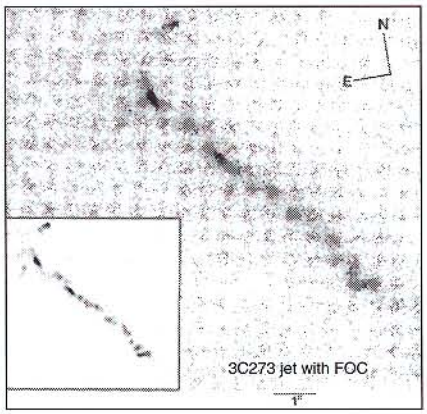
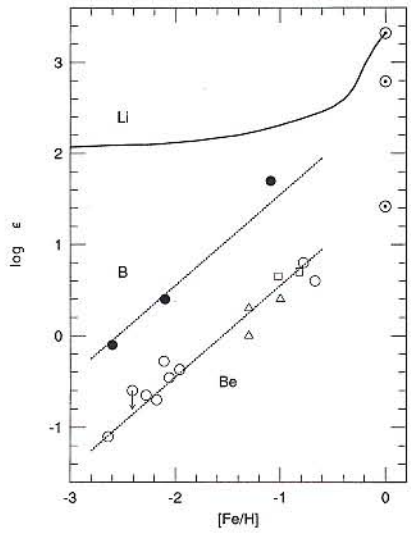
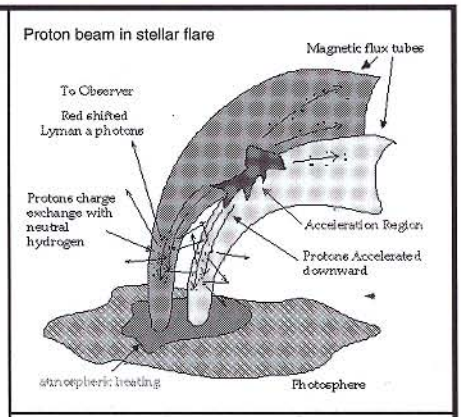
Number 18 July 1992

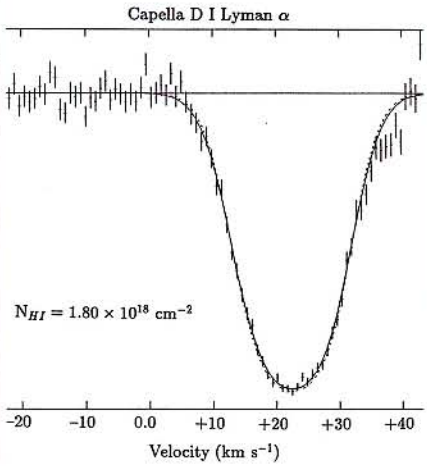
ST-ECF Newsletter

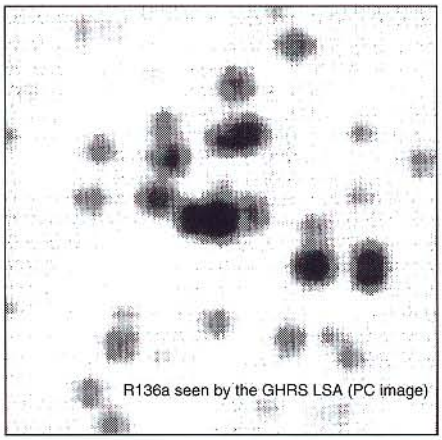
Space Telescope — European Coordinating Facility

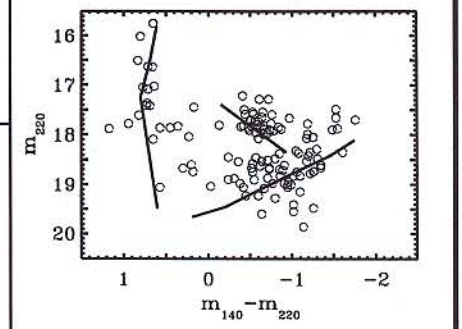




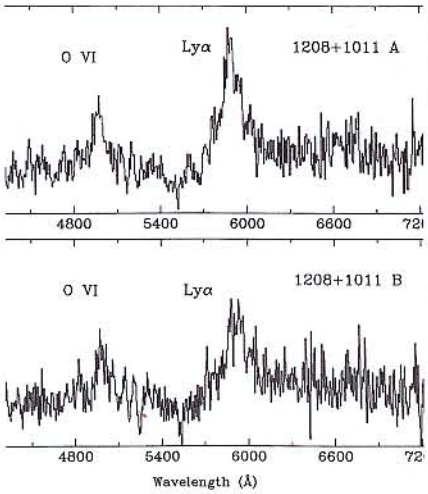


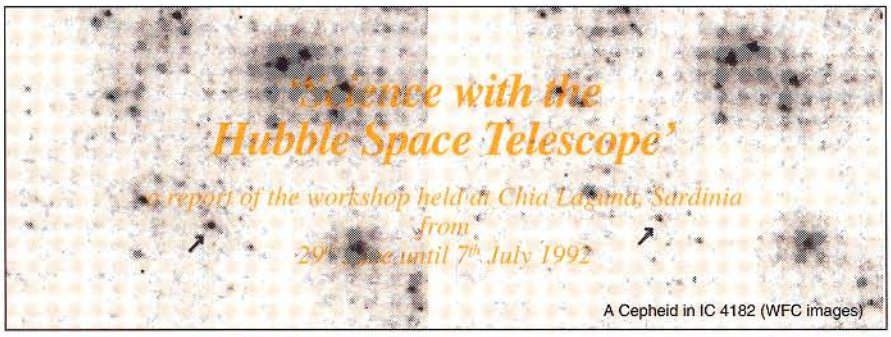



R136a seen by the GHRS LSA (PC image)



Blue stragglers in 47 Tuc (FOC data)



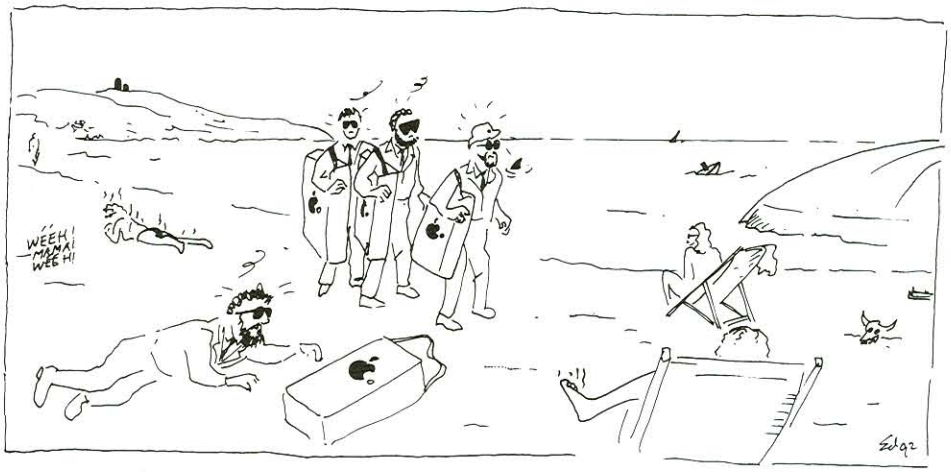


A Cepheid in IC 4182 (WFC images)

Editorial

This is a special issue of the ST–ECF Newsletter with the express purpose of providing a rapidly published account of the second of the HST scientific workshops. The full proceedings will be published later this year by ESO and so this is intended to be a summary account containing only highlights and comments.

