AXRO 2016
BOOK OF ABSTRACTS

Contents

AXRO Introduction and Historical Background

Rene Hudec

AXRO introduction and historical hackground will be given with short summary of past and recent efforts in the field if astronomical X-ray optics in the Czech republic.

Space activities in the Czech republic

Vaclav Kobera

ATHENA Phase A System Studies Status Update

Ivo Ferreira

ATHENA has recently been selected for the 'L2' slot in ESA's Cosmic Vision Programme, with a mandate to address the 'Hot and Energetic Universe' Cosmic Vision science theme. The mission is currently in Phase A, with a view to formal adoption after a successful System Requirements Review. This presentation will describe the reference mission architecture and spacecraft designs currently under elaboration during Phase A of the study by the ESA Concurrent Design Facility (CDF), in response to the technical requirements and programmatic boundary conditions. The main requirements and their mapping to resulting design choices will be presented, at both mission and spacecraft level. An overview of the spacecraft design down to subsystem level will then be presented, touching upon the critically-enabling technologies where appropriate. Particular emphasis will be placed on the design choices made in response to the angular resolution requirements of the telescope (5" Half-Energy Width), and the challenges related to accommodating the large mirror and payloads. Finally, a programmatic overview will be given of the on-going assessment/definition phase (A/B1), including the technology development effort, and the challenge to fit ATHENA within the L-class mission Cost-at-Completion limit.

Status of the Athena optics development

Marcos Bavdaz

The Athena mission builds on the use of advanced X-ray optics, providing large effective area, good angular resolution, low mass and cost effective implementation. The Silicon Pore Optics technology has been selected for Athena, a technology under development by ESA and its industrial and institutional partners. The presentation will provide an overview of the technological preparation activities and the status of the technology.

The THESEUS mission concept

Lorenzo Amati

The Transient High Energy Sky and Early Universe Surveyor (THESEUS) is a mission concept under development by a large international collaboration aimed at exploiting Gamma-Ray Bursts for investigating the early Universe and monitoring the X-ray sky with an unprecedented combination of deep sensitivity and large field of view. These goals will be achieved through a unique combination of instruments allowing GRBs and X-ray transients detection and arcmin localization over a broad FOV (more than 1sr) and an energy band extending from several MeVs down to 0.3 keV with unprecedented sensitivity, as well as on-board prompt (few minutes) follow-up with a 0.6m class IR telescope with both imaging and spectroscopic capabilities. THESEUS is thus perfectely suited for detecting, locating and identifying the electromagnetic counterparts to sources of gravitational radiation, which may be routinely detected in the late '20s / early '30s by next generation facilities like aLIGO/aVirgo, eLISA, KAGRA, ILIGO, Einstein Telescope, Cosmic Explorer.

JEUMICO: Bavarian-Czech cooperation on X-ray optics

Thorsten Döhring

Within the project JEUMICO, an acronym for "Joint European Mirror Competence", the Aschaffenburg University of Applied Sciences and the Czech Technical University in Prague started a cooperation to develop mirrors for X-ray telescopes. This bilateral project is jointly funded by the Bavarian State Ministry of Education, Science and the Arts and the Ministry of Education, Youth and Sports of the Czech Republic. The X-ray telescopes developed within this Bavarian-Czech project is using an optical design of Lobster-Eye type. The corresponding individual mirror segments are based on substrates of flat silicon wafers which are coated with thin iridium films, as this material is promising high reflectivity in the X-ray range of interest. After integration of the produced prototype mirrors into mirror modules measurements of their optical performance are planned at an X-ray test facility.

The AHEAD Joint Research Activity on X-ray Optics

Vadim Burwitz

In the EU funded AHEAD consortium a Joint Research Activity on X-ray Optics was set-up to study different X-ray optic technologies. This includes measurements of different X-ray optics and a comparison the result with simulations. Also work on developing and implementing a parallel (collimated) X-ray beam for testing Athena type mirror modules. Further activity includes on preparing a publicly available ray tracing package is for X-ray optics.

