Peering into the Dust: News from VISIR

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VISIR – ESO's VLT Imager and Spectrometer for mid-InfraRed – is a combined imager and echelle spectrograph, providing access to the atmospheric N and Q-band windows (7.7–13.3 and 16–24 μm) with a great variety of observing modes. Starting in Period 81 a new set of filters is available to the users of VISIR, and the characteristics of the filters and their science verification are described. The installation of the filters is the most visible result of a technical intervention performed at Paranal between April 24 and May 8, 2007, however more upgrades were also performed.

The Intervention

To minimise downtime, the re-coating slot of UT3 (Melipal) in 2007 was used to dismount VISIR. This operation, and the opening of the instrument, was aimed at realising a number of upgrades and repairs, but, at the same time, served also as a training for the technical staff. VISIR (*http://www.eso.org/instruments/visir/* and Lagage et al. 2004, Pantin et al. 2005) has up to now been operated in principle fully under ESO's responsibility. In fact in 2004 the instrument was shipped to Paranal completely assembled and so little practical experience in handling it existed at ESO. During the 2007 intervention it was also possible to include some envisaged upgrades in the instrument long-term plan, such as the installation of a new IRACE system and a new temperature controller for the detectors. Moreover the thermal inertia of the detector cooling system was increased by adding a disk of lead (note that the VISIR detectors operate at ~ 6–8 K where the thermal capacity of normal metals tends to become very small). As for the first intervention that took place in Paranal in October 2005, the activities were performed with the support of the VISIR Consortium.

Removal of the instrument, vessel opening and separation of imager and spectrometer are already standard procedures in Paranal (see Figure 1). On this occasion it was possible to review new tools to further improve the procedures. One of the key subsystems of VISIR, the rotational cable wrap, which routes a fibre bundle, cables, pipes and flexible helium lines (up to 25 bar!), is normally not accessible and so is subject to inspection and maintenance every time we have the necessity to access it. Covers to improve the operational safety of the unit were added. A new procedure to directly remove the optical bench, which holds both the spectrometer and imager (see Figure 1), from the cryostat, with the latter remaining at the telescope, is in progress. The mechanical interfaces for this operation were tested. Various upgrades in the cryogenic assemblies were performed but the most relevant was the installation of a new optical baffle – completely redesigned and manufactured by CEA/Saclay – in the imager three-mirror anastigmats (see Figure 2). This new baffle is made of metallic plates perpendicular to the optical beam, thus avoiding the spurious reflections which had produced a strong imager ghost. The effect was quite remarkable, the ghost has disappeared.

Figure 1: The VISIR optical bench in the laboratory, awaiting further disassembly. The lower (shiny) part contains the spectrometer, while the triangular, black anodised structure on top contains the imager. The three cup-like structures, forming an isosceles triangle, are the mechanical fixation to the telescope reference frame via the cryostat. In the future it is planned to dismount only this unit for interventions, while the vacuum vessel of the cryostat would stay on the telescope, thus simplifying the operation and minimising the impact on telescope operations substantially.

Figure 2: The new imager baffle. **Left:** being assembled by Gilles Durand, the VISIR project engineer of CEA/DAPNIA. **Right:** after assembly but before integration into the camera assembly.

The scientific filters originally delivered with VISIR were a “model pay-load” dating back from 1992/93 and did not include a silicate filter set. The plan was to add such a set, similar to the one in TIMMI2 (known in the community as the “OCLI filter set”), and which could be ordered on short notice for a relatively moderate price. Unfortunately, however, without advance warning the supplier disappeared from the market about two years before VISIR’s first light. Thus a new supplier had to be found, so that the entire process took much longer than initially expected. Silicate dust has a very strong feature in the atmospheric 10-μm window. This feature is frequently observed in dusty objects as different as comets or active galactic nuclei; depending on circumstances the feature is sometimes in absorption, sometimes in emission. The absence of a filter set dedicated to this feature was seriously affecting the scientific productivity of VISIR. The main characteristics of the new filters are listed in Table 1.

