Upgrade of VISIR the mid-infrared instrument at the VLT

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ABSTRACT

The European Southern Observatory (ESO) is preparing to upgrade VISIR, the mid-IR imager and spectrograph at the VLT. The project team is comprised of ESO staff and members of the original consortium that built VISIR: CEA Saclay and ASTRON. The goal is to enhance the scientific performance of VISIR and to facilitate its use by the ESO community. In order to capture the needs of the user community, we collected input from the users by means of a web-based questionnaire. In line with the results of the internal study and the input from the user community, the upgrade plan calls for a combination measures: installation of improved hardware, optimization of instrument operations and software support. The limitations of the current detector (sensitivity, cosmetics, artifacts) have been known for some time and a new 1k x 1k Si:As Aquarius array (Raytheon) will be the cornerstone of the VISIR upgrade project. A modified spectroscopic mode will allow covering the N-band in a single observation. Several new scientific modes (e.g., polarimetry, coronagraphy) will be implemented on a best effort basis. In addition, the VISIR operational scheme will be enhanced to ensure that optimal use of the observing conditions will be made. Specifically, we plan to provide a means to monitor precipitable water vapour (PWV) and enable the user to specify it as a constraint set for service mode observations. In some regions of the mid-IR domain, the amount of PWV has a fundamental effect on the quality of a given night for mid-IR astronomy. The plan also calls for full support by ESO pipelines that will deliver science–ready data products. Hence the resulting files will provide physical units and error information and all instrumental signatures will have been removed. An upgraded VISIR will be a powerful instrument providing diffraction-limited performance at an 8-m telescope. Its improved performance and efficiency as well as new science capabilities will serve the needs of the ESO community but will also offer synergy with various other facilities such as ALMA, JWST, VLTI and SOFIA. A wealth of targets for detailed study will be available from survey work done by VISTA and WISE. Finally, the upgraded VISIR will also serve as a pathfinder for potential mid-IR instrumentation at the European Extremely Large Telescope (E-ELT) in terms of technology as well as operations.

Keywords: VISIR, upgrade, ESO, VLT, Aquarius array, science-ready data products, mid-IR,

1. INTRODUCTION

VISIR is the mid-IR imager and spectrograph on the VLT. It was built by a French-Dutch consortium (Service d'Astrophysique CEA and ASTRON - PI: P.O. Lagage, Co-PI: J.W. Pel) and has been operational since the end of 2004. It is located at the Cassegrain focus of unit telescope (UT) 3 (Melipal) at ESO's Very Large Telescope (VLT) on Cerro Paranal, Chile. The instrument provides diffraction-limited imaging at high sensitivity in the two mid-infrared (mid-IR) atmospheric windows: the N band between 8 to 13 μm and the Q band between 16.5 and 24.5 μm. In addition, it features a long-slit spectrometer with a range of spectral resolutions between 150 and 30,000.

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For technical details of the instrument and its use we refer to the VISIR homepage at ESO: http://www.eso.org/sci/facilities/paranal/instruments/visir/ and to the description of the instrument by the consortium[1]. ESO issues a call for proposals twice a year; preparation of proposals asking for observing time with VISIR is supported by an exposure time calculator: http://www.eso.org/observing/etc/.

The VISIR upgrade project plans to optimise the science performance and output of VISIR by re-enforcing its strengths and by improving weaknesses as well as facilitating its use by the community. The outcome of a dedicated study shows that the upgrade is both feasible and scientifically well justified. It will take advantage of developments in technology, synergies with other facilities and an improved understanding in the atmosphere and its impact on operations. The upgrade of VISIR has been approved by ESO's Instrumentation division in May 2010 and will be conducted in close collaboration between the project team and La Silla-Paranal observatory. Hardware replacements and modifications are envisaged for mid-2011 followed by a commissioning phase on Paranal. The upgraded VISIR should become available to the community in 2012.

1.1 Mid-IR at ESO

The mid-infrared domain is a relatively new branch of observational astronomy the potential of which is not yet fully exploited. Since about 1990 panoramic detectors exist but technical progress has been somewhat less rapid than in the near-IR. In particular the step from 256 x 256 to 1k x 1k devices took more than 10 years longer in development time. In the past, ESO has contributed significantly towards opening the 10 μm (N-band) and 20 μm (Q-band) atmospheric windows for scientific use by the astronomical community. For ground-based observations, of course the thermal emission from the telescope and the atmosphere represent a complication as its brightness can be orders of magnitudes larger than celestial sources. Hence, the maximum "sensitivity" a mid-IR instrument can achieve is to observe in the background-noise limit. Evidently, the thermal background is almost zero for a satellite observatory, a fact that has been exploited by a string of successful projects (IRAS, MSX, ISO, Spitzer and most recently by ESA's cornerstone mission, Herschel). Also, NASA's flagship observatory JWST will take advantage of its unique vantage point at the L_2 Lagrange point. While ground-based mid-IR astronomy is limited to reasonably transparent atmospheric windows (see section 1) and provides background noise limited performance (BLIP), it historically has a significant advantage in spatial resolution due to availability of much larger telescopes on the ground. The highly successful Spitzer observatory used an 85-cm telescope.

