X-ray views of the solar system

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

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Charge exchange (CX)
Highly ionised ions collide with neutrals/molecules
→ electron capture (‘charge exchange’)
→ de-excitation with X-ray line emission
   e.g. $\text{H}_2 + \text{O}^{7+} \rightarrow \text{H}_2^+ + \text{O}^{6+} + \text{hv}$

Solar wind (SWCX) or magnetospheric ions

Comets, heliosphere, Earth geocorona, Venus/Mars exospheres, Jupiter aurorae

Electron bremsstrahlung

Elastic and K-shell fluorescent scattering of solar X-rays in planetary atmospheres and on surfaces

**Dennerl 2009**
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\textsubscript{J}, precipitating along magnetic field lines

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

Attempted to answer with *XMM-Newton* ...
X-rays from Jupiter: *XMM-Newton* EPIC

- **OVII** (0.55–0.60 keV)
- **OVIII** (0.63–0.68 keV)
- **FeXVII** (0.70–0.75, 0.80–0.85 keV)
- **MgXI** (1.30–1.40 keV)
X-rays from Jupiter: \textit{XMM-Newton} EPIC
X-rays from Jupiter: \textit{XMM-Newton} EPIC

Auroral and disk spectra

Branduardi-Raymont et al. 2007
RGS clearly resolves **auroral** CX emission lines from **disk** contribution
Jupiter

Disk only

Fe XVII

OVIII Lyα

OVIII Lyβ

OVIII Lyγ

OVIII Lyδ

Wavelength (Å)

photons/m²/sec/Å
Jupiter

Disk+charge exchange

FeXVII
OVIII Lyγ
OVIII Lyδ
OVIII Lyβ
FeXVII
OVII Heδ
OVII Heβ
OVII Lyα
OVIIr OVII f

photons/m²/sec/Å

Wavelength (Å)
X-rays from Saturn: XMM-Newton EPIC

Oct. 2002

Apr. 2005

Oct. 2005

Branduardi-Raymont et al. 2009, in press
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 CO$_2$ atmosphere
- Solar wind charge exchange (SWCX) in the exosphere

Dennerl et al. 2006

XMM-Newton RGS

Optical

XMM-Newton

Dennerl et al. 2003
Comet C/2000 WM1: combined RGS + EPIC pn spectrum

Dennerl et al., in prep.
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!