The 'SV Workshop', held at the STScI last year, was really too early for users to make a realistic assessment of the scientific potential of the telescope and it is only now, as we near the end of the Cycle 1 GO observations, that a picture is emerging from which we can see what it is possible to do in the current state and what we can expect to achieve after the first refurbishment mission. Planned for late in 1993, this will install WFPC II and COSTAR and so recover essentially the full capability of the observatory.



The editorial team, showing supreme devotion to duty, struggle to avoid temptation...

The ST–ECF/STScI Workshop on "Science with the Hubble Space Telescope" was held at Chia Laguna on the southern coast of Sardinia, Italy, from June 29 to July 7, 1992. The proximity of the congress centre to 4 swimming pools, 4 tennis courts, 2 squash courts and numerous bars and beaches caused the speakers to work extra hard on honing their talks to a high state of perfection in order to compete with these attractions. A few thunderstorms during the week helped to keep a full-house but, in general, the audience showed remarkable stamina in the face of the prevailing diversions. A few computers scattered about the building to satisfy the cravings of the 'email junkies' also helped to nucleate the meeting.

In addition to the astronomical talks, there were discussions of the second generation instruments and of an advanced camera which could become a third generation device at the end of the decade. There was also a panel discussion which addressed the question of the future of near-IR/optical/UV astronomy in space. With the proximity of the Cycle 3 proposal deadline, the last day consisted of a "Cycle 3 mini-workshop" to review the current state of the instruments and the application, observing, archive and user-support procedures.

...meanwhile, exciting revelations continue in the Congress Centre.

In producing this issue, I should like particularly to thank Hans-Martin Adorf, Jeremy Walsh and Richard Hook who sacrificed numerous opportunities to swim, sail and just lounge about in order to report on the sessions and write copy in near real-time on the several ST–ECF Macintoshes. These were SE/30s—not Power-Books yet!—which were lugged to Sardinia as hand-baggage with great physical effort and some damage (to us, not the machines). Leon Lucy reviewed the final text and gave me the benefit of his considerable editorial experience. In the interest of brevity, I decided to include neither references nor to give names of collaborators in the reports of talks. The full proceedings will, of course, provide this information.

Finally, I should apologise for the questionable quality of some of the illustrations which do not come up to our usual high standard. This is not the fault of the contributors—whom I thank for their co-operation—but simply that, due to severe time limitations, we had to resort to scanning hard-copy rather than working from the original digital or PostScript versions.

Extragalactic sessions

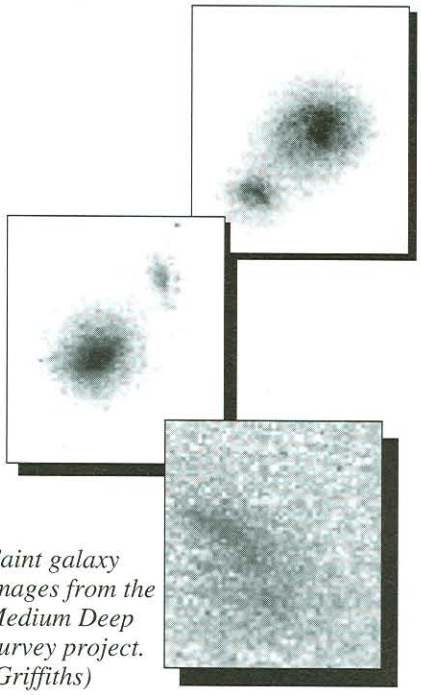
In the quest to understand the nature of galaxy formation and evolution, observations of distant radio galaxies have played a crucial rôle. The radio source—for this purpose—serves merely as a means of identifying 'galaxy-like' objects at a high redshift, a procedure which carries with it the risk that the activity associated with the radio emission will produce structures at other wavelengths and contaminate the starlight which carries the evolutionary messages. Since ground-based images of galaxies at a redshift of one or greater are usually the 'formless blobs' to which Spitzer referred in his original discussion of the need for a large space telescope, *George Miley* and collaborators started out with a pilot project to image with the WFC two sources—having redshifts close to 3 and 4—out of a sample of some 60 galaxies now known with $z > 2$.

It was already known from the 1987 ground-based discoveries of McCarthy and Chambers and their collaborators that, above redshifts of 0.7 or so, the optical images of powerful radio galaxies were aligned (but not co-spatial) with the radio-axes. To understand the nature of this alignment is a primary goal of the HST observations. The 'aligned component' is known to be blue in colour ($f_\nu \sim$ const) from the work of observers in Hawaii and there are currently two alternative explanations for the phenomenon: star formation induced locally by the passage of a radio jet through a galactic 'atmosphere' or the scattering—by dust or electrons—of anisotropically emitted radiation from the active, quasar-like nucleus. While neither of these explanations provides completely satisfactory explanations on their own, they make different predictions which could be tested with WFC observations.

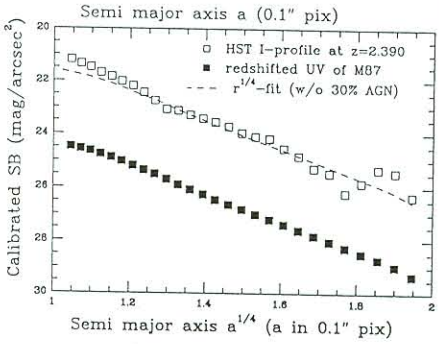
The two objects chosen in this pilot study (4C 28.58 and 4C 41.17) both show multiple structure on a sub-arcsecond scale and are both rather well-aligned with their radio axes. There is a suspicion, in the latter case, that both the radio and the optical structures bend in the same direction. This effect—if it appears frequently in other objects—will be difficult to reconcile with the beaming/scattering hypothesis. On the other hand, the jet-induced star formation picture cannot explain the high linear polarizations observed in many of these sources. This causes Miley to argue for a 'mixed' explanation of what must be a rather complex physical situation. Whatever the answer, it is clear from these first WFC observations that a large fraction of the ultraviolet light in these objects comes from compact clumps well under a kiloparsec in size.

Three less radio-luminous galaxies have been imaged with the WFC in "V" and "I" by *Rogier Windhorst*. After restoration using a version of the CLEAN algorithm, the two lowest redshift objects—at $z = 0.311$ and 0.545—reveal S0 and E light profiles respectively. The higher redshift object ($z = 2.390$) has a considerably higher radio luminosity and shows a narrow-line active nucleus, while the extended structure in the continuum shows only a marginal alignment with the radio-axis.

The Medium Deep Survey project is designed to to exploit the 'parallel observation' capability of the HST whereby two instruments—the second of which is usually the WFPC—can be operated simultaneously. By its nature, the WFPC observation is of a random position on the sky and what you get depends on the design of the associated primary (pointed) observation. *Richard Griffiths*, as leader of a large, Atlantic-spanning team, described the early results from the programme which should produce some 200 hours/year of exposure. Starting in April 1992, the deepest image so far (nearly 30,000 sec in I) is of one of Lilly's fields. In comparison with ground-based telescopes, the HST is very sensitive to high surface brightness regions and it is noticable that many galaxies break-up into multiple structures, a feature which will have to be incorporated into the modelling procedures being used to analyse the data. The galaxy number/magnitude counts do not appear to reveal any surprises and, at the faintest magnitudes ($I \sim 25$ mag), we are probably seeing spirals with a scale-length of about 0.15 arcsecond.



