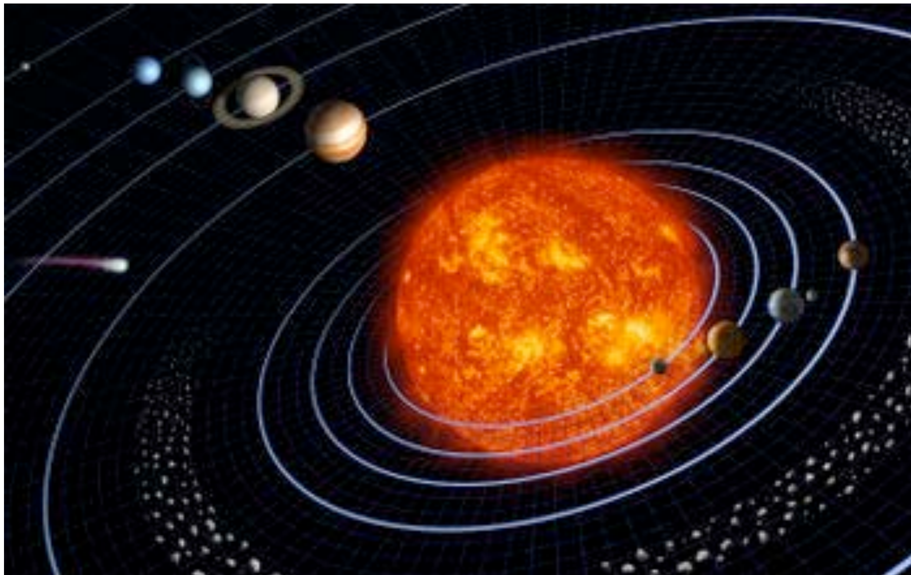
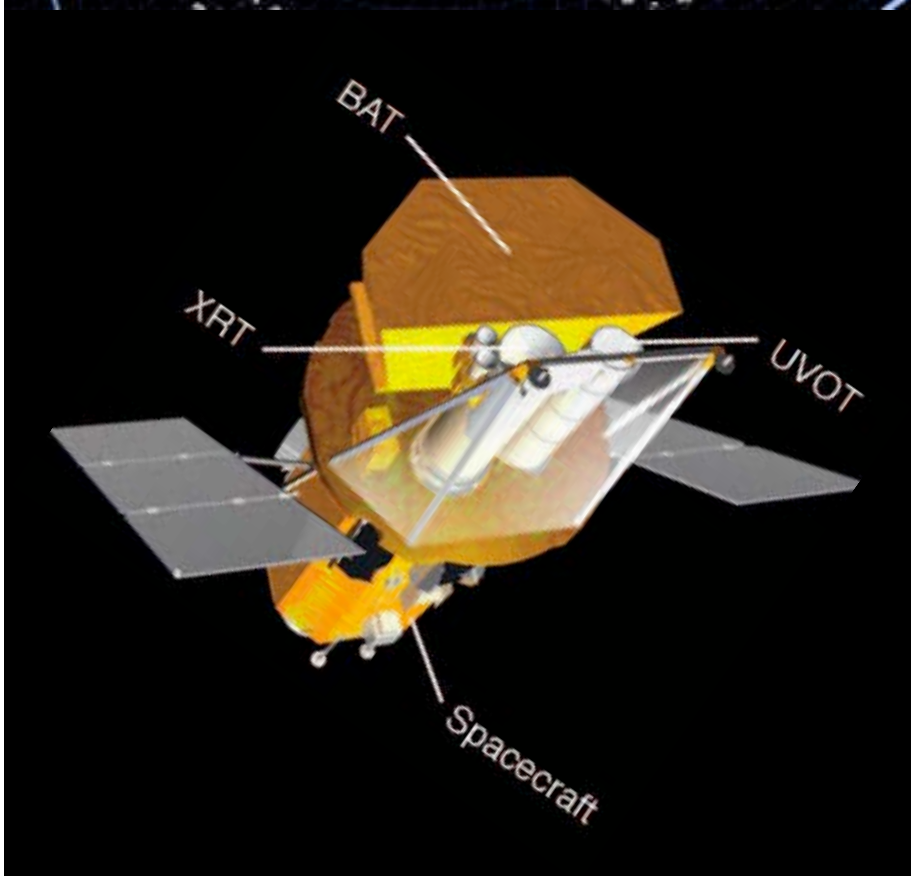
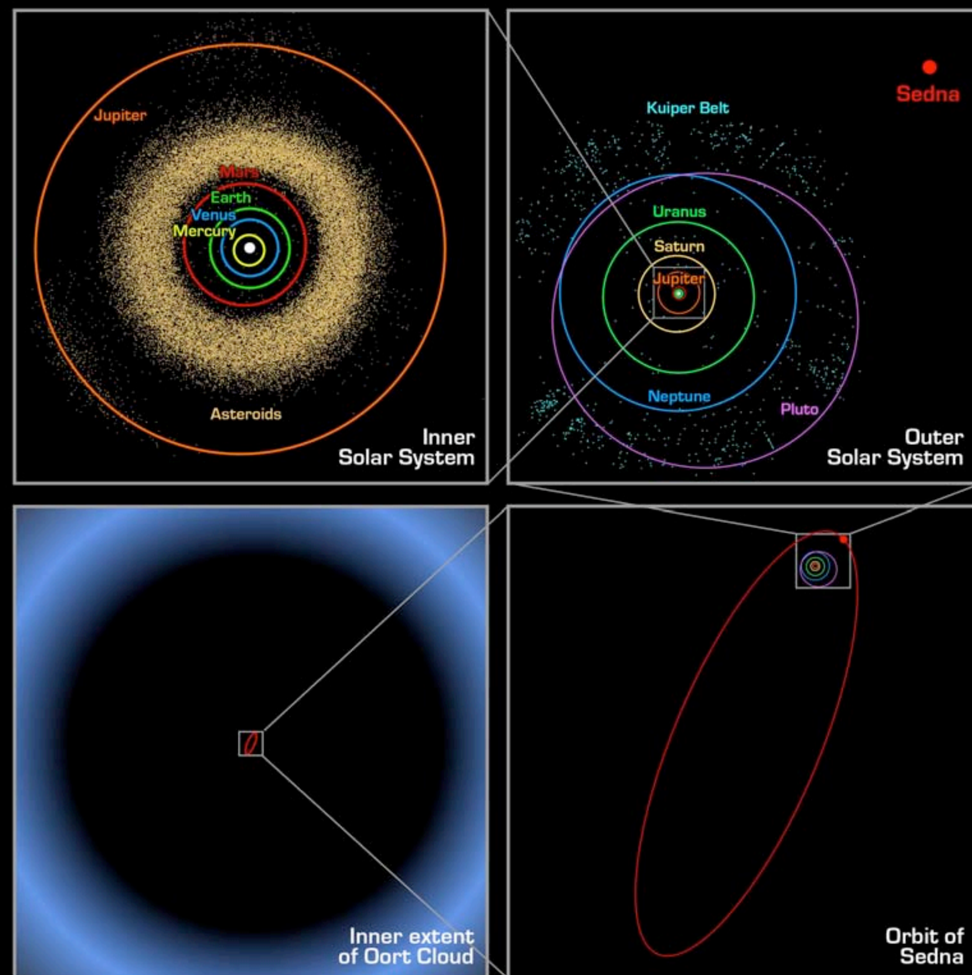
SWIFT Next : TBD Solar System Observations

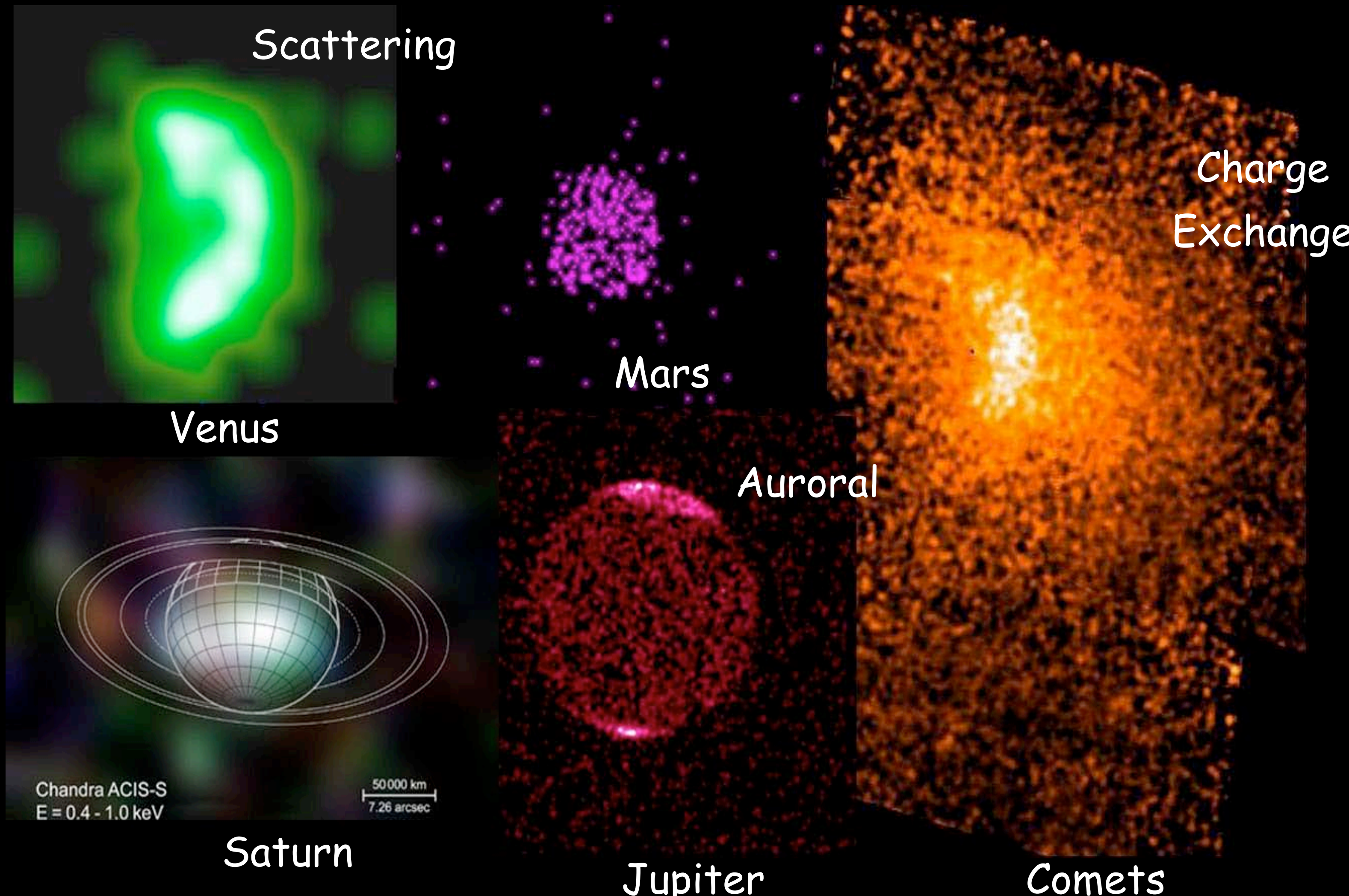
CM Lisse, JHU-APL







There Are Many Sources of X-rays in the Solar System (Planets, Moons, Io Flux Torus, Comets, Sun) => But the 0.3 - 1.5 keV Emission Mechanisms Are Still Uncertain



