

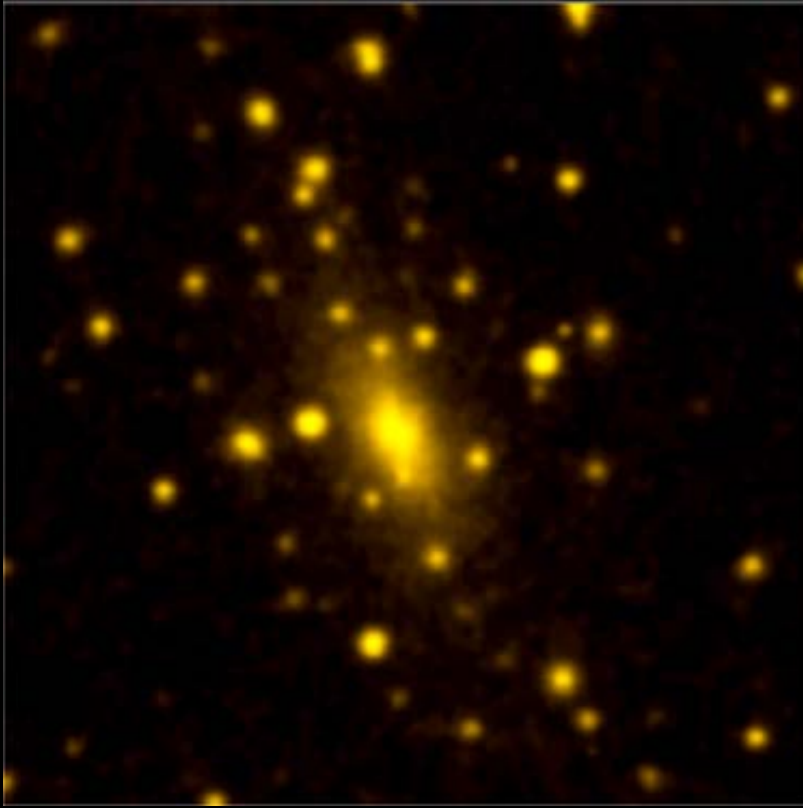
X-ray Astronomy at Marshall Space Flight Center

Chandra, IXPE, Lynx

Martin C. Weisskopf
Chief Scientist for X-ray Astronomy
Chandra Project Scientist
IXPE Principal Investigator
(NASA/Marshall Space Flight Center)

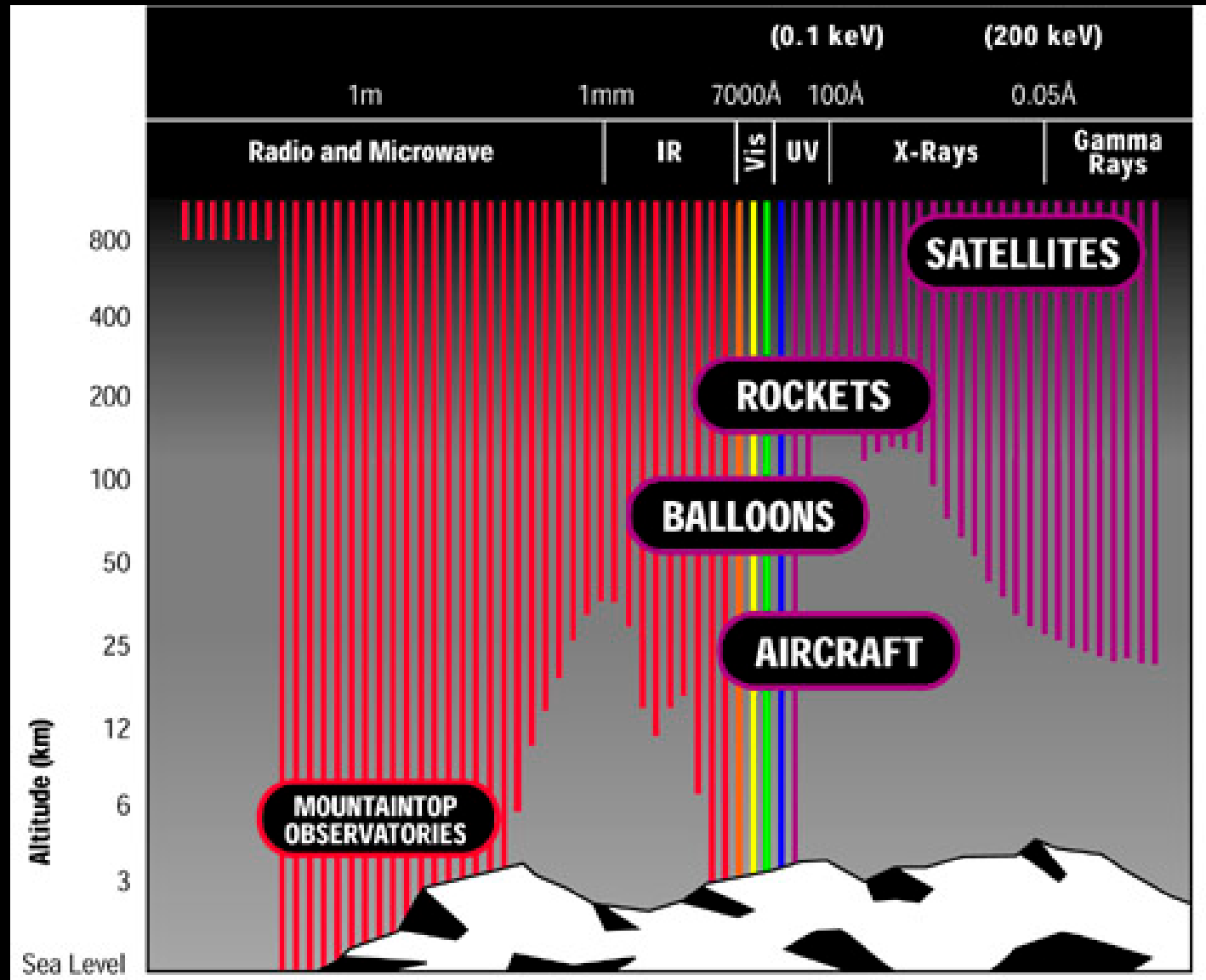
- Why X-ray Astronomy is so important
- NASA's Great Observatory Program
- A (very) brief history of X-ray astronomy
- The building of the Observatory
- Launch, deployment, first light!
- Some of the wonderful science
- The Nobel for Riccardo

The importance of X-ray Astronomy



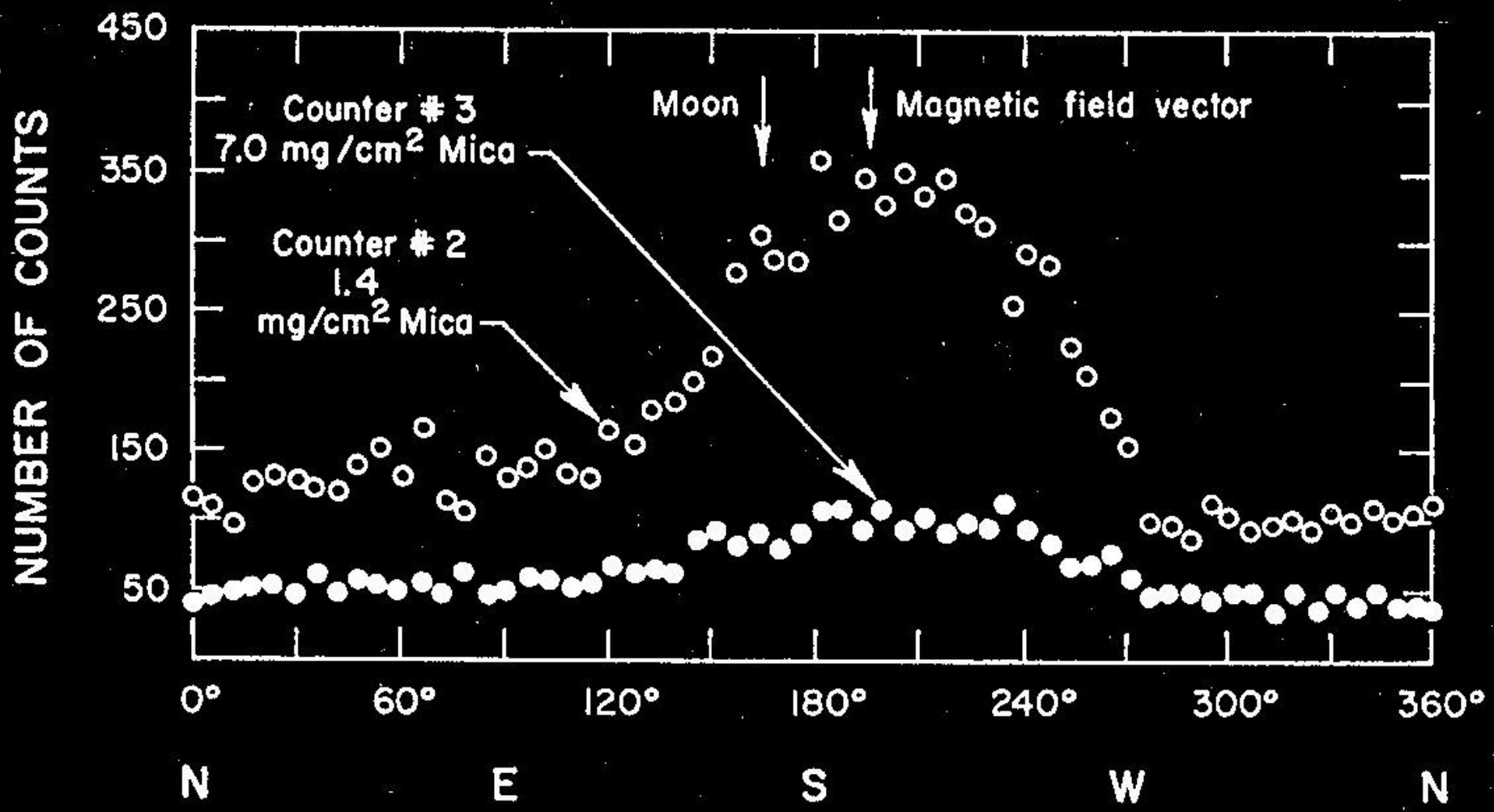
- Most of the matter that we “see” in the universe is via its X-ray emission
- The bulk of this matter is the hot, X-ray-emitting gas in the great galaxy clusters

