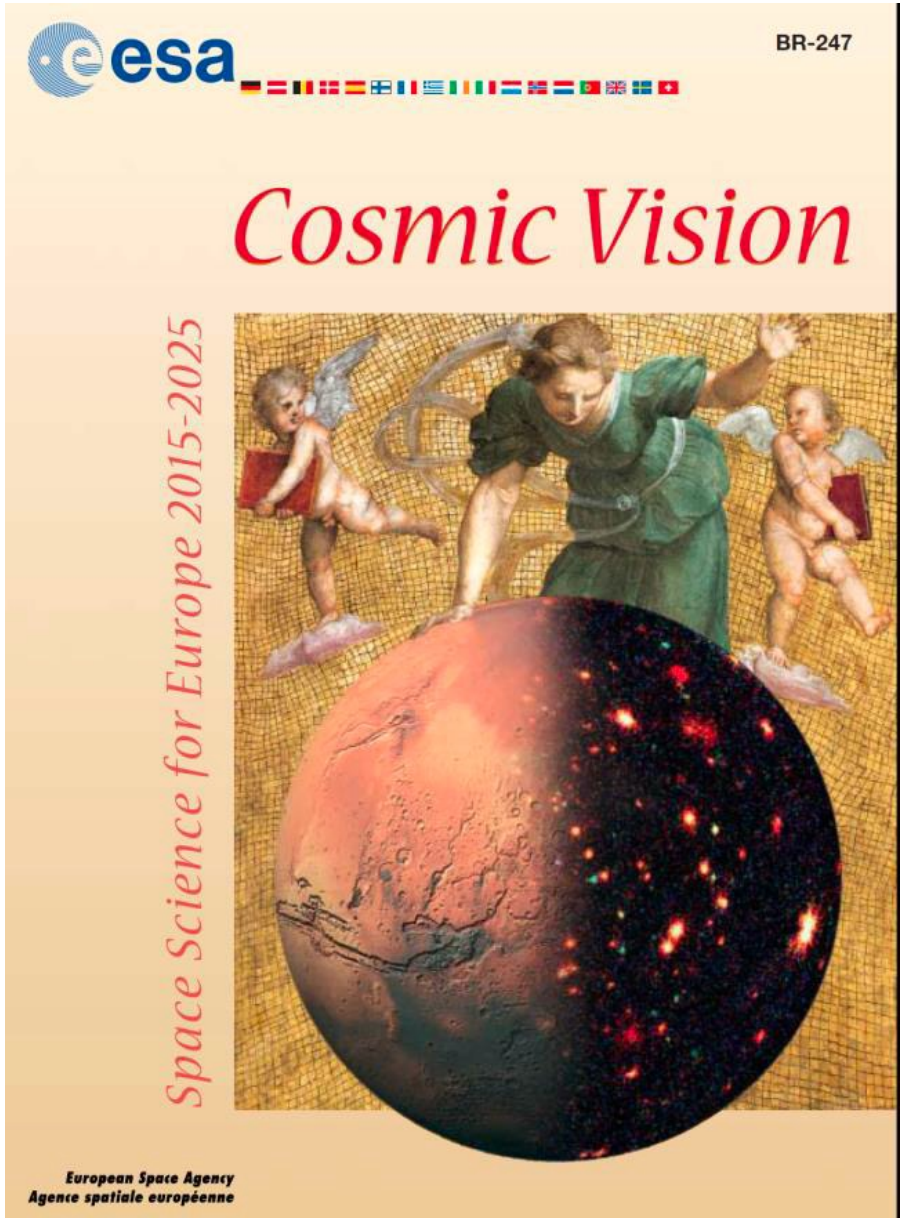
The WFM (Wide Field Monitor) onboard eXTP (enhanced X-ray Timing and Polarimetry mission)

Technological Status in Spain

Margarita Hernanz - on behalf of the Spanish eXTP collaboration

Institute of Space Sciences (ICE - CSIC and IEEC) - Barcelona (Spain)

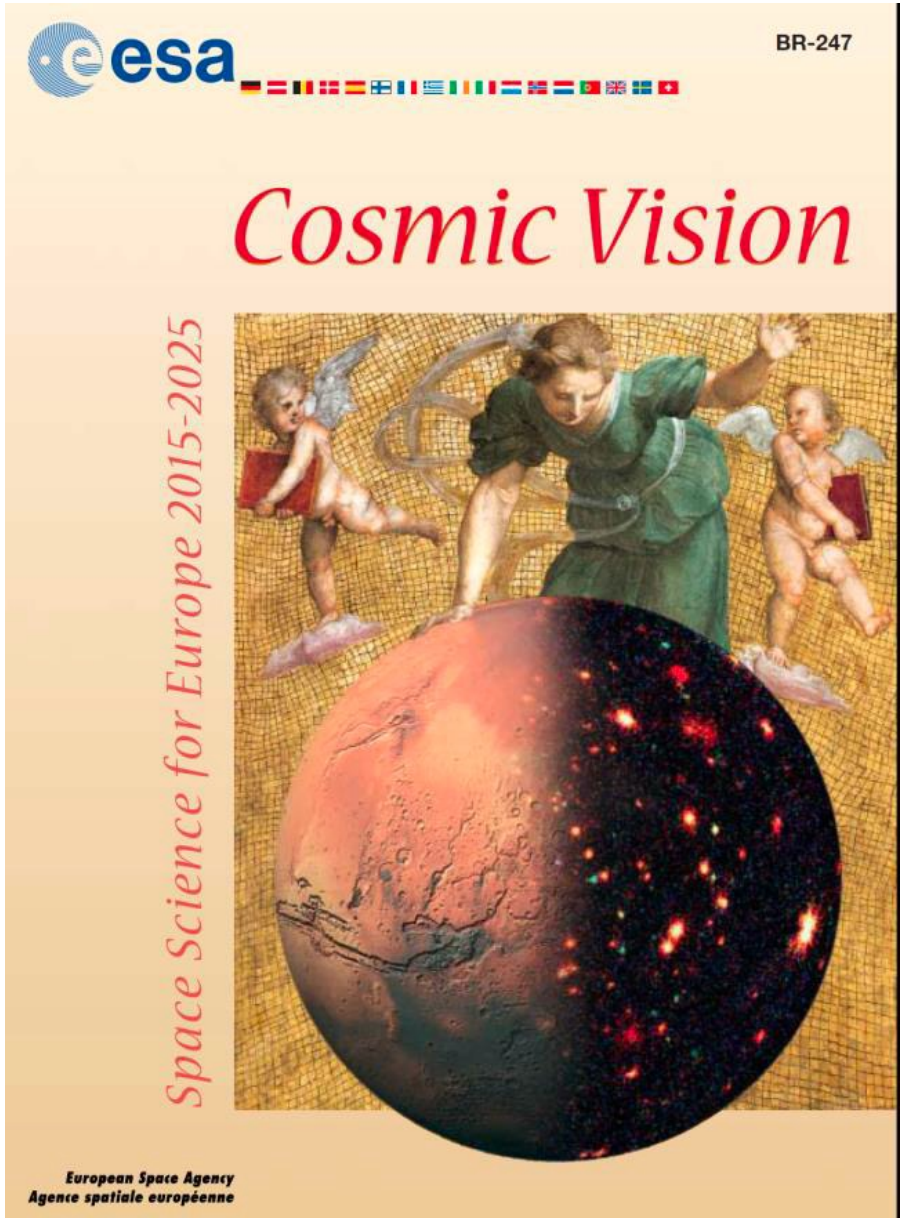


Cosmic Vision 2015-2025 from ESA addressed four main questions of research across Europe and worldwide concerning the Universe and our place in it

3. What are the fundamental physical laws of the Universe?

3.3 Matter under extreme conditions

Probe gravity theory in the very strong field environment of black holes and other compact objects, and the state of matter at supra-nuclear energies in neutron stars



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Compact objects - black holes, neutron stars – are excellent laboratories for fundamental physics

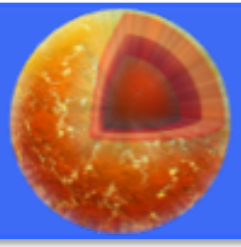
- strongest densities, gravitational fields, magnetic fields
- conditions not reachable in terrestrial labs

X-ray emission produced where material falls in a strong gravitational field - compact stars (NSs, BHs) → X-ray observations with high-time-resolution provide a unique tool to investigate strong-field gravity, and the equation of state of ultra dense matter in neutron stars

1st LOFT(ESA M3 proposal) and after eXTP: science drivers

CORE SCIENCE

Dense matter

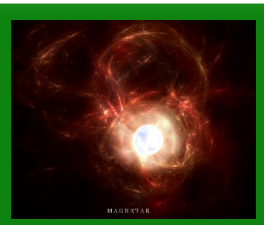


Constrain EOS of ultra-dense matter: Neutron Stars

Accretion in strong gravity

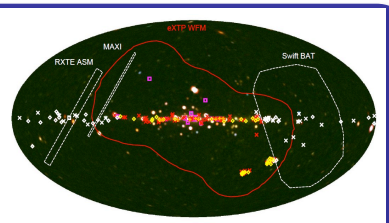
Tests of General Relativity in Black Holes and Neutron Stars

Strong magnetism



Light and matter in ultra-strong magnetic fields

Observatory science



Monitoring of transient sources, including electromagnetic counterparts of Gravitational Waves, for rapid follow-up

eXTP: the enhanced X-ray Timing and Polarimetry mission
IHEP/CAS (Chinese Academy of Sciences) - Europe - ESA (TBD)

X-ray space mission aimed to study "the fundamental laws of the Universe"

https://www.isdc.unige.ch/extp/

launch expected < 2030

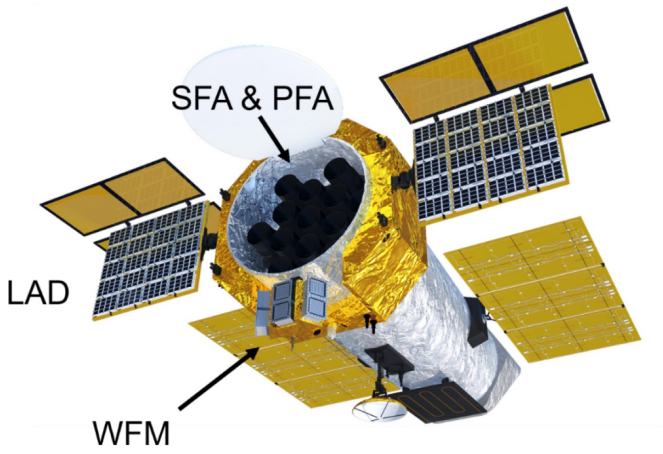
Now in Phase B2

Energy range (keV)	
0.5 - 10	**SFA (Spectroscopic Focusing Array)** grazing incidence X-ray telescopes, Silicon Drift Detectors
2 - 10	**PFA (Polarimetry Focusing Array)** X-ray telescope optimized for polarimetry, Gas Pixel Detectors
2 - 30	**LAD (Large Area Detector)** Large-area Silicon Drift Detectors, capillarity plates collimators
2 - 50	**WFM (Wide Field Monitor)** Large-area Silicon Drift Detectors, coded mask

