

2023 ANNUAL REPORT

INSTITUTE OF ASTRONOMY, ASTROPHYSICS,
SPACE APPLICATIONS AND REMOTE SENSING

NATIONAL OBSERVATORY OF ATHENS



MISSION

The mission of IAASARS is to carry out state-of-the-art basic and applied research in ground-based and space-borne astrophysics, from distant galaxies to the solar neighborhood, as well as near-Earth space physics, remote sensing, earth observation and signal processing. In particular, the three main scientific disciplines represented by the Institute are: (i) Observational Astrophysics using both space and ground-based facilities, (ii) Solar-Terrestrial Environment - Space Physics, encompassing Solar and Heliospheric, Space and Ionospheric Physics, and (iii) Remote Sensing and Machine Learning for Signal/Image Processing.

Preface from IAASARS Director



The Institute for Astronomy, Astrophysics, Space Applications and Remote Sensing (IAASARS) is one of the three Institutes of the National Observatory of Athens (NOA) and the largest Institute in its field in Greece. The Institute operates a wide range of national facilities aiming to support research and services in the respective disciplines, including: (a) the Aristarchos 2.3m and Kryoneri 1.2m telescopes and corresponding instrumentation; (b) the European Digital Upper Atmosphere Server System - DIAS and the Athens Digisonde DPS4D station for monitoring the ionosphere; (c) the BEYOND operational unit maintaining satellite acquisition antennas and computational infrastructure; (d) The HESPERIA operational unit for forecasting space weather, (d) the remote IAASARS Evaluation Report 2022 sensing part of the PANGAEA climate observatory of Antikythera; (e) the Hellenic GeoMagnetic Array – ENIGMA.

Clearly the annual report shows the impressive scientific achievements of IAASARS teams, all enjoyed international recognition and have established international relationships and collaborations. In 2023, IAASARS researchers have published 118 articles in high-impact journals, receiving more than 9,000 citations, and attracted a total funding of ~8.2 M€ from competitive European and national research grants (HORIZON2020, ESA, Marie Curie, ELIDEK etc). The excellence of the Institute is further demonstrated by the three European Research Council (ERC) Grants that are currently running, the ASSESS project for the Astronomy & Astrophysics team and the other two, the ERC Consolidator Grant D-TECT and the ERC Proof of Concept project PM-Scanner, to the ReaCT team of the Remote Sensing Group. On top of that, three IAASARS researchers appeared in the Stanford's list of world's top 2% scientist, while the BEYOND scientific team was awarded one of the first prizes from EUSPA EU Agency in the framework of "myEUspace competition".

The coordination role for IAASARS on space science activities is also critical as it concerns its role as a national hub for the Space Agencies (ESA, EUMETSAT) and other relevant organizations and bodies within the European Union (GEO, WMO). Some highlights include the activity of IAASARS in the European Space Agency (ESA) Space Situational Awareness (SSA) program to improve the monitoring and understanding of potential Earth hazards by developing experimental methods and analysis techniques to study the impact of asteroids on the Moon. ESA has also singled out IAASARS to produce time-domain value-added products for the Hubble Space Telescope Archive, while the cosmology team participates in the LISA experiment.

Within this framework, the strategic partnership with ESA (MoU signed in September 2023) and thus the participation of IAASARS in the iconic ARTES/ScyLight and EuroQCI projects brought the Institute to the forefront of optical/quantum communications research by developing new synergies with Space Agencies and worldwide space companies. Specifically, as part of NASA's Psyche mission, IAASARS telescopes are the only ones chosen by ESA to participate in the flagship mission aiming to create a 300-million-kilometer-long communication "bridge" in space. Moreover, IAASARS is participating as a key partner in the Greek-French synergy (Hellas Sat/IAASARS and CNES/Thales Alenia) on the development of an optical communication payload for the upcoming new mission to be embarked on the future Hellas Sat 5 satellite. This innovative payload aims to connect with Optical Ground Station of the National Athens Observatory in Greece, Optical Ground Stations in France, Optical Ground Stations of ESA and

Thales Alenia Space's LEO HydRON telecommunication satellite. Concerning Kryoneri Observatory the plan of NOA administration is to transform it into a major Space Hub for Space Security and Earth Observation in Southern Europe. Space security refers to development of a European Space Situational Awareness (SSA) capability that will underpin the exploitation of European space assets, contributing to autonomous access to space for Europe. The SSA program will cover two major scientific segments: (a) Space Surveillance & Tracking (SST) and (b) Near Earth Objects (NEOs). Regarding the national GR-SST program, with the Operational Unit BEYOND being assigned the role of the National Operation Center for Greece, EU-SST partnership funding for the next programmatic period (up to 2027) will be used. This has been secured in the implementation of Space Regulation and HE TOPs Actions for SST (contracts signed in 09/2023) and also through additional competitive funds from the delivery of third-party SST services (e.g. satellite operators, ESA, etc.).

IAASARS offers critical information to the Greek State Authorities and the public, through the operation of its operational units for providing dedicated services on Natural Disasters, Climate Change and Space Weather. In particular, IAASARS is a key service provider to the Copernicus flagship Earth Observation program, by delivering a portfolio of standardized products tailored to disaster risk reduction and mitigation, land use/ land cover and marine applications.

Another flagship initiative of NOA is the establishment of the "PANhellenic GEophysical observatory of Antikythera (PANGEA)". Starting from 2018, IAASARS via the ReACT team put a tremendous effort to establish, operate and maintain the Remote Sensing Facility of NOA's PANGEA Climate Observatory at the island of Antikythera. Finally, the Institute is providing continuously and in real-time, innovative standardized and validated services to the ESA SSA Program for the Space Weather System of Federated Services, through the European Ionosonde Service that is supported from the DIAS system.

Last but not least, in 2023 IAASARS operated two visitor centers. The first in Penteli and the second at the heart of Athens, in Thiseion. All visitor centers are open on a daily basis, in order to, facilitate educational visits from school, while each center opens about three times per week accommodating visits of the public combined with observations of the night sky with our historical telescopes. Indicative numbers that highlight the Educational & Public Outreach service provided by IAASARS this year, are the ~28.000 visitors among which ~12.000 students from 290 schools that visited our telescopes at both Penteli and Thiseio.

Finally, I'd like to thank the Scientific Council and the entire personnel of IAASARS for their intense efforts in order to growth all aspects of the Institute. I'd also like to express my appreciation to the editorial board of this annual report (Drs. Saridakis Manos, Sykioti Olga, Tziotziou Kostas, and Xilouris Manolis) for their careful editing and proofreading as well as Dr Papaioannou Thanasis for collecting all the relevant metrics presented here.

Dr. Spyros Basilakos
IAASARS Director and
Vice President of NOA

ABOUT US

The Institute for Astronomy, Astrophysics, Space Applications and Remote Sensing (IAASARS) is one of the three institutes of the National Observatory of Athens (NOA). It obtained its current structure in 2012, after the merging of two Institutes: the Institute of Astronomy and Astrophysics, which carried on the tradition of optical astronomy in Greece since the establishment of the Observatory of Athens in 1842, and the Institute for Space Applications and Remote Sensing, which evolved from the old Ionospheric Institute, founded in 1955. A short description of the three active groups of the Institute follows:

☐ **ASTRONOMY – ASTROPHYSICS Group**

The Astronomy-Astrophysics group focuses on four general thematic areas. The Ground-based Astrophysics team has expertise in ground-based observations with optical telescopes in both photometry and spectroscopy. They mainly address problems related to stars, their evolution, the complex interplay with the Interstellar Medium (ISM) as well as binary stars and the study of the morphology and evolution of nearby galaxies. The X-ray Astrophysics team has extensive experience in X-ray data analysis mainly from the XMM-Newton space observatory and from the Chandra X-ray observatory, focusing on problems related to AGN formation. The Infrared Astrophysics team has strong expertise in infrared data analysis and extragalactic astrophysics obtained with the Spitzer Space Telescope of NASA, and ESA's Herschel Space Observatory and Infrared Space Observatory. Finally, the Cosmology team's research activities focus on the fields of theoretical and observational cosmology and specifically in the study of the Universe as a whole, from its primordial to its late-time era.

☐ **SOLAR-TERRESTRIAL ENVIRONMENT – SPACE PHYSICS Group**

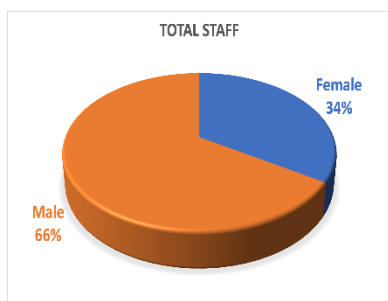
The Solar-Terrestrial Environment – Space Physics Group is composed of three thematic teams. The Solar and Heliospheric Physics team studies the Sun using observational data from satellites and/or ground-based observatories combined with theory and modeling and analyses Solar Energetic Particle (SEP) data and complementary plasma and magnetic field data collected by ESA and NASA spacecrafts to study the effects of eruptive solar events in the interplanetary space and the Earth's environment. The Space Research and Technology group specializes in studies of planetary and interplanetary plasmas, geomagnetism and space magnetism, and space weather prediction techniques for flaring and SEP activity. The main activities of the Ionospheric Group focus on the performance of systematic ionospheric monitoring and the development of ionospheric and trans-ionospheric nowcasting and prediction systems through the online implementation of advanced modeling techniques ingesting ground and space data from all geospace regions.

