## Recommended Space Astronomy Road Map

A select group of future space astronomy missions has been identified in major studies by national scientific committees to be of the highest priority. Critical technologies and instrumentation for these missions have been brought to a high level of technical readiness. Though these missions do not provide complete coverage of the electromagnetic spectrum, the WG considers these missions to be the most feasible core of the near-term major space astronomy missions, and recommends this list as a Road Map for the next few decades.

JWST. JWST is a collaborative mission of NASA, ESA and the Canadian Space Agency (CSA). It is the only future large space astronomy mission already approved for development, with a planned launch in 2018. It was the highest priority programme recommended in the US National Academy of Sciences decadal survey in 2000 ("Astronomy and Astrophysics for the New Millenium"), and its central importance to astronomy was reiterated in the 2010 survey ("New Worlds, New Horizons"). With a combination of near- and mid-infrared imagers and spectrometers, JWST will provide unprecedented capability to study systems from the first galaxies that formed in the early Universe, to newly forming stars and planetary systems, and to bodies in our solar system.
**The WG recommends completion and launch of this major observatory as soon as possible. JWST is recognised to be the only new large space astronomy Observatory to be possibly operational in the next 10-20 years. It is an essential asset for space science investigations complementing "ground based".**

Euclid/WFIRST. Both ESA and NASA are currently evaluating missions to study dark energy: Euclid (ESA; dark energy and dark matter) and Wide-Field Infrared Survey Telescope (NASA; dark energy, exoplanets and near-infrared sky survey). The scientific goals of these missions have been recommended as being of the highest importance by the worldwide astronomical community. Euclid has been selected as an ESA M-Class mission; NASA is conducting a definition study for WFIRST. Possible collaboration has been discussed by the national agencies, but the situation is unclear at the time of this study.
**The WG believes it would best serve the interests of science and the community to have a single optimised mission or programme, combining the resources and technical capabilities of NASA and ESA. Canada, India, China, Russia and others could be added as partners.**

International X-ray Observatory (IXO). IXO has been extensively studied and reviewed as a collaborative NASA/ESA/Japan mission, now re-scoped by ESA as an L-Class candidate for the 2020-2025 time-frame, Athena, without NASA collaboration. The proposed IXO/Athena satellite, or a similar large high energy observatory, would be able to exploit a broad scientific scenario, possibly including investigation of the 'first stars' via a high-z γ-rays burst detection capability.
**The WG recommends development of a large X-ray space observatory, operative in the next decade.**

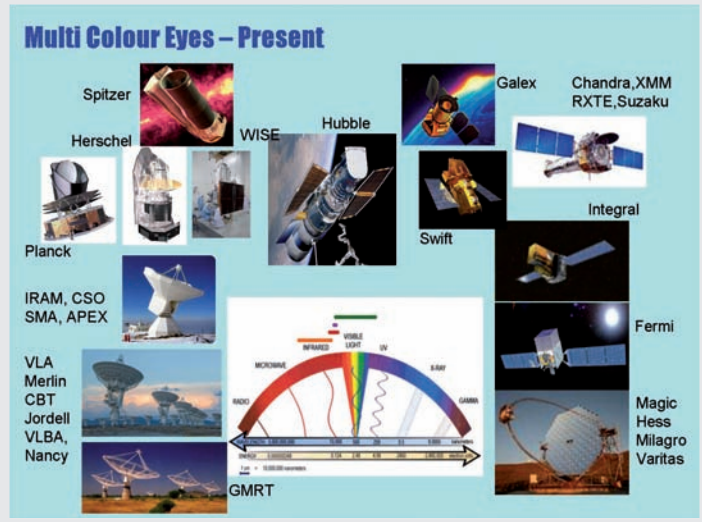
Large Interferometer Space Antenna (LISA). LISA is a pioneering gravitational wave mission, designed to open a new window on the cosmos. LISA has been extensively studied as a collaborative NASA/ESA mission, but, though highly ranked in the 2010 US Decadal Survey, programmatic constraints are preventing NASA from proceeding. The LISA Pathfinder mission is in development in Europe. ESA has re-scoped LISA as NGO, an L-Class mission candidate.
**The WG recommends that the agencies involved support, exploit and finalise the R&D programmes necessary to have in operation a gravitational wave mission at the latest in the time-frame 2025-2030. Even though the previous collaborative mission concepts for IXO and LISA are not feasible in the current ESA or NASA plans, the Working Group recommends that some multinational aspect of the missions be preserved to prevent significant loss of scientific capability.**

