Time Allocation Committee for
MPG time at the ESO 2.2m-telescope
c/o MPI für Astronomie
Königstuhl 17
D-69117 Heidelberg / Germany

Application No.	
Observing period	P108
Received	

APPLICATION FOR OBSERVING TIME

from [X] MPIA [ ] MPG institute [ ] other

1. Telescope: 2.2-m [X]

2.1 Applicant

Prof. Luigi **Mancini**	MPIA & University of Rome
Name	Institute
Königstuhl 17	69117 Heidelberg
street	ZIP code - city
mancini	mancini@mpia.de
ESO User Portal username	e-mail

2.2 Collaborators

S. Desidera	INAF – Astronomical Observatory of Padova
name(s)	institute(s)
V. Nascimbeni	INAF – Astronomical Observatory of Padova
name(s)	institute(s)

2.3 Observers

L. Mancini	
name	name

By specifying the names under item 2.3 it is obligatory to also send out these observers to La Silla, if required. Correspondence on the rating of this application will be sent to the applicant (P.I.) as quoted under 2.1 above.

3. Observing programme: Category: E

Title : **Characterization of the most inflated transiting planet**

Abstract : The TESS satellite identified a giant transiting planet candidate (TOI-447.01; $R_{\rm p} = 2.5\,R_{\rm Jup}$) orbiting the F6 V star HD 33512, with a period of 5.53 days. We observed HD33512 with HARPS, deriving an orbital solution with RV semi-amplitude $K = 46$ m/s, which corresponds to a planetary mass of $0.48\,M_{\rm Jup}$ and planetary density of only $0.03\,\rho_{\rm Jup}$, making it the less dense known to date. Our preliminary spectroscopic and kinematic analysis indicates that the star is member of the Octans association and therefore just 20 Myr old. We propose to observe HD 33512 continuously with GROND during one of the next available time-critical transit dates to measure the wavelength dependence of transit depth and validate such extreme case of low-density and unique case of very young hot-Jupiter planet.

4. Instrument: [ ] WFI [ ] FEROS [X] GROND

5. Brightness range of objects to be observed: from 9.3 to 9.3 V-mag

6. Number of hours:

applied for			already awarded	still needed
7			none	none
no restriction	grey	dark		

7. Optimum date range for the observations: .... 16.11.2021 – 17.11.2021
Usable range in local sideral time LST: .... 00:00h – 23:59h

Astrophysical context

Detections of extrasolar planets allow us to measure the frequency of planets with different masses, sizes, orbital characteristics and host star properties, and are now beginning to probe the diverse outcomes of planet formation and evolution. In this context, observations of young planets at short/intermediate orbital periods are crucial to explore the regimes of planet migration. Theoretical models suggest that in-situ formation of close-in planets is unlikely and that the existence of such planets is an evidence of large-scale migration scenarios (e.g., Lin+1996, Nat, 380, 606; Rakov+2006, AJ, 648, 666). The statistics of orbital properties and frequencies of young planets are to-date very poor because young stars are difficult to handle, since they are characterized by an intense stellar activity that heavily hampers the detection of planetary signals (e.g., Lagrange+2013, A&A 559, A83). Based on recent K2 and TESS detections (e.g. Mann+2016, AJ, 152, 61; David+2019, A&A, 885, 12; Benatti+2019, A&A, 630, 81; Rizzuto+2020, AJ 160, 33; Plavchan+2020, Nat. 582, 497), a tentative emerging picture is that young planets are larger and less dense than their older counterparts. Theoretical models by Linder+2019 (A&A, 623, A85) also predict larger radii at young ages. However, if and how these behaviour extend to Hot Jupiters (HJ) at young ages remain unknown, because of the lack of confirmed transiting HJs at very young ages.

