TEXAS TECH UNIVERSITY

Current and Future possibilities – unique synergy with high resolution new and upcoming large multi-wavelength facilities

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This is mostly a review, but I will highlight some work done by TTU undergraduates Ashley Cleveland, Jacob Ellerbroek, Rachel Clapshaw, Alex Martinez, and Amaris McCarver (now grad student at Virginia)

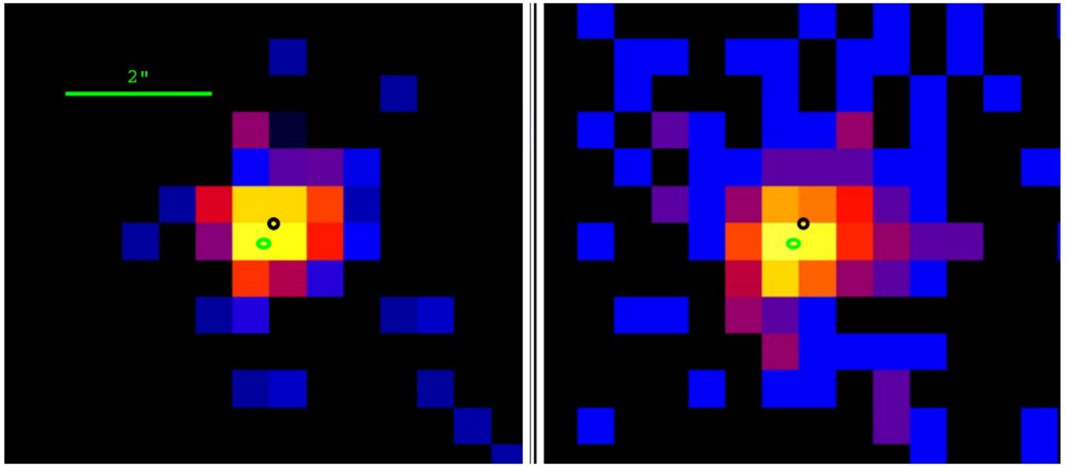
Others will be named within

Overview

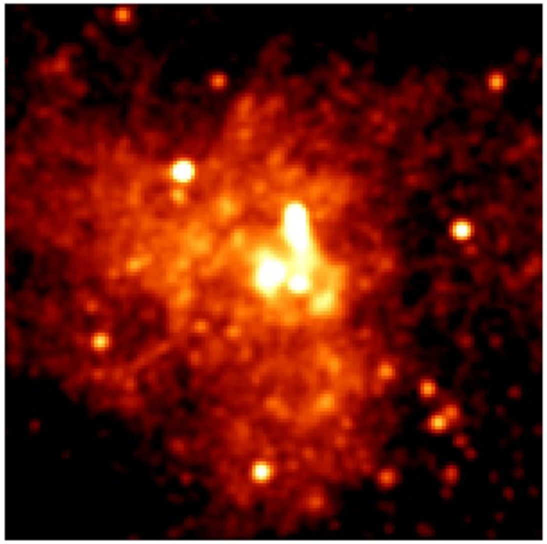
- Why high resolution?
- High resolution from long to short wavelength
  - Will run through the wavelengths, first talking about facilities, next talking about examples of science to be done
  - Will have some of my own biases in the science topics list
  - Will consider future projects for discussion if they have sufficiently little competition that it is a question of "when, not if", and the timetable is realistically compatible with Chandra
- Future of sub-arcsecond X-ray astronomy
- Unlike Chandra, my talk will be broad and shallow

Why high resolution?

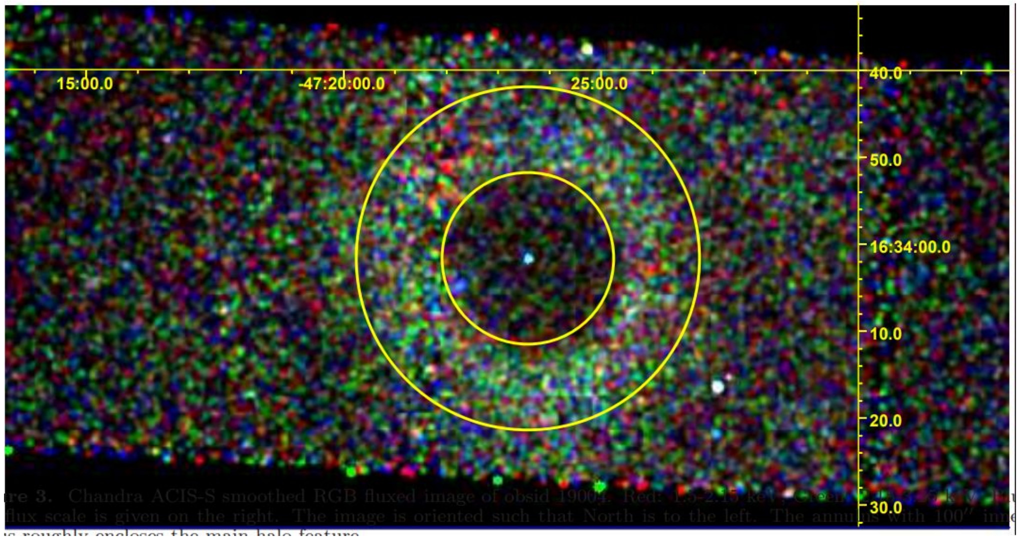
CDF-S, reduce background



van Etten et al. 2012 - proper motions



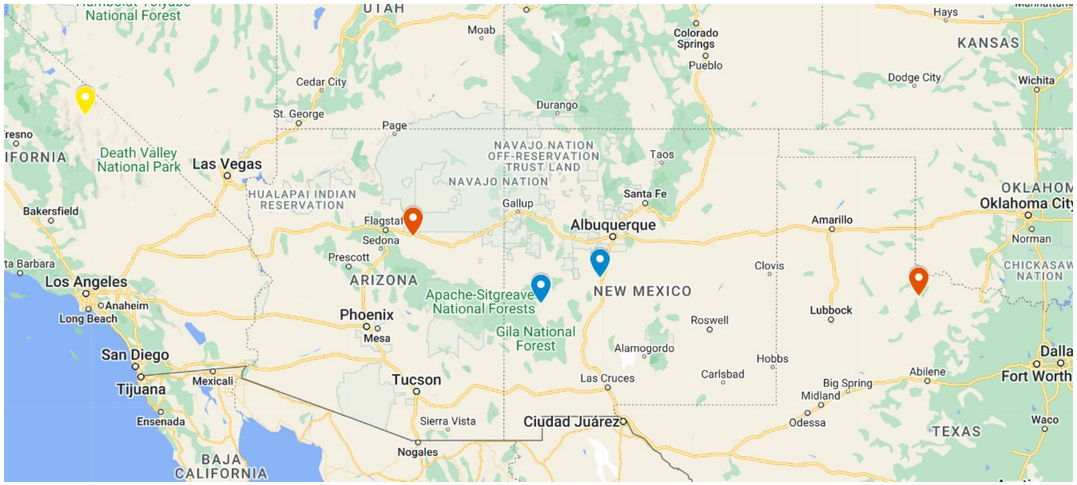
Separate close-by sources



Kalemci et al. 2018 - image sources

Long Wavelength Radio facilities

Long Wavelength Array (UNM+TTU+ASU)



