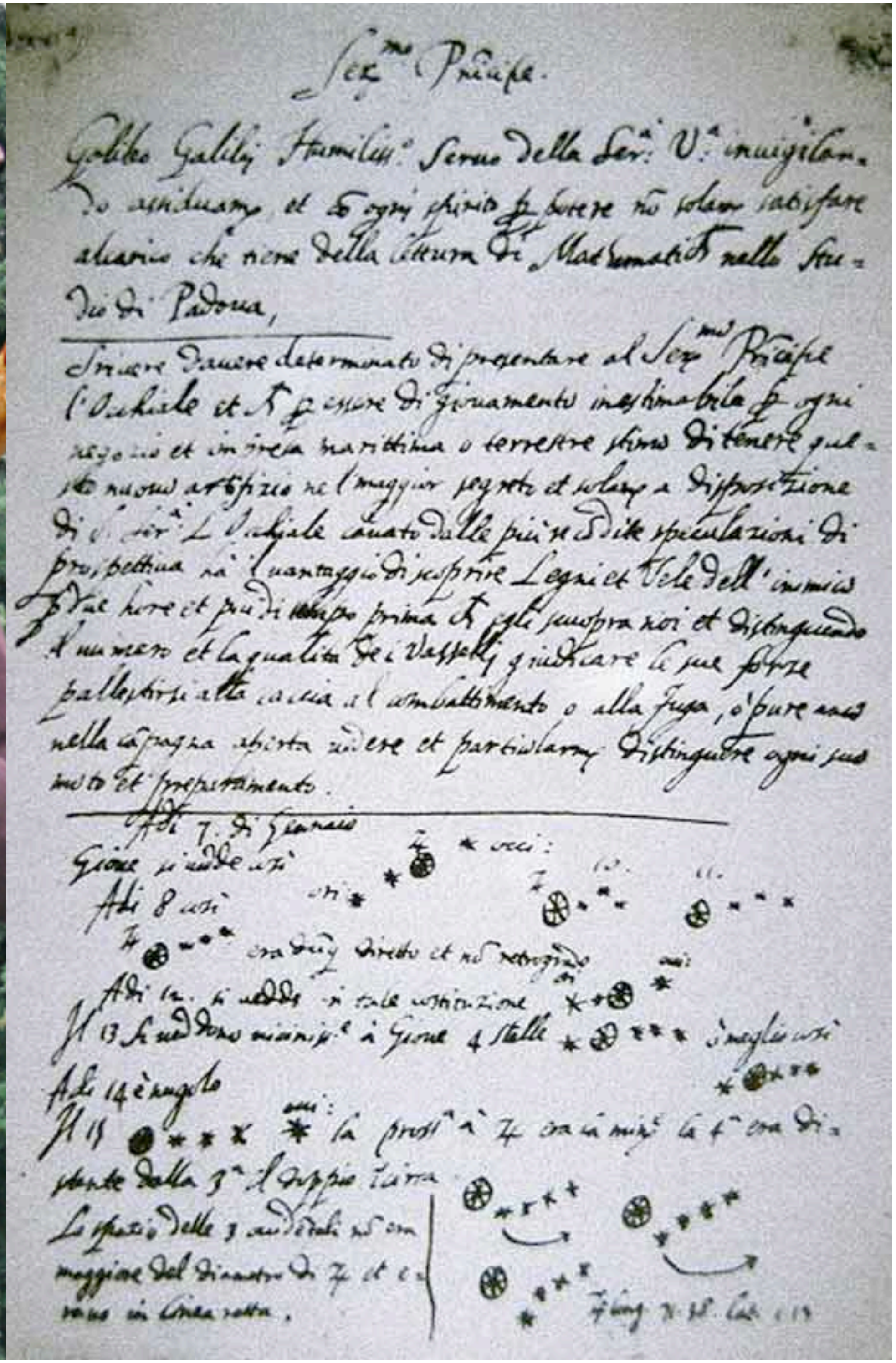
THE UNIVERSE
YOURS TO DISCOVER

INTERNATIONAL YEAR OF
ASTRONOMY
2009



Ser.mo Principe.

Galileo Galilei Humiliss.o Servo della Ser.tà V.a invigilando assiduamente, et con ogni spirito per potere non solamente satisfare al carico che tiene della lettura di Matematica nello Studio di Padova,

Haver determinato di presentare al Ser.mo Principe l'Occhiale et per essere di giovamento inestimabile per ogni negozio et impresa marittima o terrestre stimo di tenere questo nuovo artifizio nel maggior segreto et solamente a disposizione di V. Ser.tà L'Occhiale cavato dalle più recondite speculazioni di prospettiva ha il vantaggio di scoprire Legni et Vele dell'inimico due hore et più di tempo prima che egli scuopra noi et distinguendo il numero et la qualità dei Vasselli giudicare le sue forze pallestirsi alla caccia al combattimento o alla fuga, o pure ancora nella campagna aperta vedere et particolarmente distinguere ogni suo moto et preparamento.

Adi 7. di Gennaio
Giove si vedde così ... occi:

Adi 8 così

era dunque diretto et non retrogrado

Adi 12. si vedde in tale costituzione

Il 13 si veddono vicinissime à Giove 4 stelle ... o meglio così

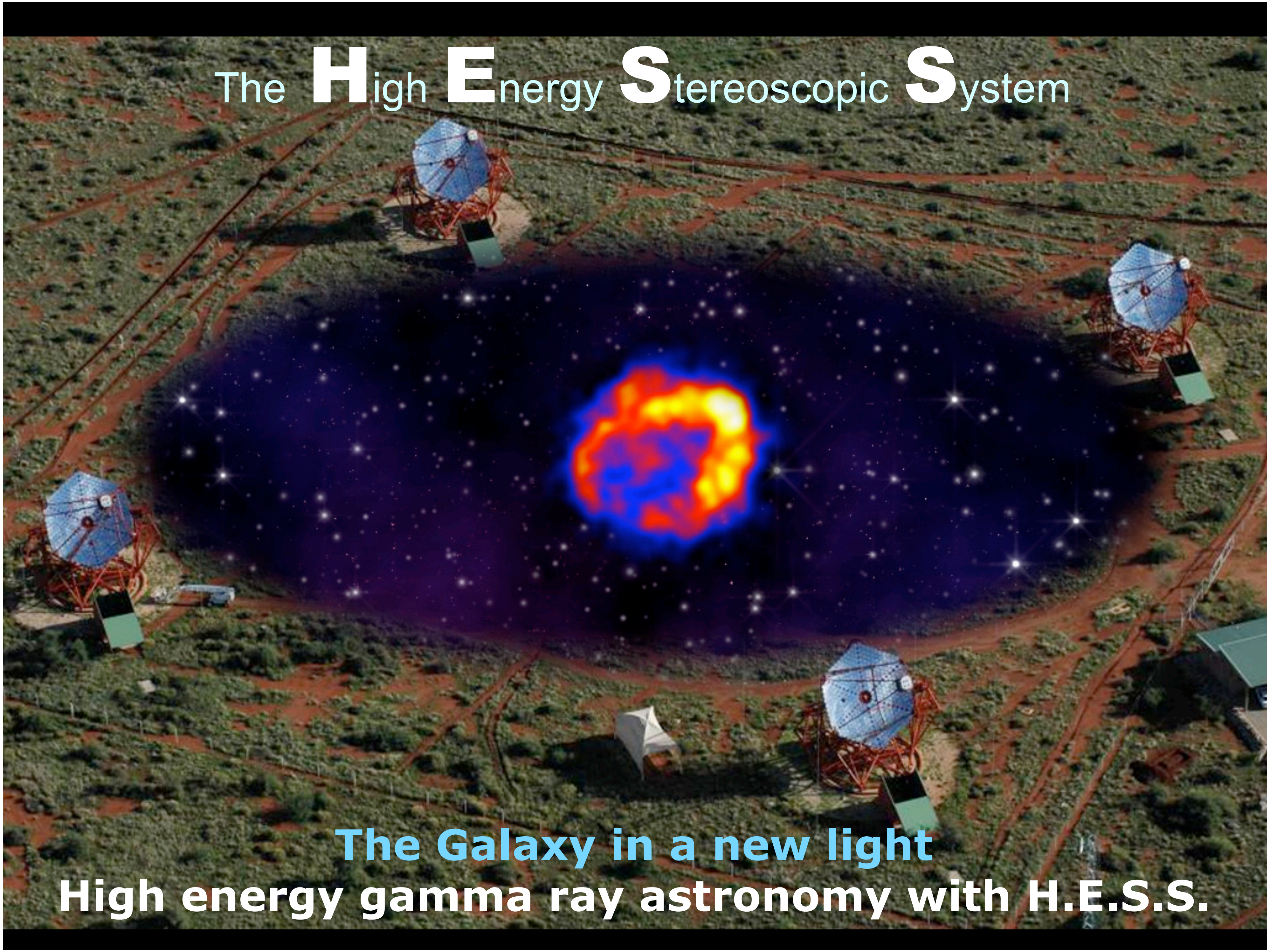
Adi 14 è nugolo

Il 15 ... la prossima à Giove era la minore la 4a era distante dalla 3a il doppio in circa

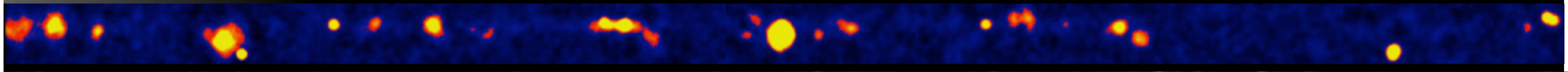
Lo spazio delle 3 occidentali non era maggiore del diametro di Giove et erano in linea retta.

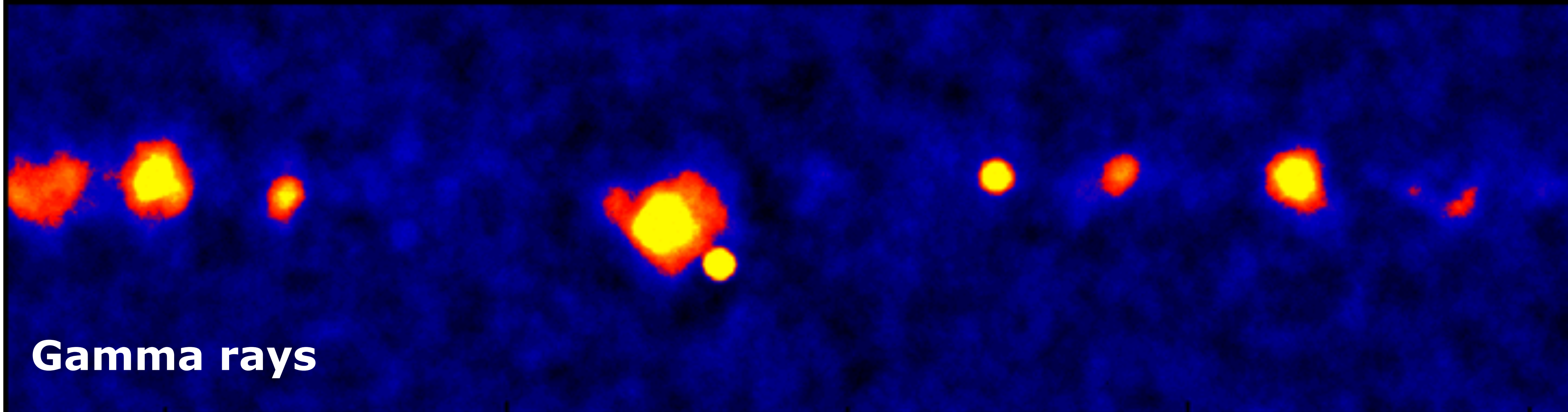
Long. 71.38. Lat. 1.13

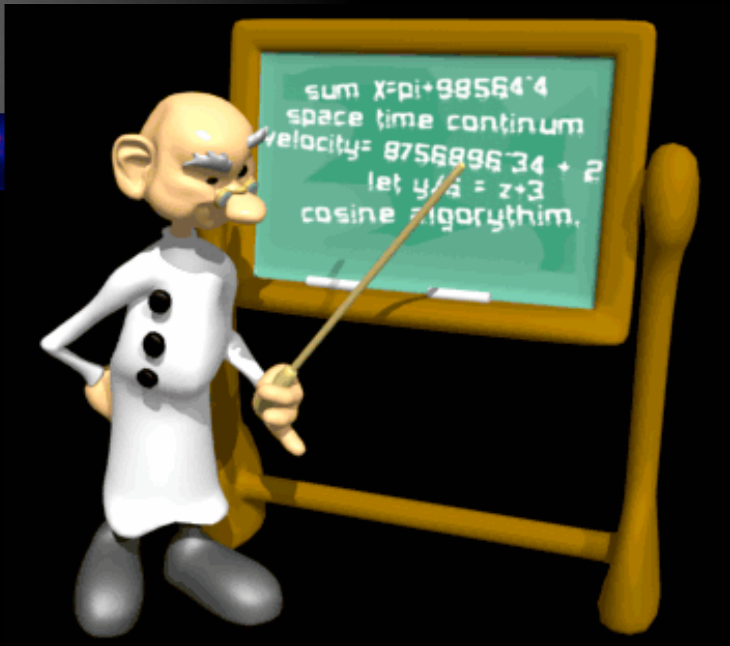

N
Image © 2009 DigitalGlobe
Google

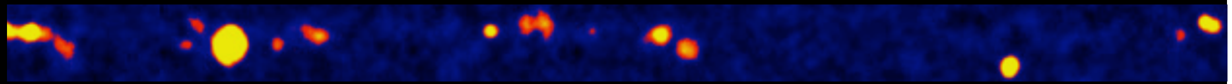

The High Energy Stereoscopic System
The Galaxy in a new light
High energy gamma ray astronomy with H.E.S.S.

The Milky Way









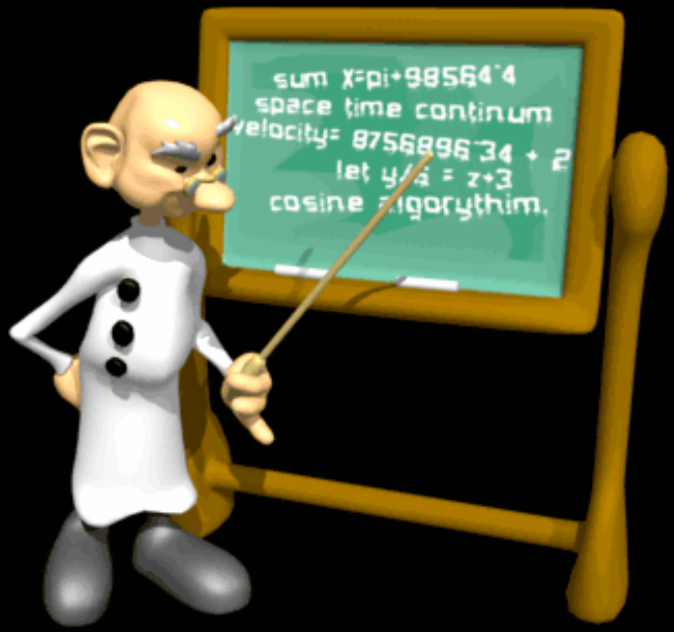
Why?
Exploring the nonthermal universe

How?
Detecting VHE gamma rays: The H.E.S.S. telescopes

What?
A tour of galactic particle accelerators

Whow …
Recent news

What’s next?



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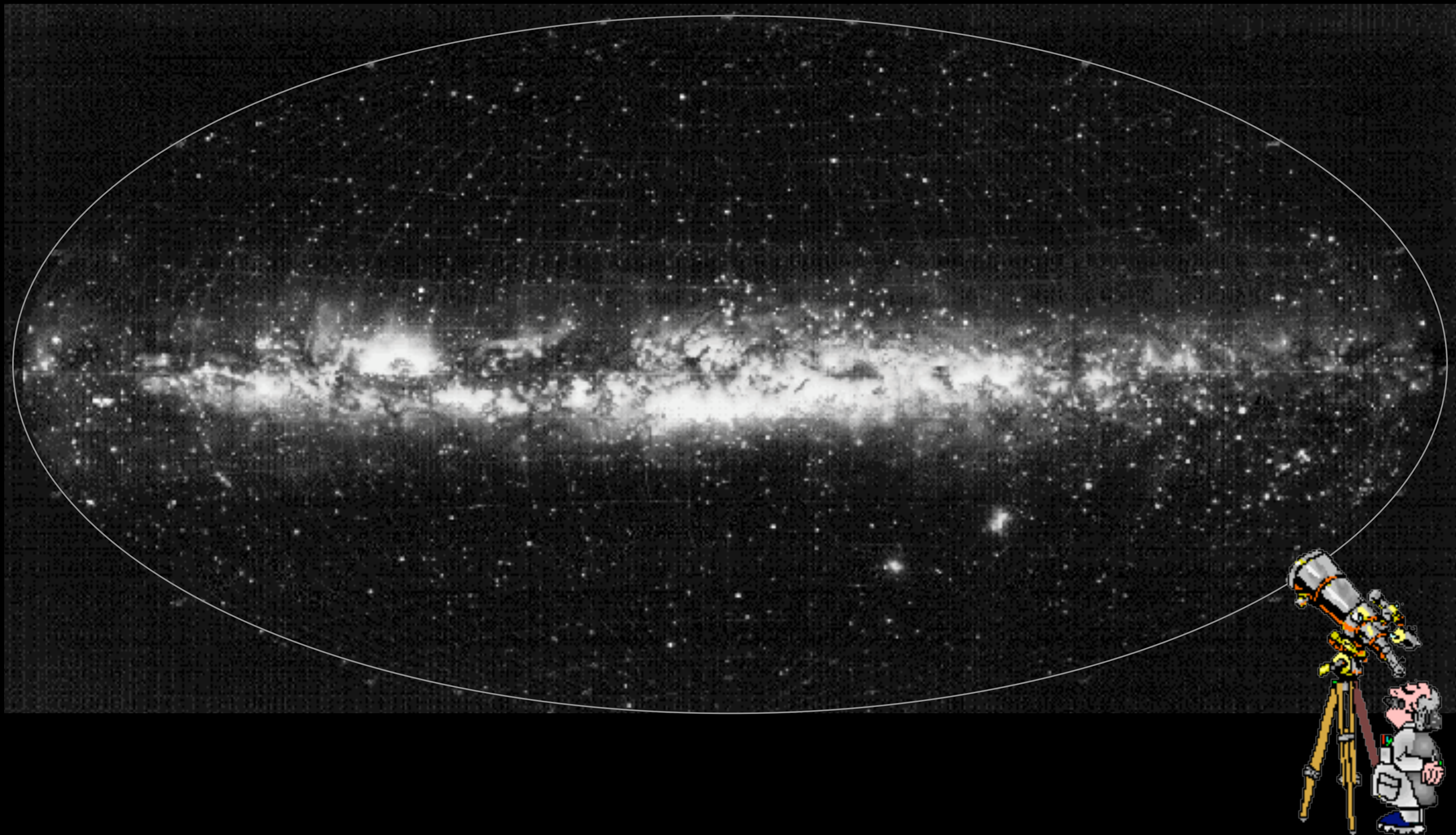
What’s next?

Radio Infrared **Visible Light (eV)** X-rays Gamma rays



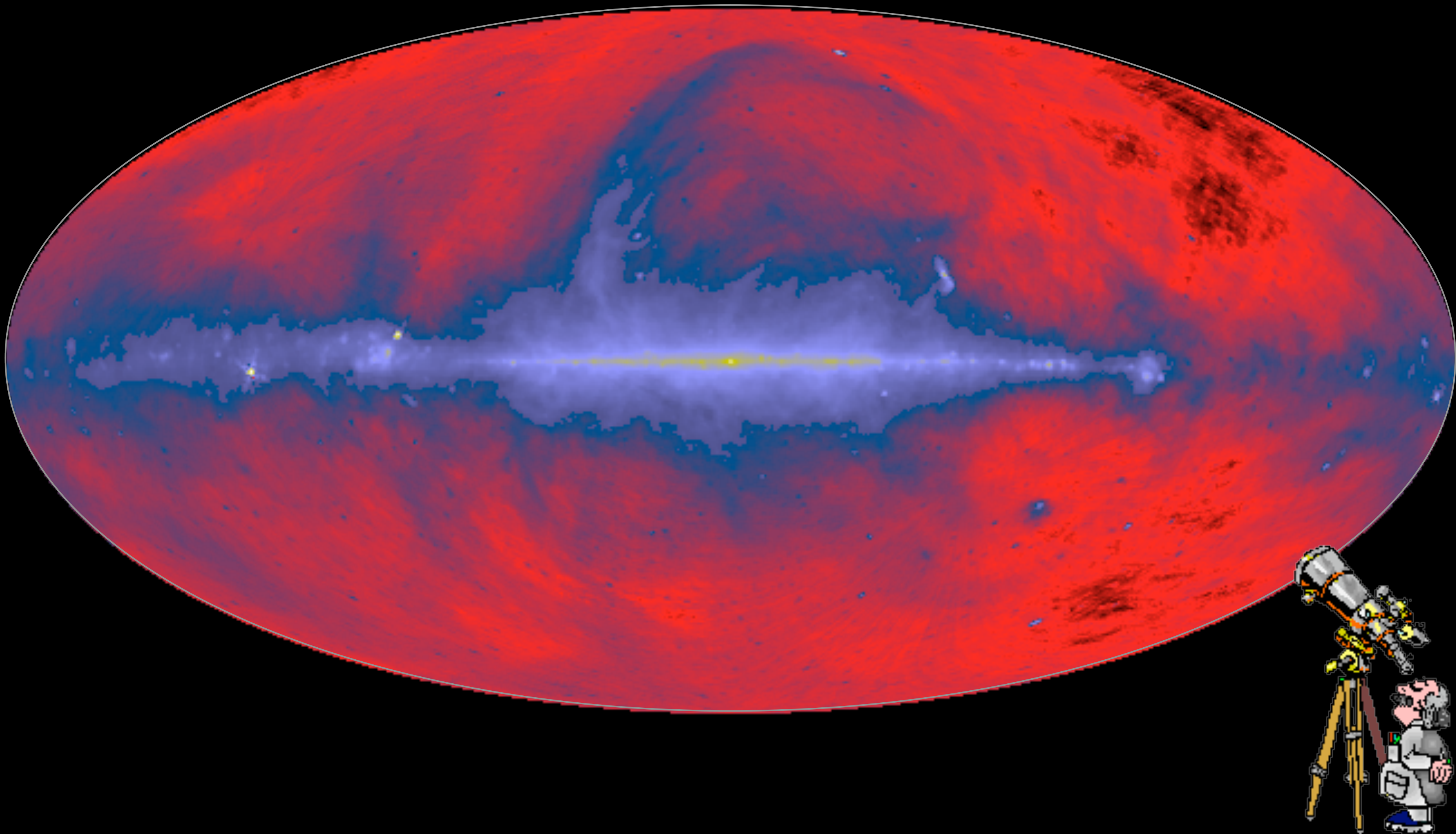
Radio
(10^{-6} eV)

Infrared

Visible Light

X-rays

Gamma rays



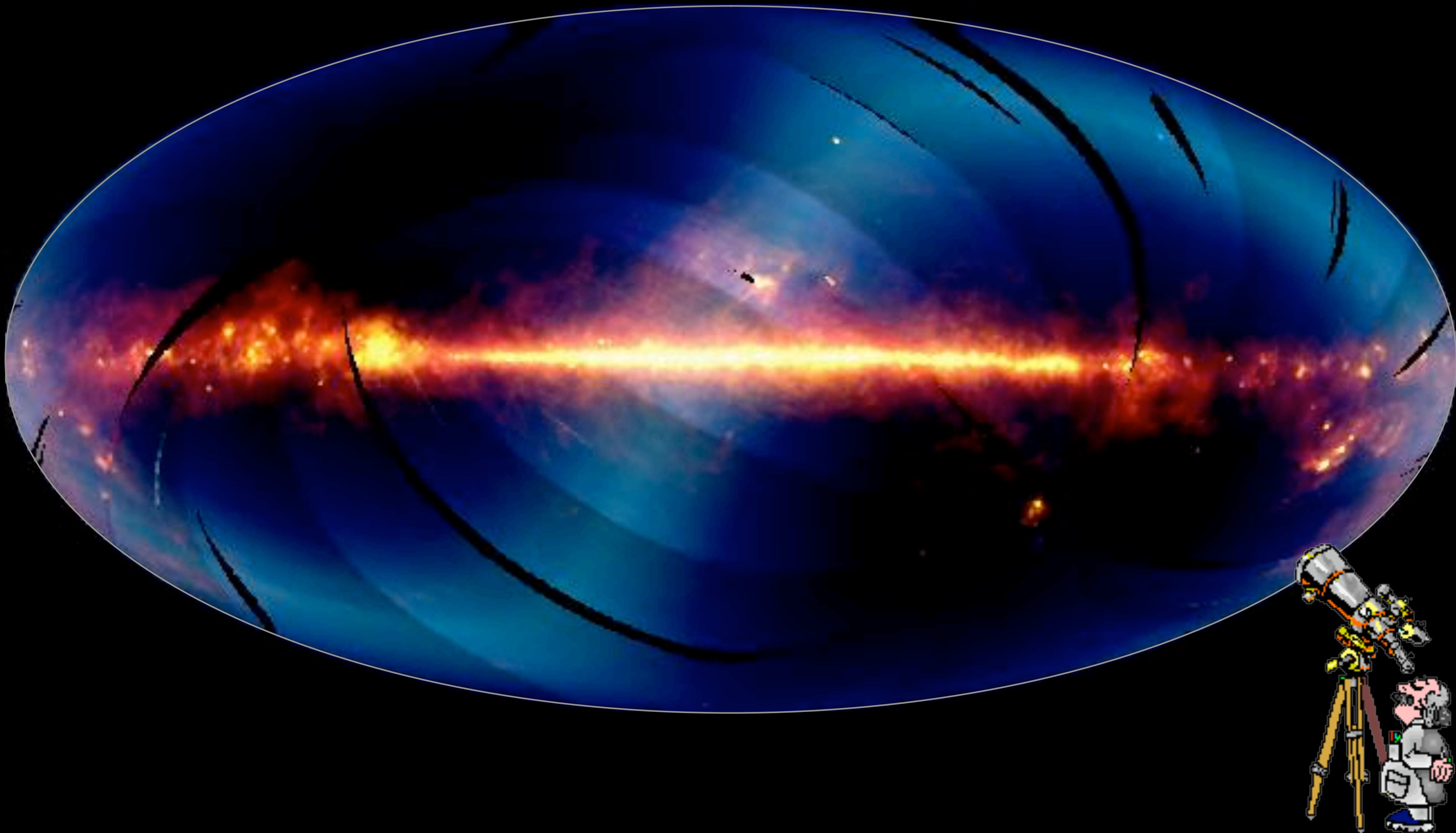
Radio

Infrared
(10^{-2} eV)

Visible Light

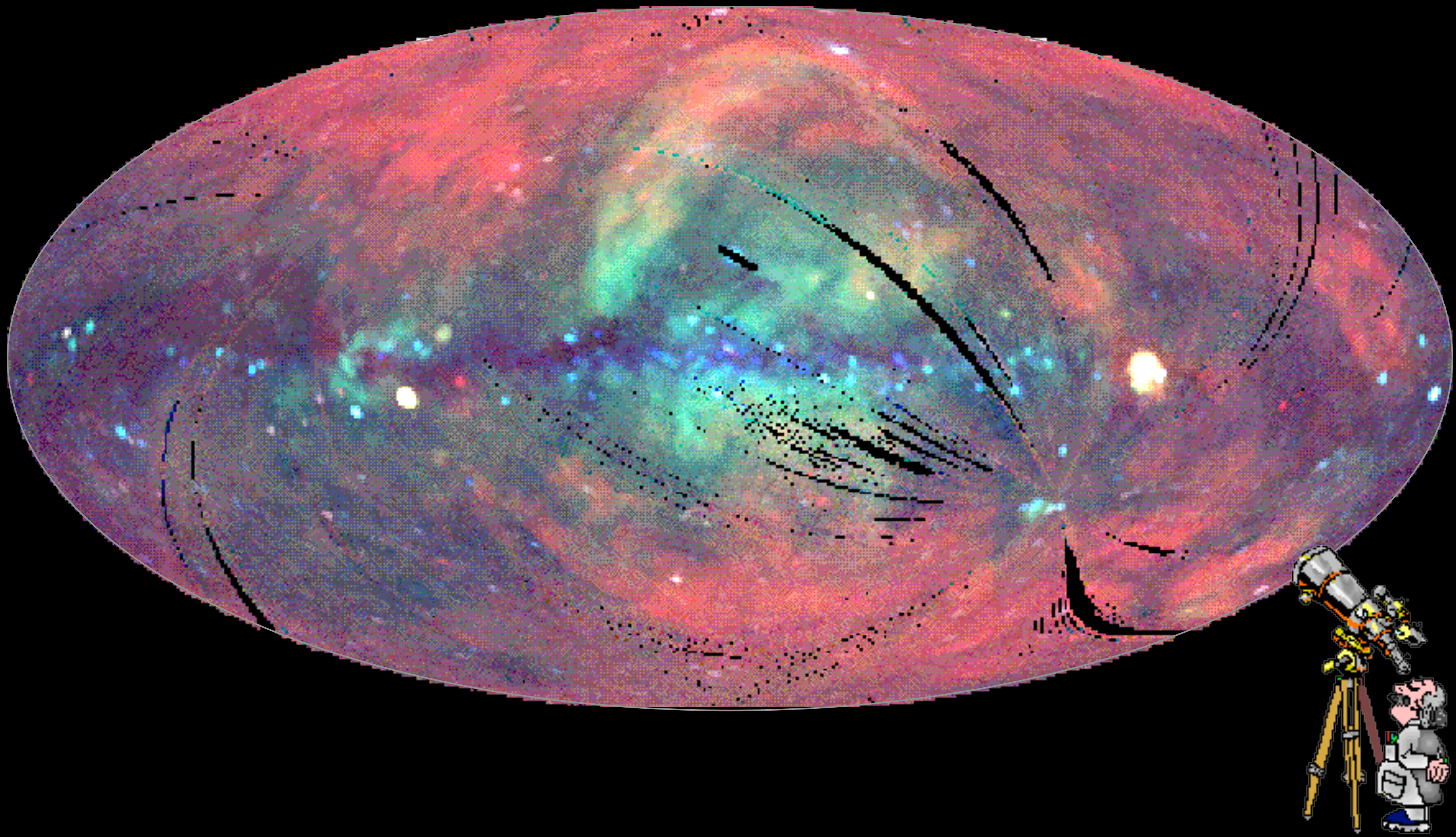
X-rays

Gamma rays



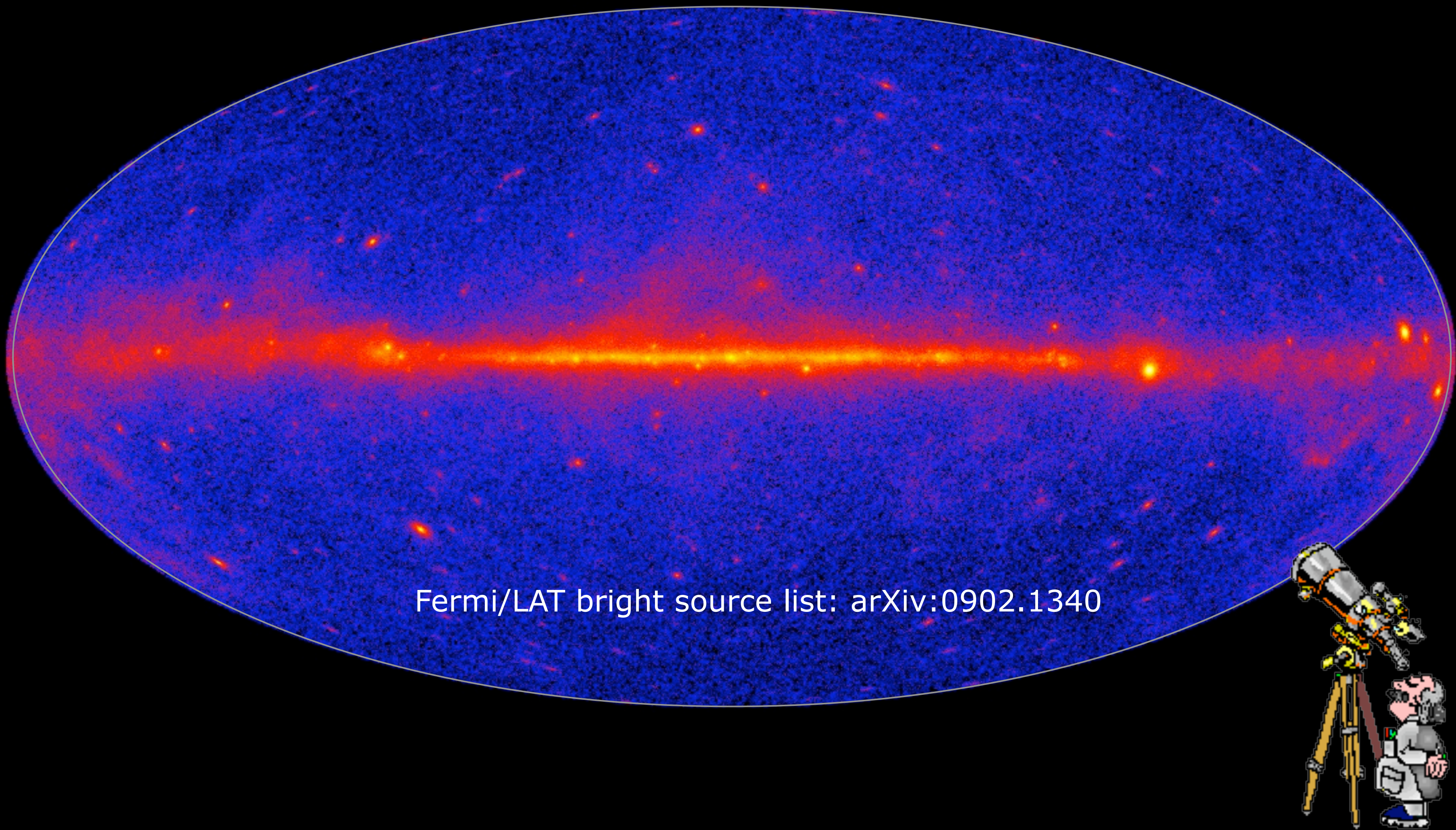
Radio Infrared Visible Light X-rays Gamma rays

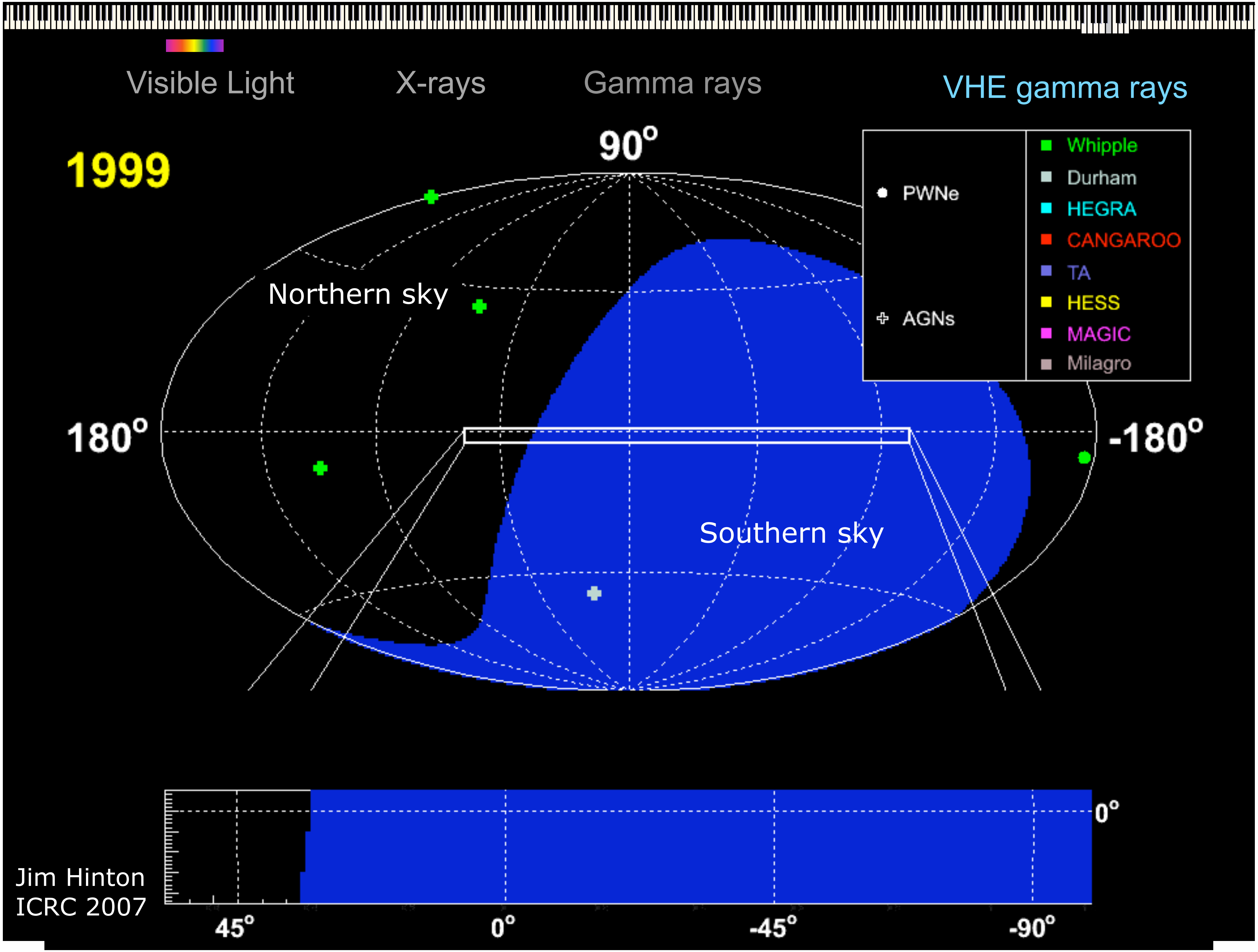
(10^3 eV)



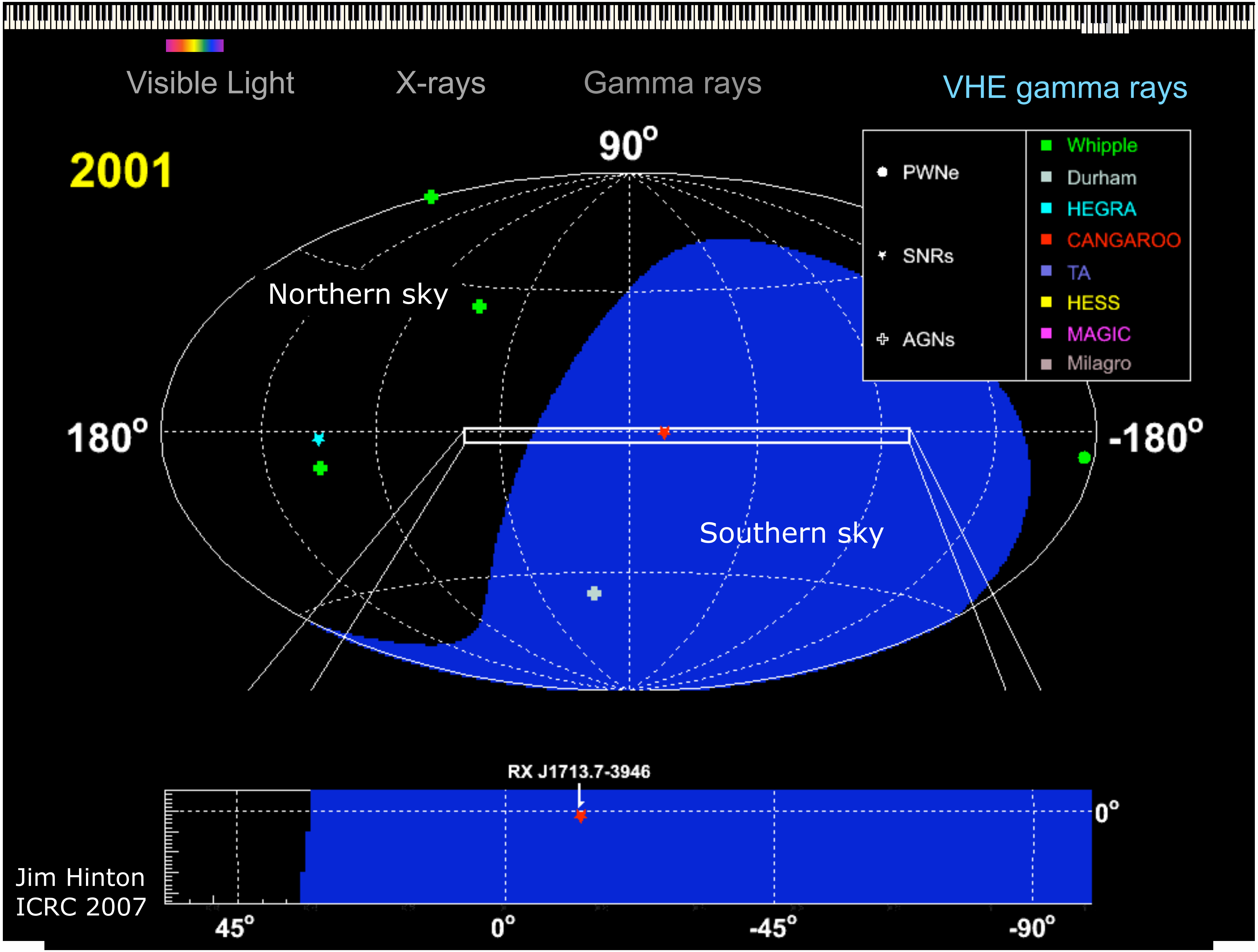
Radio Infrared Visible Light X-rays VHE gamma rays (10^{12} eV)

