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

Confirming Transiting Exoplanets from HATSouth and TESS

2. Abstract

Transiting planets around bright stars are key objects for exploring the physical properties of planets outside the Solar System. The incontestable method for confirming candidate transiting planets, which are identified by the surveys, is through high-precision spectroscopic follow-up observations. The HATSouth is one of the most efficient ground-based survey for discovering these class of exoplanets. Here we propose to use the HARPS-N spectrograph to perform final confirmation and determine the mass and density of a small sample of HATSouth transiting planet candidates, which we detected in several equatorial fields. In particular, we will focus on confirming 4 relatively long-period planets ($6 < P_{\rm orb} < 28$ days), 3 of them having Neptune-Saturn size, with the goal of expanding the sample of such objects known around bright stars. We will possibly incorporate TESS data into our identification of candidates for follow-up with the HARPS-N instrument. The planets discovered through this effort will be amenable to detailed follow-up studies, such as transmission spectroscopy with JWST.

3a. Number of requested hours per telescope and instrument

TNG					REM	
DOLORES	DOLOR.+MOS	NICS	HARPS-N	GIANO-B	ROSS	REMIR
			27			

3b. Observing modes

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

4a. Preferred months

first choice: 9 second choice: 9

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

5a. Past and future of the project

a) Hours already awarded to the project: 0

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

6. Principal investigator

Name Luigi Mancini

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7. Co-investigators (name and institution)

R. Brahm, Pontificia Universidad Católica de Chile

8. Status of the project

Telescope	Instrument	Date	Hours	Notes
Keck I 10 m	HIRES	2017-2018	10	Radial velocity follow-up
Subaru 8 m	HDS	2012-2015	32	Radial velocity follow-up
Magellan6.5 m	PFS	2012-2017	120	Radial velocity follow-up
AAT 3.9 m	CYCLOPS	2012-2013	137	Radial velocity follow-up
ESO 3.6 m	HARPS	2013-2018	310	Radial velocity follow-up
APO 3.5 m	ARCES	2012-2013	27	Recon
NOT 2.56 m	FIES	2010-2013	14	Radial velocity follow-up
duPont 2.5 m	Echelle	2011-2016	138	Recon
ANU 2.3 m	WIFES	2010-2018	888	Recon
ANU 2.3 m	Echelle	2012-2014	55	Radial velocity follow-up
MPG 2.2 m	FEROS	2011-2018	2120	Radial velocity follow-up
Euler 1.5 m	Coralie	2010-2018	681	Radial velocity follow-up

Description

Our team is conducting the HATSouth project (Bakos et al. 2013; https://hatsouth.org/), one of the most successful survey in terms of exoplanet discoveries. HATSouth is a network of automated wide-field telescopes, consisting in 6 homogeneous units located at 3 different places in the southern hemisphere, i.e. Las Campanas Observatory (LCO) in Chile, the H.E.S.S. site in Namibia, and Siding Spring Observatory (SSO) in Australia. Each unit is equipped with four 18 cm $f/2.8$ Takahashi astrographs, each working in pairs with Apogee U16M Alta 4k×4k CCD cameras, with a total mosaic field-of-view on the sky of $8^\circ \times 8^\circ$ at a scale of 3.7 arcsec pixel^{-1}. The unique global nature and large aperture of the HATSouth telescope network make it the most sensitive ground-based wide-field transit survey to all of these classes of planets. Since first light in 2009, the HATSouth survey has so far monitored the light of more than 5 million stars from observations covering 2609 square degrees, identifying over 2000 transiting planet candidates. Follow-up observations of these candidates, including high-precision time-series photometry and radial velocity measurements, have led to the publication of more than 65 well-characterized transiting planets (Fig. 1), including transiting Neptunes (Bakos et al. 2015), a giant planet transiting an M dwarf (Hartman et al. 2015), and the longest period transiting planet discovered by a ground-based wide-field survey (Brahm et al. 2015).

