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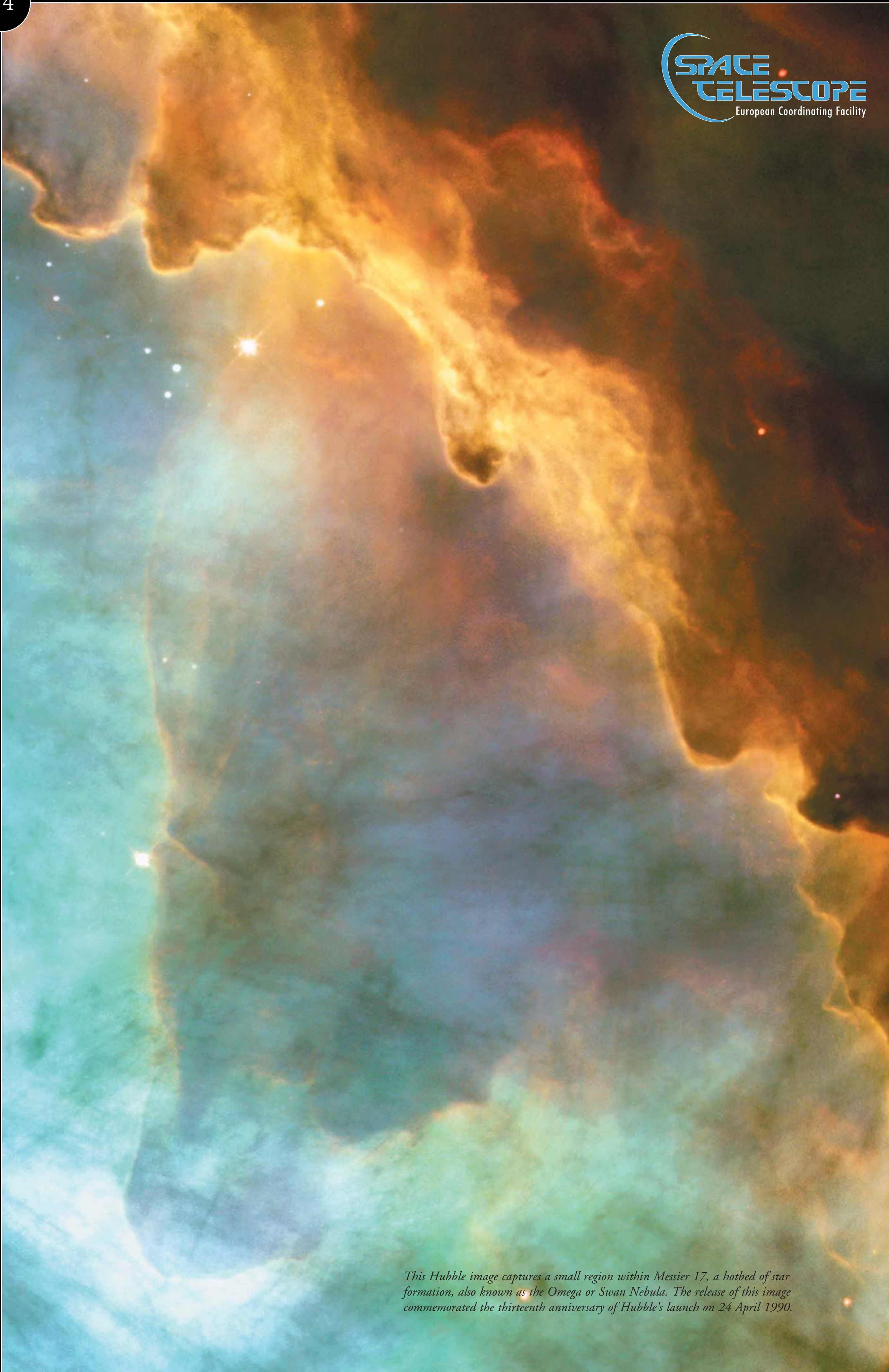
September 2003

ST-ECF Newsletter

Space Telescope European Coordinating Facility



This Hubble image captures a small region within Messier 17, a hotbed of star formation, also known as the Omega or Swan Nebula. The release of this image commemorated the thirteenth anniversary of Hubble's launch on 24 April 1990.

European Space Agency, NASA, and J. Hester (Arizona State University, United States)

Editorial

Richard Hook

The last few months have proved to be a time when both the Hubble project and the ST-ECF are considering the transition period when Hubble will end its life and the James Webb Space Telescope (JWST) will begin operations. It is also a phase that has seen major changes in the staff at the ST-ECF and these are described in the article on page 4.

The NASA plans for future astronomy missions have been developed from the Decadal Reviews of astronomy in the United States. The lifetime of Hubble had been extended to 2010 following these recommendations and the launch of JWST was anticipated to be around 2007. This would have allowed a significant overlap and smooth transition, although it has always been appreciated that, as a facility operating primarily at infrared wavelengths, JWST is not a true replacement for Hubble and has different science aims. The launch date for JWST is currently scheduled for 2011, but significant delays have affected all previous NASA observatory missions. In addition the options for servicing Hubble are now highly constrained by safety considerations for the space shuttle in the aftermath of the Columbia tragedy. To provide input and independent advice from the science community on the Hubble/JWST transition NASA established a distinguished panel, chaired by John Bahcall. This “Bahcall Committee” has encouraged input from the community and held a public meeting in Washington DC on 31st July 2003 that was attended by more than one hundred astronomers, NASA staff and other interested parties including the press.

The meeting included presentations of the status of Hubble, JWST and SIRTF, a passionate and dramatic view from Riccardo Giacconi, a technical description of the options and limitations of “upper stages” – small rocket systems that could de-orbit Hubble in a controlled way when the time came – as well as a number of volunteer presentations. The latter included descriptions of possible instruments for a speculative future servicing mission and a moving view of future shuttle servicing missions from the perspective of the astronauts in the light of the Columbia accident. Although the highly charged atmosphere was dominated by those who hoped for an extended Hubble lifetime there were also well-argued presentations of why new space observatories, rather than extending the life of older ones, were more likely to lead to paradigm shifts and major steps forward in understanding. NASA, represented by Anne Kinney, clearly laid out how it is keen to help, but tightly constrained by budgetary limits, which often mean that extra money for one mission would have to be taken from the budget of another, on the one hand and the priorities of astronaut and orbiter safety on the other.

The committee surprised the community by rapidly coming to unanimous conclusions and preparing its report several weeks earlier than expected. This report is available from:

http://www.nasa.gov/audience/formedia/features/MP_Public_Reports.html

and copious background information, including the panel’s membership and charter, as well as many of the presentations given at the public meeting, is available at:

http://hst-jwst-transition.hq.nasa.gov/hst-jwst/.

The panel makes three recommendations based on successively more pessimistic options for the future of space shuttle visits to Hubble. Their preference is for SM4 to occur as soon as possible and for another mission (SM5) around 2010 to fit a de-orbiting booster, new gyros and, if successful in peer-reviewed competition with other comparably-priced space astronomy options, possibly the installation of new Hubble science instruments. The other options make suggestions for the case of just one, or no future servicing missions to Hubble.

Within the ST-ECF the management has been asked to review future options for the group in the period after the current memorandum of understanding between ESA and NASA expires in 2006. These are to be guided by consideration of the long-term plans of both ESA and ESO. Preliminary presentations have been given to ESO management and will be discussed with ESA in Autumn 2003.

JWST News

Robert Fosbury

Early in 2003, the JWST was the subject of a major NASA replanning exercise to adjust the spending profile to enable a launch in mid-2011 and to bring the overall NASA cost to below 1.6 billion dollars. The project has now passed its initial confirmation review and is making the transition from phase A to B. The telescope primary mirror will have a collecting area of 25 square metres and be in the form of 18 hexagonal segments. The mirror technology remains to be chosen and cryogenic tests of demonstrator mirrors are currently underway.

The 18 segment solution was chosen over the 36 segment option in order to mitigate risk and to give a cleaner, higher contrast point spread function.

The European contributions to the observatory remain the ESA-provided NIRSpec instrument, an Ariane V launch and a contribution to operations, while a consortium of European institutes, led by Gillian Wright (UK ATC, Edinburgh) will provide the opto-mechanical half of the MIRI imager/spectrograph. Although not contributing to the hardware, ESA will assume the position of responsible interface to NASA for MIRI and, by so doing, take on the associated system-level risks.

The JWST Science Working Group participated in detail in the replan exercise. It is now in the final stages of preparing the Science Requirements Document using sensitivities agreed with the instrument teams.

The study phase for the NIRSpec instrument, carried out by the two industrial consortia, EADS/Astrium and Alcatel Space, drew to a close in mid-summer although work is continuing while ESA prepares a formal Invitation to Tender to be issued later in the year. Several major parts of the planning and specification documentation have been completed, including an instrument Operations Concept – developed in collaboration between the ST-ECF and the STScI – that illustrates the complexity of operating a space-borne multi-object spectrograph and the stringent requirements on pointing precision and target astrometry.

Early in June, NASA awarded the STScI with the contract for the JWST Science and Operations Center. This is running now and will continue until one year after launch. The scope of the contract for JWST is substantially the same as it has been for HST and will ensure a very efficient transfer of knowledge and experience between the two observatories.

HUBBLE European Space Agency Information Centre

The mysterious 'Garden-sprinkler' nebula

Jets are long outflows of fast-moving gas found near many objects in the Universe, such as around young stars, or coming from black holes, neutron stars, and planetary nebulae, for example. The NASA/ESA Hubble Space Telescope has imaged the young planetary nebula Henize 3-1475 and its bizarre jet. Astronomers have nicknamed it the 'Garden-sprinkler' Nebula.

The origin of jets in the Universe is unclear, but they appear to originate in small regions of space where even Hubble's sharp vision cannot penetrate. To produce a jet, you require some sort of nozzle mechanism. So far, these theoretical 'nozzles' remain hidden by dust that obscures our view of the centres of planetary nebulae.

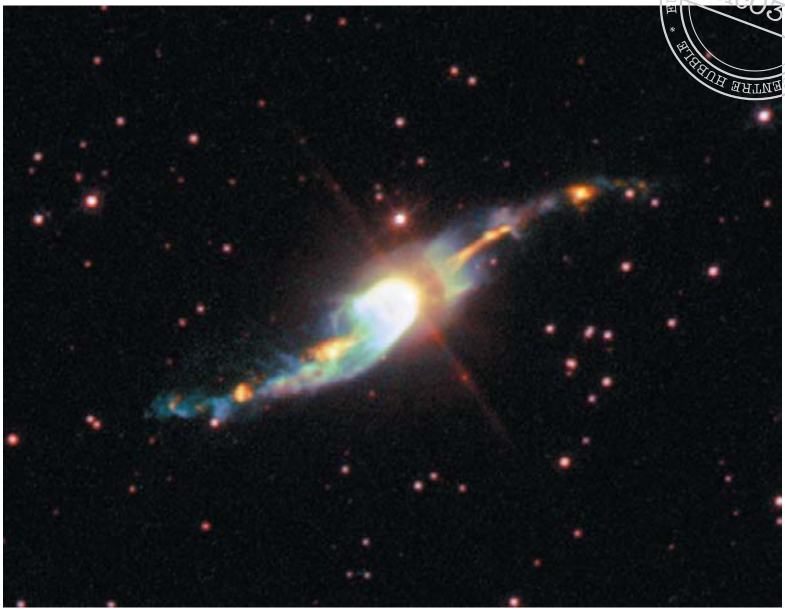
Despite decades of intense effort, there is no single example of a jet whose origin is clearly understood. The curious S-shape and extreme high speed of its gaseous outflow gives Henize 3-1475 a special place in the study of planetary nebulae.