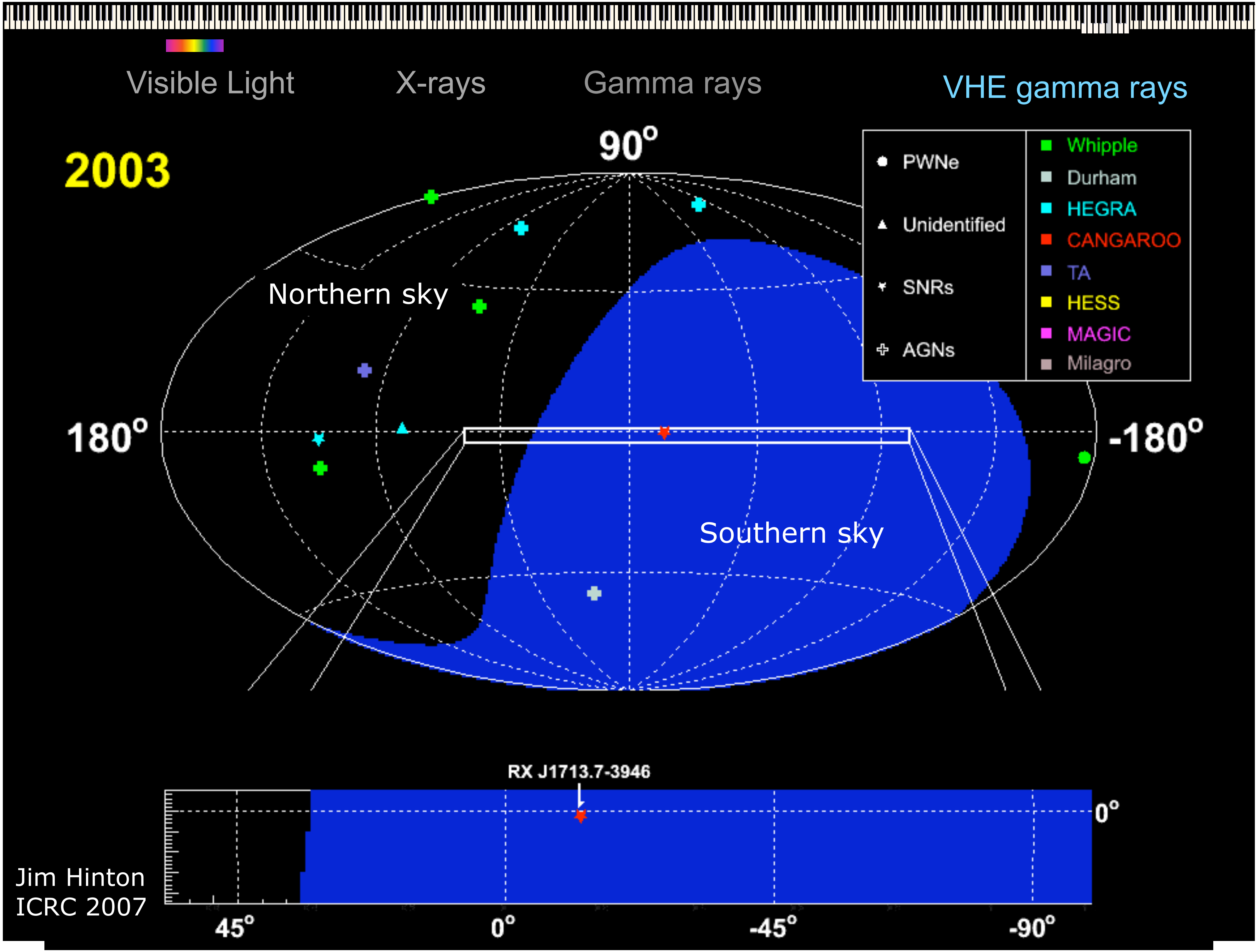
Gamma rays (10^{8} eV)





Visible Light
X-rays
Gamma rays
VHE gamma rays
1999
90°
180°
-180°
PWNe
AGNs
Whipple
Durham
HEGRA
CANGAROO
TA
HESS
MAGIC
Milagro
Northern sky
Southern sky
0°
45°
0°
-45°
-90°
Jim Hinton
ICRC 2007


Visible Light
X-rays
Gamma rays
VHE gamma rays
2001
90°
180°
-180°
Northern sky
Southern sky
PWNe
SNRs
AGNs
Whipple
Durham
HEGRA
CANGAROO
TA
HESS
MAGIC
Milagro
RX J1713.7-3946
0°
45°
0°
-45°
-90°
Jim Hinton
ICRC 2007


Visible Light
X-rays
Gamma rays
VHE gamma rays
2003
90°
PWNe
Unidentified
SNRs
AGNs
Whipple
Durham
HEGRA
CANGAROO
TA
HESS
MAGIC
Milagro
Northern sky
180°
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0°
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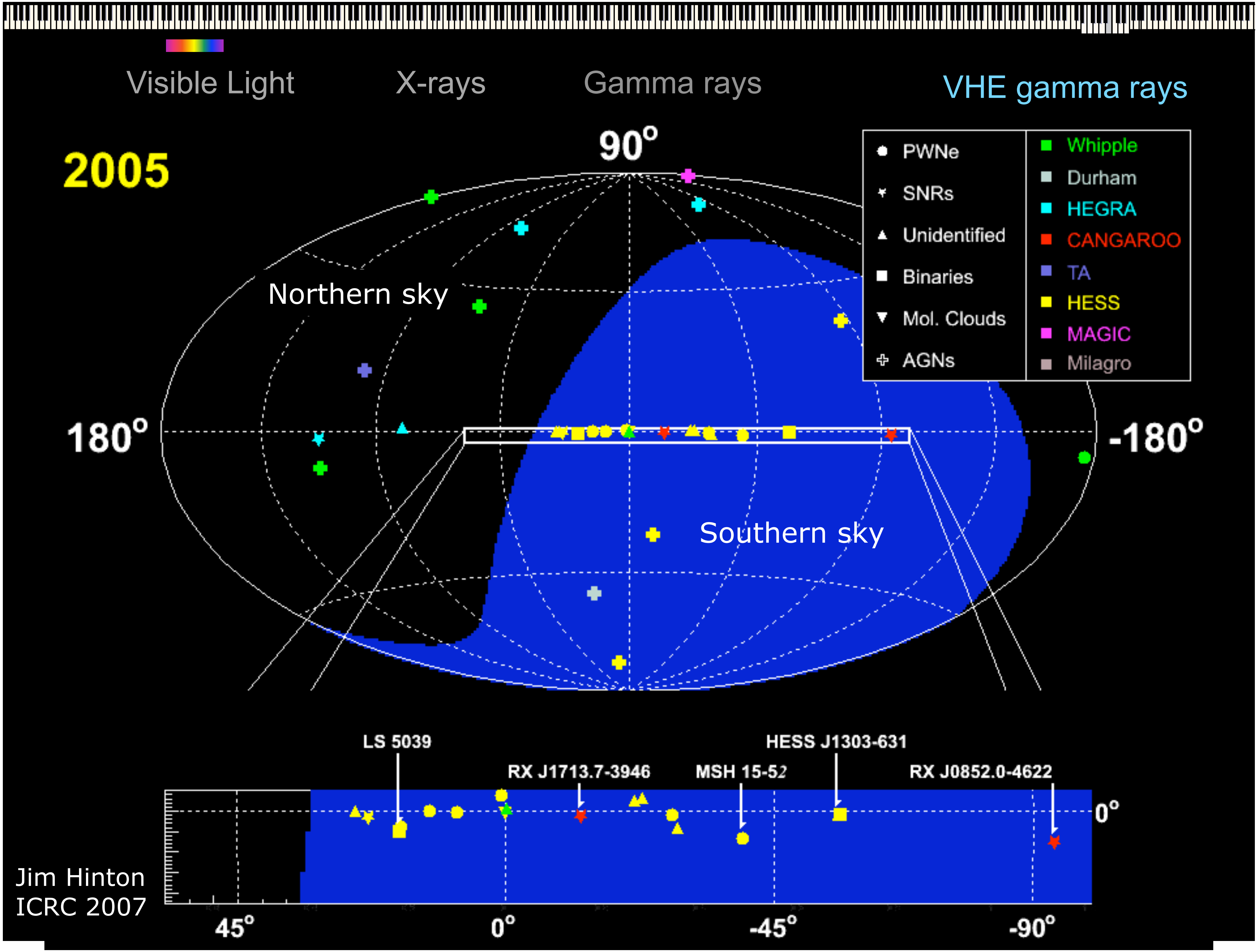
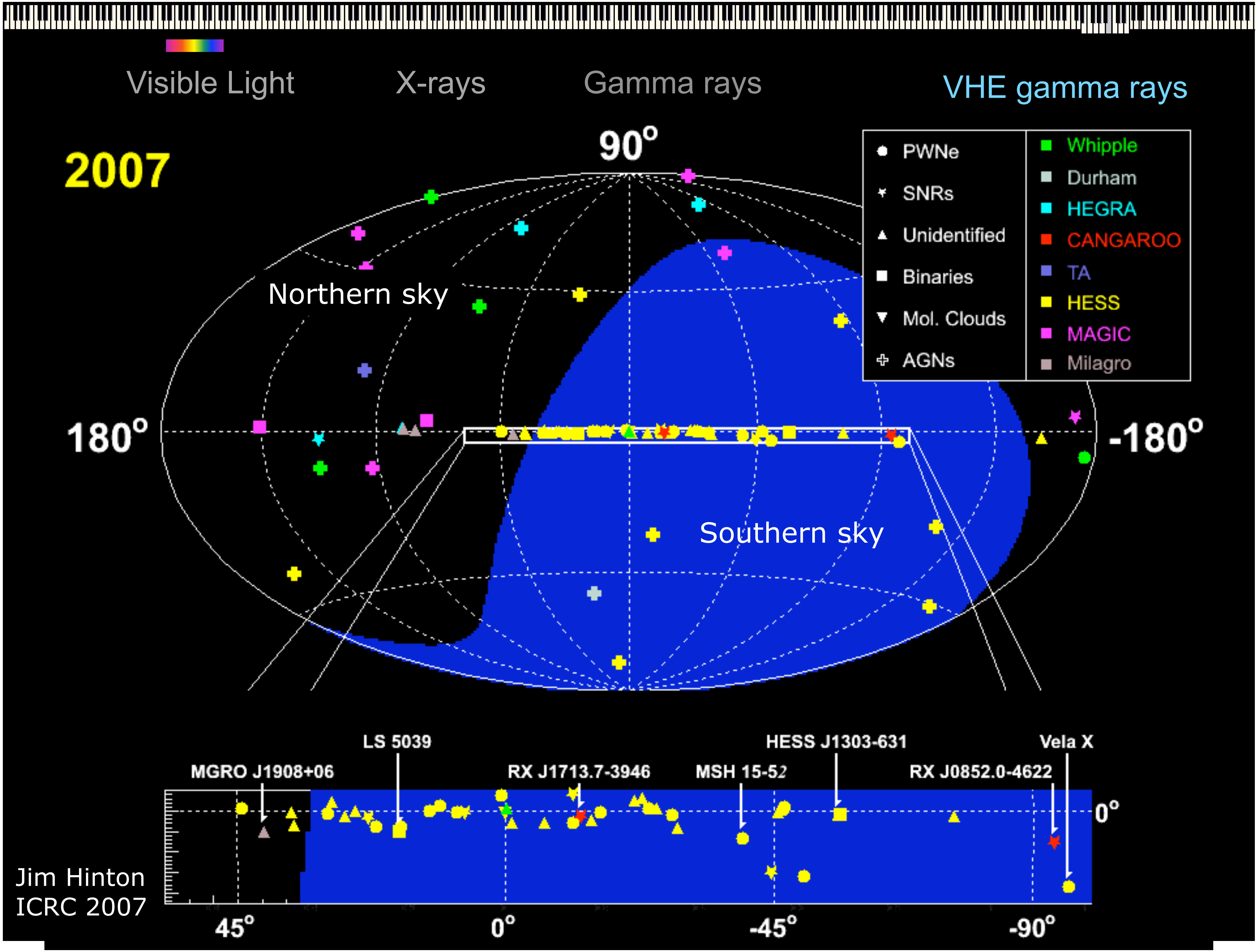


Visible Light
X-rays
Gamma rays
VHE gamma rays
2005
90°
180°
-180°
Northern sky
Southern sky
PWNe
SNRs
Unidentified
Binaries
Mol. Clouds
AGNs
Whipple
Durham
HEGRA
CANGAROO
TA
HESS
MAGIC
Milagro
LS 5039
RX J1713.7-3946
MSH 15-52
HESS J1303-631
RX J0852.0-4622
0°
45°
0°
-45°
-90°
Jim Hinton
ICRC 2007


Visible Light
X-rays
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2007
90°
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Unidentified
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Mol. Clouds
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CANGAROO
TA
HESS
MAGIC
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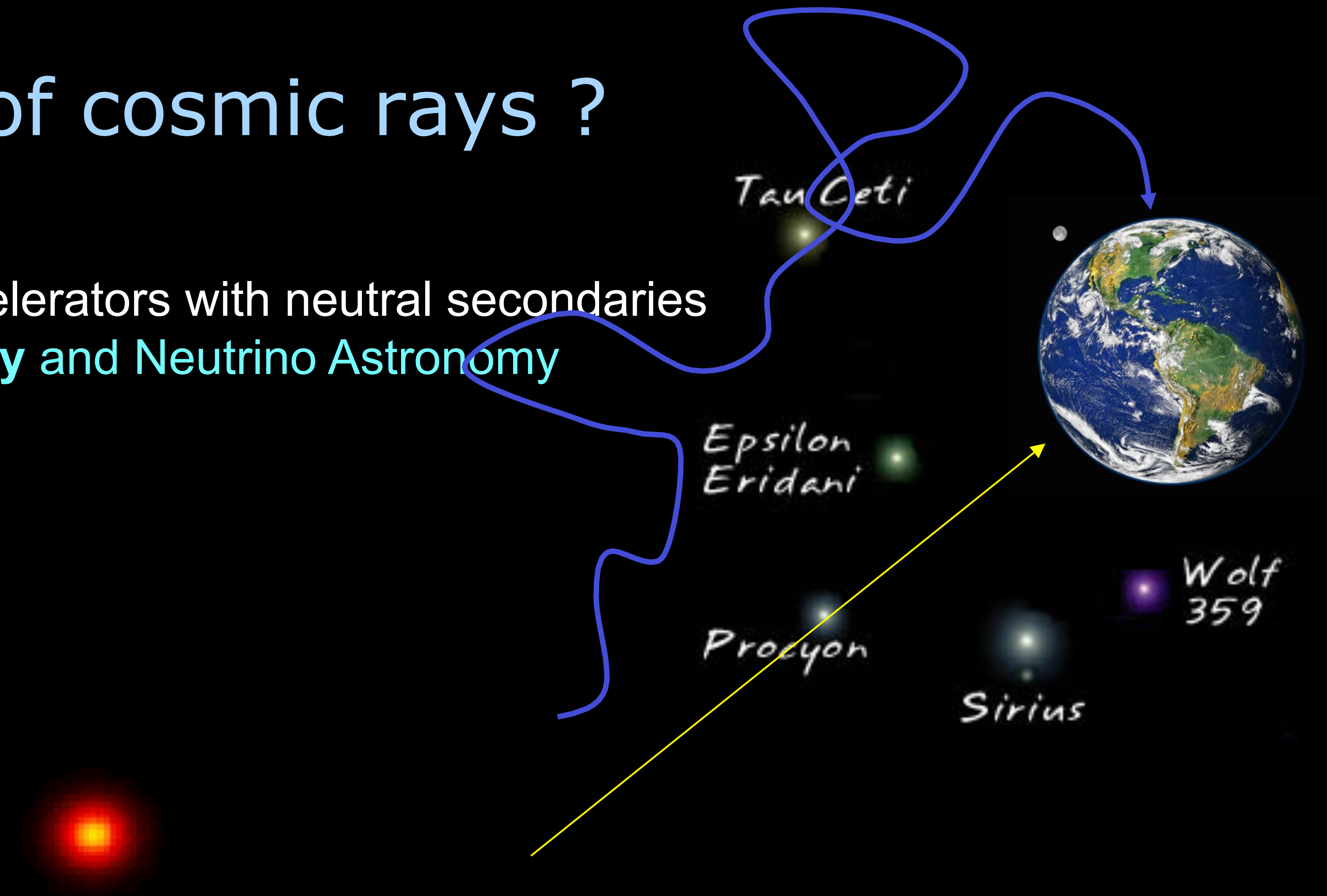
Northern sky
180°
-180°
Southern sky
LS 5039
HESS J1303-631
Vela X
MGRO J1908+06
RX J1713.7-3946
MSH 15-52
RX J0852.0-4622
0°
45°
0°
-45°
-90°
Jim Hinton
ICRC 2007

Origin of cosmic rays ?

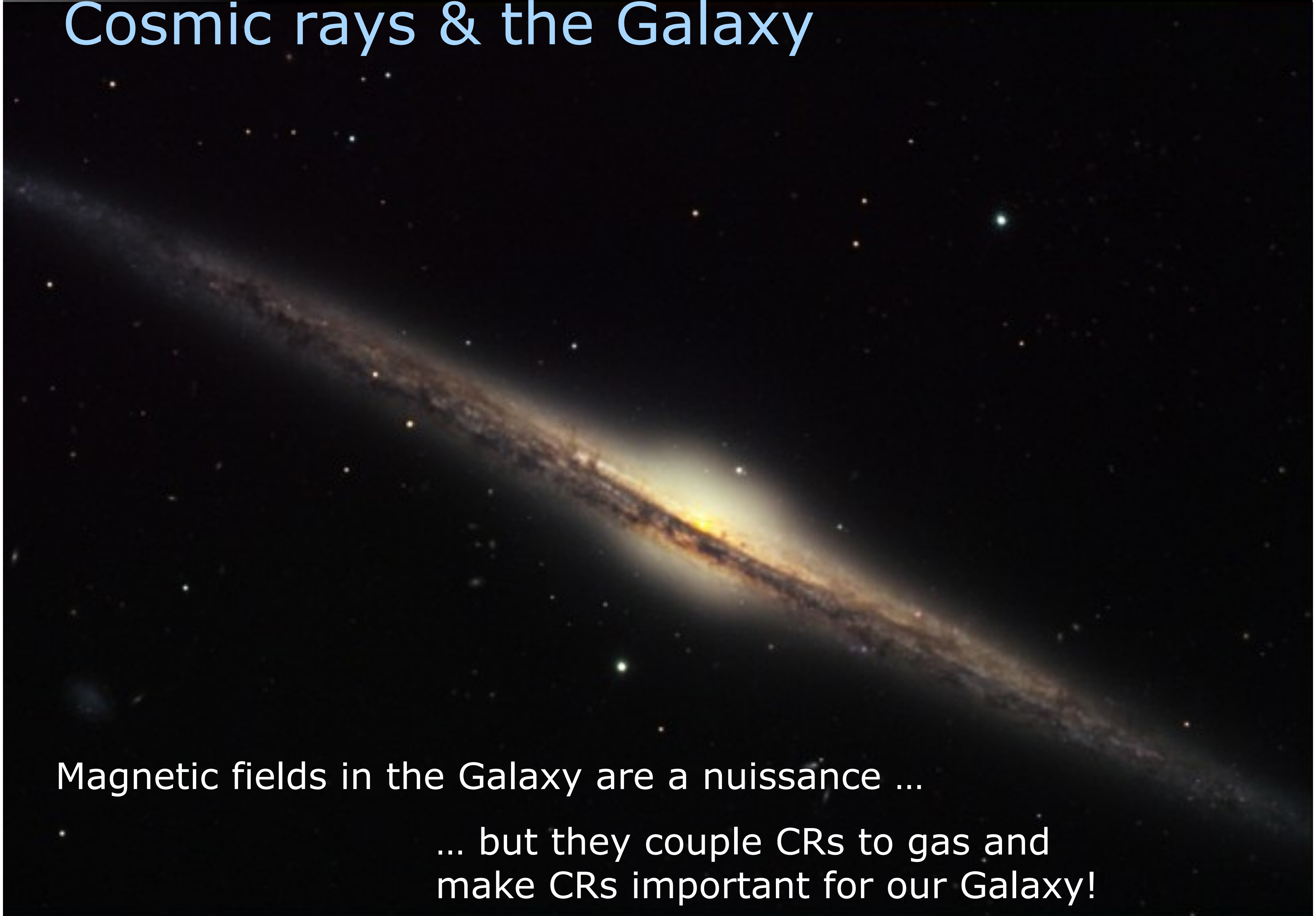
→ Image accelerators with neutral secondaries
→ **Gamma-ray** and Neutrino Astronomy



$$p + \text{nucleus} \rightarrow \pi + X$$

$$\pi^{o} \rightarrow \gamma\gamma$$
$$\pi^{\pm} \rightarrow \mu^{\pm}\,\nu$$

Cosmic rays & the Galaxy



Magnetic fields in the Galaxy are a nuissance …

… but they couple CRs to gas and
make CRs important for our Galaxy!

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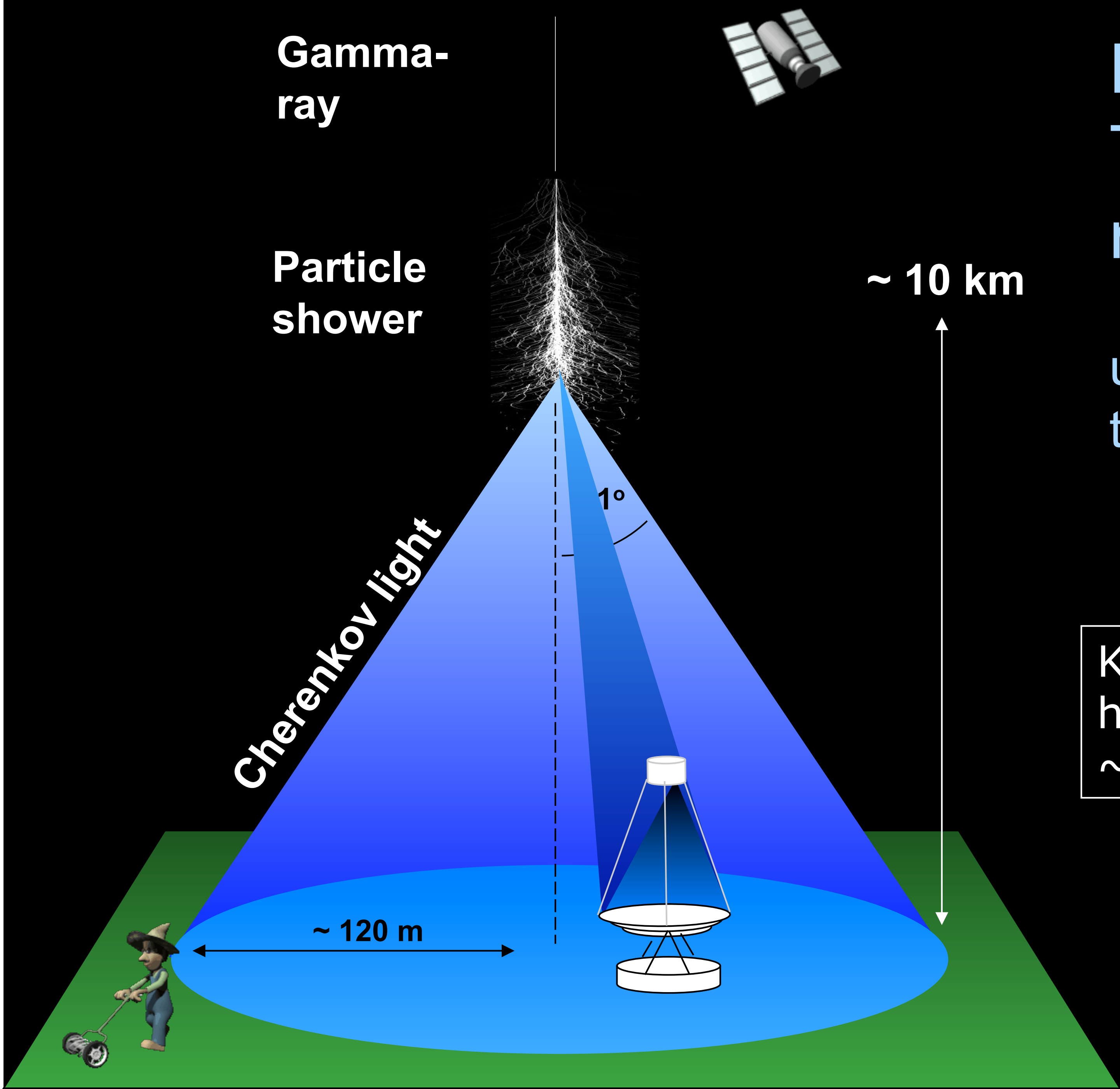
Whow!
Recent hot topics

What’s next?

Detection of TeV gamma rays

using Cherenkov telescopes

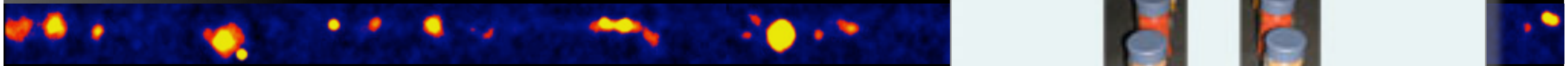


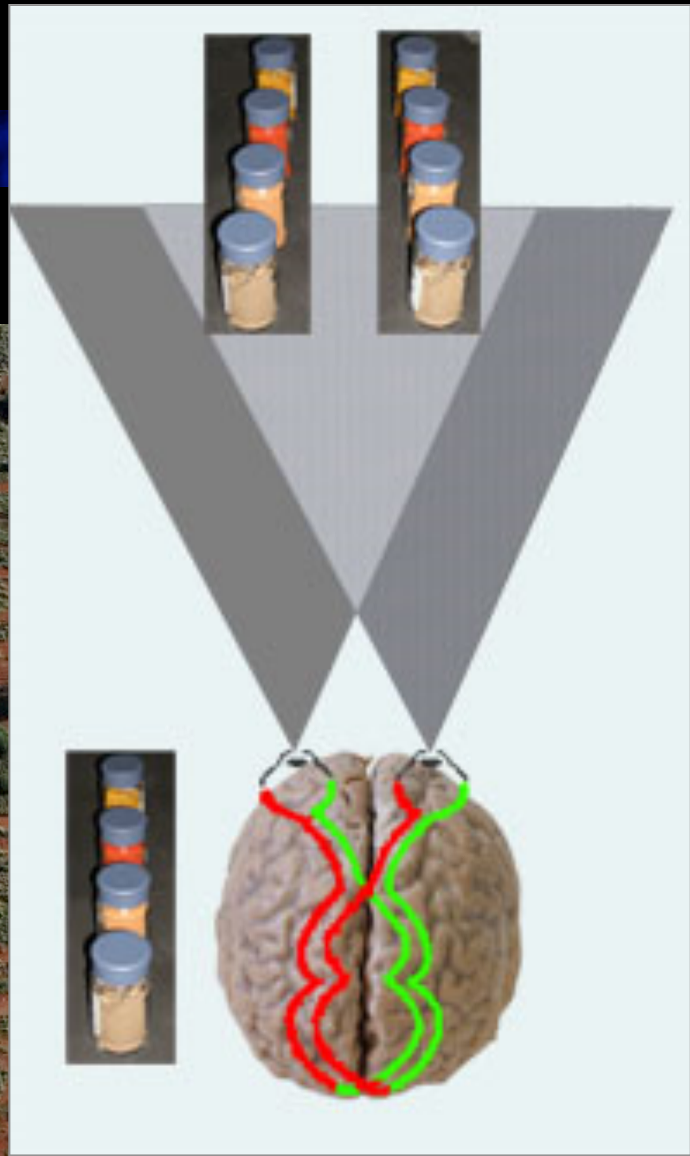
Key issue:
huge detection area
~ 10^5 m^2

Air showers
look a bit like meteors

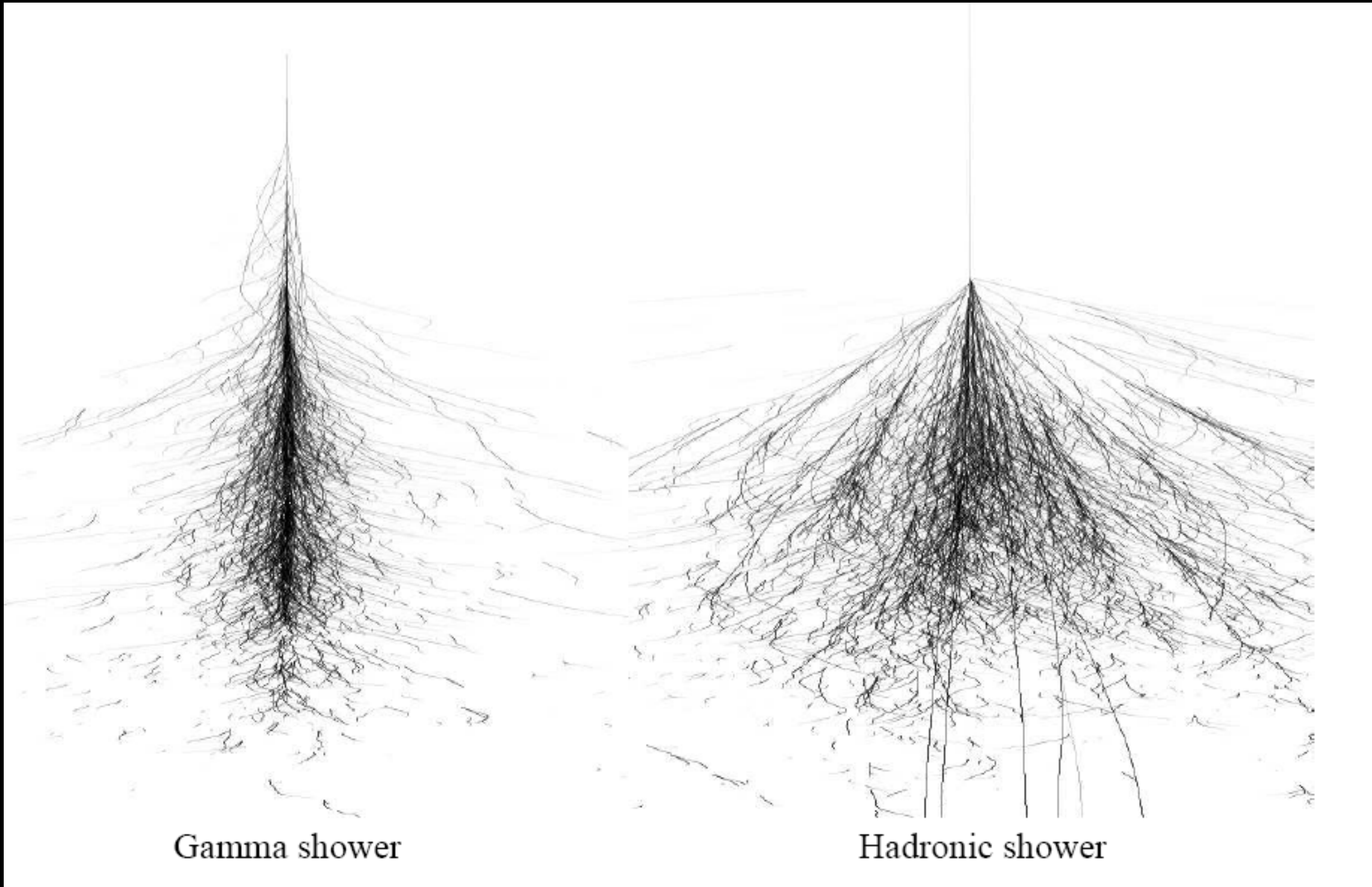
(from Sky & Telescope)

Why four eyes?



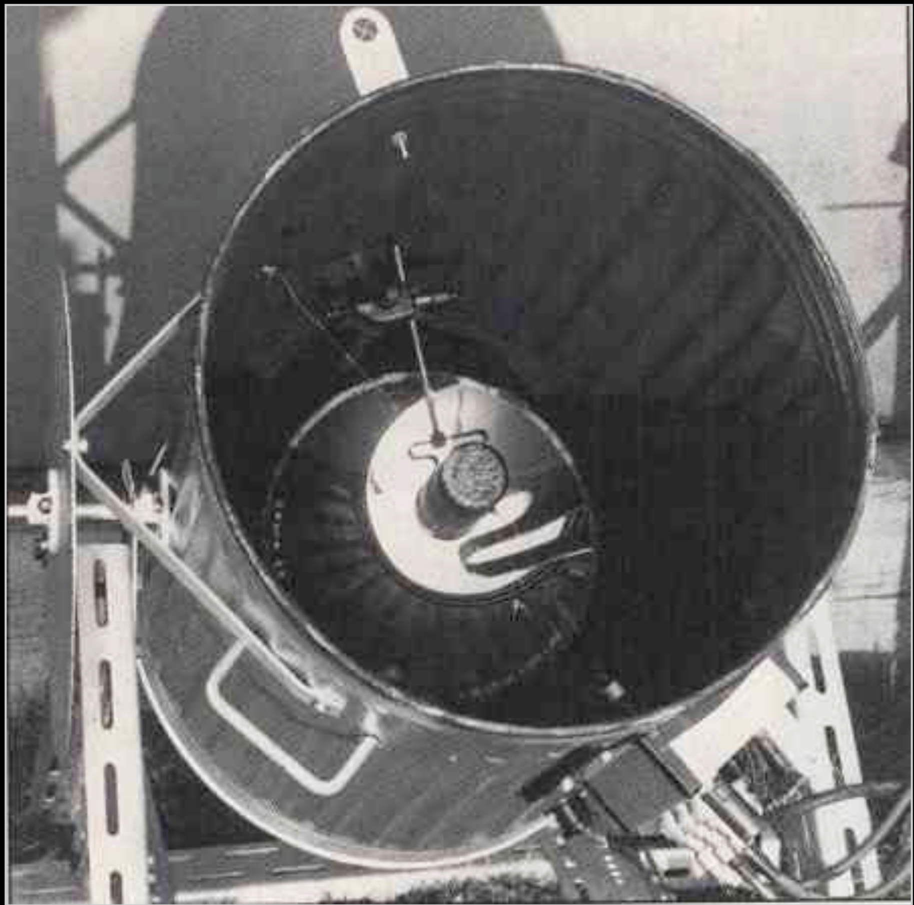


Background rejection



The early days

Source:
T. Weekes



Galbraith and Jelley, 1953

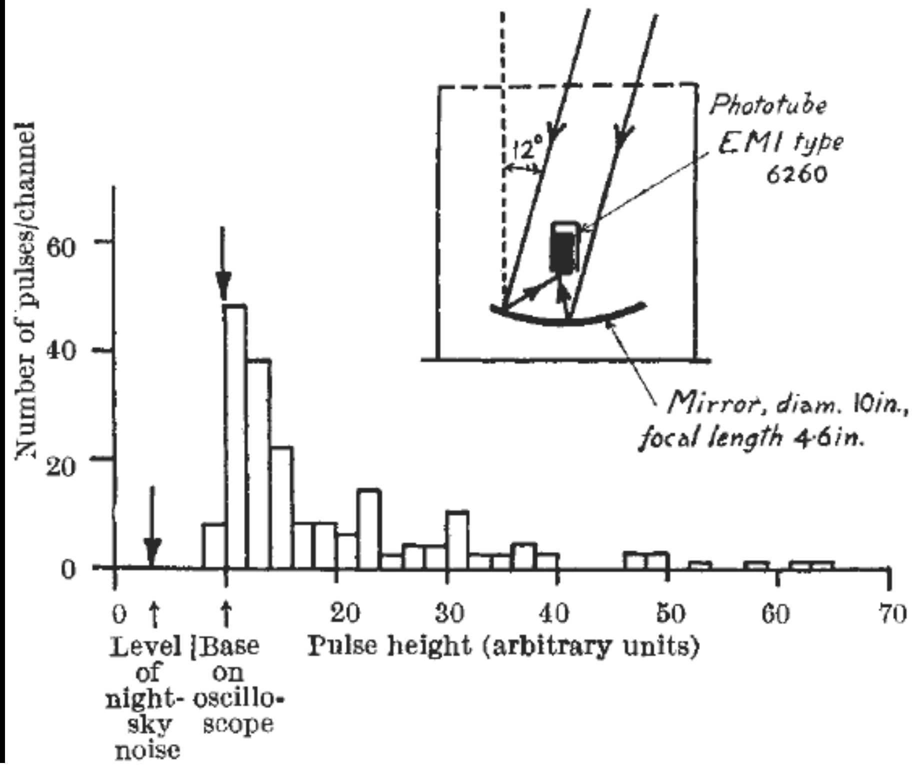
February 21, 1953 NATURE

Light Pulses from the Night Sky associated with Cosmic Rays

In 1948, Blackett[1] suggested that a contribution approximately 10^{-4} of the mean light of the night-sky might be expected from Čerenkov radiation[2] produced in the atmosphere by the cosmic radiation. The purpose of this communication is to report the results of some preliminary experiments we have made using a photomultiplier, which revealed the

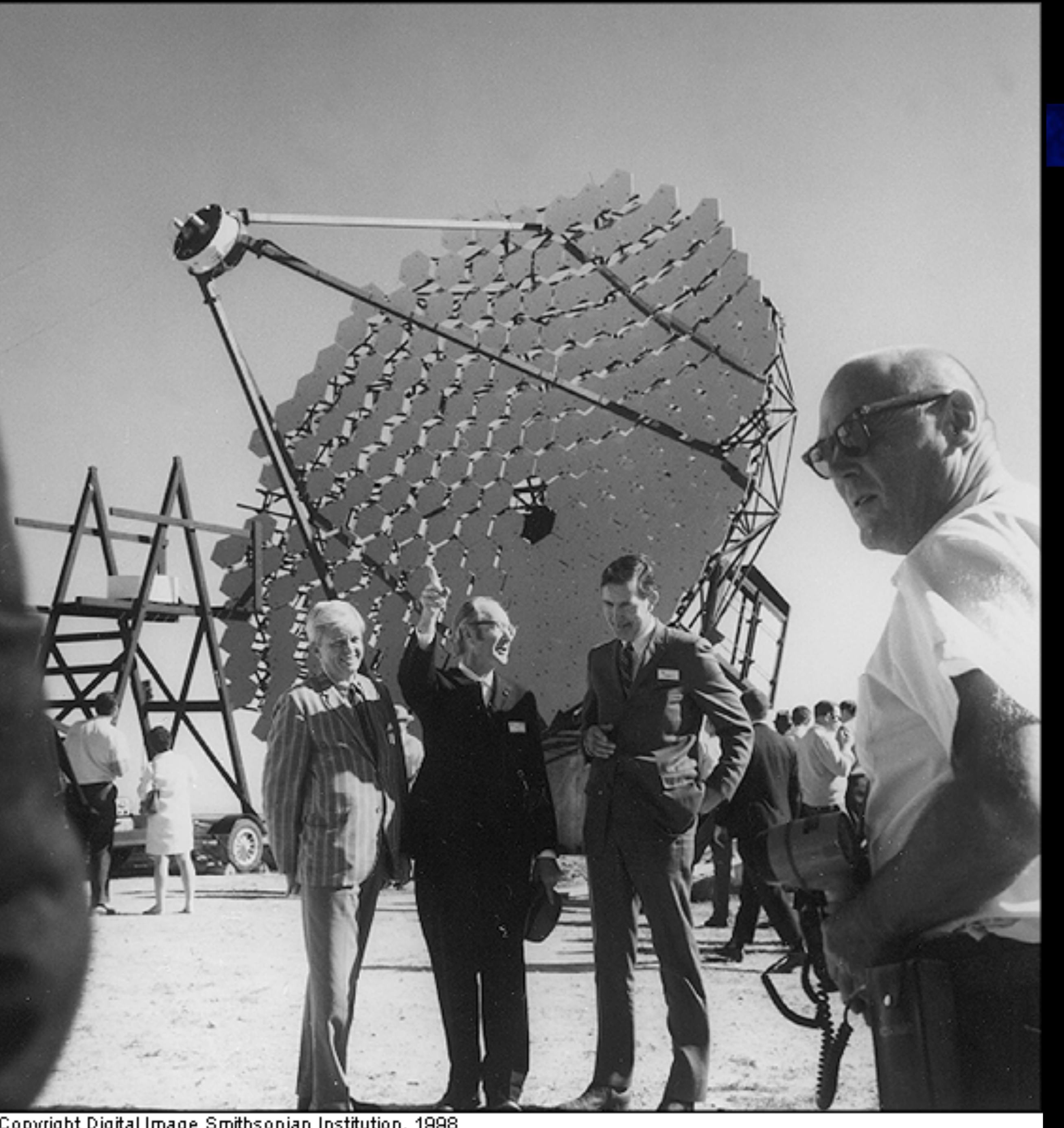
thank Mr. W. J. Whitehouse and Dr. E. Bretscher for their encouragement, and Dr. T. E. Cranshaw for the use of the extensive shower array.

