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Voyager 1 Observations of Galactic Cosmic Rays in the Local Interstellar Medium: Energy Density and Ionization Rates

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Voyager 1 (V1) has been in the local interstellar medium (LISM) since August, 2012. We present the galactic cosmic-ray (GCR) energy spectra of most elements from H through Ni, and also of electrons, for a period exceeding two years. The V1 energy spectra define the newly-revealed, low-energy part of the interstellar spectra of nuclei down to ∼1 MeV/nuc and of electrons down to ∼8 MeV. We use these observations, along with estimates of the higher-energy portion of the interstellar nuclei spectra and estimates of the interstellar electron spectra at both higher and lower energies, to estimate the energy density of cosmic rays in the LISM and the cosmic ray ionization rate of atomic H. We find that the total energy density of cosmic rays is ∼1.0 eV cm^{-3}, which includes a contribution of 0.02 eV cm^{-3} from electrons. This energy density is somewhat larger than the energy density of the local interstellar magnetic field (∼0.6 eV cm^{-3}).

We find the cosmic ray ionization rate of atomic H to be 1.7 x 10^{-17} s^{-1}, which is a factor of ∼10 below the ionization rates in diffuse interstellar clouds based on astrochemistry methods. The cross section for ionization of H atoms peaks at lower energies than our observations, so a significant contribution to the total ionization rate of the LISM could be occurring below our detection threshold. In order to match the higher ionization rate, the new V1 observations would require that one or both of the interstellar spectra of nucleons and electrons turn up at energies below ∼1 MeV/nuc for nuclei and ∼8 MeV for electrons.

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