MAGIC Observations of Distant AGNs

Koji Saito

12.03.2010 PPSM Colloquium

MAGIC Telescopes

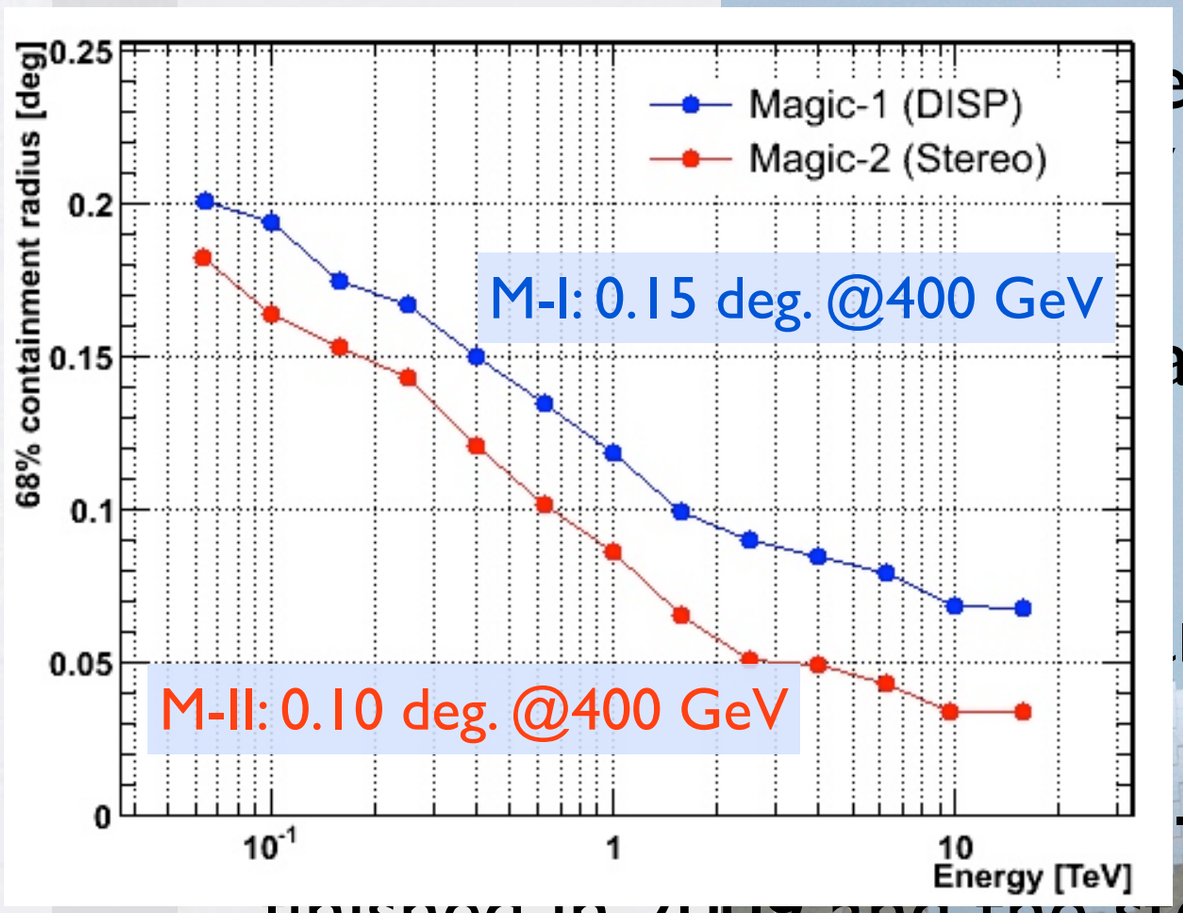
* MAGIC is currently a largest imaging air Cherenkov telescope in operation (17 m diameter)

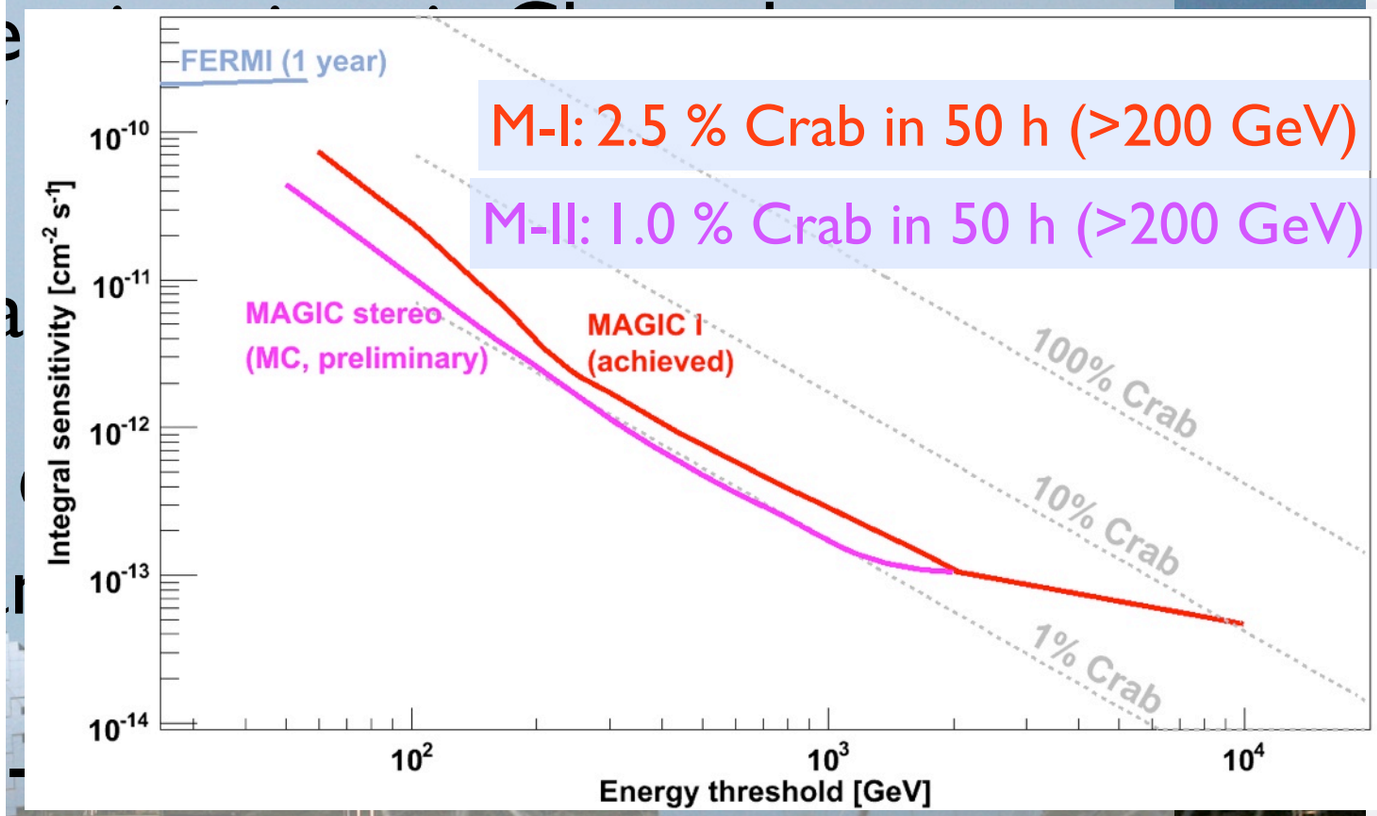
* Location: La Palma of Canary Island (Spain) at 2225 m a.s.l.

* Low energy threshold (50 GeV-60 GeV), good sensitivity at low (~100 GeV) energy range

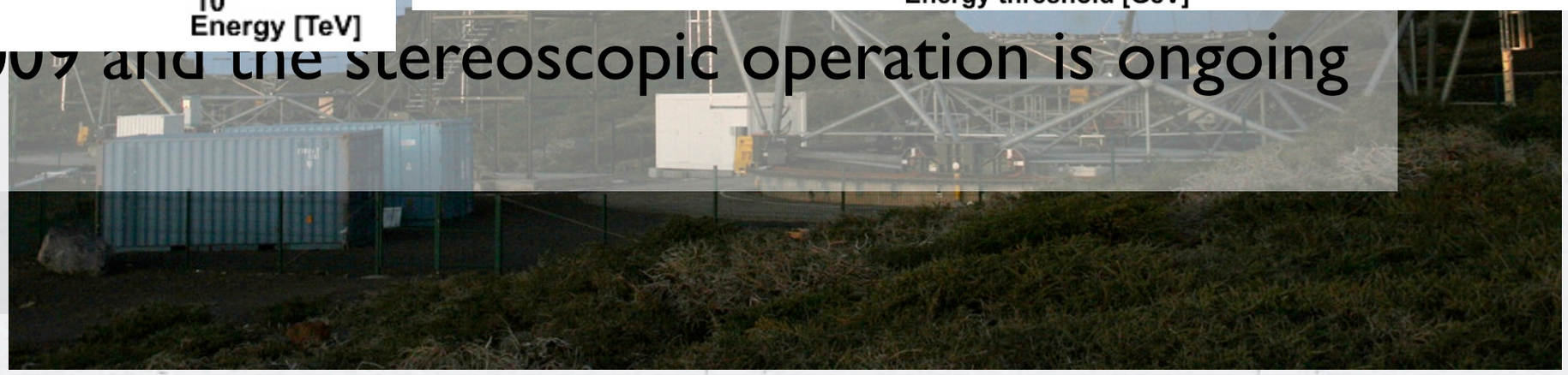
* Commissioning of MAGIC-II, clone of MAGIC-I was finished in 2009 and the stereoscopic operation is ongoing

MAGIC Telescopes



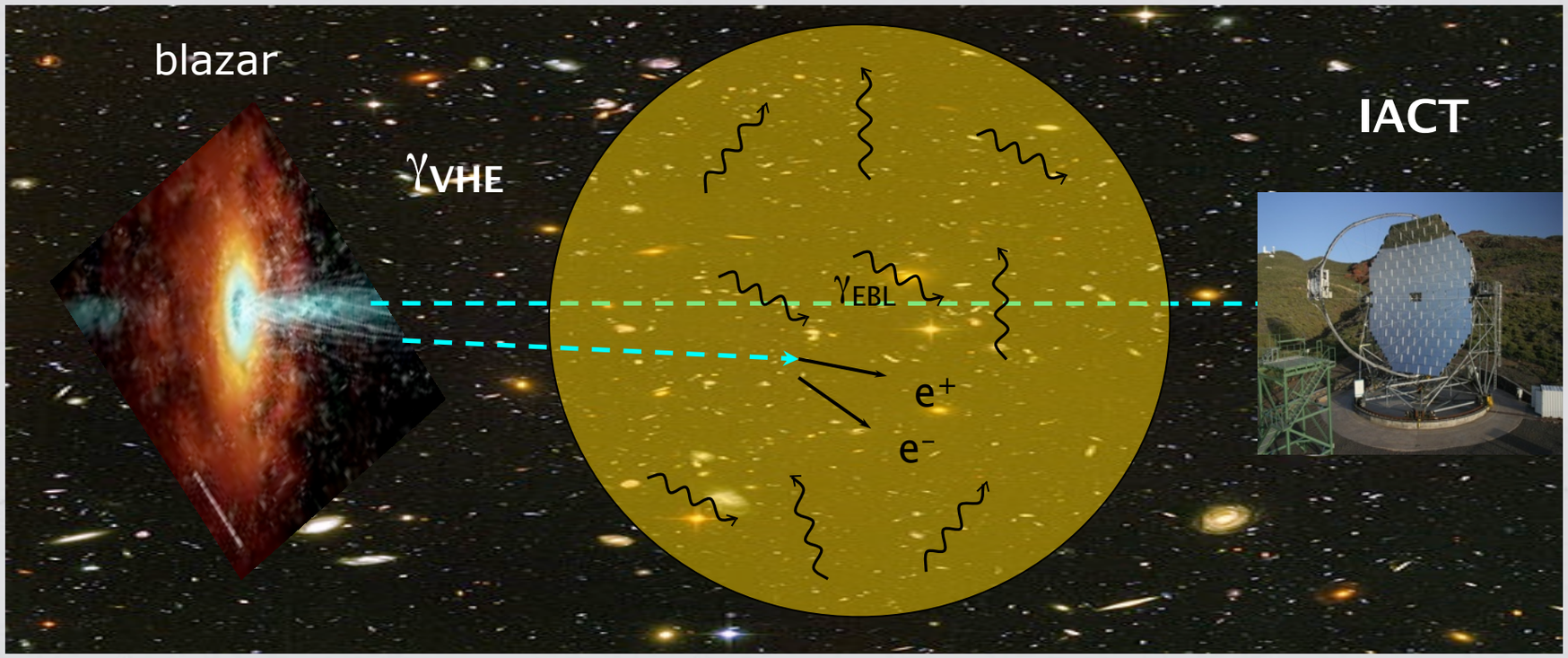


finished in 2009 and the stereoscopic operation is ongoing



MAGIC observation of Distant AGNs

The detection of VHE γ-rays from high-redshift AGNs is important, since γ-rays at VHE region from distant sources are expected to be strongly attenuated by the interaction with low energy photons (extragalactic background light (EBL)).



MAGIC observation of Distant AGNs

The detection of VHE γ-rays from high-redshift AGNs is important, since γ-rays at VHE region from distant sources are expected to be strongly attenuated by the interaction with low energy photons (extragalactic background light (EBL)).

