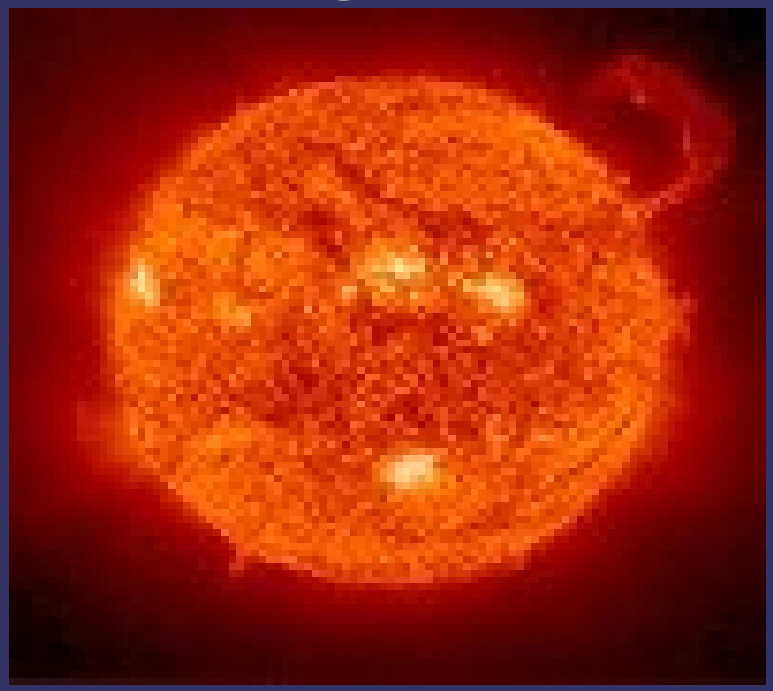
A Coronal Mass Ejection as observed by XMM-Newton



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University of Leicester

YGT 2004 – 2005
Supervisor: Andy Pollock

Image credit: SOHO

University of Leicester

Coronal Mass Ejections

CME movie 1

CME movie 2

Movie credit: SOHO

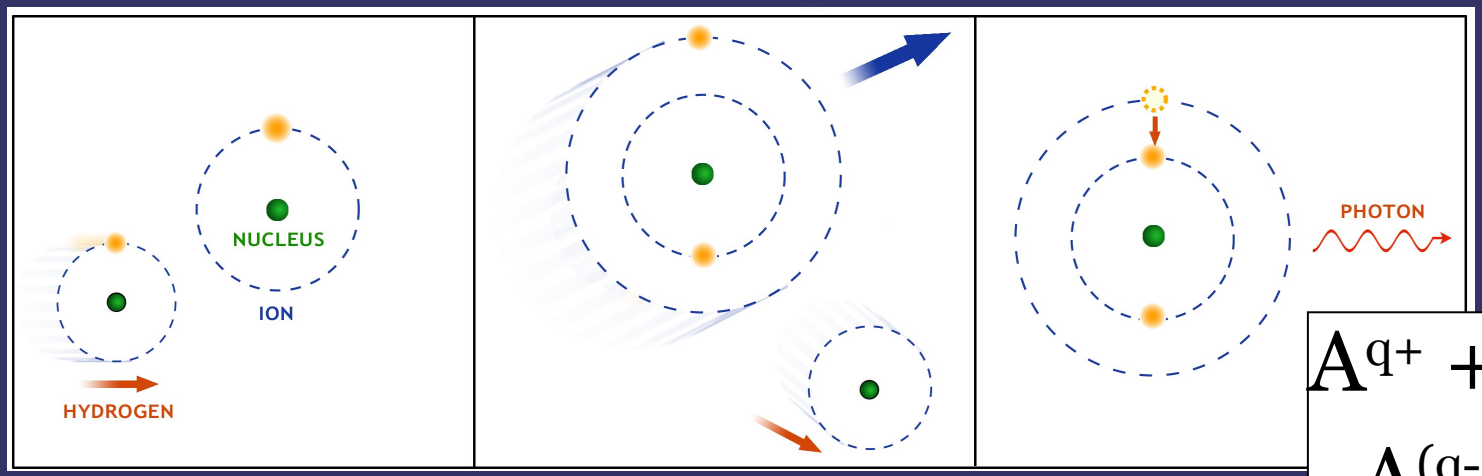
Frequent, a few per week

Solar Wind at 1 AU, typical density ~7 cm^{-3}

Event on 19th October, 2001, identified as CME (Wang et al, 2005), using upstream solar wind monitors

Solar Wind Charge Exchange (SWCX)

- How could a CME be detected by XMM-Newton?



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

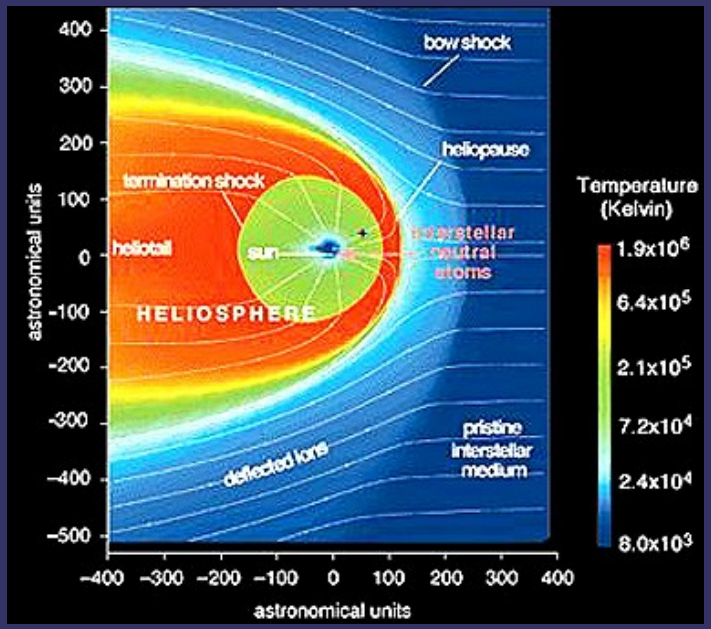
$$A^{(q-1)+*} \rightarrow A^{(q-1)} + h\nu$$

