

Results from the HESS Array of IACTs

TrevorFest, October 2013

Michael Punch
APC CNRS/IN2P3



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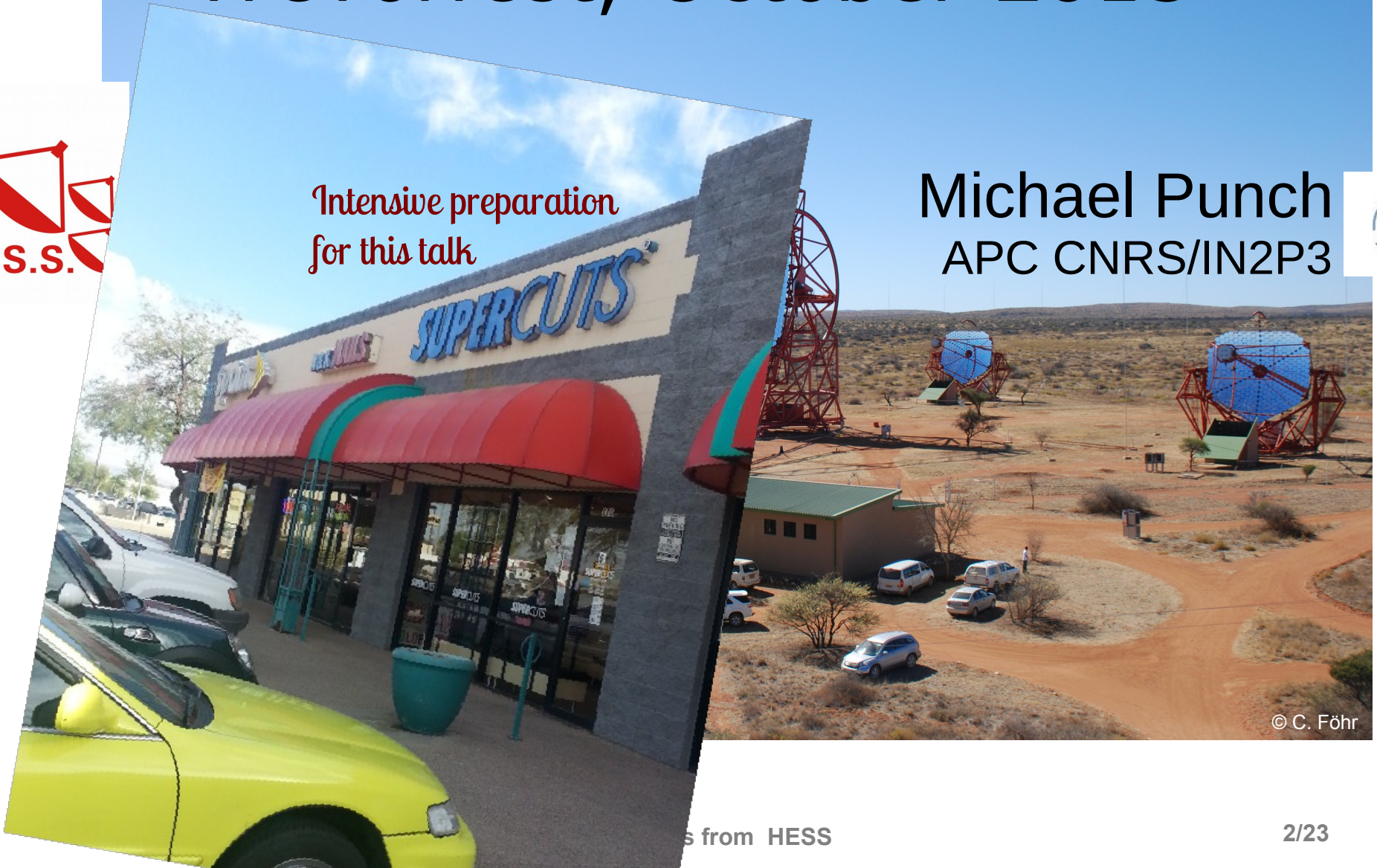
Results from the HESS Array of IACTs

Trevorfest, October 2013



*Intensive preparation
for this talk*

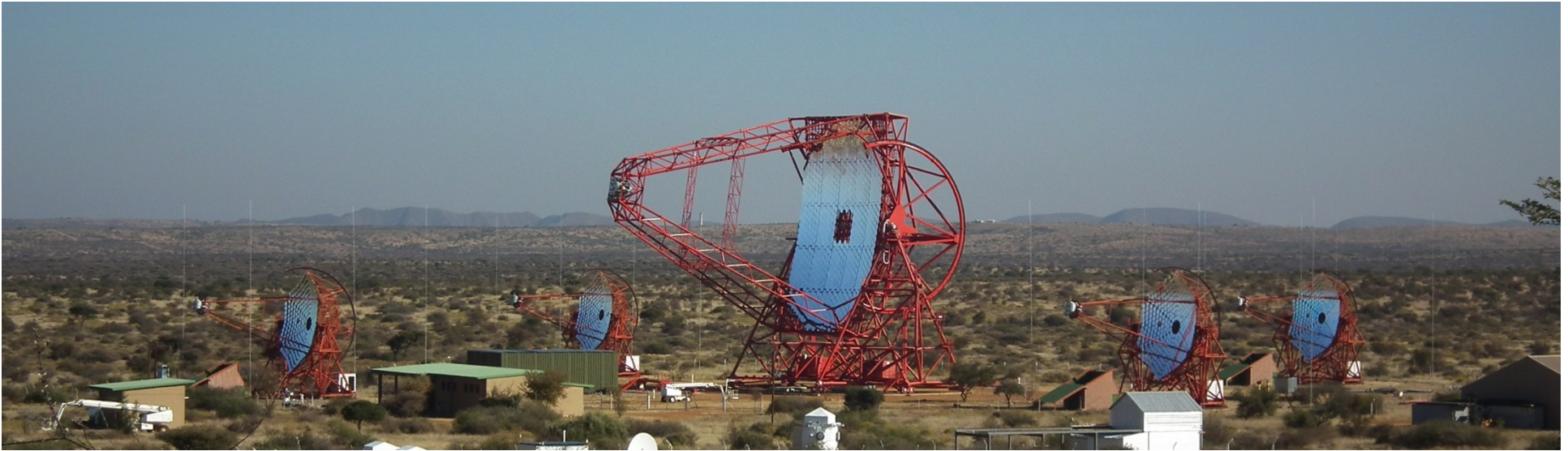
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The H.E.S.S. Observatory



H.E.S.S. I

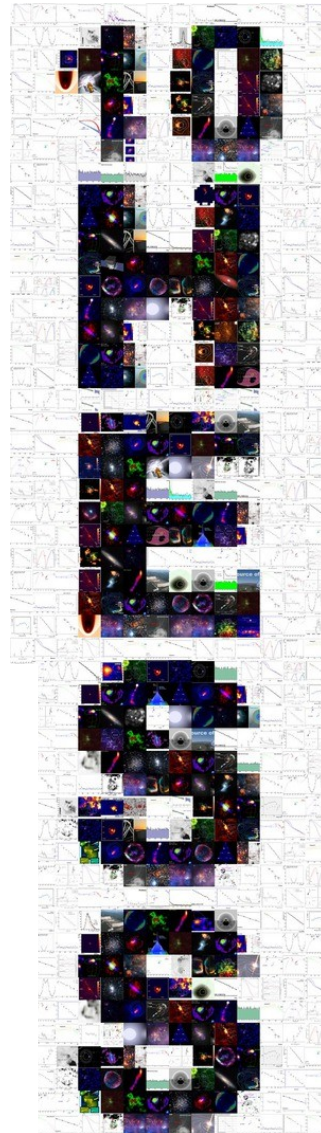
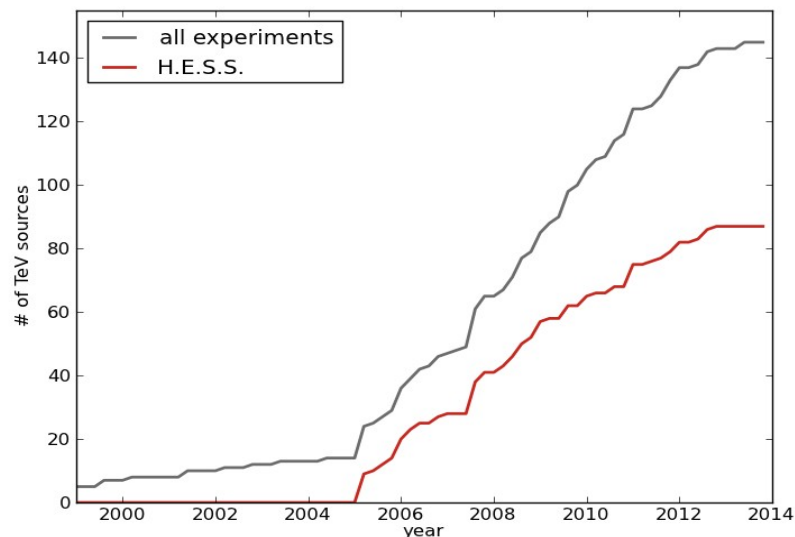
- 4 telescope system in Namibia
- Field of view 5°
- energy threshold ~ 200 GeV
- energy resolution $\sim 15\%$
- angular resolution $\sim 0.1^\circ$
- High sensitivity (5σ): 1% Crab in 25h

