

# ESA's flagship X-ray multi-mirrors for flagship science



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Mosaic telescopes Technology and Science  
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# Multi-Messenger Astronomy



## COSMIC OBSERVERS

IN DEVELOPMENT



ACTIVE



microwaves

sub-millimetre

infrared

optical

ultraviolet

x-rays

gamma rays

gravitational waves

LEGACY



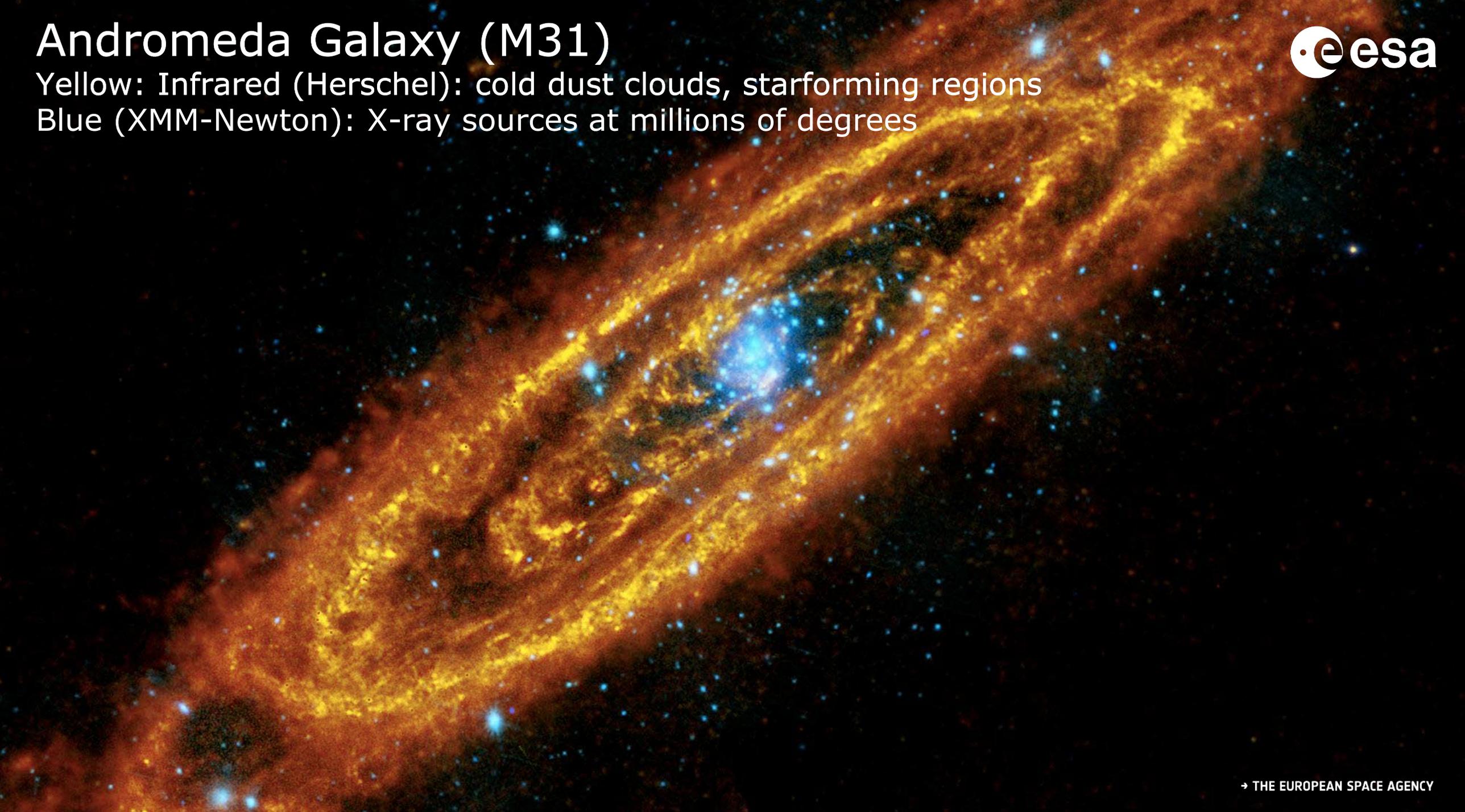
# Andromeda Galaxy (M31)

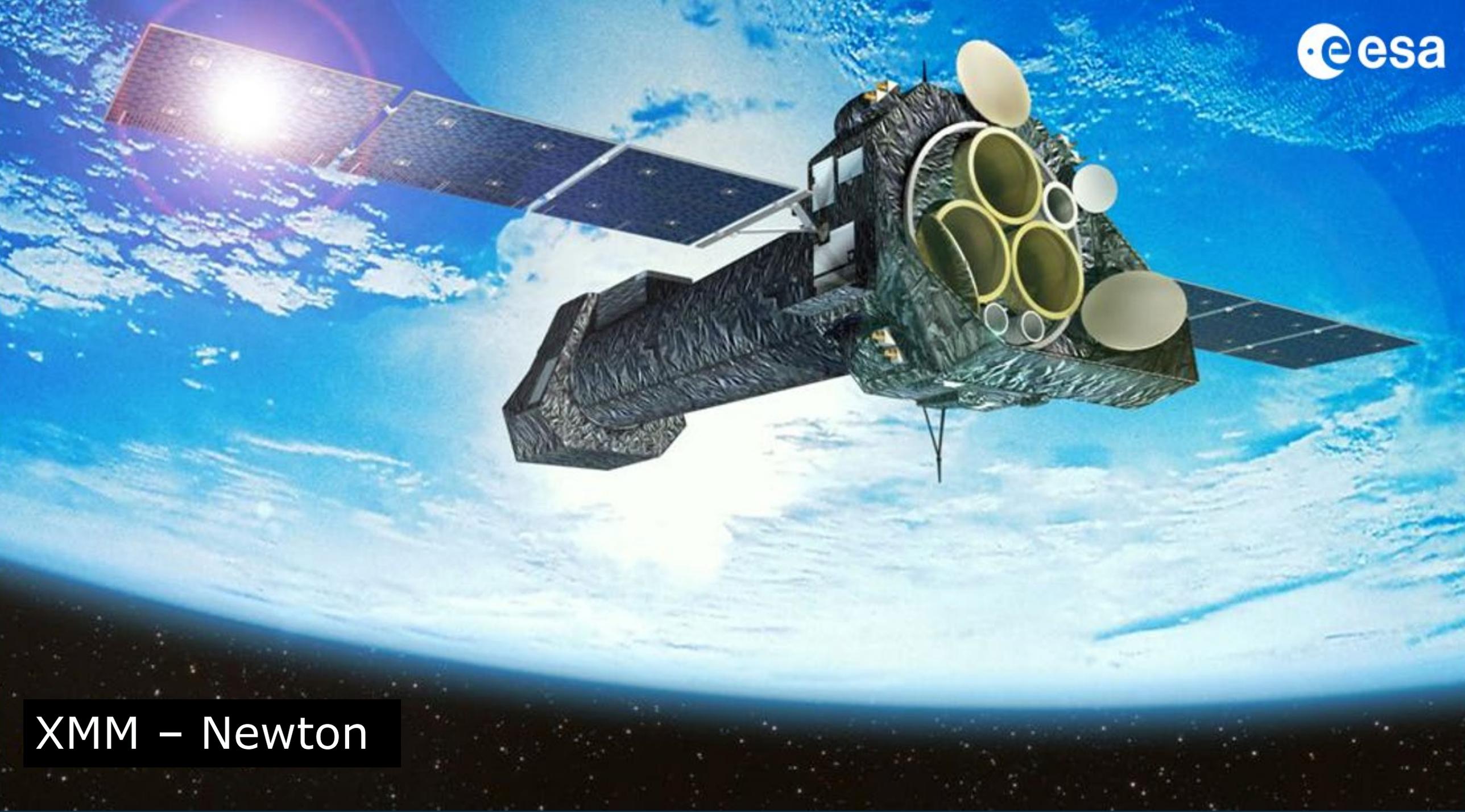
Visible light: adult stars, thousands of degrees



# Andromeda Galaxy (M31)

Yellow: Infrared (Herschel): cold dust clouds, starforming regions  
Blue (XMM-Newton): X-ray sources at millions of degrees