The Atmosphere is a Nuisance



Altitude
(km)

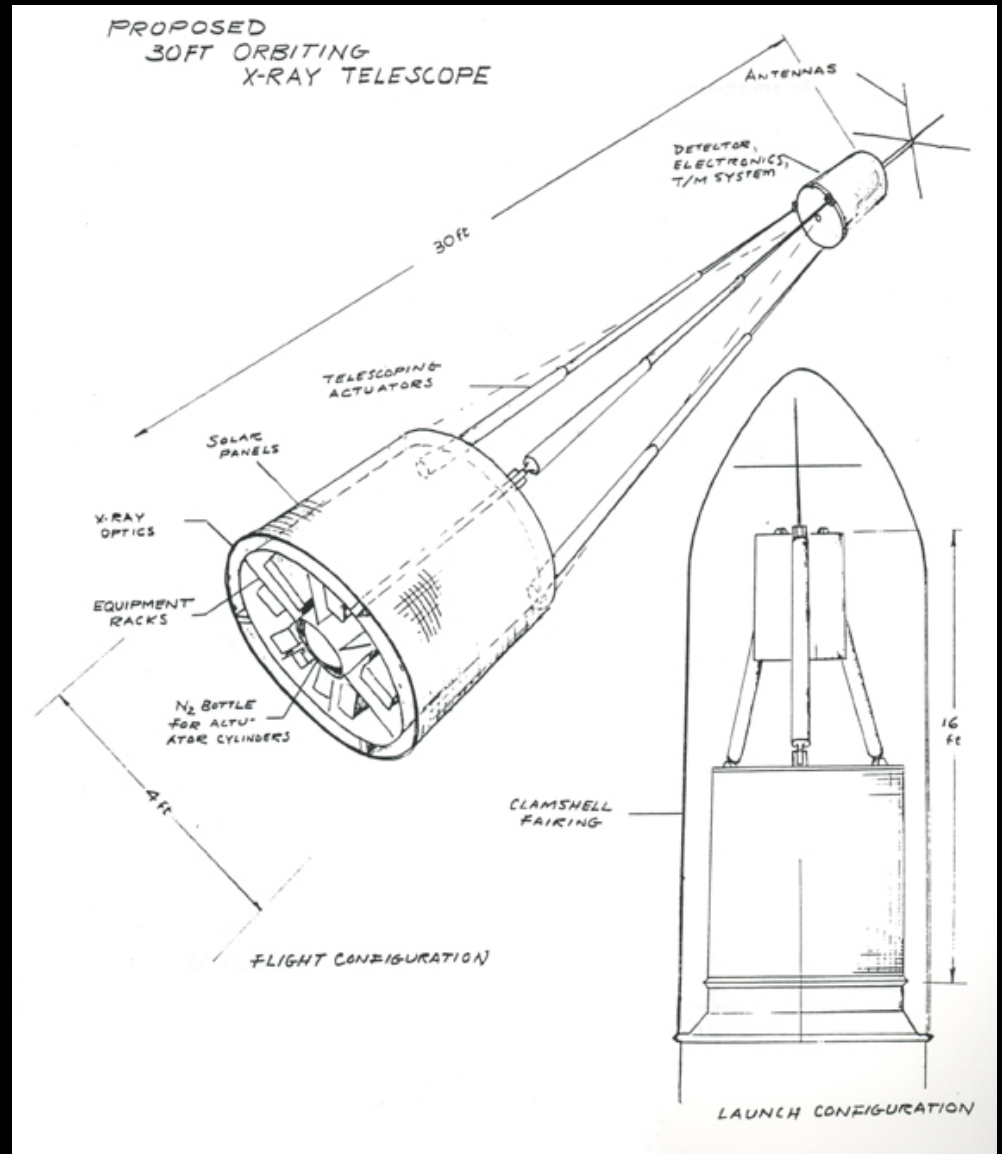
The First Extra-Solar X-ray Source (1962)



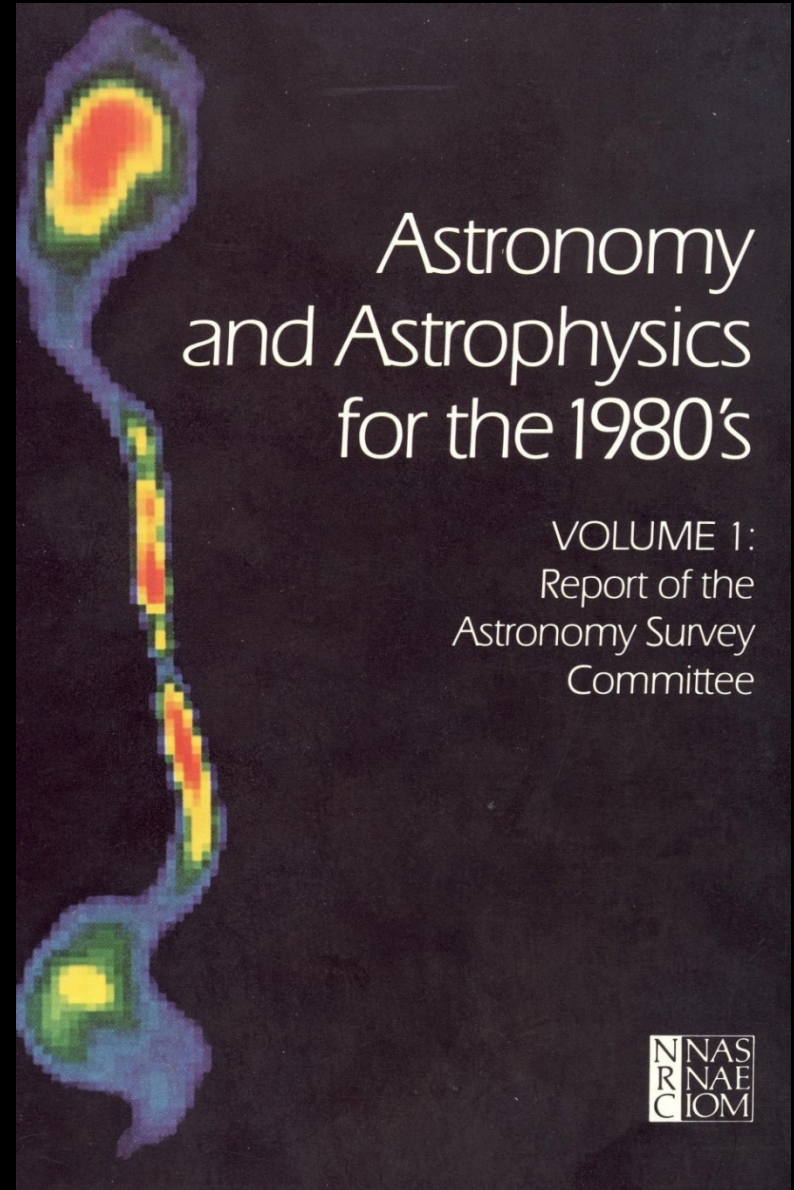
The Vision (1963)



