Cygnus X-3's " Little" Friend

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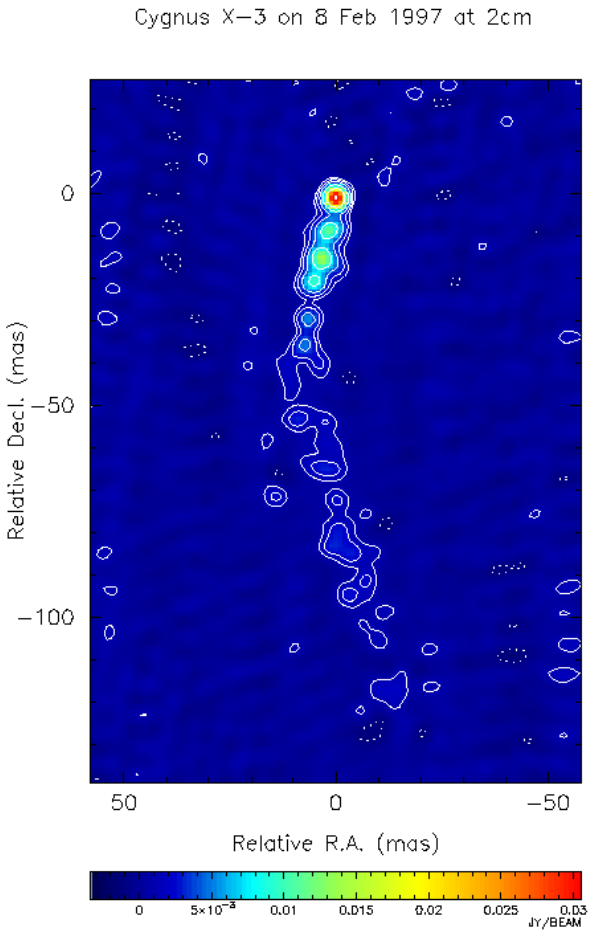
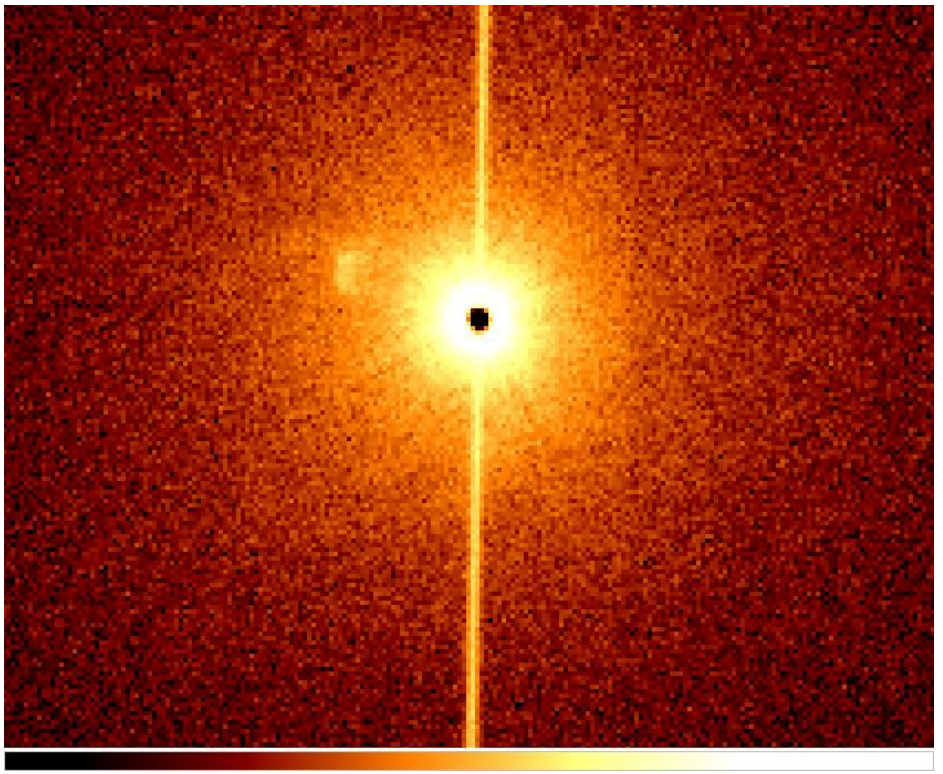
Cygnus X-3

- High Mass XRB
- Wolf-Rayet Companion
- 4.8 hr Orbital Period
- Strong Stellar Wind
- 2 X-Ray States:
  (a) low/hard
  (b) high/soft
- Relativistic Radio Jets

