# Causes and Effects of Temporal Variations in the Soft X-Ray Background

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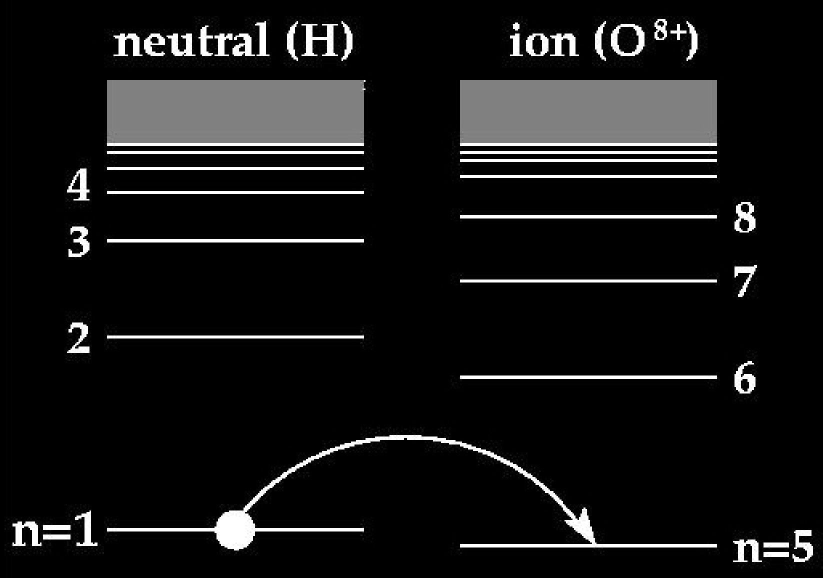
# Outline

- Solar wind charge exchange (CX) X-ray emission
  1. Time dependence
  2. Spatial dependence

