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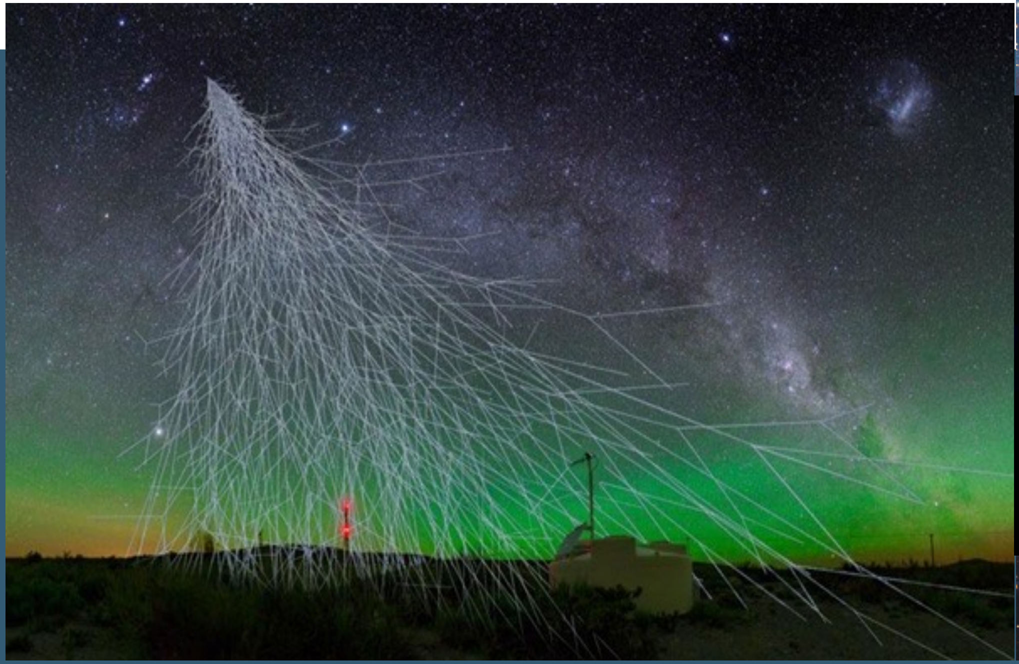
PRESENTATION BIENNALE 2024
PHD 1ST YEAR

Subject : **Study the origin of PeV Cosmic Rays using ultra-high energy gamma-rays**

WHAT ARE COSMIC RAYS ?

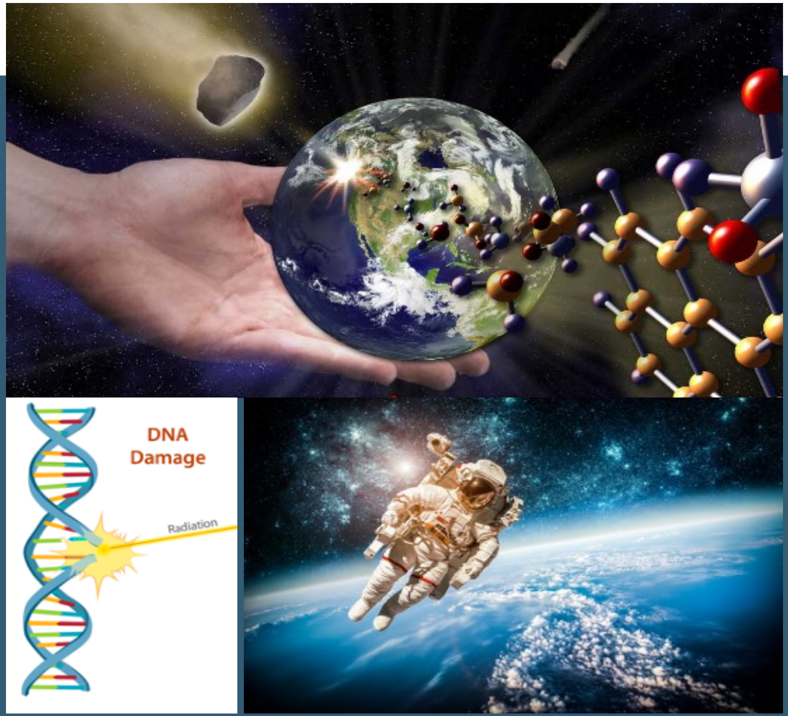


Observations on Earth:
Energetic charged particles:
- Mainly protons
- Other nuclei
- e-, e+, …

