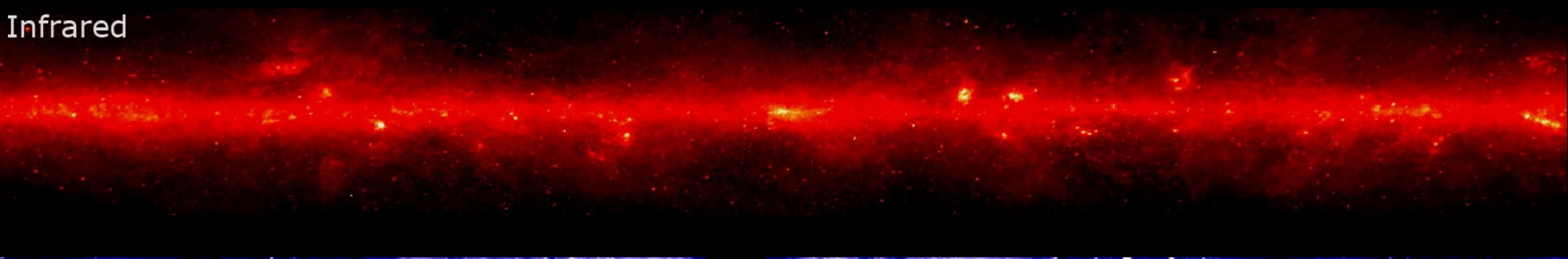
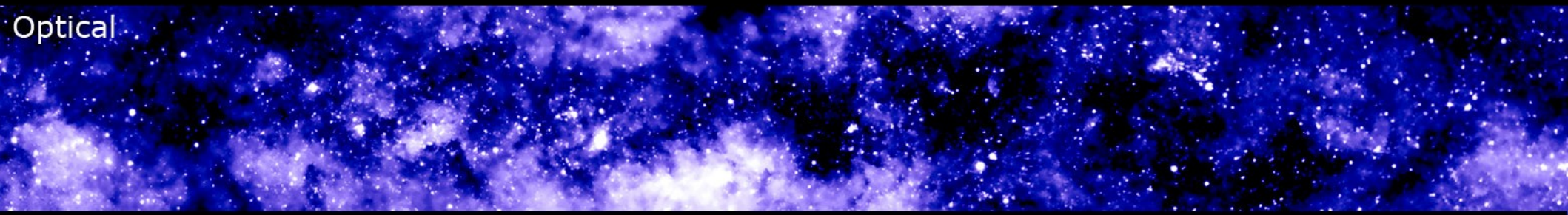
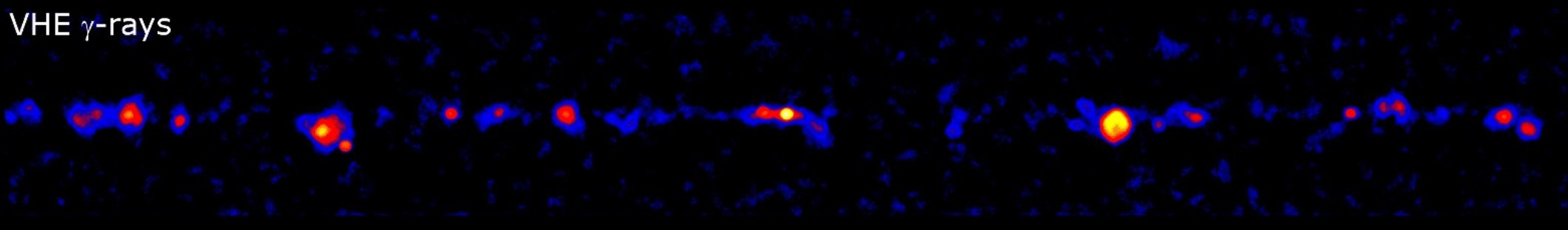
The H.E.S.S. Galactic Plane Survey

Emma de Oña Wilhelmi
H.E.S.S. Collaboration
Laboratoire d'Astroparticule et Cosmologie-APC
CNRS, Université P7, Observatoire de Paris, CEA







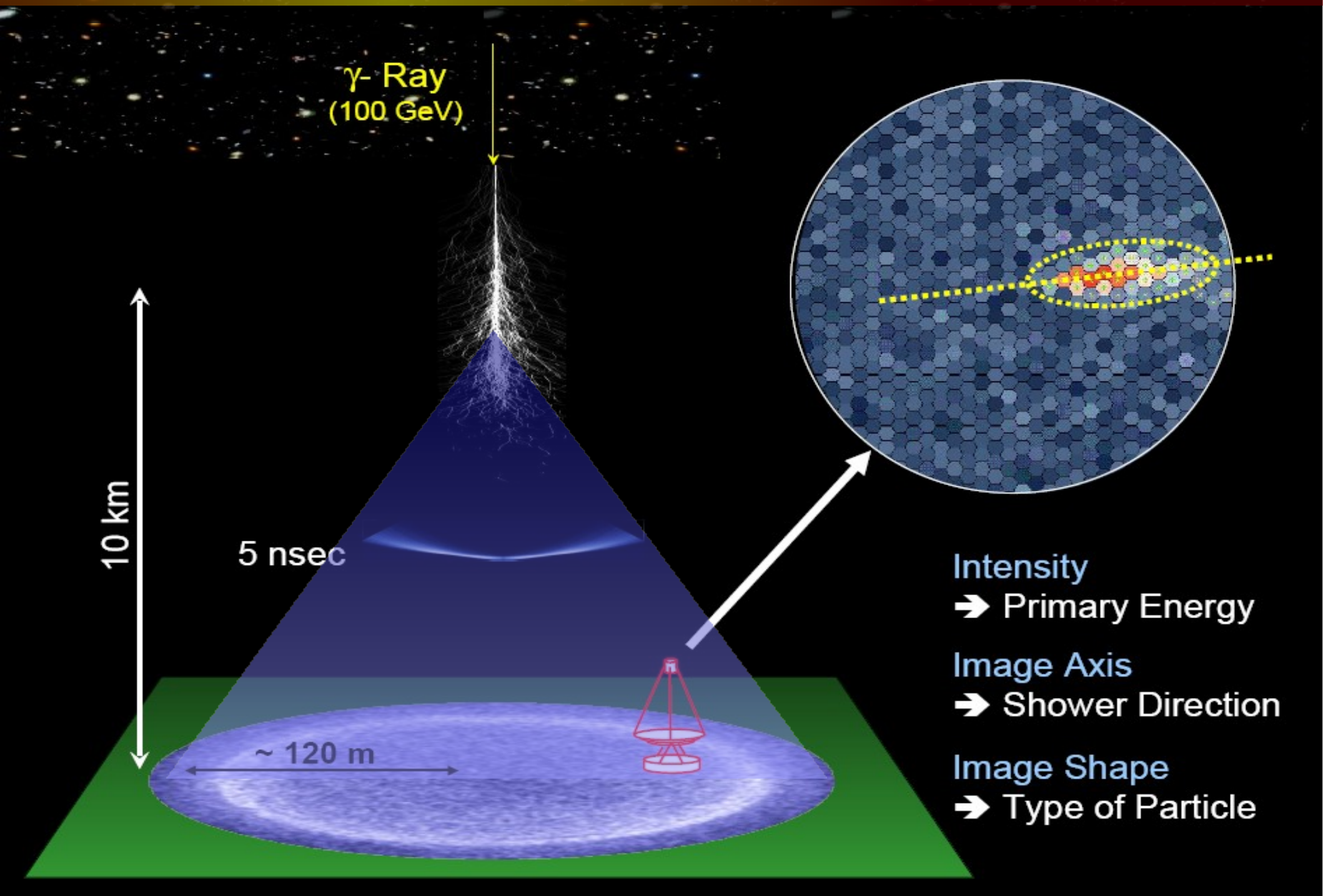
High Energy Stereoscopic System

An Array of 4 Imaging Atmospheric Cherenkov Telescopes in Namibia

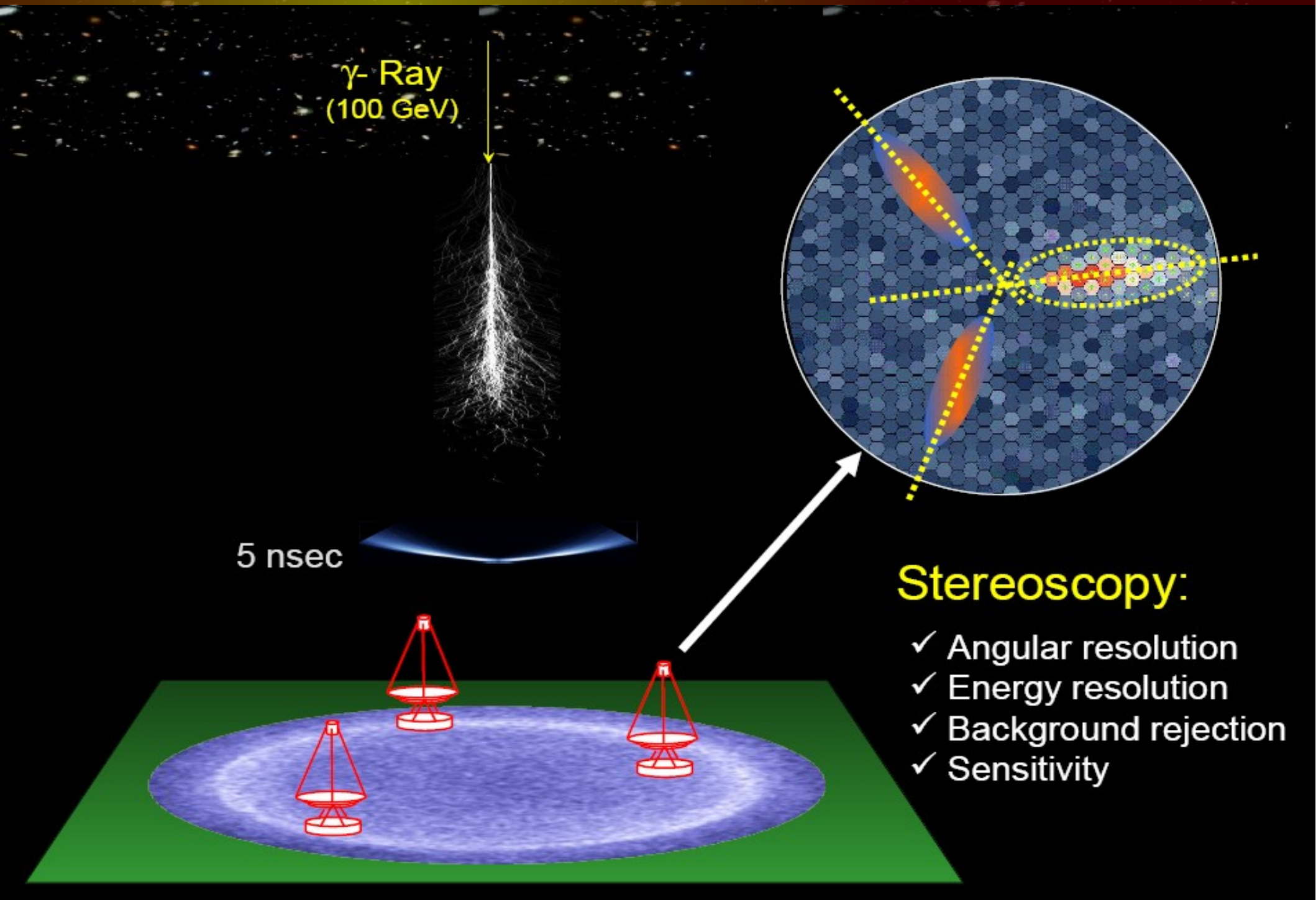
- Large ~5° Field of View camera
- Φ 13m, mirror area 107m^2
- Good angular resolution < 0.1°
- High Sensitivity: 1% Crab in 25 h
- Wide energy range 100 GeV – 100 TeV
- In operation since January 2005

Key location: Namibia

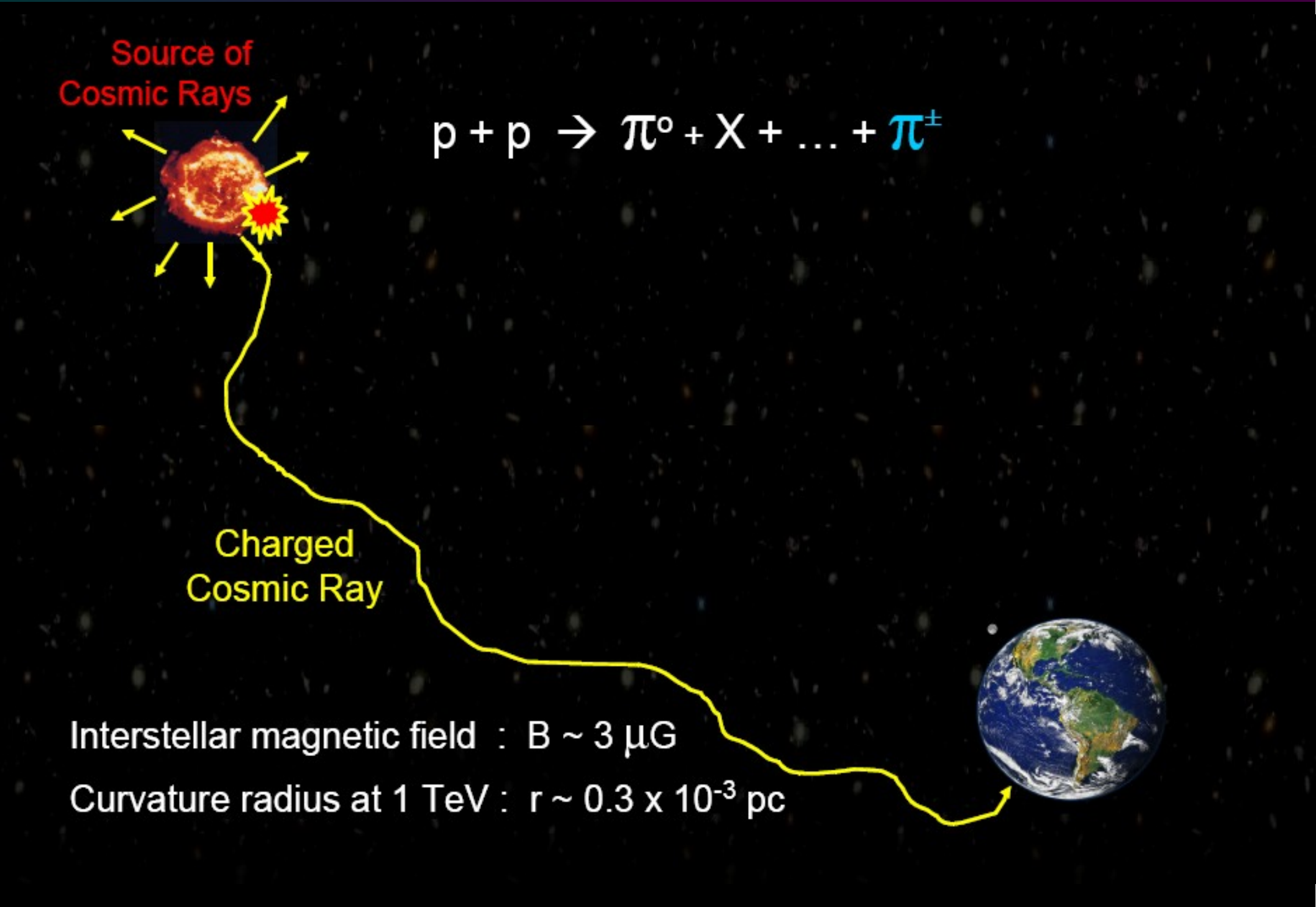
The Cherenkov Technique



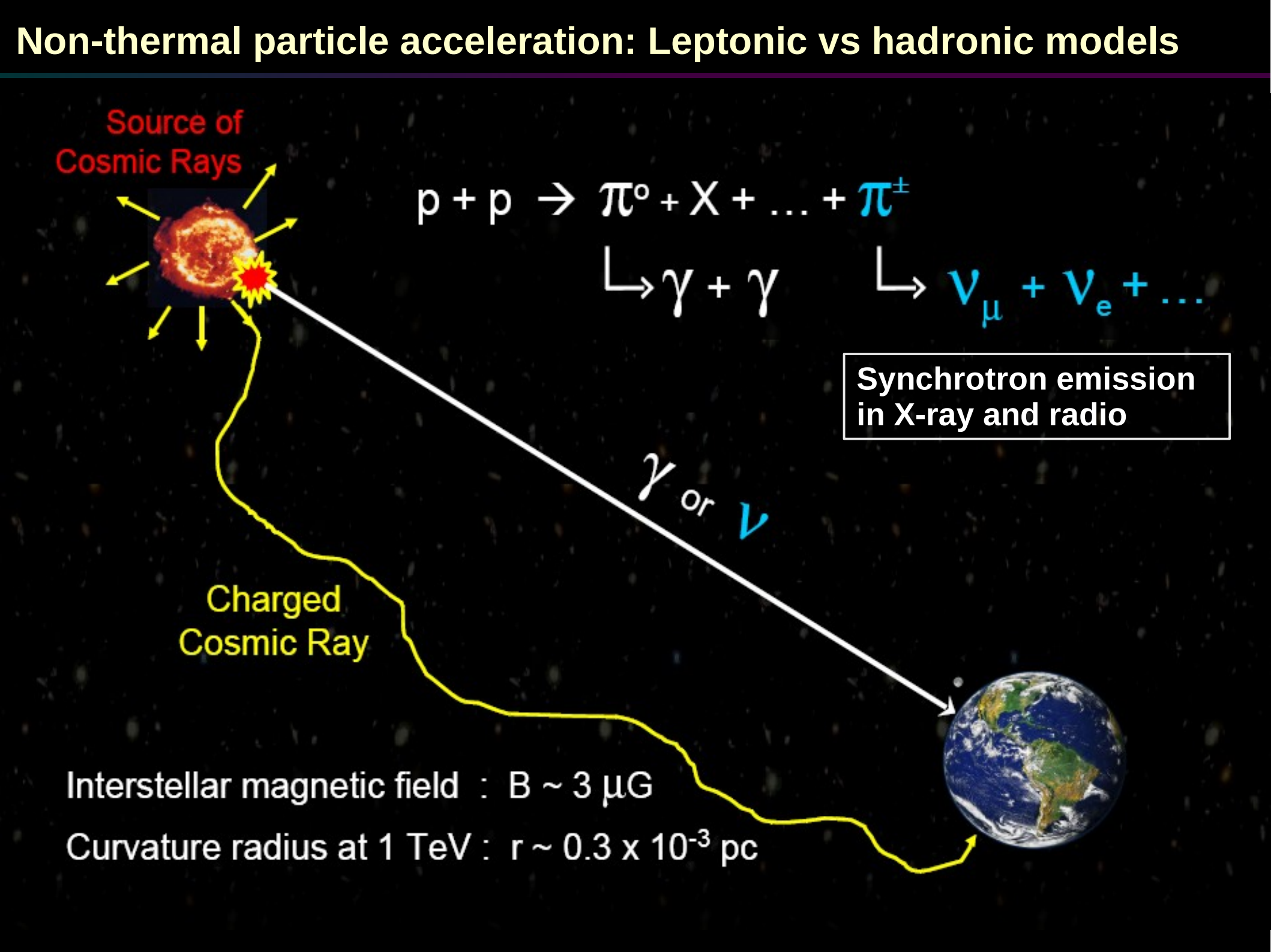
The Cherenkov Technique



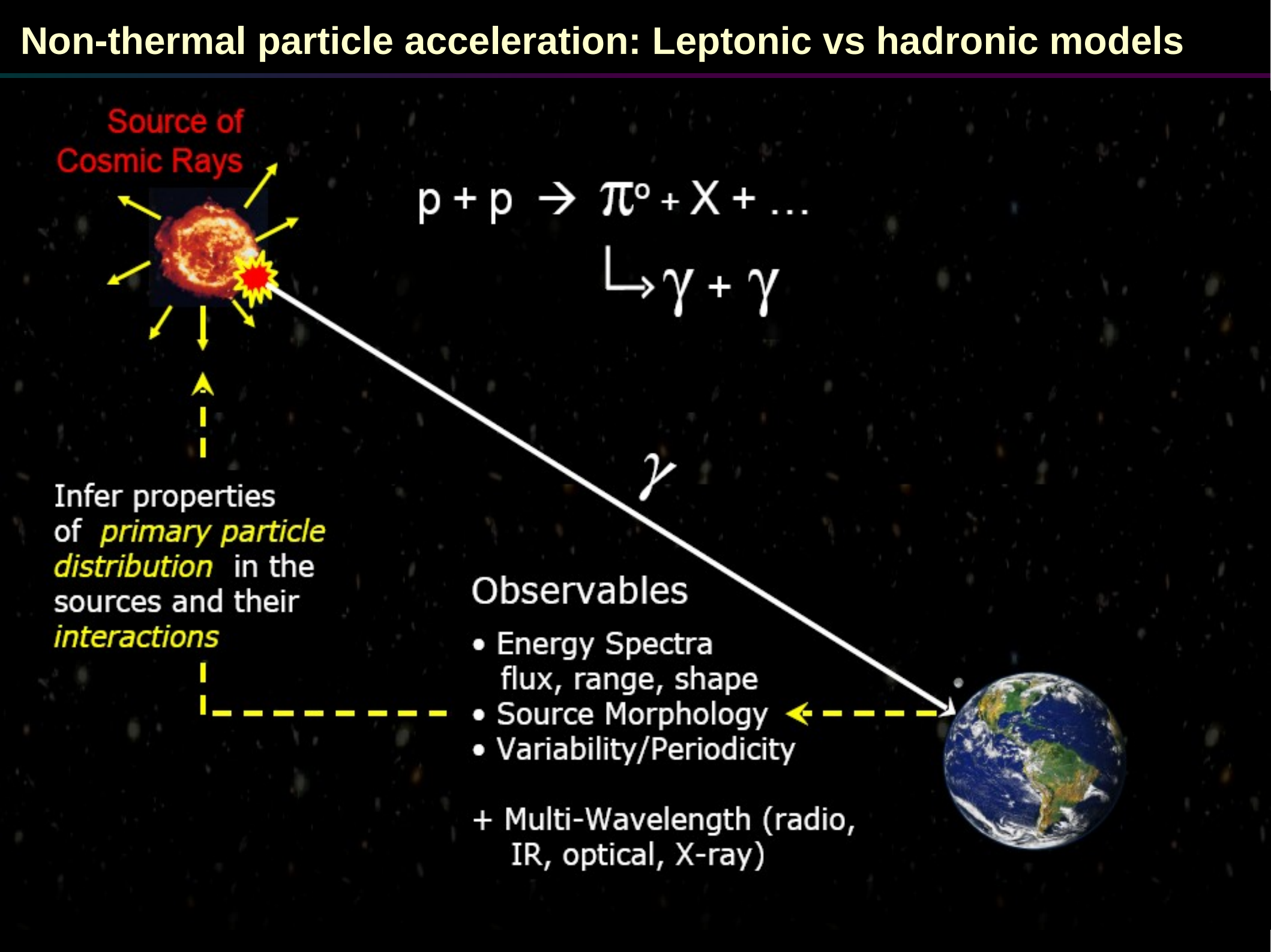
Non-thermal particle acceleration: Leptonic vs hadronic models