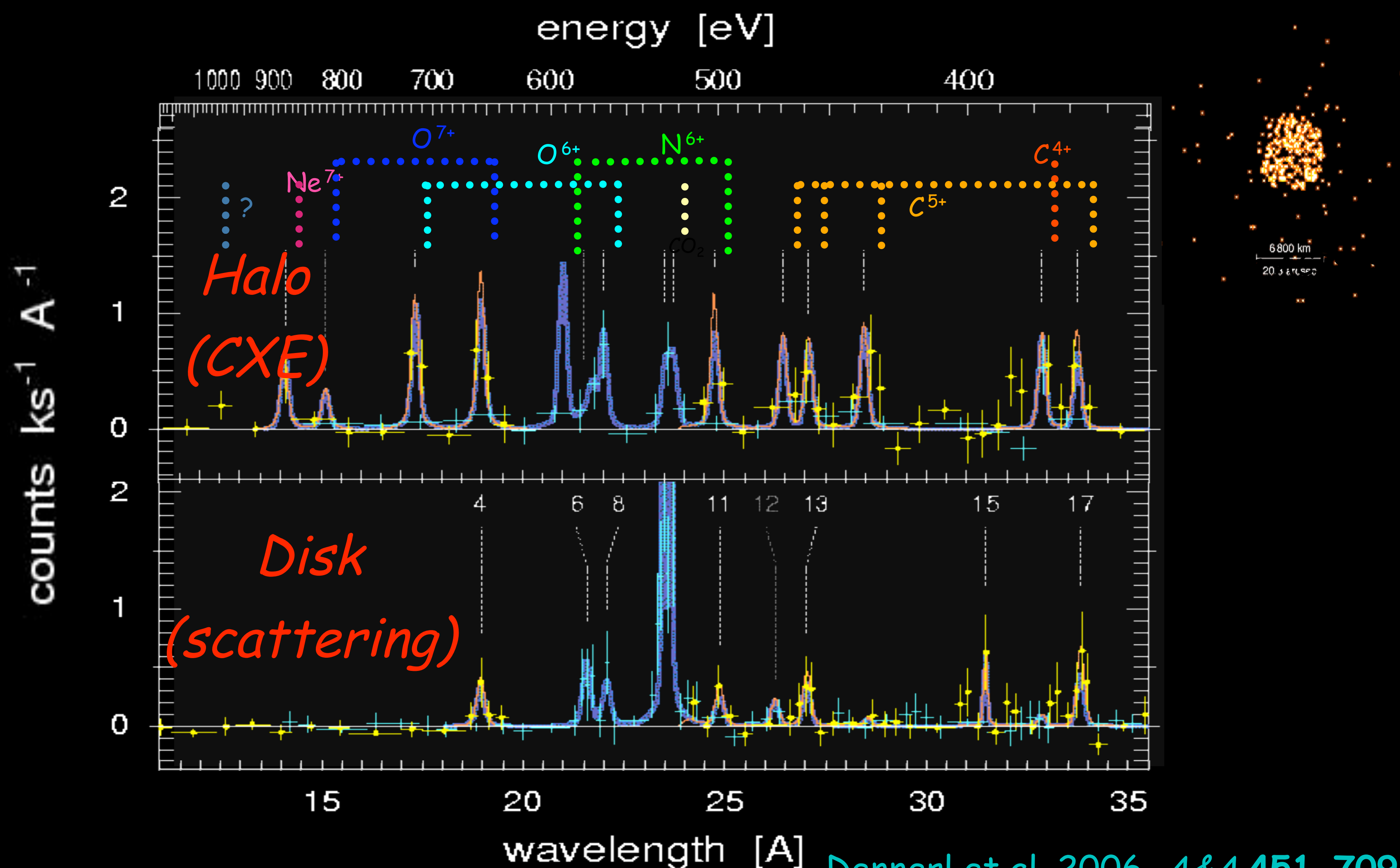
Bhradwaj et al., PSS, 2007

January 2001: first X-ray image of Venus (Chandra ACIS-I)

First X-ray observation of Venus during solar maximum: **Scattering of solar X-rays detected, but no conclusive evidence of charge exchange.** => To understand the charge exchange component, the solar wind flux and charge state will have to be very well known. The first two-spacecraft measure of the solar wind at another planet, by MESSENGER and Venus Express during the V2 flyby, will provide this data.

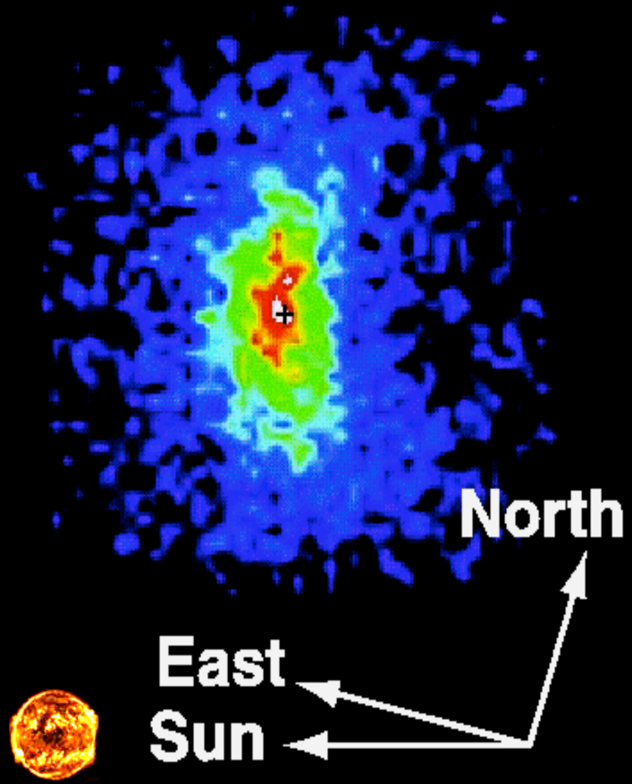
Dennerl et al. 2002, *A&A* **386**, 319

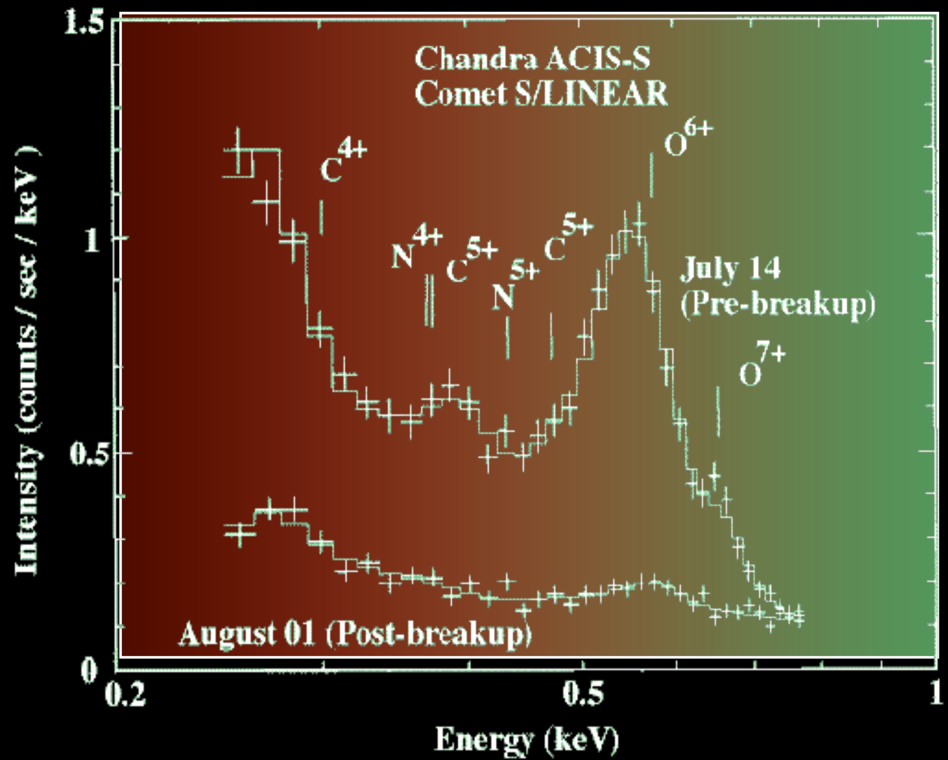
November 2003 : First high resolution spectrum of charge exchange induced X-ray emission from Mars, observed with XMM-Newton RGS.



Dennerl et al. 2006, *A&A* **451**, **709**

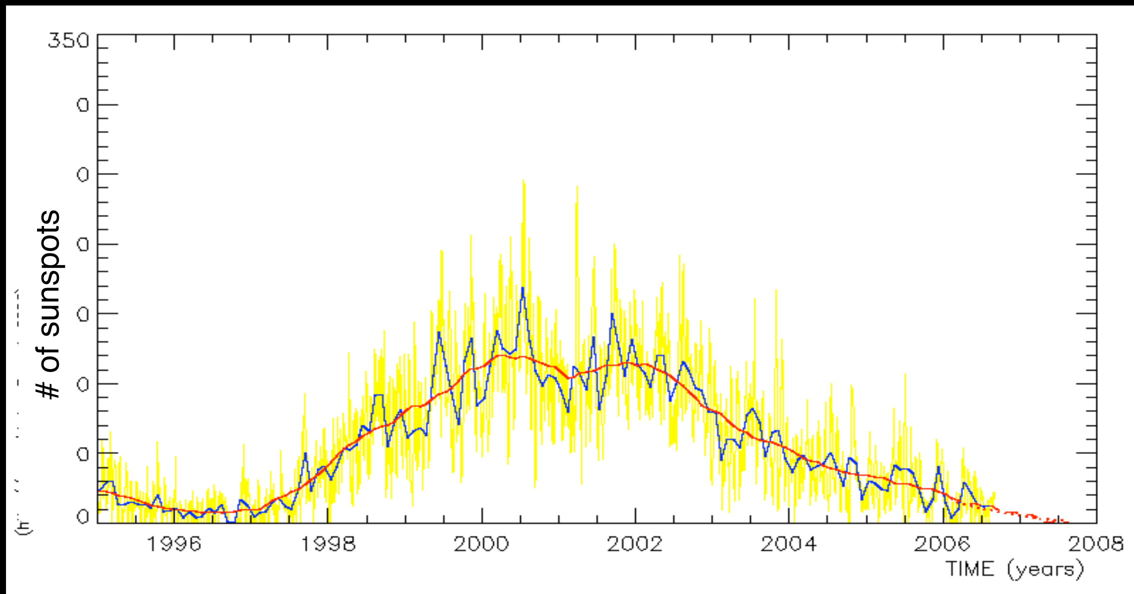
July 2000: First direct detection of charge exchange induced line emission from a solar system body: Comet C/1999 S4 (LINEAR) with Chandra ACIS-S

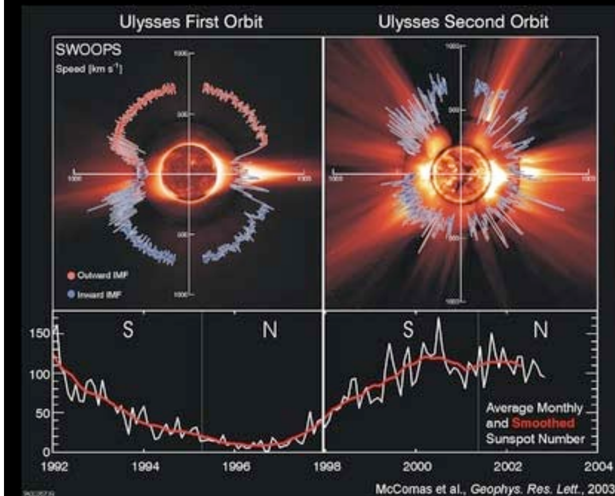




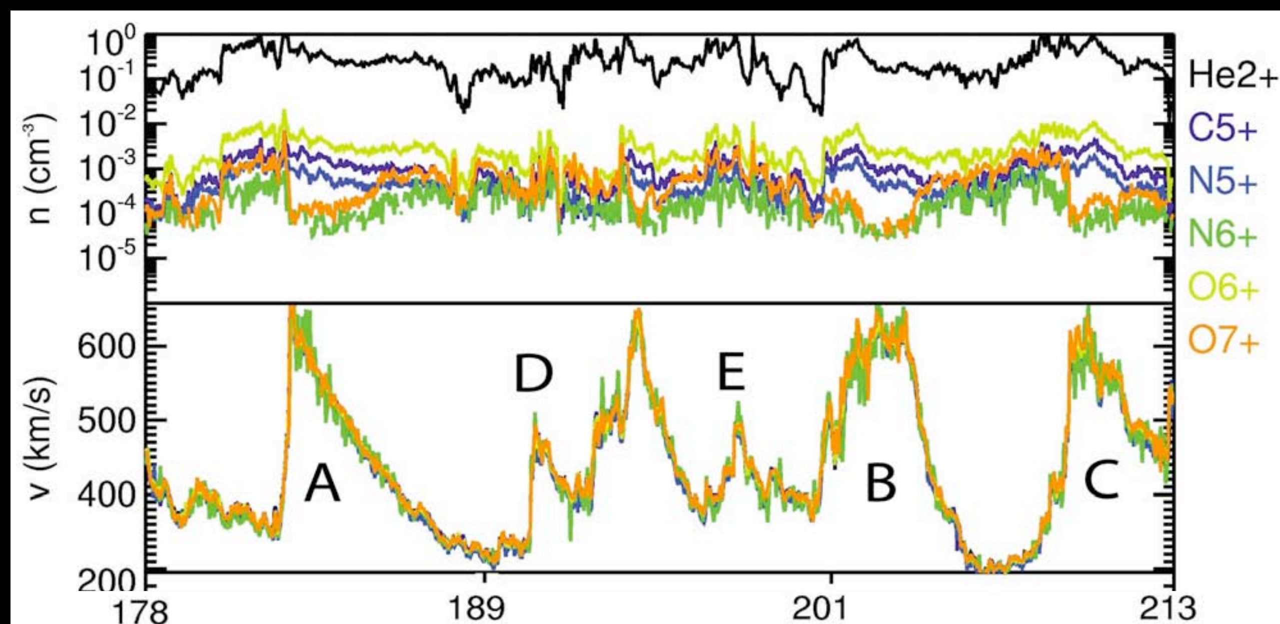
Lisse et al. 2001, *Science* **292**, 1343

