Solar Wind Charge Exchange X-Ray Emission as a Probe of the Solar Wind Interaction with Planets

Thomas E. Cravens

University of Kansas

(and ISSI soft x-ray imaging team -- Sibeck, Collier, Sembay,…..)

EPSC London Sept. 2013

Outline

- The Solar Wind Charge Exchange (SWCX) X-Ray Mechanism
- X-Ray Emission from comets
- X-Ray Emission from the terrestrial magnetosheath *****
- X-Ray Emission from Mars
- Jovian X-ray emission

Solar Wind Charge Exchange (SWCX) Mechanism for X-Ray Emission

- Solar wind ion M^{q+} (O, N, C, Fe, Si, Ne..)
  (O^{7+} , C^{6+}……)
- Cometary, terrestrial. interstellar neutrals H, He, or H_2O, …..
- Charge transfer collisions:

  $M^{q+} + H \rightarrow H^{+} + M^{(q-1)+*}$

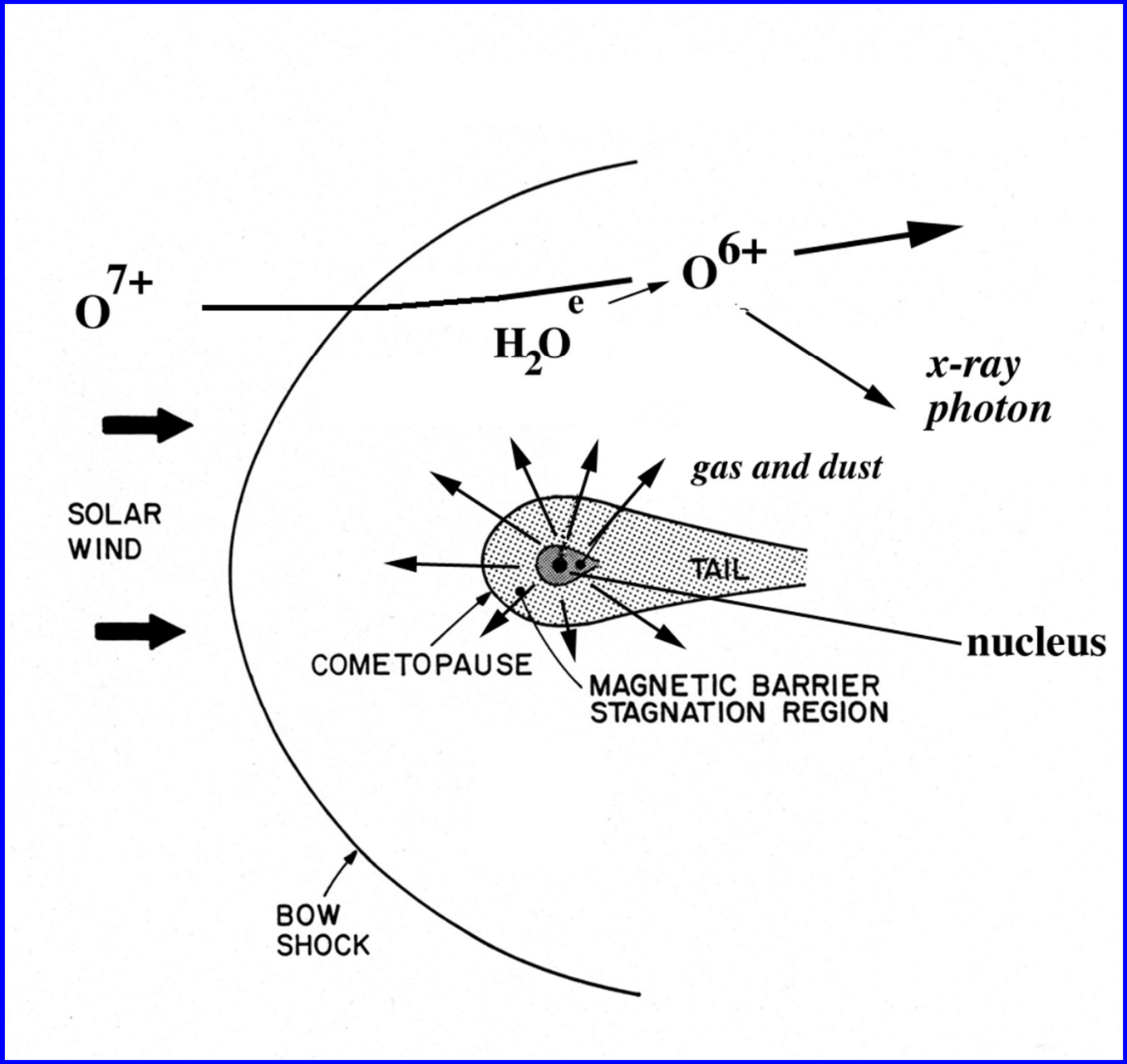
  $M^{(q-1)+*} \rightarrow M^{(q-1)+} + h\nu$

Solar Wind Charge Exchange (SWCX) Mechanism for X-Ray Emission contd.

