) Constrain the evolution of 'normal' galaxies by estimating the luminosity function of our X-ray selected 'normal' galaxies at *z~0.1*, the mean expected redshift of our sample and comparing with the normal galaxy sample of Hornschemeier et al. (2003) based on *Chandra* ultra-deep data at a mean redshift z~0.3 will allow us to constrain the X-ray evolution of these systems.

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The birth of "ARISTARCHOS"

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1. History

The National Observatory of Athens (NOA), the primary observational astronomical establishment in Greece, was pursuing the installation of a new advanced technology telescope in Greece soon after the author of this article was elected Director of the Astronomical Institute for the period June 1996-June 1999. Following elaborate discussions with colleagues from NOA and the Greek National Committee of Astronomy (GNCA), the new telescope project was suggested to the General Secretariat for Research and Technology (GSRT), early in 1996.

The initial proposal was submitted to GSRT in March 1997 and the final in September 1997. Upon approval of the proposal by the Board of Directors of NOA, the project was also approved by GSRT in November 1997. It was financed through funds of the 2nd Framework Supporting Program of EU, while the author was leading the project as Principal Investigator (until the 13th of June 2000).

Construction of the telescope was awarded to the company Carl Zeiss Jena GmbH following an international tender, which took place at the premises of NOA on the 18th of February 1998. The author was the chairman of the committee for the international tender and the contracts between NOA and Zeiss were signed on the 31st of July 1998. According to the original schedule, first light of the telescope was expected in late 2001.

The scientific case and the technical details of the new telescope were presented to the Hellenic astronomical community during the Workshop "Astronomy 2000+: Greek Prospects for the 21st Century", organized by GNCA in November 1998. Soon after investigations started to locate the best feasible site and the name of "ARISTARCHOS" was given to the new telescope.

Initially, the telescope was planned to be installed in the Kryonerion Station of NOA (altitude 900 meters). In the meantime it was suggested to the author, by Dr Sinachopoulos, that a much better site would be "Neraidorachi", the highest peak of Mount Helmos, at an altitude of 2340 meters. After several tests, the Helmos site was indeed proved appropriate and on the 17th of November 1999 GSRT endorsed the author's proposed change.

When the new telescope was proposed, our aim was not only to advance Greek observational astronomy but also to promote a wider astronomical collaboration (Kontizas et al. 1999a) which could include the Balkan, East European and Black Sea countries. This is a realistic and feasible goal, especially now that efforts to organize a Mediterranean astronomical collaboration have been undertaken by the Southern European countries. In this collaboration Greece can play a significant role since the new telescope would be the largest telescope in the Eastern Mediterranean.

In June 1999 the author's five year period of directorship of the Institute of Astronomy and Astrophysics expired. At that time the telescope was expected to be in operation by the end of 2001.

On the 17th of January 2000 a committee of "Operations and Equipment Development" (from members of the Institute), was appointed by Dr. D. Lalas (the acting director of the Institute of Astronomy and Astrophysics) with the aim to define the equipment still needed to complete the infrastructure, to prioritize the use of instrumentation, to plan the initial operation of the telescope and to negotiate with potential partners. Since July 2000 this committee has been enlarged to include two members of Hellenic Astronomical Society as representatives of the Greek astronomical community, namely Prof. J.H. Seiradakis and Prof. P. Laskarides (Hipparchos, Vol.1, issue 8, p 4, 2000).

On the 13th of June 2000, Dr. Lalas appointed the new Principal Investigator of the "Aristarchos project", Dr. P. Rovithis and the late Dr. E. Harlaftis (deputy). A few months later Dr. Rovithis retired and Dr. Harlaftis took over as P.I. until the appointment of the new director in 2001.

2. Seeing and weather conditions at the Helmos site

Mount Helmos (Aroaneia) is in Peloponnese (E 22° 12' 32.5", N 37° 59' 35.3") and the telescope is located at *Neraidorachi*, at an altitude of 2340 meters (Kontizas, 1999b). The selected location is very near the fountain of Styx, where Thetis, the mother of the famous hero Achilles, plunged him while an infant to make him invulnerable. The site profits from the existing infrastructure provided by the near-by ski center, which is operated by the city of Kalavryta.

The site is very dark (Cinzano *et al,* 2000), actually one of the darkest in continental Europe. During winter, the top of the mountain is above the clouds for about half of the time and this yields a great number of clear nights yearly. It is expected that the number of clear nights at Helmos will be more numerous than at Calar Alto southern of Spain.

In addition, the site very often is above the inversion layer of the atmosphere and this yields excellent astronomical images. Indeed, a first series of image motion measurements yielded values between 0.3 and 1.5 arcsec, with median value 0.7 arcsec (Sinachopoulos *et al.* 2000). This median value is about the same as the published values by Birkle *et al* (1976) for a near-by (to Helmos) area.

At this site, the new telescope will become a world-class instrument. It is expected to be able to observe in the near infrared too. Moreover, at this location there is no light pollution at all, since all major cities are far away and well hidden by the intervening mountains.

3. Specifications of the telescope when ordered

The critical design review was approved on the 23rd of March 1999 at ZEISS in Jena and the factory acceptance of the enclosure on the 11th of April 2000 in Rudolstadter Stahlbau factory.

The new Hellenic telescope "Aristarchos" was planed to be of altazimuth type, with a 2.3m primary mirror and Ritchey-Chretien optics that would give a corrected field of view of 1.04 degrees. It was planed to embody the latest developments of technology and to be equipped with state-of-the-art astronomical instruments. In addition, it would be automated and remotely controlled through the network. The wide field of the telescope would make it suitable for observations of extended objects such as stellar clusters, galaxies and clusters of galaxies.

The initial instrumentation of the telescope would consist of a high efficiency CCD camera, a CCD spectrograph and a CCD mosaic. These equipments would support a great variety of observational programs, based on direct imaging, spectroscopy and photometry of faint objects.

The initial specifications of the telescope, as they appear in the first contract and remain unchanged for the period that the author was the PI of the project are:

- Height (telescope in vertical direction): 9000mm
- Weight of moving parts: ~ 3000 Kg
- Mounting system: Altazimuth with 6 drivers per axis
- Encoding systems: 2 tape encoders per axis with a resolution of 0.02 arcsec
- Maximum rate of movement on each axis: 2degrees/sec
- Accuracy of pointing: < 4 arcsec, up to z=70°
- Accuracy of tracking in 10 minutes: <0.25 arcsec
- Operating humidity range: up to 80% R.H.
- Operating temperature range: –10 to +35 °C
- Resistance against wind in operation: up to 15 m/sec
- Balance: Automatic telescope balancing system
- CONTROL SYSTEM
  - – Manual mode
  - – Automatic mode
  - – Remote control mode
  - – Three levels of safety (software limits, signal limits and hardware limits)
- OPTICS
  - – Primary mirror diameter: 2.28m
  - – Optical system: Ritchey-Chretien
  - – Final focal ratio: f/8
  - – Field of view: 1.04 degrees
  - – Image quality: 0.35 arcsec (80% encircled energy) on axis, from 350nm to 1000nm.

4. Observational capabilities of the 2.3-m telescope

The new "Aristarchos" telescope will be the major astronomical instrument in Greece in the beginning of this century. It will significantly expand the observational horizons of Greek astronomy, since it will be able to observe down to ~24 mag for imaging and photometry and to ~18 mag for spectroscopy. With its equipment it will be able to support a great variety of observational programs. Considering the specifications of the telescope, a list of potential projects are:

- Search for N.E.O. (Near Earth Objects)
- Search for new planetary systems
- Young stellar objects
- Monitoring Novae and variable stars
- Studies of black hole X-ray transients
- Interacting binary stars
- Stellar clusters and associations
- A.G.N (Active Galactic Nuclei)
- Clusters of galaxies
- Observational cosmology

Through the remote control mode, the new telescope was planned to be controlled from the home institutes of the astronomers, significantly facilitating the astronomical observations in Greece. In addition, it could be linked to Schools and Universities, for educational and training purposes.

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The Kryoneri Observatory

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1. History

In 1916 D. Eginitis, at that time Director of the National Observatory of Athens and Professor of Astronomy in the University of Athens, writes:

> "The Greek national benefactor and personal friend of mine, Marinos Korialenios, who lately died in London, has disposed nearly the whole of his great estate for national purposes and bequeathed at my request to the National Observatory of Athens the amount of Drs 200.000 for the purchase of a big equatorial telescope. By means of this bequest, the major part of which has already been collected and deposited with the National Bank of Greece, our Observatory will soon obtain the desired powerful instrument which under the clarity of the sky of Attica will undoubtedly offer great services to the science".

In 1969 Dr. S. Plakidis, Emeritus Professor of Astronomy in the University of Athens and Honorary Director of the Astronomical Institute of the National Observatory of Athens writes the following in connection with the M. Korialenios bequest: "Unfortunately it has not been possible to acquire the Korialenios telescope owing to the intervention of several events, such as the First World War, the Asia Minor disaster and other internal anomalies. The Korialenios bequest, which later was amalgamated by Prof. D. Eginitis with the estate of the National Observatory, has suffered considerable mutilation after the Second World War and the subsequent distress of this country to such a degree that it was not sufficient for bringing into effect its purpose".

In 1971, under the supervision of Dr. D. Kotsakis, (Professor of Astronomy in the University of Athens and Director of the Astronomical Institute of the National Observatory since 1965) an application was submitted for the credit of Drs 12.000.000 which was approved by the Government. So an essential increase of the bequest was effected permitting to start enquires and discussions with a view to buy a telescope of 100-120 cm.

Figure 1. The dome of the 1.2 m telescope at Kryoneri.

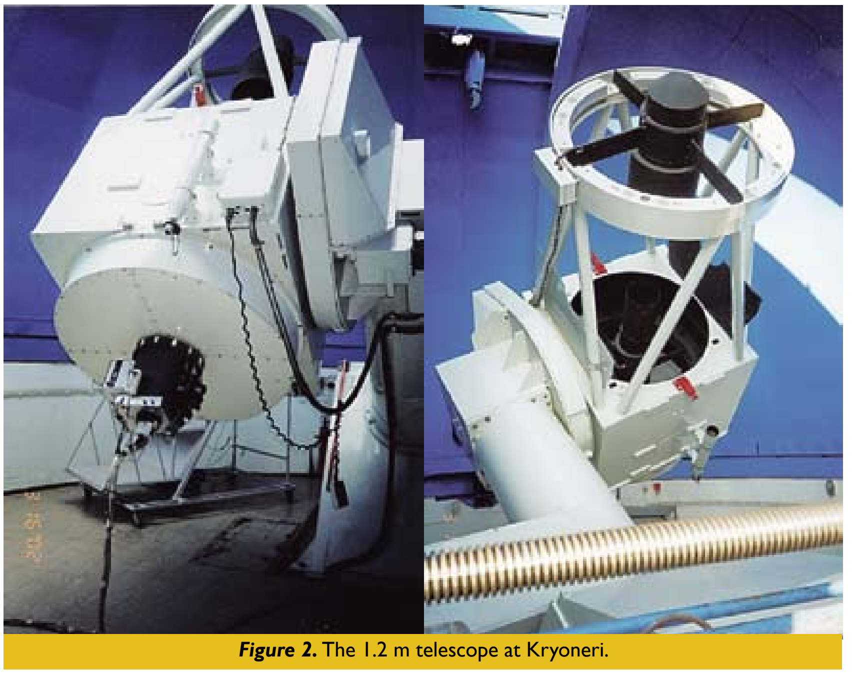

Figure 2. The 1.2 m telescope at Kryoneri.

On August 1972 a contract was signed in Athens between the National Observatory of Athens and the factory Grubb – Parsons and Co of Newcastle, England for the construction of a Cassegrain type equatorial reflector of 120 cm aperture and other auxiliary equipment included (revolving dome etc) for the total price of £ 156.000. The aluminizing plant for the mirrors has also been ordered at Edwards High Vacuum Company of Crawlay Sussex, England at a price of £ 35.000.

In parallel with the placing of the order for the telescope several sites away from the plain of Attica were examined by members of the Astronomical Institute on the basis of climatic and meteorological conditions. Among them, a region of Corinth, 22 km SW of Kiato near the village of Kryoneri at a hight of 930 m was selected as the most appropriate, considering that many reasons such as the morphology of the ground, the meteorological conditions, the easiness of access as well as of supply of electricity, water and telephone. The National Observatory of Athens proceeded to the purchase of a land of 60 thousand sq. m. on the selected hill.

Figure 3. The aluminizing plant unit at Kryoneri Observatory.

The construction of the building for the 120 cm telescope and the installation of the dome and the telescope were completed in September 1975. In the mean time a road of 1200 m leading from the highway up to the top of the hill was paved and electricity current was supplied. In parallel water supply from a fountainhead at a distance of 200 m and the fencing of the ground were completed. In 1976 the aluminizing plant was installed in the same building.

2. Telescope and instruments

The installed reflector's primary mirror is an f/3 paraboloid, with a focal length of 3.6 m and a prime focus unvignetted field of about 40 minutes of arc. The f/13 hyperboloidal secondary, 30.6 cm in diameter, gives a Cassegrain effective focal length of 15.6 m. Both primary and secondary mirrors are made from Zerodur blanks and have very low expansion coefficients. There are two 7.5 cm finders.

Throughout its lifetime Kryoneri telescope has been equipped with several instruments which were used, mainly, to perform photometric and spectrographic observations. Amongst the most important one that have been used are (a) an *Infrared Photometer* (constructed by the Royal Observatory of Edinburgh, Scotland) operating in the λλ (1-6 μm) range (b) a *two-beam Multi-mode Nebular-Stellar Photometer* (constructed by the Department of Astronomy, University of Manchester, England) designed to work on both extended and discrete objects emitting either line or continuum radiation in the wavelength range 3700 Å to 9000 Å (c) a *Planetary Camera* (constructed by the National Observatory of Athens) (d) a *Photoelectric spectrum scanner* (constructed by the Department of Astronomy, University of Edinburgh, Scotland) (e) a *Camera for Stellar fields* (constructed by Grabb-Parsons) (f) a *P21 Photometer.*

Since 1996 a Series 200 CCD *Photometrics* camera (516×516 pixels) is the main scientific instrument of the telescope.

3. Research Activities

Throughout its thirty year lifetime several projects have been conducted leading into more than 100 refereed publications in international astronomical Journals. These projects include:

- Optical variability studies of Active Galactic Nuclei (AGN) on time scales of a few minutes to long term monitoring campaigns (Fig. 4).

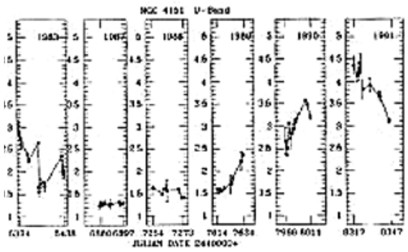

Figure 4. Light curve of the Seyfert galaxy NGC4151.

- Photometry and monitoring of Cataclysmic Variables (CV) for determining their photometric properties as well as deriving kinematical information of their systems.