Space Infrared Observatory for Cosmology and Astrophysics (SPICA). SPICA is large aperture, cryogenically cooled far-infrared observatory studied as a collaborative JAXA/ESA/Canada mission. Contribution of an additional instrument was recommended by the US 2010 Decadal Survey, but may not be possible due to US programmatic constraints.
**The WG believes that a large aperture, cryogenically cooled far-infrared observatory is essential to bring about the major advance in sensitivity needed to continue investigation of the cold and dust obscured Universe.**

In the longer term, it is to be expected that detailed characterisation of Earth-like exoplanets, a major scientific priority, will require the stability and sensitivity afforded by a large space mission. Numerous UV/optical and infrared mission concepts have been proposed and studied.
**The WG recommends further technical development to bring the most promising approaches to readiness.**

**The WG also recommends that space-faring nations pursue robust cooperative programmes devoted to solving specific burning scientific questions via the implementation of multilateral medium and small size dedicated missions.**

In addition to the specific high priority near-term missions listed above, the WG compiled a list of additional missions of interest around the globe, some of which might be accomplished by 2030. Such missions are listed, by approximate size class, in section 3 of the Ubertini at al., ASR paper in press (2012).




Present panorama for ground and space large facilities.

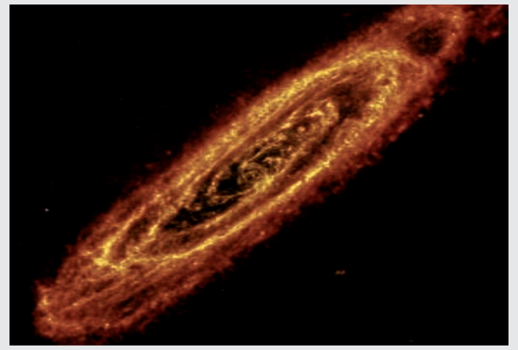

In the post 2020 scenario only JWST is actually planned and approved. In the high energy astrophysics domain the only foreseen Observatory Class Mission is IXO/Athena. This ESA lead mission is now under final selection process.

*Composite X-Ray/Infrared image of the Andromeda Galaxy: from the birth to the death of the stars*

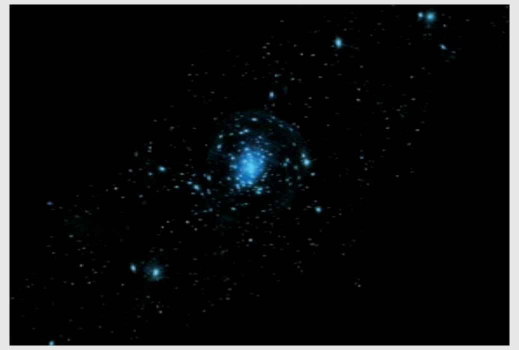

The best scenario. A few small/medium size missions are expected to be completed and placed in orbit. Current operative missions, like Chandra, XMM, INTEGRAL, SWIFT, etc. will hopefully be supported and in good hardware status in the future years. Few new entries are expected: ASTROSAT, Nustar, Astro-H, GEMS, e-Rosita etc.

### ANDROMEDA OBSERVED AT DIFFERENT WAVELENGHT

*Optical image of the Andromeda Galaxy. Credit: NASA/ESA/R. Gendler, T. Lauer (NOAO/AURA/NSF), and A. Field (STScI)*



*IR-Herschel image of the Andromeda Galaxy. Credit: ESA/Herschel - PACS/SPIRE/J. Fritz, U. Gent*



*XMM-Newton image of the Andromeda Galaxy. Credit: ESA/XMM Newton/EPIC/W. Pietsch, MPE*

# COMMITTE ON SPACE RESEARCH (COSPAR)

**Expanding the knowledge frontier of space for the benefit of humankind**

## COSPAR Working Group: Future of Space Astronomy

# A Global Road Map for the Next Decades

## EXECUTIVE SUMMARY

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9 March 2012

# Future of Space Astronomy: a Global Road Map for the Next Decades

## Executive Summary

Astronomers today have access to an impressive set of space missions and "ground based" observatories that gives them nearly continuous coverage of the electromagnetic spectrum from the γ-rays to the radio regions. But there is serious concern about the situation in the next 10 - 15 years, when current space astronomy missions will have ended and new missions will be much less numerous.

