Israel Large Astrophysics Infrastructure - A Proposal for Joining the European Southern Observatory (ESO)

Overview

Astrophysics is entering a golden era. Large international collaborations are building new telescopes at the multi-*billion* dollar level, with an aim at understanding what the Universe is made of, how it formed, and whether there is life out there. Indeed, three of the Nobel prizes in the past five years[1] were awarded in areas related to astrophysics. Some of the forthcoming efforts are described in the US 2020 Decadal Survey report[2].

In addition to using small and versatile facilities, astronomy is transitioning to large scale projects that involve hundreds or even thousands of researchers from different countries, some as collaborations of universities and others as collaborations of nations. The combined new technologies, expertise, manpower and budget make possible observations that were not imaginable before. The new projects include giant optical telescopes, multiwavelength observatories (e.g. observations of radio emission and ultrahigh-energy gamma rays) and multi-messenger detectors (neutrinos, ultra-high energy cosmic rays. and of course the famous LIGO-Virgo-Kagra gravitational radiation detectors; see detailed list below).

So far Israel has joined only a single collaboration of this kind, the Las Cumbres Observatory (LCO). This is a network of relatively small (0.4-2 meter) optical telescopes, dynamically scheduled and distributed world-wide. Joining LCO was possible with funds from the Astrophysics I-Core and a 100% commitment of the 1 meter telescope at Tel-Aviv University's Wise Observatory to the LCO system. The Israeli-led discovery (featured on the cover of Nature) of the kilonova optical transient accompanying the famous neutron star binary merger is one indication of the success of joining LCO. However, LCO is only a first step in the right direction. In order for the Israeli astronomical community to remain competitive, we must join one of the large multi-national collaborations to gain access to the aforementioned telescopes. It is only with the state of the art large facilities, that Israeli astrophysics can continue to flourish in the next decades.

Indeed, one of the first recommendations of the MALAG independent review committee of the Israeli Physics Departments was that, given the high international stature of Israeli astronomy, Israel should join the European Southern Observatory (ESO), the best option among the international collaborations[3] (the

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[1] https://www.nobelprize.org/prizes/lists/all-nobel-prizes-in-physics/

[2] https://www.nationalacademies.org/our-work/decadal-survey-on-astronomy-and-astrophysics-2020-astro2020

[3] https://che.org.il/wp-content/uploads/2021/01/Physics-Evaluation-Committee-General-Report_Final-Aug-2019.pdf

alternatives are outlined below). This echoes a similar recommendation by the Visiting Committee on Astronomy in Israel from 2002[4] and testimony provided to the Kneset[5].

Academic Advantages

ESO is the world's largest and leading astrophysics "laboratory", with 16 member states, numerous telescopes at several high-altitude sites in Chile (the best ground-based observing sites in the world), and headquarters in Munich. ESO is leading the world in exploration of the Universe and can be described as the astronomical equivalent of CERN, the European research center for nuclear physics, the leader in exploring the subatomic world, that Israel has joined.

Joining ESO will provide access to a large amount of cutting-edge facilities, covering a large range of electromagnetic wavelengths and addressing a wide variety of science cases, each providing unique opportunities unmatched by any competitor. Among many examples, ESO's flagship facilities include:

1. The Very Large Telescope (VLT) - an array of four 8-meter aperture telescopes operating at visible and near-infrared wavelengths that can work individually or as an interferometer, and which have produced Nobel-Prize-winning images of the immediate surroundings of the supermassive black hole at the center of our Milky Way galaxy. The VLT has been the most productive ground-based facility for astronomy, with only the Hubble Space Telescope generating more scientific papers among facilities operating at visible wavelengths[6].

2. The Atacama Large Millimeter Array (ALMA) - a mm-radio-wave interferometric array of antennae on a 5000 m-altitude plateau, which has revealed the first and many detailed images of planetary systems, shedding new light on planetary formation, and paving the way for search of life in the Universe. ALMA has also discovered the faint emissions, impossible to see with any other facility, by dust and molecules from the first galaxies formed in the Universe, 10 billion light years away, as seen when the Universe was a small fraction of its current age.