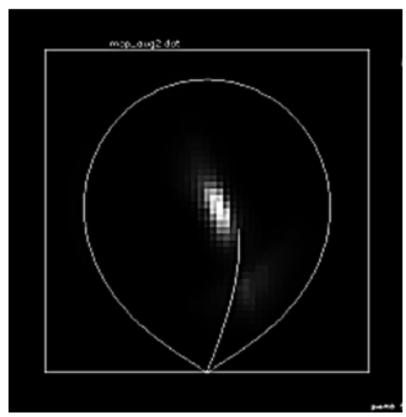

Figure 5. Velocity field of the Cataclysmic Variable EX Draconis created by a series of images taken with the 1.2 m telescope at Kryoneri.

- Variability studies of Symbiotic Stars and their kinematics where velocities as high as 6000 km/sec are observed.
- Observations aiming at the detection of extrasolar planets have been conducted from the Kryoneri site using the WASP camera.
- Wide-field observations of the filamentary structures of Supernova Remnants have been acquired with the 1.2 m telescope at Kryonei (using the MWFC camera) aiming at de-

termining their formation and evolution as well as their correlation with other filamentary structures in their region.

- Variability studies of gravitational lenses aiming at determining the time delay in different optical bands and subsequently a more accurate calculation of the Hubble constant.

4. Future prospects of the 1.2 m Kryoneri Telescope

Currently (summer 2007) the Institute of Astronomy and Astrophysics of the National Observatory of Athens has reached an agreement with members Cork Institute of Technology, Ireland, in funding the upgrade and robotization of the telescope (including a new telescope control system and new motor drives as well as automatic dome rotation).

In parallel, a fast, high-precision optical photometer (Toffee-cam – see Fig. 6) is currently being developed in the Cork Institute of Technology (funded by the Irish Research Frontiers Programme 2005) which will be used both with the Kryoneri and the "Aristarchos" telescopes. At the heart of the photometer will be two state-of-the-art, essential noiseless CCDs (iXon – Andor Technology) with a high read-out-rate (34 frames per second) aiming at high-time-resolution, high-precision photometry. One of the two CCDs have already been tested with the Kryoneri telescope during an observing run in April 2007 and it's unique performance was witnessed.

We foresee that, after its transformation, the telescope will become a state-of-the-art facility for performing top quality astronomical observations as well as having a large contribution in public outreach activities.

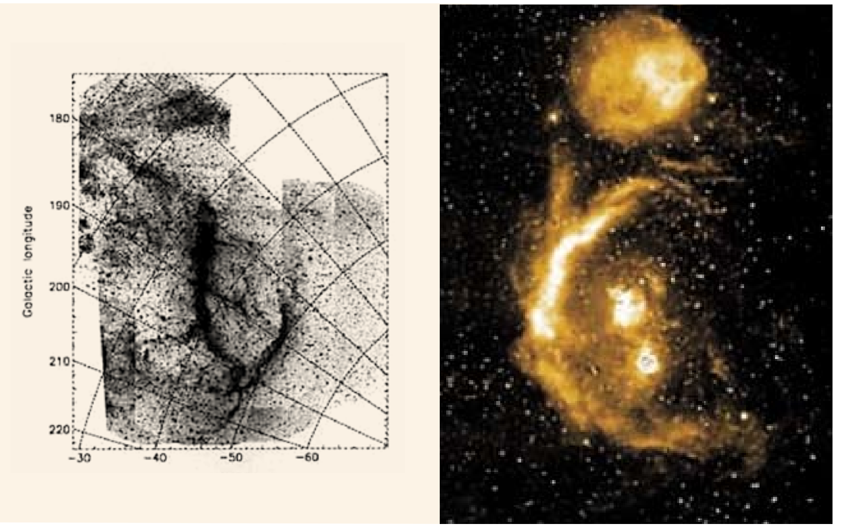

Figure 6. Wide Field imaging (~50°) of the Cygnus arc (left) and of the Orion nebula (right) taken with the MWFC camera attached to the 1.2 m telescope at Kryoneri.

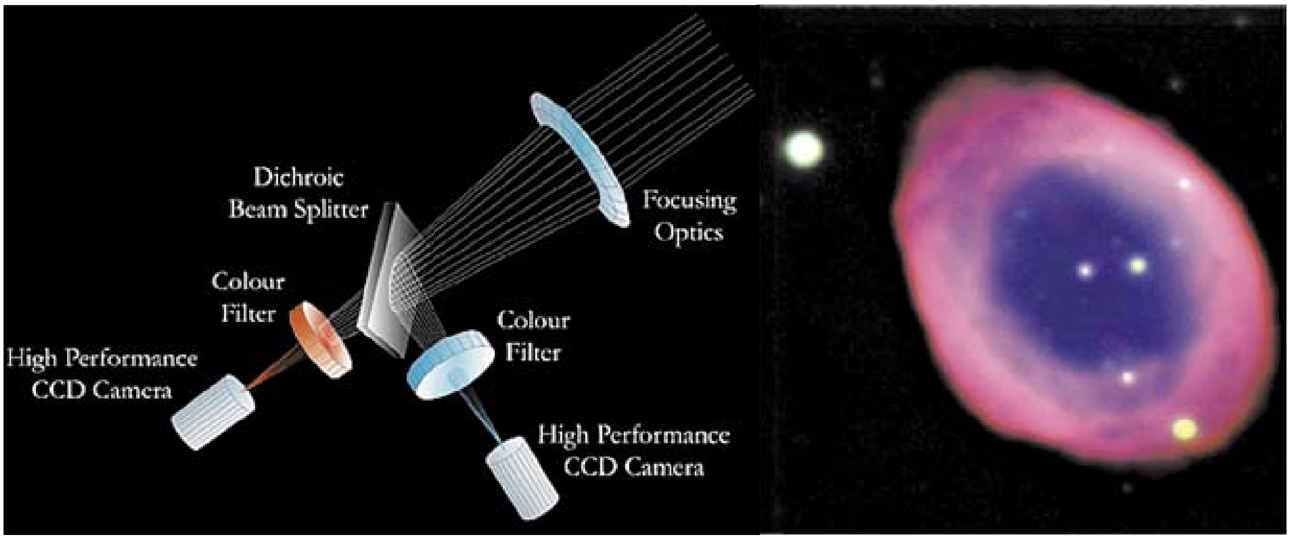

Figure 7. The optical train of the Toffee-cam (left) and sample observation of the Ring Nebula taken with the iXon camera on the Kryoneri telescope. A seeing of 0.9" was measured during these observation.

DIMM sampling of the "seeing" at Kryonerion

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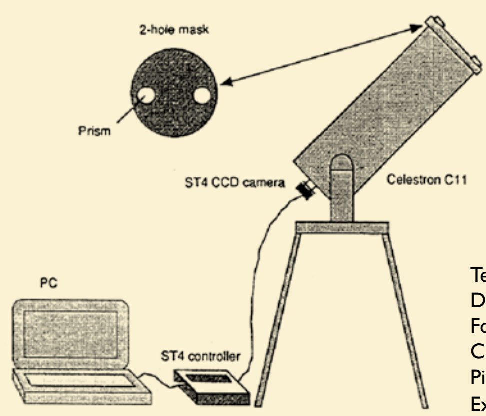
Abstract

We present a test-study of the "seeing" at the Kryonerion Station of the National Observatory of Athens. We used a Differential Image Motion Monitor (DIMM) during July and October 2002 and find a median "seeing" of 0.68 arcseconds and 1.42 arcseconds, respectively. We also compared the technique against the Hartmann-version of the ESO-type DIMM method and found similar results within 0.05 arcseconds. For some reason, which is under investigation by international teams, the measurements of our ESO-type DIMM are underestimated by ~10% compared to ESO-standard DIMM measurements. Simultaneous ESO-type DIMM measurements and standard gauss-fitting-technique measurements, taken with the Kryonerion 1.2m telescope (inside the dome) indicate that the "seeing", as measured by the telescope is by ~1 arcsecond larger. The above tests were performed in order to calibrate, test and make a brief sampling of the "seeing" at the Kryonerion Station with the aim to move eventually the equipment to the Helmos Station –the site of the new 2.3m ARISTARCHOS telescope– for a long-term "seeing" monitoring. As a by-product of this project, a new DIMM station became operational at Mt. Holomon, in the premises of the University of Thessaloniki, in 2004.



Telescope	:	Celestron G11
Diameter	:	11-inch
Focal length	:	2000 mm
CCD	:	ST-4, SBIG
Pixel array	:	192 x 164
Exposure time	:	0.01 – 300 seconds

Figure 1. The "SAAO DIMM" equipment

1. Introduction

The new station for the 2.3m telescope of the National Observatory of Athens lies at the peak of the 2.3km Helmos mountain, close to the historic-town of Kalavryta in North Peloponese (longitude 22°13' E and latitude 37°59' N). The site characterization of the Helmos Station was immediately one of the concerns for developing further international collaboration and exploiting in full the scientific potential of the new site. In particular, addressing concerns within the OPTICON network regarding the unknown properties of the Helmos night sky, we took initiative to put together a package with the aim to address at least the "seeing" characteristics by setting-up a portable differential image motion monitor (DIMM; Sarazin & Roddier 1990; Tokovinik 2002). Previous measurements of the site "seeing", using the stellar trail technique, were indicating a median seeing as good as 0.7 arcseconds from a sample of 30 winter nights (Sinachopoulos et al. 2000), though this technique is known to be instrument-dependent. As a matter of interest, the stellar trail technique gave similar relative "seeing" measurements between Calar Alto and Mount Parnon (Pyrgaki, 1.8 km) at south-east Peloponnese (longitude 22°.6 E and latitude 37°.2 N) back in the 70's (Birkle et al. 1976). The DIMM method removes every error due to bad tracking, wind or mirror blotches by using a differential measurement of the stellar image motion (through two apertures). Given the minimal resources available, we adopted a portable-version of DIMM, leaving for the next stage the construction of a fixed tower.

2. Instrumentation and set-up

All major Observatories had set-up such "seeing" measuring instruments in the 90's and therefore ample expertise was at hand in the 00's. For example, the IAC DIMM at La Palma (Vernin & Munoz-Tunon 1995), the ING DIMM at La Palma (Wilson et al. 1999), and the Mount Stromlo portable DIMM (Wood, Rodgers & Russell, 1995). SAAO also built an identical set-up for the SALT site testing at Sutherland (Erasmus 2000). The latter was cross-calibrated with the ESO-standard DIMM (Sarazin & Roddier 1990) at various sites and only recently (end of 2004) it was confirmed that it gives a small under-estimate of ~10% (under investigation but most likely due to software pixel sampling). This portable ESO-type DIMM ("SAAO DIMM" – Fig. 1) was then duplicated and used at Kryonerion, NOA. After the Sutherland site-testing finished, some core equipment (CCD-Celestron telescope, interface, mask, ST-4 CCD) was shipped to NOA. The equipment, hardware and software was assembled and tested at the Kryonerion Station (height 898±5 m, longitude 22° 37' 06" and latitude 37° 58' 18"), due to lack of infrastructure and logistics at the Helmos Station. Here, we describe the test measurements we took at Kryonerion during the summer season in 2002. It was envisioned, then, to take up the equipment at a purpose-built hut at the Helmos Station and monitor the "seeing" for one full year.

The technical equipment we used included a 11-inch CELESTRON telescope, a ST-4 SBIG CCD camera and a front-edge telescope mask (Fig. 2). The mask had two apertures, and one of them had a prism that displaced the direct light from the star by ~20 arcseconds. This meant that when we observed a star we were observing two spots from the same source whose differential motion is given as variance errors in the x and y-axis on the CCD chip (Sarazin & Roddier 1990):

$$\sigma_X^2 = 2 \cdot \lambda^2 \cdot r_{oX}^{-5/3} \cdot (0.179 \cdot D^{-1/3} - 0.0968 \cdot d^{-1/3}) \quad (1)$$

$$\sigma_Y^2 = 2 \cdot \lambda^2 \cdot r_{oY}^{-X/3} \cdot (0.179 \cdot D^{-1/3} - 0.1450 \cdot d^{-1/3}) \quad (2)$$

where λ is the wavelength, r_o is the Fried parameter (average turbulent cell), D the diameter of apertures and d the distance of the apertures.

The set-up is displayed in Fig. 1 and the instrumentation is described in detail at Wood et al. (1995). Using the CCD's turbo-pascal software, we measure the variance of the relative positions of the two spots very precisely in both axes. Then, from equations (1) and (2) we can calculate the Fried parameter and from there, the "seeing" (Vernin & Munoz-Tunon 1995; Fried 1965):

$$Seeing(FWHM) = 0.98 \cdot \frac{\lambda}{r_o} \quad (3)$$

3. Seeing Methods and airmass calibration: Results

In addition to the mask/prism DIMM, there is a simpler method just using the Hartmann mask (H-DIMM; Bally et al. 1996) which we also used for comparison. This method uses the same equipment as the SAAO DIMM, but instead of using a prism we just defocus the telescope by a few millimetres to create two image spots. The distance to defocus is given by

$$X = \frac{F}{D} \cdot P \quad (4)$$

where X is distance from the focus in mm, F is the telescope's focal length in mm, P is the pixel size in mm and D is the distance between the two apertures. We typically found that the de-focusing length needed was only 1.3 mm. Our purpose was to check if the H-DIMM method gives the same results as the SAAO DIMM method. We made two masks, one with a prism (prism-DIMM method) and one without (H-DIMM method). During the test observations, the masks were changed every ten minutes. The result of our observations on a photometric night (28 May 2003), using the star α Boo, is shown in Fig. 3, proving that the two methods give identical results within a 0.05 arcseconds accuracy (prism-DIMM Seeing Average = 0.98 arcseconds and H-DIMM Seeing Average = 1.00 arcseconds).

Every time that we measure the seeing from a star, we need to calibrate the data for the changing airmass. This is necessary because "seeing" is a function of the air mass, therefore it is also a function of the star's altitude. For this reason we normalized all measurements at the air mass minimum (zenith). To do that we use equation 5 (Humphries et al. 1984),

$$S \propto S_o \cdot \alpha^{-0.6} \quad (6)$$

where S is the calibrated value at zenith and S_o the "seeing" at airmass α. In the figures following (Fig. 4) we give the corrected "seeing" measurements during our test DIMM observations in July and October 2002.

Figure 2. The CELESTRON telescope and PC driving the "seeing" measurements, next to the small enclosure built to protect the telescope from weather. At the background, the 1.2m telescope dome of the Kryonerion Observatory can be seen.

