Variable Galactic Gamma-ray Sources with the H.E.S.S. telescopes

Variable Galactic Gamma-ray Sources III

Heidelberg, May 4th 2015

Pol Bordas

H.E.S.S. collaboration

outline

0 - H.E.S.S.: phase I → II

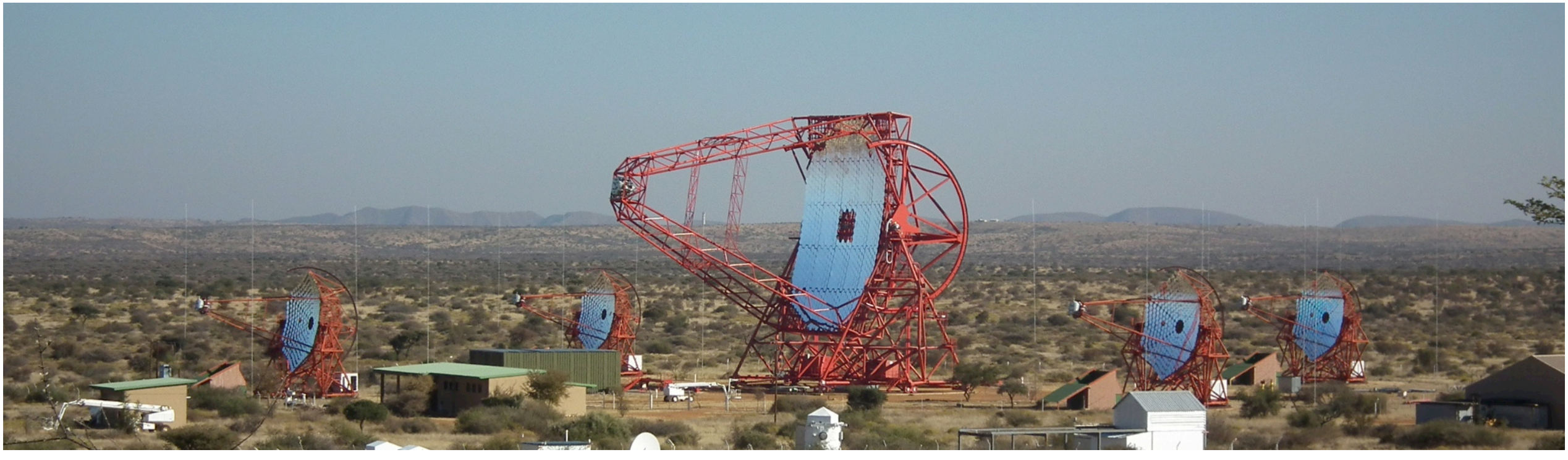
1 - recent reports

- Vela PSR
- Crab flares
- 1FGL J1018.6-5856
- HESS J0632+057

2 - ongoing studies

- PSR B1259-63
- LS 5039
- Eta Carinae
- mQs, novae, transients

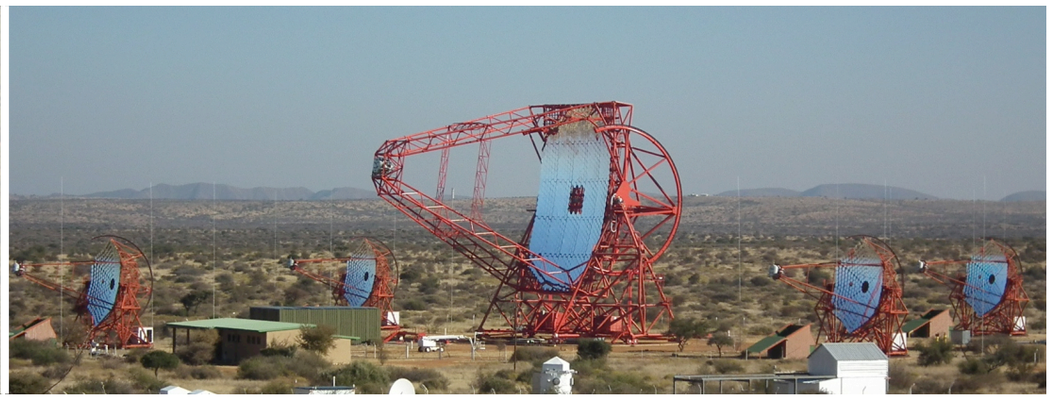
H.E.S.S. collaboration



- MPIKernphysik,Heidelberg,Humboldt Univ.Berlin, Ruhr-University Bochum, University Erlangen- Nuremberg, University Hamburg, LSW Heidelberg, University Potsdam, University Tübingen, DESY
- Ecole Polytechnique, APC Paris, Univ.ParisVI-VII, Univ. Bordeaux, Observatoire Paris Meudon, LAPP Annecy, LUPM Montpellier, CEA Saclay, IPAG Grenoble
- Stockholm University, Royal Institute, Linnaeus University, Durham University, University of Leicester, Dublin Institute for Advanced Studies, GRAPPA University of Amsterdam
- Jagiellonian University, Nicolaus Copernicus University, University of Warsaw
- Univ. Adelaide, North-West University Potchefstroom, Wits Univ. Johannesburg, University of Namibie

H.E.S.S.

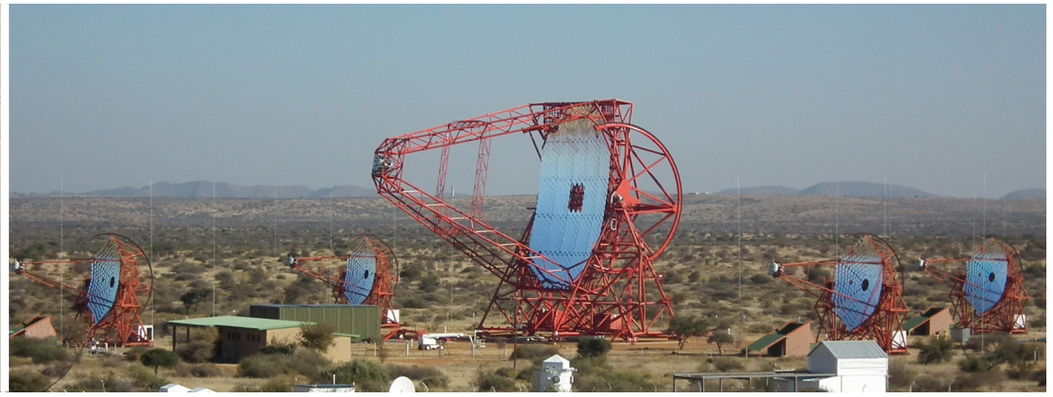
H.E.S.S. I / II

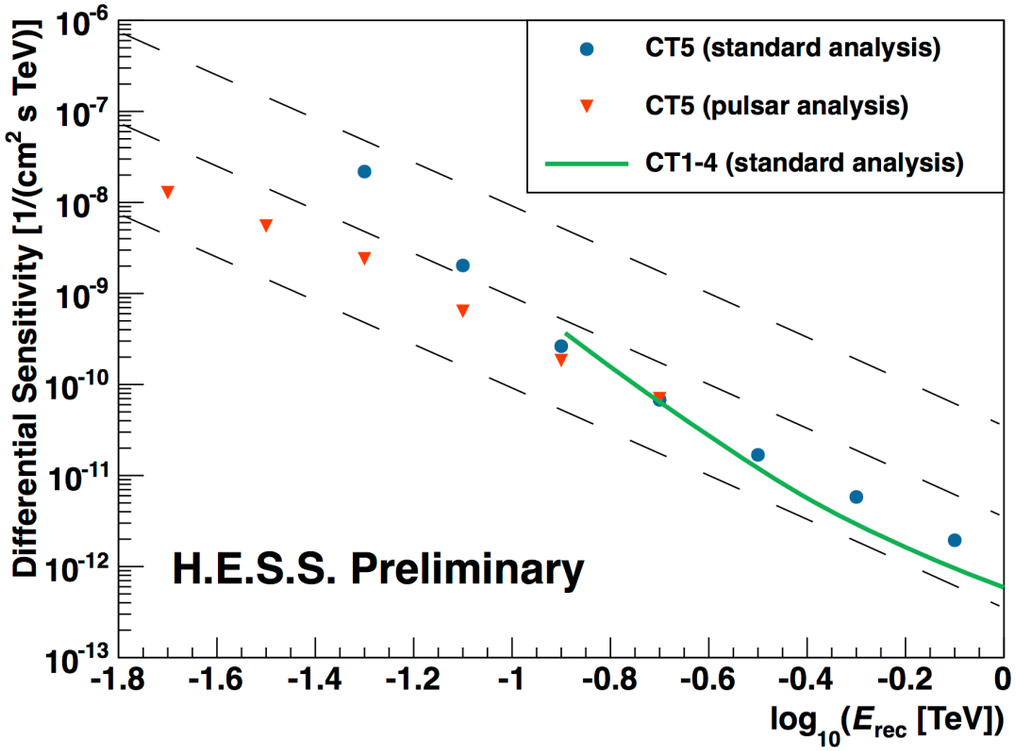


- H.E.S.S. phase I
  - four 12m telescopes
  - FoV 5 deg
  - energy threshold 100 GeV
  - angular resolution < 0.1 deg

- H.E.S.S. phase II
  - four 12m telescopes
  - one 28m telescope (FoV 3.5 deg)
  - energy threshold O(30 GeV)
  - angular resolution 0.4 to ≲ 0.1 deg

H.E.S.S. I / II




CT5 (standard analysis)
CT5 (pulsar analysis)
CT1-4 (standard analysis)
H.E.S.S. Preliminary
Differential Sensitivity [1/(cm² s TeV)]
log10(Erec [TeV])
10-6
10-7
10-8
10-9
10-10
10-11
10-12
10-13
-1.8
-1.6
-1.4
-1.2
-1
-0.8
-0.6
-0.4
-0.2
0

outline

- recent reports
  - Vela PSR
  - Crab flares
  - 1FGL J1018.6-5856
  - HESS J0632+057

Vela PSR

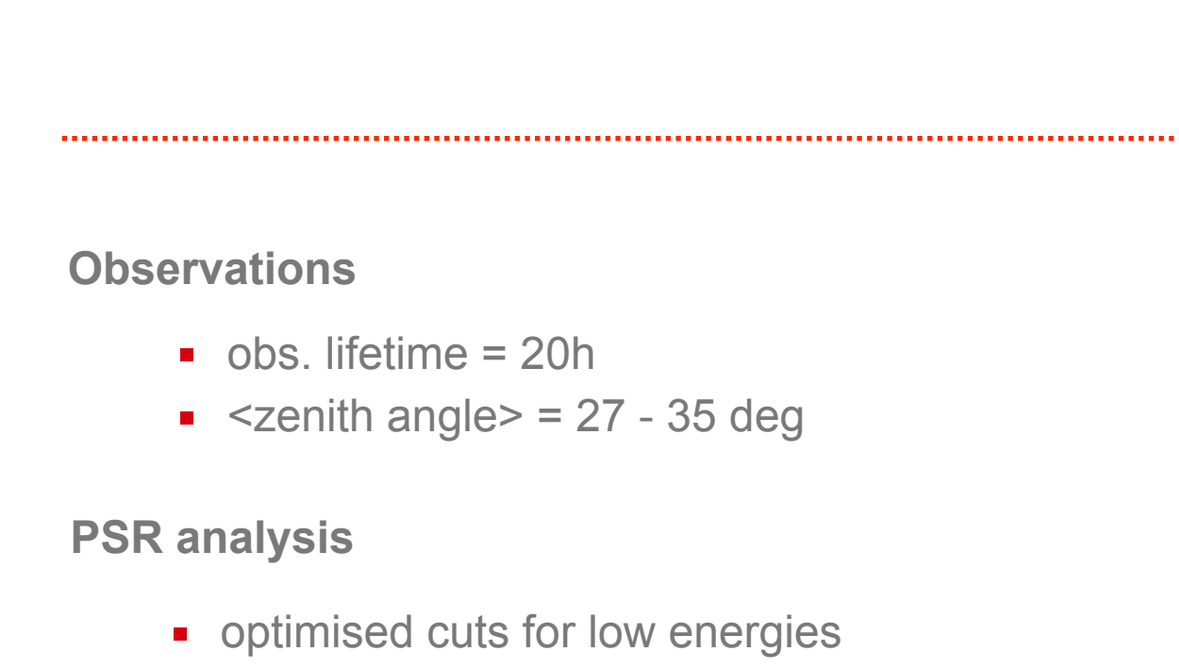
Observations

- obs. lifetime = 20h
- <zenith angle> = 27 - 35 deg

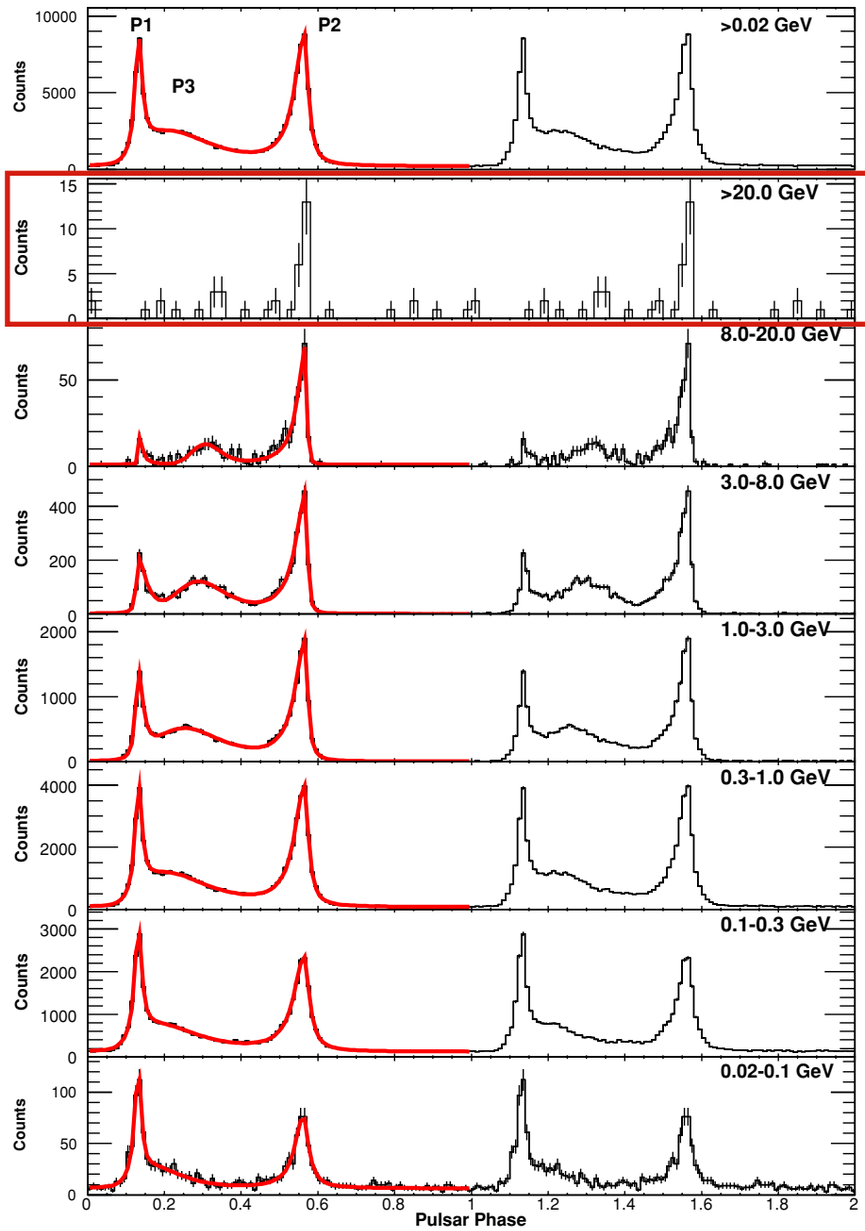
PSR analysis

- optimised cuts for low energies
- unblinded data-set analysis
- **N_{ON} - N_{OFF} = 6059 +/- 640, LiMa = 9.5σ**

