Detection by the MAGIC telescopes of the farthest very high energy gamma-ray source, S3 0218+35, thanks to its delayed gravitationally lensed emission

Daniel Mazin (ICRR, Tokyo and MPI for Physics, Munich)

J. Sitarek, J. Becerra, S. Buson, D. Dominis, E. Lindfors, M. Manganaro, M. Nievas, A. Stamerra, Ie. Vovk for the MAGIC collaboration*

*MAGIC collaboration: https://wwwmagic.mpp.mpg.de/

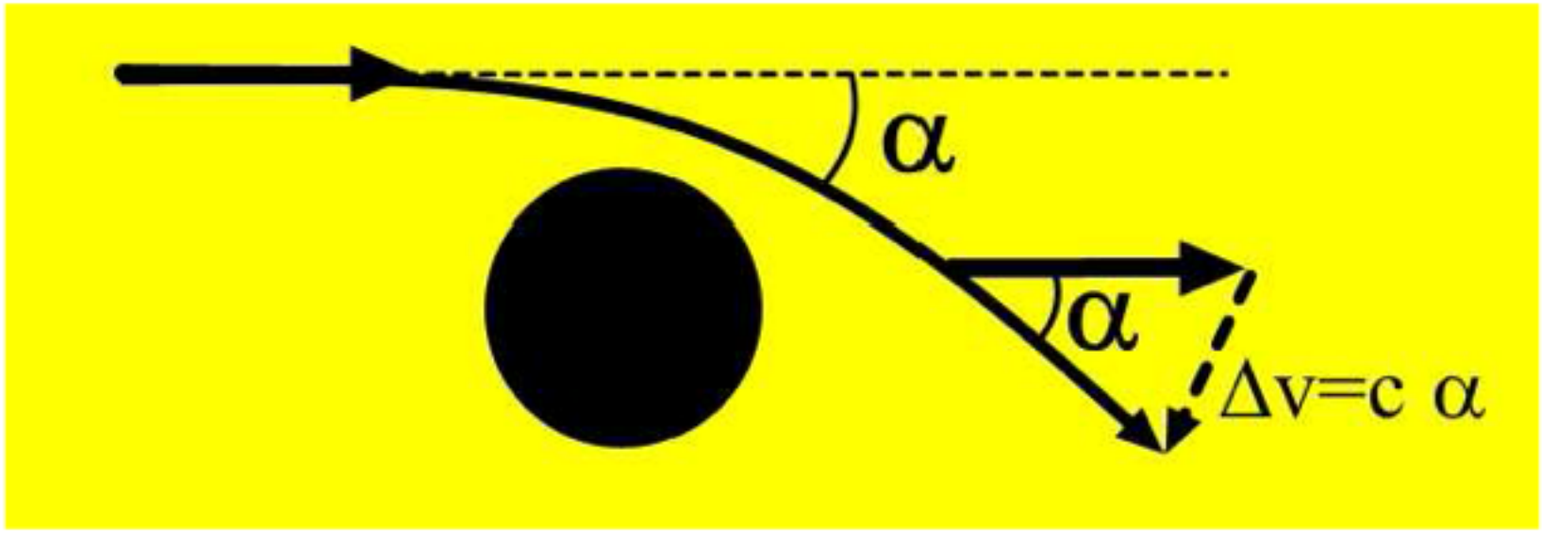
The MAGIC telescopes

Observatorio del Roque de los Muchachos, La Palma, Canary Islands, 2200m a.s.l.

- Two 17m Imaging Atmospheric Cherenkov Telescopes
- MAGIC-I: since 2004 in mono mode
- MAGIC-II: since 2009; start of stereoscopic mode
- Energy range 50 GeV to 30 TeV, 0.6% Crab sensitivity above 250 GeV

GRAVITATIONAL LENSING

Sir HENRY CAVENDISH (1784)

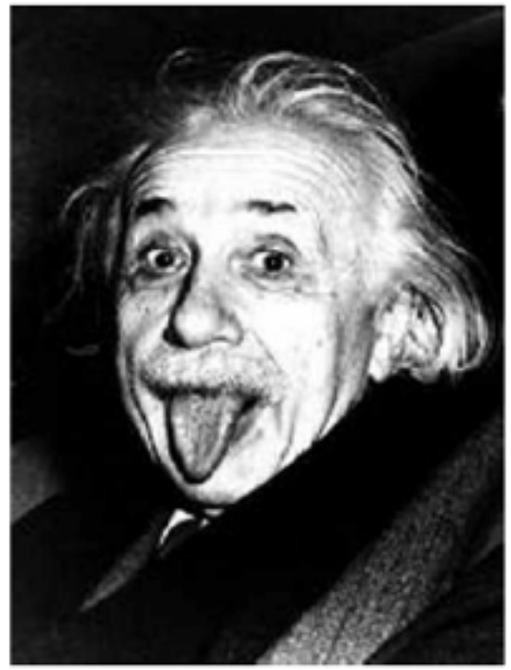


$$\frac{dv}{dt} = \frac{GM}{r^2} \qquad \int dv = GM \int \frac{dt}{r^2}$$

$$\alpha = \frac{2GM}{c^2 R} \qquad \alpha_\odot = \frac{2GM_\odot}{c^2 R_\odot} \approx 0.85\ arcsec$$

