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1. PREFACE

The Institute of Astronomy and Astrophysics (I.A.A.) has evolved from the former Astronomical Institute and constitutes the ‘heart’ of the National Observatory of Athens (N.O.A.). Its aim is the study of extraterrestrial cosmic space and the exotic phenomena taking place in the Universe, which largely define the progression and evolution of our own ‘terrestrial’ world. Our scientists use modern technology and advanced research methods, contributing in this way to the participation of our country in the great adventure of the modern quests of the human spirit.

The portrait of the Institute and its evolution during the decade 2001-2011, during which I had the honor to be its Director, constitutes the expression of a collective identity which was shaped by its members, culminating firstly in the successful completion of the installation and commissioning of the ultramodern telescope ‘Aristarchos’ in the newly-built Helmos Observatory, and secondly, in the active participation of its researchers in the big space missions of ESA: XMM-Newton, Herschel, Gaia and Solar Orbiter.

The use of the staff employed prior to 2001 as well as the enhancement of the Institute with the recruitment of new talented researchers, during the current decade of its scientific progression, created a broad spectrum of international research projects, technological, educational and societal activities, achieved by a spirit of team collaboration, volunteering and dedication, from which the distinct profile of our Institute has emerged, in its pursuit of modern science and research in the field of Astronomy and Astrophysics.

The identity and the accomplishments of the Institute constitute part of another “bright Greece” which renders us more optimistic for the future of our country.

Professor Christos Goudis
Director of the Institute of Astronomy and Astrophysics
National Observatory of Athens
2. Helmos Observatory

Helmos Observatory is already visible from the city of Kalavryta. “Aristarchos”, the largest telescope of southeastern Europe, is one of the largest national research developments of the last decades in Greece and it is anticipated to promote Greek astronomy in the European and International research arena.

The Institute of Astronomy and Astrophysics aims at using Helmos Observatory as a tool for developing research, education and culture in Greece.

Helmos Observatory is situated on “Neraidorachi”, a mountaintop of the Helmos mountain chain in the Peloponnese, at an altitude of 2340 m above sea level, 220 km northwest of Athens. This site is one of the darkest places in continental Europe, which is evident from satellite maps showing the light pollution in Europe.

2.1 “ARISTARCHOS” TELESCOPE

Helmos Observatory hosts the modern “Aristarchos” telescope. “Aristarchos” is an optical telescope designed and manufactured by the german company Carl Zeiss GmbH. The main characteristic of this telescope is its 2.3 m mirror which, combined with the super-sensitive detectors that the telescope is equipped with and the excellent atmospheric conditions of the site, makes it a very valuable tool for observing astronomical objects, even very faint and very distant objects located in the outskirts of the Universe.

The telescope combines technology that is currently applied to larger telescopes (10 m class telescopes) allowing for superb pointing accuracy (it can point to an object within two seconds of arc) as well as excellent tracking (it can follow an object for more than an hour with imperceptibly small changes in the image position).

The well-designed optical system that “Aristarchos” is equipped with, along
The "Aristarchos" telescope. Its moving part weighs about 40 tons and can point to astronomical objects on the sky with an unprecedented accuracy (2 seconds of arc).

with techniques for automatic flexure corrections of the mechanical body of the telescope, guarantee the high quality of astronomical observations that this telescope can support.

The telescope is already equipped with state-of-the-art scientific instruments, which cover a wide range of observations in modern astronomy and astrophysics. A brief description of each instrument follows:

**CCD camera** (field of view 5 minutes of arc) SITeAB, 1024 x 1024 pixels. The electronics of this camera are cooled, using liquid nitrogen, down to -120° C, permitting astronomical objects to be mapped at optical wavelengths through special filters. Images obtained with this camera are presented in Chapter 6.

**Low/Medium resolution spectrometer** (ATS: Aristarchos Transient Spectrometer).

Light originating in distant astronomical objects is collected with the telescope and fed to the spectrometer through a bundle of 50 fibers resulting in a detailed spectrum which traces chemical elements and molecules, in the form of spectral lines, which are present in the observed object.

This spectrometer is equipped with an Apogee CCD camera, with 1024x1024 pixels. Spectra observed with this...
spectrometer are presented in Chapter 6.

■ **Exoplanet detection system** (RISE-2). This instrument, already installed at the telescope, is equipped with a special optical system and a CCD camera that allows the monitoring of very rapid luminosity changes of stellar objects. This allows us, for example, to detect and monitor transits of planets in distant solar systems. RISE-2 is an updated version of the RISE-1 camera, which is installed and operating on the Liverpool Telescope in La Palma (Canary Islands). These two instruments together, taking advantage of the longitude difference between the two sites (Greece/Canary Islands), can achieve full coverage of a transit thus providing characteristics of the planetary system.

■ **Wide-Field Vernikos-Eugenides CCD camera (VEC)** (12 minutes of arc) Fairchild-486, with 4096 x 4096 pixels and a liquid nitrogen cooling system. This camera with its unprecedented sensitivity in optical light can perform deep observations of very distant objects at cosmological distances.

■ **High resolution spectrometer** (MES-AT: Manchester Echelle Spectrometer). This spectrometer, already tested on telescopes in Mexico (San Pedro Martir Telescope), Australia (Anglo Australian Telescope) and the Canary Islands (William Herschel Telescope), can perform high resolution observations and provide information not only on the chemical composition of astronomical objects, but also on their kinematical properties. MES-AT is equipped with a SITe CCD camera, with 2048 x 2048 pixels.

■ **The Meaburn Filter Measuring Spectrometer (MFMS)** is used to provide detailed properties of the transmission curves of the photometric filters that are used with this telescope. This special instrument is located in the optical-
electronics laboratory of the Institute of Astronomy and Astrophysics in Penteli.