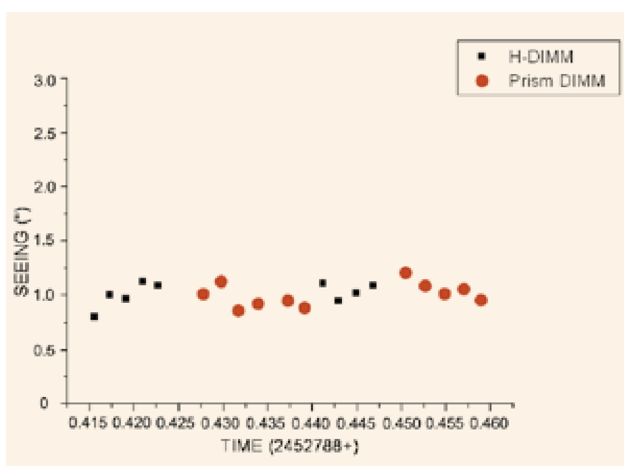


Figure 3. Prism-DIMM vs. H-DIMM. 28/05/2003, α Boo

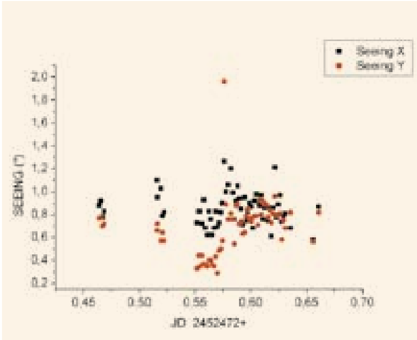


Figure 4a. 16/07/2002, α Lyr

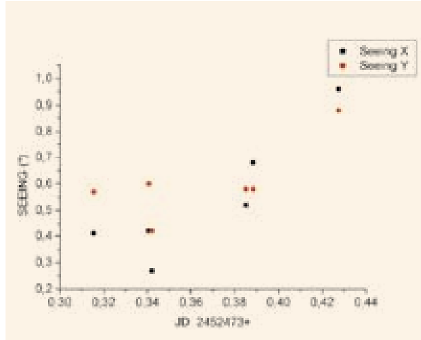


Figure 4b. 17/07/2002, γ Cyg

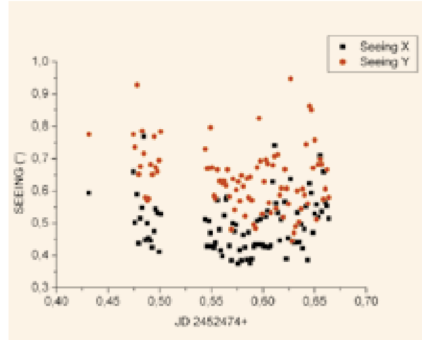


Figure 4c. 18/07/2002, α Lyr

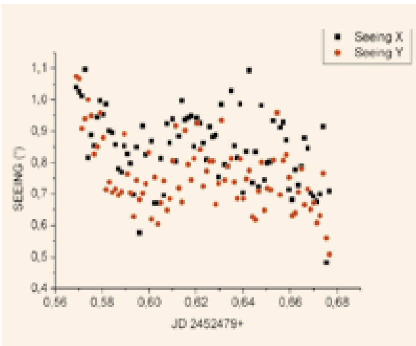


Figure 4d. 23/07/2002, α Lyr

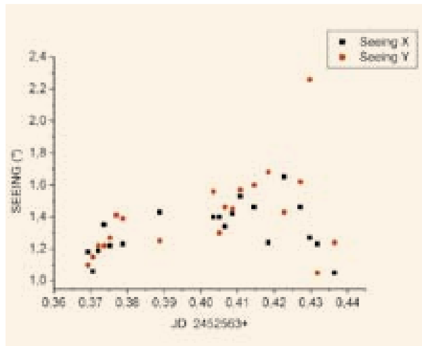


Figure 4d. 23/07/2002, α Lyr

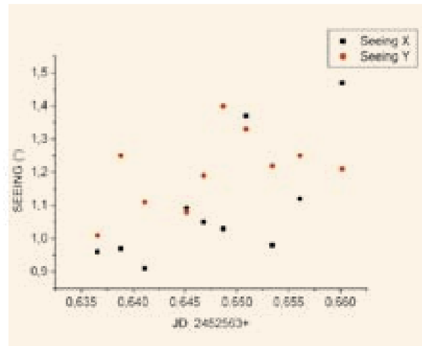


Figure 4f. 15/10/2002, β Ori

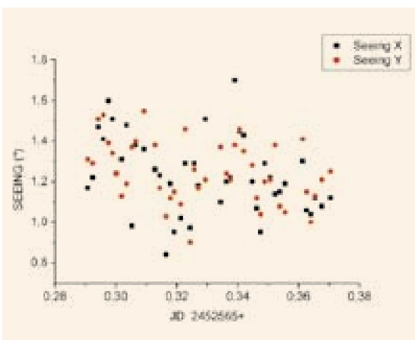


Figure 4g. 17/10/2002, α Lyr

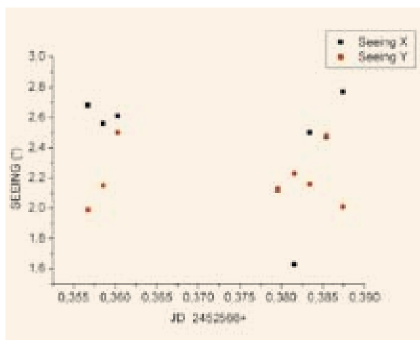


Figure 4h. 18/10/2002, α Cyg

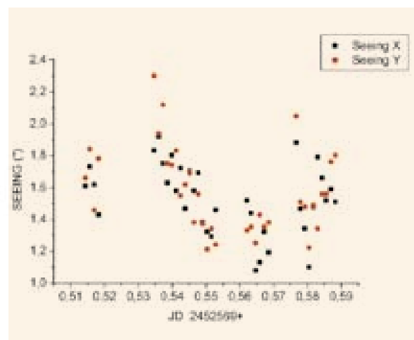


Figure 4i. 21/10/2002, β Ori

From the SAAO DIMM measurements we have:

Table 1: Seeing measurements at Kryonerion Station

Date	Seeing x-axis (arcsec)	Seeing y-axis (arcsec)	Standard Deviation X-axis	Standard Deviation Y-axis	Median "seeing" (arcsec)	Average "seeing" (arcsec)	Standard Deviation of Average
16/07/2002	0.85	0.69	0.10	0.14	0.71	0.77	0.12
17/07/2002	0.54	0.61	0.15	0.09	0.61	0.58	0.12
18/07/2002	1.60	1.42	0.30	0.27	0.80	1.51	0.29
23/07/2002	0.48	0.61	0.10	0.20	0.68	0.55	0.22
13/10/2002	1.69	1.64	0.28	0.19	1.60	1.67	0.24
14/10/2002	1.06	0.98	0.32	0.33	1.06	1.02	0.33
15/10/2002	1.40	1.43	0.11	0.15	1.38	1.42	0.13
16/10/2002	1.10	1.21	0.12	0.16	1.10	1.16	0.14
17/10/2002	1.23	1.25	0.13	0.11	1.33	1.24	0.12
18/10/2002	2.42	2.21	0.21	0.11	2.42	2.32	0.16
21/10/2002	1.53	1.58	0.30	0.34	1.05	1.56	0.32
Average	1.26	1.24	0.19	0.19	1.06	1.25	0.19

Using the data in Table 1, we extract the average and the median seeing value per month (Table 2).

Table 2:
Monthly seeing average at Kryonerion Station

Month (2002)	Median "Seeing" (arcsec)	Average "Seeing" (arcsec)	Standard Deviation (arcsec)
July	0.68	0.87	0.15
October	1.42	1.49	0.21

4. "Seeing" as measured through the telescope

For comparison reasons, we present "seeing" measurements obtained with star trails, using the 1.2m telescope, between 20 October – 6 November 1999 (whilst the neutron-star X-ray transient XTE J1859+226 was in outburst). The air mass has been calibrated and the results are given in Table 3 and the figures below (Fig. 5).

Table 3:
Seeing measurements with the 1.2 m Kryonerion telescope, using star trails

Date	Average "seeing" (arcsec)
20 October 1999	2.40
24 October 1999	2.00
25 October 1999	2.00
26 October 1999	2.46
29 October 1999	2.93
31 October 1999	2.39
1 November 1999	2.02
2 November 1999	2.57
3 November 1999	3.00
6 November 1999	3.50
Average	2.53
Standard Deviation	0.47

5. Discussion

We constructed a prism DIMM setup at Kryonerion Station, based on the SAAO DIMM. The setup was tested at Kryonerion, a well known observing site, in order to use it later at the new Helmos site. We also constructed and tested an H-DIMM setup. The two methods gave almost identical results. The "seeing" at Kryonerion (using the above setups), from a sample of nights in October 2002, was 1.42 arcseconds (median) or 1.49±0.21 arcseconds (average). For comparison, the average "seeing" measurements made with the 1.2 m telescope (from inside the dome), in October/November 1999, was 2.53 arcseconds with a standard deviation of 0.47 arcseconds. The "seeing" at Kryonerion from a sample of nights in July 2002 was 0.68 arcseconds (median) or 0.87±0.15 arcseconds (average). Note that there is an underestimate of ~10% in the above measurements, which were based on the SAAO DIMM, as mentioned above. DIMM measurements, taken outside and measurements taken with the Kryonerion 1.2 m telescope (from inside the dome) gave ~1 arcsecond and ~2 arcseconds, respectively, on 1 July 2002.

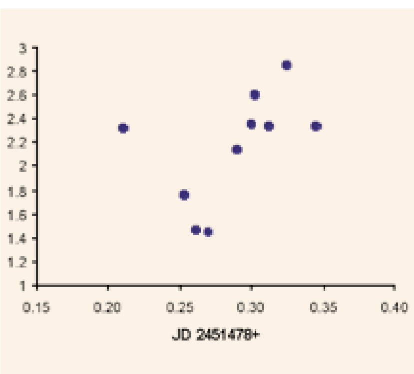


Figure 5a. 26/10/1999, XTE J1859+226

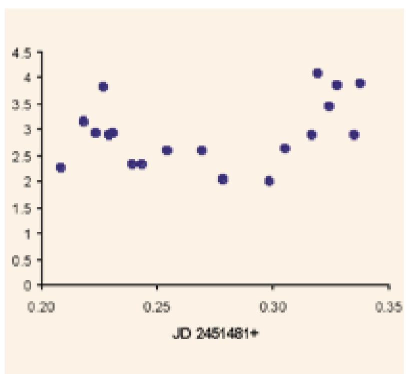


Figure 5b. 29/10/1999, XTE J1859+226

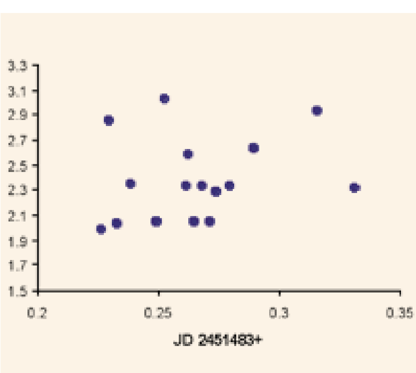


Figure 5c. 31/10/1999, XTE J1859+226

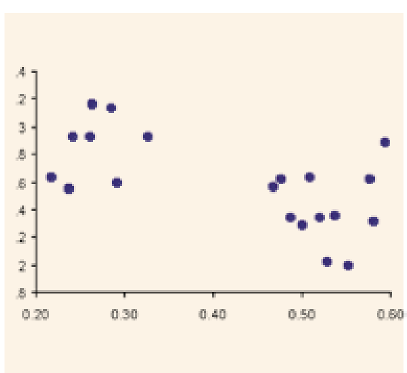


Figure 5d. 02/11/1999, XTE J1859+226

Therefore, the typical difference between the seeing value inside the dome and outside the dome is approximately 1.0 arcseconds. This prompted a follow-up analysis of the optical system of the telescope (Worswick S., Harlaftis, E.T., Dimou, G., this volume). Some of the equipment has been moved to Mt. Holomon Station of the University of Thessaloniki where a DIMM setup is operating since 2004.

Acknowledgements:

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The Image quality of the 1.2m telescope of the National Observatory of Athens

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Abstract

We derive f/13.6 for the 1.2m telescope of the National Observatory of Athens (image scale 0.303 arcseconds per 24 μm pixel) and find that the image quality is dominated by large spherical aberration (2.5 arcseconds for 100% encircled energy). Sub-arcsecond "seeing" convolved with the telescope's optics cannot deliver better image quality than 1.54 arcseconds and real "seeing" is not dominated by spherical aberration for values larger than 3 arcseconds. The combined mirror polishing error is 0.49 arcseconds for 95% encircled energy. The peak to valley error on the primary mirror is 0.236 μm. Out-of-focus images indicate that the support of the mirror is not optimized causing its edge to be raised by 3 μm.

1. Introduction

The f/13.6 1.2m telescope built by Grubb Parsons in 1973 for the National Observatory of Athens resides nearby the village of Kryoneri at prefecture of Korinthia (Rovithis et al. 1999).

Summer research observations by Harlaftis et al. over the past five seasons indicate that the measured "seeing" through the telescope rarely becomes better than 2 arcseconds. DIMM measurements in 2002 showed, on the other hand, that the Kryoneri site could deliver sub-arcsecond "seeing" (Mislis et al. 2005). Thereafter, one of us instigated an optical analysis of the telescope optics in order to verify the "Optical test Reports for the 1.2m telescope for Athens" (Grubb Parsons, hereafter "GP", March 1975) and analyse the image quality. We perform two different analyses: the first is using the optical prescription as given in the "Optical test reports" (design optical system). The second is to use out-of-focus images at both sides of the focal plane (current optical system). The "ZEMAX" optical analysis tool is used throughout the report.

2. Optical Prescription

In a Cassegrain telescope the spherical aberration of the primary mirror is fully corrected by making the surface a paraboloid (conic constant k=-1). The secondary mirror operates with a virtual object, lying at the primary mirror focus, and a finite image lying at the Cassegrain focus. These conjugates define a hyperboloid. The mirror separation required is purely determined by the radii of curvature of the two mirrors and the position of the final Cassegrain focus with respect to the primary mirror surface. The hyperboloidal secondary should have a conic constant (aspheric figuring) that corrects the spherical aberration for the mirror separation and back focal distance that is used on the telescope mount.

Thereafter, the inherent image quality of the telescope optical prescription can be assessed by knowing the conic constant and the mirror separation. The surfaces of the primary and secondary mirrors are defined by the radii of curvature and the form constants (b_2) in the GP report to give the conic constant for a surface $k=-(b_2)^2$ (Table 1).

The manufactured value for k for the secondary mirror is further confirmed by the wavefront error (0.0025 waves or ~1.5nm) obtained for the null test configuration and the secondary mirror parameters given in the GP report.

An estimate of the back focal distance (1001.1mm) has been made by combining the distance between the front surface of the primary and the back of the mirror cell (485.4mm; Grubb Parsons drawing TA1.220) with the measured distance between the back of the mirror cell and the CCD focal plane (458+10+47.7=515.7mm). The separation between the primary and secondary mirrors is 2770.63 mm for the image behind the primary to be at 1001.1 mm. The telescope prescription is given below (Table 2); all the dimensions are in mm. "Surface" is the virtual or real surface (primary or secondary mirror) that the ray reflects to or passes through. "Radius" is the radius of curvature of the surface and "Thickness" is the distance from the surface to the next one in the system.

