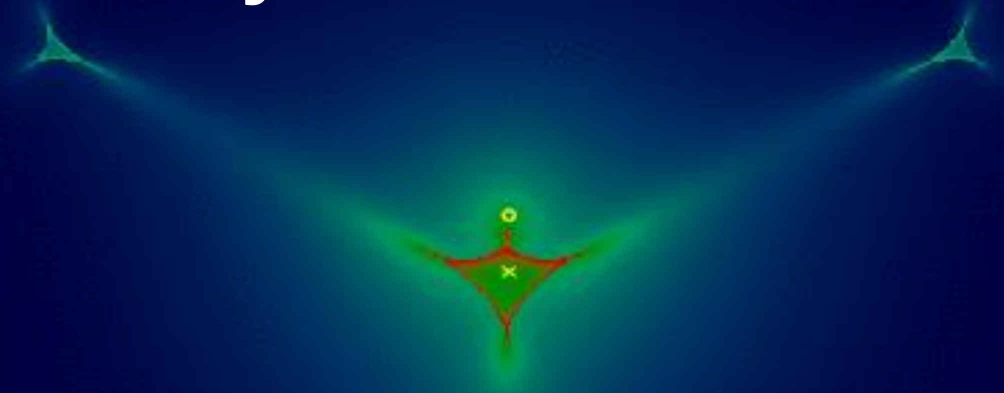
MAGIC detection of the most distant AGN observed in VHE γ-rays, gravitationally lensed blazar B0218+357



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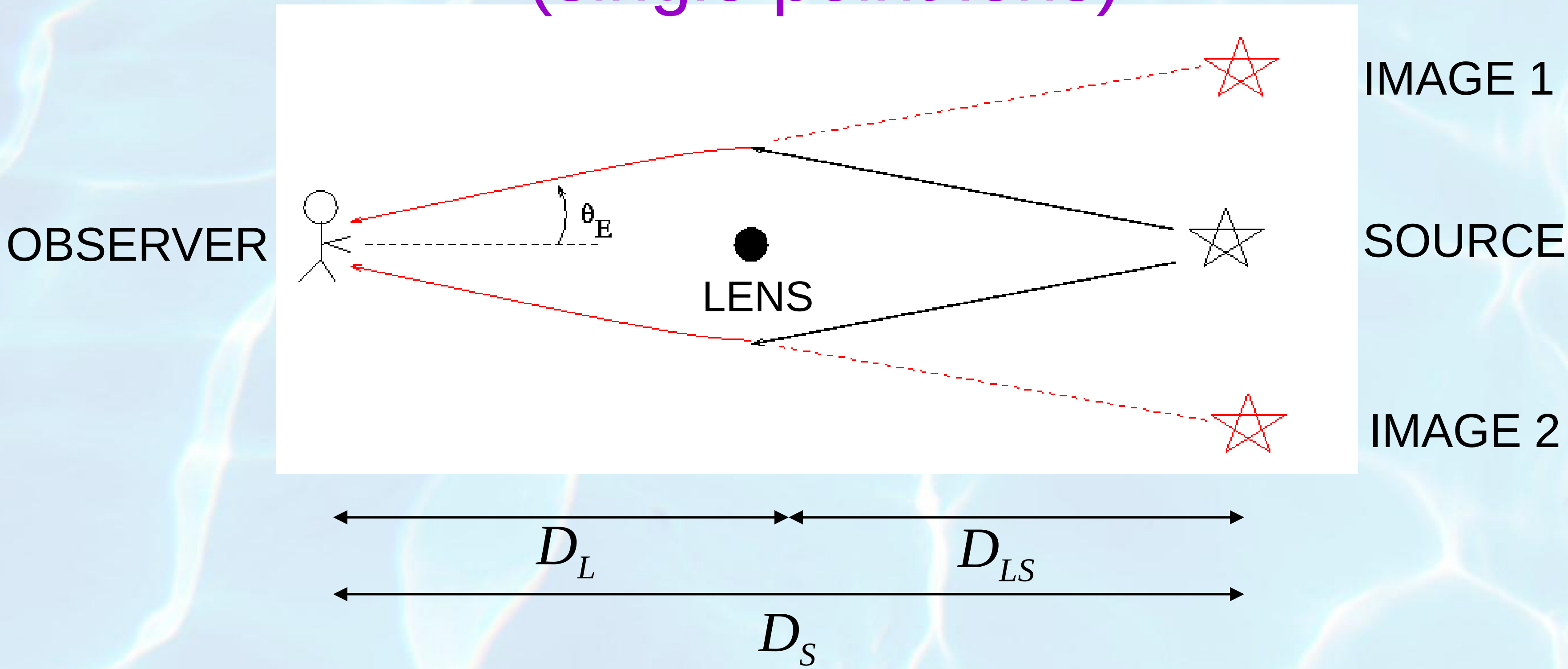
26 October 2015, TeVPa, Kashiwanoha, Japan