□ REMOTE SENSING – MACHINE LEARNING/SIGNAL PROCESSING Group

The research focus of the Remote Sensing and Machine Learning/Signal Processing group is Remote Sensing for physical parameter estimation including optical, atmospheric and thermal remote sensing, GNSS and InSAR, modeling based on EO products, Radiative Transfer Models, Signal and Image processing (e.g. Machine Learning, big data-information extraction) and Cal/Val research campaigns for validation and certification of new mission data and value-added products. Furthermore, a substantial effort is invested in applied research and production of new complex value-added products, concerning temporal mapping of the Earth, monitoring and changes in sensitive ecosystems and human environment as a result of climate change and economic activity, natural disaster management (forest fires, floods, earthquakes, volcanic activity, air pollution), monitoring the Urban Heat Island phenomena, geological mapping and mineral exploration.

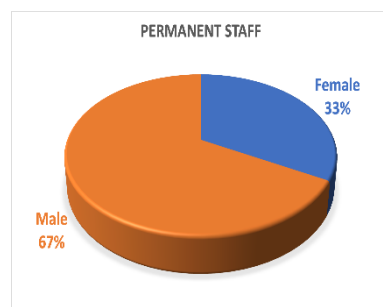
PERSONNEL AND ETHICS

Each discipline is supported by the scientific and technical staff that is responsible for boosting cutting-edge research as well as scientific and technological excellence. At the



end of 2023, the permanent staff of the institute consisted of the Director, 28 researchers, 1 secretary and 6 research support specialists. Moreover, 25 postdoctoral researchers, 25 PhD students, and 54 research and technical associates were on contract, making IAASARS the largest institute in its field in Greece. IAASARS, and NOA as a whole, is a research, working and educational environment that respects the constitutionally enshrined principle of gender equality and non-discrimination. It

seeks to promote and ensure substantive equality between women and men at all levels of operation and areas of activity, as well as to ensure that no discrimination appears in terms of race, religion, political views, or class origin. In line with EU objectives, directives, the broader EU strategy and the corresponding initiatives at national level, IAASARS and NOA, through a special Committee, are devoted to implementing targeted actions, tailored to its structures and needs, in order to address any disparities and inequalities, so that the gender and non-discrimination dimension shall become a key pillar within NOA in human resources management, as well as in the access and participation of the personnel in management and decision-making bodies.



IAASARS ORGANISATION STRUCTURE

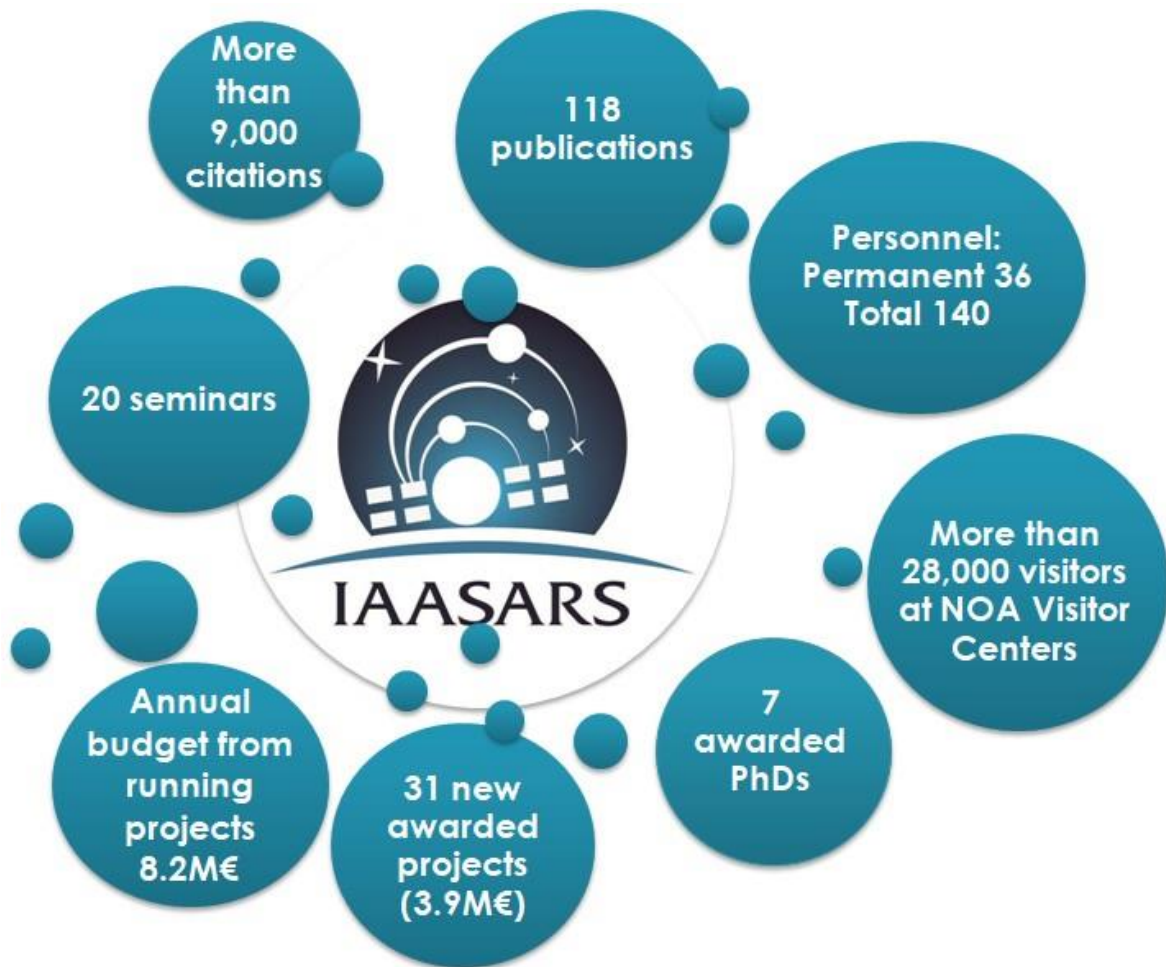
The institutional structure of IAASARS is based on well-defined roles and responsibilities ensuring organizational effectiveness and efficiency. The Director of IAASARS serves as the head of the Institute. He coordinates and oversees all the activities fulfilling the mission, strategic goals and commitments to the State and the scientific community. The Deputy Director is proposed by the Scientific Council (SC) and approved by the Board of Directors. He replaces the Director when not present at the Institute. The IAASARS secretariat is the contact point with internal (NOA's) and external institutions as well as with other bodies. An important component of IAASARS is the SC, which plays an auxiliary role concerning the scientific policy of the Institute. The SC, currently consisting of Drs G. Balasis (president), K.

Tziotziou (vice-president), O. Sykioti, E. Saridakis, and I. Georgantopoulos, serves as an advisory entity for decision-making and planning, having also the role of monitoring the overall progress toward achieving the Institute's vision and strategic goals. The members of the SC are elected by the researchers of the Institute every two years and consist of five (5) researchers of A' and B' Grade. The Chair is designated by the SC. The SC, in collaboration with the Director, addresses the present needs and defines the Institute's priorities from a short- and long-term perspective. The SC has regular meetings with the Director in order to fulfill its mission, while the SC Chair communicates the minutes of the meetings to the Institute. In order to ensure full transparency, awareness and communication of decision rationale at the Institute's level, regular plenary meetings are organized where all the members of IAASARS have the opportunity to be informed directly from the higher-level governance units as well as to express their opinion, concerns and potential solutions aiming at improving the overall performance of the Institute.

The names/photos of the IAASARS permanent staff are presented here below:



2023 IN NUMBERS



INFRASTRUCTURE

The Institute operates a wide range of national facilities aiming to support research and services in the respective disciplines.

The HELMOS Observatory



The 2.3 m “Aristarchos” telescope, the largest research infrastructure of NOA, is installed at Helmos Observatory (<https://helmos.astro.noa.gr/en/>).

Helmos Observatory is located at an altitude of 2340 m, approximately 220 km southwest of Athens, near the city of Kalavryta, in one of the darkest locations in Europe. The Aristarchos telescope (Ritchey-Chretien design) was manufactured by the Carl Zeiss GmbH and was inaugurated in summer 2007. It has a 2.3 m diameter aperture and a focal length of 17.8 m. The

telescope's positional accuracy is better than 4 arcseconds, while it can follow targets with a positional offset better than a fraction of an arcseconds within an hour. 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. A small optical/electronics laboratory, supporting activities for the maintenance of the telescope, is also available. In November 2009, the Helmos Observatory was connected to the National telecommunication network through fiber optics allowing for speeds up to 1 Gb/s for internet connection and data transfer.

