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Identifying XMM-Newton observations affected by solar wind charge exchange

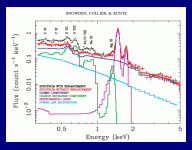
Solar wind charge exchange (SWCX) emission occurs when an solar wind ion, of sufficient charge state, interacts with a neutral atom and in the subsequent relaxation of the ion an X-ray photon is released. SWCX can be an important source of background in XMM-Newton and is a diagnostic of the state of the solar wind. We discuss a method to assess the level of SWCX contamination of an XMM-Newton observation. We present several example cases of geocoronal SWCX emission as identified by this method.

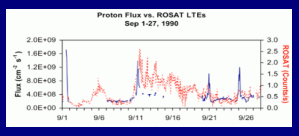
SWCX and the production of X-rays

SWCX produces X-rays when heavy ions in the solar wind interact with neutrals in the Earth's exosphere, cometary nebulae, planetary atmospheres, interstellar neutrals and at the heliospheric boundary by a process such as:

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

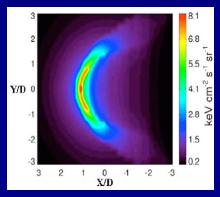
Where *A* is the ion and *B* the neutral atom. If the ionisation state q is sufficiently large, the ion de-excites, emitting a soft X-ray photon. ROSAT found a correlation between solar activity and enhancements in the soft X-ray background which has been explained as SWCX emission. The SWCX can tell us about the constituents and speed of the solar wind. The spectrum below, taken from an observation with XMM-Newton of the Hubble Deep Field North, clearly shows ions from solar wind C, O, Fe, Ne and Mg [1].



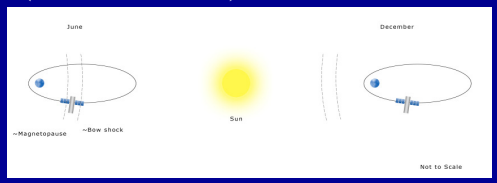


Left – SWCX ions. Above, X rays with solar activity

XMM-Newton's orbit and the SWCX



XMM-Newton is not able to study geocoronal SWCX at all times due to the configuration of its orbit. Geocoronal SWCX occurs in the Earth's magnetosheath between the magnetopause and bow shock.
In addition, solar viewing angle and radiation belt restrictions mean that the areas of highest X-ray emission (as modelled, above right, [2]) occur only at certain times of the 48 hour orbit and year (see schematic below).



Method

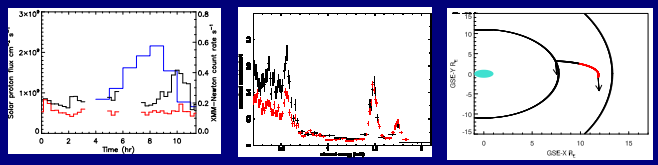
The method was designed to search for the major indicators of geocoronal SWCX enhancement; short term variability of emission at energies characteristic of solar wind ions.

- approx. 200 observations tested in this initial study
- data from MOS cameras, in full-frame mode
- processed with ESAS software (see EPIC Background web pages)
- search for short term variations in the SWCX line band
- significant deviations from a linear relationship between line and continuum count rates indicate possible SWCX contamination
- investigate suspect cases by creating spectra where appropriate, splitting observation into SWCX enhanced and SWCX quiet times

Results

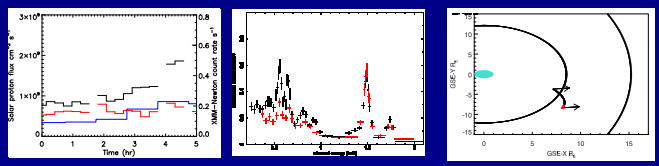
We present several previously unpublished SWCX cases below with varying spectral characteristics. We show lightcurves (graphics a) for the line (black) and continuum (red) band, comparing this to the solar proton flux (blue) as seen by ACE (no ACE-Earth delay applied). Spectra (graphics b) in black and red are for the SWCX enhanced and quiet periods respectively and black represents the enhanced periods for the GSE position of XMM-Newton (graphics c). The arrows represent the pointing angle of the telescope projected on this X-Y plane. The approximate positions of the bow shock and magnetopause are shown.

Case 1:
Solar proton flux and line band counts appear correlated (a)
Emission from OVII, OVIII and C below 0.5 keV (b)
XMM-Newton views through the area of expected highest x-ray flux (c)



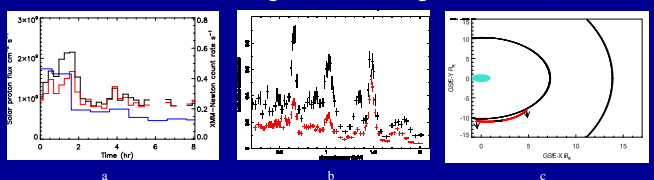
a b c

Case 2:
Solar proton flux possibly correlated with line band counts (a)
Emission from OVII, OVIII, less C below 0.5 keV than case 1 (b)
XMM-Newton views through the area of expected highest x-ray flux (c)



a b c

Case 3:
Solar proton flux possibly correlated with line band counts (a)
Emission from OVII, OVIII, C and MgXI (b)
XMM-Newton views through flanks of magnetosheath (c)



a b c

Conclusions

- method successfully identifies observations with SWCX (~5%)
- correlation with solar proton flux and XMM-Newton lightcurves
- some correlation with XMM-Newton viewing angle and season
- considerable spectral differences between enhanced spectra

Future work

- apply the method described to the entire XMM-Newton archive
- investigate links between SWCX enhancement and the solar cycle
- create a tool for the general XMM-Newton user

References:
[1] Snowden, S., Collier M.R. and Kuntz K., 2001, ApJ, 610, 1182-1190, 2004
[2] Robertson I.P. and Cravens T.E., Geophysical. Research Letters, Vol. 30., 8, 1439, 2003