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Boosting Chandra's Vision:

Gravitational Lensing and the Quest for Binary AGNs

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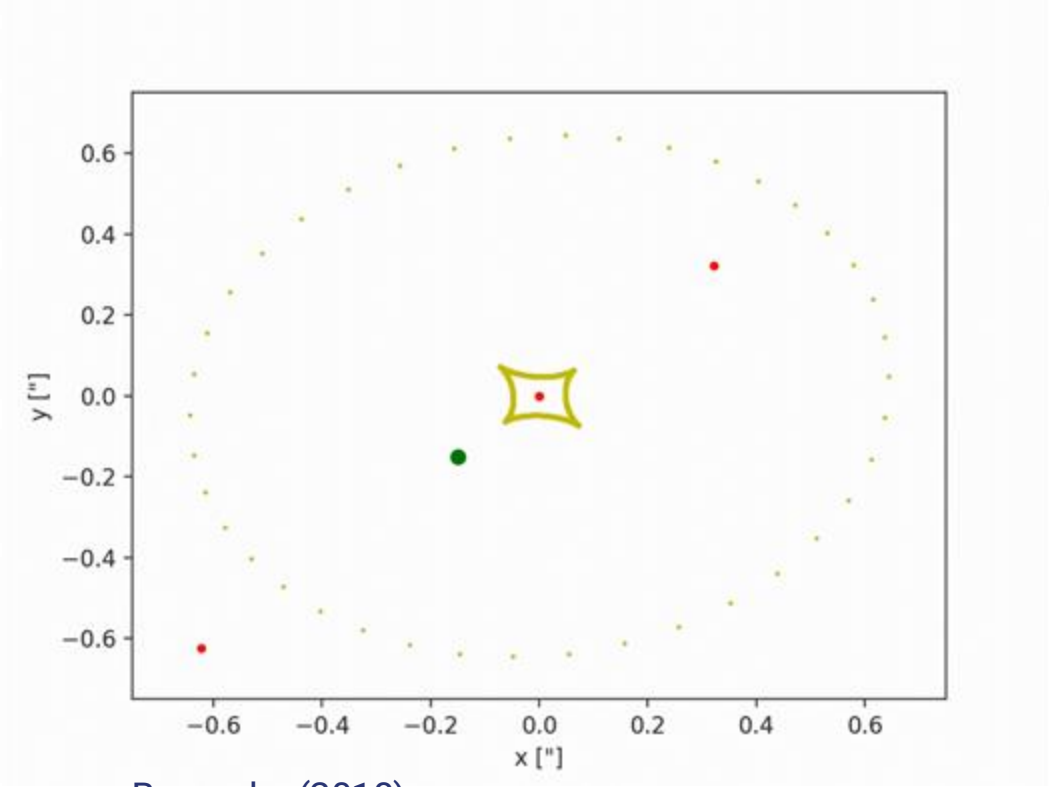
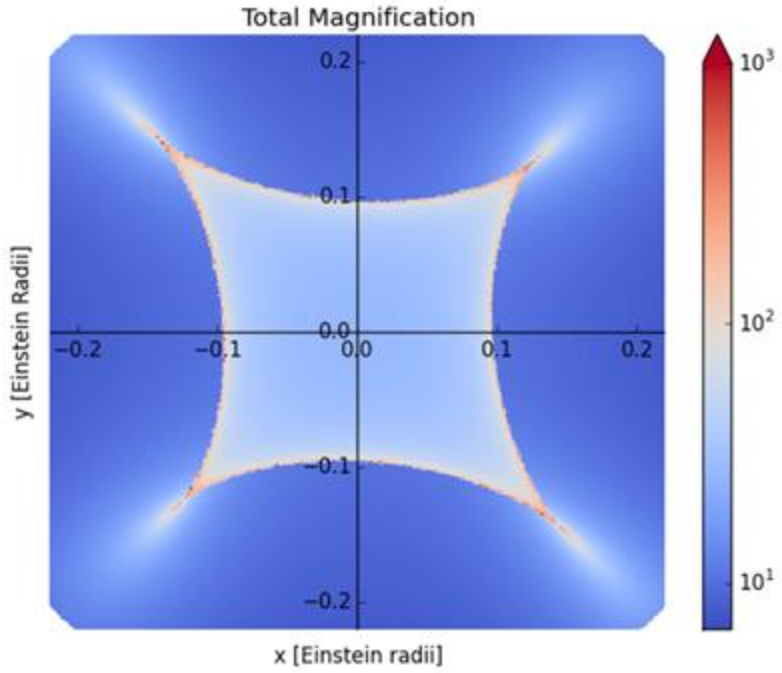
Gravitational Lensing

As High Resolution Telescope

Boosting Resolution Using Caustics of Lens Galaxy

Caustics are curves in the source plane where the magnification of the background object theoretically becomes infinite. They are the locations where lensed images merge, are created, or disappear as the source crosses the caustic line.