slide from S. Covino

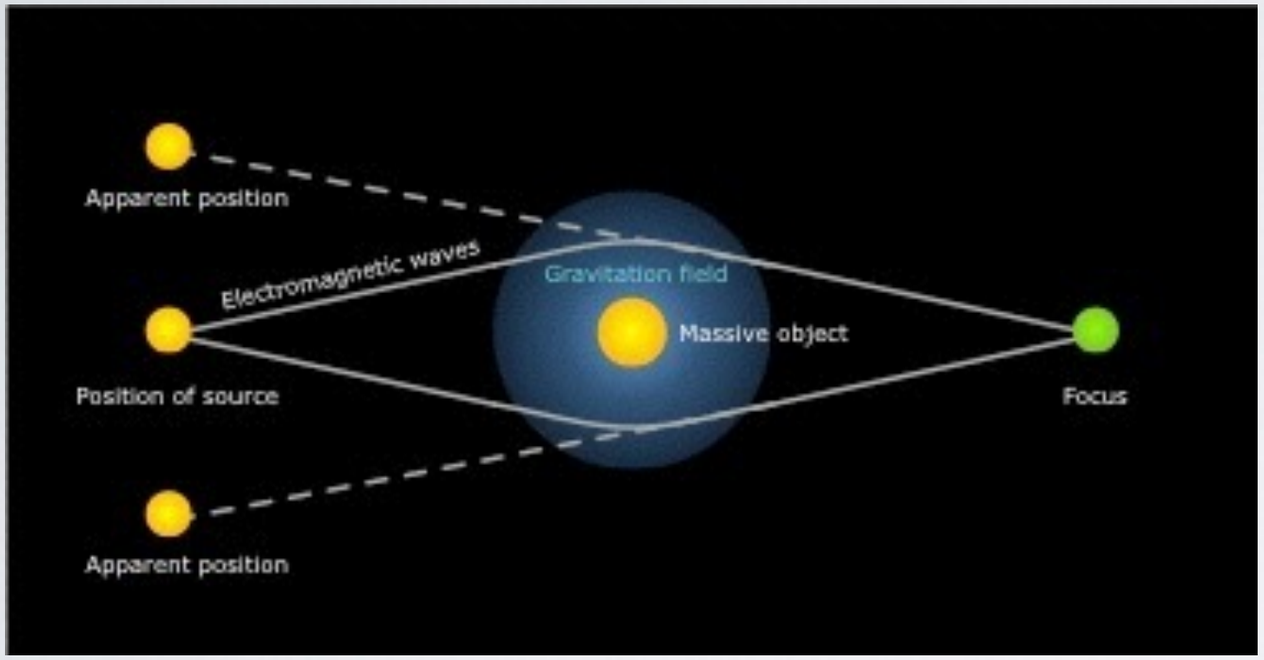
ALBERT EINSTEIN (1915)

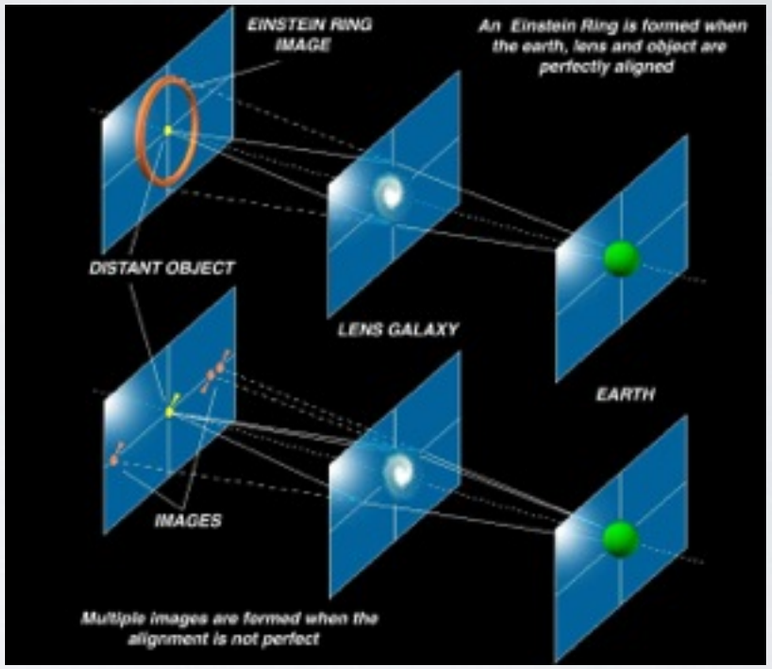


$$\alpha_{rel} = \frac{4GM}{c^2 R}$$

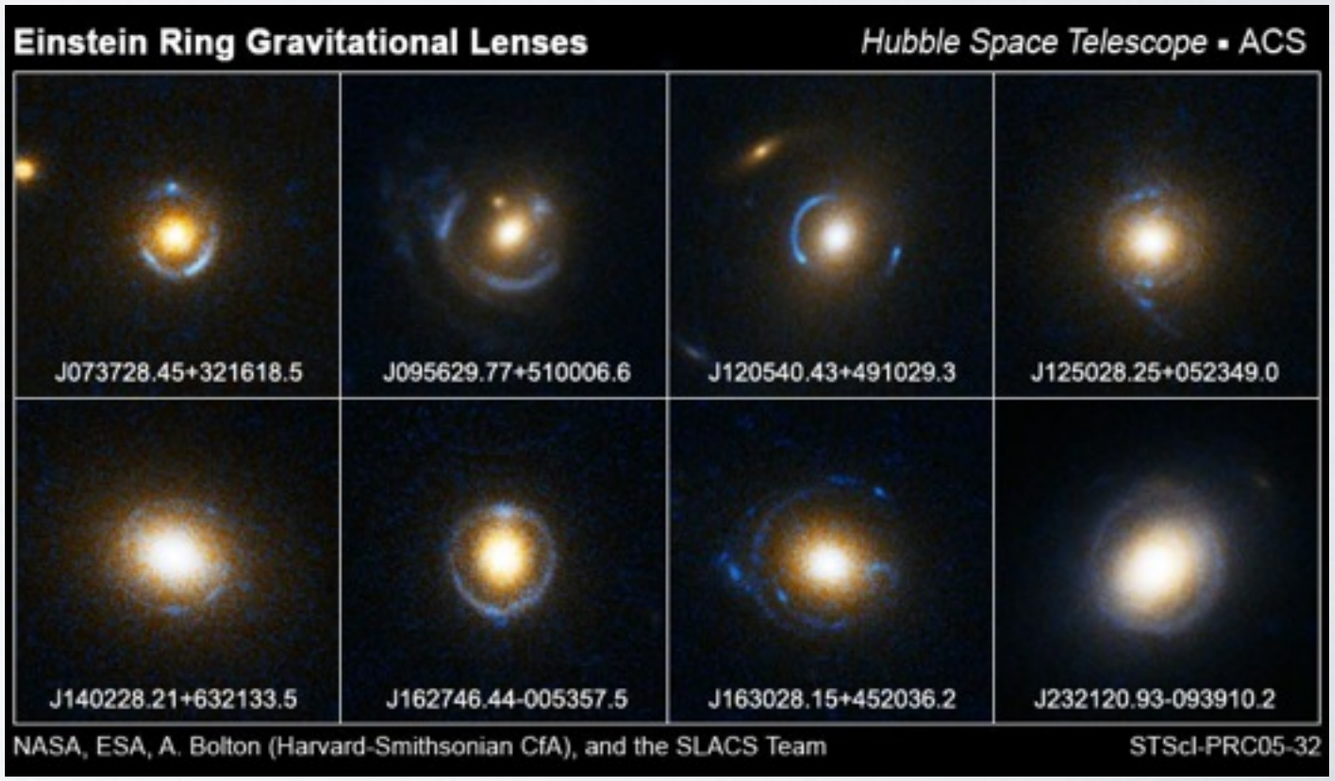
$$\alpha_{rel\odot} \approx 1.7\ arcsec$$

