

TeV BLAZARS with **H.E.S.S.**

Matteo Cerruti

Torino, 06-11-2018



H.E.S.S. II



Array of 4+1 Cherenkov telescopes located on Khomas Highland, Namibia
(1800m asl, $23^{\circ}16' S$, $16^{\circ}30' E$)

2012: installation of the central telescope (CT5)

2016: upgrade of H.E.S.S. I cameras

Detection of photons above 30 GeV

Energy resolution: $\sim 10\%$ at 1 TeV

Angular resolution: $\sim 0.1^\circ$ at 1 TeV

H.E.S.S. II

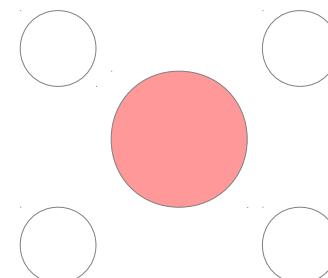


Array of 4+1 Cherenkov telescopes located on Khomas Highland, Namibia
(1800m asl, $23^{\circ}16' S$, $16^{\circ}30' E$)

Two different reconstructions:

Monoscopic (CT5 only)

Stereoscopic (any 2 out of 5 telescopes)

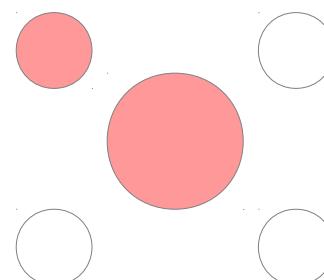


H.E.S.S. II



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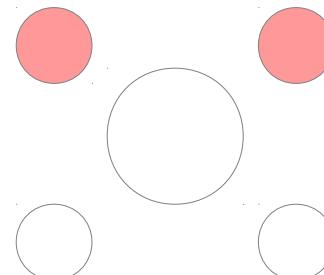


H.E.S.S. II

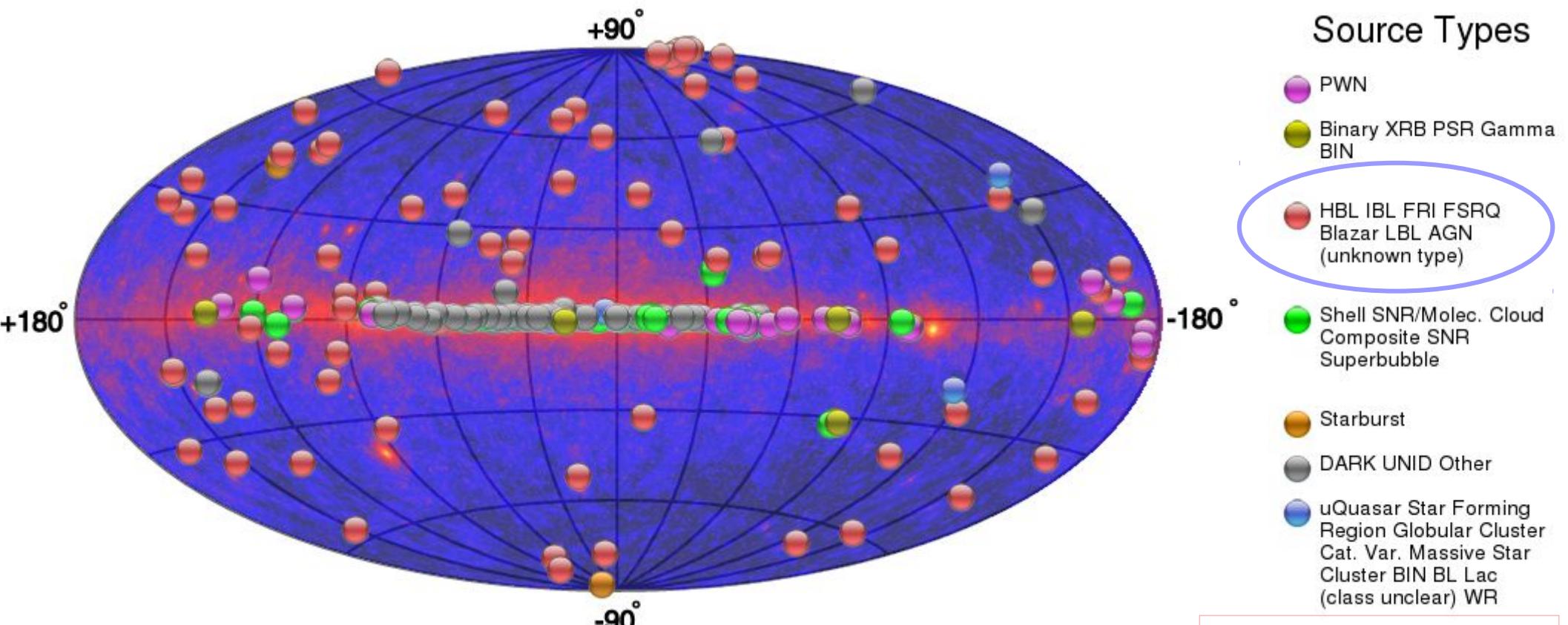


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Stereoscopic (any 2 out of 5 telescopes)



THE TeV SKY

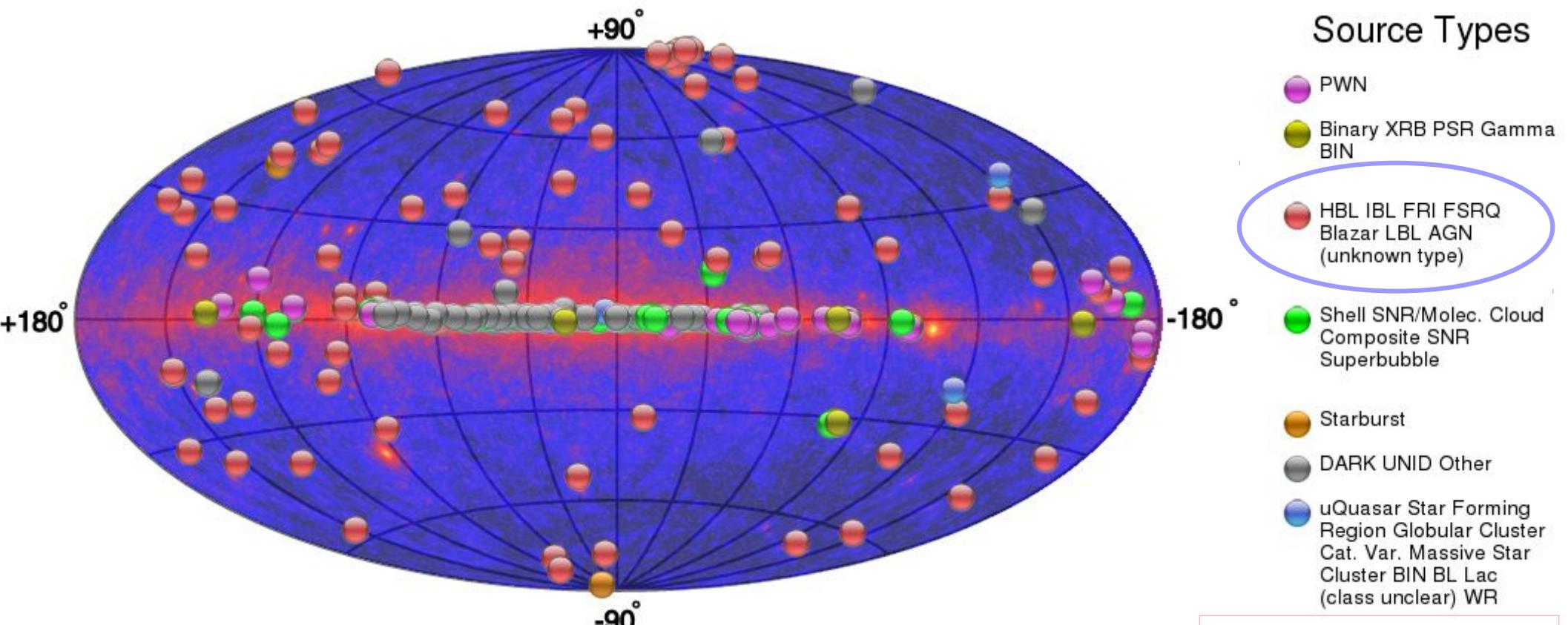


From TeVCAT

Extragalactic TeV sky:

2 starburst galaxies
4 radio-galaxies
71 blazars

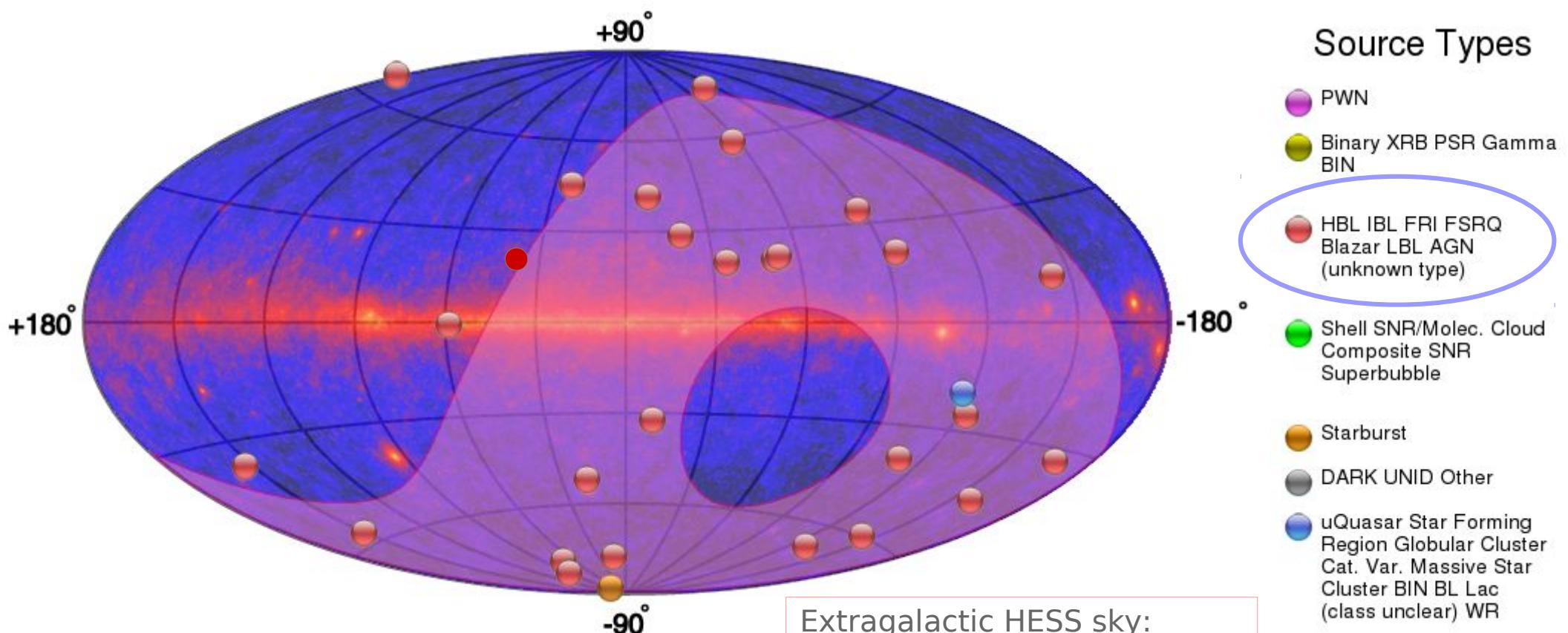
THE TeV SKY



From TeVCAT

Extragalactic TeV sky:
of these 71 blazars
52 are HBLs
12 are I/LBLs
7 are FSRQs

THE H.E.S.S. XGAL SKY

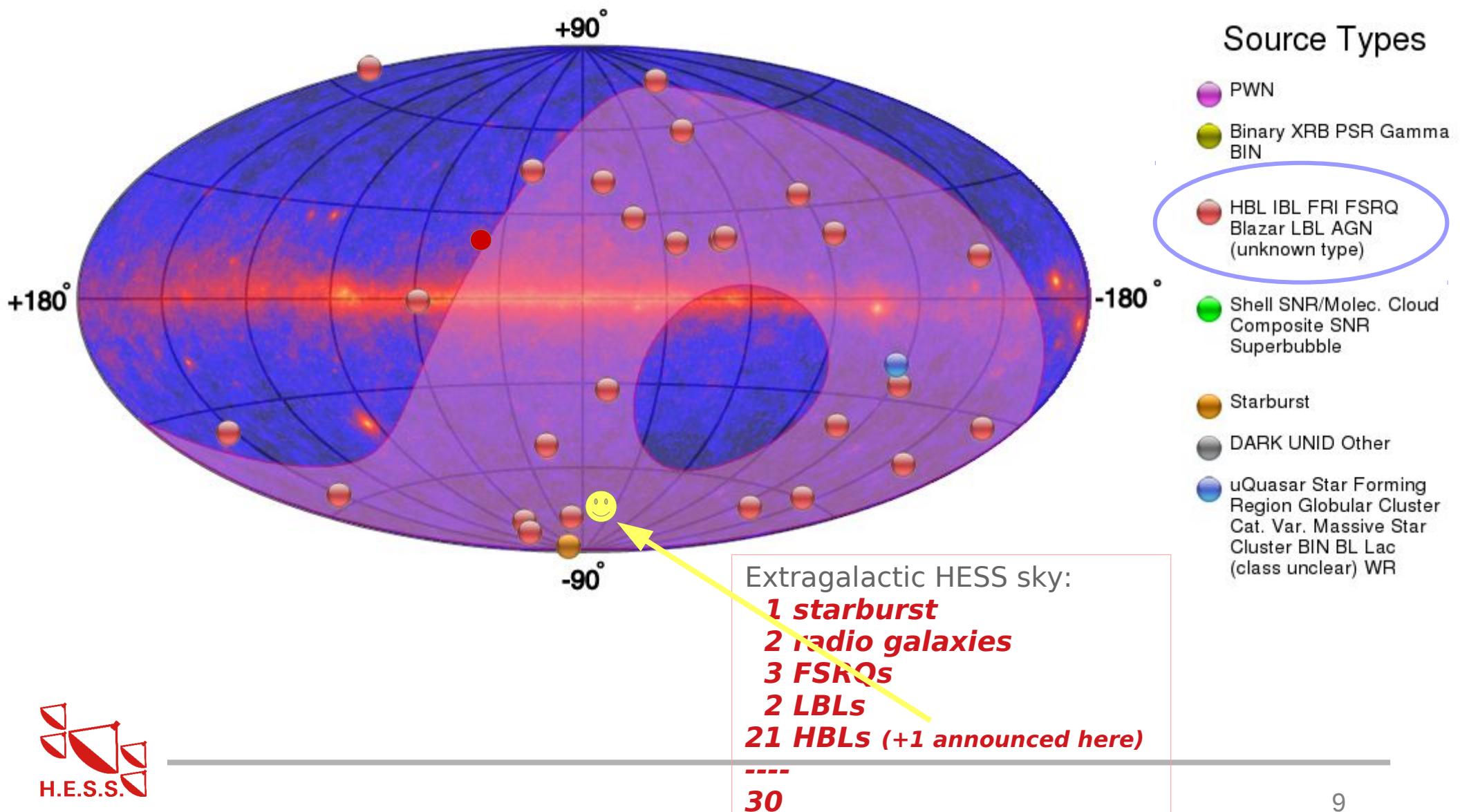


Extragalactic HESS sky:

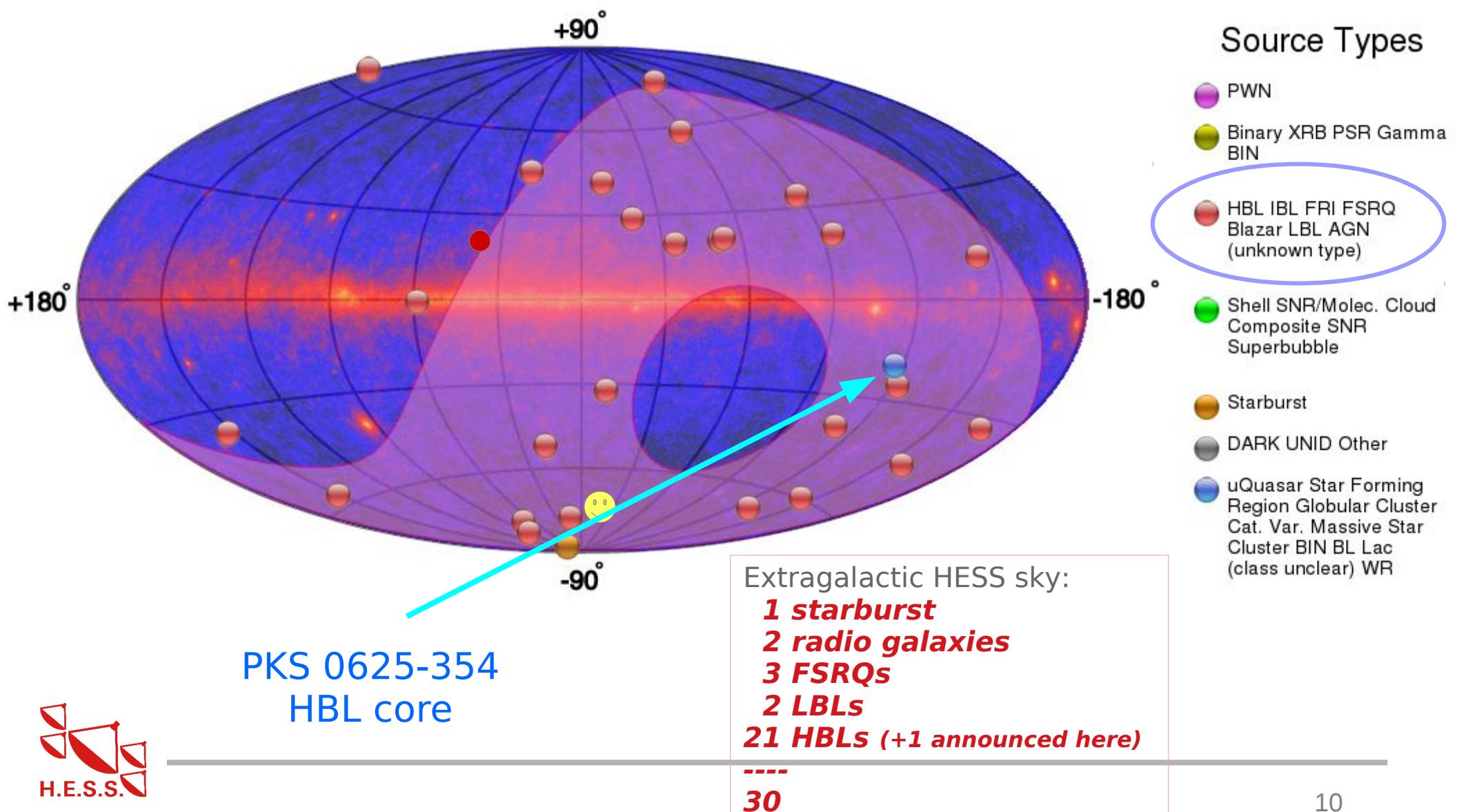
1 starburst
2 radio galaxies
3 FSRQs
2 LBLs
21 HBLs (+1 announced here)

30

THE H.E.S.S. XGAL SKY



THE H.E.S.S. XGAL SKY



H.E.S.S. BLAZARS

SHBL J001355.9-185406	HBL	0.095
KUV 00311-1938	HBL	>0.506
RGB J0152+017	HBL	0.08
1ES 0229+200	HBL	0.14
1RXS J023832.6-311658	HBL	0.232
PKS 0301-243	HBL	0.266
1ES 0347-121	HBL	0.188
1ES 0414-009	HBL	0.287
PKS 0447-439	HBL	0.343
PKS 0548-322	HBL	0.069
PKS 0625-35	HBL	0.055
PKS 0736+017	FSRQ	0.189
1RXS J101015.9-311909	HBL	0.143

