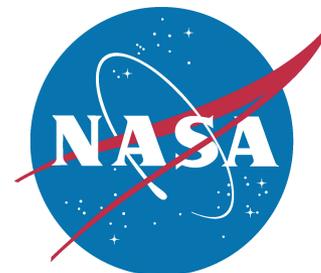


# Suzaku Observations of the X-ray Emission from Comets



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Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344

LLNL-PRES-400775

# Comets emit X-rays

Cometary X-rays discovered in 1996

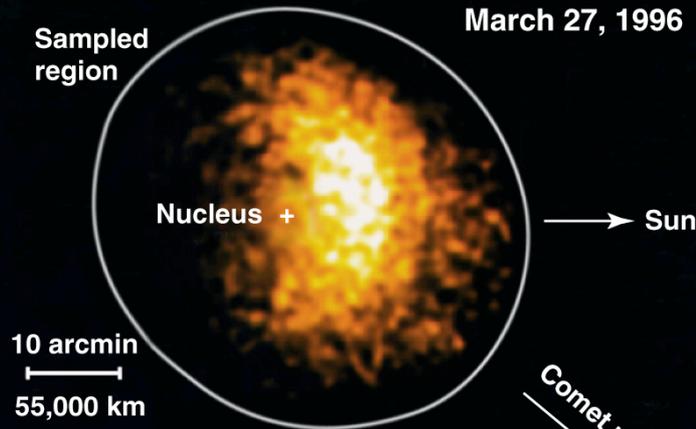
FIRST X-RAY IMAGE OF A COMET

Comet Hyakutake • C/1996 B2

ROSAT HRI

March 27, 1996

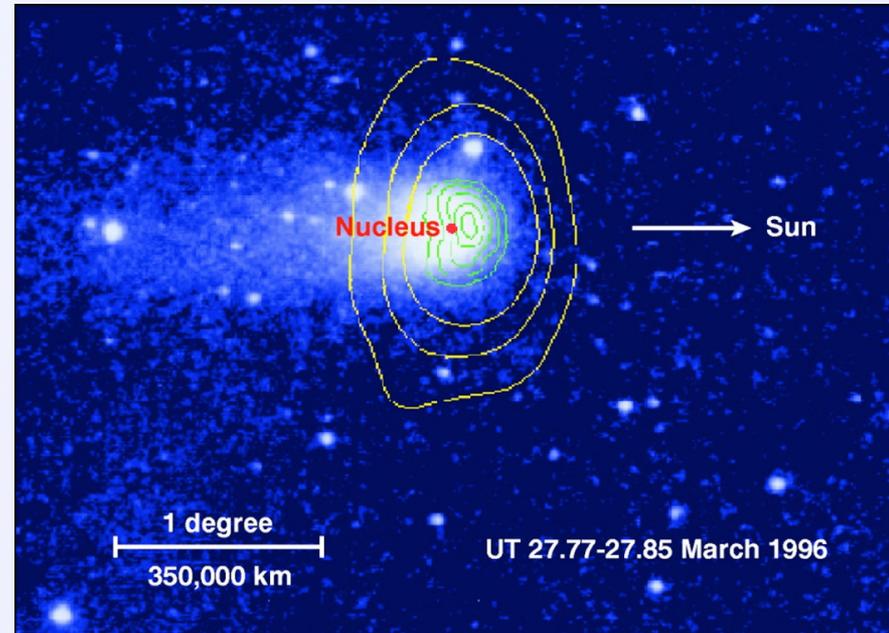
Sampled region



