First Science with SINFONI

Since the beginning of 2005 another success story has gone into regular operation at the ESO facilities on Paranal. On UT4 (Yepun) an adaptive optics assisted near infrared integral field spectrometer makes an astronomer's dream come true: Obtaining a diffraction-limited image of which each pixel contains a full spectrum. In fact, such data are best thought of as a cube rather than a flat image. SINFONI is the name of the new instrument and a whole symphony of exciting science results has been obtained already.

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The new instrument SINFONI consists of two major components: The integral field spectrometer SPIFFI (Eisenhauer et al. 2003) and the adaptive optics (AO) system MACAO (Bonnet et al. 2003). At the very heart of the system is an image slicer, which cuts the image in the focal plane into slices which are then spectrally dispersed simultaneously by a grating. By means of computers the registered information can then be reassembled into the desired data cube. SPIFFI offers four different gratings, one for each of the three infrared-bands *J*, *H* and *K* and one for the combined *H*+*K*-band. The pixel scale in the spatial dimension can be chosen from 0.25 × 0.125 arcsec/pixel, 0.1 × 0.05 arcsec/pixel or 0.025 × 0.0125 arcsec/pixel (corresponding to a field of view of 8 × 8 arcsec^2, 3.2 × 3.2 arcsec^2 or 0.8 × 0.8 arcsec^2 respectively). The two smallest pixel scales are for AO assisted observations with MACAO. The latter allows one to obtain diffraction-limited spatial resolution by analyzing the wavefronts in the optical of either a natural or in near future also of a laser guide star.

SINFONI was working reliably early on, so that both science verification observations and first GTO nights (guaranteed time for the institutes that contributed to SINFONI) could be interleaved with commissioning activities in the second half of 2004. There were four GTO programmes involved: The Galactic Centre, high redshift galaxies, AGN and starburst galaxies. The science verification programme (SV) consisted of 12 programmes (see ESO web pages > Science Verification of VLT Instrument > SINFONI) for which the data were made publicly available immediately. The observations ranged from high-redshift galaxies to solar-system bodies, covering many samples of the science cases envisioned to be covered by SINFONI. Many results presented in this article are still unpublished and should not be referenced, as they are in preparation for fully refereed journal articles.

Orbits of stars in the immediate vicinity of Sgr A* (GTO, Eisenhauer et al. 2005)

One of the prime targets for SINFONI is the Galactic Centre region. Unlike in the optical bands the infrared offers a relatively unobscured view to the very centre of the Milky Way. One finds a densely populated field which has been resolved into individual stars up to 18th magnitude. Over the last 15 years, the positions of the innermost stars have been measured continuously, which has allowed one to detect actual orbits around the dynamical centre. The central mass could be measured in turn to be 4 million solar masses for an assumed distance of 8 kpc. This mass measurement and the resulting density constraint is the best evidence for the existence of a supermassive black hole in the centres of galaxies. However, in order to determine the distance and the true 3D structure of the stellar orbits, one needs also information about the radial component of the velocities. This can be obtained spectroscopically and hence brings SINFONI into play. By applying Doppler's formula the measured wavelengths of stellar lines provide absolute velocities. SINFONI now allows one to make these measurements simultaneously for all the stars. Already the first observations carried out have substantially reduced the uncertainties, leading to orbital elements with remarkably small error bars. The distance according to the new data is 7.6 ± 0.3 kpc, the mass of the central black hole is now estimated to be 3.6 ± 0.3 million solar masses (Eisenhauer et al. 2005). For six of the stars there are now determined full 3D orbits (Figure 1). The orientation of these orbits seems to be at random – e.g., they are not related with the system of two discs at radii between 0.1 and 0.5 pc (Genzel et al. 2003).

A paradox of youth in the Galactic Centre (GTO, Eisenhauer et al. 2005)

The high-quality SINFONI spectra allow determinations of the spectral types of the stars individually: 24 stars in the inner 0.7″ could be classified. By dropping stars with a total (3D) velocity lower than 500 km/s one gets a sample of stars that is free of fore- and background stars. This leaves 10 stars within the central 0.7″ – all of which surprisingly have spectral types between B0 and B9 (Figure 2). These innermost stars of our galaxy have magnitudes between 14 and 16 implying they are ordinary main-sequence stars. This is puzzling: How can we see stars so close to the central mass? The tidal forces should effectively suppress *in-situ* star formation. However, the stars are too young to have migrated from far away. Some violent formation scenarios can already be excluded: The spectra show no apparent broadening of the lines as one would expect for fast-rotating stars. Hence, SINFONI has strengthened the previ-

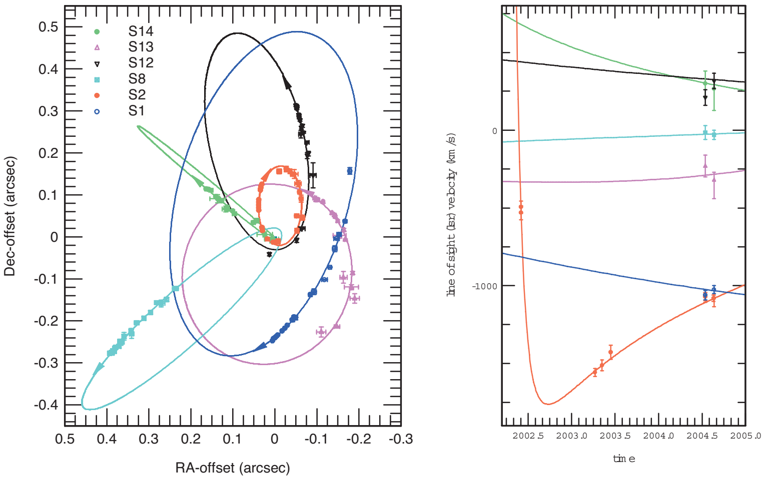


Figure 1: Position on the sky (left inset) and in radial velocity (right inset) of the 6 S-stars in the Galactic Centre included in the orbital fitting. The radial velocities are observed with SINFONI, except for S2 in 2002 which is taken from Ghez et al. (2003). The various colour curves are the result of the best global fit to the spatial and radial velocity data of S1, S2, S8, S12, S13 and S14.

