X-ray Astronomy at Marshall Space Flight Center
Chandra, IXPE, Lynx

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Outline – Part 1 Chandra

- 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
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
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

- CGRO
- CHANDRA
- HST
- SIRTF

Wavelength (nanometers):
- Gamma: 0.0005
- X-ray: 0.5
- Visible light: 500
- Infrared: 10,000
- 5,000,000,000

Energy (electron volts):
- Gamma: 2,480,000
- X-ray: 2,480
- Visible light: 2.48
- Infrared: 0.124
- 0.000000248
Mirror elements are 0.8 m long and from 0.6 m to 1.2 m diameter.
Optics: Coated, Assembled & Aligned
Include the Upper Stage and in the Shuttle

The longest and heaviest payload ever launched by the Shuttle
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
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

75% DARK ENERGY
21% DARK MATTER
4% NORMAL MATTER
Colliding clusters of galaxies and dark matter

Blue – most of the mass
Pink – normal X-ray emitting matter

This study examined 300 galaxy clusters.

Size versus time depends on dark energy.

Confirms the "cosmological constant".
The 2002 Nobel Prize Riccardo Giacconi
The opportunity for exploration and discovery with Chandra remains as high today as it was at launch.
• 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

<table>
<thead>
<tr>
<th>Institution/Team/University</th>
<th>Responsibility</th>
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<tbody>
<tr>
<td>NASA Marshall Space Flight Center</td>
<td>PI team, project management, SE and S&amp;MA oversight, mirror module fabrication, X-ray calibration, science operations, and data analysis and archiving</td>
</tr>
<tr>
<td>IAPS INAF INFN</td>
<td>Polarization-sensitive imaging detector systems</td>
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<tr>
<td>CU LASP</td>
<td>Mission operations</td>
</tr>
<tr>
<td>Roma TRE Stanford University</td>
<td>Scientific theory</td>
</tr>
<tr>
<td>McGill</td>
<td>Science Working Group Co-Chair</td>
</tr>
<tr>
<td>MIT Massachusetts Institute of Technology</td>
<td>Co-Investigator</td>
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[Image of flags representing the countries involved]
IXPE deployed

- Solar Array
- Boom w/ Thermal Sock deployed
- X-ray Shields (×3) deployed
- Metrology Camera
- Forward Star Tracker
- Aft Star Tracker
- Spacecraft w/ Avionics
- Detector Unit (×3)
- Tip/Tilt/Rotate Mechanism
- Mirror Module Assembly (×3)

5.2-m total length deployed
4.0-m focal length
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
• 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
• 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?? 😊