The image spread at the measured back focal distance is large and shows that the conic constant of the secondary mirror is not correct. The spot diagram in Figure 1 is plotted for a wavelength of 590nm (0.59 microns; consistent with

Table 1

	Radius of curvature mm	Form constant b_2	Conic constant k
Primary mirrr	7198	1.0000	–1.0000
Secondary mirror	2123	1.4358	–2.06152

Table 2: Surface Data summary

Surface	*Radius*	*Thickness*	*Glass*	*Diameter*	*Conic*
object	Infinity	Infinity		0	0
p. m.	Infinity	2800.00		1200	0
stop	–7198	–2770.632	MIRROR	1200	–1
sec. m.	–2123	2770.632	MIRROR	330	–2.06152
p.m. shell	Infinity	485.4		73.91	0
focal plane	Infinity	515.7		1200	0
image	Infinity			0.784	0

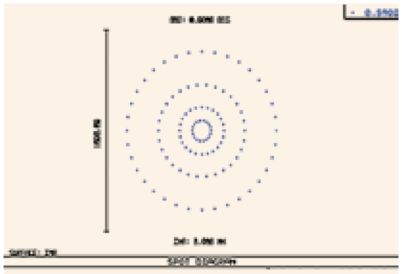

Figure 1.

GP report) and the 4 rings represent the image positions for rays at 4 different radii across the telescope aperture. The telescope can be refocused, by increasing the mirror separation by about 0.4 mm, to minimise the image spread from spherical aberration. The total spread is then contained within 208 microns (2.6 arcseconds). The 50% encircled energy is contained in a diameter of 1.51 arcseconds. The peak to valley wavefront error is reduced to about 2.3 waves (~1400nm). The manufactured value of k, –2.01652, would require the focus of the pair of mirrors to lie a further 1143 mm from the primary for the spherical aberration of the mirror combination to be zero and would yield a focal length of 20115 mm and an f-number of f/16.76.

The correct secondary conic constant for an f/13 telescope configuration would be –2.443 to yield zero spherical aberration. For a separation of 2771 mm between the primary and secondary mirrors and 1001 mm focal plane distance from the front of the primary mirror, the focal length of the telescope is 16359.8 mm and the focal ratio is f/13.63. A 7 mm movement of the secondary mirror corresponds to a 140mm movement of the Cassegrain focal plane. The f/13.6 gives an image scale of 79.3 microns per arcsecond or 0.303 arcsecond per 24 μm pixel. This is consistent with the 0.301 arcsecond per 24 μm pixel derived by Synachopoulos et al. (1999) using Hipparchos double stars (with around 15 arcsecond separation).

3. Polishing errors

A summary of the polishing errors for the primary and secondary mirrors is presented in the GP report. The primary mirror analysis, presented in the GP report, gives the following encircled energy diameter results. The secondary mirror analysis in the GP report states that the wavefront errors are of the opposite sign to those on the primary and so the spread for the two mirrors in combination will be smaller than those from the primary mirror alone (0.49 arcsecond at 95% encircled energy). These errors represent a much smaller contribution to the image spread than the effects from the incorrect conic constant for the secondary mirror. The results are given the Table 3.

The GP report gives a summary of the radial distribution of wavefront errors for the primary mirror and two profiles across the diameter of the secondary mirror. They represent the variations in mirror height, which are fitted using a polynomial distribution in order to estimate the image spread obtained by the combination of the polishing errors from both mirrors (see Figure 2). For both mirrors the RMS on the fit is of the order of 0.03 waves. The peak to valley error on the primary mirror (similar for the secondary mirror) is about 0.2 waves on the surface, which will be 0.4 waves on the wavefront because of the doubling on reflection; this is 236 nm or 0.236 microns. The test wavelength used throughout this paper and in the GP report is 590 nm. The data presented in the GP report do not provide sufficient information to produce a detailed, two dimensional, wavefront error map.

Table 3

Encircled energy %	Primary mirror Energy diameter (arcseconds)	Combined mirrors Energy diameter (arcseconds)
80	0.46	0.34
85	0.50	0.40
95	0.58	0.49
99	0.68	
100	0.72	

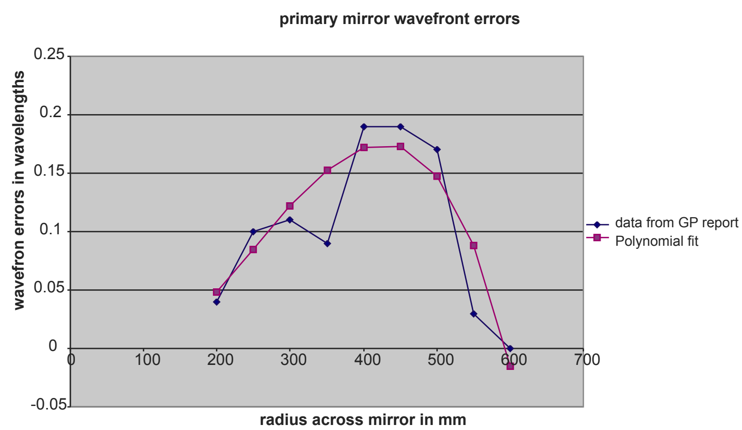

Figure 2. The radial distribution of the wavefront errors for the primary mirror.

4. Out-of-focus image analysis

The current status of the focus drive on the 1.2 m telescope does not permit accurate, known, focus offsets to be applied to the secondary mirror. However it is possible to produce pairs of images with approximately equal and opposite secondary mirror offsets about the best focus position. By defocusing the image it is possible to assess whether there are any aberrations present that may be degrading the image. A pair of images was obtained on 14/09/2004, indicative of the current optical system status.

The frame size for each picture represents an area approximately 12.3x12.3 mm. The CCD frames have been binned up 2x2 yielding a pixel size of 0.048 mm. The diameter of the out-of-focus images is approximately 215 pixels (10.3 mm). This would be an equivalent of a defocus of about ±140 mm at the Cassegrain focus or ±7 mm at the secondary mirror.

The out-of-focus images show the central obstruction from the secondary mirror baffle (480 mm giving a 40% linear obstruction ratio for the telescope). The two images show a change in the relative size of the central obstruction on either side of focus, typical of spherical aberration. This has a larger diameter if it is closer to the primary (intra focal

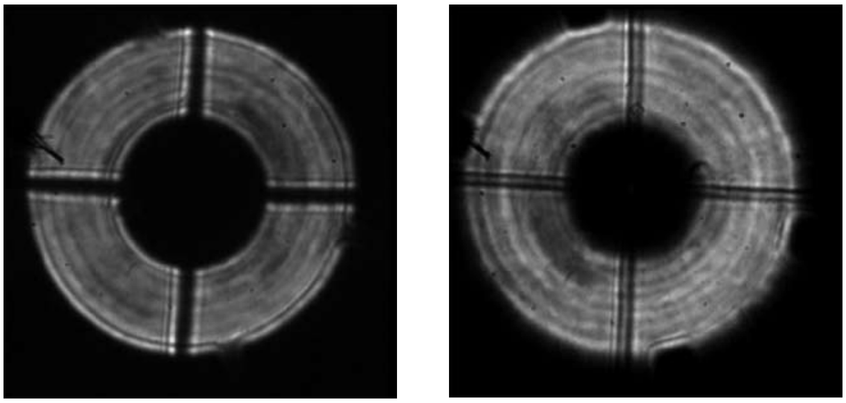

Figure 2. Intra focal image (left) and Extra focal image (right)

position) and a smaller diameter when it is away from the telescope (extra focal position).

We can estimate the amount of spherical aberration by using the relative diameters of the central obstructions of the two out-of-focus images (Wilson 1999). Both the outside and inside diameters are used of the intra and extra focal images as a consistency check. If D_I is the diameter of the central obstruction and d_I is the outer diameter for the intra focal image and D_E and d_E are the same parameters for the extra focal image. A quantity ΔD is derived which is given by

$$\Delta D = D_I - D_E\,(d_I/d_E)$$

The diameter of the best focus image for the telescope with a normalised central obstruction ratio of ε (0.4 in the case of the Kryoneri telescope) is given by

$$\Delta D/(8\varepsilon^{*}(1-\varepsilon^{2})^{*}scale)$$

where *scale* is the image scale at the telescope focal plane in mm per arcsecond (0.0793 in the case of the 1.2m telescope). Measurements have been made in several different directions across the out-of-focus images (Table 4). The average value for ΔD is 0.48 ± 0.08 mm. This yields a best focus image spread (100% encircled energy) of 2.25 ± 0.37 arcseconds. The error in the measurements comes from the signal to noise in the exposures but also from effects around the mirror boundaries such as "seeing".

5. Models of out-of-focus images

We model the out-of-focus images produced by the telescope optical prescription (GP report) for comparison to the observed pair of the out-of-focus CCD images. The image size has been set to 12.3x12.3 mm and is divided into 256x256 pixels. Secondary mirror displacements of ±7mm have been used and the system is illuminated with a source representing a seeing disc of 1 arcsecond FWHM. The shape of the images (GP report) is in agreement with those taken on the telescope except for the sign of the spherical aberration. As the secondary mirror is moved away by 7 mm from the primary mirror the extra focal image will fall on the detector (larger obstruction diameter corresponding to negative spherical aberration). The opposite is true for the out-of-focus CCD images where the larger obstruction diameter corresponds to the secondary mirror movement towards the primary mirror (positive spherical aberration). Spherical aberration is positive for a system that has the marginal (edge of the mirror) rays coming to focus before those that lie toward the centre of the aperture. In this case the central obstruction appears larger for the intra focal CCD image. Additional pairs of out-of-focus images were obtained to confirm the secondary mirror unit direction. Then, this discrepancy must be due to differences in the mirror support between the factory (GP report) and Kryoneri (CCD out-of-focus images) support mount.

It is possible to make an estimate of the deformation of the mirror surfaces that is required to change the sign of spherical aberration between that predicted from the mirror prescription and what has been measured on the telescope. Positive spherical aberration (measured from the out of focus images) means that the rays from the outermost edge of the mirror come to focus first, and thus the outer edge of the mirror is higher than it should be, with respect to its centre. This means, that the spherical aberration can be changed from negative to positive, by raising the edge of the primary mirror. This change will be of the order of 3-4 microns at the edge of the mirror. This would change the wavefront error from the edge of the telescope aperture by about 11 wavelengths, going from ~-6 waves of negative spherical aberration to +5 waves of positive spherical aberration.

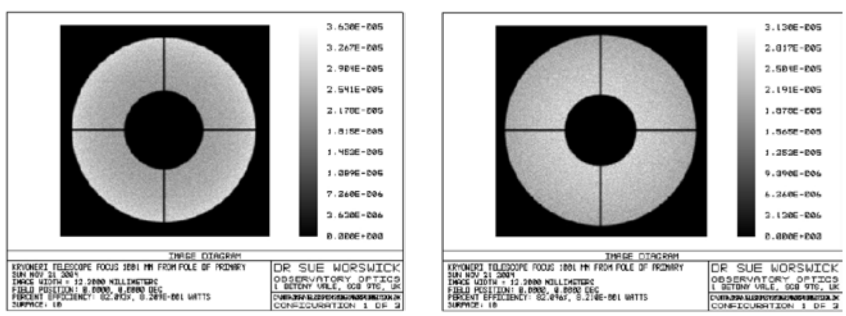

Figure 2. Extra focal image (left) and Intra focal image (right)

Table 4.

Position angle on image	DI pixels	Di pixels	DE pixels	de pixels	ΔD pixels	ΔD mm	Image diameter mm	Image diameter arcsec
0°	98.10	213.15	91.10	216.15	8.26	0.397	0.147	1.87
45°	99.05	212.60	90.71	215.50	9.56	0.459	0.170	2.16
90°	101.10	212.30	90.14	215.20	12.17	0.584	0.217	2.75
135°	99.60	212.80	90.84	215.70	9,98	0.479	0.178	2.26
Mean						0.479		2.25
SD						0.078		0.37

6. Image quality on the telescope's CCD

The diagram shows the image profiles produced when a spherical aberration image, refocused for minimum image spread, and with a 100% EE diameter of 2.25″ is convolved with a Gaussian profile ("seeing"). It can be seen that the effects of spherical aberration dominate the image spread under sub-second seeing. The image broadening imposed by the spherical aberration present in the Kryoneri telescope optics will lead to a pessimistic assessment of the seeing conditions at the site, as confirmed from DIMM tests (Mislis et al. 2005). The table below shows exactly how the spherical aberration dominates the "seeing" disk. Even at 2 arcsecond "seeing" the FWHM broadening factor is 1.23 times.

It can be seen that the spherical aberration distorts the Gaussian profile. If, instead of direct measurement, the FWHM of the convolved profile is estimated using Gaussian fitting, the following results are obtained (which only deviate by 30% from the results in table 5 under conditions of very good seeing where the profile strongly deviates from the Gaussian form):

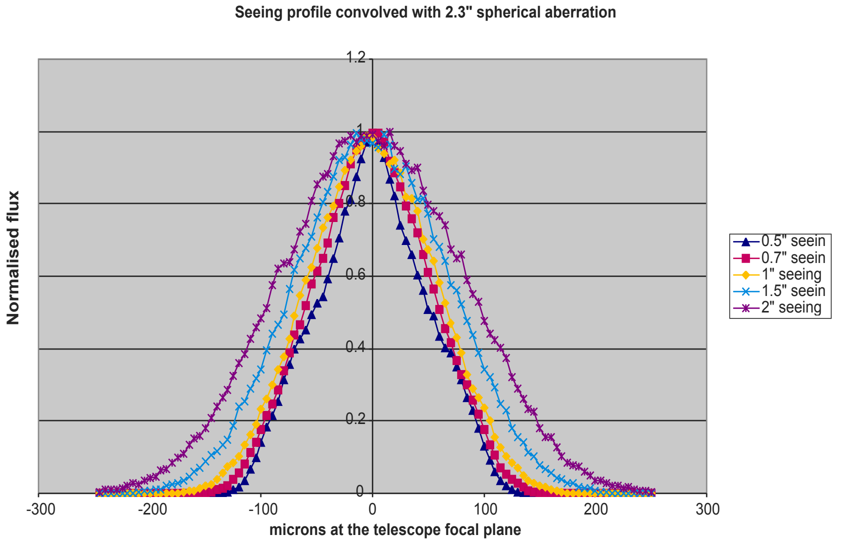

Figure 5.