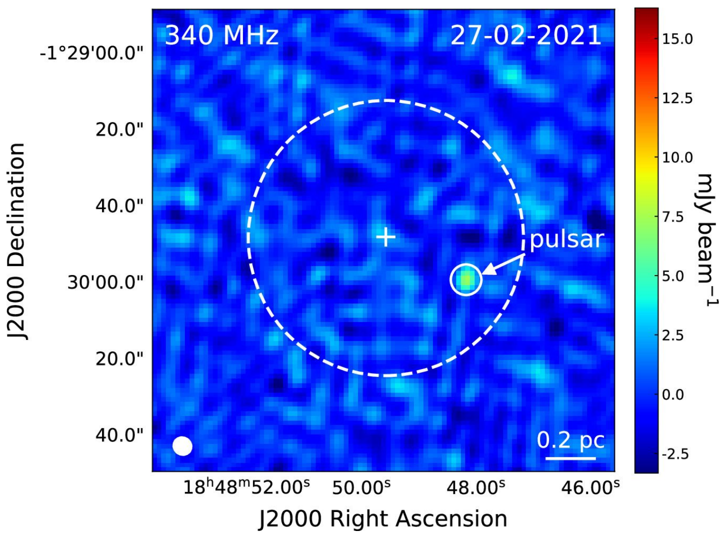
LOFAR

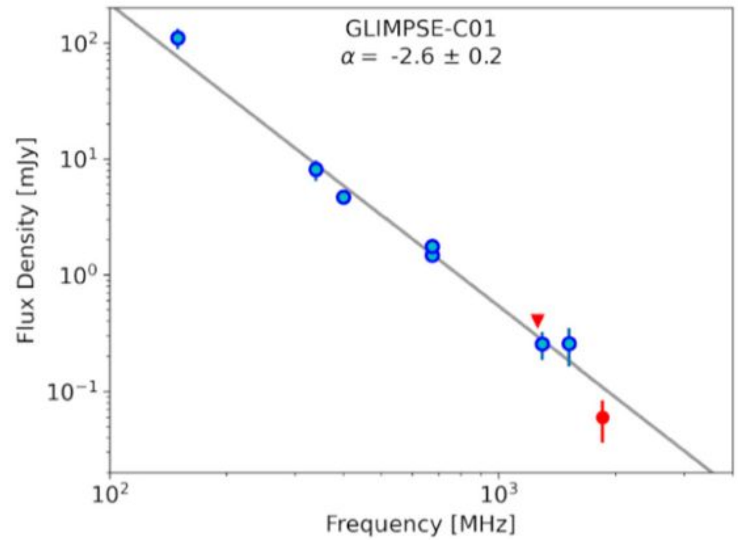
SKA-Low

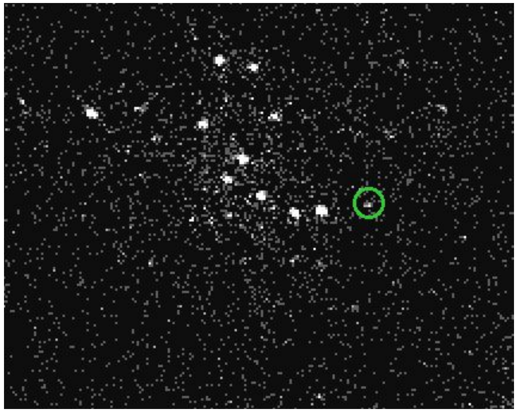
- Dipoles & computing
- Military money on US side (VLITE, too)
- Hardware can do non-astronomy science!

