ONTHEFRINGE

Direct determination of the radius of an extrasolar planet candidate host star giant in the Hyades with the VLTI

T. Eisenbeiss (AIU Jena, D) & M. Vanko (AIU Jena, D)

M. Mugrauer (AIU Jena, D), M. Wittkowski (ESO Garching, ESO), R. Neuhäuser (AIU Jena, D)

Abstract

We would like to determine the radii of extra-solar planet host stars by interferometry using AMBER with the ATs in low resolution mode. Host stars of extra-solar planets are usually bright and nearby, some of them are even gaints with expected large radii.
For this investigation, we have selected the targets HD 27442, ε Tau and HD 219449 (giants with luminosity class III and IV), where a planet (candidate) has been detected by radial velocity. From the stellar temperature and luminosity, we can expect the stellar radii and apparent diameter.
A better stellar radius, together with stellar temperature and/or gravity, will determine the stellar mass more precisely than before, so that the mass of the planet (as function of the host star mass through Keplers 3rd law) can be better constrained.

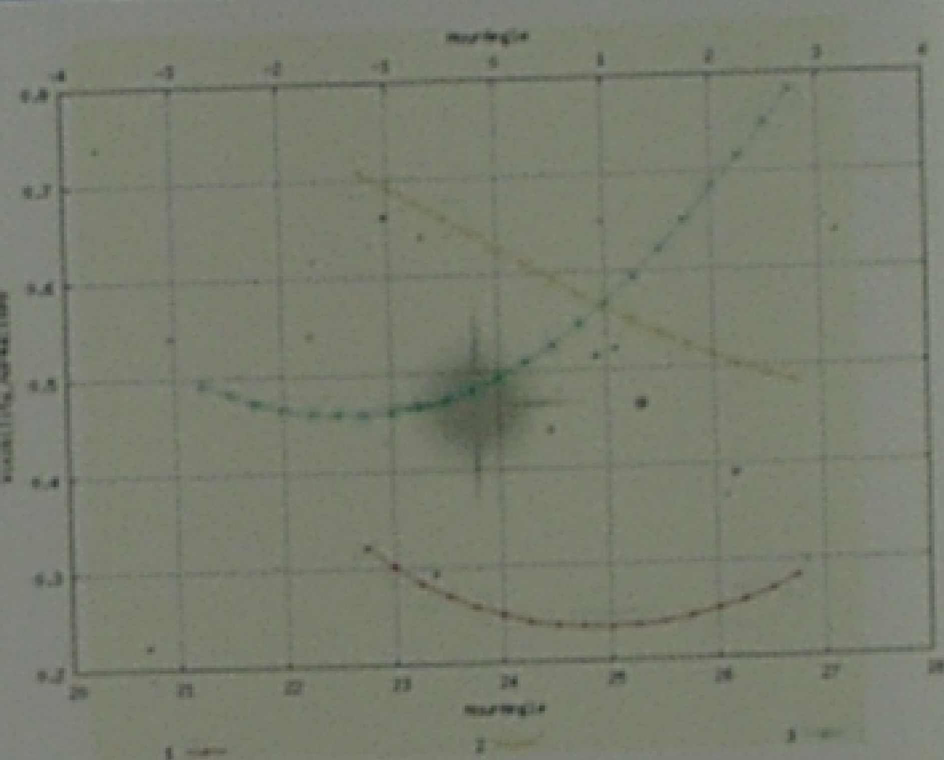

Fig. 1: This image shows the visibility values that can be measured for the planet host star ε Tau using the baseline A0-K0-G1 at hour angles between -3h and +3h

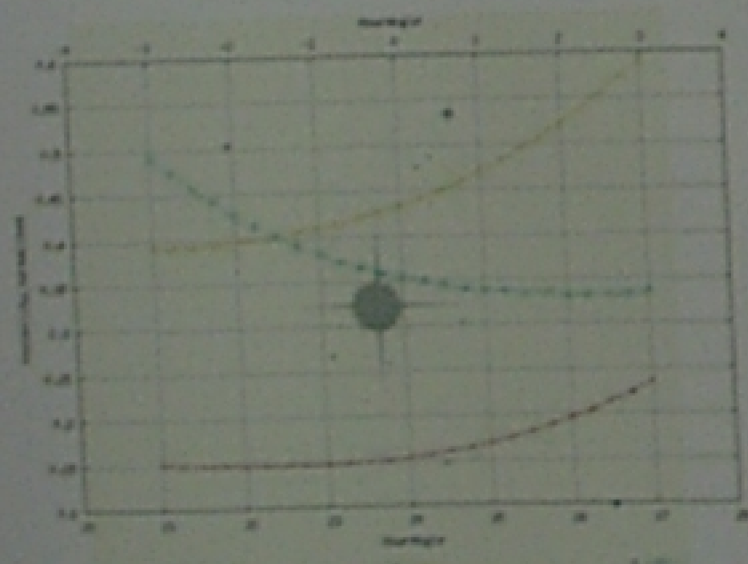

Fig. 2: Same as Fig. 1 for HD 27442.

