

MAGICによる最近の観測結果

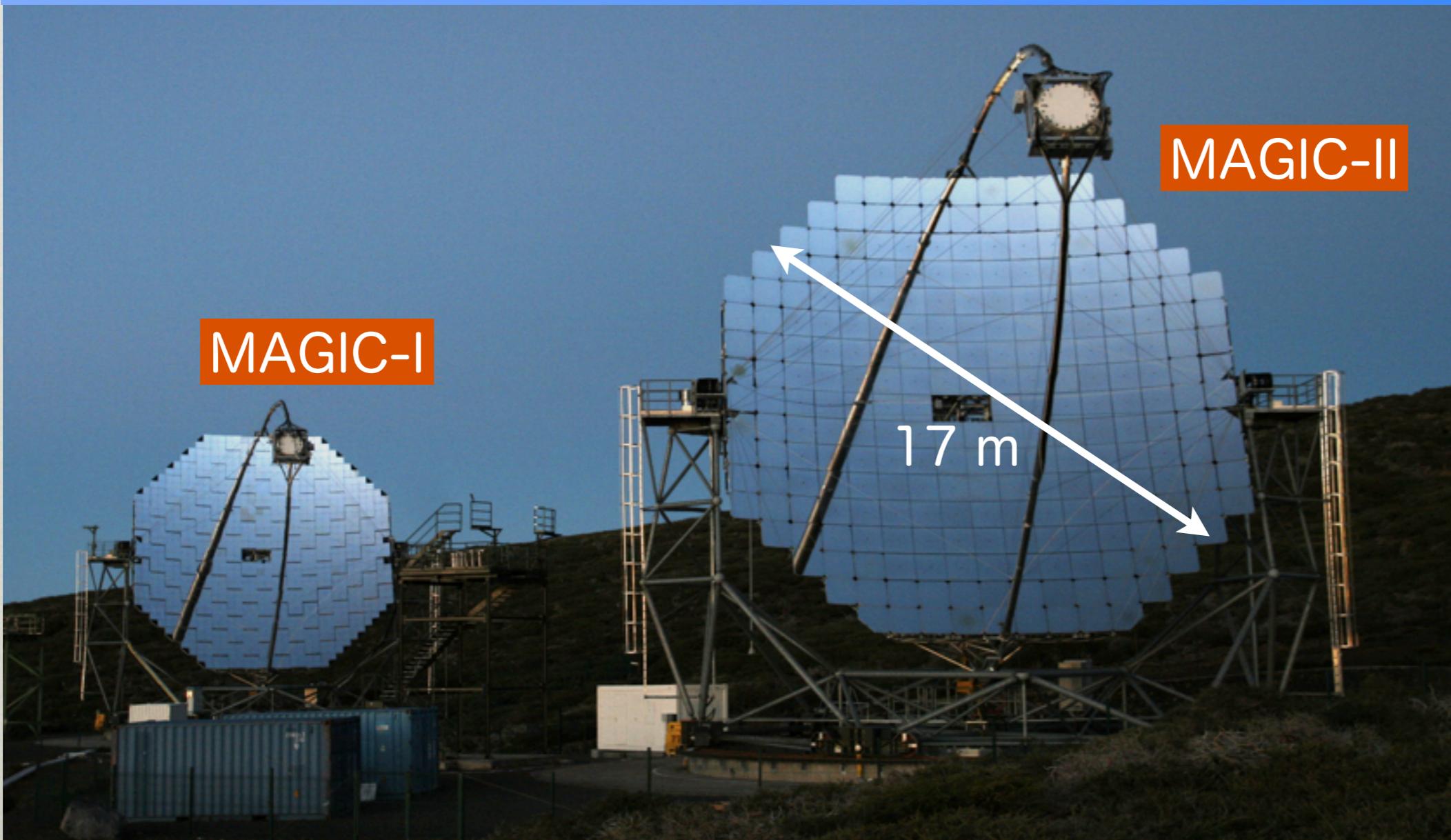
齋藤浩二 (ICRR)

03.09.2013

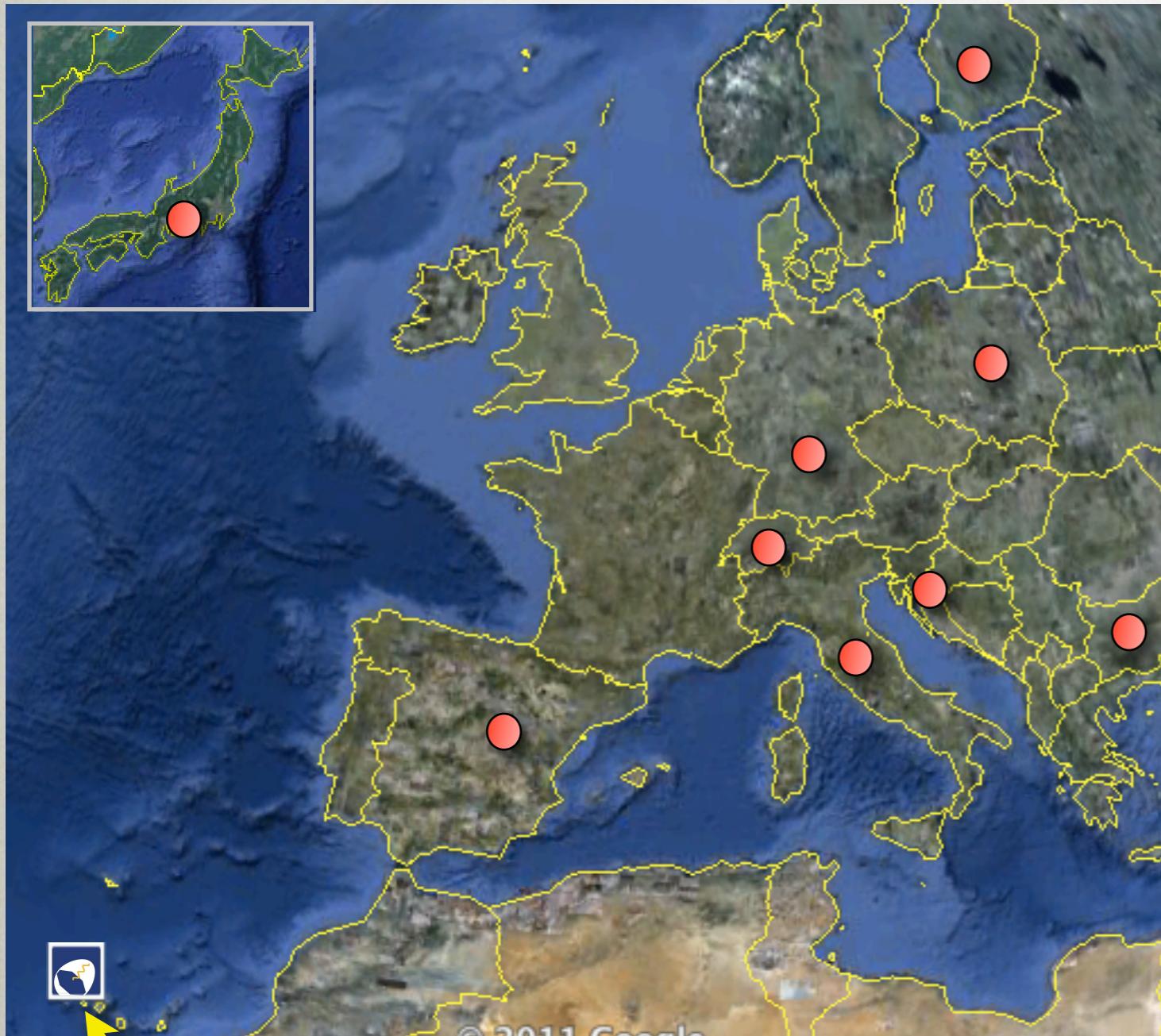
MAGIC望遠鏡

MAGIC(Major Atmospheric Gamma-ray Imaging Cherenkov)

- * 17 m鏡面を持つ大気チエレンコフ望遠鏡
- * エネルギー閾値: 50 GeV
- * 2004年～ MAGIC-I、2009年～2台の望遠鏡によるステレオ観測
- * 2011-2012年 望遠鏡アップグレード



MAGIC望遠鏡



- **Bulgaria:** Sofia
- **Croatia:** Consortium (Zagreb+)
- **Finland:** Consortium (Tuorla+)
- **Germany:** U. Dortmund, MPI München, U. Würzburg, DESY Zeuthen
- **Italy:** U. Como, INFN Padova/U. Padova, INAF Rome, INFN Pisa/U. Siena, INFN Trieste/U. Udine
- **Japan:** Consortium (Kyoto+)
- **Poland:** Univ. Łódź
- **Spain:** IFAE Barcelona, UAB Barcelona, U. Barcelona, IEEC-CSIC Barcelona, IAA Granada, IAC Tenerife, U. Complutense Madrid, CIEMAT Madrid
- **Switzerland:** ETH Zurich

MAGIC望遠鏡: スペイン・カナリア諸島ラパルマ島
($28^{\circ}46'N$, $17^{\circ}53'W$, 2231 m a.s.l.)

望遠鏡アップグレード

新MAGIC-Iカメラ: MAGIC-IIカメラクローン

- 567 PMTs → 1039 PMTs
- トリガー領域 $1.9^\circ \Phi \rightarrow 2.5^\circ \Phi$
- PMT量子効率向上
- etc.