XMM – Newton



# XMM-Newton: Replicated Nickel Optics



Launched 1999

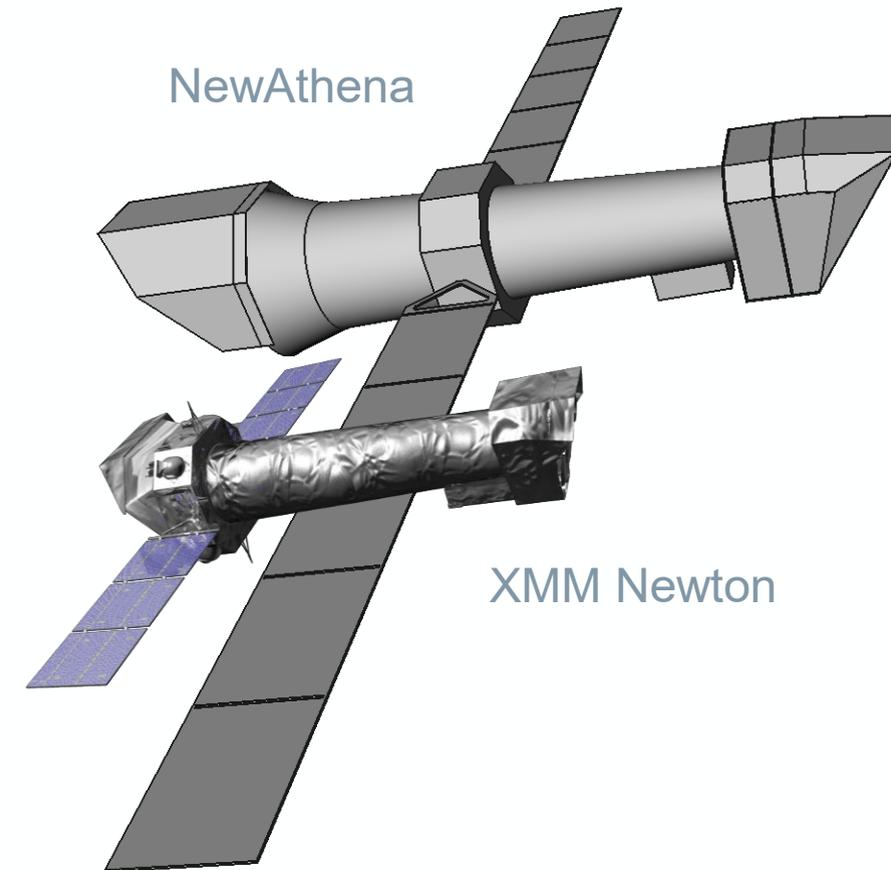


# Chandra Optics: polished Zerodur

Launched 1999

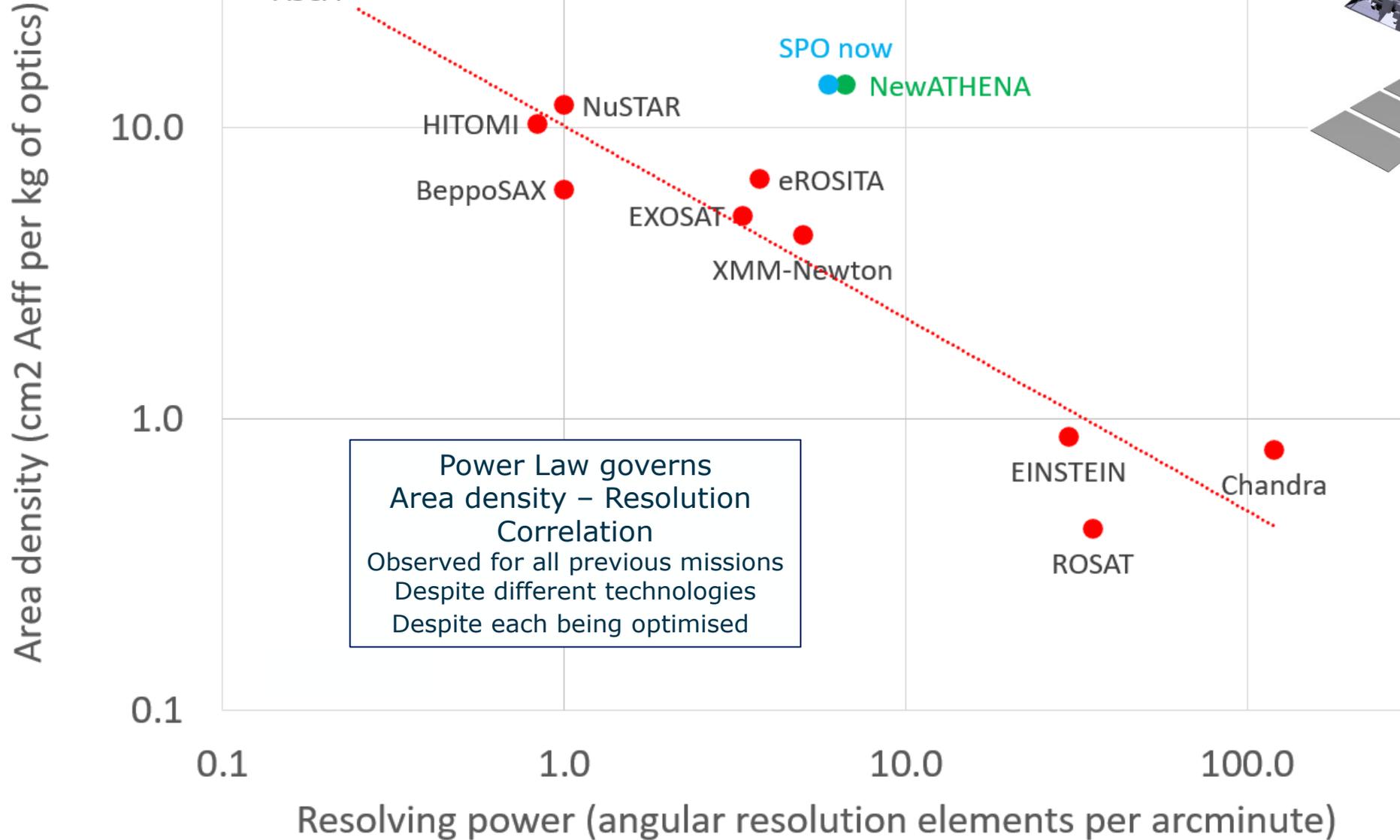
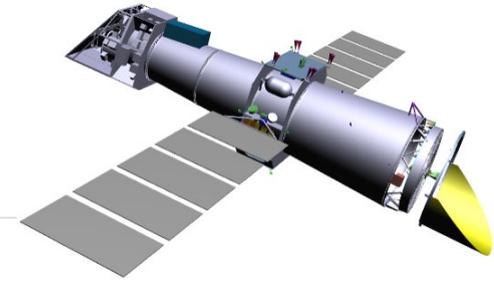


- NewAthena was designed to deliver on the “**Hot and Energetic Universe**” Science Theme for the 2nd Large Class launch-opportunity of Cosmic Vision
- NewAthena is a powerful, **general-purpose open observatory**, with unprecedented sensitivity to study astronomical phenomena, including :
  - distant **gamma-ray bursts**
  - the **hot gas** found in the space around clusters of galaxies
  - accreting compact objects such as **black holes** over their whole mass range
  - **Jupiter's auroras** and comets in our own Solar System