* 3C 279: z = 0.536
  2007 observations
* 3C 454.3: z = 0.859
  2009 stereo observations
* 3C 66A: z = 0.44 (uncertain)
  2009/2010 stereo observations

3C 279

* One of the brightest sources in all wavelength

* Flat Spectrum Radio Quasar (FSRQ)

* Redshift: z = 0.536

* First blazar discovered with EGRET aboard the Compton Gamma Ray Observatory

* Apparent luminosity ~10^{48} erg/s

* Fast time variation: T ~ 6 hr in EGRET observation

3C 279: MAGIC Observation in 2006

- Observation period: January ~ April of 2006

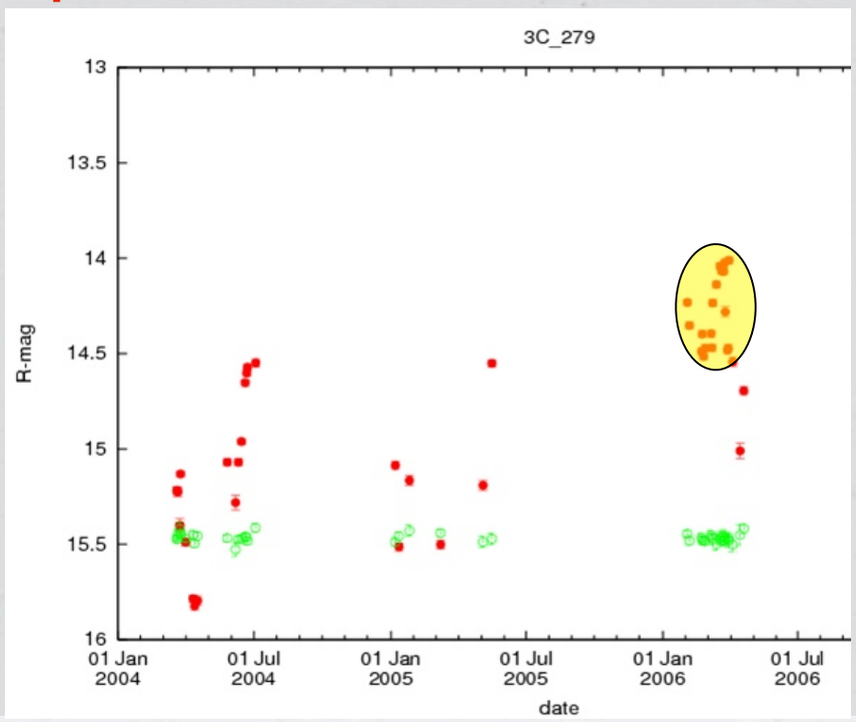
- Total observation time: 9.7 hr

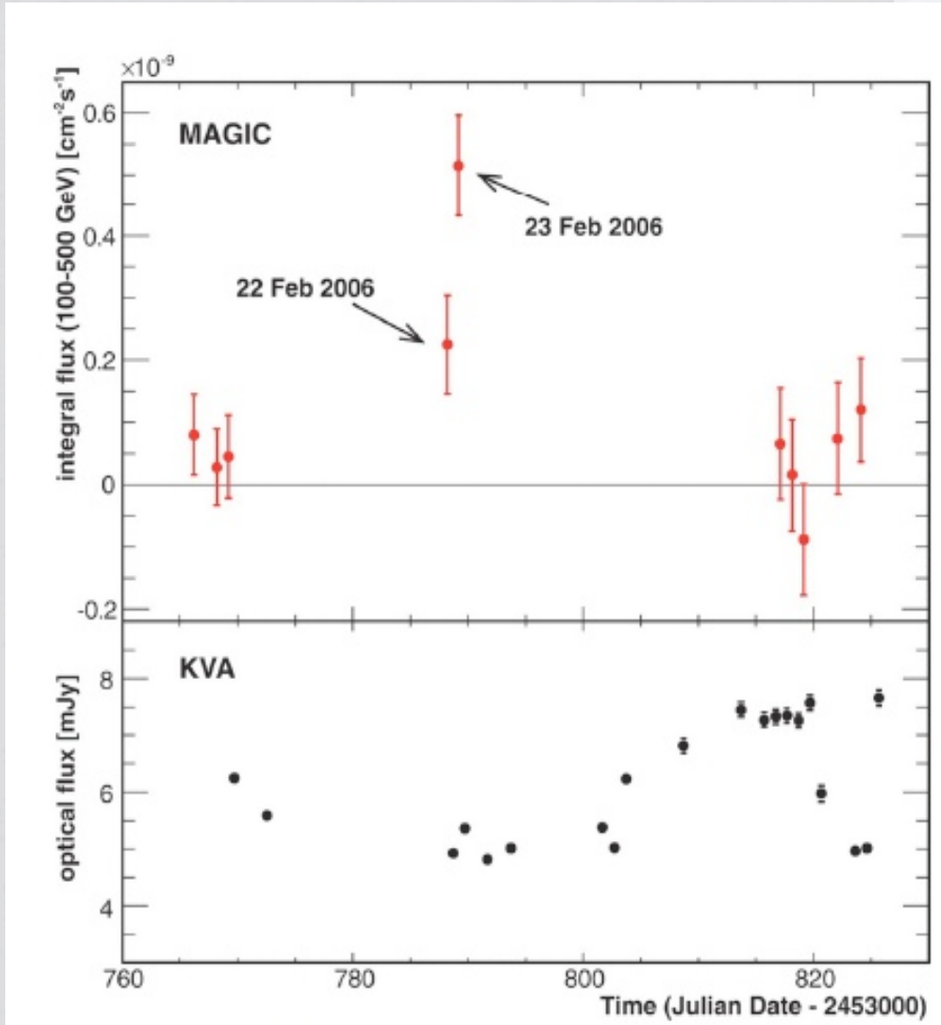
- Signal detected with 5.8 σ (only one day)

VHE distant champion!!

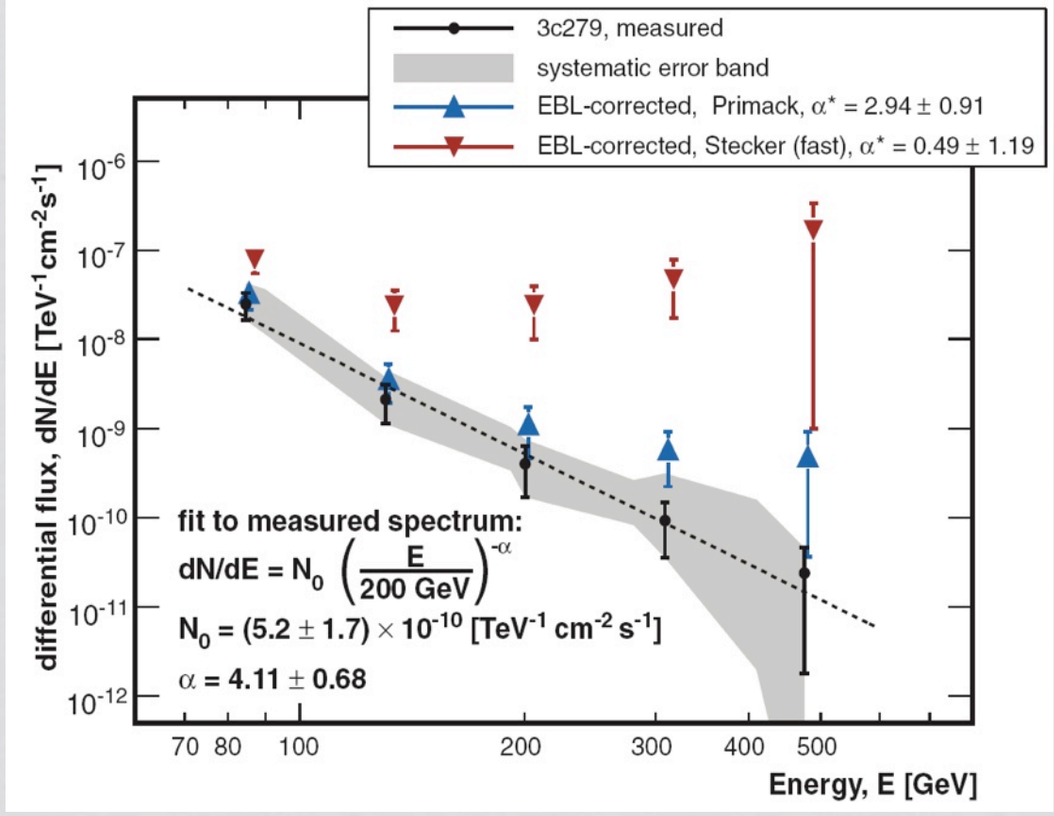
- Optical flux:

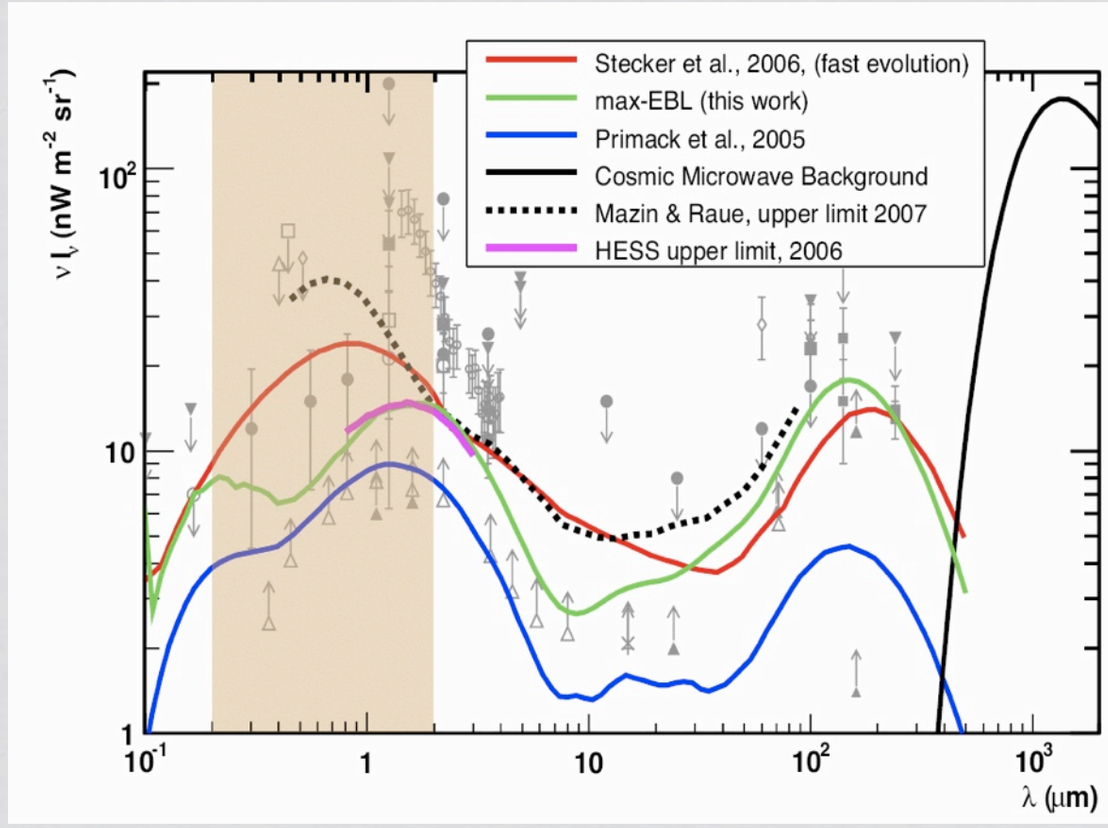
twice as high as the baseline





MAGIC collaboration, Science 320 (2008) 1752





2006 spectral index = 4.11 ... provides interesting information for the EBL model

Two extreme EBL model
- Primack et al. 2005, close to the lower limits set by galaxy counts
- Stecker et al. 2006, "fast-evolution" model

Assuming the intrinsic spectral index cannot be harder than 1.5, model parameters can be tuned to give EBL upper limit

SED (spectral energy distribution)

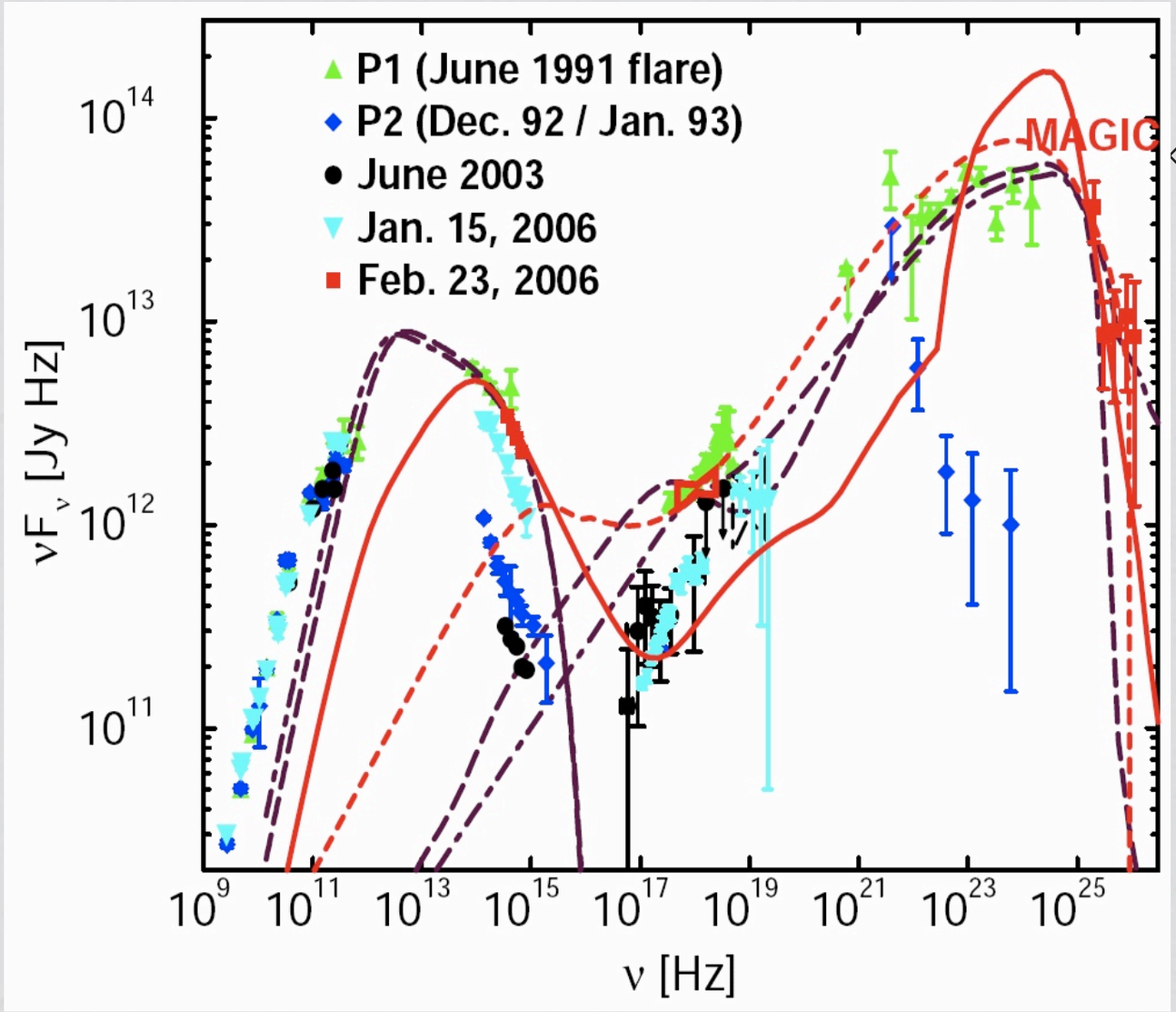
Leptonic model:

* One zone EC model fails to reproduce X-ray flux, unusually low B-field (0.03 G) or high Γ factors

* Multi-zone emission seems to be needed

Hadronic model:

* Hadronic model seems to describe the data, but very large jet luminosity is required (10^{49} erg/s)

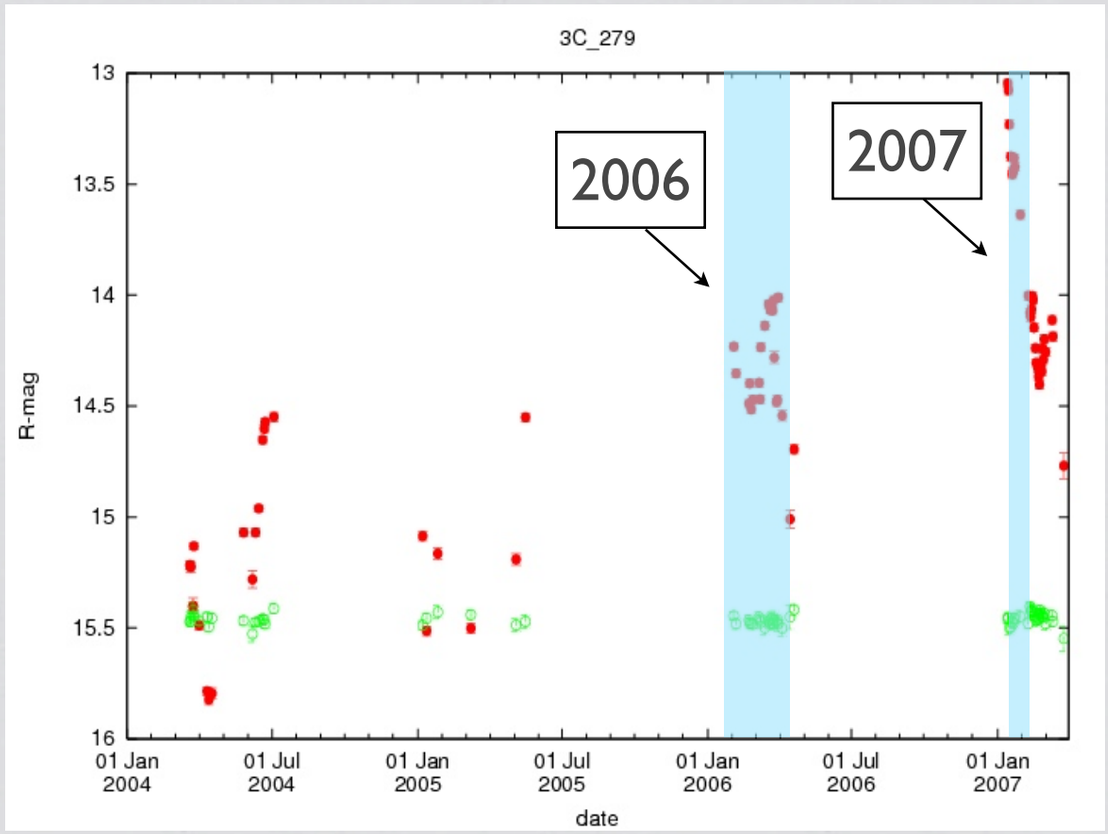


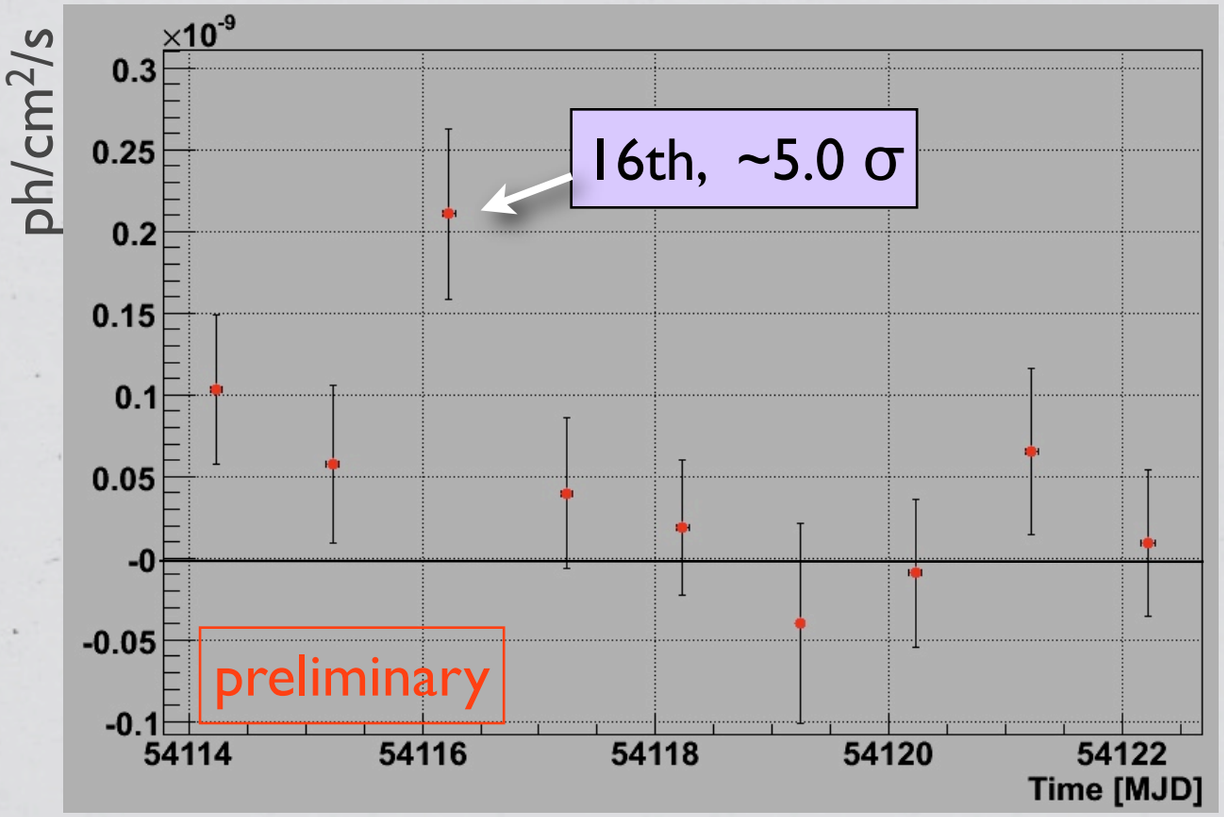
Böttcher et al. 2009

Red: Leptonic
Maroon: Hadronic

More (multi-wavelength) observation is needed to understand the emission process

3C 279: MAGIC Observation in 2007

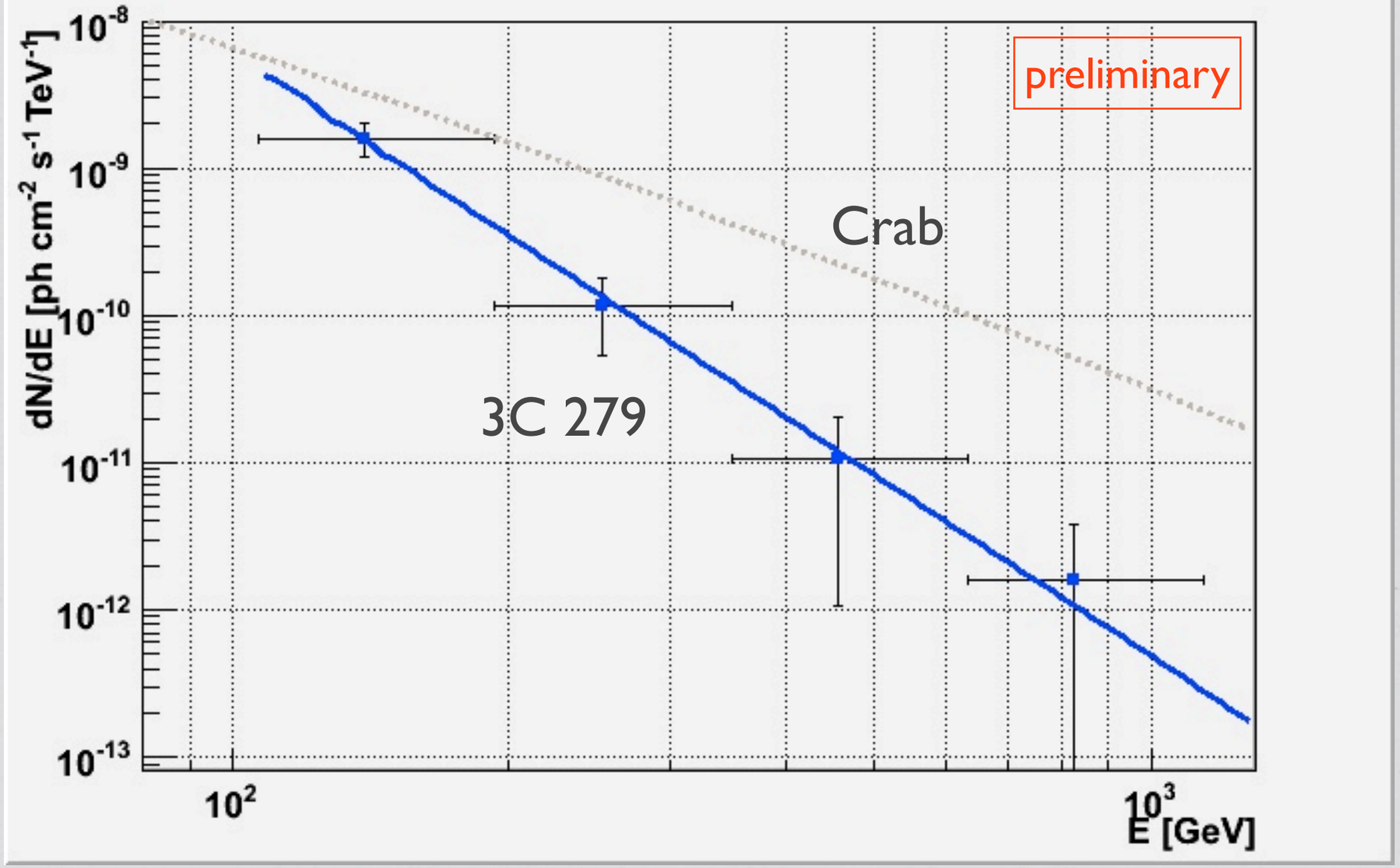




In January 2007, since the optical R-band flux reached historically high level, MAGIC observations were triggered

VHE γ-ray flare was detected at only the 16th of January → similar to 2006

Differential spectrum: spectral index is consistent with 2006 observations within errors



$(6.6\pm1.8) \times 10^{-10}\ (E/300\ \mathrm{GeV})^{-\alpha}\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}\ \mathrm{TeV}^{-1}$