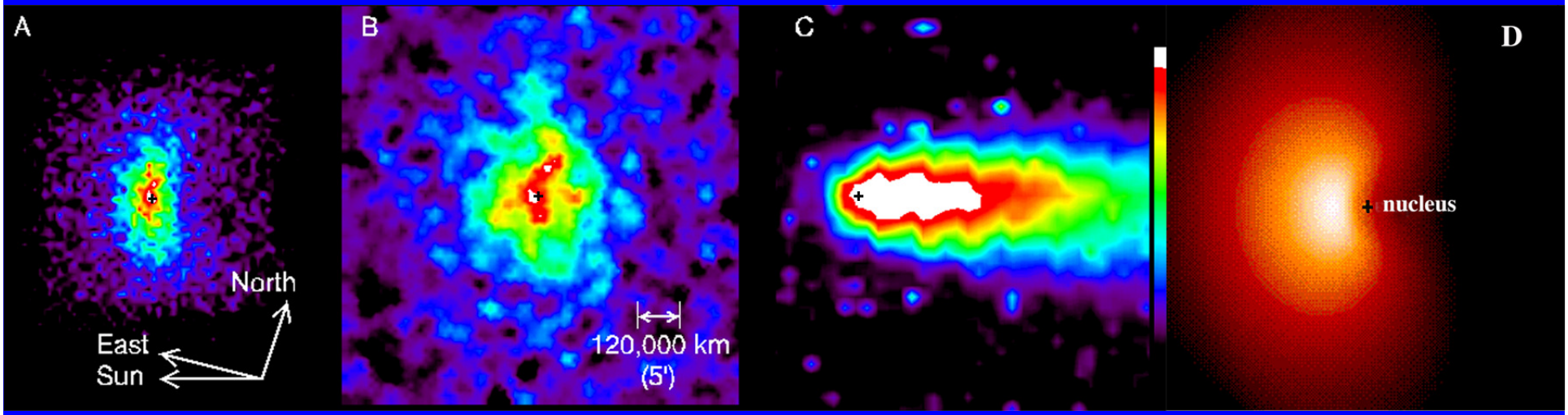
- First observed in 1996 during ROSAT observations of comet Hyakutake (Lisse et al., 1996).
- Explained with the SWCX mechanism by Cravens (1997) and applied by many authors to non-comet solar system bodies.
- However, recognized earlier in lab plasmas (edge effects in tokomaks - Isler et al., 1981).

Comet Hyakutake

Solar Wind Interaction with comets

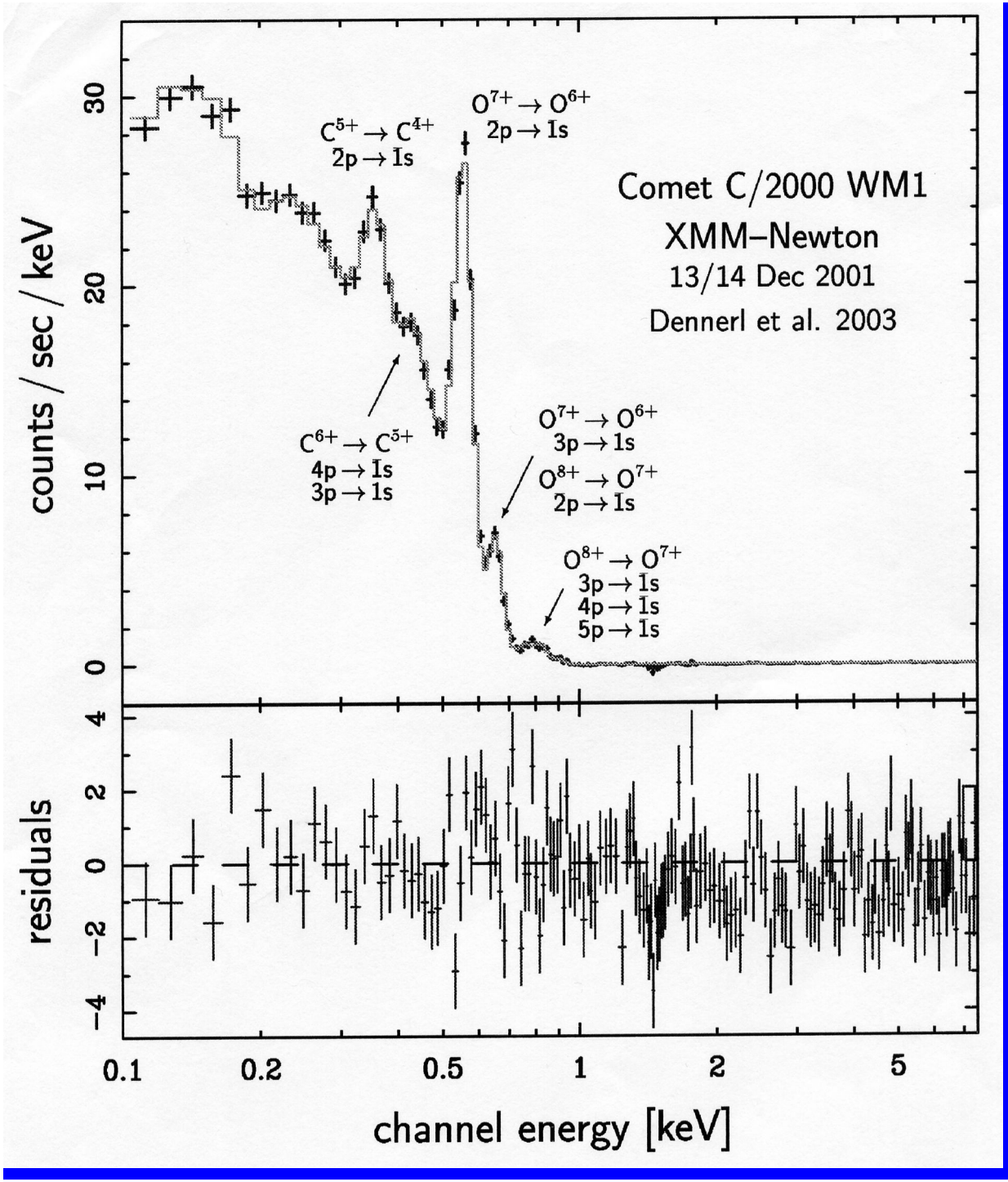


Chandra image of Comet LINEAR (Lisse et al., 2001)



