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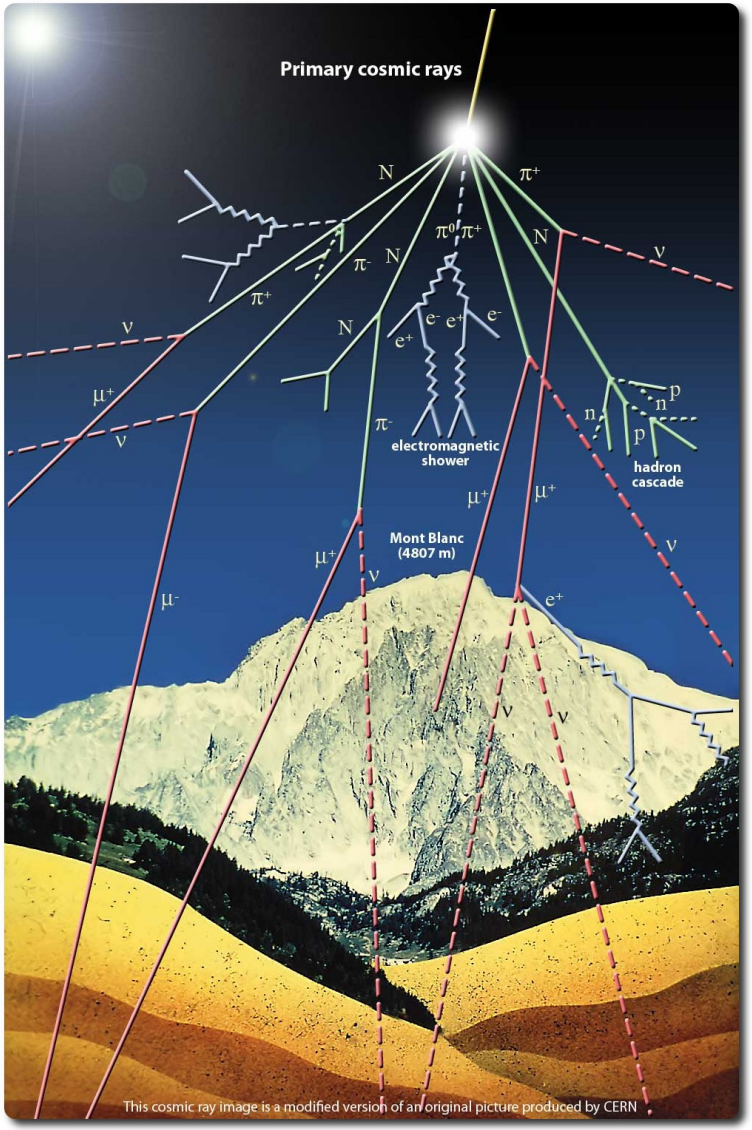
(2nd year)
CENBG (Bordeaux)

JRJC 2015

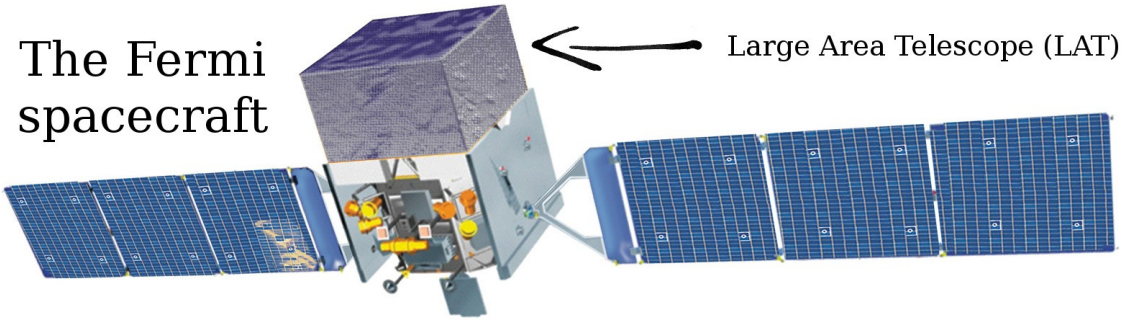
Observation of Supernova Remnants at high energy with the Fermi Large Area Telescope

Outline

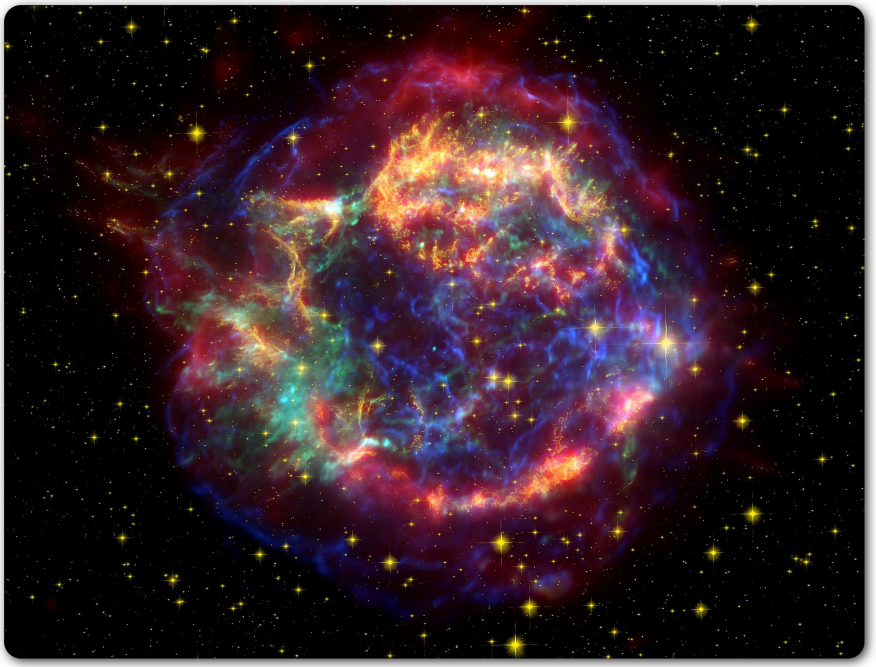
1. Cosmic rays



2. Fermi-LAT



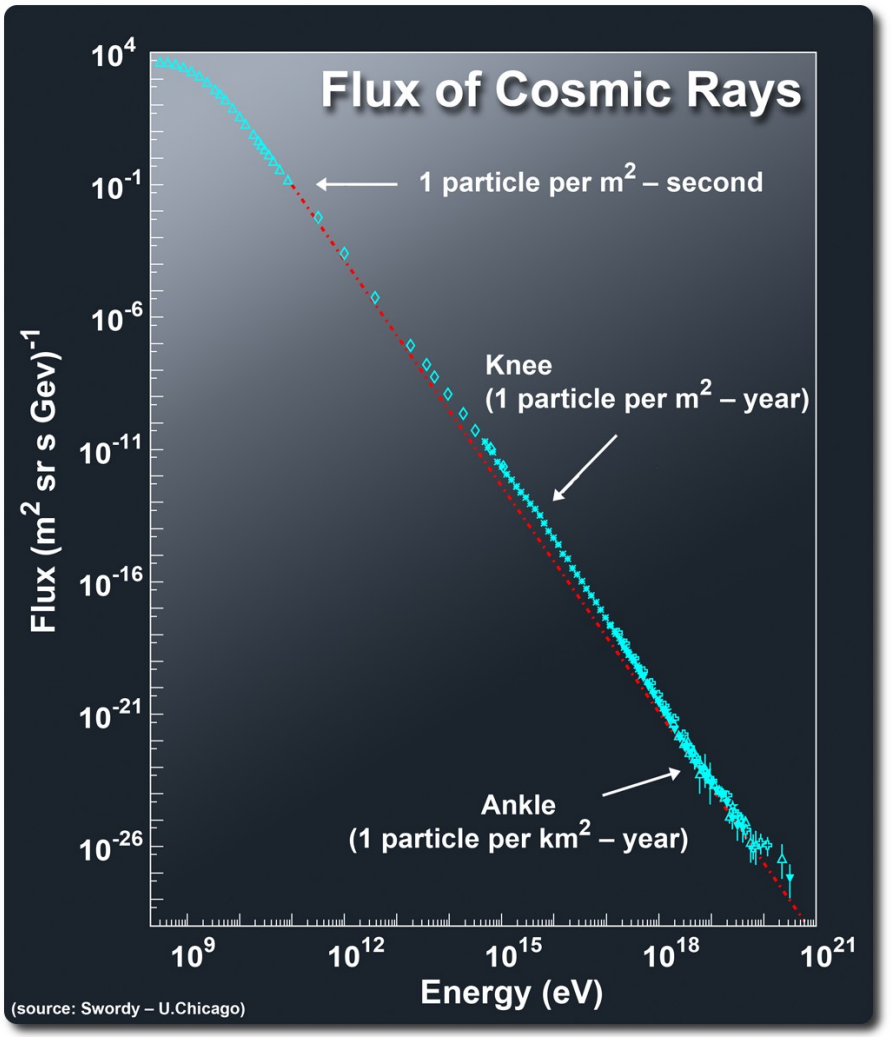
3. Supernova Remnants



Cosmic rays

About cosmic rays...