Table 5

Image spread from convolution of seeing with spherical aberration					
Seeing FWHM ″	**0.5**	**0.7**	**1.0**	**1.5**	**2.0**
Image FWHM μm	106	122	136	162	195
Image FWHM ″	**1.34**	**1.54**	**1.72**	**2.04**	**2.45**
Broadening factor	2.68	2.2	1.72	1.36	1.23

Image spread obtained from Gaussian fitting to convolved profile					
Seeing FWHM ″	**0.5**	**0.7**	**1.0**	**1.5**	**2.0**
1-sigma μm	51	54	59	70	84
Image FWHM μm	120	127	139	165	197
Image FWHM ″	1.51	1.6	1.75	2.08	2.48
Broadening factor	3.02	2.28	1.75	1.39	1.24

Summary and conclusions

1. The manufacturing specification for the telescope secondary mirror is not consistent with correction of spherical aberration at the focus position used on the telescope.
2. Using the parameters within the GP mirror prescription and the current measured image position (1001 mm from the front surface of the primary mirror) the f-number is f/13.6 (focal length 16360 mm) and the image spread from spherical aberration would be 100% encircled energy within 2.6 arcseconds.
3. Previous measurements of the telescope image scale, undertaken by Synachopoulos et al., give a value of 0.301″ per 24-micron pixel. The calculated telescope focal length (cited in 2 above) gives an image scale of 0.0793 mm per arcsecond or 0.303″ per 24-micron pixel. This good agreement between calculated and measured image scale means that the focal lengths for the primary and secondary mirrors given in the GP report are correct.
4. The out-of-focus CCD images taken with the telescope show the presence of spherical aberration with 100% encircled energy within 2.25±0.37 arcseconds. However the sign of the spherical aberration measured derived from the CCD images is opposite to that within the factory telescope prescription. This discrepancy could be explained by a deformation of the primary mirror on its support.
5. The image quality from mirror polishing errors gives 95% encircled energy within 0.49 arcseconds and thus, the telescope performance is dominated by spherical aberration rather than "site seeing" or mirror polishing errors.

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The Skinakas Observatory in Crete: *a short description of its infrastructure and activities*

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The Skinakas Observatory is located on the Ida mountain in central Crete at an altitude of 1750 m and on a site with excellent seeing conditions (the median seeing has been measured to be sub-arc second). It was founded and has been operated by the Physics Department of the University of Crete, the Foundation for Research and Technology-Hellas (FORTH) and the Max-Planck Institut für Extraterrestrische Physic (MPE, Garching) since 1986. Its infrastructure and activities have been presented in detail in a recent issue of HIPPARCHOS (Volume 2, Issue 2).

There are currently two telescopes operating at the Observatory: a 1.3 m modified Ritchey-Chretien and a 30 cm, wide field Schmidt-Cassegrain telescope, installed in 1995 and 1986, respectively. Four LN2 cooled CCD cameras are available for imaging and/or spectroscopy (two Photometrics cameras with 1k × 1k chips, and two ISA cameras equipped with 2k × 0.8k chips). A deep Peltier cooled Andor camera, with a 2k × 2k, back illuminated E2V chip has been acquired recently. Finally, a Near-Infrared camera was commissioned in 2006, equipped with a Rockwell Hawaii Array of 1k × 1k pixel size. A full set of broad band and Strömgren optical filters, as well as 16 narrow optical interference filters, are available for imaging/photometric observations. In the near Infrared, the new camera is equipped with both narrow and the usual broad band J, H and K filters.

For spectroscopic observations the focal reducer has been installed on the 1.3 m telescope can be used as a slit spectrograph. There are 10 blazed gratings with dispersions ranging from 530 Å/mm down to 25 Å/mm. Finally, a high resolution fiber-fed Echelle Spectrograph was installed at the 1.3 m telescope last year. The spectrograph is working with a microlens coupled 50 μm fiber, achieving a resolution of R~38000.

At the beginning, research work at Skinakas was mainly focused on the study of the interaction of Cometary tails with the Solar wind, and of Planetary nebulae and Supernovae remnants (SNRs). For example, 44 new Planetary nebulae have been discovered during the Galactic bulge survey that was performed the last few years from the 30 cm telescope with the use of the OIII filter. The same telescope has also been used for deep, narrow band observations to study in detail the morphology of more than half of the known SNRs. Work on these objects has been intensified since the 1.3 m became operational. Long slit spectra at selected positions of the target objects have been used to study in detail their energy distribution.

The 1.3 m telescope has been used in the past for the study of the structure of nearby, edge-on spiral galaxies (i.e. the determination of the dust layer, disc and bulge scale parameters with the use of sophisticated radiative transfer models), the accurate determination of the H-R diagrams of a few, poorly studied, globular clusters, and the study of the RR Lyrae variables in them. Apart from the on-going work on Planetary nebulae and SNRs, the following projects have also been (and still are) conducted at the Observatory, mainly with the use of the 1.3 m telescope:

a) Fast photometry of BL lac objects, on time-scales of minutes/hours, with the aim to characterize accurately their flux and spectral variations. The Observatory participates frequently in the World Earth Blazar Telescope campaigns. b) Photometric and spectroscopic observations of Be/X-ray binaries to monitor their disc evolution on time scales of years. c) Photometric and spectroscopic observations of field objects in order to optically identify newly discovered X-ray sources by satellites like XMM, ASCA, SWIFT and INTEGRAL. d) R-band and Hα nightly monitoring observations of the central part of M31 for the detection of new novae.

Regarding educational activities, a large number of under- and post-graduate students have participated in past and ongoing research projects at the Observatory, as part of their last year or Diploma thesis work. The 1.3 m telescope is regularly visited by students of the International University of Bremen, and has also been remotely operated from Secondary School classes as part of their Astronomy courses. Finally, each year the Observatory organizes 5 "open (to the public) nights". These are highly popular events, during which members of the Astronomy group in Crete give public lectures and organize the public night sky star-gazing!

The Gerostathopoulio Observatory of the National & Kapodistrian University of Athens

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Abstract

A description of the new, 40 cm, telescope of the University of Athens is given, along with its role in astronomical education at the under-graduate and post-graduate level and in carrying out specialized research projects. Its participation in international campaigns and in time-demanding projects is also briefly outlined.

1. The University of Athens Observatory

1.1. Infrastructure

A small observatory has been built at the Campus of the University of Athens (Panepistimioupolis, Zografos). A 5m dome from OBSERVADOME, on the roof of the building of the Faculty of Physics, houses the 0.4 m telescope. The observatory, apart from the dome, includes a large control room and a small apartment used for overnight accommodation for the observer and for the occasional foreign visitors. The telescope was installed in March 1998 and was a gift by the chairman of the construction company DYNAMIKI S.A., the late L. Gerostathopoulos, in memory of his mother. The total cost of the telescope and its accessories was estimated at that time to be about 140.000 US $.

1.2. Instrumentation

The main characteristics of the new telescope are the following:

OPTICS

- Cassegrain reflector (type CCT-16, DFM ENGINEERING, INC., USA) with primary mirror 40 cm.
- Focal ratio F/3 for primary mirror.
- Effective ratio of F/8 or F/12. Both mirrors have a pyrex substrate and are aluminized with a silicon monoxide overcoat,
- The focal plane position is between 0 and 20 cm from the instrument mounting surface.
- The focus may be either manually controlled or commanded by the control system.
- Low temperature (–40 °C) operation for the optical encoders.
- 2-speed motorized focus.
- Finderscope: 9 × 60 with illuminated reticle.

Figure 1. Outside view of the observatory

Figure 2. The 0.4 m telescope with the CCD camera (above) and the spectrograph (below)

TELESCOPE MOUNT

- Equatorial fork mounting.
- RA and DEC axes driven by DC servo motor/encoders for fast response and low power consumption.
- Combination of steel and aluminum construction for responsive and long lasting performance.
- Tracking accuracy: ± 2.0 arc seconds in 2 minutes, ±20.0 arc sec in 1 hour.
- Pointing accuracy (with refraction and alignment correction) better than 1 arc minute RMS.
- Optical incremental position encoder drives are independent of the motor drives to provide excellent pointing.
- Cool operation - very low heat generation at telescope (less than 10 watts average).
- 4 deg/sec slew rate.
- High acceleration and deceleration rates for fast pointing to the object.
- Variable set, guide and tracking rates: 0 to 4 deg./sec.
- Pedestal allowing elevation and azimuth adjustments for polar alignment.
- Supports 20 kg instrument load with CG 18 cm behind mounting surface.

CONTROL SYSTEM

- The Telescope Control System (TCS) provides a user-friendly interface to the telescope. Utilizing an IBM-compatible PC we have continual position display, status reporting, and an easy-to-use, menu driven command set the pointing model corrects for precession, nutation, aberration, atmospheric refraction, mount misalignments and flexure.
- Control electronics may be located up to 50 m from the telescope for remote control.
- DOS 6.0 operating system.
- Development and application software plus source code are licensed to user for long-term maintainability.
- 28 commands provide complete control.
- Built in library of astronomical objects.
- Compatible with commercial auto guider systems.
- Operates and displays in any epoch.
- Hybrid digital/analog servo controller with zero position error integrator.
- Extensive system protection via computer-calculated limits.
- Hand paddle functions include: guide, set, slew, focus and dome right-left.
- Limits switch enhances system safety by preventing telescope over-travel.
- Remote dome monitor and keyboard for public night viewing and instruction where direct access to telescope is required.
- Dome control using existing motor.

AUXILIARY INSTRUMENTS

- SPP3 single channel Photon Counting Photometer.
- Fully computerized Pulse Counting Photoelectric Stellar Photometer.
- CCD camera ST-8 (SBIG).
- CCD camera ST-8 XME (SBIG).
- A Diffraction Grating Spectrograph with a dispersion 61 Å/mm and resolving power 48000 (built by D. Papathanasoglou and K. Gazeas in the Laboratories of Astronomy and Applied Optics of the Department of Astrophysics, Astronomy and Mechanics of the UOA).
- Solar filter, focal reducer etc.

2. Education and Research with the new telescope

2.1. Education

In all Greek Universities the Physics courses include practical exercises in performing astronomical observations and reducing the acquired data. The goal of a modern course in Observational Astronomy is to provide the students with the possibility of observing with a telescope and using modern detectors to obtain astronomical data (photometer, CCD camera or spectrograph). In addition, students should learn how to use reduction packages in order to reduce and analyze the astronomical data obtained. Some of the students, who are interested in astronomy, can also do their final-year essay or master theses on observational subjects. Small University telescopes are the ideal instruments for (a) the education of students at a graduate and postgraduate level, since student access to large telescopes is almost impossible, and (b) for their preparation to use larger facilities in other observatories.

Our new telescope has been the tool for providing high-level astronomical education at an undergraduate and postgraduate level. The main topics of practical exercise are: photometry of variable stars, imaging of extended objects and photometric reduction of stellar images, monitoring of solar and lunar eclipses, spectral classification and line identification in stellar spectra, spectroscopic studies of fast rotating stars, etc.

2.2. Research programs

It is well known that very important and fundamental research has already been carried out with small telescopes. It has been pointed out (see reports from ESO, PPARK) that small telescopes are absolutely suitable for specialized research projects, for trying novel ideas, for testing new auxiliary instruments, for teaching and training people on the general practice of astronomy.

The rapid advancements in detector technology upgraded small telescopes and made it possible to perform tasks which were possible to do in the past only on large telescopes. Some types of observations, like photometry of variable stars, can be performed much better and easier with small telescopes, since new relatively cheap detectors (CCDs) and powerful methods of reduction and analysis are available now. It is widely admitted that small telescopes are essential both for astronomical education and for carrying out some specialized research projects, like:

- Discovery and photometry of variable stars (with the use of CCDs).
- Supporting multi-wavelength observations from space and those made from ground-based observatories by large optical and radio telescopes.

Figure 3. The partial lunar eclipse of September 7th 2006, observed with the 40 cm telescope. *(Image courtesy of K. Gazeas)*

- Photometry of eclipsing and cataclysmic variables.
- Monitoring the gravitational microlensing events in the Milky Way
- Solar observations in the optical regime.

Among the most suitable research programs for small telescopes are the long-term (monitoring) projects, since it is easier to be awarded long observing time in small telescopes than in large ones. Usually, such projects are part of international observing campaigns, where small telescopes in the range 0.4 - 1.0m belong to a network (24-hour coverage) and are dedicated to long-term monitoring.

It is well recognized that the operation of a small telescope is much more efficient, if it belongs to a local or international network of small telescopes, such as the Whole Earth Telescope (WET), the Backyard Center of Astrophysics (CBA) and the North European Observatories Network (NEON). The advantages from the participation in such a network are obvious.

It should be stated that the 40 cm telescope has been successfully used to carry out high quality CCD observations within the frame of international campaigns and bilateral collaborations. We particularly mention the international campaign *'Multisite observations of the δ Scuti star V1162 Ori'* (1999-2002), the *'W UMa program'* (Greece, Canada, Poland) which is in progress, and the international campaign *'Searching for β Cephei Stars in the open clusters NGC 6910 and NGC 884'* (2006-2007).

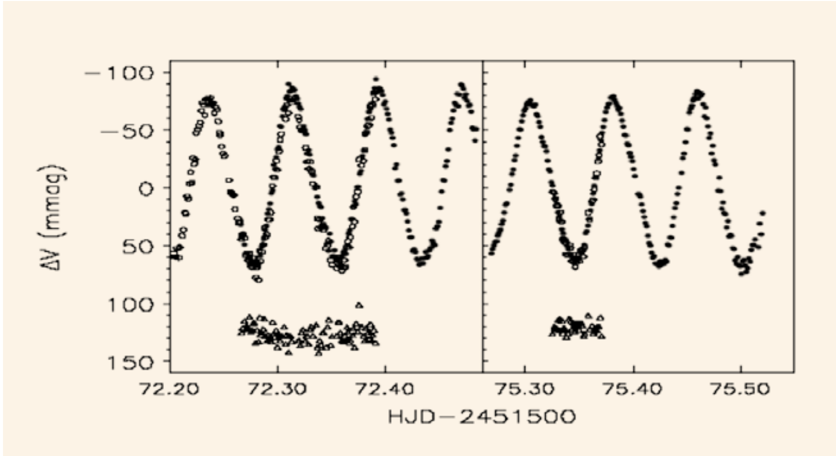

Figure 4. Examples of light curves of the *δ Scuti* star V1162 Ori in two of the cases of overlapping data obtained at SAAO and Athens University Observatory. Dots are from SAAO, open circles from Athens University Observatory. The agreement between the overlapping data is very good. The difference between the datapoints from Athens and interpolated values of the SAAO datapoints (triangles, shifted by 120 mmag) is also shown.

3. Summary

The 0.4 m telescope of the National and Kapodistrian University of Athens has revolutionized the astronomical education offered at the Un. of Athens at the undergraduate and postgraduate level. Modern observational and data reduction techniques are possible with the use of the telescope's modern instrumentation. The high quality of the new instrument guarantees its use for carrying out some specialized research programs and its participation in international networks.

ΕΘΝΙΚΟΝ & ΚΑΠΟΔΙΣΤΡΙΑΚΟΝ ΠΑΝΕΠΙΣΤΗΜΙΟΝ ΑΘΗΝΩΝ
NATIONAL & KAPODISTRIAN UNIVERSITY OF ATHENS

The European Southern Observatory

by Iason Spyromilios
ESO

The European organization for astronomical research in the southern hemisphere, as ESO is officially named, was conceived of in the mid-1950s and founded in 1962. The required ratification of the convention signed in 1962, however, was only completed in January 17, 1964 at which time the funds and support for the creation of the observatory began to flow. Of the original signatories of the convention Germany, France, Belgium, Sweden, the Netherlands and the UK, the UK decided not to participate in the endeavour and at that time went its own way. By October of 1964 the La Silla site in Chile had been selected and the agreements with the Chilean government established. By 1967 Denmark had joined the organization.