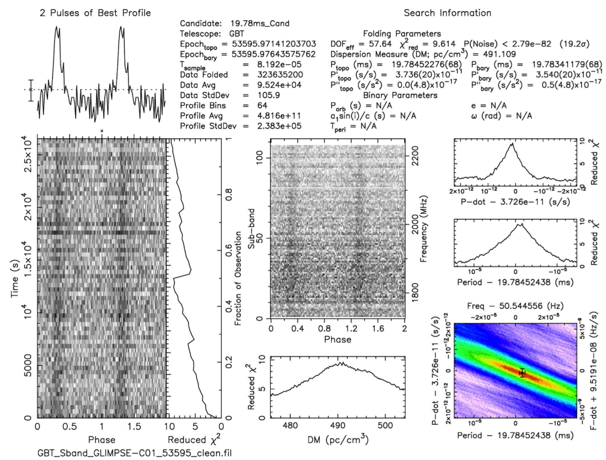
Long Wavelength Radio facilities

Long Wavelength Radio Science Synergies:pulsars



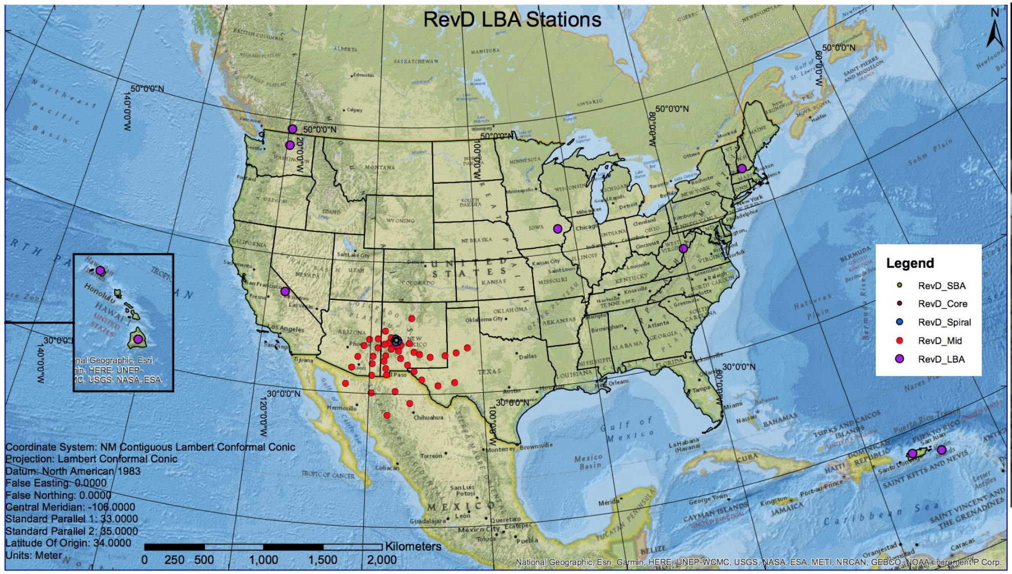


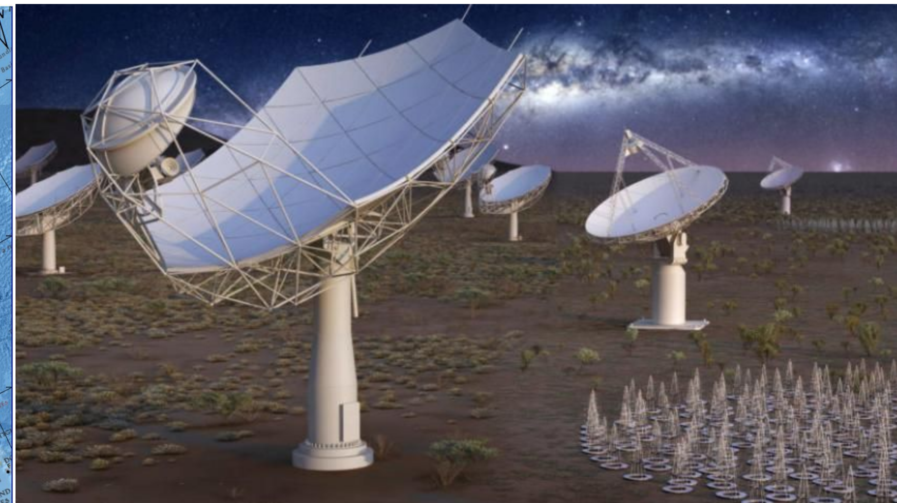




McCarver et al. 2024, using VLITE

Centimeter-band radio





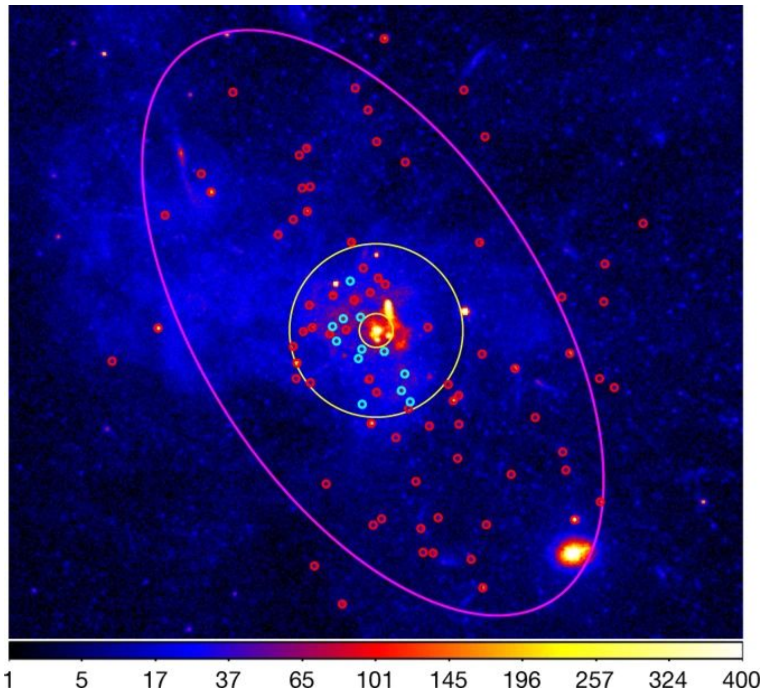
ngVLA: 1-100 GHz, with continental baselines

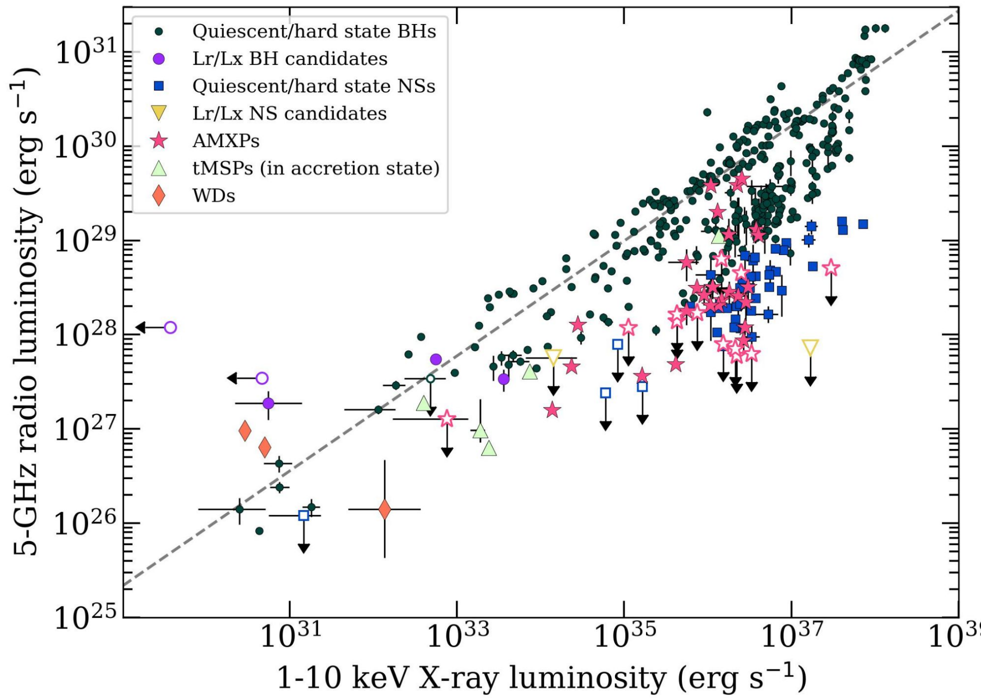
- will be like VLA+VLBA combined with 10 times the sensitivity
- reaches 10 masec or better resolution at all wavelengths

SKA-Low (Australia): 50-350 MHz, 50 km baselines (24”-3.5” resolution)

SKA-Mid (South Africa): 350 MHz-14 GHz, 150 km longest baseline (1.2” to 28 masec)

cm-band science applications



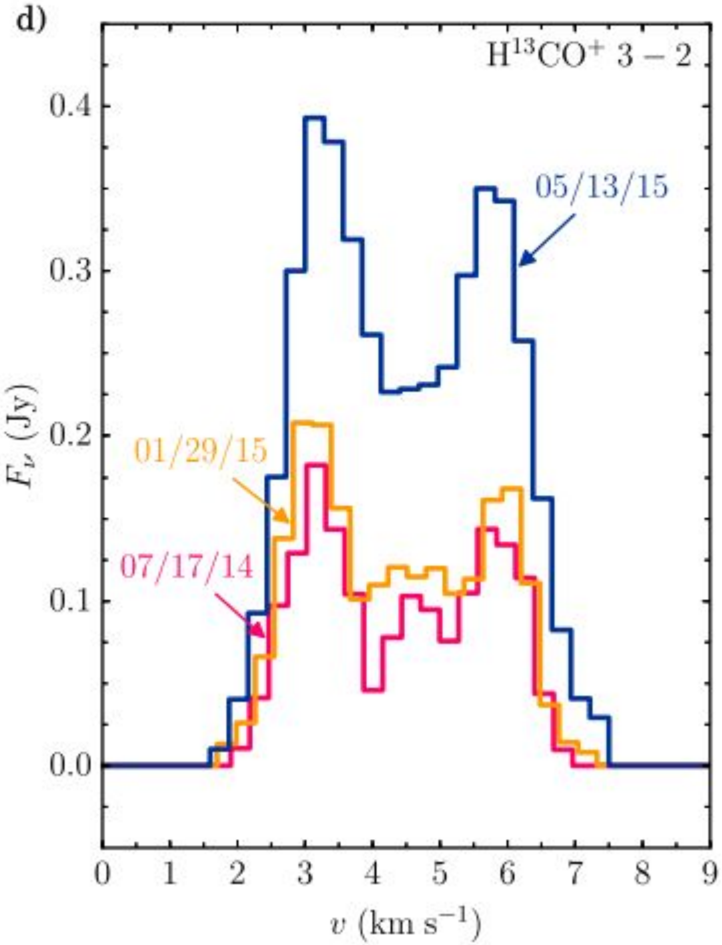


Cluster of bright sources with weak Fe lines in Galactic Center region (Hailey et al. 2018)