> Highly energetic particles coming from space
> 1912 : discovered by Victor Hess
> Galactic and extra-galactic origin



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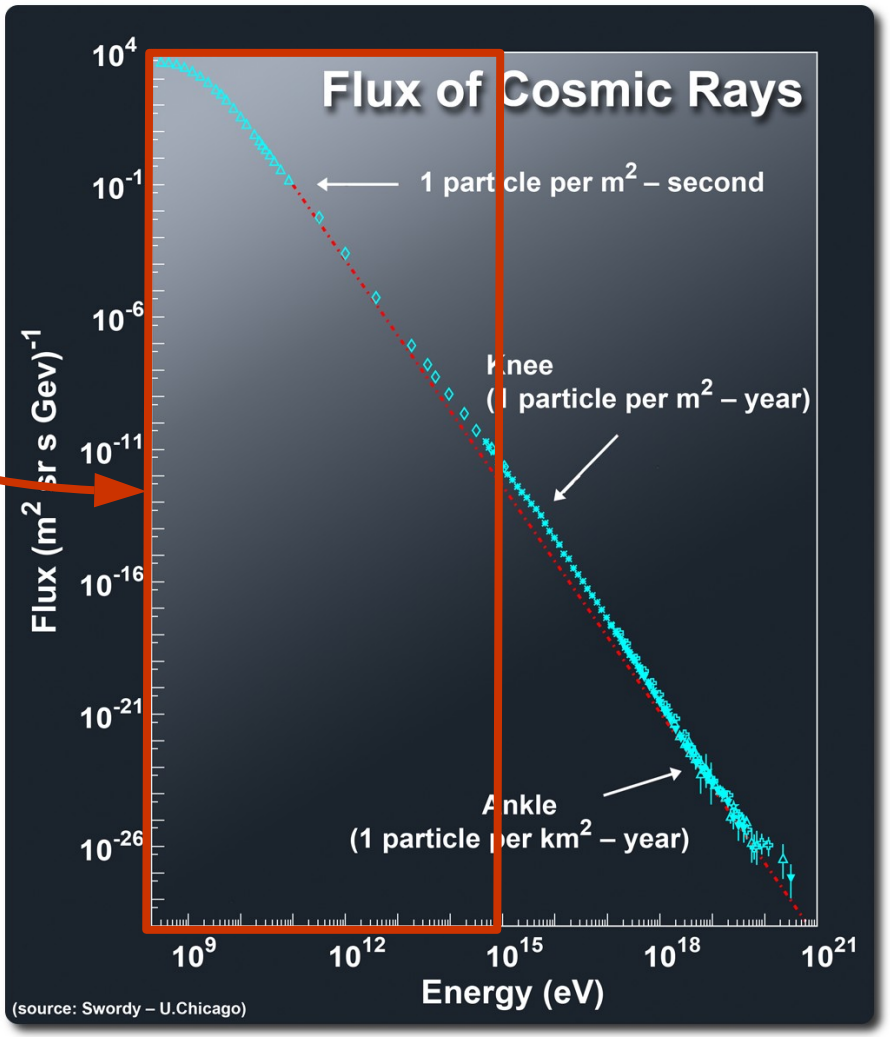

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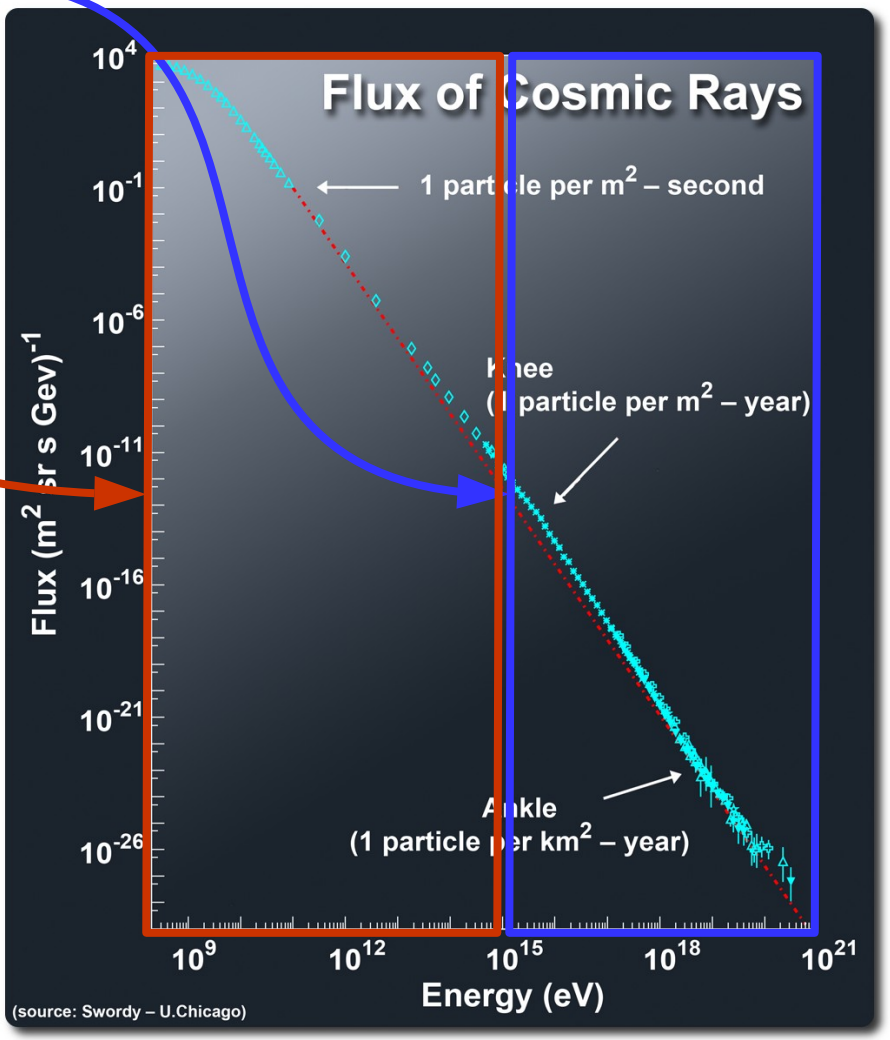

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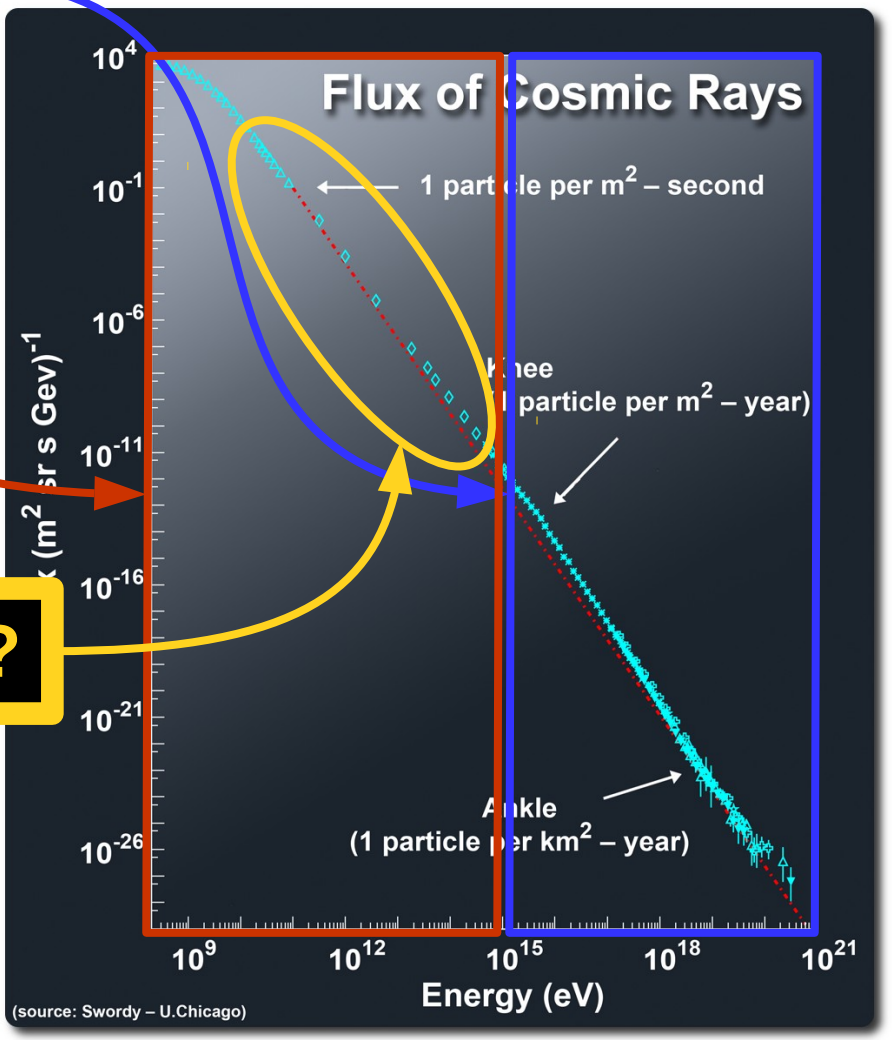
Supernova Remnants ?



