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XMM-Newton Observations of X-ray Emission from Jupiter

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X-rays from Jupiter

First detection with the *Einstein Observatory* (Metzger et al. 1983)

Analogy with Earth → e^- bremsstrahlung of auroral origin expected

Alternative: K shell line emission following charge exchange of energetic S and O ions, precipitating along the magnetic field lines

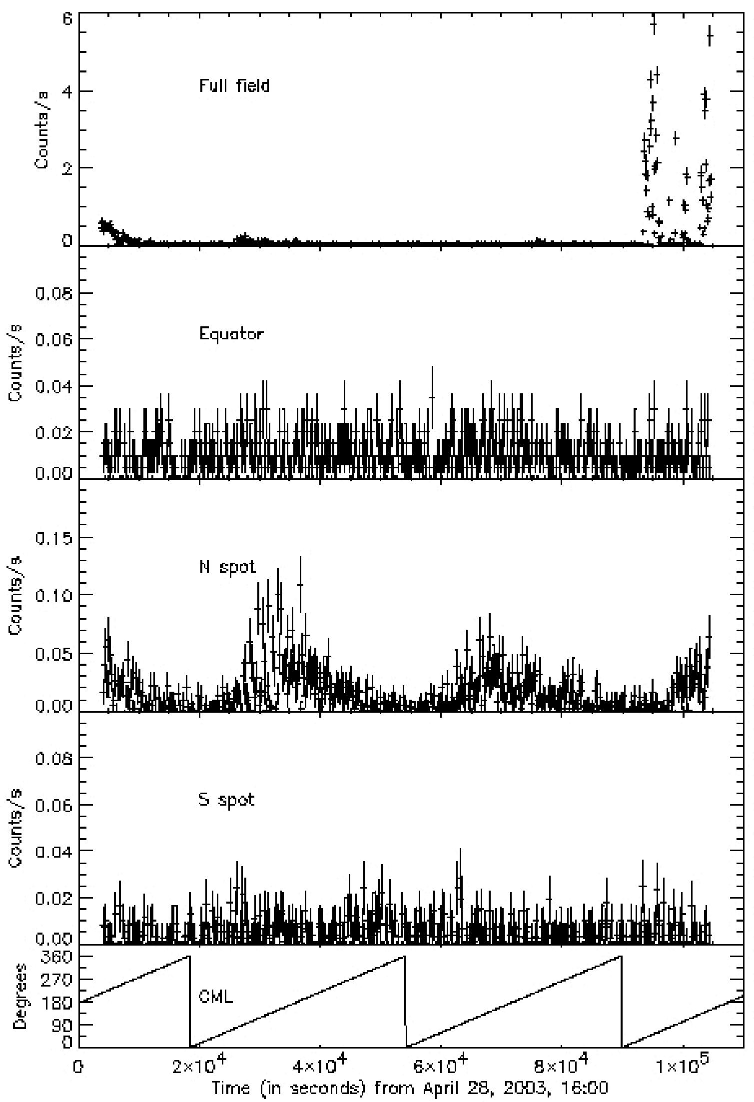
e.g. $H_2 + O^{7+} \rightarrow H_2^+ + O^{6+} + h\nu$

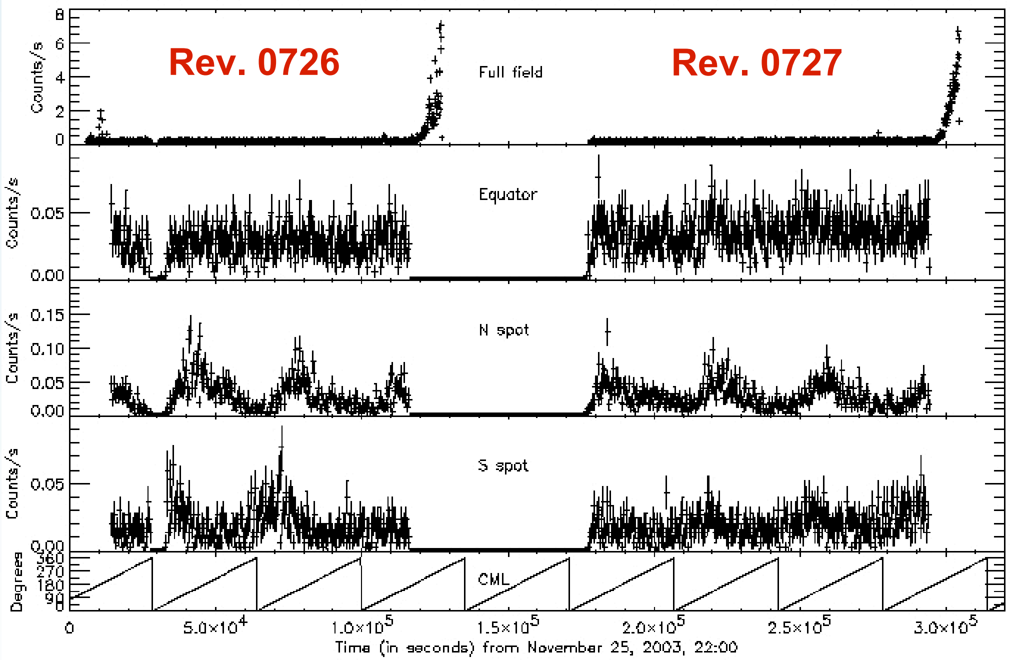
ROSAT spectrum consistent with recom. line emission (Waite et al. 1994)

Ions first thought to originate in the inner magnetosphere ($8–12R_J$)
Dec. 2000 *Chandra* observations point to origin at $>30\ R_J$