Soft x-rays EUV Optical MHD model

Cometary X-Ray Emission

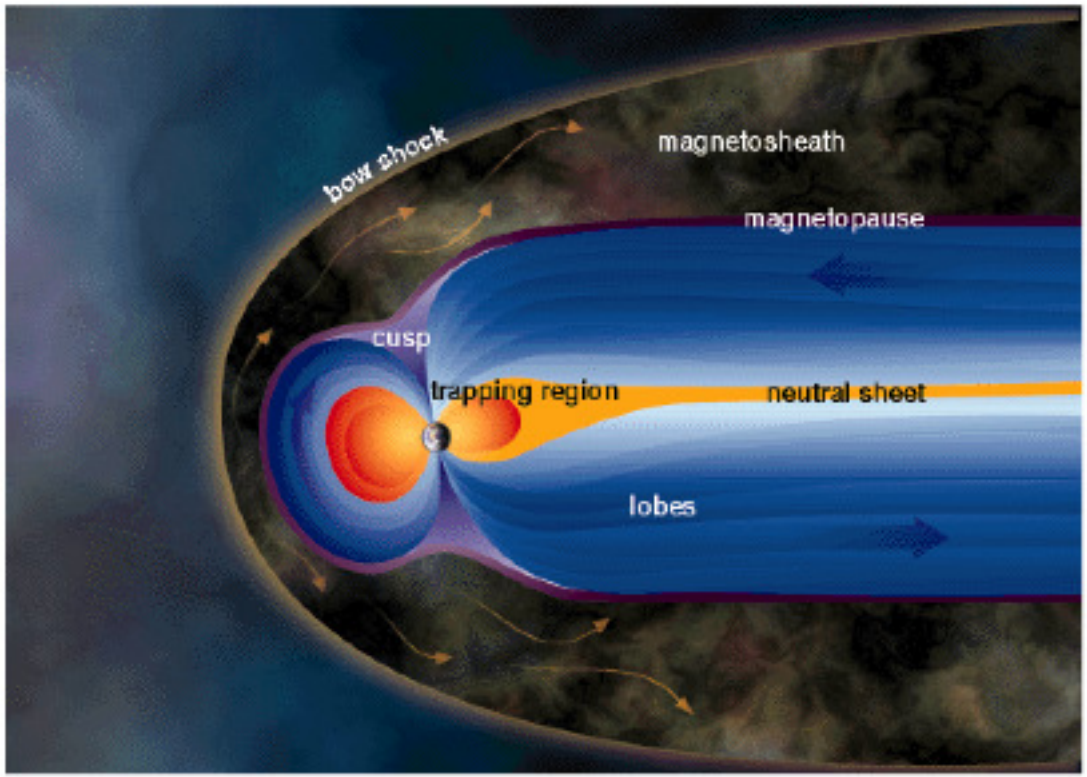


Dennerl et al (2003)

X-Ray Spectrum

X-Ray Emission from the Magnetosheath / Geocorona due to SWCX

- Geocoronal atomic hydrogen extends tens of Earth radii above the surface.
- The shocked solar wind is diverted around the magnetopause.
- The SWCX mechanism operates in the magnetosheath due to collisions with the H.
- Apparently, this has been seen as emission from the dark side of the Moon (ROSAT - Schmitt et al., 1991, and CXO -- Wargelin et al. 2004)



