Upper limits on the cosmic-ray luminosity of supernovae in nearby galaxies

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Secondary gamma ray production

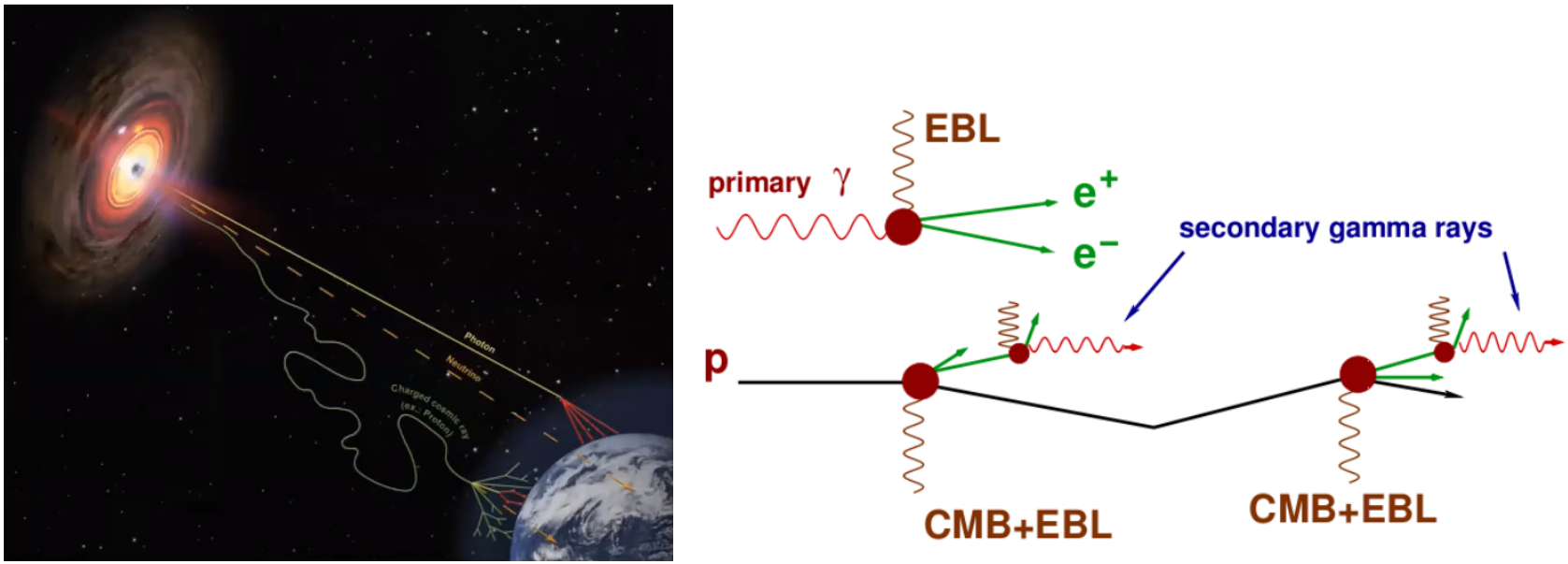

Figure 1: Production of gamma rays and secondaries [1]

[1] KUSENKO, UCLA, *physics and astronomy*, Available in: http://www.pa.ucla.edu/. Access: 06/30/2021.

Upper Limit on Cosmic Ray Luminosity from Gamma Ray Sources

The cosmic-ray flux observed on Earth is defined as:

$$I^{UHECR} = \frac{L_{CR} W_s(\hat{n})}{4\pi(D_s^2)(1+z) < E >_0} K_{RC} P_{RC}(E) \quad (1)$$

This same source generates the flux of secondary gamma rays. Defined as:

$$I_\gamma(E_\gamma) = \frac{L_{CR}}{4\pi(D_s^2)(1+z) < E >_0} K_\gamma P_\gamma(E_\gamma) \quad (2)$$

We can write the Luminosity as:

$$L_{CR}^{UL} = \frac{4\pi D^2(1+z_s)}{\sum_A f_A \frac{K_\gamma^A}{\langle E_0^A \rangle} \int_{E_{th}}^{\infty} dE_\gamma P_\gamma^A(E_\gamma)} I_\gamma^{UL}(> E_\gamma^{th}) \quad (3)$$

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The method of calculating the UHECR Luminosity Limit from limits on the gamma flux is given from the measurement of the upper limit on the integral of the gamma ray flux in GeV-TeV of a source, obtained by H.E.S.S.[2].