The eROSITA X-ray Telescope: Design, Development, Manufacturing, Test and Calibration

Peter Friedrich

eROSITA's X-ray telescope consists of 7 co-aligned mirror assemblies, each with 54 nested Wolter-1 electro-formed mirror shells and an X-ray baffle made of concentric invar foils. After a development phase of several years the mirror modules were manufactured from 2011 to 2013. The optical performance of each mirror module was tested in MPE's X-ray test facility PANTER: the on-axis resolution is ca. 15-16 arcsec HEW. The final calibration, including a precise measurement of the focal length (< 0.1 mm), was finished in June 2016. Subsequently, the 7 best modules, together with their associated cameras, were integrated into the telescope structure.

The Soft X-ray Imager (SXI) on SMILE

Steven Sembay

The Soft X-ray Imager (SXI) is a Lobster-eye telescope on the forthcoming ESA-CAS Solar wind Magnetosphere Ionosphere Link Explorer (SMILE) mission, due to be launched in 2021. The SXI optical system is an array of micropore optic (MPO) plates, the technology of which is being developed as a collaboration between the University of Leicester, UK, and the manufacturer, Photonis France SAS. We describe the configuration of the SXI optical and detector systems and the science goals of the SXI within the context of the SMILE mission. The SXI consortium is is led by the United Kingdom with proposed contributions from a number of European and external partners including the Czech Republic.

eROSITA in SRG

Peter Predehl

eROSITA, the primary instrument on the Russian-German Mission SRG, is completely calibrated, assembled and tested, now ready for shipment to Russia.

Achievements on ultra-precise optical elements for Synchrotron and FEL application, their metrology and deterministic surface finishing

Frank Siewert

Photon sources of 3rd and 4th generation synchrotrons as well as upcoming facilities like the European XFEL will require ultra-precise optical components to collimate and focus highly brilliant photons under preservation of coherence and wave front from its source to the experiment. These optical components of flat, toroidal, elliptic or parabolic shape feature nanometre accuracy on a macroscopic length scale. In the challenging case of the European XFEL the heat load on these mirrors ranges from several Watts in the time average to many kW during FEL pulse trains on the millisecond time scale. The maximum peak-to-valley figure error allowed for the first two plane distribution mirrors at the XFEL is less than 3 nanometers peak to valley along the entire aperture length of 800mm [1] to enable a wave front preserving transport of photons along very long distances (up to 1km in length) from its source in the undulator section to the experimental hall. Thus it is mandatory these optics to be inspected by use of metrology devices of comparable precision before and after surface finishing as well as in the mounted state before installation at the beamline. The topography of these mirrors will be inspected by use of slope measuring de-flectometry [2]. This contribution will give an overview on the state achieved on the field of metrology as well on recently provided optics including a discussion on optics distortion caused by clamping.

Use of ion beam and RF sputter cleaning as a surface treatment for X-Ray optics

Lenka Mikulickova

We compare the methods of ion beam etching/milling and RF sputter cleaning with regard to their application in production of grazing incidence X-ray optics. We studied its effects on smooth surfaces and its potential for achieving low microroughness. The sample surfaces were measured by atomic force microscopy and X-ray reflectometry.

X-ray Surveyor optical designs and development of adjustable X-ray optics

Paul Reid

X-ray Surveyor (XRS) is a NASA mission concept that will succeed the Chandra X-ray Observatory, providing the same half arc sec imaging of Chandra while also providing 30 to 50 times the effective area at 1 keV. With a suite of new instrumentation, XRS will both complement Athena and also transform high resolution X-ray astronomy. We present several "trade" designs developed for XRS, showing expected area and off-axis performance as a function of mirror diameter and focal length. We also present current status in the development of adjustable X-ray optics, a candidate technology for the XRS mirrors.

Preparing for the Future: NASA's Planning for the Decadal Survey

John Nousek

Paul Hertz, Director of NASA's Astrophysics Division, has publicly presented his evolving strategy to advance astrophysics through a carefully articulated plan covering the next five years (2016-2020). Highlights of this plan include a CAA assessment of NASA's execution of the last Decadal Survey (New Worlds, New Horizons), and the associated technology development and program solicitation opportunities, which will define how future missions after the James Webb Space Telescope will be created.

Prospects for high-throughput X-ray Astronomy in the next decade

Marco Feroci

In this paper I will review the current developments in Europe, China, Russia and US in the field of high-throughput spectral-timing. In particular, I will present the mission concepts LOFT, eXTP, STROBE-X and MVN-M2.

