Recent X-ray Variability of Eta Car Approaching The X-ray Eclipse

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Chandra ACIS-I “true color” image (Seward et al. 2000); low energy is red, high energy blue-white. The X-ray variable is the hard source marked by the red circle.

Massive stars are rare (by number or by mass) but they have a disportionate influence on the chemistry and energy budget of the ISM.

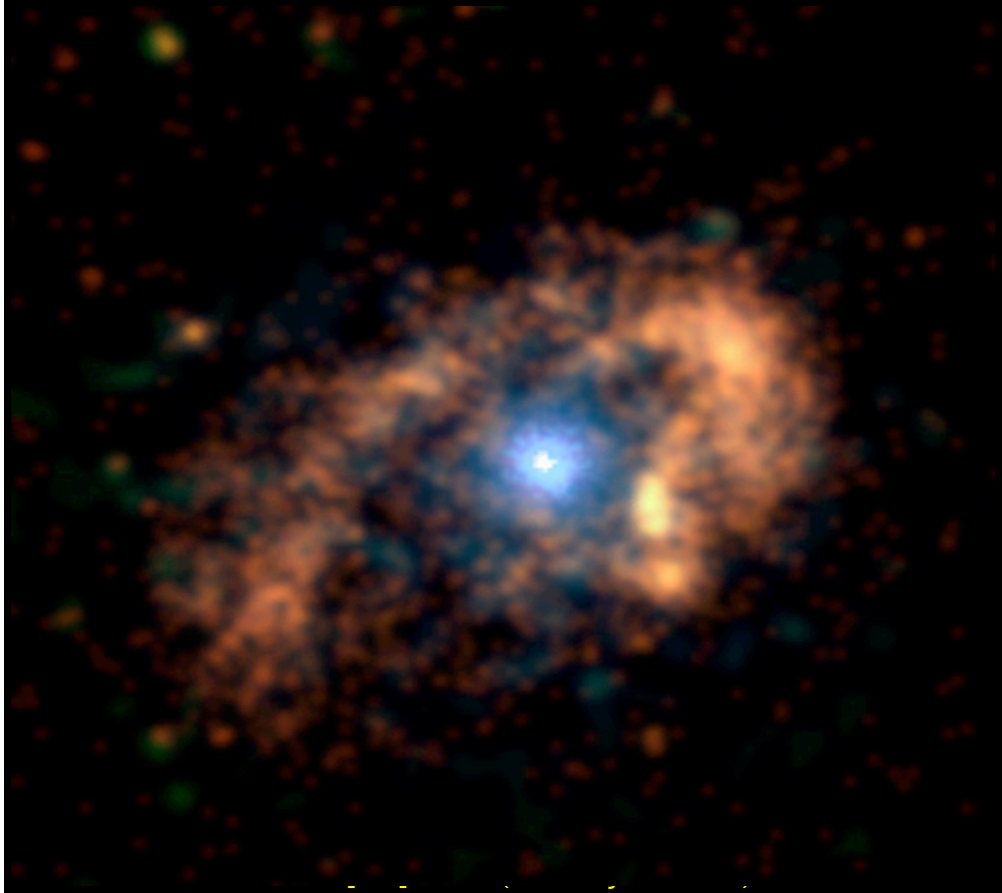
Some (largely) Unsolved Problems:

- *how do such massive stars form? (*High luminosities affects protostellar accretion, and can halt or reverse accretion)
- *How do massive stars change their environments?* (Wind-driven vs. episodic ejections; what causes episodic ejections anyway?)
- *How do massive stars produce supernovae and hypernovae, and what is their relation to GRBs?* (tied to angular momentum evolution; B fields?)
- *What is the true binary fraction?*

