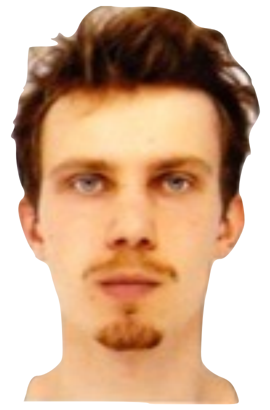
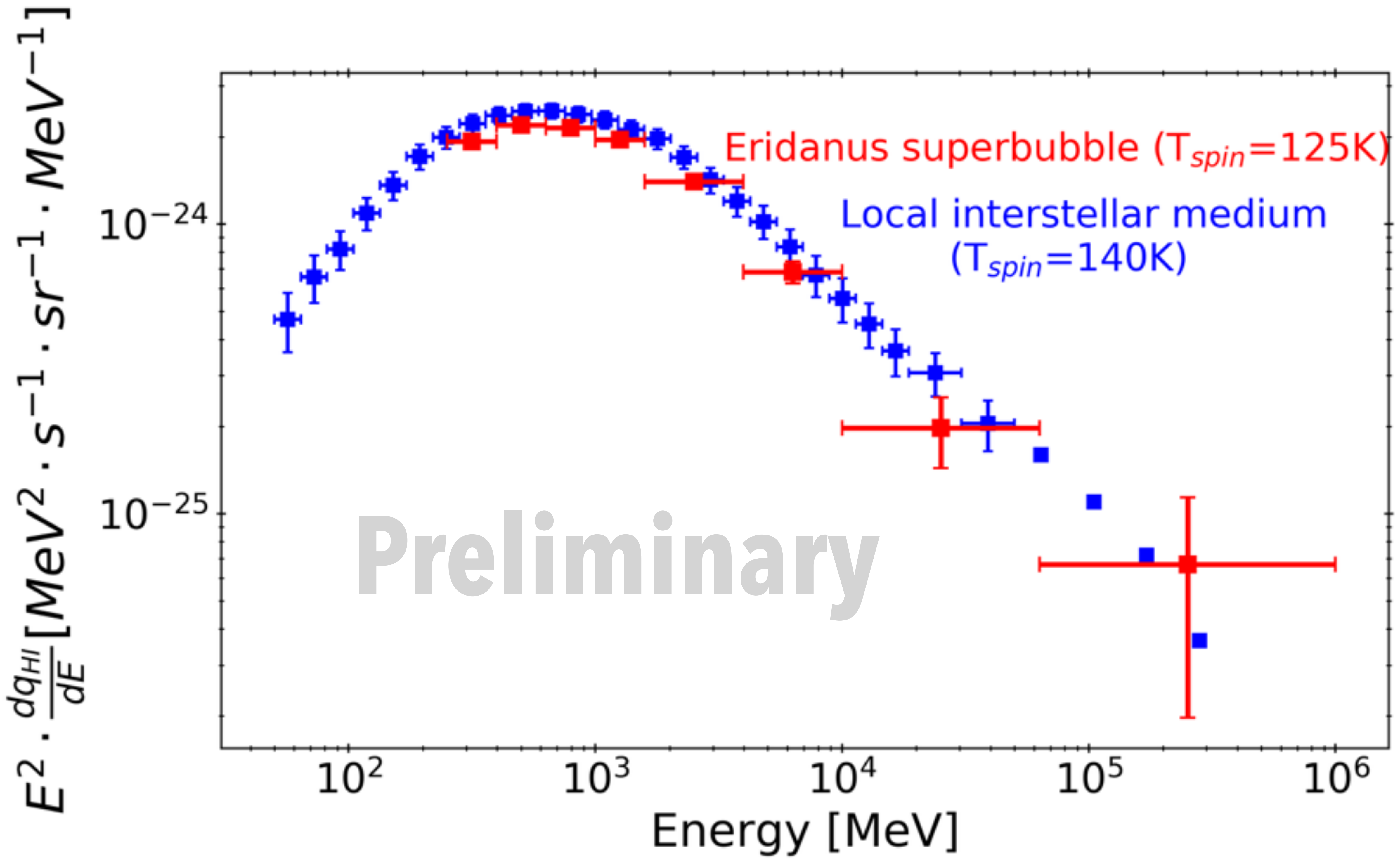
Cosmic rays in the Orion-Eridanus superbubble