2.2 FACILITIES

The facilities of Helmos Observatory include the dome building, which encloses the telescope, the telescope control and the guest house building as well as the building that contains the electrical power equipment that connects the observatory with the public electricity network and the supporting power generators. The construction of the buildings at Helmos Observatory was undertaken by Greek companies. Complementary facilities include a small dome that encloses the instruments for monitoring the quality of the atmosphere (which influences the astronomical observations) as well as a small room for the liquid nitrogen tank.

The dome building was constructed by the Greek company “PROTER”. The main part of the building is divided into three levels. The first level encloses the telescope control cabinet with all the electronic devices that support the operation of the telescope. For thermal insulation from the rest of the building the second level is kept empty while the third and last level contains the “Aristarchos” telescope, which is mounted on a concrete peer, with an independent foundation from the rest of the building in order to avoid propagation of vibrations that could influence the telescope and the observations. The top part of the building can be rotated so that it always follows the direction of the telescope. This moving part also slides apart allowing for a “window” about 3 m wide, through which the telescope can point. The benefit of this dome design is that it allows for the optical systems of the telescope to quickly reach thermal equilibrium with the surrounding environment, minimizing possible local atmospheric turbulence, which may influence the quality of the observations.
The telescope control room and the guest house are located 35 m away from the dome building so that human activities, as well as heat coming from various instruments, computers, etc will not influence the functionality of the telescope and, most importantly, the quality of the astronomical observations.

The control room of the telescope encloses all electronic devices and computers that are necessary for the control of the telescope, the dome and all the scientific instruments that the telescope is equipped with. Additional computers for performing analyses of the raw data from the telescope also exist in this room. A small optical/electronics laboratory, supporting activities for the maintenance of the telescope, also operates in this building. The largest part of this building consists of rooms for accommodating the observatory personnel as well as the observers coming to the telescope. Three bedrooms, able to accommodate up to seven people, two bathrooms, a dining room and a living room, as well as a fully equipped kitchen are available for the comfort of the personnel and observers.

The existing facilities include two more buildings. One of them hosts two power generators (75 kVA and 12 kVA) that support the functionality of the telescope in case of a failure of the power provided by the national power network. The second building, established in 2007, contains the facilities and the power supply devices that are necessary to distribute the electrical power coming from the national network. The electrical power from the national distributor reaches the telescope site via an underground cable network starting from the existing facilities of the Kalavryta Ski Center.
The power supply station of the national electricity network inside its specially designed room established in 2007.

Between the dome building and the control room and guest house building is a small dome housing a small, 30 cm MEADE telescope used for monitoring the atmospheric quality (local atmospheric turbulence can degrade the quality of astronomical observations).

Attached to the northern part of the building that houses the electrical power network devices, is a small room equipped with a liquid nitrogen tank. This tank has a capacity of 600 liters and is refilled with liquid nitrogen by a special vehicle of the company Air Liquid Hellas.

The 600 liter liquid nitrogen tank. Liquid nitrogen is used for the cooling, down to -120 °C, of the very sensitive CCD cameras of the telescope. This way, the thermal noise of the CCD detectors is minimized allowing for the detection of even the most faint radiation coming from distant objects in the outskirts of Cosmos.

The water supply of the guest house building comes from three underground water tanks, each having a capacity of 10 tons. Rain water is collected from the roof of the buildings, guided to the tanks via water pipes and then pumped to the guest house for cleaning purposes.

2.3 ACCESS

A paved road exists up to the main buildings of the Kalavryta Ski Center (altitude 1700 m) which is maintained open all year round. During the off-snow season access to the observatory site is made via the pre-existing 8.5 km mountain road.
For this purpose Helmos Observatory is equipped with two 4-wheel drive vehicles. During the winter months (usually from early December until late March) access to the site from the road is prohibited due to snow. During these months snow accumulation can reach up to 15 m in height in many places, blocking access to the observatory. Under these conditions the only way to reach the observatory is via the ski center facilities (either using the ski lifts or the special snow vehicles).

Helmos Observatory is located 18 km away from the city of Kalavryta. The road to the Kalavryta Ski Center is asphalt paved and maintained in good condition. From this point on a 8.5 km dirt mountain road leads to the observatory facilities.
Snapshots of the improvement projects on the mountain road leading from the Ski Center to the observatory. The first two pictures show the bad condition of the road before September 2005 while the rest show the improved road after the construction work in September and October 2005.

Important construction work was undertaken in September 2005 for the improvement and the repair of the mountain road leading to the observatory. Some sections of this road were completely reconstructed.

2.4 COMMUNICATION NETWORK

In November 2009 Helmos Observatory was connected to the National telecommunication network through fiber optics allowing for speeds up to 100 Mb/s for internet connection and data transfer. This network also supports voice communication via regular telephone lines. Before the connection to the public network, telecommunications were made through microwave links allowing for speeds up to 13 Mb/s. Since there is no direct line-of-sight between Athens and Helmos Observatory, the connection is made through an intermediate station located at Gerania Mountain. This link is still in operation, mainly acting as a back up supporting system for the telephone lines of the whole National Observatory of Athens but also for backing up the existing public telecommunication network.

2.5 COMPUTER CENTER

Helmos Observatory is equipped with a computer network (including servers, work stations and PCs, etc) supporting the operation of the telescope and the scientific instruments, the telecommunications as well as the data storage system with a capacity of 15 Terabytes. On some of the PCs, special software packages have been installed, to be used by the researchers of the Institute and the visitors, for the immediate reduction of the raw data taken from the telescope.

2.6 KALAVRYTA ASTRONOMICAL STATION

An office, located in the city of Kalavryta, is permanently given to the Observatory by the local authorities. This office can accommodate up to two persons and is equipped with telephone lines and a 10 Mb/s internet line.
The office, located in the city of Kalavryta, which provides accommodation and working facilities for the observers and the personnel of the Observatory.