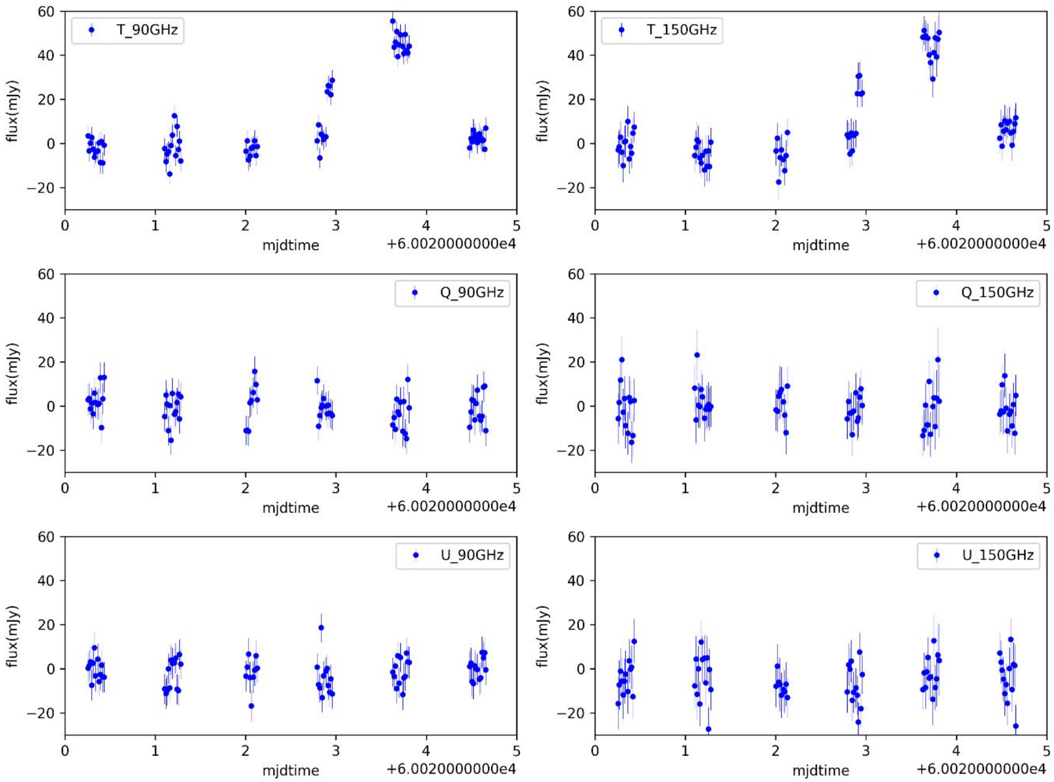
Radio data could test if they are BHs or NSs (Maccarone et al. 2022; Heinke et al. 2024); not knowable with just X-ray data due to high absorption