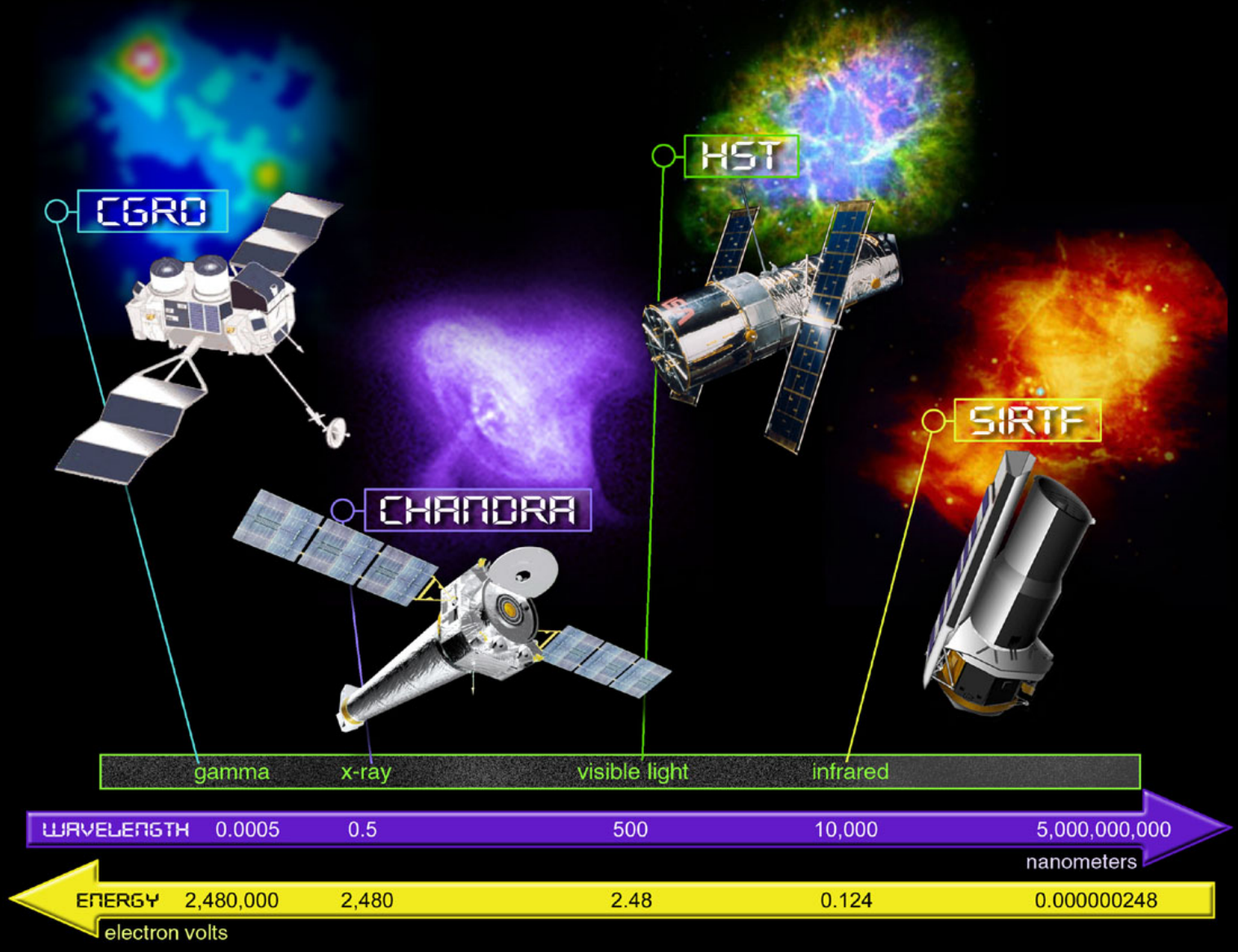
Riccardo Giacconi



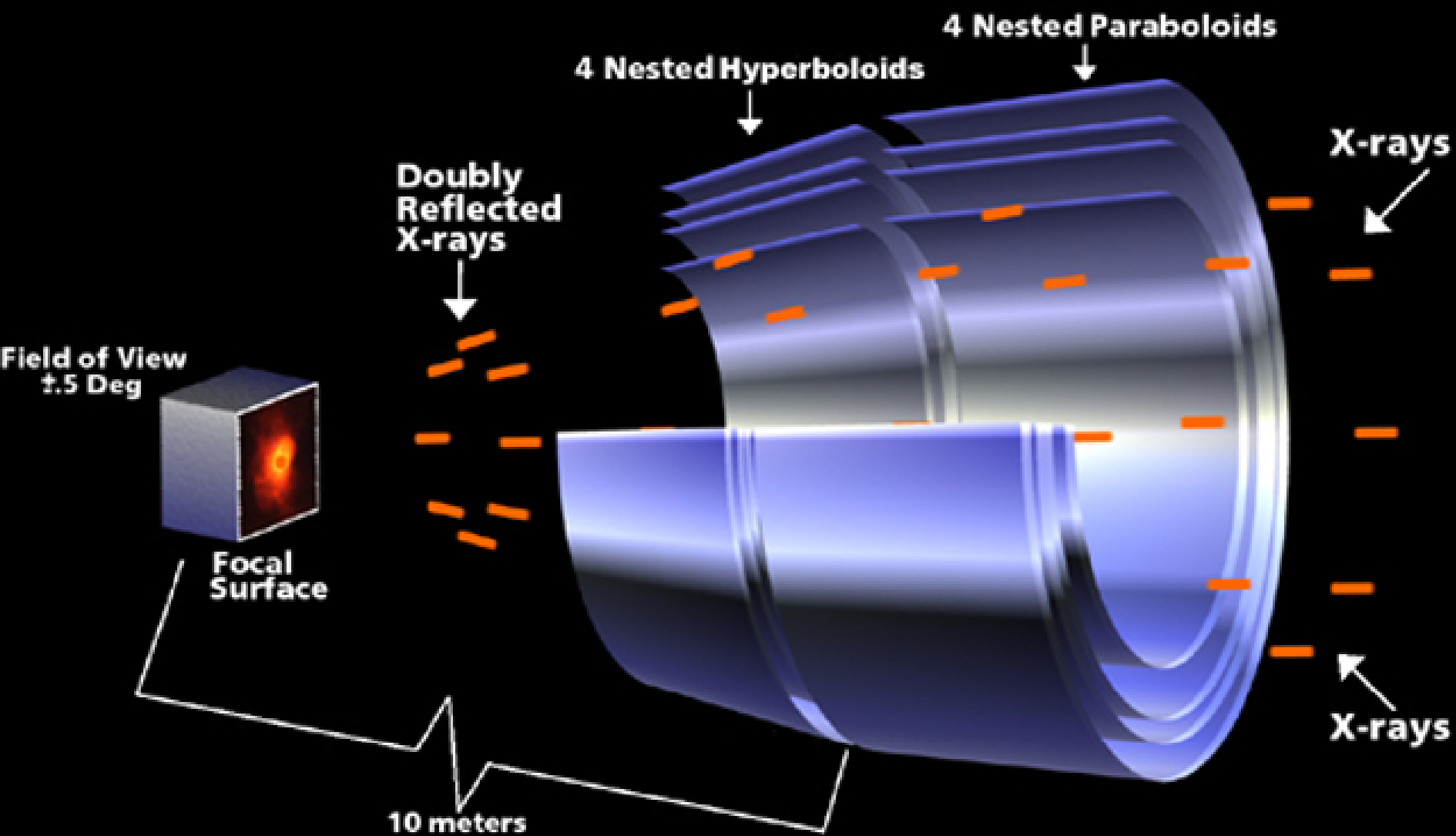
Major New Programs
#1: An Advanced X-Ray
Astrophysics Facility (AXAF)



NASA's Great Observatories

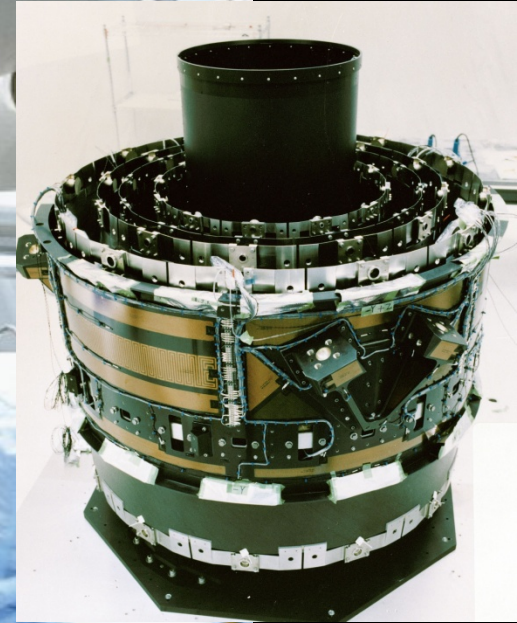
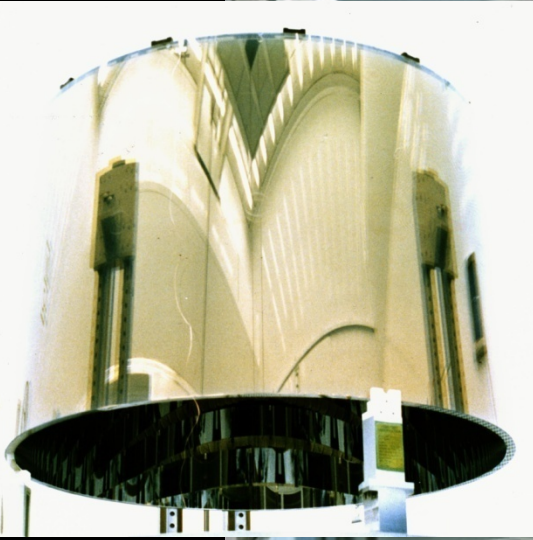
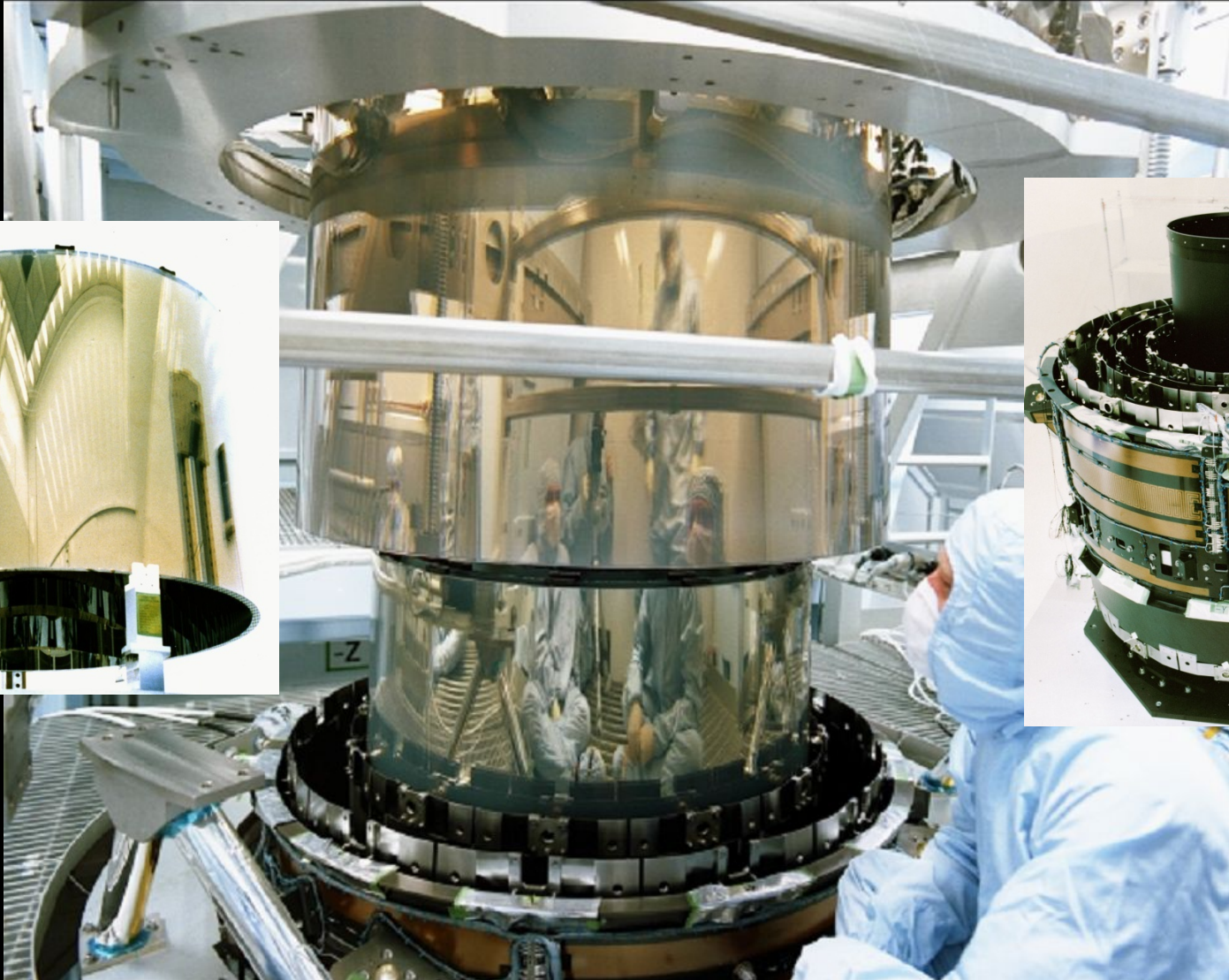