2.7 OPTICAL – ELECTRONICS LABORATORY AT PENTELI

An optical - electronics laboratory operates in the main building of the Institute of Astronomy and Astrophysics at Penteli, aimed at supporting the maintenance, calibration and upgrade of the scientific instruments of the telescope. It is equipped with special optical benches for testing the scientific instruments of the telescope.

View of the optical and electronics laboratory located at the I.A.A. building at Penteli. The laboratory is equipped with special optical benches for testing the scientific instruments of the telescope.

More information on Helmos Observatory is available at the following website: http://www.astro.noa.gr/helmos/

Kryoneri Observatory (established in 1972) is located in the district of Corinth in the northern Peloponnese at the top of mount Kyllini, close to Kryoneri village. It is equipped with a 1.23 m telescope, which is one of the largest telescopes in Greece, with many successful scientific observations during its long operation (scientific observations started in 1975). We indicate that during the period 2000 – 2010 there have been more than 50 scientific papers published in international refereed astronomical journals with observations obtained from Kryoneri Observatory.

3.1 THE 1.23 M TELESCOPE

The optical telescope of Kryoneri Observatory was manufactured and installed in 1975 by the British company Grubb Parsons Co., Newcastle. The telescope is a Cassegrain reflector with a primary parabolic mirror (1.23 m in diameter) and a secondary hyperboloid mirror (0.31 m in diameter) and
The 1.23 m telescope at Kryoneri Observatory. Indicative of its long successful operation is the large (more than 50) number of scientific peer-reviewed papers (with data taken with this telescope) published in international astronomical journals during the decade 2000-2010.

A focal ratio f/13. The mirrors were manufactured by Zerodur.

The telescope is equipped with an Apogee 47p CCD camera (with a 1024 x 1024 pixel format) providing a field-of-view of about 3 minutes of arc on the sky and a filter wheel system (along with a broad-band U,B,V,R,I set of filters).

3.2 FACILITIES

Kryoneri Observatory includes the basic facilities to support the operation of the telescope and is connected to the public electricity network. A guest house (80 sq. m.) can accommodate a sufficient number of persons (up to 10 persons). It includes bedrooms, a kitchen and working areas for the personnel.

The aluminizing unit for recoating the telescope’s mirrors. This room hosts all the equipment for cleaning and re-aluminizing the mirrors.

The observatory is also equipped with an aluminization unit for the re-coating of the mirrors. The basement of the telescope dome building hosts all the necessary equipment for the re-aluminization of the mirrors of the telescope. It is worth mentioning that this facility (which is unique in Greece) is also used for re-aluminization of smaller mirrors of other smaller telescopes throughout Greece (especially telescopes that belong to Universities).

3.3 ACCESS

An asphalt paved road leads all the way to the telescope site (altitude of 930 m
above sea level). This road is kept open all year round (even in snow conditions).

3.4 COMPUTER CENTER

Kryoneri Observatory is equipped with two PCs, which are used to operate the CCD camera and to provide supporting software for the telescope.

3.5 COMMUNICATION NETWORK

A telephone line connected to the public telecommunication network operates at the observatory providing a low speed ADSL internet connection.

More information on Kryoneri Observatory is available at the following website:

http://www.astro.noa.gr/ASK_1.2m/ask_main.htm

4. RESEARCH PROJECTS

4.1 SOLAR AND HELIOSPHERIC PLASMA PHYSICS

At the I.A.A. the sources and the acceleration processes of Solar Energetic Particles (SEPs) to very high energies during solar eruptions are investigated, which are directly related to the topic of Space Weather. With international collaborations data analysis of SEP measurements by the STEREO, ACE, Ulysses, WIND and SOHO spacecraft of ESA and NASA is carried out, as well as their association with electromagnetic emission from the Sun. The high energy SEPs reach the Earth in less than one hour after the eruption on the Sun and can penetrate the walls of spacecraft and satellites, thus destroying their electronics. They can also penetrate astronaut uniforms causing damage in the astronauts’ DNA. The forecasting of SEP events in the framework of Space Weather is of very high importance.

With international collaborations, the study of the so-called ‘particle reservoir’ phenomenon is implemented at the I.A.A., as well as the study of the effect of the large-scale structure of the Interplanetary Magnetic Field (IMF) on the intensity profiles of SEPs. Comparisons of the intensities, the spectra and the composition signatures of SEP events are made, with simultaneous analysis of data collected in completely different regions in the 3-dimensional Heliosphere. Analysis of the intensities and the angular distributions of SEPs is carried out with the aim to find magnetic reflectors in space and to investigate their effect on the SEP events as well as the radiation hazards involved. At the I.A.A. (a leading member of an International Academy of Aeronautics Working Group) the effect of solar eruptions on the Martian environment and on astronauts of future manned space missions is studied. The I.A.A. strongly participates in the implementation of a European Space Weather Alert System.

1 A list of publications in refereed journals by members of I.A.A., during the period 2001 – 2011, is presented in Section 7, page 31.
These studies are implemented in the framework of the FP7 research projects ‘SEPServer’ and ‘COMESEP’, in which the I.A.A. participates as a Principal Investigator. The I.A.A. also participates as a Science Co-Investigator of the Energetic Particle Detector (EPD) of the future mission SOLAR ORBITER of ESA (to be launched in 2017) which, in synergy with Solar Probe Plus (NASA), will lead to enormous progress in space weather forecasting.

4.2 PHYSICS OF THE INTERSTELLAR MEDIUM

Important research is conducted by researchers at the I.A.A., who study the properties of matter in the interstellar medium within galaxies (gas and dust) in various evolutionary stages (from the “birth” to “death” of stars and the subsequent formation of new stars). The I.A.A. hosts one of the most internationally active groups in the detection and study of supernova remnants in our Galaxy and in nearby galaxies.

It is known that the stars "die" through violent, or not, explosions depending on their mass and result in the ejection of material into the interstellar medium, the majority of which moves at supersonic velocities.

This ejected material creates shells of gas, which depending on the initial mass and evolution can be supernova remnants or planetary nebulae.