Non-thermal particle acceleration: Leptonic vs hadronic models

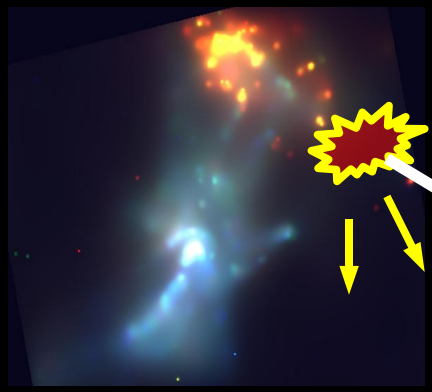


Non-thermal particle acceleration: Leptonic vs hadronic models



Non-thermal particle acceleration: Leptonic vs hadronic models

Source of e^- acceleration



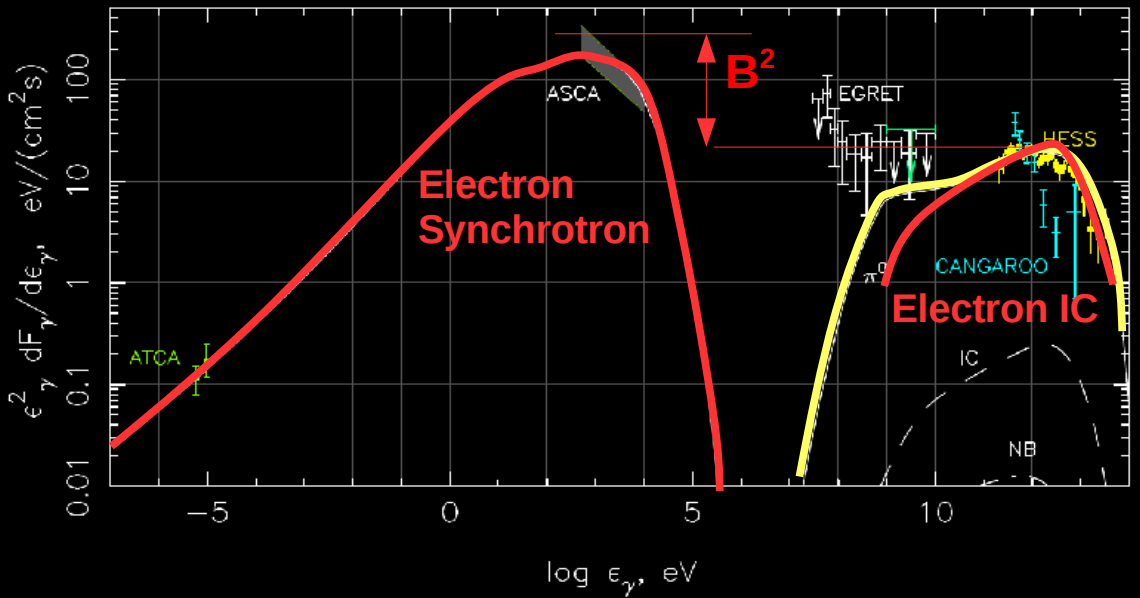
$\gamma_{LE} + e^{\pm}_{HE} \rightarrow \gamma_{HE} + e^{\pm}_{LowerE}$