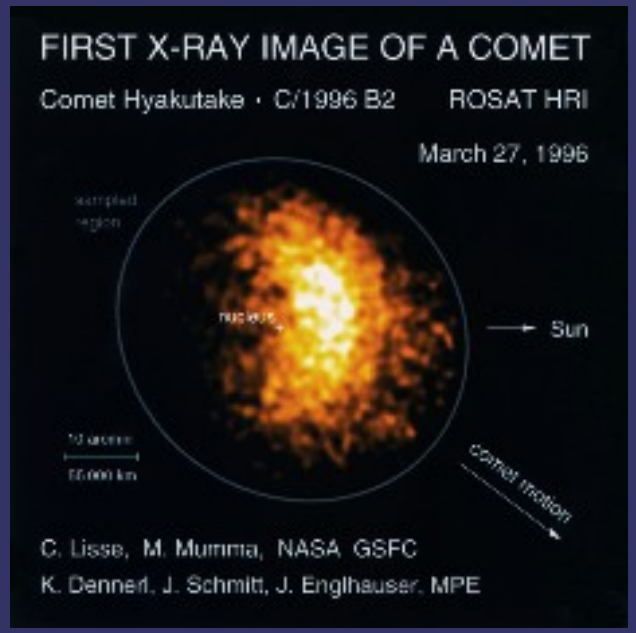
Flux seen $\propto$ Density and speed of SW (n_{SW}, $\langle g \rangle$)
Density of neutrals (n_H), donor molecules
Composition of SW and cross-sections (α)

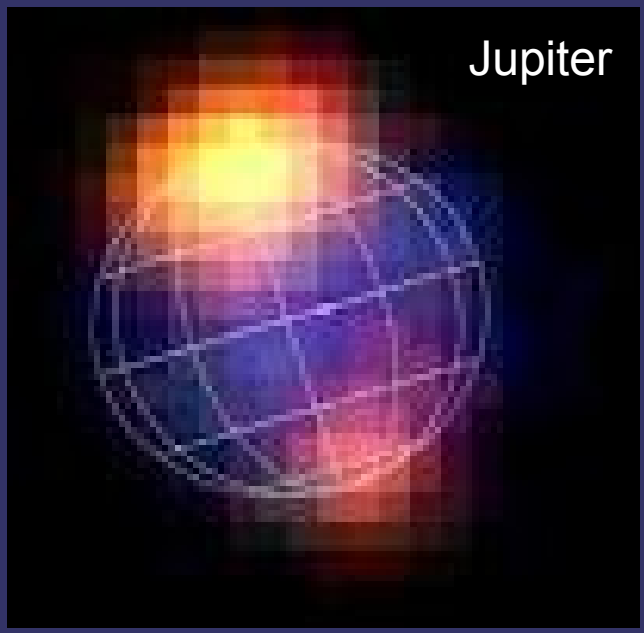
$$P_{X\text{-}ray} = \alpha n_H n_{SW} \langle g \rangle \ (eV\ cm^{-3}\ s^{-1})$$

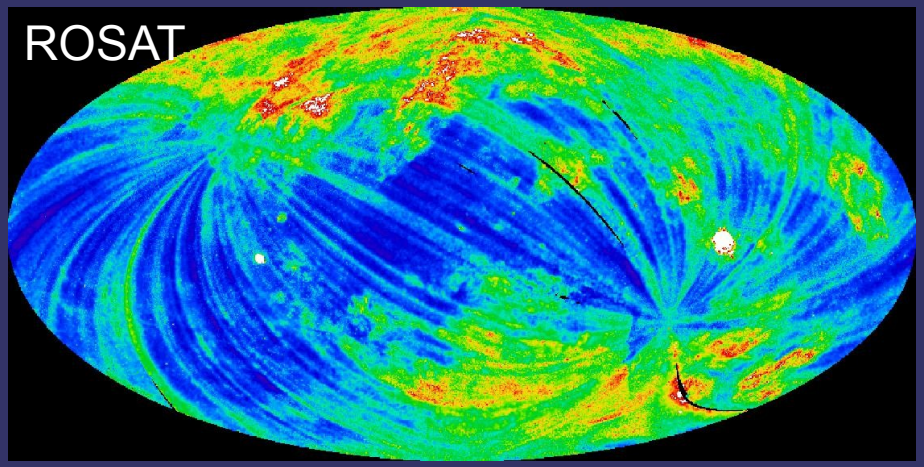
Example ions: OVII, OVIII, CVI, MgXI
SWCX emission characterised by emission lines, no continuum