In this process another special filter (J7.9) was added at the suggestion of Glenn Orton (JPL/Caltech). This filter is sensitive to methane and can be used to measure the temperature in the Jovian and Saturnian atmospheres. The potential of VISIR in this context has recently been demonstrated for Neptune where thermal infrared imaging allowed the temperature above the South pole of Neptune to be determined (see ESO Press Release 41/07 and the article on page 21).

The thermal control of the detectors was improved by relocating the thermal sensor and heaters as close as possible to the imager detector, through the use of a new fast high-quality thermal controller, an intervention to the cooling braid and by adding 342 grams of lead as thermal buffer to the cold head.

A new version of ESO’s front-end electronics for detector read-out (IRACE) and a Linux workstation were installed, to put VISIR into the same configuration as the more recent IR instruments (SINFONI, CRIRES and HAWK-I), but also to correct some recurring operational errors. After some problems in connecting a VISIR special interlock to the detector power supply, the system was tested and is working according to specifications. To accommodate the burst-mode, an operational mode very similar to Speckle mode in optical instruments, the bandwidth for the data transfer was also improved by upgrading the communications.

The warm calibration unit was maintained and upgraded. This unit is located between the instrument and the telescope adaptor and in normal operation is not accessible. The main actions were to repair a vacuum line, to replace a linear slide for switching between the calibration sources, and the fine tuning of the monochromator, for wavelength verification of the VISIR astronomical filters, which is located deep in the instrument and thus normally inaccessible.

Finally in line with the UT3 recoating schedule, VISIR was mounted back to the Cassegrain flange to start the cool-down process. Then the VISIR special controller for vacuum and cryogenics (an industrial PLC[1]) autonomously started the procedures to achieve the operational temperatures: 3–4 K at the cold fingers and around 20 K for the optics and the instrument structure.

Commissioning

The recommissioning began off-sky starting on May 18 and on-sky during the nights of May 21 and 22, unfortunately not with the best atmospheric conditions. All the new filters mounted in the imager where checked with the monochromator of the calibration unit, and in particular the 50% cut-on and cut-off wavelengths were measured.

A test with the extended calibration source for all three magnifications (0.075, 0.127 and 0.2 arcsec/pixel) showed, that there is no indication of the imager ghost anymore, while there is positively no vignetting. We found instead that the J7.9 filter creates a noticeable filter ghost (~ 5%) and the J8.9 filter introduces an offset so substantial that the field mask produces a shadow. This shadow affects the detector and hence this filter is of questionable use.

The observing parameters required for operations (optimal combination of the detector on-chip integration time (DIT) and detector capacity) were determined on sky. Standard stars were observed and reduced with the pipeline to determine sensitivities. Table 1 presents the results. The measurements were repeated

[1] A PLC (Programmable Logic Controller) is a small special-purpose computer used to automate machines and considered as reliable as a pure hardware solution.

Filter Name	Cut on 50% [μm]	Cut off 50% [μm]	Sensitivity Small Field Best [mJy, 10 σ in 1 h]	Sensitivity Small Field Median [mJy, 10 σ in 1 h]	Sensitivity Intermed. Field Best [mJy, 10 σ in 1 h]	Sensitivity Intermed. Field Median [mJy, 10 σ in 1 h]
J 7.9	7.483	8.035	12	15.2	21	39
J 8.9	8.338	9.068	2.5	3.0	5	6.9
J 9.8	9.123	10.059	5.5	6.3	10	13.9
J 12.2	11.700	12.216	11.0	11.0	no data yet	no data yet
B 8.7	8.436	9.410	no data yet	no data yet	no data yet	no data yet
B 9.7	9.402	10.242	8	9.8	20	27.7
B 10.7	9.970	11.338	4.5	5.1	8	11.8
B 11.7	11.098	11.950	4	4.6	6.5	9.4
B 12.4	11.971	12.961	8	9.3	11	14.9

Table 1: The characteristics of the new filters and the sensitivities measured since commissioning. Sensitivities, as usual at ESO for the mid-infrared, are given in milli-Jansky for a 10 σ detection in 1 hour detector exposure time. To actually execute the whole Observing Block would take, including acquisition, approximately 1 h 40 m. These filters are also incorporated into the VISIR Exposure Time Calculator.

in the following months to improve the statistics so that the filters could also be reliably incorporated into the VISIR Exposure Time Calculator.