EU Instruments
LOFT (ESA M3) heritage

- LAD PI: Marco Feroci, INAF/IAPS, Rome, Italy
- WFM PI: Margarita Hernanz, ICE-CSIC & IEEC

eXTP: a set of complementary instruments

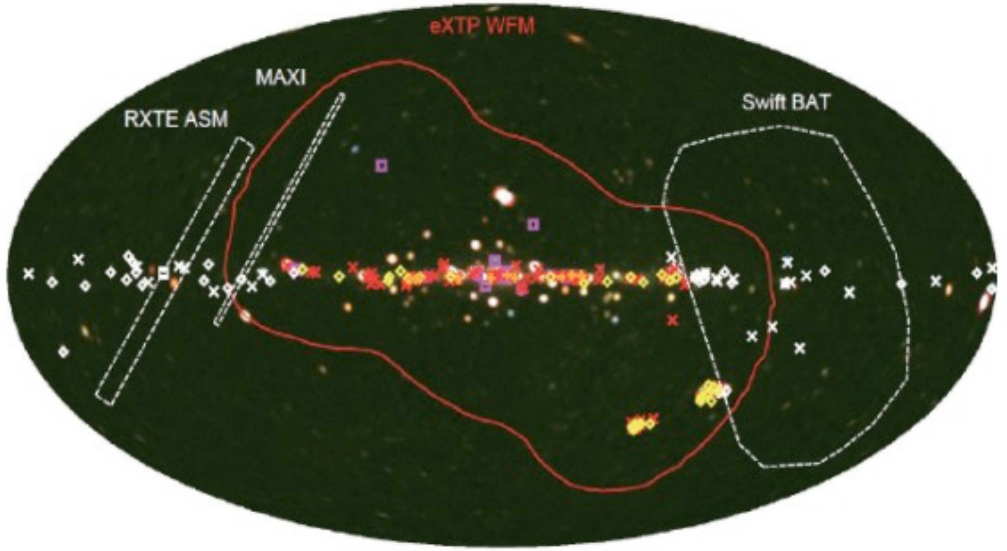


SFA - soft response

PFA - polarimetry

LAD - large area

WFM - monitoring



- Imaging: <5 arcmin angular resolution, 1 arcmin PSLA
- Same detectors as LAD (SDD). Single photon: <10μs
- Energy band: 2-50 keV
- Energy resolution: 300 eV FWHM @6 keV

Simultaneous FoV of eXTP/ WFM compared with most relevant facilities (background map courtesy of T. Mihara, RIKEN, JAXA, and the MAXI team)

The WFM has an unprecedented combination of large FoV and imaging capability down to 2 keV

eXTP: focus on detailed studies of bright phenomena – "brightest" BHs and NS – with excellent timing and polarimetric capability

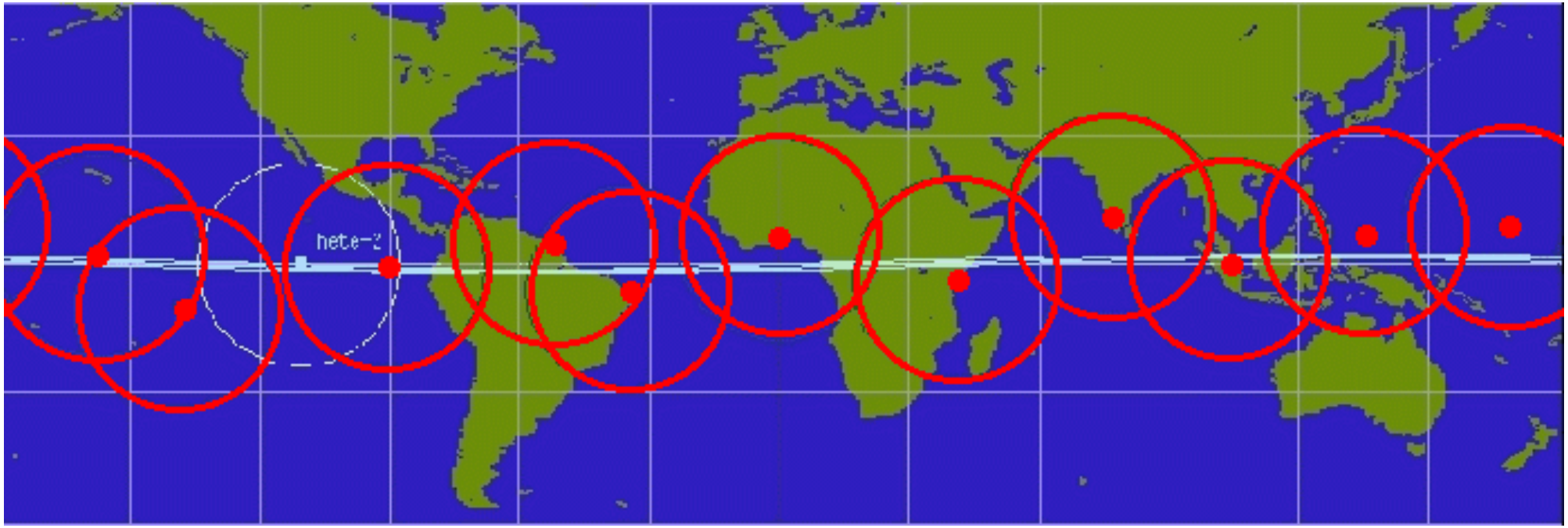
WFM scientific goals

- Primary goals: *core science -* Provide triggers for target of opportunity observations with the narrow-field instruments (LAD, SFA, PFA) (less than 1 day reaction time):
  - Stellar black holes and neutron stars transients, state changes in accretion-powered sources: Strong Gravity and Dense Matter goals
    - *A field of view as wide as possible* - to catch rare events is required
- Secondary goals: "observatory science"
  - Monitor the long-term behavior of X-ray sources - Detect short (0.1-100 s) bursts and record data with full resolution
  - Provide Gamma-ray Burst Alerts (also Fast Radio Bursts): quick dissemination of GRB sky positions via VHF/Beidou
  - Provide GW EM alerts: quick dissemination of GW locations from GW EM detections

eXTP Burst On-board Trigger - XBOT

A dedicated burst alert system will enable the distribution to the community of ~100 gamma ray burst positions per year with a ~1 arcmin location accuracy within 30 s of the burst

- SVOM satellite [CNES - CAS collaboration, to be launched **on June 24, 2024**)] heritage + Beidou (Chinese GPS)

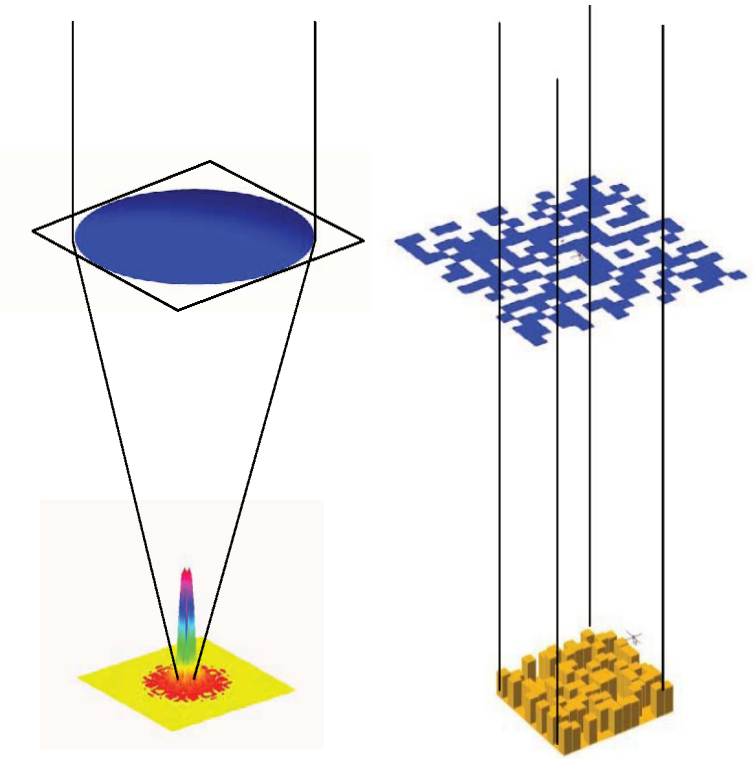


WFM (Wide Field Monitor): a coded mask X-ray instrument

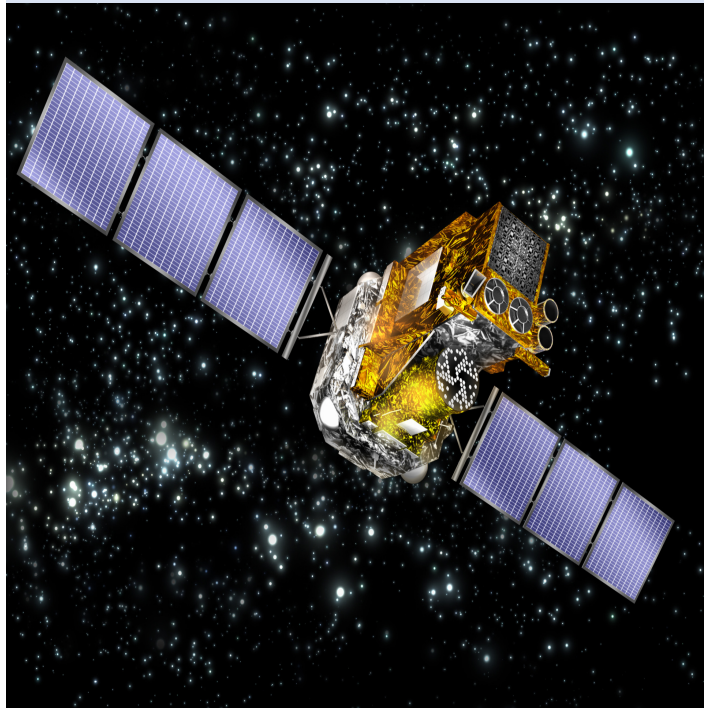
Two active ESA high energy missions

- XMM Newton (X-rays): focusing optics, like the SFA and PFA of eXTP
- INTEGRAL (gamma-rays): coded mask imaging, like the WFM

