

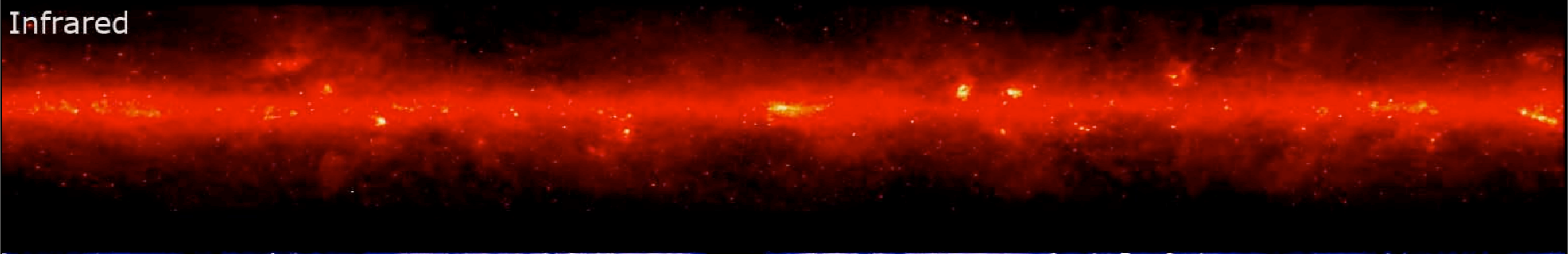


MAX-PLANCK-GESELLSCHAFT

# TeV Observations of Galactic Sources

Emma de Oña Wilhelmi for the HESS Collaboration  
Max-Planck Institut für Physik, Heidelberg

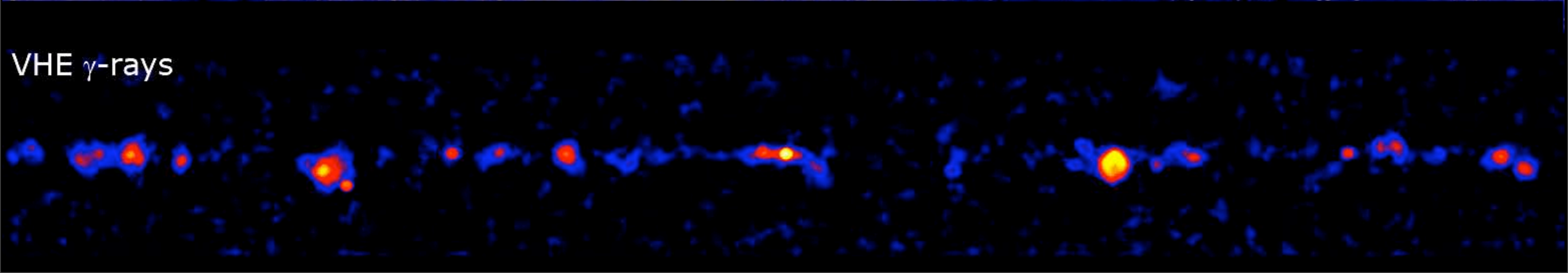
Infrared



Optical



VHE  $\gamma$ -rays





## High Energy Stereoscopic System

An Array of 4 Imaging Atmospheric Cherenkov Telescopes in Namibia

### H.E.S.S.

The HESS GPS  
SNRs

shell-like  
interacting with MC

### PWN

young PWN  
evolved PWN

Binary Systems

Dark Sources

New Source Type



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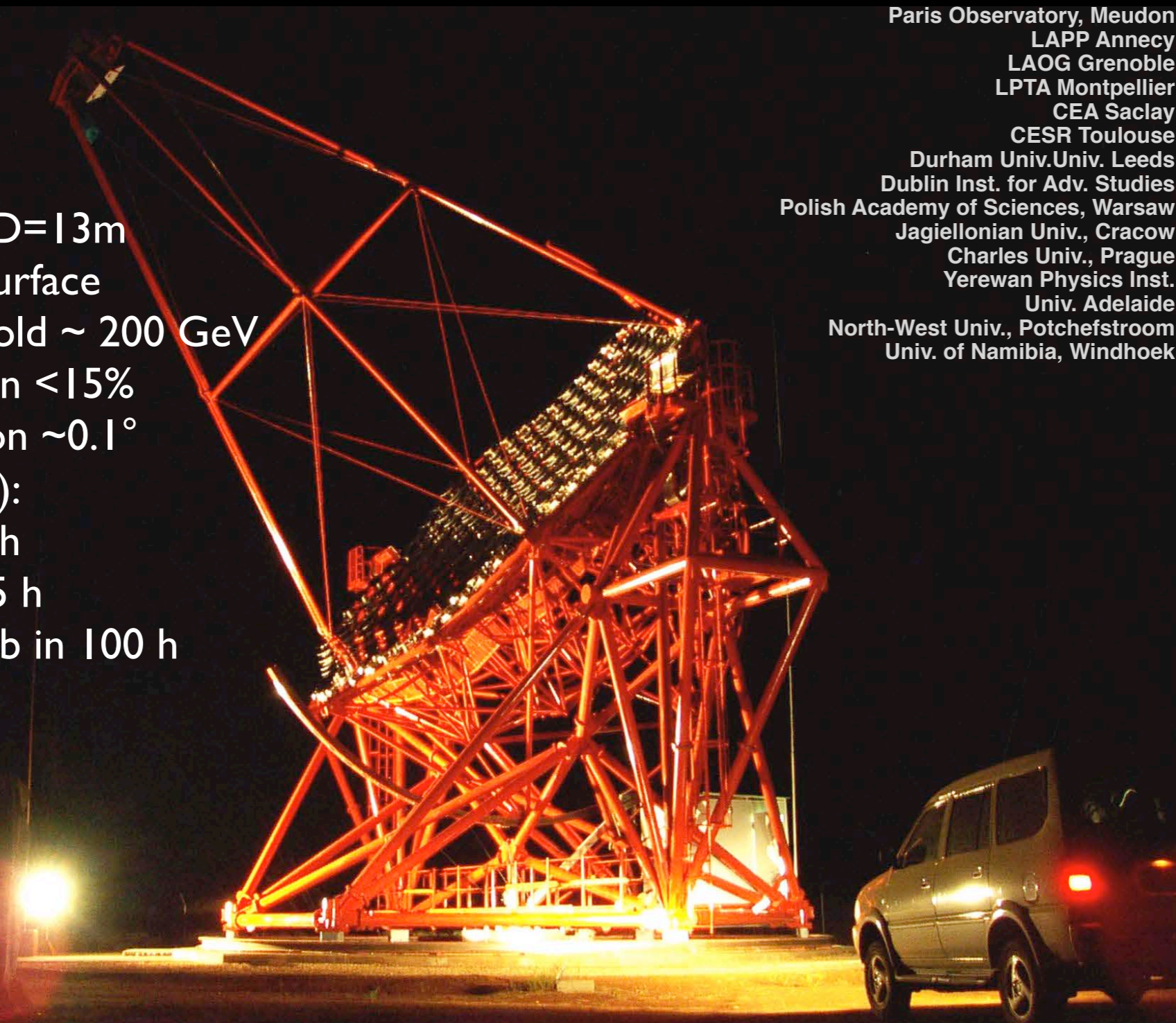
evolved PWN

**Binary Systems**

**Dark Sources**

**New Source Type**

- 4 telescopes
- 120 m spacing ,  $D=13\text{m}$
- 107 m<sup>2</sup> mirror surface
- energy threshold  $\sim 200$  GeV
- energy resolution  $<15\%$
- angular resolution  $\sim 0.1^\circ$
- sensitivity ( $5\sigma$ ):
- 5% of Crab in 1 h
- 1% of Crab in 25 h
- HEGRA: 5% Crab in 100 h



MPI Kernphysik, Heidelberg  
 Humboldt-Univ. zu Berlin  
 Ruhr-Univ. Bochum  
 Univ. Erlangen-Nürnberg

Univ. Hamburg  
 LSW Heidelberg  
 Univ. Tübingen  
 Ecole Polytechnique, Palaiseau  
 APC Paris  
 Univ. Paris VI-VII  
 Paris Observatory, Meudon  
 LAPP Annecy  
 LAOG Grenoble  
 LPTA Montpellier  
 CEA Saclay  
 CESR Toulouse  
 Durham Univ. Univ. Leeds  
 Dublin Inst. for Adv. Studies  
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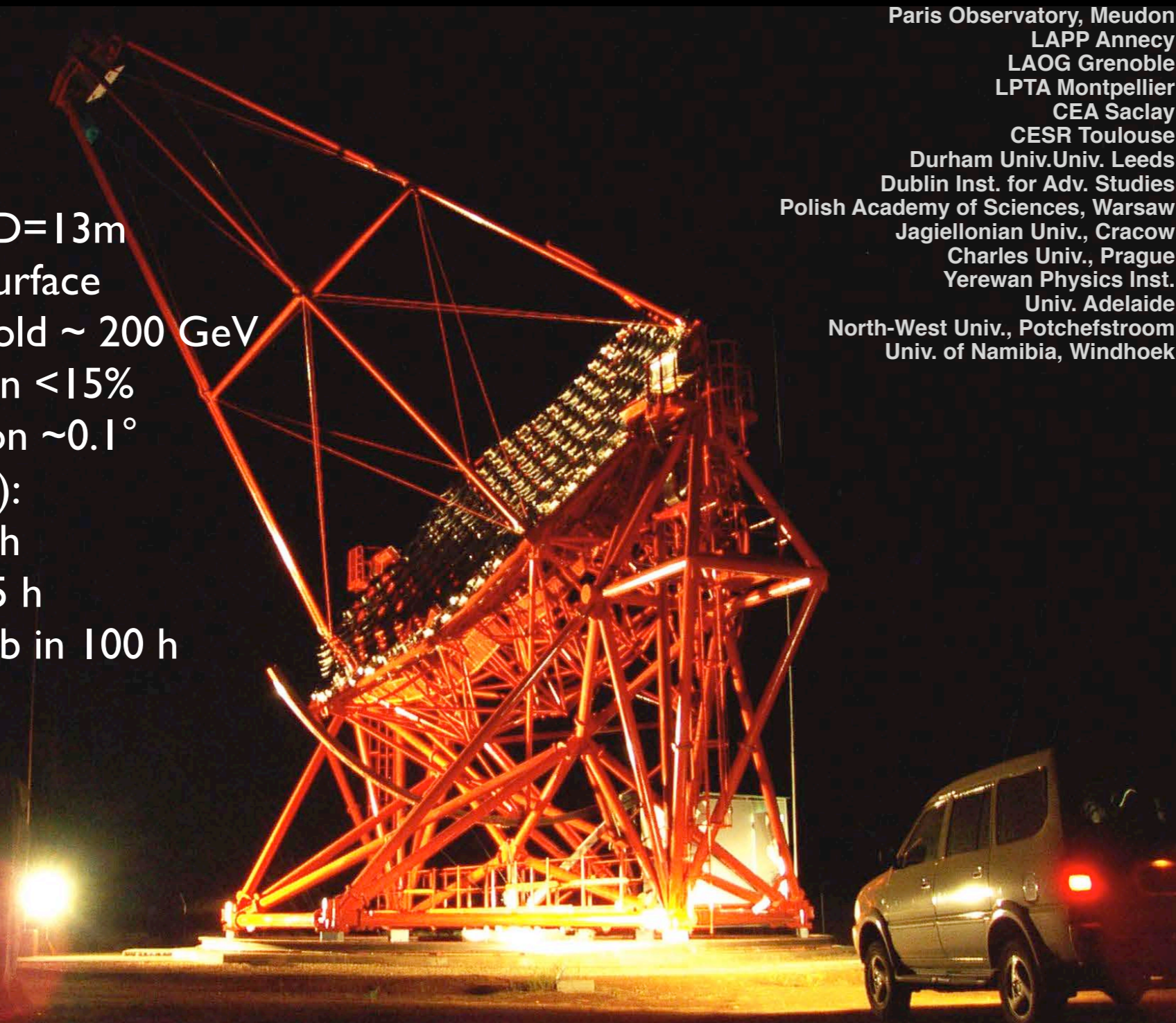
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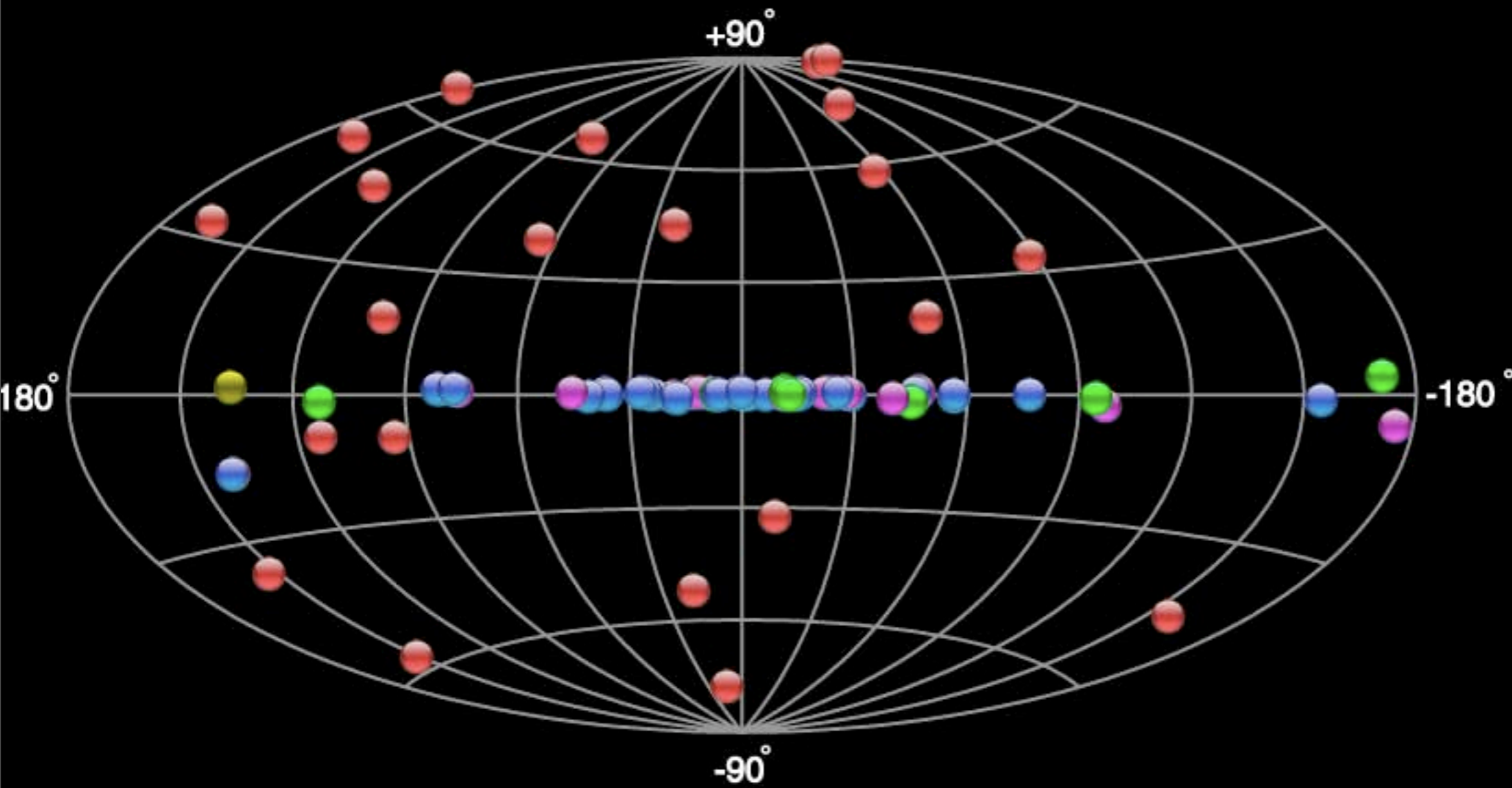
**New Source Type**

From <http://tevcat.uchicago.edu/>

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

### Source Types

- Plerion PWN
- XRB PSR
- HBL IBL FRI FSRQ LBL
- Shell
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- DARK
- MQS Cat. Var. UNID  
Other BIN WR

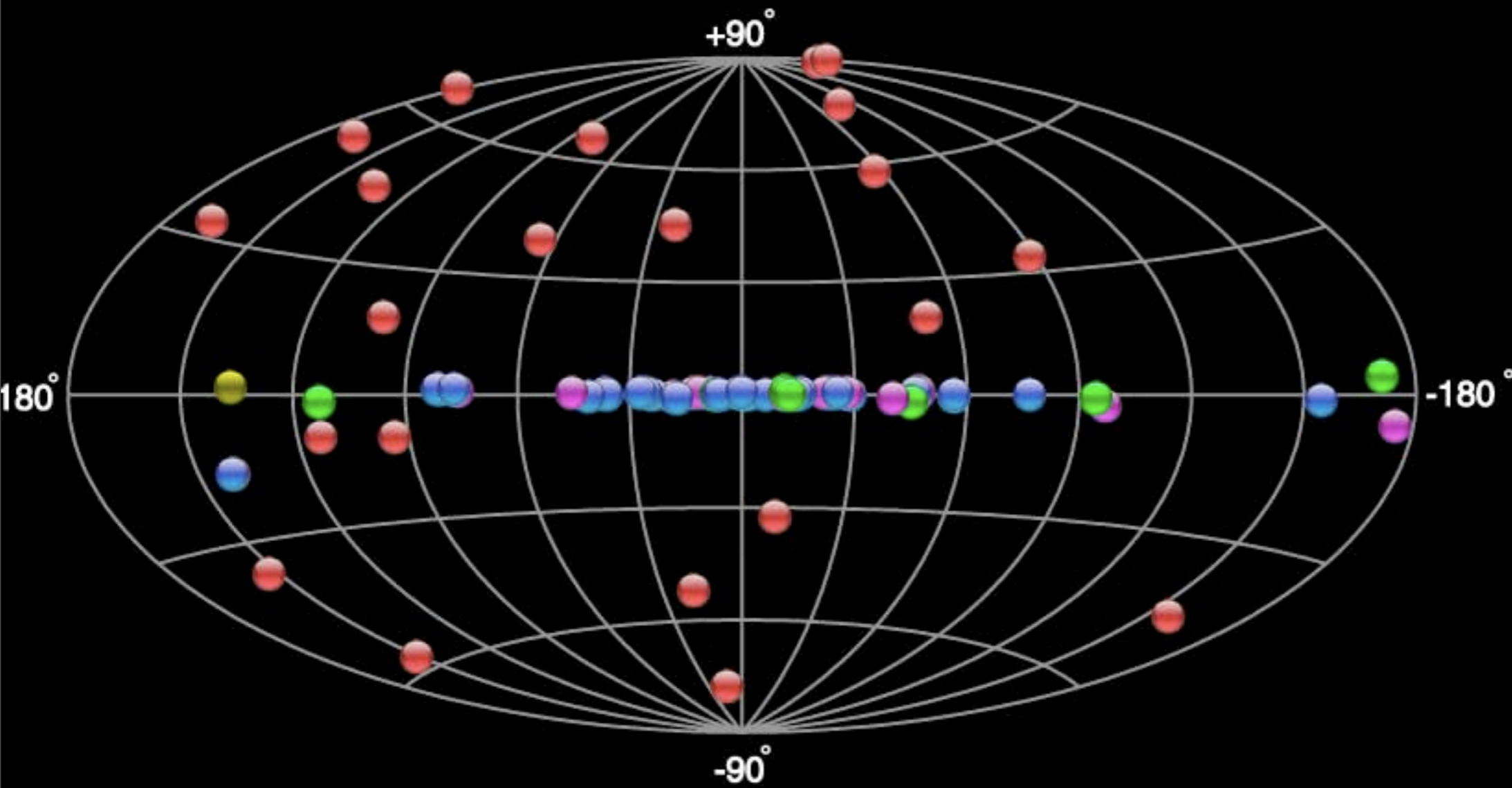


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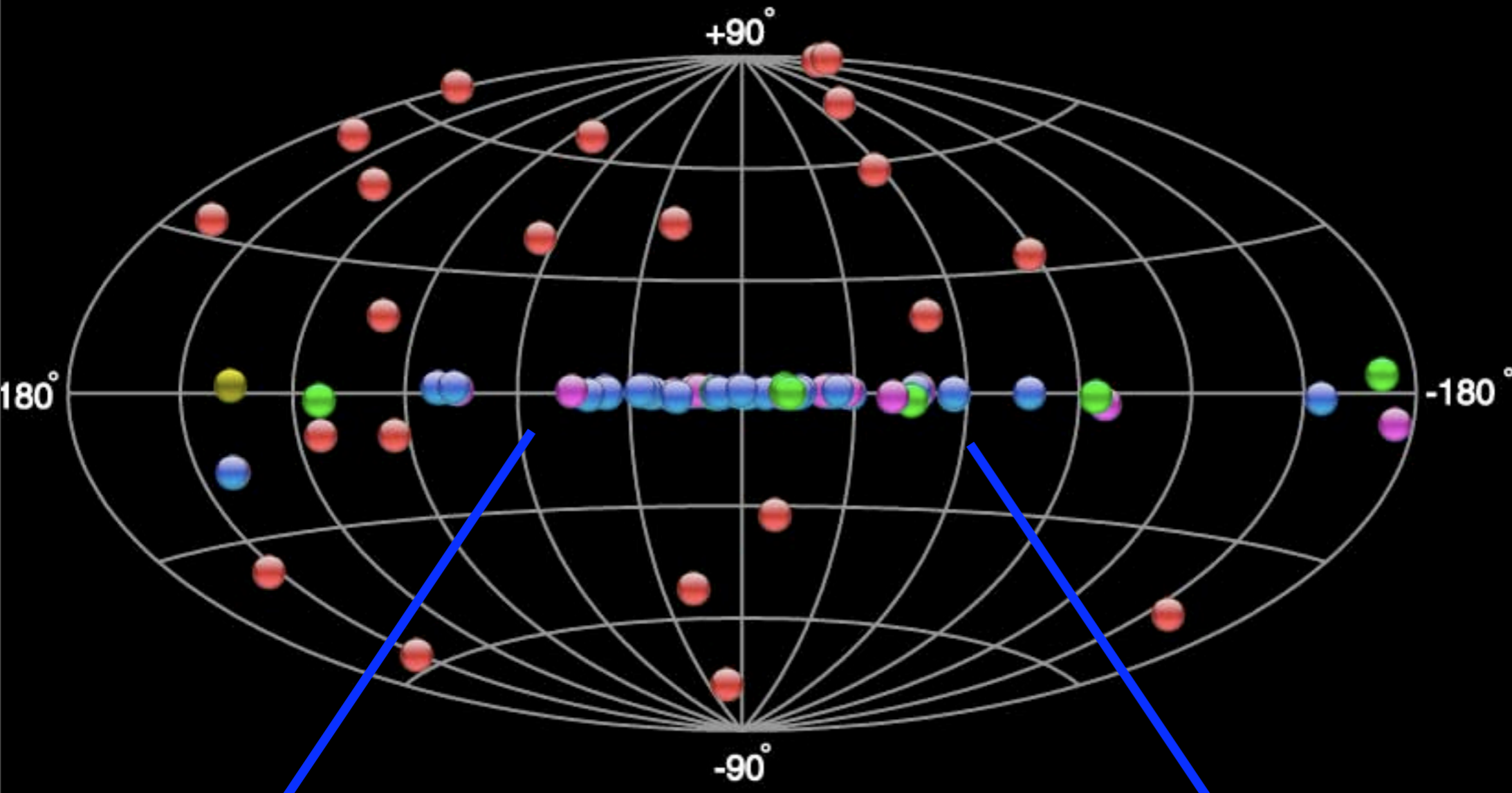


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1997

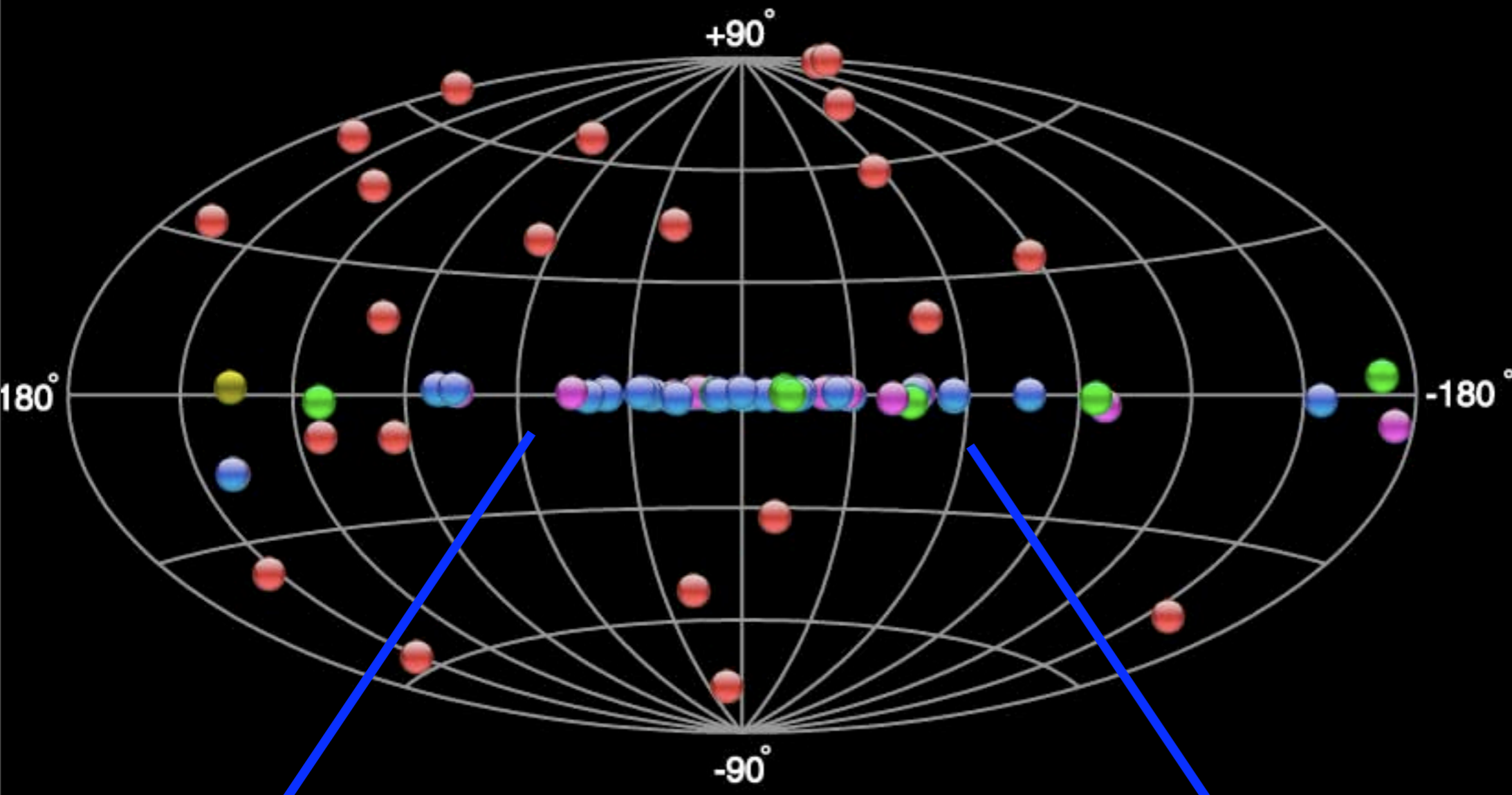


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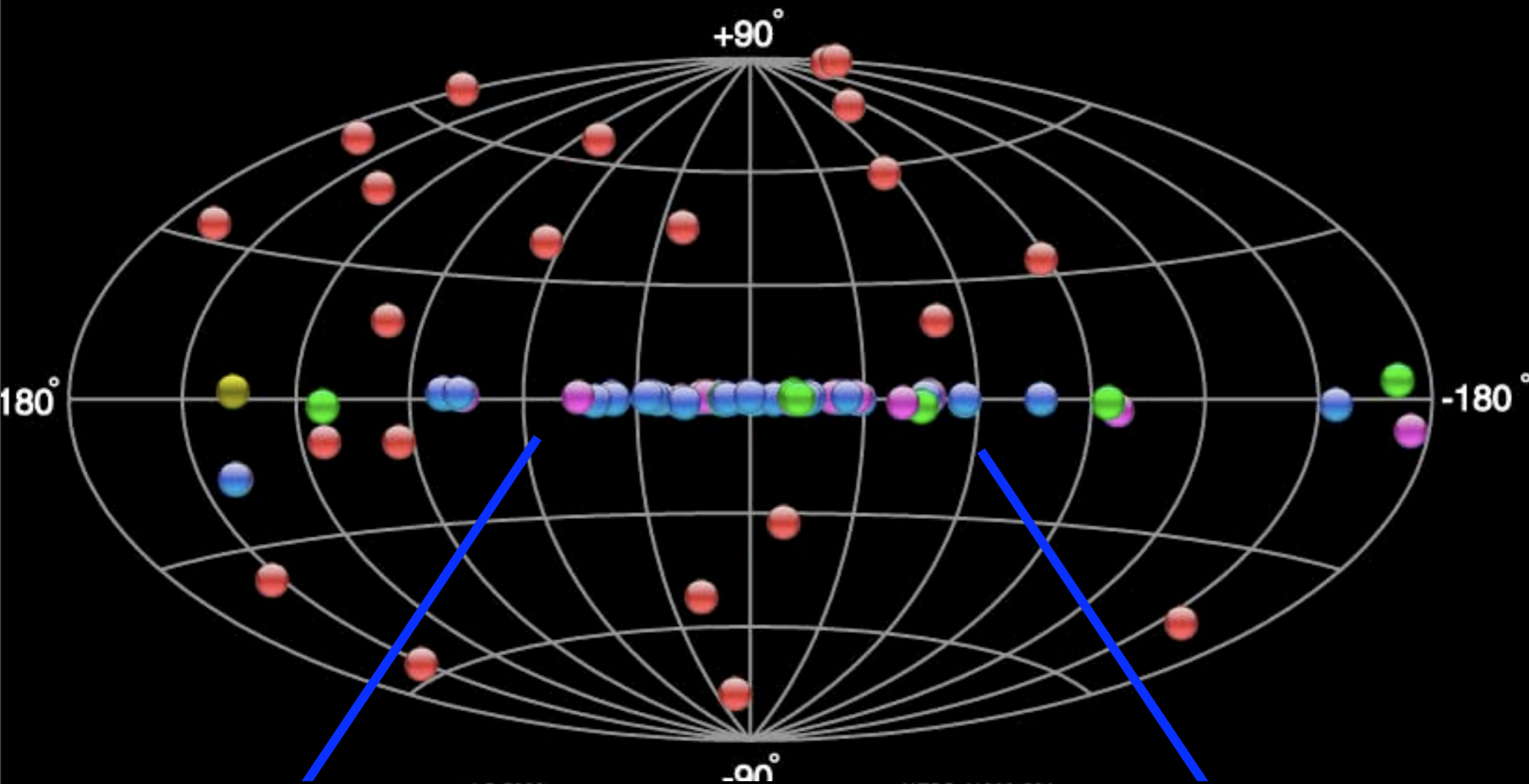
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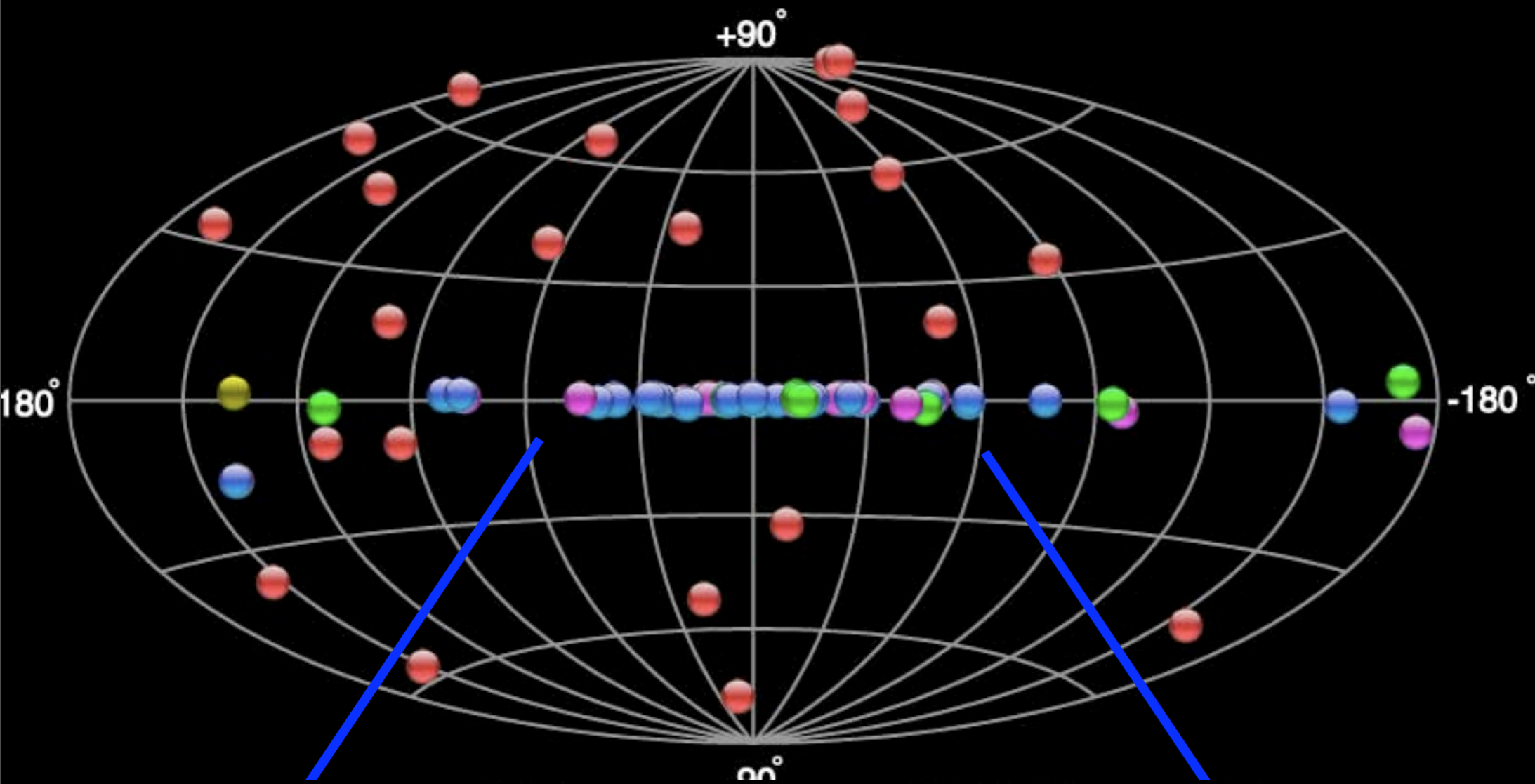
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2007