The spectrograph detector temperature is now quite stable, however, there is little margin to change it[2]. The imager detector is still oscillating with typically ±10–30 mK. While the detector artifacts are now less prominent, it is obvious that there is further room for improvement, before the planned fundamental detector upgrade takes place. At the next opportunity we will add a disk of Neodymium[3], having a specific heat ~ 5 times that of lead in the relevant temperature regime. An attempt was made to assess the performance of the imager-detector as a function of operating temperature by taking ramps with the flat-field (extended) source and analysing the pixel-to-pixel variance of ~ 50 × 50 pixel in the centre. This did not result in conclusive findings. Similar tests of S/N vs. operating temperature on the sky have been done. Weather did not however permit study of this dependence to be measured completely "noise-free". For the moment it appears, that 6 K for the imager is a "good" compromise.

Methods to establish and verify the calibration of the monochromator in the calibration unit were implemented, based on a combination of checking the reproducibility of the zeroth-order spectrum and using VISIR itself as a spectrograph. The originally-delivered VISIR-internal calibrators (plastic foils with characteristic absorption spectra) were found not to be useful for this purpose.

When switching from "thru-the-slit imaging" to spectroscopy, a strong remanence is found. For a DIT of 30 ms, detector ghost images were visible for up to ~ 100s; reducing the DIT by a factor of 2 also reduced the time of ghost visibility to ~ 50s. This suggests that the remanence decay depends on the number of reads and not so much on time. This finding will be applied to the templates by adding fast dummy read-outs. The templates to measure filter curves (imager and spectrometer) have been tested and they basically work; regular tests of the filters thus will now become part of the operations of VISIR.

New templates for burst-mode observations were tested allowing the storage of thousands of single DIT frames in a data cube. However the telescope chopping secondary (M2) status cannot be identified from the frames yet. Thus the automatic reduction of the data via pipeline recipes is not yet possible. The overheads for burst mode were originally very large (up to a factor of five too long) and could be reduced by changing the outdated network link to a state-of-the-art device.

Science Verification

To test the new Silicate filter set on sky, a few hours were used to observe two regions of star formation with dust-embedded young stellar objects (YSOs): M17, UC1 and IRS5; and NGC 3603, IRS9. In Figure 3 we show results of this observation for M17 in comparison to previous data obtained with TIMMI 2 in imaging and long-slit mode (c.f. Nielbock et al. 2007). While the VISIR photometry nicely reproduces the TIMMI 2 results, it allows us in the future to search systematically for YSOs embedded in silicate

