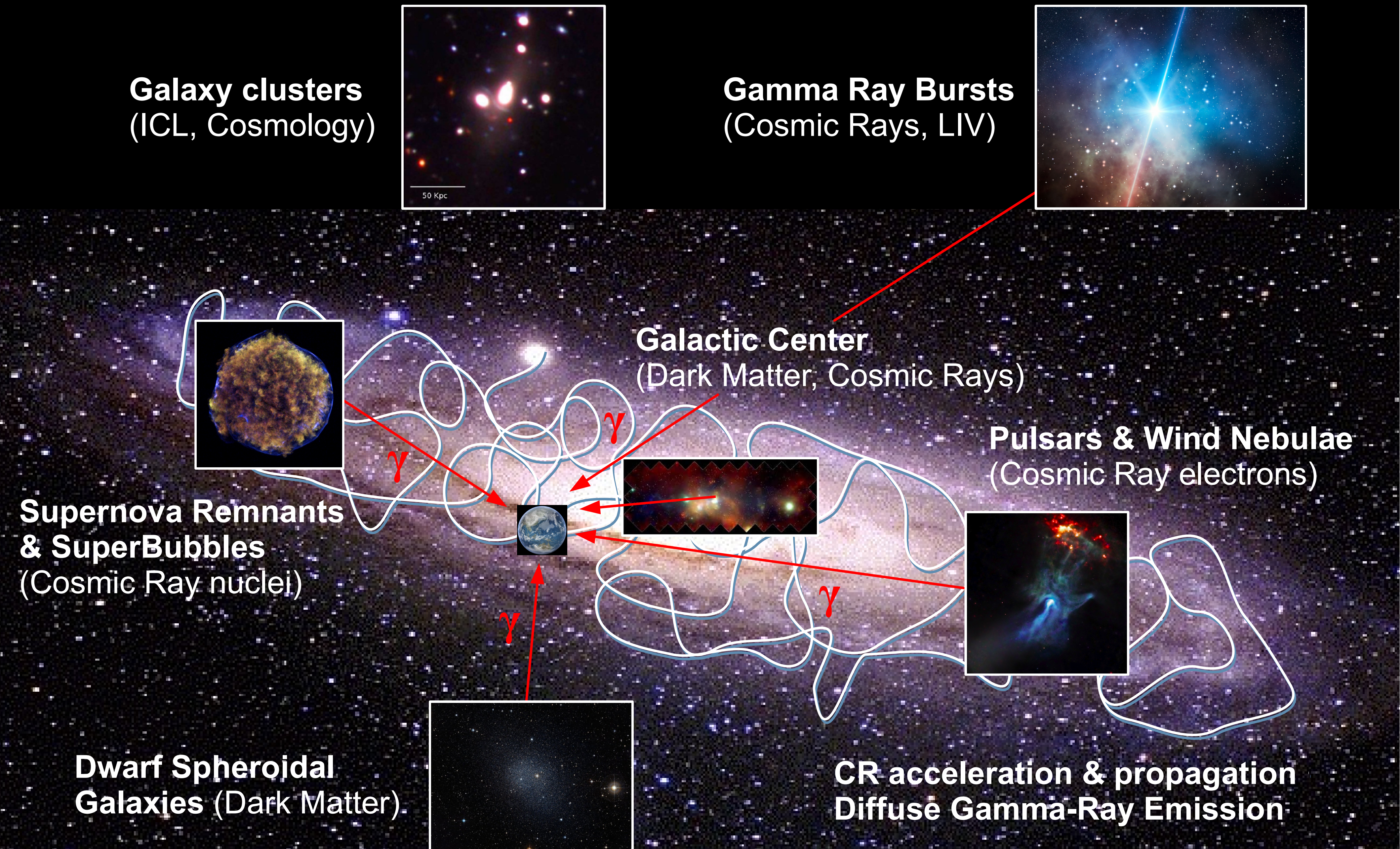
# Highlights from the LUPM team
# « ***E***_xpériences et_ ***M***_odélisation en_ ***A***_stroparticules_ »

