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Unveiling dust formation and stellar properties at 8 kpc distance

First infrared fringes at the Galactic Center

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Introduction

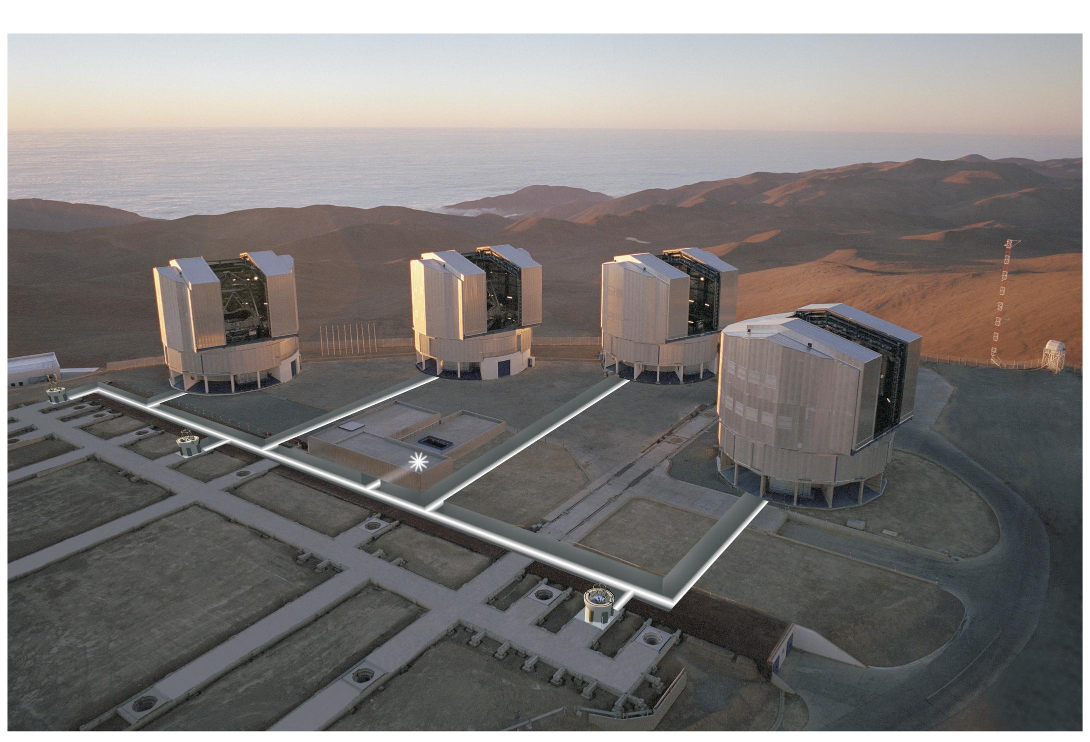
NIR observations of the Galactic Center (GC) probe our understanding of star and dust formation under the direct influence of the gravitational potential of the supermassive black hole SgrA* ($3.6 \cdot 10^6 M_\odot$; (1,2)) at the nucleus of a late type galaxy. The distance from the earth to the core of the Milky Way has recently been re-estimated to be 7.6 kpc or $25 \cdot 10^3$ ly (1), making the GC by far the closest center of a large spiral galaxy. Its astrophysical properties can be studied at a unique angular scale of 40 mpc/" (or 1.5 light months/"), and is two orders of magnitude smaller than the angular scale at the nucleus of M31, the next comparable galaxy. General relativistic effects may be observable with the as resolution of the new generation of interferometric instruments (3).

The unusually large number of massive, young stars in the stellar cluster at the GC(4,5) are indicative of a most recent star formation episode taking place not more than a few million years ago. This "paradox of youth" (6) is still unsolved. The strong tidal shear forces of the black hole appear to suppress lower mass star formation(7).

This poster presents the recent achievements in establishing optical long baseline interferometry (OLBI) as valuable observational tool to resolve finest details at mas-resolution. We successfully obtained fringes in the *K*- and *N*-band atmospheric window of the most prominent sources at these wavelengths and interpret the scientific meaning of the data(10,12). (11) discuss OLBI-GC observations as test-bed for state of the art optical stellar interferometry.