W. Galbraith
J. V. Jelley

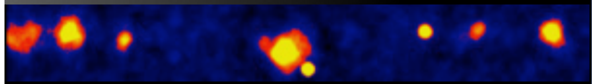


Whipple 1968

Detection of
the Crab Nebula
1989 as first
VHE gamma ray
source

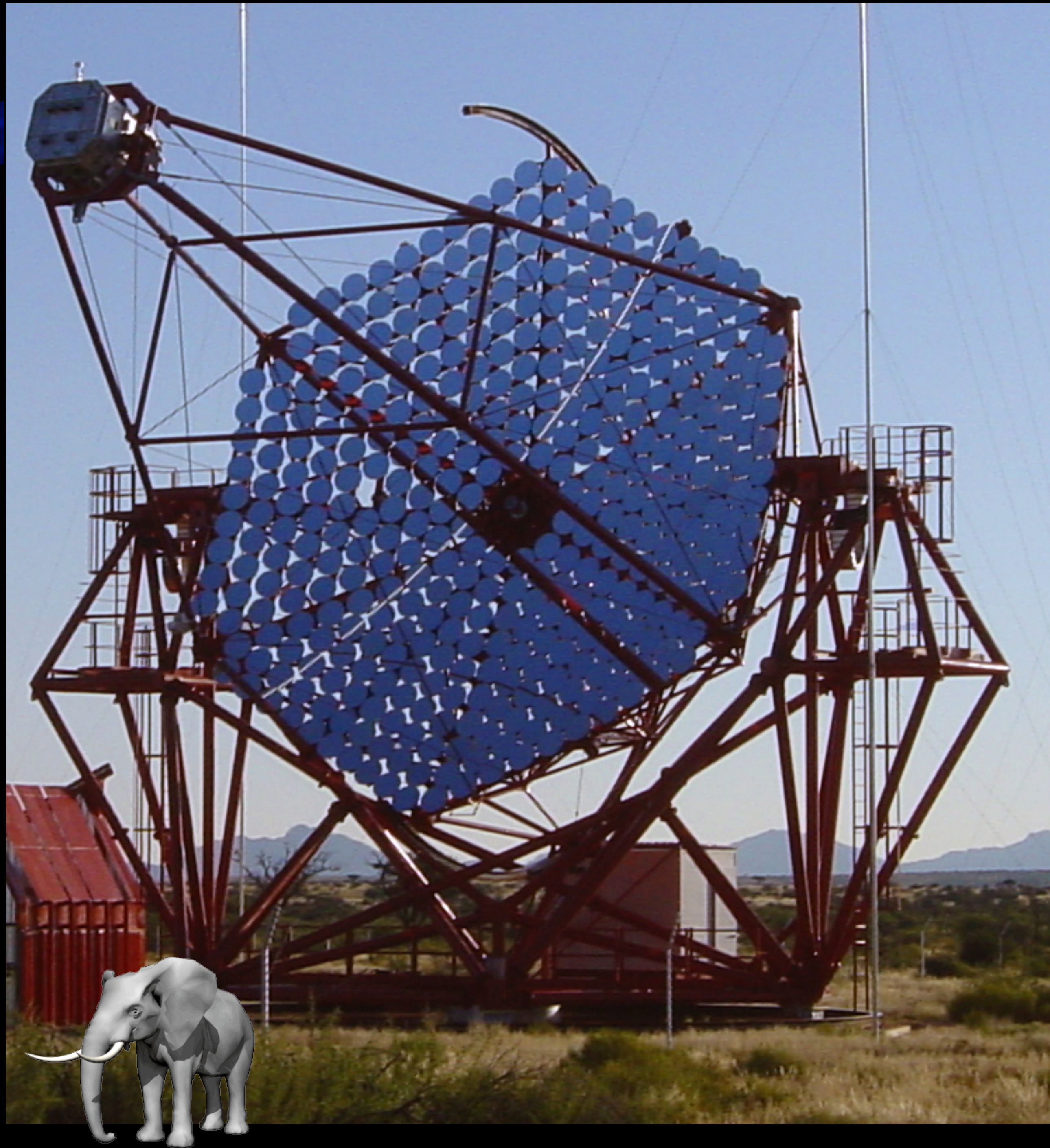


Copyright Digital Image Smithsonian Institution, 1998



H.E.S.S.
2003

100 times more
sensitive



GEFÖRDERT VOM

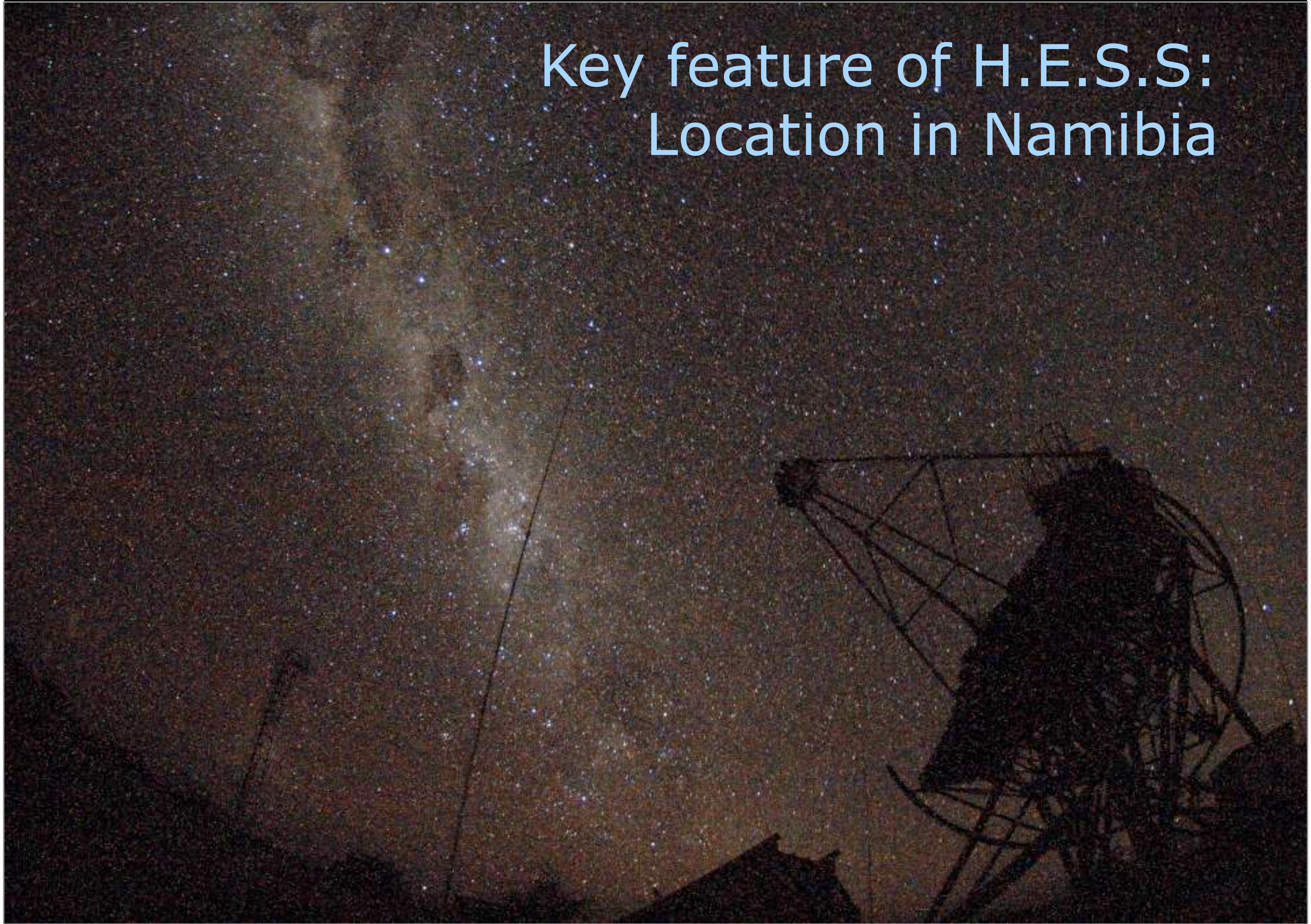
Bundesministerium
für Bildung
und Forschung

Key feature of H.E.S.S: Wide field of view of 5^o

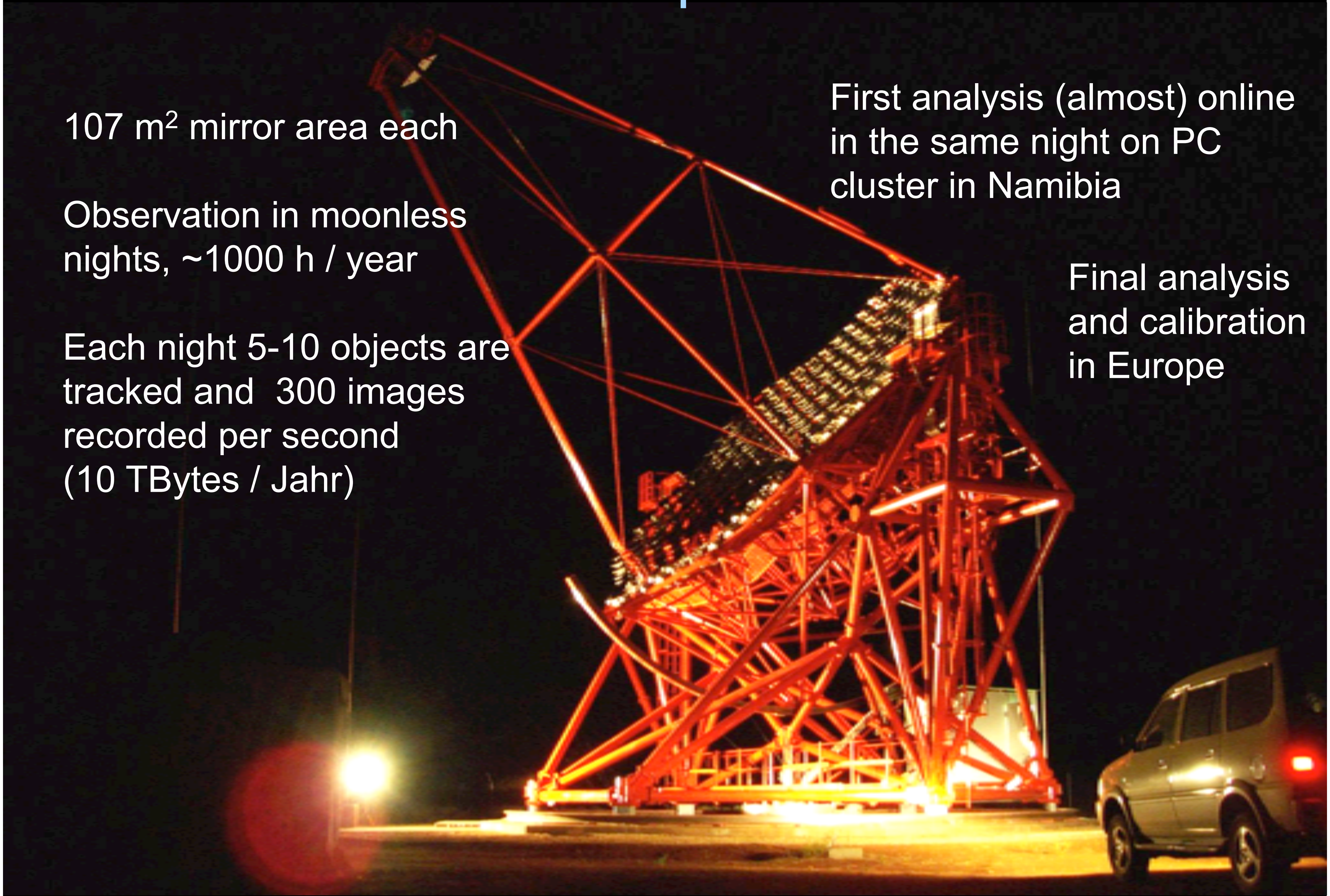
Camera:

960 pixels, 0.16^o
5^o field of view
Readout electronics in camera body
1 GHz analog memory for signal recording


Why Namibia ?


Key feature of H.E.S.S:
Location in Namibia

The H.E.S.S. telescopes



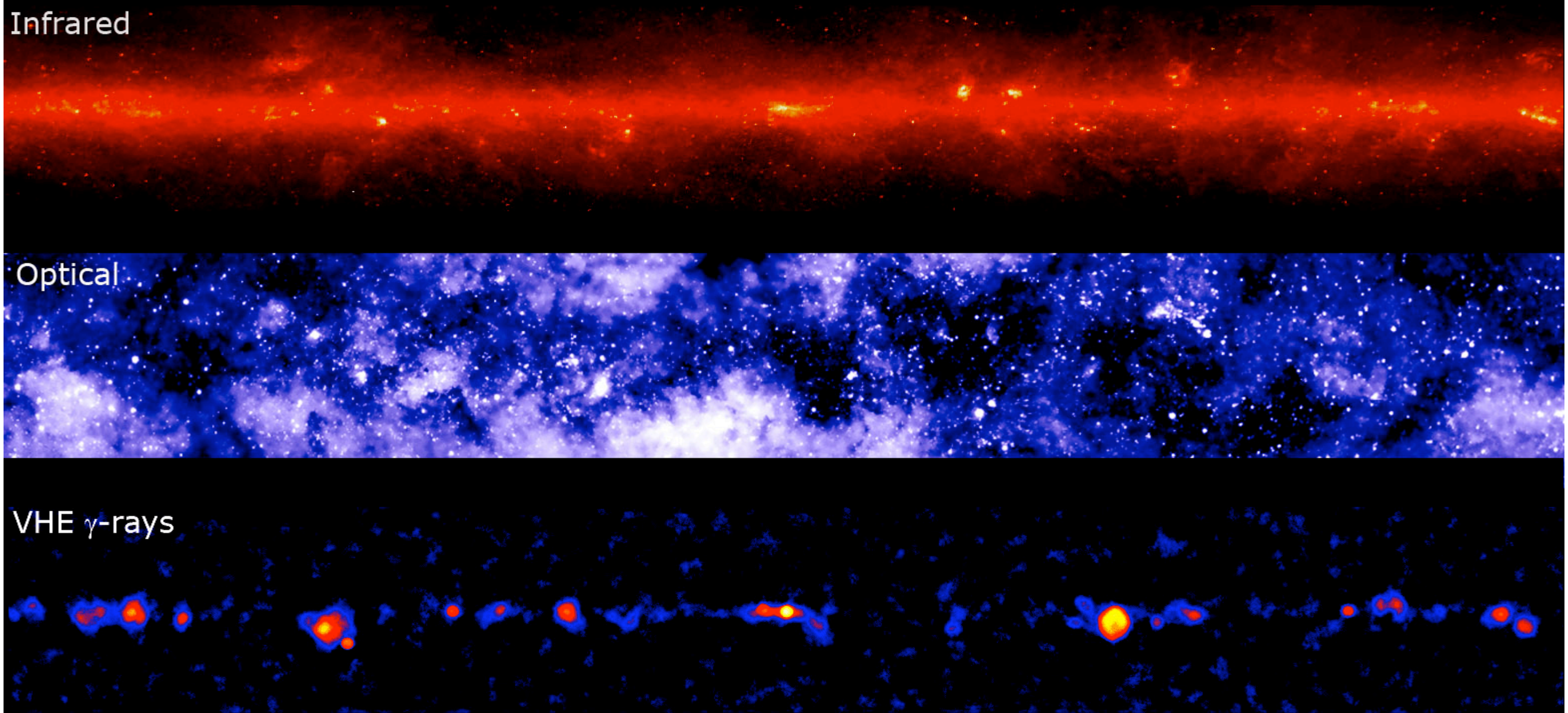
107 m² mirror area each

Observation in moonless nights, ~1000 h / year

Each night 5-10 objects are tracked and 300 images recorded per second (10 TBytes / Jahr)

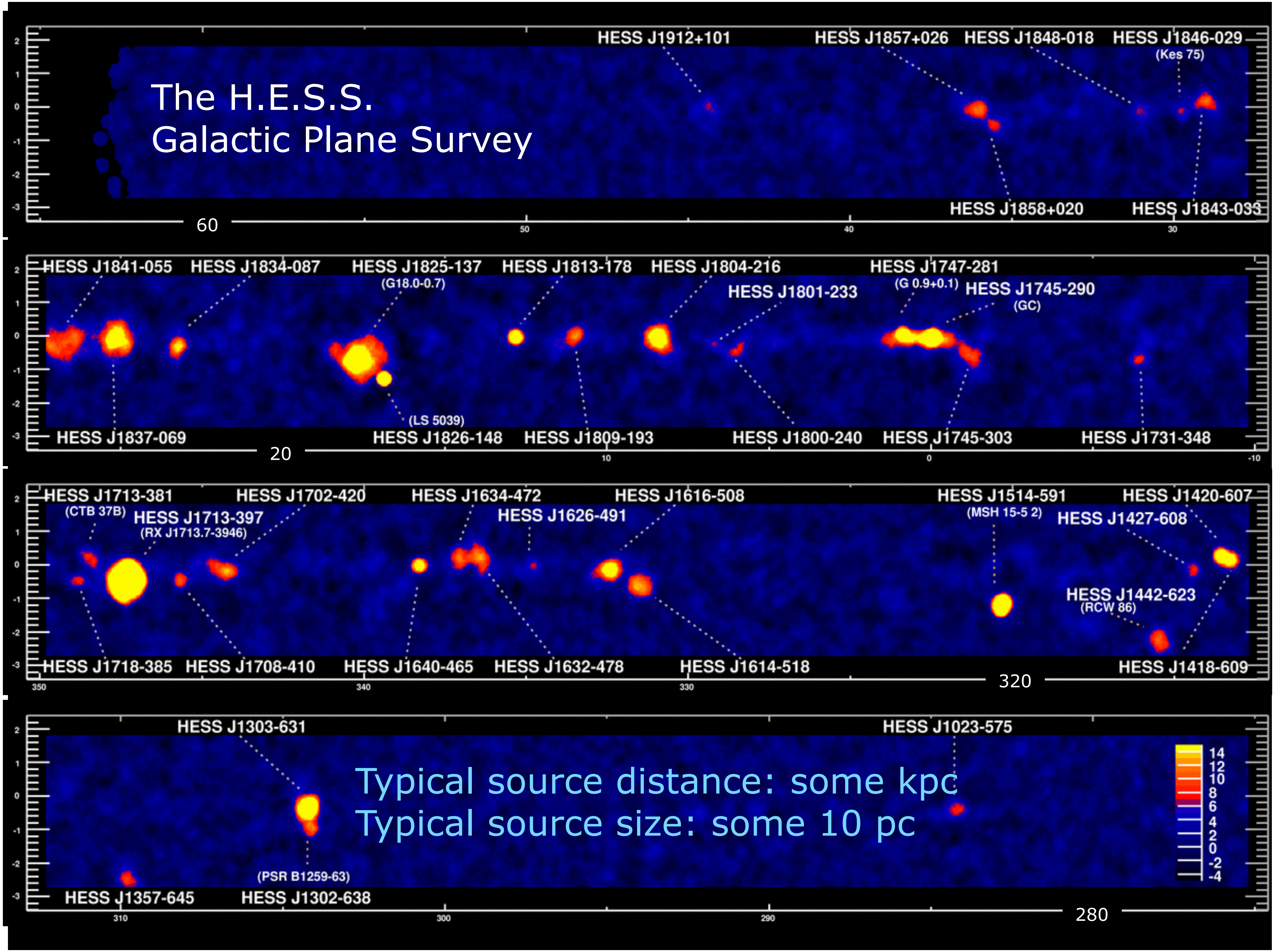
First analysis (almost) online in the same night on PC cluster in Namibia

Final analysis and calibration in Europe



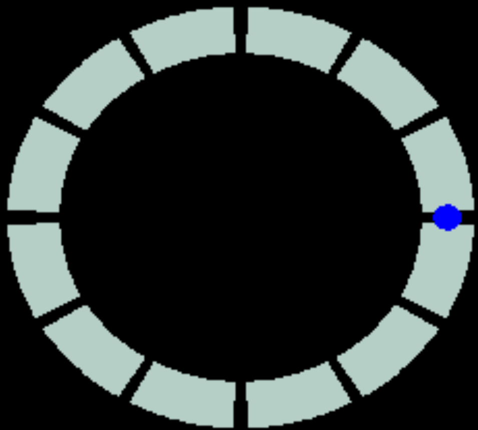
What?
A tour of galactic particle accelerators:

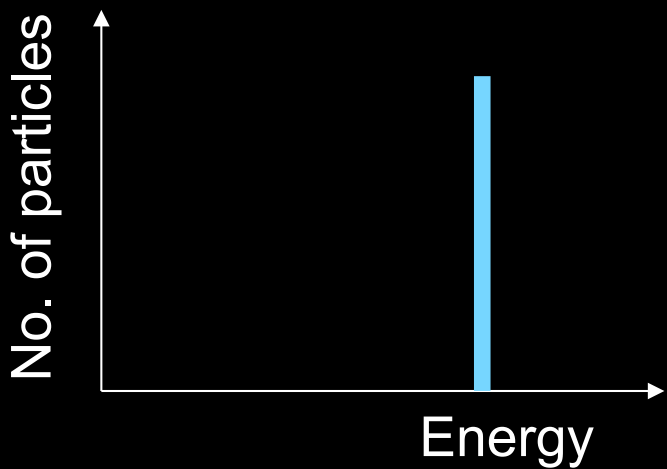
- Binaries
- Pulsar wind nebulae
- Supernova remnants
- Star clusters
- {"Dark sources"}


The H.E.S.S.
Galactic Plane Survey
HESS J1912+101
HESS J1857+026
HESS J1848-018
HESS J1846-029
(Kes 75)
HESS J1858+020
HESS J1843-033
60
50
40
30
HESS J1841-055
HESS J1834-087
HESS J1825-137
(G18.0-0.7)
HESS J1813-178
HESS J1804-216
HESS J1801-233
HESS J1747-281
(G 0.9+0.1)
HESS J1745-290
(GC)
(LS 5039)
HESS J1837-069
HESS J1826-148
HESS J1809-193
HESS J1800-240
HESS J1745-303
HESS J1731-348
20
10
0
-10
HESS J1713-381
(CTB 37B)
HESS J1713-397
(RX J1713.7-3946)
HESS J1702-420
HESS J1634-472
HESS J1626-491
HESS J1616-508
HESS J1514-591
(MSH 15-5 2)
HESS J1427-608
HESS J1420-607
HESS J1442-623
(RCW 86)
HESS J1718-385
HESS J1708-410
HESS J1640-465
HESS J1632-478
HESS J1614-518
HESS J1418-609
350
340
330
320
HESS J1303-631
HESS J1023-575
Typical source distance: some kpc
Typical source size: some 10 pc
(PSR B1259-63)
HESS J1357-645
HESS J1302-638
310
300
290
280
14
12
10
8
6
4
2
0
-2
-4

How could cosmic accelerators work?

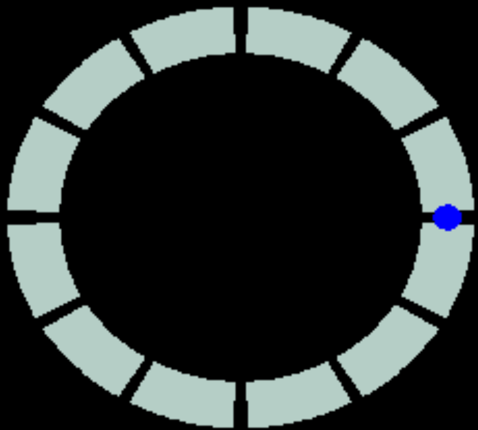
Man-made accelerators



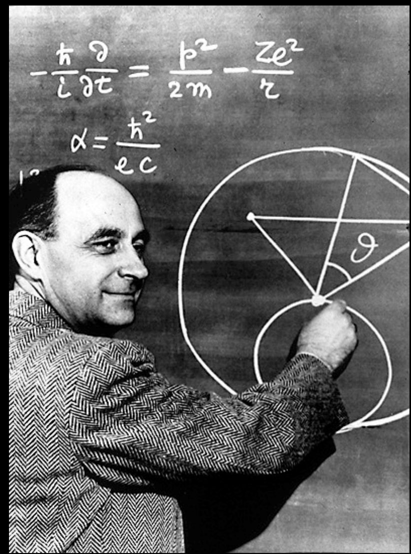


How could cosmic accelerators work?

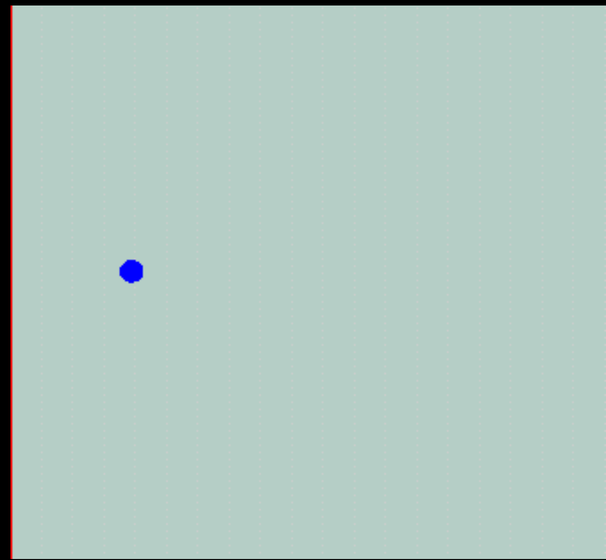
Man-made accelerators

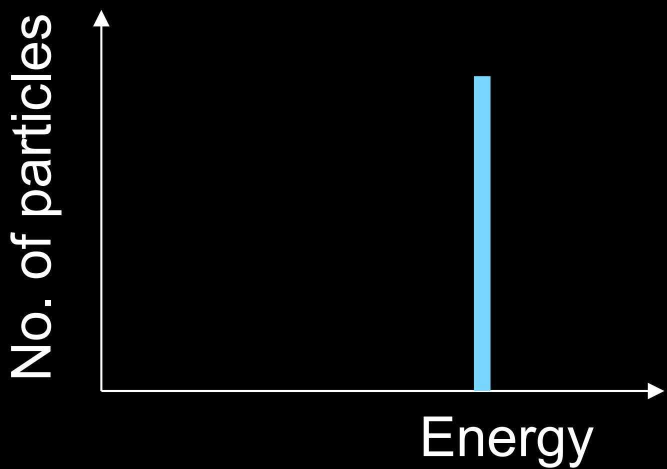


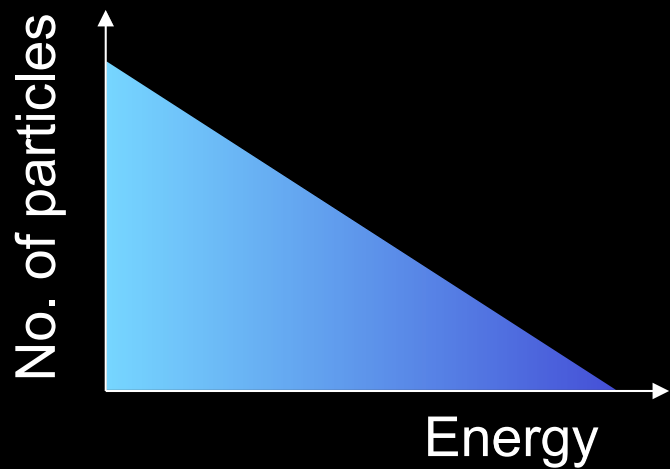
Nature's accelerators



Enrico Fermi

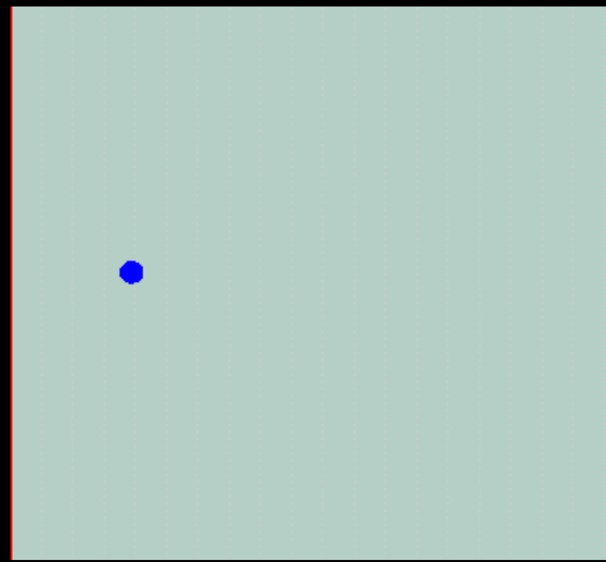






How could cosmic accelerators work?

Nature's accelerators



Energy gain / cycle $\Delta E/E \sim \beta_{shock}$

... many 100 cycles to reach TeV energies …

... takes several 100 years

Generates power law spectrum $dN/dE \sim E^{-2}$

… at some point, particle escapes …

… to be precise: $dN/dE \sim E^{-\Gamma}$, $\Gamma = (R+2)/(R-1)$

R = shock compression ratio

For strong shocks (Mach # >> 1): $R = 4 \rightarrow \Gamma = 2$

For weaker shocks: $R < 4 \rightarrow \Gamma > 2$

Peak energy $\sim 10^{15}$ eV

… depending on size of shock front …

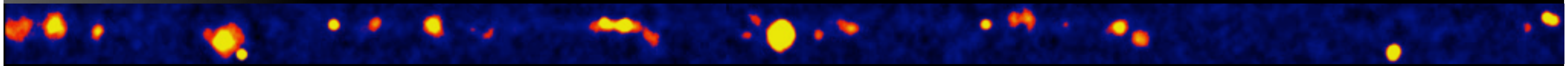
Nonlinear process with efficiency ~50%!

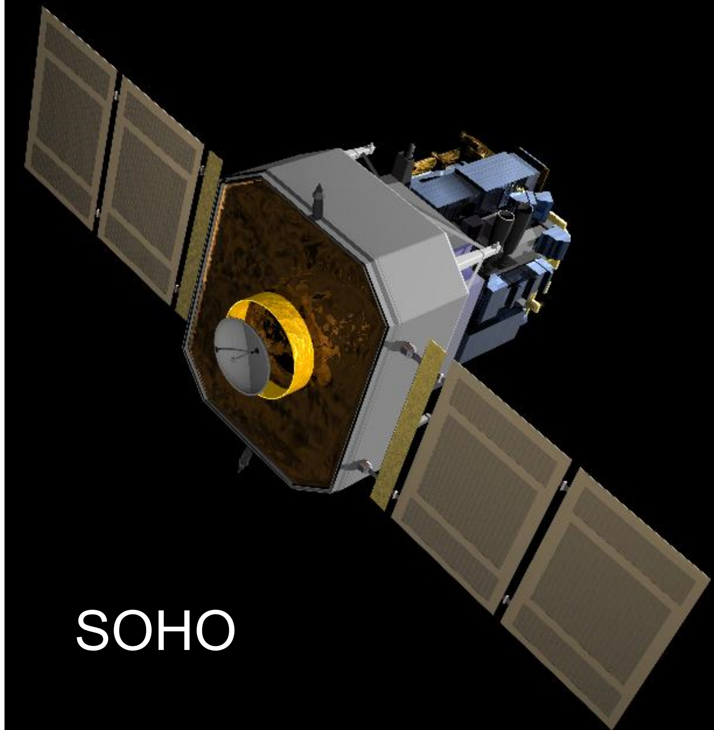
… accelerated particles generate plasma waves …

Shocks are everywhere!

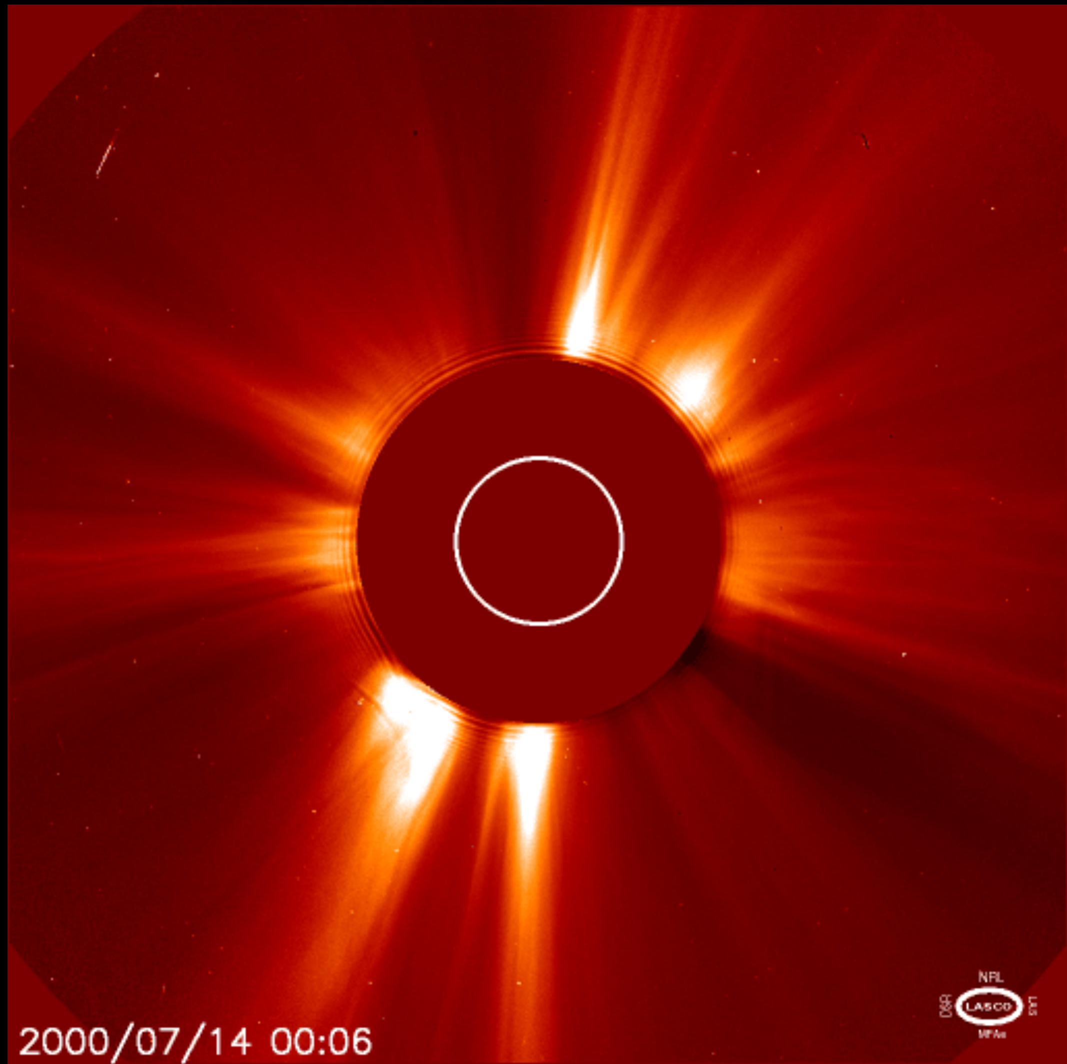
- *Supernovae*
- *Pulsars*
- *Stellar winds*
- *Jets of active galaxies*
- *Galactic mergers*
- *Solar system …*

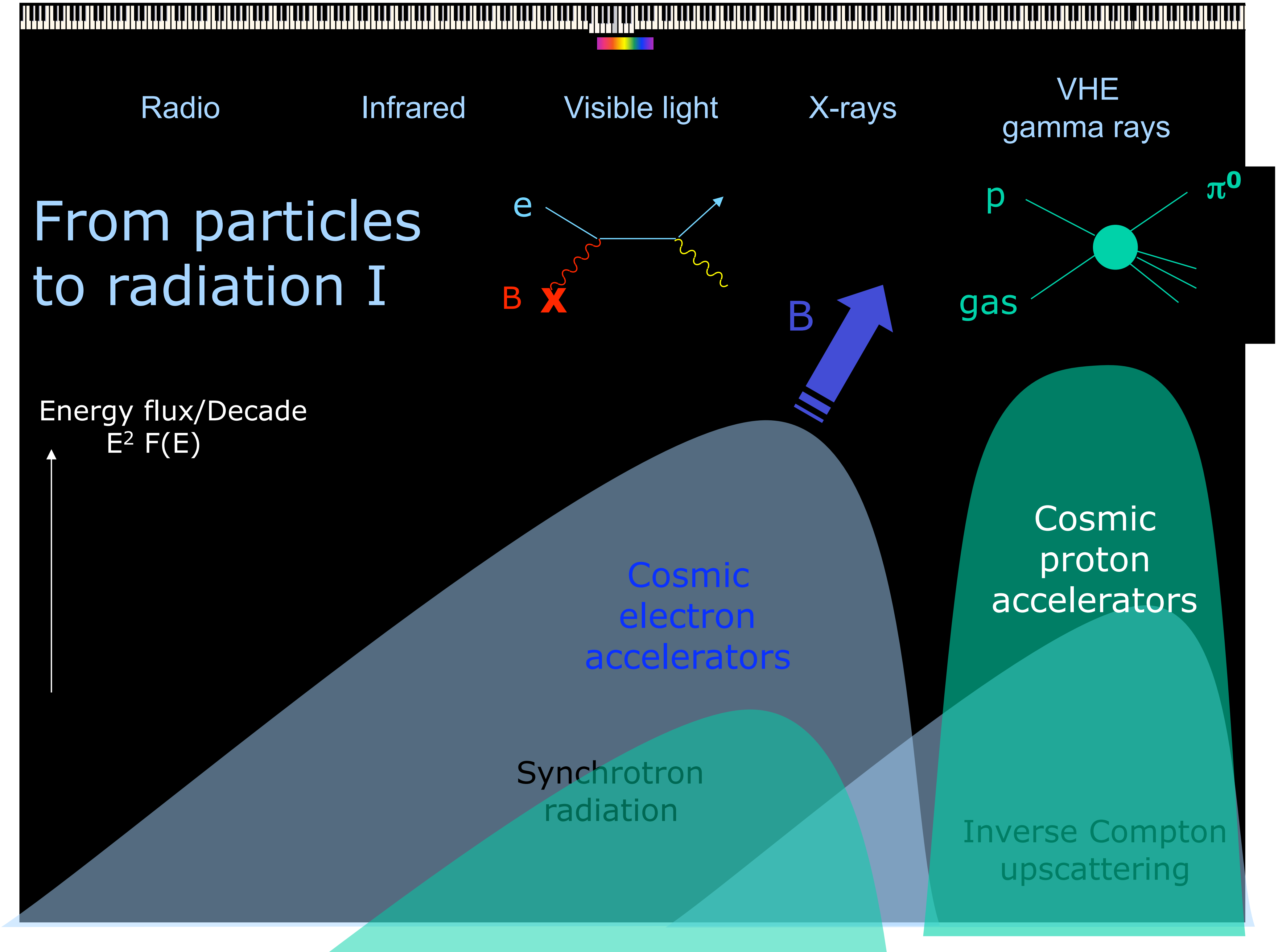
A particle accelerator in the Solar System



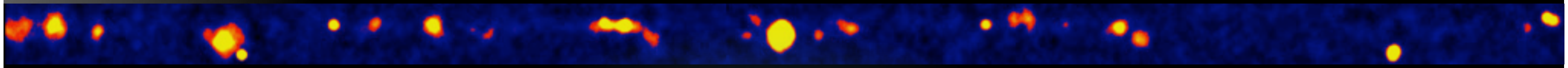


SOHO




Radio
Infrared
Visible light
X-rays
VHE gamma rays
From particles to radiation I
e
B
x
B
p
π^0
gas
Energy flux/Decade
E^2 F(E)
Cosmic electron accelerators
Cosmic proton accelerators
Synchrotron radiation
Inverse Compton upscattering

From particles to radiation II



For uniform distribution of targets, **γ-rays probe particle distribution**

Energy-dependent propagation modifies spectrum as a function of distance

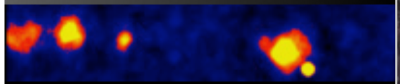
Source of particles (e.g. pulsar)

Target "material"

Source size given by diffusion / convection speed and age of source or "livetime" of particles

Radiative losses steepen spectrum as a function of distance

Bubbles: Gas density $10^{-2}/cm^3$



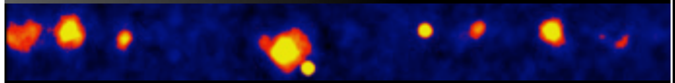
The N44 Superbubble (250 LY across)
Credit & Copyright: Gemini Obs., AURA, NSF

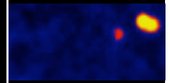
Lifetime of 10 TeV proton: $\sim 10^9$ years