H.E.S.S. II

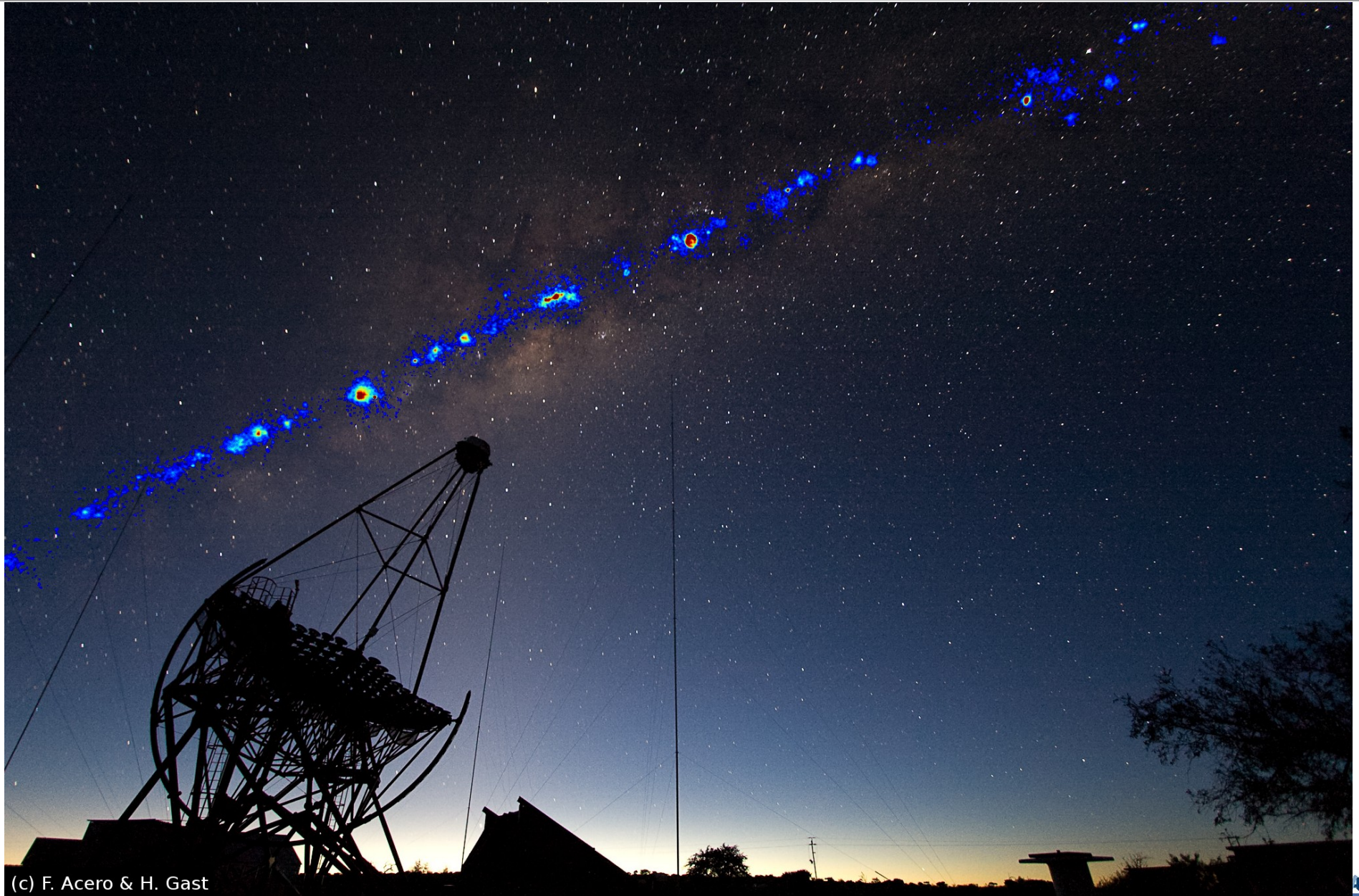
- H.E.S.S. I + single large telescope
- CT5
 - mirror area 600 m^2
 - Field of view 3.2°
 - energy threshold $O(30 \text{ GeV})$

H.E.S.S.: 10 years operation in 2012

- Taken 9415 hours of data
 - with 4234 h along the Galactic plane (latitude $< 10^\circ$) and
 - 5181 h in extragalactic space (latitude $> 10^\circ$)
- Discovered over ~90 new VHE gamma ray sources (according to TeVCat)
 - ~60 Galactic objects
 - ~30 extra-galactic sources
- Published over 100 scientific papers in reviewed journals, plus numerous conference contributions
- Listed among the 10 most influential astronomical instruments



Most fruitful observations: H.E.S.S. Galactic Plane Scan



H.E.S.S. GPS Observations

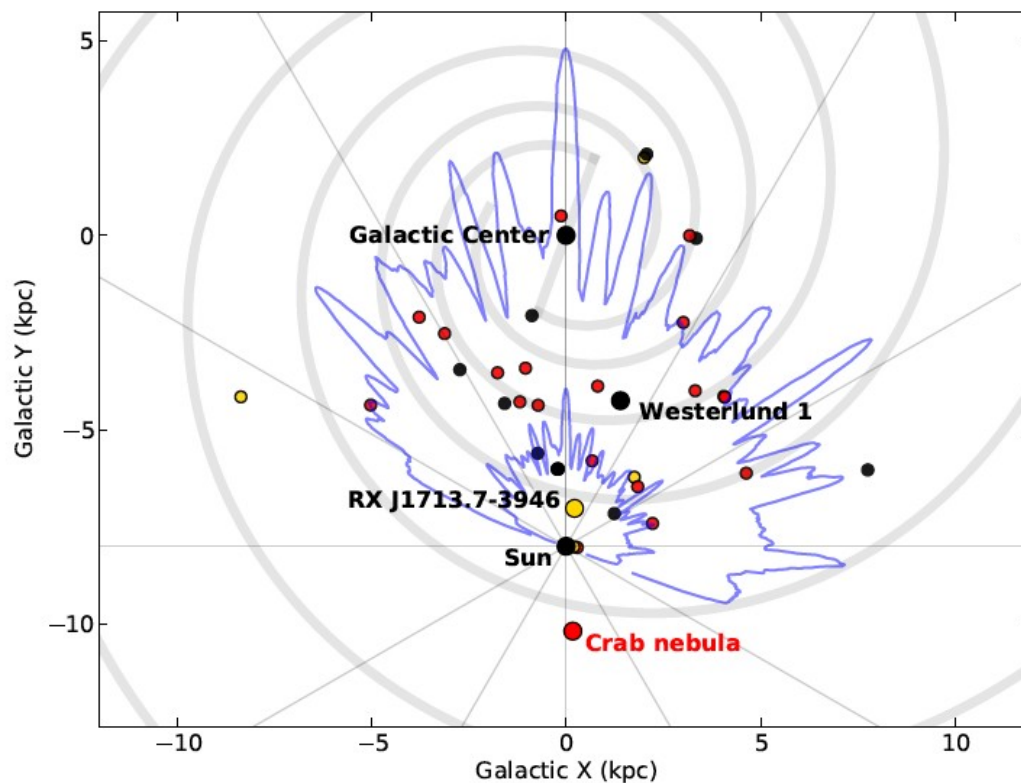
2800 hours of high-quality data, taken in the years 2004 to 2013.

Longitude $l = 250$ to 65 degrees, latitude $|b| < 3.5$ degrees

- Sensitivity for point-like sources at the 2% Crab level or better

Populations:

SNR, PWN, unidentified sources, binaries,
one extreme BL Lac, open star cluster, globular cluster, ...