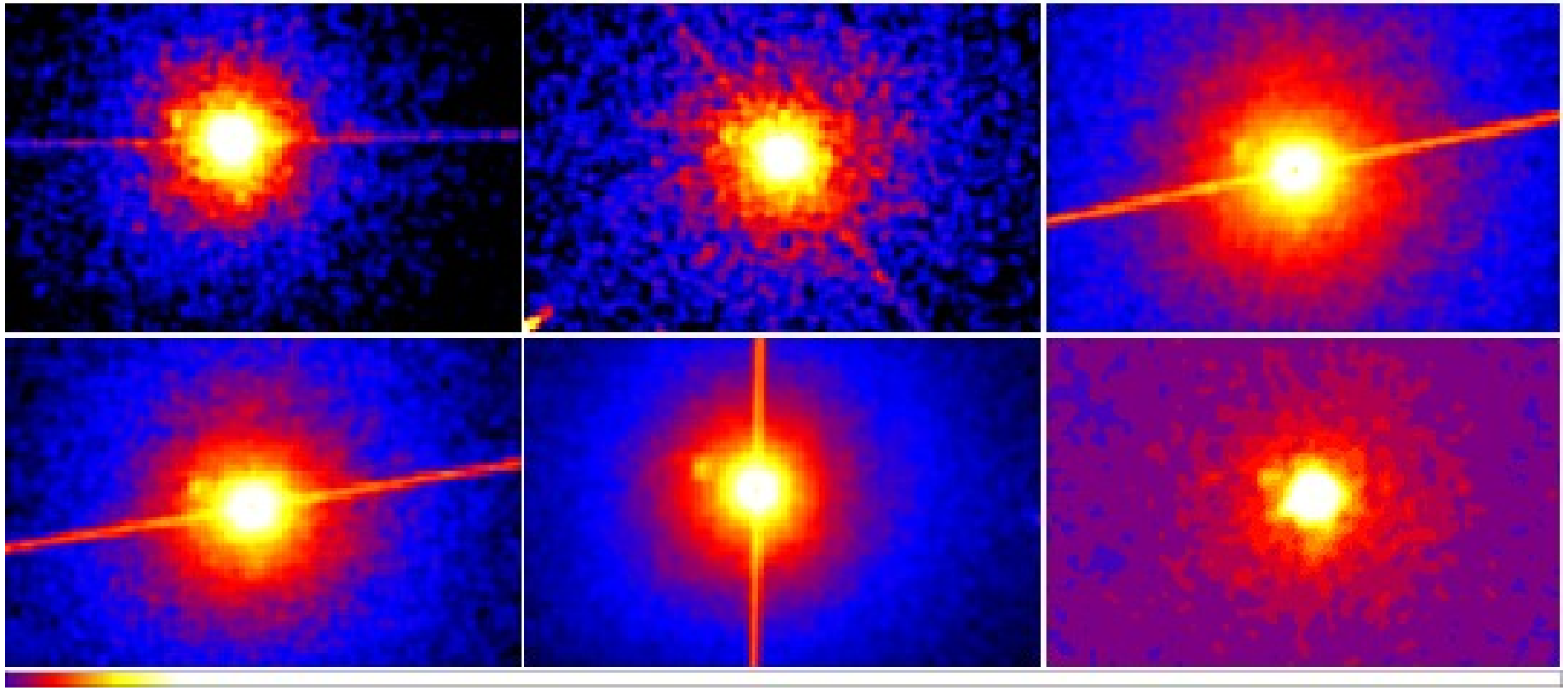


Cygnus X-3's " Little" Friend

- First noted by Heindl, et al. 2003.
- Extend emission located ~16 " from Cyg X-3.
- Distance of 2.7 D_{10} light-yrs from Cyg X-3
- Proposed as a possible jet impact area.