The TESS satellite identified a grazing transiting planet candidate (TOI-447.01), orbiting the F6 V star HD 33512 every 5.53 d (Fig. 1). Once corrected for blending from the wide companion TYC 7053-832-1, the planet radius results of $2.5 \pm 0.3 R_{\rm J}$. Photometric diagnostics derived from TESS data show that the transit occurs on the primary. There are no additional sources that might explain the observed transit as a diluted blended eclipsing binary from Gaia DR2, from speckle imaging (Ziegler+2020, AJ 159, 19) and SPHERE observations. By observing HD 33512 with HARPS, we derived a preliminary orbital solution with RV semi-amplitude $K = 46$ m/s (Fig. 2), which corresponds to a planet mass of $\approx 0.48\,M_J$ and a density of just $\approx 0.03\,\rho_J$ (Fig. 3). The analysis of HARPS spectra shows a very young age (from lithium measured on the G-type companion) and coupled with kinematic data indicates the system is a member of the Octans association and then just 20 Myr old. The planet around HD 33512 would then represent a unique case of a very young HJ planet with an extremely low density.

Immediate aim

We propose to observe the grazing transiting planet around the HD 33512 (TOI-447.01) continuously during one of the two suitable time-critical transit dates in P108 (UT): [first choice: transit mid-point 17 Nov 2021 05:14 UT; i.e., the night between the local 16 and 17 Nov] (for a total of 6.5 hours, including off-transit transit windows) to obtain a high-precision photometric time series in order to demonstrate unambiguously the reality of the planetary transit and to perform a first characterization of the planetary atmosphere. The monitoring of this transit event could be simultaneously performed with ESPRESSO, which should measure the RM effect and also probe the chemical composition of the planetary atmosphere with a better spectral resolution (a proposal was submitted, PI S. Desidera, for observing with ESPRESSO the same transit requested in the present proposal).

Additional aim. For grazing transiting planets, as observed in the case of WASP-67b (Mancini et al., 2014; see also The Exoplanet Handbook, 2nd edition, pag. 224 by M. Perryman, 2018) and WASP-174b (Mancini et al., 2019), the transit depth gradually increases moving from blue to red bands (Fig. 4), contrary to what is expected for higher-inclination systems. This phenomenon happens because grazing transiting planets only covers the limb of the star (as this is a grazing eclipse), which is fainter in the blue part of the optical spectrum than the red one due to the stronger limb darkening. We therefore expect to see shallower eclipses in the bluest bands for the HD33512 system and the GROND observations will confirm this interesting astrophysical phenomenon.

Previous work

We have obtained high-quality light curves for more than 50 known transiting exoplanets and, so far, have refined the main physical parameters of roughly 40 of them and published more than 30 papers in peer-reviewed journals. The GROND instrument played an fundamental role in our programme.

Layout of observations

The observations will be carried out using the defocussing method, which is particularly efficient to diminish many sources of noise and obtain precisions smaller than a 1 mmag per observation over complete transit events. Bias and twilight sky flat-field images will be taken for each night of observation. Differential photometry with respect to several comparison stars will be performed using our robust reduction pipeline.

Strategic importance for MPIA

We aim to give another important contribution in the study and characterization of exoplanets, which is one of the main strategic research themes at the MPIA.

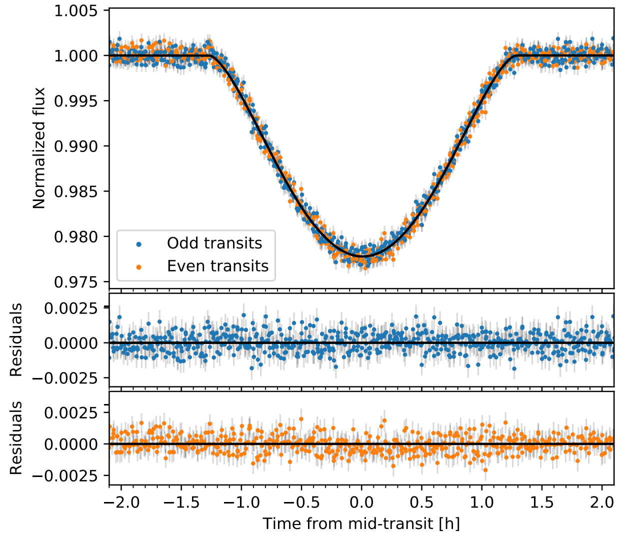

Figure 1: Composite TESS light curve of the transit of HD 33512 b with our best fit model overplotted.

