APPENDIX II: Helmos Observatory and the 2.3 m "Aristarchos" Telescope

1. Introduction

Helmos Observatory is one of the largest contemporary research infrastructures in Greece with an invested value of 11 million euros. It hosts the 2.3m "Aristarchos" telescope, the largest optical telescope in the Balkans and the second largest in continental Europe, located on the top of Helmos mountain in the central Peloponnese, at an altitude of 2340 meters. Due to its high altitude, the observatory very often lies above the clouds and the inversion layer of the atmosphere, yielding excellent seeing conditions. This location is one of the darkest sites in Europe (Figure 1). The mild climate of southern Greece translates to a yearly average of 150-200 clear nights, compared to the yearly average of less than 100 clear nights in mainland continental Europe (NASA International Satellite Cloud Climatology Project). Moreover, Helmos mountain has a low frequency of lightning, while dust from the Sahara is rare at this latitude. Last, but not least, the nearby Kalavryta Ski Center enabled the development of the basic infrastructure at Helmos Observatory, i.e. access by road and electric power, and guarantees access to the observatory during the winter via the ski lifts.

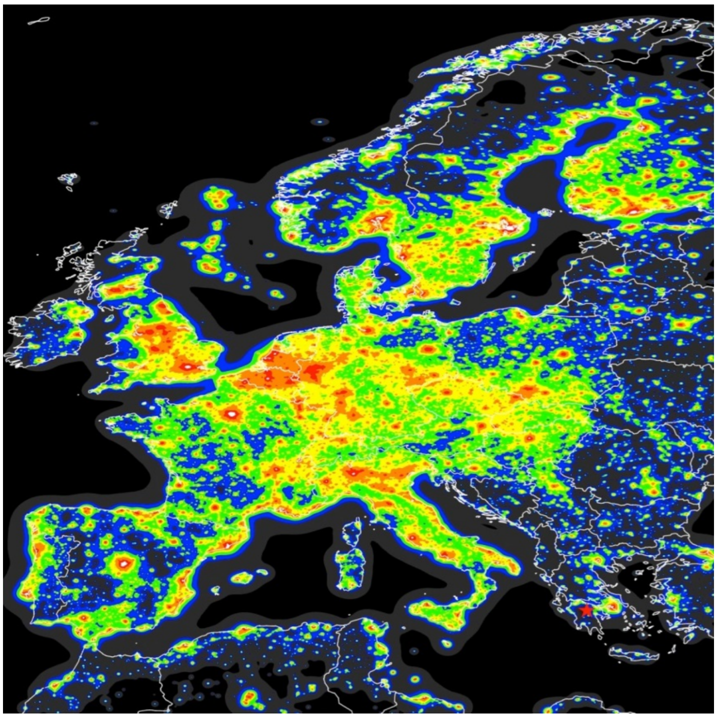

Figure 1. *Light pollution map of Europe from the Light Pollution Atlas 2006. The red star marks the location of Helmos Observatory.*

2. The 2.3m "ARISTARCHOS" telescope

2.1 Instrumentation

The main section of this report summarizes the main features of the 2.3m "Aristarchos" telescope and the instruments that have been commissioned. The following instruments will be commissioned in the near future:

- Vernikos-Eugenides CCD camera (VEC). This is a FAIRCHILD-486 (4096x4096 pixels) camera with a field of view of 10x10 arcmin. The camera has been acquired by EU/GSRT funds and partially by a donation from the Eugenides Foundation.

- Aristarchos Transient Spectrometer (ATS). The spectrograph resolution and spectral range depend on the grating: (a) RED yields a resolution of 2.5 Angstroms and a wavelength range 5780-7070 Angstroms, (b) BLUE yields a resolution of 2.5 Angstroms and a wavelength range 4370-5780 Angstroms and (c) FULL yields a resolution of 6 Angstroms and a wavelength range 4120-7200 Angstroms. The spectrograph is fed using a bunch of 50 optical fibers, giving a 10 arcsec diameter field of view. The spectrograph is equipped with an Apogee U47, E2V-CCD4710 back illuminated CCD camera with 1024x1024 pixel, 13μm pixel size.

- Manchester Echelle Spectrometer (MES-AT). The instrument has been already used at the following telescopes: 2.1-m San Pedro Martir in Mexico, 3.9-m Anglo-Australian Telescope in Australia, 3.9-m William Herschel Telescope in the Canary Islands, Spain. The spectrograph uses a SITe 2048x2048 pixel CCD camera. The spectrograph's spectral resolving power is ≤ 10^5 while it covers the wavelength range 3900 - 7500 Angstroms.

- A focal reducer is currently being constructed in collaboration with the University of Manchester. The focal reducer, which will be installed at the telescope before the end of 2015 will increase the telescope's field-of-view to 27x27 arcmin. Hence the telescope will become capable of observing a wide field of view in the following bands: *u,g,r,i,z*,Y.

