MAGIC latest results and multiwavelength observations of FSRQs: 3C 279 and PKS 1510-089

E.Lindfors

Finnish Centre for Astronomy with ESO

On behalf of the MAGIC Collaboration

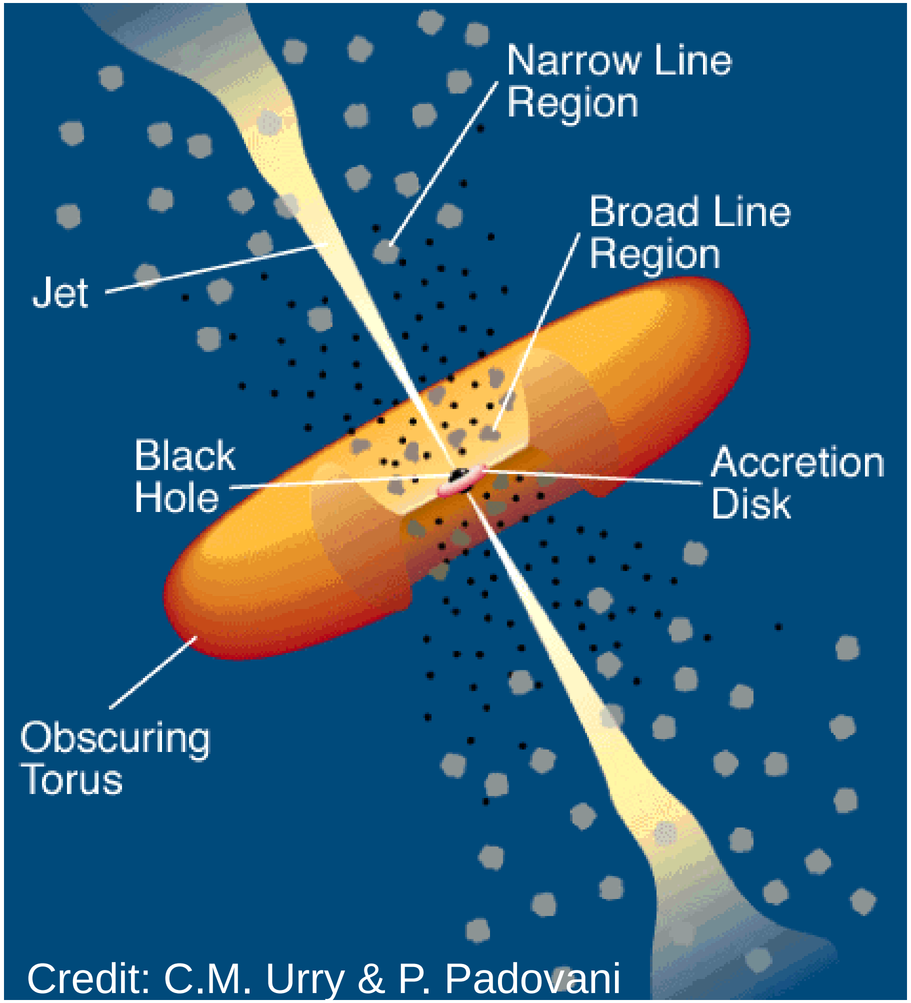
...and MWL collaborators from Fermi-LAT, AGILE, GASP, LT, F-Gamma, Metsähovi Radio Observatory, OVRO, Boston group

MAGIC

Major Atmospheric Gamma Imaging Cerenkov Telescopes

Flat Spectrum Radio Quasars (FSRQs)

- **Blazars**, AGNs with relativistic jet pointing towards the observer;
- FSRQs multiwavelength features:
  - **radio**: relativistic jets with knots traveling in the jet;
  - **optical**: broad emission lines in the spectra;
  - **variability**: all wavelengths at various time scales (weeks to minutes);
- > 300 FSRQs seen by *Fermi*-LAT (100 MeV<E<100 GeV);
- only 3 FSRQs detected in VHE (E>100 GeV) γ rays:
  3C 279 (z=0.536),
  PKS 1222+21 (z=0.432),
  PKS 1510-089 (z=0.36).