新リードアウトシステム

Mux FADCs(M-I) & DRS2(M-II) → DRS4

- DRS2→DRS4: 帯域幅、クロストーク、リニアリティ、S/N、デッドタイム($500\mu s \rightarrow 26\mu s$)向上

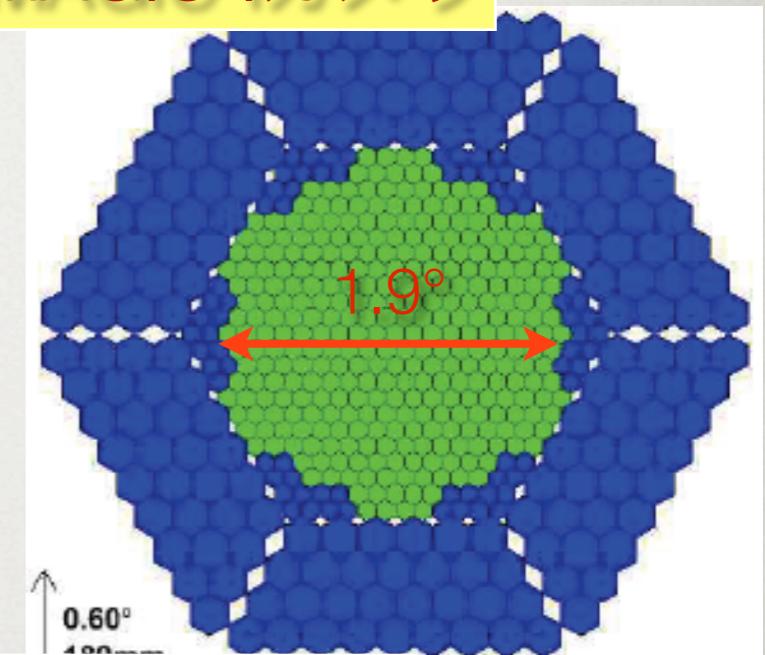
2011年6月-11月

- 両望遠鏡リードアウトDRS4へ
- Electrics roomリニューアル他

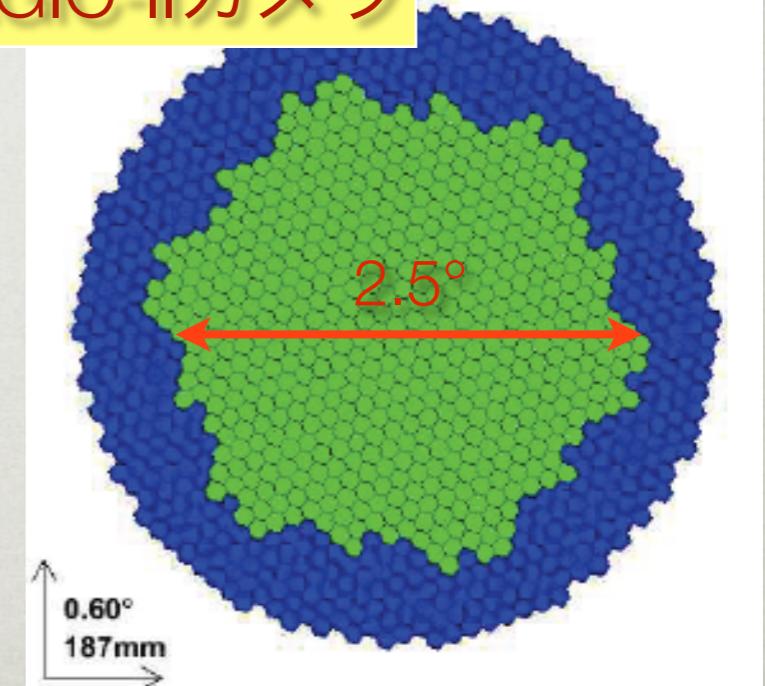
2012年6月-10月

- MAGIC-Iカメラ交換
- MAGIC-Iリードアウト、トリガーシステムアップグレード

旧MAGIC-Iカメラ

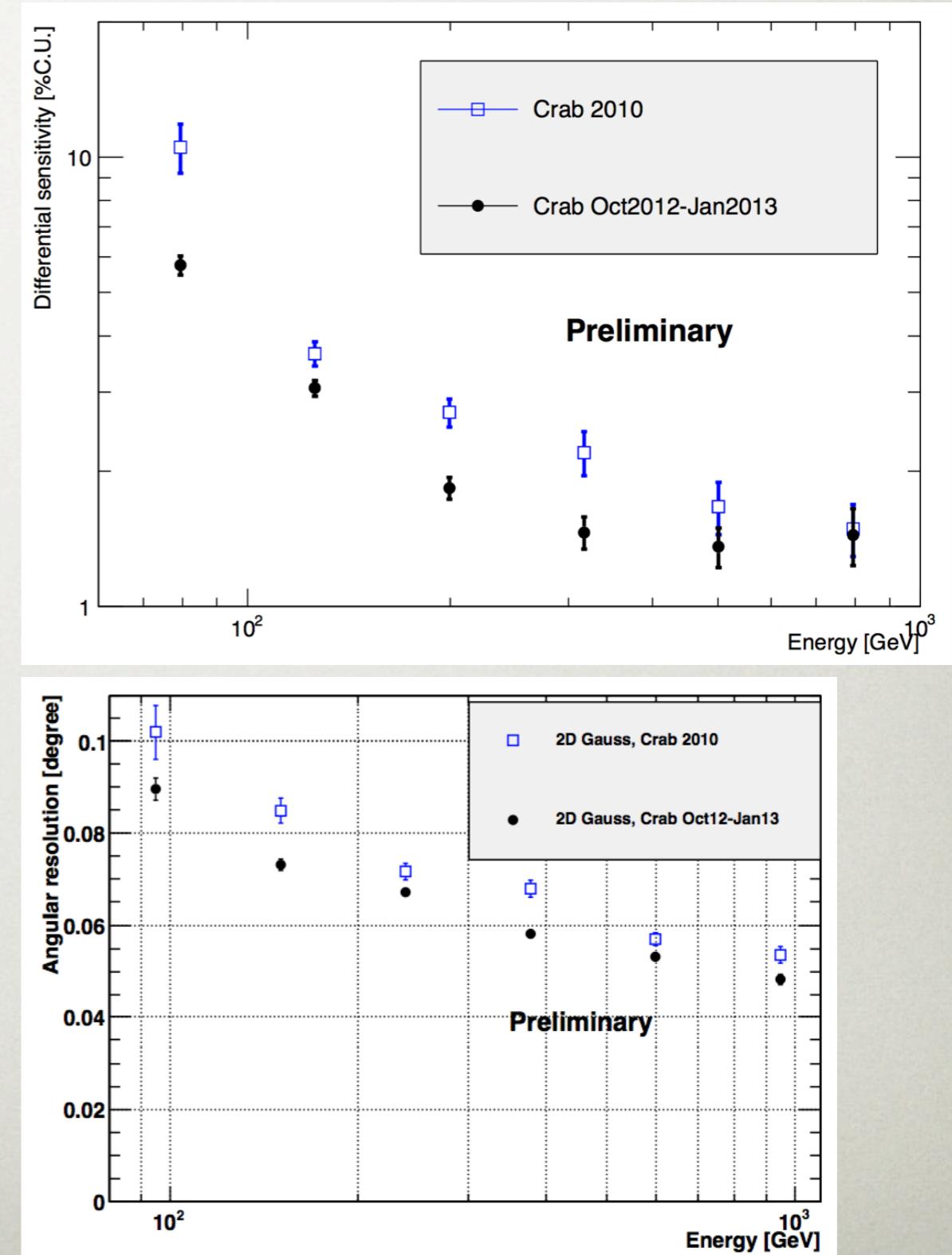
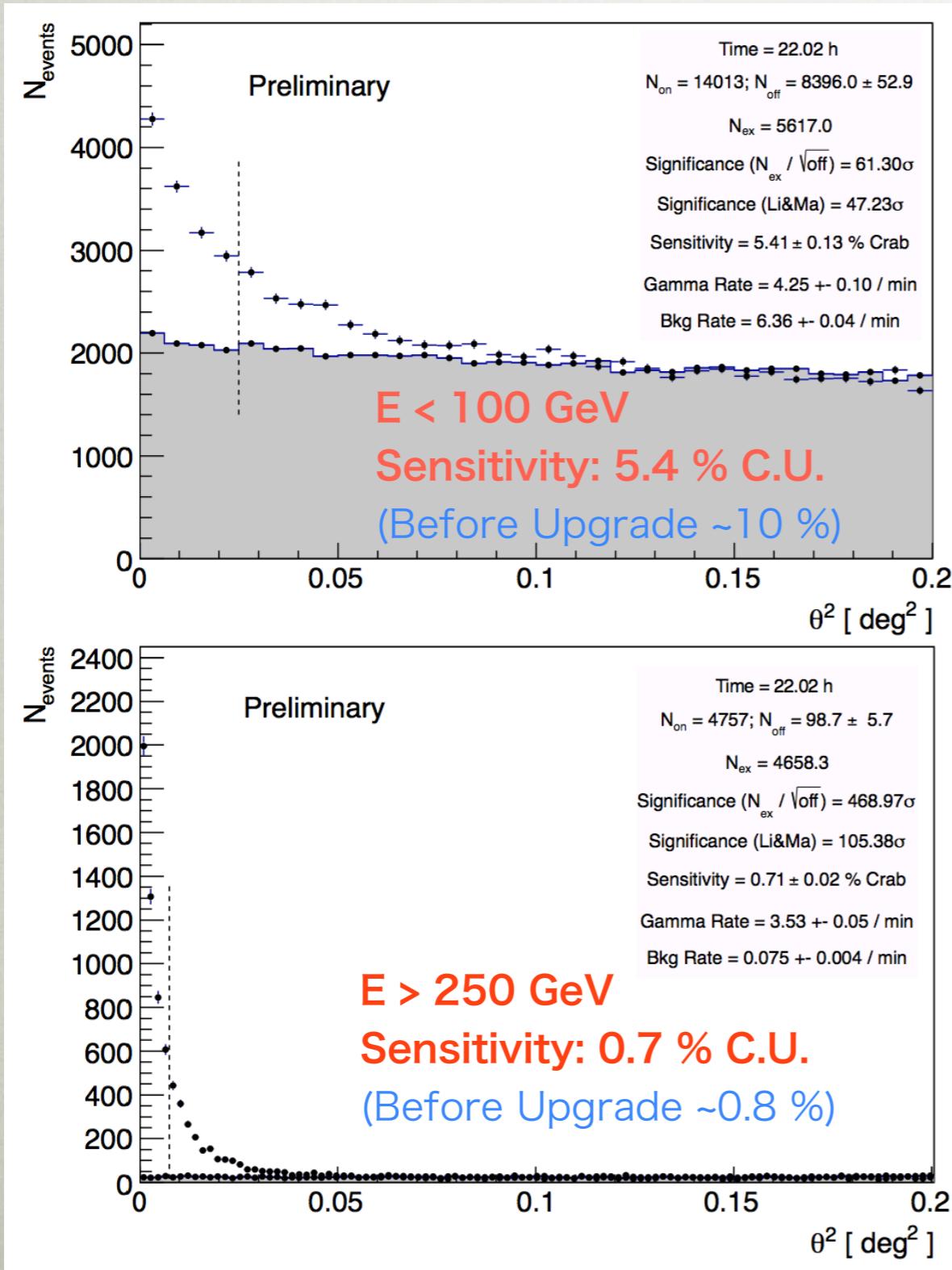


MAGIC-IIカメラ



望遠鏡アップグレード

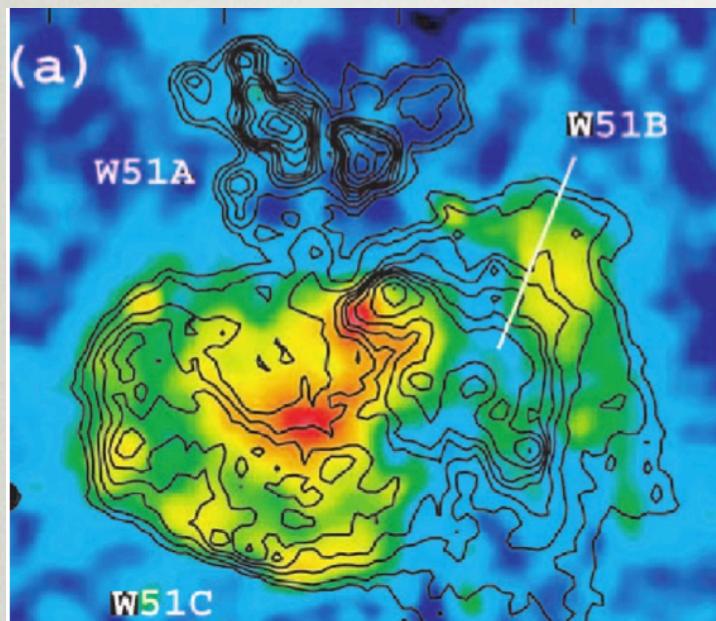
22 h CrabNebula data 2012 Oct. - 2013 Jan, Zd < 30°