Since 2016, the 2.3m Aristarchos telescope participates in the OPTICON (<https://www.astro-opticon.org/>) Trans-National Access program, making its instrumentation available to the international community. In March 2021, the optical and radio communities decided to come together in the Opticon Radionet Pilot (ORP) (<http://www.orp-h2020.eu/>) providing for the first time a coordinated and coherent plan for access to a set of optical/infrared and radio facilities, support and training for multi-wavelength astronomers, and



specific developments to improve the capabilities of facilities. In total, 23 nights have been awarded to observers, through OPTICON and ORP, for performing observations with the Aristarchos telescope.

Helmos Observatory (Aristarchos telescope) was selected in August 2020 to become the first ground station of the ScyLight (Secure and Laser communication technology https://www.esa.int/Applications/Connectivity_and_Secure_Communications/ScyLight) program of the European Space Agency (ESA). Since 2021, it has been equipped with a bistatic transmit/receive system conducting optical links with Alphasat. The large aperture of the telescope, combined with excellent atmospheric seeing conditions of the site, makes Aristarchos a valuable asset for optical communications and quantum key distribution (QKD) and especially suited for lunar, Lagrange orbit and deep space communications (DSOC). In 2025 DSOC links will be demonstrated with NASA's Psyche probe, while optical links with the ERMIS Hellenic Cubesat Demonstration Mission are expected to take place in early 2026. Furthermore, the telescope is being prepared for future space-based QKD experiments. An ESA contract (~1.8 M€) is already in place to support the upgrade of the control system of the Aristarchos telescope as well as the development of specialized instrumentation in order to perform optical communication and Quantum Key Distribution operations (compatible with ESA's EAGLE-1 mission).

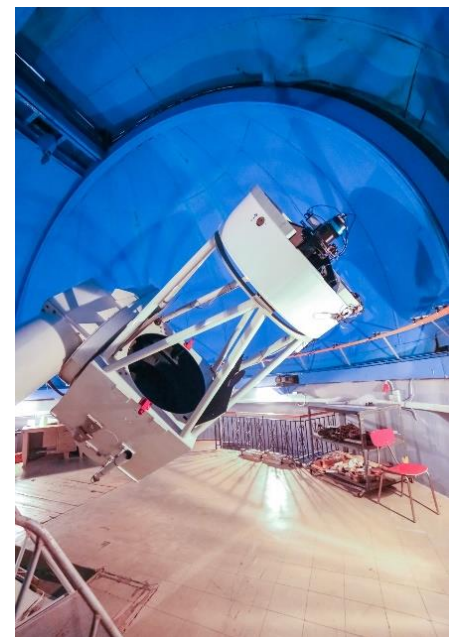
The Kryoneri Observatory



The Kryoneri Observatory (<https://kryoneri.astro.noa.gr/en/>) is situated 100 km west of Athens at an altitude of 930 m. The observatory hosts the 1.23 m telescope, built in 1975 by Grubb-Parsons Co. in Newcastle. In 2015, the 1.2 m Kryoneri telescope was selected (after a trade-off analysis) as the optimal facility of NOA for the ESA-funded NELIOTA project (<https://neliota.astro.noa.gr/>). The NELIOTA

science objectives imposed strict requirements on the optical design and therefore, in 2016, the telescope underwent an extensive upgrade by DFM Engineering Inc., within the NELIOTA project. Furthermore, and according to the requirement for lunar observations, the optics of the telescope were modified to operate with instruments at the prime focus, bringing the telescope back to its primary mirror f/3 focal ratio and providing an unvignetted field-of-view (FOV) of ~1.4 degrees. A twin imaging system, the Kryoneri Prime Focus Instrument (KPMI), designed and developed by DFM Engineering Inc., is now in use, sampling 17.0'x 14.4' of the total corrected FOV at the prime focus of the telescope, providing simultaneous high-cadence observations in two bands.

Since July 2023, the 1.2m Kryoneri telescope is a sensor in the EU-SST network contributing to the Cataloguing and the Collision Avoidance activities of the European Space





Surveillance & Tracking program with a dedication of 25% of its time. In parallel to the EU-SST, two Very Wide Field of View (VWFOV) for LEO Optical Triangulation Network sensors are also hosted at Kryoneri Observatory. In the framework of an MoU between POLSA (Polish Space Agency) and NOA, the IAASARS team operating

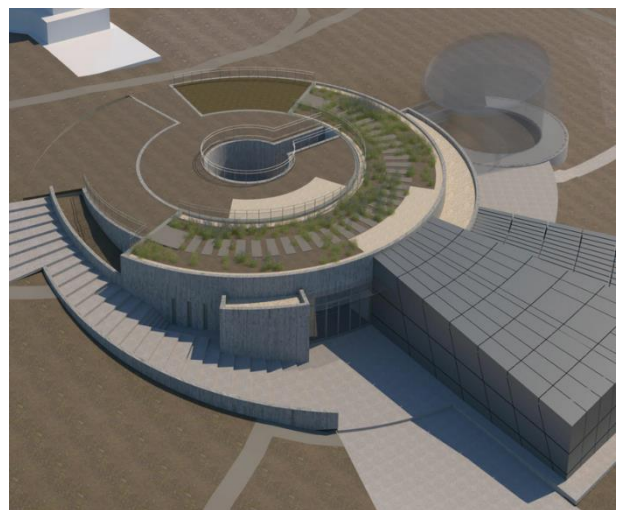
Kryoneri Observatory provides services and assists the operations of these specialized detector systems. These sensors have been developed by CILUM Engineering for observations of Low Earth Orbit objects using triangulation techniques. A network of five such stations (three in Poland and two in Greece) is currently in operation.



The Manchester-Athens Wide Field Camera (MAWFC; a joint project between the National Observatory of Athens and Jodrell Bank Centre for Astrophysics, UK) hosted at Kryoneri Observatory is a state-of-the-art, wide-field (~30 degree diameter), narrow-band, optical filter camera, which was the first scientific instrument for astronomy that was constructed and tested completely in Greece. The camera will conduct a large-area sky survey that will provide maps at

less than 1 arcmin resolution, in order to investigate the very extensive, but faint, line emission regions over the whole northern sky in the optical emission lines of Ha, [O III], H β , and [S II], from Kryoneri Observatory site. The successful outcome will have a significant impact on topical astronomical areas of research e.g. subtracting the foreground for the cosmic microwave background; estimating the electron temperature of the warm ionized gas by comparison with radio data; investigating the giant, high latitude, radio filaments from the Galactic center or very close objects in the Galactic plane of extreme angular extent; detecting the northern end of the LMC/SMC H I stream.

The current administration has developed a strategic collaboration with the local government of Peloponnese regarding the Kryoneri Observatory. Specifically, in May 2021 IAASARS was awarded a two-year funding of 362 k€ from the Operational Program for the Region of Peloponnese (under the NSRF/ESPA 2014-2020) in order to upgrade and use the infrastructures at Kryoneri Observatory for public outreach purposes. Overall the aim of the above activities is to transform Kryoneri Observatory into a public outreach center and to attract people interested in learning about the recent developments in science. Under this framework, people are able to visit the facilities at Kryoneri Observatory, familiarize with the operations of the 1.2-m telescope and its instrumentation, but, most importantly, interact with expert scientists and listen to dedicated public talks on various topics related to modern science.



On top of that in December 2021 a master plan was completed which will set the baseline for IAASARS to fulfill its strategic goal for the reconstruction of the Kryoneri astronomical station. This master plan is based on the transformation of the Kryoneri Observatory into a major Space Hub for Space Security and Earth Observation in Southern Europe. Space Security refers to development of a European Space Situational Awareness (SSA) capability that will underpin the exploitation of European space assets, contributing to autonomous access to space for Europe. The SSA programmes will cover two major scientific segments: (a) Space Surveillance & Tracking (SST) and (b) Near Earth Objects (NEOs). Our proposal has already been funded by the European Recovery fund (~10.8 M€) and by the local government of Peloponnese (~4.3 M€). Recently, Greece became a full partner in the EU-SST network with NOA coordinating the activities. Currently, IAASARS is upgrading its capabilities by building a small 0.7 m telescope with a large field-of-view. Its fast-tracking capability (more than 10 degrees per second) will make it a unique tool for the tracking of low-Earth orbit (LEO) missions. The tracking of these missions (mainly small telecom missions) presents great commercial potential.