MAGIC telescopes

- Two 17m diameter imaging Cherenkov telescopes;
- Canary island, La Palma (2200 m a.s.l., northern hemisphere);
- Energy threshold: 55 GeV; Sensitivity: (0.76 ± 0.03) % Crab Nebula flux (50h, >290 GeV) (J. Aleksić et al. 2012- pre-upgrade)
- 2011-2012: upgrade of readout system and MAGIC-I camera ((0.71±0.02)% of the Crab Nebula flux (50h, 250GeV)

Multiwavelength campaigns

Multiwavelength (MW) observations: radio to HE γ rays

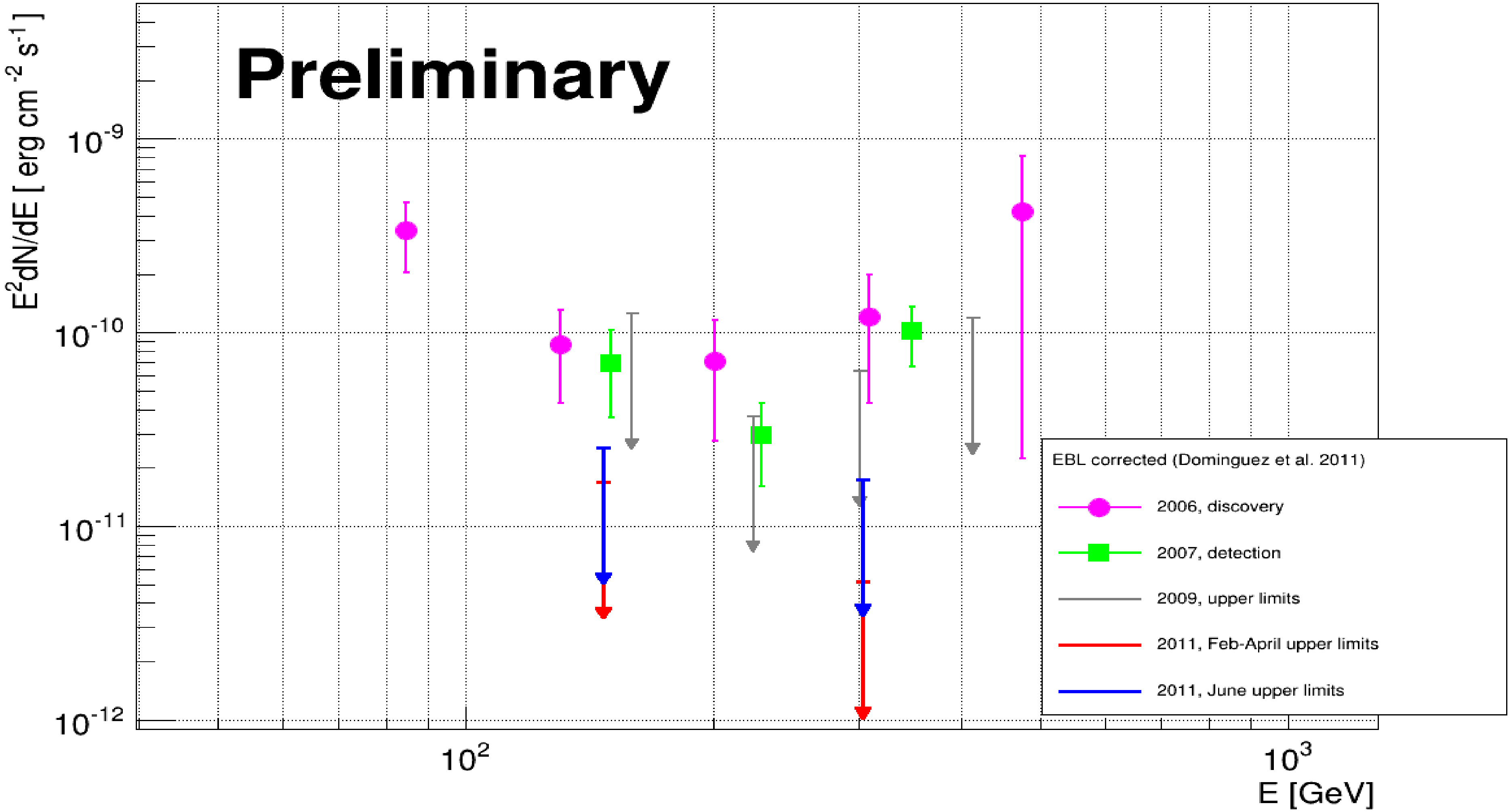
- flares in optical through HE γ rays may trigger MAGIC observations;
- radio observation: the sources are resolved, structure and properties of the jet;
- comparison of variability and time scales: constrains on location of emission region;
- We need simultaneous MW to understand physical properties and emission mechanisms taking place in the sources.