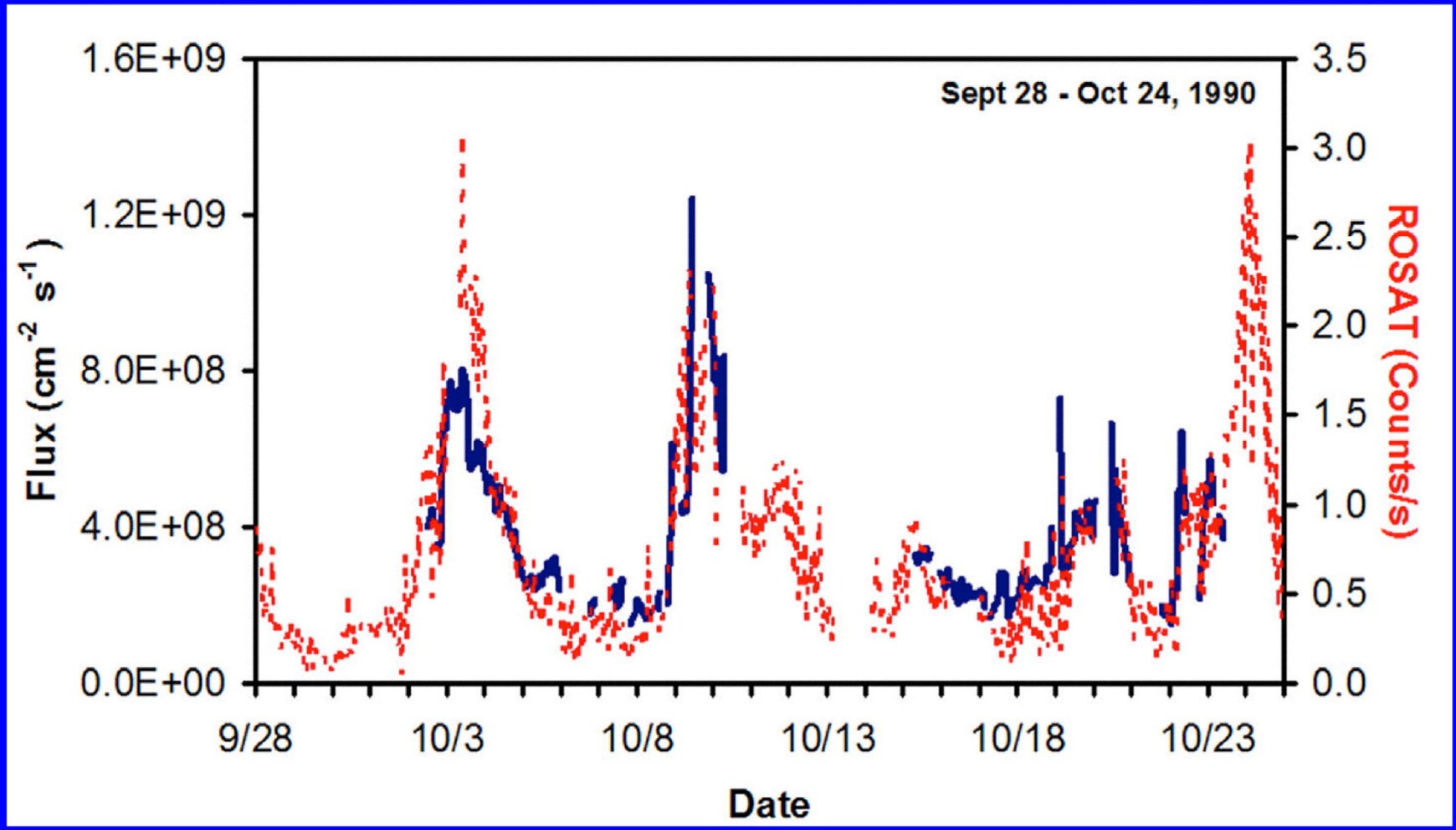
New calculations including the magnetic cusps.

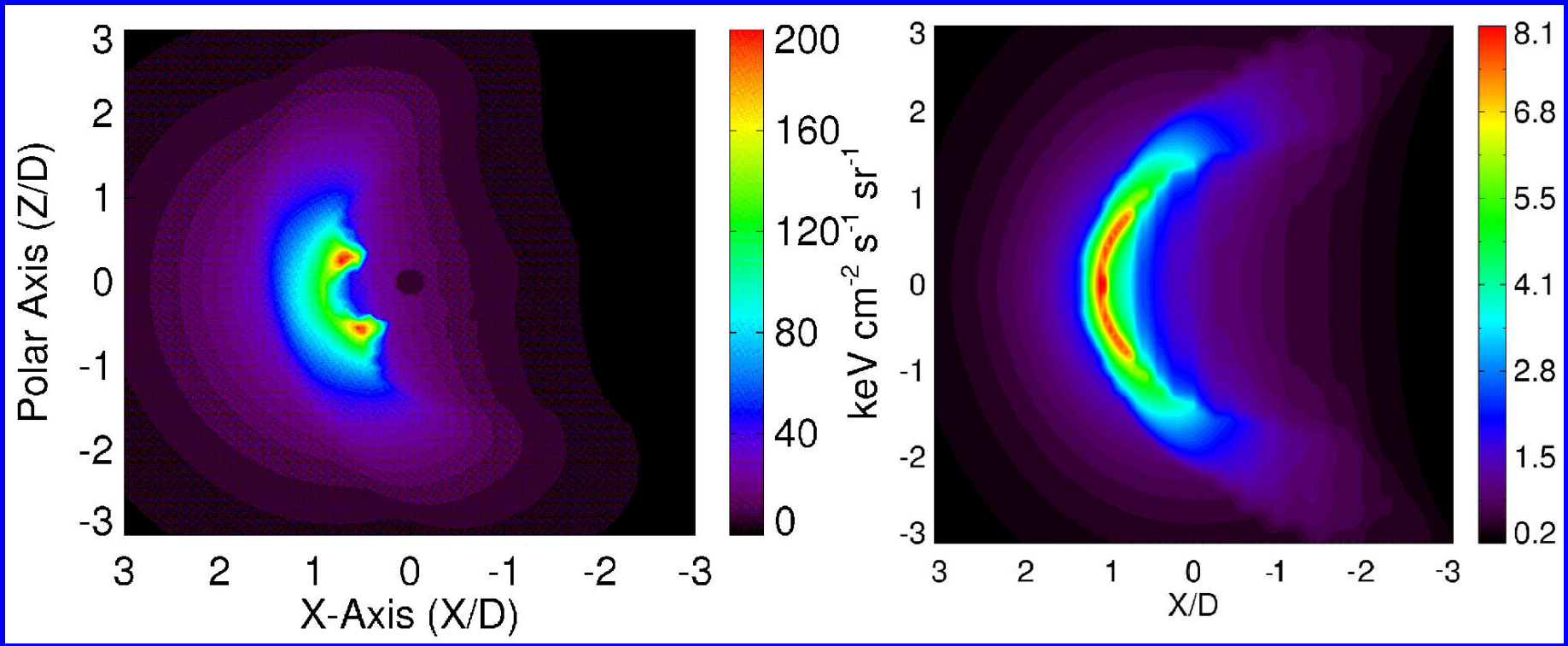
Cusps allow solar wind to access lower alt.