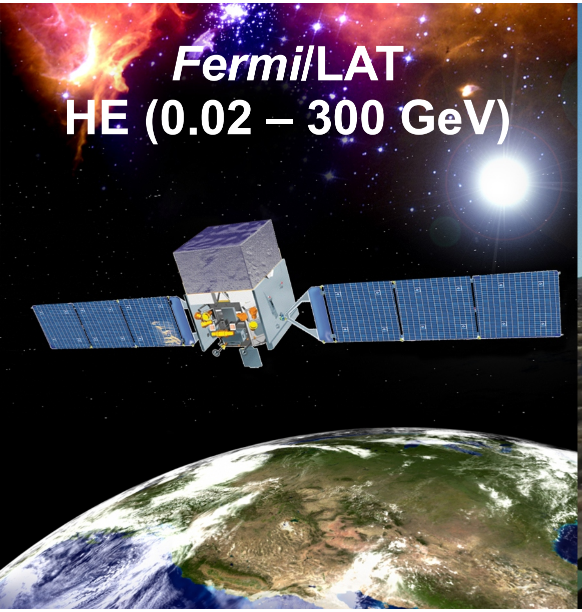
AERES meeting, 20-22 January 2014

# Gamma Rays, Cosmic Rays, Cosmology & New Physics

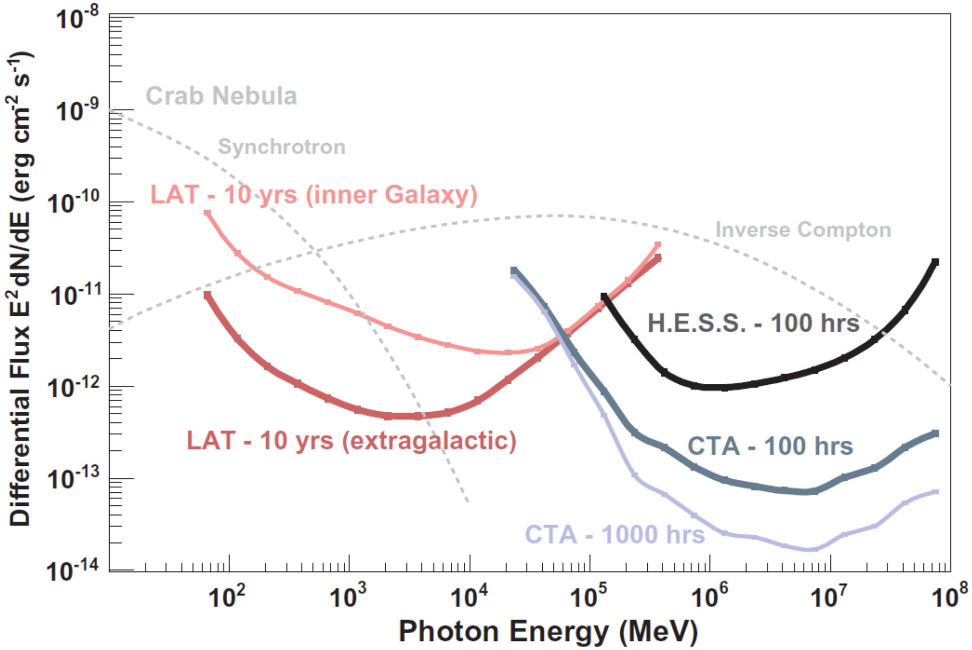


# Members of *Fermi*/LAT, H.E.S.S. and CTA collaborations

**Among the best high-energy gamma-ray telescopes (Descartes and Rossi prizes)**







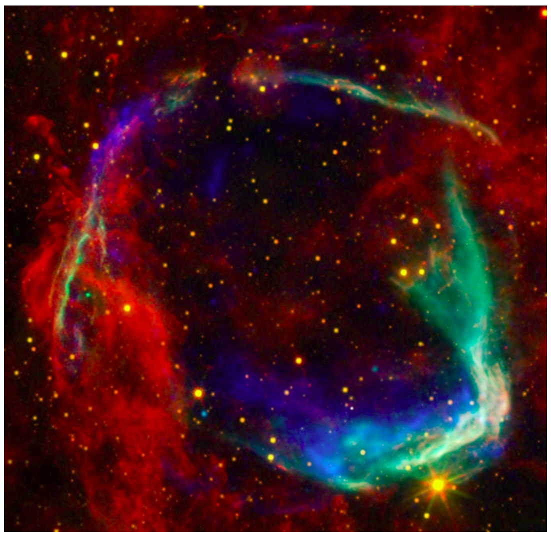

# Our team expertise:
# instrument, observation, analysis, modeling and theory

**Multi-wavelength (MWL) observations of CR sources**

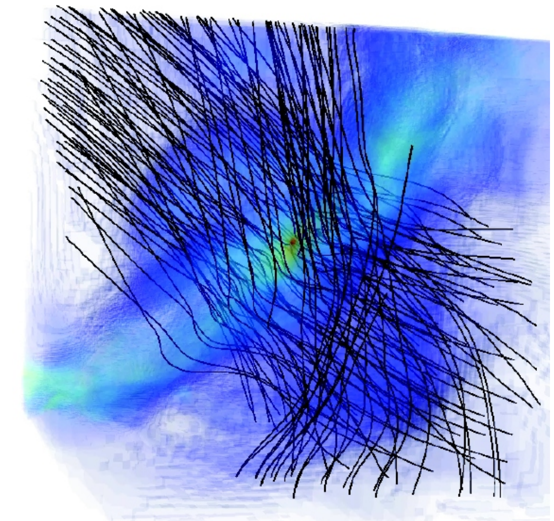
*Radio, Optical/IR, X-rays*

**Theory and Modeling**

*CR acceleration & propagation*
*Tests on Cold Dark Matter*

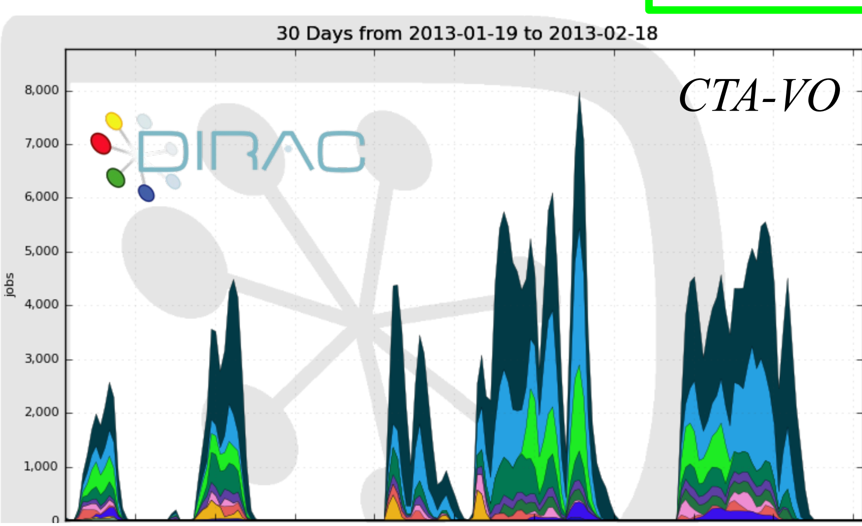


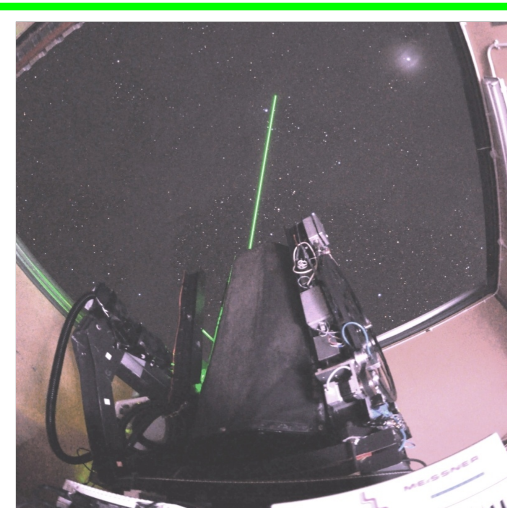
***Fermi*/LAT**
**H.E.S.S.**
**CTA**

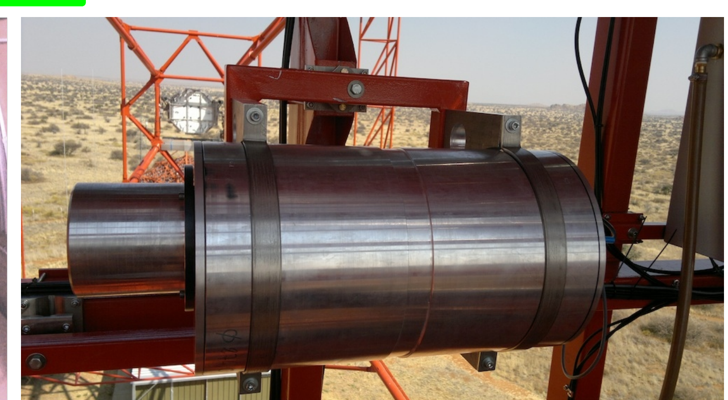


**Technical Activities**

*Calibration (Fermi, H.E.S.S., CTA)*
*LIDAR (H.E.S.S., CTA)*
*Software & Computing (Fermi, CTA)*





