Prospects for observing the Galactic Center: Combining LBT LINC-NIRVANA observations in the near-infrared with observations in the mm/sub-mm wavelength domain

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ABSTRACT

As a near-infrared (NIR) wide field interferometric imager offering an angular resolution of about 10 milliarcseconds LINC-NIRVANA at the Large Binocular Telescope will be an ideal instrument for imaging the center of the Milky Way especially in conjunction with mm/sub-mm interferometers like CARMA*, ATCA† or, in the near future, ALMA. Sagittarius A* (Sgr A*) is the electromagnetc manifestation of the $\sim 4\times10^6$M$_\odot$ super-massive black hole (SMBH) at the Galactic Center. First results from a mult-wavelength campaign focused on Sgr A*, based on the VLT‡ and on CARMA, ATCA, and the IRAM 30 m-telescope, in May 2007 show that the NIR data are consistent with partially depolarized non-thermal emission from confined hot spots in relativistic orbits around SgrA*. A 3 mm flare following a May 2007 NIR flare is consistent with SSC emission from adiabatically expanding plasma in a wind or jet. With the LBT and ALMA we will be able to study the spectral evolution of NIR/sub-mm/mm flare emission in order to constrain the emission mechanism, the jet/wind physics, and possibly determine the angular momentum of the SMBH. LINC/NIRVANA will also serve to investigate the stellar population and dynamics in the cluster surrounding Sgr A*. A particular emphasis will lie on examining dust embedded and young stars and to unravel the star formation history in the cluster.

For the 0.3 parsec core radius central star cluster the investigation of will be investigated.

Keywords: Instruments: MIDI/VLTI, LINC-NIRVANA; Telescopes: LBT, VLTI, CARMA, ATCA, IRAM 30m, ALMA; Science: The Galactic Center

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1. INTRODUCTION

At the position of Sagittarius A* (Sgr A*) the Galactic Center (GC) harbors the closest ($\sim$8 kpc distance) super massive black hole (SMBH). Sgr A* is embedded in a dense nuclear star cluster. It therefore represents an ideal laboratory for studying the physics of accretion onto SMBHs. The extinction towards the Galactic Center is of the order of $A_V\sim30$ in the optical and $A_K\sim0.1\times A_V=3.0$ in the infrared. A detailed extinction map is given in Schödel et al. (2007). In the GC we can also ideally study the stellar population, the dynamics, and stellar interactions within the environment of this super-massive object. Interferometric observations at NIR/MIR but also at mm/sub-mm wavelengths will allow us to carry out detailed investigations on the accretion process as well as on the distribution and kinematics of stars, gas and dust in this area on the smallest scales.

In order to study the time-variable emission and accretion mechanisms related to Sgr A*, the simultaneous involvement of infrared telescopes like VLT, LBT, Keck and SUBARU in the NIR as well as the IRAM PdBI and 30 m-telescope, APEX, VLA, CARMA, SMA ,and ALMA in the mm/sub-mm domain will allow us to obtain especially long lightcurves ($\sim$600 minutes; see Meyer et al. 2008 in prep.). Those will allow a detailed analysis of the evolution of source components across a wide wavelength range. In this article we expand on the discription of the scientific capabilities of the LBT for observations of the Galactic center as outlined by Eckart et al. (2006).

2. LINC-NIRVANA AT THE LBT

As a near-infrared (NIR) wide field interferometric imager offering an angular resolution of about 10 milliarcseconds LINC-NIRVANA[§] at the Large Binocular Telescope (LBT) will be an ideal instrument for imaging of galactic nuclei including the center of the Milky Way. The measurement of stellar orbits at the GC and the observation of strongly variable NIR and X-ray emission from Sgr A* have provided convincing evidence for the presence of a $\sim$4 million solar mass black hole at the position of Sgr A* (Eckart & Genzel 1996, 1997, Ghez et al. 1998, 2003 Eckart et al. 2002, Genzel et al. 2003, Schödel 2002, Eisenhauer et al. 2003a, 2005ab, see also Eckart, Schödel & Straubmeier 2005 for a review). Observations with LINC-NIRVANA will allow to investigate the stellar dynamics of the entire central cluster at unprecendented precision in order to determine the amount of extended mass within the cusp region. At the same time LINC/NIRVANA will serve to monitor the activity of the black hole on scales of only about 10 light hours or 15 Schwarzschild radii.

The LBT consists of two 8.4m diameter mirrors in one single mount over a fixed baseline of 14.4m. The Telescope is located on Mt.Graham near Tucson, Arizona. Virtually all baselines ranging from 0 to 22.8m are sampled by the 110m^2 collecting area and the resolving power at 1.25μm wavelength will be $\sim$9mas. The NIR beam combination will be carried out by LINC-NIRVANA (Herbst et al. 2003, Straubmeier et al. 2003, Straubmeier et al. 2004a, 2004b, 2004c, Bertram et al. 2006ab, 2007, Rost et al. 2006, Beckmann et al. 2004, Eckart et al. 2004a). As a Fizeau interferometer the LBT will have an exceptionally large imaging FOV of the order of at least 1 arc-minute. Using MCAO techniques (multi conjugate adaptive optics; LBT: Ragazzoni et al. 2003, 2005, Egner et al. 2004) this will be extended to at least 2 arcminutes.

