Direct determination of the radii of evolved planet hosting stars with the VLTI

P. Zieliński[2], M. Vanko[1]
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T. Eisenbeiss[1] (PI), M. Mugrauer[1], M. Wittkowski[3], M. Petr-Gotzens[3], R. Neuhäser[1], A. Niedzielski[2]

[1]*Astrophysical Institute and University Observatory, Friedrich-Schiller University of Jena, Schillergässchen 2-3, D-07745 Jena, Germany*
[2]*Toruń Centre for Astronomy, Nicolaus Copernicus University, ul. Gagarina 11, 87-100 Toruń, Poland*
[3]*European Southern Observatory, Karl-Schwarzschild Strasse 2, D-85748 Garching, Germany*
Contact: eisen@astro.uni-jena.de

Introduction

One of the challenging topics of modern astronomy is searching for extrasolar planets. Most of the nearly 300 exoplanets known today are gas giants. The basic properties of these exoplanetary systems, e.g. their capability to support life, are still under investigation.

Host stars of extrasolar planet candidates are usually bright and nearby, some of them are even giants with expected large radii. Accurate interferometric measurements of the host stars angular diameters are necessary to determine parameters more precisely than before and clarify if such giant stars are habitable. Such measurements could be done with the Very Large Telescope Interferometer.

With given gravity and distance the mass of the central star (and planets too) could be calculated with accuracy better than 10 %. These measurements allow us to constrain the evolutionary status of the star, knowing mass and age, hence the question of habitability could be clarified.

Scientific rationale

The habitable zone of exoplanetary system is defined as a region around a star where a planet could receive enough radiation to maintain liquid water on its surface and to be able to build a stable atmosphere. The habitable zone is estimated via climate calculations, describing the possible surface conditions on terrestrial planet moving in this zone. Its distance and width depend on the spectral type and the age of the central star (Kasting et al. 1993). To estimate these values precise knowledge of the stellar radius and mass is needed. The habitable zone around evolved stars is shifted outwards and extended (Fig.1). Depending on the evolution of such a giant star live could develop even in the post-main-sequence state of stars (Lopez et al. 2005).

We have selected three suitable targets – planet harboring giants. The basic informations about our stars and their planets are summarized in Table 1. The planet around HD 27442 orbits its star inside the habitable zone. This is of special interest, since this giant planet could have moons or trojan planets, which would be habitable (Schwarz et al. 2007).

According to Jones et al. (2006), who tested the habitability of exoplanetary systems by means of stellar properties, our targets are included in their sample and are assigned to be habitable. Determining better values for stellar radius would also improve mass of these systems, together with gravity and tempearture taken from literature data.

A similar study was done by Baines et al. (2008), where 24 exoplanet host star radii were measured. For as much as 5 stars a new luminosity class was assigned since their radii were up to 70 % larger than expected by other methods and so also the masses of these stars were revised.

Such investigations could also help to define targets for future astrometry missions because of mass dependency of astrometric signal and for definition the target list of coming space interferometry missions. Furthermore, the *m* sin *i* value of the planet could be better constrained, leading to understanding of radial velocity signals for the search of exoplanets around giants, which is important, since this is the only possibility to find planets around intermediate and high mass stars with the radial velocity technique (Setiawan et al. 2003a).

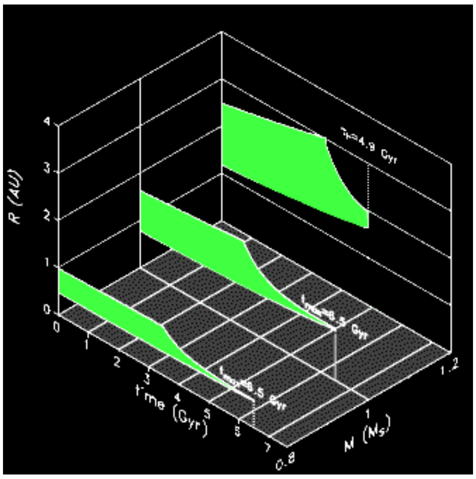
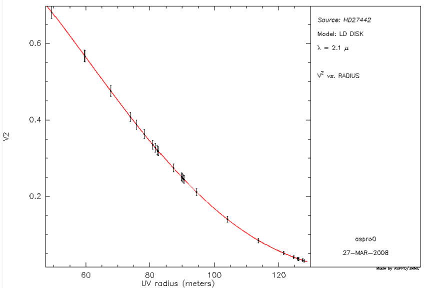


Figure 1. Width and position of the habitable zones for three stellar masses: 0.8 $M_\odot$, 1 $M_\odot$ and 1.2 $M_\odot$ (Franck et al. 2001).