Bolometers were available at the ESO's La Silla observatory: at the 1-m (1979) and at the 3.6-m telescope (1980), while the first imaging detector became available with the versatile TIMMI[2] (Thermal Infrared MultiMode Instrument) instrument in 1992 at the 3.6m telescope on La Silla. TIMMI was a member of the highly successful series of focal reducers originally developed at ESO for the visible domain, allowing imaging and long-slit grism spectroscopy. In 1996 the contract for VISIR was signed and 1st light was achieved with TIMMI2[3,4], a scaled up version of TIMMI using a 240x320 pixel AsSi detector in 2000. Since 2003, MIDI has been available to the ESO community at the combined coherent interferometric focus of the VLT,, and VISIR has been in operation since 2004. During these years, mid-IR astronomy has clearly come of age. Observing techniques as well as data reduction methods have matured, a coherent set of standard stars has been defined, and multi-wavelength astronomy has become a routine approach. A nice illustration of the maturity and scientific value of mid-IR observations is described in Mueller et al.[5] in 2005. Based on a combination of R-band photometry and TIMMI2 and VISIR observations, taken by different observers, with different standard stars, they deduced the surface properties, shape and size of the Earth-crossing small planet Itokawa (25143) as a triaxial ellipsoid of 520±50 by 270±30 by 230±20 m^3. This asteroid was subsequently visited by the Japanese interplanetary probe Hayabusa, which beautifully confirmed the predicted values to better than 10%.

The upgrade of VISIR will build on the strengths of ground-based mid-IR astronomy, providing diffraction-limited imaging behind an 8-m telescope while offering better performance and efficiency. VISIR 2 will follow the legacy of providing the best available detector technology. Its users will benefit from the availability of a multitude of targets found by survey work performed by WISE and VISTA. VISIR 2 will enhance performance at the long-wavelength end of the VLT, providing synergy with ALMA and VLTI.

1.2 Assessment of VISIR's current status

Since the beginning of operations in 2004, more than 5000 hours of observations have been obtained with VISIR, for nearly 400 different observing programmes. Using information from the ESO bibliographic database, we find that (as of Feb. 1, 2010), 67 papers have been published in refereed journals using data from VISIR in the period 2005 to 2009. Of these, 27 (40%) are based on data from VISIR alone, whereas 40 papers (60%) are based on data from VISIR in combination with data from other facilities. This publication rate is lower than for highly successful VLT instruments such as UVES or FORS2 (optical spectrographs that yield more than 100 papers per year), but is comparable to an instrument like SINFONI (a near-IR IFU spectrograph). This is quite natural, since VISIR is not a workhorse instrument, and a large fraction of its results are achieved in combination with other instruments across a wider wavelength range Hence, it is safe to say that VISIR science production is within expectations with respect to the observing time granted.

Some cause for concern is in the fact that the demand for VISIR observations is considerably lower than the average for VLT instruments, which is 150±20 runs per year requested. In fact, the number of VISIR runs requested has dropped significantly over the first 3 years following the start of operations and now remains steady at a rather low level (Figure 1). We conclude that this is in response to a number of shortcomings in VISIR's performance. The main limitation is in the detector itself, and its replacement by a larger and better array is the cornerstone of the upgrade.

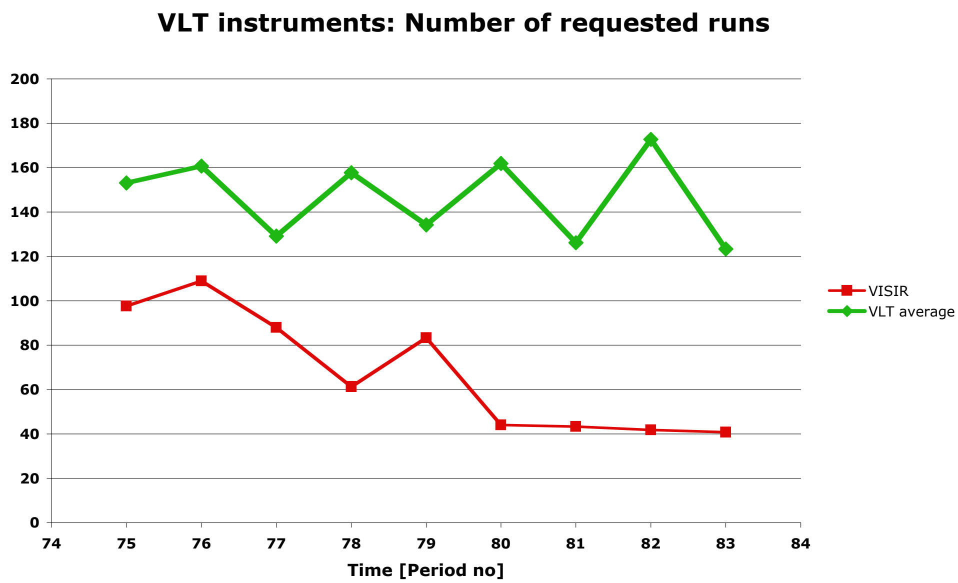

Figure 1: Number of runs requested per year for VISIR (lower curve) and, for comparison, the average for all VLT instruments (upper curve).

