Pickup Ion Distribution

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- In order to investigate the ENA flux measured by IBEX, we need a plasma model with multiple ion populations.
- And this model will be based on a kinetic treatment of pickup ions.
- One component of the big project is modeling non-thermal ion populations.

- Interstellar neutral particles streaming into the solar system are ionized by interactions with solar radiation and solar wind protons.
- They are subsequently “picked up” by the solar wind EM fields.
- This pick up process results in a ring distribution of ions in the solar wind frame.

- This distribution is unstable to the generation of EM waves and wave-particle interaction will equilibrate the distribution.
- The velocity distribution will be a shell. And adiabatic cooling will produce a filled shell.
- We assume that PUI experience wave-particle interactions on a time scale short compared to those of momentum and spatial diffusion.
- We neglect spatial diffusion and drift motions.

- Creation
    - Ionization from ultraviolet energy or electron impact
    - Charge Exchange

$$p^+(u) + H(V_0) \rightarrow H(u) + p^+(V_0)$$

$$Q = \frac{n_p V_0 \sigma_H n_H}{4\pi v^2}\delta(v-u)$$

$$n_p = n_{p,0}\left(\frac{r_{p,0}}{r}\right)^2 \qquad n_H = n_{H,0}e^{\frac{-4\ \mathrm{AU}}{r}}$$

- Transport Equation:

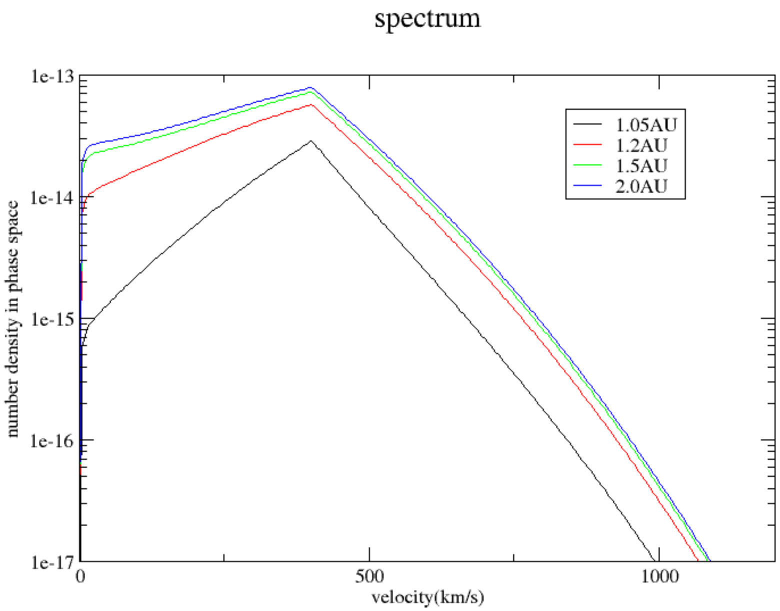
$$\frac{\partial f}{\partial t} + \boldsymbol{u} \cdot \nabla f - \frac{\nabla \cdot \boldsymbol{u}}{3} v \frac{\partial f}{\partial v} - \frac{1}{v^2} \frac{\partial}{\partial v}\left(D v^2 \frac{\partial f}{\partial v} \right) = Q$$

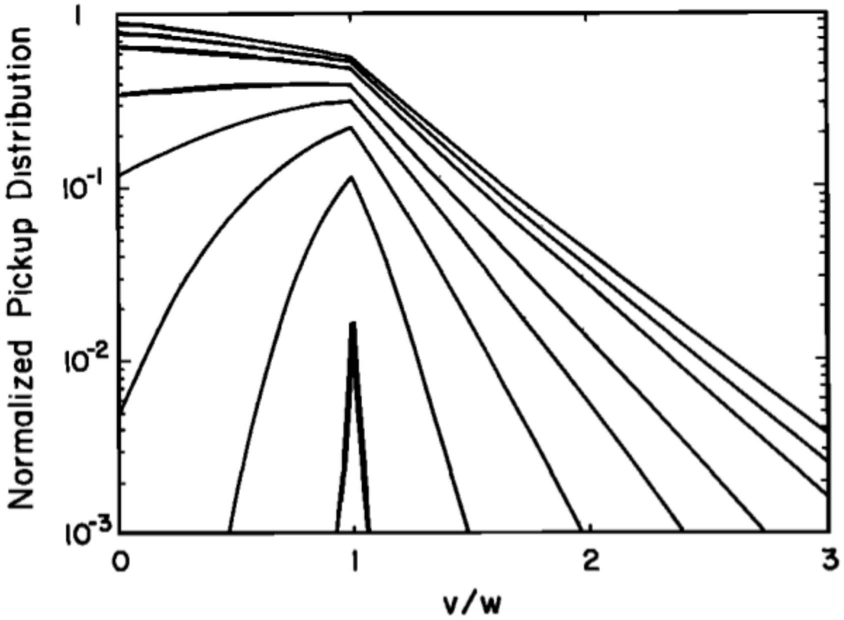
$$D = \frac{\delta u^2 v}{9 \varepsilon_c} = Cv = 0.001185 v \text{ km/s}^2$$

v is measured in plasma frame. In velocity phase space, v is isotropic, so we can ignore 2 components of v. Thus this equation is 4-dimensional.

