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The search for transiting planets using the YETI network*

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Abstract. To search for young transiting planets in continuous light curves, we monitor young open clusters (2-200 Myr) with the YETI network. Here we report the first transiting candidates (two in Trumpler 37, one in 25 Ori). Follow-up observations of the candidates are partly done.

Key words: Planets: detection – open clusters and associations: individual: Trumpler 37, 25 Ori

1. Introduction

Young transiting planets could play a key role to distinguish planet formation scenarios, as it is possible to test evolutionary models with the well determined parameters of such planets, like radius, mass, and age. As no transiting planets with ages younger than 100 Myr were found so far, we monitor young open clusters to search for transit signals among young stars. To increase phase coverage, continuous observations are needed. Therefore we established YETI (Young Exoplanet Transit Initiative), a network of ground-based telescopes with mirror diameters of 0.4 to 2 m (see Neuhäuser *et al.* 2011 for further details). Fig. 1 shows a map with all telescope sites as well as the telescope sizes. Each cluster is observed for at least three years with three campaign runs of lengths longer than one week. Observations are done in the *R*-band.

The first two target clusters of YETI were Trumpler 37 (Tr37) and 25 Ori. Some properties of both clusters are summarized in Tab. 1. The monitoring of Tr37 started in summer 2009 at the University Observatory Jena. Data of the YETI telescopes were gathered in summers 2010 and 2011, each year three campaign runs were performed. The observations of 25 Ori at the University Observatory Jena started in January 2010. In this first phase of the observation two additional telescopes (Gunma/Japan and CIDA/Venezuela) joined the photometric monitoring in January and February 2010. 25 Ori became a target of the YETI project in the winter seasons 2010/2011, 2011/2012, and 2012/2013.

* Some of the data presented herein were obtained at the W.M. Keck Observatory.

Figure 1. Map of the YETI telescopes. With the network it is possible to observe continuously.

Fifteen different observatories, spread worldwide at different longitudes, participated in the campaigns.

Data reduction (dark/bias and flat-field correction) as well as aperture photometry with adjusted aperture to the seeing conditions was done night by night and telescope by telescope. For a particular star, the final lightcurve was created by doing differential photometry (Broeg *et al.* 2005) for all nights and telescopes on a small sample of comparison stars (similar brightness and color, small angular distance). A detailed description can be found in Errmann *et al.* (2014).

Table 1. Properties of the stars in the clusters Trumpler 37 and 25 Ori.

	Trumpler 37	25 Ori
Age [Myr]	~ 4 [1]	7-10 [2]
Distance [pc]	~ 870 [3]	~ 330 [4]
Number member stars	774 [5]	~ 250 [6]

[1] Kun *et al.* (2008); [2] Briceño *et al.* (2007); [3] Contreras *et al.* (2002); [4] Briceño *et al.* (2005); [5] Errmann *et al.* (2013); [6] Briceño *et al.* (2013)

Fig. 2 shows the time coverage of the observations for a star in Tr37 for the third YETI campaign in 2011. As the star is located in a larger separation to the cluster center, it does not fit into the field of view of some telescopes. Furthermore, not all telescopes could always allocate time and some suffer from seasonal bad weather, hence only 5 of the YETI sites are present. But even with that smaller number of telescopes, we could observe nearly continuously for 48.5 h at the end of the campaign. Fig. 3 shows the phase coverage of the same star. For a period up to 10 d we reach 100% phase coverage and even for a period of 50 d the phase coverage is better than 70%. The coverage at periods of a multiple of a full day is slightly worse, as a telescope in the pacific ocean is missing.

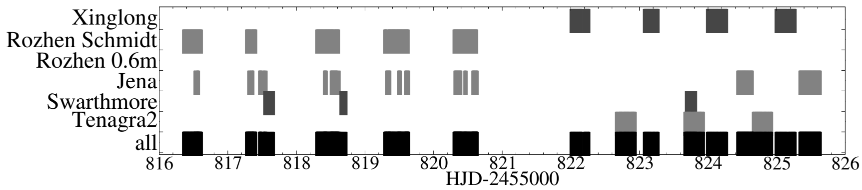

Figure 2. Observation times of the first transiting candidate in Trumpler 37 during the third YETI campaign in 2011.

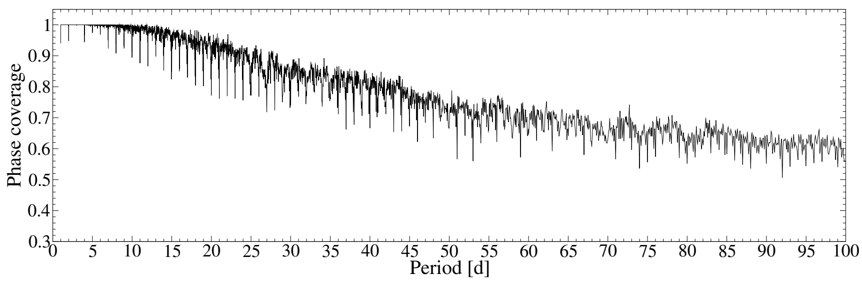

Figure 3. Phase coverage of the first transiting candidate in Trumpler 37.

