Characterizing Exoplanets with GRAVITY

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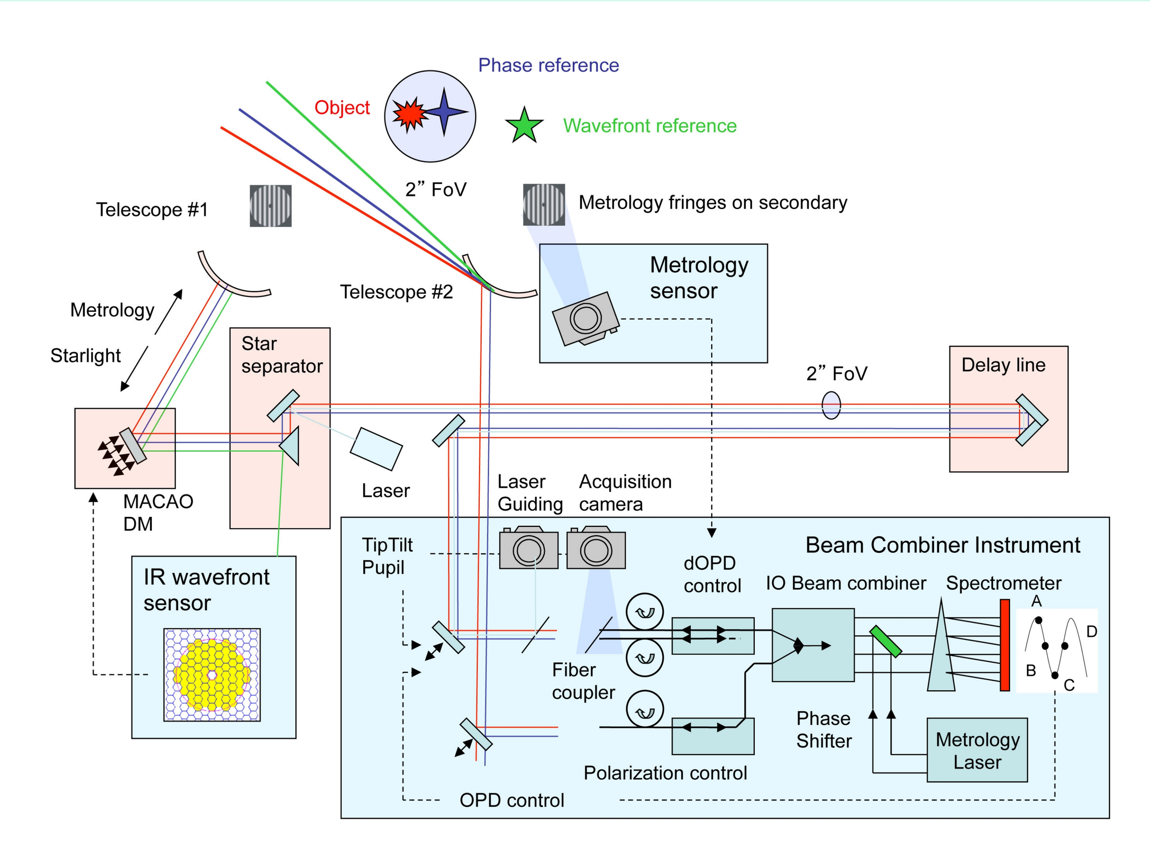
Introduction

GRAVITY is the second generation instrument of the VLTI that is designed to work with all four 8-meter Unit Telescopes. With the expected* 10 µas astrometric capability GRAVITY will open a new window in a range of planet masses that can be discovered via astrometry. GRAVITY will focus on detecting exoplanets in close binary systems with angular separation smaller than 1.7". Our target list include solar-type stars within 200 pc from the Sun, and M-dwarf binaries within 25 pc and binary stars with known RV-exoplanets. We aim to detect 4 Earth mass planets around M-dwarfs in a 5-year survey.

GRAVITY Overview



H + K-band NIR wavefront sensor will be installed on all four 8-m UTs at the Coudé focal station.

