

First spectro-interferometry on Galactic center sources in the infrared - results and science prospects at the sensitivity limit of current larger aperture arrays

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ABSTRACT

The current results of our ongoing Galactic Center (GC) observations with optical long baseline interferometry (OLB-IF) are presented. We achieved first IR-IF fringes in both available IR science regimes of the VLTI (MIDI: 10 μm) and (AMBER: 2 μm), demonstrating the new capabilities provided by large aperture telescope arrays to the Galactic center research. We show that the highest angular resolution only available through interferometric techniques is necessary to observe the GC ISM production in the making and distinguish individual sources from its dusty surroundings. An overview over the currently available IF-technology is given, biased towards the GC science case. The feasibility of phase-referencing to the supergiant GCIRS 7, located only 5'' away from SgrA*, to increase the sensitivity and spectral resolution of the observations, is discussed, and supported by the first real data. The presentation will conclude with an outlook to the near future about how the upcoming astrometric and off-axis phase-referencing capabilities of the Keck and VLT Interferometers, nicknamed ASTRA and PRIMA, will greatly extend the currently existing capabilities to observe astrophysical phenomena in the Galactic center at the borderline to General relativity in a yet uninvestigated regime.

Keywords: Galaxy: center - Infrared: stars - Stars: supergiants - Stars: winds, outflows - ISM: dust, extinction - Instrumentation: interferometers

1. INTRODUCTION

Due to its proximity, the Galactic Center (GC) offers a unique opportunity to spatially resolve astrophysical phenomena in the immediate vicinity of a massive black hole (MBH)^{1,2} and provides seminal knowledge for understanding spatially unresolved extra-galactic nuclei. For the past decade, it has been possible to achieve diffraction limited observations of the GC with 8-10m class telescopes, and therefore to probe the details of processes, such as star and dust formation at galacto-centric radii where the $\sim 4 \cdot 10^6 M_{\odot}$ black hole generates a strong tidal field, at a unique angular resolution of about 8 AU/mas.^{3,4} However, even at this angular scale, source confusion is a significant effect in the very center due to the extreme density of the central stellar cluster: $3 \cdot 10^6 M_{\odot} \text{pc}^{-3}$, in the central 0.4 pc (⁵), exceeding the core density of NGC 3603, among the densest clusters known elsewhere in the Milky Way, by an order of magnitude.⁶

Stellar interferometers offer the highest angular resolution to date, and with sufficient intensity sensitivity, large-aperture optical-long-baseline interferometry (OLBI), with baselines up to about 130 m, provides, in the pre-ELT era, the capability to study the GC region at even higher angular resolution, increased by about an order of magnitude over single-telescope experiments. Large apertures as offered by the VLTI* and the Keck Interferometer (KI[†]) have provided a break-through in sensitivity enabling first interferometric studies at 10 μm of the brightest ($N \gtrsim 1 \text{ Jy}$) GC sources.⁷

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*VLT Interferometer: <http://www.eso.org/projects/vlti/>, in this article we consider the array of 8m-UT's as VLTI, since currently the VLTI-AT's are not sensitive enough for GC observations.

[†]http://planetquest.jpl.nasa.gov/Keck/keck_index.cfm

In this contribution we discuss the current IF-technology in the light of GC research, and describe their expected impact by evaluating the applicability of the technologies to the tight sensitivity and performance requirements in the central parsec (Sect. 2). Four years ago we presented the prospects of interferometric GC-research to the SPIE community.⁸ In the meantime we successfully observed several sources within sub-parsec distances to the MBH. The different wavelengths used (*K*- and *N*-band), and different types of sources observed (circumstellar dust shells, shocked ISM, evolved stars) demonstrate the various contributions of applying modern stellar interferometry to the quest of star and dust formation in the GC. Status reports and scientific results of our ongoing observing campaigns are given in the Sect. 3-5. Sect. 6 is dedicated to further GC science cases which can be addressed in the near future of the next years when off-axis phase-referencing upgrades of the KI and VLTI will come online. This article ends with the concluding Sect. 7.

2. THE AVAILABLE IF-TECHNOLOGY

Currently two large aperture arrays, VLTI and KI,⁹ offer enough photon-collecting area in combination with interferometric technology to resolve stellar sources at mas-resolution at the GC. Three different interferometric technologies are or will be offered in the near future. The key requirements for these technologies to enable GC research are given.

