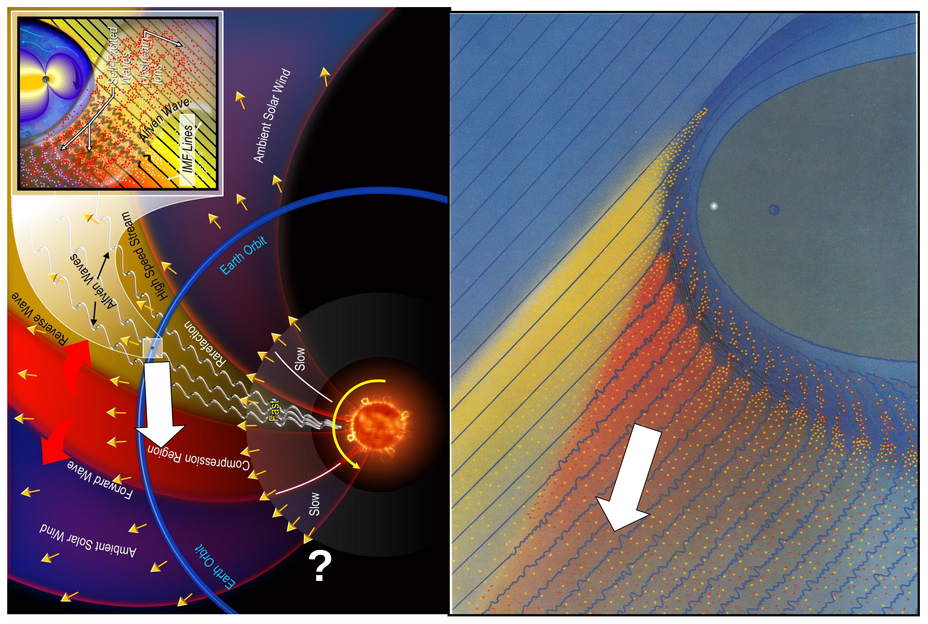
Upstream ion events with a solar-type spectrum: what can we learn for space whether prediction research?

Anagnostopoulos G.C., Maragkakis M. G., and Vassiliadis E.S.

Department of Electrical and Computer Engineering , Demokritos University of Thrace , *Greece*

Changes in plasma, magnetic field and energetic ion observations at Libration Point L1 (~220 Re) are important for space whether research. However, short-lived (from some minutes to a few hours) ion intensity enhancements at L1 have been attributed to various sources and acceleration sites: interplanetary shock acceleration, acceleration at Earth's bow shock, leakage from Earth's magnetosphere etc. **The scope of this study is to examine to which extent ion events originating from the Earth's magnetosphere environment could mimic ion events propagating up to L1 point after acceleration at (distant) interplanetary shock waves**. For this reason we performed a statistical study and compared ion events observed almost simultaneously by the Geotail spacecraft near the Earth's bow shock and by ACE moving around the Libration point L1. Due to drastic changes of several parameters between the two sites, we found that at around the point L1, **the ACE ion events show a strong spectrum with an average spectral index as low as γ_A= 2.1** (for a power law spectrum) at the level of 200 keV, while the average spectral index for the corresponding ion events observed by Goetail was found to be A_G = 5.4. We infer that a short duration ion event with **a hard "solar" / "interplanetary" type energy spectrum can originate from the Earth's magnetosphere**, and, that, therefore, these results should be seriously taken into account in space weather prediction research. More detailed information on the varying features of travelling ions and electrons from the bow shock to far distances are important as regards the problem of their origin and are also presented and discussed in the paper.



Short-lived (from some minutes to a few hours) ion intensity enhancements at L1 with a hard "solar" / "interplanetary" type energy spectrum (spectral index as low as γA≈ 2.1, for a power law spectrum) can originate from from Earth's Magnetosphere.

