Study of cosmic-ray acceleration regions through their chemical composition

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Cosmic rays (CRs) are charged particles, mostly protons and atomic nuclei. Low energy (<1 GeV) CRs ionize the gas and play a key role in the chemistry of the interstellar medium. It is necessary to know where they are accelerated and how they propagate. Supernova remnants (SNRs) have long been suspected as the primary accelerators of Galactic cosmic-ray particles via diffusive shock acceleration processes [1]. A molecular cloud located in the vicinity of a cosmic ray accelerator such as an SNR provides a dense target reservoir for the freshly accelerated CR particles to interact in. For instance, CRs interact with interstellar grains producing non-thermal desorption [2, 3, 4] or direct radiolysis of interstellar ice mantles [5]. In astrochemical models, the efficiency of all these processes are assumed to depend on a single parameter: the CR ionization rate of H_2 (ζ_{H2}). Because CRs impact the chemistry, the abundance of molecules is used to constrain ζ_{H2} in various regions of the interstellar medium. Indriolo et al. [6] for instance used H_3^+ abundances to derive a very high ζ_{H2} near the SNR IC 443, approximately two orders of magnitude larger than the "standard" one which is of 10^{-17} s^{-1} [7].

In this work, we focus on the HB3/W3 region, where HB3 is an SNR and W3 its adjacent cloud and active massive star forming region. Some observational campaigns with the IRAM 30m and Yebes 40m radiotelescopes allowed us to obtain radio data of the part of W3 interacting with the SNR, and to extract the molecular abundances. Using the 3-phase gas-grain astrochemical model Nautilus [8, 9], we were then able to constrain ζ_{H2} in the region. In parallel, we also use gamma-ray data from the Fermi-LAT telescope to probe the presence and spectrum of high-energy cosmic rays in the HB3/W3 region, providing complementary constraints on cosmic-ray propagation and interaction with the surrounding medium.

References

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