GRAVITATIONAL LENSING

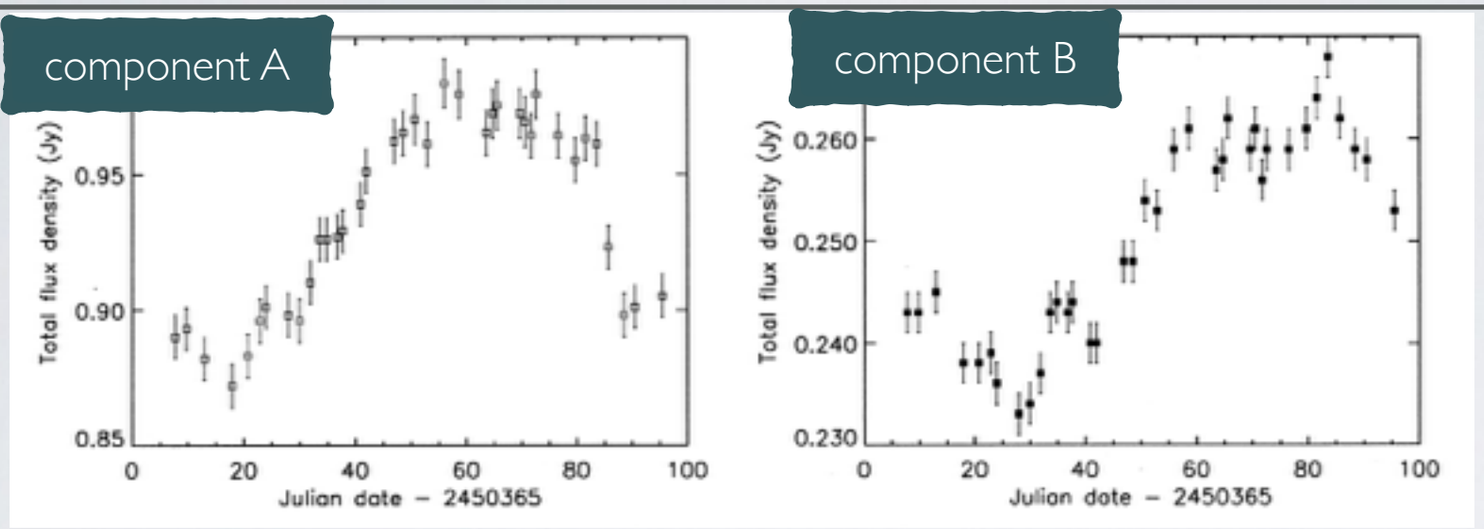


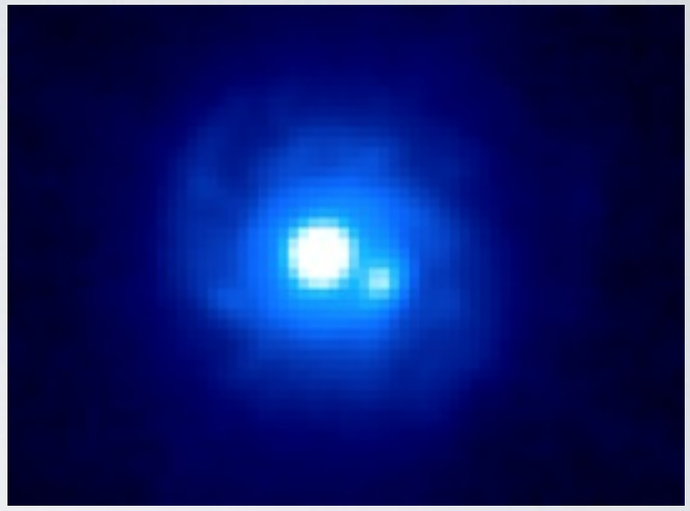


- Gravitational lensing is one of the major proofs of general relativity
- Gravitational lensing acts in two ways:
  - **Macrolensing** by the total mass of the lens galaxy → Time delay
  - **Microlensing** by relative proper motions of stars → time-dependent flux variations due to magnification of the source
- Many objects with strong lensing found in radio through X-rays
- So far no hints that lensing is not achromatic