2. Observational evidence
3. Implications for data analysis

# Charge Exchange



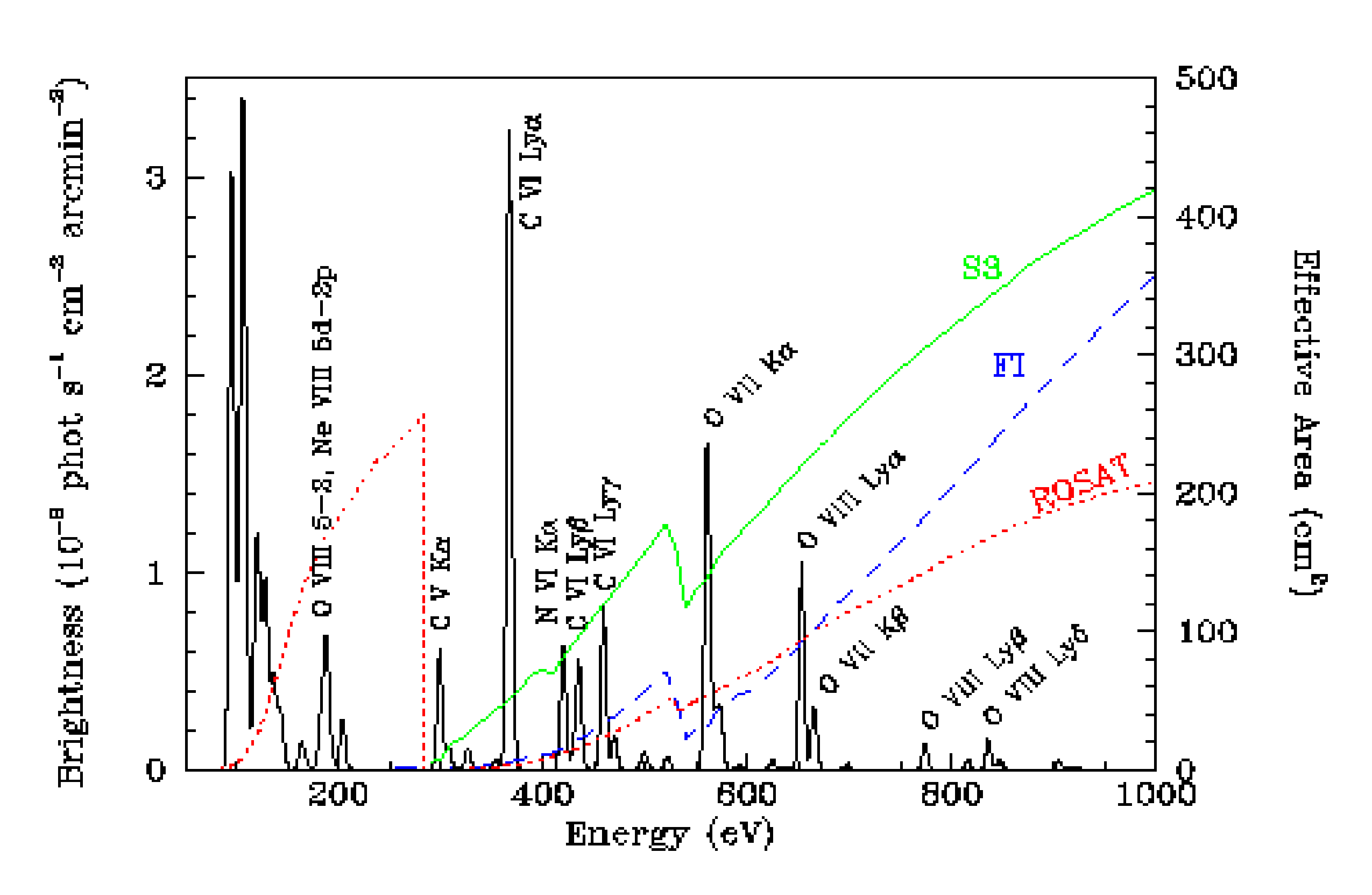

The most likely level is given by $n_{max} \sim q^{3/4}$.

Solar wind ions collide with neutral gas in the heliosphere or Earth's geocorona. One or more electrons from the atom hop over to the ion.

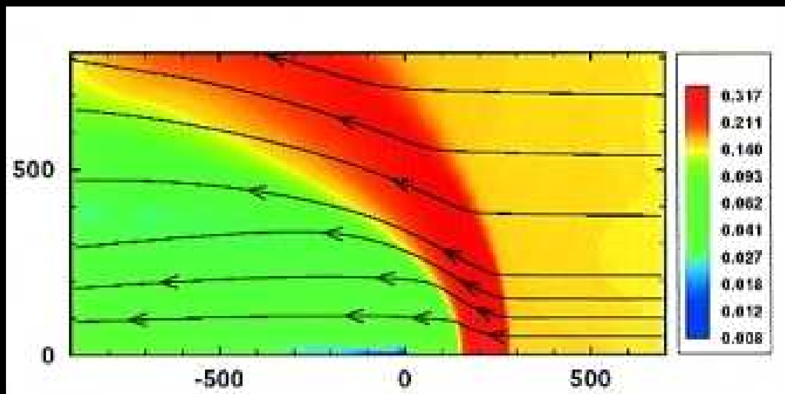
A highly charged ion will capture an electron into a high-$n$ level and then emit an X-ray. Chandra sees most emission in H- and He-like O.

Same mechanism as in comet X-ray emission (but with $H_2O$, $CO_2$ instead of H and He).