2.1 Adaptive optics - a prerequisite

Currently visible natural-guide-star adaptive-optics (NGS-AO) systems are in use to flatten the wavefront of the incoming starlight, and correct for the atmospheric tip-tilt motion. Both a continuously high Strehl-ratio, and spatially stable PSF, as delivered by these NGS-AO systems, is necessary for efficient working of the interferometric cameras. Most such cameras guarantee a calibratable signal by spatial filtering, e.g. by the usage of single-mode fibres. In particular the 8-10m class apertures require higher-order AO-correction to deliver permanently high fringe SNR. To fulfill the requirements of the NGS-AO systems in place, visible guide stars brighter as $V \sim 17$ mag need to be available within 1 arcmin around the science target for the VLTI-MACAO systems. The KI-AO has slightly more stringent requirements.

This is a challenge for the GC observations, peering along an 8 kpc long line-of-sight through the Galactic disc, leading to an interstellar extinction of $A_V \sim 25 - 30$. This high visible extinction renders the central parsec itself invisible at optical wavelengths, and the wealth of stars at the GC cannot be used for those AO systems. Fortunately foreground stars are available, but about 30'' away from SgrA*, and with a visible magnitude around 15 mag rather faint, thus we cannot expect optimal AO-correction. But several measurements at both the VLTI and KI have proven that both AO-systems, feeding the interferometers, deliver corrected wavefronts to the beam combiners under standard atmospheric conditions. However, to understand the actual precision of the measurement, an inspection of the current performance of the wavefront correction is absolutely necessary in the GC observing situation, as we outlined recently.¹⁰

Due to the Northern latitude of Mauna Kea, GC observations are always conducted at significant airmass, a potentially deteriorating factor for the AO-corrections. But currently also the second of the pair of Keck telescopes is being equipped with a laser-guide-star (LGS)-system. This will turn the KI into the only co-phased array feeding its beam combiners with LGS-AO-stabilized wavefronts. Due to the various reasons given above, the LGS-AO is expected to increase the fringe SNR, boosting the efficiency of GC-IF observations at the KI, and fully exploiting the sensitivity-advantage of the 10m Keck primaries. The improvement of LGS-AO over visible NGS-AO for GC observations have recently been shown, and are significant due to the non-optimal natural guide star situation.¹¹

2.2 Direct (fringe) detection

The simplest way of a sensitive broad-band visibility measurement at IR-wavelengths is the direct fringe detection, as performed by the VLTI/AMBER, MIDI and KI/FATCAT cameras. Alternative heterodyne or intensity interferometry approaches suffer from small observing bandwidths, and are not suited for GC observations. Due to the high optical extinction, the GC stars are extremely red, and even in the astronomical *H*-band at 1.6 μm hard to detect, with the brightest sources being $H \approx 10$ mag. This renders the *K*-band to be the prime range of observing wavelengths, with GCIRS 7 being the brightest source with a magnitude of about $K \sim 7$ mag. Direct-detection visibility measurements at low spectral resolution of $R \sim 30$ can be obtained of stars up to $K \sim 10$ mag with the KI being currently the most sensitive NIR stellar interferometer. The sensitivity is mainly limited by the atmospheric coherence time, which limits detector read-out times to no longer than a few tens of milli-seconds at NIR wavelengths.¹³ Averaging the fringe signal over longer times with a fixed optical path difference (OPD) of the interferometric delay lines, would weaken the signal due to a changing atmospheric piston between the telescopes.

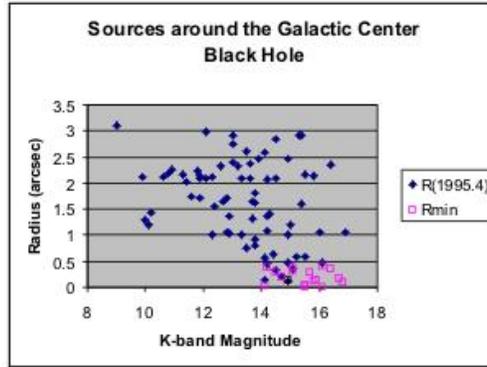


Figure 1. Showing the number of potential source in the central 6'' around SgrA*.^{2,12} Only the brightest ones are directly observable with the current interferometers, stars fainter than $K \sim 10$ mag require off-axis phase-referencing.