Henize 3-1475 is located in the constellation of Sagittarius around 18 000 light-years away from us. The central star is more than 12 000 times as luminous as our Sun and weighs three to five times as much. With a velocity of around 4 million kilometres per hour, the jets are the fastest ever discovered. Scientists are also intrigued by the converging, funnel-shaped structures that connect the innermost 'knots' and the core region.

A group of international astronomers led by Angels Riera from Universitat Politècnica de Catalunya, Barcelona, Spain, have combined observations from Hubble's Wide Field and Planetary Camera 2, the Space Telescope Imaging Spectrograph and ground-based telescopes. Their work suggests that the nebula's S-shape and hypervelocity outflow is created by a central source that ejects streams of gas in opposite directions and precesses once every 1500 years. It is like an enormous, slowly rotating garden sprinkler.

The flow is not smooth, but rather episodic with an interval of about 100 years, creating clumps of gas moving away at velocities up to 4 million kilometres per hour. The reason for these intermittent ejections of gas is not known. It may be due to either cyclic magnetic processes in the central star (similar to the Sun's 22-year magnetic cycle), or to interactions with a companion star.

EUROPEAN SPACE AGENCY INFORMATION CENTRE HUBBLE News Release heic0308



European Space Agency, A. Riera (Universitat Politècnica de Catalunya, Spain) and P. García-Lario (European Space Agency ISO Data Centre, Spain)

ST-ECF Staff Changes

Richard Hook

Departures

Piero Benvenuti, Head of the ST-ECF since its foundation back in 1984 and main architect of the group's changing roles over nearly two decades, has taken up a senior post within Italian science. He has been appointed "Commissario straordinario dell'Istituto Nazionale di Astrofisica (INAF)". We congratulate Piero and wish him all the best in this very important and challenging job. It will be very hard to imagine the ECF without him. From July 1st 2003 Rudi Albrecht has been appointed Acting Head of ST-ECF and Rudi's account of Piero's career with the ECF appears on the back page.

Norbert Pirzkal, who joined the ECF in 1997 and has made major contributions to the group's work, particularly in the areas of ACS software, has decided to return to the world of astronomical research. He is taking up a post doctoral fellowship to work with James Rhoads and Sangeeta Malhotra on observational cosmology at STScI.

Anastasia Alexov joined the Instrument Modelling Group of the ECF back in 1999 as a scientific programmer and has been the backbone for this group's success. Anastasia has returned to the United States and taken up a software post at the IPAC SIRTF Legacy Archive in Pasadena.

Francesco Pierfederici came to the ECF in 2001 to support many aspects of the AstroVirtel pilot VO project. He developed the Querator task for querying multiple archives. Francesco has now moved to NOAO in Tucson and is working within the IRAF group.

Anna Pasquali has been an Instrument Scientist at the ECF, working mostly with the ACS spectroscopic modes and also pursuing stellar research since she joined the group in 1997. Anna is moving down the road to Zurich where she is taking up a post at the Eidgenössische Technische Hochschule working with Marcella Carollo and Simon Lilly.

Arrivals

Jonas Haase joined the ECF in June 2002 directly from university in Denmark. He is working on archive software and most recently on developing web interfaces to some of the GOODS data products.

Harald Kuntschner joined the ECF in 2002 as an Instrument Scientist. His research interests are galaxy formation and evolution and he has extensive experience of integral field spectroscopy. Before joining the ECF Harald was an ESO fellow.

Diego Sforna joined the ECF in April 2003 as archive software specialist. Before that he had been working as a contractor at ESA Darmstadt working on satellite simulation software.

On HST Proposal Writing

Jeremy Walsh

Hubble is a unique space observatory and the acceptance or rejection of an observing proposal to use it can make or break a research project. Winning time is a highly competitive process that starts with the preparation of a Phase I proposal that is submitted to the Time Allocation Committee (TAC) composed of experts in the appropriate fields of Hubble science. The TAC meets once per year at the STScI in Baltimore to allocate time for the next cycle of Hubble observing.

Concomitant with its 15% contribution to HST, ESA astronomers also support the time allocation process. Every cycle around 10-15 astronomers from Europe join the meeting in Baltimore as members of the subject panels (for Cycle 12 there were eleven panels) or as chairs of the panels – hence members of the TAC. The only difference between them and their colleagues from the US, or other parts of the world, is that their trip is funded by ESA. In the early cycles, Piero Benvenuti used to recommend European astronomers as chairs and panellists; this task was subsequently taken over by Leon Lucy. For the last four cycles I have helped to select suitable European members as panellists and chairs. The selection is of course made in close collaboration with the Science Policies Division (SPD) at STScI to ensure there is an optimal mix of expertise in the various panels. Another factor to be considered in selecting European members is a balance between the various countries – not only in each cycle but between cycles. It would, for example, be injudicious to select many panellists from a country that wins little HST time or to consistently choose a greater number of members from one country.

As a European associate of SPD, I have the liberty of sitting in on the Time Allocation meeting. This allows an insider view of the vitality of contemporary astronomy and a glimpse into the future observational trends over the following few years. I can rove freely from one panel to another, my only strict remit being to check that the selected European astronomers are fitting in well. Since the direction from the 2002 review of the HST TAC process, that there should be some "memory" in the process from cycle to cycle, a fraction of panelists will be asked to stand the following year. Thus I am gauging who would be best suited to taking on the daunting task of being a panel member again, or even becoming a panel chair, next cycle.

After each TAC meeting I have asked the European members for any comments on the process either from a personal perspective or particularly from their Eurocentric position vis-a-vis differences in the success of proposals by European and US astronomers. There has been a perception in some cases that European HST proposals were not always so competitive as US ones, given the culture of proposal writing in the US. This climate is perhaps now on the verge of change with the access to EU research training money for which polished proposals have to be submitted. However, the number of successful proposals with a European PI has kept up consistently in the 14-19% range over the twelve HST proposal cycles, so there cannot be too great an imbalance in the quality of European proposals. The European panellists have also been sensitive to this aspect, but have reported that in general proposals with a European PI are not treated any differently to US ones and did not fare any worse in the very strong competition for HST time.

Of course I cannot offer a sure recipe for success in HST proposal writing! A very well written proposal for derivative science, or for a slightly incremental advance, probably will not receive time while a well written proposal, with science agreed by most as excellent, almost certainly will. Most proposals lie somewhere in-between these poles. I offer a few tips that, by making your proposal more "TAC friendly" might help the chances of its being accepted for HST orbits. I have freely selected from the comments of the European TAC and panel members and add a few reflections allowed by my observations of the allocation process. I prioritise the advice into primary and secondary: the former more or less essential for a winning proposal; the latter a series of small tips that can help improve proposal readability and hence, possibly, success rate.

Primary Advice

Since Cycle 9, the TAC process was restructured to move away from a large number of highly specialised panels to parallel panels in the major areas of astronomy with a much wider scientific remit. Thus the MAJORITY of the panellists reading a proposal will not be experts in the field – setting the proposed science into a wider frame becomes VERY important. The best proposals are written with this theme pervading the proposal and not just with a few sentences in the introduction followed by a dive into intricate details. This approach requires considerable planning of the proposal and implies that it was not written on the last two days before the proposal deadline. I have always been impressed how a panel can divine that a proposal, even by well-known experts in their field, was written at the last moment. This is often obviously betrayed by missing references or figures, wrong figures referenced, obvious cutting of text from previous proposals or out-of-date references. Panellists often react harshly to sloppiness. Some will refuse to read any pages over the allowed page limits! When you have about forty proposals to read in detail and another 60 to be acquainted with, then this attitude is not unexpected. There is, in addition, an element of unfairness that proposers can muster more arguments if they exceed the page limits.

The system of parallel panels means that there is an inevitable random element to the process. Less than 20% of submitted proposals will be allocated HST time and the position of the cut-off between accepted and rejected proposals is fuzzy. The same proposal sent to different parallel panels can fare very differently. The outcome depends of course on the competing proposals in that panel in that cycle and also on the membership of the panel. If a proposal was deemed good but could not be awarded time because of the strong over-subscription, then re-submission next cycle may improve its chances; provided of course the proposal is still scientifically keen and it is updated to reflect the recent advances in the subject. Following the suggestions made in the feedback comments from the panel (which are available again from Cycle 12, following the recommendations of the HST TAC Review Committee), is not a guarantee that a resubmitted proposal will gain HST time. If, however, there are clear recommendations or weaknesses highlighted, it is prudent to take these into account, as one would the opinion of an expert colleague who read through the proposal.

The proposals that win time are not necessarily without any identifiable fault. It is usually the case that the science is very compelling and that it cannot be done by other means – ie, that absence of the observational data would result in a loss for the advance of astronomy. Inevitably it must be shown that HST is crucial to the proposed observations. In some cases the use of HST is obvious, such as UV imaging or spectroscopy, or high resolution imaging in the optical, but very often it is the advance, rather than the increment, that can result from adding HST to ground-based and/or other HST observations that is crucial. If there is even a hint of an indication that the observations could be made from the ground, the panel will jump on this as reason to downgrade a proposal. Clear arguments must be presented to justify why HST is needed in such cases. The grey area is between NICMOS imaging and ground-based Adaptive Optics; HST observations need to be particularly well justified in these cases.

SPD has worked hard over the last few cycles to try to ensure that the acceptance rate is independent of proposal size and to counter a tendency for panels to allocate many small programs. Panels often feel frustration at only being able to allocate a handful of programs from the many tens of excellent proposals in their pool; a panel may as a result tend towards allocating smaller programs. The solution adopted is that each proposal only debits the panel orbit pool by a number of subsidised orbits; the larger the proposal the greater is the subsidy, above some cut-off size. At the beginning of the TAC meeting, each panel is allocated a number of subsidised orbits based on the proposal pressure. The aim is that the panel does not need to be too concerned about how many real orbits they actually allocate.

Since the introduction of Large (>100 orbits) and Treasury proposals, there has been a drop in the number of intermediate-large (50-99 orbit) proposals awarded. This redistribution of proposal sizes is partly a function of proposal pressure. The allocation panels are strongly encouraged not to cut proposals. Thus if there is any mismatch between the scientific aims and the proposal size, such as for a survey with many targets, but without well-defined target criteria, the proposal will be marked down. This can also apply to smaller proposals with a few targets if they are not all equally well justified. I have seen both the largest proposal in a panel's pool as top of the ranking and the smallest. Adding targets to bring a proposal into the intermediate-large or Large category usually will not work as panels (the TAC deals with the Large and Treasury proposals) often closely scrutinise the target list and question the inclusion criteria.

Secondary Advice

The level of grammar should be acceptable, but need not be polished. For non-native English writers, it is a good idea to get someone to check over the proposal. The availability of spell-checkers means that there is little excuse for poor spelling – it is indicative of a hastily written proposal.

Figures should be strictly relevant to the proposal and should not be overcrowded with detail. It is wise to ensure that an average photocopy of the figures will be able to render the salient details clear. I have seen proposals undermined by figures where the details could not be seen by the panellists. Proposing to observe a faint jet that is said to be visible on a figure, but not discernable, is likely to prejudice a proposal.

Use of the relevant Exposure Time Calculator is almost mandatory before preparing a proposal, unless previous observations can be scaled. Also the plan for analysis can be important, particularly if the proposers do not have strong experience in that field. Conversely panels can place confidence in well-established groups, usually with prior HST experience, confident that they will reap the maximum from HST observations. If venturing into a new area, then the addition of an expert with previous HST experience in that field may enhance the proposal's chances of success.

Last, but not least, the science case should be as complete and precise as possible within the limitations of proposal size. It is too easy to suggest how observations will be interpreted with expressions like "unbiased", "unlock" or "disentangle" when it is not made clear how this can be done. During one TAC meeting one of the chairs came up with a bingo game for the panel adapted from a business manual, designed to combat boredom during meetings. Adapted to the TAC context, a run of expressions such as: physics-based; conflict of interest; keystone observation; method of choice; systematic; would result in "bingo" – and perhaps the proposal being weakened in the view of the panel.