3. The European Extremely Large Telescope (ELT) - a 39 m-diameter aperture optical-infrared telescope that is now under construction, with first light expected in 2027. ELT will be, and will

[4] http://wise-obs.tau.ac.il/~dani/academyreport.pdf

[5] מידע בנושא הפעילות בתחום החלל בישראל - עדכון, הכנסת - מרכז המחקר והמידע, 2017
https://fs.knesset.gov.il/globaldocs/MMM/650aee0e-ad9b-e711-80da-00155d0ad651/2_650aee0e-ad9b-e711-80da-00155d0ad651_11_10900.pdf

[6] Trimble, V.; Ceja, J. A.. Productivity and impact of astronomical facilities: A recent sample. Astronomische Nachrichten. 331(3): 338. doi:10.1002/asna.200911339, 2010

likely long remain, the largest optical telescope in the world, with a light-collecting area 15 times greater than the current largest telescopes, and angular resolution at least 4 times better than existing today. Coupled with the superb quality of scientific instrumentation and detectors with which the ELT will be equipped (as proven by ESO's instrumentation record on current facilities, e.g. the spectacular GRAVITY instrument on the VLT), ELT will usher a revolution in scientific discovery as soon as it begins operation. ELT will permit characterizing the atmospheres of planets around other stars, perhaps even detecting biosignatures indicating the presence of life, and answering the age-old questions regarding the uniqueness (or not) of the emergence of life on Earth. ELT will resolve the details of the faintest, most distant ancient galaxies and the light from the accreting supermassive black holes at their centers. And as is the case in exploration-driven science, most exciting are the unexpected discoveries in unprecedented directions, which can illuminate the greatest puzzles in Physics today, such as the nature of dark matter and dark energy.

Access to the ELT is our primary motivation for joining ESO. The power and uniqueness of the ELT will lead to a demand for its time that will make it effectively inaccessible to non-ESO members, let alone in any project-leadership role. Thus, in the age of ELT, without access to ELT, or even to any astronomical facilities in the lower tiers, Israeli astrophysics, with its prominent international standing today, will be completely sidelined and excluded from the great wave of discovery that ELT will bring with it. In contrast, Israeli membership in ESO holds great promise to position Israeli astrophysicists at the helm of many of the ELT projects and the discoveries that they will bring. Over the past decades, Israel's astrophysicists have established their reputation as world leaders in both theory and observations, with an impact that far exceeds that expected from a community of our size.

Industry Advantages

Modern astrophysical instruments incorporate advanced optical elements from various branches in optics and photonics. From free-form optical elements, through ion-etched gratings and photonics lanterns, to solid-state detectors at the instrument focal planes. The design of such instruments requires understanding of the astrophysical questions targeted, knowledge in optical design of state-of-the-art systems, and familiarity with the latest technology. This set of pre-requisites often leads to some of the most innovative collaborations between the academic world and industry.

Several collaborations between the astrophysical scientific community and local industrial partners have formed recently. ULTRASAT, a novel wide field-of-view ultraviolet space telescope, is being built through a collaboration led by the Weizmann Institute and involving all research universities in Israel, El-Op (Elbit), the Israel Aerospace Industry (IAI), and Tower-Jazz semiconductors. The involvement of several international partners in the project, such as NASA (US) and the Helmholtz Foundation (Germany), expose the local industrial partners to possible future markets, as well as to new technologies and approaches. A similar collaboration for developing unique optical elements for the Giant Magellan Telescope between the Weizmann institute and Shamir Precision Optics (SPO) is now taking shape. Given that the field of astrophysical instrumentation is at its infancy in Israel, we expect the number of such collaborations to grow significantly in the coming decade[7].

