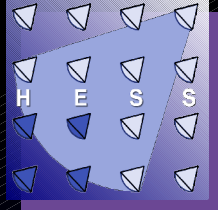




Recent Observations with the H.E.S.S. Experiment

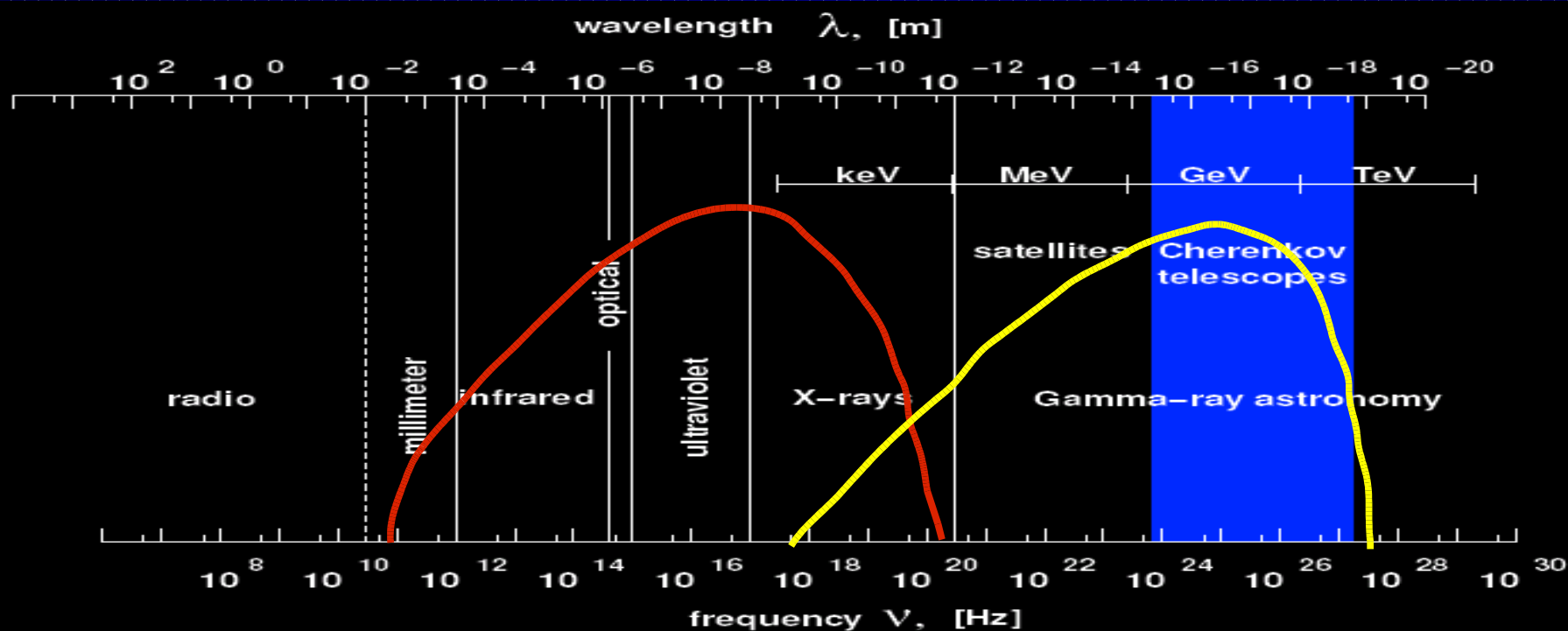
Conor Masterson
MPI für Kernphysik, Heidelberg





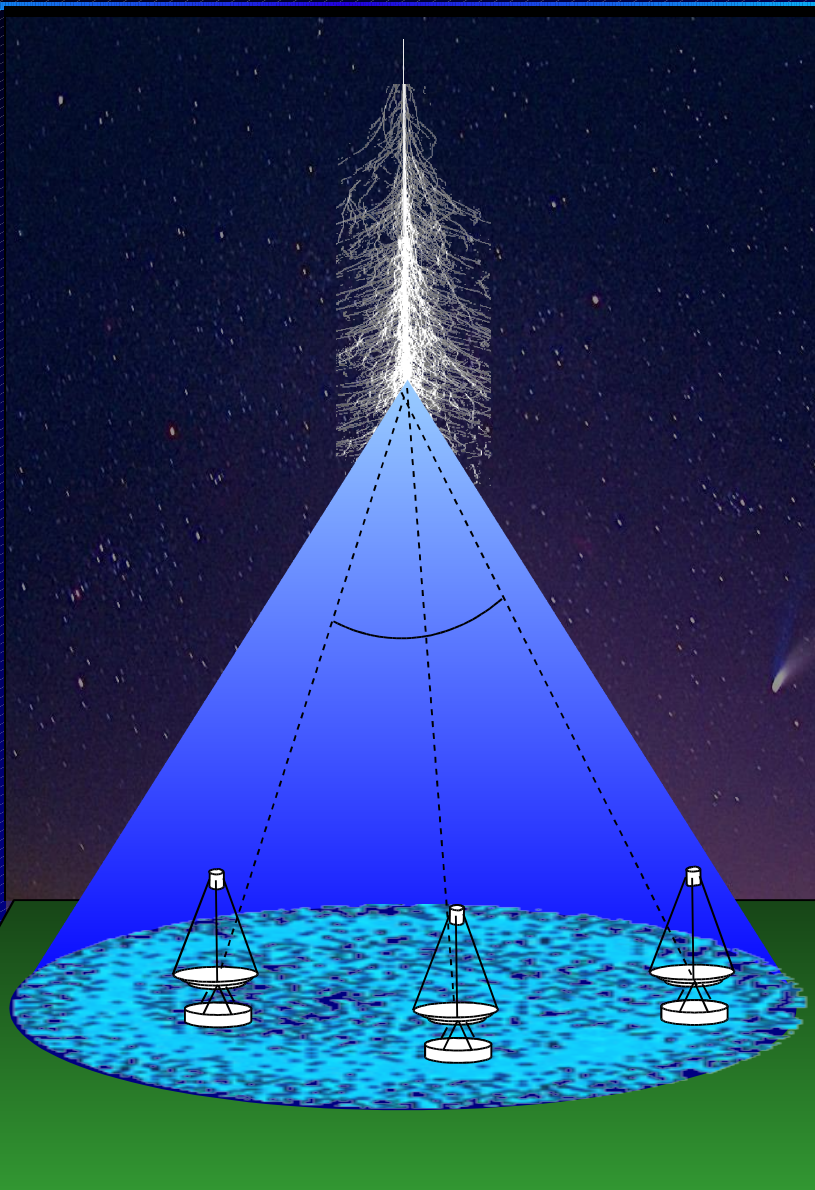
γ -rays in Astrophysics

- Highest energy astrophysical observations
 - Long lever arm for multiwavelength studies
 - Uncharted territory for top down processes
 - New energy range always brings new discoveries

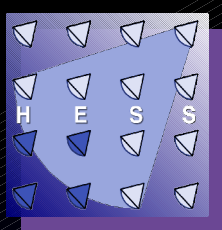




The Cherenkov technique



- γ ray interacts in atmosphere
- Cascade of charged particles produced
- Cherenkov light propagates to ground
- Large optical detectors on ground
- Record images of air shower
- Reconstruct primary particle energy, direction
- Reject background showers



H.E.S.S.



- **International collaboration**

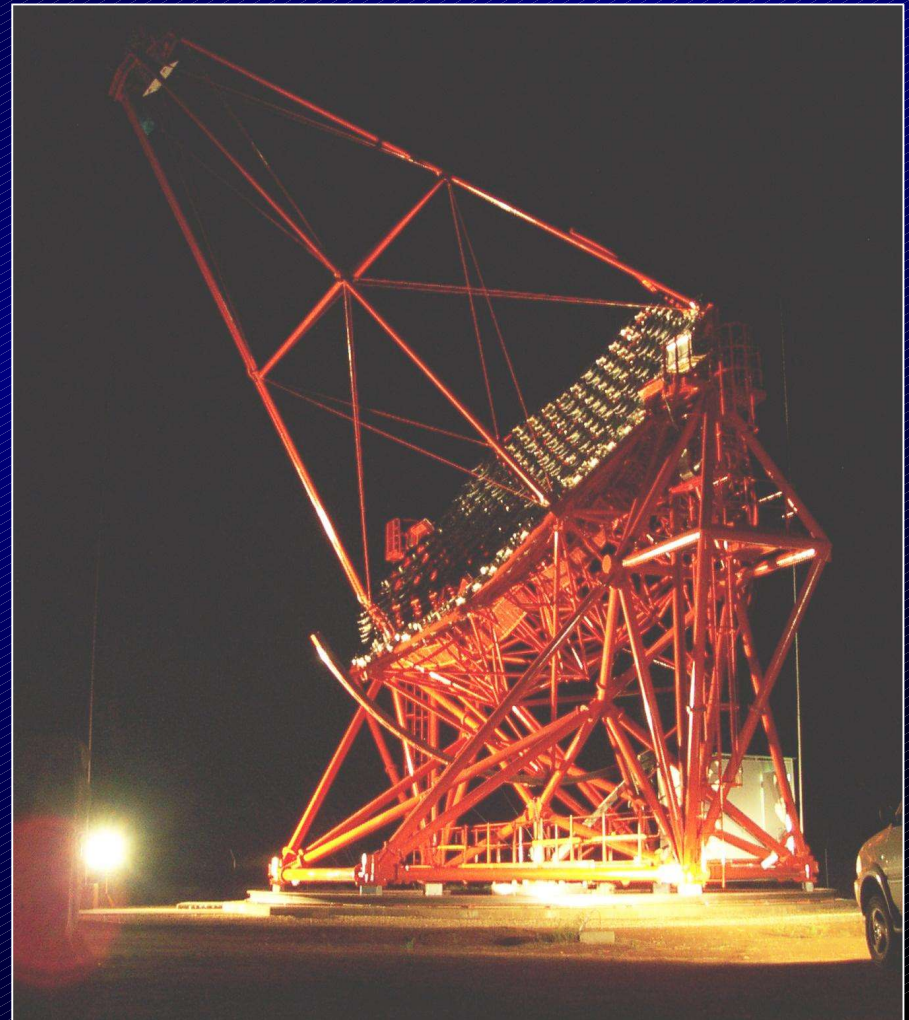
- Germany, France, UK, others

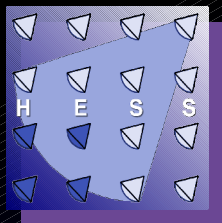
- **4 telescope array**

- Namibia, SW Africa
- 13m diameter dish
- Composite mirror
- 960 PMT camera

- **Largest Air-Cherenkov instrument**

- High sensitivity
- Wide energy range
- Precise energy resolution
- Precise angular resolution
- Large field of view





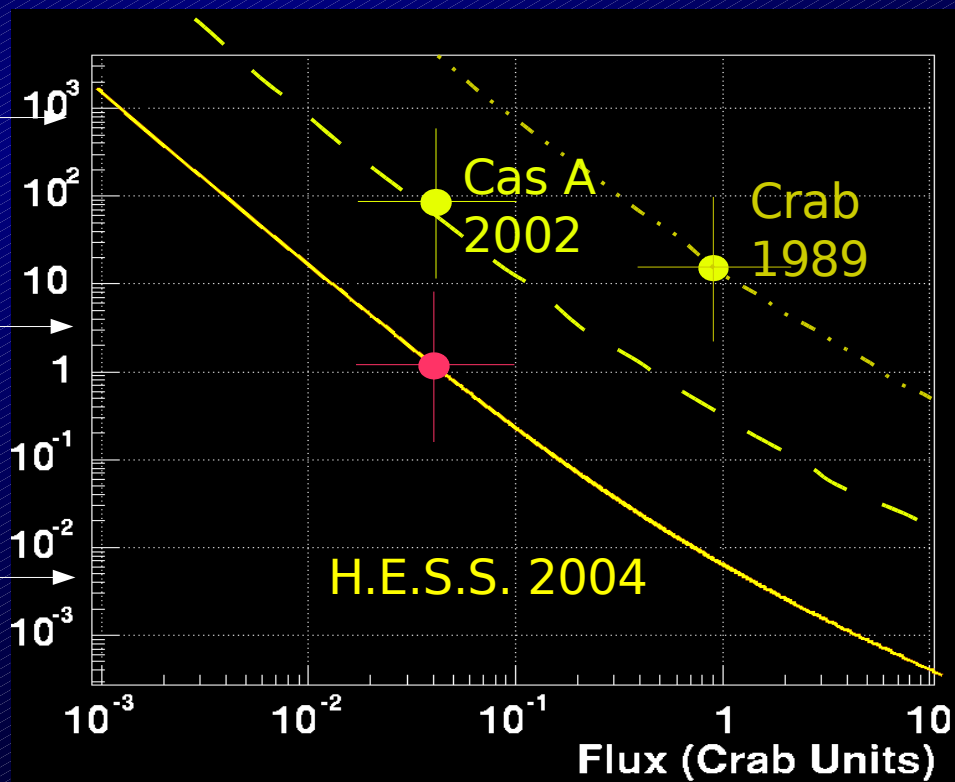
H.E.S.S. Sensitivity

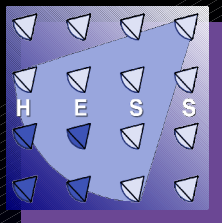
- **HEGRA**
 - 5% of Crab flux in 100 hours
- **H.E.S.S.**
 - 5% of Crab in 1 hour
 - 0.5% in 100 hours

1 year

1 night

30 sec.