Blue lines: H.E.S.S. horizons
for 1% and 10% Crab

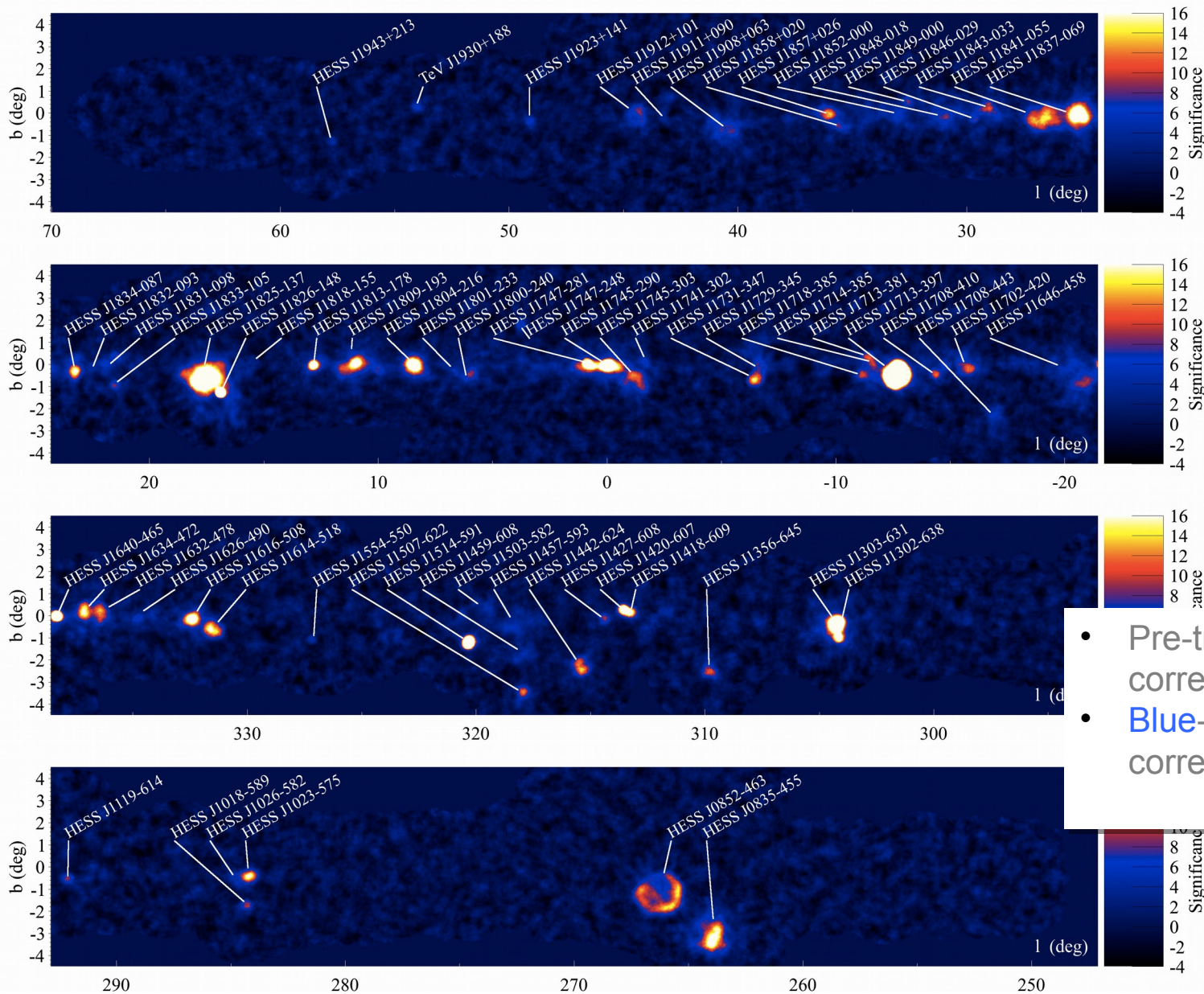
Dots:
H.E.S.S. Galactic sources

Red: PWNe

Yellow: SNRs

Black: other sources

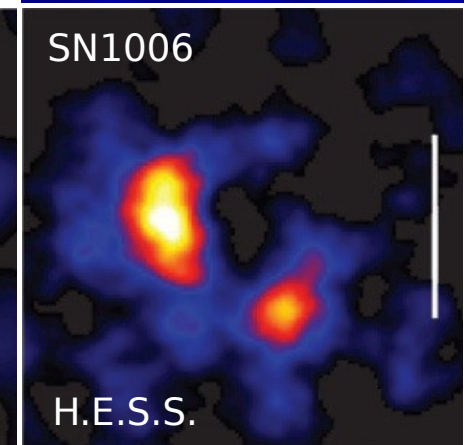
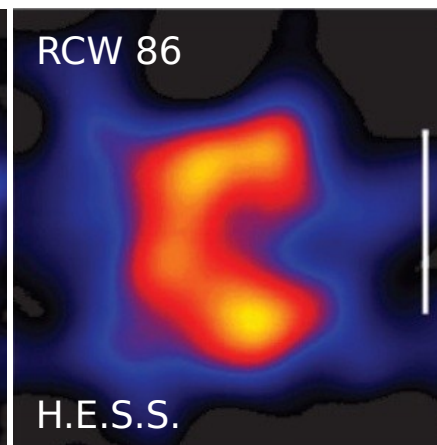
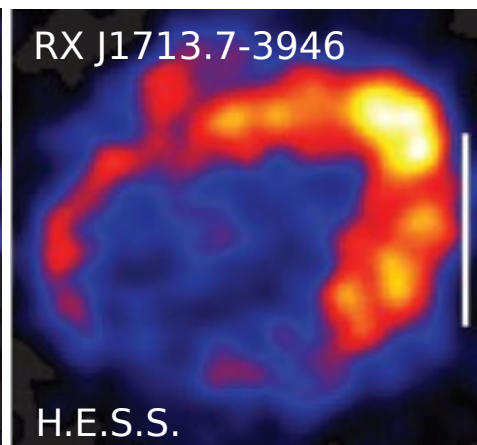
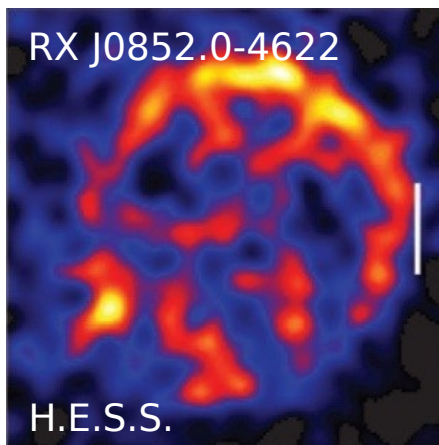
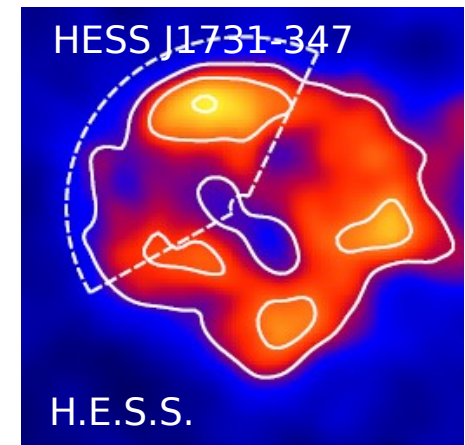
H.E.S.S. GPS maps



- Pre-trials significance map, correlation radius 0.1°
- Blue-red transition corresponds to $\sim 5\sigma$ post trial

H.E.S.S. SNR discoveries

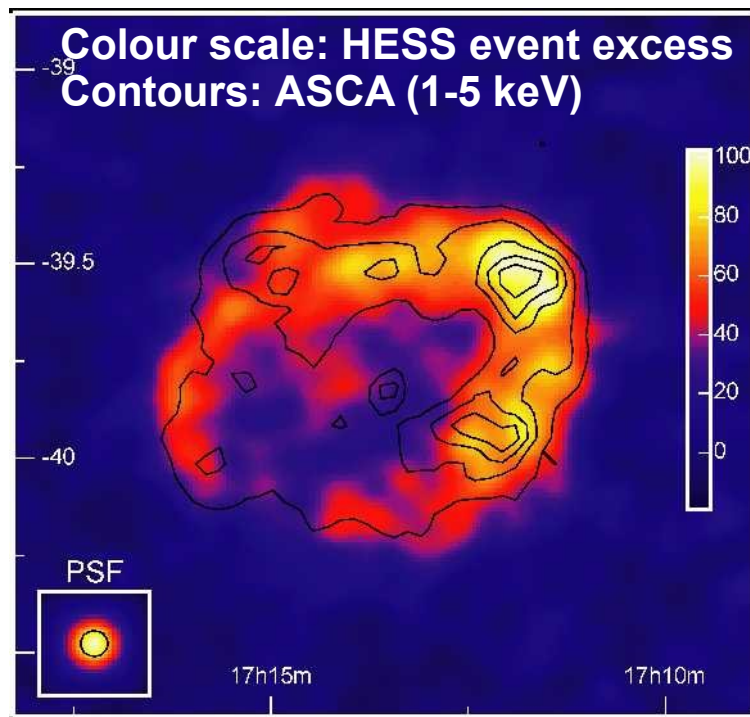
- Young Shell type SNR
 - RX J1713.7-3946, SN 1006, Vela Jr, HESS J1731-347, RCW 86
- Middle aged SNR interacting with molecular clouds:
 - W51C, W49B, W28