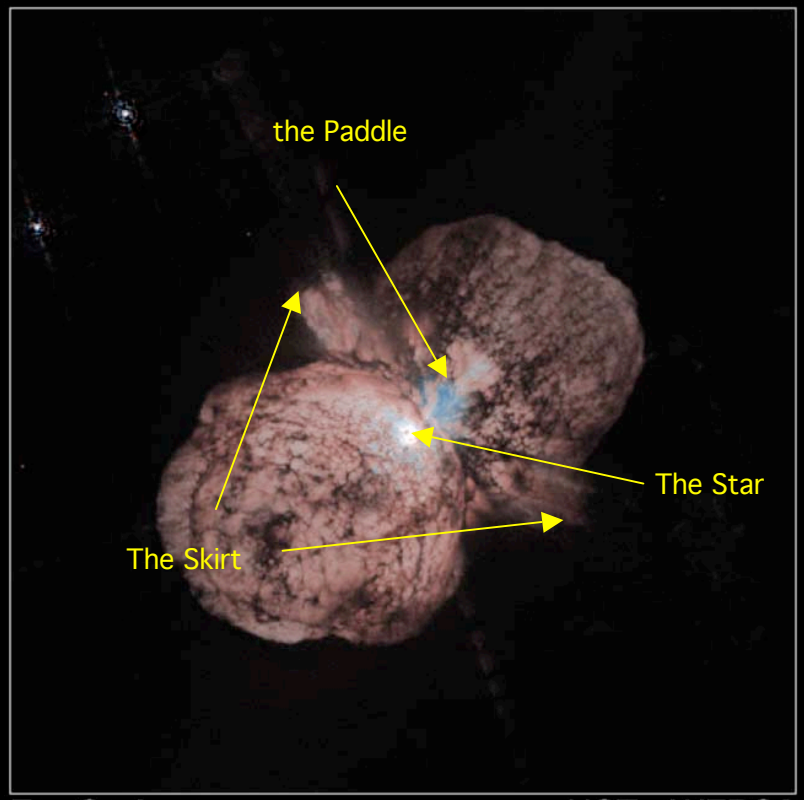
Eta Carinae: A Key Object

- Eta Car is one of the most massive (possibly the most massive) star known;
- A “Great Eruption” occurred in 1843 or thereabouts which created the “homunculus” nebula , a bipolar dusty shell (with between 2 to 15 solar masses) which surrounds the star
- A “Lesser Eruption” occurred in the 1890’s with associated mass ejection (Ishibashi et al. 2001)
- The Homunculus re-radiates the stellar flux in the IR, so that the present-day IR luminosity represents the total bolometric luminosity of the star: $L_{bol} \sim 4 \times 10^6 L_{sun}$

Eta Car: From the Outside In



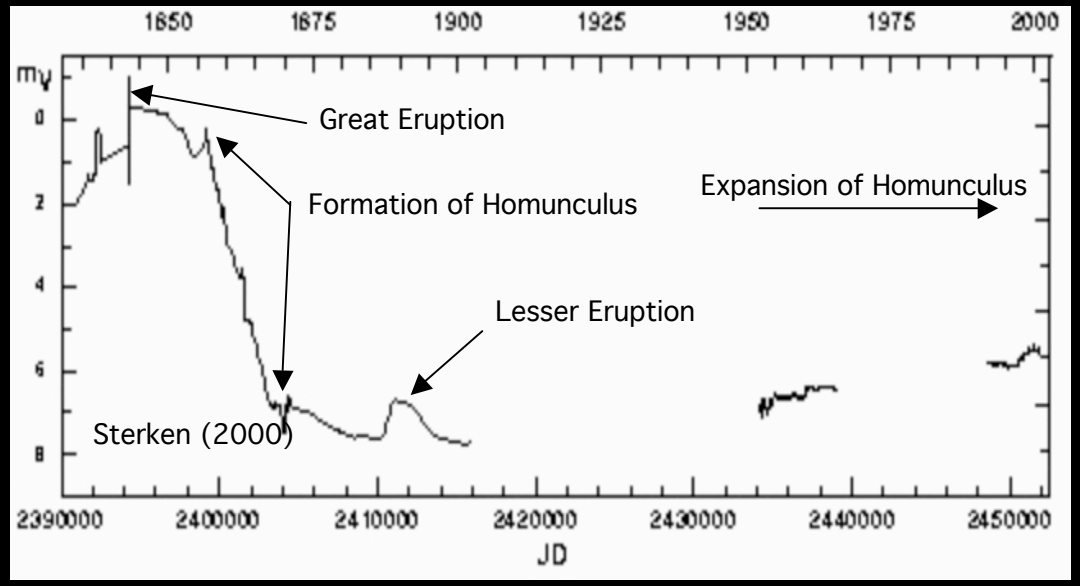
The Homunculus



Eta Carinae HST · WFPC2
PRC96-23a · ST ScI OPO · June 10, 1996
J. Morse (U. CO), K. Davidson, (U. MN), NASA

