Astroparticles Group
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In search of TeV halos, new astrophysical objects to reveal our gamma sky map

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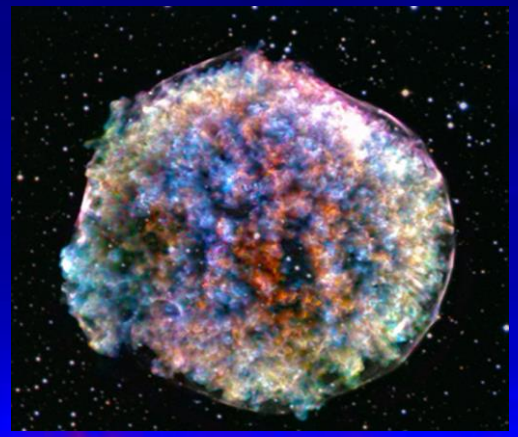
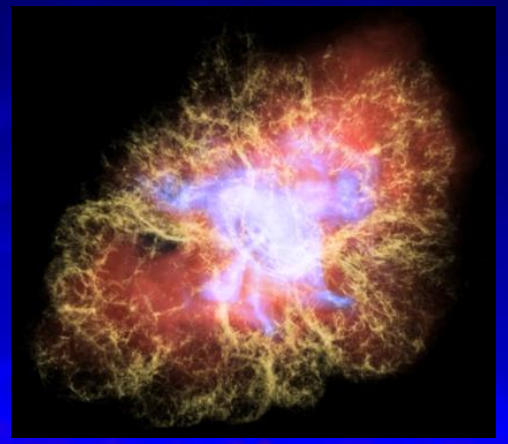
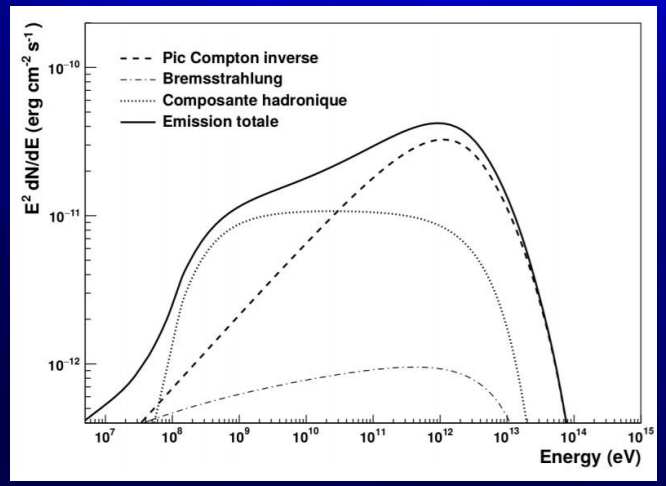
- Study of the most violent and energetic processes in our Universe : supermassive black holes, gamma-ray bursts, pulsars, supernovas,… and especially particle accelerators !





WHAT IS GAMMA ASTRONOMY ?

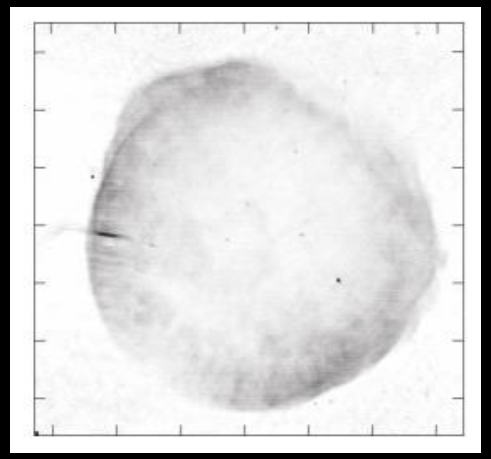
- Greatest form of light energy created by non-thermal production mechanism

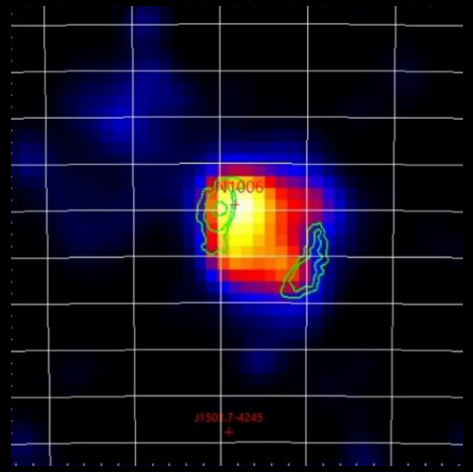


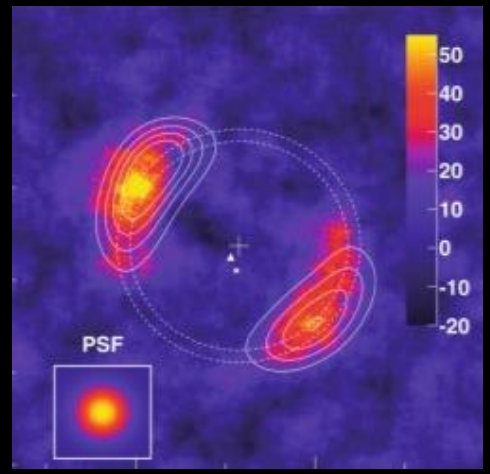
- Two ways to retrace their direction and measure their energy : direct and indirect

Why are we studying the sources of these energies ?