Outline

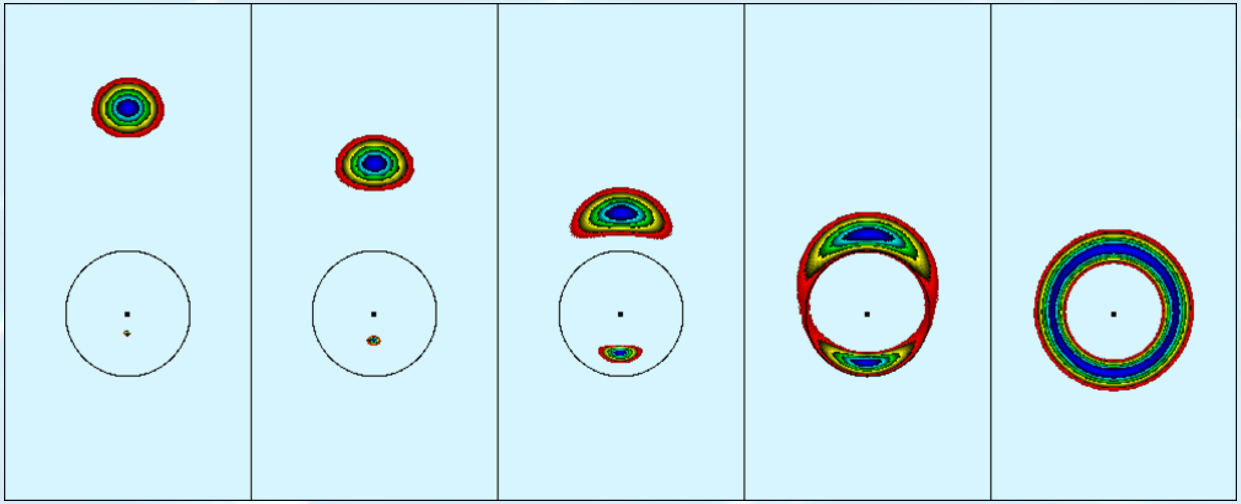
- Gravitational lensing
- Indications of the source size from microlensing
- MAGIC detection of QSO B0218+375

