

Resolving High Energy Emission of Jets Using Strong Gravitational Lensing

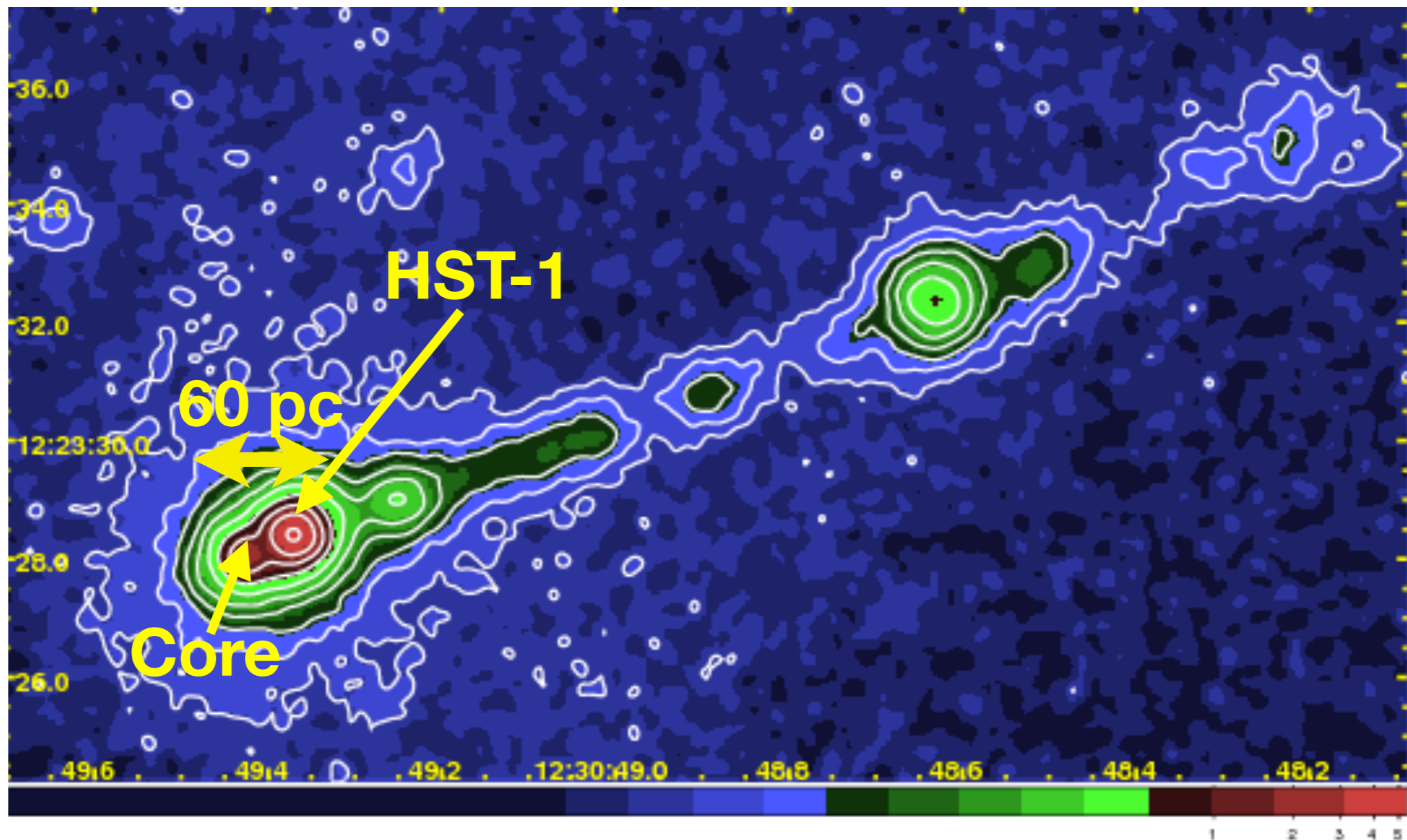
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X-Ray Jets - Lessons from Chandra

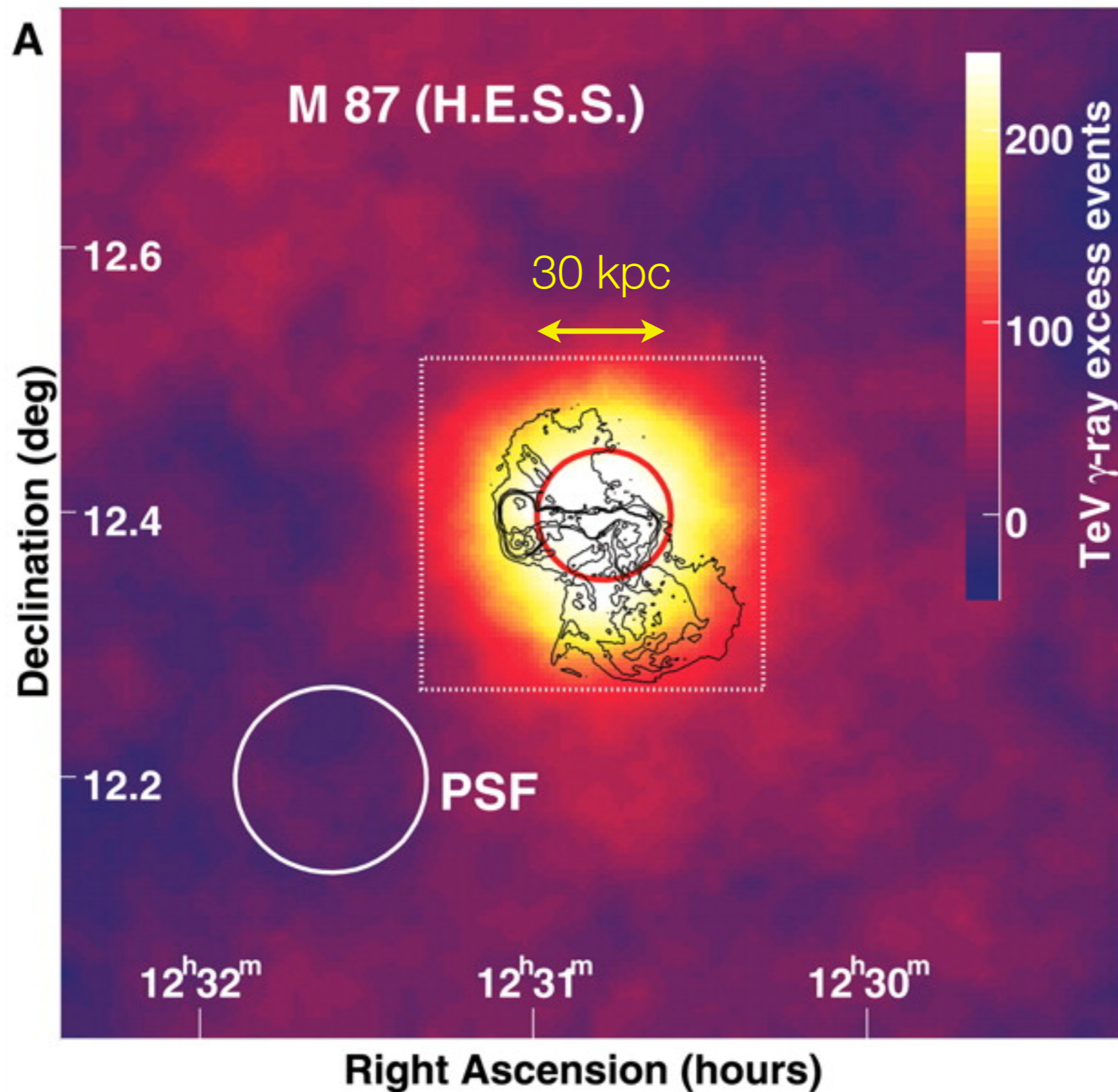
Increased x-ray emission by a factor of 50 from the HST-1 knot (Harris et al. 2006,2009)