MAGIC observations of 3C 279 in 2011

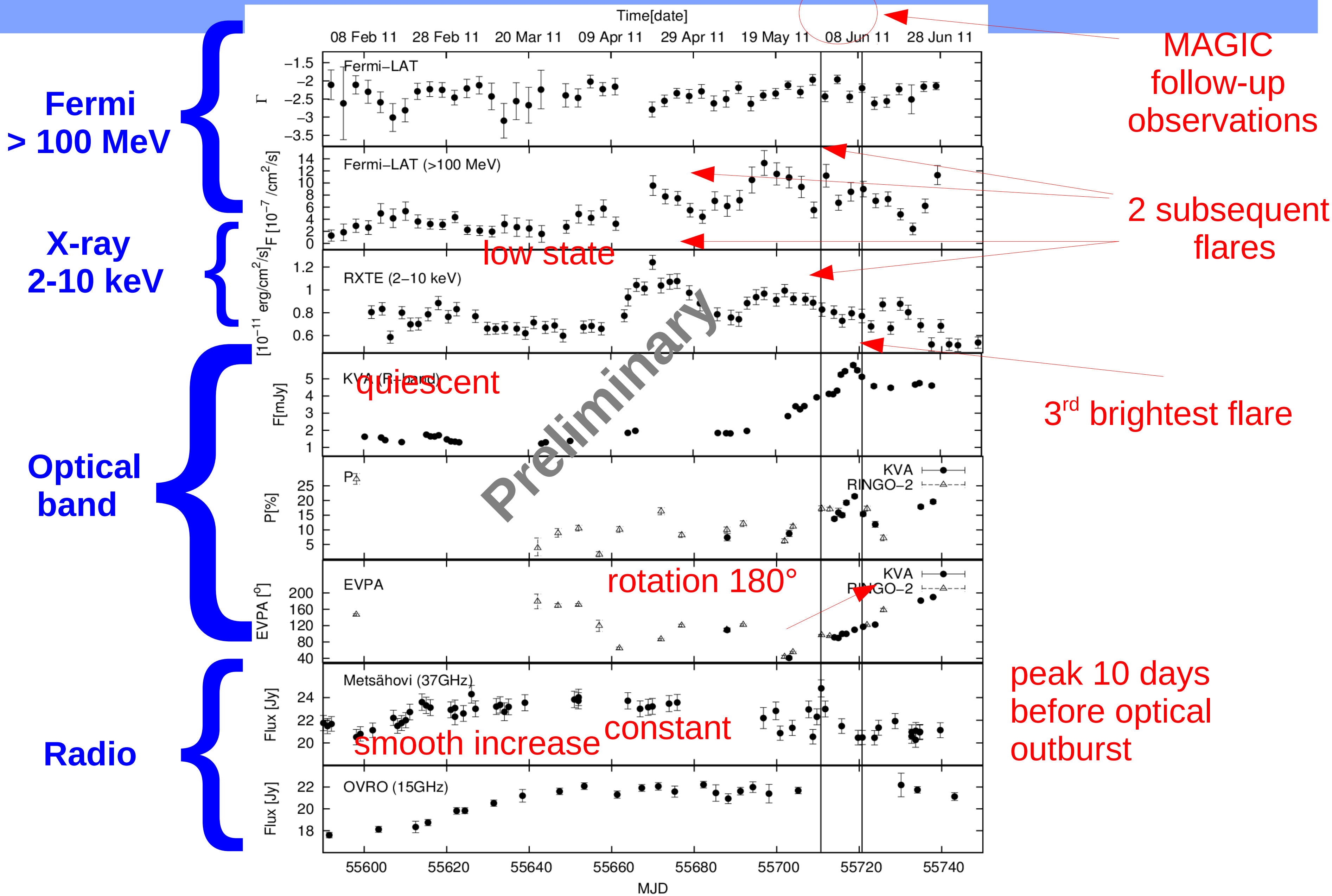
- **Great impact discovery** in 2006: Very high energy gamma rays from a distant Quasar: How transparent is the Universe? **Science** 320 (2008);
- 2 different campaigns in 2011:
  - February to April: regular monitoring;
  - June: follow up observations after alerts of high activity state in optical and HE (100 MeV-100 GeV) γ rays;
- Energy threshold ~ 125 GeV due to moon, twilight, high zenith angle observations.