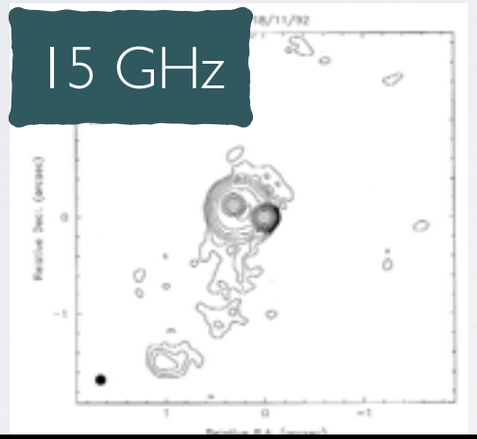
S3 0218+35

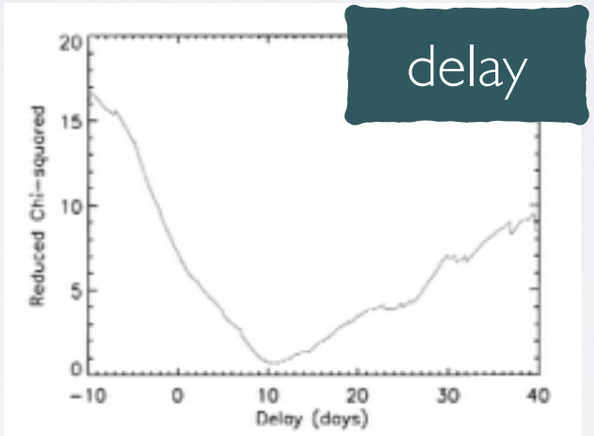




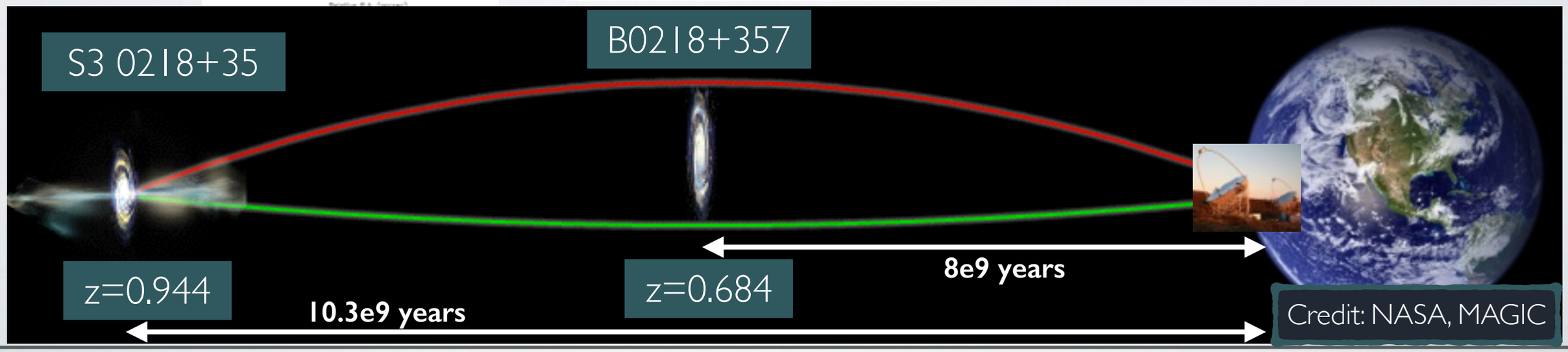
This Hubble image of gravitational lens B0218+357. Image Credit: NASA/ESA and the Hubble Legacy Archive

Biggs et al, MNRAS, 304, 349 (1999)