VLTI: OLBI at 2 and 10 μm

The VeryLargeTelescopeInterferometer (VLTI) of ESO is the world largest OLBI facility combining the light of up to four different 8m class telescopes. Only the large apertures provide enough stellar flux to the beam combining instruments to observe the GC through 25mag of optical extinction along the line-of-sight. We have used the actual first generation VLTI instruments AMBER and MIDI to measure interferometric visibilities at 2 and 10 μm, respectively. Both instruments have been used in low-resolution spectroscopic mode (R~50), providing valuable differential visibility information along the observed wavelength band. While several projected baseline lengths and orientations lead to a detailed understanding of the dust formation around GCIRS 3, the NIR fringes on GCIRS 7 demonstrate the phase-referencing and visibility calibrating capabilities of the latter source.

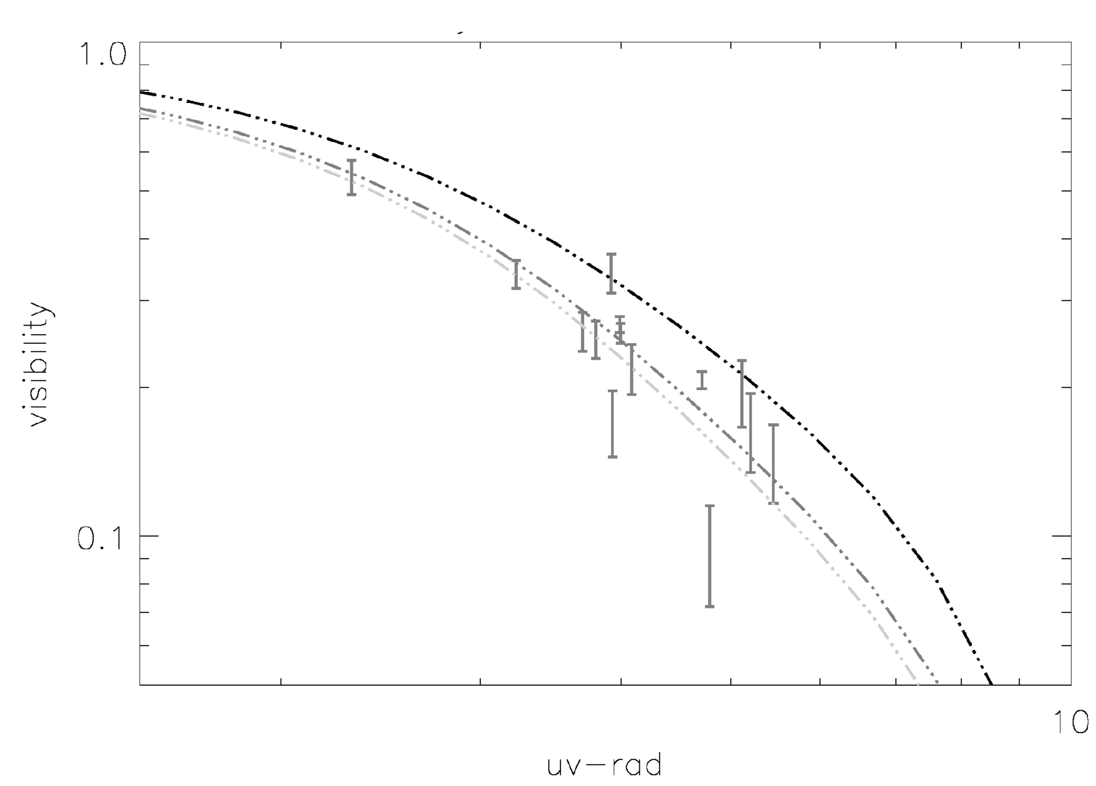


Aerial view of the Paranal observing platform, white lines are indicating the underground light paths from the larger UT telescopes to the beam combining lab, marked by the star. Courtesy of ESO.