Effective exposure [h]

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## The H.E.S.S. Galactic Plane Survey, 2005-2009

- Extension in longitude:  $-85^\circ < l < 60^\circ$
- Deep exposure: 1400+ h *scan-mode* + dedicated obs.
- Uniform exposure
- Detected a total of ~52 Galactic sources



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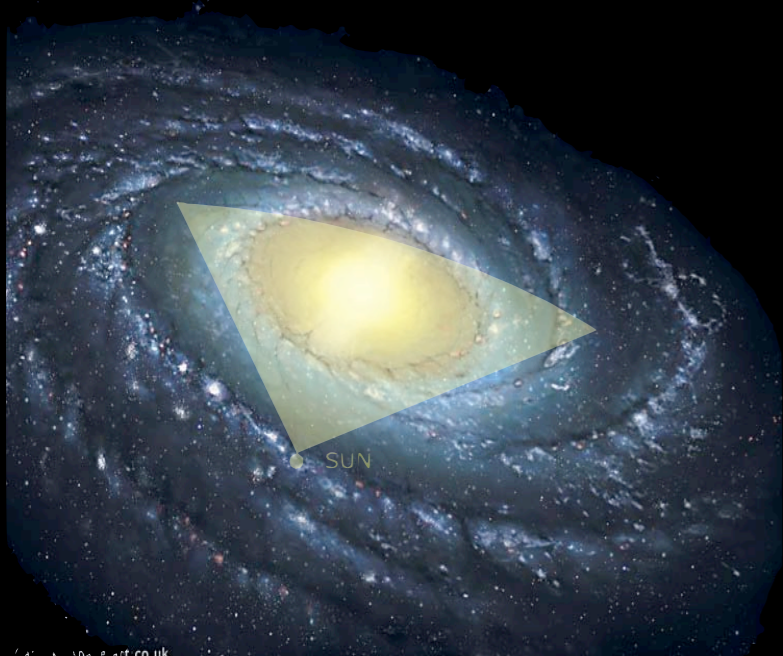
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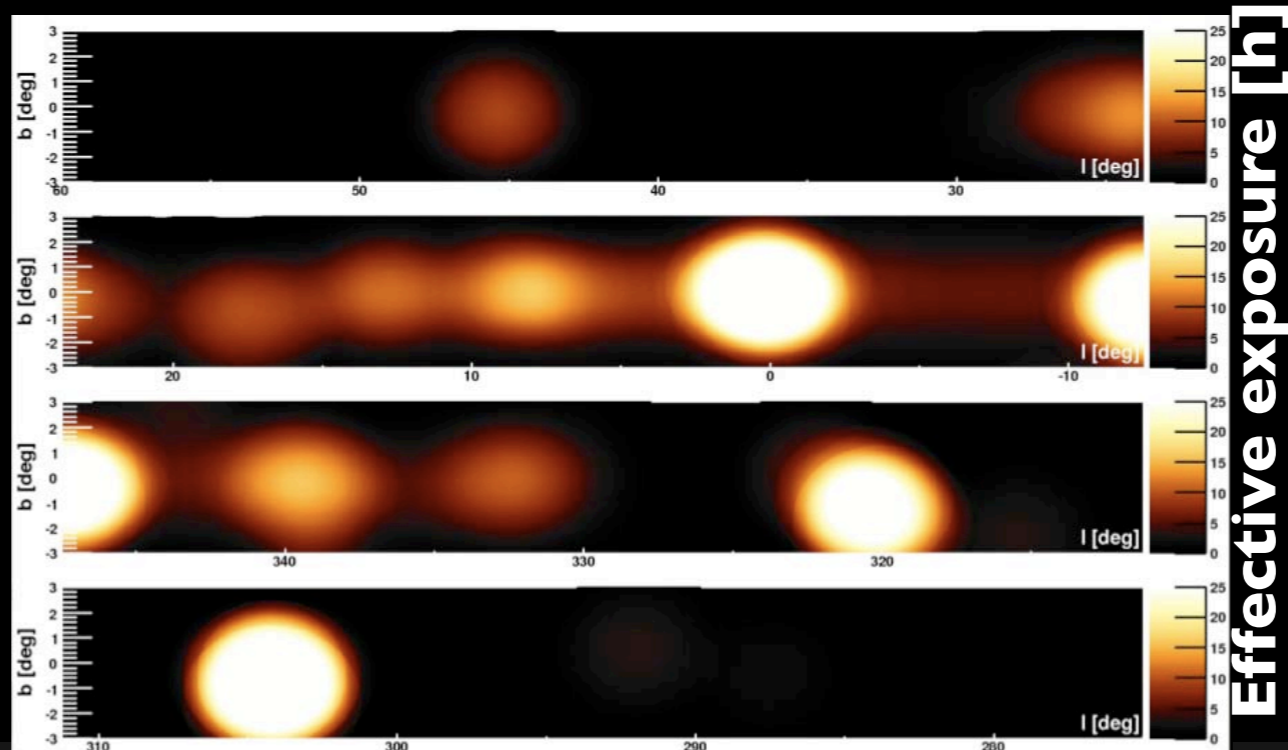
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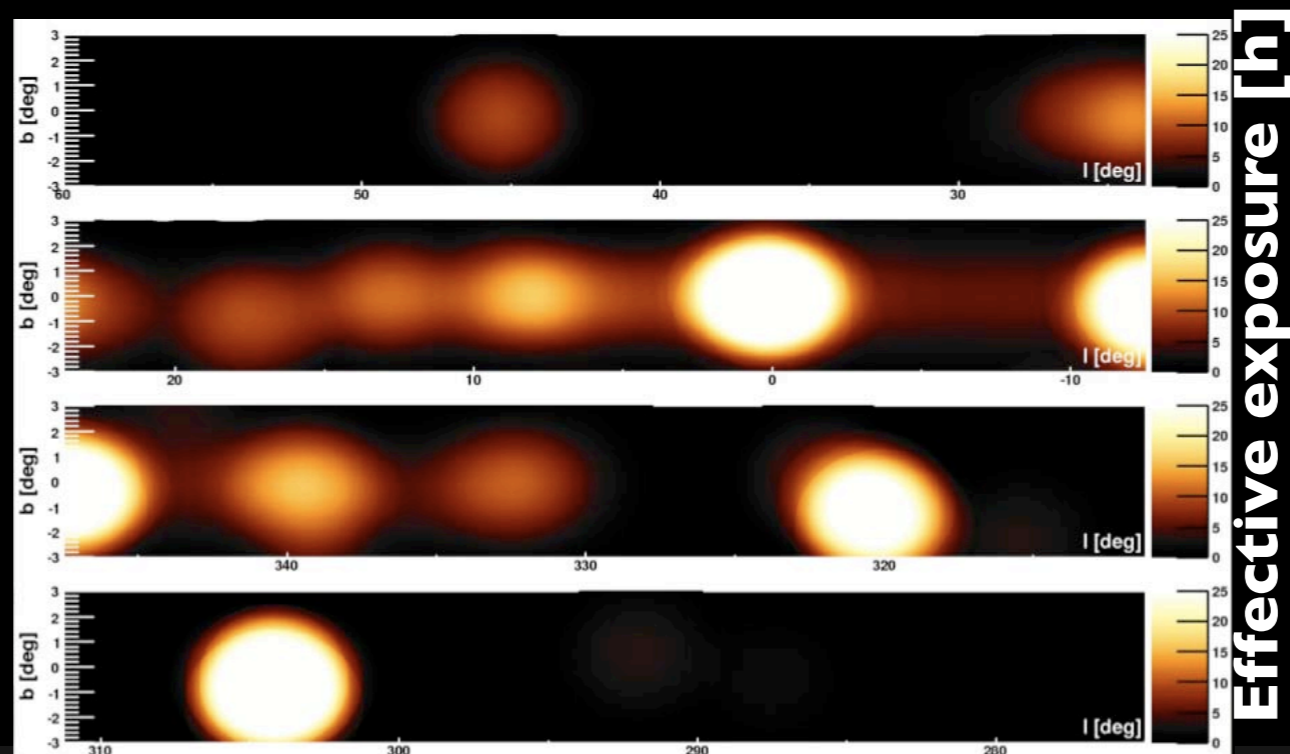
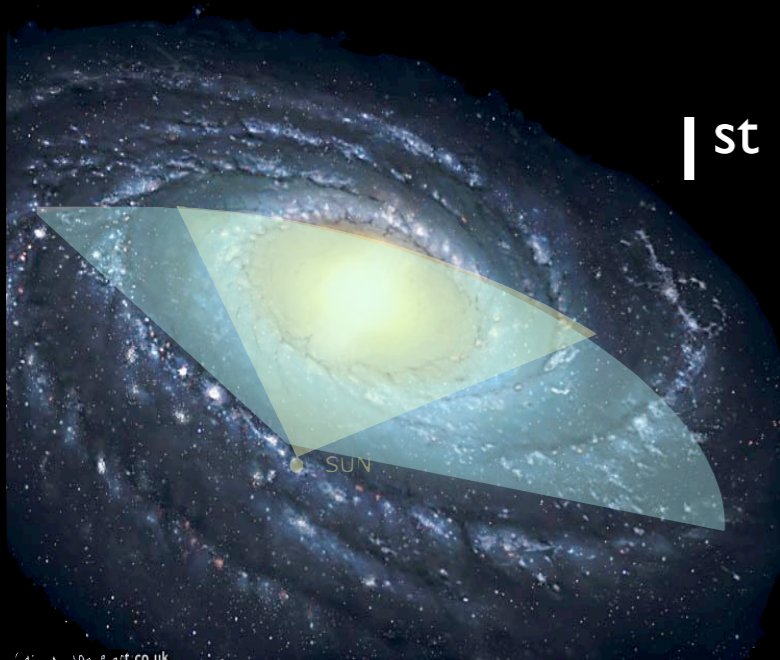
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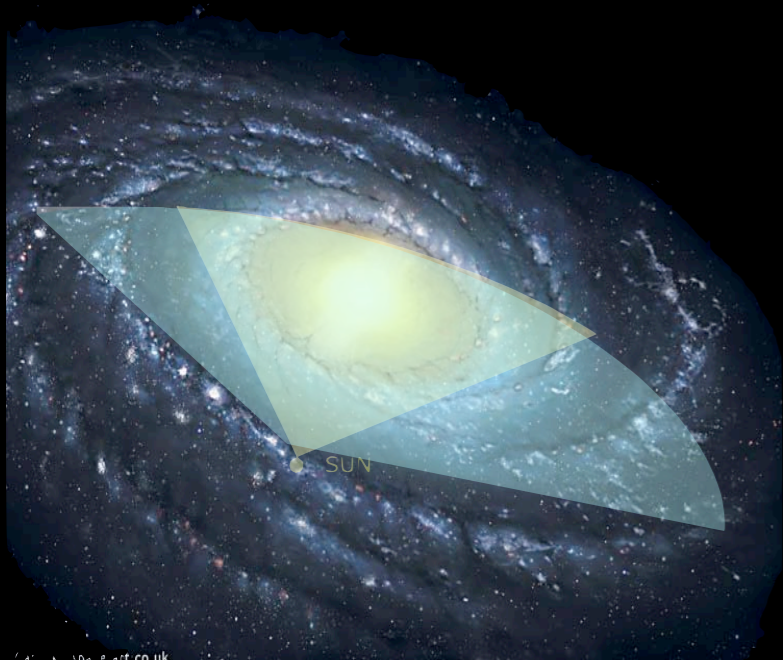
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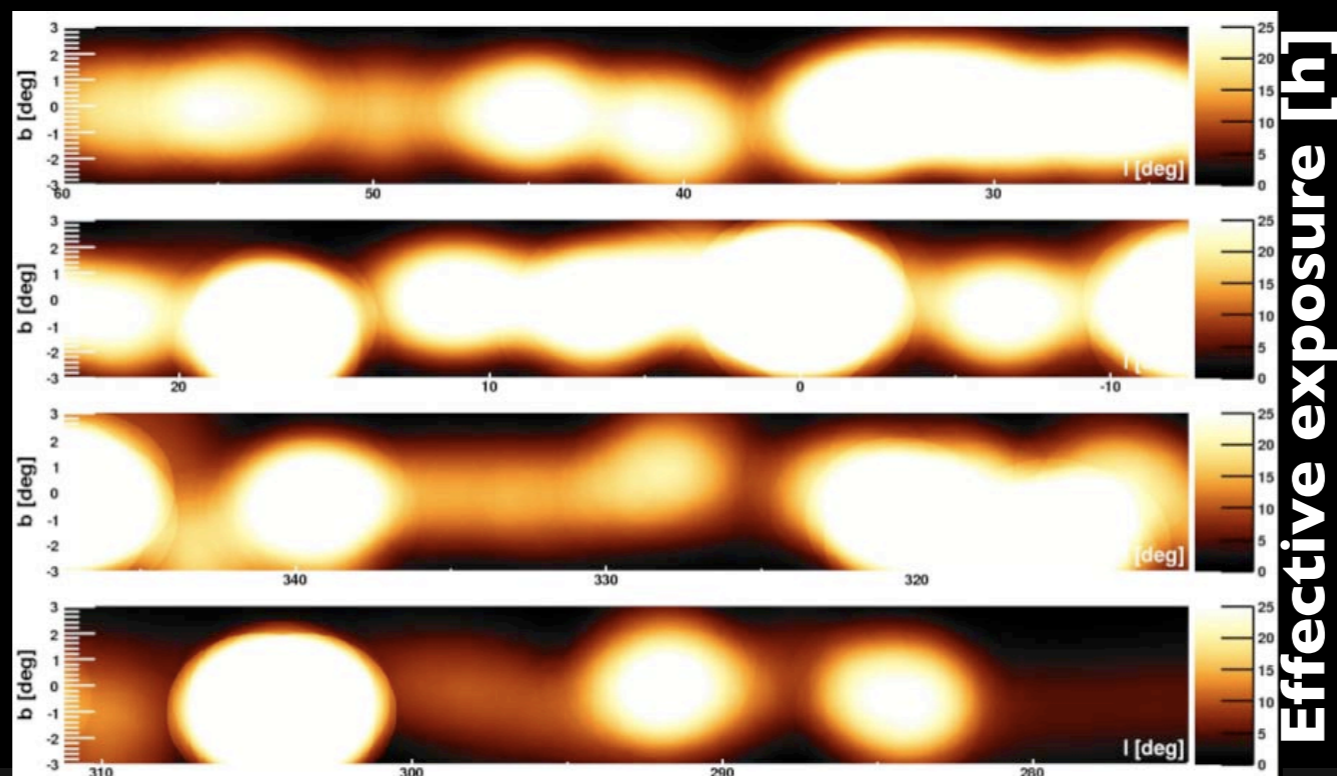
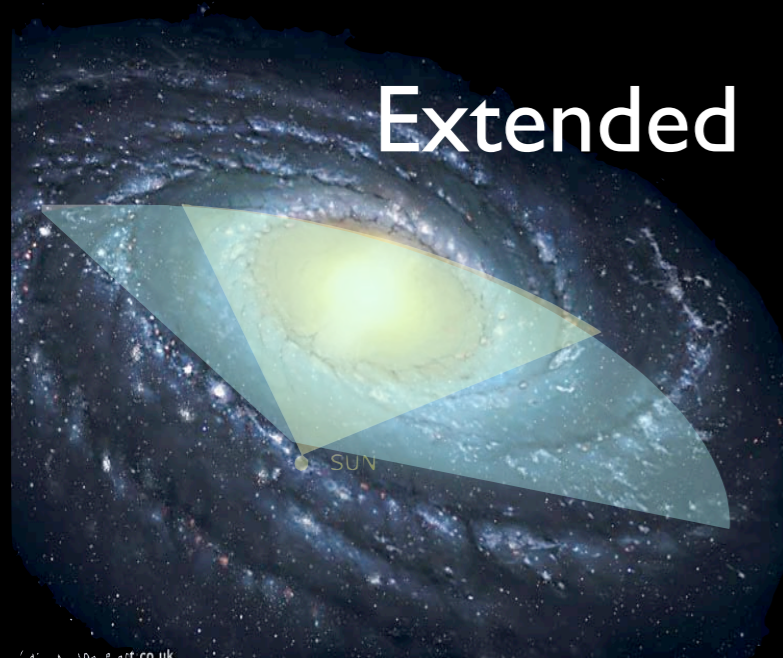
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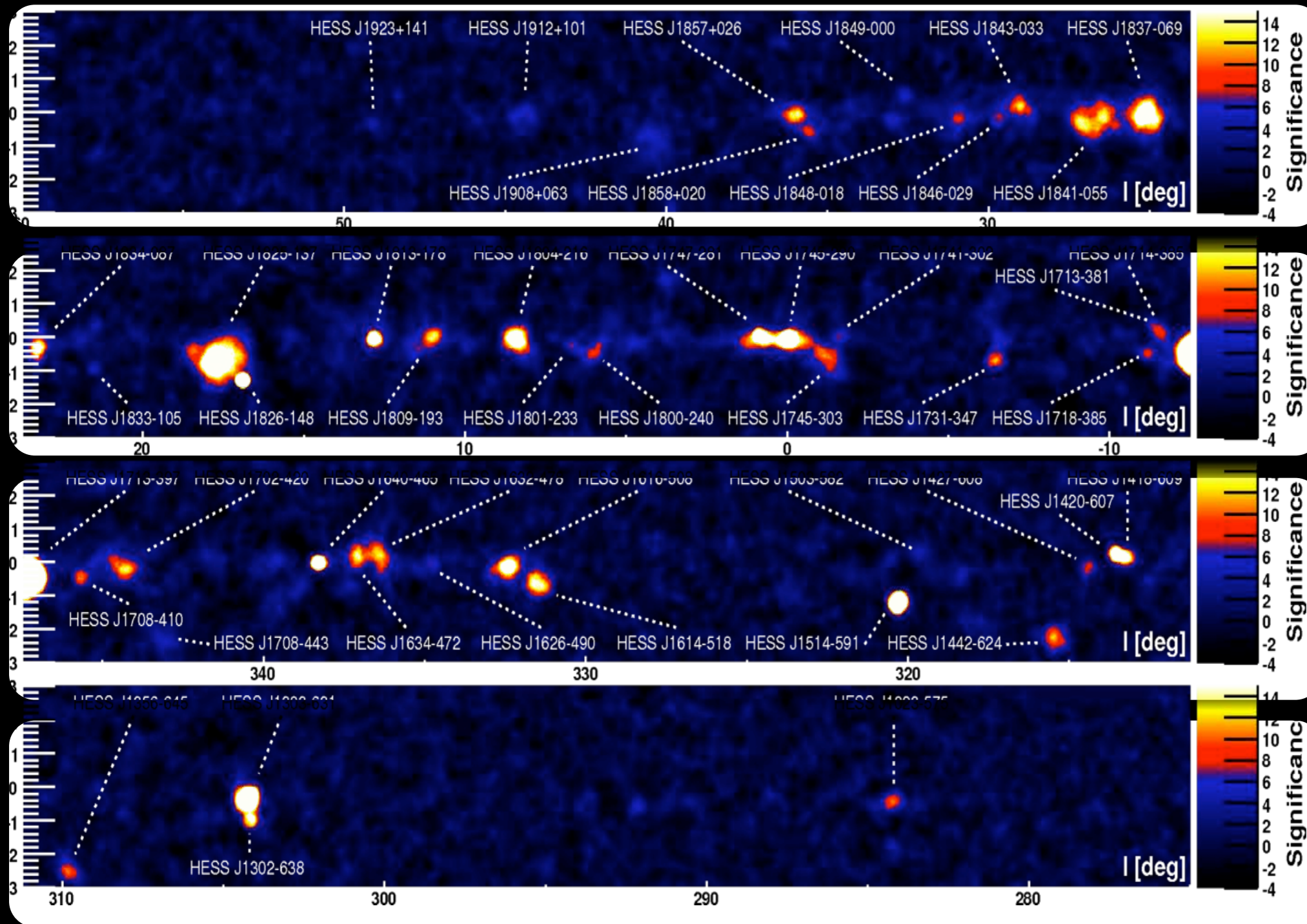
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ICRC, 2009

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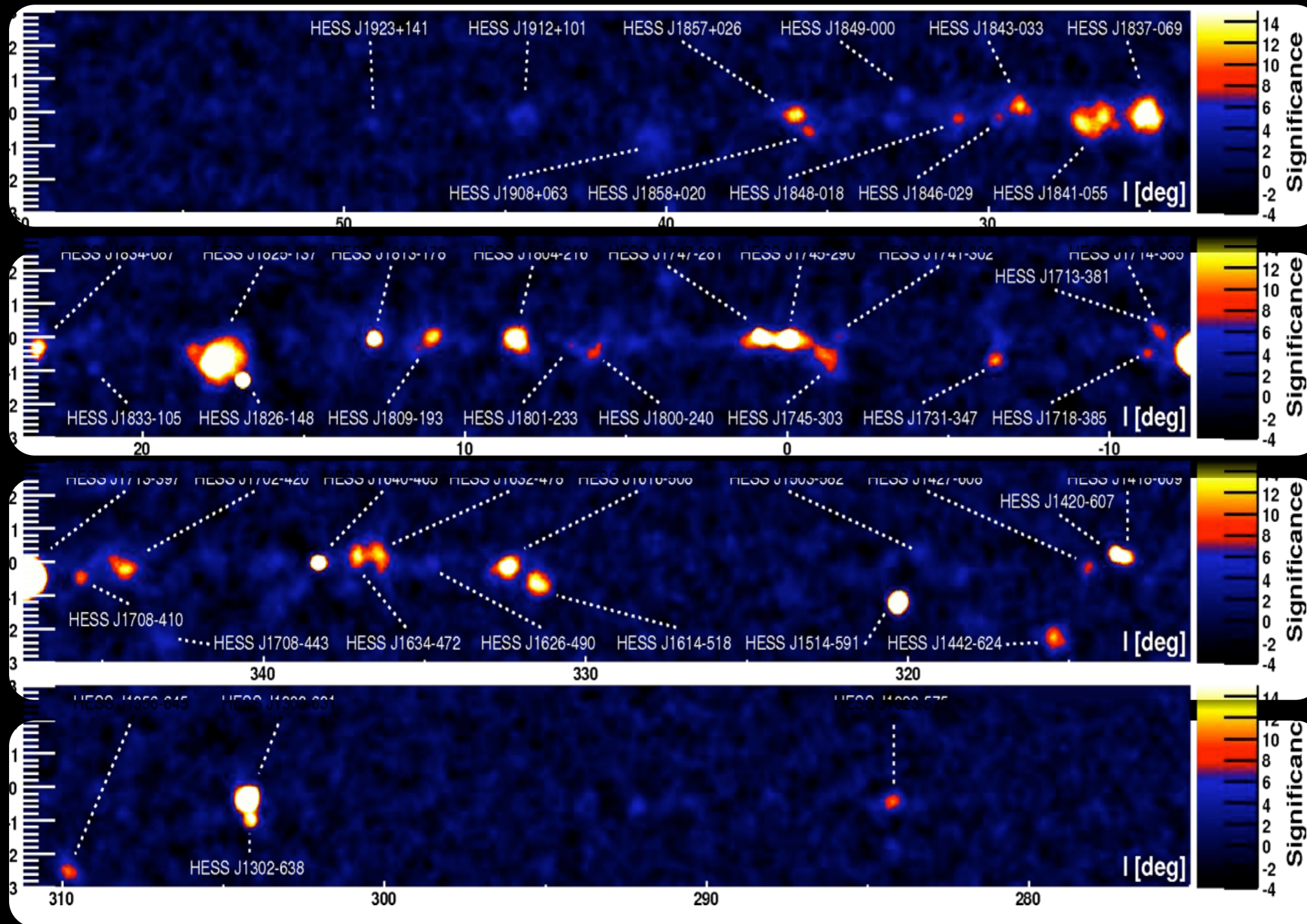
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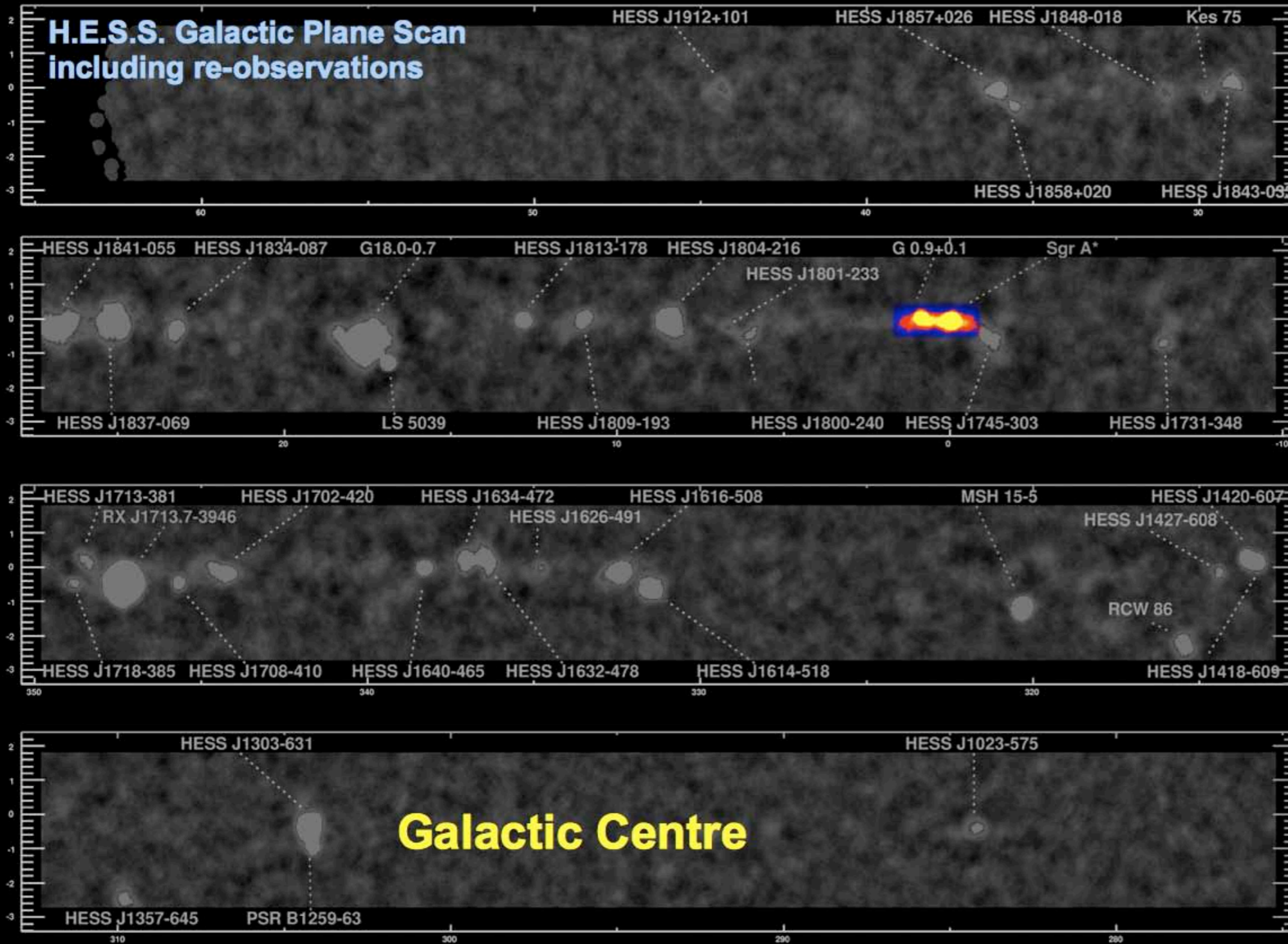
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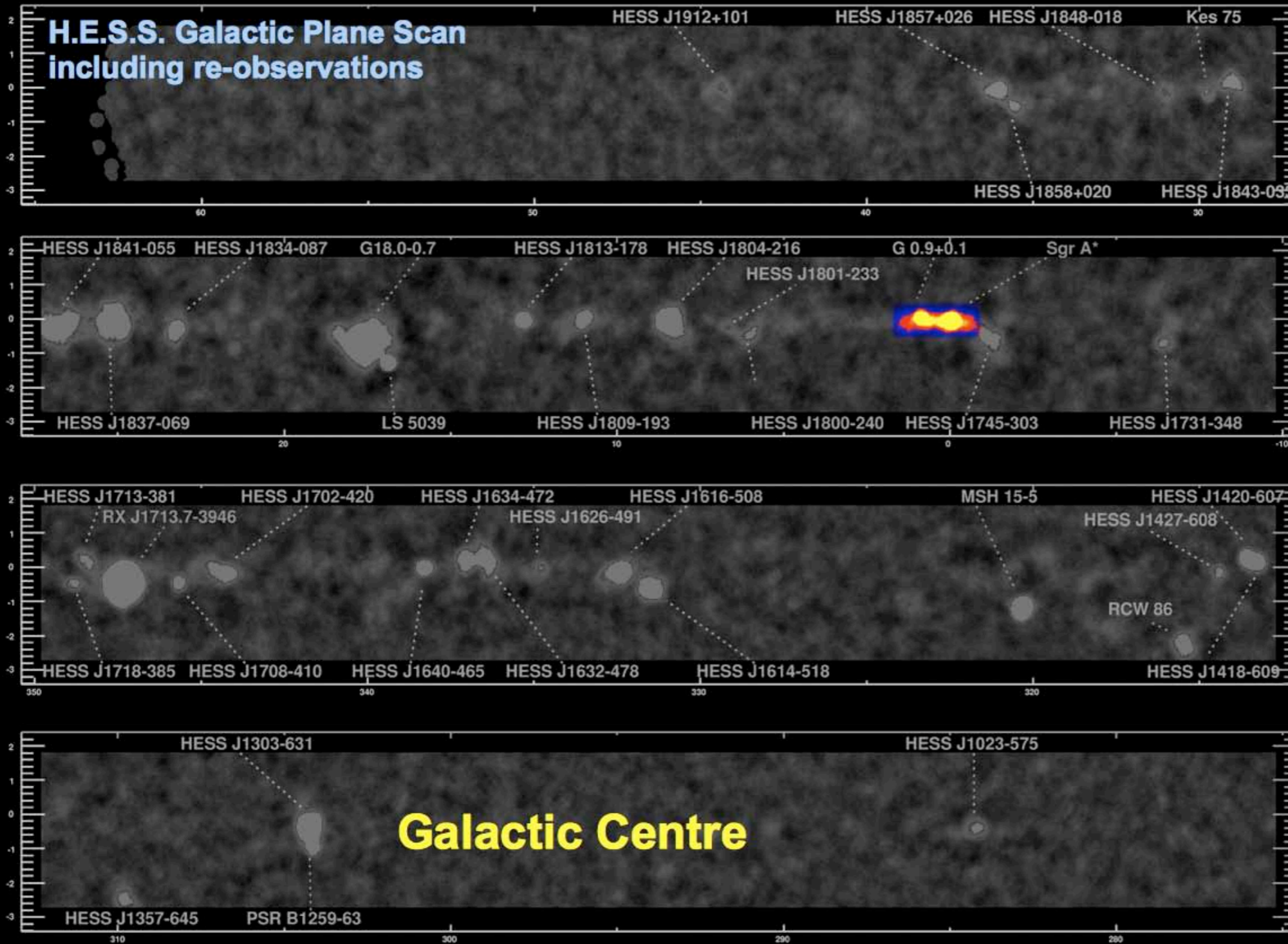
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Classification from Aharonian, Buckley, Kifune and Sinnis (2008)