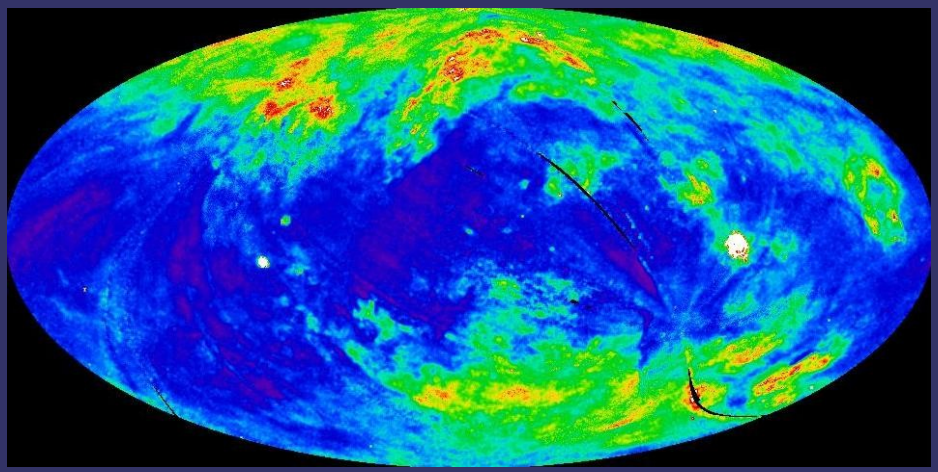
Charge Exchange in the Solar System



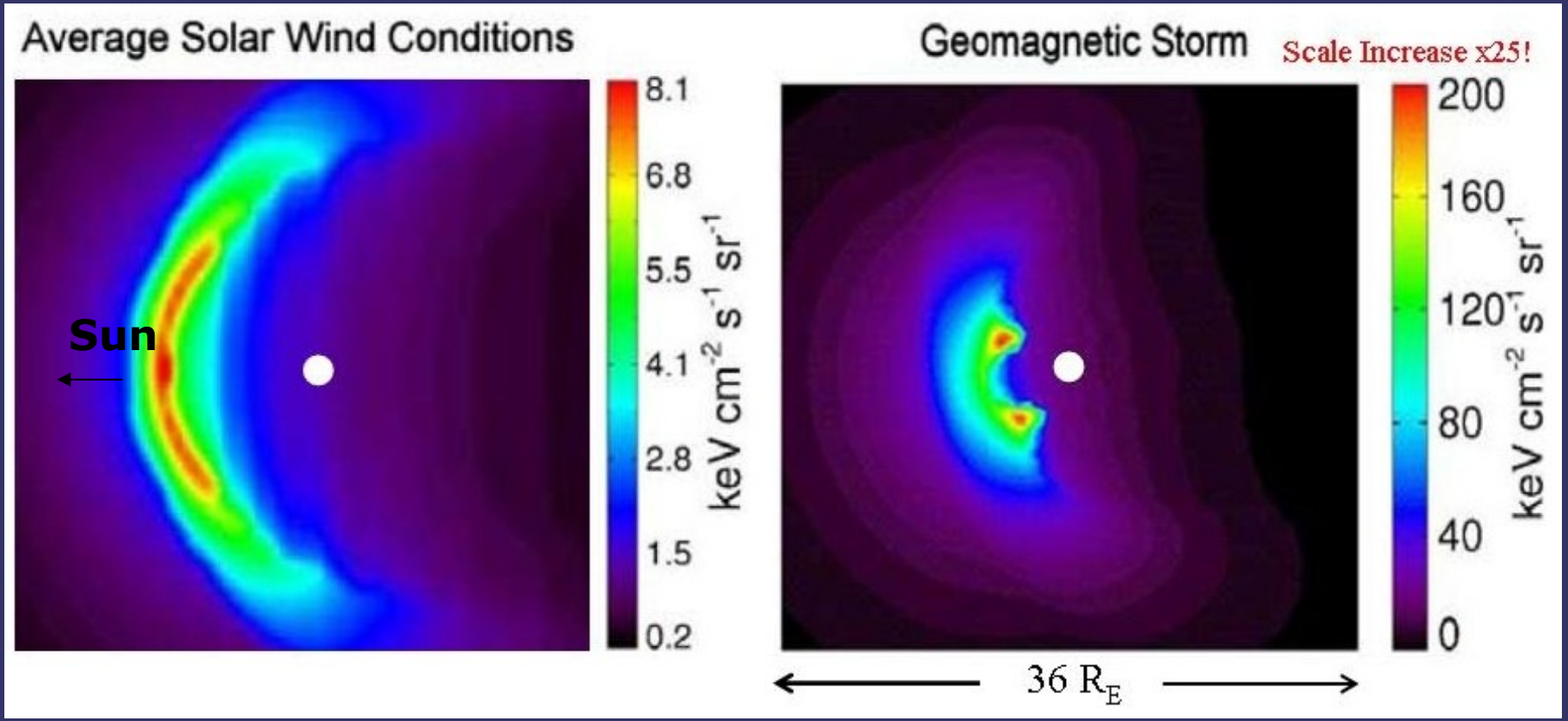








Solar Wind Charge Exchange in the vicinity of the Earth



Geocoronal modelling: Robertson & Cravens (2003, 2006)

Exospheric neutrals: hydrogen

Short term temporal variations as the magnetosheath responds to conditions in the solar wind

Geocoronal SWCX detection by XMM-Newton

Study of 187 XMM-Newton observations

Data; sources removed, soft proton cleaned

Two lightcurves;
band 1 (0.5 - 0.7 keV): SWCX band
band 2 (2.5 - 5.0 keV): Cont. band

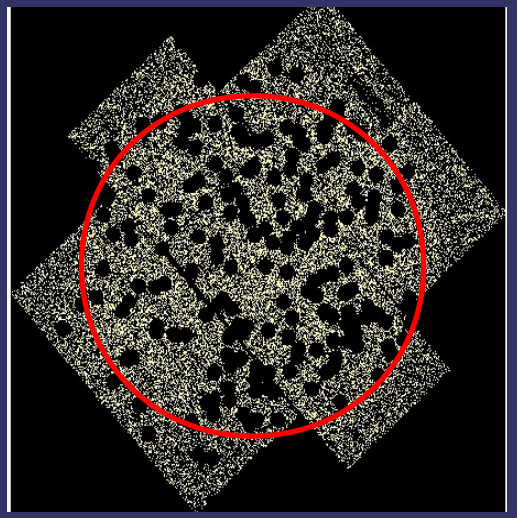
In the absence of SWCX, bands follow a straight line

