GRAVITATIONAL LENSES AS HIGH-RESOLUTION TELESCOPES

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Journey to Inner Region of M87
OFFSET: RADIO CORE – SUPERMASSIVE BLACK HOLE

The Hubble Space

6.4±1.1 mas

SOURCE CLOSE TO THE CAUSTIC OF THE LENSING GALAXY
TOY MODEL: SOURCES CLOSE TO THE CAUSTIC

Source offset 1 mas
Images offset 100 mas

FLUX MAGNIFICATION IN CAUSTIC REGION

ANGULAR AMPLIFICATION IN CAUSTIC REGION

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

$2\% r_E$

$\sim 10$ mas from the Caustic

LENSED QUASARS IN CAUSTIC CONFIGURATION

8 out of 20

CAUSTIC

CAUSTIC

CAUSTIC

CAUSTIC

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CAUSTIC

CAUSTIC
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
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 \( \cos \delta \) factor and declination.

<table>
<thead>
<tr>
<th>VLBI ID</th>
<th>Gaia ID</th>
<th>PFA</th>
<th>RNP</th>
<th>q</th>
<th>( da ) (mas)</th>
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</thead>
<tbody>
<tr>
<td>RFC J0000–3221</td>
<td>2314315845817748992</td>
<td>4.47 \times 10^{-8}</td>
<td>2.47 \times 10^{-22}</td>
<td>20.78</td>
<td>-6.51</td>
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<td>RFC J0004–0802</td>
<td>2441584492826114432</td>
<td>3.58 \times 10^{-6}</td>
<td>4.14 \times 10^{-03}</td>
<td>4.73</td>
<td>-21.39</td>
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<td>RFC J0005+3820</td>
<td>2880735411259458048</td>
<td>1.98 \times 10^{-7}</td>
<td>5.03 \times 10^{-08}</td>
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<td>RFC J0008–2339</td>
<td>233710775978510464</td>
<td>2.01 \times 10^{-8}</td>
<td>5.84 \times 10^{-06}</td>
<td>8.84</td>
<td>1.17</td>
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</tbody>
</table>
CAUSTIC OF ELLIPTICAL LENSES
M87 Gravitationally Lensed?

Observer

Lens

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

DOL  DOS  DLS

Apparent path of light to Earth
False image
Deflected light
Line of sight
False image
JET
PROBABILITY OF CAUSTIC CONFIGURATION

➤ Elliptical lens e = 0.2

➤ lens z = 0.5, source z = 2

➤ Caustic Length \( \sim 2.1 \) rE

➤ Probability that a source will be with 2%rE from the Caustic is \( \sim 1\% \)

➤ Magnification bias

➤ Magnification close to the caustic > 50

➤ Probability > 8%
SOURCE CLOSE TO THE CAUSTIC OF THE LENSING GALAXY