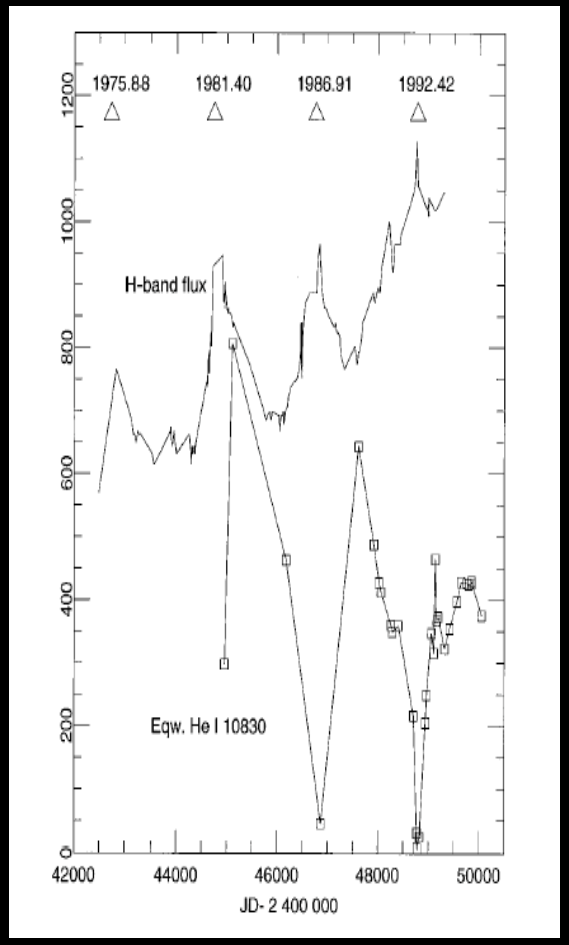
Multiple episodes of instability/mass ejections...

Eta Car in time:



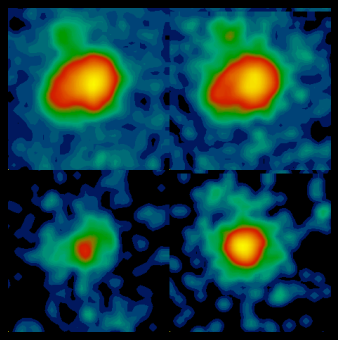
The Historical V-band lightcurve: An LBV*?

*LBV= Luminous Blue Variable, an evolved massive star near the Eddington limit; unstable



Damineli (1996) identifies a 5.52 year period in the star

The 5.52 Period: X-ray observations



E<1.5 keV

E>1.5 keV

1992 1993

- ROSAT observations in 1992 and 1993 discovered variations in the hard source associated with the star

- Radio observations (Duncan et al. 1996) also showed source brightening from 1992 to 1993

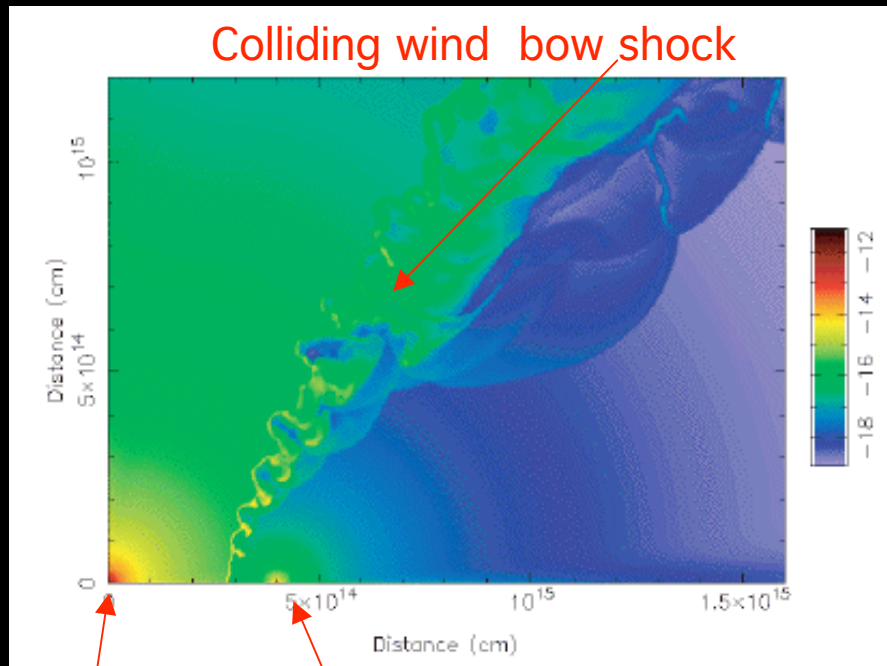
Hypothesis:

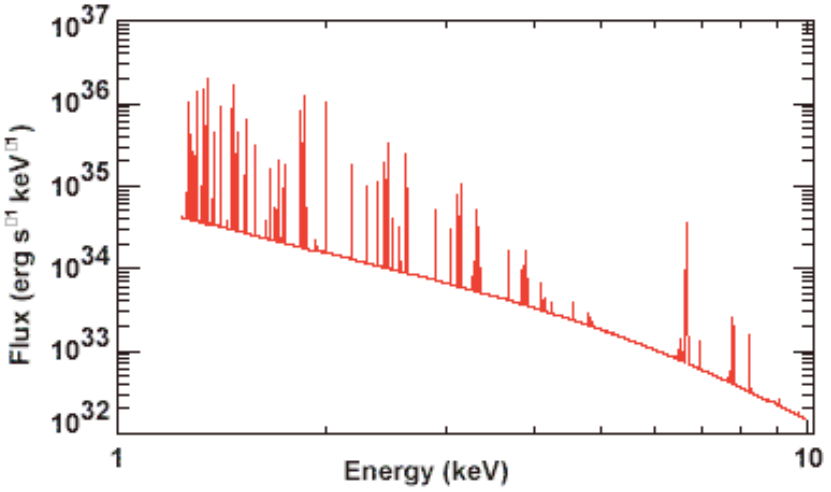
- All observed variability on the Damineli period caused by the presence of a hot, less massive companion