Acknowledgements

I am grateful to all those European panellists who responded to my enquiry of participation in the HST time allocation process and provided ammunition for this article. Leon Lucy also wrote an article in 1997 on the same theme that, though slightly out of date in some respects, makes useful reading (http://www.stecf.org/observing/proposal/TAC.html). I have included some of the tips from that article here and recommend it as an independent view.

HUBBLE
European Space Agency Information Centre

Hubble tracks down a galaxy cluster's dark matter

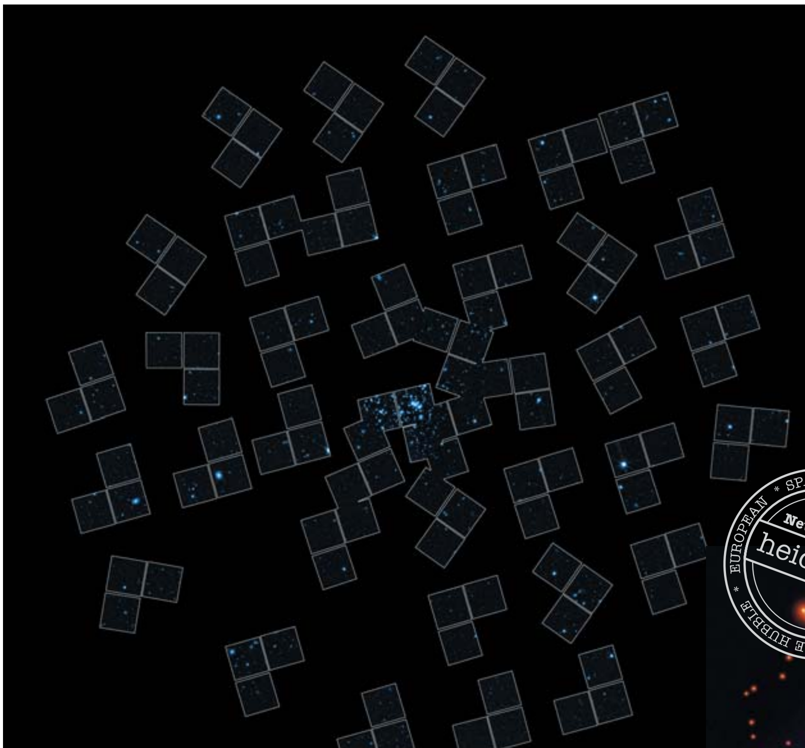
A team led by Drs Jean-Paul Kneib (from the Observatoire Midi-Pyrénées, France/Caltech, United States), Richard Ellis and Tommaso Treu (both Caltech, United States) has used the Hubble Space Telescope to reconstruct a unique 'mass map' of the galaxy cluster CL0024+1654. It enabled them to see for the first time on such large scales how mysterious dark matter is distributed with respect to galaxies. This comparison gives new clues on how such large clusters assemble and which role dark matter plays in cosmic evolution.

Tracing dark matter is not an easy task because it does not shine. To make a map, astronomers must focus on much fainter, more distant galaxies behind the cluster. The shapes of these distant systems are distorted by the gravity of the foreground cluster. This distortion provides a measure of the cluster mass, a phenomenon known as 'weak gravitational lensing'.

To map the dark matter of CL0024+1654, more than 120 hours observing time was dedicated to the team. This is the largest amount of Hubble time ever devoted to studying a galaxy cluster. Despite its distance of 4.5 thousand million light-years (about one third of the look-back time to the Big Bang) from Earth, this massive cluster is wide enough to equal the angular size of the full Moon. To make a mass map that covers the entire cluster required observations that probed 39 regions of the galaxy cluster.

The investigation has resulted in the most comprehensive study of the distribution of dark matter in a galaxy cluster so far and extends more than 20 million light-years from its centre, much further than previous investigations. Many groups of researchers have tried to perform these types of measurements with ground-based telescopes. However, the technique relies heavily on finding the exact shapes of distant galaxies behind the cluster. The sharp vision of a space telescope such as Hubble's is superior.

Future investigations using Hubble's new camera, the Advanced Camera for Surveys (ACS), will extend this work when Hubble is trained on a second galaxy cluster later this year. ACS is 10 times more efficient than the Wide Field and Planetary Camera 2 used for this investigation, making it possible to study finer mass clumps in galaxy clusters and help work out how the clusters are assembled.



Hubble observes shapes of more than 7000 faint background galaxies
Five days of observations produced the 39 Hubble Wide Field and Planetary Camera 2 (WFPC2) images required to map the mass of the galaxy cluster Cl0024+1654. Each WFPC2 image has an area of about 1/150 that of the full Moon. In total, the image measures 27 arc-minutes across, slightly smaller than the diameter of the Moon.

A Unique mass map
This is a mass map of galaxy cluster Cl0024+1654 derived from an extensive Hubble Space Telescope campaign. The colour image is made from two images: a dark-matter map (the blue part of the image) and a 'luminous-matter' map determined from the galaxies in the cluster (the red part of the image). They were constructed by feeding Hubble and ground-based observations into advanced mathematical mass-mapping models.

European Space Agency, NASA and Jean-Paul Kneib (Observatoire Midi-Pyrénées, France/Caltech, USA)

„Finding the Ashes of the First Stars“ – An Astronomer’s Account of a Press Release

Wolfram Freudling

Fig. 1: The caption for this image reads: "Artist's impression of a quasar located in a primeval galaxy (or protogalaxy) a few hundred million years after the Big Bang. Astronomers used the NASA/ESA Hubble Space Telescope to discover substantial amount of iron in three such quasars. This is the first time that anyone

Late last year, my collaborators Michael Corbin, Kirk Korista and I finished the data analysis of NICMOS spectra of high-redshift QSOs (z~6). Despite the enormous distances of these objects, their spectra are similar to those of more local QSOs and show no sign of evolution. While preparing an ApJ letter and discussing the implications of the results with colleagues, the story came to the attention of the European HST public information office – the Hubble European Space Agency Information Centre (HEIC). The Public Information Officer, Lars Lindberg Christensen inquired about the possibility of a press release. A press release about noisy spectra? Even though the results are exciting to experts, the idea of explaining them to the public seemed far-fetched. Lars convinced us that it was worth a try.

The first task was to find out if the results could be visualized. Lars made the importance of the visual side clear to us. But how do you visualise a QSO at redshift 6? And how do you show the physics that takes place? Embedded in our iron-rich spectra was the story that star formation most likely took place very early (z~20) and that subsequent supernovae explosions then dispersed the enriched material. It was decided to go for an “artist’s impression”, that, in addition to these concepts should show gas with clear signs of evolution (illustrated with different colours) and naturally the QSO itself as a bright source. Martin Kornmesser, the HEIC graphics artist, took all the ingredients and blended them to create the astonishing piece of digital art seen in Figure 1.

The next task was to explain the results in layman’s terms. Lars extracted a first version from our ApJ letter (587, L67) and this immediately sparked a healthy discussion among our collaboration. Are the statements accurate? Is there anything misleading? Are the necessary caveats in? It took many iterations before we found the right balance between a simplified, exciting, but still accurate story line.

The third element of the press release was the production of a video for TV broadcasters. Several small animations were combined into a 3 minute “A-roll”, basically telling the story in an entertaining and informative way. We even prepared a timeline of events in the early Universe, which was then animated by Martin.

An interview was taped only a few days before the release and took the better part of a very hectic and exciting day with the team scrambling to solve the usual technical problems – just when I had the right words I didn't look right, and when both text and picture were right we noticed that the sound was not recorded, and so on.

Finally, the day of the release arrived. A few hours after the official release, phone calls from press reporters started. E-mail inquiries from around the globe peaked about a week after the release and interviews were recorded for several radio programmes. In the end, the story including the picture was carried by leading international newspapers, magazines, and about 50 web sites. The video was shown on national TV at least in Germany and France. The image was used by NASA’s “Astronomy Picture of the Day” web site, in computer games and even in pieces of art.

Promoting your own scientific work is unfamiliar territory for a scientist, but publicising results in this way is important for the perception of science and ultimately for the funding of astronomical research. In addition it is even common among astronomers to learn about developments in unfamiliar areas from press releases. Although participating in a press release does involve some work for the scientist, it is truly a rewarding experience. Professional press officers know how to present seemingly difficult topics to the public. I encourage every astronomer to talk to your press office about your interesting results.

Fig. 2: Frames from the video production.

CCD Charge Transfer Inefficiency

Paul Bristow

Charge Coupled Devices (CCDs) operating in hostile radiation environments suffer a gradual decline in their Charge Transfer Efficiency (CTE), or equivalently, an increase in charge transfer inefficiency, (CTI). STIS and WFPC2 have both had their CTE monitored during their operation in orbit and both indeed show a measurable decline in CTE that has reached a level that can significantly affect scientific results (eg, Cawley et al 2001, Heyer 2001, Kimble, Goudfrooij and Gilliland 2000).

As part of the Instrument Physical Modelling Group's effort to enhance the calibration of STIS we have developed a model of the readout process for CCD detectors suffering from degraded charge transfer efficiency. The model enables us to make predictive corrections to data obtained with such detectors.

There has been a major effort by the WFPC2 and STIS groups at STScI to monitor and characterise the CTI effects seen in the data from these instruments (eg, Whitmore 1998; Whitmore et al. 1999; Kimble, Goudfrooij & Gilliland 2000). This has resulted in well calibrated empirical corrections for CTI-affected data from WFPC2 (Dolphin 2000; Dolphin 2002) and STIS (photometric: Goudfrooij and Kimble 2002, hereafter GK2002, spectroscopic: Bohlin and Goudfrooij 2003, hereafter BG2003).

Empirical corrections give the fractional flux loss due to CTI as a function of signal strength (for a point source), background, epoch and position on the chip (distance from the readout register). It is necessary to formulate and calibrate the corrections differently for photometric and spectroscopic data because of the differing nature of the spatial distributions of illumination and resulting charge. Therefore, empirical corrections only apply to point sources. By modelling the readout process we are able to correct for any charge distribution and can therefore apply this method to all data whether photometric or spectroscopic and obtain a correction for every pixel, not just extracted sources or spectra. Moreover, as the model is based on the physics of the readout process, it will be possible to apply it to other detectors simply by modifying the parameters that describe the detector.

The Model

Detailed discussion of the model development and the physics involved can be found in Bristow & Alexov et al. (2002) and Bristow (2003a). Our approach is to simulate the readout process at the level of individual charge transfers. That is we take an image (a charge distribution on a two dimensional pixel array) and transfer the charges out as they would be on a real chip. Throughout we keep track of the status of bulk traps in the silicon pixels. The timescales and densities for these known traps are appropriate to the operating temperature and on-orbit radiation exposure respectively.