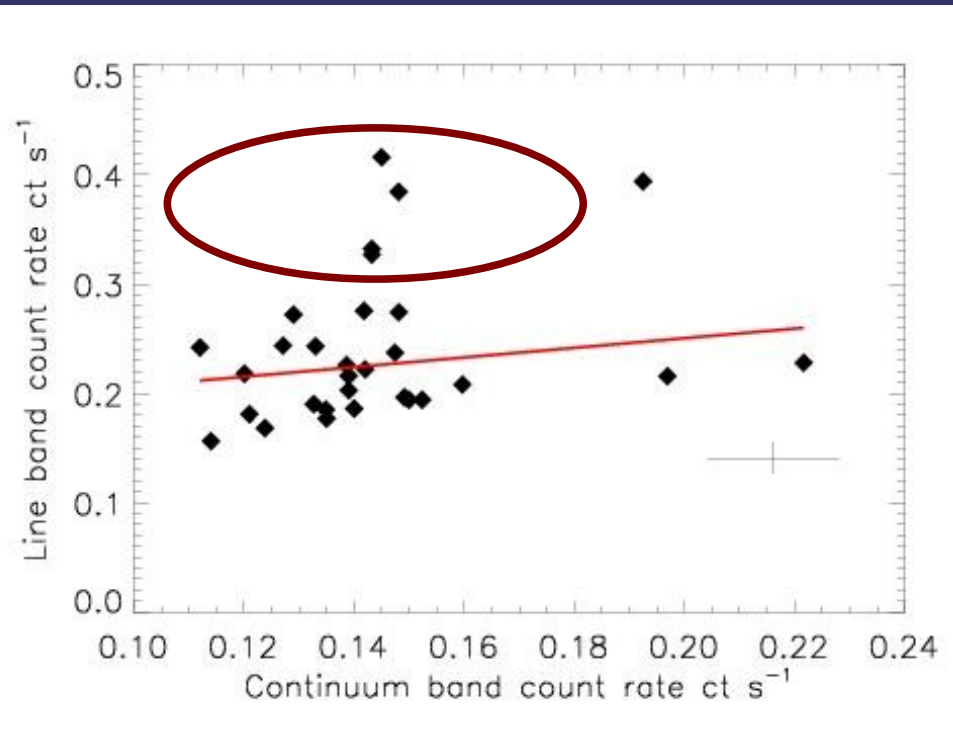
Deviation from a straight line fit; χ_μ

Variation within one band, Rχ

Largest χ_μ investigated for SWCX

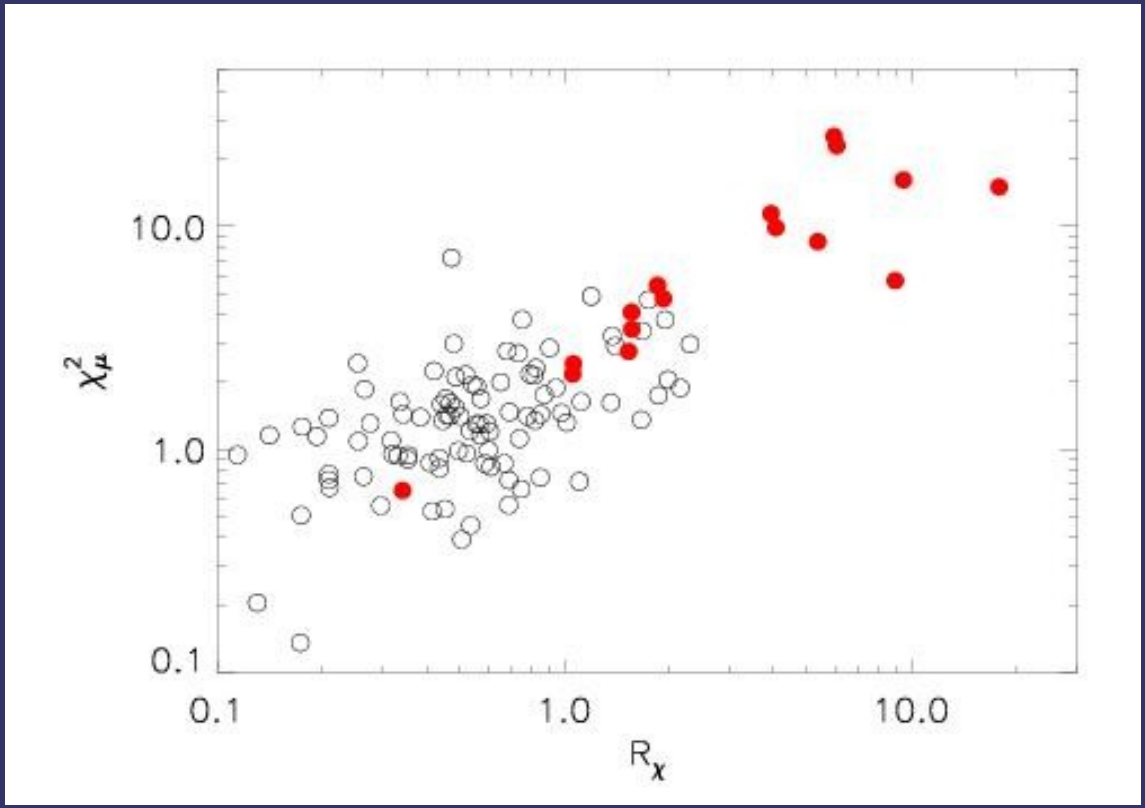
(Carter & Sembay 2008)

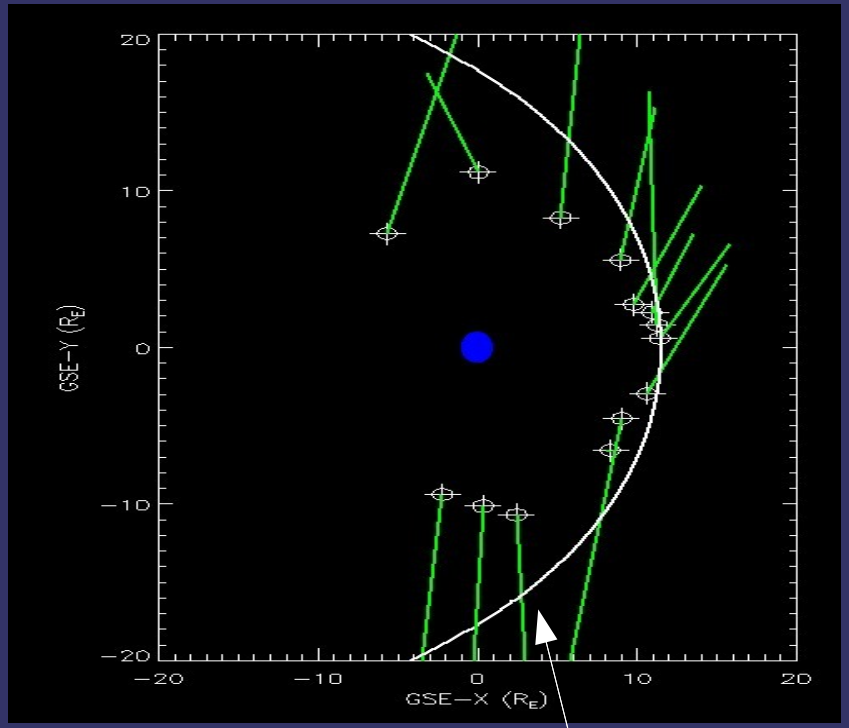




General results

~5% of 187 cases studied had geocoronal SWCX
Looked at XMM-Newton position and line of sight, magnetosheath position for geocoronal SWCX cases
Preliminary results show SWCX preferentially sunward side of system
Next steps to extend this method to entire archive, in progress