From analysis of the publications (see http://archive.eso.or/wdb/eso/publications/form), it is obvious that VISIR has enabled a wide range of astronomers to obtain, analyze and publish mid-IR imaging data. For spectroscopy with VISIR, a wide interest from our user community exists in using this, but so far few astronomers outside of the teams directly associated with VISIR have succeeded in analyzing and publishing this type of data. Improvements to the data reduction pipeline for VISIR's spectroscopic modes (as well as the burst mode) are therefore part of the VISIR upgrade plan.

In summary, VISIR in recent years has been underused by an active but comparatively small community. The upgrade therefore aims to enhance the performance of VISIR and make it an attractive option for a larger community.

1.3 Projected observing capabilities in the mid-IR 2010-2015

The study team surveyed the instruments and their capabilities available to the astronomical community at the various observatories and facilities. In summary, it is fair to say that (an upgraded) VISIR is fully competitive with respect to other existing ground based instruments in terms of sensitivity and spectral resolution. A major improvement in sensitivity can only be achieved by the next generation of extremely large (>25-m diameter) telescopes that will come online only around 2018.

Space instrumentation of course benefits from the much reduced background, while the telescope mirror diameters - and hence the spatial resolution achievable - that can be deployed is naturally limited. Figure 2 shows how VISIR is performing with respect to other existing or planned facilities.

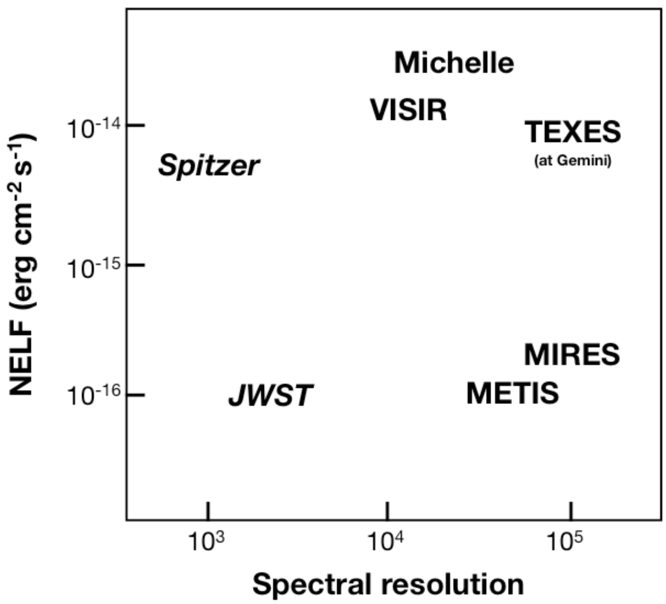

Figure 2: Noise equivalent line flux vs. spectral resolving power for ground- and space-based MIR instruments (adapted from Elias et al. 2006, Proc. SPIE Vol. 6269, 277; METIS & VISIR points added for this work only).

Past experience tells us that VISIR is often used in combination with other instruments for multi-wavelength studies. Hence VISIR is both providing and benefiting from synergies with other facilities on a routine basis.

As stated above, an upgraded VISIR will be very well-suited to provide high resolution (both spatial and spectral) follow-up observations for targets observed from space. Also, VLTI will be coming of age during the period 2011-2015 with much improved sensitivity. VISIR has already been used to complement VLTI observations in the past and is currently one standard means to provide reliable photometry of targets for VLTI Finally, ALMA will start operations in 2011, and VISIR is the obvious complement in terms of wavelength coverage and objects studied.

In summary, it is a very opportune time (Figure 3) for an upgrade to VISIR because a multitude of targets is available from survey work, such as that done by Spitzer or WISE as well as VISTA, many of which require follow-up study at high spatial resolution. Based on the projected schedules, VISIR will enjoy - in the above applications - little competition from space or SOFIA during the period 2011-2015, while it can certainly compete with any ground based instrument. Finally, the upgrade of VISIR can also serve as a pathfinder towards IR instrumentation at the E-ELT. According to the preliminary analysis of the community feedback to the E-ELT Design Reference Science Plan (DRSP)[6] an mid-IR instrument study (METIS) was the most frequently (17%) requested among the eight proposed instruments. In terms of capabilities, diffraction-limited performance – which is comparatively easily to achieve in the mid-IR - showed the highest (36%) demand.

VISIR can act as a pathfinder for future instruments at the E-ELT by demonstrating technologies, observing techniques and operational concepts. The proposed upgrade plan takes into account these aspects.