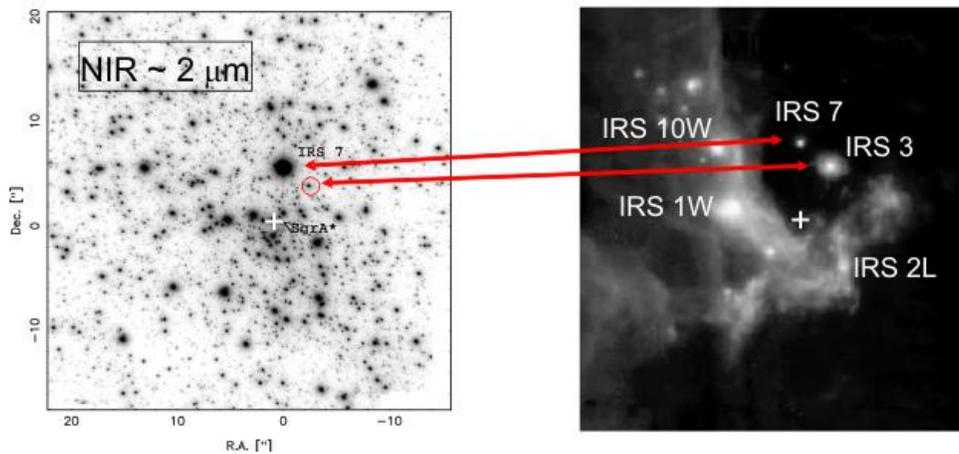


Figure 2. Central parsec in the astronomical K - and N -band, in the left and right panel, respectively. All observed sources and the position of SgrA* (white cross) are indicated. While the NIR is dominated by red stars, the MIR shows numerous extended dust features, and shock filaments in addition to compact sources. North is up, and East to the left, both images show the same patch of the sky.

While in the NIR only few GC-sources pass that limit (see Fig. 1), the situation changes at $10 \mu\text{m}$, due to longer coherence times in the MIR. Several observations could have been performed in the N -band already, as discussed in the following Sect. 3, and 4. While the single-baseline (direct-detection) visibility information measures the size-scale of the resolved source, several such measurements at different projected baseline lengths, and position angles, constrain the rough morphological type of the emission structure (multiple star system, stellar disc or more Gaussian-like dusty brightness distributions). The three-beam combining instruments like VLTI/AMBER offer in addition the capability of measuring the closure-phase, a symmetry-dependent spatial phase information which is immune against uncalibratable phase-corruption by the turbulent atmosphere.

A scientifically very important property of the current generation of fringe cameras is their spectroscopic capability. They offer spectro-interferometric measurements at spectral resolutions up to 10,000 in case of AMBER, and enable to distinguish line from continuum emission, giving a handle to estimate the distance of the line-forming region to the illuminating star. However, the sensitivity loss per channel due to the spectral dispersion, prohibits interferometric GC observations at such high spectral resolutions beyond a thousand without phase-referencing.

2.3 On- and off-axis phase-referencing

To make use of these new spectral capabilities and enable the observation of fainter targets, the atmospheric phase-corruption, which blurs out the fringe signal in case of longer integration times, needs to be stabilized by a fringe-tracker to

gain enough SNR in each spectral channel. Similar to radio-interferometry, the required phase information can be retrieved from a nearby 'phase-reference', a star bright enough to provide enough fringe signal within the atmospheric coherence time. Unless in the radio regime however, the short atmospheric coherence times in the infrared require instantaneous fringe tracking in parallel to the science observation. Also the iso-piston angle on the sky, defining the patch within which the fringe tracker correction is useful, depends on the wavelength, similar to the iso-planatic and iso-kinetic angles known from AO-theory. Depending on the outer scale of the atmosphere, a typical value for the limiting distance between phase-reference and science target is 25'' in the *K*-band,¹⁴ but good seeing conditions and accepting lower final visibility precision, can increase this number. Without having dual-star facilities in place real numbers are not yet available to support the current expectations based mostly on theory, and on-axis measurements.

Fortunately in the GC a very bright supergiant is located right within the central 400 mpc, only 5'' away from the black hole. We have started to study this source, GCIRS 7, used as NGS for GC-observations with the NIR-sensitive wavefront sensor (WFS) of the VLT/NAOS system¹⁵ (note, that the VLTI-AO MACAO does not have a NIR-WFS, NAOS is only installed on one telescope), with the VLTI to investigate its performance as reliable phase-reference. Due to its nature as supergiant, and earlier findings of varying photometry, and circumstellar dust, the star could be significantly resolved. This would corrupt its phase-referencing performance due to a lower correlated flux if the source would indeed be resolved at OLBI baseline lengths. Our first OLBI results however are encouraging, and presented in Sect. 5.

