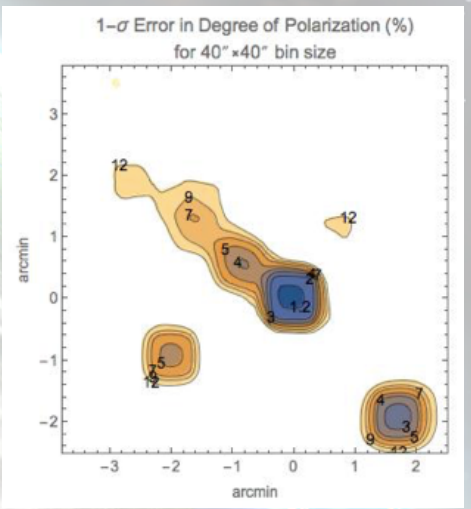
IXPE
Imaging
X-Ray
Polarimetry
Explorer

The Imaging X-ray Polarimetry Explorer (IXPE)



Herman L. Marshall (MIT)

for the IXPE team

Martin Weisskopf, PI

IXPE Imaging X-Ray Polarimetry Explorer

IXPE: NEW SCIENCE, NEW CAPABILITIES

- **Opens a new window on the universe — imaging (30“) X-ray polarimetry**
  - Is the science driver that advances and impacts high-energy astrophysics
  - Increases information space and lifts modeling degeneracies
- **Addresses key questions, providing new scientific results and constraints**
  - What is the spin of a black hole?
  - What are the geometry and magnetic-field strength in magnetars?
  - Was our Galactic Center an Active Galactic Nucleus in the recent past?
  - What is the magnetic field structure in synchrotron X-ray sources?
  - What are the geometries and origins of X-rays from pulsars (isolated and accreting)?
- **Provides powerful and unique capabilities**
  - Reduces integration time by a factor of 100 compared to the OSO-8 experiment
  - Simultaneously provides imaging, spectral, timing, and polarization data
  - Is free of false-polarization systematic effects at less than a fraction of a percent
  - Enables meaningful polarization measurements for many sources of different classes

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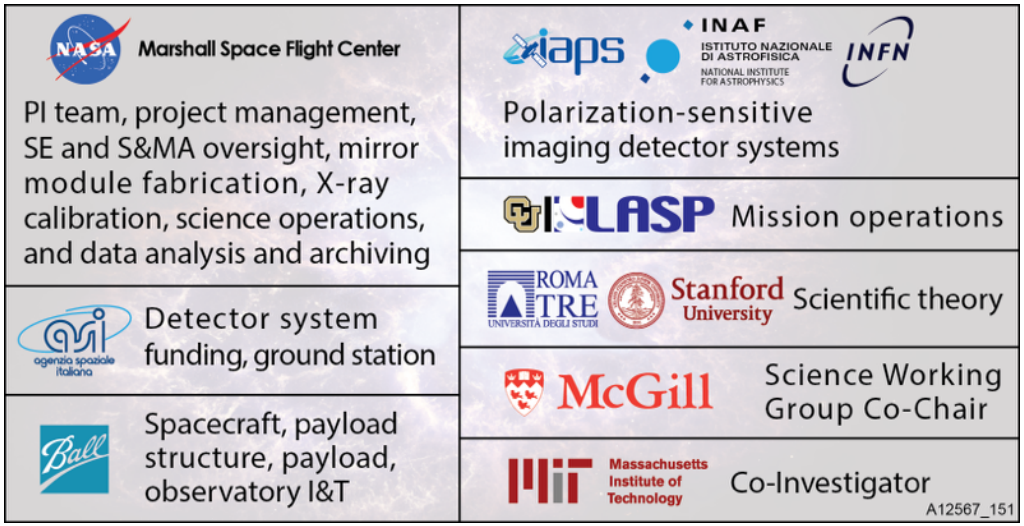
WHO IS INVOLVED?

Institutional Roles and Responsibilities



Science Advisory Team

Co-Investigators: Luca Baldini, Ronaldo Bellazzini, Enrico Costa, Ronald Elsner, Victoria Kaspi, Jeffery Kolodziejczak, Luca Latronico, Herman Marshall, Giorgio Matt, Fabio Muleri, Stephen L. O'Dell, Brian D. Ramsey, Roger W. Romani, Paolo Soffitta, Allyn Tennant

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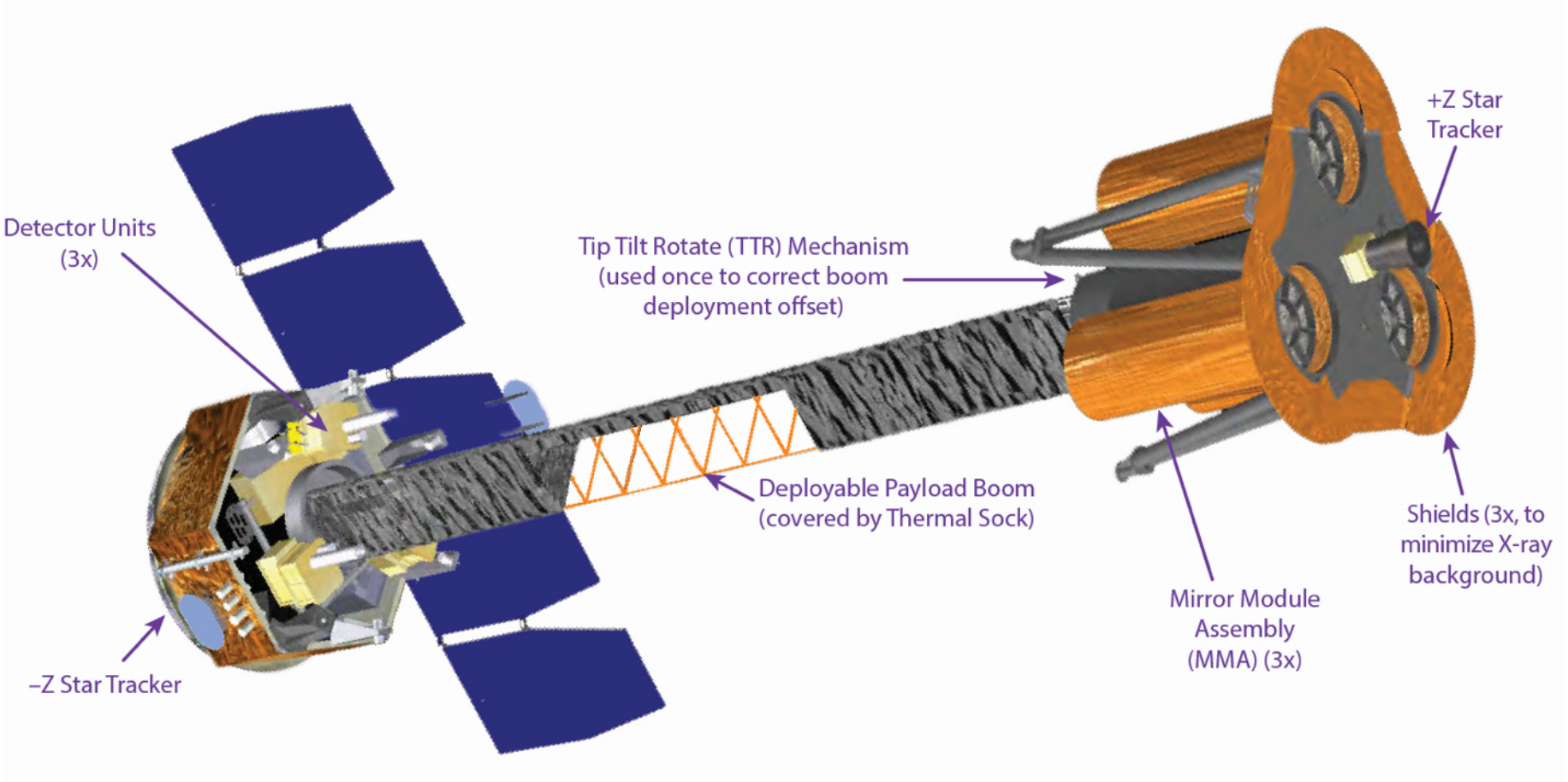
THREE SETS OF IDENTICAL X-RAY MIRROR MODULES AND IMAGING POLARIZATION SENSITIVE DETECTORS