Development and tests of novel X-ray optical system for space applications

Ladislav Pina

This work addresses the issue of X-ray monitoring for astrophysical applications. A novel approach based on the use of 1D and 2D "Lobster eye" optics in combination with Timepix X-ray detector in the energy range 3 - 40 keV was proposed. Such wide-field optical system has not been used in space yet. Designed wide-field optical system combined with Timepix X-ray detector is described together with experimental results obtained during laboratory tests. Proposed project includes theoretical study and a functional sample of the Timepix X-ray detector with multifoil wide-field X-ray "Lobster eye" optics. Using optics to focus X-rays on a detector is the only solution in cases where intensity of impinging X-ray radiation is below the sensitivity of the detector, e.g. while monitoring astrophysical objects in space, or phenomena in the Earthś atmosphere. The optical system is considered to be used in a student rocket experiment.

Development of Ir-coatings for thin X-ray mirrors: dependencies and challenges

Anne-Catherine Probst

Upon the improvement of collecting area and angular resolution, light-weight is required for future astronomical X-ray telescopes. Using thin segmented X-ray mirrors is one possibility to realize light-weight telescopes. However this induces to consider new aspects during the development of X-ray mirrors. While the X-ray reflectivity is given by the coating and the surface micro-roughness of the substrate, the angular resolution is correlated to the shape of the mirror. This shape is given both by the initial shape of the mirror's substrate (e.g. after a slumping process) and by the deformation induced by the coating stress. Beyond the density and micro-roughness of the coating, coating stress is therefore an important feature which has to be considered while developing coatings for X-ray mirrors. We are using a sputtering process to perform the deposition of Iridium coatings on thin mirror's substrates. This process offers a wide variety of parameters influencing the coating's properties. Results on the influence of the sputtering pressure will be presented together with the challenges of the characterization of coating stress.

Additive manufacturing and high resolution X-ray optics

Carolyn Atkins

Additive manufacturing has quickly become a 'go-to' technology for complex structures that cannot be fabricated via traditional methods. With continued investment and existing commercial availability, the technology is well placed for cost effective, large batch production of complex components. Research into additive manufactured optical components is becoming increasingly common and therefore consideration of the technique towards astronomical X-ray optics is not unfounded. This presentation will introduce a two year fellowship study to research additive manufacturing, without initial bias of material or print method, towards high resolution X-ray optics for astronomy. The advantages and disadvantages of the technique will be discussed and an initial experimental outline presented.

Biomimetics and X-ray Optics

Rene Hudec

The principles of biomimetics were succesfully applied in astronomical X-ray optics in the past and recently, e.g. in Lobster-Eye optical systems. However, the recent growing knowledge of sea vision, especially of peculiar mirror eyes of scallops, crustaceans, and deep sea fishes, makes possible to consider other such applications. Perhaps the most important new discovery is deep sea fish Rhynchohyalus natalensis with mirror eyes based on very large numbers of very small mirrors developed from the choroidal argentea with crystals oriented almost parallel to the mirror's surface. This arrangement may even include principles of active optics. We report on ongoing study with focus on understanding of very specific mirror eyes of sea animals and how they may help us to design and develop special optics for scientific applications. We study the ways these mirror eyes work, what are the advantages of these peculiar eye arrangements, and whether these optics can be used in advanced devices, e. g. space and X-ray optics. I will briefly present and discuss the preliminary results.

From VZLUSAT-1 nanosatellite to x-ray telescope rocket experiment

Vladimír Dániel

The presentation summarizes the activities of the VZLUSAT-1 nanosatellite x-ray team deal with miniaturized x-ray telescope onboard nanosatellite VZLUSAT-1. At present the team is participating with x-ray telescope based on the rocket experiment in USA.

Miniaturized X-ray telescope for VZLUSAT-1 nanosatellite with Timepix detector

Tomáš Báča

We present the application of a Timepix detector on the VZLUSAT-1 nanosatellite. Timepix is a compact pixel detector (256×256 square pixels, 55×55 μm each) sensitive to hard X-ray radiation. It is suitable for detecting extraterrestrial X-rays due to its low noise characteristics, which enables measuring without special cooling. This project aims to verify the practicality of the detector in conjunction with 1-D Lobster-Eye optics to observe celestial sources between 5 and 20 keV. A modified USB interface (developed by IEAP at CTU in Prague) is used for low-level control of the Timepix. An additional 8-bit Atmel microcontroller is dedicated for commanding the detector and to process the data onboard the satellite. We present software methods for onboard post-processing of captured images, which are suitable for implementation under the constraints of the low-powered embedded hardware. Several measuring modes are prepared for different scenarios including single picture exposure, solar UV-light triggered exposure, and long-term all-sky monitoring. The work has been done within Medipix2 collaboration. The satellite is planned for launch in April 2017 as a part of the QB50 project with an end of life expectancy in 2019.