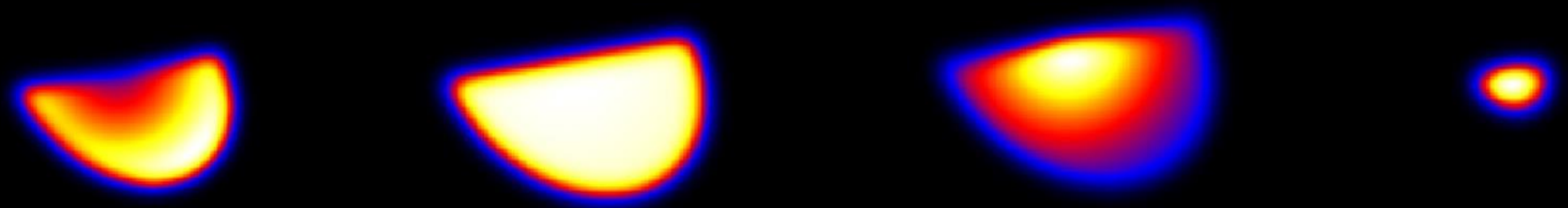
- Multiwavelength studies for more/different informations (SN 1006 supernovae remanent)







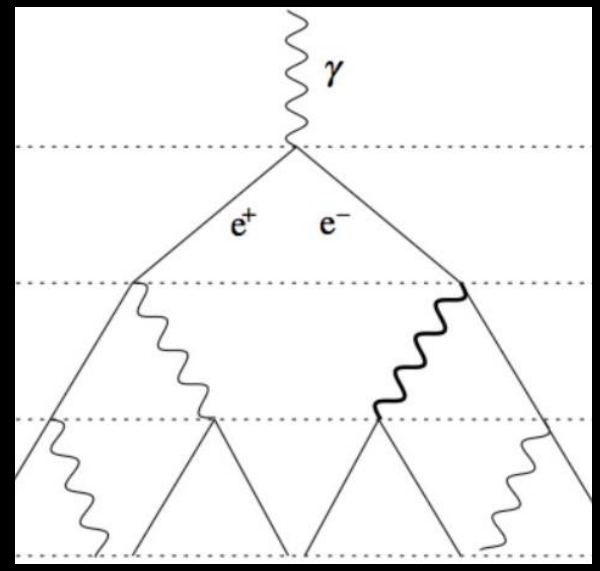
- Some astrophysical sources visible only at these energies (TeV halo, my source)



How do you indirectly detect high energies photons?

In my PhD: On the ground with an imaging atmospheric Cherenkov telescope array from electromagnetic shower

1. Electromagnetic shower



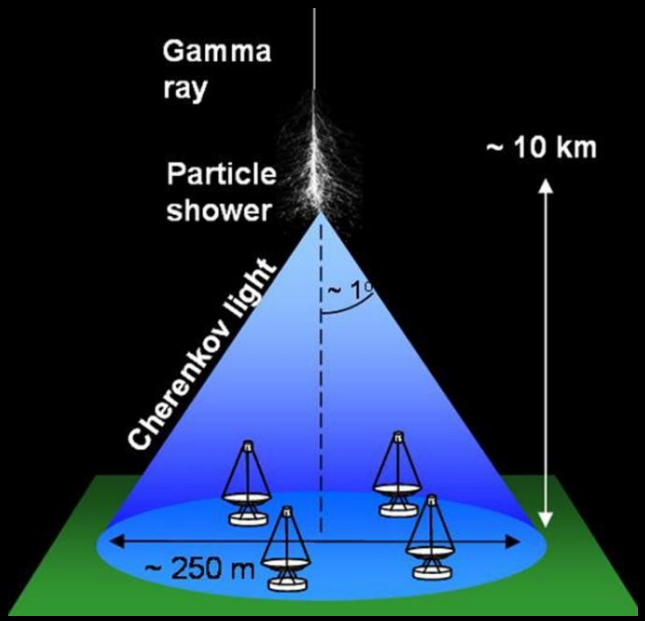
Photons from the astrophysical source

- one γ per m^2 per year from a bright source or per m^2 per century from a faint source
- $\gamma + \gamma^* \rightarrow e^- + e^+$ and bremsstrahlung emission

Electromagnetic shower

Cherenkov light emission

- $v > \frac{c}{n} \Rightarrow E > \frac{mc^2}{\sqrt{1-\frac{1}{n^2}}}$, similar to shock wave
- Emission : brief blue circle of light
- E_γ ↗, photon density ↗, distance ↗