Faint galaxy images from the Medium Deep Survey project. (Griffiths)



Light profile of the deconvolved image of the z = 2.39 radio galaxy 53W002 compared with the redshifted, K-corrected profile of M87. (Windhorst)

One of the key programmes selected by the HST project for large amounts of observing time was QSO absorption lines. *John Bahcall* leads a large group who have been working since the early release observations. So far, only results on 3C 273 have been published but large amounts of data have been collected from GTO and GO Cycle 1 programmes with FOS. Spectra at a resolution of 1200 have been obtained of 12 QSOs in the redshift range 0.16-0.86 and 79 Lyman-α systems have been identified. In addition C IV, O VI, N V and Mg II systems have been studied with a detection limit of 4.5σ. Eight Lyman limit systems have also been observed. The result, already suspected from 3C 373, that Lyman-α absorptions lines are 20 times more numerous at low redshift than expected by extrapolation of the density of lines at high redshift is strengthened. In a number of cases, follow-up optical spectroscopy of nearby galaxies has revealed the absorbing galaxy from the redshift coincidence. The characteristic radius of the absorbers has been estimated for these sources and a value of 60 kpc ($H_0 = 100$ km/s/Mpc) is found. The data reduction turned out to be anything but routine since very careful flat-fielding was required to detect weak

absorption lines. The team have very kindly offered their reduced data to the community through STScI as soon as their first papers are accepted for publication.

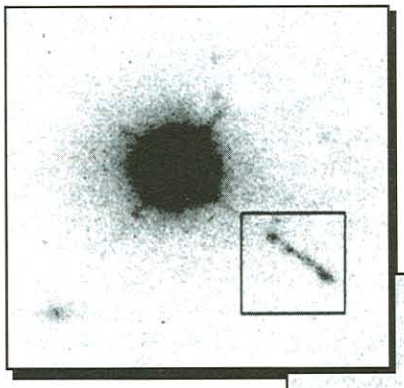
The Universe on a string! That's what the spectrum of the high redshift QSO HS 1700+6416 reveals. A remarkable spectrum was shown by *Dieter Reimers* in which seven Lyman limit systems are clearly seen. By taking into account all these Lyman limits, it proved possible to estimate the real continuum of the QSO which has the typical flat shape with a rise at the shortest wavelengths. A myriad of lines were identified: some from transitions never previously seen in the spectrum of a QSO. Ten separate redshift systems were noted and there are perhaps other systems still to be found by digging deeper into the data. Data reduction is a huge task since line blending is severe but already relative abundance ratios between elements in some absorbing sytems have been derived for Oxygen and Carbon and values similar to Population II systems found.

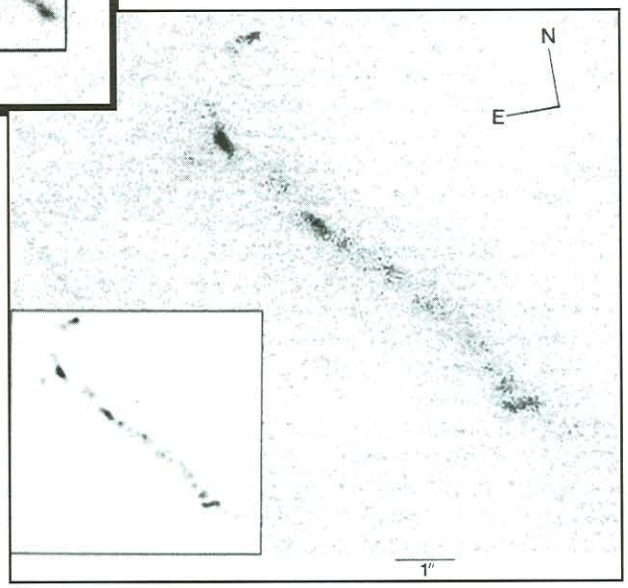
The spectroscopic description of a variety of QSOs from low to high redshift in terms of their continuum properties, emission line profiles and absorption lines is the subject of a large programme headed by *Margaret Burbidge*. The FOS in the UV was employed and combined with Lick 3m data in the optical. For one target, 3C 273, the Lyman-α and Hβ profiles are shifted in velocity and there is a progressive shift with decreasing wavelength, possibly attributable to internal extinction or optical depth effects within the line emitting region. So far no reliable evidence of He II 304Å absorption has been found in a QSO spectrum.

3C 273 was the topic of yet another talk, this time in an effort to determine the origin of the famous 'UV bump'. In the far UV, QSO spectra often show an increase in flux below the Lyman limit and there are theoretical models that suggest it could arise from very hot gas close to the central source—perhaps in the form of an accretion disk. *Art Davidsen* combined HST data from FOS with spectra from the Hopkins Ultraviolet Telescope (HUT), X-ray fluxes from Ginga and ROSAT as well as ground based data from Lick and KPNO in order to get a snapshot of the blue bump in 3C 273. There is a definite turn-up below 1200Å which appears to be consistent with the soft X-ray flux. Emission from a very hot black-body, at a temperature of around 50,000 K could be responsible.

The FOC and the FOS IDTs have been devoting a significant fraction of their guaranteed time to the study of nearby active galactic nuclei. This gave us a chance to see and compare FOC and the WFPC images of these bright—at least in the optical—sources in both line and continuum bands. *Alec Boksenberg*, with his characteristic verve and avalanche of viewgraphs, gave us a—perhaps unintended—movie of Seyfert 1s and 2s. The Seyfert 1.5 NGC 4151 is unresolved in the optical continuum with FOC *f*/96 and is also a bright point source in the far-UV. The [O III] λ5007Å line image, however, shows a beautiful bicone on a scale smaller than ground-based resolution.

Zlatko Tsvetanov, reporting work on the FOS team's PC images, remarked that the 75°±10° bicone opening angle in PA 60°±10° is difficult to reconcile with a geometry in which an obscuring torus creates the bicone shadow but still allows us to view the nucleus directly. The bicone axis aligns more closely with the VLBI than to the larger scale radio axis.





Ground-based (CFHT) V-band (above) and FOC B-band (right) images of the jet of the quasar 3C 273. The HST images were taken with the three FOC polarizing prisms in order to obtain the polarization structure at high resolution. The lower insert is a MaxEnt reconstruction of the FOC image. (Thomson)

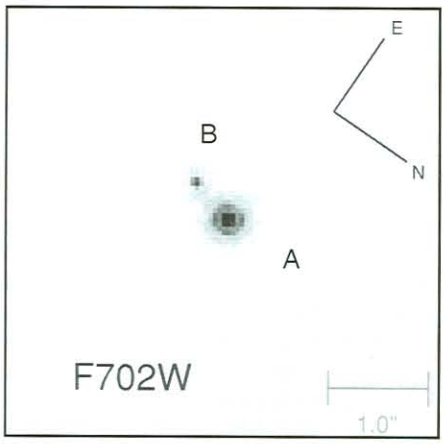
The FOC observations of NGC 1068 show—subject to the uncertainties in the relative astrometry—what is likely to be a close alignment between some of the radio and optical-line structures. An axially-aligned double structure coincides precisely with the position at which the radio jet suddenly expands into a bubble. A series of line-emitting structures beyond suggest a connection with the continuing plasma flow. This, like other Seyfert 2s, does not show a continuum point source in the UV, but it does have diffuse UV emission on *both* sides of the nucleus which suggests that there may be little obscuration associated with the disk of the galaxy.

