



# X-ray observations of Galactic H.E.S.S. sources: an update



**Gerd Pühlhofer**

*Institut für Astronomie und Astrophysik Tübingen*

**P. Eger, P. Bordas, M. Sasaki, D. Gottschall, M. Capasso, ...**

**H.E.S.S. collaboration**

*HESS = High Energy Stereoscopic System  
Also in memory of Victor Hess*

# H.E.S.S. and its multiwavelength program

- H.E.S.S.: System of Cherenkov telescopes for ground-based TeV gamma-ray observations
- H.E.S.S. phase I: Four telescope system (CT1 – CT4, 12 m), operations started 2003
- H.E.S.S. phase II: Addition of 5th telescope (CT5, 28 m), commissioned in 2013



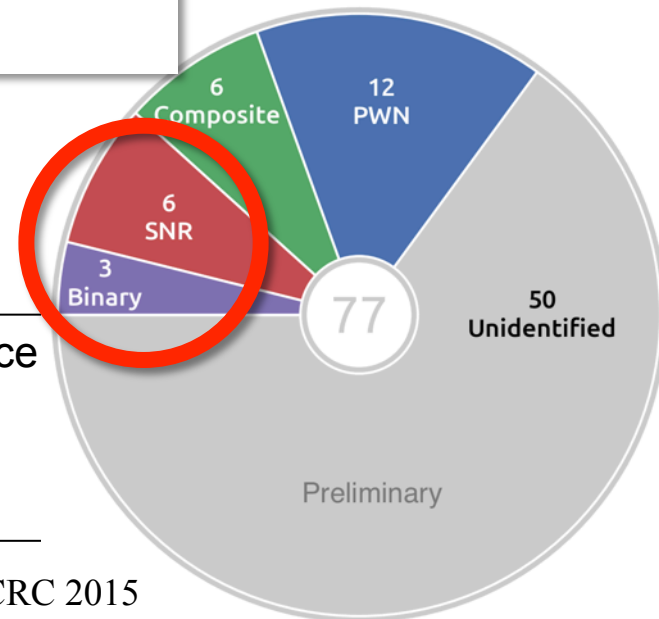
In addition to the core observation program, the H.E.S.S. collaboration continues to conduct an extensive multiwavelength program covering various topics, e.g.

- Extragalactic:
  - Continued observation campaigns on selected HBLs and FSRQs
  - Currently most involved X-ray facilities: Swift, Nustar, Astrosat, ...
- Galactic:
  - **Monitoring of variable sources (mostly binaries)**
  - Follow-up observations of new TeV sources (many → PWN candidates)
  - **Deep studies of SNRs (known and new candidates)**
  - Currently most involved X-ray facilities: XMM-Newton, Swift, Chandra, Suzaku

# H.E.S.S. observations of Galactic binaries

- Gamma-ray binaries: small class of objects
- H.E.S.S. TeV detections from well-known HMXBs:  
PSR B1259-63, LS 5039
- New discoveries of binary systems in the Gamma-ray band:  
HESS J0632+057, 1FGL 1018.6-5856, HESS J1832-093 (?)
- Topics:
  1. Multiwavelength campaigns / monitoring of known systems
  2. Search for and identification of known systems

Breakdown of source  
classification in the  
H.E.S.S. Galactic  
plane survey



HESS collaboration, ICRC 2015



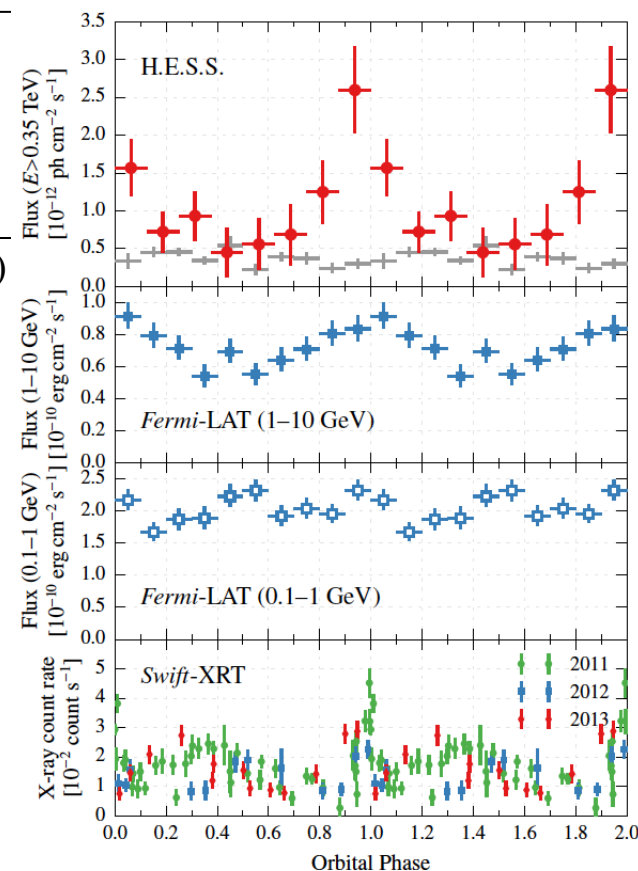
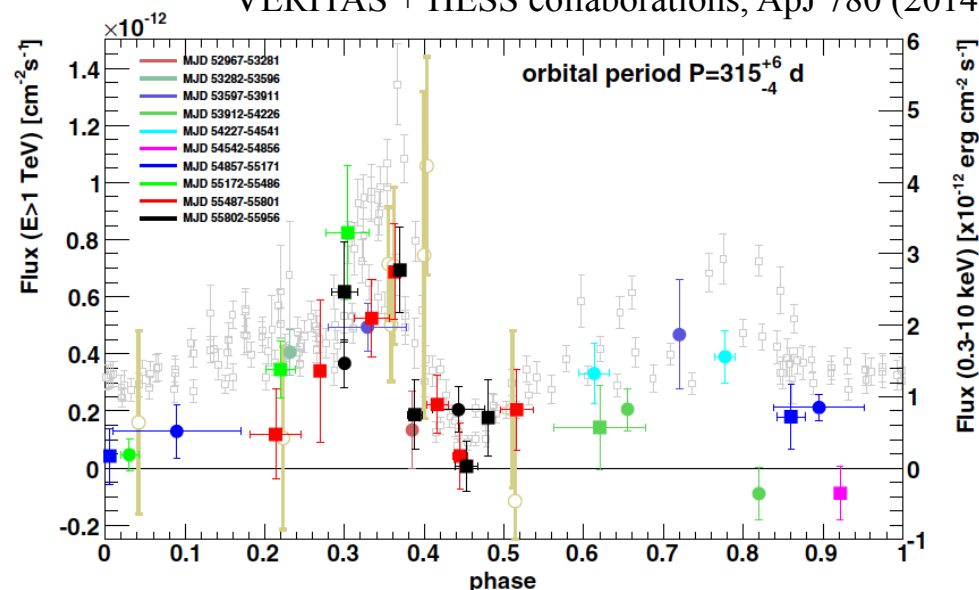
# New Gamma-ray binaries

1FGL 1018.6-5856:

- Gamma-ray binary discovery with Fermi-LAT 2012
- Orbital X-ray variability 2013
- TeV orbital variability published in 2015

HESS collaboration, A&A 577 (2015)

VERITAS + HESS collaborations, ApJ 780 (2014)

