

1 KI-ASTRA astrometry science

Fig. 1. Schematic overview of how the science cases drive the instrument requirements of ASTRA. The disks around young stellar objects (YSO) are typically bright enough to be studied in self-phase-referencing, while the dual-field phase-referencing is required to go deeper and to study the circumnuclear emission of AGN and stars in the Galactic center (GC). Finally the astrometry is designed for both exo-planet and GC observations as outlined in the Sec. 1. The astrometry relies on completion of the previous SPR- and DFPR-phases of the ASTRA upgrade.

KI-ASTRA upgrade offers a variety of new observing capabilities, including higher spectral resolution, better sensitivity and a precision of differential astrometry beyond current single telescope limits. This enables a large number of new science cases ranging from studying the stellar reflex motion of exo-planet systems, and the astrophysical properties of planet-forming disks over classical interferometry science at unprecedented sensitivity to a systematic study of AGN with the phase-referencing technology (see Fig. 1).

Here we focus on the science cases which drive the development of the astrometric mode as outlined in the following sections. Be reminded of the general requirements and assets for such an astrometry science case:

- Two stars / targets per observation only; while the astrometric precision will surpass single telescope imaging limits, the efficiency of "measured separations per observing time" is low and not applicable for complex cluster astrometry with hundreds of stars to be monitored
- High precision is achieved with only two stars whereas AO-assisted single telescope imaging requires a large number of stars to reach an astrometric accuracy of $\sim 100 \mu$as, to calibrate for the distortion over the field-of-view (Cameron et al., 2008)
- Target separation is bound to be larger than about 1 arcsec for technical reasons, and smaller than 30 arcsec due to the atmospheric limitations
- At least one target needs to be brighter than 10 mag in $K$ to track fringes on, the fainter object shall be brighter than 15 mag; the exact gain due
to phase referencing depends on the final stability on the instrument, and might be higher if minute long coherent integrations can be achieved.

- KI elevation limit is $\sim 38$ degr, limiting the observability of Southern targets

1.1 Precision astrometry to weigh stellar companions

The precise astrometry will help to increase the precision of binary kinematic studies, which are an efficient way to measure the involved masses if the distance to the binary system is known. In particular interferometric binary measurements have been shown to deliver crucial mass estimates for pre-main sequence stars where the stellar evolution is still poorly understood (Boden et al., 2007). Observational mass estimates help to gauge the models of star formation. The increased sensitivity will increase the number of accessible targets and stellar types. E.g. brown dwarfs with typical brightnesses of $K > 10$ are now for the first time within interferometric reach. ASTRA observations will help to better understand the formation and evolution of these transition objects between planets and ordinary main-sequence dwarfs.

1.2 Studying exo-planetary kinematics

Radial velocity (RV) measurements are so far the most efficient way to detect planetary systems (Santos, 2008). But RV-experiments miss the orbital inclination unless rare edge-on transiting-planet systems are observed. RV-planet surveys reveal many systems in which the stellar reflex motion can be detected with differential astrometry at the 100 $\mu$m accuracy level, that is at the level of ASTRA precision. Interferometric astrometry offers a means of measuring orbital inclinations with an accuracy of a few percent. A focus of the ASTRA planet science case are multiple-planet systems. Co-planarity and the understanding of planet migration, scattering, and capturing processes due to planet-planet interaction have long awaited an experimental input to challenge theoretical ideas and models (Marcy, 2007). To enlarge the parameter space of planet detection toward less massive planets, beyond the reach of current RV-surveys, the 50 $\mu$as accuracy level has to be reached, one of the final goals of the ASTRA-project (see Fig. 3 in Eisner & Kulkarni, 2002).

1.3 Astrometry in the Galactic center

Another area of research, where ASTRA-astrometry will have a significant impact, is the central parsec of our Galaxy (GC). Near diffraction limited imaging, since most recently assisted by laser guide stars, have led to the
The first doubtless detection of a massive black hole at the gravitational center of the Milky Way via astrometric monitoring of the Keplerian motion of stars orbiting the black hole. Higher astrometric precision will help to further narrow down the uncertainties of the black hole mass \((4.5 \pm 0.4 \times 10^6 \, M_\odot)\) and the solar distance to the GC \((R_\odot = 8.4 \pm 0.4 \, \text{kpc})\), see Ghez et al., 2008, and references therein. Currently the best constraints derive from the closest and brightest of the orbiting stars, S0-2 \((K \sim 14)\). It can be observed against the nearby evolved maser stars, only 5-10 arcsec away from the GC, bright enough to deliver an astrometric phase reference of an ASTRA astrometry observation (see Fig. 15 in Ghez et al., 2008).

The differential absolute astrometric measurement of the orbiting star will give for the first time an independent estimation of the accuracy of the imaging astrometry in that field. The higher angular resolution of the interferometer will help estimate astrometric biases of the single telescope measurements, such as source confusion or stellar multiplicity. Currently these biases prevent from increasing the measurement accuracy of the properties of the black hole by using more orbiting stars in addition to S0-2. The final limiting magnitude of the ASTRA-astrometry mode will be crucial to observe numerous stars in the GC due to the high amount of interstellar extinction along the line-of-sight to the GC through the disk of the Galaxy. Further chances and challenges of the ASTRA-GC science case have recently been discussed elsewhere (Pott et al., 2008).

References

Cameron, P. B., Britton, M. C., & Kulkarni, S. R., preprint 0805.2153
Santos, N. C. 2008, New Astronomy Review, 52, 154