Near-Infrared Light Curves of a Young, Eclipsing Binary of Brown Dwarfs

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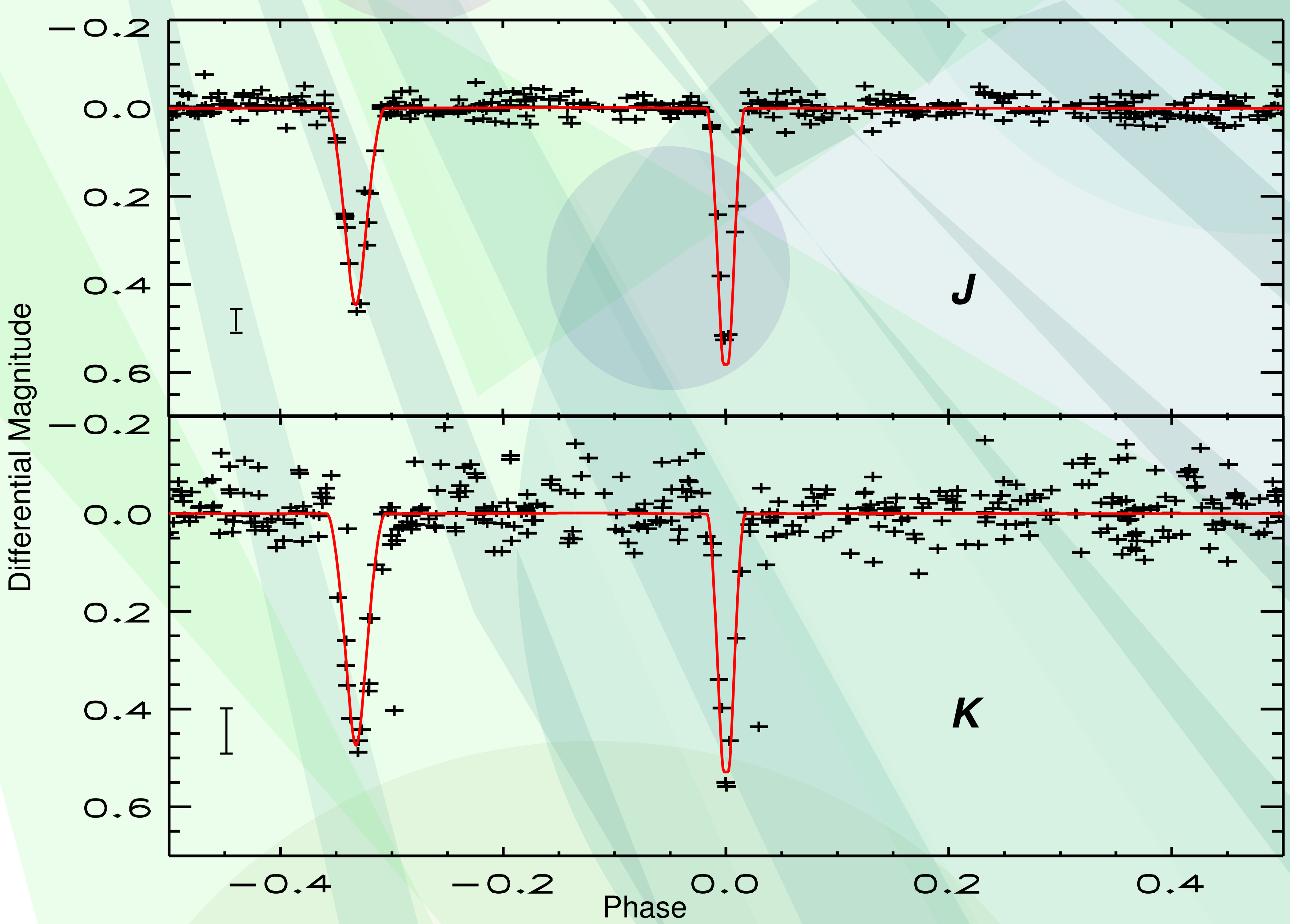
First Direct Measurements of Fundamental Brown Dwarf Properties

Masses of pre-main sequence objects are the foundation of the understanding of star formation since they define the outcome of the formation processes and they represent the observational tie to the theoretical models of stellar formation and evolution.

This eclipsing binary system, 2MASS J05352184–0546085, in which both components are brown dwarfs (Stassun et al. 2006), is of particular interest because it provides with the measurements of the two least massive of pre-main-sequence objects known to date, and consequently furnishes useful data for testing the predictions of current early evolution and star formation models. The system is a member of the Orion Nebula Cluster, and therefore has a likely age of only a few million years. Its eclipsing binary nature yields, thorough spectroscopic and photometric analysis, highly accurate properties of the system and of its components, in such a manner that they are determined independently of their distance and other assumptions.