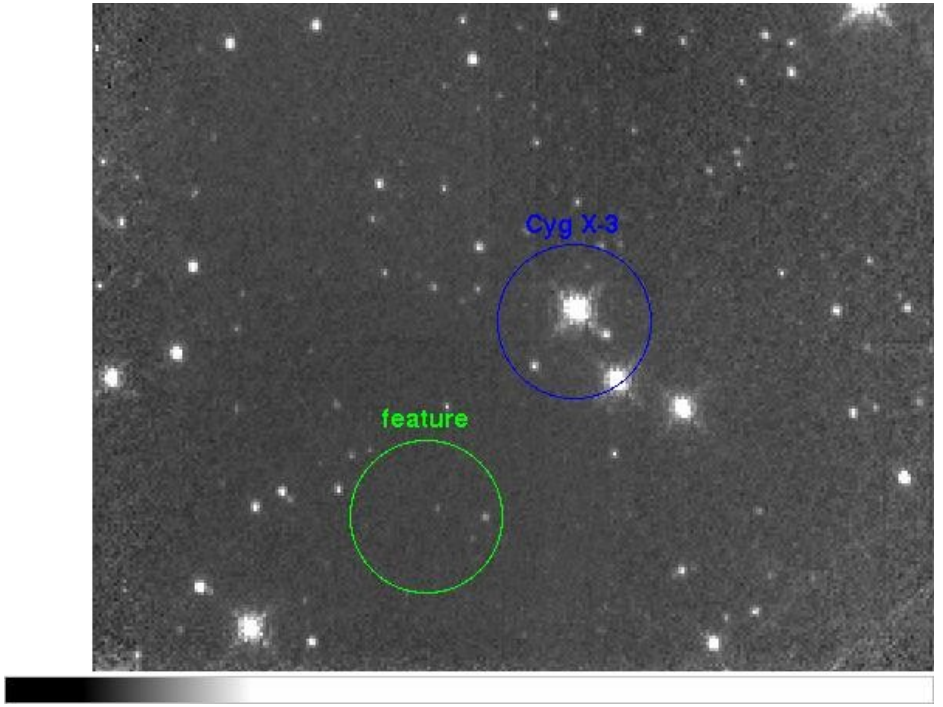
Persistent Feature During the Chandra Mission



Chandra observations spanning 1999-2006. Five ACIS (HETG) and one HRC (lower right). Note the different spacecraft rolls (orientation of the readout streak) of the ACIS observations. Observations cover different states of Cygnus X-3's activity.

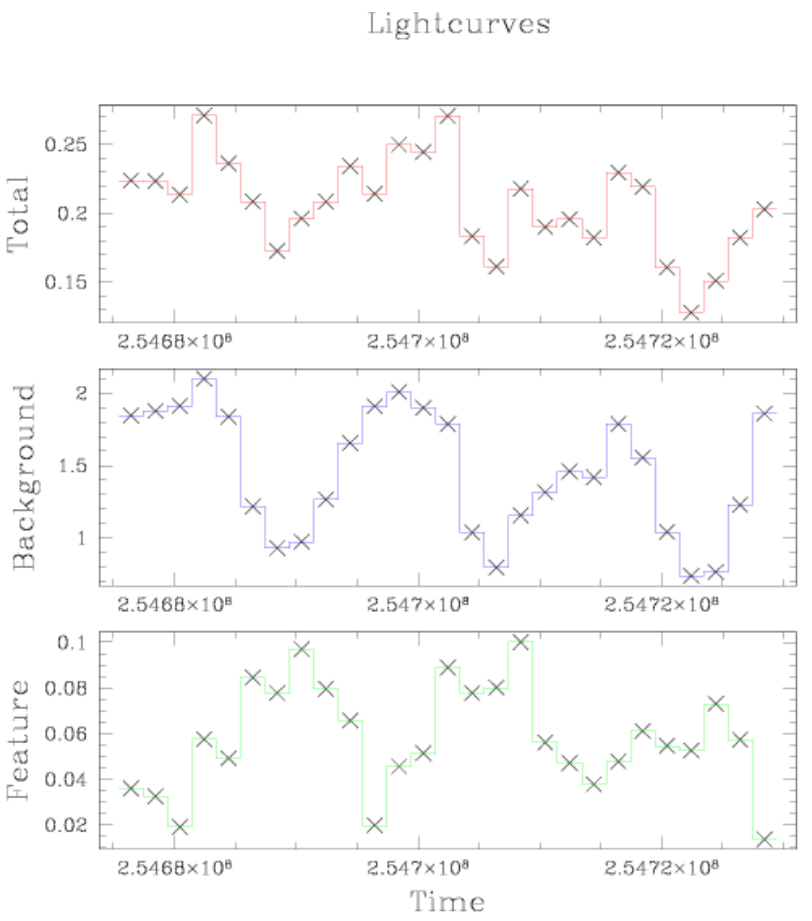
No Counterparts at Other Wavelengths

- No evidence for the feature at other wavelengths.
- NICMOS (1.76 micron image) to the right shows no obvious counterpart.