$e^{\pm}_{LE} + B \rightarrow \gamma_{LE} + e^{\pm}_{LowerE}$

IC on CMBR, dust and starlight component

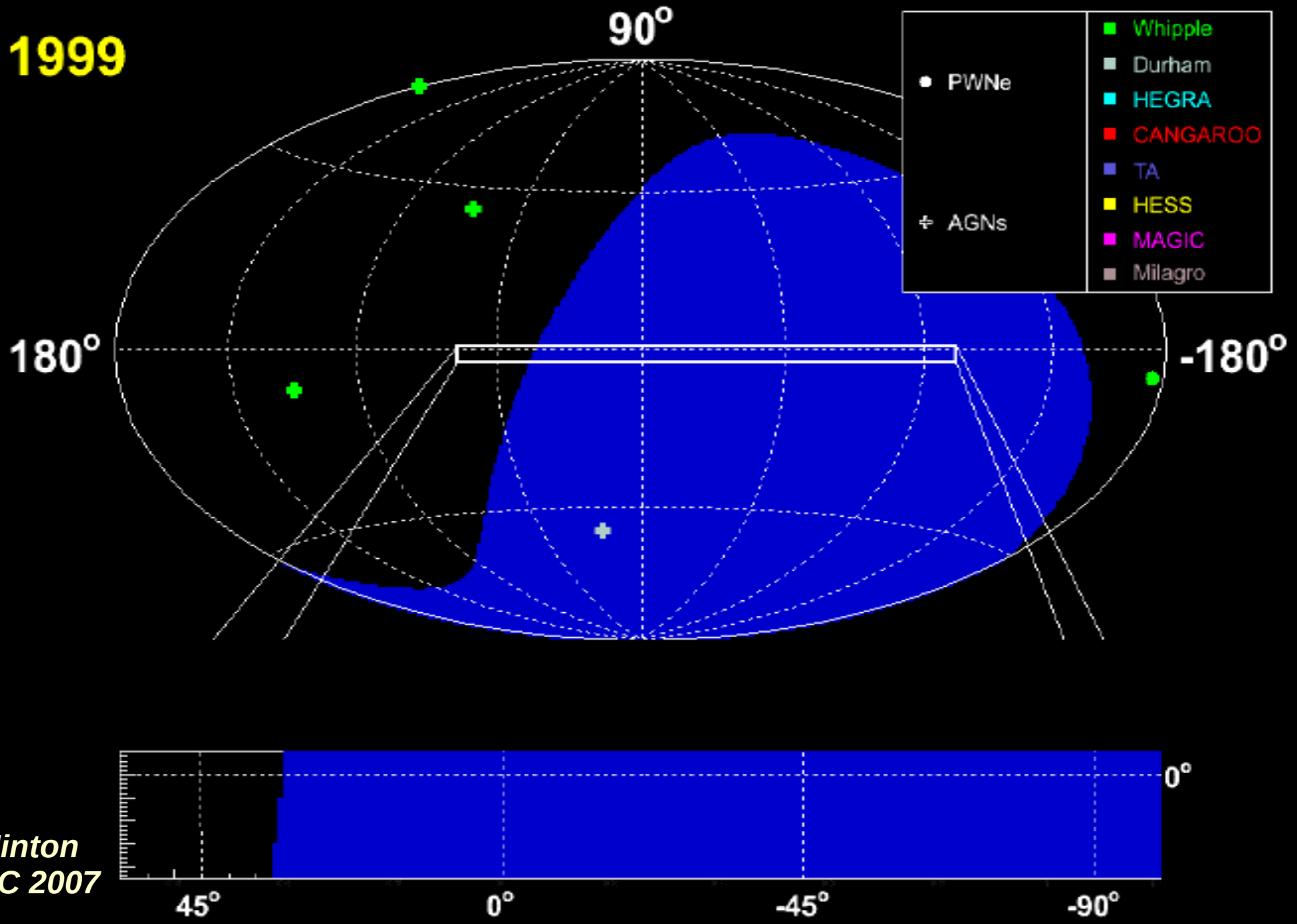
Synchrotron emission in X-ray and radio

γ



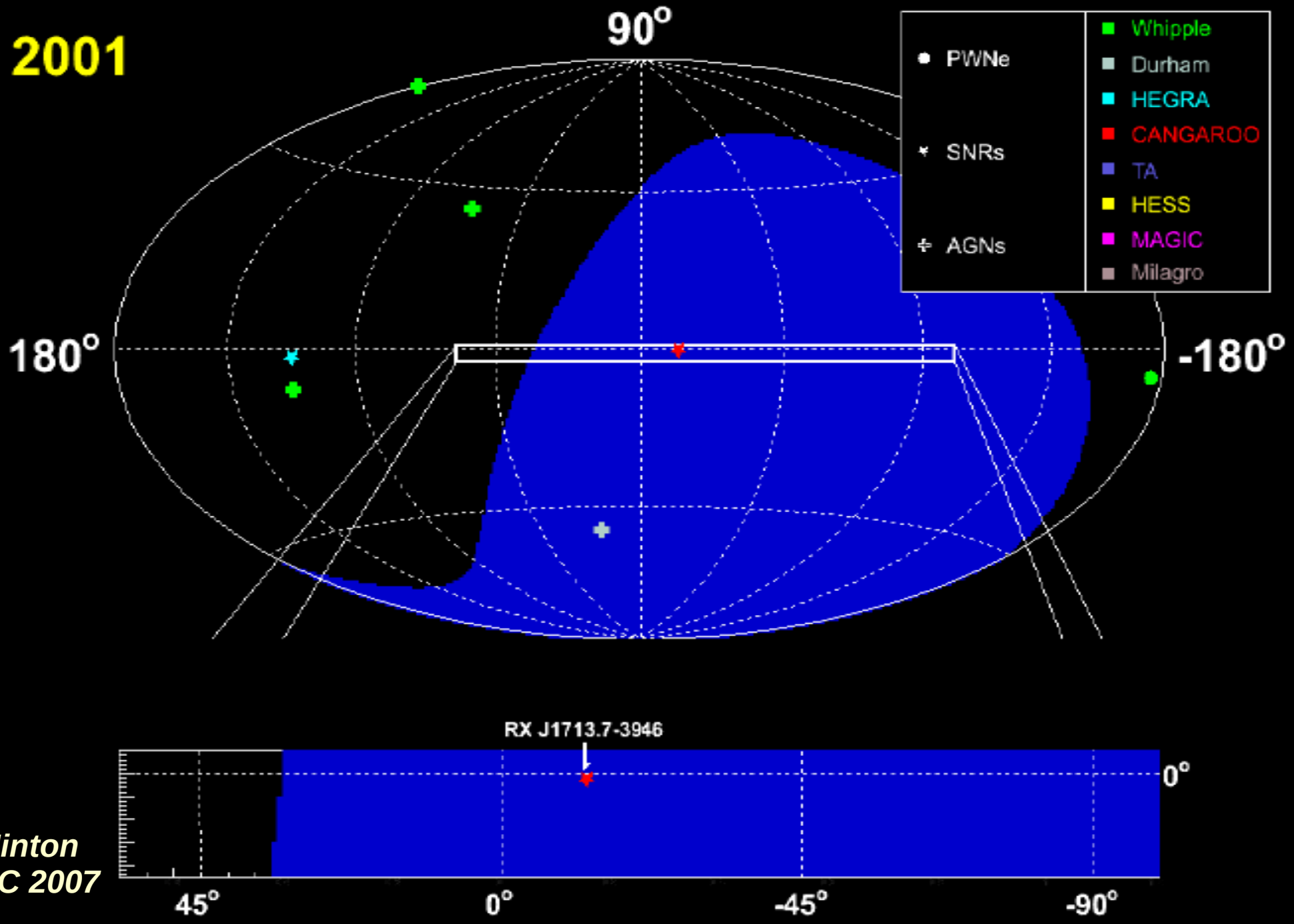
High B-field ~100 μG

Evolution of the field



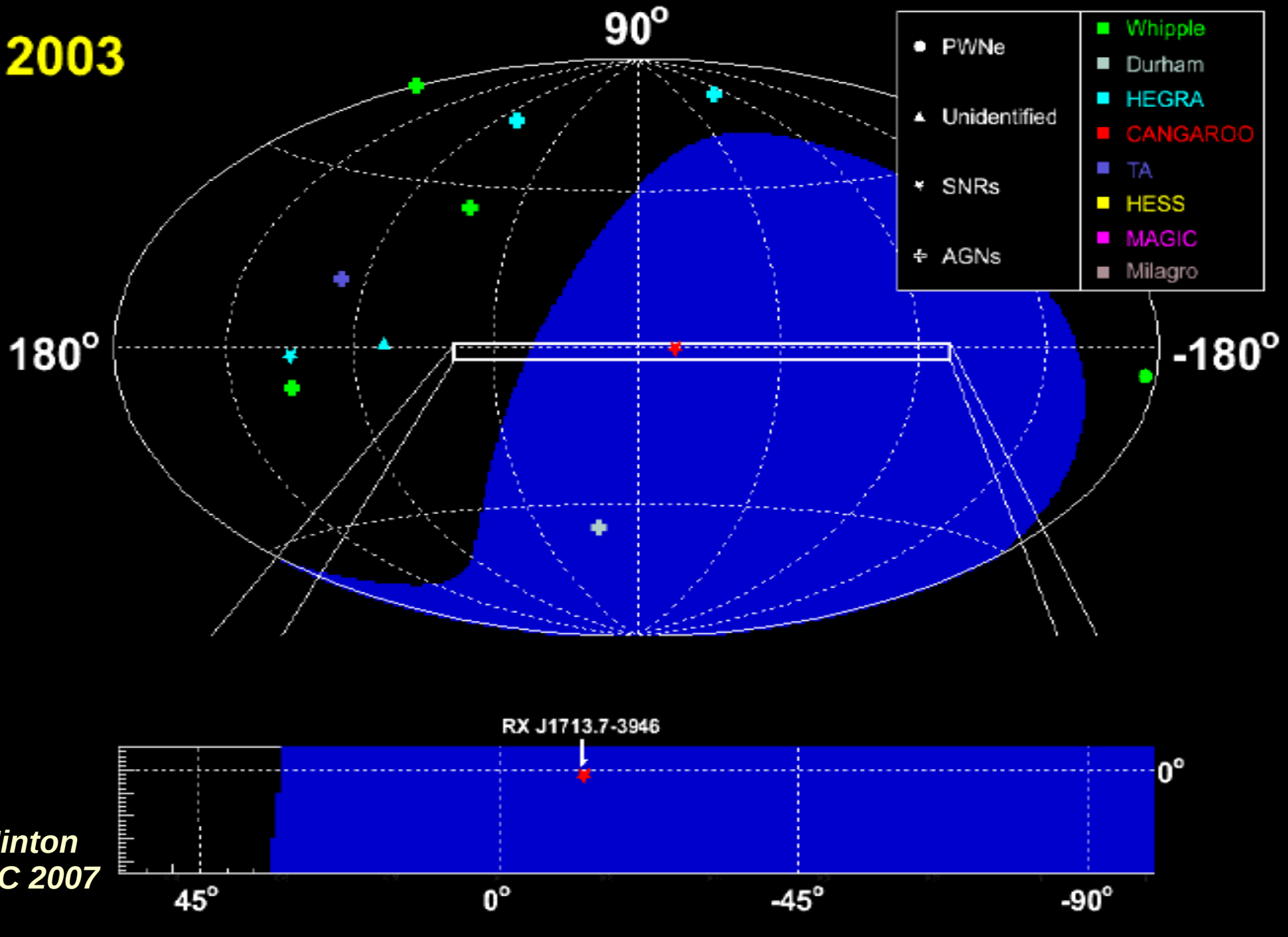
J. Hinton
ICRC 2007

Evolution of the field



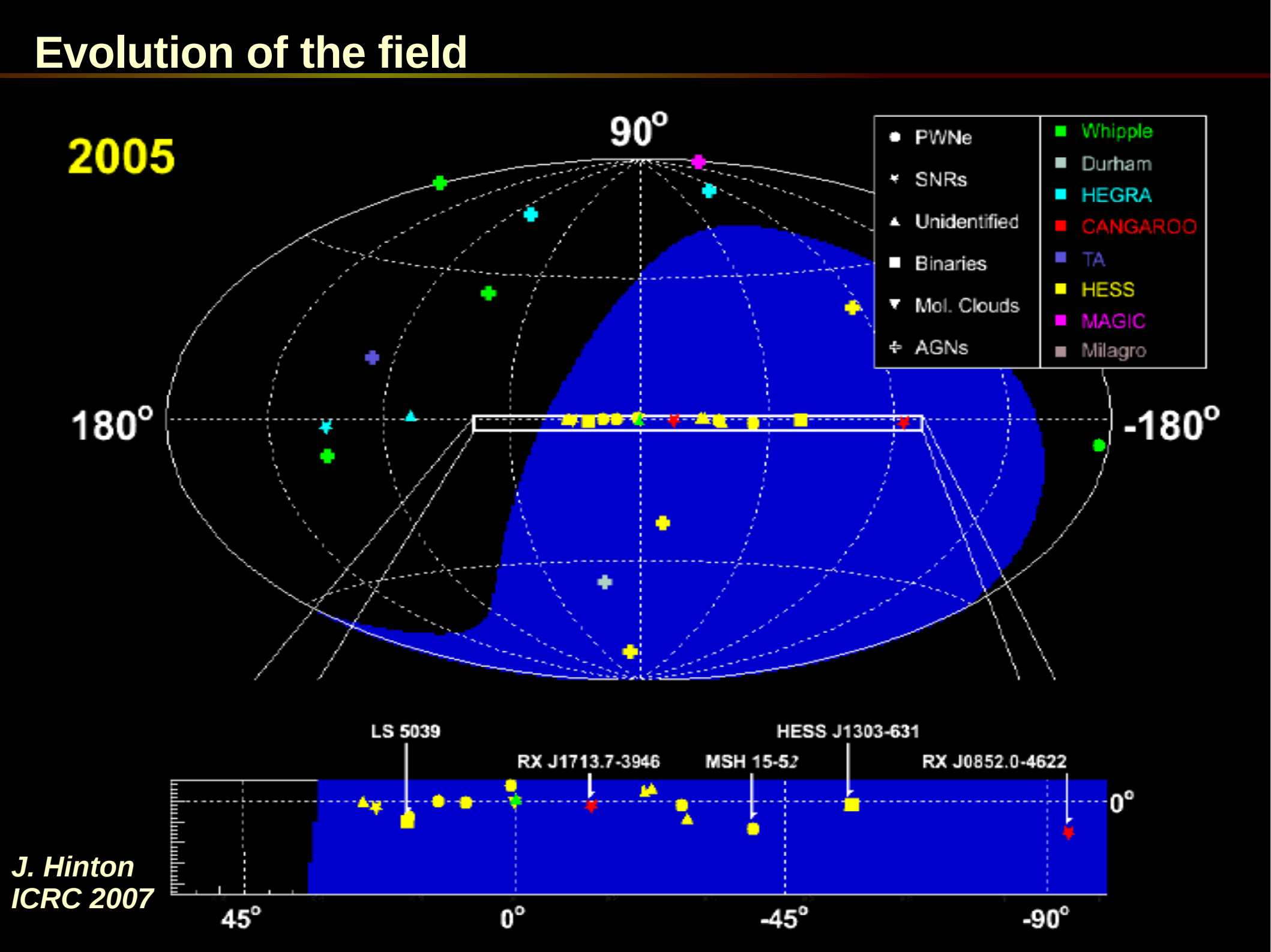
J. Hinton
ICRC 2007

Evolution of the field



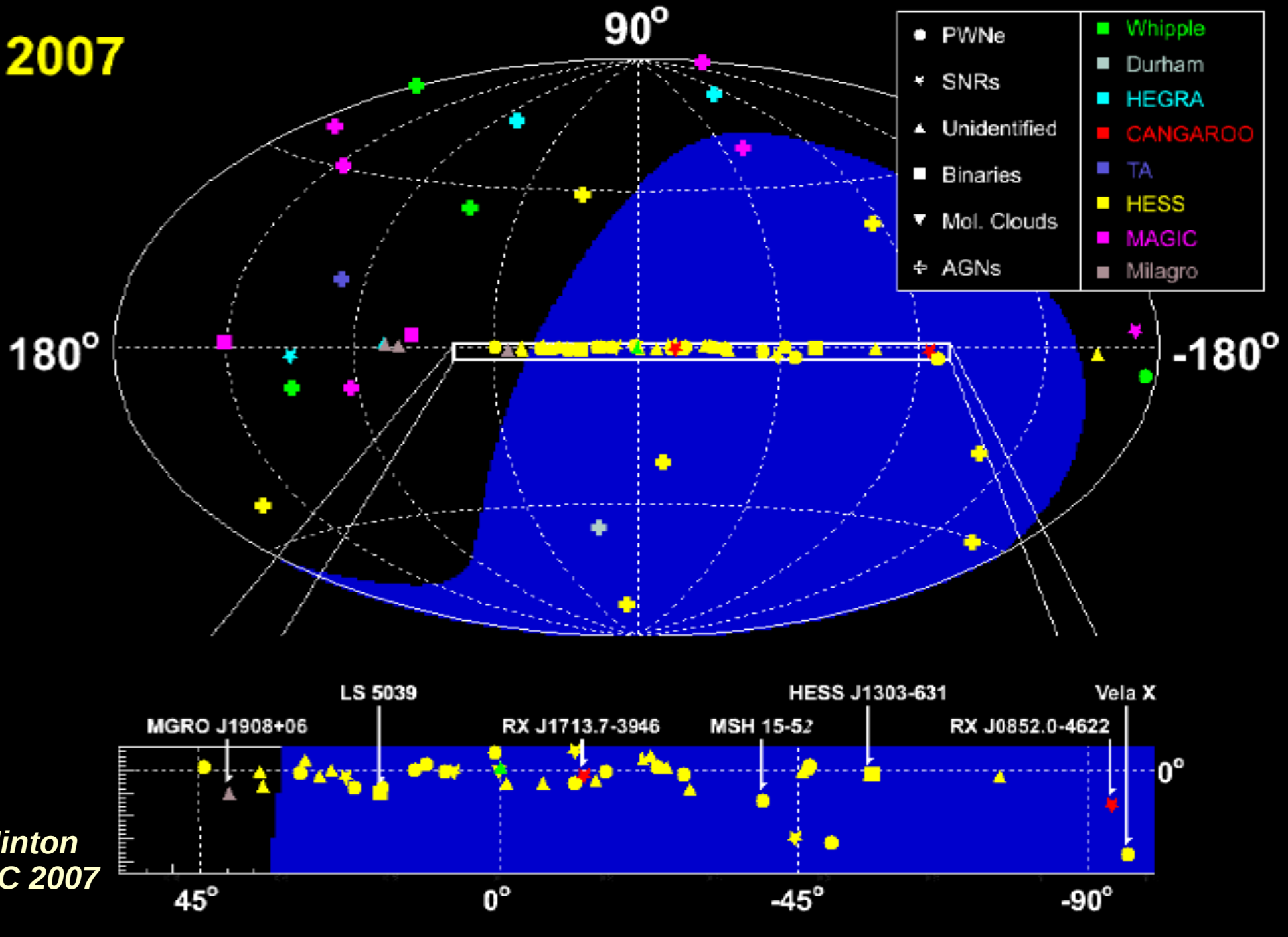
J. Hinton
ICRC 2007

Evolution of the field

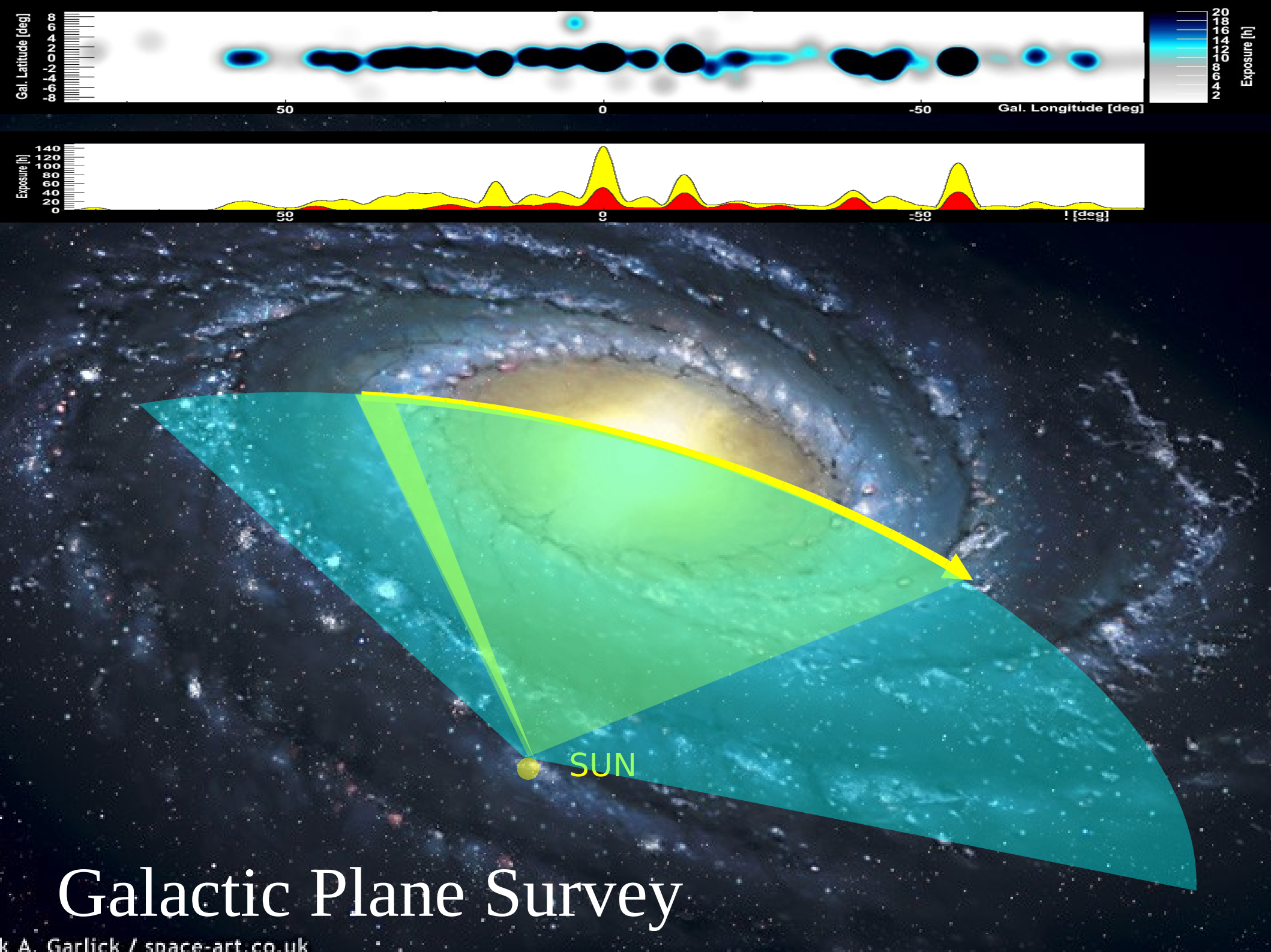


J. Hinton
ICRC 2007

Evolution of the field

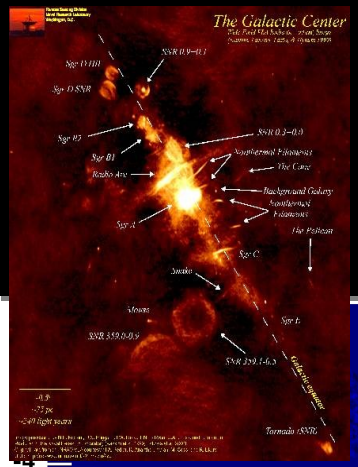


J. Hinton
ICRC 2007

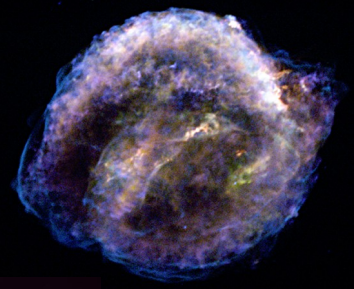

Gal. Latitude [deg]
8
6
4
2
0
-2
-4
-6
-8
50
0
-50
Gal. Longitude [deg]
20
18
16
14
12
10
8
6
4
2
Exposure [h]
Exposure [h]
140
120
100
80
60
40
20
0
50
0
-50
SUN
Galactic Plane Survey
k A. Garlick / space-art.co.uk

The GPS Significance Map

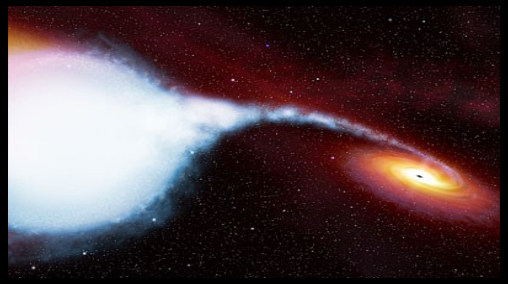
Dark matter



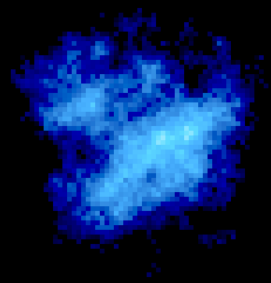
Supernova Remnants (SNR)



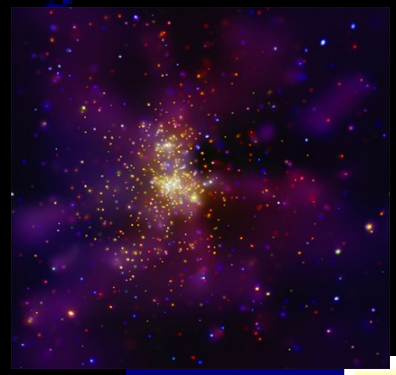
Pulsar Wind Nebula (PWN)



Dark Sources



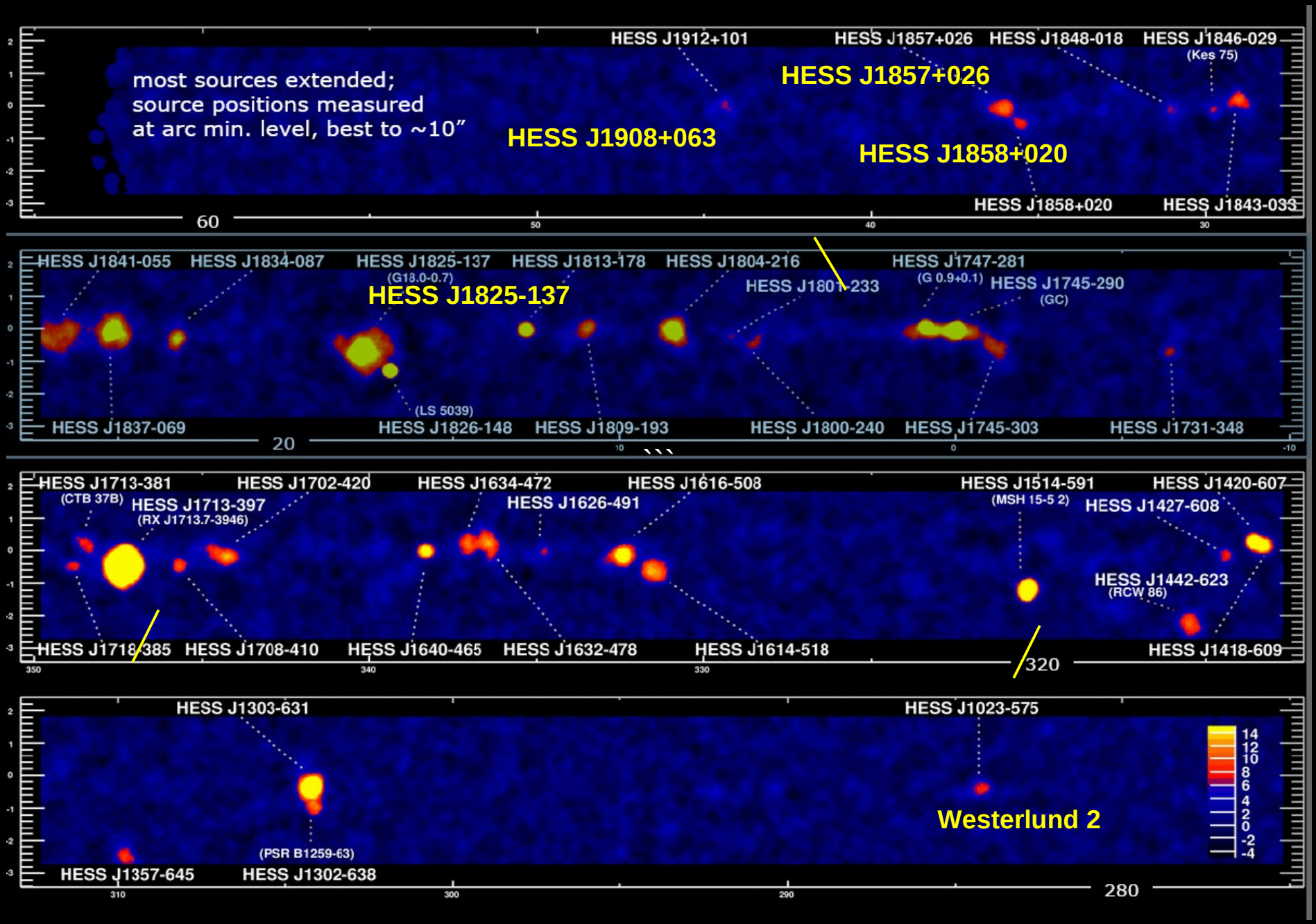
Open clusters

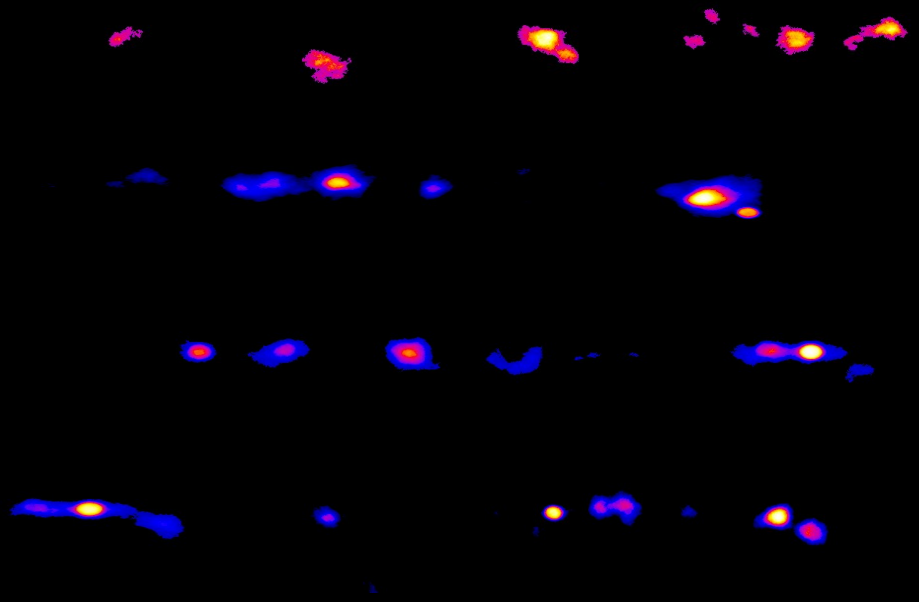


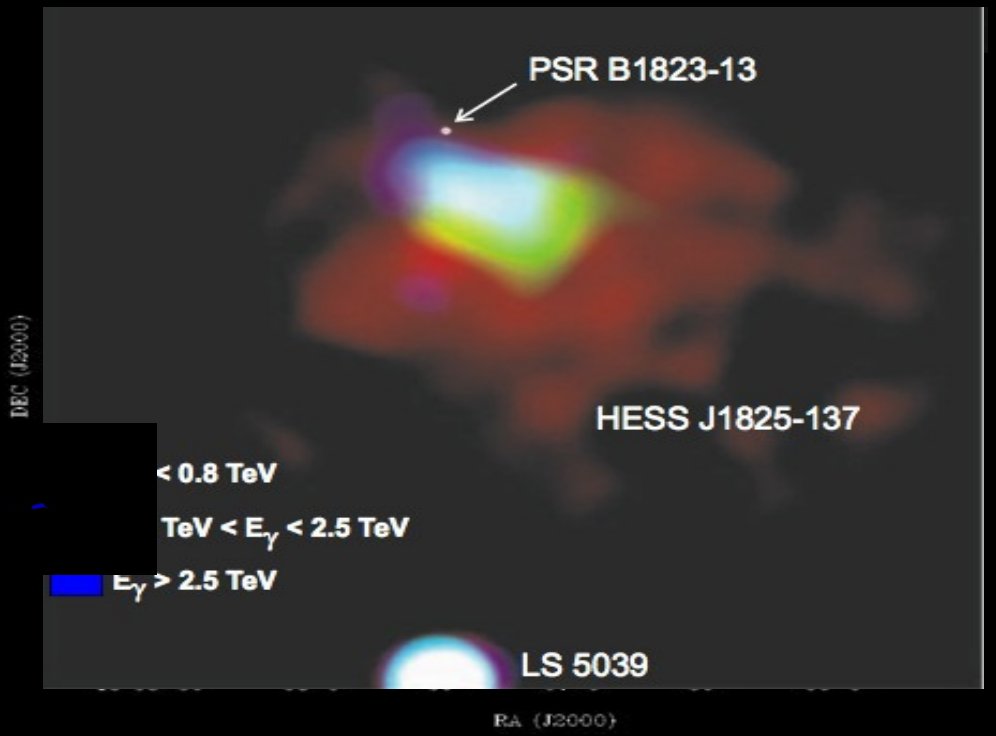
- VHE sources related to late phases of stellar evolution and/or star formation:
  - PWNs (G18.0-0.7)
  - SNRs (RX J1713.7-3946)
  - Open star clusters (Westerlund 2)
  - Gamma-ray binaries
  - ... (Pulsars, Wolf Rayet stars)
  - clustering along the Galactic plane -> Survey is the most effective non-biased approach -> Large FoV camera and high sensitivity
- Discovery of many unidentified sources.
- Multi-wavelength approach necessary.

