X-ray views of the solar system



G. Branduardi-Raymont Mullard Space Science Laboratory University College London







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X-ray production of the solar system

Charge exchange (CX)

Highly ionised ions collide with neutrals/molecules
→ electron capture ('charge exchange')
→ de-excitation with X-ray line emission

e.g. $H_2 + O^{7+} \rightarrow H_2^+ + O^{6+} + hv$

Solar wind (SWCX) or magnetospheric ions

Comets, heliosphere, <u>Earth geocorona</u>, Venus/Mars exospheres, Jupiter aurorae

Electron bremsstrahlung





X-rays from Jupiter

Early work by *ROSAT* and *Chandra* → Aurorae + 'disk' X-rays

Auroral soft X-rays (< 2 keV): K-shell line emission from charge exchange, by energetic ions from > 30 R_J, precipitating along magnetic field lines

→What are the ion species (C or S) and thus their origin (solar wind / magnetosphere)?



Rodriguez 2004

Attempted to answer with XMM-Newton ...

X-rays from Jupiter: XMM-Newton EPIC









X-rays from Jupiter: XMM-Newton EPIC







X-rays from Jupiter: XMM-Newton EPIC

Auroral and disk spectra



Branduardi-Raymont et al. 2007

X-rays from Jupiter: XMM-Newton RGS



RGS clearly resolves auroral CX emission lines from disk contribution







X-rays from Saturn: XMM-Newton EPIC



Oct. 2002

Apr. 2005





Branduardi-Raymont et al. 2009, in press

Saturn and Jupiter as solar mirrors



Saturn's disk X-ray emission decreases over the years following the decay of solar activity

Same trend observed in Jupiter

Mars disk and exosphere (halo)

XMM-Newton EPIC indicates Mars is an extended X-ray source

→ RGS strategy



Dennerl et al. 2006

Mars disk and exosphere (halo)

- Fluorescent scattering of solar X-rays in CO₂ atmosphere
- Solar wind charge exchange (SWCX) in



Comet C/2000 WM1, 2001 Dec. 13 - 14



Optical

XMM-Newton

Dennerl et al. 2003

Comet C/2000 WM1: combined RGS + EPIC pn spectrum



Looking to the future ...

- The X-ray view is a global view
- Learning about the Universe at large, by studying the worlds next door
- X-rays as a test bed for theoretical models
- Longer looks for spectral quality and variability
- Direct response to solar activity and solar wind conditions

 → more comprehensive understanding of
 solar terrestrial planetary relationships
- Saturn X-ray aurorae?
- Further afield?
- *XMM-Newton* still has great potential, and plenty to do!