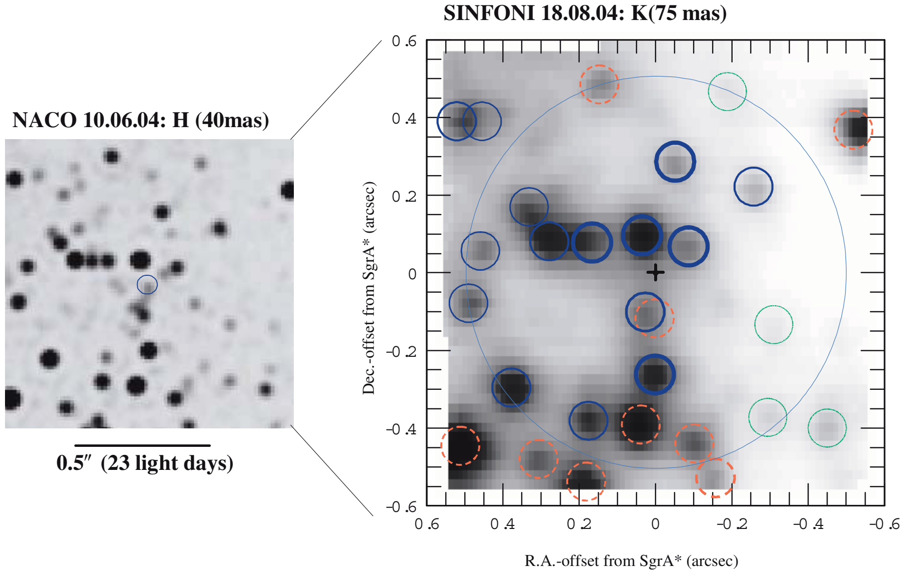


Figure 2: The central arcsecond of the Milky Way. **Left:** A processed NACO *H*-band image from June 10, 2004, showing stars from K ~ 13.3 to 17.8. SgrA* is indicated by a circle. **Right:** SINFONI *K*-band image from August 18/19, 2004, obtained by collapsing the data cube in spectral dimension. The circles around the stars encode their spectral identification: blue: early type, red: late type, thin green: uncertain but not late type; early- and late-type stars with 3D-velocities ≥ 1000 km/s are marked by thick circles, between 500 and 1000 km/s by medium thick and < 500 km/s by thin circles.

ously known paradox of youth (Ghez et al. 2003), which was before based on one star only. From the combination of the normal rotation of the stars and the random orbital orientations one can conclude that the stars were most likely brought into the central light month by strong individual scattering events.

INFRARED EMISSION FROM SGR A* (GTO, EISENHAUER ET AL. 2005)

During SINFONI observations two smaller flares of SgrA* were caught in their entirety. In each case excess emission over about an hour of roughly 16th *K*-magnitude was detected (Figure 3). The spectral slope of both flares was red and a synchrotron emission model with highly energetic, non-thermal electrons fits the data very well (Figure 3). In such a model during a flare, perhaps caused by a magnetic field reconnection event, a few per cent of the electrons near the event horizon are highly accelerated (up to energies larger than 1 GeV) and subsequently radiate in the near-infrared via synchrotron emission. More stringent tests should be possible in future by simultaneous observation of a stronger flare in different regimes of the electromagnetic spectrum.

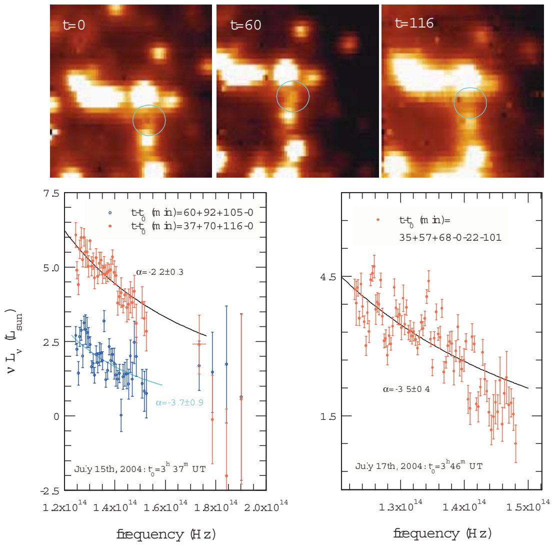


Figure 3: Observations of infrared flares from SgrA*. **Top:** Wavelength-collapsed data cubes from July 15, 2004: ‘before’ (t = 0), ‘peak’ (t = 60 min) and ‘after’ (t = 116 min) (relative to $t_o = 3^h\,37^m$ UT). **Bottom left:** dereddened spectral energy distribution (SED) of the SgrA* flare on July 15, 2003. Red circles: H/K SED averaged over three 10-minute frames near the maximum; blue circles: averaged over three frames at the rising/falling flanks; solid curves: best power law fits. **Bottom right:** The *K*-band SED for the flare on July 17, 2004, averaged over three 10-minute integrations near the peak.