Théo Joubaud, Isabelle Grenier, Jean-Marc Casandjian
on behalf of the **Fermi-LAT collaboration**

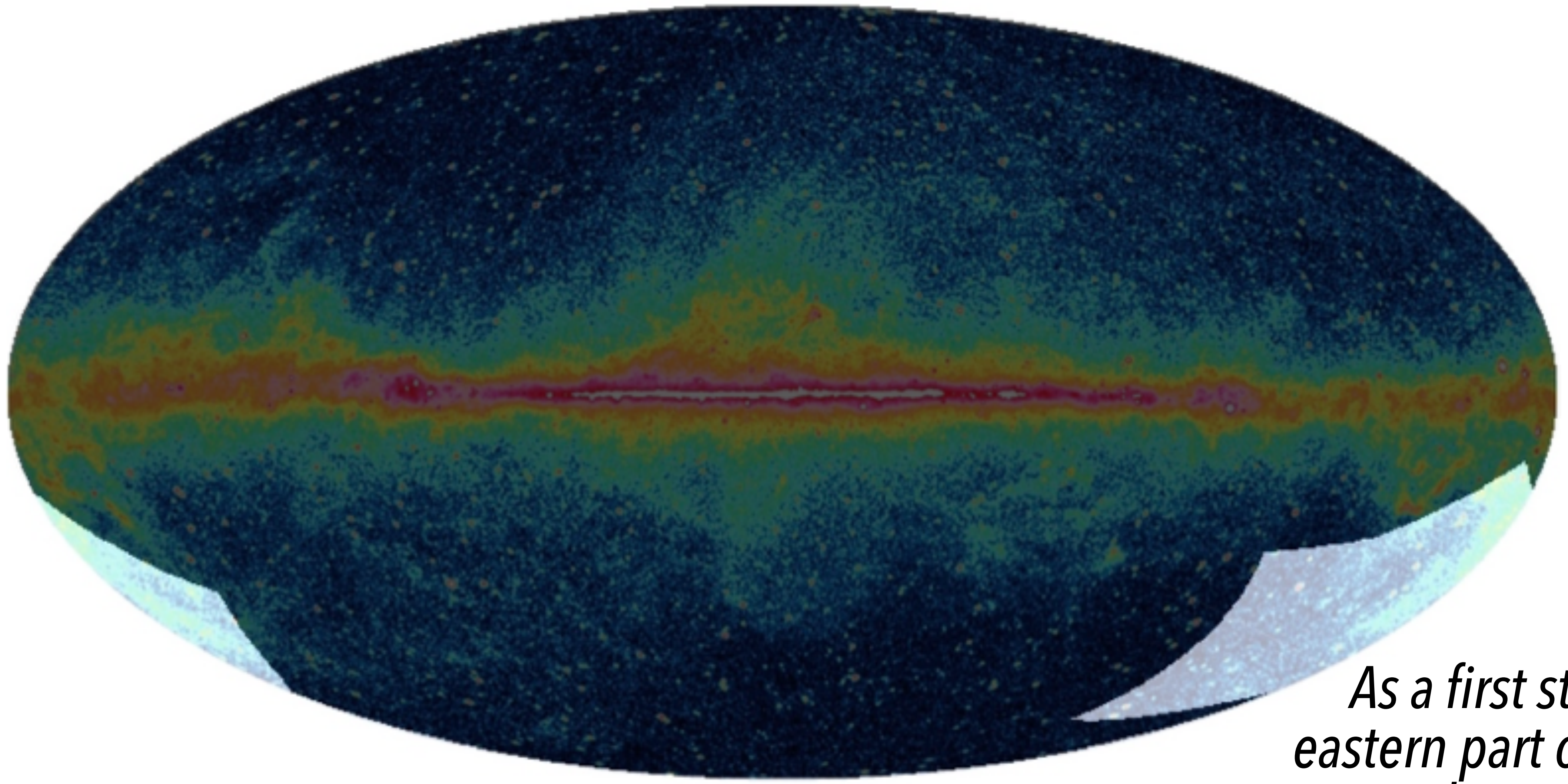
7th Fermi Symposium, Germany

The nearby **Orion-Eridanus superbubble**, blown by the supernovae and winds of Orion's massive stars, has likely **produced cosmic rays** and **altered their diffusion** in the highly turbulent medium. Yet, the analysis of the Fermi LAT data yields a γ-ray emissivity spectrum of the gas inside the bubble that **agrees with the average** measured in the broader, but still nearby interstellar medium of the Gould Belt. This uniformity calls for a detailed assessment of the past supernova rate and of the particle propagation in and around the superbubble.