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The X-ray mirror modules

Parameter	Value
Number of mirror modules	3
Number of shells per mirror module	24
Focal length	4000 mm
Total shell length	600 mm
Range of shell diameters	162–272 mm
Range of shell thicknesses	0.16–0.26 mm
Shell material	Electroformed nickel–cobalt alloy
Effective area per mirror module	230 cm^2 (@ 2.3 keV); >240 cm^2 (3–6 keV)
Angular resolution (HPD)	≤ 25 arcsec
Field of view (detector limited)	12.9 arcmin square

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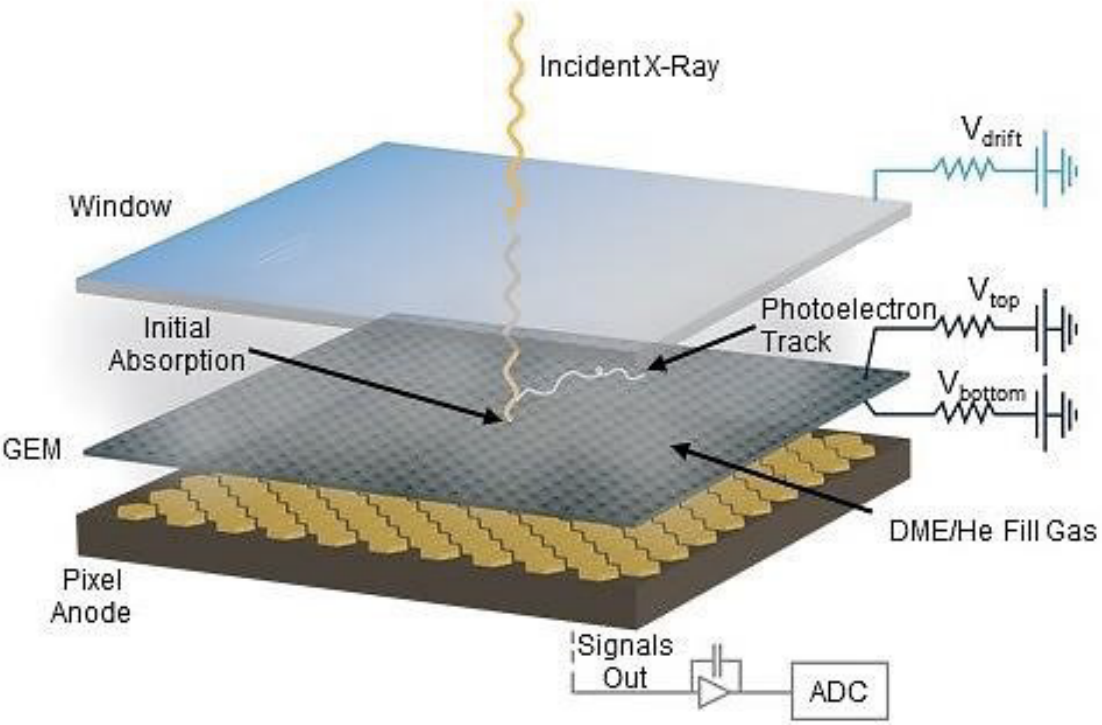
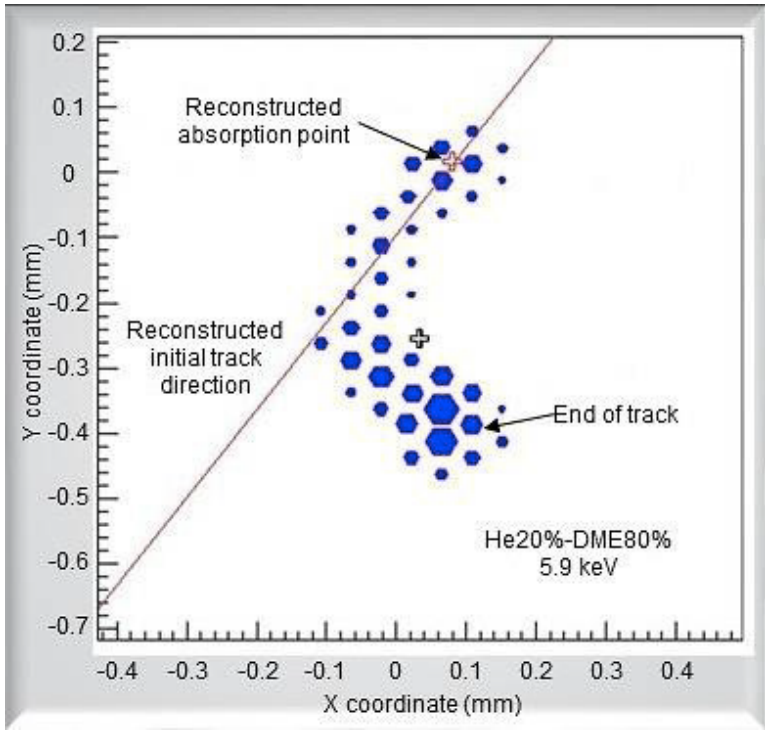
IMAGING POLARIMETRY DETECTOR