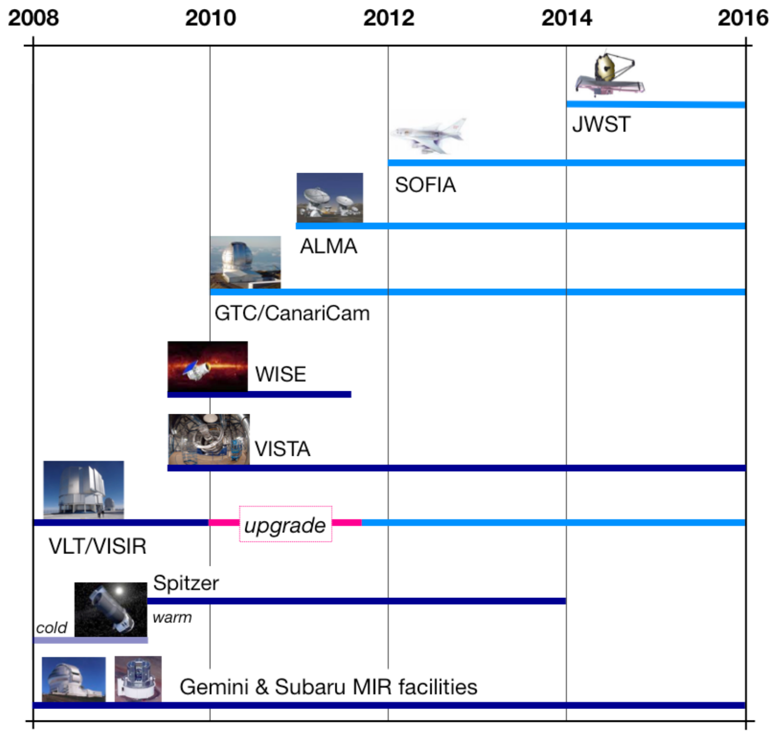

Figure 3: Timelines for major mid-IR facilities and VISIR upgrade.

1.4 Summary of reasons for a VISIR upgrade

VISIR is the only mid-IR instrument available to the ESO user community at large, providing unique science opportunities to European astronomy. Fed by an 8-m UT of the VLT, VISIR is providing diffraction-limited performance combined with good sensitivity, which allows detailed studies of Galactic and Extra-galactic sources. It also excels in the study of solar system objects. Its high-resolution spectroscopy mode provides an excellent tool for the analysis of physical properties of objects. The science cases developed for the original VISIR are still mostly applicable today.

As an instrument, VISIR is reliable, well built and requires low maintenance only. Its limitations in performance are well known and mostly understood. A meaningful upgrade is feasible; in particular, a much improved detector is available. The upgrade will be a service to the European user community and will make it possible to exploit synergies with space missions, VLTI and ALMA. An upgraded VISIR will also bridge the gap towards and act as a pathfinder for future mid-IR instruments at the E-ELT.

1.5 Needs of VISIR user community – Results of Questionnaire

As part of the study for the VISIR Upgrade Project, a user questionnaire has been created – a first at ESO - to inventory the opinion of the VISIR user community on the desirability of this upgrade project, to ask for their input on some of the trade-offs that will have to be made, and to ask them to prioritize the various upgrade options. Although the questionnaire (June/July 2009) was open to all interested parties to fill out, 206 past VISIR, TIMMI or TIMMI2 users had been prompted specifically by e-mail to fill out the form. In total, 41 replies to the questionnaire have been received, of which 34 (83%) have been filled out by users who are not part of the VISIR Upgrade team. The results of the questionnaire can be listed as follows:

- VISIR has managed to attract a stable user base, which is planning to continue to use VISIR for their science.

- Star- and planet-formation are the themes most popular with VISIR user, but extragalactic studies account for about 1/3 of the observations.
- Most of VISIR science is done in combination with other instruments (multi-wavelength).
- Improved sensitivity and image quality/stability for the existing modes are the most urgent request by the users.
- The users are enthusiastic about an upgrade of the low resolution N-band spectroscopy, with a goal to cover the entire wavelength range in a single setting.
- The user are interested in adding new science capabilities.
- The user community remains divided about having science-ready data products.
- For operations, the users would like to see PWV established as the relevant constraint for mid-IR observations.

Based on the questionnaire, the user community wants to have the existing modes of VISIR improved, in particular in terms of sensitivity and observing efficiency. It is desirable to expand the scientific capabilities by adding new modes.

2. UPGRADE PLAN

The VISIR upgrade will comprise a number of tasks, addressing needs in terms of hardware, software and operational aspects. The emphasis is on improving existing observing modes and enhancing the ease and efficiency of observing. In addition some new science modes have been approved for implementation on a best effort basis. At the core of the upgrade is the replacement of the detector array.

2.1 Aquarius detector array

Table 1: Comparison of Aquarius detector versus last generation detectors and Hawaii-2RG

Parameter	VISIR Instrument	TIMMI2 Instrument	AQUARIUS	HAWAII-2RG
Manufacturer	Boeing/DRS	Raytheon	Raytheon	Teledyne
Material	Si:As	Si:As	Si:As	HgCdTe
Array size [pixels]	256x256	320x240	1024x1024	2048x2048
Pixel size [m]	50	50	30	18
Unit cell format	Direct Injection	Direction Injection	Source Follower per Detector	Source Follower per Detector
Temperature [K]	6	6	6	70
Outputs	16	16	64	32
Spectral Response [m]	5-28	5-28	5-28	0.6-5
Well Capacity [electrons]	2E6/20E6 (switchable)	10E6/30E6 (switchable)	1E6/11E6 (switchable)	1E5
Noise [e rms]	300/2000 e rms	1000/3000 e rms	100/1000 e rms	< 10 e rms
Dark Current [e/pixel/s]	2500 e	100 e	1 e	1 e
Frame Rate [Hz]	100	100	120	1
QE	>50%	>40%	>50%	>90%
Year	1990s	1990s	2010	2005
Issues	Cosmetics	Cosmetics		None