Astronomy is a difficult observational science requiring continuous and simultaneous access to the full electromagnetic spectrum to explore our complex Universe and to pursue answers to fundamental scientific questions. The history of space astronomy, especially the past three decades, has demonstrated clearly the importance and benefits of access to the γ-rays, X-ray, UV-optical, near IR and far-IR spectrum from space. To build on this success, continuing technical and scientific advances and commitment to space science on the part of the world's space agencies are going to be needed. It will be essential to complement the powerful "ground based" facilities that will soon be available, and to ensure that the next generation of astronomers has access to the whole spectrum.

To this end, COSPAR appointed the "Future of Space Astronomy" Working Group under the aegis of Commission E with the aim to analyze the difficult situation of space astronomy over the next two decades and recommend ways to improve the prospects.

Having assessed the scientific needs and the current plans of a number of space agencies worldwide, the Working Group identified some major concerns about the lack of a secured future plan. This study was conducted during the period April 2010 - April 2011. During this time and in the months following there were significant changes in the plans of multiple space agencies as they adjusted to programmatic realities in their countries. This Executive Summary reports the conclusions of the Working Group as of the end of the period of our discussions. We hope that our findings will remain of value as a vision statement in spite of the rapidly changing short-term circumstances.

*Prof. R. M. Bonnet, former COSPAR President and Prof. G. F. Bignami, COSPAR President*

*COSPAR scientific organization:*
*http://www.cospar2010.org/files/Finalprogramme-2010.pdf*
*http://cosparhq.cnes.fr/Scistr/Scistr.htm*

## Recommendations concerning international planning and implementation of large space astronomy missions

It is important to maintain the rate of fundamental scientific discoveries in space science that has been achieved in recent decades. This success will continue to derive from the ability to use spaceto access the full electromagnetic spectrum.

Large and powerful space astronomy missions have an outstanding track record of technical success, new discoveries, and long-lasting legacy science. In the future, such missions will continue to be essential to address key questions in astrophysics including the properties of dark matter and dark energy, gravitational wave astrophysics, the formation of the first stars, the evolution of galaxies like the Milky Way, the development of planetary systems, and the characteristics of exoplanets.

The astronomy community has developed methodologies to implement ambitious and powerful "ground based" observatories as multinational projects. It is necessary to bring about an equivalent paradigm for large space missions based on international cooperation and coordination. Without this, space agencies will implement only smaller scale and more fragmented projects. Whilst these will continue to be important and productive, without a balancing large-mission programme the overall outcome will be less effective, less competitive, and less successful scientifically.

Recent indications that major space agencies may adopt a go-it-alone policy with respect to large mission implementation are a concern. Such missions will not be as powerful as they could be if carried out as international projects, and may result in unnecessary duplication or not occur at all.

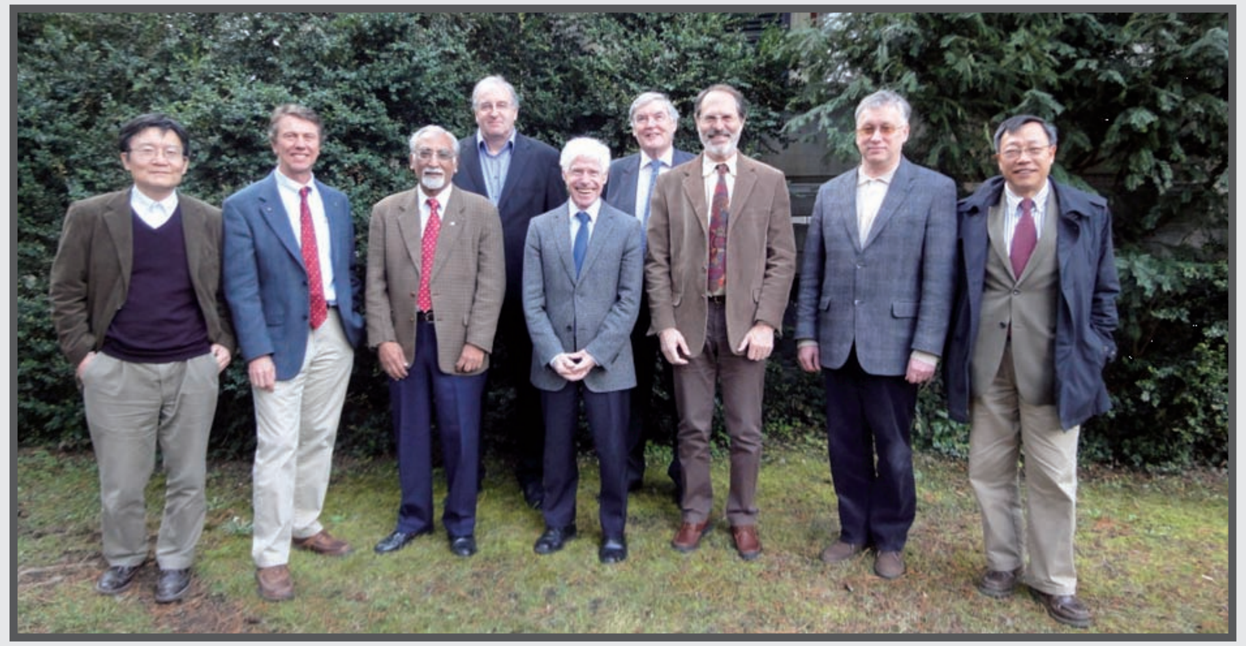
The international astronomical community, matured in the developed countries, is now spreading worldwide and is fertilizing the scientific environment and the intellectual life of newly developed countries. Participation in major international space missions is a great opportunity for developing nations, both to help make such endeavours possible, and to share in the technical and scientific benefits.

