From Interacting Binaries to Exoplanets: Essential Modeling Tools
Proceedings IAU Symposium No. 282, 2011
Mercedes T. Richards & Ivan Hubeny, eds.

doi:10.1017/S1743921311027219

Asymmetric Transit Curves as Indication of Orbital Obliquity: Clues from the Brown Dwarf Companion in KOI-13

G. M. Szabó[1], R. Szabó[1], J. M. Benkő[1], H. Lehmann[2], G. Mező[1], A. E. Simon[1], Z. Kővári[1], G. Hodosán[1], Z. Regály[1] and L. L. Kiss[1,3]

[1]Konkoly Observatory of the Hungarian Academy of Sciences, P.O. Box 67, H-1525 Budapest, Hungary, email: szgy@konkoly.hu
[2]Thüringer Landessternwarte, 07778 Tautenburg, Germany
[3]Sydney Institute for Astronomy, School of Physics A28, University of Sydney, NSW 2006, Australia

Abstract. Exoplanets orbiting rapidly rotating stars may have unusual light curve shapes. These objects transit across an oblate disk with non-isotropic surface brightness, caused by the gravitational darkening. If such asymmetries are measured, one can infer the orbital obliquity of the exoplanet and the gravity darkened star, even without the analysis of the Rossiter-McLaughlin effect or interferometry. Here we introduce KOI-13 as the first example of a transiting system with a gravity darkened star.

1. Summary

• KOI-13 is a common proper motion binary, with two rapidly rotating components ($v \sin i \approx$65–70 km/s). The transit curves show significant distortion that was stable over the ∼130 days time-span of the data.

• These distortions are due to gravity darkening of a rapidly rotating star. KOI-13 is it *the first example for detecting orbital obliquity for a substellar companion without measuring the Rossiter-McLaughlin effect from spectroscopy.*

• After correcting the *Kepler* light curve to the second light of the optical companion star, we derive a radius of 2.2 R_J for the transiting object, implying that the object is a late-type dwarf. KOI-13 is *also the first example for a late-type dwarf on close-in orbit around an A-type primary.*

See further details in Szabó *et al.* (2011).

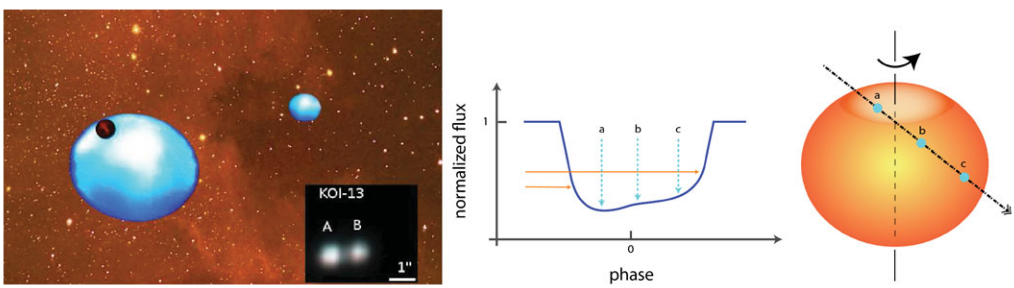

Figure 1. Fig. 1. Left: An artist's concept of KOI-13 (main panel) and its false color (V,I) image (insert) with lucky imaging from Konkoly Observatory, 2011 April 20. Right: Predicted distortion in transit light curves with stellar temperature gradient due to gravity darkening caused by the rapid rotation of the host star. This schematic figure is based on the Barnes (2009) models.

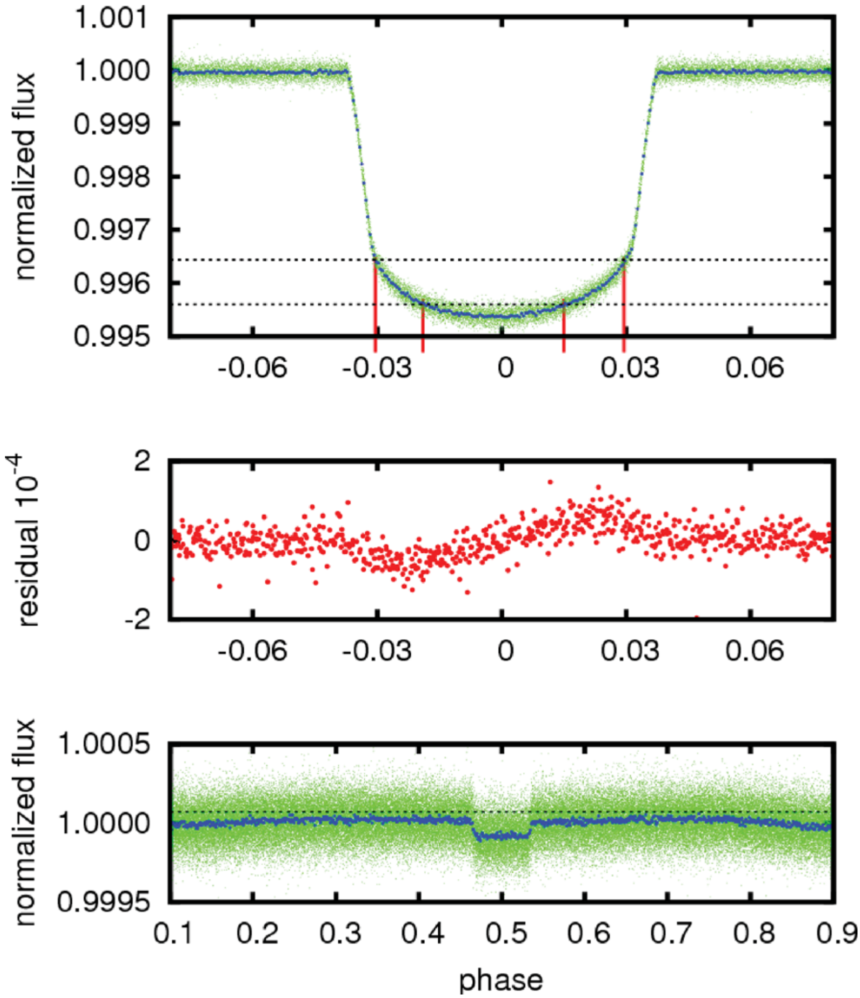

Figure 2. Fig. 2. Fig. 3. Top: folded *Kepler* light curve of KOI-13 (A and B components together; epoch=JD 2454953.56498, period=1.7635892 (Borucki *et al.* 2011) with a grid highlighting the most important asymmetries. The lower grid line intersects the light curve at a relative flux of 0.9956, and the orbital phase of the bottom of the transit is marked. Evidently, the floor of the light curve is shifted towards the ingress phase. Middle: the residuals of the transit to a symmetric template.The residuals contain about 1/40 of the total light variation. Bottom: the out-of-transit phase and the eclipse. The depth of the eclipse results in an effective temperature of 3150 K, which is compatible to the equilibrium temperature of the close-in companion and some internal heating. The size of KOI-13.01 is 2.2±0.1 R_J. There is no example for such large planets among the known exoplanets (Szabó and Kiss, 2011). Thus, we conclude that KOI-13.01 is likely a brown dwarf, or at the very low-end of the red dwarf stars.

This work is supported by the Hungarian OTKA Grants K76816, K83790 and MB08C 81013, and the “Lendület” Young Researchers’ Program.

References

Barnes, J. W. 2009, *ApJ*, 705, 683
Szabó, Gy. M. *et al.*, 2011, *ApJ* (Letters), 736, 4
Szabó, Gy. M. & Kiss, L. L. 2011, *ApJ* (Letters), 727, 44