ESO has fully funded the development of a new high background mid-IR detector to upgrade VISIR, to furnish a suitable detector for the 2nd generation mid-IR interferometric instrument MATISSE[7] and to meet the needs of next-generation instrumentation. The contract was placed with Raytheon Vision Systems in 2007, and first delivery of the contract for 5 science grade devices is imminent. The design of the detector has been kept as simple as possible and is based in part on the low-background detector developed for the MIRI instrument on JWST. Table 1 gives a comparison of the main characteristics of this new device compared to previous generation devices. A comparison is also made with the Teledyne H2RG near-IR devices, to give an indication where mid-IR detectors are in relation to more typical astronomical detectors.

The main points to note from the table about Aquarius are its increased pixel number, smaller pixel size and its expected performance in terms of noise and frame rate. The detection material is Si:As Impurity Banding Conduction (IBC) using n-on-p detectors with the electrons collected in a simple Source Follower per Detector (SFD) structure which is typically used in near-IR detectors to minimize noise. The detector material is hybridized to a silicon readout circuit, which is the typical construction for most IR detectors. The detection material itself is fabricated on a Si substrate and this is then hybridized to the readout circuitry using indium bump bonds. This ensures that there is no thermal mismatch between detector substrate material and the readout circuitry. To minimize manufacturing costs, the detector uses the same 124 pin LCC ceramic package as used with the Aladdin III detectors. This is shown in the picture below, where the detector, is mounted in its package on a simple PCB for test purposes.

The detector operation scheme is more complex than "normal" NIR detectors, but compared to the previous generation devices such as the CRC 774 used in TIMMI2 and MIDI it is clearly an improvement. It requires upwards of 20 biases voltages and 15 clock signals. A real challenge are the 64 outputs, each capable of operation at 3 Mpixels/second, which gives a sustained data rate of more than 250 Mbytes/second. This is an order of magnitude higher than any detector system build at ESO in the past. The detector output sits at a DC level of 7.1V, with the signal modulation downwards of approximately 1V. Our detector control electronics (NGC) require an input voltage level of -2V to +2V. To ensure high speed readout then, the cable capacitance seen by the detector outputs must be less than 50 pF. However, astronomical instruments typically have a cable run of a few metres from detector to the digitisation stage. This mismatch of voltage levels, together with the long lengths of cables that astronomical instruments require, means that cryogenic impedance matching, signal gain and level shifting electronics are required 64 times to allow operation of the detector at the required speeds. This has entailed the development of new high-speed cryogenic preamplifier circuits, which will be described in a future publication.

At present, we are in the process of designing and manufacturing all the complex electronics required to operate the detector. We therefore hope to have first light images from our science devices before the end of 2010. We hope to report on actual performance of the detector in a future publication.

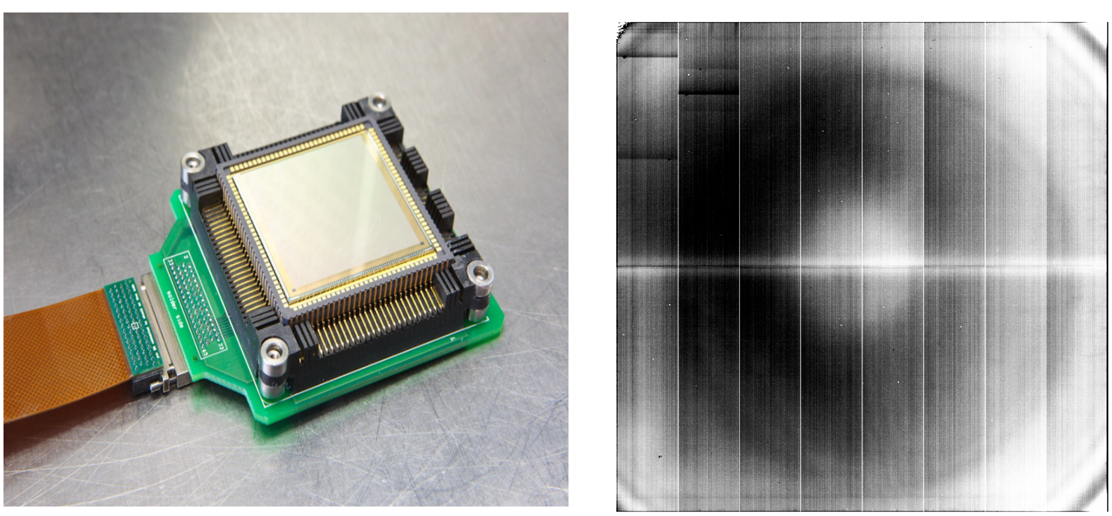

Figure 4: Aquarius detector - here the bare MUX - mounted in test PCB and first light image from Raytheon

2.2 Detector test facility

For characterization of the Aquarius detector, an adequate test facility is needed that provides the required operating temperature levels, low thermal background and appropriate cryogenic optics for homogeneous illumination of the array. To avoid a complex new design, it was decided to recycle the decommissioned Thermal Infrared MultiMode Instrument TIMMI-2[3,4]. This instrument, which was formerly installed at the La Silla 3.6-m telescope, is best suited and capable of meeting the requirements driven by the AQUARIUS detector. Prior to the VISIR upgrade study phase TIMMI-2 was shipped, partially disassembled, from La Silla to ESO headquarters in Germany, with the goal of first re-commissioning the original instrument with respect to reproduction of detector read-outs, and second, upgrading it as a test facility with respect to the special Aquarius detector needs, especially enlarging the focal plane accordingly.