*Fermi*/LAT GRB catalog

Galactic Sources with H.E.S.S. and *Fermi*/LAT
& multi-wavelength studies

Modeling of particle acceleration in SNRs
& Prospects with CTA

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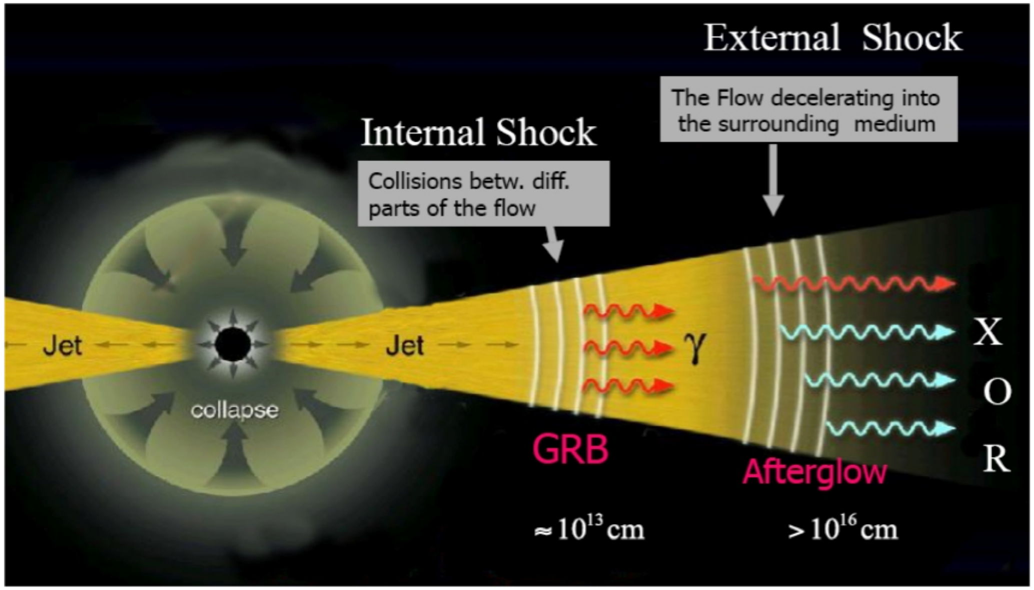
# The first *Fermi*/LAT GRB catalog




- **How do GRB jets accelerate high-energy particles?**
  - Internal shocks or external shock (jet interaction with circumburst medium)?
  - Nature of accelerated particles? electrons or nuclei (UHECRs)?
  - Emission processes and location?
  - Properties of GRB jets (speed, energetics)?

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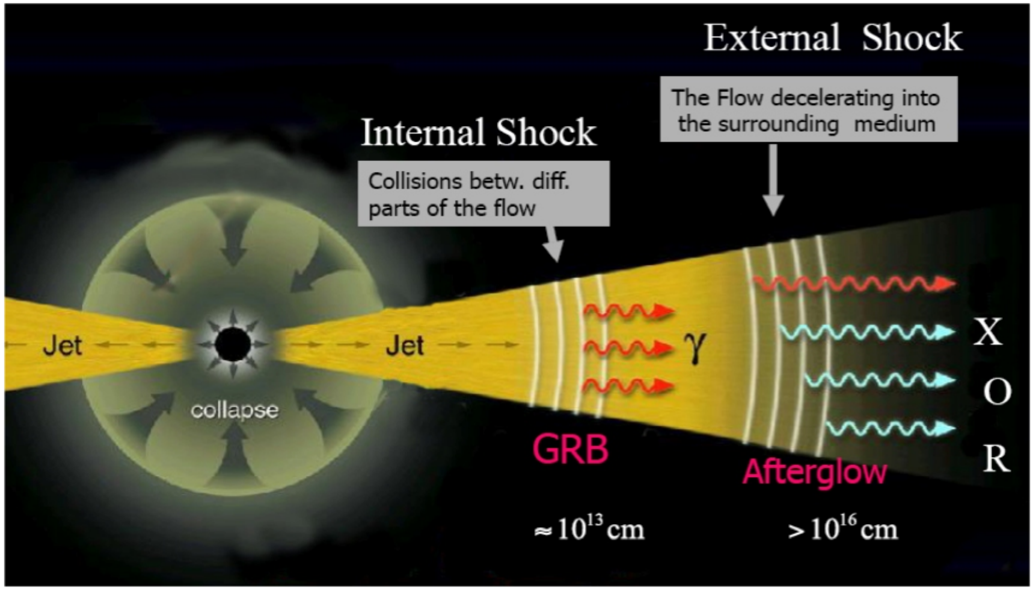


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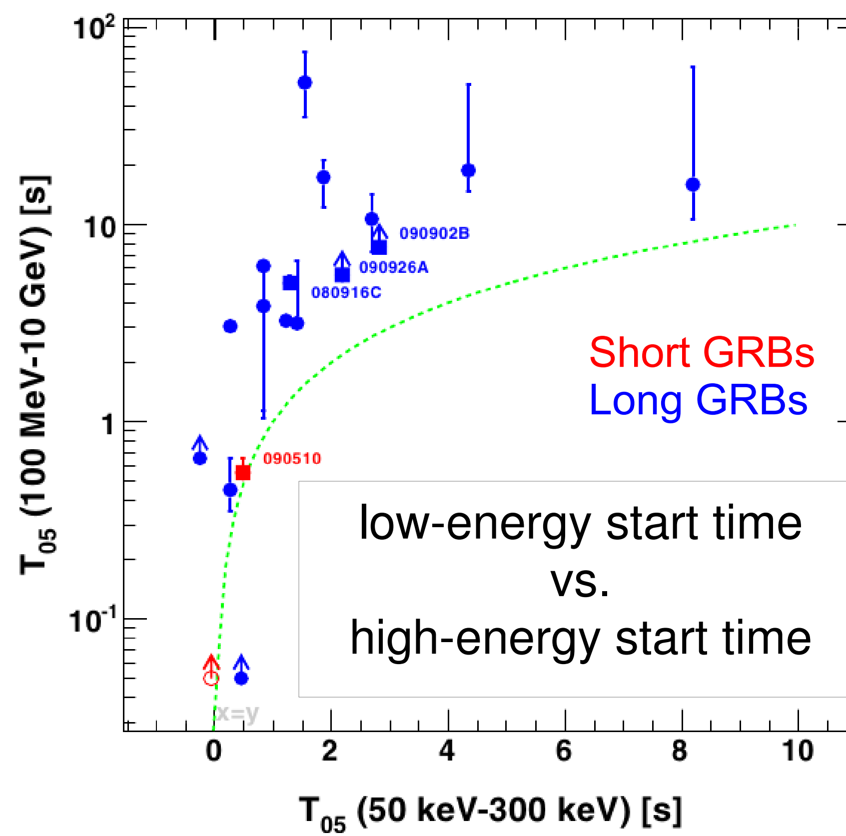
- **First *Fermi*/LAT GRB catalog**