W51

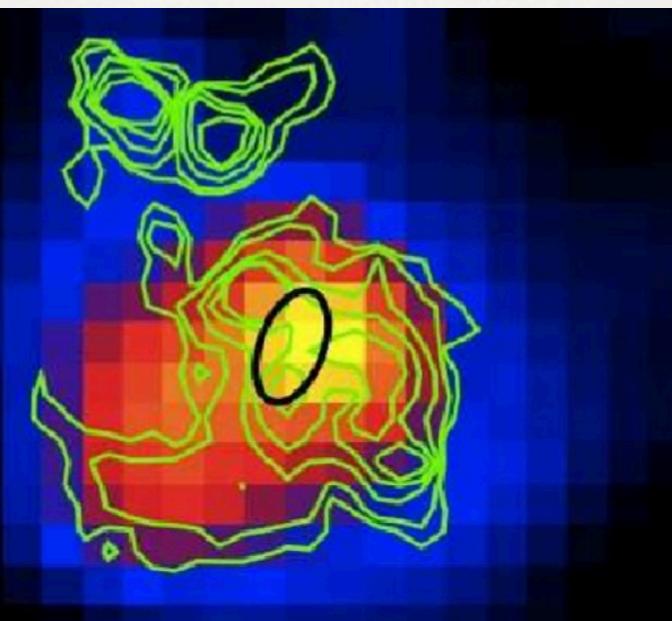
ROSAT 0.7-2.5 keV

Koo+ 2002



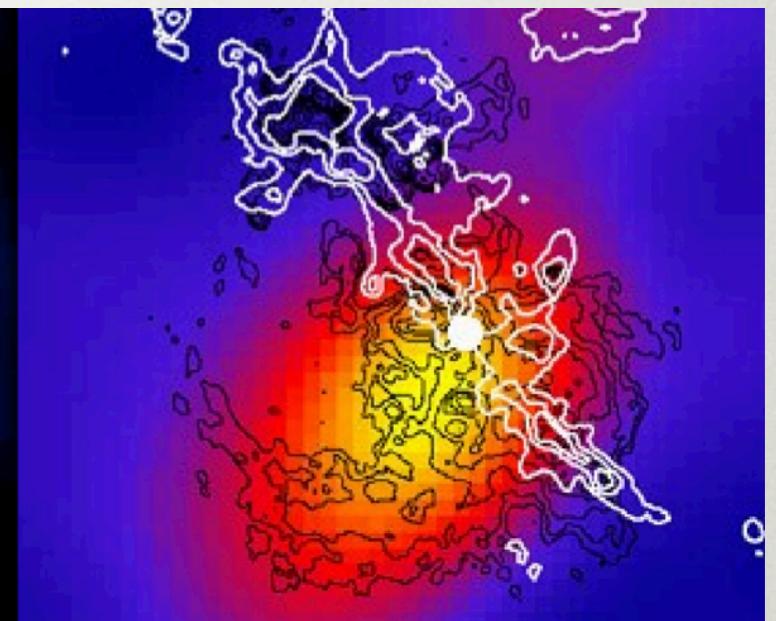
Fermi-LAT 2-10 GeV

Uchiyama+ 2011

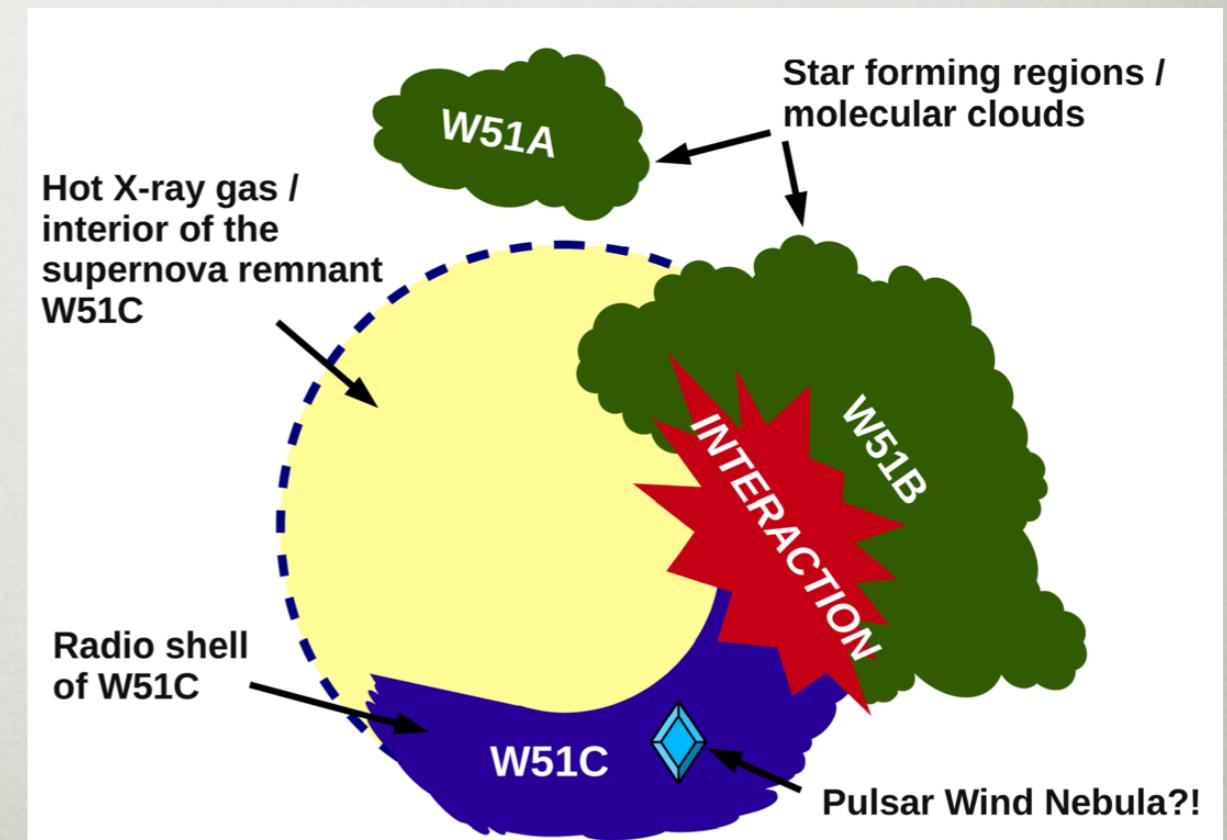


H.E.S.S. >1 TeV

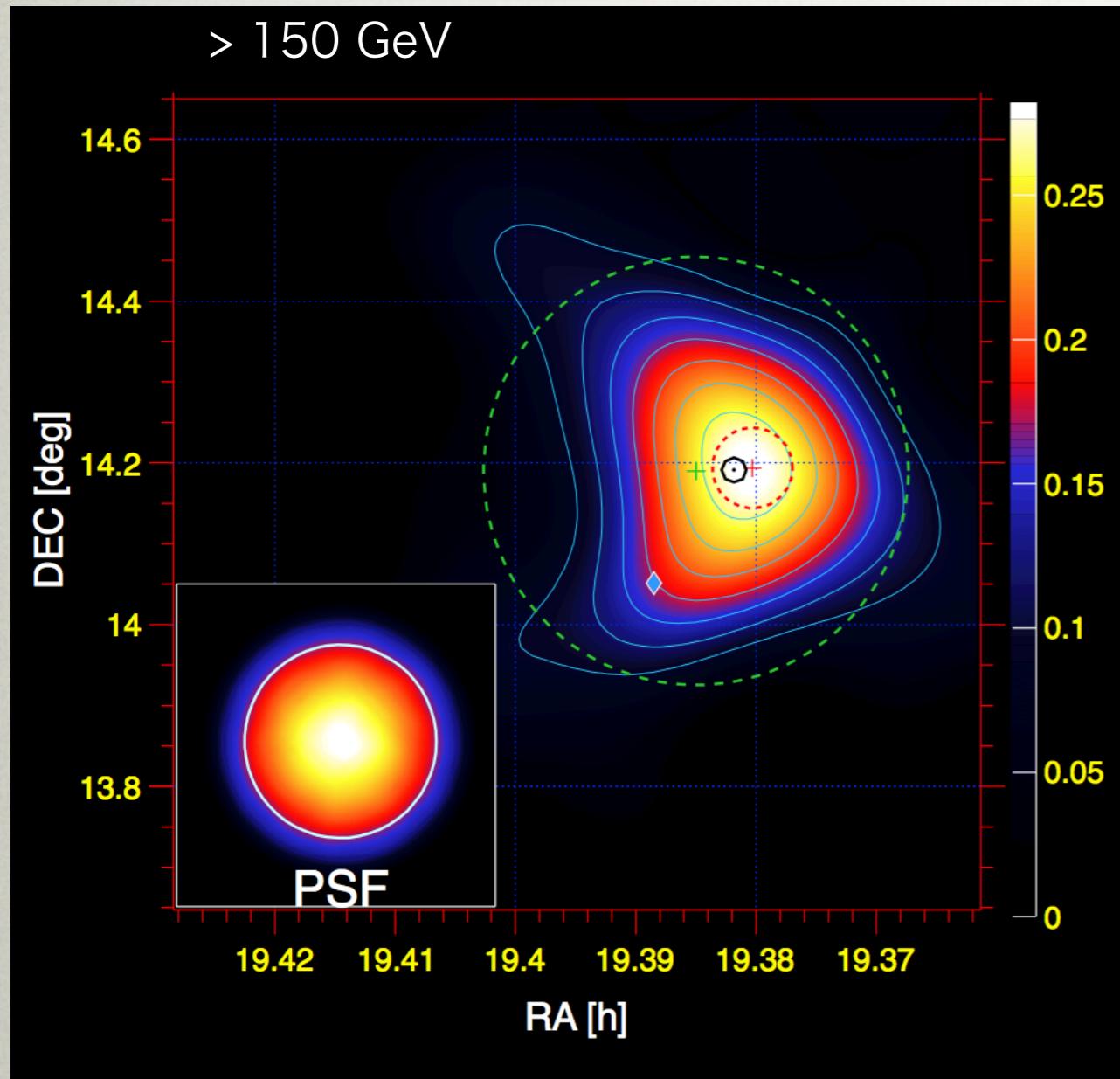
Fiasson+ ICRC2009



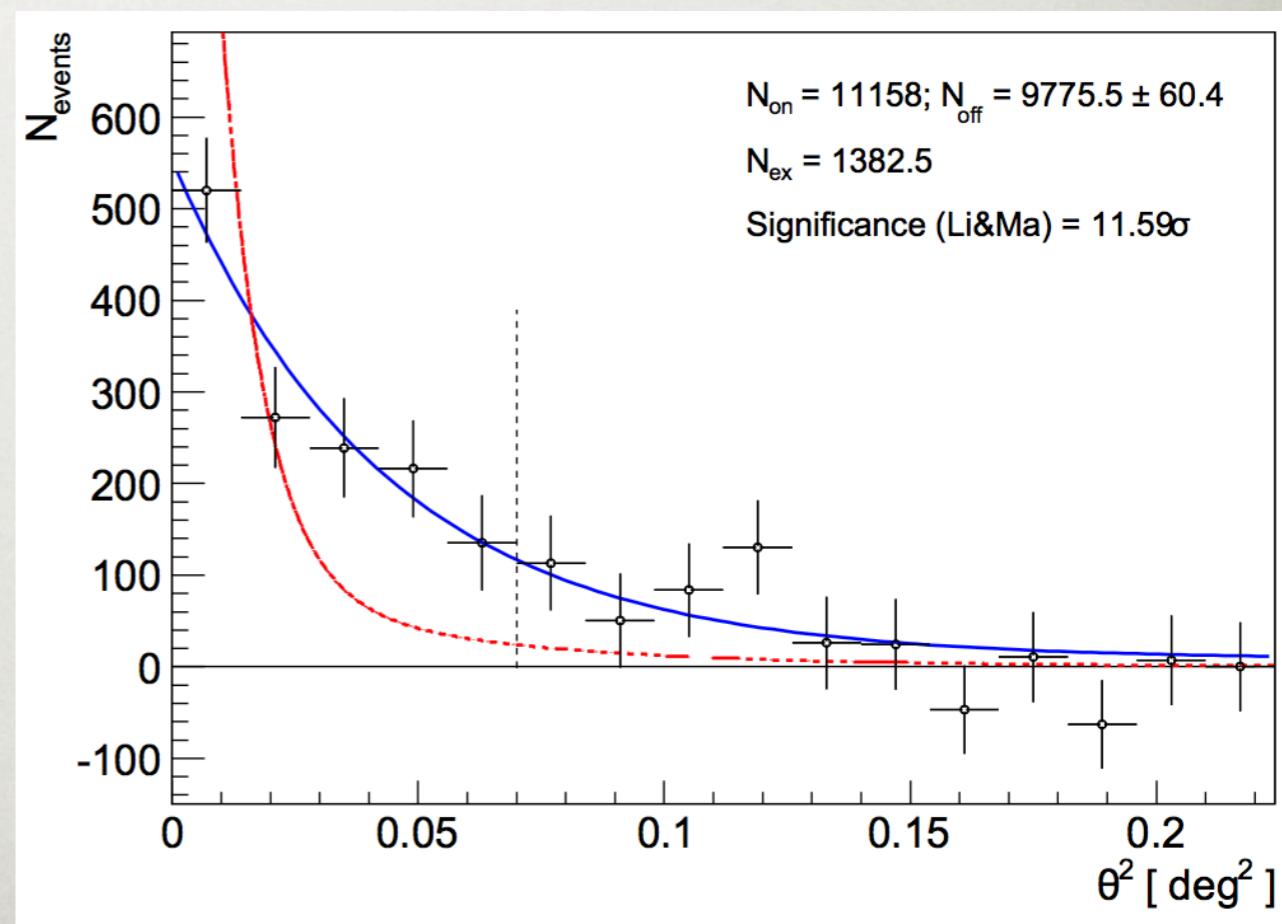
- ◆ W51C: d ~ 5.5 kpc, medium age (30 kyr) supernova remnant (SNR)
- ◆ Possible pulsar wind nebula associated to W51C
- ◆ W51C interacts with W51B
- ◆ Discovered by Fermi (~GeV)
- ◆ H.E.S.S. 4.4σ (>1 TeV)



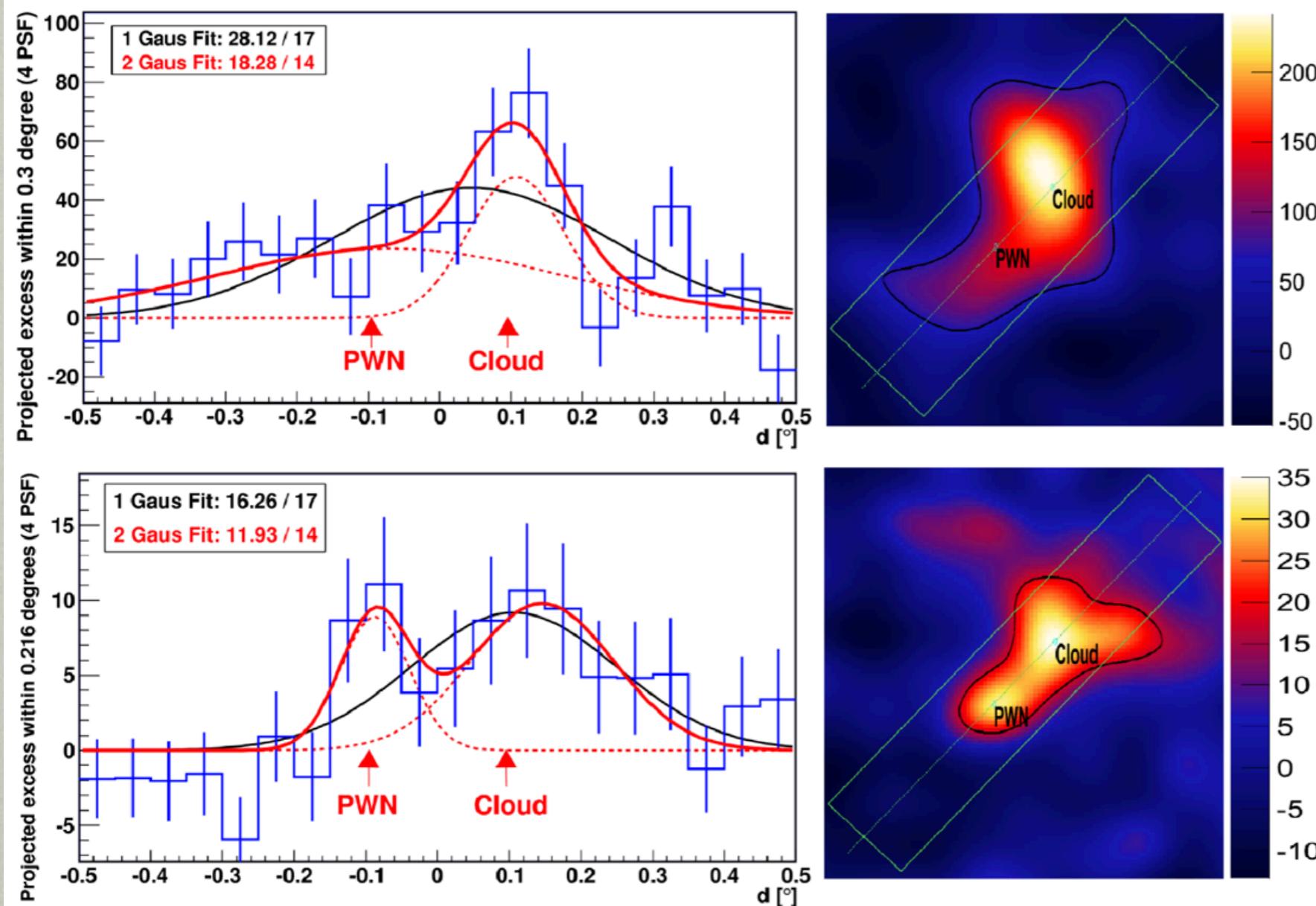
W51



- ◆ Data taken in 2010 & 2011
- ◆ 53 h effective time
- ◆ 11.6σ detection ($> 150 \text{ GeV}$)
- ◆ Extension:
 $0.12^\circ \pm 0.02^\circ_{\text{sys}} \pm 0.02^\circ_{\text{stat}}$



W51



- ◊ Top: 300 GeV - 1 TeV
- ◊ Bottom: > 1 TeV
- ◊ Underlying structures?
- ◊ Two independent resolved sources cannot be statistically established
- ◊ No energy dependent
- ◊ Cloud: 1.2 % C.U. (> 300 GeV)
- ◊ PWN: 0.7 % C.U. (> 300 GeV)

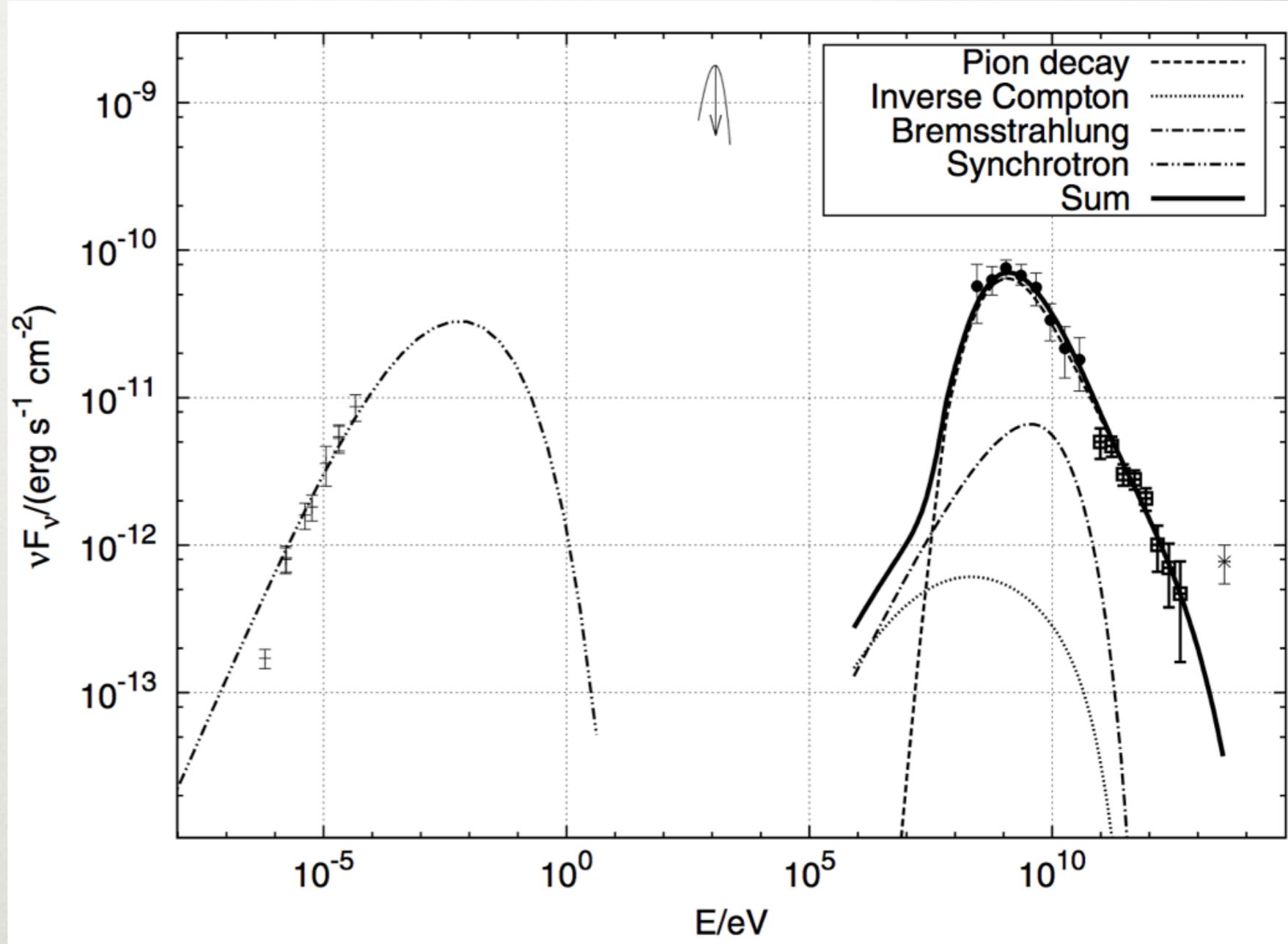
E [GeV]	cloud	PWN	cloud/all [%]	PWN/all [%]
> 300	200 ± 30	132 ± 25	30 ± 5	19 ± 4
> 500	116 ± 17	79 ± 17	32 ± 6	22 ± 5
> 1000	48 ± 10	27 ± 10	43 ± 12	24 ± 10

W51

◆ Best fit results:

- ▶ $s = 1.5$
- ▶ $E_{\text{br}} = 10 \text{ GeV}$
- ▶ $\Delta s = 1.2$
- ▶ $n = 10 \text{ cm}^{-3}$
- ▶ $B = 53 \mu\text{G}$
- ▶ $K_e/K_p = 1/80$
- ▶ $W_p = 5.8 \times 10^{50} \text{ erg}$