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POLARIZATION SENSITIVITY

- **For point sources, sensitivity is described in terms of the Minimal Detectable Polarization (MDP)**
  - The MDP depends upon source count rate (R_S), background count rate (R_B), exposure time Δt, and the count-weighted modulation factor <μ>
    - The modulation factor μ is the fractional amplitude in the histogram of initial photoelectron directions for a 100%-polarized source
    - For *IXPE*, R_B is negligible; thus the MDP is inversely proportional to <μ> $(R_S\,\Delta t)^{1/2}$
  - MDP_{99} is the degree of polarization (independent of the position angle) that has only a 1% chance of being a statistical fluke

$$\mathrm{MDP}_{99} = \sqrt{-2\ln(1-\mathrm{CL})}\,\sqrt{2}\,\frac{\sqrt{C_S + C_B}}{C_S\langle\mu\rangle} \xrightarrow{\mathrm{CL}=0.99} 3.035\sqrt{2}\,\frac{\sqrt{C_S + C_B}}{C_S\langle\mu\rangle} \xrightarrow{C_S \gg C_B} \frac{4.292}{\sqrt{C_S}\,\langle\mu\rangle}.$$

For *IXPE*,

$$\mathrm{MDP}_{99} \approx 4.5\%/\sqrt{\left[\frac{F_{2-8}}{10^{-11}\,\mathrm{erg\,cm^{-2}s^{-1}}}\right]\left[\frac{\Delta t}{10\ \mathrm{day}}\right]}$$

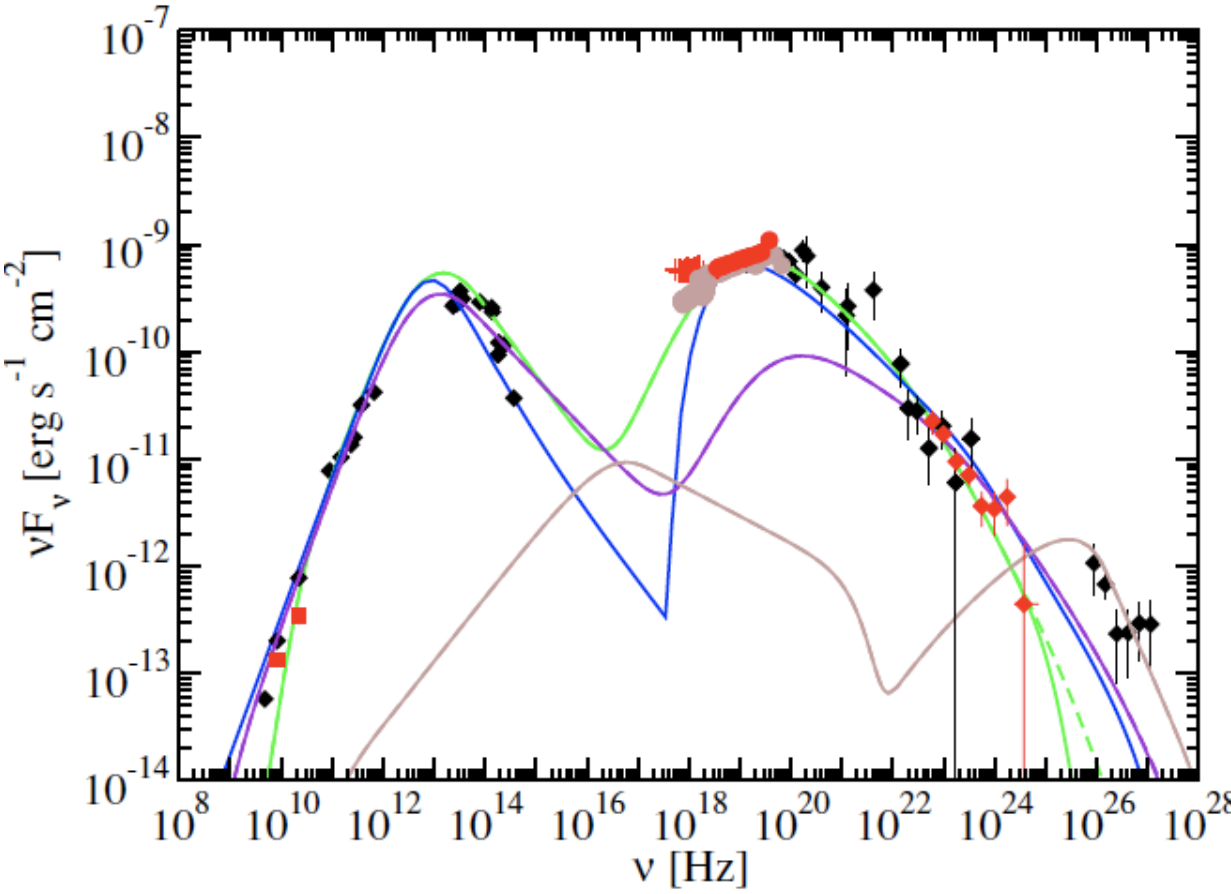
Observing Cen A with IXPE: Overview

- **Closest radio galaxy, at 3.8 Mpc, z=0.0018**
  - Galaxy: giant E with warped dust lane obscuring core
  - Scale: 1 mas = 20 l-d, 1" = 18 pc, 1' = 1 kpc
- **BH mass estimate: 3-8 10^7 M_{sun}**
- **Radio (Fanaroff Riley type I)**
  - core with lobes >5° across
  - total flux of 700 Jy at 5 GHz
- **VLBI (Tingay, et al. 1998)**
  - unresolved core, 2 Jy (8.6 GHz), νL_ν = 2e38 erg/s

IXPE Imaging X-Ray Polarimetry Explorer

Core SED Overview

- **Simultaneous data**
- **2 zones needed**
  - $\Gamma = 7$ is OK (green)
  - TeV is separate
- **Spine-sheath model may be needed**