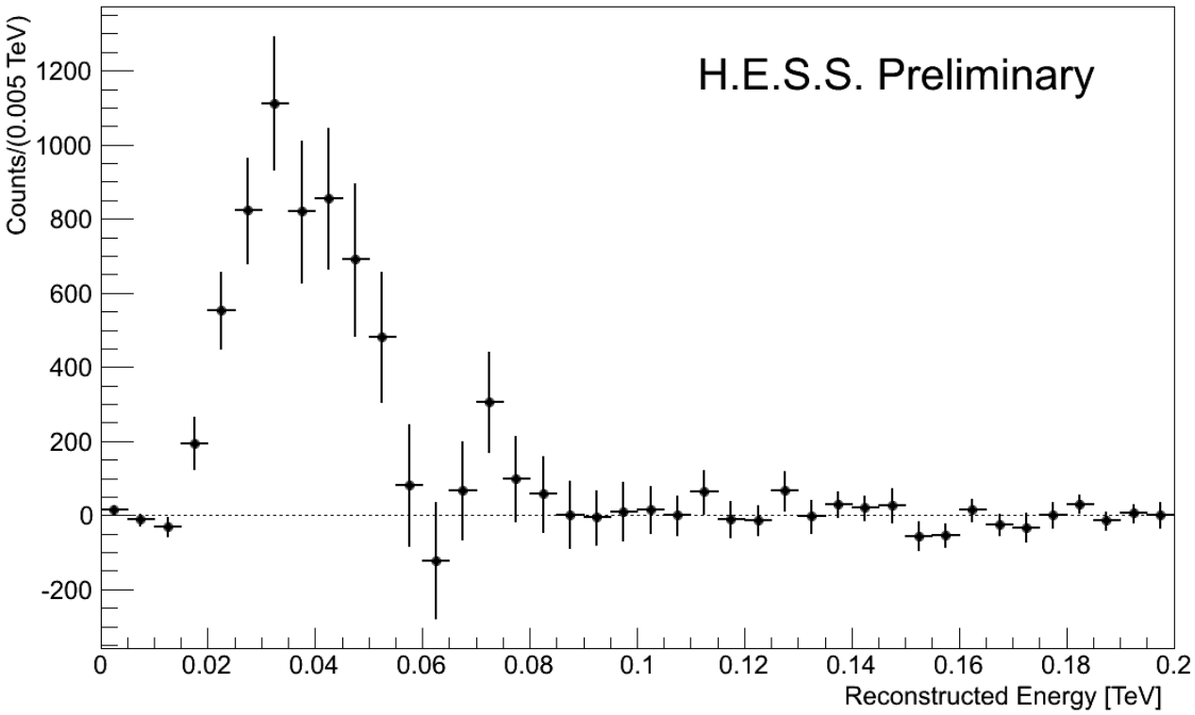
H.E.S.S. II mono analysis



Fermi-LAT (2010)



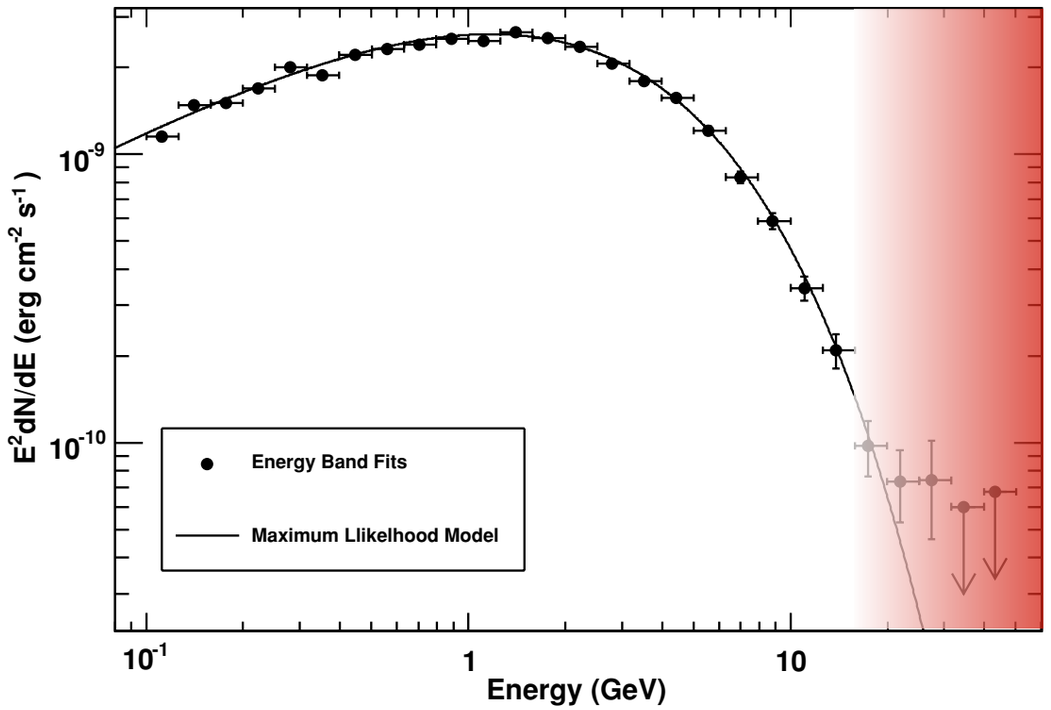
outline



energy distribution

- mean E = 40 GeV
- RMS = 13 GeV
- energy resolution = 50%
- angular resolution < 50 GeV = 0.4 deg

H.E.S.S. II



Pulsar physics (not only Vela?)

- characterise spectrum above few x 10 GeV
- constrain the cutoff ?
- P2 energy-evolution

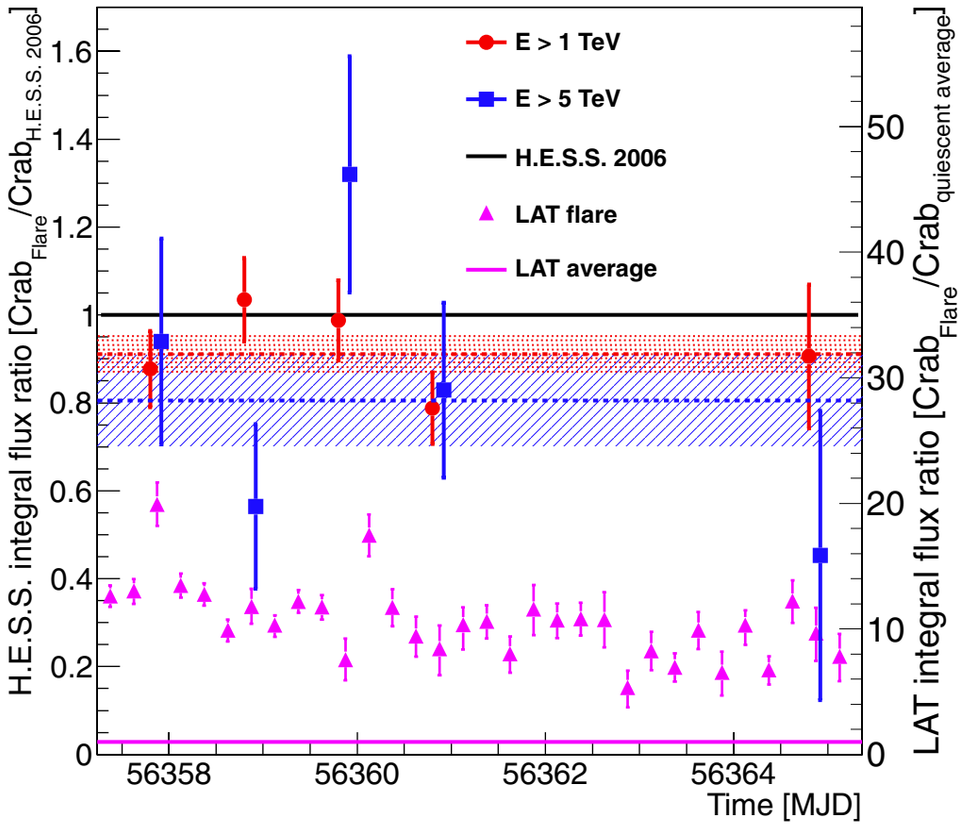
Crab Nebula flares

H.E.S.S. observations of the Crab during its March 2013 GeV gamma-ray flare

H.E.S.S. collaboration 2014, A&A, 562L ,4H

- March 2013: *Fermi*-LAT and AGILE report HE flare from Crab (~ 6 × Φ_{HE})
- H.E.S.S.: 5-consecutive nights observations (acc. corrected lifetime = 4.4h)
- no increased TeV emission: $\Delta\Phi_{VHE} \leq 63\%$ (>1 TeV), 78% (> 5 TeV) at 95% C.L.
- in agreement with VERITAS/MAGIC results
- ARGO-YBJ: $\Delta\Phi_{1TeV}$ ~ 4-8 × $<\Phi V_{HE}>$?

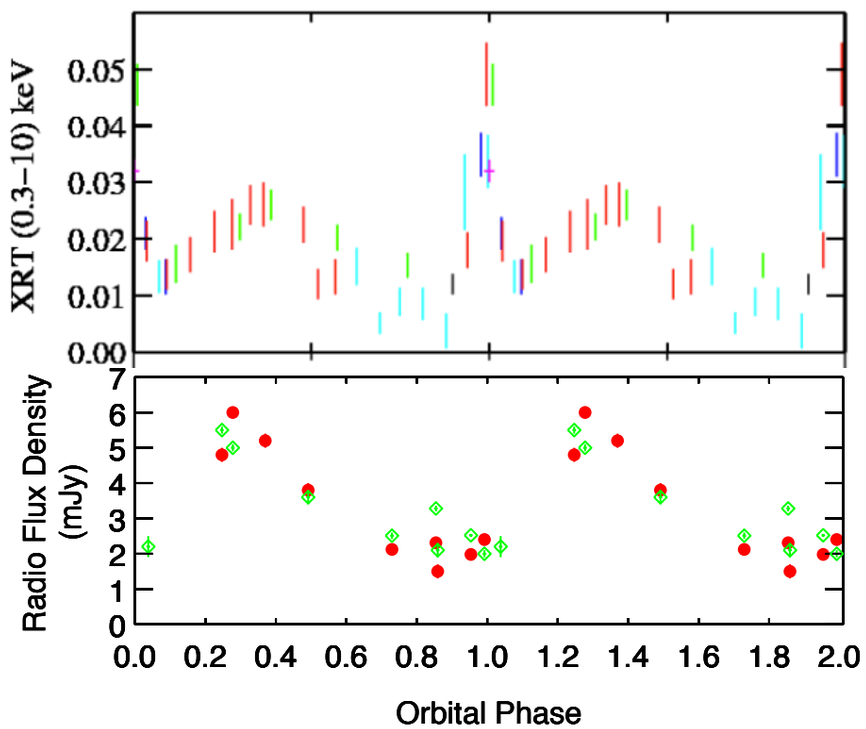
(see R. Zanin's talk on Wednesday)