- X-ray variability caused by wind-wind collision

A colliding wind binary model:

Shocked Gas produces a thermal spectrum of a few keV





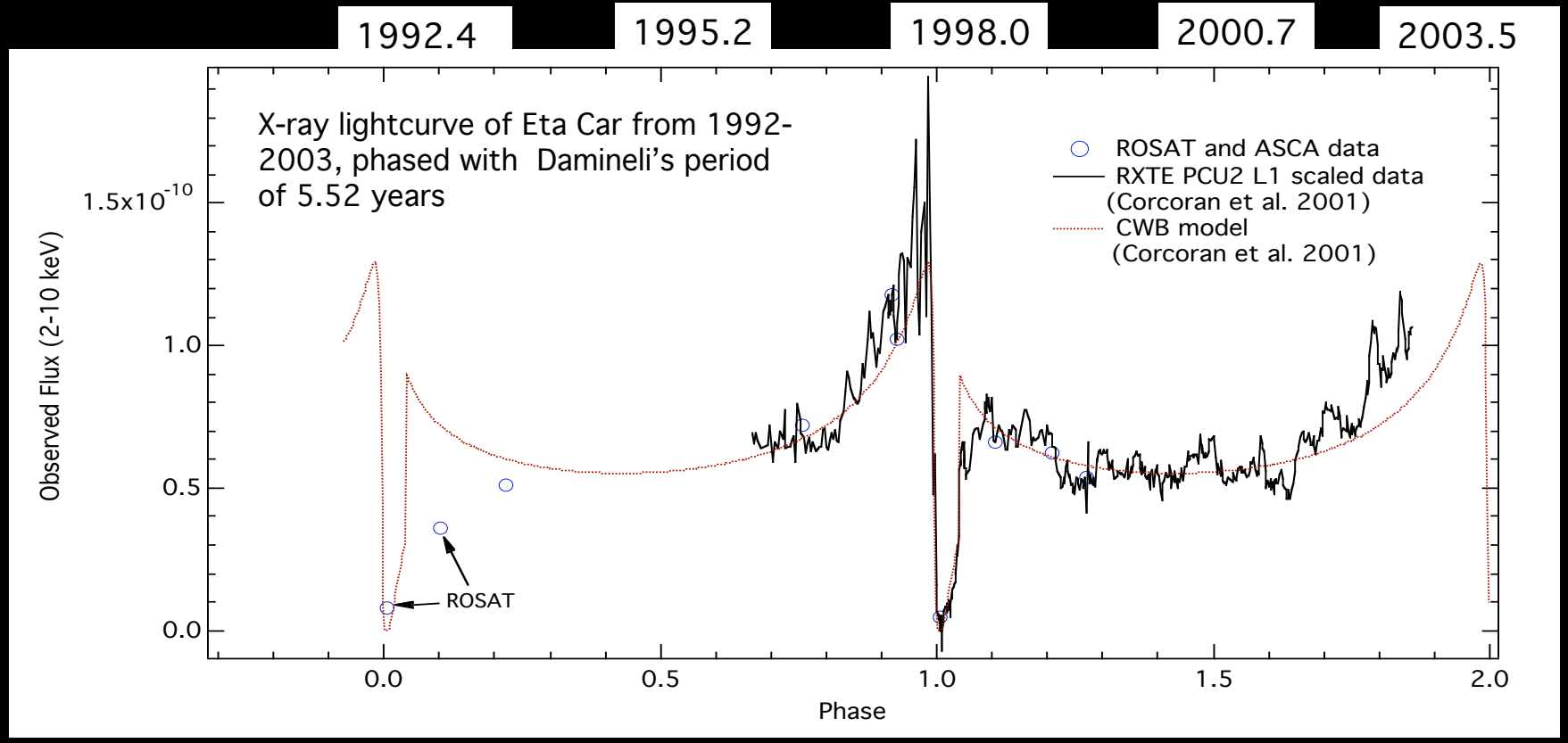
Eta Car

Companion star

Pittard & Corcoran 2002

X-ray Monitoring

Since 1992, X-rays from Eta Car have been monitored by ROSAT, ASCA, BeppoSAX and (since 1996) by RXTE. The 2-10 keV X-ray flux variation is below (ASCA and ROSAT shown as individual points, RXTE observations as a solid line). The red line is a colliding wind emission model from Corcoran et al. 2001.