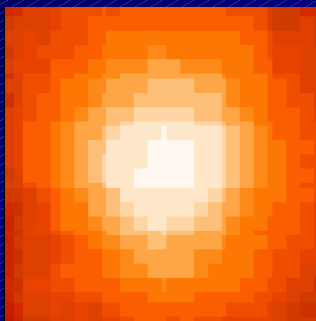


H.E.S.S. For Extended objects

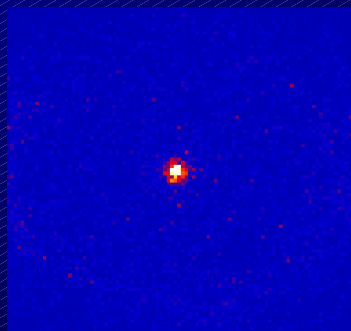


- Large extended sources
 - Supernova shells
 - Galactic clusters
- Unidentified Sources
 - Surveys
 - Egret unidentifieds
 - Other VHE unidentifieds

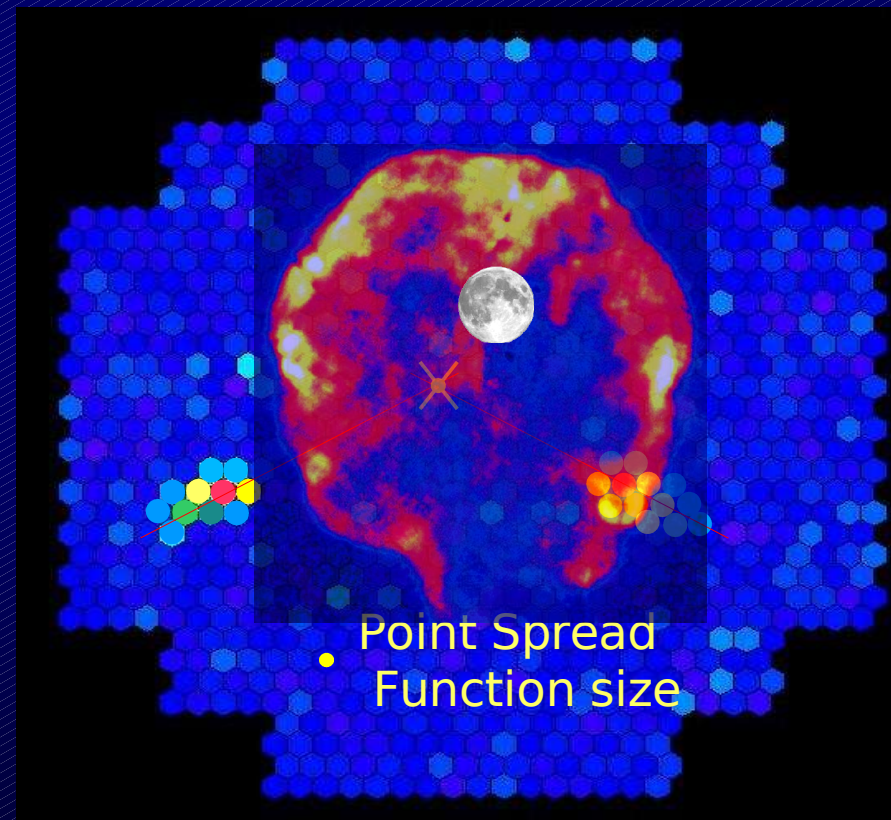
Point spread function



Egret



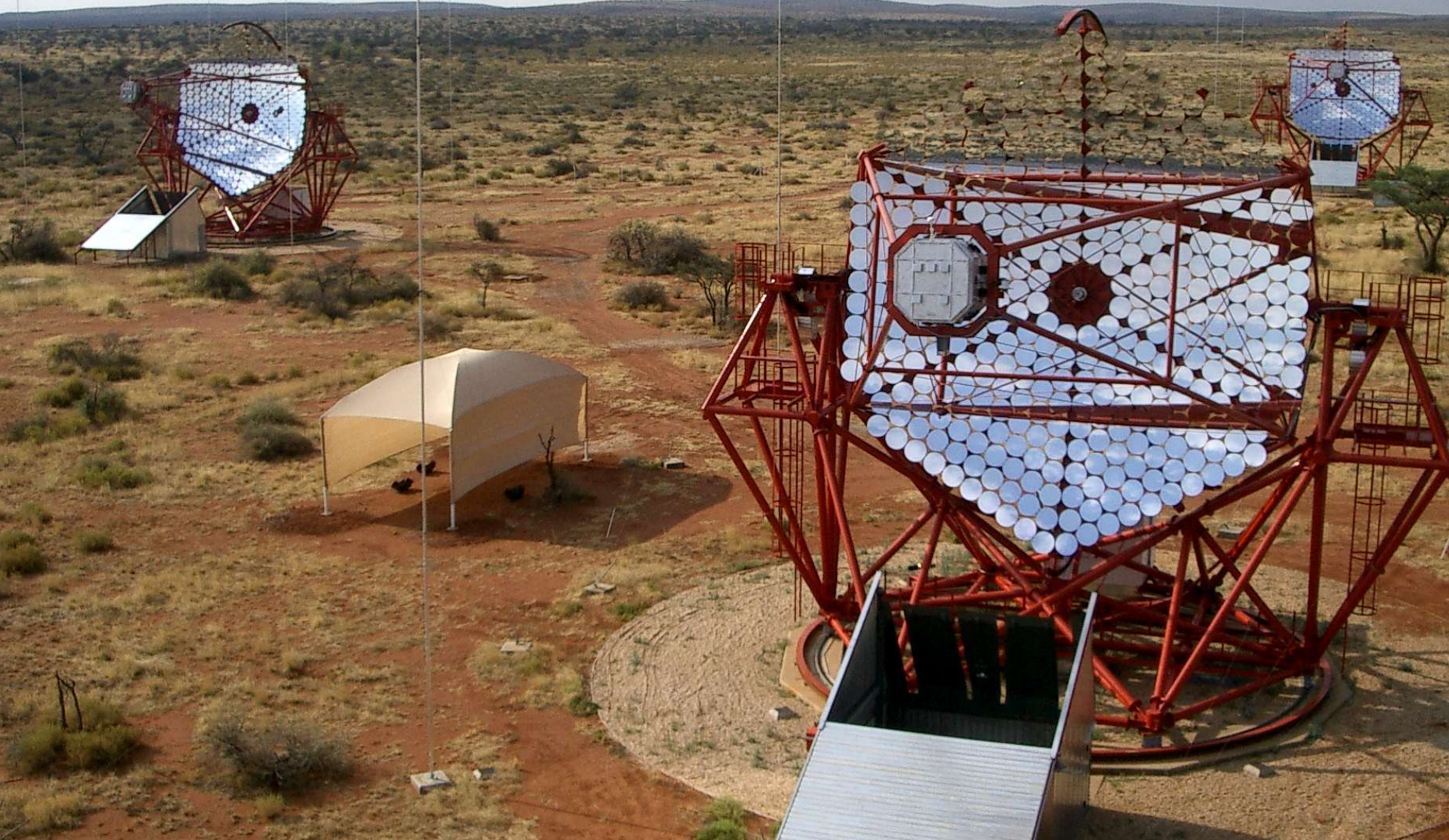
H.E.S.S.

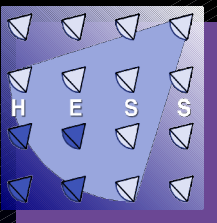


Point Spread Function size

Current Status

- All four telescopes operational since February 2004



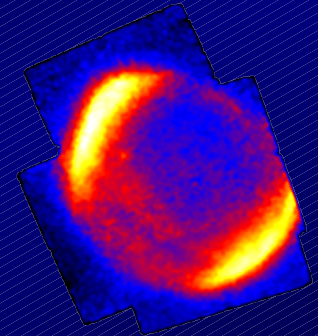


Science with H.E.S.S.



- **The source of Cosmic Rays**

- Remnants of exploded massive stars?
- γ -rays – messengers of cosmic ray production



Direct evidence of dark matter

- Collections of massive particles in gravitational wells
- Look for line features, cutoffs in spectra



- **Phenomenology of energetic objects**

- AGN - Huge jets from centres of Galaxies
- Pulsars – pulsed emission from neutron stars
- Plerions – non-thermal clouds surrounding pulsars
- γ -ray bursts – rapid transient bursts from massive stars?

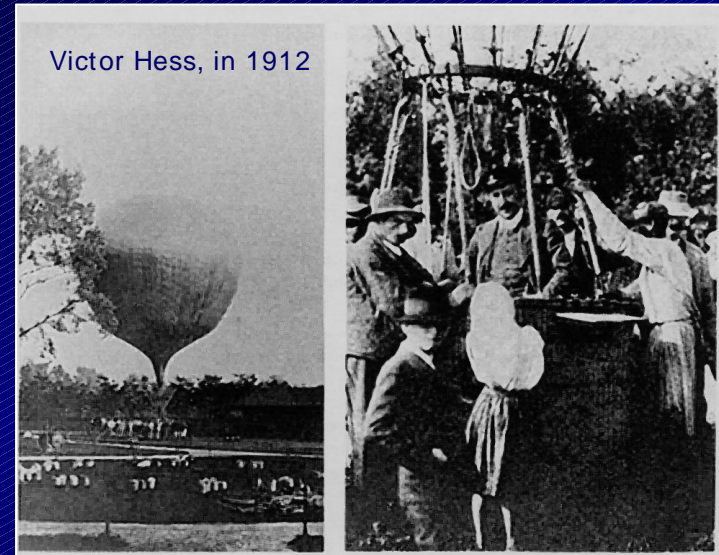


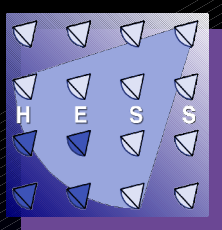


The Mystery of Cosmic Rays



- **Discovered in 1913**
 - Victor Hess
- **High Energy radiation from space**
 - Flux increased with altitude
- **Difficult to trace origin**
 - Cosmic rays do not travel in straight lines!
 - Complex galactic magnetic fields
- **γ -rays can help**
 - Also produced at sites of acceleration
 - Give direct indication of conditions at source

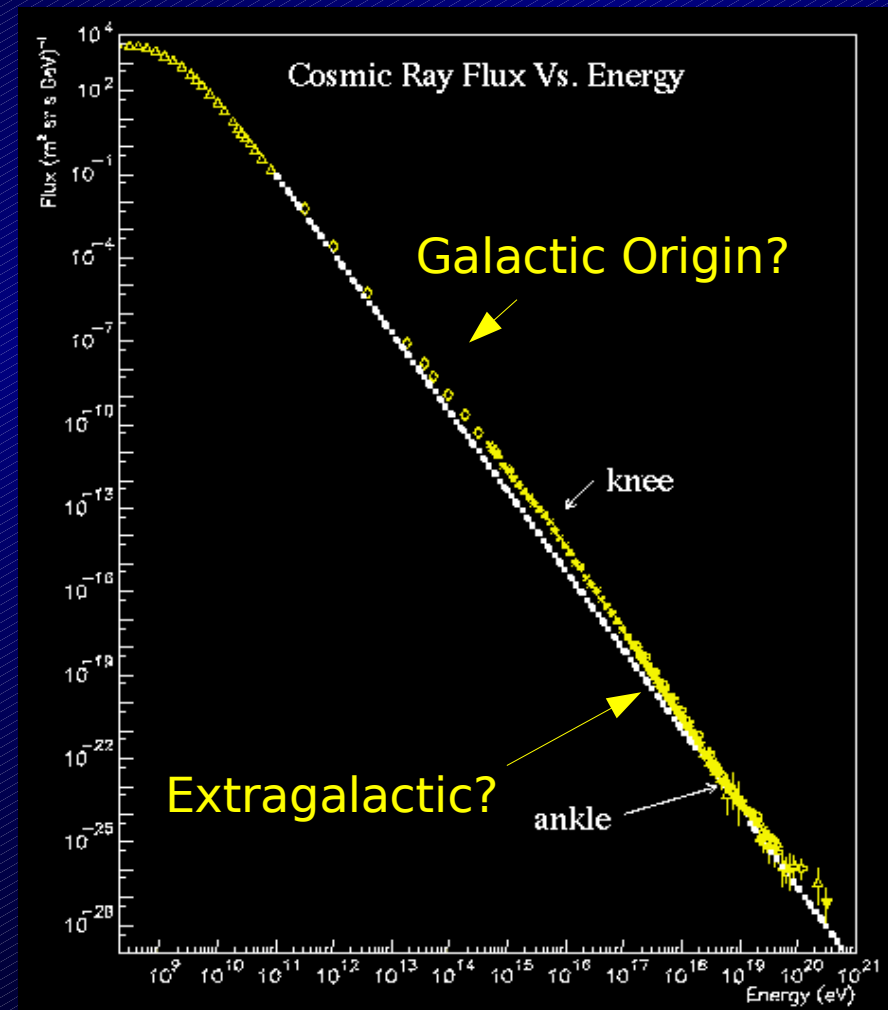


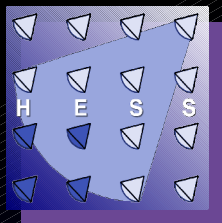


The Cosmic ray spectrum



- **Charged Particles**
 - Accelerated to very high energies
 - Nuclei, mostly protons
- **Power law spectrum**
 - Non thermal
 - Extends over huge energy range
- **Partly Galactic Origin**
 - Particles up to Knee
 - Mostly follow stellar composition
- **Partly Extra-Galactic?**
 - Mostly higher energies
 - Source must be further away