C. Lisse, M. Mumma, NASA GSFC

K. Dennerl, J. Schmitt, J. Englhauser, MPE

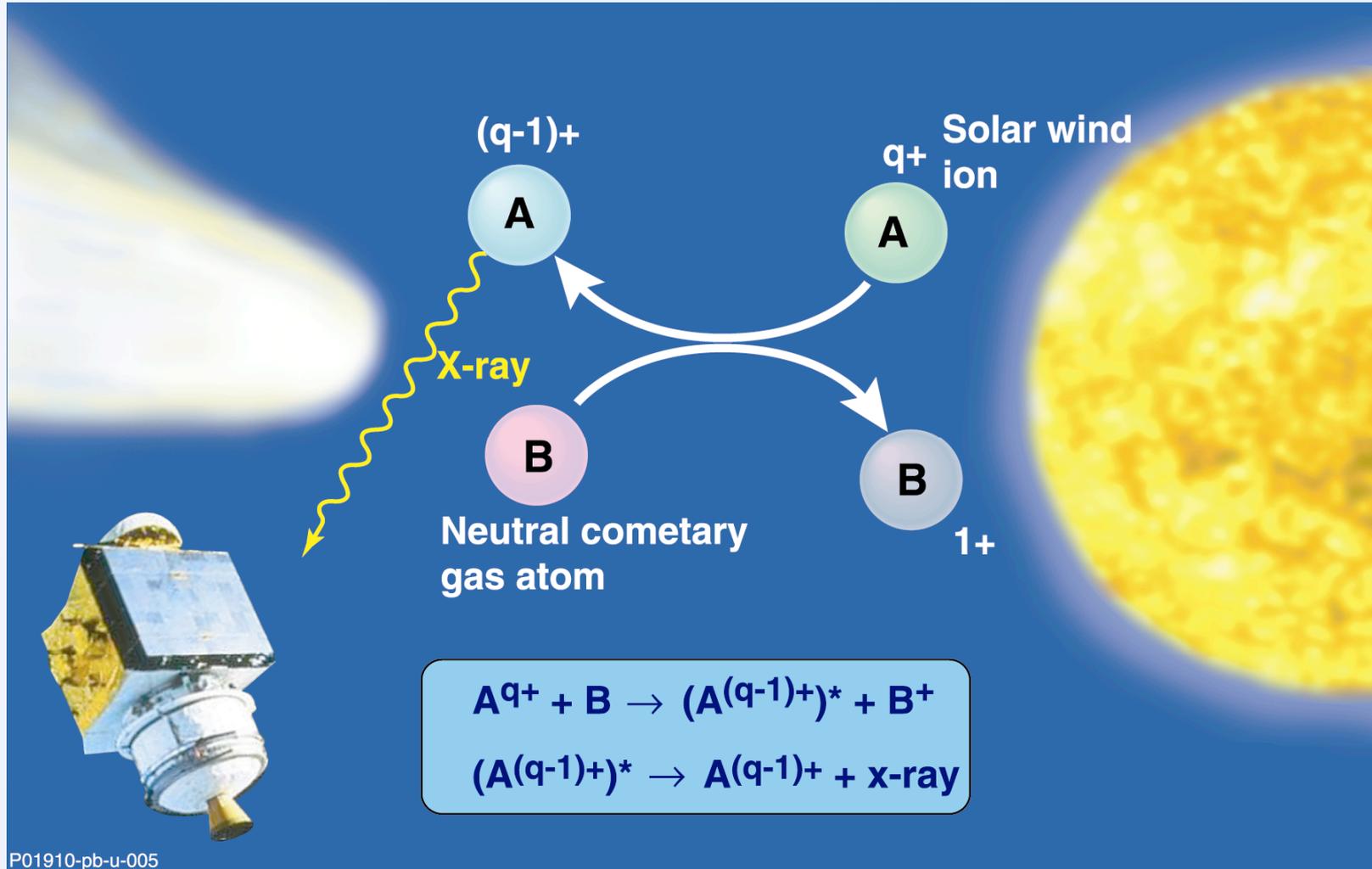
ROSAT+ Optical Image



More than 10 comets have been observed in the X-ray band, including every comet passing within 1 AU of the Earth.

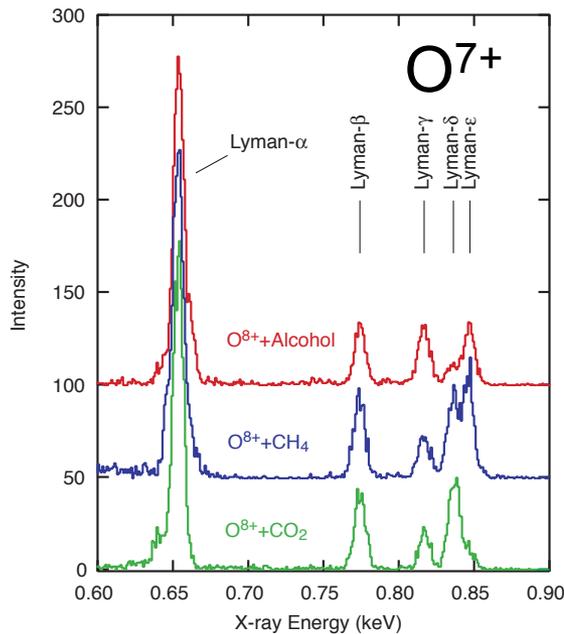


# Cometary X-rays are produced by charge exchange recombination



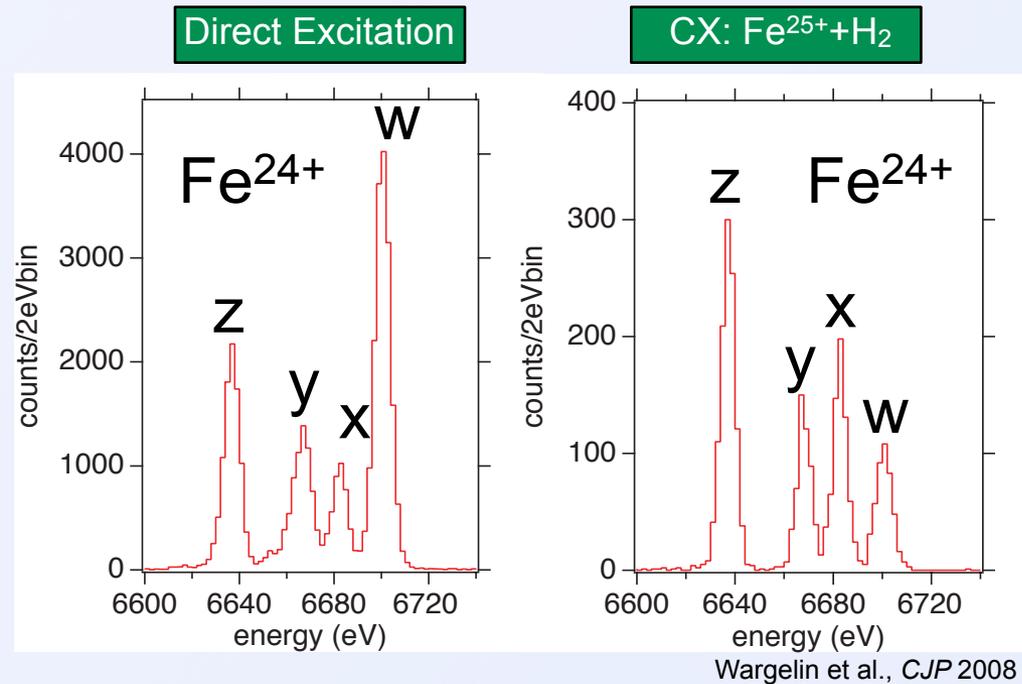
# Charge Exchange spectra are highly diagnostic and easily recognizable