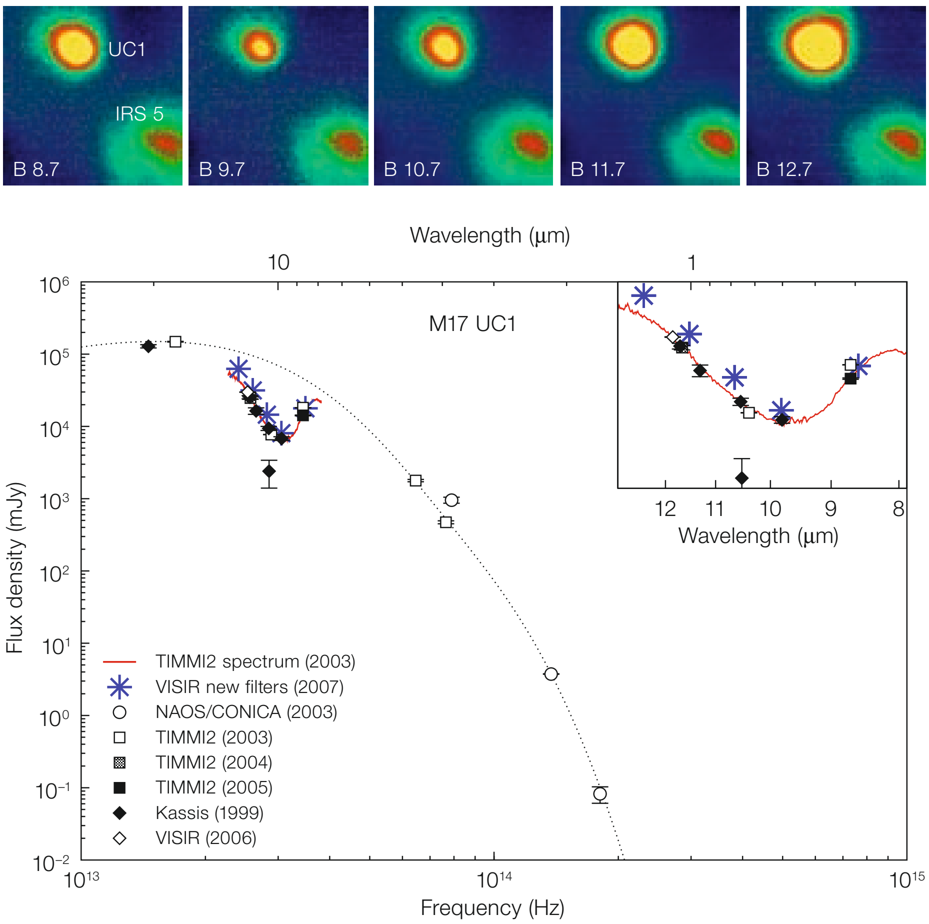

Figure 3: Top: Sequence of VISIR images of the M17 UC 1/IRS 5 region using the new set of Barr filters: B 8.7, B 9.7, B 10.7, B 11.7 and B 12.4 centred at 8.92, 9.82, 10.65, 11.52 and 12.47 µm, respectively. The frames have provisionally been normalised such that IRS 5 has approximately the same brightness in all filters. Each panel displays a field of view of 7.6 × 7.6 arcsec^2, corresponding to about 17 000 × 17 000 AU^2 at the distance of the M17 region. **Bottom:** Overall SED of M17 UC 1 (from Nielbock et al. 2007), with blue asterisks marking the fluxes measured with the new silicate filters manufactured by Barr Associates.

[2] The present VISIR detectors show a variety of artifacts which can be mitigated to a certain extent by choosing the right operating temperature.

[3] Neodymium is a relatively reactive material, and hence machining it is beyond the scope of the ESO workshop. Lead, which is much easier to handle, was chosen for a first try as this had solved the corresponding problem in TIMMI2.