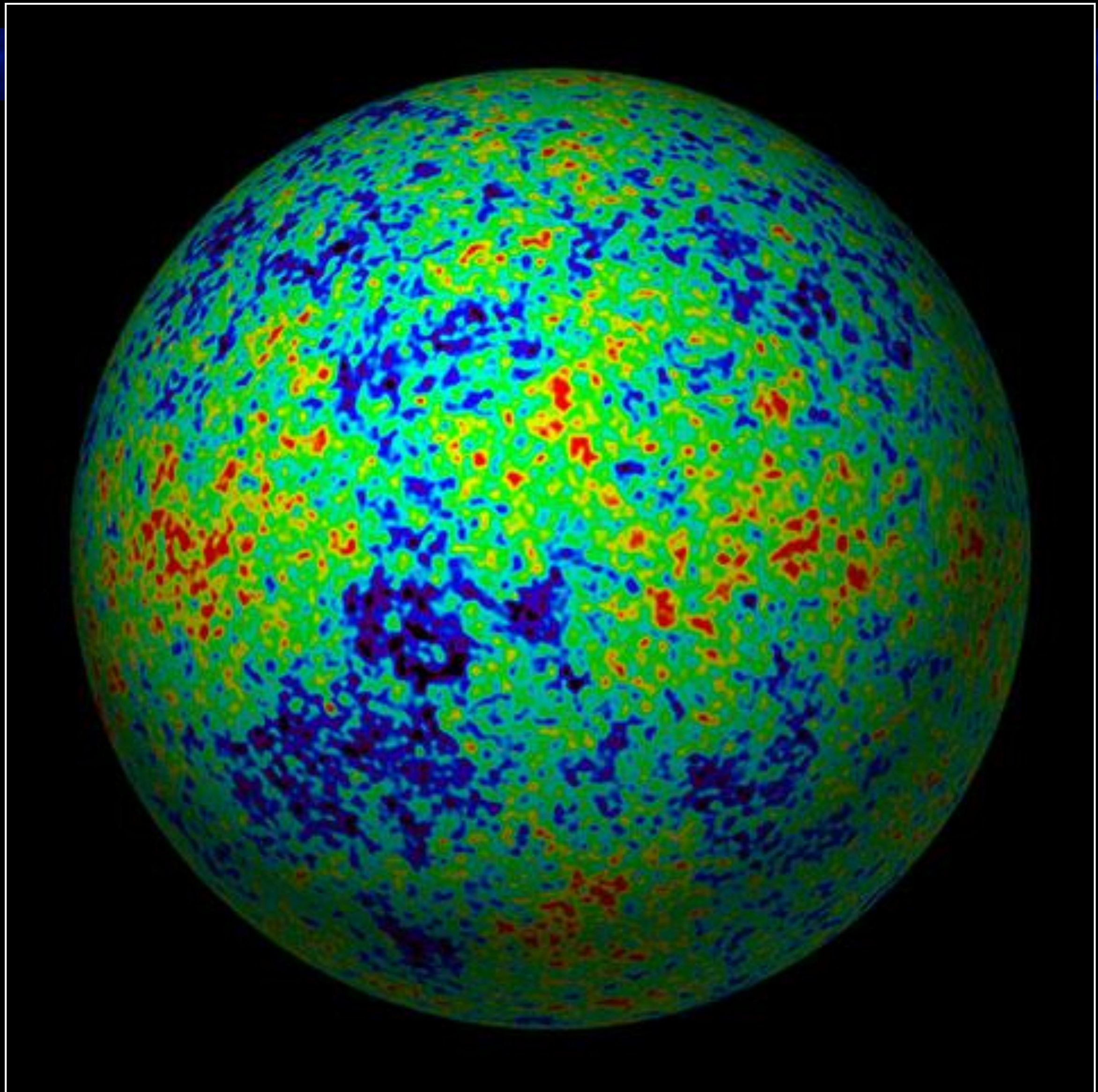
Clouds: Gas density $>10^3/cm^3$

Lifetime of 10 TeV proton: $\sim 10^4$ years

CMB: Photon density 0.26 eV/cm^3

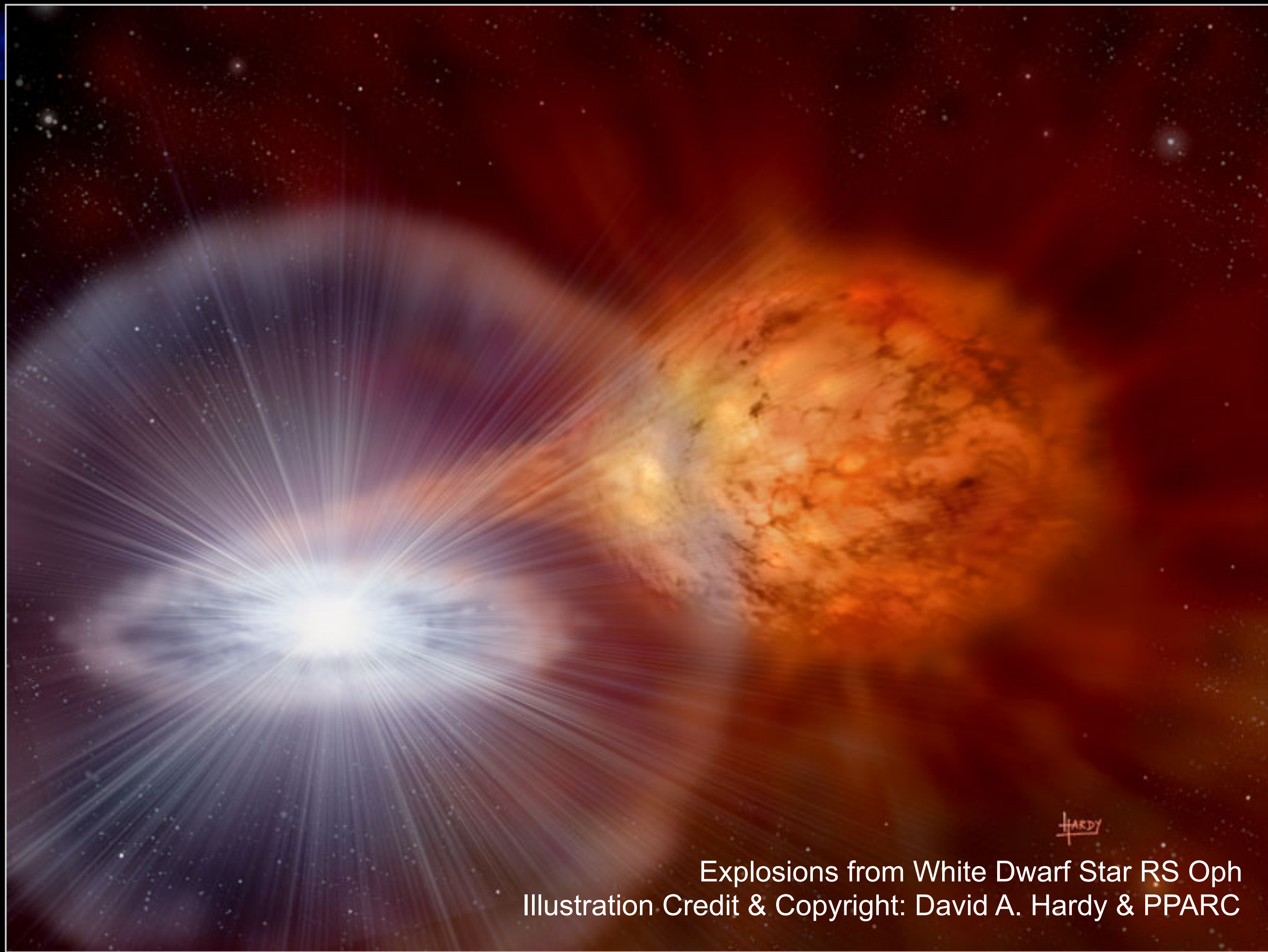






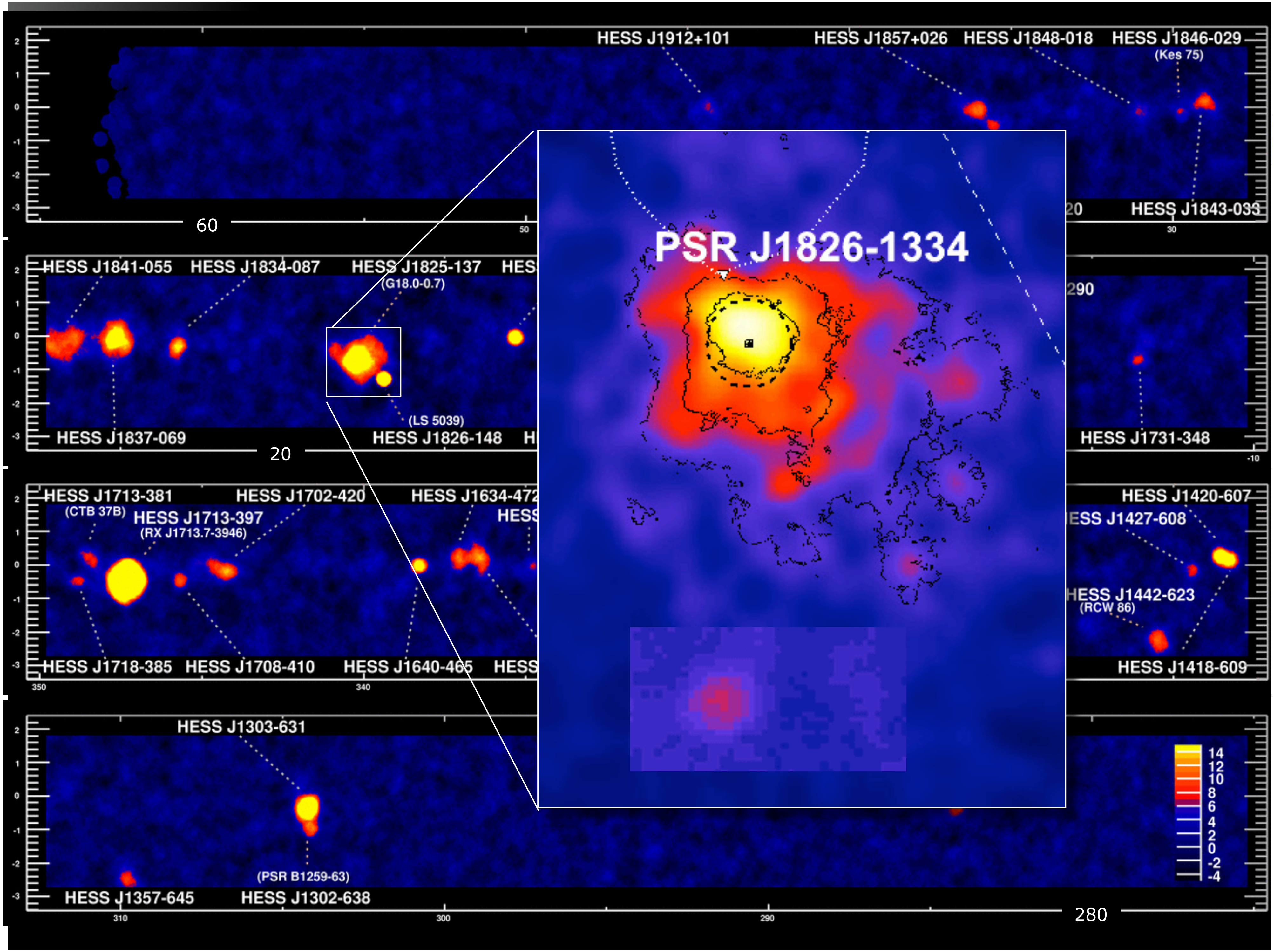
Lifetime of 10 TeV electron: ~10^5 years

In binary systems: 10^4 eV/cm^3



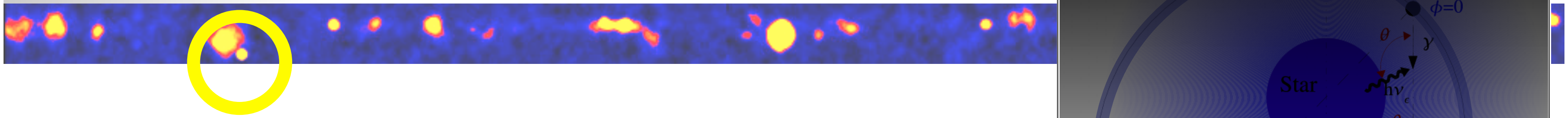
Explosions from White Dwarf Star RS Oph
Illustration Credit & Copyright: David A. Hardy & PPARC

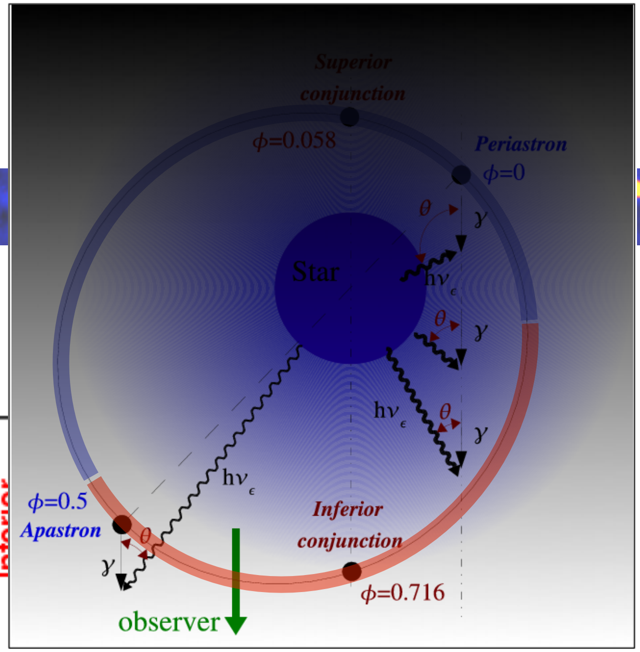
Lifetime of 10 TeV electron: <100 years



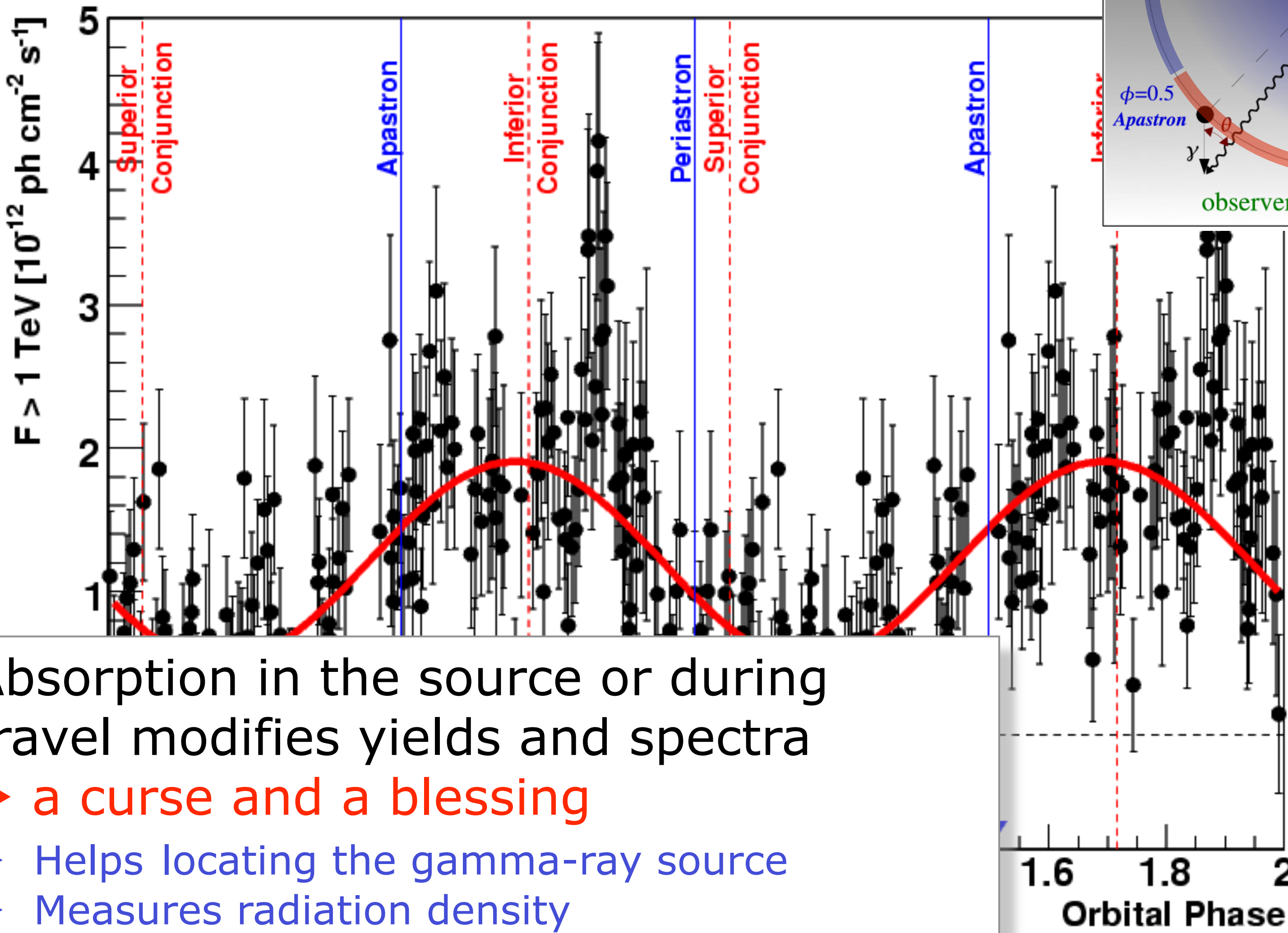
HESS J1912+101
HESS J1857+026
HESS J1848-018
HESS J1846-029
(Kes 75)
HESS J1843-033
60
HESS J1841-055
HESS J1834-087
HESS J1825-137
(G18.0-0.7)
(LS 5039)
HESS J1837-069
HESS J1826-148
20
HESS J1731-348
HESS J1713-381
(CTB 37B)
HESS J1713-397
(RX J1713.7-3946)
HESS J1702-420
HESS J1634-472
HESS J1420-607
HESS J1427-608
HESS J1442-623
(RCW 86)
HESS J1718-385
HESS J1708-410
HESS J1640-465
HESS J1418-609
HESS J1303-631
(PSR B1259-63)
HESS J1357-645
HESS J1302-638
280
PSR J1826-1334

LS 5039 lightcurve





γ-Period: 3.908±0.002 days



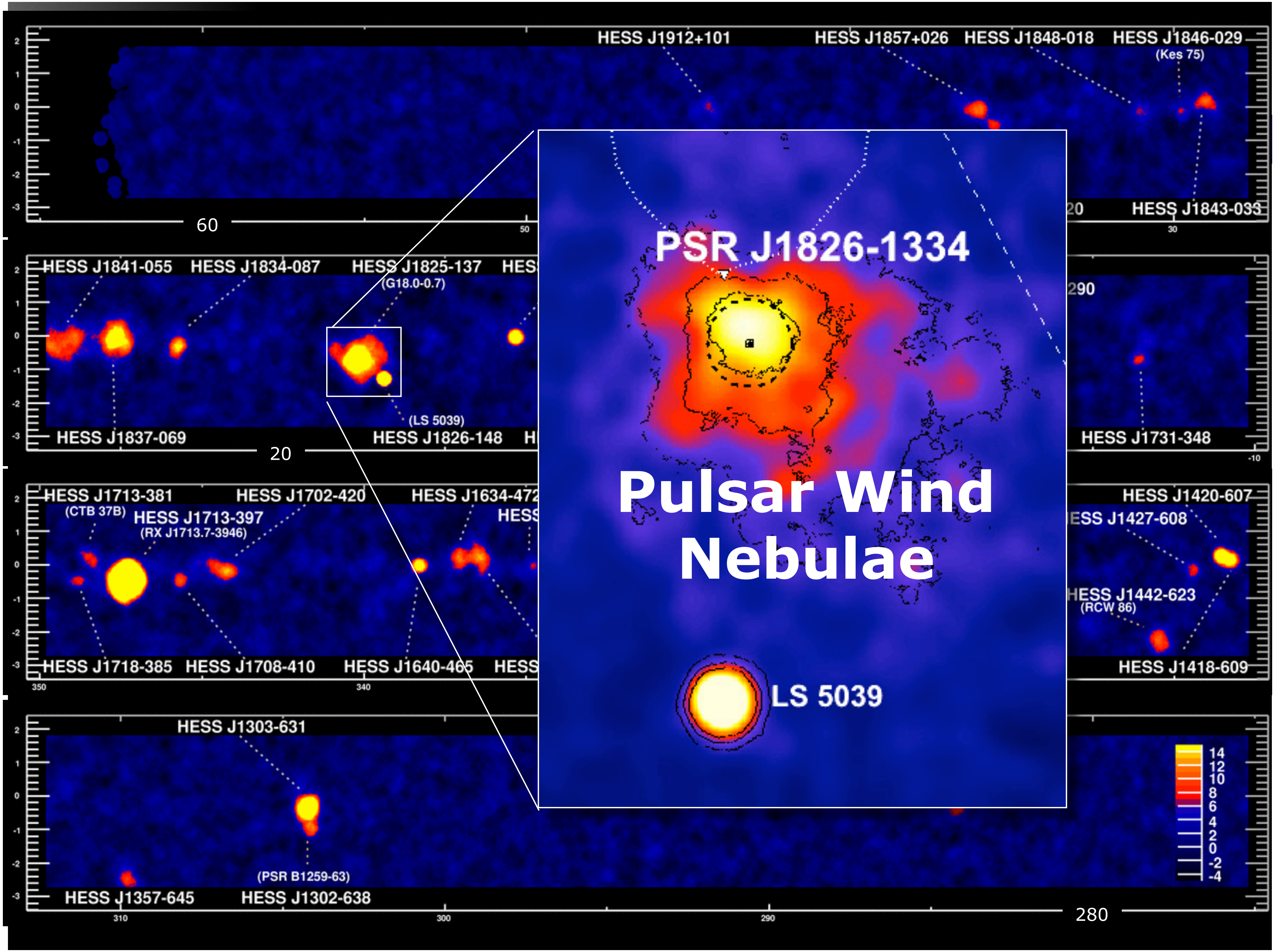
Folded using optical period

Data repeated for 2 cycles

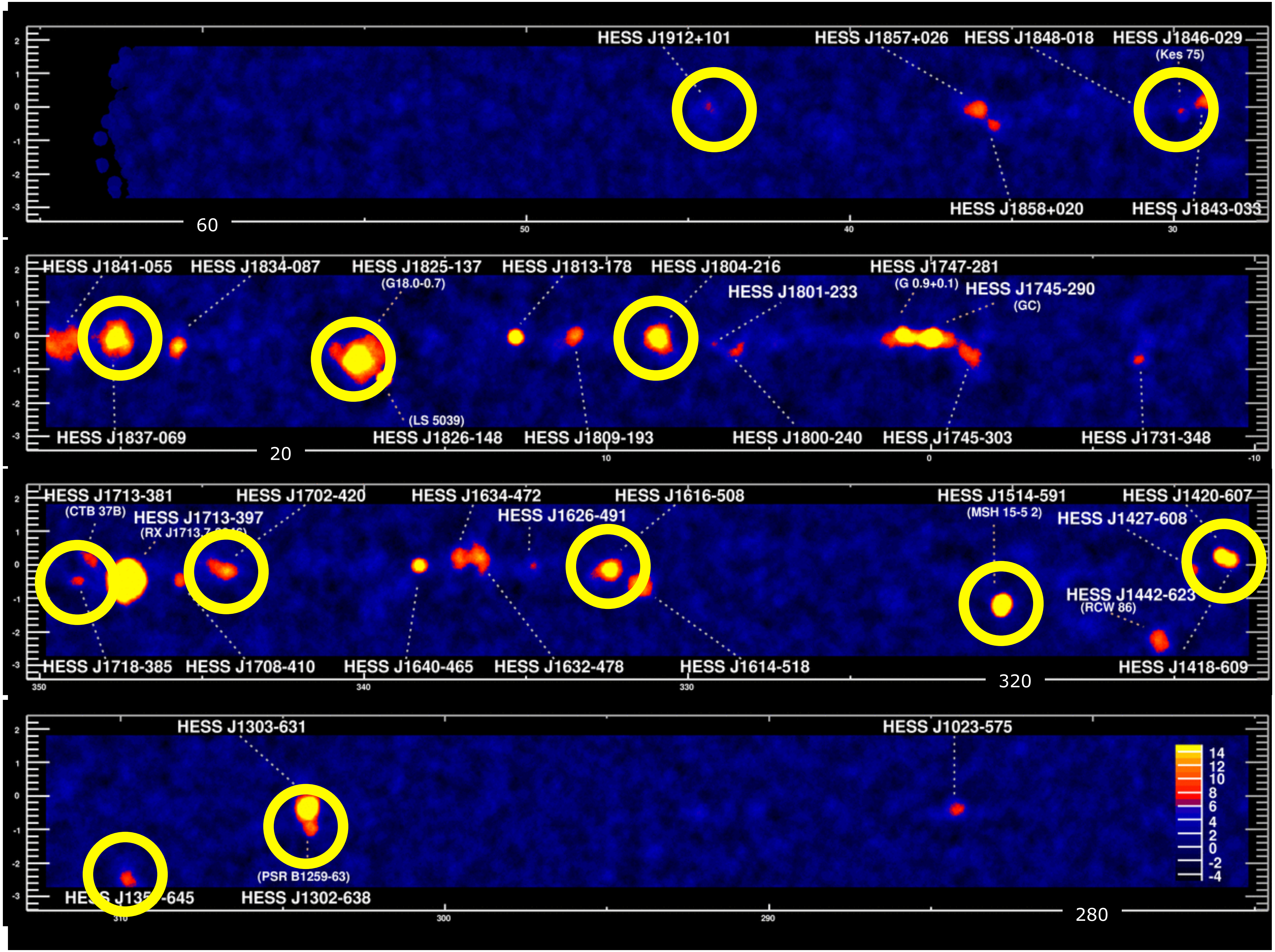
Absorption in the source or during travel modifies yields and spectra

▶ a curse and a blessing

- Helps locating the gamma-ray source
- Measures radiation density

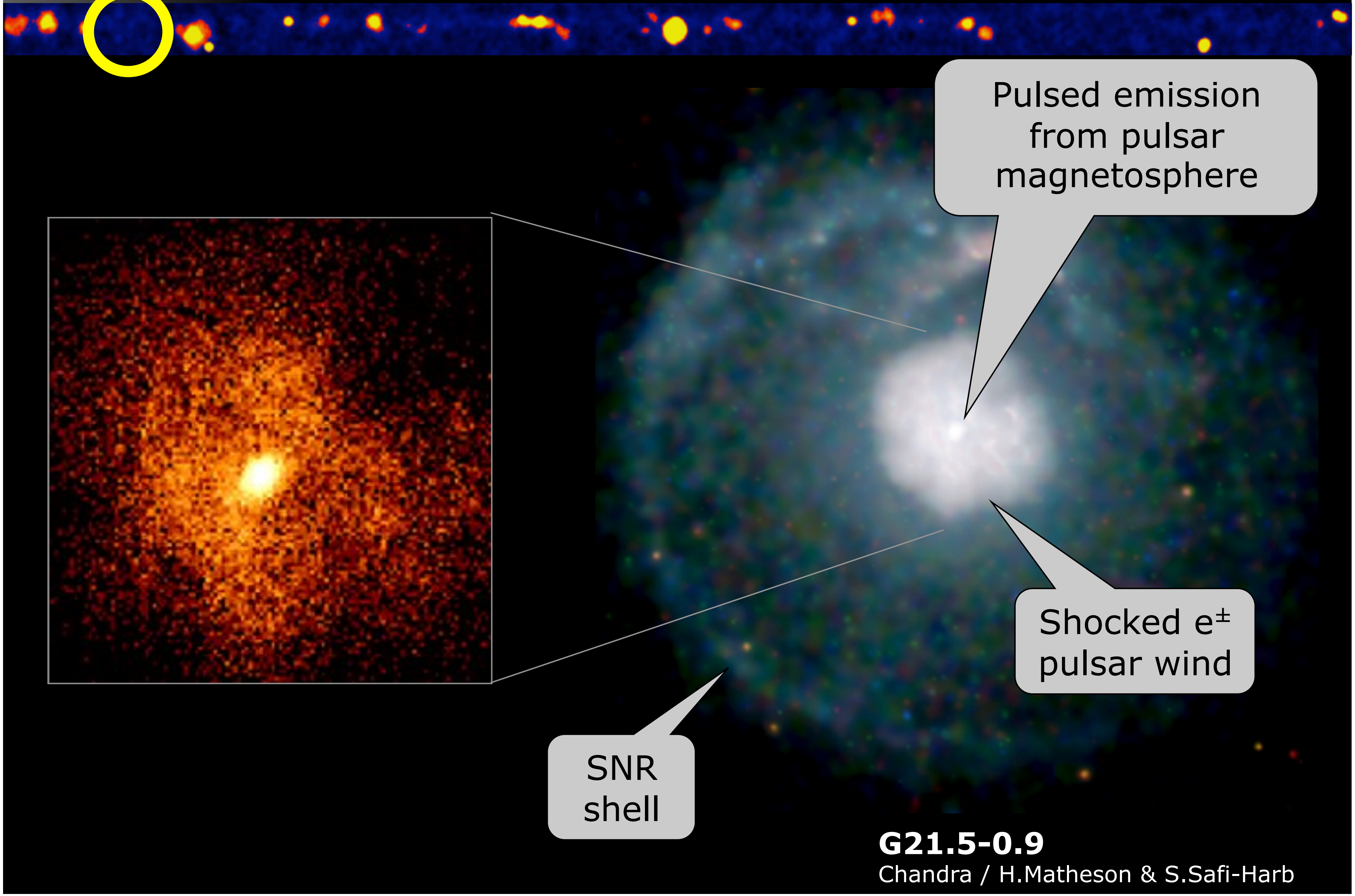


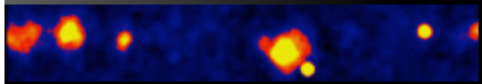
HESS J1912+101
HESS J1857+026
HESS J1848-018
HESS J1846-029
(Kes 75)
HESS J1843-033
60
HESS J1841-055
HESS J1834-087
HESS J1825-137
(G18.0-0.7)
(LS 5039)
HESS J1837-069
HESS J1826-148
HESS J1731-348
20
HESS J1713-381
(CTB 37B)
HESS J1713-397
(RX J1713.7-3946)
HESS J1702-420
HESS J1634-472
HESS J1420-607
HESS J1442-623
(RCW 86)
HESS J1718-385
HESS J1708-410
HESS J1640-465
HESS J1418-609
HESS J1303-631
(PSR B1259-63)
HESS J1357-645
HESS J1302-638
280
PSR J1826-1334
Pulsar Wind Nebulae
LS 5039



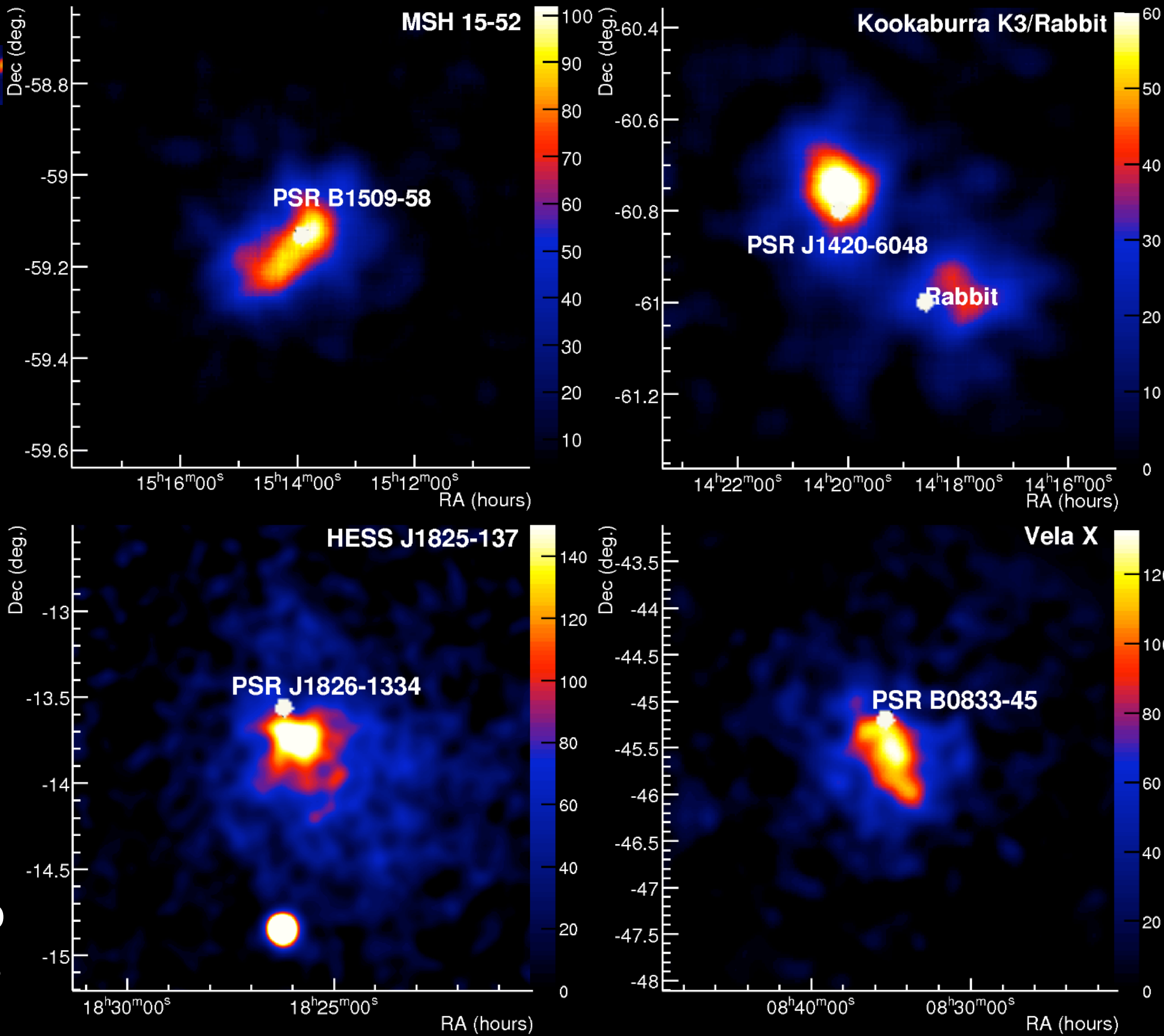
HESS J1912+101
HESS J1857+026
HESS J1848-018
HESS J1846-029
(Kes 75)
HESS J1858+020
HESS J1843-033
60
50
40
30
HESS J1841-055
HESS J1834-087
HESS J1825-137
(G18.0-0.7)
HESS J1813-178
HESS J1804-216
HESS J1801-233
HESS J1747-281
(G 0.9+0.1)
HESS J1745-290
(GC)
(LS 5039)
HESS J1837-069
HESS J1826-148
HESS J1809-193
HESS J1800-240
HESS J1745-303
HESS J1731-348
20
10
0
-10
HESS J1713-381
(CTB 37B)
HESS J1713-397
HESS J1702-420
HESS J1634-472
HESS J1626-491
HESS J1616-508
HESS J1514-591
(MSH 15-5 2)
HESS J1420-607
HESS J1427-608
HESS J1442-623
(RCW 86)
HESS J1718-385
HESS J1708-410
HESS J1640-465
HESS J1632-478
HESS J1614-518
HESS J1418-609
350
340
330
320
HESS J1303-631
HESS J1023-575
(PSR B1259-63)
HESS J1302-638
310
300
290
280
14
12
10
8
6
4
2
0
-2
-4

Pulsar wind nebulae





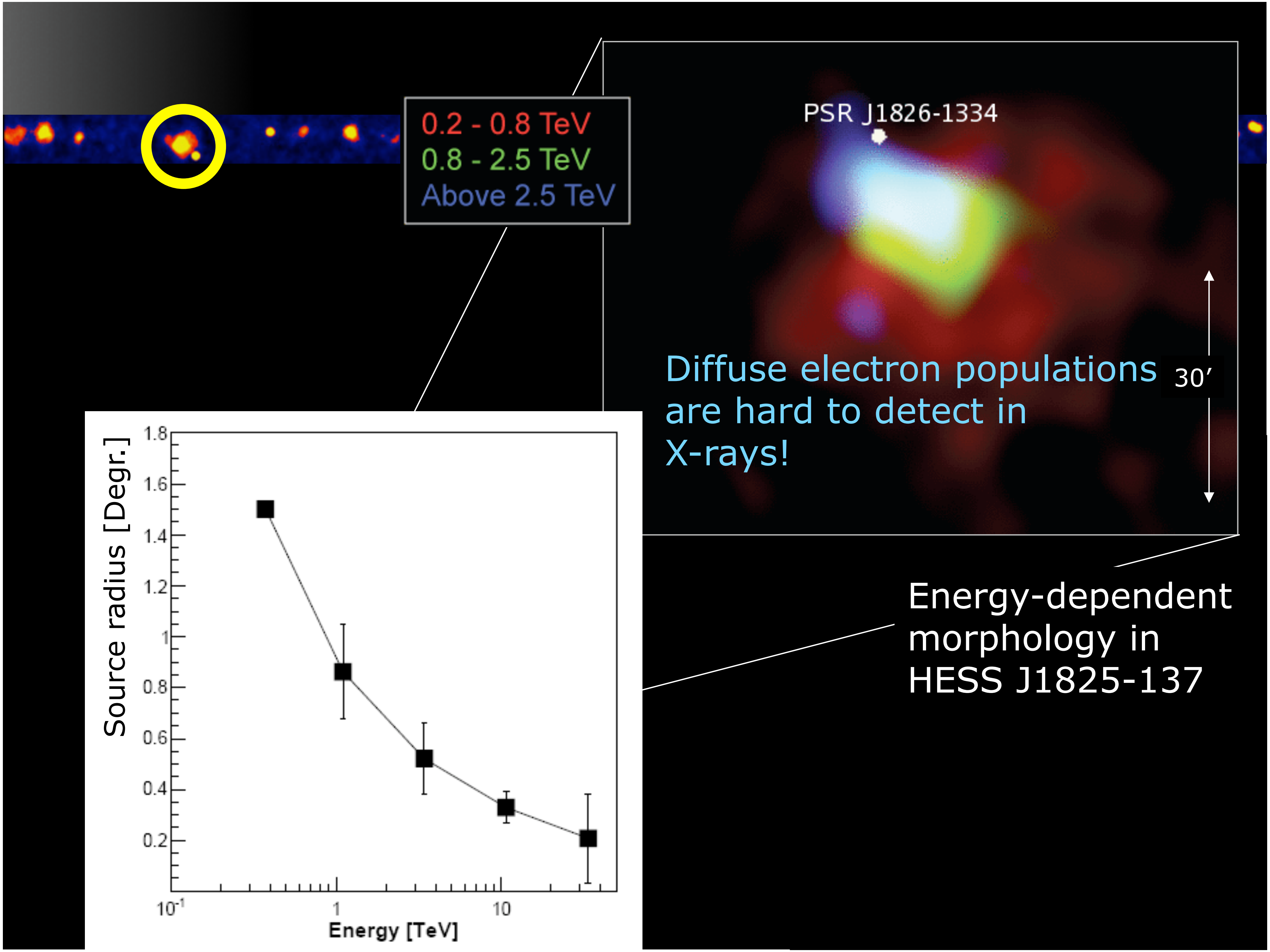
PWN



γ-ray sources are

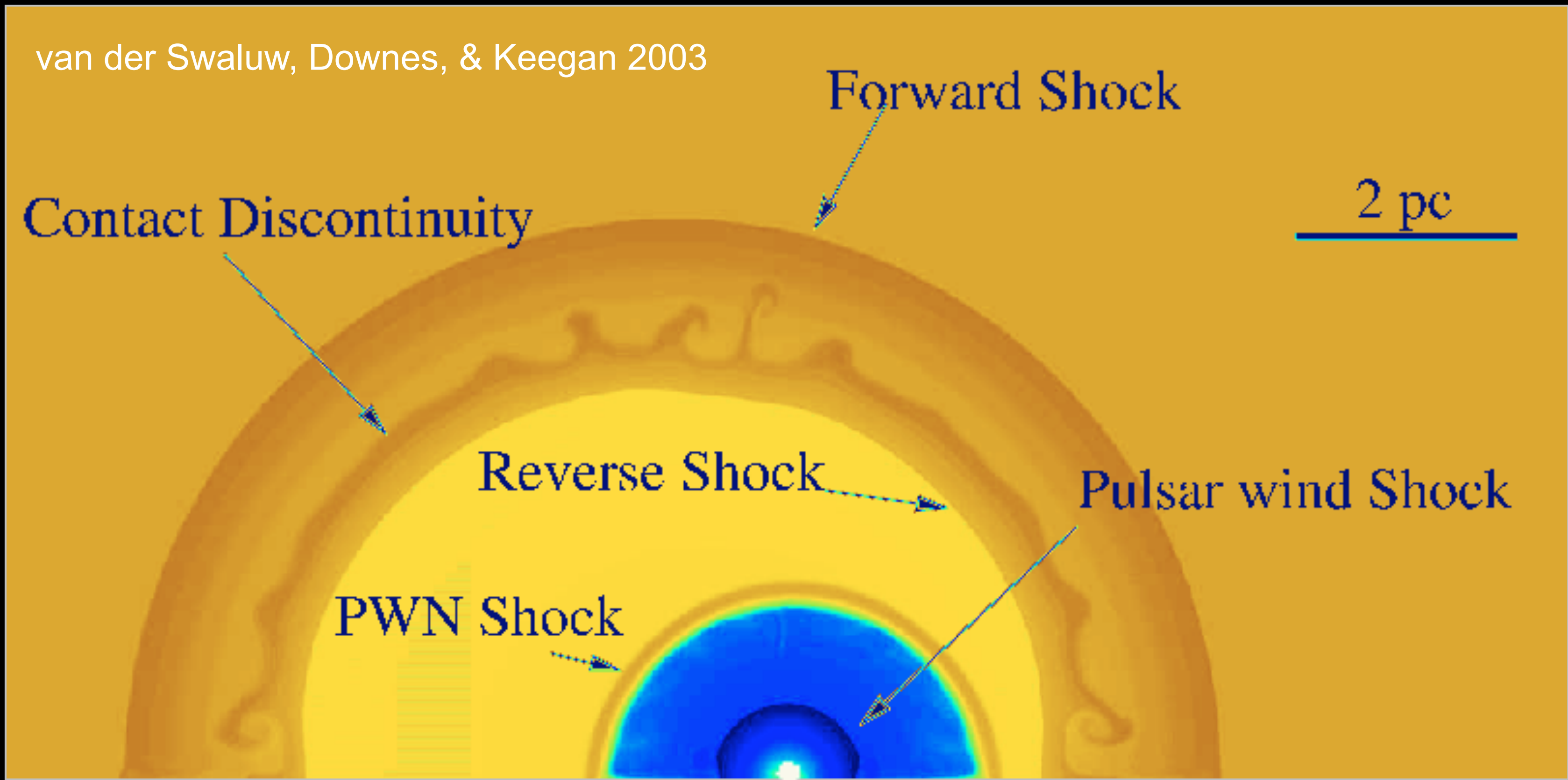
- extended
- displaced from pulsar

- O(1%) of spin-down energy loss converted to gamma rays

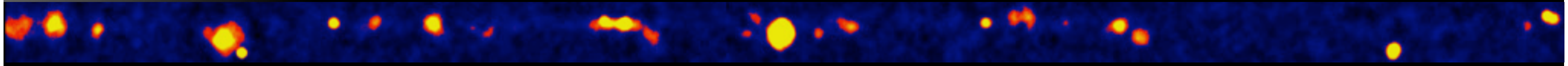


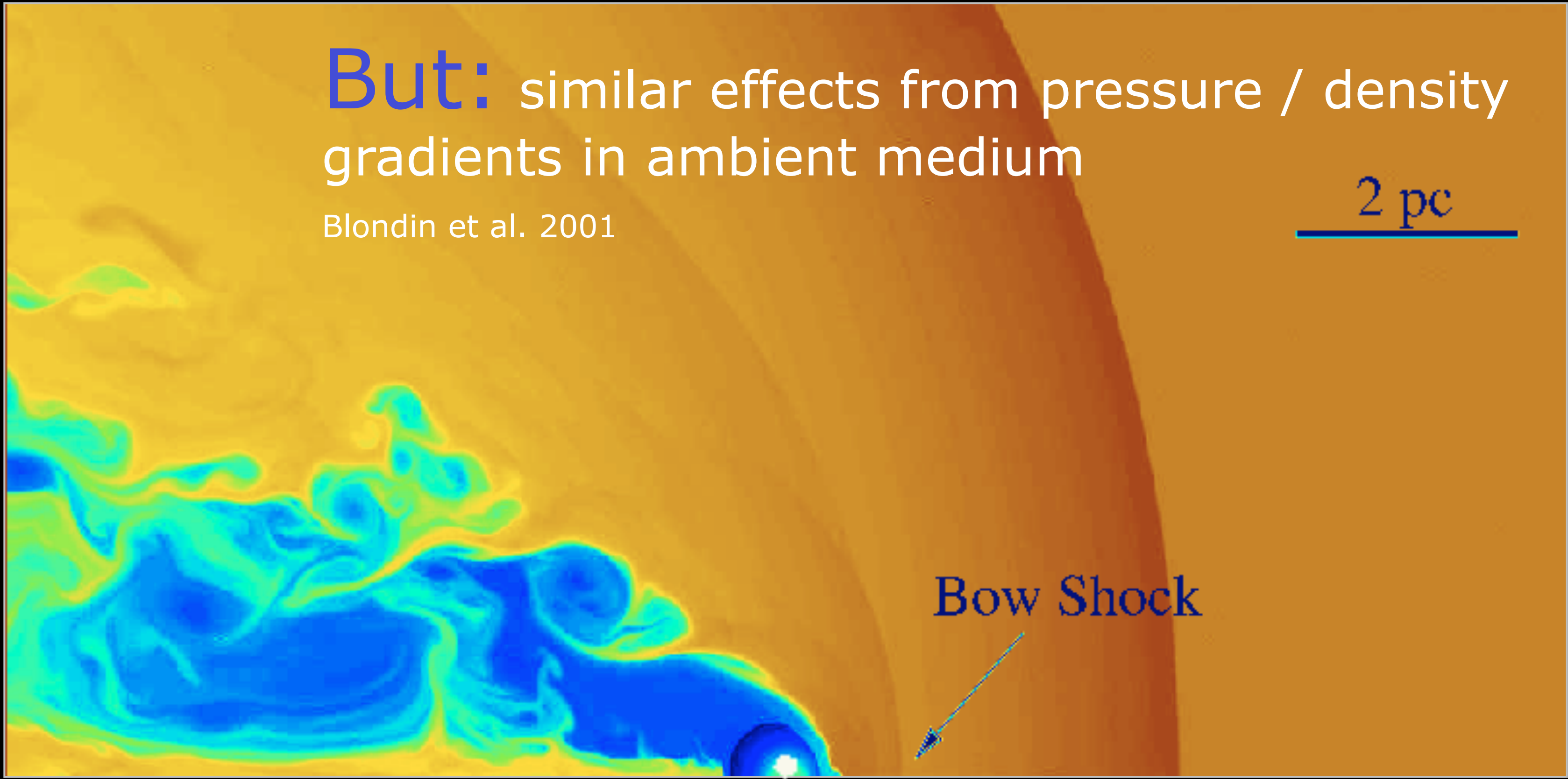
0.2 - 0.8 TeV
0.8 - 2.5 TeV
Above 2.5 TeV
PSR J1826-1334
30′
Diffuse electron populations are hard to detect in X-rays!
Energy-dependent morphology in HESS J1825-137
Source radius [Degr.]
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
10^{-1}
1
10
Energy [TeV]

Pulsar “Kick” ?


van der Swaluw, Downes, & Keegan 2003
Forward Shock
2 pc
Contact Discontinuity
Reverse Shock
Pulsar wind Shock
PWN Shock

Pulsar "Kick" ?