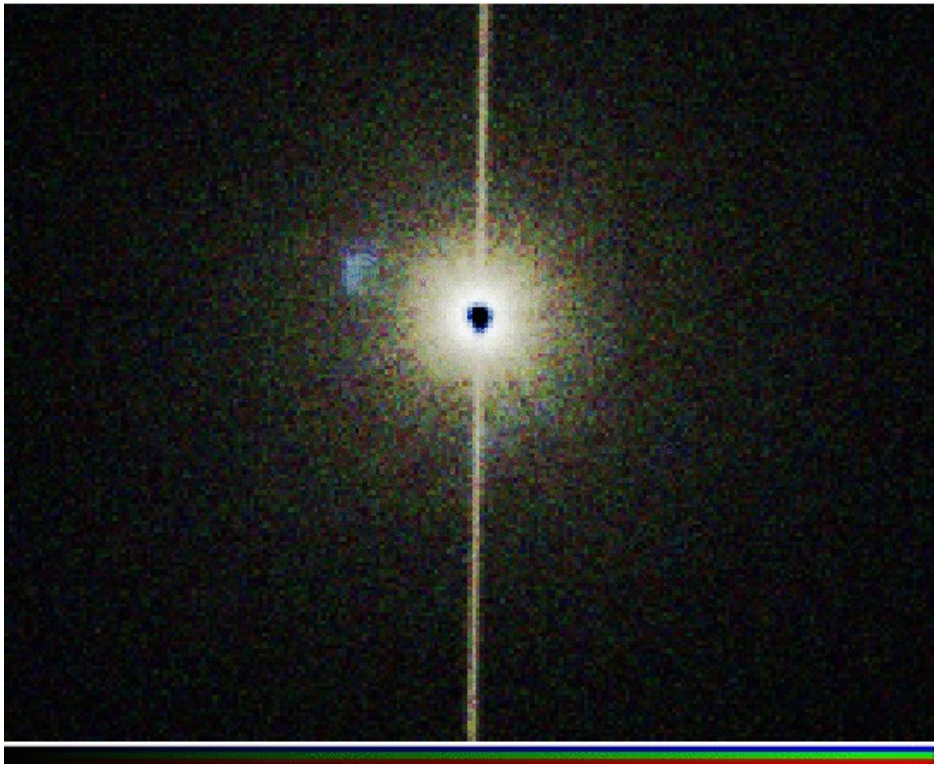
Time Variability of the Feature

- Feature is located on a large scattering halo due to Cyg X-3.
- Background varies with Cyg X-3 4.8 hour period.
- Feature appears to vary in time and be anti-correlated with Cyg X-3.