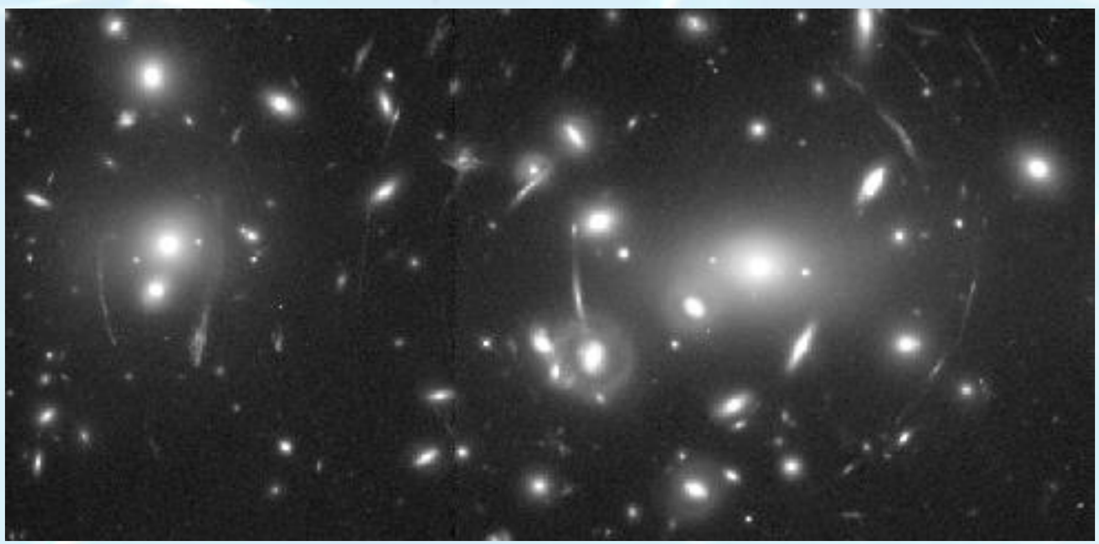
Gravitational lensing effect (single point lens)



Einstein radius: $$R_0 = \sqrt{\frac{4GM_{tot}D_{LS}}{c^2 D_L D_S}}$$

Einstein ring

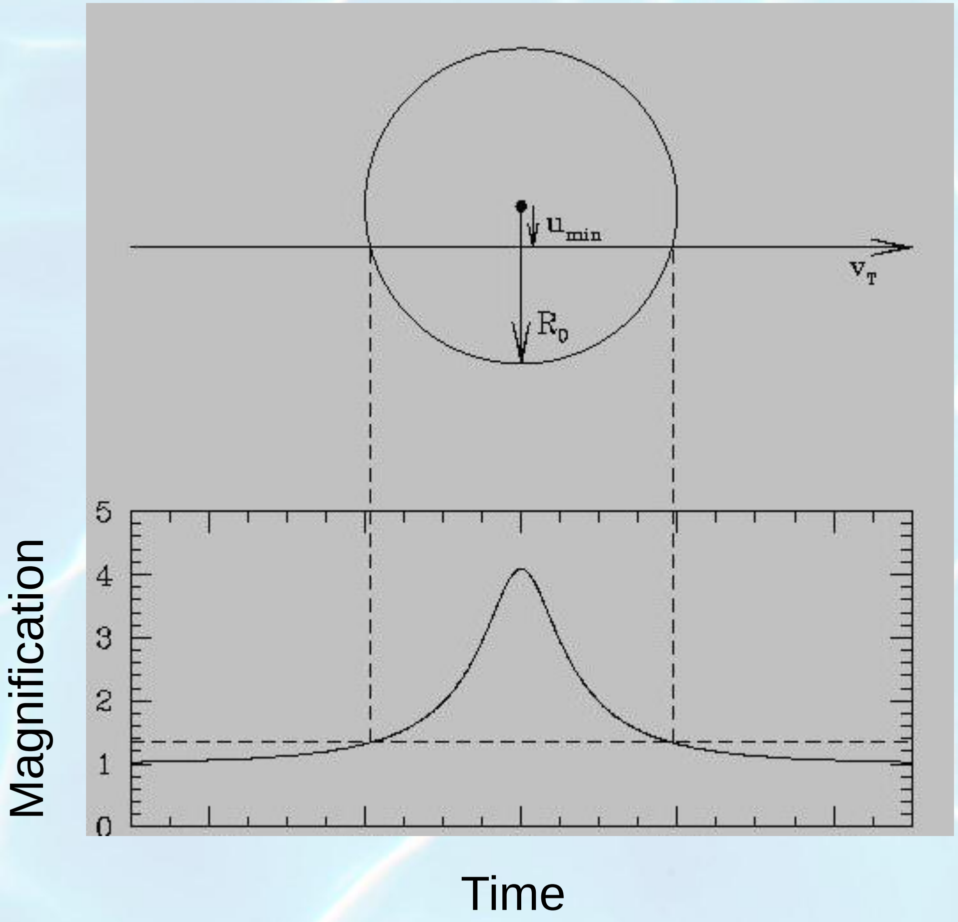




Gravitational lensing in galaxy cluster Abell 2218
(Credit: W.Couch, R. Ellis, NASA/ESA)