Focusing optics
- Low background
- Small field of view

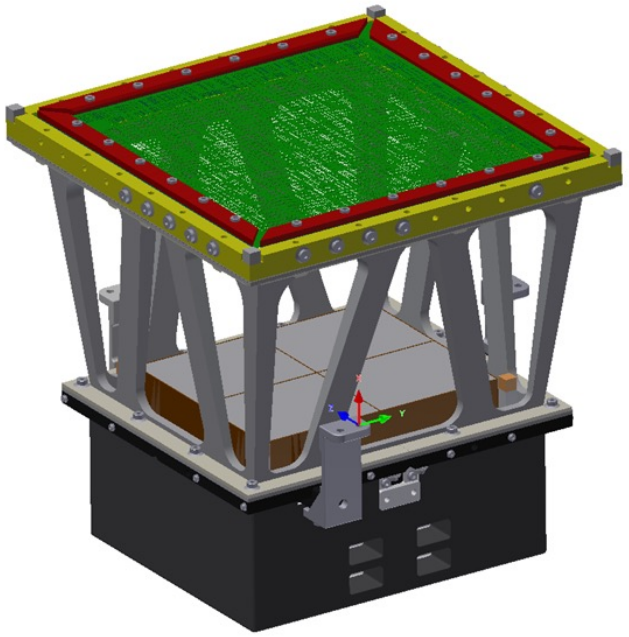


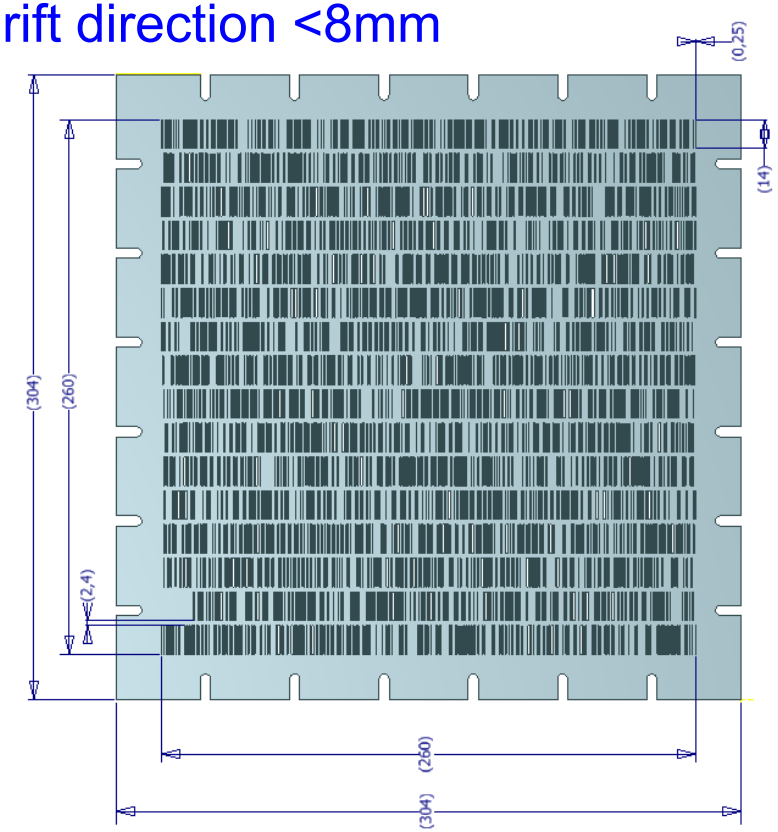
Coded mask optics
- Relatively high background
- Large field of view

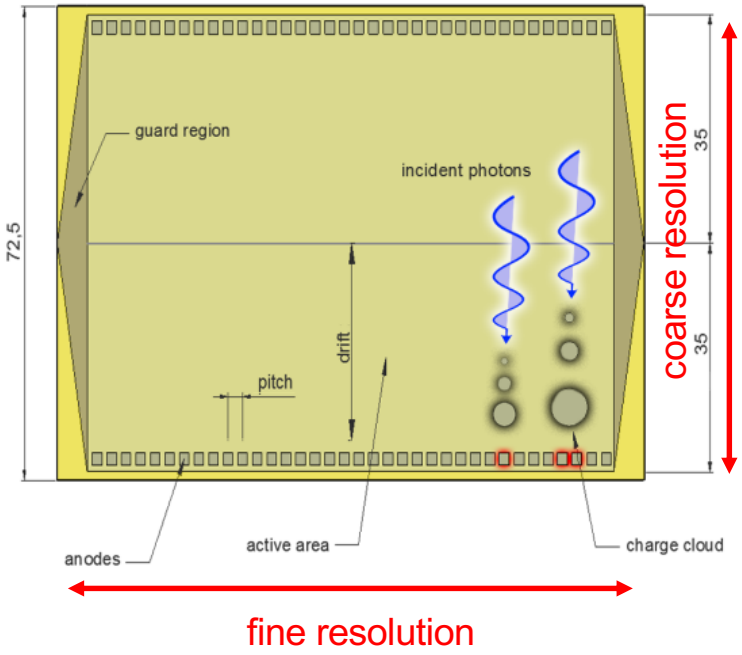


WFM camera design

- Each camera contains 4 Si drift detectors (SDDs) - same detector type as for the LAD except for a smaller pitch ➔ better spatial resolution
- 1.5D position resolution
  - ➢ Fine position resolution in anode direction <60μm
  - ➢ Coarse position resolution in drift direction <8mm

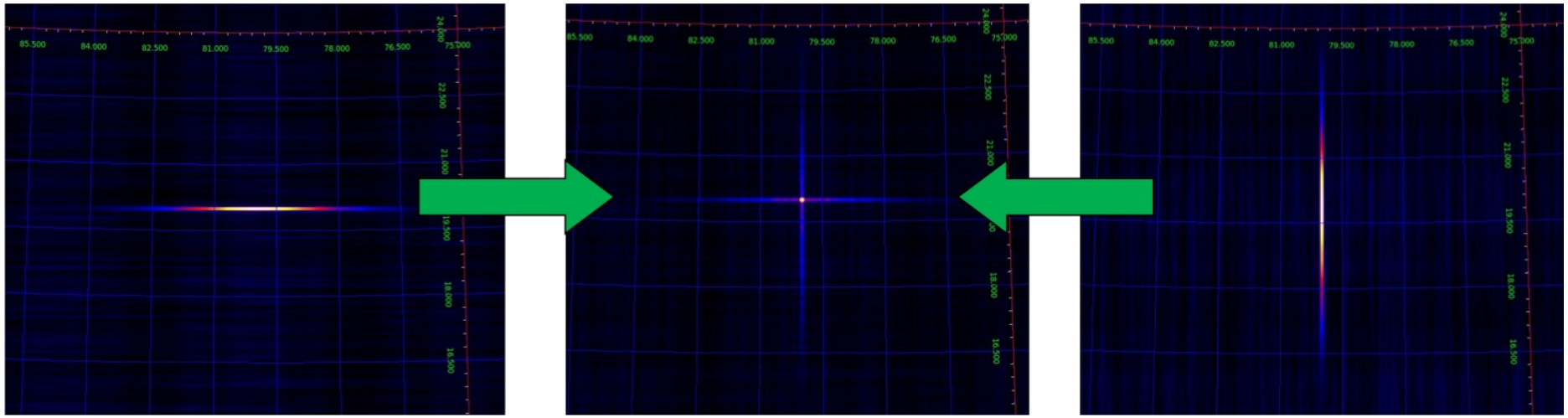






WFM imaging

- Each WFM camera produces a "**1.5D** image": ~5 arcmin x 5 degrees
- **2D** position is found by combining the two independent orthogonal positions found by the cameras in a pair



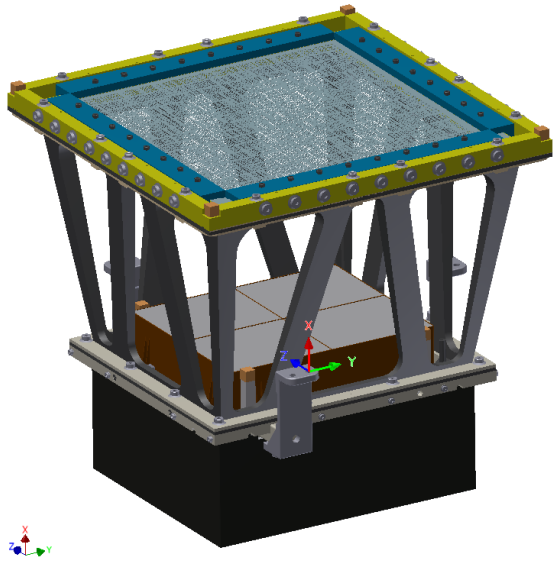
Note: positions and intensities are independently determined in each camera of the camera pair

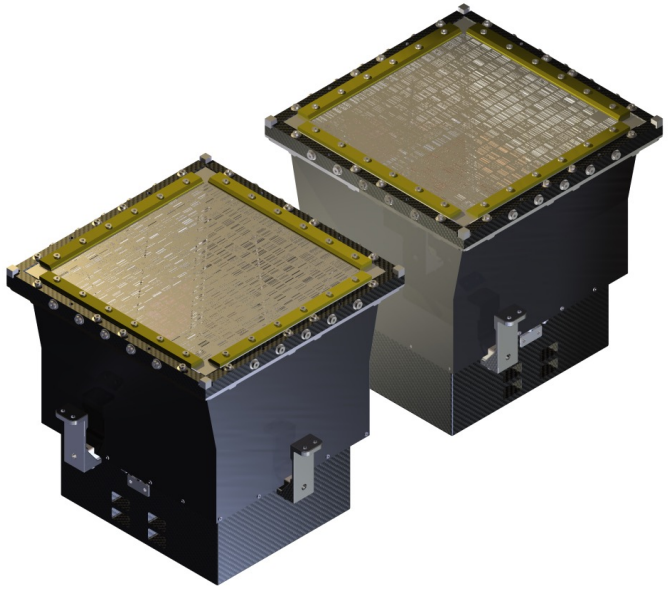
WFM camera design

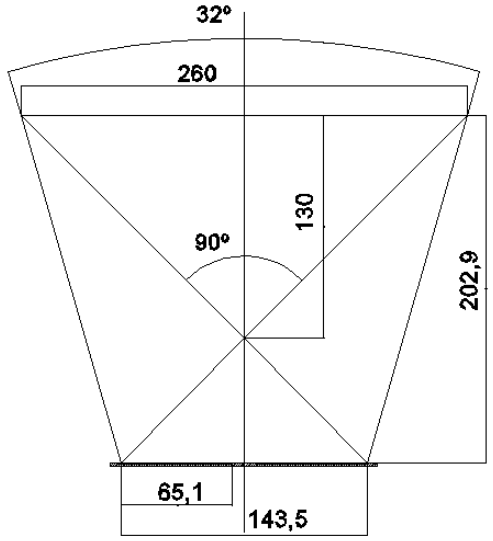
Two orthogonal cameras - with perpendicular orientations of their coded masks - make a ***WFM camera pair***