Barnacka (2018)

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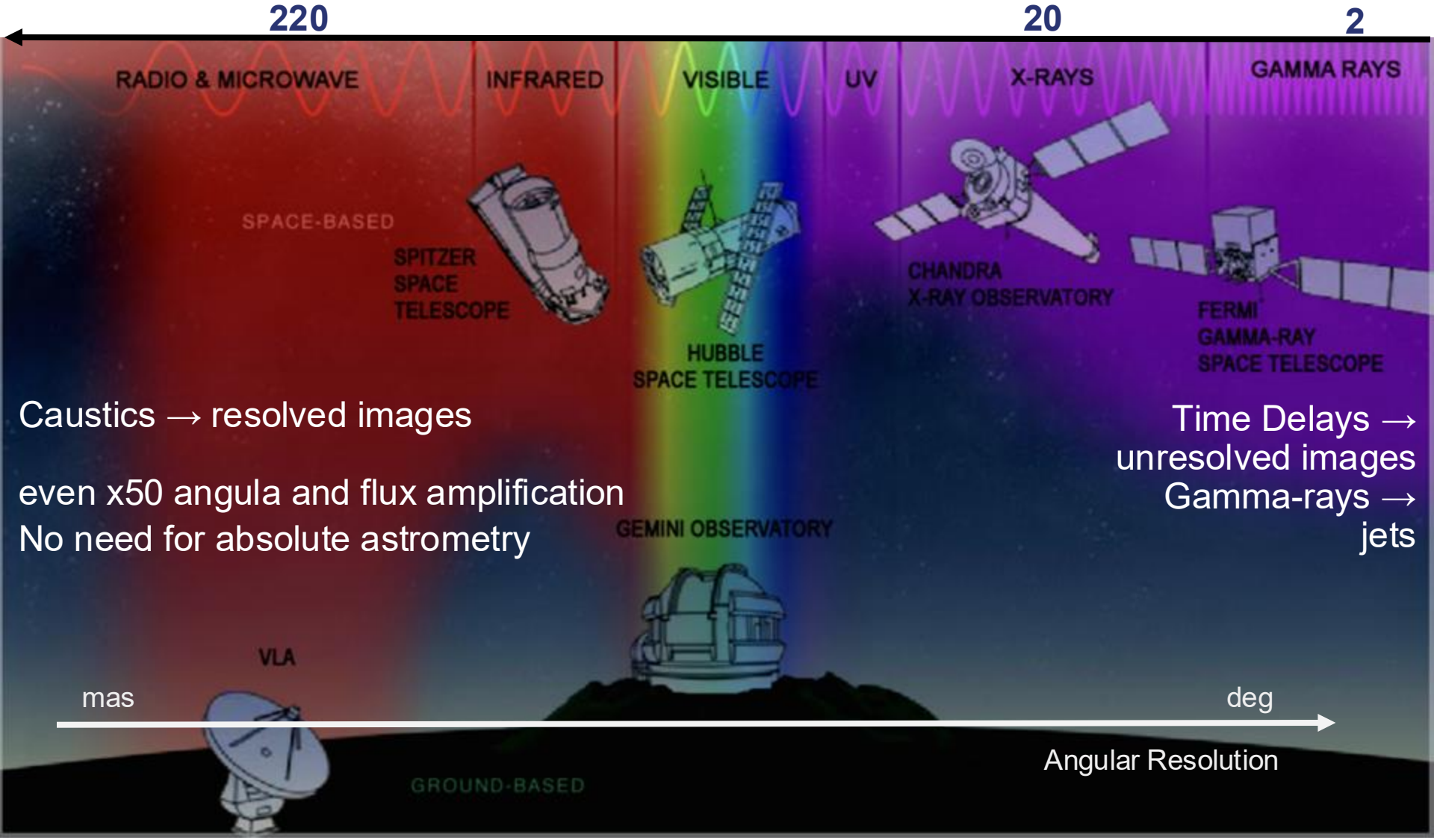
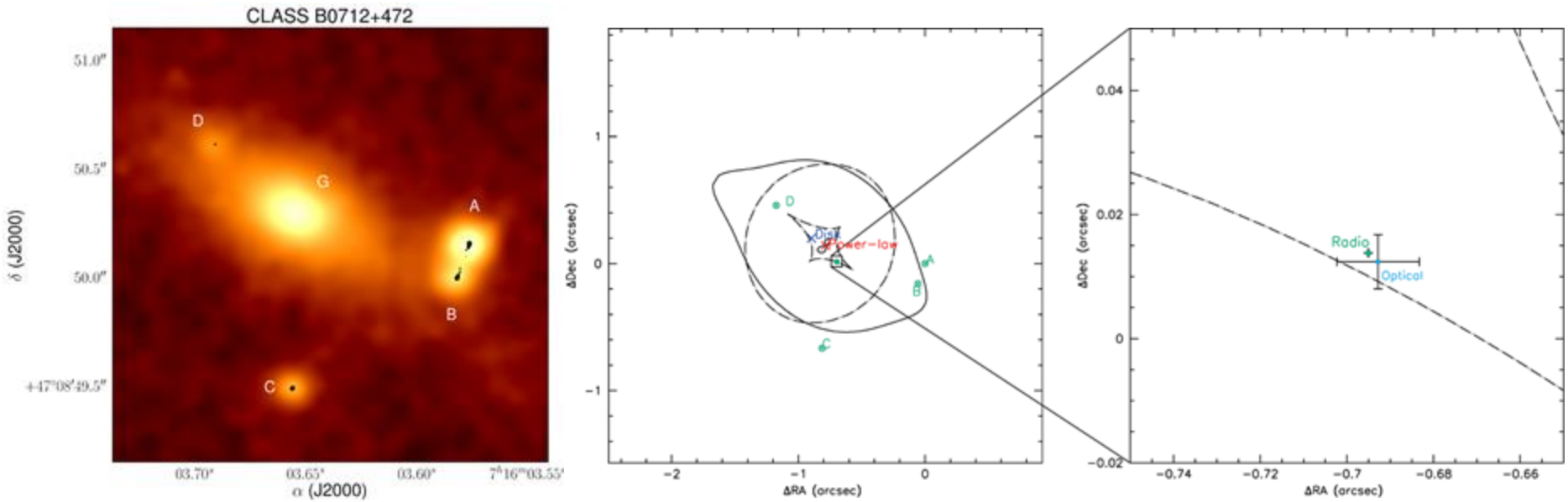
Number of gravitationally lensed quasars