Gravitational microlensing:

The images cannot be resolved from the source
=> MAGNIFICATION (or Amplification)

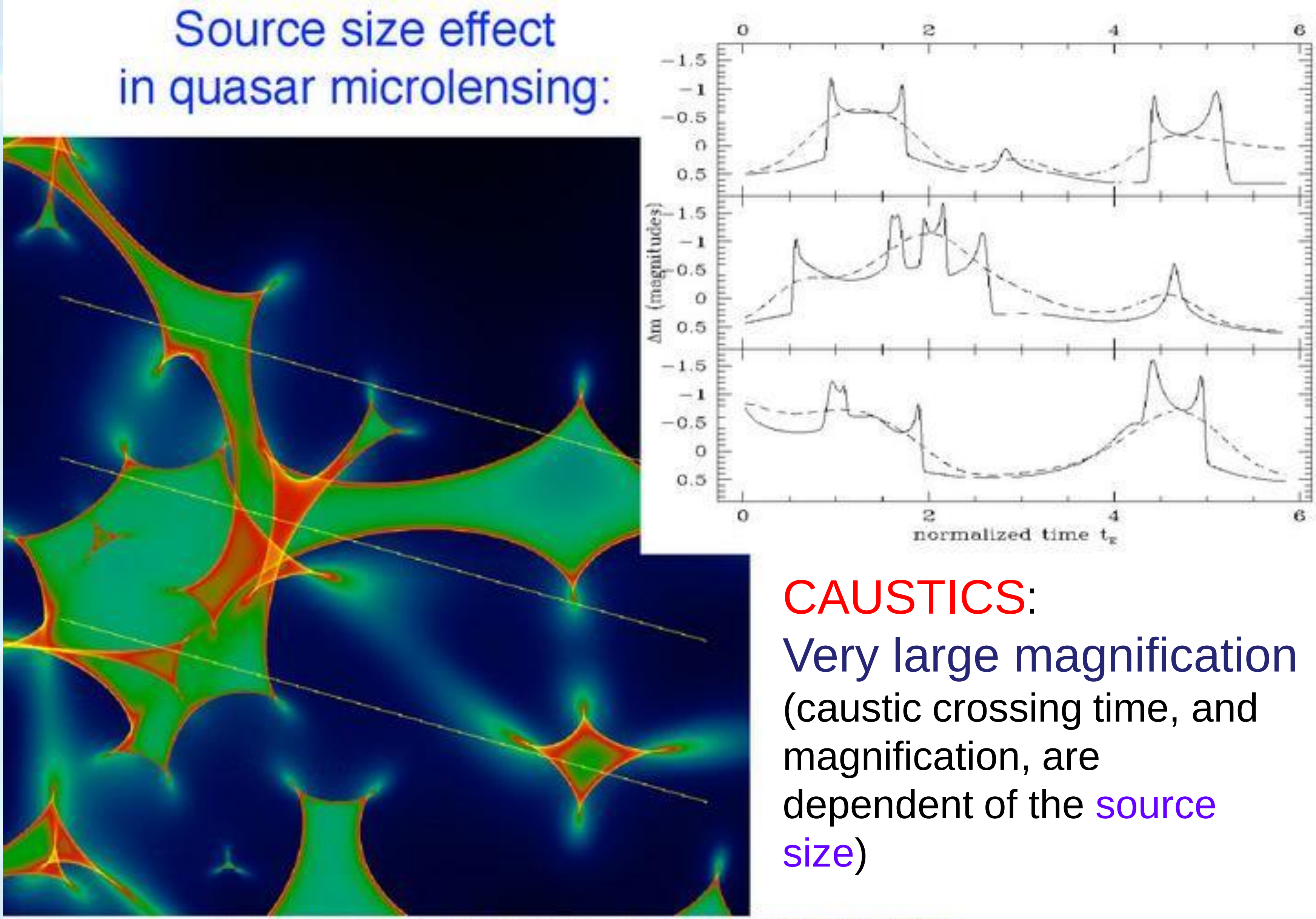


Einstein crossing time:

$$t_E = \frac{R_0}{v_T}$$

Light curve of a single point mass lens

Microlensing by multiple lenses



CAUSTICS:
Very large magnification
(caustic crossing time, and magnification, are dependent of the source size)