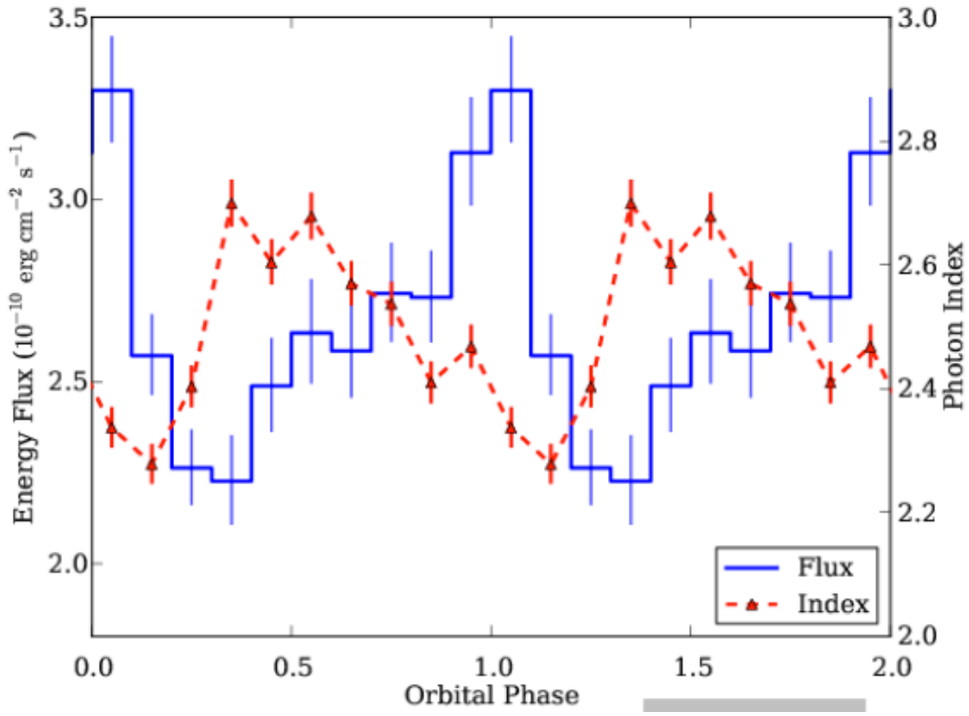


1FGL J1018.6-5856

Periodic Emission from the Gamma-Ray Binary 1FGL J1018.6-5856

Fermi-LAT coll. 2012, Science, 335, 189F



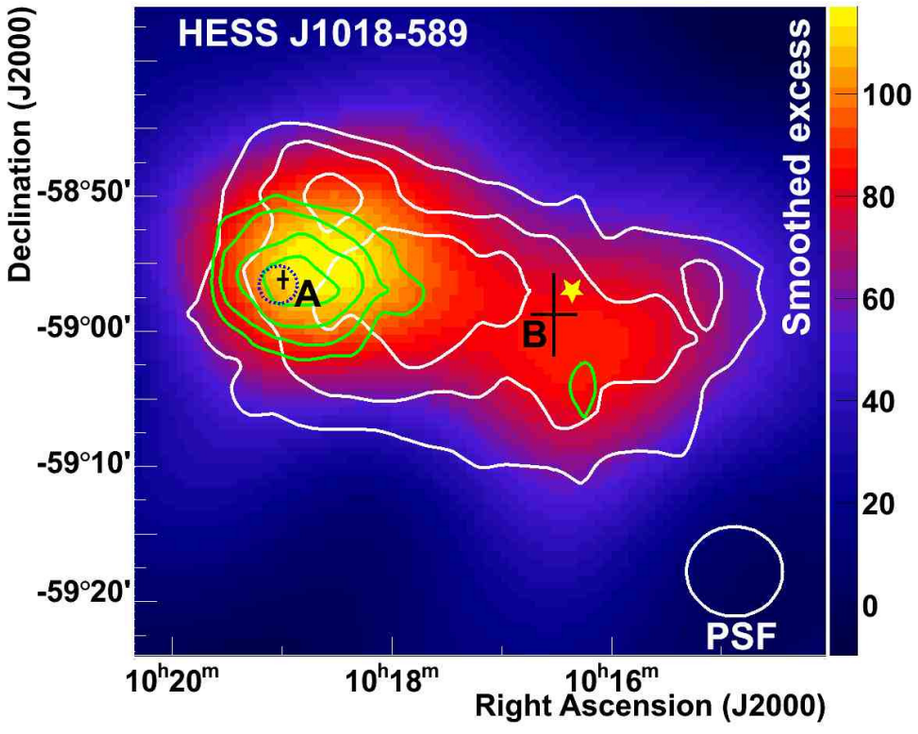


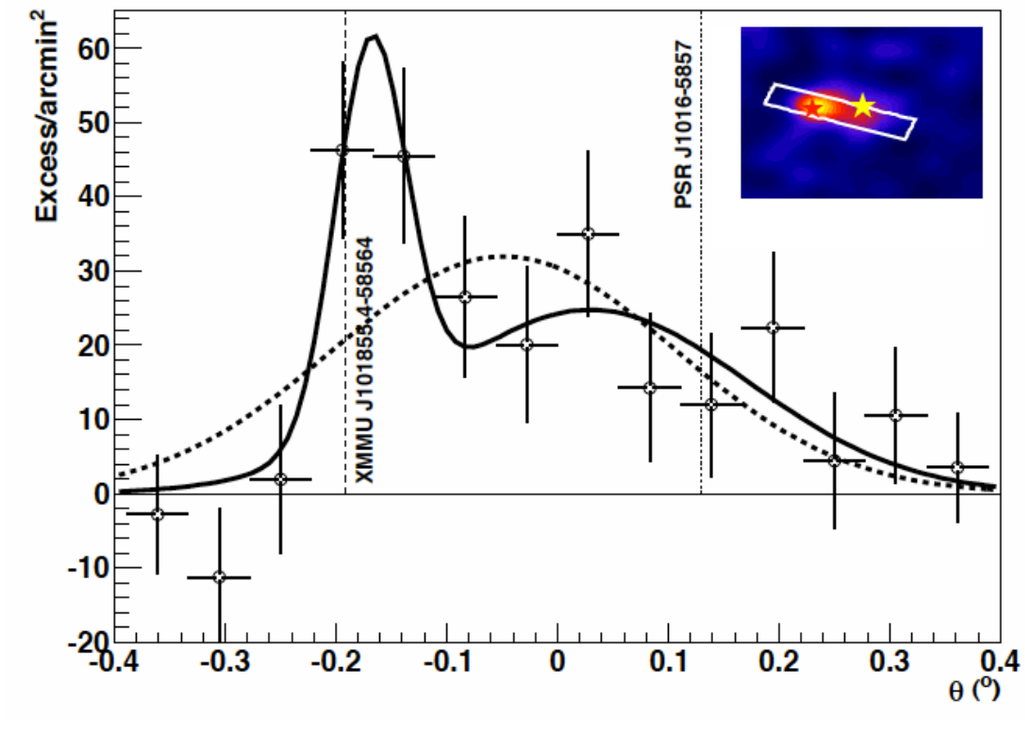
- "genuine" γ-ray binary, *Fermi*-LAT discovery through periodicity (16.6d) *(Fermi-LAT coll. 2012)*
- periodic emission observed also in X-rays (+ radio variability, but no peak at phase 0)
- similar to LS 5039 (e.g.companion O6Vf)… but correlated hardness-intensity at GeV

1FGL J1018.6-5856 / HESS J1018-589

Discovery of VHE emission towards the Carina arm region with H.E.S.S.: HESS J1018-589
H.E.S.S. coll. 2012, A&A, 541, A5

- two sources, point-like (1FGL J1018?) + extended source (PSR J1016's nebula?)
- possible TeV counterpart to 1FGL J1018: HESS J1018-589 "A"?
- source confusion and no clear sign of variability precluded clear identification





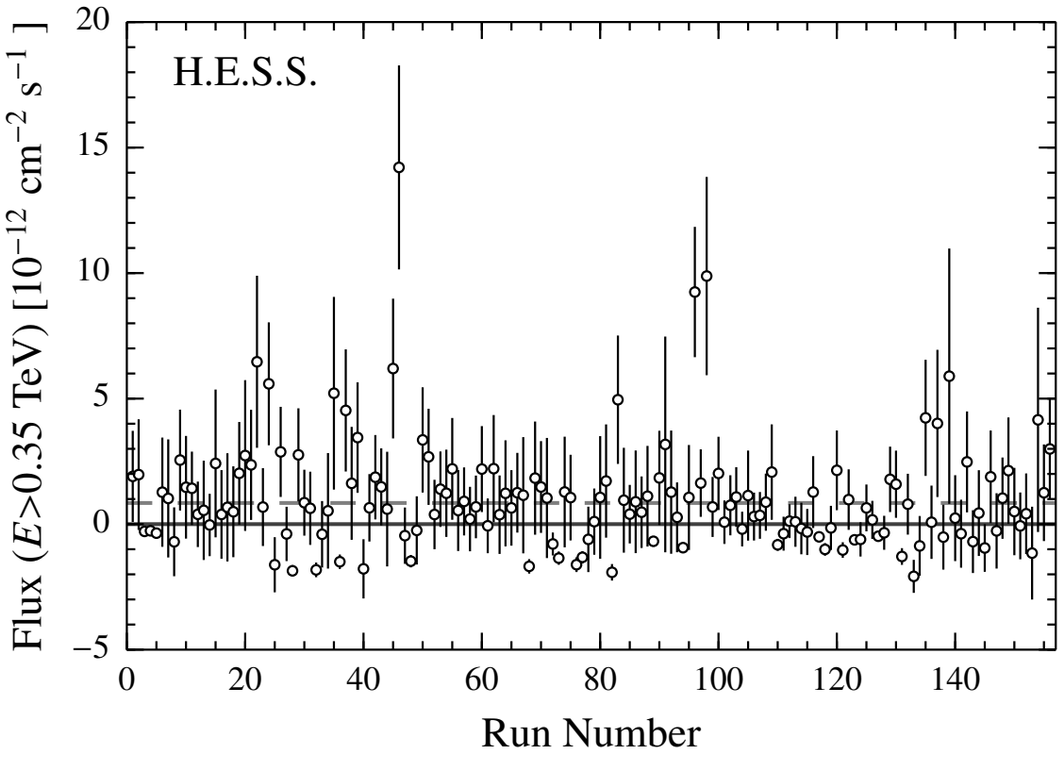
H.E.S.S.

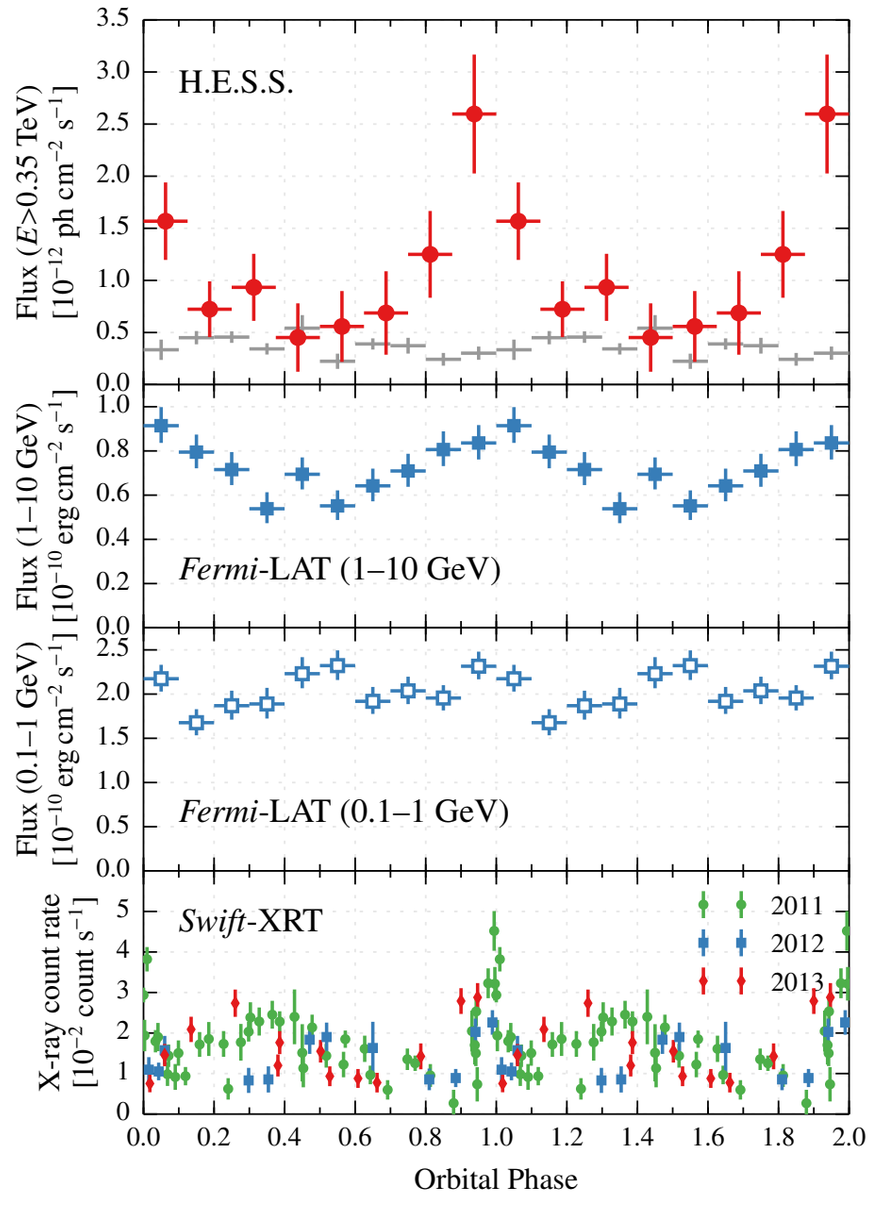
1FGL J1018.6-5856 / HESS J1018-589

Discovery of variable VHE gamma-ray emission from the binary system 1FGL J1018.6-5856

H.E.S.S. coll. 2015 (arXiv:1503.02711)

- Variability: LTR with cte. flux as null hypothesis:
  χ^2/v = 238.3/155 => **4.3 σ**
- Periodicity: P = 16.58d, MJD_0 = 55403.3
  χ^2/v = 22.7/7=> **3.1 σ**

