MAGIC:
Possible optical-TeV correlation in blazars and new constraints on extragalactic background light

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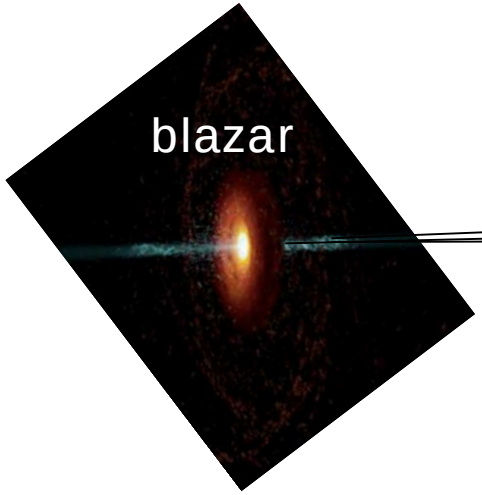
for the MAGIC collaboration

Outline

1. TeV blazars
   - **Sources**
     - ***Mkn 180 (z = 0.045)***
     - ***1ES 1011+496 (z = 0.212) !***
     - ***3C279 (z = 0.536) !!***

redshift

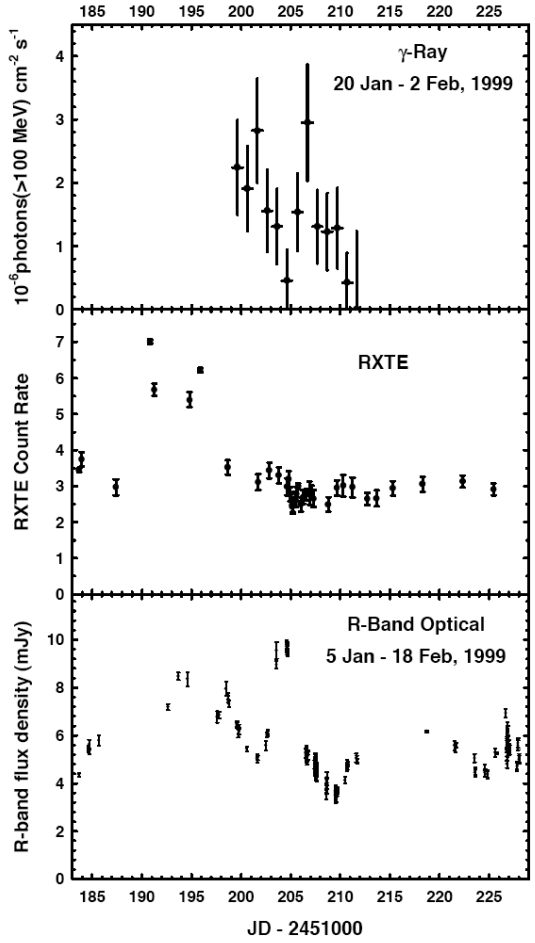
2. EBL “status” and intrinsic TeV blazar spectra



Very high energy γ-rays

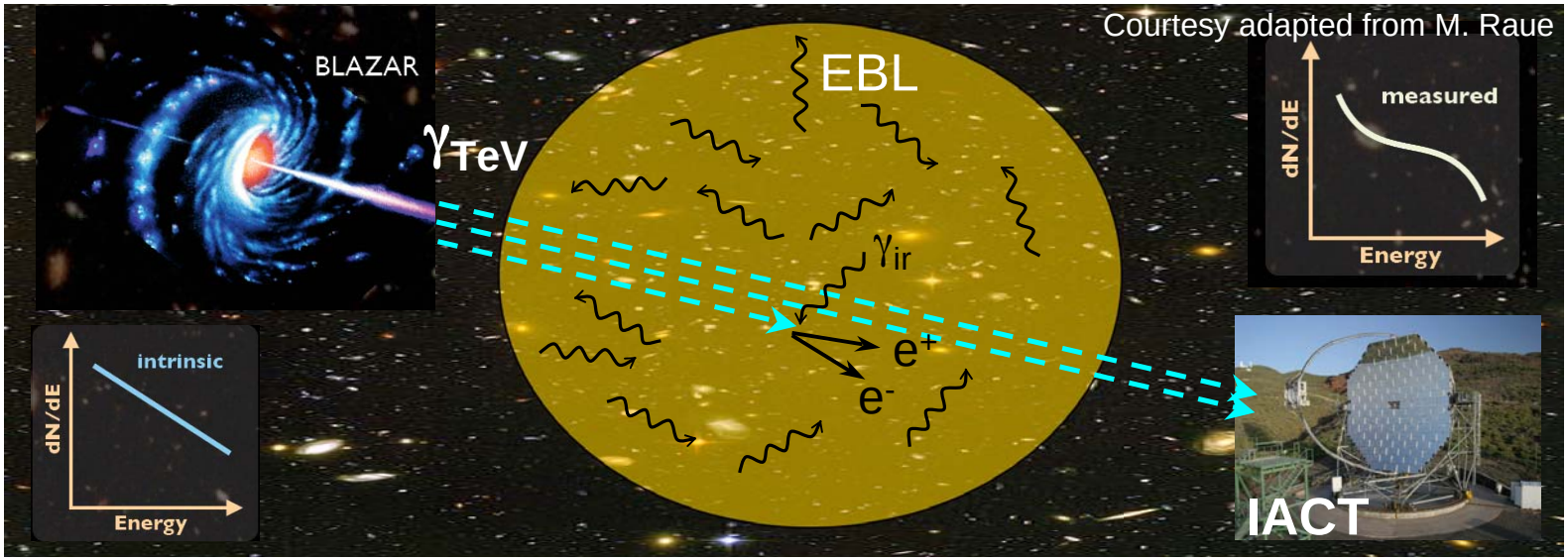
TeV blazars

- AGNs with ultrarelativistic jet pointing to us
- VHE gamma-rays:
  - **where in the jet?**
  - **what mechanism?**
- 19 known sources:
  16 HBL + 1 LBL + 1 FSRQ + 1 radio galaxy
- Correlations:
  - **X-ray - TeV: yes, but ...**
  - **Optical - GeV: yes, but ...**