CX X-ray spectrum depends on neutral donor



Beiersdorfer et al., *Science* 2003

X-ray emission from He-like systems produced by CX is drastically different from direct excitation



Wargelin et al., *CJP* 2008

Diagnostics include: solar wind charge balance, solar wind velocity, cometary gas production rate, composition and distribution, and possibly rotation period nucleus.



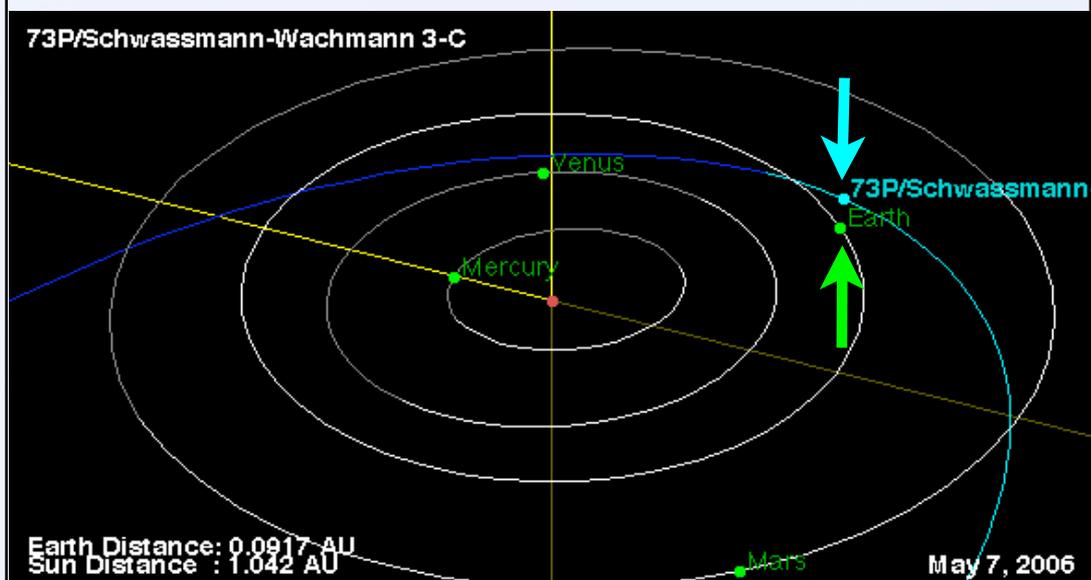
# Suzaku observed comet

## 73P/Schwassmann-Wachmann 3 in May and June of 2006

### Three Suzaku Observations

1. pre-obs: May 7  
exposure time : 5 ks  
Range to Earth : 0.091 AU
2. Closest approach : May 13  
exposure time : 25 ks  
Range to Earth : 0.078 AU
3. Just after perihelion: June 8  
exposure time : 35 ks  
Range to Earth : 0.23 AU

### 73P/Schwassmann-Wachmann 3C's ephemeris



Prior to our observations, the comet broke into over 60 fragments. Suzaku observed the brightest, fragment "C".