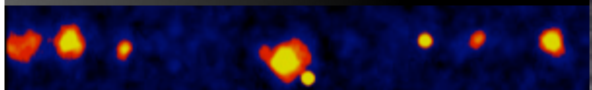


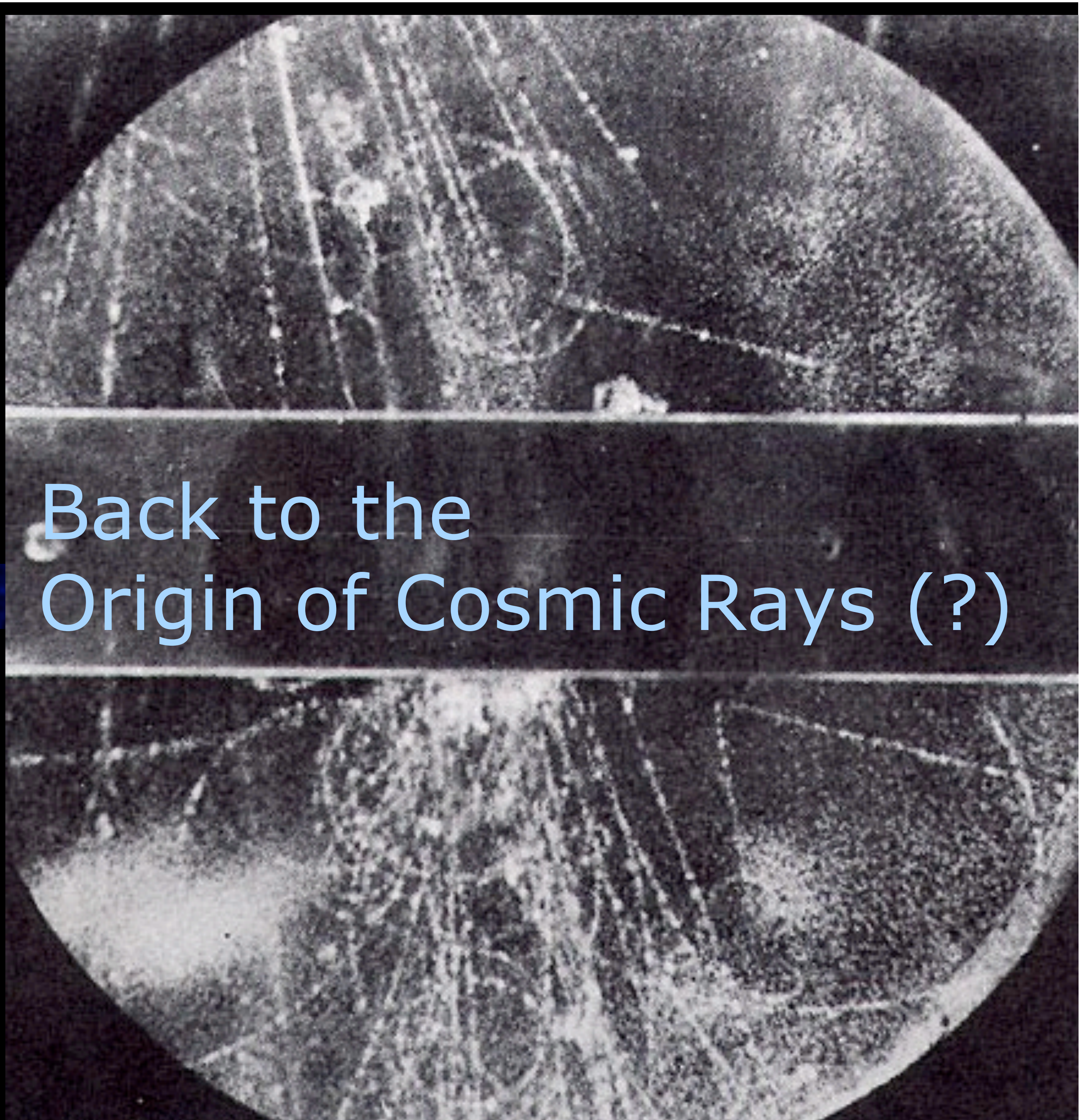
But: similar effects from pressure / density gradients in ambient medium

Blondin et al. 2001

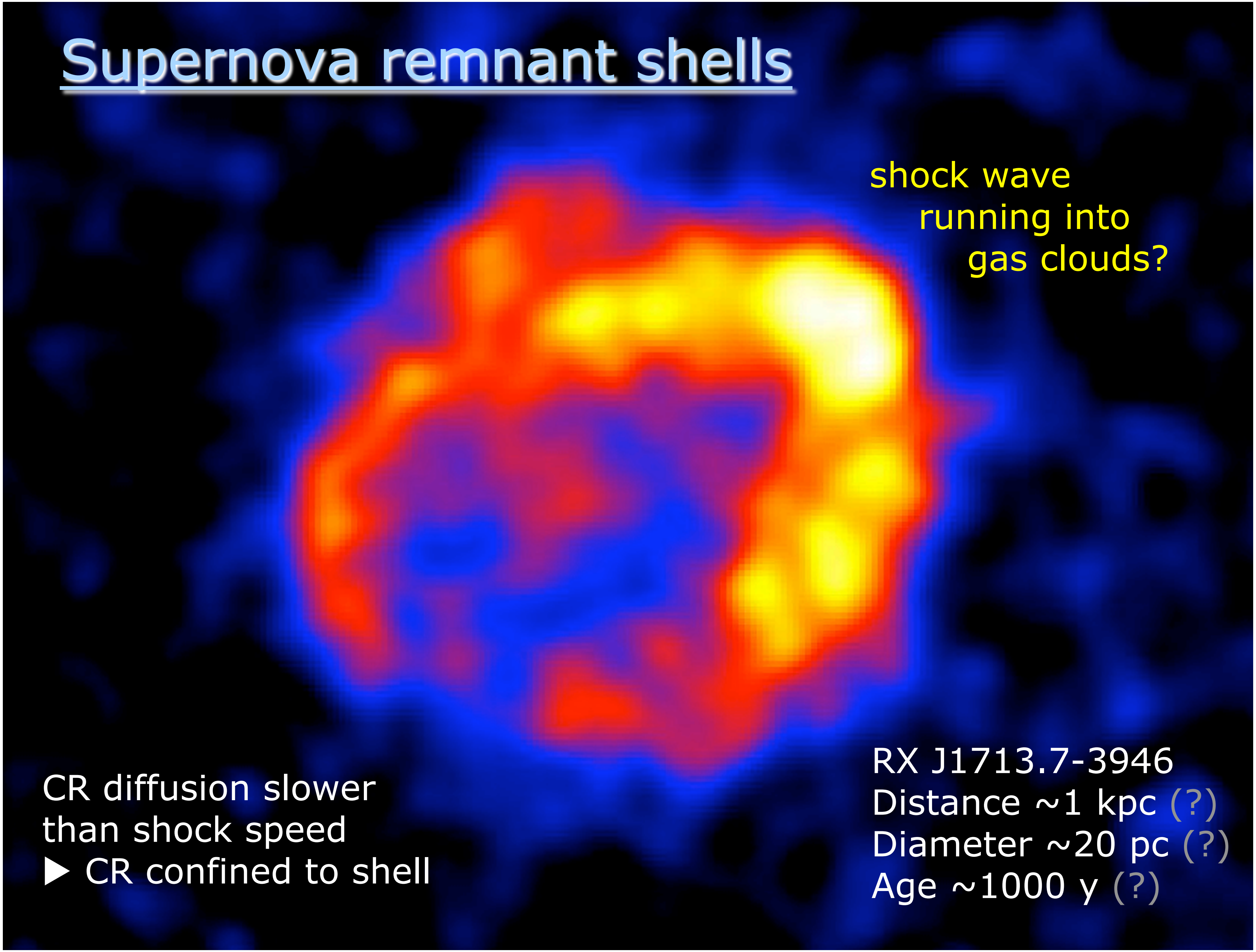
NO! … not for Vela-X, HESS J1825-137

Back to the Origin of Cosmic Rays (?)





Supernova remnant shells

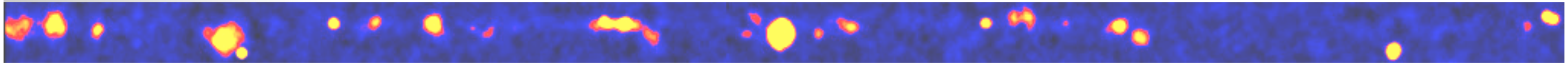


shock wave
running into
gas clouds?

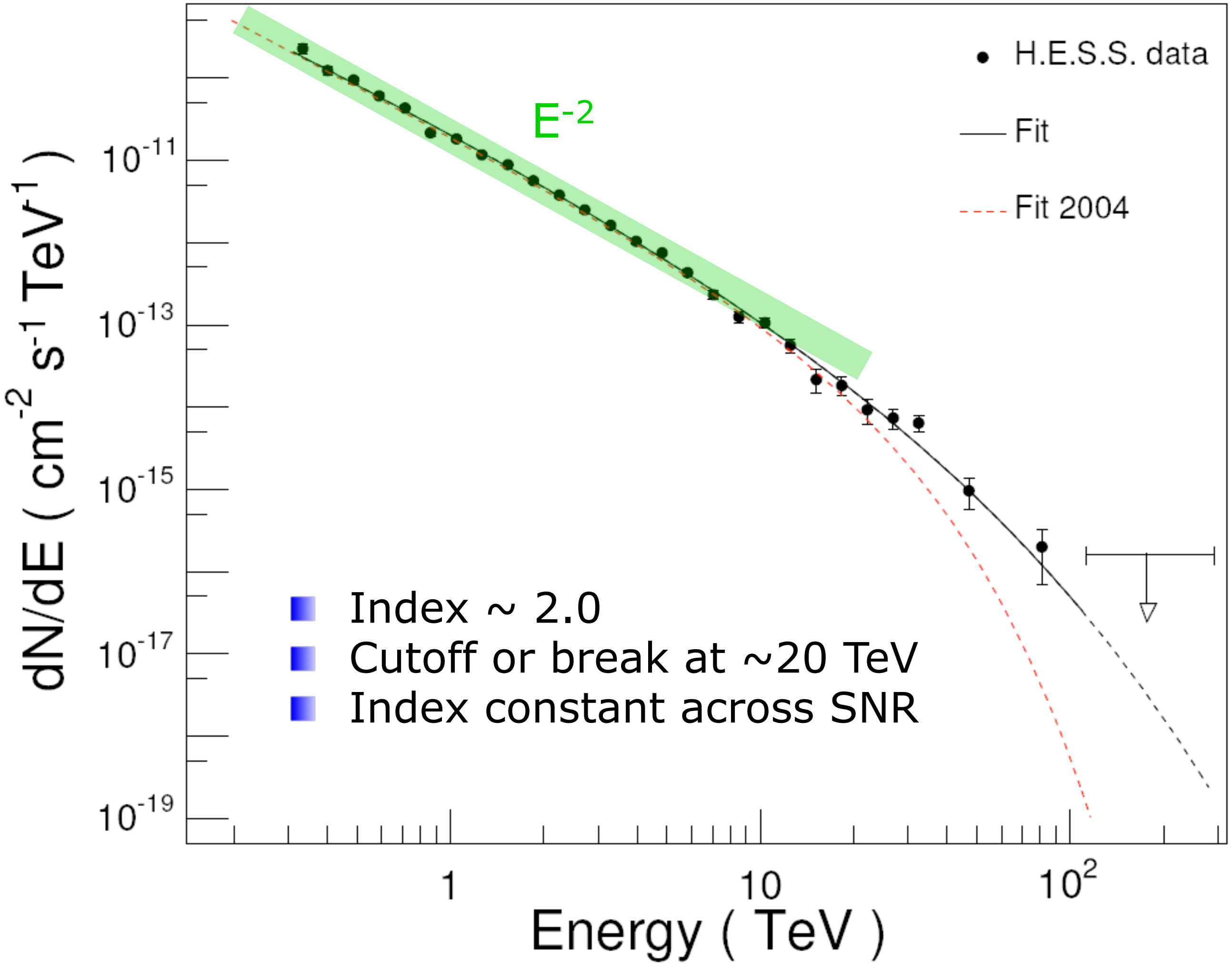
CR diffusion slower
than shock speed
▶ CR confined to shell

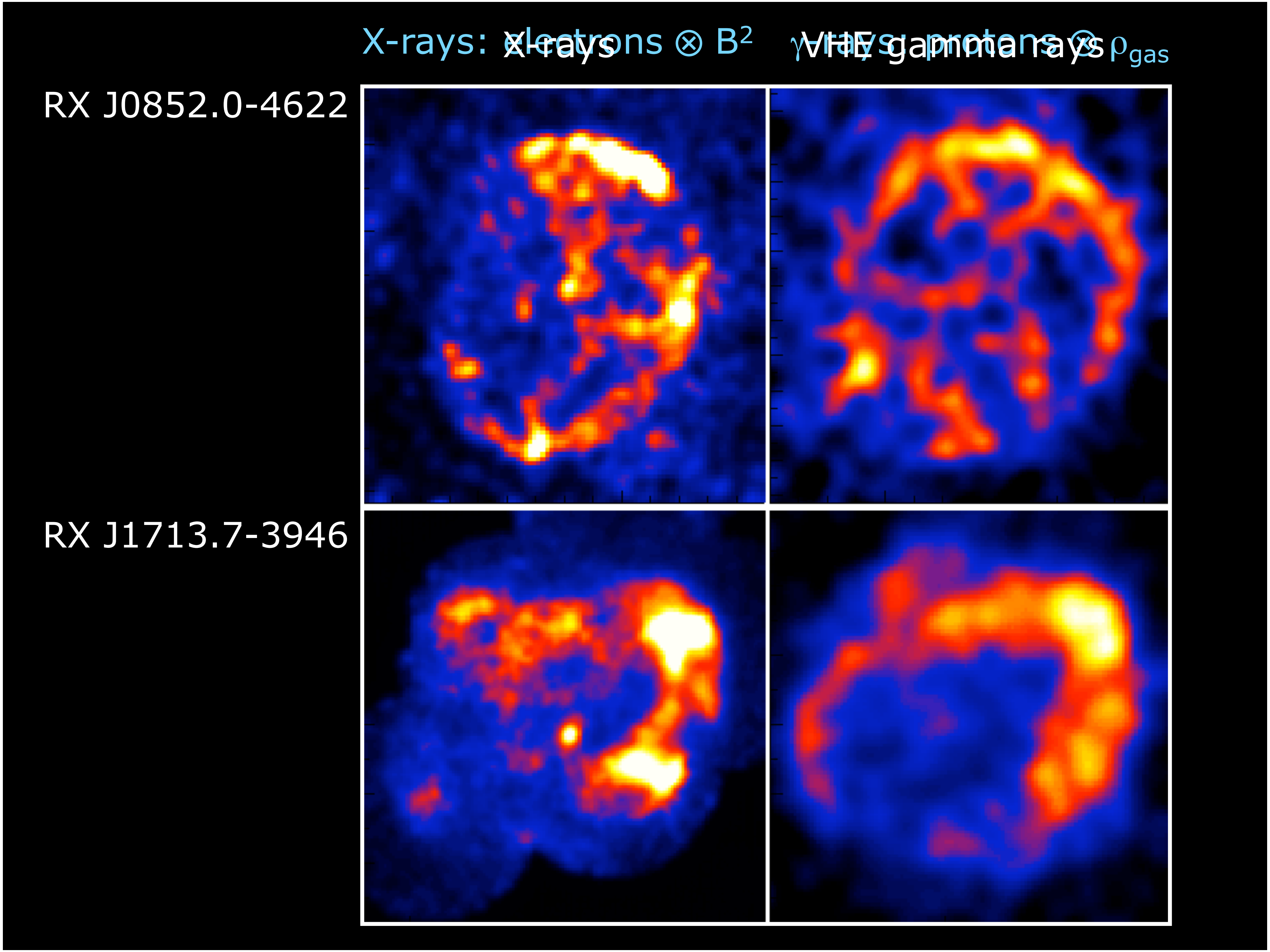
RX J1713.7-3946
Distance ~1 kpc (?)
Diameter ~20 pc (?)
Age ~1000 y (?)

RXJ 1713.7-3946

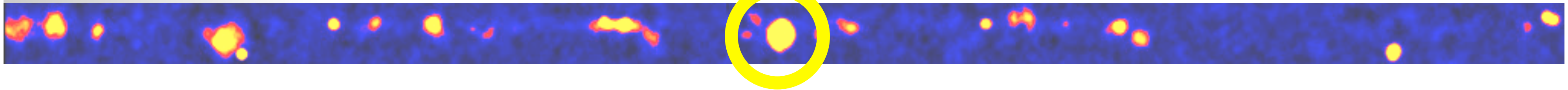


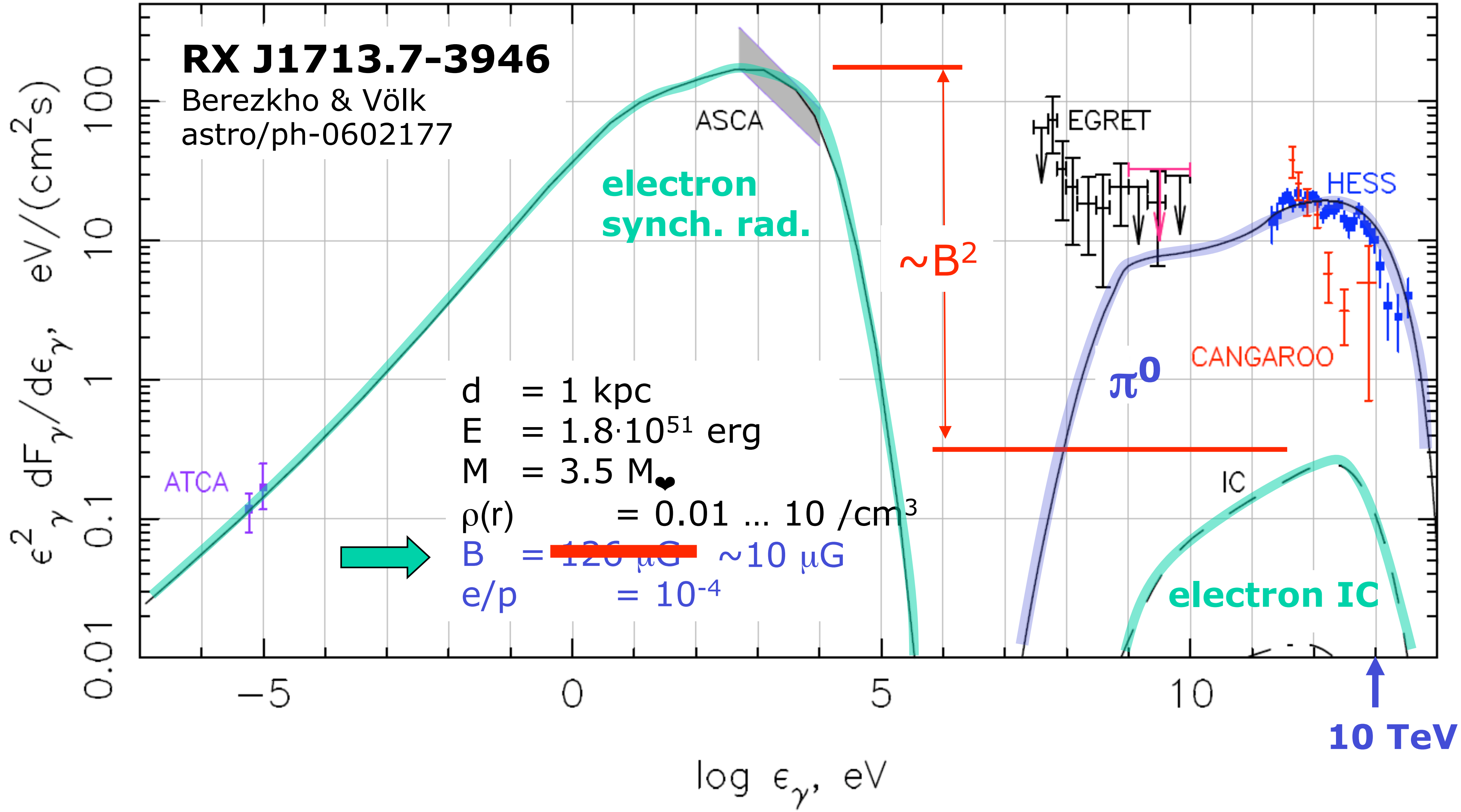
Proof that supernova shells accelerate particles to 100 TeV and beyond



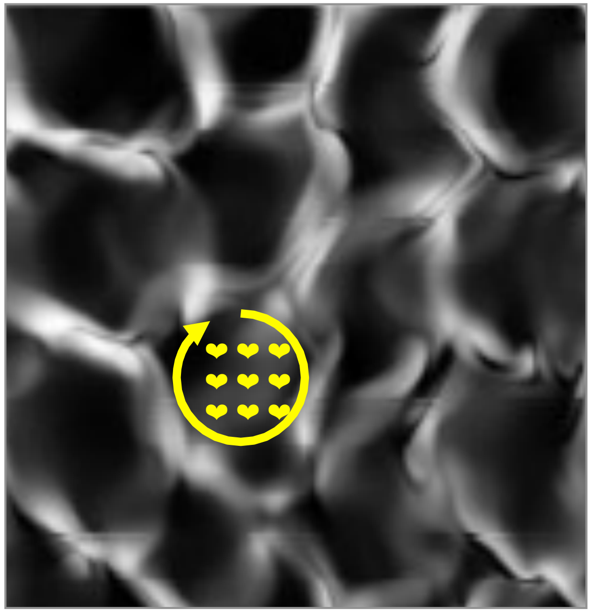

X-rays: electrons ⊗ B²
X-rays
γ-rays: protons ⊗ ρgas
VHE gamma rays
RX J0852.0-4622
RX J1713.7-3946

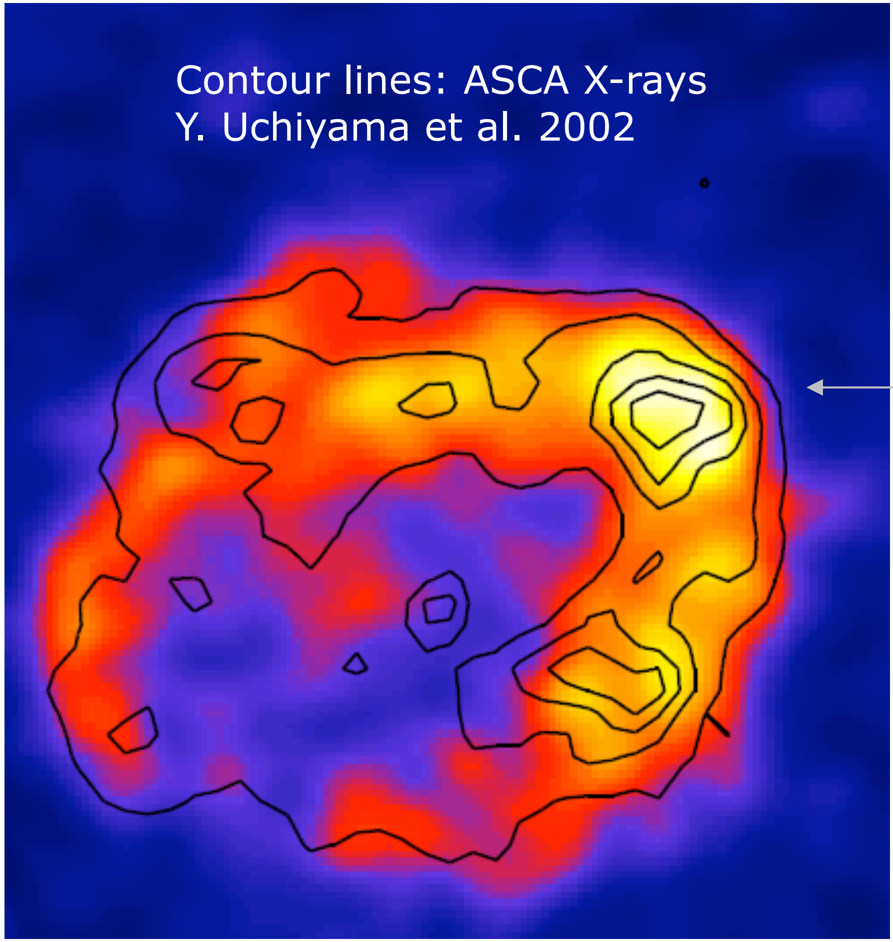
Spectral energy distribution



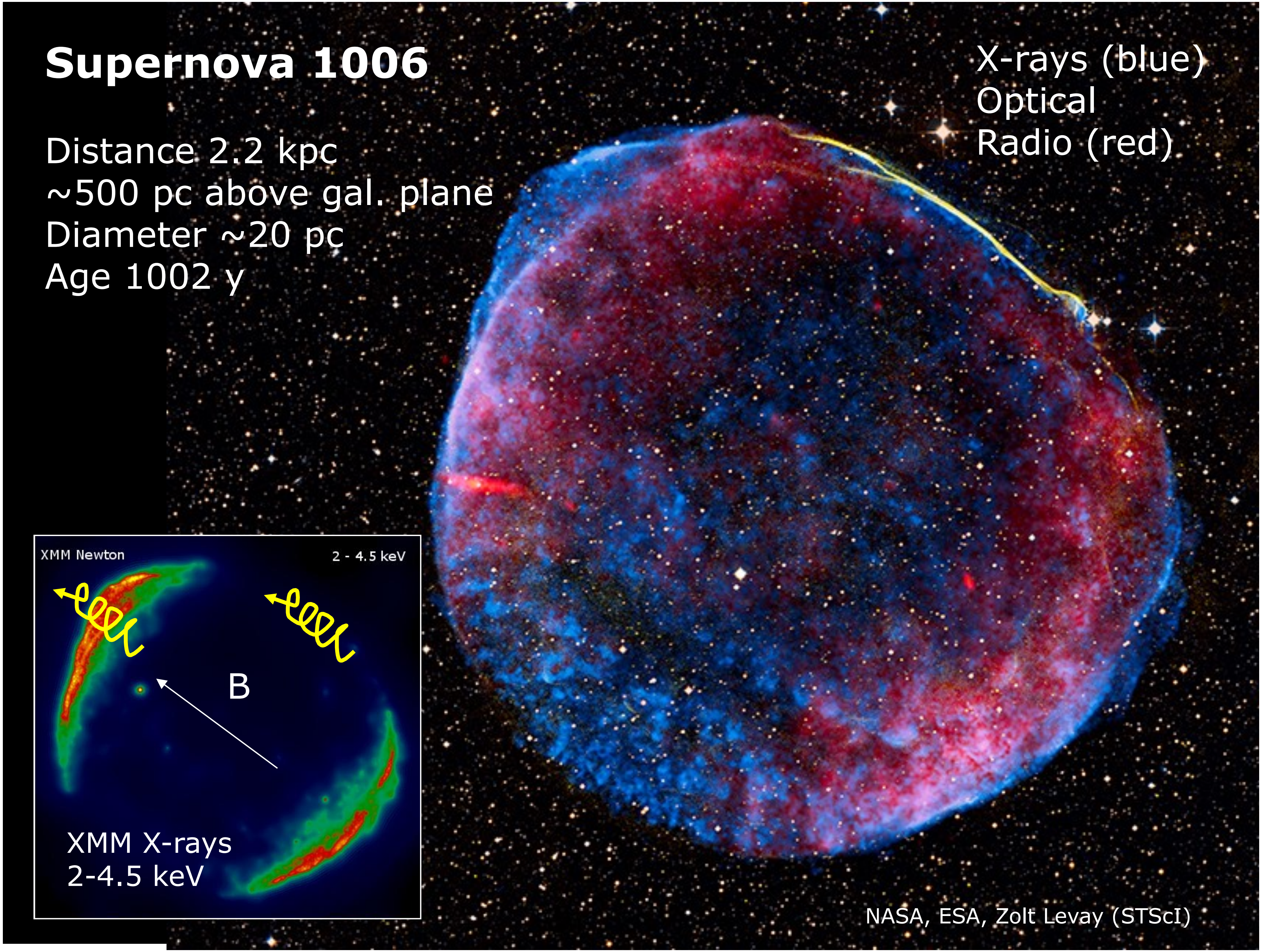


X-ray / γ-ray correlation



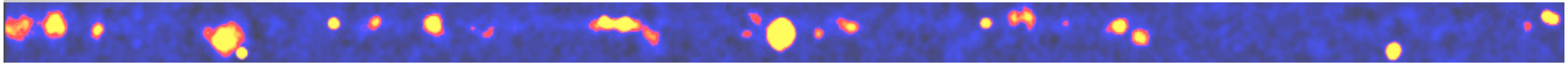


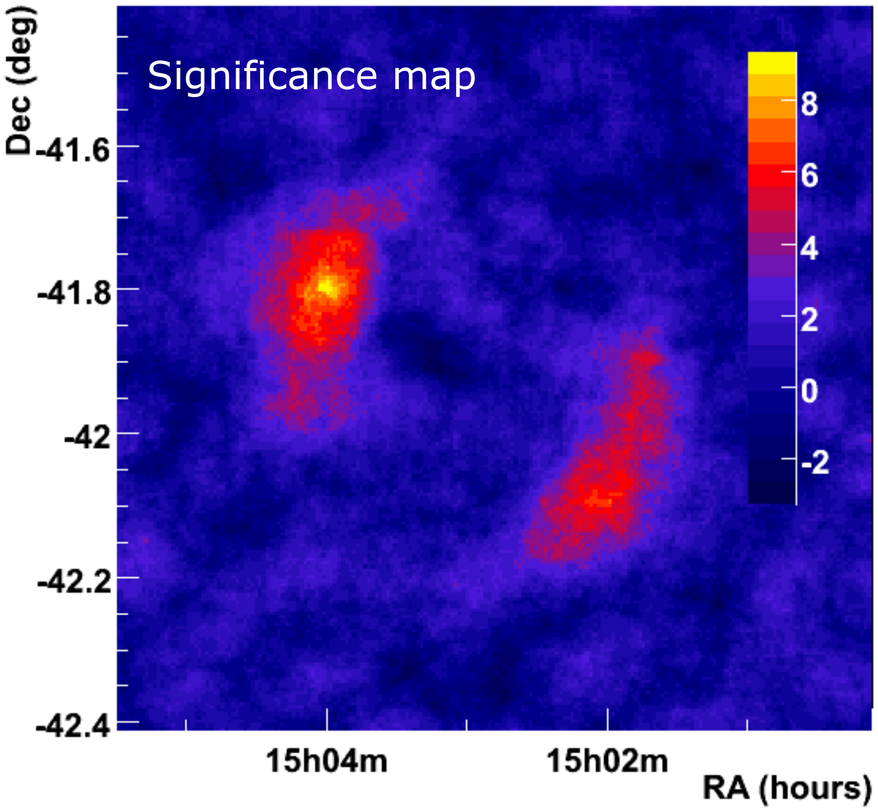
Dynamic field amplification:
$B^2 \sim \Phi_{CR} \sim \rho_{gas}$?