  Ackermann, M. et al., 2013, ApJS, 209, 11
  (Piron & Vasileiou corresponding authors)
  - Broad-band time-resolved analyses (8 keV – 30 GeV)
  - Analysis methods & interpretation (90 pages)
  - 35 GRBs in 3 years (30 long, 5 short)

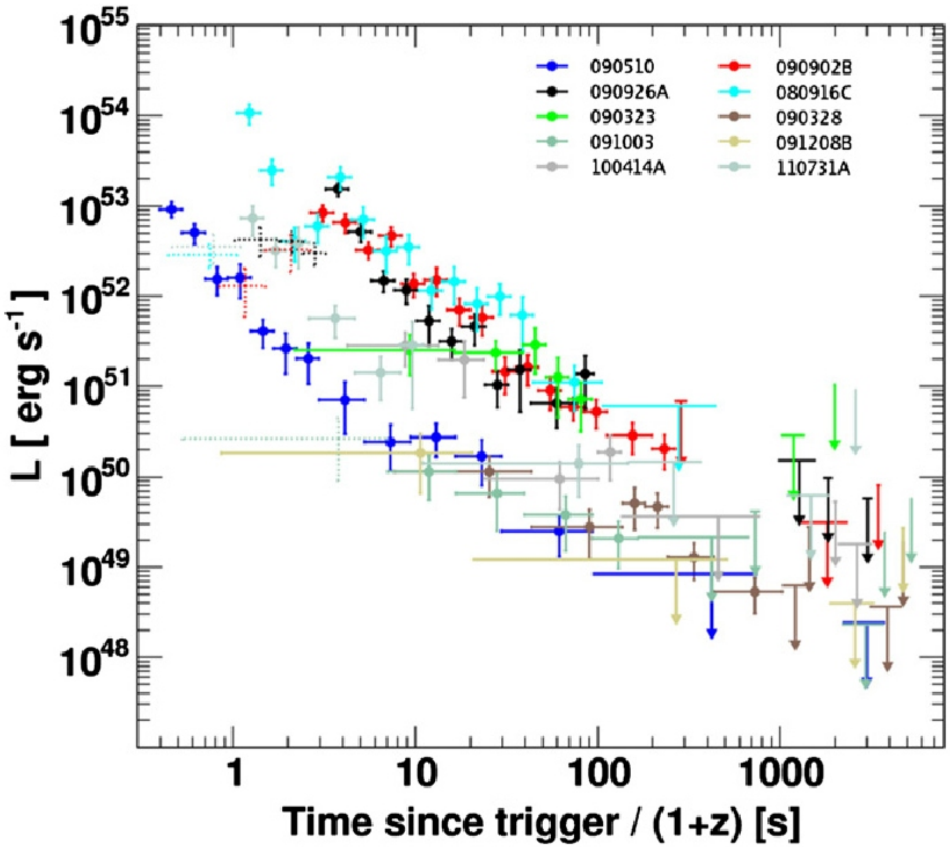
- **GeV emission onset is delayed**
  - Likely from early afterglow: external shock → synchrotron emission from accelerated electrons
  - Late internal shocks (inverse Compton scattering) or hadronic emission (proton synchrotron and/or photopion-induced cascades) still possible



# The first *Fermi*/LAT GRB catalog

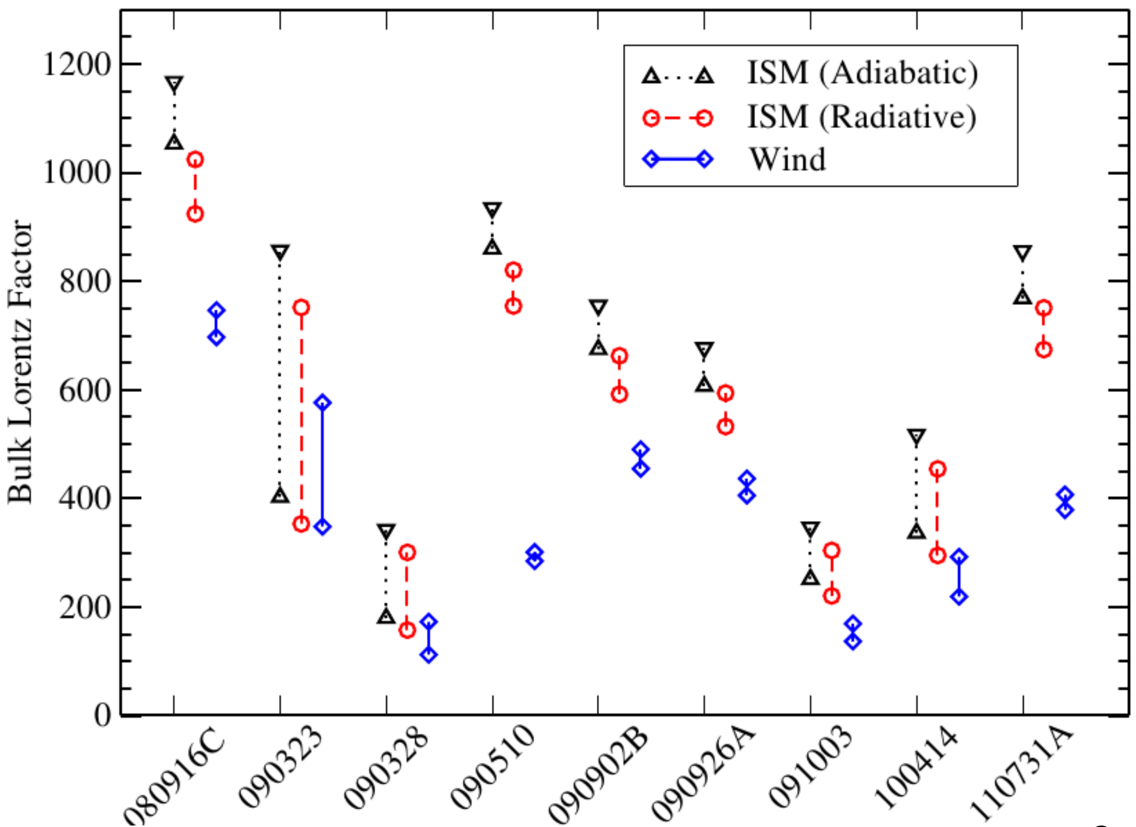
- **Long-lasting GeV emission consistent with the canonical afterglow model**
  - No strong spectro-temporal variability
  - Emission decays as $t^{-1}$ with a photon spectral index of -2 at late times