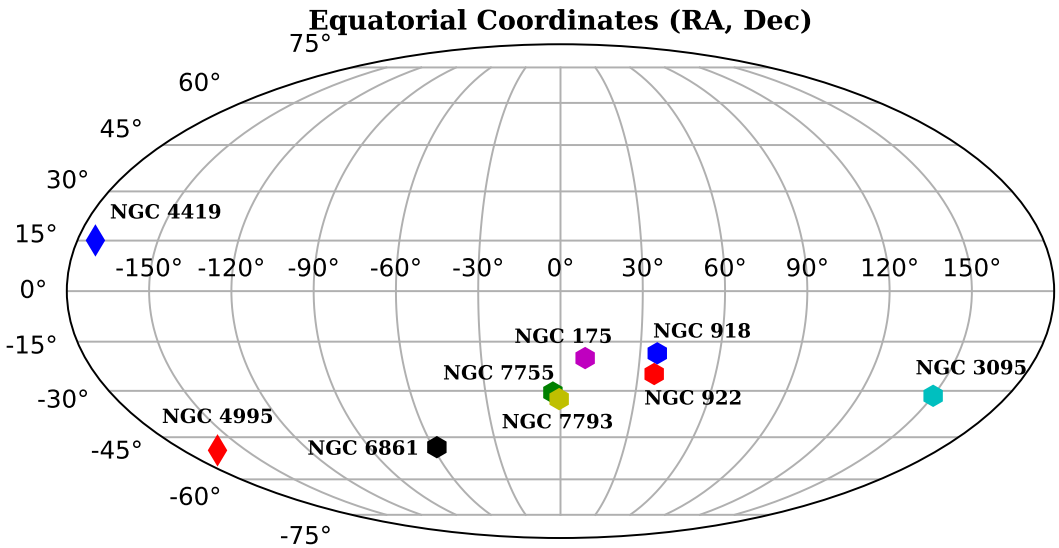

Figure 2: Supernovae observed with H.E.S.S.

[2] H.E.S.S. Collaboration, *Upper limits on very-high-energy gamma-ray emission from core-collapse supernovae observed with H.E.S.S.*, A&A 626 A57 (2019). Access: 06/30/2021.