- **2D position resolution**

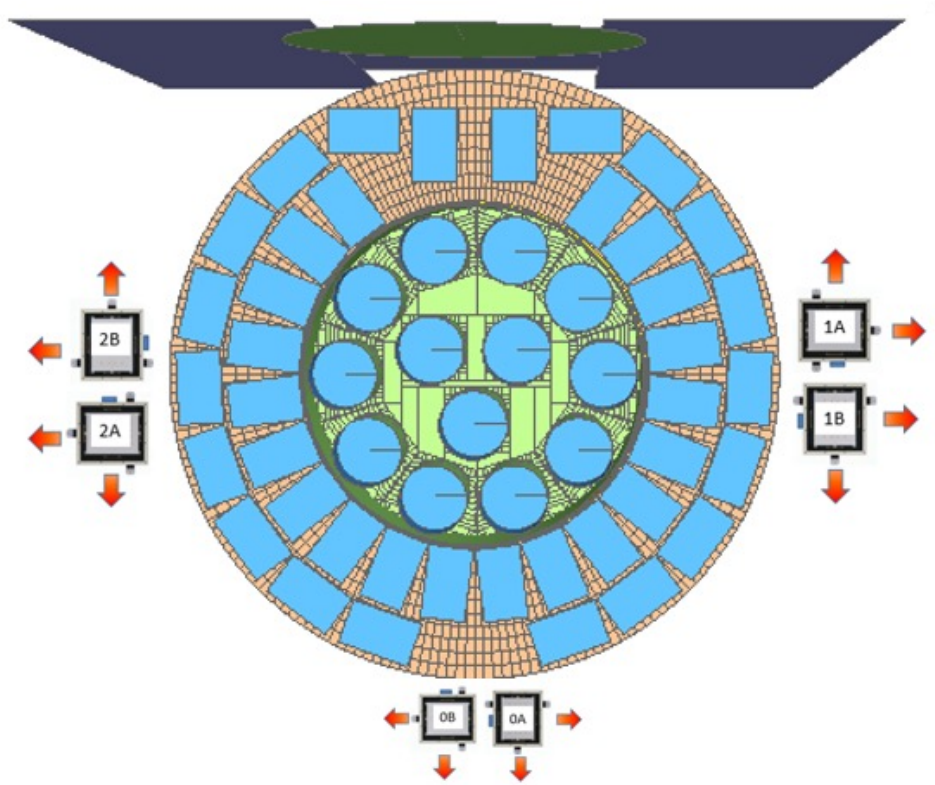
- 90 x 90 degree zero response field of view
- 30 x 30 degree fully illuminated field of view

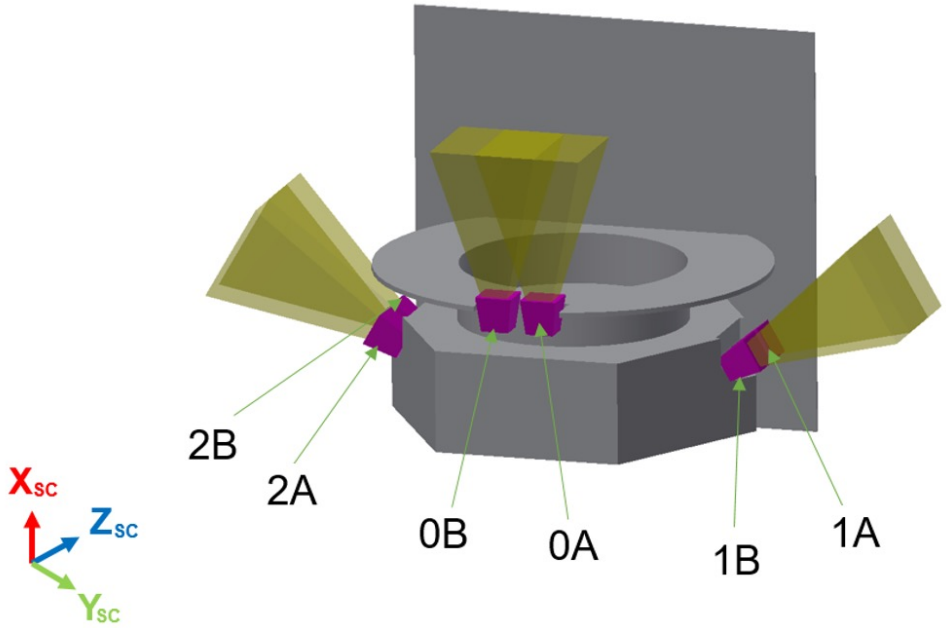






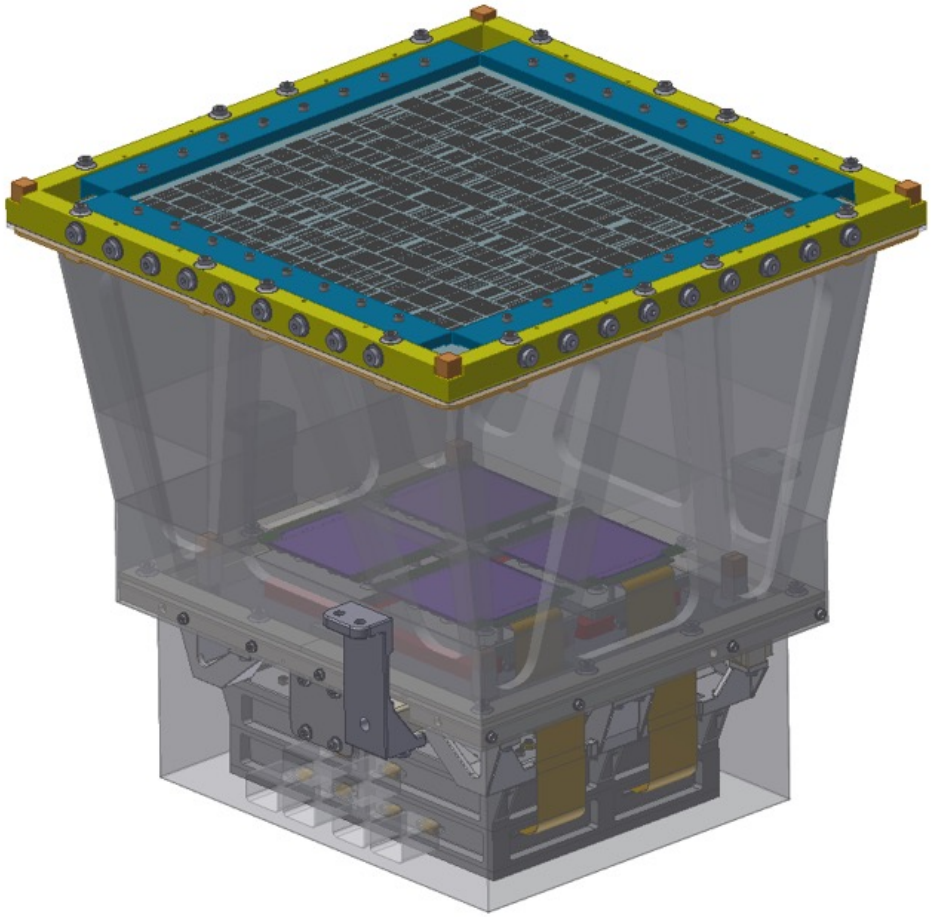
WFM on the eXTP spacecraft

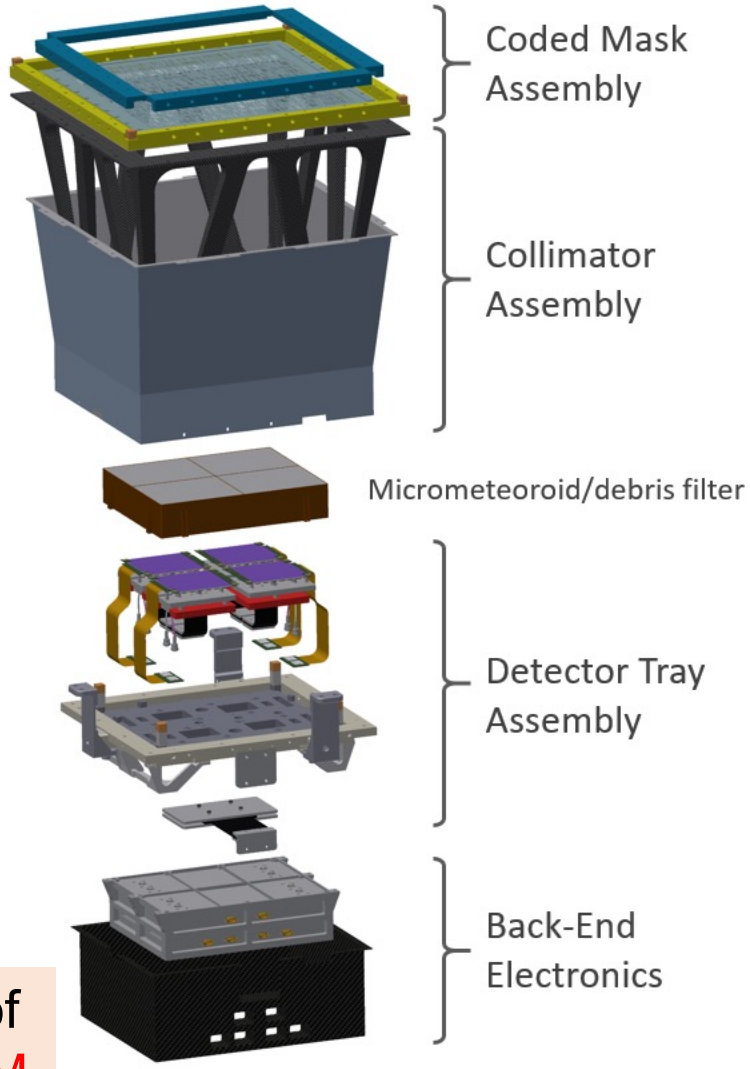




- WFM cameras are organized in pairs with 90º x 90º FoV
- Configuration with 6 identical cameras arranged in 3 Camera Pairs (-60º, 0, 60º)
- Sky coverage: 180º x 90º FoV