Solar Variations





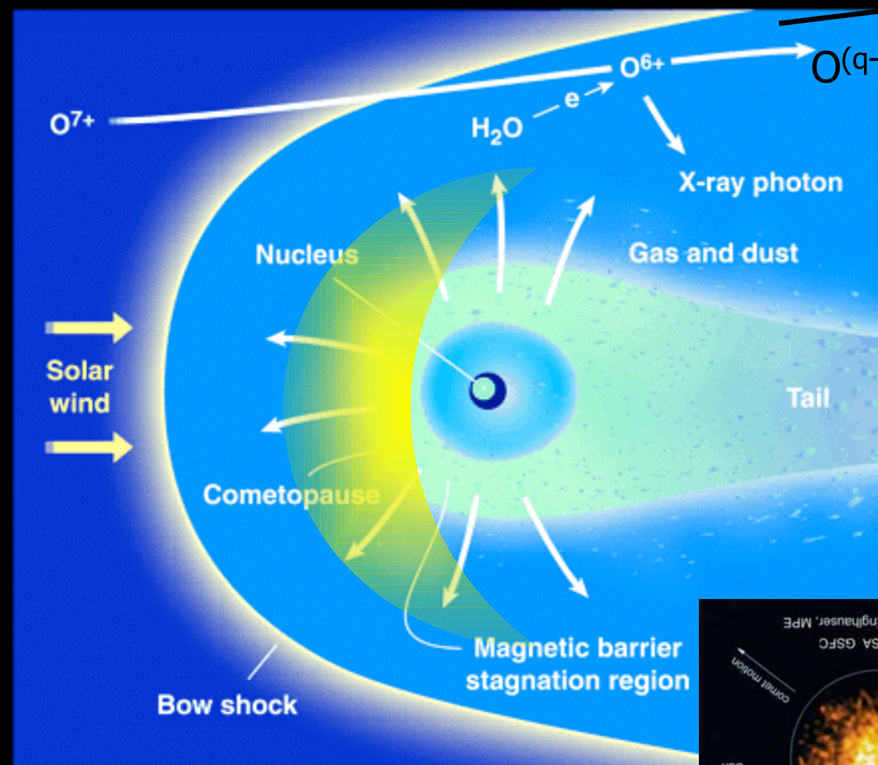
- •Elemental variations: factor ~2
- •Charge state: ~10
- • Temp source region



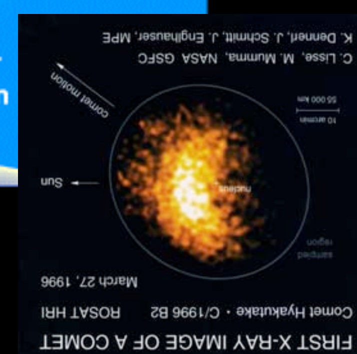
T. Zurbuchen - ACE/SWICS

Interaction between comet and the solar wind

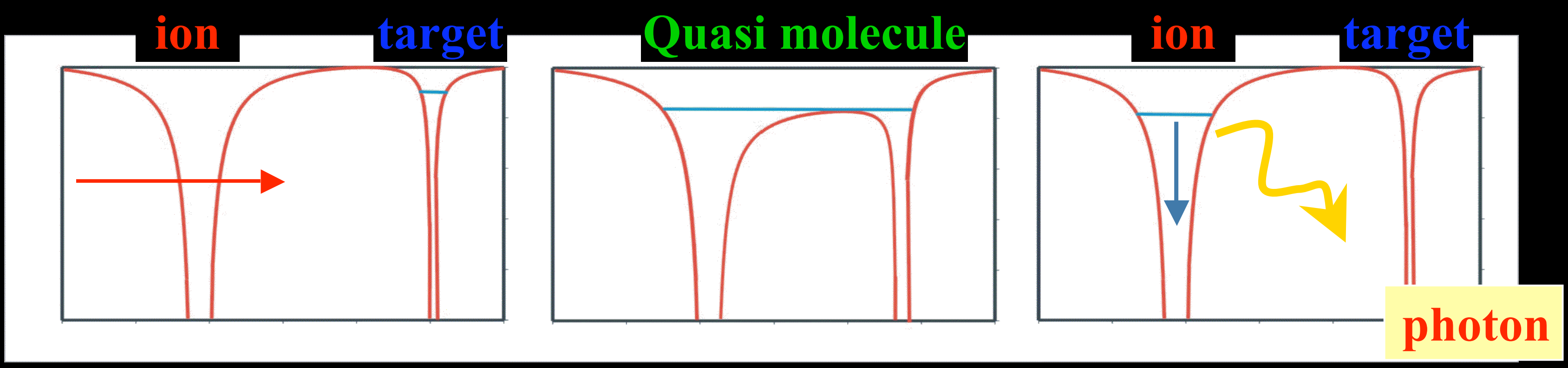
- 10 km Nucleus
- 10^3 km Contact surface
- 10^6 km Bowshock
- 10^8 km Tails



(adapted from Cravens '00)



Charge Exchange

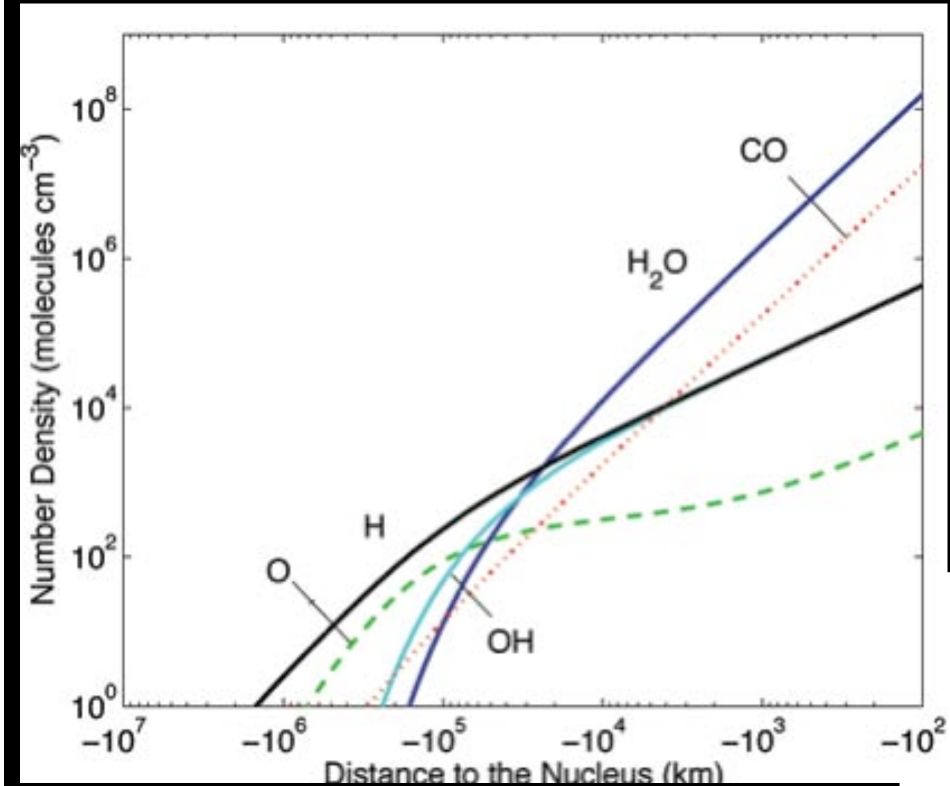


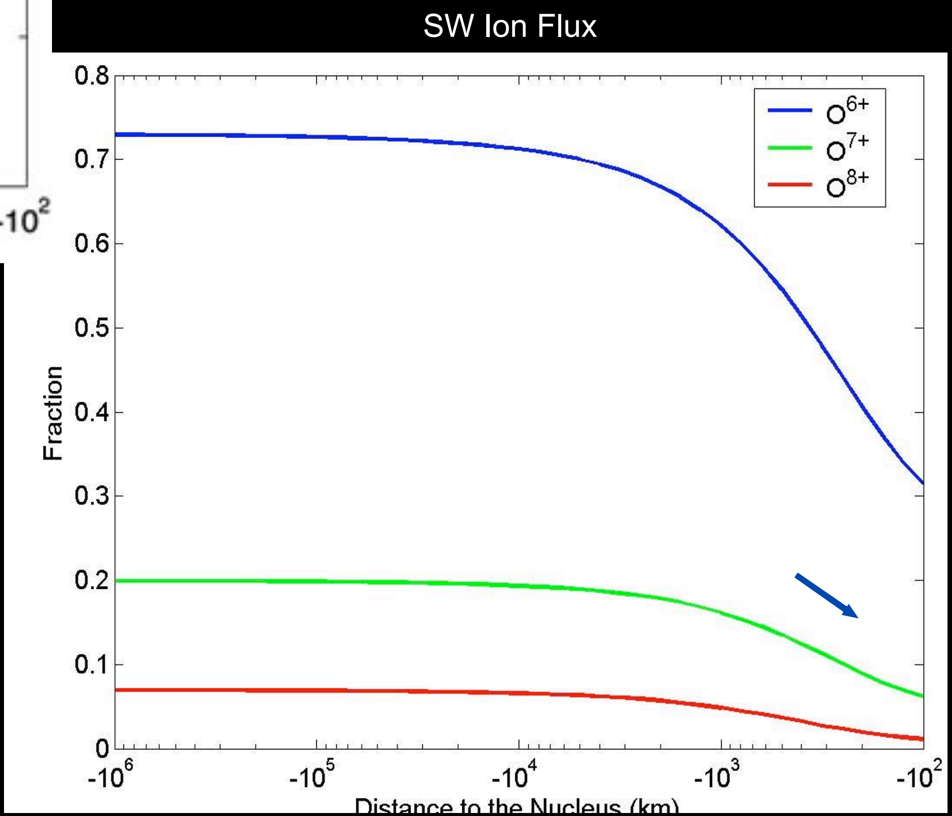
$$A^{q+} + B \longrightarrow \boxed{A^{(q-1)+}(nl)} + B^{+}$$

Photon(s)

- Quasi resonant reaction
- Electron captured into high excited state *(nl)*
- Depends on I_b, q and v

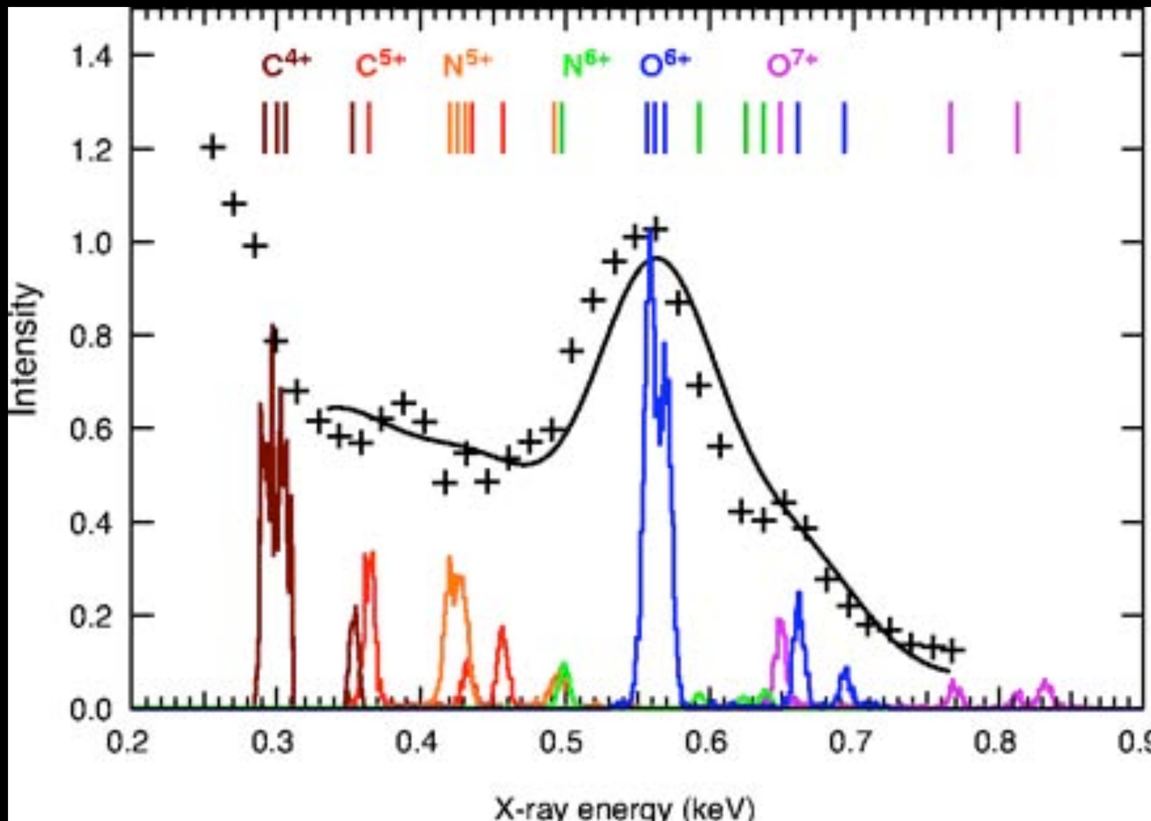
CX is an important source of coma chemistry





