Solar Wind Charge Exchange X-ray emission from the Earth's Magnetosheath

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Collisions between solar wind ions and neutral atoms in the Earth's exosphere produce X-ray emission due to the solar wind charge exchange process (SWCX). The X-ray emissivity from SWCX is predicted to be strongest in the Earth's magnetosheath where the solar wind density is most enhanced. SWCX has been detected by the EPIC detectors on XMM-Newton where it appears as a diffuse and variable component of the sky background characterised by strong emission lines from the high charge-state ions within the solar wind. We are performing a systematic search for signatures of SWCX emission in the XMM-Newton archive and we here report on a preliminary study which has detected several new examples. XMM-Newton, however, is not optimised for studying SWCX due to observational constraints and its narrow field of view. We report on two instrument concepts, MagEX and STORM, being developed with collaborators in NASA/GSFC, which have the necessary wide field of view, soft X-ray response and sensitivity to make global studies of the dynamical interaction of the solar wind with the Earth's magnetosheath.

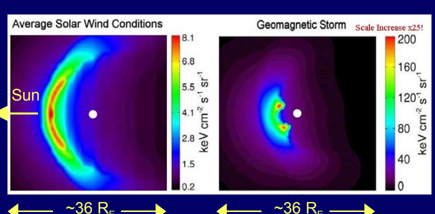
Geocoronal SWCX X-rays

SWCX in the vicinity of the Earth produces X-rays when heavy ions in the solar wind interact with neutral hydrogen in the Earth's exosphere:

$$A^{q+} + B = A^{(q-1)+*} + B^{+}$$

Where *A* is the ion and *B* the neutral atom. If the ionisation state q is sufficiently large, the ion de-excites, emitting an X-ray photon. The SWCX (line emission) can tell us about the constituents and speed of the solar wind.

Modelling in the Earth's magnetosheath shows strong predicted SWCX emission from the sunward and cusp regions, right. (Robertson and Cravens, 2003)

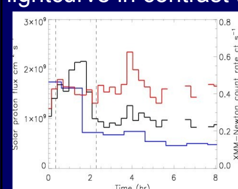


XMM-Newton study

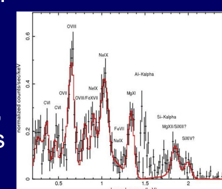
The major indicator of geocoronal SWCX enhancement is short term variability of emission at energies characteristic of solar wind ions (OVII and OVIII) in the diffuse sky background. Approximately 200 XMM-Newton observations were tested in this initial study. We searched for significant deviations from a linear relationship between line and SWCX-free continuum count rates that indicate possible SWCX emission. We checked data from the solar wind monitor ACE and the orientation of XMM-Newton for those cases with suspected SWCX emission. Only observations that have a line of sight through the sunward magnetosheath (i.e. May-August) were expected to experience SWCX emission, due to the observational constraints of XMM-Newton.

Current results

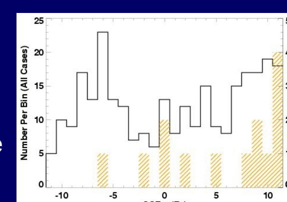
We find several SWCX cases with varying spectral characteristics (5% of sample). The strongest case shows evidence (Mg/O ratios for example) that XMM-Newton detected a passing Coronal Mass Ejection. For this case (below/left) the solar proton flux (ACE, blue) peaked as did the SWCX (black) lightcurve in contrast to the continuum (red).



The difference spectrum (right) shows strong OVIII, MgIX and NeX lines



The histogram (right) shows SWCX (orange) and all cases in terms of the position of XMM-Newton. Statistics confirm preferential SWCX emission is seen from the magnetosheath nose in agreement with simulations.



Conclusions

- Method successfully identifies SWCX
- Correlation with solar proton flux, viewing angle and season
- Considerable spectral differences between observations

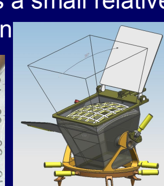
Future work

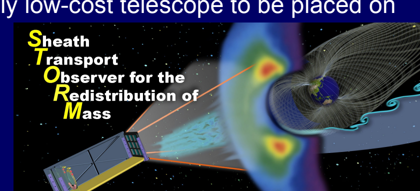
- Apply the method to the entire XMM-Newton archive
- Investigate links between SWCX and the solar cycle

Reference: Carter & Sembay, A&A 2008, Volume 489, Issue 2, 2008, pp.837-848

MagEX/STORM: Future missions to observe SWCX

Current X-ray telescopes, such as XMM Newton, which spend a large fraction of their orbit within the magnetosheath and have a relatively small field of view, are not suited to imaging SWCX in the vicinity of the Earth. Two proposed, dedicated missions, MagEX and STORM (collaborations between NASA/GSFC and Leicester University), aim to address this issue. Both would employ light-weight, micro-pore optic technology (left image) to provide the necessary field of view (around 30°). The preferred detectors system would be wide-area, back-illuminated CCDs, which give good spatial and spectral resolution. As the science goals concentrate on the 0.1 to 2.0 keV energy band, they can be made relatively thin (around 30 micron active depth) to reduce instrumental background. The MagEX instrument concept (centre) envisages a small relatively low-cost telescope to be placed on the lunar surface by an astronaut, as part of NASA's return to the Moon vision. Funding for a preliminary instrument study has already been secured from NASA. STORM is a more ambitious concept to place a larger instrument in orbit, around halfway to the Moon, on a free-flying spacecraft (right).





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