Table 1. Basic parameters of our stars (spectral type, visual magnitude, distance, mass and radius) and their companions (mass and semimajor axis). The references of these objects are given respectively: Butler et al. (2001), Setiawan et al. (2005) and Setiawan et al. (2003b).

Name	SpT	V (mag)	d (pc)	M ($M_\odot$)	R ($R_\odot$)	*m* sin *i* (M_J)	a (AU)
HD 27442	K2 IV	4.55	18.2	1.2	6.6	1.43	1.18
HD 11977	G5 III	0.57	66.5	1.91	10	6.54	1.93
HD 47536	K1 III	5.25	121.4	1.1	23.5	5	1.61



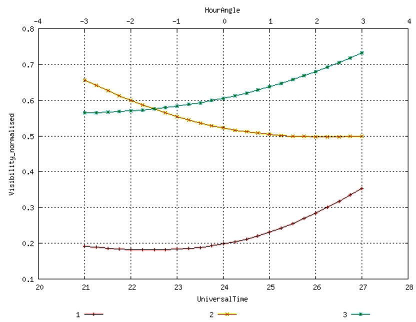
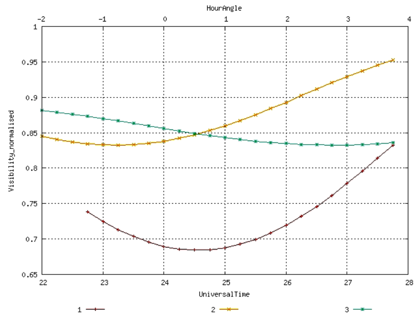


Figure 2. *Left:* Expected squared visibility and model fit of a limb darkened disk for HD 27442. Estimated angular diameter is 3.39 mas at 18.2 pc. *Right:* Visibility values for HD 27442 using the baseline A0-K0-G1 at hour angles between –3h and +3h.



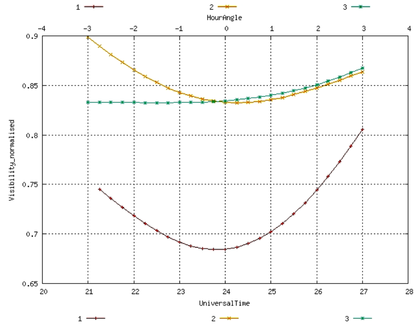


Figure 3. Expected visibility for HD 11977 (*left*) and HD 47536 (*right*) using the baseline A0-K0-G1 at hour angles between –1.25h and +3.75h and between –3h and +3h respectively. Obtained apparent diameters are 1.82 mas at 66.5 pc for HD 11977 and 1.8 mas at 121.4 pc for HD 47536.

Observations and data analysis

We are interested in observing three planet candidate host stars using AMBER in low resolution mode. Estimates of the radii through temperature and luminosity proof that these stars are resolvable with Auxiliary Telescopes. The most precise angular diameter measurements can be obtained using the baseline triangle A0-K0-G1 (longest offered baseline). Figures 2-3 show the visibility values that can be obtained.

The star will be modeled using state-of-the-art atmosphere models done by Wittkowski et al. (2004, 2006). We will obtain high-precision (~1 mas) Rosseland angular diameters, because the true intensity profile is not a uniform disk. In this way the radii can be determined with an accuracy better than 5 %. Placing the stars on the theoretical HR diagram, together with Hipparcos parallaxes and bolometric fluxes available in the literature, we will estimate the stellar masses with precision ±0.1 to 0.2 $M_\odot$. This is much better compared with previous calibrations.

From high-resolution spectra, available in archive, we can measure rotational velocity *v* sin *i* of the star. Comparing this value to typical rotational velocities of similar stars (de Medeiros et al. 1996) we can get an estimate of the inclination of the rotational axis and also inclination of the companion. It allows us to confirm or neglect its planetary status.

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