$\alpha = 4.00\pm0.56$

SED modeling ... ongoing

3C 454.3

* Well known FSRQ

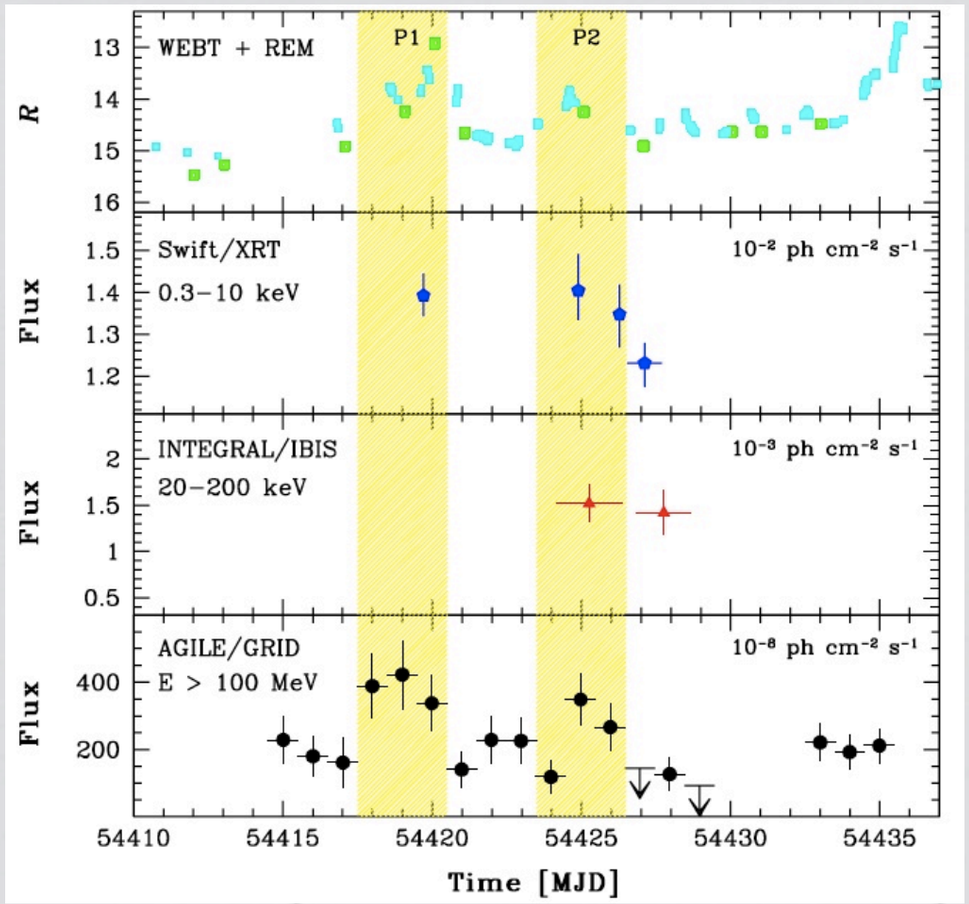
* Redshift: z = 0.859

* EGRET detected γ-ray emissions several times

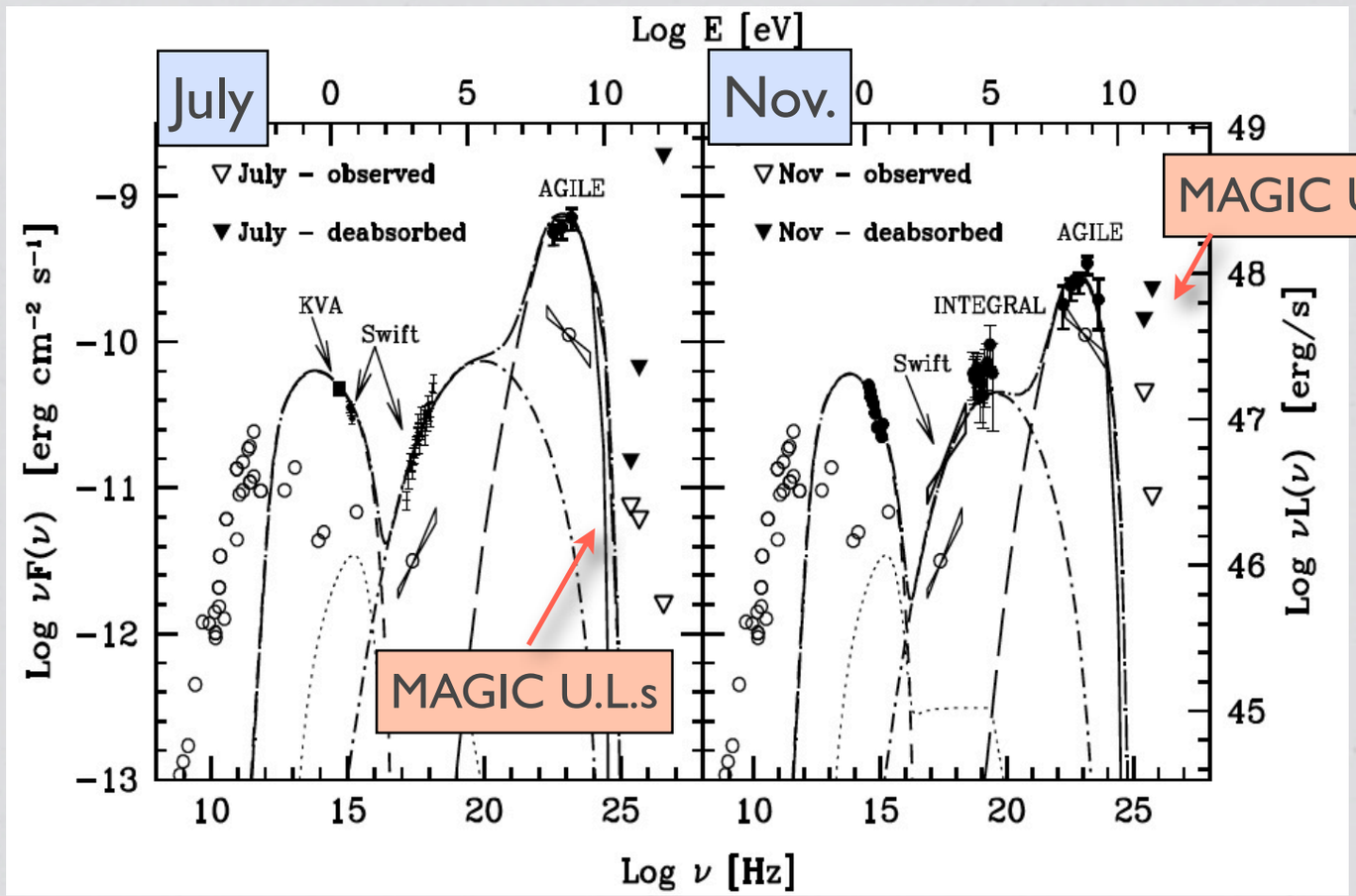
* In 2007 intense flaring observed in optical, triggered X-ray observations (Swift), γ-rays (AGILE), those triggered MAGIC

3C 454.3

Light curves in November 2007



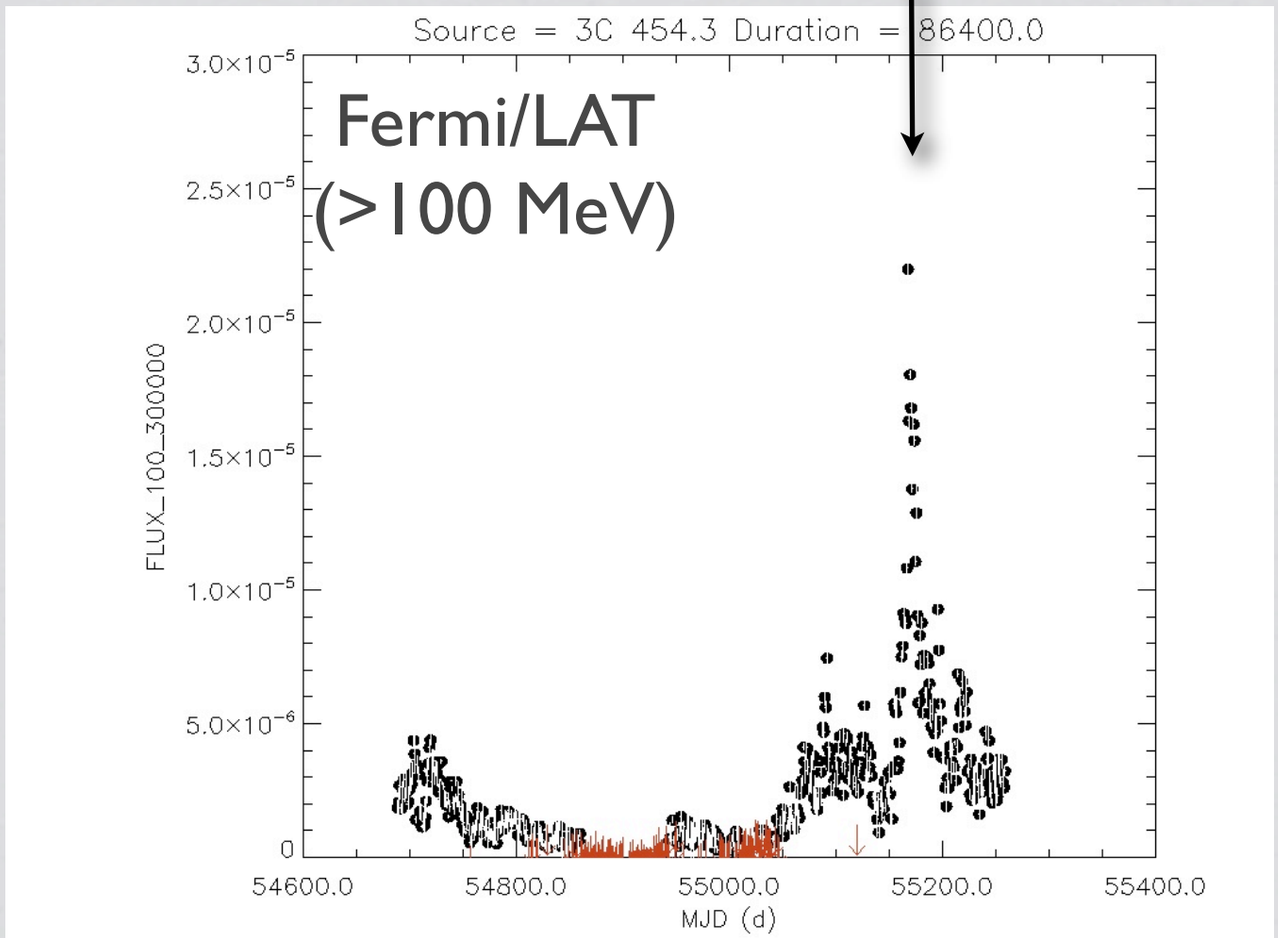
SED 2007



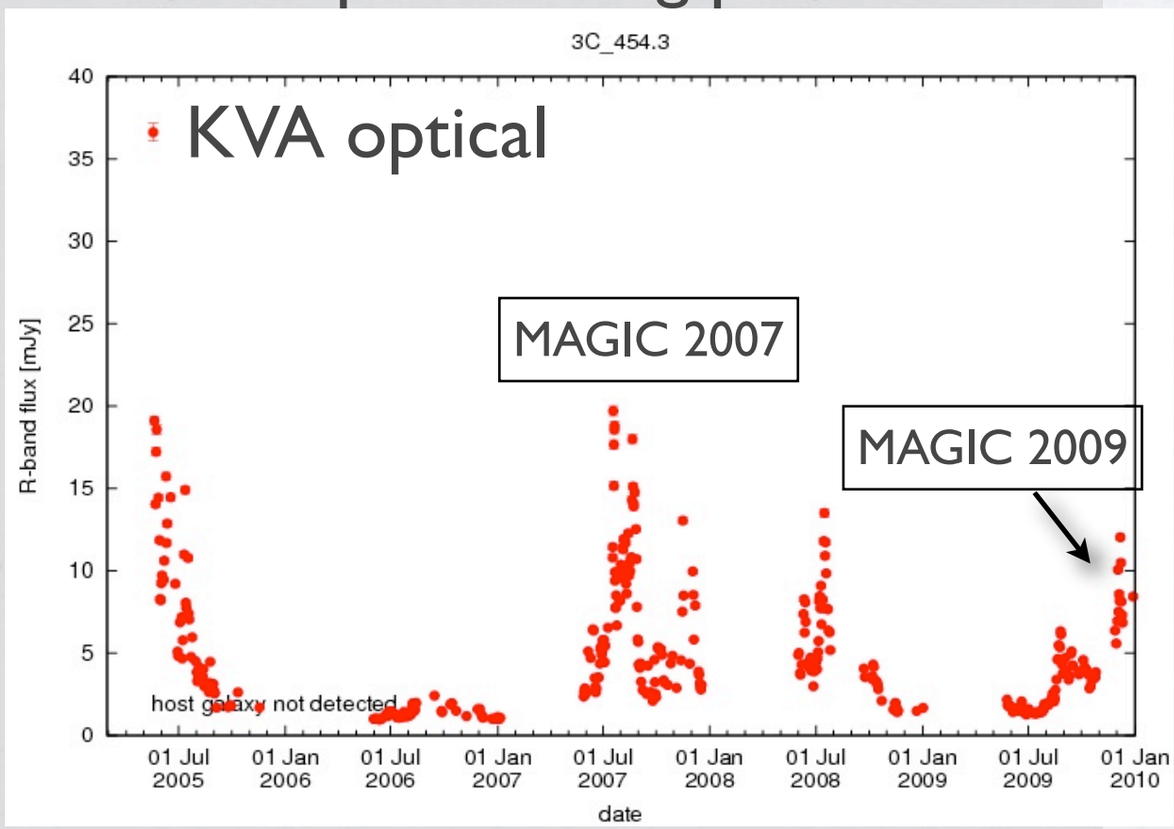
No VHE γ-ray emission was seen, U.L. derived

3C 454.3: MAGIC observations in 2009

extraordinarily flare in December!!