Beyond the visibility amplitudes delivered by spectro-interferometry, differential phase information can be retrieved. This differential phase, also in combination with the closure-phase quantity of three-telescope measurements, offers crucial spatial constraints on models for the light emitting structures. For such spectro-interferometric GC observations at significant spectral resolution, phase-referencing is essential to get enough sensitivity. If the science target is brighter than the low-spectral-resolution limit of the beam combiner camera, the light can be split, and separately sent to the fringe tracker, and the science camera. While the fringe tracker controls the fringe-stabilizing delay-line fine-tuning, the science camera can run at much longer integration times. This mode is called on-axis phase-referencing, and is the first phase of the ASTRA sensitivity upgrade of the KI.¹⁶ First such on-axis phase-referencing observations have been performed already successfully, proving the concept.¹⁷ The current VLTI fringe tracker FINITO is not suited for such on-axis phase-referencing of the extremely red GC sources because it operates in *H*-band, but the VLTI/PRIMA and KI/ASTRA upgrades will offer fringe tracking in *K*.

The key instrument to enable off-axis fringe tracking within the iso-piston angle is a 'dual-field', or 'star-separator' facility, required to be located in the focal plane of the telescope.¹⁸ The current designs of the VLTI- and KI-star separators will enable to fully exploit the iso-piston angle, defining the radius of interested around the phase-reference, and pick-up science star light about 30'' away from the phase-reference. In case of the GC, and GCIRS 7 as phase-reference, this includes the entire central parsec as show in Fig. 2, and its innermost region around SgrA*, where the MBH's gravitational fields dominates the stellar and gas proper motions.

2.4 Differential narrow-angle astrometry

The basic ideas of interferometric narrow-angle astrometry are discussed elsewhere.¹⁹ This technique is complementary to the fringe-contrast measurements of stellar interferometers, leading to visibility amplitudes. In differential astrometry, the angle between the slightly different line-of-sights towards two nearby stars is measured by estimating the differential piston of the incoming starlight. This differential piston originates from a differential geometric delay from above the atmosphere, and is (within the iso-piston angle) not corrupted by the turbulent atmosphere. The longer the baseline, and the closer the two stars are, the higher the achievable differential astrometric accuracy is. Early experiments with the PTI[‡] proved the technical feasibility of this idea, and reached differential astrometric precision of a few tens of μas for subarcsec star-star separations.²⁰

Potential science cases for such high precision astrometry in the central parsec are discussed in Sect. 6. Here we mention challenges in its application to GC observations. An obvious prerequisite is a star-separator and a star bright enough to track fringes on, so very similar to the previously described phase-referencing. Again the constraint is given by the limiting magnitude of the brighter of the two stars, which is required to fulfill the role of the phase-reference. Both this limiting magnitude, and its impact on the achievable astrometric precision depends on the final performance of the star separators, and is not known yet, but given the sensitivity limit of current direct detection methods, at least GCIRS 7

[‡]Palomar Testbed Interferometer: <http://msc.caltech.edu/missions/Palomar>

appears to be bright enough to enable such an interferometric astrometry measurement relative to its position. Another major challenge of the IF-astrometry in the GC is the astrometric reference frame. Since the sources have relatively high proper motions of often several mas per year, cross-calibration measurements will be required to check the final accuracy.

3. NEW INSIGHTS INTO THE SPECIAL GC DUST CHEMISTRY DUE TO MIR-INTERFEROMETRY

Both GCIRS 3, and GCIRS 7 have been well resolved in MIDI measurements at low spectral resolution (Fig.3). Both sources are shown to be surrounded by considerable amounts of dust at moderate temperatures of a few hundred Kelvin. The detailed analysis of the MIDI data of IRS 3 includes a radial radiative transfer model which is an important tool to physically interpret such MIR data, since (depending on the optical depth) the (circum-)stellar MIR-radiation is not only reddened and weakened or partially absorbed MIR starlight, but the dust itself re-radiates stellar flux absorbed primarily at optical wavelengths. While NIR-spectroscopy shows GCIRS 7 to be an M-type supergiant, GCIRS 3 is deeply embedded in dust, and does not show any spectral signature in the NIR. However the analysis of the MIDI experiment suggests GCIRS 3 to be a C-rich evolved AGB-star.¹⁰

The size constraints from the interferometer are needed to clarify the intrinsic fluxes and temperatures, and have shown that the outer dust around GCIRS 3, resolved by MIDI, is in part illuminated by an external source, probably a nearby Wolf-Rayet star. Since this outer dust is only 50 mas away from the star this fact clearly demonstrates that the high angular resolution of the interferometer is absolutely necessary to understand and derive the correct local radiative properties from sources at the GC. Resolving the individual stellar sources is a requirement to analyze the properties of the central GC star cluster in detail.