The stochastic nature (not to mention intricacy) of this simulation makes it impossible to run in reverse. Instead we derive corrections to a given image by using the raw image itself as a first guess at the charge distribution before readout and, effectively, add extra CTI effects to it. To estimate a correction from this we subtract the raw image from the simulated one. Once we have used this to correct the image a first time we can use the corrected image as a new first guess at the original charge distribution and compute further iterations. In practice,

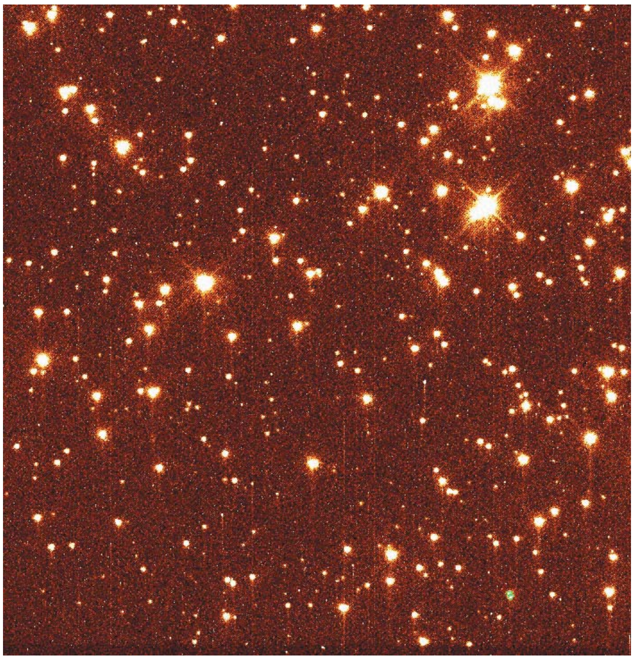


Fig 1a*: Section of a STIS image showing CTI trails under bright objects.*

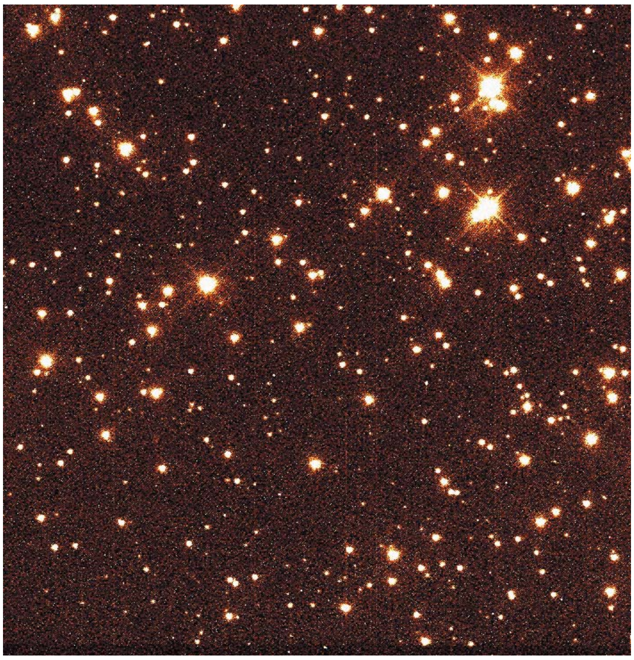


Fig 1b*: Same image section as 1a corrected by our CCD readout model. Note the absence of trails.*

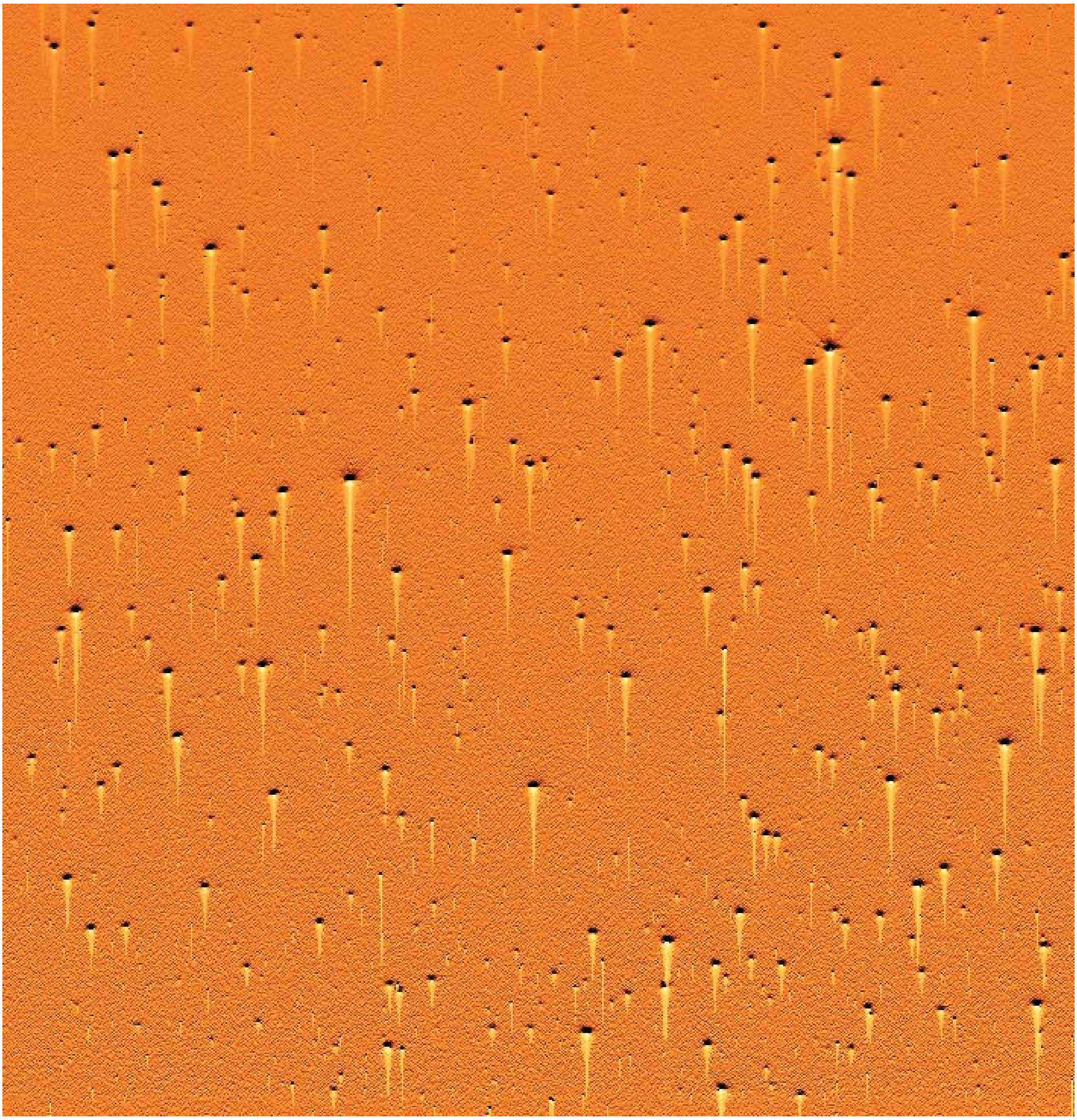


***Fig 1c:** The difference between 1a and 1b (ie, 1a subtracted from 1b).*

subsequent iterations provide a relatively small further improvement (and at the cost of increased noise, see Bristow 2003a), therefore all of the results presented here were obtained with only one iteration.

Cleaning CTE Trails

The clearest aesthetic diagnostic of data suffering from poor CTE is the presence of trails behind (in the sense away from the readout register) bright objects. This can be seen clearly in the section of STIS data shown in Figure 1a. Figure 1b shows the success of the simulation derived correction in cleaning these trails, whilst Figure 1c is simply the difference between the 1a and 1b. Dark pixels in Figure 1c are those that would have lost charge in the readout process (and have had the charge restored in Figure 1b) and vice versa.

Qualitatively then, the model-based correction appears to perform well. To get a quantitative validation we ask whether the charge is restored to the object cores correctly.

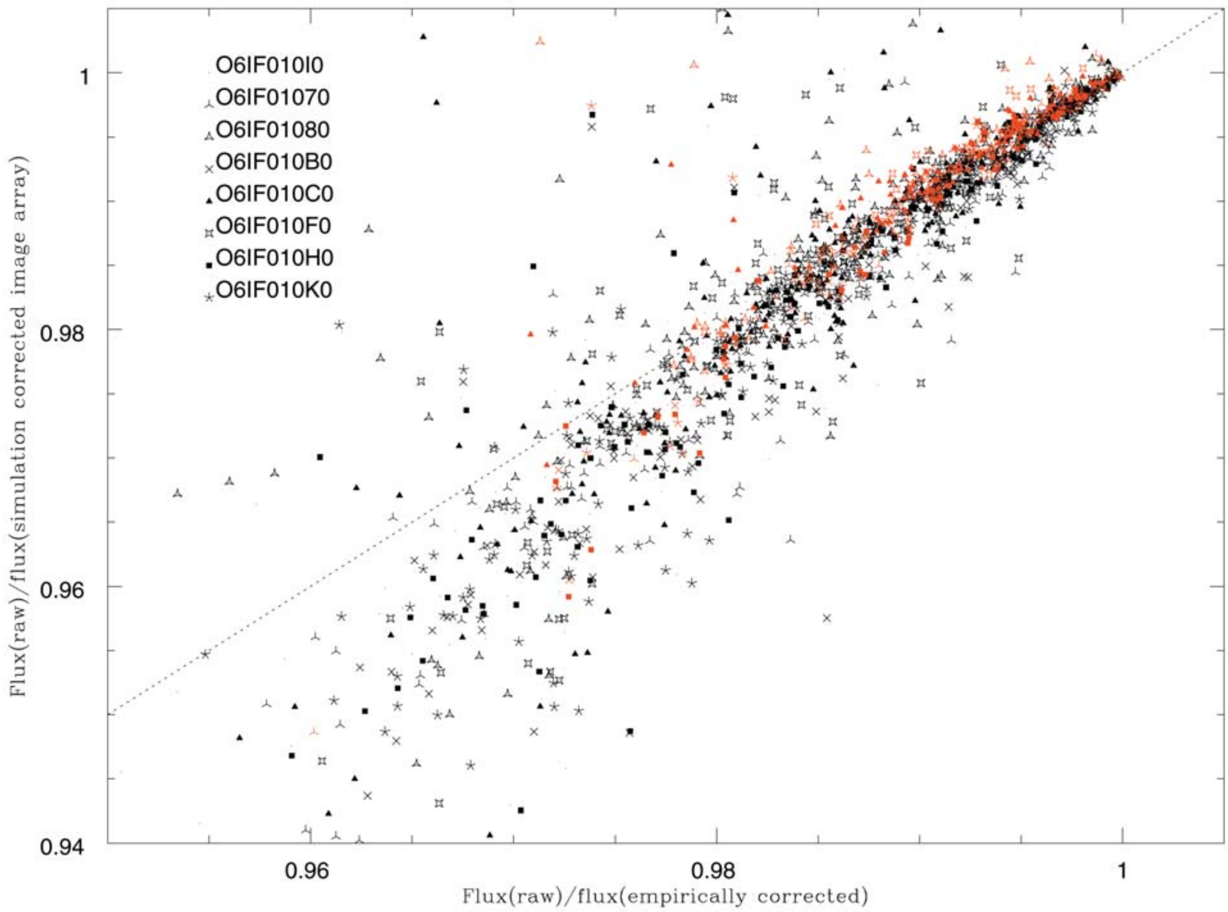


***Fig 2**: Comparison between model and empirical photometric corrections for the flux within a 7 pixel diameter aperture. Detections come from the datasets according to the key in the figure. The dotted line represents perfect agreement between model and empirical corrections. The meaning of the black and red colouring is given in Table 1.*

Comparison with Empirical Photometric Corrections

We should expect that the model-based corrections are in general agreement with the empirical corrections for point sources. Indeed, by demanding such a general agreement we can use the empirical corrections to calibrate the physical model. This is much easier than returning to, and re-analysing, the calibration data itself as the empirical corrections are essentially a distillation of what is to be learnt from the data with respect to CTI. That is not to say that the physical model is simply constrained to reproduce the empirical corrections. However, our hypothesis is that if the CTE model reproduces empirical results on average for point sources then it is reasonable to conclude that it is correctly modifying the charge distribution and will also therefore correctly predict the CTI in extended sources and indeed the whole image array. Instances of disagreement between model and empirical results are interesting as they will tell us if the model-based correction is either failing (if we can see no good reason for the disagreement) or improving upon the empirical corrections by predicting differences in the charge distribution that empirical corrections could not have dealt with.

