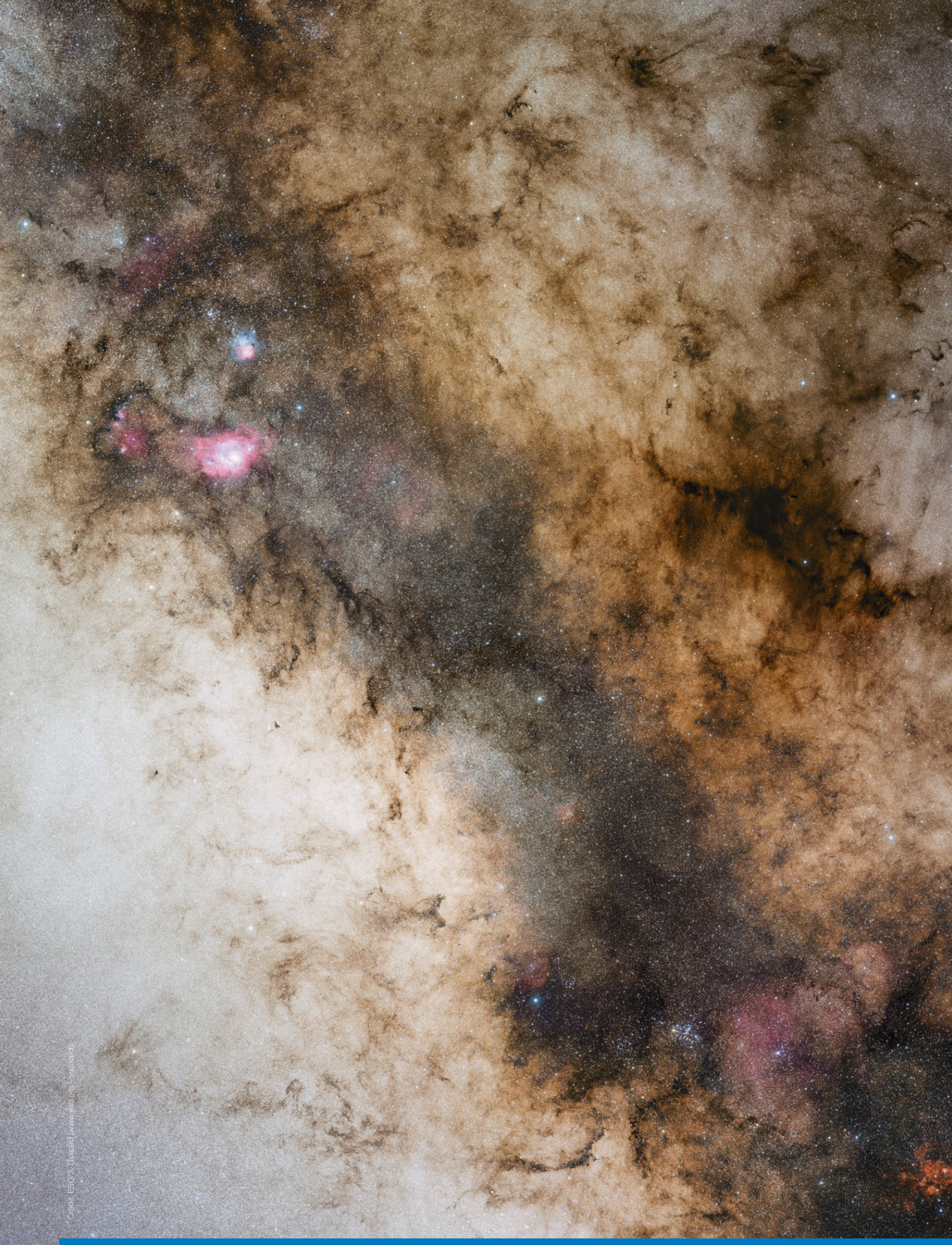
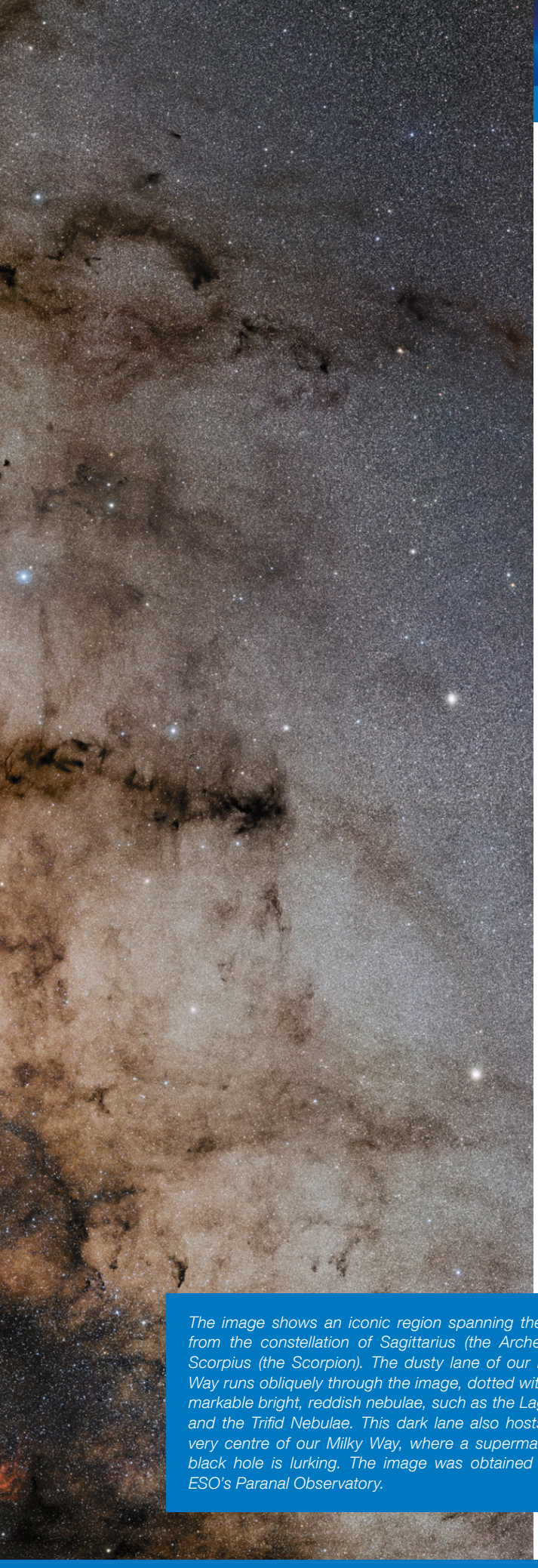
Position Paper on the Post-2020 Framework Programme