Transported in the turbulent and magnetised ISM
→ particles deflected

Accelerated from (galactic) sources :
- pulsars
- supernova remnants
- stellar clusters (winds)
- supermassive black holes
- …

WHY STUDY COSMIC RAYS ?



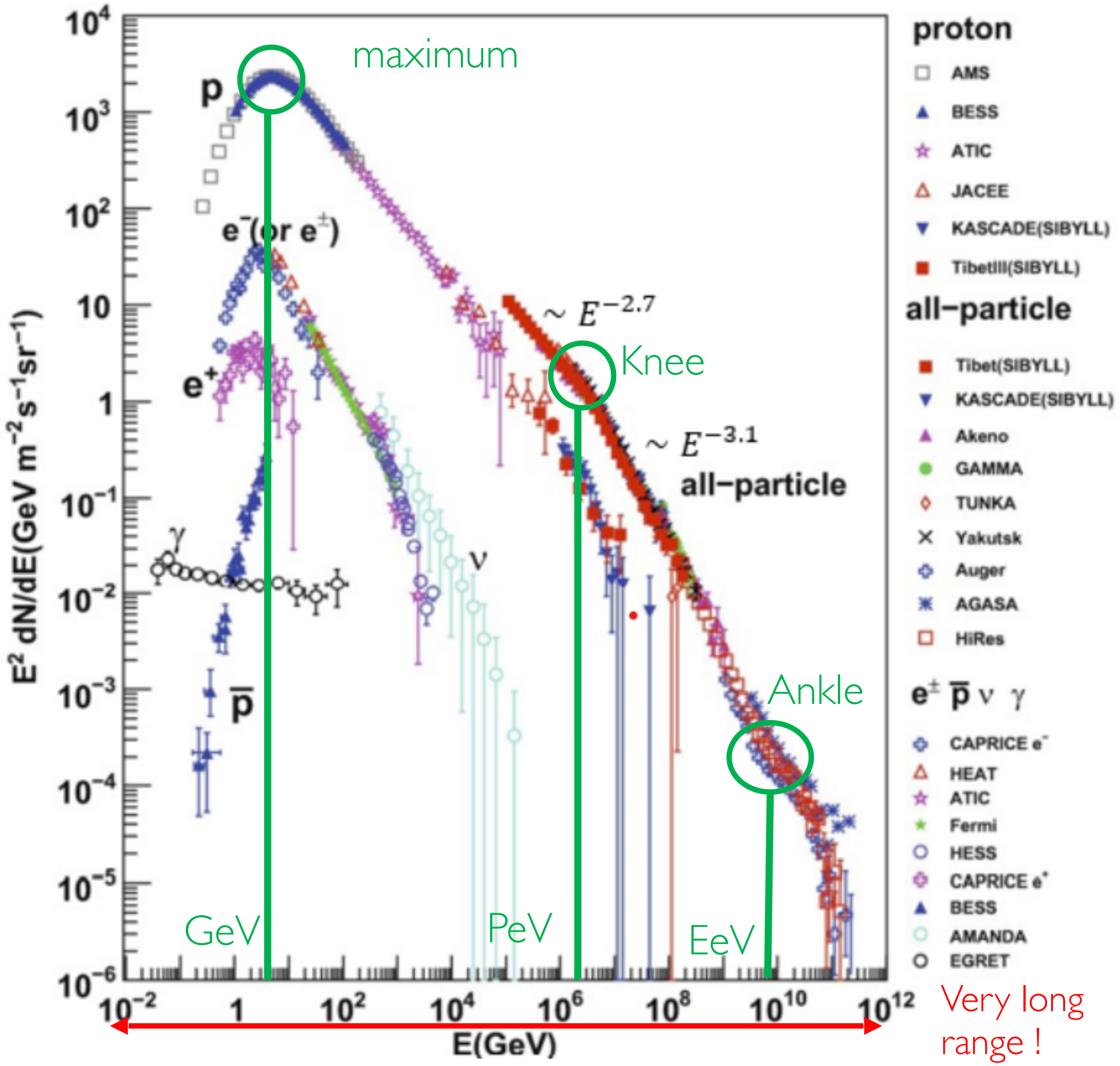
Fundamental questions on the Universe:

- Impact on molecular clouds, gas dynamics and light elements
- Information on acceleration sources
- Potential developments in particle physics
- Potential consequences on dark matter

Impact on Earth and humans:

- Origin of life on Earth
- Effects on DNA
- Consequences for space journeys

COSMIC RAY SPECTRUM AND PEVATRONS



What happens at PEV ?

- Change of slope at PeV→ interesting zone (change in the acceleration process + other nuclei become important)

- PeVatrons : most energetic protons that can be accelerated by galactic sources

→ push acceleration models to their limits

→ Good tool to understand better acceleration of CRs and the contribution of sources to the spectrum

- Problem to observe CRs: CRs diffused

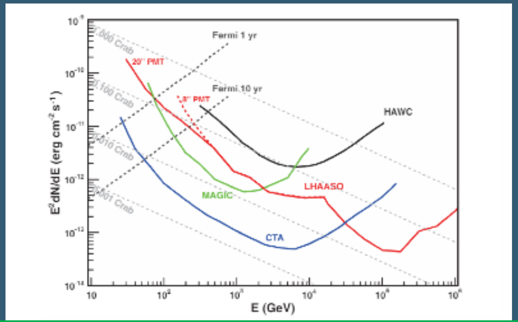
→ we can't link them to their original sources → have to use γ-ray astronomy

GENERAL IDEA OF THE THESIS

- Model the acceleration of PeVatrons in several types of sources (SNRs, stellar winds, all these in star clusters, with collective effects)



- Model the transport of PeVatrons between the source and a molecular cloud and the consequent production of γ rays with energy >100TeV (analytic + Python)