COSPAR and the IAU can play an influential role in promoting the involvement of developing countries in major missions, and should establish and pursue an active joint programme to foster increased international cooperation in the area of space astronomy.

Space agencies worldwide should develop a process for strategic planning that takes into account and exploits opportunities for international cooperation. Technical and programmatic challenges are inevitable, but must be overcome.

The scientific community at large must find ways to provide the necessary encouragement and support to space agencies, and to help create the conditions in which international cooperation can bring about a better scientific outcome for all.

We note that many of the ideas and conclusions of this report are reflected by Bonnet and Bleeker (A Dark Age for Space Astronomy? Science, 333, 161, 2011). Having reviewed the current situation and prospects, these authors propose a global equivalent of the Horizon 2000 programme which ESA successfully implemented over a 25-year period from the mid 1980s. This would involve inter-agency agreement on a long-term programme with defined large missions to be built within fixed budgets, and scope for additional smaller missions to be proposed and selected in a flexible manner. As a starting point, such a programme would require the establishment of an inter-agency coordination group to formulate a long-term programme for observatory-class missions. The Working Group regards this suggestion as one option that is quite consistent with the key conclusions of the COSPAR Working Group report.



### Working Group membership:

Pietro Ubertini, Italy (Chair) - Neil Gehrels, USA (Co-Chair) - Paolo De Bernardis, Italy - Ian Corbett, UK, and IAU General Secretary (IAU liaison) Matt Griffin, UK - Michael Hauser, USA - Nobuyuki Kawai, Japan - Marcos Machado, Argentina - Ravinder K. Manchanda, India - Mikhail Pavlinsky, Russia - Shuang-Nan Zhang, China

*Paolo De Bernardis, Michael Hauser, Marcos Machado*

## Road Map Principles

• The Working Group considers it essential to develop a space astronomy Road Map in the context of some important underlying principles:

• Science driven: pursue top priority science topics stemming from state-of-the art observations and theory, and set in a worldwide context;

• Observatory class missions: provide open access to the scientific community at large, preferably with data available with no more than a short turn-around time (6-12 months) after observations;