2.2 Optical and Electronics Laboratory

In addition to the facilities at the Helmos site, an Optics and Electronics Laboratory was set up at the premises of the Institute in Penteli in 2005 and began operating in mid-2006. The Laboratory is equipped with all the necessary equipment (two optical tables with special isolator legs for removing vibrations, calibration lamps, laser equipment, etc.) in order to support the 2.3m "Aristarchos" telescope, to test existing instruments and to develop new scientific instruments.

3. Helmos Site Characteristics

In this section we provide the first site characteristics mainly derived from the meteorological station installed at Helmos Observatory. Given the lack of formal site testing prior to the installation of the telescope and the lack of permanent staff on site, the data were taken only when personnel from our premises in Athens were sent for observations or technical work. In addition, due to the various technical problems of the telescope during the first years of operation, there were long intervals of downtime and little activity on the site. For this reason, the yearly sampling of meteorological data is not very dense and concentrates mainly in the summer and autumn periods. Currently (as of the 2013 observing season), the telescope is in good operating condition and the data sampling has improved significantly.

3.1 Cloud Coverage

For the cloud coverage statistics, we used in situ observations carried out by the personnel on site. The cloud coverage was categorized into three levels (namely, clear sky, intermediate cloudiness, and heavy cloudiness) in a log that was kept. In Table 1 we present the data (yearly sampling), which were limited to the period of operations. Specifically, 90% refer to the period from June to November and only 10% to the rest of the year. With the telescope currently being functional, we expect to collect more data for the winter – springtime. Apart from that, in September 2013 we also installed a heavy-duty meteorological station 250m from the telescope to monitor the conditions all year round.

Table 1: Site Observations

Year	# days with cloud data (night)	# days with cloud data (day or night)	# days with meteo data
2001	No data	No data	26
2002	No data	45	45
2003	No data	No data	No data
2004	No data	No data	54
2005	No data	No data	12
2006	No data	No data	25
2007	53	54	58
2008	36	40	60
2009	12	40	43
2010	46	99	101
2011	0	40	41
2012	9	30	30
2013	No data	96 (Mar-Oct)	99 (Mar-Oct)
Total	156	444	594

For the 156 nights in 2007-2012 with night activity (whole or partial), which are equivalent to 120 full nights, we determined the percentage of observable nights to be 60%, having subtracted the time lost to high humidity and winds. If we instead consider the 444 days with both meteorological data and cloud coverage observations (daytime or night-time), we find the observable nights to be >60%. Figure 2 shows a histogram of the breakdown per year.

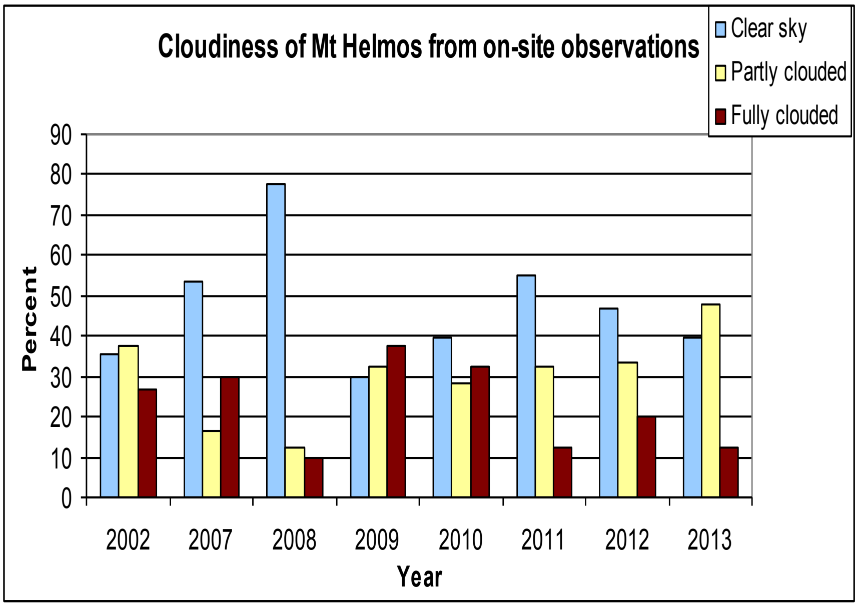

Figure 2. Cloud coverage assessed by on-site observations.

The results are in agreement with satellite data. Satellite observations (mainly using data from NOAA, MeteoSAT, and MeteoFrance providing resolutions between 1 and 2 km) were visually inspected and evaluated and the cloud coverage was determined based on three categories mentioned above. Analysis of the satellite data per month showed that the lowest cloud coverage months are: June, July, and August (percentage of clear skies >70%) and the highest cloud coverage months are: December, January, and February (percentage of clear skies <30%).