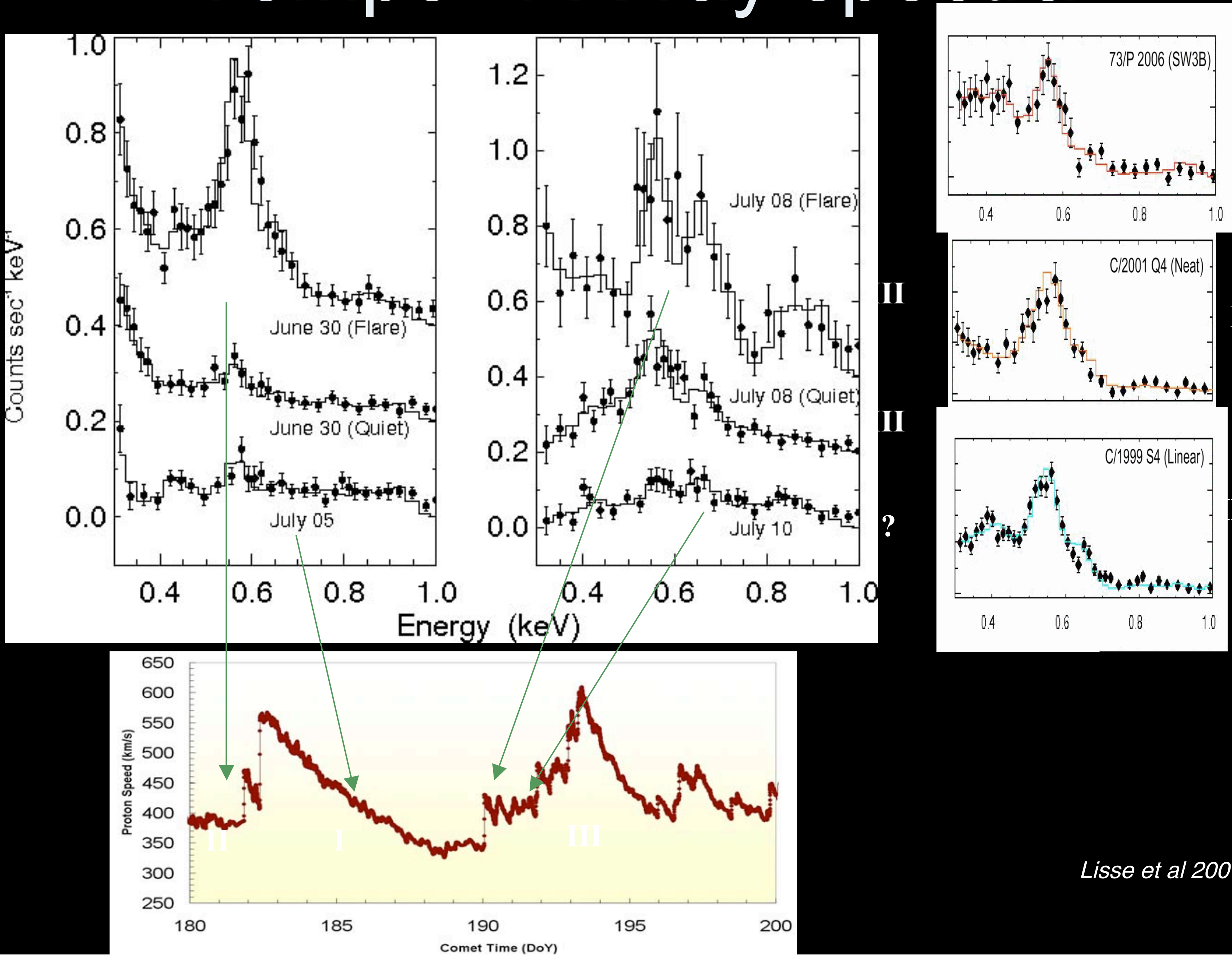
X-ray Spectra

Lisse et al '01, Beiersdorfer et al. '03



•Fits with 6 -10 -… 'free' lines
•Simplified (nl) distributions
•No velocity dependence CX
→ Analyze spectra based on atomic physics input

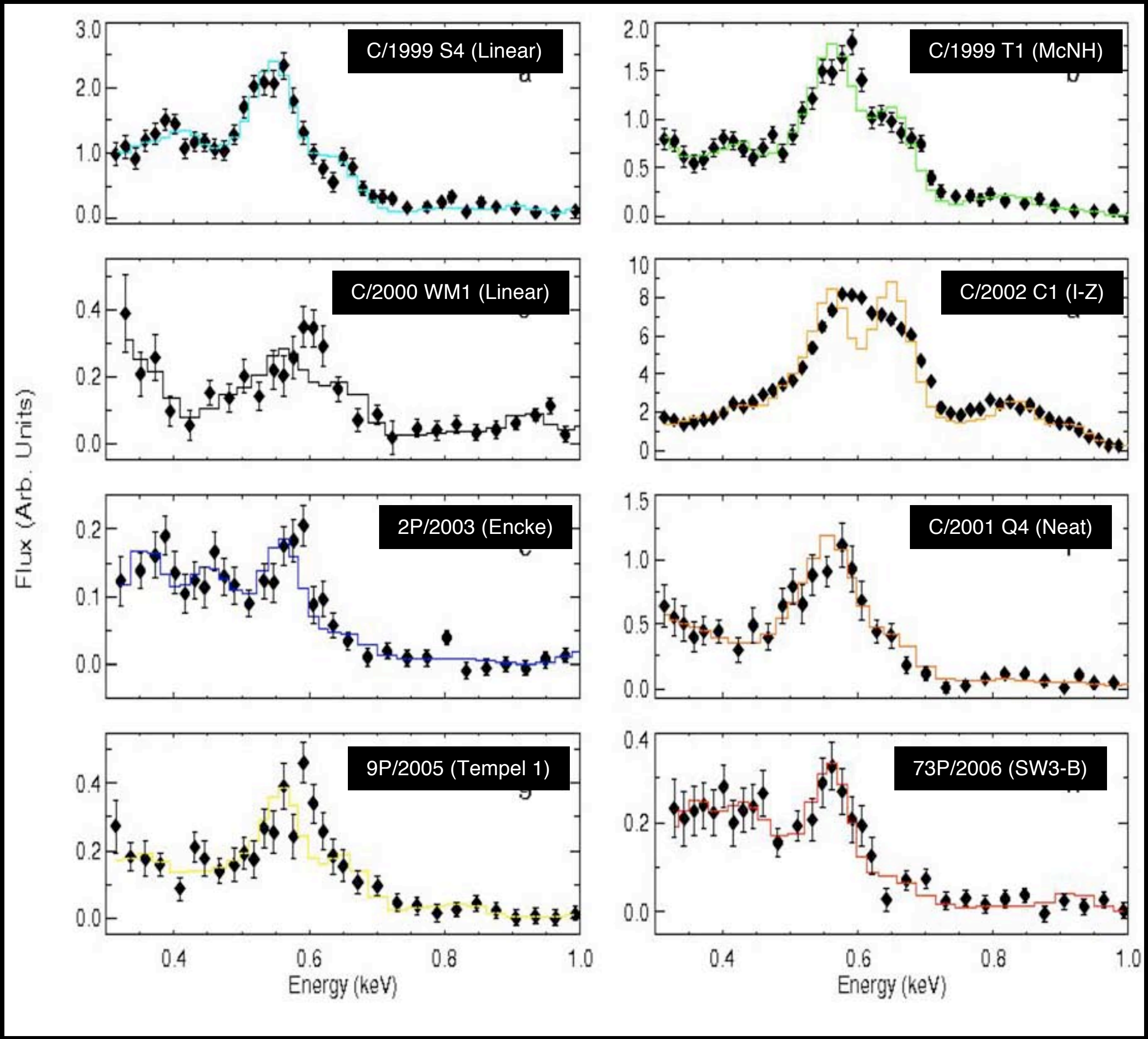
Tempel 1 X-ray spectra



Lisse et al 2007

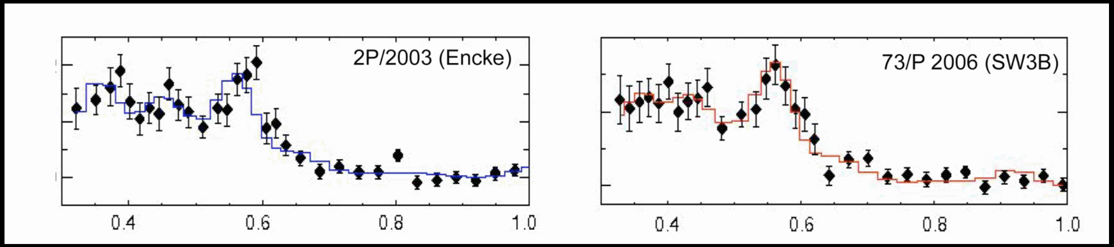
Chandra spectral survey

- Chandra ACIS S3
- 8 comets
- 2000 - 2006
- Q = $9*10^{27} – 2*10^{29}$/s
- D = 0.1 – 1.4 AU
- R_h = 0.8 – 1.5 AU
- |Lat| = 0 – 34 deg
- Phase = 41 – 103 deg
- Fit based on E_{line} , composition free