SINS: Survey of high redshift galaxies (GTO, Lehnert)

Over the last decade, a new standard set of cosmological parameters has been established, including a fairly mature view of hierarchical structure formation. The basic premise of all models of large-scale structure is that fluctuations in the mass density of the early universe grow through simple gravitational aggregation/collapse. However, the evolution of the baryonic component of galaxies does not simply follow the merging of dark-matter structures. Phenomenological models have been developed to describe the formation of galaxies. These models rely heavily on simple parameterizations of the physical mechanisms that likely drive galaxy evolution. The most important ingredients are metallicity, angular momentum, stellar initial mass function, and spatial distribution of the gas, the frequency of mergers, as well as the star-formation and feedback processes such as radiation pressure and mechanical energy injection from both stars and supermassive black holes.

To begin to understand these processes, an ambitious programme is being carried out to determine the spatially resolved dynamics, ionization, and metallicity of a large sample of high-redshift galaxies with SINFONI. This survey, which was christened SINS, constitutes a major part of the MPE GTO programme. The sample is chosen to be a representative subsample of several samples such as the "BM/BX" (Shapley et al. 2004), Lyman break galaxies at $z \sim 3$, bright *K*-band selected, (sub)mm, infrared (ISO), and other optical/near-IR colour (e.g., R-K, J-K, etc.) selected galaxies in the redshift range of 1–3.5. Thus far, SINS have concentrated observing time on "BM/BX", *K*-selected, and submm-selected galaxies, having observed ~ 30 objects over ~ 10 nights. The total integration times per band range from one hour to 10 hours depending on the (not *a priori* known) surface-brightness distribution of the emission-line gas. These data demonstrate that the integral field capability and high efficiency of SINFONI are necessary to study the properties of high-redshift galaxies: the dynamics can be complicated and one does not know *a priori* the emission-line distribution or the kinematic major axis.

SINS have found that high-redshift galaxies often show spatially extended kinematics and emission-line distributions. A significant velocity shear or perhaps rotation is often observed, with a shear larger than the velocity dispersion of the gas. This is illustrated in Figure 4 for one example.

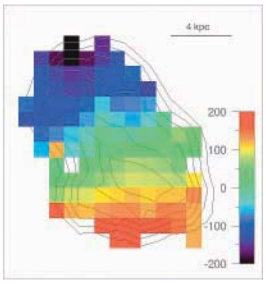


Figure 4 (left): Velocity map of SSA22a-MD41 at $z = 2.1713$ in H-α observed in the *K*-band with SINFONI: The colour bar to the right shows the relative velocities and the bar at the upper right shows the physical scale. The contours represent the H-α surface-brightness distribution. The integration time was 2.75 hours, taken as part of the SINFONI GTO SINS survey. SSA22a-MD41 shows simple rotation in relatively quiescent gas.

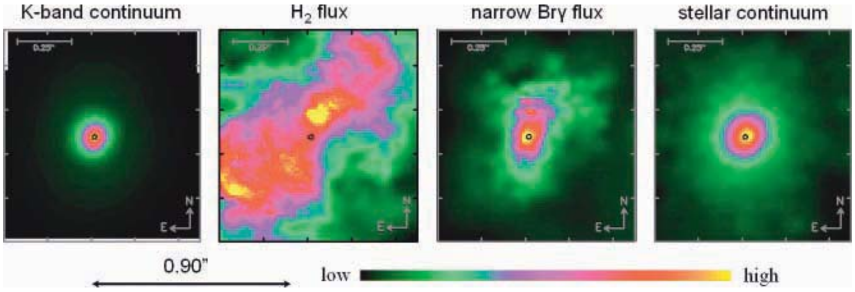


Figure 5 (above): The central arcsec of NGC 3227 with SINFONI. **Far Left:** *K*-band continuum; **Centre Left:** H_2 1-0S(1) line flux; **Centre Right:** Narrow Brγ line flux; **Far Right:** Stellar continuum. The continuum peak is marked by black circles. The morphologies are remarkably different. The 1-0S(1) suggests a very turbulent medium, the stellar continuum is more regular with slightly elongated isophotes.

Taking the measure of AGN – the extreme environment of NGC 3227 (GTO, Davies)

The main goals of the MPE GTO programme, on AGN are, on scales less than 100 pc, to (1) quantify the recent star formation and understand its history; (2) constrain the velocity field and dynamical mass distribution; and (3) determine the central black-hole mass via stellar dynamics. NGC 3227 is an ideal subject for AO-assisted observations since it lies at a distance of 17 Mpc, so that the 60 mas diffraction limit of the VLT at 2.3 µm corresponds to less than 5 pc. From previous estimates of its black-hole mass (30 million solar masses), the radius of influence over which it dominates the gravitational potential is 7 pc. The size scales on which models predict the canonical torus to exist are similar.

Moving inwards from the disc at large scales and the $r^{1/4}$ bulge in the central kpc, one finds a high-surface-brightness ring of gas and stellar continuum emission at radii less than 140 pc. SINFONI data (Figure 5) show that in the central 0.75 arcsec, 60 % of the stellar continuum originates from this inner disc. The timescale for star formation in this disc, determined from the ratio of supernova rate (based on the radio continuum flux) to the *K*-band stellar continuum yields an age upper limit of 250 Myr. This means that in the central 16 pc where the surface brightness is highest, the star-formation-rate density is 300 $M_\odot$/yr/kpc^2, comparable to the most intensely star-forming galaxies such as ultraluminous infrared galaxies.

Further evidence that stars lie in a disc is given by the isophotes, which are slightly elongated (suggestive of a weak bar), and have a position angle offset of 20° from the kinematic axis – both features of disc dynamics. But this is no thin disc: direct measurements of the stellar rotational velocity and dispersion give values more typically associated with an oblate spheroid. The gas also has a velocity dispersion of 100 km/s or more, indicative of a highly turbulent environment.