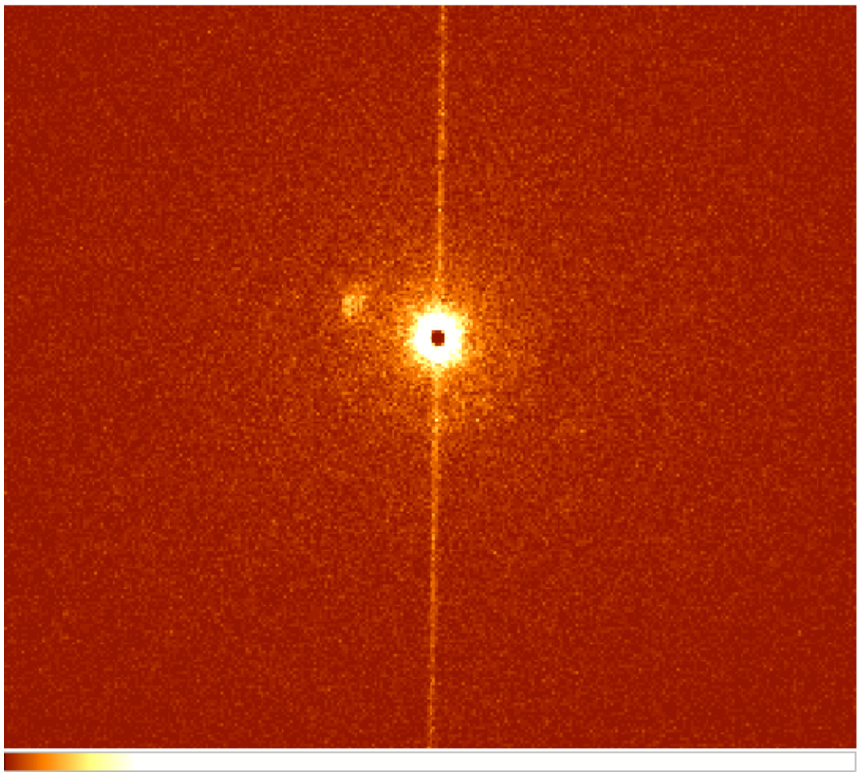


Cygnus X-3 Color Coded Phase Image

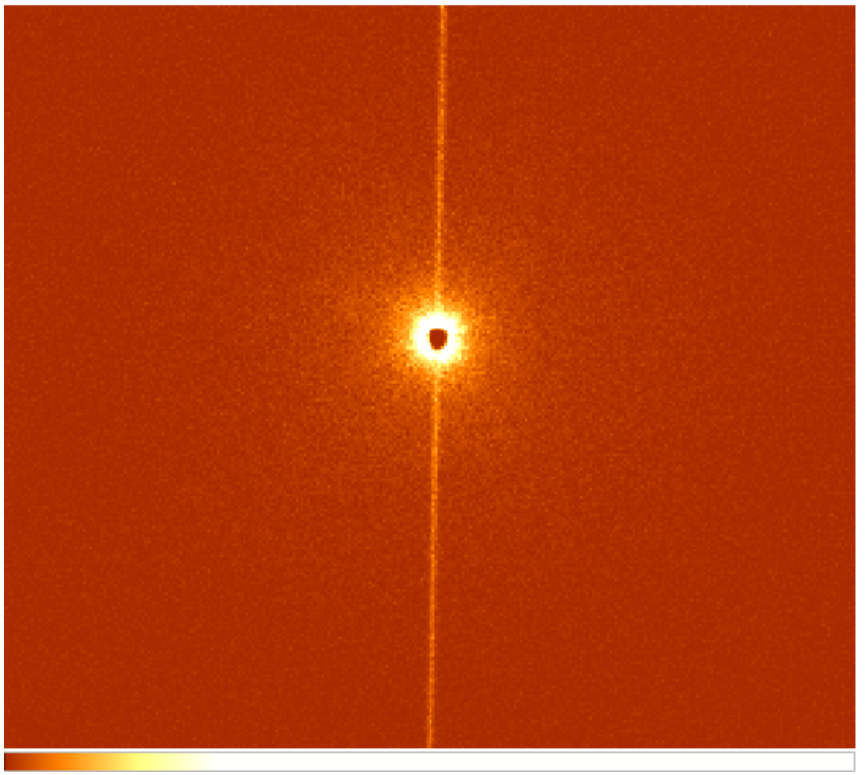
- Determine a Cyg X-3 phase for all events.
- Assign a color for each event depending on a phase range.
- Red:0.30-0.63
- Green: 0.63-0.96
- Blue: 0.96-0.30