In order to compare the corrections to point sources predicted by the simulation with those predicted by the empirical algorithm of GK2002 we have created catalogues of sources detected in the raw data by SExtractor. Each source has its empirical correction calculated and thus the ratio of raw to empirically corrected flux (abscissa in Figure 2). A simulation corrected frame is derived and sources are once again extracted with SExtractor so that the ratio of raw flux to simulation corrected flux is computed for each source (ordinate in Figure 2). All detections and matches were subject to the limits in Table 1.

Parameter	Fig. 2 (black)	Fig. 2 (red)
Detection threshold	4s	4s
Area (pixels above detection threshold)	>4	40
SGC in corrected dataset	>0.9	0.95
Minimum peak flux (ADU above background)	>100.0	1000.0
y-offset between raw and corrected images	<1.0 pixel	<1.0 pixel
x-offset between raw and corrected images	<0.5 pixel	<0.5 pixel

***Table 1**: Explanation of colour coding in Figure 2.*

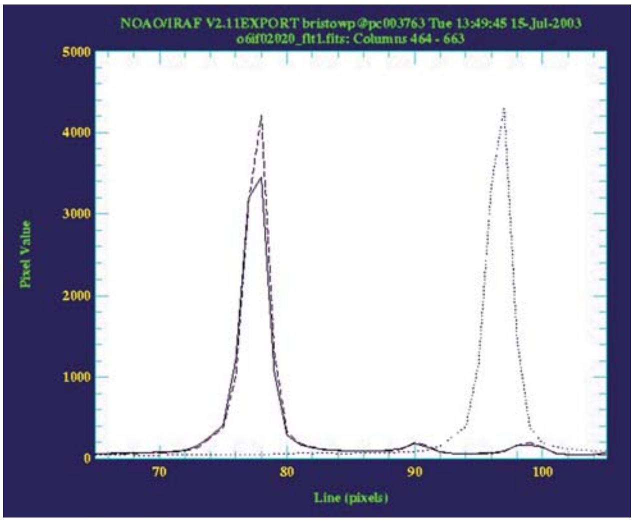


Fig 3: Cross section, perpendicular to the dispersion axis (horizontal rows), averaged over 200 columns. The solid line is the raw CTI degraded data. The dashed line is also raw data but from a near identical exposure that is almost CTI free (see text). The dotted line (offset for clarity) is the model correction to the CTI degraded raw data.

On the whole the black points in Figure 2 show a good agreement between empirical and simulation derived corrections. There is, however, some scatter and a systematic overestimate from the simulation derived corrections relative to the empirical corrections as the corrections become larger (lower values in the plot). The scatter merely reflects the fact that the simulation deals with the actual, inherently noisy, charge distribution (see below).

Regarding the systematic disagreement, it is worth pointing out that the level of agreement between the empirical and simulation derived corrections depends to some extent upon the selection of sources. Restricting the selection to larger, brighter objects with higher SGC always results in a closer agreement as seen in the red points in Figure 2 (see Table 1 for the modified detection limits). This is to be expected if the empirical corrections were calibrated mainly using relatively bright stars. For this reason we do not consider the apparent discrepancy seen for lower values in Figure 2.

Correcting Spectroscopic Data

Whilst there already exists a great deal of discussion of the effects of CTI upon astronomical imaging data in the literature, there is very much less where spectrometry is concerned. In the case of HST this is simply because STIS is the first spectroscopic instrument to suffer from CTI. Moreover, in most cases, the CTI effects in spectroscopic data can often be mitigated by careful planning of the observation so that the spectra from the object of interest fall close to the readout register (Kimble et al. 2000). Nevertheless, there exists data for which this was either not possible, or simply not done, and there are cases where even well-planned data may still suffer from CTI degradation.

Clearly spectra will be less seriously affected by CTI if the dispersion axis is perpendicular to the parallel readout direction so that the trailing does not distort the line profiles of spectral features. This is indeed the case with STIS, however, the consequence is a distortion of the perpendicular cross section of the spectrum. This can be seen in Figure 3 where we plot, as a solid line, the average (over 200 columns) vertical cross section of a spectrum suffering very little CTI (situated very close to the readout register) and, as a dashed line, an identical spectrum suffering significant CTI. The loss of signal is clear. A further dotted line (offset for clarity) represents the simulation corrected D amplifier data for the CTI degraded spectrum. The restoration of the signal in the corrected data is also clear.

Bohlin and Goudfrooij (2003) present a detailed analysis of CTI effects in STIS data specifically obtained for this purpose and derive an empirical algorithm for correcting CTE loss in spectrometry of point sources. This enables us to perform a similar analysis to that above for imaging data. Figure 4 is similar to Figure 2 except that here each point represents one (7 pixel high) bin in an extracted spectrum. The abscissa is the ratio of the value measured in the raw data to that given by the empirical algorithm and the ordinate is the ratio of the value measured in the raw array to that measured in the simulation corrected two dimensional array. A number of datasets covering a range of background and signal strengths are represented in Figure 4, so the general agreement is encouraging.

Special Cases

As noted above, there is considerable scatter in Figures 2 and 4. This is because of the non-uniformity of the charge distribution that causes the CTI experienced by each source to vary in a way that cannot be accounted for in the empirical corrections.

In order to illustrate this we have labelled some of the outlying sources in Figure 5a, which is the same as Figure 2 except that it only contains data from the single STIS dataset O6IF01070 to

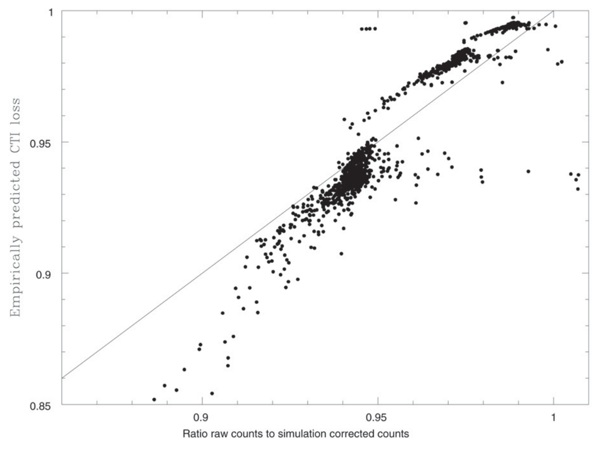


Fig 4: Comparison between model and empirical spectroscopic corrections for the flux within in a 7 pixel high extraction. The solid line represents perfect agreement between model and empirical corrections.

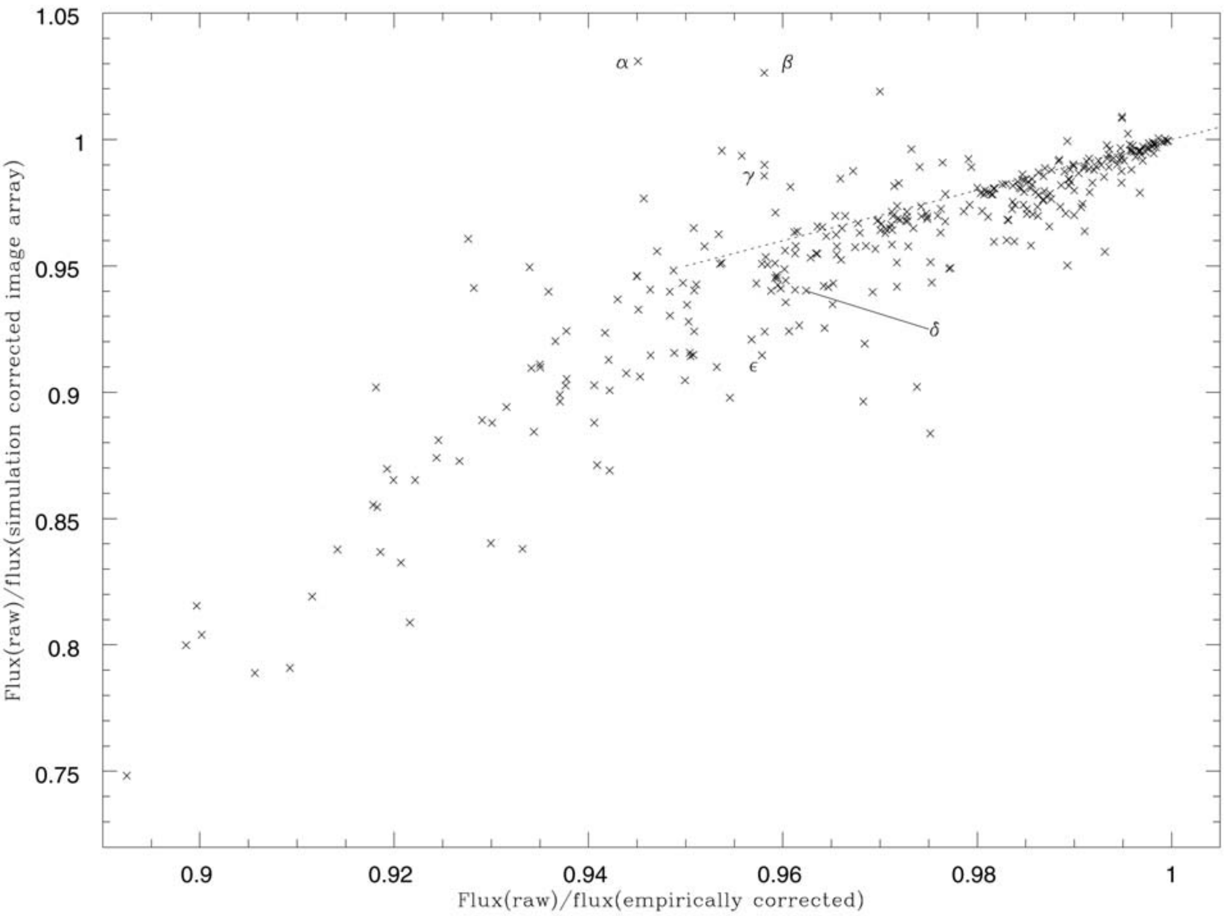


Fig 5a*: Close up of Figure 2 in which several of the outlying sources are labelled.*

reduce the confusion. The sources labelled α and β have simulation-derived corrections that are somewhat smaller than those that the empirical algorithm would assign to them. We can see why by looking at the raw image data from which they were extracted in Figure 5b. The sources are highlighted with green boxes, α is the lower one and β is above and to the right. Both are situated just below a larger source. In the readout process, the source above (and nearer to the D readout amplifier in use) leaves charge behind that reduces the charge loss of sources α and β. In Figure 5b (right) we see the two sources in the difference image (as Figure 1c above), ie, the charge lost (dark) and gained (light) during the readout process according to the

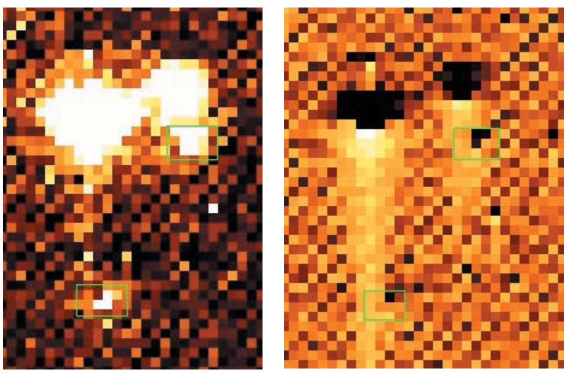


Fig 5b*: Sources α and β from Figure 5a as they appear in the raw data (left) and difference image (right) .*