Another surprising result of this MIDI experiment is the flat but resolved visibility curves, showing visibility amplitudes significantly smaller than one (Fig. 3). A visibility of unity would refer to a compact, unresolved source. The surprise comes from the fact that both sources show in the spatially unresolved *N*-band VLT-photometry a huge optical depth in the silicate feature of $\tau_{9.8 \mu\text{m}} \sim 7$ which is twice as large as expected for the interstellar extinction towards the GC. This could be explained by locally formed silicate dust in stellar winds and dust shells around the two observed, evolved stars, but the increase of optical depth towards the center of the silicate feature would imply an apparent size increase of the resolved source, and result in a spectral visibility shape which decreases towards $9.8 \mu\text{m}$. This is not seen in the data, and in combination with other indications the MIDI data are the final key to conclude that the $\tau_{9.8 \mu\text{m}}$ -excess seen towards the star is due to the interstellar dust in the central parsec. It was not detected at similar depth in earlier observations, due to the lack of spatial resolution.

A larger survey of the interstellar dust chemistry in the GC is underway, but the here discussed results suggest a relative overabundance of oxygen-rich silicate dust over amorphous carbon, with respect to standard ratios throughout the Galaxy. A possible reason for such special GC dust chemistry is the often claimed but hard to prove top-heavy initial mass function (IMF) of star formation in the GC. While more and more observational evidence for in-situ star formation at the GC is collected, the direct observational proof for changes in the IMF is hard to obtain because the less massive stars, outnumbering the more massive ones, are simply too faint to be observed. On the other hand, a change in the IMF can result in a different interstellar dust chemistry, thus a careful investigation of the interstellar dust at the highest available resolution at single telescopes and stellar interferometers could provide a means to indirectly investigate the IMF and star formation properties of the GC stellar cluster. Spectroscopic resolution of the observations is a key to this science, and now offered by the interferometers.

4. HUNTING FOR SHOCKS IN THE ISM

One heating mechanism in the dense environment of the central parsec are stellar winds which shock-compress the ISM while hitting stellar winds from neighboring stars²² or a denser part of the ISM. Diffraction-limited imaging with the Keck telescope revealed a couple of bow shocks in the denser parts of the ISM, significantly offset by nearby the stellar point sources.²³ The bow shocks are thought to be created by evolved and windy stars plowing through the interstellar dust at a differential velocity, and due to this differential velocity the dust is compressed and heated. It is important to understand the origin of such heated dust features to distinguish processes related to rather evolved stars like in this bow-shock scenario from YSO-scenarios directly related to the star forming process.

