Search for (sub)stellar companions of exoplanet host stars

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Motivation

- An important aspect in the diversity of extrasolar planets (exoplanets) is the multiplicity of their host stars.
- Theoretical studies predict that a stellar companion of a star alters the formation process of its planets and the evolution of their orbits.
- Observations can test these theoretical predictions.
- This is a very important astrophysical research objective, since a large fraction of stars with their planets is located in multiple stellar systems.
- The closest stellar systems with exoplanets are most intriguing, due to a maximal gravitational perturbation of the stellar companion.
- Searches for close stellar systems with exoplanets were conducted so far only with small samples sizes compared to the exoplanet population.

Objectives

- Perform the first homogeneous multiplicity study of exoplanet host stars with a large enough sample size (more than 340 targets) to draw statistically significant conclusions for the whole exoplanet system population.
- Utilize the AO imager SPHERE/VLT for southern and the lucky imaging camera AstraLux for northern exoplanet host stars, to discover and characterize close stellar companions (projected separation > 15 au) of all observed stars and to clarify the multiplicity status of our targets.
- Search for differences between the properties (masses, orbital elements) of single-star and multiple-star planets.
- Explore the differences in the correlations between the properties of both exoplanet populations, as well as between their distributions.
- Determination of $a_{critical}$ in all multiple stellar systems with exoplanets and comparison with the orbits of the planets found in these systems.
- Search for differences in the properties of detected multiple-star planets, dependent on the properties of the stellar host systems (e.g. mass-ratio, separation).

Previous work

We have searched for wide stellar companions of exoplanet host stars using Seeing-limited IR imagers with large fields of view e.g. MAGIC at the CAHA/2.2 m, Sofl at ESO-NTT, and UFTI at UKIRT. In the course of these imaging surveys, beside several stellar companions, we could also directly detect the first brown dwarf companion of an exoplanet host star, the T7-8 dwarf HD3651B (Mugrauer et al. 2006, MNRAS 373L, 31). Furthermore, these studies revealed several differences between the orbital parameters and masses of exoplanets in stellar systems and of those orbiting single stars (Mugrauer et al. 2007, A&A 469, 755).

In addition, we also have utilized AO and speckle imaging and could detect very close companions of our targets, e.g. (1.) the faint secondary component of γ Cep (M4 dwarf, with 0.4 $M_{\odot}$, at a ~ 20 au), which was directly detected by us for the first time using the 8.2 m Subaru telescope, and the CAHA 3.5 m telescope (Neuhäuser, Mugrauer et al. 2007, A&A 462, 777), or (2.) the faint companion of Gl86, a white dwarf (with about 0.6 $M_{\odot}$, at a ~ 20 au), whose true nature was derived by us with NACO/VLT imaging and spectroscopy (see Mugrauer & Neuhäuser 2005, MNRAS 361L, 15), proving by observations that planets can survive the post main sequence evolution of a nearby star, as described by theory. Beside close binaries we could also identify triple stellar systems with exoplanets (e.g. Mugrauer et. al. 2007, MNRAS 378, 1328).

Today about 90 multiple stellar systems with exoplanets are known and 35 of them were detected in our multiplicity study (24 double, 8 triple and 3 evolved binary systems with white dwarf companions). This demonstrates the efficiency of these projects and shows that the multiplicity rate of the exoplanet host stars is underestimated at least by a factor of about 90/(90-35) ~ 1.6! The results of our projects are described in 15 refereed papers. The latest ones are: Mugrauer & Dincel (2016, AN 337, 627), Mugrauer & Ginski (2015, MNRAS 450, 3127), and Mugrauer, Ginski et al. (2014, MNRAS 439, 1063).

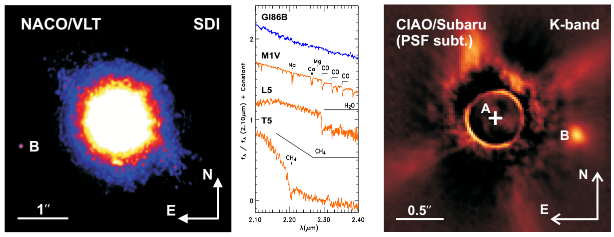
Observing Schedule

ALREADY EXECUTED OBSERVING CAMPAIGNS:

- ☑ Oct 2016, Apr & Oct 2017: **AstraLux** 1st & 2nd epoch observations successfully executed in visitor mode (9 nights) 145 targets observed, co-moving companions and companion-candidates detected (see examples ☞).
- ☑ ESO-P98 & 99 : **SPHERE/VLT** 1st epoch observations successfully completed in service mode (23.5 hours) 35 targets observed, several companion-candidates detected (see examples ☞).
- ☑ ESO-P100: **SPHERE/VLT** 1st & 2nd epoch observations successfully completed in service mode (10.5 hours) 30 targets observed, data-reduction and analysis in progress (see examples ☞).