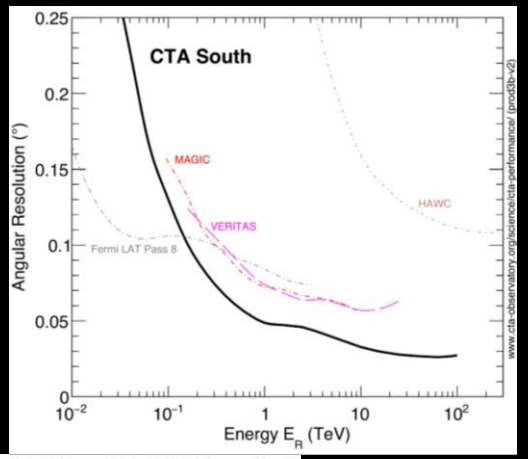


2. How a system of Imaging Atmospheric Cherenkov Telescopes works ?

Instruments and detectors

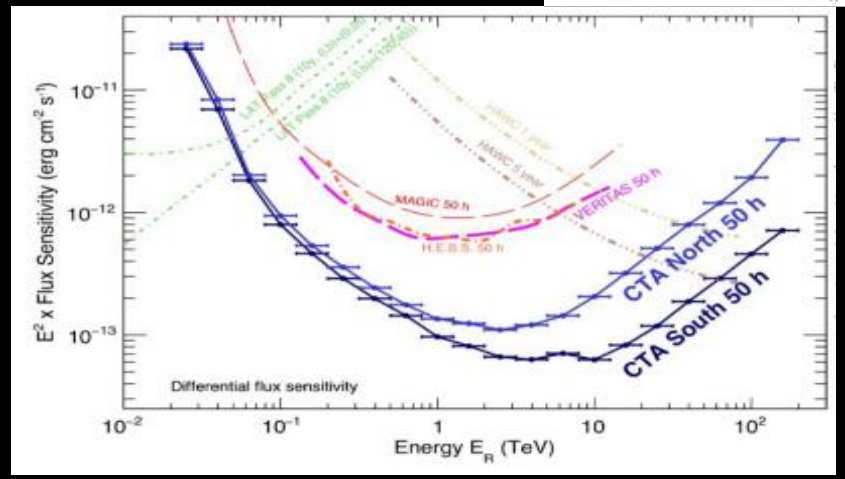
An imaging Atmospheric Cherenkov Telescope

- Mount quickly on the source
- Large reflecting mirror focusing photons
- High speed camera (short flash) and fine pixelation (sensitivity)
- Photomultipliers

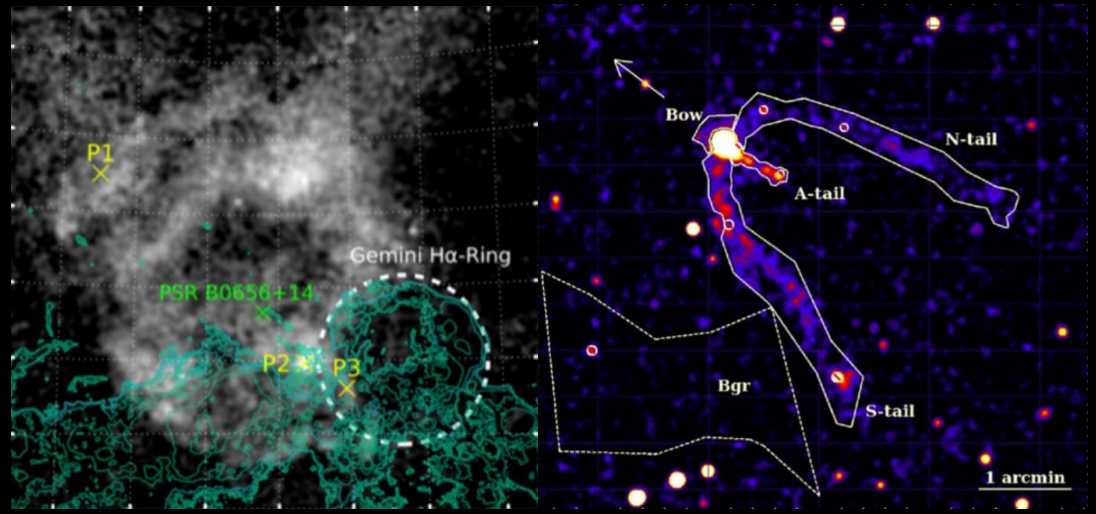


Imaging Atmospheric Cherenkov Telescopes array

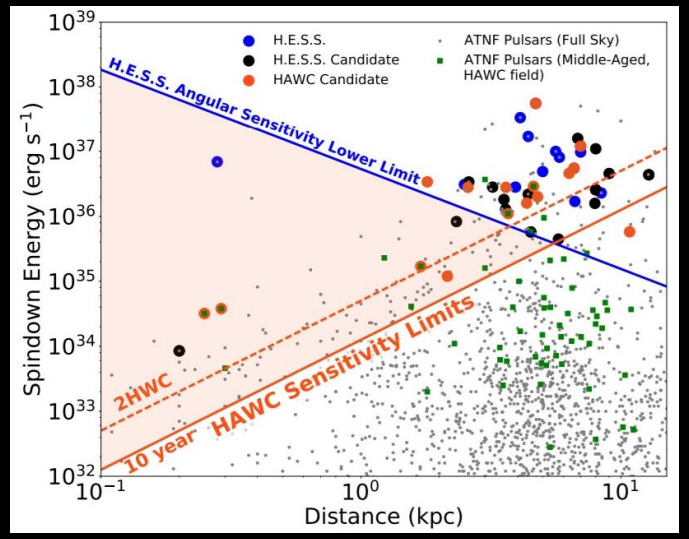
- γ direction reconstruction
- γ energy reconstruction
- Large field of view : to increase the probability of detection
- HESS and CTA



Why are you studying the halo at TeV?

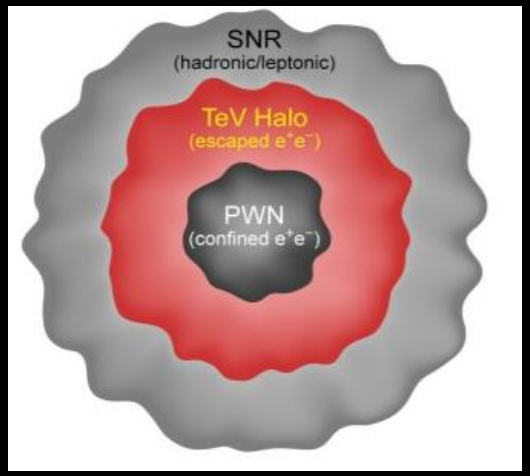


- Discovered less than 5 years ago by HAWC
- Observed of excess positrons at Earth by Pamela and AMS: PWN/TeV-halos ?
- Detection 3-40 with HESS, 30-160 with CTA ? → TeV galactic dominant emissions and the nature of a TeV halo ?
- Confined and escaped particles experience substantially different physical conditions



What is a TeV halo ?