Low-latitude 'disk' X-rays detected by *ROSAT*, originally proposed to be from precipitating energetic S and O ions, later from elastic and fluorescent scattering of solar X-rays

XMM-Newton – EPIC (0.2 – 2 keV)

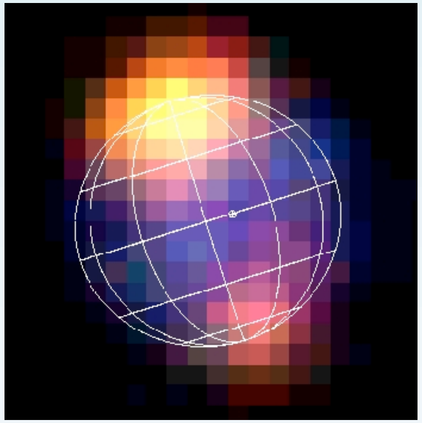




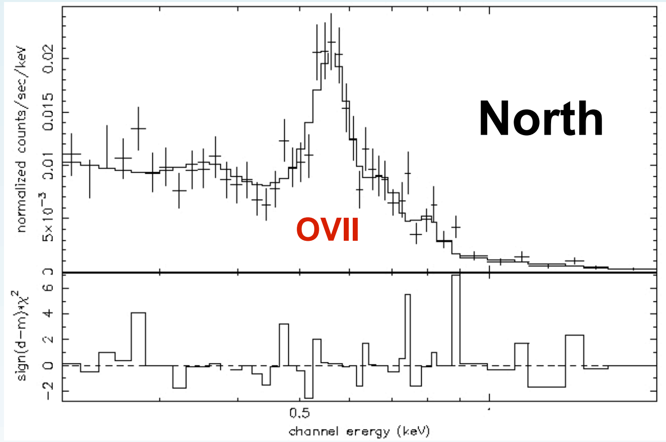
Nov. 2003

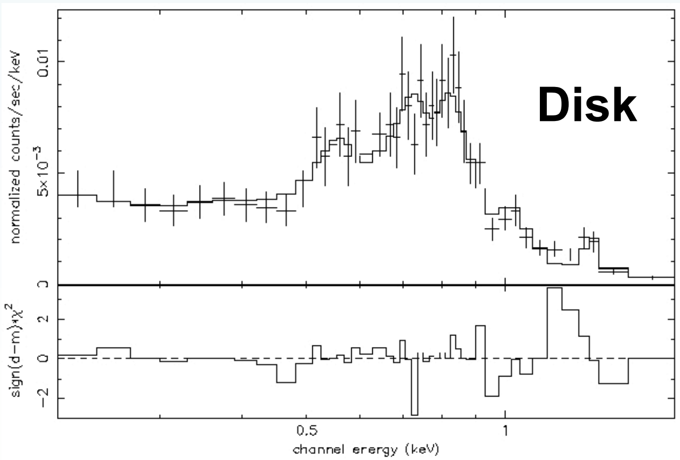