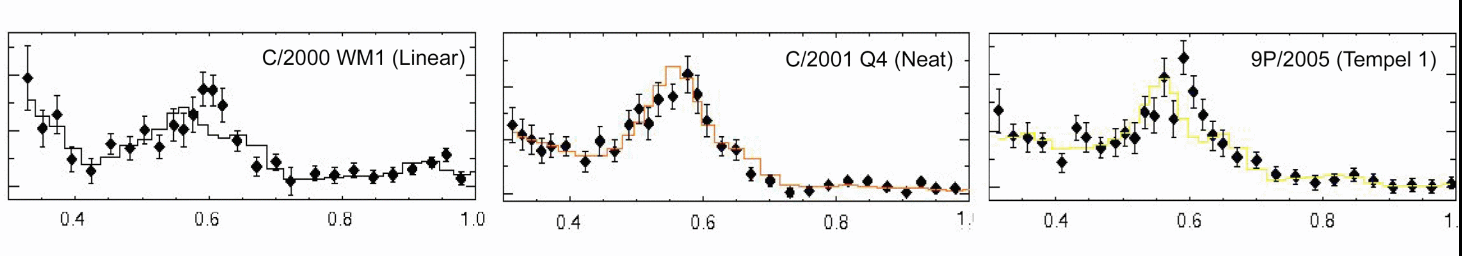


Comet X-ray Spectral Classification

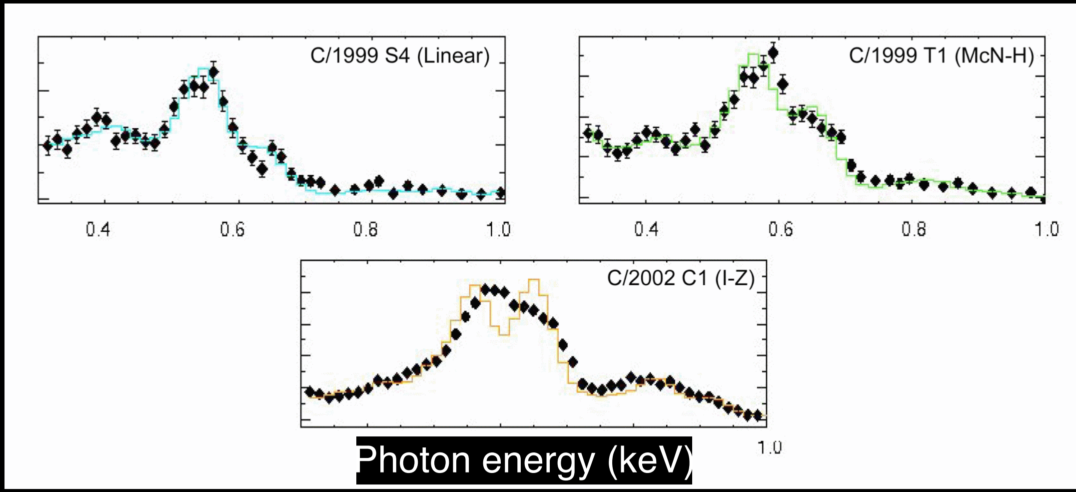
I. Fast, cold wind



II. Slow, hot wind

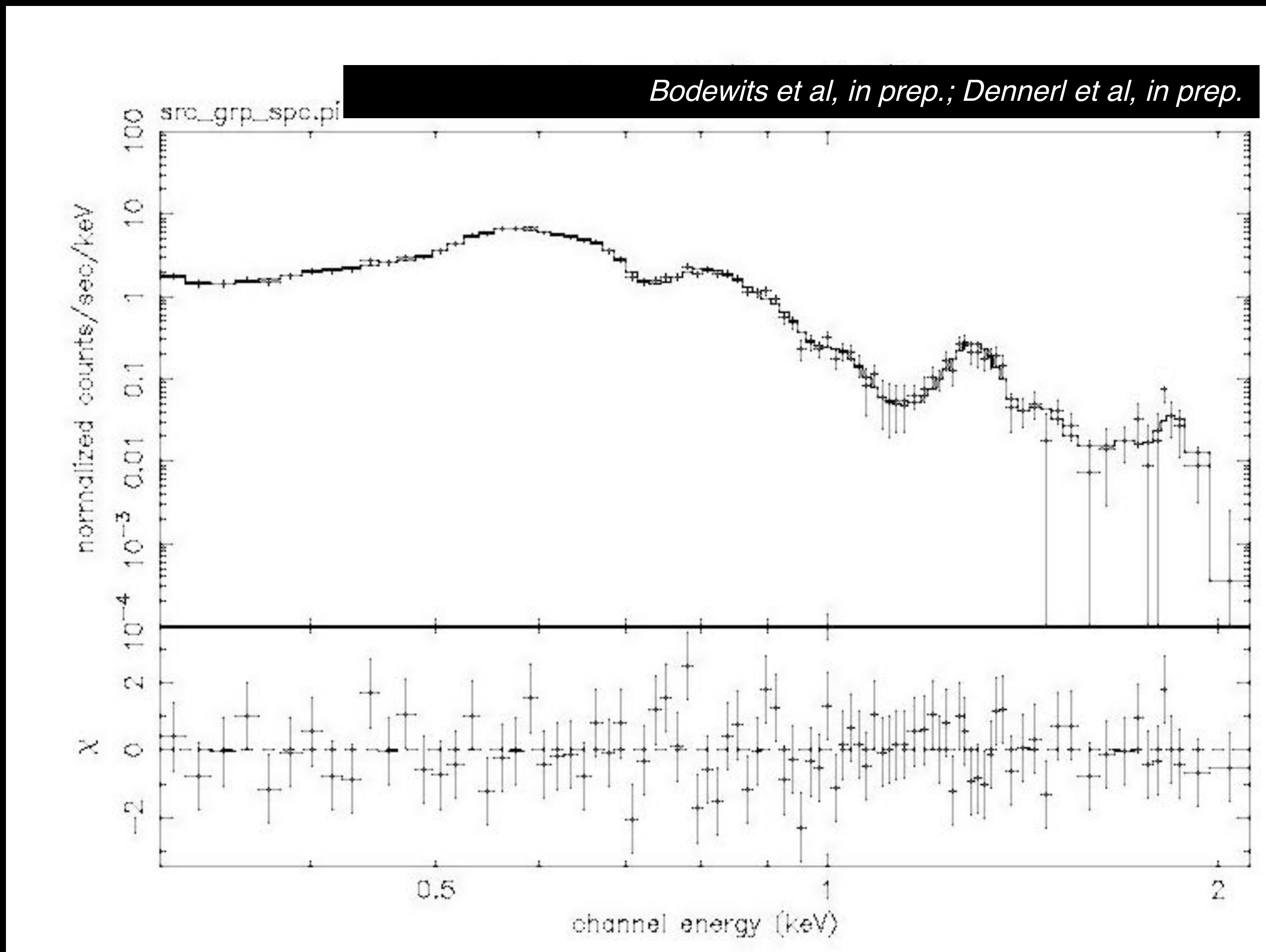


III. ICMEs



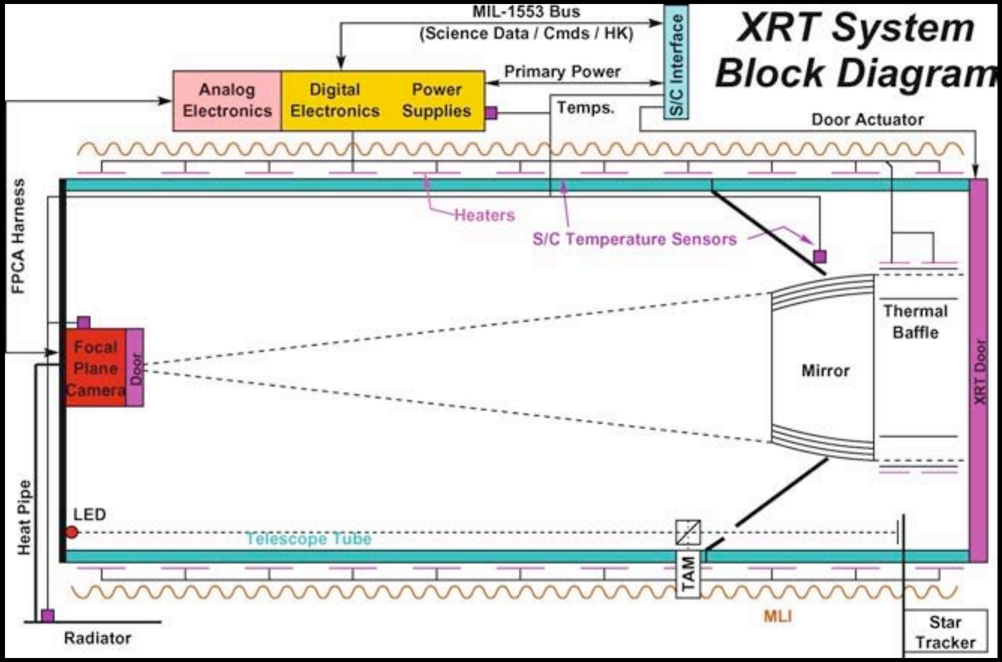
Bodewits et al, 2007

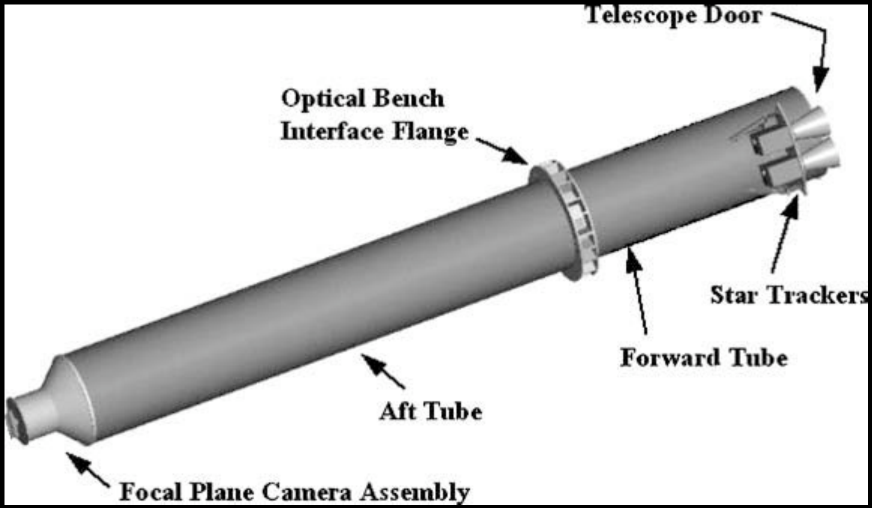
First detection of Mg XI-XII and Si



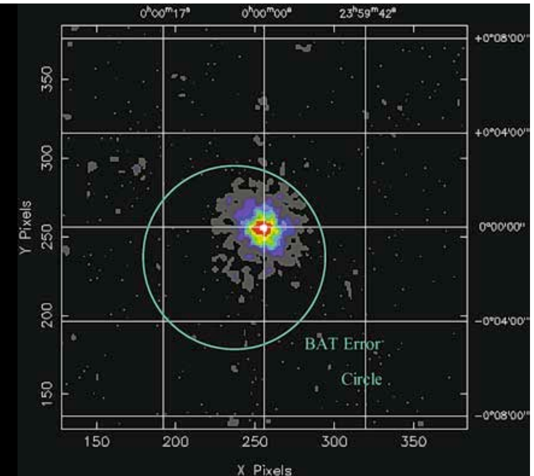
[redacted]

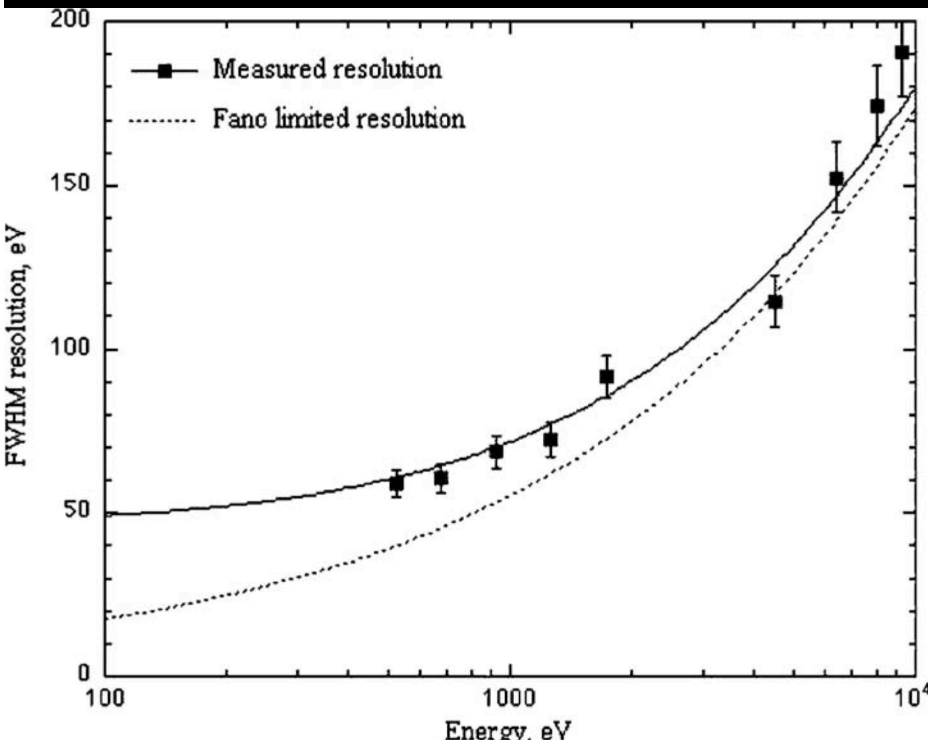
XRT

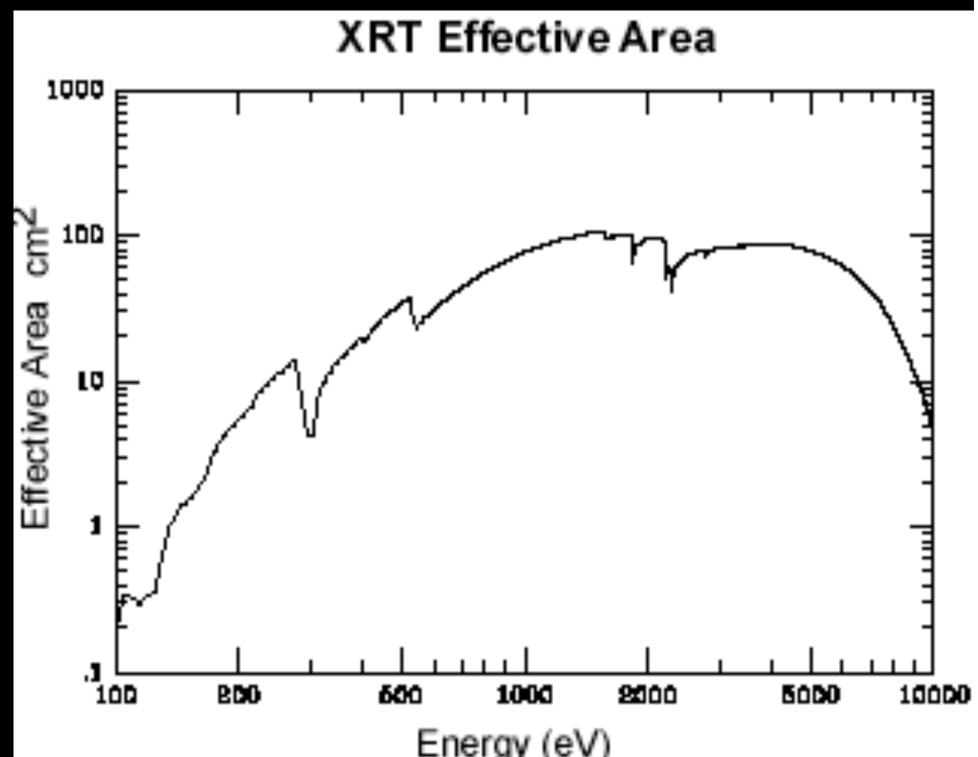

XRT System Block Diagram
MIL-1553 Bus
(Science Data / Cmds / HK)
S/C Interface
Primary Power
Analog Electronics
Digital Electronics
Power Supplies
Temps.
Door Actuator
FPCA Harness
Heaters
S/C Temperature Sensors
Thermal Baffle
Focal Plane Camera
Door
Mirror
XRT Door
Heat Pipe
LED
Telescope Tube
TAM
MLI
Radiator
Star Tracker


Telescope Door
Optical Bench Interface Flange
Star Trackers
Forward Tube
Aft Tube
Focal Plane Camera Assembly