- TeV-halo :
  - interactions of $e^{+/-}$ that escaped from the Pulsar wind nebula
  - trapped in larger region with pure diffusion

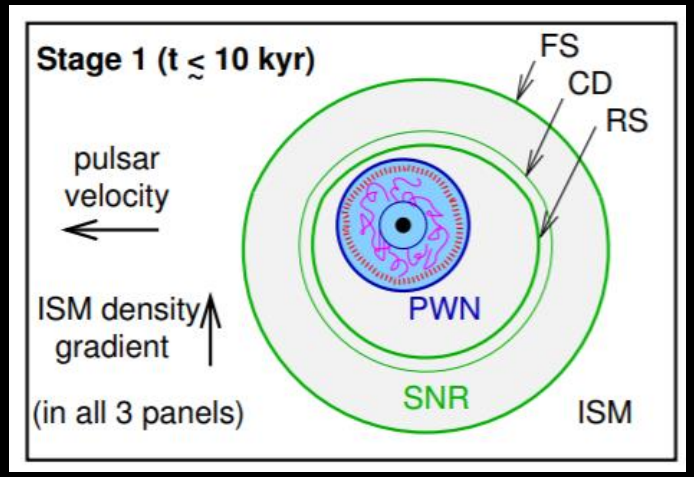


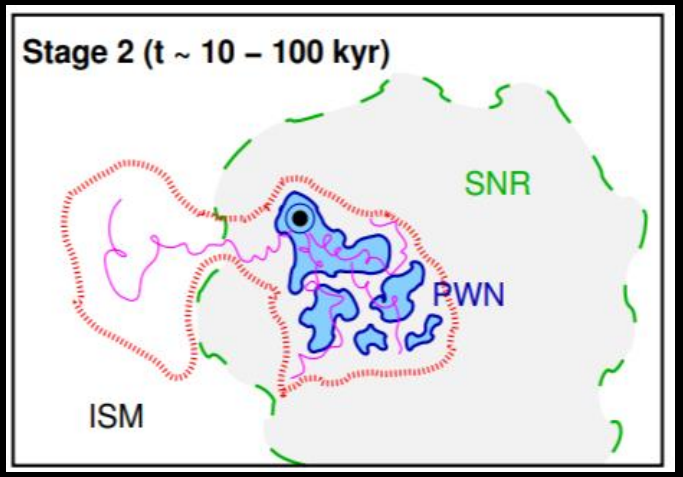
Evolution to the halo from a PWN…

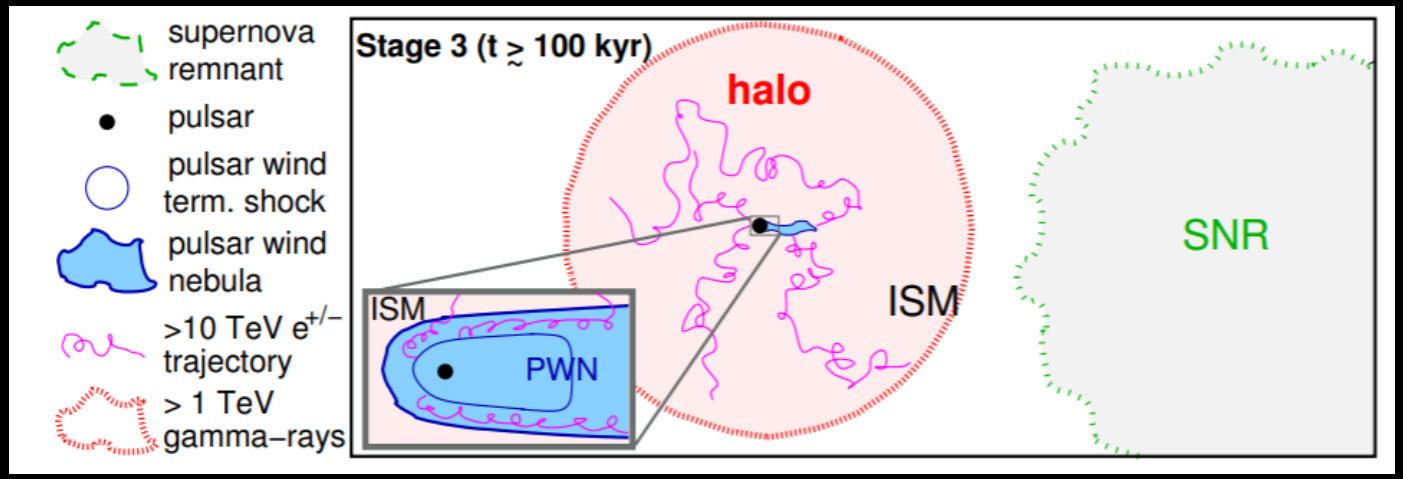
Stage 1 : Age $\leq 10\ kyr$, PWN in SNR and before reverse shock interact with PWN : $e^{+/-}$ giving TeV in PWN

Stage 2 : Age $\sim 10 - 100 kyr$, PWN disturbed by reverse shock, before pulsar escapes SNR: $e^{+/-}$ giving TeV start to escape from PWN