Credit: ESO/S. Guisard (www.eso.org/~sguisard)



The image shows an iconic region spanning the sky from the constellation of Sagittarius (the Archer) to Scorpius (the Scorpion). The dusty lane of our Milky Way runs obliquely through the image, dotted with remarkable bright, reddish nebulae, such as the Lagoon and the Trifid Nebulae. This dark lane also hosts the very centre of our Milky Way, where a supermassive black hole is lurking. The image was obtained from ESO's Paranal Observatory.

The ASTRONET Consortium was created in 2005 by Europe's major astronomy funding organisations and agencies in order to develop a long-term science vision and research infrastructure strategy. The Consortium received funding from the European Commission under Framework Programme Six and Seven.

In 2016, ASTRONET became a self-sustaining partnership with the signature of a Memorandum of Understanding. ASTRONET's primary goal is to provide a forum for the strategic coordination of European astronomy. At the time of writing, ASTRONET consists of eight partner organisations from European states. It is expected that many other European agencies and organisations representing national astronomy communities will join in the coming months.

This document has been created by the ASTRONET Board, acting on the behalf of the following member agencies and organisations:

- Belgium: Research Foundation Flanders / Fonds Wetenschappelijk Onderzoek Vlaanderen (FWO)
- France: The National Centre for Scientific Research / Le Centre national de la recherche scientifique (CNRS)
- Hungary: Hungarian Academy of Sciences / Magyar Tudományos Akadémia (MTA)
- Italy: National Institute for Astrophysics / Instituto Nazionale di Astrofisica (INAF)
- Netherlands: Netherlands Organisation for Scientific Research / De Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO).
- Sweden: Swedish Research Council / Vetenskapsrådet
- United Kingdom: Science and Technology Facilities Council (STFC)
- The European Organisation for Astronomical Research in the Southern Hemisphere (ESO)

Editors:
Andrew Williams (ESO); Denis Mourard (CNRS); Ronald Stark (NWO).