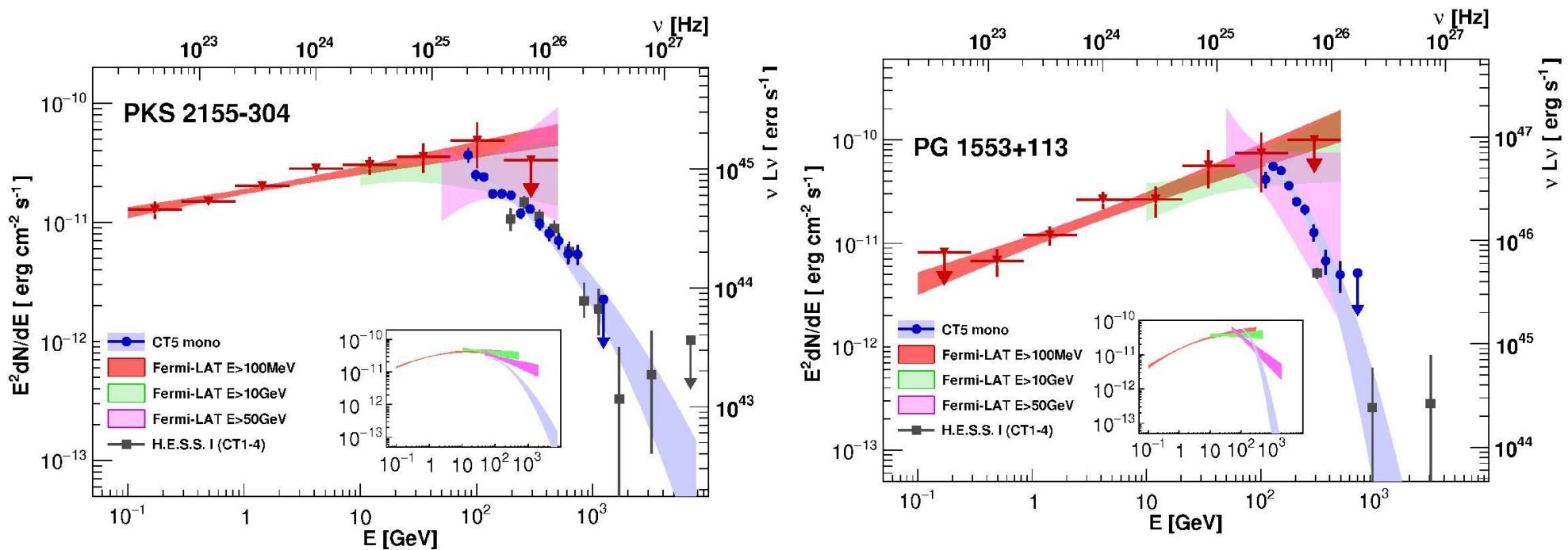
1ES 1101-232	HBL	0.186
Mrk 421	HBL	0.031
3C 279	FSRQ	0.536
1ES 1312-423	HBL	0.105
PKS 1440-439	HBL	?
PKS 1510-089	FSRQ	0.361
AP Librae	LBL	0.049
PG 1553+113	HBL	>0.43
PKS 1749+096	LBL	0.32
HESS J1943+213	HBL	?
PKS 2005-489	HBL	0.071
PKS 2155-304	HBL	0.116
<u>1ES 2322-409</u>	HBL	?
H 2356-309	HBL	0.165

NEW

H.E.S.S. II BLAZARS

Spectra of bright blazars with improved energy threshold

PKS 2155-304 and PG 1553+113



HESS Collaboration 2017

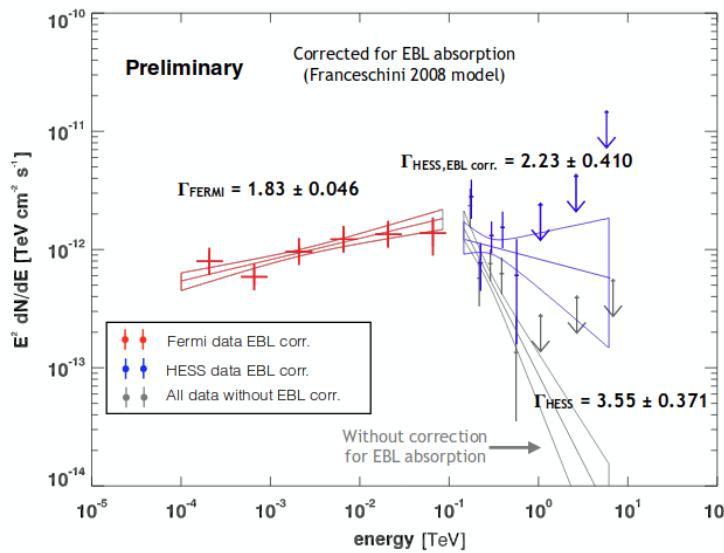
H.E.S.S. II BLAZARS

Discovery program

Focusing on extending the TeV blazar population

- LBLs (AP Librae like)
- UHBLs (1ES 0229+200 like)

One new discovery : 1RXS J023832.6-311658 (z=0.232)



Selected as hard Fermi source,
but **not really 1ES0229-like**

New HBL at moderate redshift

Gat  et al., ICRC 2017

H.E.S.S. II BLAZARS

ToO program

Increasingly important within HESS

Recent results on FSRQs:

- **3C 279** : 2015 & 2018 flares
- **PKS 1510-089** : 2016 flare
- PKS 0736+017 : 2015 flare (new VHE discovery)

Recent results on BL Lacs:

- PKS 1749+096 : 2016 flare (new VHE discovery)
- PKS 0447-439: 2016 flare
- Mrk 421: 2017 flare

3C 279

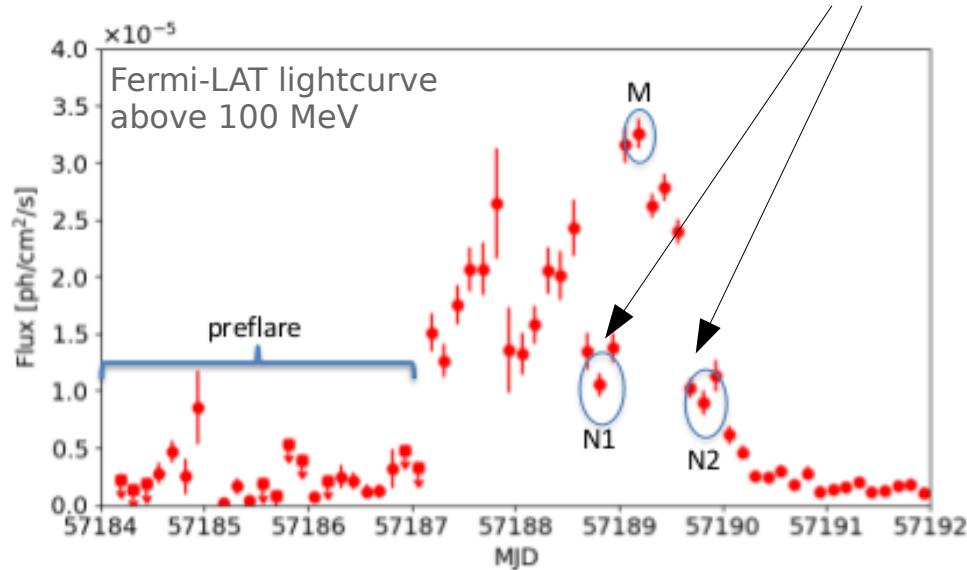
Bright γ -ray flare seen with Fermi-LAT in June 2015:

3-days flare with peak flux of $3.6 \times 10^{-5} \text{ cm}^{-2} \text{ s}^{-1}$

80 times brighter than 3FGL average

Minute-scale variability detected with Fermi-LAT

Target of Opportunity observations with H.E.S.S.



Romoli et al. ICRC 2017 arXiv 1708.00882

3C 279

H.E.S.S. observations : Detection only during the second night:

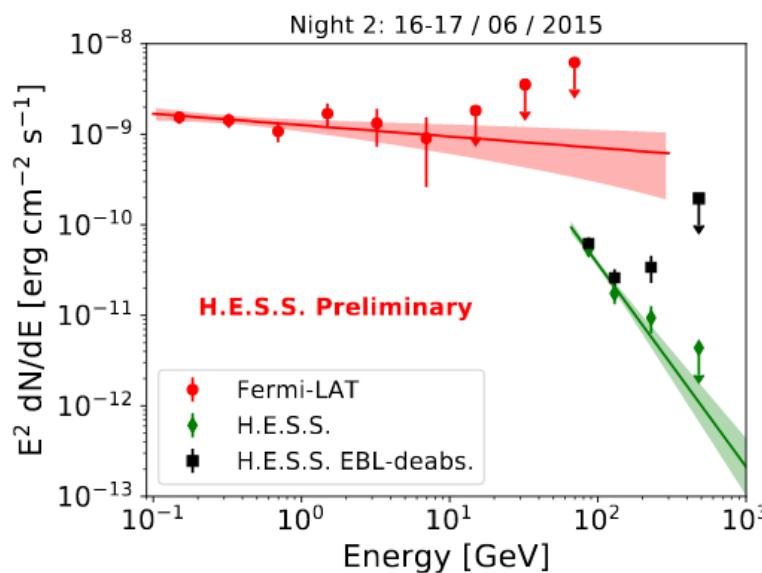
$$E_{\text{threshold}} = 66 \text{ GeV} \text{ (Monoscopic reconstruction)}$$

$$F_{100 \text{ GeV}} = (2.5 \pm 0.2) \times 10^{-12} \text{ cm}^{-2} \text{ s}^{-1} \text{ GeV}^{-1}$$

$$\Gamma = 4.2 \pm 0.3$$

Detection at 8.7σ in 3 hours of observations

Strictly simultaneous Fermi-LAT – H.E.S.S. II spectrum



Romoli et al. ICRC 2017 arXiv 1708.00882

3C 279

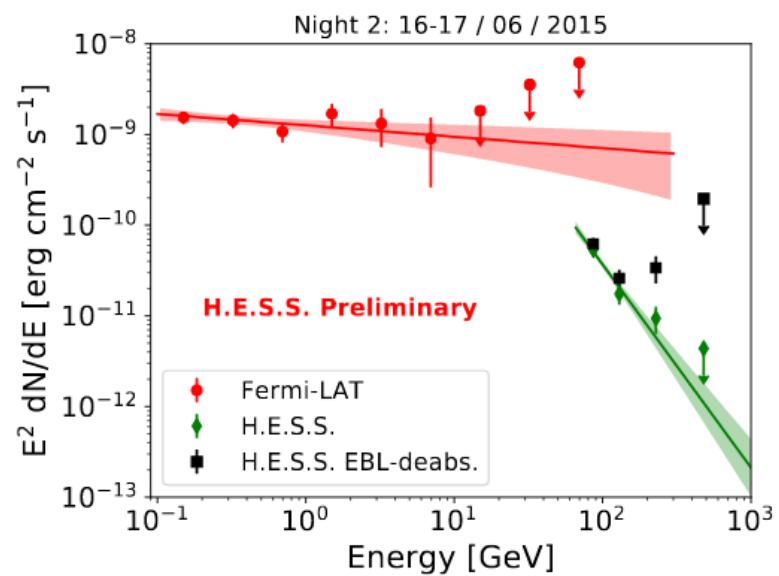
Internal absorption of VHE photons:

- spectrum corrected from EBL absorption (Franceschini et al. 09)
- assumption on intrinsic spectrum (power-law)
- assumption on external photon field & BLR geometry (Finke 2016)

Maximum internal optical depth:

$$\tau = 3.3 \pm 0.7$$

$$r_{\min} = 10^{17} \text{ cm (0.1 pc)}$$

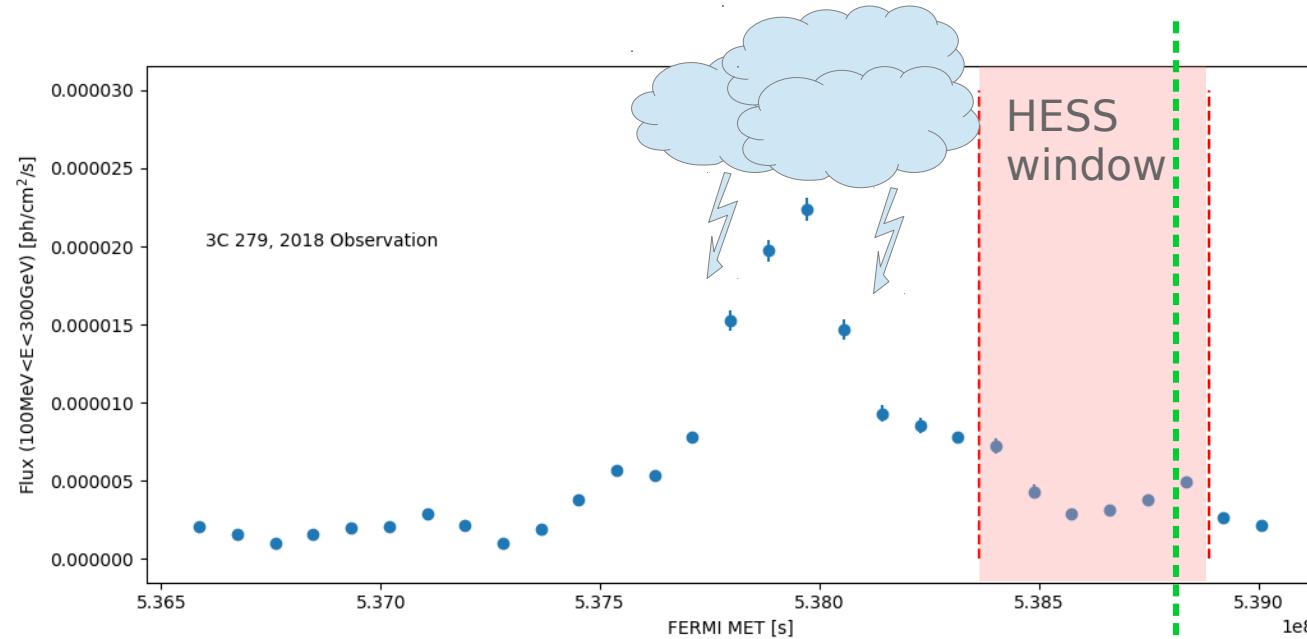


3C 279

Second bright γ -ray flare in January 2018:

Peak flux in Fermi-LAT at $2.5 \times 10^{-5} \text{ cm}^{-2} \text{ s}^{-1}$

Target of Opportunity observations with H.E.S.S



Strong VHE flare during a single night, after the HE peak

3C 279

Second bright γ -ray flare in January 2018:

Peak flux in Fermi-LAT at $2.5 \times 10^{-5} \text{ cm}^{-2} \text{ s}^{-1}$

Target of Opportunity observations with H.E.S.S

H.E.S.S. detection of a strong VHE activity from the blazar 3C 279

ATel #11239; **Mathieu de Naurois for the H. E.S. S. collaboration**
on 28 Jan 2018; 15:00 UT

Credential Certification: Jean-Philippe Lenain (jlenain@in2p3.fr)

Subjects: Gamma Ray, VHE, Request for Observations, AGN, Blazar, Quasar

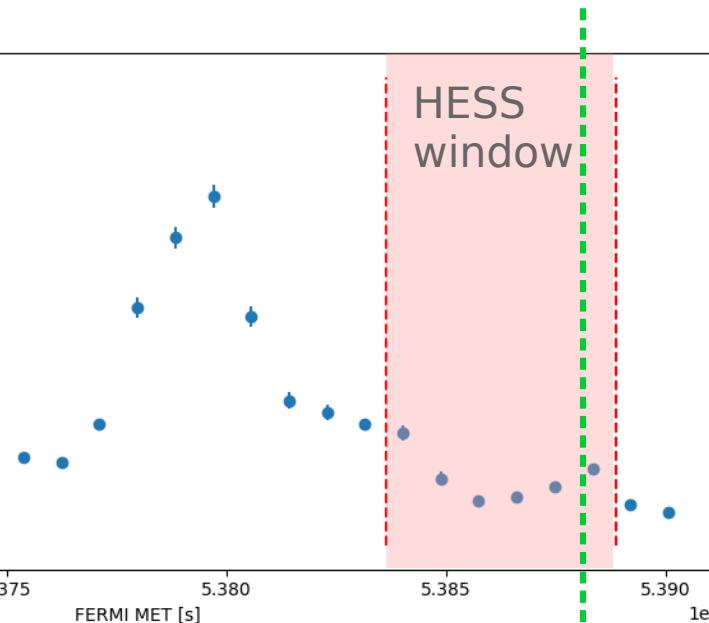
Referred to by ATel #: [11246](#), [11464](#), [11680](#)

Tweet

H.E.S.S. observations of the flat spectrum radio quasar 3C 279 (redshift $z=0.536$, R.A.: 12h56m11.1665s, Dec: -05d47m21.523s (J2000)) have been carried out during the past 2 weeks, on the basis of the detection of flaring activity in the gamma-ray band with Fermi-LAT (ATel #[11189](#)) and AGILE (ATel #[11200](#)), as well as in the optical band (ATels #[11190](#), #[11196](#), #[11202](#), #[11216](#)).

A preliminary online analysis of the data acquired with CT5 (monoscopic analysis) of previous nights indicates no detection, while during the night January 27-28 the online analysis shows an unprecedented flux with a total significance of ~ 11 standard deviations in 1.8 hours of observation. This could be the highest flux level of this source ever seen at very high energies ($E > 100$ GeV). Unfortunately, further observations cannot be planned beside the upcoming night due to Moon constraints, however a multi-wavelength coverage is strongly encouraged.

H.E.S.S. is an array of five imaging atmospheric Cherenkov telescopes for the detection of VHE gamma-ray sources. H.E.S.S. is located in the Khomas Highland in Namibia. It was constructed and is operated by researchers from Armenia, Australia, Austria, the Czech Republic, France, Germany, Ireland,



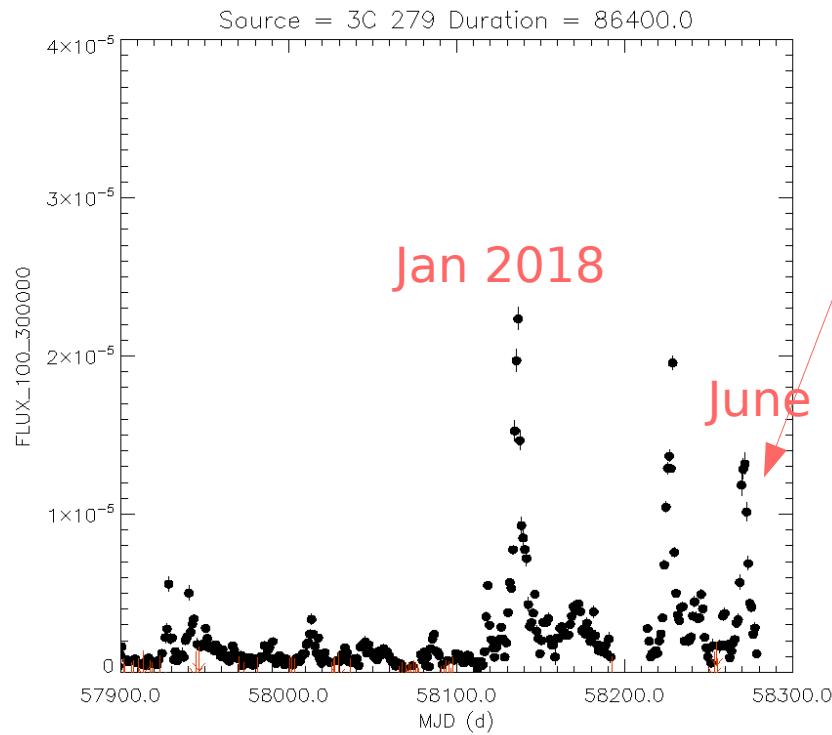
Strong VHE flare during a single night, after the HE peak

3C 279

Two new γ -ray flares in April & June 2018:

Peak fluxes in Fermi-LAT are very similar

Detection announced by MAGIC in April, by HESS again in June



H.E.S.S. and ATOM detection of renewed activity of the FSRQ 3C 279

ATel #11680; **Mathieu de Naurois for the H. E.S. S. Collaboration**
on 4 Jun 2018; 14:05 UT

Credential Certification: Michael Zacharias (m.zacharias@lsw.uni-heidelberg.de)