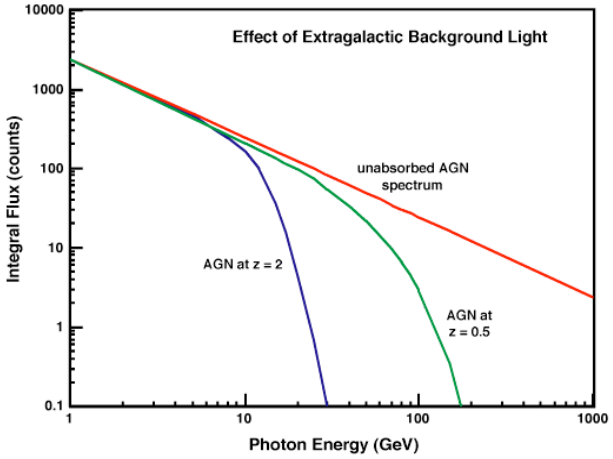


Hartman R.C. et al (2001): 3C279

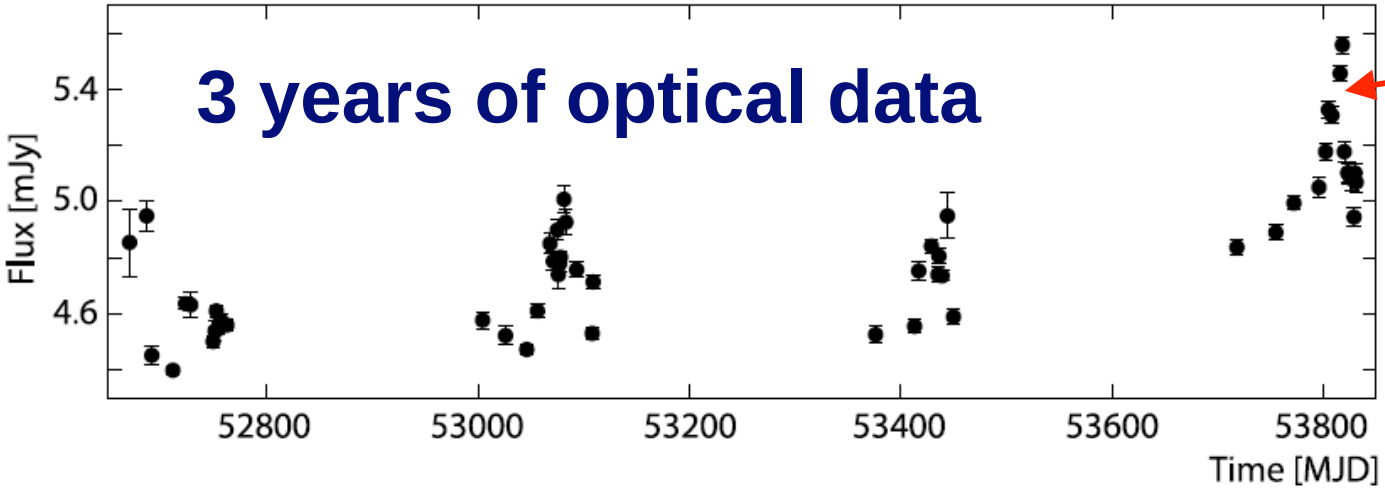
Absorption of VHE gammas by EBL



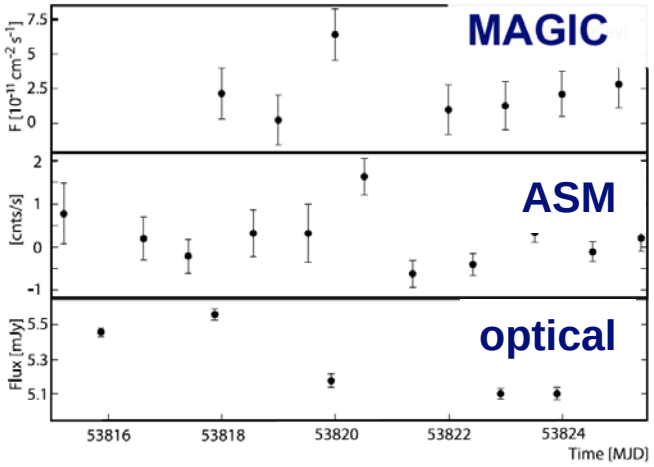
- TeV photons are attenuated via pair production with UV to IR photons from the extragalactic background light (EBL)
- γ-ray horizon depends on energy threshold of the experiment
- How far can we see above 100GeV?



Markarian 180: trigger, correlations

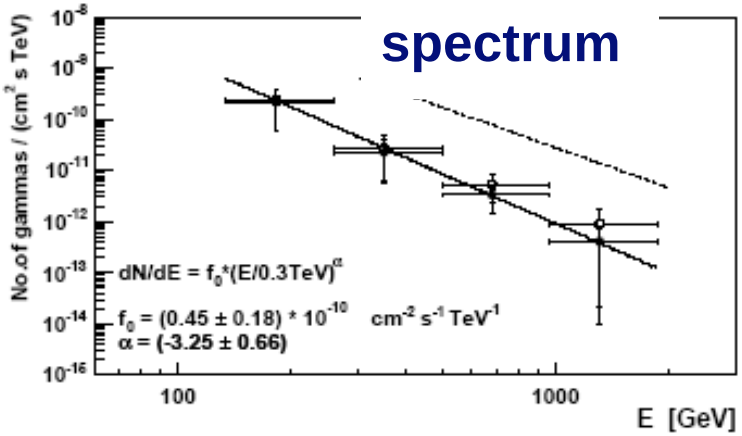


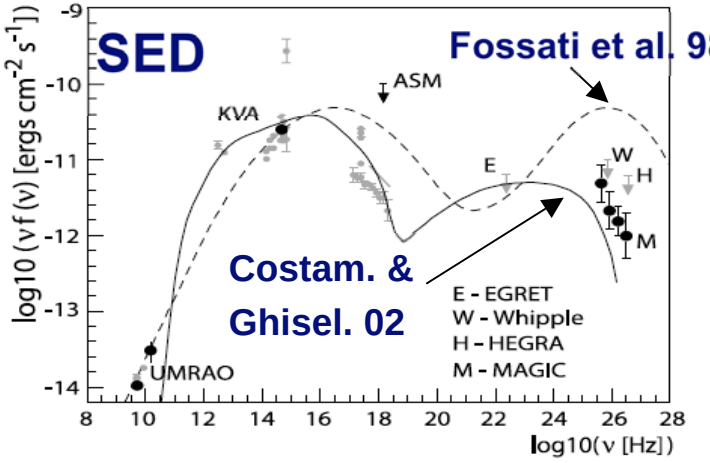
- Historical high in optical!
- No significant detection in ASM (3 σ on one of the nights)
- No clear correlation found: 7 MAGIC nights with a flux compatible with a constant



Markarian 180 (z=0.045) optical trigger

- April 2006: optical flare triggered MAGIC observations (11.1 h)
- 5.5 σ: **DISCOVERY**
- $F_{(>200GeV)}$ = 11% crab units
  index: -3.3 ± 0.7
- No significant variability
- Re-observations in May 2006 (optically low state) did not succeed due to bad weather
- December 2006: lower γ-ray flux during a lower optical state
- More observations are planned