# The NewAthena Optics Challenge



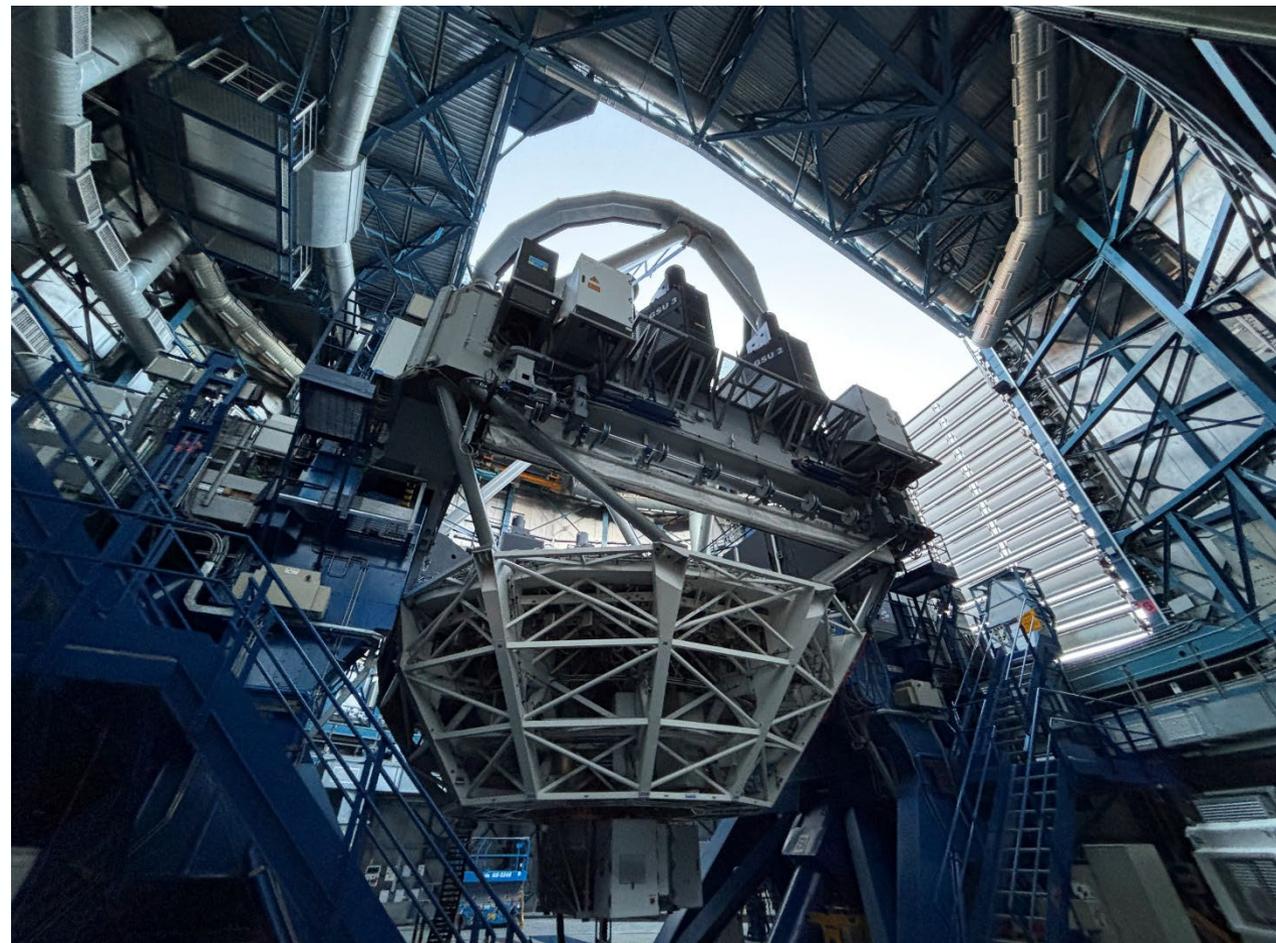
NewATHENA optics must combine:

- Good angular resolution
- Large effective area
- Low mass

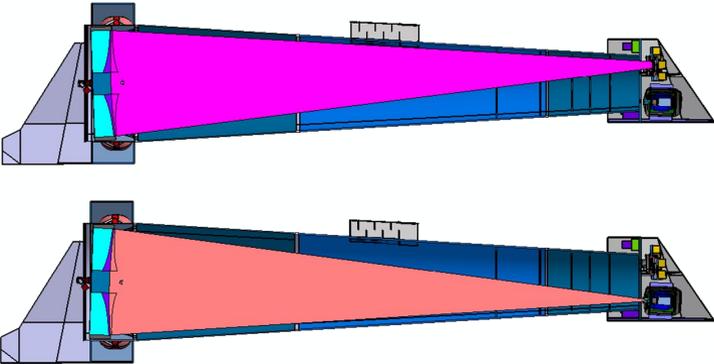
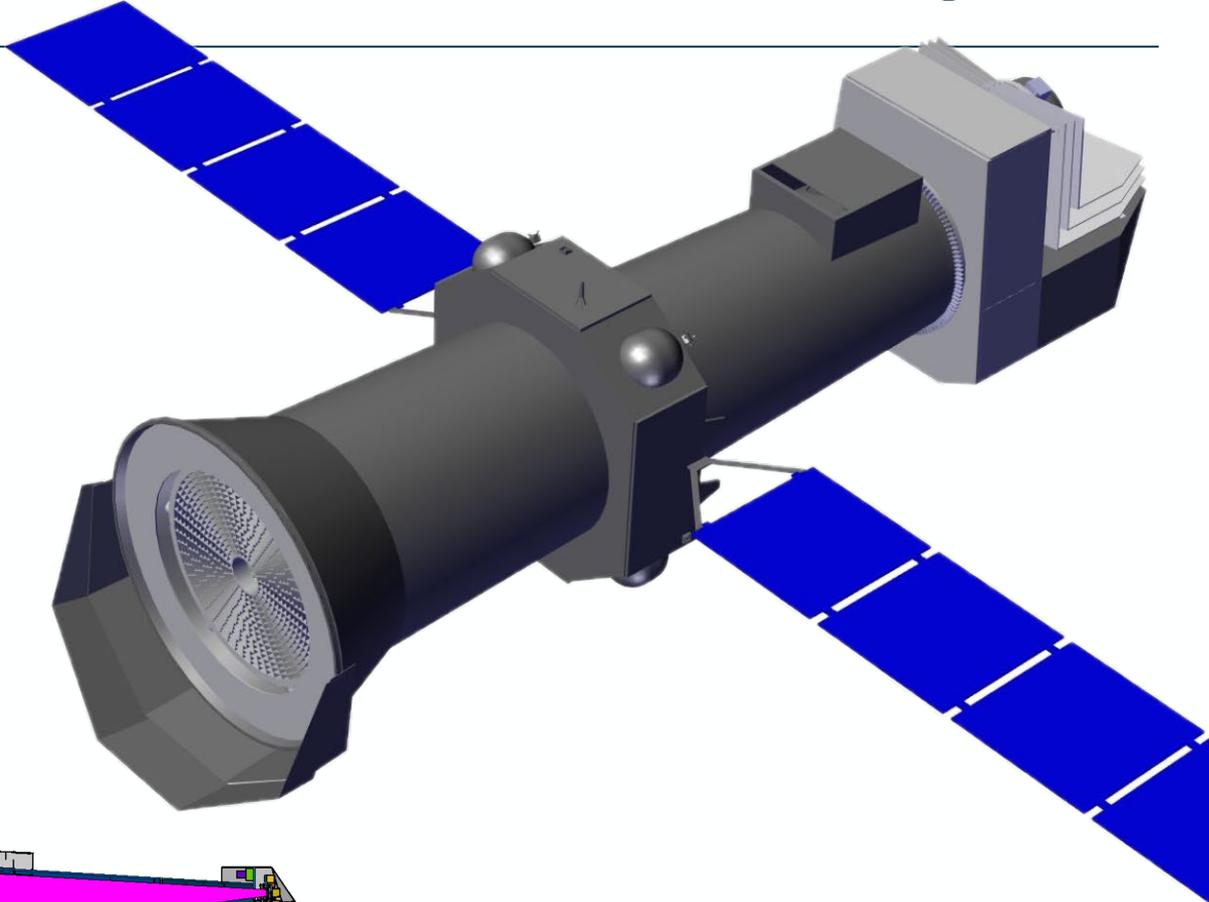
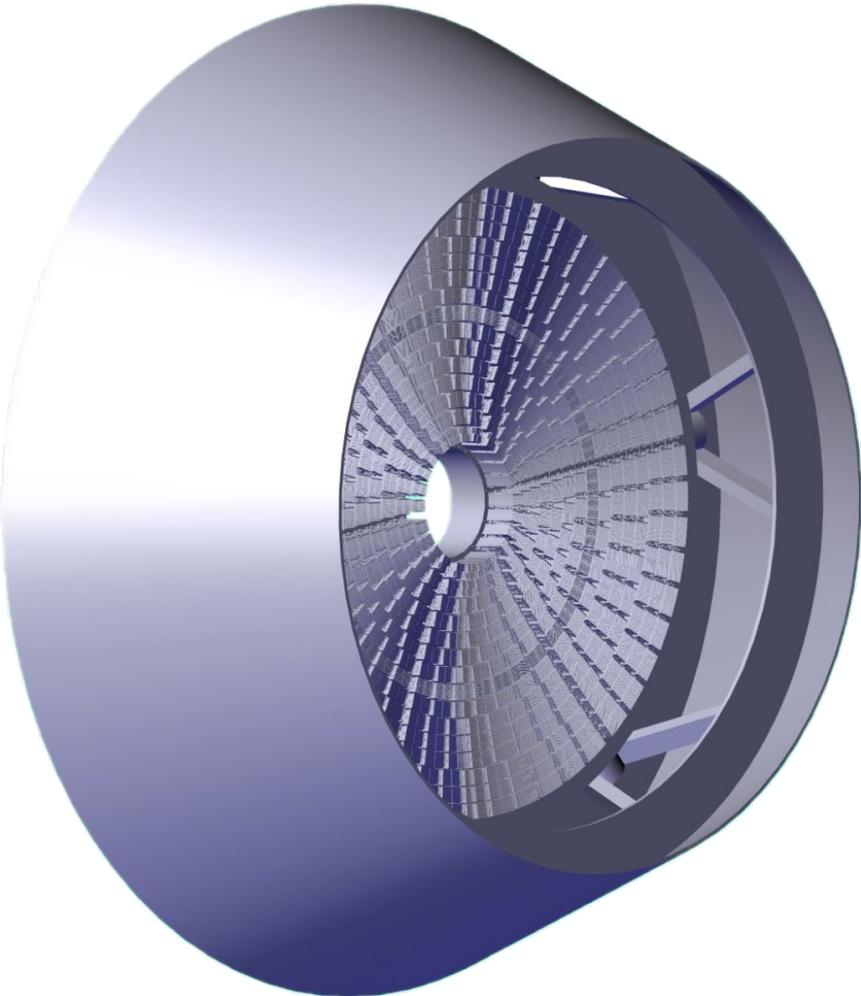