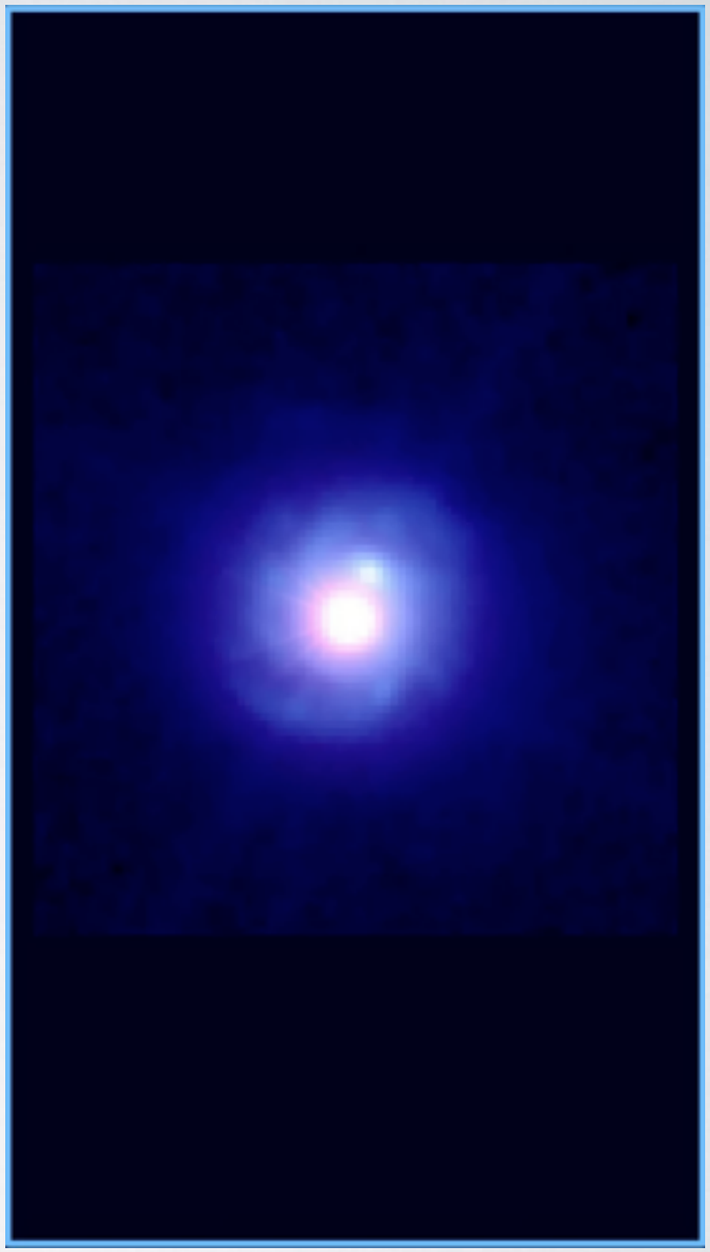


delay: 10.5+/-0.4days



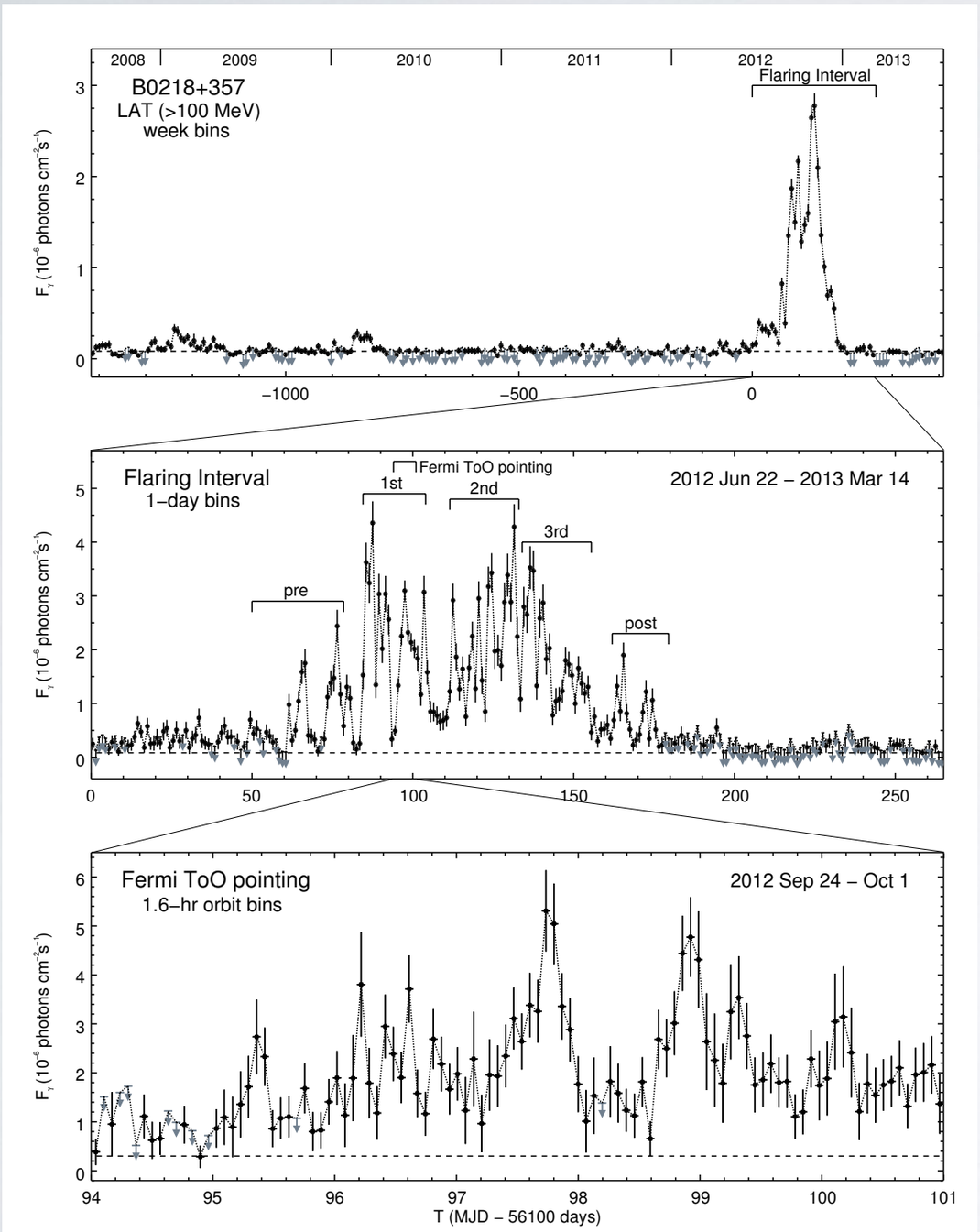
S3 0218+35

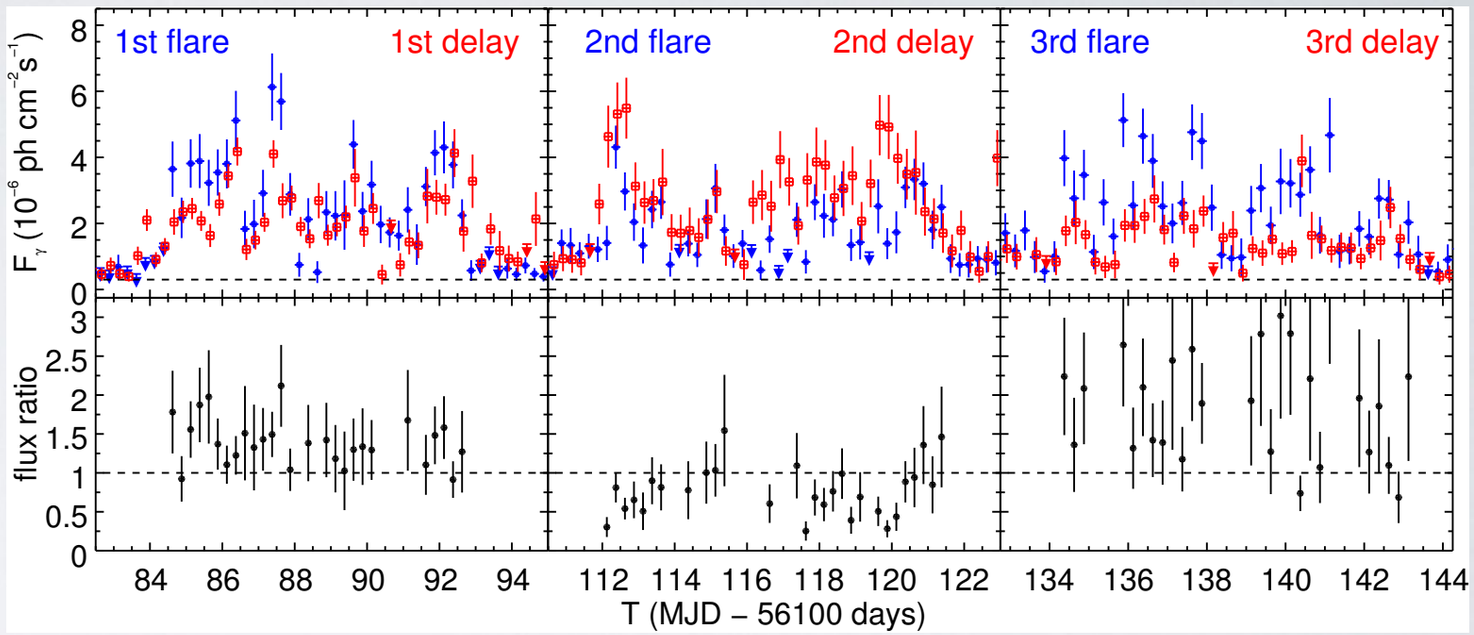
- Blazar S3 0218+35, **z=0.944!**
- Lensing spiral galaxy, face on, B0218+357 z=0.684
- smallest Einstein ring (0.335”) among known systems of lensed blazars; MAGIC cannot spatially resolve the blazar from its lensed images
- Delay (10.5 +/- 0.4) day (95% CL); Biggs et al. 1999
- Bright radio source (1.2 Jy at 8 GHz)
- Associated 0FGL J0220.9+3607, 1FGL J0221.0+3555, and 2FGL J0221.0+3555
- Beginning mid-2012, increased gamma-ray activity from S3 0218+35 observed by the LAT (next slide)