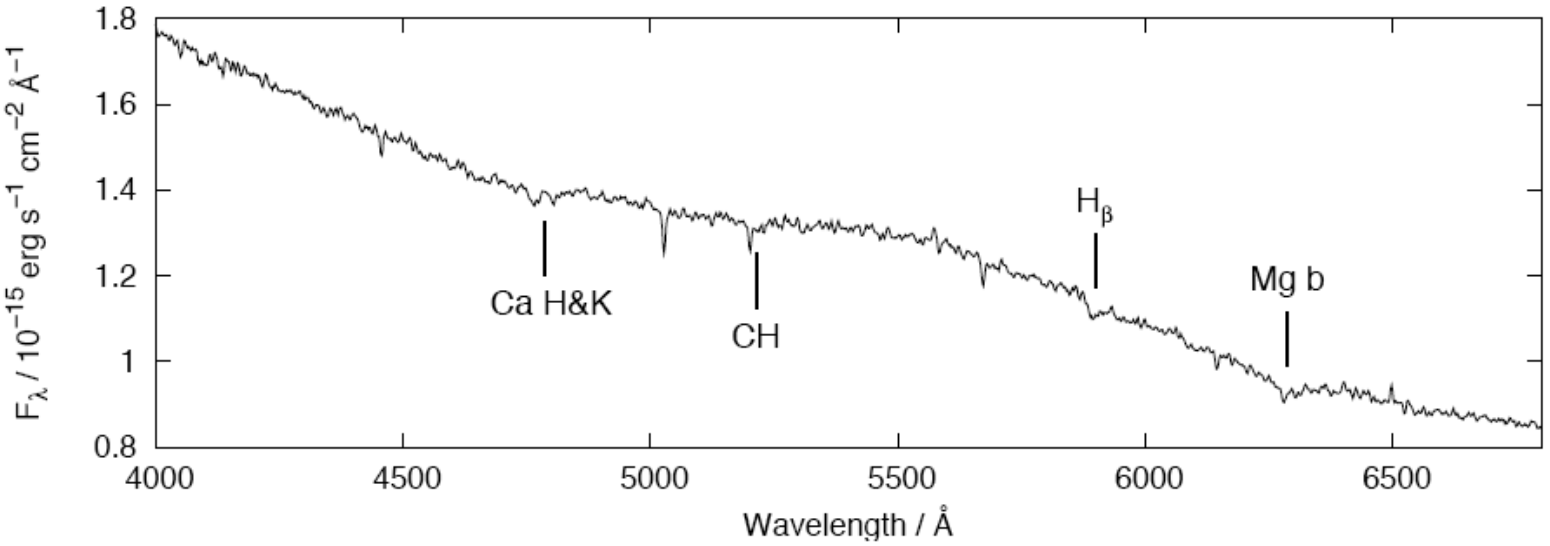




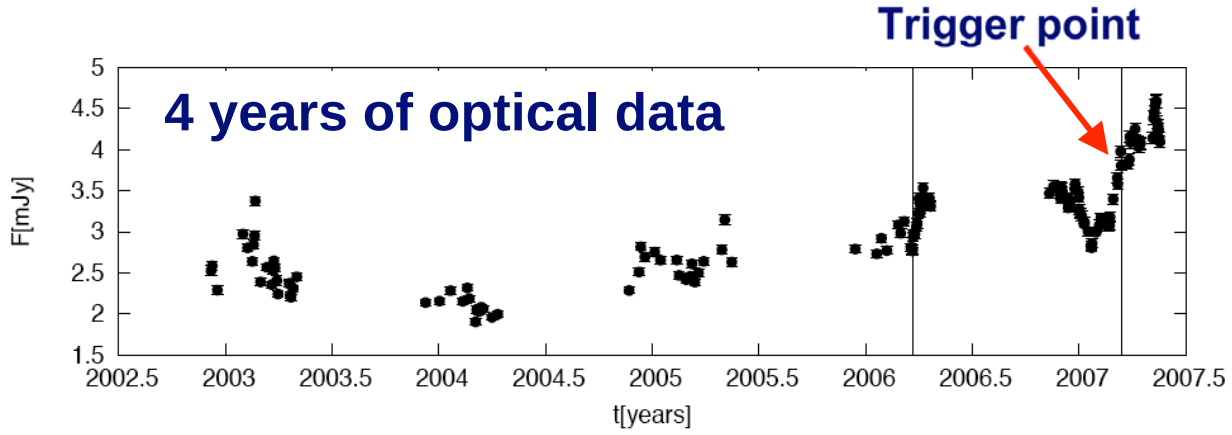
ApJL 648 (2006) L105 - 108

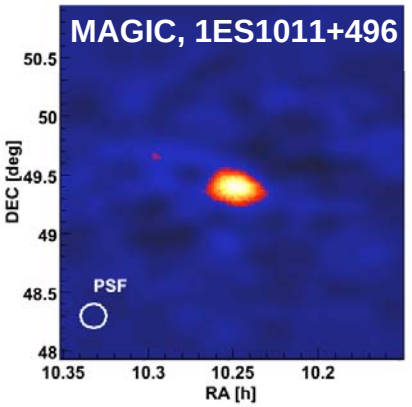
1ES 1011+496 (z=0.212) optical trigger

- 1ES 1011+496: HBL, possibly an EGRET source, too low X-ray flux to be detected by RXTE/ASM or Swift/BAT
- Redshift of z=0.200 was “guessed” because of a possible association with Abell 950 (Wisniewski et al. 1986)
- From the optical spectrum (E. Perlman), we determined the redshift to be **z = 0.212 ± 0.002**



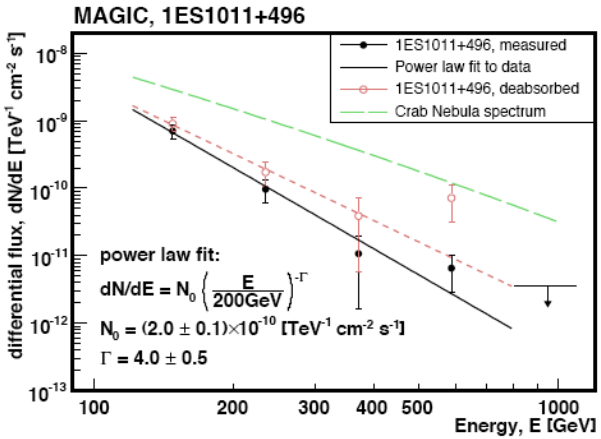
1ES 1011+496: results

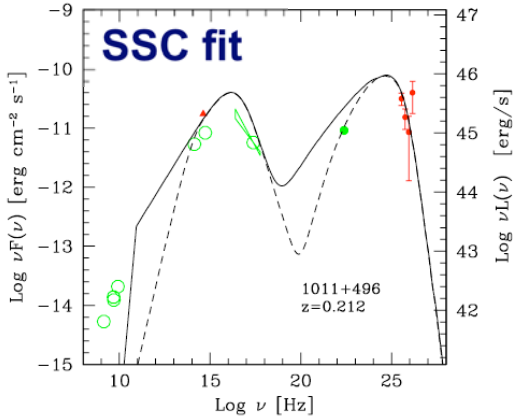




Optical trigger: MAGIC observations in March-May 2007, 18.7h of data, clear signal (6.2 σ): discovery ! ApJ 667, L21-24 (2007)