Apr. 2003

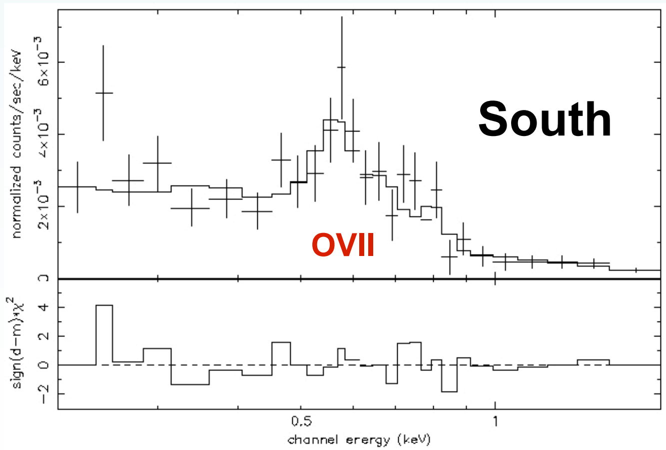
XMM-Newton – Apr. 2003: EPIC



0.2 – 0.5 keV
0.5 – 0.7 keV
0.7 – 2.0 keV

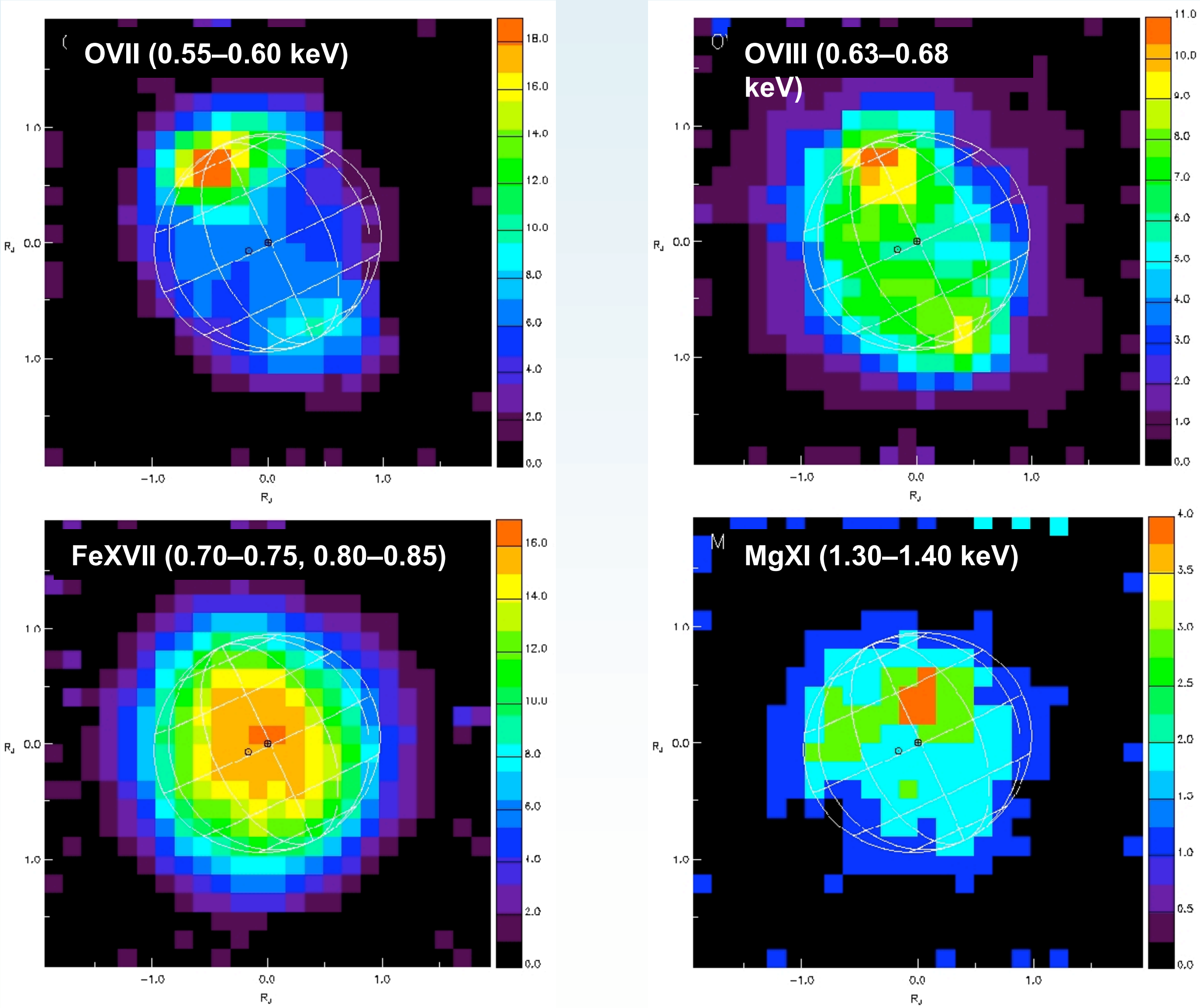




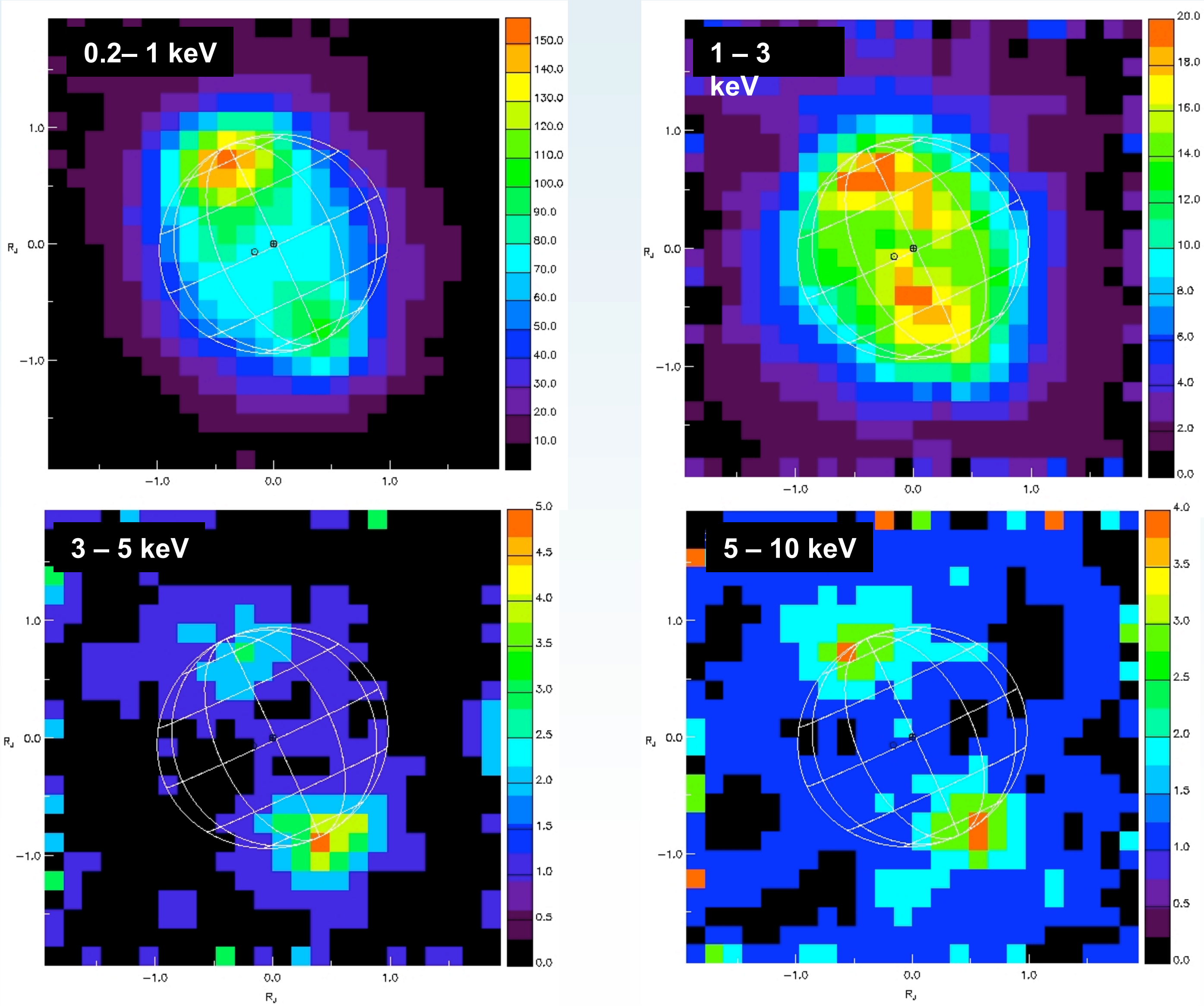


Branduardi-Raymont et al. 2004

XMM-Newton – Nov. 2003: EPIC

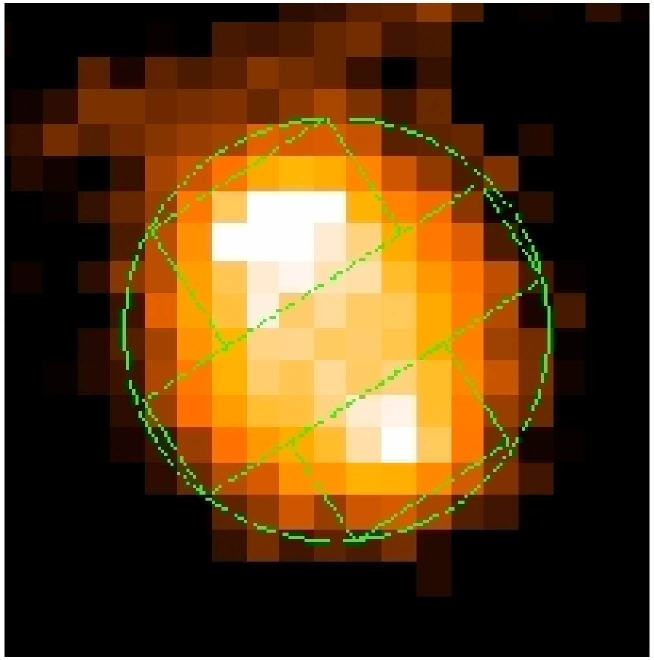