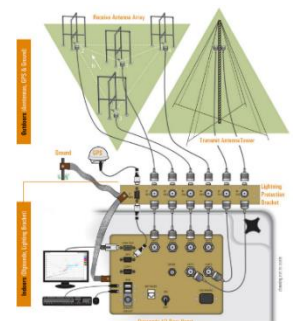
The PANGEA Observatory



PANGEA (PANhellenic GEophysical observatory of Antikythera) is an ambitious strategic goal of NOA to establish a sustainable climate observatory at the island of Antikythera (35.861N, 23.310E, 110m a. s.l.). The site has been selected by NOA and PANACEA due to its representativeness of the broader region of Eastern Mediterranean. The region is a crossroad of air masses transporting different aerosol types, significantly impacted by mineral dust from Africa, smoke from frequent regional forest fires, anthropogenic pollution from megacities and background sea-salt particles. NOA is currently implementing the PANGEA-ReACT facility at Antikythera, an instrumental suite that fulfills the optimum requirements of the ACTRIS RI, including POLLYXT-NOA 24/7 multi-wavelength lidar (fully operational at Antikythera), and a NASA-AERONET sunphotometer. Since 2023 the PANGEA-ReACT facility is included in the GAW stations network, while the measurements were used for the validation of the ESA Aeolus mission products.

Athens Digisonde (AT138)

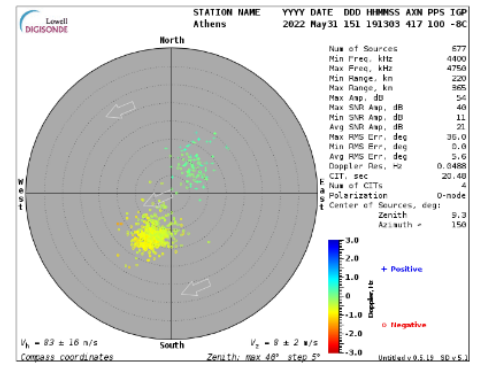
The Ionospheric Group operates the Athens Digisonde (URSI Code: AT138), a Digital Portable Sounder 4D (DPS4D) since 2000, with continuous upgrades regarding its hardware and software components. This scientific instrument operates in real-time and provides observed characteristics for research investigations and for the derivation of ionospheric specification data-products.



The Athens Digisonde operates in monostatic and bistatic mode and derives vertical ionograms, oblique ionograms, synchronized vertical sounding ionograms with other Digisonde stations, sky maps and oblique Digisonde-to-

Digisonde skymaps (<http://www.iono.noa.gr/athens-digisonde>).

The Athens Digisonde is the main contributing sounder to the European Ionosonde Service (EIS) and to the Travelling Ionospheric Disturbances Warning and Mitigation Service (TechTIDE) which are part of the Space Weather Network of the European Space Agency (ESA). Athens Digisonde data are exploited for the derivation of data products able to support High Frequency (HF) direction finding and communication systems, HF over the horizon radars, satellites orbiting at LEO and MEO heights, radio astronomy telescopes, and support the development of mitigation technologies and strategies against ionospheric disturbances and irregularities triggered by space weather events and lower atmosphere forcing.



Fireball monitoring cameras



In 2023, IAASARS joined the allsky7.net (<https://allsky7.net/>) network and obtained two camera systems for recording meteor, bolide, and fireball events. This network collects data from over 200 similar systems in Europe and aims to determine the appearance frequency of such events in the Earth's atmosphere. Simultaneous recording from two or more systems allows for an accurate determination of their velocity as well as their entry angle in Earth's

atmosphere, hence their trajectory. In cases of fireball events, that a small fraction of the projectiles potentially reaches the surface, the simultaneous recording allows for the determination of the impact location, hence, the discovery of new meteorites. Each system consists of eight cameras in total. Seven with a field-of-view of 45x80 degrees that cover the whole sky and one camera with a fisheye lens that covers all the sky at lower resolution. Each individual camera has a recording rate of 25 fps and can detect events with a brightness up to 4th magnitude. Each system has a pre-installed automated software for data reduction and analysis. The two camera systems were installed at NOA in Penteli (Attica) and at Kryoneri Observatory (Corinthia). These stations are the first of this network to be installed in South-East Europe and the systematic very good weather conditions at both sites allow the acquisition of large amounts of high-quality data.



Global Positioning System (GNSS) geodetic stations

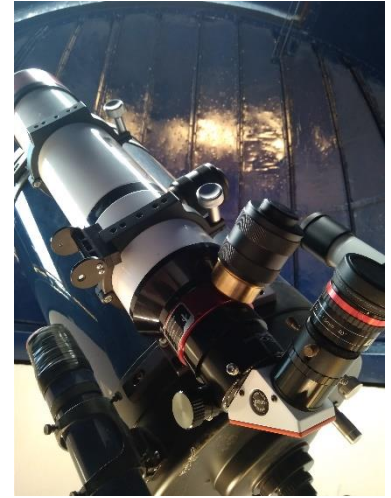


The two Global Navigation Satellite System (GNSS) geodetic receivers of NOA, installed in Penteli and Florina, support the observation of space weather by recording ionosphere fluctuations due to terrestrial natural disasters. They are also used to study the primary effects of natural and geological hazards on the Earth's crust, environment and troposphere, contributing to the characterization and modeling of their source. Finally, they are used collaboratively with remote sensing

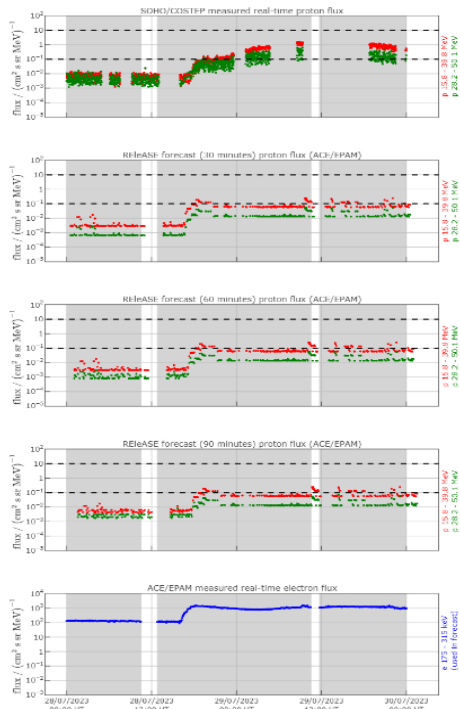
satellite data for calibration and validation of added-value products.

Solar Telescope

The solar telescope, which is placed in a permanent dome at the premises of the National Observatory of Athens in Penteli, was constructed by Lunt Solar Systems and has an objective lens diameter of 100 mm, a focal length of 800 mm. It is equipped with a cut-off filter of 1800 nm and a built-in H α filter with a spectral range less than 0.75 Å that becomes 0.5 Å with the use of an external double stack filter. Two different cameras are available for acquiring solar images, a CCD camera with a resolution of 1200x1600 pixels and a field of view (FOV) on the Sun of 30'x23' to capture partial images of the solar disc and a CMOS camera with a resolution of 2048x2048 pixels and a FOV of 57'x57', allowing to observe the entire solar disk with a resolution of approximately 1.6 arcsec. In addition, focal ratio reducers and Barlow lenses permit us to visualize parts of the solar disk and record specific active regions (ARs) of interest. Real-time processing of registered solar images results in high-quality images of the solar disk and ARs that are archived and presented through the website of the Center for Space Weather Monitoring and Forecasting (<http://spaceweather.space.noa.gr>).



The Space Weather Operational Unit



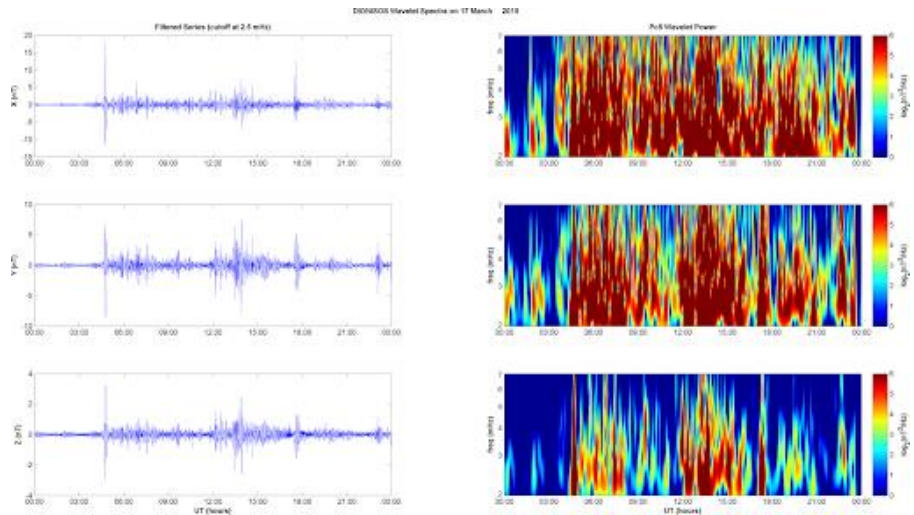
The forecasting of Solar Energetic Particles (SEPs) generated by solar eruptive events is crucial for spacecraft and launch processes, as well as for estimating the conditions of radio wave propagation in the Earth's ionosphere. It is mandatory for interplanetary travel beyond Low Earth Orbit (LEO), especially outside the Earth's magnetosphere. In addition to the general prediction of SEP events, the forecasting of high-energy SEPs is of potential interest, as these particles can penetrate deeper into the Earth's atmosphere and contribute to the radiation dose received by aircraft crews and passengers. As part of the Space Weather Operational Unit of NOAA, the HESPERIA REleASE tool has been developed, providing real-time forecasts of solar energetic protons with energies of 30-50 MeV in Geospace. It is based on observations of electrons traveling at the speed of light and crossing the distance between the Sun and Earth in tens of minutes, collected by the spacecrafts SOHO and ACE near Earth, as precursors of protons arriving 30-90 minutes later. This tool provides more comprehensive forecasts

compared to others based solely on observations of solar flares in the solar hemisphere. The other operation tool of the unit is the HESPERIA UMASEP-500 which provides real-time forecasts of events detected on the ground by very high-energy protons (> 500 MeV). The tool provides more timely forecasts compared to ground-based neutron detectors and relies solely on space data. The forecasts are available through the website of the National

