



Introduction

The three basic mechanisms that can produce gamma-ray fluxes associated with CRs are: i) the decay of neutral pions, ii) electron/positron bremsstrahlung, and iii) inverse Compton scattering of light by electrons/positrons coming from pions. These cascade processes show a correlation between the upper limit on the integral GeV - TeV gamma-ray flux and the upper limit on the ultra-high energy CRs (UHECRs) luminosity [1], motivating multi-messenger studies to calculate the luminosities of UHECRs for specific point sources.

Observations and Results

We calculate the upper limits on the cosmic-ray luminosity with mixed compositions that fit both measurements on the UHECR energy spectrum and mass composition acquired by Auger Collaboration [2]. The secondary gamma-ray flux is proportional to its cosmic-ray flux or luminosity produced by NGC 6861. Therefore, the production of the gamma-rays is conservative and in function of the cosmic-ray luminosity that may be expressed:

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

Figure 1 illustrates the sources for which we can calculate the UHECR luminosity from integral of GeV-TeV gamma-ray measurement. Figure 2 shows the sample of supernovae in nearby galaxies and the UHECR events around the sources.

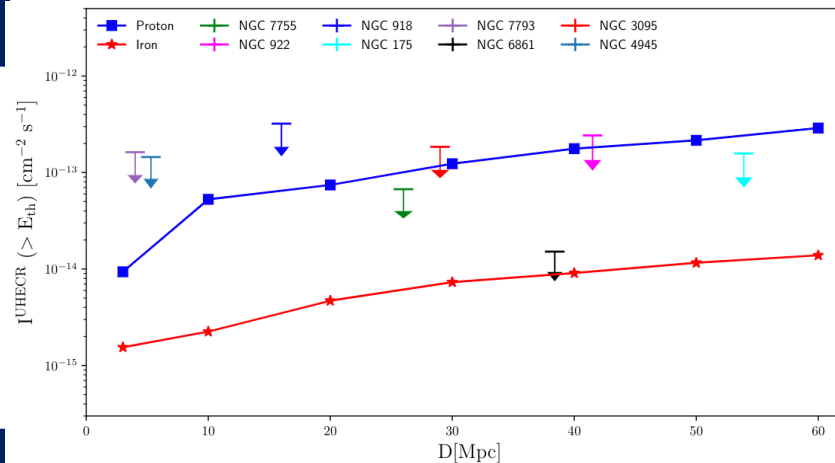


Figure 1: $|J_{UHECR}$ as a function of the source distance.

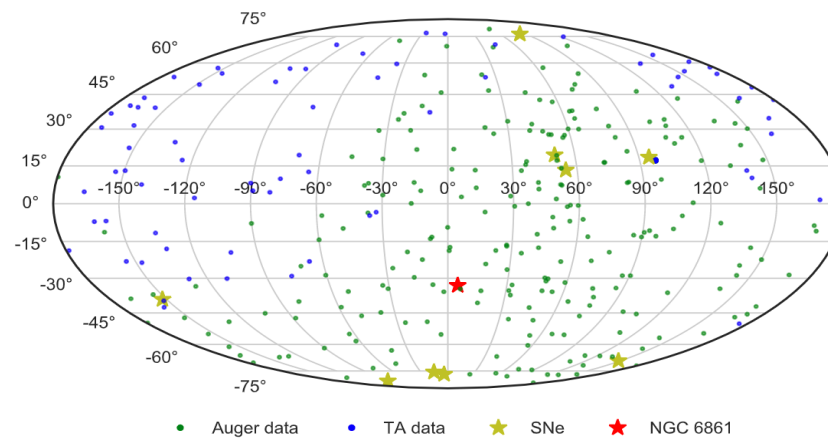


Figure 2: UHECR event locations with SNE in Galactic coordinates. The red star indicates the location of NGC 6861.

The upper limit on the cosmic-ray luminosity as a function of the spectral index for NGC 6861 hosting SN 2005dn for several compositions at source and for $E_{cut} = 10^{21}$ eV. See Figure 3.

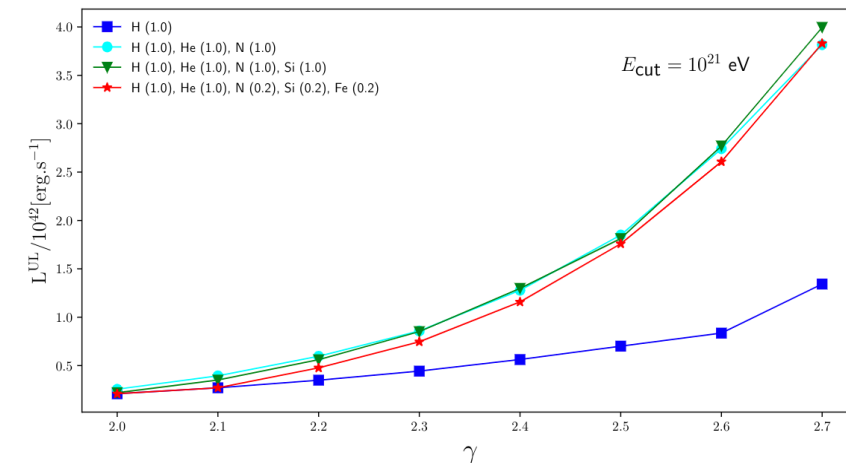


Figure 3: Cosmic-ray luminosity from gamma-rays observations.

Conclusion

In this work we calculated the luminosity for the supernovae NGC 6861 using integral of gamma-ray measurement. The upper limits on the UHECR luminosity for sources will be investigated in different environments in future papers.

References

- [1] K. Kotera and A.V. Olinto, *The astrophysics of Ultrahigh Energy Cosmic Rays*, 49, 119 (2011). [arXiv:1101.4256].
- [2] A.D. Supanitsky and V. de Souza. *An upper limit on the cosmic-ray luminosity of individual sources from gamma-ray observations*, JCAP12, 023 (2013).