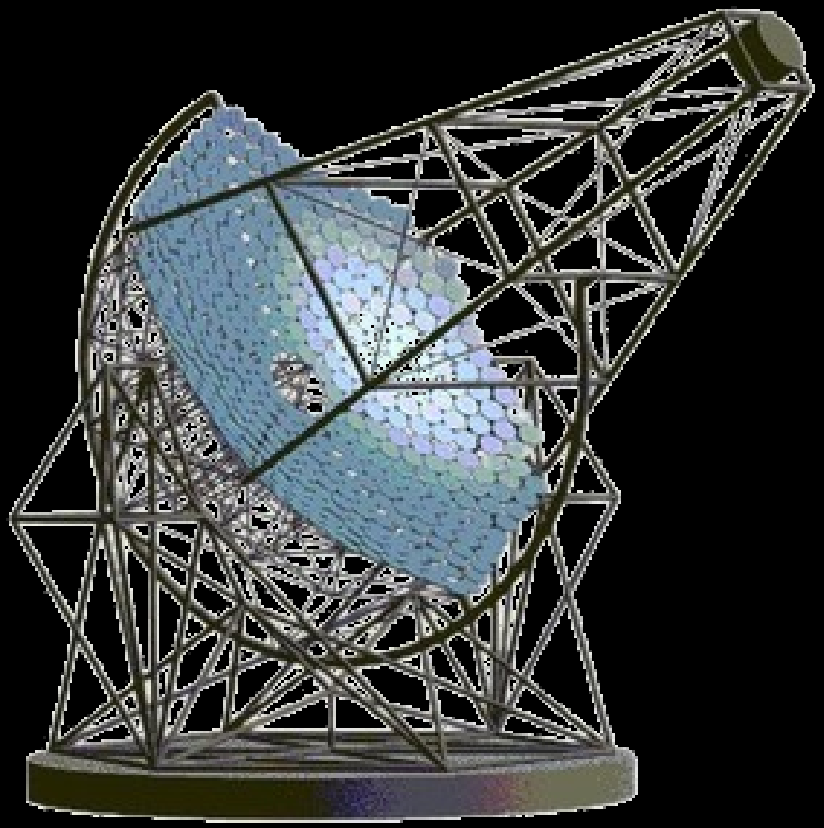
Chaves, de Oña Wilhelmi, Hoppe et al, Gamma08, 2008

The GPS Significance Map`





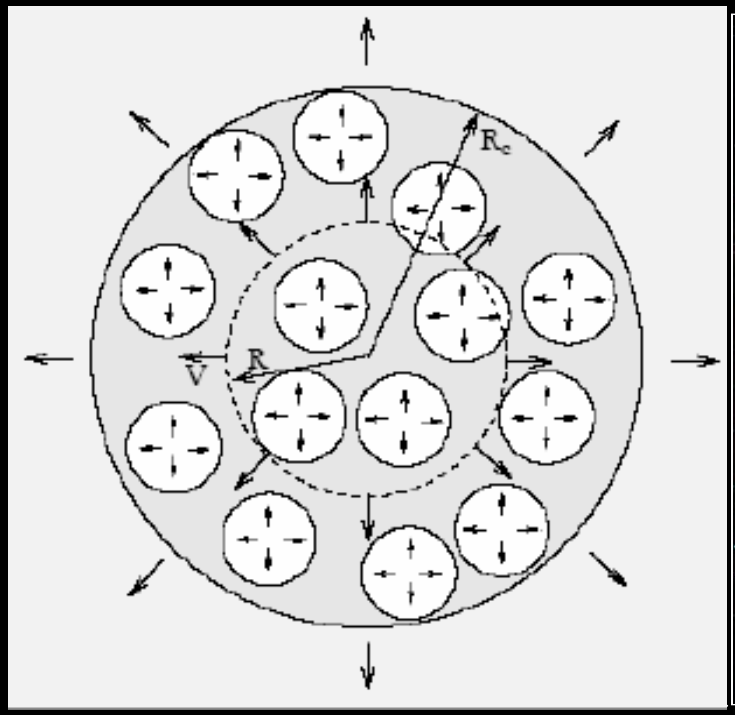


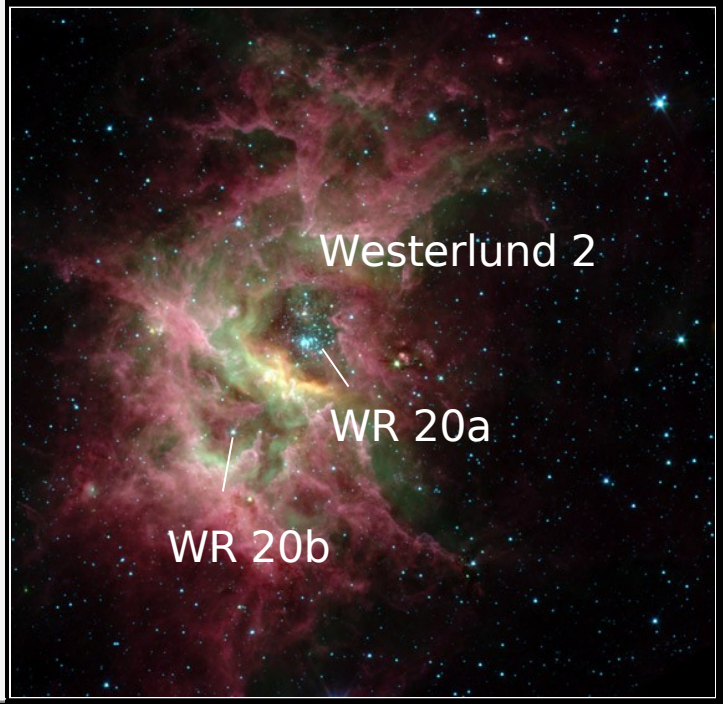


- New type of VHE source:
  Open Clusters
- Dark sources:
  HESS J1908+063
  HESS J1857+026
- Pulsar Wind Nebulae

Stellar clusters: A new type of TeV source?

- Open Clusters : thousands of solar masses Wolf-Rayet & young stars
- Winds excavating bubbles in the ISM
- Clearly visible in infrared and radio images.
- Integrated over their lifetime, the wind energy output ~ kinetic energy released in supernova explosions.





Stellar clusters: Westerlund 1

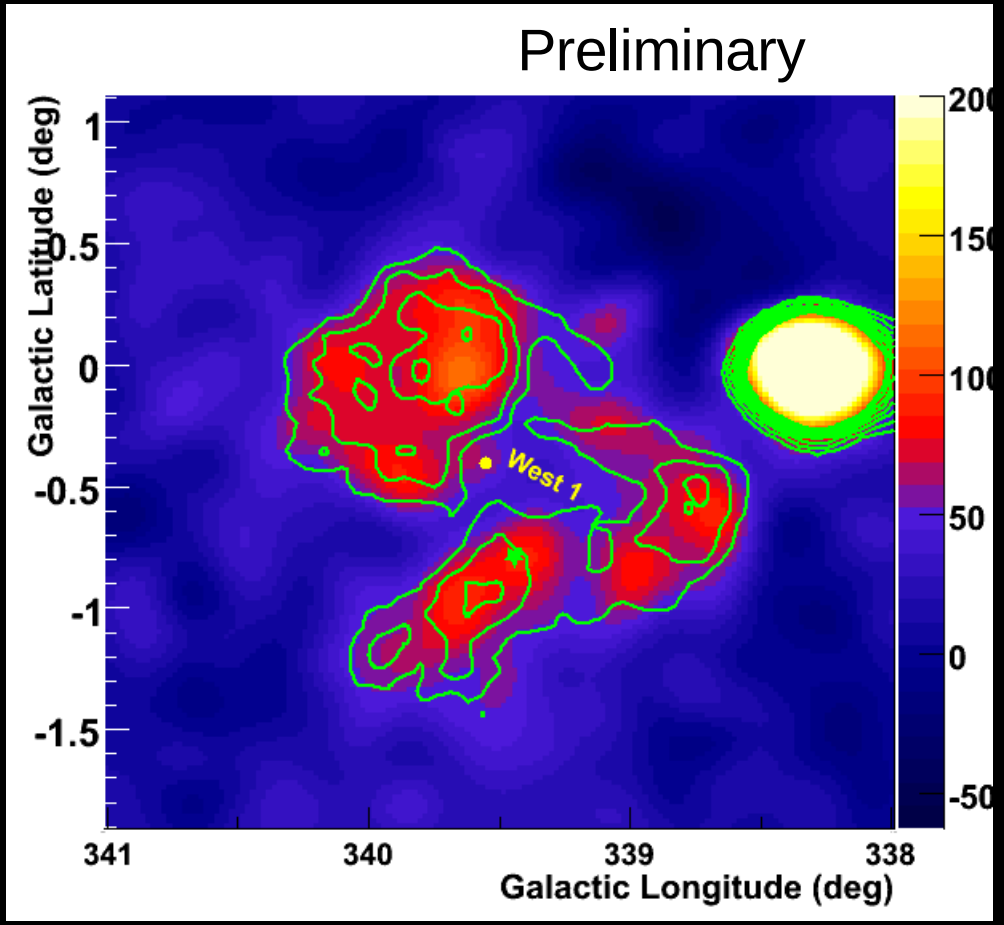
- Most massive star cluster in our galaxy
- Age:~5 Myrs, Mass:~3.7-5. Kpc, Distance: 3.7-5.0 kpc
- > 24 WR stars, supergiants and hypergiants, binaries

It means:

- Massive Stars -> SN explosions
- Age -> Most massive stars already evolved into Sne
- Binaries -> colliding winds

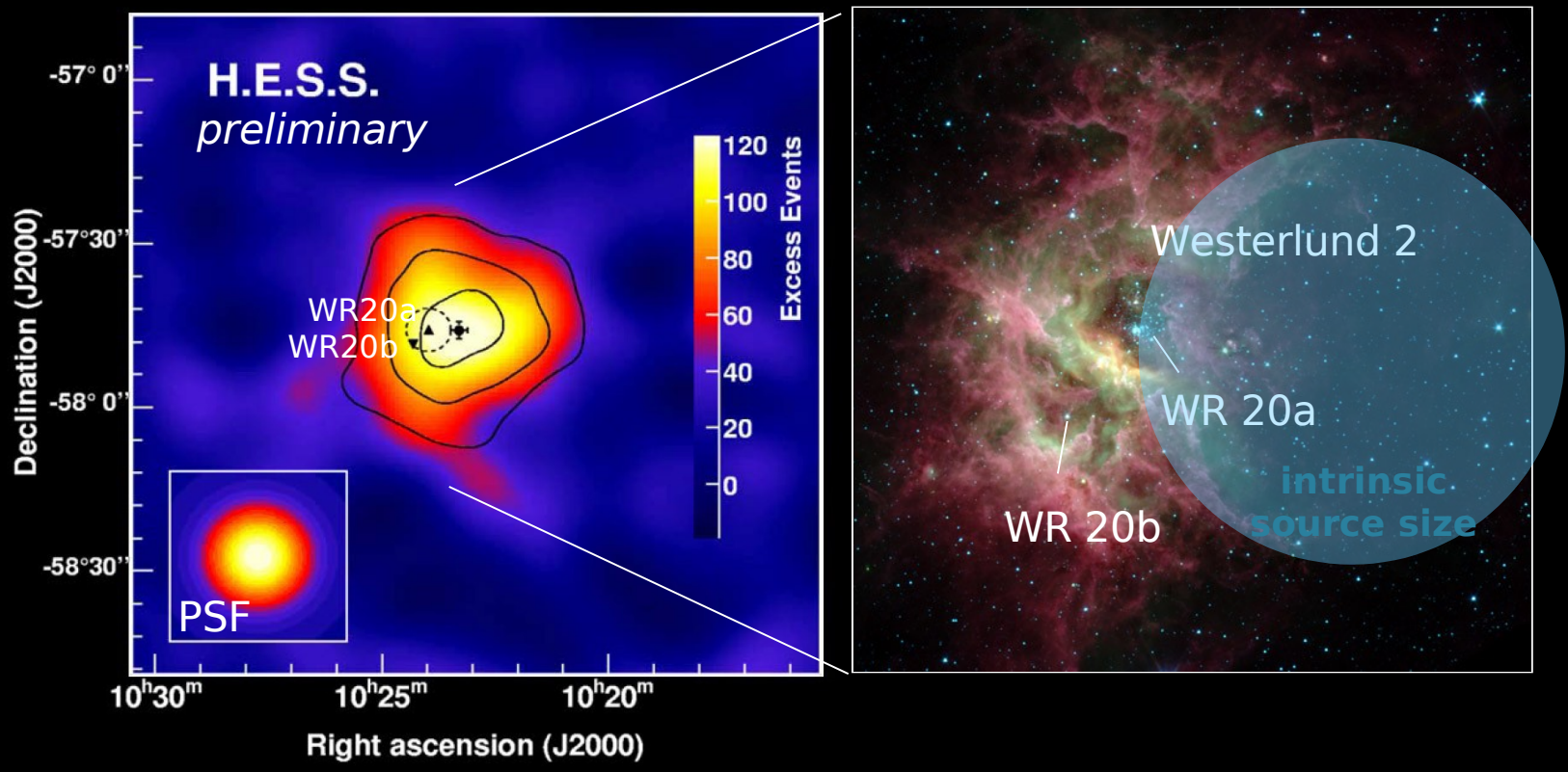
Energy:

- WR winds -> 10^{39} erg s^{-1}
- SNe -> 3 10^{39}erg s^{-1}



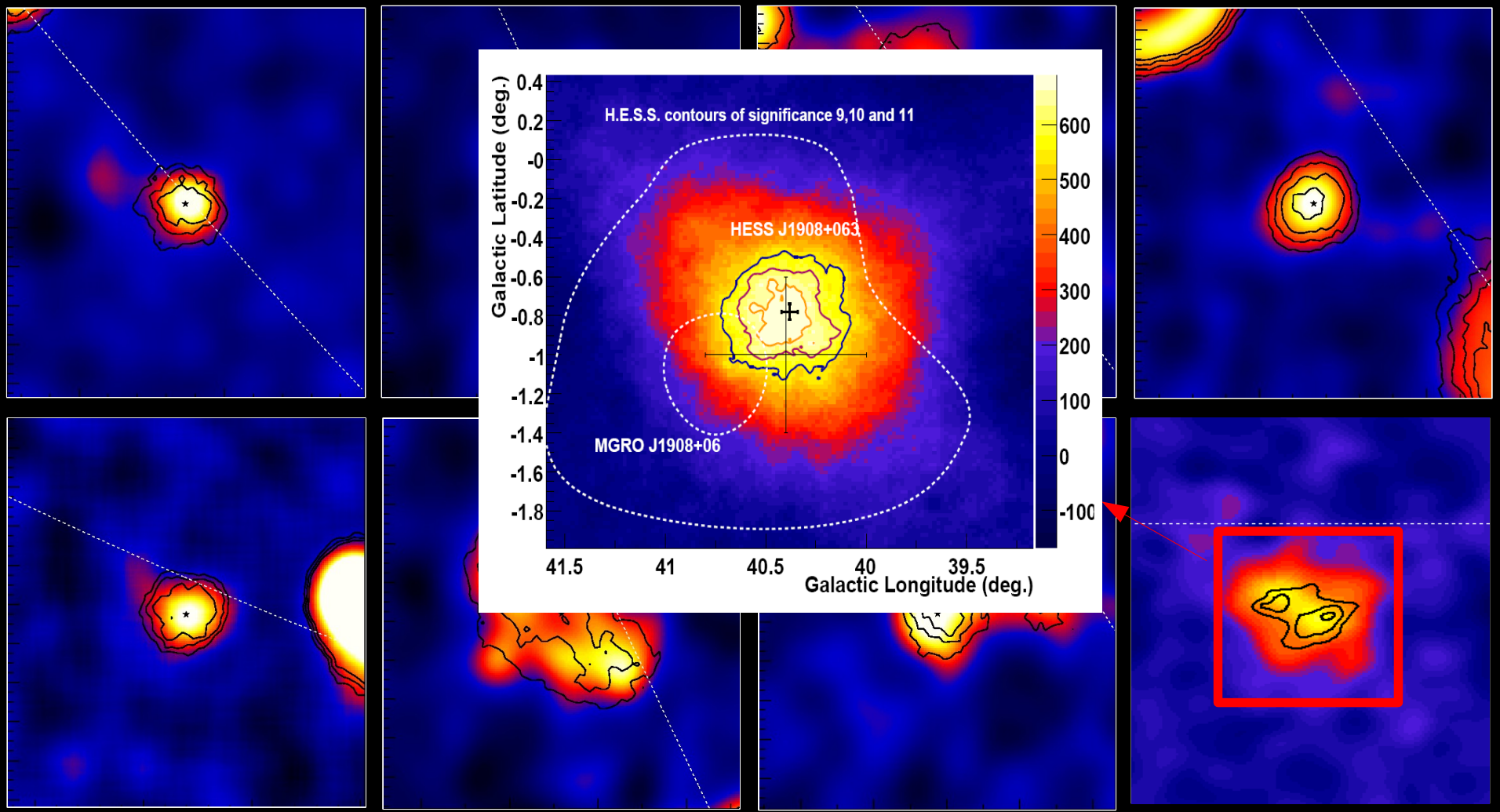
Stellar clusters: Westerlund 2

- HESS source coincides with the most proeminent one in RCW 49
- Acceleration through collective wind effects or DSA at the boundary?
- Systematic search program undertaken with HESS
- WR 20a Binary System but! Extension (28 pc if d=8 Kpc) compatible with theoretical predictions
- L = 1.5×10^{35} erg/s



Dark Sources

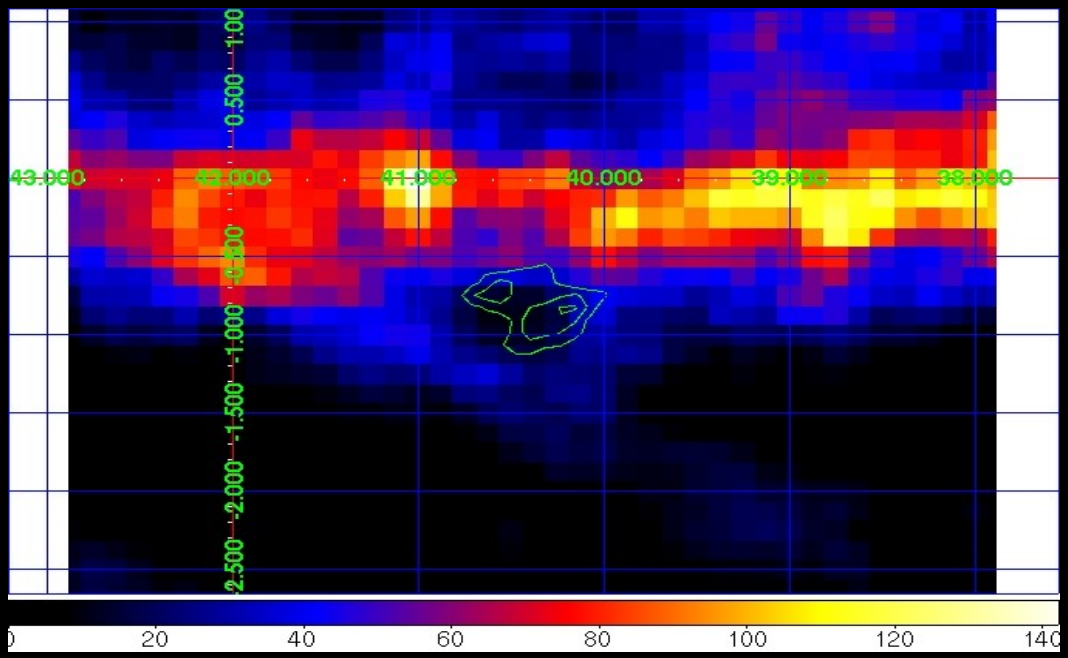
- Seem to shine only in gamma-rays : rather hard spectra and mostly extended
- No plausible counterparts in radio, x-rays, ...
- Two of HESS dark sources out of 10 have been identified recently:
  1 PWN (faint but young & energetic pulsar) , 1 SNR (composite source)
- New type of CR accelerators? (if leptons expect x-rays, radio)



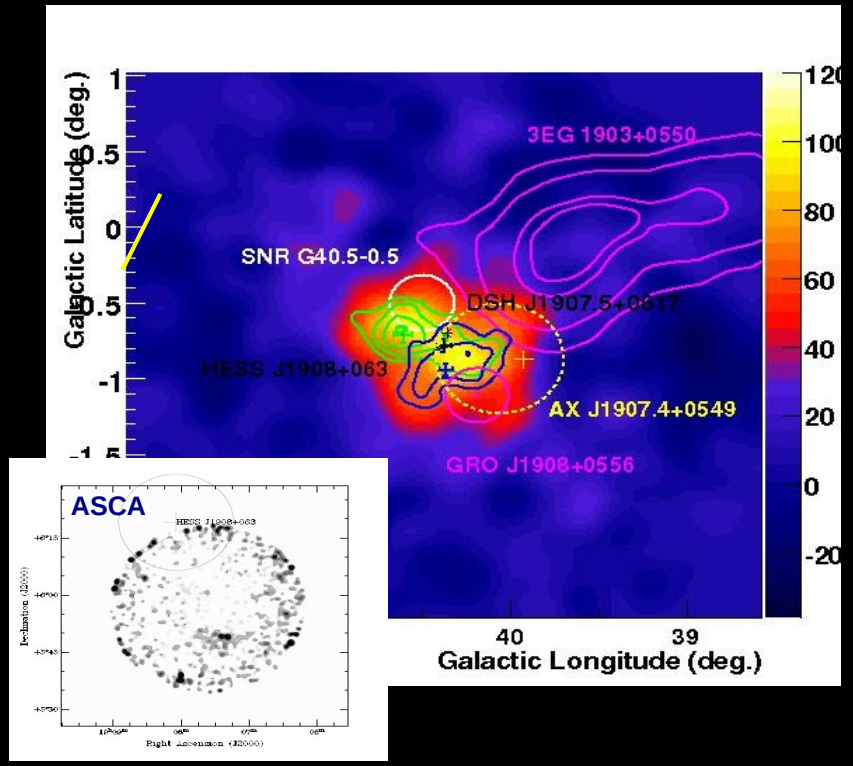
Dark Sources : HESS J1908+063 = MGRO J1908+06

- **HESS J1908+063=MGRO J1908+06 :**
  Bright extended source: 12.0 σ
  In coincidence with another GeV Egret source (Fermi?)