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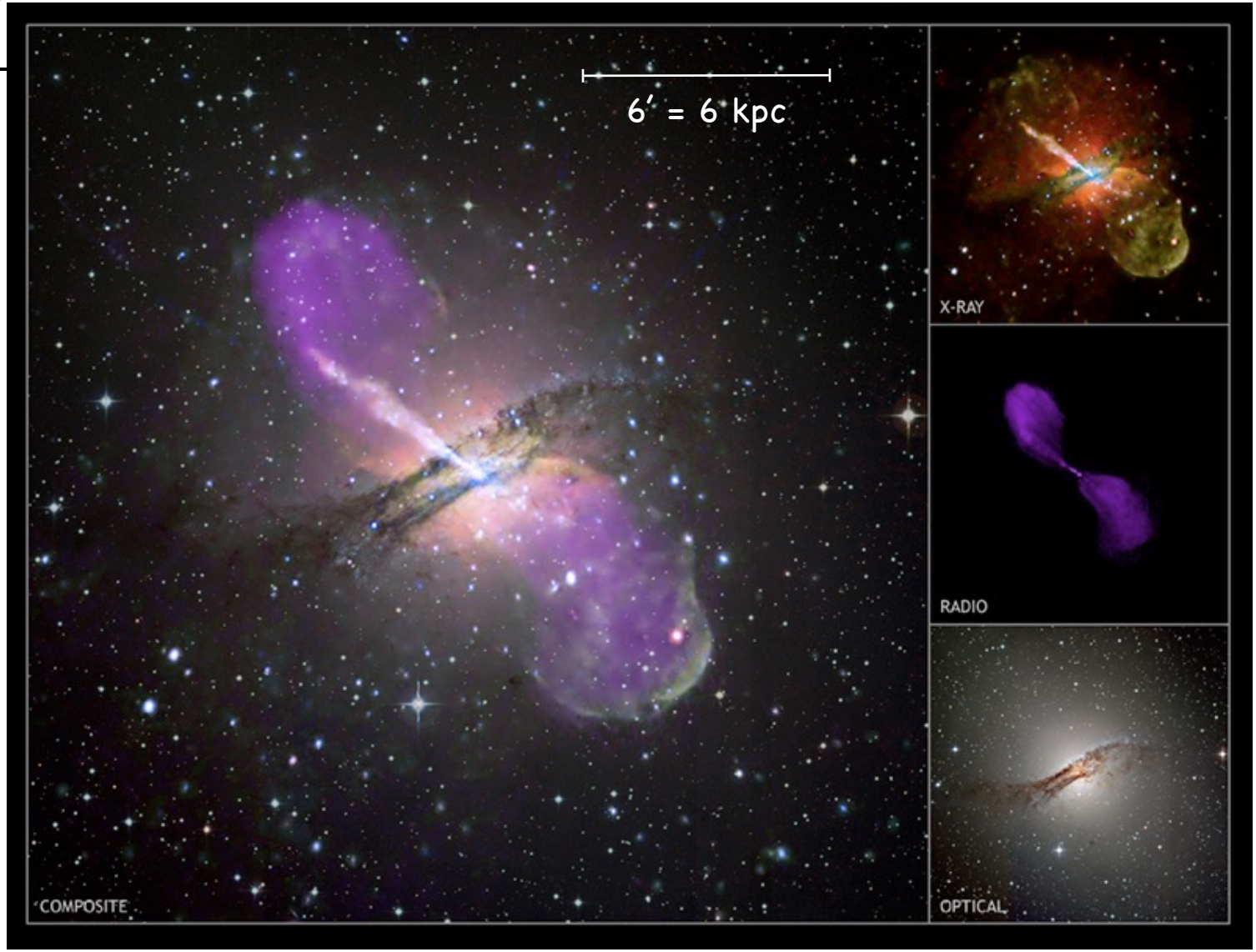
Cen A Imaging



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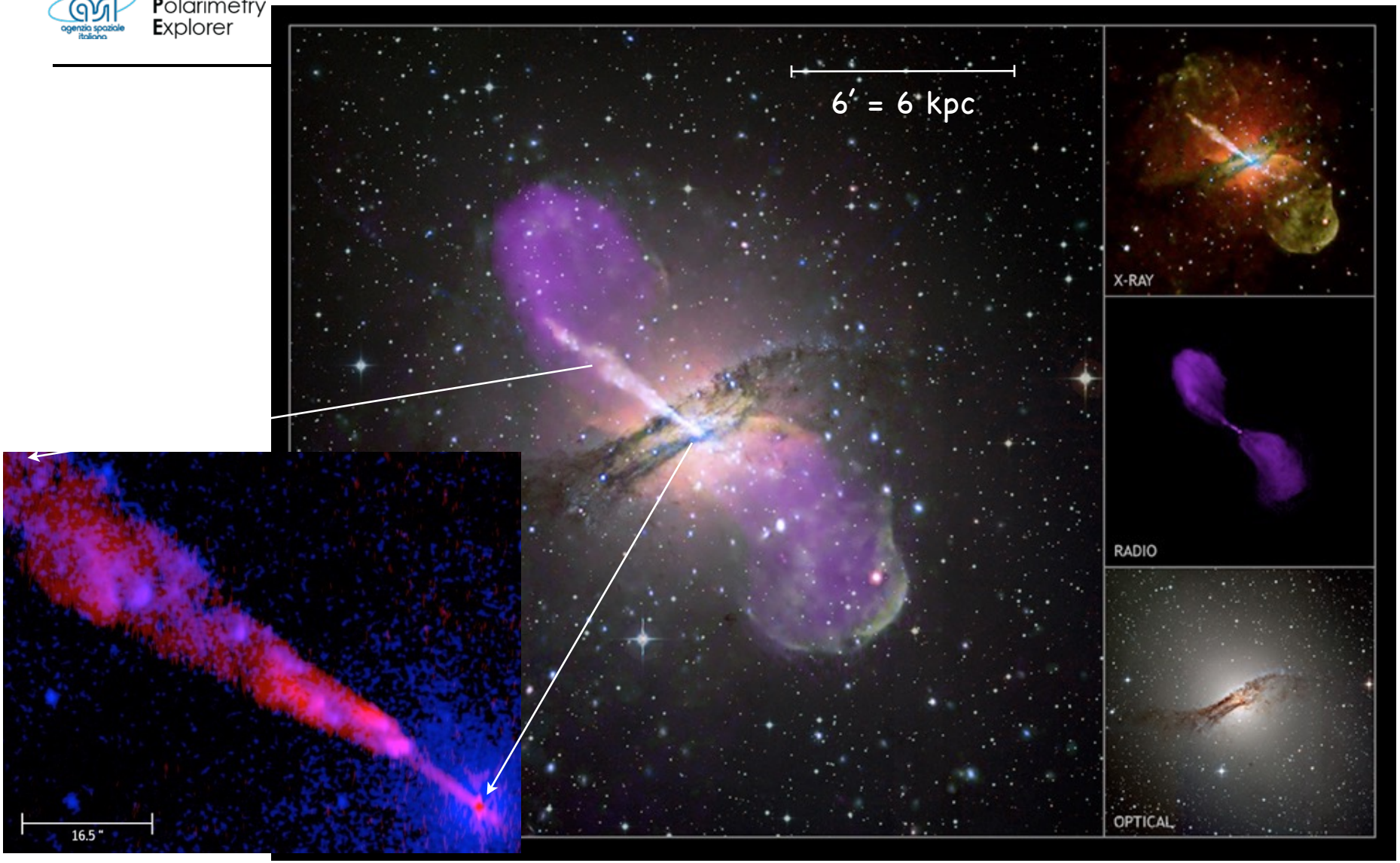
CEN A IMAGING