The Orbit:

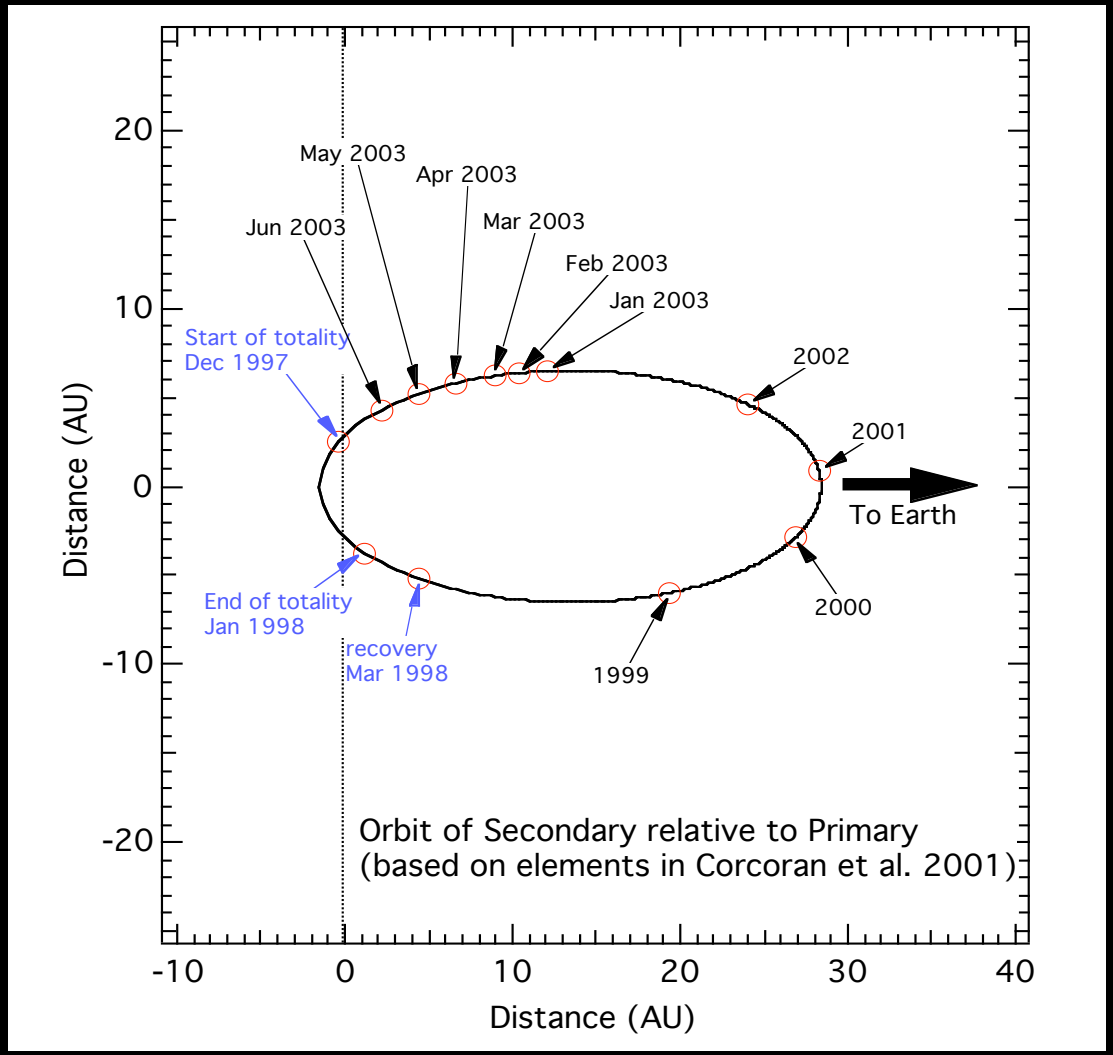


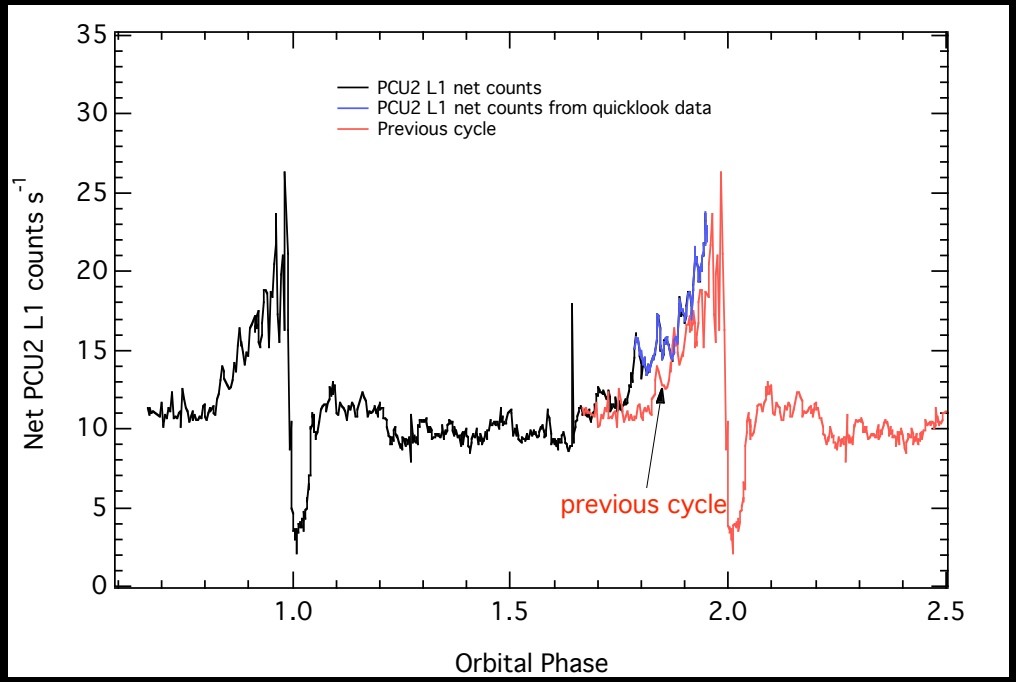
TABLE 1

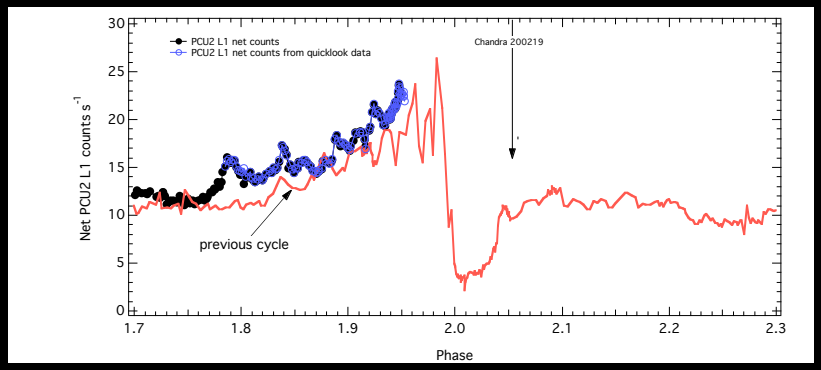
COLLIDING-WIND MODEL PARAMETERS

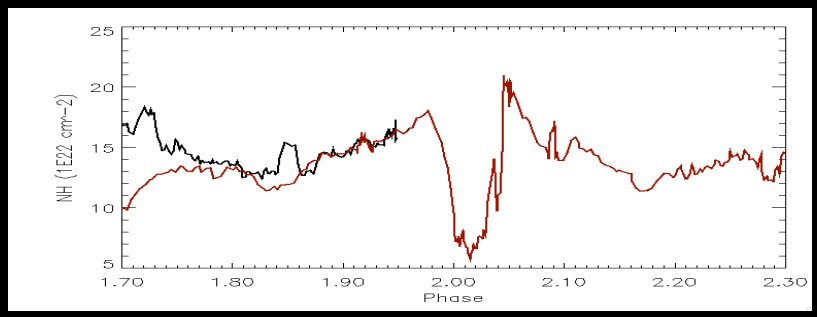
Parameter	Present Work	Damineli et al. 2000 Value
T_0 (periastron)	1997.95 ± 0.05	1998.13
e	0.90	0.75
P (yr)	5.52	5.53 ± 0.01
M_η ($M_\odot$)	80	70
M_c ($M_\odot$)	30	68
ω (deg)	275	
i (deg)	50	
γ (km s^{-1})	−12	
$\dot{M}_\eta$ ($M_\odot$ yr^{-1})	10^{-4}	
$\dot{M}_c$ ($M_\odot$ yr^{-1})	10^{-5}	
$V_{\infty,\eta}$ (km s^{-1})	500	
$V_{\infty,c}$ (km s^{-1})	2000	

- Highly eccentric (e~0.9) orbit
- line-of-sight along major axis
- X-ray totality when the companion moves behind Eta Car

Cycle-to-cycle variations:

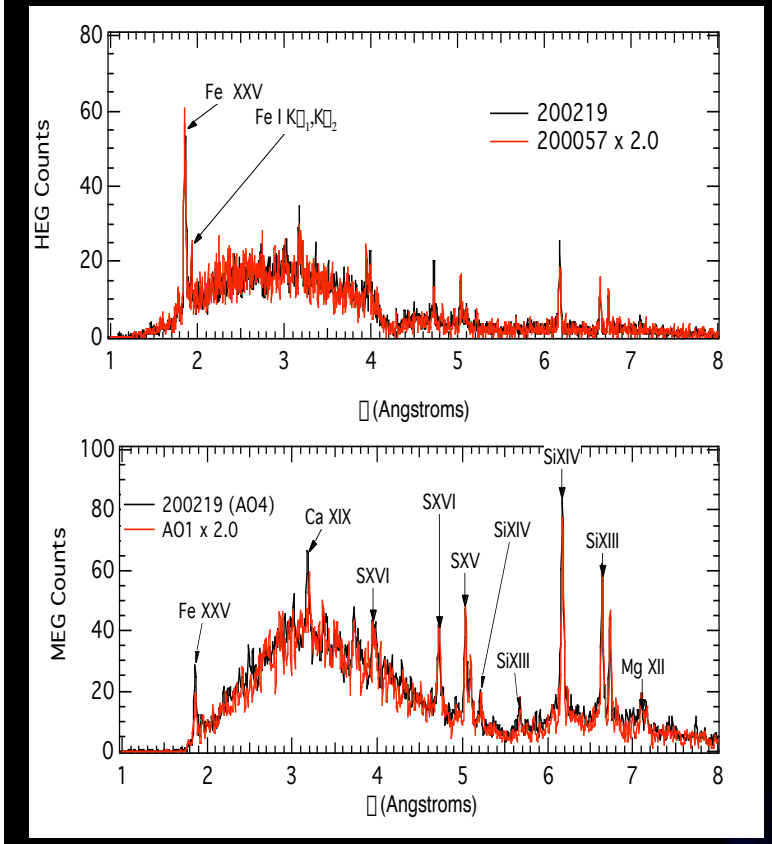


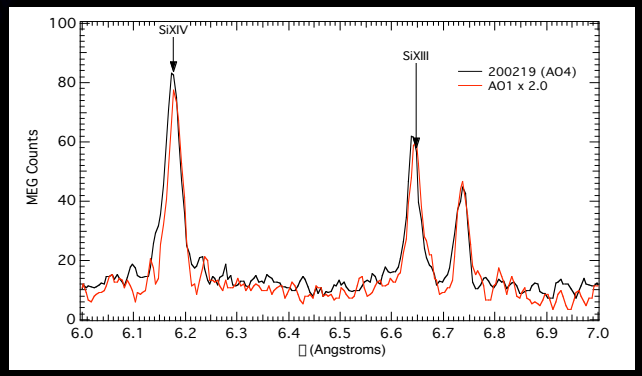


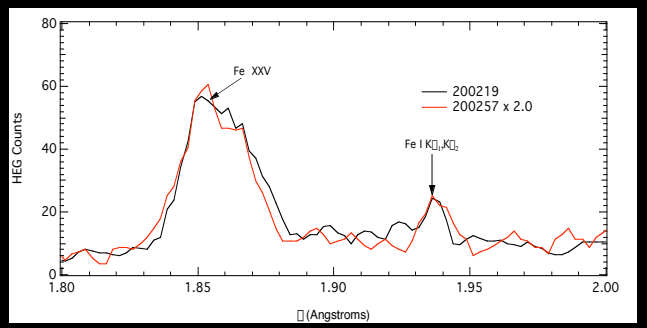


- A significant increase in the overall X-ray flux in the interval 1.78<□<1.95 compared to the 0.78<□<0.95 interval. This seems to suggest an overall increase in the X-ray flux in each cycle.
- despite the higher X-ray flux, the NH derived from the RXTE spectra in the 1.88<□<1.95 and 0.88<□<1.95 are in good agreement, though before that the NH seems to be larger in the current cycle

Grating Spectroscopy: Nov 2000 vs. Oct 2002







Conclusions…

- The X-ray emission from Eta Car is fairly consistent with simple colliding wind models
- BUT, as noted in Corcoran et al. (2001), the width of the eclipse suggests enhanced absorption after the companion moves in front of the primary, possibly evidence of enhanced mass loss from Eta Car near periastron
- Some evidence of enhanced mass loss near periastron in radio (Duncan & White 2003) and from STIS UV line profile changes (Smith et al. 2003)
- short-term (weeks) variations in X-rays with quasi-period of 85 days (Ishibashi et al. 1997; Ishibashi et al. 1999); origin still not clear

...and more Conclusions

- There is a significant cycle-to-cycle brightening in X-rays; the cause of this is unknown (maybe due to an increase in mass loss from the companion)
- The apparent increase in X-ray emission stands in contrast to the apparent decline in radio brightness in the most recent cycle (Stephen White et al. 2003) and a continued decline in the equivalent width of the He I 10830 line (Damineli et al. 2003).
- Aside from an overall increase in the flux (by about a factor of 2) the most recent CHANDRA spectrum is nearly identical to that obtained in A01. In particular the lines are still narrow, unshifted and the f/i ratio is large. What will happen near periastron?