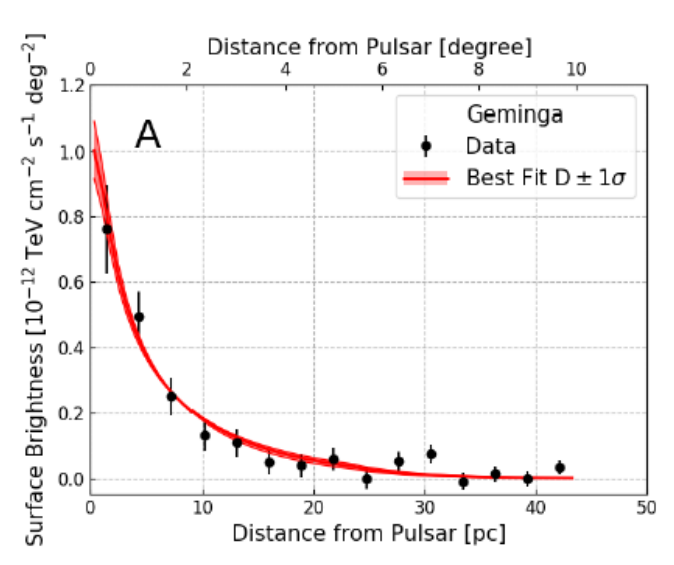
Stage 3 : Age $\geq 100 kyr$, pulsar escapes SNR which disappears, high energy $e^{+/-}$ in ISM and can form TeV-halo

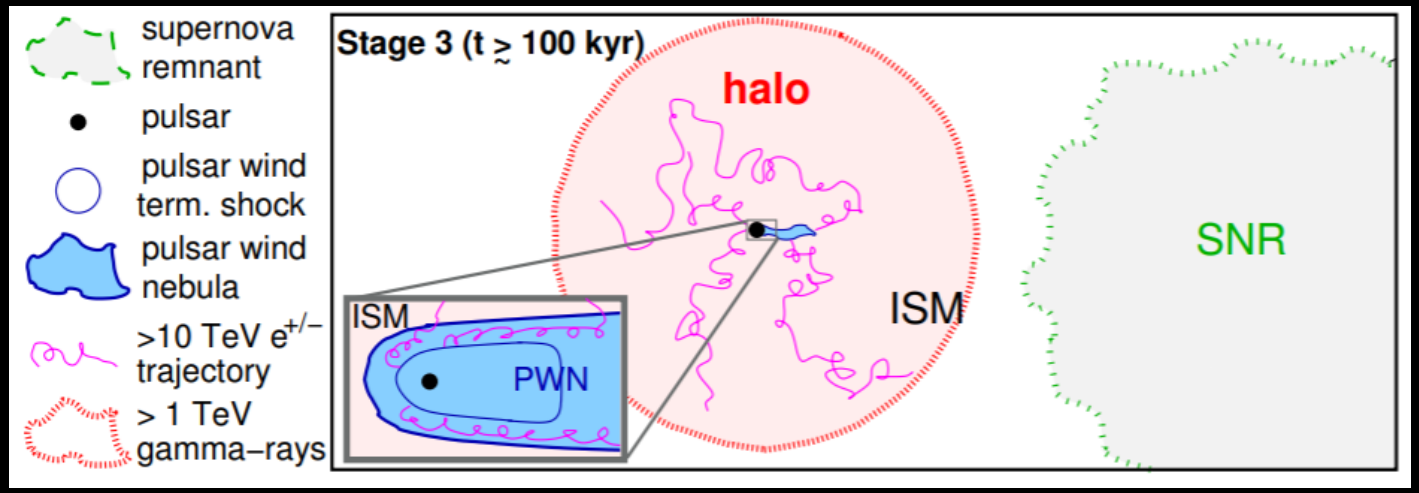






Most recent theoretical results on this unknown acceleration of particles



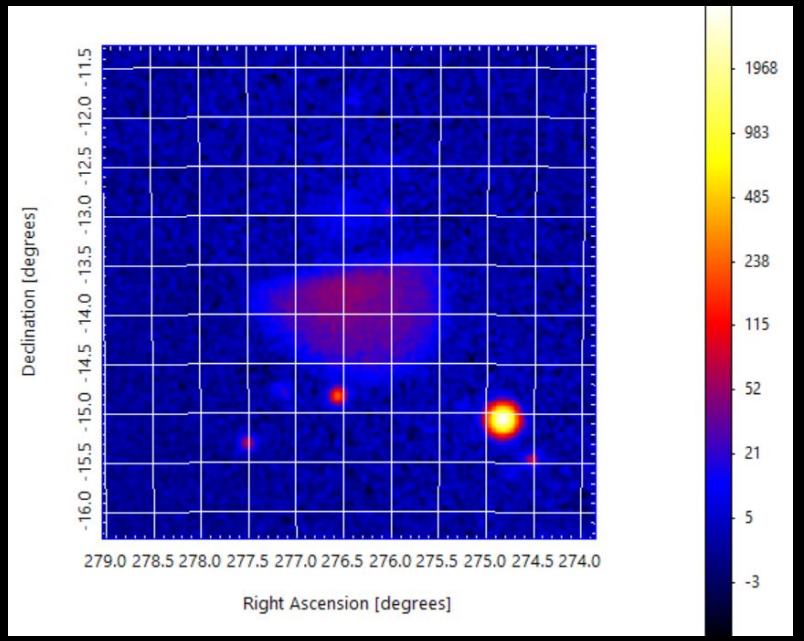


- An original gamma-ray profiles
- 3 main explanations:
  1. Diffusion in SNR-generated turbulence
  2. Combined ballistic and diffusive paths
  3. $e^{+/-}$ pair resonant streaming instability

PhD objective : How to analyze these halos?

