H-ALPHA LINE PROFILES OF KH 15D: WHAT DO THEY REVEAL? C. M. Hamilton[1], C. M. Johns-Krull[2], W. Herbst[3], R. Mundt and C. A. L. Bailer-Jones[4] [1]Mount Holyoke College/Five College Astronomy Department (chamilto@MtHolyoke.edu), [2]Rice University (cmj@rice.edu), [3]Wesleyan University (wherbst@wesleyan.edu), [4]Max Planck Institut für Astronomie (mundt@mpia.de, calj@mpia.de).

KH 15D, located in the young (2-4 Myr) open cluster NGC 2264 ($d \approx 760$ pc), is an extraordinary pre-main-sequence eclipsing binary system with a strongly eccentric orbit ($e \sim 0.7$). The observable star in this system is a K6/K7 [1-2], which undergoes deep eclipses (~ 4 mag in *I*) every 48.37 days. The eclipse depth and duration have been steadily increasing over the last decade [3]. The very slow advance of an occulting edge explains the evolution of the light curve of the system from the 1950's until the present [4-7]. A physical model of the system has been proposed in which the advance of this edge is the result of nodal precession of a circumbinary disk or ring [8-9]. The currently visible star is spending an increasingly large fraction of its orbital cycle (currently > 50%) obscured by the same material that obscures its companion 100% of the time. The system is very close to the Cone Nebula and undoubtedly a member of NGC 2264. It has all of the indications of a typical T Tauri star jet/outflow source, including forbidden optical emission lines [10], very broad H-alpha profiles [10], inverse P-cygni profiles and shocked molecular hydrogen emission [11-12]. The K6/K7 star is an X-ray source but a very weak one for its mass and age [13].

The edge of the occulting matter is remarkably sharp, and as it cuts across the visible star and its inner disk, it acts like a "natural coronagraph", progressively covering or revealing structure within a few stellar radii of the photosphere. During each ingress and egress we get convolved information on its density structure as well as the distribution of luminous material in the vicinity of the star. In the context of the model of a circumbinary disk, the sharpness of the occulting edge implies that dust has settled into a vertically thin and dense layer. The properties of this dusty layer resemble those imagined for the formation of planetesimals. Furthermore, it is now quite clear that there is an extended (blue) nebula around the visible star and probably around the invisible star [3]. This could be an inner disk or ring, a magnetically channeled accretion zone, an inner part of the jet or outflow, or a corona.

Here we present high-resolution echelle spectra (Keck/HIRES, VLT/UVES, McDonald/CE) of KH 15D in each of the four previous observing seasons. Our observations focus heavily on the phases of ingress and egress (see Fig. 1) in an effort to exploit the natural coronagraphic behavior of this system. The near IR colors of KH 15D show no signs of an inner dust disk [14]; however, our line profile observations clearly indicate ongoing accretion and outflow, and possibly provide direct detection of gas in the circumbinary occulting disk. An absorption feature in Na I D appears at or close to the systemic velocity and is, therefore, presumably arising in gas associated with the circumbinary material.

Our spectroscopic studies have revealed intrinsic variability and amazing structure in the H-alpha line profiles caused by high velocity gas flows in the vicinity of the stars. A strong, red-shifted (50-60 km/s) absorption component in the H-alpha profile is clearly observed while out of eclipse (see Fig. 2, top panel). The gas producing this feature must be along the line of sight to the star since the absorption reaches below the stellar continuum. This absorption component disappears as the star sets behind the occulting screen, suggesting that the gas causing this absorption feature is in an accretion flow onto the currently visible star.

During eclipse, the H-alpha emission-line profile takes on an entirely different shape (see Fig. 2, bottom panel). In general, it is narrower and double-peaked, with an underlying broad component, which ranges from roughly -350 to +350 km/s. At mid-eclipse however, the red-shifted part of this broad component is weak or absent. Of particular interest is the observation that near mid-eclipse and as egress begins, the double-peaked profile and its central absorption feature remain at roughly the same velocity even though each star's predicted radial velocity varies by more than 30 km/s during this time period. We suggest that the gas responsible for these components of the line profiles is in an outflow associated with the overall system.