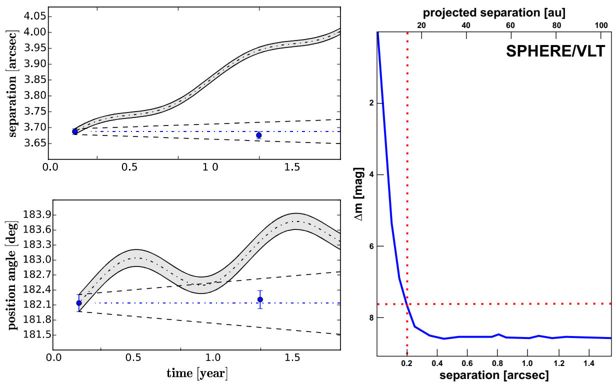
APPROVED OBSERVING CAMPAIGNS:

- ☐ ESO-P101: observing time (9.1 hours in service mode) is granted for 1st & 2nd epoch imaging with **SPHERE/VLT**
- ☐ May 2018: observing time (3 nights in visitor mode) is granted for 1st & 2nd epoch imaging with **AstraLux**

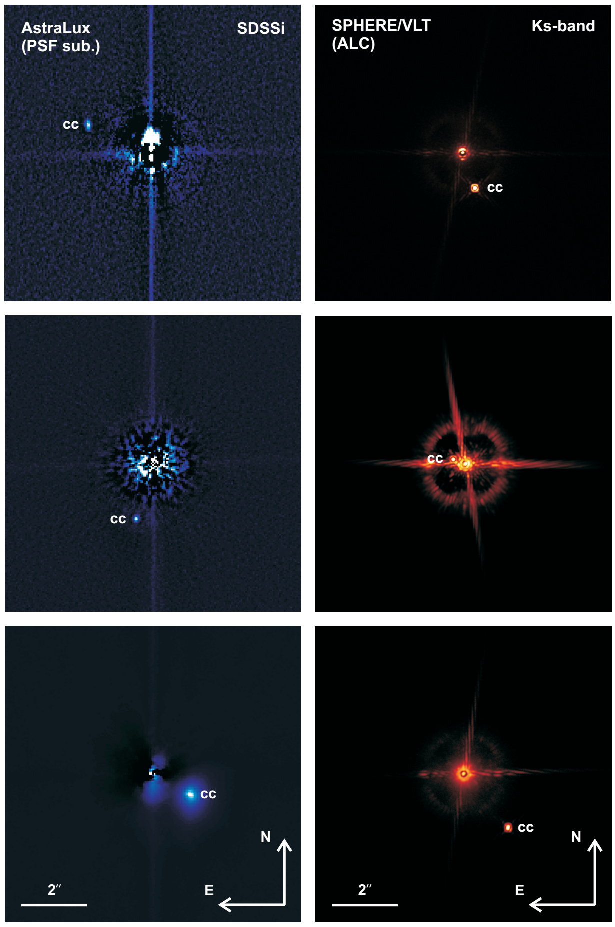


Left: Our NACO/VLT SDI image of the exoplanet host star Gl86 and its faint co-moving companion (B). **Right:** The NACO/VLT K-band spectrum (blue) of Gl86B in comparison with M1V, L5, and T5 spectra (red) of cool dwarfs. Our NACO/VLT spectroscopy together with the photometry of the companion confirms its white dwarf nature.

Our CIAO/Subaru coronographic K-band image of γ Cep. The exoplanet host star (A) is located behind the coronographic mask. The faint secondary B is well detected after PSF subtraction next to its primary star.



Left: Astrometric test for companionship. Angular separation (top) and position angle (bottom) of a faint companion-candidate of an exoplanet host star, detected in our project, measured in two observing epochs. The solid wobbled lines indicate the expected change of both quantities, if the candidate would be a non-moving background source. The faint companion-candidate clearly shares a common proper motion with the exoplanet host star (detected on the 23 σ-level). Hence, the newly detected co-moving companion and the exoplanet host star form a close binary system with an exoplanet in orbit around its primary component.
Right: Detection limit, achieved with SPHERE/VLT, using the standard imaging setup-up of our project. All stellar companions down to 0.1 $M_{\odot}$ are detectable outside of 0.2″, about 15 au of projected separation at the average distance of our targets.



Examples of companion-candidates (cc) detected by us in visitor mode with AstraLux in the I-band (left), and with SPHERE/VLT in the Ks-band (right) in our service mode observing campaigns. The PSFs of the bright exoplanet host stars are subtracted in the AstraLux images, while the SPHERE/VLT data is taken in coronographic mode to suppress the flux of the bright exoplanet host stars.