Objective: Developing codes/strategies for this difficult sources analysis:

1. very extensive, larger than the field of view
2. Faint, flux close to that of the galactic background
3. highly energy dependent



General Idea of analysis:

Selected data + IRF + Defined sky model

↓

model optimization : spatial and spectral parameters fitting by optimizer

↓

Overall spectrum = flux as a function of energy and morphology of the source

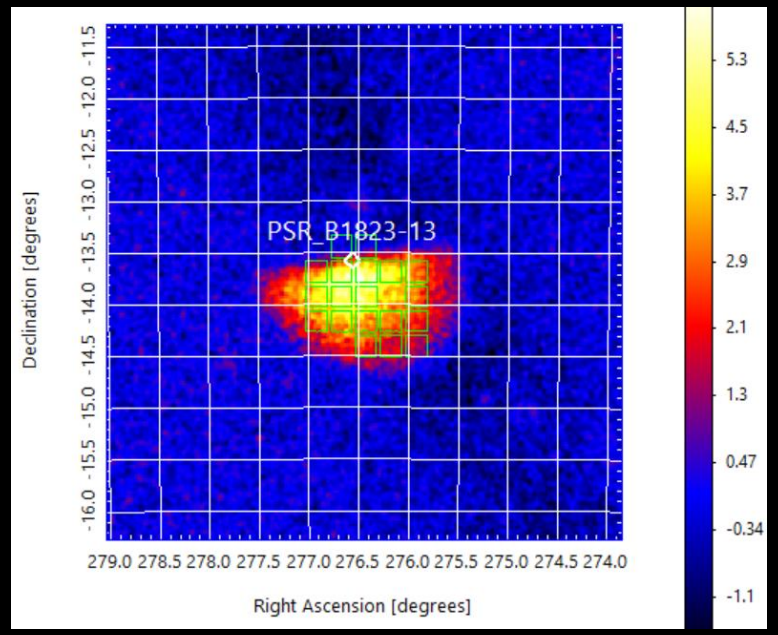
+

Detail on slope of the spectrum as a function of the distance to the pulsar