Several challenging technical requirements will have to be fullfilled by LINC-NIRVANA in order to efficiently observe the Galactic Center. The Adaptive Optics will have to work at low elevations (best down to 20^o; at the location of the LBT the culmination of the Galactic Center will be around $\delta\sim30^o$). Currently it is foreseen that the AO will operate with optical guide stars. The best suited optical reference star is located at a distance of about 30" NNE of SgrA* with R=13.2. In NIRVANA-mode a variety of reference stars can be used within a $\sim$6' field. In Fig. 1 we show the optimal asterism for (LINC-NIRVANA) MCAO supported observations of the Galactic Center. Underlying is a digitized sky survey image in the visible. In addition to the well known 13-14 magnitude visible stars near the position of SgrA*, there are several other objects of similar brightness that can be used for MCAO correction (see Bertram 2007, PhD thesis, University of Cologne). With a total V-band magnitude $V_{\rm tot}$ =10.55 the overall asterism is relatively bright.

For the Galactic Center NIR fringe tracking the bright ($\rm mag_K\sim7$) super-giant IRS7 located 5.5$''$ N of SgrA* would be the best suited reference star. In order to carry out deep investigations of stellar populations narrow

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[§] LBT: lbto.org; LBT/Köln: www.ph1.uni-koeln.de/workgroups/astro-instrumentation/LINC/; LBT/LINC: www.mpia-hd.mpg.de/LINC

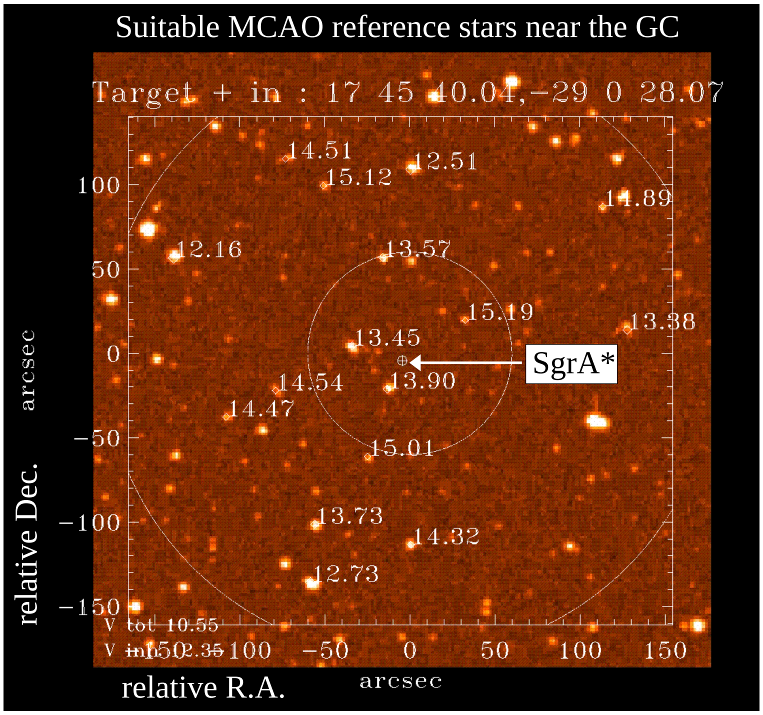

Figure 1. Optimal asterism for (LINC-NIRVANA) MCAO supported observations of the Galactic Center. Underlying is a digitized sky survey image in the visible. With a total V-band magnitude $V_{\rm tot}$ =10.55 the asterism is relatively bright.

band filters in JHK bands are required - both at line and continuum wavelengths. The central He-stars are bright - exposures longer than of the order of a second in JHK broad band will be difficult in combination with full AO correction. For imaging narrow band filters could be used for the central regions and wider band filters for the outer regions of the central stellar cluster. Polarization measurements are highly desirable. They require two Wollaston prisms positioned orthogonally to each other. Polarization calibration could be done within the target field using stars in the central cluster.

3. OBSERVATIONS IN THE MM/SUB-MM DOMAIN

Interferometric observations in the mm/sub-mm wavelength domain are especially well suited to separate the flux density contribution of SgrA* from the thermal emission of the Circum Nuclear Disk (a ring-like structure of gas and dust surrounding the Galactic Center at a distance of about 1.5-4 pc.