Millimeter-band radio

mm-band science applications

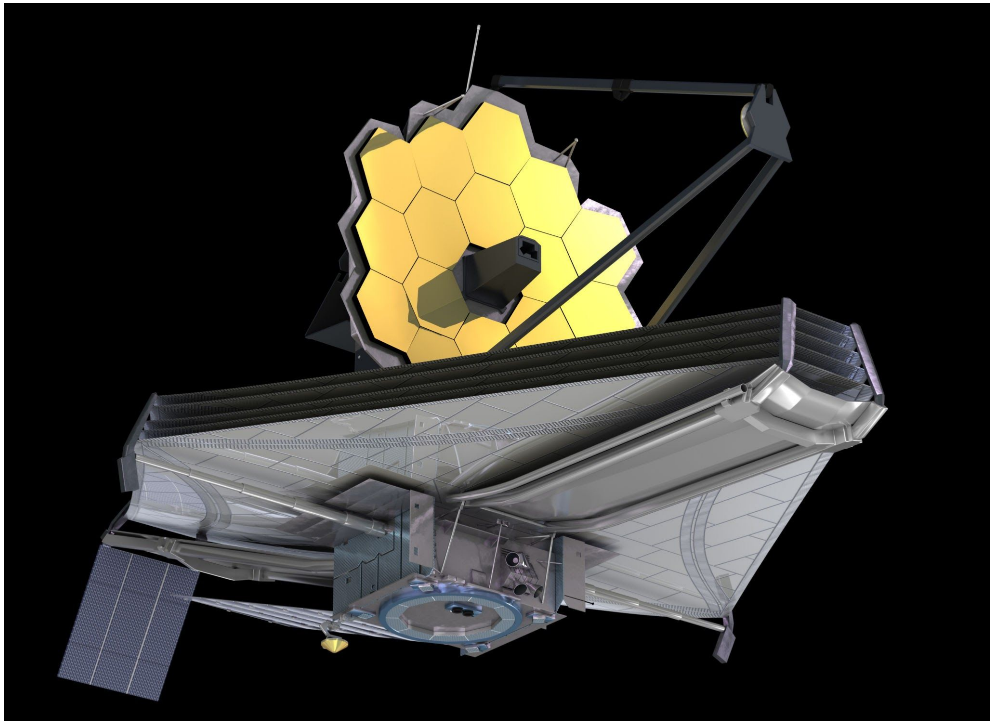


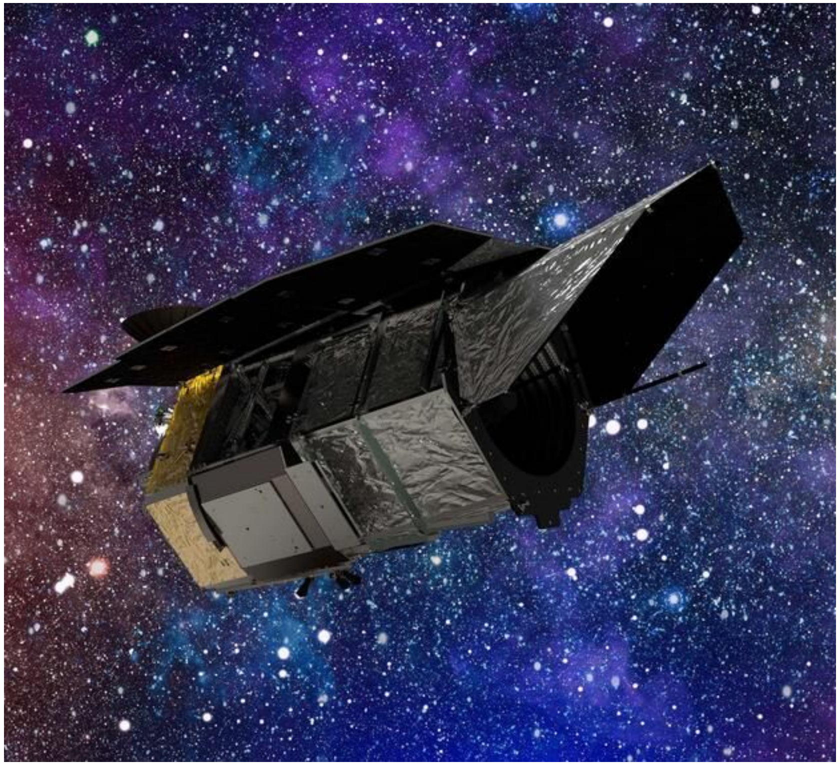
Cleeves et al. 2017



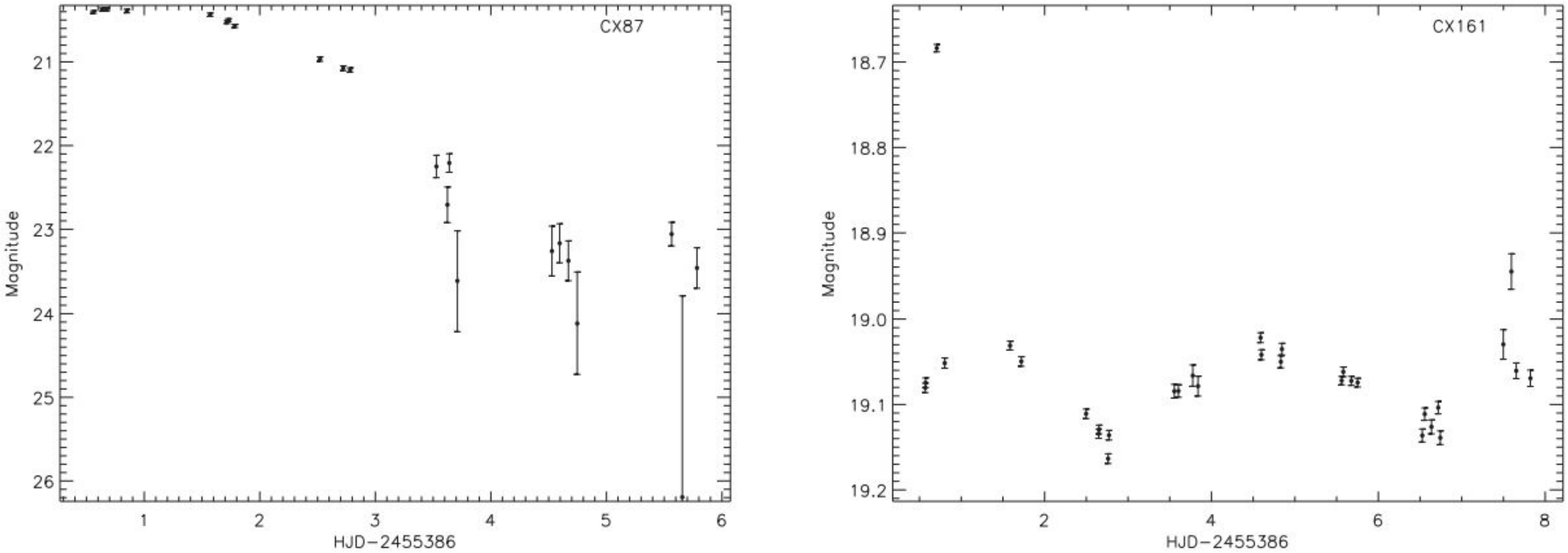
Yujie Wan et al., in prep, SPT transient

Mid-to-near infrared





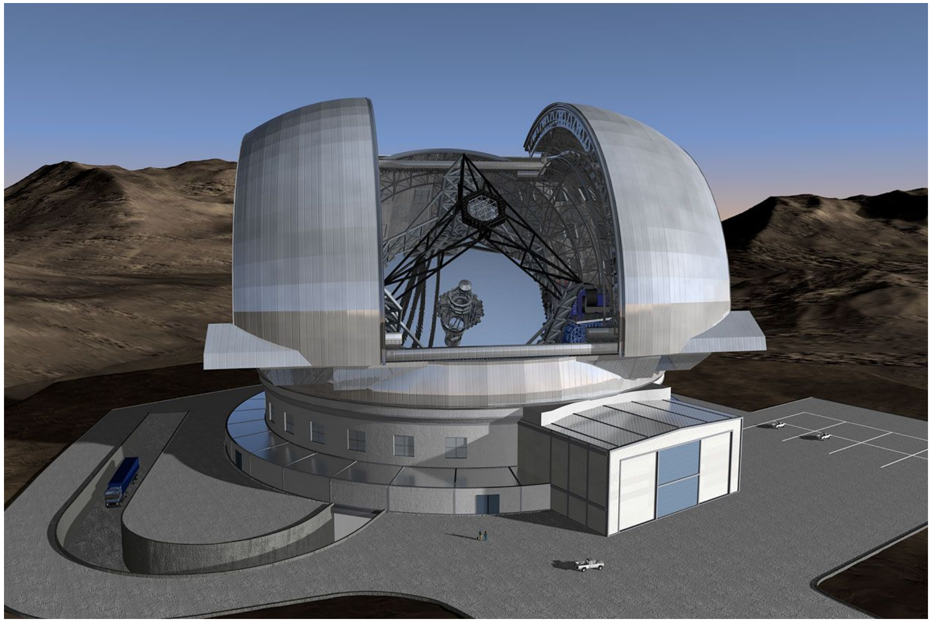
Applications of Roman (see Akos Bogdan talk for JWST application)



Roman Bulge Survey will overlap Chandra Galactic Bulge Survey, get IDs and light curves for most of the X-ray sources

Fig from Britt et al. (2014)

