INAF – TIME ALLOCATION COMMITTEE

Application for observing time **Category: C**

Period AOT39 (April 2019 – September 2019) **Submit using: www.tng.iac.es/submit.html**

1. Title

A new super-Earth in a binary system?

2. Abstract

Binary systems are an interesting laboratory to study the planet formation and evolution and to investigate whether this environment is favorable to form planets.
From a sample of binary systems already observed with SARG, a study of Radial Velocity (RV) variations and activity was performed in order to look for a periodic signal in these systems. Only 2 planets orbiting one star of 47 binary systems were found. Three stars of this sample with a higher RV jitter with respect to what expected from their activity were further studied with HARPS-N and GIANO, resulting in two false alarms (due to contamination and binary nature). On the other hand, the third object, namely HD213013A, is a very interesting case. This star shows an RV periodicity of 12.54 days with semi amplitude of 3 m/s. This periodicity is neither related to the activity cycle nor to the stellar rotation, once the activity level and several fundamental parameters have been considered. Thus, it may have a planetary origin. A follow-up covering the whole phase could give a conclusive result and provide a further step in the knowledge of the statistics of planets in binary systems.

3a. Number of requested hours per telescope and instrument

TNG					REM	
DOLORES	DOLOR.+MOS	NICS	HARPS-N	GIANO-B	ROSS	REMIR
			9			

3b. Observing modes

TNG:	X	Visitor		Service		ToO
REM:		Rapid Response		Queuing		ToO

4a. Preferred months

first choice: Jul second choice: Aug

4b. Other scheduling constraints (use also box 14)

April, May, June: impossible due to moon separation and oject visibility

5a. Past and future of the project

a) Hours already awarded to the project: 18

b) Hours foreseen to complete the project: 0
(not including this request)

6. Principal investigator

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7. Co-investigators (name and institution)

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A. F. Martinez Fiorenzano, Fundacion Galileo Galilei - INAF, TF, Spain
M. Bonavita, Institute for Astronomy, University of Edinburgh, Edinburgh, UK

8. Status of the project

Telescope	Instrument	Date	Hours	Notes
TNG	HARPS-N	apr-aug 2018	18	executed in time sharing with GAPS2 LP and GTO; data analysis already performed

Description

This program is the completion of A37TAC_29 program "Follow-up observations of three SARG binary survey stars with unknown RVs variation origin". The program consisted on the RV monitoring of three objects selected according to Sissa et al. (2016) that could potentially host a planet candidate, due to the unexpected high jitter in RVs. Observation were executed and data are already reduced. The data already achieved permit us to conclude on the nature of the jitter for two of the stars. In the case of HD213013A, HARPS-N spectra indicate a smaller RV jitter than what observed in SARG and a quite clear periodicity that we need to further investigate.

Publications

9a. If this proposal is a part of a PhD thesis, write here the name of the student, the thesis title and briefly describe the relevance of these observations for the thesis goals.

9b. Is this, or a similar application submitted to other time allocation committees (e.g. ESO, TNG-CAT, ITP)? If yes, please specify which and explain if and why the proposals should be considered complementary.

No

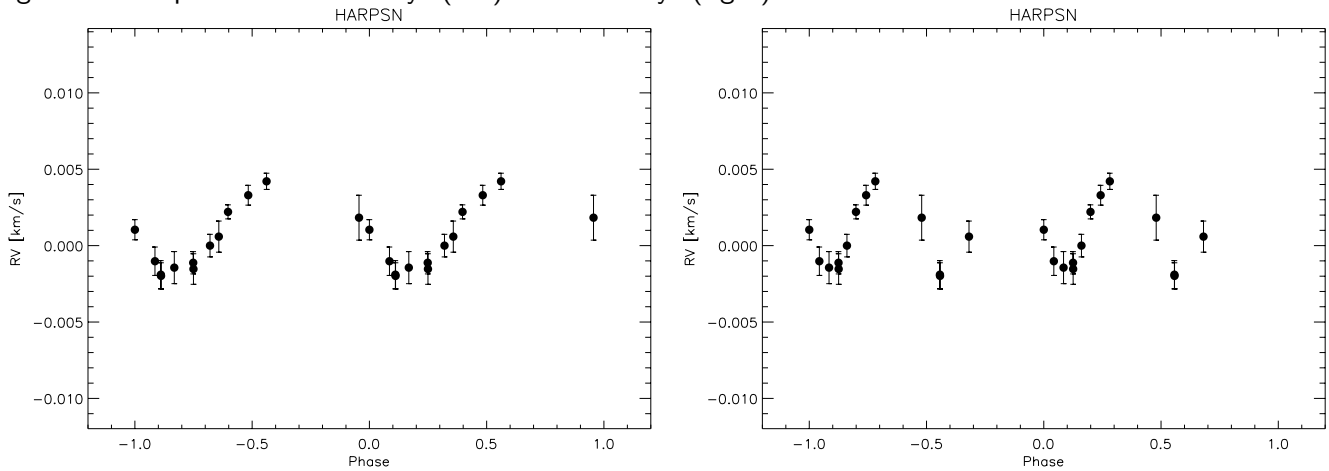
10. Description of the programme (max. 3 pages, including references, tables, and figures.)

