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The effect of self-consistent stochastic preacceleration of Pickup Ions on the composition of anomalous cosmic rays.

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Abstract. We have previously calculated the spectrum of anomalous cosmic rays (ACR) by employing the supposed spectrum of interstellar pickup ions as the seed population for a Monte Carlo model of the solar wind termination shock. This pickup ion spectrum was extrapolated from measurements some distance from the shock under the assumption that adiabatic loss was the only energy change process acting prior to reaching the shock. Our results while reasonable in many respects were underabundant in He^+ and O^+ ions relative to H^+ as determined by observation. le Roux and Ptuskin have shown that stochastic preacceleration is more effective for He^+ and O^+ ions than for H^+ ions thereby redressing this underabundance. We have employed the results of le Roux and Ptuskin as input to our previous model and will show to what extend the relative abundances are improved thereby.

1 Introduction

IIn a previous work (Ellison, Jones & Baring (1999)) we employed our Monte Carlo shock acceleration model to explore the question of whether or not the Anomalous Cosmic Rays could be produced from the interstellar pickup ions by the solar wind termination shock using reasonable shock parameters. In this study we employed the values for pick up ions of Cummings,& Stone (1996) and employed a variety of parameters for solar wind speed, density, diffusion parameters etc. The pick up ion density spectrum that we employed at the shock is shown in Figure(1).

As can be seen the phase space density cuts off at a ion velocity in the wind fram equal to the speed of the solar wind, the speed with which they are picked up. The low energy tail is from adiabatic deceleration of ions injected deeper in the wind but note that there are no ions with velocities higher than their injection velocity. Employing this injection spectrum we were able to obtain an ACR spectrum as shown Figure (2).

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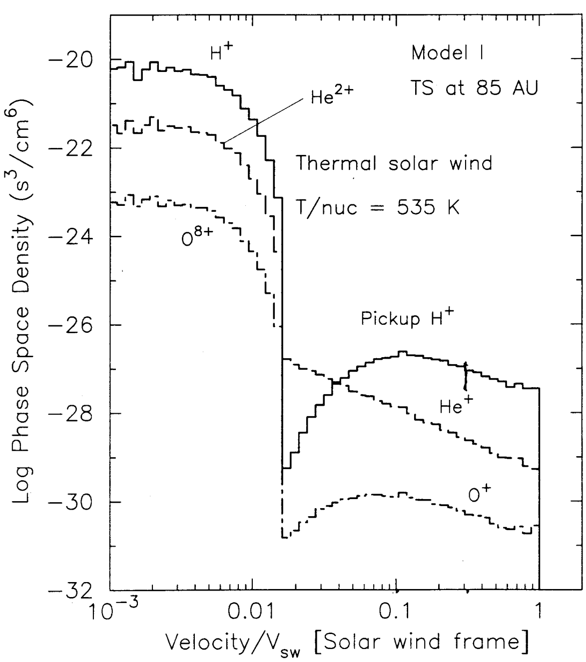

Fig. 1. Pick up ion phase space density employed in Ellison, Jones & Baring (1999).

2 The Problem

Although most models could be made to fit the H^+ data, as can be seen by comparing to Voyager data (Cummings, Christian & Stone (1995); Cummings,& Stone (1996)) taken at an average radial location of 57 AU and the straight line representing an extrapolation of the H^+ data to the termination shock (Cummings,& Stone (1996)) the flux of He^+ and O^+ are under produced by factors of 4 and 5 by the model. This result held true for all values of parameters that were tried.

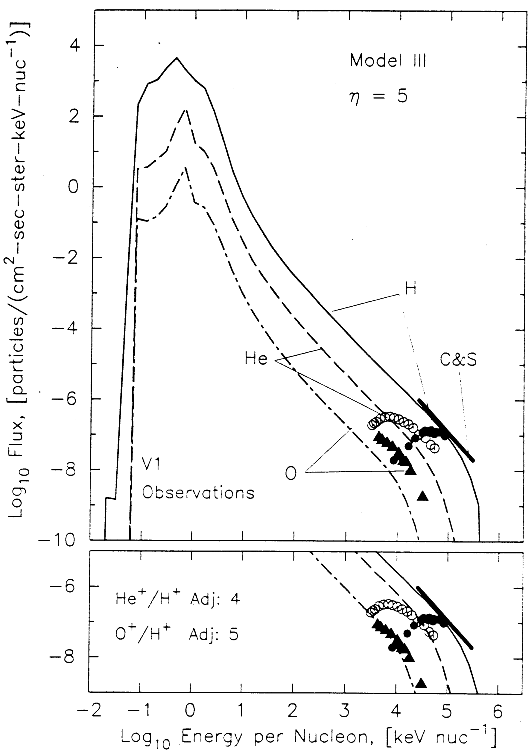

Fig. 2. Spectrum of ACR derived in Ellison, Jones & Baring (1999).