Observatory of Athens (NOA) at <http://www.hesperia.astro.noa.gr>. The HESPERIA tools were selected by NASA as a top priority internationally to be included in the simulation of the manned mission to Mars. Currently, the HESPERIA tools provide real-time forecasts for NASA's CCMC, as part of the Moon to Mars (M2M) initiative. The space weather unit has maintained close cooperation since 2020 with the above NASA departments as a consultant on space weather issues. Finally, the HESPERIA tools have been integrated, operated, and provide forecasts for space weather at the European Space Agency (ESA), and are used in collaboration with a foreign company partnering with ESA for predicting events affecting international civil aviation.

ENIGMA - the Hellenic GeoMagnetic Array

IAASARS operates ENIGMA (Hellenic GeoMagnetic Array), an array of 4 ground-based magnetometer stations in the areas of Trikala (Klokotos), Attiki (Dionysos), Lakonia (Velies) and Lasithi (Finokalia) that provides measurements for the study of geomagnetic pulsations, resulting from the solar wind – magnetosphere – ionosphere coupling. ENIGMA is the first magnetometer station array to operate in Greece, and within a



few years of operation has achieved the status of a SuperMAG contributor. SuperMAG is a worldwide collaboration of organizations and national agencies, that currently operate more than 300 ground-based magnetometers. ENIGMA monitors the variations of the geomagnetic field associated with the occurrence of geospace magnetic storms and magnetospheric ultra-low frequency (ULF) electromagnetic waves. One of the ENIGMA main research objectives is the study of space weather effects on the ground, i.e., Geomagnetically Induced Currents (GIC). GIC flow along electric power-transmission systems and other electrically conducting infrastructure during increased geomagnetic activity and can cause wide-spread blackouts and power failures.

BEYOND Center for Earth Observation and Satellite Remote Sensing



The "Center for Earth Observation and Satellite Remote Sensing BEYOND" is an Operational Unit of IAASARS/NOA since 2013. It was developed as part of the FP7-REGPOT-2012-2013-1 program of the European Union (EU) with funding amounting to €2.3 million, creating excellence and infrastructure at scale in the field. Its operational function is autonomous and is secured through funding from competitive, research, and operational excellence programs. BEYOND conducts research and provides innovative services for risk mitigation of disasters caused by

natural and anthropogenic factors in the broader region of Southeastern Europe, the Balkans, the Middle East, and North Africa. It utilizes extensive ground-based satellite data

collection infrastructure installed at NOA. The goal is to provide timely information to relevant operational authorities dealing with disaster management and emergency situations, offering information throughout the crisis management spectrum. It develops research, and provides services in critical areas beyond natural disasters, such as food security, assessment of equivalent solar energy, health-epidemiology, support for agricultural policies, raw material exploitation, and cultural heritage preservation. Centre BEYOND of Earth Observation Research and Satellite Remote Sensing of IAASARS/NOA runs the GR SST NOC that coordinates the operations of the Greek Assets (AUTH, NTUA, AI/FORTH) in the implementation of the SpReg Service Contract and the 5 HETOP research projects. Finally, it leverages emerging technologies and modern infrastructure to provide high-level information and knowledge such as Artificial Intelligence (AI), Machine Learning (ML), and Distributed Computing (DC).

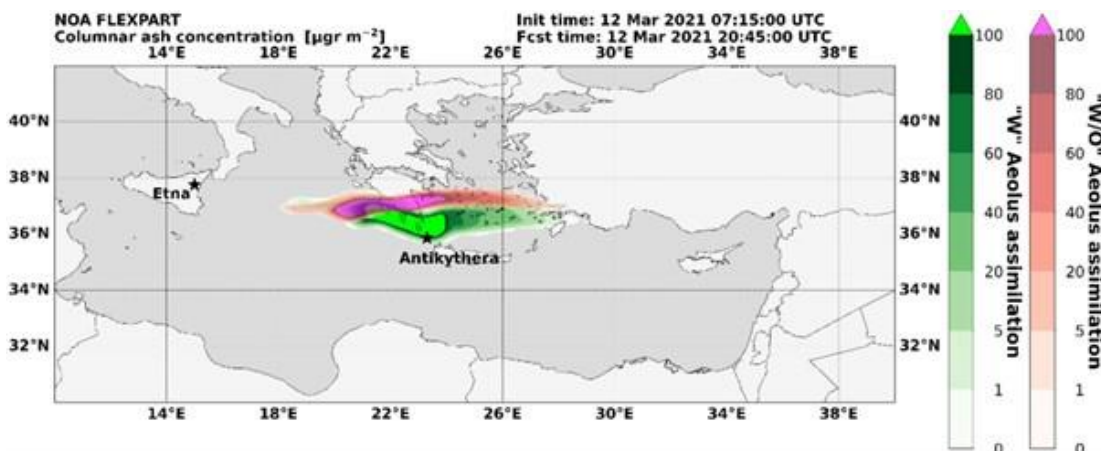


provide high-level information and knowledge such as Artificial Intelligence (AI), Machine Learning (ML), and Distributed Computing (DC).

EXCELLENCE

In 2023, IAASARS researchers have published 118 articles in high-impact ISI journals, receiving ~9071 citations, and attracted a total funding of ~3.9 M€ from competitive European and national research grants. Furthermore, three IAASARS researchers, namely, Spyros Basilakos, Kostas Koutroumbas, and Emmanuel Saridakis, appeared in the Stanford's list of world's top 2% scientists. The list is conducted based on a large number of indicators of excellence, influence and impact of their published works during the year 2022. Furthermore, IAASARS has established within 2023 strategic partnerships by signing relevant MOUs with ESA and Hellas Sat, and several academic institutions and private companies. Some indicative science highlights produced by researchers of IAASARS as well as funded research grants initiated within 2023 are presented below.

Volcanic ash dispersion forecasts

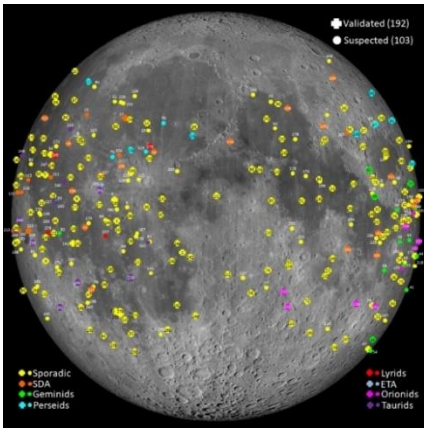


In the framework of validation and exploitation of ESA-AEOLUS mission for volcanic ash early warning systems in aviation, Dr. Vassilis Amiridis and ReACT team published a scientific paper in Nature scientific reports. The paper

examines the impact of measured wind fields on the regional numerical weather prediction (NWP) model and subsequent volcanic ash dispersion forecasts, with a focus on the March 2021 eruption of Mount Etna and utilizing measurements from the PANGAEA observatory on Antikythera island. The results of this case study demonstrate a significant improvement of the volcanic ash simulation when using Aeolus-assimilated meteorological fields, highlighting the necessity of future wind profiling satellite missions for improving volcanic ash forecasting and hence aviation safety. For further details see: Amiridis, V., Kampouri, A., Gkikas, A. et al, "Aeolus winds impact on volcanic ash early warning systems for aviation", Sci. Rep., 13, 7531, <https://doi.org/10.1038/s41598-023-34715-6>, 2023.