Joachim Wambsganss: "Microlensing and Compact Objects in Galaxies"
at: "Applications of Gravitational Lensing", KITP, Santa Barbara, October 4, 2006

Gravitational lensing of blazars

Gravitational lensing can affect our observations of blazars in the following ways:

1. Time delay (due to the mass of the lens galaxy)
2. (De)magnification of individual images
3. Microlensing effect due to the relative motion of the single stars in the lens galaxy: $v_T \simeq 1000 \frac{km}{s}$
4. Microlensing due to the angle of the jet to the line-of-sight
5. Microlensing would appear different due to relativistic motion of the emission region (?)

Microlensing and source size

- Putting constrains on the source size, can help to determine the location and mechanisms of the production of electromagnetic radiation at different energies in blazars
- Smaller emitting region => higher magnification during the caustic crossing, shorter caustic crossing time
- In case of blazar microlensing, microlensing can cause different flux ratios of the flare images (for different flares), or different durations of the original flare vs. time-delayed image

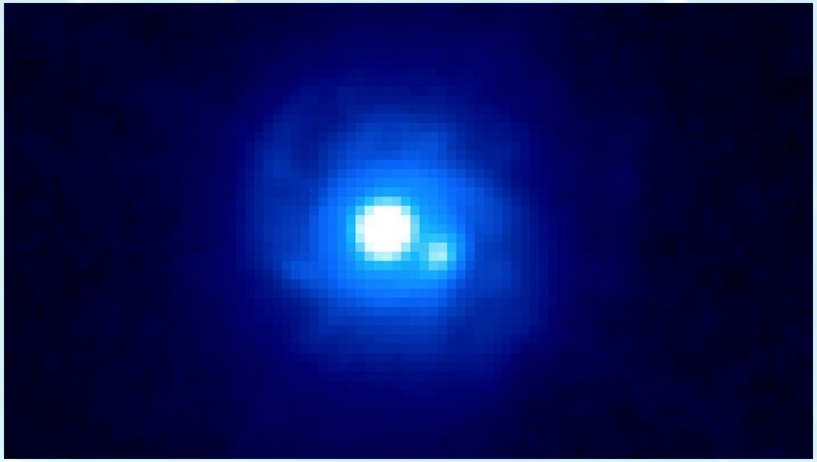
  (see the talk by I. Vovk)

MAGIC telescopes

- A stereoscopic system of two 17m IACT telescopes located on La Palma, Canary Islands (ORM)
- MAGIC I (since 2003) and MAGIC II (since 2009)
- Angular resolution: 0.1 degree
- Sensitivity ~0.7% of Crab Nebula flux (>220 GeV)

QSO B0218+375

- B0218+357: a quasar lensing system with the smallest Einstein radius known (i.e. separation source-image): 335 milliarcseconds (~0.3 arcsec)
- MAGIC cannot spatially resolve the images (resolved in radio and optical)
- The lens galaxy is at redshift z = 0.6847, spiral, face-on
- Blazar B0218+357 at z = 0.944 ± 0.002



Hubble image of B0218+375 (Credit: NASA/ESA and the Hubble Legacy Archive)