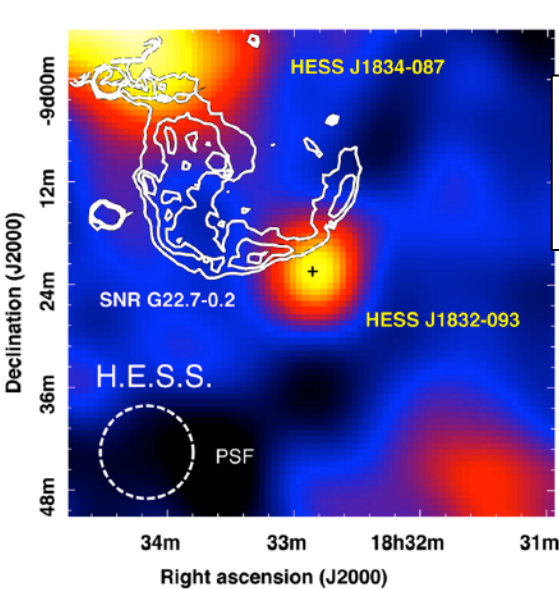


HESS J0632+057:

- source discovered in 2007
- orbital periodicity with Swift-XRT 2010/11
- modulated TeV lightcurve published 2014



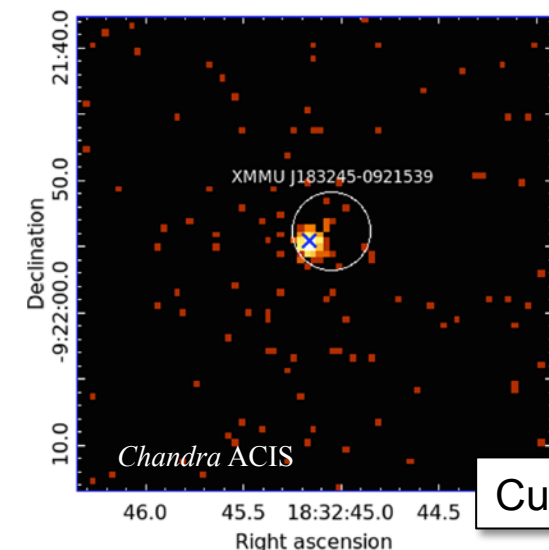
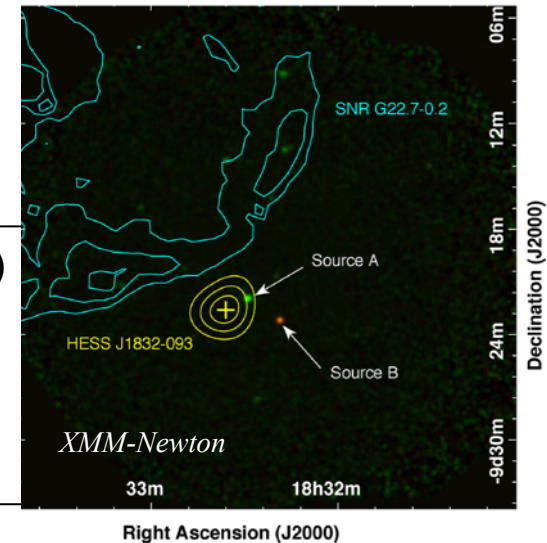
# HESS J1832-093: The new kid in town?



100 HESS collaboration, MNRAS 446 (2015)

1. TeV point source just outside SNR G22.7-0.2, published 2015

2. XMM-Newton (point-source) localisation  
→ likely identification with TeV source + likely identification with optical counterpart

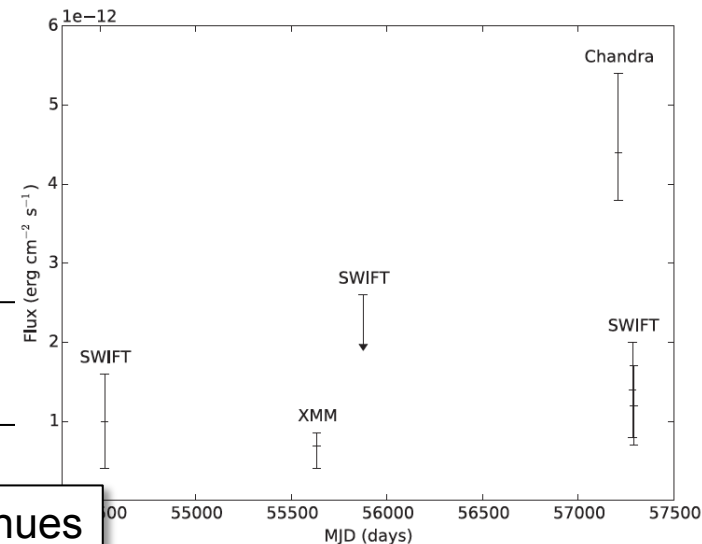


P. Eger et al., MNRAS 457 (2016)

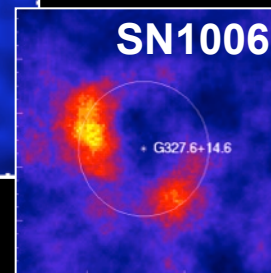
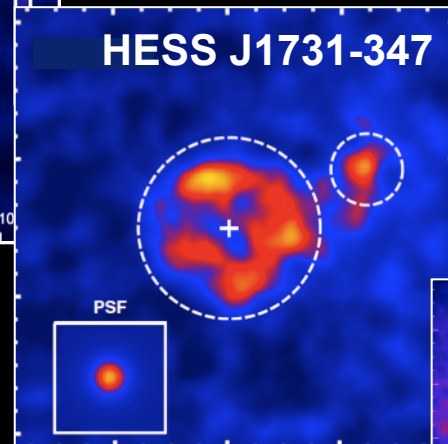
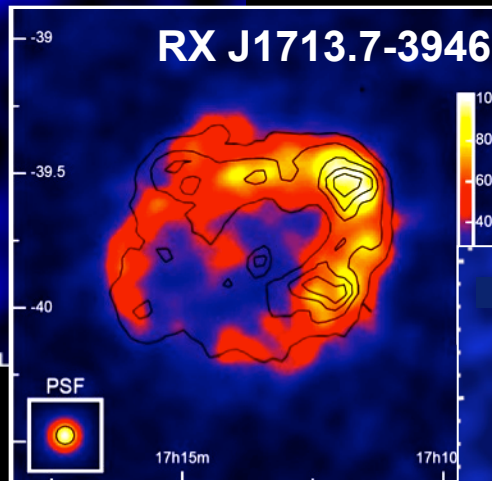
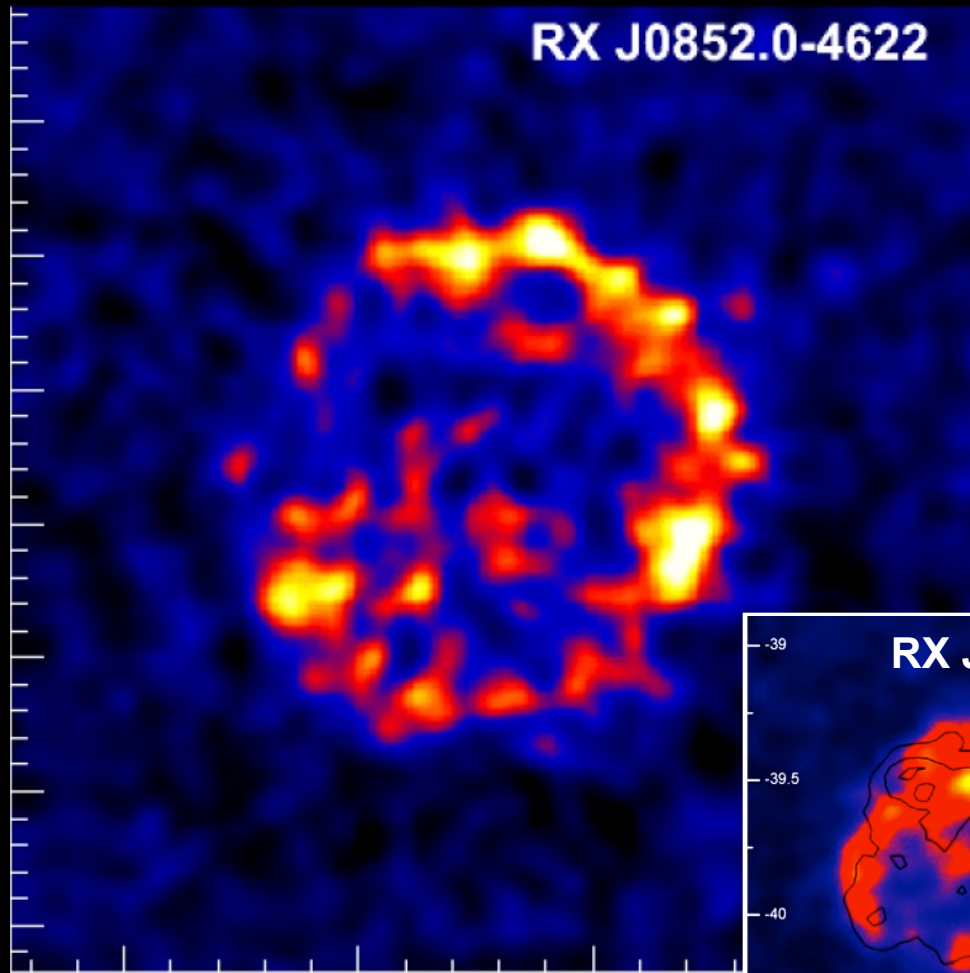
3. Chandra localisation  
→ firm identification with optical counterpart