Optics



Mirror elements are 0.8 m long and from 0.6 m to 1.2 m diameter

Optics: Coated, Assembled & Aligned



The X-ray Calibration Facility at MSFC



Include the Upper Stage and in the Shuttle



The longest and heaviest payload ever launched by the Shuttle

The Launch – July 23 1999

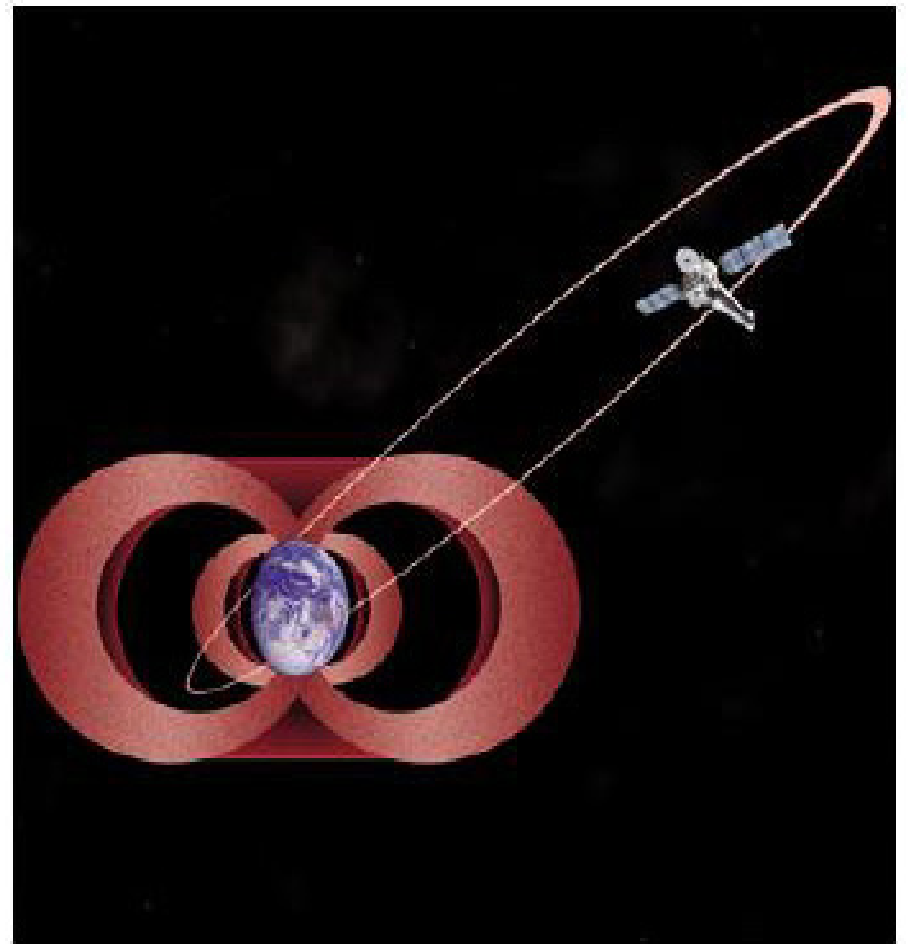
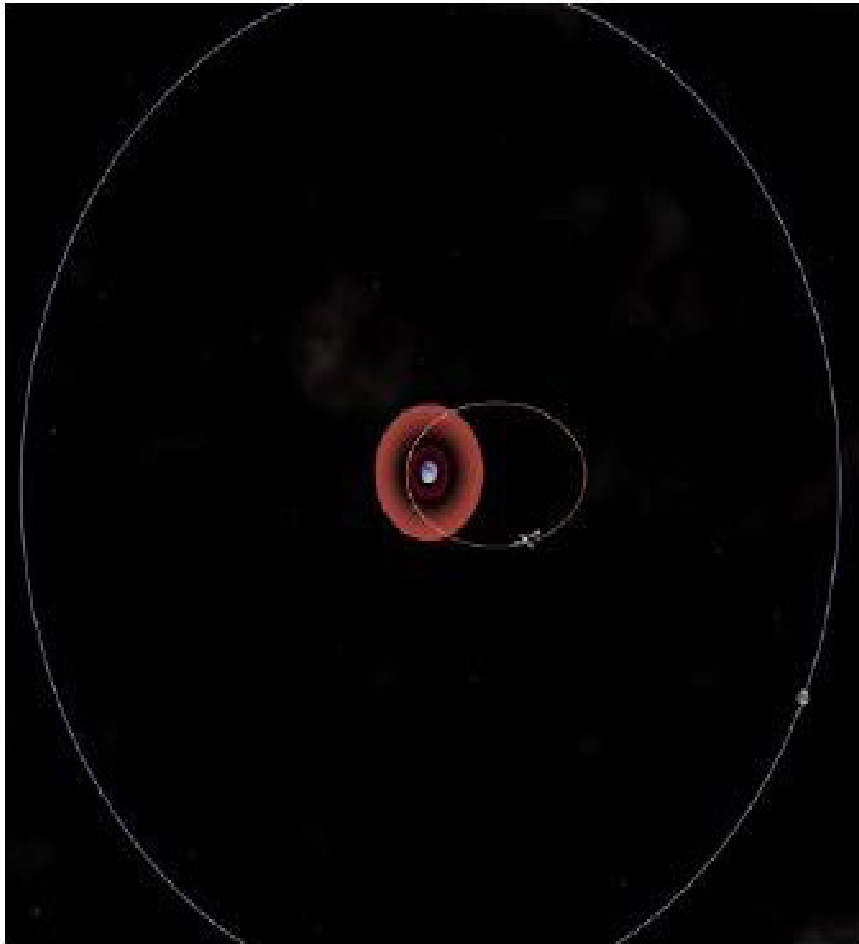
Beyond the Sky

Words and Music by Judy Collins

And we will fly beyond the sky
Beyond the stars beyond the heavens
Beyond the dawn we'll carry on
Until our dreams have all come true
To those who fly - we sing to you