Phase Selected Images

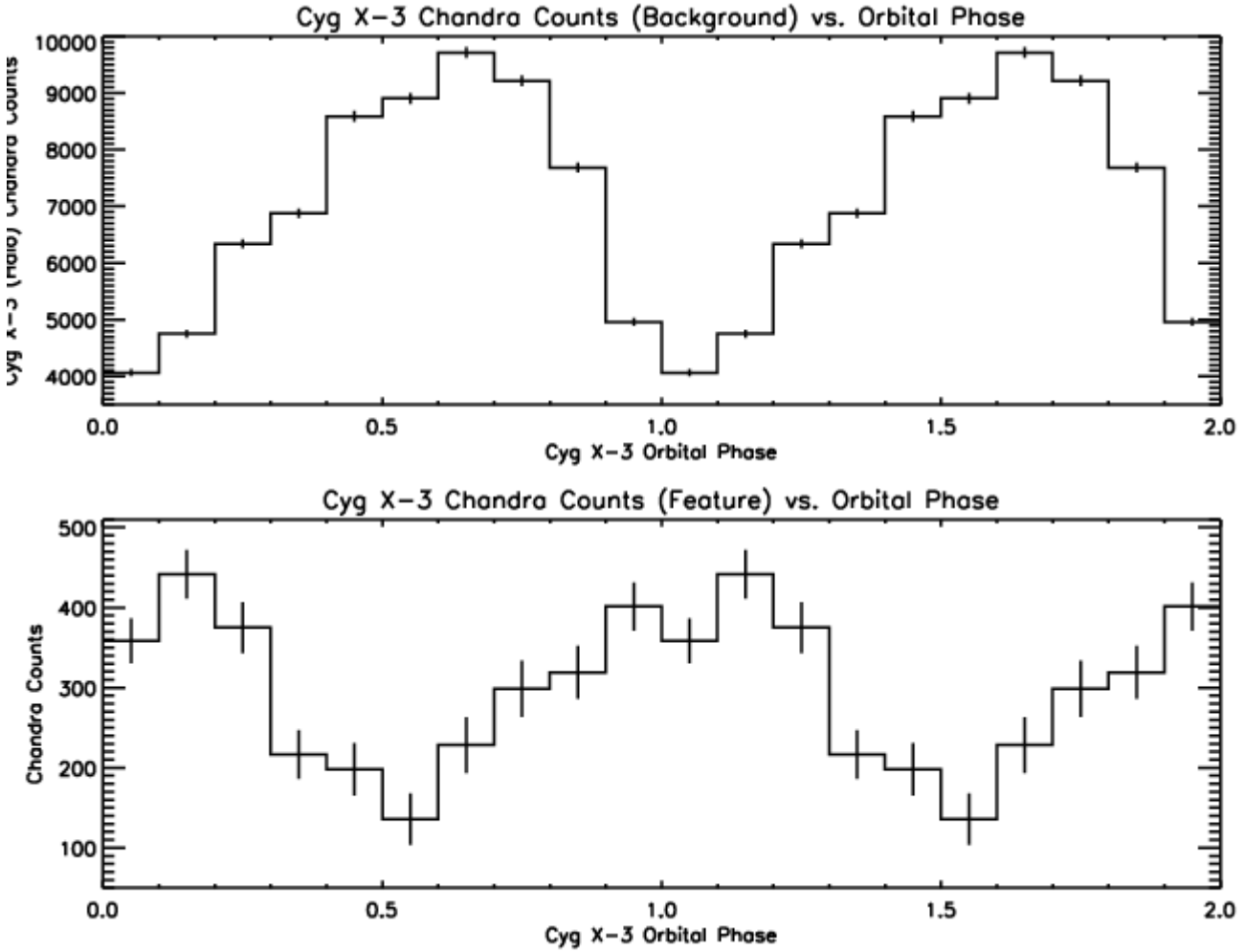


Phase range 0.96-0.3 image



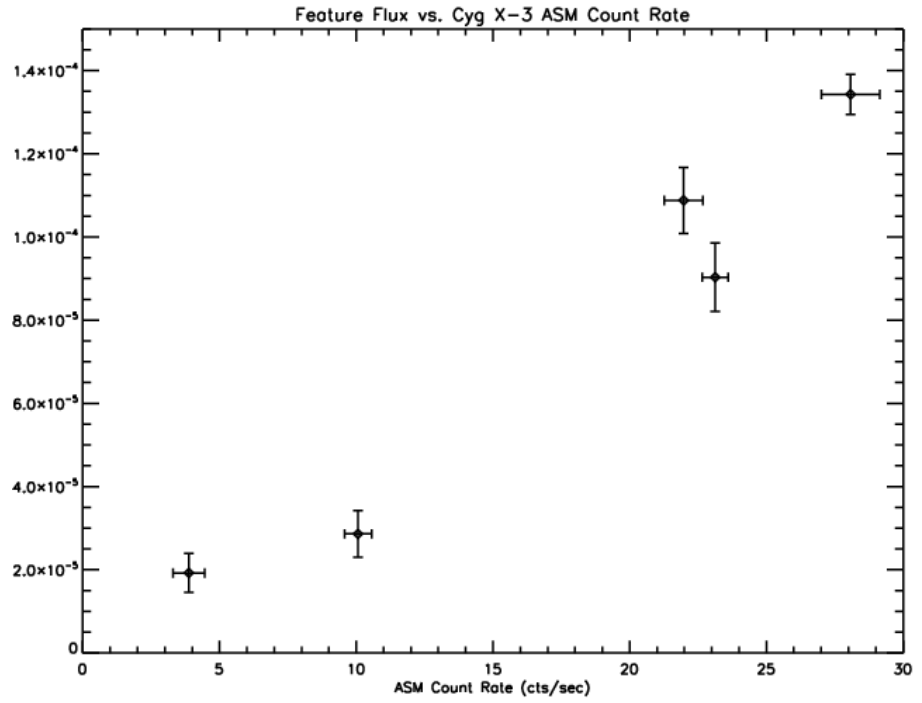
Phase range 0.5-0.8 image

Phase Folded Light Curves of Cygnus X-3 and the Feature

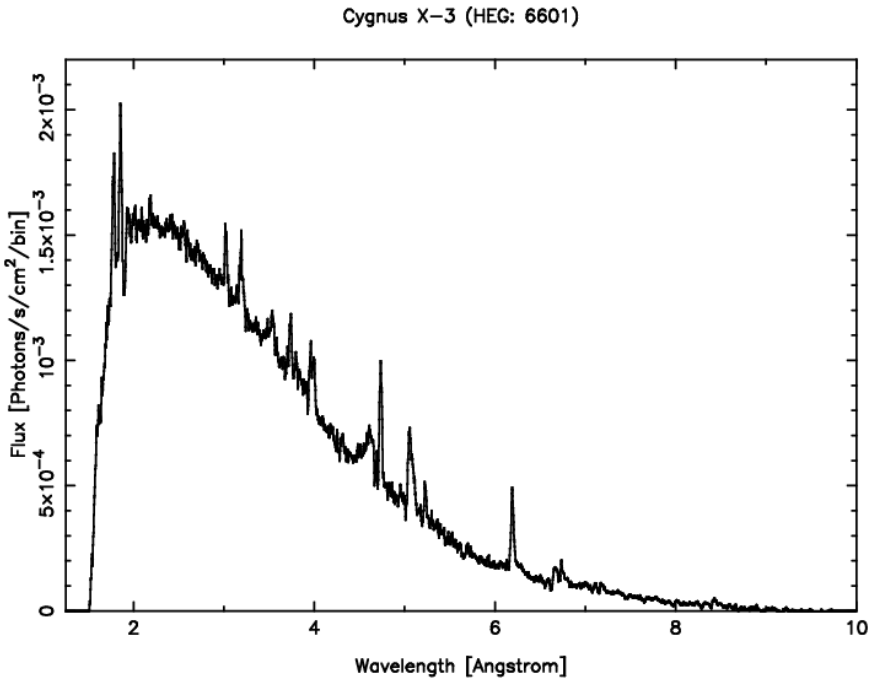