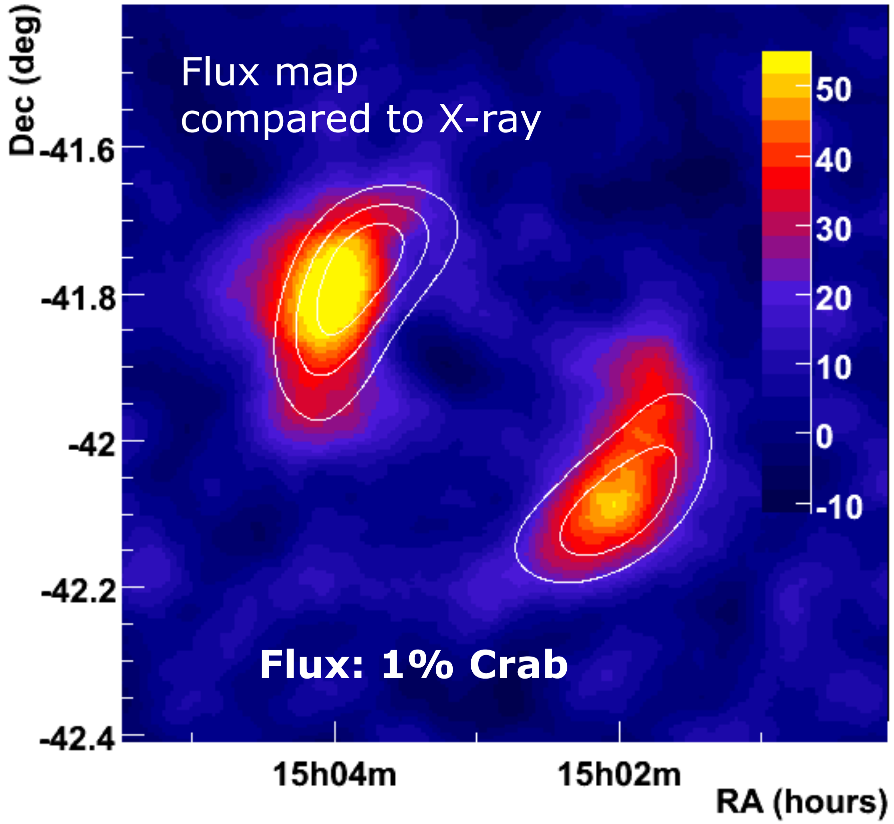

Supernova 1006
Distance 2.2 kpc
~500 pc above gal. plane
Diameter ~20 pc
Age 1002 y
X-rays (blue)
Optical
Radio (red)
XMM Newton
2 - 4.5 keV
B
XMM X-rays
2-4.5 keV
NASA, ESA, Zolt Levay (STScI)

SN 1006 H.E.S.S. 2008

103 h of data



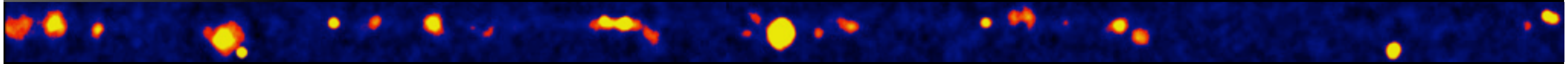




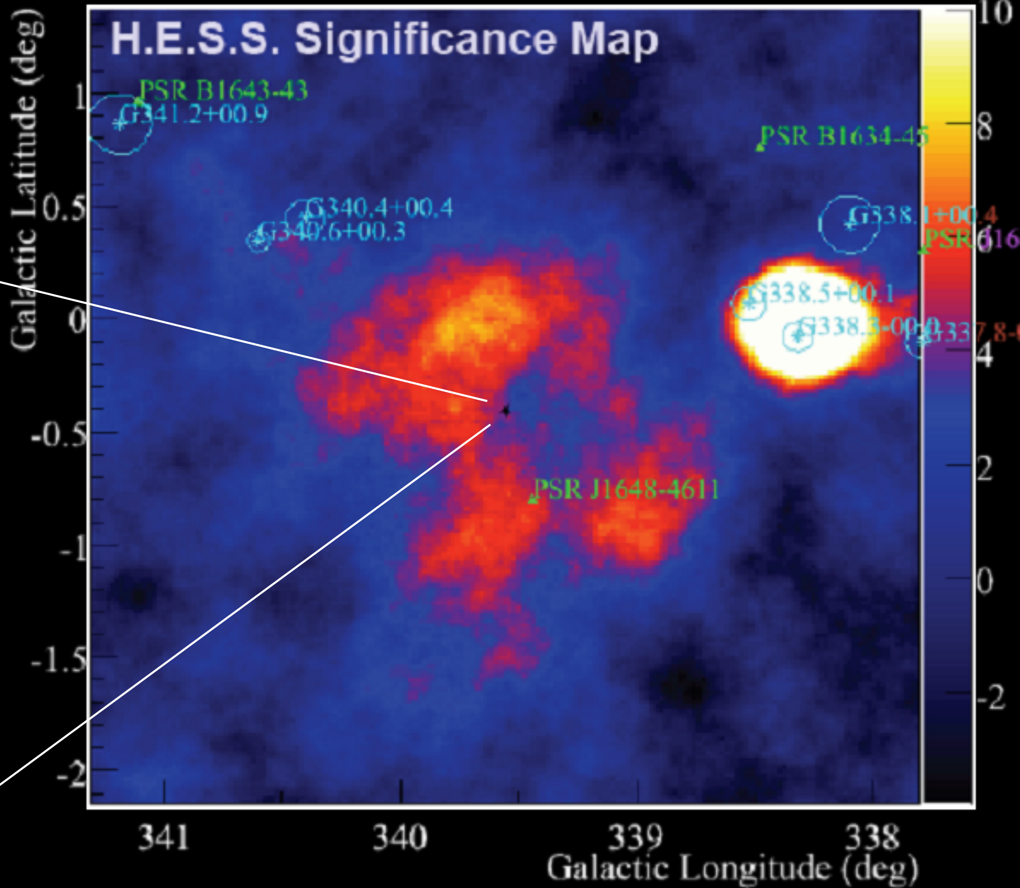
Interpretation Electrons in 30 μG field

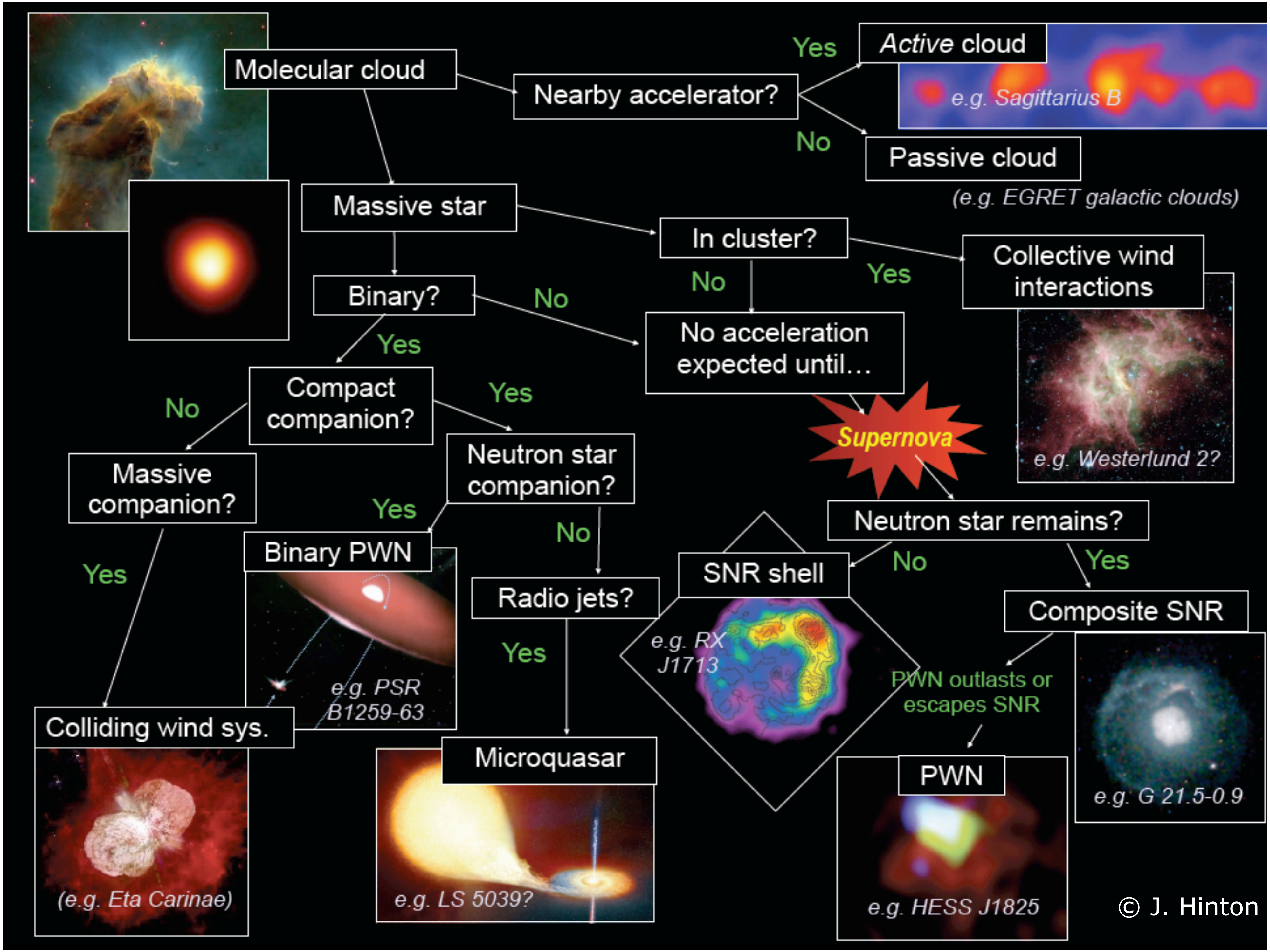
or Protons in 0.05/cm^3 gas

Westerlund 1 Stellar Cluster



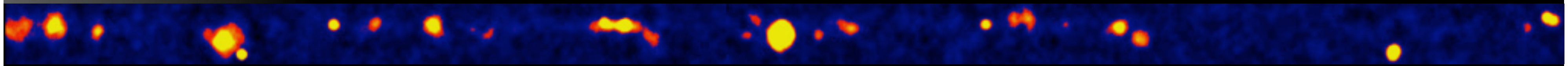
- most massive compact young star cluster
- 5 kpc distance
- 13 WR stars, ~30 hot supergiant stars
- in 0.5° gas bubble





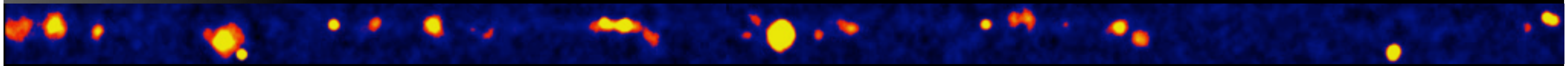
Molecular cloud
Nearby accelerator?
Yes
Active cloud
e.g. Sagittarius B
No
Passive cloud
(e.g. EGRET galactic clouds)
Massive star
In cluster?
Yes
Collective wind interactions
e.g. Westerlund 2?
No
Binary?
No
No acceleration expected until…
Supernova
Yes
Compact companion?
Yes
No
Massive companion?
Neutron star companion?
Yes
Binary PWN
e.g. PSR B1259-63
No
Radio jets?
Yes
Yes
Colliding wind sys.
(e.g. Eta Carinae)
Microquasar
e.g. LS 5039?
Neutron star remains?
No
SNR shell
e.g. RX J1713
Yes
Composite SNR
e.g. G 21.5-0.9
PWN outlasts or escapes SNR
PWN
e.g. HESS J1825
© J. Hinton

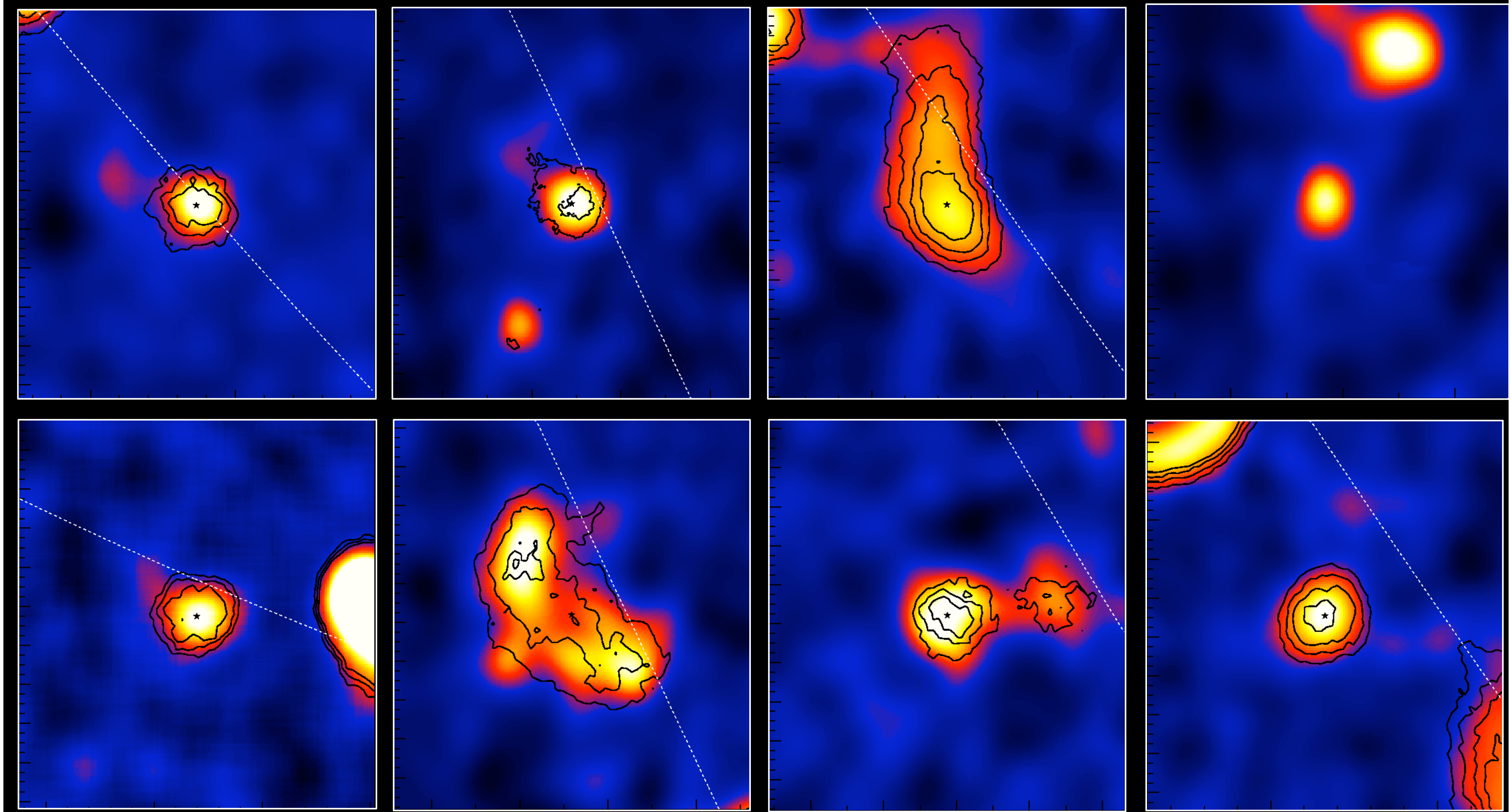
A tour of galactic particle accelerators



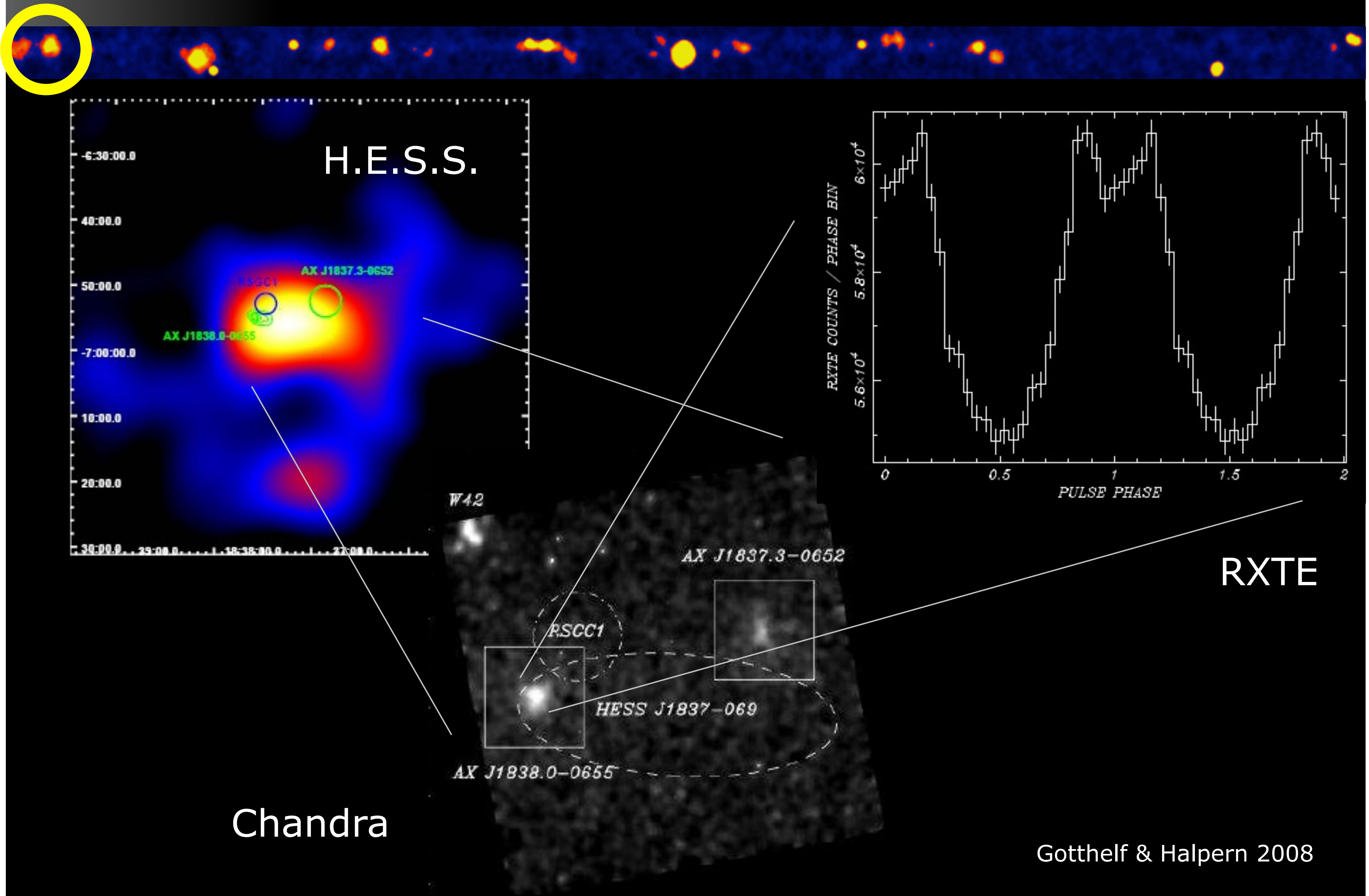
- Binaries
- Pulsar wind nebulae
- Supernova remnants
- Star clusters
- “Dark sources”

Sources without (known) counterparts



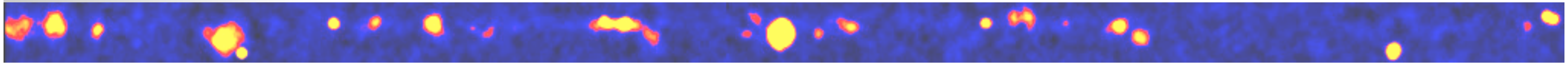


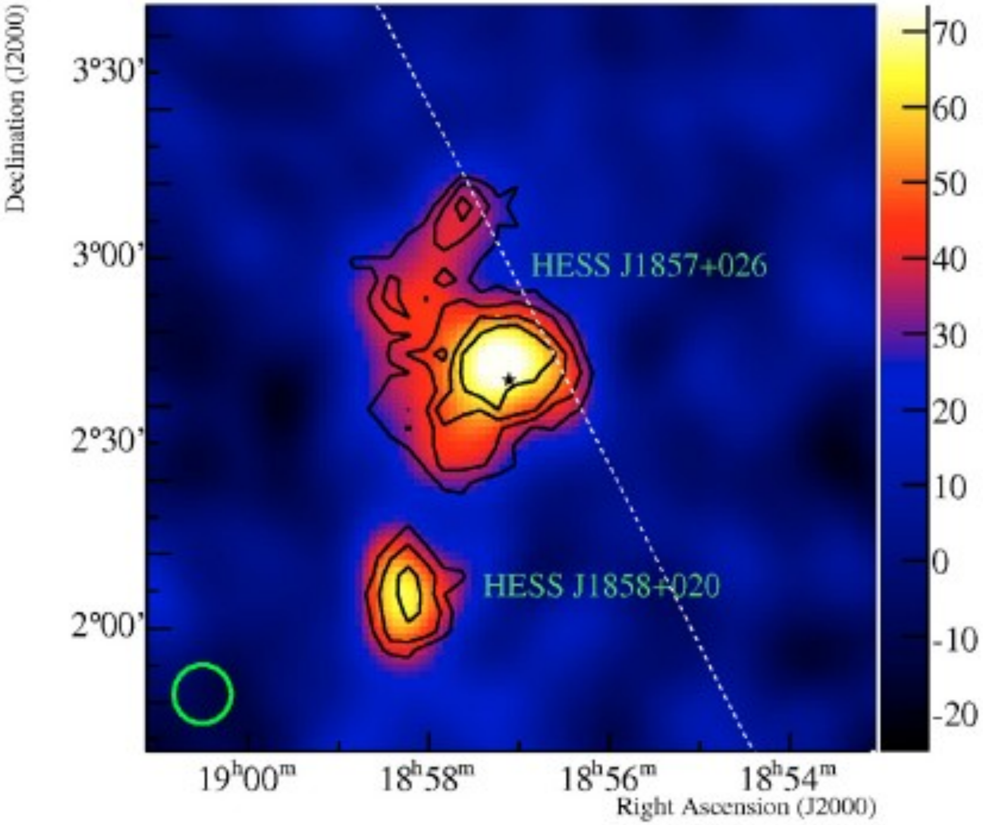
Not all remain dark… HESS J1837-069

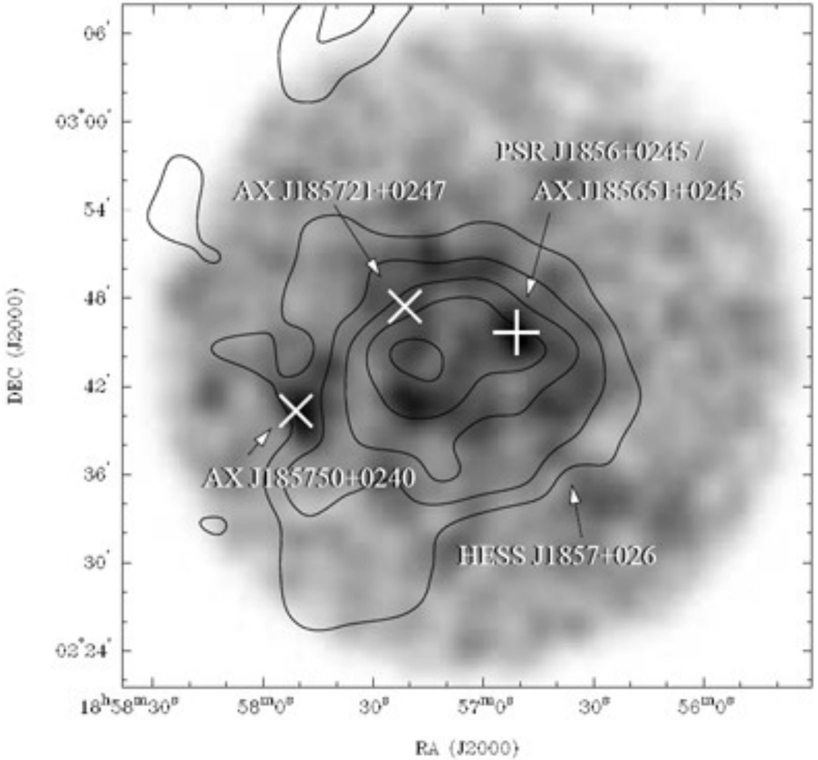


Gotthelf & Halpern 2008

Not all remain dark… HESS J1857+026

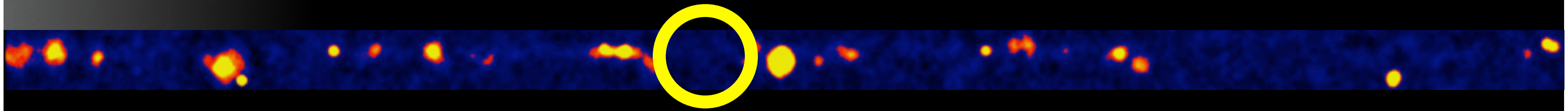




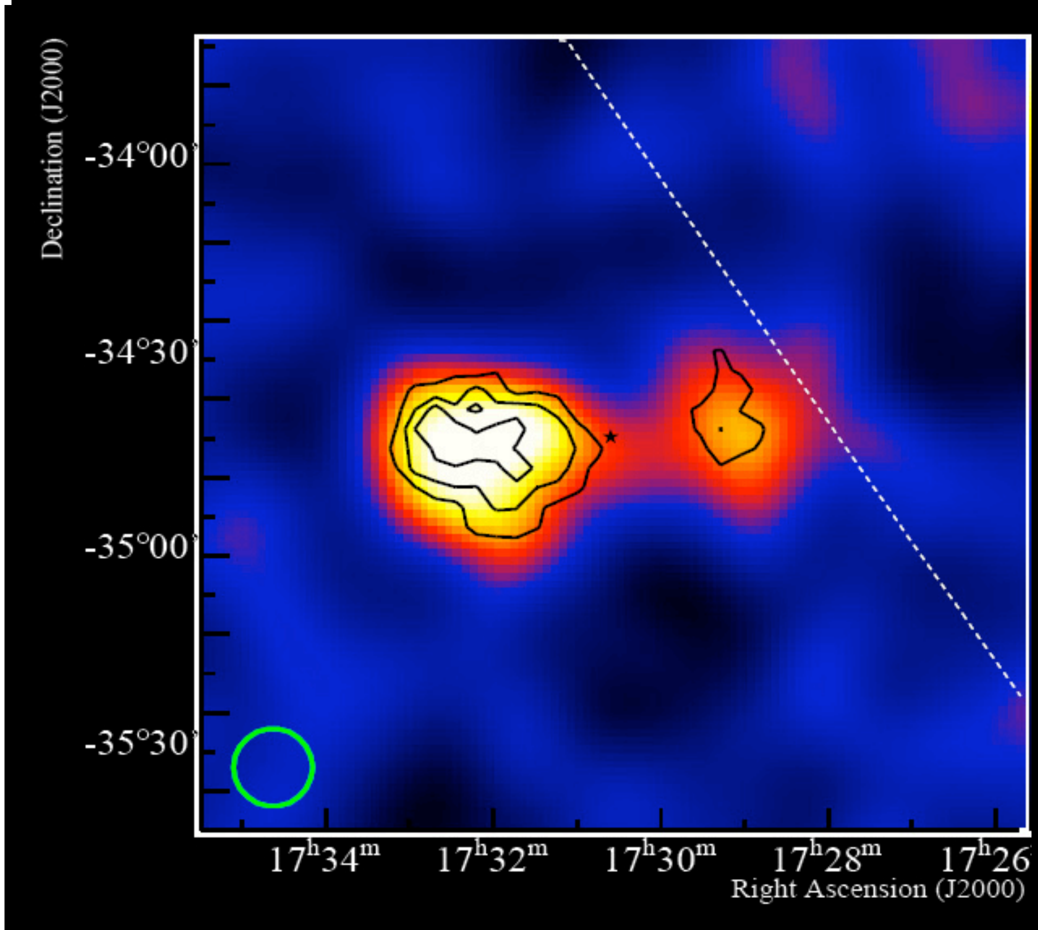


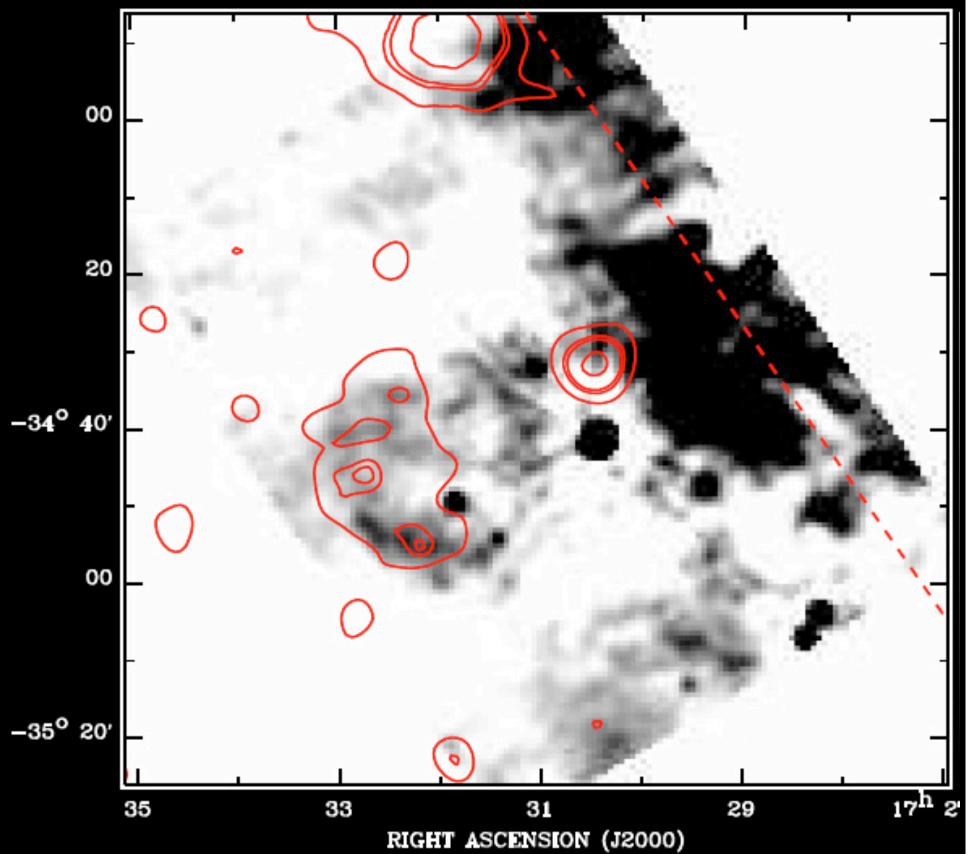
PSR J1856+0245 discovery
Hessels et al. 2008, Arecibo
period 81 ms,
spin-down energy loss 4.6 x 10^{36} ergs/s
age 21000 y
distance 9 kpc

Not all remain dark… HESS J1731-347

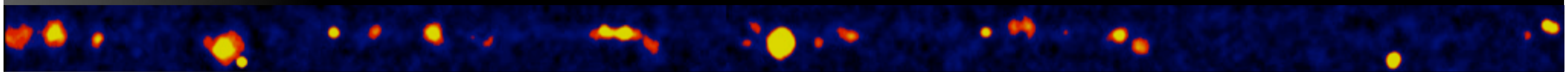


HESS J1731-347
Tian et al., arXiv:0801.3254





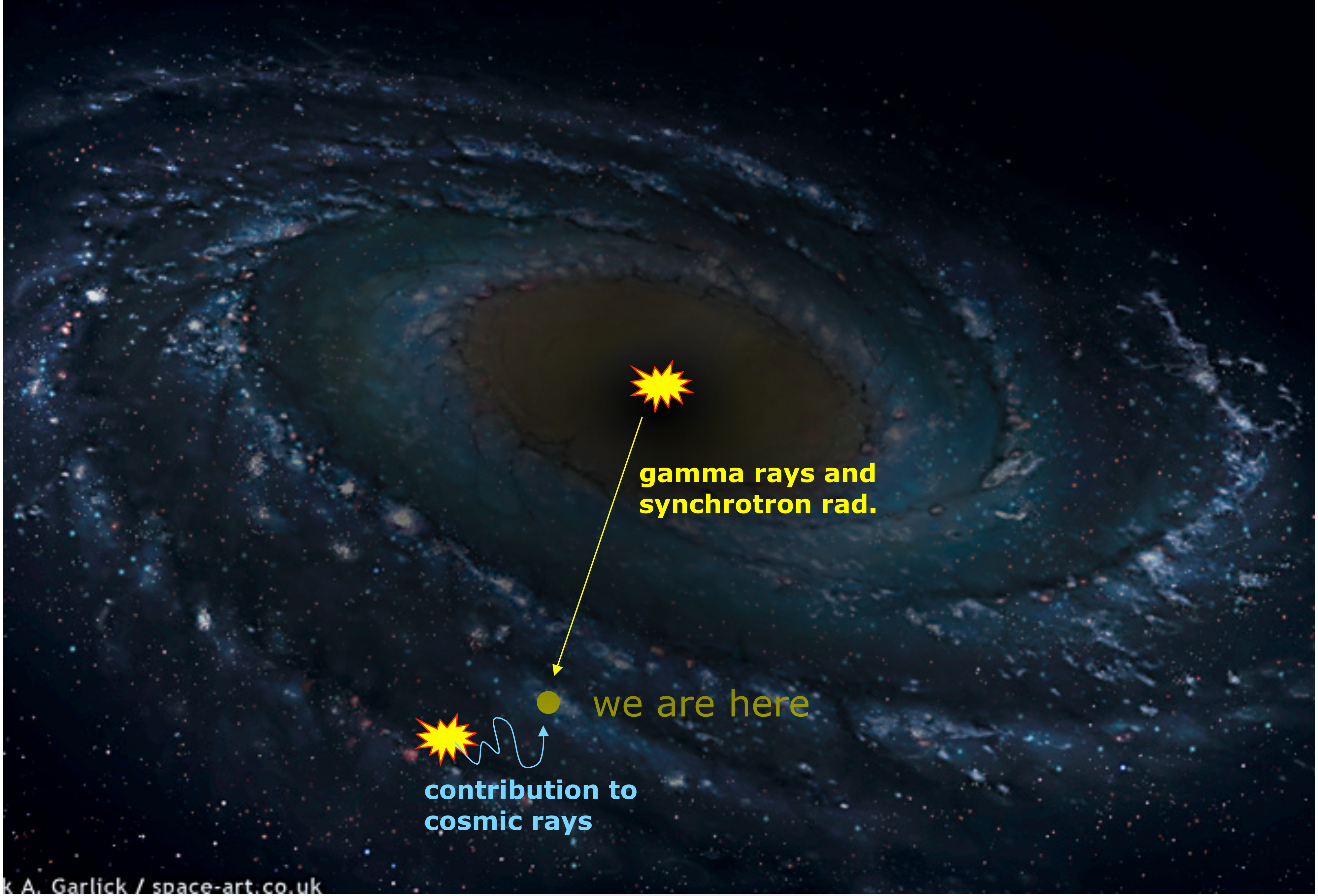
Recent news



Electrons: Dark Matter & H.E.S.S. ?

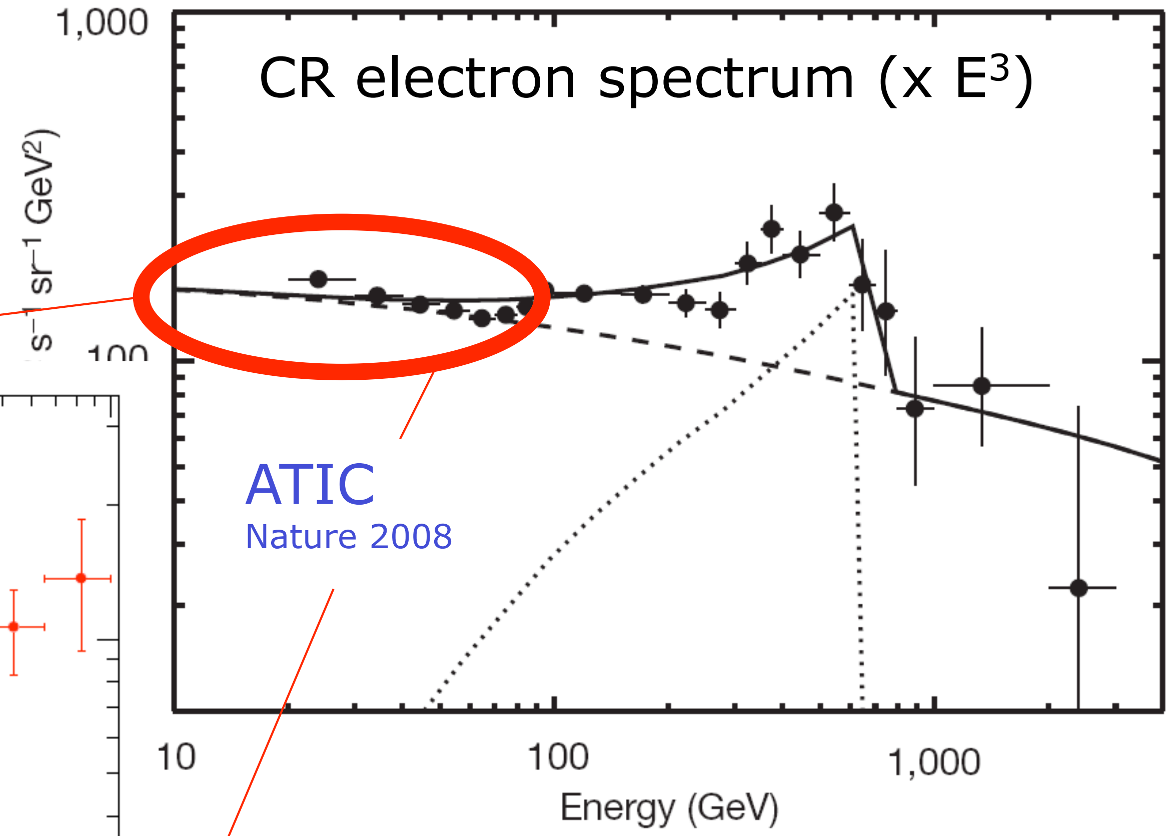
UHECR sources ?

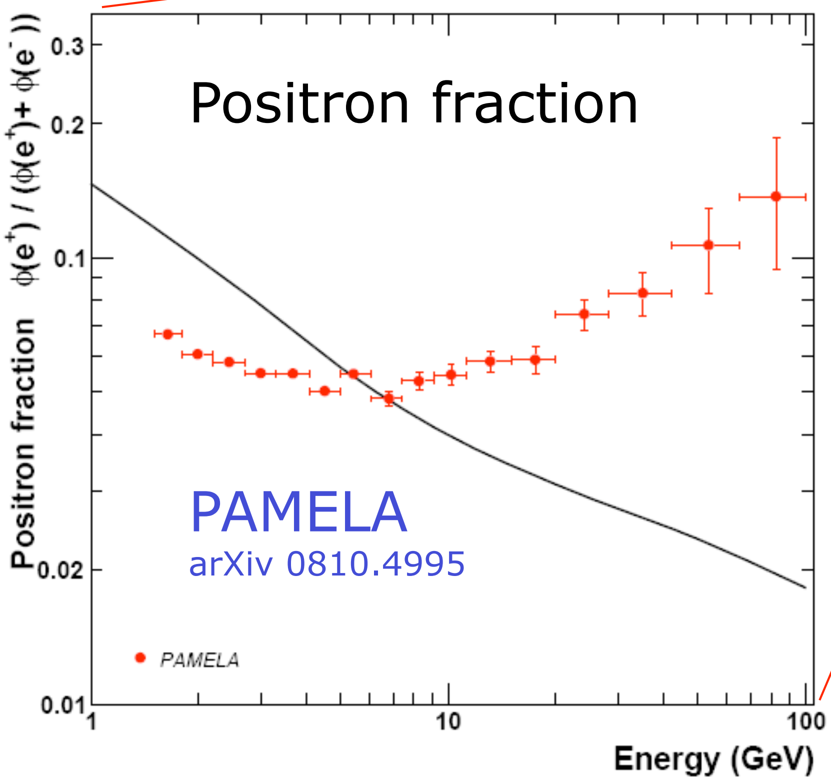
Dark Matter in the Galaxy



ATIC & PAMELA Cosmic Ray Electron News

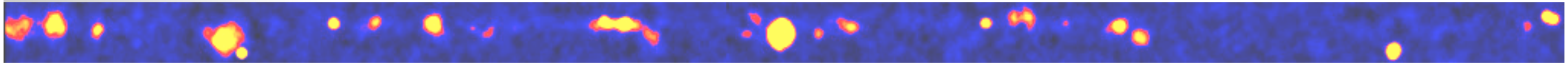
No anomaly seen
in antiprotons…

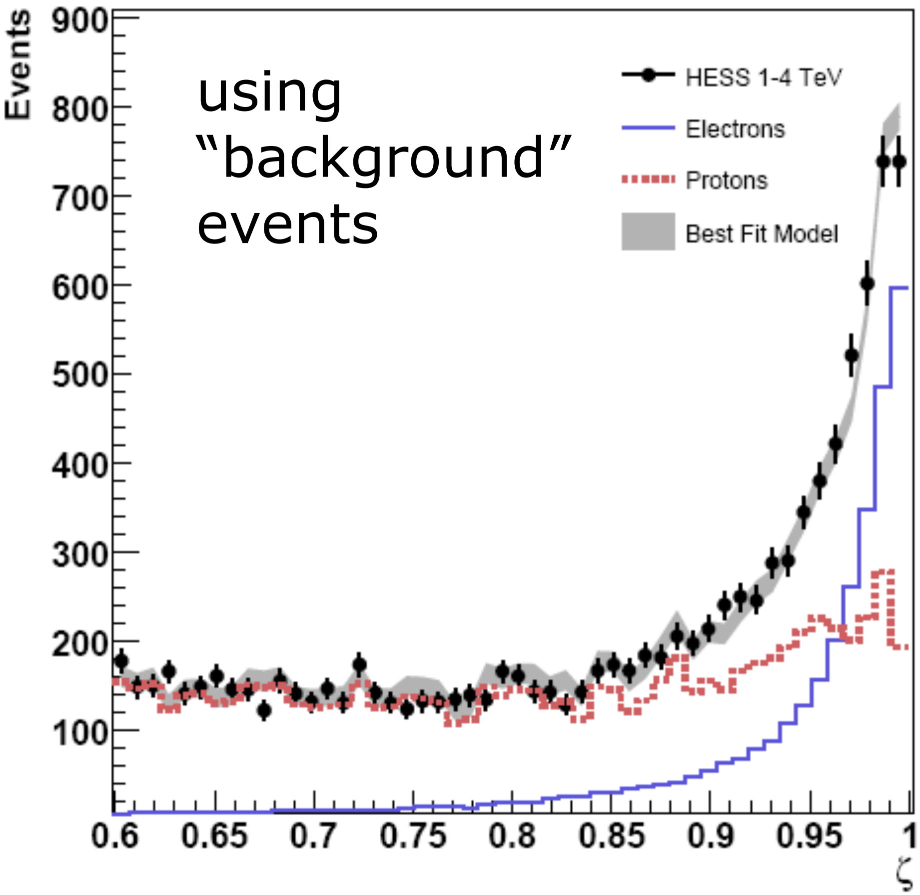


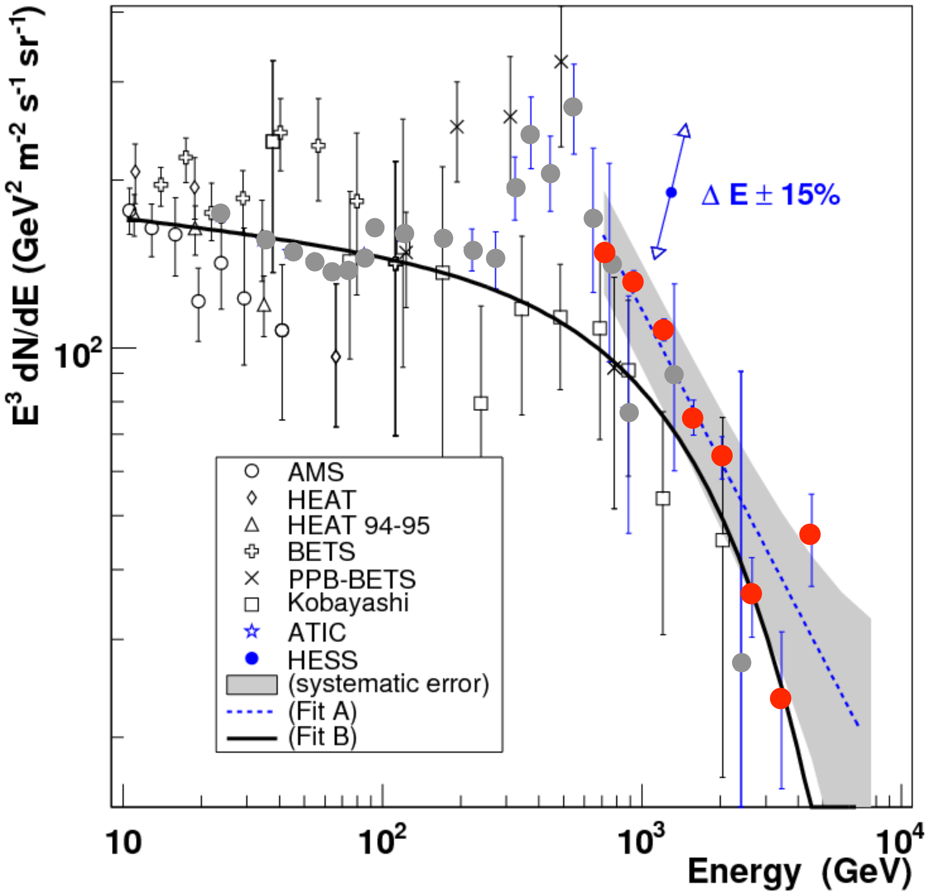


Possible explanation:
> 600 GeV DM particle which decays to e^+e^-, $\mu^+\mu^-$, $\tau^+\tau^-$