One curious result is the offset between the centroids of the continua at 2.1 µm and 2.3 µm. With respect to the centroid of the 2.1 µm continuum (dominated by stellar light), that of the 2.3 µm continuum (dominated by emission from dust heated to 500–1 500 K by the AGN) is shifted. The offset arises naturally in a torus model (Figure 6) with the same geometry as imposed by the kinematics. This is because dust at such high temperatures is located only near the inner edge of the torus, about 1 pc from the AGN; and if the clouds in the torus are optically thick at 2 µm, only one side of the inner edge is visible. In such a model the separation corresponds to the 1-pixel shift seen in the data.

While this latter result confirms the basic concept of the standard thick dusty obscuring torus, it is also clear that the concept needs to be adapted – so that it can account for the intense star formation in a disc around the AGN on scales of a few parsecs as recently observed in NGC 7469 and Mkn 231 (Davies et al 2004 a/b).

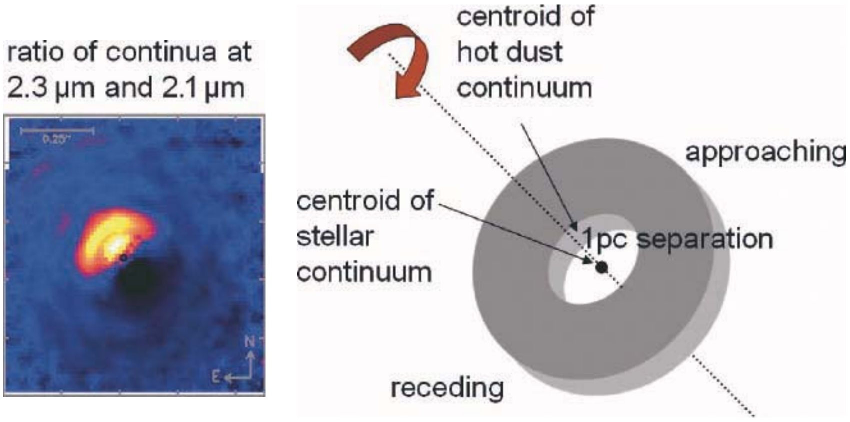


Figure 6: The ratio between the continuum at 2.3 µm and at 2.1 µm (left) indicates that there is an offset of about 1 pixel. The same is apparent between the 2.3 µm stellar and non-stellar continuum. This can be explained in terms of the idealised star-forming torus (right).

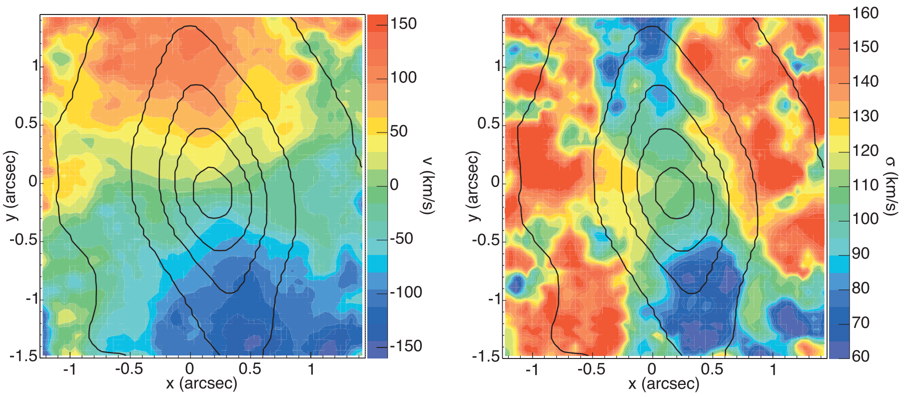
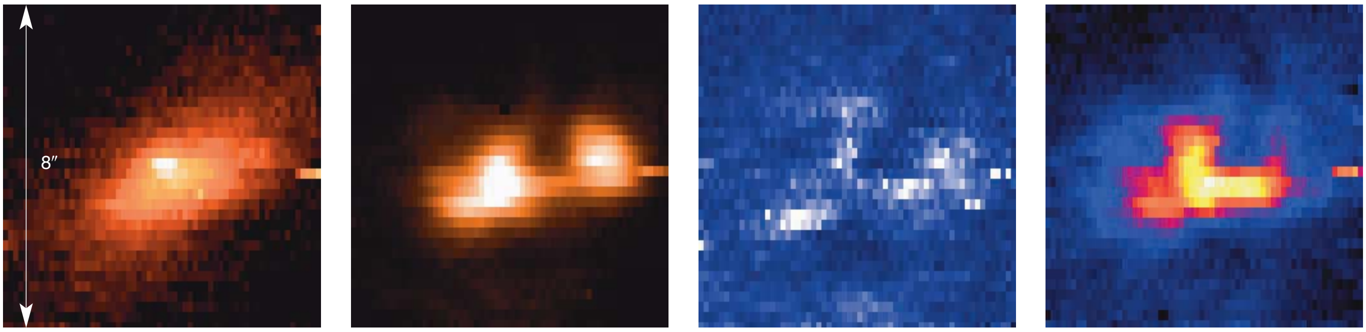


Figure 7 (left): SINFONI measurements of NGC 4486a based on a combination of fourteen 600s exposures. The stellar velocity map (left) and the velocity dispersion map (right) show a regular rotation pattern and a cold disc inside a hotter bulge component. Isophotes are overlaid for reference.

Figure 8 (below): The starburst galaxy He2-10 as seen with SINFONI. From left to right: Integrated *K*-Band image, Bracket-γ linemap (tracing the youngest stars), H_2 linemap and Fe II linemap (tracing supernova remnants).