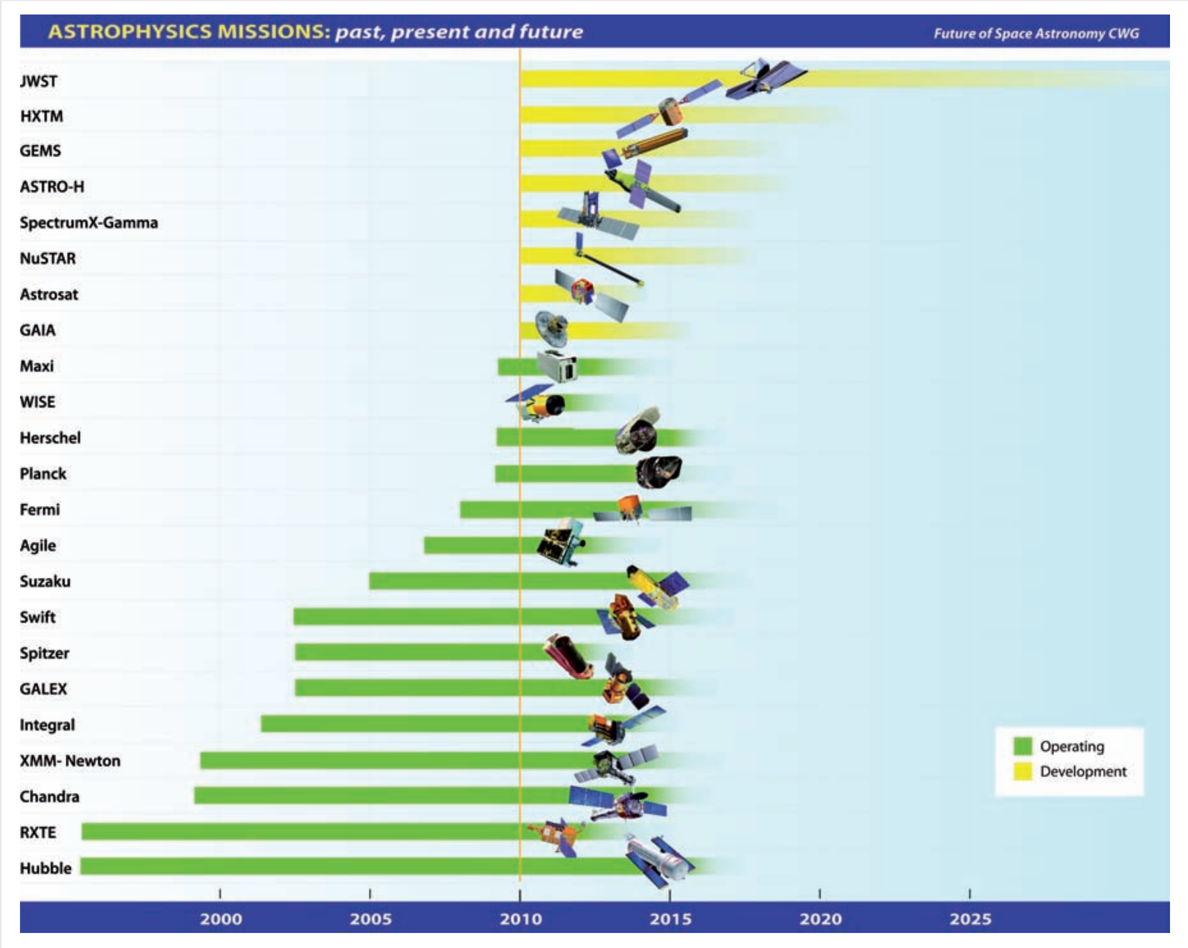
• Innovative enabling technology and cutting-edge scientific instrumentation: focus research and development support on innovative technologies and instrument concepts driven by science requirements for future observatory-class missions;

• Technology development: national agencies and scientific councils support research and development programmes to advance the Technical Readiness Level of mission-critical elements to flight-ready status early in mission preparation;

## Conclusions

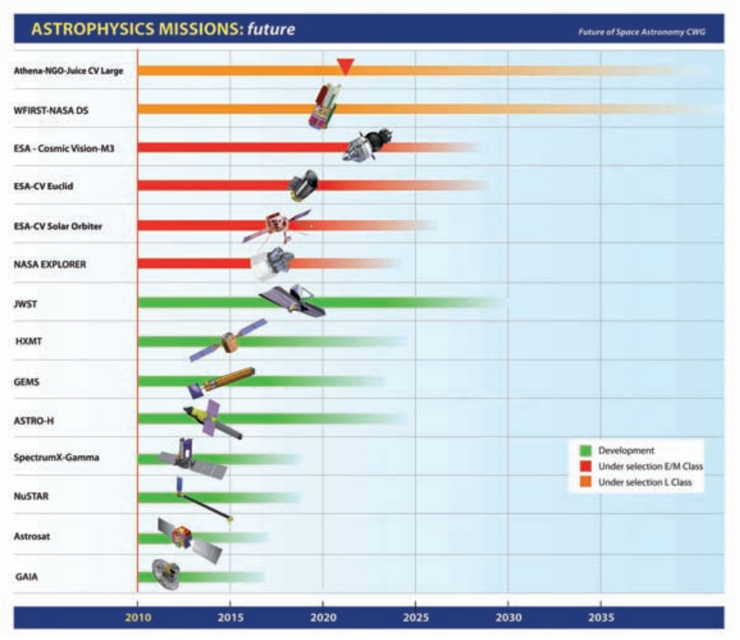
The Working Group members and all who have worked on or participated in the year long activity that resulted in the COSPAR Working Group report have been aware of the extraordinary "golden age" which astronomers have experienced in the last decade, with unique and great opportunities for science. The use of space-borne observatories continues to play a key role in the advance of astronomy and astrophysics by providing access to the entire electromagnetic spectrum from radio to high energy γ-rays. The existence of an impressive fleet of space observatories complemented by "ground based" facilities has given the worldwide scientific community an incredible opportunity to make spectacular advances in our knowledge of the Universe. The open availability of existing and future datasets from space and "ground based" observatories facilitates powerful and relatively inexpensive collaboration to address problems that can only be tackled by the application of extensive, multi-wavelength observations. Unfortunately, the future panorama, with only a few main space missions planned, requires remedial global action to correct this negative trend, to ensure positive prospects for future research, and to avoid a "dark age" for space astronomy.