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Executive summary

This position paper represents the view of ASTRONET — a consortium of the European Organisation for Astronomical Research in the Southern Hemisphere (ESO) and European astronomy funding agencies, which is now a self-sustainable organisation after receiving ERA-NET support from the European Commission in Framework Programmes 6 and 7. Three key recommendations are presented concerning the design of the forthcoming post-2020 framework programme (FP9):

Recommendation 1

Astronomy in particular, but also fundamental curiosity-driven science more broadly, should be recognised as critical to developing a scientifically aware, enlightened and inspired society, and as a prerequisite for innovation in Europe. Adopting fundamental science questions in the proposed FP9 “missions” would achieve these aims.

Recommendation 2

European astronomy research infrastructures and their user communities should be further strengthened. Research infrastructures are a unique European public good, which reduce overlapping investments and capitalise on the strength of collective action to make European astronomy world-leading in many respects.

Recommendation 3

Financial support to Europe’s science base in the form of the European Research Council grants, the Marie Skłodowska-Curie Actions, and Integrating Activities should be continued and further strengthened. Some suggestions on potential enhancements of these schemes are offered.

This image, taken with the NASA/ESA Hubble Space Telescope, shows the galaxy NGC 4490. The scattered and warped appearance of the galaxy are the result of a past cosmic collision with another galaxy. Hubble is a collaboration between NASA (85%) and ESA (15%).

Credit: ESA/Hubble & NASA

1 The Importance of Astronomy and Fundamental Science

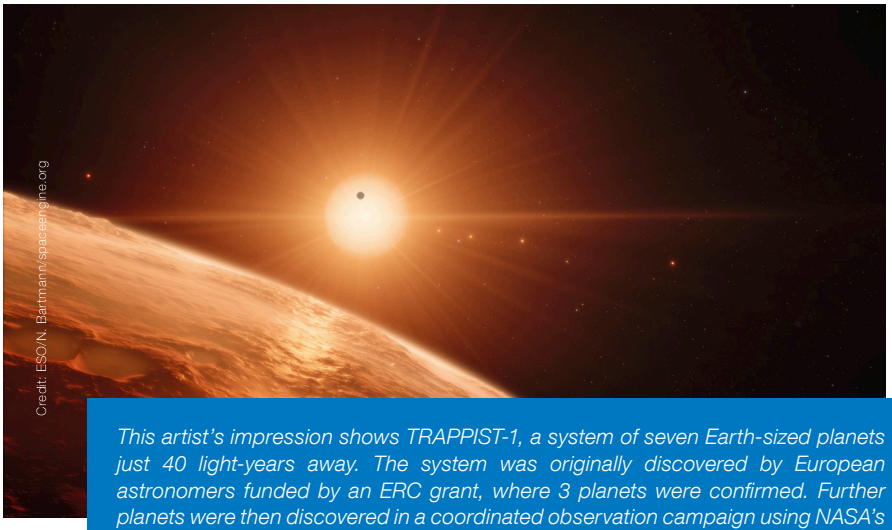
Humankind has looked to the heavens for millennia in search of meaning and understanding about how the Universe works. The endless frontier of the cosmos has spurred our curiosity to explore and to develop scientific methods to do so, with wide-ranging impacts on our civilisation.[1,2] Our notions of time, seasons, nature, navigation, and agriculture originated from close study of celestial objects. Astronomical knowledge about our place in the cosmos has yielded several transformational paradigm shifts, with sometimes dramatic societal consequences, by giving us an objective picture of our existence, location, and importance. After the great astronomer and public communicator, Carl Sagan, convinced the operators of the Voyager 1 probe to take a photograph of Earth from six billion kilometres, he distilled the ultimate message of astronomical science in his book, The Pale Blue Dot[3]:

"It has been said that astronomy is a humbling and character-building experience. There is perhaps no better demonstration of the folly of human conceits than this distant image of our tiny world. ***To me, it underscores our responsibility to deal more kindly with one another, and to preserve and cherish the pale blue dot, the only home we've ever known."***

Much of the current discussion on science funding emphasises economic impact, return on investment, industrial development, and innovation. While recognising the tensions between the economic, scientific and societal value of curiosity-driven research, it is also important to emphasise the value of a peaceful pursuit of scientific knowledge and be clear about its broader purpose for society.[4]

Astronomy gives humankind a collective knowledge of where we fit in the vastness of the cosmos. Astronomical discoveries have taught us that we are not the centre of the world, that the laws of physics are the same throughout the Universe, that the Universe had a beginning and started with the Big Bang, that our current understanding can only explain approximately 5% of the matter in the Universe, and that there are other planetary systems, some of which include habitable planets[5].