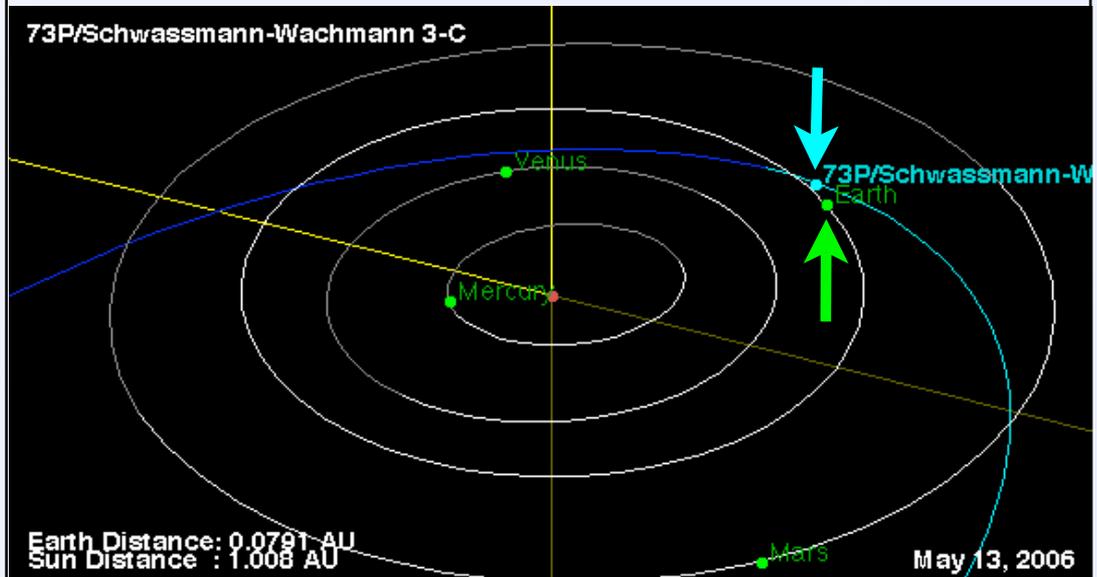
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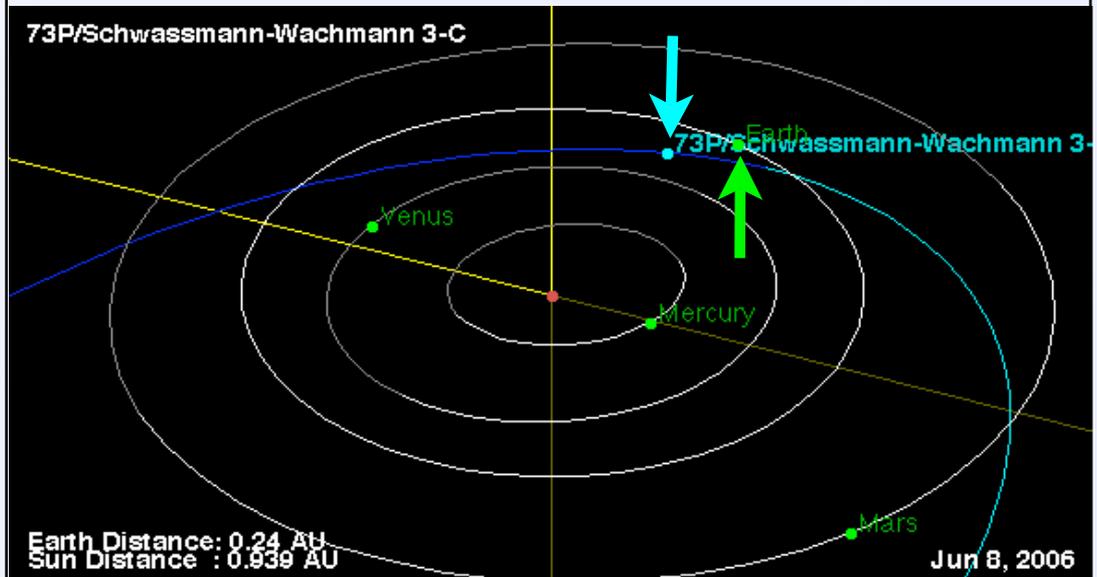
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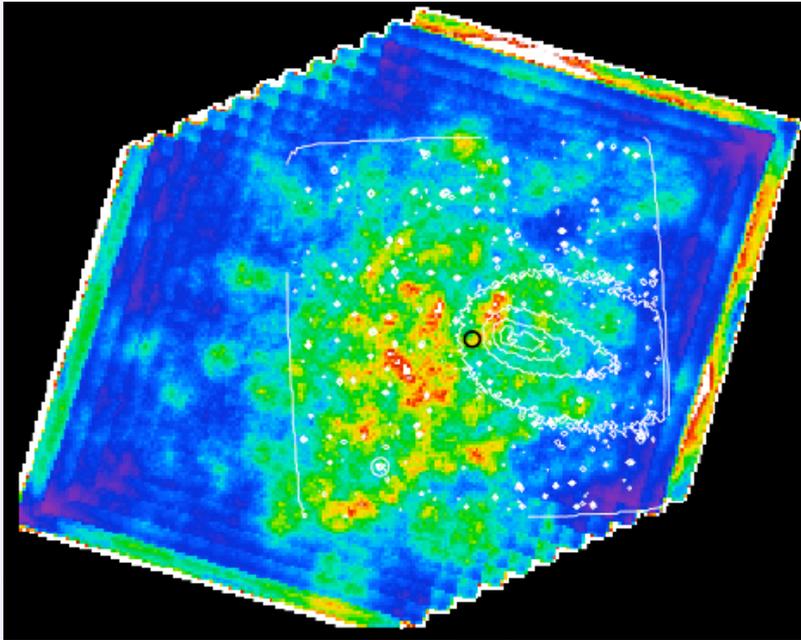