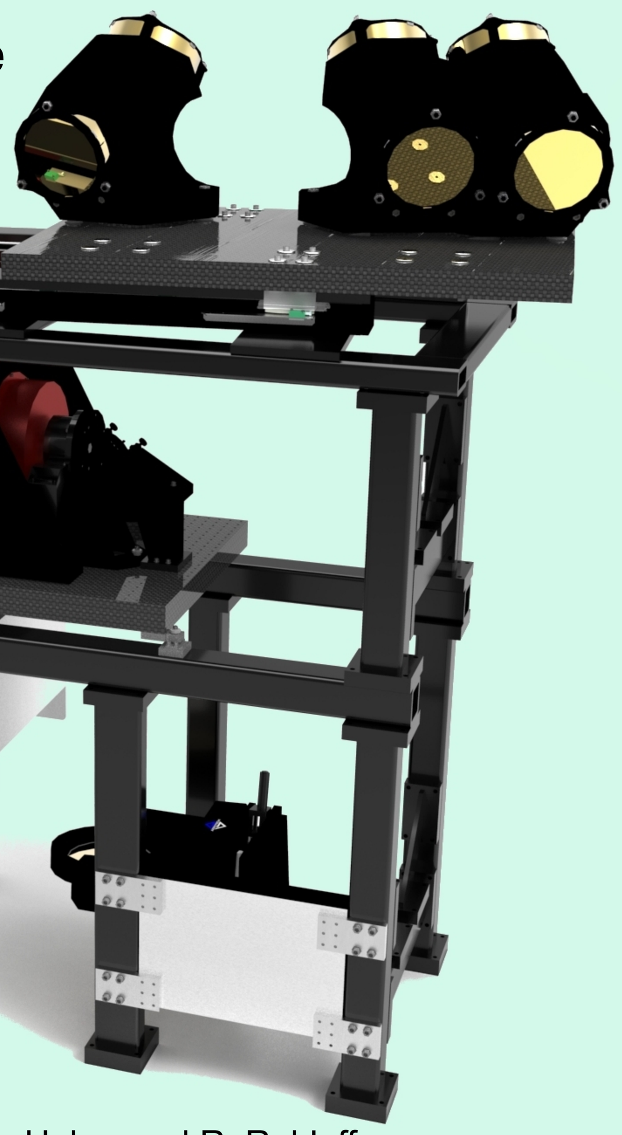


Image credit: A. Huber and R. Rohloff

GRAVITY AO Mode Selector