Supermassive black holes in galaxies (GTO, Nowak)

Every galaxy with a massive bulge component probably hosts a supermassive black hole whose mass follows the mass-velocity dispersion relation and amounts to ~ 0.15 % of the bulge mass. The MPE GTO programme on supermassive black holes aims at an investigation of whether these correlations remain valid when galaxies with pseudobulges, very low-mass bulges or bulgeless galaxies are considered. SINFONI is ideally suited for this task because it allows one to resolve the innermost dust-obscured regions of disc galaxies. So far SINFONI obtained *K*-band data cubes in the 0.1″ pixel scale of the low luminosity elliptical NGC 4486a, a neighbour galaxy of M87, and the Sd galaxy NGC 3137, both at a distance of ~ 16 Mpc. Preliminary results of NGC 4486a are shown in Figure 7. HST images already revealed that this galaxy has an almost edge-on nuclear disc with a dust lane. With the SINFONI data this can now be verified kinematically. The spectra show no emission lines but strong CO absorption bands which were used to determine the stellar kinematics of the galaxy. The resulting velocity and velocity dispersion maps show a regular rotation pattern and a cold disc with a velocity dispersion of ~ 115 km/s in the centre, which decreases along the major axis. Outside the disc in the bulge the velocity dispersion is overall larger. The dust lane cannot be seen in the *K*-band image, but it can be uncovered by unsharp masking. To constrain the central black-hole mass the stellar kinematics will be modelled using a fully general axisymmetric orbit superposition code.

The starburst galaxy He2-10 (GTO, van der Werf)

SINFONI is an ideal instrument for studying starburst galaxies. These objects are generally obscured, making it necessary to go to the near-infrared, which luckily contains a number of highly diagnostic features, such as Bracket-γ (tracing the youngest stars) and [Fe II] 1.64 µm (tracing supernova remnants). SINFONI was used to obtain full JHK-band datacubes of the nearby starburst dwarf galaxy He2-10, with only 10 minutes integration time on-source per wavelength band with the 0.25″ pixel scale (see Figure 8). The *K*-band continuum reveals a fairly featureless object, dominated by a bright core which is known to host a number of bright star clusters, as shown by HST imaging. The image of Bracket-γ is strikingly different: two cores appear, one of which is close to (but not coincident with) the *K*-band core. This image is remarkably similar to the 10 µm emission as observed with VISIR, but differs strongly from the optical HST image, underlining the fact that the youngest star clusters are optically obscured. The [Fe II] image is different again, showing a slightly older starburst population which allows the progression of the starburst to be followed spatially and temporally. Finally, faint H_2 emission is seen to trace mostly the outskirts of the ionized gas as seen in Bracket-γ. Given the different morpholo-

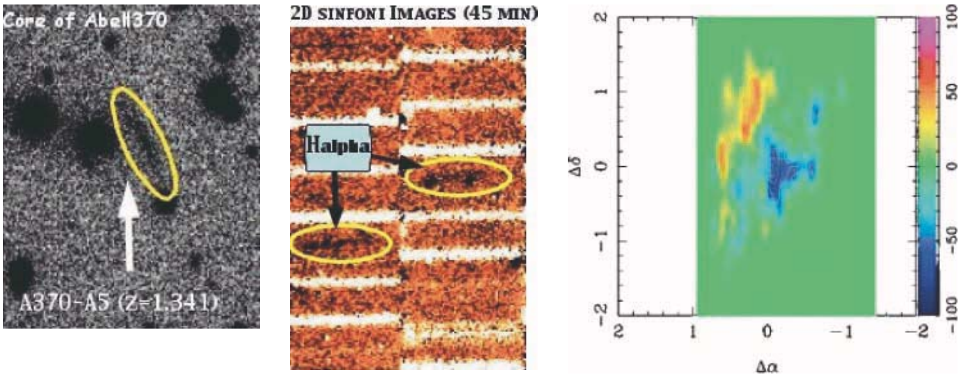


Figure 9: **Left:** A CFHT-I band image of the target: A370-A5; **Middle:** The SINFONI 2D negative image of the detection of the H-α emission line; **Right:** The H-α velocity map in km/s obtained by fitting the emission line of each spectrum to a single gaussian function after correction of the lensing effect.

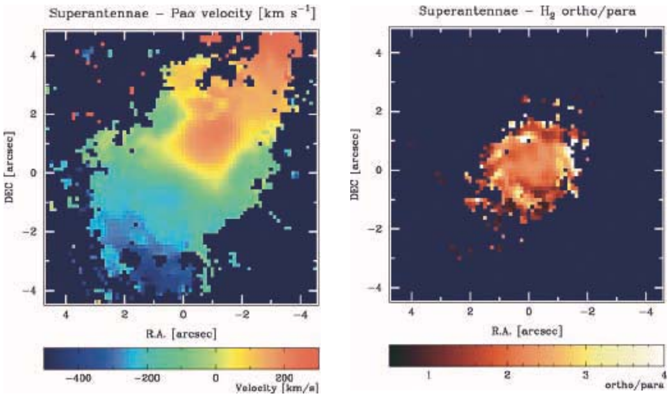


Figure 10: **Left:** Smooth velocity field of the "Superantennae" as traced by Paschen-α. **Right:** Ortho/para ratio map of the galaxy, showing an intriguing spiral structure.

gies of these tracers it is clear that simple slit spectroscopy would not have given a complete picture of the starburst; for a complete inventory an integral-field spectrograph such as SINFONI is required.

The mass and star formation of high-redshift lensed galaxies (SV, Lemoine-Busserolle)

The study of the physical properties of high-redshift galaxies has become one of the major goals of extragalactic astronomy. In particular the mass-assembly histories of galaxies have been the focus of many studies at redshifts 1 to 3 (see above). SINFONI has been used to obtain 2D velocity maps from the H-α emission line of a star-forming lensed galaxy ($z = 1.341$), behind the core of the massive galaxy cluster Abell 370. The natural magnification allows one to spatially resolve and constrain the dynamics of young star-forming galaxies 1 to 3 magnitudes fainter than those selected in blank fields. Thus, the study of lensed galaxies allows one to probe a low-mass regime of galaxies not accessible in standard observations. In this particular case (Figure 9), a rotation of 110 km/s in a disc-like geometry was measured for A370-A5.