Micro-channel plate optics for the SVOM MXT

Charly Feldman

The SVOM MXT is a narrow field lobster eye telescope designed for the detection and accurate location of gamma ray bursts (GRBs) very soon after the initial GRB trigger. The mirror comprises of an array of square pore micro-channel optics (MPOs) which are slumped to a spherical radius of 2m giving a focal length of 1m. We present results from the ongoing X-ray tests of the baseline design MPOs performed at the University of Leicester (UoL). Examples shown include several MPOs which have been slumped and mounted on a breadboard frame, and other samples tested flat in a point-to-point focusing mode as part of a step-by-step process study. Some of the plates were tested as bare glass and others after coating with Iridium or Platinum. In addition we present details of modelling and analysis which reveals the factors that limit the angular resolution and characteristics of the point spread function (PSF) and the efficiency/collecting area of the MPOs with and without the coating with high-z material.

Determination of the eROSITA PSF

Konrad Dennerl

An accurate knowledge of the Point Spread Function (PSF) of the eROSITA mirror assemblies is crucial for the success of the eROSITA mission. Obtaining the PSF over the full field of view, over the full energy range, and for all of the seven mirror assemblies, however, is challenging in many respects. The talk will describe these challenges and their solutions, and will present the results.

MEMS X-ray optics for the ORBIS mission

Yuichiro Ezoe

A light-weight and high-resolution telescope based on MEMS (Micro Electro Mechanical Systems) technologies is being developed for future astronomy and planetary exploration missions. The optical system, composed of two spherically bent silicon wafers having a number of curvilinear micro pores, works as a Wolter type-I telescope. Because of the thin silicon wafers, this optical system can be one of the lightest X-ray optics and can achieve high angular resolution at short focal length, even though it is a conical approximation. We have verified X-ray reflection and imaging for the first time with this method. This telescope will be onboard a Japanese micros satellite mission ORBIS.

Science with X-ray Surveyor

Douglas Swartz

X-ray Surveyor is a Concept Study intended to aid the 2020 Astrophysics Decadal Survey Committee in formulating their recommendation for the priorities for NASA's large strategic mission portfolio. The study is led by a community-selected Science and Technology Definition Team charged to deliver a scientifically compelling and technically executable concept. I will provide a brief overview of the current status of the Study and highlight some of the key Science Questions that will drive the technology needs of X-ray Surveyor.

Scientific Capabilities of the X-ray Surveyor Optics

Dan Schwartz

Unique features planned for the X-ray Surveyor mission optics are the combination of half arcsecond resolution with very large collecting area, and the use of Wolter-Schwarzchild optics to optimize the off-axis response. The latter is especially important to enable efficient surveys with the greatest possible sensitivities. We will present simulations illustrating some of the breakthrough science which can only be achieved via X-ray observations.

A Suborbital Soft X-ray Polarimeter

Herman Marshall

I will describe a design for a soft X-ray polarimeter that can obtain a significant detection of linearly polarized X-rays in a suborbital rocket flight. The method uses critical angle transmission (CAT) gratings developed at MIT, laterally graded multilayer coated mirrors, and the usual focussing optics and CCD detectors. The primary target is an extragalactic source, Mk 421, which is bright enough in the 0.2-0.3 keV band for a detection at the 10% level. Other potential targets include isolated neutron stars and nearby black hole binaries in outburst.

Using Swift to Find Gravitational Wave & Neutrino Sources

John Nousek

The Swift Gamma-Ray Burst Explorer has reinvented our understanding of gamma-ray bursts by discovering and localizing more than 1000 bursts. Now that we have the first detections of gravitational waves and sensitive astrophysical neutrino detectors we can discover their sources using the highly flexible, rapidly responsive and wide wavelength coverage of the Swift instruments. We have developed special operations to allow Swift to rapidly conduct hundreds of short observations to detect counterparts within the large and unusually shaped error regions resulting from these non-electromagnetic signals. I describe the new process and our plans for followup using Swift.