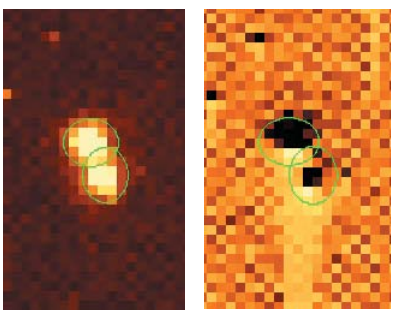


Fig 5c*: Sources γ and δ from Figure 5a as they appear in the raw data (left) and the the difference image (right).*

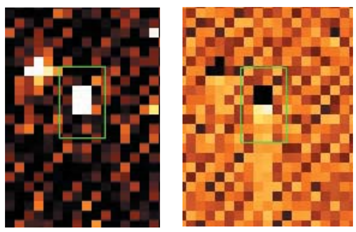


Fig 5d*: Source ε from Figure 5a as it appears in the raw data (left) and the difference image (right).*

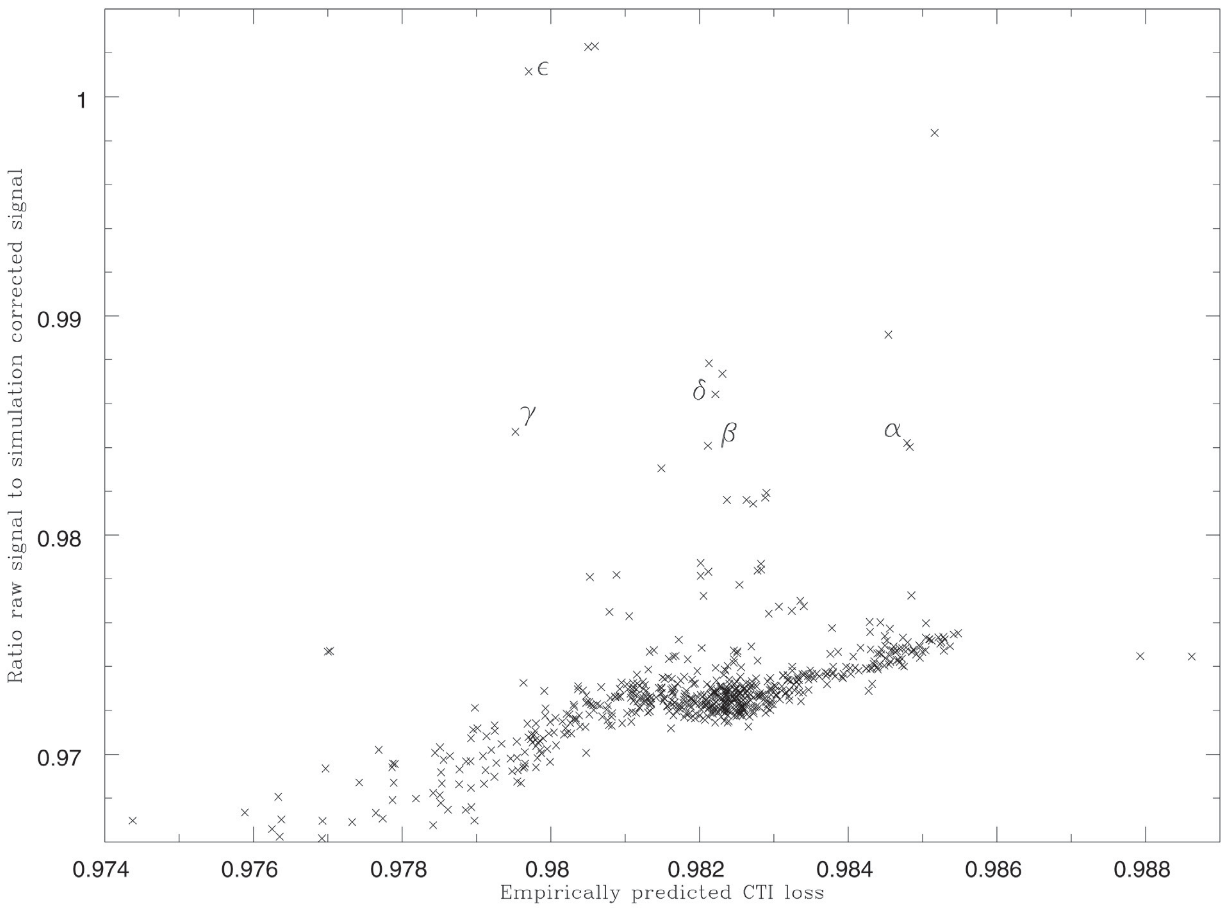


Fig 6a*: Close up of Figure 4 in which several of the outlying sources are labelled.*

simulation. Both sources can be seen to lie in the CTE trail of the source above.

The source labelled γ is a similar example, it lies below and extremely close to source δ, as can be seen in Figure 5c. The smaller simulation-derived correction for source γ can then be explained in the same way as sources α and β above (see also the difference image on the right of Figure 5c). Also apparent here is that δ has a simulation derived correction that is larger than the empirical value. This could be due to the uncertainty in the flux estimate for each source arising from the fact they have been de-blended by the detection software. If δ was assigned a flux that was too great, then the empirical CTE correction (as a fraction of the total flux) would be too low. What is interesting is that Figure 5a suggests that if the two objects had not been de-blended, and a single large object had been detected instead, then the empirical and simulation derived corrections would have agreed.

Finally source ε has a simulation-derived correction that is somewhat larger than the empirical algorithm would assign to it. In Figure 5d we see that this source has a far from stellar profile and shape. Instead it has a very sharply defined upper edge. This kind of profile will suffer CTI more acutely than stars and therefore more than an algorithm that only takes total flux into

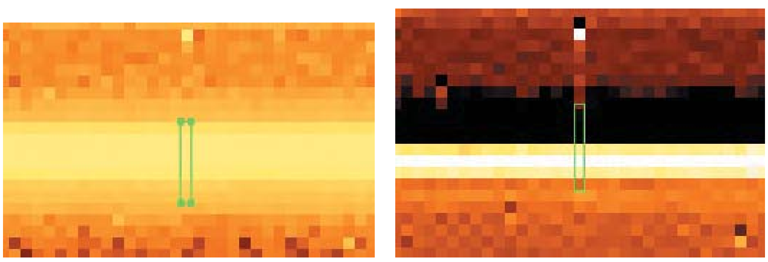


Fig 6b*: Source α from Figure 6a as it appears in the raw data (left) and the difference image (right).*

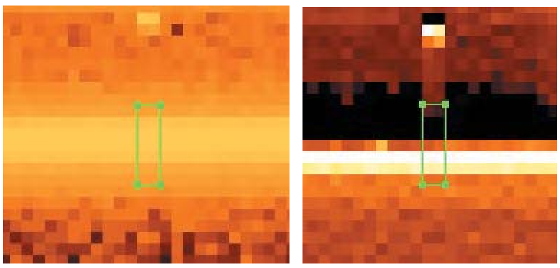


Fig 6c*: Sources β and γ from Figure 6a as they appear in the raw data (left) and the difference image (right).*

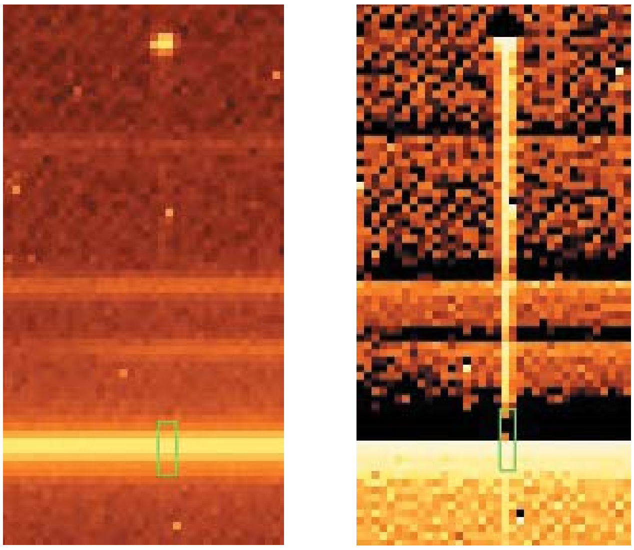


Fig 6d: Sources δ and ε from Figure 6a as they appear in the raw (left) and the difference image (right).

account would predict (see the considerable trail in the difference image on the right of Figure 5d).

A similar case can be made for the spectroscopic outliers in Figure 4. We consider the outliers highlighted in the close up section of Figure 4 shown in Figure 6a and identify the parts of the spectrum on the raw data to which they correspond. The point labelled α in Figure 6a corresponds to the spectrum bin highlighted in Figure 6b. Clearly visible directly above this bin is a bright pixel that turns out to be a hot pixel. The right of Figure 6c shows the corresponding difference. As expected the hot pixel is dark, but more importantly, beneath is a trail of pixels that would have gained charge, this continues into the extraction area. During the readout process, charge collected in the spectrum pixels would always be being transferred up the chip behind the charge trail of the hot pixel. The state of the charge traps in the pixels traversed by the spectrum charge when it arrived would be quite different from the usual case of low background in the column immediately above the spectrum bin. This leads to reduced attenuation and even accretion of charge left by the hot pixel. For this reason point α lies to the right of the main group in Figure 6a.

Points β and γ are actually adjacent bins in the spectrum and have a similar explanation to that of point α, the only difference being that in this instance the CTI trail came from a cosmic ray that affected the two columns, not a hot pixel. This can be seen in Figure 6c, whilst Figure 6d illustrates the identical cause of the displacement of points δ and ε.

Software Pipeline Details, Availability and Future Development

Much of what needs to be done to derive and apply the model-based CTE corrections has been automated. Given a STIS dataset the current version of the software will:

- Prepare the raw data for input to the simulation by running CALSTIS with a modified set of header keywords.
- Extract details needed by the model from the dataset header (eg, observation date in order to set the appropriate level of radiation damage, CCD Amplifier used for the readout direction, etc).
- Run the simulation to produce an image array with "additional" CTE and statistics describing the behaviour of traps and charge packets during readout.
- Calculate the correction for each pixel and the resulting corrected image array.
- Run subsequent iterations of the simulation.
- Compile statistics that will enable the user to understand the effects of the correction upon extracted sources or spectra:
    - Run SExtractor on the input and output images,
    - Match the detections from the two images,
    - Calculate photometric or spectroscopic (as appropriate) empirical, corrections for all extracted sources or spectrum bins.

The re-insertion of the CTE-corrected raw data into the CALSTIS pipeline is not yet automated.

Enquiries regarding the software should be directed to bristowp@eso.org. The model itself is described in greater detail in Bristow (2003a) whilst the above results are more fully explained in Bristow (2003b) and Bristow (2003c) for imaging and spectroscopic data respectively.

Possible areas of further development include:

- The model could potentially be adapted for use with WFPC2 or ACS data (or indeed any CCD detector suffering CTE degradation);
- Better understanding of the physics;
- Proper integration into the STIS pipeline.

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The Performance of the ACS HRC/G800L Grism

Anna Pasquali, Norbert Pirzkal & Jeremy Walsh

Over the past year the Advanced Camera for Surveys (ACS) has been operating routinely aboard the Hubble Space Telescope and gathering a wealth of high angular resolution images. Although mostly requested in direct imaging mode, the ACS can also be used for spectroscopy, based on an optical range grism (G800L) and three UV prisms (PR110L, PR130L and PR200L). No slit is provided so spectroscopy with the ACS is multi-object, but with a resolution that is dependent on the object size and orientation (see Pasquali et al. 2002). This article discusses the HRC G800L grism mode.

The ST-ECF is responsible for the support of the ACS spectroscopic modes, including the in-orbit calibration and the release of the slitless spectra extraction software (aXe, see http://www.stecf.org/software/aXe/index.html).