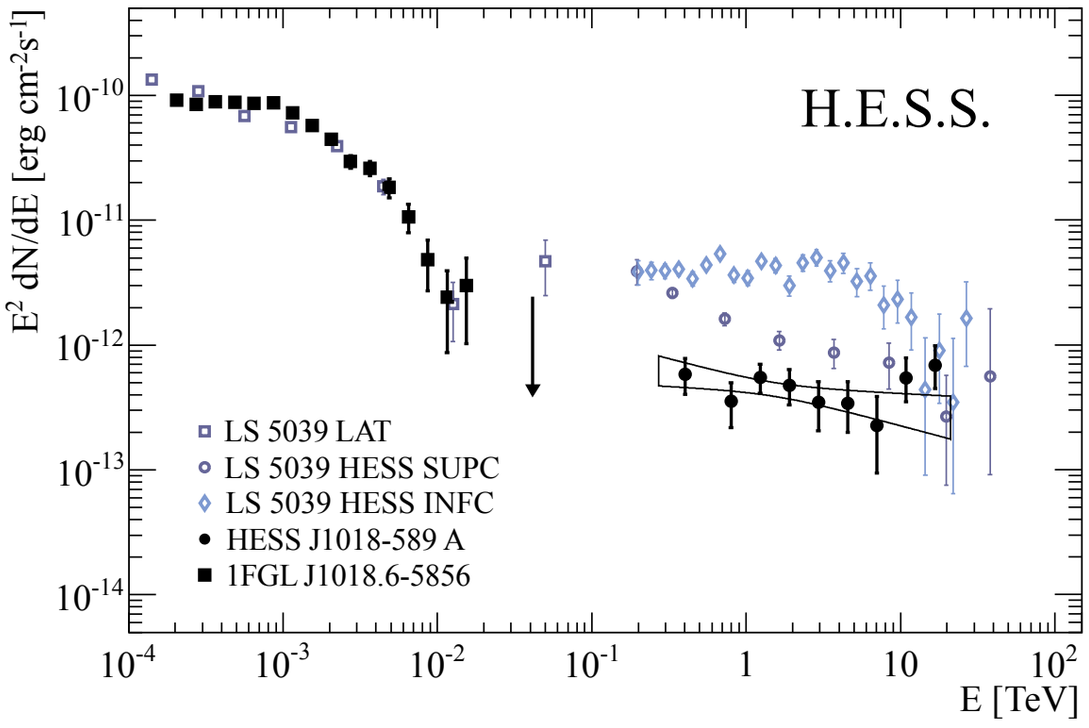


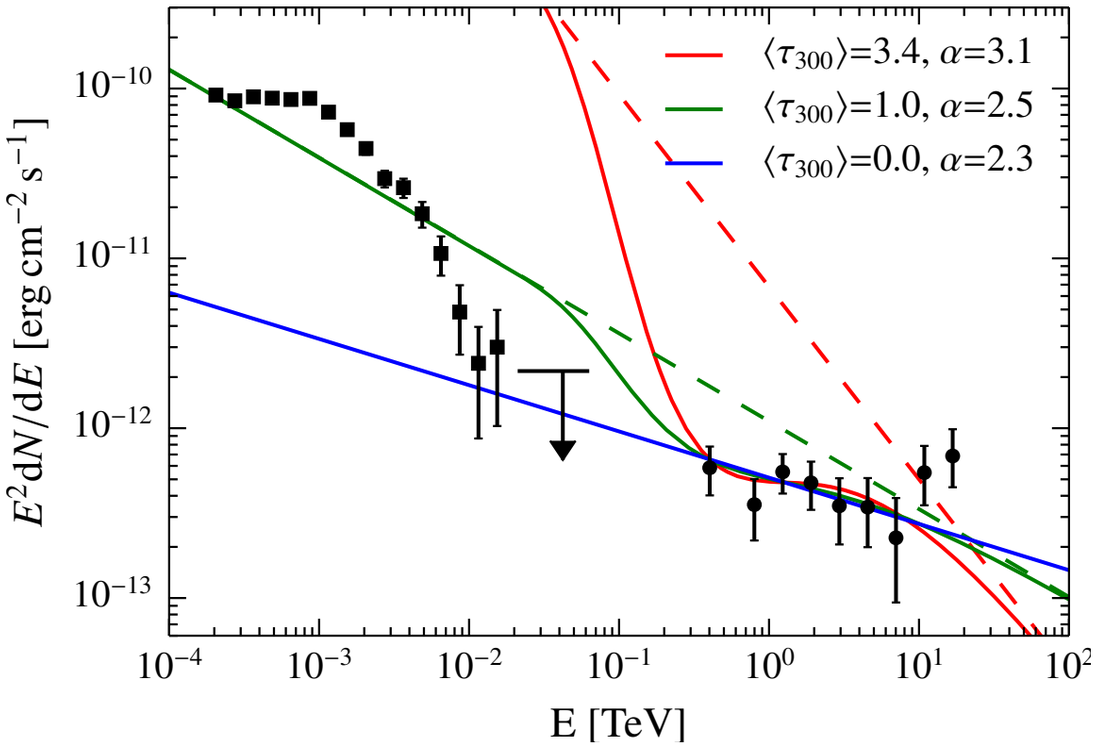


1FGL J1018.6-5856

Discovery of variable VHE gamma-ray emission from the binary system 1FGL J1018.6-5856

H.E.S.S. coll. 2015 (arXiv:1503.02711)





- Low absorption required to explain narrow peak at phase 0 and correlated GeV/TeV emission:
- Lack of absorption features (pair production) in spectrum: low absorption or break at 100-300 GeV

(see E. de Oña Wilhelmi's talk)

HESS J0632+057

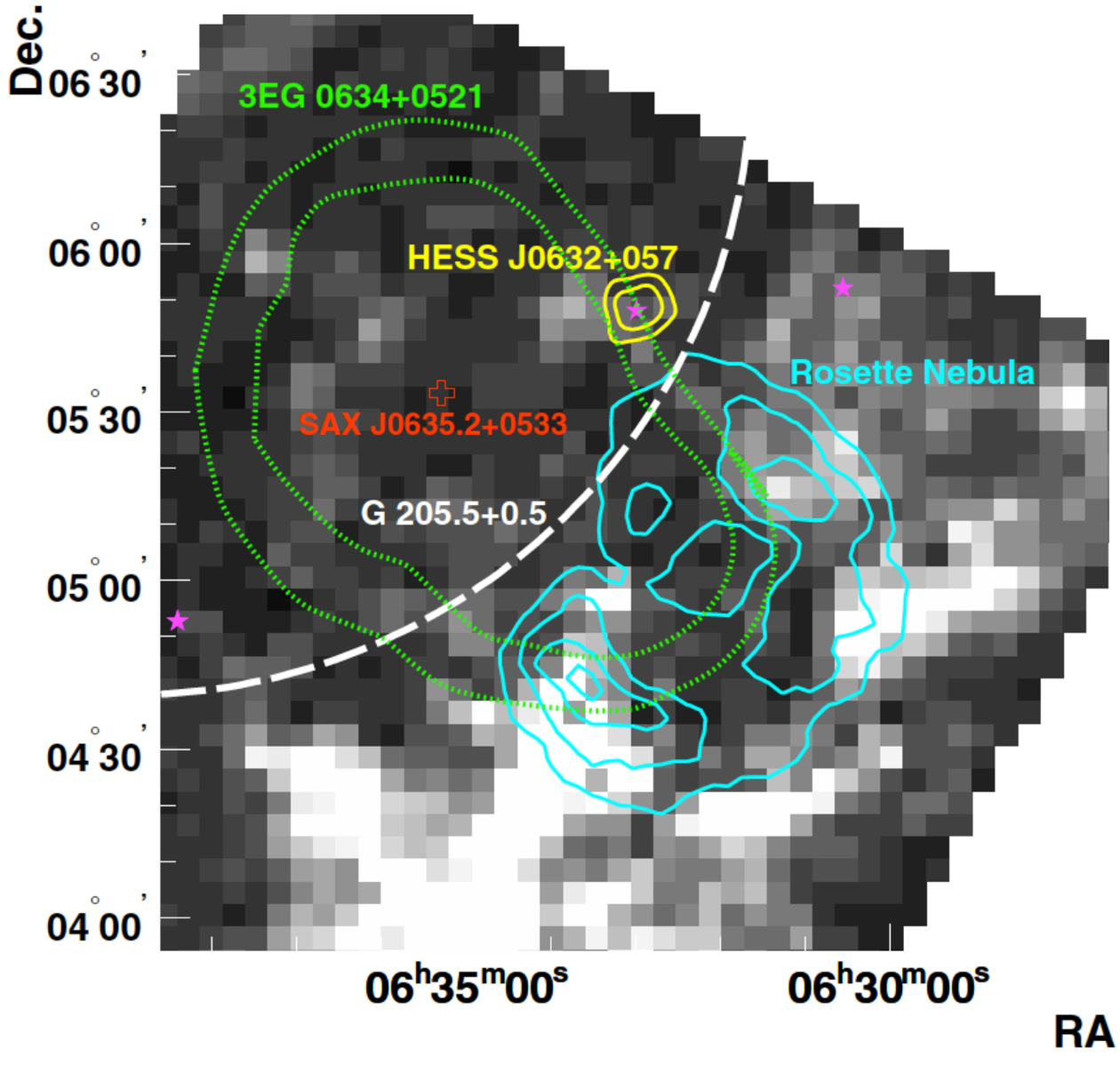
- ***"Discovery of a point-like VHE γ-ray source in Monoceros"***

  (Aharonian et al. 2007, A&A, 469, L1)

- **possible associations**

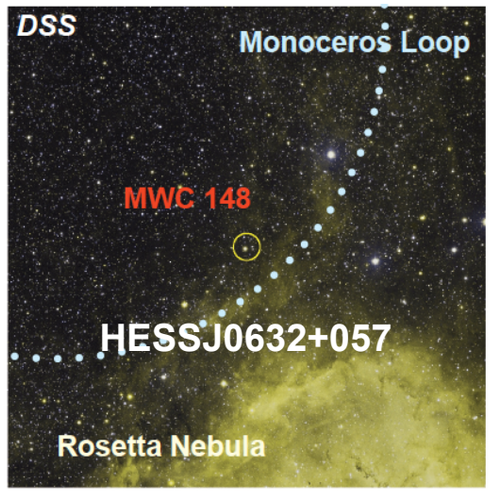
  - The Monoceros Loop SNR ✘
  - 3EGJ0634+0521 ✘
  - 1RXS J063258.3+054857 ✘
  - MWC148 (HD259440) ✔

*"A related possibility is that MWC148 is part of a **binary system** with an, as yet undetected, compact companion. Such a system might then resemble the known VHE γ-ray source PSR B1259-63/SS2883 (Aharonian et al. 2005a). Further multiwavelength observations are required to confirm or refute this scenario."*

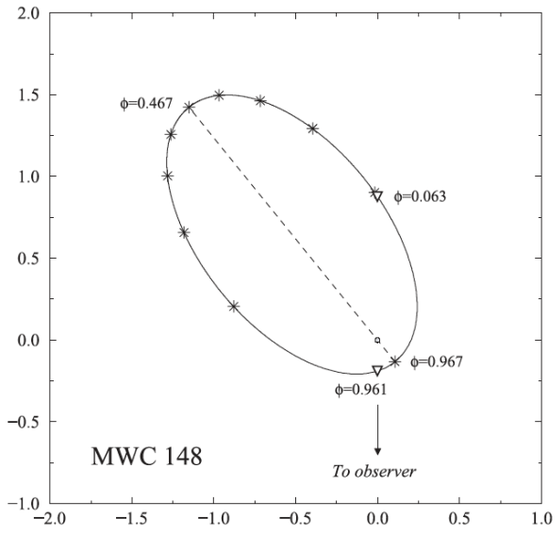


HESS J0632+057

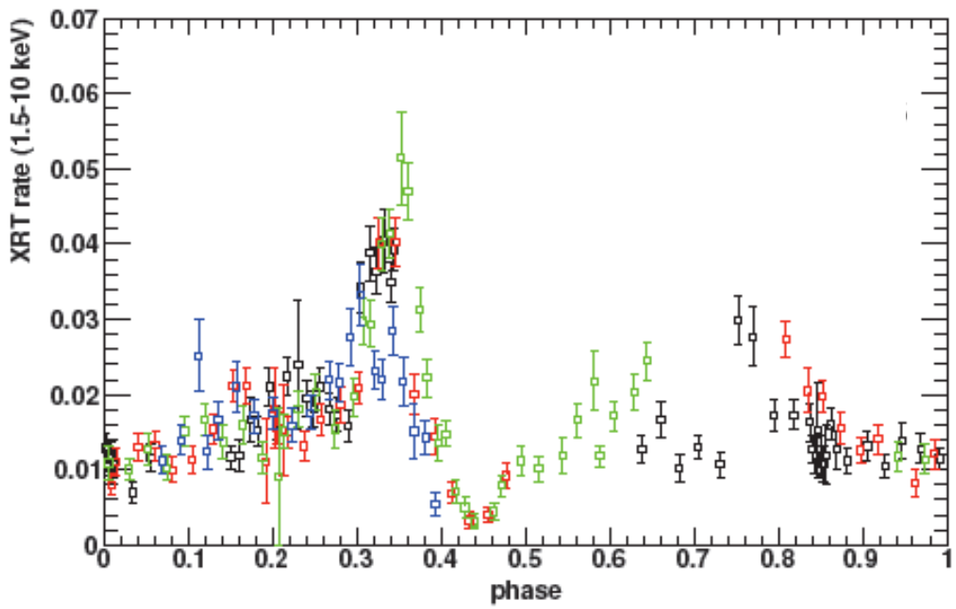
- **HESS J063+057: a new γ-ray binary system**
  - binary nature from optical data (Casares+ 2012)
  - **MWC 148**: High-Mass, B0pe star, d = 1.1 - 1.7 kpc
  - X-rays: 321±5d periodic modulation (Bongiorno+2011)
  - no pulsations found (Chandra, GBT) (Rea & Torres 2011)
  - point-like → extended radio source (+30d after X-ray burst) (Moldón+ 2011)



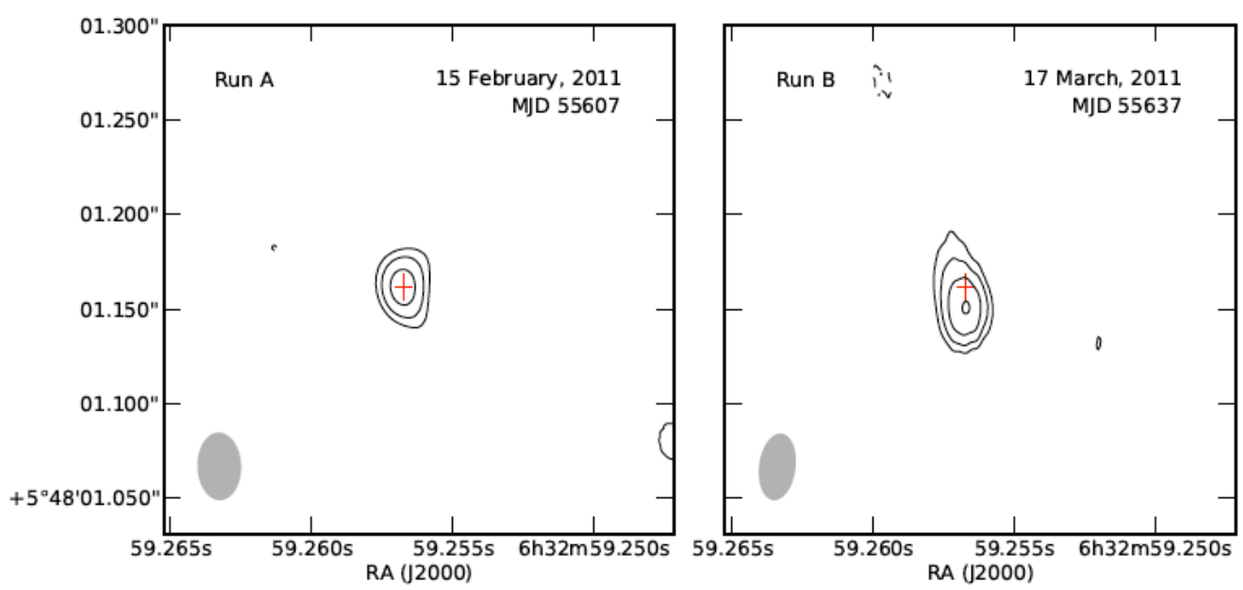
Skilton et al. (2011)