	Time [h]	Significance [σ]	Differential Upper limit [10^{-12} TeV^{-1} cm^{-2} s^{-1}]	
			147 GeV	304 GeV
Feb-Apr	11.6	0.4	309	5.7
June	6.2	0.8	463	19.4
All	17.9	0.8	316	5.1

3C 279: MAGIC historical SED



MW observations of 3C 279 in 2011



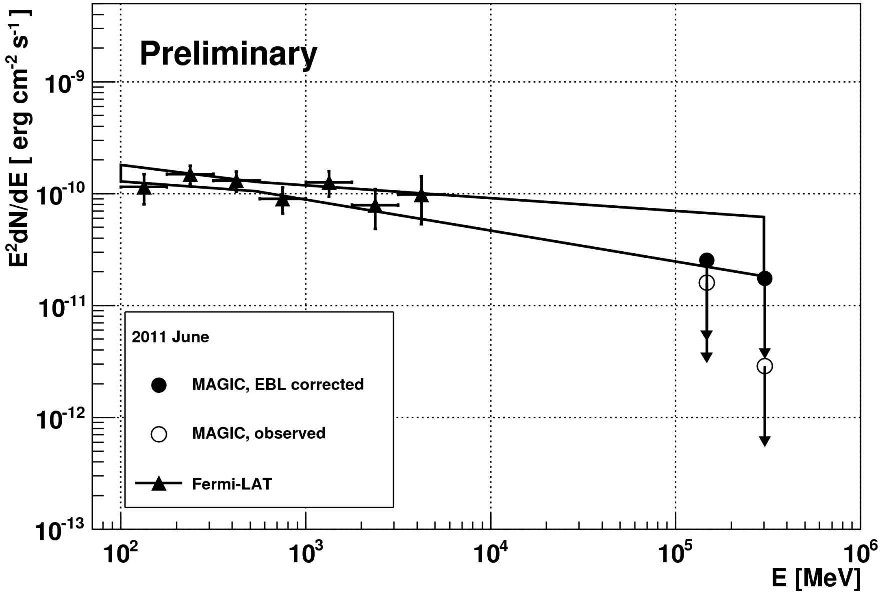
Fermi-LAT and radio 43 GHz

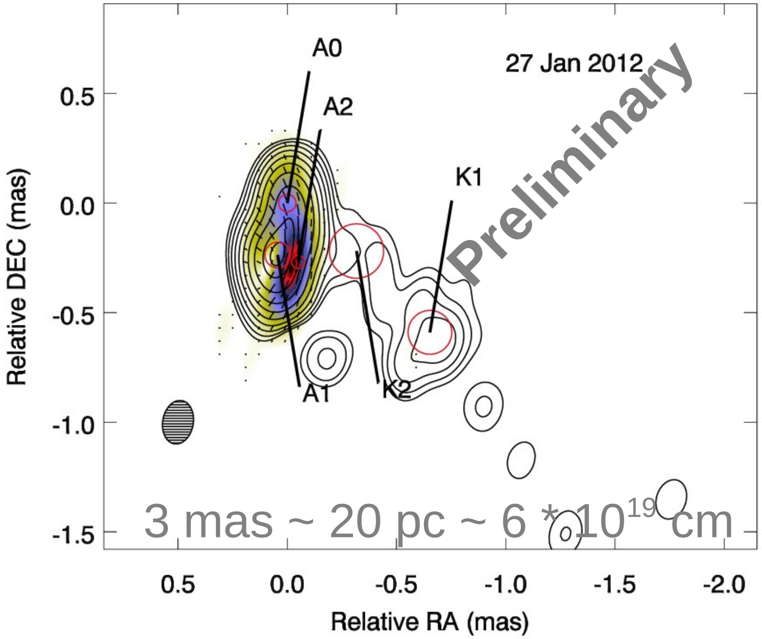
Fermi-LAT spectra:

- detection significance (TS~400) no hint of spectral break in *Fermi*-LAT data alone;
- *Fermi*-LAT & MAGIC spectra: hint of break in June 2011 observations.