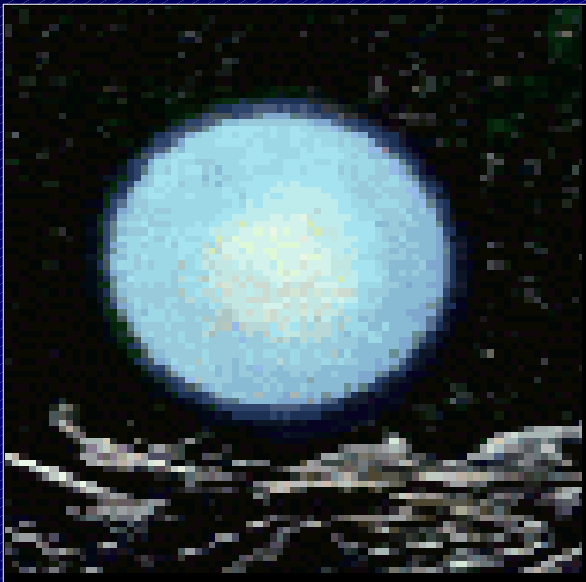
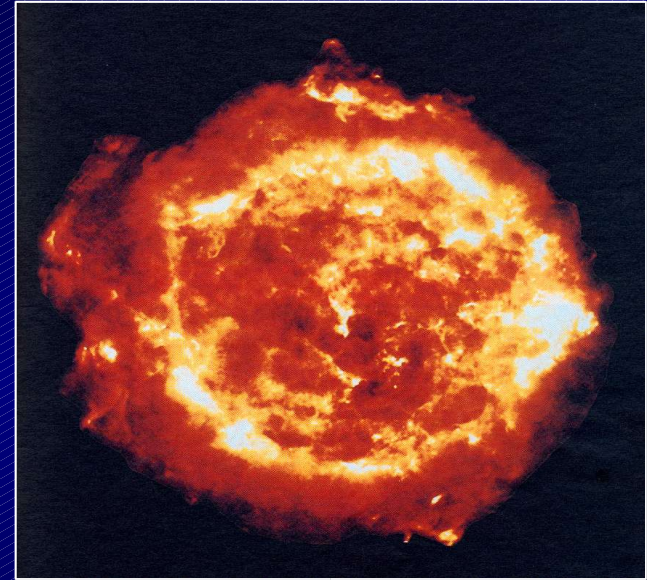




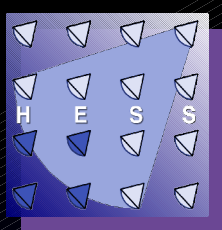
Supernova remnants



- Death of a massive star
 - End of life
 - Runs out of fuel
 - Core collapses
 - Massive explosion

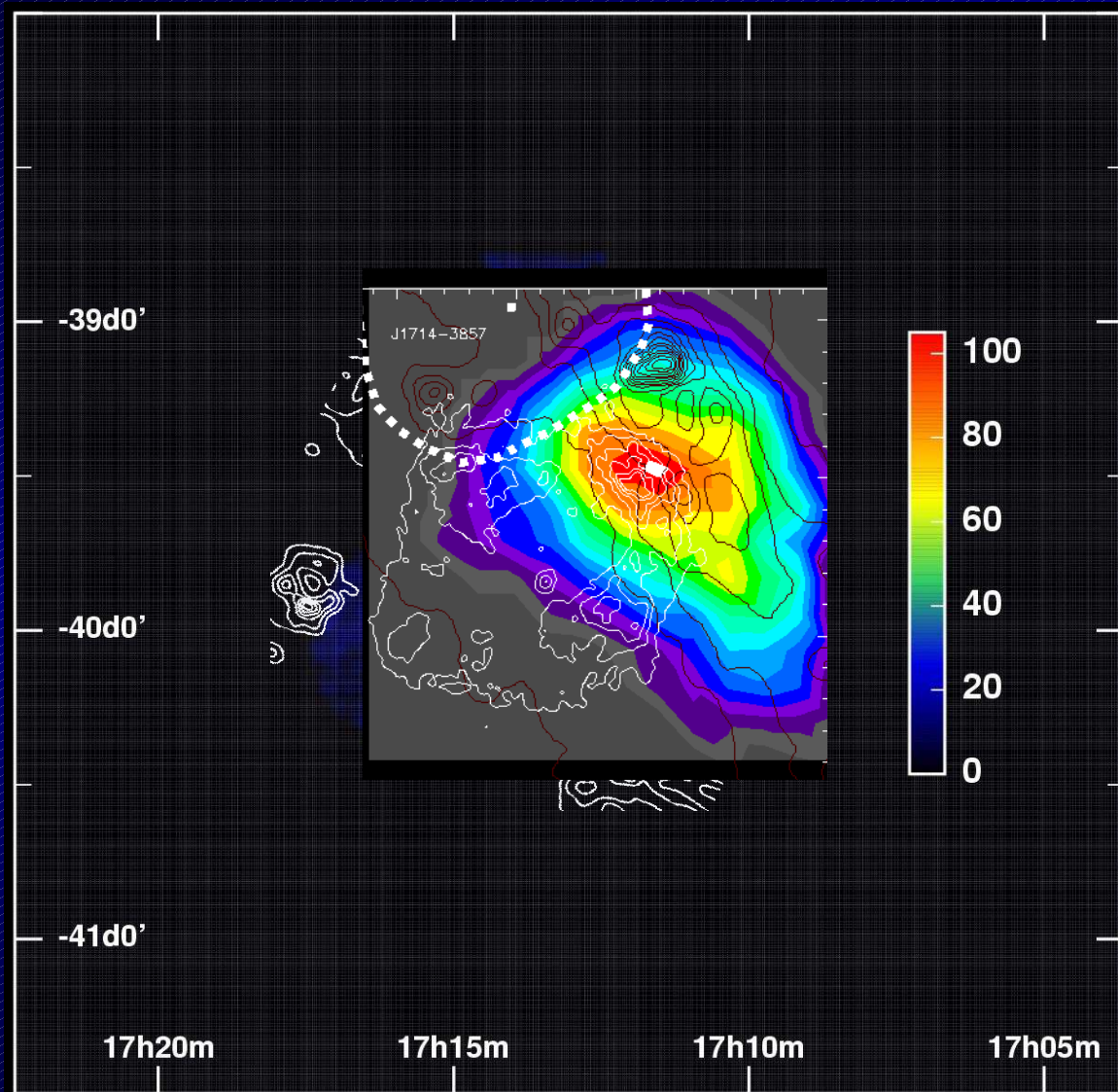


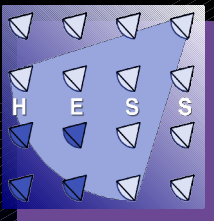
- Expanding shock wave
 - Kinetic energy dispersed
 - May accelerate surrounding matter
 - Cosmic rays
- Enough energy to explain flux



RXJ 1713-39

- ASCA X-ray image
- Dense molecular cloud regions
 - Correspond to X-ray hotspots
- Interaction with cloud?
 - Target protons accelerated?
 - Expect to see γ -rays
- Detected in VHE by CANGAROO
 - 2000



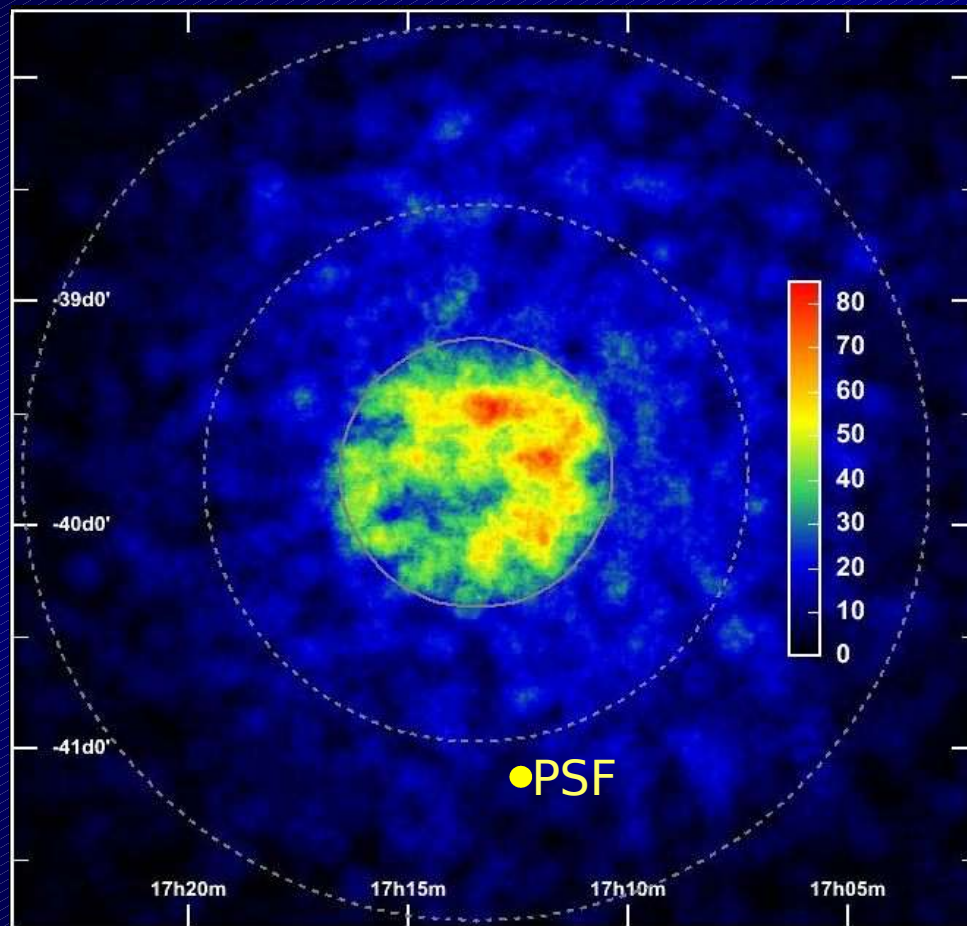


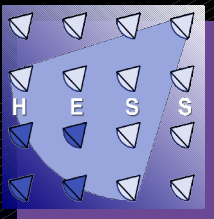
RX J1713 with H.E.S.S.