Nebulae are also created around other objects such as Luminous Blue Variable Stars because of their instability and continuing mass loss.

One of the goals of I.A.A. researchers is the detection and, subsequently, the kinematical and dynamical study of nebulae through images and spectroscopic observations. The latter, can provide information on their morphology, their expansion velocities, the mechanisms by which they were created, their distances, dimensions etc., which help the theoretical models to match as closely as possible what is actually happening to the nebulae and hence to the Galaxy.
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Mapping the region of the supernova remnant G 32.8-0.1 by the team from the Institute of Astronomy and Astrophysics. This observation was selected by the international refereed journal Astronomy & Astrophysics to appear on the cover of issue 3 of volume 499 (2009).

Furthermore, studies are also conducted on the population of supernova remnants in nearby galaxies, which are finding that the properties (e.g. temperature, brightness) of the population depend on their local environment and the formation rates of massive stars.

In addition, studies of the properties of dust in supernovae, supernova remnants and the surrounding medium are also conducted. The dust in galaxies is an important component determining the morphological characteristics and the rate of star formation, which is essential for understanding their evolution.

Another important research activity conducted by I.A.A. researchers is the calculation of basic physical parameters resulting from observations of planetary nebulae, which provide us important information about Galactic chemical evolution, stellar evolution and the enrichment of chemical elements in the interstellar medium. Through the determination of the chemical composition of planetary nebulae, conclusions are drawn about the composition of stars’ nuclei and the mass transfer to the outer layers. Moreover, the number of planetary nebulae and their masses determine the amount of material that enriches a galaxy.

The «Ring» planetary nebula observed by the «Aristarchos» telescope.

Each year I.A.A. researchers perform a significant number of observations at different telescopes around the world (using both ground-based and space telescopes), collecting the necessary information (data) to study all these aspects of the interstellar medium.

4.3 MASSIVE STARS

The study of massive stars is an active area of research at the I.A.A. The main scientific question researched is: what is the maximum mass of star that nature can create? Due to the complex instabilities that occur during the formation of massive stars, a theoretical estimation of the maximum mass is difficult. The widely accepted limit of 150 solar masses has recently been
challenged by observations of a star with an estimated mass of 300 solar masses.

Astronomers at the I.A.A. use a special technique of mass measurement with eclipsing binary stars. The goal is to detect and accurately measure massive stars in young, massive clusters, not only in our own Galaxy, but also in neighboring galaxies. The resulting precise measurements are essential for understanding the formation and evolution of massive stars. These stars end their lives in supernova explosions or gamma-ray bursts.

Furthermore, at the I.A.A. astronomers are studying the properties of massive stars in the infrared. With the launch of the Spitzer satellite, which operates at infrared wavelengths, it is now possible to systematically study hundreds of massive stars in several nearby galaxies in environments with varying metallicity. Infrared radiation is emitted by massive stars exhibiting hot or cold dust. The detection of massive stars in the infrared therefore reveals the presence of dust. Studying the dust around such stars is very important for understanding how they evolve. I.A.A. astronomers are investigating these properties, as well as the nebulae that are formed to understand the mechanisms of mass loss and enrichment of the interstellar medium.

During the last five years astronomers at the I.A.A. have been involved in asteroseismology, conducting studies of the way some types of stars, generally old and massive stars, pulsate, as well as inferring the physical conditions in the inner parts of these stars, which produce such pulsations. These studies are based on observations made with telescopes in Greece and in South Africa.

### 4.4 STELLAR SYSTEMS AND GALAXIES

The investigation of stellar populations and stellar systems in nearby galaxies, the classification of distant galaxies, the estimation of their astrophysical parameters, and the study of the distribution of particular galaxy types contribute to (a) the exploration of star formation, an important factor for our understanding of their evolution, and (b) for studying the visible and dark matter in the Universe. Researchers at the I.A.A. have extensive knowledge of astronomical data and image processing.
as well as Artificial Intelligence analysis systems, techniques that are necessary for such studies.

The galaxy NGC 6822 and its stellar complexes (red contours). The grey-scale reveals the number density of the young stars.

Using observations of stellar clusters in the LMC and SMC obtained with the Hubble Space Telescope, as well as for the galaxy NGC 6822, I.A.A. researchers have found evidence for hierarchical star formation, in terms of their spatial distribution and time evolution, and for a past interaction with another galaxy.

Researchers at the I.A.A. are also involved in the construction of catalogues of visual double stars. Such stellar systems were formed simultaneously, in the same region of the Galaxy, and from the same material. Studying such systems helps to check and improve the relevant evolutionary theories for both the stars and the galaxies.

I.A.A. researchers are active members of the Data Processing and analysis Consortium (2006-2020) formed for the preparation and implementation of the ground-based scientific pipeline for the ESA/Gaia mission. Researchers of the I.A.A. are developing a model of the stellar content distribution in the LMC and the SMC galaxies aiming at producing libraries of synthetic and semi-empirical spectra of galaxies. The I.A.A. participates in the GREAT-project, Gaia Research for European Astronomy Training (2010-2015), a pan European science driven research infrastructure which will facilitate, through focused interaction on a European scale, the fullest exploitation of the ESA Gaia 'cornerstone' astronomy mission. Finally, I.A.A. researchers are developing special software for computing the physical parameters of extended objects (e.g. galaxies). This software produces images of extended objects simulating the real images that Gaia will observe and detect.

4.5 INFRARED ASTRONOMY

Infrared Astronomy is one of the most important fields of modern astronomy. The rapid technological evolution has allowed for the development of special instruments that can detect radiation coming from the coldest astronomical objects emitting in the infrared. The recently launched Herschel Space Telescope, built by the European Space Agency (ESA), is a typical example of the importance of this field of astronomy.
Astronomers at the I.A.A. are actively involved both in scientific astronomical projects as well as in space technology related to infrared astronomy.