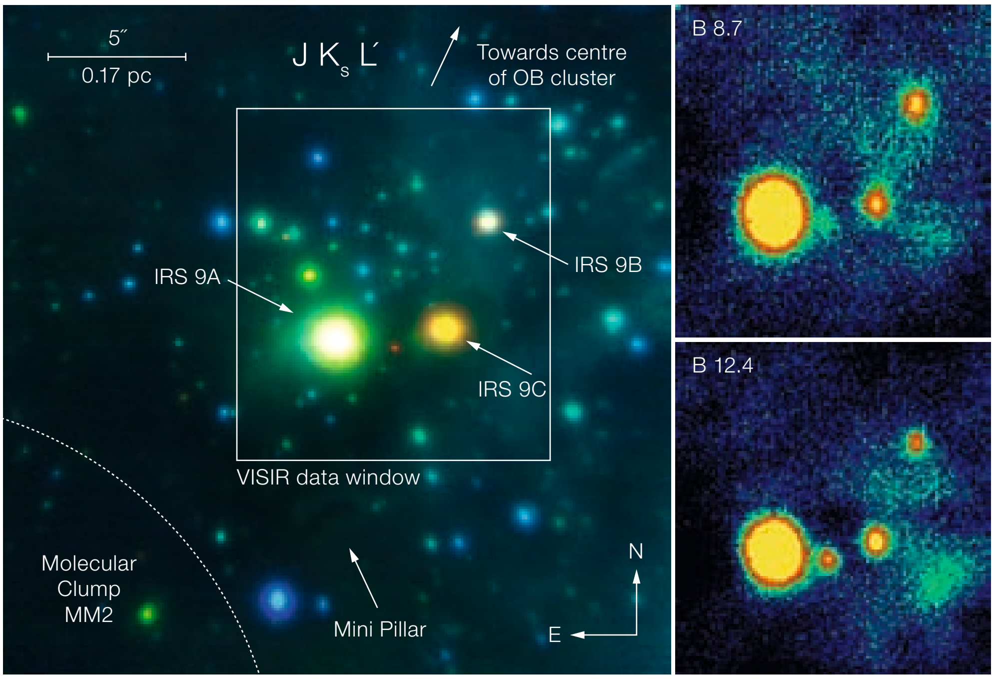

Figure 4: Left: (Nürnberger et al. 2008, in preparation) shows a composite near-infrared image of the IRS9 region, part of the massive star-formation region in NGC 3603. The images were taken in three colours (J, Ks and L′) with VLT-UT4 and the adaptive optics instrument NACO. The object of particular interest is the faint red dot between IRS 9A and IRS 9C. This object is so deeply embedded in dust that it could only be detected in the L′-filter (λ ~ 3.8 μm). A white frame indicates the location of the window for the VISIR images which are shown on the right. **Right:** The region around IRS 9A–C is shown with two of the new VISIR filters. In the B 8.7 filter, centred at λ ~ 8.7 μm right in the middle of the silicate absorption band, the object appears faint (upper); in the B 12.4 filter image (λ ~ 12.4 μm), well outside the absorption feature, the object is bright (lower).

dust. It is also obvious, that the five filter photometry, yielding an effective spectral resolution $\lambda/\Delta\lambda$ ~ 10, is perfectly suited to this problem. In many cases the dust is arranged in a circumstellar disk, and VISIR will allow characterisation of such disks with a spatial resolution of 0.3 arcsec, approximately 10 times better than the Spitzer Space Observatory. In Figure 4 we show a similar data set, but for the IRS 9 complex in NGC 3603. This is an extremely rich cluster of young stars with ongoing star formation. The source situated between IRS9A and C is nearly extincted in the B 8.7 filter (upper panel in Figure 4 right), thus it is obvious that the circumstellar dust around this YSO contains silicates. The nature of the extended emission in the VISIR frames ~ 2 arcsec south-west of IRS 9C, which is brighter in the continuum filter, (B 12.4) still needs to be established. In this example it is very obvious how the combination of high spatial resolution, that only ground-based 8 m-class telescopes can currently provide, and the new silicate filter set allows for the identification of objects of yet unknown properties, or even completely unknown so far.

Outlook

For the immediate future another small upgrade to VISIR is anticipated. This will encompass a further improvement of the thermal regulation and add more and better specialised filters for the VISIR high-resolution Echelle mode. This upgrade will in particular enable observers to follow the [NeII]-line at 12.8 μm to a redshift of a few percent – sensitivity permitting. Implementation of the burst mode with full support by pipeline recipes will be implemented on the fly. As to the scientific potential of this mode, reference is made to very recent work on NGC 1068 (Poncelet et al. 2007). At present ESO is also preparing a fundamental upgrade of VISIR which will at least provide for next-generation detectors (most likely 1024 × 1024 pixel As:Si BIB detectors) to overcome the excess noise of the present detectors and to exploit the full field of VISIR of ~ 50 × 50 arcsec^2 in imaging. Similarly, in spectroscopy, the new detector will allow to take full advantage of the cross-dispersed echelle mode, presently hardly used due to various operational handicaps. Similarly, the new detector format will allow implementation of a new, very high-efficiency, low-resolution mode covering the N-band in one single exposure.

The power and maturity of thermal infrared spectro-photometric imaging has lately been demonstrated in a rather impressive way by Müller et al. (2007). For the near-Earth asteroid Itokawa, which was later visited by the Japanese spacecraft Hayabusa, the careful inversion of optical and thermal infrared light curves (using the VISIR precursor TIMMI2 at ESO's 3.6-m telescope on La Silla) has allowed for the construction of a shape model of this asteroid with a precision of few per cent, including geological characterisation of the surface. This shows not only the potential of ground-based thermal infrared instrumentation, but also that all the basic calibration issues required for precision photometry are now solved.

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