# NewAthena X-ray Optics: polished area equivalent to VLT

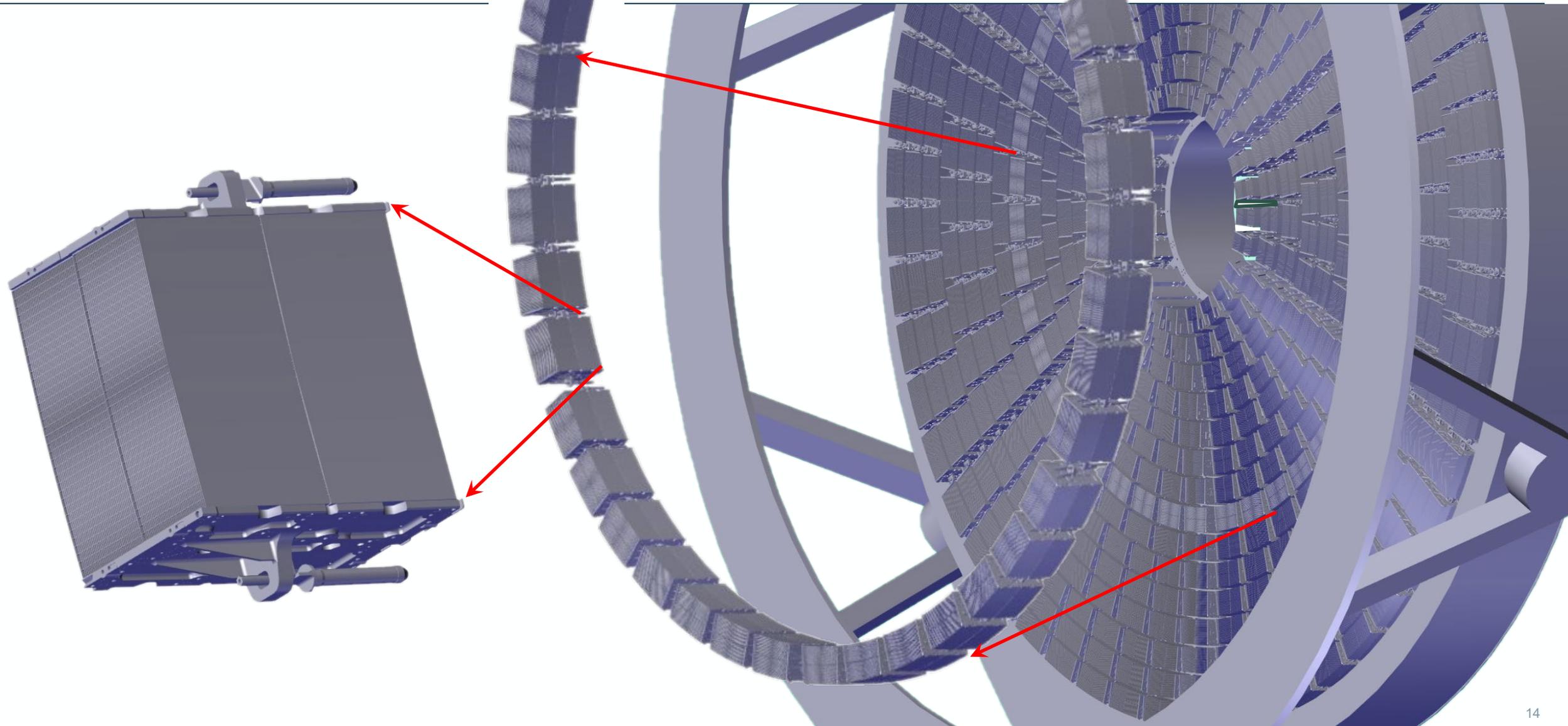
NewAthena: Largest X-ray optics ever conceived  
~100 000 Mirror Plates, area comparable to the mirror surface of the four VLT telescopes (ESO) combined



# Silicon Pore Optics (SPO) enables NewAthena



# Modular Optics for efficient and cost-effective production

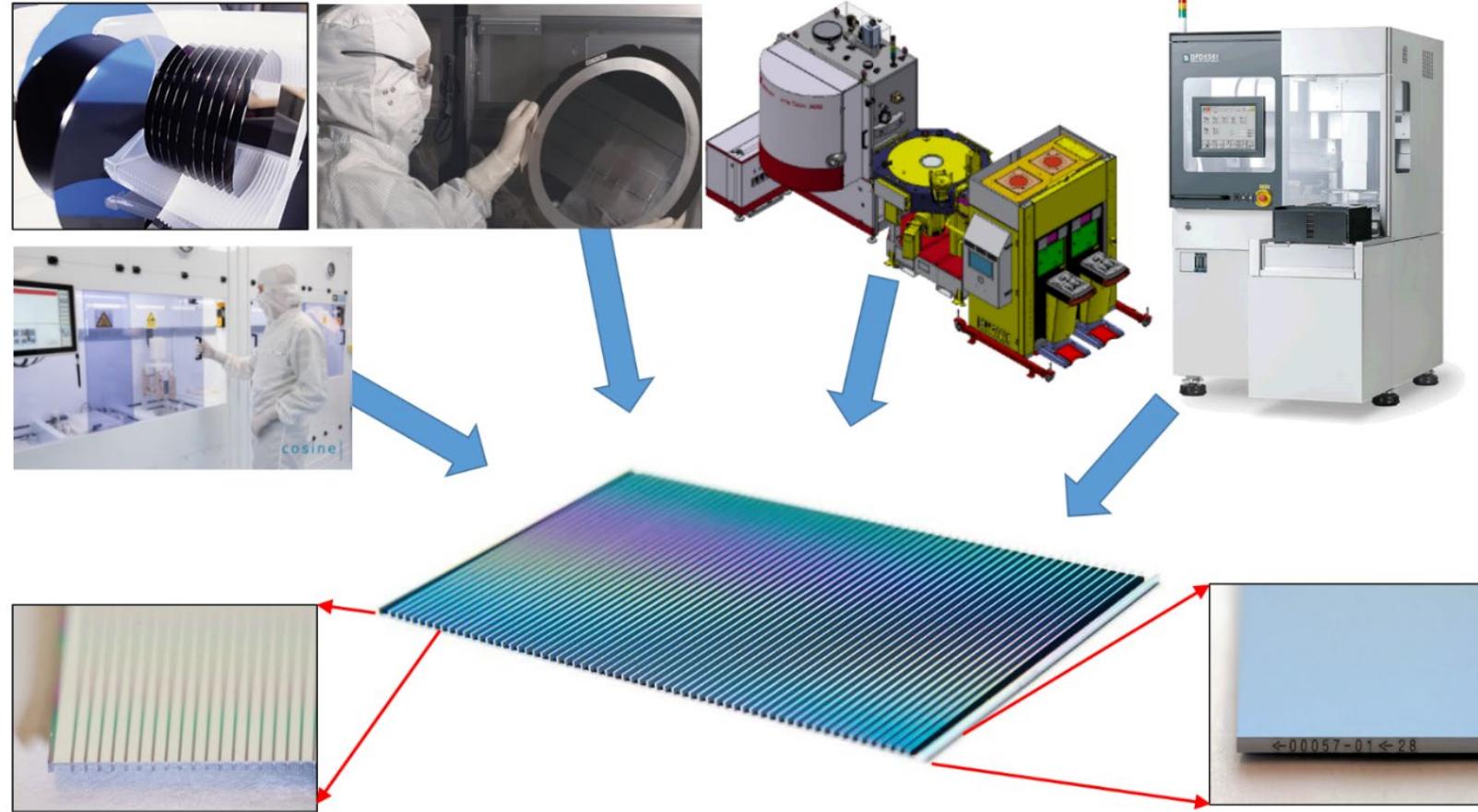




# Technology Spin-in is key to SPO Development

Proven equipment, processes and materials utilised:

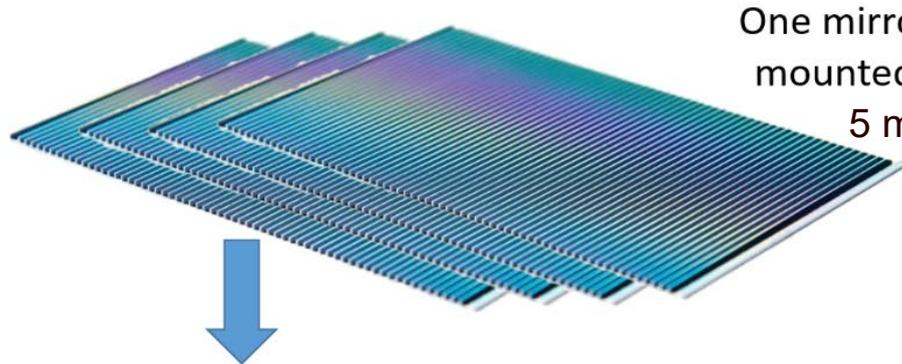
- Mirror plates are made from latest generation commercial silicon wafers, using semicon processes and equipment (currently ~2500 mirror plates per year)
- Mandrels are polished from silicon (semicon) using established optical manufacturing (Zeiss)
- Coating uses solar panel and display industry technology and equipment
- Stacking uses semicon cleaning and robotics processes and tools
- Metrology based on automotive and display industry measurement systems



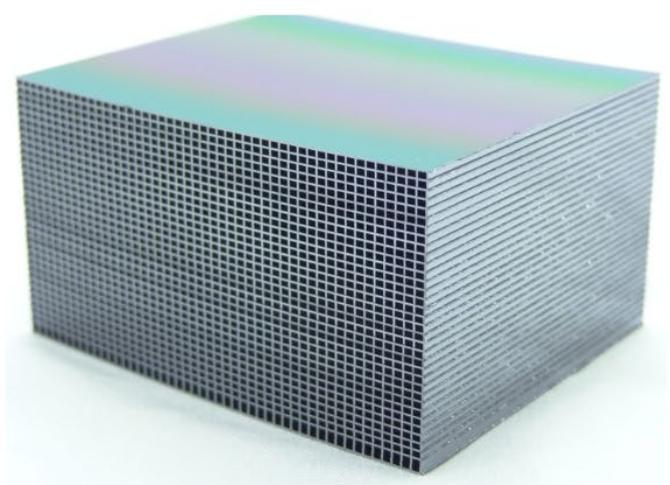
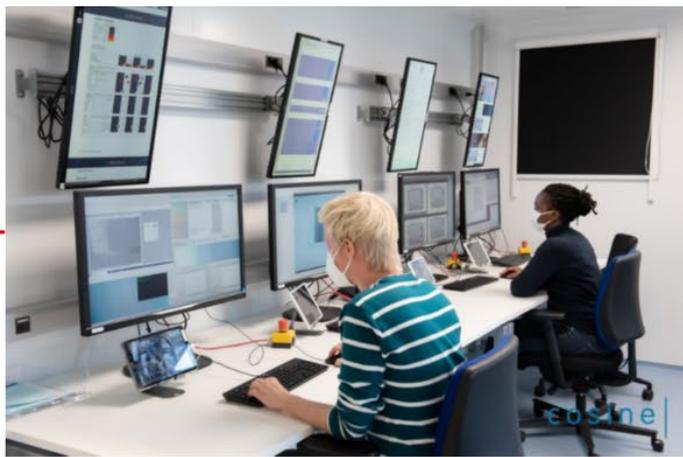
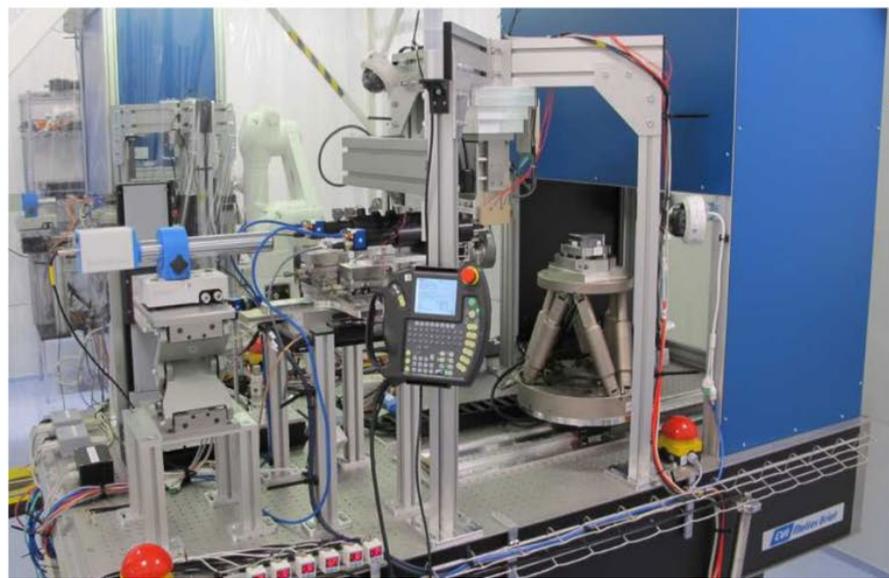
# Mounting of Mirror Plates by Stacking Robots

## Core of the SPO technology:

- Mounting of mirror plates requires very high precision and repeatability
- Have 4 independent stacking robots in operation
- Each robot in its own clean tent, operated remotely
- On-line x-ray performance prediction by fringe reflection metrology
- Stacking speed: 5 min/plate (demonstrated FM requirement)
- Used for ESA, MPE and SRON developments



One mirror plate mounted every 5 minutes

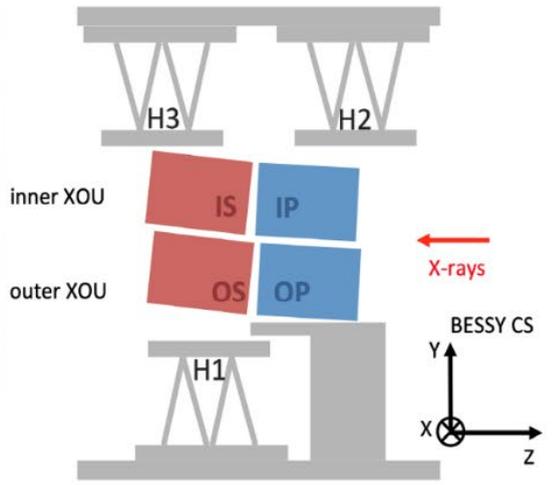
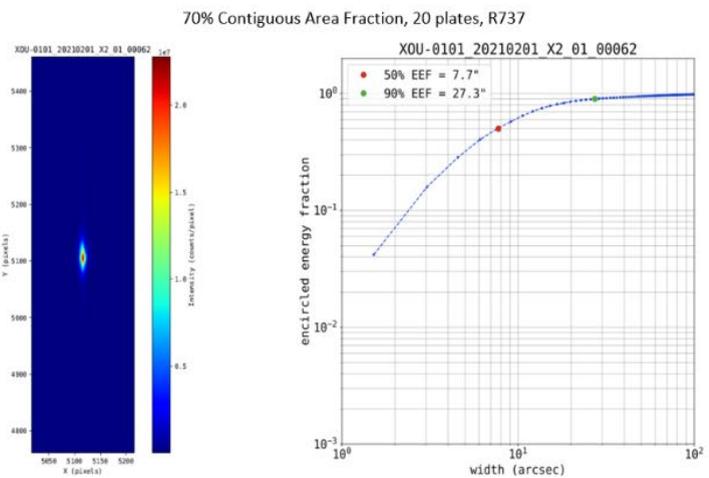


# Mirror Module Assembly using Synchrotron Radiation



## In-vacuum alignment and assembly:

- X-ray metrology with highly collimated synchrotron beam
- Independent laser tracker and auto-collimator metrology systems
- 4 hexapods provide 24 degrees of freedom to position the 4 stacks comprised in a mirror module
- Mirror module performance characterisation