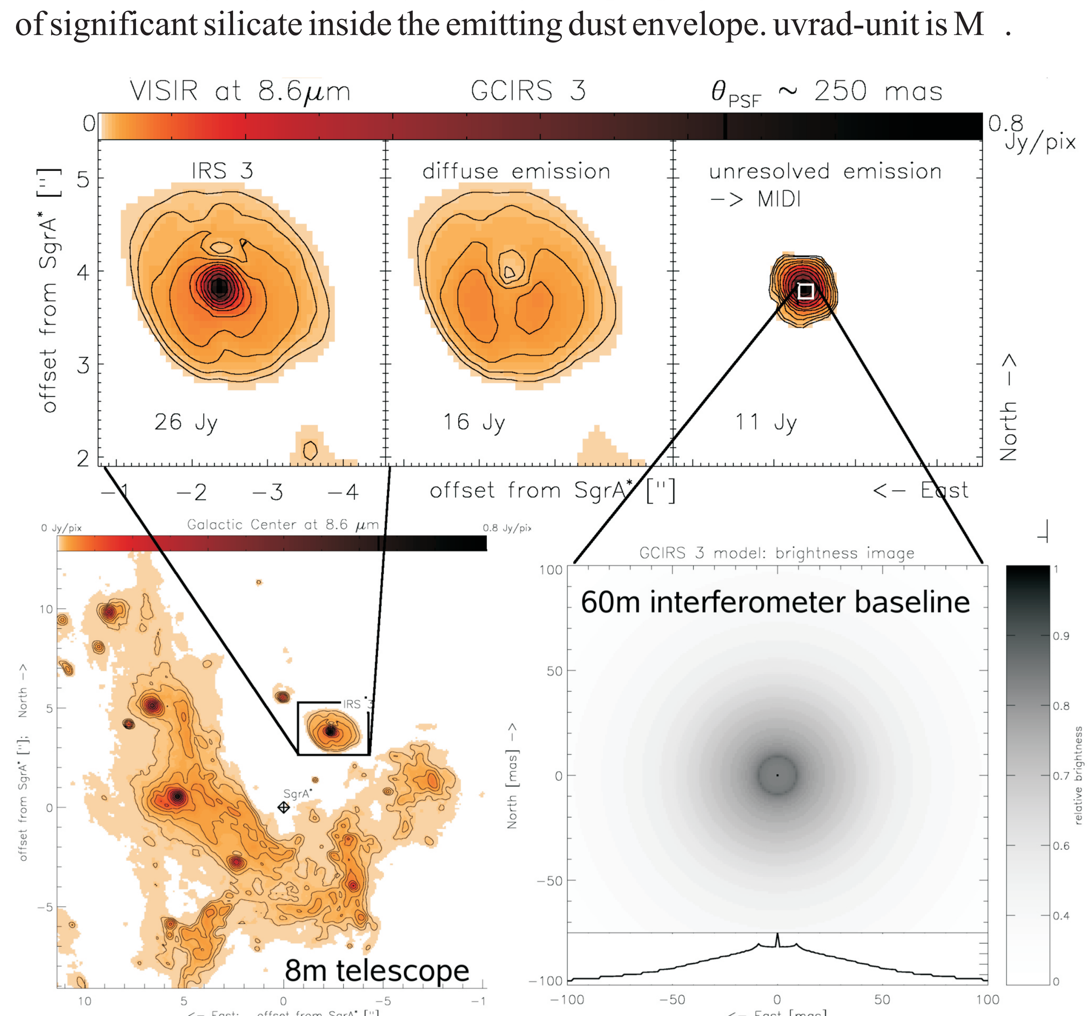
The enigma of GCIRS 3

IRS 3 is located about 5" away from SgrA*, but appears rather isolated in 10 μm images of the central parsec. Its prominent dust envelope hampers a spectral classification of the central star, but MIDI has the resolving power to estimate detailed physical parameters of the source to probe ist nature. Over two seasons we could show by using orthognal baselines that the inner zone of dust formation around the star can be resolved by the VLTI and that it is circularly symmetric, thus not strongly compressed by external stellar winds as seen in single telescope images of the outer dust structures around IRS 3 (8).

By means of radiative transfer modeling(9) we derive from (i) the broad band infrared spectral energy distribution (*H-Q*), (ii) the dereddened *N*-band spectrum of the MIDI measurements, and (iii) the absolute and differential visibility information a physically self-consistent model of the inner dust envelope around IRS 3, which constrains the underlying star to be a red carbon-rich AGB star in a late stellar evolutionary phase(10). The dominating features in the measured data can be explained by a rather cool stellar source (T_{eff}=3000K), forming C-rich dust at a distance of about 18 stellar radii, or 55 AU. To power the fitted dust sublimation temperature of 900 K, a stellar luminosity of $3.3 \cdot 10^4 L_\odot$ is required. A detailed analysis of the measurement model fit uncertainties is given in (10). Hot stars like the earlier proposed Wolf-Rayet scenario can now be excluded. The combination of the interferometric data with spatially unresolved single telescope measurements was an indispensable step to fully exploit the spatial information given by the VLTI.