QSO B0218+375 flare: time delay

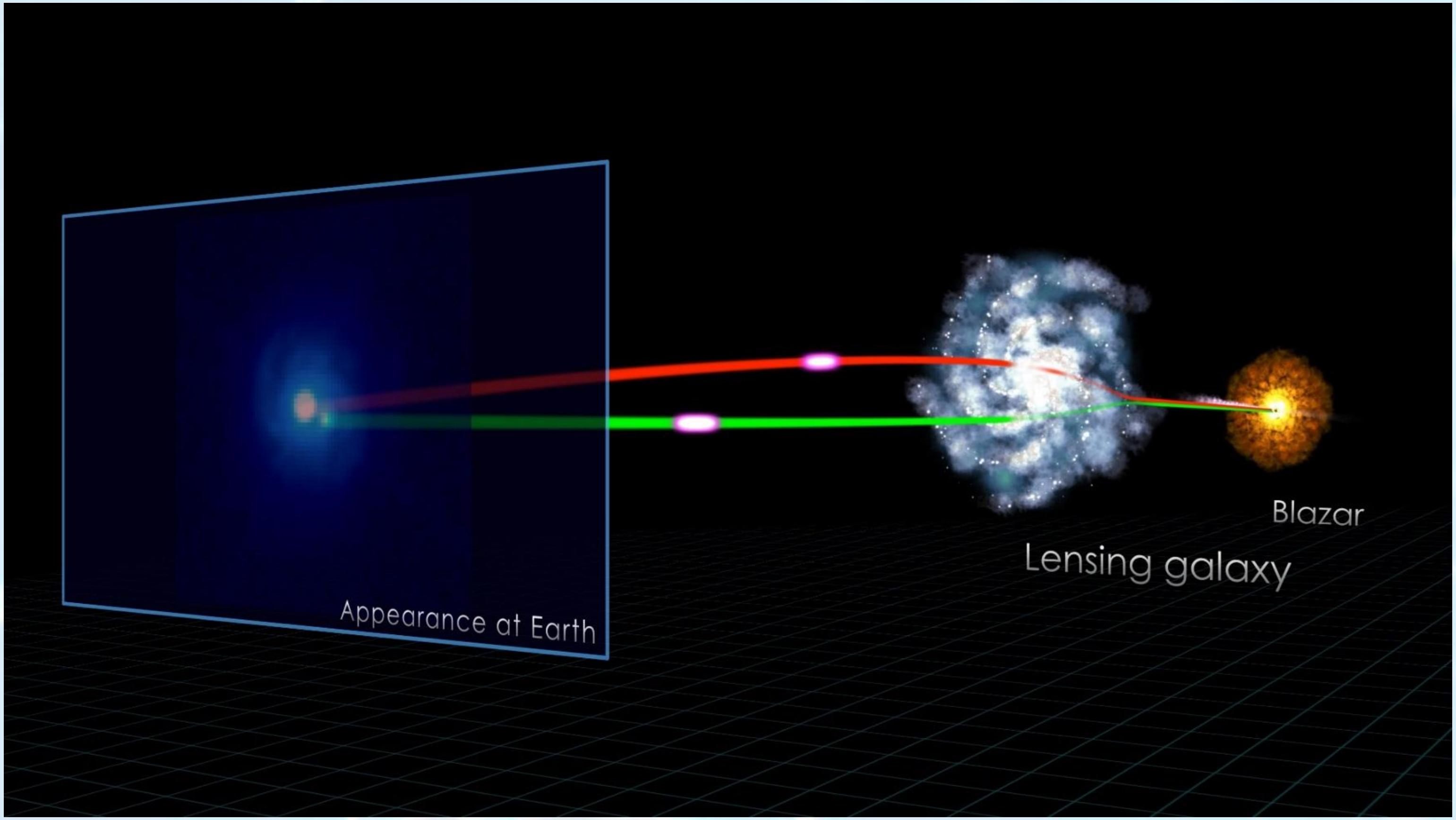