Radio observations: VLBA, 43 GHz

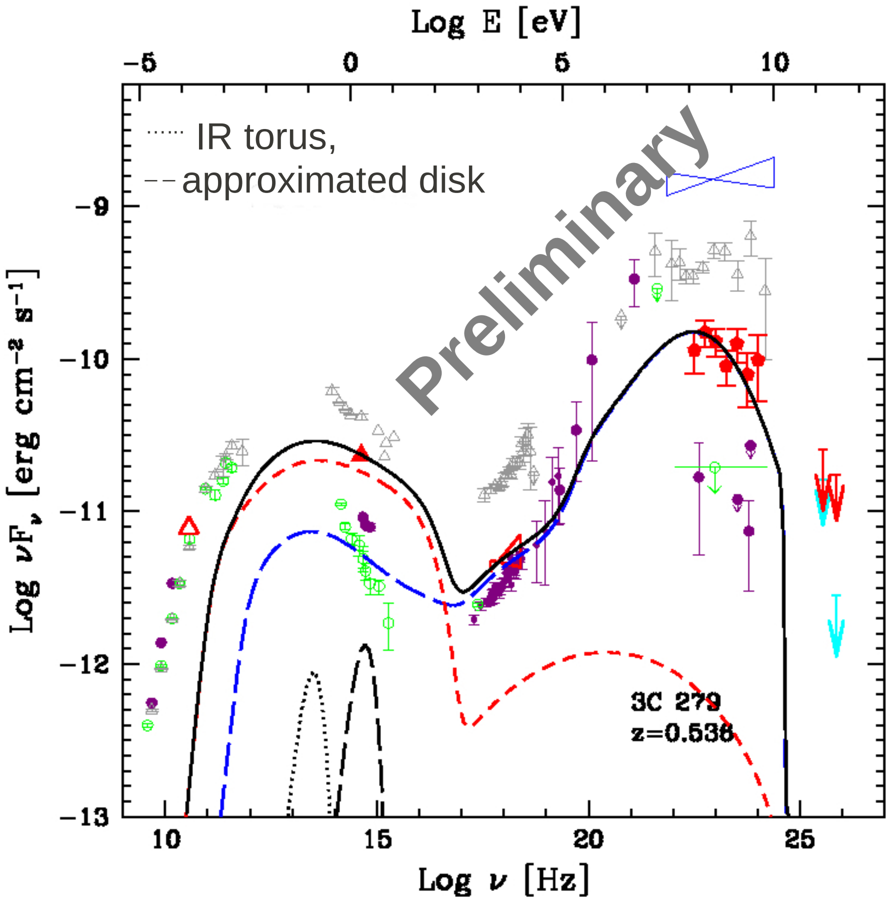
- no ejection of new component;
- brightening of (old) components A0 and A1;
- radio polarization: constant during optical flare.





Multiwavelength spectral energy distribution (June)

- Leptonic model: blob (radius R) filled with relativistic electrons and magnetic field B (Maraschi & Tavecchio 2003);
- suggested spectral break between *Fermi*-LAT & MAGIC + similarity of X-ray & *Fermi*-LAT light curves;
- 2 zone emission model:
  inner region (internal to BLR)
  X-ray & HE/VHE γ rays
  outer region (external to BLR):
  optical – UV emission



	internal region	external region
B [G]	1.45	0.8
R [cm]	1.1×10^{16}	1.15×10^{17}

Fit with 10 parameters for emission region; (some of them) astrophysical parameters:

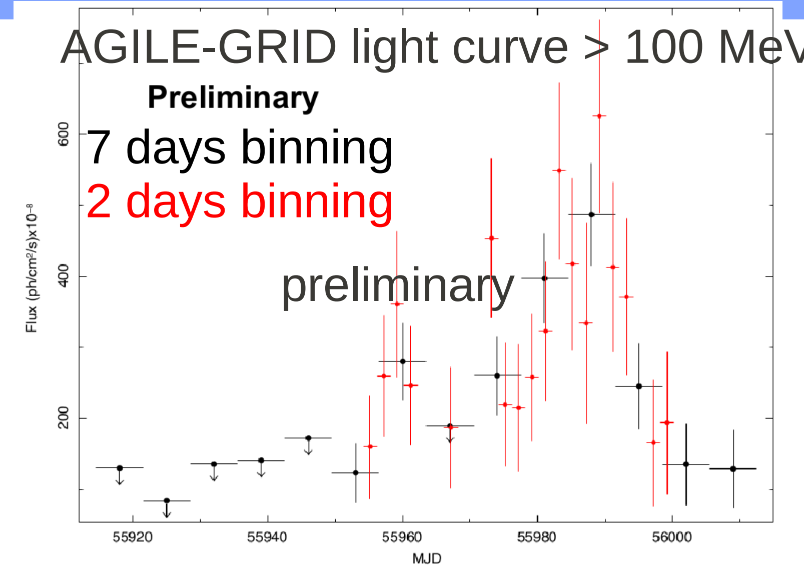
PKS 1510-089

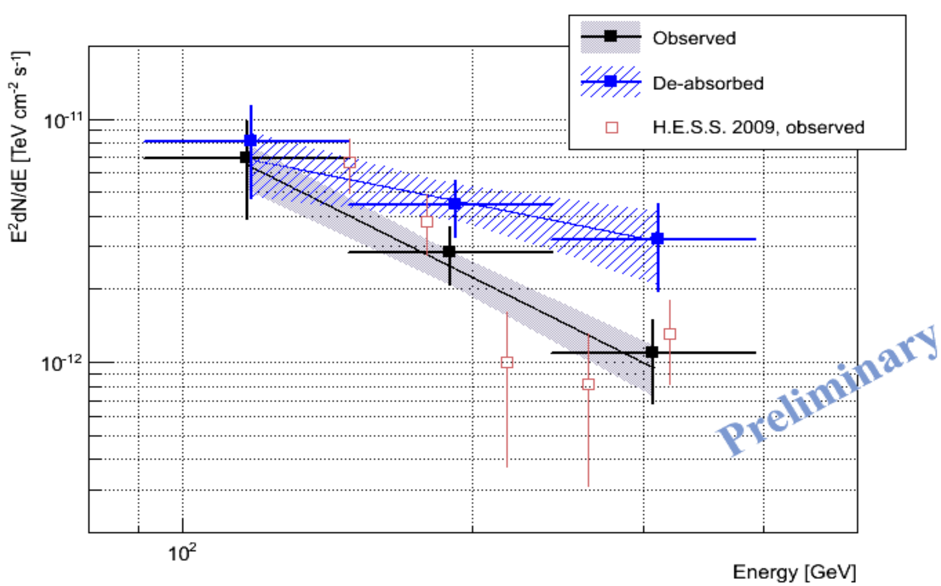
Discovered by H.E.S.S. in spring 2009 (Abramowski et al. 2013, A&A, 554, 107):

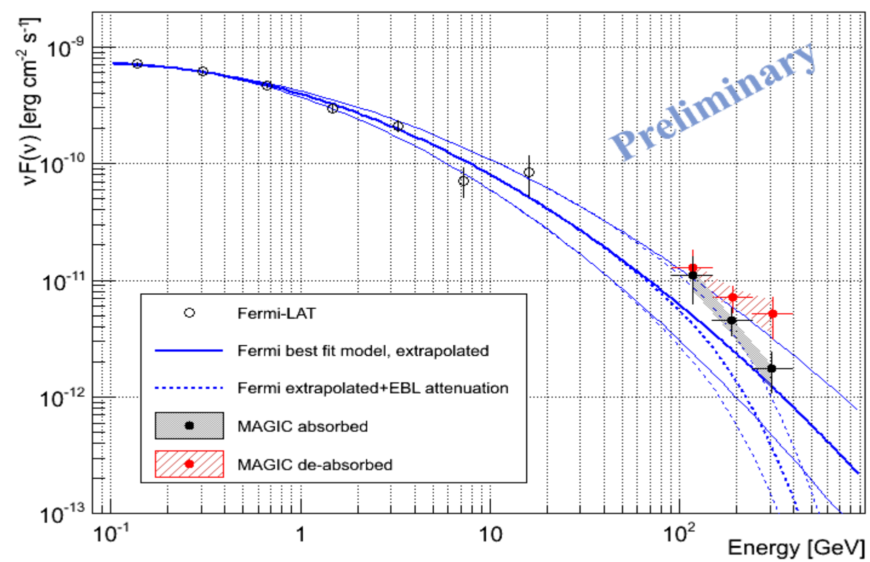
- VHE: Flux: $I(0.15\ \mathrm{TeV} < E < 1.0\mathrm{TeV}) = (1.0 \pm 0.2_{stat} \pm 0.2_{sys}) \times 10^{-11}\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}$ corresponds to ≈3% of the Crab Nebula flux in the same band, very soft spectra ($\Gamma = 5.4 \pm 0.7_{stat} \pm 0.3_{sys}$), no significant variability
- major outburst in optical, radio, γ-ray but not much activity in X-rays (e.g. D'Ammando et al. 2010, Abdo et al. 2010);
- ejection of the new knot + rotation of the optical and radio polarization angle of >720° (Marscher et al. 2010);
- HE γ-ray spectrum in agreement with negligible amount of internal absorption (Poutanen & Stern 2010);
- size of BLR ~0.07 pc, dust torus ~3.2 pc (Nalewajco et al. 2012), distance of the VLBA core ~17.7 pc (Pushkarev et al. 2012).

HE & VHE PKS 1510-089 observations

- MAGIC observations triggered by alerts of flaring state in HE γ rays (AGILE and Fermi-LAT);
- MAGIC observed for 28 nights from February to April 2012 (~ 25h);
- soft spectra in agreement with HESS (4.16 +-0.4stat +-0.3sys);
- MAGIC & Fermi-LAT spectra connect smoothly.