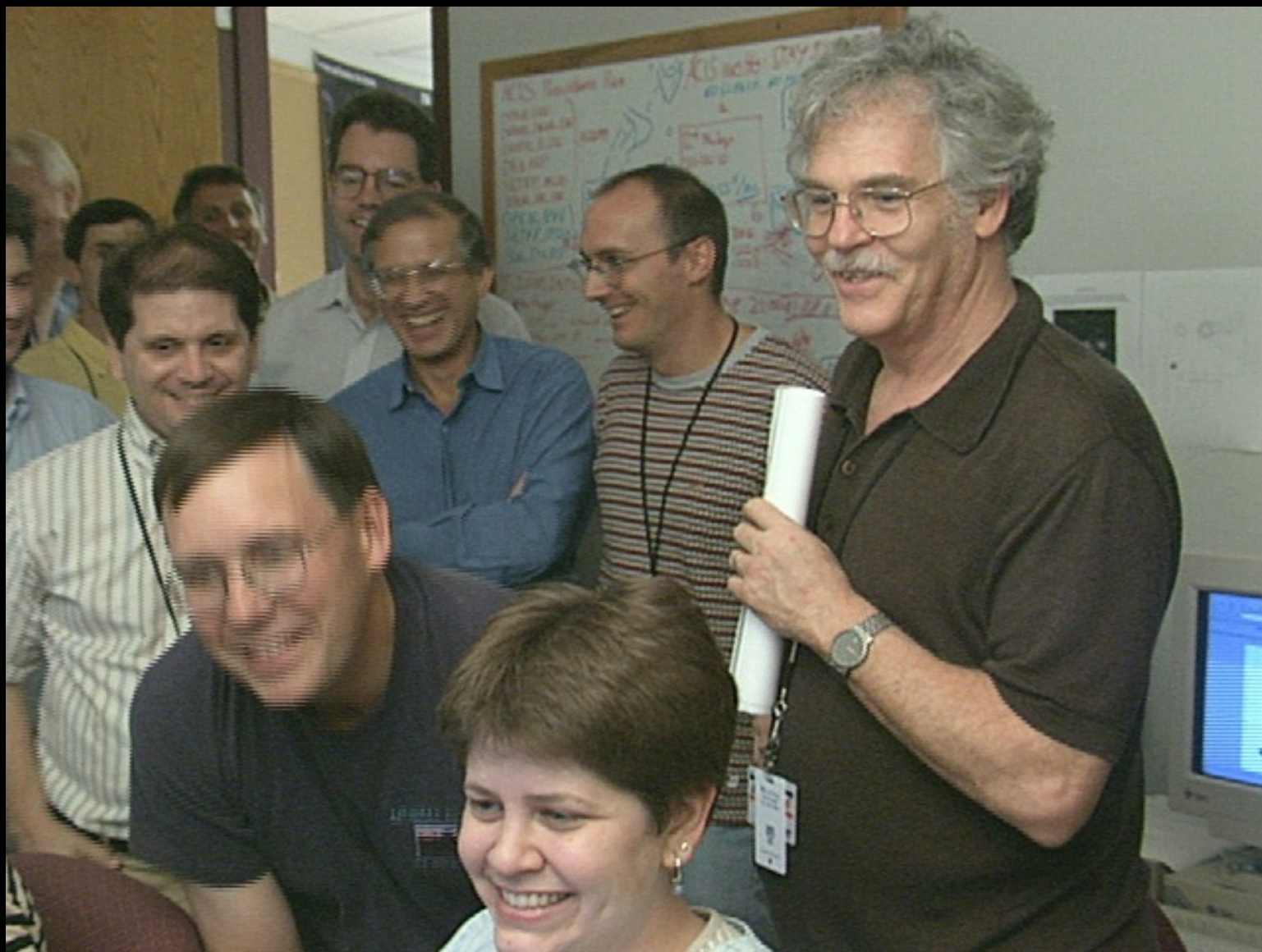
The final orbit



From above, with radiation belts & Moon

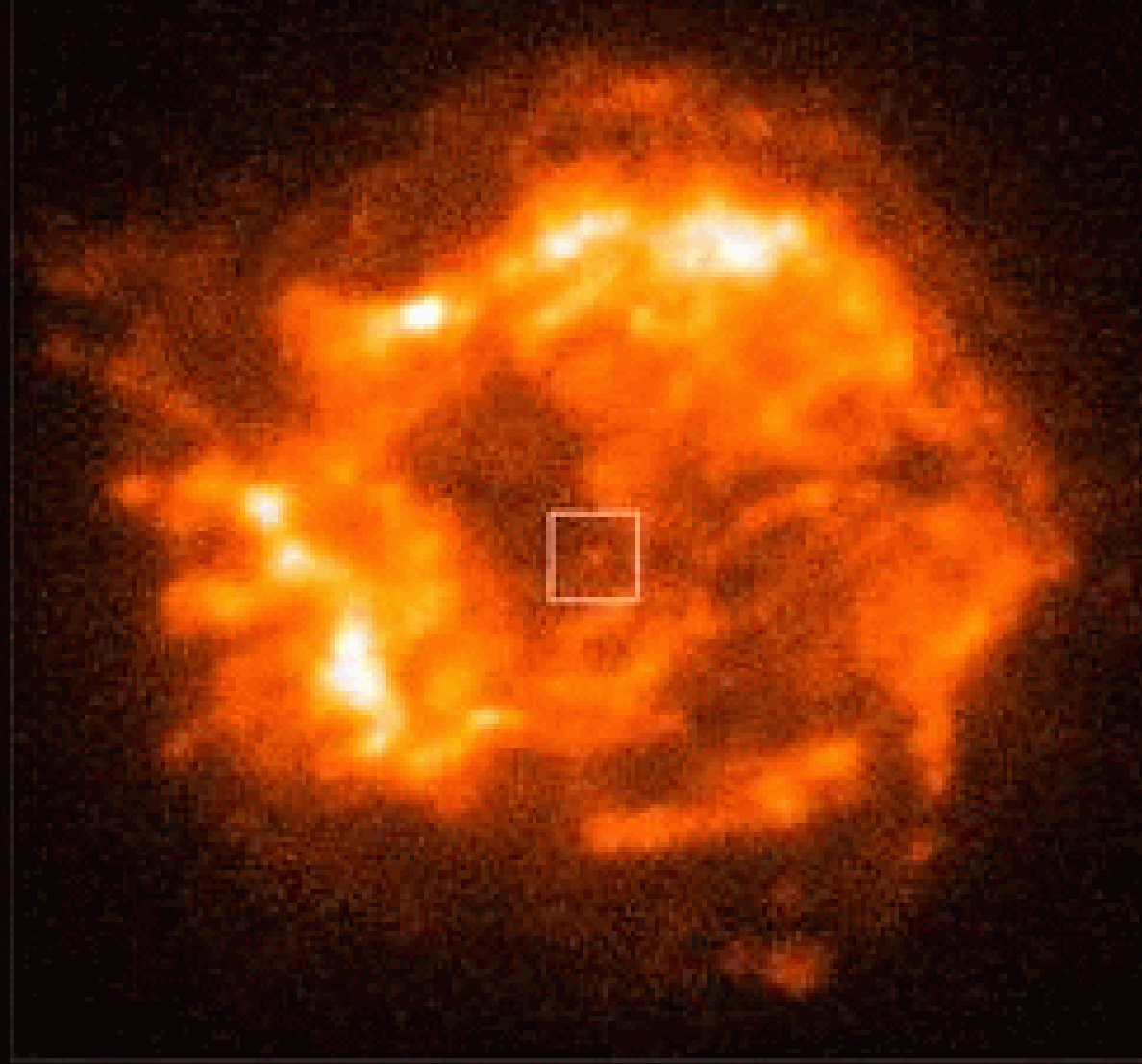
Side view, showing radiation belts

First light!

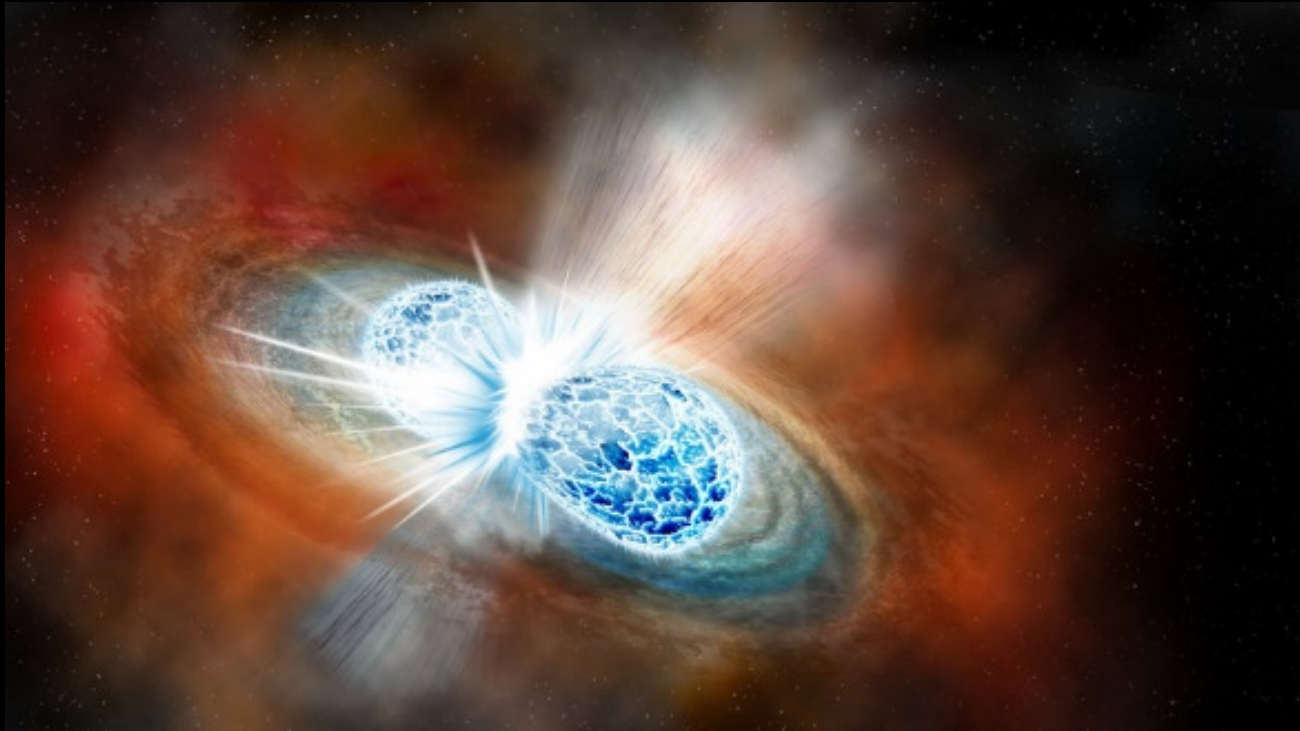


The Official First Light: Cas A

1 arcminute



Two Neutron Stars Collide! (Wow)