◆ Possible 20 % contribution from PWN, within the statistical and systematic errors of MAGIC observation



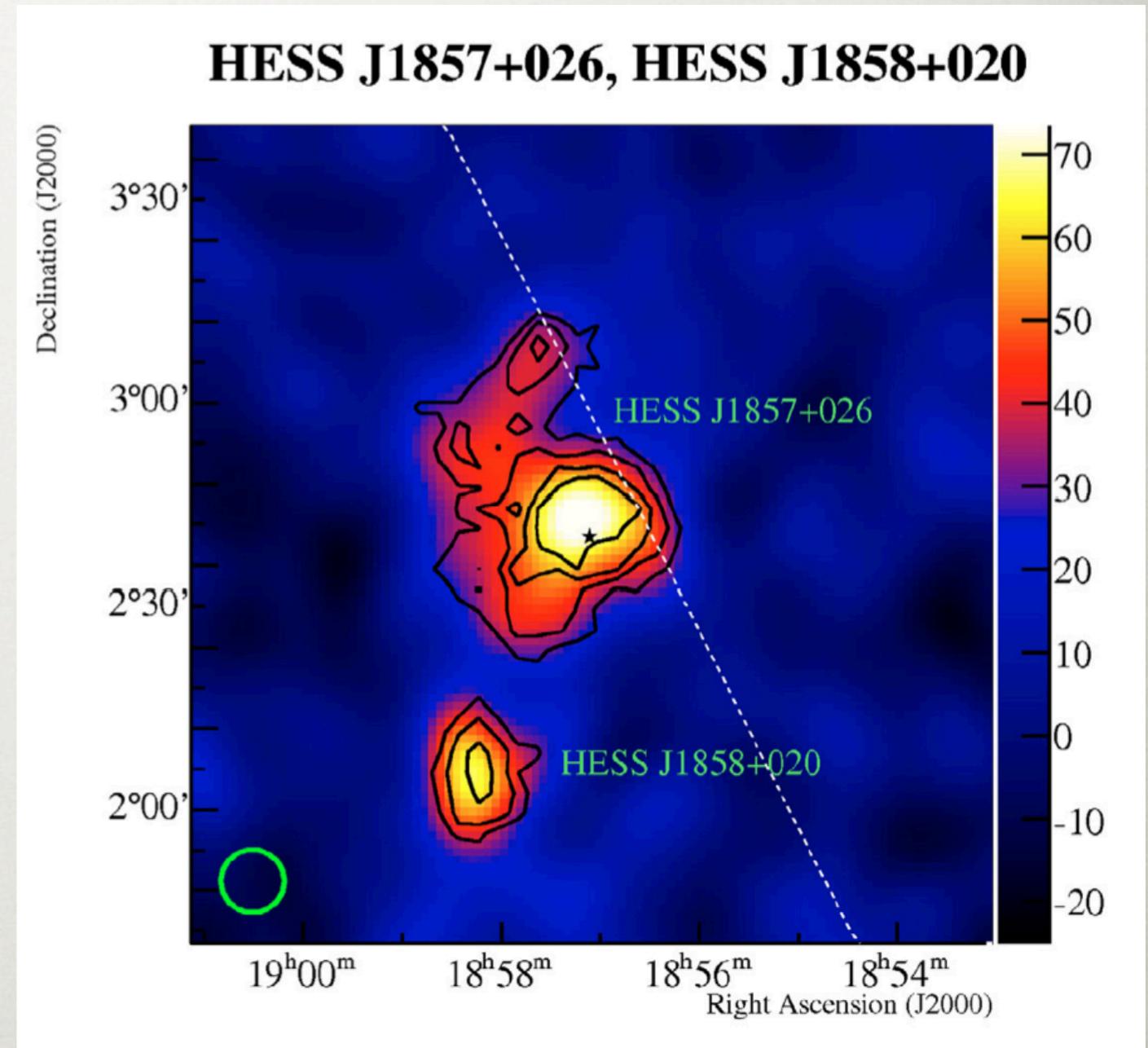
◆ No one-zone Leptonic model matching the data is found.

Agreement with Abdo+ 2009

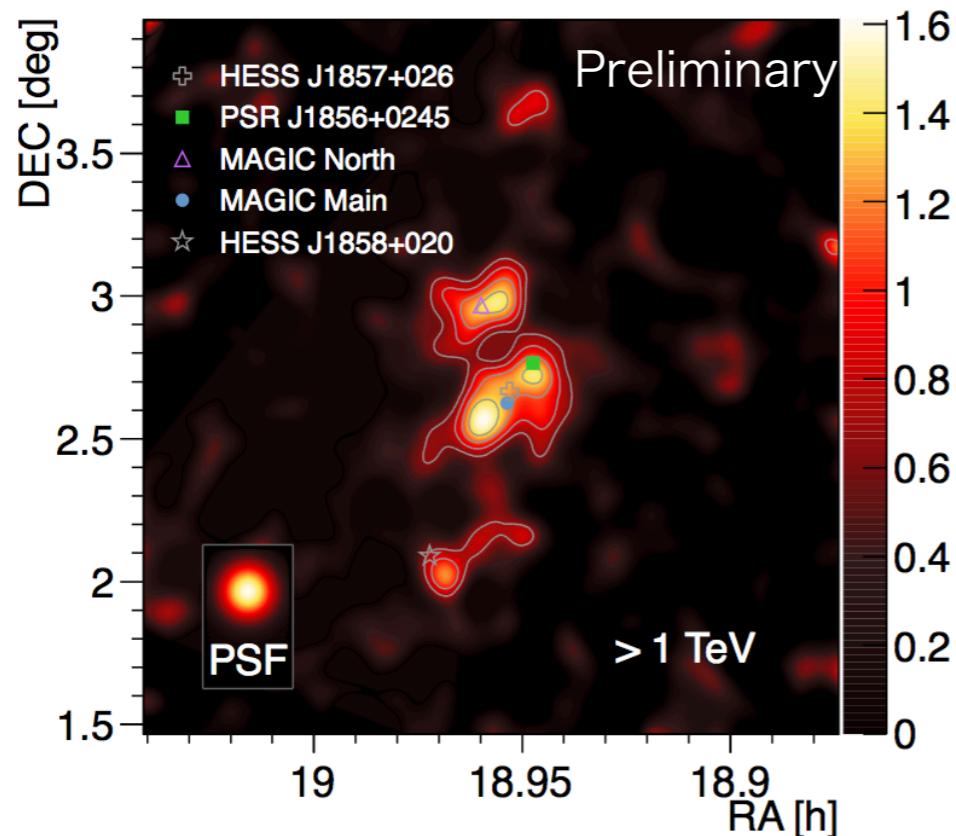
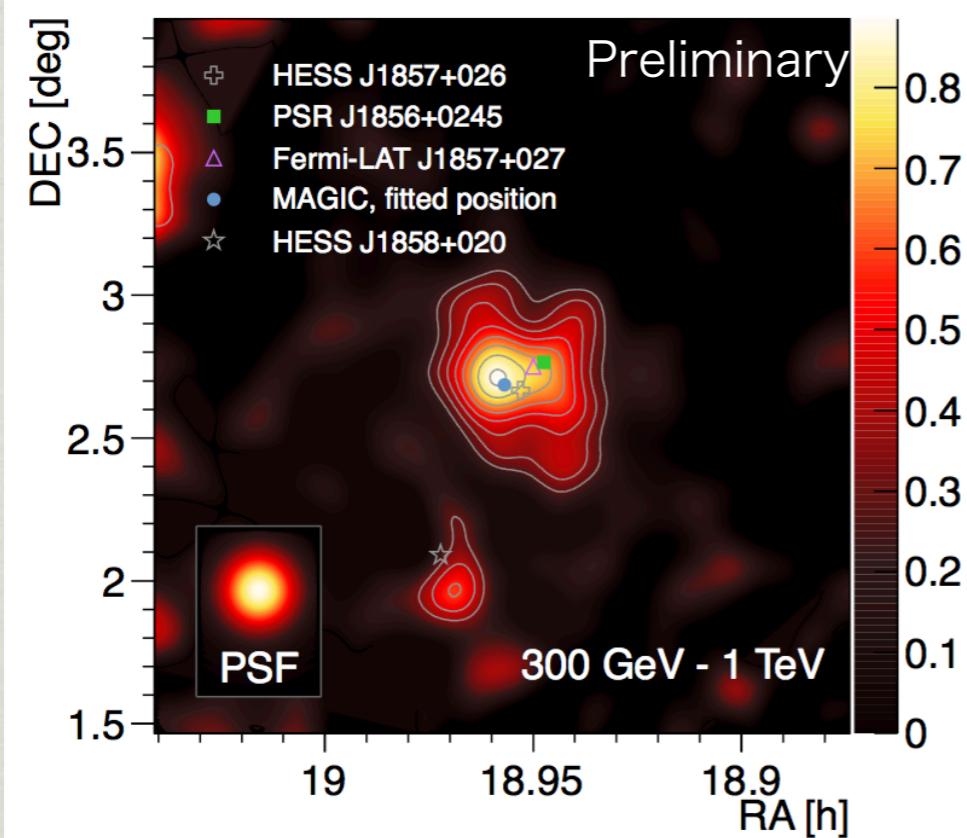
◆ Simple one-zone hadronic model explains the data

HESS J1857+026

- Discovered by H.E.S.S.
(Aharonian+ 2008)
- Spectral slope -2.4 (>500 GeV)
- ~0.1° extension
- Possible pulsar wind nebula
PSR J1856+02245 (Hessels+
2008)
- Distance ~9 kpc
- $\dot{E} = 4.6 \times 10^{36}$ erg/s
- Fermi-LAT (Rousseau+ 2012):
 - Spectral slope -1.5 (< 100 GeV)
 - Point like (>10 GeV)



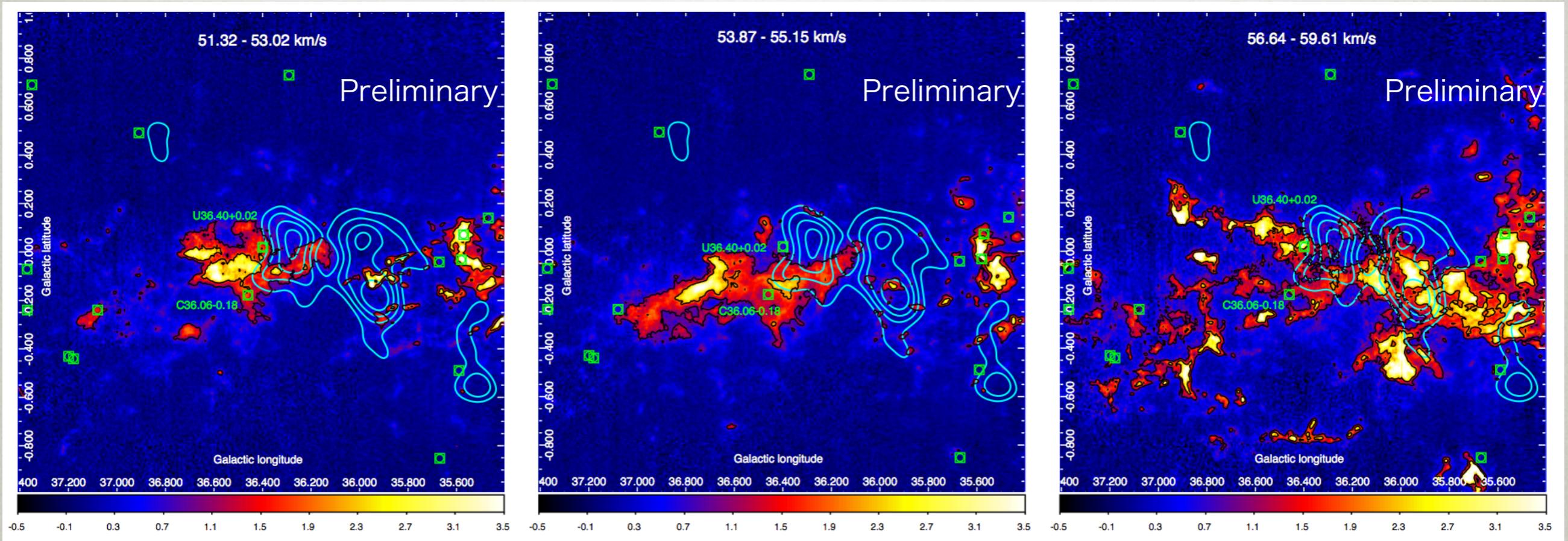
HESS J1857+026



- Observed in 2010
- ~30 h effective time
- ~ 12σ detection
- 2 sources above 1 TeV
- MAGIC J1857.2+0263:
 - 0.21° extension
 - 45 % flux contribution
 - Counterparts: HESS J1857+026, PSR J1856+0245, Fermi-LAT
- MAGIC J1857.6+0297:
 - 0.14° extension
 - 20 % flux contribution
 - No counterpart

HESS J1857+026

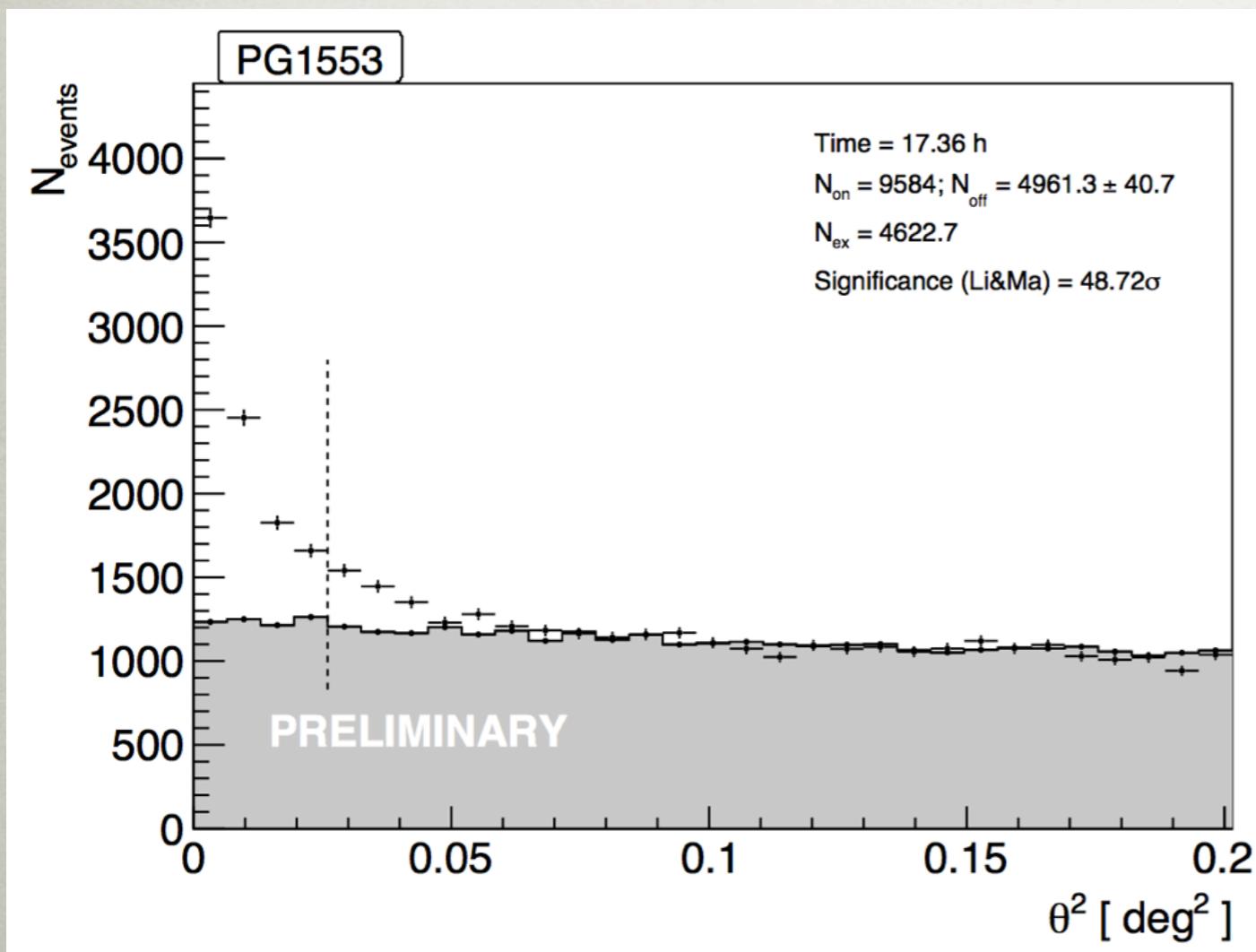
$^{13}\text{CO}(J = 1 \rightarrow 0)$ line emission integrated intensity