**→ blast wave in adiabatic expansion**




- **Consequence: GRB jet Lorentz factors**
  - Inferred from LAT peak-flux time ~ blast wave deceleration time
    - For 9 GRBs with measured z
  - $\Gamma$ between ~200 and ~1000

**→ highly relativistic speeds**



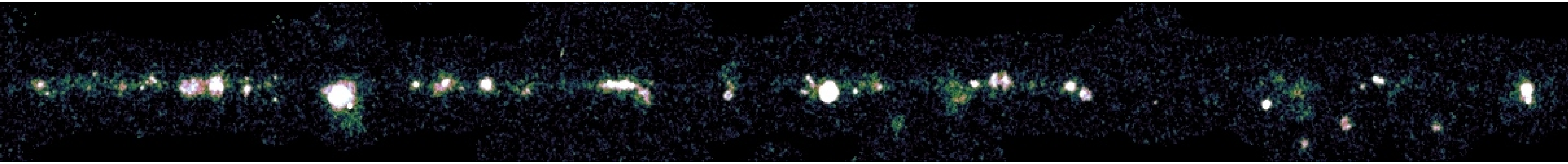
*Fermi*/LAT GRB catalog

**Galactic Sources with H.E.S.S. and *Fermi*/LAT & multi-wavelength studies**

Modeling of particle acceleration in SNRs & Prospects with CTA

# Galactic Plane Survey with H.E.S.S.

- **~2800 hr of observations of the inner Galaxy (2004–2012)**
  - ~100 sources above the H.E.S.S.-I sensitivity ~1 % of Crab
  - Large variety of source types & ~1/3 of unidentified sources



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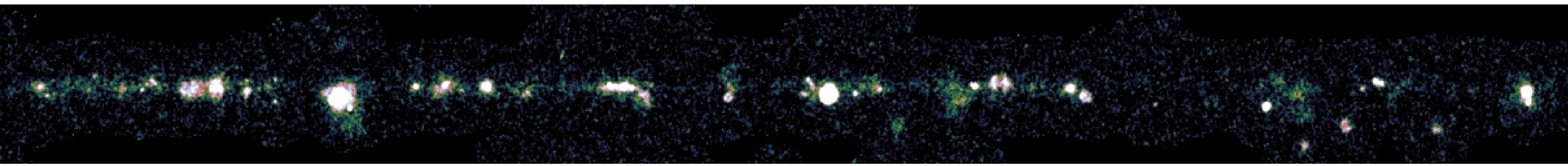
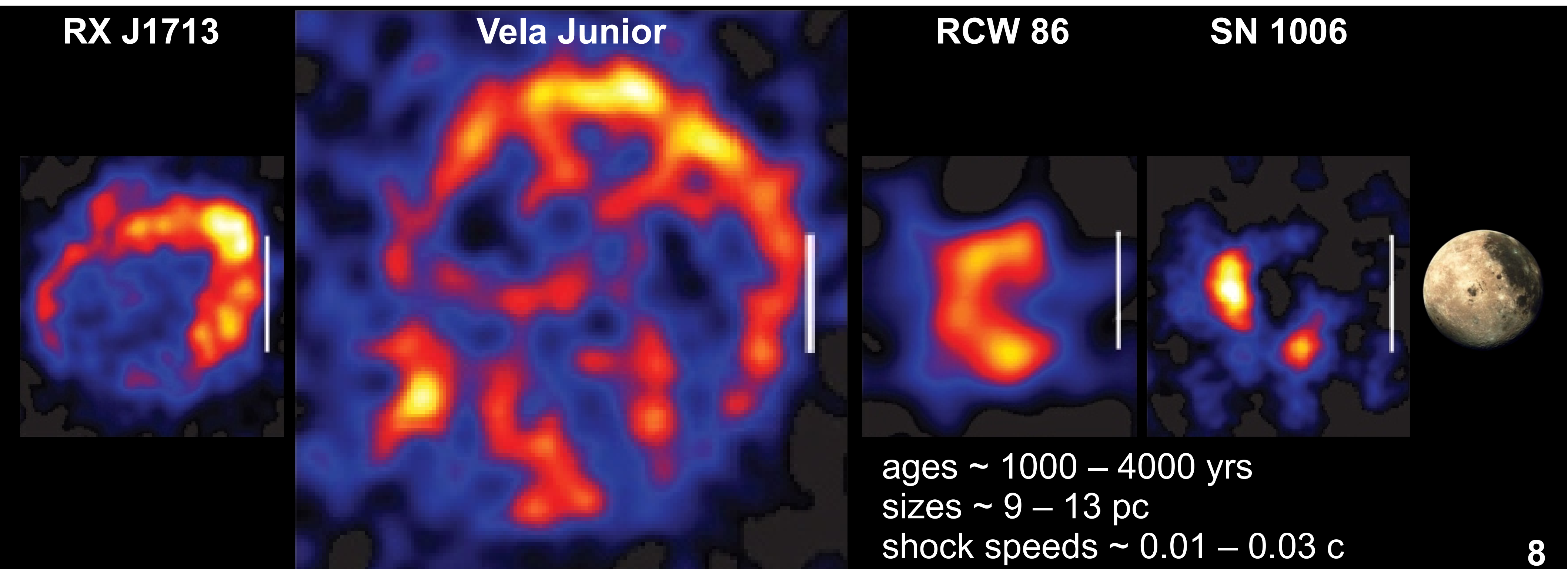
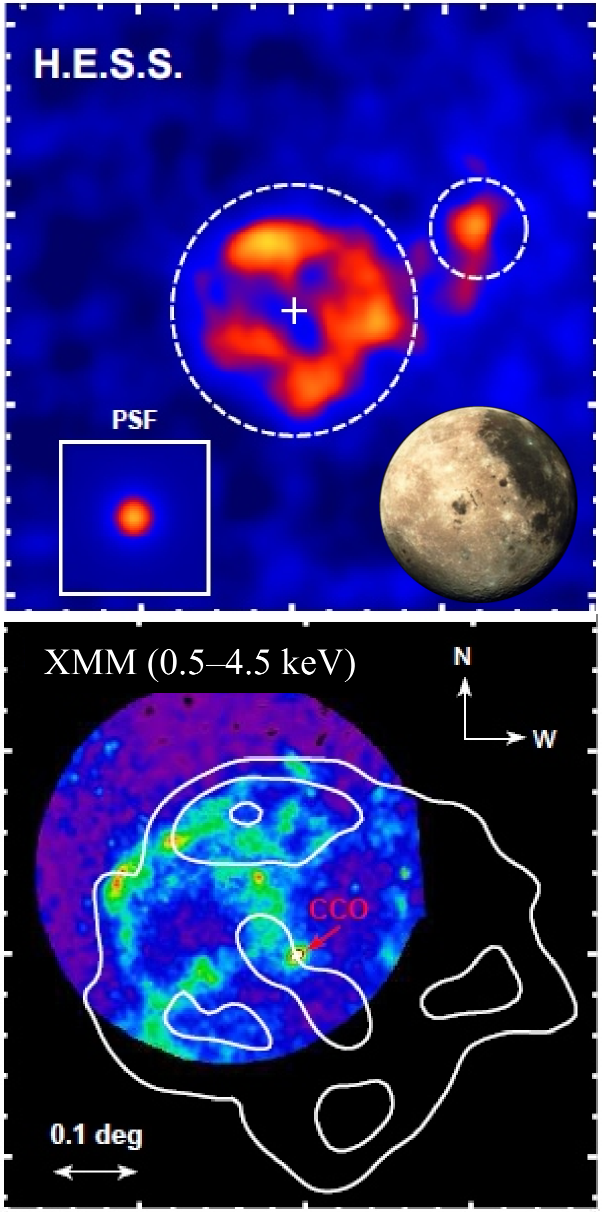