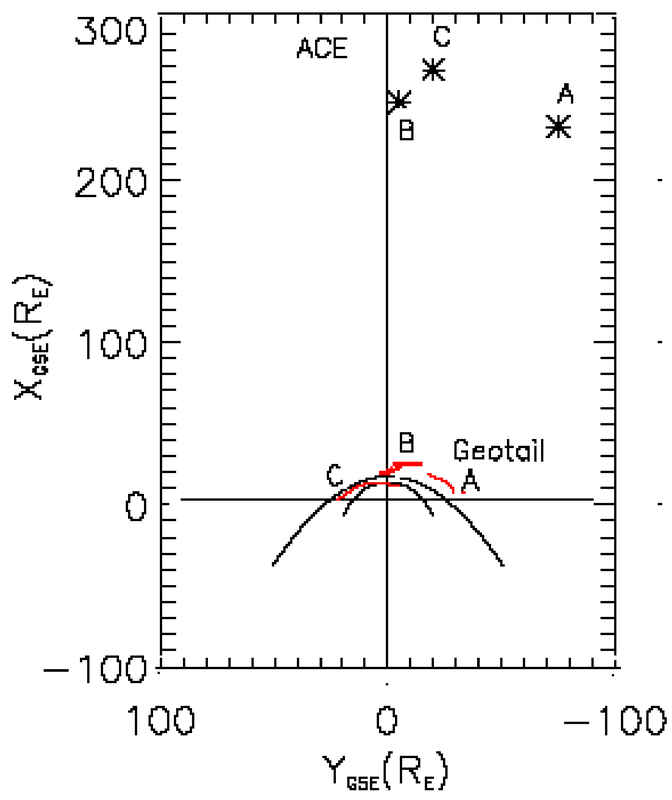


Fig. 1. Representative time intervals for which propagation of energetic ions and electrons has been studied by simultaneously obtained observations outside the Earth's magnetopause (Geotail) and far upstream from the bow shock (ACE).

Observations

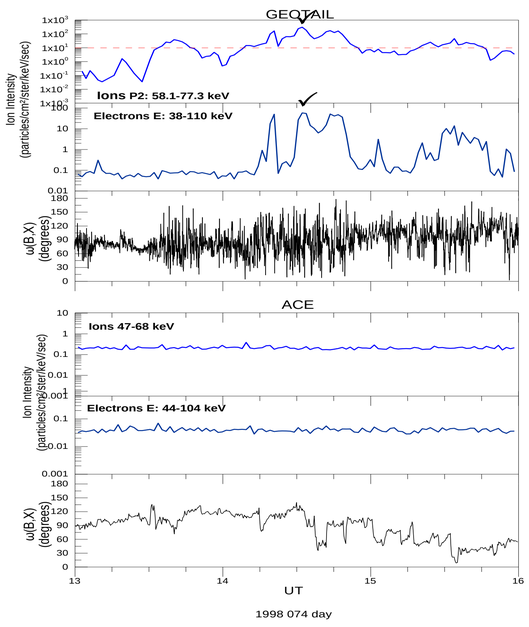


Fig. 2. The majority (%) of energetic ion events at Geotail (near the magnetopause / bow shock) is accompanied by the presence of energetic magnetospheric electrons (59.7 %).

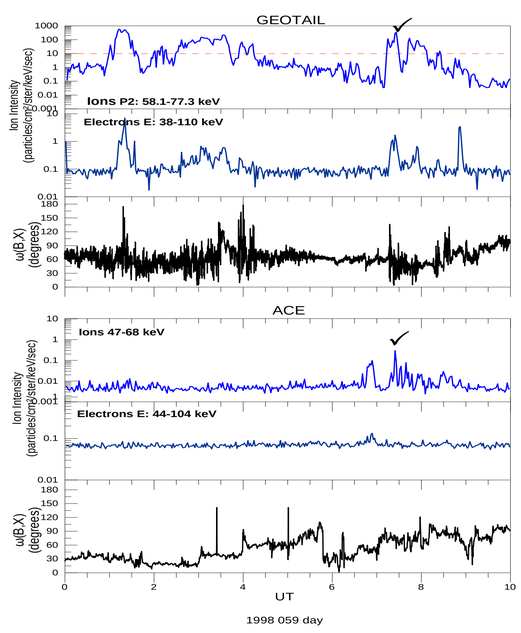


Fig. 3. A large percentage of energetic ions Events detected by Geotail were also detected by ACE (85.10 %).

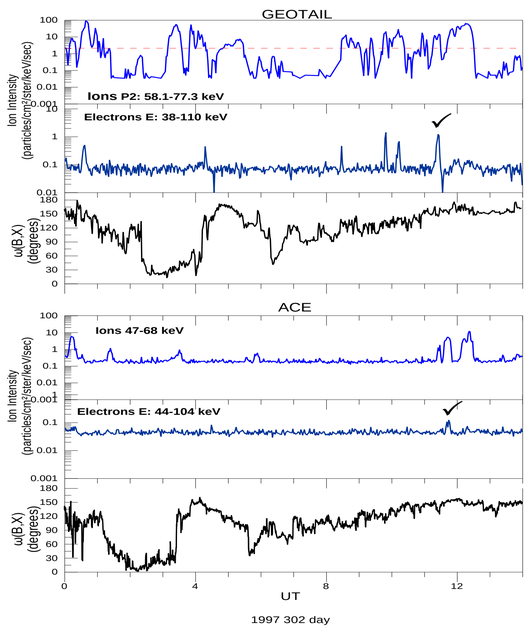


Fig. 4. Only a small percentage (%) of energetic electrons detected by Geotail were observed at ACE (18.9 %).