4. X-ray variability by  $\times 6$   
→ likely a new binary

Currently: Swift-XRT monitoring continues



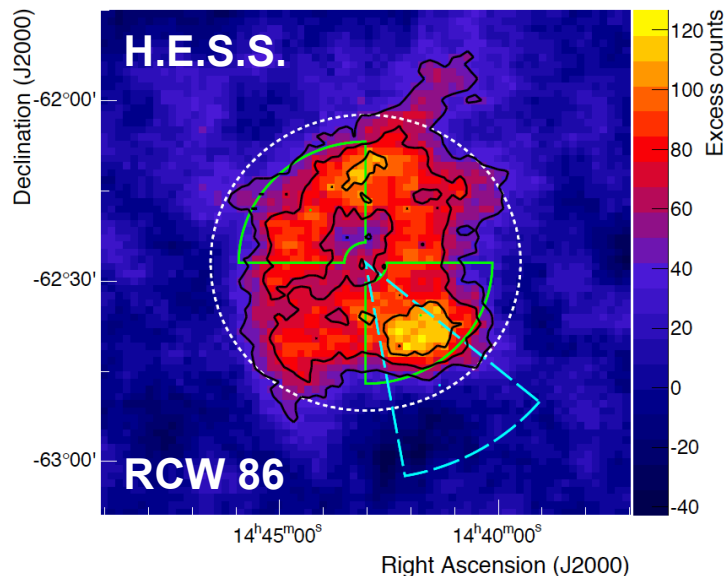
# Resolved shell-type supernova remnants in the TeV band



roughly to scale

- Topics:

1. Finding new TeV SNR (candidate) shells
2. Study of relativistic particle populations through correlation with (synchrotron) X-rays and with gas density data
3. Escape of CR particles beyond the SNR shell boundary (defined through X-rays) as signature for proton acceleration in SNRs



RCW 86, 2016 update:

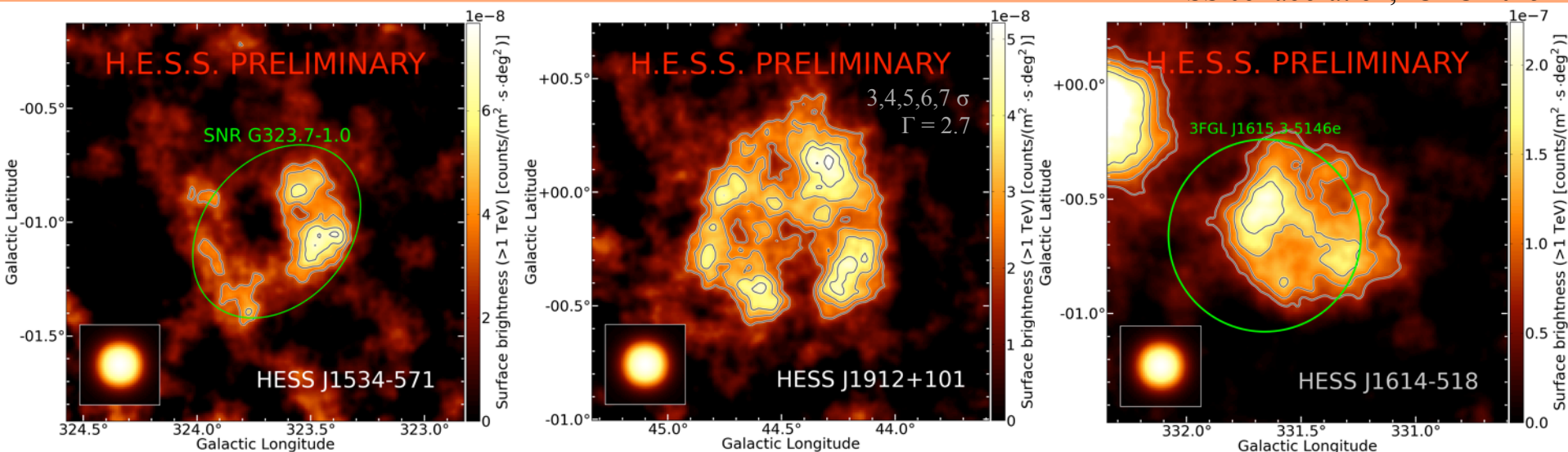
- Confirmation that the TeV source itself has a shell morphology

HESS collaboration, A&A in press (2016)



# New TeV SNR candidates in the HGPS

HESS collaboration, ICRC 2015



H.E.S.S.:

Pure morphological search: significant improvement of a projected 3d-shell morphology over a 2d-Gaussian (=null hypothesis)

Counterpart search:

Clear morphological association with radio SNR candidate

→ New TeV SNR

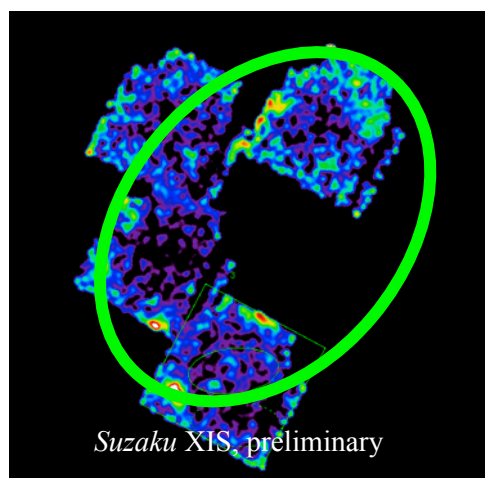
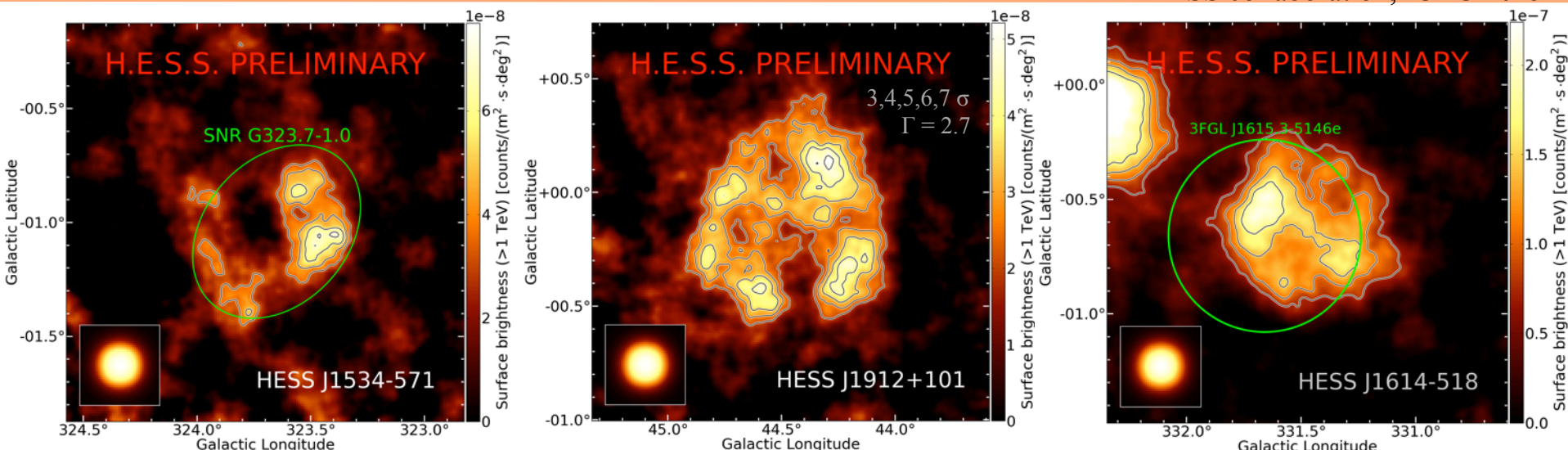
No known counterpart  
→ TeV SNR candidate

