The Implications of a High Cosmic-Ray Ionization Rate in Diffuse Interstellar Clouds[a]

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Diffuse interstellar clouds show large abundances of H_3^+ which can be maintained only by a high ionization rate of H_2. Cosmic rays are the dominant ionization mechanism in this environment, so the large ionization rate implies a high cosmic-ray flux, and a large amount of energy residing in cosmic rays. In this study we find that the standard propagated cosmic-ray spectrum predicts an ionization rate much lower than that inferred from H_3^+. Low-energy (~ 10 MeV) cosmic rays are the most efficient at ionizing hydrogen, but cannot be directly detected; consequently, an otherwise unobservable enhancement of the low-energy cosmic-ray flux offers a plausible explanation for the H_3^+ results. Beyond ionization, cosmic rays also interact with the interstellar medium by spalling atomic nuclei and exciting atomic nuclear states. These processes are responsible for the production of the light elements Li, Be, and B, as well as gamma-ray lines. To test the consequences of an enhanced low-energy cosmic-ray flux, we adopt two physically-motivated cosmic-ray spectra with high fluxes at low energies, which by construction reproduce the ionization rate inferred in diffuse clouds. We then investigate the implications of these spectra on dense cloud ionization rates, light element abundances, and gamma-ray fluxes. In reproducing the inferred cosmic-ray ionization rates, one spectrum matches light element abundances and their ratios to within factors of 2 and 1.5, respectively, while the other only predicts absolute abundances to within a factor of 5. However, both spectra predict gamma-ray fluxes slightly below the reach of *INTEGRAL*. The global Galactic power input required in both spectra is about 0.2×10^{51} erg $(100\ \mathrm{yr})^{-1}$, a significant fraction of the energy released in supernovae explosions. This means that either supernovae or some other mechanism(s) must be rather efficient at converting mechanical energy into the acceleration of cosmic rays. Overall, one spectrum proposed in this study provides an explanation for the high ionization rate seen in diffuse clouds, and still appears to be broadly consistent with other observables.

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