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- Usefulness of Gamma Astronomy :

  ==> Search for cosmic ray accelerators using gamma rays

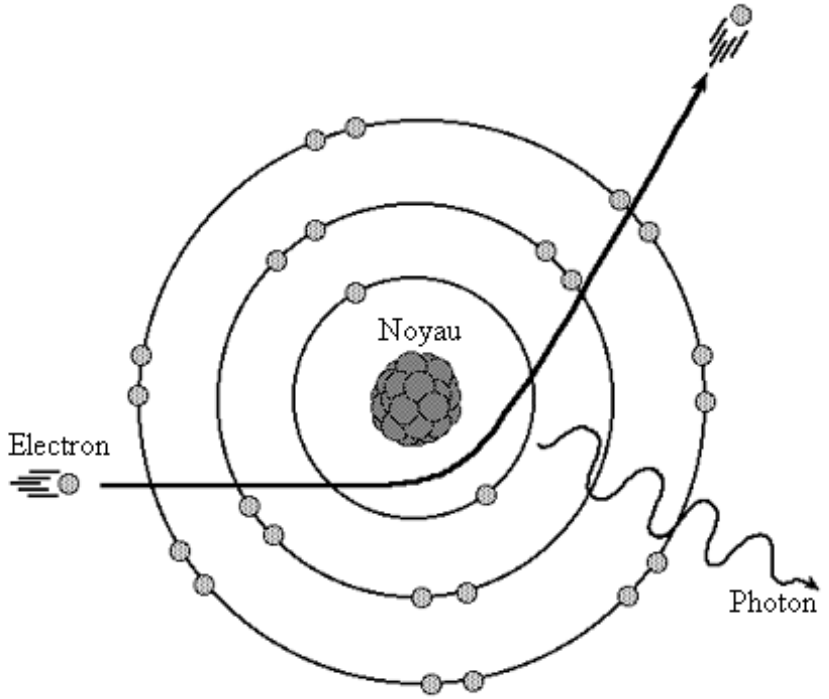
  Ground-based telescope : H.E.S.S., Veritas, MAGIC, ...

  Space-based telescope : Fermi Large Area Telescope

Gamma-ray emission in SNRs

Gamma ray emission in SNR

- Three ways to produce gamma-rays in SNR :
  - **Bremsstrahlung radiation (charged particules)**
  - Inverse Compton Scattering (electrons)
  - Decay of neutral pions (protons)



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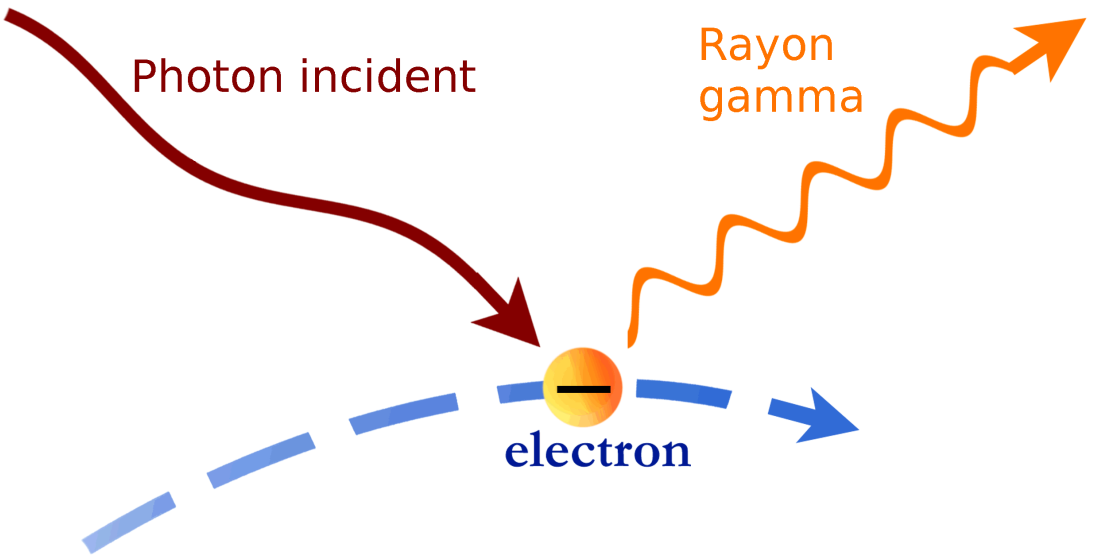