GeV counterpart, but counterpart nature not identified

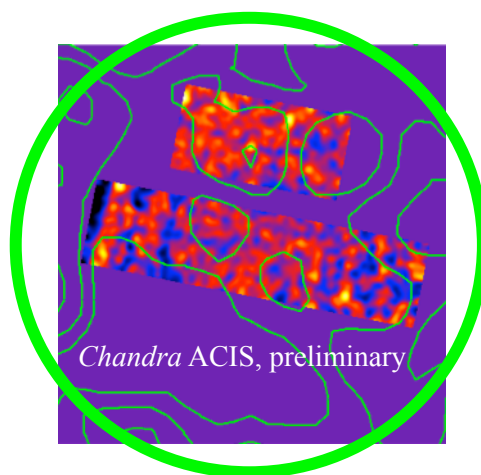
→ TeV SNR candidate

# New TeV shells: What about X-rays?

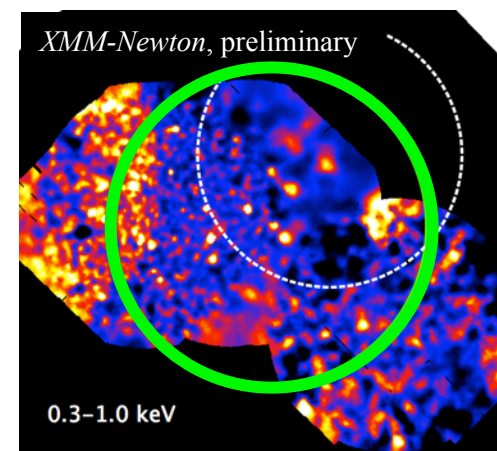
HESS collaboration, ICRC 2015



Sensitive limit with Suzaku-XIS



No sensitive coverage yet



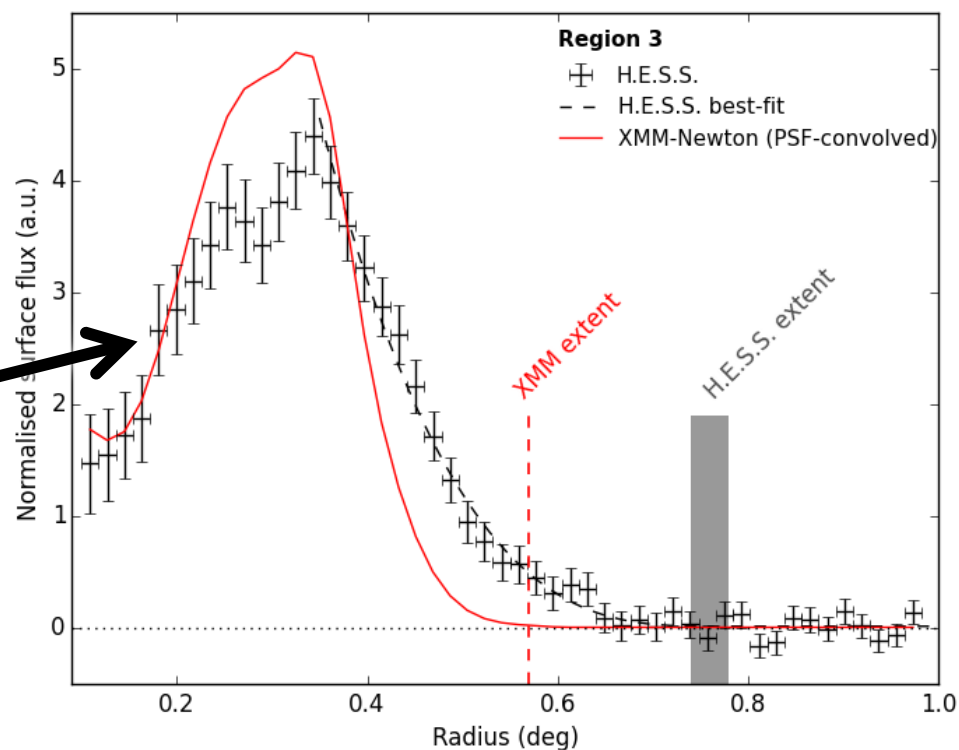
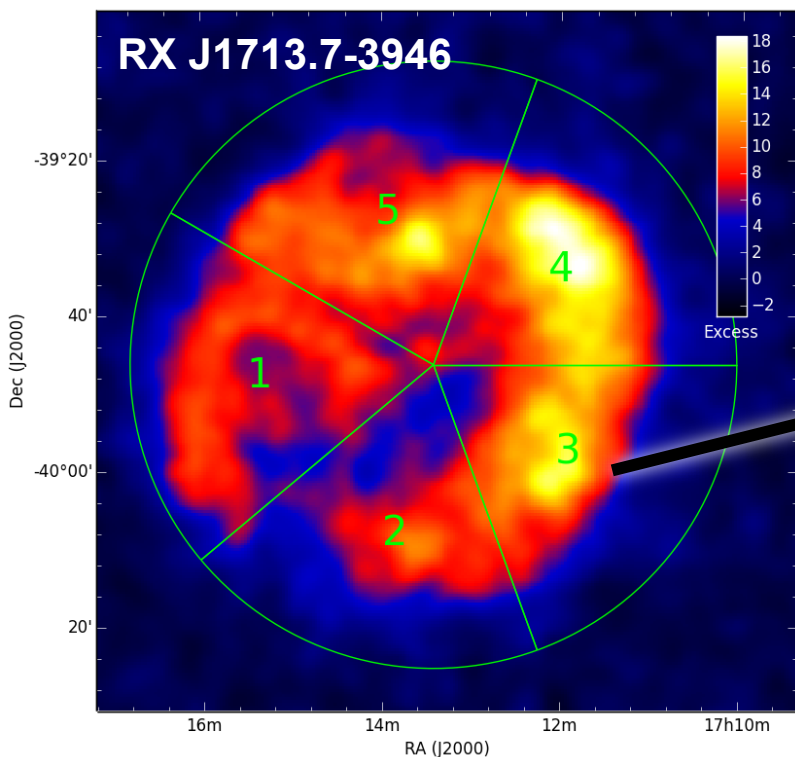
XMM-Newton coverage so far inconclusive due to straylight