Yet astronomy's potential to expand our capacity for wonder, and its ability to provide inspiration to study science — and inspiration for countless stories and art forms — is far broader than its economic benefits. The need to know for the sake of knowing is a driver of innovation and creativity. This drive is limitless and the follow-on results endless. Astronomy, along with other basic sciences, is littered with examples of "spillovers" — practical innovations that result unintentionally from the pursuit of pure knowledge[6]. Science conducted only to meet impact criteria and economic benchmarks, on the other hand, risks being constrained by safe research questions, defined problems, and limited scope.

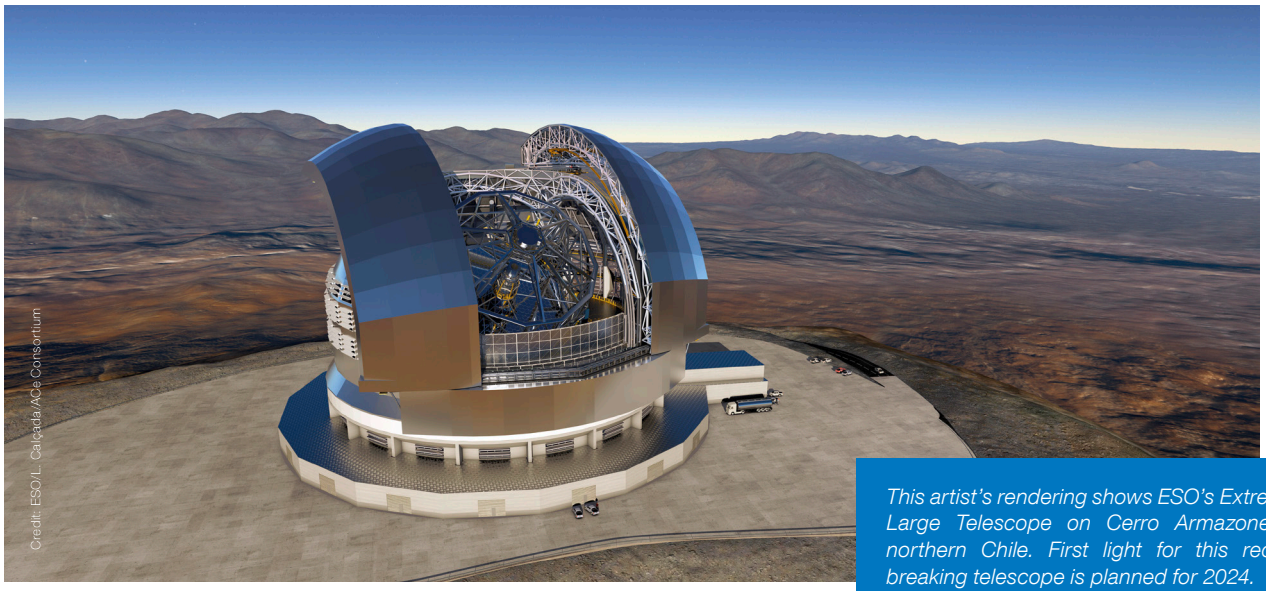


Credit: ESO/N. Bartmann/spaceengine.org

This artist's impression shows TRAPPIST-1, a system of seven Earth-sized planets just 40 light-years away. The system was originally discovered by European astronomers funded by an ERC grant, where 3 planets were confirmed. Further planets were then discovered in a coordinated observation campaign using NASA's Spitzer space telescope and ground-based telescopes around the world.

[1] http://sites.nationalacademies.org/bpa/bpa_049810
[2] http://www.denkschrift2017.de/
[3] Sagan, Carl (1994). Pale Blue Dot: A Vision of the Human Future in Space (1st ed.). New York: Random House. ISBN 0-679-43841-6.
[4] Fabian, A. (2010). The impact of astronomy. Astronomy & Geophysics, 51(3), p3.25–3.30. https://doi.org/10.1111/j.1468-4004.2010.51325.x
[5] http://www.astronet-eu.org/FP6/astronet/www.astronet-eu.org/spip33fa.html?rubrique27
[6] Astronomy Means Business: How UK research benefits industry, education and society. Royal Astronomical Society, UK, 2016. https://www.ras.org.uk/publications/other-publications/2798-astronomy-means-business

A Fundamental Science Mission for FP9



This artist's rendering shows ESO's Extremely Large Telescope on Cerro Armazones in northern Chile. First light for this record-breaking telescope is planned for 2024.