Feature vs. Cygnus X-3 Flux Variations

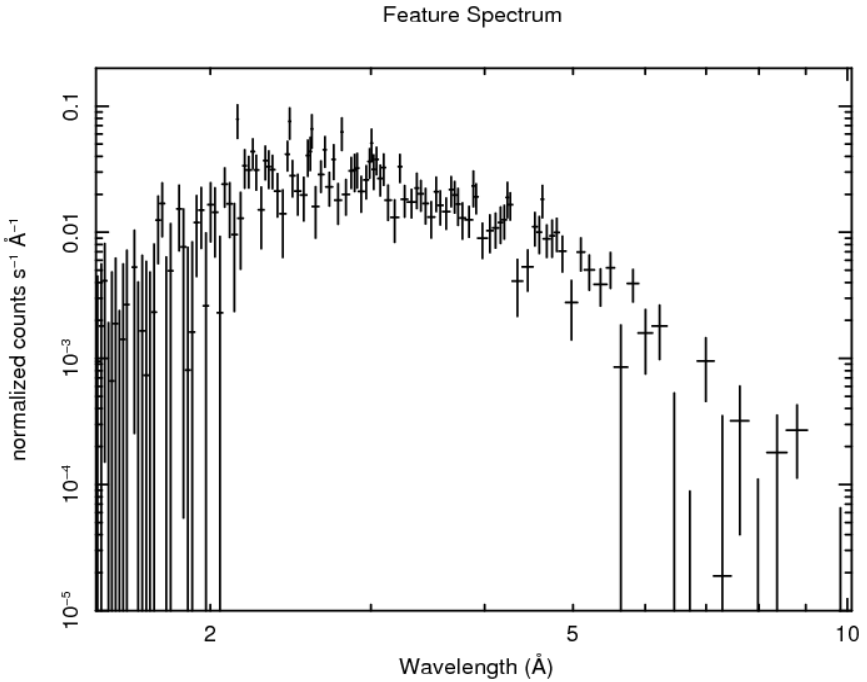
- Calculated the photon flux for the feature using exposure maps (3.5 keV).
- Compare with ASM count rate for the time of the observation.
- There appears to be a direct correlation between the them.