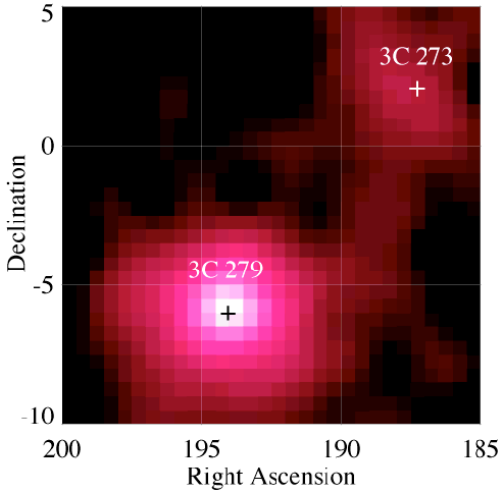
- Soft spectrum: Γ=3.3 after deabsorption
- 10% crab at 200 GeV
- No significant variability
- 3 σ in 2006 data. If it was due to genuine signal, then 40% lower flux then in 2007

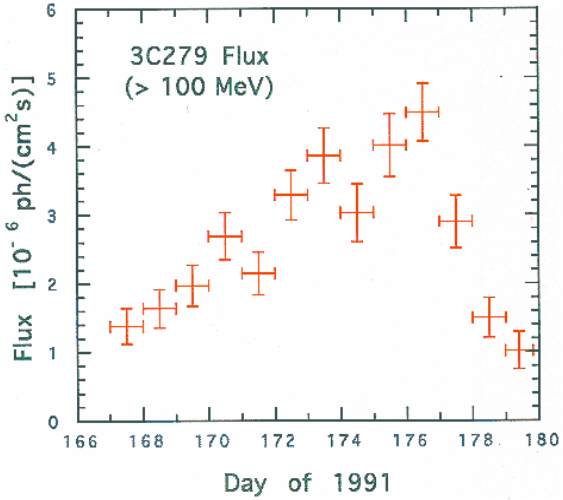


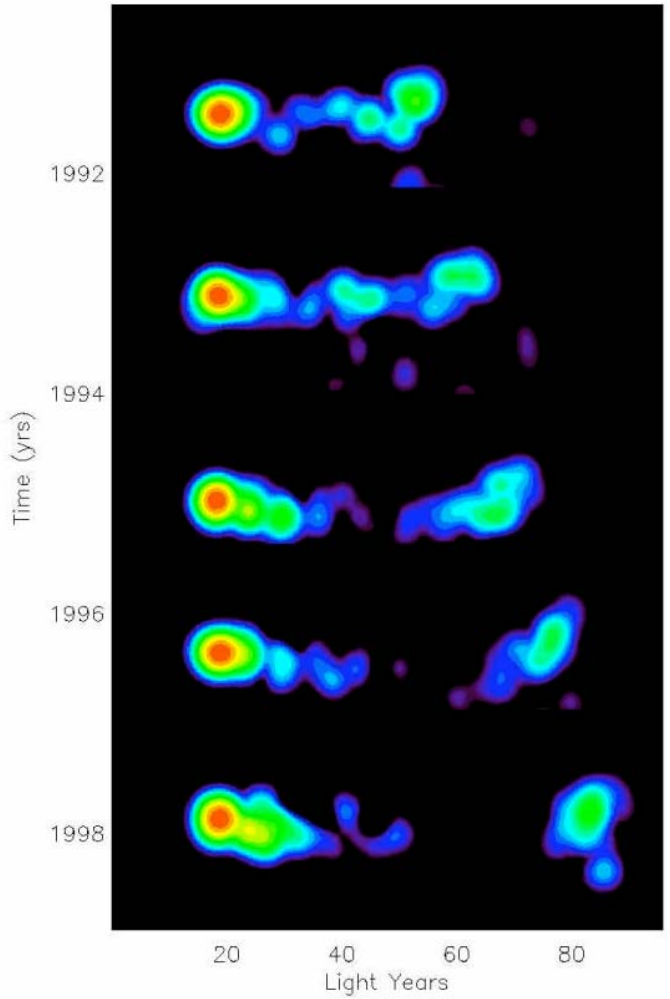


3C279, z=0.536

- EGRET brightest AGN (Flat spectrum radio quasar)
  - **Gamma-ray flares in 1991 and 1996**
  - **Apparent luminosity ~ 10^{48}erg/s**
  - **First time variation △T ~ 6hr in 1996 flare**
- Typical OVV (Optically violent variable)
- Superluminal motion
  - **γ~ 20~30, B ~ 0.3Gauss**
- z = 0.536, L_d ~ 3Gpc