H.E.S.S. electron spectrum

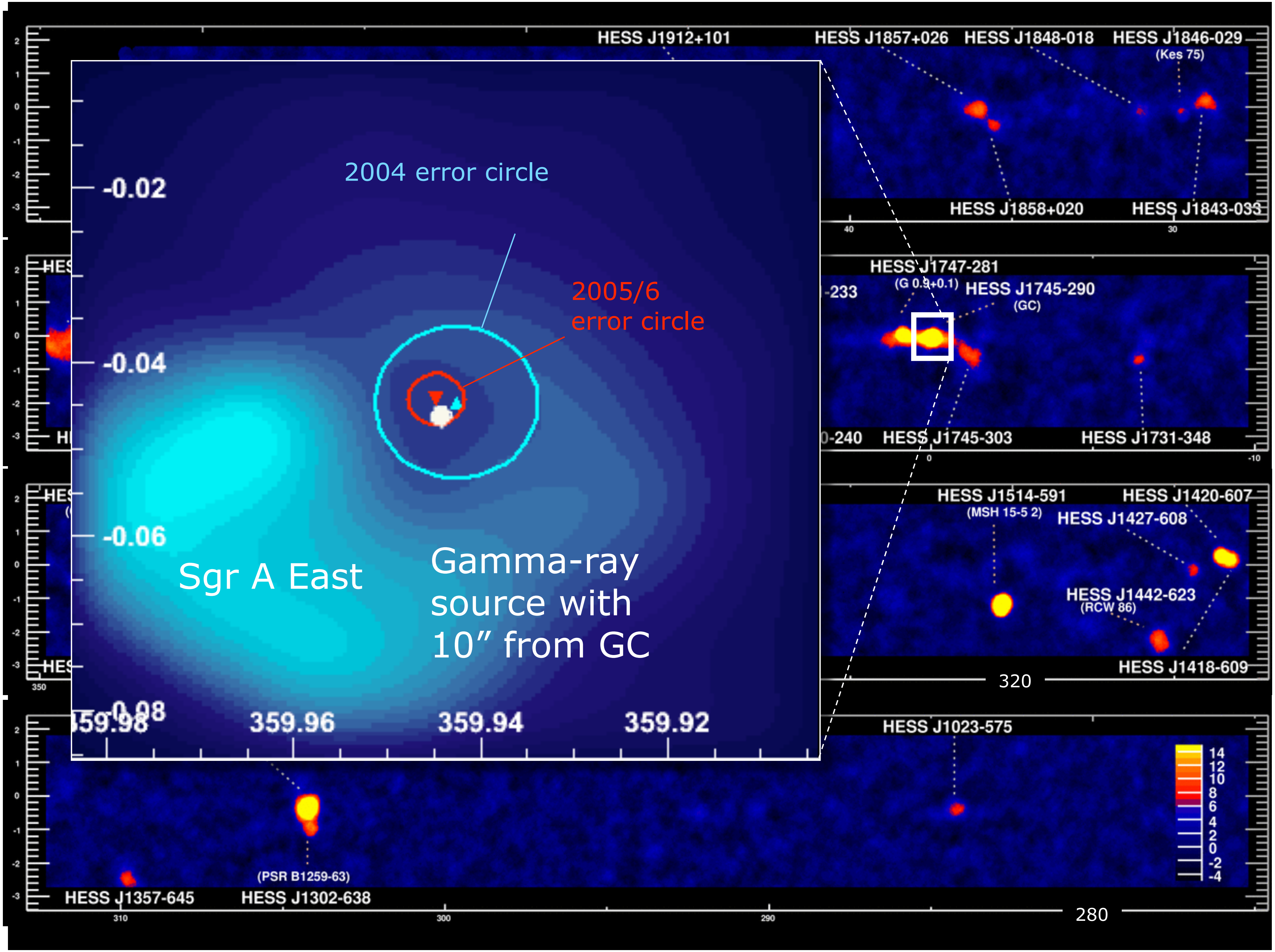




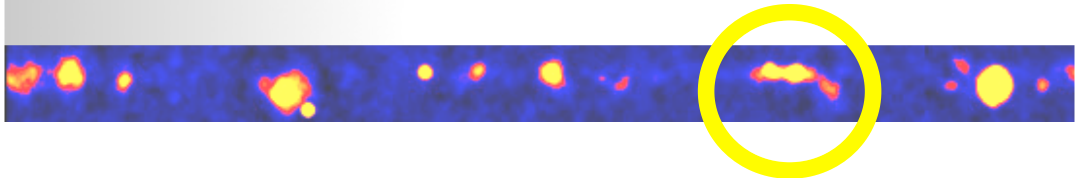


ζ = 0: proton shower

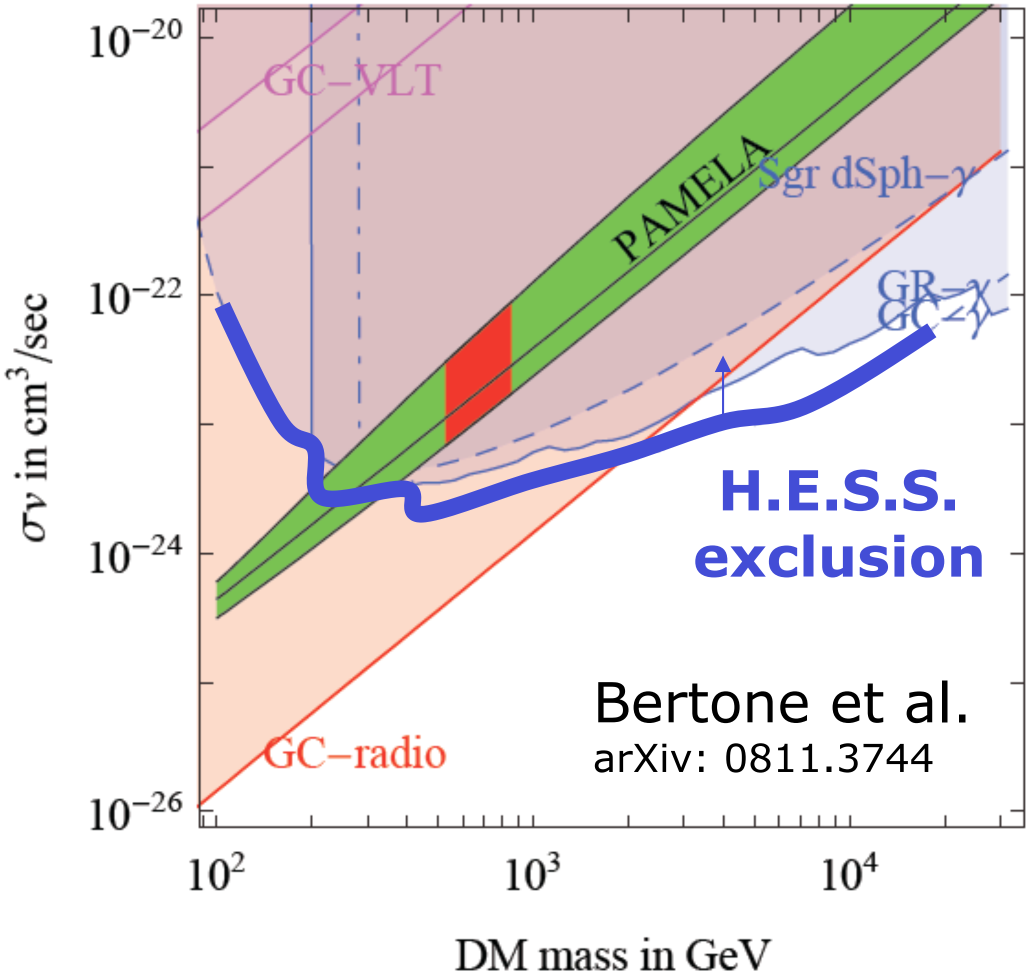
ζ = 1: γ / electron shower

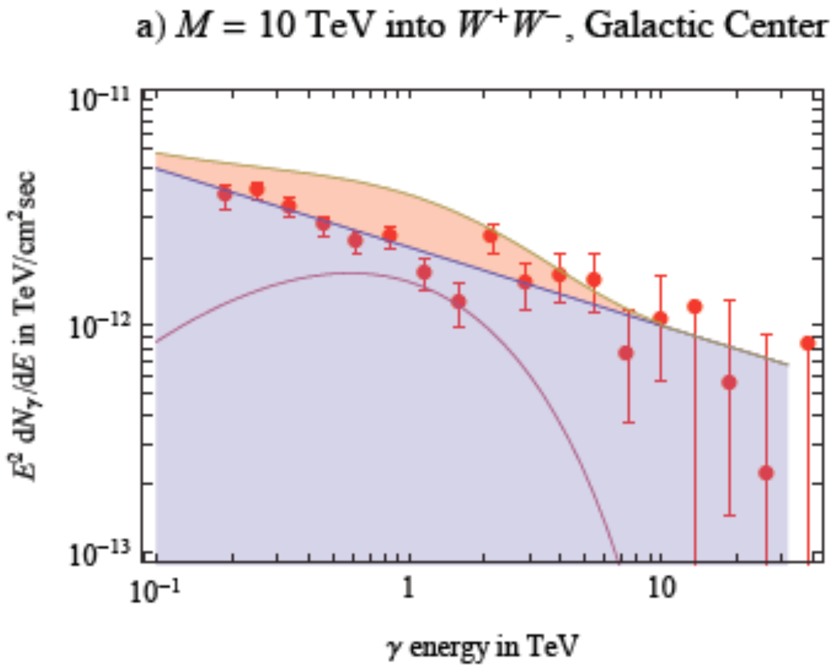


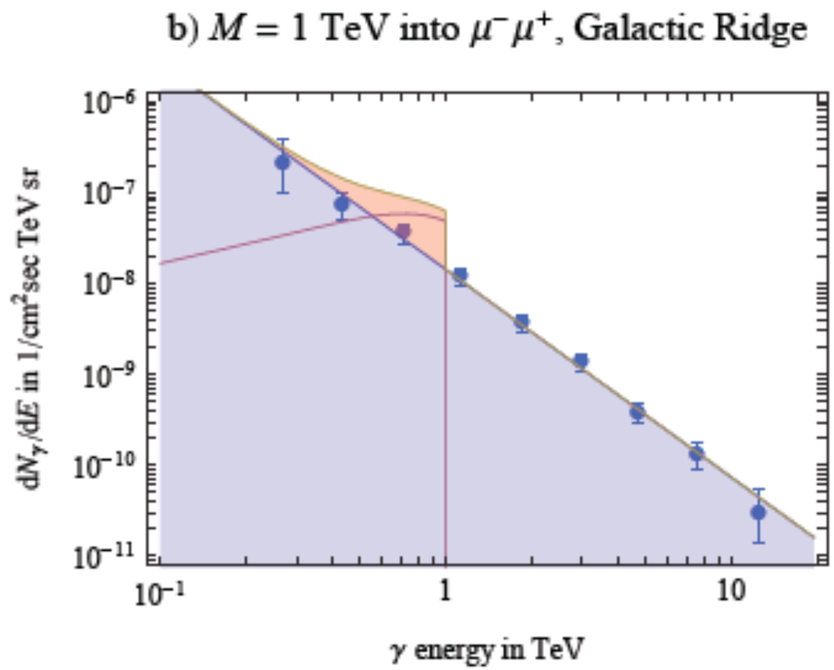
HESS J1912+101
HESS J1857+026
HESS J1848-018
HESS J1846-029
(Kes 75)
HESS J1858+020
HESS J1843-033
HESS J1747-281
(G 0.9+0.1)
HESS J1745-290
(GC)
HESS J1745-303
HESS J1731-348
HESS J1514-591
(MSH 15-5 2)
HESS J1420-607
HESS J1427-608
HESS J1442-623
(RCW 86)
HESS J1418-609
320
HESS J1023-575
HESS J1357-645
(PSR B1259-63)
HESS J1302-638
280
2004 error circle
2005/6
error circle
-0.02
-0.04
-0.06
-0.08
359.98
359.96
359.94
359.92
Sgr A East
Gamma-ray
source with
10" from GC



DM DM → e^+e^-, NFW profile

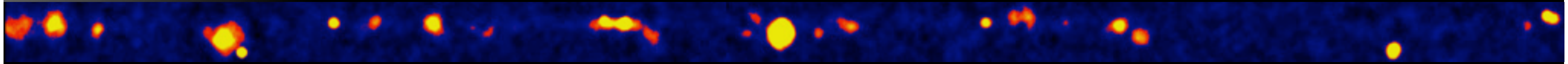




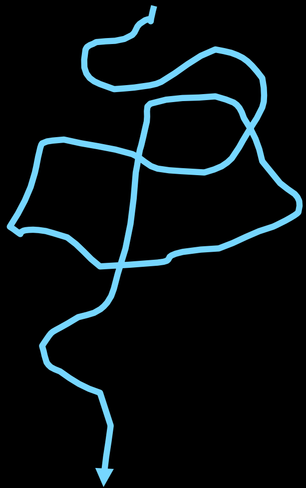


Simpler explanation: Pulsars

Atoyan et al. 1995
…
Profumo 2008

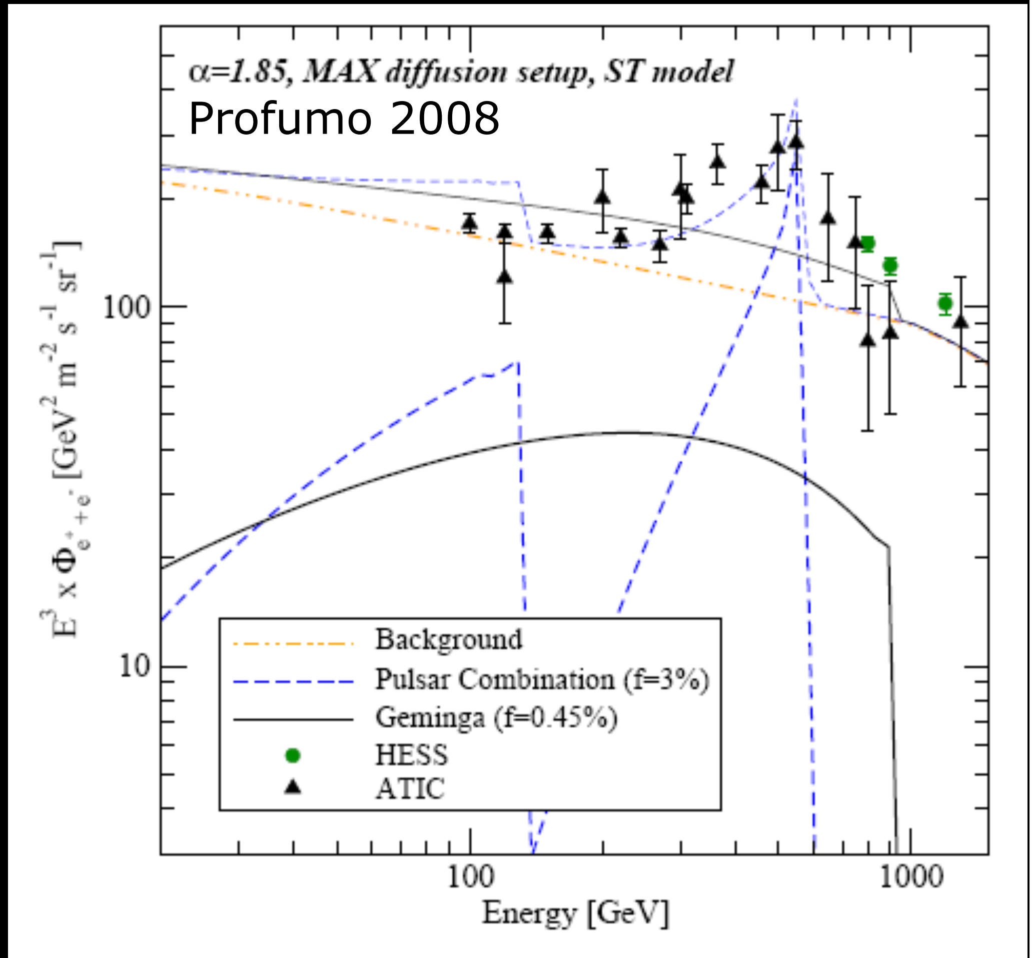


Generates burst at time of pulsar creation

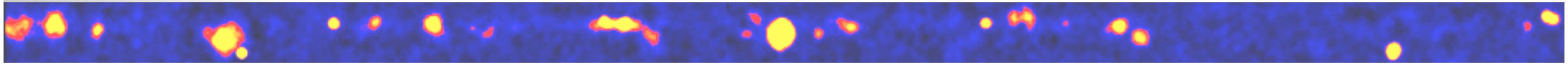


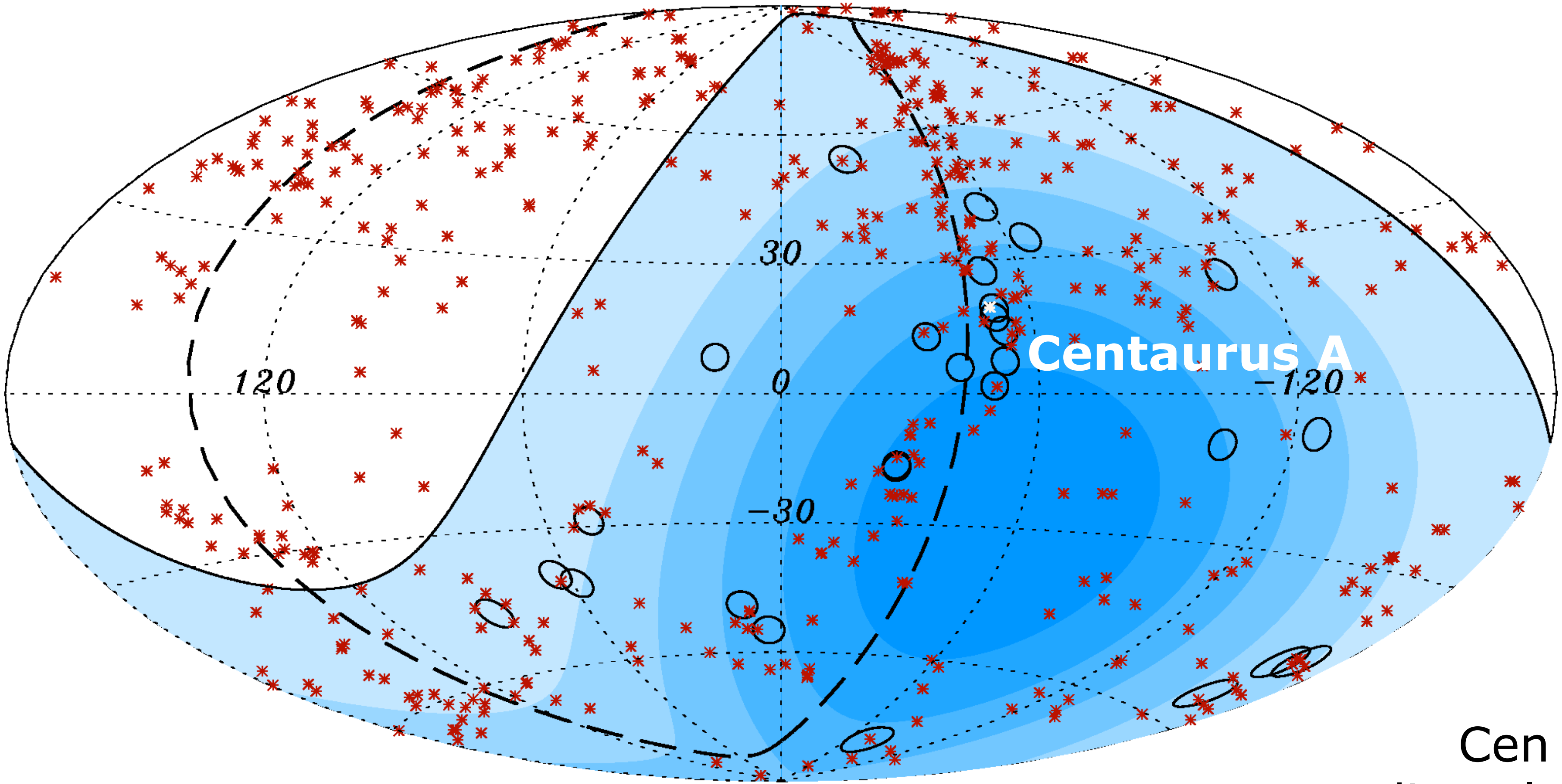
Synchrotron losses result in high-E cutoff as a function of age; tune age to match peak energy

Tune pulsar distance such that only particles just below the cutoff reach us



Beyond our Galaxy

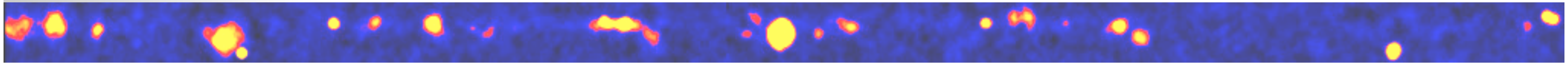


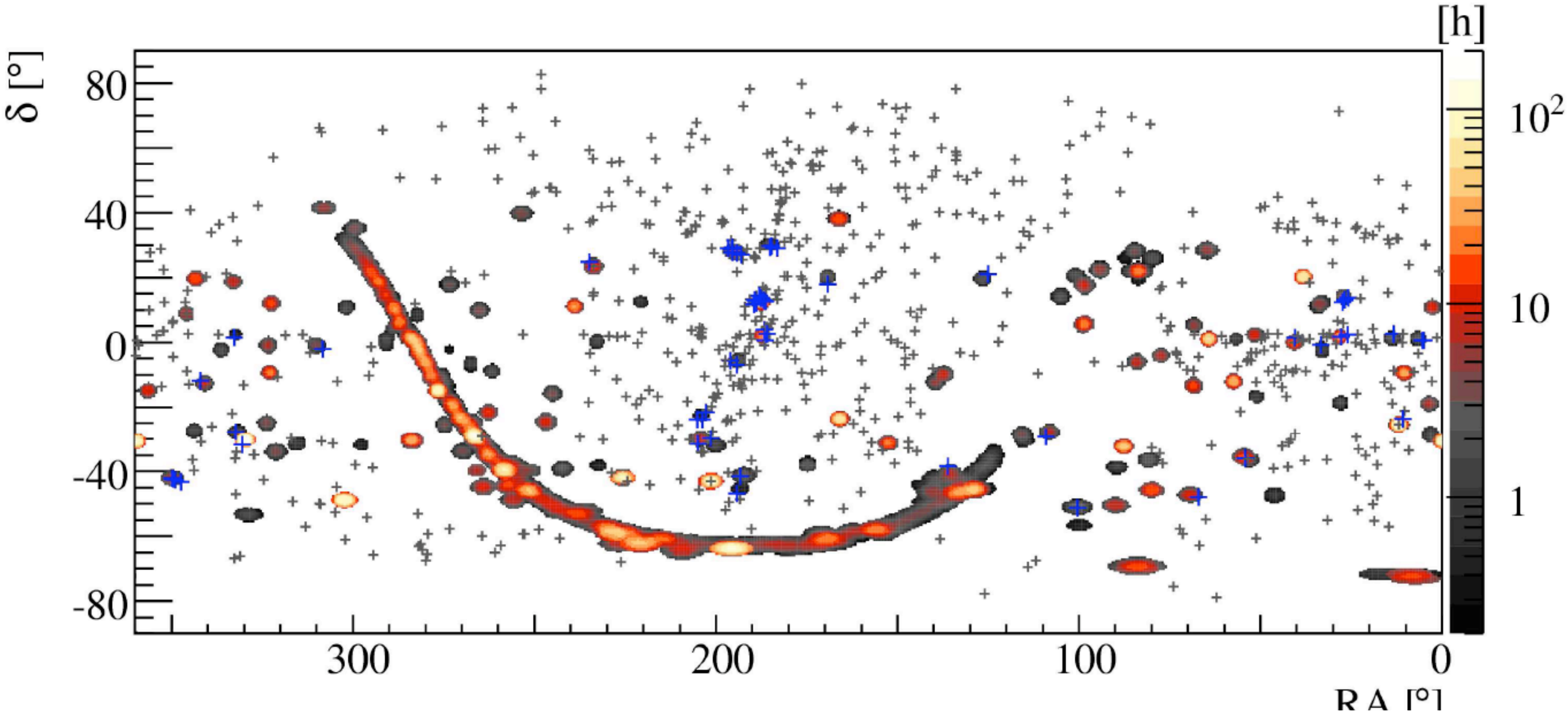


Cen A:
nearest radio galaxy
6×10^7 solar mass BH
4 Mpc distance
4^{o} radio lobes

AUGER
UHECR map

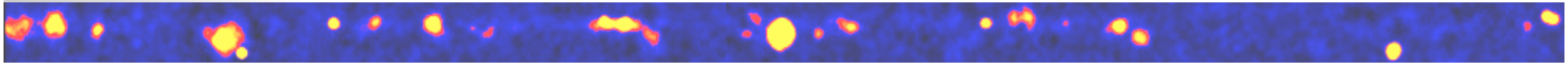
H.E.S.S. Extragalactic Coverage

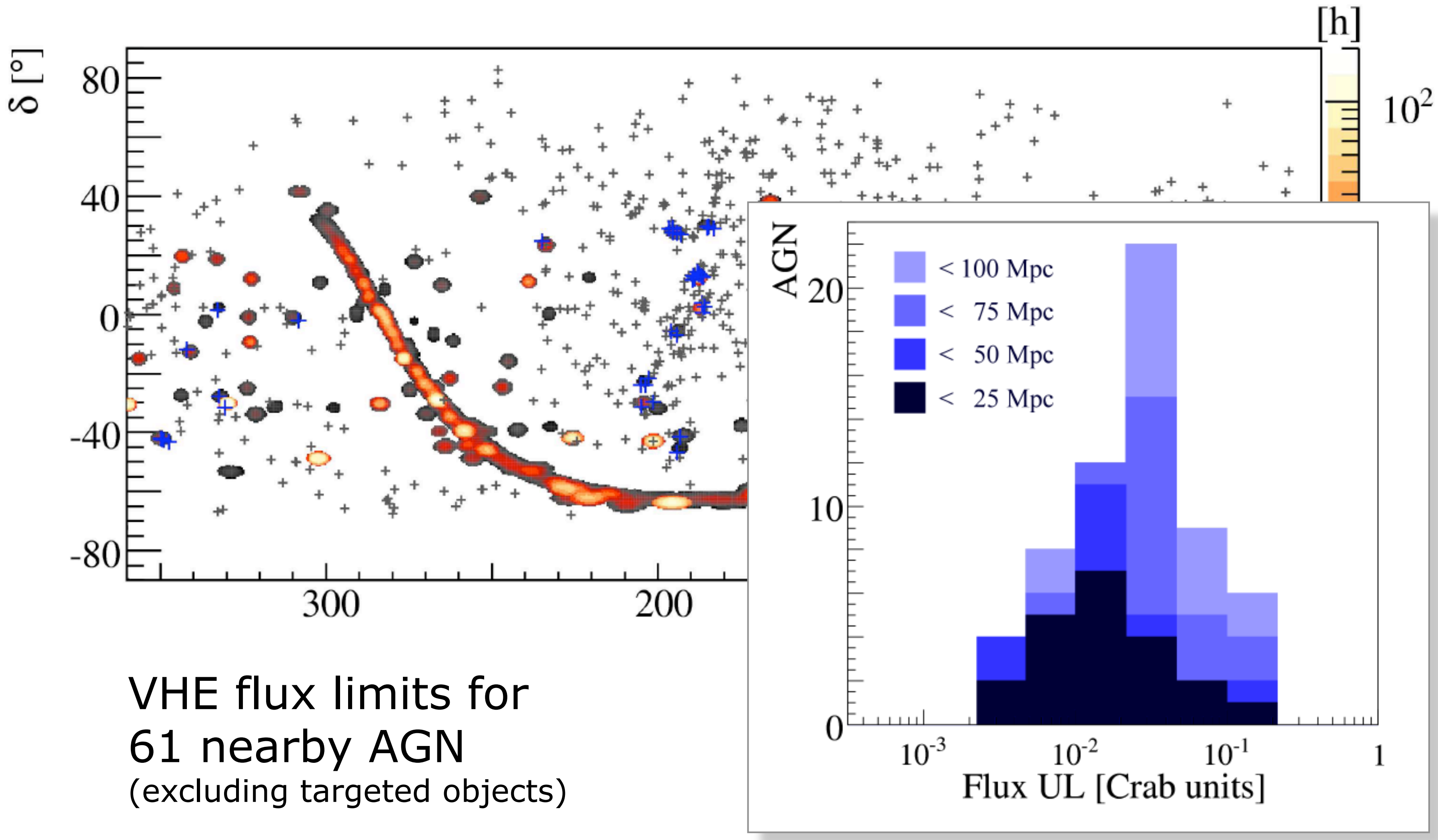




- more than 0.6 sr of extragalactic space covered
- including about 100 “Auger” AGN within 100 Mpc
- 1 10^{20} eV particle / 5000 km^{2}y ≅ 10^{-13} ergs/cm^{2}s

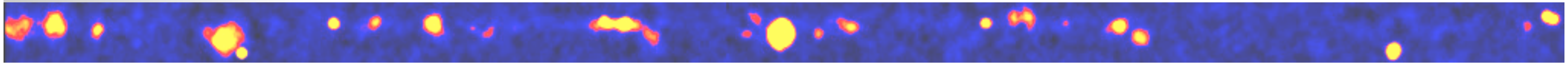
H.E.S.S. Extragalactic Coverage

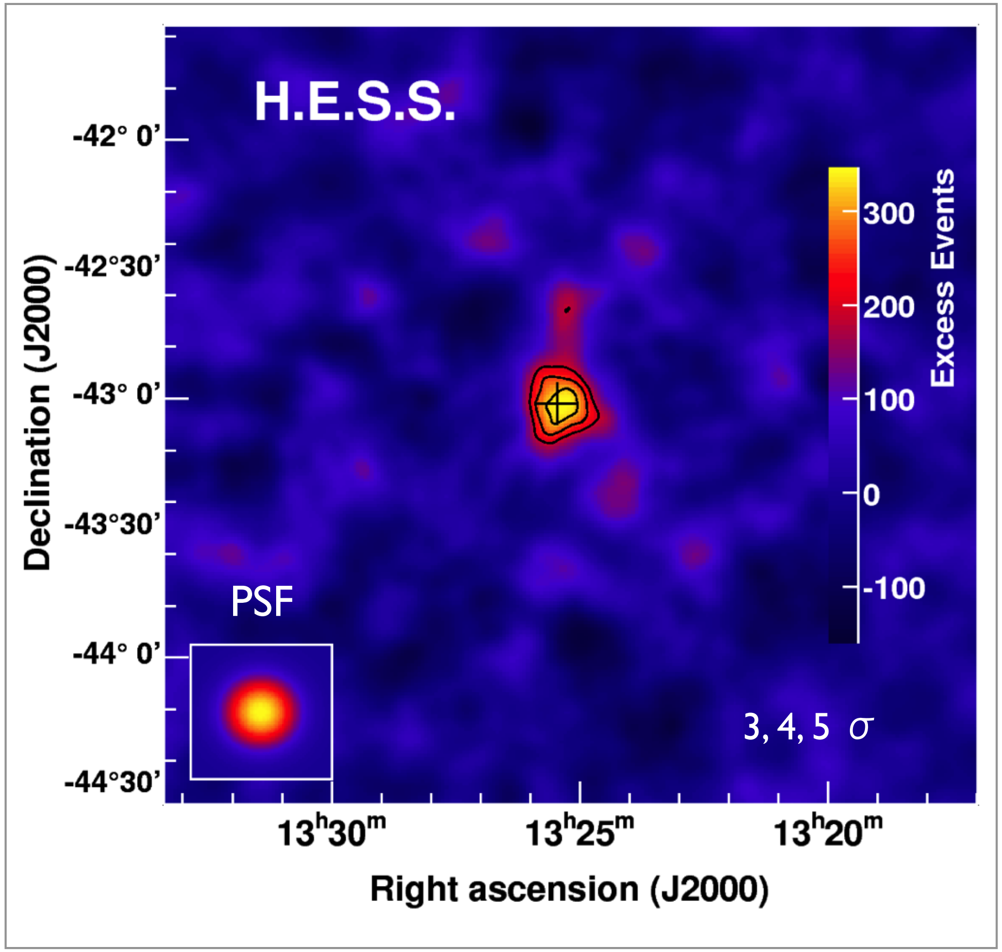


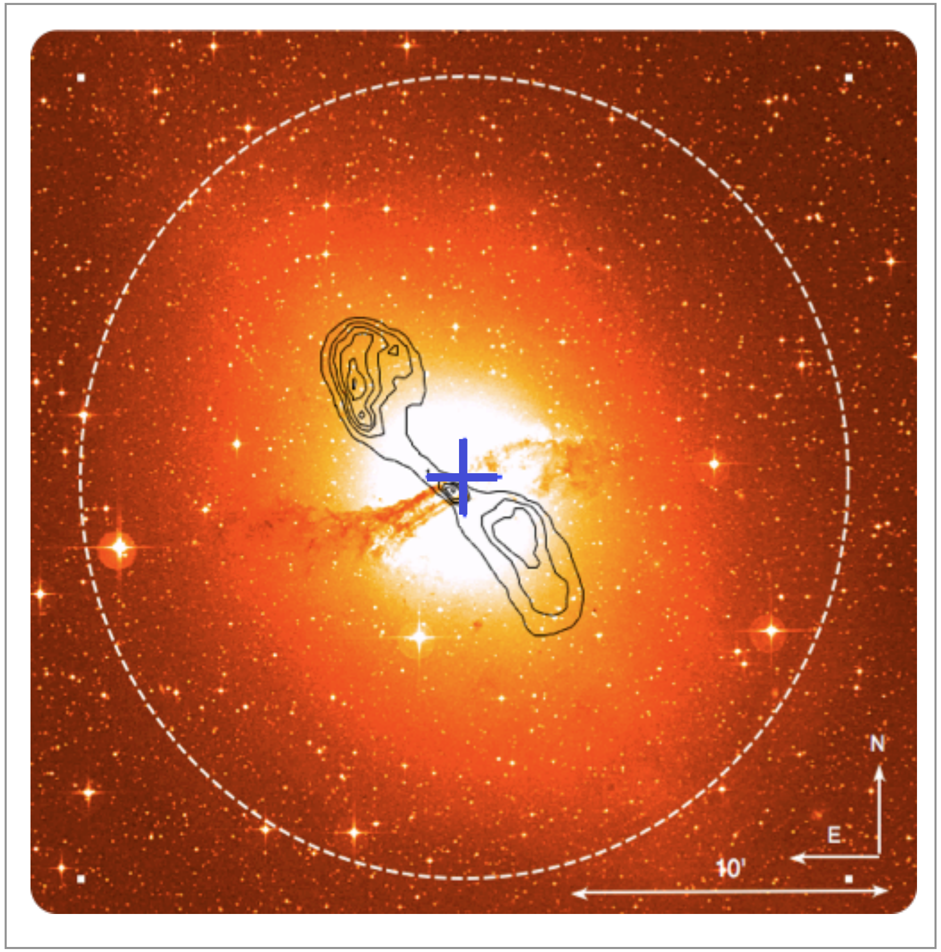


VHE flux limits for
61 nearby AGN
(excluding targeted objects)

Centaurus A

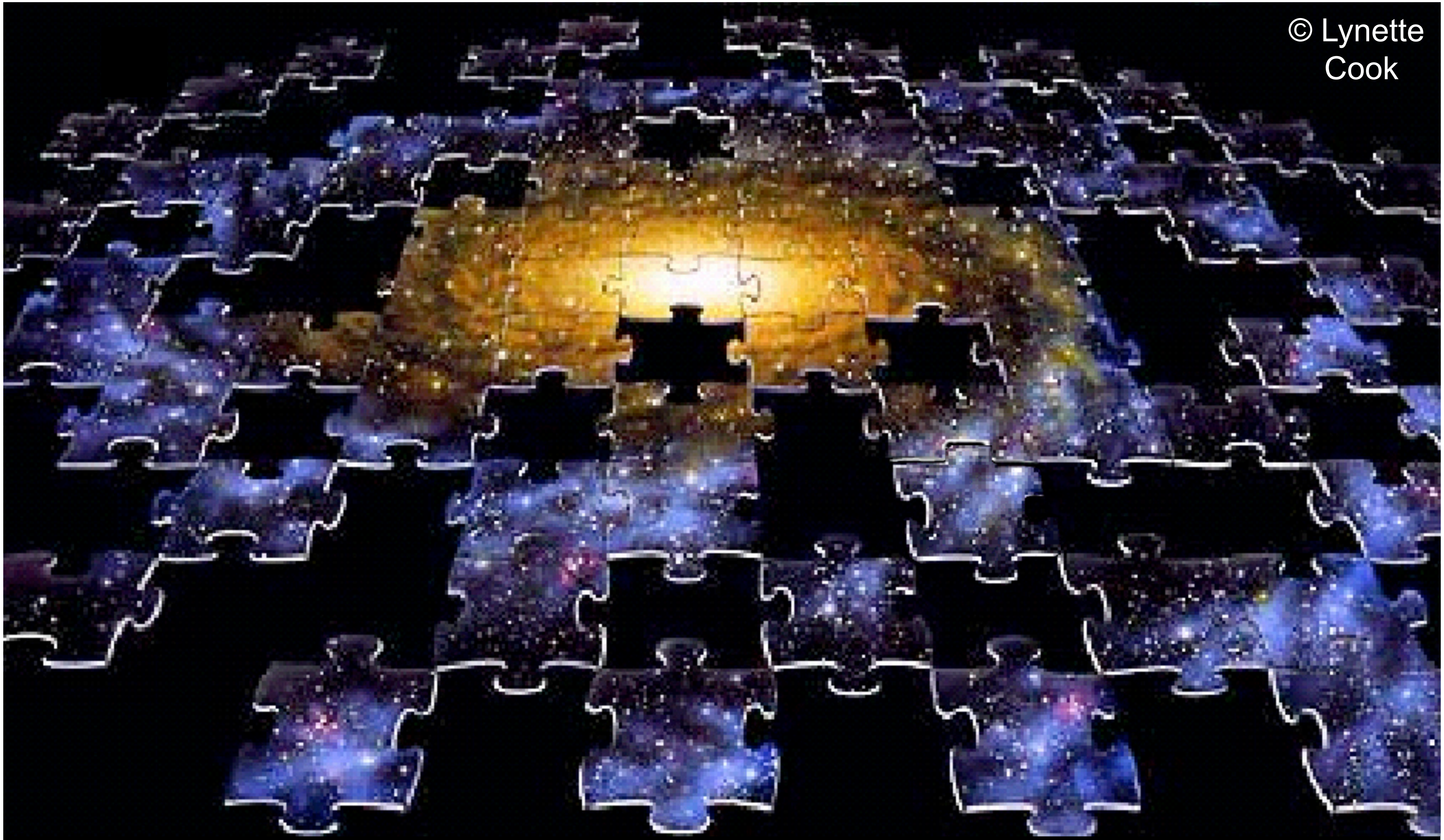






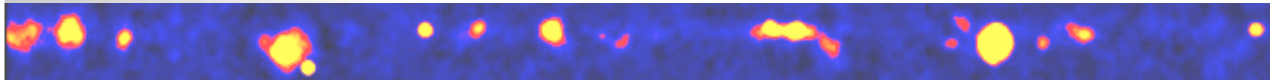
Flux ~0.8% Crab
Spectral index 2.7±0.5±0.2