MW observations of PKS 1510-089 in 2012

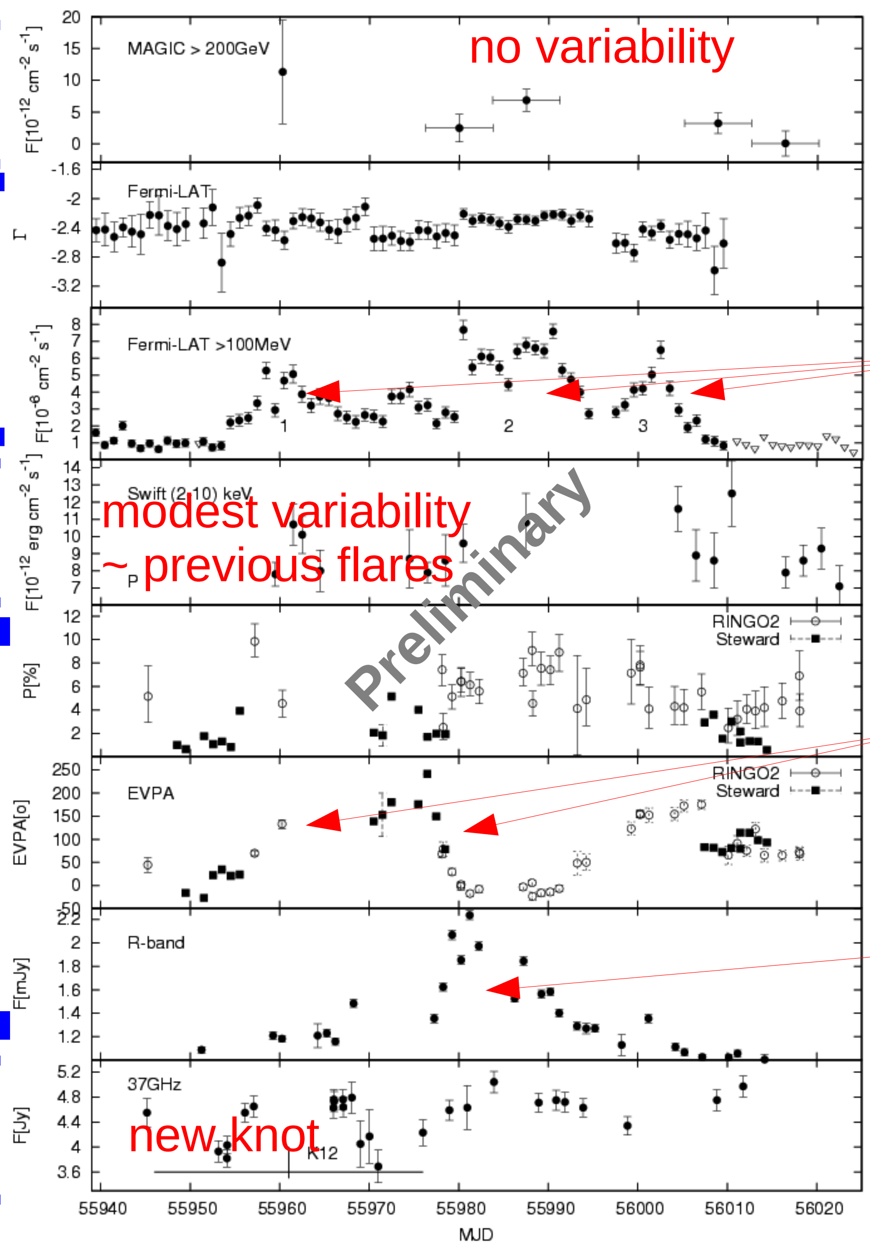
MAGIC > 200 GeV

Fermi > 100 MeV

X-ray 2-10 keV

Optical band

radio



3 distinct flares

3 distinct EVPA Rotations >180°

optical outburst contemporaneous to 2[nd] HE flare

2 flares simultaneous to 1[st] and 3[rd] HE flares

Interpretation

The flaring event took place far out from the central engine at the VLBA core (co-spatiality of mm and γ-ray emission, smooth connection HE and VHE γ-ray spectra);

moving emission feature:

- flare 1: emission feature passes the VLBA core;
- flare 2: sudden energization of electrons in emission feature;
- flare 3: sudden increase in local seed photon field.