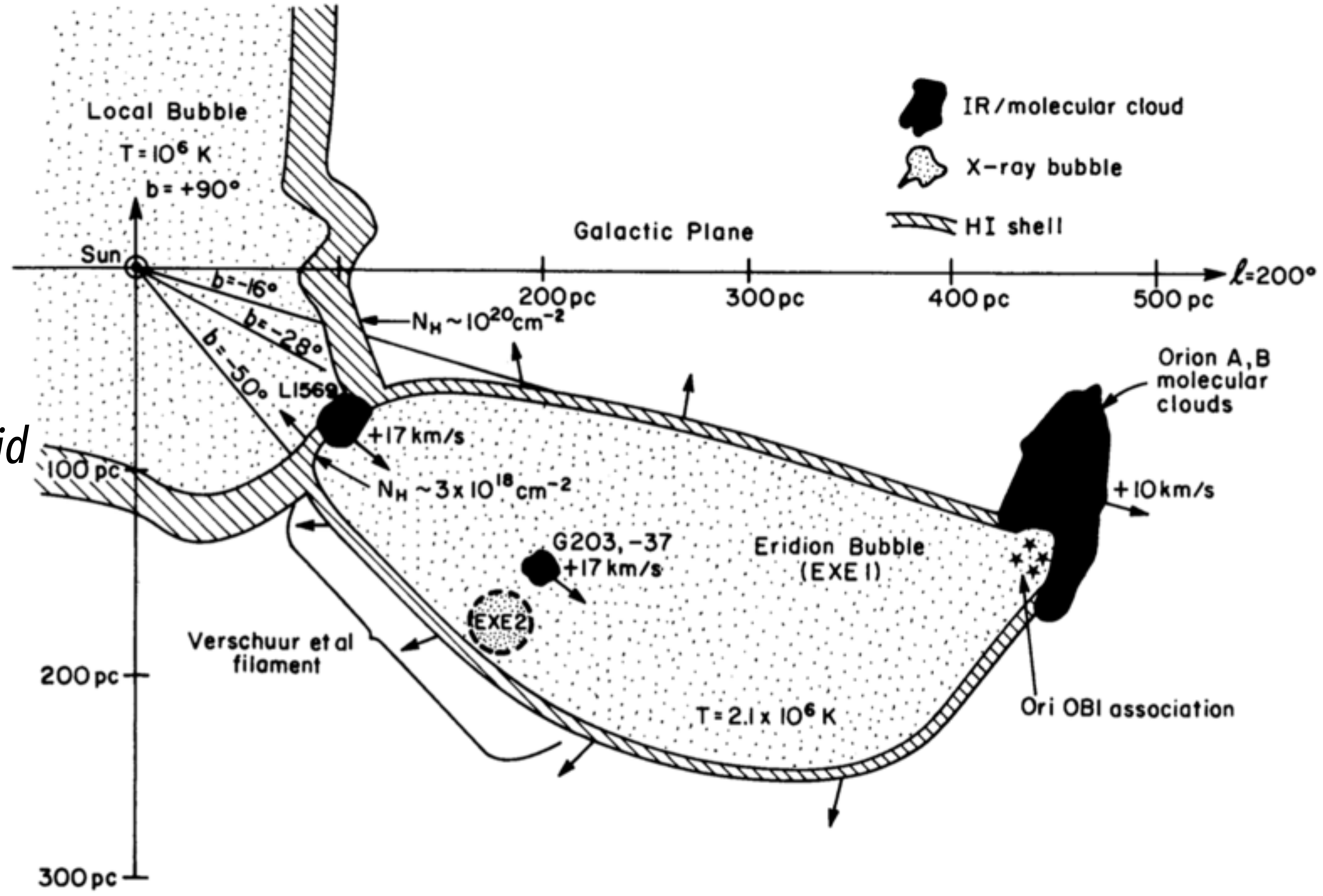


The Orion-Eridanus superbubble

The ~12 Myr-old superbubble [3] has been blown by the supernovae and supersonic winds of Orion's massive stars. It has likely **fostered cosmic-ray acceleration.** The large level of MHD turbulence in the bubble can also affect the diffusion properties of cosmic rays. We aim to **probe the cosmic-ray flux** inside the superbubble