By the mid-70s the pioneering nations were already operating the La Silla observatory and the construction of the 3.6-m and the ESO Schmidt telescopes was well underway. An excellent and obviously authoritative account of the early history of ESO can be found in the eponymous book by the second director general of ESO, Professor Adrian Blaauw[1]. In the 80s Italy and Switzerland joined the organization and ESO relocated from Geneva to Munich to a new headquarters building. The Italian and Swiss participation to ESO made it possible to design and construct a truly revolutionary telescope. The brainchild of Ray Wilson, the New Technology Telescope, was to be the first active telescope. Although taken very much for granted in these days of 8-m class telescopes, active optics marked a profound change in telescope construction. The problems faced by telescope designers have not changed very much over the past couple of centuries. Keeping the primary mirror shape and maintaining the alignment of the optics to ensure that the images are not unduly aberrated have, over the past decades, resulted in a number of innovations. The Serrurier truss that maintains passive collimation of the primary and secondary mirrors and astatic levers and airbags to support the mirrors without distorting them had been staples of telescope design since their introduction in the Palomar telescopes in the 1940s.

Figure 1. The La Silla site

For the NTT, ESO chose a different path, albeit rather conservatively[2]. The primary mirror was to be supported by force actuators and therefore its shape could be modified to combat distortions caused by gravity. The secondary could also be moved and a sophisticated control system was installed using Shack-Hartmann wavefront sensors to monitor the optical quality of the telescope during observations and to correct any errors. The NTT was to be the first telescope to use metrology to modify its configuration and ensure the best possible images were delivered to the astronomers. The NTT saw first light in 1989 with images as good as 0.3 arcseconds. By 1990 Portugal had entered into an agreement with ESO to join within a decade, a feat achieved by the end of that period.

While the ESO council had already given its blessing to the ambitious VLT project in 1987, the NTT experiment was a powerful enabler of the VLT technologies. Following the construction of the VLT and the leadership in ground based astronomy that this brought, the UK, Finland, Spain and the Czech republic have all joined ESO. The new membership has provided both the impetus and the financial backing for ambitious new projects such as ALMA and the EELT.

Currently ESO operates the three sites (La Silla, Paranal and APEX) in Chile under a single umbrella, the La Silla Paranal observatory and is constructing, with its north American and Japanese partners, the ALMA facility in the north of Chile. Plans are underway to construct a European Extremely Large telescope. In the remainder of this article a very brief description of these facilities is given.

La Silla

On La Silla, ESO operates the 3.6-m telescope, the NTT and the 2.2-m tele-

1. Blaauw, Adriaan, 1991, "ESOs early history. The European Southern Observatory from concept to reality."
2. The NTT optical configuration was such that even if the experiment had not worked the telescope would work passively.

scope. In parallel it provides a robust infrastructure to host multiple national experiments such as the Danish 1.54-m telescope, the REM gamma-ray burst follow-up telescope, the 1.2-m Euler telescope, TAROT and others. On the 3.6-m telescope the ultra stable HARPS spectrograph is complemented by high efficiency optical focal reducer EFOSC while on the NTT, SofI, an IR imaging spectrograph is complemented by the multi-mode instrument EMMI. The 2.2-m telescope hosts the wide field imager and the high resolution echelle FEROS.

The VLT, VLTI and VISA

On cerro Paranal, a new site 700 km north of La Silla, ESO began the construction of the Very Large Telescope in the early 90s. The VLT comprises of four 8.2-m Unit Telescopes that can be used standalone or combined in a coherent manner as an interferometer or incoherently with the light collecting power of a 16-m telescope. The First Unit telescope, Antu, had first light in May 1998 and Kueyen, Melipal and Yepun[3] (telescopes 2, 3 and 4) in 1999 and 2000. In part thanks to the work originally done at the NTT and the experience the ESO team developed in active optics, the 8.2-m telescopes and their instrumentation had a very rapid transition from first light to science operations. The telescopes operate with less than 3% system down time and the instrument efficiencies (shutter open time) are as high as 90%. Combined with the exceptional quality of the Paranal site –the weather down time is of order 10% per year– and the high efficiency of the operations the VLT has become the benchmark for ground based facilities.

Each of the Unit telescopes of the VLT is equipped with a Cassegrain, two Nasmyth and a coude focus. The Ritchey-Cretien design of the optics applies for the f/15 Nasmyth configuration while the f/13.6 Cassegrain focus is achieved by changing the conic constant of the primary mirror using the active optics force actuators and refocusing the secondary mirror. The coude focus is achieved by re-imaging the Nasmyth focal plane through a mirror train.

Figure 2. Paranal with the VLT, VISA & VST and VISTA in the foreground

The telescopes have been, from the very beginning, equipped with advanced instrumentation. The two FORS optical imagers and spectrographs at the Cassegrain foci of UT1 and UT2 provide direct imaging (at two plate scales), long slit spectroscopy, multi-object spectroscopy and imaging and spectropolarimetry from the atmospheric cut-off at the UV end of the visible spectrum until 1 micron where the CCD detectors are no longer efficient. For both the FORSes the telescope provides a wide field Atmospheric Dispersion Compensator. ISAAC at the Nasmyth focus of UT1 is a 1-5 micron infrared imager and long slit spectrograph which includes polarimetric capabilities. On the other Nasmyth focus the adaptive optics assisted cryogenic echelle spectrograph CRIRES also working from 1 to 5 microns has recently been released into operations. UVES, at one of the Nasmyth foci of UT2, is a very stable and sensitive echelle spectrograph. On the other Nasmyth focus of UT2, the FLAMES facility combines a fibre positioning robot (OzPoz) with the fibre fed spectrograph with a resolution of 30,000 (Giraffe). Up to 100 targets can be observed simultaneously and 6 targets can have their light fed into UVES for higher resolution work. Integral field fibre units can be used instead of the single target fibres and a large fibre IFU can also be used in the centre of the field. At the UT3 Cassegrain focus the thermal infrared 10 to 20 micron camera and multi-resolution spectrograph VISIR is mounted. One Nasmyth focus of UT3 host the 1000 galaxies at a time optical wide field camera and multi-object spectrograph VIMOS. In addition to multi-object work with masks, VIMOS also provides a wide field IFU unit. The other Nasmyth focus of UT3 is available for visitor instrumentation. On UT4 Nasmyth the adaptive optics system NACO is installed. NACO provides the observer with an optical and an infrared wavefront sensor and the near IR camera CONICA provides multiple plate scales to sample the diffraction limited high Strehl PSF as well as spectral differential imaging capabilities, spectroscopy using grisms and polarimetry. At the Cassegrain focus on UT4 the AO assisted integral field spectrograph SINFONI operates in the near IR. Both NACO and SINFONI can be operated with the newly installed and commissioned laser guide star.

The VLT instrumentation is an ongoing fully funded programme with second generation instrumentation in construction. HAWK-I, a 7 arcminute IR high efficiency camera has just been shipped to Paranal while MUSE and KMOS (optical and near infrared multi-object systems) are in construction. A four laser guide star system, deformable secondary mirror for the VLT and associated ground layer and laser tomography systems are in construction.

The observatory at Paranal has been designed and constructed to allow the telescopes to be combined coherently,

3. The telescopes are named after the Sun, the Moon, the Southern Cross and Venus in the indigenous Mapuche language.

giving baselines as long as 200 m. The interferometer at Paranal can use either the four 8-m telescopes or a combination of four 1.8-m auxiliary telescopes (VISA) that can move on railway tracks between any of 30 docking stations. The coude foci that are used to transport the light to the interferometric combination laboratory are all equipped with adaptive optics systems. Within the interferometric complex 6 delay lines, each 60-m in length compensate for the optical path difference between the telescopes before sending the beams into the instruments. Currently MIDI, a two beam combiner in the thermal infrared, and AMBER, a three beam combiner working in the near IR are fully operational. Second generation instruments for the VLTI are in design phase.

With 7 adaptive optics systems in routine operation, 3 Integral field spectrographs, 4 multi-object spectrographs, three echelle spectrographs, 4 infrared cameras and spectrographs the VLT is the most versatile ground based facility in operation.

The Paranal site will also host the VISTA telescope, a 4.2-m wide field IR survey telescope and VST a 2.6-m wide field optical survey telescope. Both of these projects are expected to have first light in 2008.

APEX

The Atacama Pathfinder Experiment is a collaboration between ESO, Onsala space observatory in Sweden and the Max Planck Institute for radioastronomy in Bonn. The telescope is located on the 5000-m high Chanjantor llano within the ALMA reserve and is a modified prototype ALMA 22-m antenna. APEX is equipped with a bolometer array working at 850-microns and a variety of heterodyne receivers and is blessed with the exceptional quality of the site which is one of the driest locations on earth. Other instruments are provided on a PI basis and can be accessed collaboratively with the institutes responsible.

ALMA

The Atacama Large Millimetre Array is a joint venture between Europe, North America and Japan. 62 antennae shall be located at Chanjantor working in the mm regime. Construction is ongoing and the site preparation activities are well on the way. The high site infrastructure to host the correlator has been recently completed and at the low site (2700-m) the support facilities are under construction. The first antenna has been shipped to the site and is being reassembled. The prototype systems in Socorro New Mexico have been combined to test the receivers, local oscillators and other electronic systems. First light with a subset of antennae is planned for 2009 with complete operation planned for 2012. Early science operations are planned for the period between the first light and the completion of the observatory.

Receivers covering as many as ten bands are foreseen for ALMA although initially not all will be installed. A more detailed description of ALMA can be found at:

http://www.eso.org/projects/alma/publications/Brochure-2006.pdf

EELT

In December 2006 the ESO Council gave the go-ahead for the design phase of a European Extremely Large Telescope. The baseline reference design is for a telescope of 42-m diameter primary mirror, built in adaptive optics and unprecedented discovery capabilities. A proposal for construction is likely to be considered in 2010 with current planning giving first light around 2016.

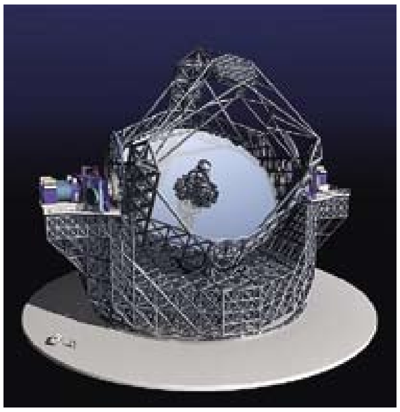

Figure 5. A computer model of the EELT.

The EELT is planned to be equipped with the most sophisticated instrumentation suite ever proposed for a ground-based telescope. Multi-conjugate adaptive optics, multi-object infrared spectrographs and ultra stable high resolution spectrographs are part of the proposed complement. From imaging of extra-solar planets to direct detection of the expansion of the universe by measuring the evolution in the Lyman-alpha forest, the EELT science is pushing all fronts of optical and near infrared astronomy.

Figure 3. The APEX telescope

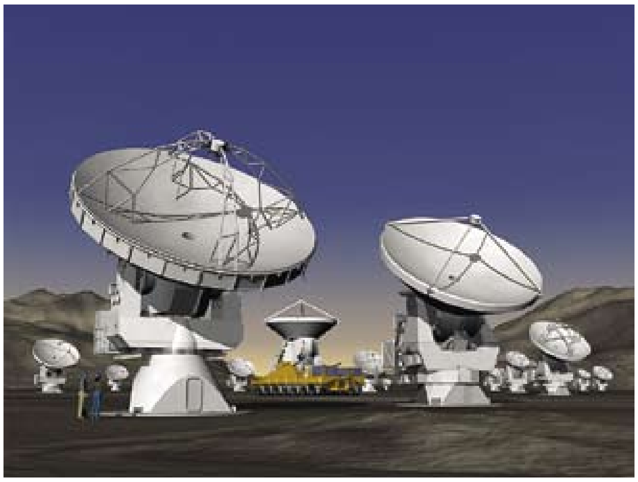

Figure 4. Artist's impression of one ALMA configuration.

Scientific operations

With the VLT ESO pioneered service observing in a massive scale for ground-based observatories. Starting with a 50/50 split of service observing and classical observing the demand rapidly has shifted to strongly favour service observing. Extensive user support at all stages of the process of getting observing time, preparing the programme, executing and then analysing the data has been a keystone of the VLT programme. The science archive includes all calibrations and is accessible to the worldwide community of astronomers. On La Silla a more experimental mode of observing is possible with astronomers having much more of a hand on experience.

ALMA is envisaged to be a 100% service operation as the optimization of the array usage and the exceptional weather slots is a key to the performance of the facility. For the EELT discussions are ongoing within ESO and with its community and committees on how to best optimize the operations scenario.

Science from ESO telescopes

It is clearly impossible in a short paper to identify all, or even the majority, of the major highlights of recent work at the ESO telescopes and the selection below is clearly a personal one. Certain observations could only be made with the ESO facilities either thanks to the instrumentation complement or the observing scenario. The orbit of S2 around Sagitarius A* observed with NACO is a particularly exciting result from the VLT that was made possible thanks to the unique IR wavefront sensor in that instrument. The extremely deep survey FIRES and similarly the GOODS field with 100s of hours with better than 0.5 arcsecond image quality were made possible thanks to the service observing scheme employed at the VLT and the excellent performance of ISAAC and UT1. The determination of the age of the universe from Uranium lines was achieved with the exceptional sensitivity of UVES in the blue. Observations with SINFONI of high redshift galaxies and their rotation curves are a powerful demonstration of the combination of Adaptive optics and integral field spectroscopy. Thousands of galaxies have had their redshifts determined by VIMOS as part of the very successful VVDS. On La Silla, HAPRS is pushing the radial velocity method of finding planetary systems to the most exciting limits with the recent discovery of Gliese 581c, the first almost earth like planet in the habitable zone. With the interferometer we are now resolving circumstellar disks and circumnuclear activity in galaxies.

Refereed publications from ESO telescopes exceed 600 per year with the VLT producing more than one paper per day and currently standing at over 1800 refereed papers.

ESO has a strong fellowship programme in Europe and in Chile and supports studentships. Through the visitor programme ESO welcomes to Garching a large number of scholars.

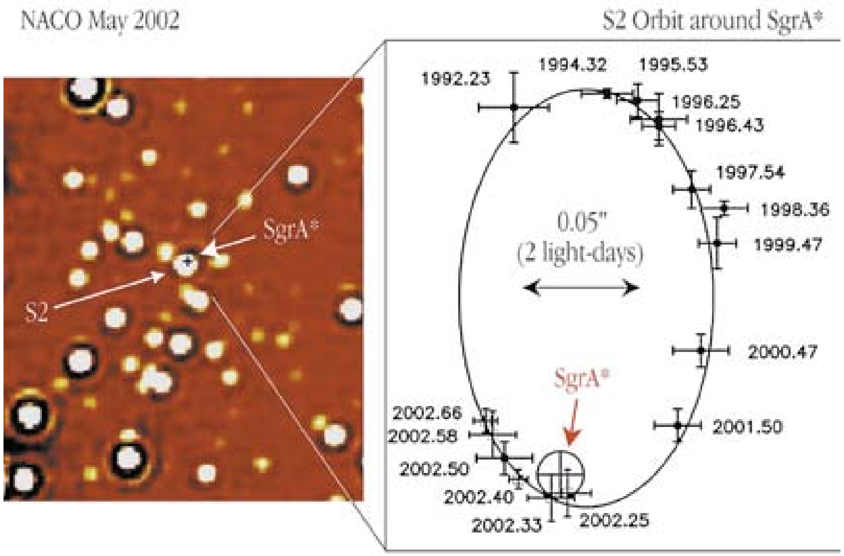

Figure 6. The orbit of a star moving within 17 light hours of SgrA*. Observations using speckle interferometry on the NTT in the early 90s were augmented with adaptive optics images from the VLT.