Publications

Bento, J., Hartman, J. D., Bakos, G. A. et al., 2018, MNRAS, 477, 3406
Bayliss, D., Hartman, J. D., Zhou, G. et al., 2018, AJ, 155, 119
Brahm, R., Hartman, J. D., Jordan, A. et al., 2018, AJ, 155, 112
Henning, Th., Mancini, L., Sarkis, P. et al., 2018, AJ, 155, 79
Bento, J., Schmidt, B., Hartman, J. D. et al., 2017, MNRAS, 468, 835
de Val-Borro, M., Bakos, G. A., Brahm, R. et al., 2016, AJ, 152, 161
Penev, K., Hartman, J. D., Bakos, G. A. et al., 2016, AJ, 152, 127
Espinoza, N., Bayliss, D., Hartman, J. D. et al., 2016, AJ, 152, 108
Ciceri, S., Mancini, L., Henning, T. et al., 2016, PASP, 128, 074401
Brahm, R., Jordan, A., Bakos, G. A. et al., 2016, AJ, 151, 89
Bakos, G. A., Penev, K., Bayliss, D. et al., 2015, ApJ, 813, 111
Bayliss, D., Hartman, J. D., Bakos, G. A. et al., 2015, AJ, 150, 49
Mancini, L., Hartman, J. D., Penev, K. et al., 2015, A&A, 580, 63
Hartman, J. D., Bayliss, D., Brahm, R. et al., 2015, AJ, 149, 166
Brahm, R., Jordan, A., Bakos, G. A. et al., 2015, AJ, 151, 89
The complete list of the HATSouth publications is available on: https://hatsouth.org/planets/

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.

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

A) Scientific rationale Our current understanding of the structure and evolution of exoplanets is mainly supported by the discovery and characterization of those which transit in front of their parent stars. The main parameter we can obtain from transiting planets is their radii, which coupled with the estimation of their masses, via radial velocity (RV) measurements, can be used to compute their bulk density, giving us insights on their internal structures. Whilst substantial progress has been made over the past decade in discovering and obtaining precise mass and radius measurements for many transiting exoplanets, most of the well-characterized planets are hot Jupiters, i.e. giant planet with $M > 0.3\,M_{\rm Jup}$ and $P_{\rm orb} < 10$ day orbiting F, G and K stars.

Finding and characterizing more low-mass planets around bright stars will enable studies of the transitions from gas giant planets to ice giants and then to rocky planets. The core-accretion model of planet formation suggests that the rapid accumulation of gas after a proto-planet reaches a critical size should result in a dearth of planets with masses between Neptune and Saturn (Mordasini et al. 2009). We also expect the atmospheric composition of Neptunes to be qualitatively different from gas giants, with much higher concentrations of volatiles and heavy elements. Transmission spectra of two exo-Neptunes and one exo-Saturn have hinted at such a trend (Wakeford et al. 2017), but many more planets are needed to confirm this. Finding these planets and characterizing their properties to determine their core sizes, atmospheric compositions and orbital orientations provides a key test of these models.

Finding and characterizing more planets with periods longer than 10 days is also critical for studying the physical properties of planets that are on sufficiently wide orbits to not be affected by extreme stellar irradiation. Theoretical arguments, supported by observations, indicate that the radii of planets around FGK stars with periods longer than 10 days are independent of the received irradiation (Thorngren et al. 2016). This makes it possible to reliably determine the core masses of these planets, and search for correlations with other parameters (e.g., host metallicity), to test planet formation theories. The orbits of these planets are also expected to be unaffected by tides, making measurements of their orbital orientations particularly valuable tests of planet migration models.

B) Scientific aim In order to make progress on these two fronts, we are proposing to use the HARPS-N spectrograph to obtain precise RV measurements of planet-candidate host stars. The candidates that we want to observe will come from a combination of (a) the HATSouth surveys and from (b) the NASA TESS survey.