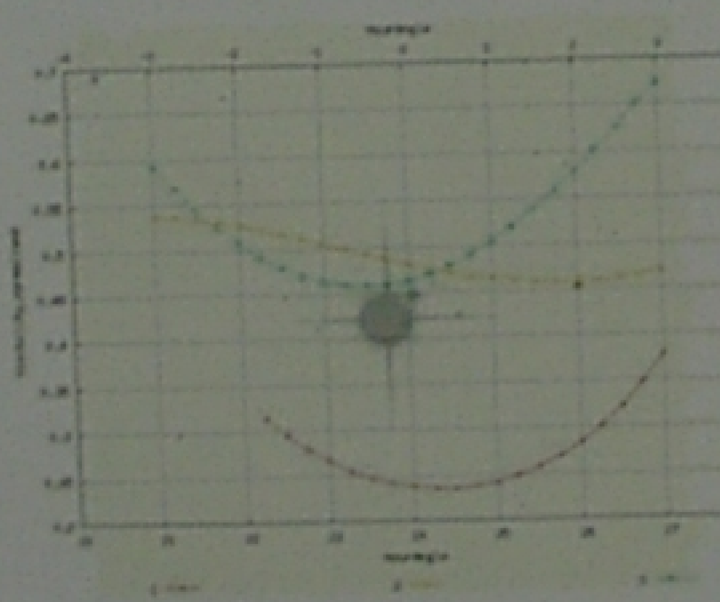

Fig. 3: Same as Fig. 1 for HD 219449.

Scientific purpose

One of the challenging topics of modern astronomy is the search for extrasolar planets. Even though today more than 200 radial velocity planet candidates around other stars, less than 20 of them are confirmed as true planets by either transit or astrometry. For all the radial velocity companions, only a lower mass limit is known, $m \cdot \sin i$. Many of them could be brown dwarfs or even low-mass stars. Most important for their classification is their mass. With the advent of the VLTI, it is now possible to determine the radii of large nearby stars directly. In this proposal, we propose to observe three planet candidate host stars to determine their radii (and, hence, get better mass estimates for star and planet).
For our observations, we have selected the targets as follows: Stars with known radial velocity planet candidates, which are observable from VLTI ($\delta \leq 20°$), $K \leq 3$ mag (so that we can use the ATs with Finito), with an expected stellar diameter ≥ 2 mas, (not being a VLTI GTO target and without any previous radius determination by interferometry). The best suitable targets are explained below.
Butler et al. (2001) found the radial velocity planet candidate around HD 27442 (see Table 1). The host star is a wide visual binary star itself with 236 AU separation (13 arc sec) between the host star HD 27442 A (K2 IV) and its white dwarf companion HD 27442 B (Mugrauer et al. 2007; Chauvin et al. 2006), the planet orbits around the primary star. The white dwarf companion will not hamper the VLTI observations, because of its large separation and faintness.
Sato et al. (2007) recently found the planet (candidate) by radial velocity around the Hyades cluster member ε Tau. See Table 1 for detailed information about the planet (candidate) and the host star.
Mitchell et al. (2003) found a rad vel planet candidate around the giant star HD 219449. Please refer again to Table 1 for more information.
Together with its gravity and temperature, one can then better constrain the mass of the planet host star. Because the lower mass limit of a planet is determined as mass function from the host star (Keplers 3rd law), a better mass of the host star will yield a better constrain on the planet mass.

Table 1: Basic parameters for planet candidates and host stars

	Planet candidate				Host star			
	$m \sin i$	a [AU]	P_{orb} [days]	T_{eff} [K]	R [$R_\odot$]	$app.diam$ [mas]	d [pc]	sp. type/ mag
HD 27442 A	1.28	1.18	424	4750(50)	6.6	3.39	18	K2IV/V = 4.44
ε Tau	7.6	1.93	595	4900(20)	13.7	2.83	45	K0III/V = 3.53
HD 219449	2.9	0.3	182	4580	11.1	2.3	45	K0III/V = 4.21

Observation plan

We propose to observe the 3 planet candidate host stars using AMBER with the ATs in low resolution mode. The most precise radius determination can be obtained using the baseline triangle A0-K0-G1 which provides the currently longest offered baseline lengths (90m and 128m). Fig. 1-3 show the visibility values that can be obtained for our three planet candidate host stars using this baseline. For all three stars, we are limited to the first lobe of the visibility function, but can probe a wide range of visibility values between 0.15 and 0.80. We propose two observations per star, before and after meridian, to increase the range of visibility data, leading to a more precise determination of the radius.
The stars will be modeled using state-of-the-art atmosphere models as done in Wittkowski et al. (2004, 2006b,a). Since the observations proposed here are limited to the first lobe of the visibility function, we will obtain high-precision Rosseland angular diameters. A simple uniform disk fit would not be satisfactory because the true intensity profile is not a uniform disk, and the resulting diameter would not correspond to a well-defined atmospheric layer. The Rosseland angular diameter will be transformed to the linear Rosseland radius using the Hipparcos parallaxes and to the luminosity using the bolometric flux obtained from the literature. Placing the star on the theoretical HR diagram, we will obtain a high-precision estimate of the stellar mass.
As done before, we can determine the angular diameters with a precision of ~ 0.5 %, i.e. ~ 1 mas. Given the parallaxes of our target stars (and their errors), the radii can be determined with a precision of better than ~ 5 %, i.e. for about 10 solar radii better than $\pm 0.5\ R_\odot$. The largest error source is in the parallaxes. As done before, the masses will then be precise to ± 0.1 to $0.2\ M_\odot$. This is much better than before.
For γ Cep, also a (sub-)giant with a radial velocity planet (candidate), i.e. a typical example for our program stars, Torres (2007) found mass values from 0.8 to 1.7 $M_\odot$, and even after critical assessment of recent works, a mass range from 1.18 (Torres 2007) to 1.59 $M_\odot$ (Fuhrmann 2004) remains possible, i.e. an uncertainty of 30 %. Hence, our VLTI data will improve the precision in mass significantly.

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