GW170817

NGC 4993

August/September 2017

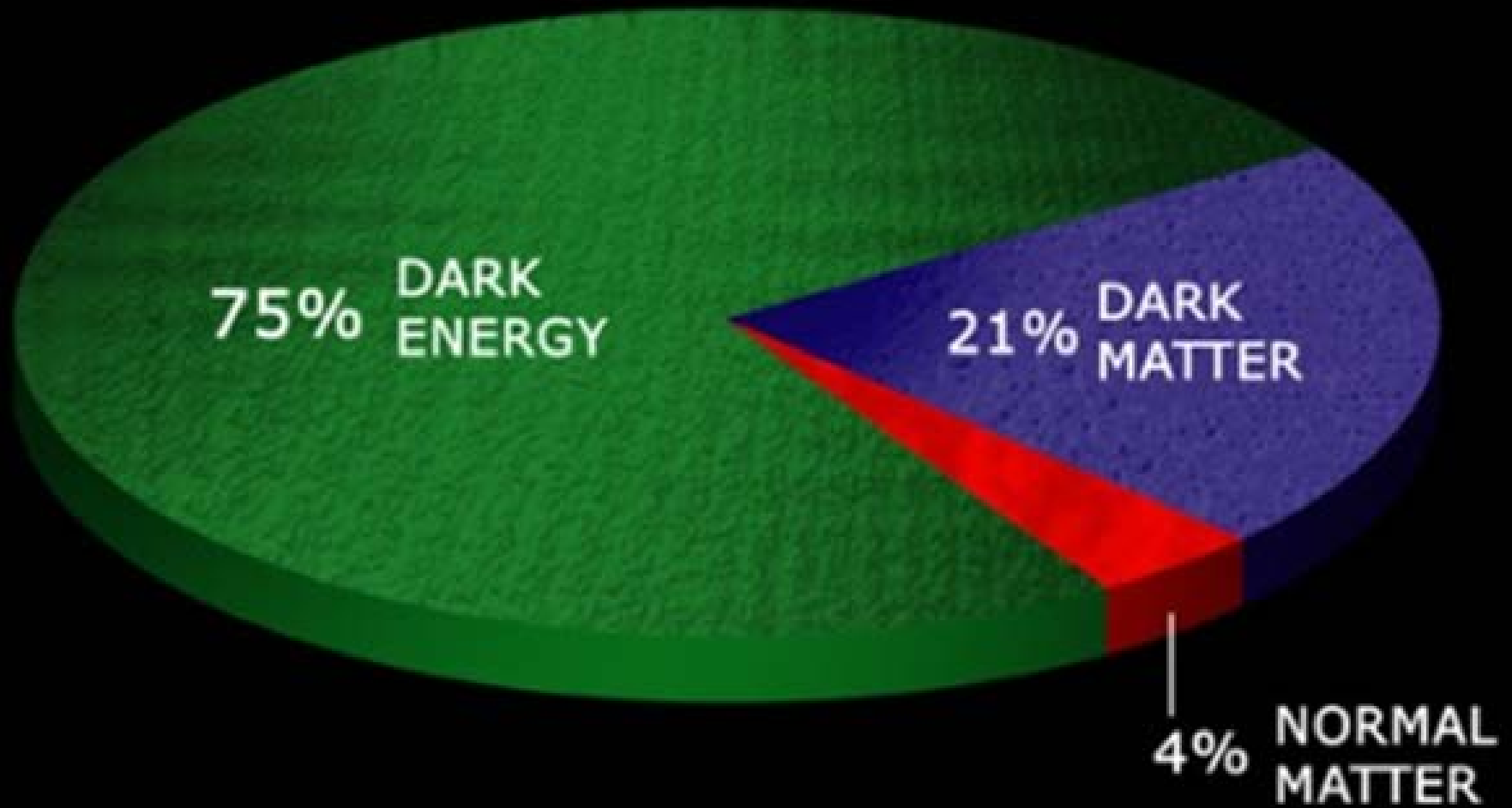
GW170817

NGC 4993

December 2017

Ruan et al, ApJL, Jan 18, 2018

Dark Energy and Dark Matter



Colliding clusters of galaxies and dark matter

Blue – most of the mass

Pink – normal X-ray emitting matter

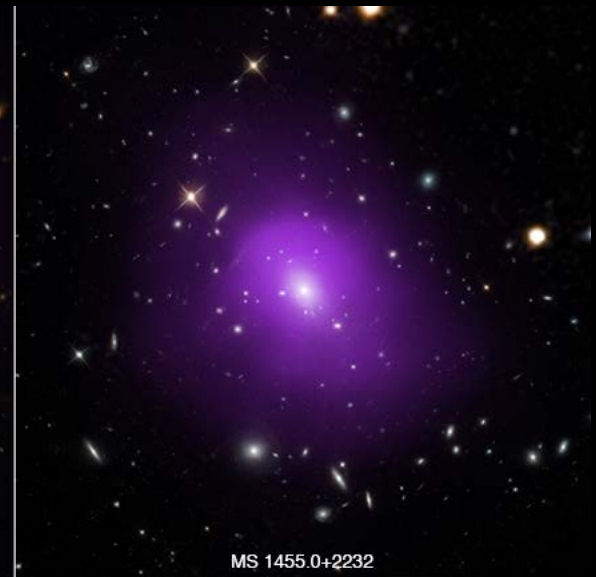
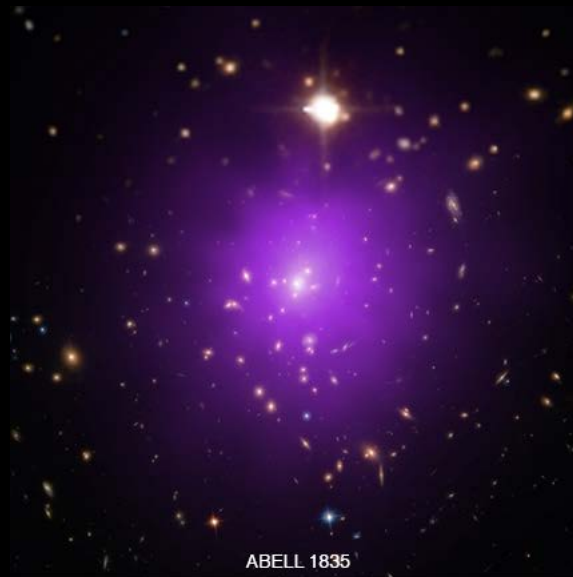


Probing Dark Energy with Chandra

This study examined
300 galaxy clusters

Size versus time
depends on dark
energy

Confirms the
“cosmological constant”



The 2002 Nobel Prize Riccardo Giacconi



Where to Learn More

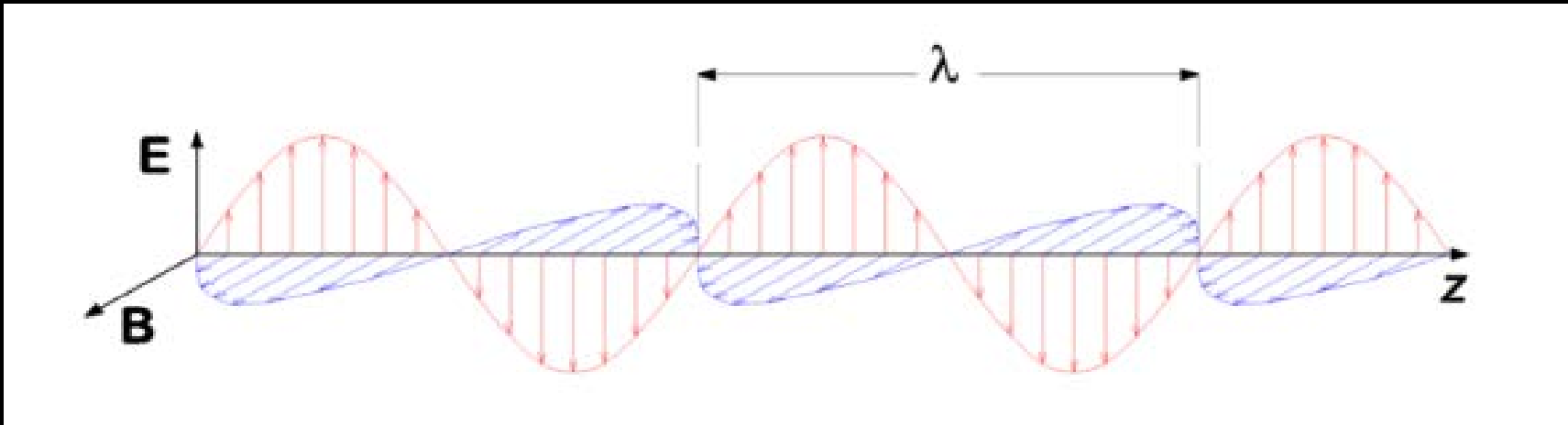


The opportunity for exploration and discovery with Chandra remains as high today as it was at launch