Strong detection in 2003
Two telescopes
18 hours observations

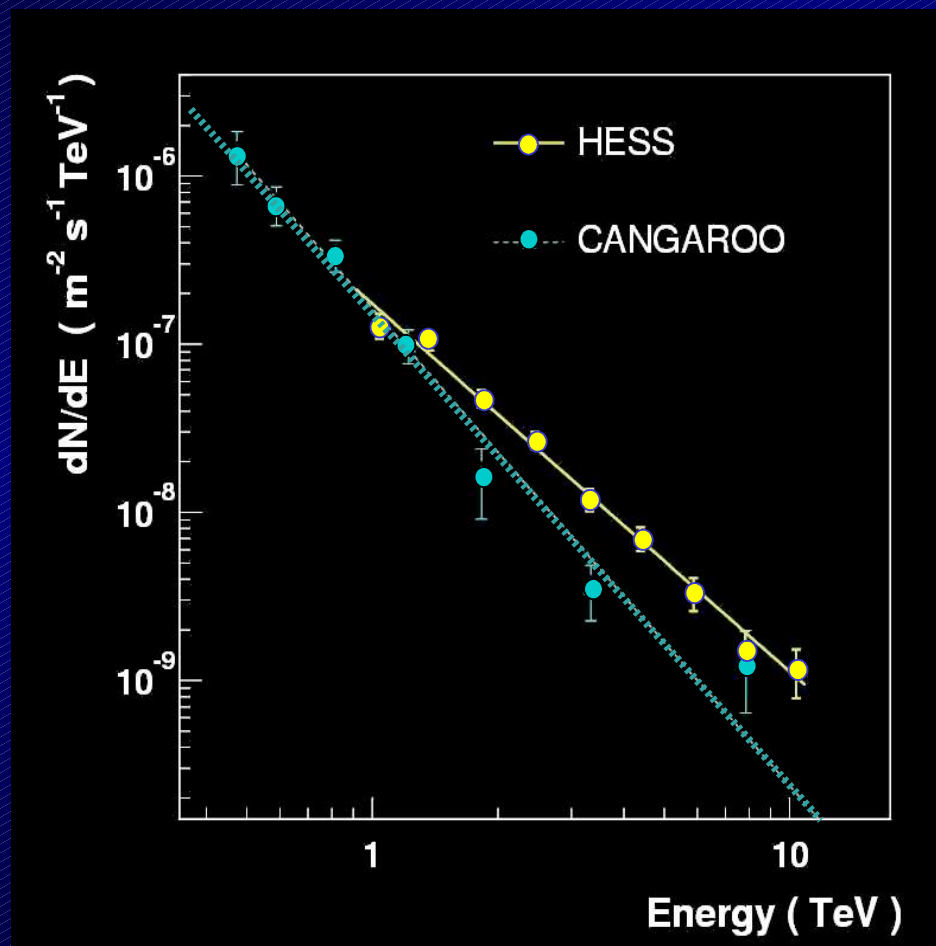
Confirmed in 2004
Full array

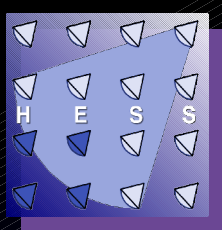




RX J1713 Spectrum

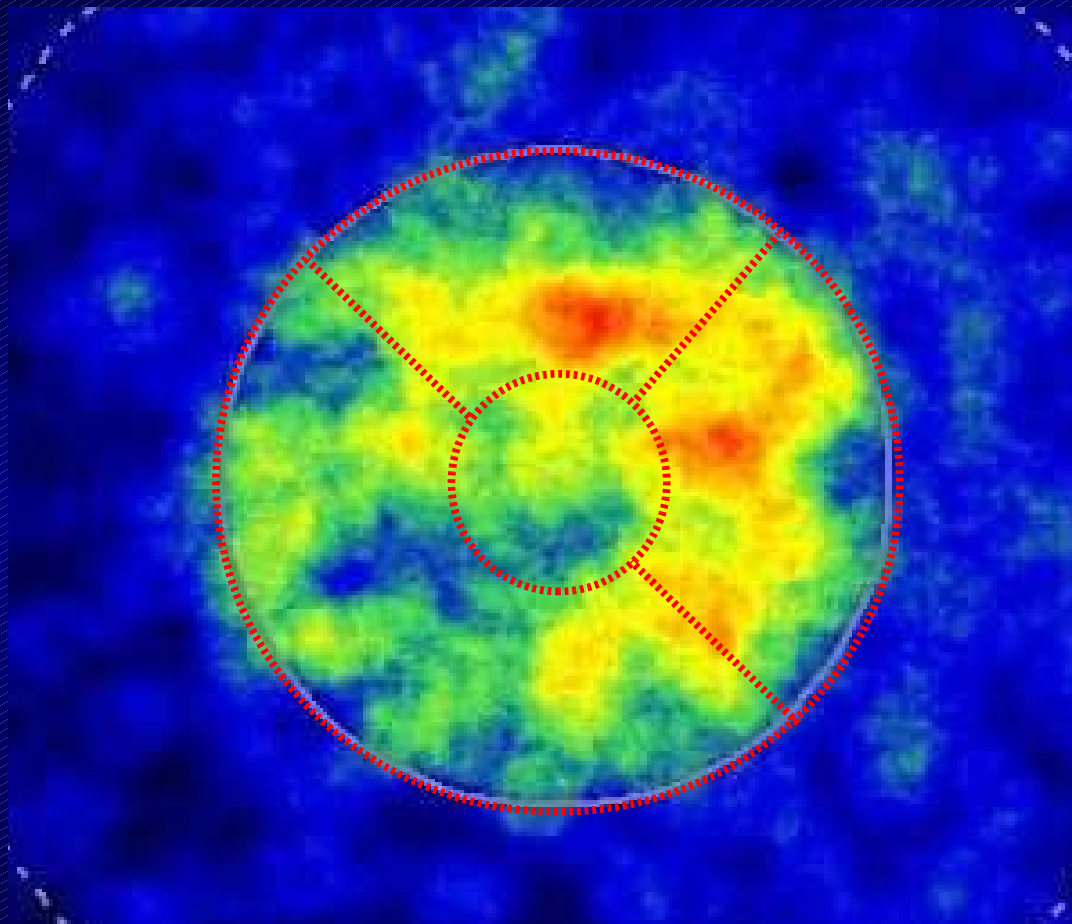
- **H.E.S.S.**
 - Hard flat spectrum
 - Consistent with cosmic ray acceleration
- **Previous measurements**
 - Not inconsistent

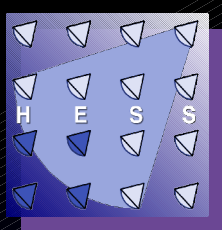




Precise measurements

- Good Correlation with X-ray image
 - Extended shell structure
 - Limb brightened, close to dense regions
- More detailed studies
 - Shape
 - Spectral variations

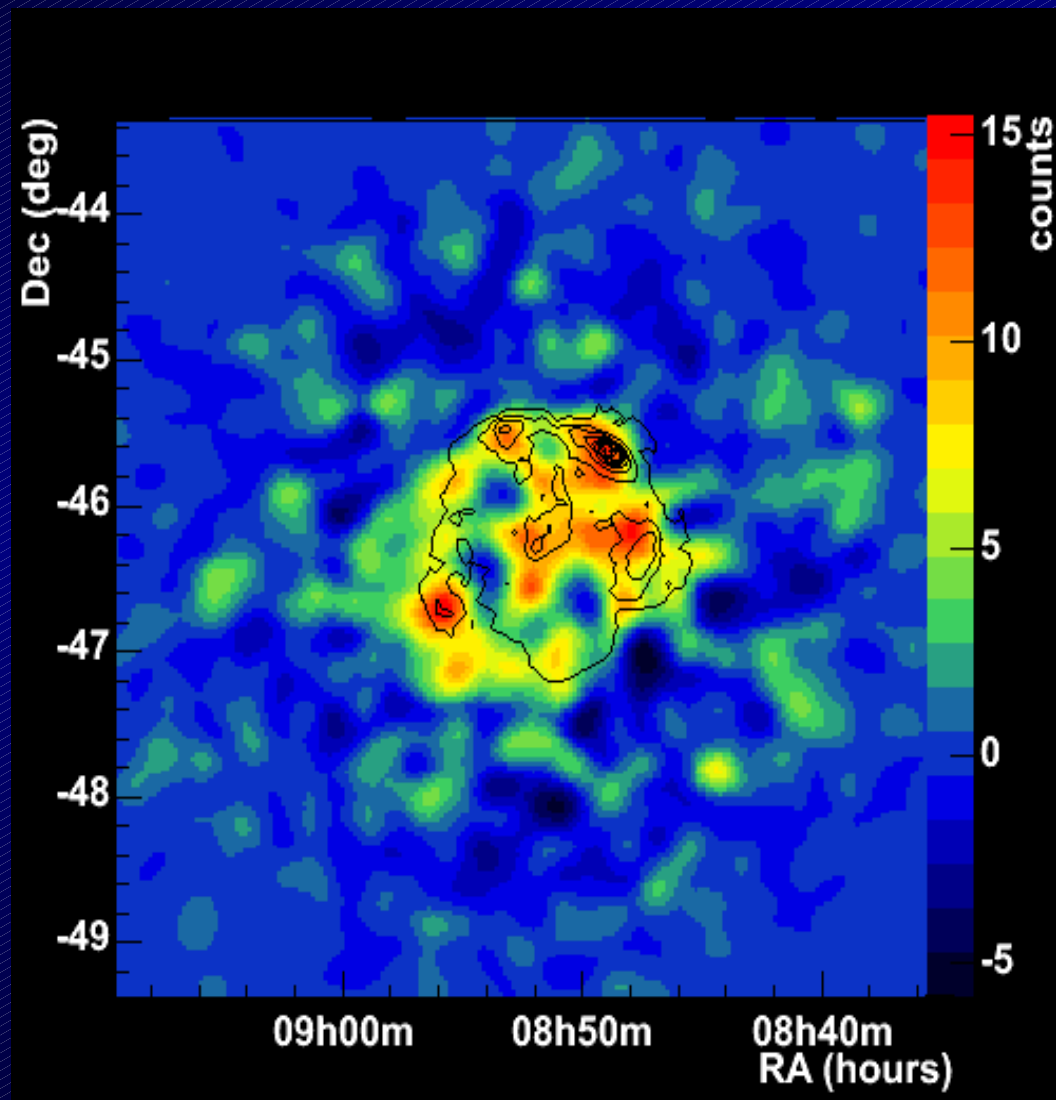




Vela Junior (RX J0852)



- 2nd extended SNR shell detected by H.E.S.S.
 - Hard, flat spectrum
 - High flux
 - ~ 1 Crab
 - Largest VHE source
 - $\sim 1^\circ$ across
- Strong correlation with X-ray
 - Shell structure seen



Is this the source of cosmic rays?



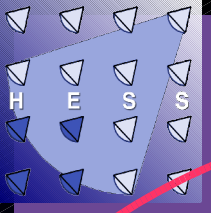
- **Multiple Shell-type SNRs**
 - Similar morphology, spectra
- **First clear proof of particle acceleration in SNR shockwave**
 - Protons or electrons?
- **Strong correlation with Molecular clouds**
 - Implies cosmic ray proton acceleration
- **Also strong correlation with X-ray**
 - Possibly caused by electrons?
- **Question probably still open**



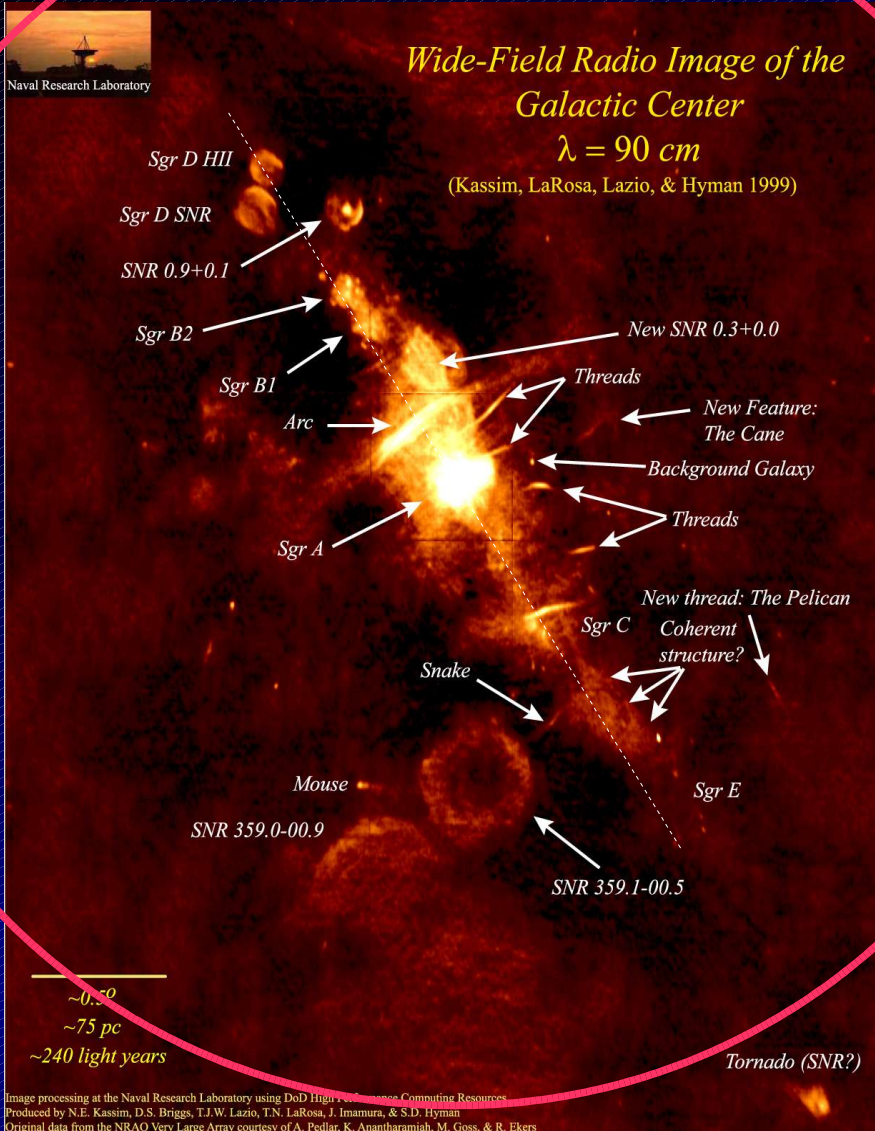
Top down Physics



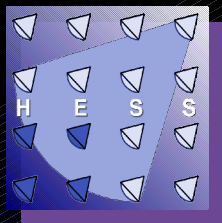
- Look for γ -rays from annihilation of exotic particles
 - Neutralinos, axions, supersymmetric particles?
 - Evaporating black holes
 - Topological defects
- Searching for Dark Matter
 - Particles collect in gravity wells
 - centre of Galaxy
 - Star clusters
 - Galactic clusters
 - Annihilate to emit γ radiation
 - Would be direct evidence of new physics
 - Flux strongly model dependant
 - Difficult to set useful upper limits