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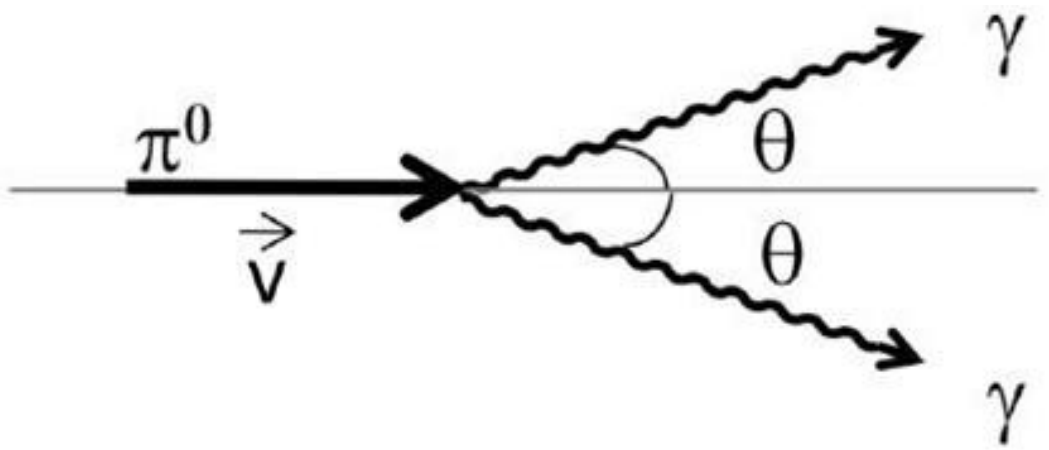
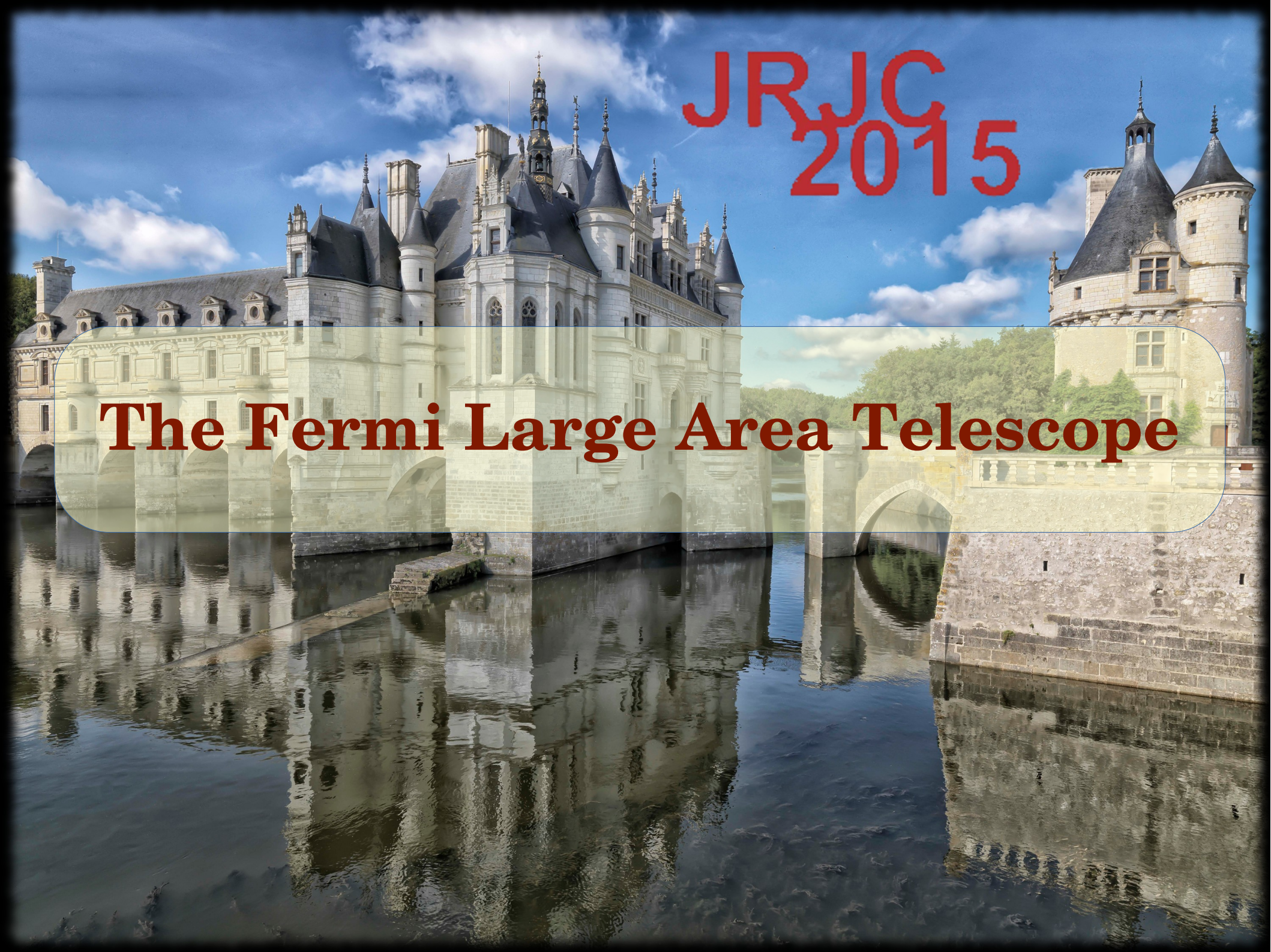
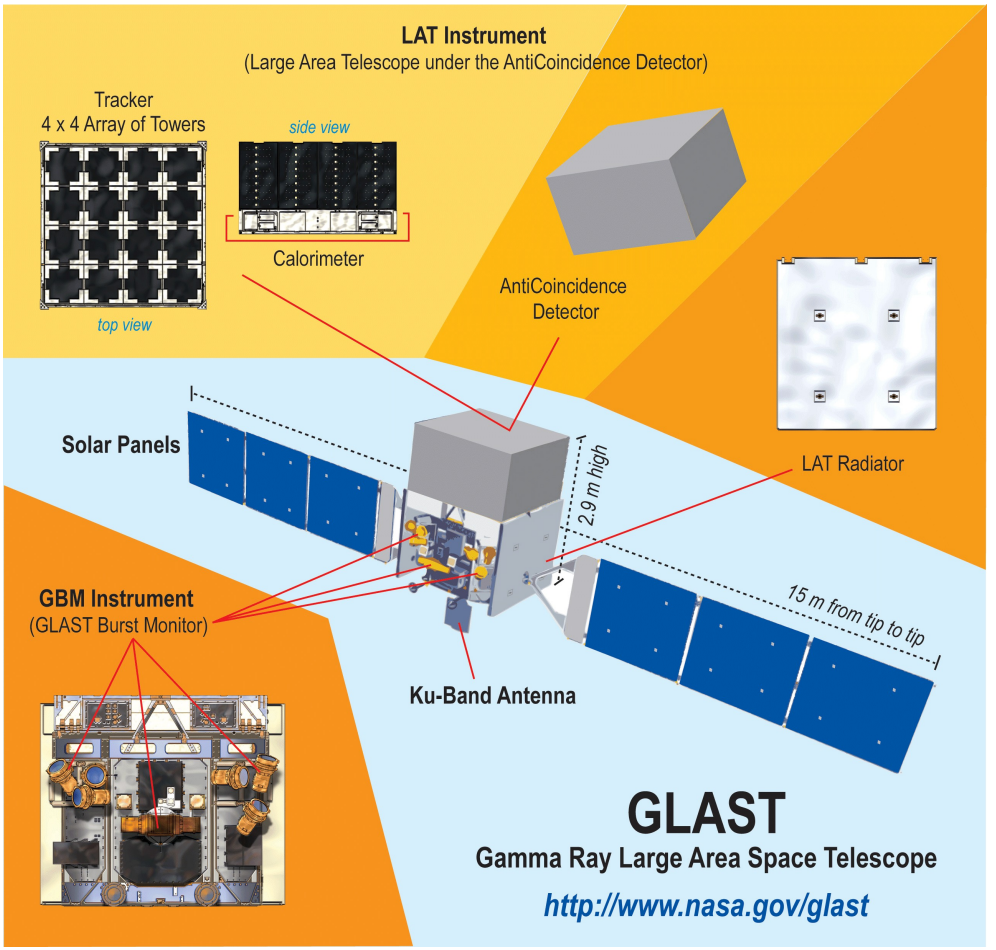




The Fermi Large Area Telescope

The Fermi - Large Area Telescope (LAT)



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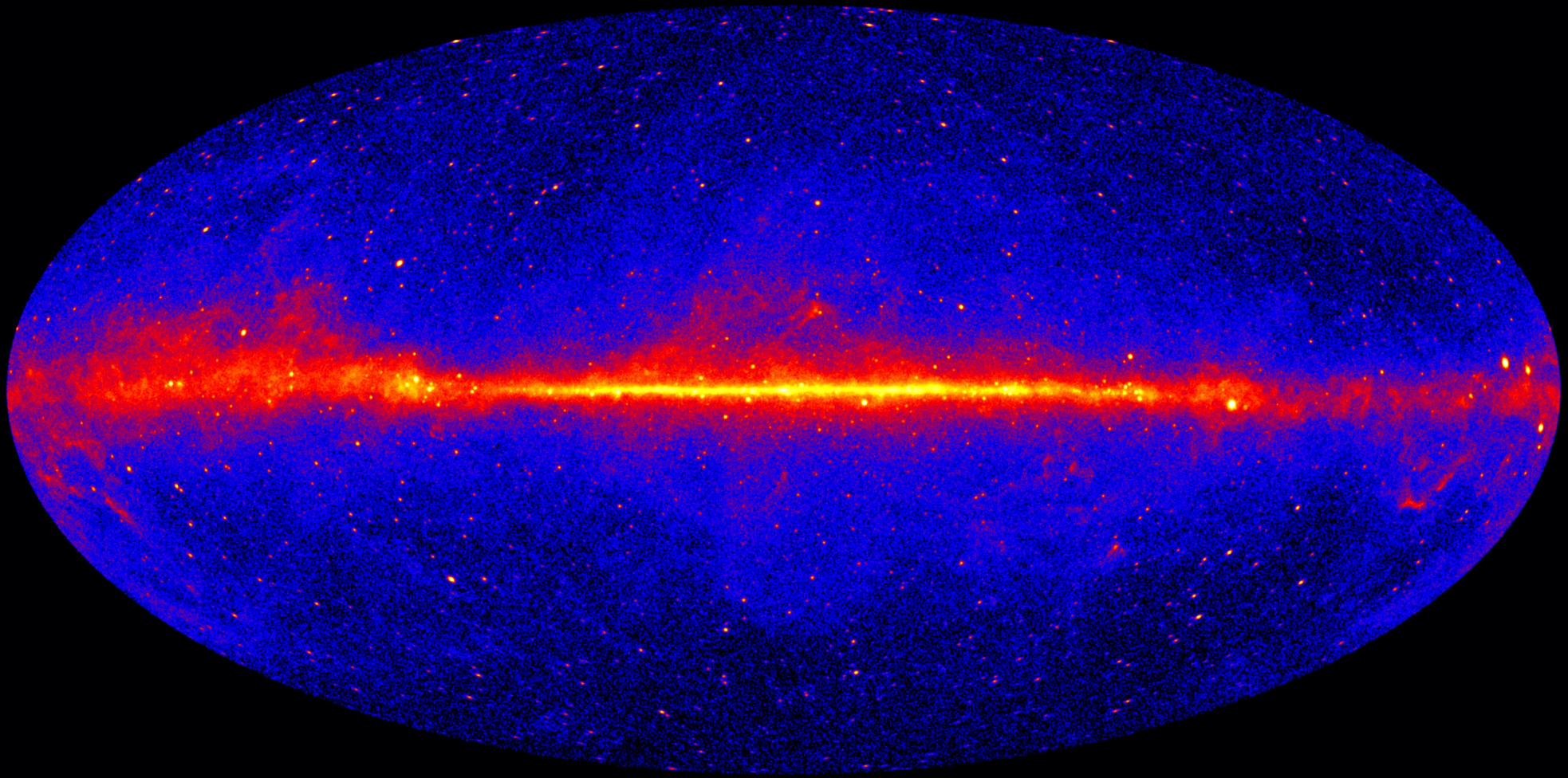