A) Scientific rationale Among the ~ 800 extrasolar planets discovered to date by RVs, more than 70 are known to orbit one of the members of a double or multiple-star system (see e.g. Patience et al. 2002; Eggenberger, Udry & Mayor 2004; Raghavan et al. 2006; Desidera & Barbieri 2007; Han et al. 2010; Desidera et al. 2011, Desidera et al. 2014; Howard et al. 2014). The search for planets in binary systems allows to improve our knowledge on planet formation and evolution. The frequency of planets in binary systems has a strong effect on the global frequency of planets, as more than half of solar type stars are in binary or multiple systems (Duquennoy et al. 1991). On the other hand, the properties of planets in binaries, and any difference with those of the planets orbiting single stars, would shed light on the effects caused by the presence of the two bounded stars.
A search for planets around the components of binary systems was performed in the visible range (VIS) using SARG (Spettrografo Alta Risoluzione Galileo) at the Telescopio Nazionale Galileo (TNG) in the past years. The sample of the SARG survey includes 47 pairs of stars from HIPPARCOS Multiple Star Catalog (Perryman et al. 1997) considering binaries in the magnitude range $7.0 < V < 10.0$, with magnitude differences between the components $\Delta V < 1.0$, projected separations larger than 0.2", parallaxes larger than 10 mas, and errors smaller than 5 mas, with B - V > 0.45 mag and spectral types later than F7. Only 2 planets were found (Desidera et al. 2012, 2014); this frequency appears lower with respect to the total exoplanets statistics. We expect to find other planets around stars in the SARG sample, using more performing instruments and a denser temporal sampling. Sissa et al. 2016 demonstrated that, among this SARG sample, two stars show a high RV jitter, that cannot be explained as activity or spectra contamination. Moreover, while almost half of the sample are moderately active stars, only a few of them show a strong correlation between RVs variation and stellar activity (Carolo et al. 2014, Sissa et al. 2016), that could hide a smaller contribution to RVs variation due to a planet. During AOT37, we made a short-term follow-up of these stars exploiting HARPS-N and GIANO. Those observations help us to conclude that HD76037B is probably itself a binary system (two stars at separation of 2" and period of 100 yr) and HD117963A data are likely contaminated. Moreover, the new HARPS-N observations confirm the presence of a periodic RV variation of HD213013A with amplitude of about 3.5 m/s and a period of 12.54 days, while GIANO uncertainty is too large to be useful to exclude an activity related origin of the signal. If these new observations will confirm the presence of 12 day periodicity, it would be mostly certainly induced by a Super-Earth. This discovery will contribute the statistics of the planet frequency in binary systems characterized by the same properties of the targets selected for the SARG survey.
B) Scientific aim With this proposal we ask for follow-up observations of HD213013A with HARPS-N. We analysed HARPS-N spectra obtained in A37TAC_29. While the RVs shows a significative periodicity of 12.54 days, the phase is not well sampled leaving room for different periodicity (Figure 1, left). While the tentative periodicity is very promising, it is well known that stellar activity can induce astrophysical false alarms on planet detection. Therefore, we performed a number of test to disentangle the origin of the observed RV variation. (i) We verify that RVs do not correlate neither with the $\log R'_{HK}$ index nor with the Hα index. (ii) $\log R'_{HK}$ and Hα periodograms do not show significant periodicity and do not have high power at the RV period. (iii) We checked that the RVs do not correlate with the bisector and other line profile indicators described in Lanza et al. (2018). The lack of any correlation between RV and line profile is a strong indicator that contamination of the spectra by the companion are not relevant in our case, as expected considering the separation (5.508"), the magnitude difference, and the observing procedure adopted masking it in the guide camera. (iv) We verify that the mean value of $\log R'_{HK}$ index from HARPS-N spectra is -4.8, that is in agreement with the $\Delta H\alpha$ activity index found in Sissa et al. 2016, showing the activity of the stars at the two epochs did not vary significantly. (v) From the analysis of the HARPS-N spectra we obtain a better characterization of stellar parameters (Table 1) . The expected rotation period from the observed $\log R'_{HK}$ is of 26.3 (Mamajek & Hillenbrnad, 2008). This is very different from the observed RV periodicity. The remaining possibility is that we are observeing a RV period which is half of the rotation period. (vi) Therefore we assume that the 12.54 days in the RVs is an alias of an hypothetical 25.1 days rotational period and re-phase RVs accordingly (Figure 1, right). (vii) while there are not available photometric light-curve of adequate precision to uncover a low-amplitude photometric modulation due to stellar rotation, we noticed that the star was observed with KELT survey (https://keltsurvey.org/publications) and that the rms dispersion in the photometric time serie is just less than 0.003 mag (Oelkers+, 2018). This argue against an high activity level.
So far all the tests we executed exclude that the 12.54 days period observed in the RV is instead an harmonic of the rotational period. However, to prove it definitively we need a better sampling of the RV variation. This will permit to answer, in a definitive way, to the open questions presented in Sissa et al. (2016). Our observing strategy is to monitor the RVs of this target for 9 hours in total, with observations distributed along one month, in order to sample the entire period suggested by HARPS-N data. For observing strategy details see Box 12.