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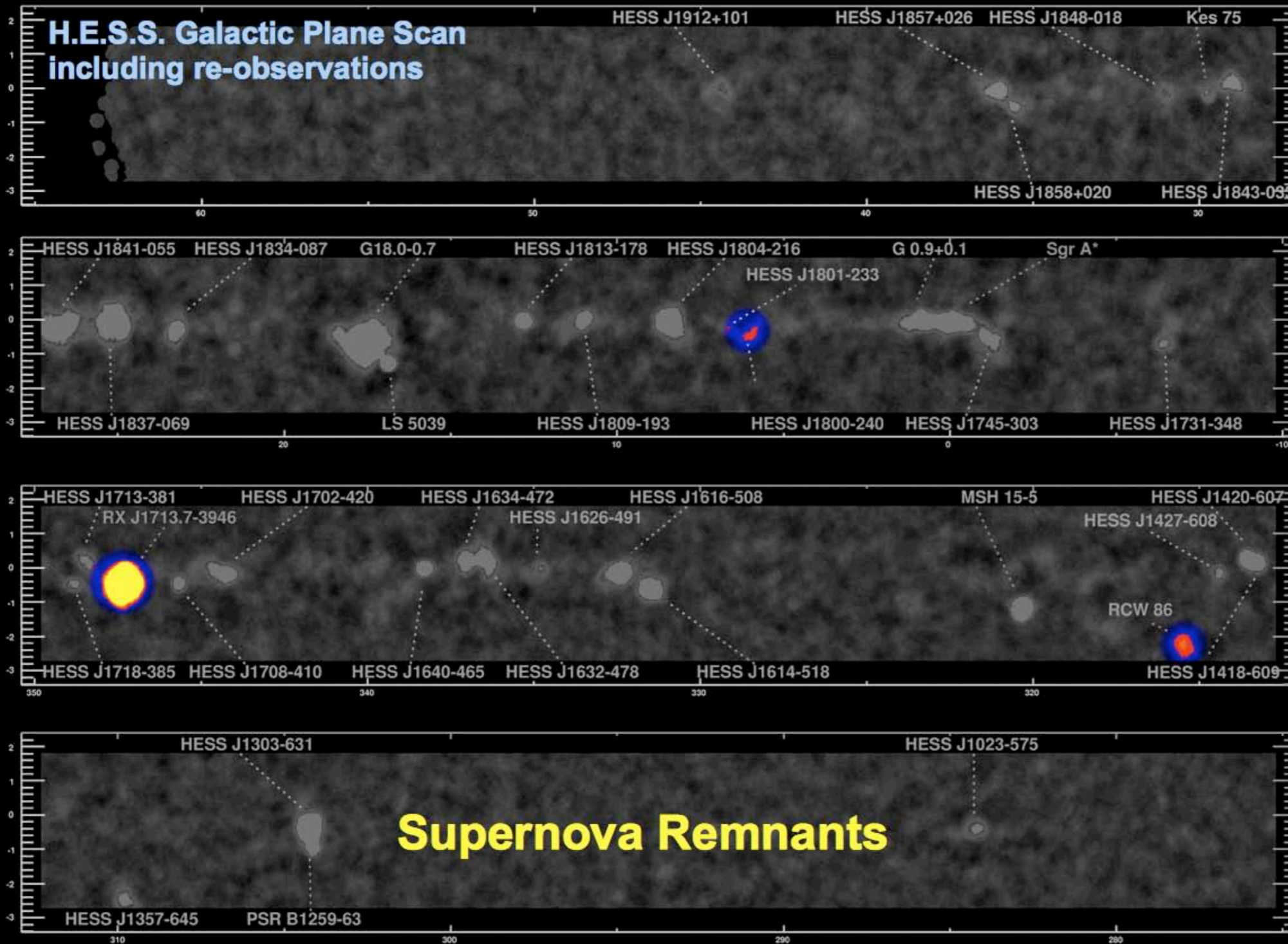
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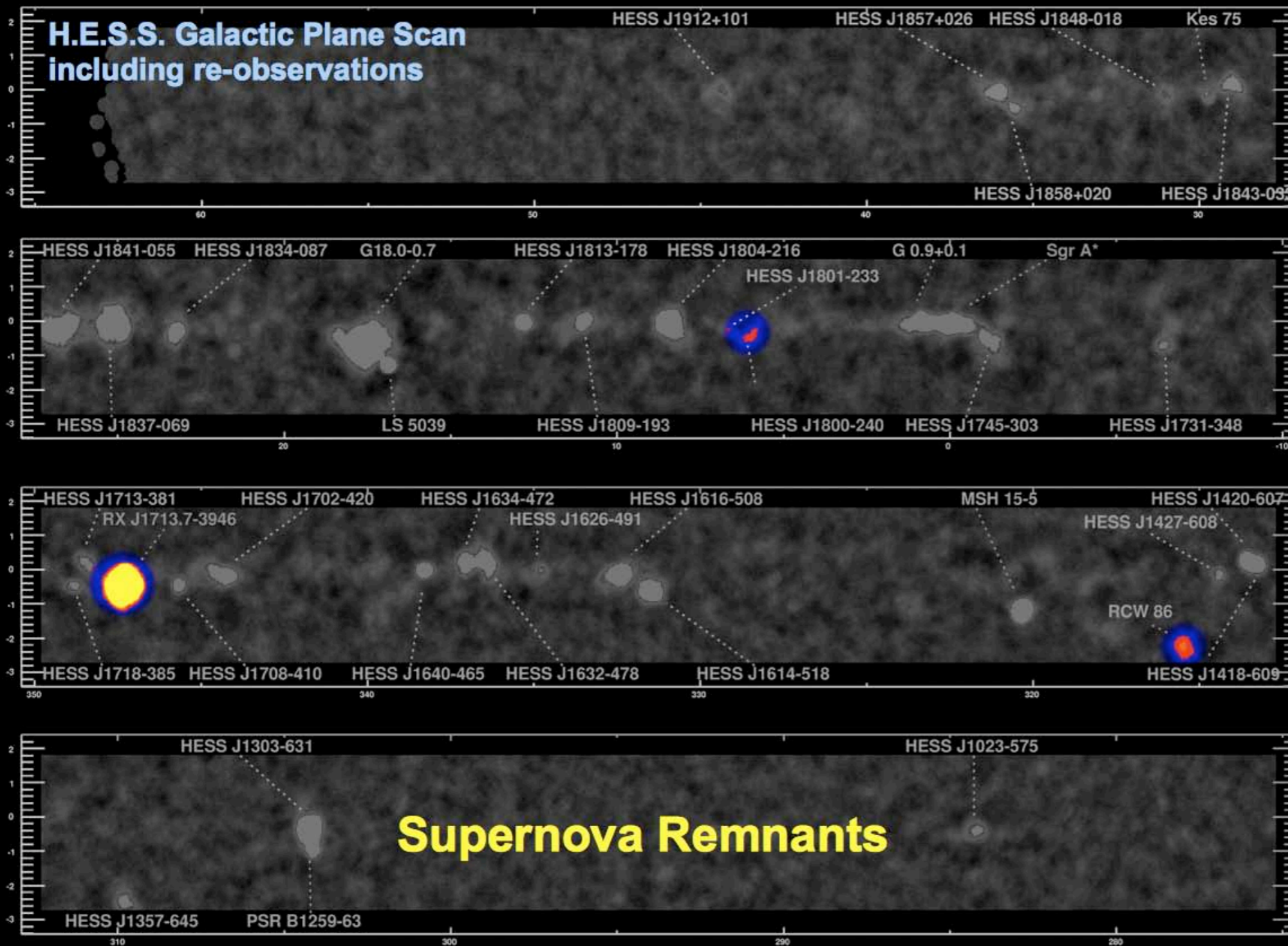
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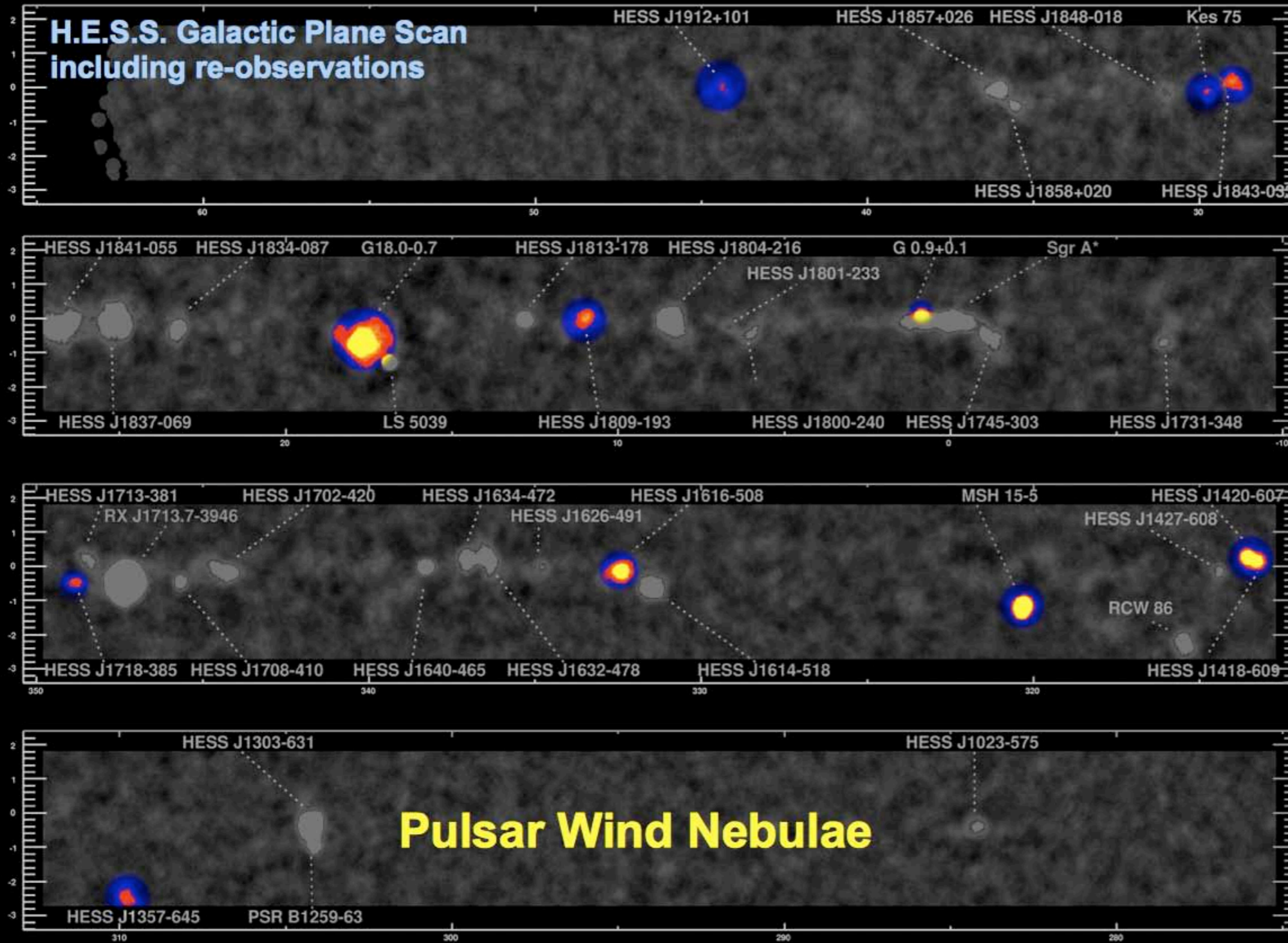
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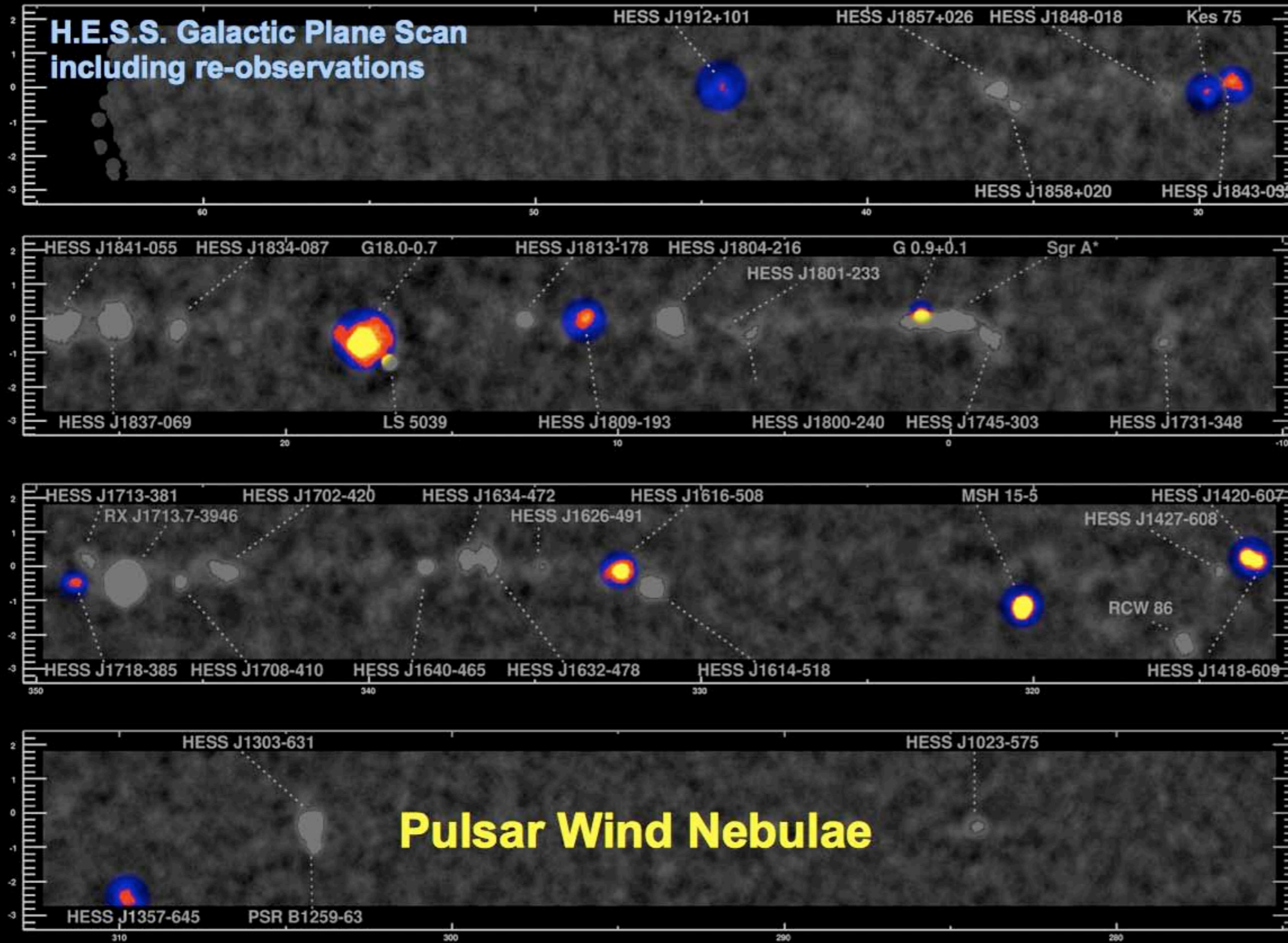


**H.E.S.S. Galactic Plane Scan including re-observations**

**Pulsar Wind Nebulae**

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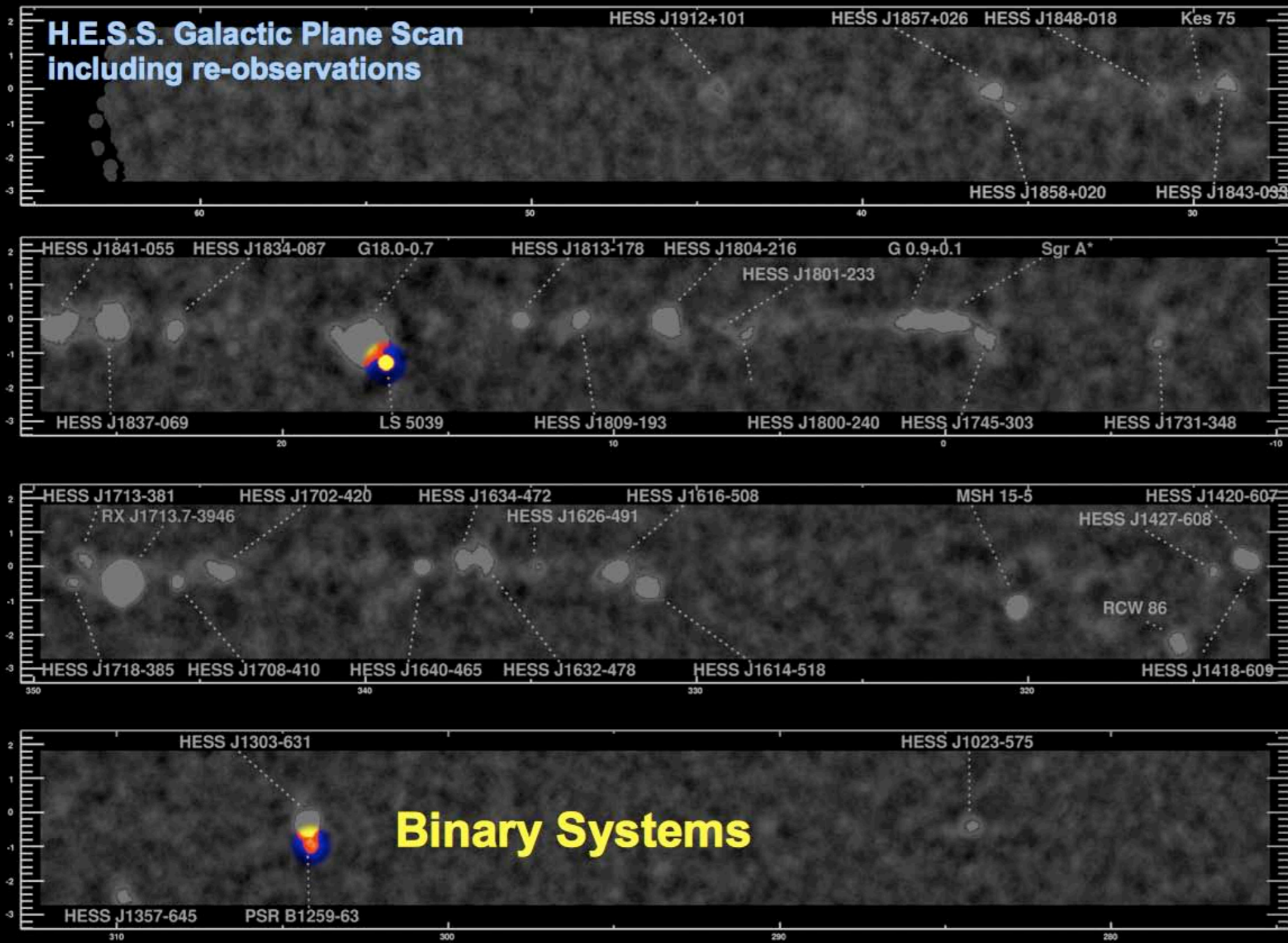


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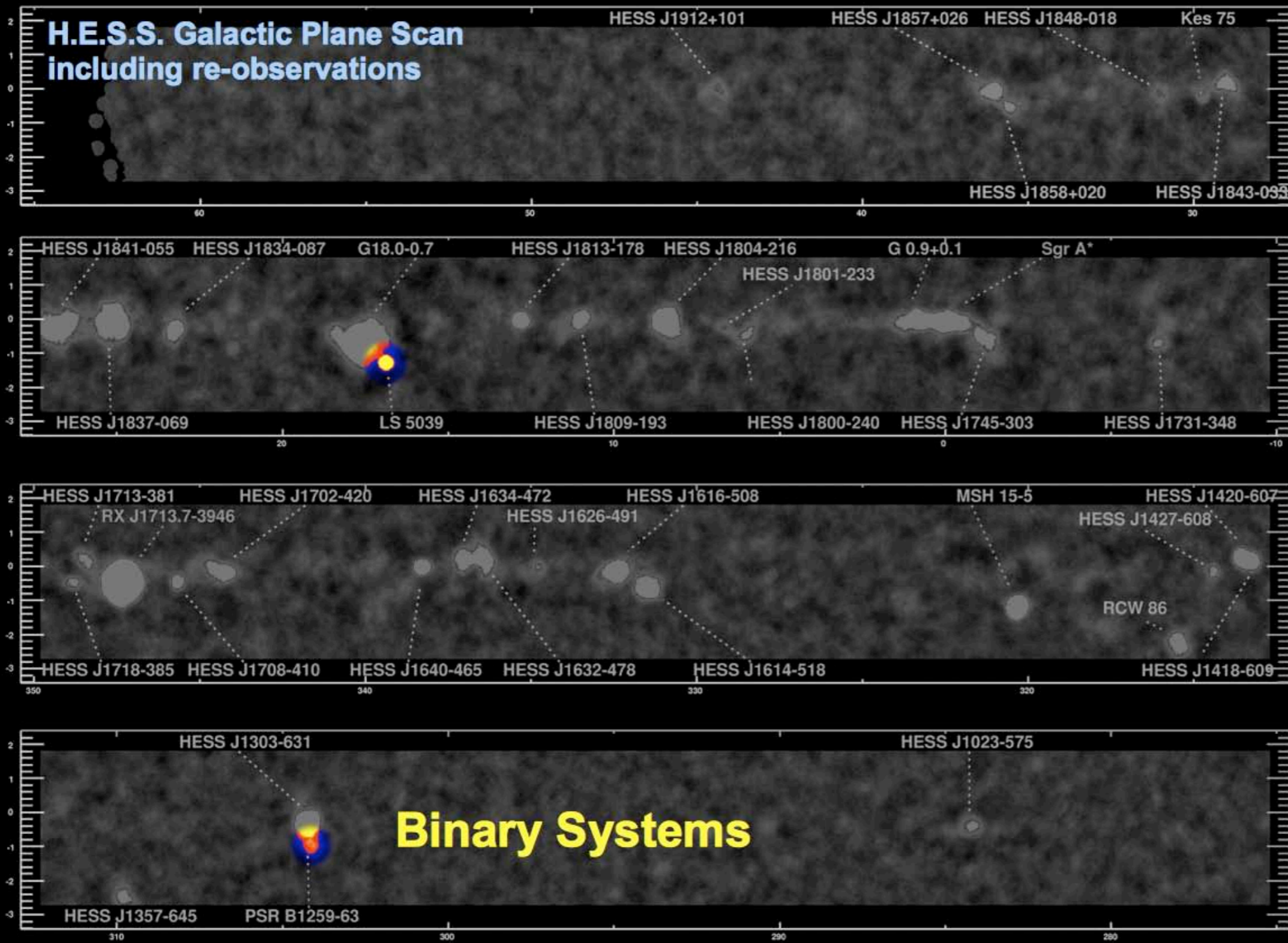
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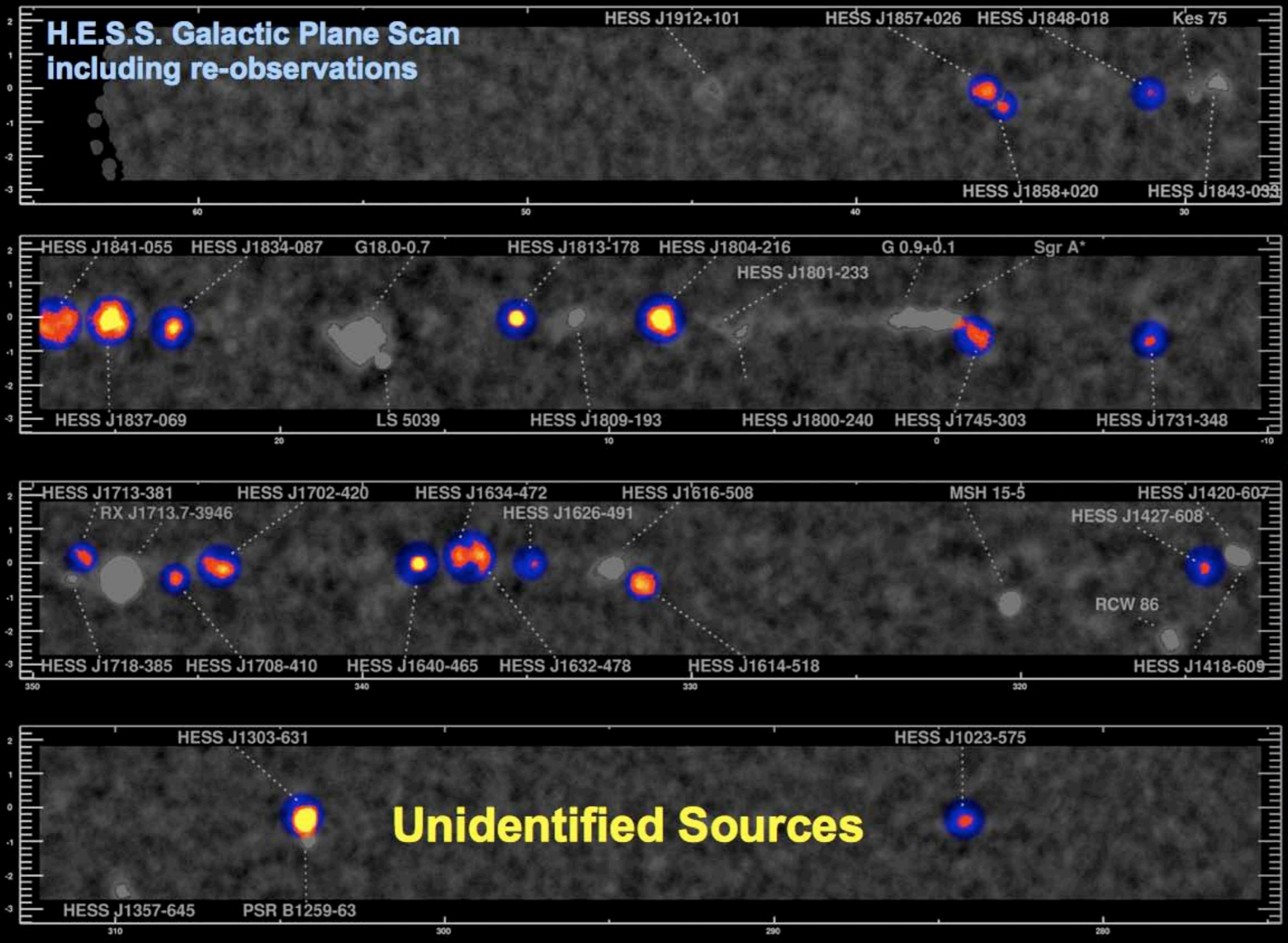
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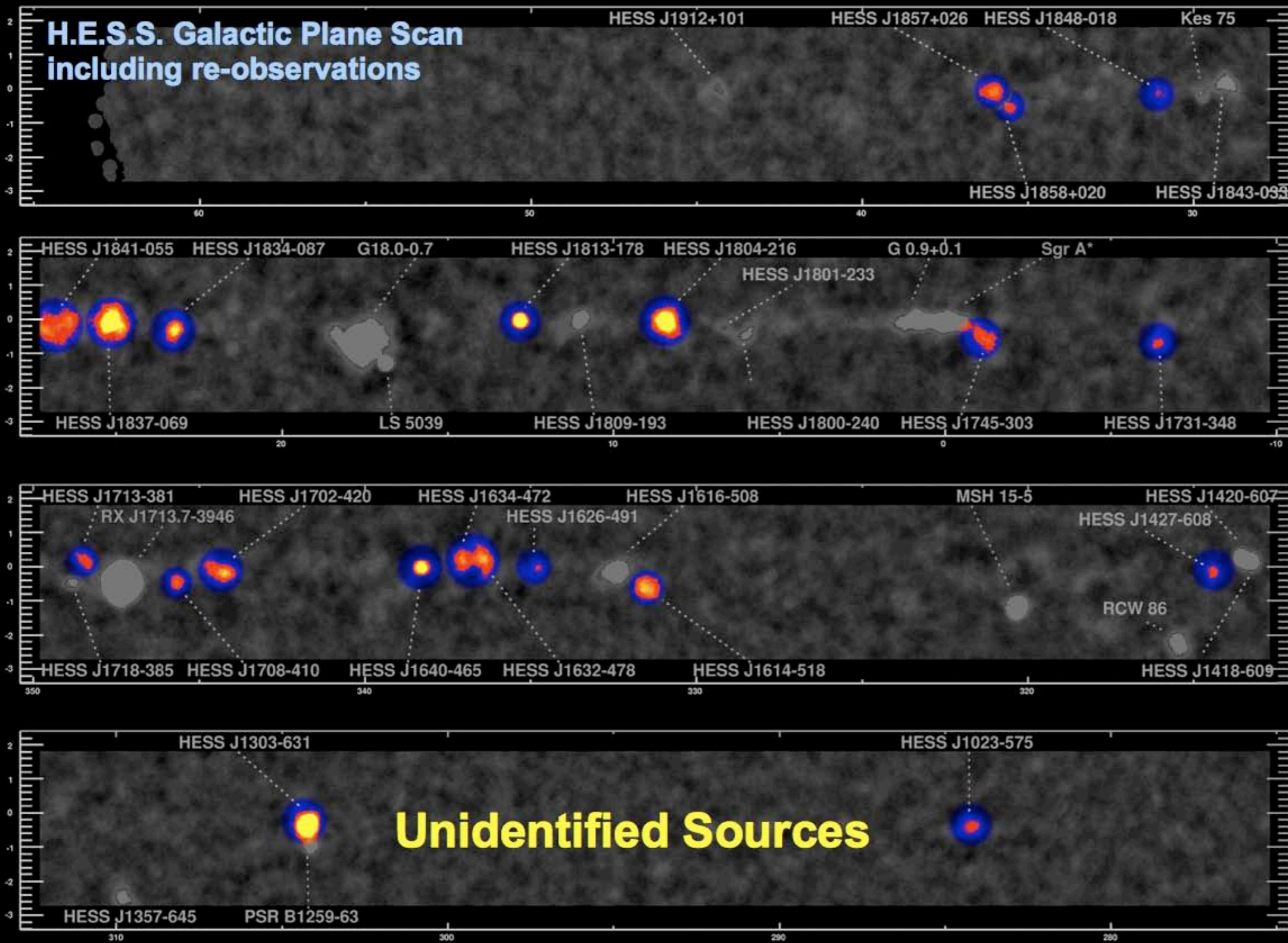
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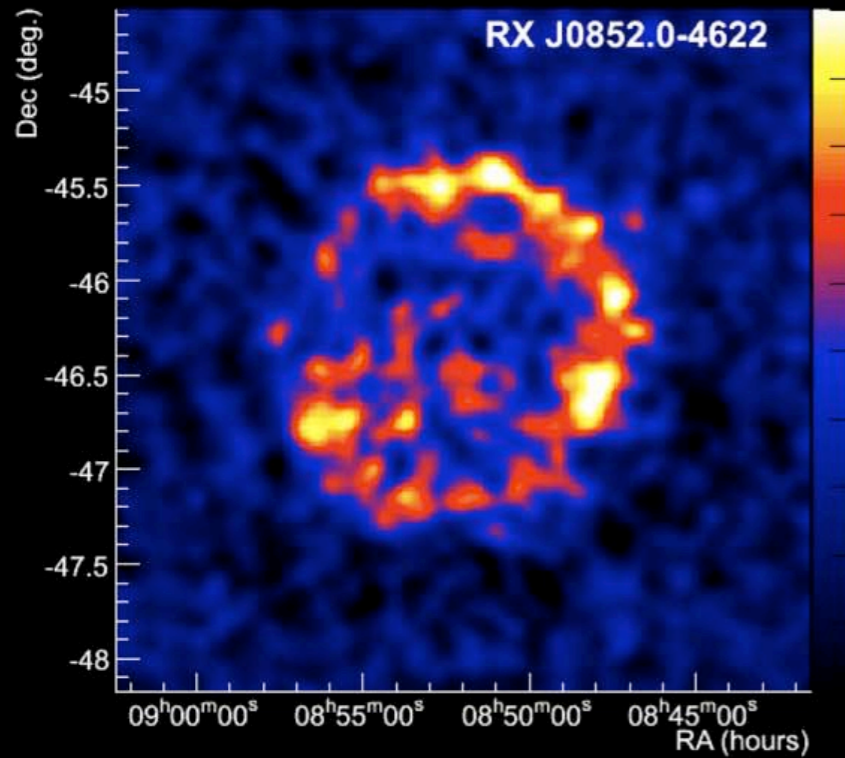
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**Unidentified Sources**