Core and HST-1: Separation ~ 60 pc



Flares from knots along the jets

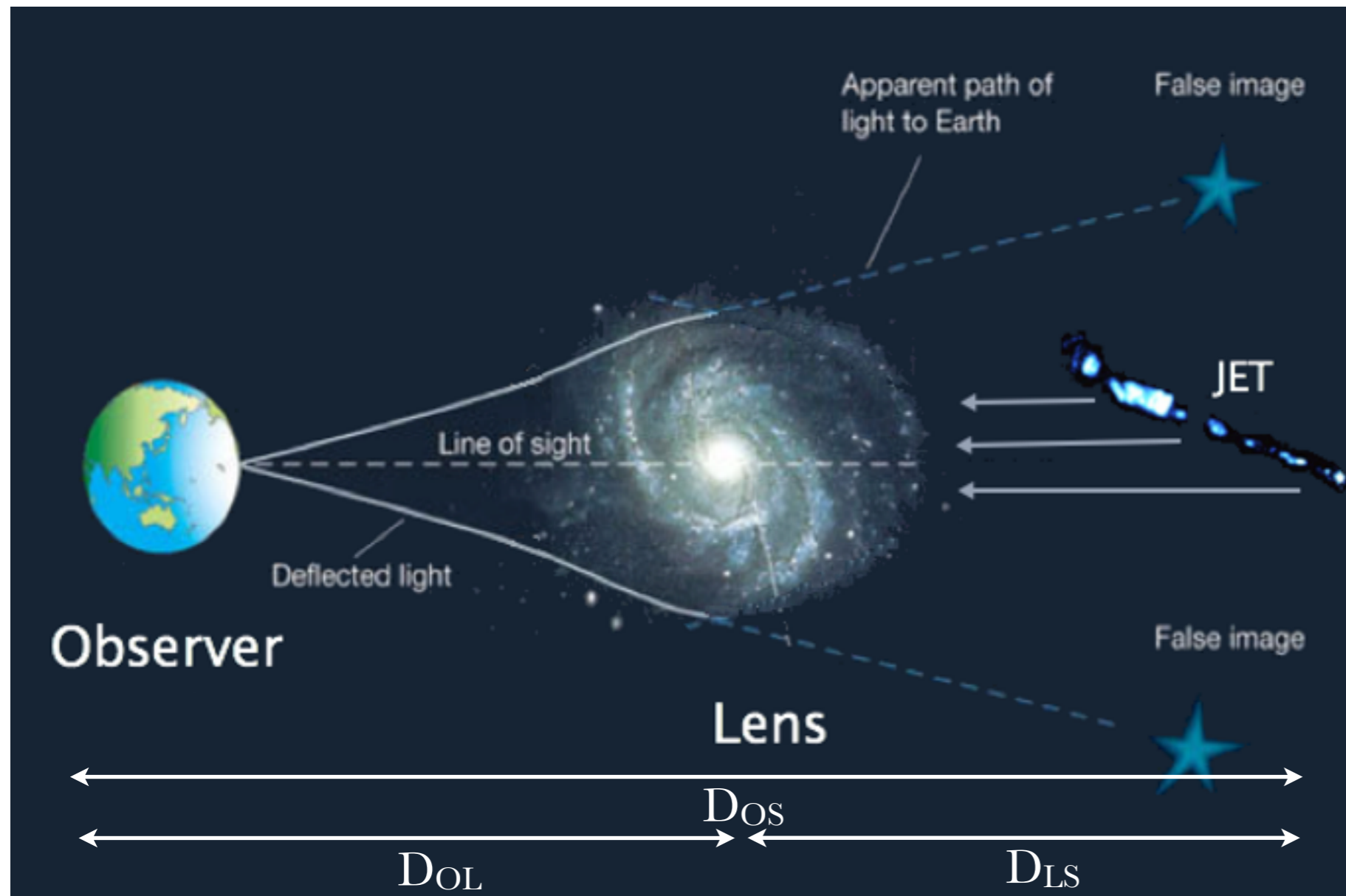
Ambiguity of Gamma-Ray Origin



Scientific Issues

- Frequency of M87-like variability
- Structure of gamma-ray jets
- Spatial origin of gamma-ray flares

M87 Gravitationally Lensed?



Deflection angle:

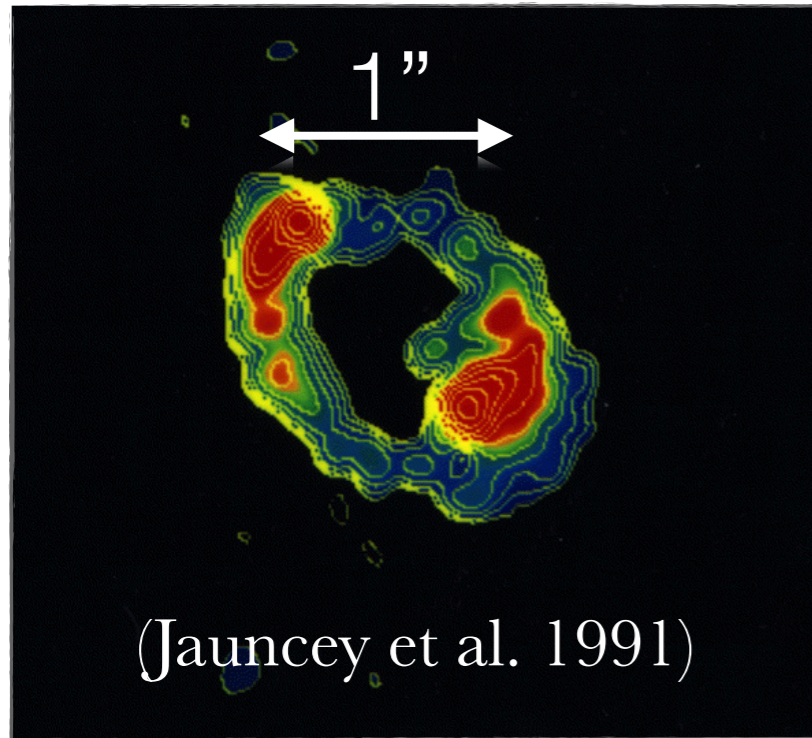
$$\alpha = \frac{4GM(r)}{c^2} \frac{1}{r}$$

Images separation - a few arcseconds
time delay
magnification ratio

M87 as a Toy Model

- $z_s=1, z_l = 0.6$
- Einstein radius ~ 2.2 kpc (0.45")
- 60 pc $\sim 0.01'' \sim 3\%$ Einstein radius
- Differences between the **core** and the **HST-1**:
 - **difference in time delay: ~ 2 days**
 - **difference in magnification ratio: ~ 0.2**