6 years of observations with Fermi-LAT

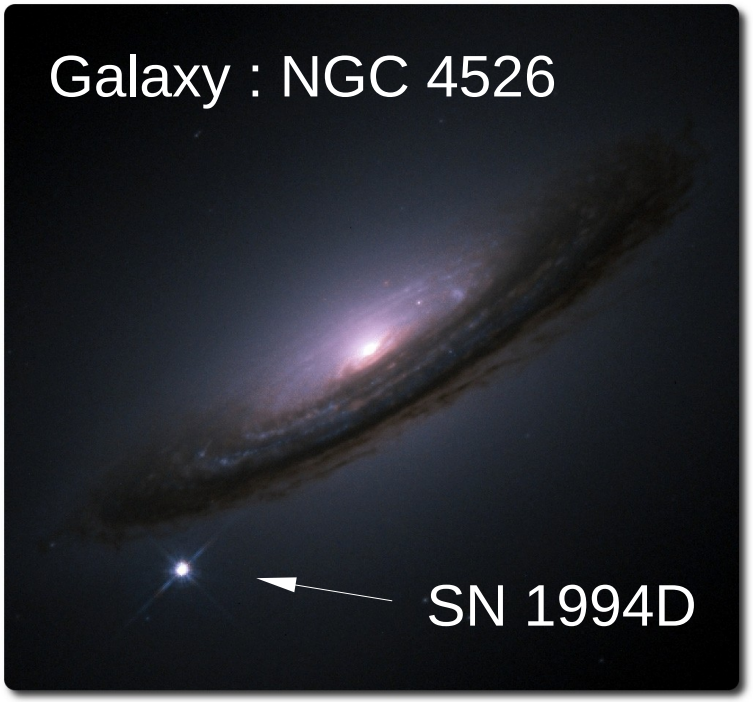
SuperNova Remnants (SNR)

Supernova Remnants

- First things first : what is a supernova (SN) ?

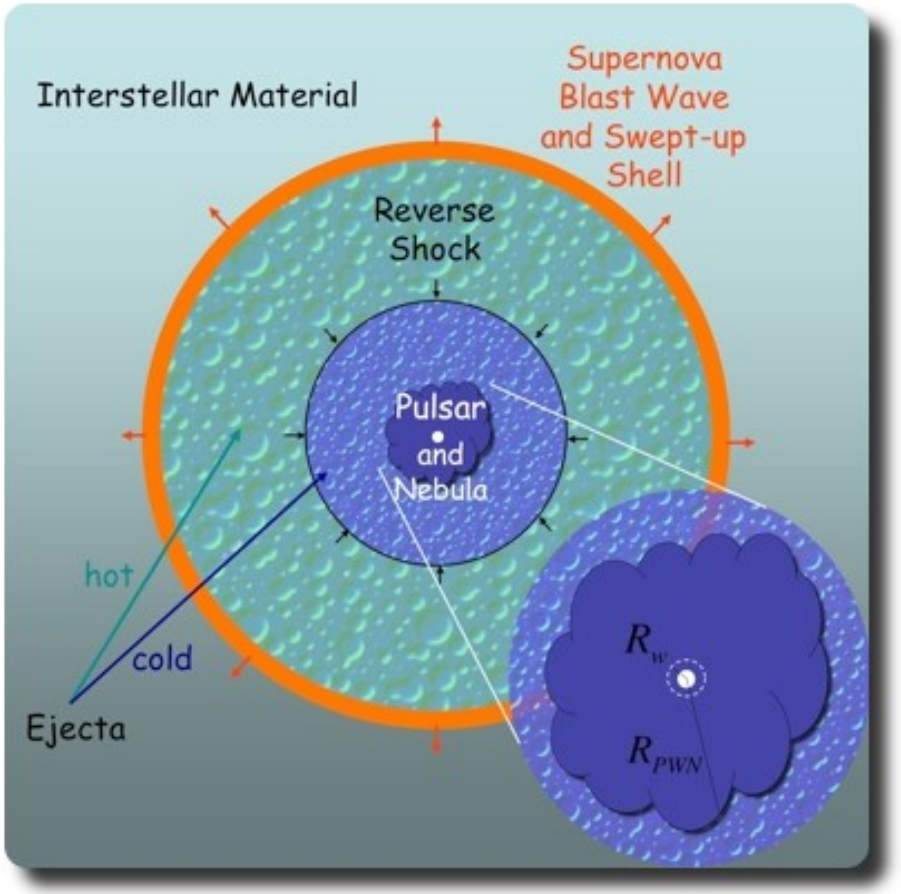
Supernova Remnants

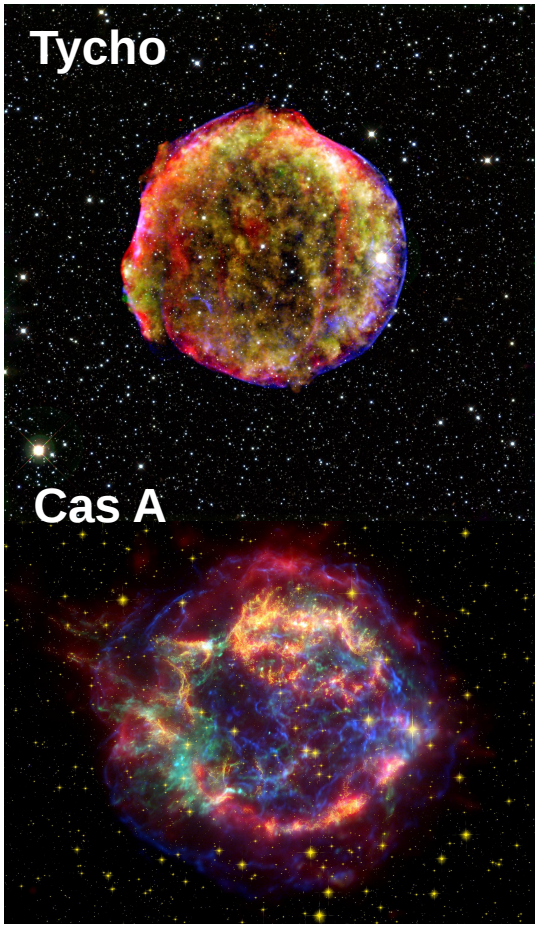
- First things first : what is a supernova (SN) ?
  - explosion of a dead/near-to-death star
  - Two major types of supernova :
    - Thermonuclear SN (Type Ia) ==> no star residue
    - Core-collapse SN ==> star residue : neutron star (pulsar)



Supernova Remnants

- What is a supernova **remnant** ?
  - Shock wave produced by the SN, propagating through space and interacting with the interstellar medium





Evolution of SNR

1) Free expansion phase :

- Mass swept up by the shock < Mass of the stellar ejecta
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  ⇒ efficient Infrared emission
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4) Merging with the interstellar medium and disappearing...

My work ...

RCW 86 - MSH 14-53 - G315.4-2.3

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- Remnant of a Type Ia supernova
- Probably associated to the historical supernova SN 185
- Why this remnant in particular ?
  - Expected to be an efficient particle accelerator (X-rays and TeV observations)
  - A lot of multiwavelength data