[7] פעילויות מו"פ, תשתיות וכ"א בתחום החלל האזרחי בתעשייה, באקדמיה ובמערכת החינוך בישראל, מוסד שמואל נאמן למחקר מדיניות לאומית, הטכניון, 2014 https://www.neaman.org.il/Files/Mop%2026-5-15%20pnim.pdf

By becoming full members of a large infrastructure collaboration such as ESO, the Israel photonics industry gains several key benefits that will allow it to further expand and advance. Local companies will be able to compete directly for tenders issued by the collaboration. This can involve both R&D projects, infrastructure projects, and construction at various scales. By ESO rules, only companies from member countries can bid for such tenders. In a similar fashion, academic research groups in Israel will be able to compete for tenders for constructing astrophysical instruments locally that will be mounted on the collaboration telescopes worldwide. Local industry partners will then work along with the academic groups in the design and construction of these systems. Contracts for instruments made in Israel would further provide guaranteed observing time to Israeli researchers.

In addition, becoming a member country in an organization such as ESO will open a new channel for building a highly qualified workforce, which is in high demand by the local industry.. Expertise and hands-on experience in optical instrumentation is hard to find among graduate students in Israel. Students involved in the design and construction of advanced instruments in astrophysics labs in Israel will be exposed to the latest technologies, and will work in leading international collaborations. This experience and the skill-set acquired during their academic training will allow them to become the leaders of the local optics and photonics industry in the coming years.

About half of the annual budget of ESO returns to the member states for instrument development, and there is no limitation on the fraction of these funds that ends up in a given member state, regardless of its economy's size. Given Israel's high profile in advanced technological industries, it is likely that Israeli industries will win an outsized share of ESO bids. Leading companies in Israel have already expressed a keen interest in taking part in such projects as they involve cutting edge technologies, and being part of such projects is considered a stamp of excellence.

Other Options Considered

We have considered a broad set of options before unanimously concluding that ESO presents the optimal choice, with a unique and varied combination of observatories. While other large facilities could be considered attractive alternatives to individual ESO facilities – for example the Square Kilometer Array (SKA) at radio wavelengths; the South African Large Telescope (SALT), the Large Binocular Telescope (LBT) and the Gran Telescopio Canarias (GTC) at optical wavelengths; the Cherenkov Telescope Array (CTA) at gamma-ray wavelengths; the IceCube neutrino observatory or the Auger high energy cosmic rays observatory - they are all limited to a single telescope and are thus inherently much narrower in terms of the range of science they address. This is one of the reasons why previous attempts to join some of these facilities only received partial support within the Israeli community, in contrast to the longstanding consensus on the advantages of joining ESO. There is no other option that offers a comparable range of capabilities from the radio to the infrared, state-of-the-art facilities, and an international collaborative framework.

Even when considering only the giant-class (~30 meter aperture diameter) telescope alternatives on their own, the ESO option has clear timing and cost advantages. There are three giant-class telescopes being planned: The ESO Extremely Large Telescope (ELT), and the US-led Giant Magellan Telescope (GMT) and Thirty Meter Telescope (TMT). While the GMT is expected to see first light in the 2030s and the schedule of the TMT is currently undetermined, the ELT is targeted to begin operations before the end of the decade. In addition, the cost of a dozen nights of observation on the GMT alone is comparable to the full ESO membership fee, which will provide the entire Israeli community access to the ELT and to the wide network of ESO facilities. Combined with proven success of Israeli researchers[8] in competing for observing resources, the benefit for our community will far surpass the relative membership cost.

Finally, another main advantage of joining ESO compared to other options, is that joining ESO is joining a major community of leading astrophysicists, sharing not only resources but also expertise. It will foster collaborations at a national and international level and reinforce Israel's role as a key player in the international astrophysics landscape.

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[8] תפוקות מחקר ופיתוח בישראל: פרסומים מדעיים בהשוואה בינלאומית, 1990-2011. מוסד שמואל נאמן למחקר מדיניות לאומית, הטכניון. 2013 https://www.neaman.org.il/Files/6-383.pdf