Lensed Gamma-Ray Jets: PKS 1830-211



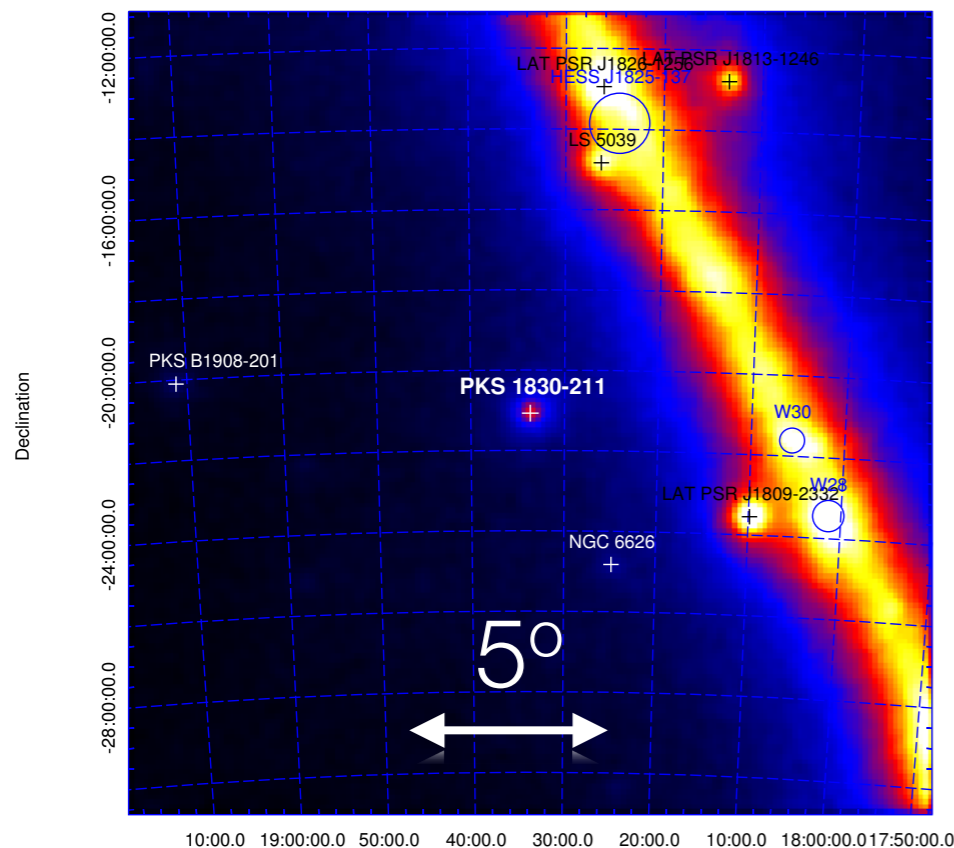
Source $z = 2.5$, Lens $z = 0.9$

Radio Time Delay 26 ± 5 days

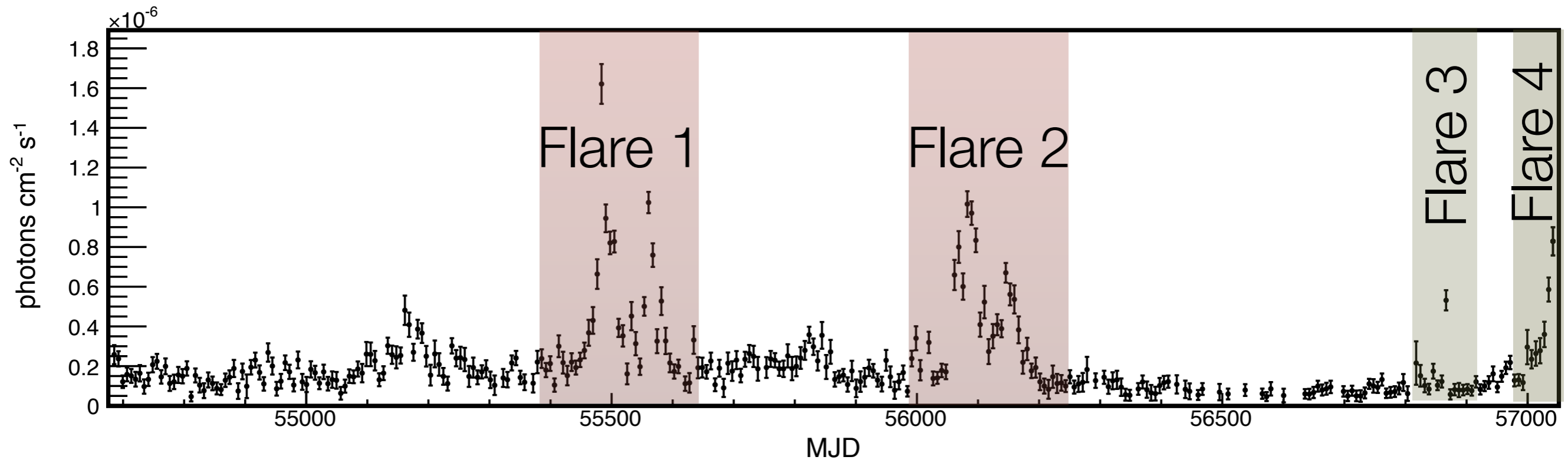
The first evidence of lensing at gamma-rays
(Barnacka et al. 2011)

Gamma-Ray Time delay 27.1 ± 0.45 days

Gamma-ray Flares Time Delays ?



