ISAAC. An Appreciation

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ISAAC was switched off, almost certainly for the final time, on 12 December 2013. The last observing block executed was OB1030962, the target, Supernova 2013ct, for a programme whose principal investigator just happened to be the first instrument scientist for ISAAC. "All constraints were respected and spectra of the target detected" are the public comments in the log. A short history of ISAAC, from the instrument scientists' viewpoint, is presented.

Building ISAAC

The Infrared Spectrograph And Array Camera, ISAAC, was the second instrument mounted on the Very Large Telescope (VLT), following the FOcal Reducer and low dispersion Spectrograph (FORS1). The Principal Investigator (PI) of ISAAC was Alan Moorwood. Although various appreciations of Alan have already been made (e.g., de Zeeuw, 2011; Leibundgut et al., 2011) and it is certain that he made profound contributions to all aspects of ESO, ISAAC was one of his proudest creations. ISAAC was one of two first generation instruments for the VLT built in-house at ESO Garching by a team of people working for Alan in a deeply personal and motivating atmosphere (the other instrument was the Ultraviolet and Visible Echelle Spectrograph [UVES]).

Although much of the discussion on the instrumentation suite for the VLT took place prior to the approval of the project in 1987, the definitive instrumentation plan was authored by Sandro D'Odorico and Alan in June 1989. It appears prescient today, since almost all first generation instruments had their genesis in that document. ISAAC in effect was the outcome of option E4 for a combined spectrometer/imager exploiting a single detector. It should also be recalled that even in 1989 the choice of site for the VLT had not been settled. Vizchachas next to La Silla with four Unit Telescopes in a linear configuration was still the default option for the VLT, with Paranal being considered as an alternate site.

At the time of ISAAC's design design, and even in the early construction period, the instrument was baselined on 256 by 256 pixel detectors. It should be recalled that the first infrared camera: IRCAM on the UK Infra Red Telescope (UKIRT) only had first light in 1986 with a 62 × 58 indium antimonide (InSb) detector (McLean et al., 1986). By the time the instrument was deployed on Paranal in 1998, the short wavelength arm had a fancy new 1024 × 1024 HgCdTe detector, but the long wavelength detector was still a 256 × 256 pixel InSb device.

The team assembled by Alan to build ISAAC relied very much on the instrumentation experience at ESO, based on the immediate previous generation of instruments (IRSPEC on the New Technology Telescope [NTT] and the two infrared cameras on the MPG/ESO 2.2-metre telescope). Alan had already brought an infrared heritage to ESO in the Geneva days, from his work at ESA and flying balloons with infrared payloads at University College London. Under his leadership and a series of ever more successful instruments, an effective team had been created.

The optical design, as with almost all instruments at the VLT, came from the trusted hands of Bernard Delabre. Gotthard Huster designed the mechanical system with help from Ralf Gonzelmann. Jean-Louis Lizon and Armin Silver built the instrument. The mass and size of the monster were daunting. Cooling the instrument required the use of a pre-cooling circuit, prototyped on IRSPEC and now common in most infrared instruments deployed at the VLT. In 1996, during the big-bang upgrade of the NTT, IRSPEC was retired and its cryostat was used to test many of the mechanical functions of ISAAC.

As the PI was fond of saying, ISAAC had diamond-turned-nickel-coated-post-polished mirrors. The cold structure where the instrument optics were mounted was particularly complex and would have been almost impossible to machine from a single block. Two cast aluminium structures were made at a local foundry and the huge vacuum vessel came from France. The bearings used to turn the massive gratings and filter wheels were off the shelf. They were disassembled by Jean-Louis down to their smallest components and then reassembled without the outgassing and freeze-prone lubricants and were equipped with new rolling elements. The bearings for the ISAAC filter wheels are comparable in size to an entire IRAC (the IR camera for the 2.2-metre telescope commissioned in 1994) filter wheel.

With the high number of functions in ISAAC, the traditional warm motor with a feed through to the vacuum vessel was not an option. A development programme inside ESO converted commercial stepper motors to function in cryogenic conditions. For ESO, ISAAC was also the first instrument equipped from the start with closed-cycle coolers. The original Leybold compressor outlasted the instrument, with more than 100 000 hours of continuous operation. The enormous platform which carried the powered co-rotator and electronics (a feature that became a common solution for instruments at Paranal) arose as the only viable option as the instrument proceeded through the construction phase.

To cool down such a massive load, a custom ESO cryogenic control system was constructed by Joar Brynnel, who also built the electronics that would drive the instrument functions using early versions of the, then, ESO standard MACCON motor controllers. The pre-

Figure 1. Jean-Louis Lizon, who powered ISAAC up in 1998, switches the instrument off for the last time in December 2013.