The Next Eclipse:

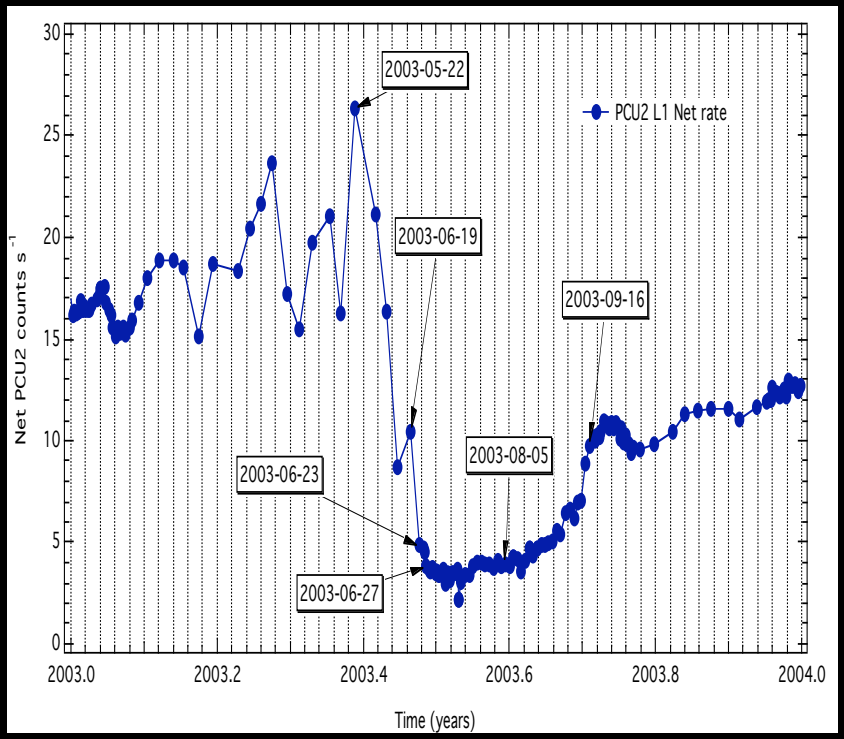
Based on the eclipse in 1998, we expect the X-rays to peak on May 22, 2003 and totality to start on June 27, 2003. X-ray observations have with Chandra, XMM & RXTE are approved.

Other observations include an HST "Treasury" Program (PI: K. Davidson), INTEGRAL observations (PI: Yousaf Butt), and ground based observations at the ATNF (B. Duncan, S. White), the LNA (Brazil: A. Damineli), CASLEO (Argentina: V. Niemela), and SAAO (P. Whitelock) and other observatories.

This will be one of the best-observed astronomical events ever

Goals of the Campaign:

- Measure/constrain radial velocity variations (Optical/UV lines: Eta Car; X-ray lines: Companion) to constrain the mass of Eta Car and the companion and provide the best measure of L/M
- Understand the changes in ionization in the Homunculus
- watch the star vary from different angles via reflection off walls of the homunculus
- Look for evidence of interactions near periastron
- Look for evidence of mass loss enhancements near periastron: “Little Great Eruptions?” Possible hint about the cause of the Great Eruption?



Expected X-ray variation, summer 2003

"They finally came together in a fearful last death grip, in the midst of thick clouds and tempestuous elements; they fell to the ground with such force that they shook the whole world."

SPEELYAI FIGHTS EENUMTLA, From: George Benson Kuykendall, 1889, in History of the Pacific Northwest: Oregon and Washington, Volume II, Part VI, Elwood Evans, North Pacific history company, Portland, Oregon, pp. 60-95. Reprinted in: Clarence B. Bagley, 1930, "Indian Myths of the Northwest", Lowman and Hanford Co., Seattle, WA.

see

http://lheawww.gsfc.nasa.gov/users/corcoran/eta_car/2003.5/

for updates on the observing campaign and

http://lheawww.gsfc.nasa.gov/users/corcoran/eta_car/etacar_rxte_lightcurve/

for the most recent RXTE lightcurve