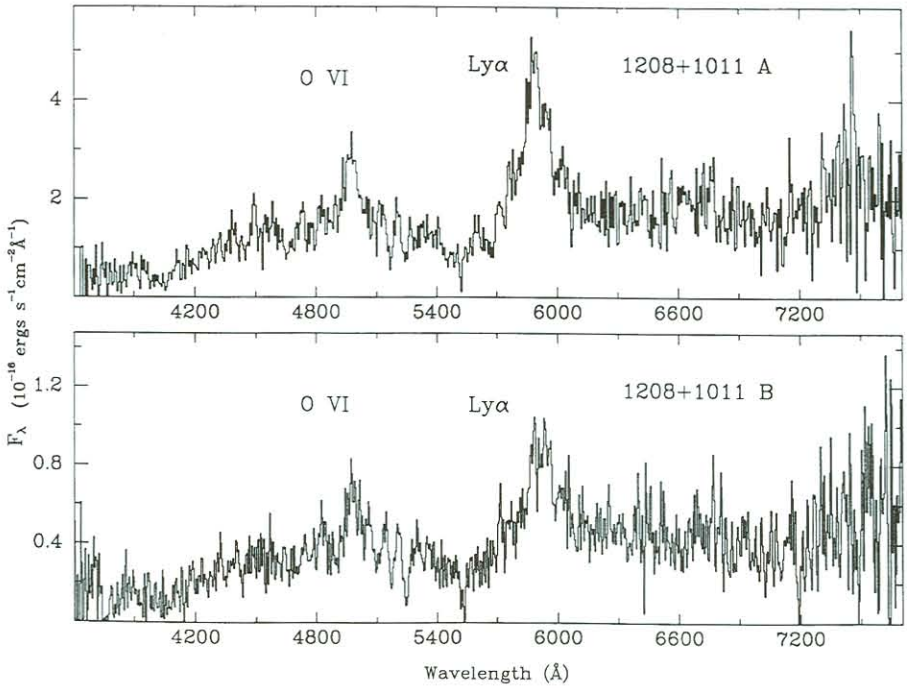
Tsvetanov showed the beautiful bicone and associated radio/optical 'bubble' in the weak active nucleus of M51. In the continuum observed with the PC there are two remarkable sub-arcsecond bands of obscuration, one of which bisects the bicone and may be associated with an obscuring torus.

Based on the widely differing behaviour shown by the different Seyferts observed with the HST, Tsvetanov suggested that there are really three angles which determine the appearance of active nuclei in disk galaxies: that between the axis of the torus and the line-of-sight, the opening angle of the bicone and the angle between the torus axis and the plane of the galactic disk. Zero and 90° for this last angle may be stable configurations and will produce rather different-looking objects.

The optical/UV extragalactic jets, because of their apparently limited dynamic range, make ideal targets for the HST and respond well to the application of restoration techniques. *Duccio Macchetto*, representing in part the FOC IDT, illustrated the diverse behaviour to be found in these very rare objects. The FOC-observed M87 jet shows a spectacular similarity to the radio object mapped with the VLA. They are not, however, identical at these two widely separated frequencies. The radio/optical spectral index steepens towards the edges of the jet, near two of the bright knots and also in the very outer part. Such detailed observations will surely usher in a new era of jet-modelling.

While the Medium Deep Survey team were obtaining their first deep WFPC parallel exposures, *Bob Thomson* was busy imaging the 3C 273 jet with the FOC polarizers. Unlike M87, this exhibits rather different structure in the radio and the optical, with a strong colour gradient along the jet. The optical polarization is very high—up to 36%—and is generally perpendicular (E-vector) to the jet axis but





A PC image and FOS spectra of the background-subtracted components of the lensed quasar 1208+1011. (Maoz)

twists by about 45° in the outermost knot.

Jerome Kristian used the HST to study the lensed quasar PG 115+080 for which he already had ground-based data at 1.2 and 0.6 arcsec resolution. Through extensive modeling he knew that four or five components had to exist. While these could be inferred from the ground-based material, they could actually be seen on the HST images. Despite the usual problems with obtaining a good PSF, a restoration with the Richardson-Lucy method revealed the lensing galaxy.

Using the data from the Bahcall/Doxsey 'snapshot' survey, *Dan Maoz* showed that gravitational lensing is a rare phenomenon, even when one is searching for lenses with the unparalleled sub-arcsecond resolution of HST.

Maoz and his collaborators have examined short exposure (~ 4 min) Planetary Camera snapshots through F555W centred on intrinsically luminous, z > 1 QSOs. Upon receipt of some intial data, the team concluded that the original goals of the programme, namely to obtain statistics on the gravitational lensing phenomenon, could be met despite HST's spherical aberration.

The programme was continued and ~500 QSOs have been observed thus far, out of which only one turned out to be a new lensing candidate. This high-redshift (z = 3.8) quasar Q 1208+1011 was re-observed later with the HST versions of the B-, V-, R- and I-band filters and the colour ratios of the components supported the lensing hypothesis. Also, spectra of the two components and the background obtained with the FOS showed that they have very similar spectra.

Taking into account other QSOs which would have been detected as lensed, but were not included as targets in the snapshot survey because of conflicts with approved GTO/GO programmes, Maoz found that out of ~ 500 luminous QSOs only 5 are lensed. This 1% fraction provides a severe constraint for some cosmological models. For instance, while in agreement with the standard model with a cosmological constant of $\Lambda = 0$, it rules out models with $\Omega_0+\Lambda = 1$ which predict 46.2 to 8.9 lensed QSO's (out of ~500) when the density parameter varies between $\Omega_0 = 0$ and 0.3. The calculations and conclusions should be taken with a grain of salt though, since they assume a single isothermal sphere (SIS) model for the lensing phenomenon which has been disputed.

Quite similar results were found by *Jean Surdej* and his group in a long-term programme dating back to 1986. They have discovered 3 lenses and an additional 12 candidates, among them Q 1208+1011. Their results constrain the lensing efficiency ("F-parameter") in the SIS-model. Surdej concludes that the spatial density of compact lensing objects appears to be much lower than the density of known galaxies.

Surdej's search for graviationally lensed QSOs is a combined effort using HST data and ground-based images obtained in excellent seeing conditions at the CFHT and the ESO-NTT. In the course of their work, Surdej's group retrieved some 200 public WFC snapshot frames with more than 2 Gigabyte from the HST archive at the ST-ECF. In total some 470 images of high luminosity QSOs were visually inspected for the presence of secondary lensed counterparts. He concludes that, given HST's current degree of spheri-

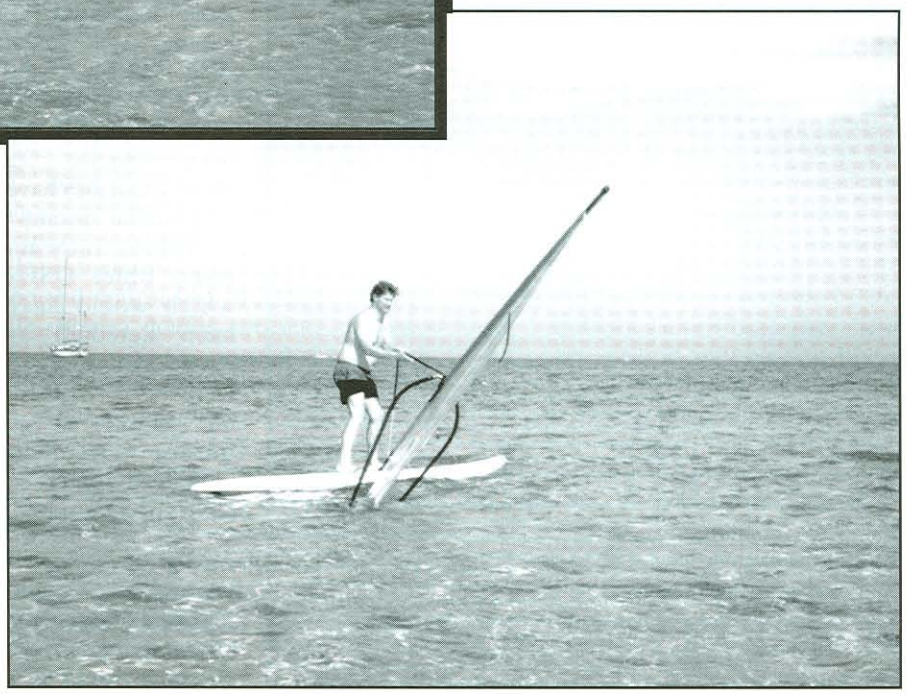
A 10 arcsecond separation, antisymmetric pair of images thought to be a quasar lensed by the cluster AC114 (WFC data). The third image, predicted from a model of the sum of the cluster and brightest member potentials, may have been identified on the far side of the cluster core. (Sharples)

cal aberration, ground based images presently are more efficient for finding lenses than the snapshot survey frames with their comparatively short 4 min exposure times and restricted dynamic range. But with WFPC II in place, the reverse is expected to be true.