- **17% Crab flux > 1 TeV**



New pulsar found recently by PALFA (J1909+06, Deneva et al. 2008)
-> another PWN ?



- SNR G40.5-0.5, d=3.4 kpc

  BUT !!! Size seems too small to explain the large HESS source

- "Void" in the 12 CO (J1-0) data
- ASCA source PWN candidate
- DSH J1907.5+0617 (Open Cluster Candidate)
- Fermi detection! Pulsed emission

Dark Sources

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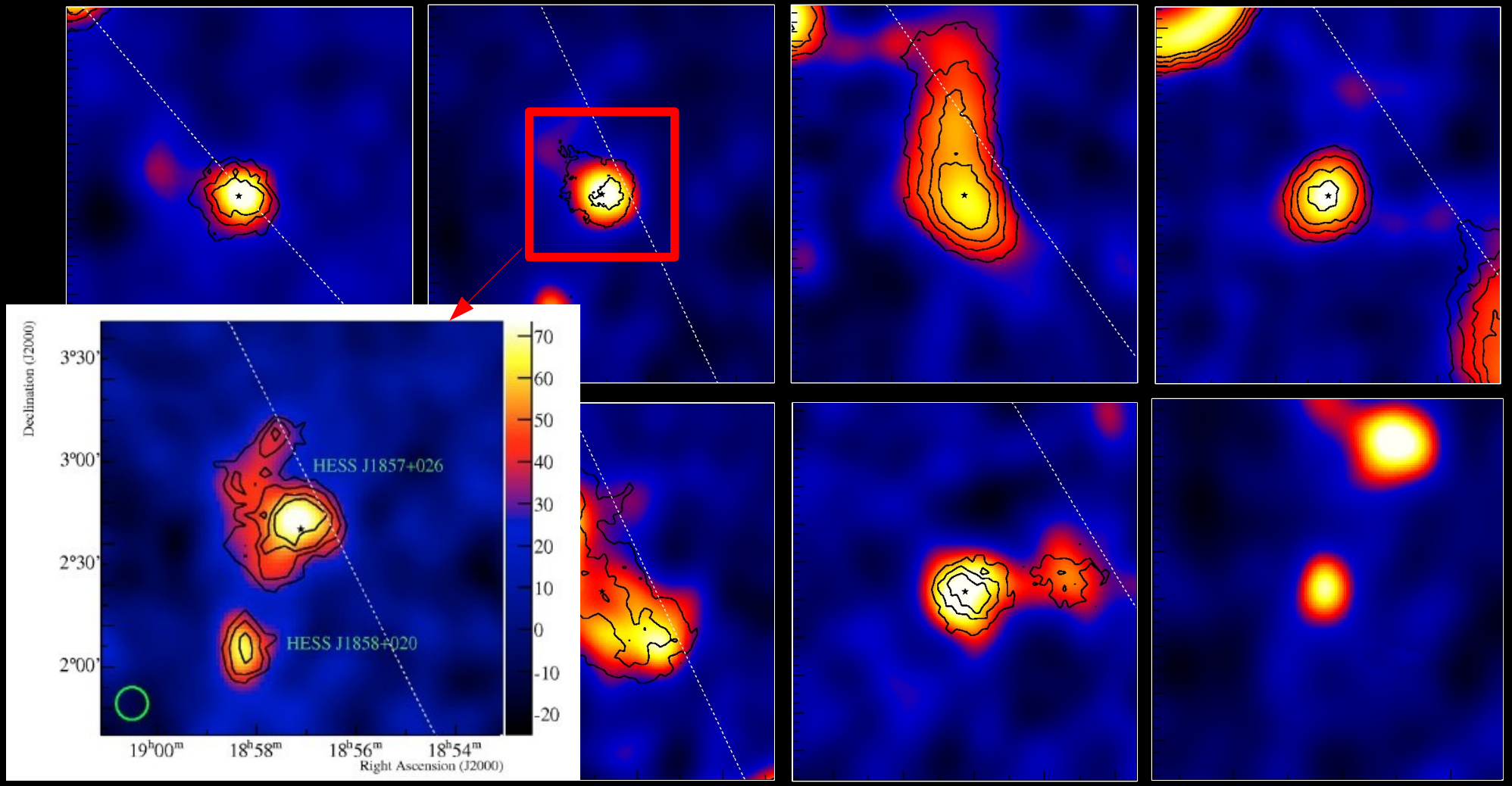

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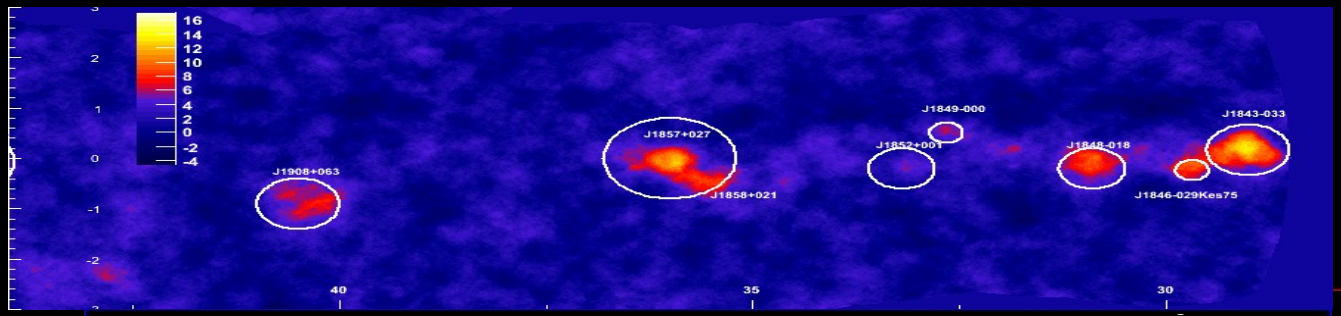
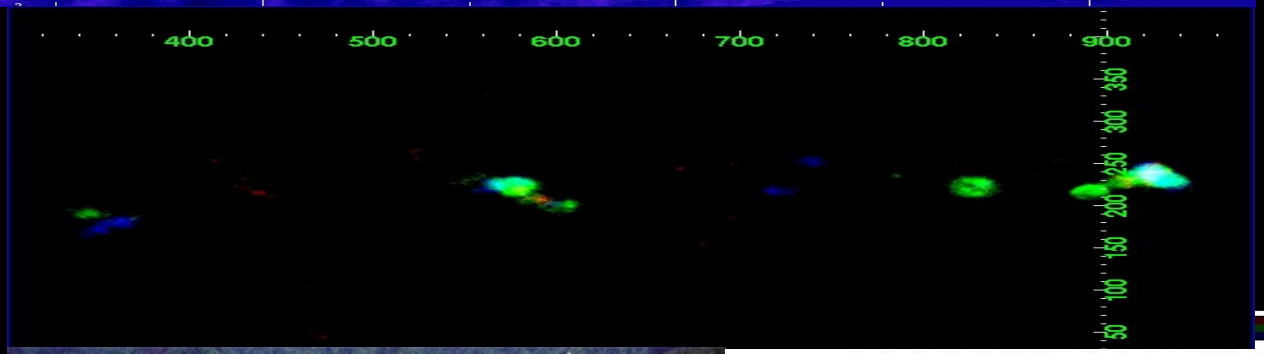
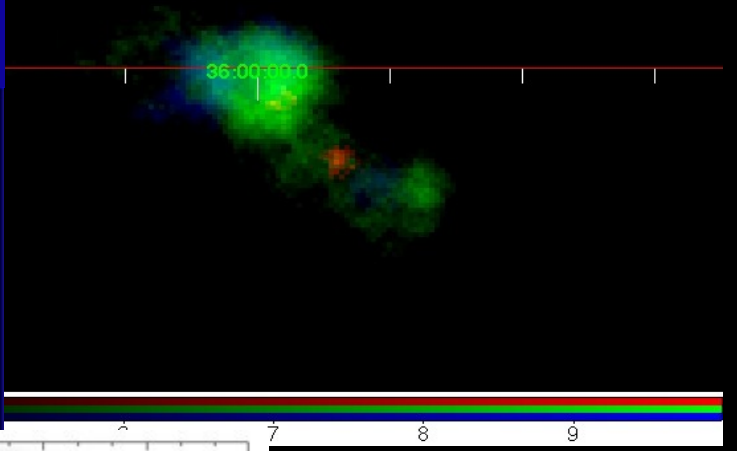
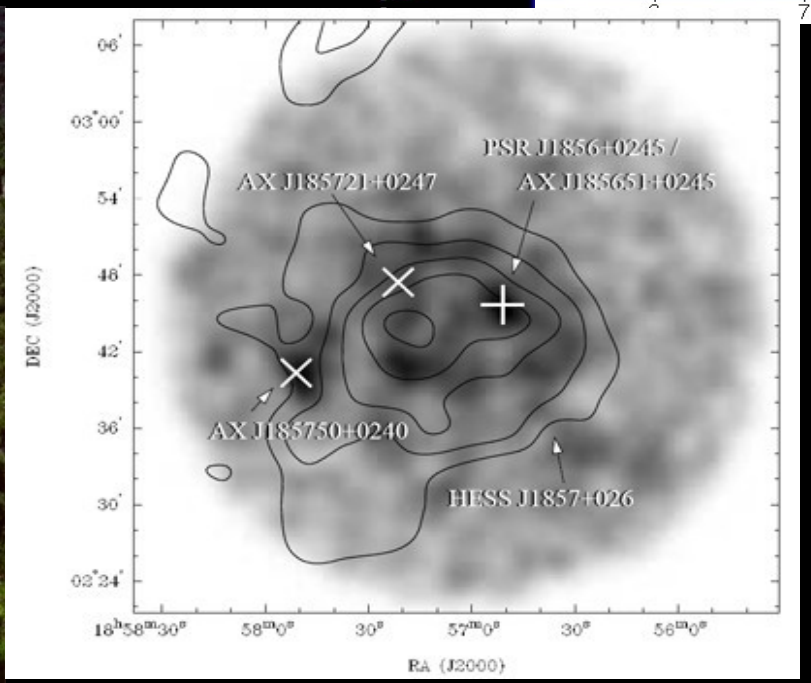
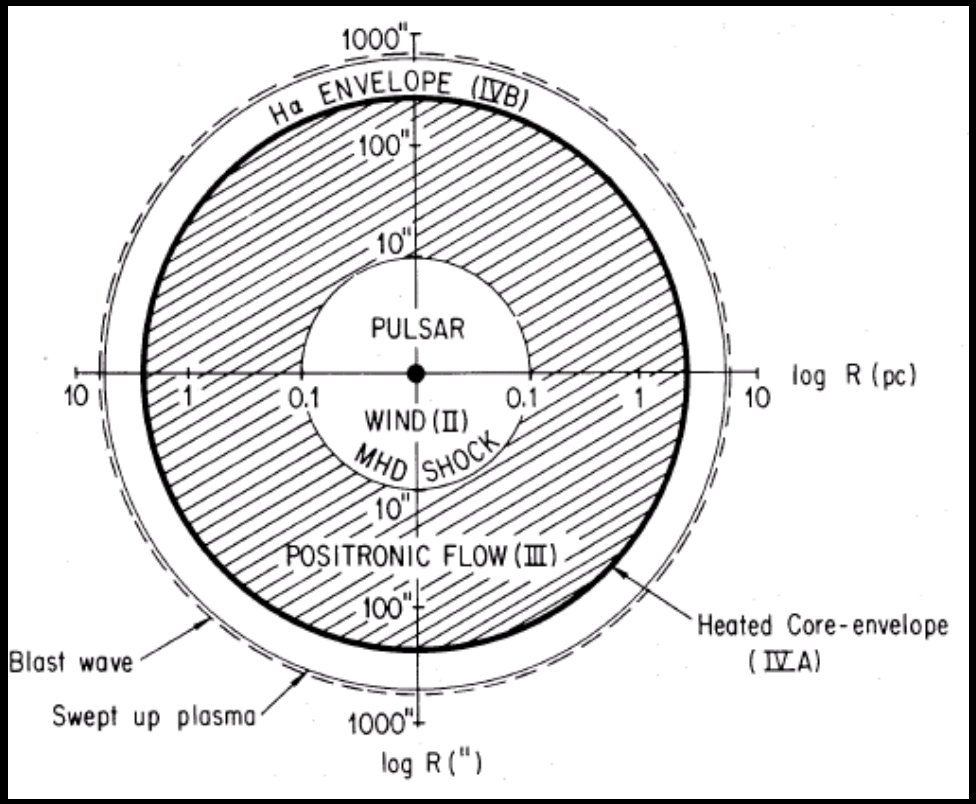


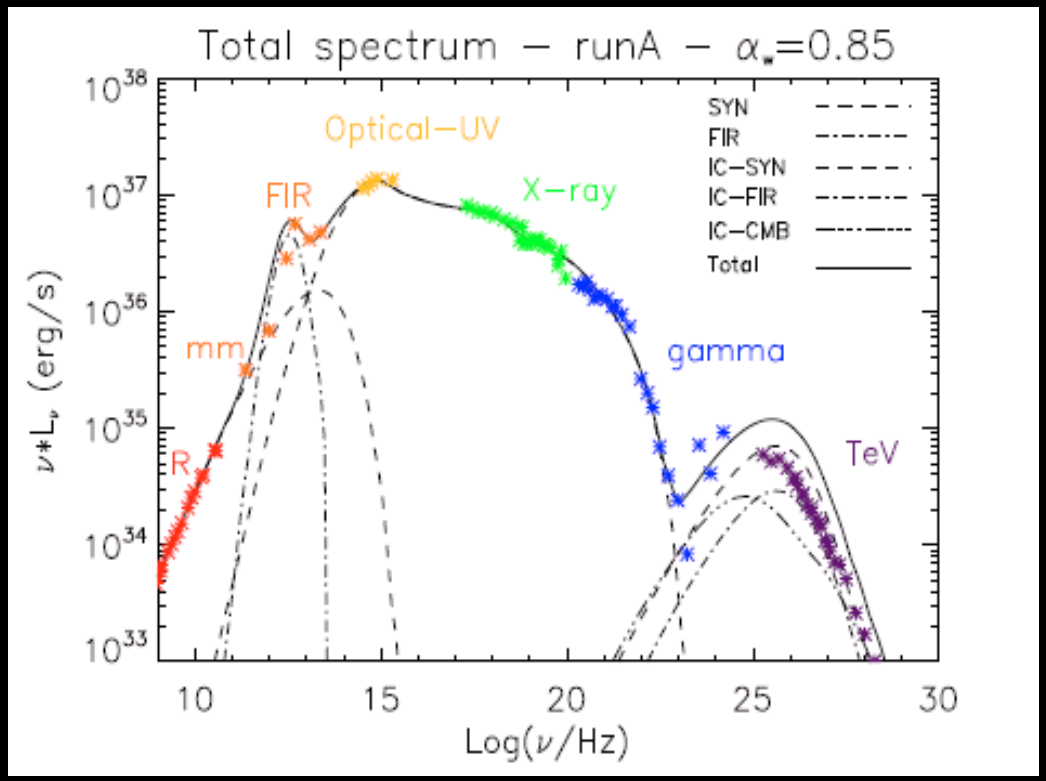






Pulsar Wind Nebulae





- Synchrotron for Radio to X-ray spectrum
- Inverse Compton for Very High Energy emission. Seeding on photons from the CMB, IR, UV and synchrotron (for the Crab)
- Measurement of the Total Energy → information on the birth period

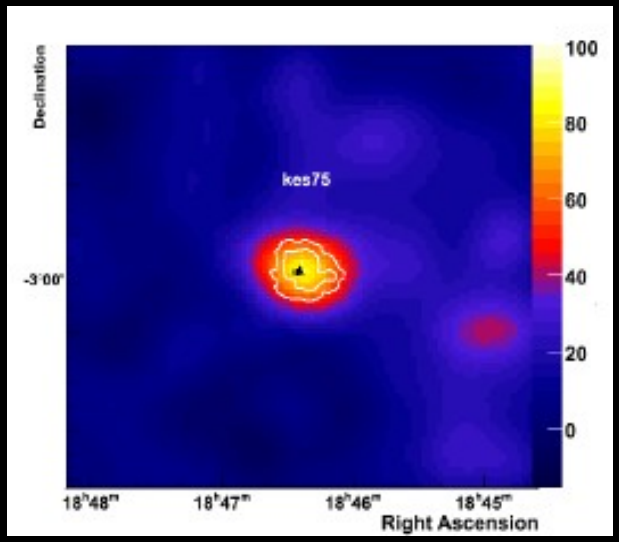
$$\frac{L_X}{L_\gamma} = \frac{B^2}{8\pi U_{Rad}}$$

$$\dot{E}(t) = \frac{\dot{E}_0}{\left(1+\frac{t}{\tau}\right)^{\left(\frac{b+1}{b-1}\right)}}$$

Pulsar Wind Nebulae

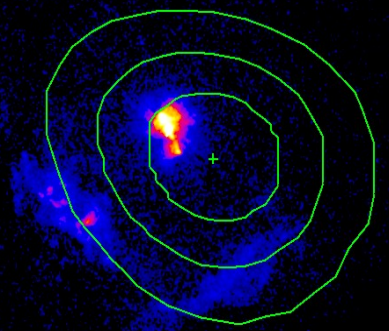
- Major galactic source population
  Revealed by HESS galactic scan
- Associated with
  very young : age < 10^5 yrs
  energetic: Edot > 10^{35} erg/s
  pulsars
- Two classes seem to emerge:
  - Young plerions
    - Point-like, centered in the pulsar candidate
    - (Crab, Kes 75)

Kes 75



Terrier et al, Gamma08, 2008

Kes 75
- Composite SNR
- PSR J1846-0258
  E_{dot}=8.3x10^{36} erg/s
  τ=723 yr
  d=6 kpc
  B=5x10^{13} G (B_{QED} =4.4x10^{13} G)
- 32 hr, 1.5' upper limit in extension
  Γ=2.29±0.14$_{stat}$ Γ_x = 1.9
  Φ=(6.15± 0.77$_{sta}$) x10^{-13} TeV^{-1} cm^{-2} s^{-1}
  -> 0.12% of spin down power
- Magnetic field B~15 uG