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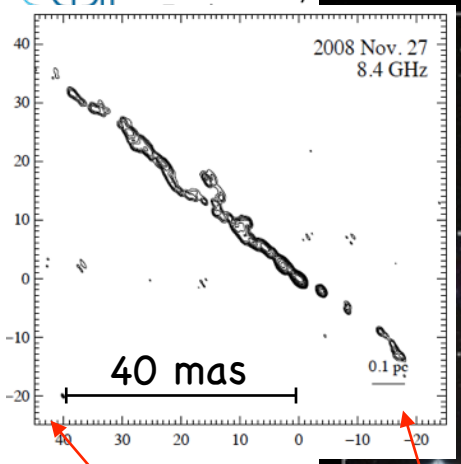
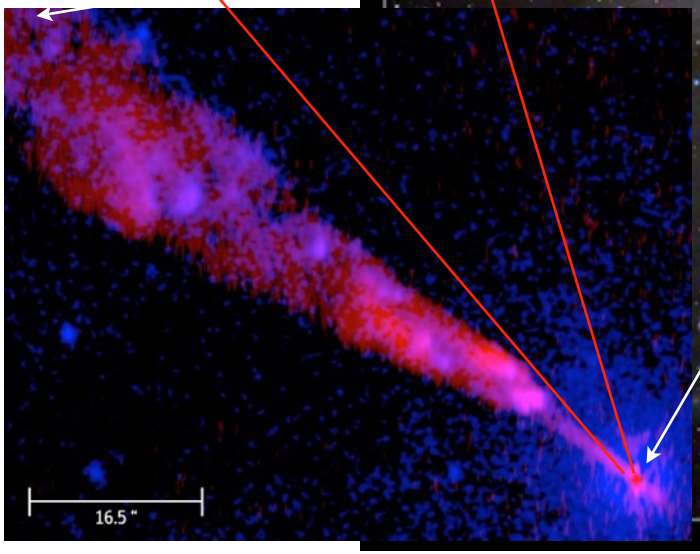
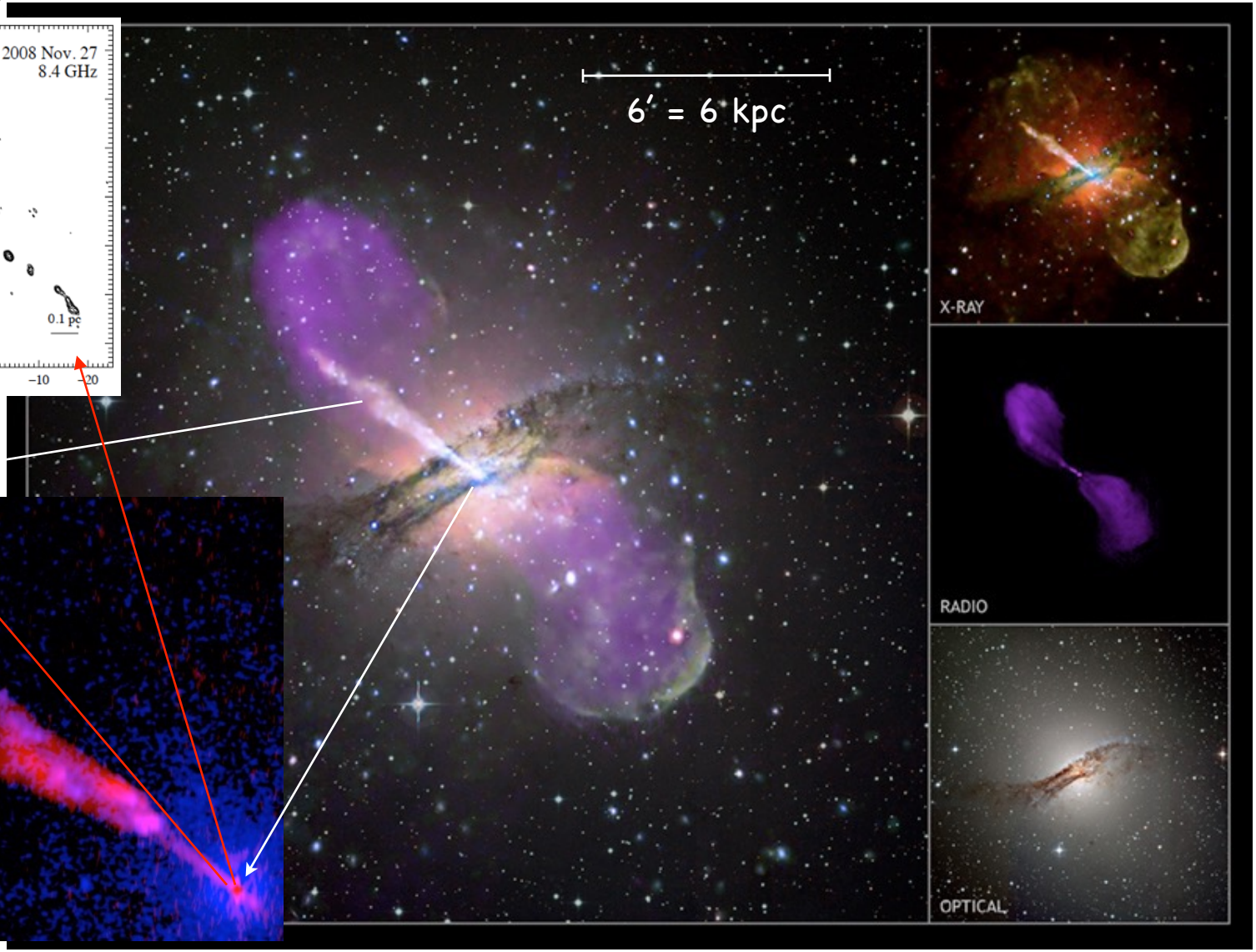
CEN A IMAGING