Figure 2. A younger Jean-Louis Lizon than in Figure 1 checks the ISAAC cold structure #1 during the construction phase in 1995.

Anton Van Dijsseldonk project-managed all this effort before the days when he would have been called project manager.

cooling accelerated the cool down, a process that came in very handy in testing, but also in operations when a stuck function had to be unstuck!

Gert Finger was in charge of the detector system, with Manfred Meyer building the readout electronics. During the programme Jorg Stegmeier and Leander Mehrgan joined the detector group to make the first generation of IRACE (InfraRed Advanced Controller Electronics) controllers. Giana Nicolini helped with the characterisation of detectors and prepared the upgrade of the Santa Barbara Research Corporation (SBRC) 256 × 256 pixel InSb array to the brand new 32-channel Aladdin 1K × 1K InSb array. Transputers formed the basis of the readout electronics, while the IRACE platform, in a shift from the VLT standards of VxWorks on 68030 processors, moved to the newfangled Sparc machines that were all the rage. In a minor panic during the early years of operation, the remaining worldwide supply of T2 and T8 transputer chips were procured by ESO so as to have sufficient spares for ISAAC and, of course, the other infrared instruments that followed in its path.

Peter Biereichel who had written much, if not all, the software for the early infrared instruments led the control software effort and along the way brought in Thomas Herlin and Jens Knudstrup to help. Much effort was needed to tame the early versions of the VLT common software.

Getting ISAAC to the sky

Following some design review (there were not so many of them in those days), Alan was convinced to hire an instrument scientist to support the commissioning of the instrument and the development of data reduction tools. The first author of this appreciation was hired in 1993 for this post and was succeeded by the second author after less than 18 months on the job, and long before the instrument ever went to sky. The third author took over after commissioning, etc, etc. The list of ISAAC instrument scientists is hopefully identical to the authorship of this article. Many large and small problems needed to be resolved, such as how the instrument interacted with the telescope, calibration challenges, observing sequences, etc, etc. For example, chopping via a synchronised timing signal, rather than a hardware connection, may be a trivial issue today, but the ISAAC controller, mentioned above, was not compatible with the VLT standard hardware for timing. A simple solution of a hardware trigger from the TIM board (a VxWorks custom board built by ESO for timing synchronisation across the VLT) was used.

The ISAAC software innovation stable provided the three state buttons that continue to plague the VLT control panels and the Real Time Display (RTD). The VLT standards forbade dedicated hardware to connect the data acquisition system in the dome with the control room. As a minimum for target acquisition there was a need for a networked workstation display that allowed astronomers to interact with the data live, rather than waiting for a data reduction system to digest a FITS file. In the days before requirements documents, a conversation between the instrument scientist and Thomas Herlin to flesh out the idea of a display that would stop astronomers looking at finding charts through lamps to get the right orientation, provide trivial zooming and scaling and allow the instantaneous data as well as the integrated frame to appear in real time, resulted. Envisaged from the very start to have an application interface to allow plug-ins, the RTD was a wild success and is not only used for all detector systems on the VLT but in various incarnations also formed the basis for the *skycat* tool, the FORS Instrumental Mask Simulator (FIMS), and ended up in wide use by many observatories. Every acquisition at ESO's optical telescopes relies on the RTD to click the target or the guide star!

For infrared astronomers, prescription observing per templates was a significant psychological challenge to overcome. However, ISAAC was in many ways responsible for bringing the concepts of templates into VLT operations. Erik Allaert was critical in making the toolkit to manage scripted observations in a sensible manner: the resulting tool is now used ubiquitously at Paranal, as the Broker for Observation Blocks, BOB. As an aside, his inclusion of positively poor sound choices also resulted in the silencing of BOB on most consoles. Copying from the Infrared Space Observatory (ISO) operations, the idea of templates was introduced into the ISAAC draft user manual in 1995 and was taken into the operations scheme as the building block for OBs by the Data Flow Project Team, co-ordinated by Preben Grosbøl, including, amongst others, Michèle Peron, Dietrich Baade and Bruno Leibundgut. ISAAC was the first VLT instrument with a full instrument observing simulator with panels and displays talking to code that generated pseudo-realistic data and simplistic pipelines.

The original proper ISAAC pipeline was developed by Nicolas Devillard and Yves Jung under the tutelage of Pascal Ballester and instrument scientists 2, 3, etc. The fixes, upgrades and updates, etc, are too numerous to mention. However, at some point after much discussion, we did get the sky subtraction right. Pascal also provided the early exposure time calculators.