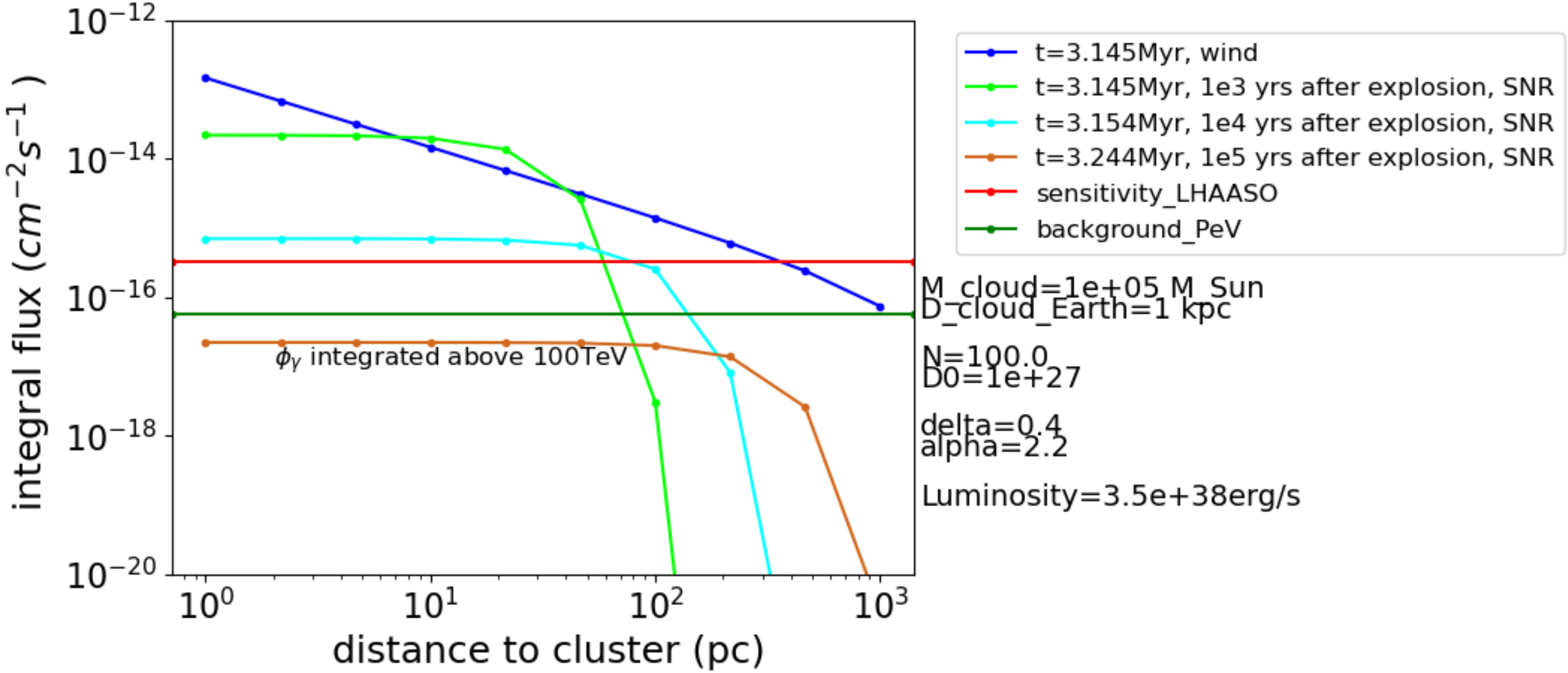


- Compare to the γ-ray flux observed by the very recent detector LHAASO

→ Identify the contribution of the different classes of galactic accelerating sources to the flux of CRs in the PeV domain.

→ And obtain better constraints on the different acceleration parameters (stellar wind efficacity, injection spectrum in the ISM,…)

PRELIMINARY RESULTS



In a certain range of parameters, stellar winds can dominate and generate **gammas rays >100TeV** detectable by LHAASO if the cloud is close enough

FOR THE FOLLOWING

1) Find an existing corresponding system, use LHAASO to obtain flux data and constrain some parameters, especially the efficacity in Wind Termination Shock and the injection spectrum

2) Create a sort of sky map giving the probability, given nearby sources and molecular clouds, to have an excess of gamma rays >100TeV so that LHAASO can then observe them.

3) Study and refine different acceleration models to explain PeVatrons with LHAASO data

Thank you for your attention !

APPENDIX: EQUATIONS

$$J(E,R,t) = 4\pi p^2(E)\frac{c}{4\pi}f(p(E),R,t)\frac{dp(E)}{dE}$$

$$J_{imp}(E,R,t) \simeq \frac{N_0}{\pi^{3/2}R_{dif}^3}(p^{1-\alpha_p}(E))\frac{E+m_pc^2}{c}\exp\left(-\frac{R^2}{R_{dif}^2(E,t)}\right)$$

$$J_{cont}(E,R,t) \simeq \frac{Q_0}{4\pi D(E)R}(p^{1-\alpha_p}(E))\frac{E+m_pc^2}{c}erfc\left(\frac{R}{R_{dif}(E,t)}\right)$$

$$q_\gamma = 4\pi n_H \int \frac{d\sigma}{dE_\gamma}(T_p,E_\gamma)J(T_p)dT_p$$

$$\boxed{\phi_\gamma = \frac{q_\gamma}{n_H 4\pi d^2}\frac{M_{cloud}}{m_p}}$$