  - 5 resolved shell-type SNRs



# A previously unknown shell-type SNR discovered in TeV gamma-rays : HESS J1731-347

H.E.S.S. Collaboration, Acero, F. et al. 2011, A&A, 531, 81



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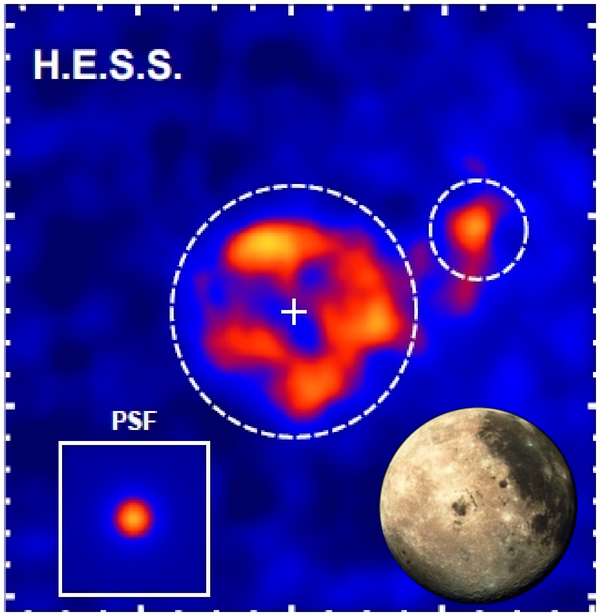
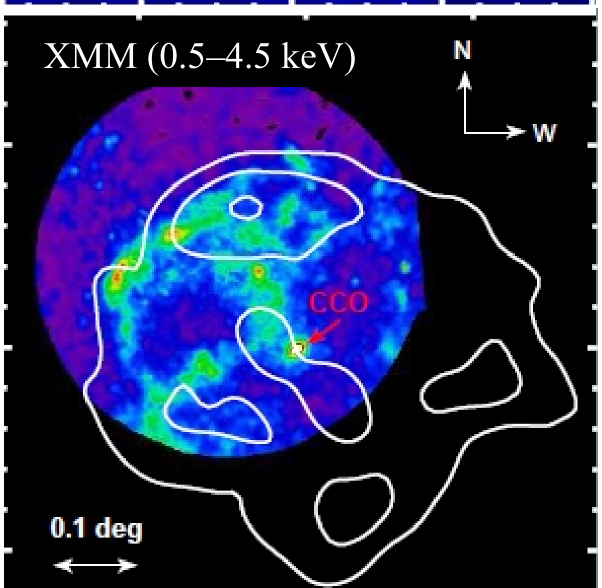
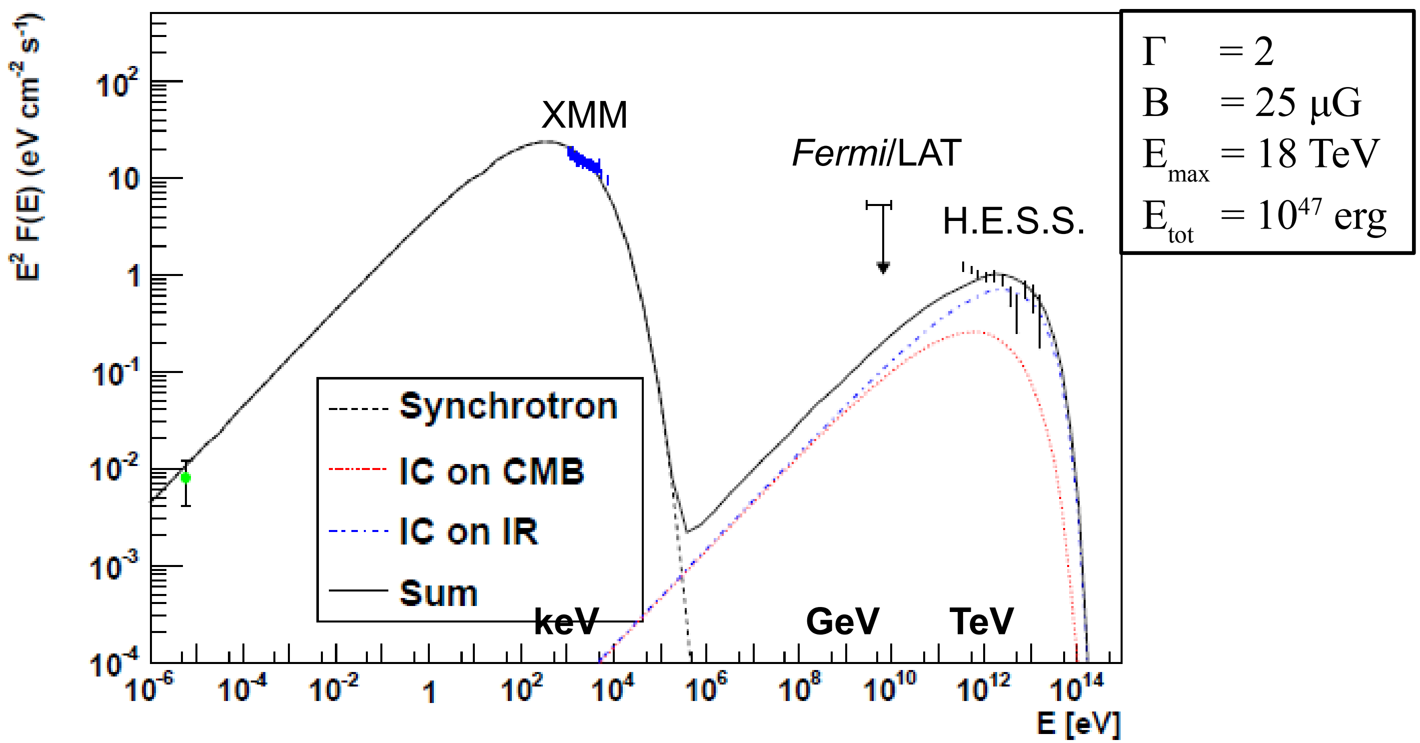