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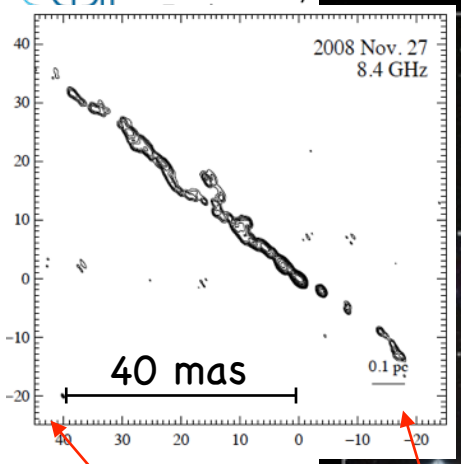
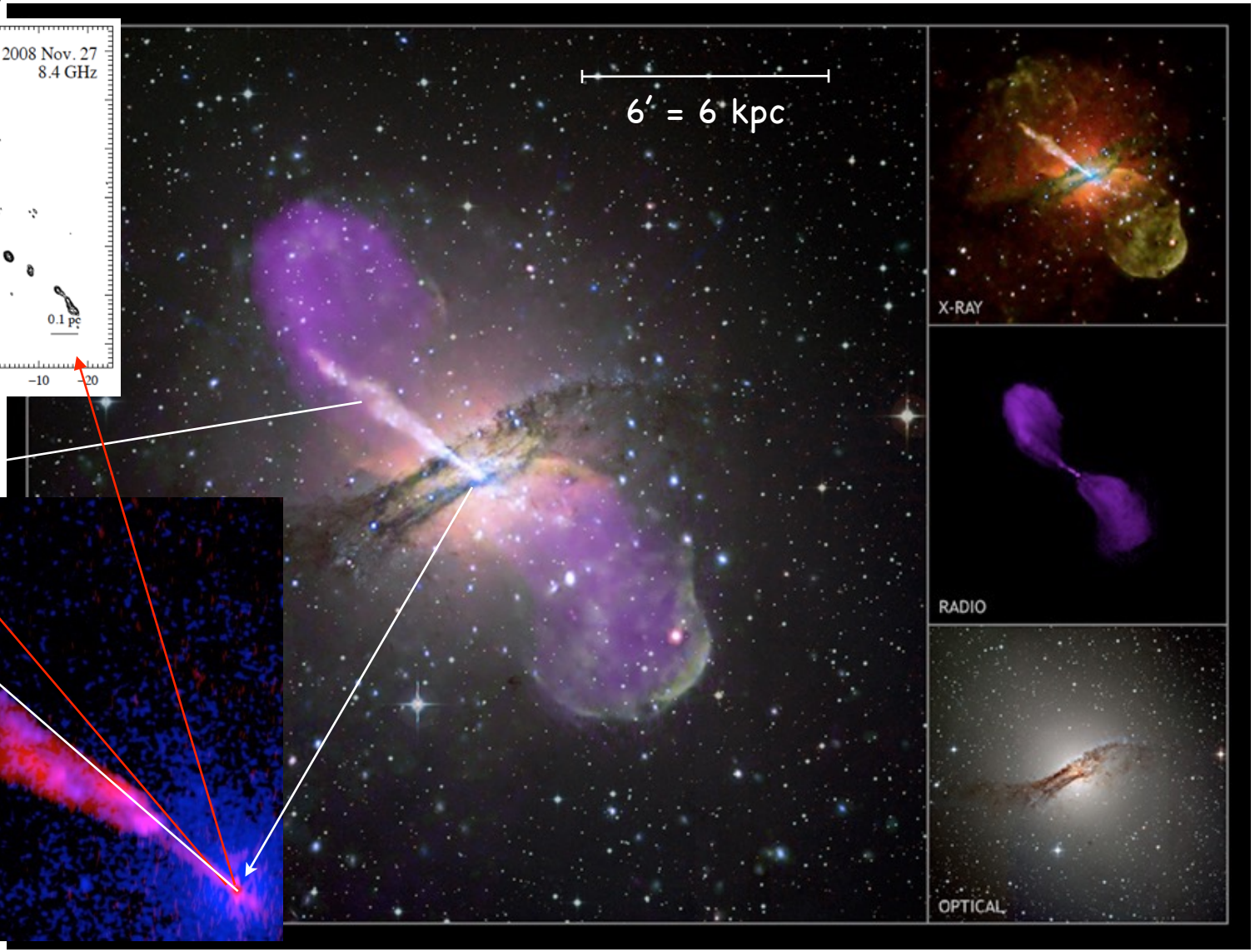
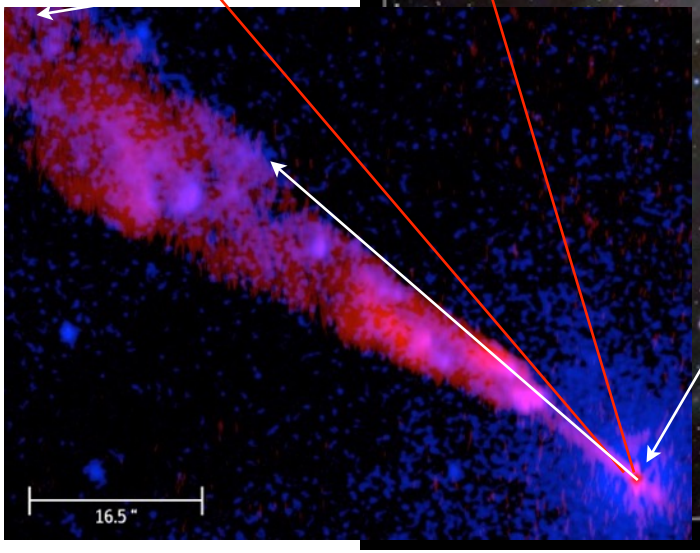
Cen A Imaging