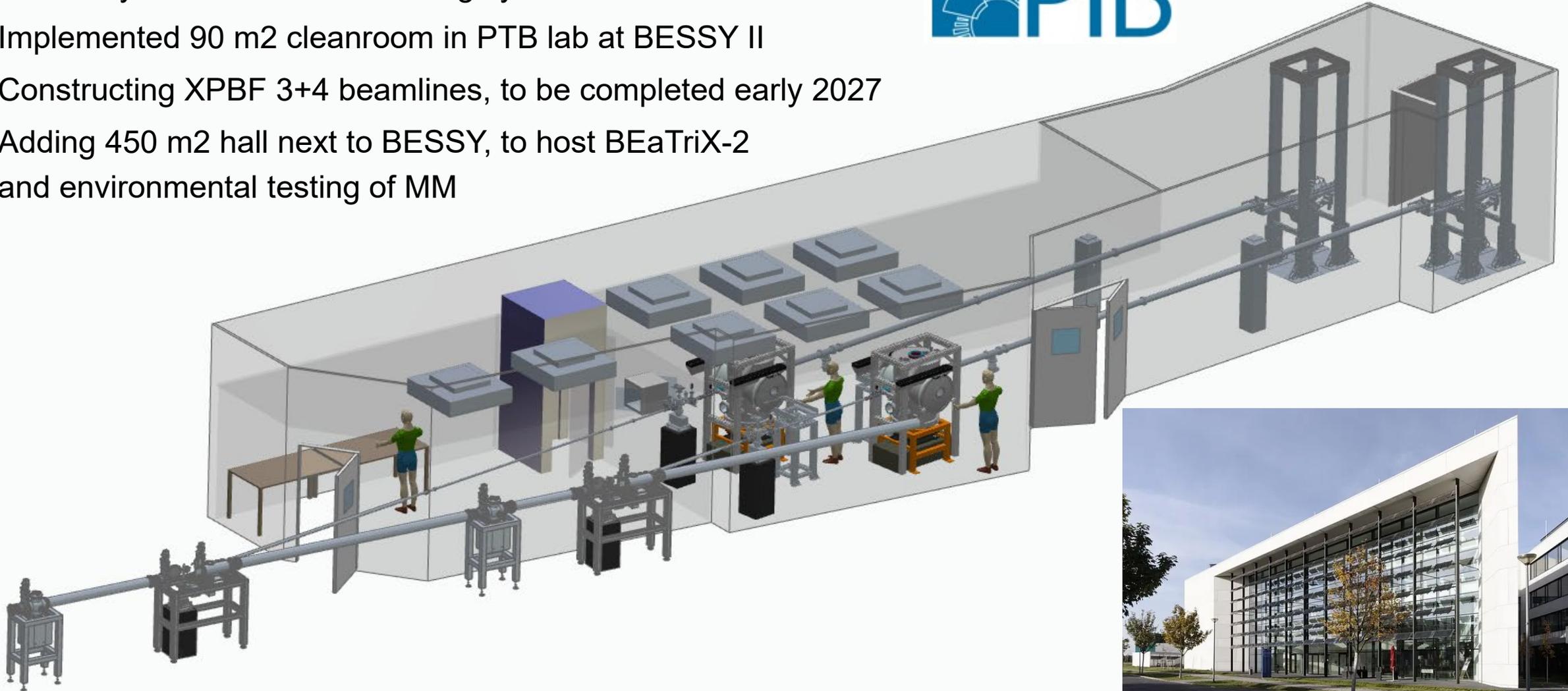


# PTB/BESSY-II: Installing XPBF3 and XPBF4 beamlines

Thermal cycling of row-08 MM-0058 at



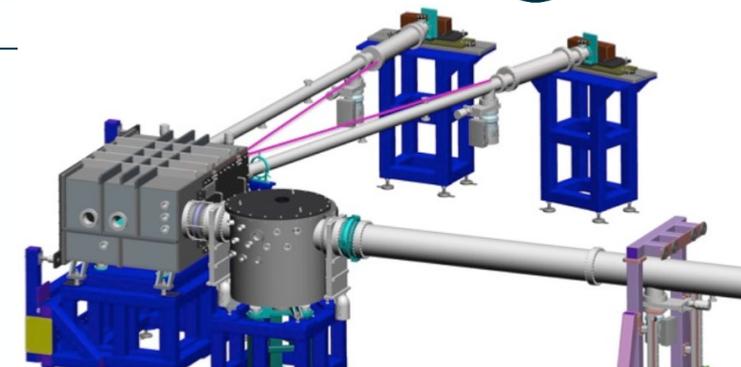
- Assembly of Mirror Modules using synchrotron radiation
- Implemented 90 m2 cleanroom in PTB lab at BESSY II
- Constructing XPBF 3+4 beamlines, to be completed early 2027
- Adding 450 m2 hall next to BESSY, to host BEaTriX-2 and environmental testing of MM



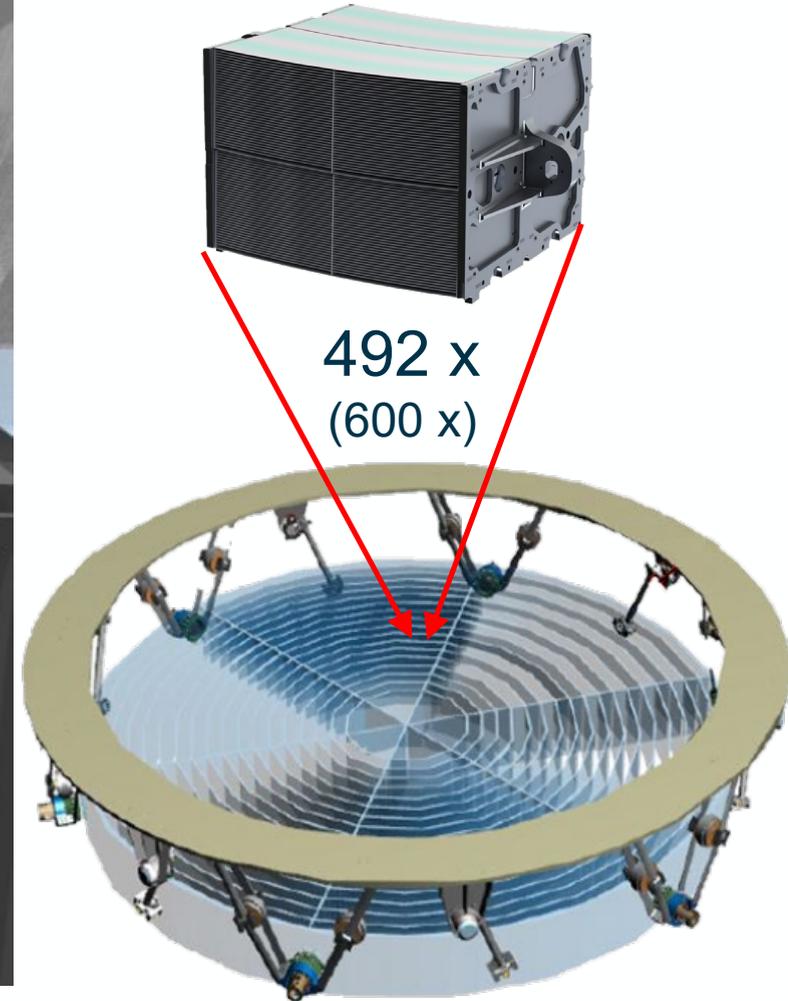
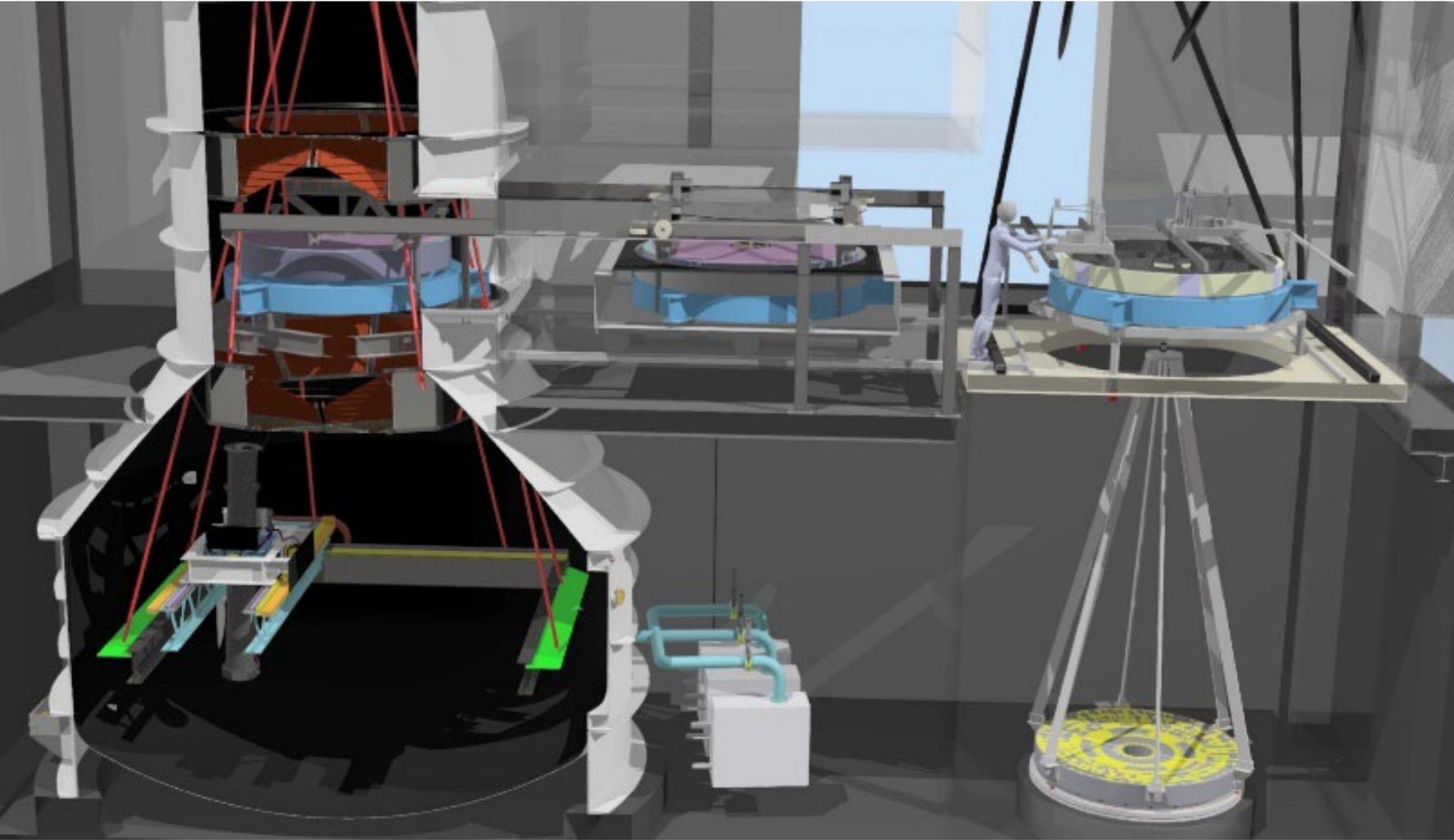
# Mirror Module Verification Facility BEaTriX