## Nature of the TeV emission? Is it an *efficient* CR source?

- Scenario involving p-p interactions ($\pi^0 \rightarrow 2\gamma$) requires a too large ambient density given the absence of thermal X-ray emission:

**CR efficiency : $\xi_{CR} \sim 0.2 \times (1\ cm^{-3}/n)$ $\leftrightarrow$ $n_{(kT > 1keV)} < 0.01\ cm^{-3}$**




- Same conclusion for RCW 86 based on *Fermi*/LAT upper limits (Lemoine-Goumard, Renaud, Vink, et al. 2012, A&A, 545, 28)

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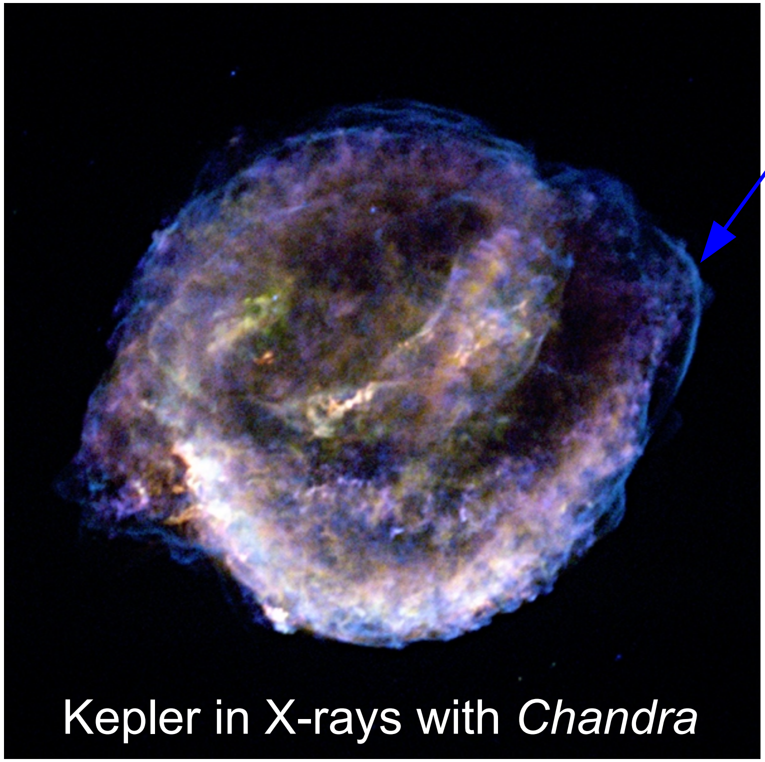
# Filaments in SNRs & turbulence diagnostics




(blue color: synchrotron [SC])

Thin X-ray filaments observed in *all* young SNRs with a width of a few % the SNR radii

- SC-limited thickness → lower limit on B-field :

  $$w \approx V_{sh} \times \tau_{SC} \approx \sqrt{D \times \tau_{SC}} \approx 0.04\ (B/100\ \mu G)^{-3/2}\ pc$$

- $B \geq 100\ \mu G >> B_{ISM}$ ↔ Diffusive Shock Acceleration
- The higher the B-field, the more efficient the particle confinement ; $E_{max} \sim 1$ PeV $\times$ ($B/100\ \mu G$) $\times$ ($w/0.01 pc$)

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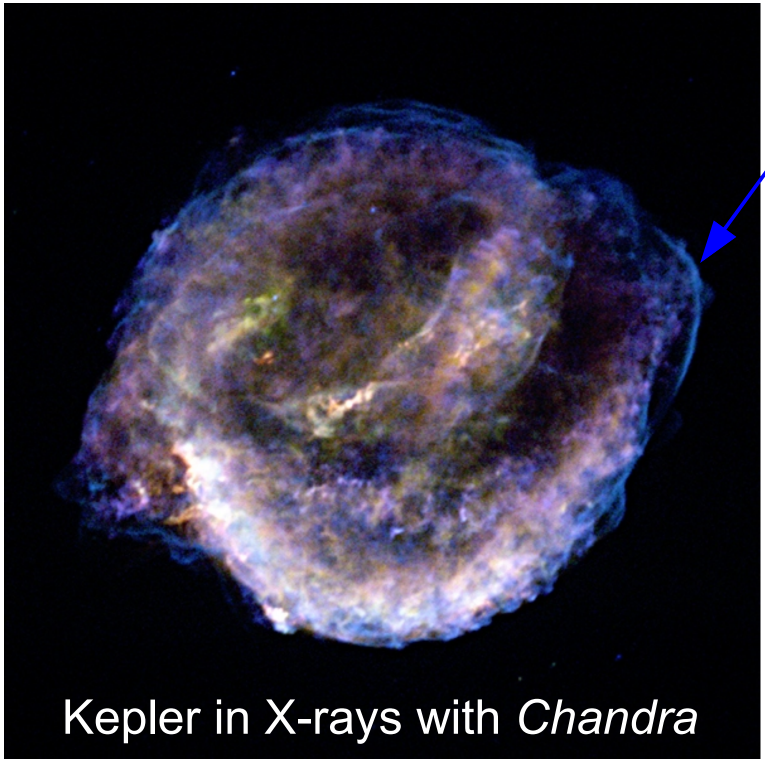