Ray Sharples reported further progress in the study of the z = 0.3 cluster AC114, a WFPC programme which was discussed in the *ST–ECF Newsletter* No. 17. This shows some spectacular lensing phenomena including a remarkable antisymmetric pair of blue sources (visible but unidentified in the Newsletter article) which may be a lensed quasar with resolved structure. Models of the cluster potential allow the prediction of the approximate positions of other images, the third of which has been identified with a blue source on the far side of the cluster core. It shows a similar resolved structure. Systems such as these—which may be found frequently in deep WFPC images of clusters—can be used to place very tight constraints on cluster mass distributions.

The stellar surface brightness distribution in the centres of galaxies can provide important clues to the presence of a black hole. The highest spatial resolution possible is required to resolve the stellar cusp which is a tell-tale signature. HST thus has an important rôle to play in this area and already some detections have been made. *Tod Lauer* discussed PC images of M87 which have resolved the globular clusters and show an unresolved nucleus. If the central point source is subtracted, the stellar density follows an $r^{-1/4}$ law from 10 arcsec radius (250 pc) right into the centre, but a steeper distribution ($r^{-1.25}$) beyond 800 pc radius. The derived black hole mass is 2.6×10^9 M$_\odot$ from comparison with (ground-based) velocity dispersion profiles. Another galaxy, M32, also shows evidence of a cusp on PC images with a $r^{-1/4}$ distribution for $r < 0.4$ pc. In this galaxy, stars are resolved on the images but there is no evidence for colour gradients or isophote twisting on the larger scale. The derived black hole mass is ~2.8×10^6 M$_\odot$. Not all galaxies observed have stellar cusps though: NGC 4472 has a flat-topped core and M33 shows a nuclear star cluster, indicating perhaps that stellar collisions are important. In M31, a double nucleus is seen which straddles the kinematic centre of the galaxy. The presence of a dust lane is suggested, possibly with large grains to explain the lack of a colour gradient in the nuclear region.

Tod Lauer and Colin Norman skip the talks on stellar winds



Second generation instruments and panel discussion

Of the three second generation instruments, WFPC II, STIS and NICMOS, only WFPC II is scheduled for launch on the first refurbishment mission. *John Trauger* described the current state of the instrument which is no longer a clone of WFPC I but has been de-scoped from eight to four cameras because of the difficulty of maintaining the necessary precision alignment of the corrected optics with a rotating pyramid selecting the beams for separate WFC and PC modes. The new configuration is therefore three WFC CCDs and one PC, all of which will be exposed simultaneously.

The optical alignment tolerances are much tighter than before and there are activators to move the pyramid and three of the four folding mirrors. The vapour contamination which plagues (with measles!) WFPC I will be reduced by four orders of magnitude and this and other improvements should very much improve stability and ease the problem of calibration. There will still be a field-dependence of the PSF—this is a feature of the design—but with a reduced dark current (which means that the chips can be run warmer), a factor of two lower readout noise, no quantum hysteresis, much smoother flat-fields and rapidly fading residual images of saturated sources (within an orbit) this will be a considerably friendlier instrument to use. A dramatic improvement for work in the UV is the addition of a sodium Wood's filter which offers a short-pass cut at 2100Å with a very low red-leak.

The other two instruments are scheduled for launch later in the decade. STIS, described by *Bruce Woodgate*, will, by the addition of a second detector dimension, greatly enhance the spectrographic capability of HST. The multiplex advantage over the FOS and GHRS for the different modes ranges up to factors of hundreds.

NICMOS will offer the first near-IR (1–2.5 μm) capability with HST. *Rodger Thompson* described the instrument and the motivation for it while *Martin Ward* argued the scientific case using examples from AGN research. The 2.5 μm cut-off is driven by the rapidly increasing thermal emission from the telescope towards longer wavelengths. The advantages, however, of the freedom from restriction to the atmospheric windows and avoidance of the rapidly time-variable atmospheric OH emission are profound. Deep surveys, with a sensitivity of ~ 1 μJy/hr, will be done at a wavelength of 1.7–1.8 μm where the background is at a minimum. The instrument is cooled with solid N_2 and enough of this will be carried for a 5 year lifetime.

Robert Brown has been charged with the task of preparing a report on the future possibilities for an advanced camera. While this brief can be interpreted more broadly than a third generation HST instrument, the schedule for the investigation is constructed around the possibility of a launch at the end of the decade. The community is now being polled for views and ideas and there will be a written report—in the style of the famous 'Strategy Panel Report'—to NASA early in 1993. There is a real possibility of international collaboration in the project and we in Europe should devote serious thought to our potential involvement.

The idea of Saturday's panel discussion was, ultimately, to elucidate some vision of the future of near-IR/optical/UV astronomy from space. We are only now attaining a position from which we can begin to assess the impact of HST on astronomy and this enables us to predict with some real confidence the performance of the corrected instruments following a successful refurbishment mission.

It is clear that, in spite of their well-known problems, the spectrographs are a great success and are in the process of producing a wealth of previously unobtainable data. The spherical aberration usually has little effect on the data quality, simply limiting the rate at which photons are collected. The cameras are somewhat more contentious but do, even now, provide us with qualitatively better views than from the ground of fields which contain sharp objects. The value is clear of the range of sophisticated image-processing tools which have appeared or been recognised for their suitability. They certainly work well on the high S/N images which have only recently been obtained.

Panel Members

Bob Kirshner
Bruce Margon
Robert Brown (moderator)
Lo Woltjer
Bob Fosbury
Riccardo Giacconi

The advantage of being able to schedule series of observations with purpose and reliability is just being appreciated: the Cepheid light-curves obtained in IC 4182 with the WFC are a splendid example. Several people emphasised that we should do the very best with what we have now— pre-COSTAR and WFPC II —and, given the residual ignorance of the state of the project within the community and the public, make sure that people hear about the scientific results.

The real observational efficiency of the spacecraft operation is an often-expressed concern. While the HST is currently working close to its designed scheduling efficiency, there are clearly ways of improving this, ultimately by 50% perhaps, but not by a factor of two. Most of the potential improvements concern the inflexibility of the ground software, e.g., the inability to make minor adjustments to requested exposure times in order to fit observations into strictly defined schedule gaps. There is also concern with the rate at which the newly available parallel observation possibilities are being exploited.

There is no plan for a successor to HST. What should we be doing about the future of near-IR/optical/UV astronomy from space? There was no detectable ground-swell of enthusiasm for an HST-II of similar complexity and breadth of objective and Giacconi expressed the view that we should be thinking of a *programme* rather than an individual spacecraft. With the rapid changes in the political balance in the world and the re-assessment of military spending which results, we have to think hard about the motivation and willingness of the taxpayer to spend money on large pure-science projects. If there is to be a 'peace dividend' at all, we must speak with a clear voice about why some of it should be spent on science.