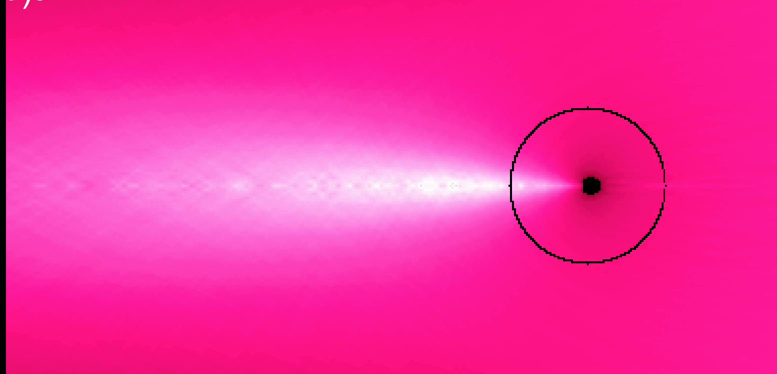
# Model CX Spectrum



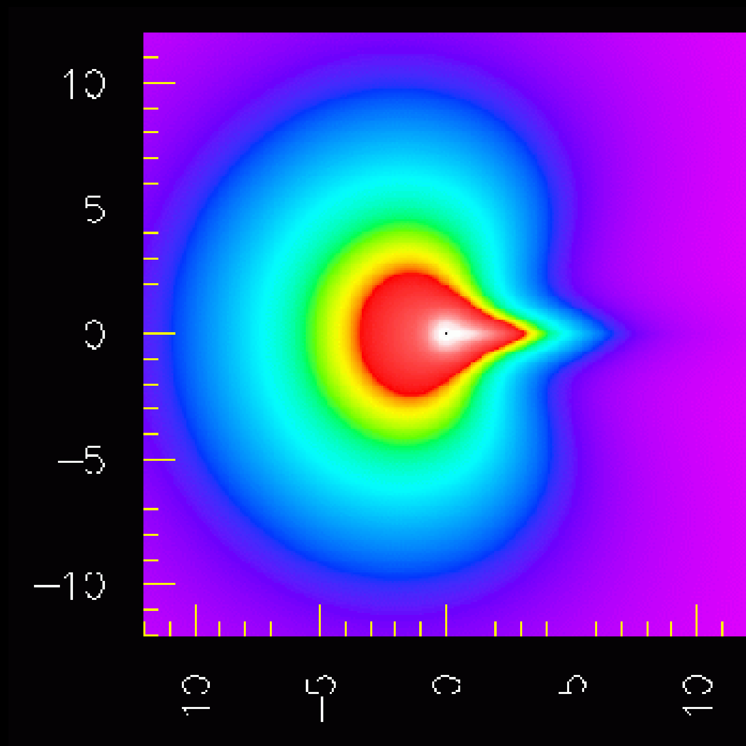
# Distribution of heliospheric neutral gas and X-ray emission




Neutral H density.  Axes in AU.  H depleted down-stream and near Sun.  Wood et al., ApJL 547 (2001).

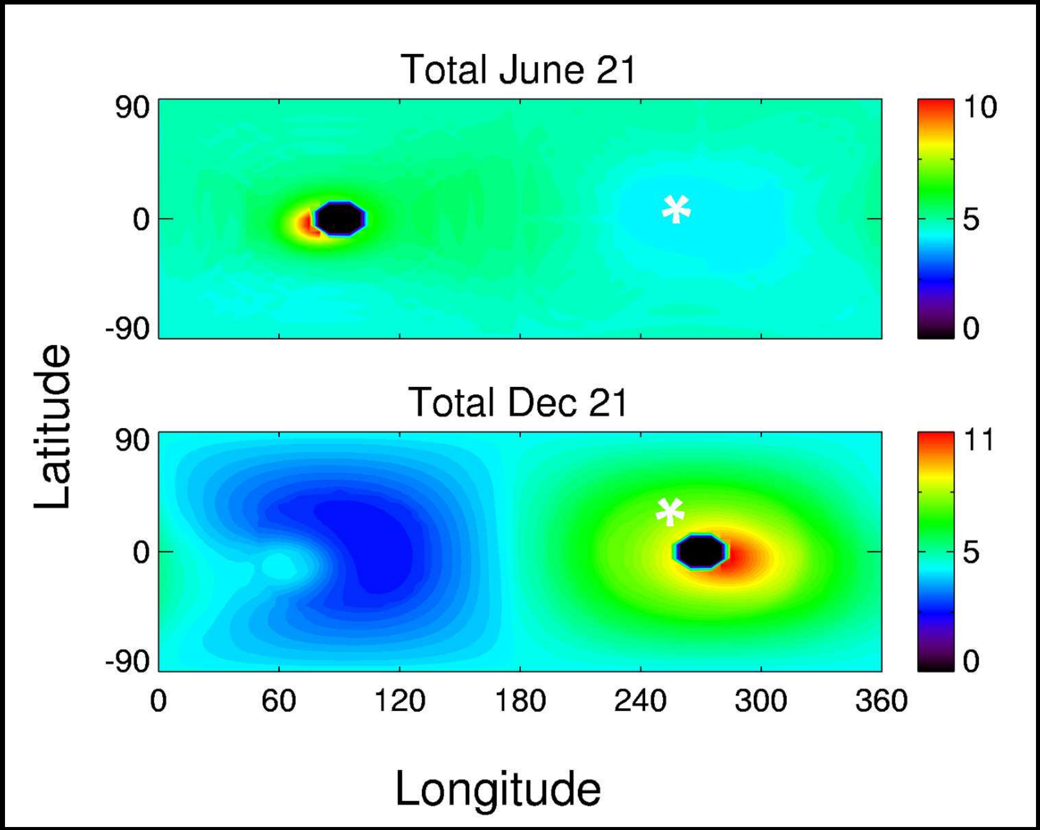


He gravitationally focused downstream (longitude centered on Dec 6).  Circle radius is 1 AU.  From John Raymond.