- Nature of the VHE emission of MAGIC J1857.6+0297 remains a mystery
- MAGIC J1857.6+0297 lies in the vicinity of HII region
- Compact HII region U36.40+0.02 with $V_{\text{LSR}} = 53.3 \text{ km/s}$ (3.3 kpc) which may be associated with the molecular cloud G036.59-00.06

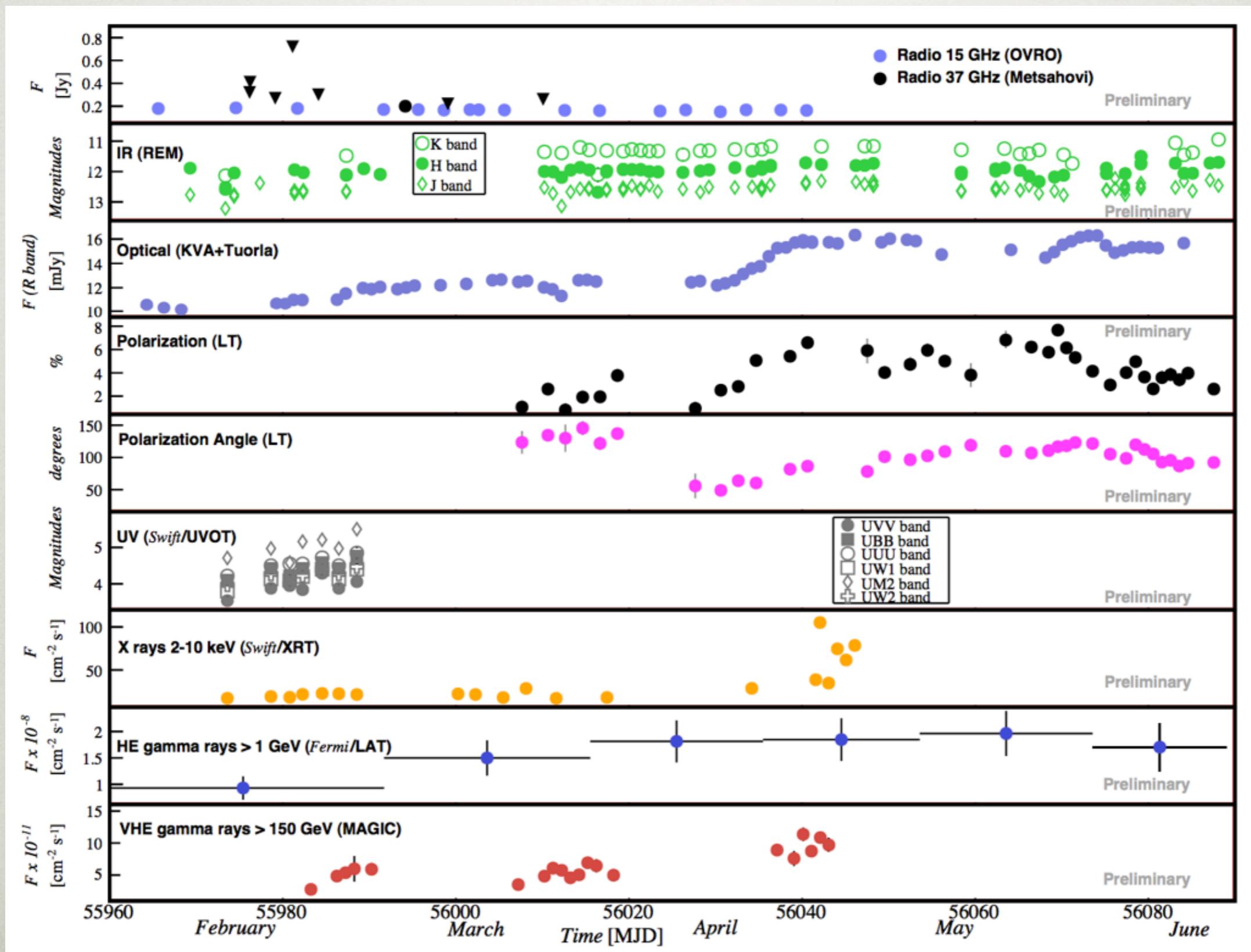
PG 1553+113

- Discovered by H.E.S.S. & MAGIC in 2005
- Uncertain redshift $z > 0.4$ (Danforth+ 2010), $z < 0.66$ (Prandini+ 2010)
- Have been observed by MAGIC since 2005, showing modest flux variation
- Stable flux seen during 4 years by Fermi-LAT



- February-March 2012 high flux state was observed by MAGIC (ATel #3977)
- April 2012 MAGIC detected flare (ATel #4069)
- Most extensive multiwavelength campaign

PG 1553+113



PG 1553+113

- Power-law fit to observed energy spectrum in flare gives low probability $\chi^2/\text{d.o.f.} = 36.2/8$

- Observed spectrum compatible with logparabola

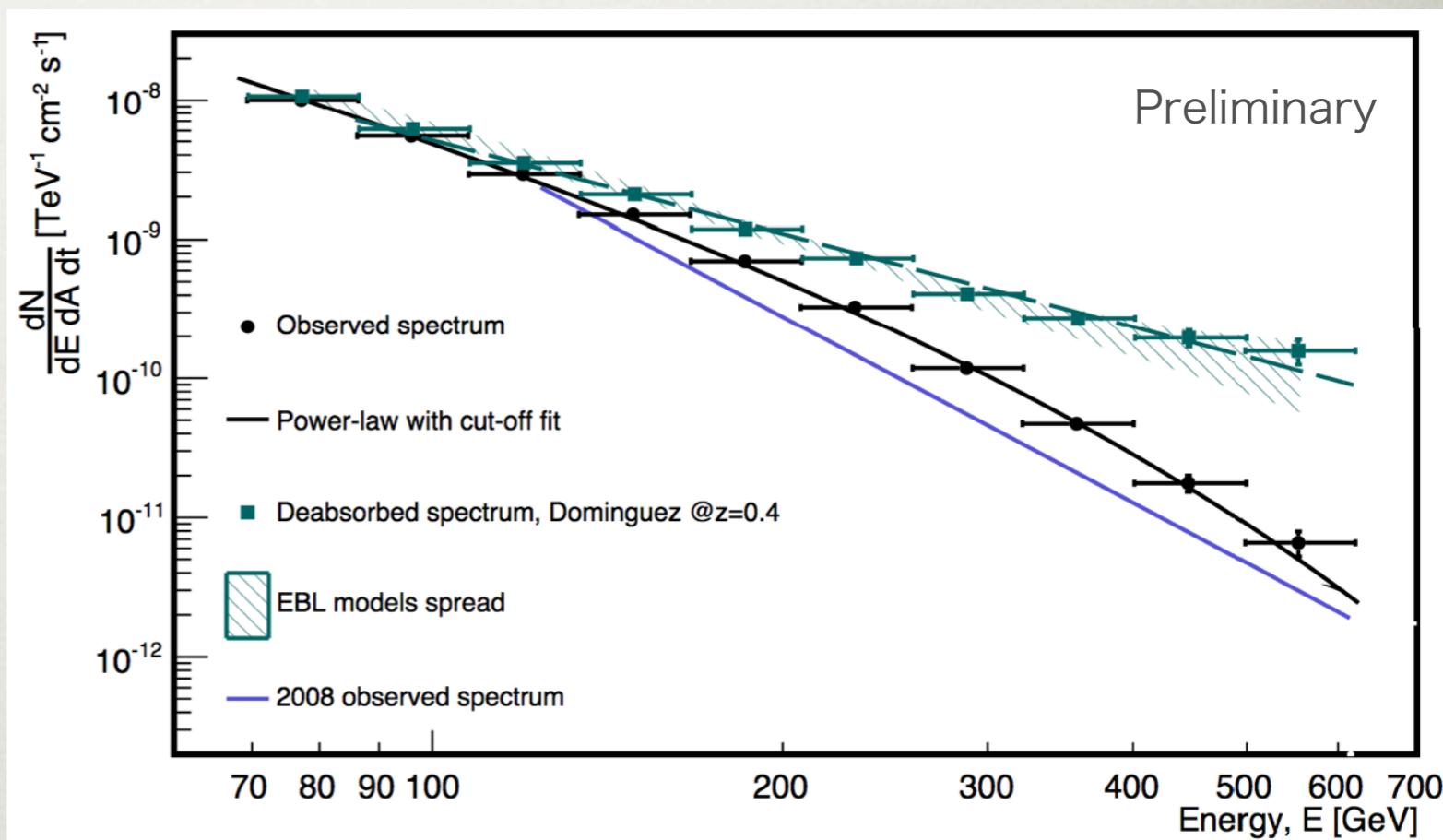
$$\frac{dF}{dE} = f_0 \cdot \left(\frac{E}{200\text{GeV}}\right)^{-a-b \cdot \log \frac{E}{200\text{GeV}}}$$

$$f_0 = 5.1 \pm 0.3 \times 10^{-10} \text{ cm}^{-2}\text{s}^{-1}\text{TeV}^{-1}$$

$$a = 3.7 \pm 0.1$$

$$b = 1.4 \pm 0.3$$

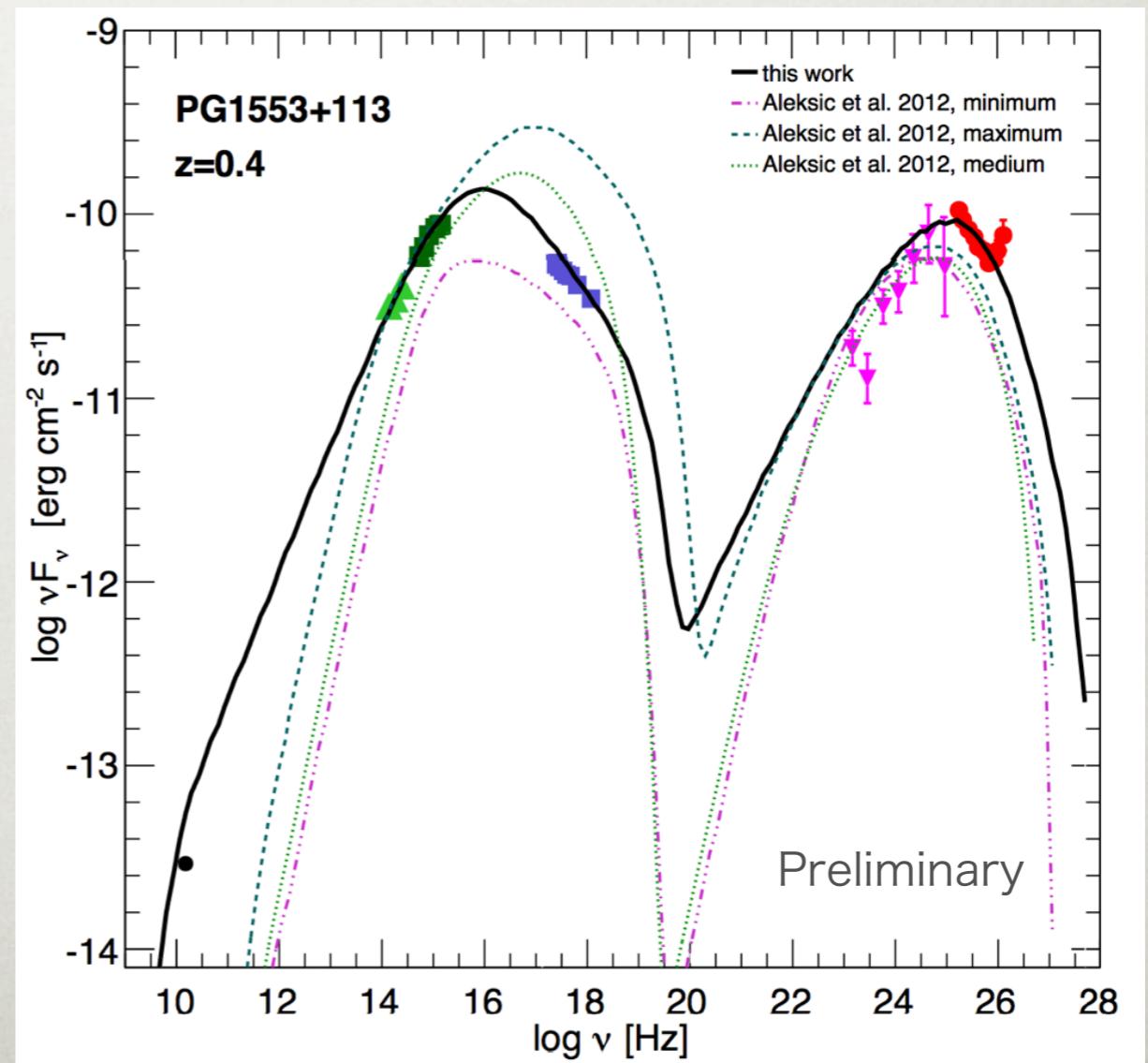
- EBL-corrected spectra (with Dominguez+ 2011): reproduced by power-law assuming $z = 0.4$



PG 1553+113

- SED modeling assuming $z = 0.4$
- One-zone SSC model, e- broken power-law distribution
- Size of emission region is one order of magnitude higher than in the previous observations in order to keep the Doppler factor not too high

γ_{min}	1.
γ_{break}	$4.3 \cdot 10^4$
γ_{max}	$1.95 \cdot 10^6$
n_1	1.6
n_2	3.8
$B [\text{G}]$	0.027
$K [\text{cm}^{-3}]$	9.1
$R [\text{cm}]$	10^{17}
δ	40
$L_p [\text{erg s}^{-1}]$	$3.4 \cdot 10^{46}$
$L_e [\text{erg s}^{-1}]$	$4.1 \cdot 10^{45}$
$L_B [\text{erg s}^{-1}]$	$5.8 \cdot 10^{43}$