Outline – Part 2 IXPE

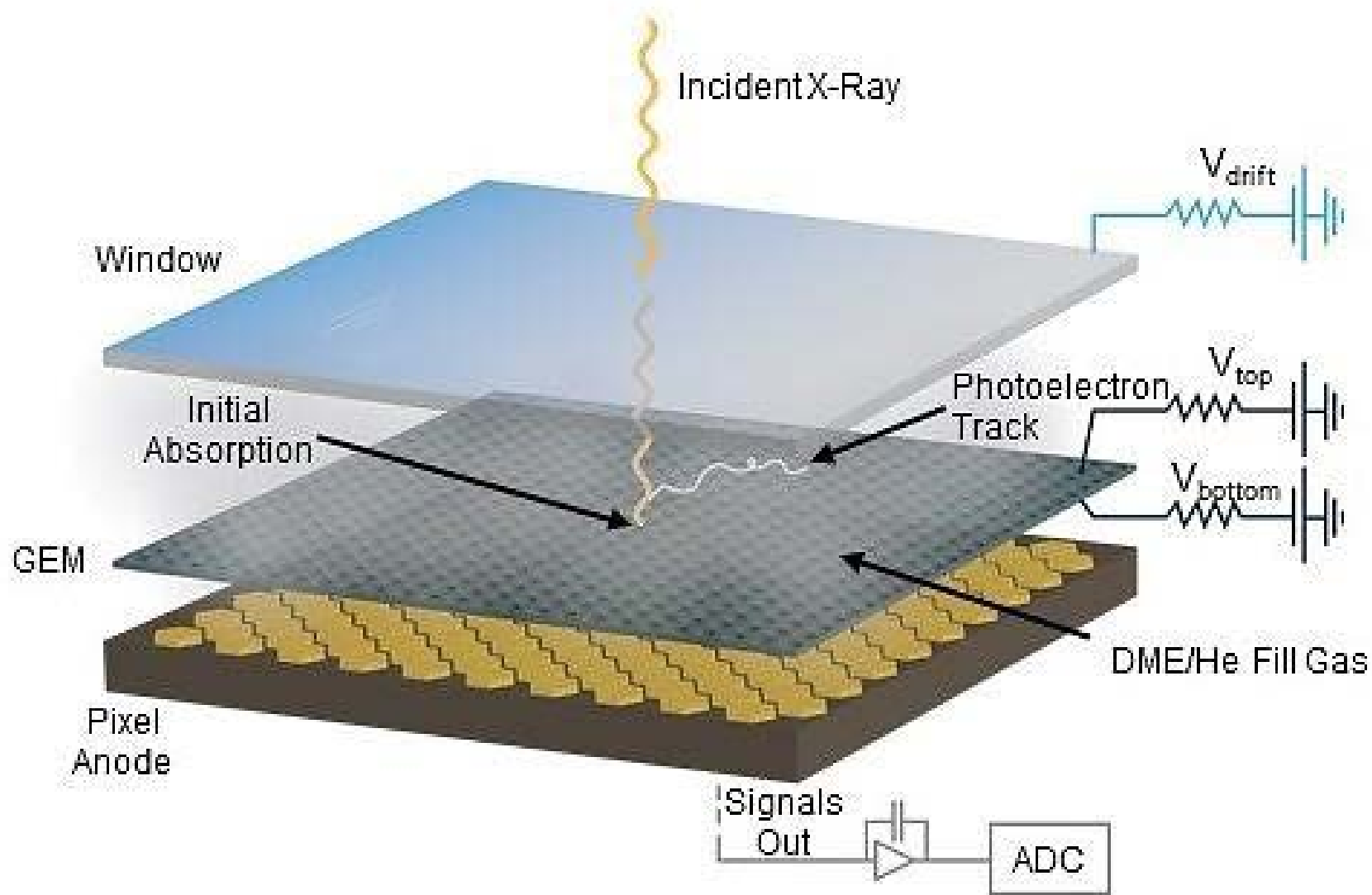
- IXPE = Imaging X-ray Polarimetry Explorer
- NASA's Explorer Program (Class D, \$200M)
- Launch no earlier than April, 2021
- Who is involved
- What does it do
- One example of the wonderful science

Polarization of an electromagnetic wave



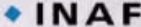











- An electromagnetic wave (photon) has an electric and magnetic field associated with it
- The fields are at right angles to the direction of motion of the wave (photon)
- The direction of the electric vector is what we refer to as the position angle
- The degree of polarization is the fraction of electric vectors of a collection of photons that line up with each other

The IXPE detectors



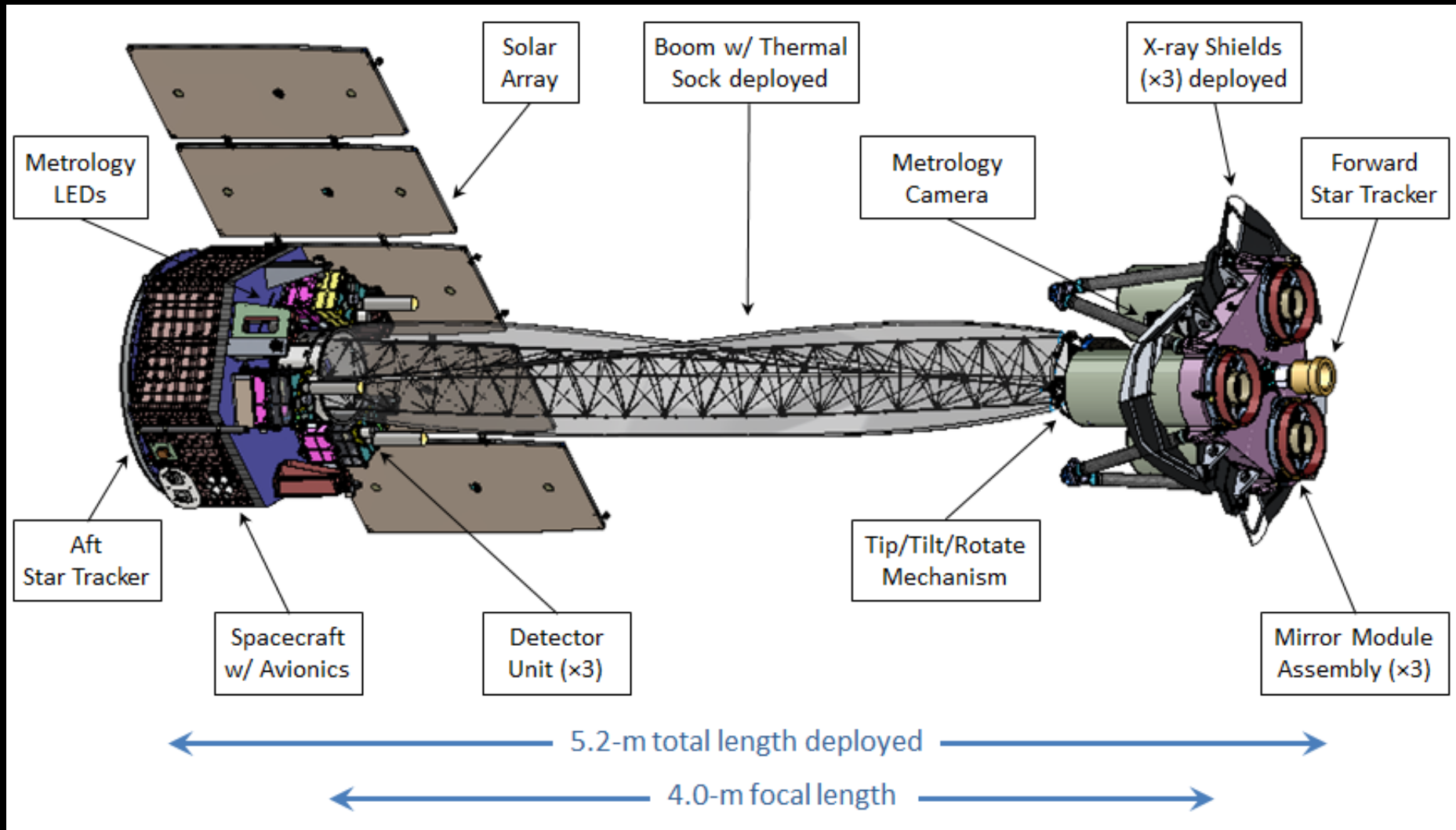
Institutions and countries involved

 <p>Marshall Space Flight Center</p> <p>PI team, project management, SE and S&MA oversight, mirror module fabrication, X-ray calibration, science operations, and data analysis and archiving</p>	   <p>INAF ISTITUTO NAZIONALE DI ASTROFISICA NATIONAL INSTITUTE FOR ASTROPHYSICS</p> <p>Polarization-sensitive imaging detector systems</p>
 <p>ASI agenzia spaziale italiana</p> <p>Detector system funding, ground station</p>	  <p>LASP Mission operations</p>
 <p>Spacecraft, payload structure, payload, observatory I&T</p>	  <p>Stanford University Scientific theory</p>
	 <p>McGill Science Working Group Co-Chair</p>
	 <p>Massachusetts Institute of Technology Co-Investigator</p>