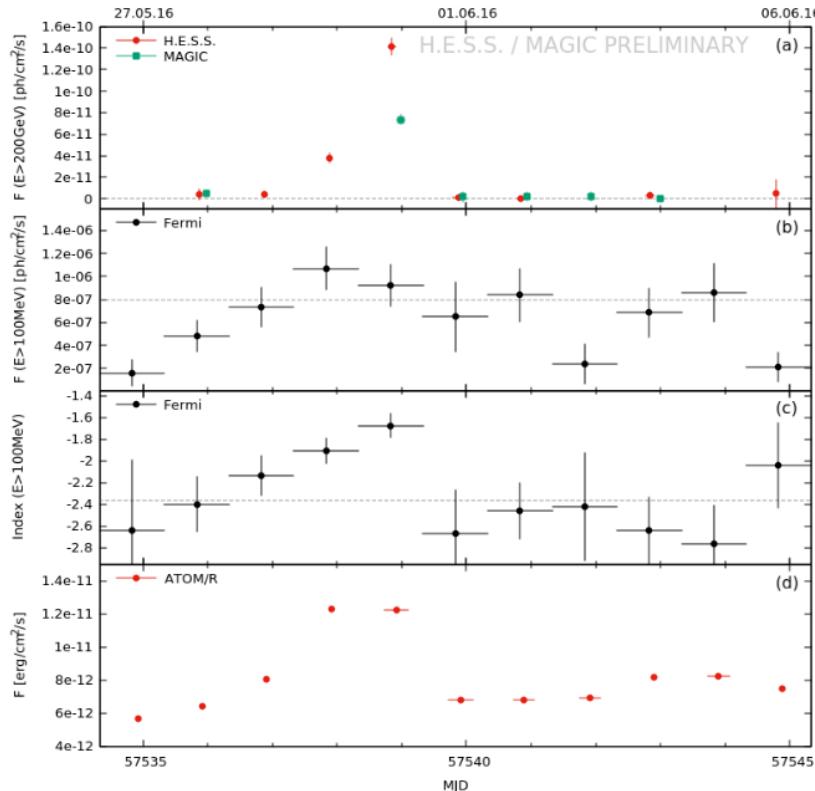
Subjects: Optical, Gamma Ray, >GeV, VHE, Request for Observations, AGN, Black Hole, Blazar, Quasar

Referred to by ATel #: [11687](#)

Tweet

H.E.S.S. observations at very-high energies ($E>100$ GeV) of the flat spectrum radio quasar 3C 279 (redshift $z=0.536$, R.A.: 12h56m11.1665s, Dec: -05d47m21.523s (J2000)) have been carried out over the last 3 nights on the basis of another strong flare in the high-energy gamma-ray band ($E>100$ MeV) detected with Fermi-LAT. A preliminary online analysis of the data acquired with CT5 (monoscopic analysis; telescope diameter 28m) indicate for the night June 2-3 a significance of 5.7sigma (in 2hrs of observations), which has risen to 7.2 sigma in 3hrs of observations in the night June 3-4. The rate of events appears constant in both nights. H.E.S.S. will continue observations of 3C 279 over the next nights, and multiwavelength follow-up observations are strongly encouraged. Optical observations with ATOM show an increase of apparent R-band magnitude from 14.4 for the night May 28-29 to 13.5 for the night June 1-2. In the following two nights, the optical flux has been detected at this elevated level with variability within 0.3 magnitudes. Observations of 3C 279 will be continued. This is the third time that 3C 279 has been detected at very-high energies this year, with a detection by H.E.S.S. in January (ATel #11239) and by MAGIC in April (ATel #11545). During this time, 3C 279 also showed strong optical variability (e.g. ATel #11624). H.E.S.S. is an array of five imaging atmospheric Cherenkov telescopes for the detection of VHE gamma-ray sources. H.E.S.S. is located in the Khomas Highland in Namibia. It was constructed and is operated by researchers from Armenia, Australia, Austria, the Czech Republic, France, Germany, Ireland, Poland, South Africa, Sweden,

PKS 1510-089



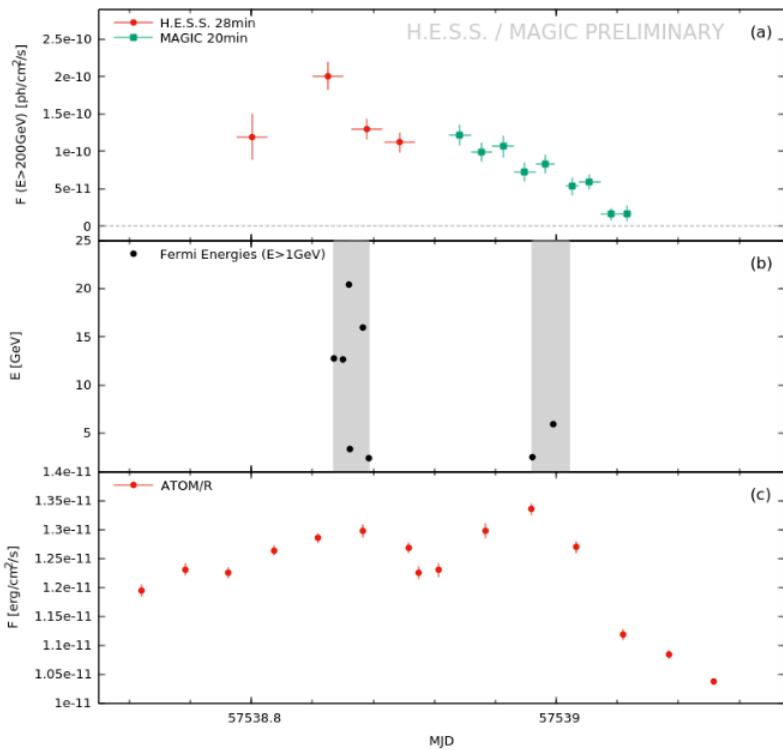
MWL lightcurve of the event with nightly averages: (a) H.E.S.S/MAGIC flux, (b) Fermi flux, (c) Fermi index, (d) ATOM flux

Rapid and bright VHE γ -ray flare
in May 2016

No counterpart in integral HE γ -ray
light-curve, but significant hardening in
the spectrum

Optical flux enhanced coincident with
VHE flare

PKS 1510-089



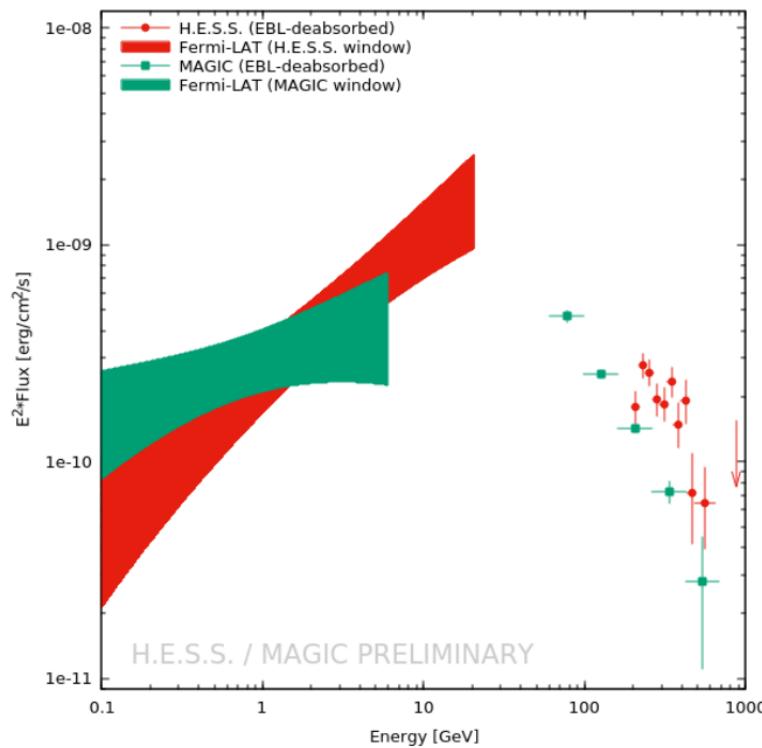
Detailed lightcurve of MJD 57538: (a)
H.E.S.S/MAGIC flux, (b)Fermi energies,
(c) ATOM flux

Peaked lightcurve at VHE:
maximum flux $\sim 80\%$ Crab ($E > 200 \text{ GeV}$)
continuous decrease to $\sim 7.5\%$ Crab

Minimum variability time-scale:
 18 ± 5 minutes

→ size of the emission region
 $R \sim 10^{15} (\delta/50) \text{ cm}$

PKS 1510-089



γ -ray spectrum during the H.E.S.S. window (red) and the MAGIC window (green). VHE spectra corrected for EBL absorption.

