Optical Spectroscopy of γ-Ray Binaries

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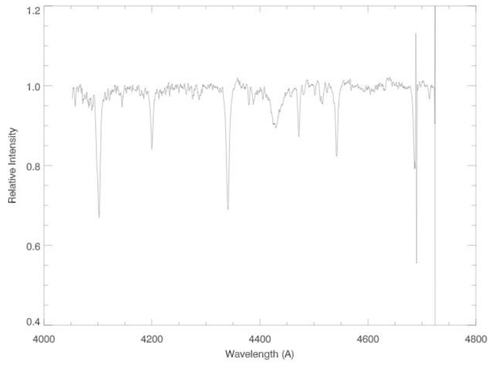

Figure 1: Spectra from the night of August 29, 2007 were coadded to create a reference spectrum. These spectra correspond with the time of inferior conjunction. V_r measurements for each spectrum in the data set were determined by cross-correlation with this reference spectrum. The data for this work were obtained at the CTIO 1.5m telescope between 2007 August and 2008 April.

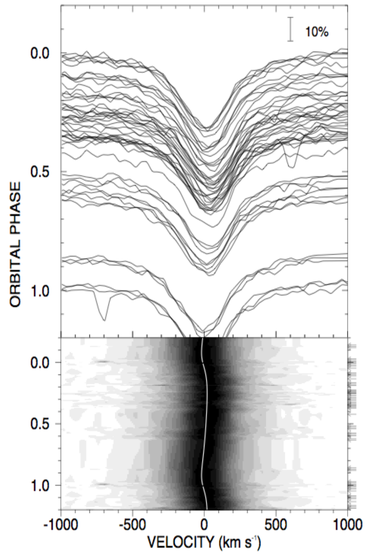

Figure 3: The Hγ line of LS 5039 is plotted as a function of orbital phase in the upper half of the figure. The lower portion shows a grayscale plot of the line. The orbital solution is overplotted as a white line.

Abstract

There are currently only 4 known HMXBs with very high energy MeV-TeV emission, or γ-ray binaries. These systems consist of O-type or B-type stars and neutron star or black hole companions. There are two models for the origin of the γ-ray emission. One suggests that the companion is an accreting neutron star or black hole. The other predicts a pulsar for the companion star, with relativistic winds that collide with the stellar winds. We are currently involved in a multiwavelength campaign to study the stellar/companion interactions and determine the mechanism producing the high energy emission in γ-ray binaries. We present optical spectra of LS 5039 from the CTIO 1.5m telescope and discuss the orbital parameters and stellar wind strengths. We also present new KPNO Coudé Feed spectra of LS I +61°303 and HD 259440, the proposed optical counterpart of the new γ-ray binary HESS J0632+057, for the first detailed optical investigation of that system.

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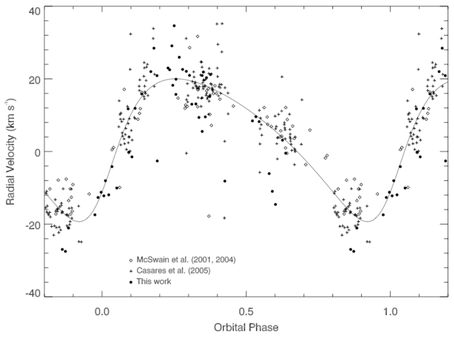

Figure 2: Radial velocity curve of LS 5039. The orbital solution was found using the least squares fitting program of Morbey and Brosterhus (1974). We find an orbital solution that is similar to that found by Casares et al. (2005).

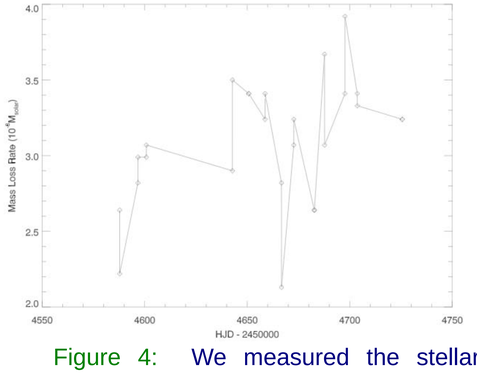

Figure 4: We measured the stellar mass loss rate of LS 5039 using the Hα equivalent width. Two measurements were made on each night of observation, so the scatter between each pair of measurements indicates the error bars in the mass loss rate. Red spectra of LS 5039 were obtained between 2008 May and September with the CTIO 1.5m telescope.

Table 1: Orbital elements of LS 5039 and LS I +61°303 (Aragona et al. 2009).