3 The Solution?

Since ions that start the shock acceleration process at a higher energy than others maintain this advantage in the final spectrum the spectrum of He^+ and O^+ would be enhanced if a way could be found to selectively heat the He^+ and O^+ while leaving the H^+ unchainged. le Roux & Ptuskin (1998) have found such a mechanism. They calculated the effect of preheating of the pickup ions by turbulence in the solar wind. They demonstrated that O^+ and He^+ would be fully heated but that H^+ would be under abundant in the heated tail due to absorption of the resonant waves by the background solar wind plasma. There is just too much hydrogen in the solar wind and in the pickup ions for it to be heated as effectivly as the much less bundant Helium and Oxygen. They speculated that this effect could produce the observed under abundance of H^+ in the ACR.

4 Results

We have taken the new pickup ion densities found by le Roux & Ptuskin (1998) (shown in Figure (3)) and used them in a

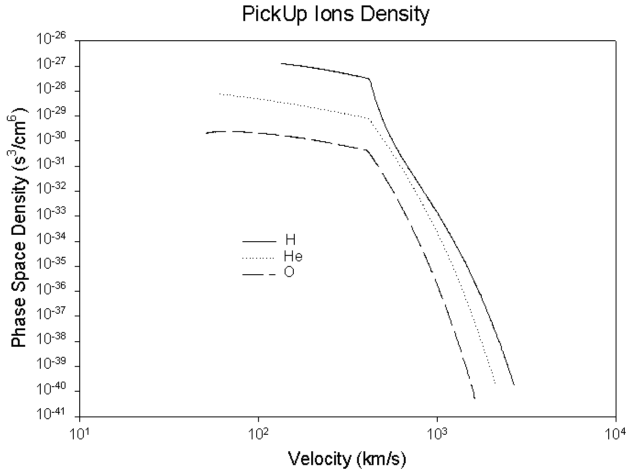

Fig. 3. Phase space density of pick up ions with pre heated tail

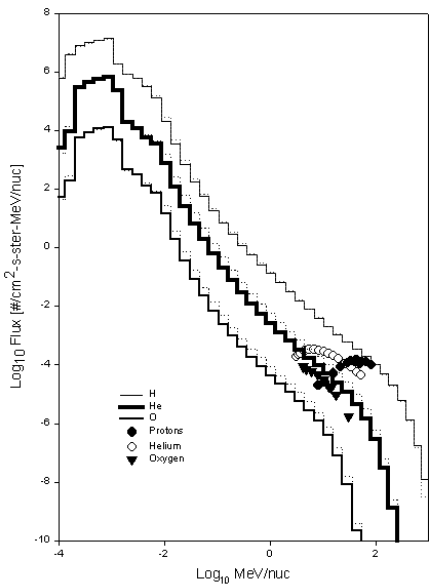

Fig. 4. ACR spectrum showing the effect of pre-heating. The dotted lines show the slight increase in the flux of Helium and Oxygen and none for Hydrogen due to the selective effect of the heating

new simulation of one of the models we previously investigated. The density of oxygen was multiplied by 0.16 to compensate for the fact that these authors used a value of the interstellar density that was larger than the one used by us.

As can be seen from this graph H^+ is seriously underabundant in the heated tail compared to He^+ and O^+. However, as can be seen from Figure (4), although adding the heated component to the shock process moves the ACR density in the right direction (enhancing He^+ and O^+ with essentially no effect on H^+) the effect does not seem to be nearly strong enough to explain the data.

Although the selective heating effect of le Roux and Ptuskin moves things in the right direction it is insufficient, by itself, to explain the under abundance of H^+ in the ACR produced by our shock model. Clearly some other method of enhancing the He^+ and O^+ must be found or the estimates of interstellar abundances must be revised.

References

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