Upper limits on the integral of gamma ray flux at 95% CL

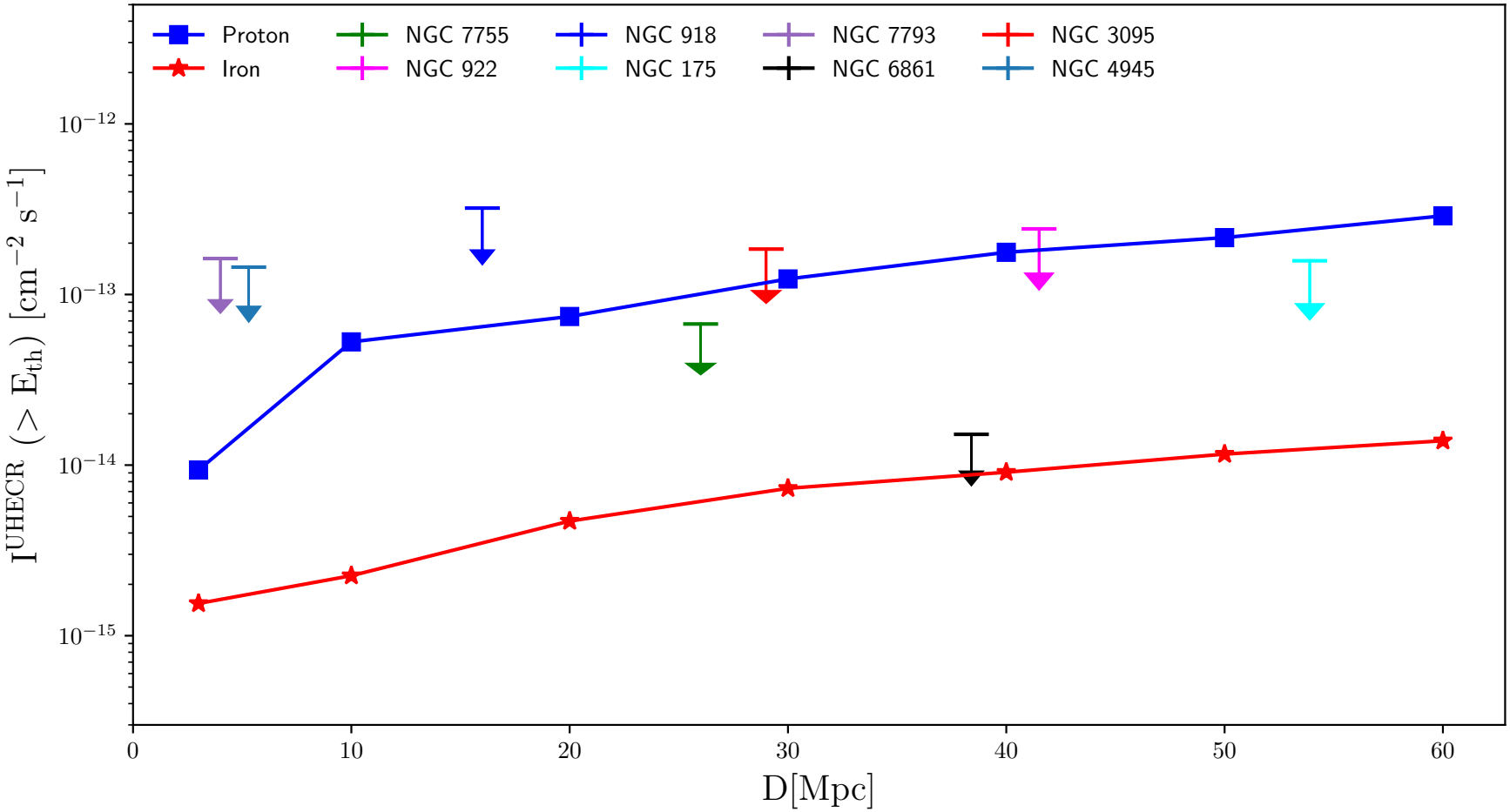

Figure 3: I^{UHECR} as a function of the source distance.

Cosmic Ray Luminosity Measurements

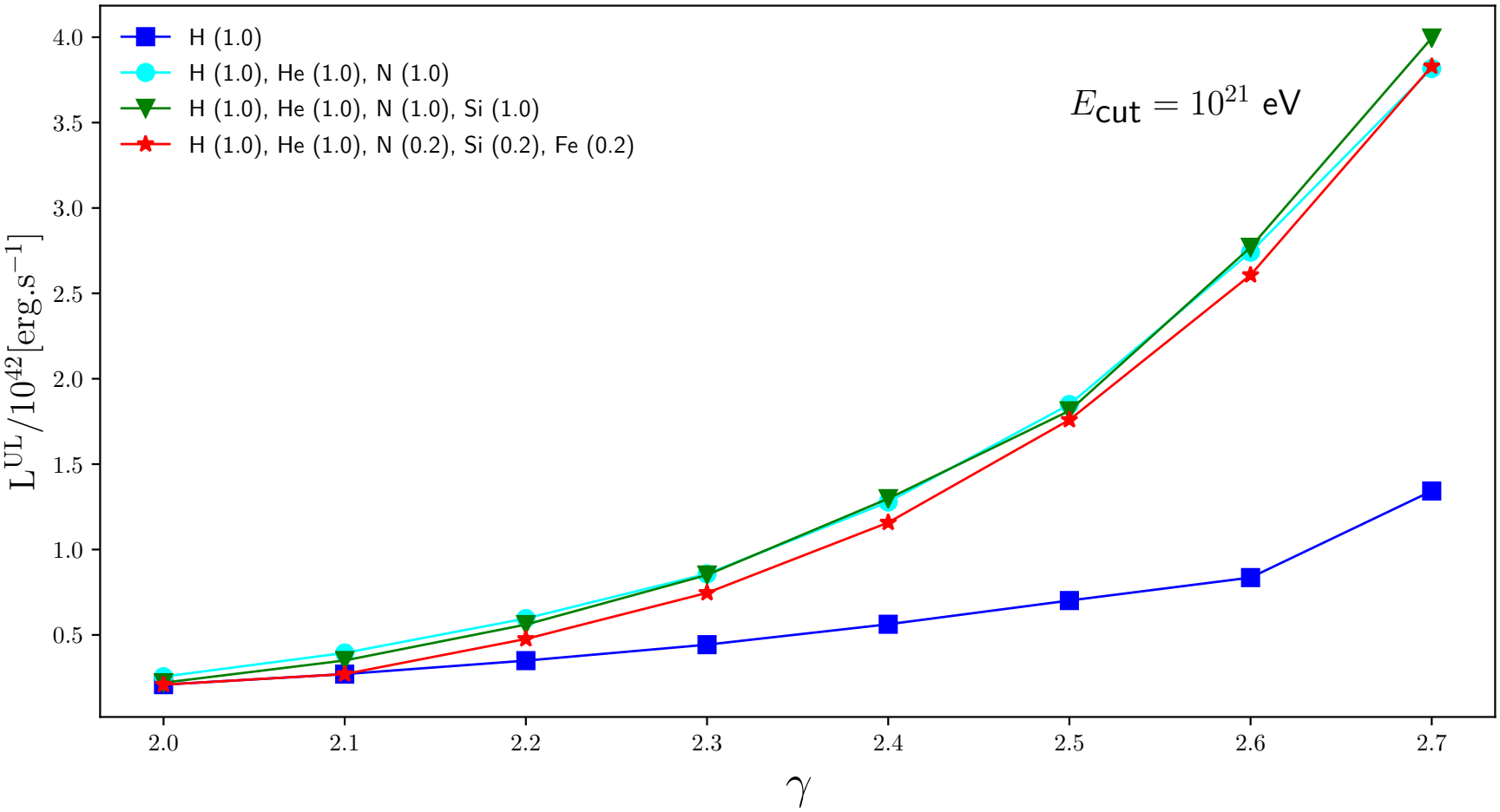

Figure 4: Cosmic-ray luminosity of the source NGC 6861.