# Updated HESS results of RX J1713.7-3946: CR escape?

HESS collaboration, ICRC 2015

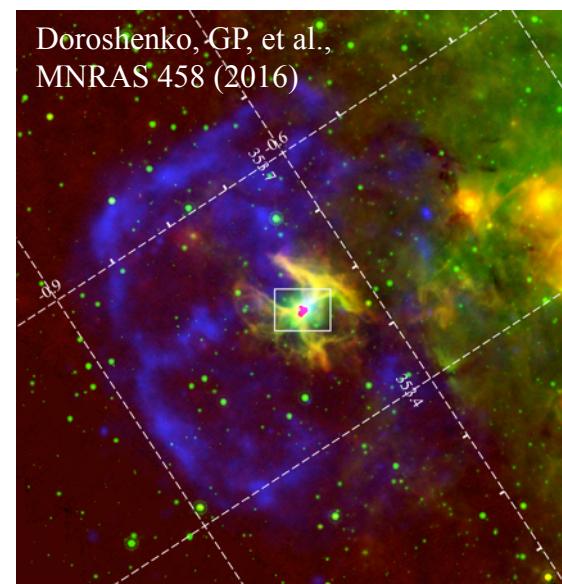
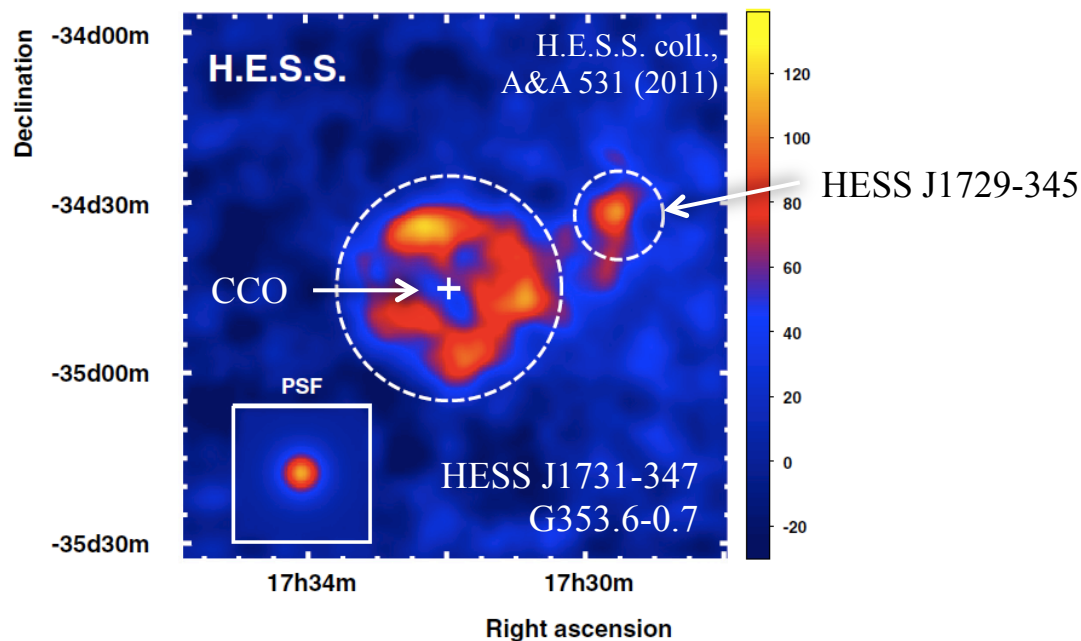
Comparison of TeV and X-ray radial profiles

- evidence for escape of CR protons?
- alternative: B-field evolution explains faster X-ray emission drop





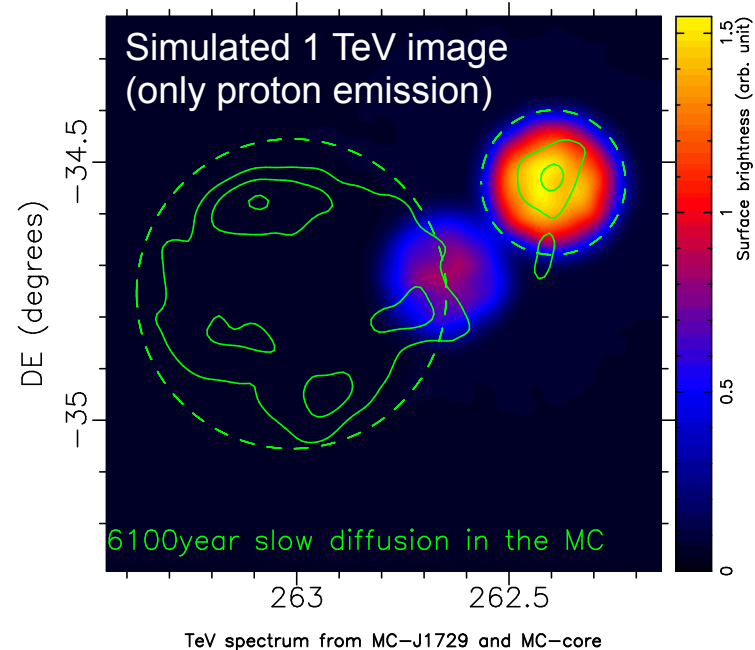
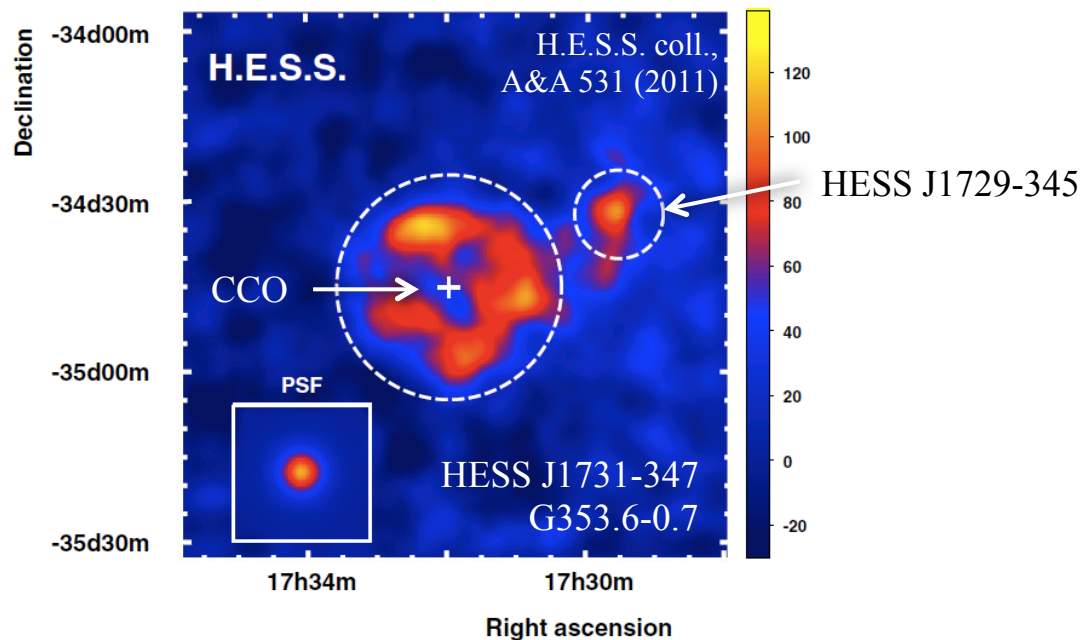
# HESS J1731-347: a young SNR with CR escape?