XMM-Newton – Nov. 2003: EPIC

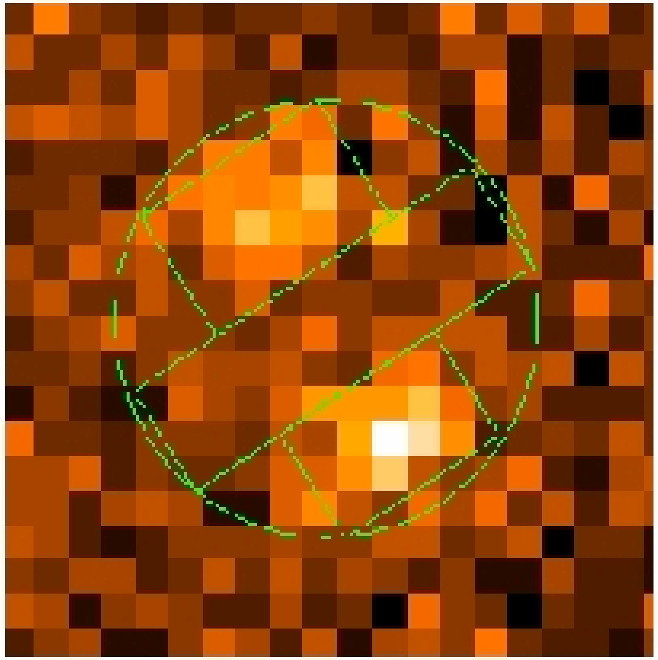


XMM-Newton – Nov. 2003: EPIC

Jupiter's spectra extraction regions



0.2 – 2 keV

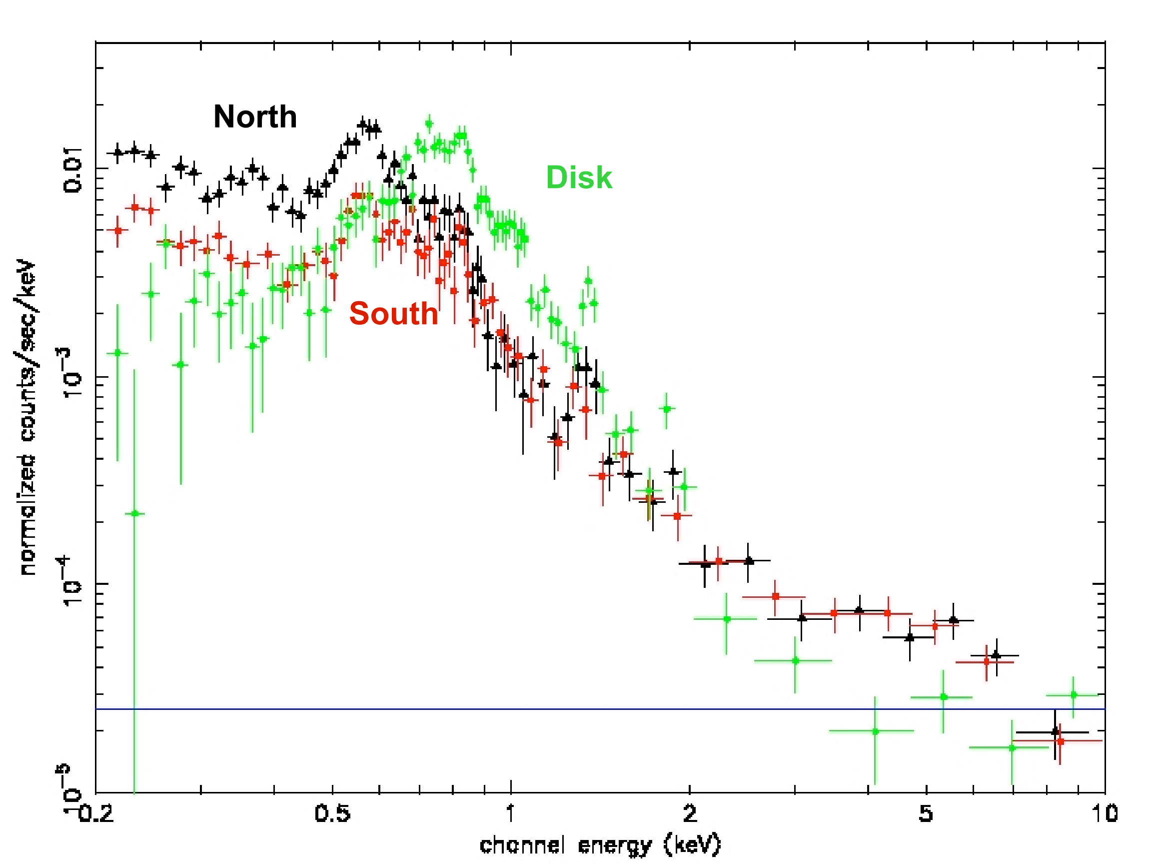


3 – 10 keV

Spectral 'mixing' corrected for by subtracting appropriate fraction of N, S and disk spectra

XMM-Newton – Nov. 2003: EPIC

