1. Introduction

- When Voyager 1 (V1) and Voyager 2 (V2) crossed the termination shock (TS), the measured spectrum was not consistent with what was expected from steady first order Fermi acceleration.

- Most recently towards the end of August 2012 at V1, low energy intensities decreased rapidly with a simultaneous jump in high energy galactic cosmic rays (GCRs). Currently, their intensities appear constant which suggest that V1 may have crossed the heliopause and is in the local interstellar medium.

- We investigate how the geometry of the TS affects the acceleration of ACRs by using a spherical TS and a blunt TS. Further we study the spatial profiles in the heliosheath and near the heliopause.

2. Plasma and Magnetic Field Background

- Plasma – axisymmetric model
  - Constant upstream velocity
  - Downstream plasma flow – incompressible & rotational (finite vorticity), derived using Stokes’ Stream function (given below)
  - Satisfies the Rankine-Hugoniot conditions at the TS

\[
\psi = -u _0 R \cos \theta - \frac{u _0 R}{2} \sin \theta - \frac{u _0 R}{2} \sin \theta + u _0 R \sin \theta - \frac{u _0 R}{2} \sin \theta
\]

- First term - point source of strength \( u _0 R \)
- Second term - uniform flow with a speed \( u _0 \)
- Third term - dipole flow of strength \( u _0 R \)
- Fourth term - Stokes flow around a sphere of radius 4R/3 moving with velocity \( u _0 \)
- Final term - spherical vortex of strength \( u _0 R \)

3. Transport Model

- We use the stochastic integration technique along the four-dimensional phase space trajectories of the Parker equation similar to Florinski & Pogorelov (2009). The GCR transport code of Florinski & Pogorelov (2009) was adapted for use with ACRs. We assume a background of pre-accelerated PUls below a fixed minimum momentum \( p _{min} \) and particles follow trajectories backward in time till \( p _{min} \) is reached.

- Transport is modeled using the Parker’s equation (Parker 1965),

\[
\frac{\partial f_{e}}{\partial t} + \left( u _{e} + v _{e} \right) \cdot \nabla f_{e} = 3 \frac{\partial f_{e}}{\partial \ln \p} - \kappa \cdot \nabla f_{e}
\]


\[
\kappa_{i} = \kappa_{e} \frac{\partial f_{e}}{\partial \ln \p}
\]

where; \( \kappa_{e} = 3.75 \times 10 ^{22} \text{ cm}^{2} \text{ s}^{-1} \), \( w \) is the particle speed, \( B _{r} \) is the radial magnetic field at 1 AU, \( P \) is the rigidity in GV, \( F (P) \) is \( P \) for \( P > 0.4 \), \( F(P) = 0.4 \) for \( P < 0.4 \) and \( a \) is a constant varied between 0.005-0.03.

- Drift velocity

\[
V _{drift} = \frac{B _{r} \times \mathbf{v}}{B _{r} ^{2}} \times B _{r}
\]

- Magnetic Field
  - Upstream => standard Parker field (Parker 1958)
  - Downstream => solve the steady state induction equation \( \nabla \times (u \times B) = 0 \)
  - along the streamlines

4. Results

5. Summary

- We developed an analytical plasma model and a semi-analytical magnetic field model for the heliosphere that is suitable for ACR acceleration problem.

- We see an enhancement of ACRs towards the flanks and the tail, which agrees with the concept that was first proposed by McComas & Schwadron (2006).

- Further there is a slight enhancement of mid ACR energies in the heliosheath.

- Recent V1 observations suggests that V1 may have crossed the heliopause and now it’s in the interstellar medium.

References