Drawing of Earth's magnetosphere. Notice that the magnetic field is much larger than the planet! *Windows Original Image*

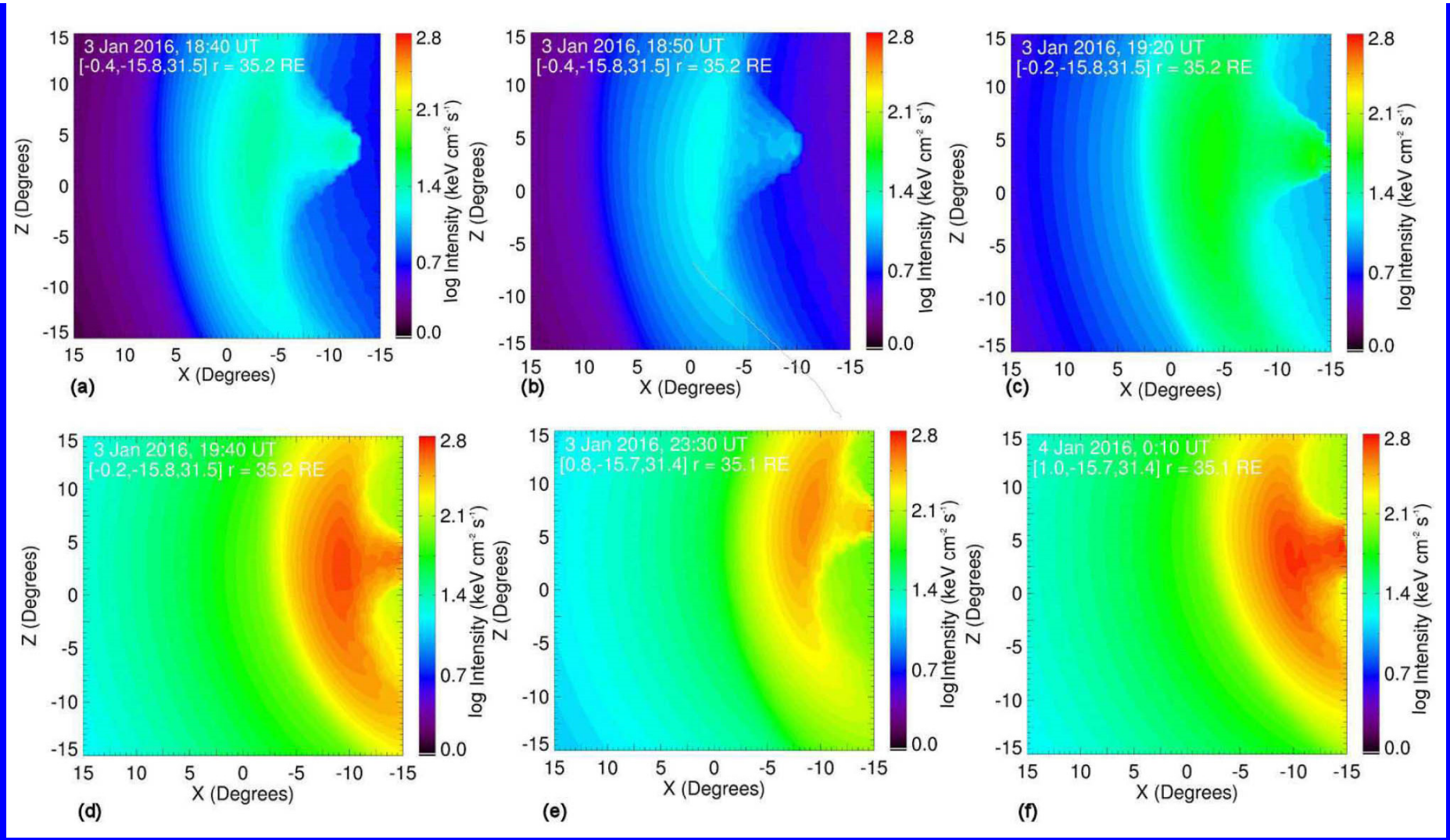
Last modified prior to September, 2000 by the Windows Team

ROSAT 1/4 keV x-ray background LTE compared with measured IMP-8 solar wind proton fluxes -- Cravens, Robertson, and Snowden, 2001.