The Galactic Centre



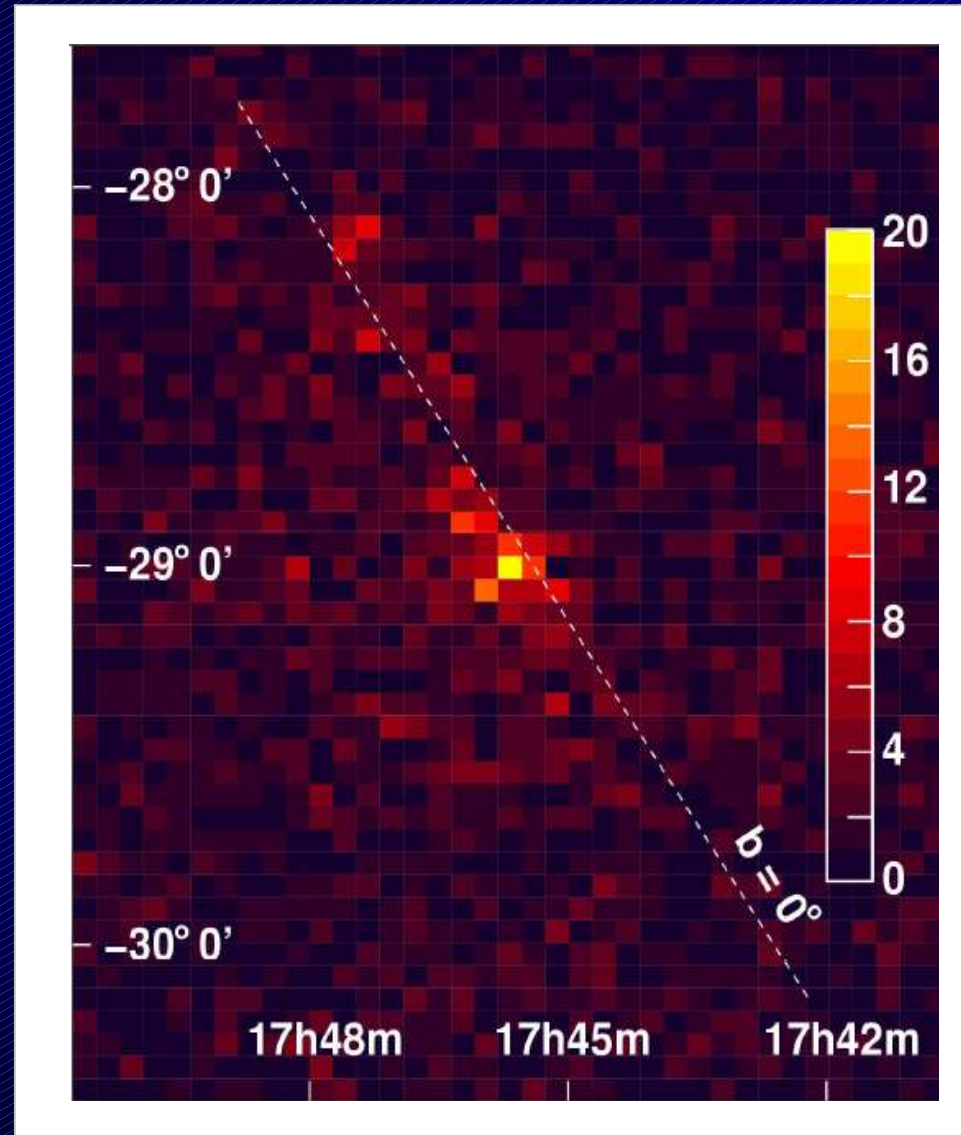
- Very dense region
 - Lots of possible sources
- VHE emission claimed by CANGAROO, Whipple
 - Not clear source
- Possibilities
 - Sagittarius A* - supermassive black hole
 - Several SNR, including Sag-A East,
 - Cosmic ray acceleration?
 - Dark matter annihilation?

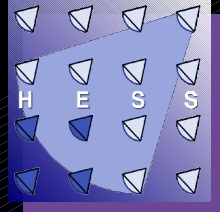


H.E.S.S. Observations

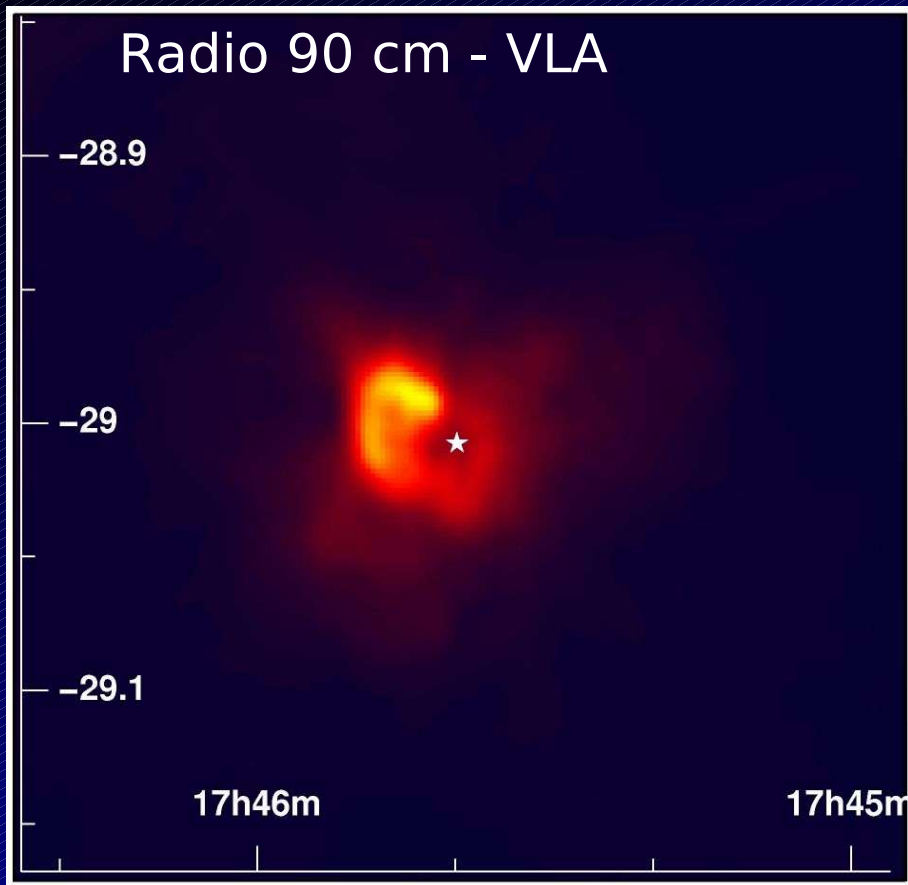


- H.E.S.S. 2004
 - Strong detection
 - Point source
 - Good source localisation
 - Hard, flat energy spectrum

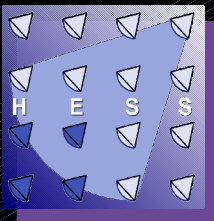




Sgr-A* and Sgr-A East

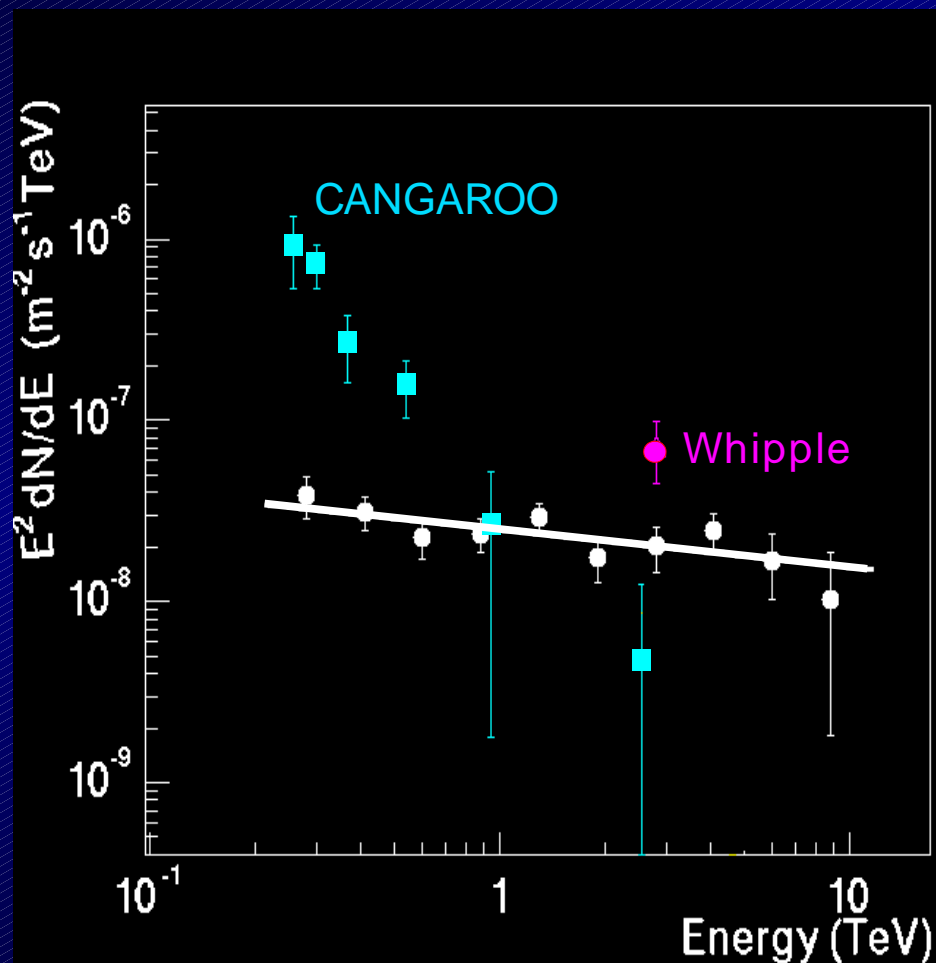


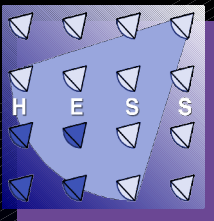
- Position compatible with Sgr A*



Galactic center energy spectrum

- Well measured
 - Hard spectrum
 - Extends to high energy
- Other measurements?
 - Agreement not very good

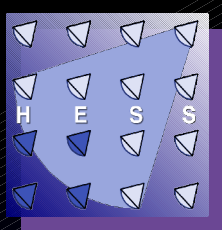




The Galactic Centre - conclusion



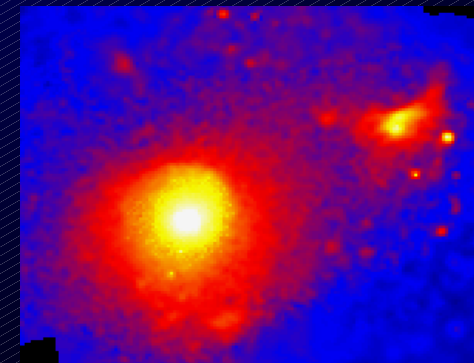
- **Strong Detection**
 - Confirm previous detection
 - Precise measurements
- **Source not clear**
 - SNR or black hole?
- **Dark matter?**
 - Spectrum is flat, featureless
 - Limits possible particle mass $m_\chi > 12 \text{ TeV}$
 - Not ruled out, but not likely
 - Many other candidates to explain γ -rays
- **To resolve the ambiguity we need:**
 - More statistics, precise spectrum, well determined position



Astrophysical sources



- Pulsars and Plerions
 - Classical VHE source - Crab
- Active Galactic Nuclei
 - Jets from centres of Galaxies
 - Strongest VHE sources
- Galactic Clusters
- Micro quasars
- X-ray binaries
- γ -ray bursts
 - Difficult to catch
 - Probably not visible