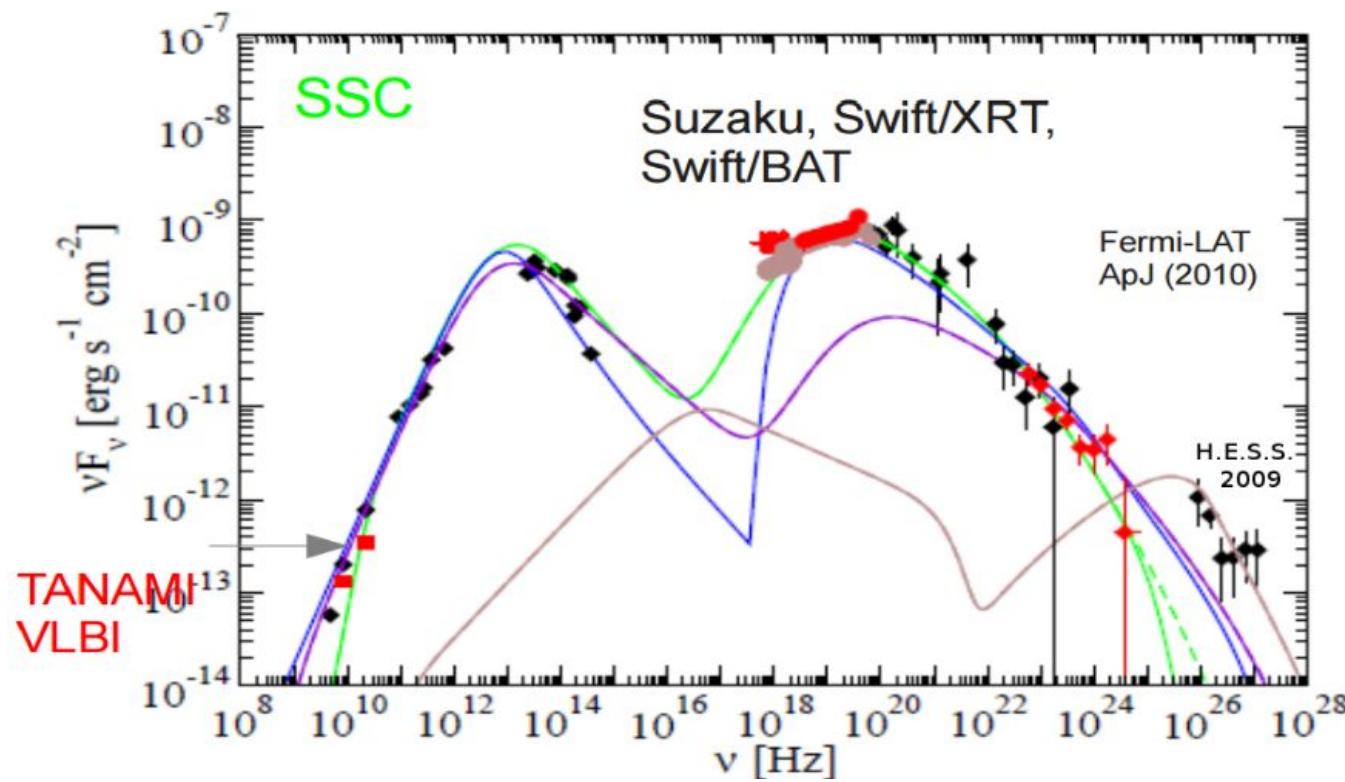
Break between HE and VHE spectra, constant over both observing window ($\Delta\Gamma \sim 1.6$)

If the break is caused by internal absorption on BLR photons, $\tau \sim 5$

→ location of the emitting region
 $r_{\min} \sim 3 \cdot 10^{17}$ cm

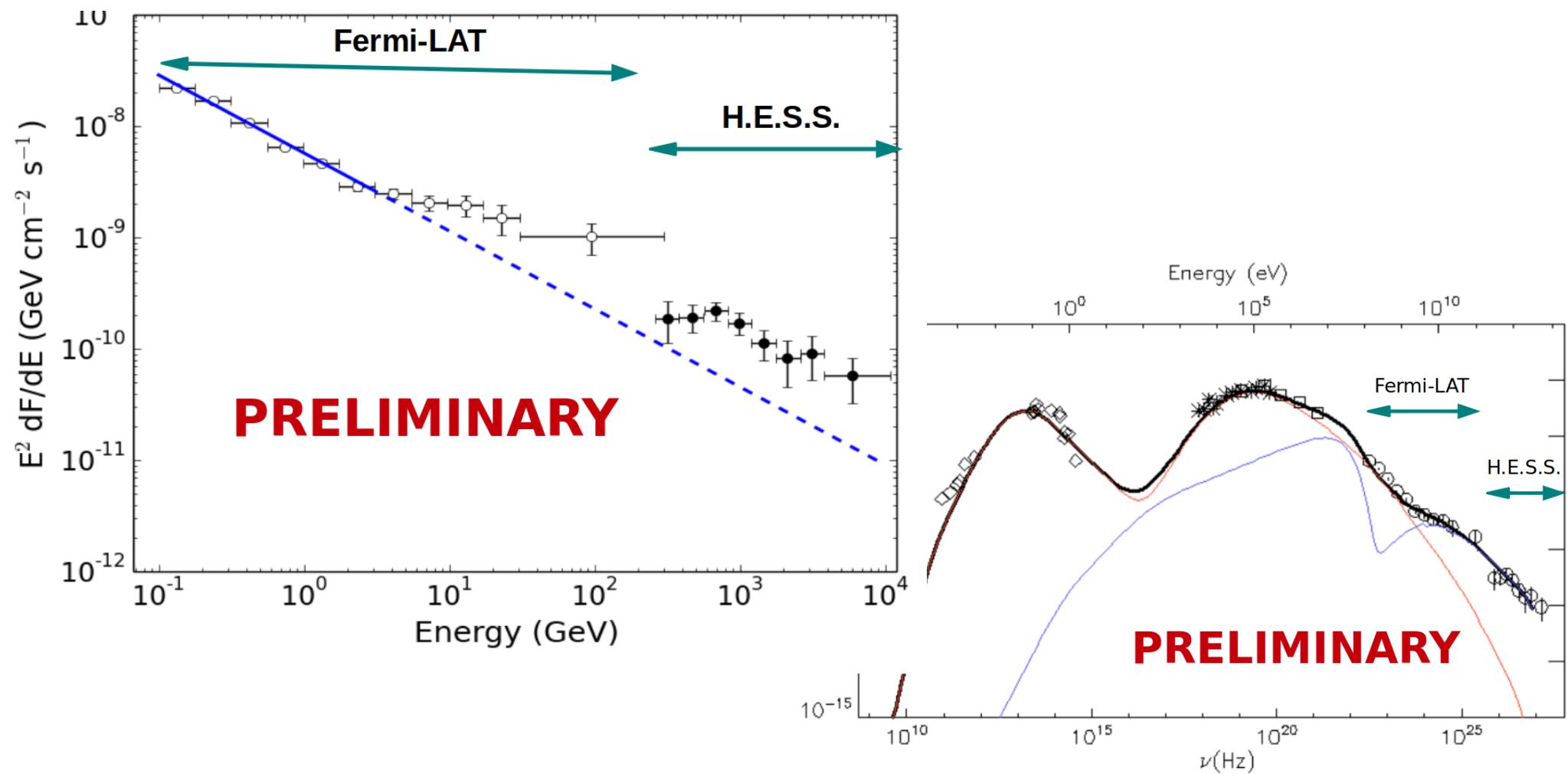
MISALIGNED BLAZARS

Centaurus A : one of the three radio-galaxies detected at VHE



MISALIGNED BLAZARS

New **H.E.S.S.** I observations (213 hours) + new analysis methods
8 years of Fermi exposure with PASS 8 event reconstruction



MISSING REDSHIFTS

Sources which still need spectroscopic z

- KUV 00311-1938 , $z > 0.51$
- PKS 1440-389 , $z < 2.2$
- PG 1553+113 , $0.43 < z (< 0.58)$
- HESS J1943+213 , $z = ?$
- 1ES 2322-409 , $z = ?$ (weak evidence for $z=0.17$)

CONCLUSIONS

H.E.S.S. II blazar program is very active, making use of the low energy threshold of the instrument

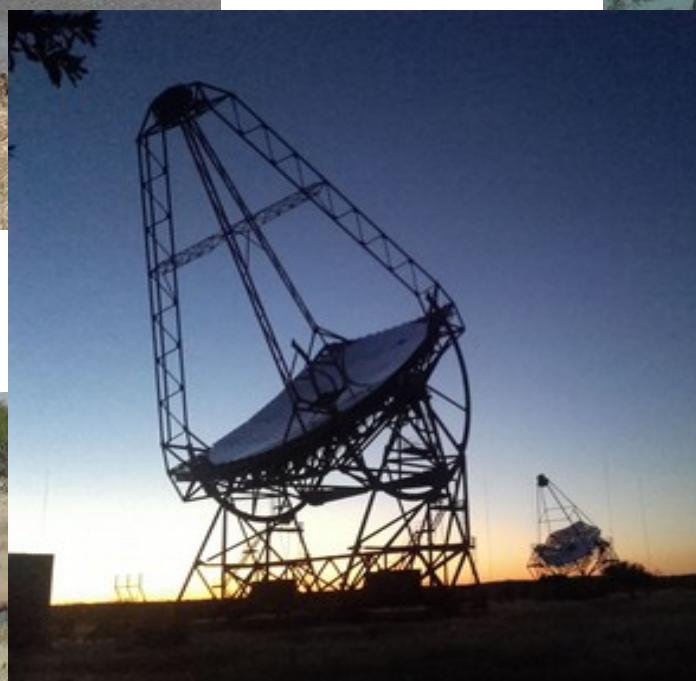
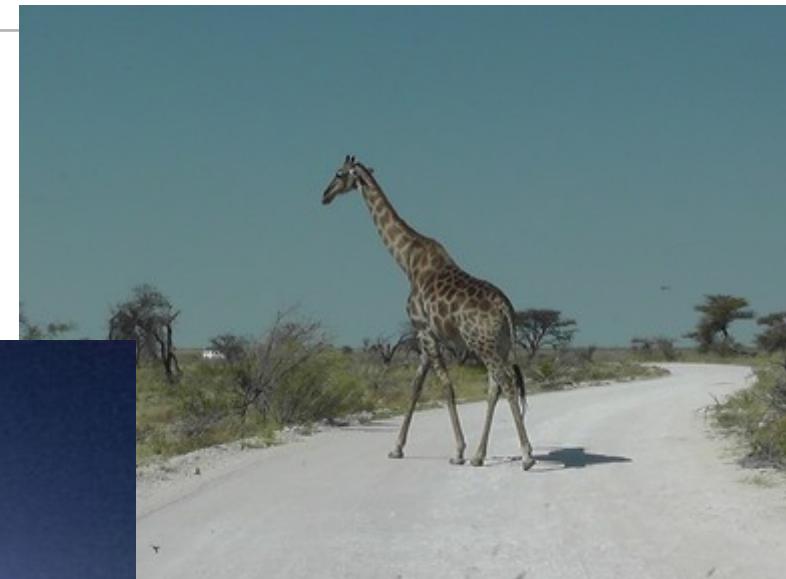
Discovery program focused on uncommon TeV blazar subclasses
(LBLs / extreme HBLs)