By observing at infrared wavelengths, astronomers can detect emission from very cold objects, such as interstellar dust, which is found in large amounts in galaxies. Furthermore, astronomers can “see” through the dust and detect other objects that are obscured at other wavelengths (e.g. optical wavelengths).

Researchers at the I.A.A. also study the morphology of galaxies. Using observations at optical and infrared wavelengths, along with a three dimensional radiation transfer model, researchers study the dust properties within galaxies, and compute the total dust masses as well as relative distribution of the dust with respect to the stars. Furthermore, spectroscopic observations at infrared wavelengths reveal atoms and molecules (such as the water molecule).

Detection of very warm dust reveals an intense radiation field, able to heat the dust grains to high temperatures. This property is used for the detection of Active Galactic Nuclei in the very centers of the galaxies which are hidden in other wavelengths. Researchers at the I.A.A. conduct such studies by combining multiwavelength observations (e.g. at infrared, X-ray and optical wavelengths).

The interstellar medium, which consists mainly of dust grains, hydrogen atoms and molecules, is in continuous interaction with its progenitors, the stars. This material is ejected into interstellar space via violent explosions of supernovae. It is this material that will, eventually, give birth to new stars through gravitational collapse processes. Astronomers at the I.A.A. study the remnants left by such supernova explosions to derive useful information.
about the evolution cycle of the stars (from their birth to their death).

I.A.A. researchers have also been actively involved in the calibration of HIFI, a spectrometer aboard the Herschel Space Telescope, the fourth cornerstone mission of the European Space Agency. HIFI was designed and manufactured by a large consortium of institutions with the PI institution being the Netherlands Institute for Space Research (SRON). With Greece becoming a full member of ESA (beginning of 2005) the involvement in this mission was very timely. The I.A.A. of the National Observatory of Athens became a member of the HIFI Instrument Control Center (ICC) with important contributions to the calibration and testing of this instrument.

4.6 X-RAY ASTRONOMY

X-ray astronomy is one the largest components of the research program of the I.A.A. X-ray photons are emitted as material is accreted onto compact objects such as neutron stars and black holes. X-ray observations therefore probe the most violent and energetic events in the Universe, such as the creation of black holes. Research at the I.A.A. focuses on the study of Active Galactic Nuclei. These objects signpost supermassive black holes, with masses as high as 1 billion solar, at the centres of galaxies, which grow their mass by sucking material from the interstellar medium. During this process the amount of energy that is emitted is huge and can easily exceed the energy output of all the stars of the galaxy.

For the study of Active Galactic Nuclei, astronomers of the I.A.A. routinely use the largest space and ground based telescopes and are also involved in large multinational research programs. Over the years, the I.A.A. has developed specific expertise in the analysis of X-ray data, such as novel routines for the reduction of observations from the ESA's XMM and NASA's Chandra X-ray telescopes.

One of the key questions in the study of Active Galactic Nuclei relates to the physical mechanism that triggers the accretion of material onto the supermassive black hole. One of the popular scenarios is that major galaxy mergers drive large quantities of gas to the nuclear galaxy regions where it is consumed by the black hole. Recent work by astronomers of the I.A.A. questioned this suggestion and showed that other mechanisms, such as secular evolution, are also in operation. The morphology of galaxies that host Active Galactic Nuclei is inconsistent with mergers as the only channel that triggers accretion onto the central compact monster in galaxies.
The deepest X-ray observation acquired with the XMM-Newton Observatory of the European Space Agency. I.A.A. researchers participate in the international research group that studies this dataset aiming at defining the fraction of the obscured Active Galactic Nuclei in the Universe.

The population of Active Galactic Nuclei changes with cosmic time. They are rare today but were much more abundant in the early Universe. What causes the observed decline of the number of Active Galactic Nuclei with time is still not well understood. Astronomers at the I.A.A. are involved in a number of research projects which combine observations at different parts of the electromagnetic spectrum (X-ray, optical, infrared, radio) to address this issue.

The huge energy output of Active Galactic Nuclei is suggested to have a strong impact on the evolution of their host galaxies. Astronomers of the I.A.A. recently found evidence that Active Galactic Nuclei quench the formation of new stars in galaxies, thereby regulating the growth of the stellar population of their hosts.

Mapping Active Galactic Nuclei in the Universe is a major challenge of current astrophysical research with implications on all the research areas outlined above. We now know that a substantial, although not well defined, population of active black holes is hiding behind clouds of gas and dust, which block the direct light emission of the central engine, thereby rendering their detection challenging. Astronomers of the I.A.A. have developed novel data analysis methods to place constraints on the fraction of obscured Active Galactic Nuclei in the Universe.

4.7 COSMOLOGY

Important cosmological studies are currently conducted at the I.A.A. These studies touch on the structure and evolution of the Universe as a whole, as well as its substructures.

The Universe is mainly formed out of three components interacting with each other forming the very complex cosmic structures that we observe, i.e. stars, galaxies, clusters of galaxies, black holes, quasars, pulsars, etc. These three components are: (a) the well known “luminous” matter (made up of protons, neutrons, electrons, neutrinos etc.), (b) the so called “dark” matter, which is basically a form of matter that does not show any electromagnetic signatures (it is thus invisible) and is about eight times more compared to the first component mentioned above, and (c) the so called “dark energy” which is the most dominant component, making up about 70% of the total amount of energy and matter in the Universe.