Classification from Aharonian, Buckley, Kifune and Sinnis (2008)

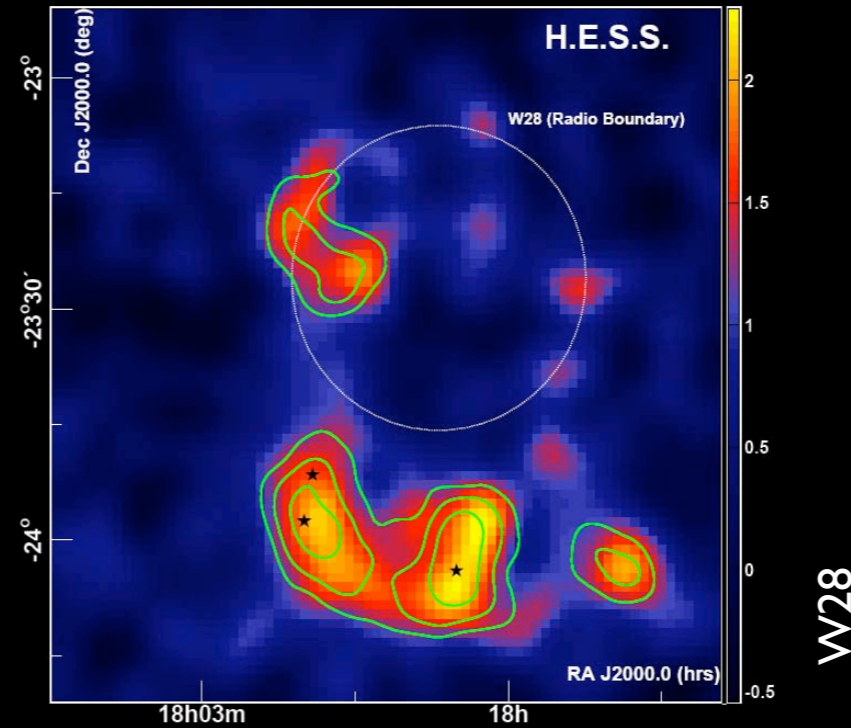
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## Shell-like SNRS



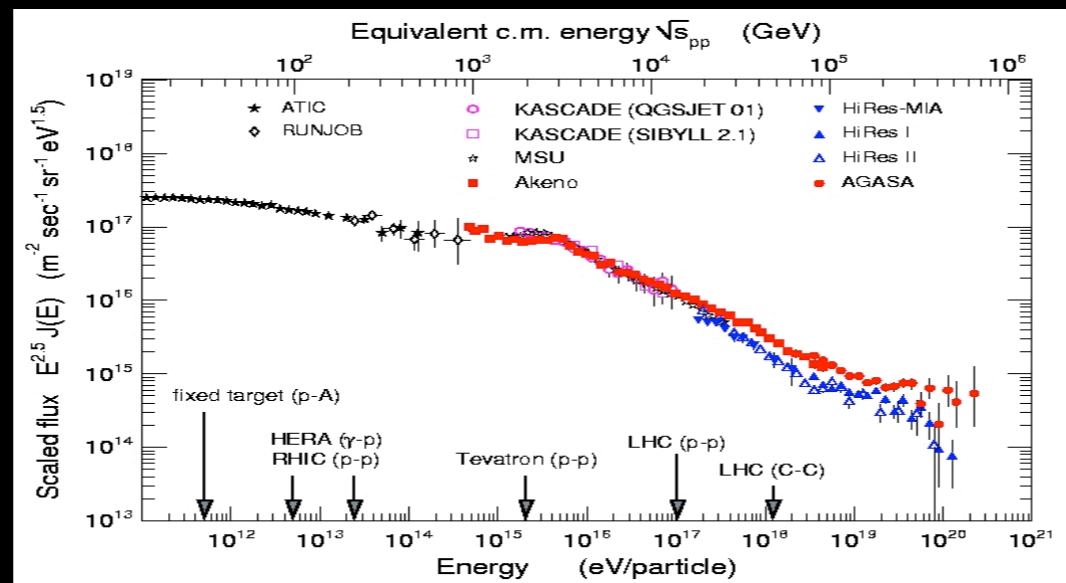
- ✓ RX J1713.7
- ✓ RX J0852 ("Vela Jr")
- ✓ RCW 86
- ✓ SN 1006
- ✓ HESS J1813-347

## Interacting with MC

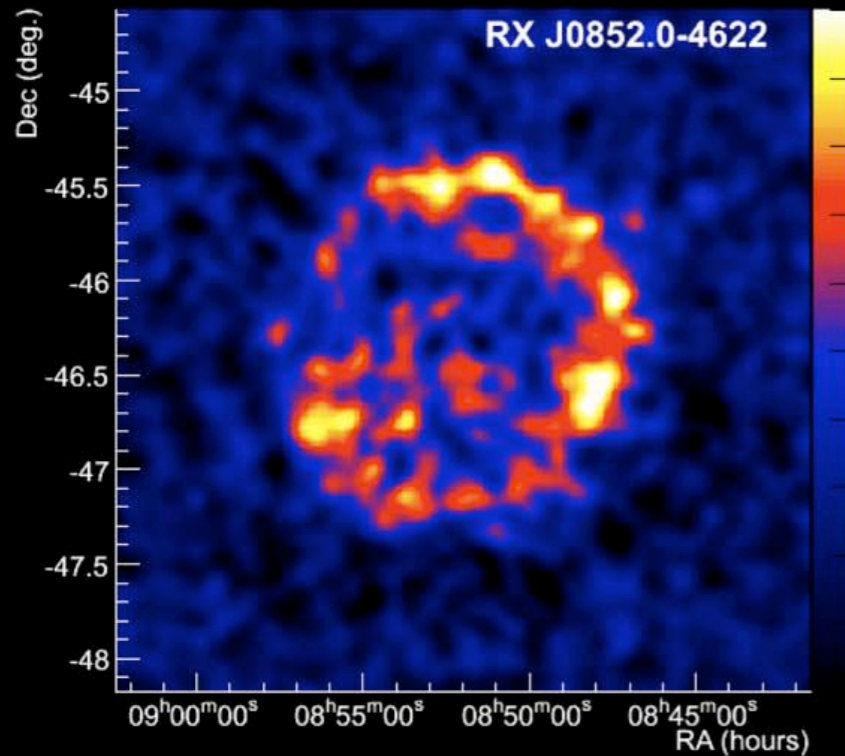


- ✓ W28
- ✓ CTB 37 A
- ✓ G349.2-0.1 (W51)

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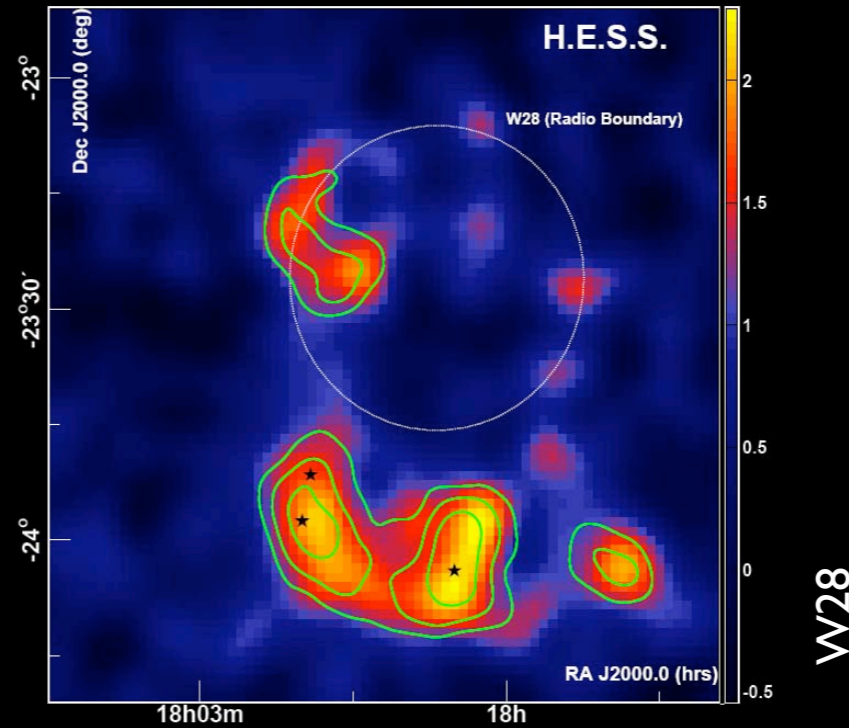


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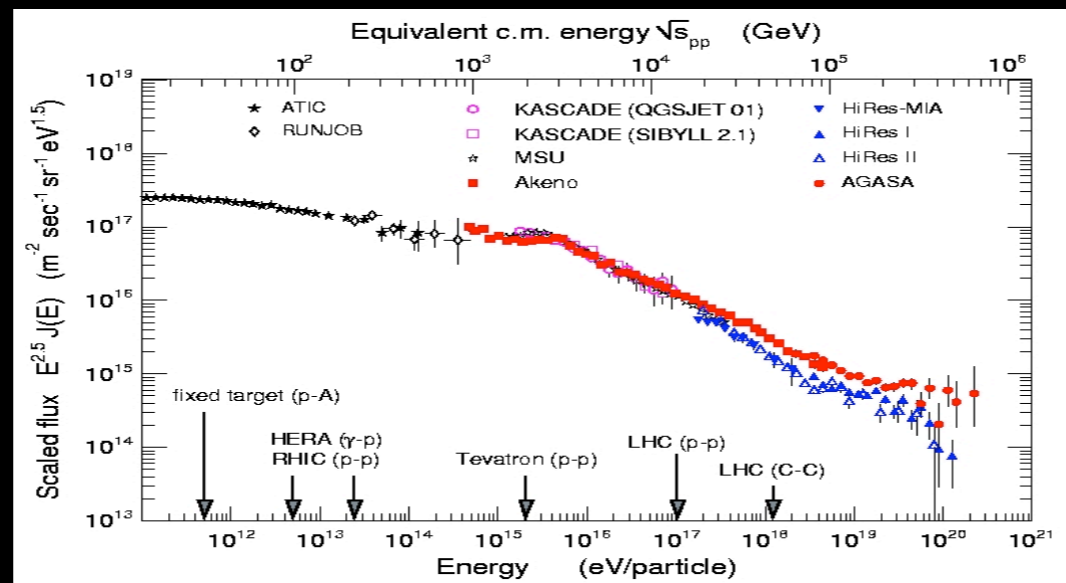
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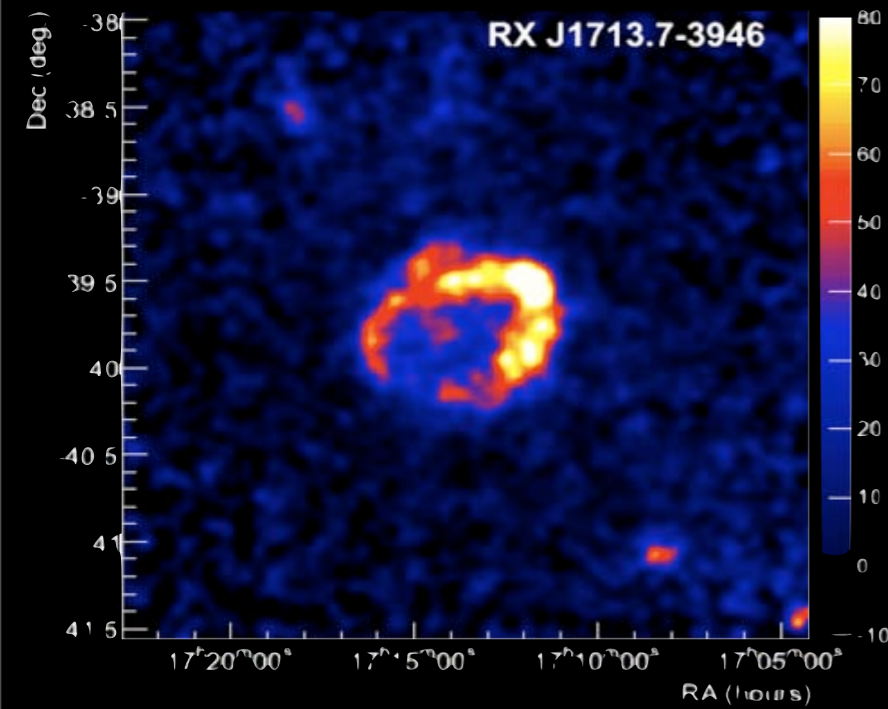
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JAXA/ TAKA AKI TANAKA/HESS

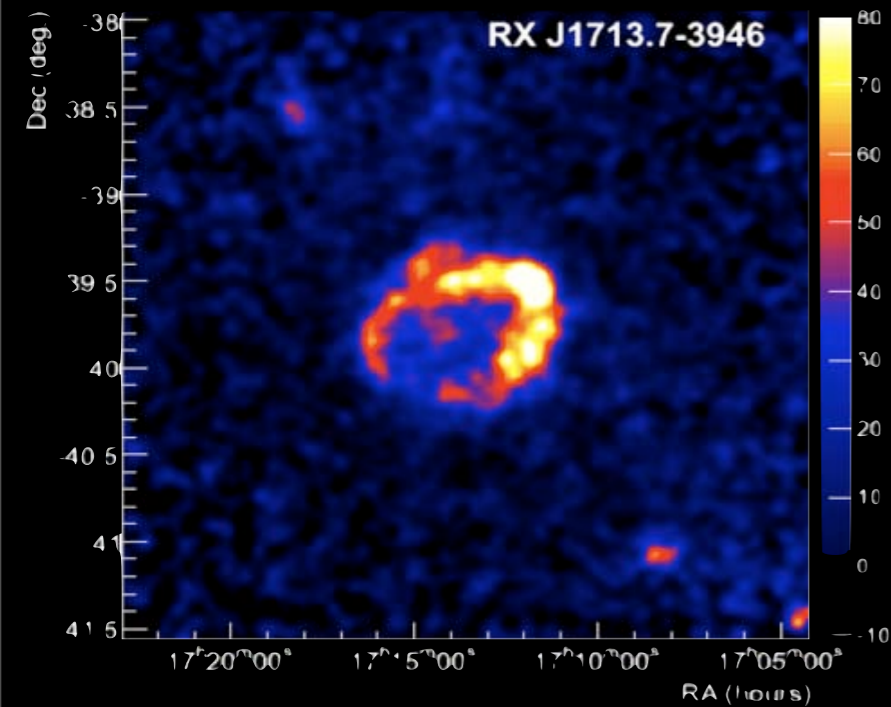


First-ever resolved  $\gamma$ -ray source  
Strong correlation with X-rays:  
~80%  
High B-fields suppress IC  
emission

Real question: what proportion  
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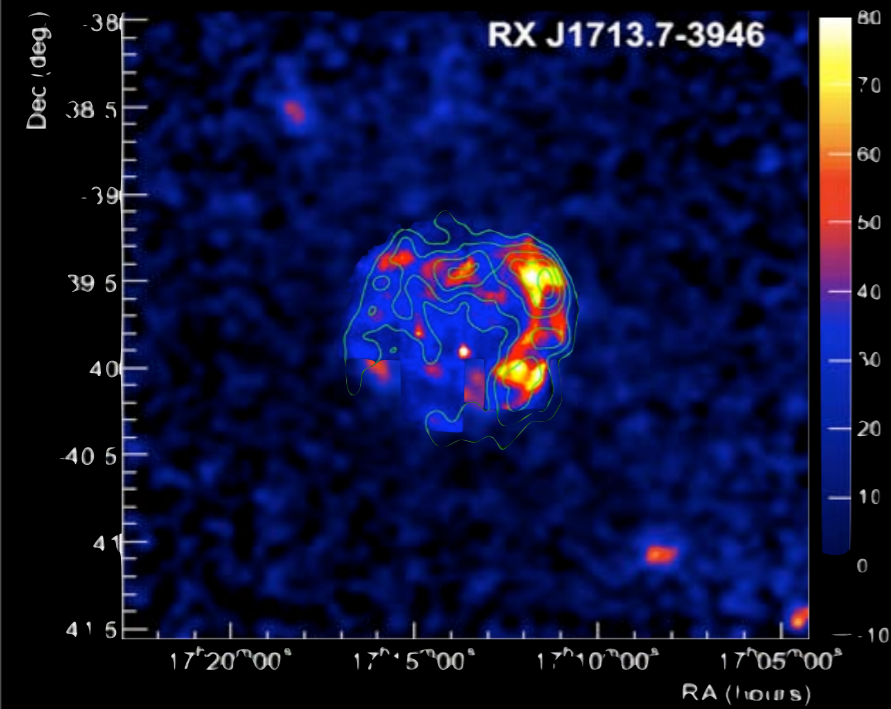
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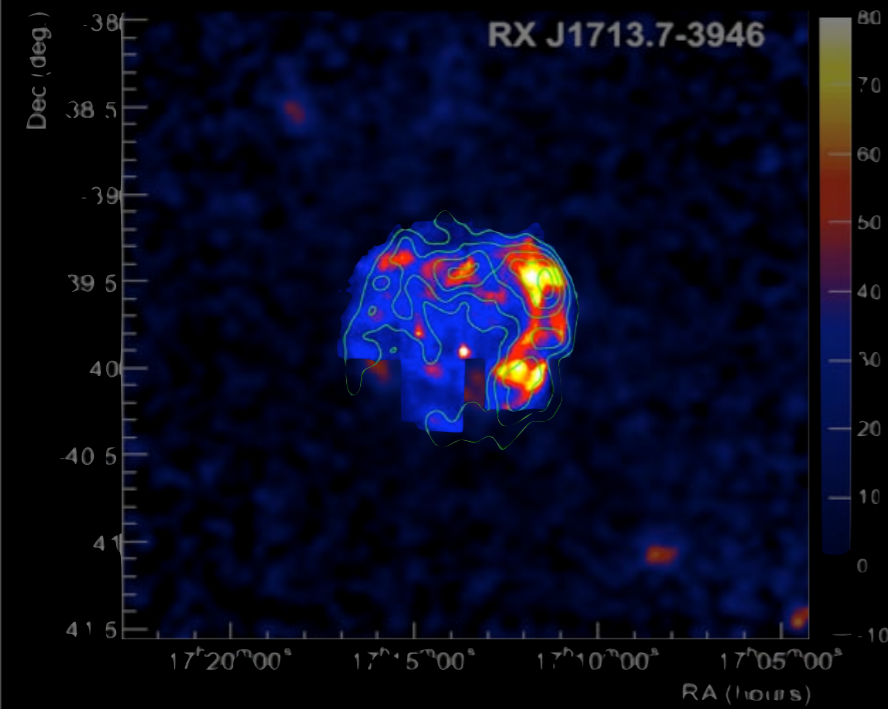
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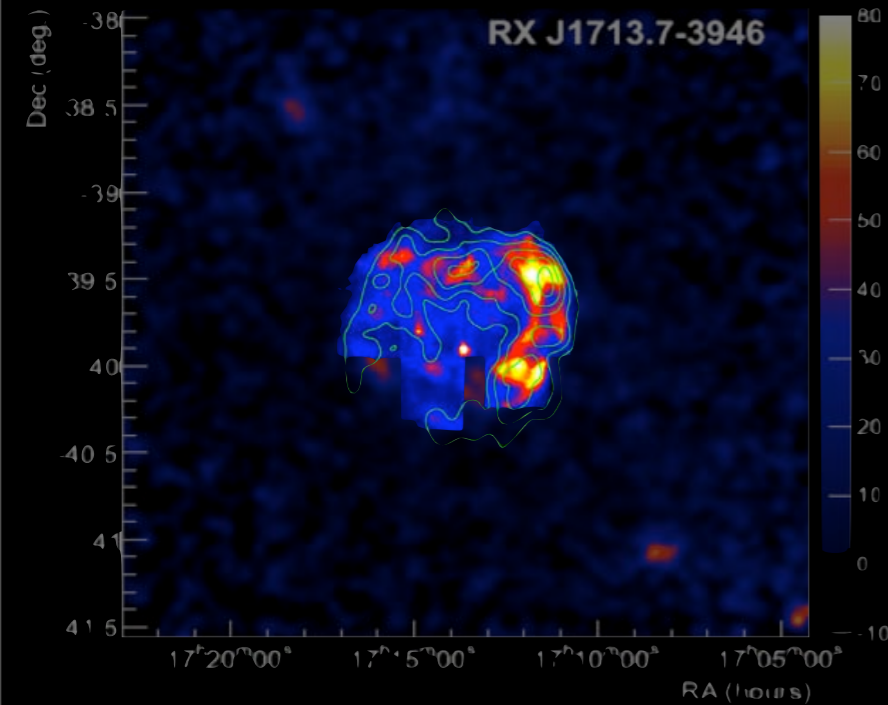
evolved PWN

**Binary Systems**

**Dark Sources**

**New Source Type**

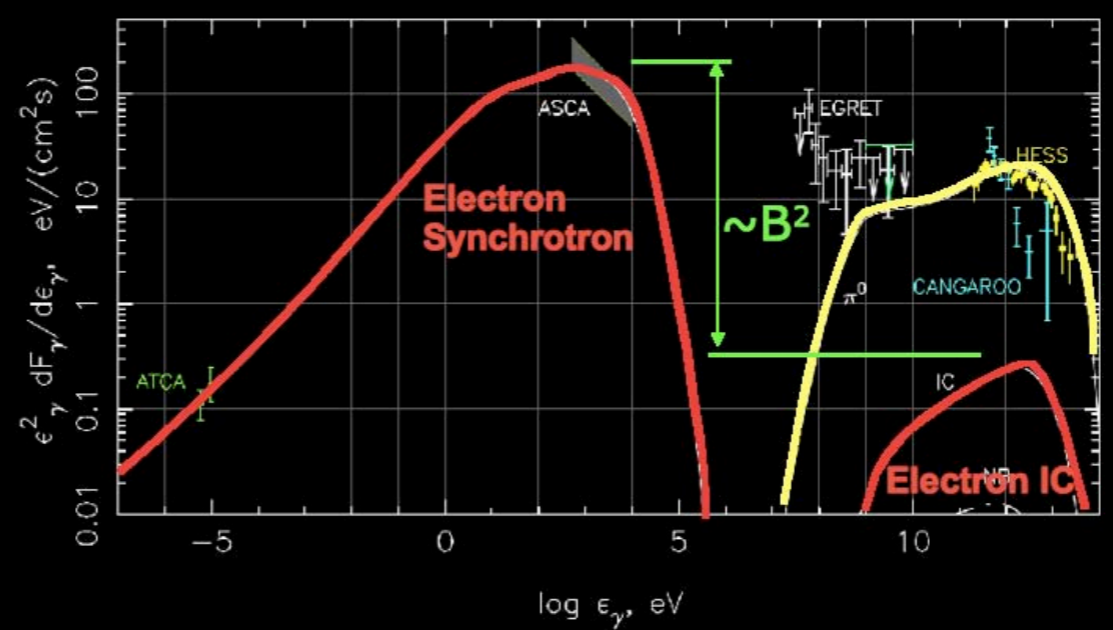
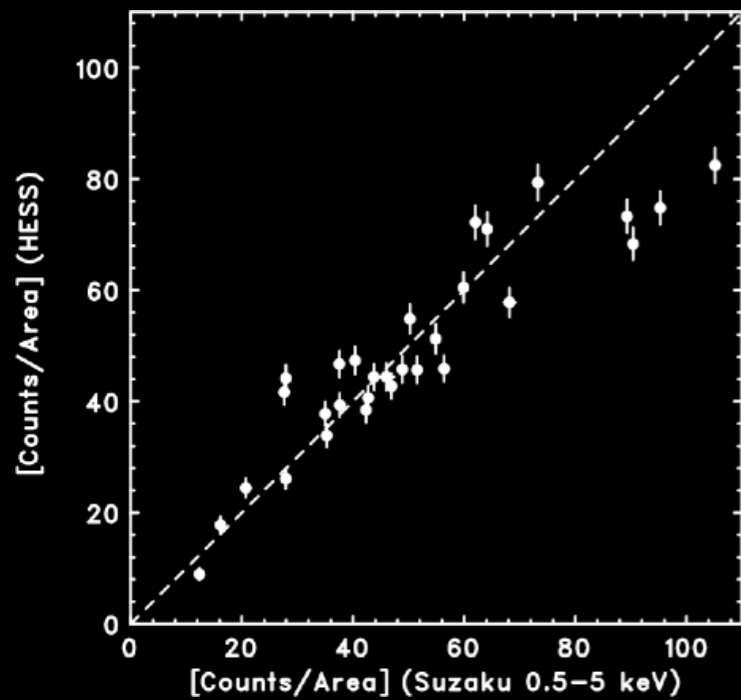
JAXA/ TAKA AKI TANAKA/HESS

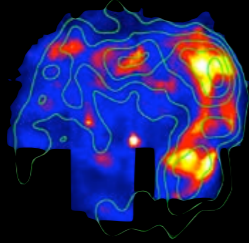


First-ever resolved  $\gamma$ -ray source  
 Strong correlation with X-rays:  
 ~80%  
 High B-fields suppress IC  
 emission

Real question: what proportion  
 of leptons/hadrons i.e. hybrid  
 models

**H.E.S.S.**  
**The HESS GPS**  
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 shell-like  
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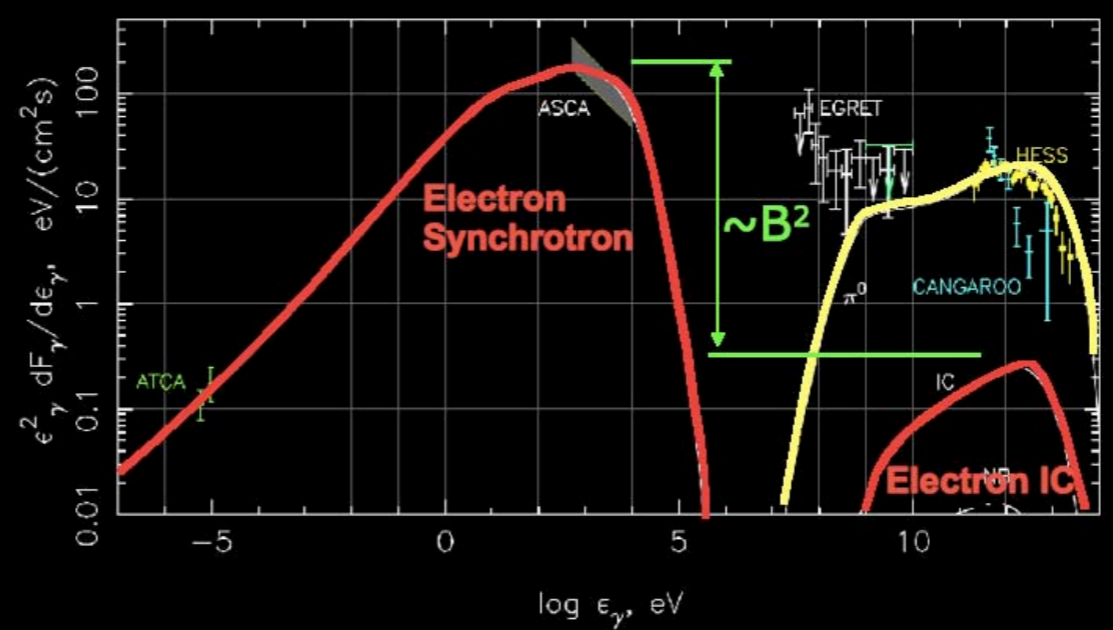
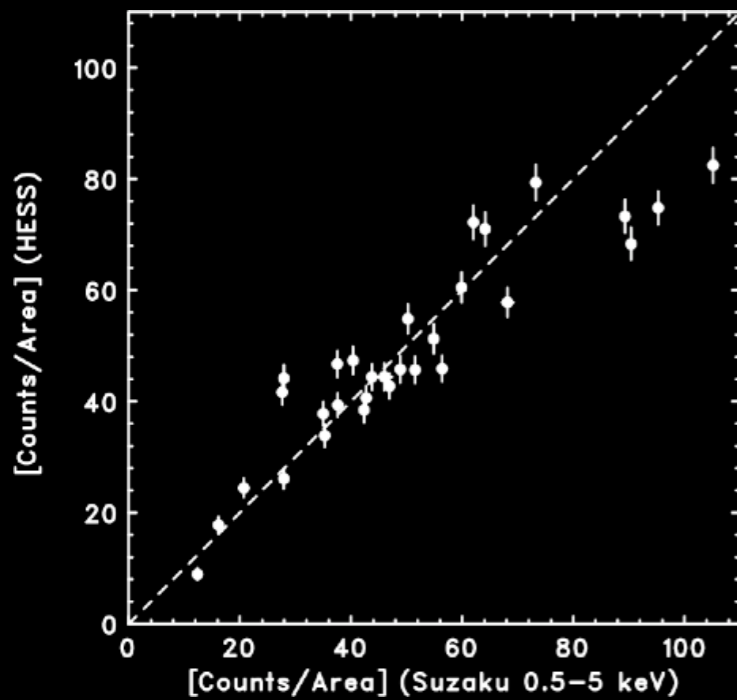