Cygnus X-3 and the Feature's Spectra



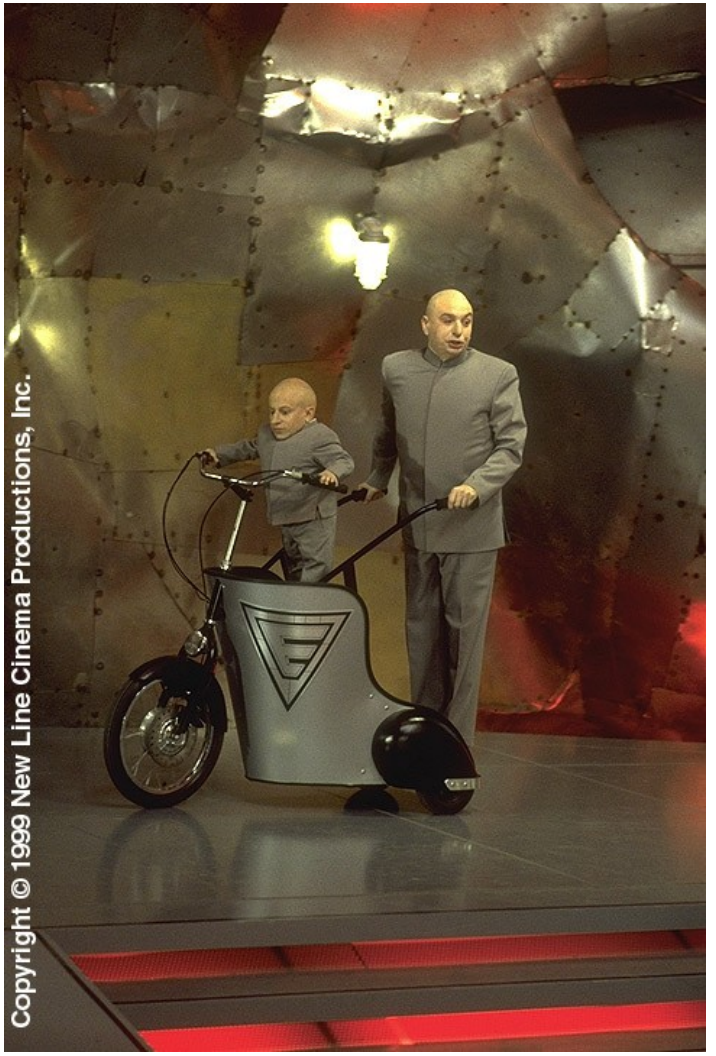
Cygnus X-3 Chandra Grating Spectrum



Chandra CCD (S3 Chip) Spectrum of the Feature

What is the feature?

- The phase averaged flux of the feature is $\sim 10^{-4}$ of Cyg X-3 and appears correlated.
- Phase variations appear anti-correlated with those of Cyg X-3.
- Time variation is 4.8 hrs but separation is 2.7 D_{10} light-yrs?



Possible Candidates

- Instrumental Effect: Unlikely
- An Unrelated Source: No
- Feature of Cygnus X-3's Wind: ?
- Jet Impact Area: ?
- Beamed Emission: ?
- Gravitational Lens (weak): ?
- Gravitational Lens (strong): ?
- Scattering by a Cloud Along our Line of Sight:?

Jets, Wind Features, & Beams

- Jet Impact and Wind Features?
- Not aligned with radio jets.
- Cyg X-3 and feature flux correlation is an issue.
- No counterpart at other wavelengths.
- Beamed emission?
- Spectrum is not what one might expect (not a power law).
- Counterparts at other wavelengths?
- Misaligned from the radio?

Gravitational Lens

- Arc-like shape to the feature (Einstein's Ring).
- Could explain the anti-correlation and correlations.
- Where is the lensing object located (stability)?
- For Cyg X-3's distance the mass of the lensing object would need to be very massive (based on angular separation of ~ 16”). ($10^{12} M_{sun}$)
- Possibility of strong lensing of the inner accretion disk?

Scattering by a Cloud

- Could explain the correlations and anti-correlations. Phase offset is simple a result path difference of scattered photons.
- Could explain the flux difference (factor of 10^{-4})
- May explain the spectra differences?
- Initial work on the overall scattering halo give reasonable column densities and indicated one or more clouds at a distance ~ 0.4 of the distance to Cyg X-3.

Scattering by a Cloud (cont.)

- If feature is due to an individual cloud the time delay will give one the distance to the cloud (Trümper and Schönfelder 1973).

$$t = \frac{\Theta_{obs}^2}{2c} \frac{Dx}{1-x}$$

- For t=2.4 hours, D=10 kpc, and Θ = 16”
- Then x=0.87 and the cloud is near to Cyg X-3.

Conclusions

- Unique time variable object.
- Jet Impact/Beaming? - Probing relativistic jets associated with this system.
- Gravitational Lensing? - Probing strong gravitational field regime.
- Cloud Scattering? - Direct probe of the interstellar medium.
- Need more Chandra and multi-wavelength observations.