A12567_151

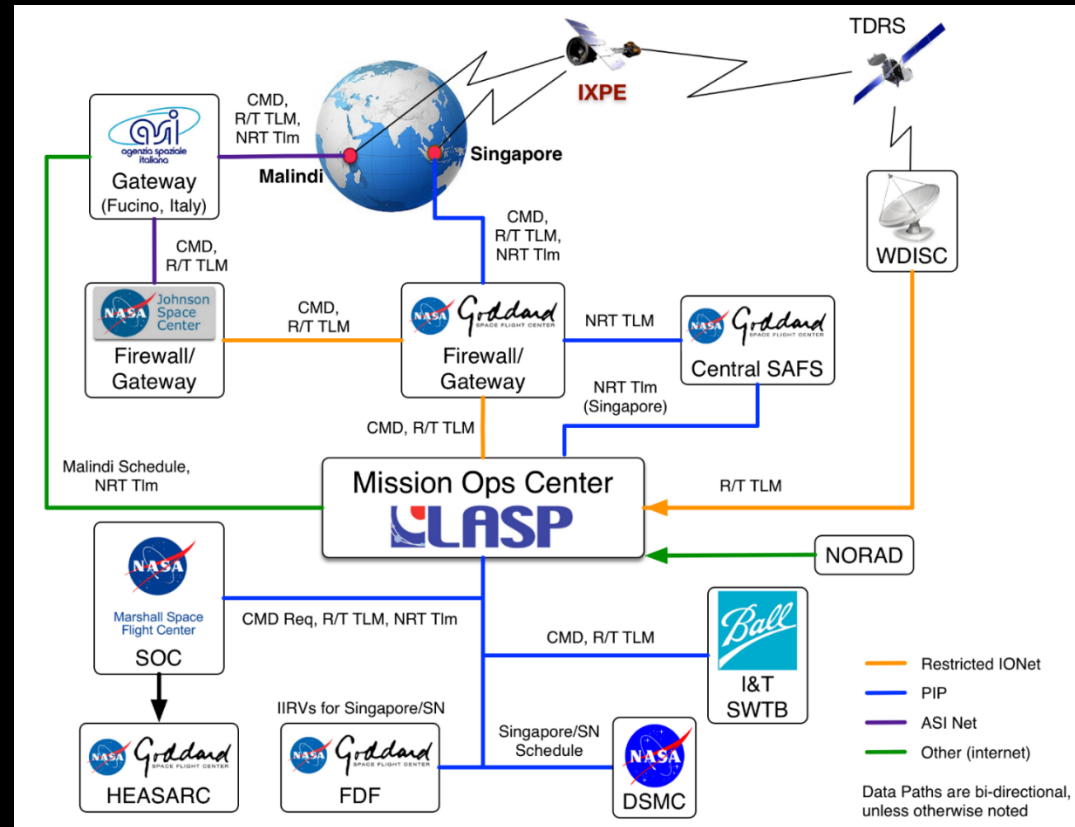


IXPE deployed



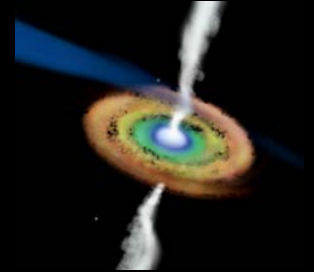
IXPE mission overview

- Pegasus XL launch from Kwajalein
- Launch ready by early 2021
- 540-km circular orbit at 0° inclination
- 2-year baseline mission, 1 year extension
- Point-and-stare at known targets
- Malindi ground station (Singapore Backup)
- Mission Operations Center at CU/LASP
- Science Operations Center at MSFC



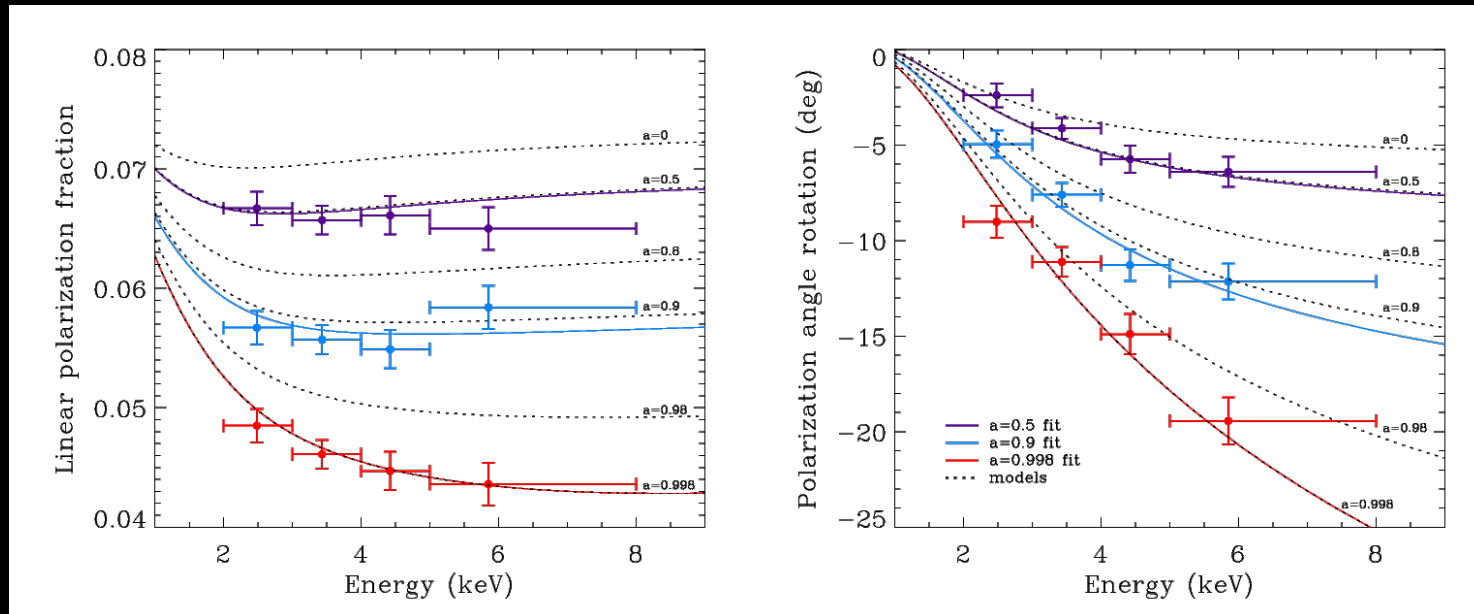
Measure black-hole spin in twisted space-time

- For a micro-quasar GRX1915+105 in an accretion dominated state
 - Scattering polarizes the thermal disk emission
 - Polarization rotation is greatest for emission from inner disk
 - Inner disk is hotter, producing higher energy X-rays
 - Priors on disk orientation also constrain model

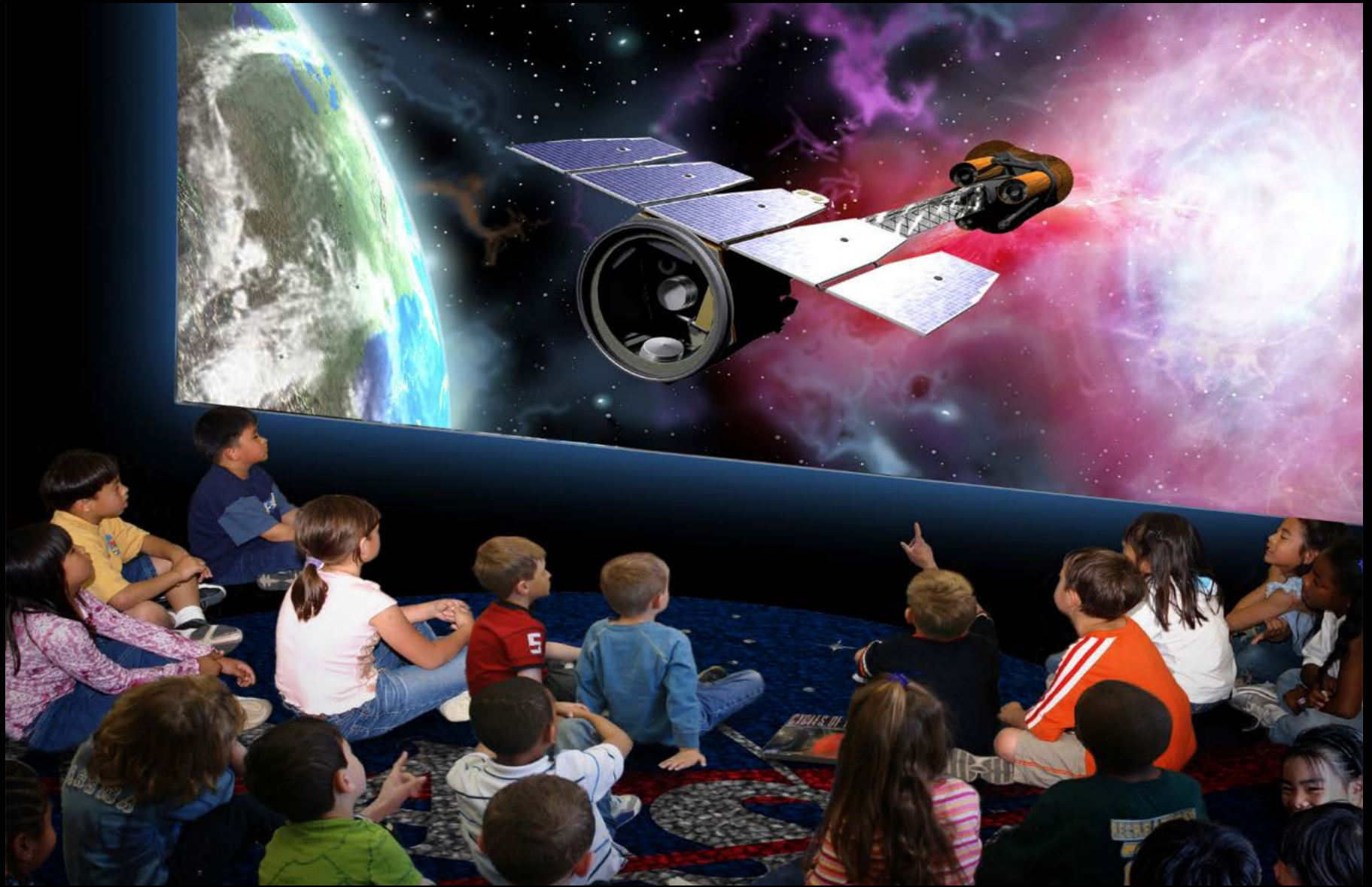


$$a = 0.50 \pm 0.04; 0.900 \pm 0.008; 0.99800 \pm 0.00003$$

(200-ks observation)



Capturing the imagination



Outline – Part 3 Lynx

- The successor to Chandra
- One of 4 large missions under study for the 2020 Astrophysics Decadal Survey
- MSFC-led study
- 50 – 100 × gain in sensitivity via high throughput with high angular resolution
- 16 × field of view for arcsec images
- 10 – 20 × higher spectral resolution
- Launch no earlier than 20?? 😊