by comparing the γ-ray emission produced in the inner clouds with the average emissivity measured in other interstellar clouds in the solar neighbourhood [1].



As a first step, we focus on the south-eastern part of the superbubble and avoid the complex vicinity of Orion.



Possible geometry of the superbubble [2]

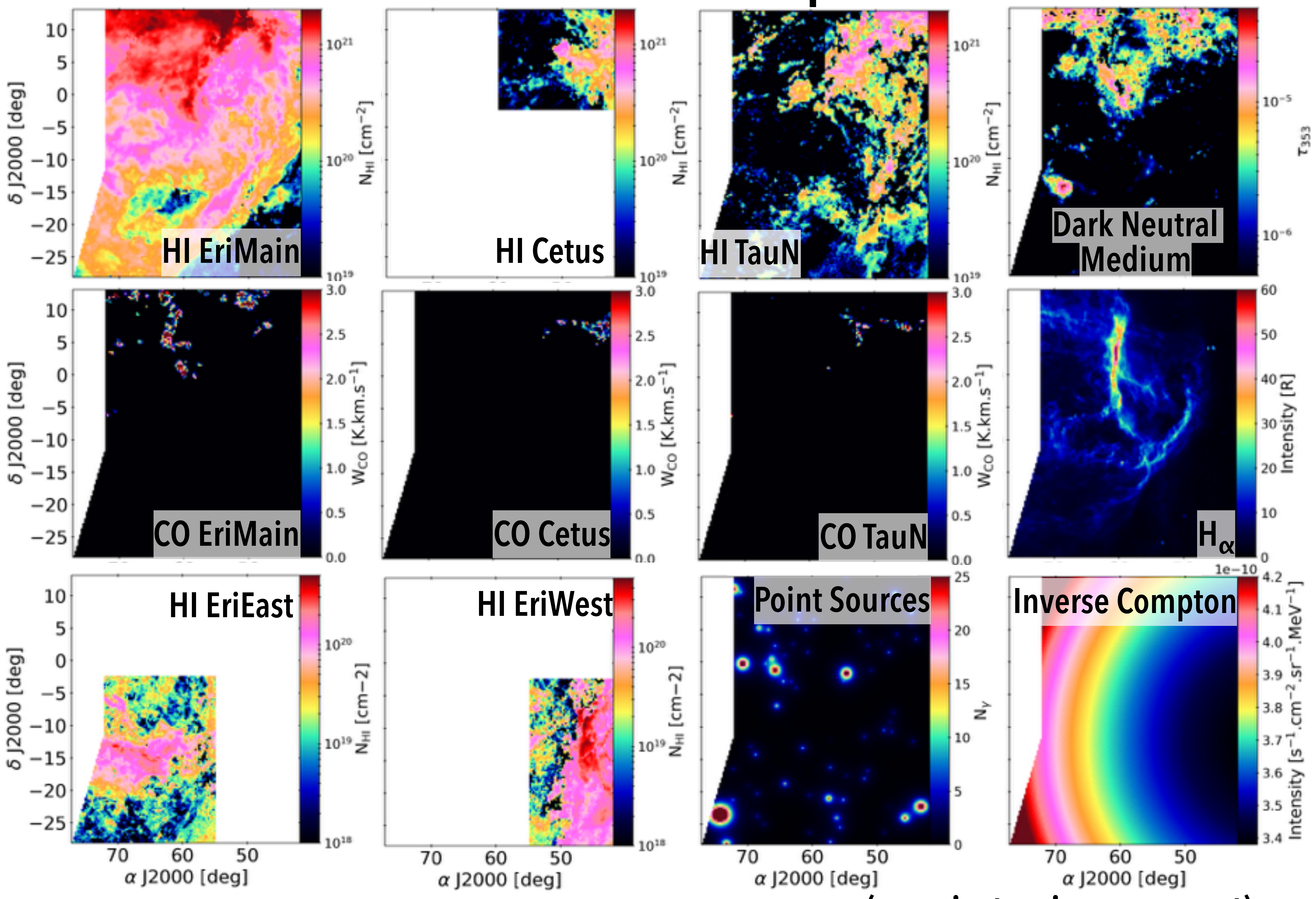
Characteristics of the superbubble [3]:

- last 12 Myr : 10-20 Supernovae
- last 12 Myr : 30–100 formed stars with M ≥ 8 M⊙
- d ~ 180-400 pc

Modelling the γ-ray emission

To this aim, we have used 8 years of Fermi LAT data above 100 MeV, **the spatial and spectral distributions of which have been modelled** in terms of interstellar emission borne in the **different gas phases** of 5 clouds (atomic, dark neutral, molecular, and ionized phases). The model includes other ancillary components such as inverse-Compton emission, point sources, and solar and lunar emissions. The **atomic and molecular gas** phases are traced by radio HI and CO emission lines, the **ionized gas** by H_α optical recombination lines, and the **dark neutral medium** from the coupled analysis of the γ-rays and of the dust optical depth derived from the Planck and IRAS observations [4].

selection of model components

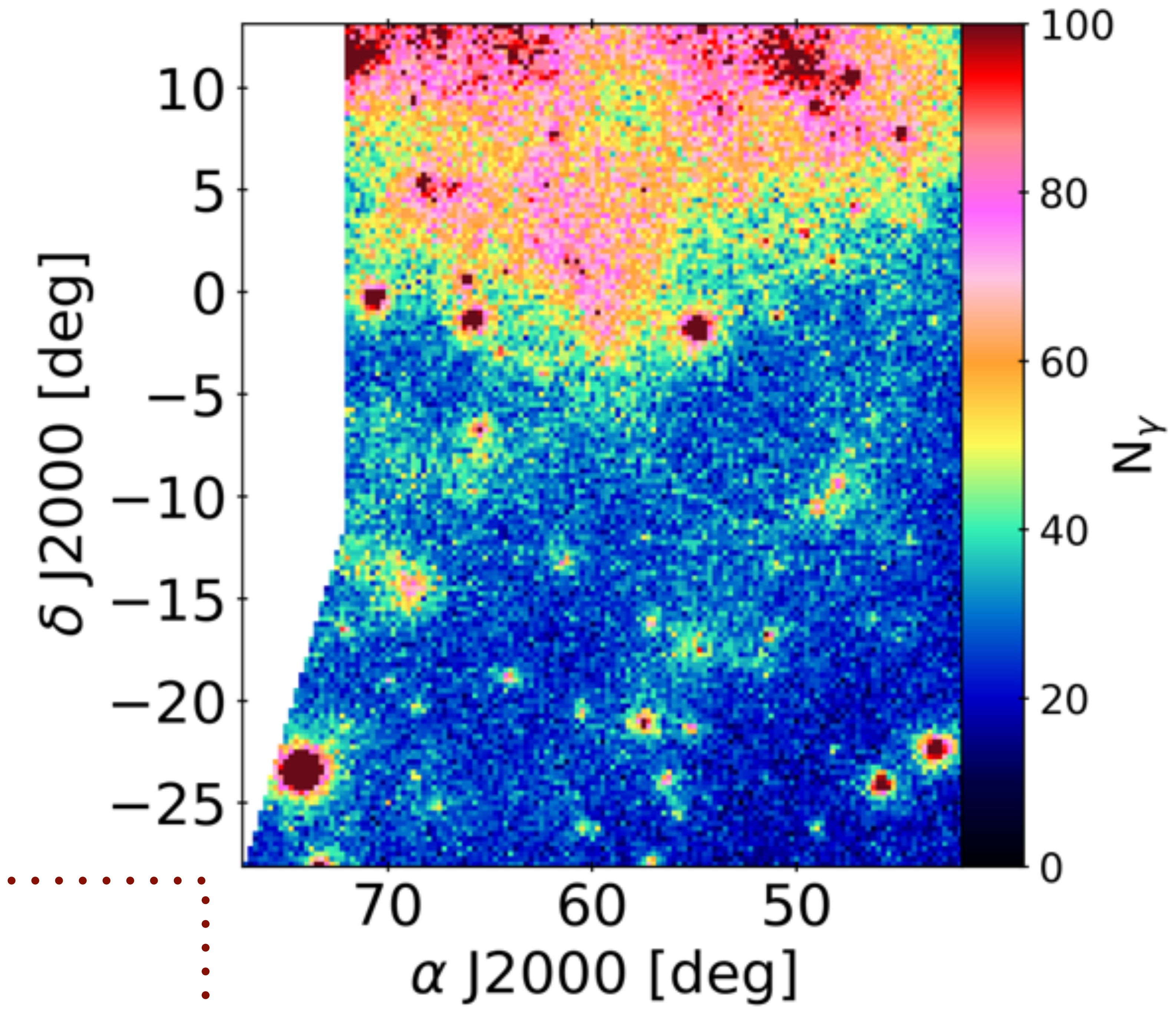


(+ an isotropic component)

FIT

- binned max. likelihood
- in 8 energy bins 0.25 GeV-TeV
- energy-dependent spatial & energy resolutions

γ rays > 250 MeV



Interstellar medium data:

HI : HI4PI (Bailin et al. 2016)

CO : CfA (Dame, 2001)