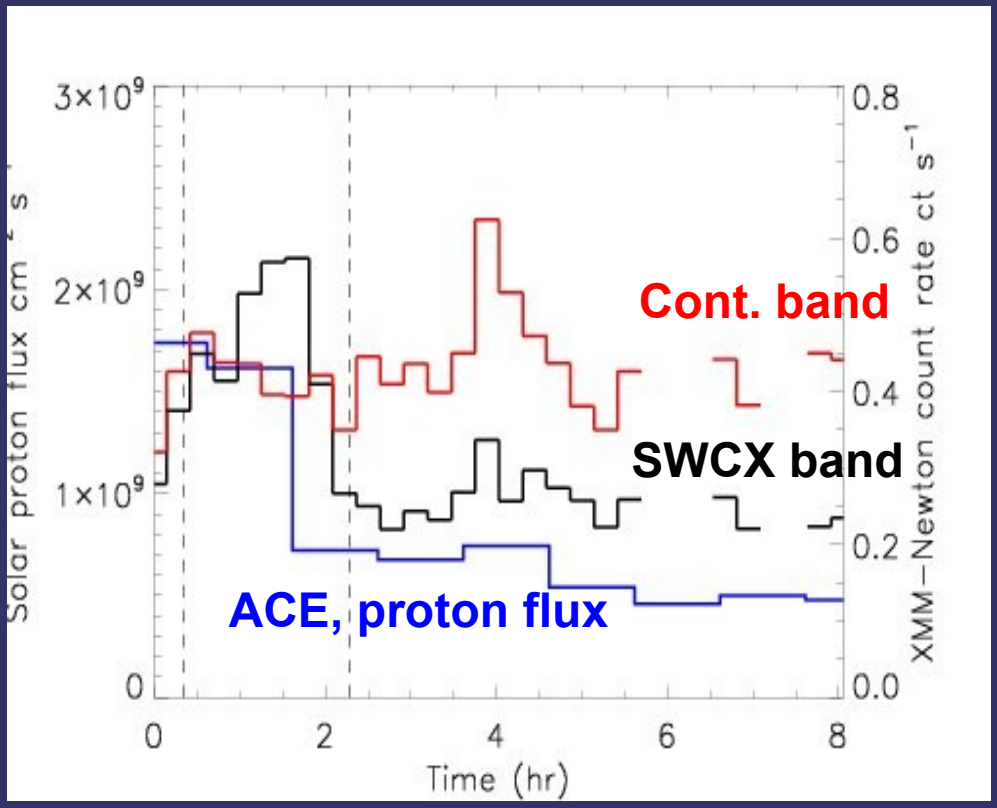


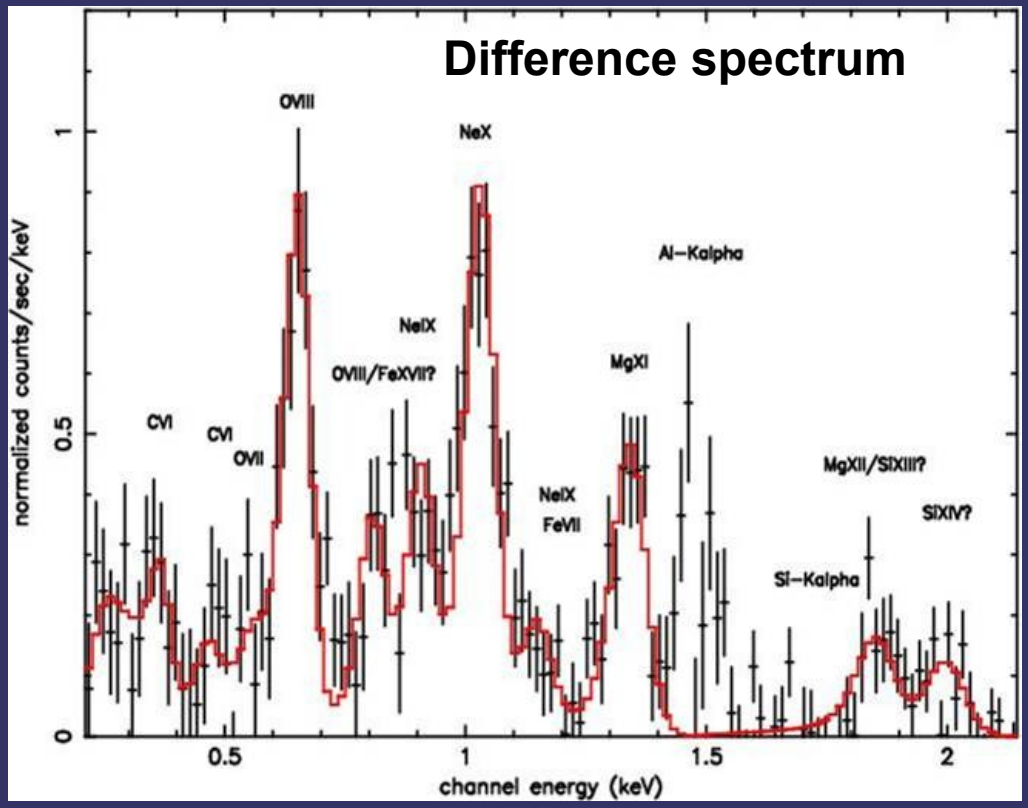
Magnteopause: rough position

Detection of the CME by XMM-Newton

Strongest case in this preliminary study (highest χ_μ & $R\chi$)

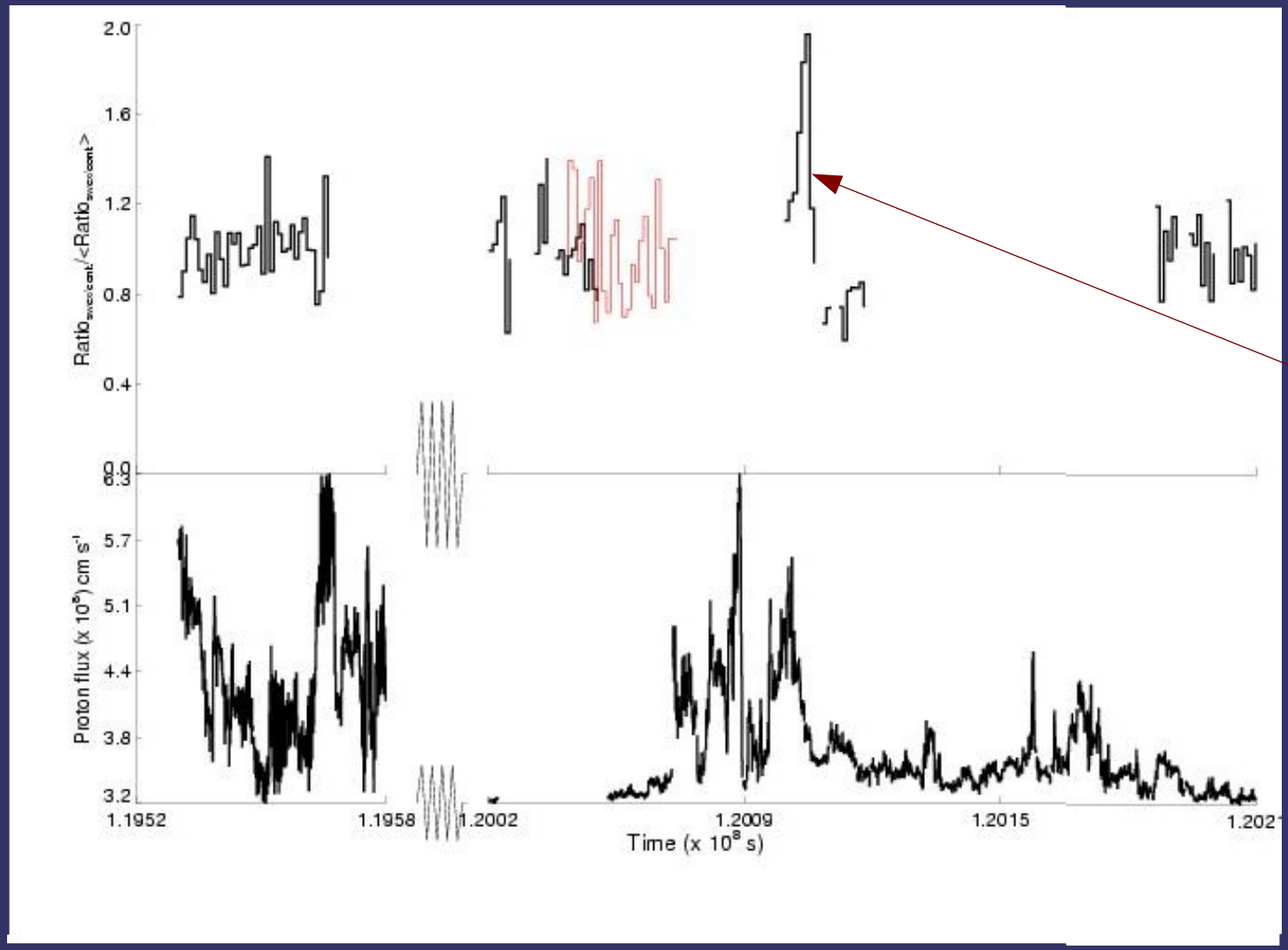
Possible on/off SWCX period
Compared spectra for on/off periods – clear enhancement
Target field: quite clean, no bright sources
Galactic longitude, latitude: 176°, 40°