We conclude that the size, complexity and costs of large space observatories must place a growing emphasis on international collaboration and multilateral cooperation. Although this poses technical and programmatic challenges, these challenges are not insurmountable, and the great scientific benefits will be a rich reward for everyone.




*Missions in operation with projected lifetime (Green), and Missions under development (Yellow) with scheduled launch date indicated by the S/C position*

| MISSION | Details: in Operation |
|---|---|
| HST 1990 | (NASA/ESA) Observatory mission: 2.4m telescope, imaging/spectroscopy of galactic and extragalactic sources |
| Rossi XTE 1995 | (NASA) Timing and broadband spectroscopy of compact X-ray sources (2-250 keV) |
| CHANDRA 1999 | (NASA) X-ray Observatory mission. High resolution imaging and spectroscopy in the soft X-ray range |
| XMM-Newton 1999 | (ESA) Observatory mission. High throughput spectroscopy and imaging in the soft X-ray range |
| INTEGRAL 2002 | (ESA) high resolution Imaging and spectroscopy in the soft γ-Ray range from 20 keV to 10 MeV |
| GALEX 2003 | (NASA) Galactic Evolution Explorer. UV all-sky survey mission |
| Spitzer 2003 | (NASA) Observatory Infrared Telescope Facility. IR telescope of 0.85 m aperture |
| Swift 2004 | (NASA/UK/Italy) Medium Explorer. Γ-ray burst detection with X-ray and optical telescopes for rapid follow-up |
| Suzaku 2005 | (Japan/NASA) X-ray and hard X-ray telescopes |
| AGILE 2007 | (ASI) high energy γ-ray mission |
| Fermi 2008 | (NASA/DOE/France/Germany/Italy/Japan/Sweden) High energy Γ ray telescope |
| Planck 2009 | (ESA) M-mission to study the spectrum and anisotropy of the diffuse MW cosmic background radiation |
| Herschel 2009 | (ESA) Observatory, 3m Cassegrain telescope, high throughput heterodyne and far IR spectroscopy and imaging |
| MAXI 2009 | (JAXA) experiment on ISS for X-ray sky monitoring and survey |
| MISSION | To be launched |
| Gaia 2013 | (ESA) 3-D mapping of the stars of the Galaxy |
| ASTROSAT 2012-2013 | (ISRO-INDIA) multi-wavelength astronomy mission from visible (320-530 nm) to hard X-ray (3-80 keV and 10-150 keV) |
| NuSTAR 2012 | (NASA) SMEX mission for hard X-rays with a focusing telescope |
| SRG 2013 | (Roscosmos) The Specturm X- Gamma - eRosita experiment |
| Astro-H 2014 | (JAXA-NASA) X-ray mission for high resolution spectroscopy and hard X-rays |
| GEMS 2014 | (NASA) SMEX X-ray polarization mission |
| HXMT 2015 | (China Space Agency) Hard X-ray Modulation Telescope (1-250 keV) |
| JWST 2018 | (NASA/ESA) Observatory, IR 6.5m mirror telescope sensitive from 0.6 to 27 micrometers |




*Missions under development (Green), Explorer/Medium class missions under selection processes from ESA and NASA (Red) and the Observatory class mission proposed by the NASA Decadal Survey (DS) and the ESA L-Class mission scheduled for a launch in 2021 (Orange).*