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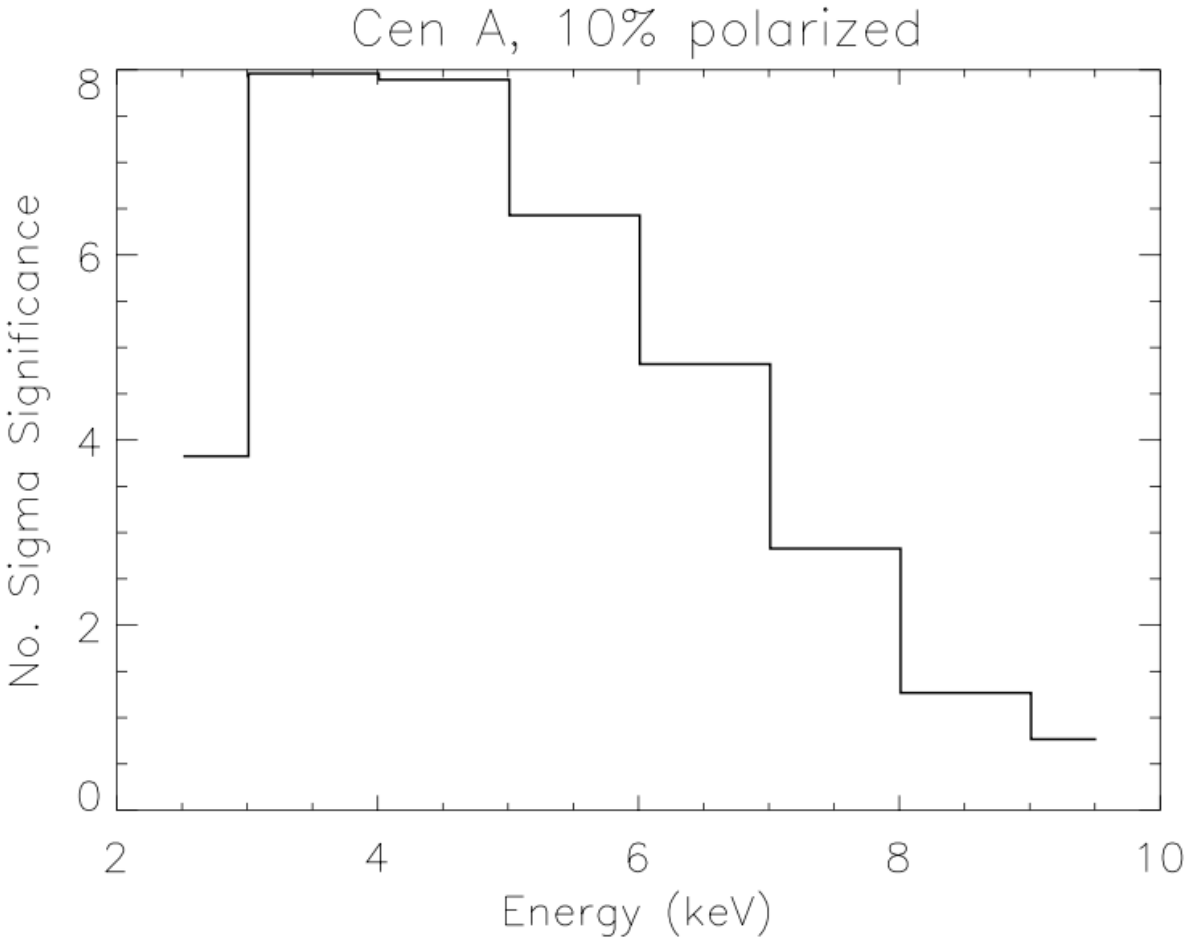
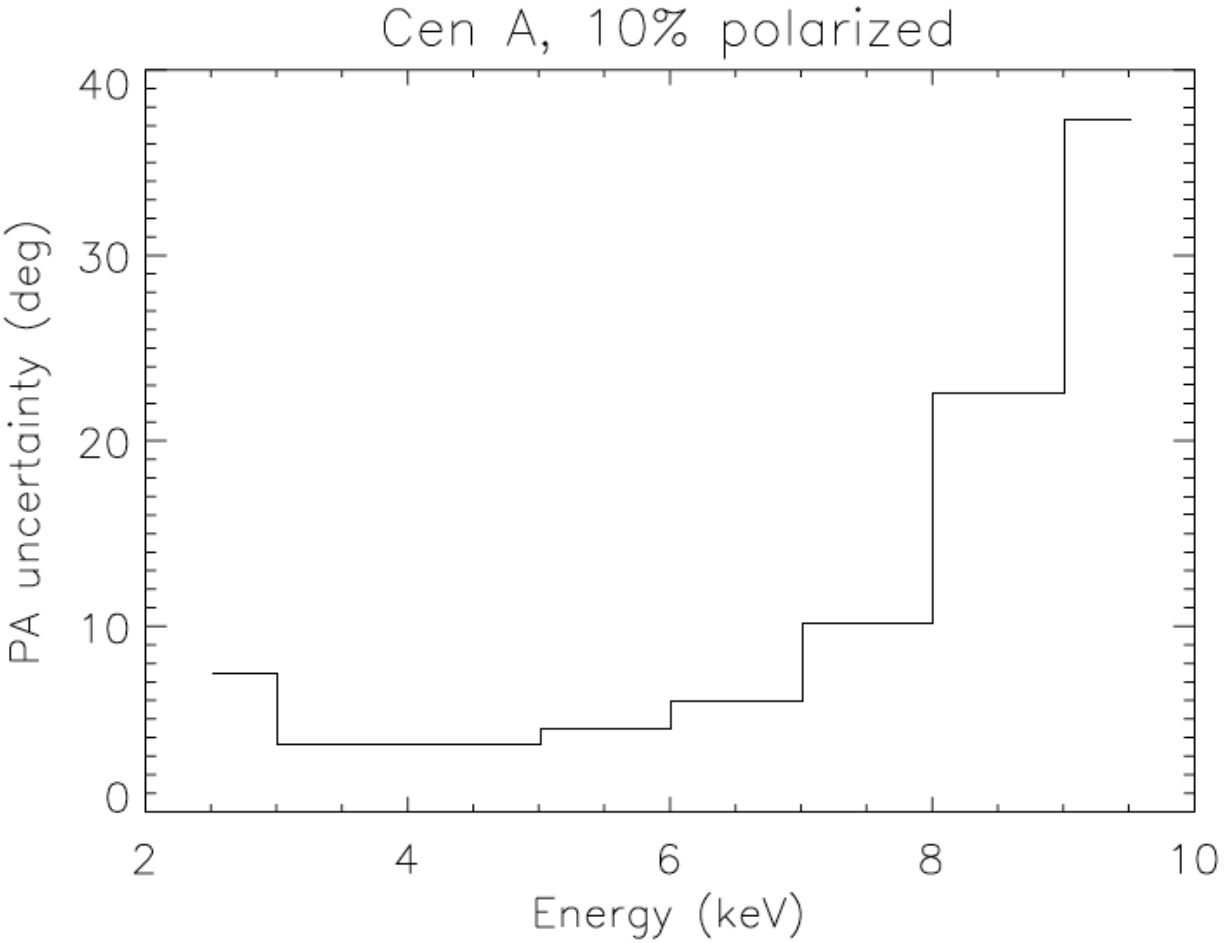
Cen A X-ray Results

- **L(2-8 keV): $10^{41.5}$ erg/s**
  - core is 90% of total flux
  - varies by > 50% on timescale of ~20 d (~r_{core})
- **Inner jet (5' long) is 10% of 2-10 keV power**
  - Consists of small scale knots moving at ~ 0.5 c
  - Knots embedded in nonthermal plasma
  - Position angle is 51°, widening to 51-63°
- **Polarization will probe scales smaller than space VLBI: r ~ 3000 R_S**

Cena A Core Polarimetry with IXPE (1 Ms exposure)

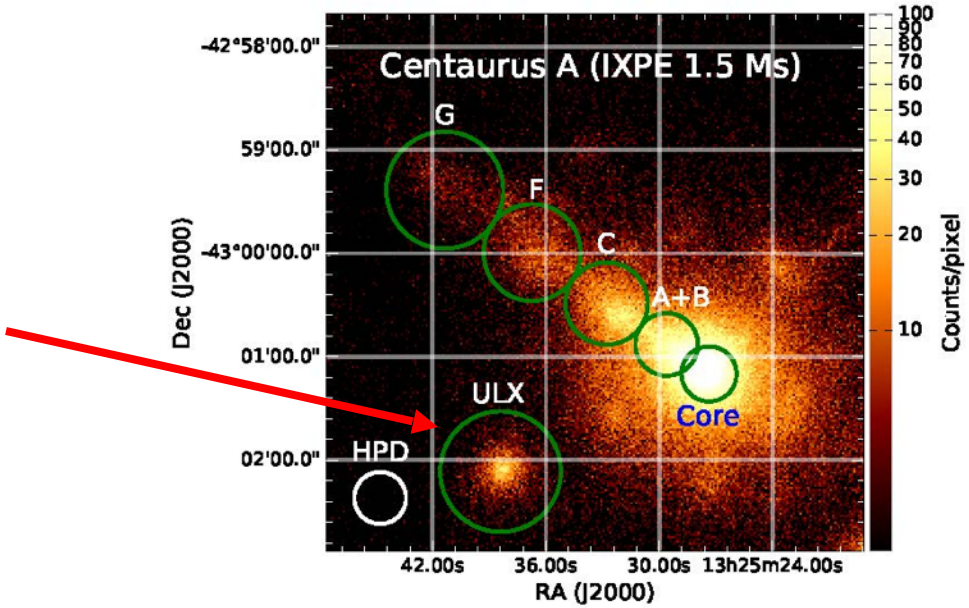


Cena A Core Polarimetry with IXPE (1 Ms exposure)