ToO program providing exciting results especially on FSRQs

H.E.S.S. fully funded up to 2019, discussions ongoing
for post-2019 operations

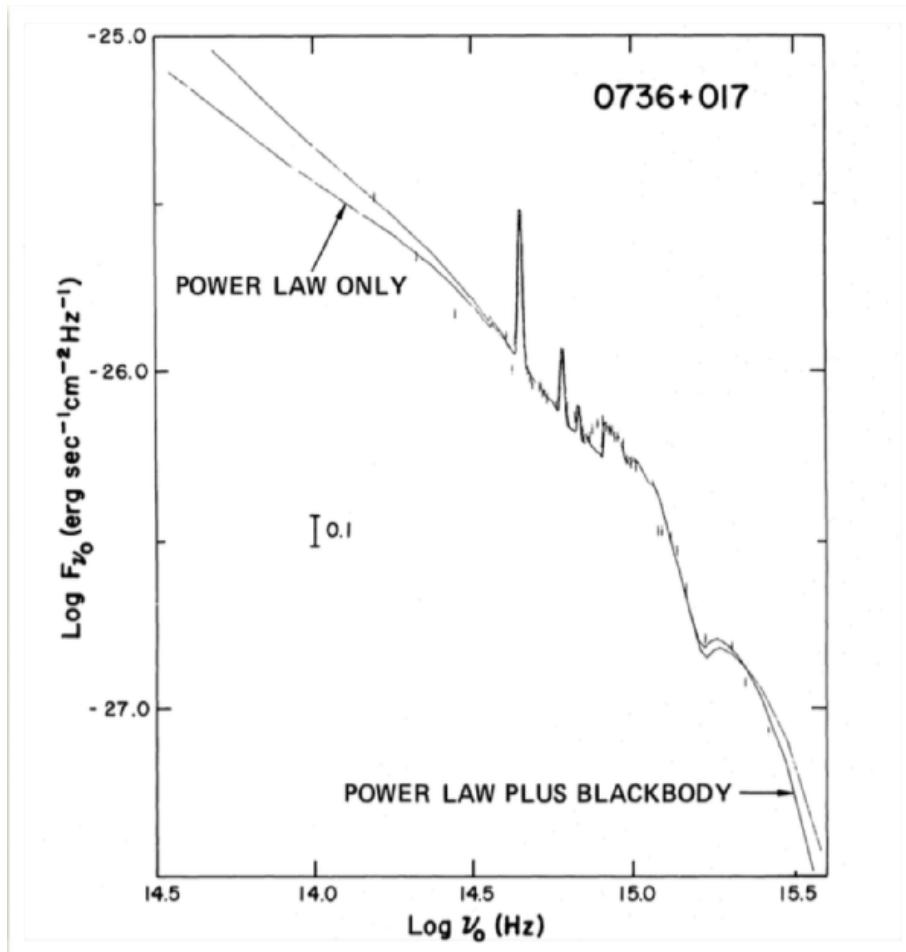
Since May 2018, fast internet in Namibia! Data don't have to be physically shipped to Europe anymore (analysis & papers a bit faster ;-)

THANKS



BACKUPS

PKS 0736+017



Well known radio quasar

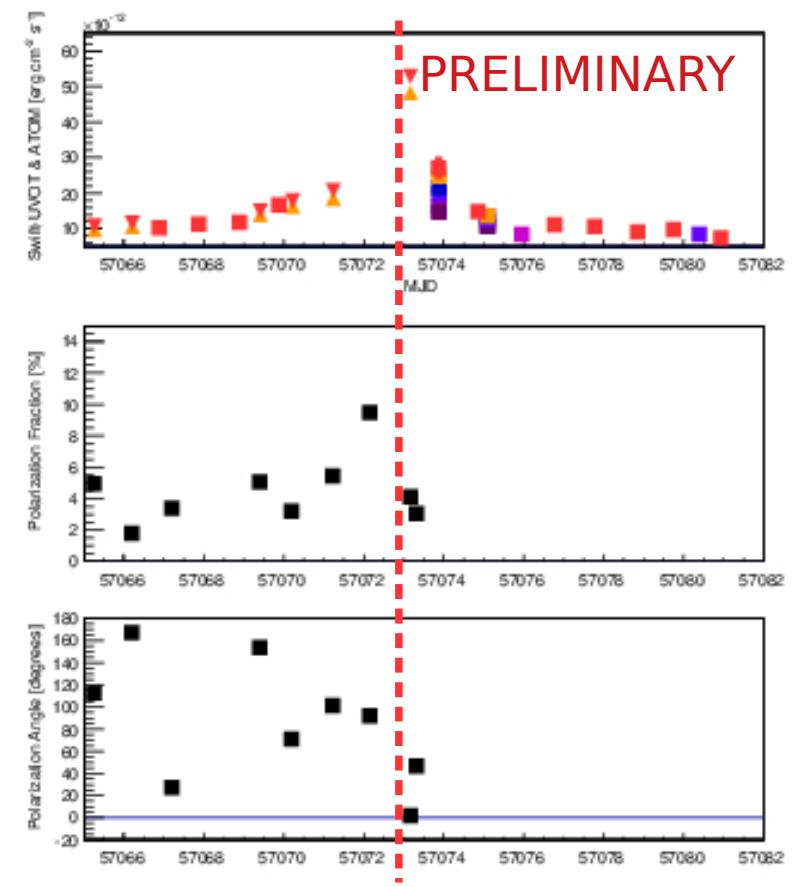
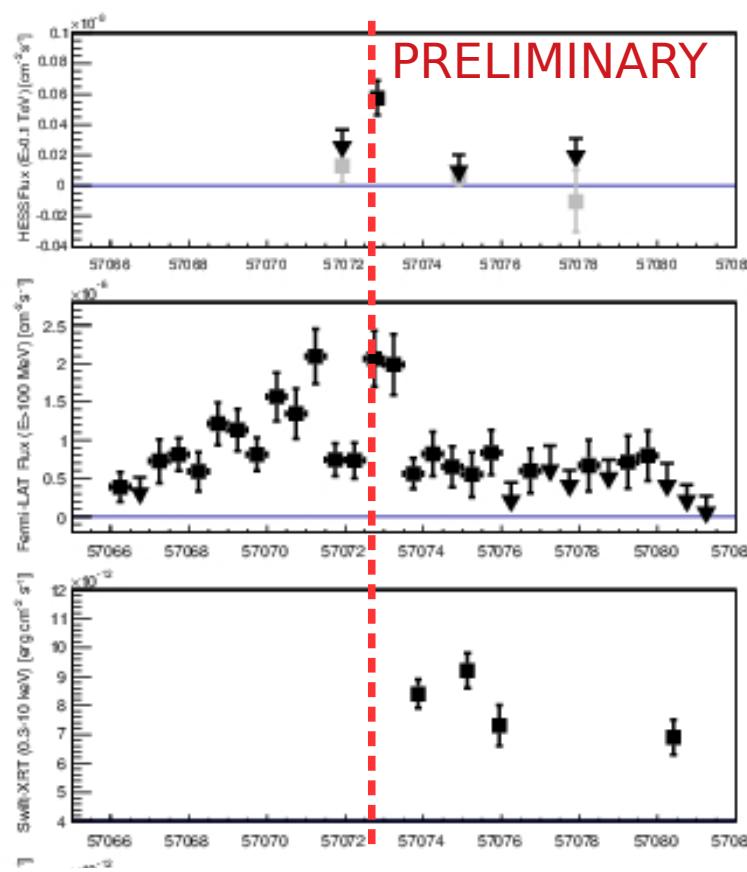
- $z = 0.1894$ (Ho & Kim 2009)
- typical FSRQ optical spectrum
- presence of big-blue bump
- SMBH mass = $10^{8.47} M_{\odot}$ (McLure & Dunlop 2001)
- Host galaxy is a standard giant elliptical (Wright 1998, Kotilainen 1998, ++)

Milkan & Moore, 1986

Cerruti et al. ICRC 2017 arXiv 1708.00658

PKS 0736+017

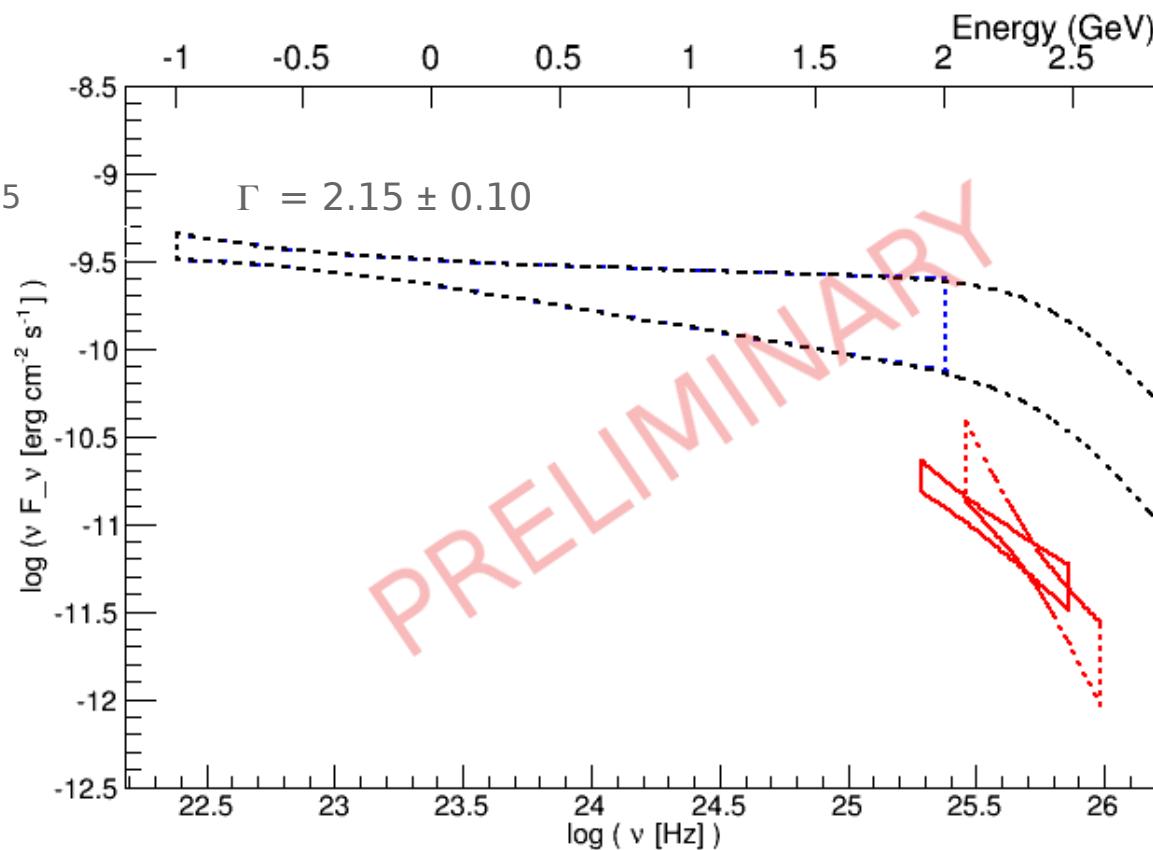
H.E.S.S. ToO observations following a Fermi-LAT flare
Detection during the second night only