The ACS High Resolution Channel (HRC) provides a field of view of 26” x 29” with a pixel size of 0”.025 x 0”.028. It shares the same G800L grism as the Wide Field Channel (WFC) and is also fitted with a prism (PR200L) that is sensitive to the spectral range between 2000Å and 4000Å. In this article we present the in-orbit calibration of the HRC and G800L grism as determined from data obtained during the Servicing Mission Orbital Verification (SMOV3B, April/May 2002). A previous article described the calibration of the WFC with the G800L grism (Pasquali et al. 2002) and a full report is available in the ACS Instrument Science Report series (Pasquali et al. 2003a).

The Observations

In-orbit wavelength calibration of slitless spectrometry depends on point sources with emission line spectra. As described in Pasquali et al. (2002), for the ACS this is optimally achieved by observing Galactic Wolf-Rayet stars that are not associated with circumstellar nebulae. Spectra of WR stars of type WC are characterised by a spectrum rich in He and C emission lines across the spectral range of the ACS grism.

Spectra of the Wolf-Rayet star WR45 were obtained at five positions across the HRC field of view (roughly the centre and four corners) to map the field dependence of the grism properties and the dispersion solution. As part of the same programme, the standard star GD153 (a Galactic White Dwarf) was observed at the same positions in order to derive the grism flux calibration. Since, in slitless spectroscopy, the position of a

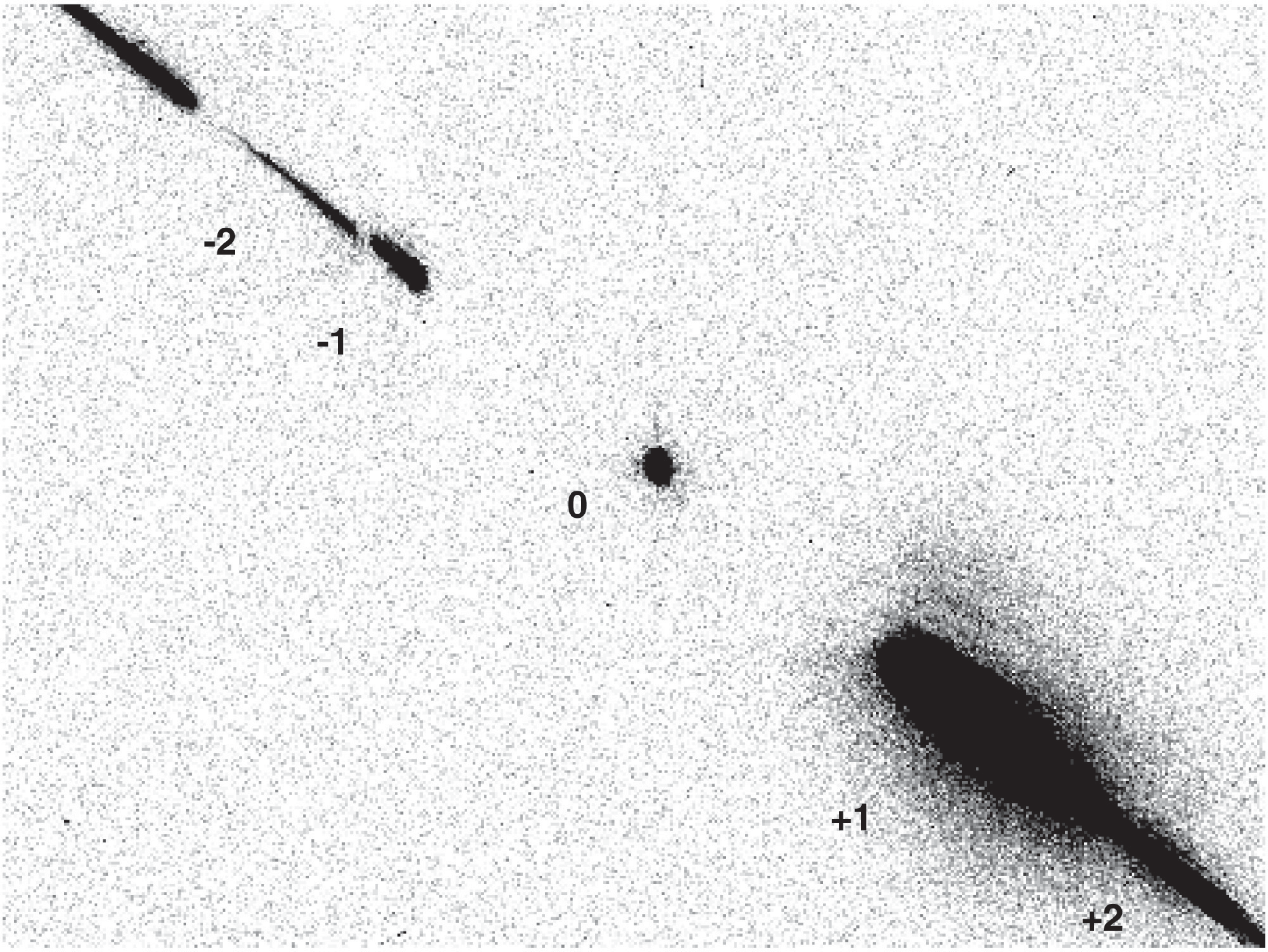

Fig 1*: The 2D grism spectrum of WR45 as observed near the centre of the HRC field of view.*

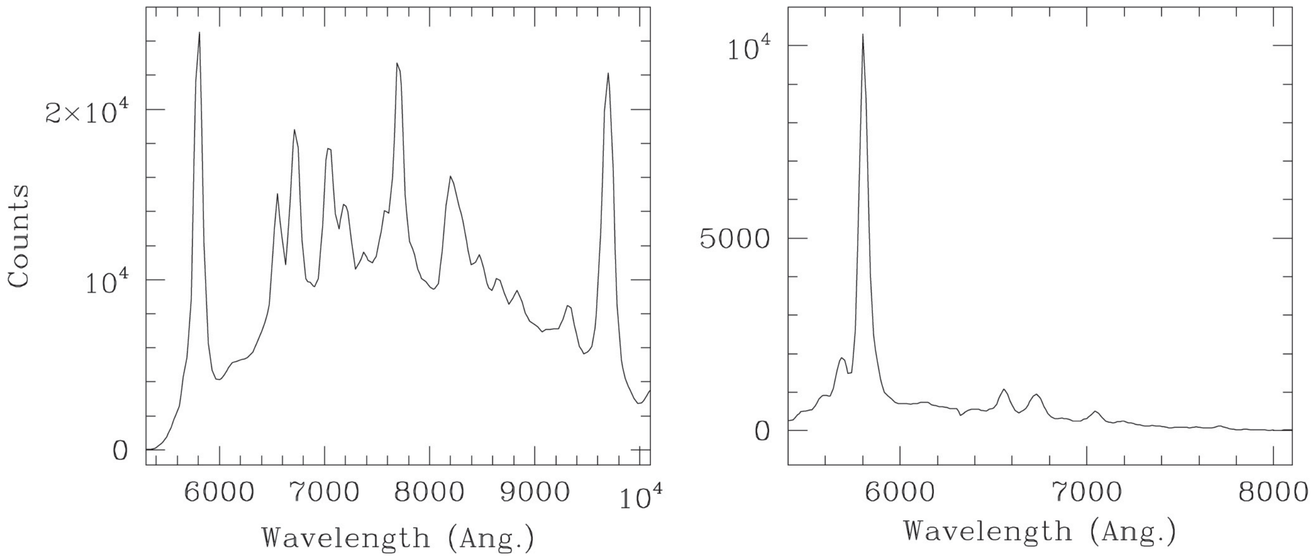

***Fig 2:** The HRC grism first and second order spectra, acquired near the centre of the HRC field of view.*

target in the field of view sets the zero point of the wavelength solution of the target spectrum, a pair of direct and grism images were always acquired. The direct images were taken through the F775W filter with an exposure time of 3s (2s for GD153), while 60s exposures were employed for grism images of both WR45 and GD153.

A 2D image of the spectrum of WR45, as observed close to the centre of the HRC field of view, is shown in Figure 1. The major feature here is the large spectrum tilt, about -38 degrees with respect to the image X axis. We also measured the spectrum tilt at each pointing and found that its maximum variation is 0.33 degrees from lower-left to upper-right corner. The zeroth order of the grism spectrum is offset with respect to the position of the target in the direct image by -145 pixels along the X axis and +113 pixels in Y, on average. These shifts turn out to be quite constant across the HRC field of view.

The Calibration Method

The procedure for deriving the final dispersion solution of the HRC/G800L spectra is identical to that used for the WFC/G800L data (Pasquali et al. 2002; Pasquali et al. 2003a). Briefly it consists of the following steps: the aXe extracted 1D grism spectra are calibrated in wavelength using the dispersion solution derived from ground tests in order to measure the line FWHM of the in-orbit spectra; the line FWHM is used to degrade the ground-based template spectrum of WR45 to the ACS grism resolution; the wavelengths of lines in the degraded template spectrum are measured by fitting multiple Gaussians; the lines in the observed spectrum of WR45 are measured in the same way and the peak positions with respect to the position of the direct image determined; the table of line peaks in pixels and wavelength is fitted with a polynomial (cf, the IRAF routine POLYFIT) wavelength solution, of 2nd order for the grism first order spectrum and 1st order for the higher and negative orders. The order of the fitted polynomial depends on the number of identified lines, which amounts to 7 for the grism first order and up to 5 for the higher and negative orders. The HRC/G800L spectra (first and second orders) from the position near the centre of the field are shown in Figure 2.

The HRC/G800L Dispersion Solution

The dispersion computed for the grism first order is plotted in Figure 3 as a function of observed position across the HRC field of view. The dispersion varies most along an axis from lower right to upper left by about 4% of the value at the field centre. This is similar to the direction of the field dependence of the dispersion for the WFC/G800L (Pasquali et al. 2003a); the amplitude of the dispersion variation is, however, smaller by a factor of about 5. More details on the wavelength solution for all the grism orders detected in the HRC/G800L configuration can be found in Pasquali et al. (2003b).

Flux Calibration

The flux calibration of a slitless grism spectrum requires a proper correction for the flat field. Depending on the position of the target in the direct image, a pixel in the grism image can correspond to any wavelength over the passband of the grism. The flat field must thus be represented by a cube of flat field images at each wavelength. The flat field cube has been determined by fitting a polynomial to the wavelength variation of the flat field at each pixel from the in-orbit flat fields taken through the HRC filters (Pirzkal et al. 2002). The flat-field correction to apply to a grism spectrum (after it has been calibrated in wavelength) is computed by interpolating, as a function of wavelength, this flat-field cube at each pixel of the spectrum.