Evaluations of the current H2020 framework programme have shown that future funding instruments should adopt a mission-oriented approach and bring research and innovation closer to the public[7]. Early proposals for this mission concept have considered, amongst others, using the UN Sustainable Development Goals as a framework for selecting topics. While addressing these global and societal challenges is welcomed, we believe that the next framework programme must make a bold statement about our values as a rational and knowledge-seeking civilisation.

The EU has an opportunity to include fundamental research-oriented missions that would bring focus to a scientific discipline, but also bring science closer to the public.

The missions would mobilise researchers, innovators, investors and educators across multiple scientific fields, to stimulate innovation and create a level of European Research Area integration across disciplines that far exceeds that of the current integrating activities and bottom-up, excellent science instruments. The missions should be designed in a science community-driven process which takes into account public interests, especially those of science educators at all levels. They should aim for challenging but fascinating scientific goals that capture the imagination of the public, and drive interest in science, technology, engineering and mathematics subjects (STEM).

ASTRONET will soon begin the process to create a new European Science Vision and Research Infrastructure Roadmap for Astronomy, which will define community priorities in line with funding agency input and the ESFRI roadmap. Without precluding the necessary community deliberation, we propose that **astronomy offers several feasible mission concepts that address fundamental questions about our Universe, and can engage European science and public on a whole new level — *Are we alone? What are our origins?*** The current Science Vision for European Astronomy[8] is focussed on four key questions where significant advances and breakthroughs can be expected in the coming decades: what is the origin and evolution of stars and planets? How do galaxies form and evolve? Do we understand the extremes of the Universe? And, how do we fit in? These research themes have become of growing interest to many other science disciplines and have led to multidisciplinary research in diverse areas such as astrochemistry, astrobiology, astroparticle physics, astrostatistics, and astroinformatics. Concentrated effort on these research areas coupled with targeted education and public outreach, would add significant value to the European Research Area.

[7] LAB – FAB – APP — Investing in the European future we want: Report of the independent High Level Group on maximising the impact of EU Research & Innovation Programmes, European Commission, 2017. https://ec.europa.eu/research/evaluations/pdf/archive/other_reports_studies_and_documents/hlg_2017_report.pdf

[8] ASTRONET: A Science Vision Update, 2012. http://www.astronet-eu.org/IMG/pdf/Astronet_SV_final_pdf1.pdf A Science Vision for European Astronomy, ASTRONET 2007 http://www.eso.org/public/archives/oldpdfs/Astronet_ScienceVision.pdf

Fundamental Research and Innovation

There is growing emphasis from European Commission and European Member State policymakers on the need to stimulate innovation in European markets. ASTRONET supports this view but stresses that our world thrives on the combination of fundamental research and return-oriented research. **Innovation requires knowledge diffusion from both the outputs of fundamental research and a resource pool of mobile and skilled scientists.**

The quest to expand our knowledge continually pushes the technical limits of research infrastructures and scientific instruments to higher precision, sensitivity and efficiency. This requires a large pool of technological expertise that both feeds and draws from industrial needs. In the case of astronomy, scientific and technical needs generate many industry-relevant and transferrable skills in data science, data visualisation, computer programming, mathematics, optics, electronics, mechanics, control systems and energy production and conservation. The need, and ability, to coherently integrate so many different and diverse disciplines is a particular hallmark of astrotechnology. Many universities now support this synergy through the inclusion of industry skills units in astronomy curricula.

This research and industry overlap has undoubtedly led to many unexpected, world-changing technological developments in recent years, and there are no indications this will abate. Optical and detector technologies for telescopes, and computer algorithms for data processing, have worked their way into a variety of medical and commercial applications — including the protocol for wireless local area networks (WLAN)[9]. Progress is set to continue: developments in adaptive optics — a technology that allows telescope mirrors to dynamically correct for atmospheric disturbances — are being employed in space-to-ground laser communication systems for satellites, with a huge range of potential commercial applications. The global challenge of powering large research infrastructures and dealing with abundances of data provides further examples where astronomy-related developments will have much wider impacts on society.Science and innovation have a beginning: a spark of curiosity about the natural world, or a pressing problem that drives the creation of innovative solutions. Yet science and innovation cannot occur without a technically and scientifically competent mind, and this begins with education. Fundamental sciences are important because they attract the attention of, and stimulate interest in, young people all over the world. They are a key driver for student uptake in academic and industrial science, technology, engineering and mathematics (STEM) fields. Astronomy may be the only scientific field with its own category of public outreach centre — the planetarium — which takes advantage of the awe-inspiring imagery from the cosmos. Under the guidance of professional scientists, astronomy projects have involved millions of amateurs and a worldwide community, which engages in ambitious and fruitful citizen science projects.[10]

