

Asymmetric transit curves as indication of orbital obliquity: clues from the brown dwarf companion in KOI-13



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KOI-13 is a common proper motion binary, with two rapidly rotating components ($v \sin i \approx 65\text{--}70$ km/s). Its planet-sized companion, KOI-13, was announced as one of the 1235 *Kepler* planet candidates in February 2011. The transit curves show significant distortion that was stable over the ~ 130 days time-span of the data. Here we investigate the phenomenon via detailed analyses of the two components of the double star and a re-reduction of the *Kepler* data with pixel-level photometry. We identify the host star of KOI-13.01 and conclude that the transit curve asymmetry is consistent with a companion orbiting a rapidly rotating, possibly elongated star on an oblique orbit. 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 transiter, implying that the object is a hot brown dwarf. KOI-13 is the first example for detecting orbital obliquity for a substellar companion without measuring the Rossiter-McLaughlin effect from spectroscopy.

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INTRODUCTION

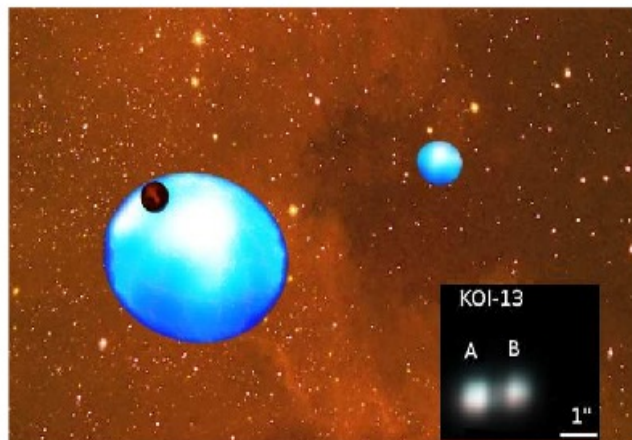
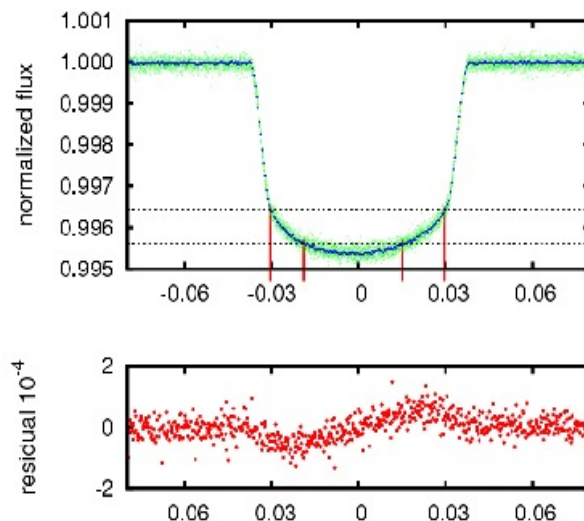


Fig. 1. Top: An artist's concept of KOI-13 (main panel) and its false color (V,I) image (insert) with lucky imaging from Konkoly Observatory, 2011 April 20.

ANALYSIS



CONCLUSION

KOI-13 is a double star, but it is unresolved in the *Kepler* images, because of the coarse image sampling of $3''/98/\text{pixel}$. With two independent tests, we found that the brighter star, KOI-13 A, hosts the transiting component. We did the pixel-level photometry based on the publicly available *Kepler* target pixel files. We segmented the vicinity of KOI-13 into 4 quarters. KOI-13 A is in the left segment, and the largest light variation of KOI-13 A was detected here. Another evidence is a transit on 17/18 April which was observed from the Piskésetető Station of the Konkoly Observatory with lucky imaging/fast photometry. The individual flux ratios were binned to 27 data points. The similarity between the predicted and observed light variation verifies that KOI-13 A has diminished (Fig. 4).

We conclude that the host of KOI-13.01 is KOI-13 A.

The measured depth of the transit is 4600 ppm before applying the correction, thus the corrected depth is 8400 ppm. We fitted a parametric planet model (Mandel and Agol 2002) to the reconstructed light curve. The resulting values are $r_p/r_* = 0.0884 \pm 0.0027$, $b = 0.75$, $D = 2.824 \pm 0.002$ h. The relative size of KOI-13.01 is $2.2 \pm 0.1 R_J$. This is consistent with a hot brown dwarf companion.