Zooms on a couple of SNRs

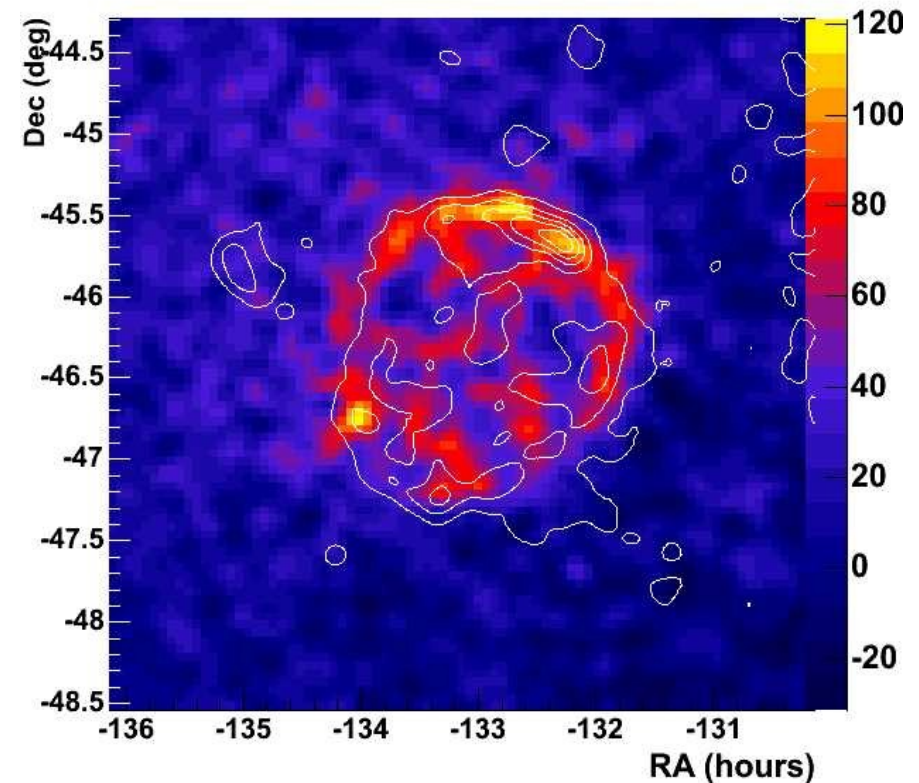
RX J1713.7-3946

First-ever resolved γ -ray source
Strong correlation with X-rays: $\sim 80\%$



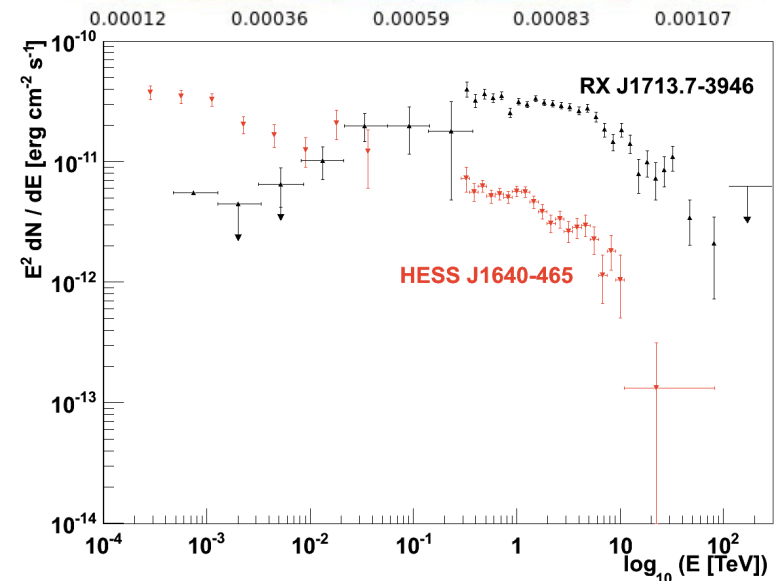
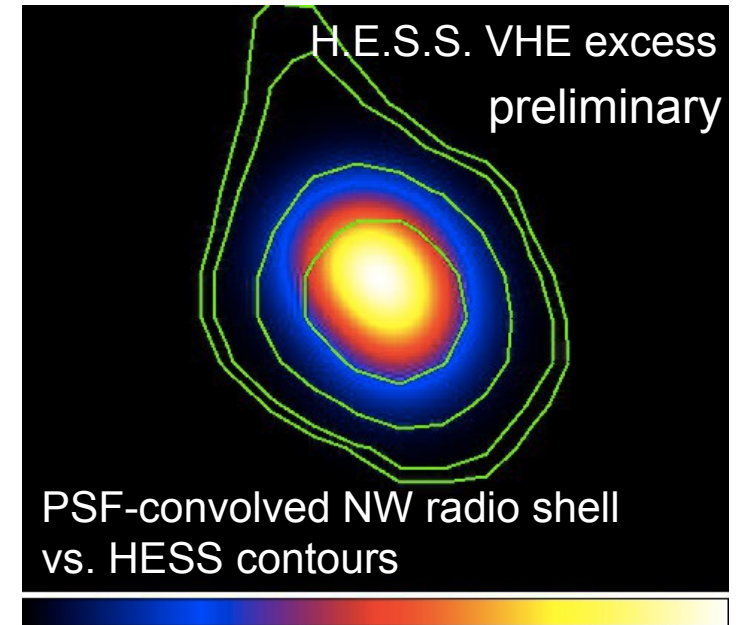
RX J0852.0-4622 (Vela jr)

Thin shell resolved with HESS
Correlation with X-rays: $\sim 65\%$
+ Correlation with Radio



The brightest SNR seen: HESS J1640-465

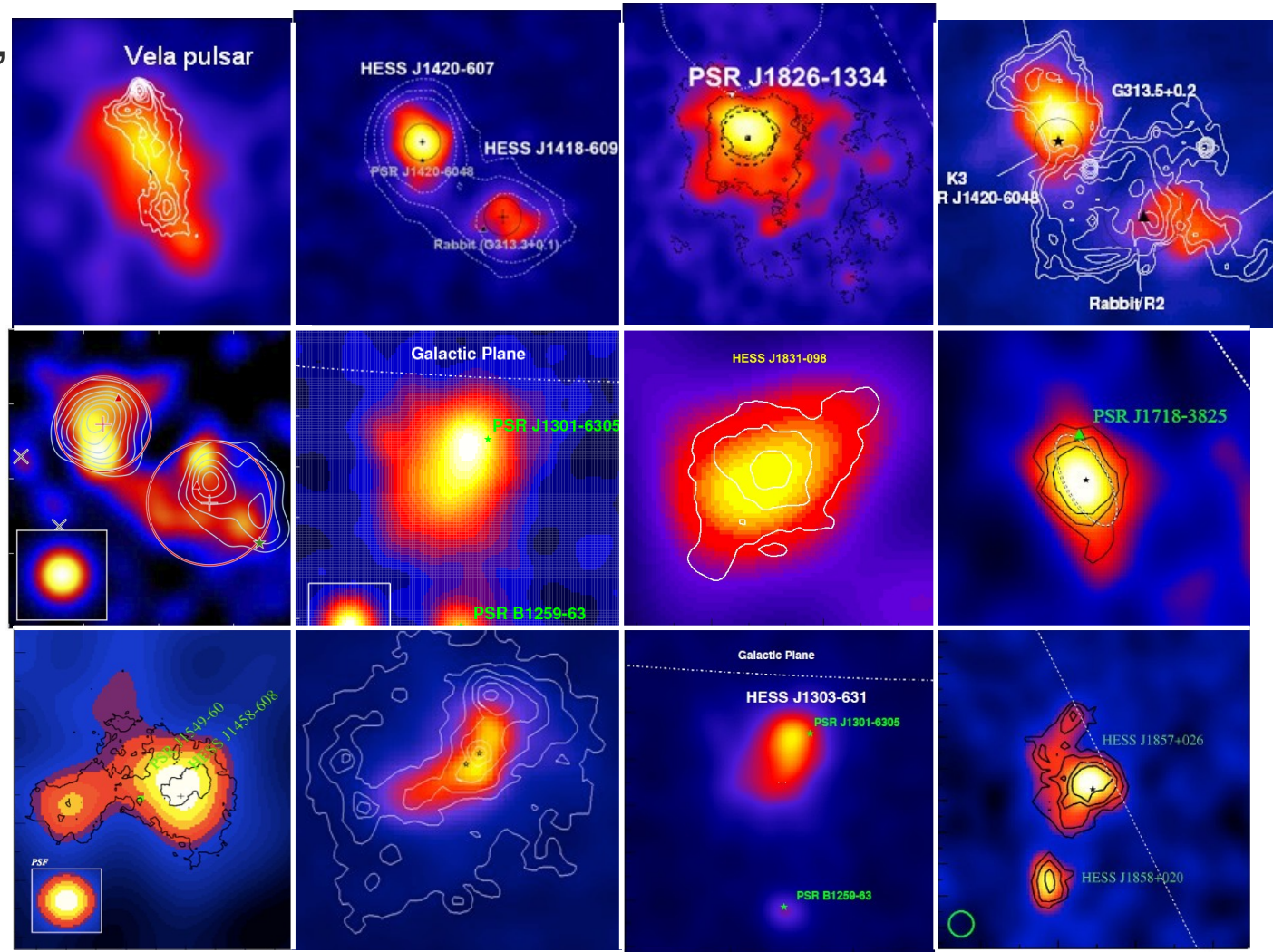
- Most luminous Galactic TeV source
- Distance: 8 – 13 kpc
- Total livetime: 63.4 h
 - ~1800 excess events
- Morphology:
 - Significantly extended:
 $\sigma = (4.3 \pm 0.3)'$
 - Asymmetric extension towards HII region slightly preferred (by 2σ)
 - Significant overlap with northwestern SNR shell



H.E.S.S. Collaboration
Eger et al. ICRC2013

Pulsar Wind Nebulae

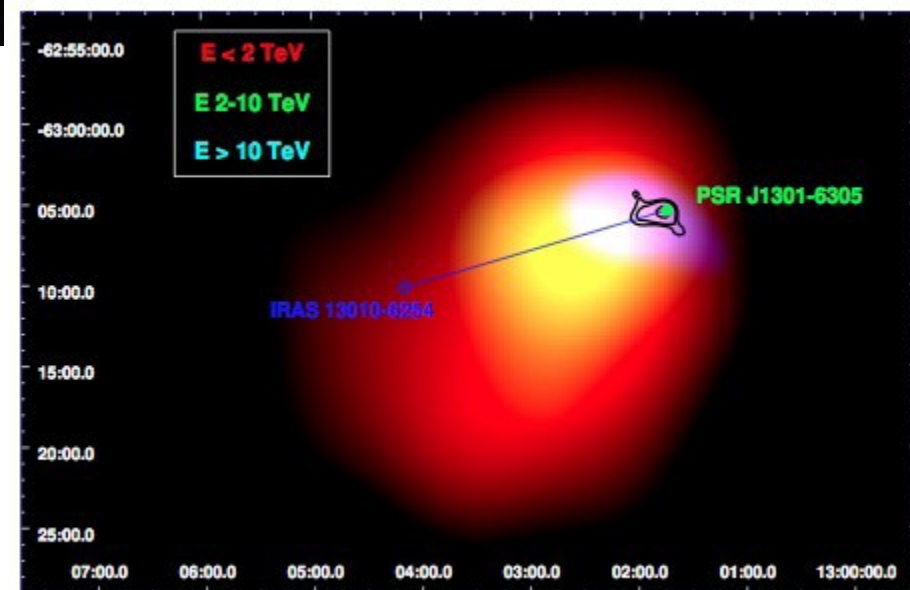
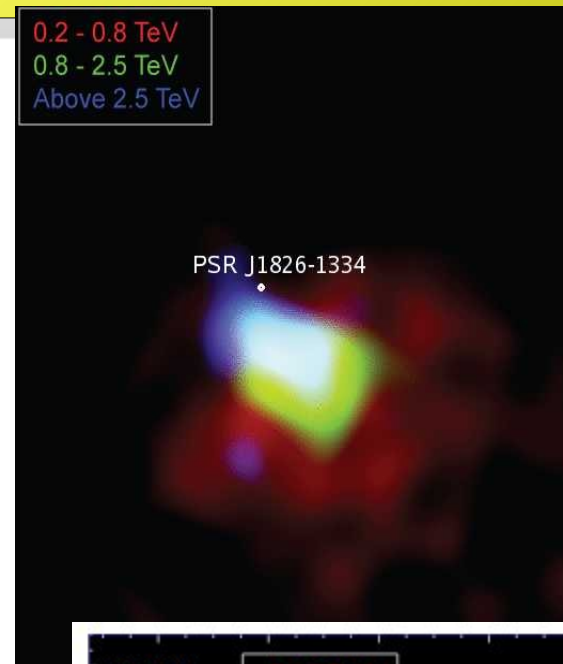
- Major galactic TeV source population
 - Associated with relatively young ($<10^5$ year old), energetic pulsars
 - Extended sources, 10s of pc
 - Often displaced from pulsar (expansion into inhomogeneous medium)
- Generally believed that we see inverse Compton emission of 1-100 TeV electrons