$$Q \approx \begin{cases} \dfrac{n_{p,0} {r_{p,0}}^{2} V_0 \sigma_H n_{H,0}}{4\pi r^2 u^2 \Delta v} e^{\frac{-4\ \mathrm{AU}}{\mathrm{r}}} & for\ v = u \\ 0 & otherwise \end{cases}$$

Results



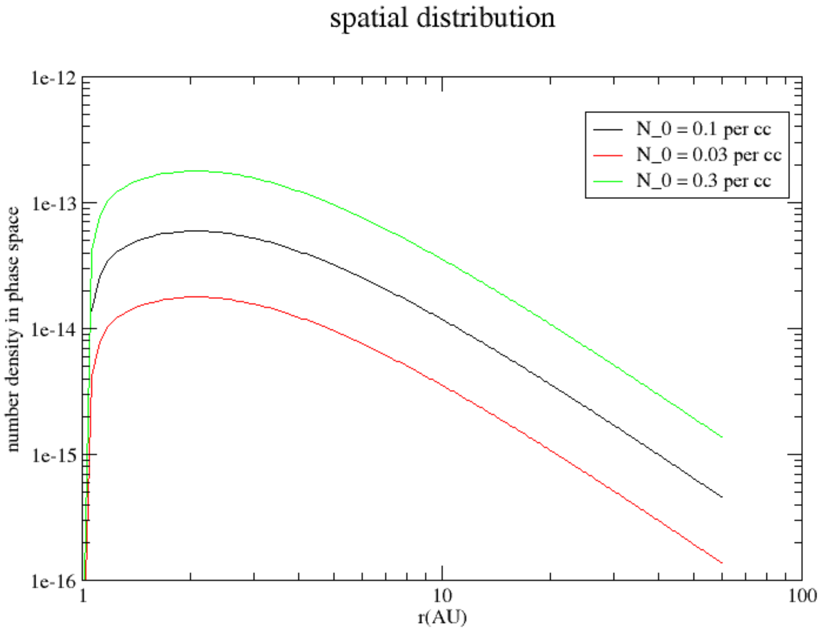


Isenberg (1987)

Starting from the bottom curve r=1.001, 1.05, 1.2, 1.5, 2.0, 4.0, 8.0 AU.

Initially the distribution remains close to the shell distribution (i.e., a delta function at v/u = 1), with the adiabatic cooling of the pickup ions with increasing heliocentric distance, the characteristic ‘flat’ distribution at energies lower than v/u = 1 develops.

Results



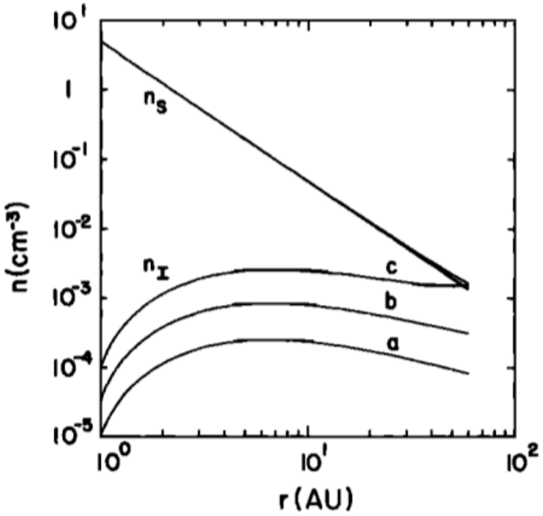


Fig. 1. Steady state proton densities as functions of heliocentric radius for three values of the interstellar hydrogen density: (*a*) $N_0 = 0.03\ \mathrm{cm}^{-3}$, (*b*) $N_0 = 0.1\ \mathrm{cm}^{-3}$, (*c*) $N_0 = 0.3\ \mathrm{cm}^{-3}$. The lower curves are the interstellar pickup densities, and the upper curves (largely overlapping) are the solar wind densities. Where the n_S curves separate at large r, the case *c* curve is above the others.

Isenberg (1986)

Thanks!