Elements of Black Hole Astrophysics in the Era of New Instruments

Vladimír Karas

We will briefly review foundation principles of classical (non-quantum) black hole astrophysics that stay valid and relevant in the context of new instrumentation, such as gravitational wave detectors (LIGO), high-resolution imaging (EHT, GRAVITY), and X-ray polarimetry (XIPE, eXTP).

Consequences of Cosmic Ray Acceleration in Supernova Remnants on their Evolution - the Case of RX J0.852.0-4622 (Vela Jr)

Aschenbach Bernd

Galactic cosmic rays are generally assumed to be accelerated in supernovae and their remnants. The acceleration of the particles is attributed to their repeatedly interaction with the supernova remnant shock front. Model calculations have shown that a significant fraction of the supernova explosion energy can be converted to energy of cosmic rays. The feedback of this large energy transfer on the dynamical evolution and its impact on the age estimates of supernova remnants is addressed. True ages might be significantly lower than the standard Sedov ages. The impact is described by a quantitative model, which is tested on RX J0852.0-4622 (Vela Jr). Independent of this test conclusions are drawn about the evolution and lifetime of shell-type X-ray synchrotron sources and TeV gamma-ray sources.

Photoionized plasmas induced by intense EUV and X-ray pulses from laser-produced plasmas equipped with dedicated reflective collectors

Andrzej Bartnik

In this work low temperature, photoionized plasmas were created in gases irradiated with a focused EUV or soft X-ray (SXR) beam from laser-plasma sources employing 10 Hz Nd:YAG laser systems (0.8 J/ 4 ns and 10 J/ 1-10 ns) or the PALS laser system (600 J/ 0.3 ns). EUV radiation created using the 0.8 J Nd:YAG laser was focused using a gold-plated grazing incidence ellipsoidal collector in the wavelength range $\lambda = 9 \div 70$ nm. The most intense emission was in the relatively narrow spectral region centred at $\lambda = 11 \pm 1$ nm. In case of the 10 J Nd:YAG laser SXR/EUV radiation was focused using a gold-plated grazing incidence multifoil collector in the wavelength range $\lambda = 5 \div 70$ nm or the paraboloidal collector optimised for the wavelength range $\lambda \geq 1$ nm. The most intense emission was in the $1 \div 15$ nm spectral region. In case of the PALS system the paraboloidal collector was employed. Different gases were injected into the vacuum chamber, perpendicularly to an optical axis of the irradiation system at the focal region, using an auxillary gas puff valve. Irradiation of the gases resulted in ionization and excitation of atoms/molecules. Spectra in SXR/EUV range were measured using a grazing incidence, flat-field spectrometer (McPherson Model 251), equipped with a 450 lines/mm toroidal grating or a home-made spectrograph based on the 5000l/mm transmission grating. Optical spectra were recorded using the Echelle Spectra Analyzer ESA 4000. In all cases the most intense emission lines were assigned to singly charged ions, however, lines corresponding to ions with higher charge were also recorded. In case of molecular gases the EUV spectra contained lines corresponding to singly or doubly charged ions. In optical range mainly molecular spectra were obtained. Based on spectral lines originating from ions electron temperature was estimated. Molecular spectra allowed for estimation of vibration and rotational temperatures.

Role of Magnetic Field in Black Hole QPOs

Arman Tursunov

We suggest two separate models related to the explanation of the high frequency quasi-periodic oscillations (HF QPOs) observed in the low-mass X-ray binary systems possibly containing black holes or neutron stars. The frequencies of QPOs from such sources as GRS 1915+105, XTE 1550-564 and GRO 1655-40 are expected to have a unique mechanism for their formation as they come in pairs of the upper and lower frequencies of twin peaks in the Fourier power spectra. The first model which I am going to present is a simplified model of the generation of observable frequencies by the charged particles in the vicinity of magnetized black holes. Assuming relevance of resonant phenomena we investigate the role of magnetic field on the oscillatory frequencies of charged particles and demonstrate that for properly chosen values of relevant parameters of the models one can fit the observational data for all three QPO sources. Second model describes the dynamics and oscillations of string loops, which are the extended 2D objects carrying electric current. Combined effects of the gravity and magnetic field allow the string loop model to fit the observed QPOs. I will show that the role of even weak magnetic field cannot be neglected. Strictly chosen values of the relevant parameters of both models during the fitting procedure allow us to estimate the strength of magnetic field in the vicinity of corresponding sources.