Pulsar Wind Nebulae

Energy-dependent Morphology

- HESS J1825-137, HESS J1303-631
- Associated with energetic pulsar
- Spectral steepening seen away from the pulsar
- Very likely this is evidence for cooling of electrons in the Nebula
 - Seen in several *X-ray* PWN
- A first in gamma-ray astronomy!
- Now seen in several VHE PWNe



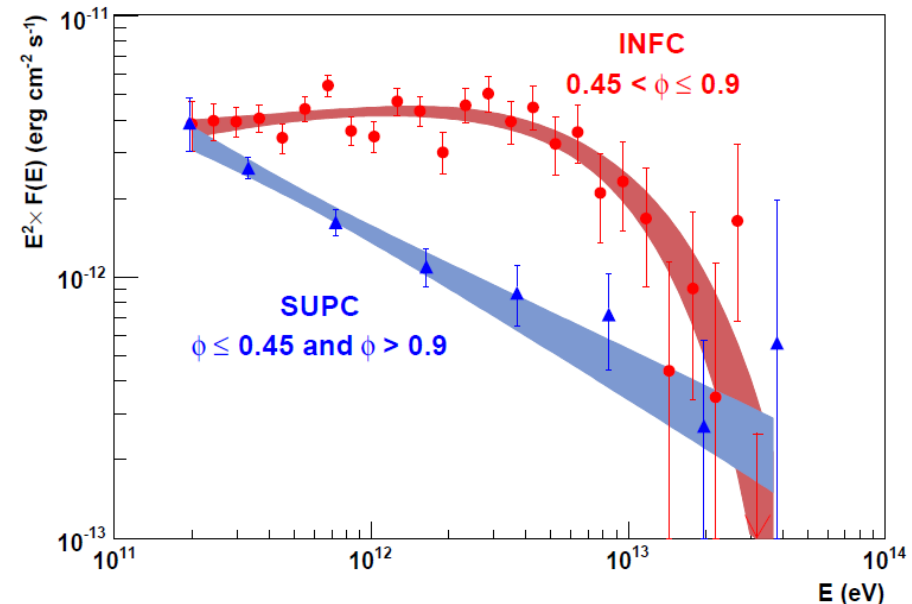
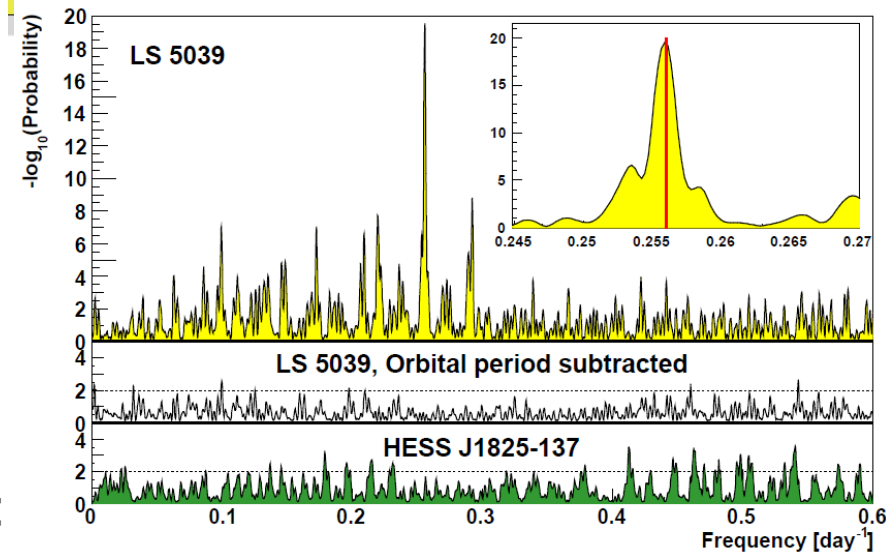
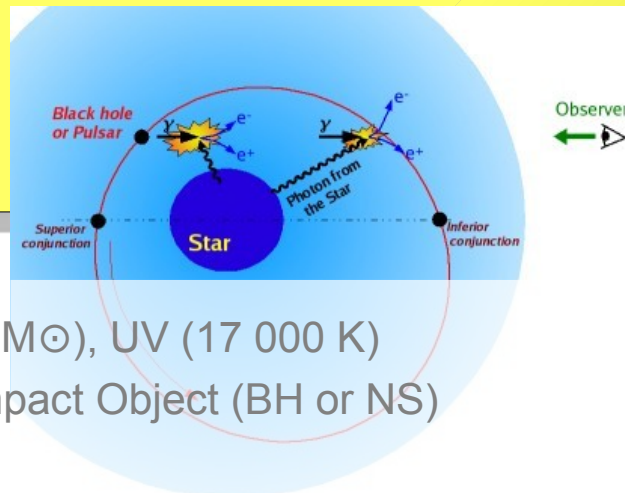
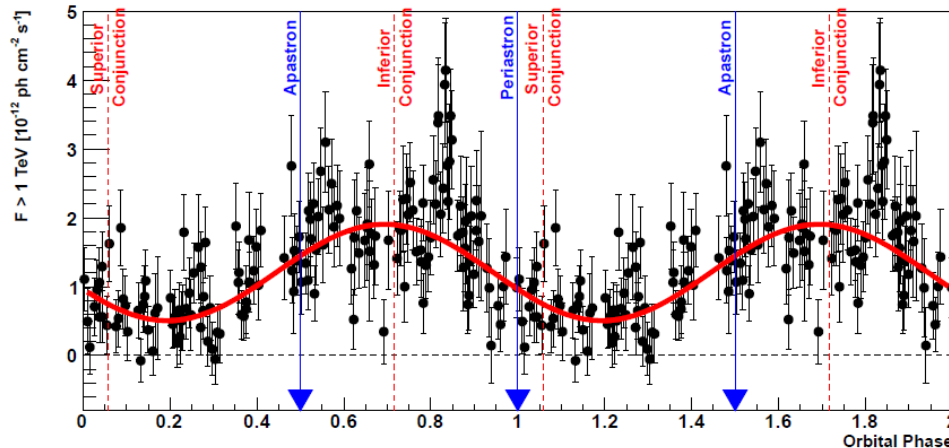
Binaries: LS5039

Binary system

- Massive star ($20 M_{\odot}$), UV (17 000 K)
- Unidentified Compact Object (BH or NS)
 $M = [1.5 - 5] M_{\odot}$
- Tight orbit ($d = [2 - 4.5] R_{\star}$), ~ 0.1 AU !
- Orbital period 3.9 days (from Doppler)
- Distance ~ 3 kpc (9000 light yr)

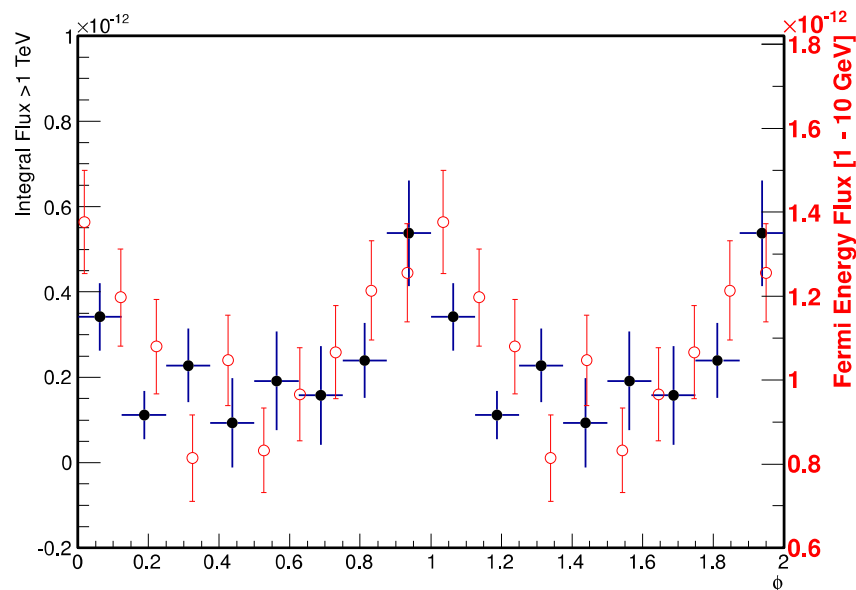
H.E.S.S. discovery, First Periodic VHE source:

- Best fit period $3,90577 \pm 0,00013$ (11 seconds precision!)
- Optical period is 3.90603 days (MJD0 = 51942.59): 2σ away
- Folded light-curve shows features to be explained and orbital phase-resolved spectra