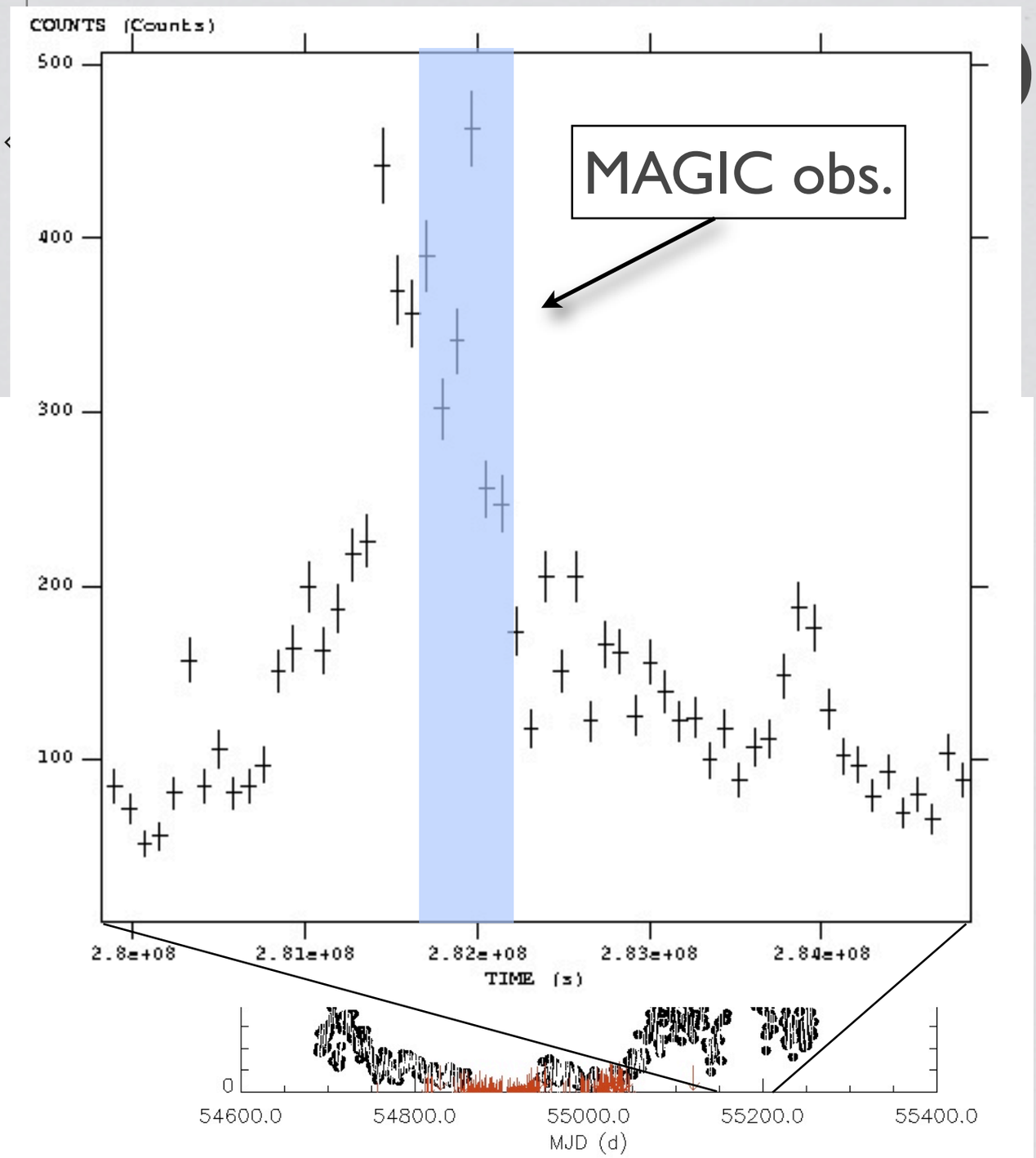


optical: rising phase

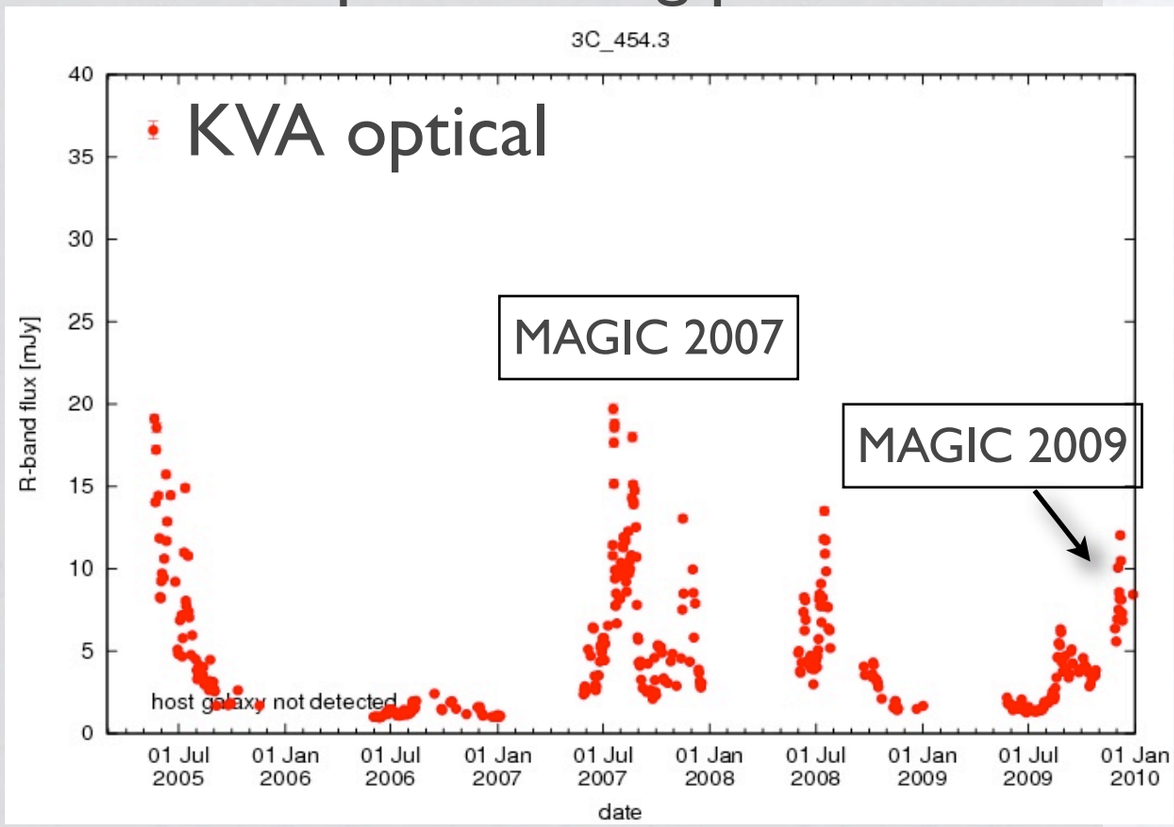


MAGIC stereo observations:
2009/12/6 ~ 2009/12/11
Total effective ovservation time:
6 hr

3C 454.3: MAGIC observations in 09



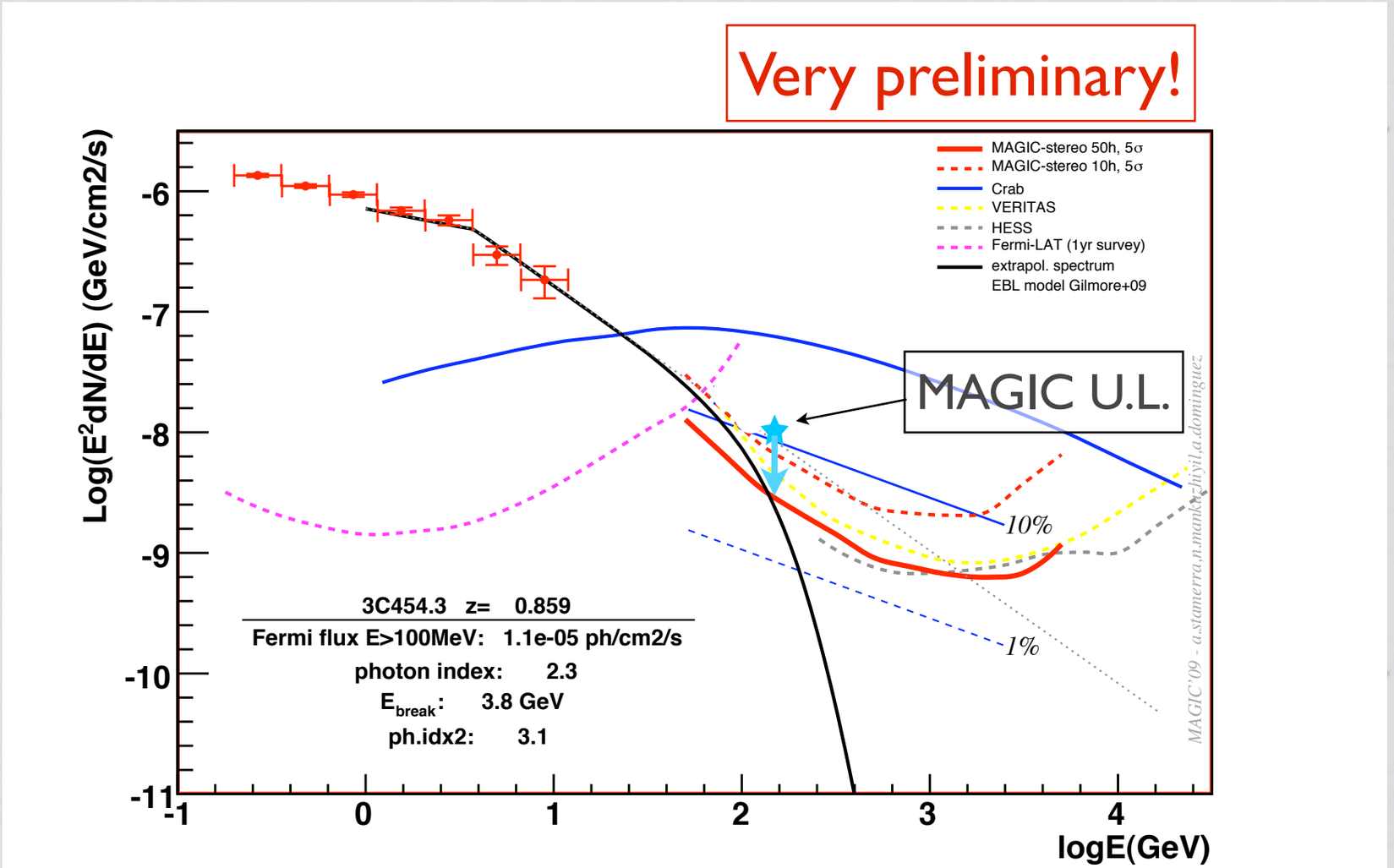
optical: rising phase



MAGIC stereo observations:
2009/12/6 ~ 2009/12/11
Total effective ovservation time:
6 hr

3C 454.3: MAGIC observations in 2009

No signal detection, U.L. was derived



3C 66A

* 3C 66A and 3C 66B are separated by 6′ in the sky

* 3C 66A:

 - Intermediate-frequency peaked BL Lac

 - Synchrotron peak is between 10^{15} ~ 10^{16} Hz

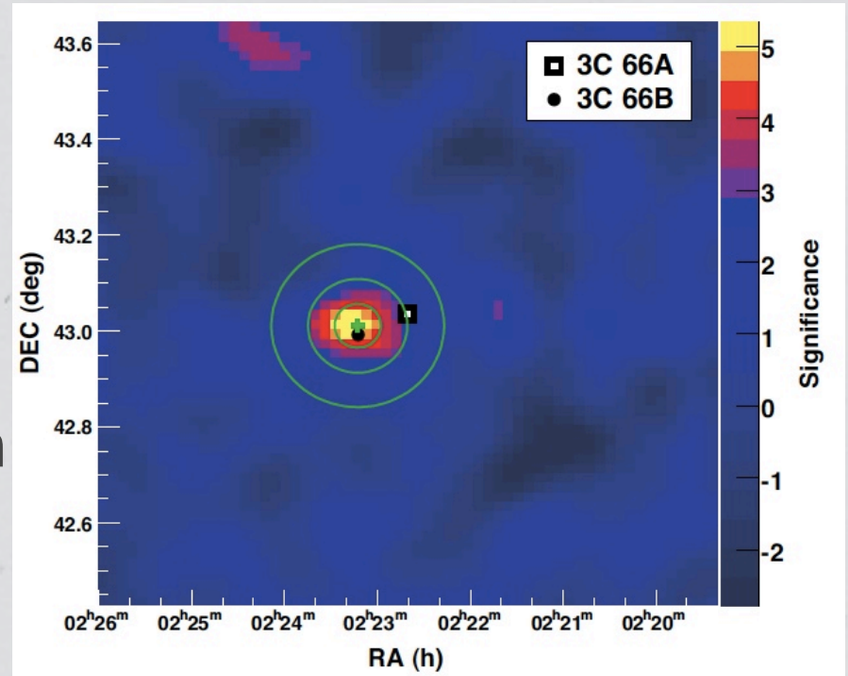
 - Redshift was reported as z = 0.44 (Miller et al. 1978, Lanzetta et al. 1993), although authors were not certain since their estimations are based on only single week line emission

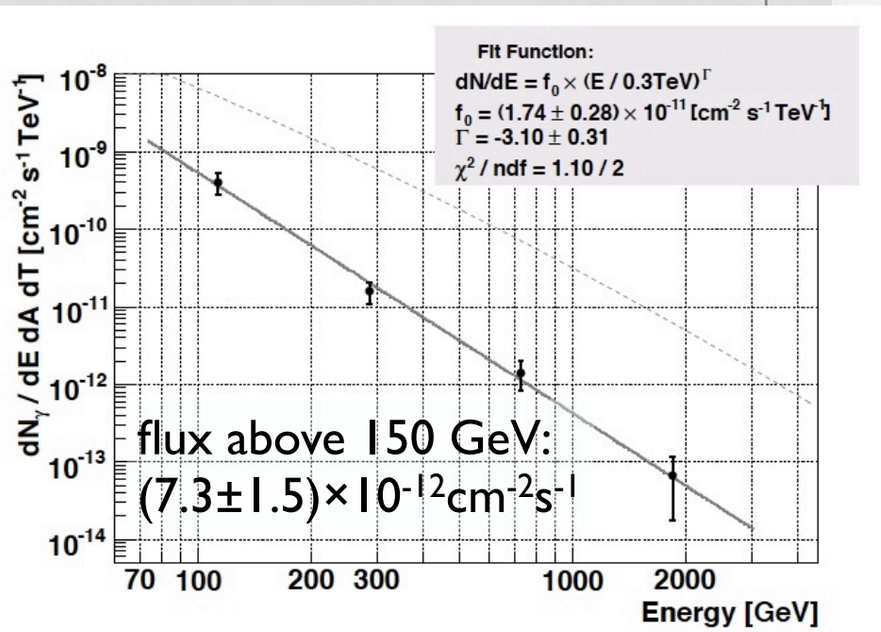
* 3C 66B: Fanaroff-Riley I type radio galaxy with a redshift of z = 0.0215 (Stull et al. 1975)