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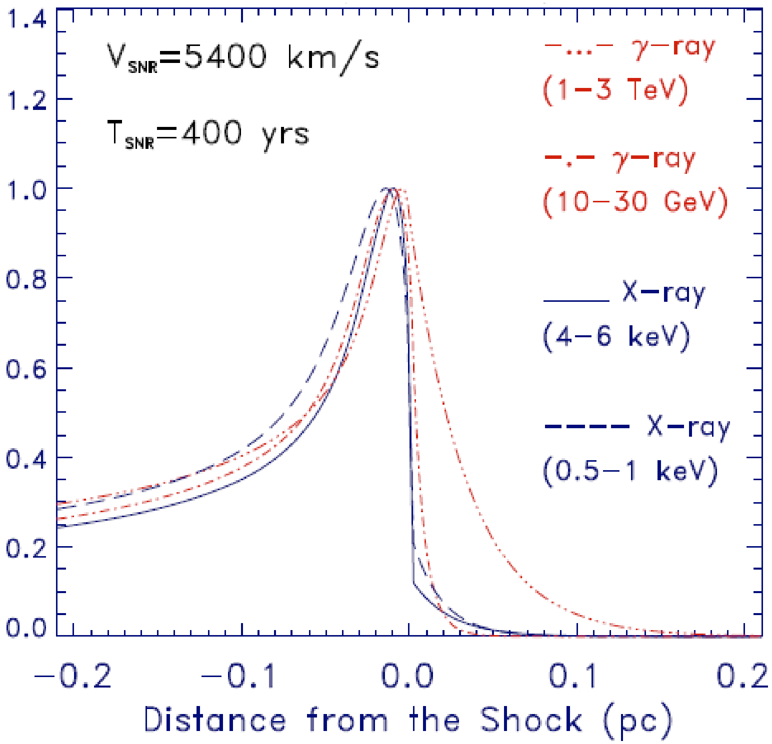
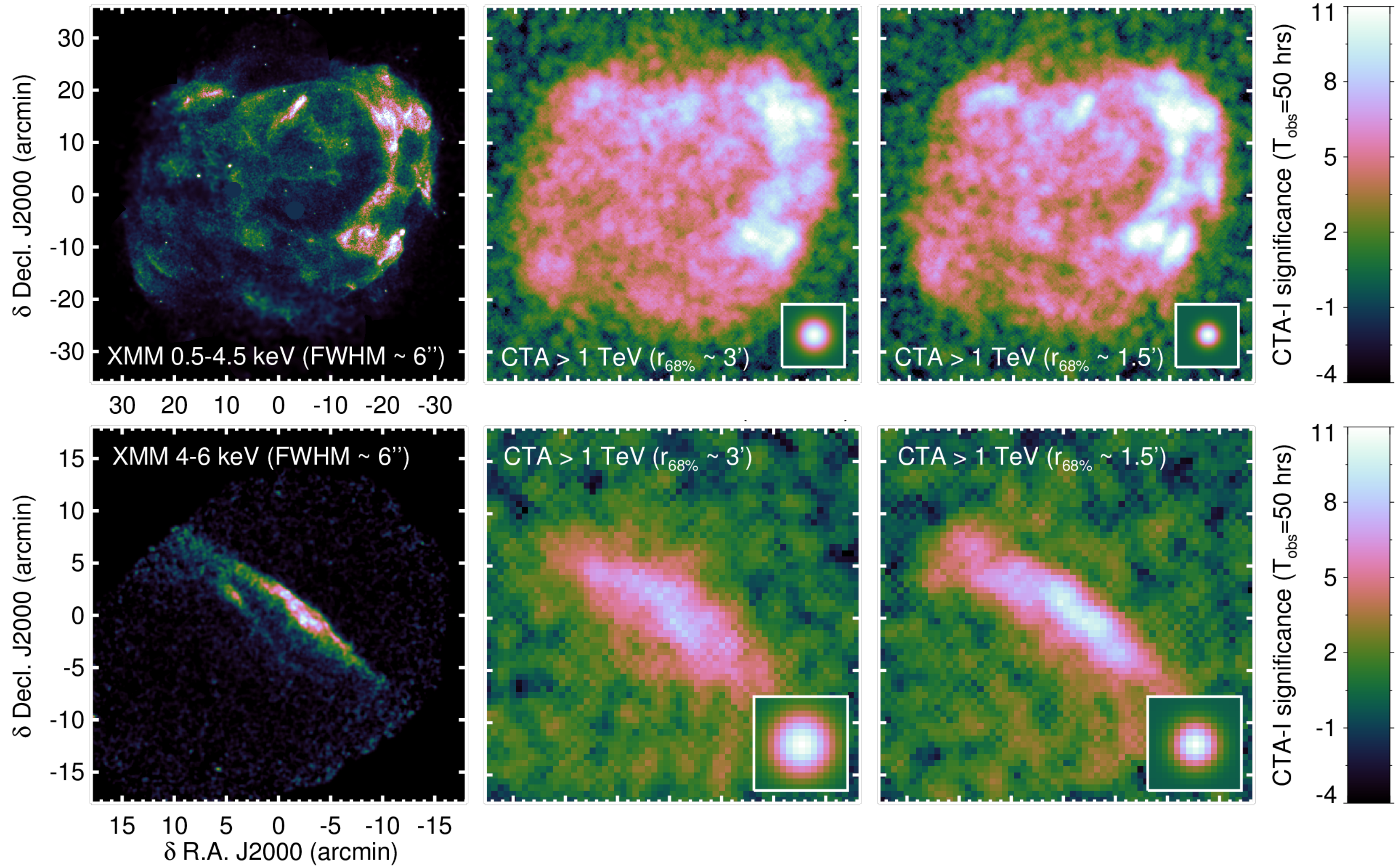
- PeV energies could be reached in young SNRs but this critically depends on the turbulence regime
- *Multiwavelength modeling of SNR filaments* by Marcowith & Casse provides constraints on the turbulence behavior & the relative contributions of the resonant and non-resonant instabilities



# Prospects on SNRs with CTA

« Seeing the High-Energy Universe with the Cherenkov Telescope Array - The Science Explored with the CTA», APh Special Issue, 2013, Volume 43 (Acero, Gallant, Marcowith, Renaud)

- Filaments in RX J1713 and Vela Jr could be resolved with an improved PSF




- Monte-Carlo studies of the Galactic SNR population
  PSF improved by a factor of 2 → almost 2× more resolvable SNRs!