In May 2007, global coordinated multi-wavelength observations were carried out in the NIR, X-ray and mm regimes to study the variability of Sgr A*. We observed the GC at 100 and 86 GHz (3 mm wavelength) with the two mm-arrays CARMA and ATCA. CARMA (Combined Array for Research in mm-wave Astronomy) is located in Cedar Flat, Eastern California, a mm-array which consists of 15 antennas (6 x 10.4 m and 9 x 6.1 m). The Australia Telescope Compact Array (ATCA), at the Paul Wild Observatory, is an array of 6 22-m telescopes located in Australia, about 25 km west of the town of Narrabri in rural NSW (about 500 km north-west of Sydney). In addition we observed with the IRAM 30 m bolometer at a wavelength of 1.3 mm. The combined light curve is shown in Fig. 2. We can combine the data from different frequencies under the assumption that the spectral index of SgrA* does not change significantly during the flux density variations between 86 and 250 GHz. In this case the flux density variations are frequency independent. The resulting light curve shows excess or lack of flux density relative to the mean of the overall flux observed with the individual telescopes. There are at least 3 maxima with amplitudes of ∼0.3 Jy, 2 of which are preceeded by 10-20 mJy flares in the NIR as observed with NACO. The flare on July 15 has been analyzed and published by Eckart et al. (2008). A summary of the results is given below.

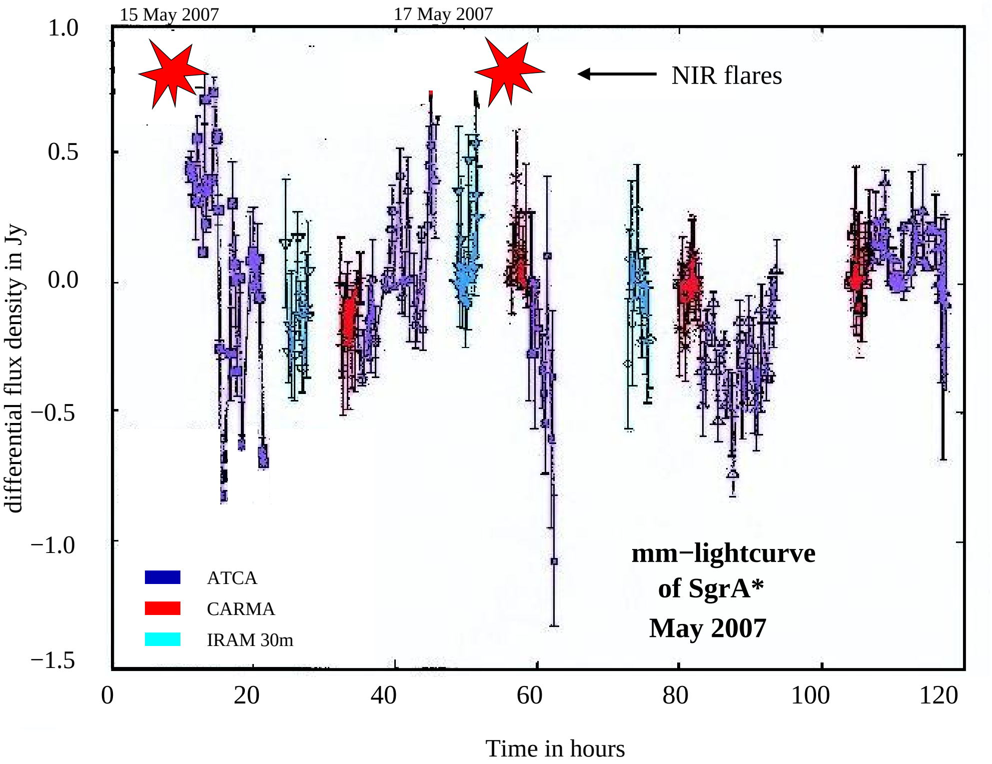

Figure 2. Combined differential mm-light curve of Sgr A* from the May 2007 multi-wavelength campaign. The MAMBO 2 bolometer at the IRAM 30 m-telescope was operated at a central wavelength of 1.3mm. The CARMA data were centered at 100 GHz and the ATCA data at 86 GHz. The time axis is labeled in UT hours starting with 0:00h on May 15.

In the near to mid-term future observations with APEX and especially with the Atacama Large Millimeter Array (ALMA) will allow us to carry out sensitive high angular resolution measurements of SgrA* in the sub-mm wavelength domain in order to investigate the non-thermal emission of SgrA* as well as the thermal emission features within the central stellar cluster.

4. SCIENCE CAPABILITIES OF LINC-NIRVANA FOR THE GALACTIC CENTER

4.1 The Black Hole at the position of SgrA*

The detectability of SgrA* in the radio, NIR, and X-ray domains allows us to perform multi-wavelength studies of its variability and the accretion processes in this low luminosity galactic nucleus in detail. Ideally suited telescopes for this puprose are interferometers or telescopes with large appertures like the LBT in the infrared, and the CARMA, VLA, VLBA, ATCA, IRAM PdBI, or, in the near future, ALMA interferometers in the mm/sub-mm wavelength domain. Coordinated multi-wavelength observations (as required to study physical processes like adiabatic expansion) are of special interest.