Gamma-ray Flares: Time Delays

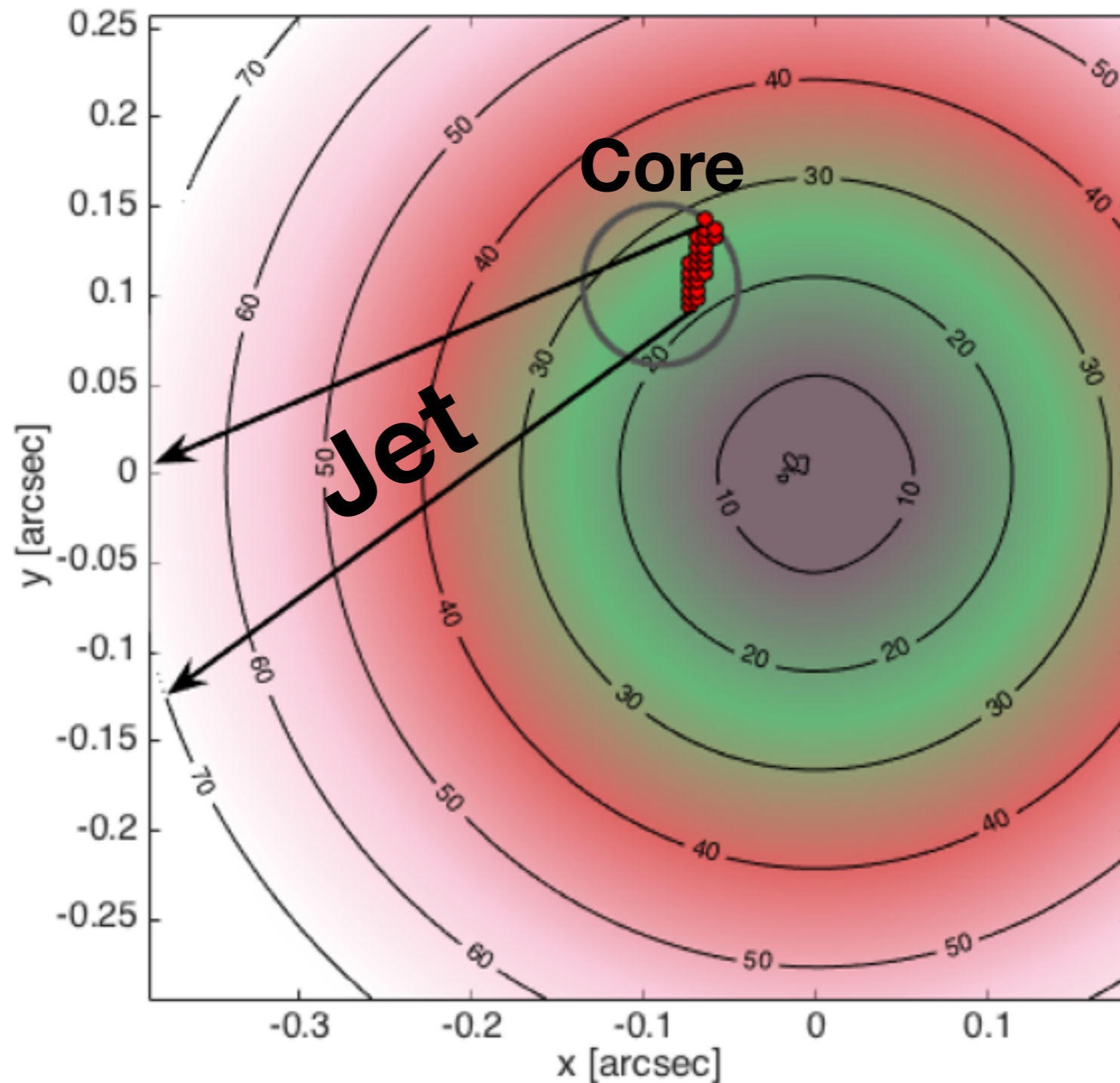


23 ± 0.5 days

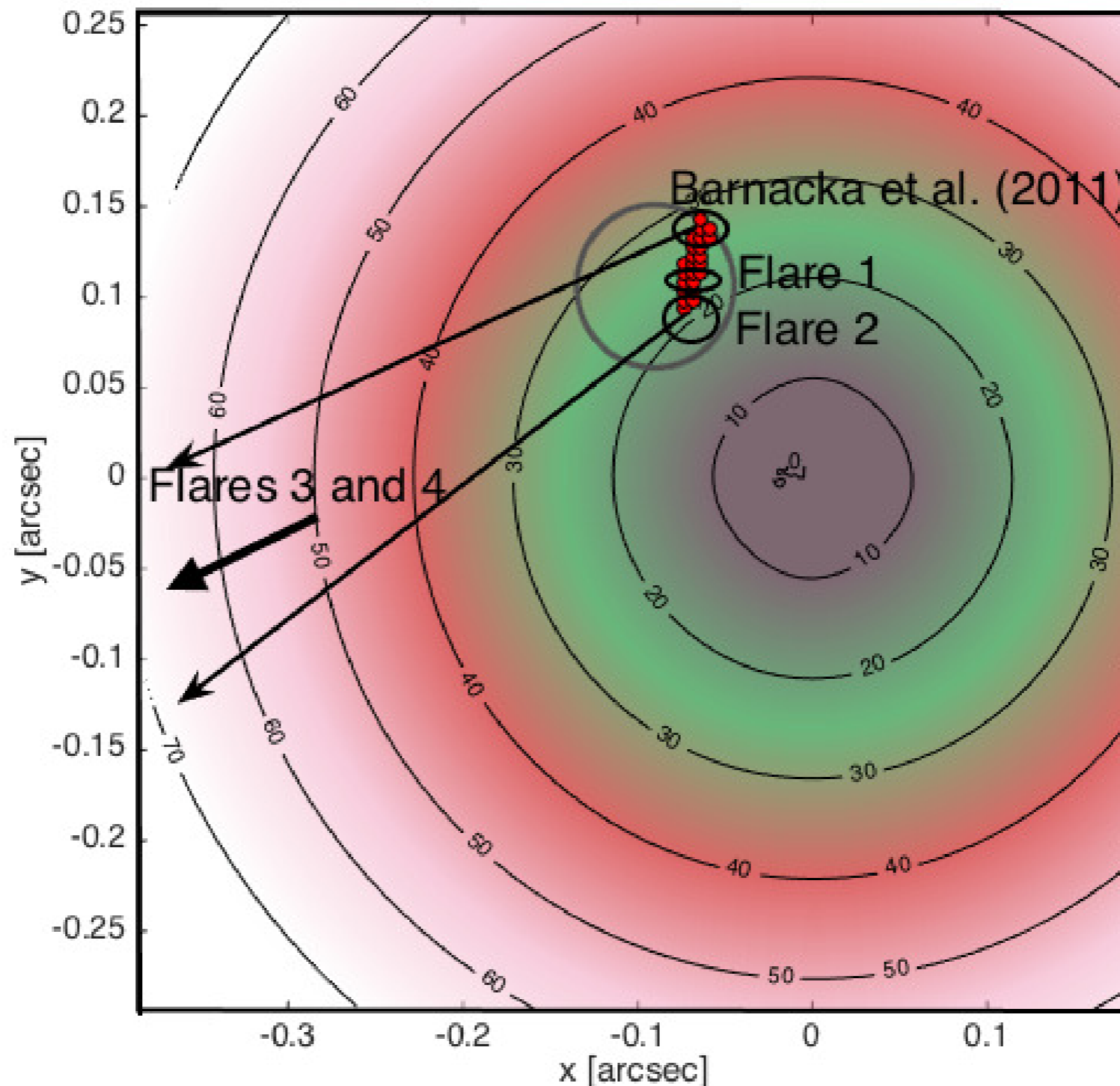
19 ± 1.2 days

> 50 days

Properties of the Lensed System



Spatial Origin of Gamma-ray Flares

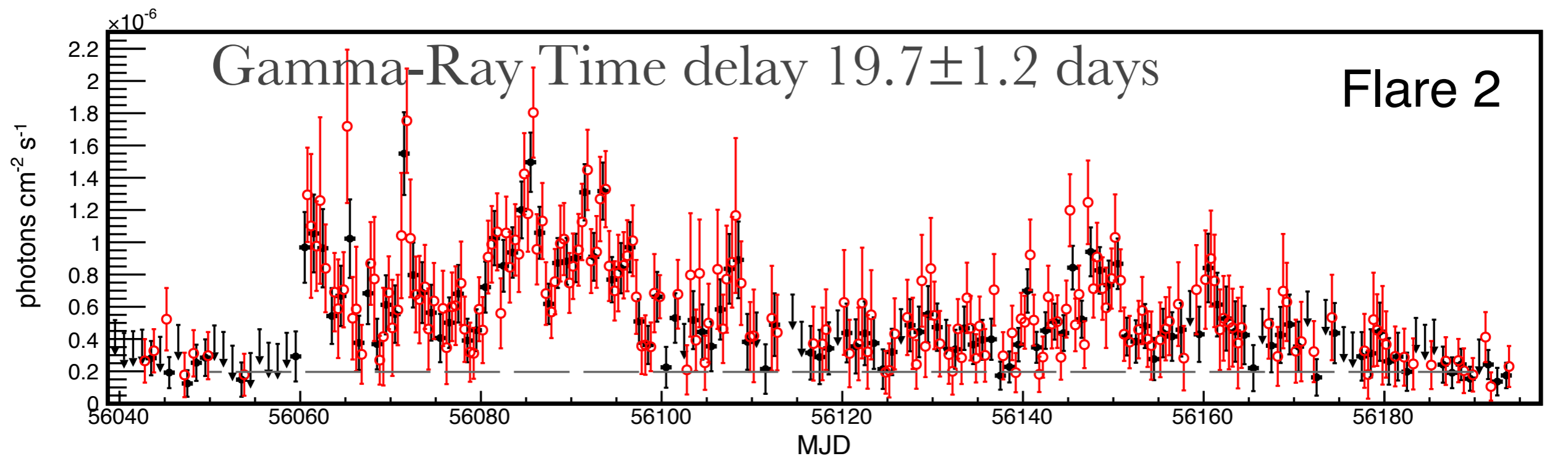
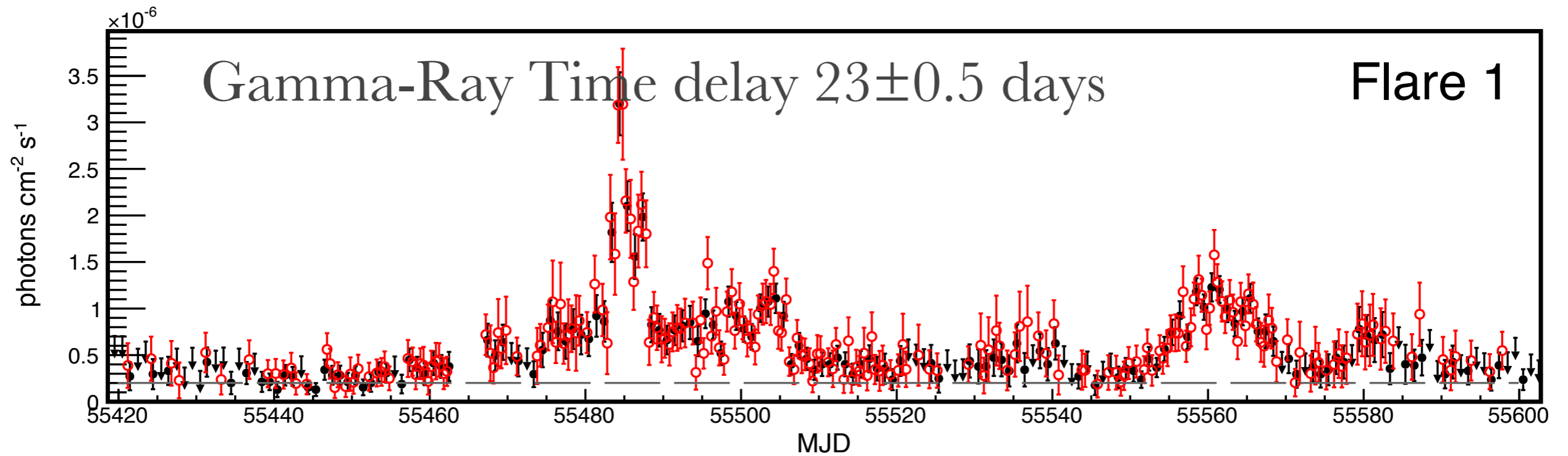


Summary

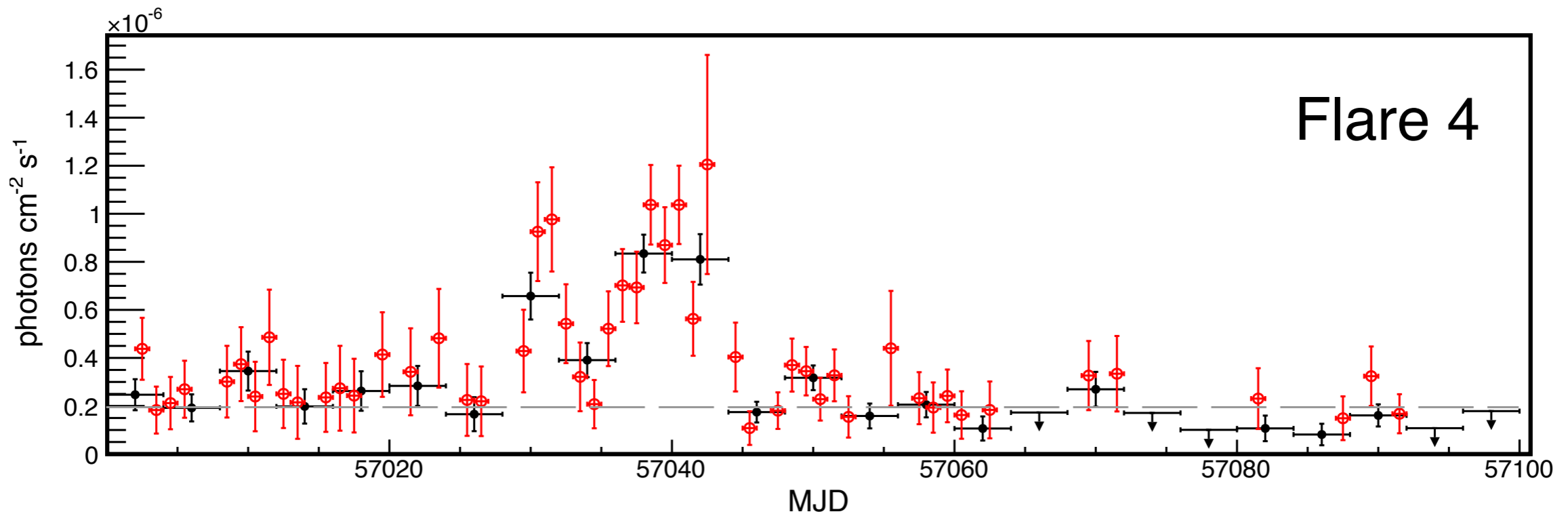