Auroral and disk spectra



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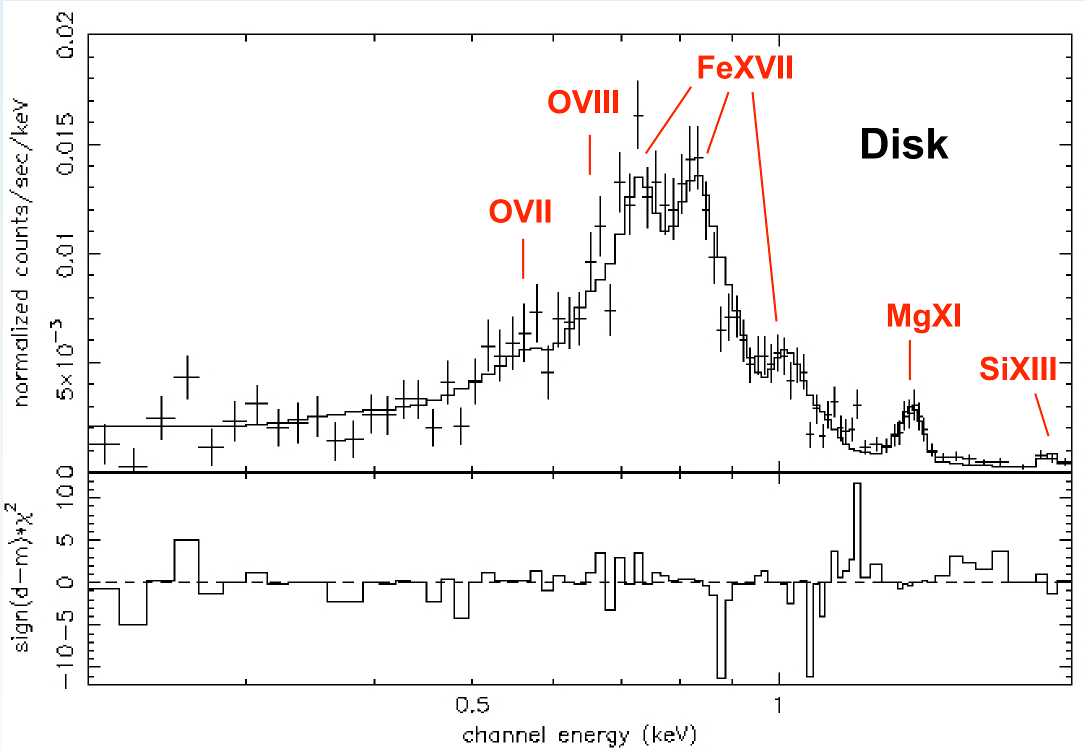
XMM-Newton – Nov. 2003: EPIC



Disk emission well fitted with one 'mekal' model (kT = 0.46 +/- 0.03 keV) with solar abundances + line contribution by OVII, OVIII, MgXI and SiXIII (solar activity)