Should we have a truly international structure for astronomical research and, if so, how would competition be maintained? Woltjer argued that the rivalry between CERN and the US particle physics community was fundamentally healthy and it would be dangerous to put all the eggs into one basket. Giacconi, it appeared, favoured competition between projects within a single community. Whichever way we go, there is now a large fund of experience in the form of a human resource which, if it is not dissipated, is available to execute new projects without starting from scratch.

Data analysis sessions

Ninety-eight percent of the HST data are processed within 48 hours and General Observers get their tapes within one week. At a data-rate of slightly more than a Gigabyte per day this performance of HST's calibration 'pipeline' is exceptional, *Ethan Schreier* proudly announced in his talk on the "Current Status of [HST] Data Analysis". Reprocessing of the whole archive to remove keyword-related and other problems should start this summer and be finished by the end of this year, when the STScI hopes to offer a decent archive research capability.

According to Schreier, the greatest data analysis challenge was and still is the correction of the spherical aberration followed by cosmic ray (CR) hit removal—a point previously also stressed by Windhorst. The 500,000 lines-of-code STSDAS package has been augmented by the standard Richardson-Lucy restoration method for space-invariant PSFs with suitable modifications for background noise and flat-fielding as suggested by Don Snyder. There are also tasks for Wiener filtering, adaptive filtering and Jansson's method. To facilitate PSF-computations a major portion of Chris Burrows' TIM package has been included into the official STSDAS release. STSDAS's capabilities to remove CRs are, however, still rather basic.

STSDAS now supports PostScript graphics and 'world-coordinates' throughout. The package has also acquired a variety of diagnostic tools. Most users will appreciate that the STScI is busy coordinating work on an X-window based user interface which has often been requested out of frustration. Prototypes are already working and can be obtained upon request from Bob Hanisch (*hanisch@stsci.edu* on the Internet).

A great challenge will be the production of the CD-ROM version of the Guide Star Catalog scans in compressed form which is going to take place in the near future.

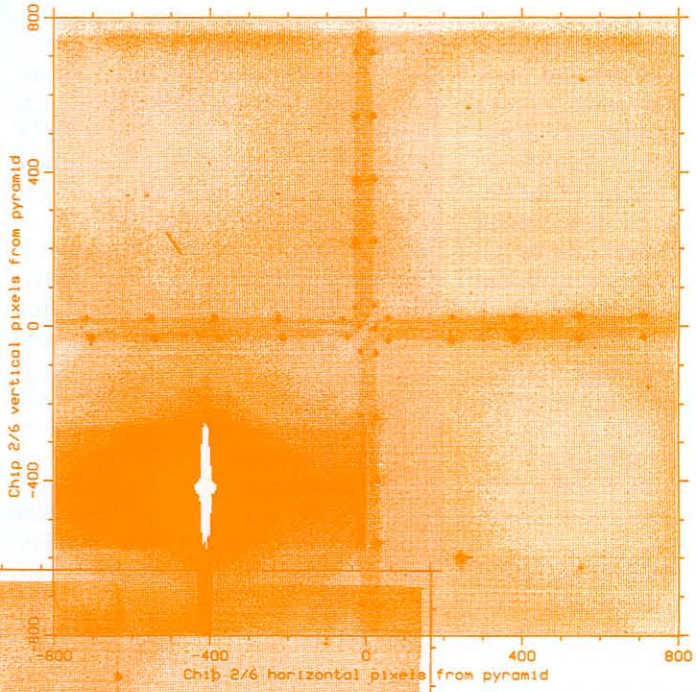
Ed Groth made heroic efforts to produce seamless 'pretty pictures' from the four separate WFPC frames in order to facilitate visual inspection of larger scale structures without the distracting seams. When developing his code, he wrestled with cubic distortions (produced by the field flattener) and various rotation, translation and scale effects which the images suffer from on their way to the detectors. His approach, which is not his first attempt, involves a complicated fitting and interpolation process across the seams where data are missing. The stand-alone VMS-based Fortran programs are available from the author (*groth@pupgg.princeton.edu* or *groth@pupgg.span*).

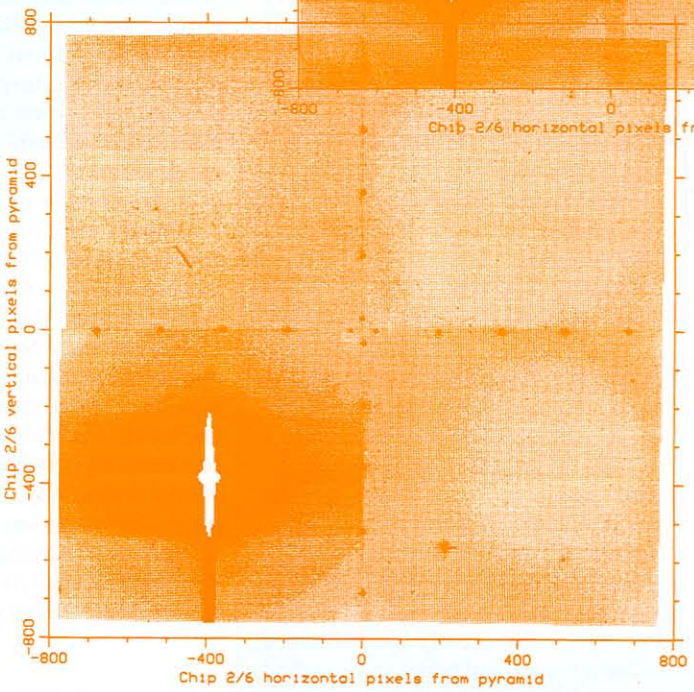
While the resulting 1600 × 1600 pixel mosaic of Jupiter looked stunning—permitting even a single frame restoration—some remnants of the chip borders remained on a similarly sewed stellar field. Groth held that photometry close to the seams is impossible and also did not claim the possibility of chip-to-chip astrometry. But he did not rule it out either. Personally he believes that it might be as good as single-chip astrometry.

Groth used images of the Kelsall spots to provide information about image distortions and registration. As opposed to real astrometric standards, the Kelsall images can be obtained on a non-impact basis.

It is remarkable that with 10 parameters one can model a complex point spread function like HST's over a dynamic range of 3 to 4 orders of magnitude. This is the conclusion which *Chris Burrows*, dubbed the 'hero of spherical aberration', drew in his talk on "Modeling the HST PSF". Burrows had originally developed his Telescope Imaging Model (TIM) to aid in focusing HST and to help understanding the performance of the overall optical system. Now it comes in handy to produce spherically aberrated point spread functions for data analysis and image restoration.

Theoretical PSFs have the virtue of being noise-free and obtainable for any desired sampling. Over time Burrows'





Stitching the WFPC chips together. Ed Groth's use of the Kelsall spots to make a clean mosaic (left) from the separate quadrants (above).

TIM software has acquired a lot of optical physics including phase errors of the primary mirror, coma and spacecraft jitter, but the complexity of the factors influencing the exact PSF shape means that 20% residuals between theory and observation still remain—although these are in the outer wings of the PSFs at low surface brightness levels.

For this (and potentially other reasons) Burrows only recommends the use of theoretical point spread functionswhen there is an emergency. Our past experience shows that emergencies are more the rule than the exception.

Experiments Burrows carried out with his model software, which is unique in allowing a fit of a PSF to an HST observation, are comforting: on WF/PC frames with their space-variant PSF, extrapolation works almost as well as fitting. In other words, the PSF parameters can be safely fitted in one chip-corner and then a good model PSF be computed for another corner. The original TIM software and the easier-to-use remake, TinyTIM, produce virtually the same results.