Credit: SKA Organisation

This artist's rendering of the SKA-mid-dishes in Africa shows how they may eventually look when completed. The 15-metre-wide dish telescopes, will provide the SKA with some of its highest resolution imaging capability.

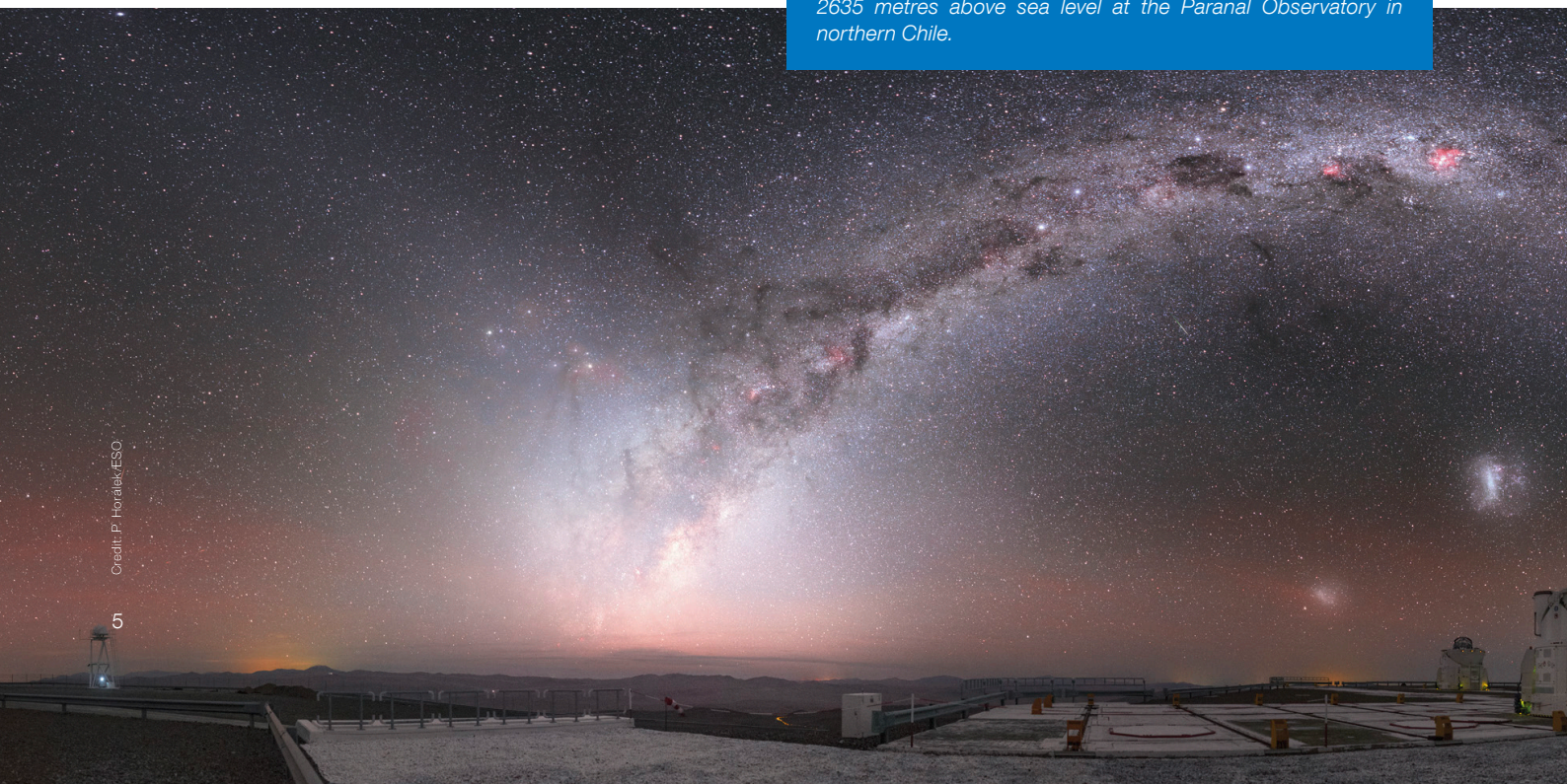
[9] https://www.capjournal.org/issues/14/14_30.pdf https://www.stfc.ac.uk/files/what-have-the-astronomers-ever-done-for-us-roger-davies/
[10] https://www.galaxyzoo.org/