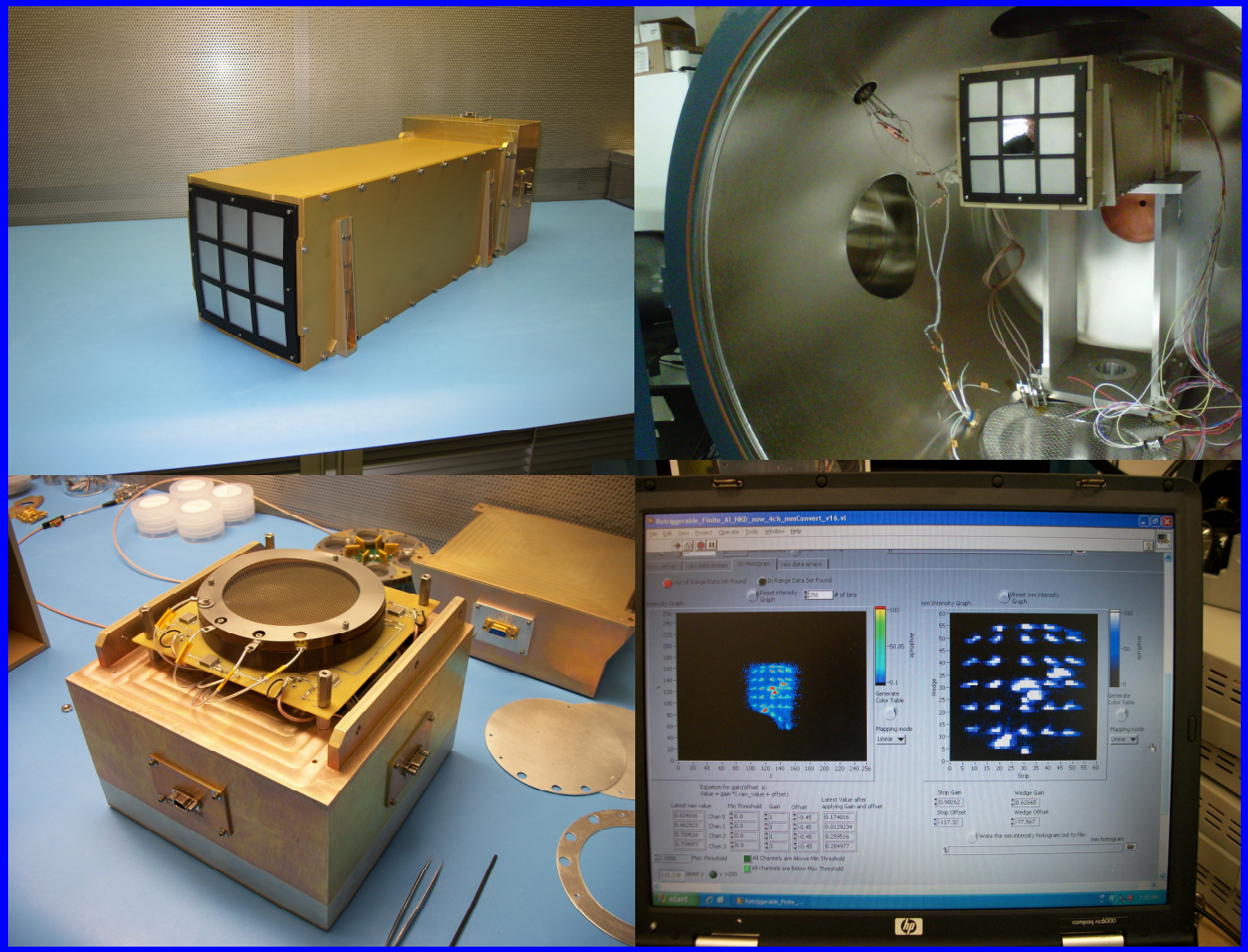


Predicted Intensity X-Ray Map with and without Cusps (Robertson et al., 2006) as would have been seen by an x-ray telescope on a spacecraft.



Simulated X-Ray Images of Earth during a storm

A prototype wide-field soft X-ray imager for launch as a secondary payload on DXL, an astrophysics sounding rocket mission that will separate charge exchange from local hot bubble emission (local ¼ kev).



STORM prototype developed, built, and undergoing testing, but more work is needed before it will be flight-ready.

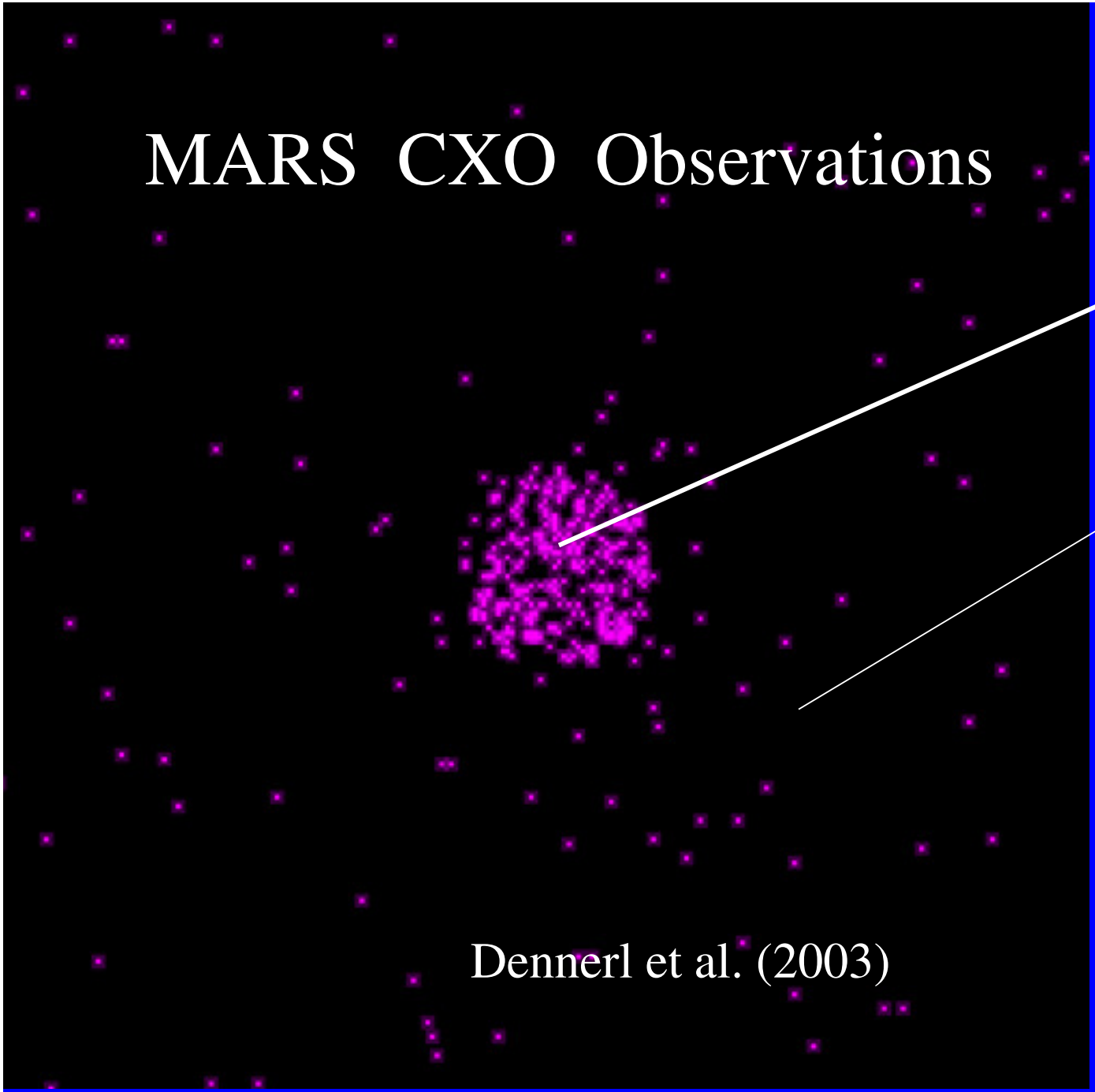
Launch in December 2012 from Wallops.