Near-Infrared Light Curves: Temperature Reversal Confirmed

We present near-infrared light curves for this system modeling them using a Wilson-Devinney based code to derive fundamental system properties, including mass, effective temperatures and radii. Our analysis confirms previous published results and includes *JK* light curves obtained with the 1.3m SMARTS telescope at CTIO in Chile, taken from October 2003 to April 2006.



System Parameters

We model simultaneously radial velocity curves and light curves using a Wilson-Devinney based code, using as initial values the published parameters (see first column in the table below). The spectral type of the primary component is *M6.5*, which was obtained through a cross-correlation technique yielding an effective temperature of **2715 ± 100 K**, according to recent calibrations of the temperature scale for brown dwarfs. The system's center of mass has a heliocentric velocity of 24.1 ± 0.4 km s^{-1}, a signature of it's membership to the star forming region of Orion.

	Previously	*JK*⁺	*IJK*⁺
Period (*days*)	9.776213	9.779578	
Eccentricity, *e*	0.3225 ± 0.0060	0.3446 ± 0.0042	0.3381 ± 0.0015
Orientation of periastron, ω	215.4 ± 1.1	221.16 ± 0.9	219.6 ± 0.3
Semi-major axis, *a* sin *i* (*AU*)	0.0398 ± 0.0010	0.0406 ± 0.0011	0.0407 ± 0.0010
Mass ratio, $q \equiv M_1/M_2$	0.625 ± 0.018	0.663 ± 0.006	0.661 ± 0.002
Total Mass, $M \sin^3 i$ ($M_\odot$)	0.0880 ± 0.0076	0.0933 ± 0.0075	0.0943 ± 0.0072
Inclination angle, *i* (°)	88.8 ± 0.2	88.9 ± 0.2	88.7 ± 0.05
Primary Mass, M_1 ($M_\odot$)	0.0541 ± 0.0046	0.0562 ± 0.0046	0.0569 ± 0.0044
Secondary Mass, M_2 ($M_\odot$)	0.0340 ± 0.0027	0.0372 ± 0.0030	0.0376 ± 0.0028
Primary Radius, R_1 ($R_\odot$)	0.669 ± 0.034	0.725 ± 0.020	0.718 ± 0.018
Secondary Radius, R_2 ($R_\odot$)	0.511 ± 0.026	0.472 ± 0.013	0.512 ± 0.013
Effective Temperature ratio, T_1/T_2	1.054 ± 0.006	1.084 ± 0.004	1.078 ± 0.001

+ Preliminary results: the errors of the fixed parameters are taken to be 0.0, and will be included in further studies.