IC 310

Serendipitously detected by Fermi-LAT (Neronov+ 2010) above 30 GeV and by MAGIC (Aleksić+ 2010) above 260 GeV

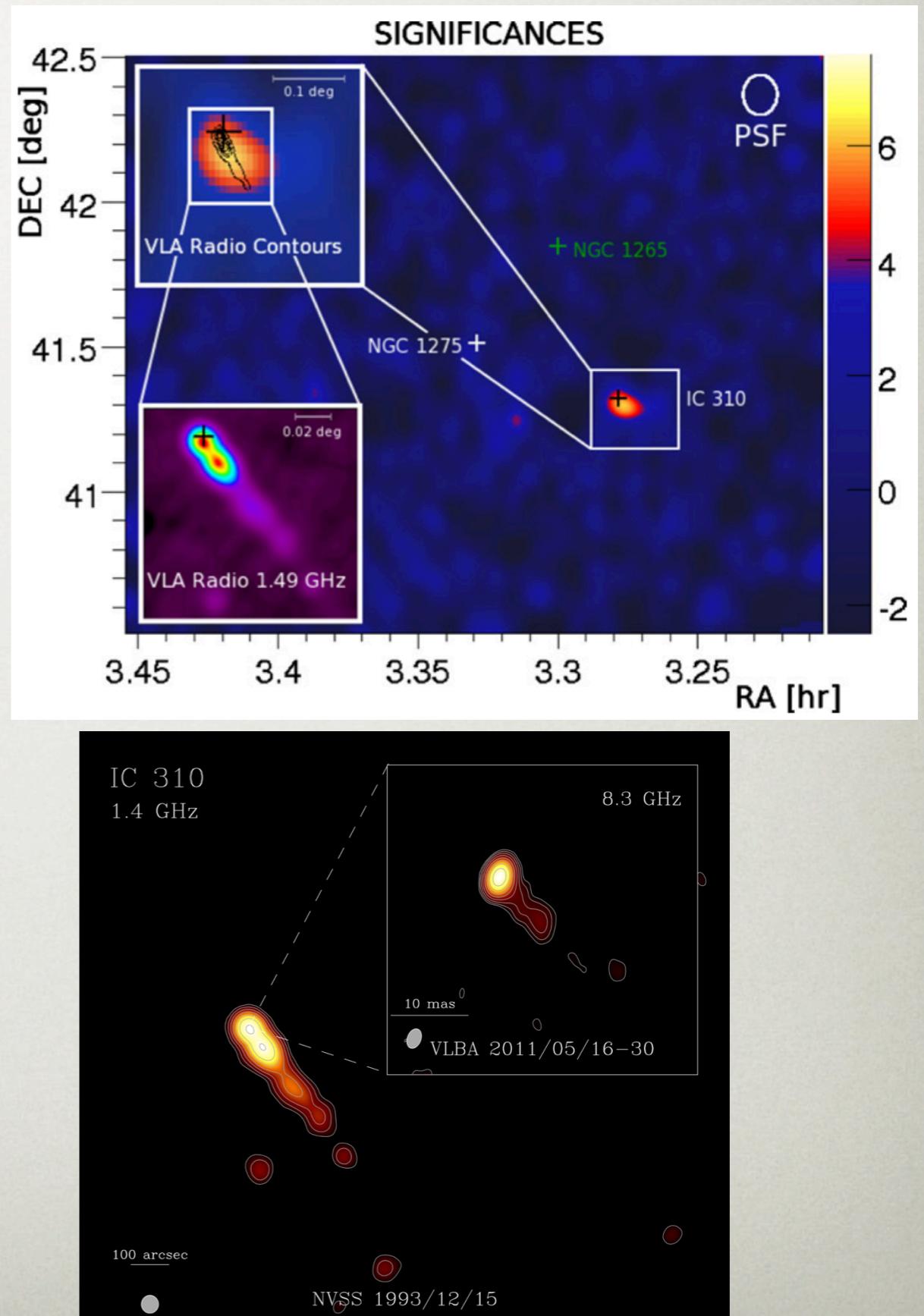
- Hard spectrum in VHE: $\Gamma = 2.0$
- Daily-scale VHE flux variability

IC 310 has been classified as a head-tail galaxy (e.g. Ryle & Windram 1968) which is found only in clusters of galaxies

- Jet direction is determined by the galaxy's motion through the intra-cluster medium (ICM)
- “head”: bow shock due to the impact of the jet on the ICM
- “tail”: redirected extended jet

However, VLBA images show a blazar-like parsec scale structure (Kadler+ 2012)

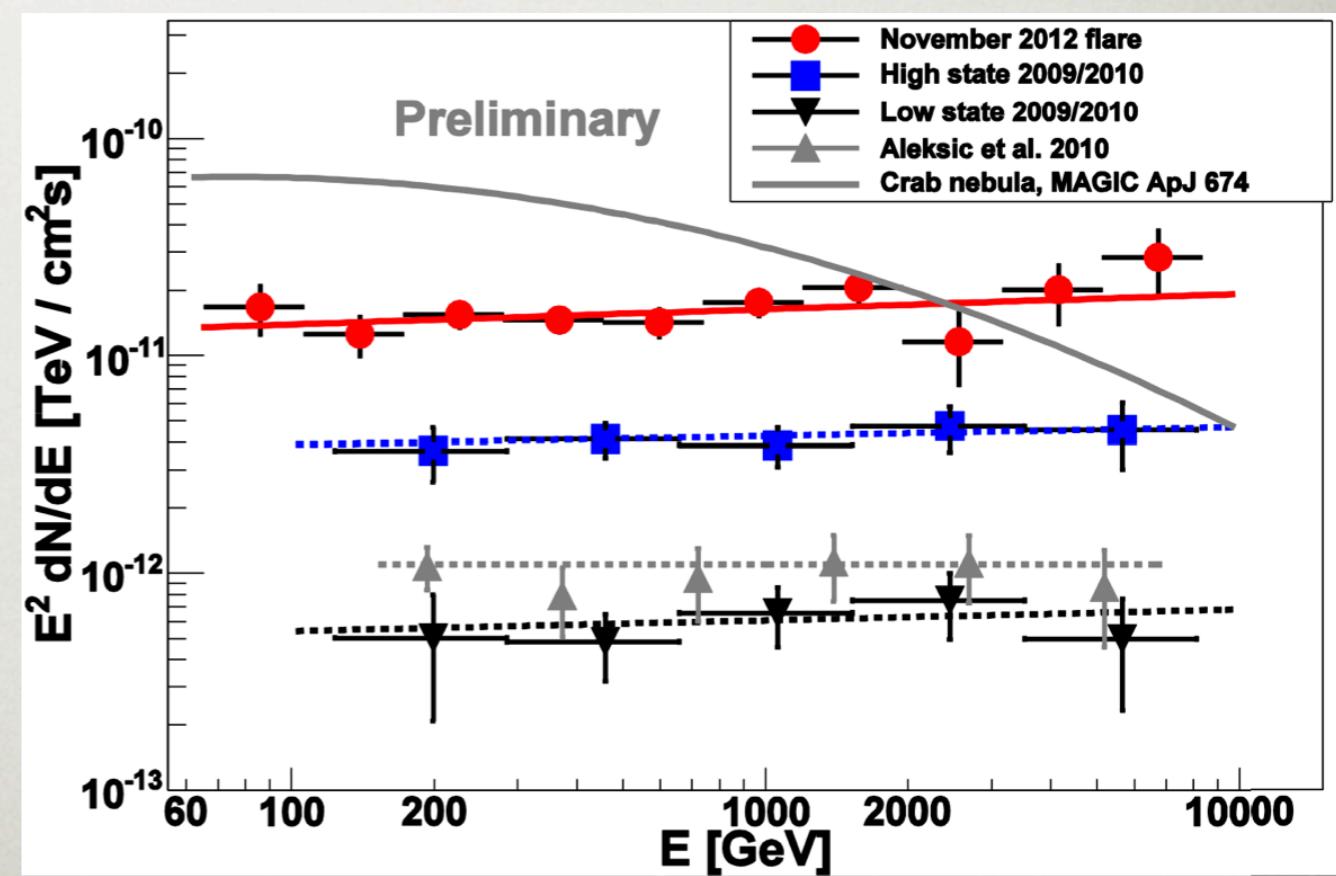
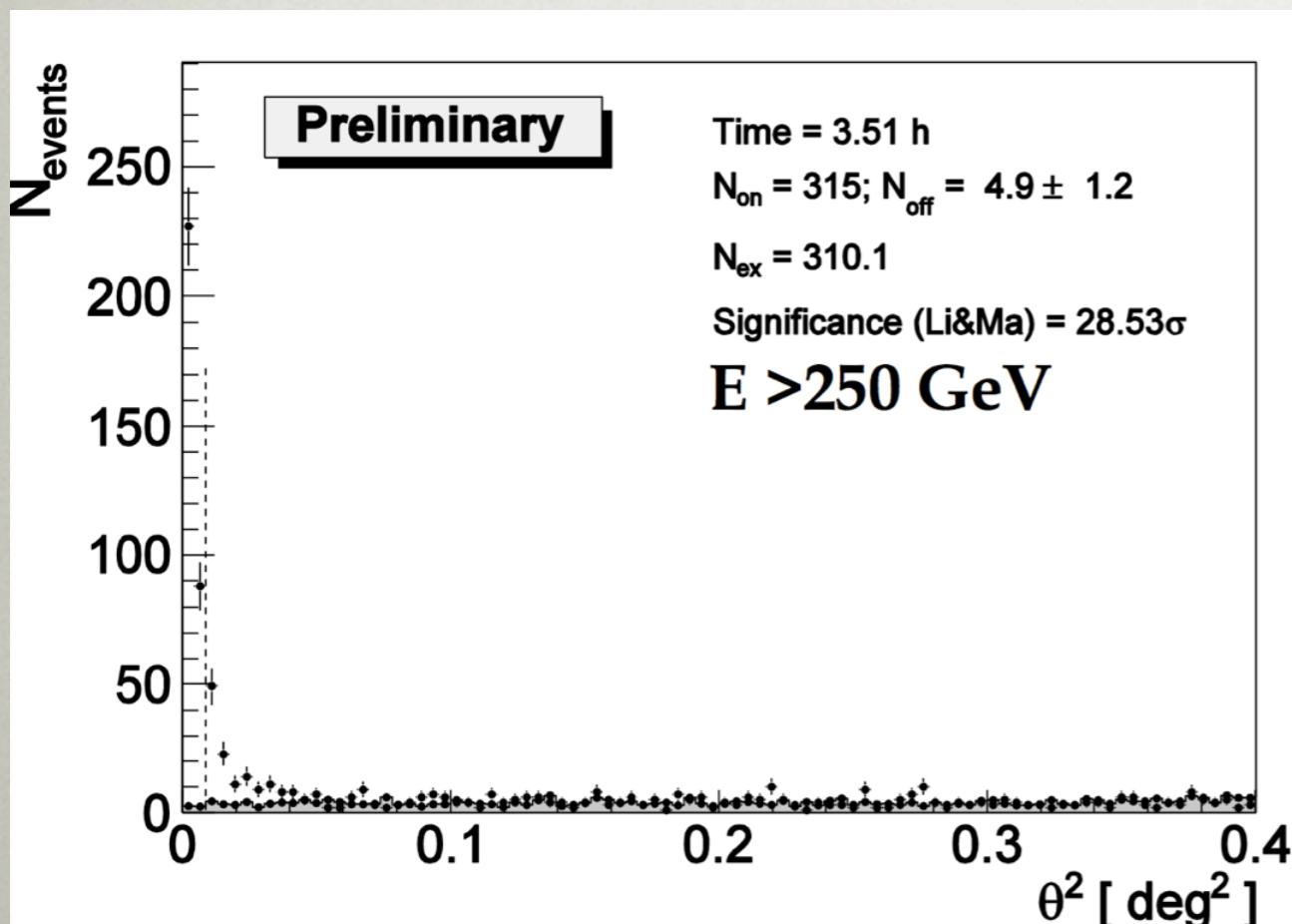
- There is no indication of an interaction with ICM
- The source belongs to a transitional population between BL Lac and FR I radio galaxy (Rector+ 1999, Kadler+2012)



IC 310

VHE flare in Nov 2012

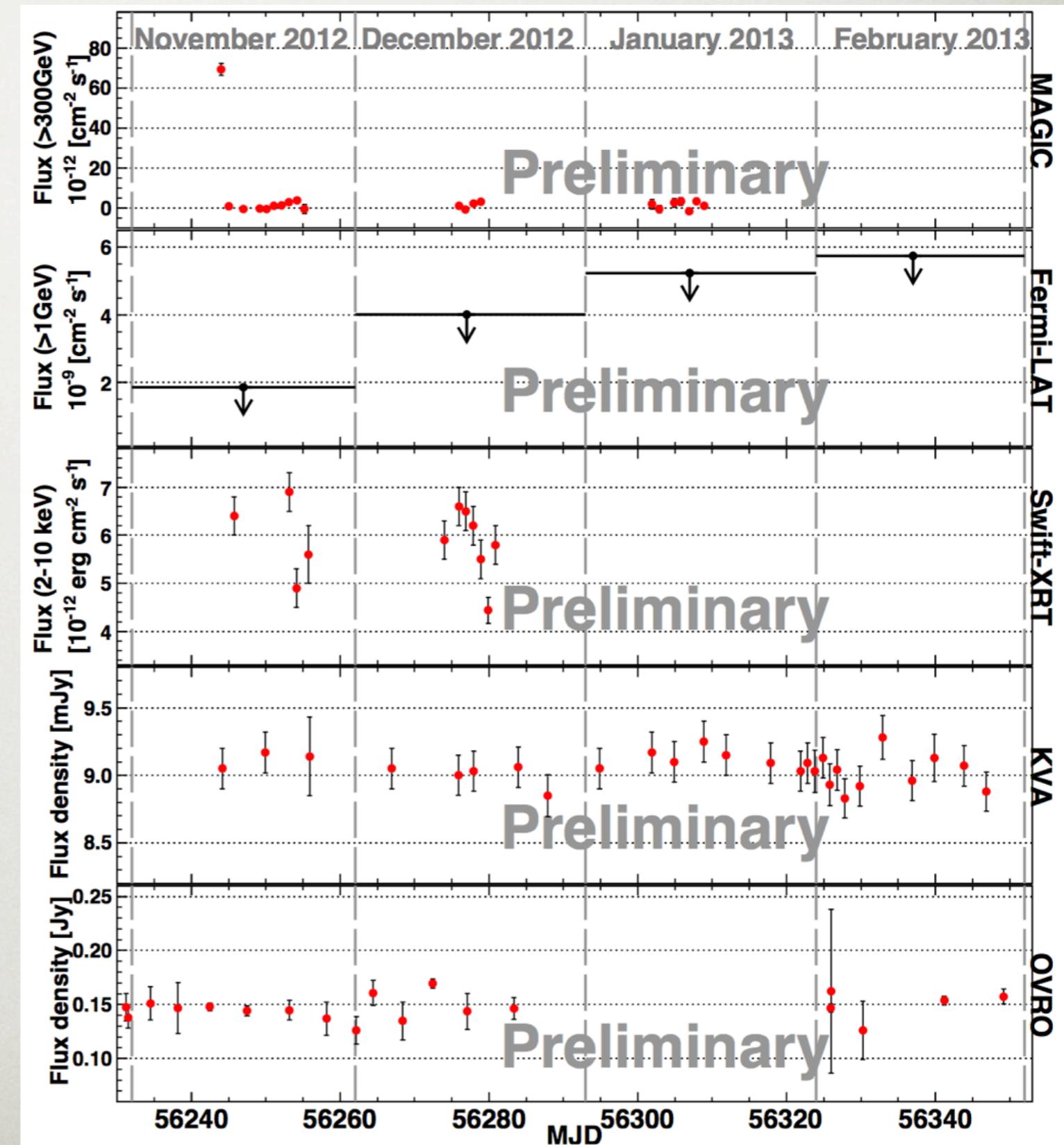
- 28.5 σ in 3.5 h (>250 GeV) at beginning of MWL campaign (Cortina et al. Atel #4583)
- 56 % C.U. (>250 GeV): 2.5 % C.U. for the mean flux in 2009/2010, 12.5 % C.U. for the high state in 2009/2010 (Aleksić+ 2013)
- Spectrum shape stayed the same in spite of the large flux variability