Galeazzi,Collier…

..

More Information: http://www.physics.miami.edu/~galeazzi/x-rays/dxl.html

MARS CXO Observations

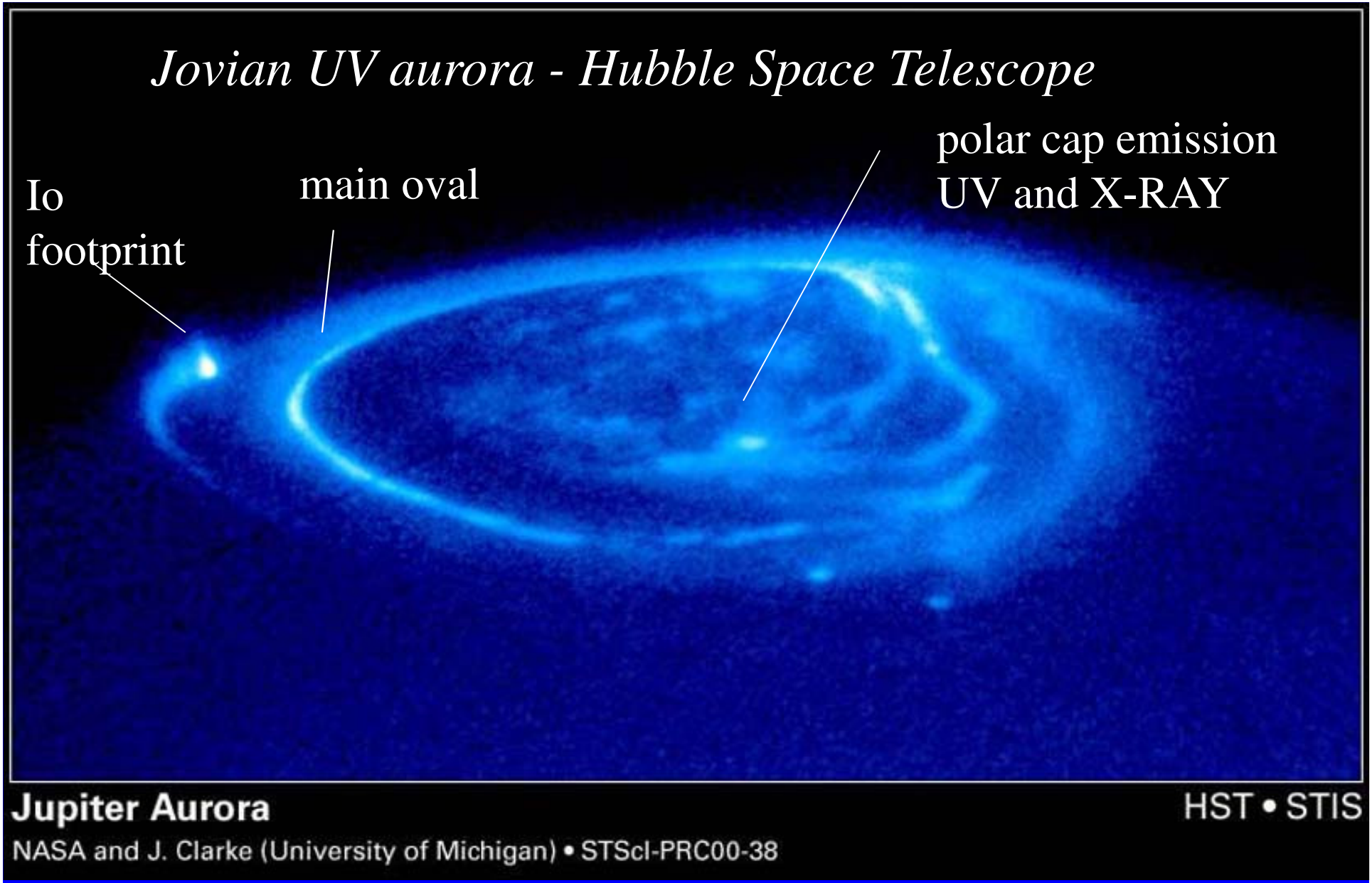


Dennerl et al. (2003)

Disk emission is from K-shell fluorescence of C and O in carbon dioxide.