PKS 0736+017

Fermi-LAT and H.E.S.S. spectra (mono & stereo)

Fermi-LAT spectrum
integrated from
MJD 57072.5 - 57073.5

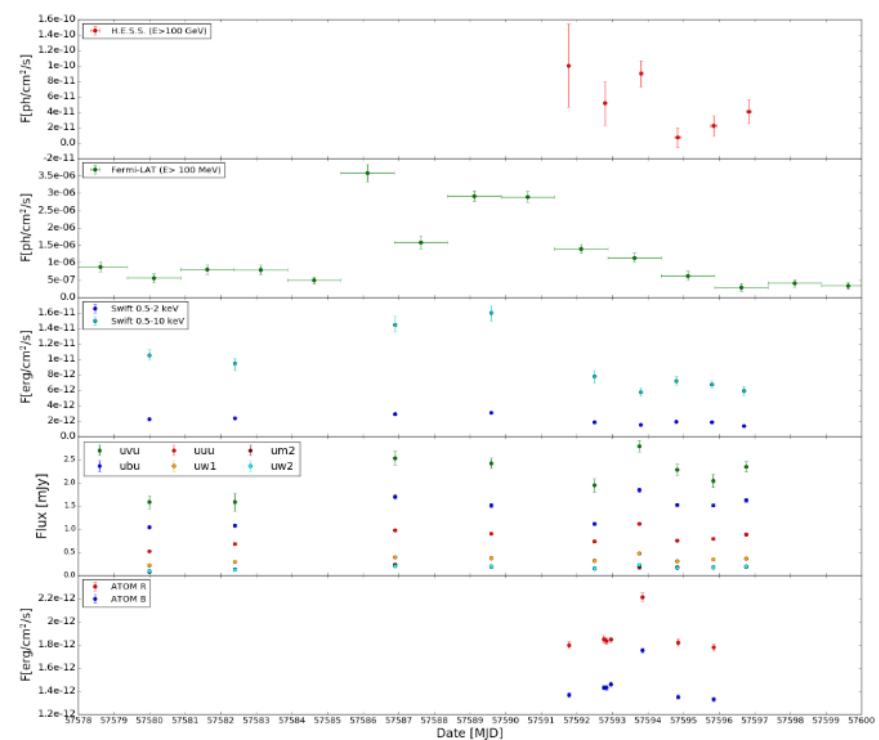
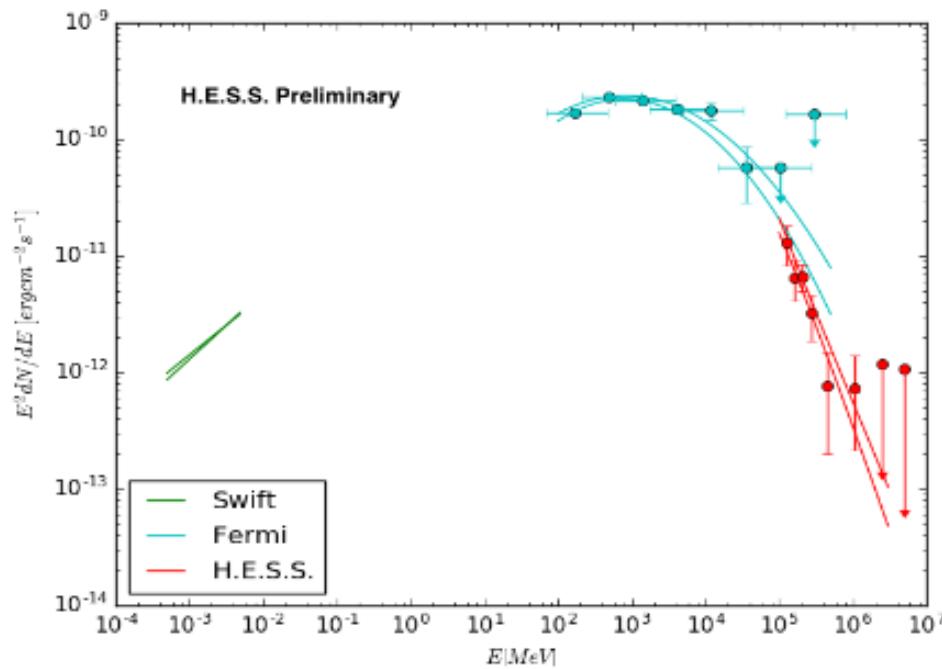


Fermi-LAT spectrum extrapolated towards higher energies, including EBL absorption → spectral break between LAT and H.E.S.S.



PKS 1749+096

Detected with H.E.S.S. in July 2016, following a Fermi-LAT flare

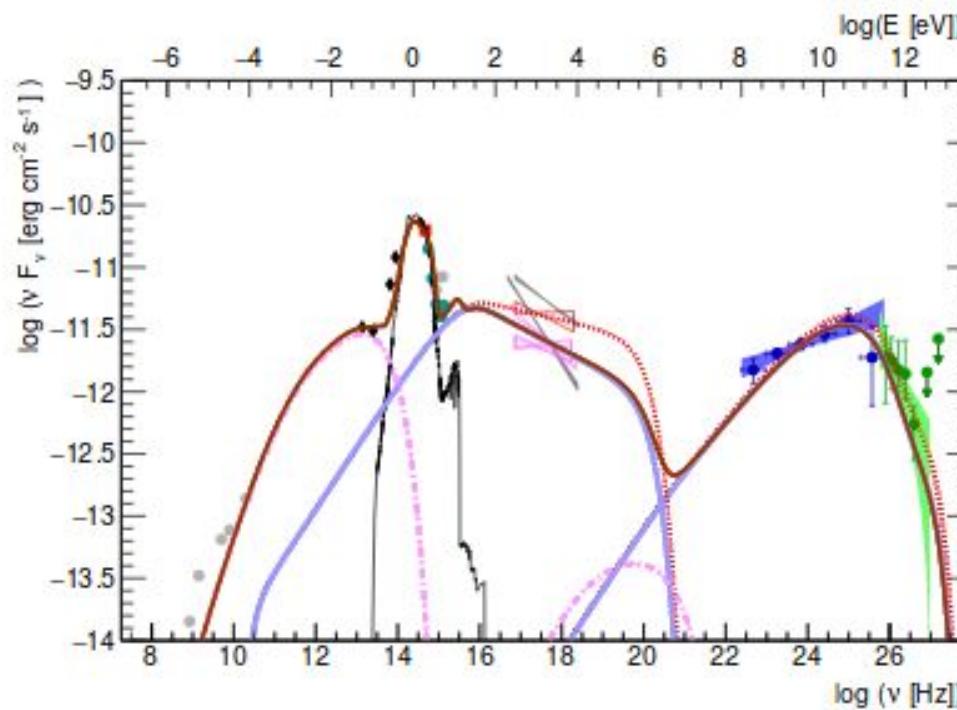


PKS 0625-354

H.E.S.S. I result (observations in 2012 only)

Source classification unclear: large-scale radio seems FRI, but core & parsec scale seem BL Lac

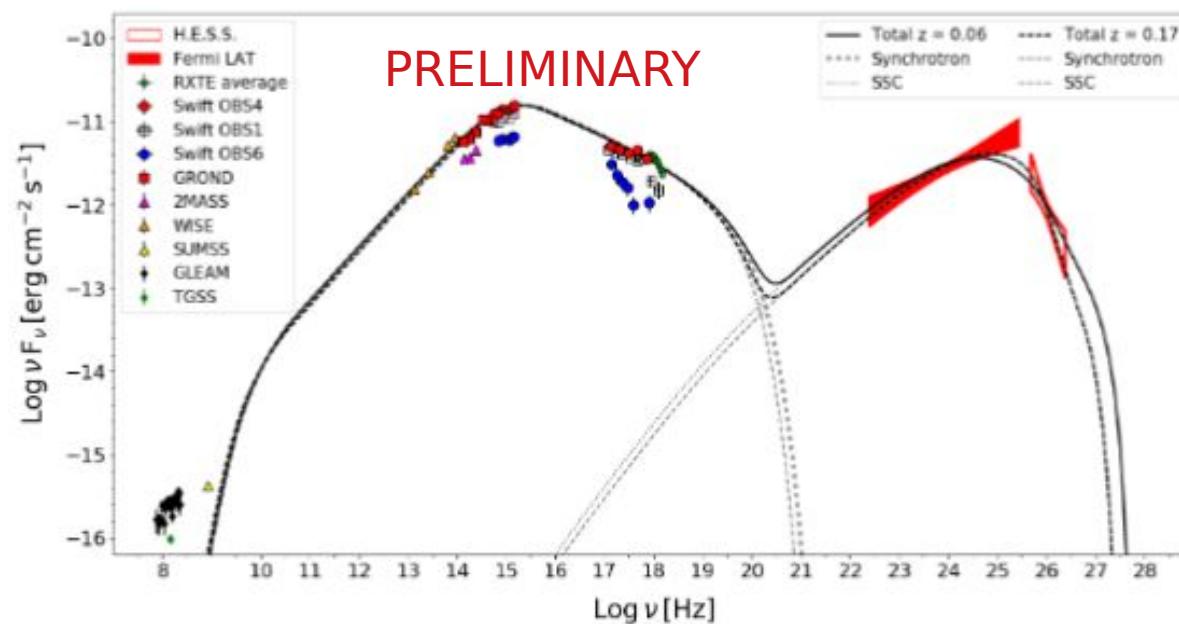
Gamma-ray & SED modeling supports HBL nature of the core



1ES 2322-409

H.E.S.S. I result (observations in 2004/2006 & 2011/2012)

One of few true serendipitous HESS discovery, seen as hotspot in FoV of PKS2316-423. Follow-up observations confirmed the detection. $z=?$ (weak evidence for $z=0.17$)



1ES 2322-409