Gotthard Richter suggested the use of adaptive filtering in order to remove noise before carrying out a full restoration on HST images. The idea of tuning the filter according to the local S/N ratio is certainly an attractive one. However one might reasonably argue that it is not a good idea to fiddle around with the data at all prior to restoration. Adaptive filtering will certainly change the noise characteristics of the data (it is meant to do that) and thereby undermine one of the basic assumptions governing the statistically founded methods such as Richardson-Lucy or maximum entropy.

Also the observational model, which Richter and his collaborator Lorenz took as a starting point, includes the inevitable noise as an additive, stationary Gaussian stochastic component, whereas for photon-limited imagery obviously the signal itself has to be considered a (non-stationary) stochastic field with Poissonian distribution. Nevertheless, adaptive filtering may be useful under certain circumstances, such as post-processing after restoration, a conclusion supported by the results Ethan Schreier showed in his talk.

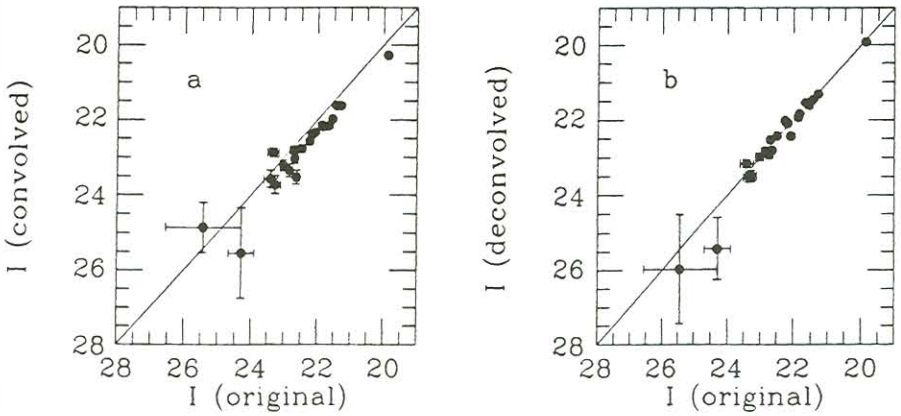
The musings of an imaginary mathematical physicist on the subject of deconvolution were voiced by *Leon Lucy*. On the one hand he realises that no gain in resolution is possible by deconvolution since an image is band-limited and, above some cut-off frequency, one has not recorded any information. However, since the Fourier transform of an object of finite extent is an analytic function, it should be possible to derive an analytic continuation of the data. But the gain is limited by noise and an analytic continuation requires derivatives which become increasingly poor for higher orders. The physicist concludes by expecting modest gains from deconvolution. However, there are two types of noise in astronomical images: Type 1—inconsistent with a physical object and Type 2—consistent with a physical object (i.e., signal is always non-negative). If Type 1 noise can be filtered out then the function can be extrapolated and deconvolved—object-feasibility filtering.

Application of statistical theory enables an estimate to be made of how far beyond the Rayleigh limit image processing can be pushed. Considering models of image duplicity and applying Monte-Carlo simulations enables the dependence of resolution on signal-to-noise to be found. The resolution increases with the counts to the one eighth power for reasonable total counts (> about 100). Thus, if the resolution is to be increased by a factor of two, 256 times as many counts are required in the image.

A powerful technique was outlined whereby images with different PSF's can be co-added (see *ST–ECF Newsletters* Nos. 16, 17). Traditionally, images with poorer seeing are discarded and only those with the best seeing are co-added. However, for space-based images, where the resolution is good but the number of photons low (the photons are expensive), it would be useful to combine with ground-based images where the resolution is low but the number of photons large (cheap photons). The images can be combined using a maximum likelihood approach with weights provided by the exposure times and iterative deconvolution applied. The final recombined image is presented with the resolution of the highest resolution image. The application to HST images shows attractive gains.

Hans-Martin Adorf pointed out a number of applications of interpolation to HST data where important gains can be made over the simple linear or cubic spline interpolation schemes. Examples are co-addition of shifted and/or rotated undersampled images (such as for WFC), correction of FOC geometric distortion where the scheme in use in the pipeline causes a low level pattern across the image, and resampling of spectra. When resampling, it is vital to preserve the high spatial frequencies and non-local interpolators, such as sinc-interpolation, are required. Spectra with unevenly spaced channels can be rebinned or images with different pixel sizes can be co-added via a 'distorted sinc' interpolation first devised by Cauchy and a band-limited continuous signal can be reconstructed without errors. A major problem yet to be tackled is combination of shifted and rotated WF/PC frames where the computational burden is huge, both in the geometric transformation and the interpolation steps.

The advantages of restoration applied to HST data have not yet been properly quantified. Although this cannot be done in a general case as it depends on the nature of the source—point source or extended—and the signal-to-noise, any guidelines in particular cases are useful. The situation of studying faint galaxies was considered by *Rebecca Elson,* with a view to determining what impact deconvolution would have on the Medium Deep Survey. Galaxies with total signal-to-noise of 10–100 were simulated and tests with MemSys5 maximum entropy code performed. Restoration showed no gain in distinguishing stars from compact galaxies at low to medium signal-to-noise but did show a distinct gain in determining the true shape of a galaxy profile allowing distinction between spirals and ellipticals to be more surely made. Generally, restoration is not important for determining magnitudes except in those cases where the extensions of the galaxy images overlap. However, characteristic radii may be equally well measured from observed or deconvolved HST images.



Photometry from deconvolved images. As part of the Medium Deep Survey project, Rebeccca Elson discussed the effects of maximum entropy restoration on aperture photometry of simulated images.

Orazio Bendinelli and his collaborators carried out surface photometry of a globular cluster in M31 using two FOC *f*/96 images taken through the F430W filter. He compared the results of three dif-

ferent restoration methods, namely Richardson-Lucy (RL), maximum entropy (MEM) and regularized multi-Gaussian (RMG). Of these the latter is less well known.

The derived cluster brightness profiles turned out to be fairly independent of the method used. The similarity between the MEM- and the RMG-curves is particularly striking. (However it should be understood that RMG is not a general image restoration method applicable to the generic 2D HST image restoration problem.) The RL-method was also successfully used to more than double the number of algorithmic detections of 'isolated' stars.