Casares et al. (2012)



Bongiorno et al (2011)

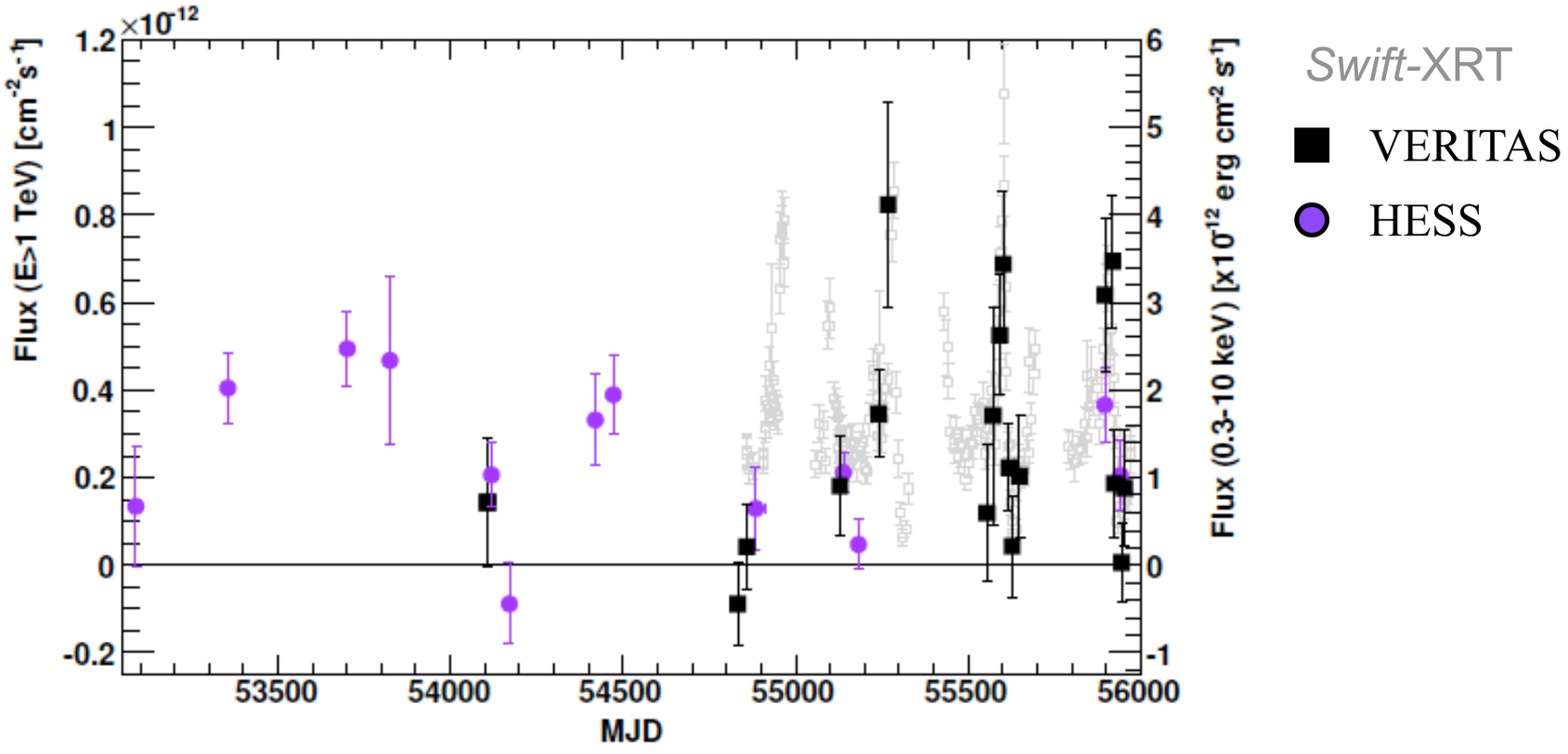


Moldón et al. (2011)

HESS J0632+057

Long-term TeV and X-Ray Observations of the Gamma-Ray Binary HESS J0632+057

Aliu+ (VERITAS coll.), Abramowski+ (H.E.S.S. coll) 2014, ApJ, 780, 168A

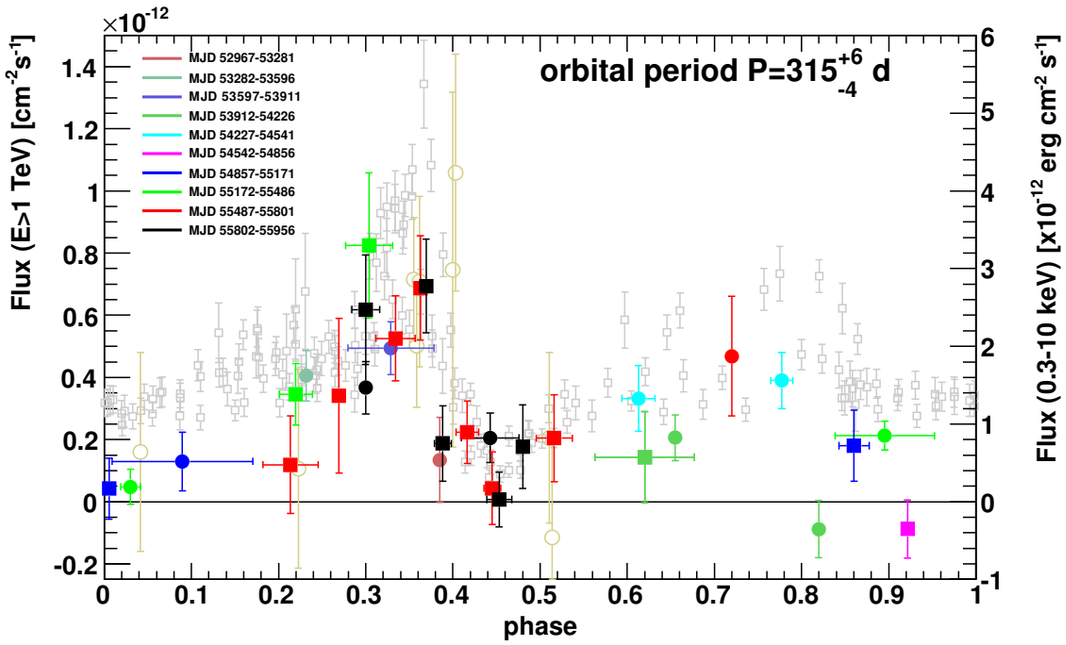


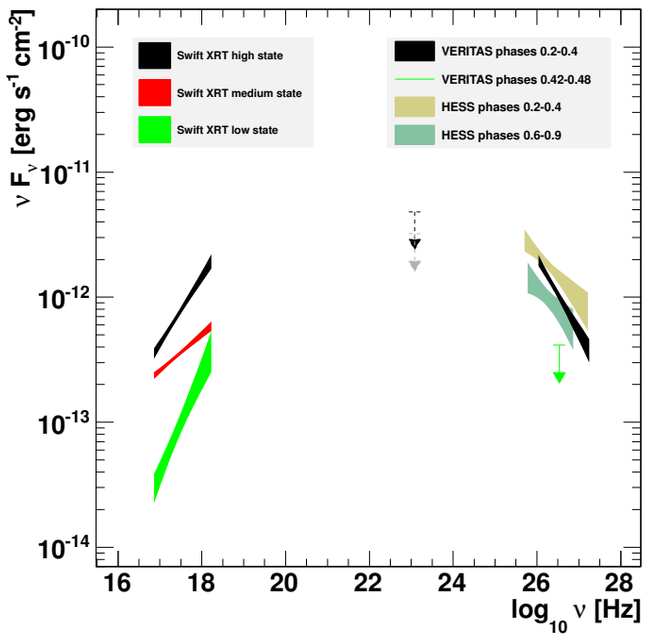
- Extremely rich VHE/X-ray data-set
  - VHE observations: MJD 53087 to MJD 55955: > 8 yrs coverage
  - Swift-XRT: MJD 54857 to 55972: ~ 3 yrs observations

HESS J0632+057

Long-term TeV and X-Ray Observations of the Gamma-Ray Binary HESS J0632+057

Aliu+ (VERITAS coll.), Abramowski+ (H.E.S.S. coll) 2014, ApJ, 780, 168A





- correlated X-ray/TeV emission driven by sharp rise-and-fall at phases ~0.3
- TeV emission reported for the first time at phases ~ [0.6 - 0.9]. Secondary peak?
- only gamma-ray binary not detected at GeV energies (Caliandro+ 2013)

(models on HESS J0632: see A. Ozazaki and T. Kawano talks)

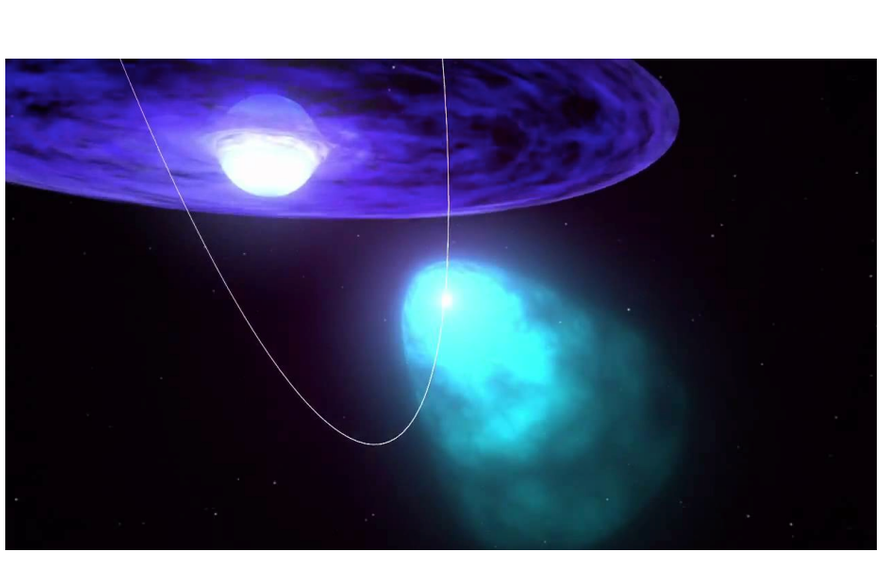
outline

- ongoing studies
  - PSR B1259-63
  - LS 5039
  - Eta Carinae
  - mQs, novae, transients

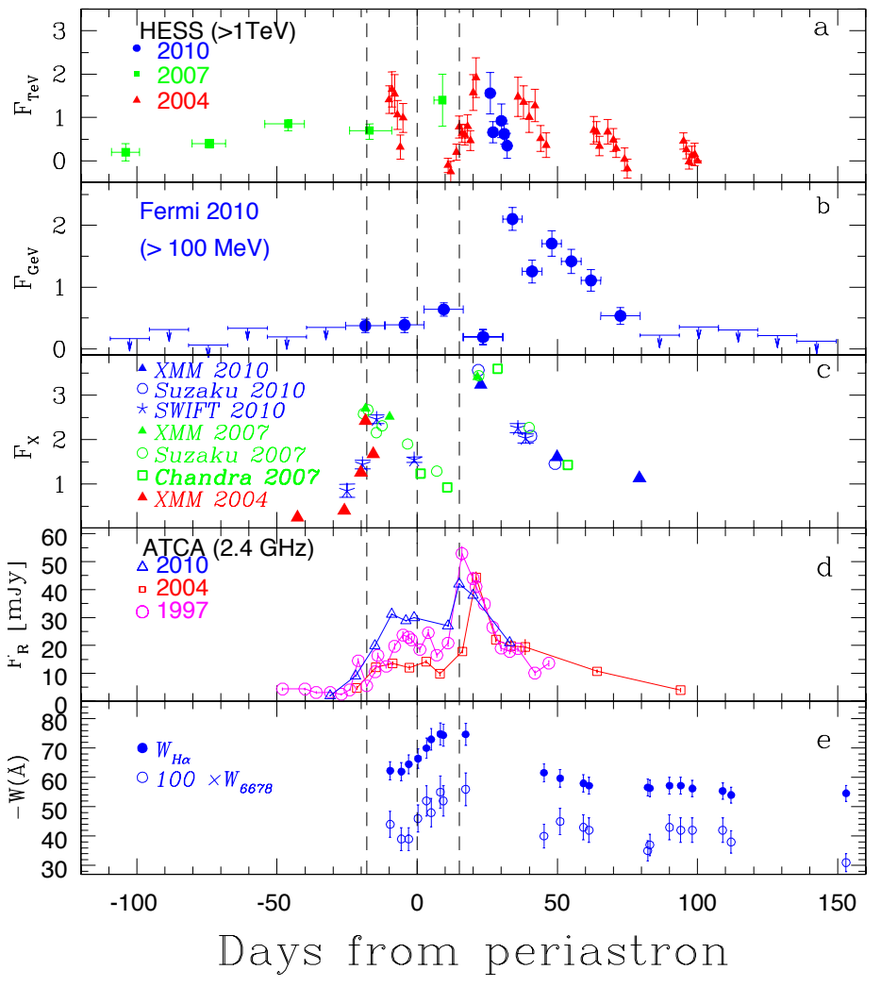
PSR B1259-63

PSR B1259-63: a γ-ray binary laboratory

- pulsar (P 48ms, L_{sd}= 8 ×10^{35} erg/s) + O9.5Ve star (L_{star}= 2.3 × 10^{38} erg/s) + circ. disk
- binary system: D = 2.3, P_{orb}= 3.4 years, eccentricity = 0.87, orbital inclination i ~24º
- variable/periodic emission in radio, optical, X-rays, GeV and TeV γ-rays
- pulsations seen only in radio (and away from periastron)
- GeV flare in 2011; happening again in 2014