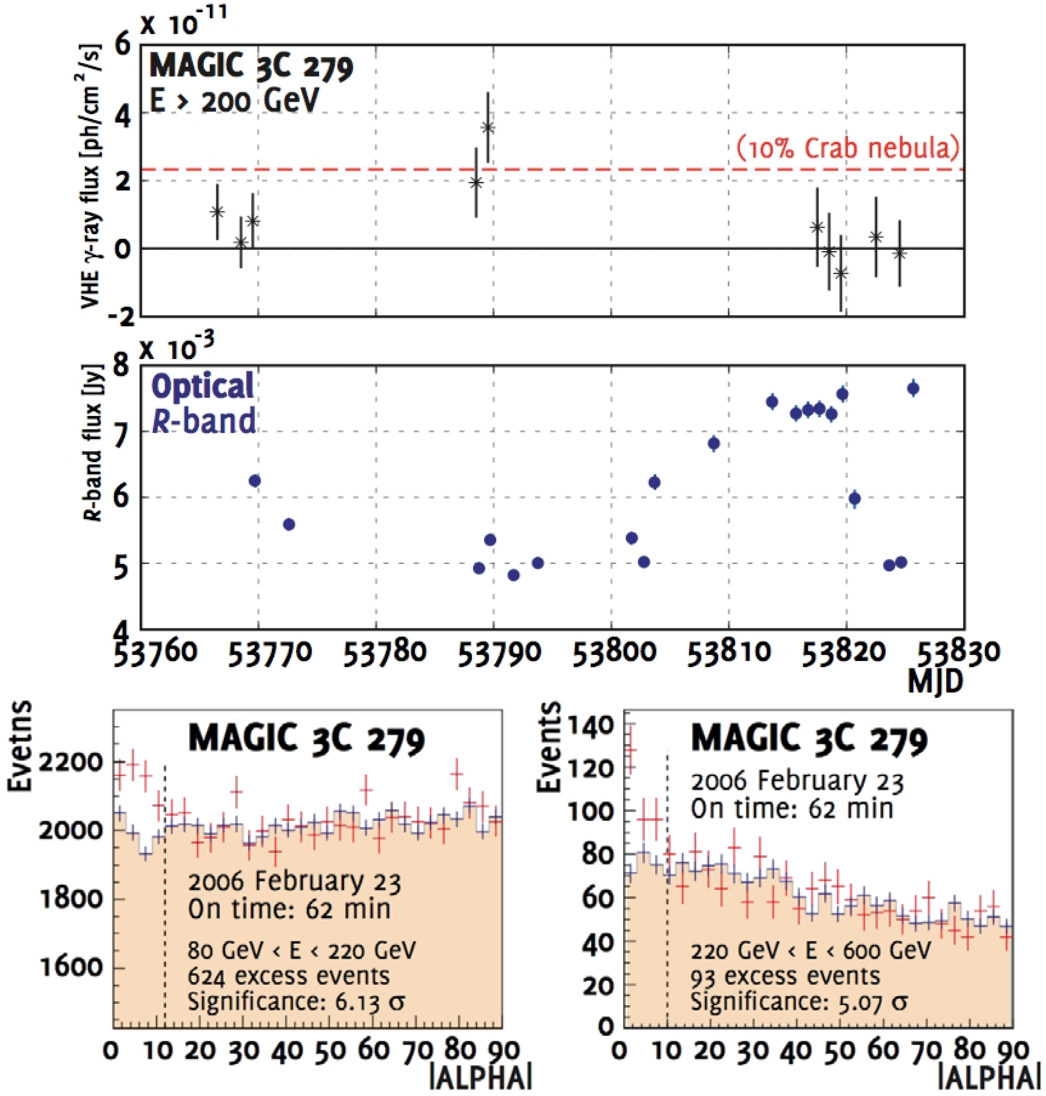




3C279, z=0.536

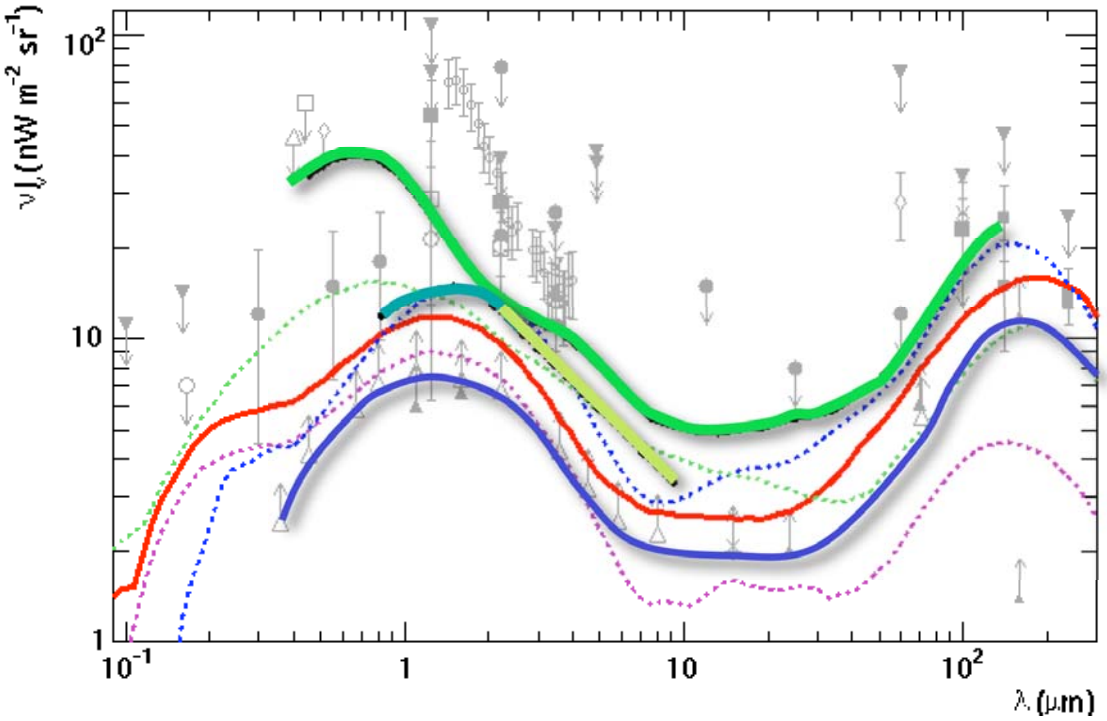
MAGIC observation:

- In the period of January - April 2006
- Observation of 9.5 hrs
- Zenith angle range is between 32 and 40 degrees
- **Discovery on 2006 February 23: 5.4 σ in standard analysis**
- Not coincident with optical flare



What does it mean for the EBL?

- Upper EBL limits get tighter: just factor 2 above the lower limits (galaxy counts)



Limits:

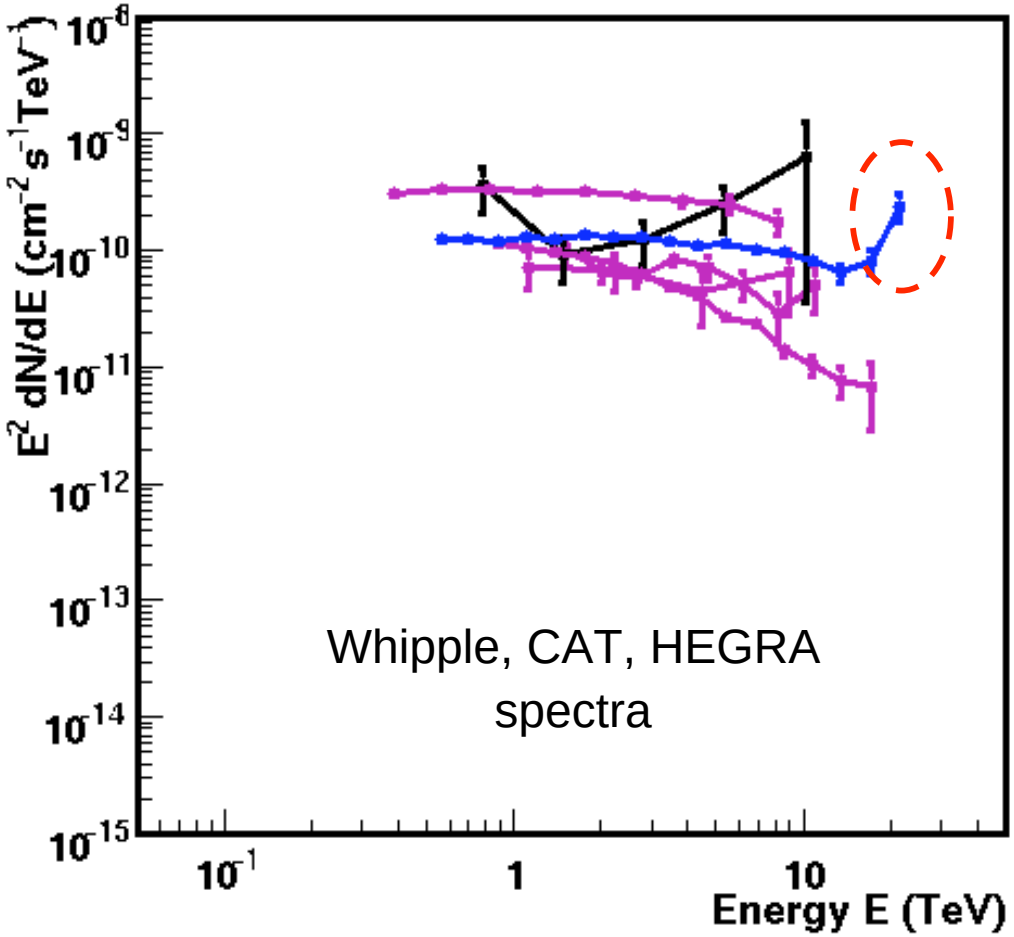
UL Mazin & Raue (2007) A&A **471**, 439
UL H.E.S.S. Coll. (2006) Nature **410**, 1018
UL H.E.S.S. Coll. (2007) arXiv:0709.4584
LL galaxy counts (HST, Spitzer, ISOCAM)