2 Research Infrastructure Funding

As a data-dependent science, research infrastructures (RI) are key to astronomy and its quest to expand the frontiers of knowledge. Europe's current and planned set of astronomy RIs are on the verge of placing Europe as a global leader. ESO's Extremely Large Telescope, for example, will likely be the first of the 30-metre class telescopes in operation, and the Square Kilometre Array (SKA) — an international effort with significant European investment — will become the world's largest radio telescope, with one square kilometre (one million square metres) of collecting area. These RI will attract the best science proposals and offer Europe's scientists and engineers excellent opportunities for professional growth. ASTRONET supports further expansion of RI funding in the next framework programme, and engagement with European Commission officials in tailoring the design. With the top ASTRONET and ESFRI priorities now underway, RI funding instruments are needed to ensure continuing excellence from these world leading infrastructures.

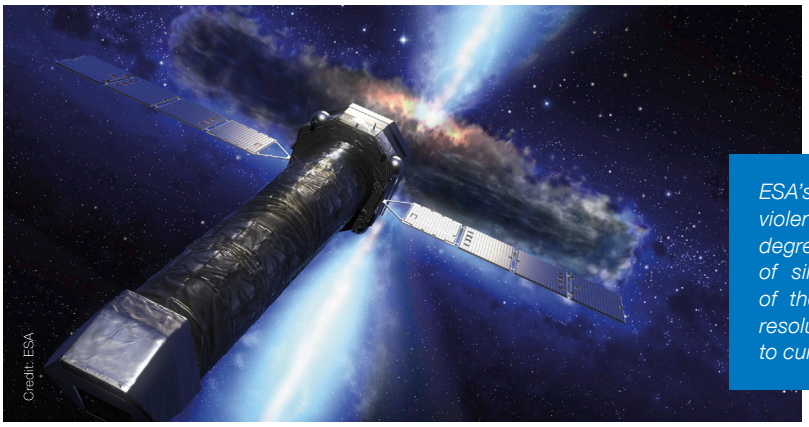
Integrating Activity projects under FP6, FP7 and H2020 including Euro-VO, RADIONET, OPTICON, EUROPLANET, and SOLARNET, have been fundamental and transformational for European Astronomy. These instruments have had a significant European added value in terms of structuring and consolidating scientific communities across Europe, and preparing for new RI such as the ELT, SKA, and the European Solar Telescope (EST). They have also strongly supported innovation in a variety of technical fields such as data handling, optics, electronics, and detectors, and have permitted the realization of an important series of critical components and software for the largest RI. In the next framework programme, funding for Integrating Activities should be continued for both starting and advanced communities and should be tightly coupled to preparing for technology and instrument development, data analysis and science exploitation from the major RI under construction.

The visible/infrared astronomy community should receive continued funding to ensure that the world-leading science from the ELT can be sustained and expanded, and to take advantage of the many new capabilities in exoplanet system detection and characterisation, and in galactic astronomy. The radio community requires further funding to ensure continued excellent science from the Atacama Large Millimetre/sub-millimetre Array (ALMA), and to prepare for the era of the SKA. Similarly, the high-energy astrophysics community involved in the European-led Cherenkov Telescope Array (CTA) could be well-supported by integrating activities.



The night sky above ESO's Very Large Telescope (VLT) displays our cosmic neighbourhood in all its glory. The VLT is located 2635 metres above sea level at the Paranal Observatory in northern Chile.

Credit: P. Horálek/ESO



ESA's Athena X-ray Observatory, is planned to survey a violent Universe of exploding stars, black holes and million-degree gas clouds. ESA has pioneered the new technology of silicon pore optics — the careful robotic stacking of thousands of silicon wafers — to provide improved resolution and a greatly enlarged collecting area compared to current X-ray missions.