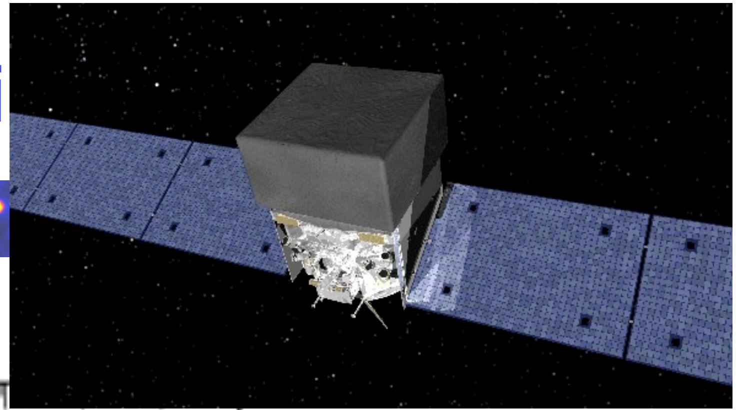
▶ M. Raue, Moriond

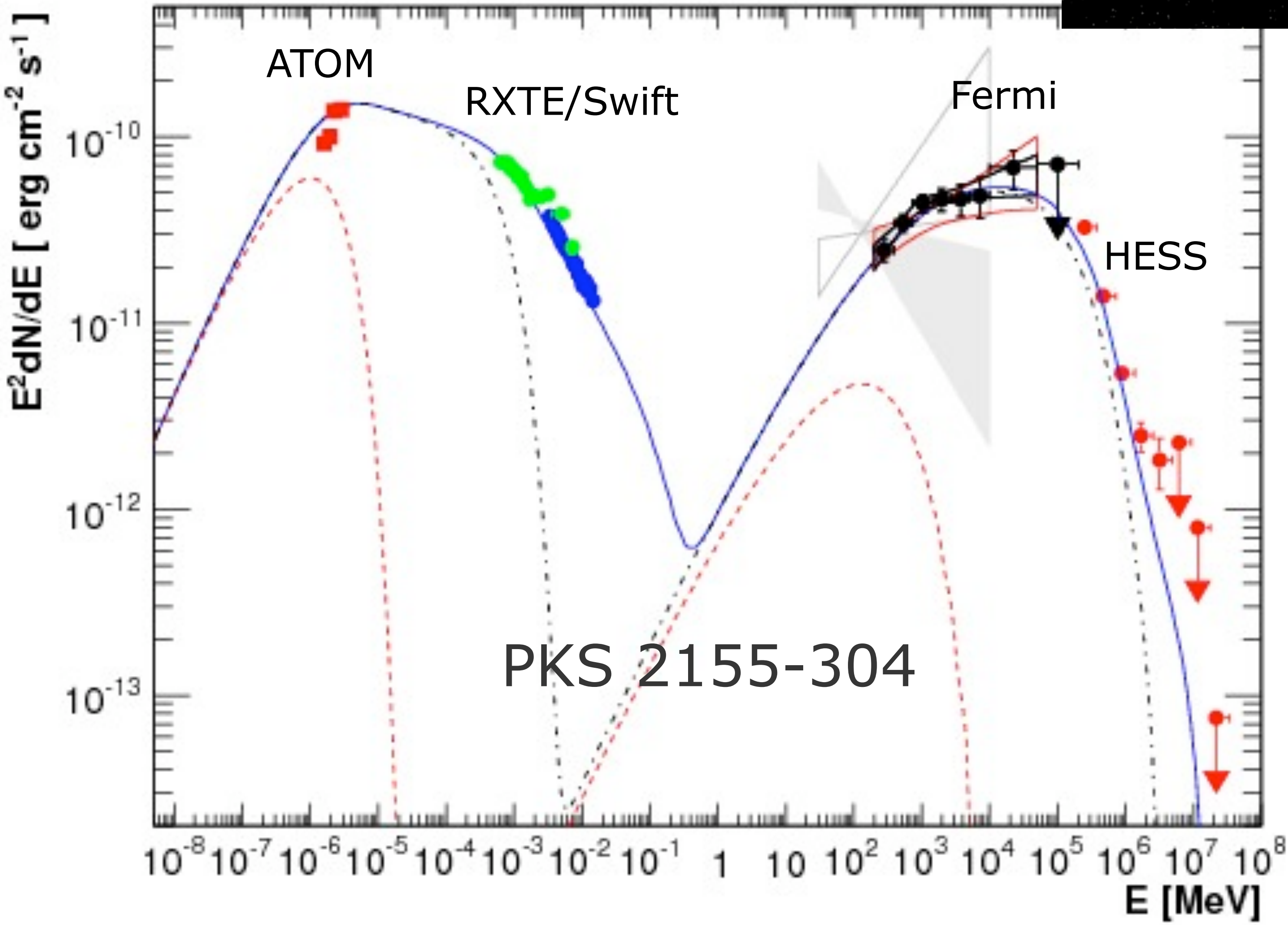


VHE gamma ray astronomy
is a key tool in the challenge
of investigating the nonthermal Universe

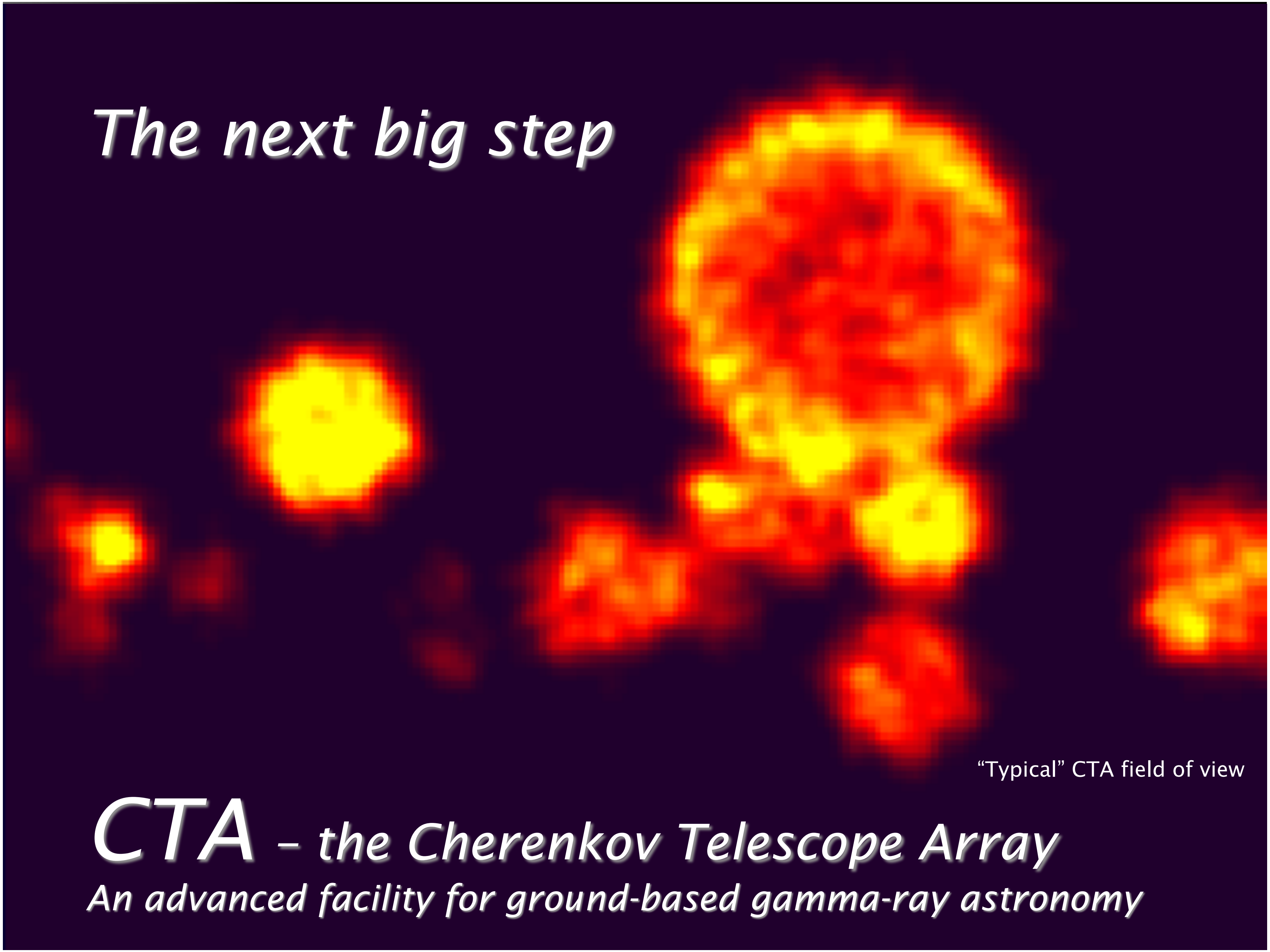
What’s next? H.E.S.S. & Fermi





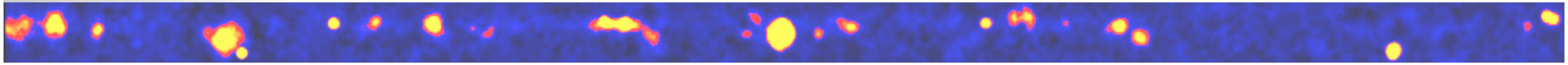


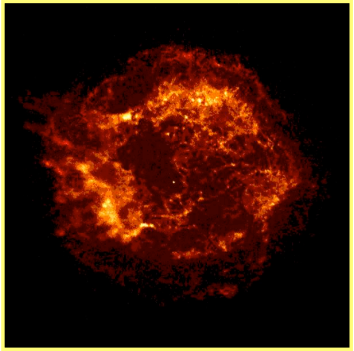
What’s next? H.E.S.S. Phase II



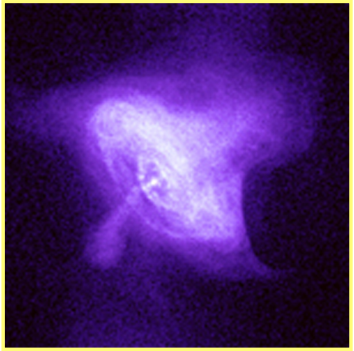
“Typical” CTA field of view

Scientific Objectives

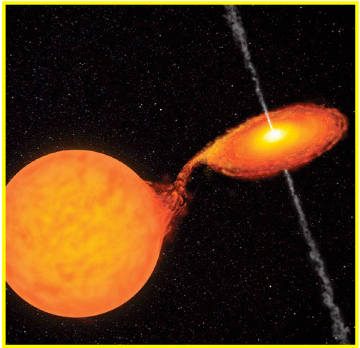




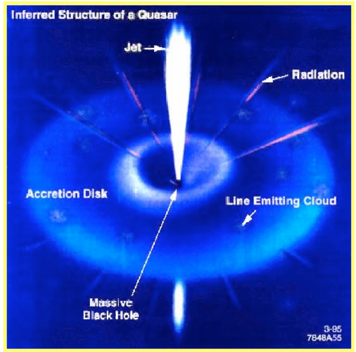
SNRs



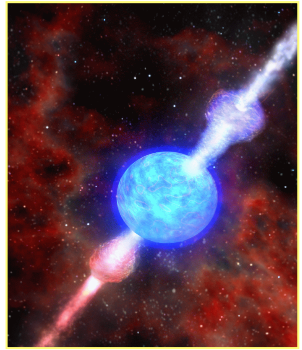
Pulsars
and PWN



Micro quasars
X-ray binaries

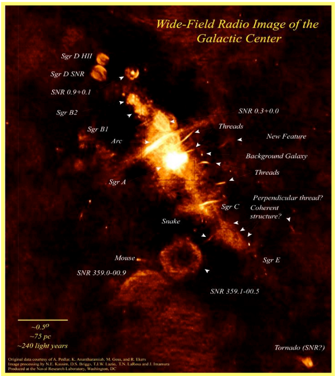


AGNs

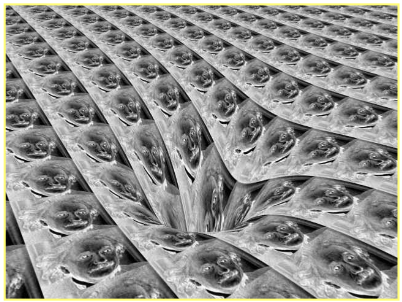


GRBs

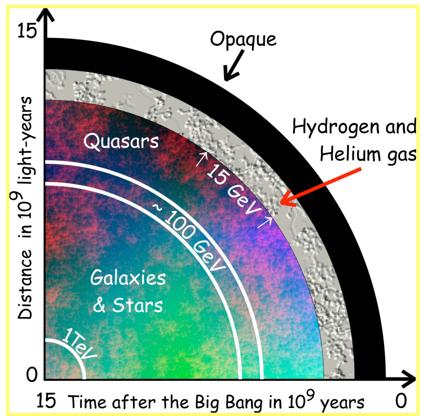
Origin of
cosmic rays



Dark matter

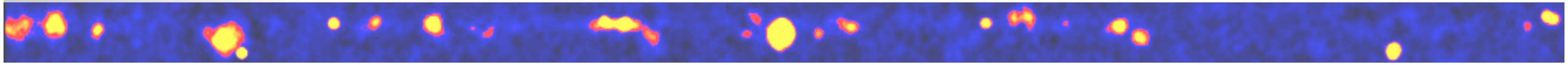


Space-time
& relativity



Cosmology

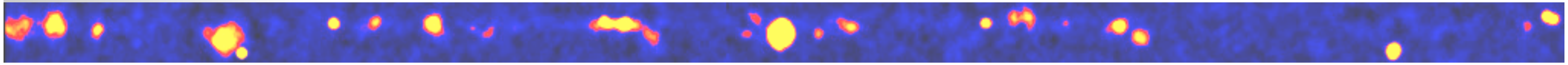
Wish list for CTA



- Higher sensitivity at TeV energies (x 10)
  more sources, details in extended sources
- Lower threshold (some 10 GeV)
  pulsars, distant AGN, source mechanisms
- Higher energy reach (100s of TeV)
  cutoff region of Galactic accelerators
- Wider field of view
  extended sources, surveys
- Improved angular resolution
  structure of extended sources
- Higher detection rates
  transient phenomena

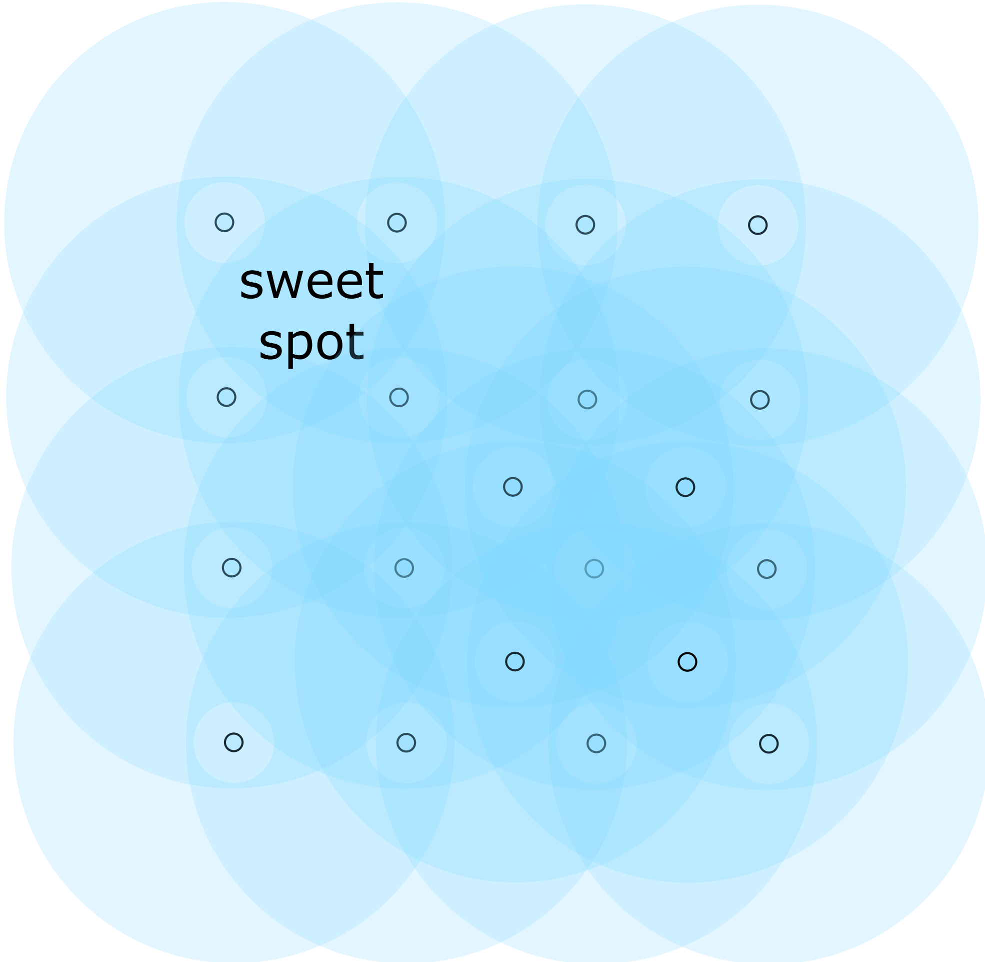
Boosting sensitivity & resolution

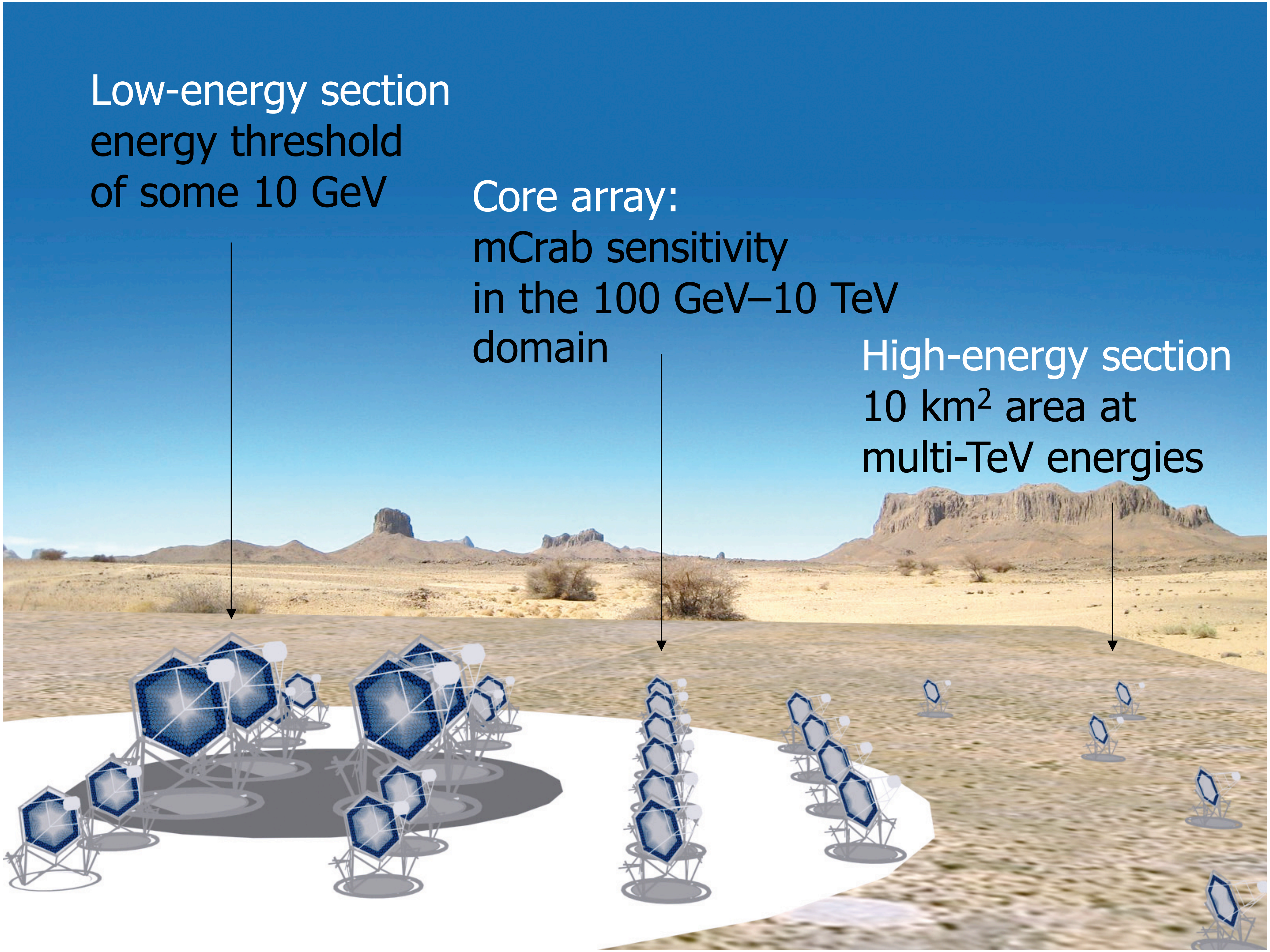
Arrays of Cherenkov telescopes



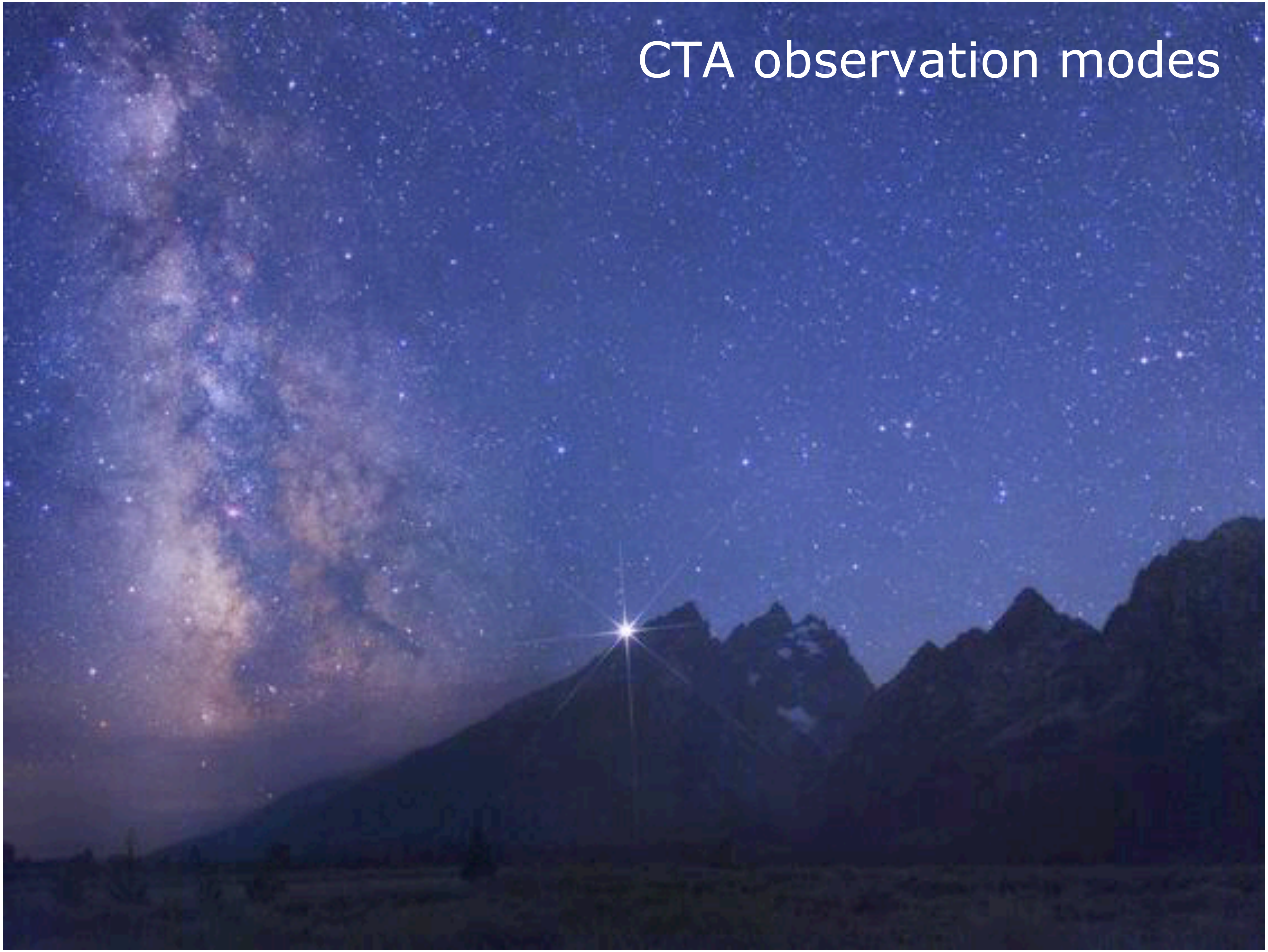
← 300 m →

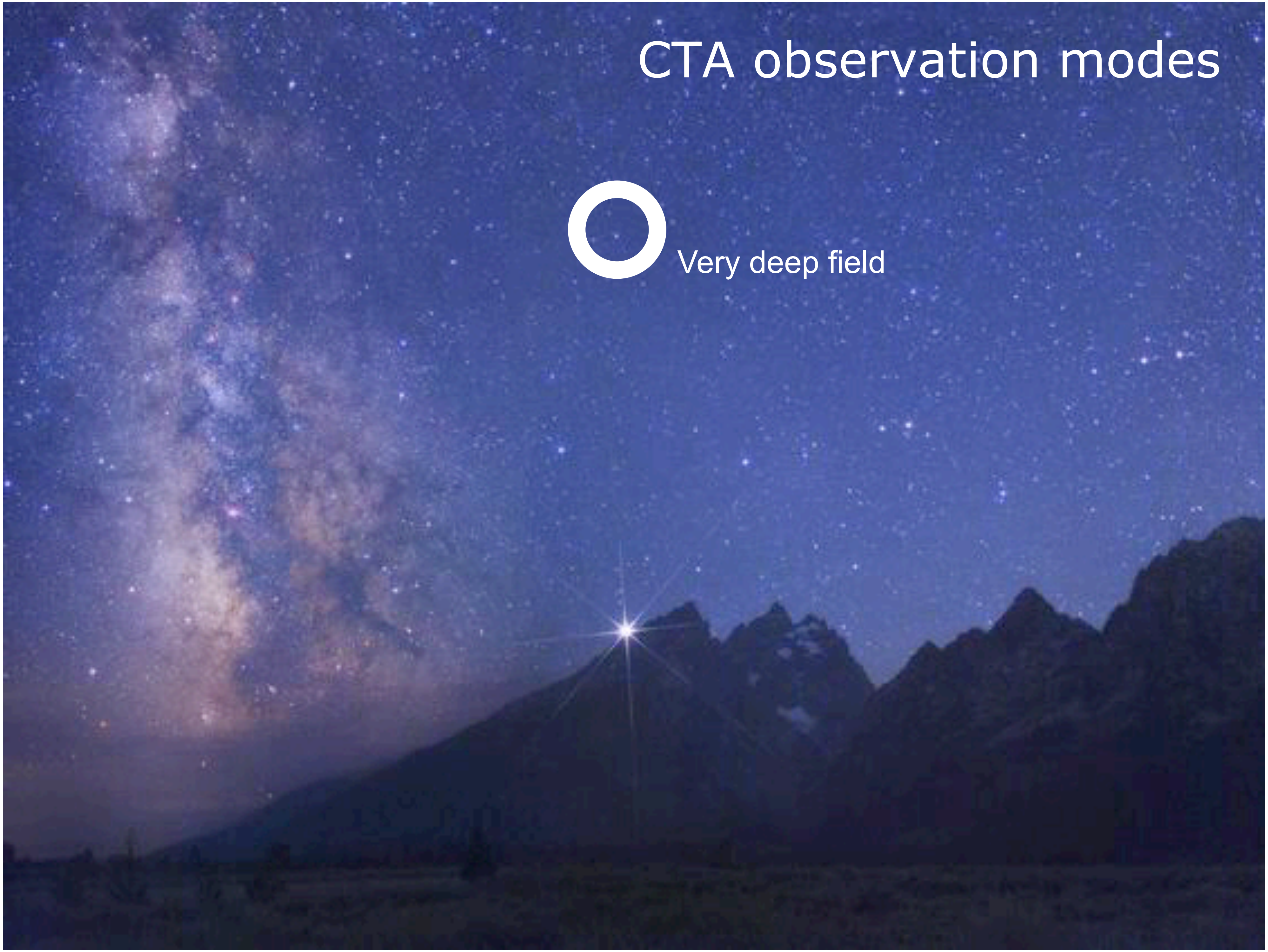
Single telescope

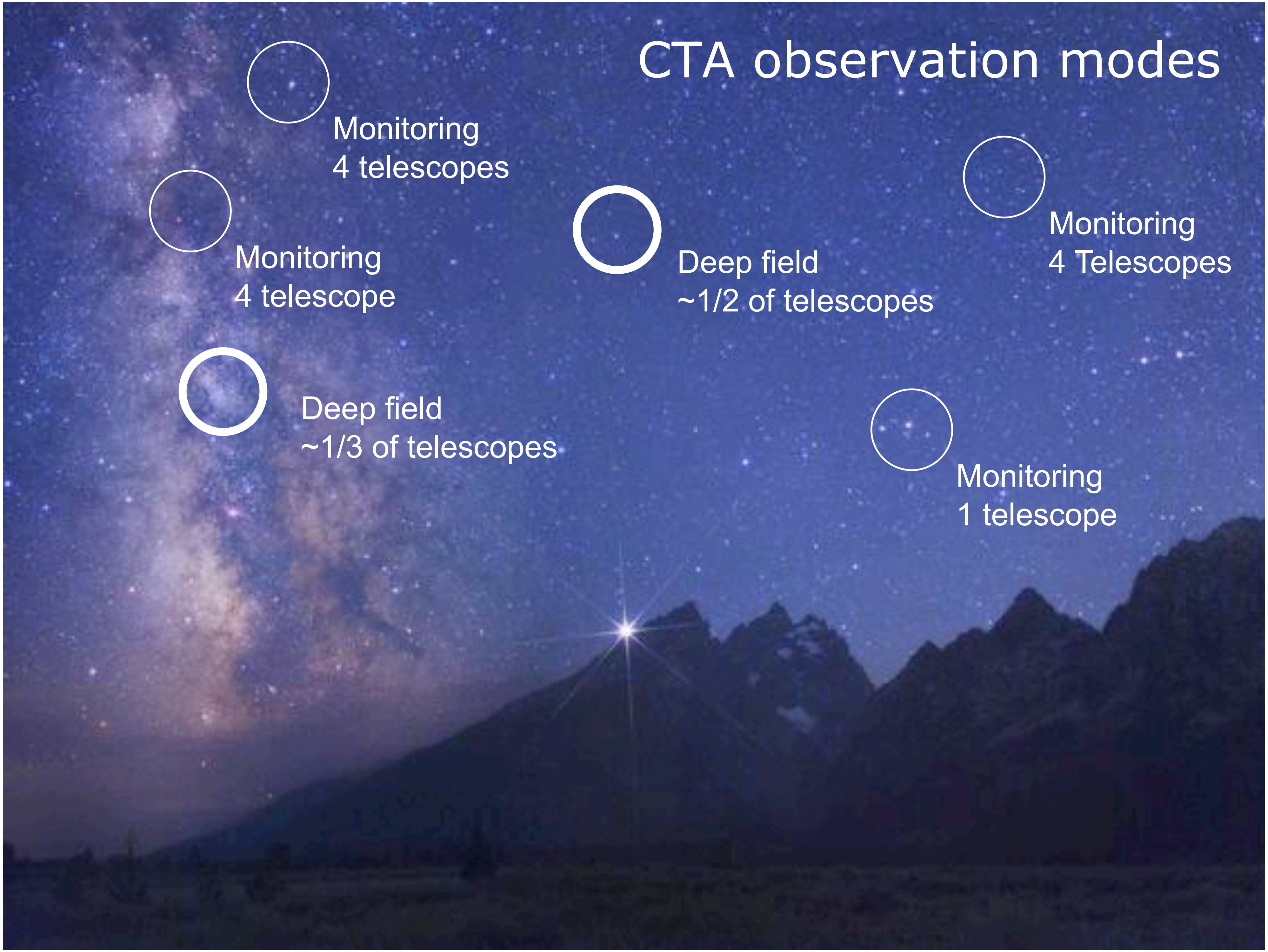



Low-energy section
energy threshold
of some 10 GeV
Core array:
mCrab sensitivity
in the 100 GeV–10 TeV
domain
High-energy section
10 km^2 area at
multi-TeV energies

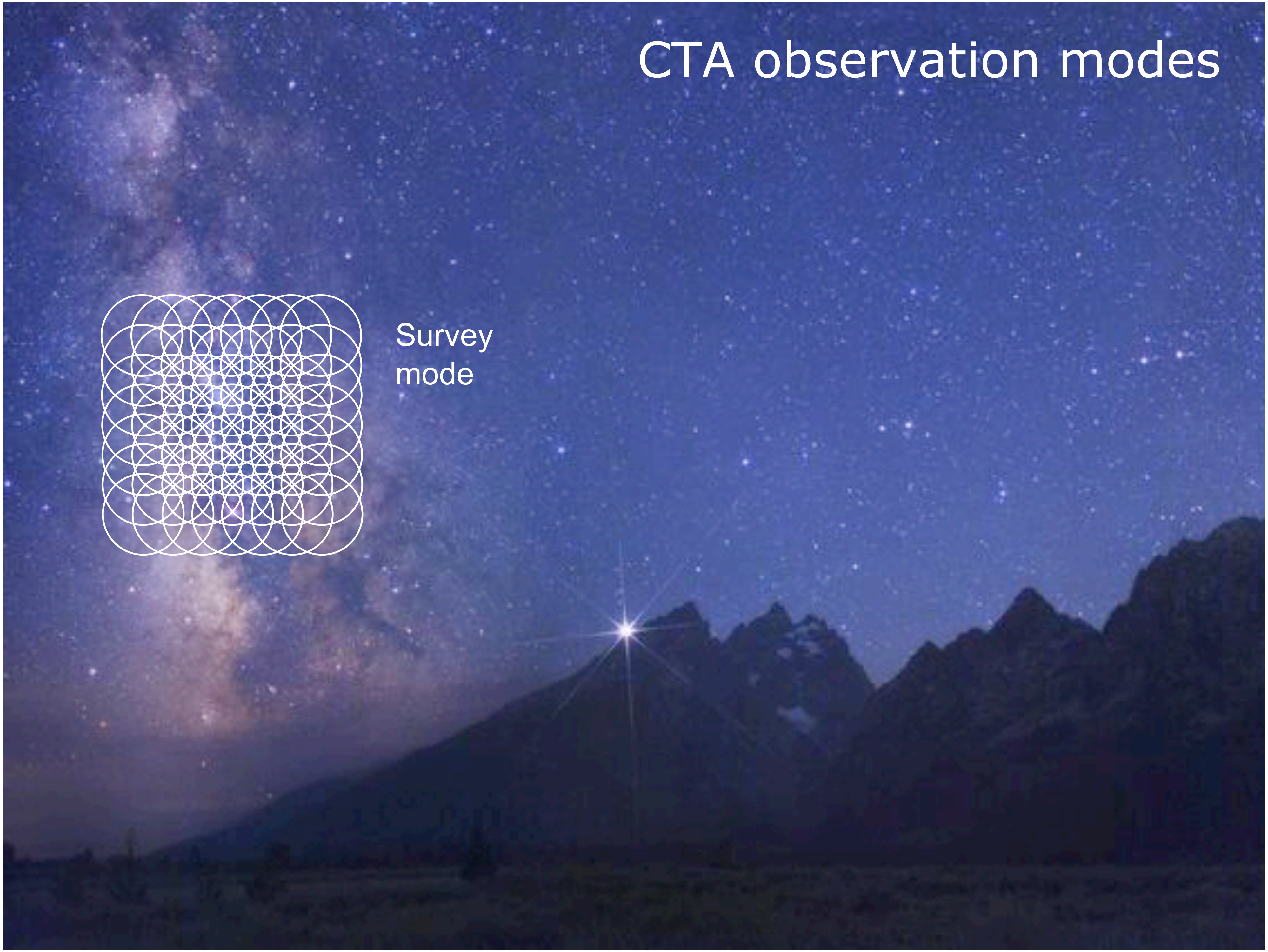
CTA observation modes



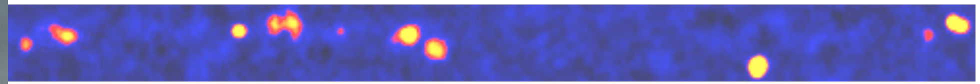

CTA observation modes
Very deep field

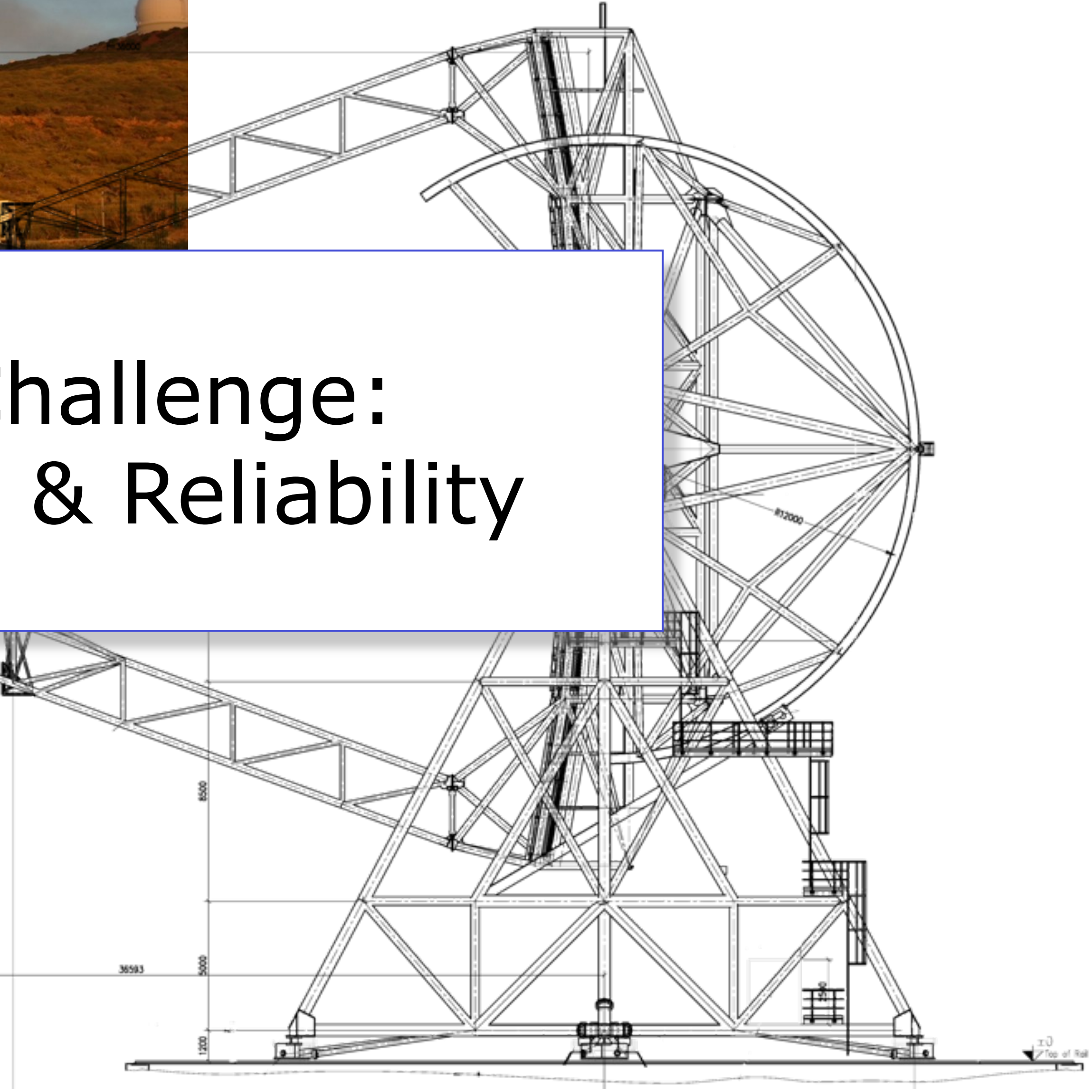

CTA observation modes
Monitoring
4 telescopes
Monitoring
4 telescope
Deep field
~1/2 of telescopes
Monitoring
4 Telescopes
Deep field
~1/3 of telescopes
Monitoring
1 telescope

CTA observation modes



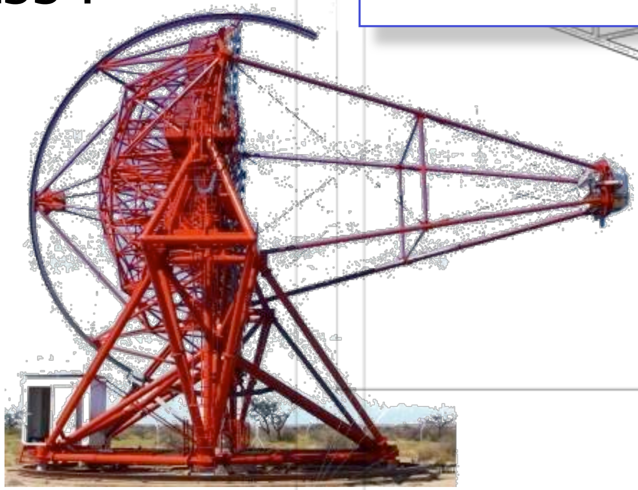
Building blocks





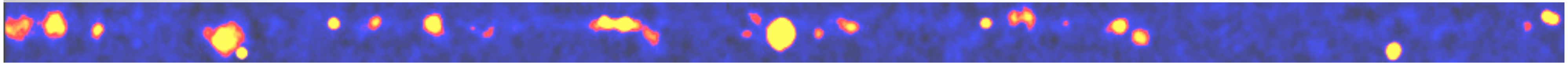
identical
scale

HESS I



Challenge:
Cost & Reliability

CTA Design Study



Armenia	Yerevan
Czech Republic	Prague
Finland	Turku
France	Annecy, Grenoble, Montpellier, LLR Palaiseau, APC Paris, Obs. Paris-Meudon, U. Paris VI-VII, CEA Saclay, Toulouse
Germany	HU Berlin, Bochum, DESY, Dortmund, Erlangen, Hamburg, MPI Heidelberg, U. Heidelberg, MPI Munich, Tübingen, Würzburg
Italy	INFN Padova, Pavia, Pisa, Trieste, Rome, Siena, INAF Rome, Brera, Bologna, Padova, Palermo, Torino, …
Ireland	DIAS Dublin, …
Japan	ICRC + Universities
Namibia	U. Namibia
Poland	Cracow, NCAC Warsaw, U. Warsaw, Lodz
Spain	IFAE, IEEC, UAB, UB Barcelona, UCM Madrid
South Africa	Northwest-Univ.
Switzerland	ETH Zurich, U. Zurich, Geneva, PSI
Sweden	Stockholm
UK	Leeds, Durham, …

more interested ….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