The research at the I.A.A. is mostly focused on the precise measurement of the contribution of the different components to the cosmic fluid, as well as the possible cosmic evolution of the “dark” energy using a variety of methods (Type Ia supernovae, cosmic microwave background radiation, etc), some of which have been proposed by I.A.A. astronomers, like, for example, the use of Active Galactic Nuclei with intense star formation activity as tracers of cosmological parameters.
Researchers at the I.A.A. are also active in studies of the structure, the dynamics and the cosmic evolution of the large scale structure of the Universe and its cosmic substructures. In particular, studies are conducted for the largest cosmic structures that are close to dynamical equilibrium, like, for example, groups and clusters of galaxies as well as the dark matter halos they are embedded in. These studies include:

- analysis of spectral observations – optical, infrared, and X-ray – in order to get a better understanding of the physical processes that are taking place in the interior of these cosmic structures as well as in their vicinity,
- the study of various predictions of cosmological theories for the amount and the masses of the dark halos embedded in groups and clusters of galaxies, using analytical solutions of the Press-Schecther formalism, and
- the use of numerical cosmological and fluid-dynamical N-body simulations, for the study of the effects of the non-linear parts of the gravity in the morphology and the dynamics of these cosmic structures as well as their interaction, which is believed to drastically affect their evolution.

![Projection of the distribution of the dark matter halo in a Cosmological simulation of the Universe at its current age (left panel) as well as when the Universe was half its current age (right panel). It is obvious that the evolution of cosmic structure is dramatically different. This simulation was conducted in collaboration with IATE research center in Cordoba, Argentina. The simulated cosmic scale is 1.6 billion light years. The size of the symbols is proportional to the mass of the dark matter haloes with the largest ones simulating the largest galaxy clusters and the smallest ones the groups of galaxies.](image)

5. Visitor Center

The Visitor Center (VC) of the Institute of Astronomy and Astrophysics was established in 1995 at the Penteli Observatory, with the financial support of the General Secretariat of Research and Technology.

The VC employs all the astronomical instrumentation existing at Penteli. The main facilities and instruments are described below.

![The Visitor Center (VC) of the Institute of Astronomy and Astrophysics.](image)
1891 it was donated to Cambridge Observatory and subsequently to the Athens Observatory in 1957. The telescope was the main astronomical instrument for Greek astronomy until 1975. After that it was occasionally used for astronomical observations until the mid-1980ies. The telescope and its building were restored in 1995, to be used by the VC for educational and public outreach purposes. The ground floor of the telescope was transformed into a lecture hall equipped with modern audio and video equipment, which can accommodate 120 visitors.

Occasionally, during special events, the VC uses the old 16-inch Gautier refractor (D. Doridis telescope) and the 6-inch meridian telescope (A. Sygros transit instrument) located on the central premises of the National Observatory of Athens at Thissio.

Furthermore, the VC uses for public viewing and educational purposes a 14 inch (35 cm) Schmidt-Cassegrain telescope, located in a nearby building under a 3.4 meter dome, and a Razdow solar telescope.

The major activities of the VC include:

(a) Regular tours of high school students and elementary school pupils during the academic year. The 2 hour tour includes a lecture about the
scientific method, the contribution of science to society and the activities of the National Observatory of Athens, followed by a 25 minute educational video, and of course visits to the telescopes.

(b) Night tours for the public. The VC hosts scheduled group tours and public nights on approximately 80 nights each year. The program is similar to that of the schools, at a more advanced level, and the visitors are given the opportunity to observe several astronomical objects through the telescopes.

(c) Special events driven by various astronomical phenomena, in coordination with the Amateur Astronomers. Some examples are the “Poetry and Astronomy” event in 2002, as well as special outreach events during the International Year of Astronomy (IYA2009).

(d) Seminars given by the Amateur Astronomers (usually once per month).

(e) Furthermore, the head of the VC gives at least 15-20 lectures each year all over the country at schools, cultural societies and municipal cultural centers.

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The VC regularly appears in the mass media providing explanations and information about contemporary astronomical issues. The VC has had more than 160,000 visitors in the 16 years of its operation.

In the framework of public outreach, researchers at the I.A.A. also participate in the following activities:

- Computation and publication of the annual astronomical ephemeris.
- Provision of astronomical information to public and private services, the mass media and the general public.
- Organization, on an annual basis, of the Summer School of Astronomy for high school students.
- Organization of Summer Schools of Advanced Astronomy for MSc and PhD students.

More information on the I.A.A. of the National Observatory of Athens is available at the following website:

http://www.astro.noa.gr
6A. Observations From The “Aristarchos” Telescope (2010)

The Crab Nebula (M1 or NGC 1952) is a supernova remnant in the constellation of Taurus located 6500 light years away. Its projected size on the sky is 6×4 minutes of arc (11.3 light years). The mass of the exploded material is estimated to be about 4.6 solar masses and is expanding with a velocity of about 1500 km/sec around the central star (a pulsar). This image is a composition of observations obtained with the “Aristarchos” telescope in the B, V, and Hα filters (300 seconds each).

NGC1999 is a reflection nebula in the constellation of Orion, which shines from the light of the variable star V380 Orionis. It is located about 1500 light years away and has a radius of 1.5 minutes of arc (0.3 light years). A foreground patchy dark nebula, made of interstellar dust and gas, is responsible for the appearance of this nebula. This image is a composition of observations obtained with the “Aristarchos” telescope in the B, V, and Hα filters (300, 480 and 900 seconds respectively).

The Ring Nebula (M57 or NGC 6720) is a planetary nebula in the constellation of Lyra and is one of the most famous planetary nebulae. It is located 2300 light years away and its radius is 1.8 minutes of arc (about 1.3 light years). It expands with a speed of 0.01 light years per century (about 20 to 30 km/sec). The central star is a 0.6 solar mass white dwarf of surface temperature of about 100000° K. This image is a composition of observations obtained with the “Aristarchos” telescope in the B, V, and Hα filters (of 600, 480 and 600 seconds respectively).

In this representation of the Ring Nebula, the same image is shown as above, but here the light levels have been stretched so that the faint halo surrounding it becomes visible. The image characteristics (filters and exposure times) are the same as above.
Little Dumbbell Nebula (M76, NGC650/651), is a bipolar planetary nebula in the constellation of Perseus. It is located about 2500 light years away and its projected size on the sky is 2.7×1.8 minutes of arc (mean diameter of 1.6 light years) expanding with a rate of 19 km/sec. This image is a composition of observations obtained with the “Aristarchos” telescope in the B, V and R filters (of 300, 240 and 180 seconds respectively). This representation was chosen to emphasize the halo around it.