Studying the variable polarized NIR emission and simultaneous radio/NIR/X-ray observations of Sgr A* are ideally suited to obtain deep insights into the relativistic physics within 10-100 Schwarzschild radii of the supermassive black hole associated with SgrA*. In several observing campaigns we found simultaneous NIR/X-ray flare variations (Eckart et al. 2004a, 2005, 2006, 2008), indications of quasi-periodicity within the NIR flares (Genzel et al. 2003a, 2003b, Eckart et al. 2006, Ghez 2003b), and highly polarized emission peaks (Eckart et al. 2006) - see Fig. 3.

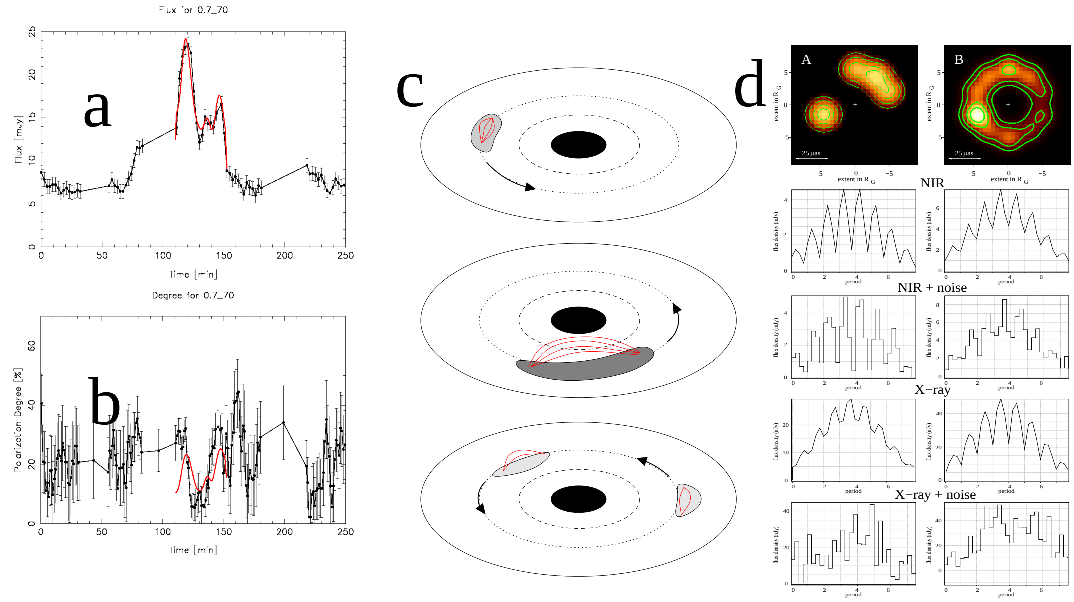

Figure 3. a) and b): The best fit that could be achieved with a hot spot model for NIR flare data from 15 May 2007 (a: overal flux, b: degree of polarization): Two spots orbit around the central Black Hole for two revolutions with the same initial orbital phases but at different radii ($\delta r = 1.2 r_g$), assuming an E-field perpendicular to the disk (Eckart et al. 2008). As the spots separate completely from each other after the first orbit, the model reproduces the observed sub-structure in flux and also the deep dip in polarization degree. c): Sketch of an expanding and evolving hot spot within an inclined temporary accretion disk of Sgr A* (see text). d): Results from multi-component spot model that combines the SSC and relativistic disk model and allows for the first time to do zero order interpretations in a time dependent flare emission model. We show results for a model with only synchrotron (A, left panels) and additional SSC contributions (B, right panels) to the NIR flux. The position of SgrA* is at the very center of the frame.

Polarization measurements of the variable near-infrared emission of the SgrA* counterpart reported by Eckart et al. (2006, 2008) have been carried out using the NACO adaptive optics (AO) instrument at the ESO VLT These observations show that the variable NIR emission of SgrA* is highly polarized and consists of a contribution of a non- or weakly polarized main flare with highly polarized sub-flares. The highly variable and polarized emission supports the assumption that the NIR emission is non-thermal.

Eckart et al. (2008) investigated the physical processes responsible for the variable emission from SgrA* using the NACO adaptive optics (AO) instrument at the European Southern Observatory's Very Large Telescope (July 2005, May 2007) and the ACIS-I instrument aboard the Chandra X-ray Observatory (July 2005). They find that for the July 2005 flare the variable and polarized NIR emission of SgrA* occurred synchronous with a moderately bright flare event in the X-ray domain with an excess 2-8 keV luminosity of about 8×10^{33} erg/s. The authors find no time lag between the flare events in the two wavelength bands with a lower limit of about 10 minutes. The May 2007 flare shows the highest sub-flare to flare contrast observed until now. It provides evidence for a variation in the profile of consecutive sub-flares. These observations confirm that the highly variable and polarized NIR flare emission is non-thermal and that there exists a class of synchronous NIR/X-ray flares. The flaring state can be explained via the synchrotron/SSC-process involving up-scattered X-rays from the compact source component. The observations can be interpreted in a model involving a temporary disk with a short jet. In the disk component the flux density variations can be explained by spots on relativistic orbits around the central super-massive black hole (SMBH). The profile variations for the May 2007 flare can be interpreted as a variation of the spot structure due to differential rotation within the disk (see Fig. 3abc).

