National Aeronautics and Space Administration

The Peculiar Periodic YSO WL 4

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Objective

To investigate the planet-forming environment of young stars through photometric variability.

Description

We present the discovery of 130.87 day periodic near-infrared flux variability for the Class II T Tauri star WL 4 (= 2MASS J16271848-2429059, ISO-Oph 128) in ρ Ophiuchus. Our data are from the 2MASS Calibration Point Source Working Database, and constitute 1580 observations of a field in ρ Ophiuchus in J, H and Ks used to calibrate the 2MASS All-Sky Survey (shown at left).

We identify a light curve for WL 4 with an eclipse amplitude of ~0.4 mag lasting more than half the period, and color variations in J-H and H-Ks of ~0.1 mag (Figure 1). The long period cannot be explained by stellar rotation or a contact binary. In fact, we identify a second period of 4.84 days attributable to stellar rotation (Figure 2).

To explain the 130.87 day period, we assume we are observing two components of a binary alternately being eclipsed by a circum- binary disk with respect to our line of sight (Figure 3), analogous to the model for KH-15D - a YSO with a strikingly similar light curve (Figure 4). From Spitzer c2d observations, we model the SED and confirm the presence of a circum-binary disk and variability out to 8 microns.

This system will be useful in investigating terrestrial zone YSO disk properties and dynamics at ~1 Myr.

Figures

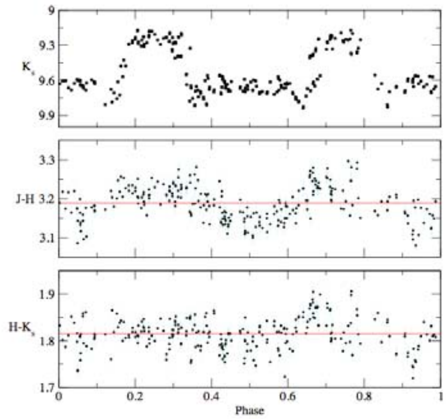

Figure 1. Top Panel - K_s band Cal-PSWDB light curve data in black for WL 4. Middle Panel: J-H Cal-PSWDB color curve. Bottom Panel: H-K_s Cal-PSWDB color curve. Data are folded to a period of 130.87 days, and plotted as a function of period phase. The "kink" in the K_s light curve at phases of ~0.28 and 0.72 is also present for the J and H light curves. For all panels, each group of six scans from a single hourly calibration observation are co-added, and 1-σ error bars are shown in teal.

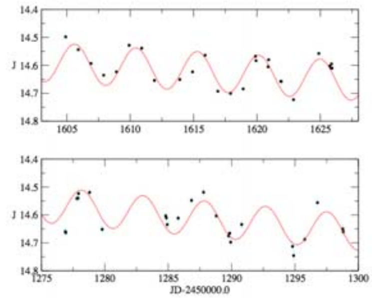

Figure 2. Portions of the J-band light curve data during the faint state to show the star-spot variability modulated by the ~5 day stellar rotation period. Overlaid in red are the best fitting sinusoids plus linear ramps. The best-fit sinusoids have different phases for all of the spans of faint or bright states that we investigate, implying star-spot evolution with a coherence time-scale longer than the rotation period and on the order of the binary period. We attribute the linear ramps of 3-16 milli-mag per day to the smoothly varying extinction of the veiled component in the faint state. Sinusoidal variations are largest in amplitude at J-band relative to Ks -band, consistent with star-spots.`

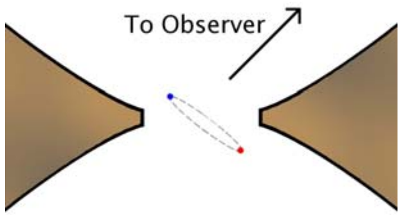

Figure 3. Schematic diagram of the model for WL 4. WL 4a is shown as a blue circle and WL 4b as a red circle, with the size of the circles representing the approximate stellar sizes. A hypothetical circular orbit is shown as a dashed black line, approximately to scale. A flared circumbinary disk is shown in brown, inclined relative to the orbit of the binary. We do not model the structure/stability of the inner edge of the disk. The arrow represents the direction from which we are observing WL 4 to explain the periodic veiling.

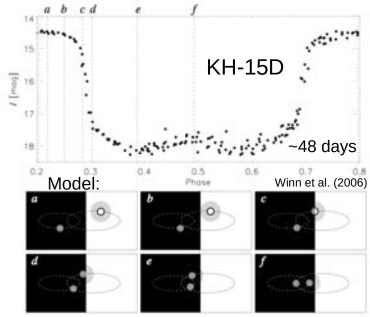

Figure 4. KH-15D light curve and model, for comparison to WL 4.

Publications

Plavchan, P, Gee, Alan H., Stapelfeldt, K., & Becker, A., 2008, ApJL, submitted