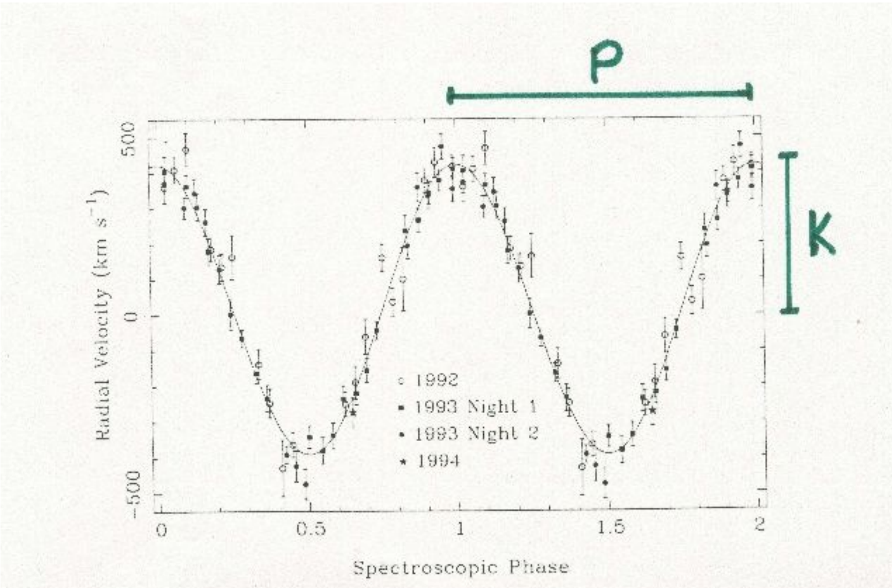
Near-infrared to optical

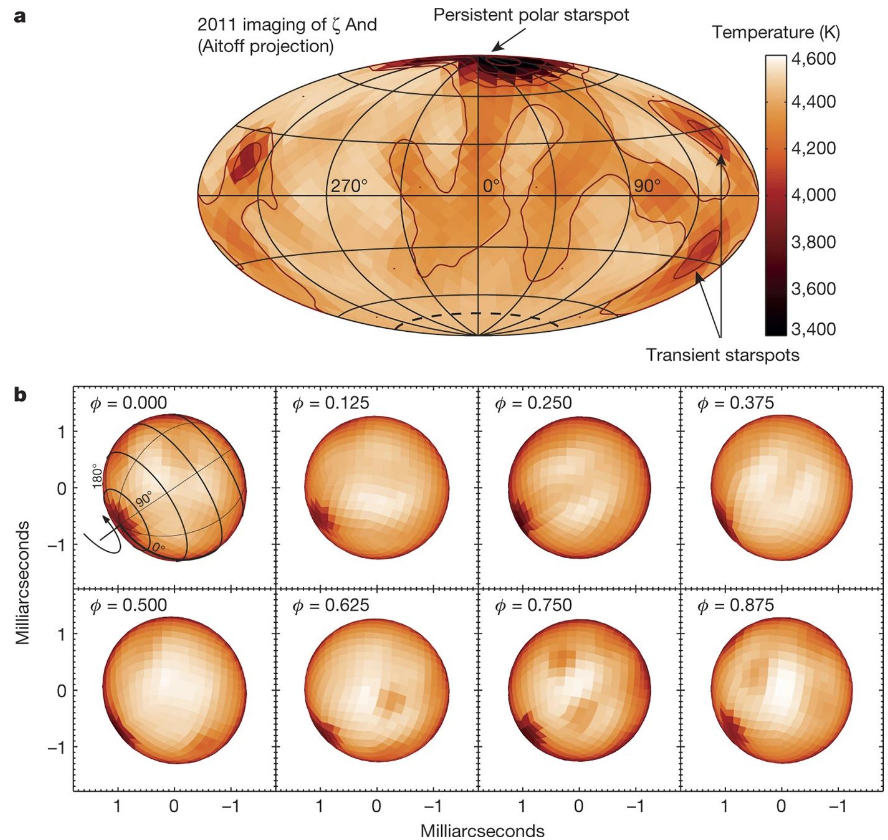


AO on 30-m class telescopes

Optical/IR interferometry

Near-IR/optical Science Applications





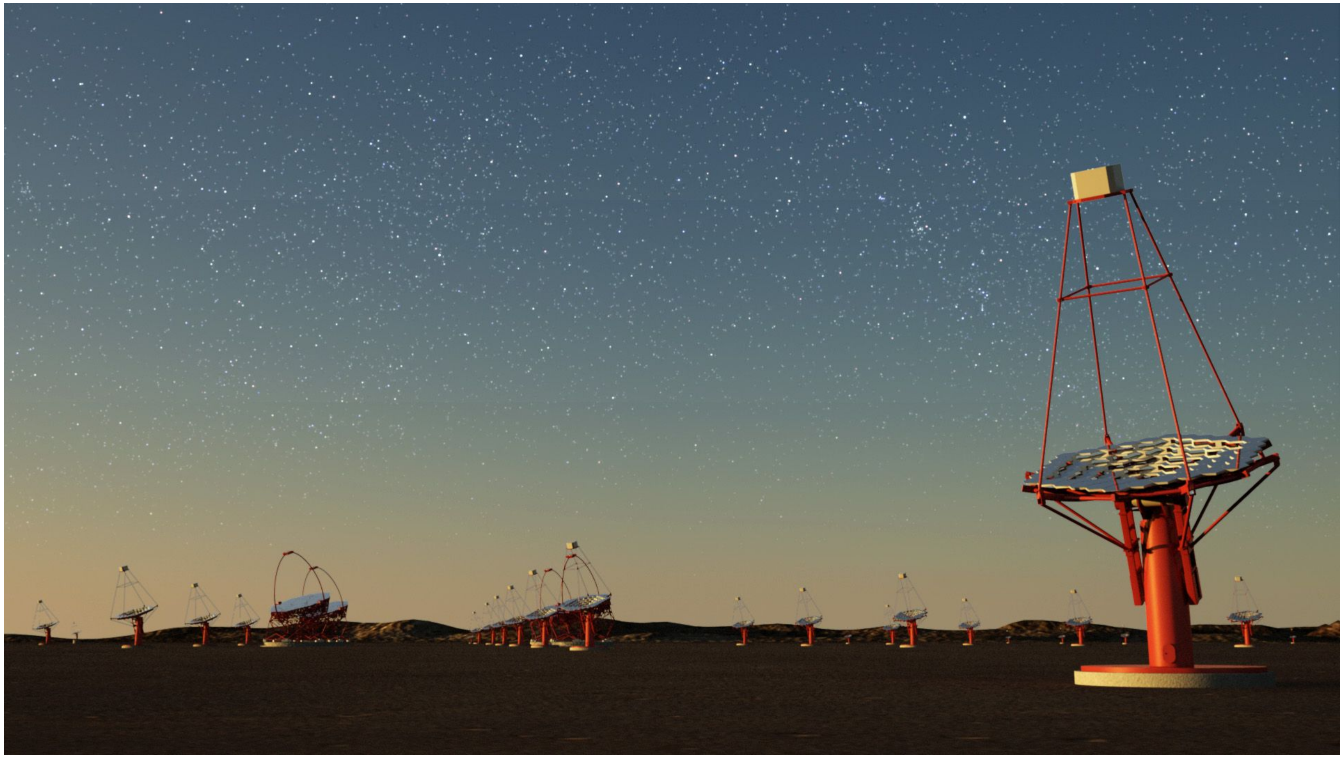
Orosz et al. 1996

Follow-up of Chandra surveys' compact binaries needs lots of time on big telescopes

Roettenbacher et al. 2016

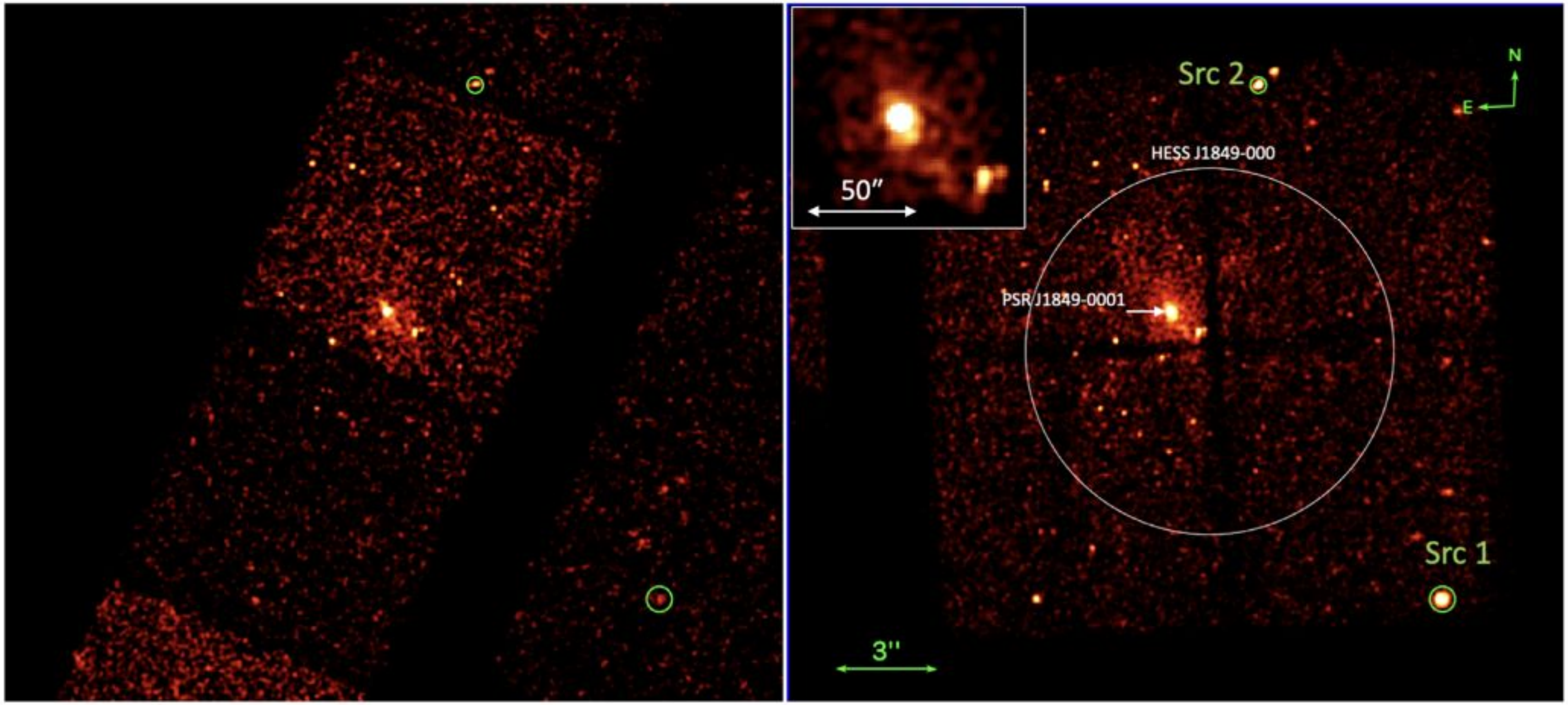
Sensitivity, also resolution to know which binary component produced X-rays