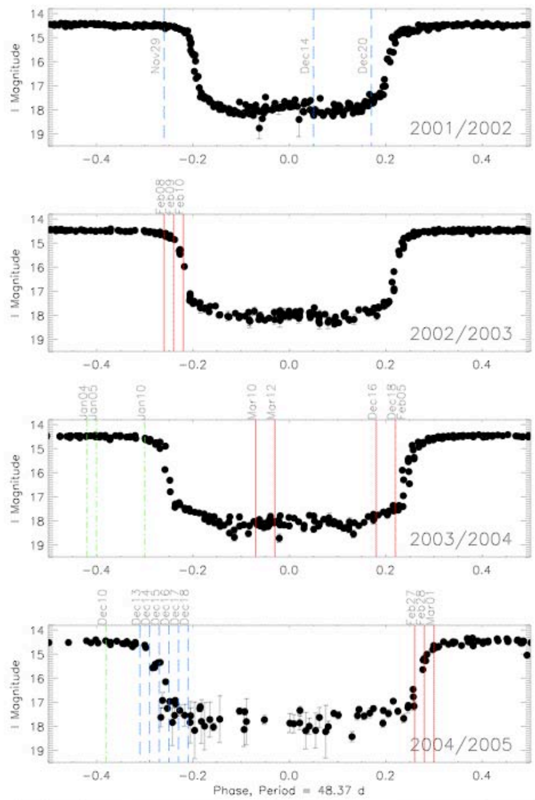

Fig. 1: The light curve of KH 15D in each of the four previous observing seasons. The UT dates for each of the high resolution spectra obtained are indicated. The blue dashed lines represent data obtained with VLT/UVES. The red solid lines represent data obtained with Keck/HIRES. The green dash-dot lines represent data obtained with McDonald/CE.

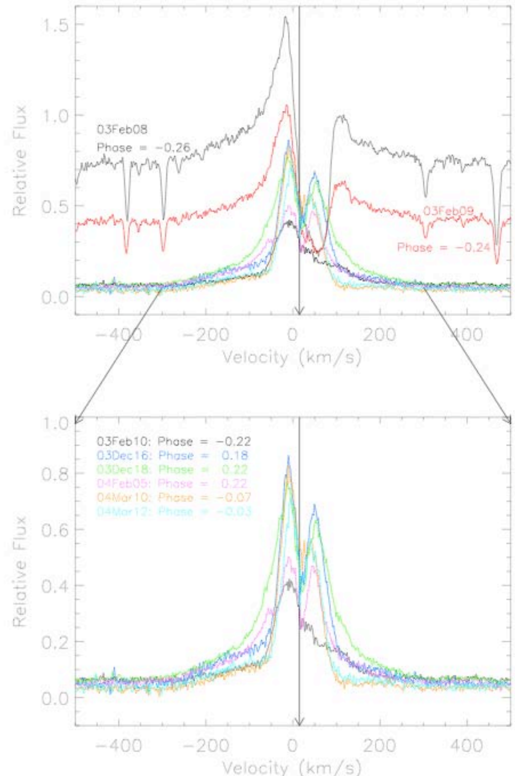

Fig. 2: UT dates, phases, and H-alpha line profiles obtained with Keck/HIRES in 2002-2004 are shown. Each spectrum has been corrected for barycentric motion and flux calibrated using the *R* magnitude that was observed closest in time. The arrow at +14.8 km/s represents the systemic velocity determined by Johnson et al. [15].

References: [1] Hamilton, C. M., et al. (2001), ApJ, *554*, L201. [2] Agol, E., Barth, A. J., Wolf, S., & Charbonneau, D. (2004), ApJ, *600*, 781. [3] Hamilton, C. M., et al. (2005), AJ, *in press*, astro-ph/0507578. [4] Winn, J. N., Garnavich, P. M., Stanek, K. Z., & Sasselov, D. D. (2003), ApJ, *593*, L121. [5] Johnson, J. A. & Winn, J. N. (2004), AJ *127*, 2344. [6] Johnson, J. A., et al. (2005), AJ, *129*, 1978. [7] Maffei, P., Ciprini, S., & Tosti, G. (2005), MNRAS, *357*, 1059. [8] Winn, J. N., et al. (2004), ApJ, *603*, L45. [9] Chiang, E. I. & Murray-Clay, R. A. (2004), ApJ, *607*, 913. [10] Hamilton, C. M., et al. (2003), ApJ, *591*, L45. [11] Deming, D., Charbonneau, D., & Harrington, J. (2004), ApJ, *601*, L87. [12] Tokunaga, A. T., et al. (2004), ApJ, *601*, L91. [13] Herbst, W. & Moran, E. C. (2005), AJ, *in press*, astro-ph/0506167. [14] Kusakabe, N., et al. (2005), *submitted*. [15] Johnson, J. A., et al. (2004), AJ, *128*, 1265.

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