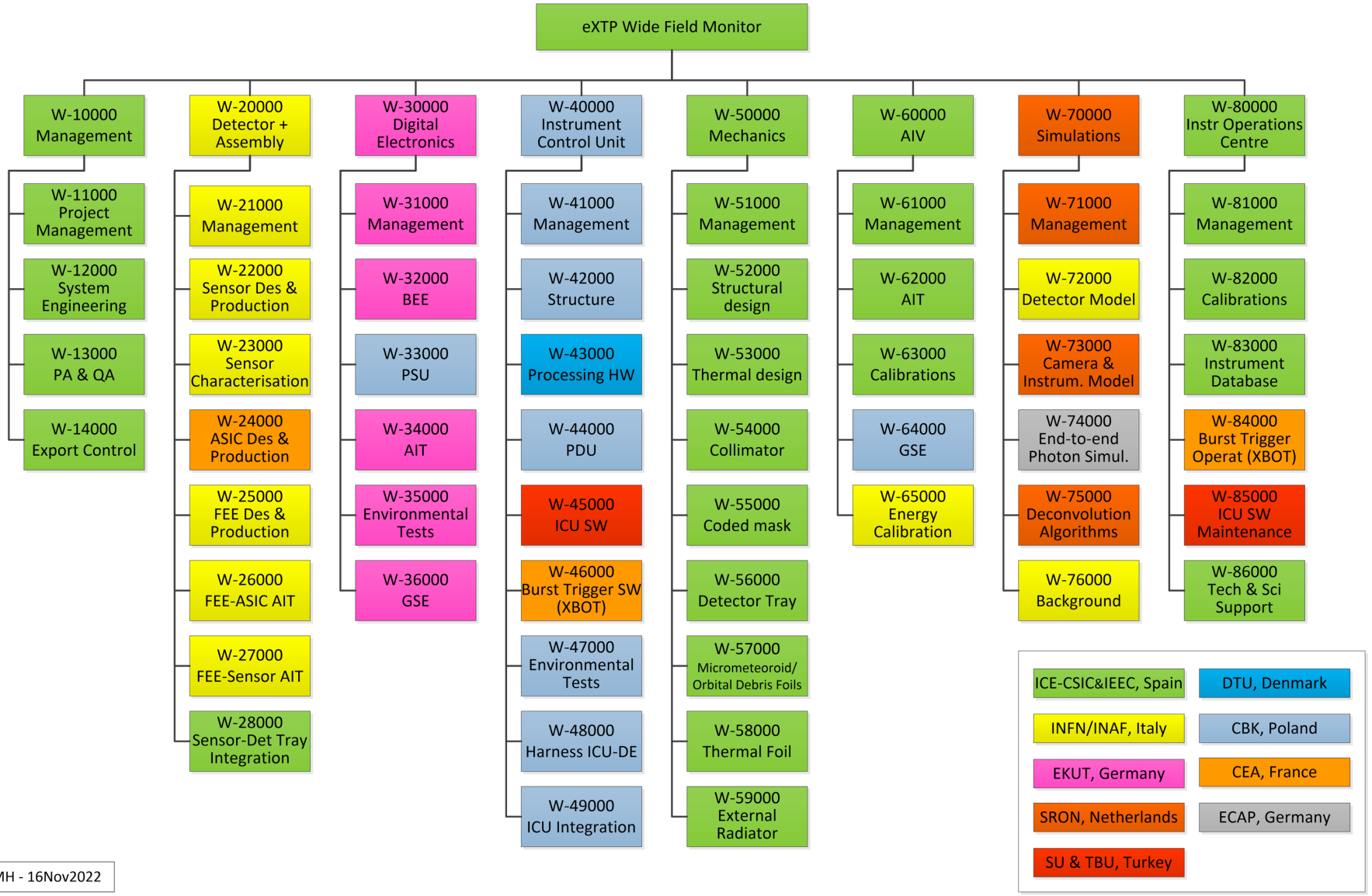
WFM camera layout and exploded view



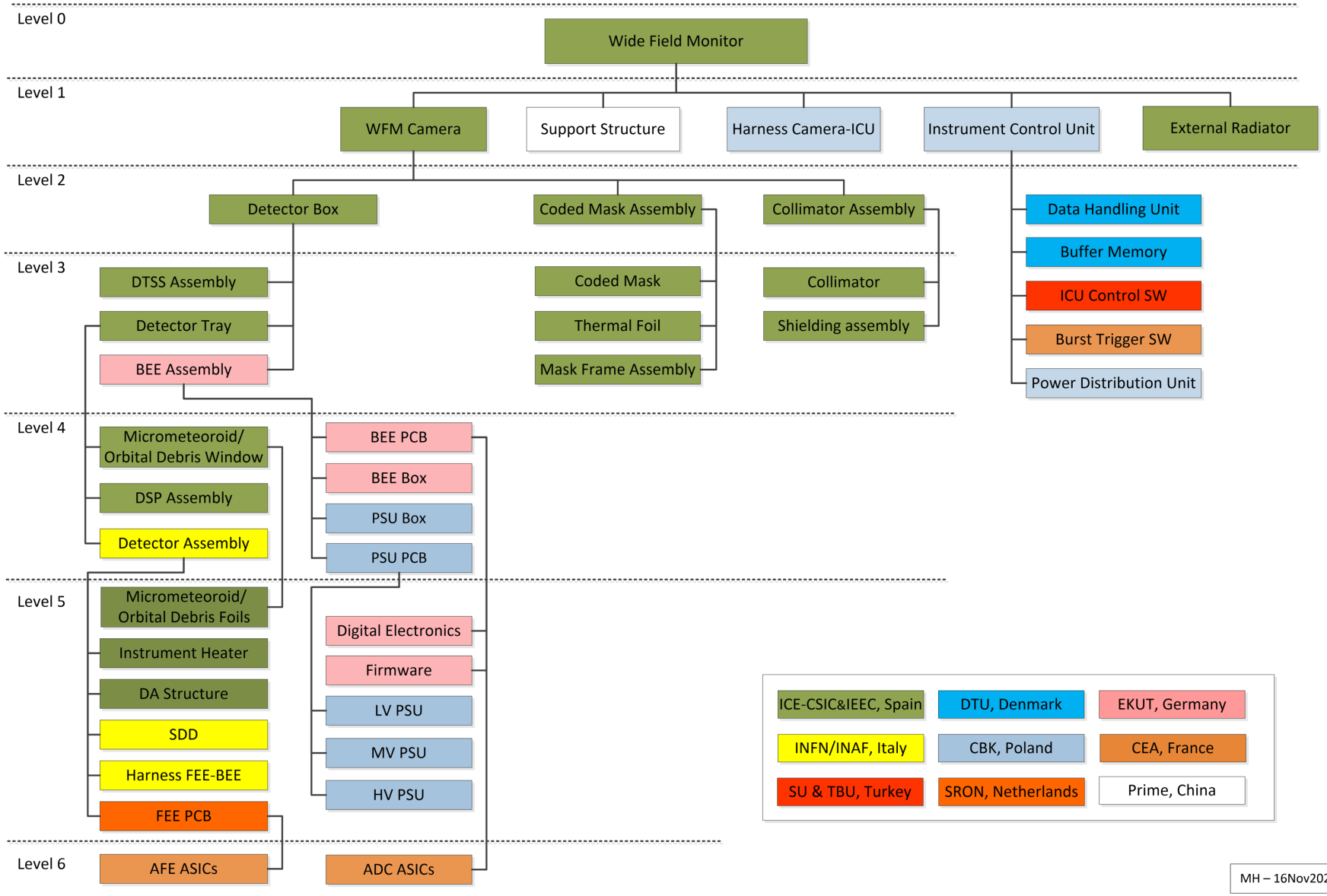


Our group at ICE-CSIC & IEEC - Mechanical and thermal design of the WFM: detector tray, collimator, coded mask. MH: PI of the WFM

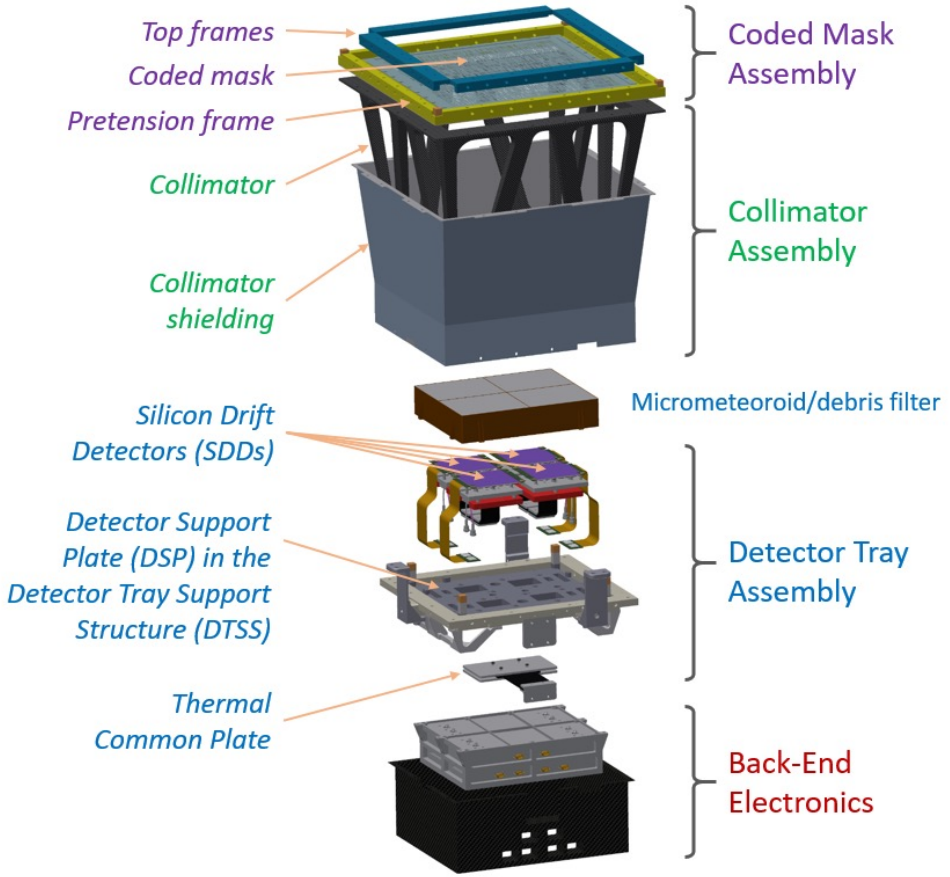
WFM organization: WBS (Work Breakdown Structure)

