The Young Exoplanet Transit Initiative (*YETI*) and results from the Bulgarian participation

D. Dimitrov[1], R. Neuhäuser[2], D. Kjurkchieva[3], and *YETI* team
[1] Institute of Astronomy, Bulgarian Academy of Sciences, Bulgaria
[2] Astrophysikalisches Institut und Universitäts-Sternwarte, FSU Jena, Schillergäßchen 2-3, D-07745 Jena, Germany
[3] Department of Astronomy, Shumen University, Bulgaria
dinko@astro.bas.bg; rne@astro.uni-jena.de d.kyurkchieva@shu-bg.net
(Conference talk)

Abstract. The paper presents the ideas of the international initiative *YETI* (**Y**oung **E**xoplanet **T**ransit **I**nitiative) for searching for young exoplanets in open clusters, information about the organization of the observational campaigns as well as the preliminary results from the observations of the first cluster Tr 37. It is noted the successful participation of the Bulgarian team in the observational campaigns of Tr 37 (27 observational nights with above 12000 images). Due to the interesting light curves of Tr 37-3132 obtained by the Rozhen telescopes this object was chosen for follow-up spectral observations with large telescopes in the framework of *YETI*.
Key words: Stars: spectroscopic – Stars: fundamental parameters – Stars individual: Tr37 3132

Международната инициатива *YETI* и резултатите от българското участие в нея

Д.Димитров, Р. Нойхаузер, Д. Кюркчиева и YETI-тим

В статията са представени основните идеи на международна инициатива за търсене на млади екзопланети (YETI) в разсеяни звездни купове. Описана е организацията на провежданите наблюдателни кампании и предварителните резултати от наблюденията на първия куп Tr 37. Представено е изключително успешното участие на българския екип в наблюденията на Tr 37: общо 27 наблюдателни нощи и над 12000 изображения. Звездата Tr-37 3132 е избрана за мониторинг поради пекулярните криви на блясъка, получени с телескопите в НАО-Рожен.

Introduction

The discovery of planets around neutron stars (Wolszczan & Frail 1992; Wolszczan 1994) and around normal stars (Latham et al. 1989; Mayor & Queloz 1995; Marcy & Butler 1996) makes possibly the study of planetary systems and their formation outside the Solar System.

Different methods for discovery, confirmation and investigation of exoplanets were proposed: radial velocity (RV) spectroscopy, transit technique, direct imaging technique, microlensing or timing, Transit Timing Variations (TTV), etc.

The quantitative results of the great efforts in this area during the last two decades may be summarized as follows: over 500 candidates of planets are found (around 20 % of them are confirmed by astrometry or transits); around 50 stars have more than 1 planet (the champion is Kepler-11 with

6 transit planets); planets around double or multiple systems are discovered (Cochran et al. 1997; Mugrauer et al. 2007).

Some of the most interesting conclusions from the exoplanet investigations are: (a) Many exoplanets orbit their stars on much shorter orbits than those in the Solar System (Goldreich & Tremaine 1980, Lin et al. 1996); (b) More planets are found around metal-rich stars than around metal-poor stars (Marcy et al. 2005, Butler et al. 2006); (c) Almost all discovered exoplanets as well as their stars are old (with age Gyrs). The age of the youngest known planetary system WASP-10 (which radius is determined from transits) is estimated as 200-350 Myrs (Maciejewski et al. 2011a).

Although the important achievements of the exoplanet study there are still many unresolved problems in this area. For instance the upper limit of the exoplanet mass is not defined unambigously (the boundary mass 13 M_{Jup} of deuterium burning (Burrows et al. 1997) or the boundary 35 M_{Jup} of the masses of the brown dwarfs (Grether & Lineweaver 2006)).

Since all detection techniques are biased towards more massive (or larger) planets, the Earth-mass planets are not yet discovered. It is expected low-mass planets in the so-called *habitable zone* to be detected around low-mass stars like the M dwarfs.

The detection of young transiting exoplanets is a main goal of the international initiative *YETI* (**Y**oung **E**xoplanet **T**ransit **I**nitiative) which main organizer is the astronomical team of the Jena University (Neuhauser et al. 2011, further Paper I).

1 The main ideas of *YETI*

One of the important requirements for the successful realization of the global aim of *YETI* is the choice of appropriate objects for observations. This choice is based on the consideration that the probability to detect a planetary transit is proportional to the number of the stars in the observed field. This means that one should choose to observe sky regions that are rich of stars. Such fields are the stellar clusters. Their stars have the additional advantage that their ages and distances are known.