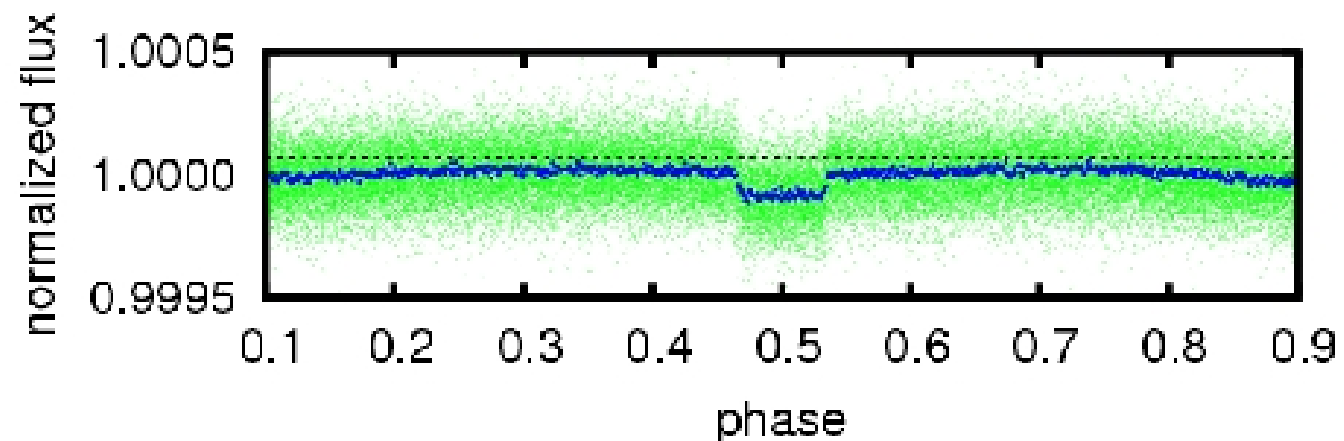
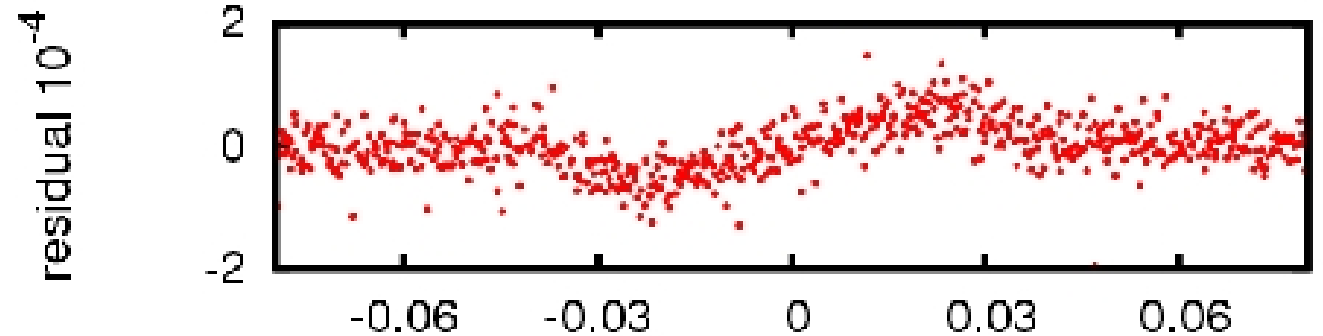
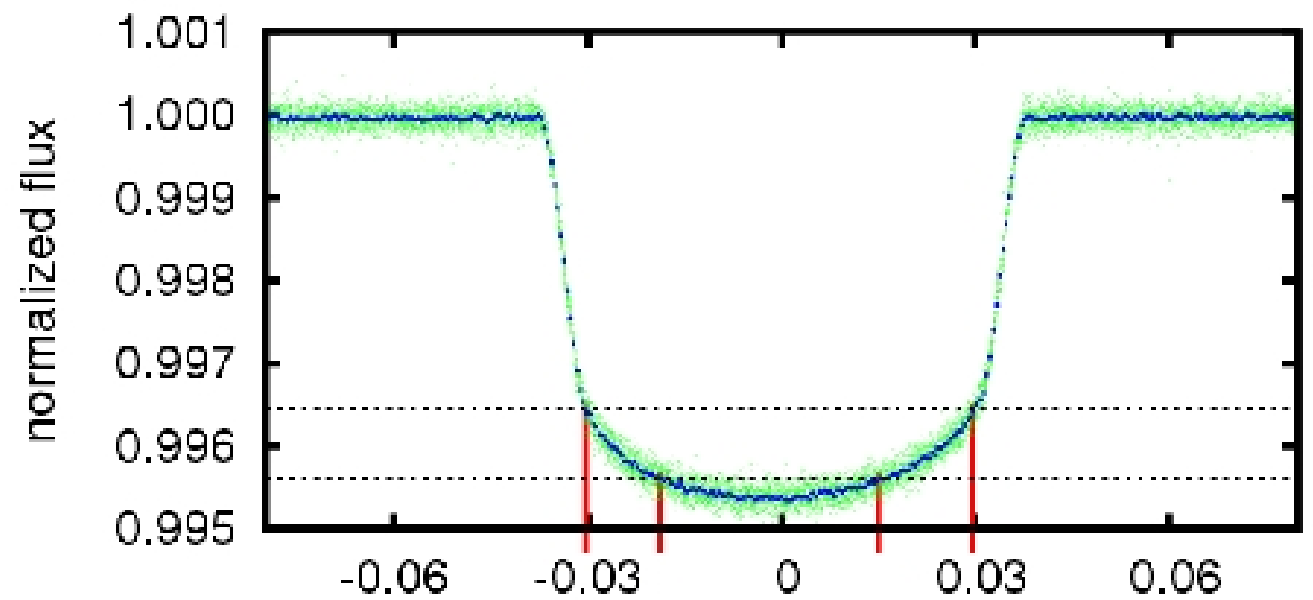
KEPLER light curve