In the last quarter of 2009, the re-assembly of TIMMI-2 started with a critical inspection of all single components. The cooling system, which consists of a 4 K 2-stage Gifford-McMahon closed cycle cooler SRDK-408D from Sumitomo Heavy Industries, was serviced and separately tested in advance. Several helium leak and out-gassing tests of the empty vacuum vessel were performed to ensure leak tightness better than 10^{-9} mbar*l/s. The pre-assembled optics structure including five cryo-mechanisms was integrated and carefully functionally tested at ambient levels. The cooler system, thermal connections and radiation shield were implemented as in the original state. Vacuum accessories and the electronics rack were configured as during telescope observation. A dedicated mounting frame including an optical bench with a blackbody source in front of the entrance window was built. A first cool down of the complete system in early 2010 proved normal vacuum and thermal behavior. Temperature levels were reached as expected: the optical bench and the filter wheel, are at 44-45 K, while the lens wheel, the last optical surface in front of the detector gets as cold as 29 K. The detector temperature of TIMMI2 is 6.0 K and there is sufficient cooling margin with the second stage of the closed cycle cooler at 3.2 K

The mechanisms, which are driven by stepper motors at ambient temperatures via vacuum feedthroughs, were tested at cryogenic temperature. Effort was made to get the detector system and its dedicated software running during a second cool down cycle in order to perform an overall optics verification test.

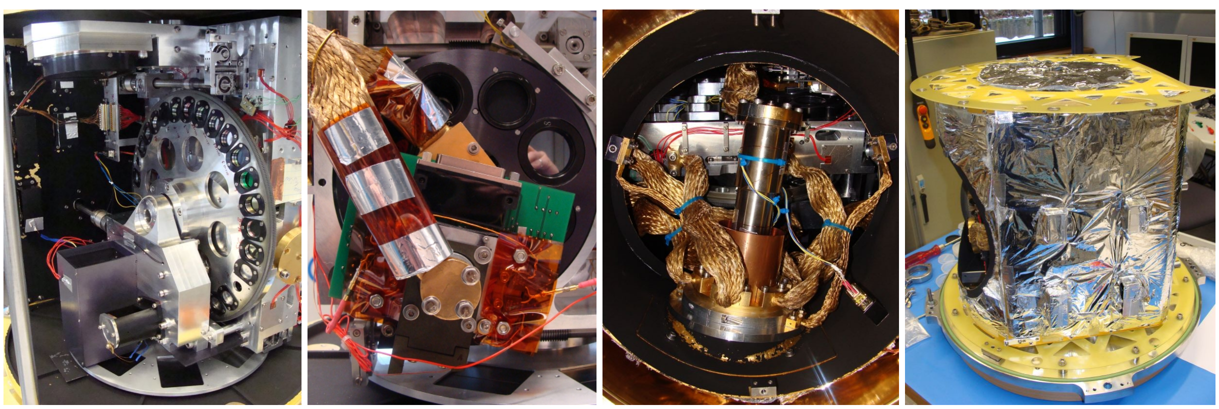

Figure 5: TIMMI-2 optics with filter wheel, original detector mount and lens wheel, closed cycle cooler cold head with thermal links, radiation shield structure with MLI. The lens wheel (2^{nd} picture from left) is mounted thermally insulated from the optical bench, while thermally connected to the 2^{nd} stage of the CCC.

After successfully completing the TIMMI-2 recommissioning, a stepwise upgrade is planned. A new Aquarius detector mount will be designed, thermally modeled, manufactured and verified to replace the original mount. A new detector harness and electrical feedthroughs are to be implemented. The optics will be slightly modified with an appropriate Ge-lens to adapt to the larger detector size. Lower detector temperatures are feasible by revised thermal connections. The present detector heat sink was found to have a thermal resistivity (including thermal contacts) of 12 K/W at 7.4 K and 100 mW dissipation, which offers range for improvements. Similar measures are feasible for other thermal straps to reduce, for example, the background if necessary.