CX emissivity (downstream to right). $n_{SW} \propto r^{-2}$ so most CX emission is within several AU of the Sun. From Pepino et al., ApJ 617 (2004).

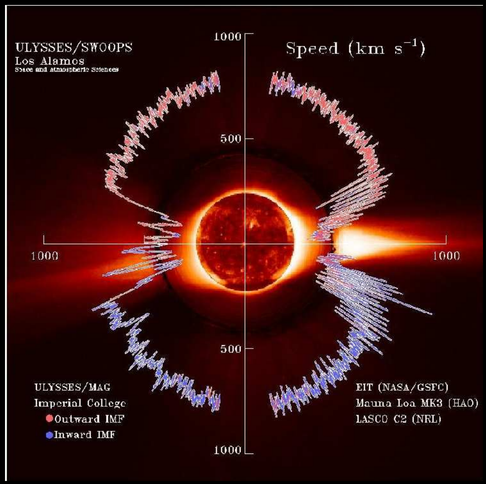
# CX intensity varies with observer location



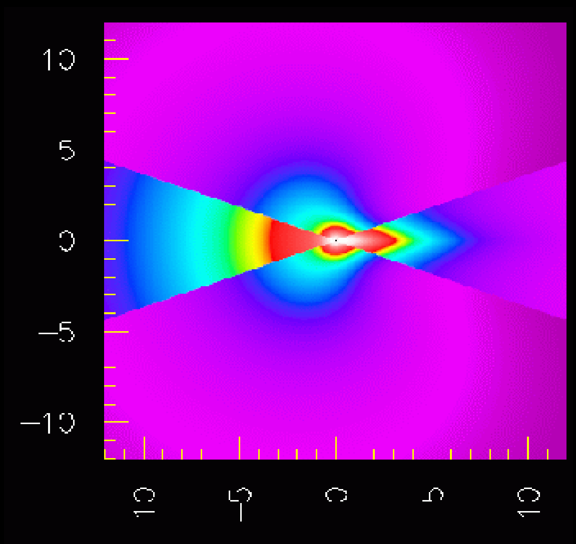

Sky maps of CX emission observed from Earth on summer and winter solstices during solar max. * marks upstream direction. From Robertson & Cravens, JGR 108 (2003).

What the SXRB looks like depends on when (i.e., from where) you look!

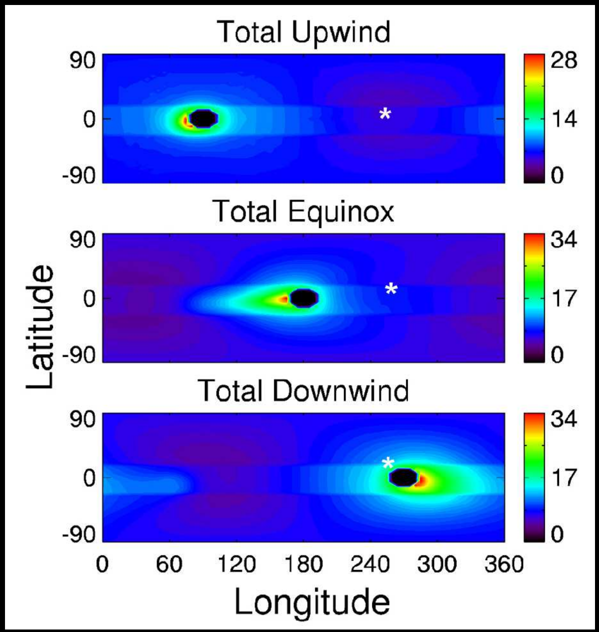
# Impact of Solar Cycle, Slow vs. Fast Wind




Solar wind speed vs. ecliptic latitude (for solar minimum). More mixed slow/fast winds during solar maximum.