1.8 d period
planet candidate

Prominent distortions near the minimum

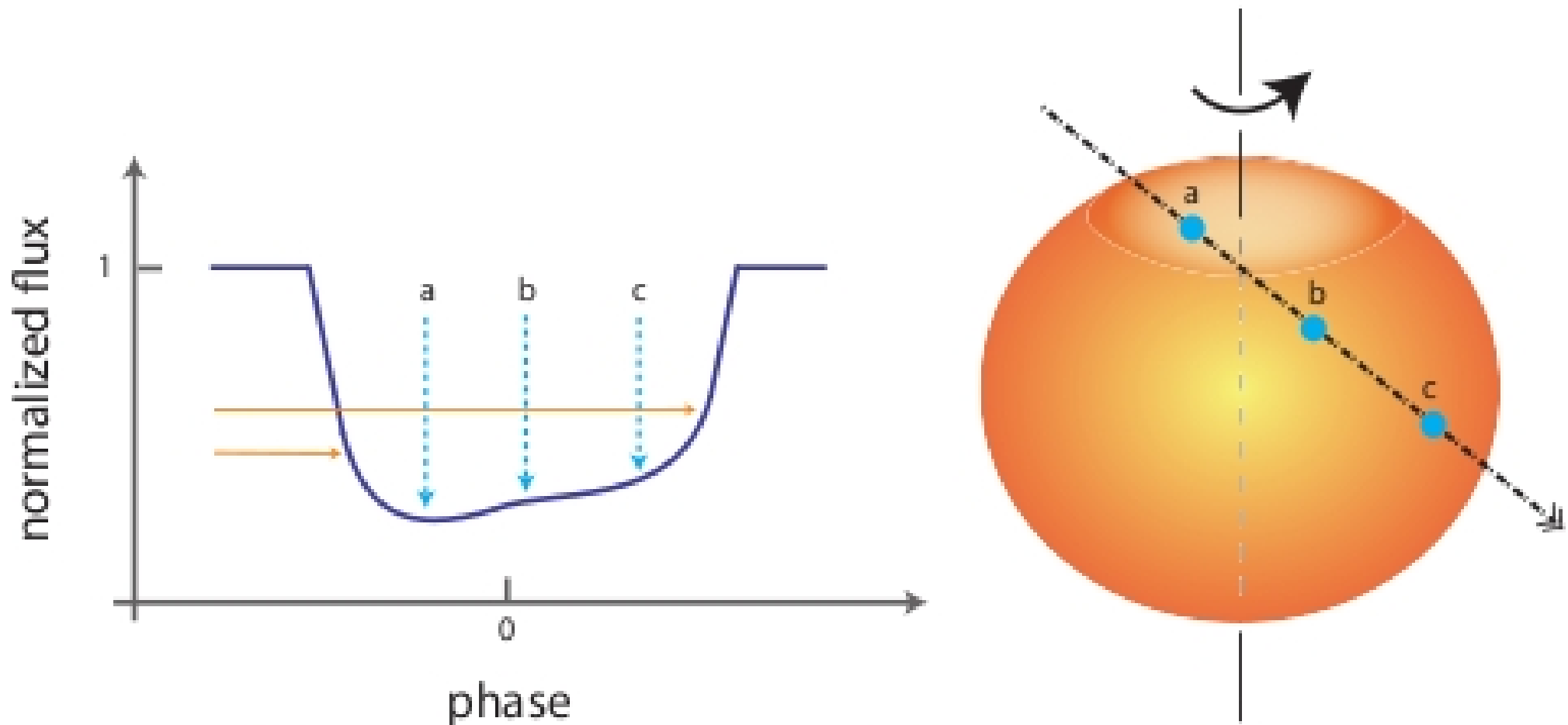
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Secondary eclipse
~3150 K companion
(A-type primary)