Offspring and early days

Jean-Louis Lizon was expeditious in the assembly of the instrument in Garching and, with Unit Telescope 1 (UT1) first light slipping to 1998, Alan decided to use the expertise developed with ISAAC to rapidly develop an instrument for the soon to be upgraded NTT. Launched as a project in 1996, SofI, the Son of ISAAC, was in effect one imaging arm of ISAAC with a grism wheel providing the spectroscopic capabilities.

While the correct name for SofI obviously should have been JACOB (Jean-Gabriel's and Alan's Camera for OBserving) or for that matter ESAU (ESO Array Unit), pronunciation and modesty issues prevailed to leave us with SofI.

SofI went to the NTT in 1997 and was successfully commissioned by the PI, the construction team and instrument scientist number 2, while at the same time bringing up to speed the future instrument scientist number 3. The commissioning went ahead with very few problems, thereby testing not only the instrument, but also the bulk of the ISAAC software. By mid-1998, with UT1 in full swing of commissioning, Jean-Louis arrived on Paranal to begin the re-integration of ISAAC.

It is worth recalling that the instrument laboratory in the control room at that time had plastic sheets instead of windows and many facilities were sorely lacking. Alan oft would debate whether the occasional stuck filter wheel in ISAAC came from dust in the early days of integration. It is true that Jean-Louis has been to Paranal many times to keep the old dog going well past the design lifetime of three years continuous operation.

Commissioning of ISAAC was successful, even if interrupted by a stuck altitude motor cover on UT1 in February 1999, a complete demolition of the control room while instrument scientist number 2 debugged software and a disconnected telescope cooling hose that washed the whole Nasmyth platform down. ISAAC, together with FORS1, were incidentally the first instruments to be brought into the QC0 (Quality Control) and QC1 processes.

Figure 3. ISAAC *JHKs* colour combination mosaic image of the Galactic HII region and star-forming complex M16 (NGC 6611). H_2 emission knots show in red.

ISAAC observations

With over 850 papers to its name, ISAAC is almost certainly amongst the most productive infrared instruments. It is especially difficult to pick particular science results and our apologies are public and up-front. We have picked a few that entertained us.

Messier 16

Mark McCaughrean was a regular Christmas visitor observer at UT1 in the first years of operation. His kind, beautifully handwritten appreciation letters were

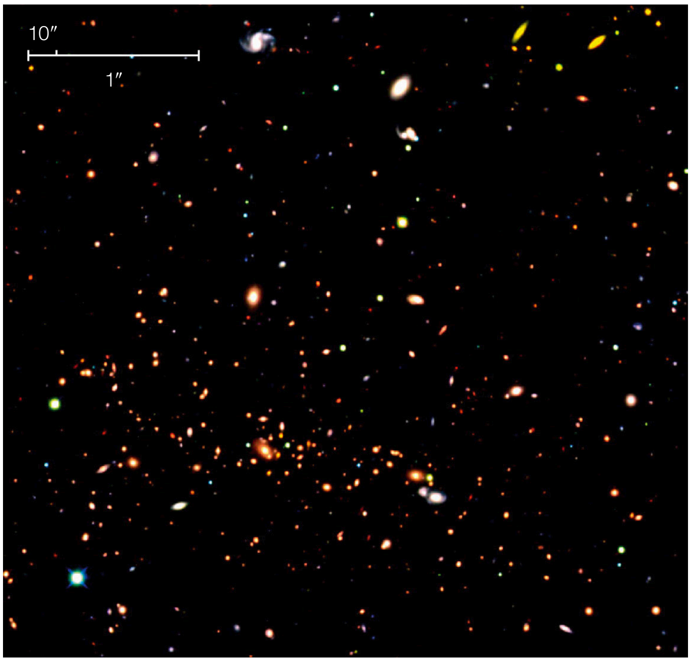

Figure 4. Three-colour composite image of the field around the massive galaxy cluster MS 1054-03 (z = 0.83) taken as part of FIRES. ISAAC *Js* and *Ks* and HST WFPC2 F814W images were combined as green, red, blue respectively. From Förster Schreiber et al. (2006).

posted on the whiteboard behind what was the UT1 console (now the VLT Interferometer), and his spectacular images of various nebulae (one is shown in Figure 3) have been icons of infrared astronomy since the very first images of Orion with IRCAM at UKIRT.

Faint Infrared Extragalactic Survey (FIRES)

Marijn Franx pestered the observatory into improving its efficiency of operations and calibration until we finally agreed that he was right all along. A 26.5-hour total integration time in *Ks*, 25.9 hr in *Js* and 24.4 hr in *H*, provided one of the most impressive deep fields from the ground.

The image quality of the data was truly spectacular with the final combined images below 0.52 arcseconds. An image from the FIRES programme is shown in Figure 4.