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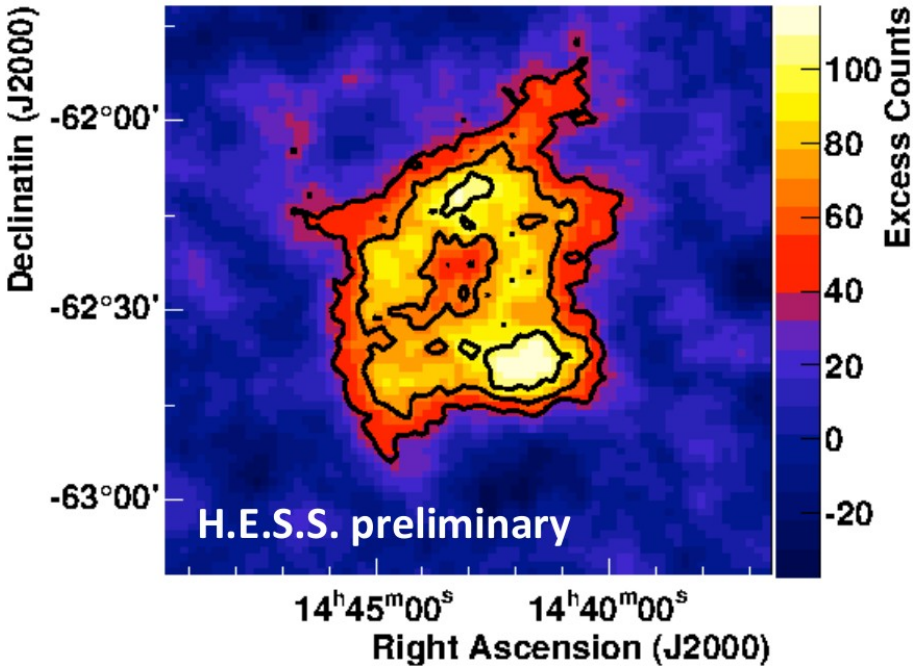
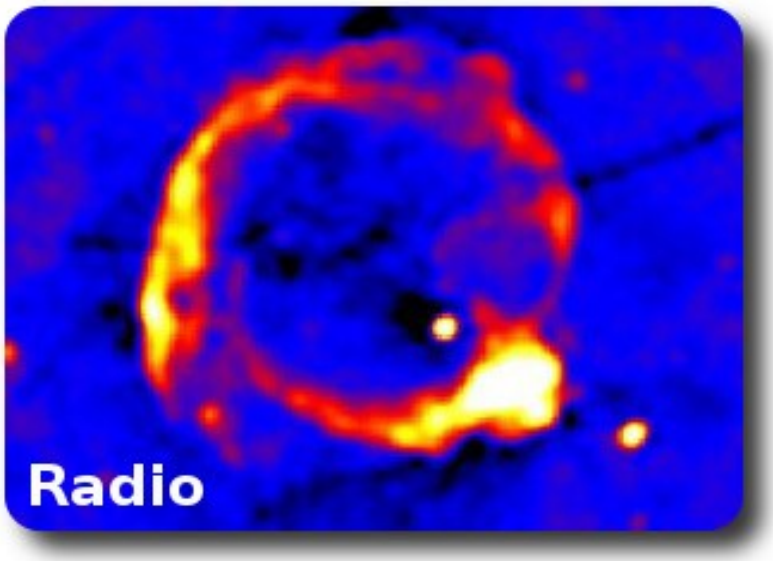




Analysis of Fermi-LAT data

1) Data selection

- region of the sky (coordinates of the center + radius)
- energy range (100 MeV - 500 GeV)
- time interval
- max zenith angle ⇒ avoid gamma-ray coming from the Earth limb

Analysis of Fermi-LAT data

1) Data selection

2) First fit of the data with a model

The model contains a list of gamma sources :

- sources from the Fermi-LAT catalog (3FGL)
- Galactic diffuse emission
- Isotropic diffuse emission

Each source is defined by :

- a spectral shape
- a spatial model

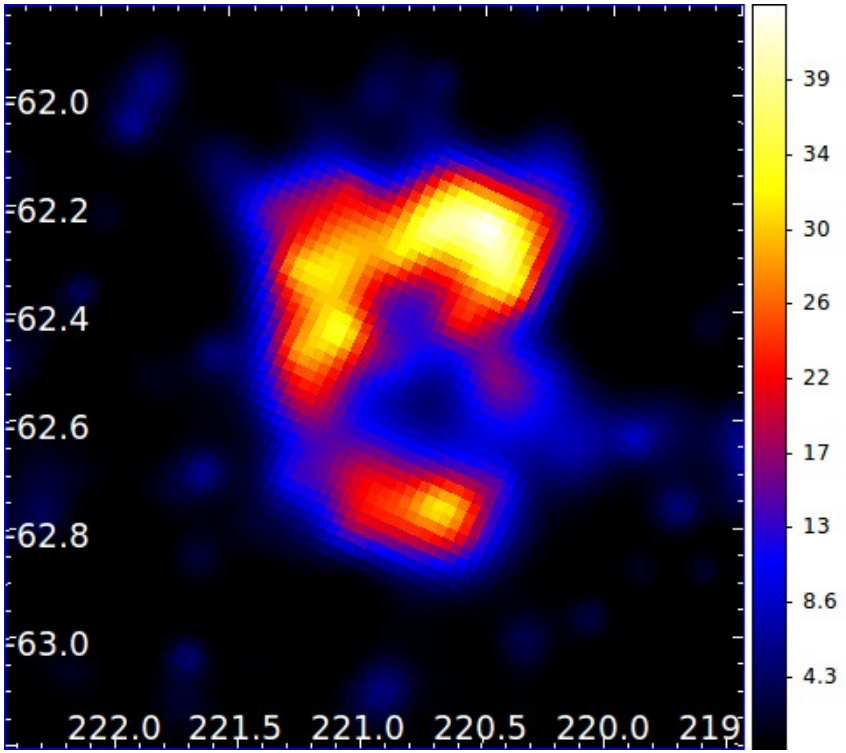
Analysis of Fermi-LAT data

1) Data selection

2) First fit of the data with a model

3) Significance map

We look for gamma-ray excess in the region.



- Map centered on the position of RCW 86 (above 1 GeV)
- Colors represent the significance of the source in each pixel

==> We add a source in the model to fit this gamma-ray emission

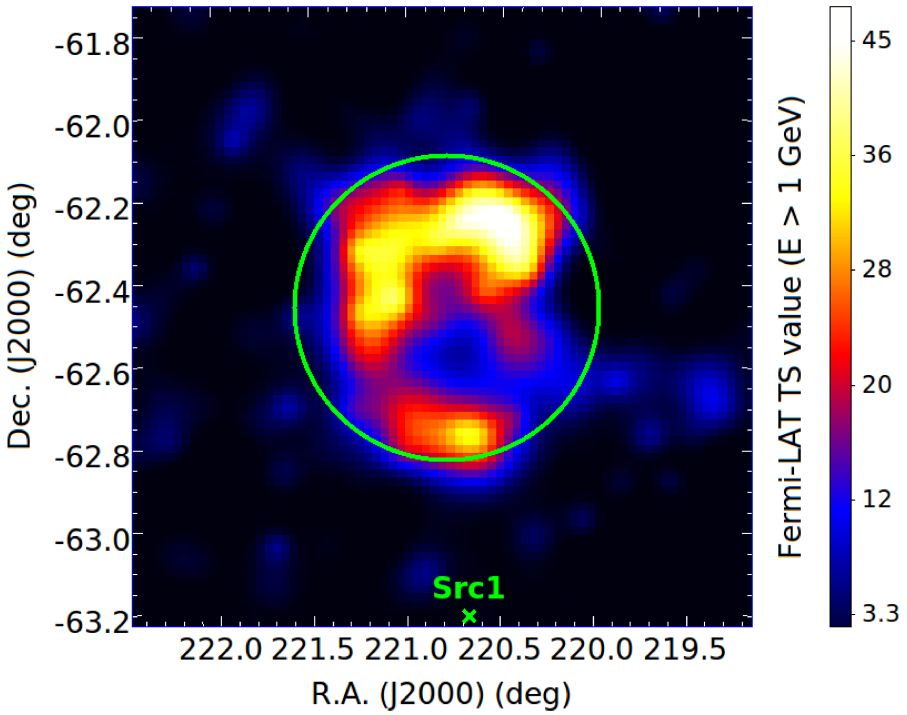
Analysis of Fermi-LAT data

1) Data selection

2) First fit of the data with a model

3) Significance map

4) Morphological analysis



- Fit with different spatial model :
  - point-like
  - disk
  - ring
  - multiwavelength morphologies