Stellar population and kinematic properties of ULRIGs and Seyfert galaxies (SV, Ivanov)

One of SINFONI's early science cases was ultraluminous infrared Galaxies (ULIRGs) in the nearby universe. Observations were obtained for the ULIRG/Seyfert-2 galaxy IRAS 19254-7245, best known for its 350-kpc antennae, providing the galaxy a well-earned nickname "the Superantennae". Kinematics were derived from ionized and molecular gas tracers. Paschen-α was detected over much of the field of view (Figure 10, left). Surprisingly, the velocity field is relatively smooth for such a merging system. The kinematics of other emission lines, notably various H_2 lines, are similar but not identical. Furthermore, different H_2 emission lines also exhibit significant variations in their velocity fields, reflecting changes in excitation temperature and mechanism.

Both the H_2 emission-line ratios and the ortho/para ratio (Figure 10, right) rule out the UV fluorescence as the dominant excitation mechanism for the molecular hydrogen at the nucleus, despite the on-going starburst evident in Paschen-α emission. Intriguingly, there appears to be spiral structure present in the ortho/para map. Part of this structure is also visible in the Paschen-α/H_2 ratio map, so these regions are likely to be star-forming knots with higher-density molecular gas than in the surrounding areas. Based on the line ratios, the molecular hydrogen in the Superantennae appears to be dominantly shock-excited.

Supernova 1987A (SV, Spyromilio)

SN 1987A is located in the Large Magellanic Cloud and thus close enough to study its transition to a supernova remnant. Currently the pre-explosion circumstellar ring is hit by the ejecta from the supernova itself and disintegrated. With SINFONI, the ring can be spatially resolved and information about the shock processes in the different parts of the ring can be obtained. The collapsed image of the supernova ring (lower-right panel of Figure 11) reveals interesting facts of this system. The flux is very asymmetric across the ring, which is due to the inclination and light travel time. It could possibly also indicate asymmetry of the supernova explosion. Further, the data cube clearly reveals velocity dispersions of roughly 70 km/s between the two regions marked with circles on the collapsed image. Comparing the full spectra of the different bands (*J*, *H* and *K*) from spatially different regions provides a thorough account of the shock interactions taking place. As the system is changing on a timescale of ~ 0.5 yr this interaction can be followed as it evolves.

Constraining the Galactic structure with stellar clusters in obscured H II regions (SV, Messineo)

Galactic H II regions are good tracers of spiral arms. However, their distances are often poorly constrained and based only on radial velocities from gas. SINFONI can be used to improve the understanding of the spatial distribution of such H II regions by observing obscured stellar clusters in them at *H*- and *K*-band. The simultaneous classification in spectral subclasses of early-type stars and the determination of extinction correction allows one to obtain spectrophotometric distances independent from the kinematic ones. SINFONI allows one to detect the H I recombination lines from the H II region itself (gas) as well as the spectrum of the candidate ionizing star. Thus, a proper decontamination is possible. SINFONI observations of one such