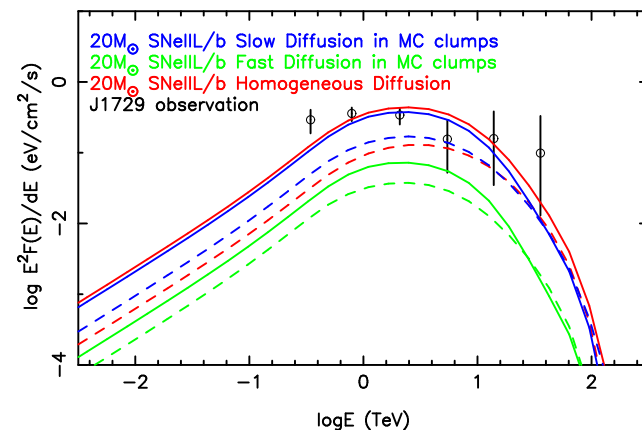
Blue: XMM-Newton X-rays  
Red: 70  $\mu\text{m}$ ; Green: 24  $\mu\text{m}$

- Similar case as RX J1713.7-3946: Pure non-thermal X-ray spectrum from XMM-Newton (H.E.S.S. coll. 2011), Suzaku (Bamba, GP et al. 2012)
- But: adjacent TeV source (HESS J1729-345) may permit to better trace CR proton escape?

# HESS J1731-347: a young SNR with CR escape?



→ Energetically very plausible SNR evolution / CR escape scenario possible that explains J1729-345 through CRs illuminating a cloud



Cui, GP, et al., astro-ph/1605.00483

# Conclusion

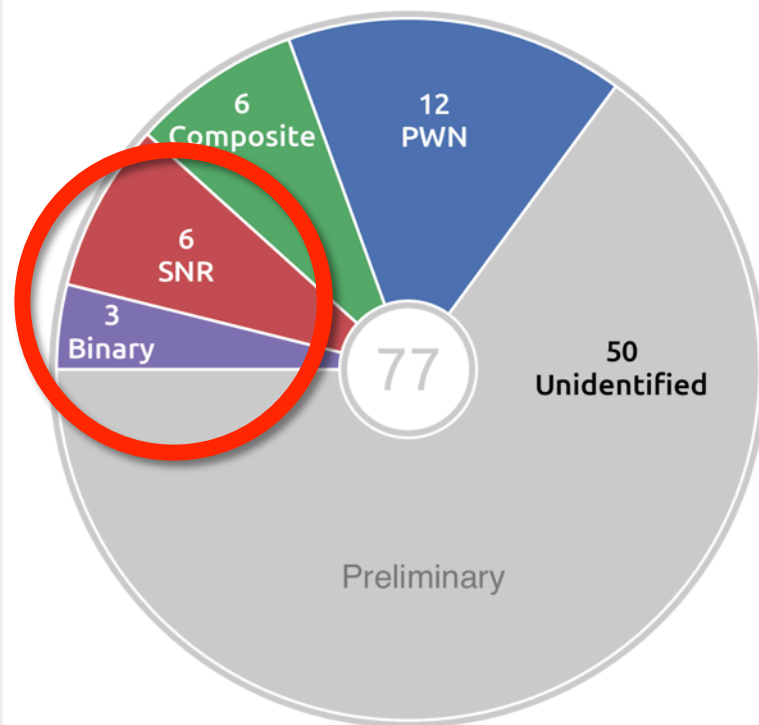
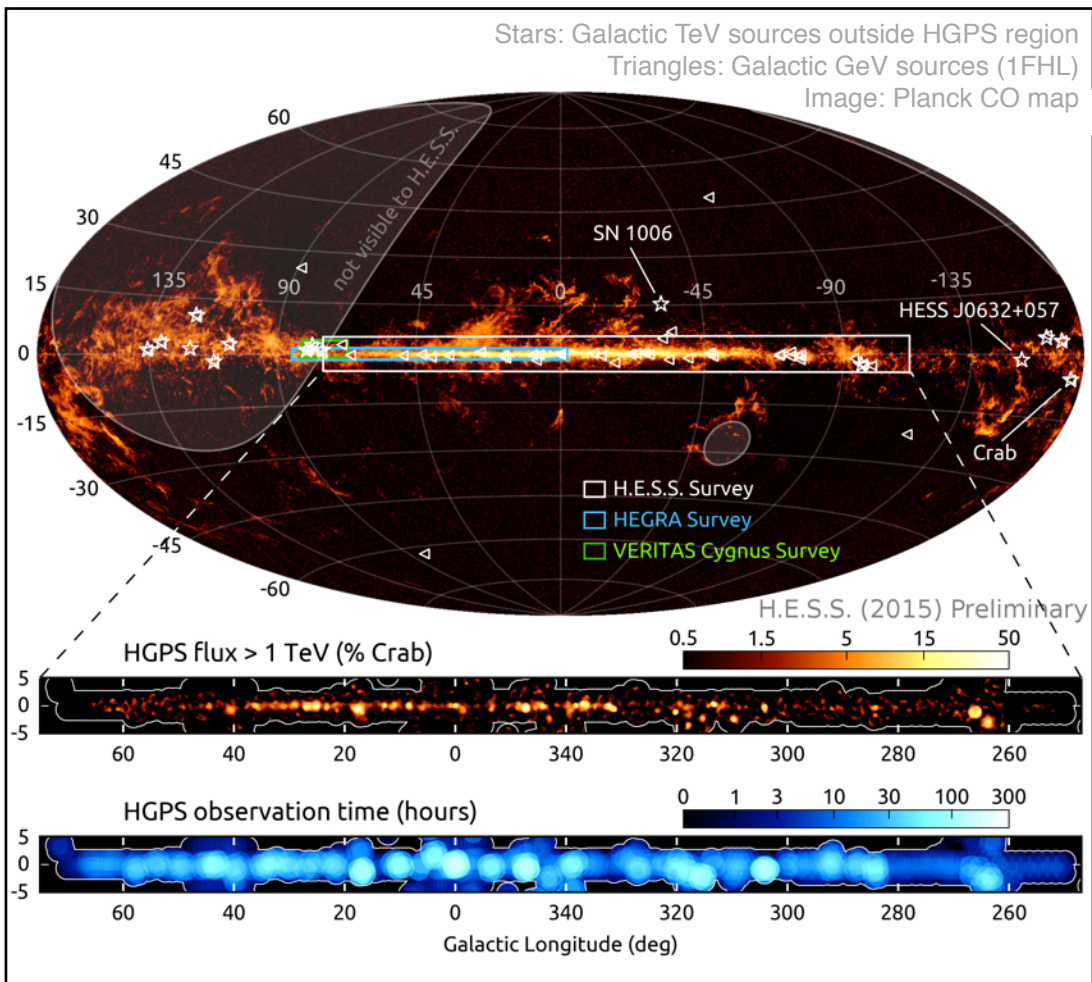
- With H.E.S.S. (as for the other TeV instruments), joint observations + follow-up observations with XMM-Newton and other X-ray instruments continue to be an important tool for science exploitation of TeV particle accelerators
- Sometimes, we are excited about a non-detection with sensitive X-ray observations (→ dominant proton accelerator?)
- Multiwavelength program will continue with H.E.S.S. and CTA



**Backups**

# HGPS: The H.E.S.S. Galactic Plane Survey

HESS collaboration, ICRC 2015



- H.E.S.S. I, ~3000 hours of observations, years 2004-2013
- $-110^\circ < l < 65^\circ$ ,  $-3.5^\circ < b < 3.5^\circ$ ; 0.2-100 TeV ;  $R_{68\%} \sim 0.07^\circ$