Analysis of Fermi-LAT data

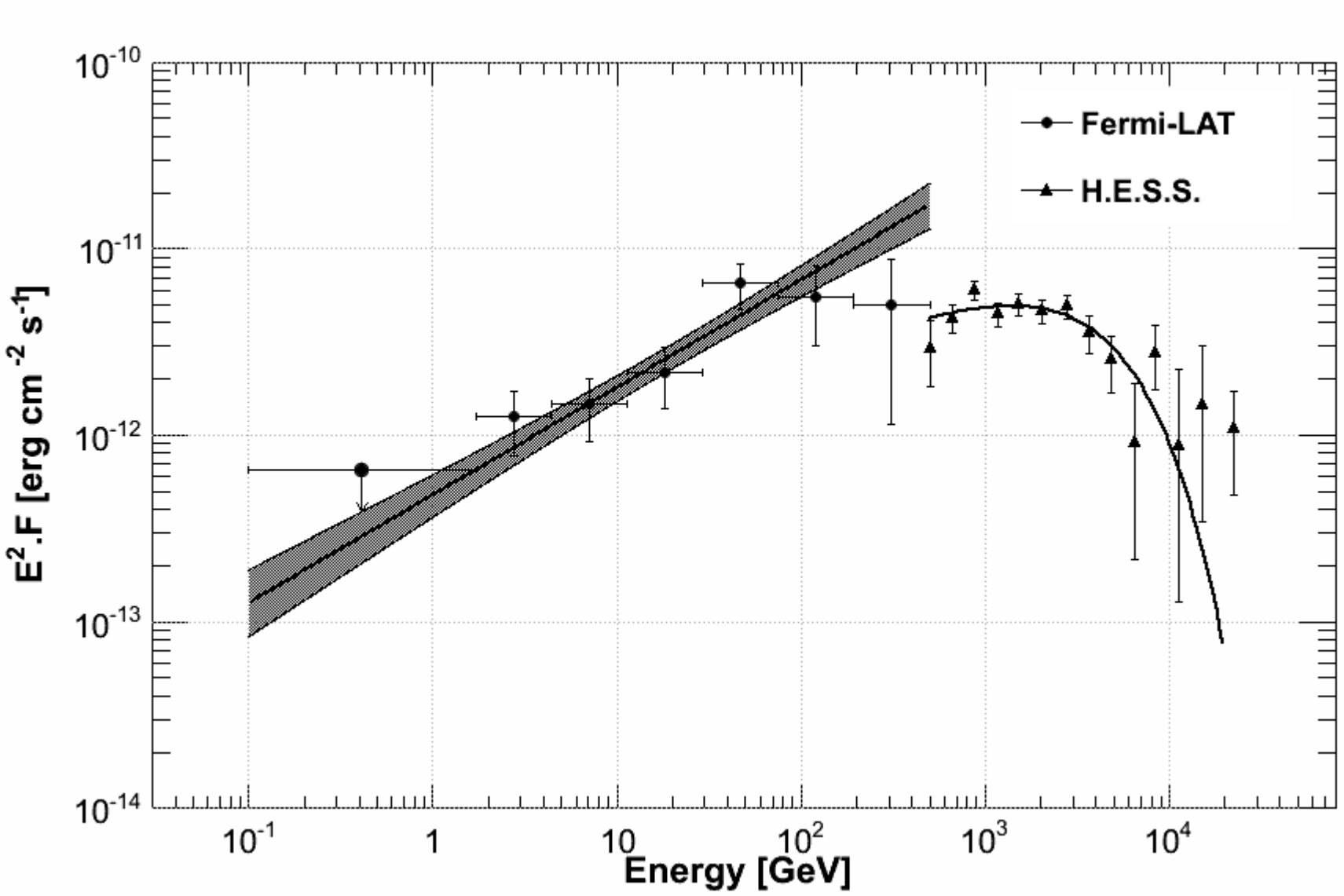
1) Data selection
2) First fit of the data with a model
3) Significance map
4) Morphological analysis
5) Spectral Analysis

- Fit with different spectral shape :
  - power law
  - broken power law
  - log parabola

- Compute the Spectral Energy Distribution

Analysis of Fermi-LAT data

Spectral energy distribution of RCW 86.



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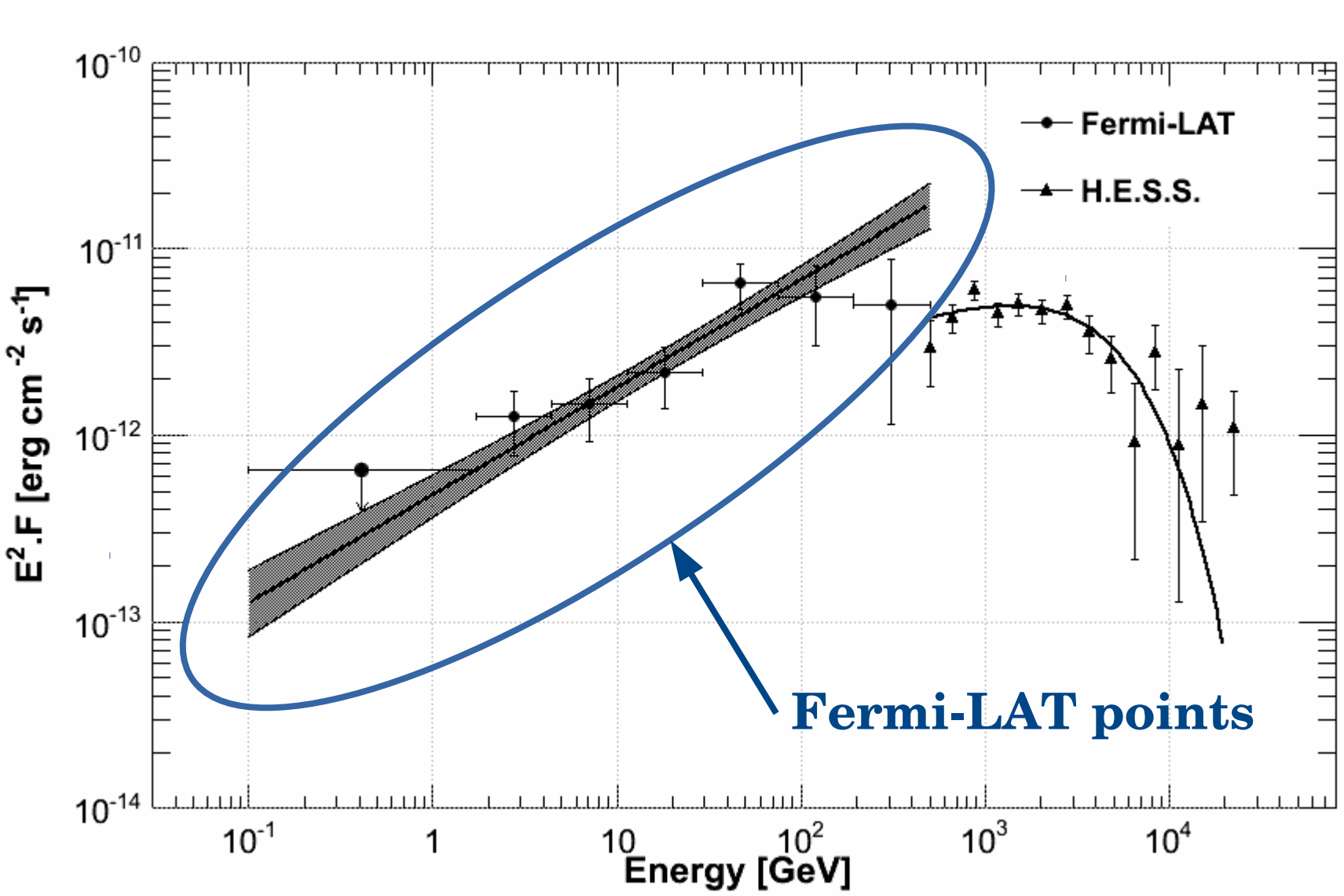