When meteoroids hit the Moon

The NELIOTA Project (PI: A. Bonanos) officially ended in July 2023 after 6.5 years of continuous monitoring of the Moon with the 1.2 m telescope at Kryoneri Observatory, with a dedicated fast-frame dual-band twin-camera imaging system. The detected flashes are available on the project website (<https://neliota.astro.noa.gr/>). The project was funded by ESA and aimed to study the size frequency distribution of impact flashes due to collisions of meteoroids on the lunar surface. During the NELIOTA operations, 192 validated and 103



suspected lunar impact flashes were observed. Most of the meteoroids producing these events have masses less than 100 g and diameters less than 6 cm. Moreover, most of the peak temperatures developed during the collisions range between 2000-4500 K. The results of the project will be published within 2024. Two members of NELIOTA (A. Bonanos and A. Liakos) are currently members of the science team of the ESA/LUMIO space mission that will observe impact flashes on the dark side of the Moon. Moreover, the NELIOTA team aims to re-initiate the ground-based observations using the Kryoneri telescope by seeking new funding by ESA.

MINOTAUR: a comprehensive study of Planetary Nebulae

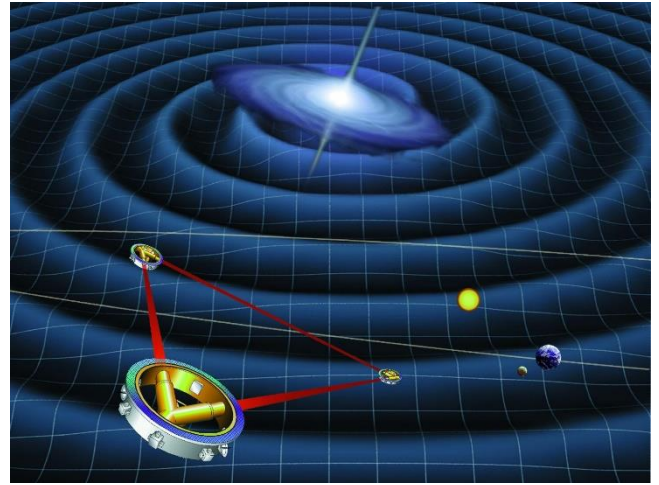


The Multi-wavelength investigation Of planetary nebulae problems (MINOTAUR) research program, whose principal investigator is the associate researcher of IAASARS Dr. Stavros Akras, received funding from the Hellenic Foundation for Research and Innovation (H.F.R.I.) in the context of the "Basic Research Financing (Horizontal support for all Sciences), National Recovery and Resilience Plan (Greece 2.0). The MINOTAUR group will study the evolution of low mass stars like our Sun, with particular focus on their final evolutionary stage of planetary nebulae. Planetary nebulae (PNe) are complex associations of expanding and interacting shells of gases and dust expelled from low-to-intermediate mass stars, like

our Sun. During the evolution of the stars, a cold molecular envelope is formed around them which is dissociated after the exposure of the luminous and hot core and, consequently, the resultant atomic gas is ionized, making the nebula glow. PNe play a crucial role in the chemical enrichment of interstellar medium, star-formation and galaxies evolution. Yet, there are nebular problems that need to be solved. The recent discoveries of molecular hydrogen (H₂) clumps embedded in ionized gas of PNe have intrigued scientists as to how H₂ was formed and survived the dissociation phase. The nature of these microstructures as well as the formation mechanisms of H₂ are still poorly understood. The MINOTAUR group aims to conduct a thorough and multi-instrumental study of these low-ionization/molecular clumps in PNe, to determine the physical conditions of the ionic and molecular gas, to probe the mechanisms that govern these microstructures, to investigate their link with the stellar winds and mass-loss processes of evolved stars and to search for the presence of polycyclic aromatic hydrocarbons (PAHs). Image and integral field spectroscopic data from state-of-the-art instruments mounted at world-class telescopes, such as Gemini, VLT and JWST will be used to demystify the nature of these clumps. Thus far, two observing programs were submitted to the European Southern Observatory in September 2023, requesting observations with X-Shooter and VISIR at VLT. Both programs were awarded with 24 hours. The observations are expected to be conducted between March and October 2024.

Advances in Cosmology

The IAASARS cosmology team members S. Basilakos and E. Saridakis, the postdoc researcher T. Papanikolaou and the PHD student Ch. Tzerefos, alongside the Academician Dimitris Nanopoulos, published two Letters, showing for the first time that Superstring Theory may indeed have observable effects on data related to the primordial Universe. In particular, they showed that it affects strongly the phase of Inflation, leading to the production of small primordial black holes, which in turn produce stochastic gravitational waves, which propagate in the Universe and change the flow of time through which they pass. And it is precisely this change in the flow of time that was observed in the change in frequency in the emissions of pulsars announced on June 29 by the NANOGrav Collaboration.



In 2023 the IAASARS cosmology team was officially accepted as organic participants in the Laser Interferometer Space Antenna (LISA) Consortium, one of ESA's key missions for the next two decades. LISA will be a space-based interferometer consisting of 3 spacecraft in heliocentric orbit, which will be 2.5 million kilometers apart forming a triangle, expected to launch in 2035. LISA will be detecting gravitational waves from multiple of sources, such as binary systems of supermassive and astrophysical black holes, supercompact binaries in our galactic neighborhood, etc., and possibly the stochastic background of gravitational waves originating from the primordial Universe.

Award at the “myEUspace competition of EUSPA - EU Agency for the Space Programme



BEYOND'S scientific team was awarded one of the first prizes for their idea “Blockchain-enabled Crowdsourcing – based Space2 Ground Data Availability @AI Framework_DeGenS” at the “myEUspace competition of EUSPA - EU Agency for the Space Programme” in the “Dive in Deep Tech” category. The idea was based on the context that by integrating blockchain, AI, earth observation and NFT, the DeGenS framework maximizes the potential of these technologies to incentivize crowdsourcing, streamline space-to-ground data availability, empower AI4EO research, and increase the reach of scientific outputs. Members of the BEYOND'S team were George Choumos, Alkiviadis Koukos, Vasileios Sitokonstantinou, Thanassis Drivas and Foteini Salta under the guidance of the Research Director and Scientific Coordinator of the Centre BEYOND of Earth Observation Research and Satellite Remote Sensing of IAASARS/NOA Dr. Charalampos (Haris) Kontoes.

Greece in EU Space Surveillance & Tracking (SST) Program

After two years of intense negotiations that were coordinated by the Task Force represented at the level of the Steering Committee of the EU SST Partnership by NOA (Haris Kontoes, the assigned delegate), NOA (the signatory authority and owner of telescopes GR KRYONERI GR HELMOS and the GR SST NOC) signed the EU SST Partnership. Furthermore, NOA and the associated institutions AUTH, NTUA, IA/ITE (owning the telescopes GR THESSALONIKI 1- 2 GR HOLOMON 1- 2 GR SKINAKAS 1 - 2 and GR BAKER NUNN) countersigned as partners (among the partners from 15 member countries) the SpReg Service Contract and the HE TOP 1- 5 RIA contracts assigned to the EU SST Partnership. The telescopes GR THESSALONIKI 1, GR HOLOMON 1, GR KRYONERI and the GR SST NOC passed successfully twice the EU SST calibration



campaigns and a full end to end preoperational campaign according to the EU SST standards and were nominated as CAT A sensors approved for full scale operations in December 2023. The Associated partners and NOA, with their key staff operating the NOC and the telescopes, participate in the Expert Teams and the Implementation Teams of EU SST. Centre BEYOND of Earth Observation Research and Satellite Remote Sensing of IAASARS/NOA runs the GR SST NOC that coordinates the operations of the Greek Assets (AUTH, NTUA, AI/ITE) in the implementation of the SpReg Service Contract and the 5 HETOP research projects. The Centre BEYOND of Earth Observation Research and Satellite Remote Sensing of IAASARS/NOA, through the SST NOC, schedules the tasks (survey and tracking) and uploads orbital data in the EU SST Data Base to address the daily tasking for services of Collision Avoidance, Re Entry, and Fragmentation. Greece's contribution to the 6 EU SST Contracts is estimated at ~ 2,6 ME funded by the EU.