	LS 5039	LS I +61°303
P (d) ÉÉÉÉ.....	3.906116 (73)	26.4960[a]
T (HJD Š 2,450,000)	2825.972 (40)	1057.89 (23)
e ÉÉÉÉ É ÉÉ..	0.318 (25)	0.537 (34)
ω (deg) ÉÉÉÉÉ	234.2 (43)	40.5 (57)
K_1 (km s^{-1}) ÉÉÉ...	19.67 (58)	19.6 (11)
γ (km s^{-1}) ÉÉÉ.....	4.01 (31)	-41.41 (60)
f (m) (M$_\odot$) ÉÉÉ...	0.00263 (24)	0.0124 (22)
$a_1 \sin i$ (R$_\odot$) ÉÉÉ.	1.439 (44)	8.64 (52)
σ (km s^{-1}) ÉÉÉ.....	5.06	7.41

[a]Fixed.

For more information on the multiwavelength campaign, see the poster "X-ray And Radio Monitoring Of The Gamma-ray Binaries LS I +61°303 and LS 5039" by Mallory Roberts on Wednesday, January 7 (# 432.12).

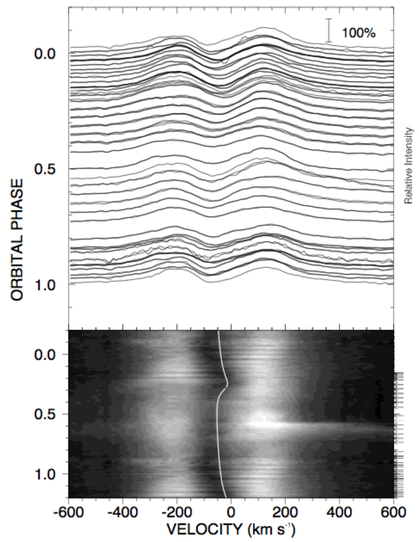

Figure 5: The Hα line of LS I +61°303 is plotted with respect to orbital phase in the top half of the figure. The lower portion of the figure shows a grayscale plot of Hα with our orbital solution for this system superimposed on the line core.

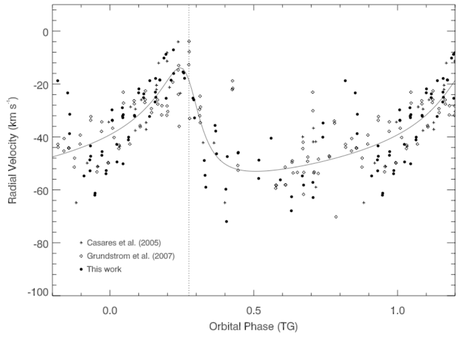

Figure 6: Radial velocity curve for LS I +61°303. The data were collected using the KPNO Coudé Feed telescope between 2008 October and November. Our orbital solution is similar to that of Grundstrom et al. (2007).

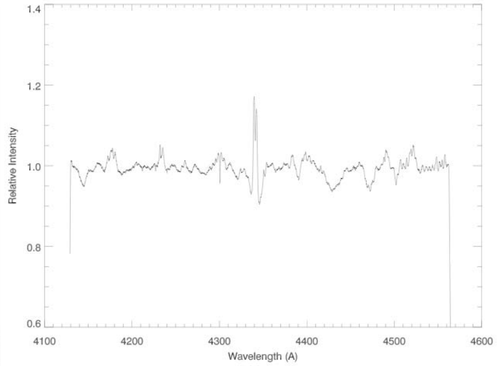

Figure 7: We present the mean blue spectrum of HD 259440 from our 2008 Coudé Feed run.

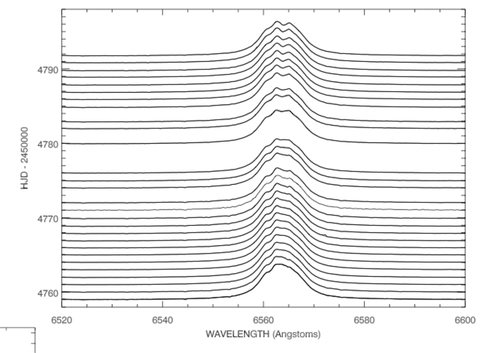

Figure 8: We present the Hα line profile variations of HD 259440 that we observed during our 2008 Coudé Feed run. The ripples moving across the line profile suggest changes in the disk density profile, possibly due to interactions with the companion.

References

Aragona, C. et al. 2009, ApJL, submitted

Casares, J. et al. 2005, MNRAS, 360, 1105

Casares, J. et al. 2005, MNRAS, 364, 899

Grundstrom, E. D. et al. 2007, ApJ, 656, 437

Hinton, J. A. et al. 2009 ApJL, 690, L101

McSwain, M. V. et al. 2001, ApJL, 558, L43

McSwain, M. V. et al. 2005, ApJ, 600, 927

Morbey, C. L. & Brosterhus, E. B. 1974, PASP, 86, 455