Models:

Primack et al. (2005) AIP Proc. **745**, 23
Stecker et al. (2006) ApJ **648**, 774
Kneiske (2007) in preparation
Raue & Mazin (2007), **generic shape**

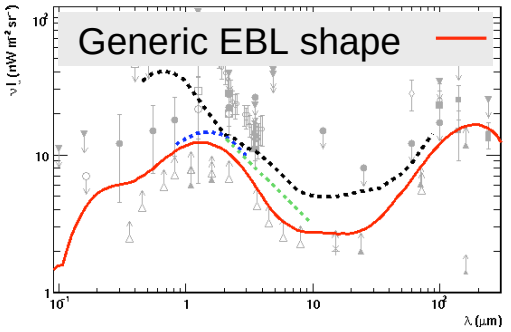
Using the generic shape for all GeV-TeV spectra ➔

Intrinsic spectra of TeV blazars

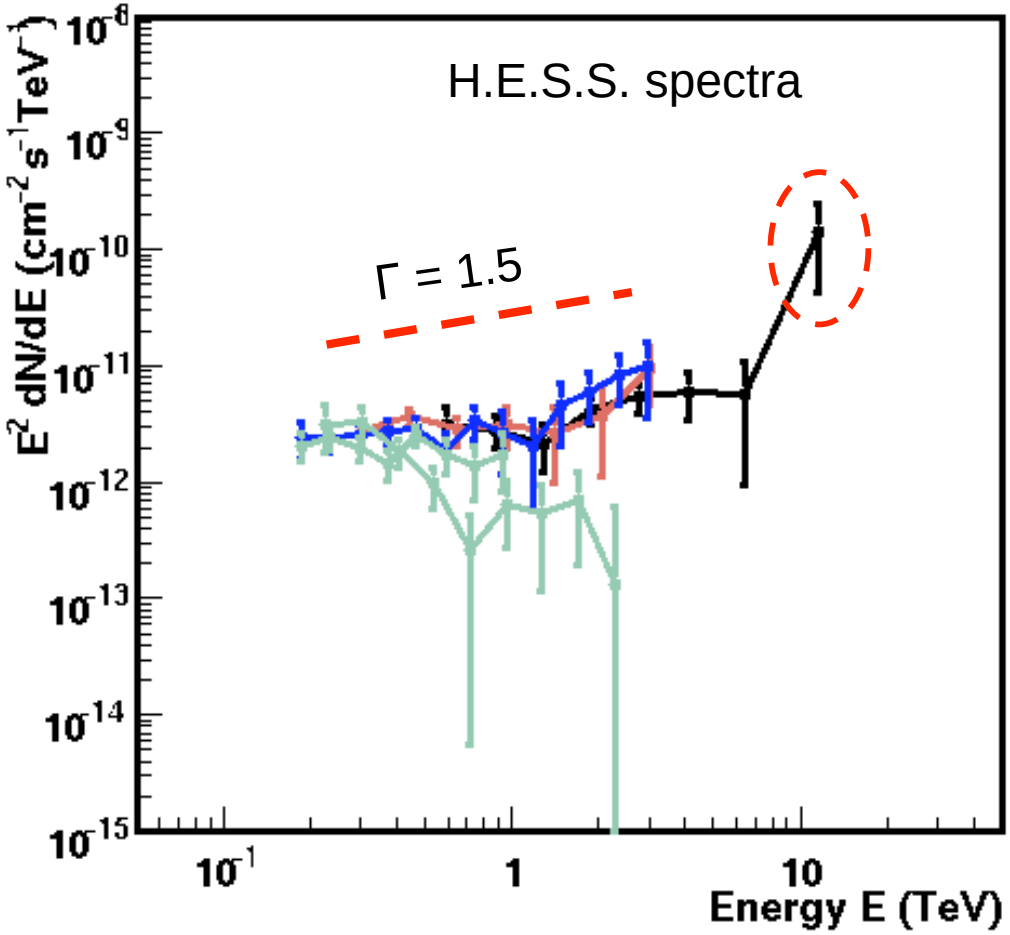


- Whipple, CAT and HEGRA have put some constraints in the past

A possible pile-up at energies above 10 TeV in the HEGRA spectrum of Mkn 501

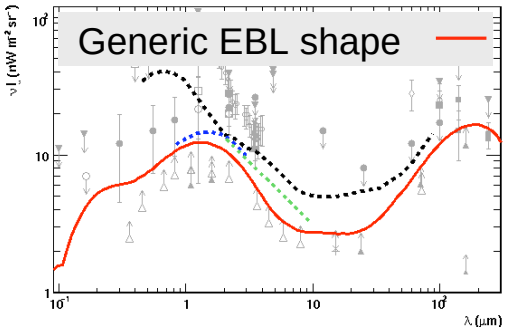


Intrinsic spectra of TeV blazars

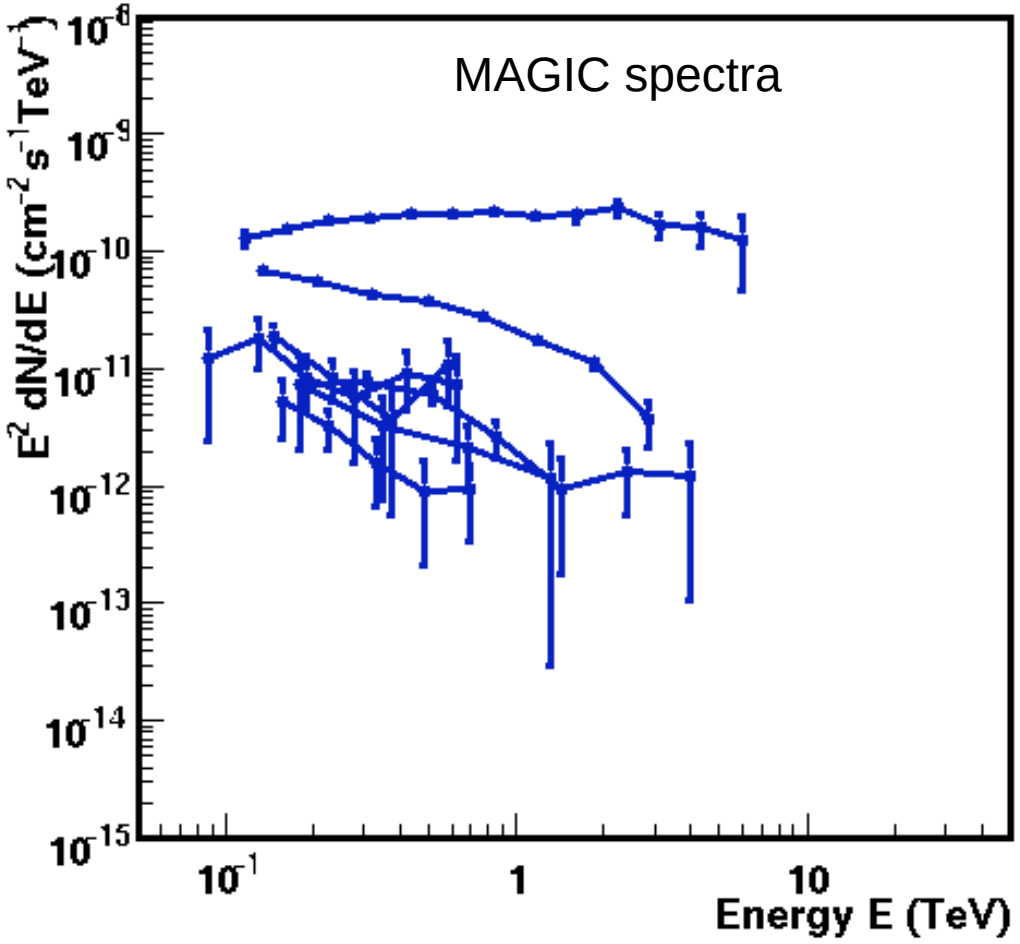