Conclusions

ESO was created to enable European astronomers to have access, with high quality instrumentation, to the southern skies and to do together what could not so easily be achieved by individual member states. In joining forces the European community of astronomers has not only been able to build competitive telescopes and instrumentation but has created an infrastructure that allows ever more ambitious scientific projects to be considered. ESO is a major player in worldwide astronomy with a proven ability to deliver and operate the largest projects and as ALMA shows the natural European partner for global projects in astronomy. As an exercise in European collaboration, ESO is a remarkable success. The majority of the scientific publications arising from data taken on ESO telescopes are published by collaborations of astronomers located in different member states, collaborating on the basis of skills rather than nationality. The instrumentation at the telescopes is constructed by consortia of institutes from a number of the ESO member states and the telescopes are the product of active collaboration between scientists and European industrial firms.

Participation of the Institute for Space Applications and Remote Sensing of the National Observatory of Athens in space science programs

by Ioannis A. Daglis, Anastasios Anastasiadis, Georgios Balasis, Anna Belehakis
Institute for Space Applications and Remote Sensing of the National Observatory of Athens

The research activities of the Institute for Space Applications and Remote Sensing encompass a wide area in Space Research and Applications. In the past 15 years the Institute has participated in a large number of space science programs. Below we briefly present a selection of programs, grouped according to the phase where the ISARS involvement was initiated.

In the data analysis phase:

▶ **AMPTE**: The Active Magnetospheric Particle Tracer Explorers program was a three-nation, three-spacecraft mission designed to study the sources, transport and acceleration of energetic magnetospheric ions, and to study the interaction between clouds of cool, dense, artificially injected plasma and the hot, magnetized, rapidly flowing natural plasmas of the magnetosphere and solar wind. The three AMPTE spacecraft were the NASA Charge Composition Explorer (CCE), the Federal Republic of Germany's Ion Release Module (IRM), and the United Kingdom Satellite (UKS). All three were launched together on 16 August 1984, into near-equatorial elliptical orbits. All contained extensive instrumentation supported by a diverse team of investigators, with the CCE and IRM providing the only existent complete data set on energetic ion spectra, composition and charge state throughout the near-earth magnetosphere. ISARS researchers have worked on data analysis and interpretation of CCE observations.

▶ **Geotail**: The Geotail mission is a collaborative project undertaken by the Institute of Space and Astronautical Science (ISAS) and the National Aeronautics and Space Administration (NASA). Its primary objective is to study the dynamics of the Earth's magnetotail over a wide range of distance, extending from the near-Earth region (8 Earth radii (R_e) from the Earth) to the distant tail (about 200 R_e). The Geotail spacecraft was designed and built by ISAS and was launched on 24 July 1992. The Geotail mission measures global energy flow and transformation in the magnetotail to increase understanding of fundamental magnetospheric processes. ISARS researchers have worked on data analysis and interpretation of Geotail observations.

▶ **CRRES**: The Combined Release and Radiation Effects Satellite program was a joint NASA and U.S. Department of Defense undertaking to study the near-Earth space environment and the effects of the Earth's radiation environment on state-of-the-art microelectronic components. To perform these studies, CRRES was launched with a complex array of scientific payloads. These included 24 chemical canisters which were released during the first 13 months of the mission at various altitudes over ground observation sites and diagnostic facilities. The spacecraft was originally built for launch by the Space Shuttle, but was modified for launch on the Atlas I vehicle after the Challenger accident. CRRES was launched on 25 July 1990, from Cape Canaveral Air Force Station on an Atlas I expendable launch vehicle into a low-inclination geosynchronous transfer orbit. ISARS researchers have worked on data analysis and interpretation of CRRES observations.

▶ **Polar**: Polar is a NASA mission to study the region over the poles of the Earth. It was launched on 24 February 1996. Three of the twelve scientific instruments aboard the Polar satellite are used to image the aurora in various wavelengths when the satellite is near apogee, high over the northern polar region. The other nine instruments make measurements in-situ, at the location of the satellite, around the entire orbit. They measure the fluxes of charged particles, electrons and protons, as well as heavier ions, from thermal energies into MeV energies, as well as magnetic and electric fields, plus electromagnetic waves. An ISARS researcher is a Co-Investigator of the Polar mission.

▶ **CHAMP**: The CHAllenging Minisatellite Payload is a German small satellite mission for geoscientific and atmospheric research and applications, managed by GFZ Potsdam. CHAMP was launched in 2000. With its highly precise, multifunctional and complementary payload elements (magnetometer, accelerometer, star sensor, GPS receiver, laser retro reflector, ion drift meter) and its orbit characteristics (near polar, low altitude, long duration) CHAMP generated for the first time simultaneously highly precise gravity and magnetic field measurements. This allows detecting besides the spatial variations of both fields also their variability with time. The CHAMP mission will open a new era in geopotential research and will become a significant contributor to the Decade of Geopotentials. ISARS researchers have worked on data analysis of CHAMP observations as Co-Investigators.

▶ **RHESSI**: The Reuven Ramaty High-Energy Solar Spectroscopic Imager is a NASA mission to explore the basic physics of particle acceleration and energy release in solar flares. It was launched on 5 February 2002 with an OSC Pegasus

Figure 1. The five spacecraft of the THEMIS mission. © University of California Berkeley

XL rocket. ISARS researchers have worked on data analysis and interpretation of RHESSI observations.

▶ **THEMIS**: NASA's Time History of Events and Macroscale Interactions during Substorms (THEMIS) aims to resolve one of the oldest mysteries in space physics, namely to determine what physical process in near-Earth space initiates the violent eruptions of the aurora that occur during substorms in the Earth's magnetosphere. THEMIS is a mission consisting of 5 identical probes, which were launched on 17 February 2007. An ISARS researcher is a Co-Investigator of the THEMIS mission.

In the development phase:

▶ **BepiColombo**: a cornerstone mission of the European Space Agency to planet Mercury. BepiColombo will set off in 2013 on a journey lasting approximately 6 years, to explore Mercury, the planet closest to the Sun. Europe's space scientists have identified the mission as one of the most challenging long-term planetary projects, because Mercury's proximity to the Sun makes it difficult for a spacecraft to reach and survive in such a harsh environment. The scientific interest to go to Mercury lies in the valuable clues that such a mission can provide in understanding the planet itself as well as the formation of our Solar System; clues which cannot be obtained with observations from Earth. Only one probe has visited Mercury so far, NASA's Mariner 10 which flew past three times in 1974-5 and returned the only close-up images of the planet so far. The information gleaned when BepiColombo arrives will shed light not only on the composition and history of Mercury, but also on the history and formation of the inner planets in general, including the Earth. The mission will consist of two separate spacecraft that will orbit the planet. ESA is building one of the main spacecraft, the Mercury Planetary Orbiter (MPO), and the Japanese space agency ISAS/JAXA will contribute the other, the Mercury Magnetospheric Orbiter (MMO). The MPO will study the surface and internal composition of the planet and the MMO will study Mercury's magnetosphere.

In the proposal phase:

▶ **Cross-Scale**: A 10-spacecraft mission that study multi-scale coupling in space plasmas.

▶ **MEMO** (Mars Environment and Magnetic Orbiter): A mission consisting of a low periapsis orbiter, using controlled aerobraking, for magnetic field mapping and characterization of fluid envelops of Mars, and a high apoapsis micro-satellite for monitoring solar conditions

▶ **TANDEM** (Titan AND Enceladus Mission): A mission to perform an in situ exploration of Titan and Enceladus in *tandem*.

Figure 2. Artist impression of BepiColombo's future arrival at Mercury. © EADS Astrium

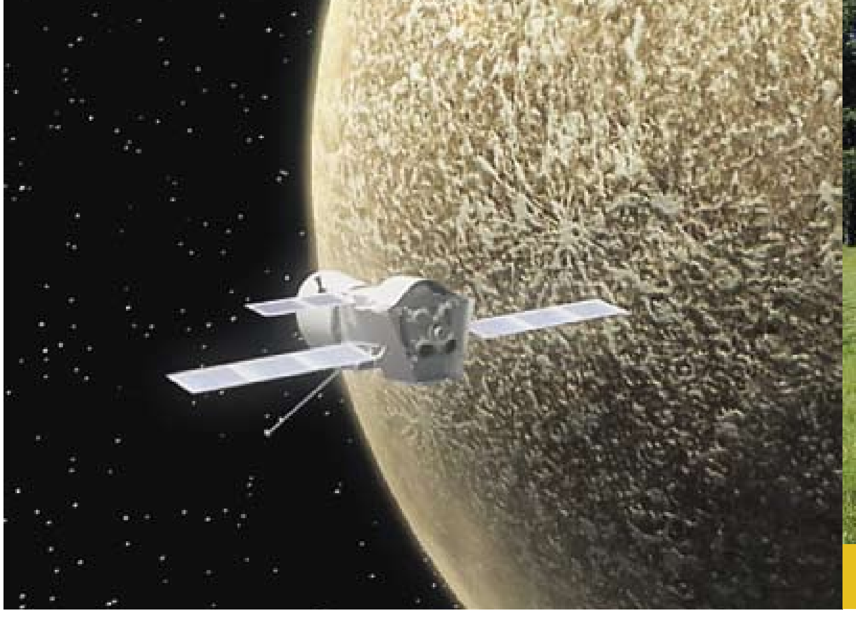

Figure 3.
One of the new magnetometers of ISARS.

▶ **WARP** (Waves and Acceleration of Relativistic Particles): a mission consisting of a tetrahedron spacecraft constellation for studies of kinetic plasma physics in the Earth's inner magnetosphere.

Ground measurements:

Furthermore, the Institute has initiated the installation of a **magnetometer array** in Greece, in collaboration with the Space Research Institute of the Austrian Academy of Sciences. The magnetometers will be providing measurements primarily for the study of geomagnetic pulsations, resulting from solar wind – magnetosphere coupling. The array will eventually consist of 4 stations latitudinally equi-spaced between 37° and 42° N geographic latitude. The particular spatial configuration is suitable for detecting field-line resonance signatures, thus allowing the study of the dynamics of the inner magnetosphere. Field line resonance frequencies can be accurately determined by means of a cross-phase analysis of ground-based ULF wave measurements recorded at stations closely spaced in latitude. This enables monitoring of the temporal variations of the plasma mass density in the inner magnetosphere, which is a critical parameter in geospace storms dynamics and space weather dynamics in general. The new array will provide the potential for collaboration with the South European GeoMagnetic Array (SEGMA) and with arrays in other parts of the globe for a more efficient and comprehensive space weather monitoring, nowcasting and forecasting.

Observational X-ray Astronomy in Greece

by I. Georgantopoulos[1], I. Papadakis[2], M. Plionis[1]

1. *Institute of Astronomy & Astrophysics, National Observatory of Athens*
2. *Physics Department, University of Crete*

Observational X-ray Astronomy has been developed in Greece in the last decade mainly through the efforts of two groups, one in the National Observatory of Athens and the other in the Physics department of the University of Crete. The X-ray Astronomy work in Greece revolves mainly around the fields of extragalactic astronomy and cosmology. When added together, the two groups have produced over 150 scientific refereed publications in the last decade.

Both groups acquire, analyse and model data from the two major X-ray missions in Space: ESA's *XMM* and NASA's *Chandra*. *XMM* is a cornerstone mission of the European Space Agency *XMM*. It was launched in 1999 and is funded to operate for at least 5 more years. *XMM* is the mission with the largest X-ray telescope ever built, having an area of 5000 cm^2 at the energy of 1 keV. It can detect X-rays with energies between 0.2 and 12 keV. The *Chandra* mission has a much smaller telescope (1000 cm^2 at 1 keV) but with amazing angular resolution (1 arcsec) as compared to *XMM*'s 6 arcsec. Therefore these two X-ray telescopes have quite complimentary capabilities: *XMM* can produce high signal-to-noise X-ray spectra while *Chandra* renders images of the X-ray Universe with unprecedented resolution rivalling those at optical wavelengths.

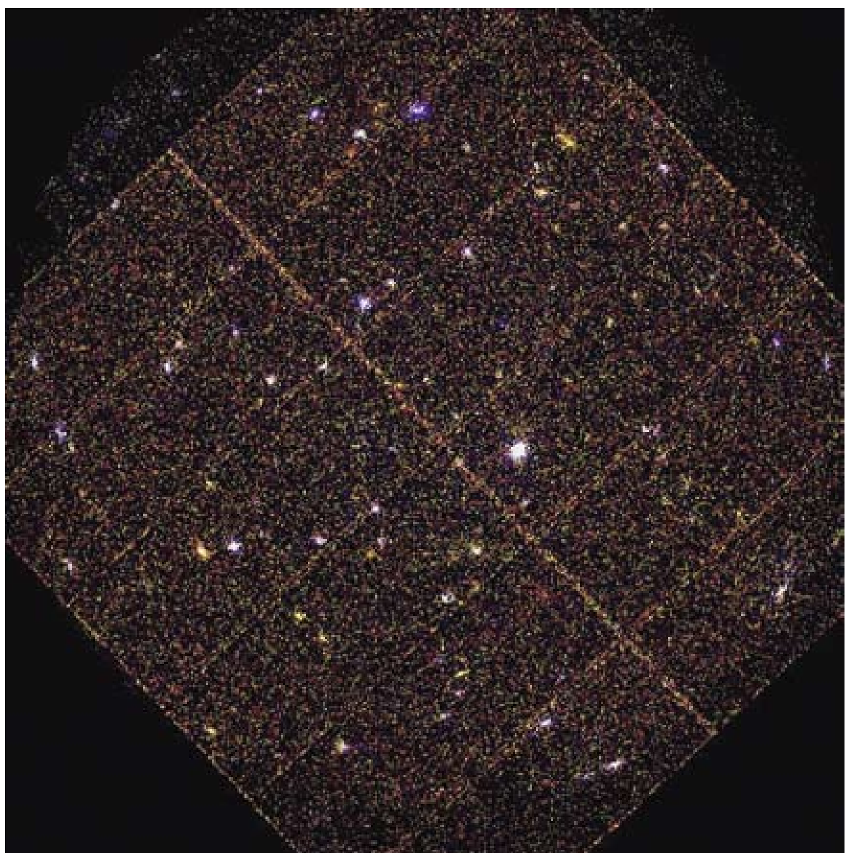

Figure: A deep survey image with the XMM-PN detector (15x15 arcmin). The different colours denote the source energy: redder sources correspond to hard energies, while blue correspond to soft energies.