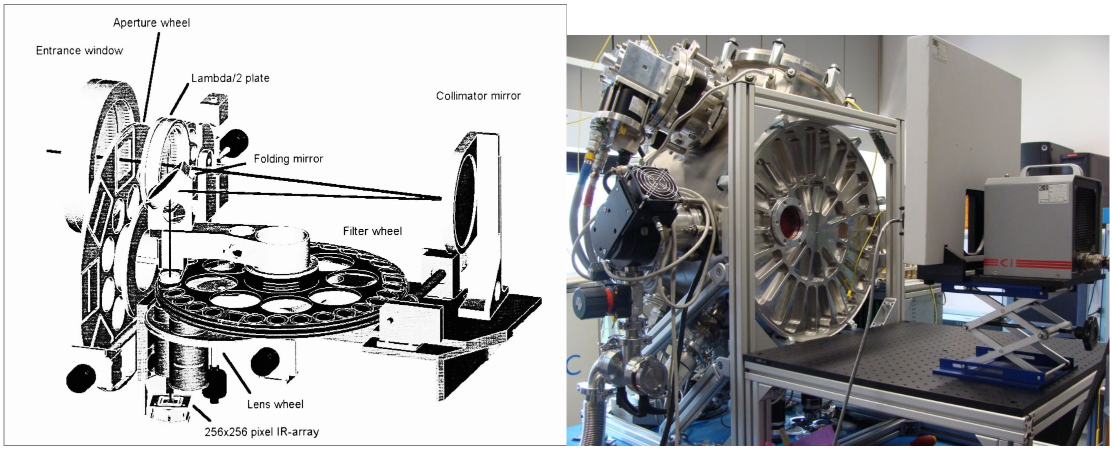

Figure 6: TIMMI 2: optical layout (left); As detector test facility in Garching lab with optical bench and blackbody (right).

To facilitate the access to the detector and to ensure detector installation with minimized risk for other components (optics, mechanisms, harness, electrical continuity, etc.), we designed a revised vessel implementing an additional vacuum port close to the detector. The radiation shield was changed accordingly with an extra pass-through and a closable cover. First tests with the implemented Aquarius detector array are planned for the second half of 2010.

TIMMI2 is equipped with a polarimetric mode. This allows us, to rapidly ramp up or down the thermal radiation on the detector by using a second linear polarizer at the filter wheel. So we can do systematic analysis of the flatfield, linearity etc, and hopefully arrive at conclusions as to the 1/f-noise which are of high relevance for the E-ELT-instrument METIS, where telescope secondary mirror chopping is no longer feasible.

2.3 N-band Spectroscopy

VISIR as is features in its spectrograph arm two collimators, one for high-resolution Echelle spectroscopy, the other for low and medium resolution work. We will replace the low resolution gratings with one singe ZnSe prism, which will allow for long-slit spectroscopy in the N-band with a spectral resolution $\lambda/\Delta \sim 500$ at $\lambda \sim 8\mu m$ and ~800 at $\lambda \sim 13\lambda\mu m$ in one exposure. This mode will have both uncompromised through-put – no order sorting filter – and very good image quality, as a prism will perform much better than a grating. The upgrade of the low-resolution mode will give a boost to spectrometric differential observing techniques.

Extrapolation of work done with TIMMI2 at the 3.6m telescope[8] yields that spatial features of the order of about 10mas should become resolvable. The low resolution mode of VISIR will be made mechanically more robust, by taking advantage of the fact, that the spectral range $\Delta\lambda$ observed in one exposure will increase by more than 230%.

The high-resolution echelle mode is particularly demanding on detector performance, as the flux per pixel can vary by a factor of 10, depending whether one observes a narrow saturated telluric absorption line or in the clear part of the spectrum only the grey body emission of the mirror. For the existing detector such observing conditions were particularly problematic due to the cosmetic properties of this device. With a detector performance more along the lines of the experience with the TIMMI2 or TIMMI detectors which is expected for the Aquarius device, one can expect a much improved general performance. If this mode can approach BLIP needs to be seen.

2.4 Data reduction software

The data reduction software needs to be updated in order to support the modified and new observing modes of VISIR and to support quality control. A case in point is to fully support the existing "burst mode" that could become a standard imaging mode on VISIR.

2.5 Maintenance and cryo-control

VISIR is a reliable instrument with very low down time (~2% level). A number of modifications of the PLC (programmable logic controllers) and alarm system are proposed to further facilitate maintenance of the instrument and minimise technical downtime. Particularly important in this context is, to gain more flexibility in cases of power outages when the standard recovery procedure as hardcoded into the PLC can lead to significant instrument downtime.

2.6 Science ready-products

We plan to facilitate analysis of VISIR data and synergy with other facilities by providing science ready products. As stated above, VISIR is mostly used in combination with other instruments and facilities, some of which provide very advanced data products. Also, the ASTRONET roadmap stipulates that data from future instruments will be published using the standards of the Virtual Observatory and that science ready products should become the norm for data providers, i.e. observatories. The upgrade of VISIR will follow these recommendations.

2.7 Atmospheric precipitable water vapour (PWV) as parameter for scheduling observations

PWV is the main source of opacity in the mid-IR. Extensive tests during site characterization for the E-ELT have demonstrated our ability to accurately measure PWV at high time resolution and in real-time[9]. The current scheme on Paranal requires the use of UT time for such measurements, while we plan to deploy a stand-alone monitor. It is noteworthy that other IR instruments (e.g., CRIRES and ISAAC) will equally benefit from this upgrade. The second step in optimising the use of favourable atmospheric conditions is to introduce PWV as a user-defined constraint for scheduling observations in service mode. Efforts to this end have already started some time ago. In the end, PWV is the most crucial environmental parameter for VISIR – depending on the exact type of observation and wavelength - and should guide scheduling rather than seeing or lunar phase. Based on archival data and E-ELT campaigns, we are in a position to provide quantitative information to the user concerning the use of PWV constraints.