## BEaTriX Beamline

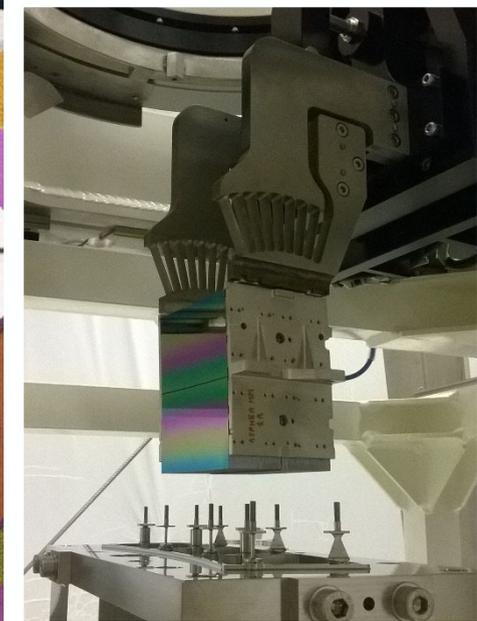
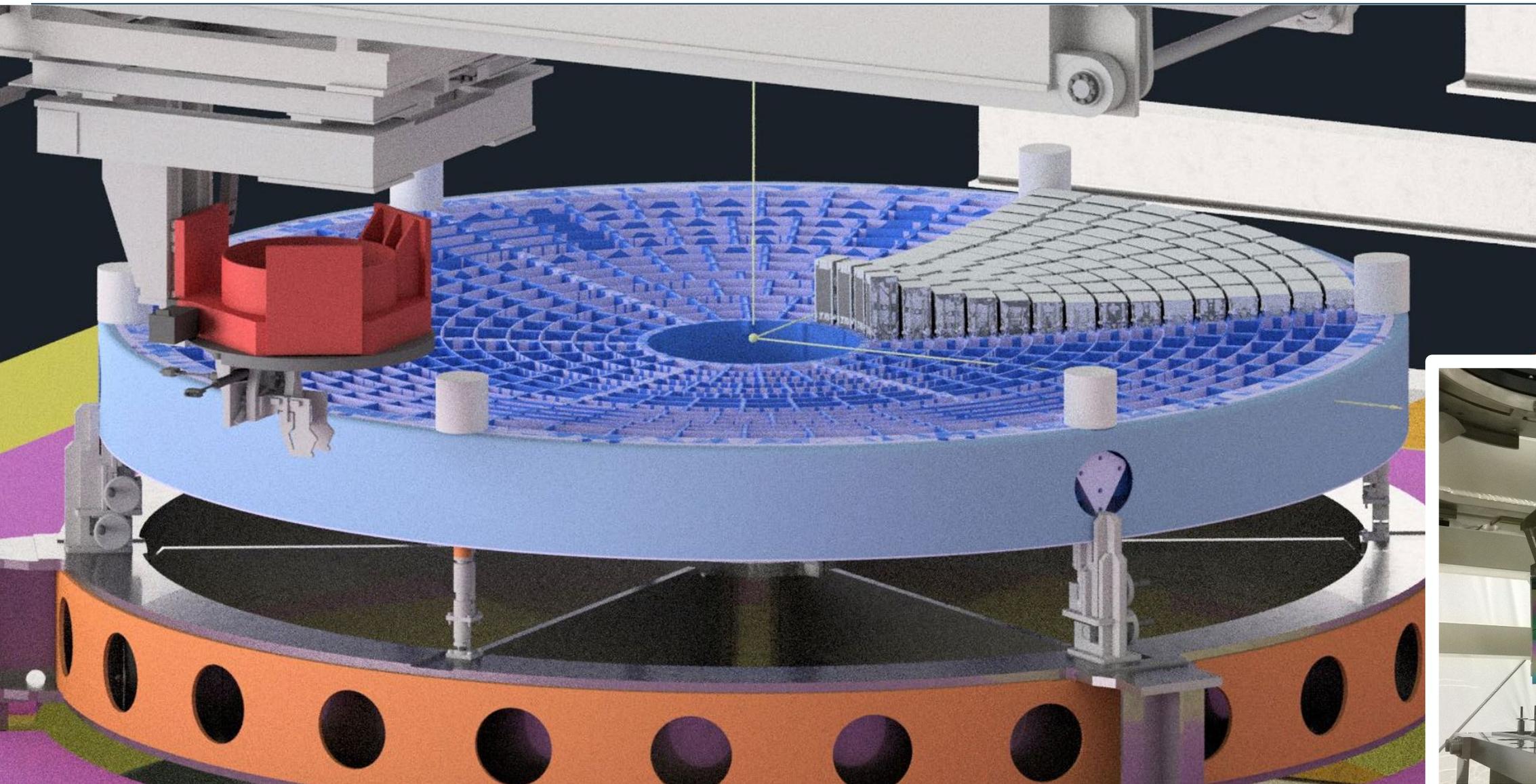
- Mirror Module handover facility (MM manufacturer -> S/C Prime)
- Parallel beam of MM size
- Acceptance testing of MMs
- 4.51 keV and 1.49 keV (new TDA)
- First MM measured successfully Feb 2022