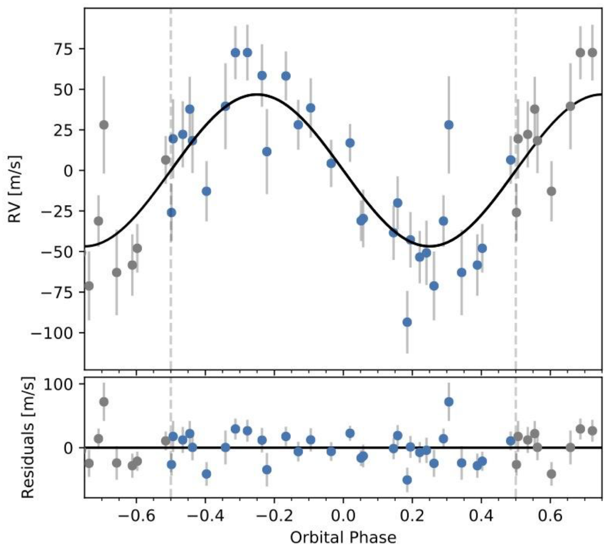

Figure 2: Our RV orbital solution for HD 33515 b from HARPS data.

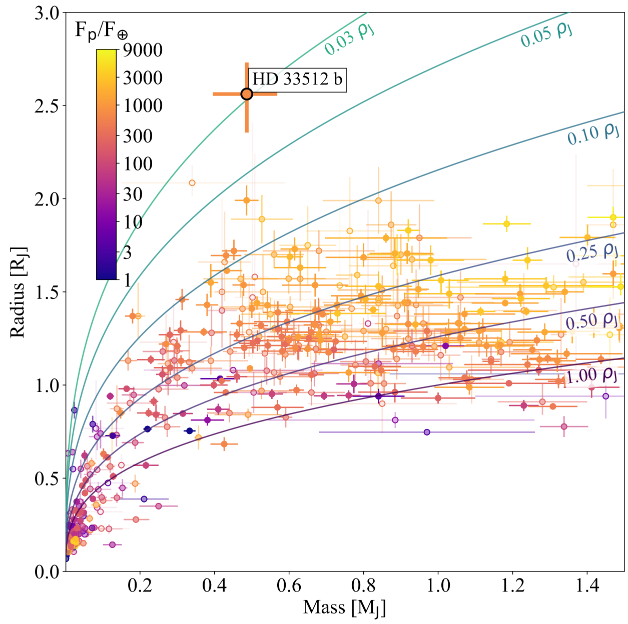

Figure 3: Mass-radius diagram for transiting planets. Points are shaded according to the precision of the planet density estimate. The extreme position of HD 33512 b is marked.