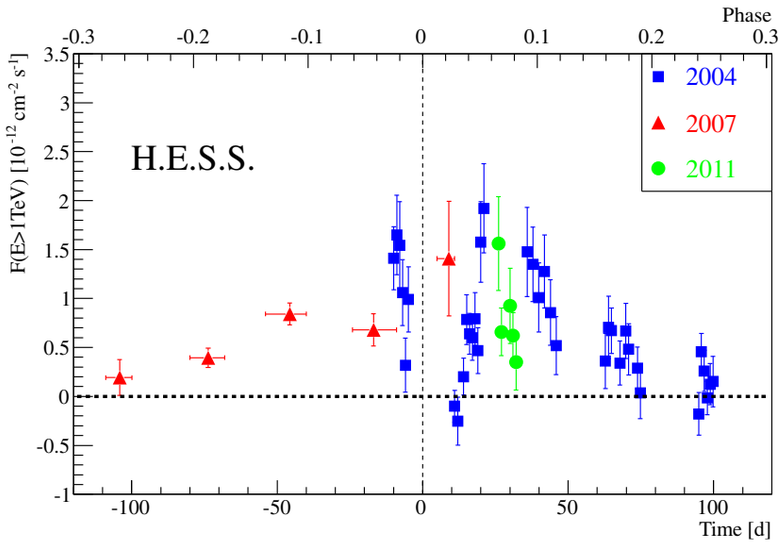
PSR B1259-63, credits: NASA archive

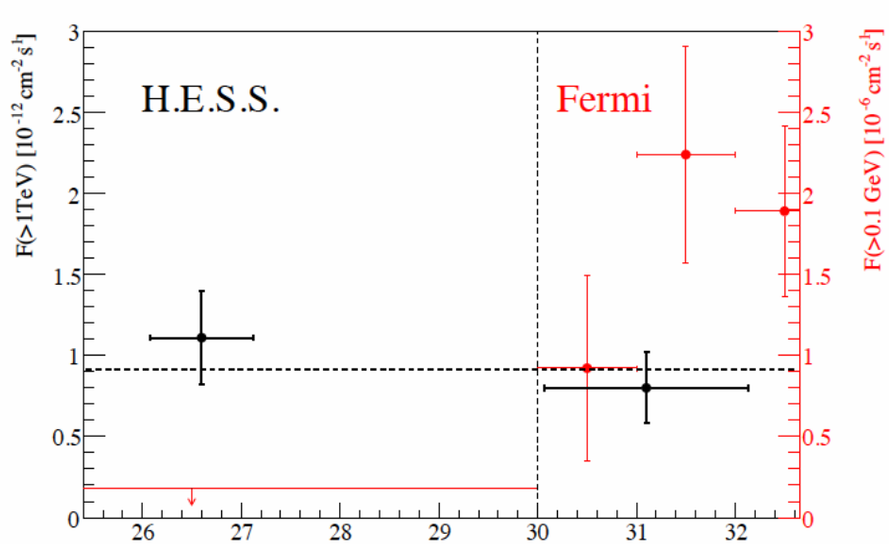


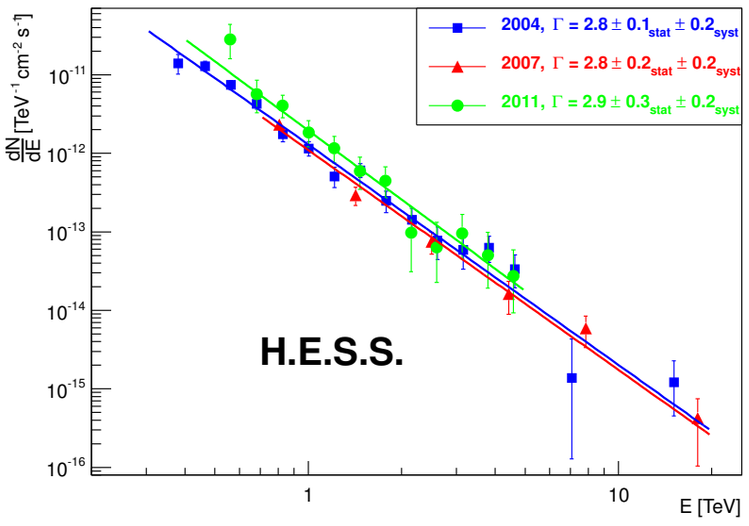
PSR B1259-63

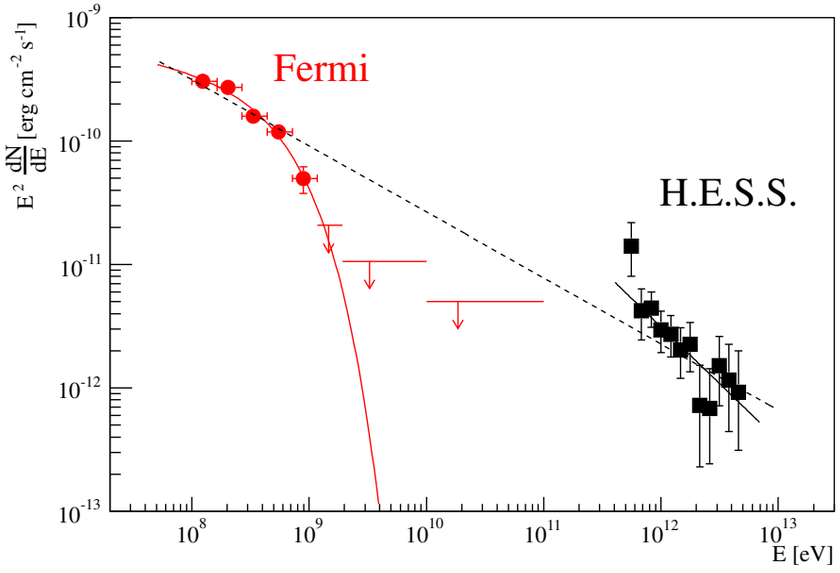
H.E.S.S. observations of PSR B1259-63/LS 2883 around the 2010/2011 periastron passage

H.E.S.S. coll. 2013,A&A, 551A, 94H



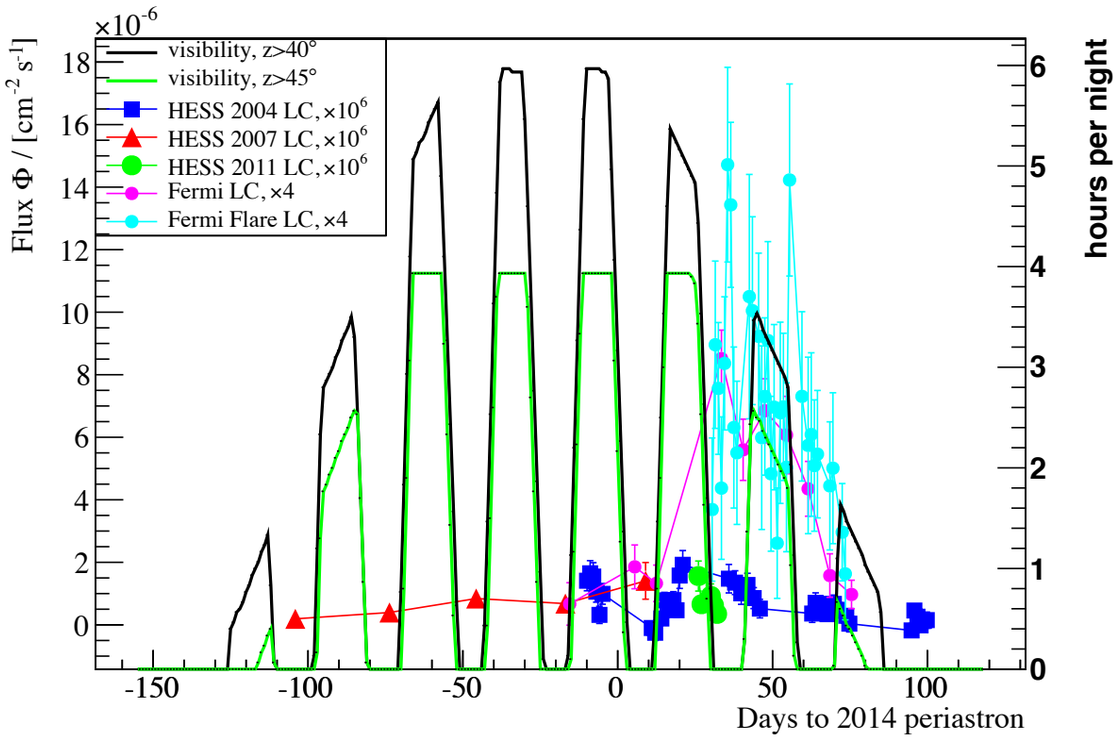


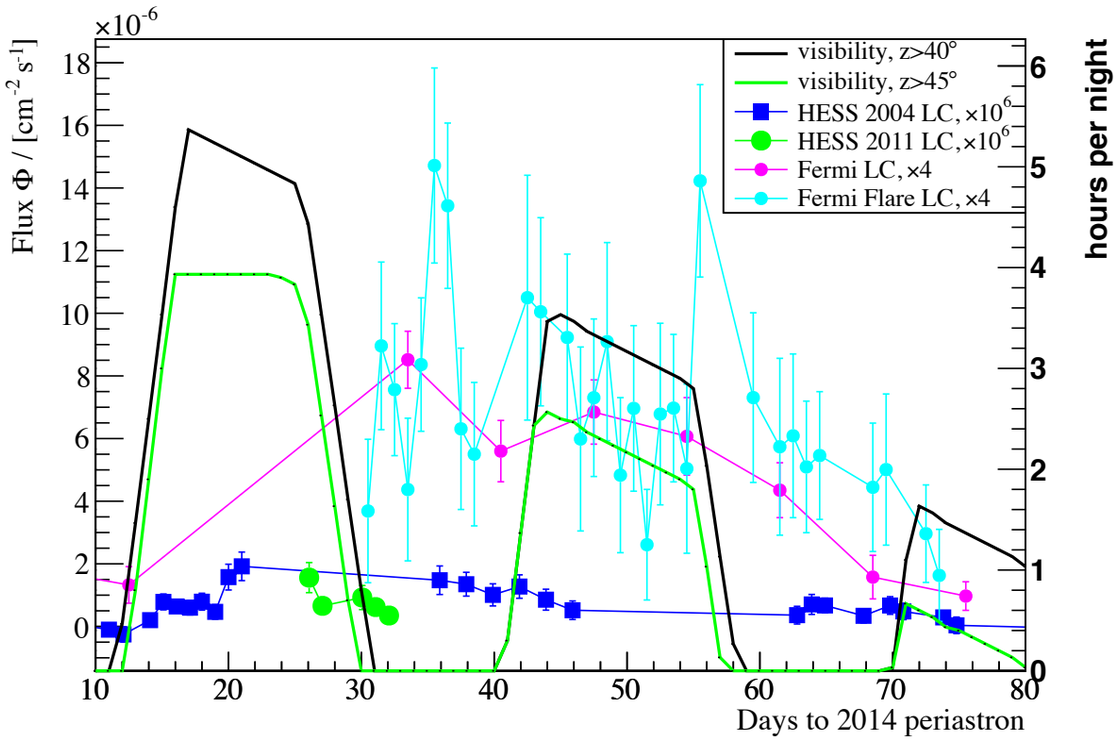




PSR B1259-63

- **H.E.S.S. observations in 2014 periastron passage** (+ Fermi, Swift, INTEGRAL, NuStar, SALT, ATCA…)





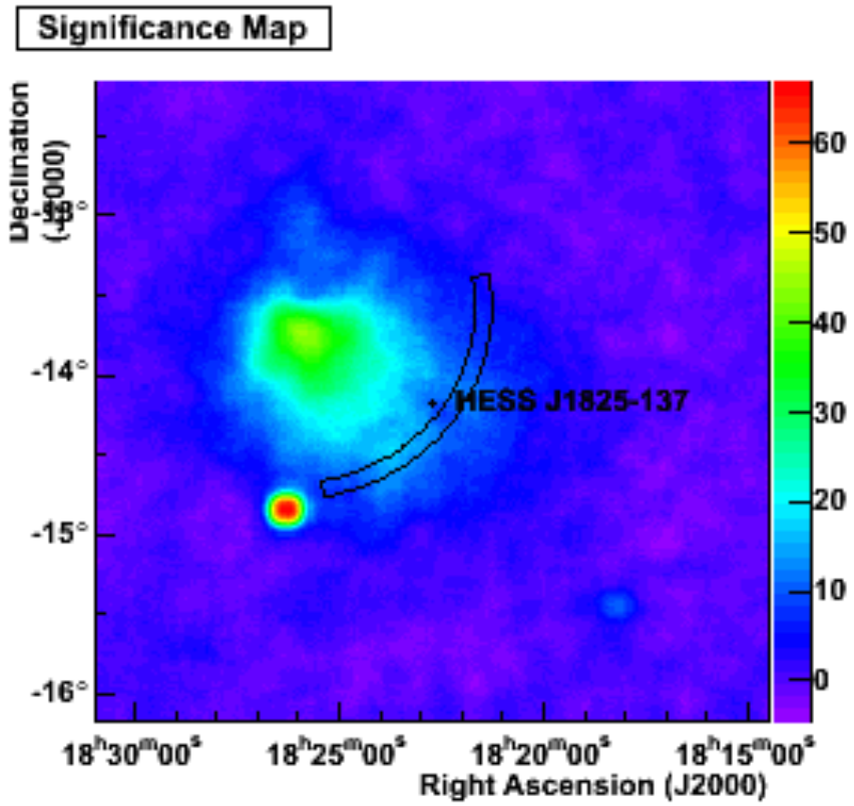
- simultaneous observations of the 2014 GeV flare
- long-term variability through coverage of previously studied orbital phases (2004, 2007, 2011)
- first-time VHE observations during exact $t_{periastron}$
- studying double-peak profile at VHEs in a single orbit
- spectral extension down to ~100 GeV