B0712+472:Optical & Radio

Target	Source	$\Delta\alpha$ (arcsec)	$\Delta\delta$ (arcsec)	Offset (arcsec)	z_s
B0712+472	Radio	−0.69505±0.00005	+0.01380±0.00002	0.003±0.008	1.34
	Optical	−0.6928±0.0095	+0.01238±0.00435		

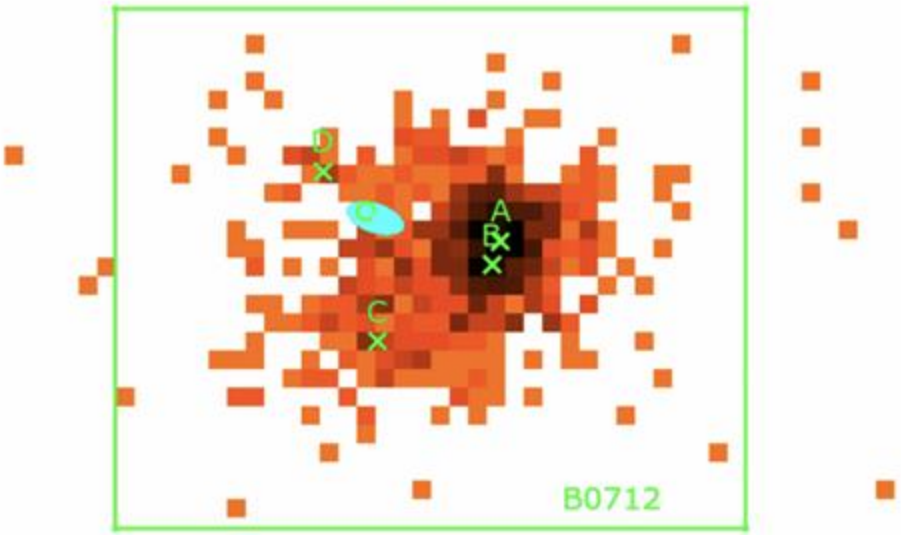


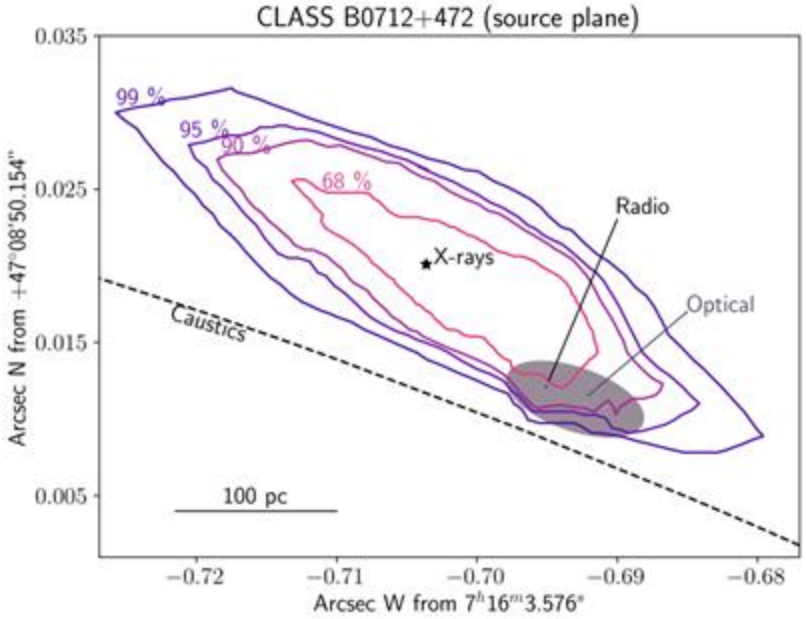
Spingola & Barnacka (2020)

B0712+472: Optical, Radio & X-ray

> We spatially locate the X-ray sources in CLASS B0712+472 within 11 mas from the radio source, we find that the X-ray emission is co-spatial with the radio and optical emission.