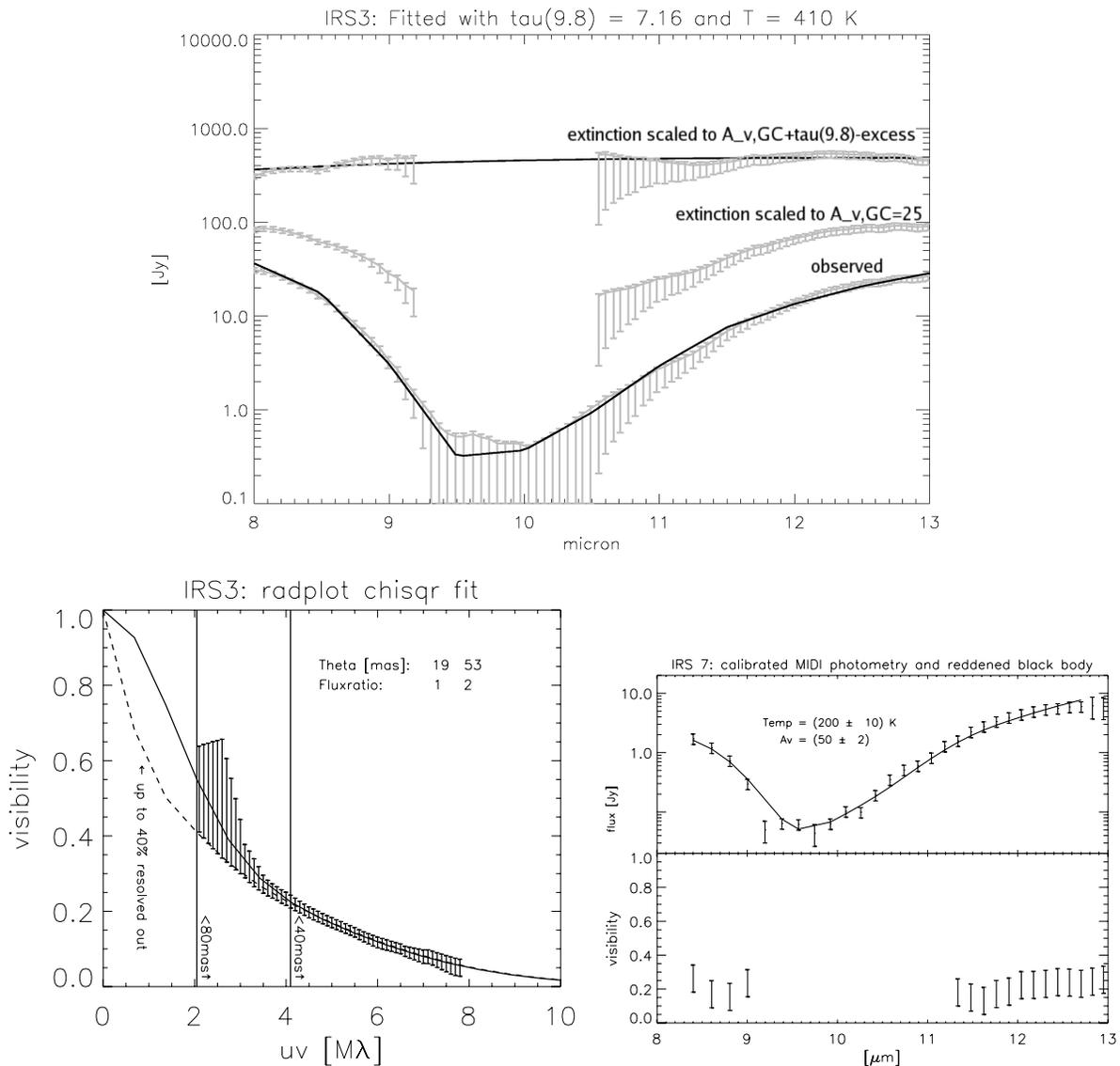


Figure 3. Top: Flux-calibrated and dereddened MIDI photometry of GCIRS 3. The upper spectrum is dereddened with $\tau_{9.8} = 7.2$, and its error bars indicate the wavelength intervals used to fit the temperature. The middle spectrum is dereddened with $\tau_{9.8} = 3.3$, which corresponds to the standard average optical extinction of $A_V=25$ towards the central parsec, assuming the extinction law by²¹. The lower spectrum is the extinguished, measured spectrum. The black solid lines show the extinguished and dereddened χ^2 -minimized temperature fit of $T=410$ K.

Bottom left: Best-fit model of the brightness distribution of GCIRS 3 with a *two*-component model of Gaussian components. The error bars are the azimuthally averaged data of several MIDI measurements. In addition, the probed spatial scales are indicated by vertical lines. To the right of each of these lines, the visibility of a Gaussian component of the indicated FWHM would contribute less than 10% of its flux. The dashed line stems from a model adding a third Gaussian of arbitrary size larger than 80 mas and illustrates that up to 40% of the total flux could have been resolved out by the interferometer.

Bottom right: Calibrated MIDI total-flux spectrum and spectro-visibility of IRS 7. The plotted flux errors show an absolute calibration uncertainty of about 20%. In the upper panel, the best-fit, reddened black-body is overplotted as solid line, the two fit-parameters are indicated with their 1σ uncertainties.