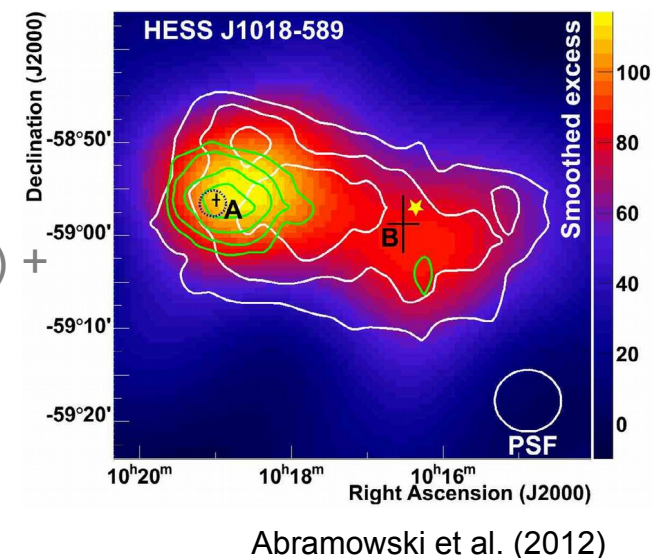
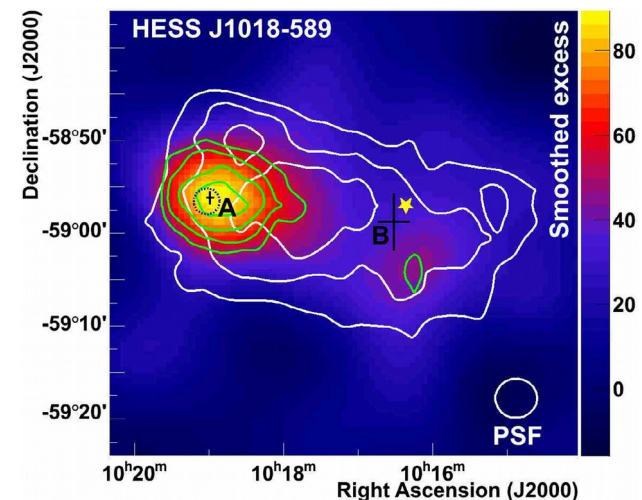


Binaries: 1FGL J1018.6-5856 / HESS J1018-589A

- HE gamma-rays:
 - “genuine” γ -ray binary: Fermi discovery
 - Periodic modulation = 16.58 days
- Optical:
 - O6V((f)) companion star
- X-rays:
 - periodicity seen also in X-rays, with a double peak structure in the phase-folded light-curve
- Radio:
 - flux variability, but no peak at $\phi \sim 0$



- H.E.S.S.:
- Two sources, point-like (1FGL J1018?) + extended (PSR J1016?)
- Search for variability in H.E.S.S.
- \Rightarrow Similar orbital variation as Fermi: peak at phase 0(3.1σ).



Extragalactic: Active Galactic Nuclei ... +

Radio Galaxies:

M 87

Centaurus A

FSRQ(s):

PKS 1510-089

BL Lacs:

SHBL J001355.9-185406

Markarian 421

RGB J0152+017

1ES 1312-423

1ES 0229+200

AP Librae

1ES 0347-121

PG 1553+113

1ES 0414+009

HESS J1943+213

PKS 0447-439

PKS 2005-489

PKS 0548-322

PKS 2155-304

1RXS J101015.9-311909

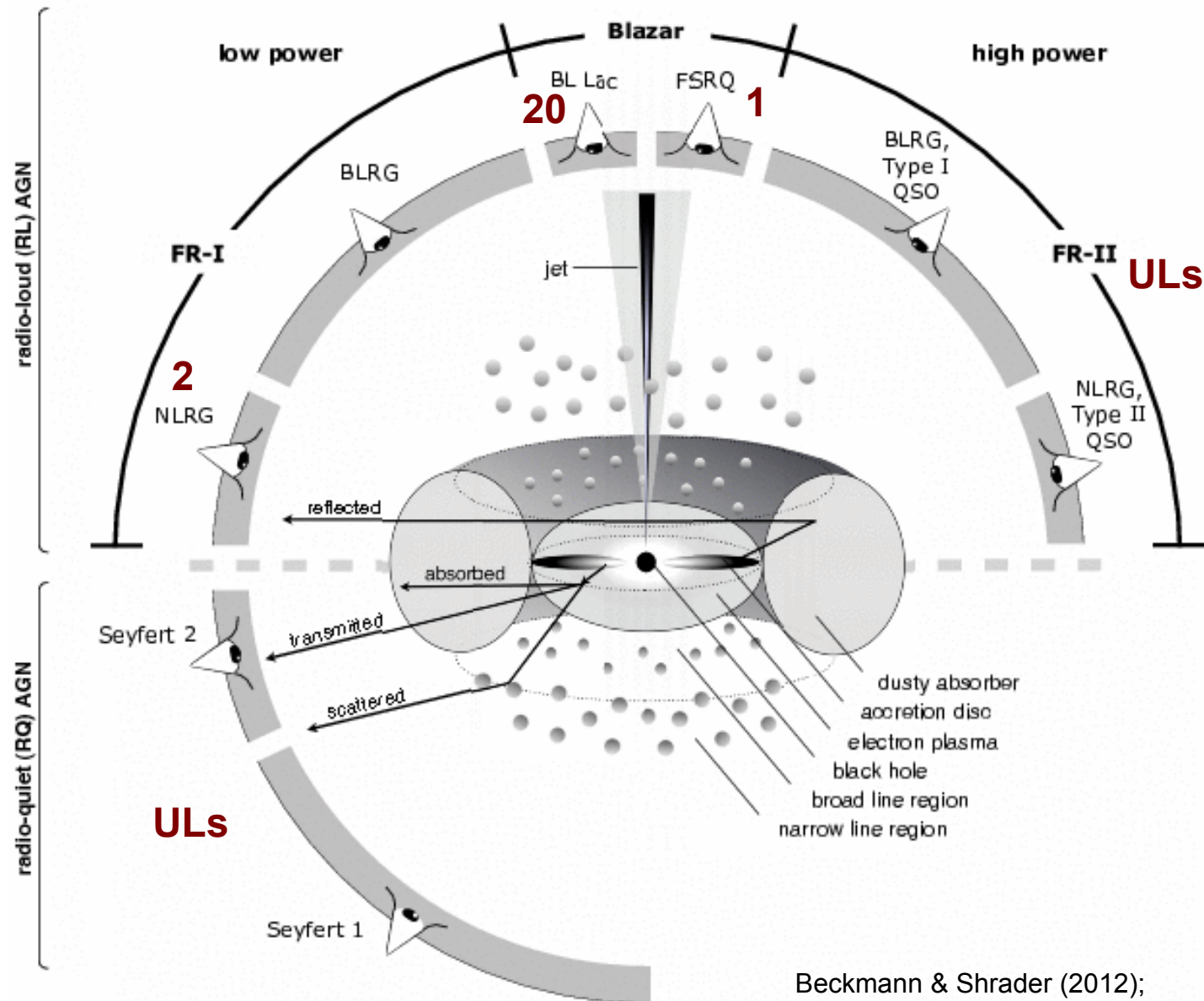
H 2356-309

1ES 1101-232

(new) KUV 00311-1938

(new) PKS 0301-243

(new) PKS 1440-389



... but also non AGN, starburst galaxy NGC 253

Beckmann & Shrader (2012);
graphic by Marie-Luise Menzel

Extragalactic: Active Galactic Nuclei ... +

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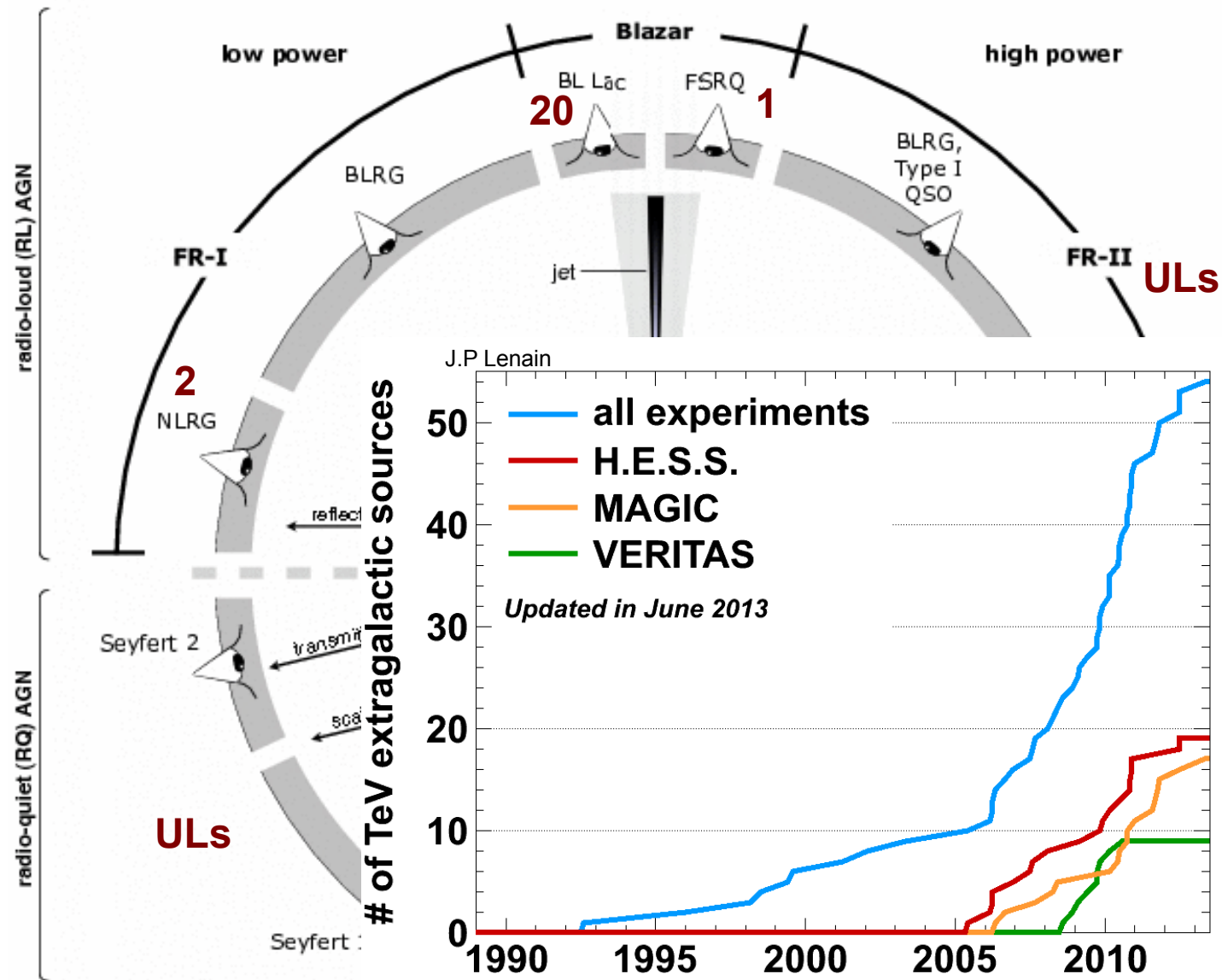
H 2356-309