In Fig. 3c we show a sketch of an expanding hot spot within an inclined temporary accretion disk of SgrA* based on Hawley & Balbus (1991) and Balbus (2003). The black center indicates the event horizon of the massive black hole, the solid line the outer edge of the accretion disks (see e.g. Meyer et al. 2006ab, 2007), The long dashed line marks the inner last stabile orbit. The dotted line represents a random reference orbit to show the effect of differential rotation of an extended emission region. The red solid lines across the grey shaded extended spots depict the magnetic field lines that provide a coupling between disk sections at different radii.

In addition to processes within the inermost parts of a potential accretion disk combined radio/mm/NIR observations also indicate adiabatic expansion of source components within an SSC model (Eckart et al., 2005, 2006, 2008: Yusef-Zadeh et al., 2006ab, 2008; Marrone et al., 2008). The emission from Sgr A* thus originates very likely from a combination of a temporal accretion disk with a short, low-luminosity jet.

⊙ Key scientific target: Monitoring the variability of SgrA* in coordinated campaigns (radio/mm/MIR/X-ray) and in polarized radio/NIR emission. The LBT will be best suited to separate SgrA* especially during faint phases from the surrounding high velocity stars. Similarly mm-interferometers can separate Sgr A* from the thermal emission of the CND and the mini-spiral. Therefore the combination of the LBT with mm-interferometers like CARMA, ATCA and ALMA is well suited to study the evolution of evolving source components.

4.2 Stellar Population

An increased sensitivity and angular resolution will decrease crowding and LINC-NIRVANA will provide observations of stars near Sgr A* down to one solar mass, over large areas of the central stellar cluster. There is now clear evidence for the presence of young, massive main sequence stars in the immediate environment of the super-massive black hole Sgr A* at the center of our Galaxy. Those stars have probably formed in a formerly present heavy accretion disk (e.g. Nayakshin, Cuadra, Sunyaev 2004). Such a process could also account for the observed top-heavy IMF. It is however not yet clear how the high velocity B-type main sequence stars within less than 0.05 pc of Sgr A* could form and/or migrate to their present position within their lifetimes. An open question of high interest is furthermore whether and how they influence accretion onto Sgr A* that also determines its long-term variability at all wavelengths.

⊙ Key scientific target is the investigation of the stellar population at the GC with an unprecedented statistical quality through multi-color imaging and supported by imaging spectroscopy (e.g with Lucifer at the LBT). One further goal will be the investigation in the immediate vicinity of Sgr A*. How much do the individual stellar populations (e.g. He-stars at distances of 1 to 3 arcseconds or B-star at distances of 1 arcsecond) contribute to the accretion flow onto SgrA* and how much do they contribute to the wind from the central few arcseconds (see following section)?

4.2.1 Interactions of the GC ISM with a central wind

L'-band (3.8 μm) images of the Galactic Center show a large number of thin filaments in the mini-spiral, located west of the mini-cavity and along the inner edge of the Northern Arm (Muzic et al. 2007). Only a few of these filaments are associated with stars. Similar filaments have been seen in high-resolution radio data (Zhao & Goss 1998) and NIR Pa α (Scoville et al. 2003), Br γ (Morris 2000) and HeI (Paumard et al. 2001) emission line maps. One possible mechanism that could produce such structures is the interaction of a central wind with the mini-spiral. Muzic et al. (2007) present the first proper motion measurements of the thin filaments observed in the central parsec around SgrA* and investigate possible mechanisms that could be responsible for the observed motions. The observations have been carried out using the NACO adaptive optics system at the ESO VLT. [The authors also derive the proper motions of 2 cometary shaped dusty sources close (in projection) to SgrA*.] They show that the shape and the motion of the filaments does not agree with a purely Keplerian motion of the gas in the potential of the supermassive black hole at the position of SgrA*. Therefore, additional mechanisms must be responsible for their formation and motion. The authors argue that the properties of the filaments are probably related to an outflow from the disk of young mass-losing stars around SgrA*. In part, the outflow may originate from the black hole itself. We also present some evidence and theoretical considerations that the outflow may be collimated.

⊙ Key scientific target is the investigation of the sizes, shape, kinematics, and excitation of the thin, elongated filaments in the ISM and of the dust shells associated with luminous stars. The results are essential for the understanding of the physics of the stars and the GC interstellar medium (ISM) as well as the interaction between both. Is there a one-to-one identification between the narrow dust features and radio features? Do they have the same proper motions? Is the central wind dominated by the hot stars or (in certain directions?) by a possible wind from SgrA*?