IC 310

Multiwavelength Light Curve

- Fermi-LAT: only upper limit (>1 GeV)
- Swift-XRT: no strong variability but flux is higher than in previous observations
- Optical: dominated by host galaxy
- Radio: at 15 GHz no significant variability
- Detailed analysis on the MWL data is ongoing

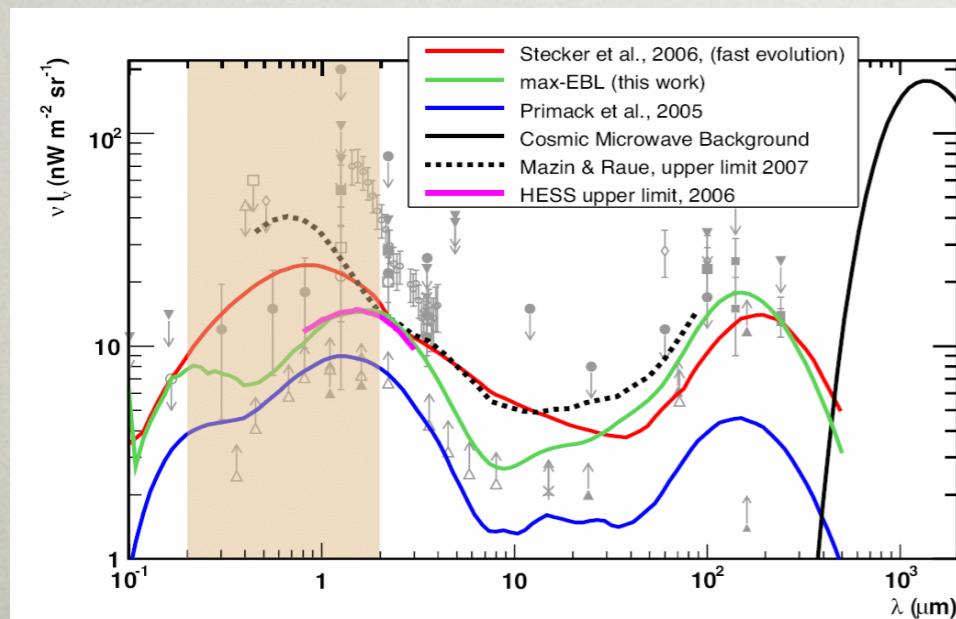


FSRQs

Flat Spectrum Radio Quasars: Only 3 sources seen by IACTs

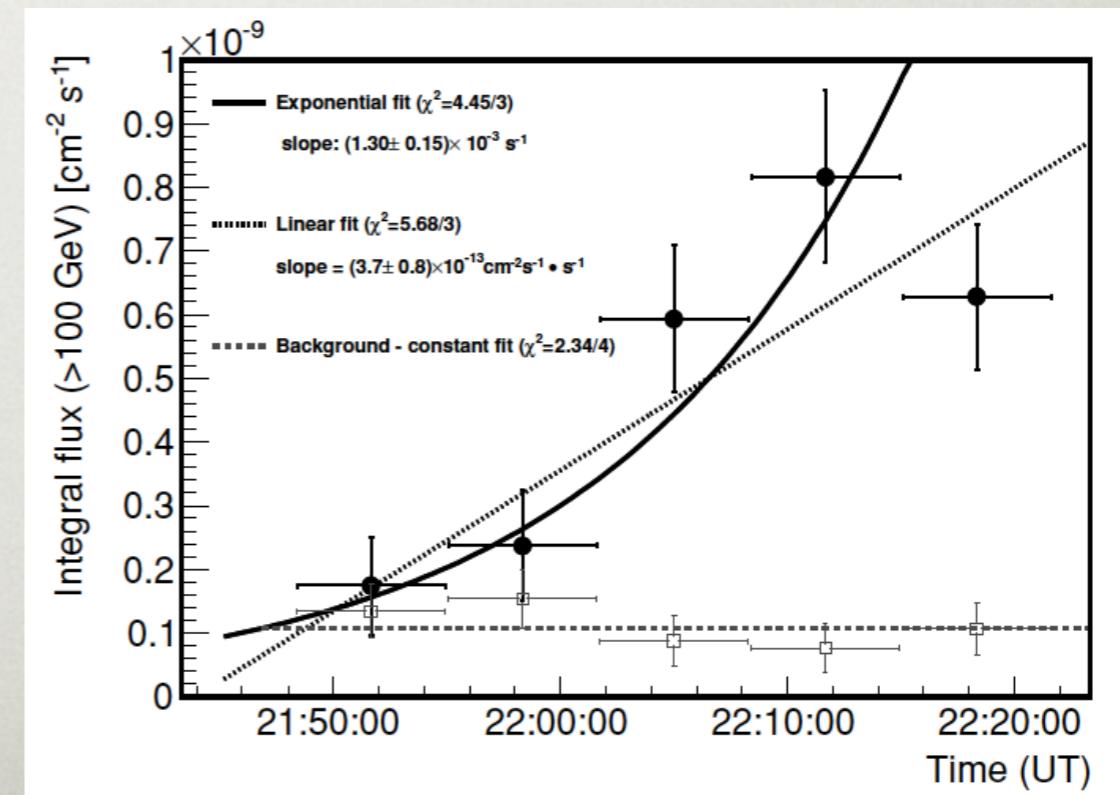
3C 279 ($z = 0.536$)

- Great impact discovery by MAGIC in 2006
- Detected again during historical optical flare in 2007
- No signal in 20 h monitoring in 2011
- ToO in June 2011 results in no detection



PKS 1222+216 ($z = 0.432$)

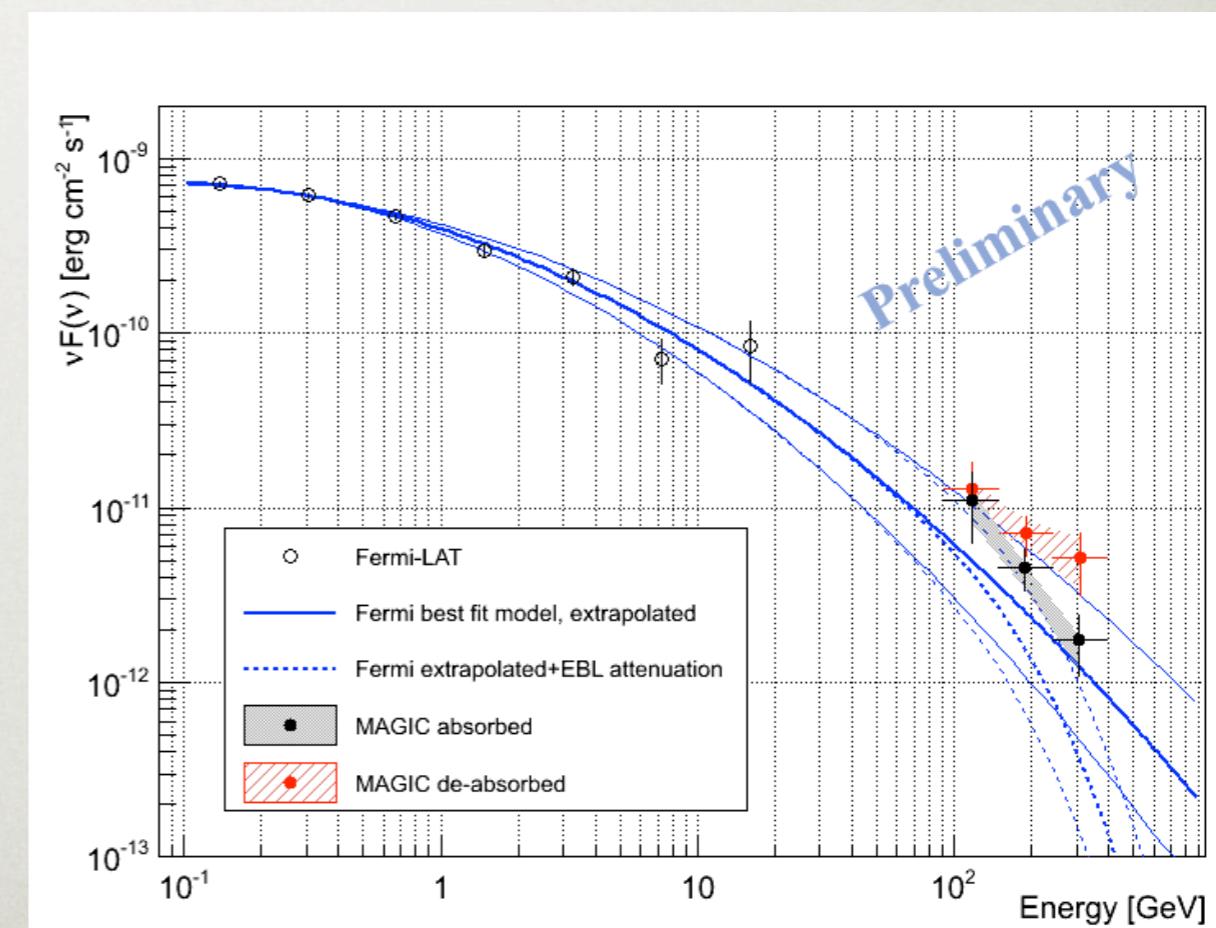
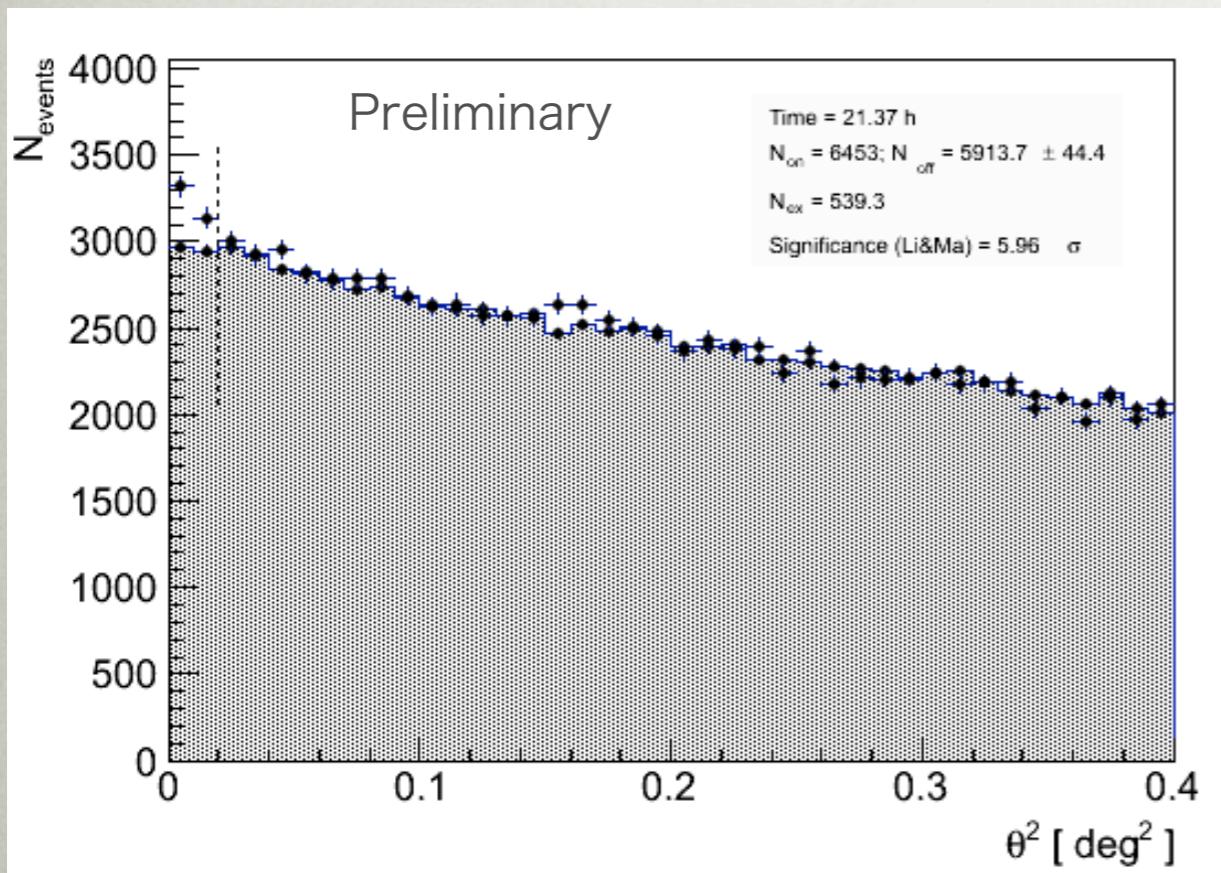
- Discovered by MAGIC in 2010 during GeV flare observed by Fermi-LAT
- Fastest time scale variability (~10 min) among FSRQs
- Challenges canonical emission models