X-ray data in the 0.5 – 7 keV band



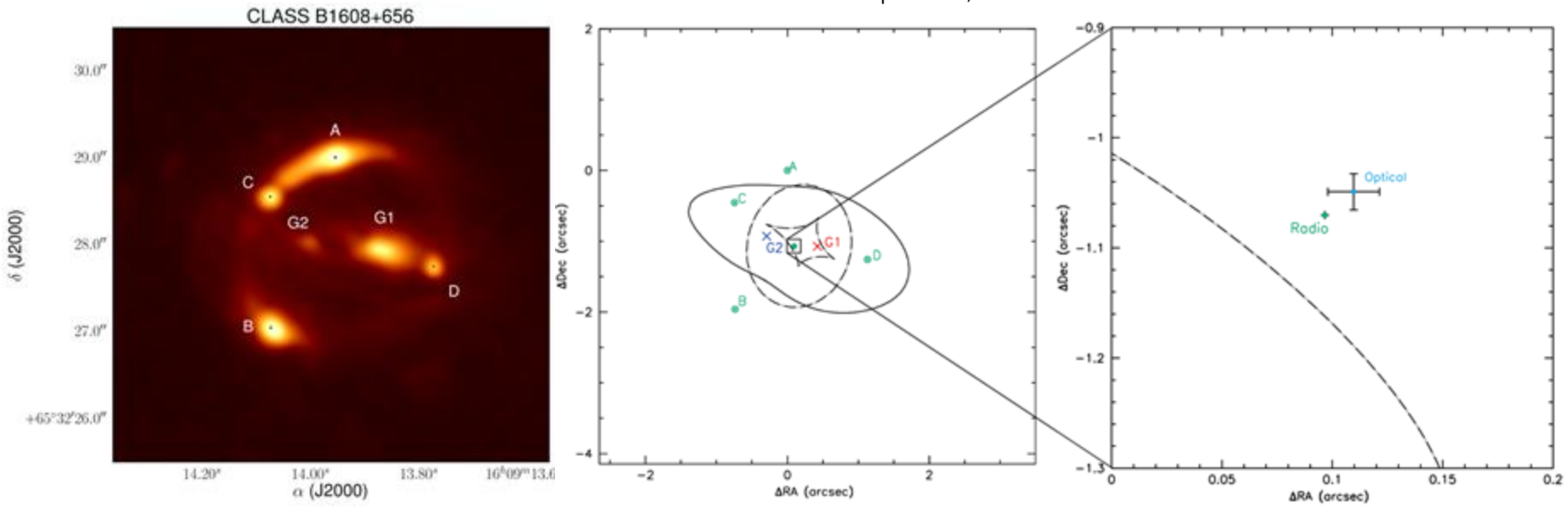


Spingola, Schwartz, Barnacka (2022)

B1608+656:Optical & Radio

Target	Source	$\Delta\alpha$ (arcsec)	$\Delta\delta$ (arcsec)	Offset (arcsec)	z_s
B1608+656	Radio	0.096638±0.000005	−1.070248±0.000009	0.025±0.015	1.394
	Optical	0.1097±0.0117	−1.0490±0.0165		