Measured visibilities (gray errorbars) at 11.5 μm fit the model (dot-dashed) and lies between the 8 μm (black) and 13 μm (light gray) data. This favours absence of significant silicate inside the emitting dust envelope. uvrad-unit is M .



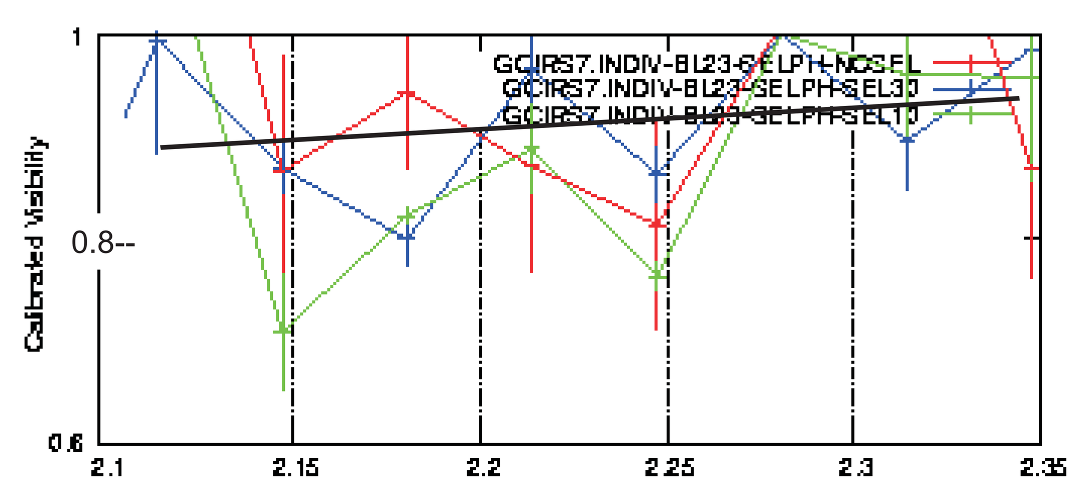
Only the compact emission as seen by VLT/VISIR (left and upper panel) is observed by MIDI. In our resulting C-rich model for the dust spherical dust envelope the sublimation zone appears spatially well resolved as a ring (right).

Differential visibilities in the NIR

The NIR is dominated by stars. Recent number counts, based on high resolution single telescope measurements, suggest the existence of a stellar cusp towards the very center, due to the existence of the supermassive black hole. Due to the lack of angular resolution, little is known about the fraction of binaries, which most probably significantly contribute to the massive part of the dense GC cluster.

AMBER can overcome the resolution limit of modern single telescopes. It delivers differential visibilities, which can reveal deviations from single star uniform disc brightness distributions. Furthermore in case of successful instantaneous fringe measurement at three baselines, the closure phase can be estimated, which gives symmetry information, uncorrugated by the atmosphere.

Our first measurements prove a high fringe contrast and the feasibility of NIR-OLBI GC measurements. But the data may indicate a slight extension of about 2mas of IRS 7, which is contradictory to the theoretically calculated 0.5 mas for such a red supergiant.



Calibrated differential visibility over wavelength. Shown is an average over the best 10% (green), 30% (blue) and all data (red), ordered by SNR. Within the uncertainties a visibility close to one is obvious, indicated by the black line and resembling a uniform disc radius of 2 mas.

Outlook

We demonstrated for the first time that VLTI provides a high-resolution tool to investigate the stars and circumstellar dust at the GC with a precision which enables to understand local stellar properties and dust formation in detail. The announced increase in sensitivity will greatly improve the number of observable targets in the *H*-, *K*- and *N*-band.

A new observing campaign with the Keck Interferometer will finally reveal the possibilities of using IRS 7 as a phase calibrator for future faint source and astrometric OLBI measurements. This will be the basis to investigate a putative non-Keplerian shape of the stellar orbits of the innermost stars due to General Relativity and the spatial structure of the NIR-flares of SgrA*, directly related to the mass accretion onto the black hole.

References

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