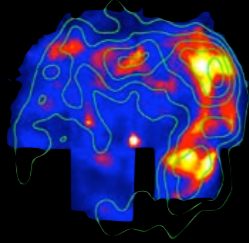


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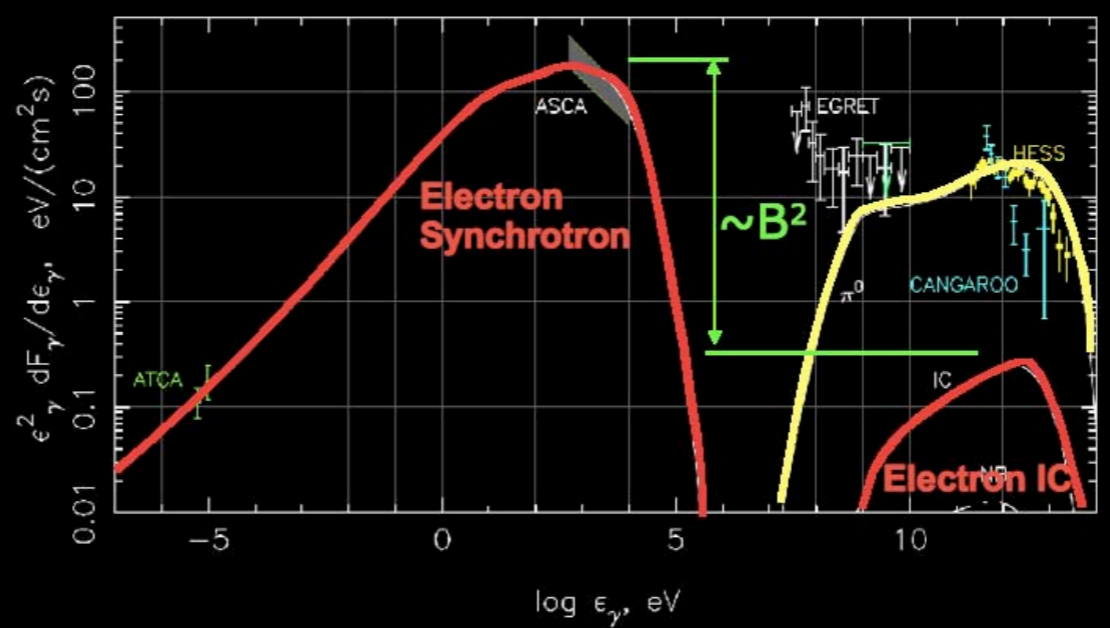
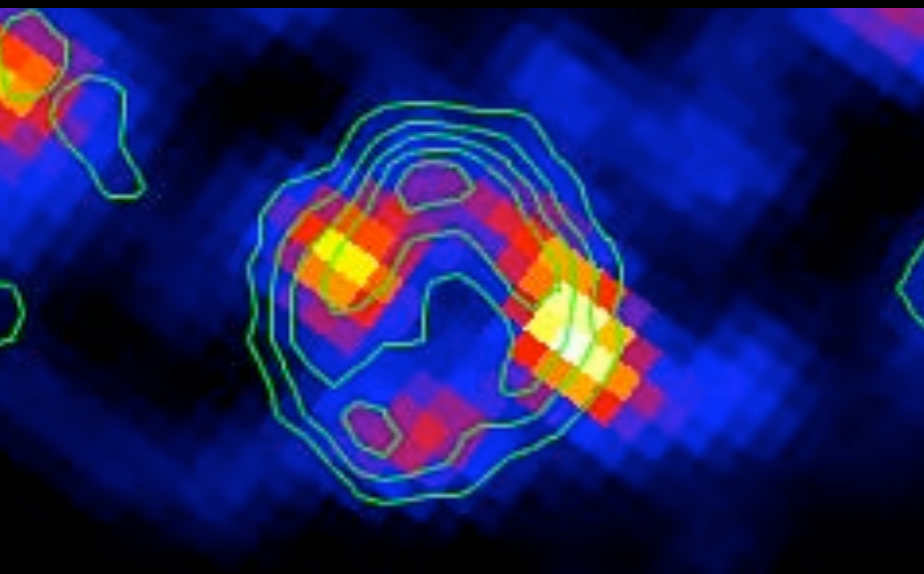




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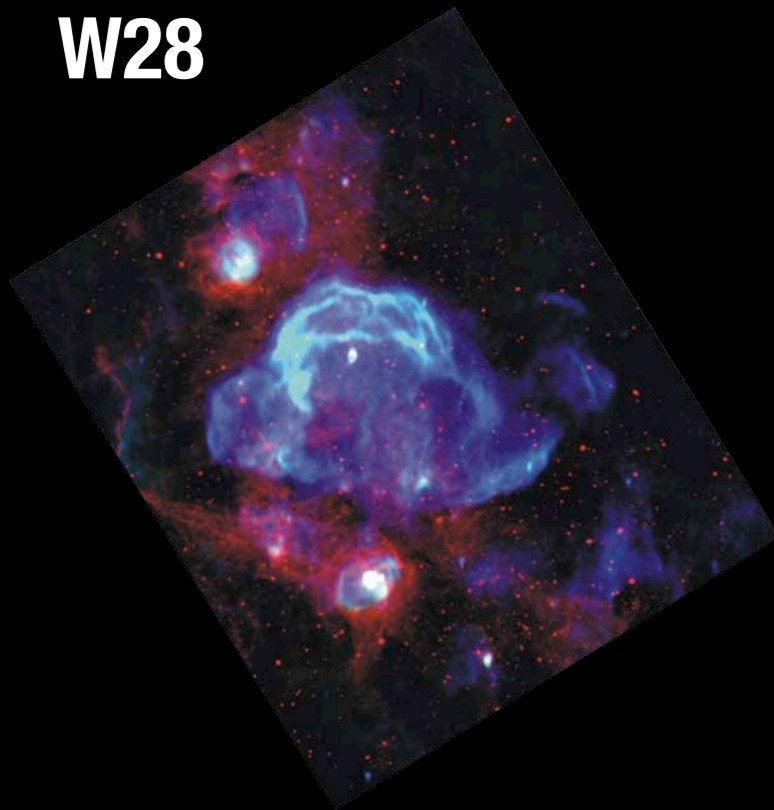
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>10 TeV

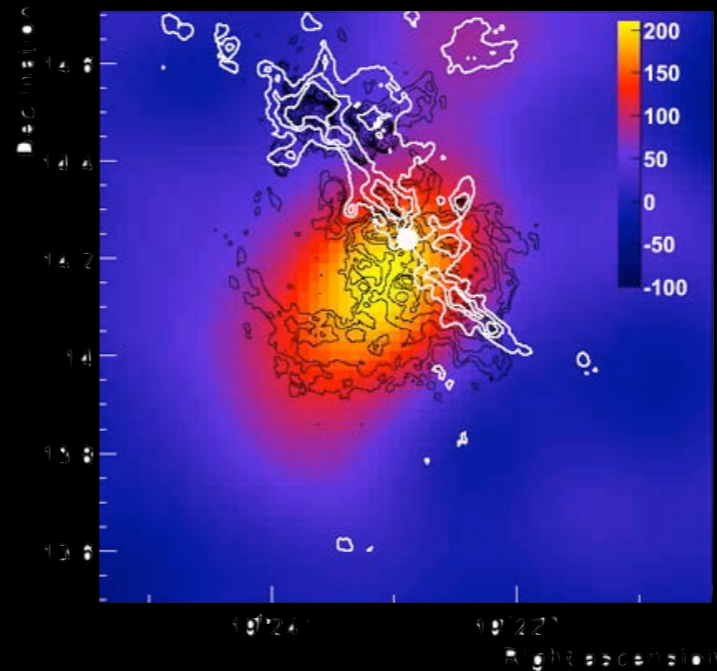
Fermi + AGILE results

**W28**

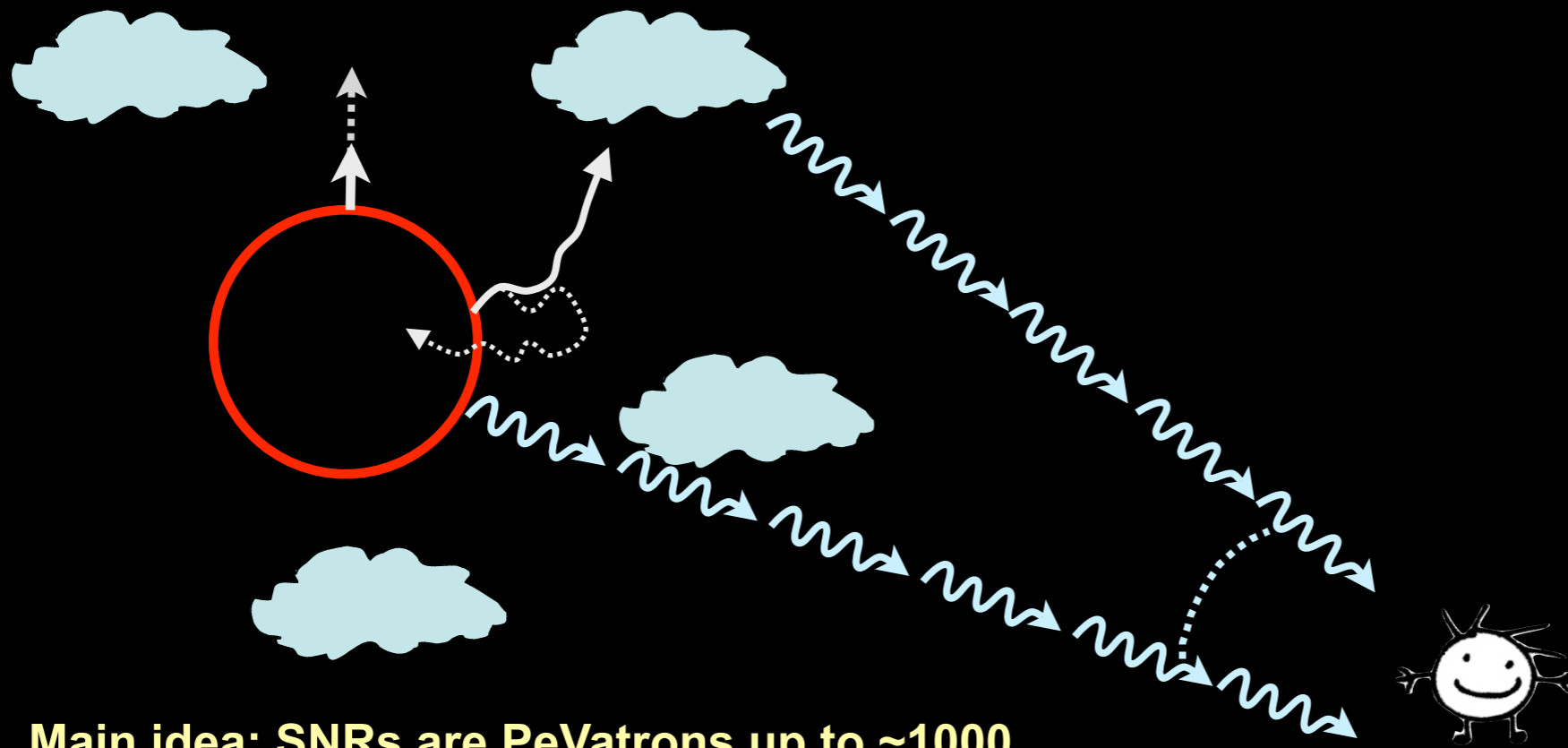


Evidence of cosmic ray acceleration?

**W51**



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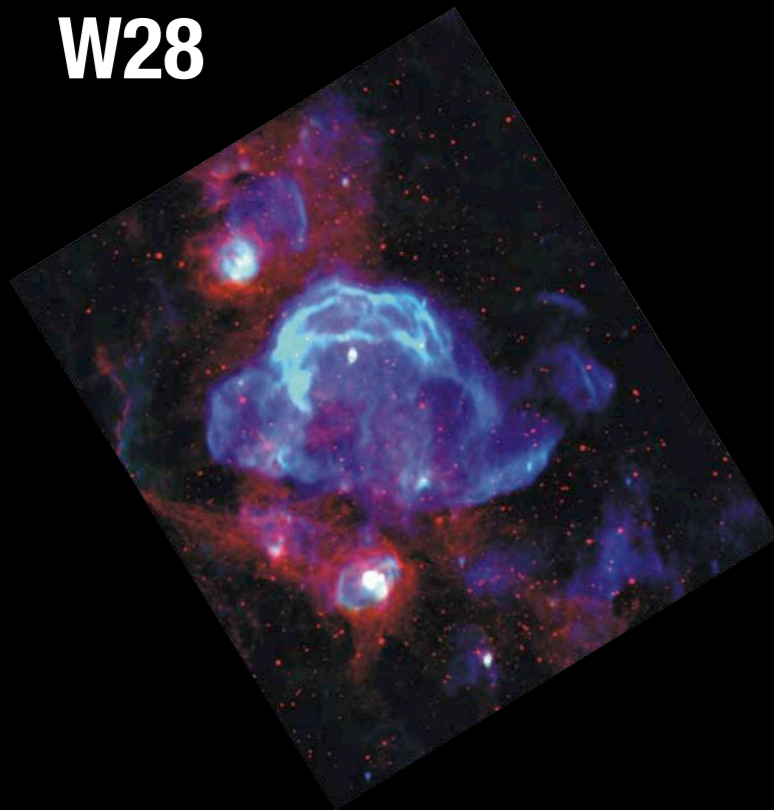
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*Gabici, Aharonian et al, 2009*

*E. de Oña-Wilhelmi, Astrophysical Plasmas, St. Barbara*

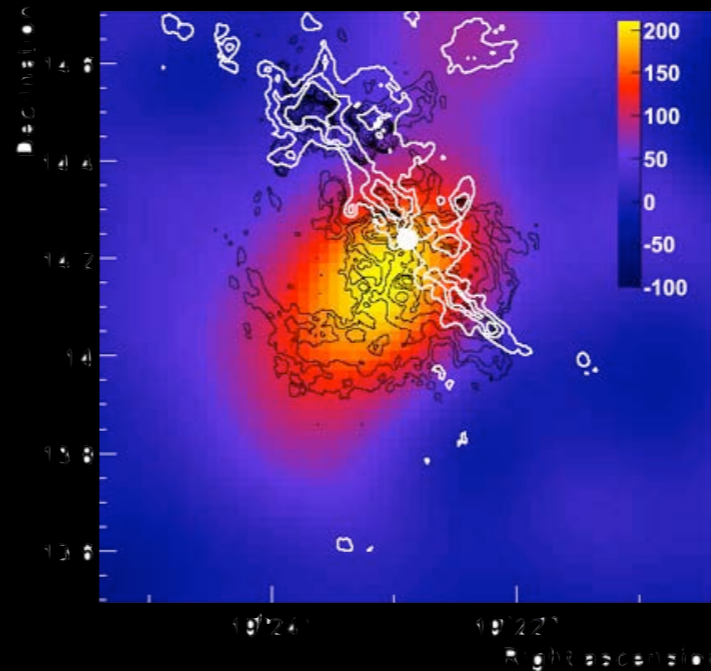


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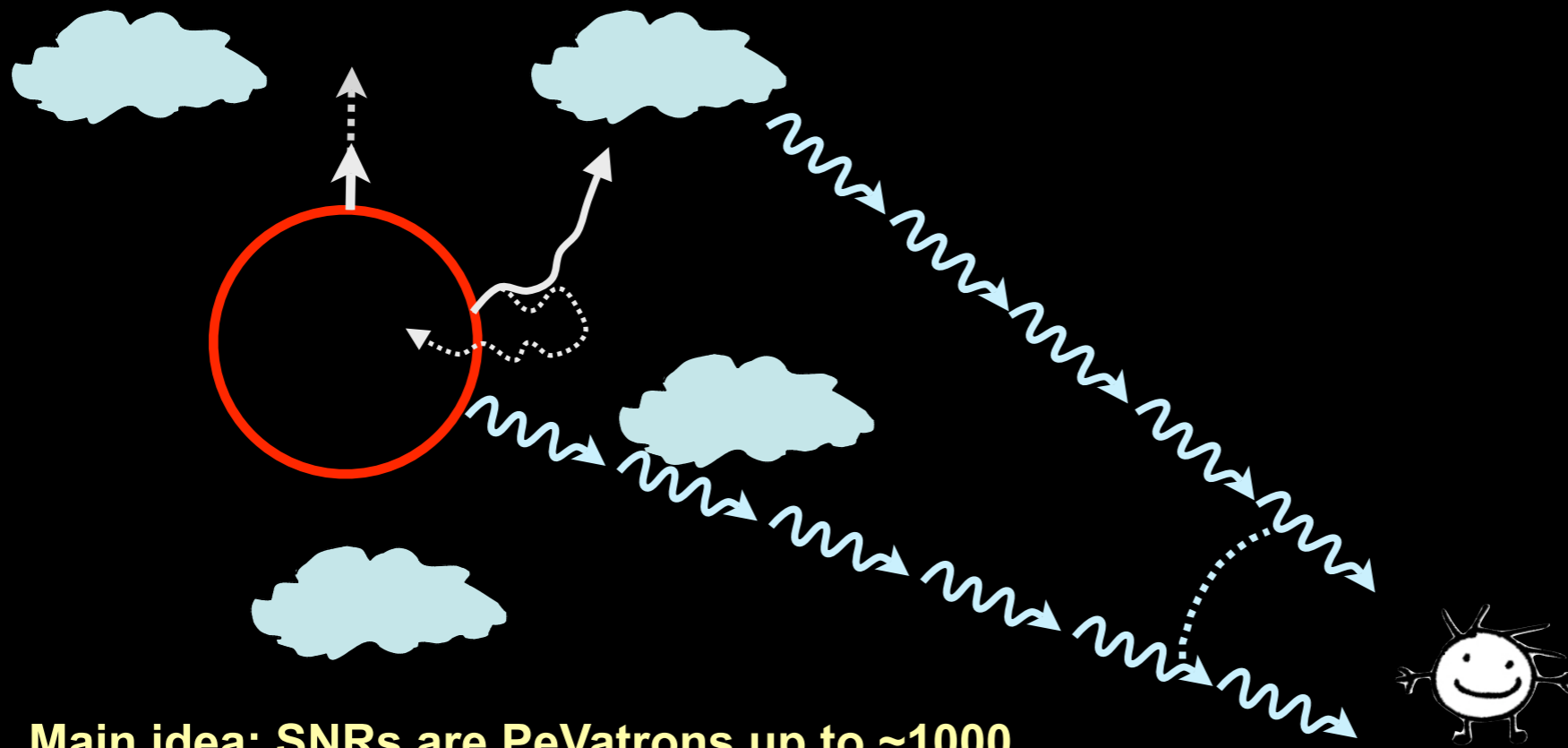


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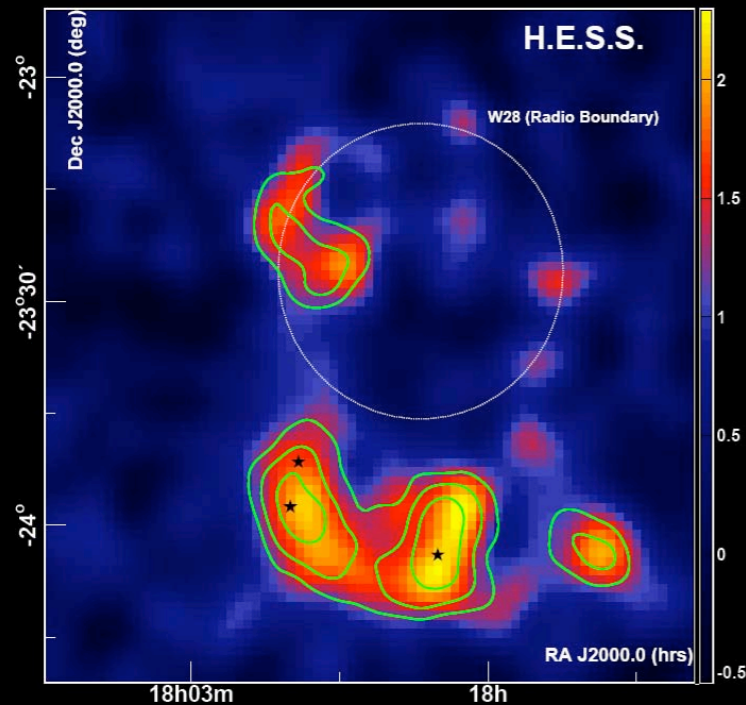


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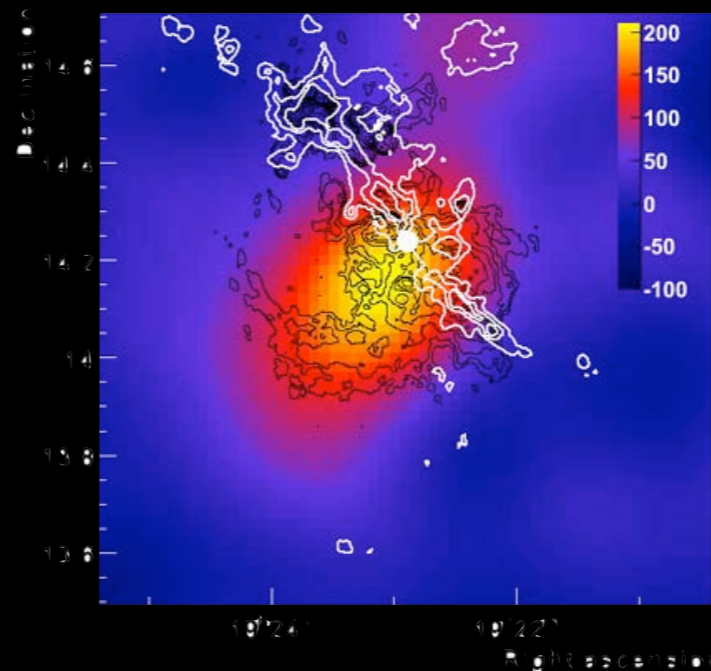
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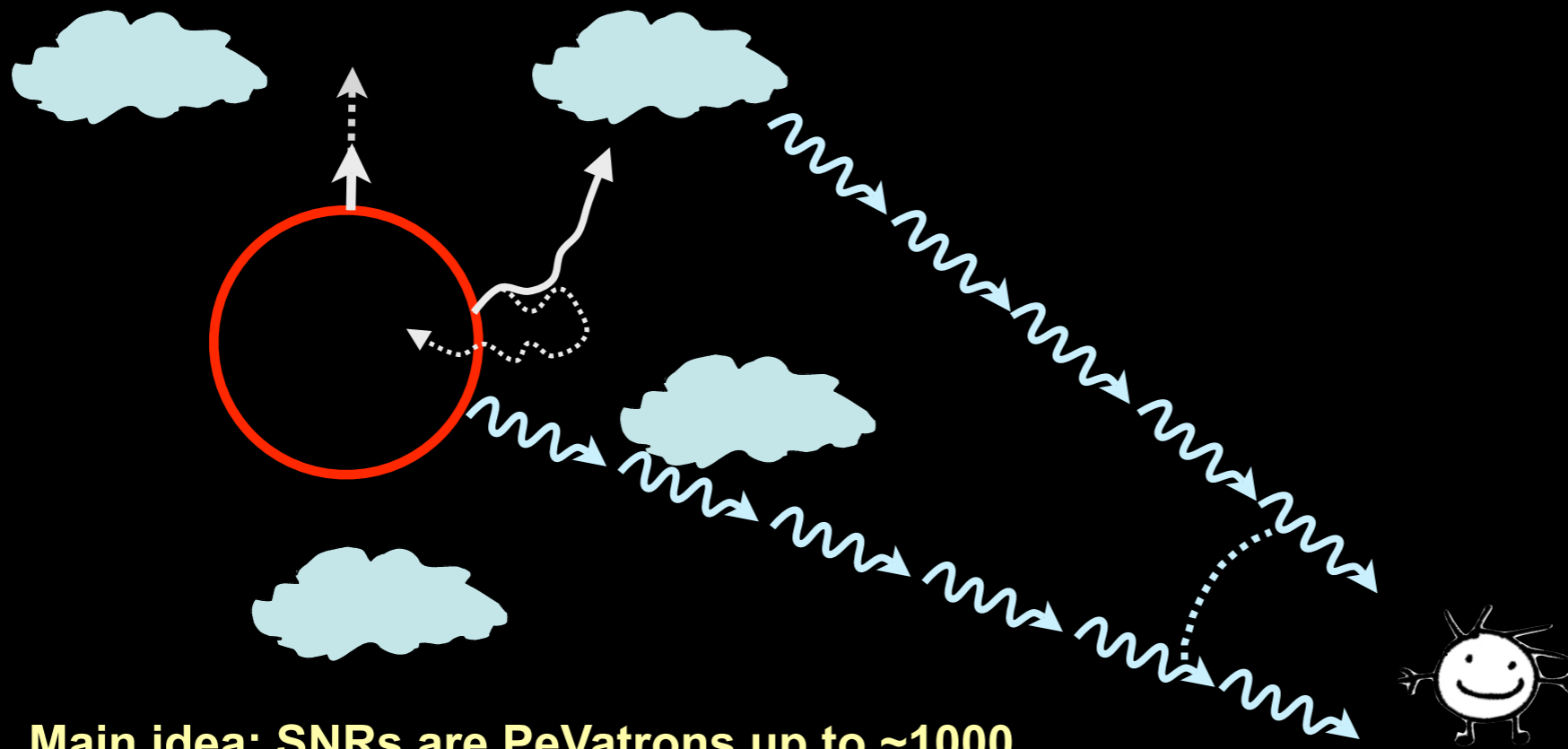