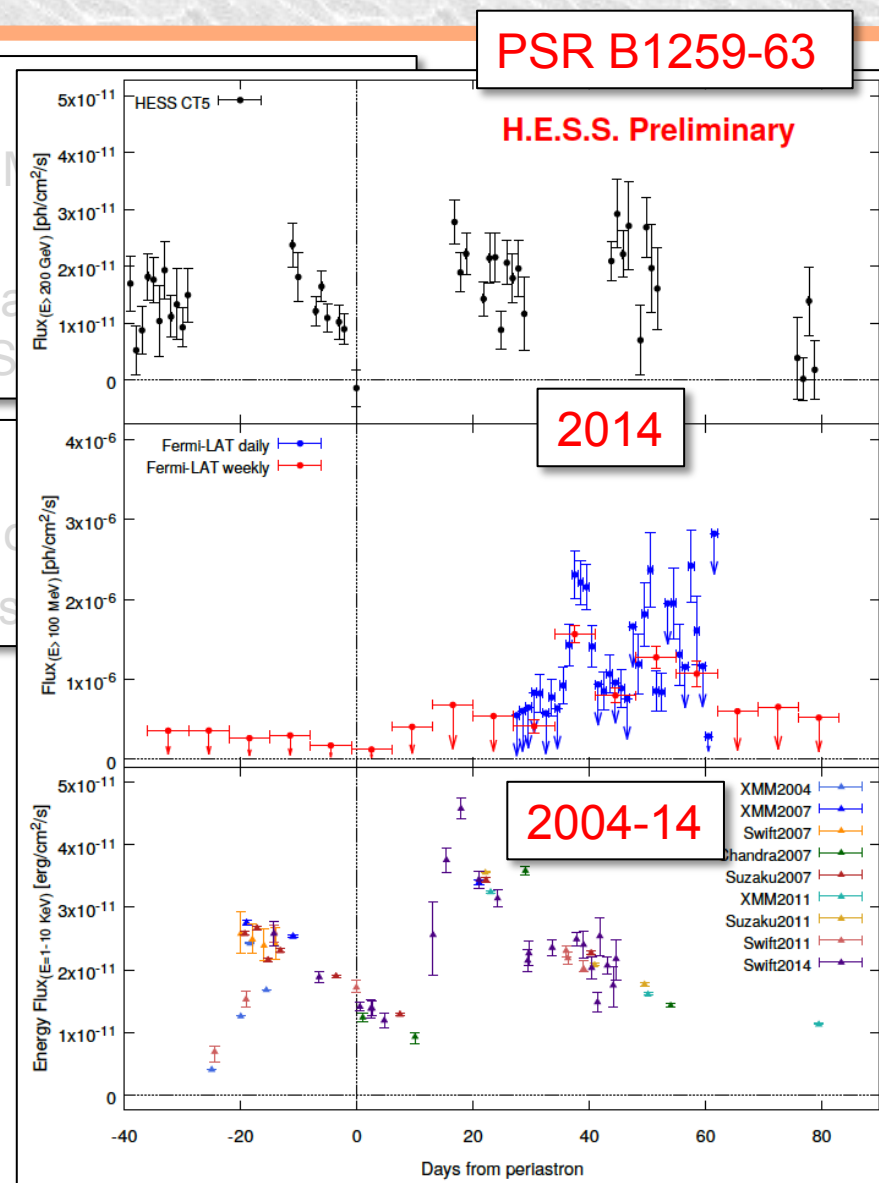
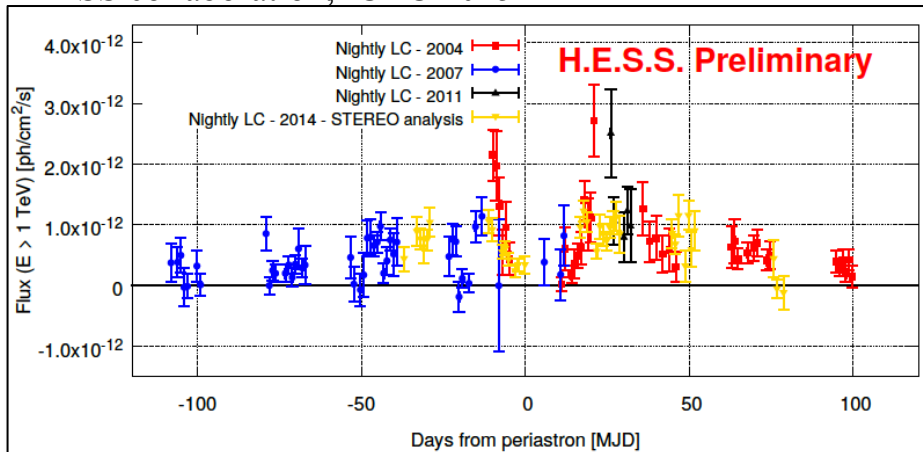
# H.E.S.S. observations of Galactic binaries

- Gamma-ray binaries: small class of objects
- H.E.S.S. TeV detections from well-known H.E.S.S. sources  
**PSR B1259-63**, LS 5039
- New discoveries of binary systems in the Galactic plane  
HESS J0632+057, 1FGL 1018.6-5856, HESS J1825-088

## Topics:

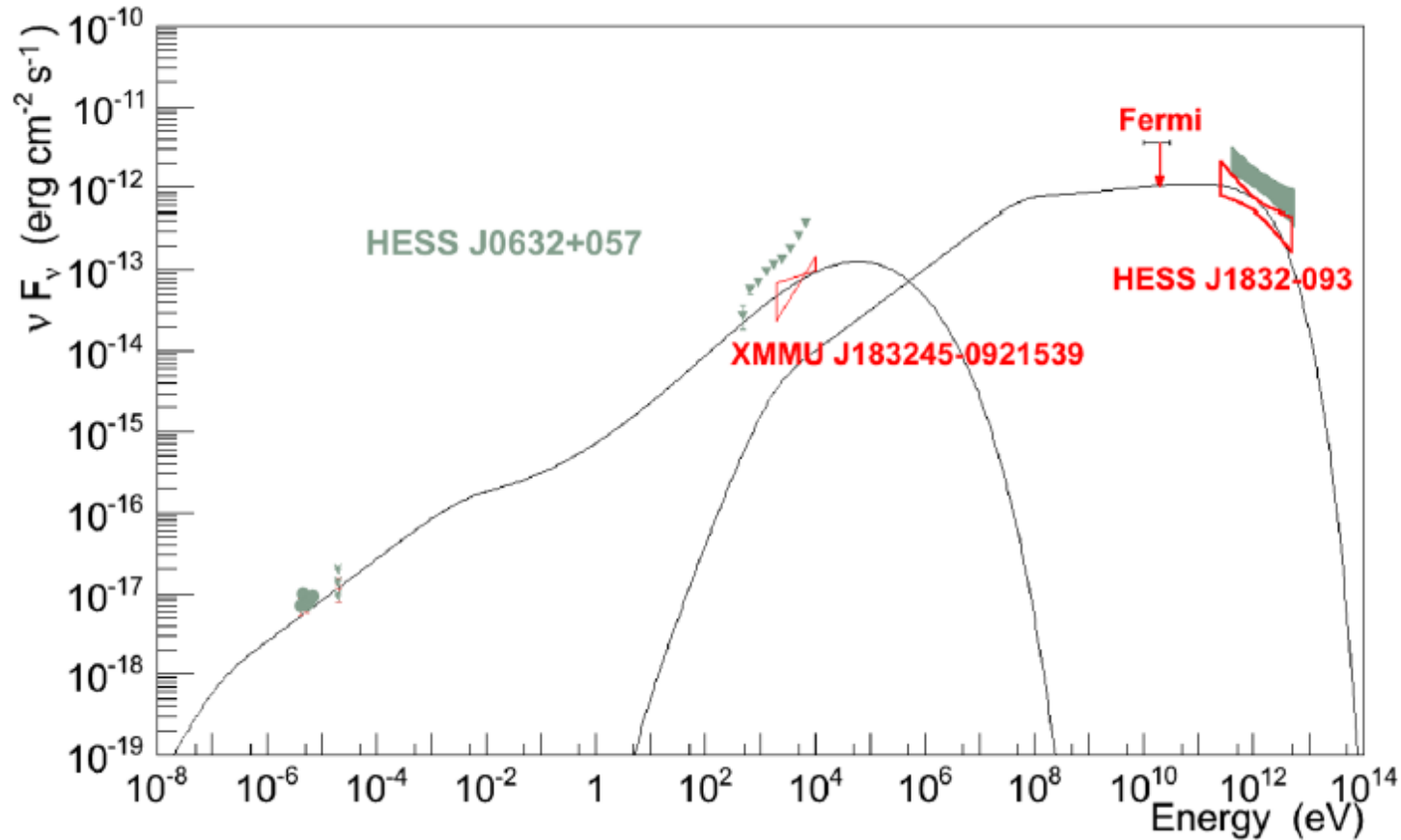
- Multiwavelength campaigns** / monitoring of known systems
- Search for and identification of known systems