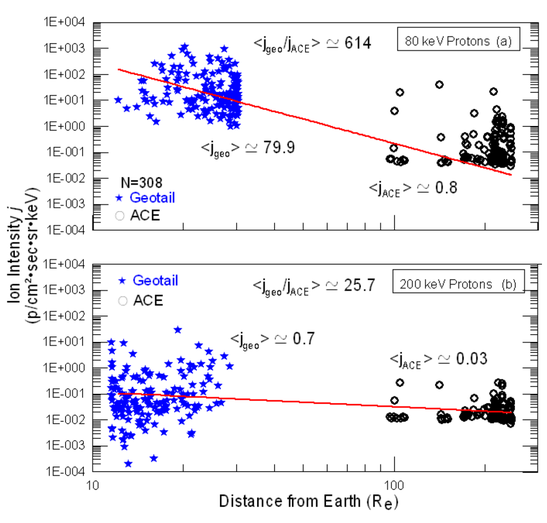


Fig. 5. **The ion intensity decreases with the Distance from the magnetopause.**

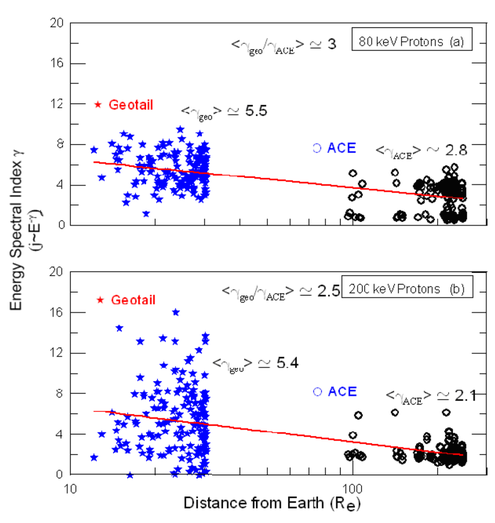


Fig. 6. The average **spectral index γ** drops from ~5.4 to ~2.4 at ACE at 80 keV and from ~5.2 to **~1.8** at 200 keV **resembling a "solar" / "interplanetary" type energy spectrum .**

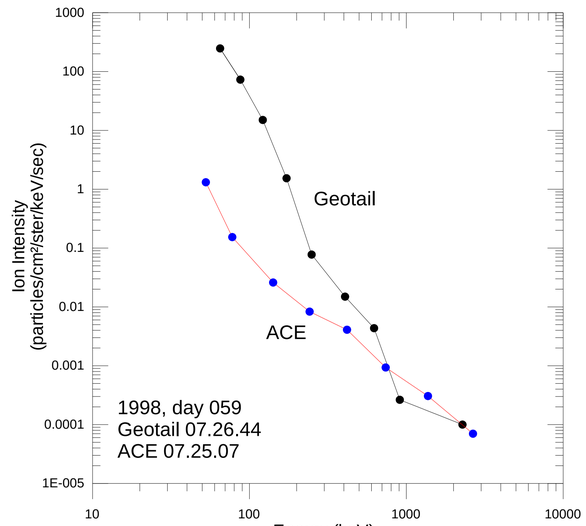


Fig. 7. Significant hardening of the spectrum of the ion population propagating from the magnetopause to the Libration Point L1.

Conclusions

We present statistical results from a comparison of ion and electron events observed by the Geotail spacecraft near the Earth's bow shock and by ACE moving around the L1 point. The major results are:

a highly decreased value of the spectral index γ_{ACE} (**<γ> = 1.8**) near the L1 point by an average factor as high as ~3 compared to the spectral index value $\gamma_{Geotail}$ outside the magnetosphere, and

a very low percentage (~22%) of the electron events near the magnetosphere is also detectable around the L1 point.

We infer that short duration **ion events showing a hard energy spectrum far upstream from the Earth's bow shock**, despite the fact that they may be non-accompanied by energetic electrons, **can originate from the Earth's magnetosphere and not from an interplanetary shock.**

In many cases it is difficult to decide about the origin of far upstream ion events by using one spacecraft data (the magnetospheric upstream ion spectrum can mimic that of a solar / interplanetary population)

Summary of Observations

➢ the ~ 60 - 300 keV ion intensities in general decrease with distance from the magnetopause, with the decrease being more intense at lower energy ions; in particular a percentage of **~15 % of Geotail ion events were not correlated with ACE electron events.**

➢ **the spectrum of propagating low energy (<~ 300 keV) ions in general hardens throughout their trip.**

➢ in most of cases, at ACE, the intensities of high (>~ 300 keV) energy ions remain at the same level as that measured by Geotail, (4) ~59 % of the ion events seen by Geotail were accompanied by the presence of energetic (>~40 keV) electrons, whereas **only ~20 % of these ion events showed an electron counterpart at the position of ACE.**

These observational results suggest **a rigidity dependent propagation of low energy** (~ 60 - 200 keV) ions and electrons and **a scatter free propagation of high (>~ 300 keV) energy ions.**

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References.

Maragkakis, M.G., Anagnostopoulos, G.C. and Vassiliadis, E.S., Upstream ion events with hard energy spectra: Lessons for their origin from a comparative statistical study (ACE / Geotail), Planet. Space Sci., 85, 1–12, 2013.