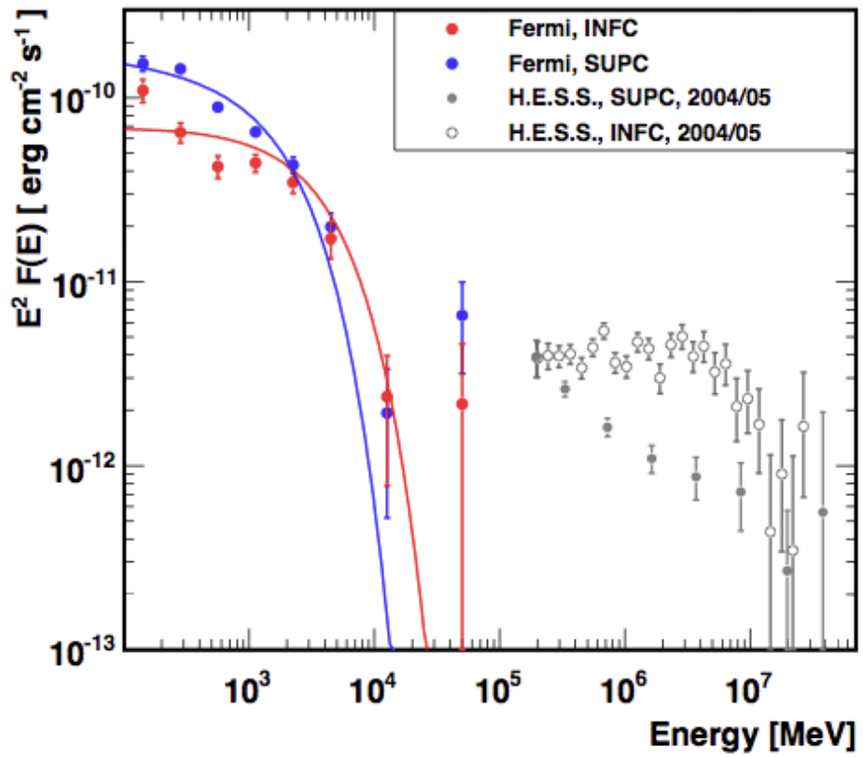
(see C. Romoli's talk later today)

LS 5039

LS 5039: the only swiss-clock gamma-ray binary

- well-studied @ TeVs with H.E.S.S. and GeV with *Fermi*-LAT
- still many unknowns: accelerator/emitter location, SUPC TeV "excess" and spectral shape…
- H.E.S.S. I: deep obs. campaign conducted: contamination by HESS J1825, fine phase-resolved spectra
  H.E.S.S. II observations ongoing: probe GeV-TeV transition, signatures of pair-production @ SUPC…



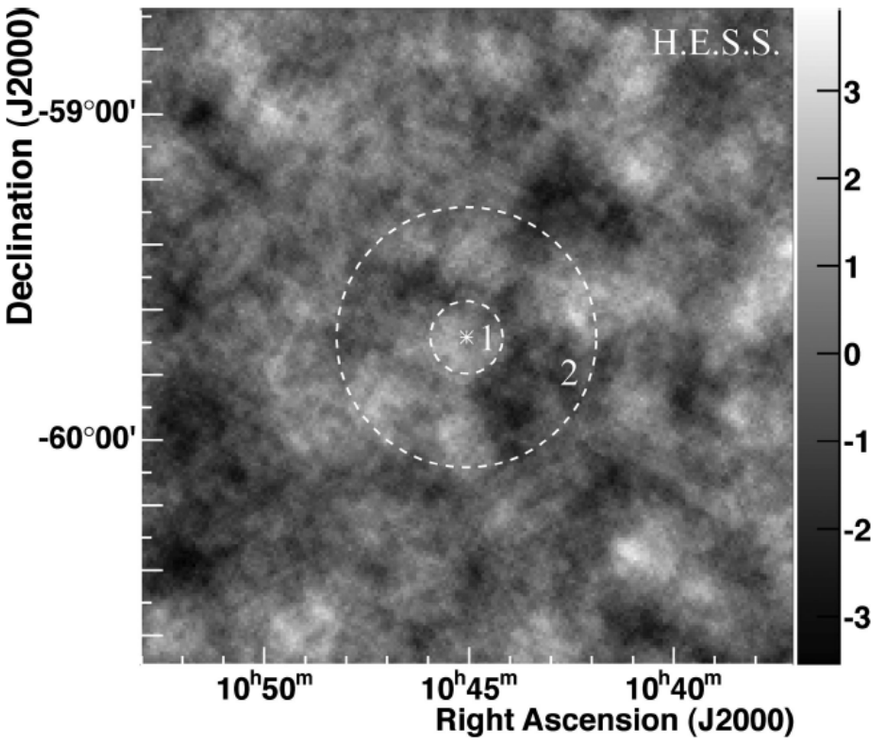


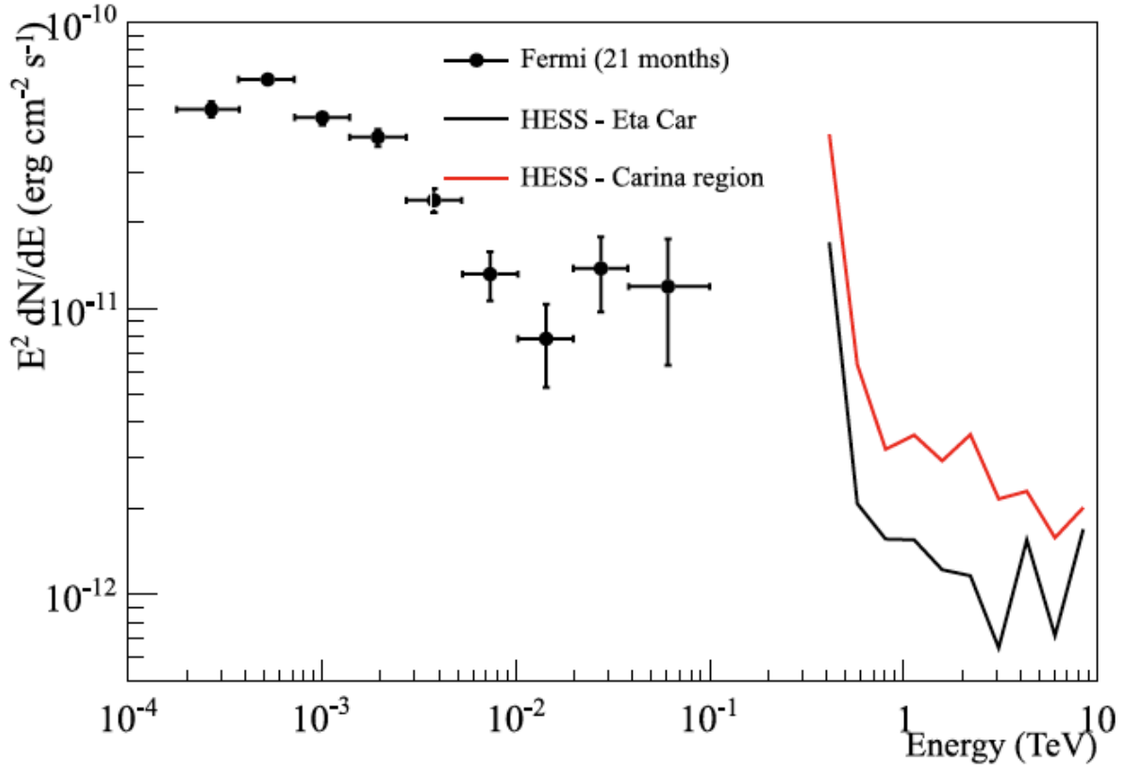
Hadasch et al. 2012

Eta Carinae

H.E.S.S. observations of the Carina nebula and its enigmatic colliding wind binary Eta Carinae

H.E.S.S. coll. 2012, MNRAS 424, 128H

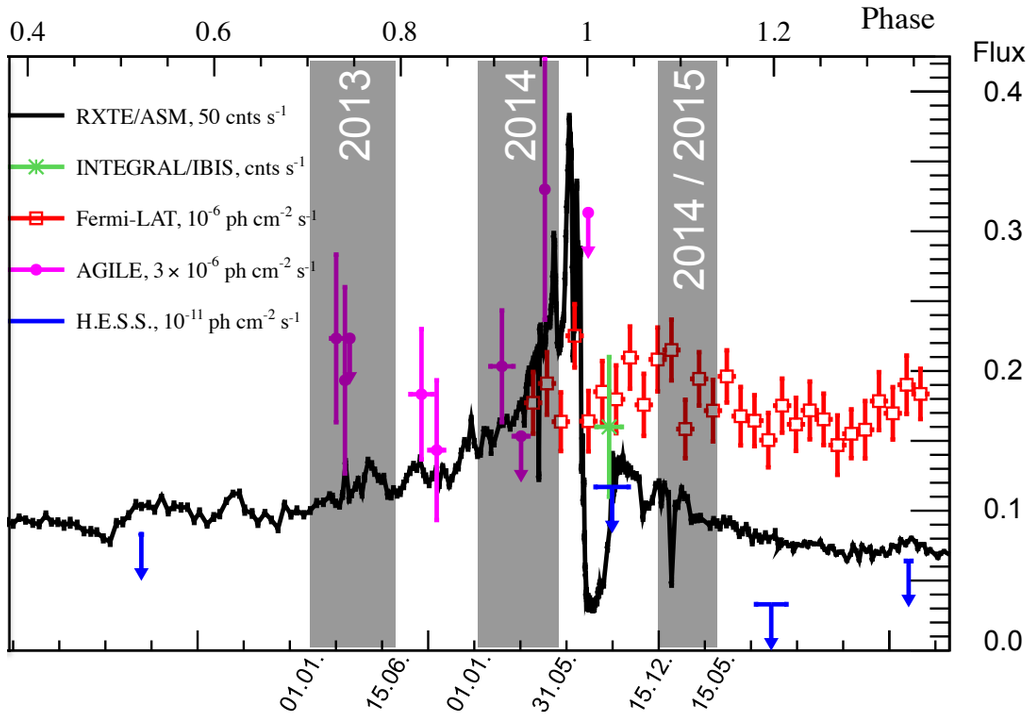


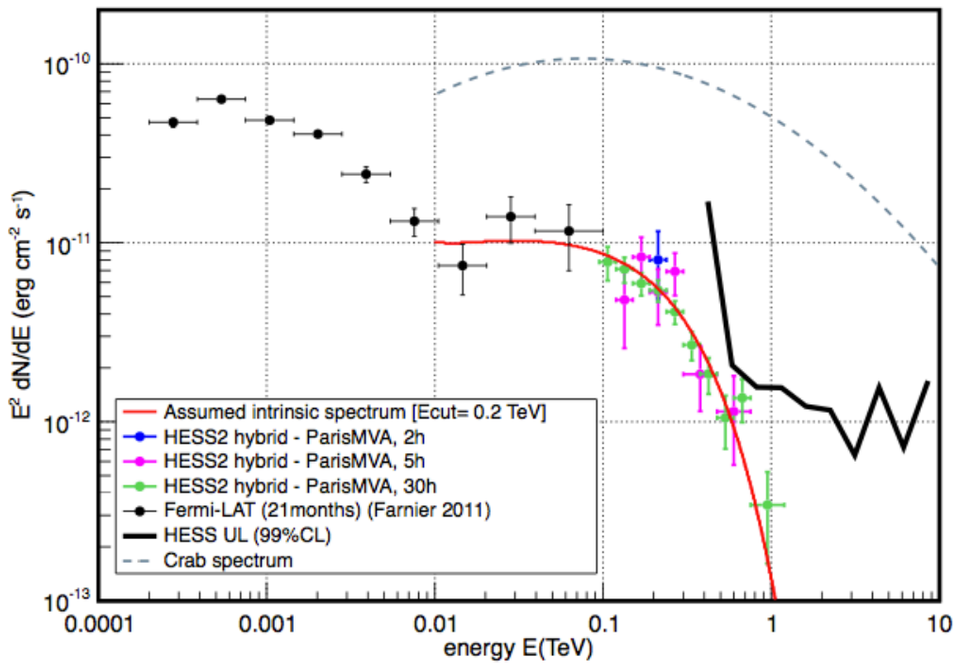


- Search for Eta Carinae (+ phase-folded analysis) + extended emission from Carina Nebula
- No signal ⇒ uu.ll. > E_{th} = 470 GeV: η-Car ≤ 7.7 ×10^{-13} ph cm^{-2} s^{-1}; Nebula: ≤ 4.2 ×10^{-12} ph cm^{-2} s^{-1}

Eta Carinae

- H.E.S.S. observations planned for 2014 periastron passage
  (last call: next passage in 2020 → CTA?)