Table 1: stellar parameters of HD213013A from our analysis of HARPS-N spectra.

Parameter	Value
T_{eff}	5430 ± 50 K
$\log g$	4.52 ± 0.02 dex
$[Fe/H]$	+0.07 ± 0.01
V_t	0.57 ± 0.10 km/s
A(Li)	$<$ 0.55 dex
B-V	0.753
logR$'_{HK}$	-4.76
P$_{rot}$	$>$26 days
Age	2-3 Gyr

Figure 1: RVs phased to 12.54 days (left) and 25.1 days (right)



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11. List of targets (note that the absence of a proper object list and information may weaken the proposal)

Name	α	δ	Epoch	Mag.	Time	Additional Information
HD 213013A	22 28 13	+23 31 57	J2000	V8.96	15360s	K0, science target, HARPS-N

12. Observational strategy and justification of requested time, including overheads.

Based on the A37TAC_29 program results, we require to use HARPS-N. As in A37TAC_29, an exposure time of 900 seconds is necessary to obtain a good S/N with HARPS-N in case of good weather. For this star we expect photon-noise errors of $\sim$ 1 m/s for HARPS-N on single-night RV measurement. So we ask for the equivalent of 1 night, distributed in one observation per night for 34 nights covering two months. Moreover we need a moon separation larger than 30 degrees (see box 14b.), therefore HD213013A observations should be allocated after June 23rd, otherwise it would be impossible to obtain the requested time serie. The observations can be scheduled sharing time with other short/long programs that exploit same instruments configuration, as already done for A37TAC_29 with great success. So that, a combination of visitor mode and service mode is also possible. Being binary systems, the observing procedure should be optimized according to the system geometry.

13. Requested instrument(s) setup

Id	Instrument	Binning	Filter(s)	Slit	Grism	Time	Additional Information
1	HARPS-N					9hr	

14a. Moonlight constraints

Max. # of days from new moon ☐

14b. Scheduling constraints, special requirements and other remarks
(please include justification of constraints in 14a)

All observations need an airmass lower than 1.7. In order to avoid moon contamination to the HARPS-N spectra, our target should be observed with a moon separation larger than 30 degrees. So that the time serie should be acquired after June 23rd. The project will greatly benefit by covering two of the hypothetical rotational descending phase: 13-23 jul, 7-17 aug, 1-10 sep, 23-30 sep. The observations can be scheduled sharing time with other short/long programs that exploit same instruments configuration, as already done for A37TAC_29. So that, a combination of visitor mode and service mode is also possible.

15. Observational background of the applicants

Name of the observer(s) at TNG: I. Carleo, S. Benatti, E. Sissa, A. F. Martinez Fiorenzano, V. D'Orazi

Experience of the observer(s) with the requested TNG instrument(s)

S. Benatti, I. Carleo, M. Bonavita and A. F. Martinez Fiorenzano observed with HARPS-N for several nights. S. Benatti and I. Carleo took part to the commissioning runs of GIANO-B and GIARPS at TNG and are then fully familiar with the new instrumentation.

Experience of the observer(s) with other telescopes/instruments

S. Benatti observed at the 182 cm Copernico Telescope at the Asiago-Cima Ekar Observatory (Vicenza, Italy) with the AFOSC spectro-photometer for several runs. I. Carleo has experience with the NIR spectrograph IGRINS at McDonald Observatory in Texas. E. Sissa has experience with the 122 cm telescope in Asiago with the Boller & Chivens spectrograph and also with SPHERE (Spectro-Polarimetric High-contrast Exoplanet REsearch) at VLT. A. F. Martinez Fiorenzano has lot of experience with different instruments of TNG, and is trained to use GIANO-B. V. D'Orazi observed with FLAMES at VLT, HERMES and UCLES at AAT