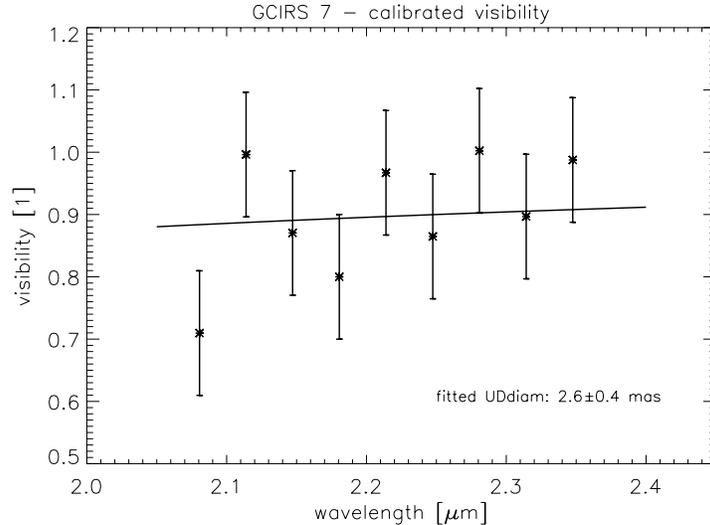


Figure 4. Calibrated K -band visibility of GCIRS 7, observed with VLTI/AMBER. A uniform disc model is over-plotted (solid line), the fitted diameter and the statistic uncertainty is given.

We followed up this earlier single-telescope study with VLTI/MIDI measurements of the sources bright enough to match the direct-detection limits of the instrument. All such successfully observed bow-shock sources in our experiment (GCIRS 1W, 2L, 10W, 8) appear to be over-resolved, leading to upper limits on the correlated flux estimates, and lower limits on the MIR bow-shock structures.²⁴ Although no further constraints like direct size, and geometry of the bow-shocks in the MIR could be derived with the available sensitivity of MIDI at the time of the observations (June 2004), this finding supports the proposed evolved star-bow-shock scenario. The estimated minimum sizes of a few hundred AU are to be expected for the cooler dust of such shocks if observed at $10 \mu\text{m}$ as opposed to the hotter dust dominating the diffraction limited images in the NIR. Instead no indications have been found for significant point-like central, compact and dust-embedded objects.

5. PHASE REFERENCING ON GCIRS 7 - A STATUS REPORT

In the NIR the sensitivity constraints are even tighter than at the longer mid-IR wavelengths due to significantly shorter atmospheric coherence times, and higher sensibility to instrumental vibrations along the optical path. In Sect. 2.3 we introduced the concept of phase-referencing to overcome this challenges, and announced GCIRS 7 as the prime candidate to deliver such a phase-reference for interferometric GC observations. In March 2006, we achieved the first successful near infrared fringe detection on this star to prove that GCIRS 7 is indeed compact enough to deliver high correlated fluxes at a 100 m baseline length scale.

The data was taken with the VLTI first generation science beam combiner AMBER²⁵ on the short UT3- UT4 baseline, and a detailed analysis is in press (Pott et al. A&A). Although the precision of this first experiment was limited, the calibrated data (Fig. 4) clearly shows visibilities mostly larger than 0.8. This is a promising result, and certainly would suffice to use GCIRS 7 as fringe reference, but a simple uniform-disc fit to the data taken shows that the star might have been slightly resolved by the interferometer. A follow-up observation with higher precision and better control of systematics is scheduled for Summer 2008, and we will further investigate this issue. If indeed the source is already resolved at the $\sim 50\text{m}$ baseline used, the correlated flux will drop towards longer baseline lengths, and higher spatial resolutions.

Furthermore indications of photometric variability,²⁶ and significant amounts of warm dust as seen in the MIR, suggest variable visibilities in the NIR, or the existence of a binary system, yet unresolved. A precisely known intrinsic visibility of GCIRS 7 would help to efficiently calibrate phase-referencing visibility measurements at the GC. Our interferometric monitoring program of this source is designed to answer these questions, and establish a basis for future phase-referencing measurements in closest vicinity to the MBH.

6. FUTURE SCIENCE PROSPECTS FOR VLTI/PRIMA AND KECK/ASTRA

VLTI/PRIMA and KI/ASTRA will be implemented within the next few years, and in Sect. 2 we discussed that phase-referencing and interferometric differential astrometry will be feasible in the GC, if large apertures are combined to ensure the required intensity sensitivity. Thus it appears timely to discuss here some future science cases of such observations to motivate the effort of coping with the technical challenges of turning this technology into regular science instruments.

Binaries at the GC

Increasing the interferometric resolution by an order of magnitude down to a few mas results in a linear resolution of few tens of AU at the GC, enough to spatially resolve a significant fraction of the binary population in the central star cluster. Until now only one binary system is known by measuring its photometric and spectroscopic variability, the eclipsing and equal mass binary GCIRS 16SW.^{26,27} The spectroscopic sensitivity and spatial resolution of single telescope observations is not adequate to efficiently identify more systems.