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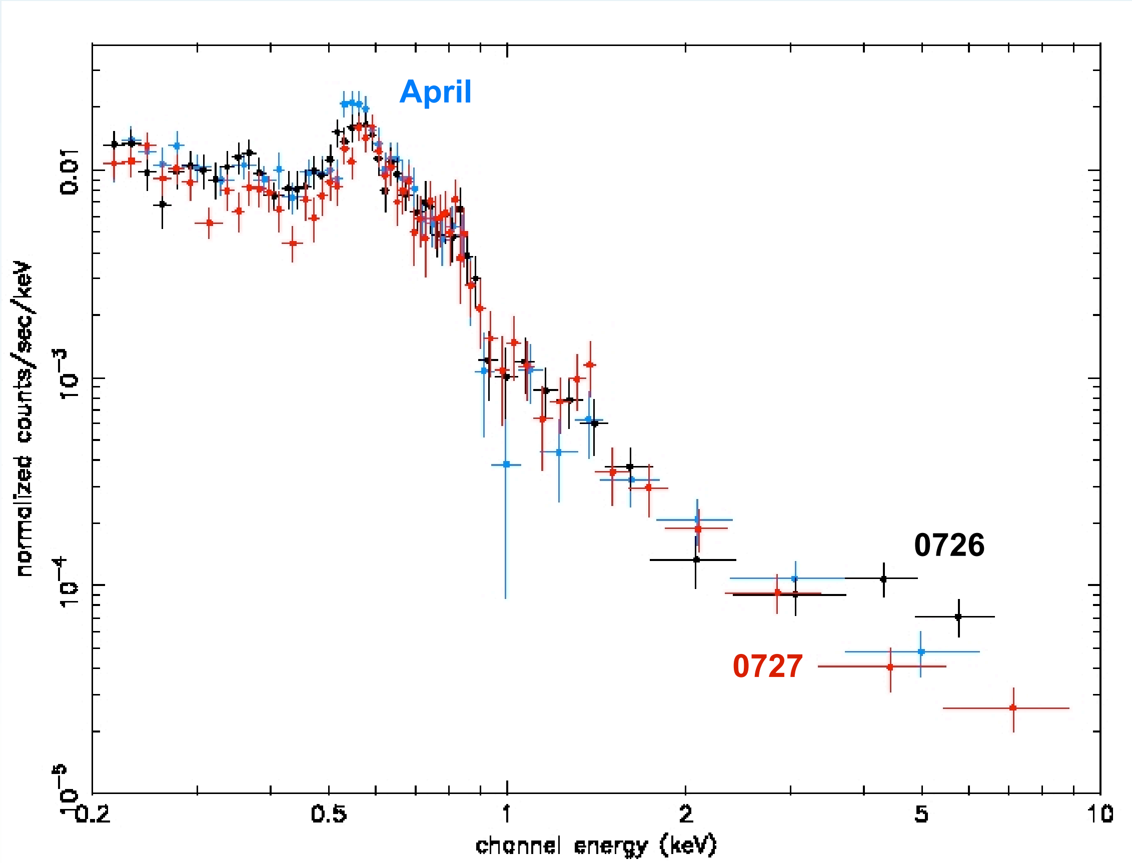
XMM-Newton – Apr. & Nov. 2003: EPIC

Apr. & Nov. 2003: North aurora



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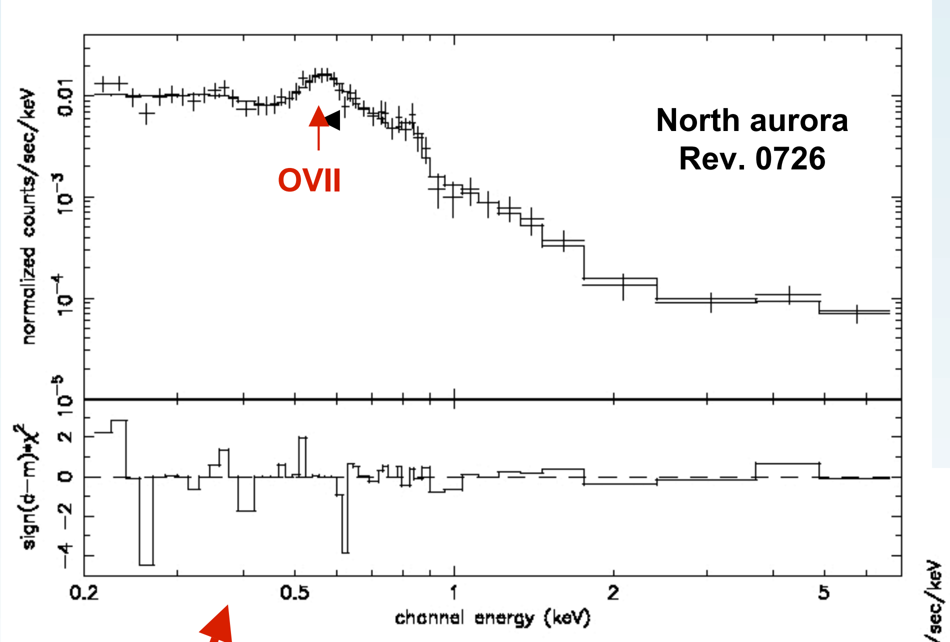
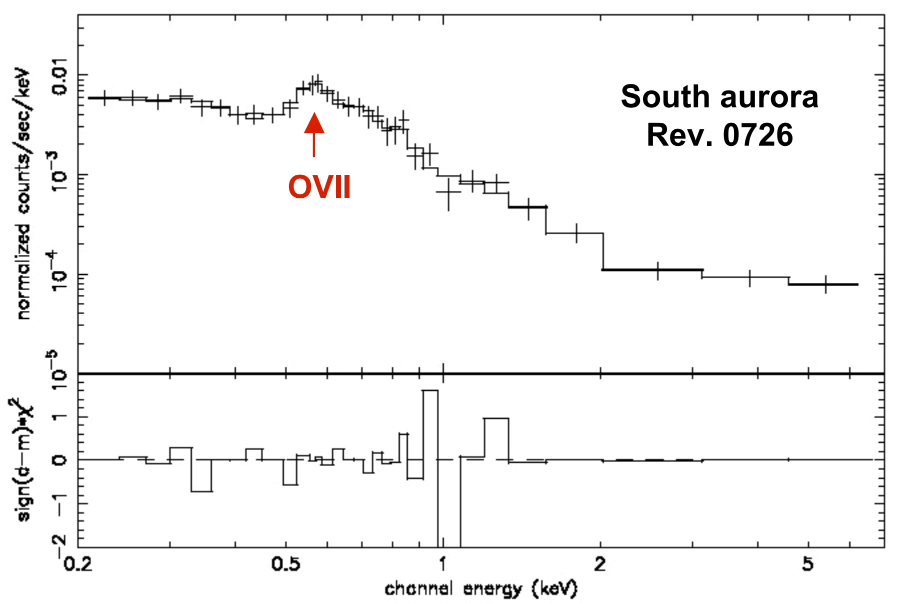
XMM-Newton – Nov. 2003: EPIC