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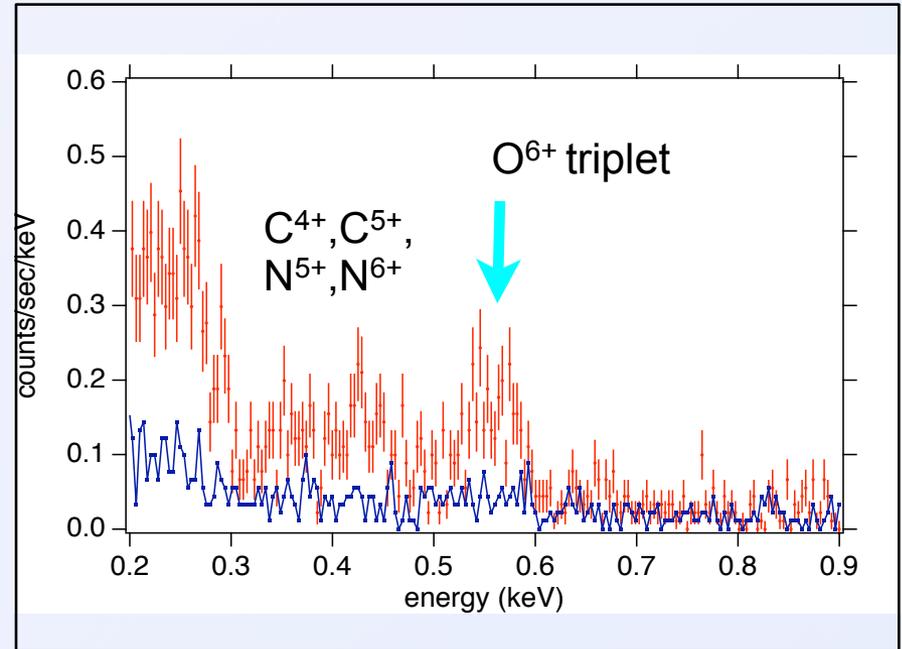