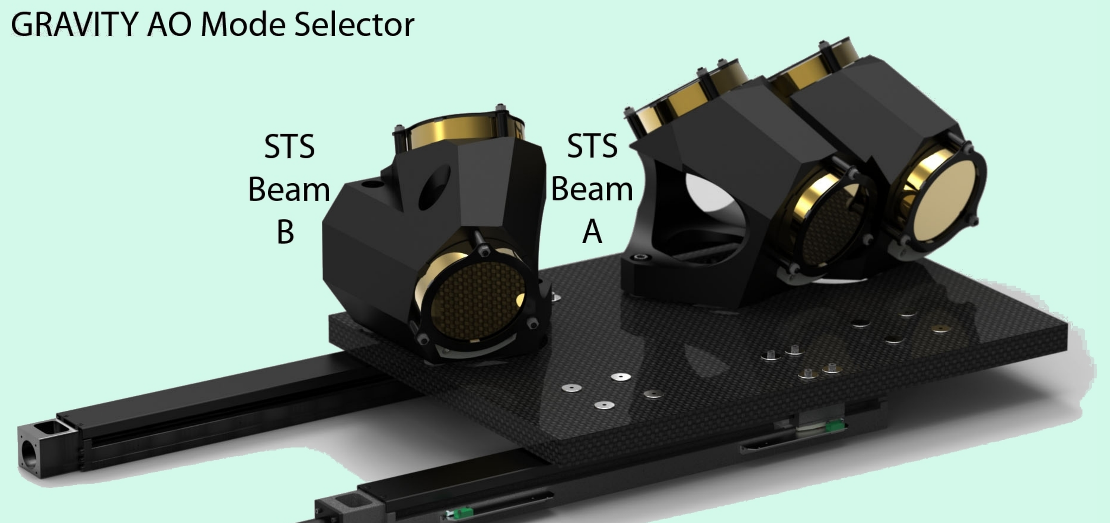
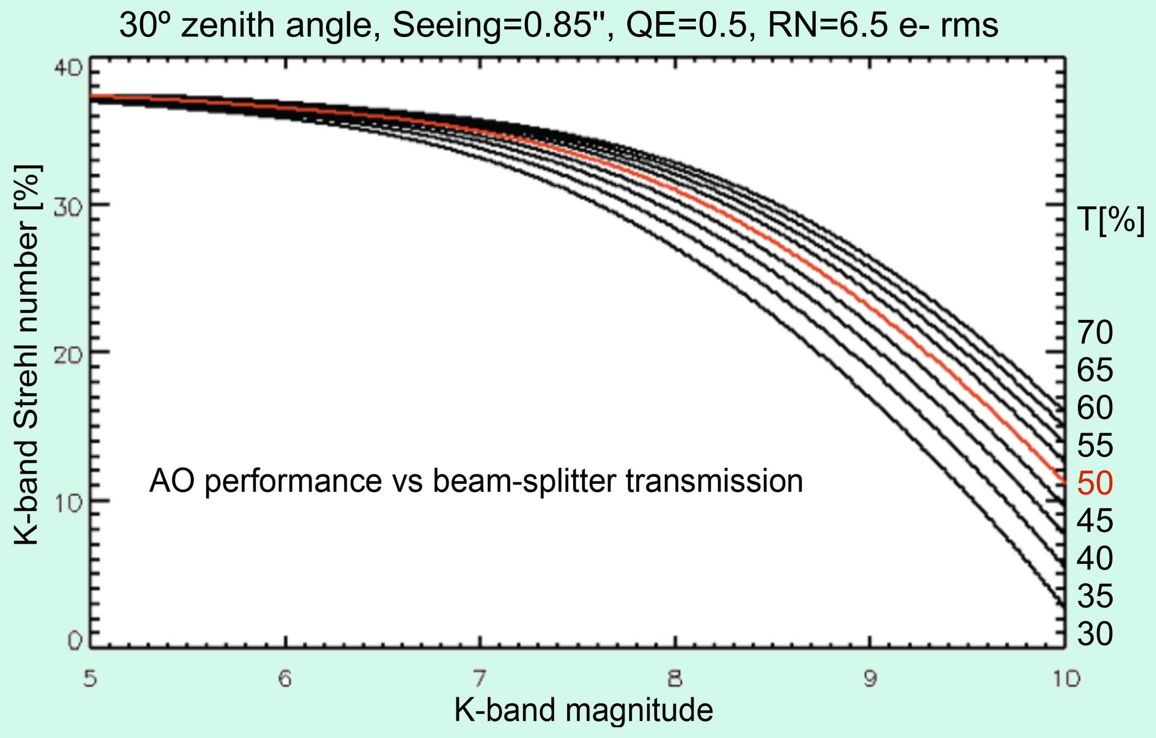