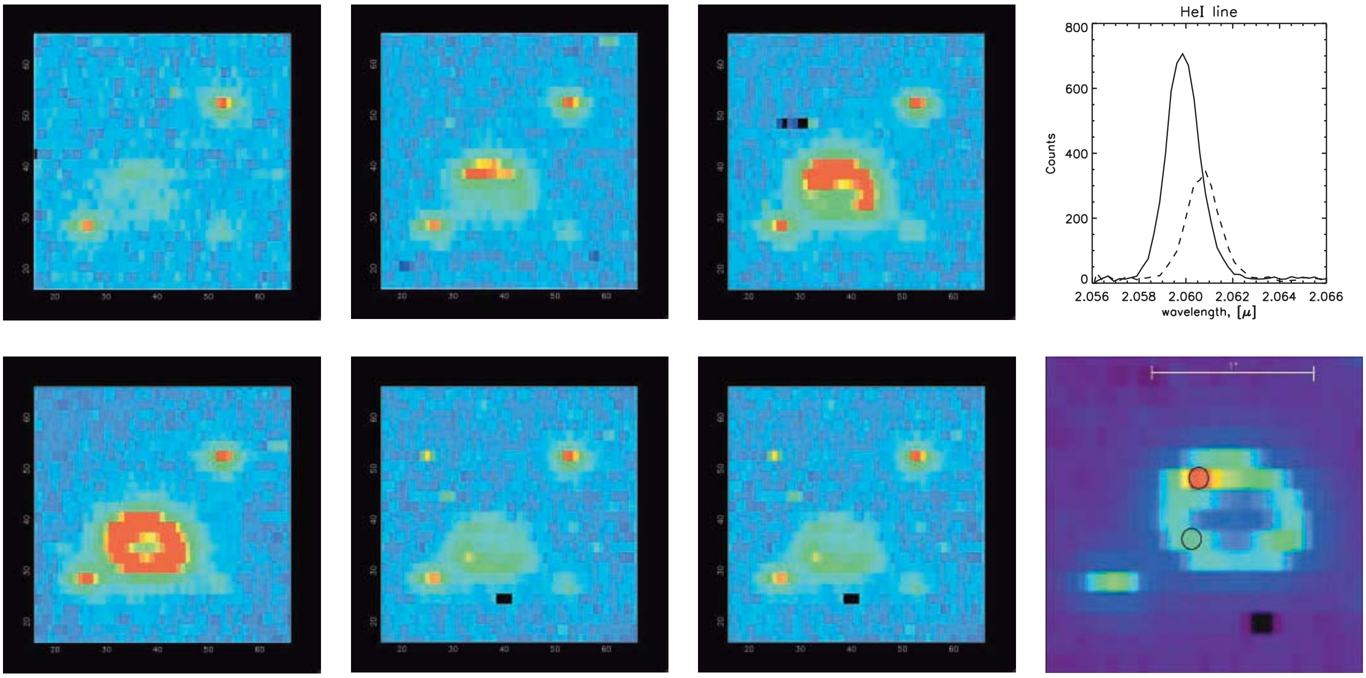


Figure 11: SN 1987A with SINFONI. **Left six frames:** different wavelengths in the data cube. The two red spots in the first frame are stars in the LMC. The green spot on the first frame is the first appearance of the HeI line (2.058 μm) when going through the cube from short to long wavelengths. Going further this line becomes visible in different places and with different strengths. The velocity difference of 70 km/s is apparent when the green spot in the first frame (full line) and the yellow spot on the last frame (dashed line) are plotted (top right). **Bottom right:** collapsed image from 2.057 to 2.063 μm.

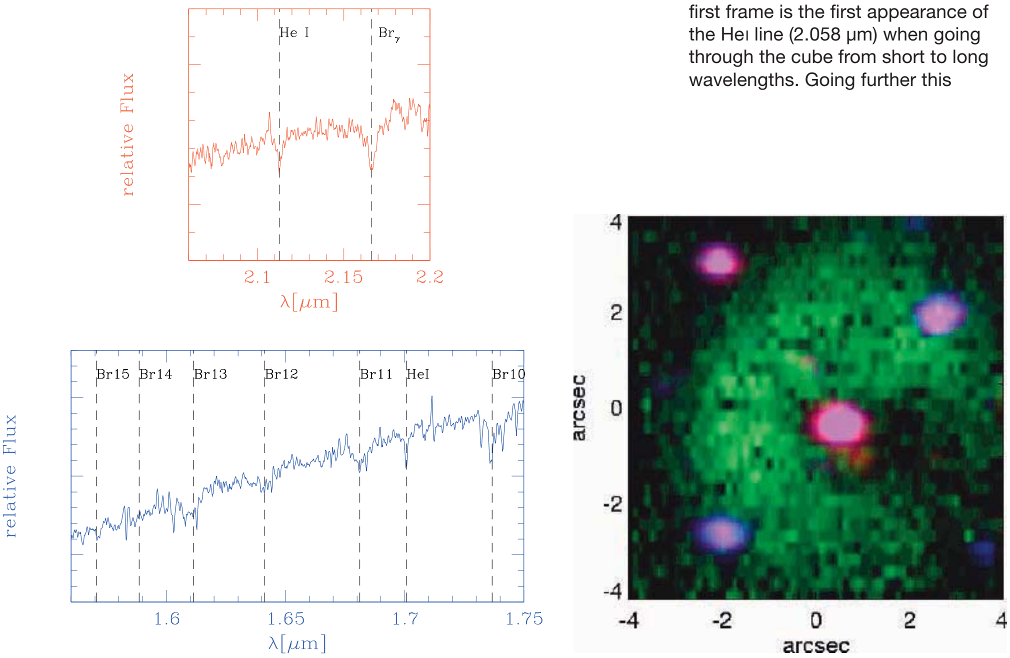


Figure 12: Right: Three-colour image of a Galactic stellar cluster at (l, b = 234.64 deg, 0.83 deg). *H*-band is in blue, Bracket gamma in green and *K*-band in red. The cluster centre is resolved and four bright stars are detected in both *H*- and *K*-band. The central star is surrounded by a nebula. **Left:** *H*- and *K*-Spectra of the central star.

cluster are shown in Figure 12. From a first comparision with a near-infrared spectroscopic atlas the spectral type of the ionizing star falls in the O9-B1 category, using the HeI and H absorption lines and the Bracket-gamma nebular emission. Apparent *H* and *K* magnitudes were also derived from the SINFONI data cube with an accuracy of 0.1 mag. Assuming a spectral type (i.e. absolute *K* magnitude and *H-K* colour) one can derive the extinction and the distance to the HII region.

Formation of a massive proto-star through disc accretion of gas: discovery of an H_2 jet associated with the M17 silhouette (SV, Nuernberger)

The basic processes leading to the formation of high-mass stars are still a big mystery. On the one hand, they may accumulate their mass by accretion of large amounts of gas and dust through their circumstellar envelopes or discs. On the other hand, they may emanate from collisions of protostars of lower masses in the very centres of dense and massive starburst clusters. AO supported integral-field spectroscopy of the M17 silhouette disc hosting a massive protostar was performed using SINFONI (Figure 13, next page). The silhouette disc is seen almost edge-on and the diameter of its innermost densest part is more than 4 000 AU. The flared, wing-like appearance might result either from the slight inclination of the disc plane against the line-of-sight or from the external pressure which is exerted on the disc surface by ionizing photons and strong winds originating from the nearby main-sequence OB stars of the M17 cluster. The images produced from the