Chandra 2-10 keV

Pulsar Wind Nebulae

- Major galactic source population
  Revealed by HESS galactic scan
- Associated with
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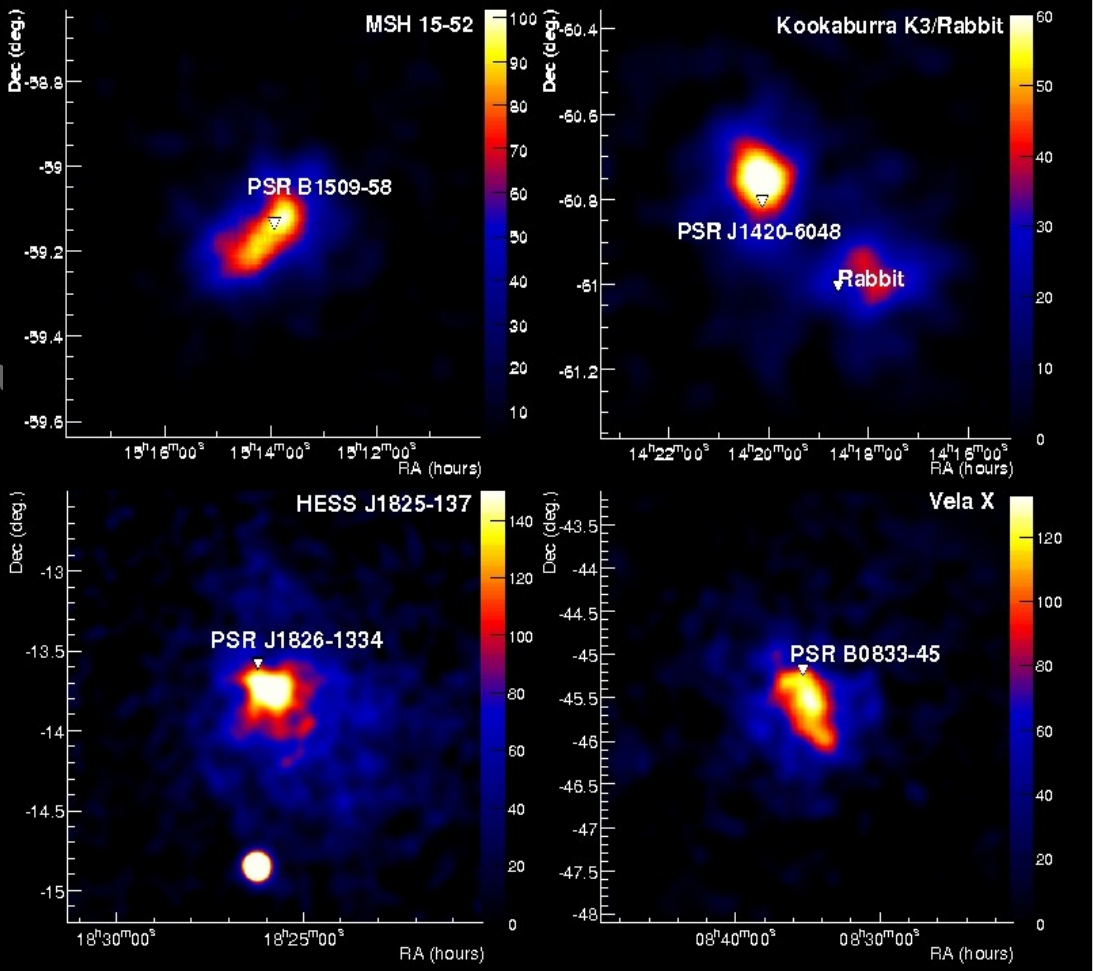
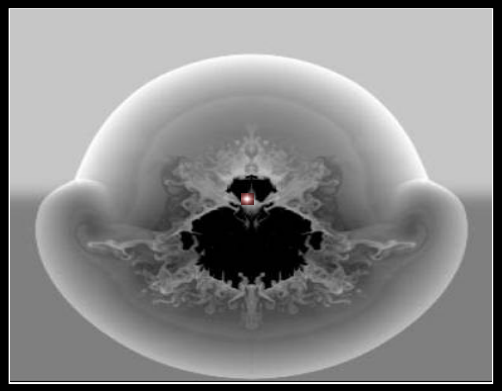
  energetic: Edot > 10^{35} erg/s
  pulsars
- Two classes seem to emerge:
  - Young plerions
    - Point-like, centered in the pulsar ca
    - (Crab, Kes 75)

Evolved PWN

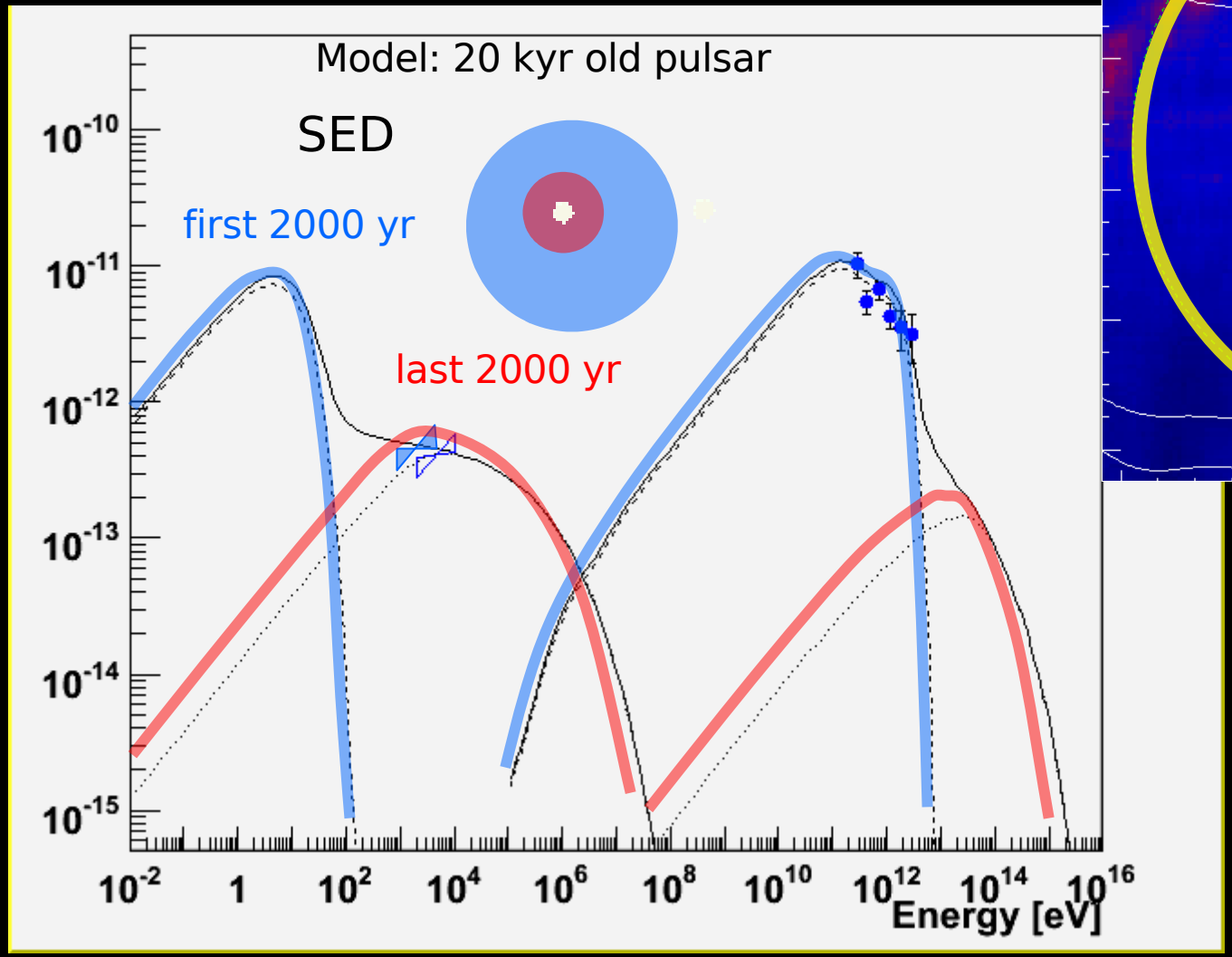
- **Nebulae with huge caracteristic sizes ~ few tens of pc**
- **Mostly displaced TeV emission wrt pulsar position: "Crushed nebulae"**

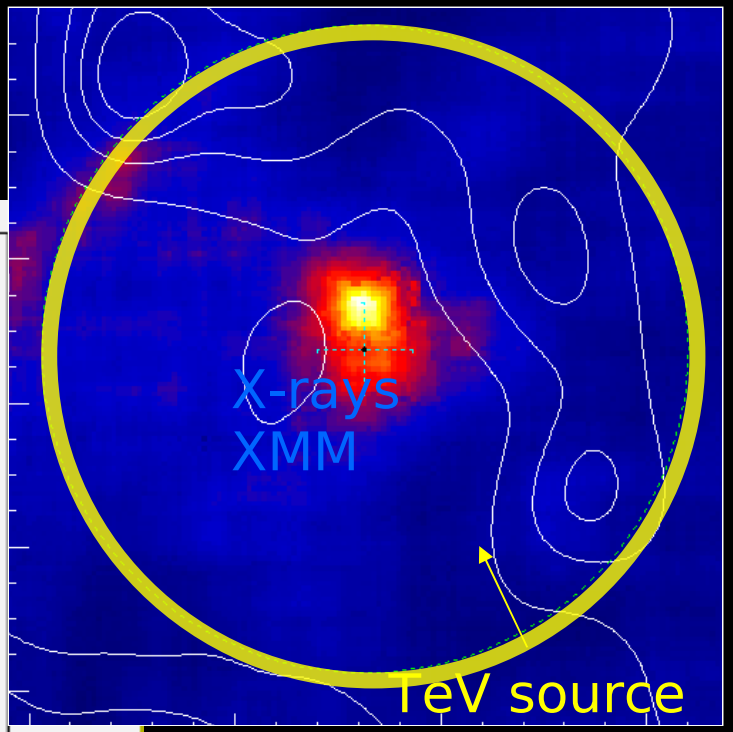




SN Explosion in inhomogenous medium→ reverse shock pushes the nebula

Old PWN VHE Emission



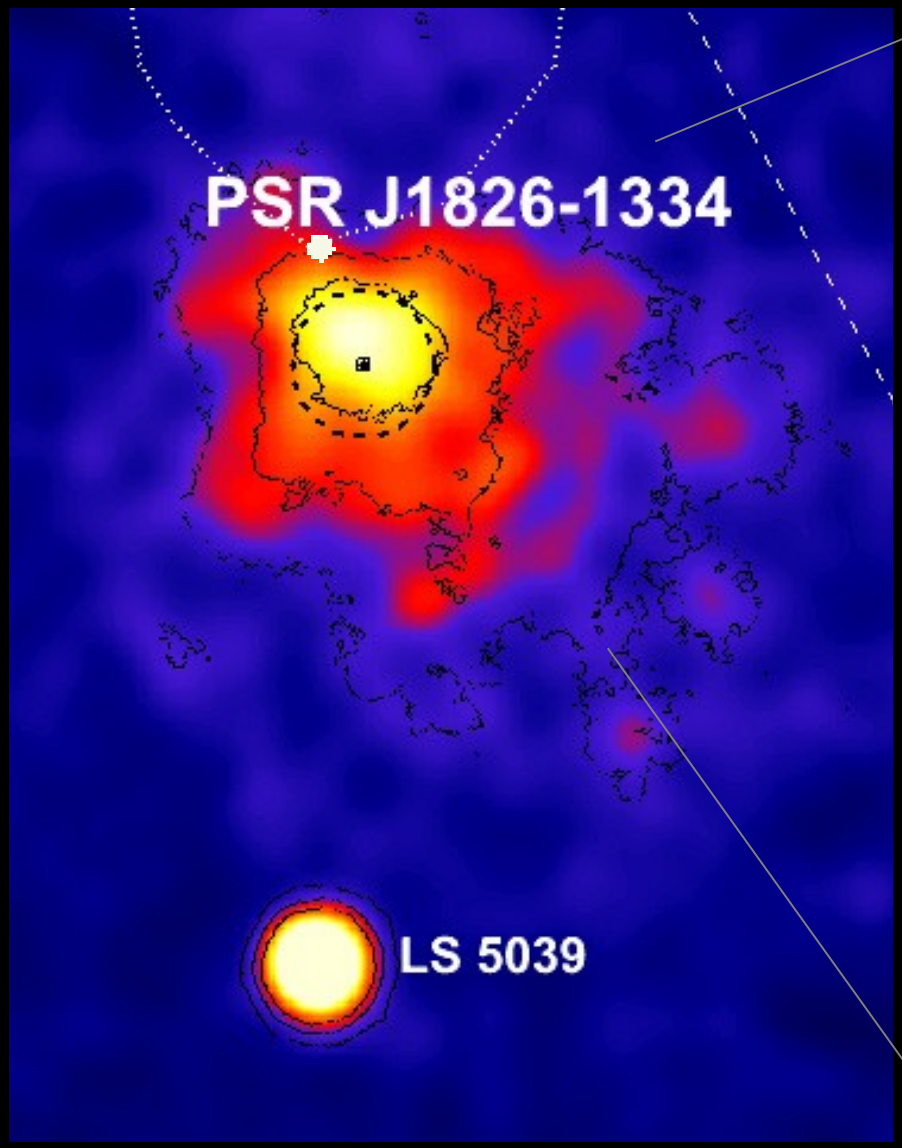


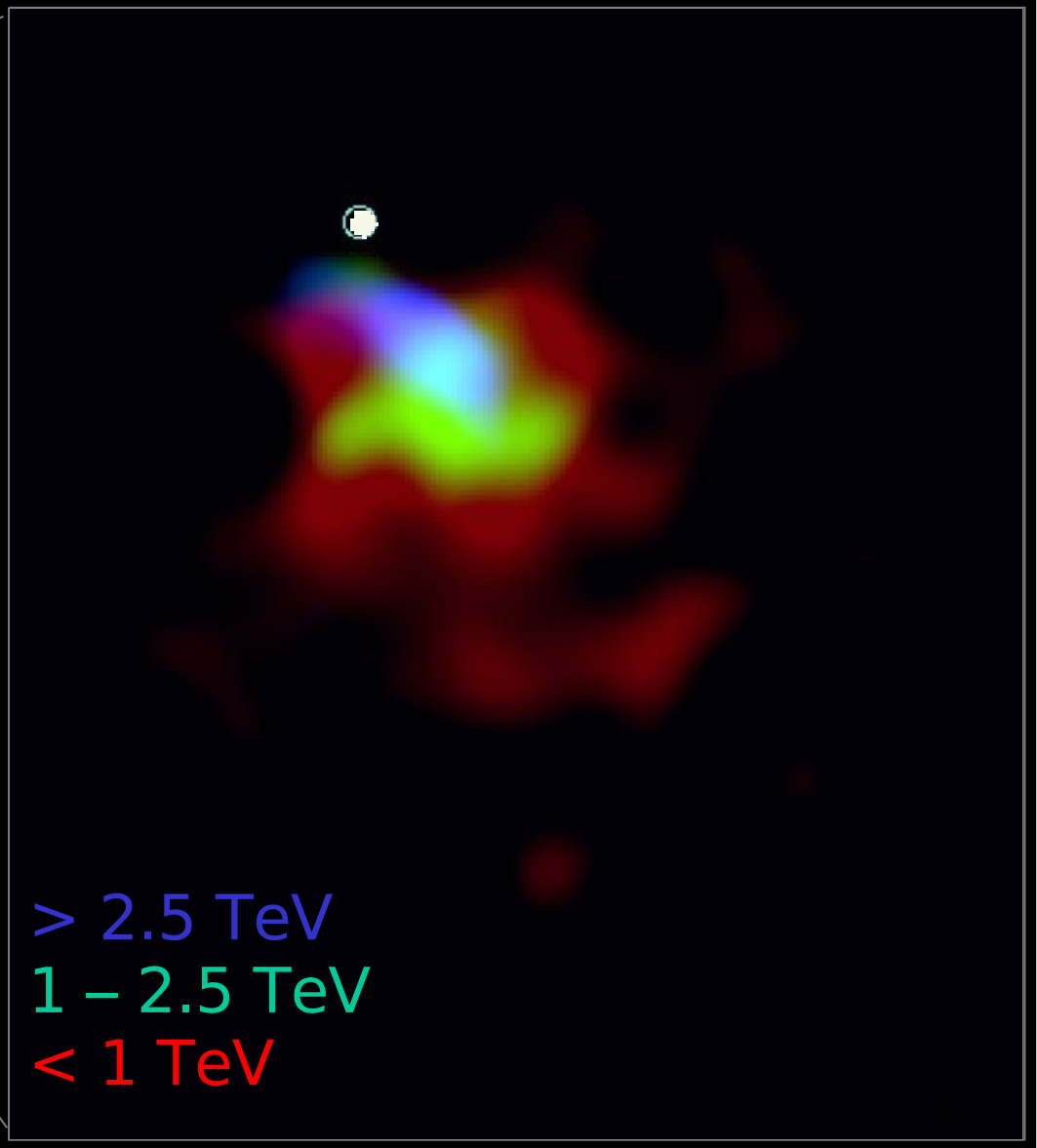
σ_{TeV} = 2.7'

Why are TeV / X-ray source sizes different?

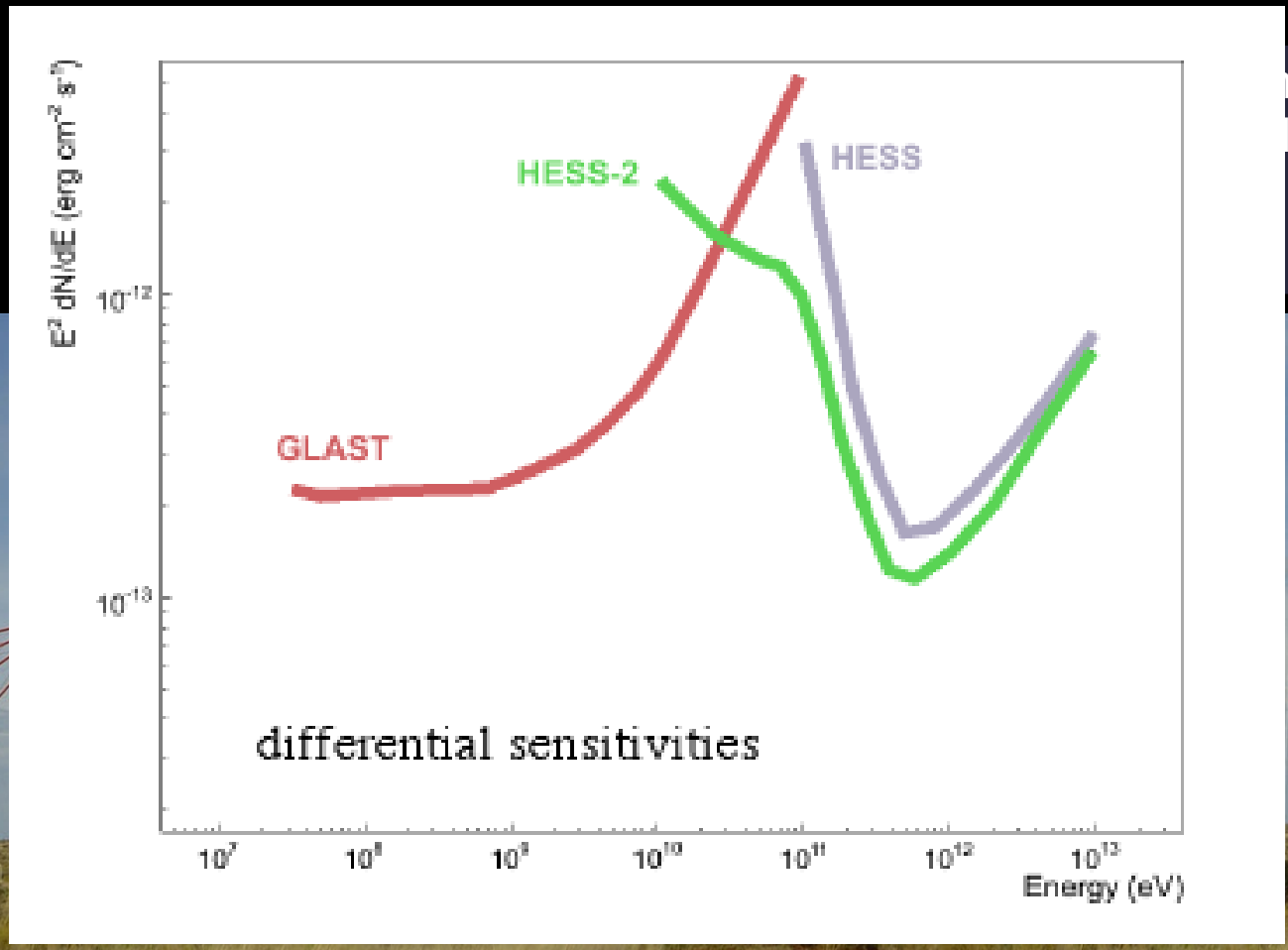
Why is the TeV flux higher?