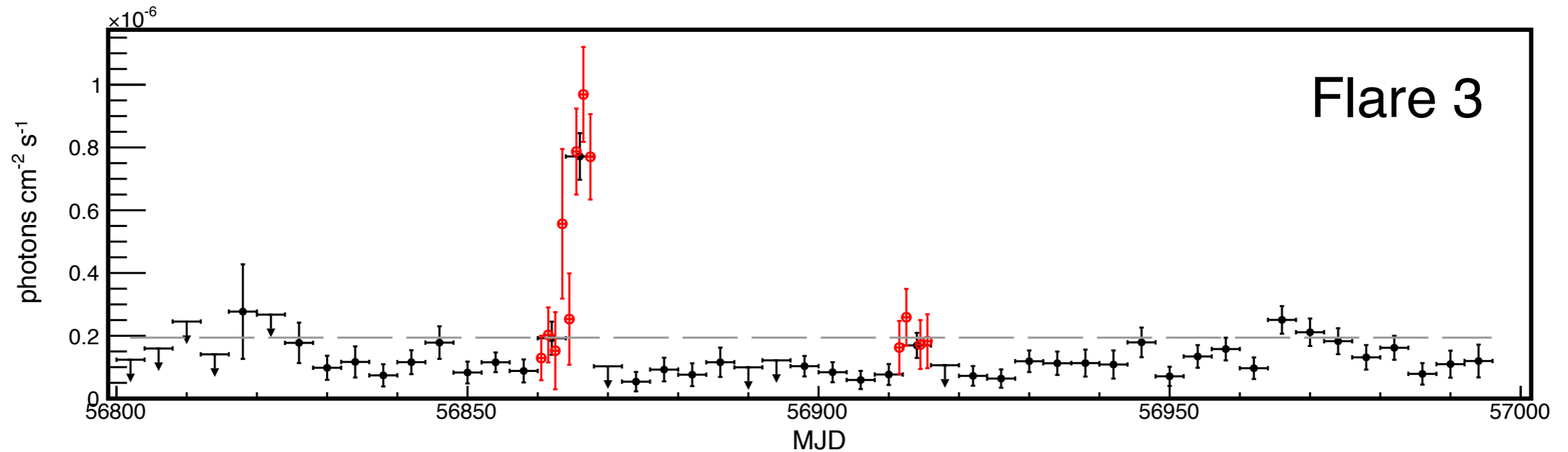
- **Strong Lensing:**
 - **Powerful Tool to Resolve High Energy Universe**
 - **Effective Spatial Resolution $\sim 0.02''$ - improvement $\times 10000$**
 - **Flares of PKS 1830-211:**
 - **Flare 1 and 2 consistent with the core within 100 pc**
 - **Flares 3 and 4 spatial origin > 1.5 kpc from the core**