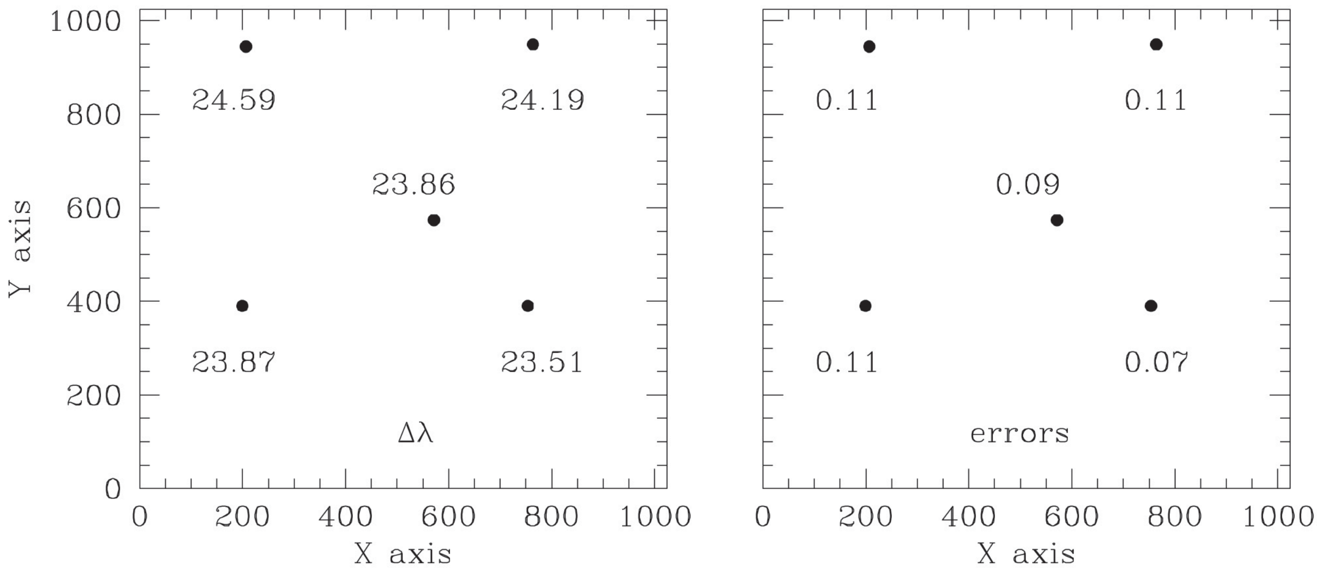

***Fig 3**: The dispersion of the grism first order as a function of position across the field of view of the HRC.*

The spectra (for each grism order) of the standard star GD153 have been extracted, corrected for flat-field, gain and exposure time, and ratioed by the standard's flux (available in the CDBS directory of STSDAS). The resulting sensitivity function for the HRC G800L first order is shown in Figure 4. Given the relative faintness of the grism orders other than the first, and the fact that the higher orders are often truncated, we have derived the sensitivity functions only for the grism first and second orders. The sensitivity functions computed for each grism order at each field position agree to within 5% at wavelengths bluer than ~9500Å (Pirzkal et al. 2003).

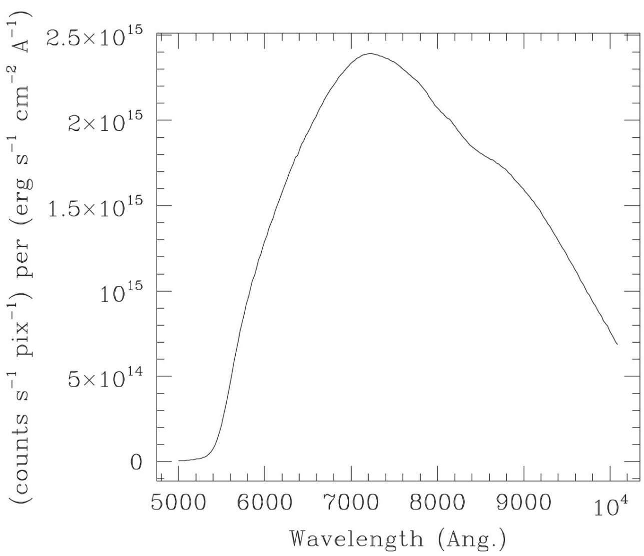

***Fig 4**: The mean HRC G800L sensitivity computed for the grism first order.*

HRC Calibration Files for aXe

In order to be able to extract and calibrate in wavelength a grism spectrum at any position in the HRC field of view, we have fitted 2D polynomials to the tilt, offsets and wavelength solutions (dispersion and zero point) as a function of the target (X,Y) position in the direct image for each grism order. The coefficients for the HRC are available in a configuration file that is used by the spectral extraction software aXe.

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HUBBLE
European Space Agency Information Centre

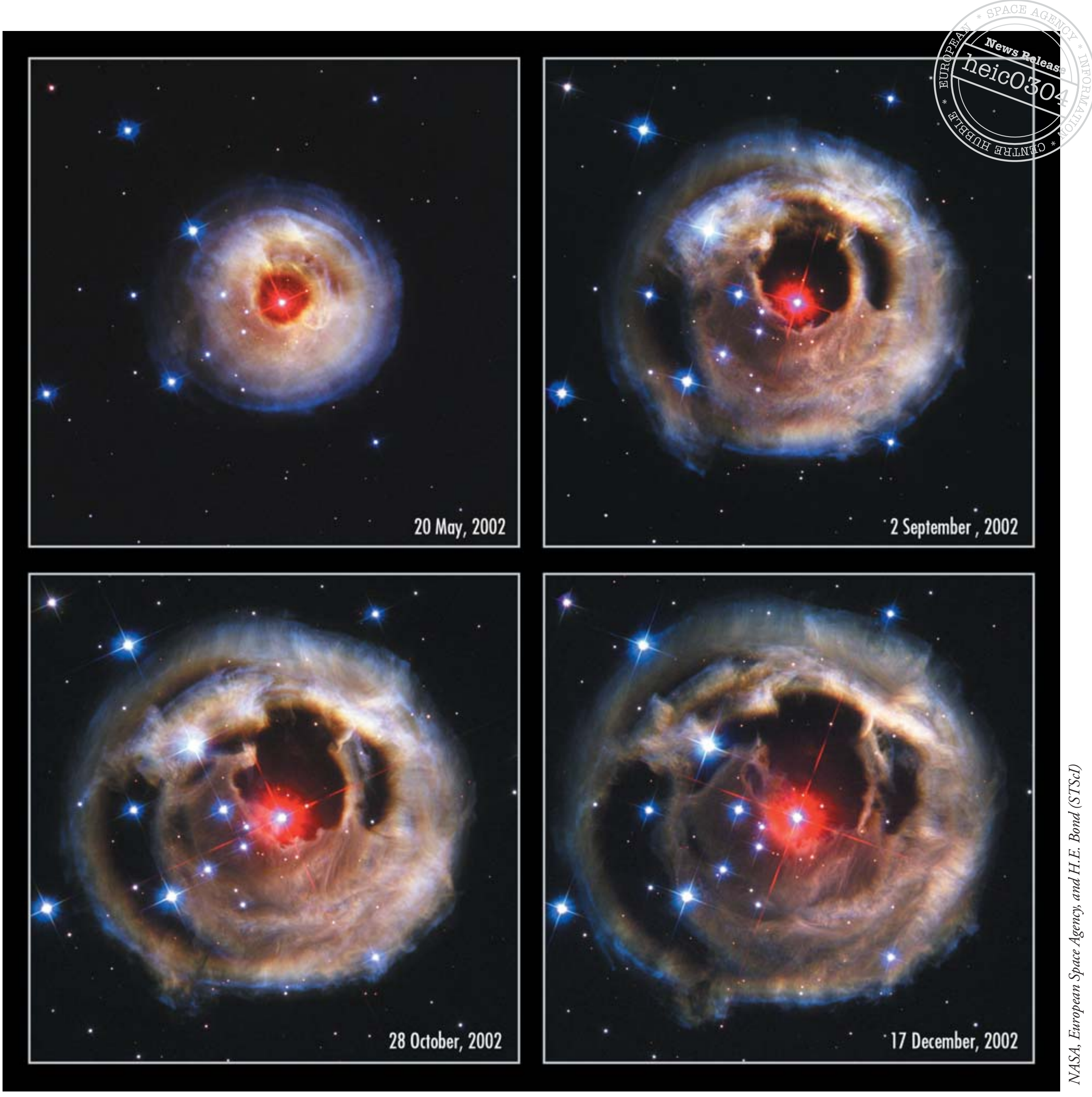
Hubble watches light echo from mysterious erupting star

This sequence of pictures from the Hubble Space Telescope's Advanced Camera for Surveys dramatically demonstrates the echoing of light through space caused by an unusual stellar outburst in January 2002. A burst of light from the bizarre star is spreading into space and reflecting off surrounding shells of dust to reveal a spectacular, multicoloured bull's eye.

The pictures show apparent changes in the appearance of the dust surrounding the star when different parts are illuminated sequentially. This effect is called a 'light echo'. From the first to last image the apparent diameter of the nebula appears to balloon from 4 to 7 light-years. This creates the illusion that the dust is expanding into space faster than the speed of light. In reality, the dust shells are not expanding at all, but it is simply the light from the stellar flash that is sweeping out into the nebula. The different colours in the nebula reflect changes in the colour of the star during its outburst.

The red star at the centre of the eyeball-like feature is an unusual erupting supergiant called V838 Monocerotis. It is about 20 000 light-years away in the winter constellation Monoceros (the Unicorn). During its outburst the star brightened to more than 600 000 times our Sun's luminosity.

The circular feature has now expanded to slightly larger than the angular size of Jupiter on the sky. It will continue expanding for several years as reflected light arrives from more distant portions of the nebula. Eventually, once light from behind the nebula begins to arrive, the light echo will create the illusion of contraction, and the echo will disappear by about 2010. The black gaps around the red star are regions of space in which there are holes in the dust. This shows the nebula has a Swiss-cheese structure.



NASA, European Space Agency, and H.E. Bond (STScI)

Good Luck, Piero!

Rudi Albrecht

Piero Benvenuti and I first met in 1982 when he was in charge of the European IUE operations at Vilspa and I was busy building up the data analysis system at the STScI. We met again in March 1984 and together we started to implement the Space Telescope European Coordinating Facility at ESO in Garching. We enjoyed the ultimate luxury of starting from scratch and being able to hand-pick the people we felt we needed for the task. We were well under way when the first problem hit: the Challenger accident, which grounded the Shuttle fleet for four years. We used the time to enhance our ability to handle large format data sets, and we built a science data archive, which eventually became the nucleus of the ESO archive and now is being merged into the Astrophysical Virtual Observatory.

Piero Benvenuti, Head of ST-ECF, 1984-2003.

Everybody was shocked when it was discovered that HST suffered from spherical aberration. Under Piero's leadership the ECF developed some of the best procedures for the enhancement of images, much appreciated at the time and still in use today. We implemented the ECF Web server in 1993 and installed a Web-interface to our archive in 1994.

Many of the concepts developed for the HST found their way into the ESO VLT when, during 1995 and 1996, Piero was acting head of the ESO Data Management Division. Experience has now shown that the approach adopted then is by far the most efficient way to operate large facilities of this type.

Developments in the HST project, technological changes, and evolving new science changed the boundary conditions for the operation of the ST-ECF. Working with the decision makers of ESA, ESO, and NASA Piero succeeded in positioning the ECF at the cutting edge of HST developments. Advanced calibration and data analysis concepts were generated, and, at long last, an ESA HST public outreach capability was developed.

Piero relinquished his post as the Head of the ST-ECF in July 2003 when he was appointed Commissario Straordinario of the Istituto Nazionale di Astrofisica in Rome. He has a formidable task ahead of him, which he, I am certain, will tackle with his usual determination and competence.

Contents

ST-ECF

Acting Head
Rudolph Albrecht
+49-89-320 06 287
Rudi.Albrecht@stecf.org

Science Instrument Information
Robert A.E. Fosbury
+49-89-320 06 235
Robert.Fosbury@stecf.org

Public Outreach
(Hubble European Space Agency Information Centre):
Lars L. Christensen
+49-89-320 06 306
lars@stecf.org

The Space Telescope-European Coordination Facility
Karl-Schwarzschild-Str.2
D-85748 Garching bei München, Germany

Website
http://www.stecf.org

Telephone
+49-89-320 06 291

Telefax
+49-89-320 06 480

Hot-line (email)
stdesk@stecf.org

Email
<user>@stecf.org

ST-ECF Newsletter

Editor
Richard Hook, Richard.Hook@stecf.org

Editorial assistant
Britt Sjöberg, Britt.Sjoeberg@stecf.org

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