3.2 Observable Nights

The percentage of observable nights depends not only on cloud coverage, but also on the humidity and wind speed. The telescope and dome operational limits for relative humidity and wind speed are 80% and 50 km/h. The percentage of clear and partly clear days and nights in our sample is 77%. Subtracting the percentages lost to high winds (6.2%) and high humidity (10.5%) yields a fraction of 64.1% of nights having observable weather conditions, in agreement with the results of section 3.1. However, these values refer to the summer/autumn period and we are in the process of collecting data to determine the total number of observable nights per year. *Between June and November we have on average 100 clear or partly clear observable nights, with ~15% of them being photometric*.

Below we present the summary of the meteorological conditions for Helmos Observatory determined from 594 days of data collected during 2001 – 2013.

3.2.1 Temperature

The average temperature at Helmos Observatory is 8.4C, with a recorded minimum of -9C and maximum of 25C. A typical temperature difference between day and night on a clear day in August is 8C.

3.2.2 Humidity

The average relative humidity is 60%, with a recorded minimum of 10% and maximum of 100%. The relative humidity exceeds the telescope operation limit (humidity > 80%) on average 17.4% of the time, 47.5% for cloudy days/nights and 8.5% for clear days/nights.

3.2.3 Wind

The average of the mean wind speed is 15 km/h and the average of the peak wind speed value (gust) is 25 km/hr. The maximum mean wind speed measured is 90 km/hr and the maximum gust measured is 145 km/h. The percentage of times with winds stronger than the operating limits of the telescope (> 50 km/hr) is 7.1%, while for 20% of the days/nights there was practically no wind (speed < 10 km/h). The strongest winds measured are coming from the west–northwest direction.

3.2.4 Seeing

A Differential Image Motion Monitor (DIMM) was installed in 2013 to record the seeing parameter, which is a measure of the atmospheric turbulence that affects the sharpness of the observed astronomical images. We have so far collected 19 nights of seeing measurements (see Figure 3), which yielded a median value for the seeing of 0.78 arcsec and contained values as low as 0.25 arcsec. The planned installation of an autoguider to automatically correct the tracking is expected to improve the measured values for the seeing. We therefore have a first indication of a very stable atmosphere, which we plan to characterize in detail by collecting a large amount of seeing data.

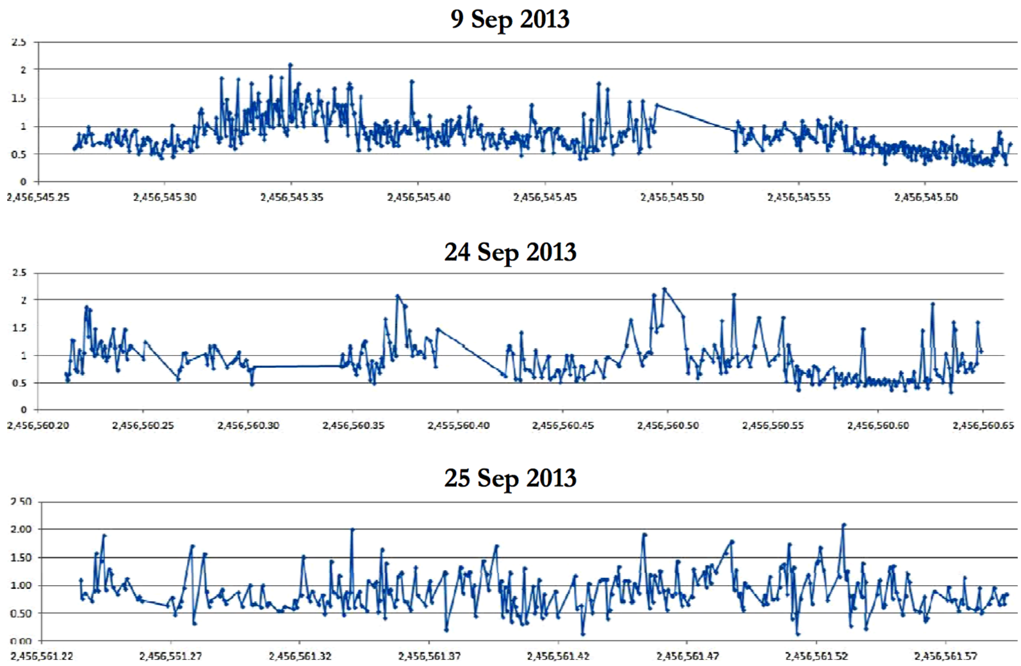

Figure 3*. Seeing monitoring sequences for a sample of three nights using the DIMM method.*

3.2.5 Night sky brightness. The sky brightness was measured in the moonless night of 10 September 2013 and yielded the following values in the U, B, V, R, I photometric bands:

