A Science Vision for European Astronomy in the Next 20 Years

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By the end of the last century, European astronomers had secured large access to world-class facilities and produced cutting-edge science at all wavelengths, both from the ground and in space. To maintain that position and to ensure the necessary high level of international coordination and collaboration, it is essential to set up a European astrophysical strategic plan for the next two decades. This task is currently carried out by the ASTRONET network of funding Agencies, sponsored by the European Commission. A comprehensive Science Vision has now been produced. It will be followed in the autumn of 2008 by a prioritised roadmap of the facilities needed to implement this Vision.

European astronomy today is fully competitive on the global scene and at the forefront in many domains, with such recent breakthroughs as the first detection of an earth-like planet in the habitable zone around its parent star, the successful landing of a probe on Titan, the evidence for a massive black hole in the centre of our own Galaxy, the discovery of gravitational arcs in galaxy clusters and the proof that most gamma-ray bursts are caused by massive exploding stars at cosmological distances. The rise of European astronomy to this top position by the end of the last century has been achieved through extensive cooperation and coordination of efforts, in particular – but not only – through ESO for optical astronomy and ESA for space astronomy.

The ASTRONET programme

To strengthen Europe's position and extend it to all branches of astronomy and all nations of the enlarged European Research Area, a group of European funding agencies set up an ERA-Net programme, called ASTRONET and coordinated by INSU-CNRS, with the goal of establishing a comprehensive long-term strategic plan for European astronomy. The ASTRONET mandate covers all astrophysical domains from cosmology to the Solar System, and every observing window to the Universe, from space and from ground, and from electromagnetic radiation to particles and gravitational waves, to in situ exploration of the objects in our Solar System. It encompasses the links with neighbouring disciplines and, in particular, with the astroparticle community which is also developing its own strategic plan within the ASPERA ERA-Net programme (*http://www.aspera-eu.org/*). Cross membership of panels and overlapping interests of scientists ensure a fruitful collaboration in both endeavours.

ASTRONET addresses the whole astronomical 'food chain' from infrastructure and technology development to observation, data access, modelling, laboratory data and theory, and the human resources needed to make it all work. It also covers public awareness via education and public outreach. This effort is actually quite similar in scope to the 'decadal surveys' produced in the USA over the last fifty years, although conducted within a different setting. Extensive information on the full ASTRONET programme, currently supported by ESO, ESA and 18 funding agencies from across Europe is available from *http://www.astronet-eu.org/*.

Within this overall programme, a two-step procedure has been adopted. The first step was to produce an integrated Science Vision, an essential input to the subsequent task of drawing up a prioritised infrastructure roadmap to implement the Vision. Together they will provide the full strategic plan for the next two decades.

The Science Vision

The Science Vision document was released at the end of September 2007. This is the result of intense work by the Science Vision Working Group, aided by four thematic panels, a total of 50 scientists drawn from the community of European astronomers. Detailed mid-term feedback from the community was secured through a web forum and an open symposium that took place last January in Poitiers, France, in which 228 astronomers from 31 countries participated. The resulting scientific landscape was finally distilled by the Science Vision Working Group.

The Science Vision provides a comprehensive overview of the scientific issues that European astronomy should address in the next twenty years. The four key themes retained are: the extremes of the Universe, from the nature of dark matter and dark energy that comprise over 95 % of the Universe to the physics of extreme objects such as black holes, neutron stars, and gamma-ray bursts; the formation and evolution of galaxies from the first seeds to our Milky Way; the formation of stars and planetary systems and their evolution up to the origin of life; and the major question of how do we (and our Solar System) fit in the global picture of the Universe. These themes reach well beyond the realm of traditional astronomy into the frontiers of physics and biology.

Each of the four themes was further broken into five or six critical science questions that were analysed in depth. One important aspect of the effort was to identify the goals that we aim for and the

Figure 1: Cover of the ASTRONET Science Vision book.

Figure 2a: Current ground-based observatories. From left to right and from top to bottom: VLT, APEX, GREGOR, Gemini North, Gemini South, Magic, WSRT, La Palma, IRAM, SMA, Merlin, SST, La Silla and Effelsberg.