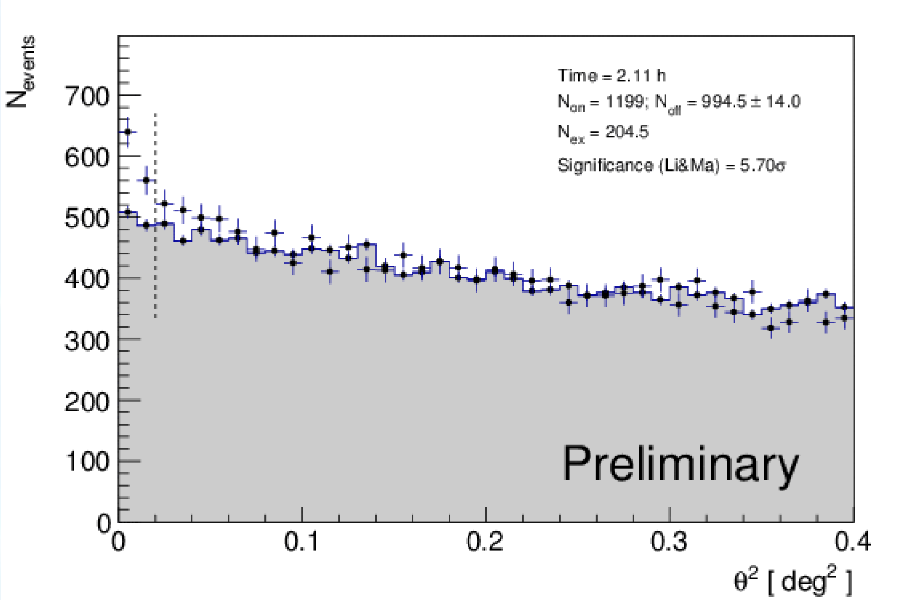
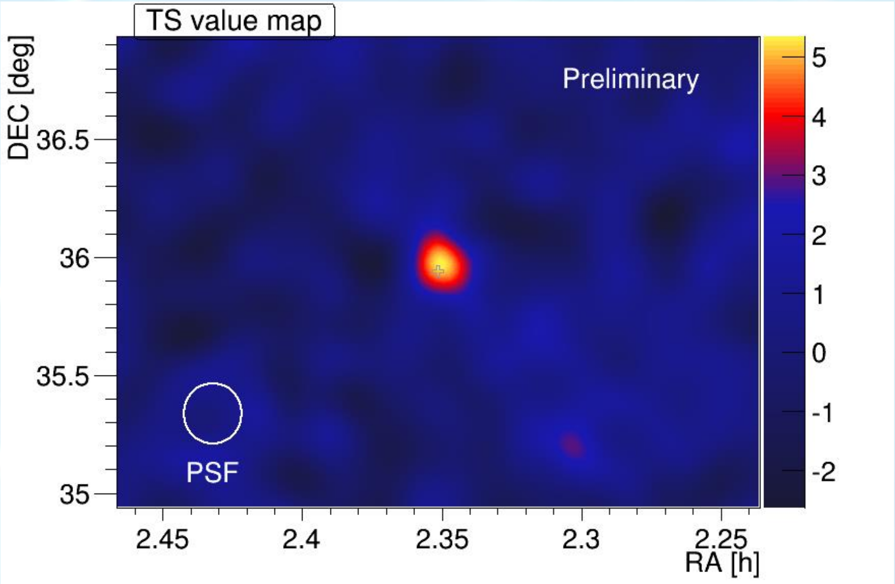