Auroral spectra well fitted by two bremss. components + 4 soft X-ray lines

Shape of high energy component varies between rev. 0726 and 0727…

… high energy spectral slope of North and South aurorae in rev. 0726 best fitted by a $\Gamma \sim 0.2$ power law



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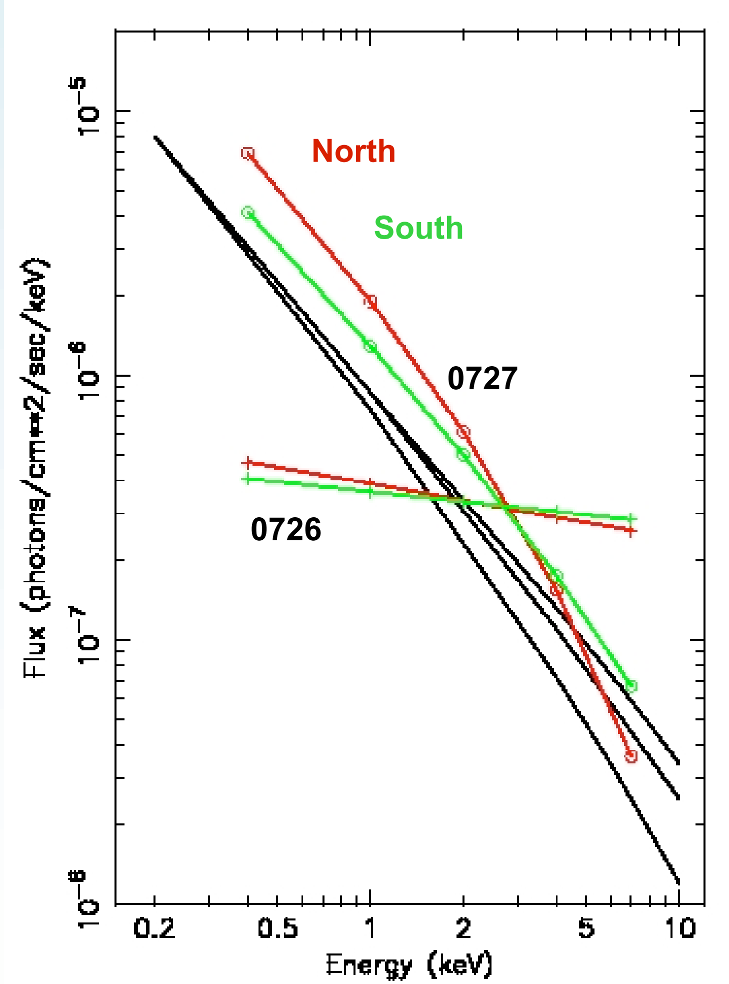
XMM-Newton – Nov. 2003: EPIC

Singhal et al. (1992) predicted the bremsstrahlung flux expected from precipitating electrons with characteristic energies of 10, 30 and 100 keV (black lines)