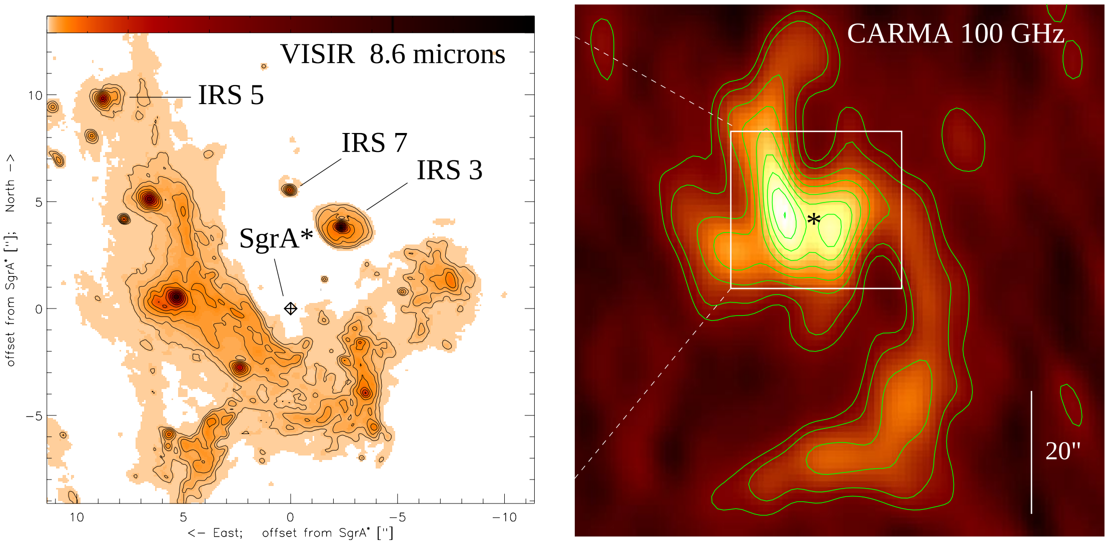

Figure 4. Left: Flux-calibrated Lucy-Richardson deconvolved image at 8.59 μm after restoration with a 250 mas Gaussian beam (see Pott et al. 2008). The pixel scale is 75 mas per pixel. The logarithmic contours levels are $1.6^n \cdot 7$ mJy. The flux scale is given on top. IRS 3 and SgrA* are highlighted. Details of the data reduction are given in Schödel et al. (2007). Right: Source (i.e. SgrA*) subtracted Galactic Center CARMA 100 GHz map composed of the 3 best of 4 full D array coverages (0.05, 0.1, 0.2, ... Jy/beam). The image shows the mini-spiral continuum and demonstrates the high data quality of the 2-3" resolution map.

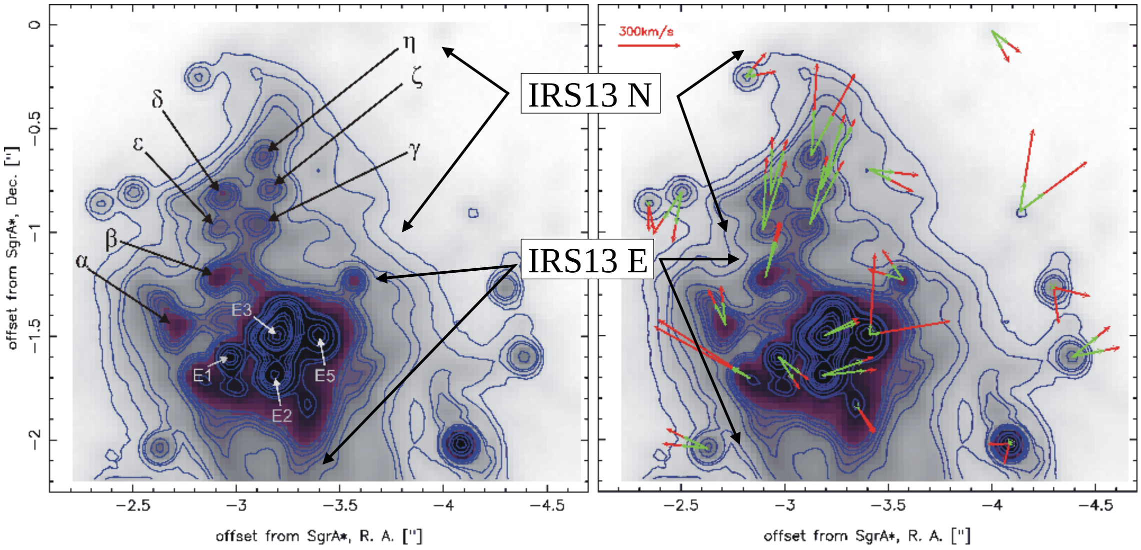

Figure 5. Identification and proper motions of stars in IRS 13 complex. To the left we give the names of individual stars (see also Eckart et al. 2004b). To the right we show the proper motion results obtained by Muzic et al. (2008). Four arrows are shown for each source, indicating the $\pm 3\sigma$ uncertainty of the value and direction of its proper motion.