Backup Slides

Gamma-ray Flare 1 and 2: Time Delays

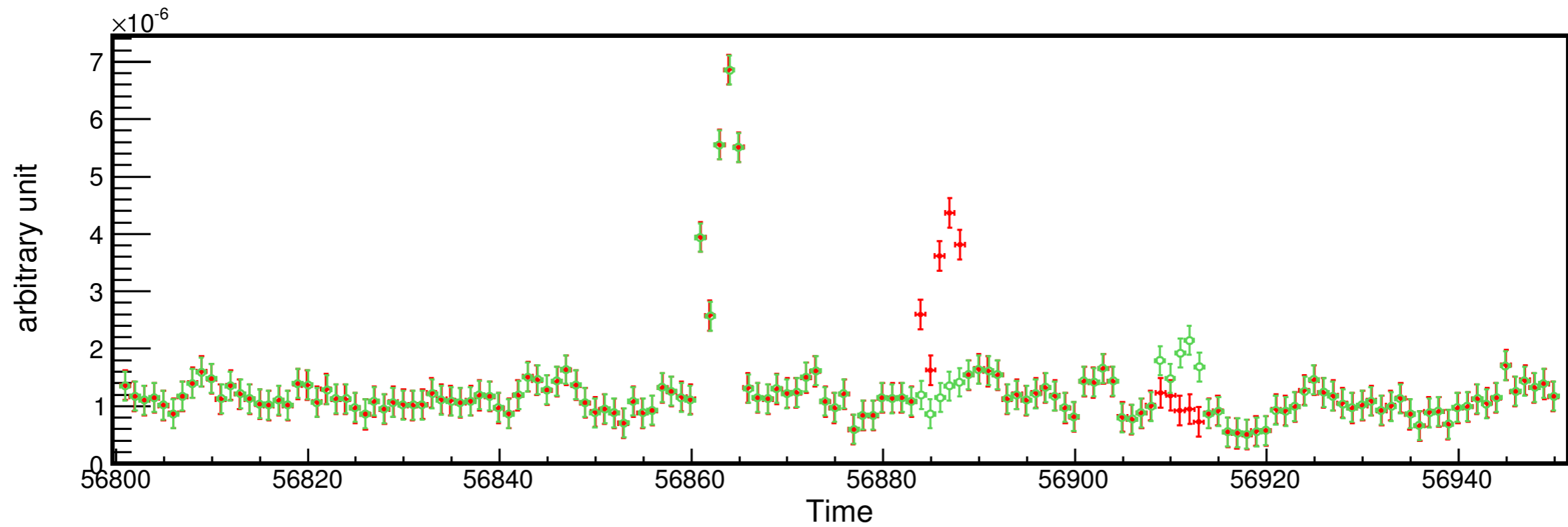


Gamma-ray Flare 3 and 4: Time Delays

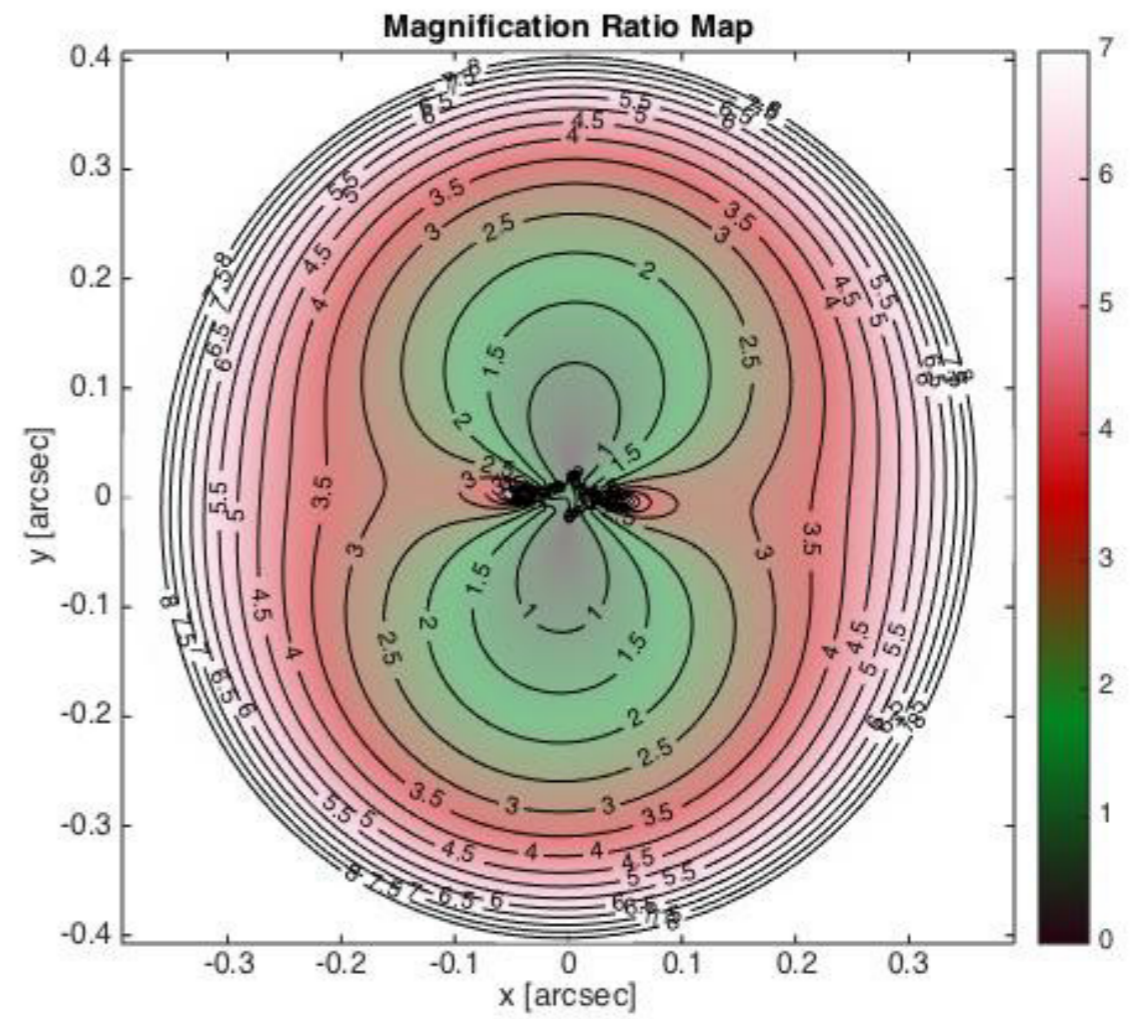
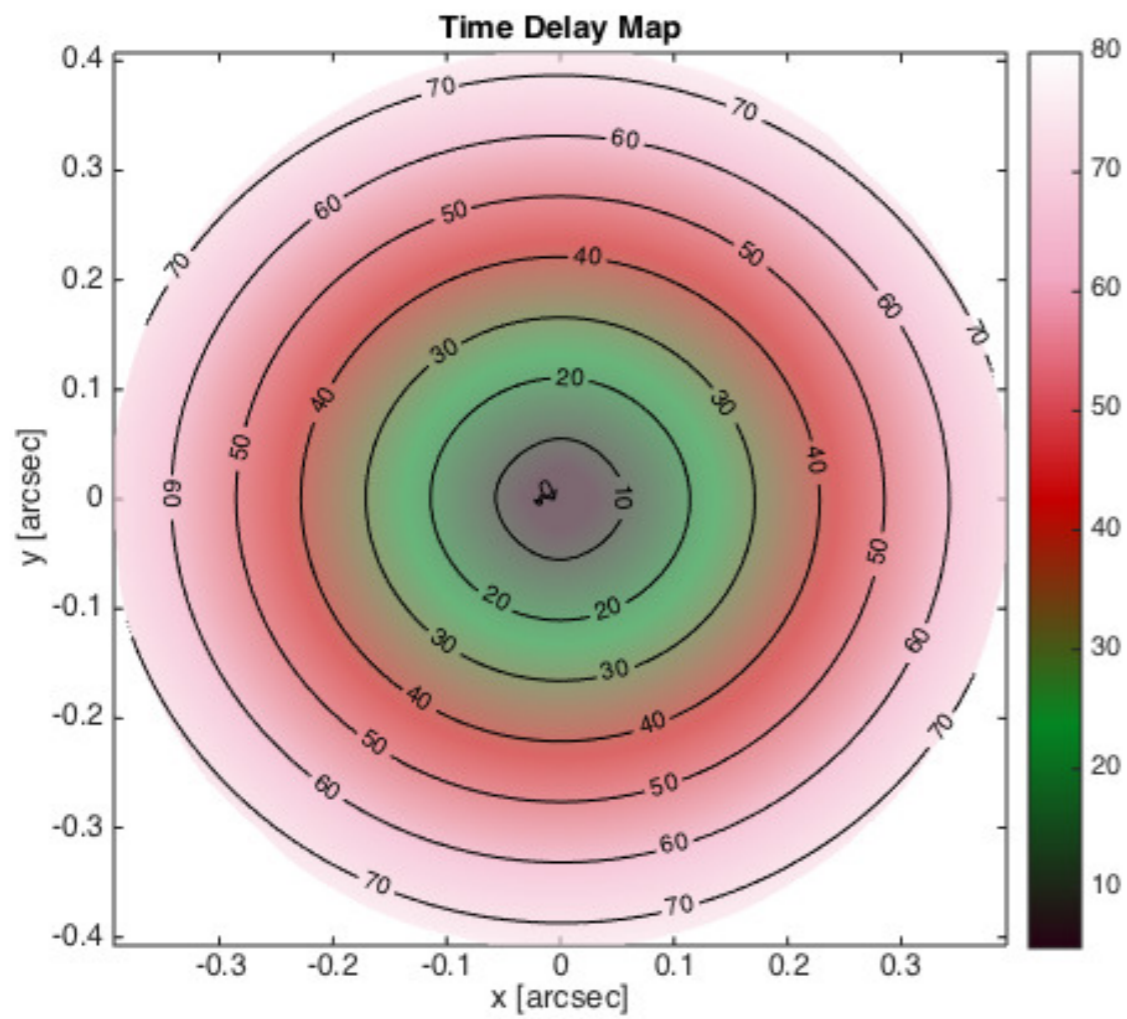