Copernicus Emergency Management service (CEMS) Risk and Recovery Mapping (RRM) – Tailor-Made Products (FLEX)



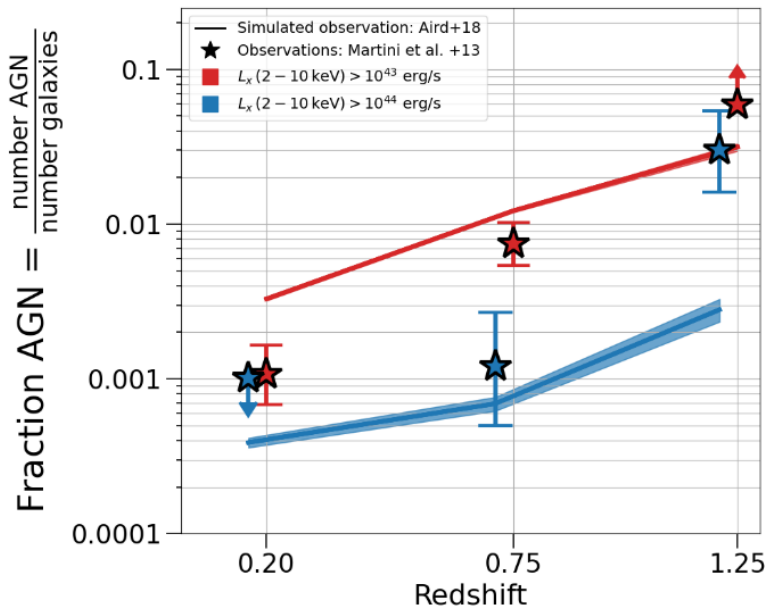
At the end of 2023, the Operational Unit BEYOND/IAASARS/NOA was selected between the contractors for realizing the Copernicus Emergency Management Service (CEMS) Risk and Recovery Mapping (RRM) for the benefit of societies on a global scale. The consortium is led by the Centre

BEYOND of Earth Observation Research and Satellite Remote Sensing of IAASARS/NOA, with the participation of the School of Mining and Metallurgical Engineering/ Engineering Geology & Hydrogeology Lab/NTUA and the IT company IDC.COM. Copernicus Emergency Management Service (CEMS) Risk and Recovery Mapping RRM is the European contribution to assist global efforts of the authorized service users in Disaster Risk Reduction, communities and businesses to natural disasters, and minimization of losses in human lives and economic

assets. The project aims at promoting knowledge-based decision making with the use of products generated through applying adequate processing of Earth Observation data, specifically using the Copernicus knowledge base. The project will last 24 months and is funded by the European Commission, Joint Research Centre.

Cosmic evolution of the incidence of active galactic nuclei in massive clusters

The physical conditions and processes that lead to the activation of supermassive black holes at the centres of galaxies (Active Galactic Nuclei; AGN) are among the science priorities of the extragalactic group of the IAASARS. In a recent study (Munoz-Rodriguez et al. 2023, MNRAS, 518, 1041) they explore the role of the large scale environment in triggering accretion events onto the black holes. It is known that the distribution of matter in the Universe has a web-like structure with strong overdensities (e.g. clusters or groups of galaxies) separated by largely empty regions (voids). It has long been speculated that the position on this web plays an important role in the evolution of galaxies and the activity level of their black holes.



The work of the IAASARS researchers focus on the most massive and densest structures in the Universe, clusters of galaxies, where environmental effects are likely to be maximal. They model the incidence of AGN in these environments by developing a novel semi-empirical simulation of the distribution of galaxies and AGN in the Universe, under the zero order assumption that AGN triggering is agnostic to the environment. The Figure demonstrates striking differences between the model predictions (blue and red curves) and observations (blue and red stars) on the fraction of AGN in clusters of galaxies from the local Universe (redshift parameter $z=0.2$), to intermediate ages (redshift $z=0.75$) and earlier times (redshift $z=1.25$, corresponds to half the age of the Universe). These discrepancies question the zero-order assumption of the model and demonstrate (i) the suppression of AGN activity in massive galaxies at present day and (ii) the acceleration of black hole growth in dense environments at earlier times.

HellasQCI – the National Quantum Communication Infrastructure



At the end of 2019, Greece signed the European Quantum Communication Infrastructure (EuroQCI) Declaration, signaling its commitment to the EuroQCI initiative, which aims to build a highly secure quantum communication infrastructure (QCI) that will span the whole European Union. Being the south-east border of Europe, and in

view of the latest geopolitical challenges, Greece's commitment is of strategic importance for the success of EuroQCI. In response to this commitment, this proposal presents HellasQCI, the National QCI of Greece, which aims to boost Europe's scientific and technological capabilities in cybersecurity and quantum communication technologies. The project will

deploy the HellasQCI infrastructure, an advanced quantum systems and networks national testbed, for experimenting with quantum communication technologies, and for integrating them with existing communication networks. HellasQCI high level architecture comprises three metropolitan test-sites: Athens (HellasQCI-Central), Thessaloniki (HellasQCI-North) and Heraklion (HellasQCI-South). Given that Greece is the south-east border of Europe and has been selected by ESA to host three primary Optical Ground Stations (OGS) systems for sat-QKD, HellasQCI aims to capitalise on this unique opportunity to



apply QKD technologies in military/police/intelligence applications, not only to strengthen its national security, but also to enhance the European sovereignty in this strategic part of the continent. To achieve this, three Greek telescopes that constitute a national asset will operate as OGSs and participate in the HellasQCI consortium. These are Helmos in Peloponnese, Holomondas in Thessaloniki and Skinakas on the island of Crete. They have been selected by ESA and are currently in the upgrade phase through the “Secure and Laser communication technology” programme (ScyLight), for the development and evolution of optical communication – laser – technologies that will be used, among others, for the EuroQCI space segment. IAASARS administration is fully supporting this national activity by providing Helmos OGS. Within the HellasQCI project it is anticipated that Helmos OGS is anticipated to act as the largest facility in the world (given the large aperture of 2.3 m of Aristarchos telescope) to conduct space-based QKD experiments.

ERMIS - Hellenic Cubesat Demonstration Mission



IAASARS, and its current administration, actively participates as one of the main pillars in the Hellenic network for the ERMIS Hellenic Cubesat Demonstration Mission that aims to certify new, innovative space technologies and applications, such as 5G communications for the Internet of Things (IoT), satellite telecommunications and a multispectral camera for earth observation. ERMIS is a pathfinder demonstration of key space connectivity capabilities linked to Greece's 200 M€ national small satellite project using a constellation of small satellites. Coordinated by the National Kapodistrian University of Athens (NKUA) the consortium includes

leading space, small satellite and IoT/communications entities OQ Hellas, University of Patras, University of the Aegean and the National Observatory of Athens. As the first Greek small satellite constellation, ERMIS will bring novel space communications (Low Earth Orbit 5G-IoT communication services, Inter-Satellite Link (ISL) and laser optical downlink), hyperspectral earth observation applications focused on national needs (e.g. precise agriculture) and small satellite technology capabilities for Greece and Europe, and create unprecedented new space capacities, synergies, and infrastructure in Greece. The ERMIS mission consists of a constellation of three advanced, cubesats, one of which will carry a laser communications terminal (LCT) which will demonstrate 1 Gbps downlink to the Helmos Optical Ground Station. The launch of the ERMIS constellation is planned for the end of 2025. The initiative

underpins efforts – led by ESA on behalf of the Greek Ministry of Digital Governance – to expand the nascent space industry in Greece, enabling the digital transformation of society while creating jobs and generating prosperity, as part of the nation's EU-funded Recovery and Resilience Facility. The ERMIS 4.8 M€ project is funded by the European Union – NextGenerationEU and by the Greek Ministry of Digital Governance and is coordinated by the Department of Aerospace Science and Technology of the National and Kapodistrian University of Athens (www.aerospace.uoa.gr).

OUTREACH AND EDUCATION

IAASARS has always placed great emphasis on science dissemination and outreach. After all, IAASARS research is funded by public (national or European) grants, and thus the research results should return in a suitable way to the public itself. The institute's main components to this aim are the Penteli Visitor Center (since 1995) and quite recently the Thiseio Visitor Center (since 2014). Both visitor centers are now unified on a single structure within IAASARS, namely the Visitor Centers of National Observatory of Athens, and are very active, engaging in a huge variety of outreach indoors and outdoors activities covering a large age-range, which was non-existent in the previous years.



The purpose is to mediate between science and the public using diverse activities paved by modern educational means which is always based on the interaction between the specialized staff and the audience. This has been made possible through customized schemes that serve the needs of a particular age group. The Visitor Centers have also welcomed to their educational programs unemployed people, refugees, guests of Mental Health Centers, disabled persons, and students from Special Schools. Special presentations are chosen from a plethora of topics in coordination with the main research areas of the IAASARS. Other educational activities of the Institute include the annual astrophysics summer school for high-school seniors, regular organization of international conferences and a vigorous seminar program.

During 2023, the Visitor Centers were visited by 263 schools, with 10837 pupils in total, plus 28 schools with ~1000 pupils with free entrance due to social requirements. Additionally, 10052 visitors participated in the night actions of Visitor Centers, in 212 events, while the Visitor Centers organized 23 special events with more than 6000 visitors. Moreover, Visitor Centers staff visited 16 schools in remote areas of Greece, in person or online, for special events. Finally, the Visitor centers organized 11 actions for kids, and 42 theater/music performances. More than ~2000 citizens had free entrance due to social requirements, while 744 were citizens with special needs.