- H.E.S.S: hard spectra, difficult to model, strong constraints on the EBL

Spectral slope close to the theoretical maximum of $\Gamma = 1.5$ ($dN/dE \sim E^{-\Gamma}$) for several sources at different redshifts

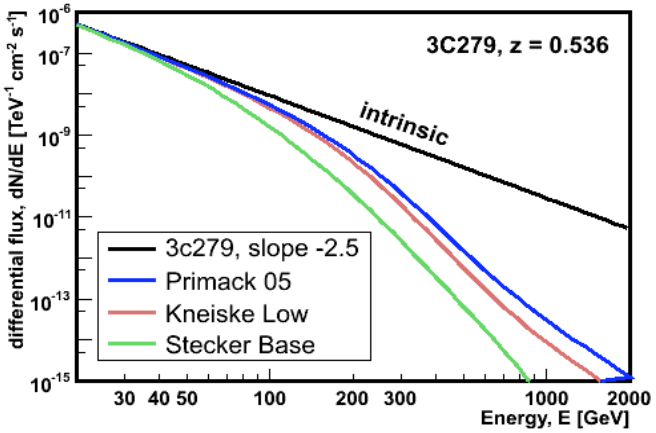


Intrinsic spectra of TeV blazars

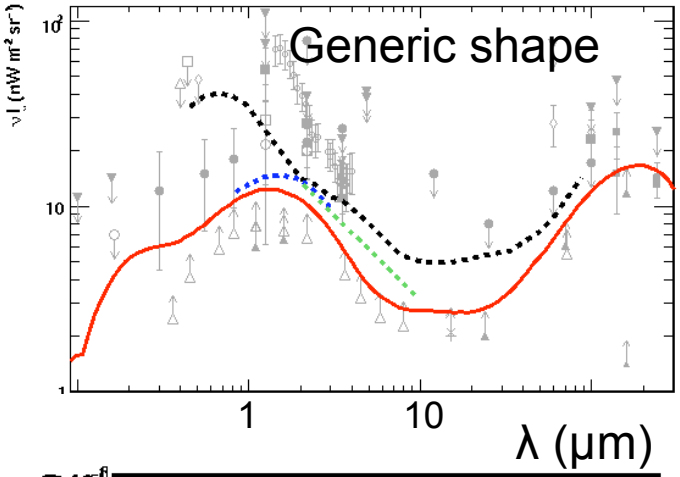


- MAGIC: no pile-ups at high energies, spectra are not too hard, “easy” to model

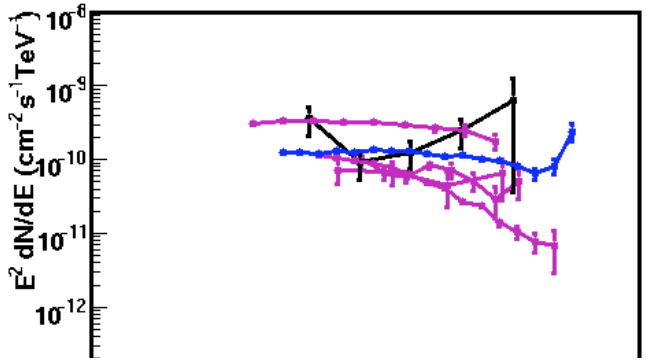
However, significant signal from 3C279 (z=0.536) above 200 GeV means already that the intrinsic spectrum **must be hard**