Gamma-Ray Time delay > 50 days

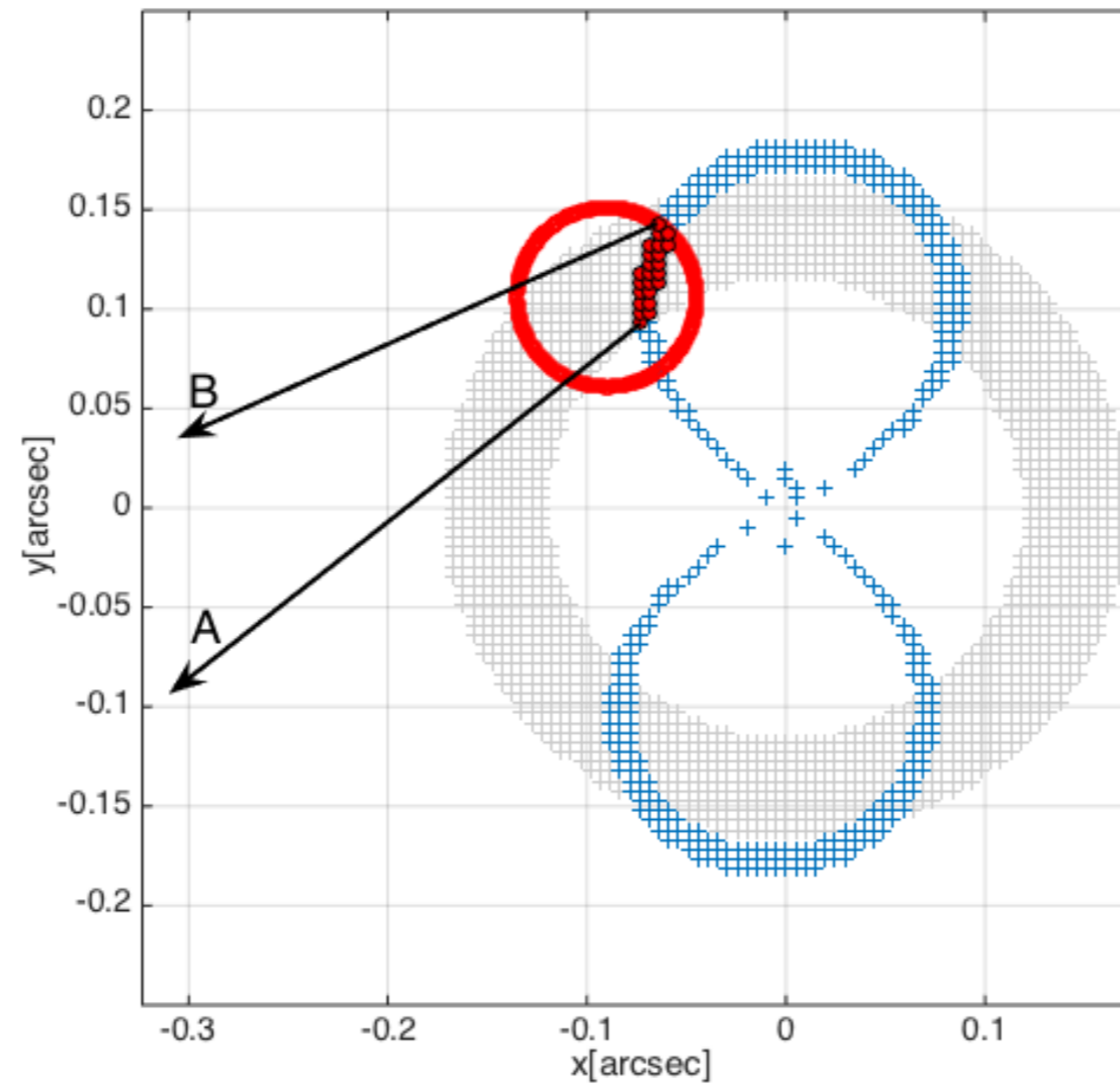
Monte Carlo Simulations



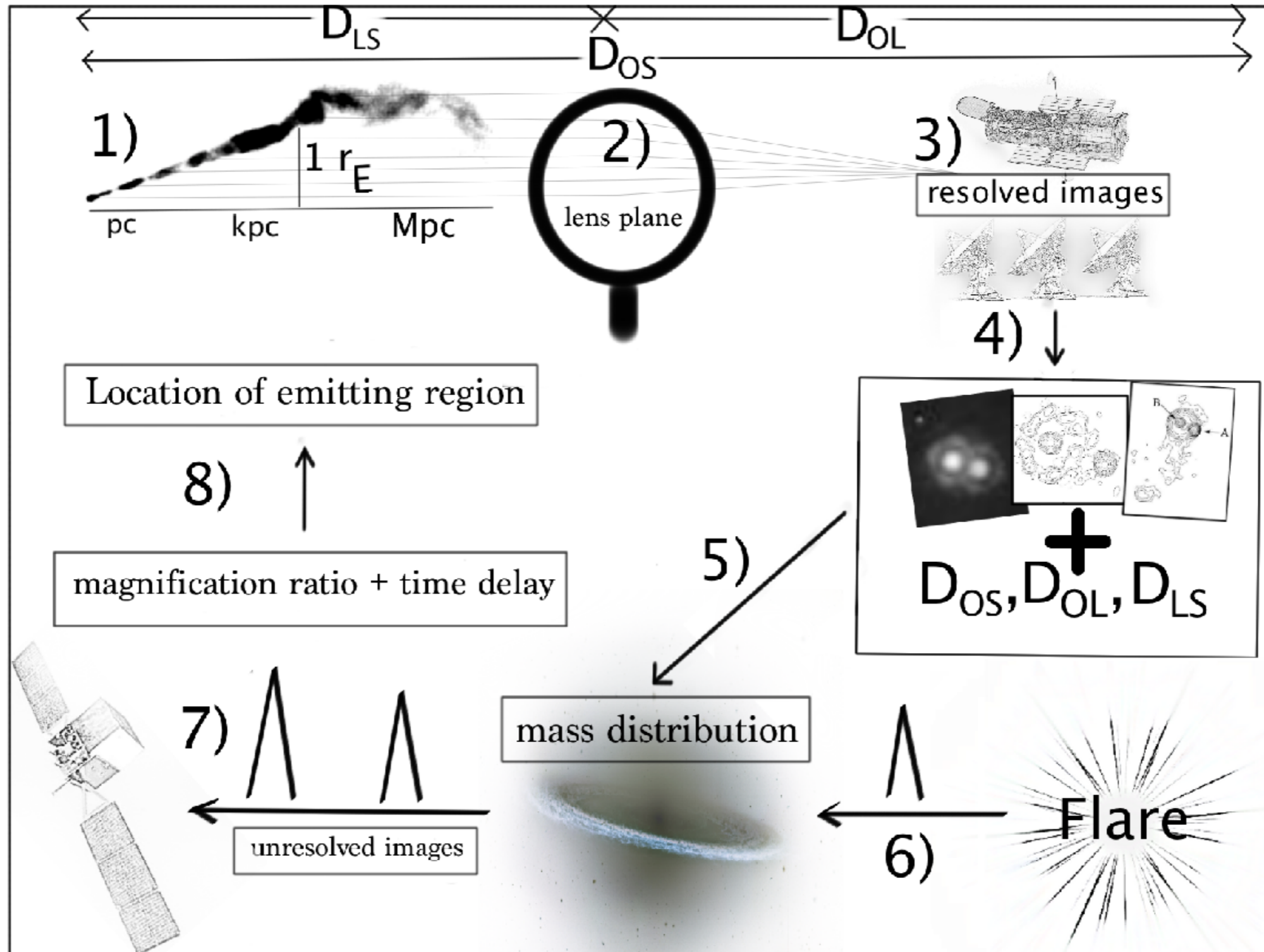
Lensing Maps