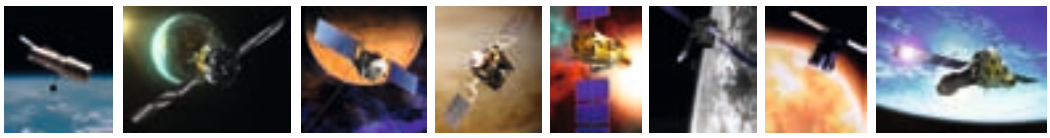

Figure 2b: Current space-based observatories. From left to right: HST, Integral, Mars Express, Venus Express, CoRoT, Rosetta, SOHO and XMM-Newton.

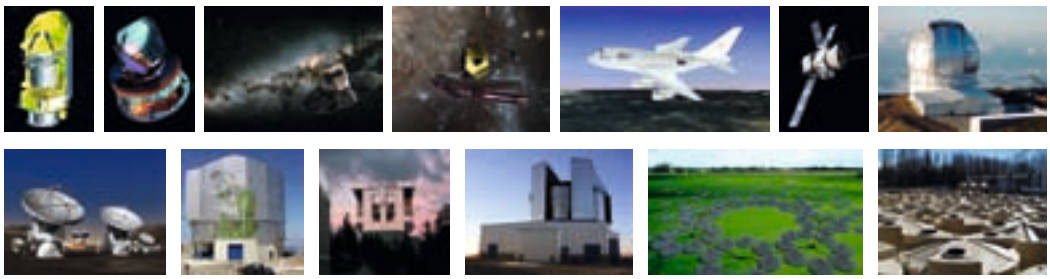

Figure 2c: Observatories under construction. From left to right and from top to bottom: Herschel, Planck, Gaia, JWST, Sofia, Bepi Colombo, GTC, ALMA, VST, LBT, VISTA, LOFAR and Auger.

generic key technologies and facilities that are needed to tackle the scientific issues. Detailed recommendations were made, covering essential observing needs as well as complementary ones, i.e. not absolutely needed to solve a key issue but nevertheless bringing a strong scientific added value. Most importantly, this exercise took into account both current facilities, including those under development and fully funded, like ALMA, Herschel, Planck, LOFAR, JWST, GAIA, Rosetta and Bepi Colombo, as well as future needs. The panels and the Science Vision Working Group also outlined and stressed the need for parallel developments in theory and numerical simulations, high-performance computing resources, efficient astronomical data archiving, as well as a substantial commitment on laboratory astrophysics.

The ASTRONET Science Vision book (Figure 1) has been distributed to the funding agencies for further dissemination and is available on-line either in low-resolution format (17 MB) at *http://www.eso.org/public/outreach/press-rel/pr-2007/Astronet_ScienceVision_lowres.pdf* or in normal format (47 MB) at *http://www.eso.org/public/outreach/press-rel/pr-2007/Astronet_ScienceVision.pdf*.

The two-year Science Vision development was managed by ESO and NWO, with the scientific effort led by Tim de Zeeuw, then at Leiden Observatory, and Frank Molster of NWO.

Figure 2 offers a bird's eye view of current and planned observational facilities with significant or large European involvement.

The Infrastructure Roadmap

Preparation of the detailed Infrastructure Roadmap process began in the spring of 2007. The approach very much resembles the Science Vision's one with five Panels and an Infrastructure Roadmap Working Group. Programmatic breakdown is as follows. Panel A: High energy, astroparticle astrophysics and gravitational waves; Panel B: UV/Optical/IR and radio/mm, including survey instruments; Panel C: Solar telescopes, 'in situ' (Solar System) missions, laboratory studies; Panel D: Theory, computing facilities and networks, Virtual Observatory; Panel E: Education, recruitment and training, public outreach. Two major milestones ahead are the release of the first draft of the roadmap with the opening of a web-based forum in the spring of 2008, and a community-wide open meeting in Liverpool on 16–19 June 2008.

The Infrastructure Roadmap development, is managed by Michael Bode and Maria Cruz of Liverpool University and Frank Molster of NWO.

Conclusions

With the September 2007 release of the Science Vision and the subsequent Infrastructure Roadmap effort now in full gear, European astronomy is for the first time ever fully engaged in the production of a global strategic plan, an essential prerequisite to ensure a vibrant future. Getting the community to agree by the end of 2008 on a common set of priorities, hard choices, and delicate balances is bound to be a tough task, but there is no other option open other than success.

Acknowledgements

The Science Vision could not have been produced without the essential contribution from Europe's astronomical community at many different levels and the help and trust of the ASTRONET partners and of the European Commission.

Telescopes and Instrumentation

A view from inside
the dome of VLT UT2
(Kueyen)

Photo: H. H. Heyer, ESO