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Propagation of Low-Energy Cosmic Rays in Molecular Clouds: Calculations in Two Dimensions

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MOTIVATION: Low energy (< 1 GeV) cosmic rays drive interstellar chemistry and may cause specific spectral features recently measured, such as the 6.7 keV emission line. Yet the origin and flux of low energy cosmic rays is currently unknown because the Sun's magnetic field deflects these particles, so that they cannot be directly observed. A robust model of cosmic ray transport in molecular clouds is important in order to better understand interstellar chemistry and to explore possible line emissions caused by these cosmic rays.

METHOD: We calculate cosmic ray transport with a collisional Boltzmann Transport Equation, treating both elastic and inelastic collisions, including external electromagnetic forces. We apply the Crank-Nicholson Method to solve the Boltzmann Transport Equation. At each time step, the spatial distribution of cosmic rays is applied to the ZEUS 2D magnetohydrodynamics model. The ZEUS model is then utilized to calculate the resulting electromagnetic field. Finally, the field is applied to the Boltzmann Transport Equation. This sequence is repeated over many time steps until a steady state is reached.

RESULTS: We consider results from $t = 0$ until steady state for an isotropic low energy cosmic ray flux, and also for an enhanced cosmic ray flux impinging on one side of a molecular cloud. The calculated flux is related to the distance into the cloud, and fit by analytic functions.

IMPLICATIONS: This cosmic ray flux is used to determine an ionization rate of interstellar hydrogen by cosmic rays, ζ. Astrochemical implications and possible spectral features are briefly mentioned.

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Classification de Session: Impact of cosmic rays over chemistry and climate