XRT Capabilities







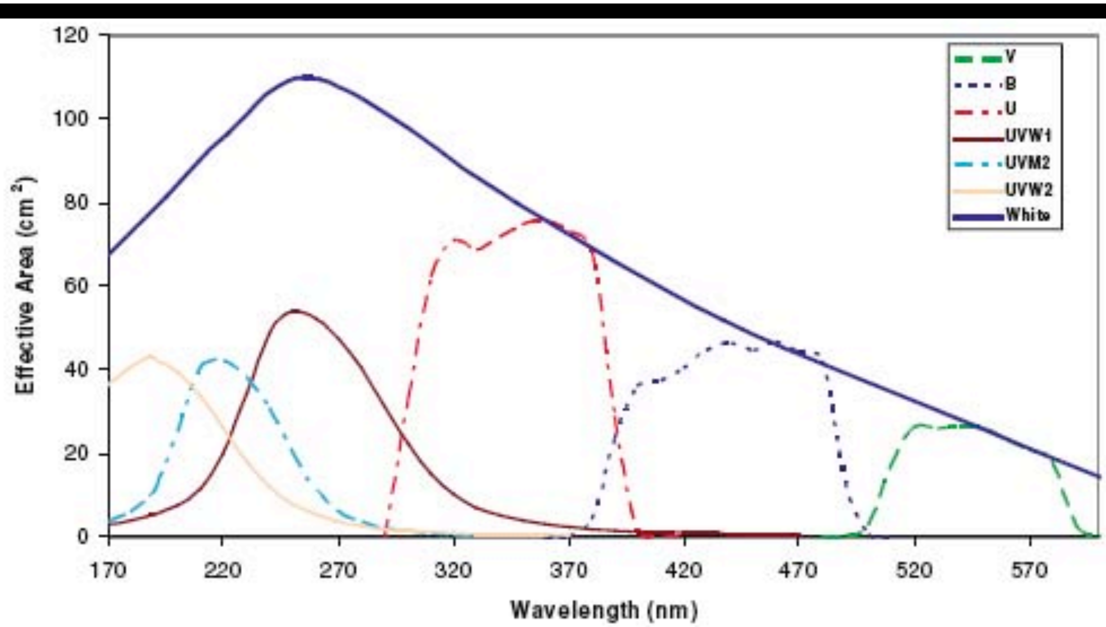


Figure 4. UVOT Lenticular color and white-light filter response.

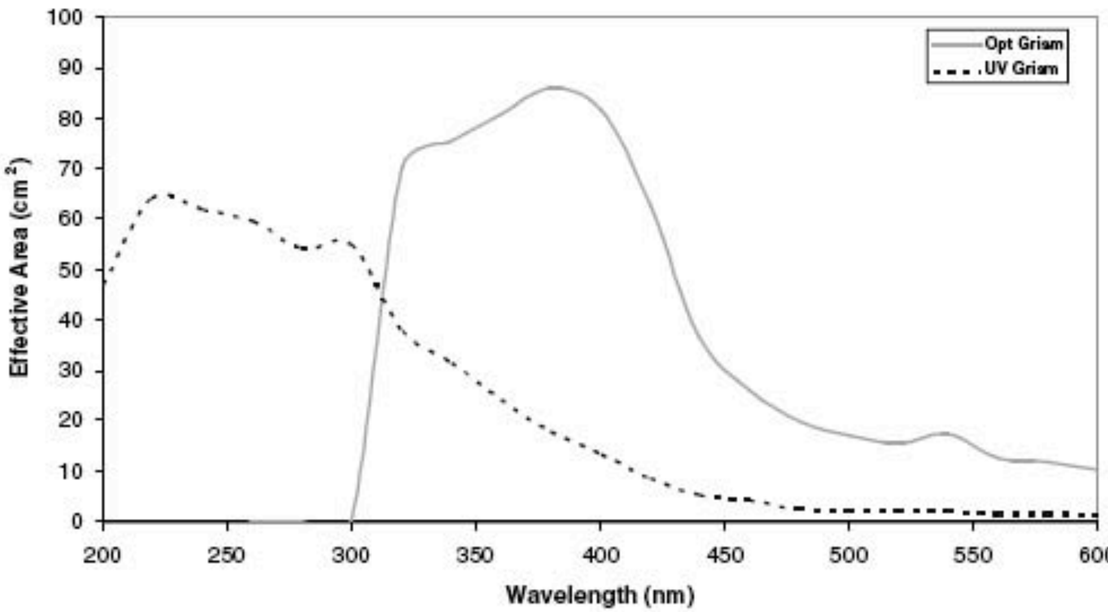


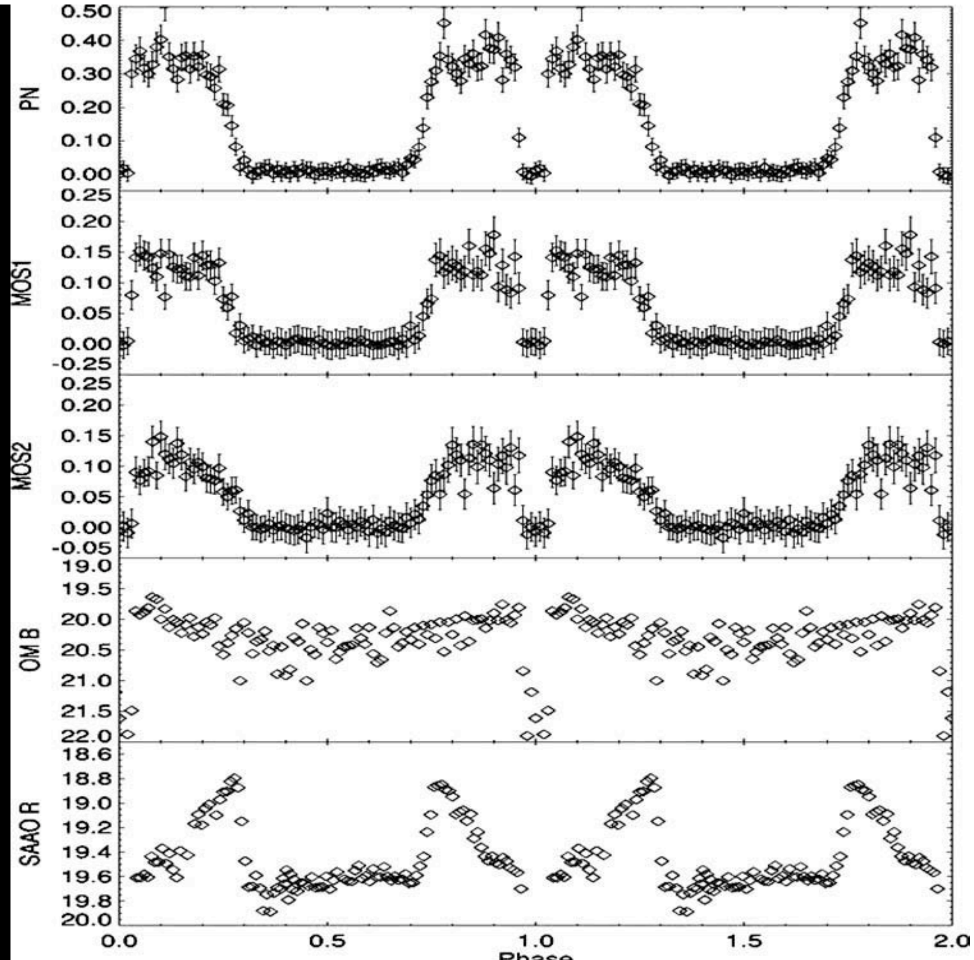
Figure 5. UVOT Anticipated Grism Response. Insufficient quality data was obtained during ground calibration to characterize the grism response pre-launch.

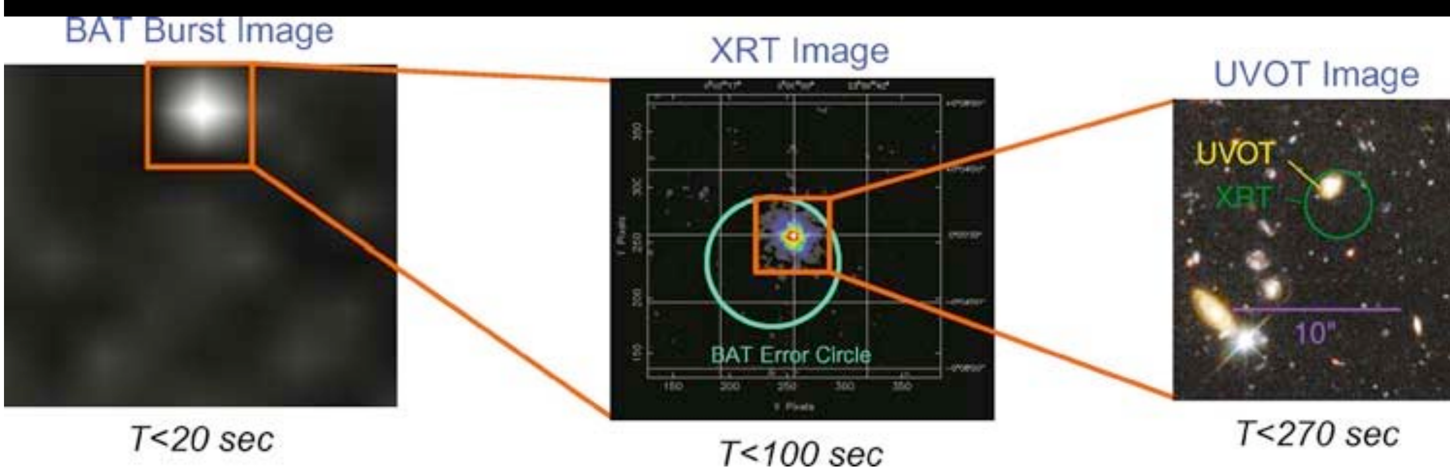
UVOT:
Important Comet Gas Emission Lines

- OH - 309 nm
- CN - 387 nm
- C2 - 514 nm

- B= 24 in 1000s

Simultaneous
SWIFT
X-ray/UV/Optical
Observations Very
Promising for Solar
System Studies