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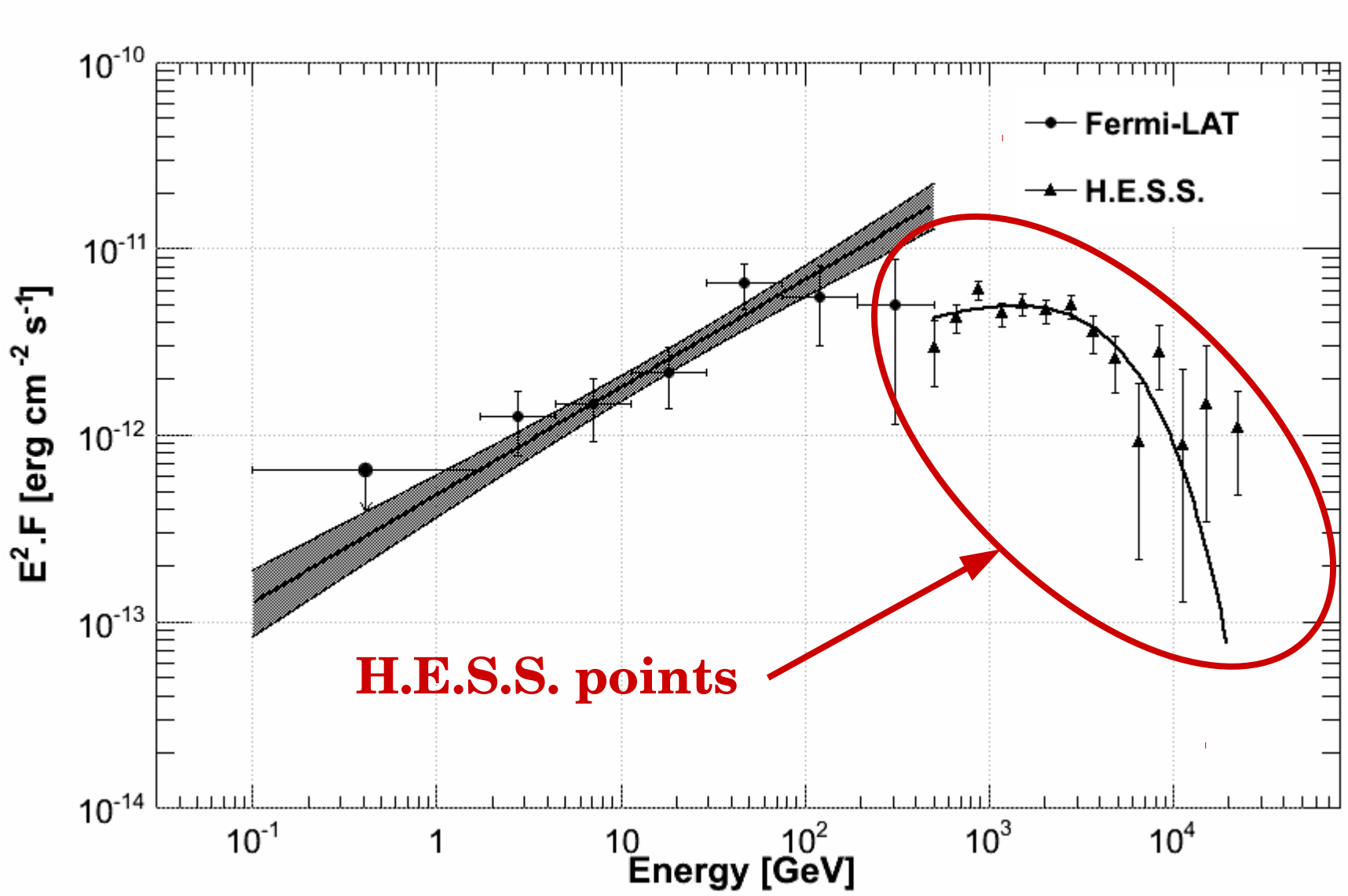
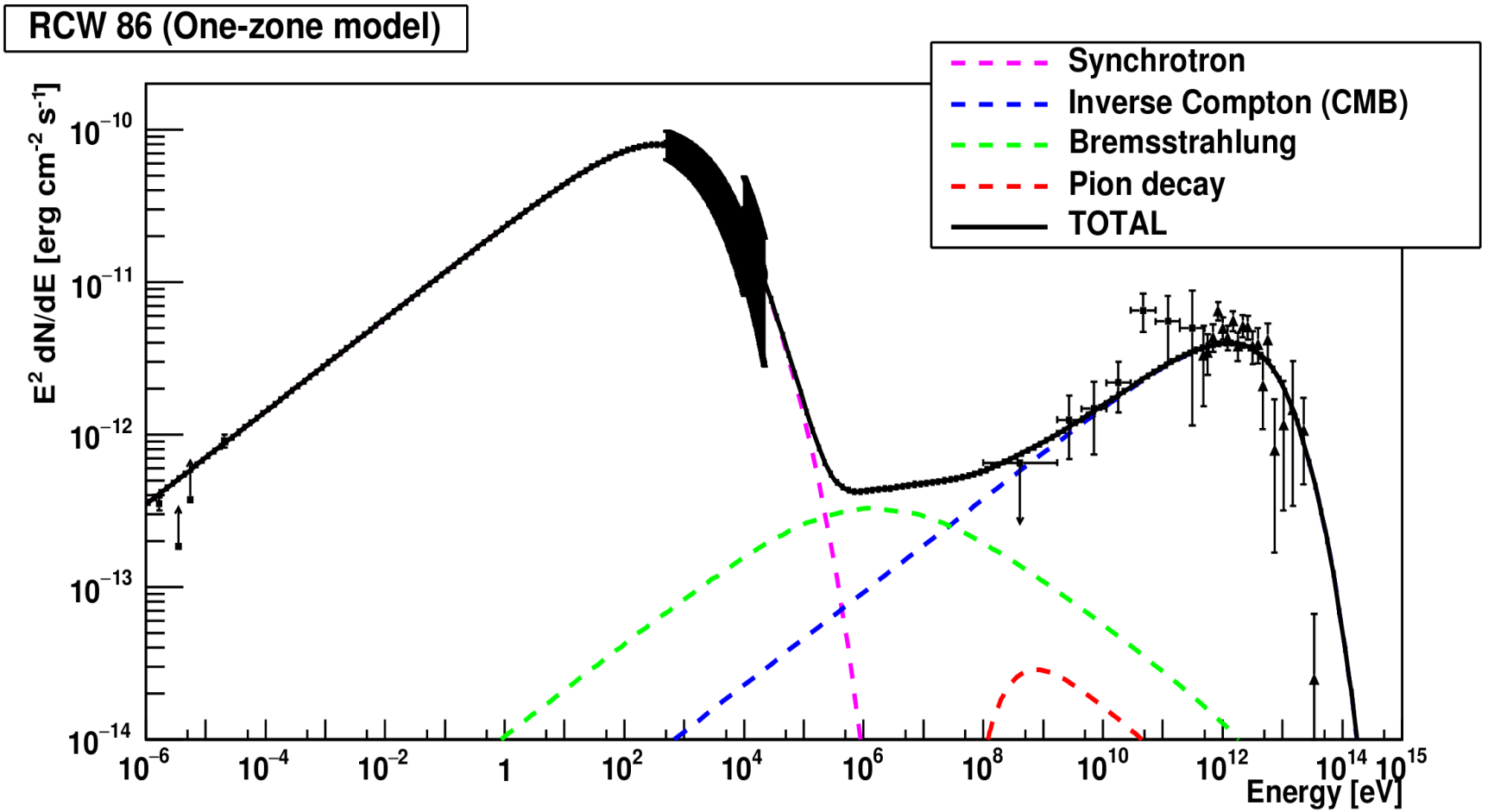


Analysis of Fermi-LAT data

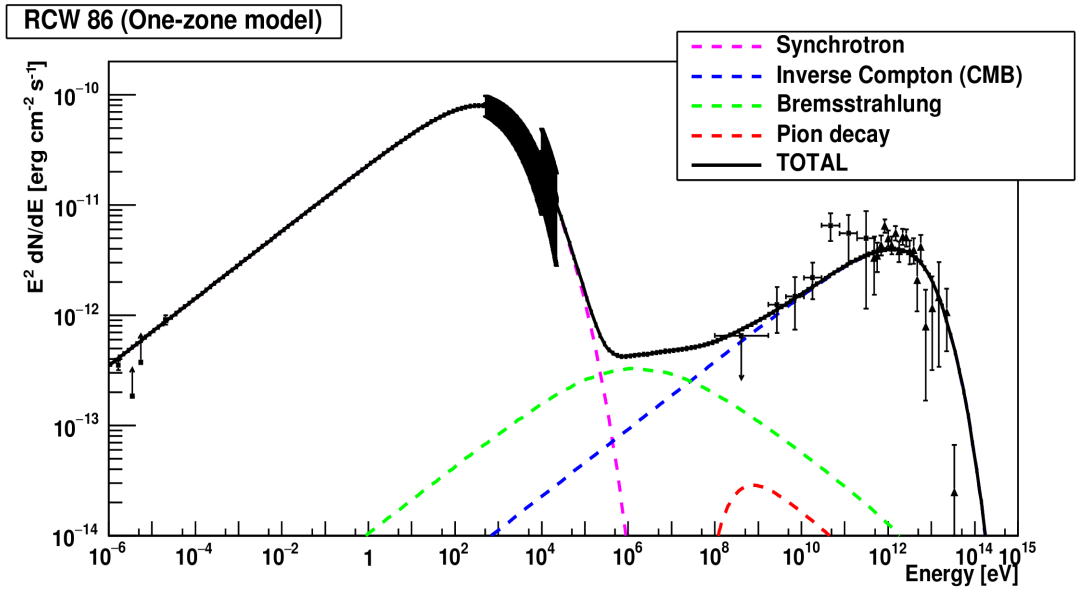
1) Data selection
2) First fit of the data with a model
3) Create of a significance map to look for new gamma excess in the region
4) Morphological analysis
5) Spectral Analysis
6) Modeling of the Spectral Energy Distribution

Modeling of the spectral energy distribution



Radio X-rays Gamma-rays

Modeling of the spectral energy distribution



Parameter	Value
Density (cm^{-3})	0.1
B-field (μG)	10.2 ± 0.5
$\Gamma_{e,p}$	2.37 ± 0.03
E_{max} (TeV)	75 ± 5
η_e (% of E_{SN})	3.84 ± 0.6
η_p (% of E_{SN})	2
K_{ep} (x 10^{-2})	11.1 ± 1.5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2015
Thanks for your attention !