Gamma-rays



Note: also COSI+Chandra for nova spectroscopy, but will leave that to the nova talk

Gamma-ray science applications



Gagnon et al. 2023

Where we are now: X-rays

Best resolution to date: Chandra, 0.5” at about 600 cm^2 (28 cm diameter equivalent)

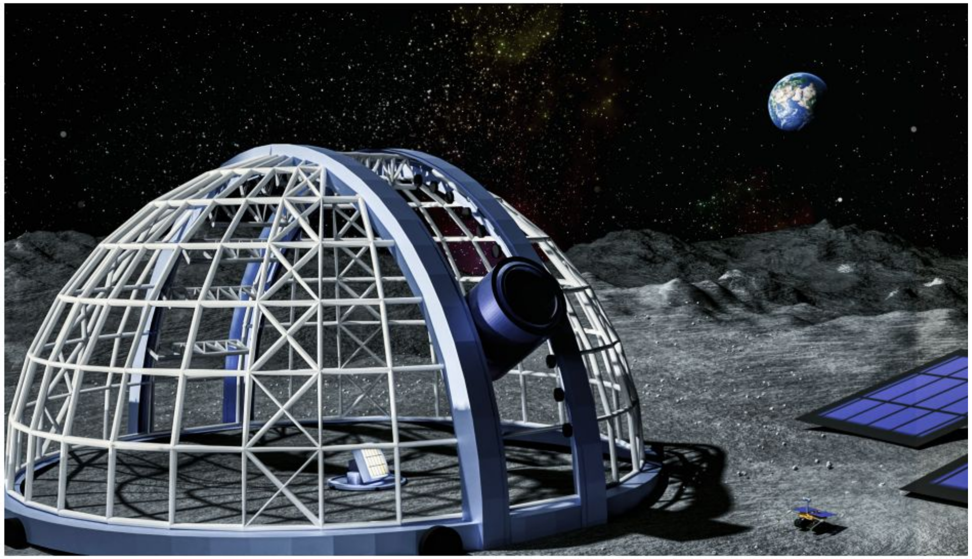
At 2 keV, diffraction limit for 28 cm would be about 0.5 milli-arcsec, comparable to VLBI

Biggest collecting area to date: RXTE, 6000 cm^2, equivalent to 0.87 m diameter (high end amateur for optical astronomy), 1 degree resolution

Geometric mean between 1 degree and 0.5 masec is 1.3”

We have a better handle on how to increase collecting area at low resolution than resolution at high collecting area

Improving X-ray imaging: occultation



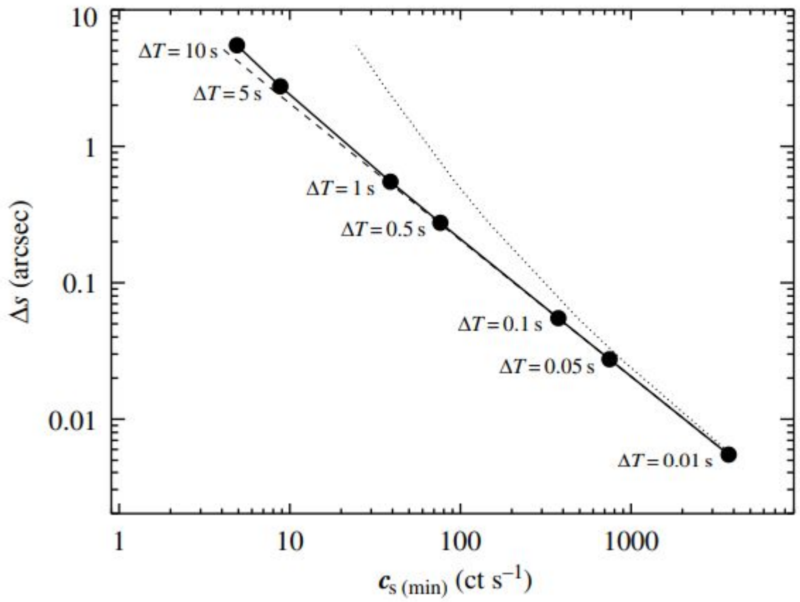
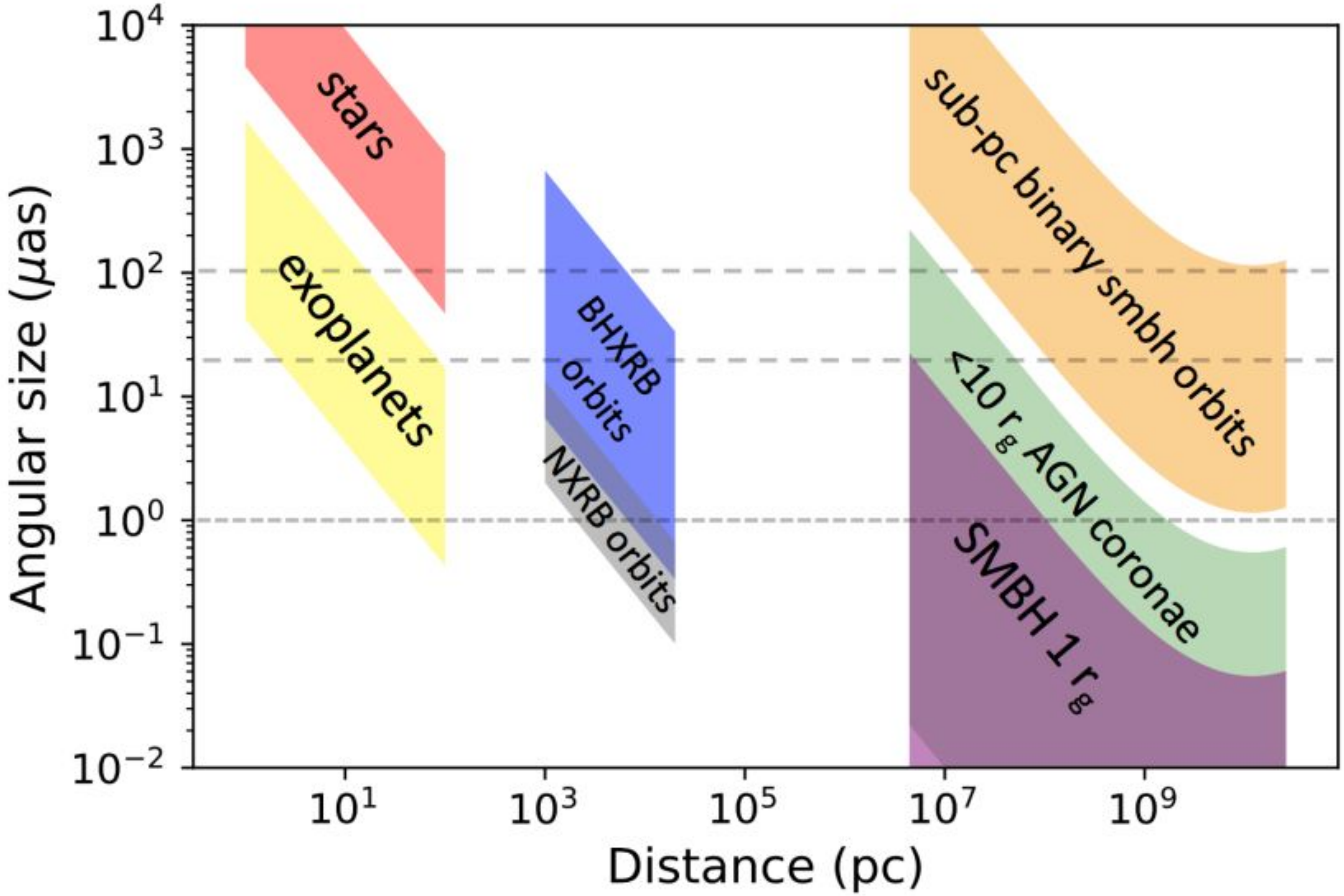