2. Transiting candidates

In the Tr37 data two transit candidates were found using a simple box fitting algorithm. Another transiting candidate, first reported in van Eyken *et al.* (2012), is also visible in the 25 Ori data from YETI.

2.1. First candidate in Trumpler 37

At the late F-type star ($R = 15.1$ mag), a transit-like signal of $\Delta R = 54$ mmag and Period $P = 1.36491$ d is visible. The time and phase coverage for this star is shown in Fig. 2 and Fig. 3, respectively.

The follow-up observations of this candidate are already finished and will be presented in detail in Errmann *et al.* (2014). We got a high-quality light curve in the I-band and a low-resolution spectrum from *CAFOS* at the 2.2 m telescope at Calar Alto. A medium-resolution spectrum was taken with *Hectochelle* at MMT. The host star has a late F spectral type. Eclipsing background stars in the optical point-spread function could be ruled out from high-resolution images from IRCS observations at Subaru. To solve the radial velocity orbit, 5 high-resolution spectra were observed with *HIRES* at Keck-I. As the latter observations were done near the quadratures, the line shifts are already visible by eye in Fig. 4. The radial velocity variations of ~ 35 km/s semi-amplitude are too large for a sub-stellar mass companion, hence we found a false positive. The mass of the companion is about 0.15 to 0.35 $M_{\odot}$.

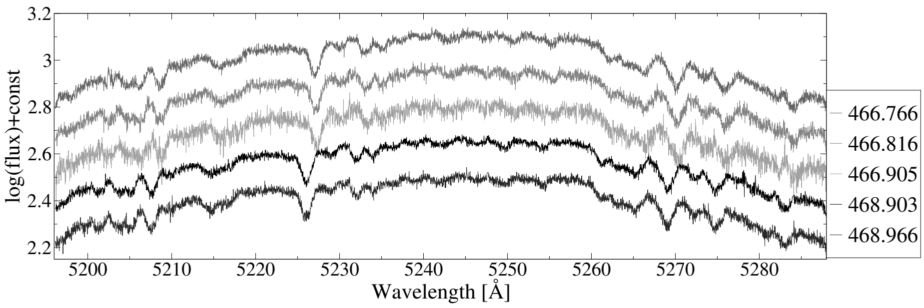

Figure 4. All obtained Keck spectra of the fourth order of the middle chip, sorted by time by adding adapted offsets (time is given in JD-2455000). The flux per spectrum is ~ 300 ADU. Between the spectra of the two nights the shifts of the lines are visible.

2.2. Second candidate in Trumpler 37

The $R = 13.4$ mag bright star shows a transit-like lightcurve with a period of $P \sim 0.74$ d and depth of $\Delta R = 11$ mmag. Additional, semi-periodic brightness variations of $\Delta R \sim 15$ mmag over time scale of $9 - 10$ d are visible. We are actively working on the follow-up observations of this candidate.

2.3. Transit candidate in 25 Ori

The host star (CVSO30) is a weak-lined T Tauri star and therefore very active. This causes brightness variations up to 200 mmag, while the depth of the transit is only ~ 40 mmag (see Fig. 5). An interesting feature of the transit light curve of CVSO30 was mentioned by van Eyken *et al.* (2012). They observed two sets of light curves in the years 2009 and 2010. It can clearly be seen that there is an overall change in the transit shape between the two years data sets, which could be explained by gravity darkening of the host star (Barnes *et al.*, 2013). Further photometric follow-up can test the proposed spin-orbit misalignment.

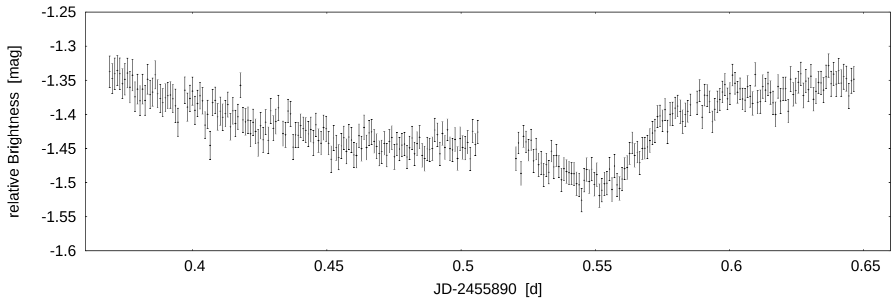

Figure 5. Lightcurve of the transiting candidate in 25 Ori in a single night. The transit occurs between 0.52 and 0.58. As the host star is a weak-line T Tauri star, variations outside the transit are visible.

3. Outlook

The monitoring of the clusters Trumpler 37 and 25 Ori with YETI has already finished, while the monitoring of IC 348, Collinder 69, NGC 1980, and NGC 7243 is ongoing. It is expected to find more transiting candidates, as we improve our routines and do further data analysis.

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