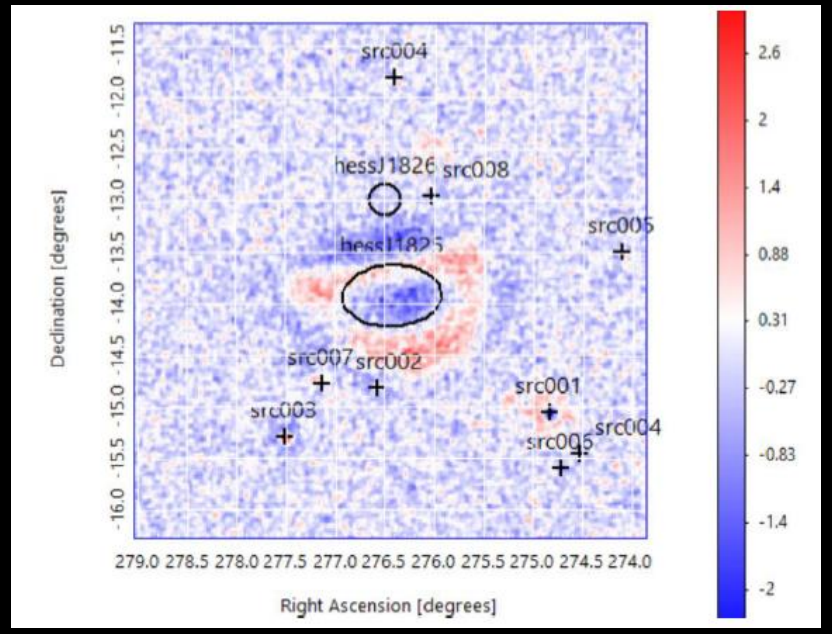
+

Morphological evolution of the source as a function of energy

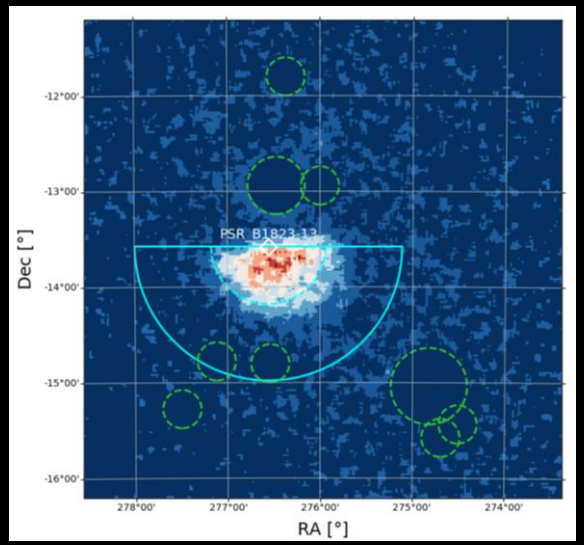
Methods always methods



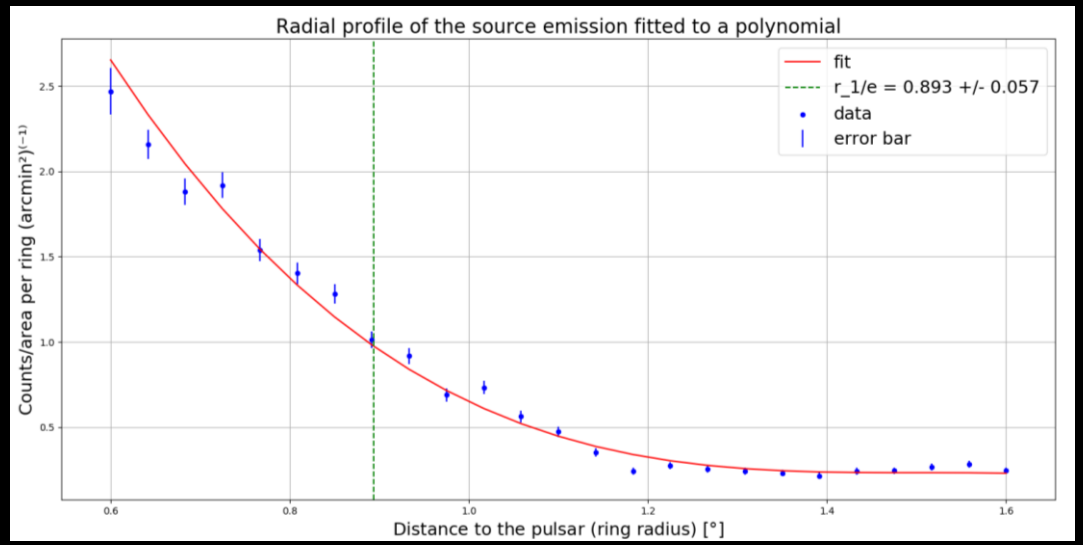
Test Morphological and spectral model and check with residuals map:



Spectral Index (spectrum slope) in little spatial boxes surrounding the source

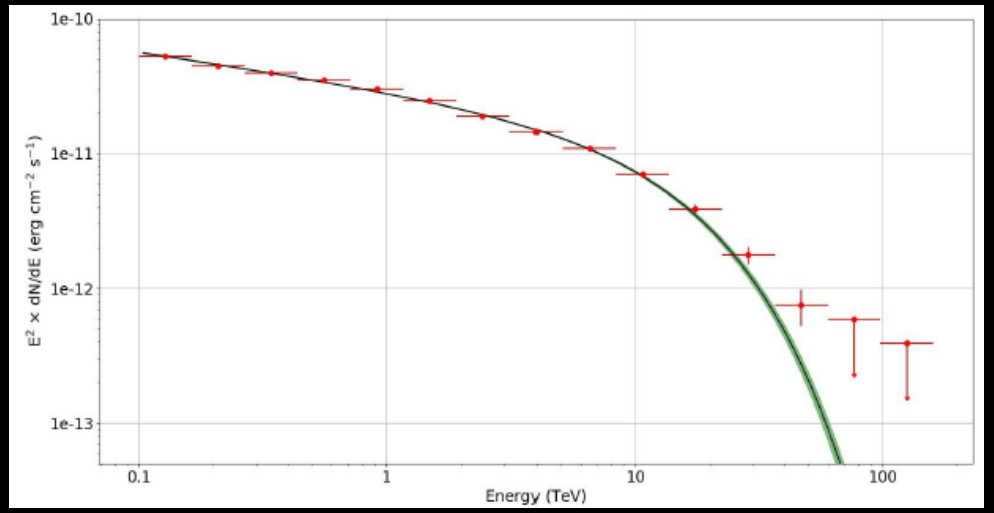


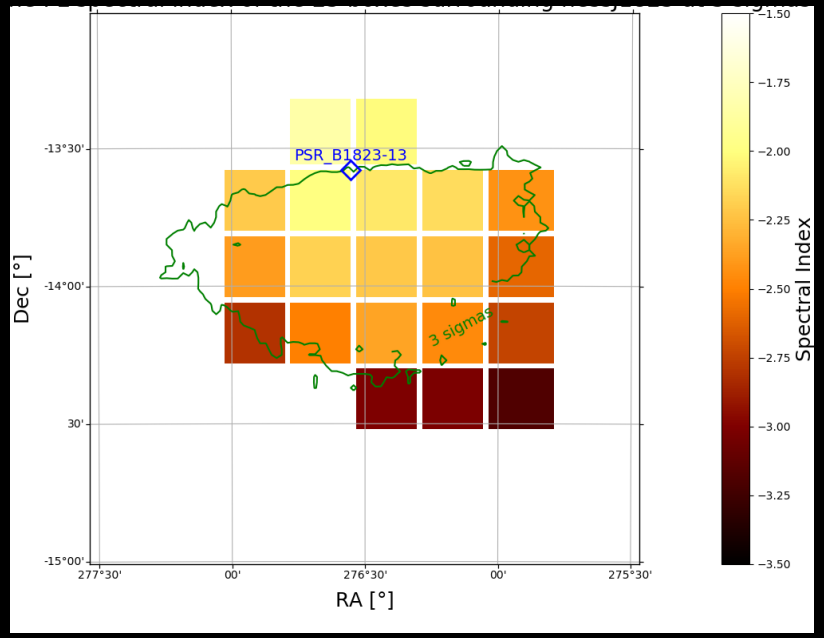
Radial profile of the source: counts in function of the distance