Fig from Gandhi 2023, but see also Fabbiano 1990, Gorenstein 1990

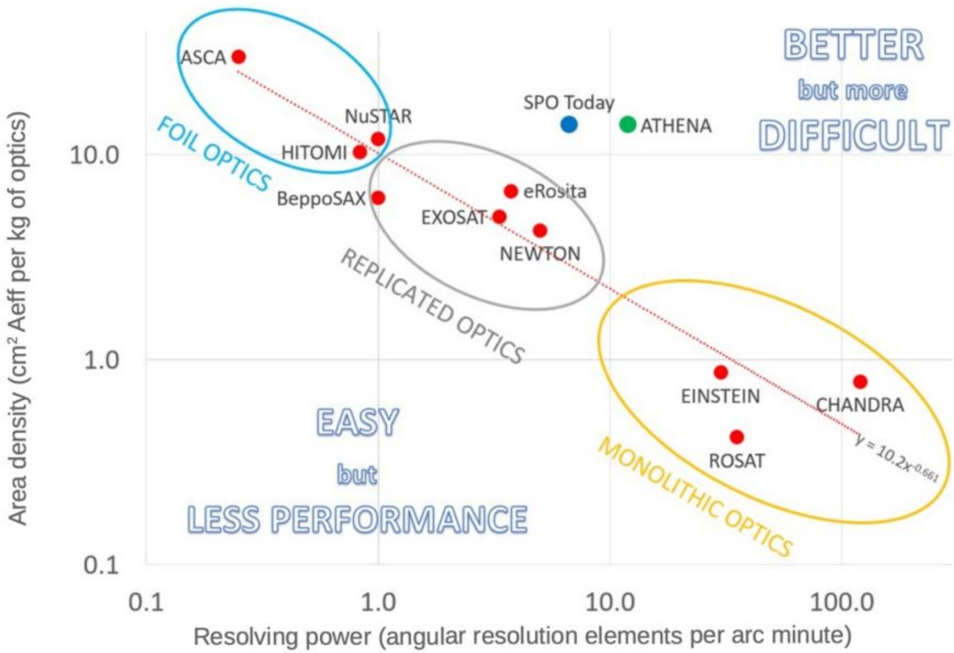
Lunar occultations from Moon itself can easily obtain millisecond positioning!

Improving X-ray imaging: interferometry



Uttley et al. 2019

Improving X-ray imaging: mirrors

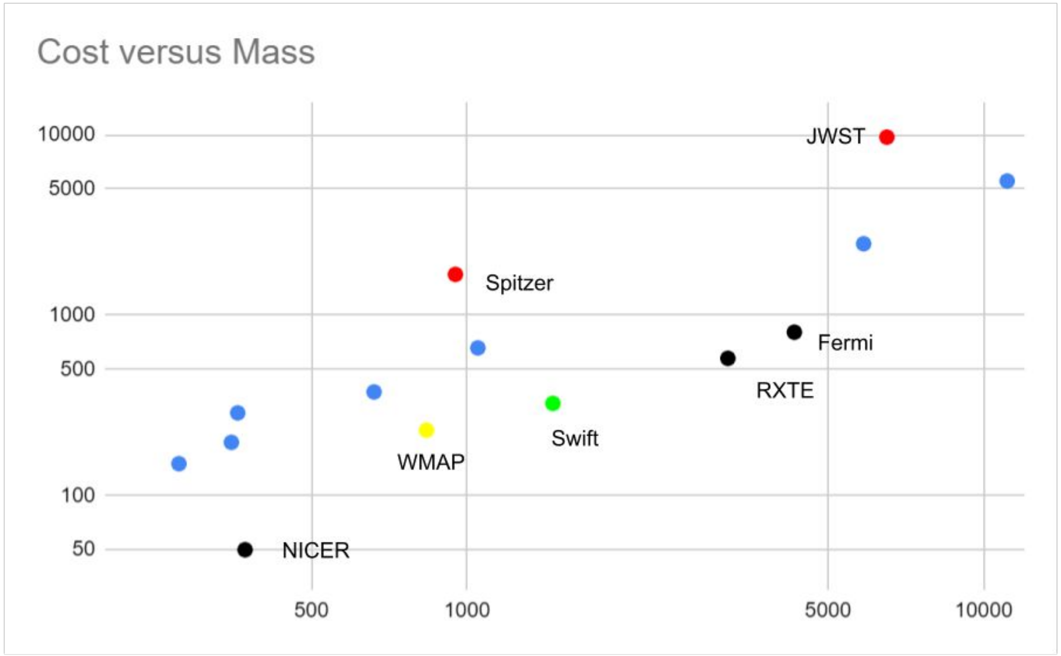


Barriere et al. 2022

Most development has included making optics lighter as a core principle

Chandra was heaviest payload ever launched by Shuttle (though mostly because of booster)

Mass is not cost; never has been, will be less so in future!



Cheaper spaceflight means not having to worry as much about mass

May require some re-thinking on the best strategies (Elvis, Lawrence & Seager 2023)

Longer focal lengths may become practical as well

(Also, PCOS-oriented missions are cheaper per unit mass than others)

Summary

Sub-arcsecond angular resolution X-ray astronomy is a unique capability of Chandra's with no replacement on the horizon

It interfaces with low frequency radio through high energy gamma-rays