Other XMM-Newton pointings & the solar wind

Other XMM-Newton pointings towards the same target



XMM-Newton and Chandra (red) data

CME observation

ACE proton flux - flux seen at L1 not always that observed at the Earth

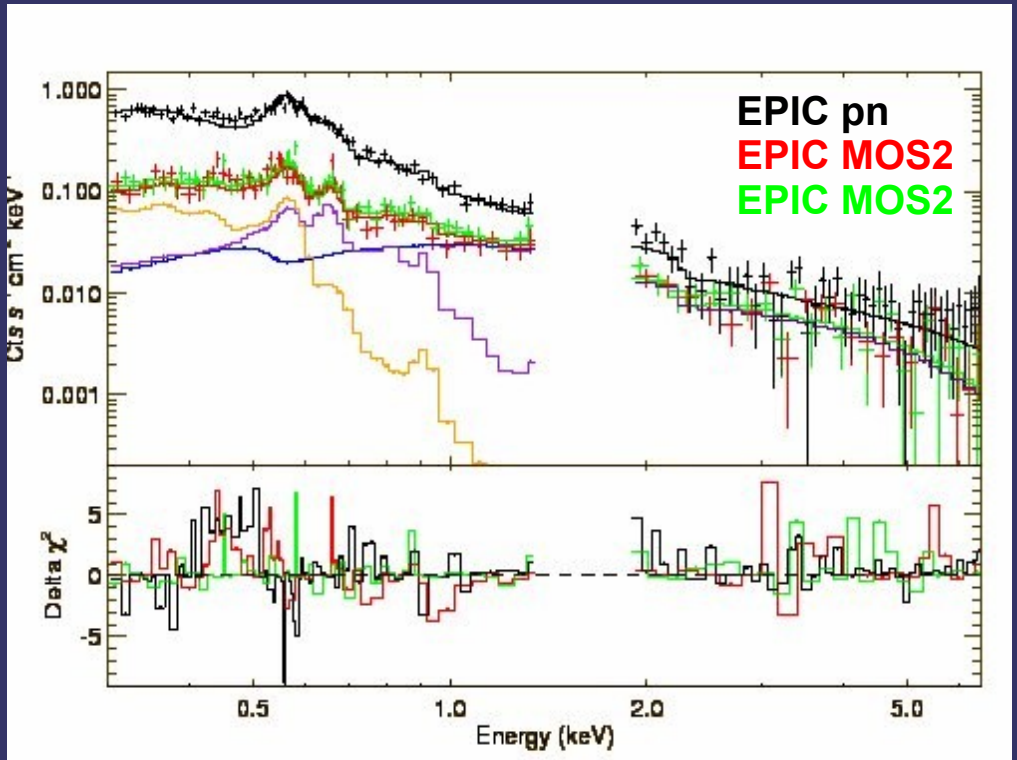
The sky model and background components

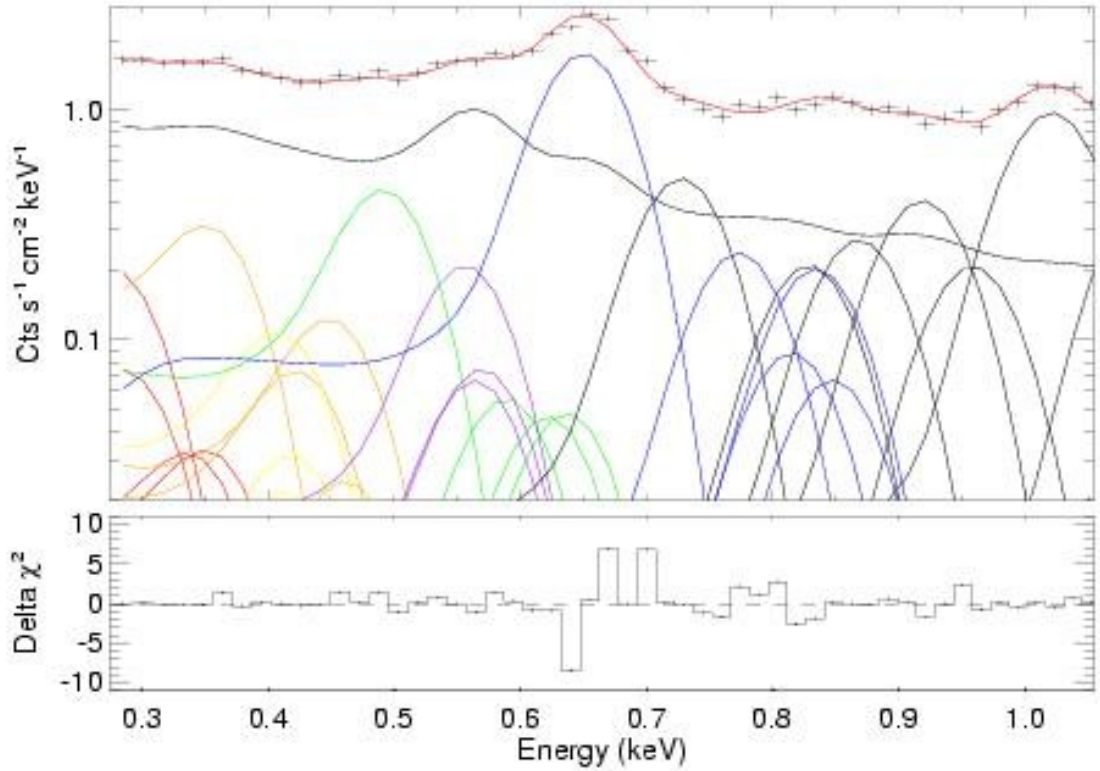
- Use previous, SWCX free observation to constraint sky model
- Previous observation had little residual soft proton contamination
- Model: un-absorbed Local Bubble + absorbed Galactic Halo + absorbed XRB