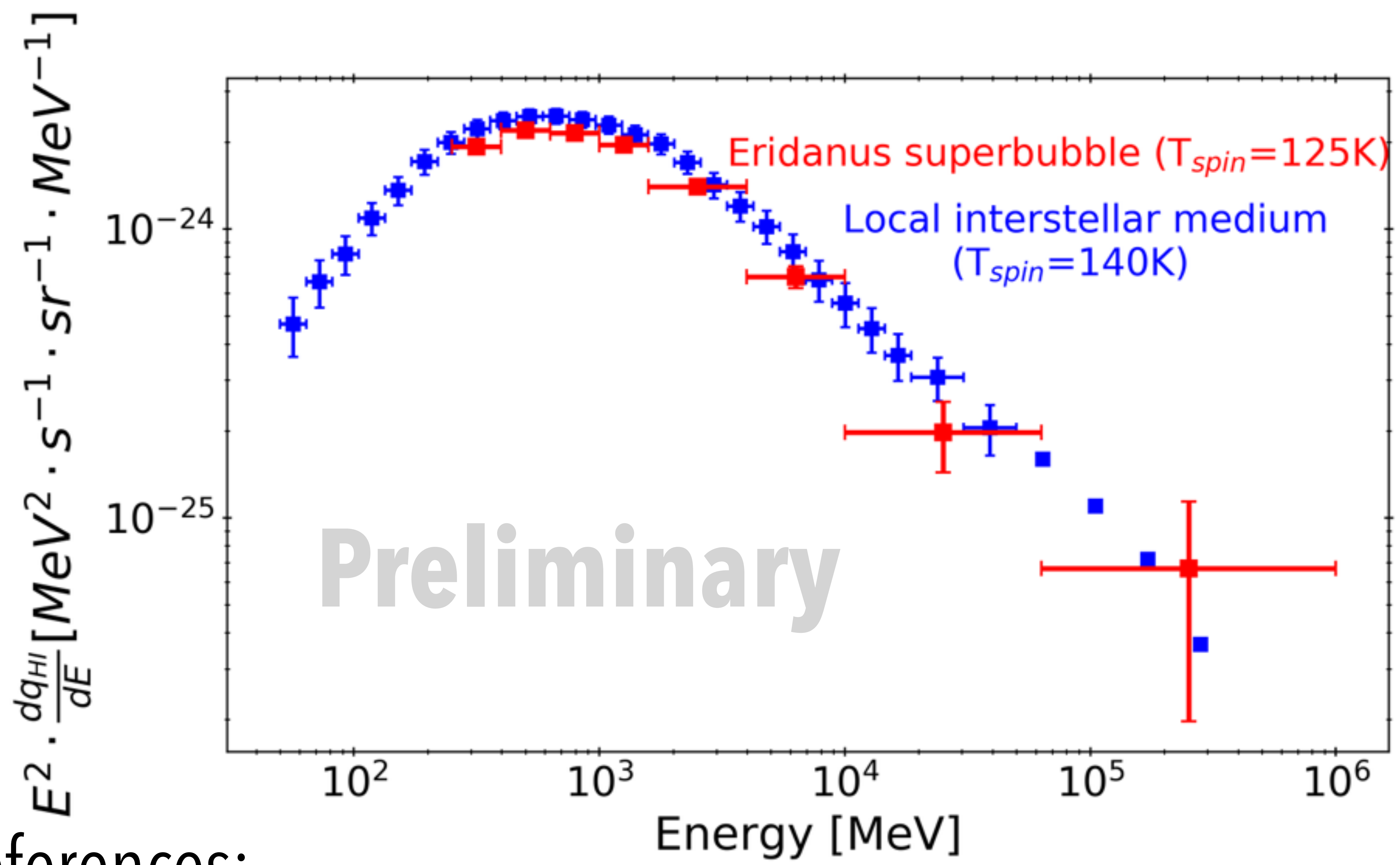
Dust : Planck + IRAS, optical depth 353GHz (Planck collab. 2016)