Explanation of the exotic light curve: gravity darkening

The first system for which the orbital obliqueness is detected only from photometry!



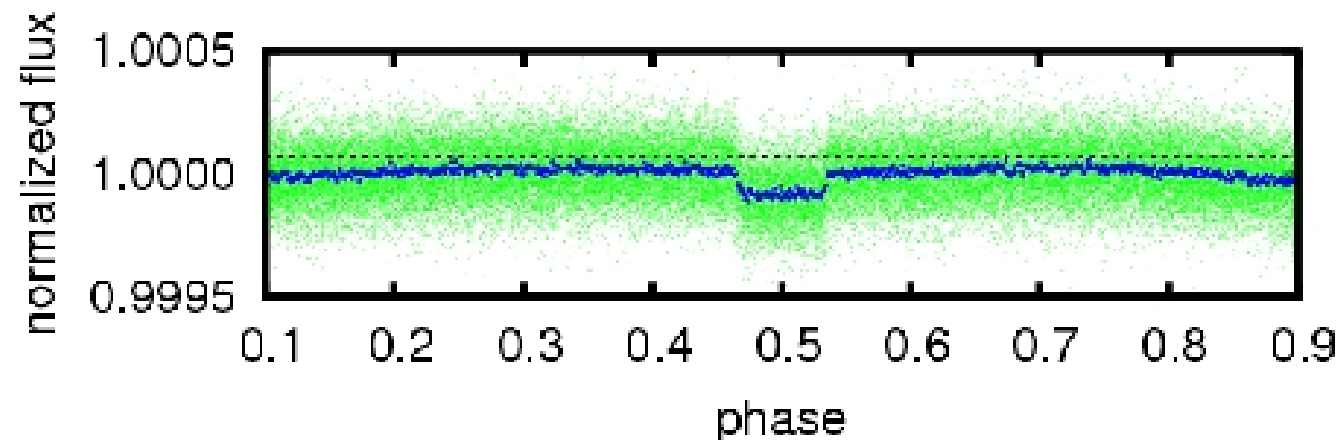
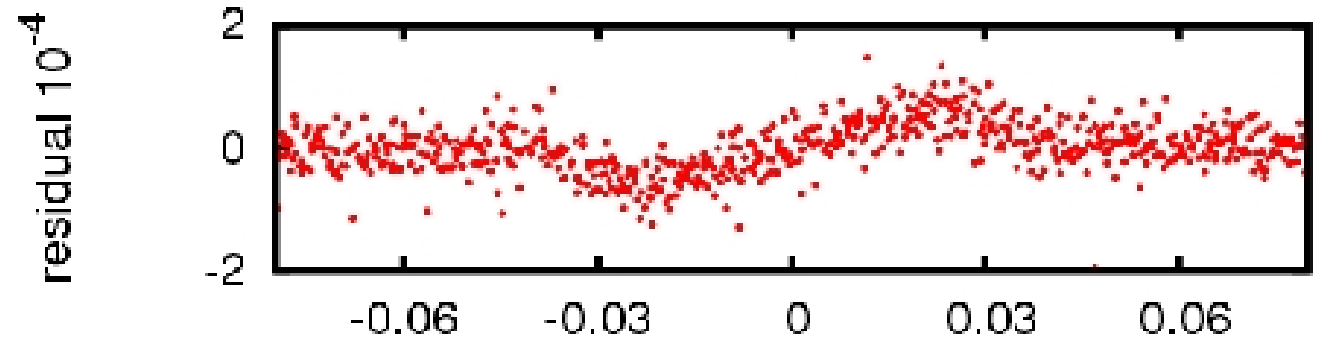
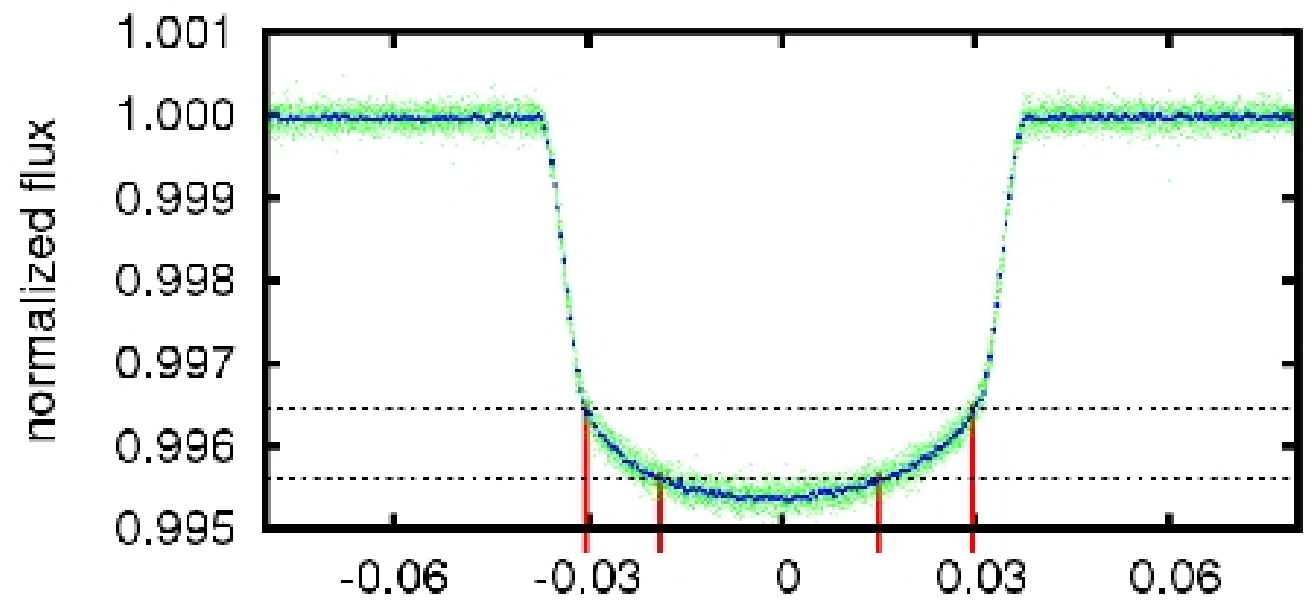
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KOI-13