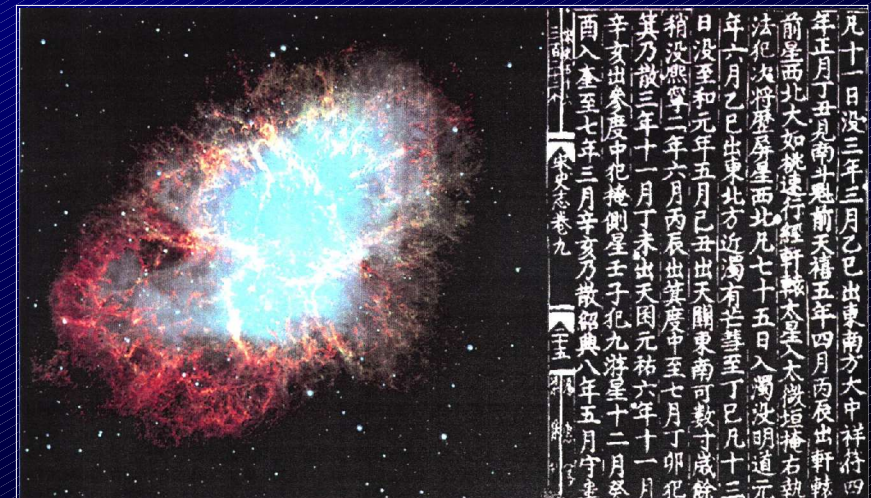




Pulsar wind Nebulae

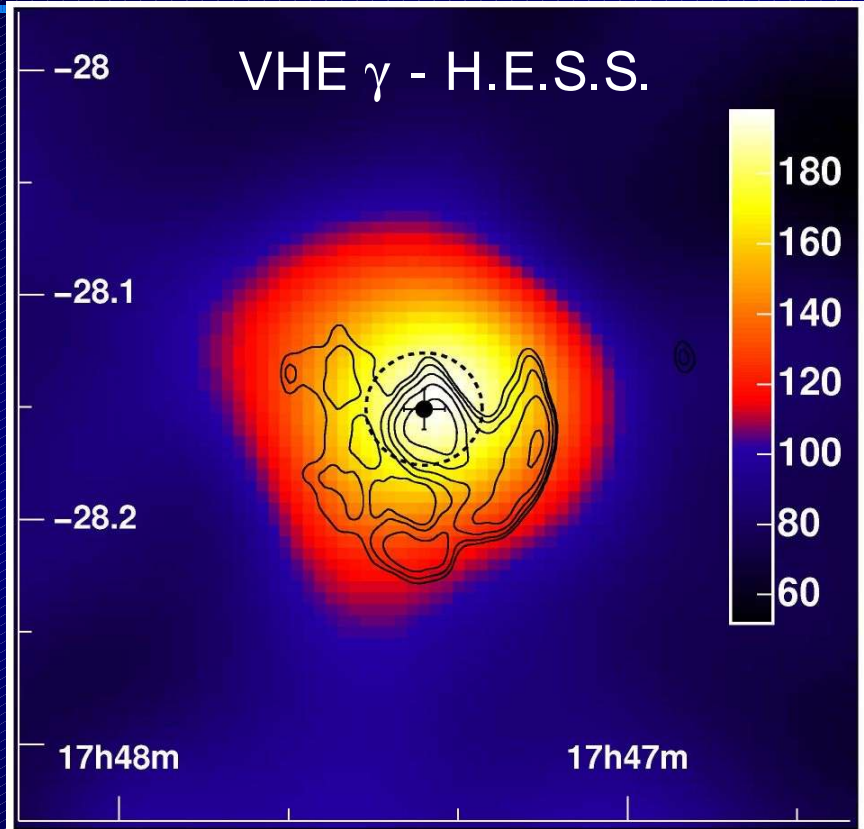
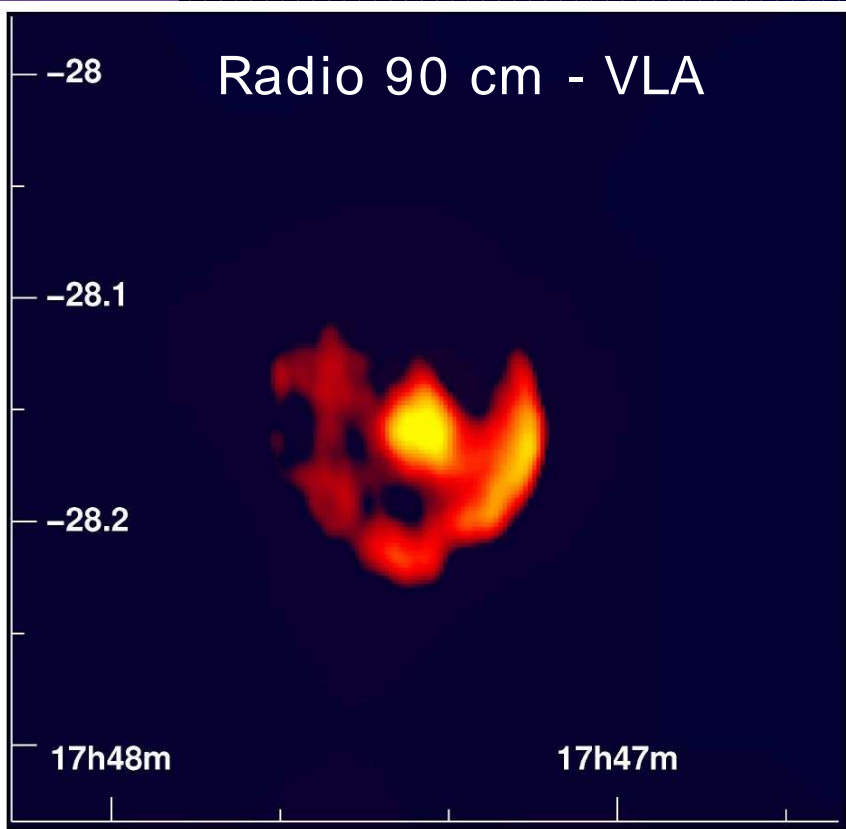


- Pulsar at centre of Supernova remnant
 - Wind of high energy electrons/positrons from pulsar
 - Interact to produce Very High Energy γ -rays
- Main example – Crab Nebula
 - Supernova recorded in 1054 AD
 - Close young SNR
 - Brightest optical/radio pulsar
 - Seen strongly by H.E.S.S.

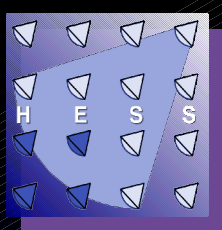




G0.9+0.1 – Composite SNR



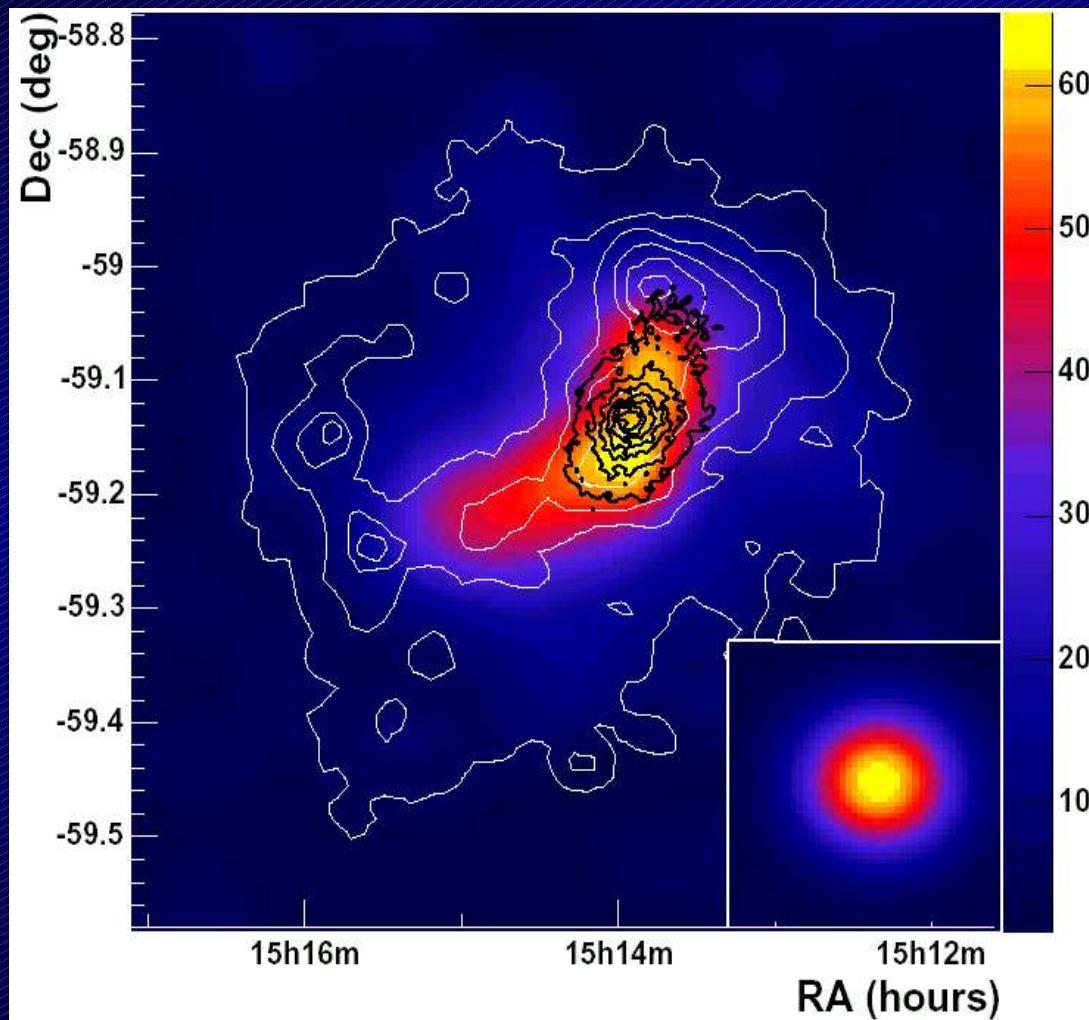
- Plerion close to Galactic centre
 - Serendipitous discovery
- Weakest known VHE source
 - 2% Crab flux

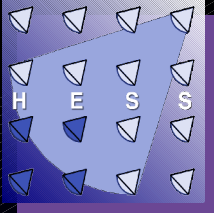


MSH 15-52



- **Plerion**
 - X-ray nebula
- **Extended features**
 - Jets?
 - Outflow regions?
- **Strong detection in VHE**
 - Flux 15% Crab
 - Clearly extended
 - Coincident with Jets
 - First ever resolved VHE plerion