- *Fermi*-LAT enhancement of HE (>10 GeV) emission in mid-2014 (*c.f.* C. Farnier's analysis)
- H.E.S.S. 2014 observations successfully obtained (including CT5 to lower E_{th})
- data analysis ongoing, difficult region (very high NSB)

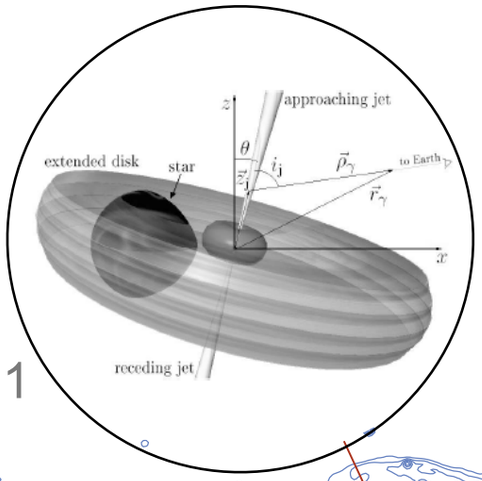
(Eta Car in gamma-rays: O. Reimer and V. Zabalza talks on Tuesday)

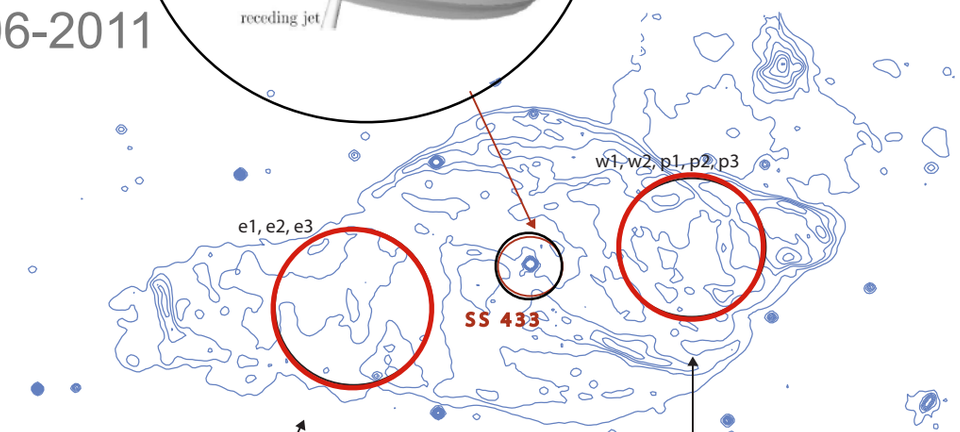
SS433/W50

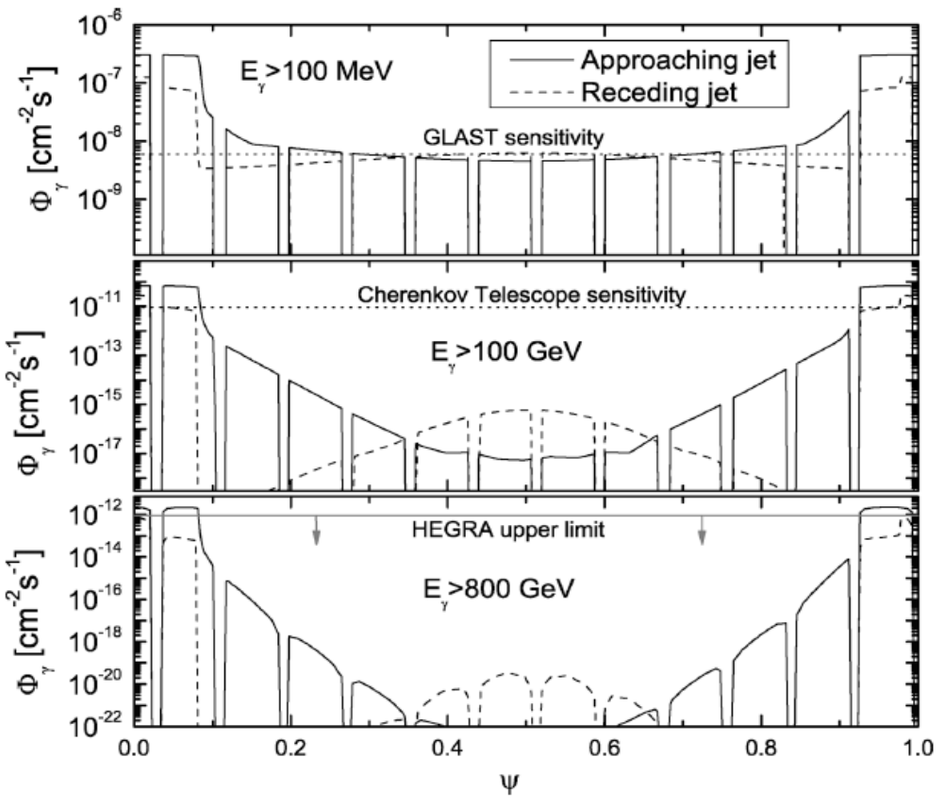
Observations of SS433 with the MAGIC and H.E.S.S. telescopes

MAGIC and H.E.S.S. collaborations, in prep.

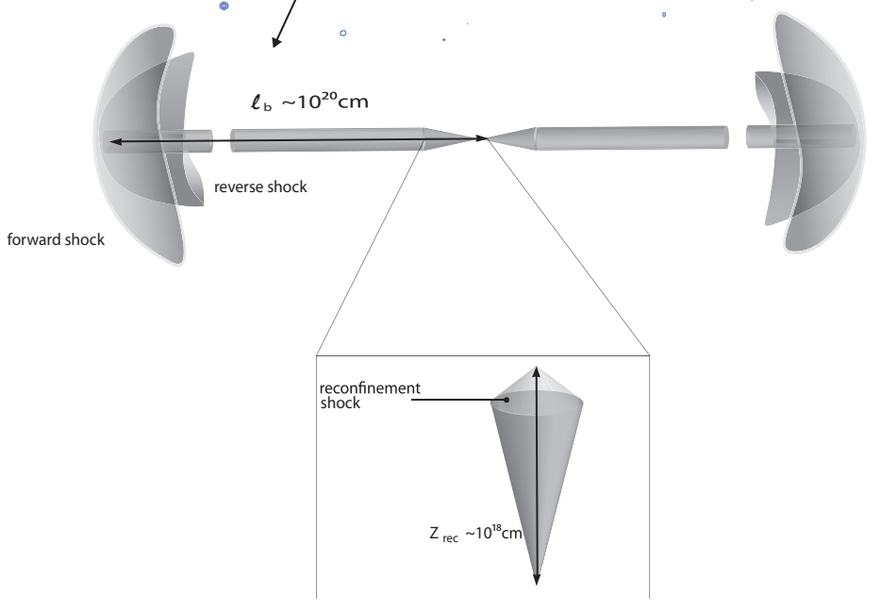
- SS433: first galactic-jets source discovered
- extremely powerful, baryon-loaded jets (L_{kin} ~$10^{39\text{-}40}$ erg/s)
- precession every ~162d covering inner system
  MAGIC + H.E.S.S. long-term coverage "good" phases: 2006-2011
- non-thermal emitting interaction regions also studied







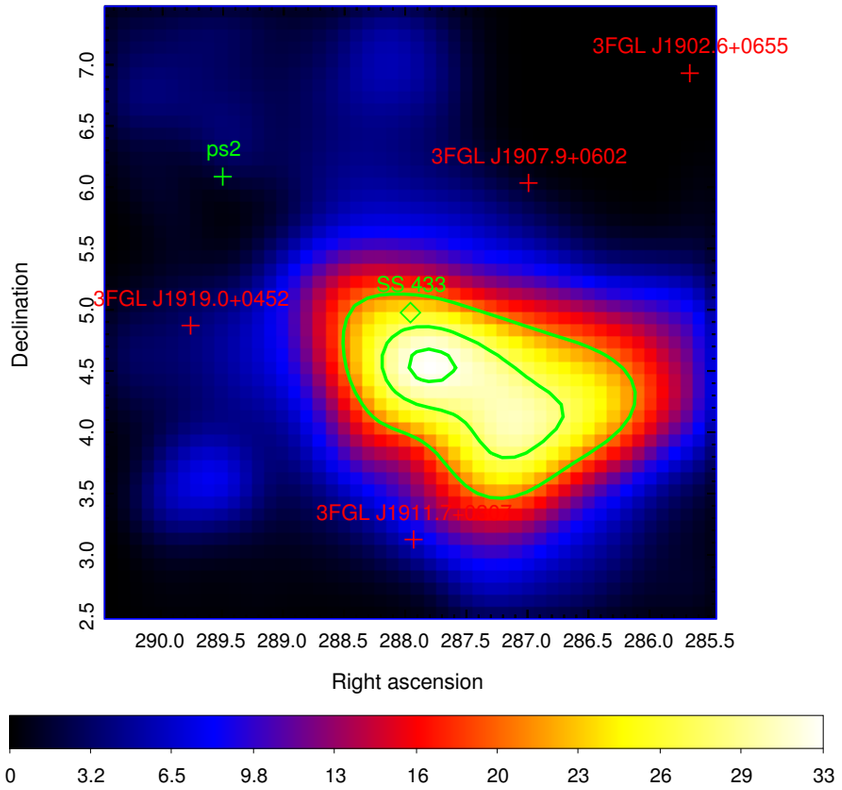
Reynoso et al. (2008)

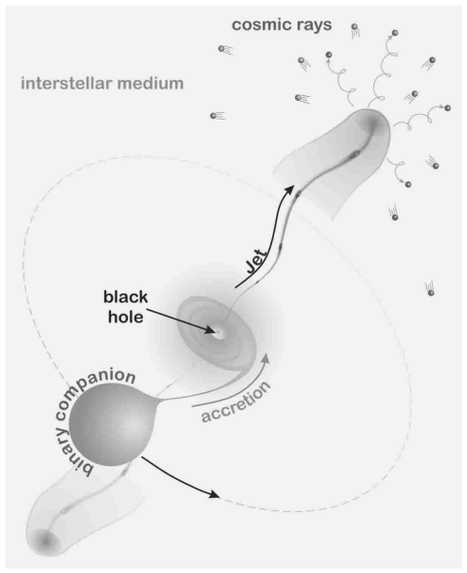


SS433/W50

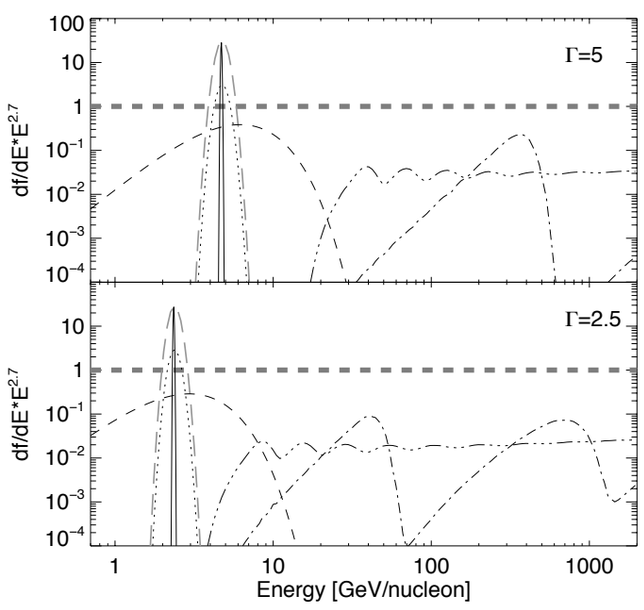
“Detection of persistent gamma-ray emission towards SS433/W50“ (Bordas+ 2014 arXiv1411.7413B)

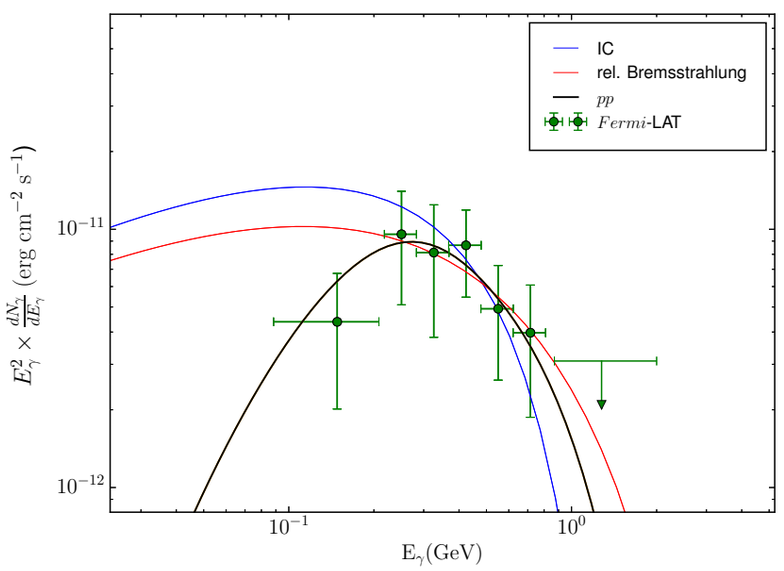
- 5-years LAT data, 3FGL: “ps1” with TS = 57
- 3-sigma position contours enclosing SS433/W50
- spectrum: sharp peak at ~250 MeV, up to ~800 MeV only
- no significant variability (phase-folded orbital/precession)
- pp-interactions favored, IC/rel.-Bremss not discarded
- jet/medium interaction regions as possible scenario





Heinz & Sunyaev (2002)



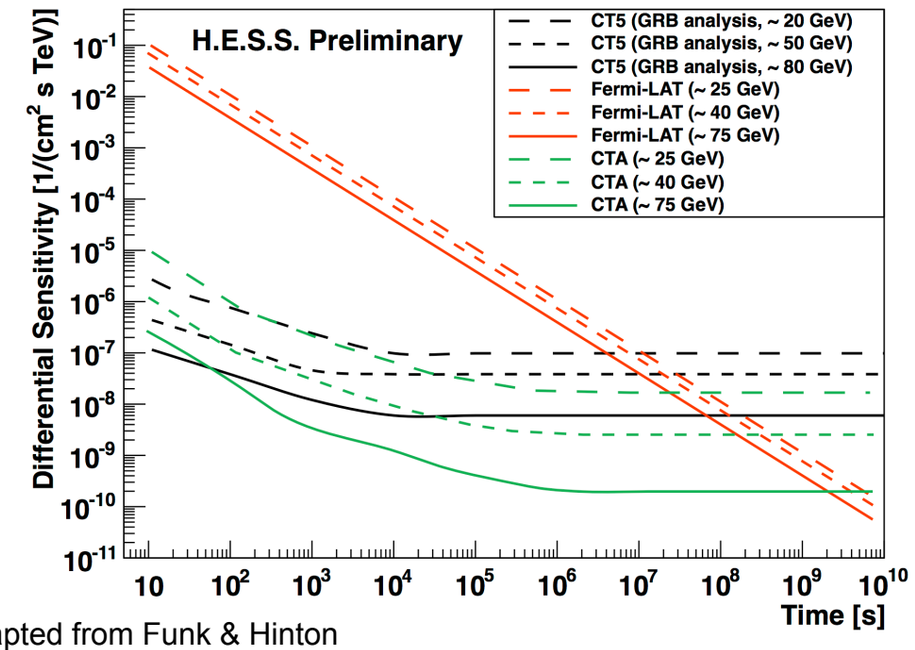


Bordas, + (arXiv1411.7413B)

Summary

- **>12 yrs observations of Variable Galactic Gamma-ray Sources with H.E.S.S**
  - unprecedented high-quality observations at VHEs reported for several (most) VGGSs
  - many source discoveries at TeVs (PSR B1259-63, LS 5039, HESS J0632+057, HESS J1018…)
  - wealth of new physics in compact sources revealed, still many enigmas remain

- **H.E.S.S. II: best-suited for variable sources → key targets for next years**
  - huge collection area for short-lived events (vs *Fermi*) + pave the way for CTA
  - first results already available (e.g. Vela PSR), many more coming soon (ICRC 2015)



adapted from Funk & Hinton