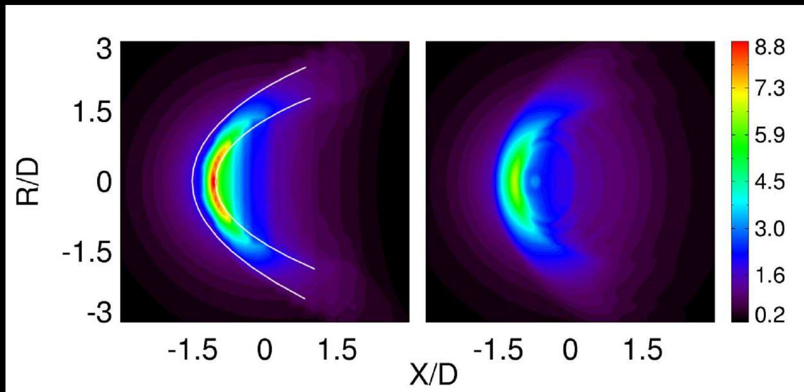

CX emissivity during solar minimum. Slow wind more ionized than fast wind ⇒ emission stratification.



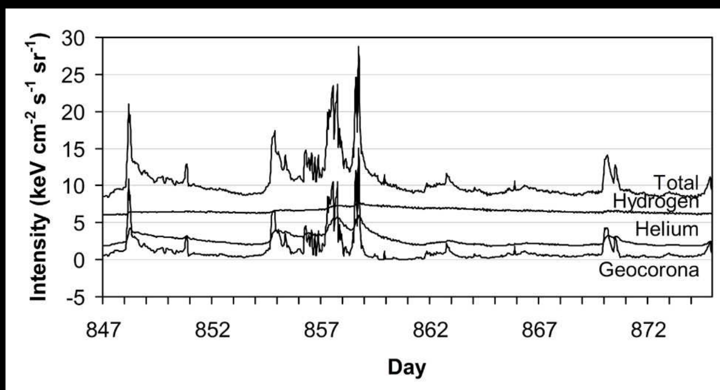

Sky maps of CX emission with slow wind, observed from Earth in June, Sept, and Dec. CX intensity is higher during solar minimum because of decreased neutral gas depletion. From RC JGR 108 (2003).

CXC

# Geocoronal CX




CX intensity as observed from Earth flank (left) and 45° from Earth-Sun line. From Robertson & Cravens, GRL 30 (2003).




Model CX intensity based on observed solar wind density and speed matches ROSAT lightcurve well. CX explains ROSAT LTEs.

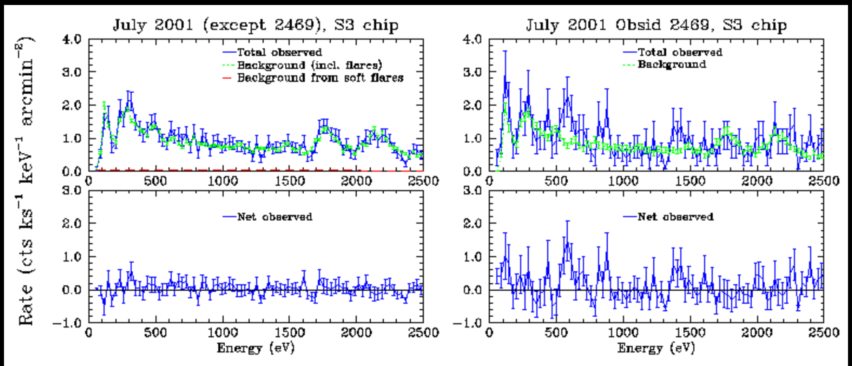
Intensity depends strongly on look direction and viewing location.

Geocoronal CX usually much weaker than heliospheric emission but can be stronger during wind "gusts."