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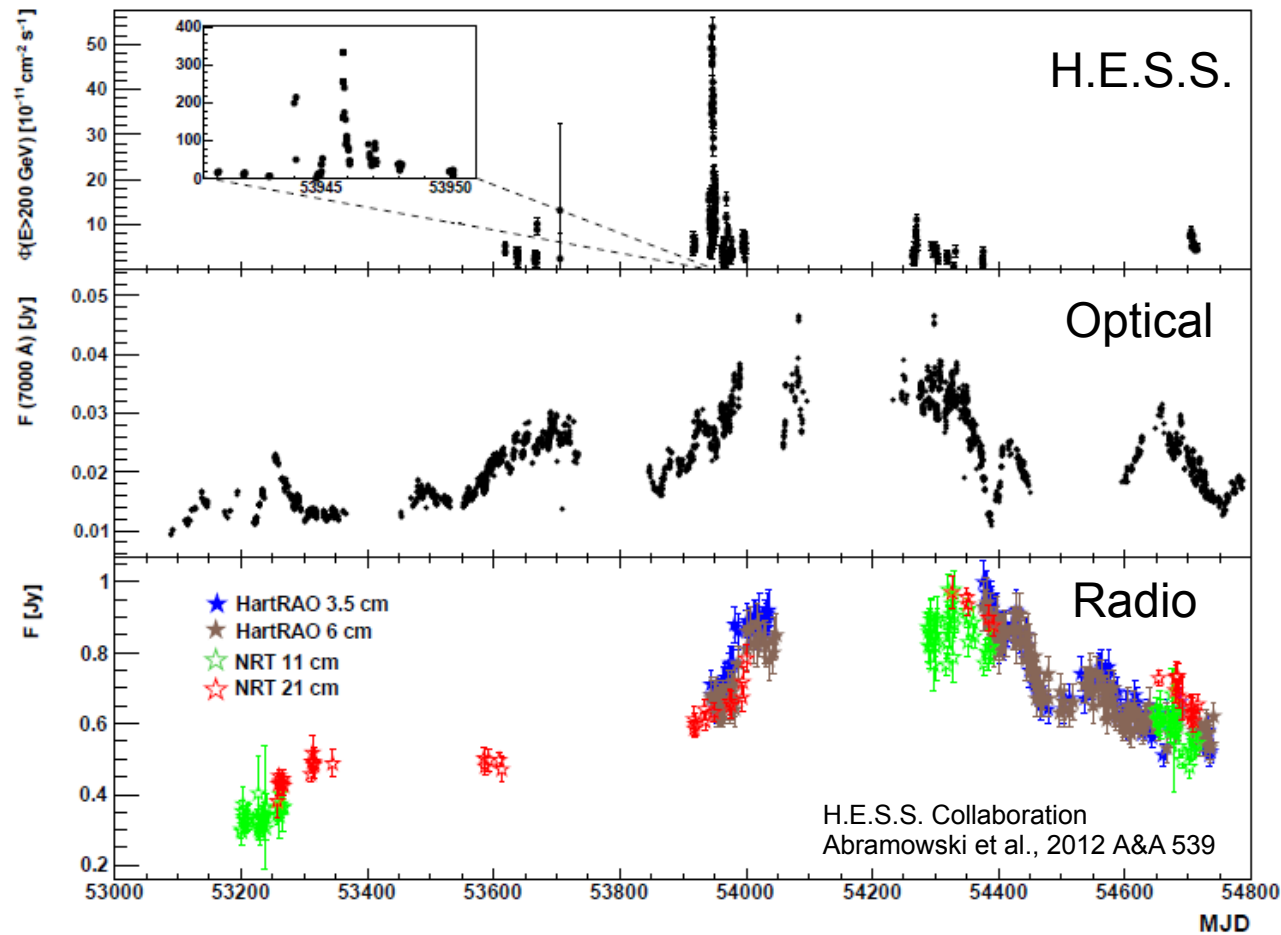
(new) PKS 0301-243

(new) PKS 1440-389



... but also non AGN, starburst galaxy NGC 253

Old faithful: PKS 2155-309



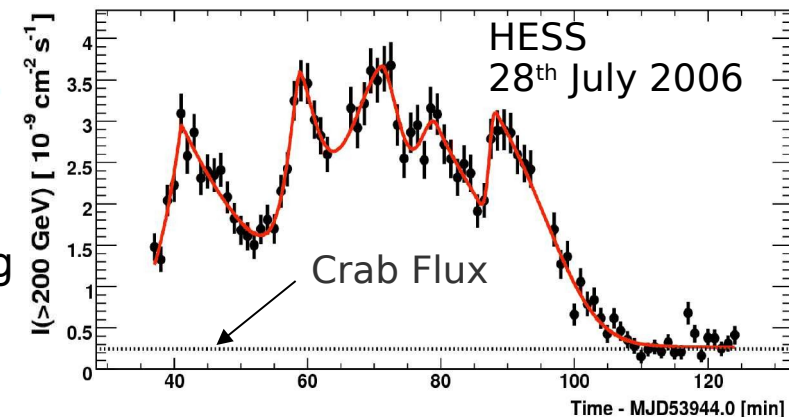
- VHE/X-ray correlation seen during flaring epoch
- Some link between long term optical/radio level & VHE flaring
- One zone SSC models only fit SED during low states

- Rich source, bright, flaring
- Not HESS-discovery
- 9 H.E.S.S. papers so far!

“Big Flare”