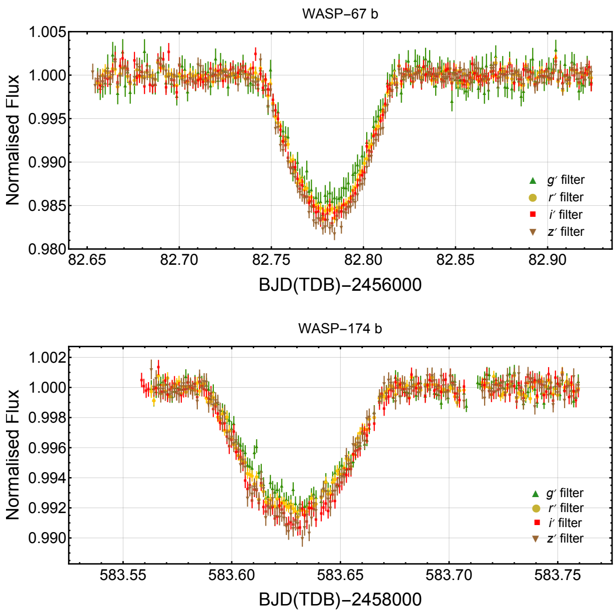

Figure 4: Light curves of WASP-67 b (top panel) and WASP-174 b (bottom panel) transits obtained with GROND, showing how the transit light curve shape changes with wavelength. The transits in the g band are shallower than the other bands, as expected for a grazing eclipse, as limb darkening is stronger at bluer wavelengths. Figures taken from Mancini et al. (2014) (see also The Exoplanet Handbook - 2nd edition, pag. 224, by M. Perryman, 2018) and from Mancini et al. (2019), respectively.

9. Objects to be observed

(Objects to be observed with high priority should be marked in last column)

Designation	α (2000)	δ (2000)	magnitude in spectral range to be observed	priority
HD 33512	$05^{\mathrm{h}}\,09^{\mathrm{m}}\,02.45^{\mathrm{s}}$	$-36^{\circ}\,27'\,52.42''$	$V = 9.3\,\mathrm{mag}$	

10. `Justification of the amount of observing time requested:`

The main aim of our project is to use GROND for obtaining simultaneous, high-precision differential photometry of a complete planetary-transit event of HD 33512 b. For this purpose, we ask a transit event that will occur in P108. The transit lasts 2 hours 21 minutes. In addition, we also request out-of-transit observations, which are mandatory in order to obtain a stable out-of-transit baseline magnitude. This point is extremely crucial for achieving accurate transit fitting models. The observability of the transit is optimal in the proposed time-critical night, with airmass of 1.02 at the transit mid-point. The target is observable at airmass < 1.7 from 02:00 UT (about 2 hours before the start of the transit) to the end of the night, thus we ask for ~ 7 hours of observations. The GROND camera at the MPG 2.2 m telescope is the ideal choice for our program. The possibility to perform simultaneous high-precision photometry in different band will allow us to obtain 7 optical light curves from whose analysis we can unambiguously confirm the planetary nature of the TOI-447.01 candidate and probe the chemical composition of its atmosphere.

11. `Constraints for scheduling observations for this application:`

The scheduling constraint is very specific and the observation is time critical. In particular, the target has to be observed during the following window (times are in UT): START: 17 Nov 2021, 01:00 UT – END: 17 Nov 2021, 08:00 UT.

12. `Observational experience of observer(s) named under 2.3:`
`(at least one observer must have sufficient experience)`

Luigi Mancini is extremely expert on precise transit photometric observations with medium-class telescopes. He already observed planetary transits many times with the MPG 2.2 m telescope and with the 2.5 m INT, the Calar Alto 2.2 m Telescope, the 1.54 m Danish telescope in La Silla, the OAB 1.52 m Cassini Telescope, and the Calar Alto 1.23 m Telescope.

13. `Observing runs at the ESO 2.2m-telscope (preferably during the last 3 years)`
`and publications resulting from these`

Telescope	instrument	date	hours	success rate	publications
2.2m	GROND	Apr 2019	6	100%	[2]

14. References for items 8 and 13:

[1] Mancini, L., Southworth, J., Ciceri, S., et al. (2014): *Physical properties of the WASP-67 planetary system from multi-colour photometry*, A&A **568**, A127

[2] Mancini, L., Sarkis, P., Henning, Th., et al. (2019): *The highly inflated giant planet WASP-174b*, A&A **633**, A30

Tolerance limits for planned observations:

maximum seeing:	3″	**minimum transparency:**	50%	**maximum airmass:**	2.2
photometric conditions:	no	**moon: max. phase / ∠ :**	1/30°	**min. / max. lag:**	0/0 nights