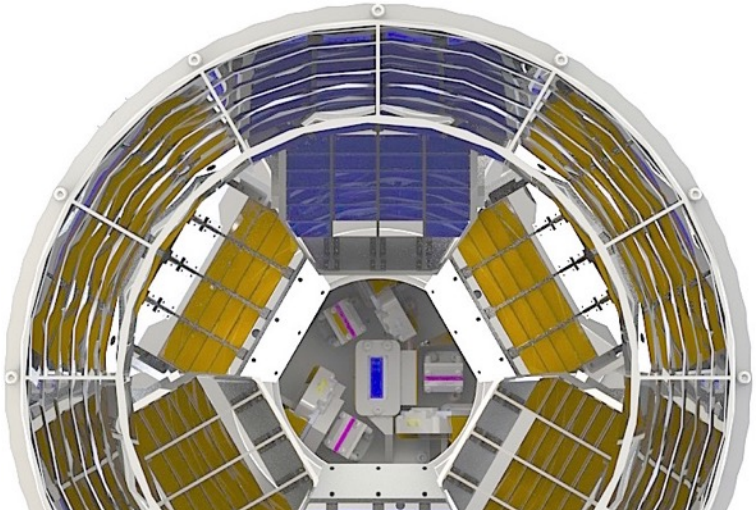
IXPE WILL IMAGE JET KNOTS AND FIND SERENDIPITOUS SOURCES

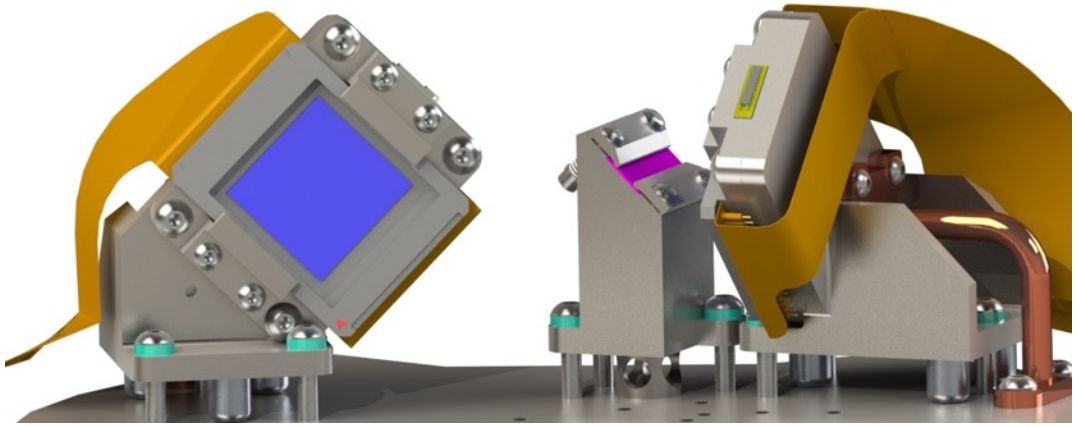
- **Active galaxies are powered by supermassive BHs with jets**
  - Radio polarization implies the magnetic field is aligned with jet
  - X-rays from core: self Compton, external Compton
  - Knot X-rays: jet spine or shocked regions?
- **Imaging Cen A will isolate other sources in the field**
  - Two Ultra Luminous X-ray sources (one to SW of core)



Region	MDP_{99}
Core	**<7.0%**
Jet	**10.9%**
Knot A+B	17.6%
Knot C	16.5%
Knot F	23.5%
Knot G	30.9%
ULX	**14.8%**

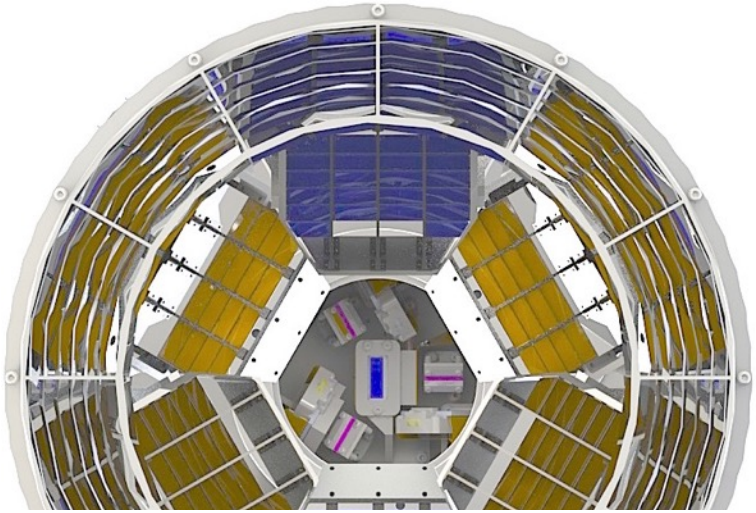
The Rocket Exper. Demonst. of a Soft X-ray Polarimeter

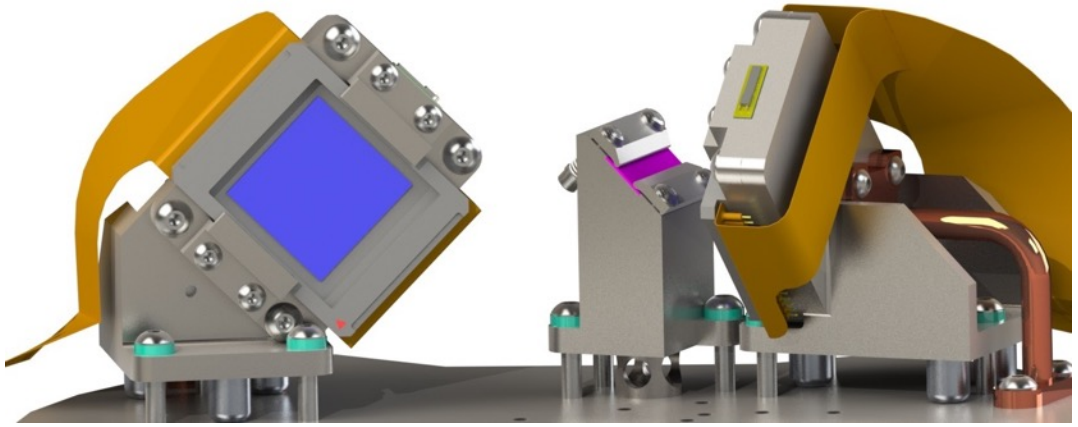




0.2-0.6 keV, MDP < 10% for Mk 421

The Rocket Exper. Demonst. of a Soft X-ray Polarimeter
REDSoX Polarimeter





0.2-0.6 keV, MDP < 10% for Mk 421

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SUMMARY

- Bandpass: 2-8 keV, Imaging: 25”
- Minimum Detectable Polarization
  - Cen A core: 1.3% in 200 ks
  - Cen A knot A&B: 11% in 1.5 Ms
  - 3C 273: 4% in 200 ks
- Launch in November, 2020
- Low Earth Orbit, 2+ yr mission
- No proprietary data
- Users involved via Working Groups