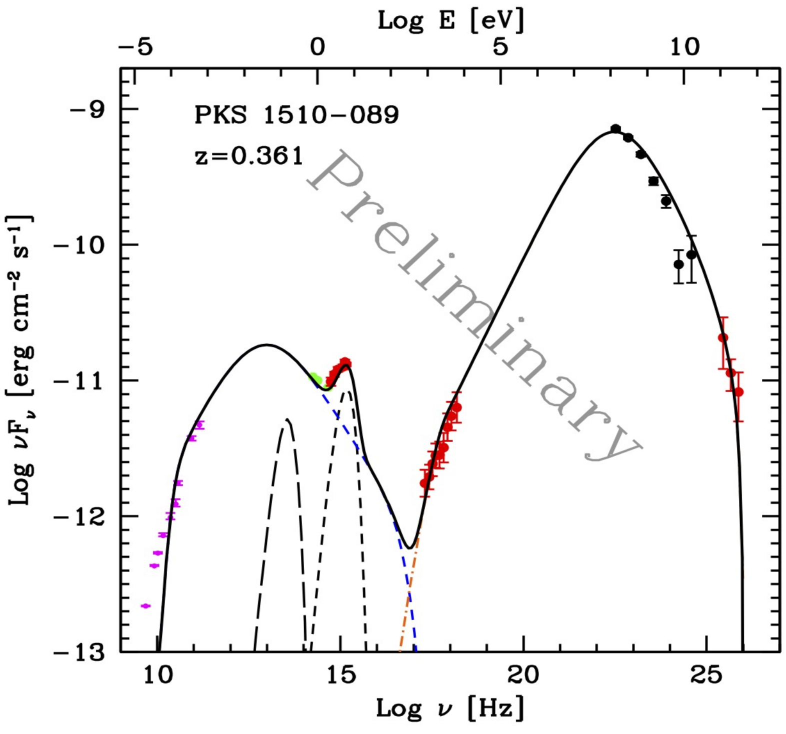
Distance traveled between flare 2 and flare 3: ~ 0.5 pc → substructures in the jet.

- Data agrees well with the Marscher et al. (2010) interpretation of the previous flaring;
- rotations not smooth, close in time and opposite directions: turbulence.

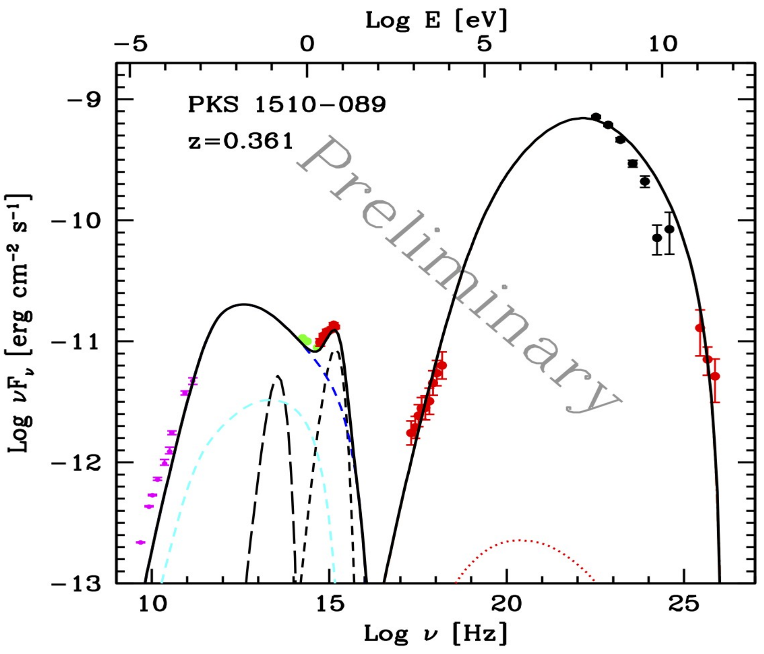
Spectral energy distribution modeling

Large emission region far out in the jet → inefficient synchrotron self Compton: seed photons for inverse Compton provided by external field

seed photons: infrared torus



seed photons: slow sheath of the jet



Conclusions & Outlook

3C 279:

- strongest upper limits on VHE γ-ray emission;
- two zone leptonic emission model + relativistic aberration;
- previous MAGIC 3C 279 detections: during high optical and/or X-ray states;
- June 2011: multiwavelength properties similar to ones of previous detections
  → **why no VHE γ-ray detection?**

PKS 1510-089:

- no VHE variability, but daily scale variability at low energies: can we detect it also in the low state?
- new radio component, optical outburst, rotation of the radio and optical polarization angle, X-rays weak, Fermi-LAT and MAGIC spectra connect smoothly
- emission far out at VLBA core, moving feature and turbulence.

open question: origin of VHE γ-ray flares in FSRQs

→ long-term and multiwavelength effort.