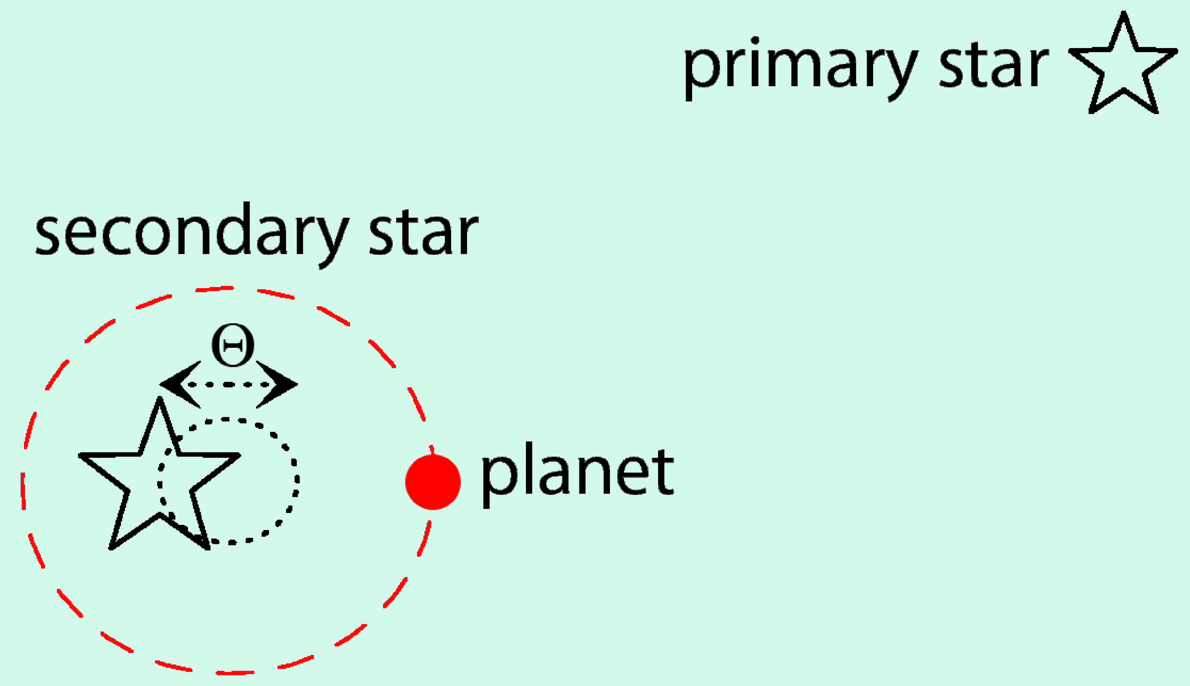
Image credit: A. Huber and R. Rohloff



*The GRAVITY goal specification is 10µas astrometric precision. The specification is to achieve 30µas in 5 min for a K=10 primary and a K=15 secondary star with 1" separation.

Methods

Astrometry



Astrometry	RV method
planet mass	(planet mass • sin i)
7 orbital parameters	5 orbital elements
(a, e, i, ω, Ω, P, T)	(a, e, ω, P, T)
sensitive to planets in wide orbits with longer periods	sensitive to close-in planets with short periods

Displacement of the star due to a planet over the full orbit
(in case of a circular orbit)

$$\theta = 20.5\,\mu as \left(\frac{M_{planet}}{4M_{Earth}}\right)\left(\frac{d}{5pc}\right)^{-1}\left(\frac{\tau}{5yr}\right)^{2/3}\left(\frac{M_{star}}{0.2M_{Sun}}\right)^{-2/3}$$