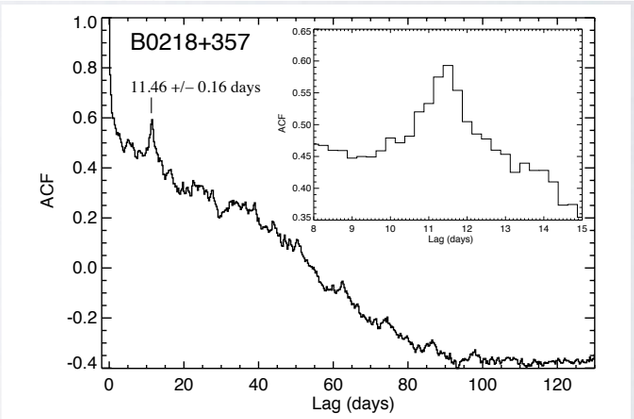


Credit: NASA

PREVIOUS FERMI-LAT RESULTS ON S3 0218+35





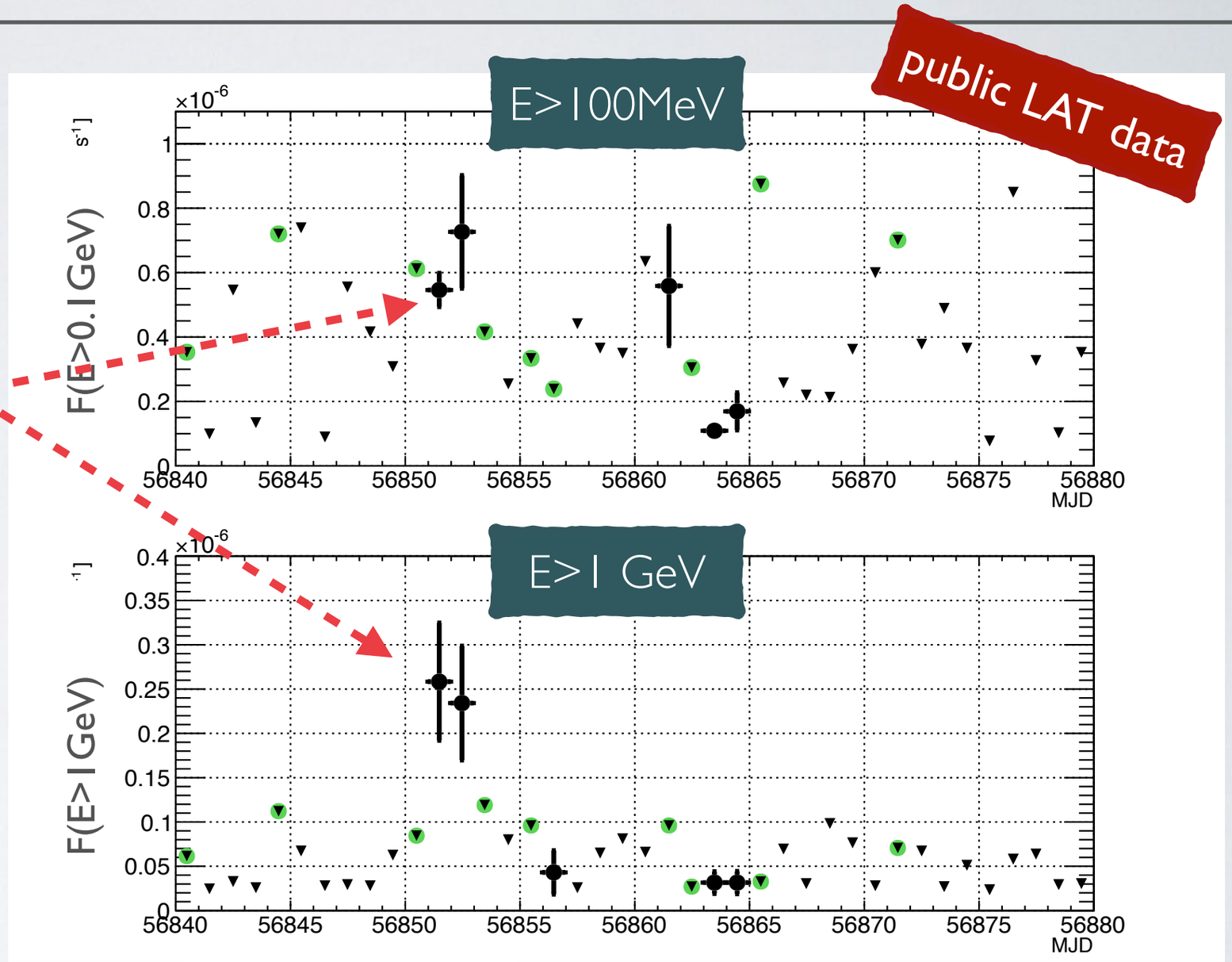


- Fermi-LAT data from 2012 clearly showed delayed emission due to gravitational lensing
- ACF analysis: the delay is (11.46+/-0.16)days

plots from Cheung et al., ApJ 782, L14 (2014)