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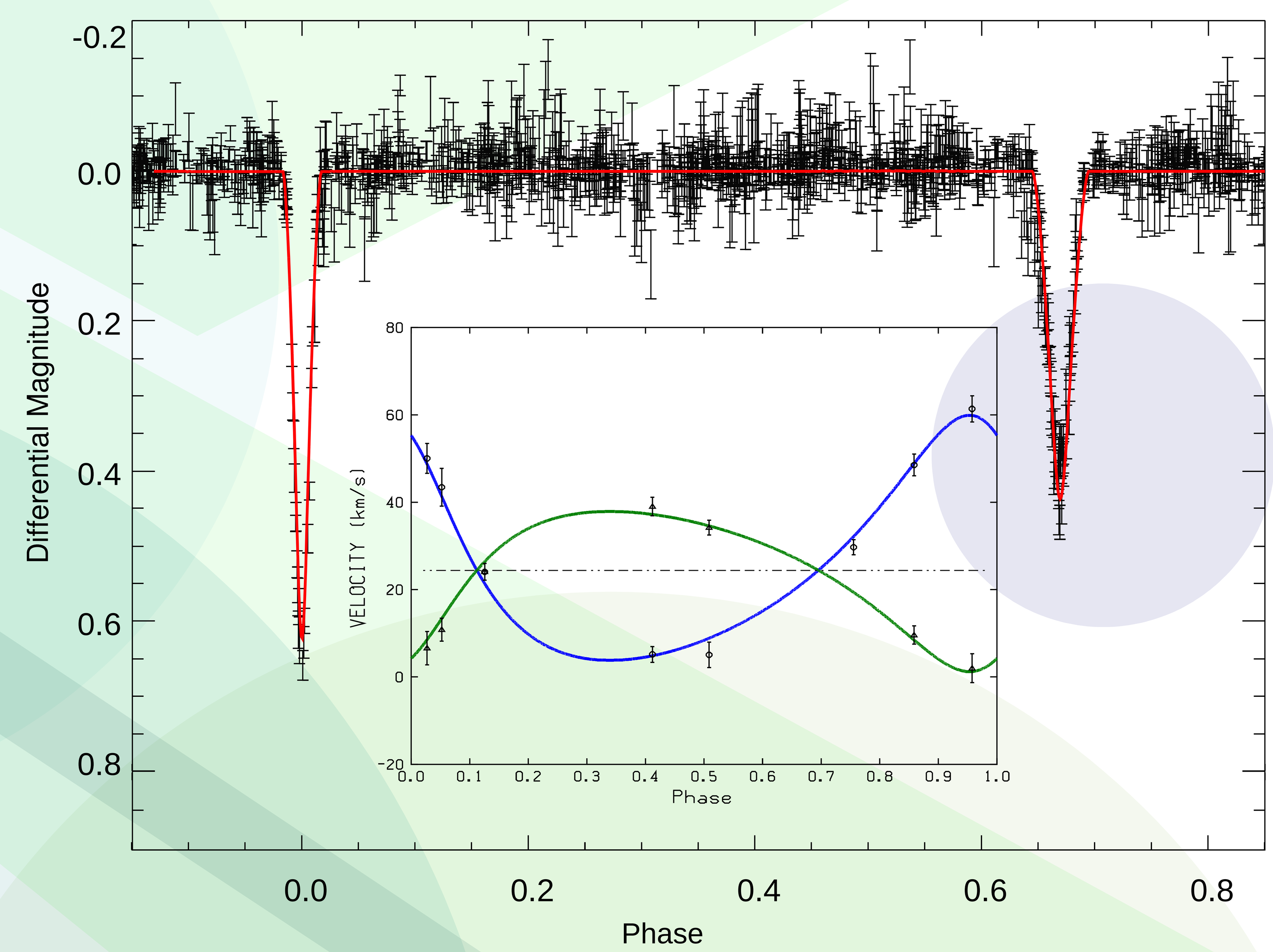
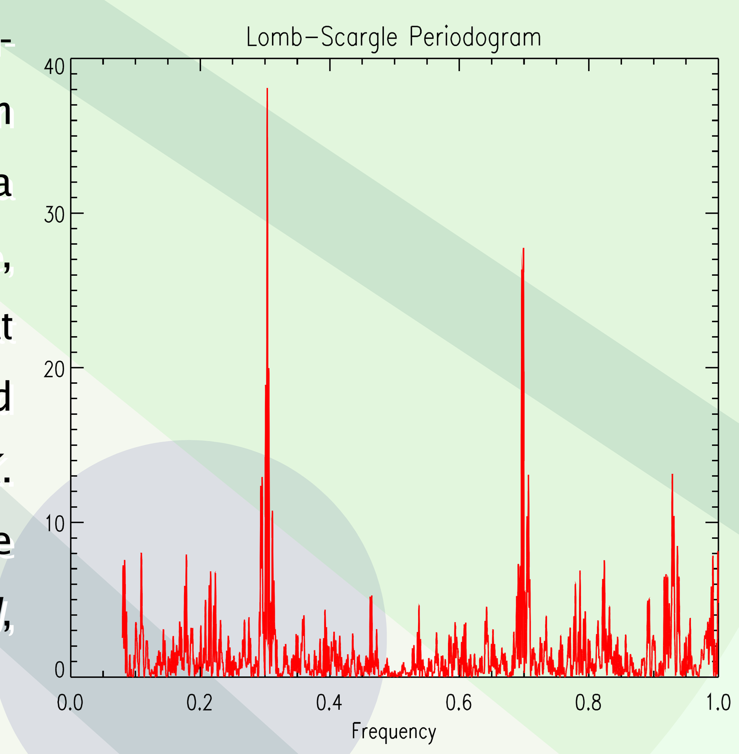
Surprising Reversal of Temperatures Revealed

The first results were published by Stassun et al. (2006), presenting an analysis of the following orbit solution and the I-band light curve. The system was found to be composed of *two brown dwarfs* and, consistent with PMS tracks, both components have *large radii* compared to older brown dwarfs. But the most surprising result was that **the most massive component is cooler than its companion**.



Might Spots Solve this Mystery?

Spots are a potential contributor of non-blackbody spectra and could explain the reversed temperature ratio. Using a Lomb-Scargle Periodogram technique, a rotation period of 3.29 days, of at least one of the components, was found in the *J* and *H* bands, and faintly in *K*. The peak-to-peak amplitude of the sinusoidal signal is 0.027 mag in *J*, 0.021 in *H* and 0.028 in *K*.



Conclusions

- We have confirmed that they are indeed **brown dwarfs** since their masses are below the hydrogen burning limit (< 0.072 $M_\odot$, Chabrier et al.)

- Their **radii** are larger than those of older brown dwarfs, consistent with the evolution theories that predict that brown dwarfs due to their lack of hydrostatic pressure cool and contract with time.

- The surprising **reversal of temperatures**, first identified in the I-band, is also present in the near-infrared bands.

- A **rotation period** of 3.29 days of one or both of the components was found. Due to its young age, the system has not yet become synchronized with the orbital angular velocity. However, in order to include spots in the light curve analysis they have to be modelled physically. Could spots be the answer to the reversal of temperatures?

References

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