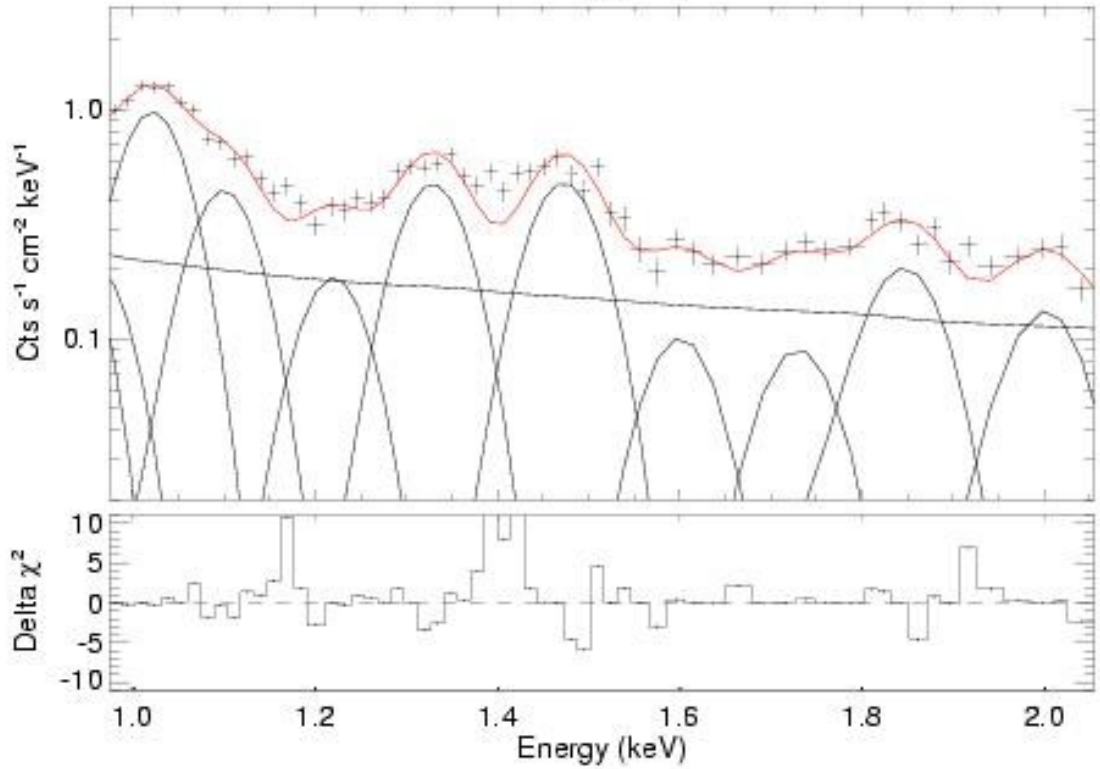
nH; 2.79 $\times 10^{20}$ cm^{-2}

XRB, Power law index ; 1.46 ± 0.12
Galactic Halo, APEC temp ; 0.23 ± 0.02 keV
Local Bubble, APEC temp. ; 0.11 ± 0.01 keV

XRB (blue), Galactic Halo (purple), Local Bubble (yellow)



