# Stream interfaces and energetic ions in corotating interaction regions: Ulysses test of Pioneer results

Cite as: AIP Conference Proceedings **382**, 519 (1996); https://doi.org/10.1063/1.51462
Published Online: 12 May 2008

Devrie S. Intriligator, George L. Siscoe, Gerd Wibberenz, Horst Kunow, and John T. Gosling

# Stream interfaces and energetic ions in corotating interaction regions: Ulysses test of Pioneer results

Devrie S. Intriligator and George L. Siscoe[1]
Space Plasma Laboratory, Carmel Research Center, Santa Monica, California

Gerd Wibberenz and Horst Kunow
Institut für Kernphysik, Universitat Kiel 24118 Kiel, Germany

John T. Gosling
Los Alamos National Laboratory, NM

This is a summary of a paper reporting the results of Intriligator et al. [1995]. Ulysses measurements of energetic and solar wind particles taken near 5 AU between 20 and 30 degrees south latitude during a well-developed recurring corotating interaction region (CIR) show that the CIR's corotating energetic ion population (CEIP) associated with the trailing reverse shock starts within the CIR at the stream interface. This is consistent with an earlier result obtained by Pioneers 10 and 11 in the ecliptic plane between 4 and 6 AU [Intriligator and Siscoe, 1994]. The Ulysses/Pioneer finding is noteworthy since the stream interface is not magnetically connected to the reverse shock, but lies 12-17 corotation hours from it. Thus, the finding seems to be inconsistent with the basic model that generates CEIP particles at the reverse shock and propagates them along field lines. Eliminating the inconsistency probably entails an extension of the standard model. We consider two possible extensions: cross-field diffusion and energetic particle generation closer to the sun in the gap between the stream interface and the reverse shock.

We concentrate here on the Ulysses middle latitude region extending approximately from 20 to 30 degrees south heliographic latitude, when Ulysses was still around 5 AU from the sun. Across the CIRs of this region, the intensities measured in the 5.4-23 MeV ion channel varied most, with increases up to four orders of magnitude. These variations were clear instances of leading and trailing CEIPs. Thus, to check the result of the Pioneer study we superposed on these Ulysses energetic ion data the positions of the stream interface as determined with data taken by the Ulysses solar wind instrument [Gosling et al., 1993]. We examined five cases selected strictly on the basis of CEIPs identified in the energetic particle data, that is, plasma data were not involved in the selection process. Each case is normalized to a common intensity at the stream interface. The normalized intensity profiles reveal that on the trailing side of the stream interface there is no interval within which the particle intensity remains at a minimum as if the interval were unconnected to a particle source. Instead, the intensity rises immediately and continuously to peaks which are generally associated with direct connection to a particle source - the reverse shock.

The Ulysses findings reported here showing an approximate coincidence within CIRs of the stream interface and the onset of the trailing CEIP agree with the Pioneer findings. The results seem to require an extension of the basic scenario that has been proposed to account for CEIPs. Among these are cross-field diffusion and energetic particle generation in the unshocked layer sunward of where the shock is formed.

CEIP particles might reside in the unshocked layer because they are produced closer to the sun on the field lines in the unshocked compression region (see figure in Intriligator et al., 1995) and propagate outward to fill the gap. This possibility amounts to a direct extension of the standard CEIP production model to let it operate also in the unshocked layer, since convergence is also occurring in the unshocked compression region, just not enough to cause a shock. The same condition of fast stream overtaking slow stream operates there, only weaker because the spiral is more radial. Thus, we might expect energetic particle production to occur within a considerable radial portion of the unshocked compression region, only with weaker intensities. Since the Fermi mechanism does not depend on the presence of the shock, there should be no sudden onset of CEIP particles near the field line which connects to the sunward-most point of the reverse shock. This aspect of the hypothesis captures a distinctive feature of the observations: there is no signature in the CEIP profile of the transition from an unshocked layer to a shocked layer. Thus, the sought-for extension of the basic model might simply be the recognition that CEIPs result from Fermi acceleration in the flows that converge at the stream interface. The CEIP profile would then be governed by the strength of convergence instead of the strength of a shock.

**Acknowledgments** The work at Carmel Research Center was supported by NASA Ames Research Center under contract NAS2-13692 and by Carmel Research Center. Work at Los Alamos was performed under the auspices of the U.S. Department of Energy with financial support from NASA under W-15847.

## References

Gosling, J.T., S.J. Bame, D.J. McComas, J.L. Phillips, V.J. Pizzo, B.E. Goldstein, and M. Neugebauer, Latitudinal variation of solar wind corotating stream interaction regions: Ulysses, *Geophys. Res. Lett.*, *20*, 2789-2792, 1993.

Intriligator, D.S., and G.L. Siscoe, Stream interfaces and energetic ions closer than expected: Analyses of Pioneers 10 and 11 observations, *Geophys. Res. Lett.*, *21*, 1117-1120, 1994.

Intriligator, D.S., G. Siscoe, G. Wibberenz, H. Kunow, and J. Gosling, Stream interfaces and energetic ions II: Ulyses test of Pioneer results, *Geophys. Res. Lett.*, *22*, 1173-1176, 1995.

[1] Also at Center for Space Physics, Boston University, Boston, MA.