Morpholgy of PWNe: evidence for cooling
Relic electrons at action: HESS J1825-137



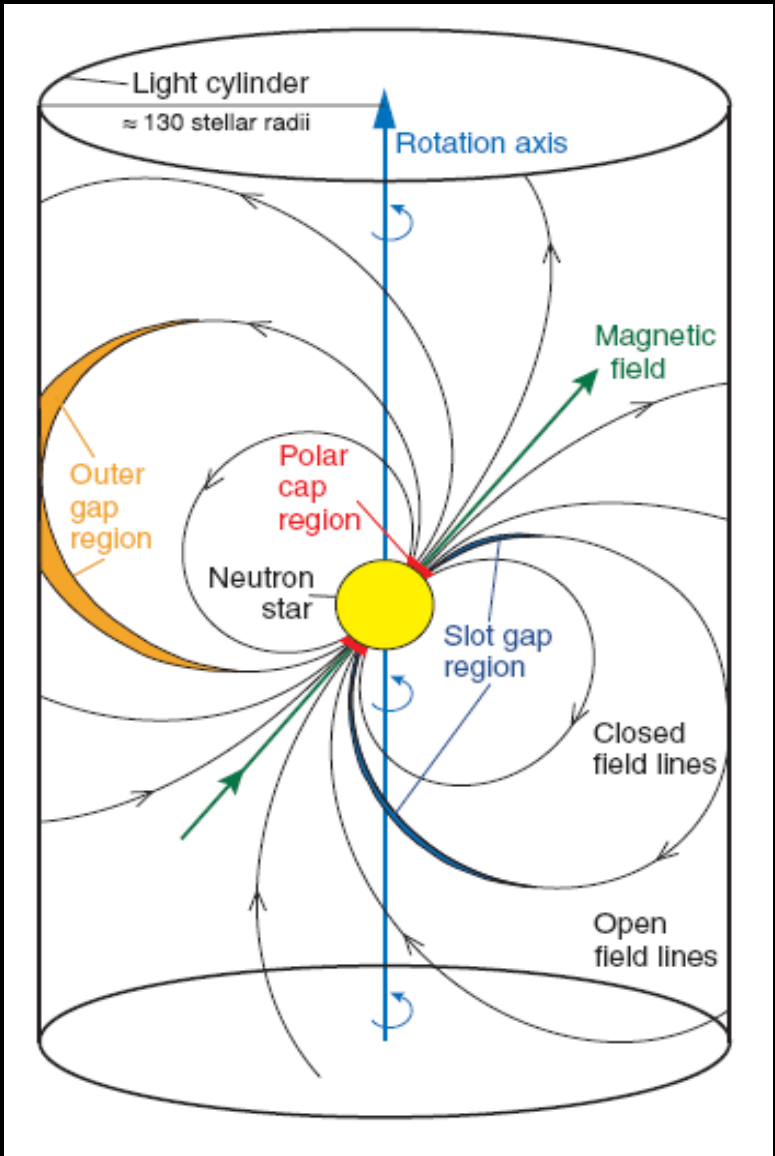


Near term: HESS-II



+
lescope
energy

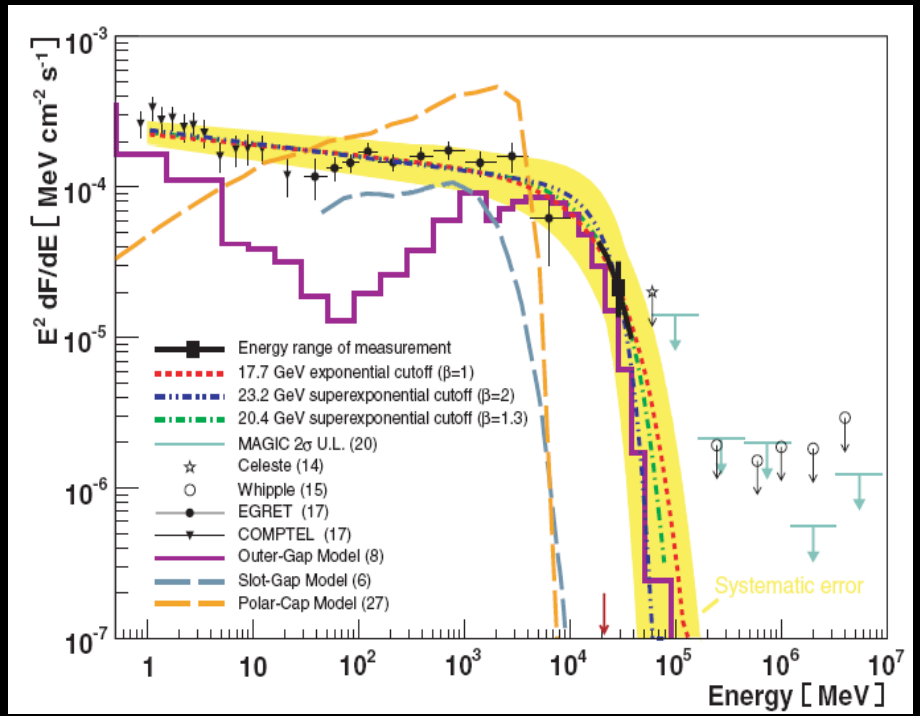
HESS-II: Galactic Physics - Pulsars



Pulsar Trigger Concept

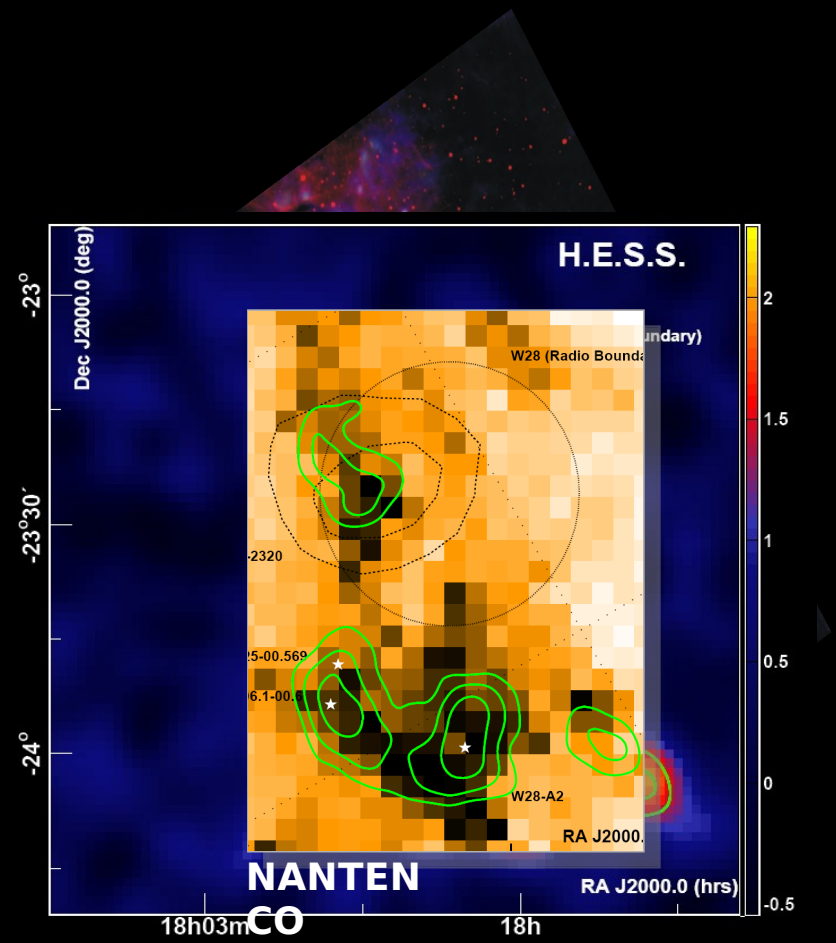
- Summing signal from several pixels to increases signal to noise ratio
- Fluctuations of shower larger than Poissonian fluctuations of NSB background

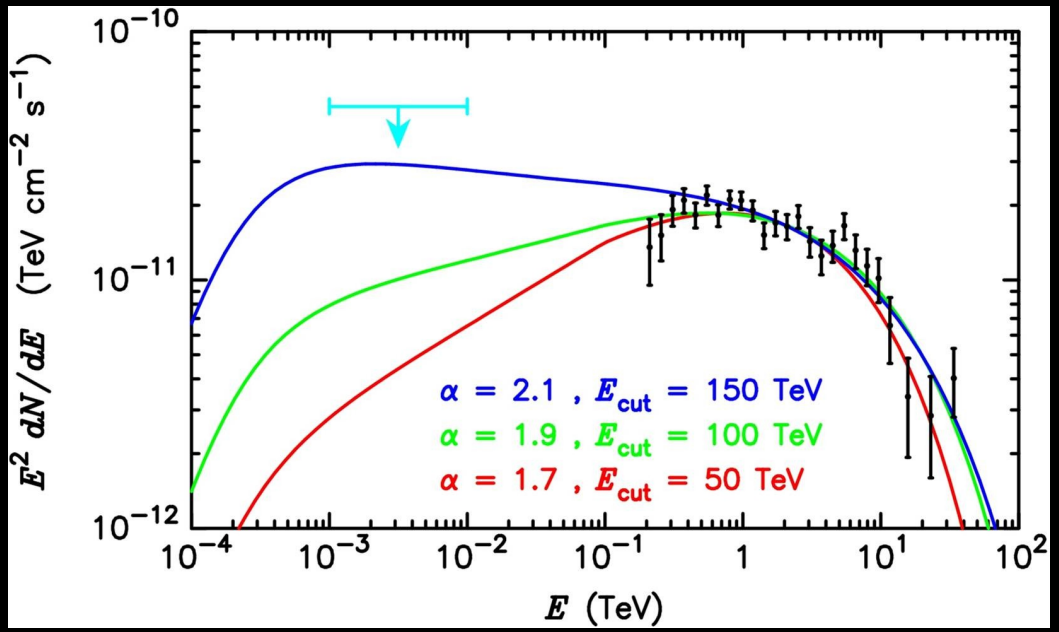
de Oña Wilhelmi & de Jager, 2004



HESS-II: Galactic Physics

- Distinguish between acceleration models
  hadronic vs leptonic
- Origin of CR?
- Dark sources -> SNRs interacting with molecular clouds?
- PWN: Time evolution -> Low energy particles and better sensitivity





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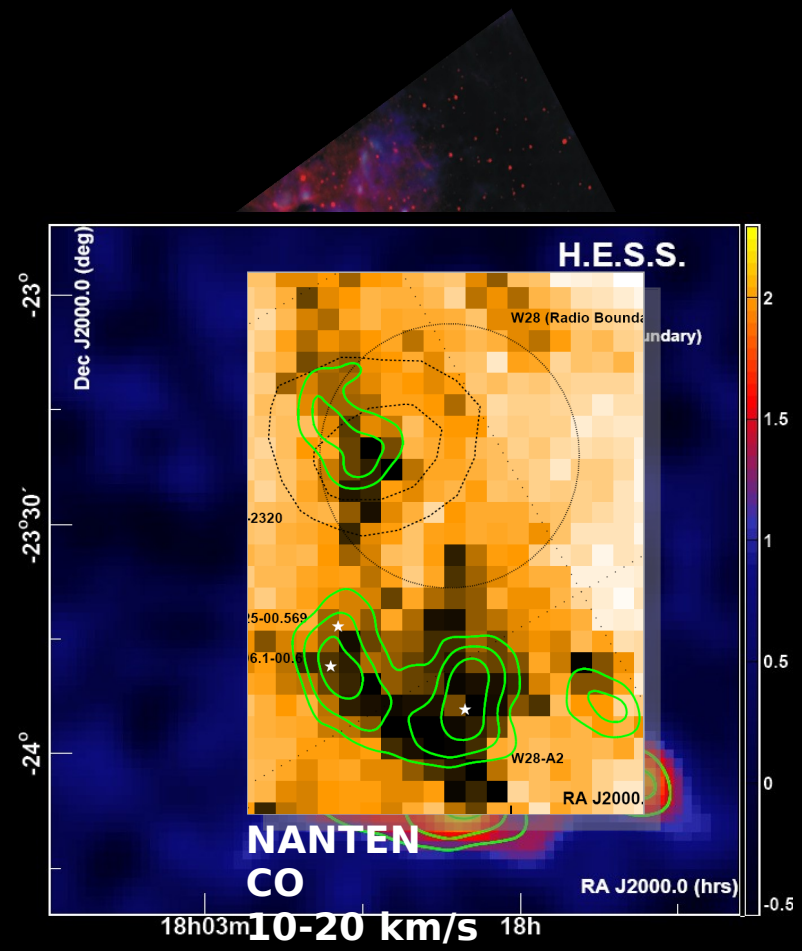
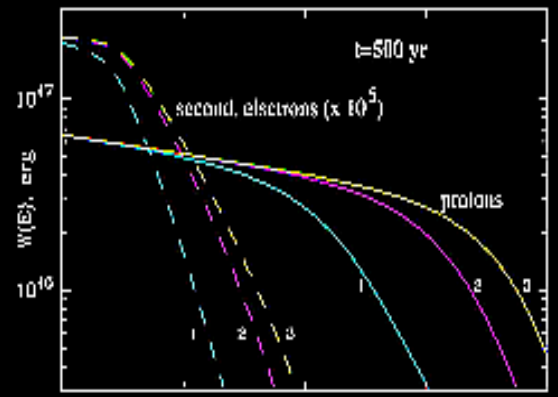
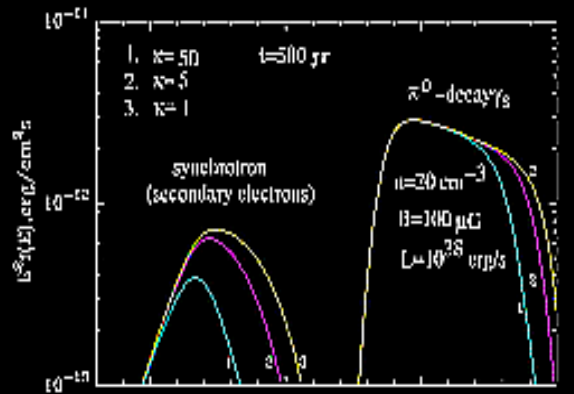
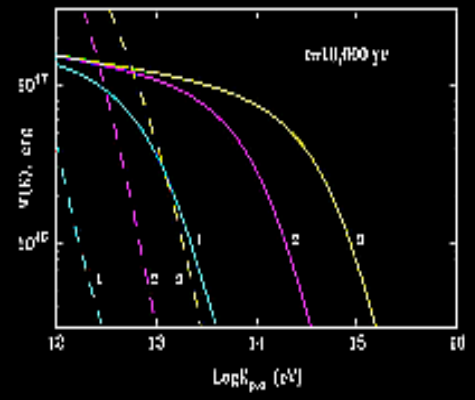
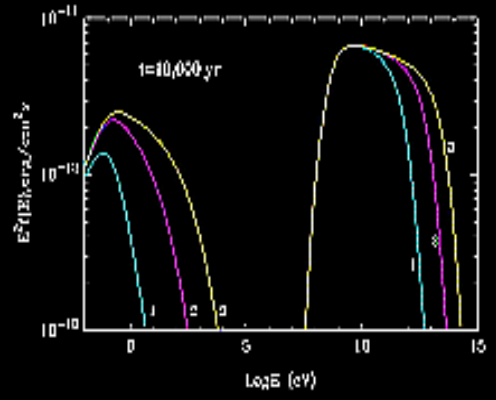


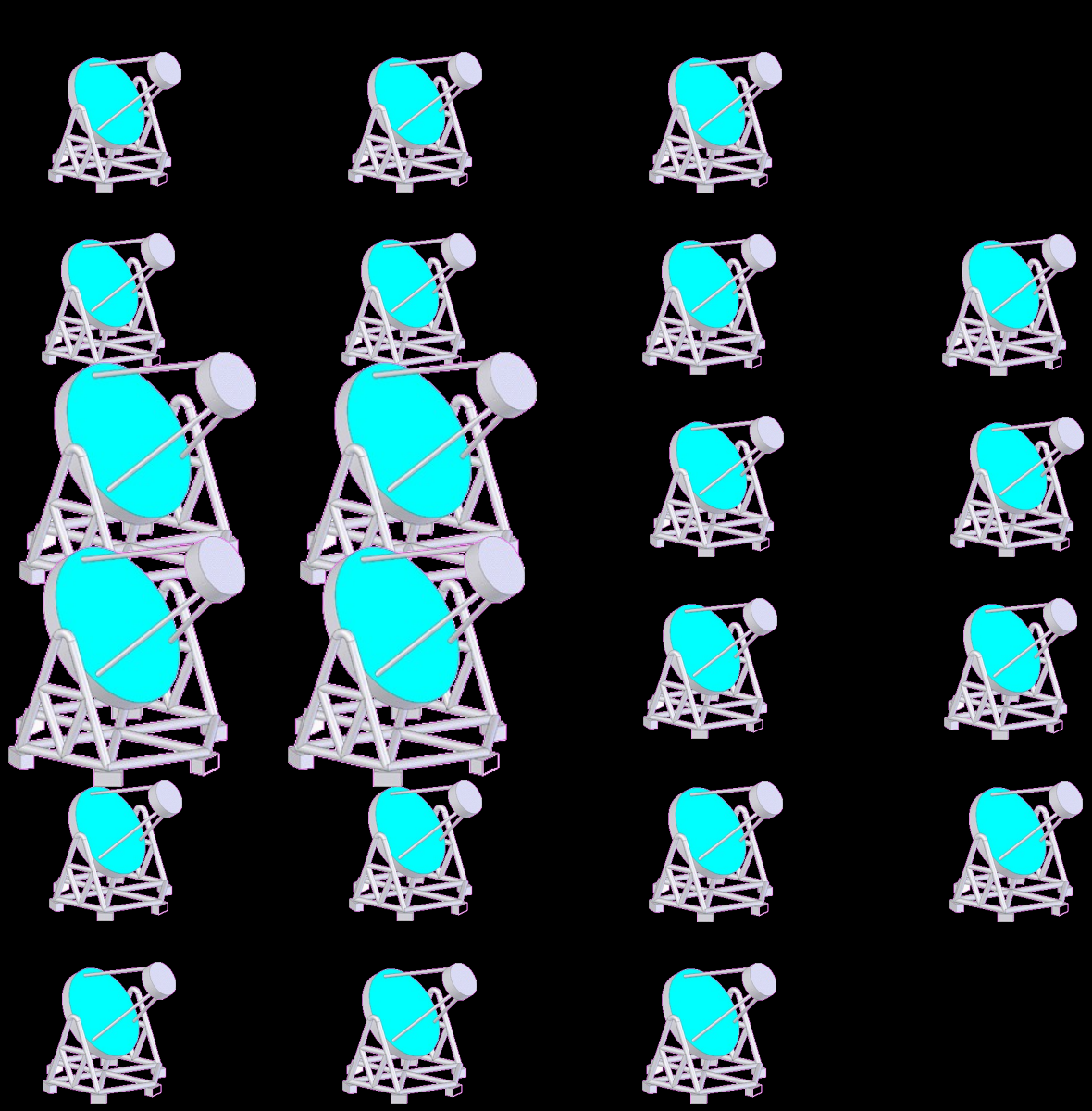


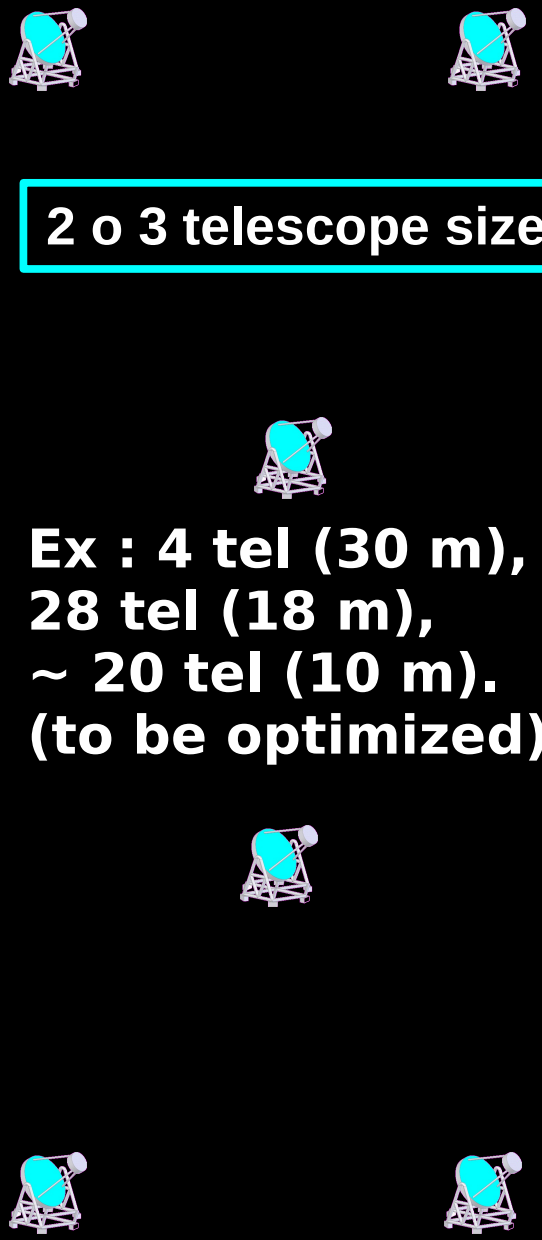






Mid term Project : CTA (Cherenkov Telescope Array)