Moreover, the probability to detect a planetary transit increases considerably if the observations are carried out by telescopes at many, different longitudes on the Earth. This gives a possibility to provide twenty-four-hour continuous observing of the selected field and to escape the miss of chance to detect the short transits.

One may expect discovery of more transits for young planets around young stars because the younger stars (pre-MS) are with larger size as well as the younger planets are also with larger radius than the old ones (Burrows et al. 1997). In fact, the probability to detect a planetary transit increases with the increasing of the relative (planet and star) radii due to the bigger range of orbital inclinations for which eclipses are possible.

The foregoing considerations led to the following criteria for selection of the targets of the *YETI* (Neuhauser et al. 2011):

(a) The age of the clusters to be above a few Myrs (for existing of planets) and smaller than 100 Myrs (the PMS time-scale of the lowest mass stars);

(b) The distance to the clusters to be in the range 50-1000 pc (for smaller distance the field with enough number of stars would be too large on the sky while for larger distance the stars would be too faint for transit detection);

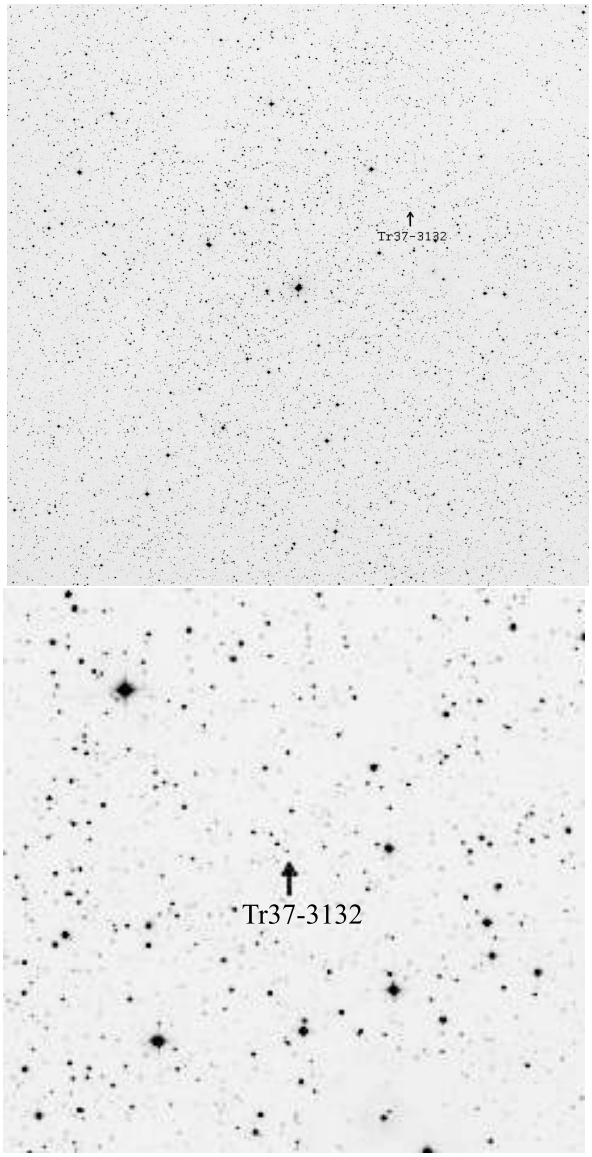

Fig. 1. Top: Trumpler 37 frame from the Rozhen 50/70cm Schmidt telescope with center α=21^h 38^m 57.8^s, δ=+57 28'15.6" (field of view 1.2×1.2 deg, I filter, exposure 60 s, North up, East to the left); Bottom: Finding chart of the unusual variable Tr 37-3132.

(c) The angular size of the clusters on the sky to be roughly 1^0 x 1^0 that is most appropriate for wide-field CCD cameras on 1-2 m telescopes (in case of smaller FoVs the observations should be made by mosaicking);

(d) The cluster should contain as much as possible young stars in a useful magnitude range in VRI (fainter than 10 mag to avoid saturation and brighter than 16.5 mag not to loose sensitivity and to be able to do RV follow-up spectroscopy of the transit candidates);

(e) The location of the cluster on the sky should allow observations by telescopes at different latitudes.