However the fraction of stars in multiple systems at the GC can give clues about the star formation properties. In young star forming regions the binary fraction can easily rise well beyond 50%²⁸ for massive stars, as the ones we observe at the very center of the Galaxy. Also the kinematics of a binary system in the extremely dense GC region, dominated by the central MBH, can be very distinct from single star motions. A disruption of a massive binary system due to a close encounter with the MBH can completely change the kinematic situation, and is actually the most likely origin for the enigmatic hyper-velocity stars found in the halo of the Galaxy.²⁹ While the current sensitivity limit of direct-detection measurements prevents a systematic binary study at the GC, off-axis phase-referencing offers the chance to significantly increase the number of observable stars.

Increasing the astrometric precision

Astrometry played a key role in establishing the non-thermal radio source SgrA* as the location of a massive black hole^{1,2} in the center of the Galaxy. The precise proper motion measurement of stars in the central arcsec lead to constraints of the enclosed mass density and absolute mass, which rule out other astrophysical scenarios. While Keplerian orbits fit this data reasonably well, a deviation of the stellar trajectories from such Keplerian orbits is expected for the innermost accelerated stars, and traces the action of General relativity or the existence of an extended mass fraction in the center.^{30,31} However this natural next step in proper motion studies requires even higher astrometric precision than the one usually obtained with single telescope diffraction limited imaging.

While for individual stars the SNR of the stellar PSF dominates the precision of the centroiding process, this astrometric analysis hits fundamental accuracy limits in the central arcsec due to source confusion. The significantly smaller interferometric PSF of a stellar interferometer with an 80 m baseline is crucial to beat this source confusion, and will help, supported by interferometric differential astrometry, to push the current accuracy limits to 100 μ as and beyond also in this very densely populated region. This accuracy is sufficient to observe the expected perihel-rotation of the orbit of S0-2 around SgrA* due to GR.

The infrared flares of the accretion disc

In the recent years, near-infrared and X-ray flares from the accretion disc around the central MBH have been detected regularly.^{32,33} Due to the lack of spatial resolution, the origin of these flares is under debate. Also the total luminosity, and the related feeding and accretion processes are unexpectedly weak, compared to the accretion discs around (super-)massive black holes in the nuclei of other galaxies.³⁴ Our results from the MIR-interferometry about the local dust chemistry in the central parsec offer an explanation for the surprising fact that the most sensitive MIR-observations to date have failed to detect the flares at 10 μ m,³⁵ probably due to a higher than expected interstellar dust extinction.

Cumulative brightness distributions from the NIR flares show that the brightest flares reach the level of $K \sim 14 - 15$ mag, as bright as the orbiting stars, but only for a relatively small fraction of the time. The chance to get a calibratable measurement with an interferometer rises significantly towards fainter magnitudes, rendering the achievement of visibility measurements at $K \sim 16 - 17$ mag a solid specification for such observations. This can only be achieved with off-axis phase-referencing, optimum AO-correction, and long integration times, but it is certainly within the horizon of the technical possibilities of today's and tomorrow's interferometric facilities.

7. CONCLUSIONS

Already today the sensitivity of co-phased large aperture telescope arrays is sufficient to study stellar sources and their immediate surroundings in the central parsec of the Milky Way. The angular resolution of spectro-interferometry in the mid-IR is necessary to distinguish between circumstellar dust forming regions and the interstellar space filled with dust from the evolved stellar population. By doing so we found indications that the 10-micron silicate absorption excess of the GC significantly increases in the central 5 arcsec and hampers the detection of starlight and in particular the mid-IR emission of the IR-flares, tracing the accretion zone around the MBH SgrA*. The excess abundance of silicate might be directly connected to enhanced massive star formation in the GC.

A leap forward in sensitivity is needed to enlarge the sample of observable stars and phenomena in the region. This soon will be realized by phase-referencing facilities PRIMA at the VLT-, and ASTRA at the Keck-Interferometer. We have shown with a pioneering AMBER experiment, that GCIRS 7 is a suitable phase-referencing source, although it is surrounded by warm dust, and shows significant amount variability. Even if the source would be resolved at the longest baselines of more than 100 m, the interferometric response has shown to be strong enough to provide the best phase-reference within that region, influenced by the gravitational pull of the MBH. Resolving the binary population with such phase-referencing experiments, and providing an increased astrometric precision on the stellar orbits in the central half arcsec will be among the prime science cases for the near-future to investigate the star formation and mass distribution around the massive black hole.

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