But there is some *halo* emission attributed to SWCX.

Jovian UV aurora - Hubble Space Telescope

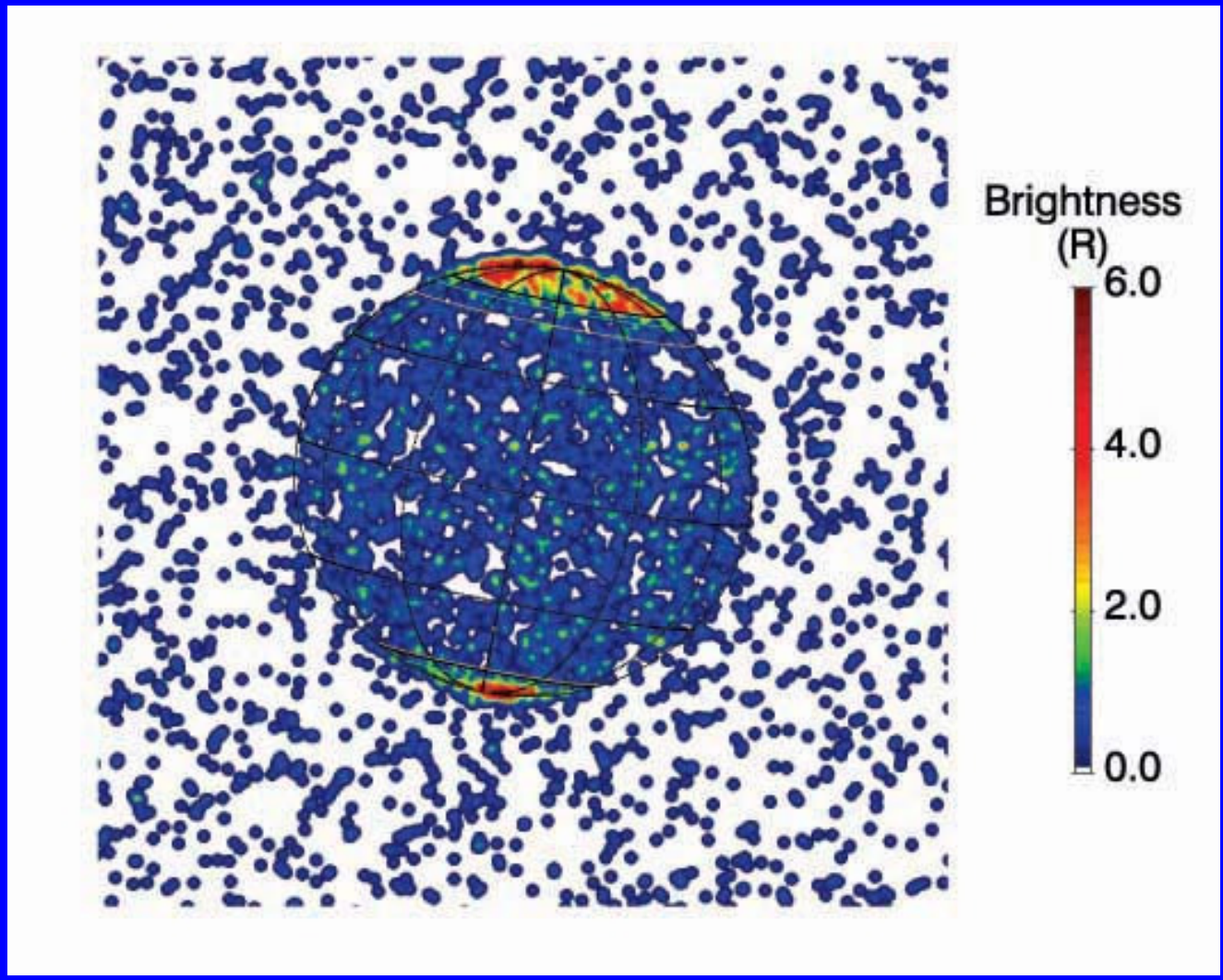


Total auroral power $\approx 10^{13}$ - 10^{14} W

UV emission: H_2 Lyman and Werner band (electron excitat.)

CXO HRC X-Ray Image of Jupiter (Gladstone et al. 2002)

1 GW X-Ray Luminosity



Probable Explanation for Jovian X-Rays *(Cravens et al., 2003 JGR; Hui et al., 2009; Ozak et al., 2011…)*

- Accelerated (≈ 10 MeV) S and O ions in the outer magnetosphere (magnetopause). Acceleration needed such that ions collisionally have electrons stripped off in collisions with Jovian H_2. Charge exchange collisions then generate x-rays.
- Implications: downward field-aligned currents (several MA), upwardly accelerated (MeV) electrons, radio waves….

Summary

- Observations of soft x-ray emission produced by the solar wind charge exchange mechanism can provide a probe of both the solar wind itself (eg., composition) and of the solar wind interaction with planets, comets, and the interstellar medium (eg., spatial extent and morphology such as shock and cusp positions).