A B

1"

Kepler re-reduction
+
Lucky photometry

=

The host of KOI-13.01
is KOI-13 A.

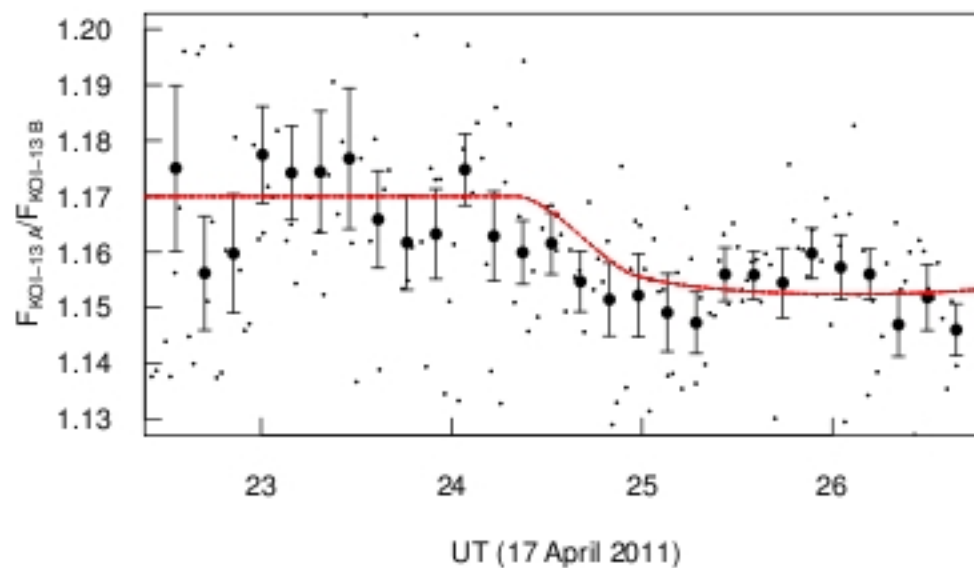
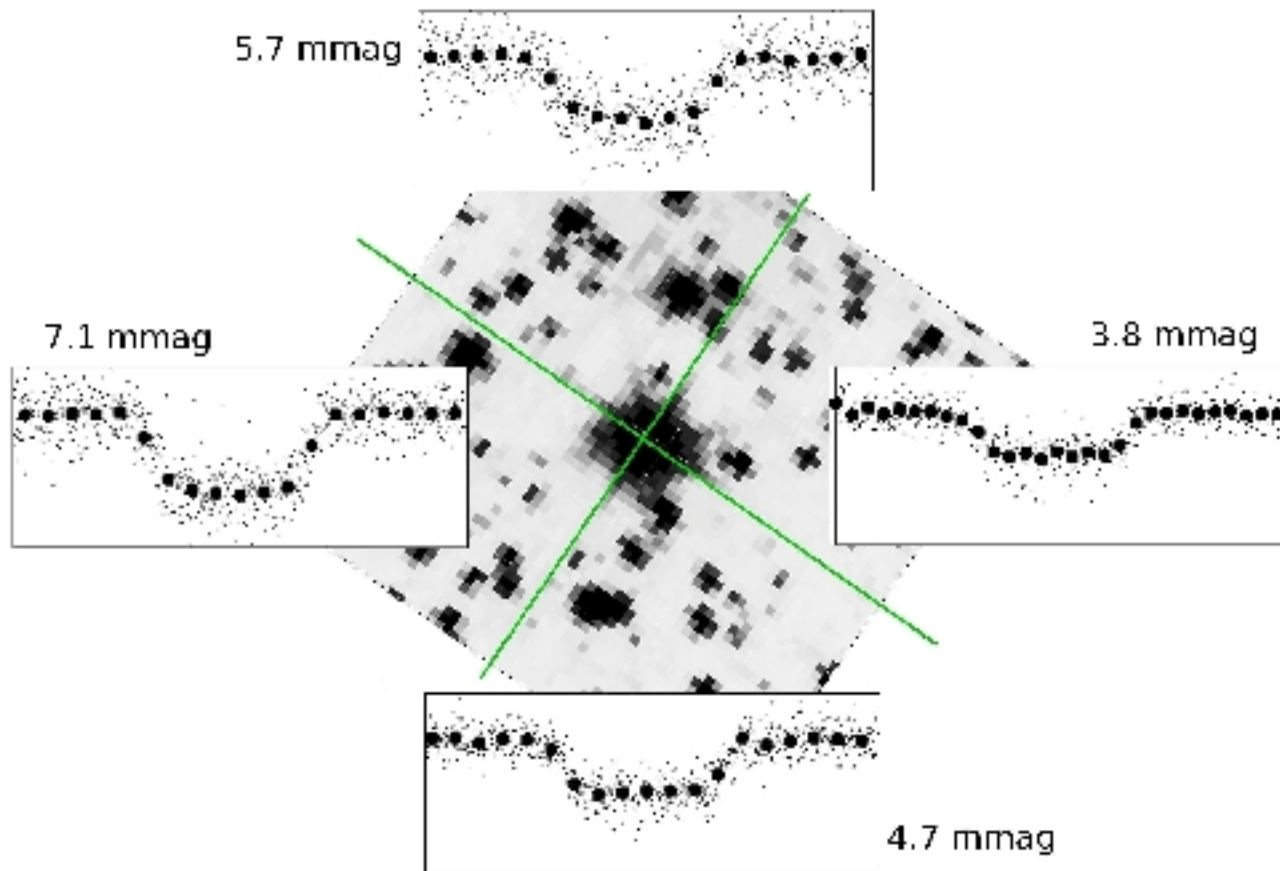


Fig. 4.

A close-up view of the stellar system KOI-13 A+B+ KOI-13.01

The companion: the first „hot” late-type dwarf discovered