Previous Observations

MAGIC

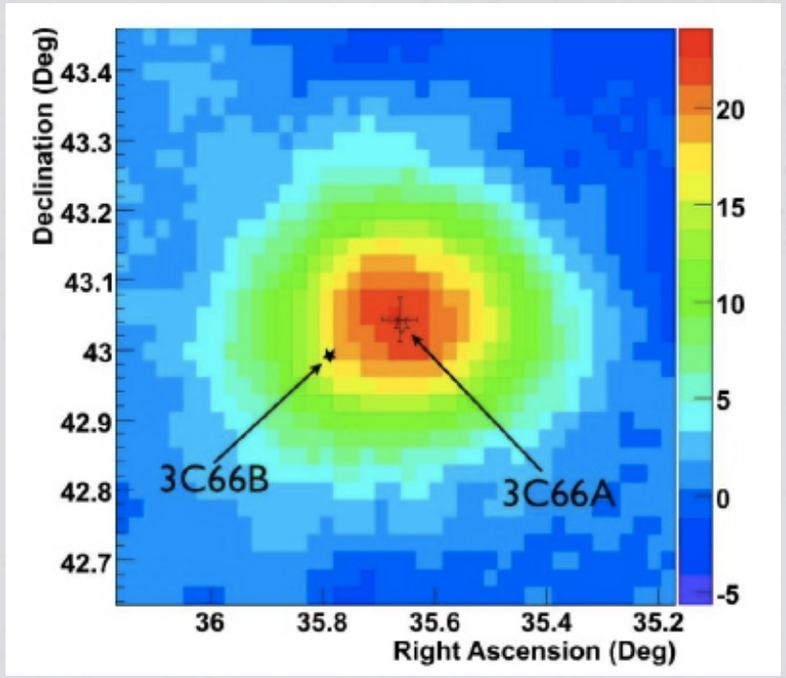
- Aug. - Dec. 2007 (45 h)
  Signal is centered on 3C 66B position

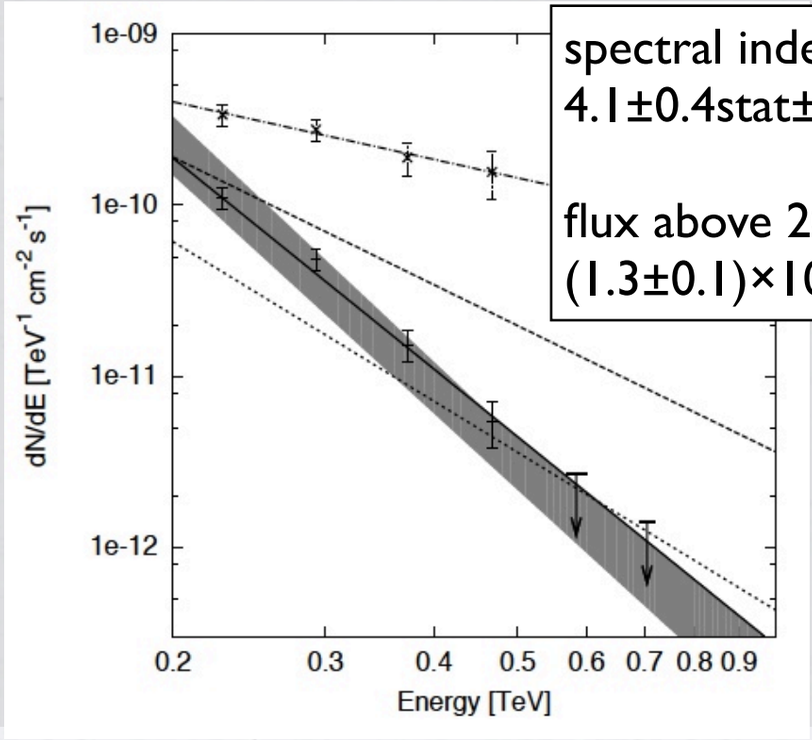




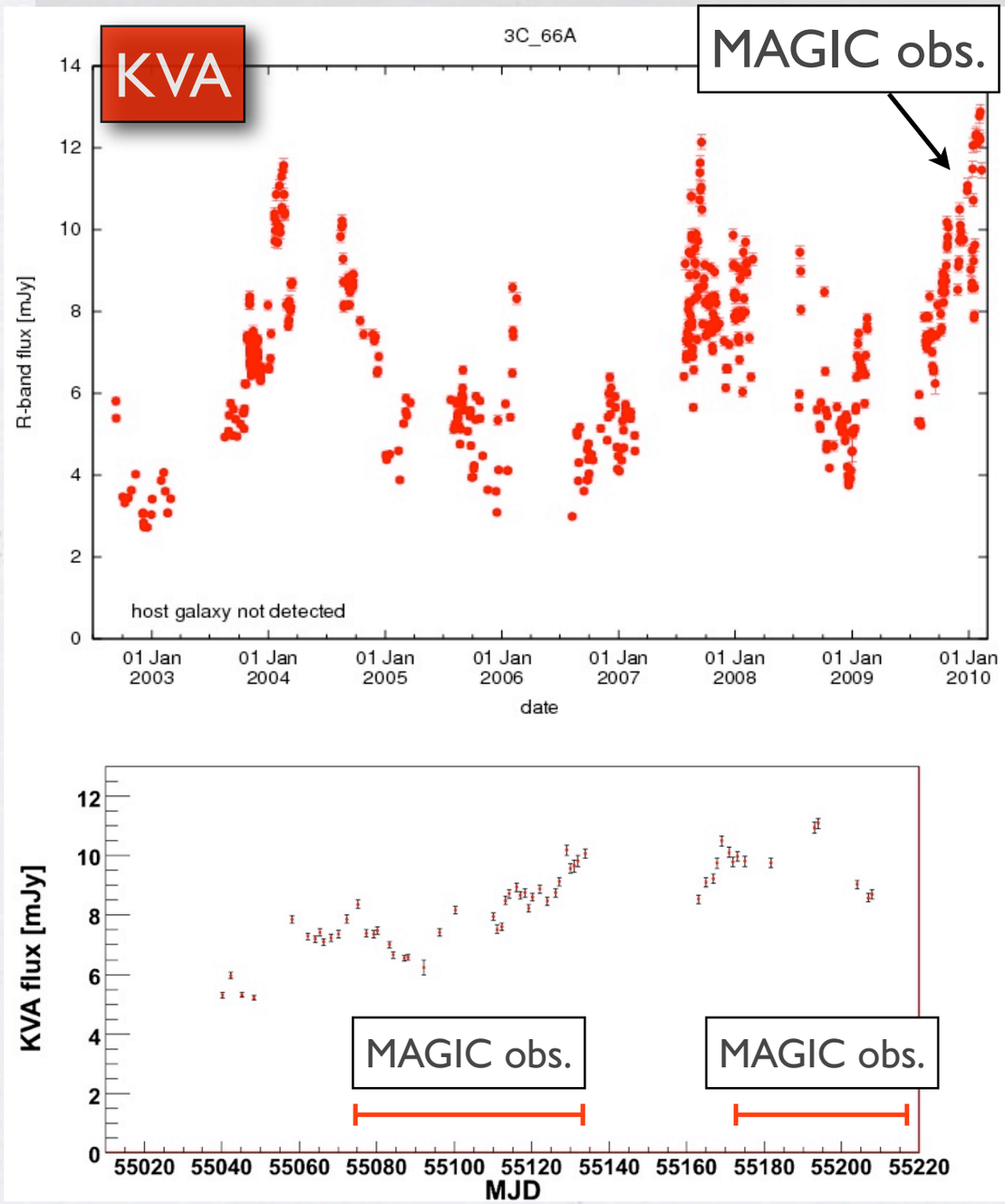
VERITAS

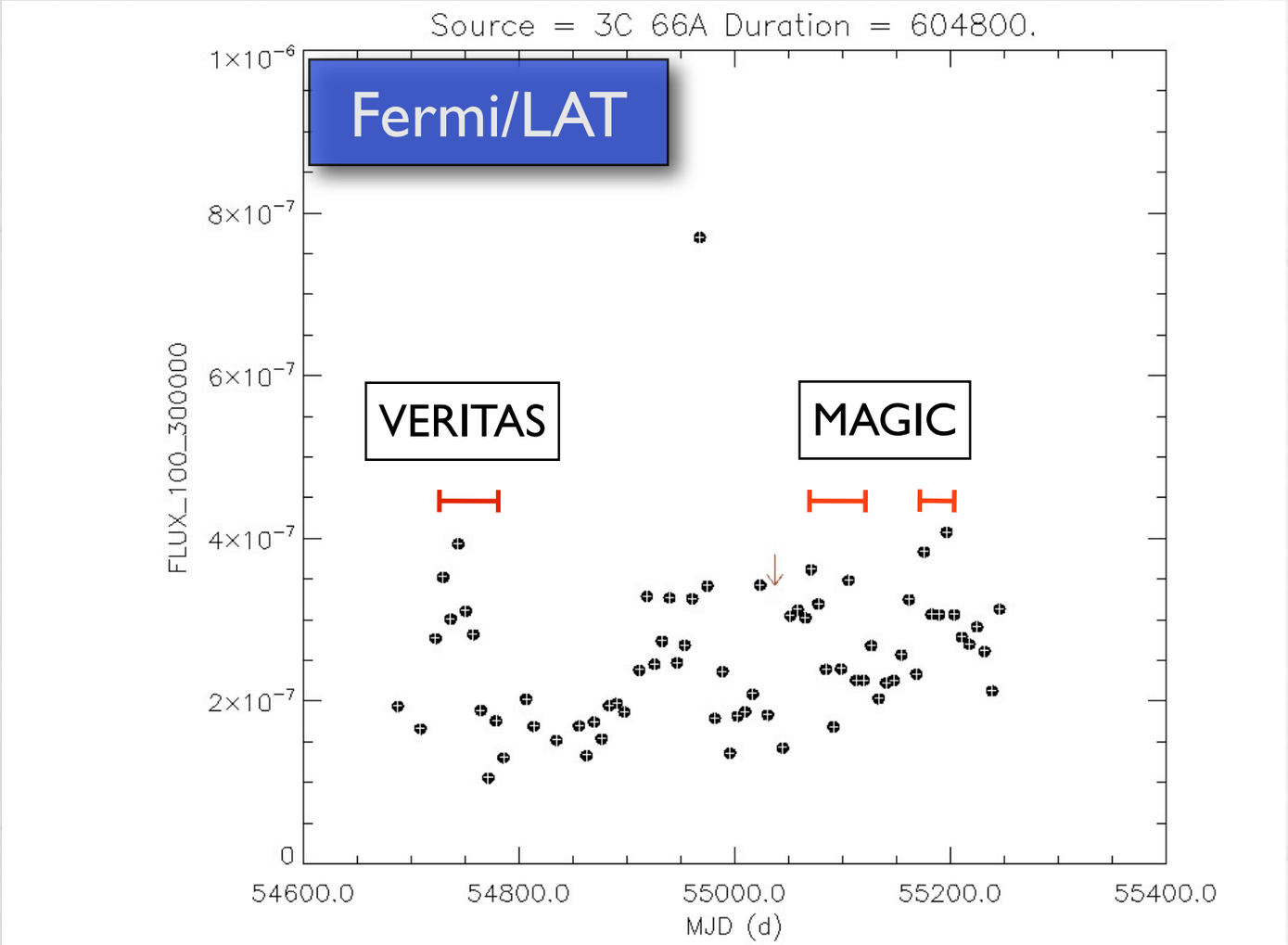
Sept. 2007 - Jan. 2008, (4.7 h)
Sept. 2008 - Nov. 2008 (28 h)
Signal is centered on 3C 66A position





3C 66A: MAGIC observations in 2009/2010





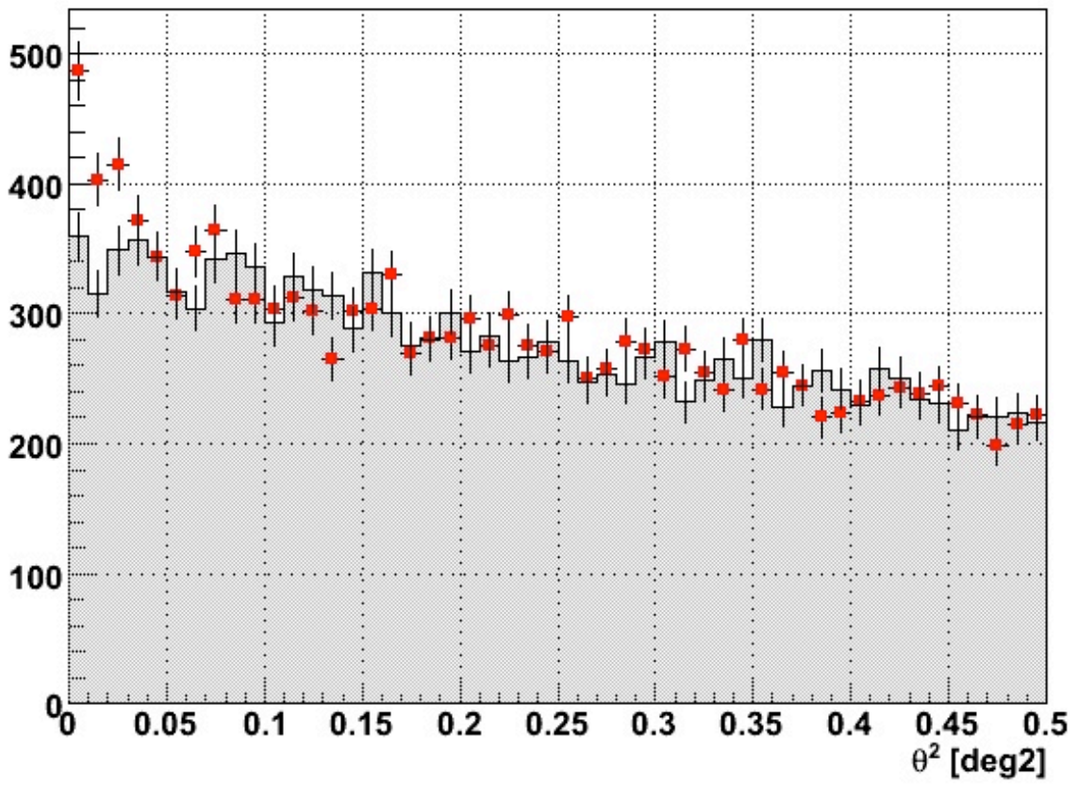
MAGIC stereo observations:

2009 Sept. (4.7 h), Oct. (12 h), Dec. (2.5 h)

2010 Jan. (2.3 h) total: 21.6 h

3C 66A: MAGIC observations in 2009/2010

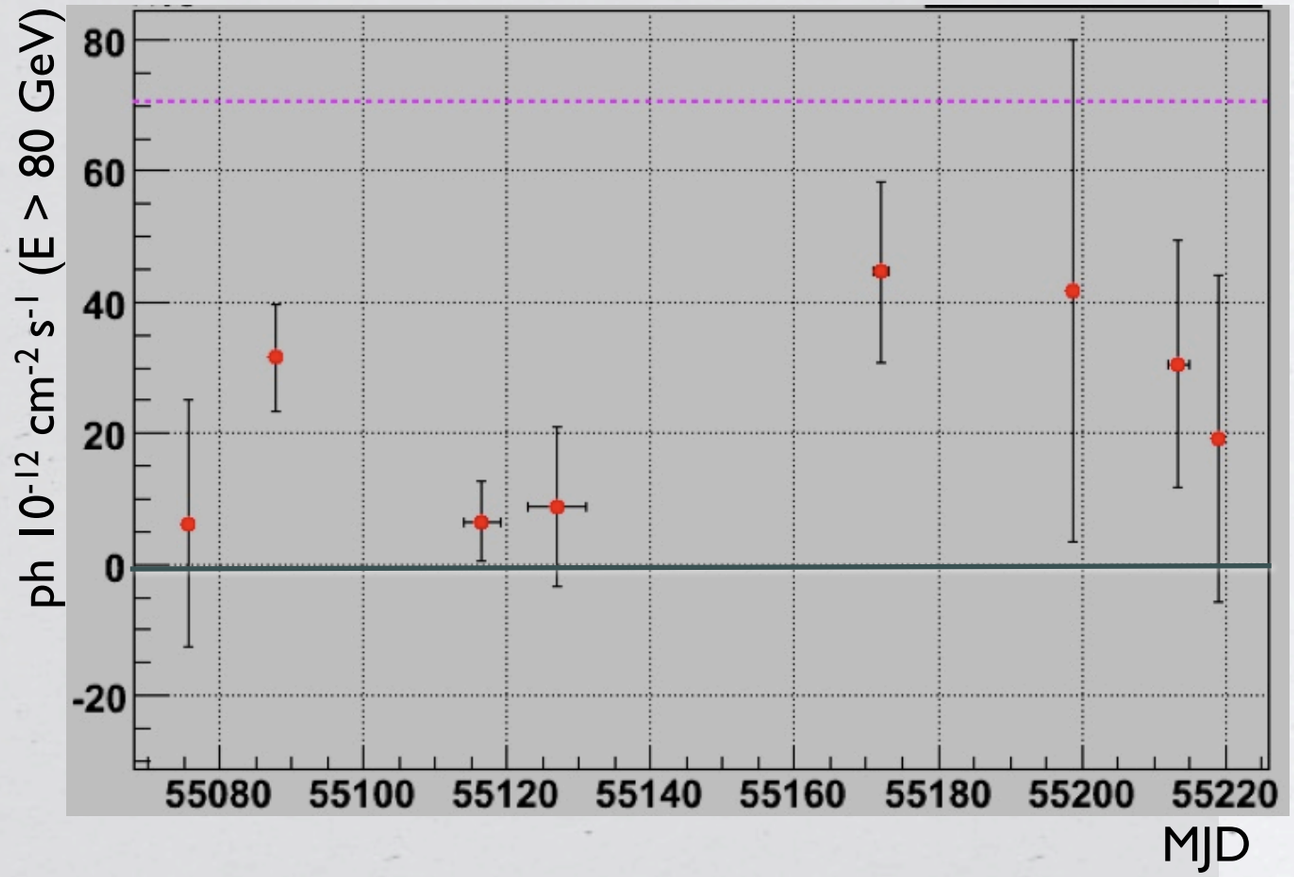
theta^2 plot



Signal: 219±30 events

Significance: 5.5 σ

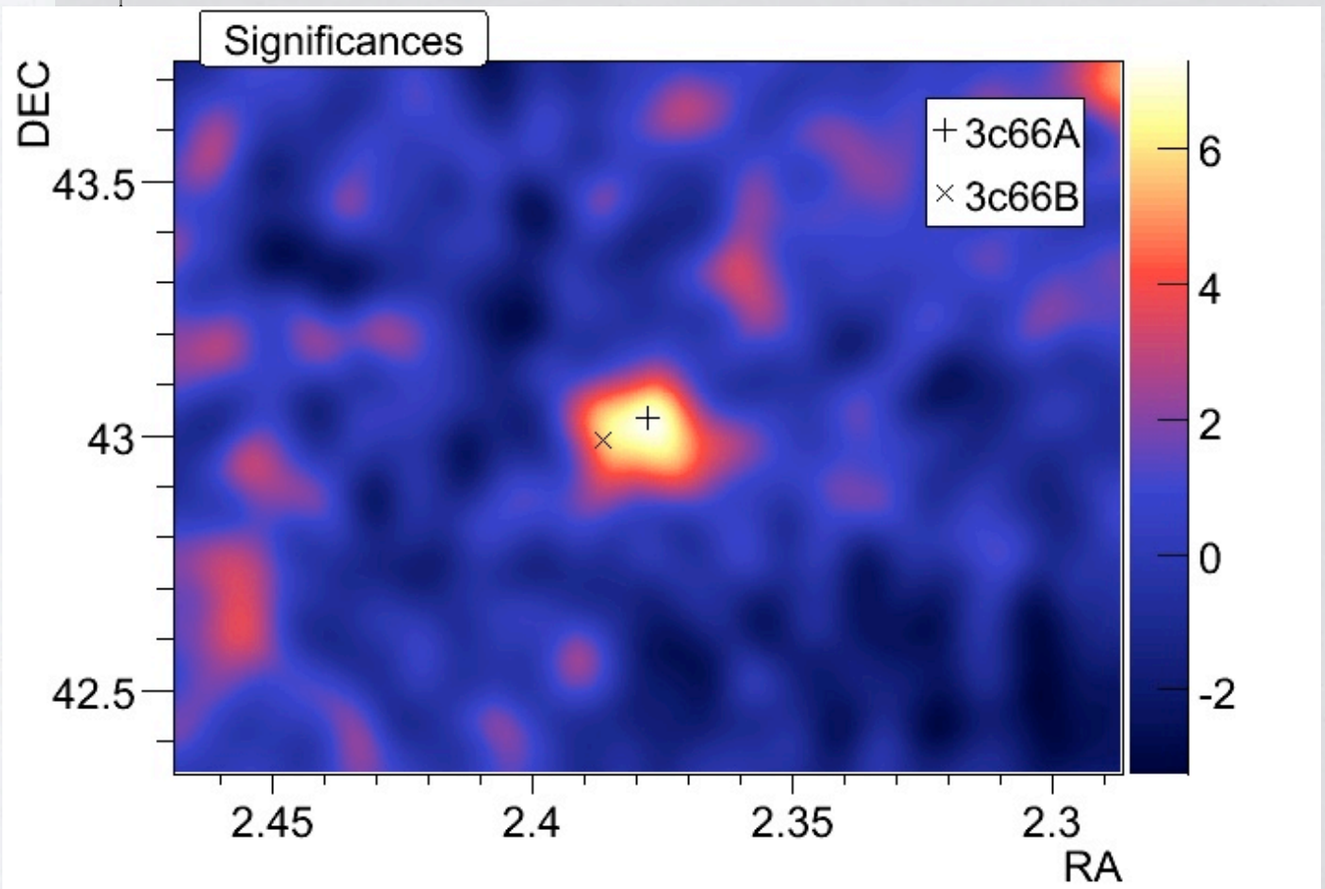
weekly light curve

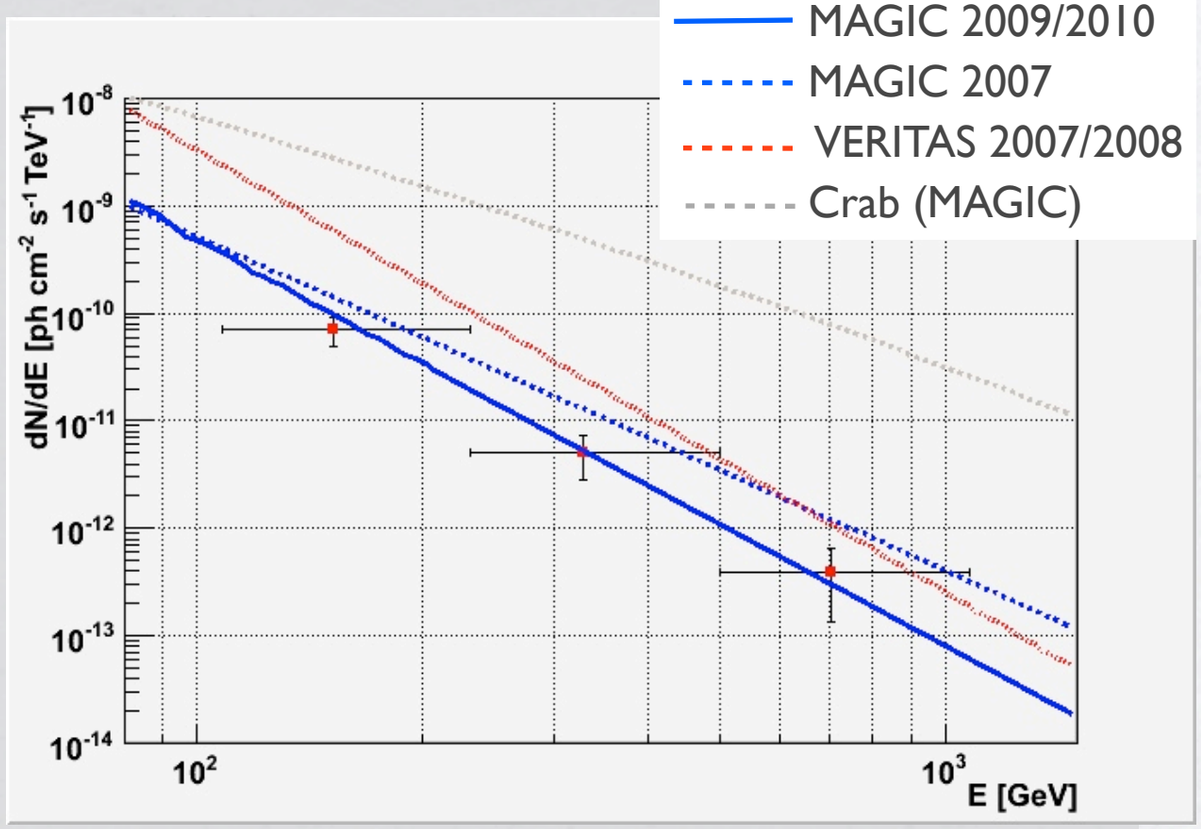


Variability ... not clear

Very preliminary!

3C 66A: MAGIC observations in 2009/2010





Fitted position:

(RA, Dec)=(35.668 deg., 43.000 deg.)

Deviation from 3C 66A: 0.03 deg., Probability: 92 %

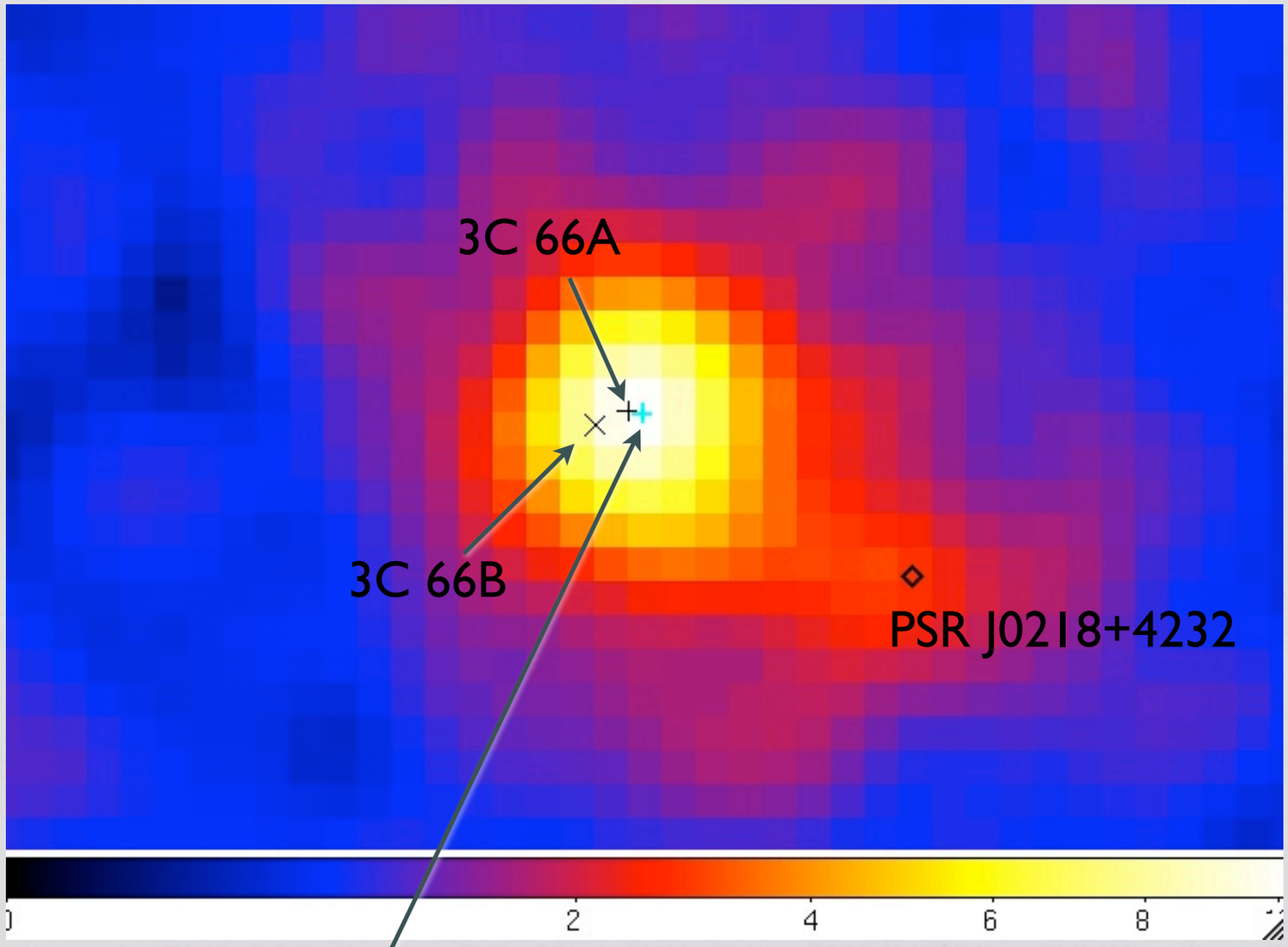
Deviation from 3C 66B: 0.13 deg., Probability: 14 %