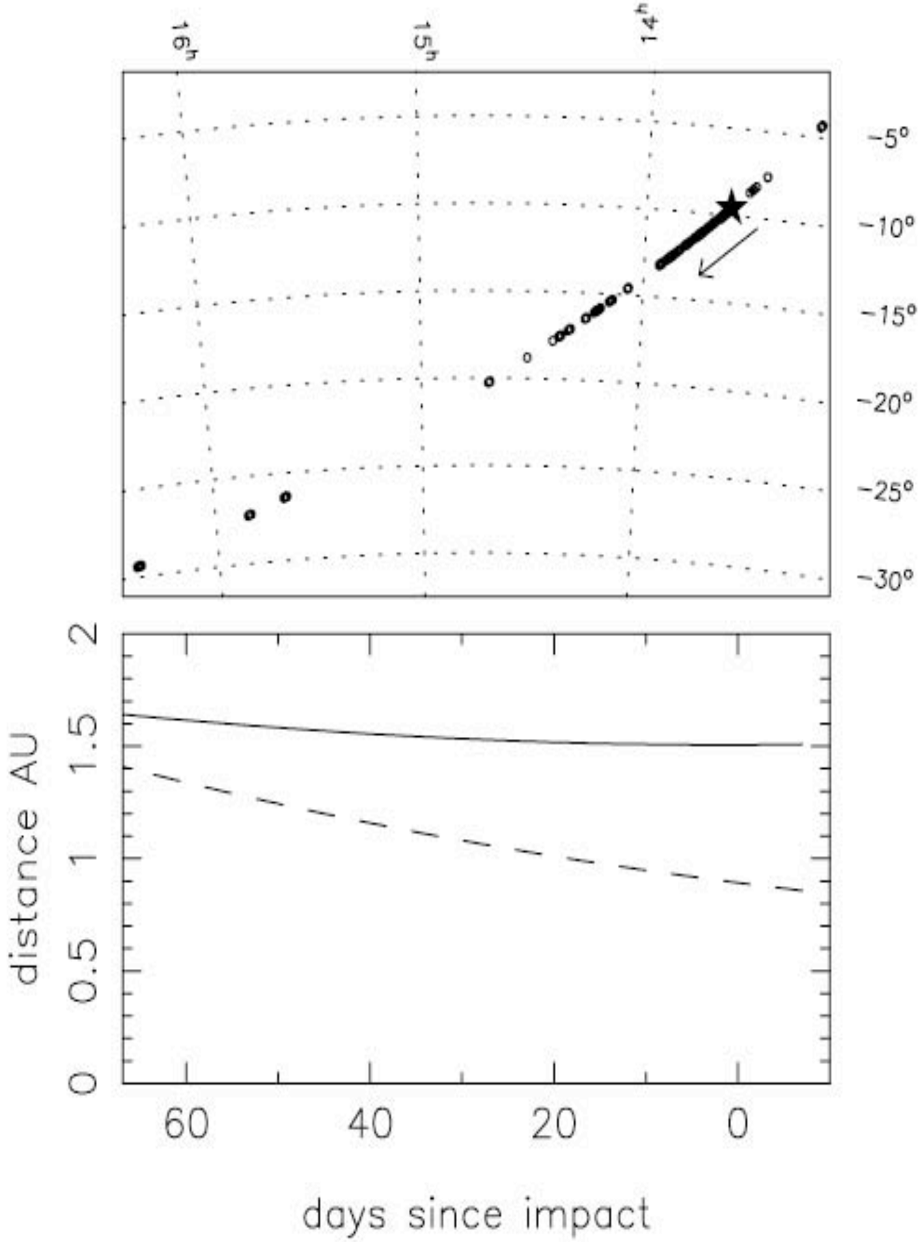
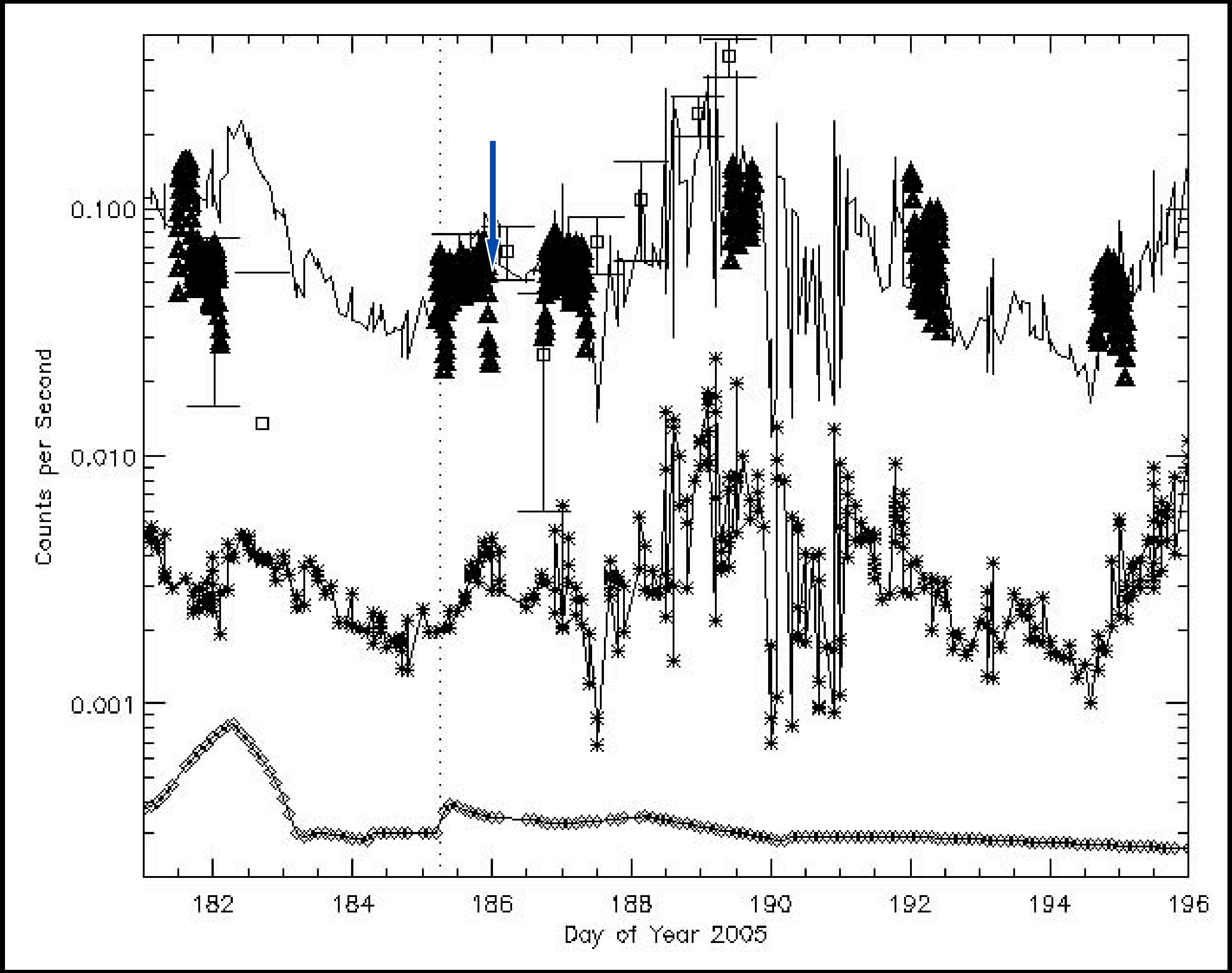


FIG. 1.—Ephemeris of 9P/Tempel 1. *Top: Swift* observations of 9P/Tempel 1 plotted in right ascension and declination. The circles represent the size of the field of view of the XRT. The black star indicates the position of impact, and the arrow shows the direction of travel across the sky. *Bottom:* Distance of the comet from the

SWIFT Monitoring of Comet 9P/Tempel 1 During the Deep Impact Experiment June-July 2005 : I-13 to I+65 Days

Observed CXO/SWIFT Photometry Consistent With Q_{gas} * N_{sw}*V_{sw}



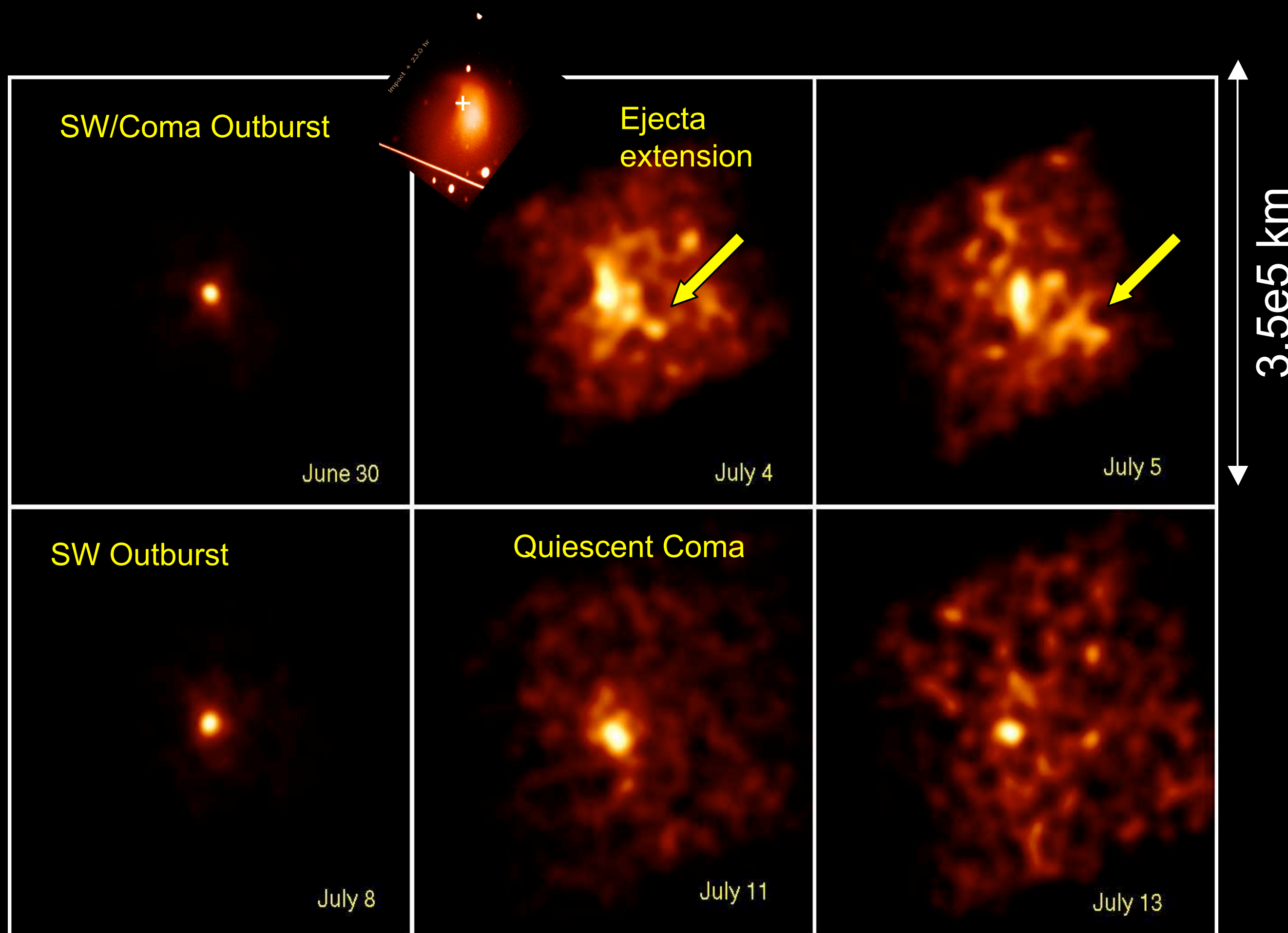
Chandra (triangles)

SWIFT (squares)

N_{sw}*V_{sw}

Q_{gas}

T1 Chandra ACIS-S3 images in 0.3-1.0 keV band



- **More than 300ksec (>83h) of observating time on Chandra**
- **Simultaneous observations with SWIFT (*Willingale et al*)**

XRT Tempel 1 Imaging Over 200 ksec, 0.3 - 1.2 keV 18” FWHM

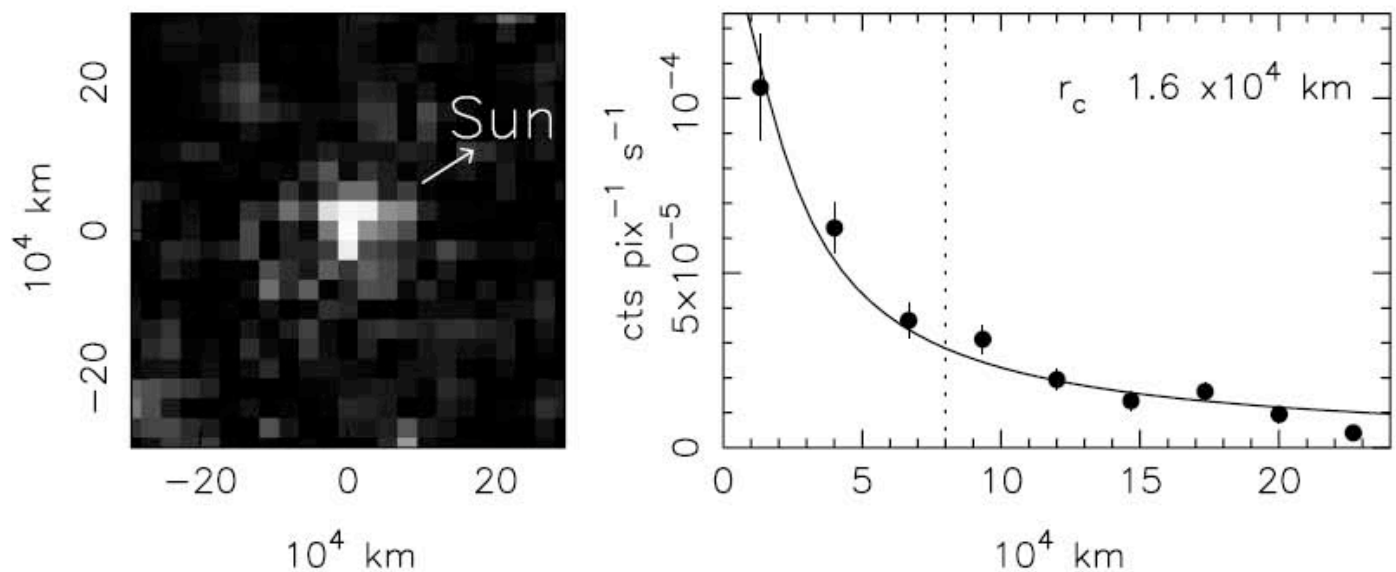
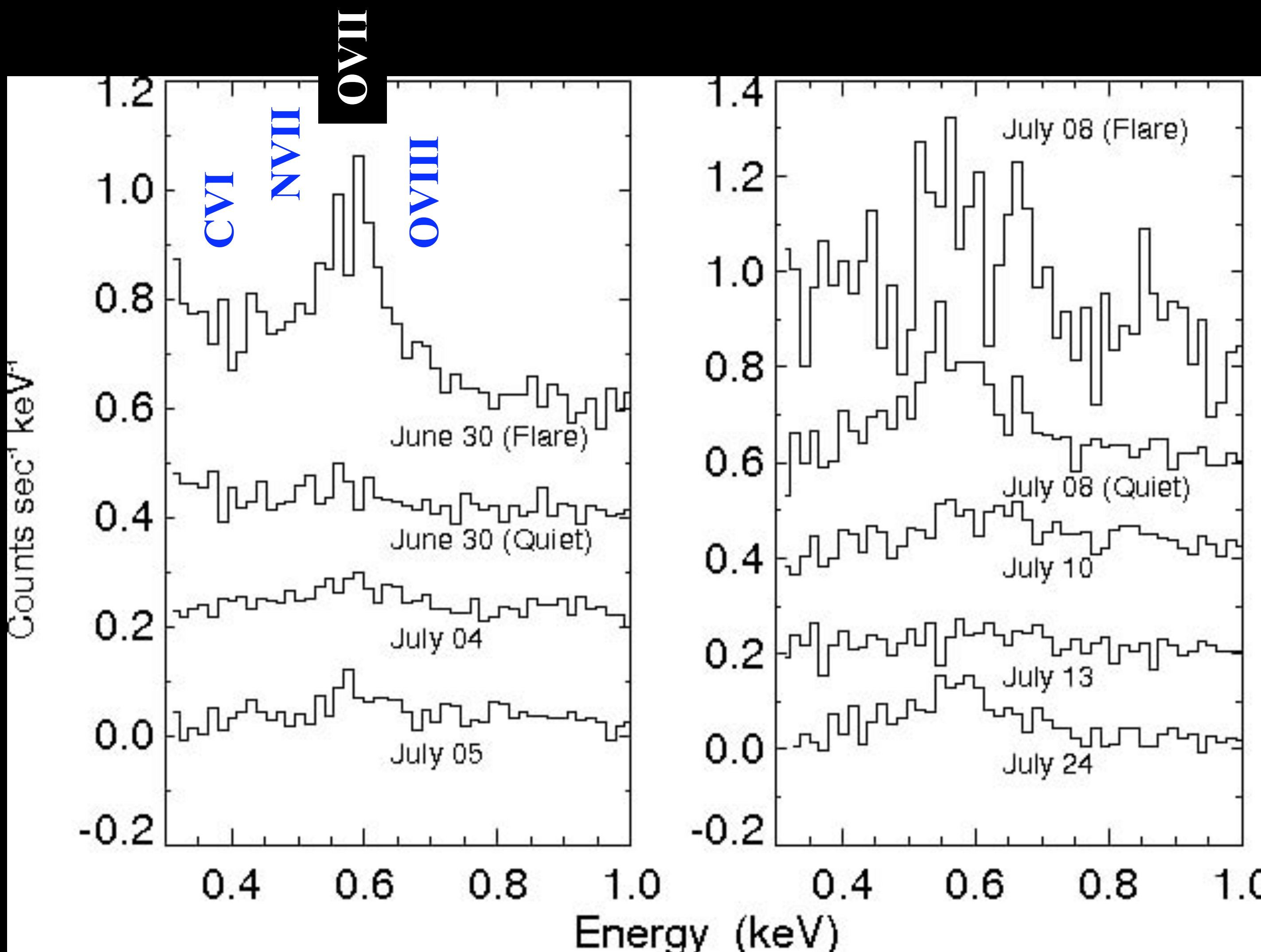