# Evidence of cosmic ray acceleration?

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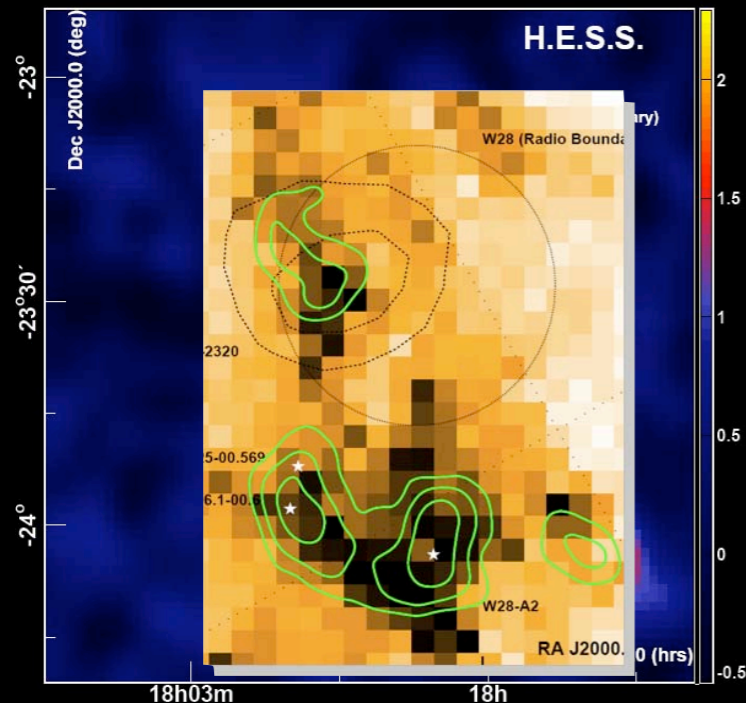
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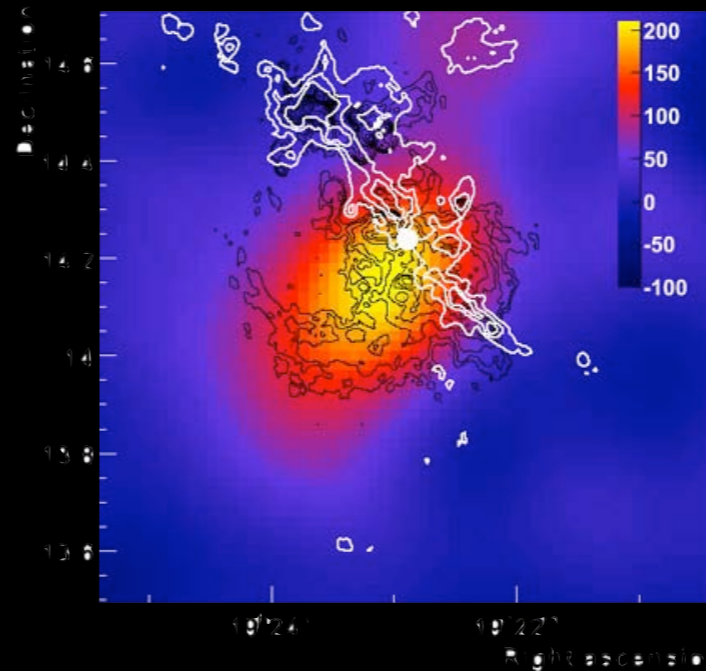
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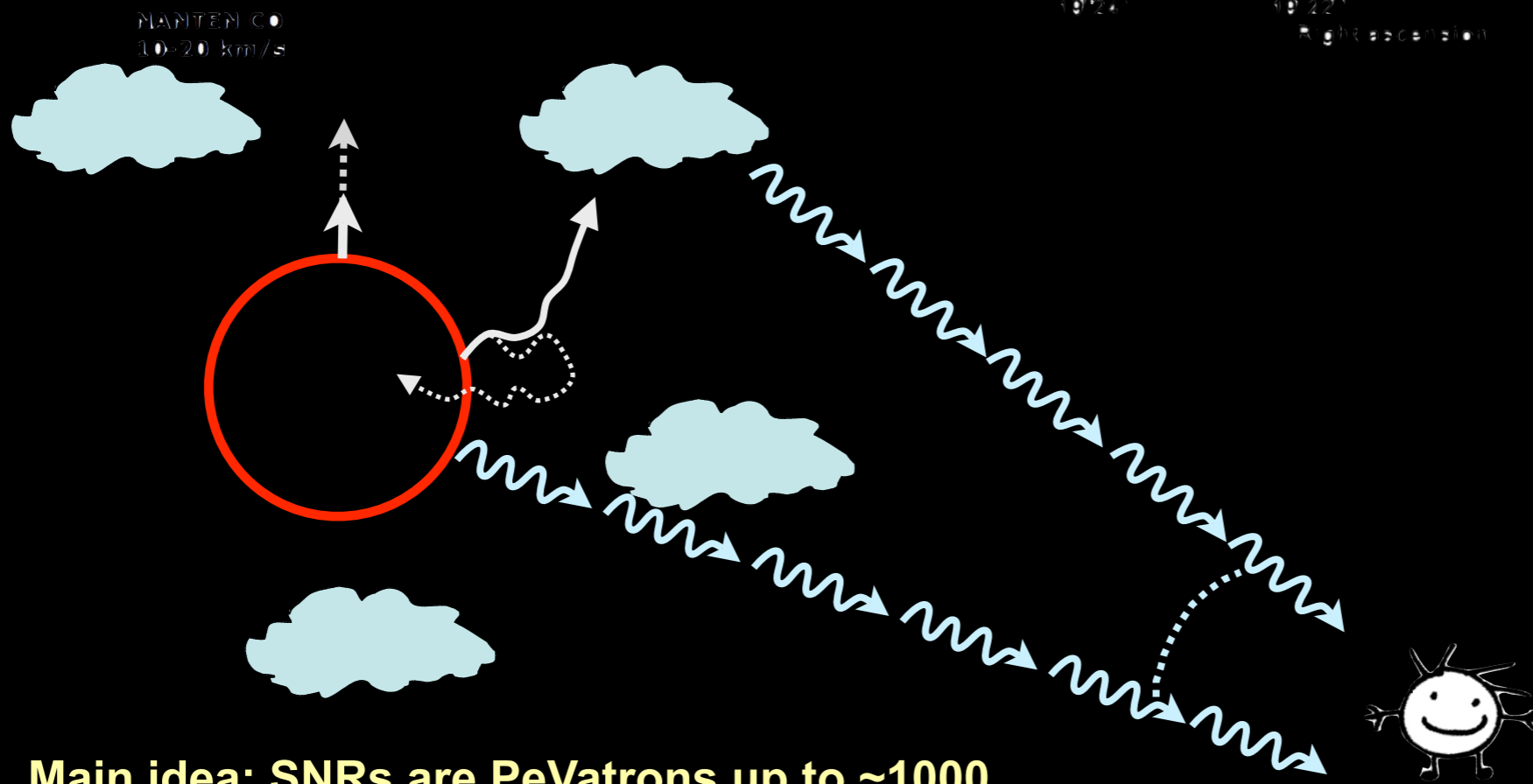
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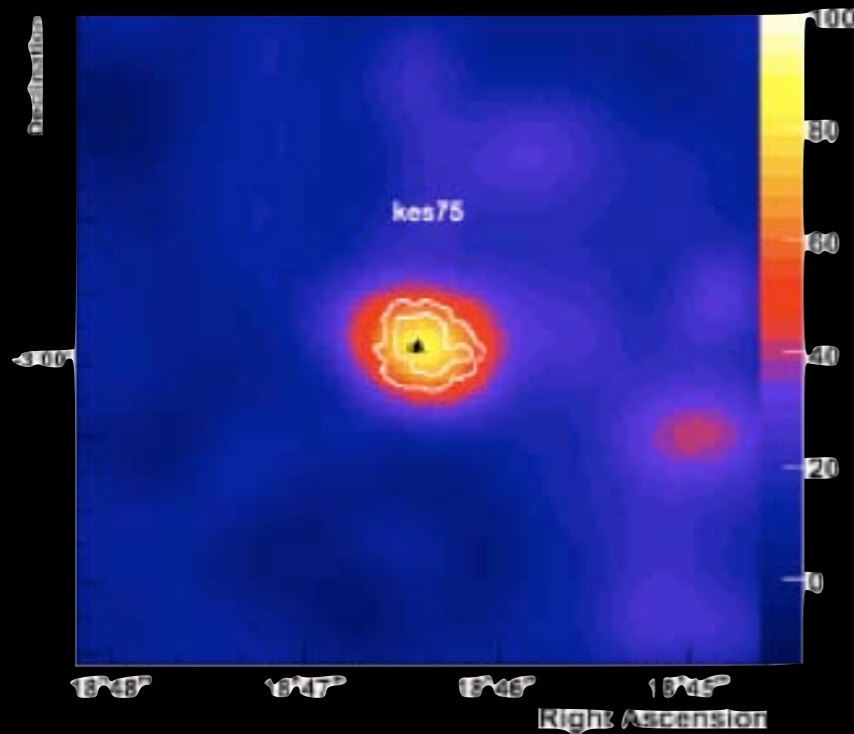


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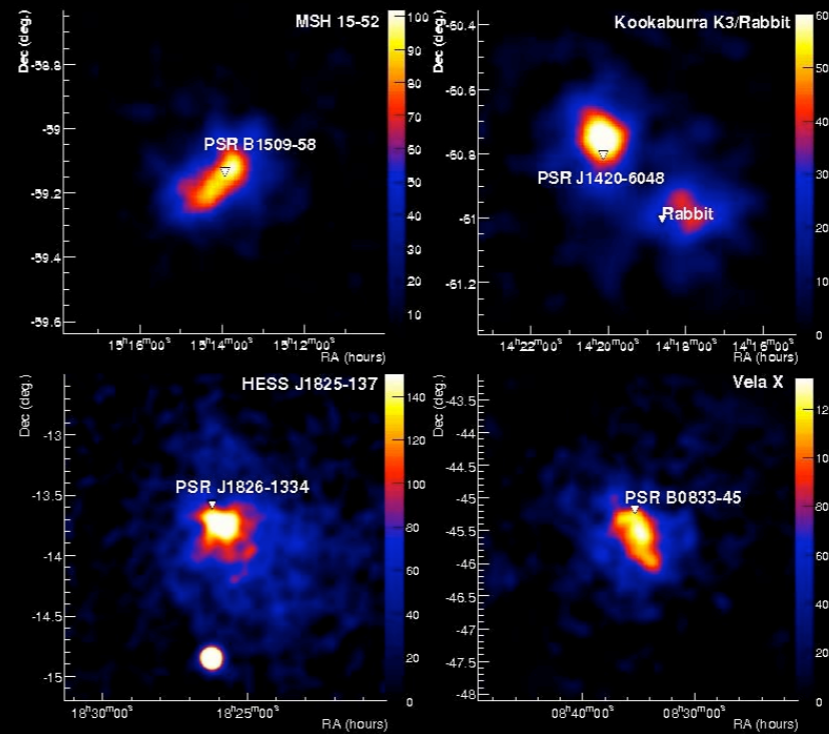
## Young PWN



- ✓ Crab Nebula
- ✓ G0.9+0.1
- ✓ N157B in LMC
- ✓ Kes 75
- ✓ HESS J1834-087
- ✓ G292.2-0.5

- Major galactic source population
- Associated with
  - very young: age  $< 10^5$  yrs
  - energetic:  $\dot{E} > 10^{35}$  erg/s

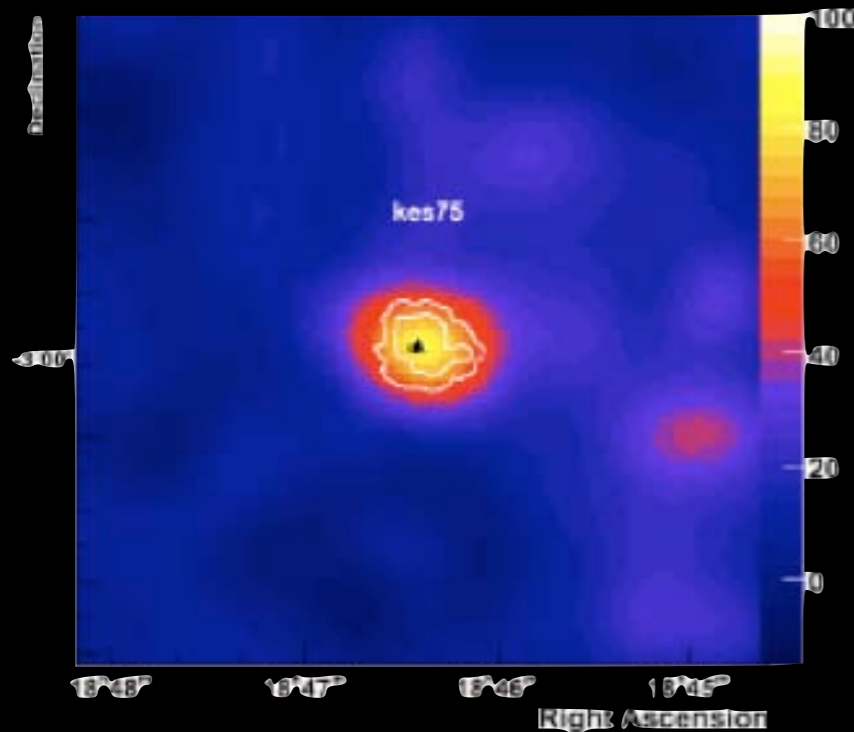
## Evolved PWN



- ✓ MSH 15-52
- ✓ Kookaburra & Rabbit
- ✓ Vela X
- ✓ PSR J1708-443
- ✓ HESS J1825-137

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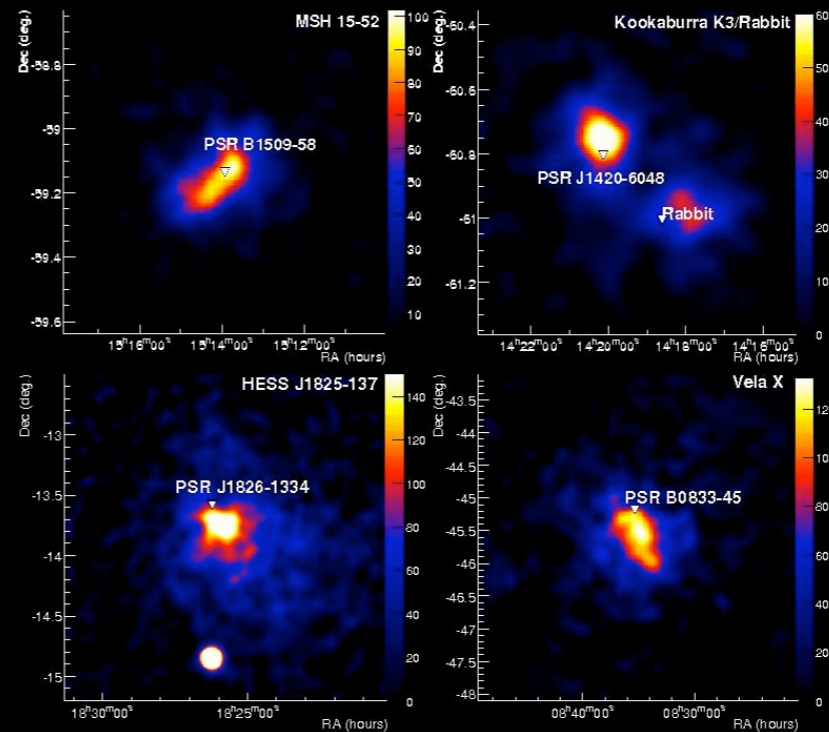
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## Young PWN

## ☑ NI57B in LMC

- Satellite spiral galaxy  $\sim 10^\circ$  extension  $d \sim 48$  kpc
- Site of the recent and closest supernova SNI987A
- 44 h observation with HESS with  $E_{th} \sim 500$  GeV

New  $\gamma$ -ray coincident with SNR N  
157 B/PSR J0537-6910

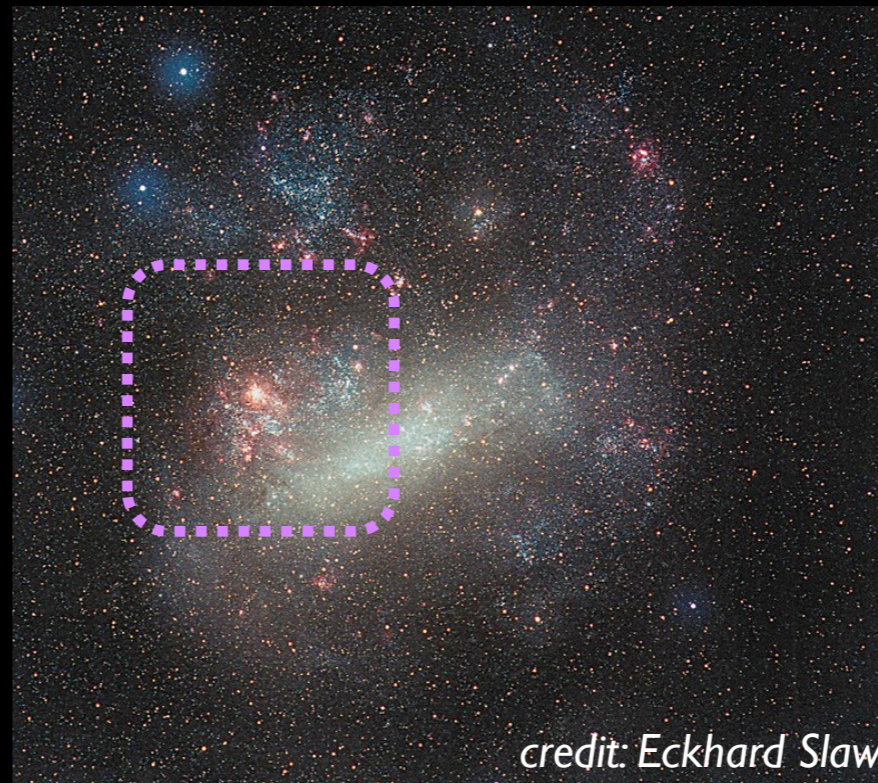
IC from PWN

flux (1-10 TeV)  $\sim 10^{-12}$  erg cm $^{-2}$  s $^{-1}$

Most powerful pulsar known

$\dot{E} = 4.9 \cdot 10^{38}$  erg s $^{-1}$

Apparent efficiency 0.01%  $\dot{E}$



credit: Eckhard Slawik

H.E.S.S.

The HESS GPS

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young PWN

evolved PWN

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Dark Sources

New Source Type

**Most distant  $\gamma$ -ray PWN**  
**First extra-galactic non-AGN TeV source**

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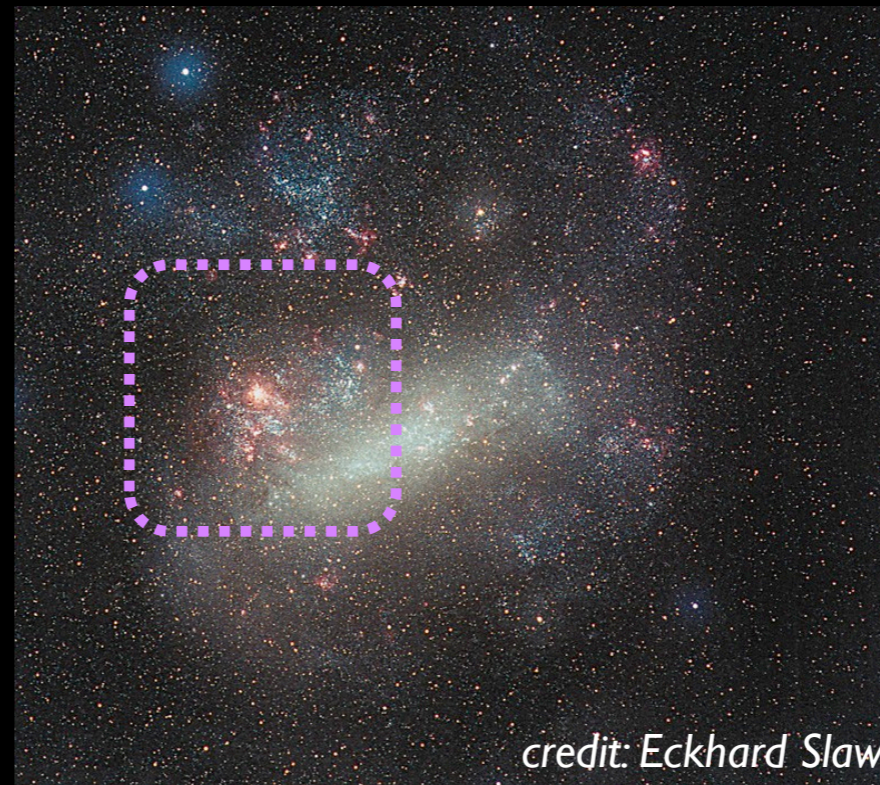
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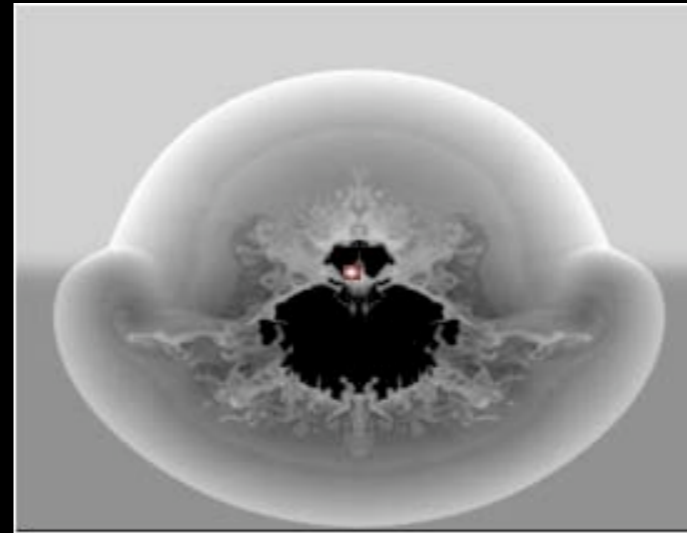
New Source Type

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✓ HESSJ1825-137

Probing cooling mechanisms in leptonic emission



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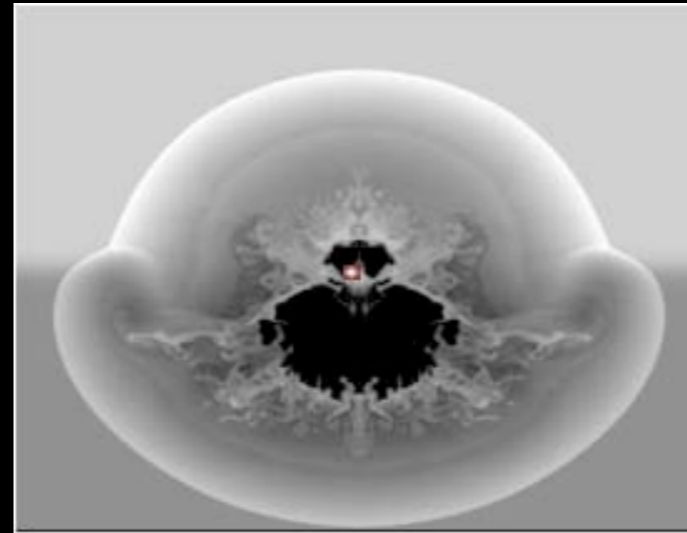
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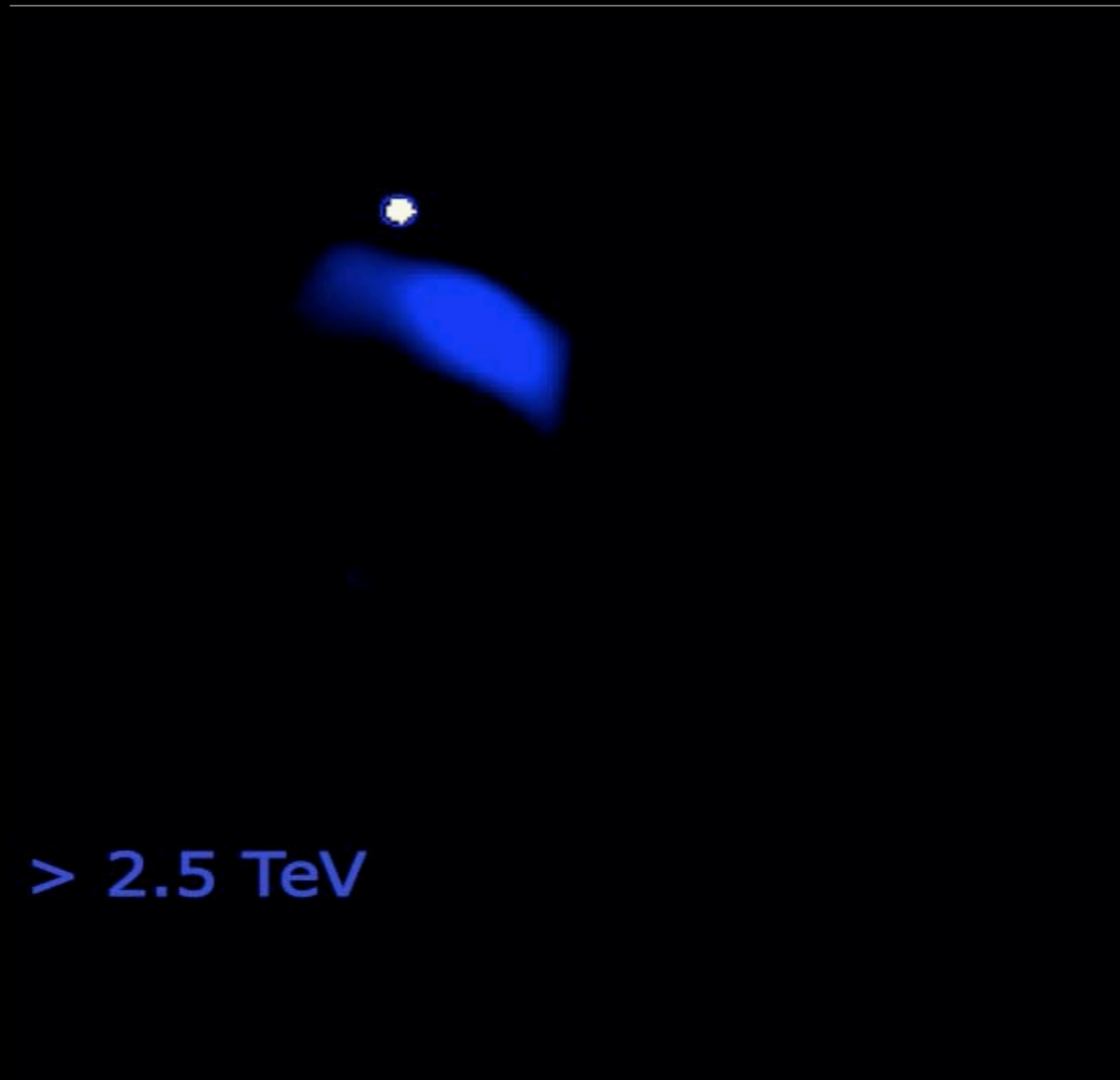
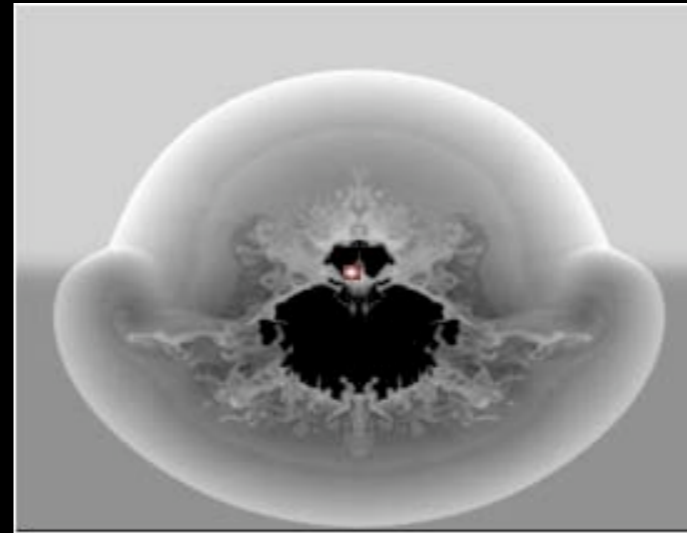
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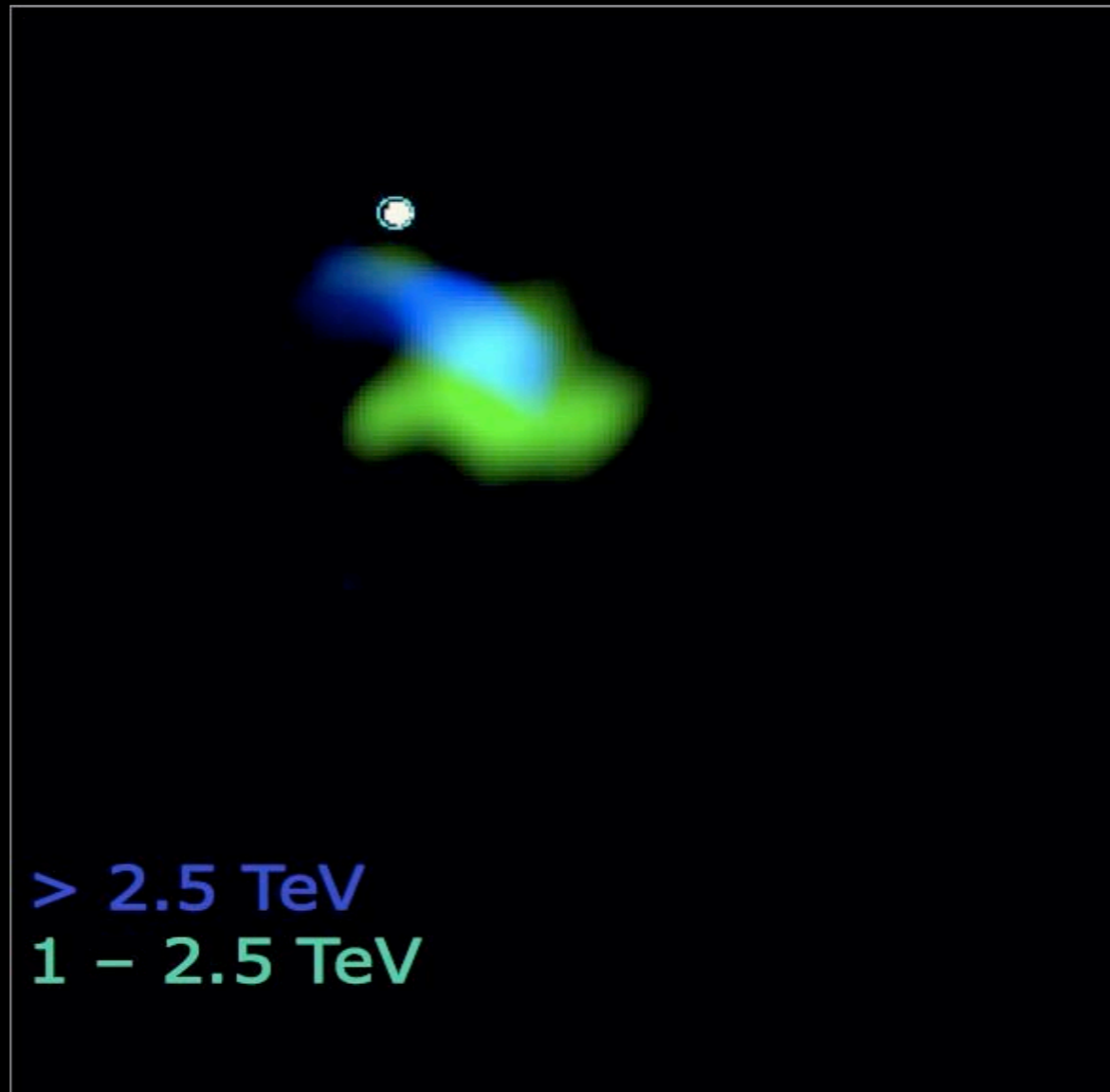
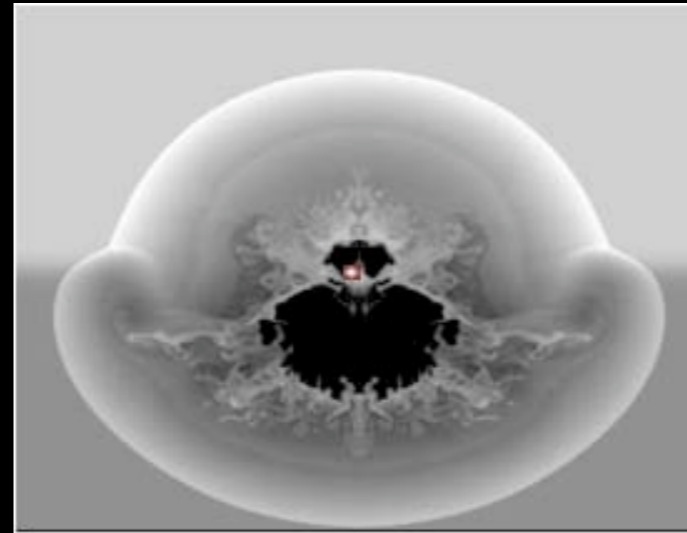
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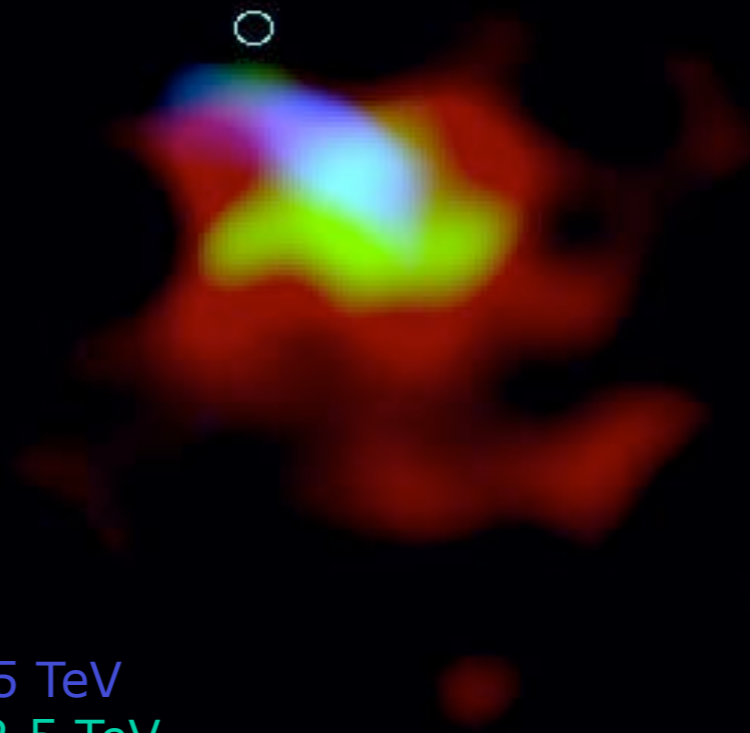
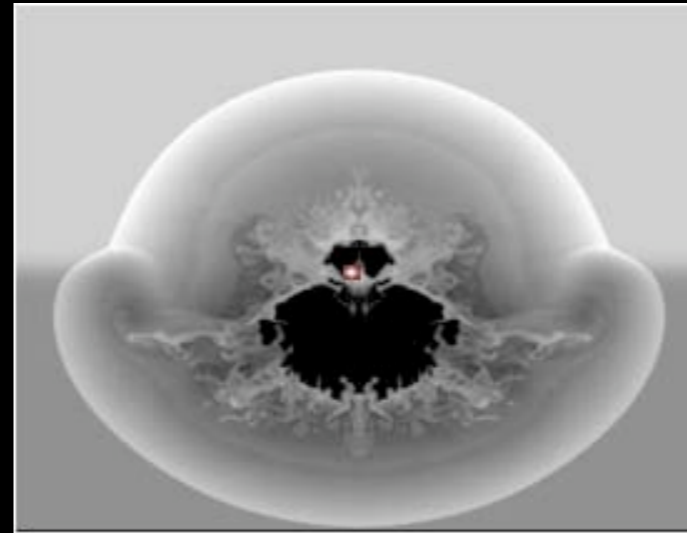
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> 2.5 TeV  
1 – 2.5 TeV  
< 1 TeV

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### ✓ PSR J1708-443

- No significant excess from the pular itself
- 17 % Crab

### PWN scenario

Vela like Pulsar

$d=2.5$  Kpc

$\dot{E}=3.4 \cdot 10^{36}$  erg  $s^{-1}$

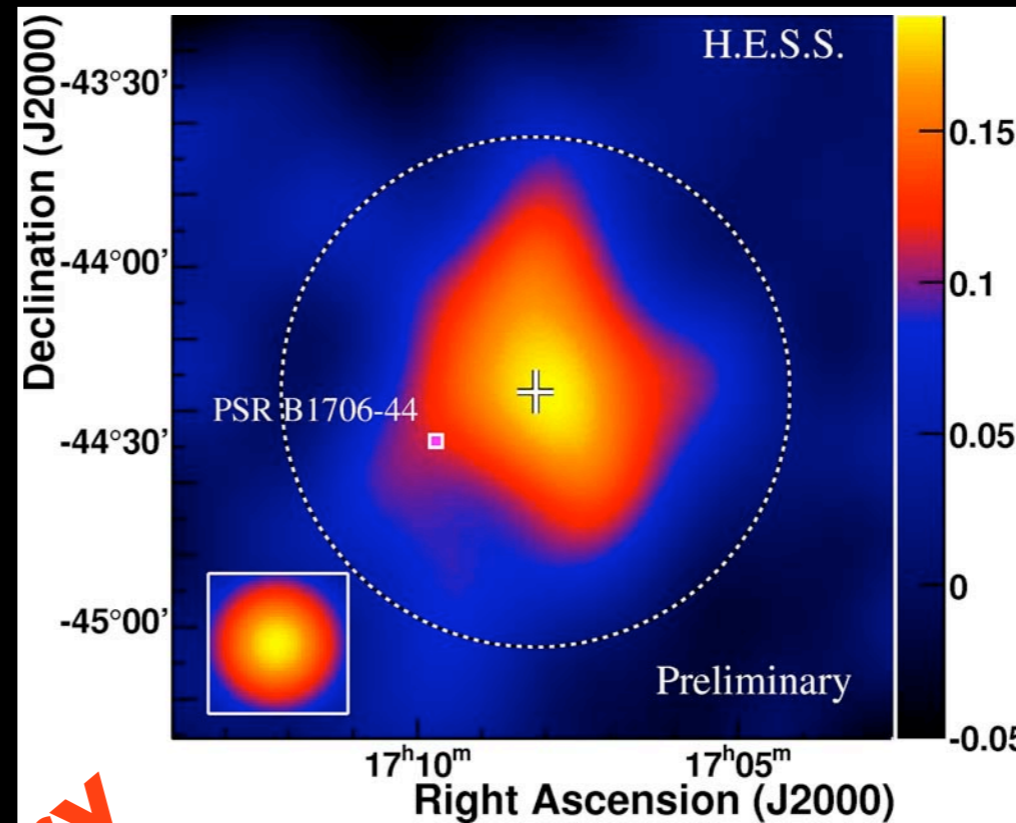
$L(1-10$  TeV)  $\sim 10^{34}$  erg  $s^{-1}$

Efficiency 0.4%  $\dot{E}$

$B \sim 140$   $\mu$ G

### SNR scenario

Non detection in X-rays  
challenges leptonic scenario



**Preliminary**

H.E.S.S.