Spectrum:

$2.7 \pm 0.8 \times 10^{-11}$ (E/200 GeV)$^{\alpha}$ cm^{-2} s^{-1} TeV^{-1}

$\alpha = 3.80 \pm 0.56$

3C 66A: Fermi skymap

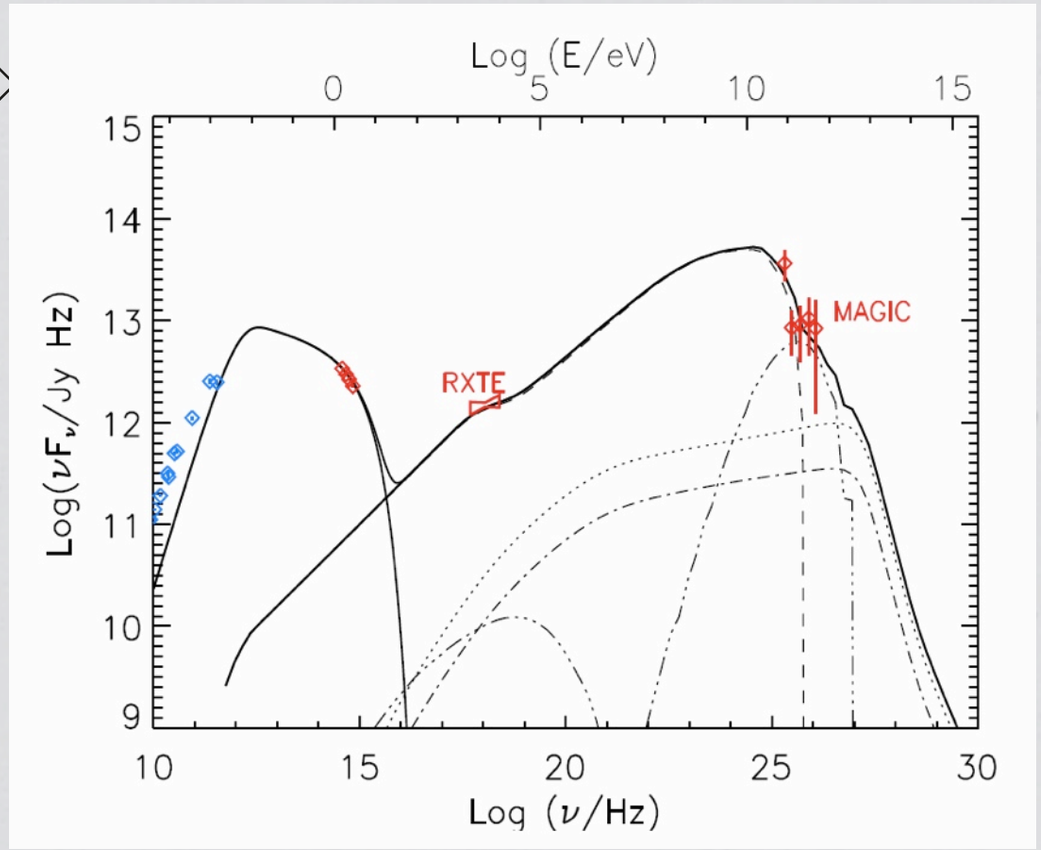


Fitted position:
(RA, Dec)=(35.6048 deg., 43.0251 deg.)
Deviation from 3C 66A: 0.0611 deg.
Deviation from 3C 66B: 0.1955 deg.

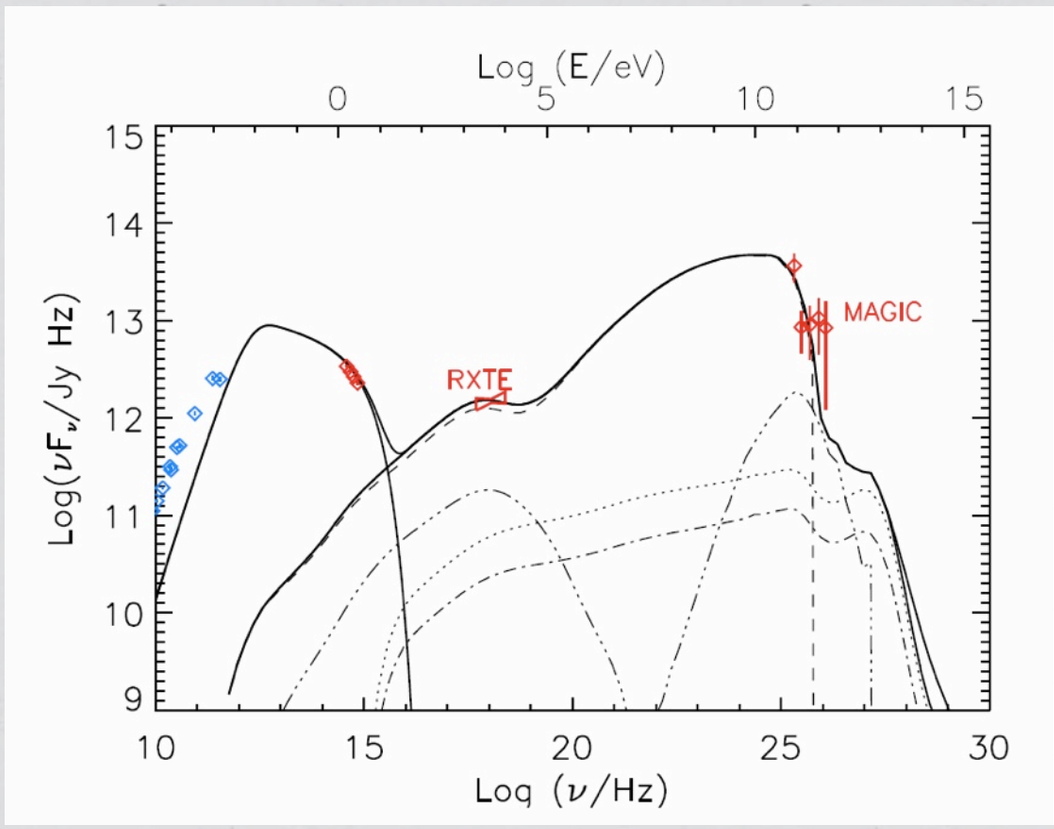
Summary

* 3C 279
  - MAGIC confirmed 3C 279 as the farthest VHE γ-ray source
  - Energy spectrum indicates low EBL models
  - We again detected VHE γ-ray signal in follow-up observation in 2007, behavior of the source is similar to 2006
* 3C 454.3
  - No VHE γ-ray signals were detected in both 2007 and 2009 observations
  - prediction of a sharp cut-off above 20-30 GeV
* 3C 66A
  - VHE γ-ray signals were detected with new MAGIC stereoscopic observation
  - SED modeling of new data is in progress

Böttcher et al. 2008

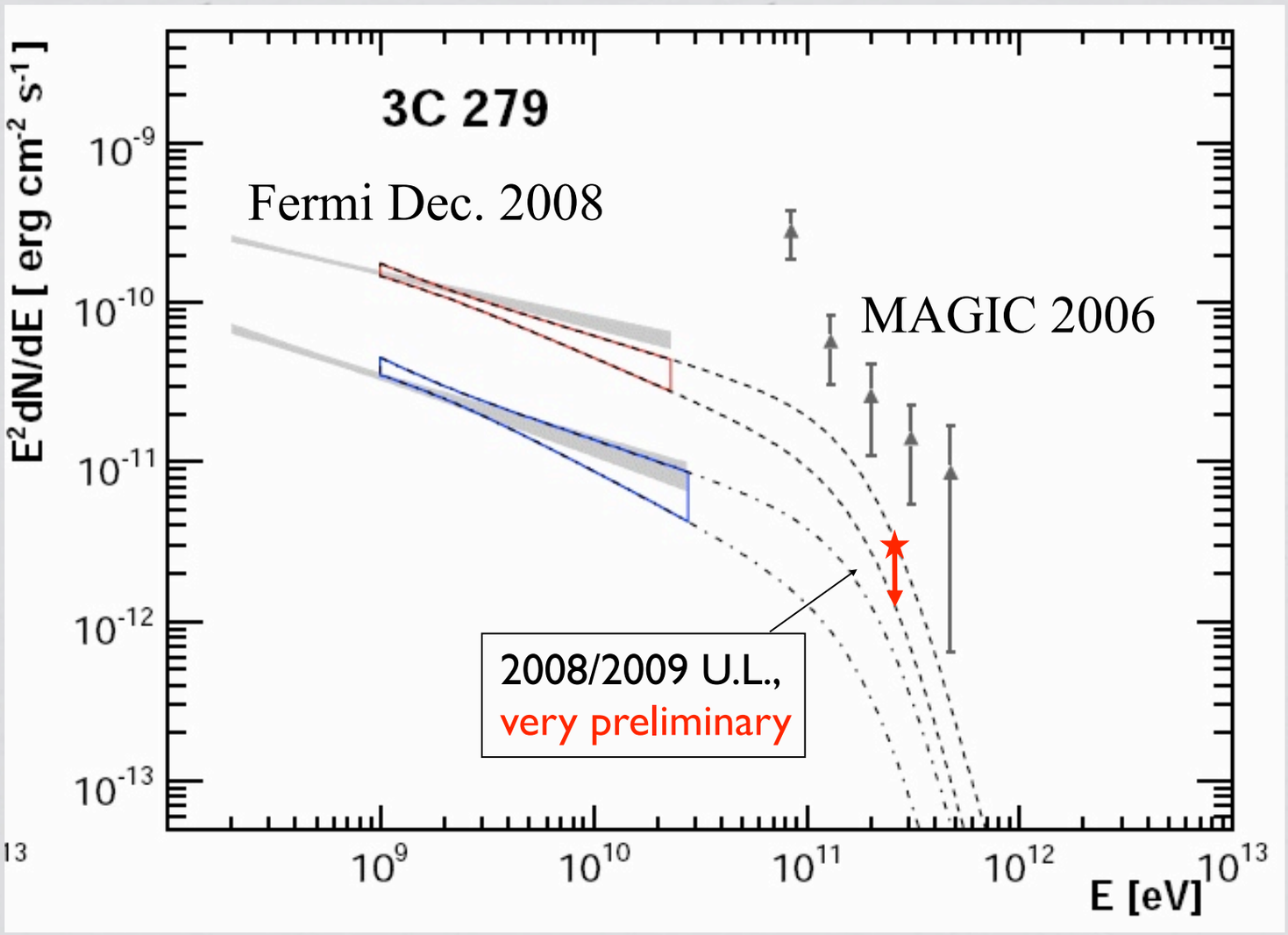


With only intrinsic synchrotron photons as targets for pγ pion production



Including external photon field from the BLR

Dashed: proton synchrotron and cascade
Triple-dot-dashed: μ synchrotron and cascade
Dotted: π^0 cascade
Dot-dashed: $\pi^{\pm}$ cascade



Abdo et al. 2009, to be submitted

AGN o

Source	z	Type	Discovery
M87	0.004	FR-I	HEGRA
Mrk421	0.031	HBL	Whipple
Mrk501	0.034	HBL	Whipple
1ES2344+514	0.044	HBL	Whipple
Mrk180	0.045	HBL	MAGIC
1ES1959+650	0.047	HBL	7TA
PKS0548-322	0.069	HBL	HESS
BL Lac	0.069	LBL	MAGIC
PKS2005-489	0.071	HBL	HESS
RGB J0152+017	0.080	HBL	HESS
PG1553+113	>0.09	HBL	HESS/MAGIC
W Comae	0.102	LBL	VERITAS
PKS2155-304	0.116	HBL	Durham
1ES1426+428	0.129	HBL	Whipple
1ES0806+524	0.138	HBL	VERITAS
1ES0229+200	0.139	HBL	HESS
H2356-309	0.165	HBL	HESS
1ES1218+304	0.182	HBL	MAGIC
1ES1101-232	0.186	HBL	HESS
1ES0347-121	0.188	HBL	HESS
1ES1011+496	0.212	HBL	MAGIC
S5 0716+714	0.310	LBL	MAGIC
3C279	0.536	FSRQ	MAGIC
3C66A/B	0.44?/0.02	IBL/FR-I	VERITAS/MAGIC
PKS1424+240	not known	IBL	VERITAS