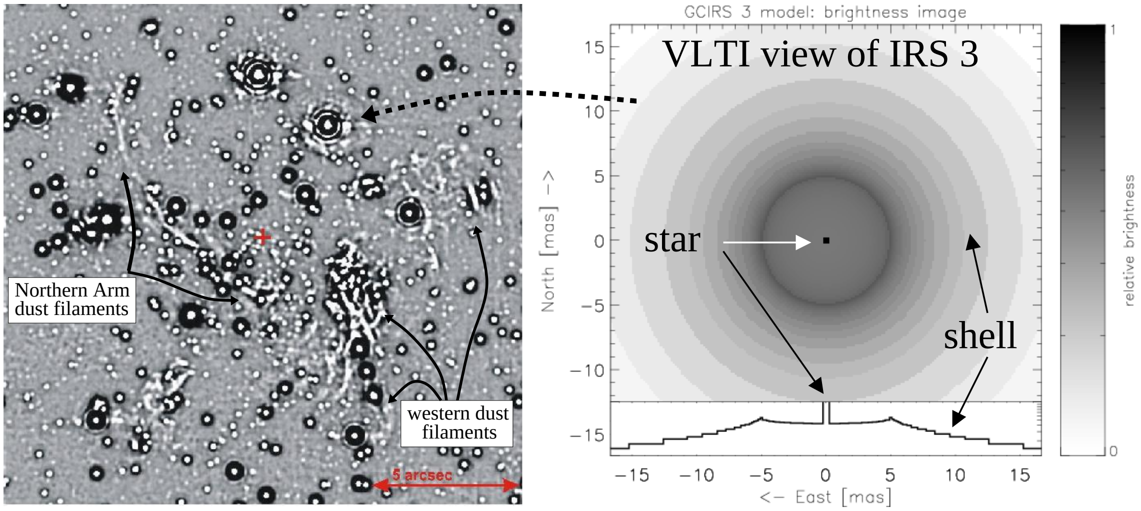

Figure 6. Right: Mean N-band surface brightness distribution of the cool carbon star model of IRS 3 by Pott et al. (2008). The inner rim, the dust sublimation zone, is visible as an annulus and resolved by fitting the RT model to the VLTI MIDI data. At the bottom the radial profile of the respective image is shown, and the image and radial plot are equally scaled logarithmically. Left: High-pass filtered 3.8 μm image (NACO/VLT) of the GC by Muzic et al. (2007) showing the compact dust filaments in the mini-spiral.

4.2.2 The case of IRS 3

An important source that shows interaction with a central wind is IRS 3 (see Fig. 4 and the right panel of Fig. 6). It is the most prominent MIR-source in the central parsec of the Galaxy. The properties and peculiarities of extreme individual objects in the central stellar cluster contribute to our knowledge of star and dust formation close to a supermassive black hole. NIR spectroscopy has failed to solve the enigma of its nature. In the late '70s (Rieke, Telesco,& Harper 1978 and Becklin et al. 1978) it was argued that IRS 3 is a dust enshrouded supergiant with a compact circumstellar dust shell. Gezari et al. (1985) identified IRS 3 as the most compact and (together with IRS 7) hottest MIR source (T$\sim$400 K) in the central cluster, with total integrated flux densities of about 30 Jy at 8 μm to 12 μm. Viehmann et al. (2005) provided evidence that the IRS 3 dust shell is interacting with the GC ISM. NIR/MIR images show a sharp interaction zone of the outer part of the dust shell with the wind arising from the IRS 16 cluster of hot, massive Helium stars.

Pott et al. (2008) initiated an unprecedented interferometric experiment to understand the nature of IRS 3. The authors investigate its properties as an interferometric reference star at 10 μm. The VLTI/MIDI instrument was used to measure spectroscopically resolved visibility moduli at an angular resolution of $\sim$10 mas of that compact 10 μm source, still unresolved by a single VLT. NIR/MIR photometry data were added to enable simple SED- and full radiative transfer-modeling of the data. As a result the luminosity and size estimates show that IRS 3 is probably a cool carbon star enshrouded by a complex dust distribution. Blackbody temperatures were derived. The coinciding interpretation of single telescope and interferometric data confirm dust emission from several different spatial scales. About $\sim$25% of the flux density of IRS 3 is concentrated in a compact component with a size of $\leq$40 mas (i.e. $\leq$300 AU). This agrees with the interpretation that IRS 3 is a luminous compact object in an intensive dust forming phase. The interferometric data resolve the inner rim of dust formation. Despite observed deep silicate absorption towards IRS 3, we favor a carbon-rich circumstellar dust shell. The silicate absorption most probably takes place in the outer diffuse dust, which is mostly ignored by MIDI measurements, but very observable in complementary VLT/VISIR data. This indicates physically and chemically distinct conditions of the local dust, changing with the distance to IRS 3. Pott et al. (2008) have demonstrated that optical long baseline interferometry at infrared wavelengths is an indispensable tool for investigating sources at the Galactic center. Our findings suggest further studies of the composition of interstellar dust and the shape of the 10 μm silicate feature in this extraordinary region.