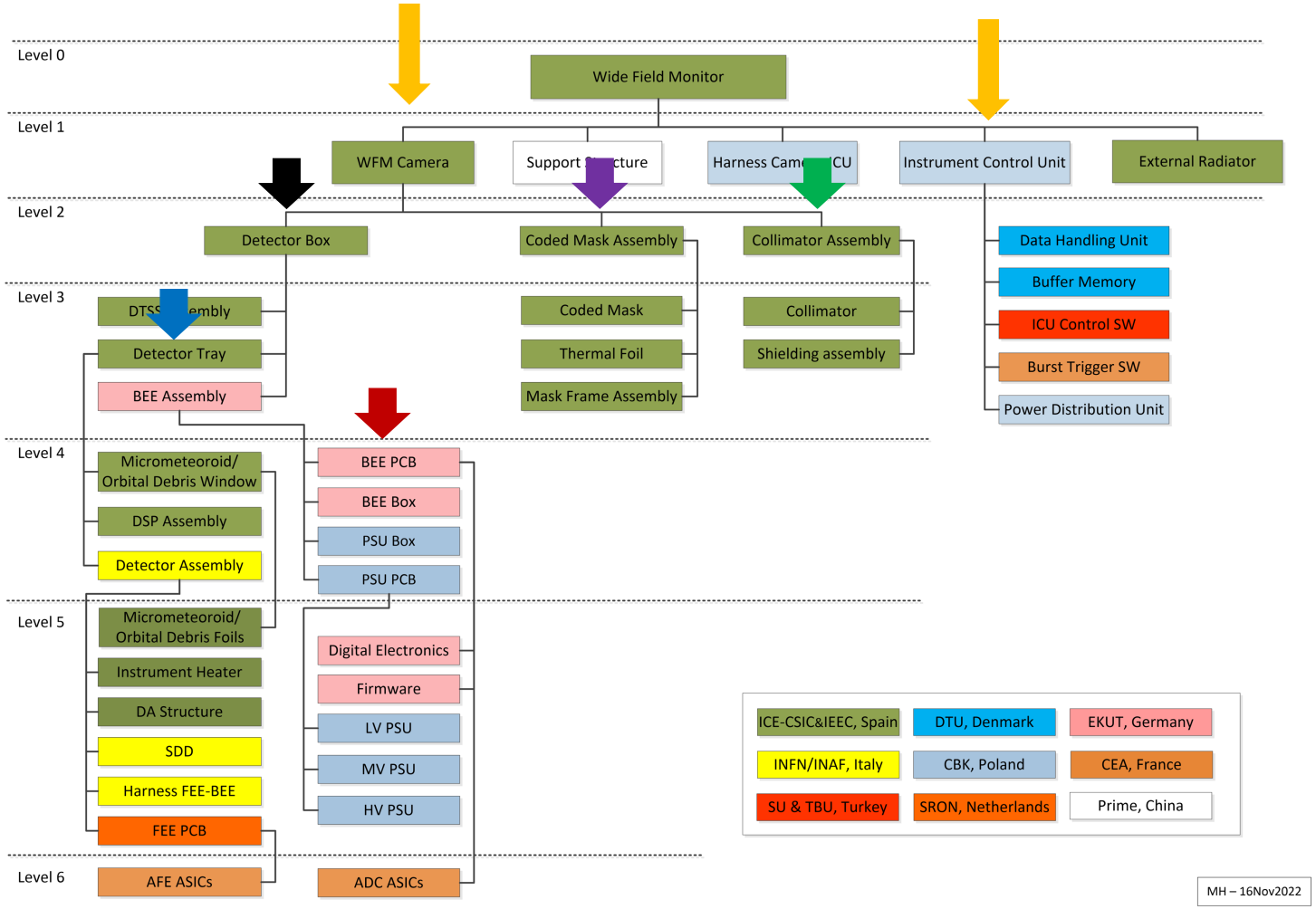


WFM Product Tree

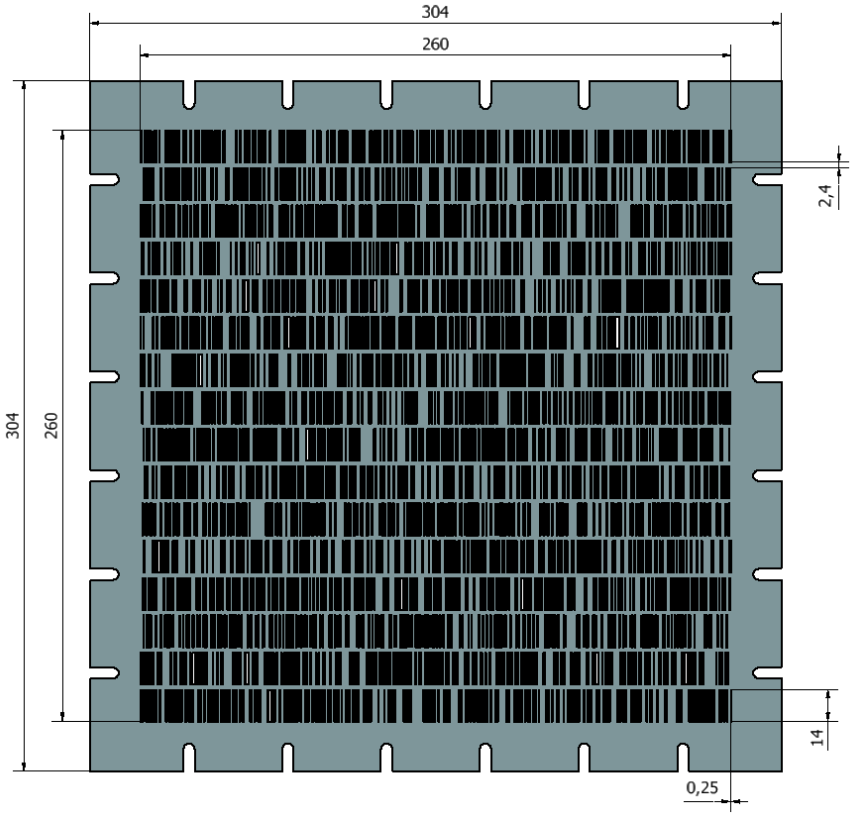


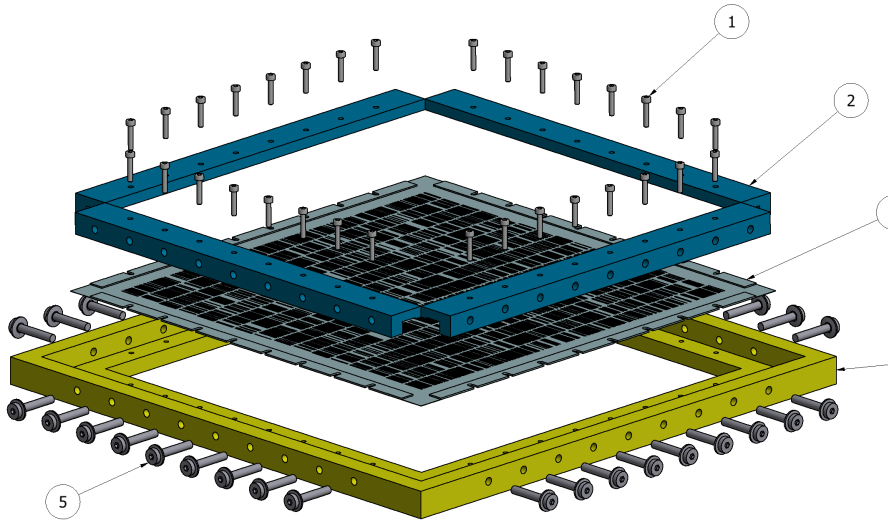
WFM camera: exploded view and Product Tree