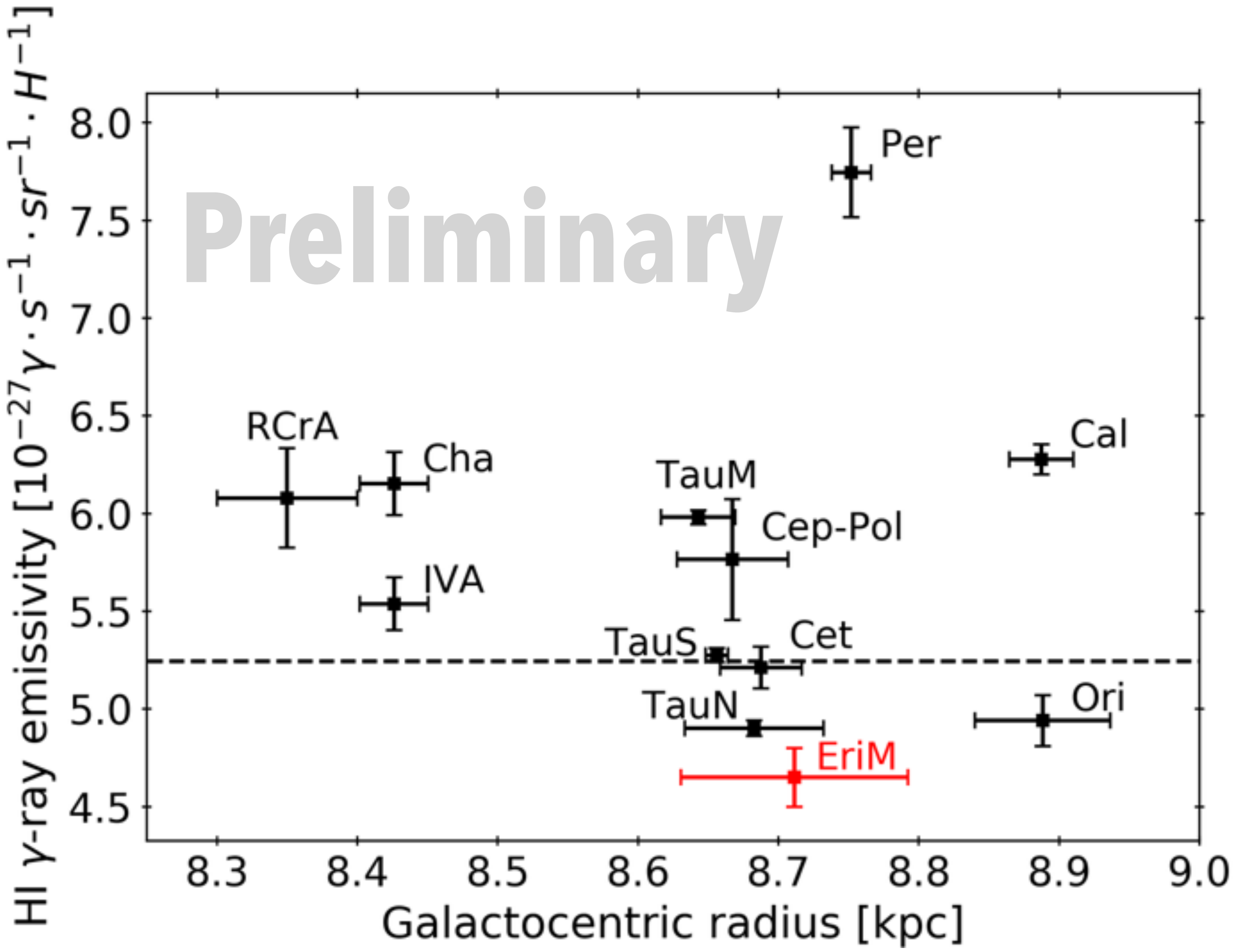
H_α : VTSS, SHASSA, WHAM (Finkbeiner 2003)

Gamma : Fermi-LAT, 8 years, 250 MeV → 1 TeV, energy-dependent cut in zmax(E) zenith angle

Results and prospects

Preliminary results show that the emissivity spectrum is **consistent with the average spectrum** measured outside the superbubble, in nearby clouds of the Gould Belt. The agreement covers the entire energy range from 250 MeV to 1 TeV, with no hint of depletion at low energies, nor of hardening at high energy. This uniformity calls for a detailed assessment of the recent **supernova rate and of the energetics of massive stellar winds** in the superbubble [5] in order to estimate the production rate and diffusion lengths of young cosmic rays and to evaluate the need, or not, to advect them away in the Gould Belt or to the halo via the local Galactic wind [6].





✢: nearby clouds [7]
––-: local interstellar medium average [1]
main Eridanus cloud
all for HI spin temperatures of 125-150 K

References:

[1] Jean-Marc Casandjian, *The Astrophysical Journal*, 806(2) :240, 2015.
[2] D. N. Burrows, K. P. Singh, J. A. Nousek, G. P. Garmire, and J. Good. *The Astrophysical Journal*, 406 :97–111, March 1993.
[3] J. Bally. Overview of the Orion Complex, page 459. December 2008.
[4] Planck Collaboration, Planck intermediate results XVII, *A&A* 566 :A55, June 2014.
[5] Grenier, I. A., Gamma-ray sources as relics of recent supernovae in the nearby Gould Belt, Astronomy and Astrophysics, v.364, p.L93-L96, 12/2000
[6] R. Schlickeiser, W. R. Webber, and A. Kempf, Explanation of the Local Galactic Cosmic Ray Energy Spectra Measured by Voyager 1. I. Protons , APJ78735
[7] Q. Remy, I. A. Grenier, D.J. Marshall, and J. M. Casandjian, A&A 601, A78 (2017)