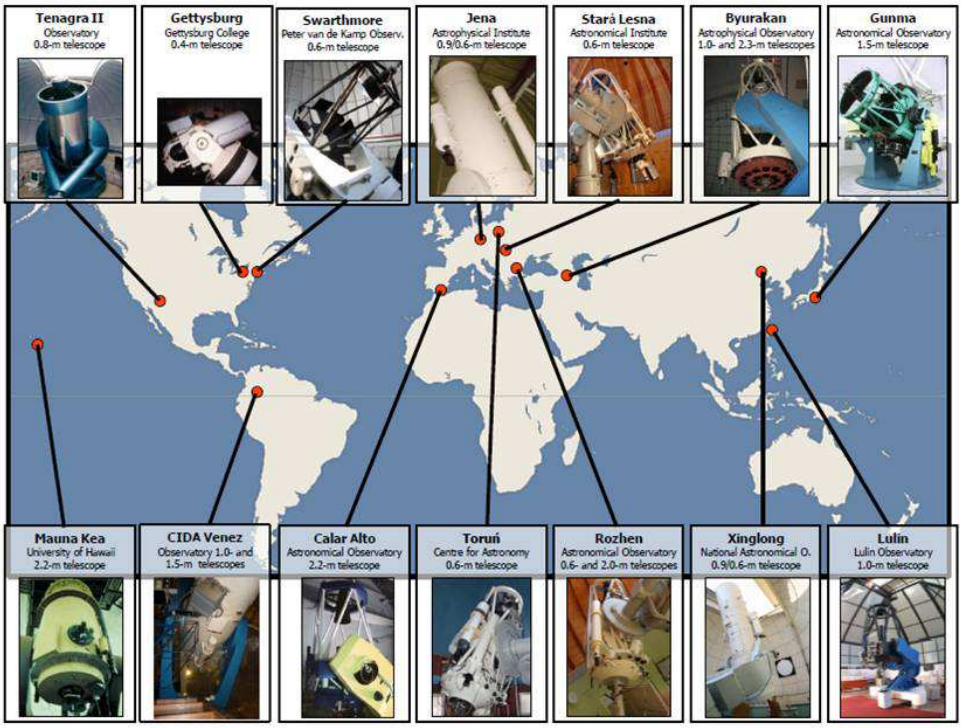

Fig. 2. Geographical positions and equipments of the partners before Oct 2010 (from www.astro.uni-jena.de/YETI.html)

On the basis of these criteria the open cluster Tr-37 was chosen as the first target for observations in the framework of *YETI*. It is at distance 870 pc into the star-formation region Cepheus OB2 (Fig. 1) and its age is 3-10 Myrs (Contreras et al. 2002, Sicilia-Aguilar et al. 2004b, 2005).

2 *YETI* teams and organization

Initially the initiators of *YETI* from the Jena University invited 9 teams to take part in the observational campaigns of Tr 37. Further the number of the

participants increased to 19 observatories with 28 telescopes (see Table 1 in Paper I). Figure 2 gives information for the net of telescopes of *YETI* before Oct 2010. All *YETI* teams have equipment for photometric observations with precision below 0.005 mag for the brightest, nonsaturated stars.

The big number of participants in the observational campaigns of *YETI* requires a good organization, synchronization and coordination of the work of obtaining, reducing and modeling of the data. These problems were objects of the Jena conference of the *YETI* teams in November 2010. There the participants made regulations of the joint work in the framework of *YETI*. Some of them are: every night from the observational campaigns each team should send information for its observations; every team makes reducing of its obtained frames by unified procedure; all reduced frames form database that is accessible to all participants (by password); etc.