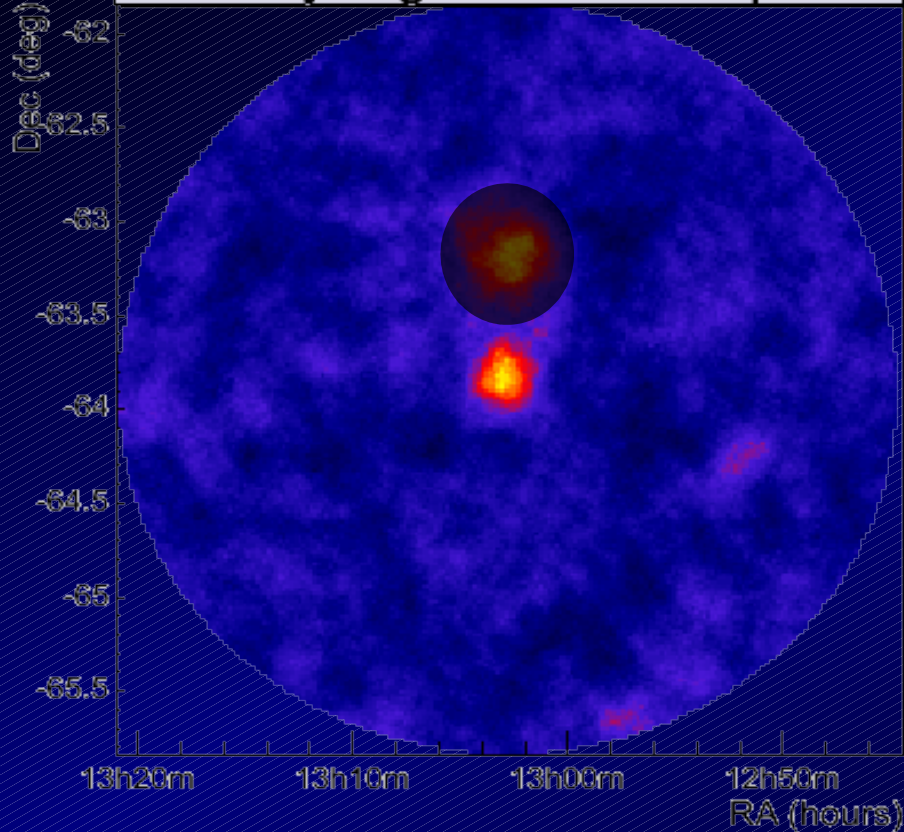




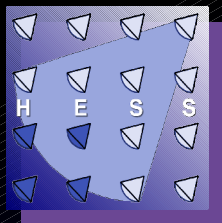
PSR B1259-63



Sky Significance Map

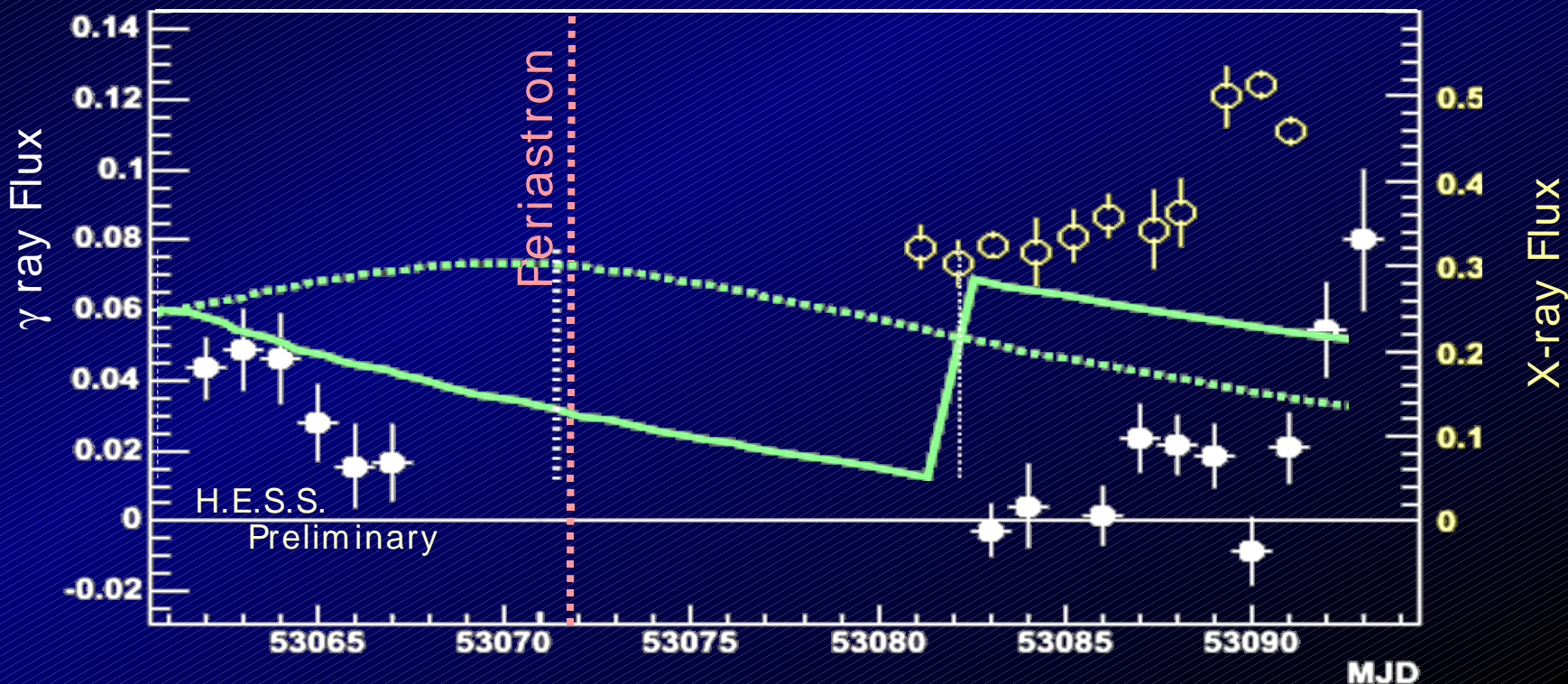


- Pulsar orbiting Massive Star
 - Unique in our Galaxy!
- Complex stellar dance
 - Pulsar passes through Stellar outflow disk every 4 years
- Observed at Periastron
 - Feb - March 2004
 - Peak in emission expected
- Strong detection
 - ~5% Crab Flux
 - Soft energy spectrum
 - Point source
 - Detected again in April/May



Flux variability

- First variable source of TeV γ -rays in our Galaxy
 - Interesting to compare with X-ray light curve
 - Interesting comparison with theoretical models
- More data needed!

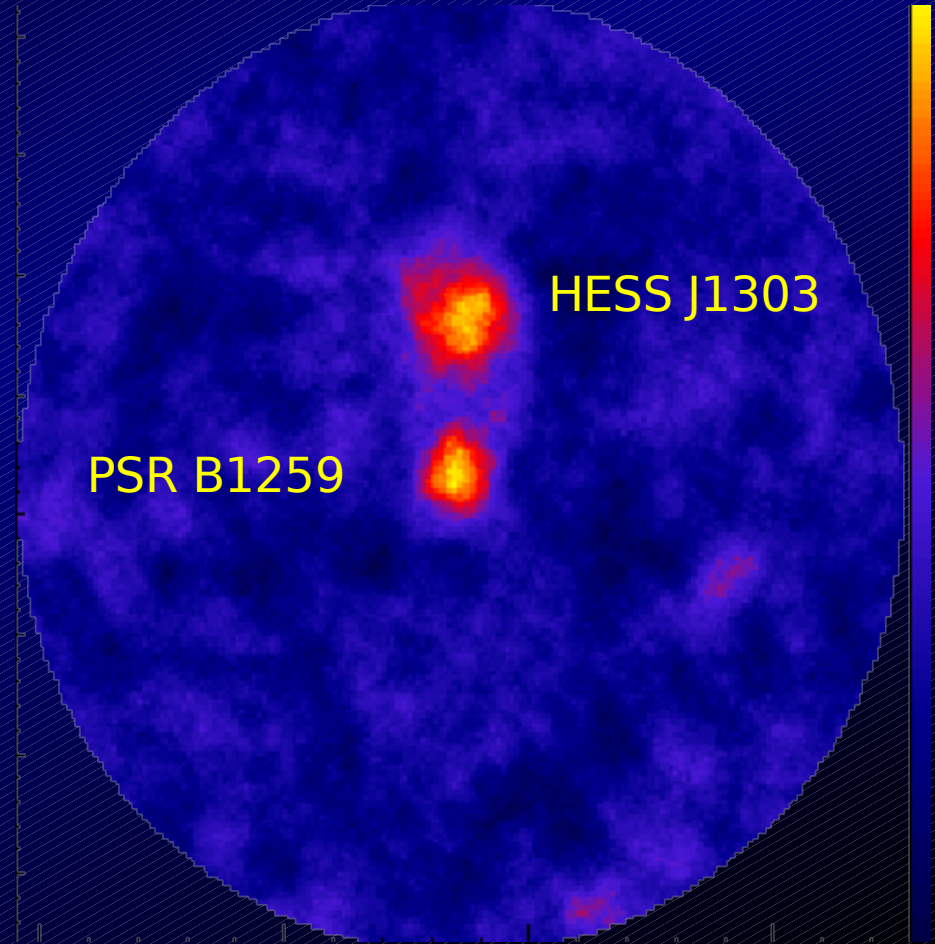




HESS J1303-63

- Unidentified TeV source

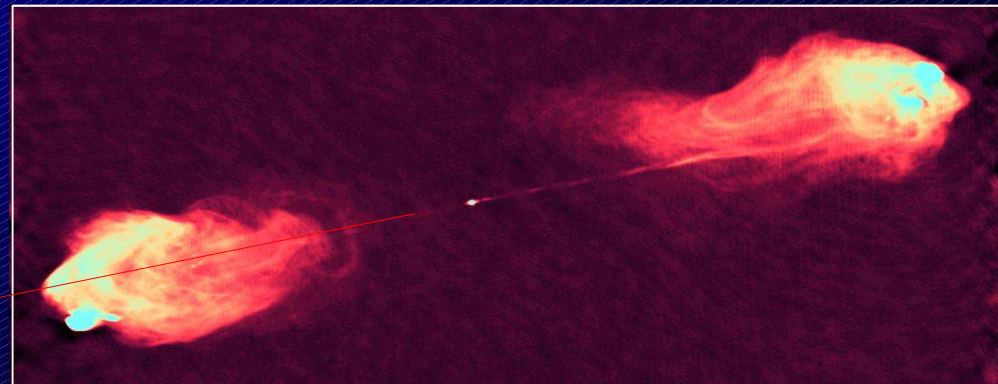
- Steady flux
- energy spectrum differs
- Seems to be extended
- 10% Crab flux





AGN with H.E.S.S.

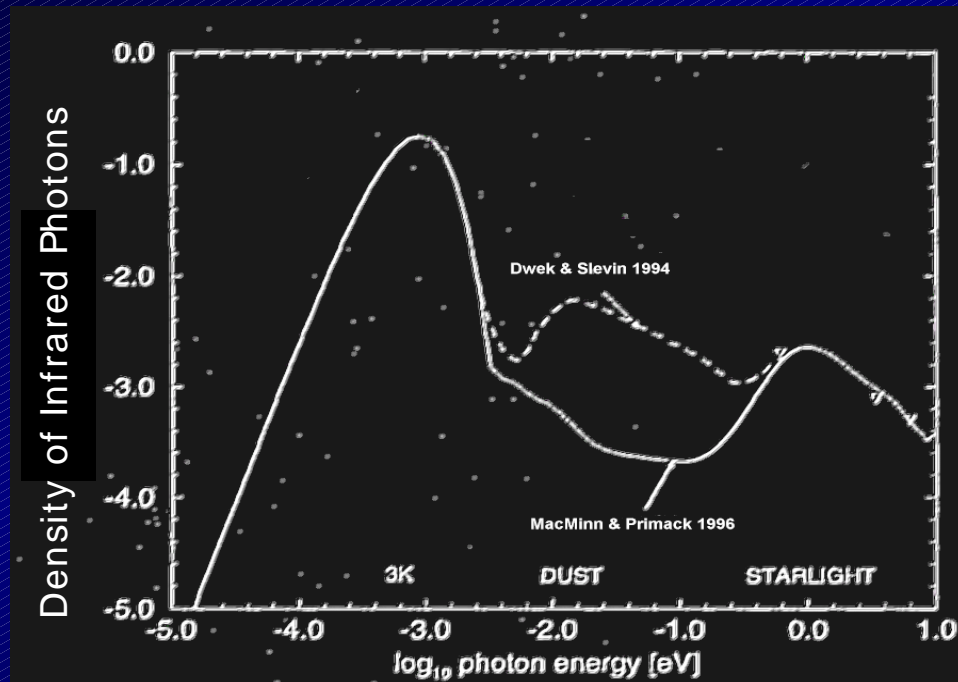
- Active Galactic Nuclei
 - Huge jets of radiation streaming from centres of Galaxies
- Black hole at centre?
 - Matter falling in, accelerated, form massive bipolar jets
 -
- Some AGN pointed straight at us
 - “Blazars”
 - Highly variable - huge flares
 - Emission process unclear
 - Cosmic ray protons?



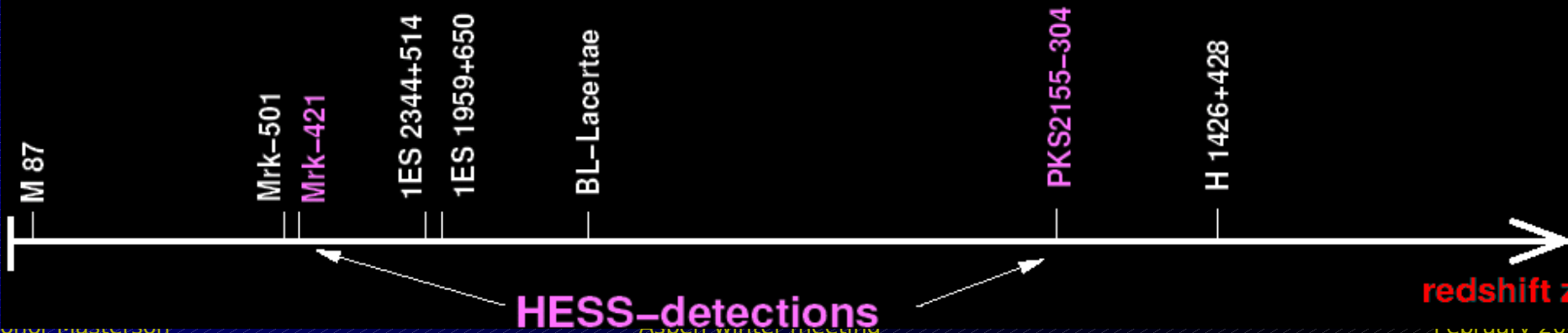


Infrared absorption

- **AGN γ -rays absorbed**
 - Interact with starlight, dust
 - Probe for conditions very far away in Universe
 - Compare AGN at different distances
- **Distant AGN seen by H.E.S.S.**