The HESS GPS

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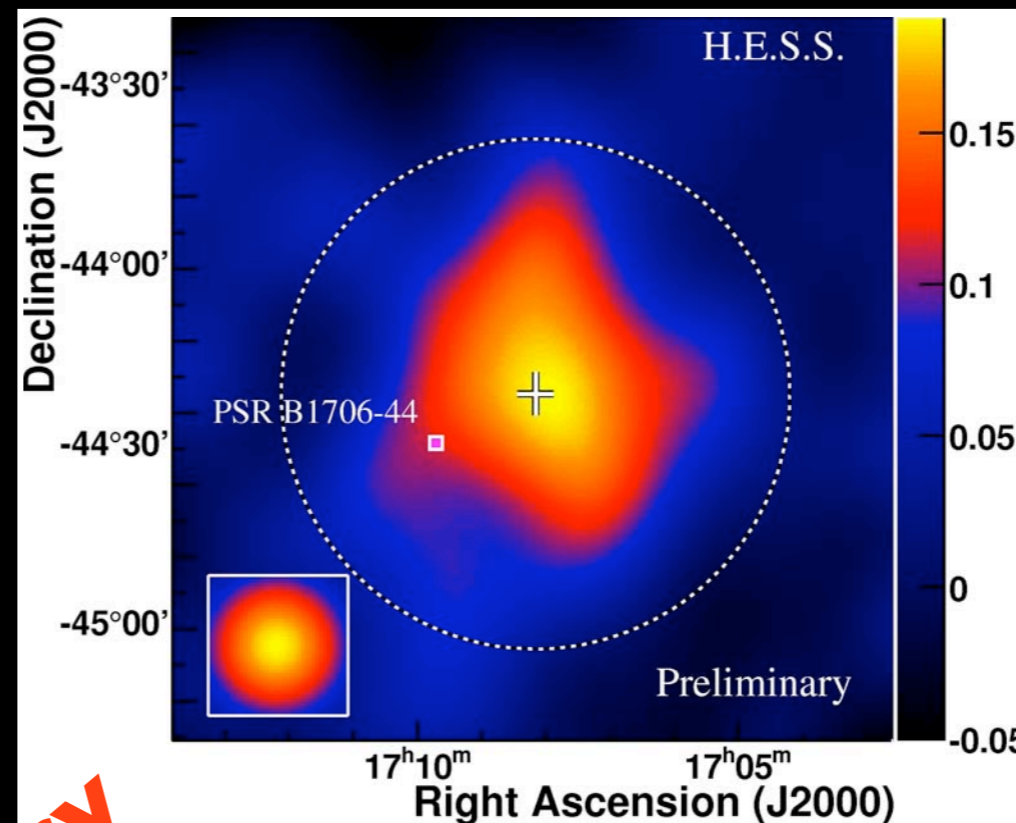
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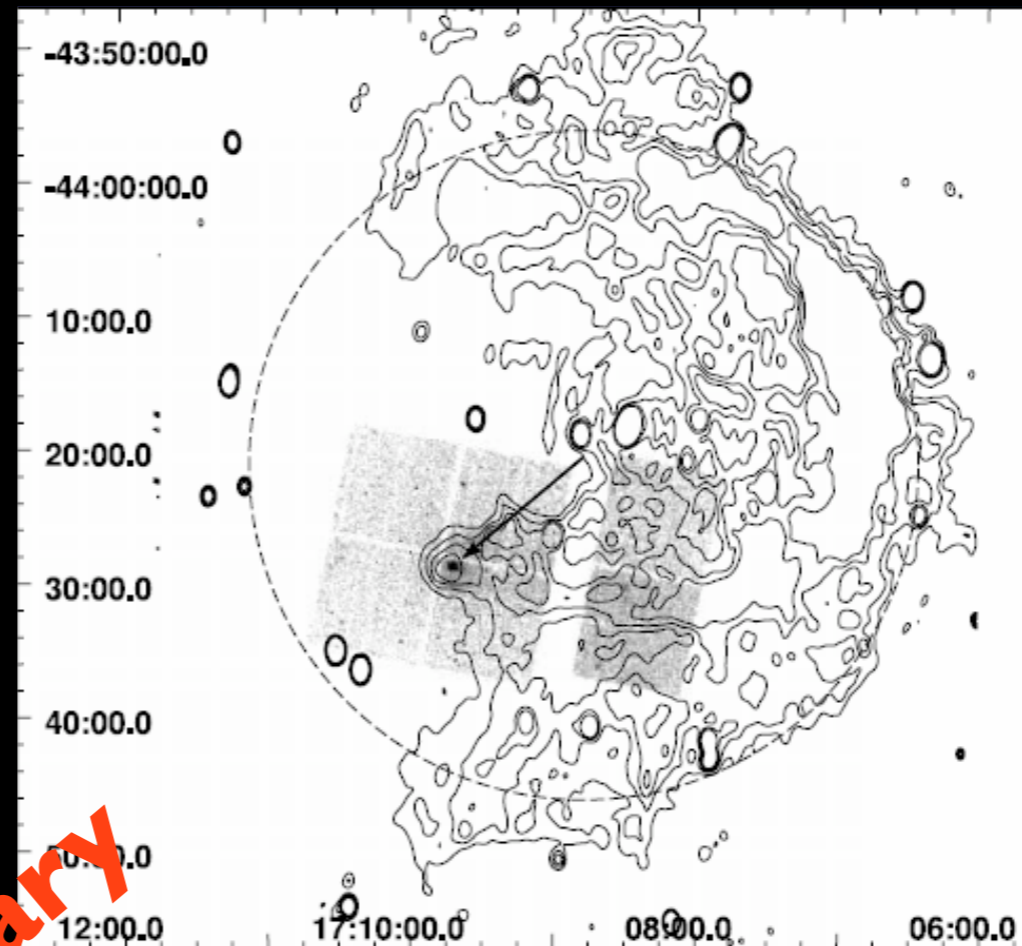
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ATCA+Chandra Romani et al 2005

H.E.S.S.

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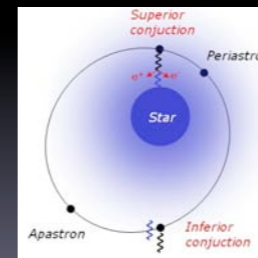
Binary Systems

Dark Sources

New source type

Preliminary

- X-ray binaries



Periodic Emission

Massive companion with a compact object in eccentric orbits

Gamma-ray emission believed to be due to interaction of leptons with the photons field of the companion

H.E.S.S.

The HESS GPS SNRs

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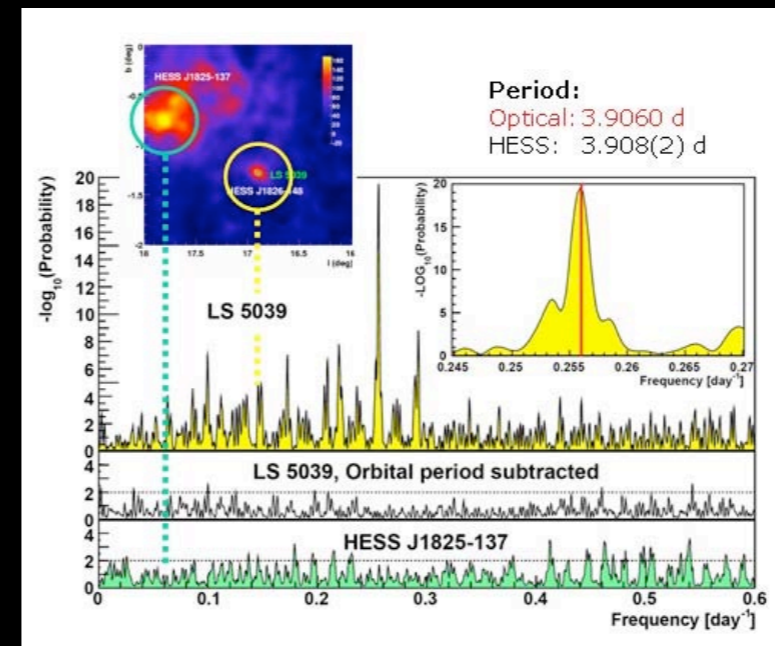
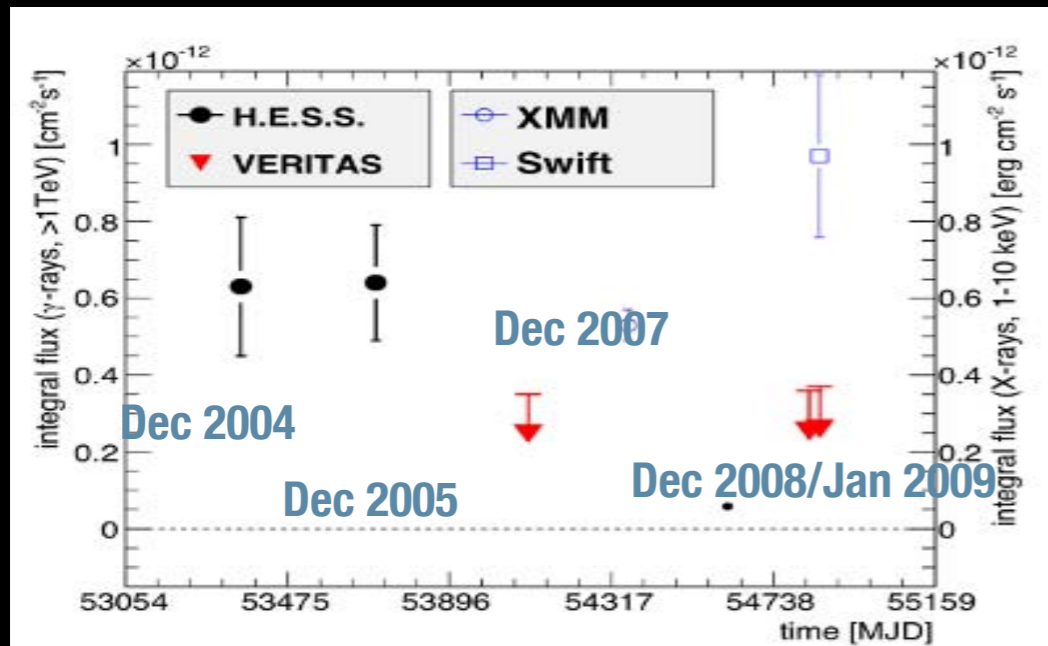
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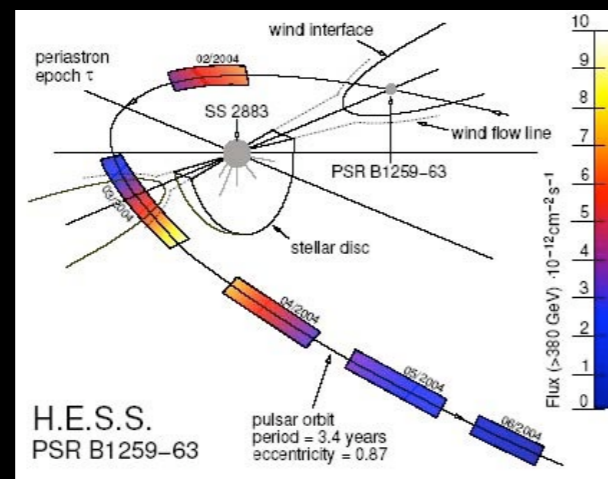
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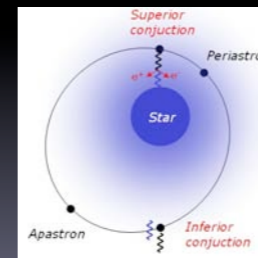


Monoceros (HESS J0632+057)





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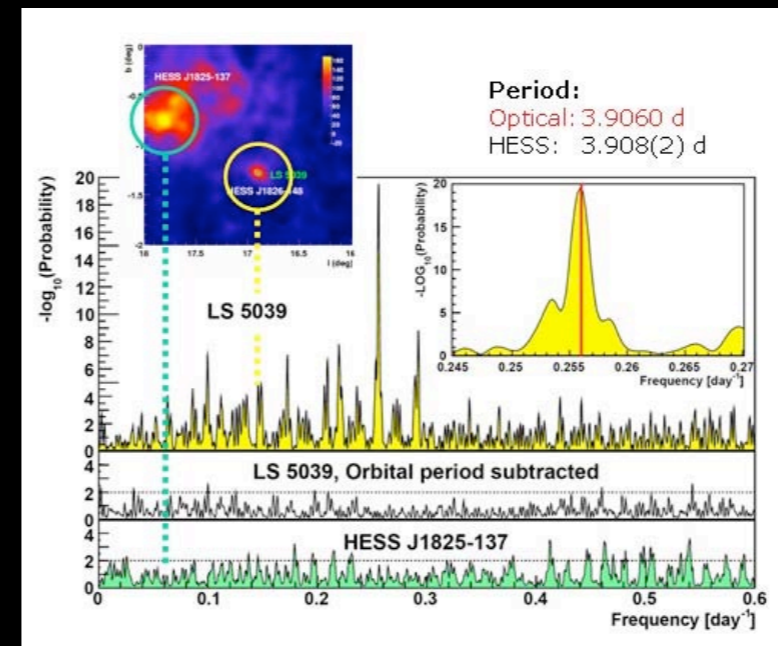
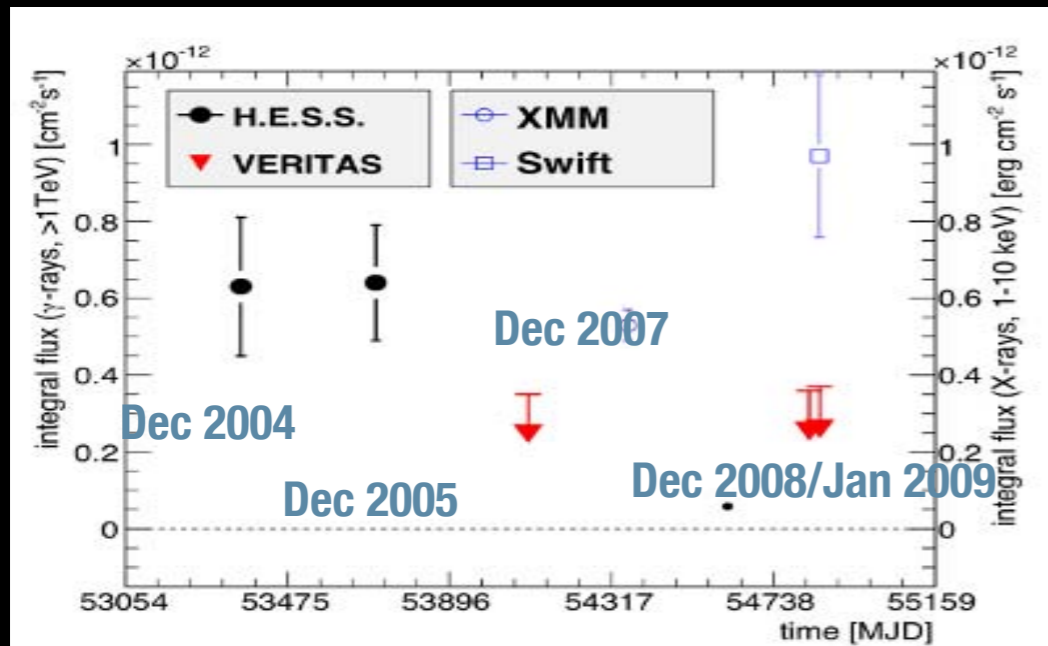
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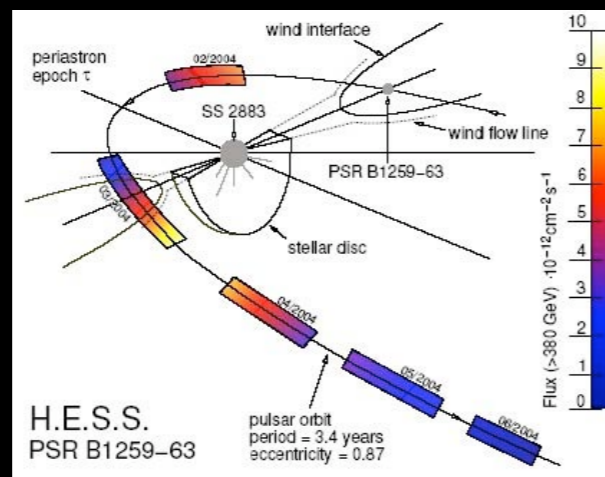
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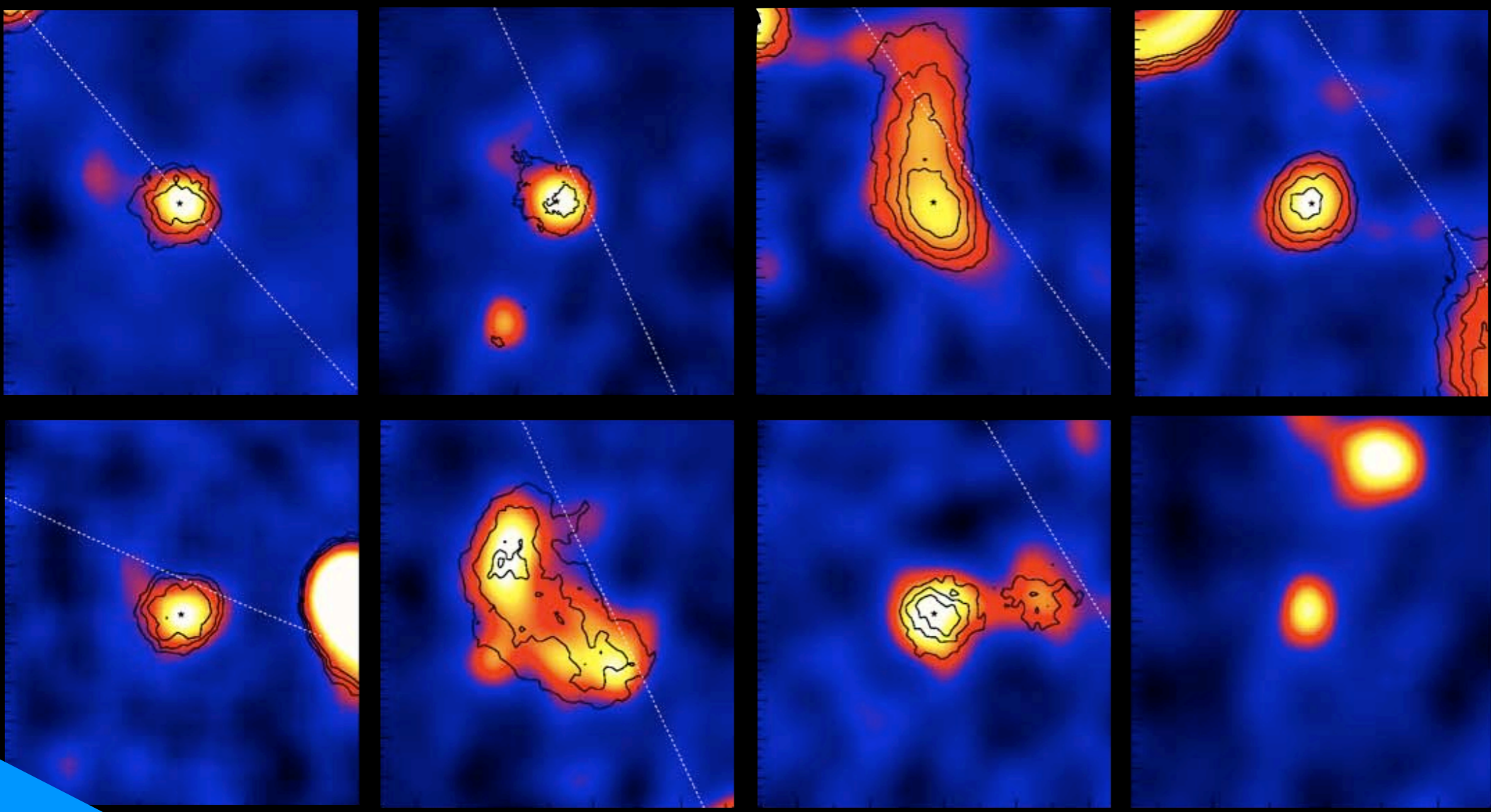


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Seem to shine only in g-rays  
No plausible counterparts in radio, x-rays...  
New type of CR accelerators? (if leptons expected x-rays, radio)

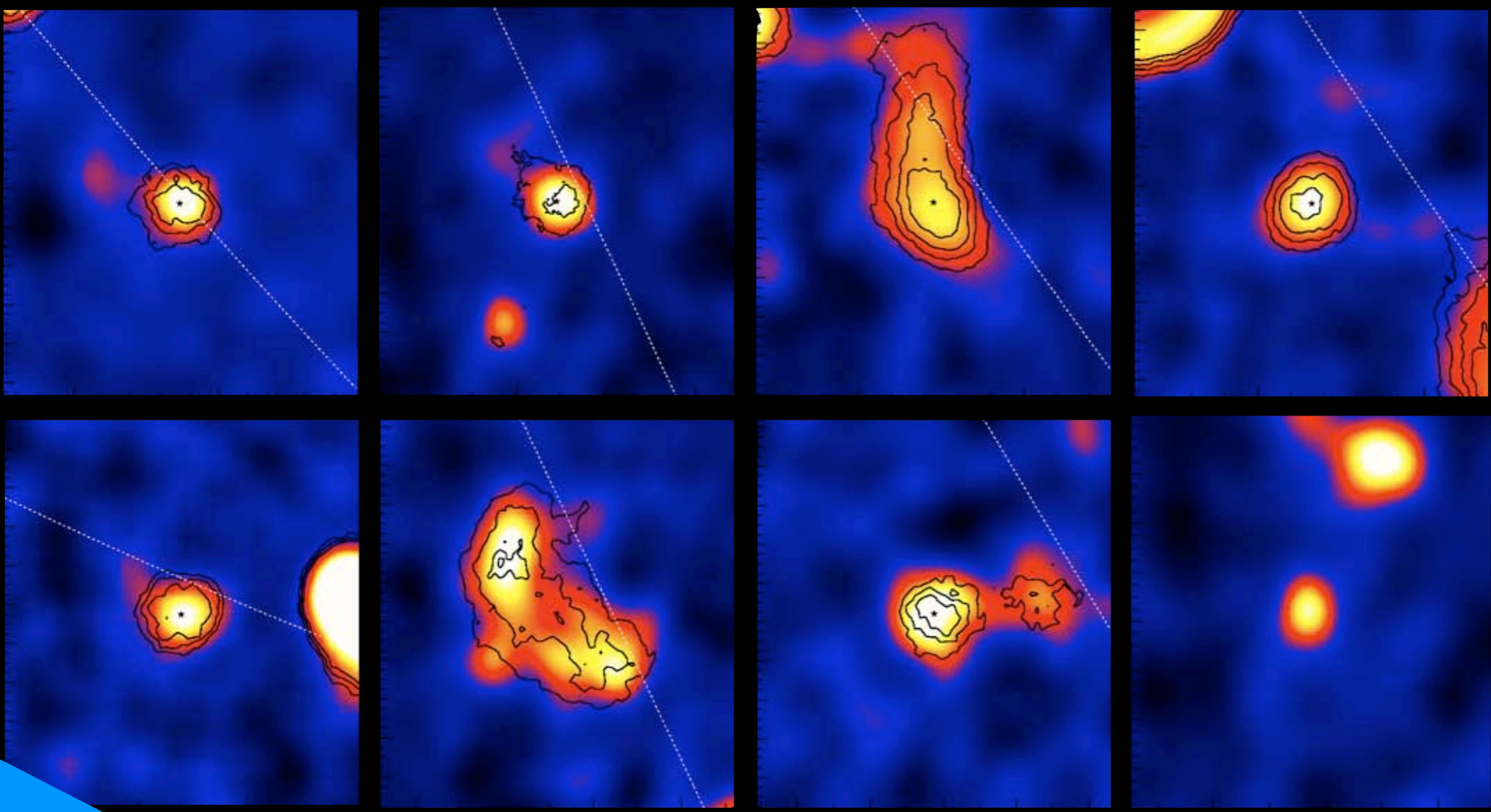
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A. Bamba Presentation

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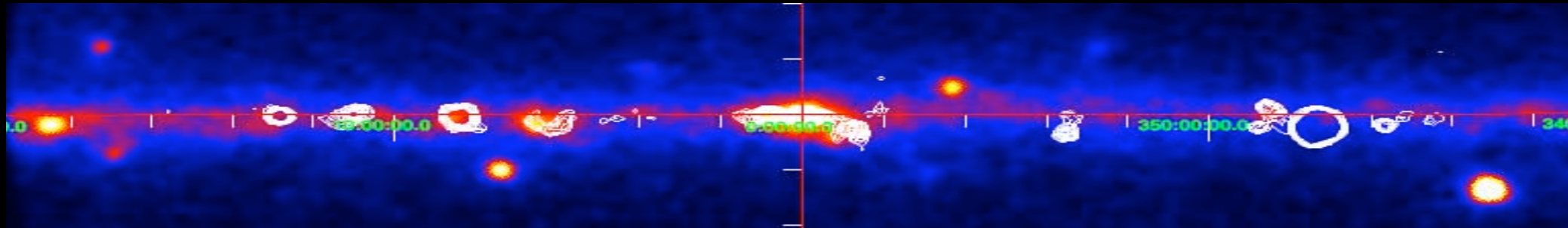
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New type of CR accelerators? (if leptons expected x-rays, radio)

Fermi LAT : 100 MeV 100 GeV



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

**The HESS GPS**

**SNRs**

shell-like

interacting with MC

**PWN**

young PWN

evolved PWN

**Binary Systems**

**Dark Sources**

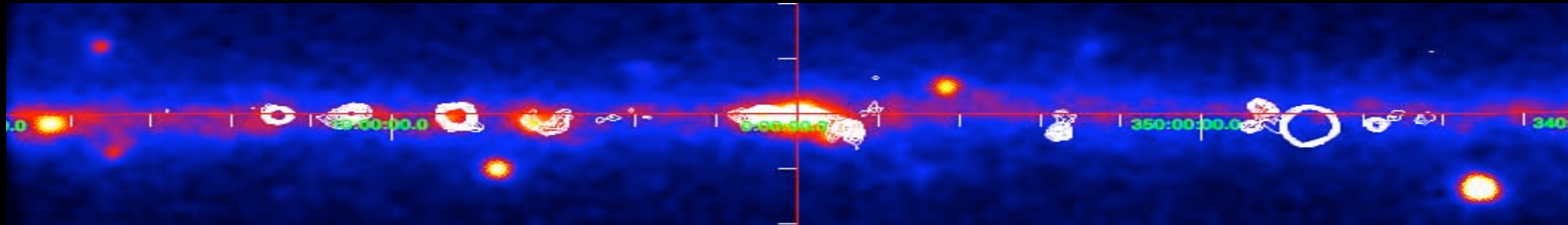
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# Stellar Clusters

## Westerlund I

- Most massive star cluster in our Galaxy
- > 24 WR stars, supergiants and hypergiants, binaries