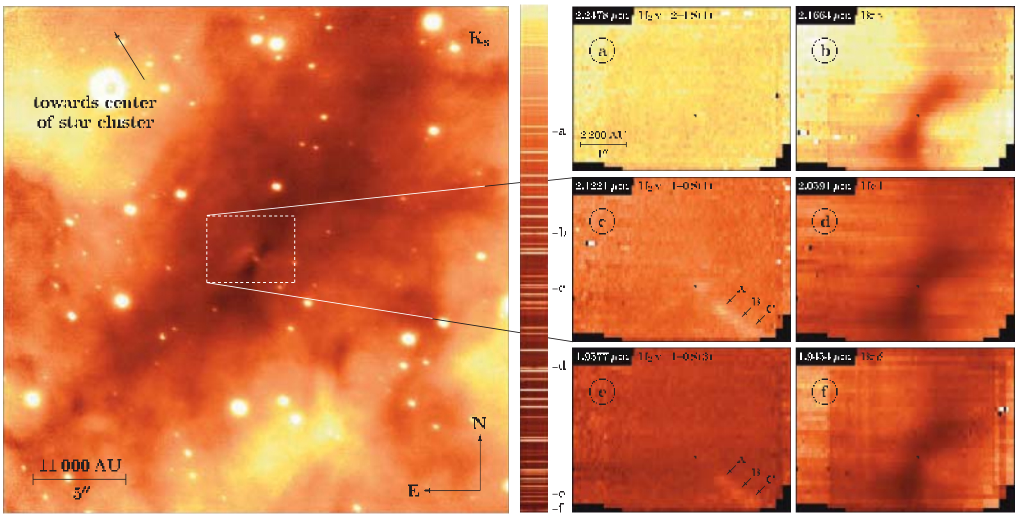
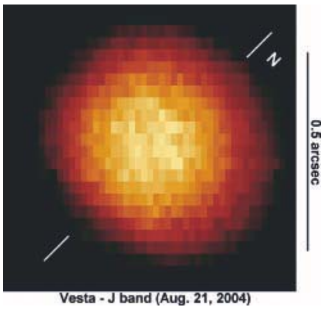
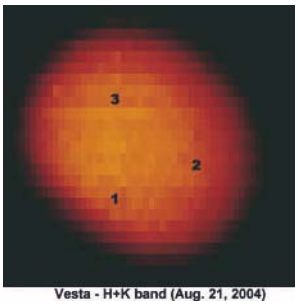


Figure 13: **Left:** NACO K_s-band image of the M17 silhouette disc, showing a field of view of roughly 60 000 AU. Dashed box: The area of the SINFONI SV study. **Centre:** *K*-band spectrum for a horizontal cut through the absorption maximum of the south-eastern part of the disc. Markers a-f denote wavelengths at which images have been extracted. **Right:** Images a-f together with the wavelengths and the most likely atomic/molecular lines. The position of the suspected protostellar source(s) at the disc centre is indicated by a cross. In panels c and e the knots of the H_2 jet are labeled with A, B and C.



Vesta - J band (Aug. 21, 2004)



Vesta - H+K band (Aug. 21, 2004)

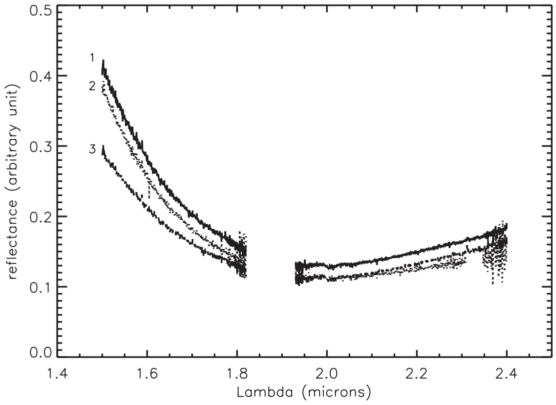


Figure 14: **Left:** Reconstructed images of Vesta obtained in bands *J* and *H+K* during the SV run of August 2004 (25 mas/pix scale). N indicates Vesta's North Pole. **Right:** Variations in the bands of pyroxenes for different locations on the surface of Vesta.

H_2 emission clearly reveal three knots of a jet. Shocks are the most likely excitation mechanism. No counter jet is seen on the other side of the disc. The SINFONI data add an important piece to the puzzle of this truly interesting source. Because ejection of material through a jet-like outflow is always linked to accretion of gas and dust either onto the circumstellar disc or onto the central protostellar source(s), the presence of the H_2 jet provides indirect evidence for ongoing accretion processes.

NEAR-INFRARED COMPOSITIONAL MAPPING OF SMALL SOLAR-SYSTEM BODIES (SV, DUMAS)

The solar system is another domain of application for SINFONI. The instrument capability is used at its best on slightly extended objects (~ 1″), for which MACAO enables the compositional study of their fine spatial structures. The asteroid Vesta (rotation period ~ 5.3 h) displayed a 0.5″ diameter during the August and October 2004 runs (Figure 14), and its brightness (V ~ 6) provided a case for high-Strehl performances for the AO. Furthermore, with an aspect angle of ~ 90 degrees at that time, the geometry of the opposition was particularly favourable to carry out a detailed mineralogical study of both hemispheres of Vesta. Vesta displays the second largest albedo variation between opposite hemispheres (after Iapetus). Its disc integrated spectrum links the asteroid to the HED (howardites, eucrites, diogenites) meteorites and Vesta could be the main source of these types of meteorites. Vesta is the sole intact asteroid that may have undergone complete planetary-style differentiation. Eucrites and diogenites formed from magmas produced inside the asteroid and migrated toward the surface. Together with the material in between (the howardites) their spatial distribution on Vesta will help to understand what occurred at an early stage of formation of what can be considered the smallest known terrestrial planet. HST images of Vesta obtained by Thomas 1997 revealed a large impact crater in the south which has excavated the surface material to reveal the internal composition of the asteroid. This is a unique terrain to explore the composition of Vesta's mantle. The J and H+K gratings of SINFONI were used to spectroscopically map, at several rotational phases, the surface of Vesta across the 1–2.4 μm region of the spectrum. At these wavelengths, the reflectance spectrum of Vesta is modulated by the absorption bands of pyroxene, feldspar and olivine. By quantifying the spatial distribution of eucrites and diogenites at an unequalled spatial resolution, and measuring the abundance of olivine-rich regions excavated from below the crust, one expects to better understand to which degree Vesta's interior melted soon after its formation.

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