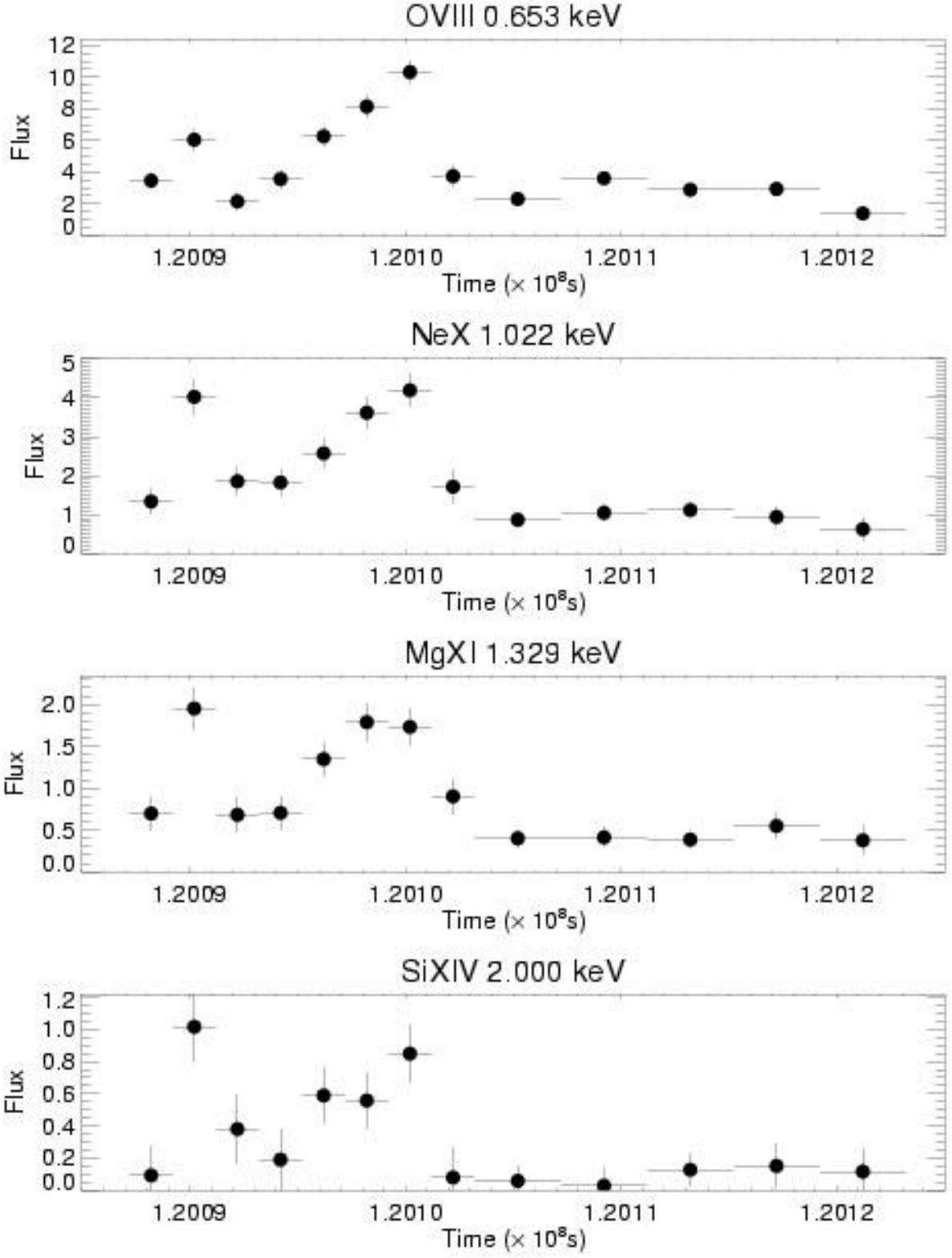




Spectral lines fitted throughout observation

Lines < 1.0 keV taken from theoretical work (Bodewidts et al. 2007); C, N, O ions

Higher energy Gaussians added; Si, Mg, Al, Fe



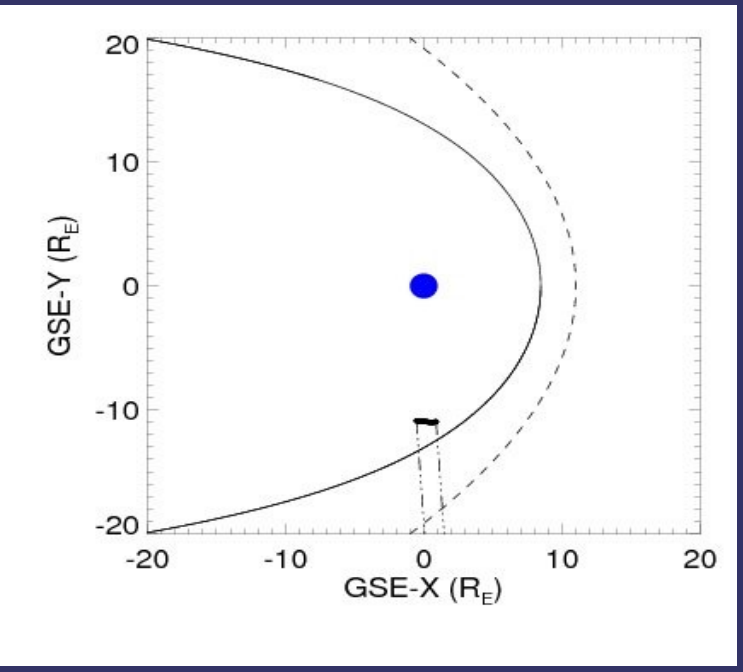
Spectral variations with time

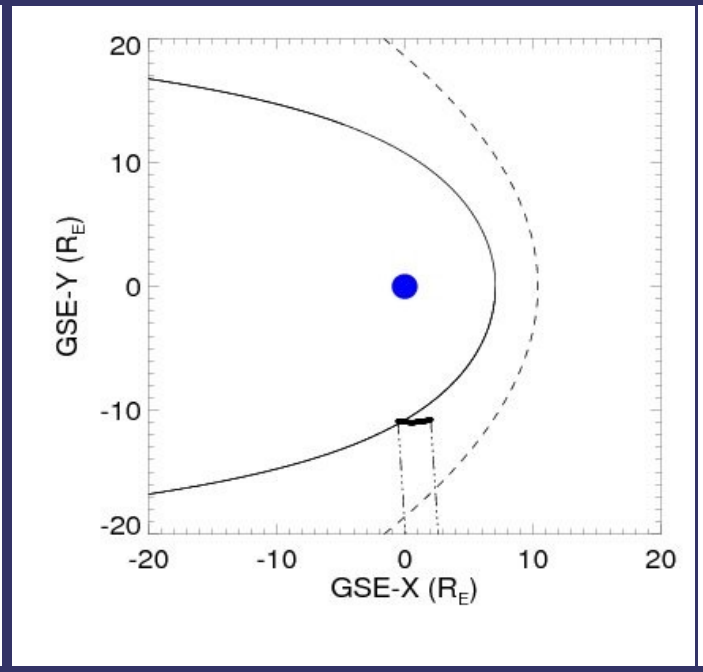
Track each other

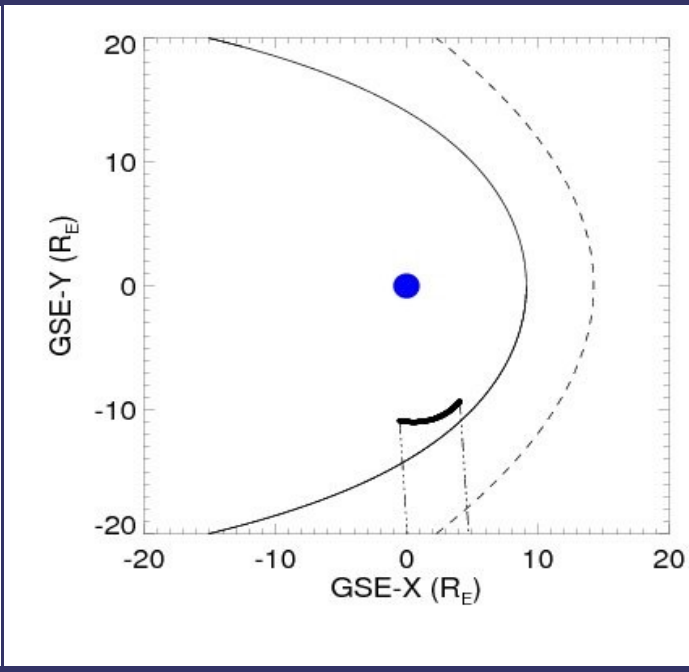
Higher energy lines imply high temp. plasma

Highest E lines not seen in previous geocoronal SWCX cases

Geometric arguments that we are observing a CME







XMM-Newton's path a various stages during this case observation
Magnetosheath pushed close to Earth due to high incoming solar wind flux
XMM-Newton observing through flanks, not normal brightest region
Signal picked up by solar wind monitors ACE and WIND

Conclusions

ACE solar proton flux enhancements tied to SOHO observations, identified as a CME (Wang et al. 2005)

Tied ACE flux solar proton flux enhancement to soft band enhancements seen by XMM-Newton

Geometric, temporal and spectral characteristics of the enhancement seen by XMM-Newton indicate observation of a CME

Obtain additional information regarding the chemical composition of a CME, to data gleaned from in-situ solar wind monitors