S3 0218+35 IN JULY 2014

- Fermi-LAT detects hardening of the spectrum in July 2014 (Buson et al. ATel #6316)
- Unfortunately MAGIC cannot observe due to full moon period
- But observations are scheduled for the delayed flare (~10 days later)



See poster by Sara Buson et al. 8.04

S3 0218+35 IN JULY 2014

- MAGIC observations centered at the expected delayed emission
- Signal with >5σ in 4 consecutive nights, point-like source
- **By far the most distant TeV γ-ray source** ahead of KUV 00311, z≳0.51, 3C279 z=0.536 and PKS1424 z≳0.6

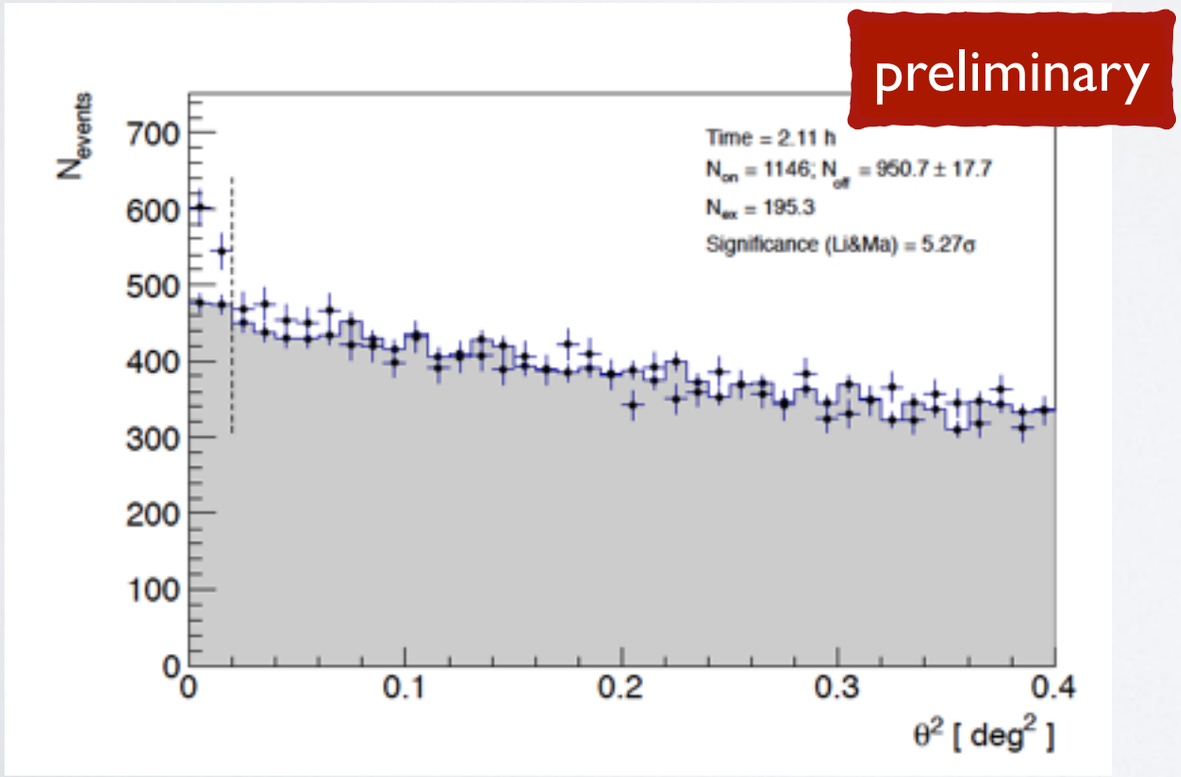
ATel#6349

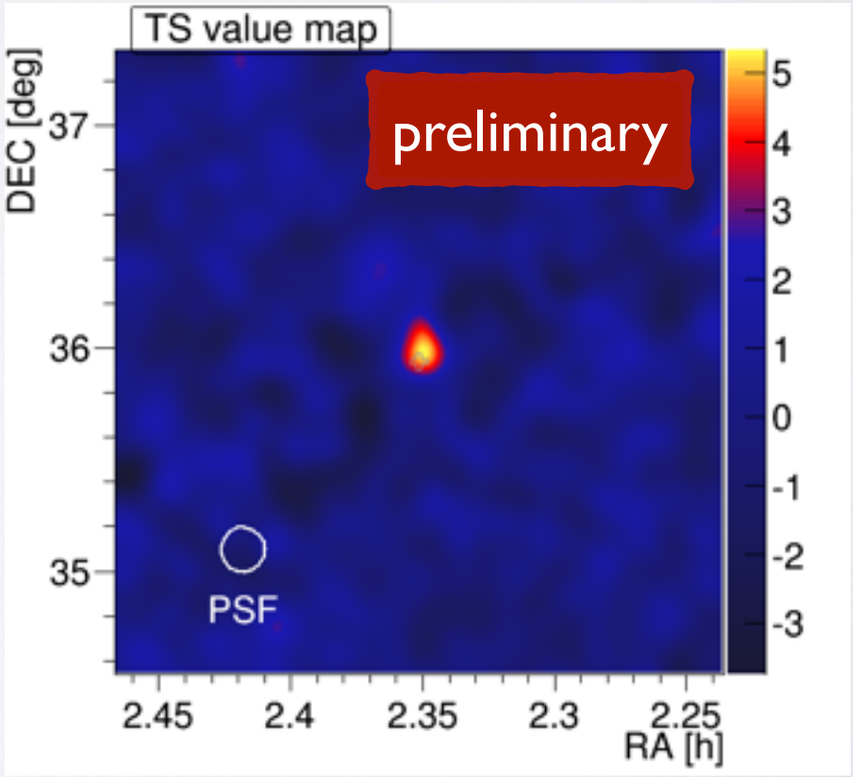
[Previous | Next | ADS]