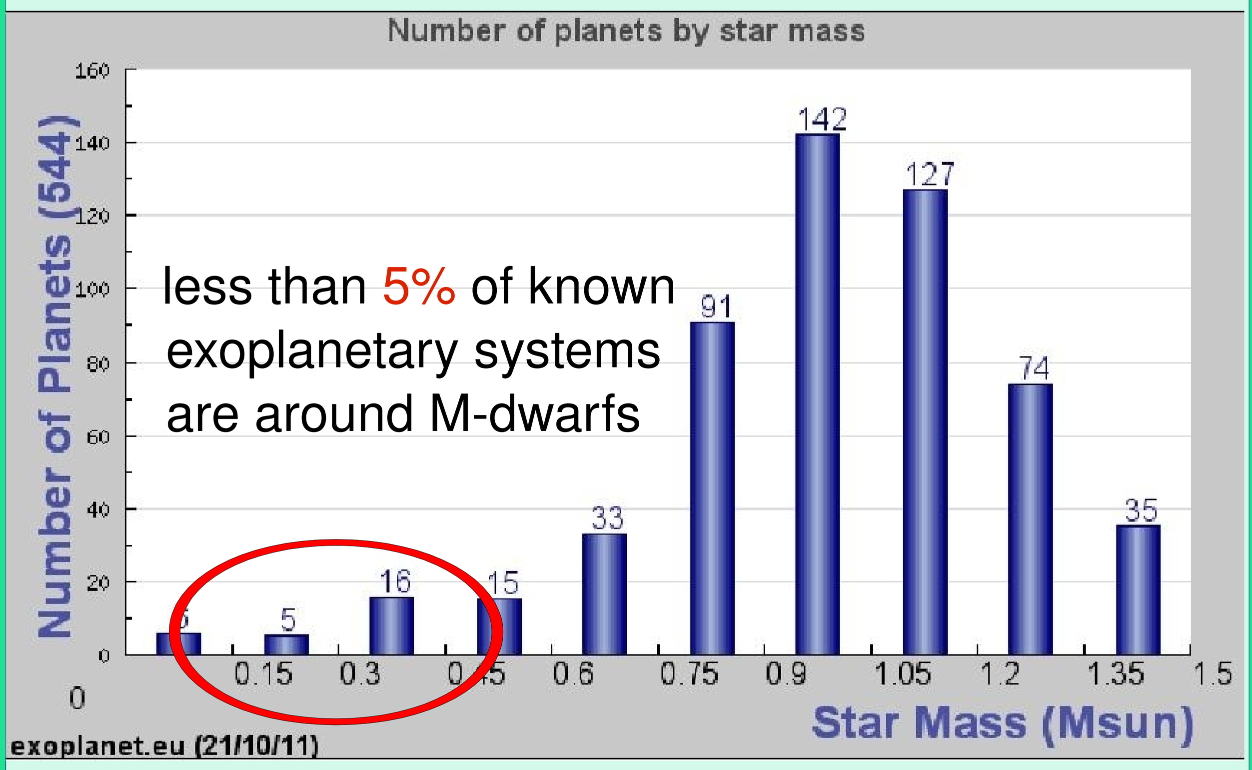
d - distance to the system in parsecs
τ - orbital period of the planet in years
M_{star} - mass of the host star in solar masses
M_{planet} - planet mass in Earth masses

GRAVITY Exoplanet Targets:

- M - dwarf binaries within 25 pc from the Sun
- Solar-type binaries within 200 pc from the Sun
- Known RV-planets within 200 pc from the Sun

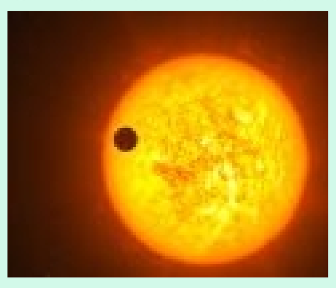
Why M-dwarf targets?

- 70 % of all the stars in the Milky Way
- small mass (0.08 Mʘ < m< 0.5 Mʘ)
- optically faint => would complement space-based astrometric missions (GAIA)