Some results of the First studied source for my PhD : Hess J1825-137

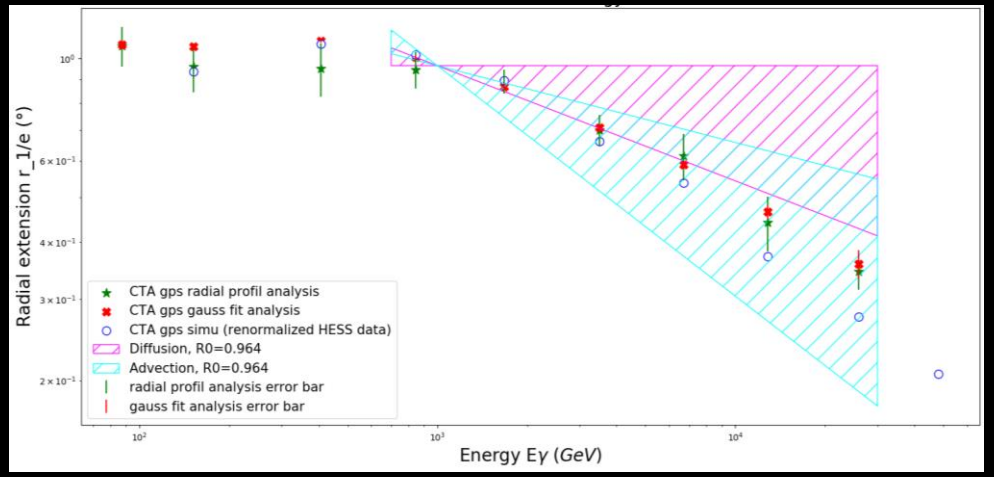
Spectral energy distribution





Spectral index depending on the position on the source

Radial extension of the source as a function of the energy: advection or diffusion ?



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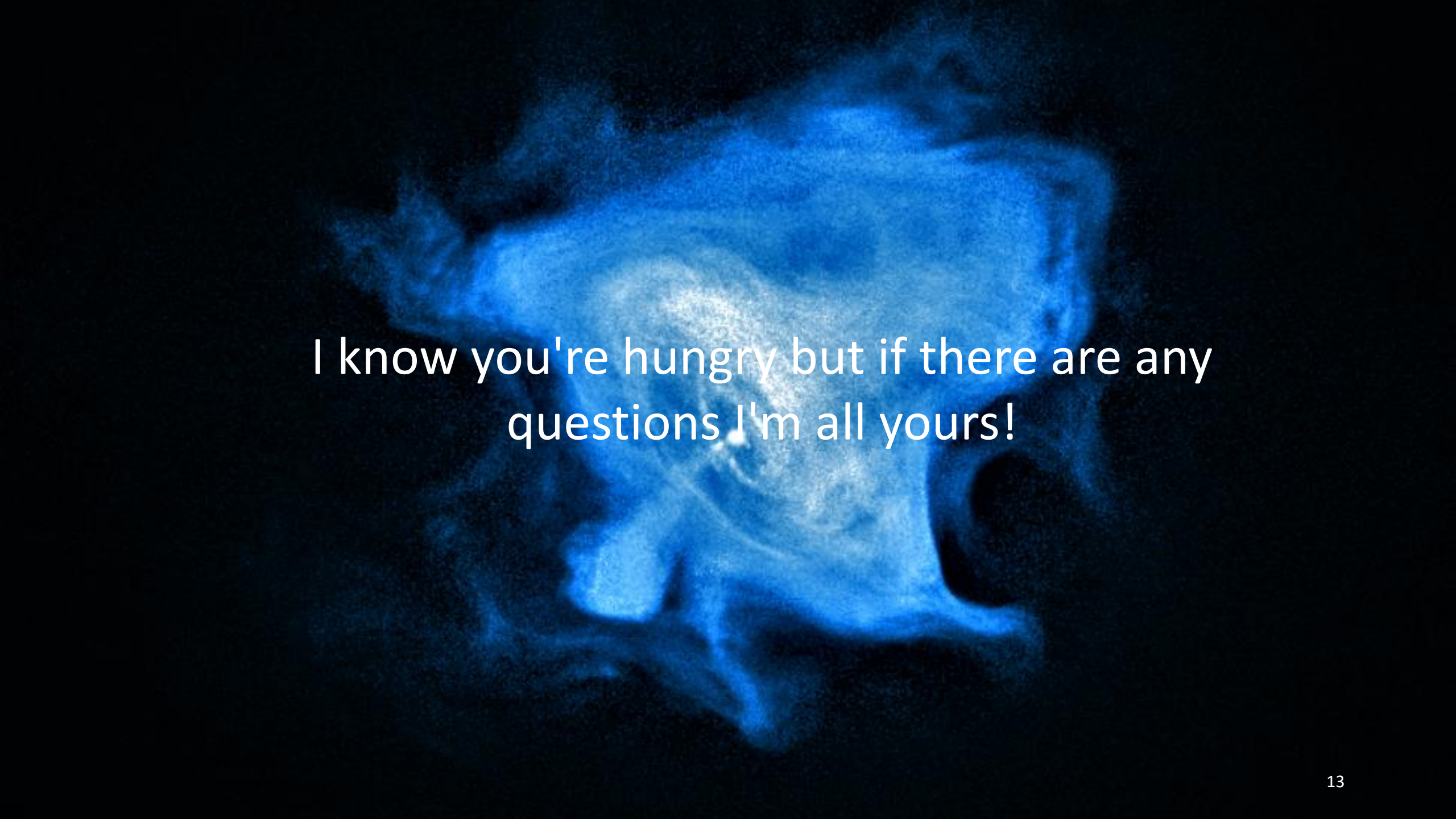
I know you're hungry but if there are any questions I'm all yours!