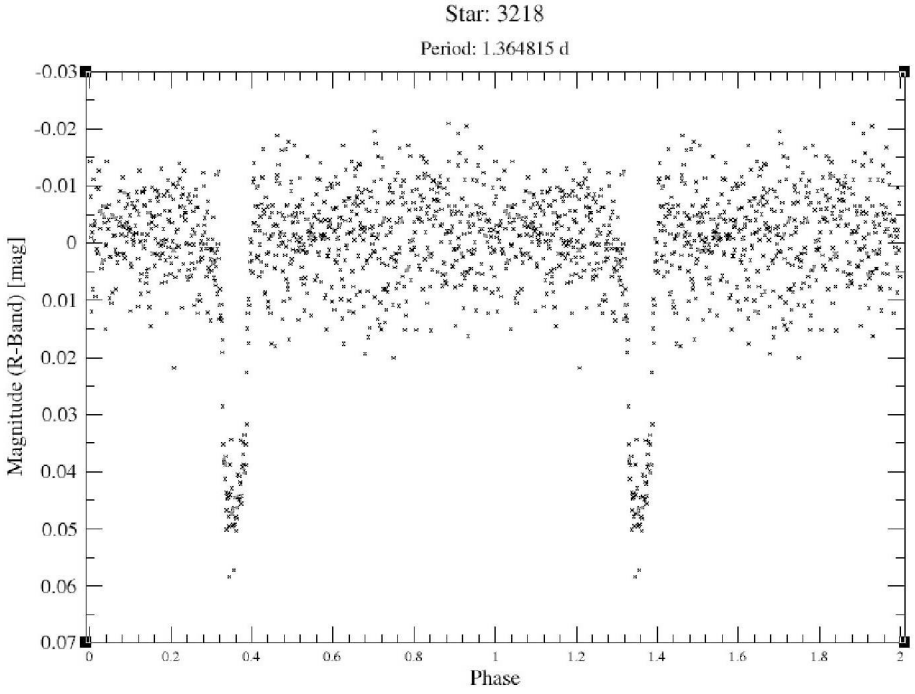

Fig. 3. The light curve of Tr-37 3218 from the 0.9 m Jena telescope (from Maciejewski et al. 2011b)

The main focus of the Jena conference was the observational strategy (fields, filters, mosaics, exposures, campaign durations, repetitions). The next clusters for observations were chosen on the basis of the criteria from the previous section: 25 Ori, h and χ Per, α Per, σ Ori, λ Ori and NGC 2244. The participants concluded that in order to reach the *YETI* goals each cluster should be observed during 2-3 years, every year the campaigns should be made for not more 2-3 clusters and every campaign should continue 10-20 nights. The *YETI* campaigns are planned to continue above 10 years.

During the Jena conference a Memorandum for the *YETI* participation was prepared concerning the publishing of the results, criteria for the coauthors and author' sequence. Moreover, the participants assumed the principles of the work activities. Each team took responsibility for different scientific tasks in the framework of *YETI* (besides the planet transits) depending on its interests and possibilities.

The preliminary results from the 3 observational campaigns of Tr-37 (July, August and September 2010) are (Paper I): 732 members of the cluster are studied; around 300 variable stars are discovered (T Tau stars, rotational variable, pulsating with periods 1 h $< P <$ 300 d, irregular variables, 50 eclipsing binaries); 30 flares are registered. The most important result is the detection of one exoplanet candidate. It is located around the star Tr-37-3218 (V=15.55 mag; B-V=1.02 mag; ΔR=0.045 mag; Spectral type G8-K5) that probably is member of the cluster due to its position on the diagram color-magnitude and its proper motion. The deep observed transit (Fig. 3) could be due to a planet with R $<$ 1.7 R_{Jup} (Paper I).

Follow-up spectral observations with large telescopes (Calar Alto 2.2 m/CAFOS; HIRES (High Resolution Echelle Spectrograph); KeckI; Hectochelle at MMT on Mount Hopkins/Arizona) as well as high angular resolution imaging observations are planned for the most interesting objects observed in the framework of *YETI*.

3 Results from the Bulgarian participation in *YETI*

The Bulgarian team received invitation from the *YETI* organizers in April 2010 to take part in the observational campaigns of Tr 37. The arguments for this invitation are: the location of the Rozhen National Astronomical Observatory; the possibilities of the Rozhen telescopes; the experience with the successful observations of exoplanets (TrES-3b, WASP-1b, WASP-3b, WASP-10b, WASP-12b) at the Rozhen National Astronomical Observatory until 2010 (Dimitrov 2009; Maciejewski et al. 2010; Maciejewski et al. 2011, etc.).

Obviously, the most appropriate telescope at Rozhen for the *YETI* tasks is the 50/70 cm Schmidt telescope due to its big FoV 1.2^0 x 1.2^0. The 2 m Ritchey Chretien Coude telescope is suitable for follow-up observations of exoplanets and precise photometry of faint interesting objects from the observed clusters in the framework of *YETI*. The 60-cm Cassegrain telescope is appropriate for follow-up observations of exoplanet transits. The expected new filters (H_α and narrow-band Sloan filters) for the 60 cm Rozhen telescope will be very useful for the goals of *YETI* project.

The presentation of the Bulgarian team at the Jena conference included short description of the Rozhen equipment, results of the campaigns of Tr 37 and suggestion the 40 cm Meade telescope of the Shumen University to be included in the future *YETI* campaigns.

The contribution of the Bulgarian team in the *YETI* campaigns of the cluster Tr 37 turned out quite successful with total 27 nights observations and above 12000 frames. The results from the observations of the second cluster 25 Ori were not so impressive due to the bad atmospheric conditions

at Rozhen (December 2010 - 7 nights, January 2011 - 4 nights, February 2011 - 1 night).