NGC6804 is a planetary nebula in the constellation of Aquila. It is located about 4200 light years away and its projected size on the sky is 62×49 seconds of arc (about 0.6×0.5 light years). This image is a composition of observations obtained with the “Aristarchos” telescope in the B, V and Hα filters (of 600, 480 and 600 seconds respectively).

The Butterfly Nebula (NGC2346) is a bipolar planetary nebula in the constellation of Ophiuchus. It is located 2000 light years away and its projected size on the sky is about 1×0.7 minutes of arc (mean size 0.5 light years). The center of the planetary nebula hosts a double star with orbiting period of 16 days. This image is a composition of observations obtained with the “Aristarchos” telescope in the B, V and R filters (of 600, 480 and 300 seconds respectively).
The **Eskimo Nebula** (NGC2392) is a double-shell planetary nebula in the constellation of Gemini. It is located 2900 light years away and its projected size on the sky is 48 seconds of arc (0.7 light years). The morphology of this planetary nebula is mainly due to the very strong winds (with velocities of about 1.5 million km/h) coming from the central star. This image is a composition of observations obtained with the “Aristarchos” telescope in the B, V and R filters (of 300, 60 and 60 seconds respectively).

NGC7094 is a faint planetary nebula in the constellation of Pegasus. It is located 7200 light years away and its projected size on the sky is 1.6 minutes of arc (3.4 light years). Its center hosts a white dwarf of surface temperature of 120,000°K, with stellar winds that can reach velocities up to 3900 km/sec, while it expands with a rate of 87 km/sec. This image is a composition of observations obtained with the “Aristarchos” telescope in the B, V and R filters (600 seconds each).

The **Owl Nebula** (NGC3587, M97) is a planetary nebula in the constellation of Ursa Major. It is located 2600 light years away and its projected size on the sky is 3.4 minutes of arc (3 light years). Its mass is 0.15 solar masses and it was created 6000 years ago. This image is a composition of observations obtained with the “Aristarchos” telescope in the B, V and R filters (of 600, 420 and 420 seconds respectively).

NGC2655 is a spiral galaxy in the constellation of Camelopardalis. It is located 80 million light years away and its projected diameter on the sky is 4.9×4.1 minutes of arc (projected size of 110 thousand light years) while its radial velocity is 1400 km/sec. This image is a composition of observations obtained with the “Aristarchos” telescope in the B, V and R filters (of 900, 600 and 480 seconds respectively).
Helix Galaxy (NGC2685) is a barred spiral galaxy in the constellation of Ursa Major. It is located about 51.2 million years away and its projected size on the sky is 4.5×2.3 minutes of arc, (projected diameter of 67 thousand light years) while its radial velocity is about 885 km/sec. This image is a composition of observations obtained with the "Aristarchos" telescope in the B, V and R filters (of 300, 240 and 300 seconds respectively).

Tiger’s eye Galaxy (NGC2841) is a spiral galaxy in the constellation of Ursa Major. It is located 58.1 million light years away and its projected size on the sky is 8.1×3.5 minutes of arc, (projected diameter of 137 thousand light years) while its radial velocity is 638 km/sec. This image is a composition of observations from the "Aristarchos" telescope in the B, V and R filters (600 seconds each).

NGC7331 (also known as Caldwell 30) is a spiral galaxy in the constellation of Pegasus (often referred to as “the Milky-Way’s twin”). It is located 46.3 million light years away and its projected size on the sky is 10.5×3.7 minutes of arc, while its radial velocity is 816 km/sec. This image is a composition of observations obtained with the "Aristarchos" telescope in the B, V and R filters (of 300, 240 and 180 seconds respectively).

NGC7814 (also known as “the little sombrero”), is a spiral galaxy in the constellation of Pegasus. It is located 56 million light years away and its projected size is 5.5×2.3 minutes of arc, (90 x 37 thousand light years), while its radial velocity reaches up to 1050 km/sec. This image is a composition of observations obtained with the "Aristarchos" telescope in the B, V and I filters (600 seconds each).
NGC7479 is a barred spiral galaxy in the constellation of Pegasus. It is located 110 million light years away with a diameter of 131 thousand light years (projected size on the sky $4.1 \times 3.1$ minutes of arc), while its radial velocity is 2381 km/sec. This image is a composition of observations obtained with the “Aristarchos” telescope in the B, V and I filters (600 seconds each).

NGC2544 is a ring-like spiral galaxy in the constellation of Camelopardalis. It is a starburst galaxy (with intensive star formation). It is located 132 million light years away with a diameter of 42 thousand light years (projected size on the sky of 1.1 minutes of arc), while its radial velocity is 2,828 km/sec. CGCG331-073 (upper left) is an Sb spiral galaxy located at a distance of 165 million light years with a diameter of 40 thousand light years and a radial velocity of 3,590 km/sec. This image is a composition of observations obtained with the “Aristarchos” telescope in the B, V and R filters (of 500, 300 and 240 seconds respectively).

Stephan’s Quintet is a group of five galaxies in the constellation of Pegasus. The galaxies shown here are NGC7317 (lower right), NGC7318a and NGC7318b (middle), NGC7319 (upper left) and NGC7320 (lower left). The first four galaxies are in distances between 267 and 311 million light years with diameters of 100 to 150 thousand light years and radial velocities ranging between 5,750 and 6,750 km/sec. The fifth galaxy (NGC7320) is not a physical member of the group and it is located at a distance of 52 million light years with a radial velocity of 790 km/sec. This image is a composition of observations obtained with the “Aristarchos” telescope in the filters B, V and I (600 seconds each).