Discovery of Very High Energy Gamma-Ray Emission From Gravitationally Lensed Blazar S3 0218+357 With the MAGIC Telescopes

ATel #6349; *Razmik Mirzoyan (Max-Planck-Institute for Physics) On Behalf of the MAGIC Collaboration*
on 28 Jul 2014; 14:20 UT
Credential Certification: Razmik Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de)

Subjects: Gamma Ray, >GeV, TeV, VHE, UHE, AGN, Blazar, Cosmic Rays, Microlensing Event





S3 0218+35 IN JULY 2014

- S3 0218+35 was observed by MAGIC for 14 consecutive nights (all good weather), 1-2 hrs per night

- The flare duration is about 4 days

- The flare can be fitted with a symmetric Gaussian shape centered at MJD=56863.7 and $\sigma \approx 1$ day

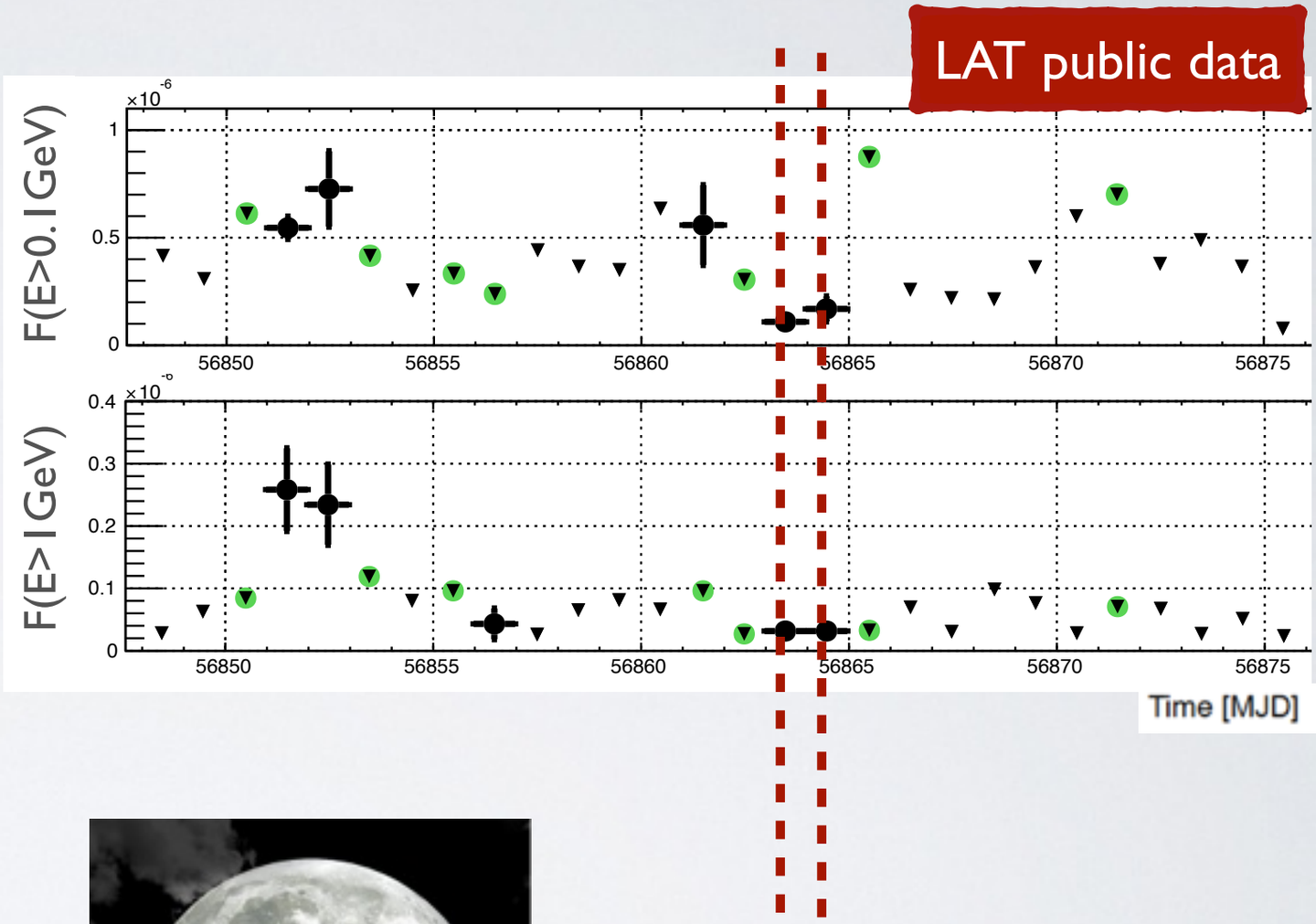
S3 0218+35 IN JULY 2014

There seems to be an intriguing fact that:

- Fermi-LAT: delayed flare is much smaller (factor ~5?) in amplitude than the first one. **See details in Buson et al. poster 8.04**

FERMI-LAT

LAT public data



- Detection in MAGIC very clear above 100 GeV at the expected time. Real pity MAGIC did not observe the first flare.

MAGIC

S3 0218+35 IN JULY 2014

- MAGIC measured spectrum is very soft, consistent with state-of-the-art EBL models for a intrinsic slope of -2

- EBL constraints using Fermi+MAGIC spectrum are under preparation

SUMMARY

- MAGIC detected by far the most distant blazar with imaging Cherenkov technique: S3 0218+35 at z=0.94

- The shape of the light curve of gravitationally delayed emission is intriguing.
  Unfortunately no MAGIC data to be sure.

- Flare in GeV very different in 2014 than in 2012

- Probe of the EBL density between 0.6 < z < 0.9, limits under way using joint Fermi+MAGIC spectrum. Stay tuned!