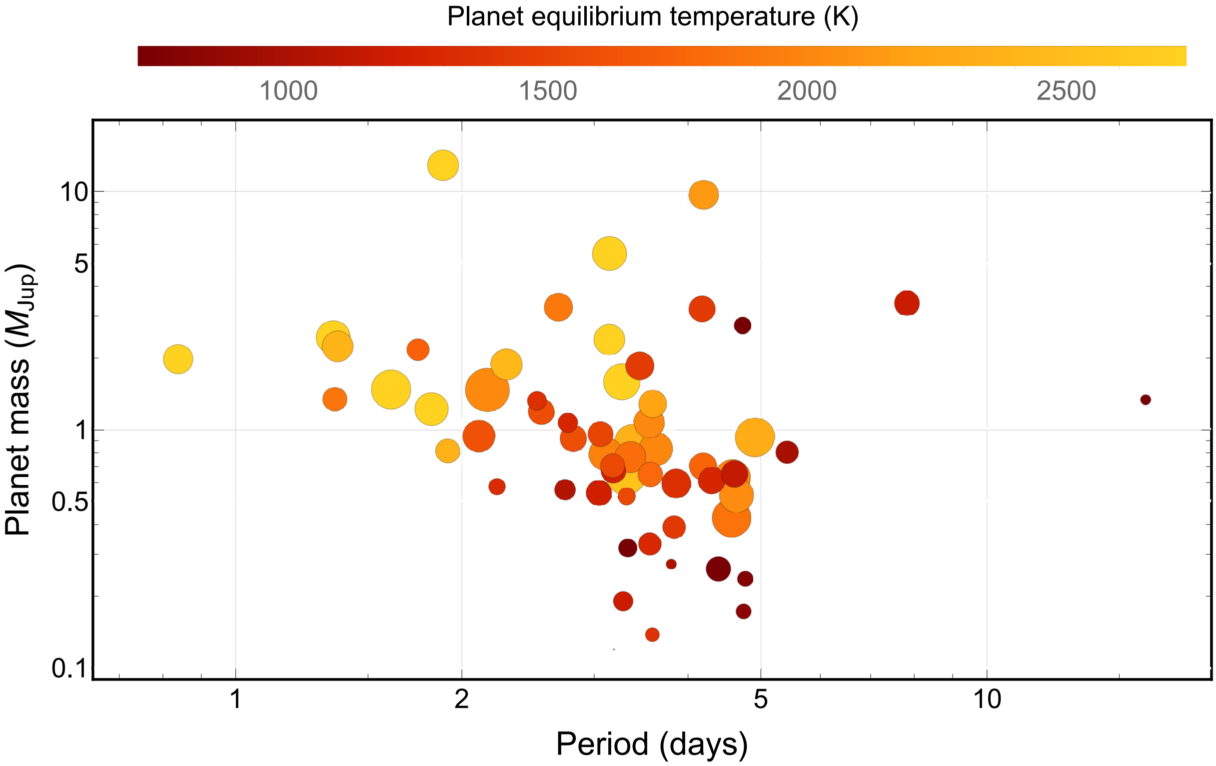
(a) The HATSouth survey is mostly focussed on the monitoring of the Southern hemisphere. Indeed, the list presented in box 8. is composed by telescopes located in the Southern hemisphere. However, we have also intensively observed several equatorial fields, detecting several tens of transiting-exoplanet candidates. The location on the sky of these new candidates make them suitable for being observed with the TNG between April and Septmber at airmass $\approx 1.1 - 1.4$. Here are some details about our four candidates and a backup target:

- *Long period – Neptune(?)* HATS398-017: This is a 0.69 $R_{\rm Jup}$ planet candidate orbiting around a 0.76 $R_\odot$ K-star with a period of $P_{\rm orb} = 29.7$ days.
- *Long period – Jupiter* HATS472-001: This is a 1.6 $R_{\rm Jup}$ planet candidate orbiting around a 1.4 $R_\odot$ F-star with a period of $P_{\rm orb} = 14.4$ days.
- *Saturn(?)* HATS398-016: This is a 0.85 $R_{\rm Jup}$ planet candidate orbiting around a 1.6 $R_\odot$ F-star with a period of $P_{\rm orb} = 6.4$ days.
- *Neptune(?)* HATS537-009: This is a 0.6 $R_{\rm Jup}$ planet candidate orbiting around a 0.84 $R_\odot$ K-star with a period of $P_{\rm orb} = 7.4$ days.
- *Backup target* HATS398-014: This is a 1.0 $R_{\rm Jup}$ planet candidate orbiting around a 1.5 $R_\odot$ G-star with a period of $P_{\rm orb} = 8.1$ days.

(b) TESS will survey over 90% of the sky by observing 26 individual sectors, 13 in the southern hemisphere and 13 in the northern hemispheres. Each hemisphere will be observed for 1 year each in the 2 year prime mission, beginning in the south. The TESS mission started science operations in June 2018 and the first public data releases already occurred. In particular, it is observing sectors close to the southern ecliptic pole, some of which will be visible from La Palma. We will therefore focus on candidates identified through a joint analysis of HATNet, HATSouth and TESS (GI Project G011214, "TESS Observations of Transiting Planet Candidates From HAT", PI Bakos). Through the TESS GI program, we will extract full-frame image light curves for all of the HAT candidates in the Southern ecliptic hemisphere observed by TESS during its first year. These high-precision continuous time-series observations will be used to rule out many false alarms and false positives. In addition to using TESS to vet the large existing sample of planets from HATS, we will also conduct a joint search of the HATS and TESS light curves to find long period planet candidates, which we will follow-up through this proposed effort.