# May 13 observation

XIS1 X-ray Image

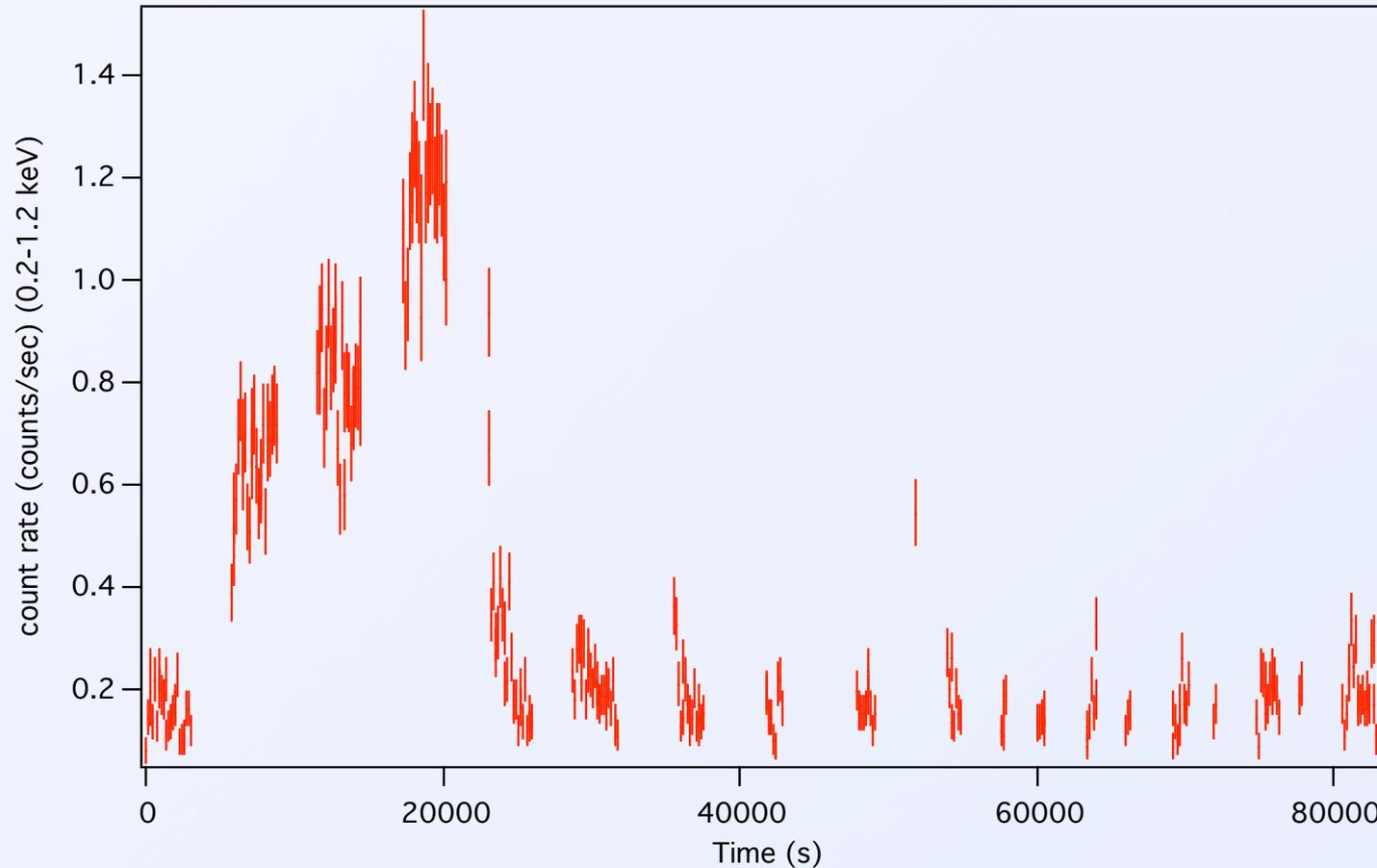


XIS1 X-ray Spectrum



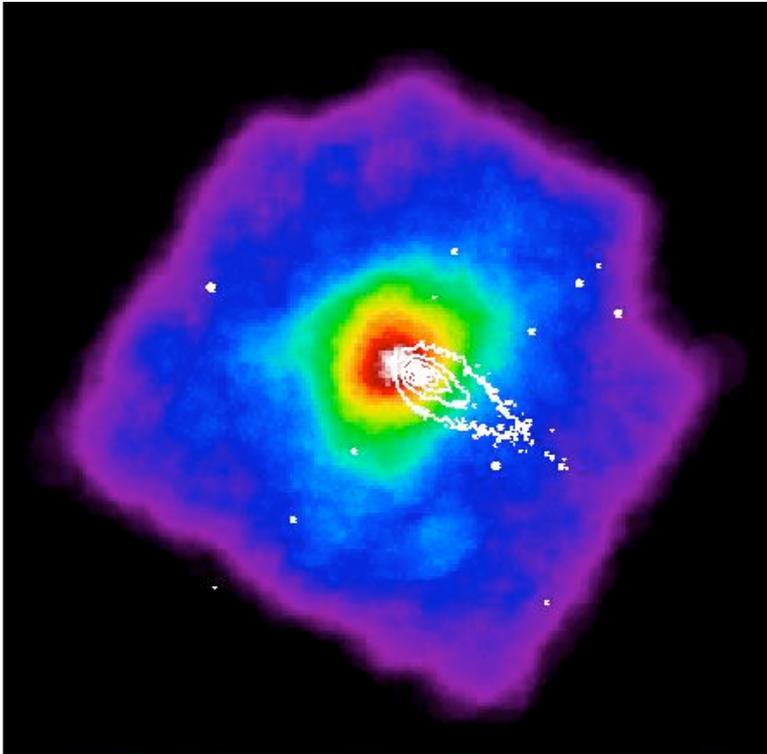
Although comet was close to Earth, the solar ion flux was low, and so was the count rate.