FIG. 3.—*Left:* X-ray image of the comet for 0–20 days since impact. The pixel size is 40″, equivalent to $\approx 2.7 \times 10^4$ km at the comet. *Right:* X-ray surface brightness of the comet. The vertical dotted line indicates the radius of the beam used to produce the X-ray light curve. [*See the electronic edition of the Journal for a color version of this figure*.]

ACIS X-ray R = 6 to 20 Photon Counting PHA Spectra



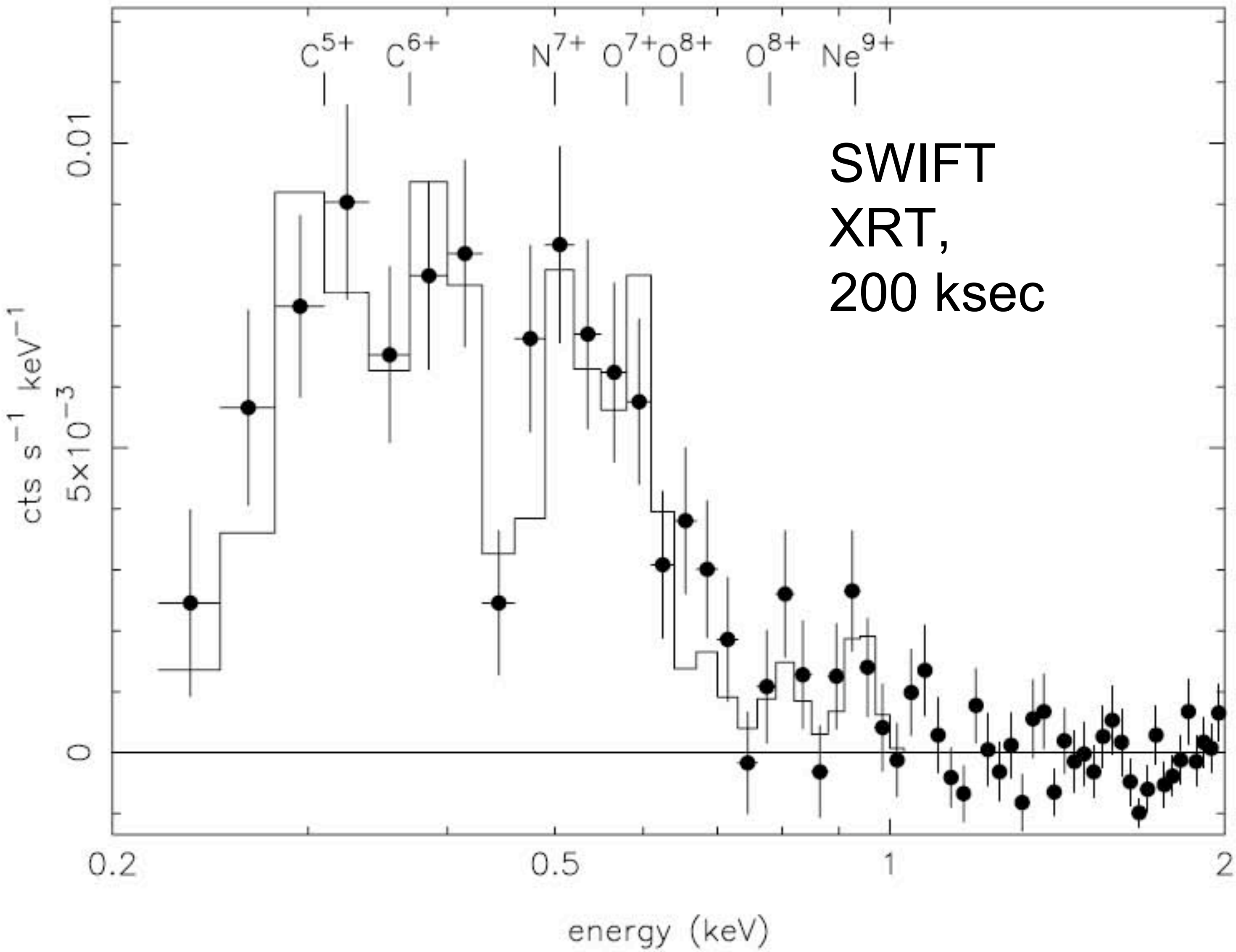


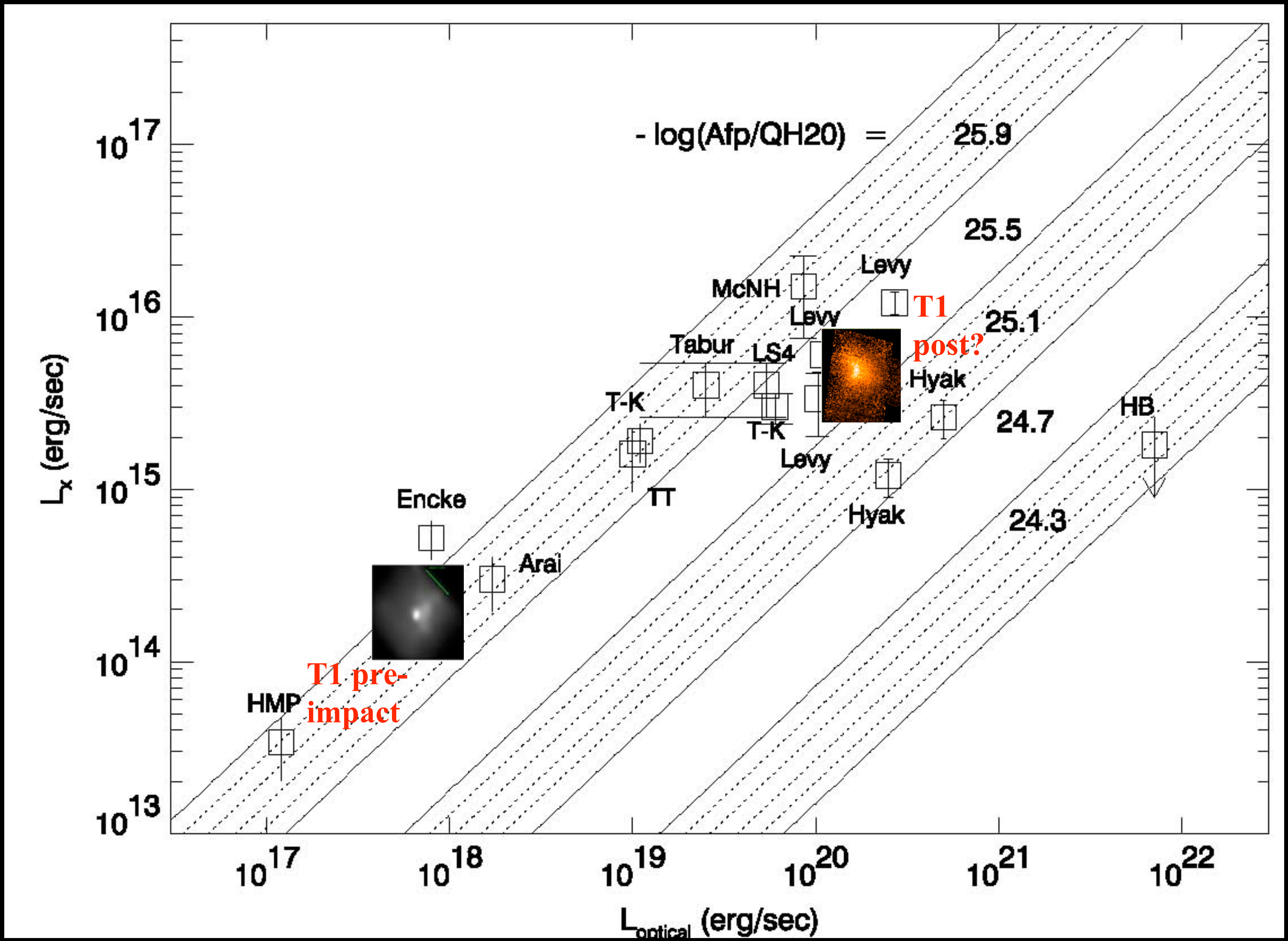
FIG. 4.—Soft X-ray spectrum of 9P/Tempel 1. The line energies marked correspond to the approximate positions predicted for charge exchange between the solar wind ion indicated and neutral gas in the comet's coma. The histogram is the best-fit model, which comprises seven emission lines.

Future SWIFT SS Observational Studies

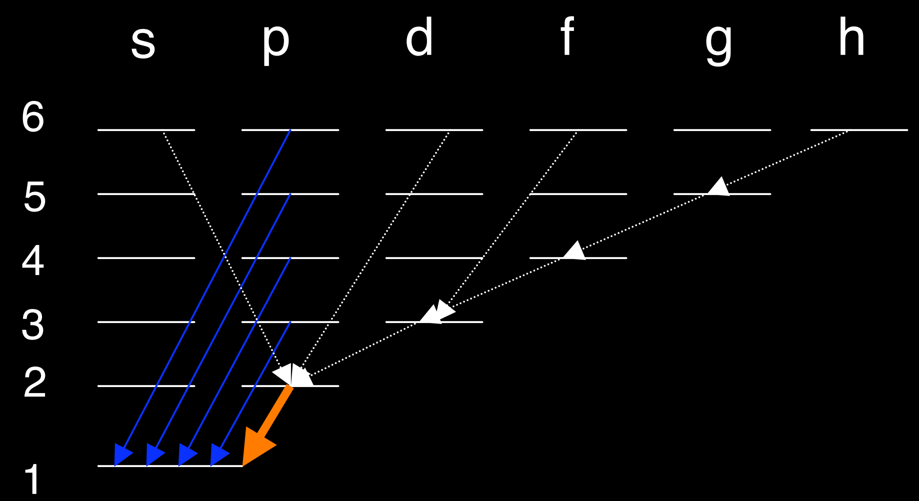
- Spectral Survey of 100 Comets
- Long Term Monitoring of High Latitude Comets to Derive SW Properties
- Long Term Studies of Jovian X-rays
- Detection of X-rays from Outer Planets
- Tracking of an CME Through the SS
- X-ray Measurements During Planetary Flybys (e.g., MESSENGER at Venus)
- OH Emission from Asteroids
- Heliosphere Monitoring - ISM Wind Variations

Different Luminosity Regime : Linear Part of L_x vs $L_{optical}$ Curve

$L_x = N_{SW} * V_{SW} * N_{neutral}$, not $L_x = N_{SW} * V_{SW}$



Charge exchange emission



•Charge changing cross section
•Population cross sections
•Branching ratios → emission cross section

•Strong Ly-α, forbidden & intercombination lines
(Kharchenko & Dalgarno '00,'01)