The HATSouth team uses automated routines, developed by the Co-PI of the present proposal, for processing echelle data for several instruments (Euler1.2m/Coralie, MPG2.2/FEROS, ESO3.6m/HARPS, Magellan6.5m/PFS, DuPont2.5m/Echelle), with the goal of measuring precision radial velocities (CERES, Brahm et al. 2017a), and atmospheric parameters (ZASPE, Brahm et al. 2017b). The use of both codes have been fundamental for the discovery and characterisation of more than 50 new planetary systems. We plan to modify the CERES code for the processing of the HARPS-N data as well.

Figure 1: Mass-period diagram of all transiting planets discovered by HATSouth. The planets are represented by circles, whose size is proportional to their radius. Color indicates equilibrium temperature. The error bars have been suppressed for clarity.



Brahm, R., Jordan, A., Espinoza, N., 2017a, PASP, 129, 034002
Brahm, R., Jordan, A., Hartman, J., Bakos, G. A., 2017b, MNRAS, 467, 971
Thorngren, D. P., Fortney, J. J., Murray-Clay, R. A., Lopez, E. D., ApJ, 831, 64
Wakeford, H. R., Sing, D. K., Kataria, T. et al., 2017, Science, 356, 628

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
HATS398-016	01 03 00.00	$+01$ 07 00.0	J2000	$V10.7$	2.0h	$T_{\rm exp} = 10$ min / high priority
HATS398-017	01 00 00.00	$+00$ 10 00.0	J2000	$V11.7$	5.0h	$T_{\rm exp} = 25$ min / high priority
HATS472-001	13 49 00.00	-11 03 00.0	J2000	$V13.4$	10.0h	$T_{\rm exp} = 50$ min / high priority
HATS537-009	22 44 00.00	-14 14 00.0	J2000	$V13.2$	10.0h	$T_{\rm exp} = 50$ min / high priority
HATS398-014	00 54 00.00	$+01$ 37 00.0	J2000	$V13.2$	0.0h	$T_{\rm exp} = 50$ min / backup target

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

We propose to observe at least 4 planet candidates with HARPS-N. Our plan is to obtain a minimum of 10-12 RV points for target. Since we already know their orbital periods, these RV points should be enough to constrain the mass and thus probe the physical nature (planetary or not) of our candidates. This is well demonstrated in our long-list of transiting-exoplanet discovery papers (https://hatsouth.org/planets/).

A preliminary list of four candidates is shown in box 11 and includes a long-orbital period (≈ 30 days) Neptune-size planet candidate, two candidates (a Neptune- and a Saturn-size) with relatively long period (6-7 days), and one giant-size planet candidate with an orbital period of ≈ 14 days. A backup target is also included in the list. Following the policy of the HAT-South collaboration, we have truncated their RA and Dec. The list may be altered as soon TESS data will be available or if most promising candidates will be revealed in the meantime by the HATSouth survey.

By using the HARPS-N Exposure Time Calculator, we have estimated that to obtain an optimum RV precision for our targets and, therefore measuring the semi-amplitude of the RV curve, we need to use the exposure times reported in box 11, considering an AirMass equal to 1.2 and a Seeing equal to $2''$. Therefore, we are asking for 27 hr.

13. Requested instrument(s) setup

Id	Instrument	Binning	Filter(s)	Slit	Grism	Time	Additional Information
1	HARPS-N	1x1	none	115000	none	27hr	

14a. Moonlight constraints

Max. # of days from new moon ☐

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

Bright targets. Poor seeing conditions not critical. No special constraints on lunar phase. HATS472-001 should be preferably observed in April, whereas the other targets in Septmeber, when they are the highest airmass.

15. Observational background of the applicants

Name of the observer(s) at TNG: Luigi Mancini – We have required service-mode observations

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

Experience of the observer(s) with other telescopes/instruments
Luigi Mancini is an extremely expert on astronomical observations and, as PI, lead photometric and spectroscopic observations at the VLT, LBT, TNG, INT 2.5m, MPG 2.2m, CAHA 2.2m, DK 1.54m, OAB 1.52m, CAHA 1.23m Telescopes.