Spectroscopy of high-redshift galaxies

In the early days of the VLT quite a lot of catch-up with Keck was necessary. One of the best compliments to the instrument was the excellent dataset collected on high-redshift Lyman-break galaxies by Max Pettini, Alan, instrument scientist number 2 and Max's California and East Coast based collaborators. An example of a long-slit spectrum of a Lyman-break galaxy at z = 3.234 is shown in Figure 5.

Observing through the limb of Jupiter

Some observations simply don't fit the template package. Measuring, amongst others, the temperature profile of the Jovian atmosphere by taking spectra of HIP 9369 during an occultation by the limb of Jupiter was certainly one of the most memorable observations made. Keeping the slit orientation parallel to the limb in real time while everything is moving and turning was an observational *tour de force*. The results were published by Raynaud et al. (2003).

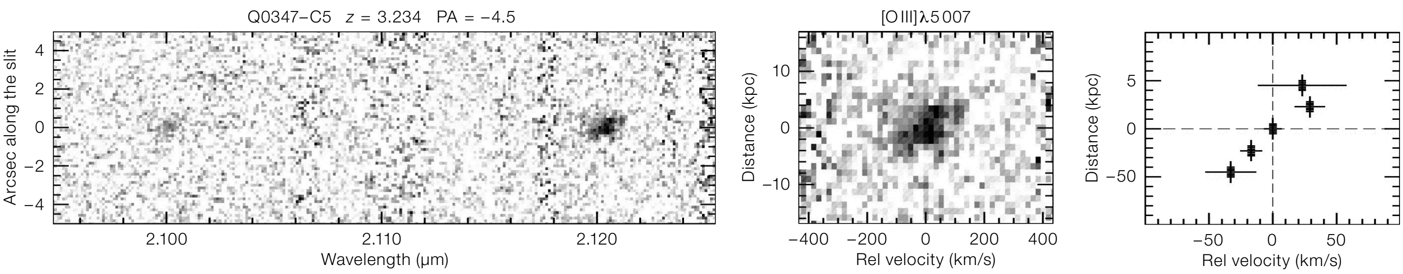

Figure 5. ISAAC long-slit spectra of the quasar Q0347-C5 taken by Max Pettini in 1999 (from Pettini et al., 2001). The left panel shows the two-dimensional spectrum with the [O III] 4959 Å and 5007 Å emission lines, the central panel an enlargement of the 5007 Å line kinematics and the right panel the fitted radial velocity along the slit.

Acknowledgements

While it is probable that we have missed some of the people who participated in building ISAAC, it is well-nigh impossible to count and name all the staff at the La Silla Paranal Observatory who have worked (almost) every day for the past 15 years to keep the instrument going. But it would be impossible to conclude without attempting to thank some of them: Hans Gemperlein, Gustavo Rahmer, Markus Kissler-Patig, Vanesa Doublier, Steen Skole, Andreas Kaufer, Gianni Marconi, Claire Moutou, Eline Tolstoy, Ueli Weilenmann, Roberto Castrillo, Pablo Barriga, Gordon Gillet, Pedro Mardones, Massimilliano Marchesi, Eduardo Bendek, Alfredo Leiva, Jorge Jimenez, Nicolas Haddad and the rest of the cast, especially the instrument operation team members over the past 15 years. Many scientists in the Data Management Division in Garching, and observing at Paranal, have had the pleasure of interacting with ISAAC: Paola Amico, Mario van den Ancker, Tom Broadhurst, Fernando Comerón, Danuta Dobrzycka, Lowell Tacconi-Garman, Christian Hummel, Wolfgang Hummel, Sabine Mengel, Palle Møller, Monika Petr-Gotzens, Almudena Prieto, Francesca Primas, Martino Romaniello, David Silva, Elena Valenti, Markus Wittkowski and Bodo Ziegler have all had to live with the flips of the orientation of the slit and the rotations, the occasional glitch and the hundreds of users.

The instrument science team of Rolf Chini, George Miley, Tino Oliva and Jean-Loup Puget followed the instrument through the trials and tribulations of construction, picking filters and resolutions, and provided constant support.

Our final thanks must be reserved for Alan.

References

Andersen, M. et al. 2004, A&A, 414, 969
de Zeeuw, P. T. 2011, The Messenger, 145, 49
Förster Schreiber, N. M. et al. 2006, AJ, 131, 1891
Leibundgut, B. et al. 2011, The Messenger, 145, 50
McLean, I. et al. 1986, SPIE, 627, 430
Pettini, M. et al. 2001, ApJ, 554, 981
Raynaud, E. et al. 2003, Icarus, 162, 344