Radial velocity follow-up of terrestrial transiting planets with ELT-HIRES

F. Bouchy[1,2], S. Udry[2], C. Moutou[1], D. Queloz[2], M. Deleuil[1]
(1) Laboratoire d'Astrophysique de Marseille, 38 rue Fréderic Joliot-Curie, 13388 Marseille cedex 13, France
(2) Observatoire de Genève, Université de Genève, 51 Ch. des Maillettes, 1290 Sauverny, Switzerland

Density of low-mass exoplanets

The knowledge of exoplanet radius by transit measurements combined with the determination of its mass through radial velocity (RV) measurements allows the determination of its bulk density. This quantity provides direct insights into the structure and composition of exoplanets. Comparative exoplanetology has risen fast thanks to the results obtained from both photometric and radial velocity surveys. Although about 200 transiting planets with a constraint on their density are know, less than 10% of them are in the low-mass regime ($m < 30\ M_\oplus$). The super-Earth family includes terrestrial planets such as Mars, Venus and Earth, water-rich planets which are similar to giant icy moons, iron-rich planets similar to Mercury, as well as ``mini-Neptune''. These sub-classes can only be distinguished from a precise determination of mass, radius and density.

Present limitations of transit and RV surveys

Both Kepler survey and RV surveys have shown that small-size and low-mass planets are numerous but the determination of their true density is far to be trivial. The relative lack of such low-mass planets in the mass - radius diagram (see Fig. 1) is due to the current detection limits. The detection of transiting terrestrial planets requires in most cases high-precision photometry from space in addition with high-precision RV (eg: CoRoT-7b, Kepler-10b). For few cases, the low-mass exoplanets are discovered by RV measurement and their transit are confirmed in a second step thanks to dedicated high precision photometry from ground-based telescope (eg: 55Cnce, GJ436b). For most of the known transiting low-mass planets shown in Fig. 1, the uncertainties on their mass and radius unfortunately do not permit to properly constraint their internal structure nor composition. This situation mainly comes from the fact that high-precision photometric surveys like CoRoT and Kepler observe quite faint stars (V=12-16) which are not appropriate for high-precision radial velocity follow-up.

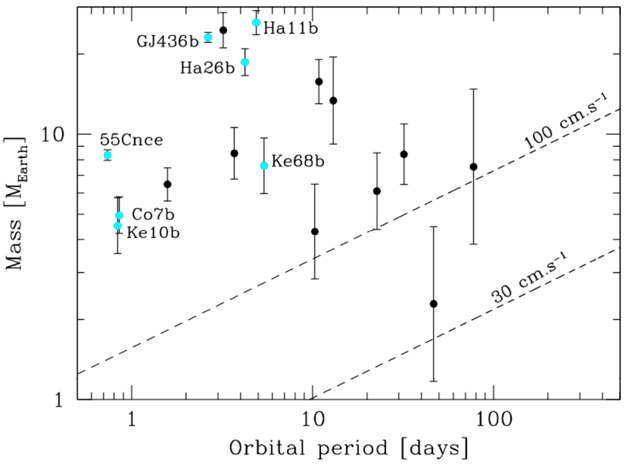


Fig 2 : Mass - Period diagram of know low-mass transiting exoplanets. The dotted lines show the RV semi-amplitude of 30 and 100 cm.s^{-1} assuming 1 solar mass star. Blue points correspond to host star brighter than V=12.

Table 1: Fundamental photon noise RV uncertainty.

	σ_{RV} in 1 hour		
mv	3.6-m HARPS	8.2-m ESPRESSO	39-m HIRES
10	0.60 $\mathrm{m\,s^{-1}}$	0.24 $\mathrm{m\,s^{-1}}$	0.06 $\mathrm{m\,s^{-1}}$
11	1.00 $\mathrm{m\,s^{-1}}$	0.40 $\mathrm{m\,s^{-1}}$	0.09 $\mathrm{m\,s^{-1}}$
12	1.60 $\mathrm{m\,s^{-1}}$	0.64 $\mathrm{m\,s^{-1}}$	0.15 $\mathrm{m\,s^{-1}}$
13	2.50 $\mathrm{m\,s^{-1}}$	1.00 $\mathrm{m\,s^{-1}}$	0.23 $\mathrm{m\,s^{-1}}$

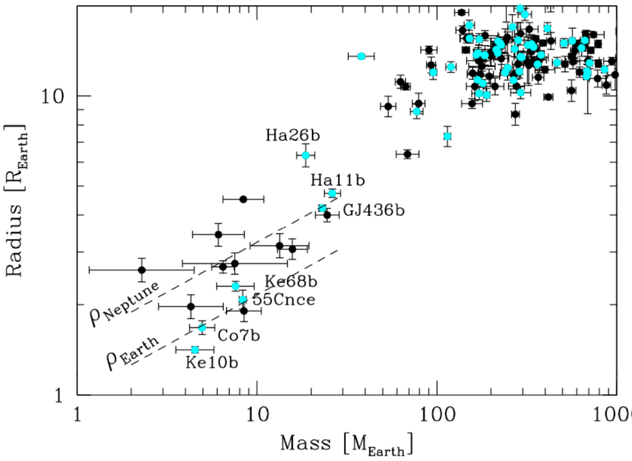
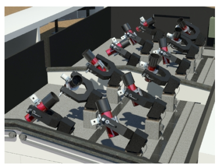
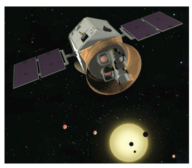
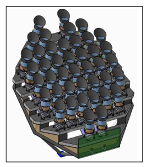


Fig 1 : Mass - Radius diagram of known transiting planets. Iso-density of Earth and Neptune are added as dotted lines. Blue points correspond to host star brighter than V=12.

Next generation of transit surveys

Next generation of transit surveys will focus towards brighter stars. The NGTS (Next-Generation Transit Survey), under construction at Paranal, will be dedicated to the search for transiting Neptunes around bright K dwarfs (V < 13). Future space projects like TESS (NASA) and PLATO (ESA) will search for transiting planets down to Earth size around on all bright stars (V < 12). On the other side, the space mission CHEOPS (ESA) will search for transiting planets among the low-mass planets found by RV surveys. One may estimate that several hundreds of validated low-mass exoplanets will be known in the next decade. The characterization of their mass and radius with an accuracy better then 10% is crucial to study their internal structure and composition and to distinguish and to study iron-rich, silicate, icy, and mini-Neptune like exoplanets.

Mass, density and obliquity determination with HIRES@ELT

As shown in Fig. 2, the detection of terrestrial planets ($m < 10\ M_\oplus$) requires RV precision better than 1 m.s^{-1}. The determination of their mass with 10% accuracy requires precision better than 30 cm.s^{-1}. Table 1 presents the RV photon-noise fundamental limitation for 1-hour exposure on a non-rotating quiet K dwarf stars for HARPS (3.6-m ESO), ESPRESSO (8.2-m ESO) and HIRES (39-m ELT) as a function of its magnitude. One can see that in the domain of magnitude of next generation transit surveys (V=10-13), HIRES@ELT will permit to characterize the mass of transiting terrestrial planets down to 1 Earth mass. HIRES will be required to measure the mass of validated transiting planets will the goal to characterize their mass and radius with uncertainty less than 10%. As a by product of RV measurements, combined high resolution spectra at high S/N will permit a detailed characterization of the parent stars. HIRES will also have the capability to measure the spin-orbit obliquity of terrestrial planetary systems through the Rossiter-McLaughlin effect.