The Chandra Delta Ori Large Project: Occultation Measurements Of The Shocked Gas In The Nearest Eclipsing O-Star Binary

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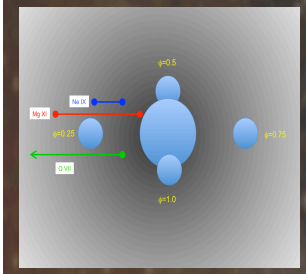


Schematic of the orbit of the secondary star around the primary in Delta Ori. The bars show the estimate of the formation regions of Ne IX, Mg XI and O VII from Miller et al. (2002 ApJ, 577, 951).

Introduction

Delta Ori is the nearest massive, single-lined eclipsing binary (O9.5 II + B0.5III). As such it serves as a fundamental calibrator of the mass-radius-luminosity relation in the upper HR diagram. It is also the only eclipsing O-type binary system which is bright enough to be observable with the CHANDRA gratings in a reasonable exposure. Studies of resolved X-ray line complexes provide tracers of wind mass loss rate and clumpiness; occultation by the X-ray dark companion of the line emitting region can provide direct spatial information on the location of the X-ray emitting gas produced by shocks embedded in the wind of the primary star. We obtained phase-resolved spectra with Chandra in order to determine the level of phase-dependent vs. secular variability in the shocked wind. Along with the Chandra observations we obtained simultaneous photometry from space with the Canadian MOST satellite to help understand the relation between X-ray and photospheric variability.

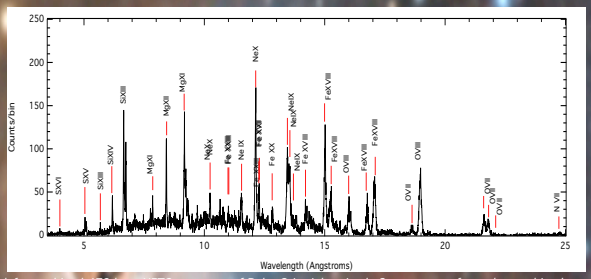
Chandra VLP Observing Log

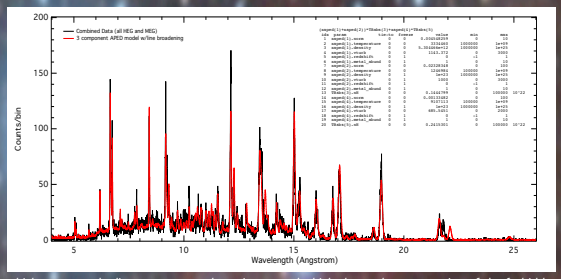
ObsID	14567	14568	14569	14570
Date Start	2012-12-19T16:54	2012-12-27T03:53	2012-12-22T06:06	2012-12-24T13:14
Phase Start	396.604	397.905	397.049	397.450
Date End	2012-12-21T01:48	2012-12-28T14:50	2012-12-23T16:12	2012-12-26T00:23
Phase End	396.844	398.159	397.297	397.705
Duration (Days)	1.34	1.46	1.42	1.46
Exposure (ksec)	115	122	119.3	122.5

δ Ori Parameters

Stellar Parameters		
	Star Aa1	Star Aa2
Sp. Type	O9.5II	B0.5 III
$R(R_\odot)$	17	7
$M(M_\odot)$	25	10
T_{eff} (K)	32900	24000
L_{bol} ($10^5 L_\odot$)	2.2	0.2
$\log g_{eff}$	3.38	3.76
$\dot{M}(M_\odot\ yr^{-1})$	10^{-6}	10^{-7}
V_∞	2000	1500
System Parameters		
P (days)	5.732436	
e	0.09	
i	67°	
ω	148°	
$T_{periastron}(MJD)$	54002.205 ± 0.060	

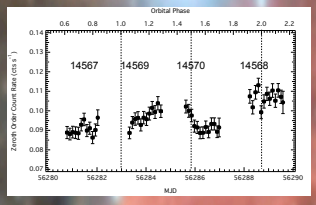
The Delta Ori HETGS spectrum:



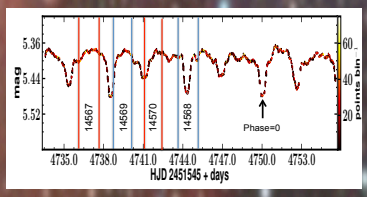


left: combined 478 ksec HETG spectrum of Delta Ori. right: simple 2 component fit to the combined spectrum, which recovers the line spectrum and continuum and which shows the suppression of the forbidden lines of OVII and Ne IX.

X-ray and Optical Variability



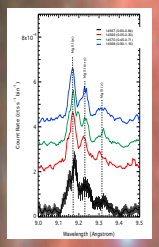
Chandra Zeroth-Order X-ray lightcurve (4-30 Angstroms)

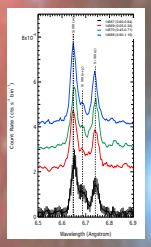


MOST lightcurve (3500-7000 Angstroms, courtesy MOST team). The vertical lines show the timing of the Chandra observations.

- *Unusually large variations in the X-ray lightcurve*
- *Significant non-phase-locked photometric variations: pulsations?*

He-like Lines: Mg XI and Si XIII





Summary

In December 2012 Delta Ori was observed by Chandra using the HETGS for a total of 478 ksec spanning an entire orbital cycle. Simultaneous photometric data with MOST was obtained, along with optical spectra by the Convento group. These observations show **changes** in the optical and X-ray photometry and X-ray emission line spectrum which are not strictly phase-locked, along with phase-locked variabilty.

See Poster by Nichols et al. (Session II #40) for a summary of the variability analysis.

This work was supported by Chandra grant GO3-14015A

H-like Lines: Ne X and O VIII