NGC7006 is a stellar globular cluster in the constellation of Delphinus. It is located 160 thousand light years away with a projected diameter on the sky of 3.6 minutes of arc (167 light years). This image is a composition of observations obtained with the “Aristarchos” telescope in the B, V and I filters (300 seconds each).
A snapshot of comet C/2009 K5 McNaught taken on October the 30th 2010 while crossing the constellation of Lynx. Its distance from Earth was 2.3 astronomical units at that time (345 million km) while it was 2.8 astronomical units (420 million km) from the Sun. It was located between the asteroid belt and Jupiter moving away from the Sun. This is a 900 second image, in the B filter, obtained with the "Aristarchos" telescope tracking along the comet’s path (which explains the trails of the stars).

**Jupiter** is the largest planet of our solar system. It is a gaseous planet (composed mainly of hydrogen) with an orbiting period around the Sun of 12 years and a rotating period of 10 hours around its axis. This rapid rotation explains the different zones in its surface (due to the differential rotation of the atmospheric layers). Its mass is 2.5 times larger than the mass of the rest of the planets and its radius is 71,000 km (about 10 times more than that of Earth’s). It is located 750 million km away from the Sun (5 times the distance between Earth and Sun) resulting in very low surface temperatures (around -141 °C). The “Great Red Spot” of Jupiter is also evident in this picture, shown as a large hurricane, known for the last 300 years, while Ganymede (the largest among its 12 moons) can be seen on the left (close to the equator of Jupiter). This image is a composition of observations from the “Aristarchos” telescope in the U and I filters (0.1 seconds each).

The spectrum of the planetary nebula M27 (Dumbbell Nebula). This spectrum shows the “signatures” of various chemical elements in terms of emission lines (e.g., for hydrogen, oxygen, helium, sulfur and nitrogen). From these kinds of observations astronomers can derive important information on the chemical composition and on the physical conditions for this planetary nebula. This observation was obtained with the ATS spectrometer installed on the “Aristarchos” telescope. The wavelength range is 4270 – 7730 Å while its resolution is 6 Å.

Spectrum from the planetary nebula M27 (Dumbbell Nebula). This observation was obtained with the ATS spectrometer installed on the “Aristarchos” telescope, like the one above, but with a different setup allowing for a better resolution (2.5 Å) while the wavelength range is now 4400 – 5780 Å.
6B. OBSERVATIONS FROM THE "ARISTARCHOS" TELESCOPE (2011)

The Ring Nebula (M57 or NGC6720) is a planetary nebula in the constellation of Lyra and is one of the most famous planetary nebulae. It is located 2300 light years away and its radius is 1.8 minutes of arc (about 1.3 light years). It expands with a speed of 0.01 light years per century (about 20 to 30 km/sec). The central star is a 0.6 solar mass white dwarf of surface temperature of about 100000° K. This image is a composition of observations obtained with the "Aristarchos" telescope in the B, V, R, Hα+[NII] and [OIII] filters (of 3900, 2850, 2400 and 3120 seconds respectively).

NGC6951 is an SAB(rs)cd spiral galaxy in the constellations of Cepheus. It is located 74.5 million light years away and its projected size on the sky is 3.9×9.32 minutes of arc (a radius of 15.9 thousand light years), while its radial velocity is 1424 km/sec. This image is a composition of observations obtained with the "Aristarchos" telescope in the B, V, R, Hα+[NII] and [OIII] filters (of 270, 300, 270, 900 and 30 seconds respectively).

NGC7331 (also known as Caldwell 30) is a spiral galaxy in the constellation of Pegasus (often referred to as “the Milky-Way’s twin”). It is located 46.3 million light years away and its projected size on the sky is 11.5×9.8 minutes of arc (a radius of 16.3 thousand light years), while its radial velocity is 816 km/sec. This image is a composition of observations obtained with the "Aristarchos" telescope in the B, V, R, Hα+[NII] and Clear filters (of 270, 300, 270, 900 and 30 seconds respectively).

NGC6946 (also known as Caldwell 12 or the Fireworks galaxy) is an SAB(rs)cd spiral galaxy between the constellations of Cepheus and Cygnus. It is located 22.5 million years away and its projected size on the sky is 11.5×9.8 minutes of arc (a radius of 16.3 thousand light years), while its radial velocity is 40 km/sec. This image is a composition of observations obtained with the "Aristarchos" telescope in the B, V, R, Hα+[NII] and Clear filters (of 570, 570, 570, 900 and 90 seconds respectively).
NGC7635 (also known as the Bubble Nebula) is an emission nebula in the constellations of Cassiopeia. It is located 7100 light years away and its projected size on the sky is 15×8 minutes of arc (a radius of 3 thousand light years). The nebula is near a giant molecular cloud which contains the expansion of the bubble nebula while itself being excited by the hot central star (SAO 20575), causing it to glow. The star is thought to have a mass of 10-40 Solar masses. This image is a composition of observations obtained with the "Aristarchos" telescope in the B, V, R, Hα+[NII], Hβ, [OIII] and Clear filters (of 180, 210, 215, 750, 900, 930 and 10 seconds respectively).

NGC6543 (also known as the Cat's eye Nebula) is one of the most famous planetary nebulae in the constellation of Draco. It is located 3300 light years away and its projected size on the sky is 0.67 minutes of arc (a radius of 0.2 light years), while its expansion velocity is 15 km/sec. It is estimated that the nebula was formed about 1000 years ago. An O7-type star is located in the center of the planetary nebula with surface temperature of 80000° K and mass of 5 solar masses. This image is a composition of observations obtained with the "Aristarchos" telescope in the B, V, R, Hα+[NII] and [OIII] filters (of 165, 165, 155, 3180 and 2700 seconds respectively).

Helmos Observatory night sky with a thunderstorm (below right).

Transit of the exoplanet system HAT-P-23 taken with the "Aristarchos" telescope and the RISE2 instrument in August 2011. The total exposure time is 5 hours (1800 images of 10 sec exposure each).
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