For comparison, the event horizon of M87 is about 22 micro-arc-sec

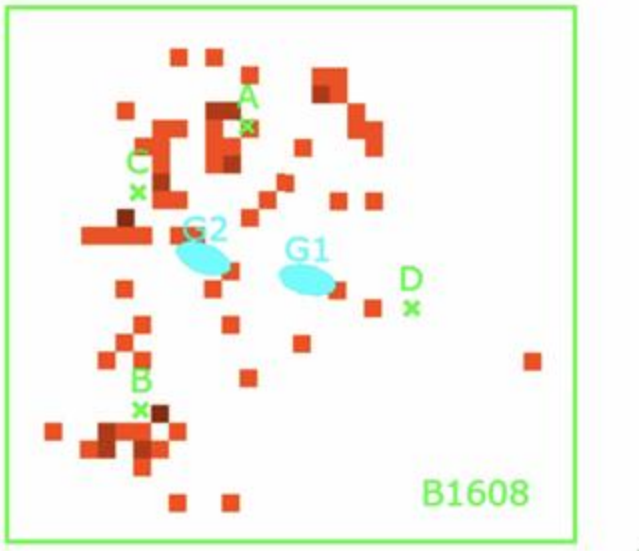


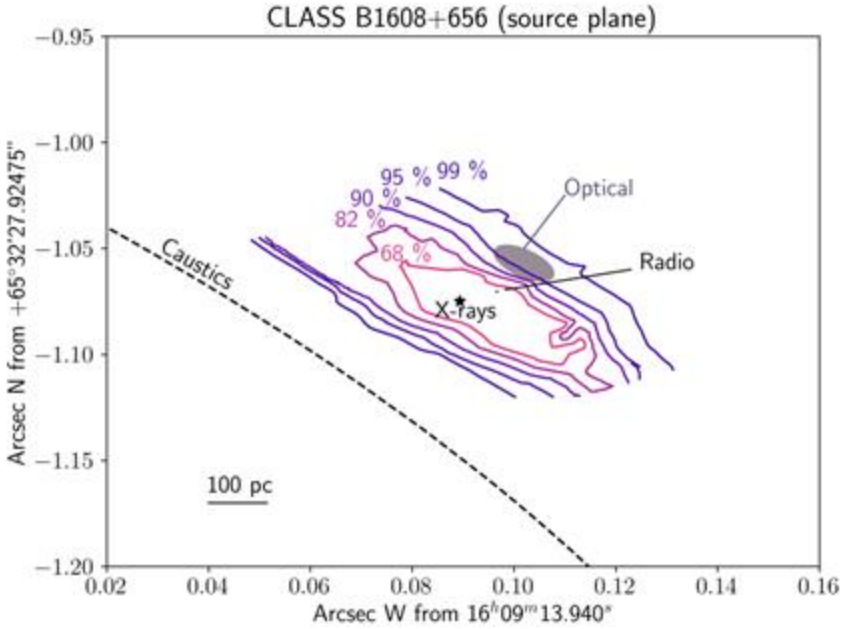
Spingola & Barnacka (2020)

B1608+656: Optical, Radio & X-ray

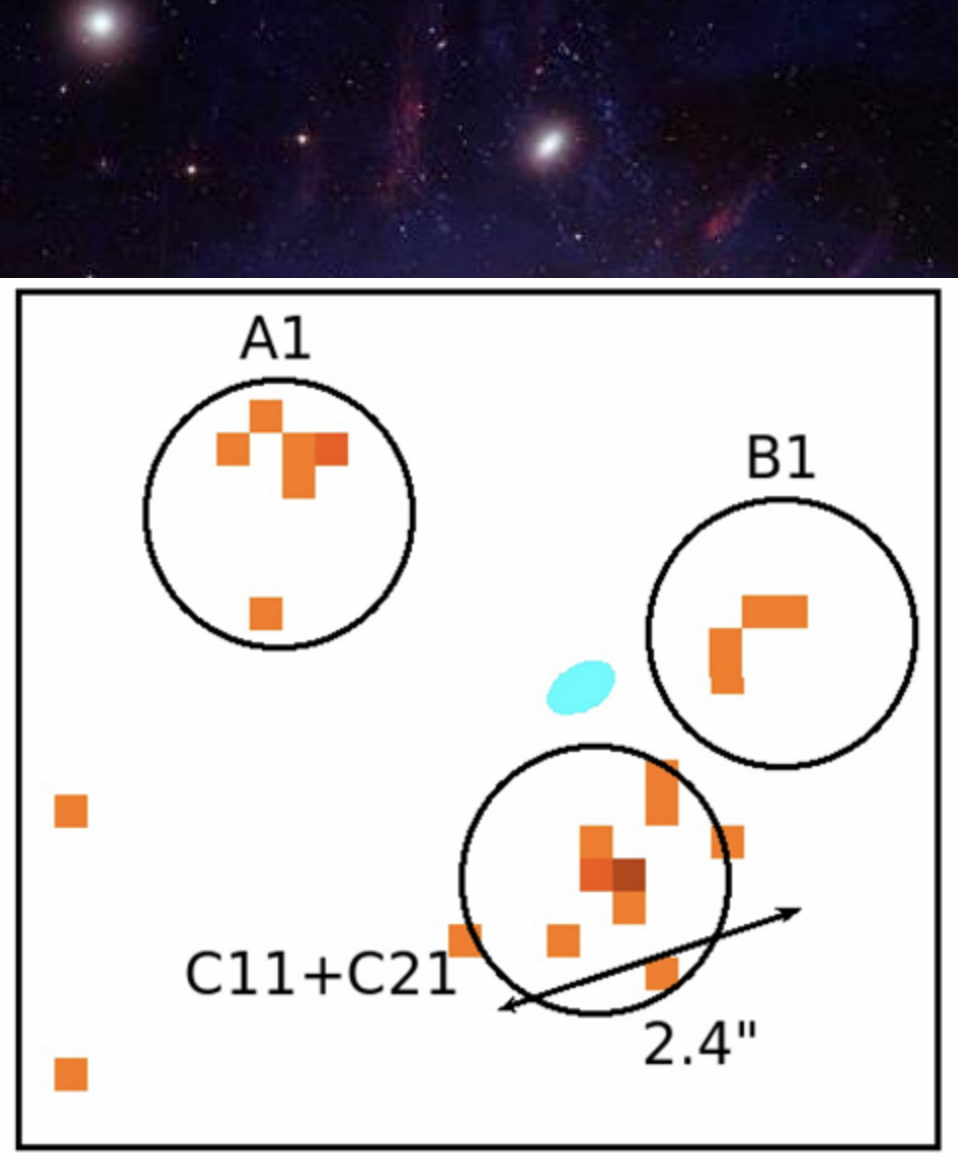
> We spatially locate the X-ray sources within 9 mas from the radio source,. The X-ray emission is co-spatial with radio, but displaced with respect to the optical emission at 1σ level, which makes this source as an offset AGN candidate.