### It means:

Massive Stars -> SN explosions

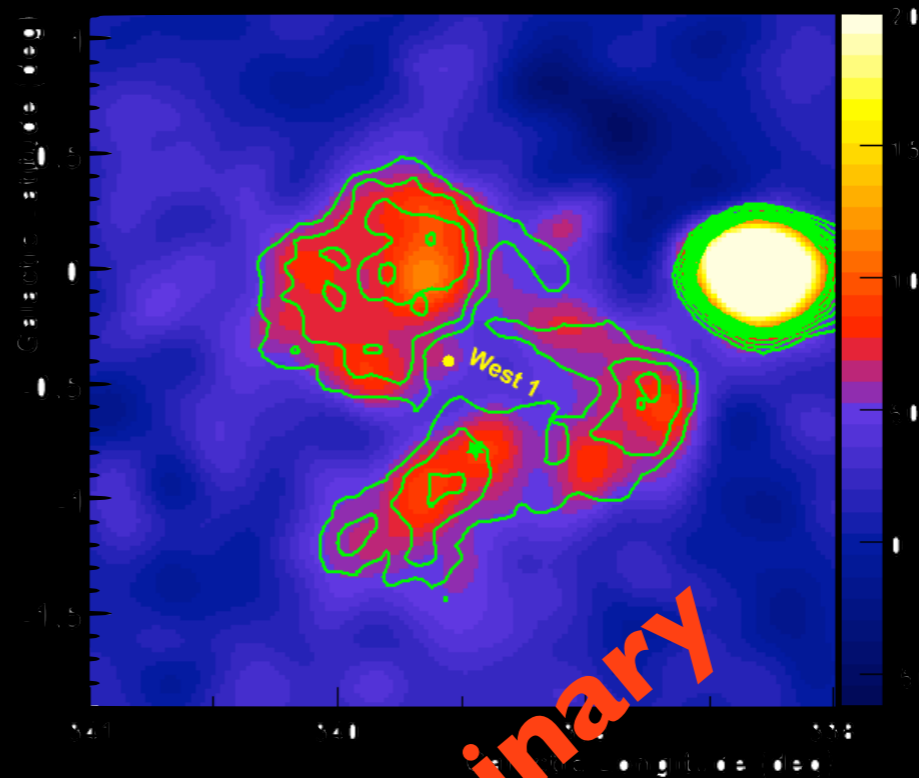
Age -> Most massive stars already evolved into SNe

Binaries -> colliding winds

### Energy:

WR winds ->  $10^{39}$  erg s<sup>-1</sup>

SNe ->  $3 \cdot 10^{39}$  erg s<sup>-1</sup>



Preliminary

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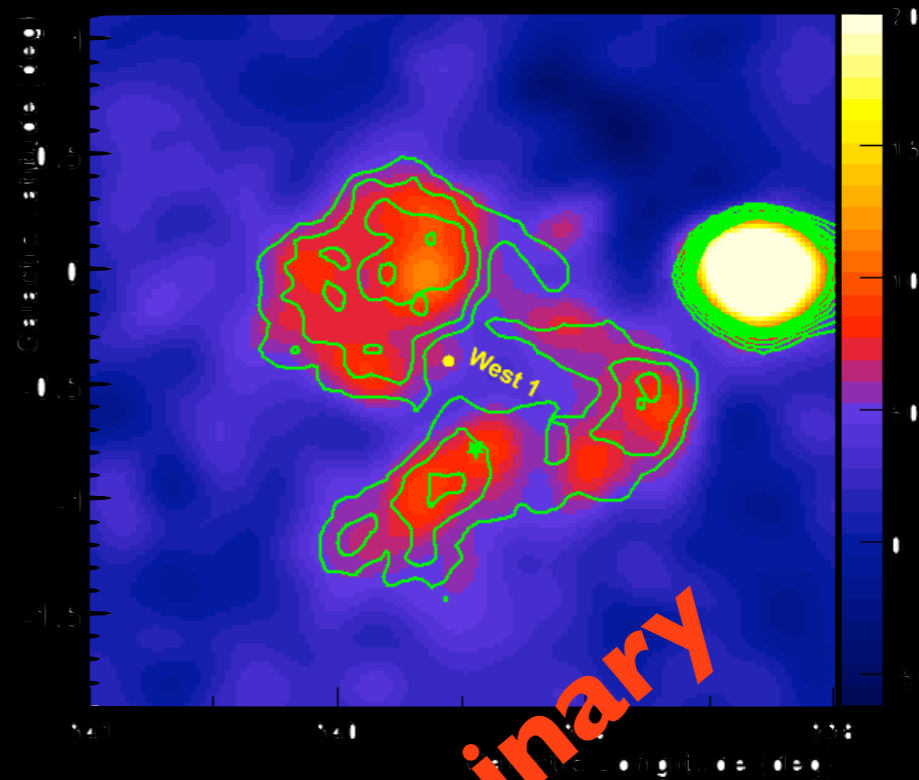
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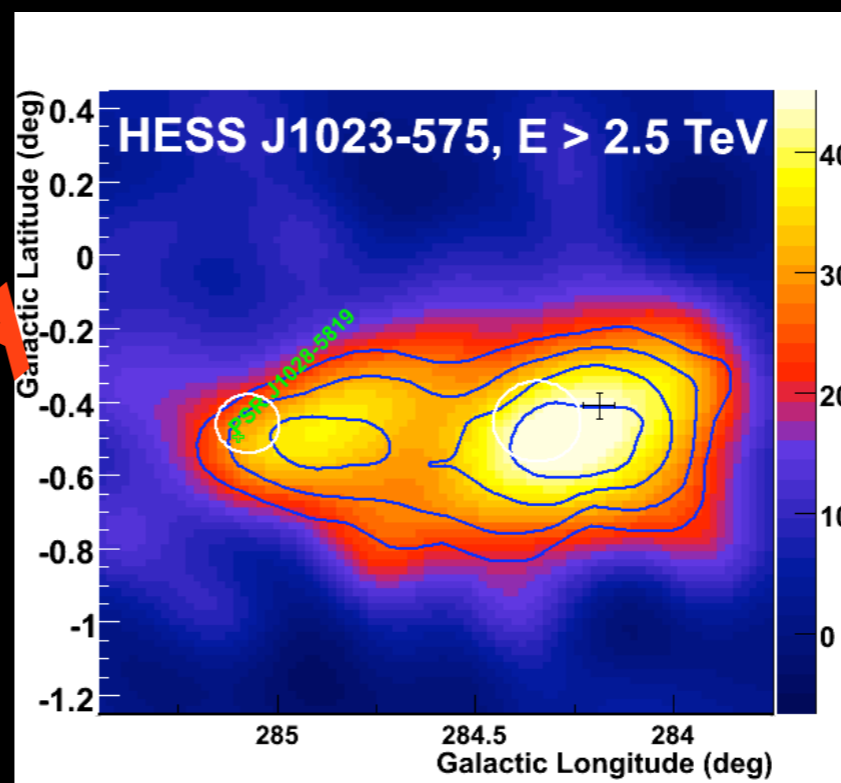
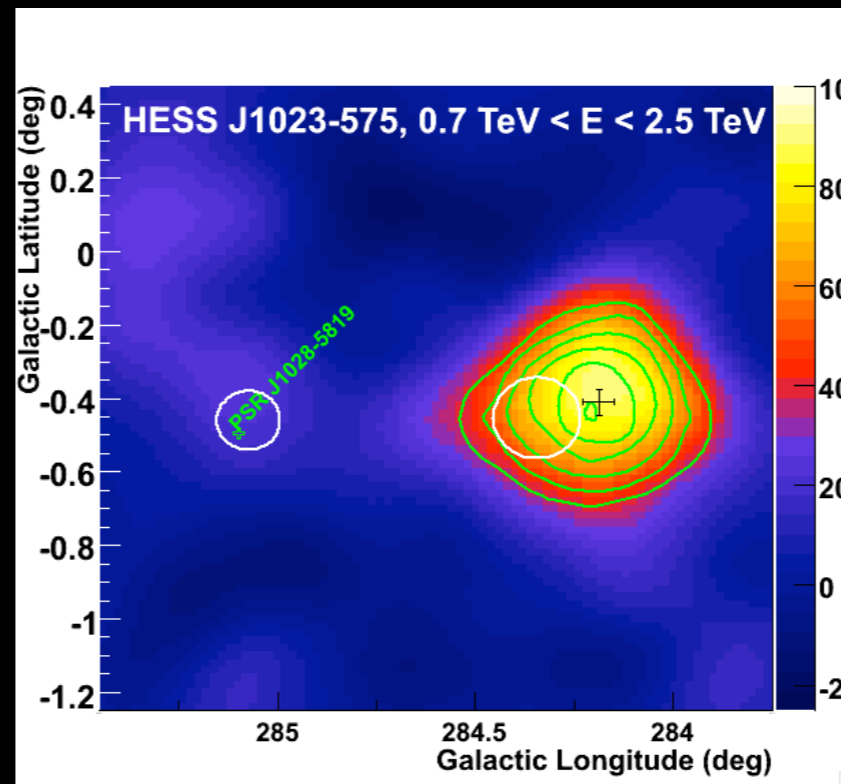
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# Stellar Clusters

## Westerlund 2

- Acceleration through collective wind effects or DSA at the boundary?
- PWN?
- Systematic search program
- WR 20a Binary System but! Extension (28 pc if d=8 Kpc) not compatible with theoretical predictions
- $L = 1.5 \times 10^{35}$  erg/s



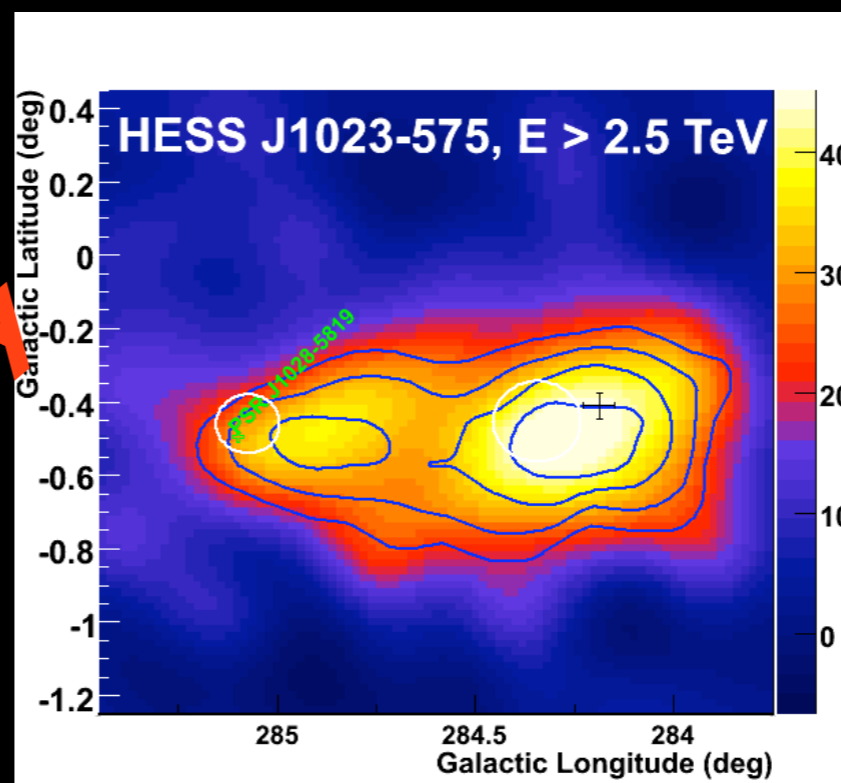
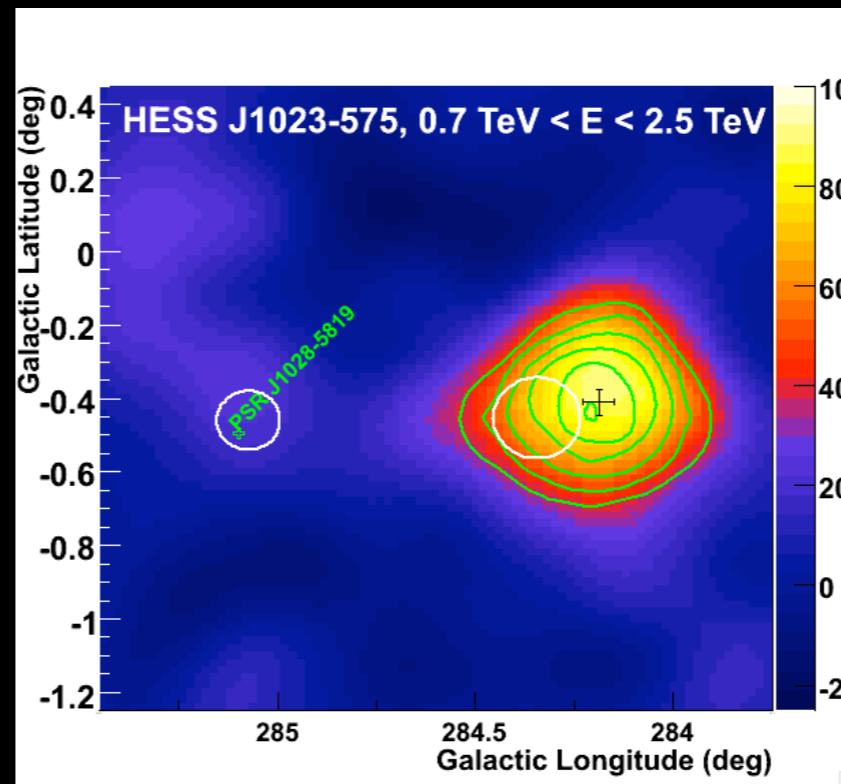
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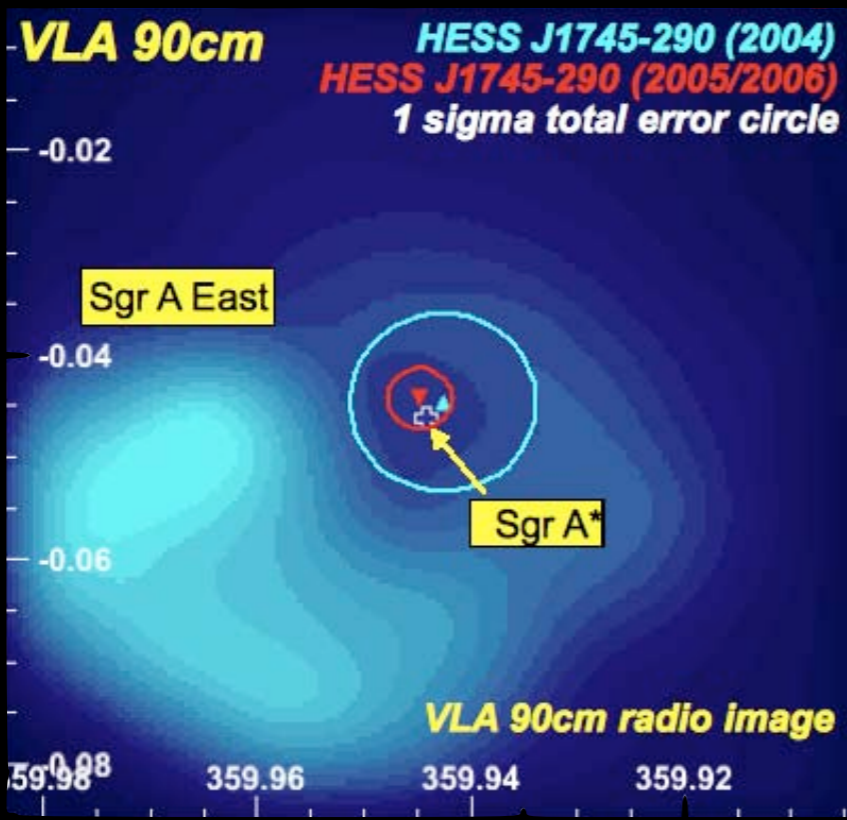
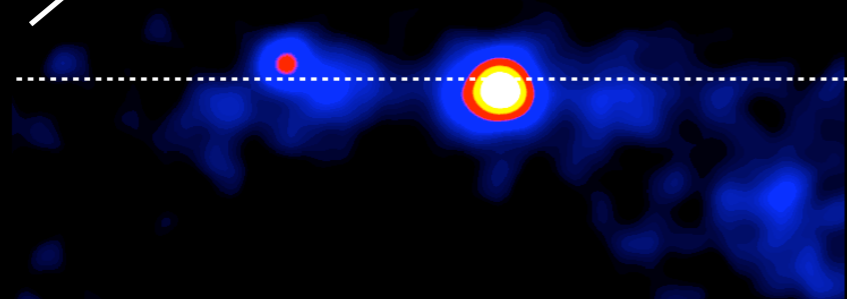
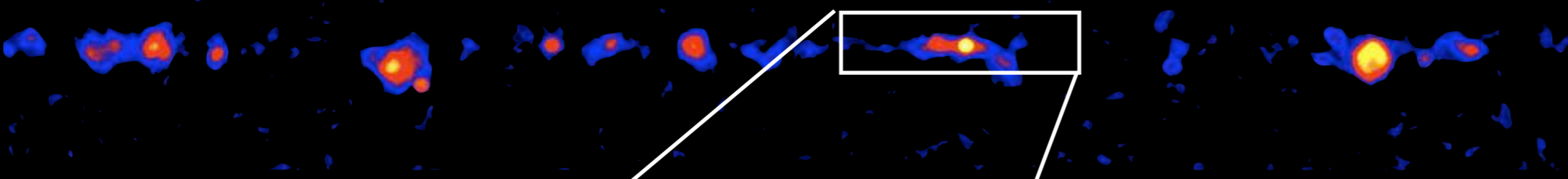




Thanks



VHE  $\gamma$ -rays

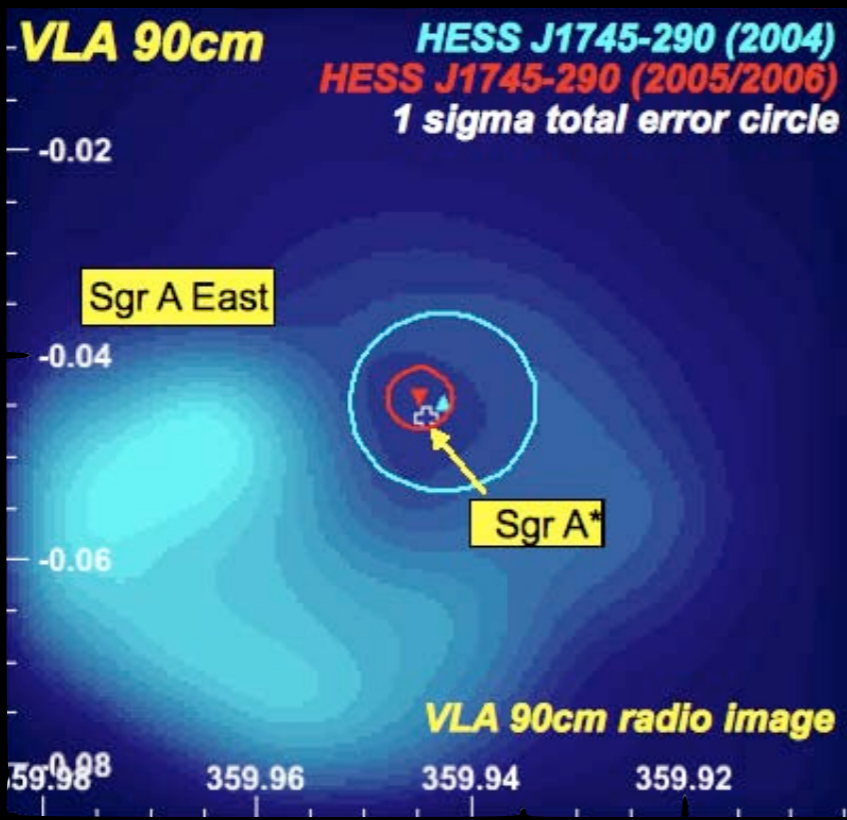
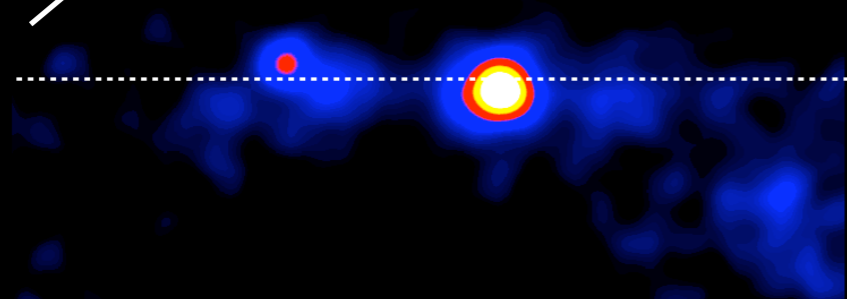
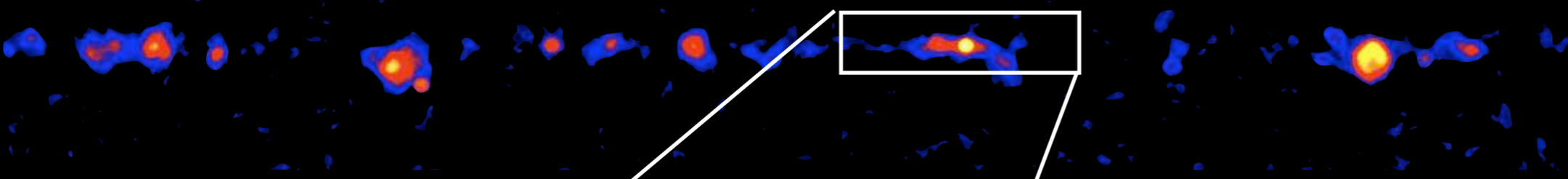


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Aharonian et al, Nature, 2006

VHE  $\gamma$ -rays



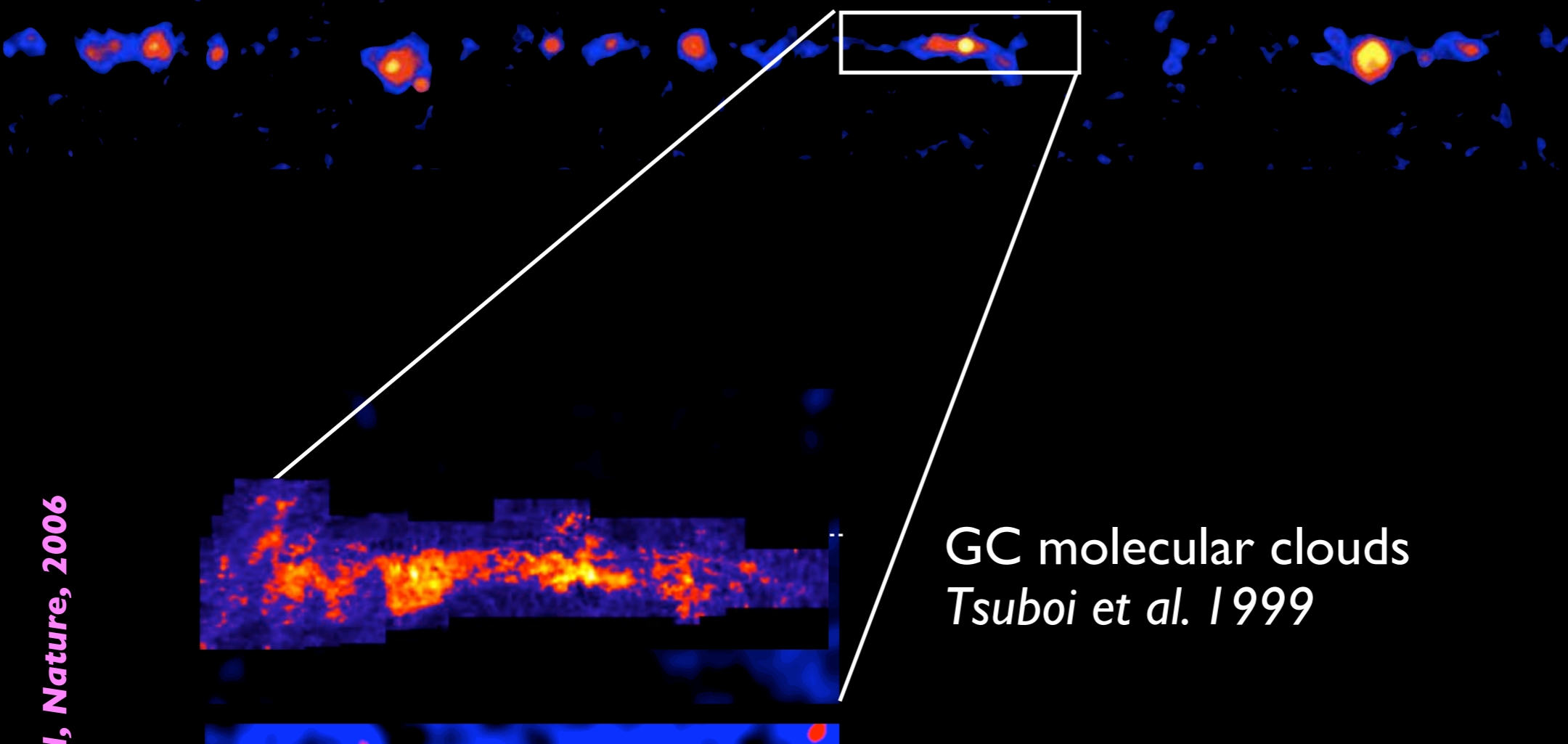
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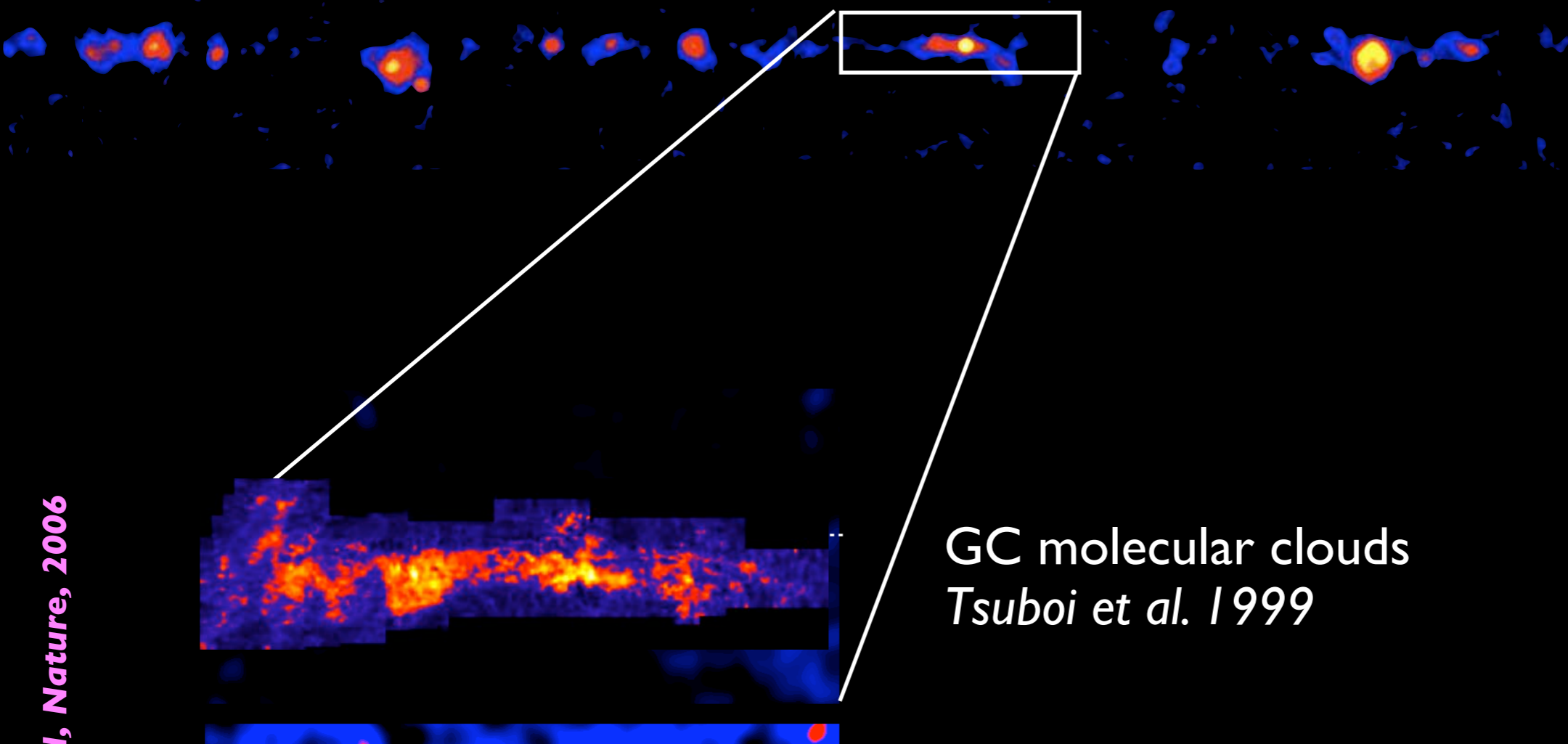


GC molecular clouds  
*Tsuboi et al. 1999*

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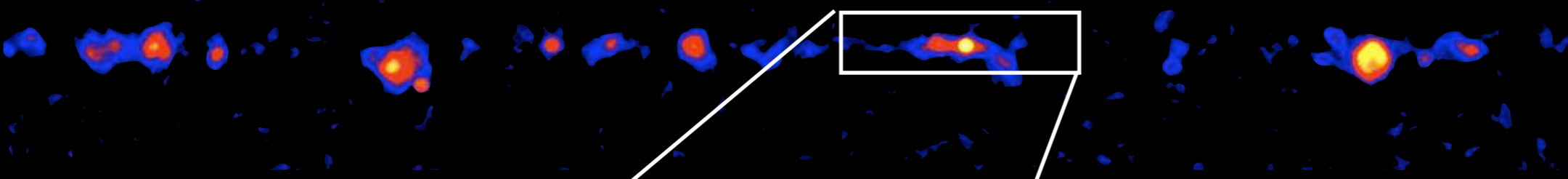


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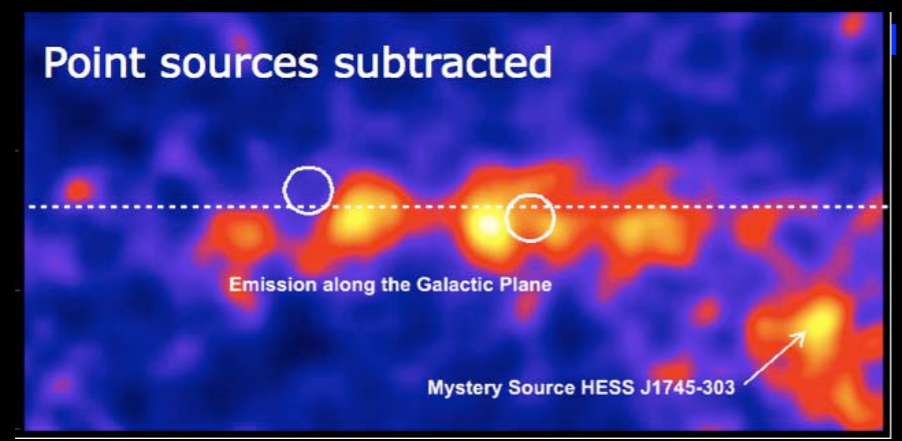
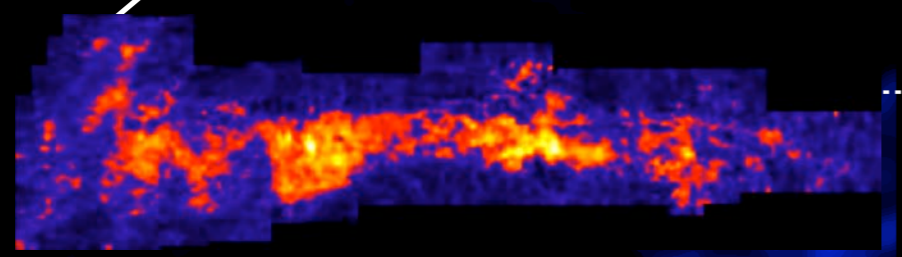
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Aharonian et al, Nature, 2006



GC molecular clouds

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- $F_{\gamma} \propto F_{cr} \times \rho_{target}$
- Correlation with Molecular Clouds
- Central Source + diffusion  $\sim 10$  Kyr  $\rightarrow$

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