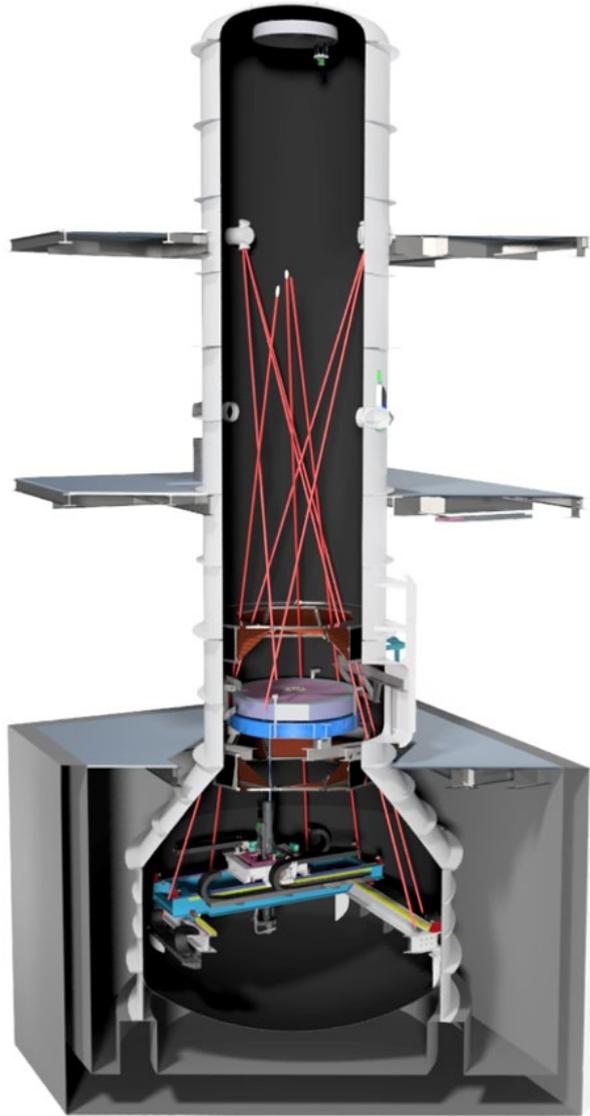
# Mirror Assembly Level AIT and X-ray Verification Facilities



# MAM-AIT facility progressing well: co-alignment of MMs



# VERT-X: Vertical X-ray Test Facility under construction



Novel approach

20 meters high  
Vacuum vessel

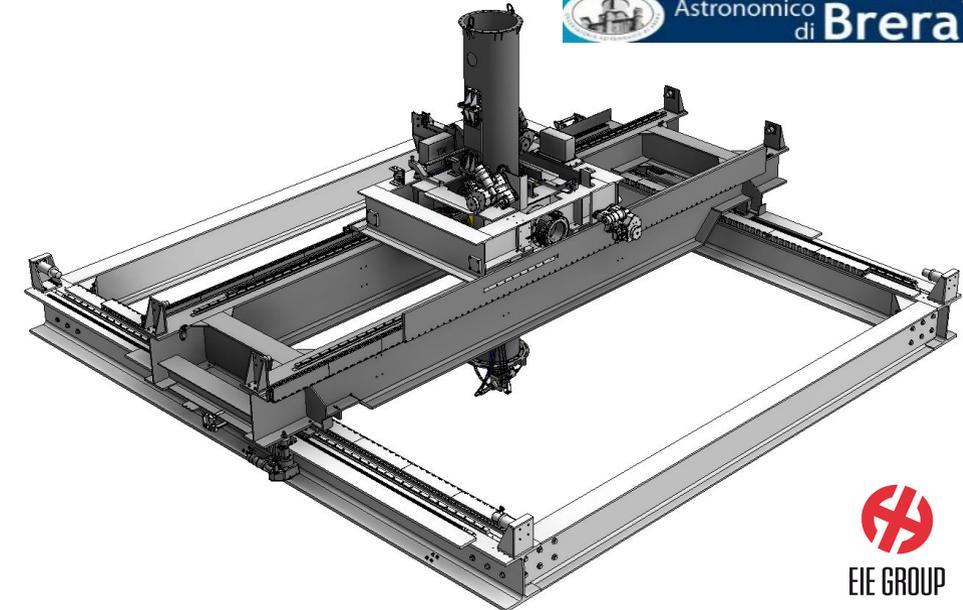
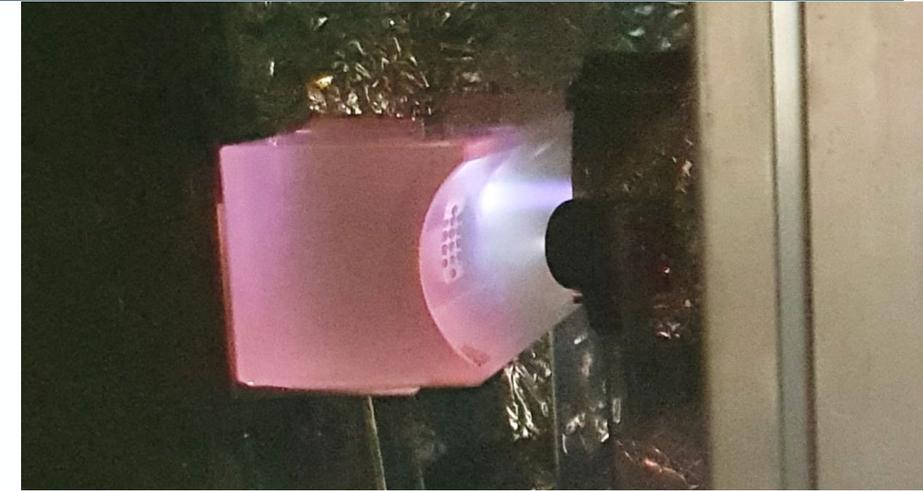
Highly collimated  
X-ray beam

Very accurate  
Positioning system

Laser tracker  
Metrology

Mirror Assembly horizontal  
(minimizes deformation by  
gravity)

Co-located with MAM-AIT facility



# NewAthena: the Next Generation X-ray Observatory



## NewAthena complements other great observatories

- Half the observable matter in the Universe is at high temperatures
- Complements other great observatories (JWST, ELT, ALMA, SKA), ...
- NewAthena will be the leading X-Ray Space Observatory for decades

## SPO delivering on NewAthena requirements

- Provides the required combination of effective area, good angular resolution and low mass
- Optics is robust and compliant with programmatic constraints

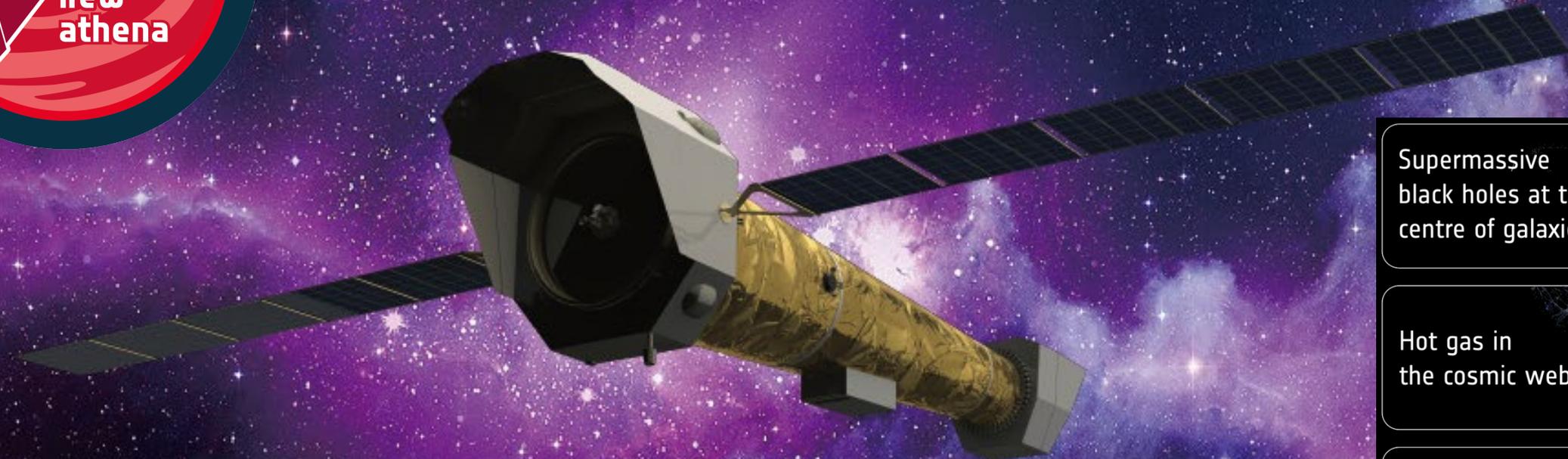
## Mosaic telescope Technology

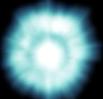
- Segmentation into SPO Mirror Modules essential
- Allows cost effective production with table-top equipment
- Industrialised fabrication of optics, 600 Mirror Modules
- Require bespoke assembly and test facilities on telescope level





# NewAthena - the next generation X-ray observatory



- Supermassive black holes at the centre of galaxies 
- Hot gas in the cosmic web 
- High-energy astrophysical events 

A Mosaic Telescope:  
Modular Silicon Pore Optics  
makes the next ESA Science Flagship mission possible