# June 8th observation: Very lucky to have caught a solar flare

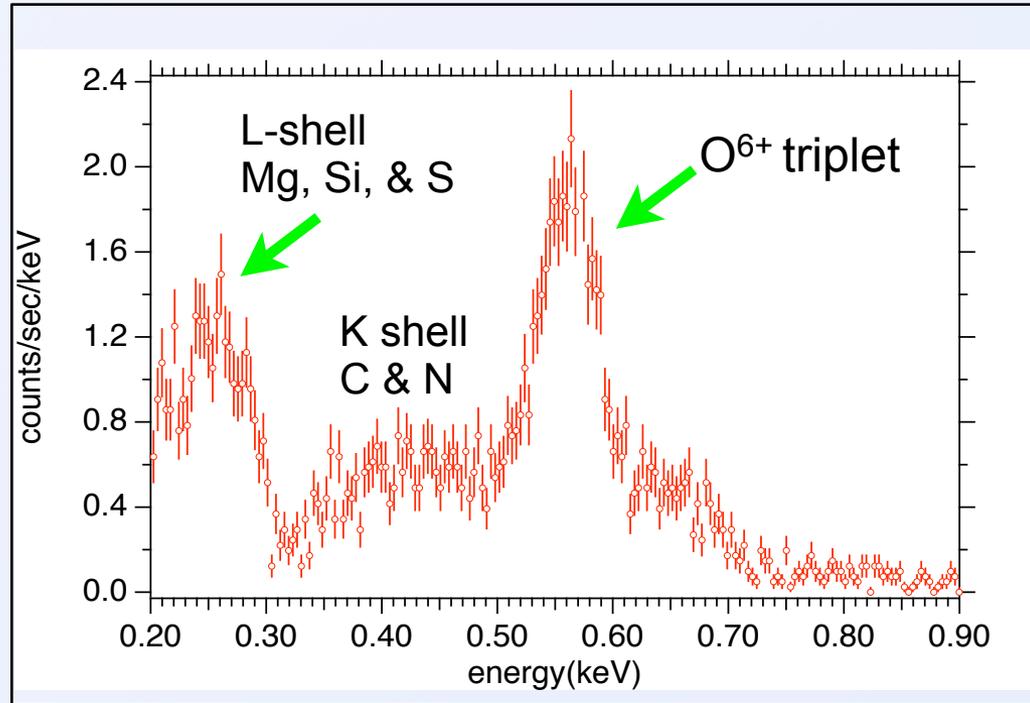


# June 8th observation

XIS1 X-ray Image



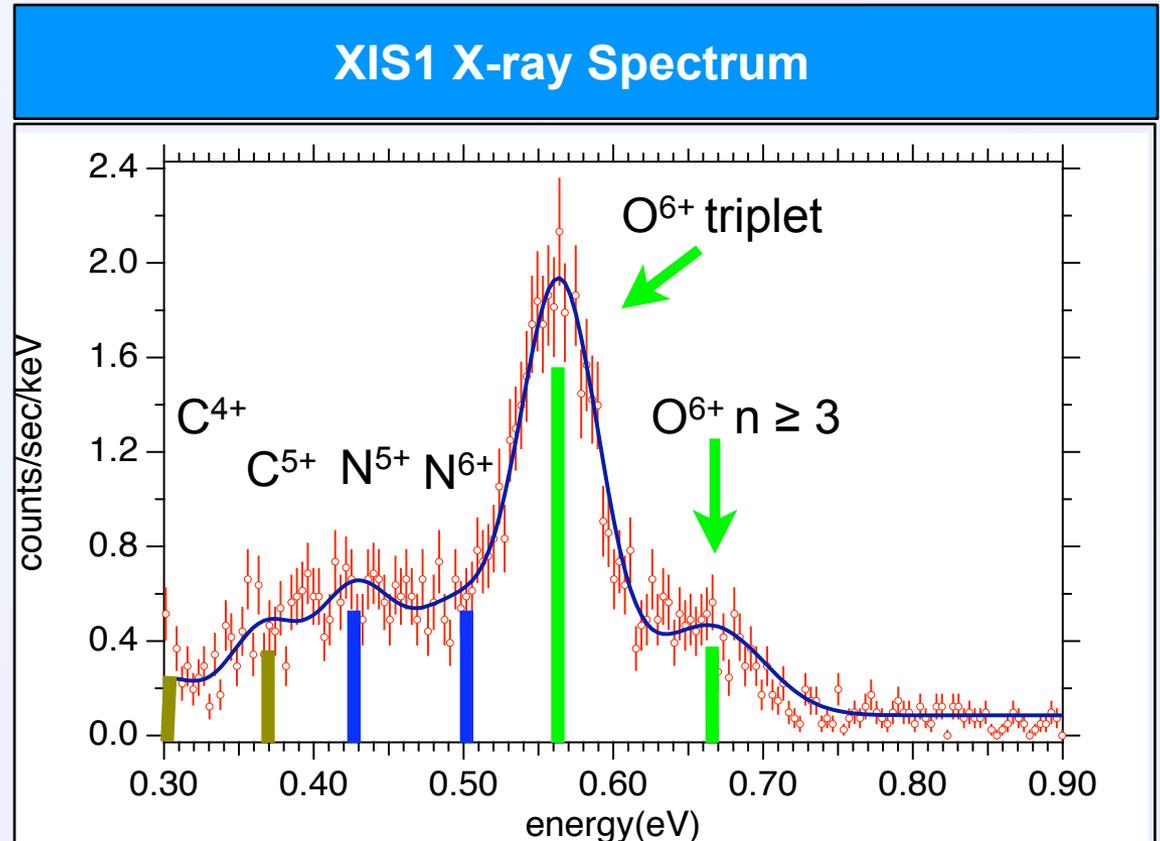
XIS1 X-ray Spectrum during peak of flare



Solar flare produces bright cometary x-ray emission

# Fit to cometary spectrum

- $O^{6+}$  triplet centroid:  
563 eV  
equal to lab. value
- Based on ACE SWICS  
data, no  $O^{7+}$  included in fit.



**Future analysis includes accounting for charge exchange lines from L-shell Mg, Si, & S.**



# Observations of comet 8P/Tuttle in January 2008

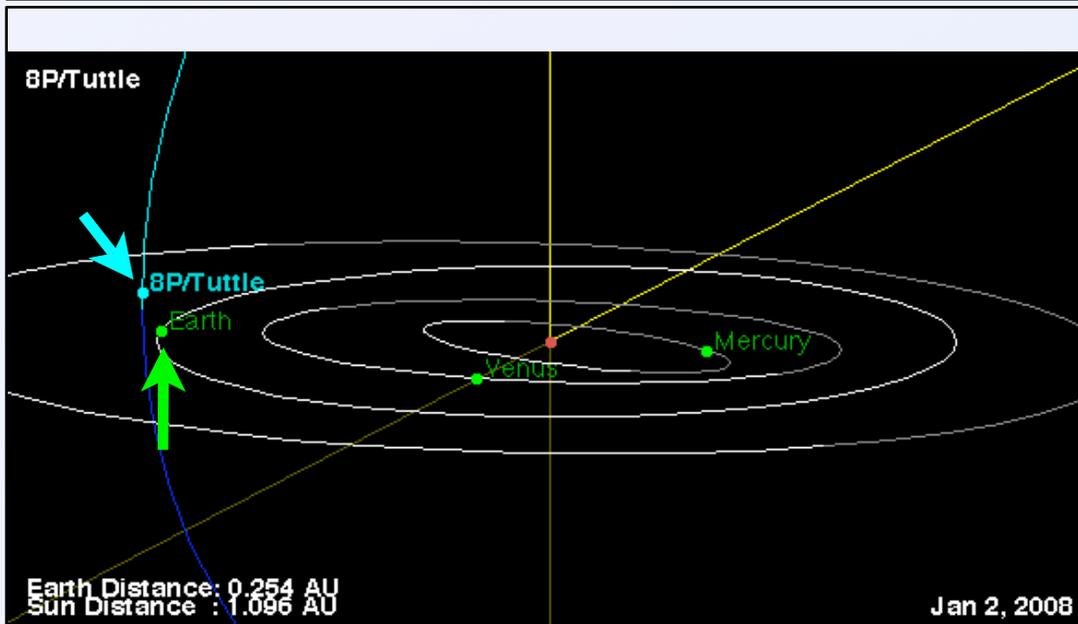
## Optical Image of 8P/Tuttle taken Dec. 4