New funding concepts are required to support European community consolidation and development in emerging fields of multi-messenger and time-domain astronomy. Parallel observations across wavelengths and time from ground and space hold the prospect of much new science, as demonstrated convincingly in 2017 with the observation of the first visible counterpart to a gravitational wave source (GW170817, a binary neutron star merger event). Additional resources for planning, coordinating and performing observations, and conducting cross-observatory data analysis are required to take maximum advantage of ground-based gravitational wave observatories and space-based gravitational wave detector projects (Laser Interferometer Space Antenna, LISA), neutrino detectors (KM3Net), and several projects to study the high-energy transient Universe such as ESA's Advanced Telescope for High-Energy Astrophysics (ATHENA), and the ground-based CTA.

All these observational efforts require interpretative support from theorists and model builders. Simulations are still much more limited in parameter-space volume and resolution than most observing facilities. On the other hand, publicly available results of simulations — especially in the area of cosmology — find increasing attention as sources of virtual observations. In addition, many modelling tools themselves have also been made public and greatly amplify the rate of progress. These developments should be strongly supported, most notably by the provision of state-of-the-art computing facilities.

As a result of the vastness of the Universe, the need to combine observations across multiple wavelengths and particles, and the relative lack of commercial or privacy barriers, astronomy has traditionally been a pioneer in open science data and good practices in data curation and archiving. Astronomy data providers will play a leading role in defining best practices and governance for the European Open Science Cloud (EOSC), and their participation in EOSC projects should be welcomed.

A key component of the RI programme is the funding for Design Studies, Preparatory Phases, and support to RI policy and cooperation. These instruments have supported consortia in overcoming the significant start-up barriers associated with moving new RI projects from concept to reality, and they should be strengthened considerably in the next framework programme.

Some of the central antennas of the Atacama Large Millimeter/submillimeter Array (ALMA). This international astronomy facility is a partnership of ESO, North America and East Asia.

3 Excellent Science

The European Research Council

The European Research Council (ERC) is one of the most important instruments for fundamental science research in Europe. The grants provided by the ERC have established a global standard for scientific excellence and should undoubtedly be continued and strengthened in the next framework programme. The categories of Starting, Consolidator and Advanced are effective, and the reintroduction of Synergy Grants is particularly welcomed. The very high over-subscription rate for the Synergy Grants in the past is a clear indication that frontier scientific research is conducted in multidisciplinary and international collaborations, thus a substantial funding increase is required. With respect to the needs of astronomy, several suggestions for small modifications to the instrument can be made.

First, the ERC could consider the option to expand the payment timescale beyond the current five years, which would improve the stability of the field and permit longer-term projects. Some astronomical research projects require years of observations, rather than surges of effort concentrated in short timescales. Solutions should be found, however, to ensure that the ERC does not contribute to broader instabilities and grant overdependency within Europe's university systems.

Second, reflecting the highly collaborative nature of astronomy and the need to source observations from across the electromagnetic spectrum, gravitational waves, high-energy particles, and neutrinos, the quality of research would be enhanced by allowing greater use of joint or multi-principle investigator grant structures.

Marie Skłodowska-Curie Actions

The Marie Skłodowska-Curie Actions (MSCA) are critical in creating a mobile and flexible European science community and should be continued and strengthened in the forthcoming framework programme. The MSCA are also one of the few instruments that support early stage researchers across Europe, and thus are important in providing early structure and integration in scientific communities.

With regards to the specific needs of astronomy, the MSCA Individual Fellowships schemes are often too short to realise highly ambitious projects. Extending the timespan to at least three years would allow better science, and place the scheme on par with other fellowship, post-doctoral and industry appointments. The possibility of freely identifying and pursuing personal research goals as opposed to instruction-driven research is an invaluable promotor of innovation and discovery.

The Innovative Training Network (ITN) instrument is one of the best tools for integrating early stage researchers into scientific communities, and generating cross-disciplinary and cross-border research collaborations. The high demand for and success rate of the MSCA programme warrant a substantial funding increase. The ITN concept will become increasingly important in the era of multi-messenger and multi-wavelength astronomy — where researchers need skills in establishing cross-disciplinary collaborations.

Credit: ESO/VST/M. Kornmesser

The star-forming region Sharpless 29. Many astronomical phenomena can be seen in this image, including cosmic dust and gas clouds that reflect, absorb, and re-emit the light of hot young stars within the nebula.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