GRAVITATIONAL LENSES
AS HIGH-RESOLUTION TELESCOPES

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JOURNEY TO INNER REGION OF M87

Journey created with World Wide Telescope
OFFSET: RADIO CORE – SUPERMASSIVE BLACK HOLE

Barnacka et al. 2016, ApJ, 821, 58
GALAXIES AS COSMIC LENSES

Credit: NASA's Goddard Space Flight Center
SOURCE CLOSE TO THE CAUSTIC OF THE LENSING GALAXY
TOY MODEL: SOURCES CLOSE TO THE CAUSTIC

Source offset 1 mas
Images offset 100 mas

Barnacka (2017, arXiv:1705.00690)
FLUX MAGNIFICATION IN CAUSTIC REGION

Barnacka (2017, ApJ, arXiv:1705.00690)
ANGULAR AMPLIFICATION IN CAUSTIC REGION

Monte Carlo Simulations of $10^6$ pair of offset sources

Barnacka (2017, arXiv:1705.00690)
LENSED QUASARS IN CAUSTIC CONFIGURATION

8 out of 20
EUCLID AND SKY SYNERGY

SKA

Resolution:
2 mas at 10 GHz
20 mas at 1 GHz

Euclid

HST like resolution to ~ 24 mag

In near future: observations of more than $10^5$ strongly lensed flat spectrum radio-loud quasars
SUMMARY

➤ Caustic Configuration:
➤ >50 x Flux Magnification
➤ >50 x Angular Amplification
➤ Resolution ~ a few mas
➤ Currently: dozen of sources
➤ Near future: SKA and Euclid dozen of thousands of sources
➤ Insight into:
➤ Inner parts of active galaxies at high redshifts
➤ Physical origin of offsets
➤ Identify the most distant quasars
➤ Follow-up observations with JWST or ELT
JOURNEY TO INNER REGION OF M87

Journey created with World Wide Telescope: Special thanks to Philip Rosenfield
GAIA–VLBA OFFSETS

Table from Petrov & Kovalev (2017)
The first four rows of the table of 384 VLBI/Gaia matches with statistically significant offsets: probability of false association (PFA) less than 0.0002 and the random noise probability (RNP) less than 0.01. The fifth column contains the normalized arc lengths, and two last columns contain positions of Gaia minus VLBI over right ascensions, including cosδ factor and declination.

| VLBI ID     | Gaia ID         | PFA     | RNP     | q     | da (mas) |
|-------------|-----------------|---------|---------|-------|----------|
| RFC J0000–3221 | Gaia 2314315845817748992 | 4.47 × 10⁻⁸ | 2.47 × 10⁻²² | 20.78 | -6.51    |
| RFC J0004–0802 | Gaia 2441584492826114432 | 3.58 × 10⁻⁶ | 4.14 × 10⁻³ | 4.73  | -21.39   |
| RFC J0005+3820 | Gaia 2880735411259458048 | 1.98 × 10⁻⁷ | 5.03 × 10⁻⁸ | 10.80 | 5.77     |
| RFC J0008–2339 | Gaia 2337107759788510464 | 2.01 × 10⁻⁸ | 5.84 × 10⁻⁶ | 8.84  | 1.17     |

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CAUSTIC OF ELLIPTICAL LENSES
M87 Gravitationally Lensed?

\[ \alpha = \frac{4GM(r)}{c^2} \frac{1}{r} \]

Observer

Lens

Deflected light

Line of sight

Apparent path of light to Earth

False image

JET

\[ D_{OL} \quad D_{OS} \quad D_{LS} \]
PROBABILITY OF CAUSTIC CONFIGURATION

➤ Elliptical lens $e=0.2$
  ➤ Lens $z=0.5$, source $z=2$
➤ Caustic Length $\sim 2.1 \, r_E$
  ➤ Probability that a source will be with $2\% r_E$ from the Caustic is $\sim 1\%$
➤ Magnification bias
  ➤ Magnification close to the caustic $> 50$
  ➤ Probability $> 8\%$
SOURCE CLOSE TO THE CAUSTIC OF THE LENSSING GALAXY