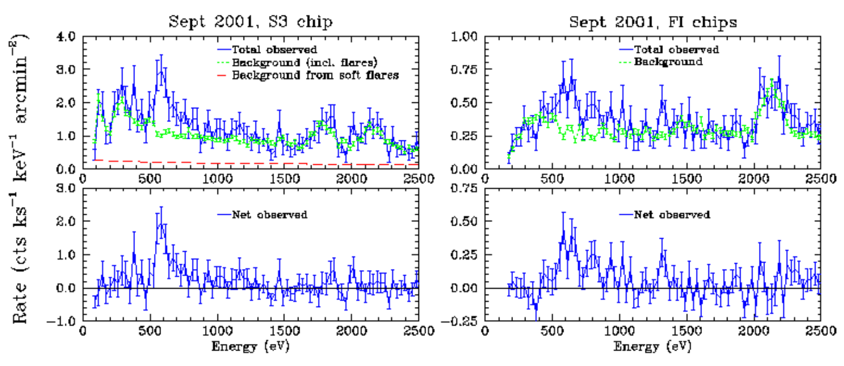
Rapid localized response to solar wind.

CXC

# Observational evidence

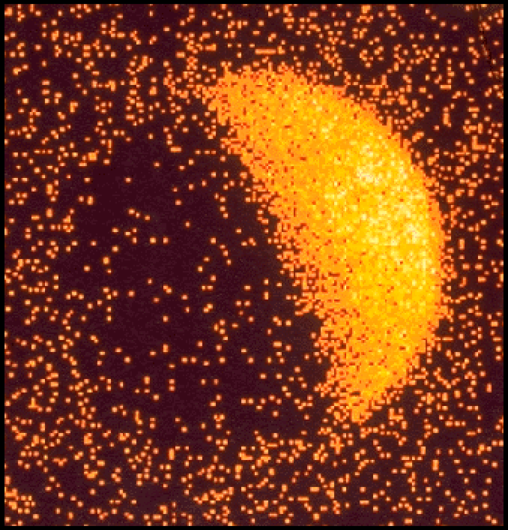



Chandra dark Moon obs, July 2001. No detectable emission for most, but weak signal at beginning.



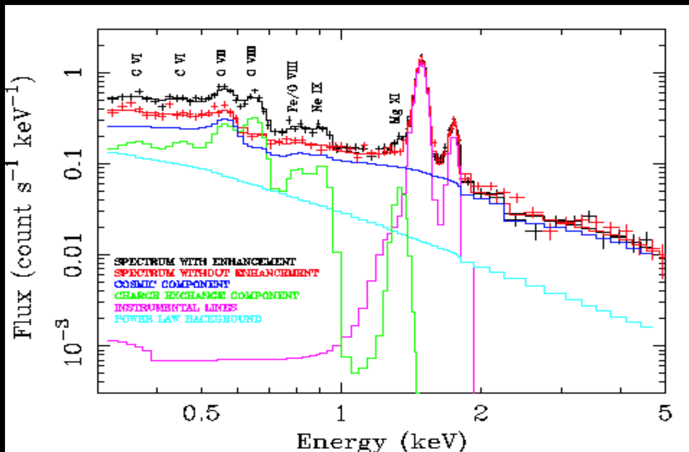

Sept 2001 obs shows strong CX emission, in good agreement with model predictions based on solar wind data. From Wargelin et al., ApJ 607 (2004).

- ROSAT LTEs strongly correlated with solar wind density × speed (Cravens et al., ApJL 532 (2000)).
- Moon observations by ROSAT and Chandra.

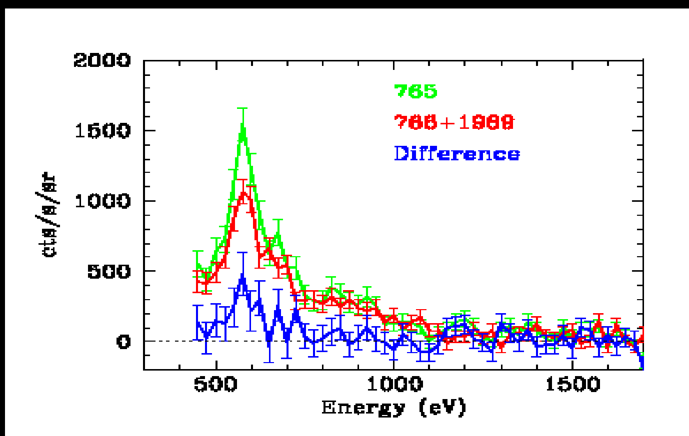


Excess emission on dark side and in SXRB indicates strong LTE. Figure from Schmitt et al., Nature 349 (1991).