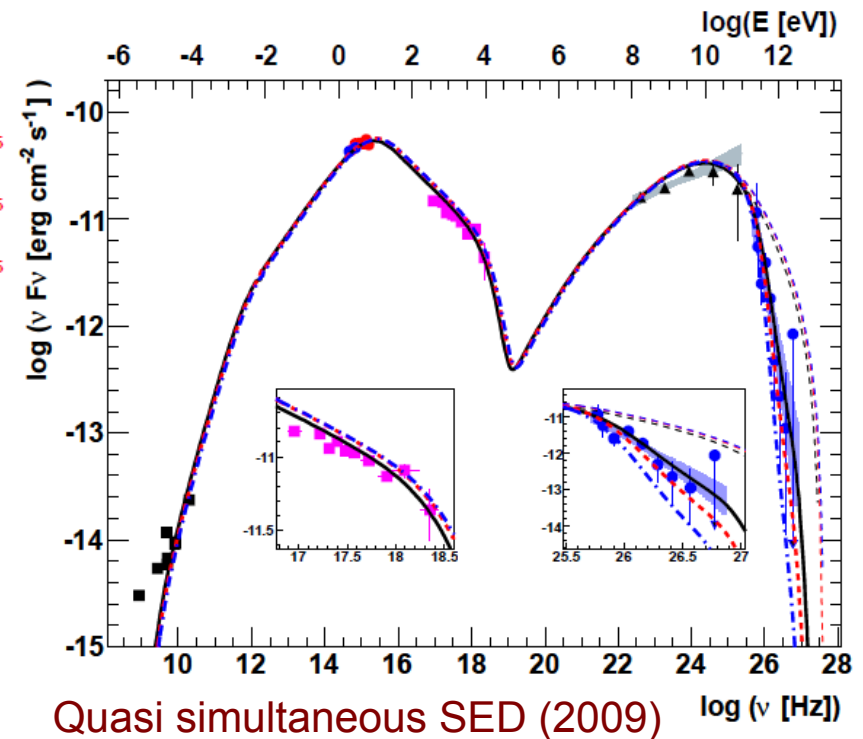
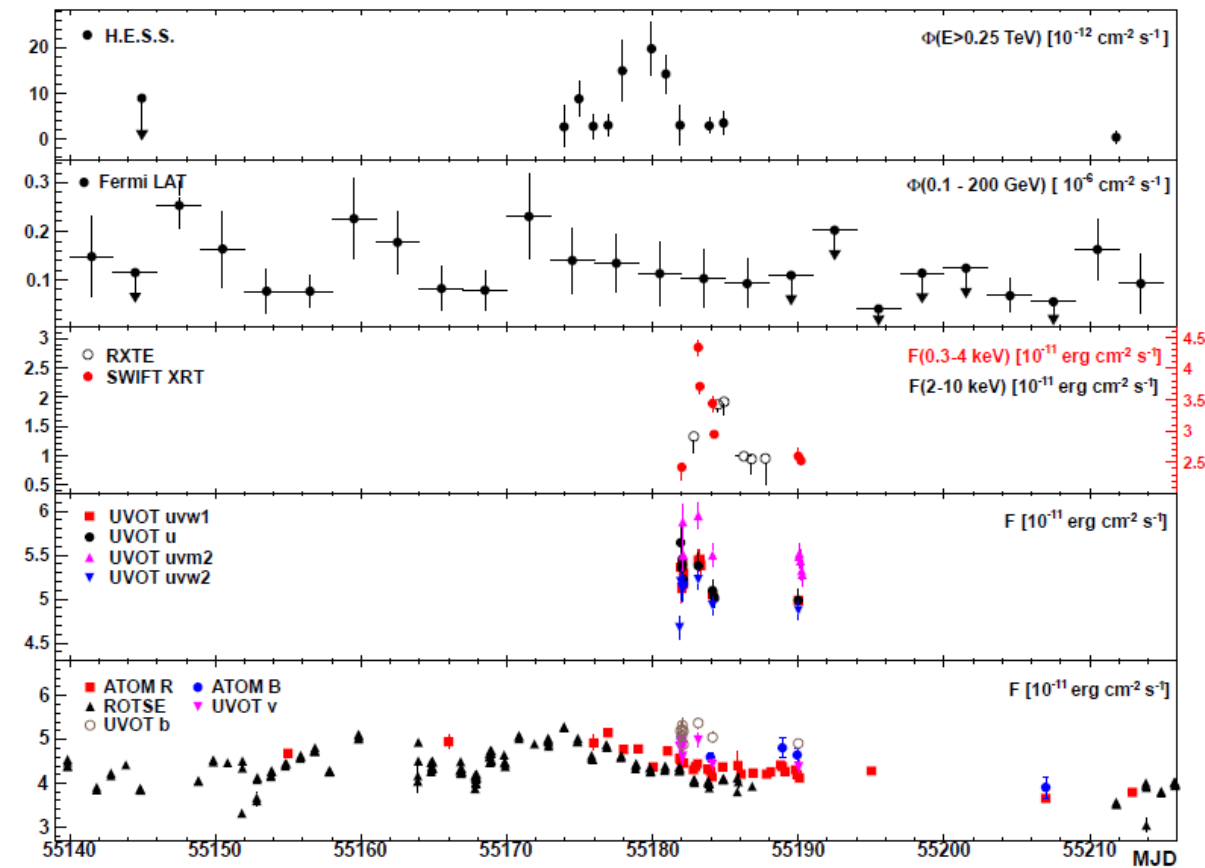
- Best measured rise-time: 173 ± 28 s
- Two orders of magnitude brighter than typical
- Time-scale probes **size of emitting region** if causality
- Also used to test **Quantum Gravity**

H.E.S.S. collaboration,
Aharonian et al.
ApJ. 664 (2007) L71-L74



New AGN: PKS 0447-439

- H.E.S.S. discovery
- 15σ after 13h in 2009 exposure
- VHE variability from days to months



- H.E.S.S. firm UL for currently-unknown redshift, $z < \sim 0.4$
- Broad-band SED overall fit by one-zone SSC, but ...
- No exact correlations between VHE, HE, X-ray, Optical \Rightarrow Challenging one-zone SSC

H.E.S.S. collaboration,
Abramowski et al.
A&A 552 (2013) A118

The H.E.S.S.-II Telescope, CT5

Dish

Total mirror area 614 m²

Focal length 36 m

Camera

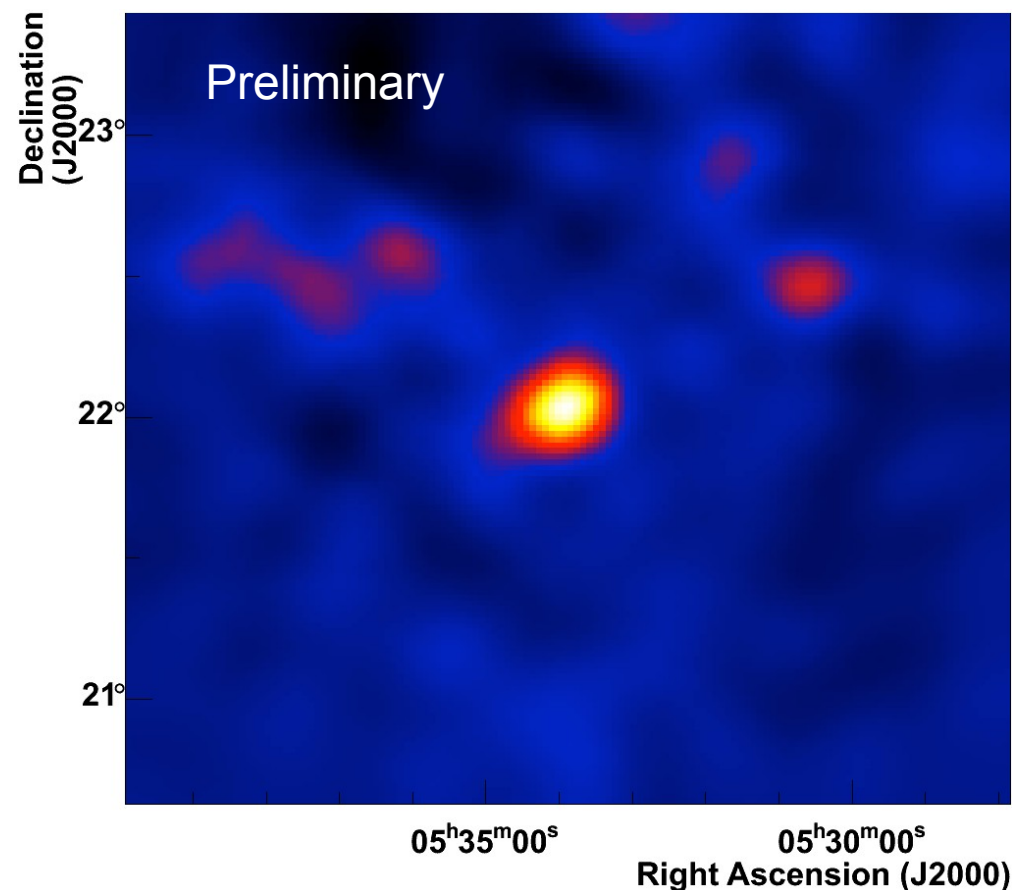
2048 PMTs

Field of 3.2°



First H.E.S.S.-II preliminary mono results

- First data from the Crab Nebula taken with the new H.E.S.S. telescope
 - Zenith angle: 46°
 - Preliminary mono-analysis
- Excess map with $E > 50$ GeV (for preliminary mono-analysis, vs. 400 GeV threshold H.E.S.S.-I)



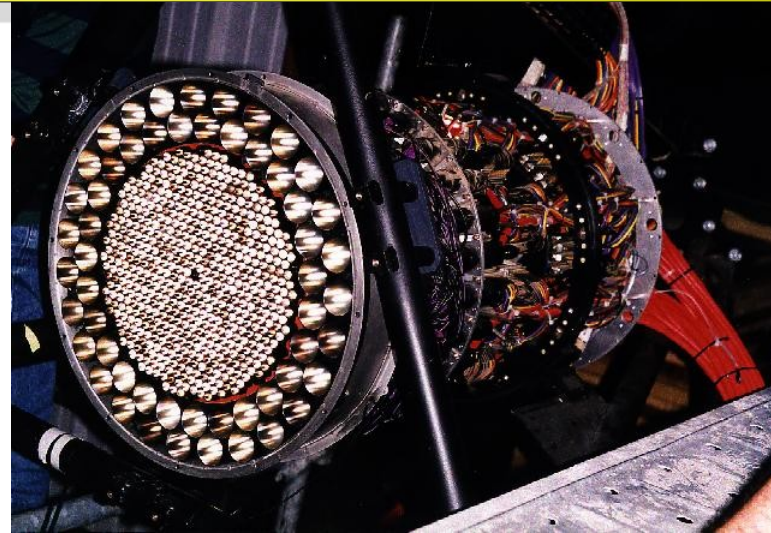
H.E.S.S. Collaboration
Holler et al. ICRC2013



Conclusions

- HESS-I
 - Technical Inheritance from Whipple + HEGRA + CAT
 - Know-how inheritance from Whipple (via Artemis & CAT) & HEGRA stereo
- ⇒ Rich harvest of results, better than hoped for, building on the Whipple Observatory & Trevor Weekes' foundations
 - Now, simple detections of PWNe / AGNs are relegated to conference posters or research notes!
- Near future, with HESS-II
 - But slow start, low-energies and mono are hard, especially combined!
 - Stay tuned ...
- Farther on the horizon: CTA

P.S. CAT 1996-2001



- Notable Mechanical / Optical characteristics
 - 17.8 m² mirror area (16 m² after shadowing), 5m Ø, 90 x 50cm Ø facets
 - Focal length 6m → high F/D ~ 1.2 (for fast timing)
- Characteristics concerning camera (some → HESS):
 - Very fine pixel camera, 600 PMs, most <0.13° (some guard rings)
 - Fast (small) PMs, low TTS (transit time spread)
 - Fast electronics
 - “Semi-integrated” camera
 - **All pre-amps, trigger logic electronics in camera**
 - External integration gate in counterweight
 - ADCs, DAQ, HVs in counterweight

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