Age and Distance of Puppis A revised - the Supernova Remnant of the 'Star of Bethlehem'

Aschenbach Bernd

Combining the proper motions of the northeast moving oxygen-rich filaments (Winkler et al., 1988 [1]) and the southwest moving neutron star (Becker et al., 2012 [2]) the position of the supernova explosion site and the age of the supernova remnant Puppis A are determined. The filaments are assumed decelerating non-radially but axi-symmetrically. The age is 1990 ± 150 yrs. Historical records are checked for a supernova including the 'Star of Bethlehem'. Reviewing the soft X-ray absorption column densities the distance to Puppis A is likely to be ∼1.3 kpc. The apparent visible magnitude of the Puppis A supernova is estimated to -7.

First results from the use of the X-ray reverberation model in XSPEC

Maria D. Caballero-Garcia

X-ray reverberation mapping has been revealed to be a valuable tool for knowing the physical condition of the accreting black holes and the matter that surrounds them. This is an important case of interest for the exploitation of the data from the next generation of big X-ray satellites (i.e. Athena). A new model has been developed for the use of X-ray astronomical data, mainly through both timing and spectroscopy techniques. Here we present this new XSPEC model and some preliminary results obtained by using it.

X-ray astronomy with LOBSTER

Vojtech Simon

We show and discuss the astrophysical aspects of observing the X-ray sky with the planned lobster-eye telescope. This proposed instrument is able to provide wide-field imaging in X-rays. For the testing observations, we propose to observe X-ray binaries (mostly persistent sources) in which matter transfers onto the compact object (mostly the neutron star) from its companion. We show the typical X-ray spectra and the features of the long-term activity of such objects. Observing in the soft X-ray band (energies of at most several keV) is the most promising because the X-ray intensity is the highest in this band. We also show that the X-ray activity can vary for the individual energy bands. Since these sources tend to accumulate toward the center of our Galaxy and in the vicinity of the galactic plane, it is sufficient to monitor these areas.

CTU participation in the AHEAD Project

Rene Hudec

The CTU participation in the AHEAD Project will be shortly presented and discussed, with emphasis on design and development of KB test module for X-ray tests at PANTER.

Lobster Eye X ray Telescopes

Rene Hudec

A short overview of astronomical Lobster Eye X Ray telescopes will be given.

Image processing from x-ray 1D and 2D Lobster eye optics

Ondrej Nentvich

Lobster Eye (LE) optics is suitable for X-Ray all-sky monitoring, because of a wider field of view. Observation output is usually an image with the objects as dots in the sky. Two-dimensional LE system can achieve similar output with Schmidtś arrangement. The disadvantage is in lower reflectivity compared to the one-dimensional LE system. One dimensional optics can be used, but the same object has to be taken two times - horizontally and vertically. These two images are necessary to process into a 2D image using mathematical algorithms. The problem is with multiple objects in the reconstructed image. The poster talks about possibilities how this issue solve.

Reflective coating layers for X-ray optics

Veronika Stehlikova

In the field of X-ray astronomy, grazing-angle based optics are used. A significant part of such optics design is type and quality of reflective coating layers. This poster compares reflectivity and other properties of iridium and golden layers, which are going to be used in optics for a rocket experiment.

New possibilities in the detection of X-ray spectra and images

Martin Urban

X-ray monitoring for astrophysical applications mainly consists of two parts - optics and detector. The poster shows an approach based on a combination of Lobster Eye optics with Timepix detector. Proposed setup using Timepix read-out and addition signal from a common electrode of pixel detector. This arrangement with two 2D LE optics designed in the energy range 1 - 3 keV and 3 - 30 keV allows to detect multiple X-ray sources and measured their spectra.

Aschenbach Bernd - PR Vaterstetten
Lorenzo Amati - INAF - IASF Bologna
Carolyn Atkins - UK Astronomy Technology Centre (STFC)
Tomáš Báča - Czech Technical University in Prague
Andrzej Bartnik - Military University of Technology
Marcos Bavdaz - ESA/ESTEC
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