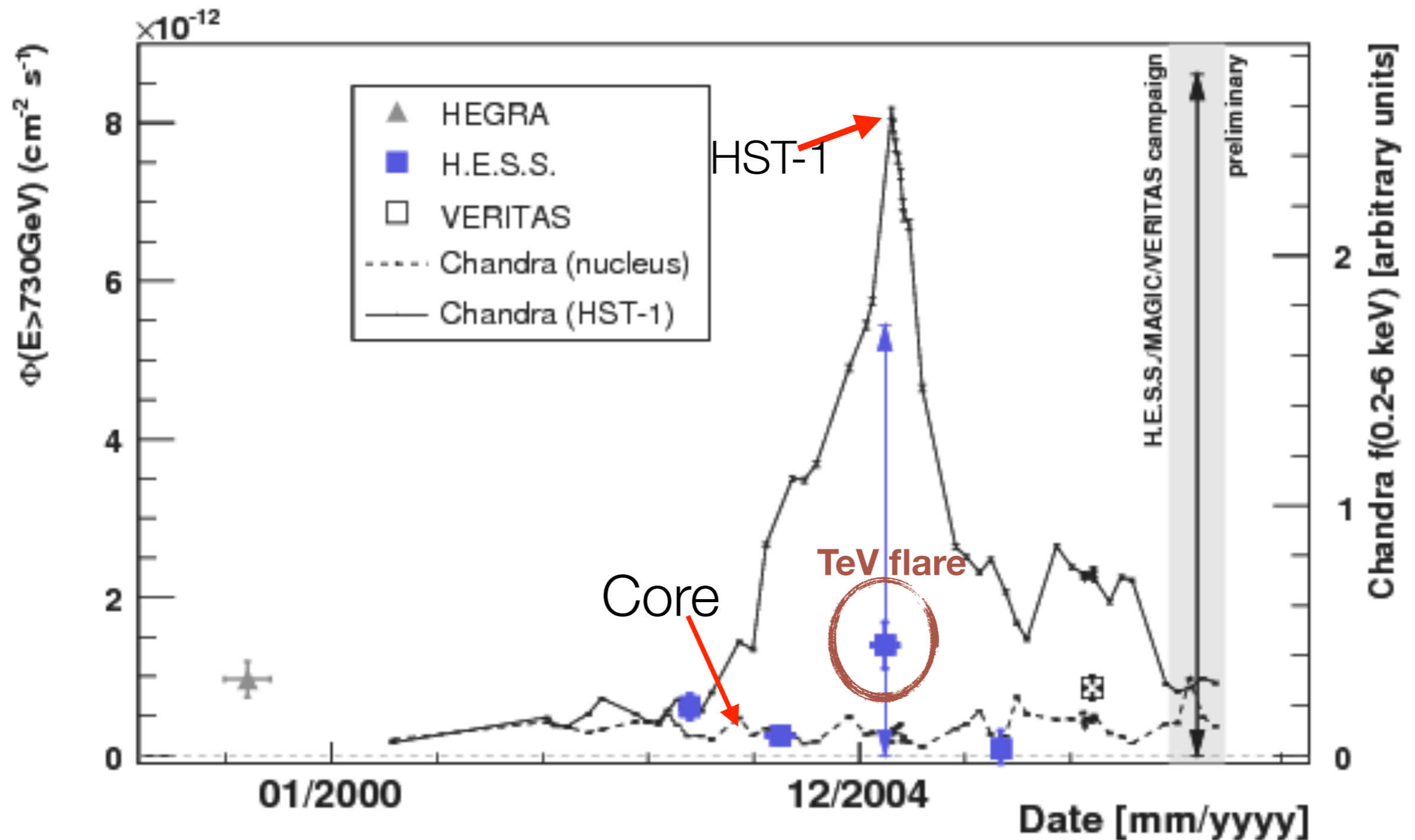
Position of the Core



Application of strong lensing



Spatial Origin of Gamma-Ray Flares



Credit: MAGIC and VERTIAS and H.E.S.S. Collaborations (2009)