### Observation Parameters:

1. Closest Approach: January 2  
exposure time : 30 ks  
Range to Earth : 0.25 AU
2. Near perihelion : January 27  
exposure time : 100 ks  
Range to Earth : 0.51 AU

## 8P/Tuttle's ephemeris



Another exciting observation for the XIS



# Observations of comet 8P/Tuttle in January 2008

## Optical Image of 8P/Tuttle taken Dec. 4

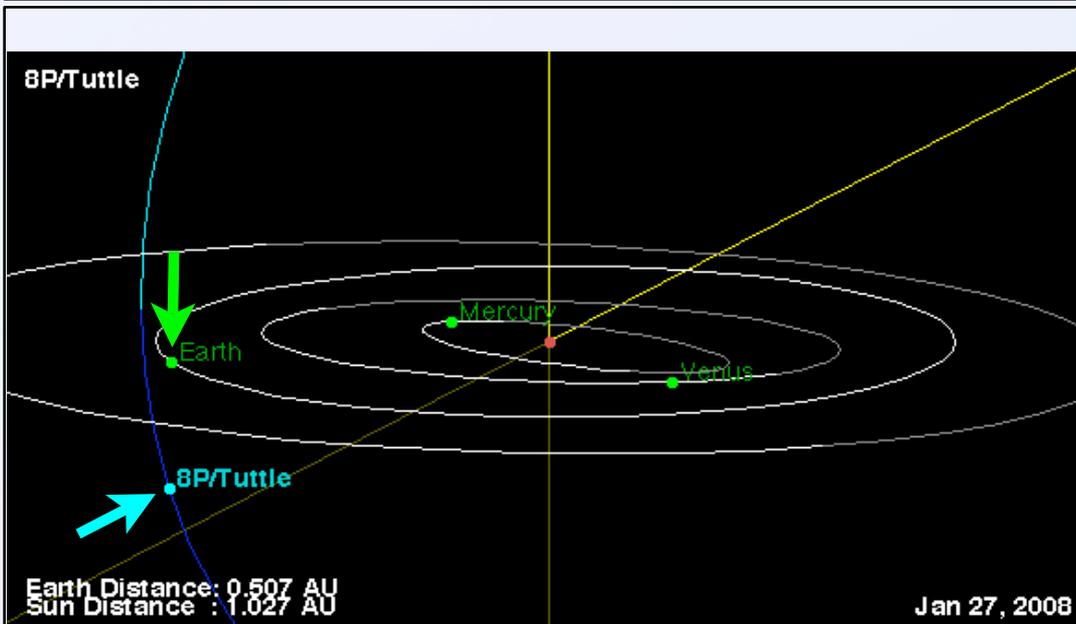


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## 8P/Tuttle's ephemeris



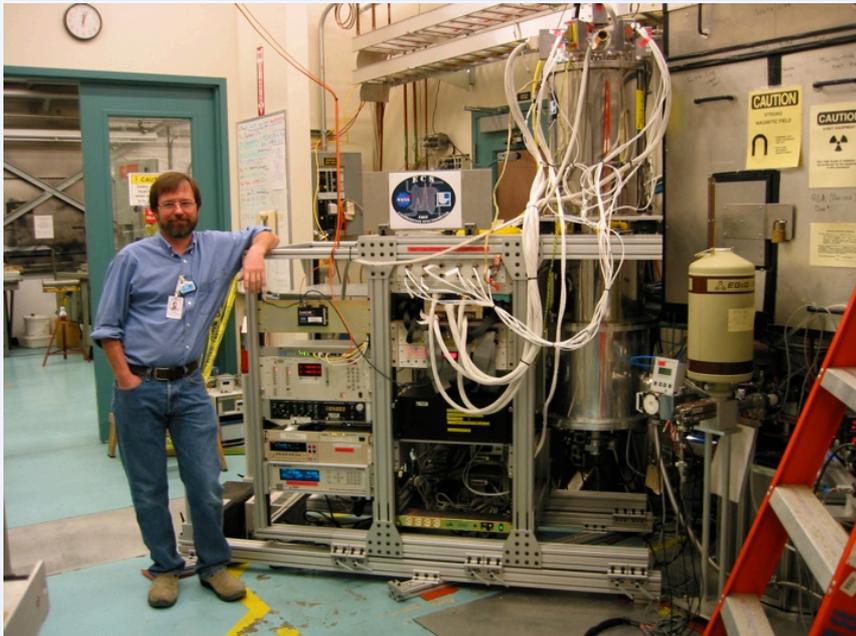
Samples of solar wind out of the ecliptic useful for solar models



# Summary

- XIS1 is well suited for studying X-ray emission from comets.
- Although it has a high potential, the diagnostic utility of cometary X-ray emission is still maturing.

## ECS at LLNL



- Future missions with larger collecting areas and higher spectral and spatial resolution, such as NeXT and Con-X, will open the door to more diagnostics.
- Charge exchange models are rapidly improving.
- CX cross sections of L-shell ions of Mg, Si, and S, falling in the 1/4 keV band remain largely untested.