2.8 New science modes

A total of three new science modes have been approved and will be implemented on a best-effort basis: polarimetry, coronagraphy and a sub-aperture masking mode.

Polarimetry

Within the mid-infrared atmospheric window at 8-13 μm many confirmed or suspected cosmic dust components possess signature resonances. Modelling by Wright et al.[10,11] using silicate as the primary dust species, shows definitively that the polarisation spectrum is more sensitive than the extinction spectrum to the presence of admixtures or mantles of other components. Furthermore, the silicate species itself, olivine or pyroxene, and the intrinsic Fe/Mg ratio, can produce a very different polarization spectra.

With the adding of a prism to the spectrograph there will no longer be the need for an order sorting filter. Thus it becomes possible to add retarder plates on one wheel in the pre-slit optics and a Wollaston to the other wheel into the optical train of the spectrograph. This can be achieved at little more than the component cost. A field mask, compatible with a Wollaston already exists, as it is required for the cross-dispersed echelle mode. The VISIR spectrograph has a quasi continuous variable entrance slit, and a “through the slit” imaging capability, so that any systematic effects can be either avoided or calibrated. Thus VISIR will be equipped with an 8-13μm spectropolarimetric mode,

Two other two new modes are tailored to take advantage of close to diffraction-limited performance behind an 8-m telescope. In particular, both modes will enable improved contrast performance for faint or extended sources close to bright sources.

The VISIR coronagraphic mode

The design is based on the four-quadrant phase masks (4QPM) developed in the framework of the MIRI instrument for JWST[12] (Rouan et al., 2007). These 4QPMs are chromatic and are designed to work at a defined wavelength (R=20). Only two them are suitable when observing from the ground: the 10.6- and the 11.3- m ones. Combined as a single optical element using a mechanical mount, these two masks will be positioned at the VISIR focal plane after the entrance window. The existing cold-stop will serve as a the Lyot stop. The simulated performances are shown in Figure 7.

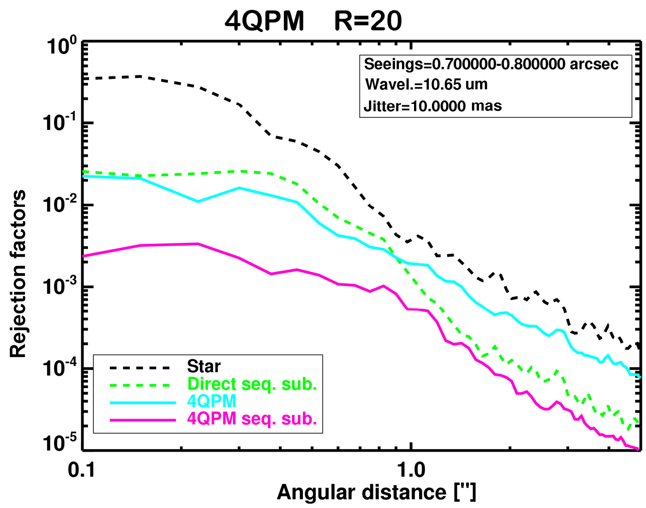

Figure 7: Rejection performances of VISIR in standard imaging mode and coronagraphic mode (assuming a seeing of 0.7"). The rejection factor is defined as the ability to detect a point source close to a bright source of flux unity. When observing in direct imaging (black dashed curve), a source 20 times fainter than the primary can be detected at a distance of 0.5". After PSF subtraction using a reference star (observed under slightly different conditions of seeing (0.8")), this factor grows to ~100 (green dashed line). When observing in coronagraphic mode, the rejection factors at the same distance are about 125 (light blue line) and 660 after PSF subtraction (magenta plain line).

The sub-aperture mode (SAM)

This mode allows us to bridge the gap between the mono-pupil imaging mode and the interferometric instruments (e.g., VLT/MIDI). It will be implemented by adding a pupil plane mask combined with a filter in a free slot of the filter wheel. This non-redundant mask[13] (Tuthill et al. 2000) contains 7 holes, building a network of 21 baselines. The integrated transmission is about 25%. This mode is particularly well suited to overcome the moderate phase errors due to the infrared seeing. It is optimized to detect faint extensions or companions around bright objects in the 0.5-2 λ/D distance range (0.1-0.4 arcsec)[14].

3. SUMMARY

ESO is planning to upgrade VISIR the mid-IR instrument at the VLT in collaboration with the original consortium that built VISIR, CEA Saclay and ASTRON. The goal is to enhance the scientific performance of VISIR and to facilitate its use by the ESO community. A new large detector array will be the cornerstone of the VISIR upgrade project. In addition various improvement in hardware, software and operations are also part of the upgrade. Priorities have been selected using input from the user community. The upgrade will take place during the year 2011.

Acknowledgements: We thank Gaitee Hussain and Uta Grothkopf (ESO) for providing valuable information on the number of requests for observing time and on the number of publications using VISIR data.

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