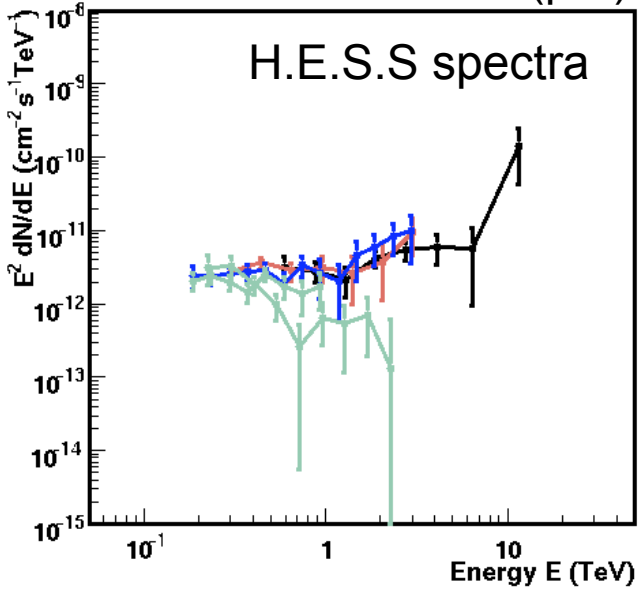


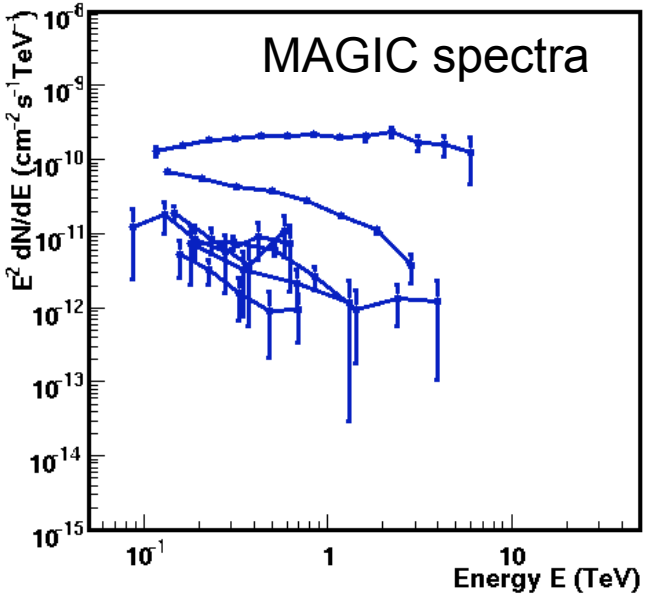
Summary of intrinsic TeV blazar spectra



CAT, HEGRA, Whipple







Conclusions

- ToO strategy using optical triggers is very successful
- Out of 2 good optical triggers discovered 2 new VHE γ-ray emitters:
  - Markarian 180 (z=0.045)
  - 1ES1011+496 (z=0.212)
- Optical-TeV connection does exist?
- Discovery of 3C279 between 80 GeV and >200 GeV
- EBL: constraints get tighter. Either all galaxies have been already resolved or TeV blazar physics is wrong
- Outlook 1: monitor sources in optical + ASM + Swift + AGILE. Also GLAST triggers in 2008!
- Outlook 2: more sources at high redshifts, stay tuned!

BACKUP

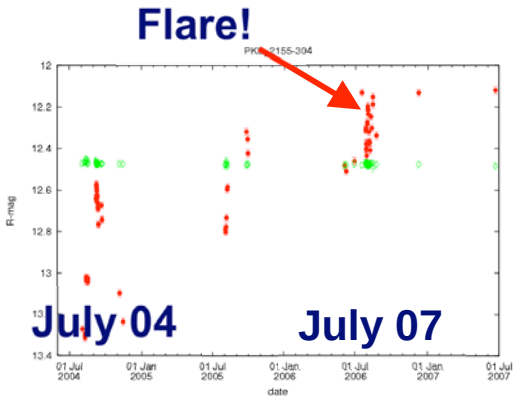
ToO strategy

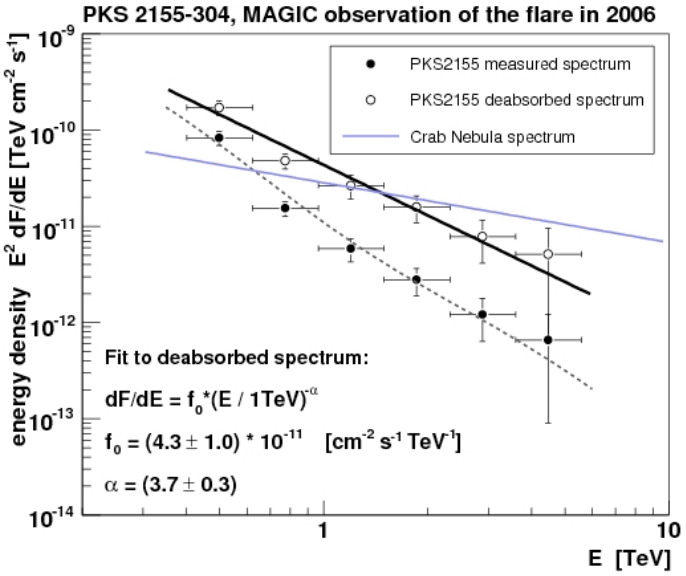
Sources are variable, field of view of Cherenkov telescopes is small (3-5 deg) → external triggers!

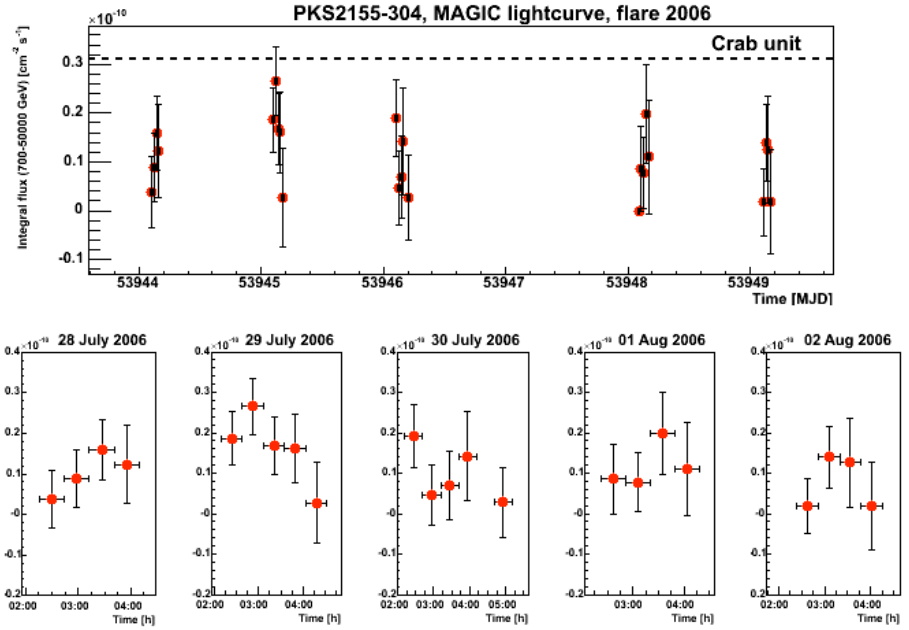
- Optical flux increases by more than 50%
  - **Monitoring by 35cm KVA (La Palma) and by 1m Tuorla telescope (Finland)**
- ASM (2-10 keV) is above 20 mCrab
  - **Data are public**
- H.E.S.S. or VERITAS report a TeV γ-ray flux above 0.5 crab units (2 crab units for Mkn 421 and Mkn 501)
  - **Bi-polar agreements between the collaborations**

PKS 2155-304 (z=0.117) H.E.S.S. trigger

- Multiwavelength campaign triggered by H.E.S.S. Atel #867 on 27 Jul 2006
- MAGIC large zenith angle observations from 28 July to 2 Aug
- Soft spectrum, index 3.7 even after deabsorption
- Clear detection on all nights, no significant variability







EBL