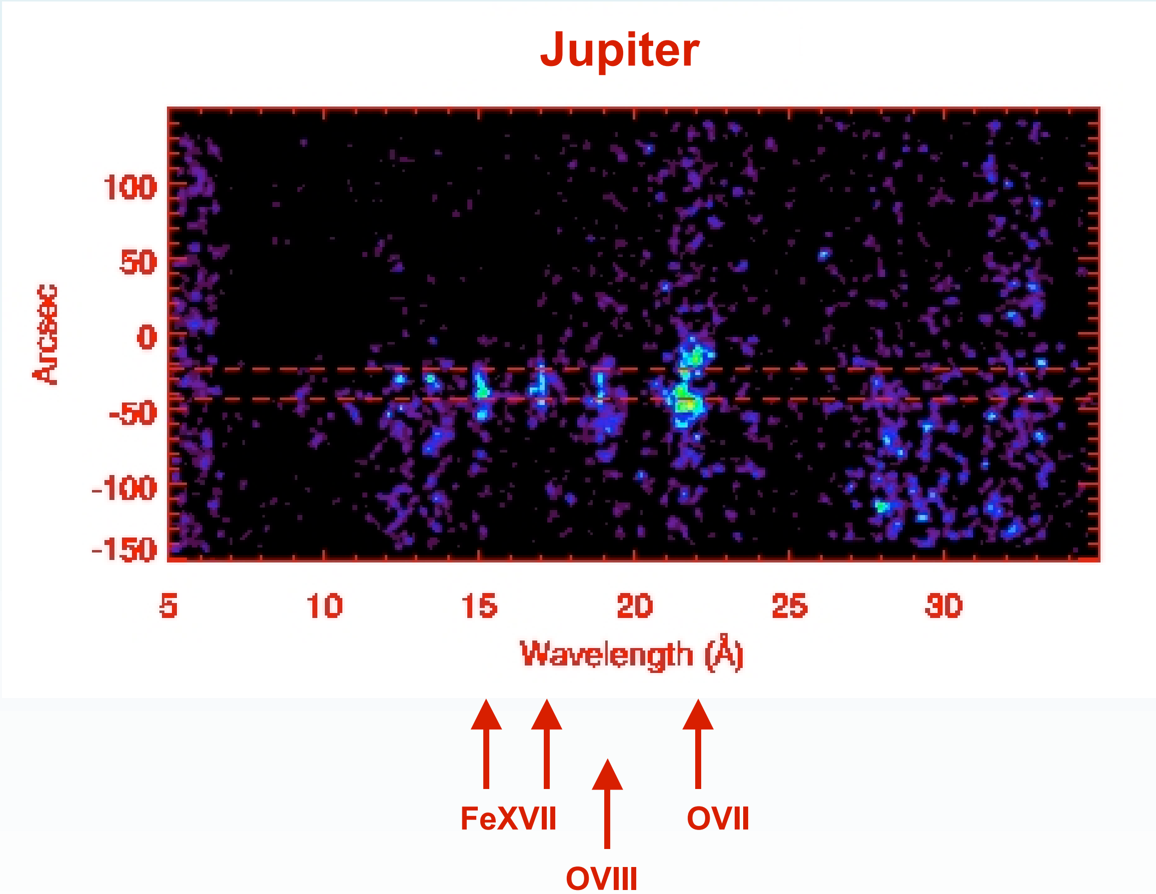


XMM-Newton reveals for the first time the predicted electron bremss. emission in Jupiter’s aurorae

and

establishes it is variable in flux and spectral shape

XMM-Newton – Nov. 2003: RGS



RGS clearly resolves the emission lines dominating in soft X-rays

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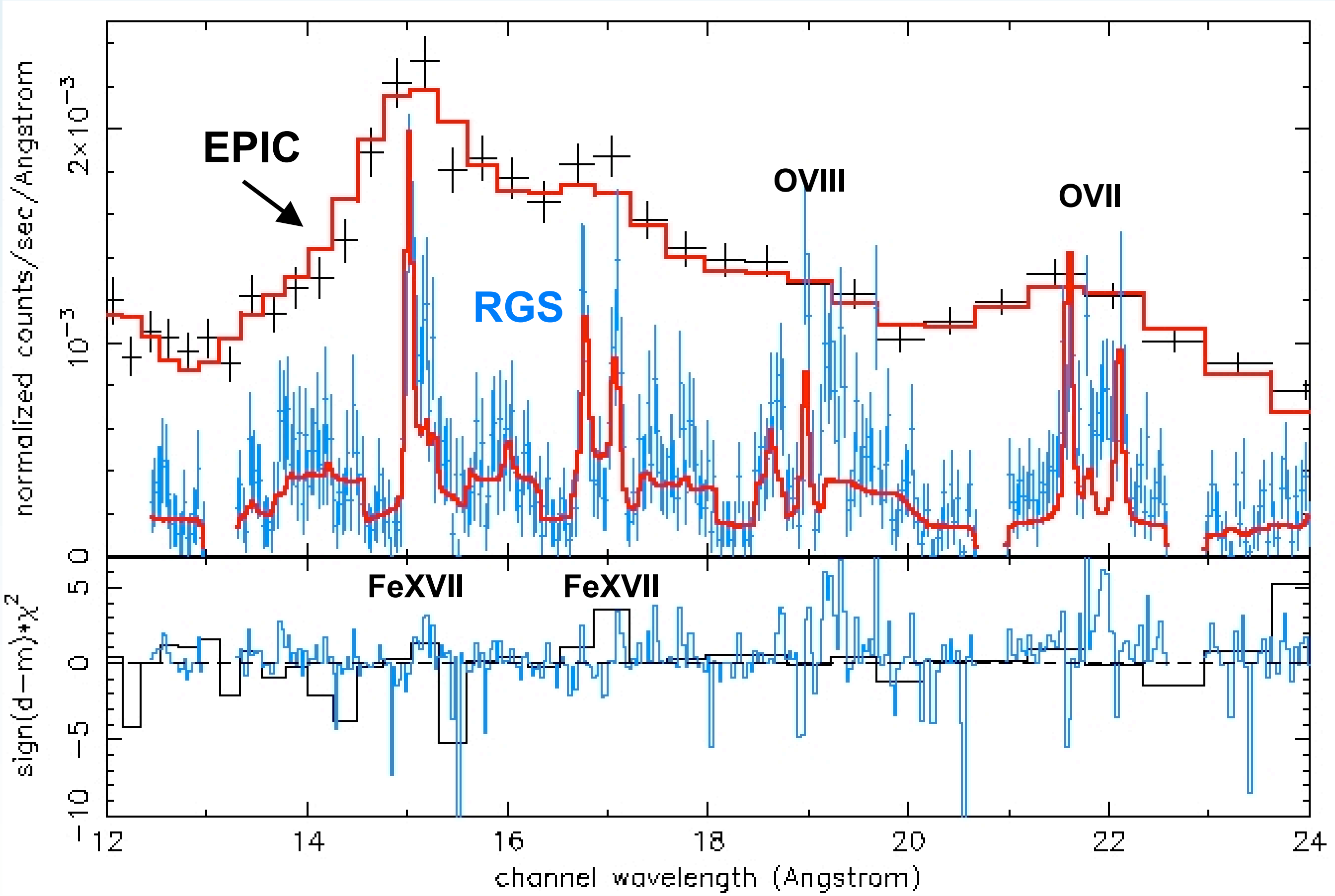
XMM-Newton – Nov. 2003: EPIC + RGS



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Conclusions

- N and S auroral X-ray spectra clearly different from disk
- Auroral soft X-rays most likely due to charge exchange by energetic ions from outer magnetosphere, or solar wind, or both
- Auroral hard X-rays **detected for the first time**, consistent with predicted electron bremsstrahlung
- Auroral hard X-rays found to be **variable** in flux and spectrum
➔ changes in the electron populations and in acceleration mechanism
- Low-latitude 'disk' X-rays most likely due to elastic scattering and carbon K-shell fluorescence of solar X-rays
- Solar control of Jupiter's disk emission