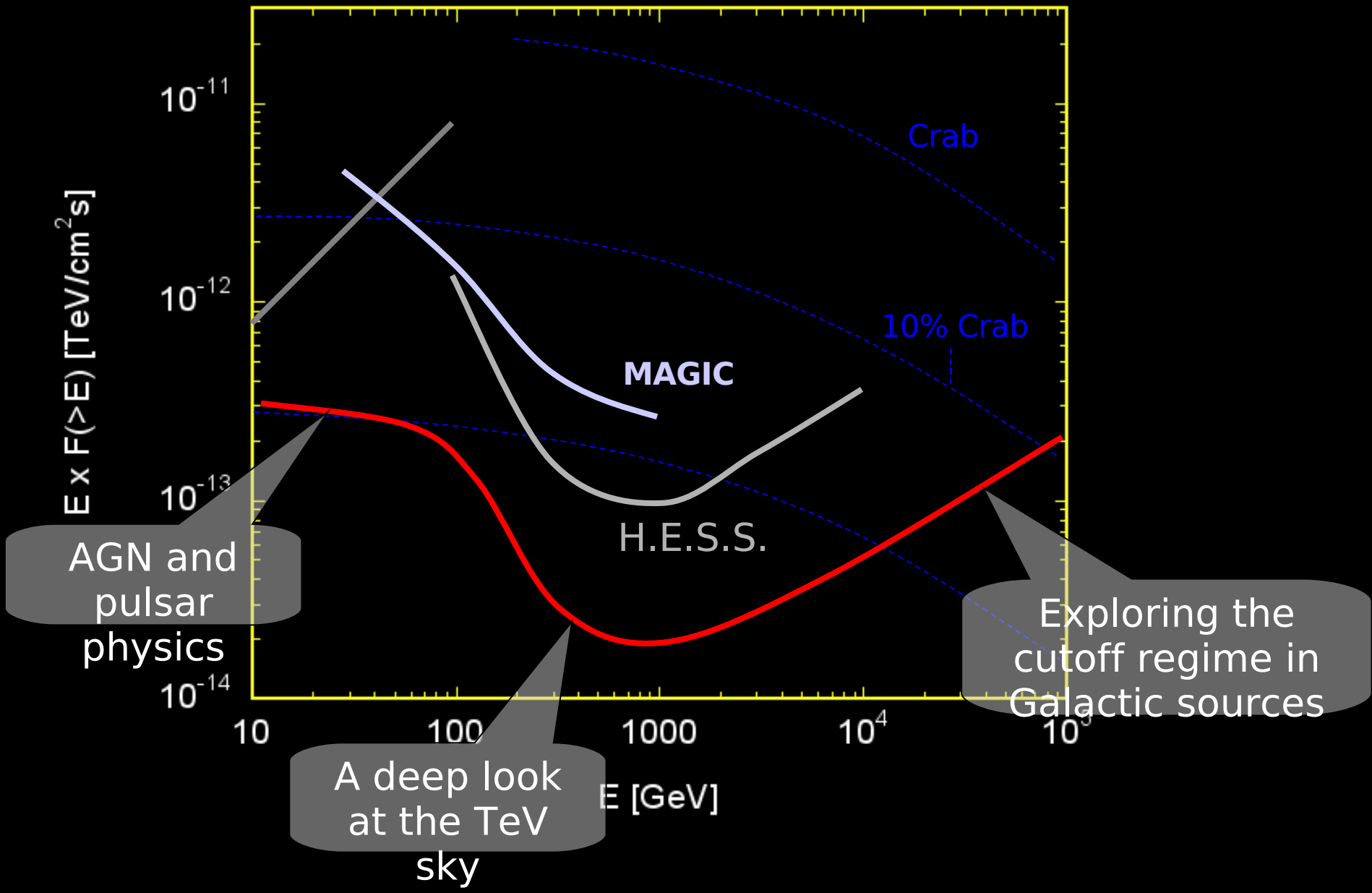




2 o 3 telescope sizes

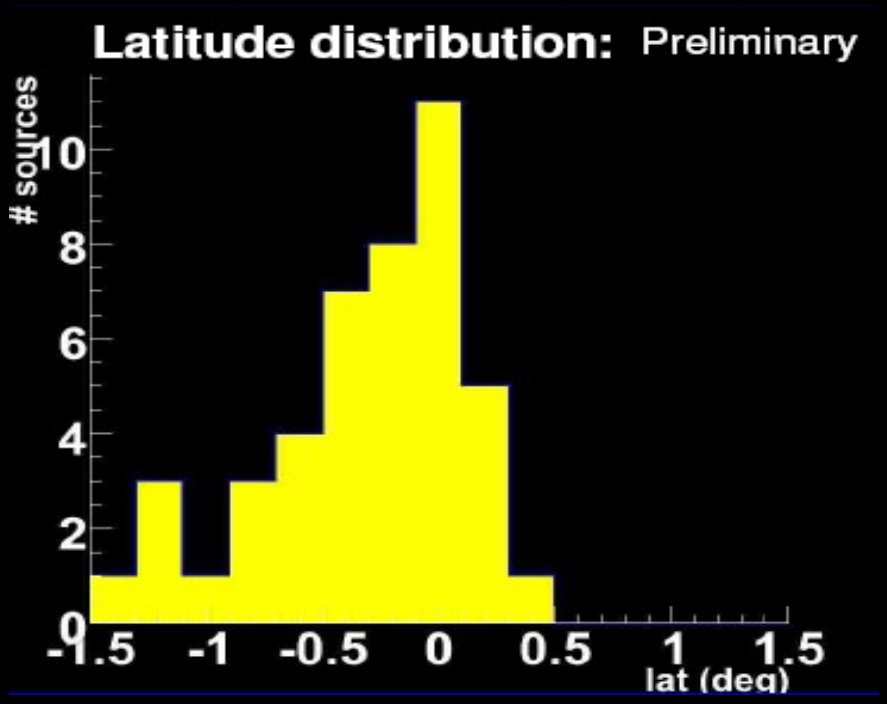
Ex : 4 tel (30 m),
28 tel (18 m),
~ 20 tel (10 m).
(to be optimized)

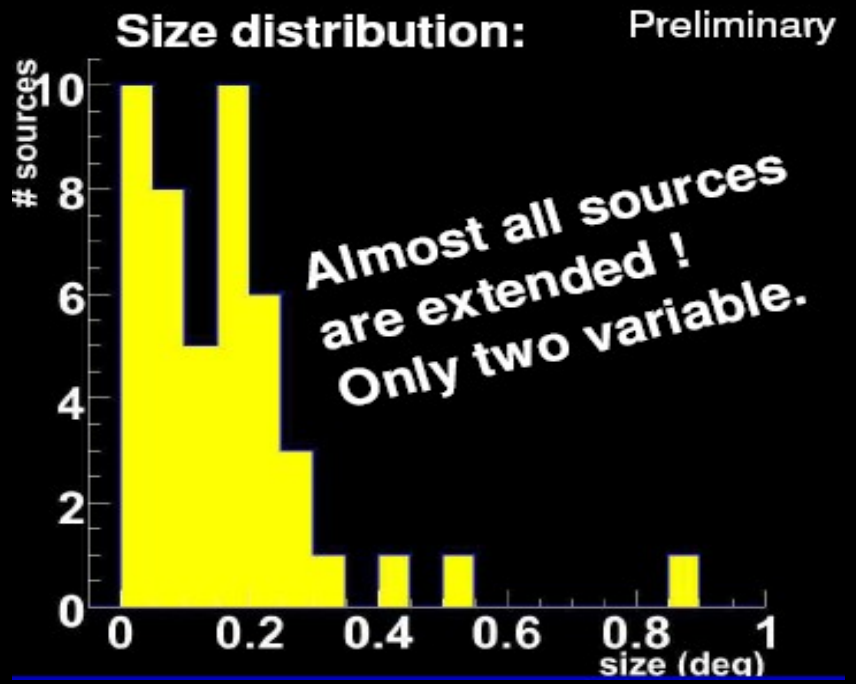
Mid term Project : CTA (Cherenkov Telescope Array)

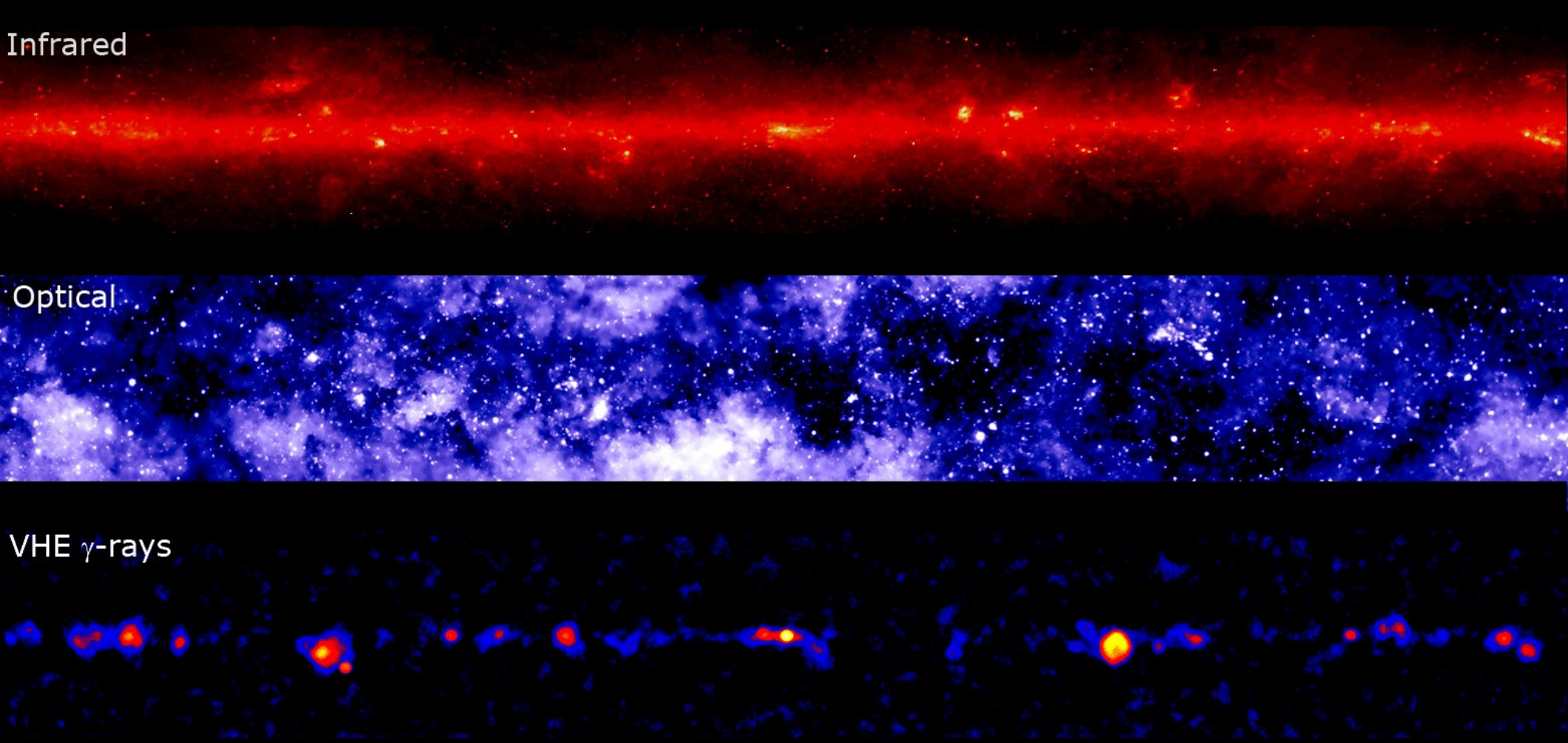


Conclusions

- The scanned region reaches from -80d to 60d galactic longitude and -2.5d to 2.5d galactic latitude.
- 12 sources with counterparts, 3 with plausible counterparts
- Case-by-case effort to nail-down counterparts with X-ray and radio observations
- PWN candidates: leptonic emission?/SNRs and Dark sources: hadronic emission?
- No cutoff at higher energies: PeVatrons? BUT systematics to be considered in the analysis

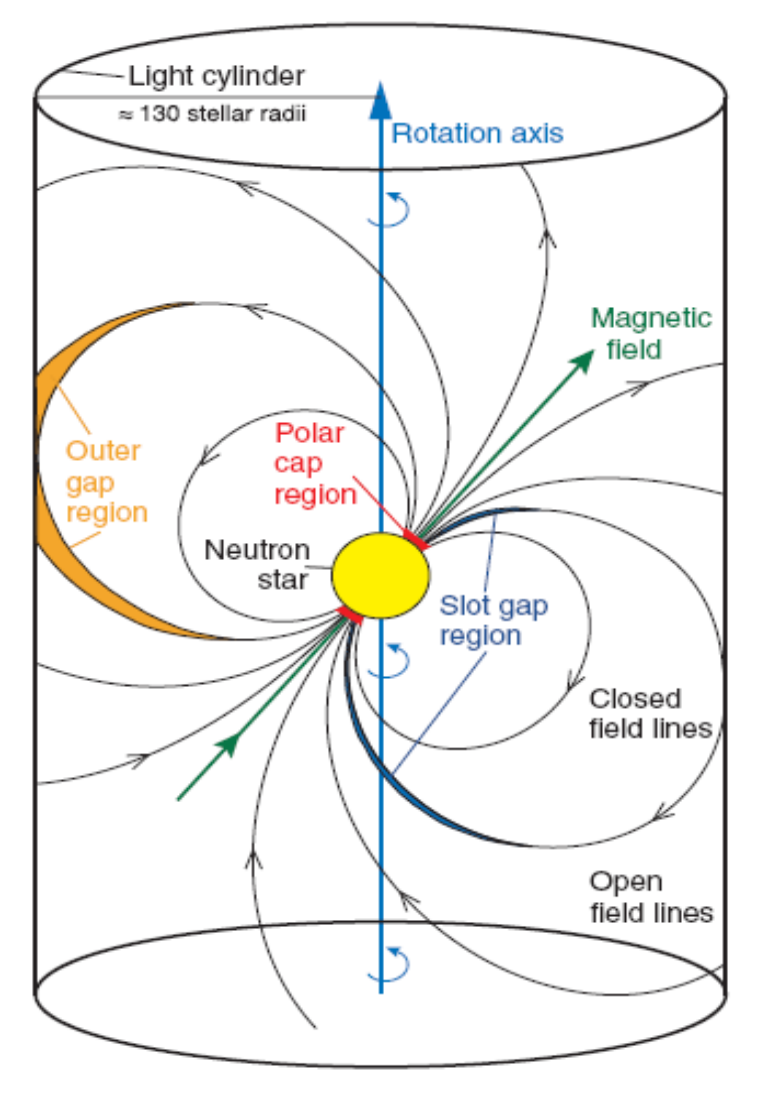






THANK YOU

Emission models: Pulsar at high energies



Polar cap models and outer gap models

Acceleration of electrons

Cooling mechanisms

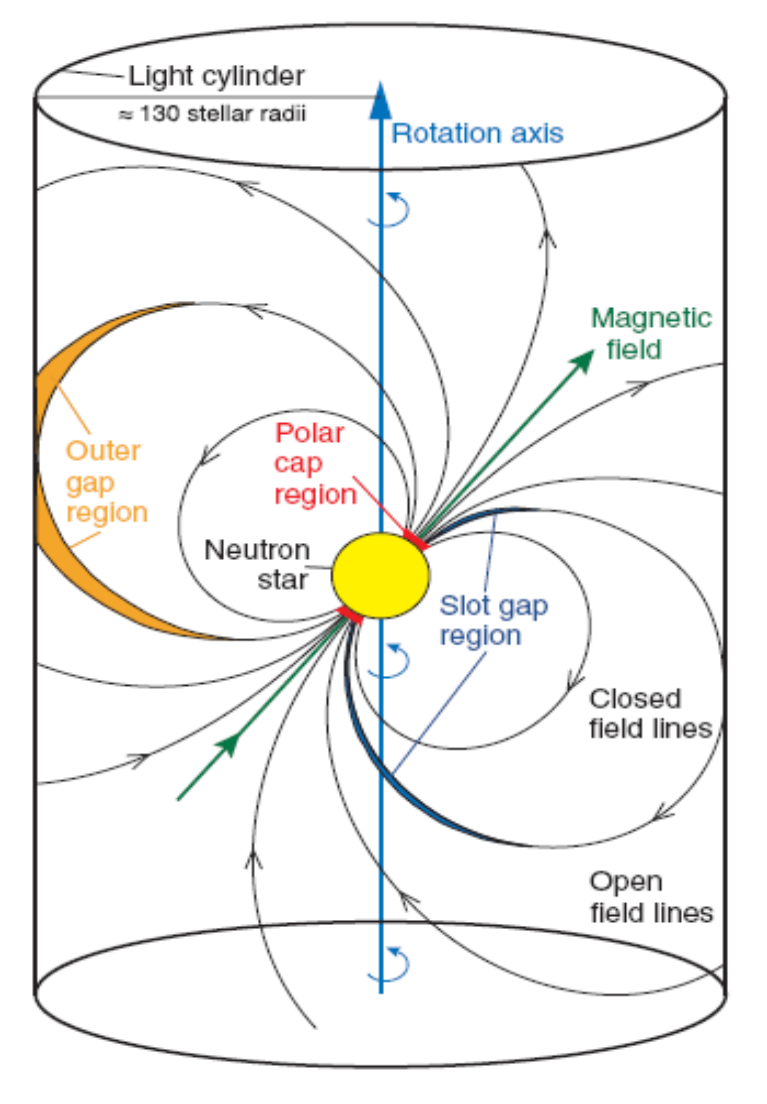
- Curvature radiation
- Synchrotron, I.C. of X-rays

γ-rays interact with magnetic field, via *Magnetic pair production*

→ **VHE emission close to the neutron star**

→ **Superexponential cutoff at few GeV**

Emission models: Pulsar at high energies



Outer gap model

γ-ray emission occurs near LC

- **Charges accelerated in vacuum gap**

  → *γ-rays via Curv. rad.*

- **B not strong enough for pair-production. But:**

- ***γ-rays* interact with non-thermal X-rays**

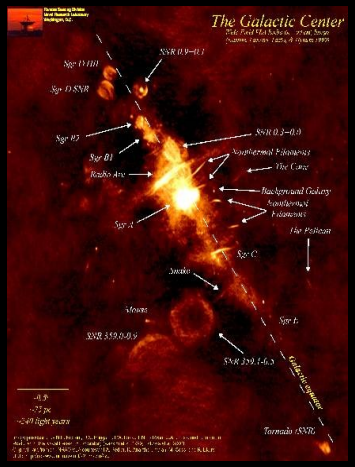
$\gamma\gamma \rightarrow e^+e^-$

→ **VHE emission far to the neutron star**

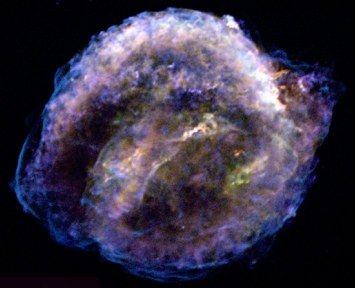
→ **Exponential cutoff at few GeV**

Galactic VHE γ-ray sources

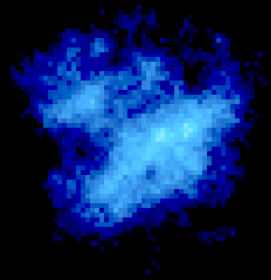
Dark matter



Supernova Remnants (SNR)



Dark Sources



Open clusters

Pulsar Wind Nebula (PWN)

Binary Systems