# CX intensity




Excess emission during part of 1 of 4 HDF-N XMM exposures. Snowden et al., ApJ 610 (2004).




Chandra BG spectra in SN1999em field. Enhanced emission when Earth in He focusing cone.

Typical RASS rates (in snowdens) in clear fields: 400 (1/4-keV), 100 (3/4-keV), 600 (full band).

ROSAT dark Moon (~1000 snowdens over full band).

Chandra dark Moon (~100 snowdens in 3/4-keV band during one obs).

XMM Hubble DF-N.

Chandra He focusing cone (~100 snowdens in 3/4-keV band.

Chandra MBM12 variable Ly$\alpha$.

RASS maps are close to the true cosmic SXRB because they were made during solar max. Even so, CX is probably 10-50%. During solar minimum, *CX may account for most of the SXRB*!

CXC

# Effects on Data Analysis--Extended Objects

Affected sources:

2. SXRB
3. Galactic plane/bulge BG
4. Comets
5. Clusters
6. Nearby galaxies
7. Large SNRs

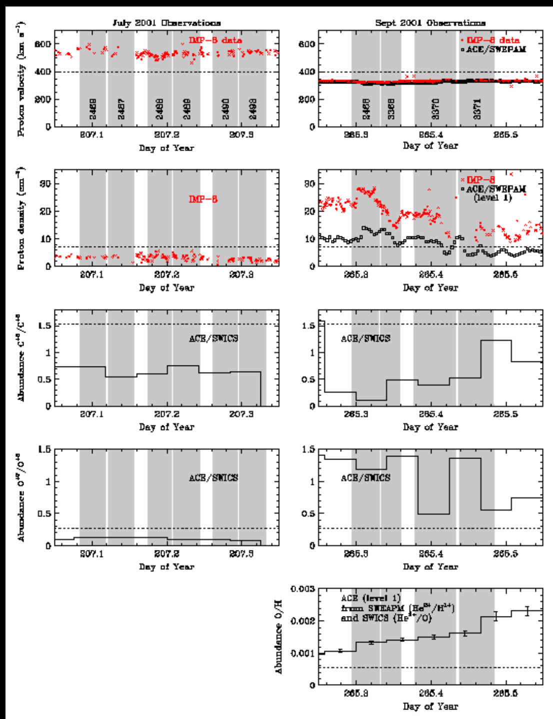
50-ks S3 spectrum of 2-3 keV cluster at 0.6-0.7 of $r_{virial}$. Surface brightness is ~1/4 of BG.

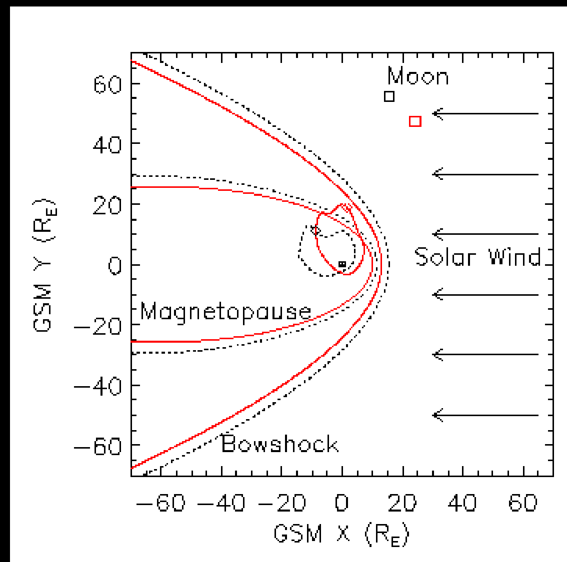
Same as above but with ~100 snowdens (3/4-keV band) LTE.

# Cluster outskirts with LTE

50-ks S3 spectrum of 2-3 keV cluster at 0.6-0.7 of $r_{\mathrm{virial}}$ with ~100-snowden LTE. Cluster surface brightness is ~1/4 of typical background.

# Theoretical Modeling




- Currently good to factor of 2 or 3. Main obstacle is neutral gas distrib.
- Good solar wind data now, but often only relevant for geocoronal CX. *ACE* database recently added $O^{8+}$ abundance (only $O^{6+}$ and $O^{7+}$ before).
- Limited analysis of solar max data so far. Solar minimum data being collected now.