X-ray data in the 0.5 – 7 keV band





Spingola, Schwartz, Barnacka (2022)



MG B2016+112

Properties

Redshift z = 3.273

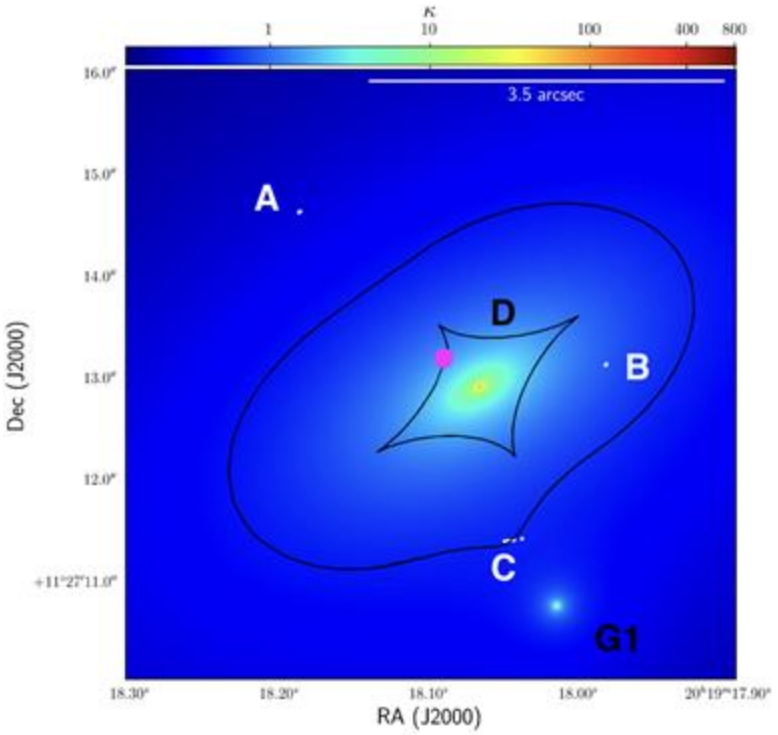
Radio Source Structure: The source comprises four sub-components separated by ~175 pc.

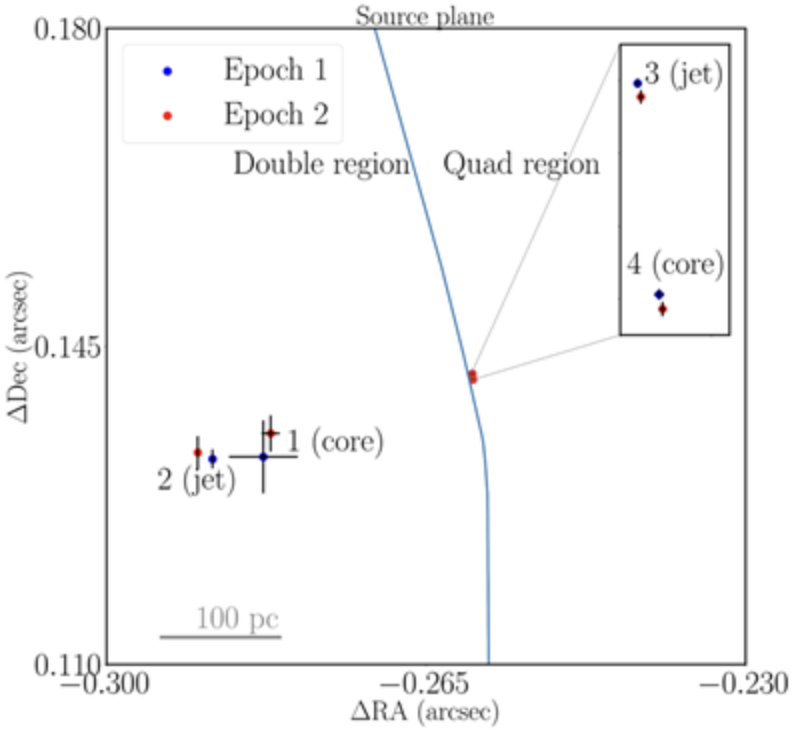
Magnification: a) Two radio components with high magnification (μ ~ 350) b)Two radio components with lower magnification (μ ~ 2).

Chandra detected **24** photons

MG B2016+112: Lens model and radio sources

Scenarios Proposed: Single Active Galactic Nucleus (AGN) with extended jet or dual AGN hypothesis.