The remaining six of the seven brightest (N-band) MIR excess sources in the GC were observed (IRS 1W, 2, 8, 9, 10, 13) with the same instrumental setup (see Pott et al. 2005abc, 2008). Most of them are located in the Northern Arm of the ISM or associated with the mini-spiral of ionized gas and warm dust (Fig. 1). None of these sources has been detected interferometrically until now. This indicates that they are more extended and/or contain fainter compact components than IRS 3.

4.2.3 The stellar groups IRS13 and IRS13N

The IRS 13E complex is an unusual concentration of massive, early-type stars at a projected distance of ∼0.13 pc from Sgr A*. It is a disputed location for an intermediate-mass black hole (Maillard et al. 2004, but see also Schödel et al. 2005). Eckart et al. (2004b) present results from diffraction-limited L'-band spectroscopy and H, K, and L'-band imaging of the IRS 13 region in the Galactic Center performed with the adaptive optics camera NAOS/CONICA at the ESO VLT. Just about 0.5 arcsec north of IRS 13 the authors have discovered a small (∼0.13 light year diameter) cluster of compact sources with strong IR excesses due to T>500 K dust. MIR spectroscopy and additional photometry using ISAAC and VISIR at the VLT is provided by Moultaka et al. (2004, 2005) and Viehmann et al. (2006).

Muzic et al. (2008) present the first proper motion measurements of the IRS 13N members and additionally give proper motions of four of the IRS 13E stars resolved in the L'-band (Fig. 5). The L'-band (3.8 μm) observations were carried out using the NACO adaptive optics system at the ESO VLT. Proper motions were obtained by linear fitting the stellar positions as a function of time, weighted by positional uncertainties. Muzic et al. (2008) show that six of seven resolved northern sources show a common proper motion, thus revealing a new comoving group of stars in the central half parsec of the Milky Way. The common proper motions of IRS 3E and IRS 13N clusters are significantly ($> 5\sigma$) different. We also performed a fitting of the positional data for those stars onto Keplerian orbits, assuming SgrA* as the center of the orbit. Our results favor the very young stars hypothesis: This explanation involves the presence of young stars at evolutionary stages between YSOs and Herbig Ae/Be with ages of about 0.1-1 million years. This scenario would imply more recent star formation in the GC than previously suspected.

⊙ Key scientific target is the interferometric investigation of a larger number of individual stars and their shells as well as stellar aggregates and their relative proper motions (like IRS 13 and IRS 13N) in the MIR/NIR. How do these stars interact with the mini-spiral material - both with the few 100 K warm gas and dust as well as the 10^4 K hot thermal plasma?

4.2.4 The nature of compact mid-infrared sources east of IRS 5

Mid-infrared observations of the Galactic Center show among the extended mini-spiral a number of compact sources. Their nature is of interest because they represent an interaction of luminous stars with the mini-spiral material or mass losing sources that are enshrouded in dust and gas shells. Characterizing their nature is necessary to obtain a complete picture of the different stellar populations and the star formation history of the cental stellar cluster in general. Prominent compact MIR sources in the Galactic Center are either clearly offset from the mini-spiral (e.g. the M2 super-giant IRS 7 and the bright dust enshrouded IRS 3) or have been identified earlier with bright bow shock sources (e.g. IRS 21, 1W, 10W and IRS 5). There are, however, four less prominent compact sources east of IRS 5, the natures of which were unclear until now. Perger et al. (2008) present near-infrared K-band long slit spectroscopy of the four sources east of IRS 5 obtained with the ISAAC spectrograph at the ESO VLT in July 2005. They interpret the data in combination with high angular resolution NIR and MIR images obtained with ISAAC and NACO at the ESO VLT. The K'-band images and proper motions show that the sources are multiple. For all but one source we find dominant contributions from late type stars with best overall fits to template stars with temperatures below 5000 K. Perger et al. (2008) conclude that the brightest sources contained in IRS 5NE, 5E and 5S may be asymptotic giant branch stars and a part of the MIR excess may be due to dust shells produced by the individual sources. However, in all cases an interaction with the mini-spiral cannot be excluded and their broad band infrared SEDs indicate that they could be lower luminosity counterparts of the identified bow shock sources. In fact, IRS 5SE is associated with a faint bow shock and its spectrum shows contributions from a hotter early type star which supports such a classification.

⊙ Key scientific target: How are the compact sources east of IRS 5 linked to the other bow-shock sources or the mini-spiral material? Are these sources young and have they been formed from material falling in along the mini-spiral - or are they simply part of the central stellar cluster, interacting with the northern arm of the mini-spiral?

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