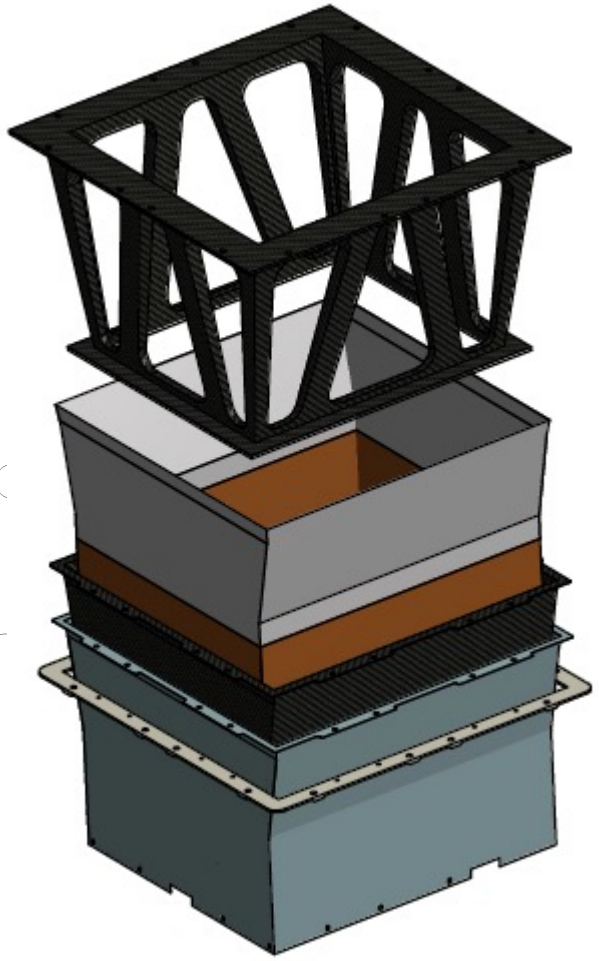




WFM camera: coded mask assembly, collimator

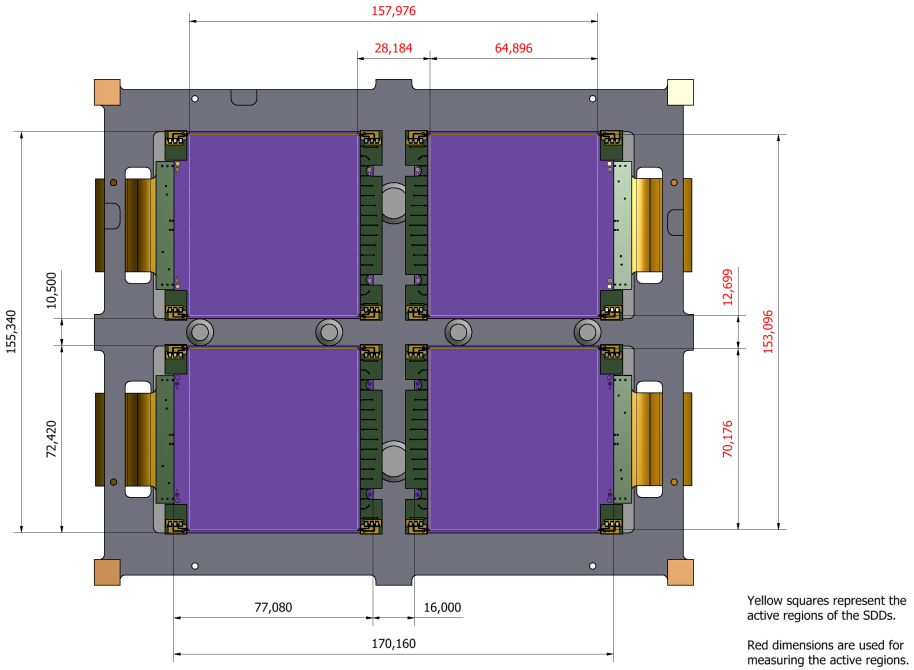




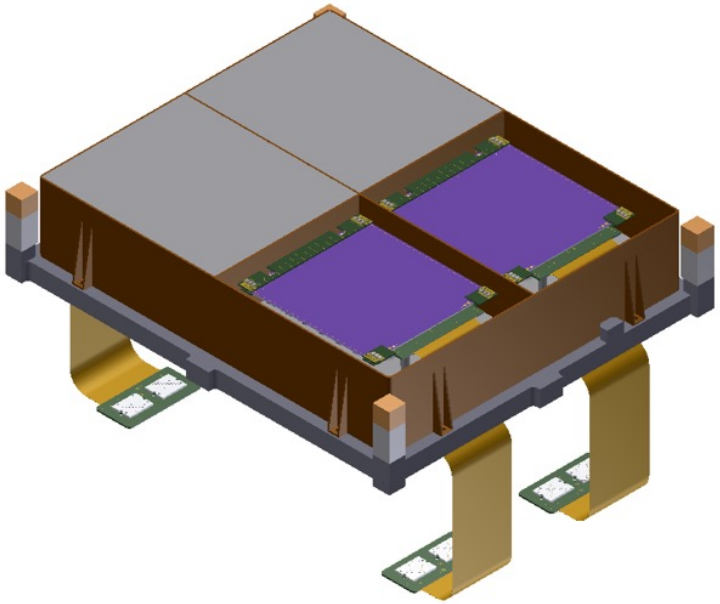


WFM camera: detector tray, Be filter

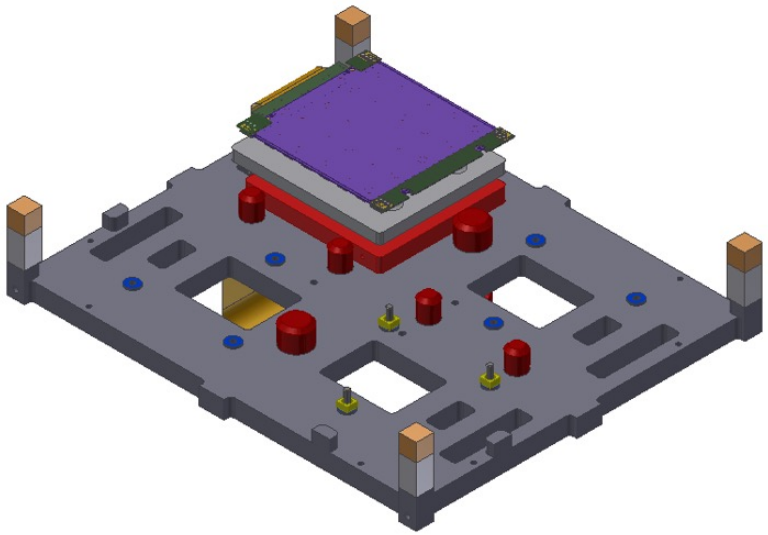
Top view of the detector plane, housing 4 detector assemblies



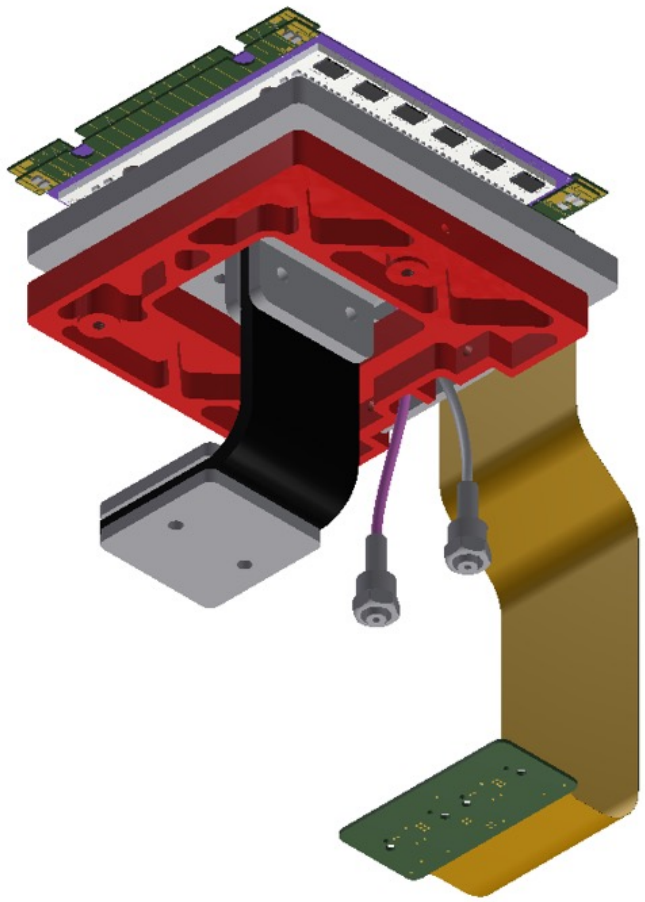
Be (or alternative) filter protecting the detectors from micrometeorites and orbital debris