The research work of the X-ray group in the National Observatory of Athens focuses on X-ray Astronomy & Cosmology (http://www.astro.noa.gr/xray). The group consists currently of 2 members of staff, 4 post-doctoral research assistants, 1 technical scientific staff and 2 research students. A new staff member is expected to join the group later this year (2007). Research topics include X-ray surveys and in particular the Large-Scale structure of the universe as revealed in X-rays with detailed studies of the clustering of Active Galactic Nuclei (AGN), the obscuration properties of AGN and clusters of galaxies. The spatial clustering of AGN presents great interest as it provides important clues on the distribution of super-massive black holes on large scales and on their cosmological evolution. In turn, the obscuration properties of AGN provide important clues on the accretion history of the Universe as well on the synthesis of the diffuse X-ray light, the X-ray background.

Moreover, the X-ray luminosity function of normal galaxies and its evolution has been studied for the first time combining large area bright *XMM* and pencil beam *Chandra* data. The study of galaxies at cosmologically interesting redshifts is painstaking as galaxies constitute a tiny fraction of the X-ray source population. In all the studies above the X-ray data alone are not enough. Optical observations are a prerequisite for obtaining the redshifts and identifications of the X-ray sources. To this end, optical observations are routinely performed in the medium and small size optical telescopes around the world such as the Anglo-Australian 3.9-m telescope, the Australian National University 2.5-m, the Cananea 2.1m and the SPM 2.1m at Mexico, the Kitt Peak 2.2-m telescope, the Calar Alto 2.5-m and 3.9 in Spain, the Isaac Newton 2.5-m telescope in La Palma, and the 1.3 m telescope at Skinakas Observatory. The new 2.3-m telescope ARISTARCHOS, armed with the wide-field VEC camera (acquired with the efforts of the X-ray group at IAA), will provide an invaluable tool in X-ray survey studies. Although the optical limiting magnitude will be rather bright, about V=19 mag for spectroscopy, the limit for photometry will easily go down to V=24 readily allowing the estimation of photometric redshifts.

The group in Crete consists of two members of staff, 1 post-doctoral research assistant and 1 research student. A third member of staff and a second post-doc will join the group in the next few months. The main research work focuses on variability studies of both Galactic and extragalactic X-ray sources. Apart from *XMM* and *Chandra*, the group also uses large amounts of data (both propriety and archival) from NASA's RXTE satellite to study the flux and spectral variability properties of Galactic black hole and neutron star X-ray binaries and those of radio quiet and radio loud AGN. The availability of the 1.3m telescope at Skinakas Observatory has been an important asset in the research work of the group. The telescope is frequently used for simultaneous multiwavelength observations, mainly of blazars, Galactic black hole and Be/X-ray binaries.

Both groups have been well established in the European and International system of X-ray Astronomy. The groups have numerous collaborations with large X-ray Astronomy groups abroad as well as participation in large European programs. Members of both groups have repeatedly acted as members of the Peer Review panels of *XMM* and *Chandra*. Finally, I. Georgantopoulos is a member of ESA's Astronomy Working Group, the panel which advises ESA on the operations of future and current space Astronomy missions.

The future of the European X-ray Astronomy lies in ESA's XEUS mission. This is a candidate mission in ESA's Cosmic Vision Program. XEUS, if finally selected, will carry the largest X-ray telescope ever (5 m^2 at 1 keV). It will be constituted of two spacecrafts one carrying the detector while the other one the telescope. This configuration will result in a large focal length (35-m) necessary for the detection of hard X-rays. The main payload will be a micro-calorimeter detector which will provide the largest spectral resolution ever achieved at X-ray energies (2eV at 0.5 keV) with a very high throughput (in contrast to grating spectroscopy). X-ray imaging at hard X-ray energies will also be feasible using mirror multilayer coating techniques. This mission is bound to change the future of X-ray Astronomy, but unfortunately these exciting developments will happen only after 2020.

The Herschel Space Observatory and the Greek Involvement

by E. M. Xilouris
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The Herschel Space Observatory is one of the 'cornerstones' of the European Space Agency's Horizon 2000 science program. Due to be launched in 2008, its mission is to explore the formation of stars and galaxies in deep space. Athough Greece joined ESA only in early 2005, a considerable effort has been invested so that scientists from Greece join, even at the latest stages, the Herschel project. The Institute of Astronomy and Astrophysics of the National Observatory of Athens joined one of the relevant consortia (the HIFI Consortium – see further below) with active involvement in the calibration of the instrument, while the Foundation for Research and Technology – Hellas (FORTH) is involved in the development of the software for the Herschel data pipeline.

The satellite, carrying the telescope and scientific instruments, is 7 m high and 4.3 m wide, with a launch mass of around 3.25 tones (Figure 1). The primary mirror is 3.5 m in diameter, which will make it the largest telescope in orbit ever. Herschel is the only space facility ever developed to cover the far-infrared to sub-millimeter parts of the spectrum (from 60 to 670 μm). After a four-month journey from Earth, Herschel will spend a nominal mission lifetime of three years in orbit around the second Lagrange point of the Sun-Earth system (L2).

Herschel's major objective will be discovering how the first galaxies formed and how they evolved to give rise to present day galaxies like our own. Additional targets for Herschel will include clouds of gas and dust where new stars are being born, disks out of which planets may form as well as planetary and cometary atmospheres packed with complex organic molecules.

In order to achieve its scientific objectives, Herschel's detectors have to operate at very low and stable temperatures. The optical bench, the common mounting structure of the instruments, is contained within a cryostat, and over 2000 litters of liquid helium will be used during the mission for primary cooling. Individual instrument detectors are equipped with additional specialized cooling systems, to achieve the very lowest temperatures ranging from –265° C to only a few tenths of a degree above absolute zero.

Herschel's science payload consists of three instruments:

- Photodetector Array Camera and Spectrometer (**PACS**), a camera and a low-to medium resolution spectrometer for wavelengths between 60 and 210 μm. It uses two bolometer detector arrays for imaging photometry and two photo-conductor detector arrays to perform imaging line spectroscopy.
- Spectral and Photometric Imaging Receiver (**SPIRE**), a camera and a low-to medium resolution spectrometer for wavelengths longer than 200 μm. It uses five detector arrays: three to take images of infrared sources in three different infrared colors (250, 360 and 520 μm) and two for an imaging Fourier transform spectrometer.

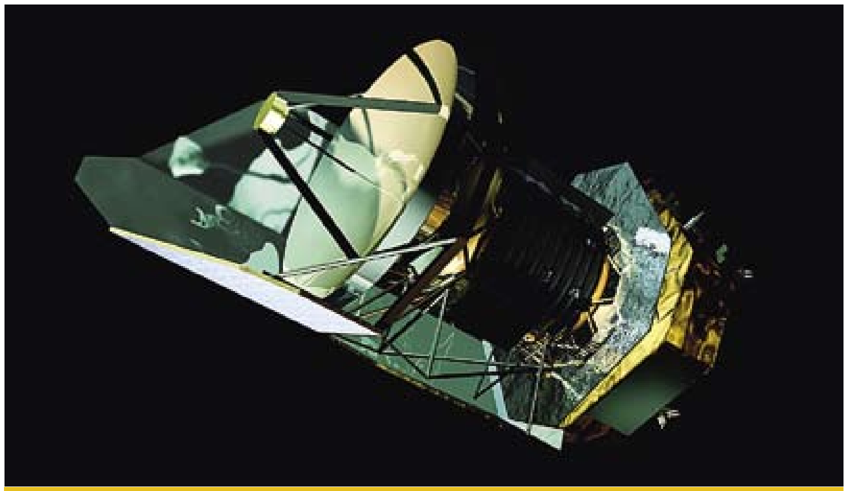

Figure 1. Artist's impression of the Herschel Space Observatory © ESA, 2002

Figure 2. Logo of the HIFI Instrument Control Center (© SRON 2007)

- Heterodyne Instrument for the Far Infrared (**HIFI**), a highly accurate spectrometer that can be used to obtain information about the chemical composition, kinematics, and physical environments of the infrared sources. HIFI was designed and built by a Consortium (lead by SRON, Groningen, The Netherlands – see Figure 2).

For more information on Herschel visit: http://herschel.esac.esa.int/

Observations of the Sun at the National Observatory of Athens

by G. Tsiropoula and K. Tziotziou
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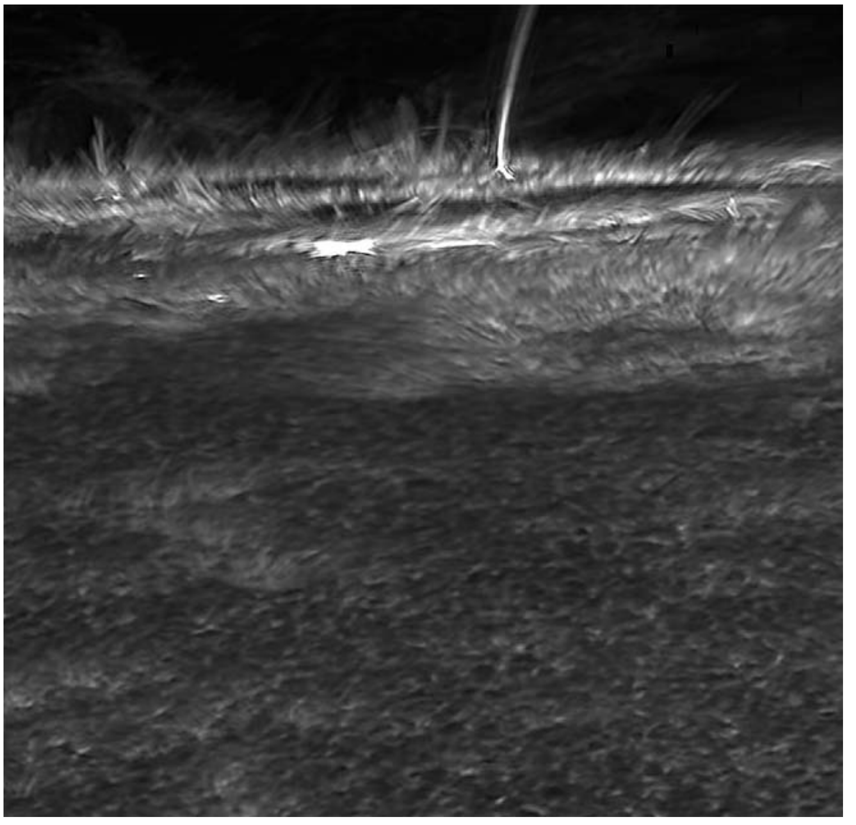
Solar physics has seen a decade of exciting discoveries and significant progress has been accomplished in all fields. These advances are due to the increased performance of ground-based instrumentation, but to a greater extent to the availability of a set of unique space missions, such as Yohkoh, SoHO and TRACE. Multi-wavelength observations involving many observatories now routinely cover the whole solar atmosphere from the photosphere to chromosphere, transition region and corona. All the efforts for the in-depth understanding of the Sun have been mainly motivated by the fact that our star is the only star where we can observe surface structures in fine detail. We have also recently witnessed a growing interest in the field of solar-terrestrial relations in order to understand better the influence of the Sun on the status and the evolution of our planet, as well as on space technology.

The group of Solar Physics at the Institute for Space Applications and Remote Sensing of the National Observatory of Athens studies the Sun using observational data from satellites (such as SoHO and TRACE) and/or ground-based observatories (such as THEMIS in Tenerife and DOT in La Palma) in combination with modelling and theoretical tools (such as radiative transfer). The SoHO satellite is a cornerstone mission of the European Space Agency. Its continuous monitoring of the outer solar atmosphere has been proven to be of immense scientific value. TRACE, a NASA space mission, has provided impressive observational information which has enabled an improved understanding of the physical processes and phenomena occurring at the solar atmosphere. These significant observational tools from space when complemented with ground-based telescopes provide, through a multi-wavelength analysis, a coverage of the solar atmosphere from the lower layers to the outer corona. THEMIS and DOT, very often used by the group for acquiring observations, are among the most high-standard solar European telescopes installed in the Canary islands. They provide images and profiles in several spectral lines covering the photosphere and chromosphere which permit the extraction of quantitative information about the physical parameters that describe the thermodynamic state of the solar plasma.

The group is currently investigating a wide range of solar phenomena occurring in active and quiet regions that include sunspots, loops, surges and fine scale structures. Quiet Sun studies of the group are mainly based on observations of fine-scale structures. These are small structures of short length (~10000 km) and width (~1500 km) observed mostly in chromospheric lines (Hα, Ca). They are called mottles when observed on the solar disc and spicules when observed on the solar limb, they occupy most of the surface of the quiet Sun regions and are associated with the network boundaries defined as the borders of supergranular cells on the Sun. They are observed either with ground-based telescopes or solar satellites. The aim of such studies is the investigation of their morphological characteristics, dynamical behaviour (evolution, lifetime, periodicities), physical properties (velocities, temperatures, densities etc), which are deduced from their spectral line profiles with the use of radiative transfer theory, and their association with physical drivers in the lower atmosphere, as well as with similar structures observed higher up in the solar atmosphere. The ongoing work of the solar group at NOA has demonstrated that magnetic reconnection is probably their driving mechanism, since it interprets well the majority of the observational characteristics of these structures. Magnetic reconnection is a very interesting process, since it provides the means for heating the solar



corona and drives material towards the solar atmosphere and away to the solar wind. Active Sun studies of the group mainly focus on sunspots. Sunspots are the best known features on the solar surface, which are sometimes much larger in size than Earth itself, and are associated with high concentrations of magnetic field fluxes. Sunspot observations and analyses of the group focus mainly on the study of oscillations and waves observed on their atmospheres through wavelet analysis. The work carried out has great impact on the solar community, since it clearly demonstrated the association of oscillations at the umbrae and of running waves at the penumbrae of the sunspots.

The group has close collaborations with several well-established solar groups like the ones in Meudon (France), Utrecht (The Netherlands), Ondrejov Observatory (Czech Republic) and MSSL (UK). It is involved in several observational campaigns under the status of Principal Investigator or Guest Investigator and has been funded several times by the European Commission or through OPTICON to carry out these campaigns. The group has succeeded recently, after a successful proposal, to include Hinode in an observational campaign which also will use THEMIS, DOT and TRACE and has been awarded two OPTICON grants. The Japanese/US mission Hinode (Solar-B) is the most recent space mission launched in 2006 and provides continuous, high-resolution imaging and spectroscopic polarimetry, along with imaging and spectroscopy of the chromospheric and upper solar layers.

While recent ground-based and space experiments have given us a glimpse of the amazing level of fine structure that governs a large part of the solar atmosphere they also uncovered a number of problems that can be solved only with future observations with even better resolution. Indeed the need of high angular resolution is a theme running through all of solar physics. The advance of a next generation large aperture ground-based solar telescopes (e.g. ATST, EAST) in combination with adaptive optics, image reconstruction techniques, and sophisticated post-focus instrumentation together with the availability of the planned space missions (e.g. Solar Probe, Solar Dynamics Observatory) will bring us closer to the goal of resolving the mysteries of our closest star. The NOA solar group has the expertise to be involved in observations with all these instruments.