HESS collaboration, ICRC 2015





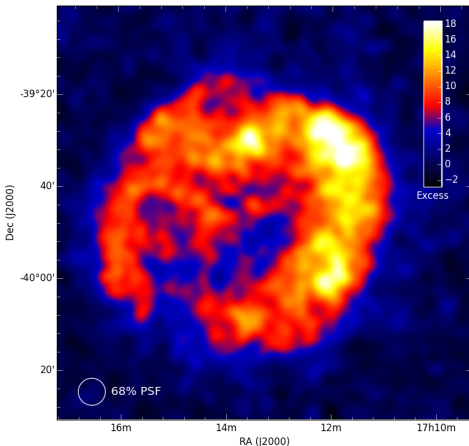
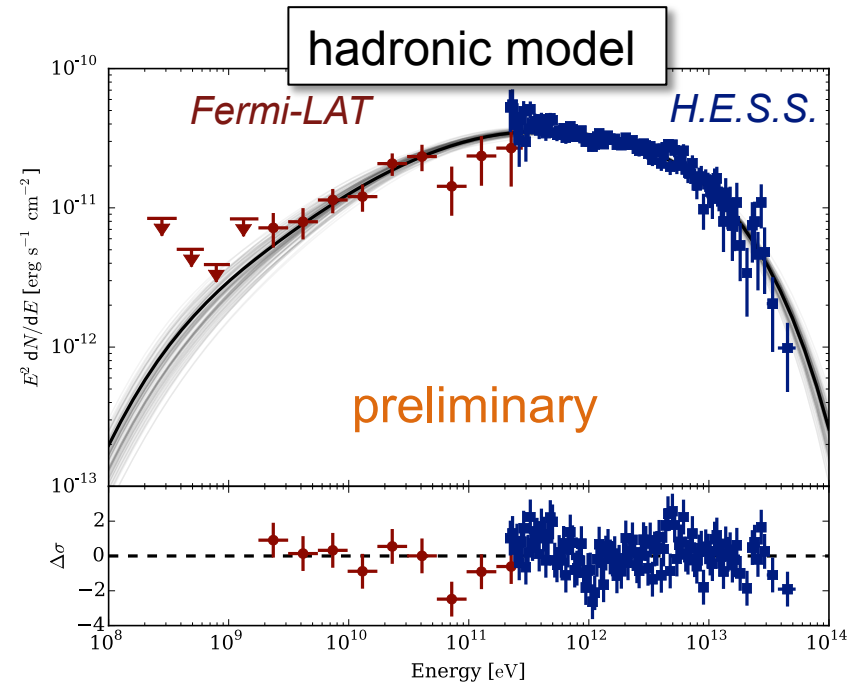
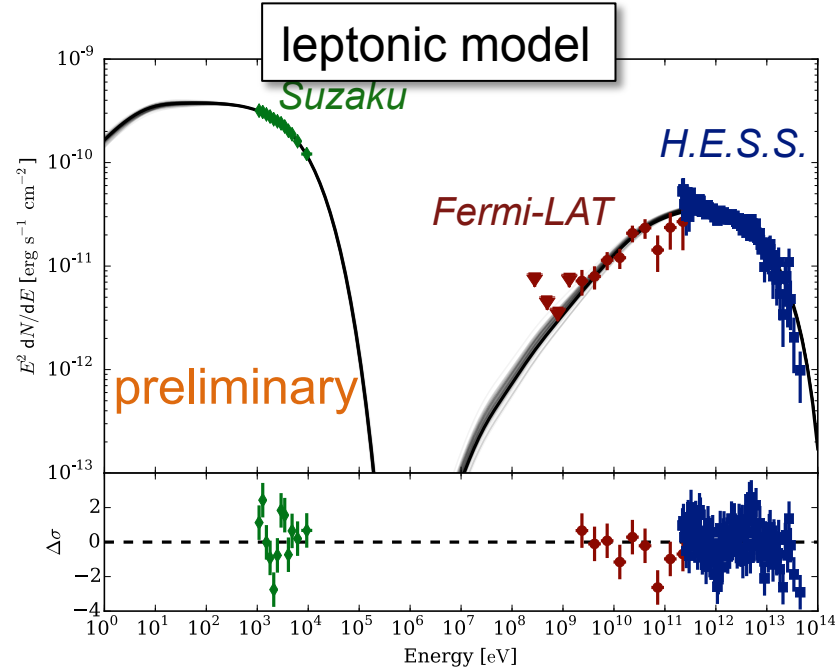
# HESS J1832-093: SED, comparison to HESS J0632+057



P. Eger et al., MNRAS 457 (2016)

# Updated HESS results of RX J1713.7-3946: SED

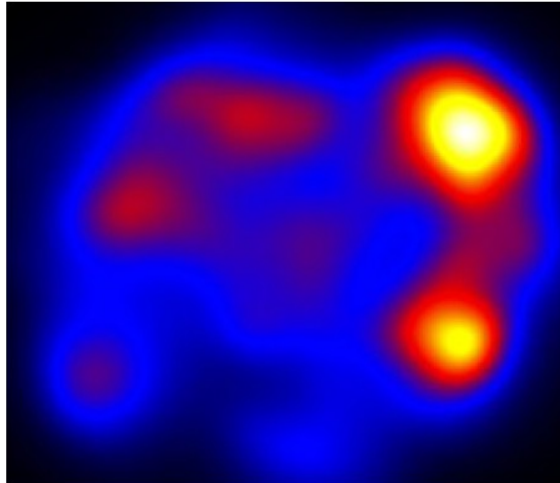
HESS collaboration, ICRC 2015



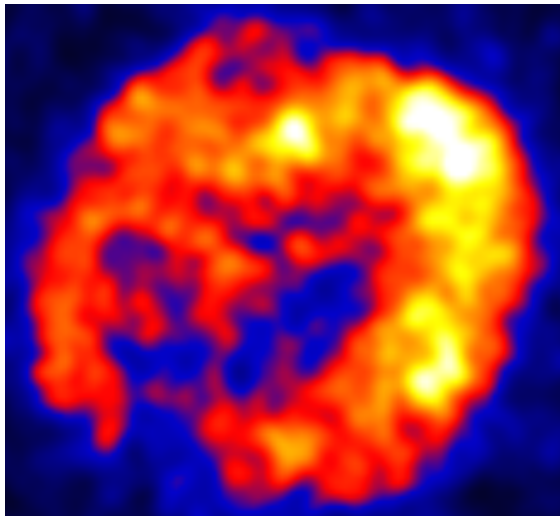
- Hard proton spectrum (break at 0.8 TeV) in hadronic model
- Could be explained e.g. by energy-dependent diffusion of CR protons into a clumpy medium inside the SNR (Aharaonian & Gabici 2014)

# Updated HESS results of RX J1713.7-3946: B-field

HESS collaboration, ICRC 2015



X-rays: XMM-Newton map convolved with H.E.S.S. psf



TeV: H.E.S.S.

→ B-field map (adopting a lepton interpretation of the TeV spectrum)