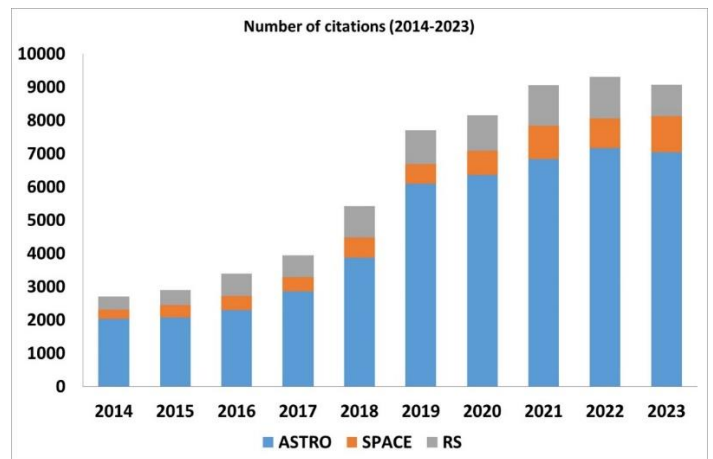
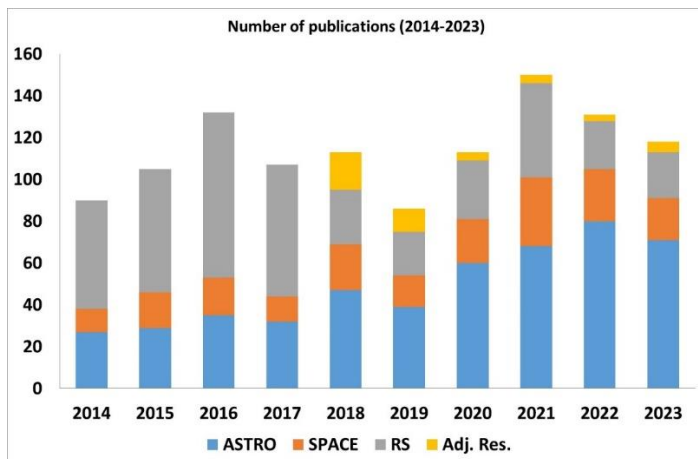


Furthermore, in January 2023 the master plan which will set the baseline for IAASARS to fulfill its strategic goal for the reconstruction of the Kryoneri astronomical station aiming to transform it (a) into a Space Hub and (ii) into a public outreach center, was completed, an investment funded directly by the Prefecture of Peloponnese. Finally, in December 2023, the action of the Visitor Centers in Kalavryta attracted more than ~500 visitors. During 2023, IAASARS researchers, including the Director of the institute, wrote tenths of articles in newspapers and sites and appeared frequently in TV

and radio interviews and broadcasts. Additionally, they had a significant contribution in KOSMOS, the NOA's on-line scientific journal, with many articles on the IAASARS research fields.

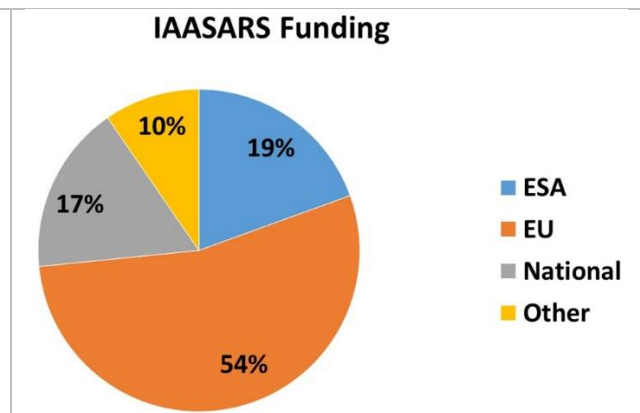
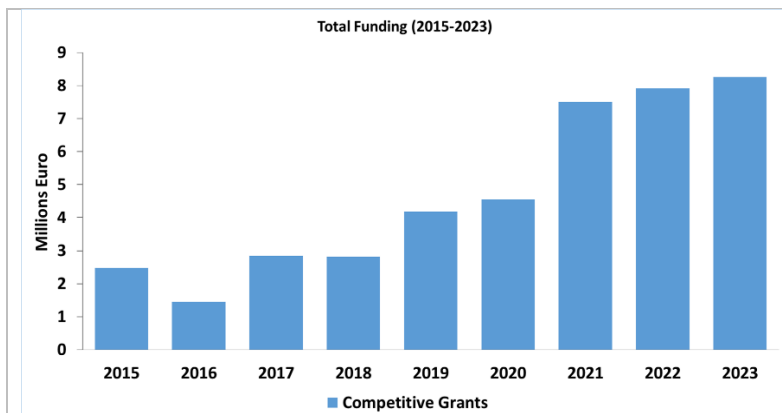
PERFORMANCE METRICS

The scientific activity within 2023 resulted in 118 papers in refereed scientific journals with more than 9000 citations. Moreover, the scientists of the Institute have been successful in attracting 3.9 M€ in 2023 from new national and European competitive research grants while the total annual running project budget is ~ 8.2 M€. IAASARS, provided novel applied and basic research results, services and public outreach activities, supporting at the same time 104 on contract positions including 25 postdocs, 25 PhD students and 54 research and technical associates, funded by external competitive frameworks.



Refereed papers per discipline (source ISI-Web of Science)

Citations per discipline (source ISI-Web of Science)

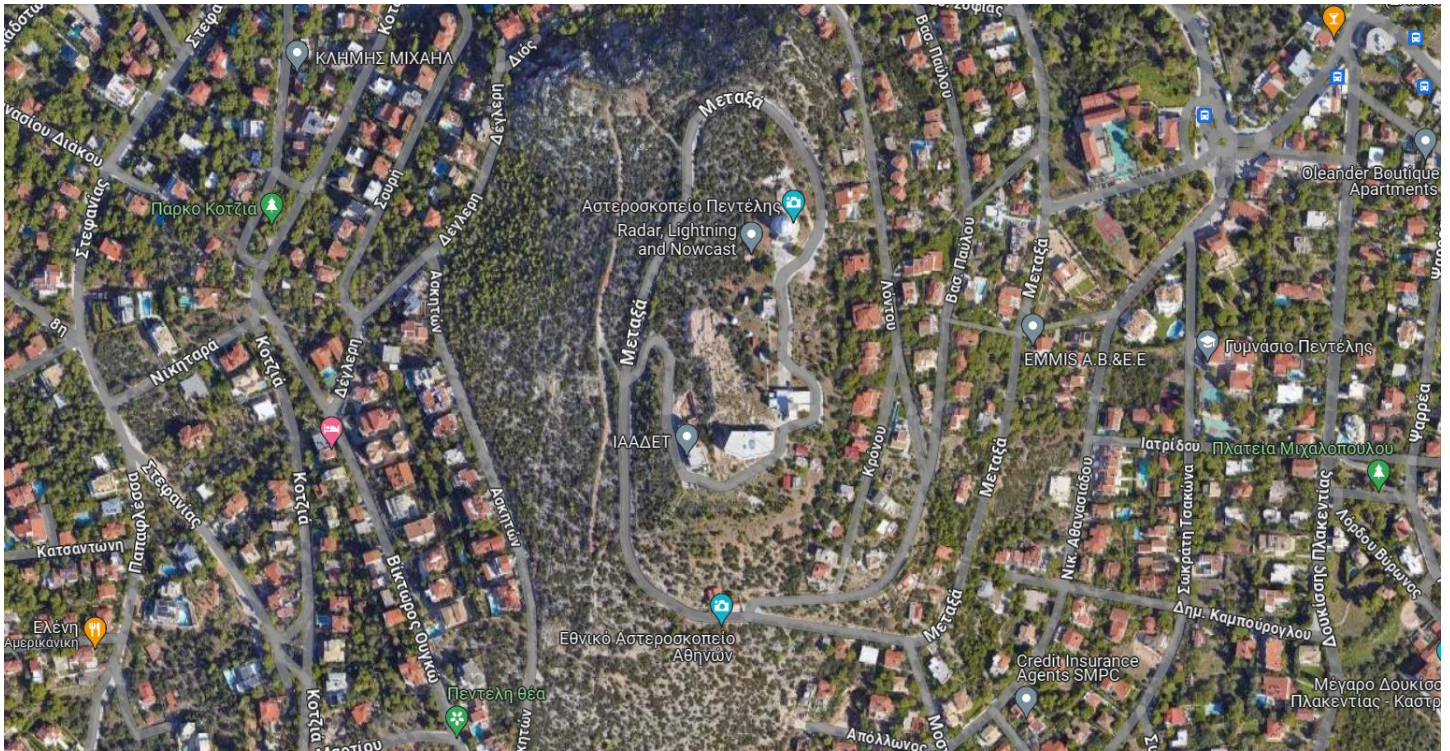


External funding from competitive grants awarded to IAASARS researchers (2015-2023). Each bar indicates the running funding in each year.

Distribution of external funding in various funding schemes.

CONTACT

IAASARS is located on the grounds of the National Observatory of Athens in Penteli, about 19 km northeast of the historical building of the Observatory at the center of Athens. The following map indicates the Institute's building location as well as the location of the Visitor Center.



 Vas. Pavlou & I. Metaxa, GR-15 236 Penteli, Greece

 +30 2103490150

 as_sec@noa.gr

 <https://www.astro.noa.gr/en>

 <https://www.facebook.com/iaasars> and <https://www.facebook.com/visitorcenters>