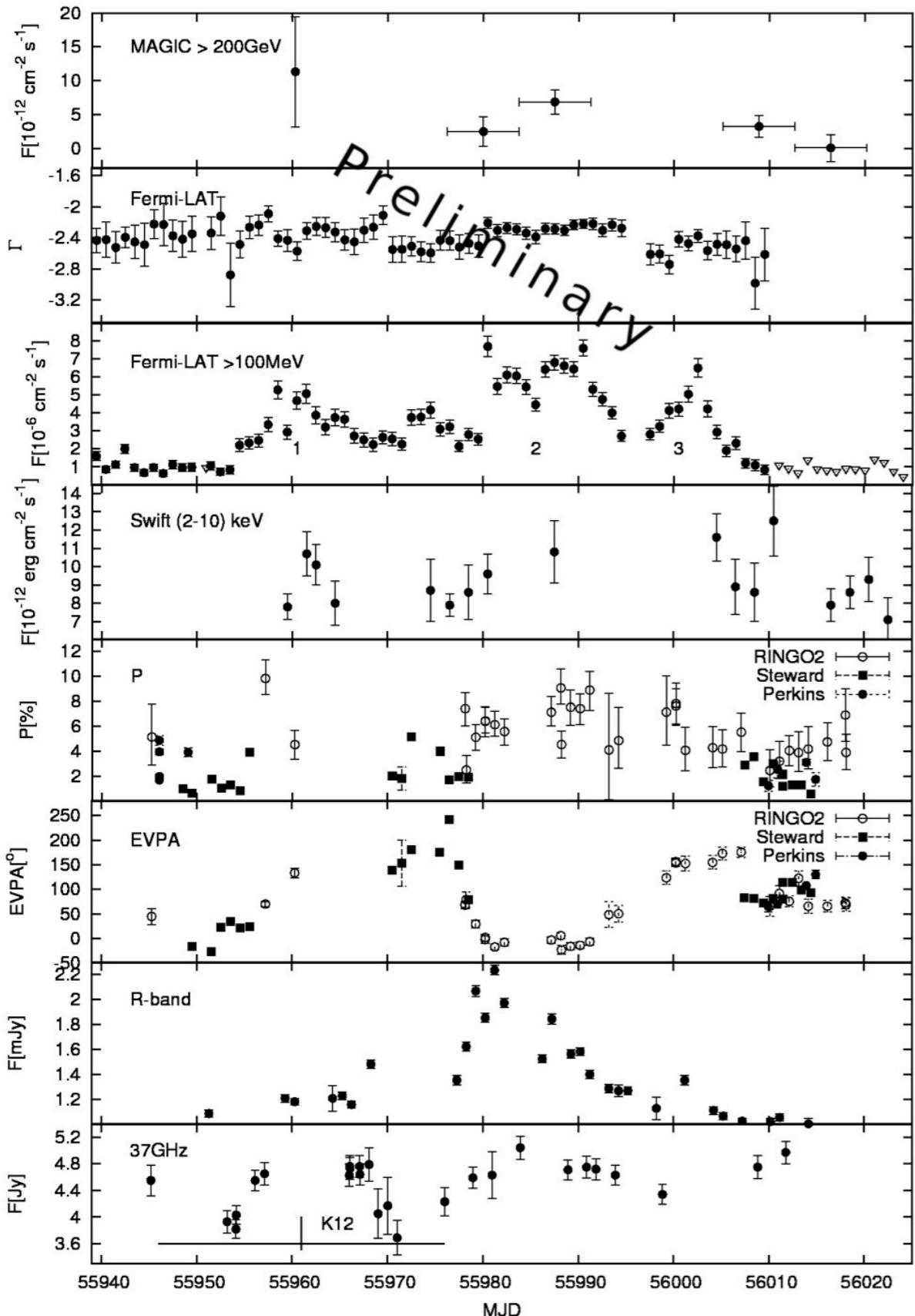
FSRQs

PKS 1510-089 ($z = 0.361$)

- Discovered by H.E.S.S. in 2009 (Abramowski+ 2013)
- MAGIC observations triggered by HE gamma-ray flare (AGILE and Fermi) in 2012
- MAGIC observed for 28 nights between February and April
- 6σ detection with 21 hour good quality data
- MAGIC & LAT spectra connect smoothly



FSRQs



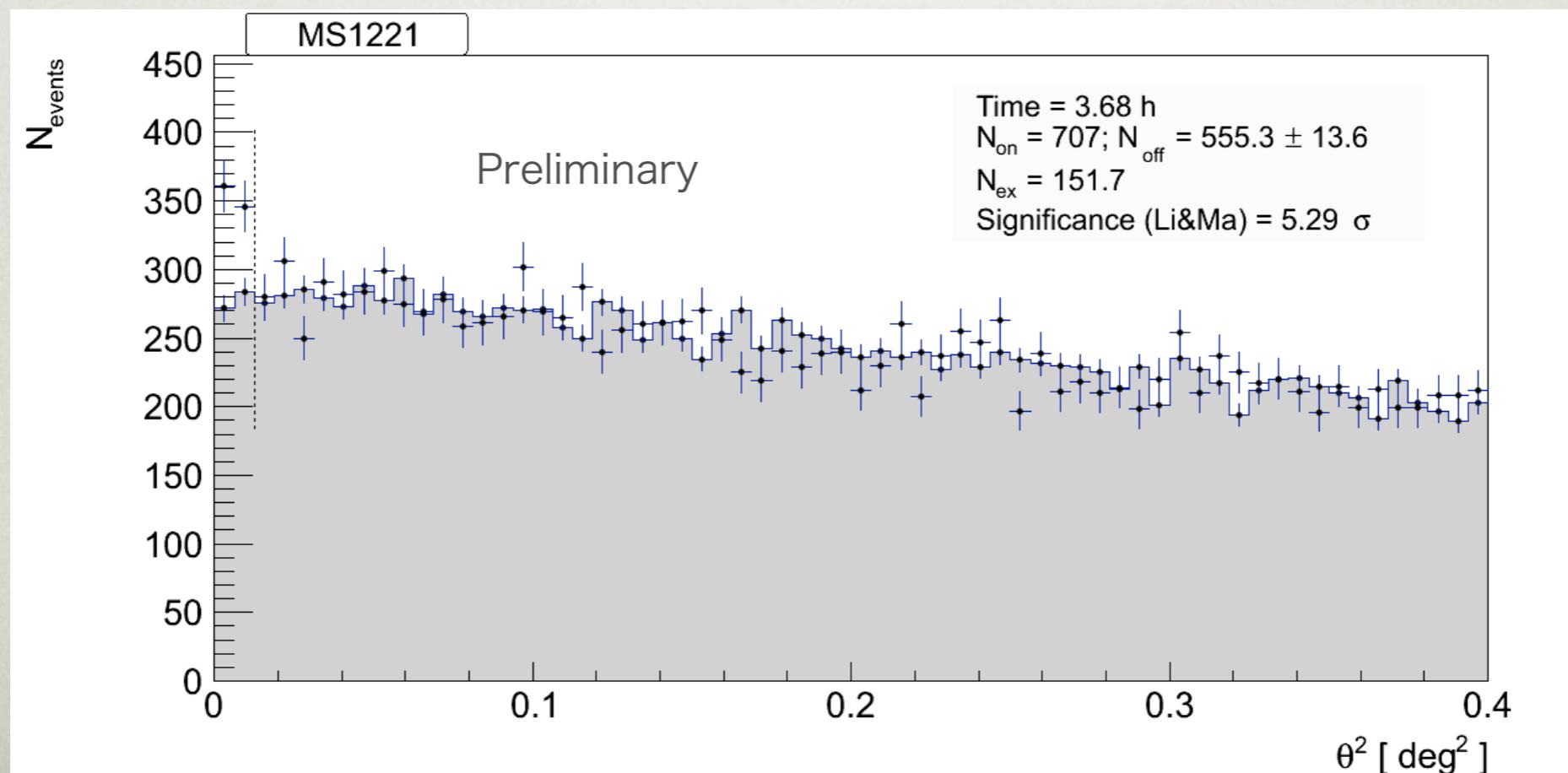
PKS 1510-089 2012 MWL

- VHE flux shows no significant variation: apparent discrepancy with the other FSRQs
- HE gamma-ray flares seem to be accompanied by the simultaneous flares in 37 GHz radio
- Gamma-ray flare also coincident with the ejection of new radio component
- Suggested that the gamma-ray and millimeter flaring activities are co-spatial
- VLBA core: $\gtrsim 10$ pc away from the central engine (e.g. Jorstad+ 2012)

NEWEST DISCOVERIES

MS 1221.8+2452

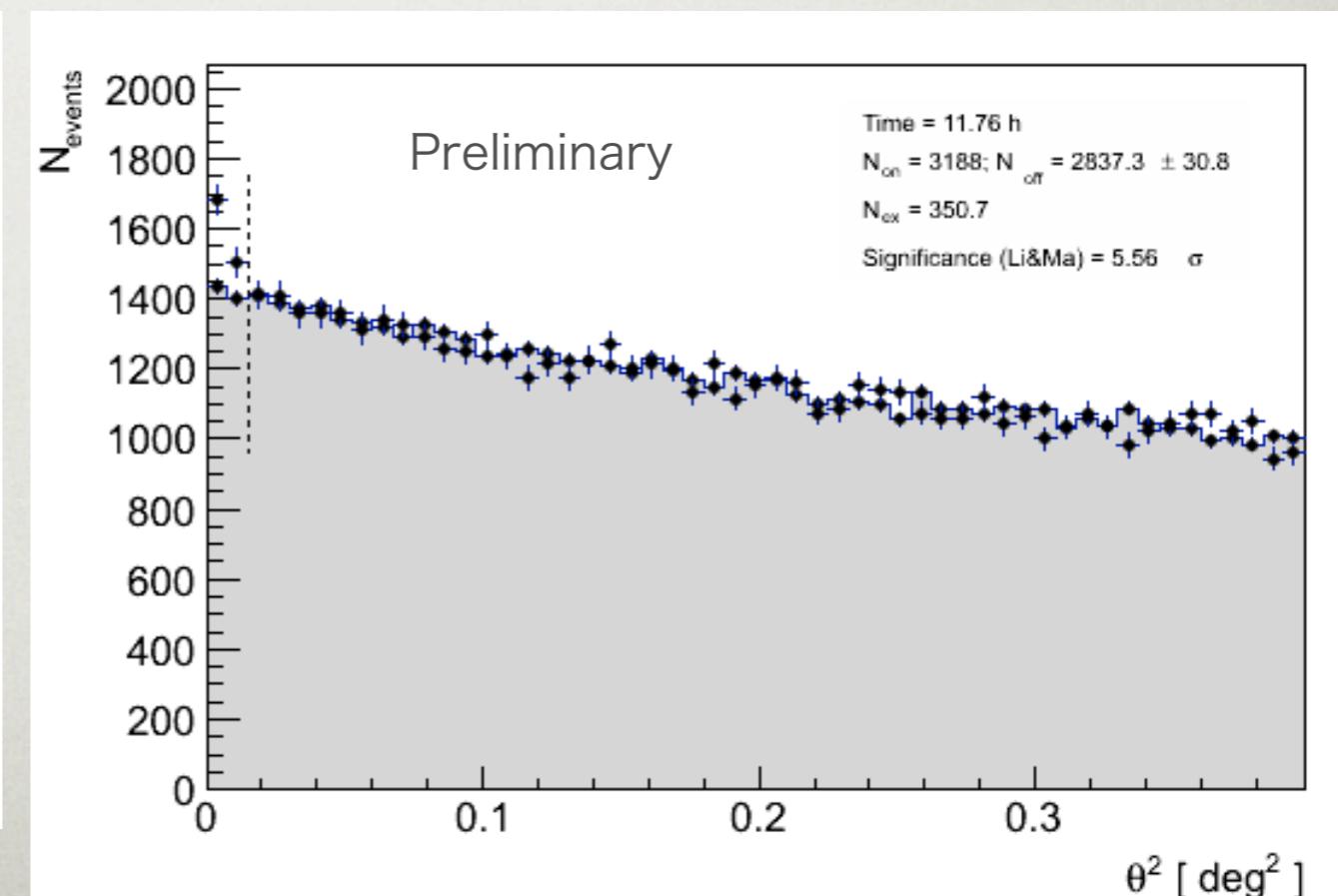
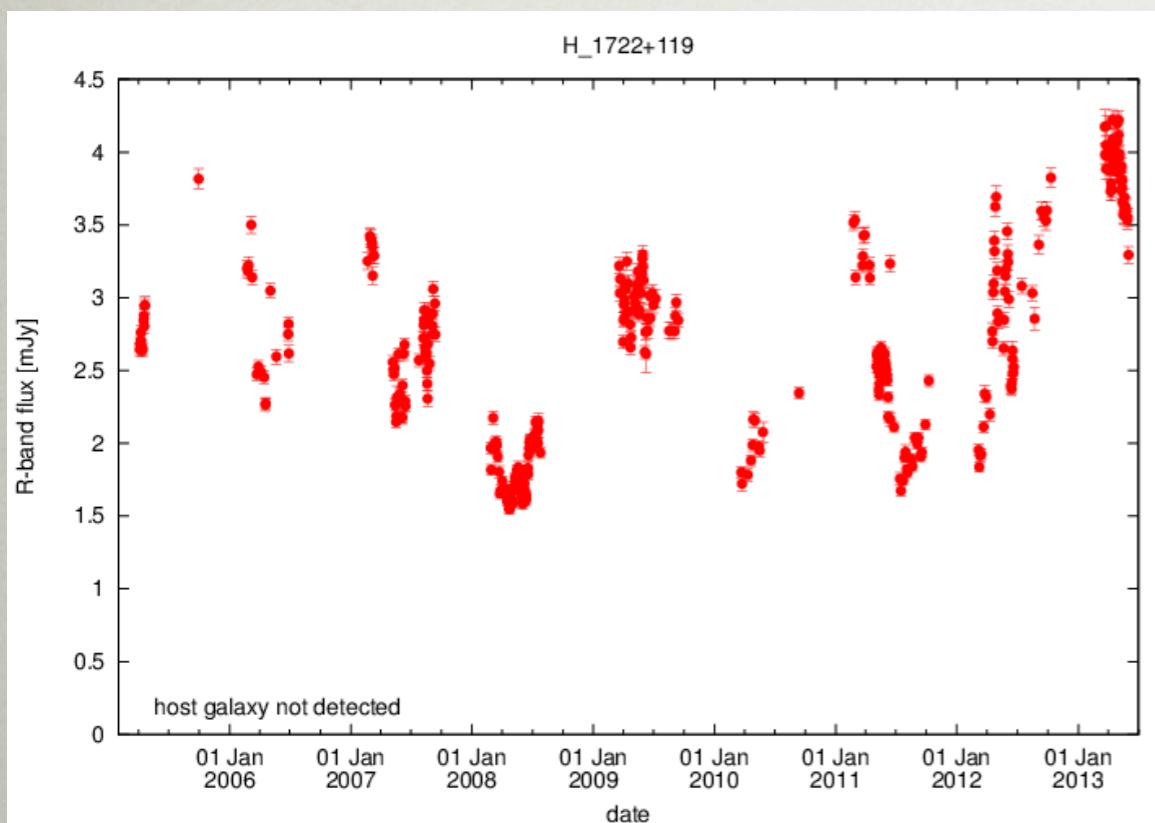
- * HBL at $z = 0.218$
- * Weak Fermi source but very hard spectrum above 10 GeV ($\Gamma = 1.26$)
- * Discovered in April 30th and May 1st 2013 ([ATel #5038](#))
- * 6σ in 3.7 hour
- * 4 % C.U. (>200 GeV)
- * For EBL and IGMF studies



NEWEST DISCOVERIES

H 1722+119

- * TeV candidate BL Lac in Costamante & Ghisellini (2002)
- * Uncertain redshift, lower limit of 0.17
- * Past MAGIC observations in 2004-2009: U.L. 4 % C.U. above 140 GeV
- * In May 2013 the Tuorla blazar monitoring program reported the highest optical flux ever observed since 2005
- * $>5\sigma$ detection in 10 hour (ATel #5080)



SUMMARY & OUTLOOK

- ☑ 2011年-2012年望遠鏡アップグレード
 - ☑ 低エネルギー領域でさらにパフォーマンス向上
 - ☑ Galactic/Extragalactic共にいくつもの興味深いサイエンス結果を提供し続けている
-
- ☑ 今後5-7年 安定したオペレーション
 - ☑ ステレオSumトリガーのインストール in 今年