The object Tr 37 3132 was chosen from the Bulgarian team for follow-up observations due to the peculiarities of its light curves obtained by the Rozhen telescopes (Fig. 4): variable levels and phases of the light maxima; wide and shallow secondary minimum; asymmetric primary minimum; existence of standstill (similar to those of the CVs) on the increasing branch of the primary minimum; variable shape of the bottom of the primary minimum.

Due to these peculiarities the object Tr-37 3132 was suggested for spectral observations with large telescopes (Calar Alto 2.2 m/CAFOS, KeckI). The expected spectra as well as all the available photometric data of Tr-37 3132 will allow to establish the nature of this interesting object and its membership to the cluster Tr 37.

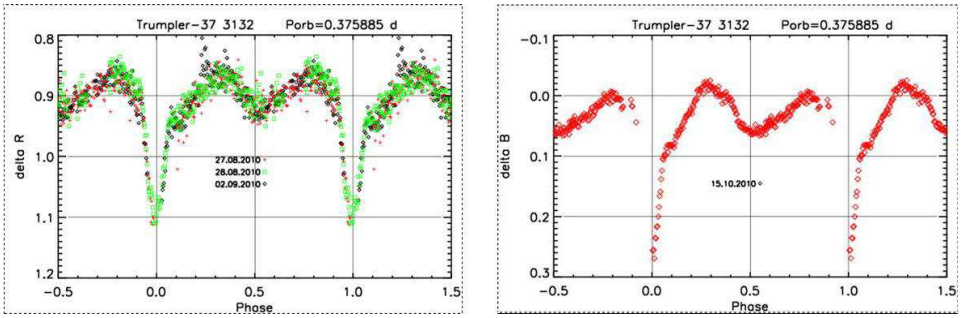

Fig. 4. The Rozhen photometric observations of Tr-37 3132 by 2 m telescope on Sept 15 2010 (left) and 60 cm telescope during different nights (right)

Besides the study of the object Tr-37 3132 the Bulgarian team took responsibility to work on eclipsing binaries, another types of variable stars (δ Sct, etc.) as well as deep photometry to search for brown dwarfs.

Acknowledgements

The research was supported partly by funds of project DO 02-362 of the Bulgarian Ministry of Education and Science.

References

Burrows, A., Marley, M., Hubbard, W.B., et al., 1997, ApJ 491, 856
Butler, R.P., Wright, J.T., Marcy, G.W., et al., 2006, ApJ 646, 505
Cochran,W.D., Hatzes, A.P., Butler, R.P., Marcy, G.W., 1997, ApJ 483, 457
Contreras, M.E., Sicilia-Aguilar, A., Muzerolle, J., Calvet, N., Berlind, P., Hartmann, L., 2002, AJ 124, 1585
Dimitrov D., 2009, BgAJ, 12, 63
Goldreich, P., Tremaine, S., 1980, ApJ 241, 425
Grether, D., Lineweaver, C.H., 2006, ApJ 640, 1051
Latham, D., Stefanik, R.P., Mazeh, T., Mayor, M., Burki, G., 1989, Nature 339, L38
Lin D.N.C., Bodenheimer, P., Richardson, D.C., 1996, Nature 380, 606
Maciejewski, G., Dimitrov, D., Neuhäuser, R., et al. 2011a, MNRAS 411, 1204

Maciejewski G., Neuhäuser R., Errmann R., et al., 2011b, 'Towards the Rosetta Stone for planet formation'. In: Bouchy F., Diaz R.F., Moutou C., (Eds.) Proc. of Haute Provence Observatory Colloquium on Detection and dynamics of transiting exoplanets (held in Haute Provence August 2010), ASP Conf. Ser., EPJ Web of Conferences 11, 04006
Maciejewski, G., Dimitrov, D., Neuhäuser, R., et al. 2010, MNRAS 4097, 2625
Marcy, G.W., Butler, R.P., 1996: ApJ 464, L147
Marcy, G.W., Butler, R.P., Fischer, D., Vogt, S., Wright, J.T., Tinney, C.G., Jones, H.R.A., 2005, PTPS 158, 24
Mayor, M., Queloz, D., 1995, Nature 378, 355 Mugrauer, M., Neuhäuser, R., Mazeh, T., 2007, A&A 469, 755
Mugrauer, M., Neuhäuser, R., Mazeh, T., 2007, A&A 469, 755
Neuhäuser, R., et al., 2011, AN (arXiv:1106.4244)
Sicilia-Aguilar, A., Hartmann, L.W., Briceno, C., Contreras, M.E., Muzerolle, J., Calvet, N., 2004, ApSS 292, 457
Wolszczan, A., Frail, D., 1992, Nature 355, 145
Wolszczan, A., 1994: Science 264, 538