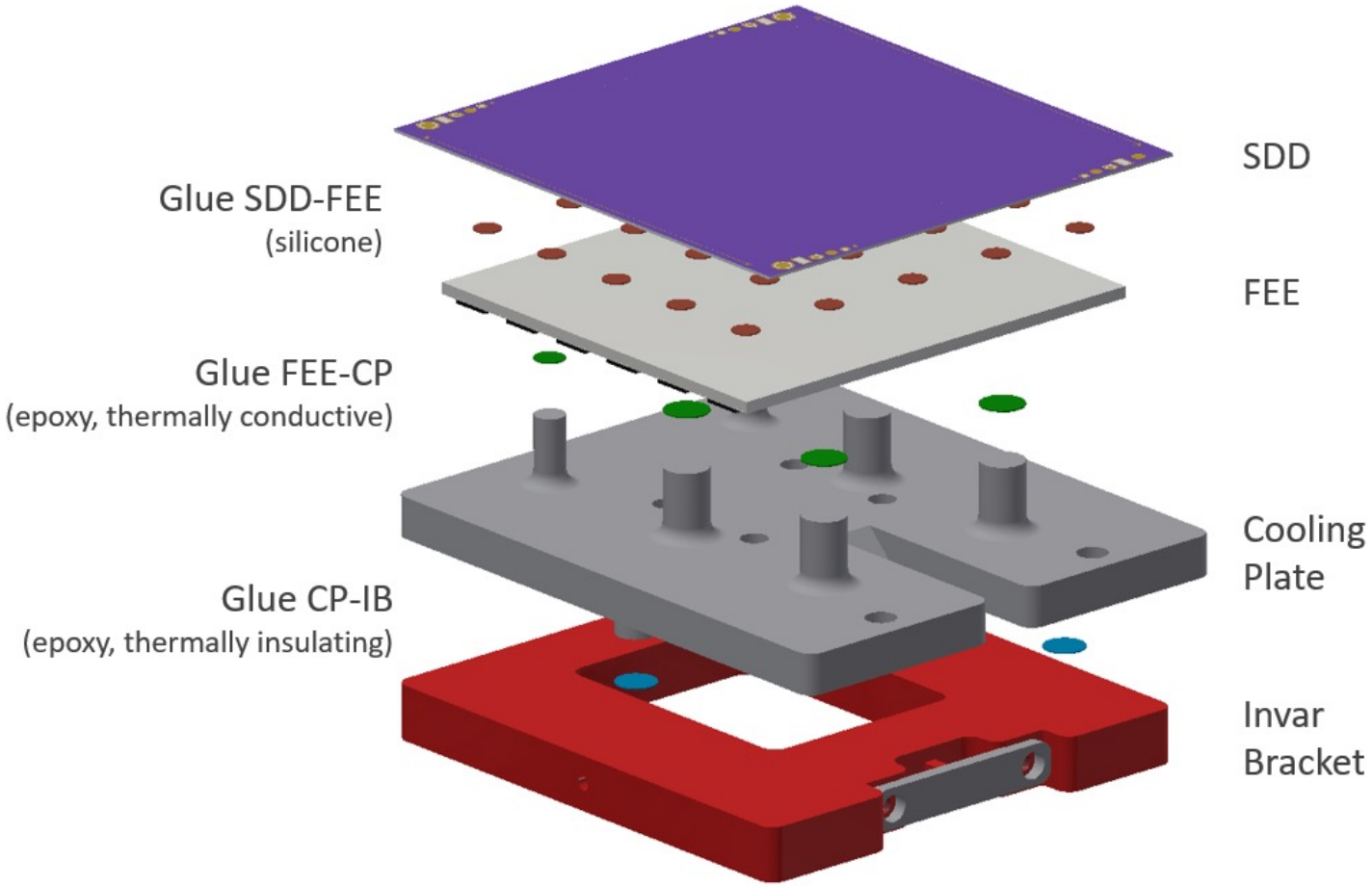


Detector support plate with one (of four) detector assembly



WFM camera: detector, FEE

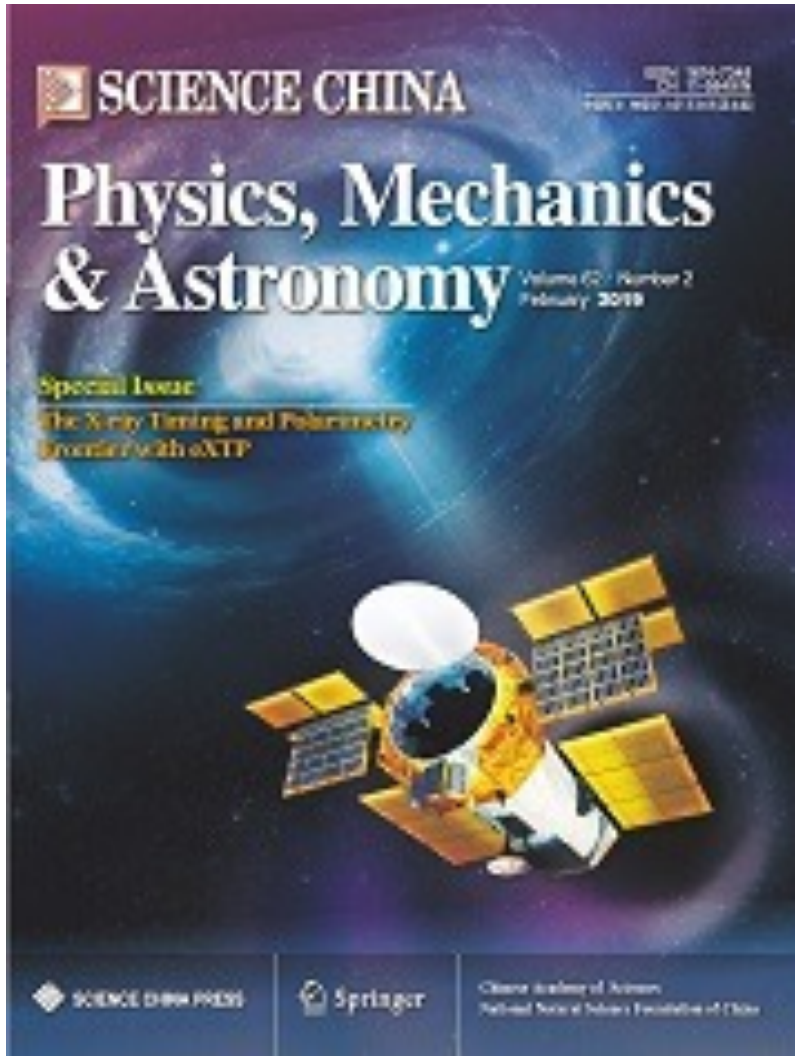




Summary

- eXTP offers a unique combination of instruments in the X-ray energy range
  - broad energy coverage
  - high spectral resolution, outstanding timing resolution
  - polarimetric capability
  - huge collecting area
- eXTP is optimized to study matter under the most extreme conditions of density, gravity and magnetism. Science areas it addresses:
  - fundamental physics topics
  - astrophysics topics, mainly related to compact stars – neutron stars and black holes, mass accretion onto them
  - time domain astrophysics: survey the dynamic X-ray sky with large duty cycle
  - multi-wavelength / multi-messenger astrophysics
- **Very relevant Spanish contribution: PI of a WFM instrument, now in Phase B2**

eXTP White Papers (science & instruments): dedicated volume in Science China (Springer) - vol. 62 (2019)



2019SCPMA..6229506I	1.000	02/2019	A	E	X	D	R	C

in't Zand, Jean J. M.; Bozzo, Enrico; Qu, JinLu; Li, Xiang-Dong; Amati, Lorenzo; Chen, Yang; Donnarumma, Immacolata; Doroshenko, Victor; Drake, Stephen A.; Hernanz, Margarita; and 174 coauthors

Observatory science with eXTP

Hernanz, Torres (ICE), José, Linares, Sala (UPC), Torrejón (UA), Pérez Torres (IAA)

2019SCPMA..6229505S	1.000	02/2019	A	E	X	D	R	C

Santangelo, Andrea; Zane, Silvia; Feng, Hua; Xu, RenXin; Doroshenko, Victor; Bozzo, Enrico; Caiazzo, Ilaria; Zelati, Francesco Coti; Esposito, Paolo; González-Caniulef, Denis; and 31 coauthors

Physics and astrophysics of strong magnetic field systems with eXTP

Rea, Coti-Zelati (ICE)

2019SCPMA..6229504D	1.000	02/2019	A	E	X		R	C

De Rosa, Alessandra; Uttley, Phil; Gou, LiJun; Liu, Yuan; Bambi, Cosimo; Barret, Didier; Belloni, Tomaso; Berti, Emanuele; Bianchi, Stefano; Caiazzo, Ilaria; and 92 coauthors

Accretion in strong field gravity with eXTP

Agudo (IAA), Linares (UPC), Miniutti (CAB), Migliari (ESAC)

2019SCPMA..6229503W	1.000	02/2019	A	E	X		R	C

Watts, Anna L.; Yu, WenFei; Poutanen, Juri; Zhang, Shu; Bhattacharyya, Sudip; Bogdanov, Slavko; Ji, Long; Patruno, Alessandro; Riley, Thomas E.; Bakala, Pavel; and 66 coauthors

Dense matter with eXTP

Tolós, Patruno (ICE), Linares (UPC)

Science case

2019SCPMA..6229502Z	1.000	02/2019	A	E	X		R	C

Zhang, ShuangNan; Santangelo, Andrea; Feroci, Marco; Xu, YuPeng; Lu, FangJun; Chen, Yong; Feng, Hua; Zhang, Shu; Brandt, Søren; Hernanz, Margarita; and 143 coauthors

The enhanced X-ray Timing and Polarimetry mission—eXTP

Hernanz, Gálvez (ICE)

Mission

Science and Development of eXTP in Spain

study of the state of matter in extreme conditions of density, gravity and magnetism

EUROPEAN ASTRONOMICAL SOCIETY ANNUAL MEETING

eas 2022 Valencia

June 27th – July 1st, 2022
Valencia Conference Centre, Spain

SPIE. The international society for optics and photonics

Search

SPIE. ASTRONOMICAL TELESCOPES + INSTRUMENTATION

Palais De Congrès De Montréal
Montréal, Québec, Canada
17 - 22 July 2022

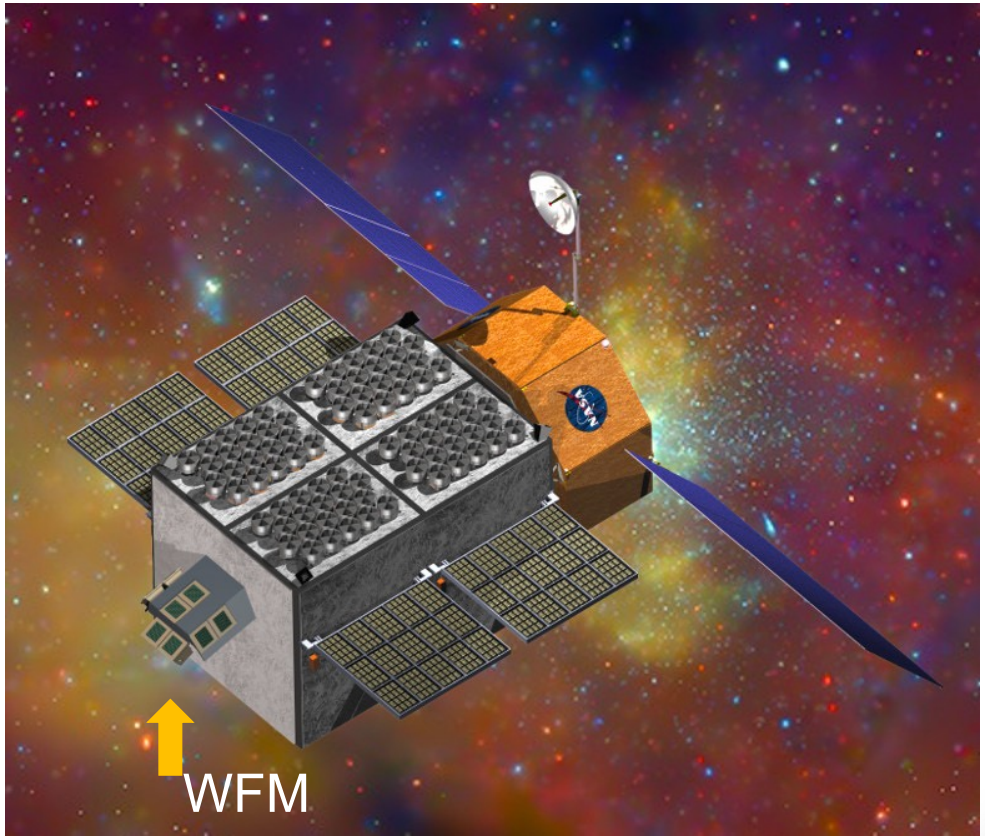
Session dedicated to eXTP: WFM talk (MH) + several posters

Also publications in previous SPIE conferences: 2018, 2020
&
WFM talk @ SPIE 2024
&
other: Marcel Grossman 2021, RIA 2018, 2022...

Complementary slide

STROBE-X: NASA Probe mission for the Decadal Survey 2020-2030

"Super-NICER (ISS) + LOFT/eXTP"



STROBE-X

STROBE-X: X-ray Timing and Spectroscopy on Dynamical Timescales from Microseconds to Years

White Paper Submitted to Astro 2020 Decadal Survey

Paul S. Ray
U.S. Naval Research Laboratory
paul.ray@nrl.navy.mil

***STROBE-X* Steering Committee:** Zaven Arzoumanian, David Ballantyne, Enrico Bozzo, Soren Brandt, Laura Brenneman, Deepto Chakrabarty, Marc Christophersen, Alessandra DeRosa, Marco Feroci, Keith Gendreau, Adam Goldstein, Dieter Hartmann, Margarita Hernanz, Peter Jenke, Erin Kara, Tom Maccarone, Michael McDonald, Michael Nowak, Bernard Phlips, Ron Remillard, Abigail Stevens, John Tomsick, Anna Watts, Colleen Wilson-Hodge, Kent Wood, Silvia Zane

Astrophysics Probe Announcement of Opportunity Community Announcement (2022)

Mission Themes: Responses to the Astrophysics Probe AO will be limited to one of the two mission themes recommended by the Decadal Survey. These areas are

- A far infrared imaging or spectroscopy mission, and
- An X-ray probe ~~to complement ESA's Athena Observatory~~.