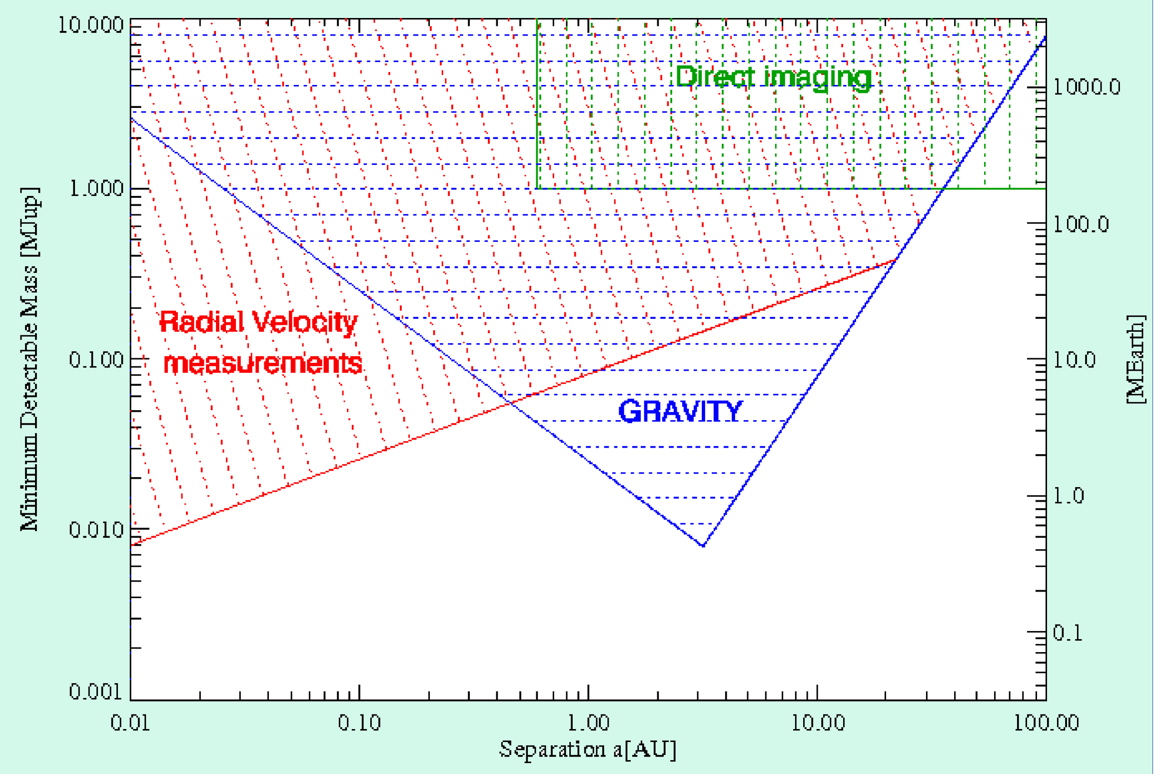
Transiting exoplanets

In addition, the GRAVITY instrument will be able to measure the position angle of the planet orbit on the sky by observations of transiting exoplanets. The planet orbit orientation combined with measurements of the degree of polarization of light reflected by the planet (e.g. SPHERE ZIMPOL observations), will give an opportunity to place constraints on the distribution of clouds and weather zones on the planet.



Planet detection

The limits in GRAVITY planet detection capabilities



GRAVITY astrometric capabilities as compared to radial velocities measurments by HARPS and SPHERE direct imaging. Blue zone corresponds to GRAVITY exoplanet detection capabilities around M7.5 dwarf star at a distance of 6 parsec.
With GRAVITY we expect to detect planets of 2-3 Earth masses around M5 dwarfs within 10 pc.

Minimum separation detectable by GRAVITY
M planet = 1 M jup

SpT	a [AU] (d=5pc)	a[AU] (d=25pc)
M0 V	0.134	0.669
M3 V	0.087	0.433
M5 V	0.055	0.276
M7.5	0.021	0.106

GRAVITY & VLTI instruments

The GRAVITY instrument will equip the VLTI with a near-infrared adaptive optics facility (CIAO, Coudé Infrared Adaptive Optics) using the same corrective element as the MACAO systems.
In contrast to the MACAO systems that use a fixed dichroic mirror to feed the MACAO systems with visible light and reflect the infrared spectrum towards the VLTI laboratory, the CIAO system offers four options (see AO mode selector image on the left):

1) wavefront sensing using an off-axis guide-star via the star separator (STS)

2) wavefront sensing using a GRAVITY instrument optimized H-K-band beam-splitter inserted in the science beam (on-axis), see AO Performance plot on the left side

3) wavefront sensing using a "to be defined" beam-splitting device in the science beam (on-axis)

4) leaving the VLTI on-axis beam unaffected (open)

In particular options 1 and 3 could be interesting for other VLTI instruments like AMBER, MATISSE, or PRIMA in case they are using the unit telescopes for observations. Please note that the GRAVITY consortium will not provide the beam-splitting device for option 3.

Thanks! Any questions?

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