Distances of GeV/TeV-AGN





Example - PKS 2155

- **First H.E.S.S. Source**

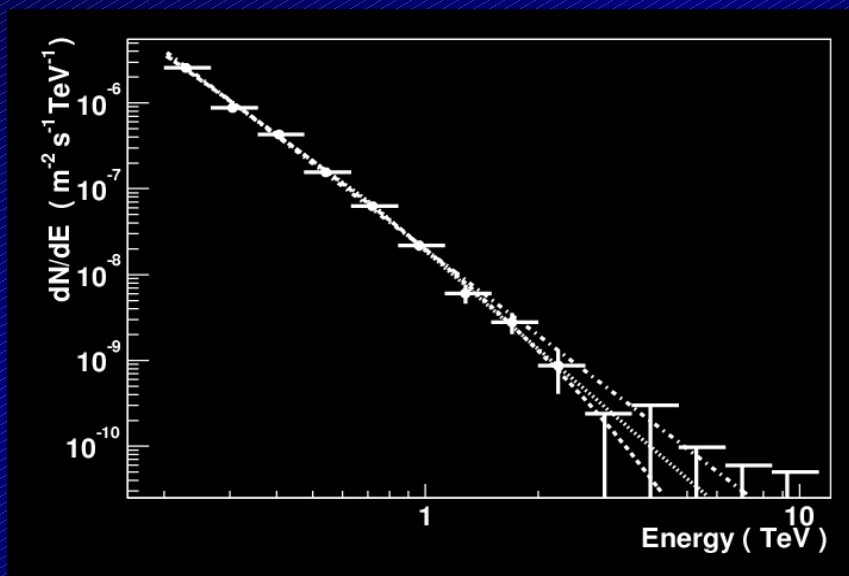
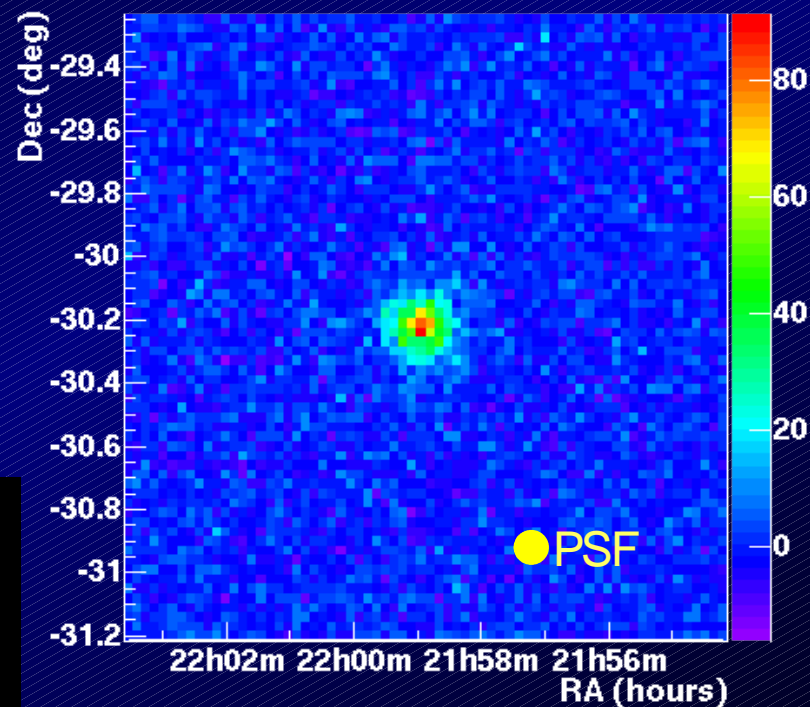
- Detected in 2002

- **Distant AGN**

- Low flux, soft spectrum

- **Some variability**

- Multiwavelength studies



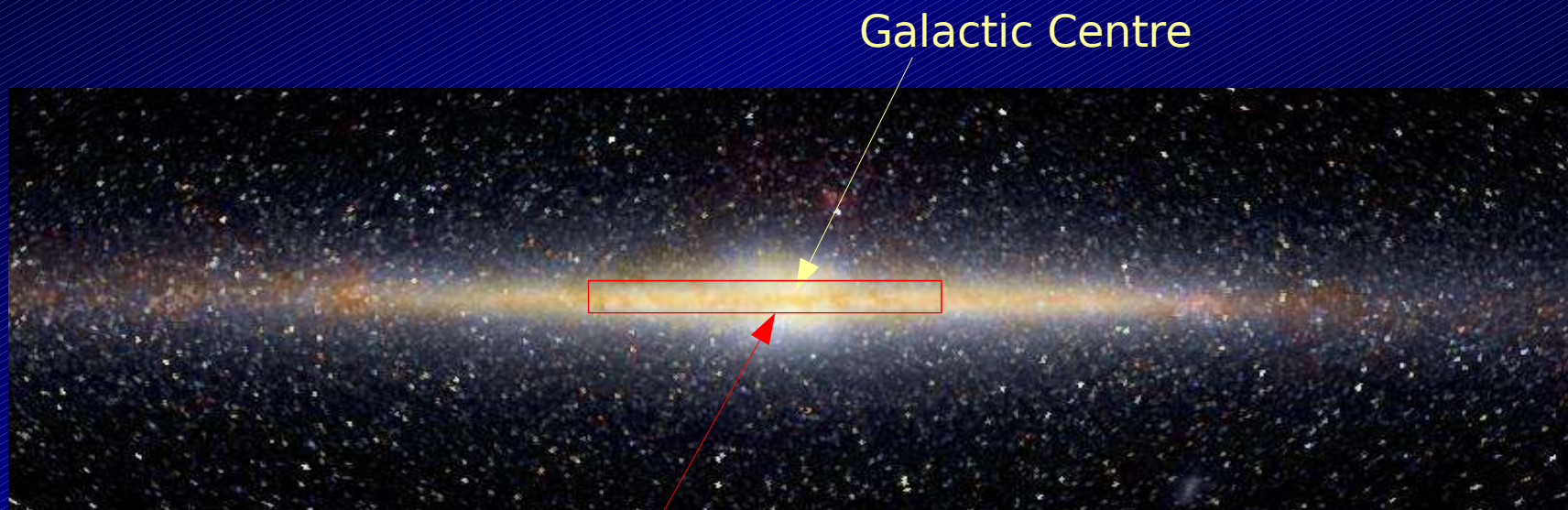
Future observations - surveys



- **Surveying the Galactic Plane**

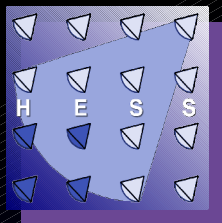
- Selected region around Galactic centre
- Scan entire region with overlapping field of view
- Look for unknown sources of γ -rays

- **Results out real soon now!**



Galactic Centre

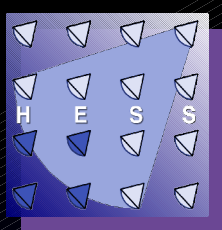
1st H.E.S.S. Galactic survey region



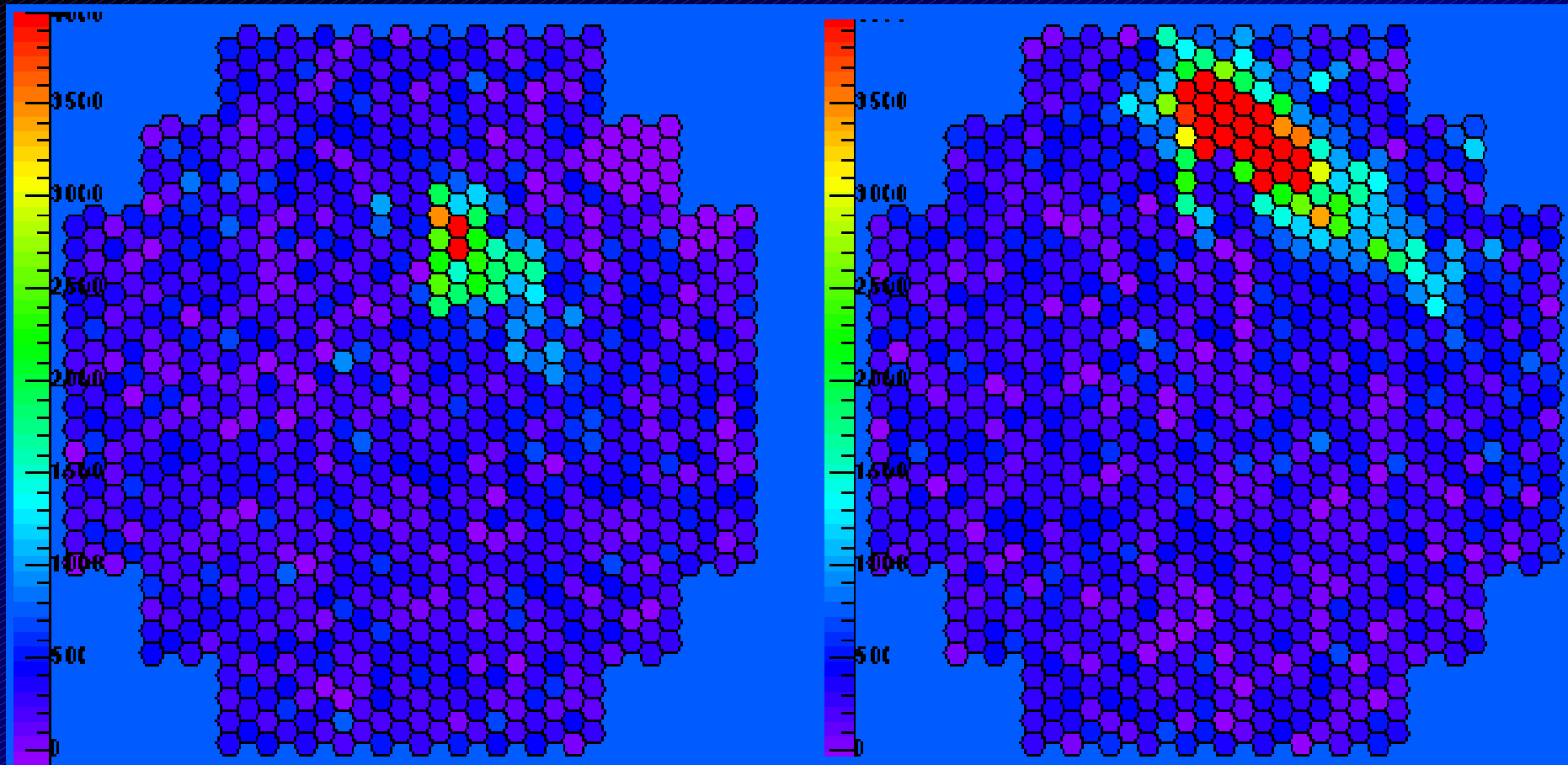
Conclusions



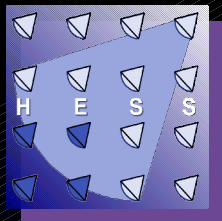
- Achieved design sensitivity with full array
- Techniques
 - Precise spectral measurements of sources at low fluxes
 - Precise positioning
 - Survey capability
 - Interesting LZA observations
- Lots of interesting sources already
 - First three extended TeV sources
 - First variable Galactic source
 - Unidentified TeV source
- Trends
 - Hard spectrum emission from sources in Galactic Plane
 - Extended sources



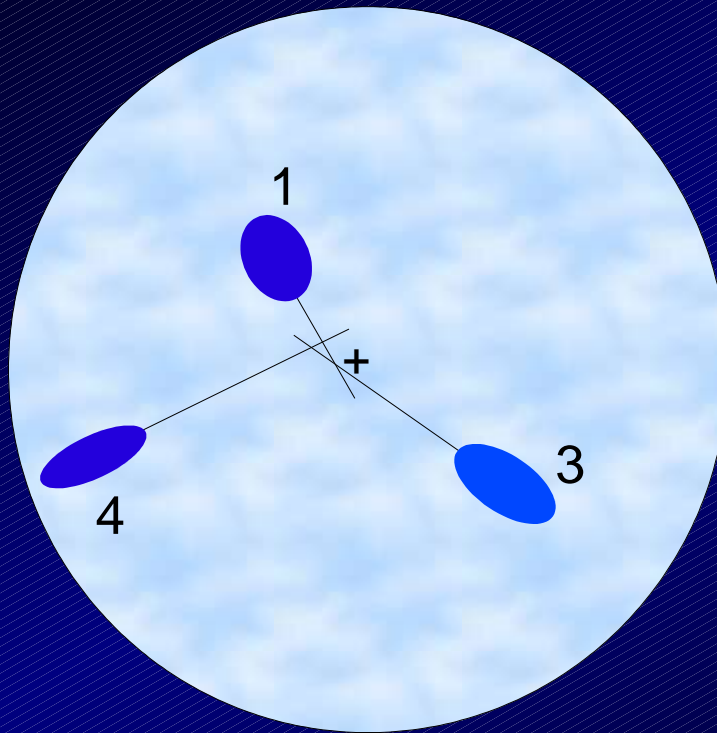
Cherenkov images in Camera



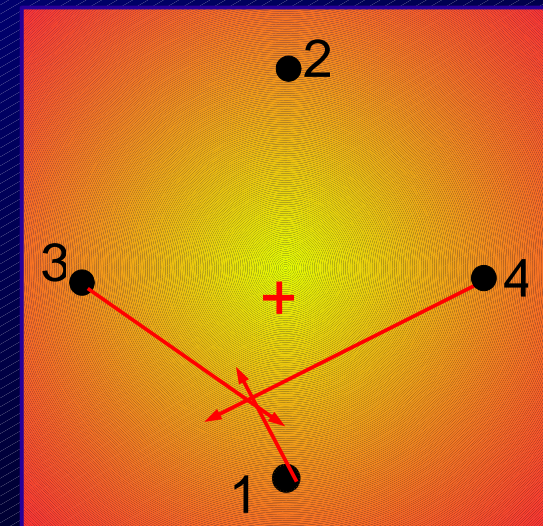
- Large background rate of hadronic cosmic rays



Geometrical Reconstruction



Field of View



Telescopes on Ground