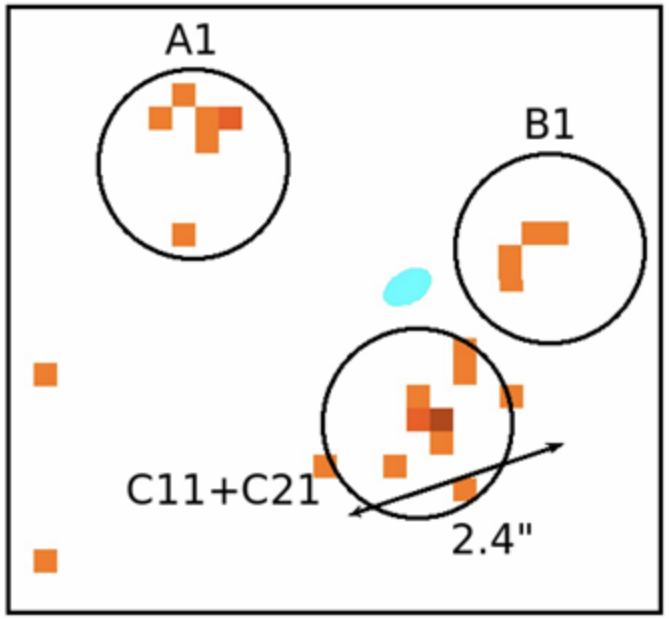


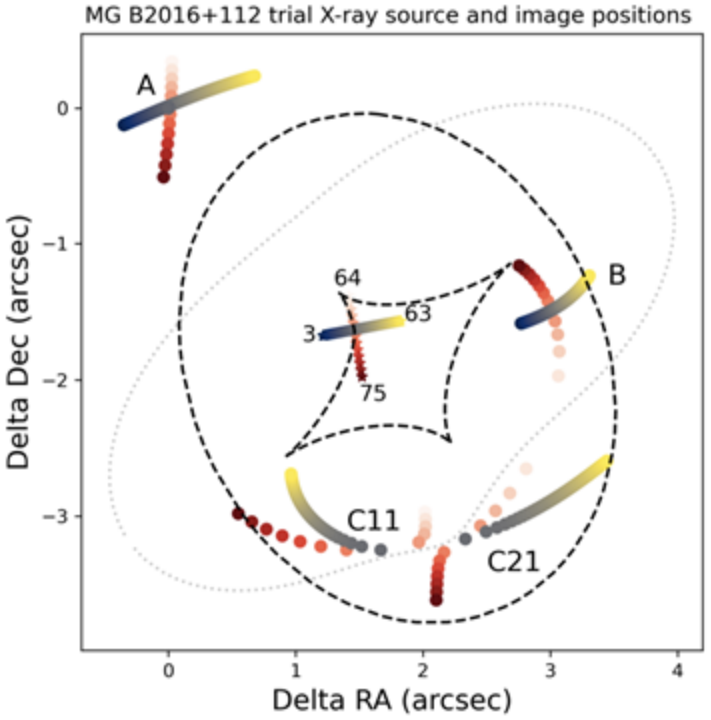


Spingola, et al. (2019)

MG B2016+112: Origin of X-ray emission

Finding the position of the X-ray source. .





Schwartz, Spingola, Barnacka (2021)