U filter: 21.6 mag/arcsec^2
B filter: 22.1 mag/arcsec^2
V filter: 21.1 mag/arcsec^2
R filter: 20.5 mag/arcsec^2
I filter: 18.8 mag/arcsec^2

However, the specific night turned out to not be photometric because there were some very thin sparse clouds, which affected the sky brightness. In other astronomical images taken in the R and I filters in mid-July during photometric nights, it was found that the sky brightness was 20.2 and 18.6 magnitudes/arcsec^2 respectively. We estimate that repetition of the measurements during a good moonless photometric night may yield sky brightness in the various filters by half a magnitude fainter on the average. In any case, the above values show that the site is very dark.

4. Activities and Achievements

On average the Observatory is accessible 10 months per year. The inaccessible periods are in mid-November to mid-December and late-April to late-May, when the access by road is inhibited by snow and the Kalavryta Ski Center lifts and snow vehicles are not operating. Our presence at Helmos Observatory was not very dense until last year, when the telescope became functional. In Table 5, we show the data for our presence on the mountain over the years 2008-2012.

Table 5: Yearly operations at Helmos Observatory

Year	Science observations		Engineering technical work	
	Days	Persons	Days	Persons
2008	35	75	105	323
2009	4	8	95	305
2010	41	89	91	409
2011	16	48	60	210
2012	9	24	62	196
2013	88	186	21	72
Total	193	430	434	1515

4.1 Current Observing Programs

Currently observing time with "Aristarchos" telescope is given to researchers within the astrophysics group of IAASARS and to close collaborators, while observing time is expected to be awarded to external observers within 2014, with the goal of becoming a full member of the

FP7 OPTICON (Optical Infrared Co-ordination Network) consortium. The main observing programs underway at the 2.3m "Aristarchos" telescopes are:

- Narrow band imaging of Supernova remnants
- Narrow band imaging of Planetary nebulae
- Broad-band imaging of Boxy/peanut bulges in edge-on galaxies
- Hα, Hβ imaging of M33
- Monitoring of eclipsing binaries in nearby galaxies for distance determination
- Monitoring of cataclysmic variables
- CCD photometry of stars in the open cluster NGC7243 (rotation period determination).

4.2 Publications using observations with "Aristarchos" telescope

4.2.1 Refereed Publications

- "The expansion proper motions of the extraordinary giant lobes of the planetary nebula KjPn 8 revisited", P. Boumis and J. Meaburn, 2013, MNRAS, 430, 3397
- "The bow-shock and high-speed jet in the faint, 40 arcmin diameter, outer halo of the evolved Helix planetary nebula (NGC 7293)", J. Meaburn, P. Boumis, S. Akras, 2013, MNRAS, 435, 3462
- "On the stability of bow shocks generated by red supergiants: application to IRC-10414", D.M.-A. Meyer, V.V. Gvaramadze, N. Langer, J. Mackey, P. Boumis, S. Mohamed, 2013, MNRAS, (submitted)

4.2.2 Conference Proceedings

- 'Aristarchos Instrumentation: Manchester Echelle Spectrometer (MES) and Aristarchos Transient Spectrometer (ATS)', 2004, P. Boumis, J. Meaburn, and C. Goudis, in the proceedings of the 6th Hellenic Astronomical Conference, 313.
- 'Aristarchos: The New 2.3m Greek Telescope', 2006, C. Goudis, P. Hantzios, P. Boumis, E. Xilouris, in the proceedings of the 7th International Conference of the Hellenic Astronomical Society, AIP Conf. Proceed., 848, 800.
- 'The Aristarchos Telescope', C. Goudis, P. Hantzios, P. Boumis, E. Xilouris, A. Katsiyannis, A. Maroussis, in the proceedings of the 9th International Conference of the Hellenic Astronomical Society, ASPC, 424, 422.
- 'Aristarchos Instrumentation: Meaburn Filter Measuring Spectrometer (MFMS)', P. Boumis, E. Xilouris, O. Giannakis, A. Maroussis, A. Katsiyannis, 2010, ASPC, 424, 424.
- 'Aristarchos RISE2: A Wide-Field Fast Imager for Exoplanet Transit Timing', P. Boumis, D. Pollacco, I. Steele, J. Meaburn, E. Xilouris, A. Katsiyannis, M. Bode, S. D. Bates, C. Goudis, F.P. Keenan, C. Watson, 2010, ASPC, 424, 426.
- 'First Images from the Aristarchos Telescope', C. Goudis, P. Boumis, E. Xilouris, A. Katsiyannis, P. Hantzios, J. Alikakos, D. Abartzi, A. Maroussis, 2012, in the proceedings of the 10th International Conference of the Hellenic Astronomical Society, 28.