Image credit: NASA’s Goddard Space Flight Center.

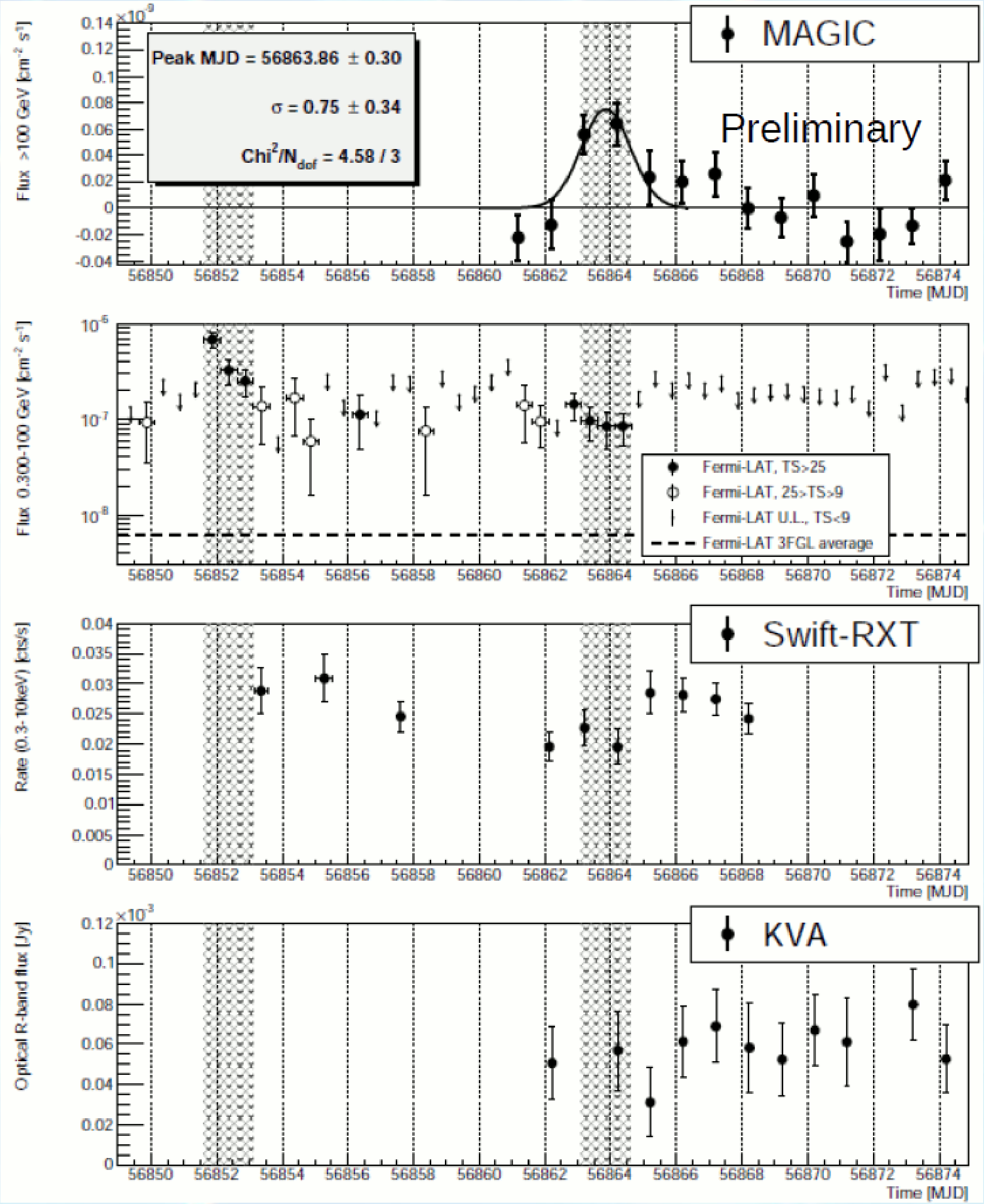
MAGIC detection of B0218+375

- FERMI observed a flare on 13/14 July 2014 *(ATel #6316),* with harder spectrum than the one in 2012
- MAGIC detected only the time-delayed flare (could not observe the initial flare due to the Full Moon) on 25 & 26 July, in 2.11 hours, with 5.7 σ *(ATel #6349)*





MWL Light Curve



- MAGIC observed the second flare lasting 2 days
- Longer duration than the original FERMI flare
- No increase in flux was observed in optical and X-rays during the second flare

=> Microlensing?

Summary

- QSO B0218+375: most distant blazar (z=0.944) detected so far in VHE gamma-rays, using MAGIC in only 2 hours of observations
- Microlensing effects are in strong connection with the source size
- Original flare was not observed by MAGIC => only hints of microlensing
- Future: MWL observations of flaring gravitational lensed blazars, to determine the Einstein radius dependence of the emission zone