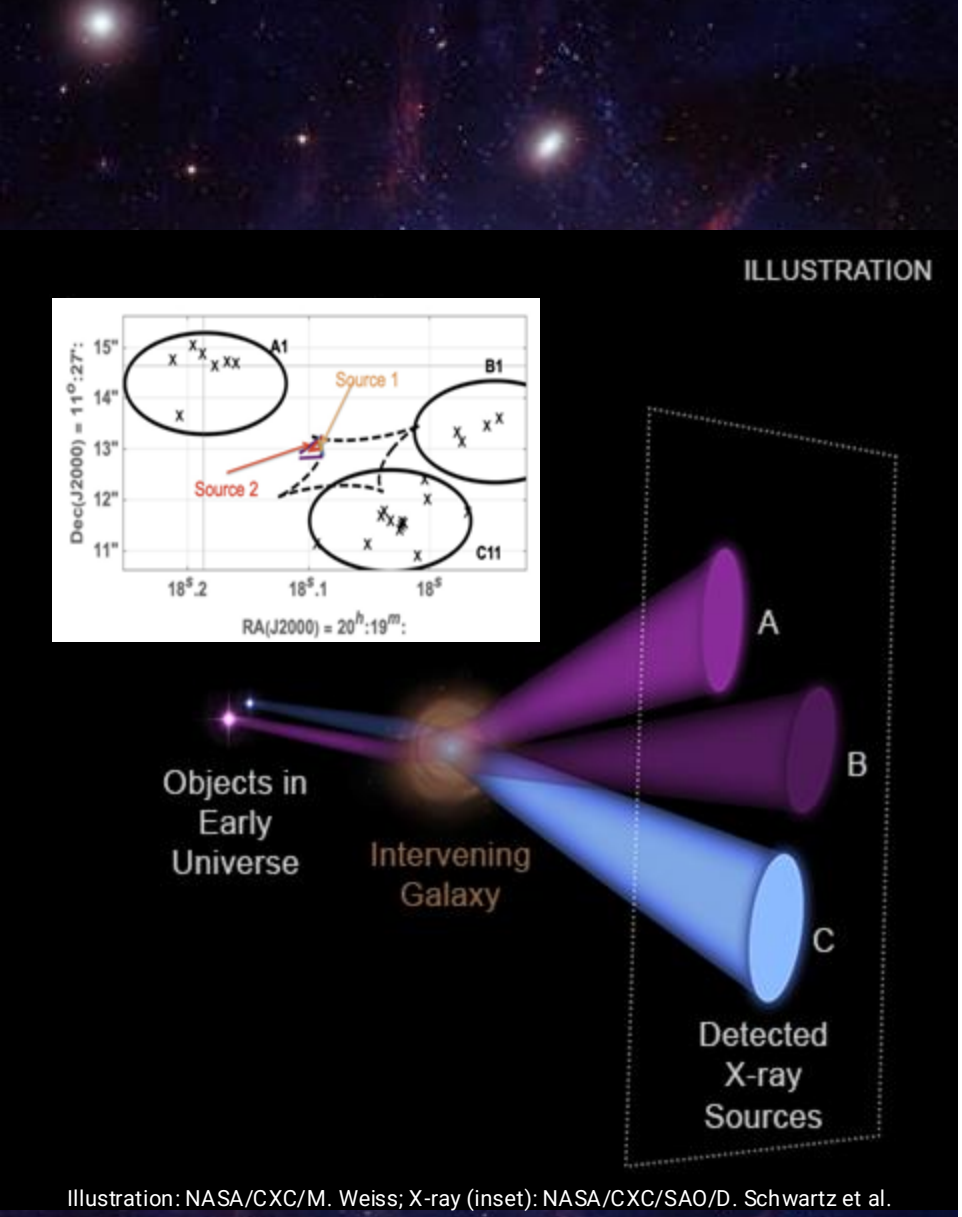


Illustration: NASA/CXC/M. Weiss; X-ray (inset): NASA/CXC/SAO/D. Schwartz et al.

Results
MG B2016+112

1 **X-Ray Source Detection**

Two X-ray sources detected, consistent with radio components separated by ~200 pc.

2 **System Composition**

Likely a dual AGN system or an AGN with a pc-scale X-ray jet.

3 **Alignment**

The quadruply lensed X-ray source aligns within ±40 pc (1σ) of its VLBI counterpart.

4 **Spatial Resolution Achieved**

Metric distance accuracy at high redshifts down to tens of mas near caustics.

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Summary

Boosting Spatial Resolution

Introduced a novel method leveraging gravitational lensing to enhance angular resolution by an order of magnitude.

Chandra Data Applications

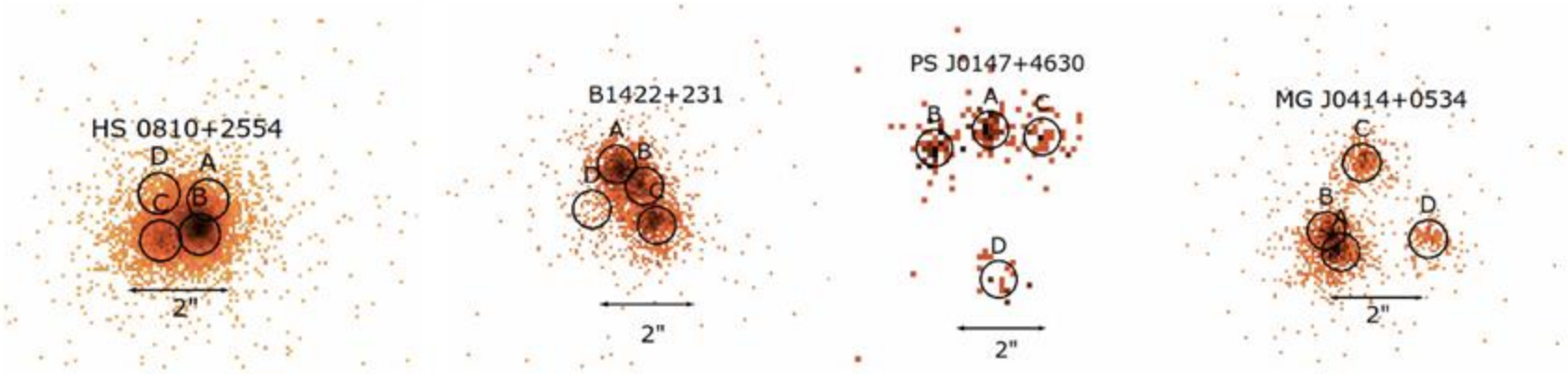
Demonstrated three case studies showcasing complex X-ray emission structures in relation to optical and radio sources.

Expanding Opportunities

Highlighted the potential to analyze dozens of additional X-ray sources in Chandra archives, with even greater insights from future deeper observations.

Impact on AGN Research

Showcased the transformative potential of Chandra, with enhanced resolution via cosmic lenses, to unravel AGN physics and identify dual AGN systems at large redshifts.



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Thank you