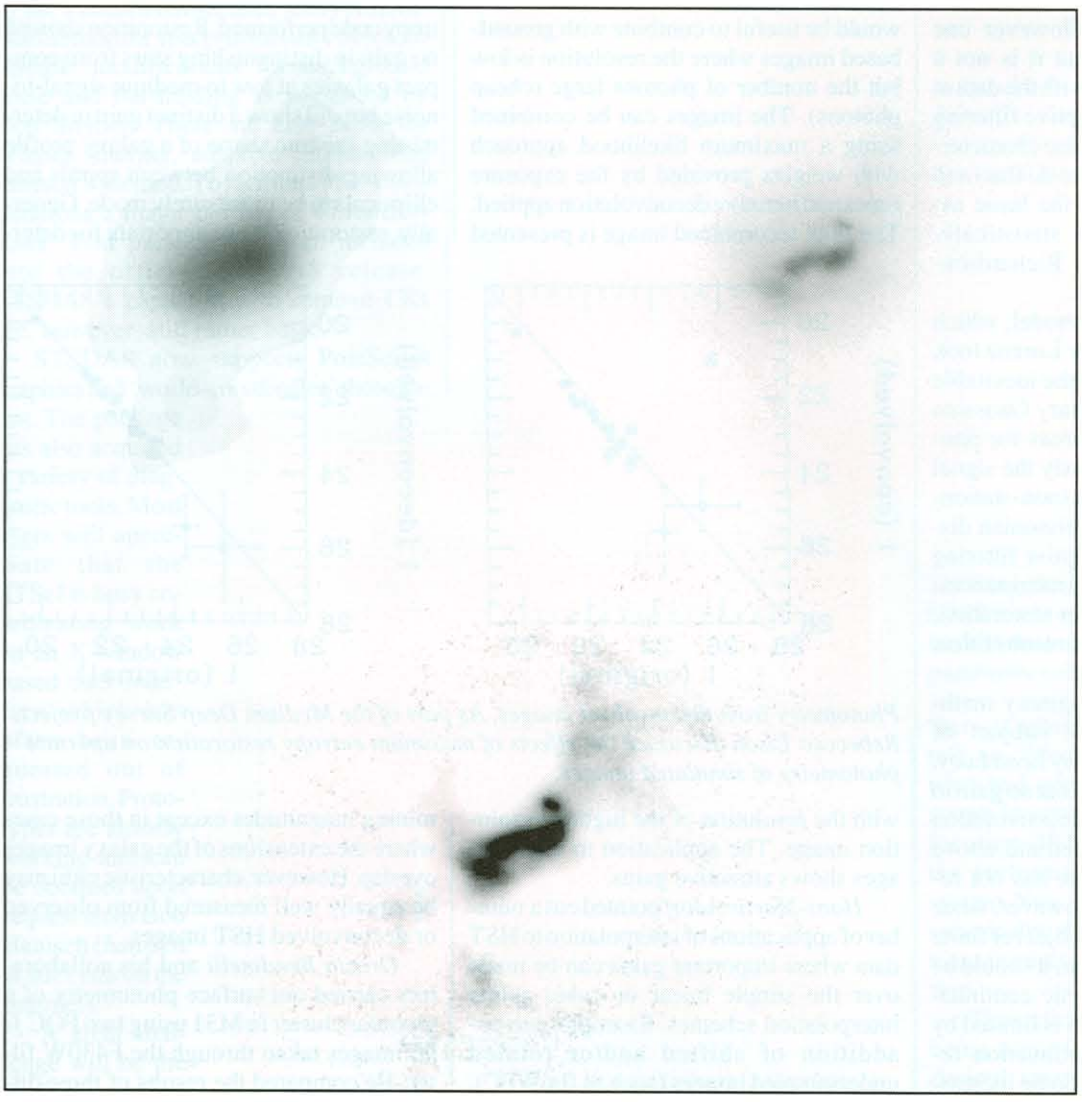
Richard Hook presented a poster with several impressive two-dimensional examples demonstrating the power and usefulness of the generalised co-addition algorithm devised by *Leon Lucy*. Co-addition works by maximizing the joint likelihood of two images (typically a ground-based and a space-born one) via a weighted variant of the standard Richardson-Lucy method. Since the maximum-likelihood restoration is carried out to convergence, it benefits substantially from the speed-up obtained with the accelerated Richardson-Lucy algorithm.

Bob Thomson and *Craig MacKay*, while working on an FOC *f*/96 image of the 3C 273 jet, part of which lies close to the right frame border, touched upon a subtle problem of the FOC that has escaped the attention of most others so far. It seems that the scanning beam of the back-end TV-camera jitters at the beginning of each new line after fly-back. Consequently each recorded image will suffer from geometric distortions which are noticable as some induced wavy intensity patterns.

How can the scanning behaviour of the beam be characterised? Thomson & MacKay have developed a simple but ingenious solution. Under the assumption that the distortions are a horizontal and vertical phenomenon only, they Fourier transform the image, interpolate across the 'cross' containing the horizontal and vertical frequency components and transform back. Subtracting the result from the original image produces a 'scan file' which can be used to derive effective pixel sizes and locations. Subsequently they rebin the data from the derived non-regular to a regular pixel grid using a simple (and fast) nearest-neighbour interpolator.

Not all FOC frames will have to be 'descanned', though. Thomson & MacKay conclude that descanning is most appropriate for images with faint sources located close to the right frame edge.

Rodgier Windhorst, in his efforts to resolve morphological structure in distant (weak radio) galaxies, used neither Richardson-Lucy nor maximum entropy, but CLEAN to restore his WFC images. Windhost worked around the undersampling problem by replacing the truly sharp PSF core by a smoother and therefore sufficiently sampled Gaussian, thereby effectively limiting the resolution. He took painstaking efforts to remove cosmic ray hits down into the noise—exploiting his data cube of twelve exposures per field. He also let CLEAN work only with small gain factors to prevent it going astray.



Lucy-Hook combination (bottom) of ground-based (top left) and HST (top right) CCD-images (courtesy of Tsvetanov). (Hook)

Planetary studies

The HST has now successfully observed most planets and several comets. The advantages of the telescope in this field are essentially the same as for other areas of astronomy—increased spatial resolution and increased spectral coverage. There is, however, the additional and very significant advantage of being able to carry out medium- and long-term monitoring; something which cannot be done with fly-by missions. Many of the new results come from UV imaging and spectroscopy. The major problem which is unique to solar system observing is that of tracking moving objects but this has proved moderately successful thanks to much work by STScI staff. Planetary images were among the early results back in 1990 and these included spectacular and widely published images of the equatorial storm on Saturn and first GO images which were the first of a long-term monitoring program of Mars.

Todd Clancy and *Steve Lee* described the first HST UV imaging of Mars which enabled the mapping of the ozone distribution in the Martian atmosphere. The images show more ozone at the poles where water vapour—which destroys ozone—is frozen out. Some surface features are also faintly visible, in particular the Tharsis region and the Hellas basin. It has also proved possible to image Mars successfully when it is smaller than 5 arcsec in diameter (the limit from the ground is about 10 arcsec). This enables much longer campaigns limited only by the HST's sun angle restriction of 50°.

The primary conclusions of this work are that the Martian atmosphere is now drier and colder than it was during earlier spacecraft visits and that there is no evidence of dust storm activity. Scattering models fit the observed characteristics of the atmosphere well and also show no evidence of dust. The image data for these, and most of the other planetary images presented, were restored using the Richardson-Lucy algorithm after preliminary removal of artifacts—a time consuming process.

An important question for the study of the early chemical composition of the terrestrial planets is the present abundance of deuterium in their atmospheres. *Jean-Loup Bertaux* described an attempt to measure the D/H ratio for Mars using GHRS, but the result is inconclusive. Scattered light makes this a difficult observation and the detection of the deuterium line in the wing of Lyman-α is marginal. However, the upper limit of D/H which may be deduced appears to be less than that seen in the lower atmosphere. These results suggest that Mars had less surface water originally than the Earth. Bertaux and others also stressed that the restoration of GHRS Side 1 would be very valuable for solar system spectroscopic work.

Many of the new results on Jupiter concerned the UV observations of Auroræ and the study of the inner Galilean satellite Io. Two groups had used the FOC to observe auroræ in the north polar region. These were timed to coincide with the encounter of the Ulysses spacecraft in February 1992. Observations described by *John Caldwell* produced two sets of UV images with the FOC. These were made in the H_2 band features at 1575Å and 1508Å. Some other images were also taken to find the accurate position of the Jovian limb. These images show very clearly the auroral oval and a bright spot which lies to the west of the expected longitude of 180° where auroræ were detected (at much lower spatial resolution) by IUE and from ground-based thermal imaging. The size of the oval is consistent with field lines outside the Io torus but Io is probably the original source of the particles. There appear to be many temporal variations. Other imaging at Lyman-α was described by *Vincent Dols*. These were of lower signal-to-noise but also clearly showed parts of the auroral ring at higher latitude than the Io torus.

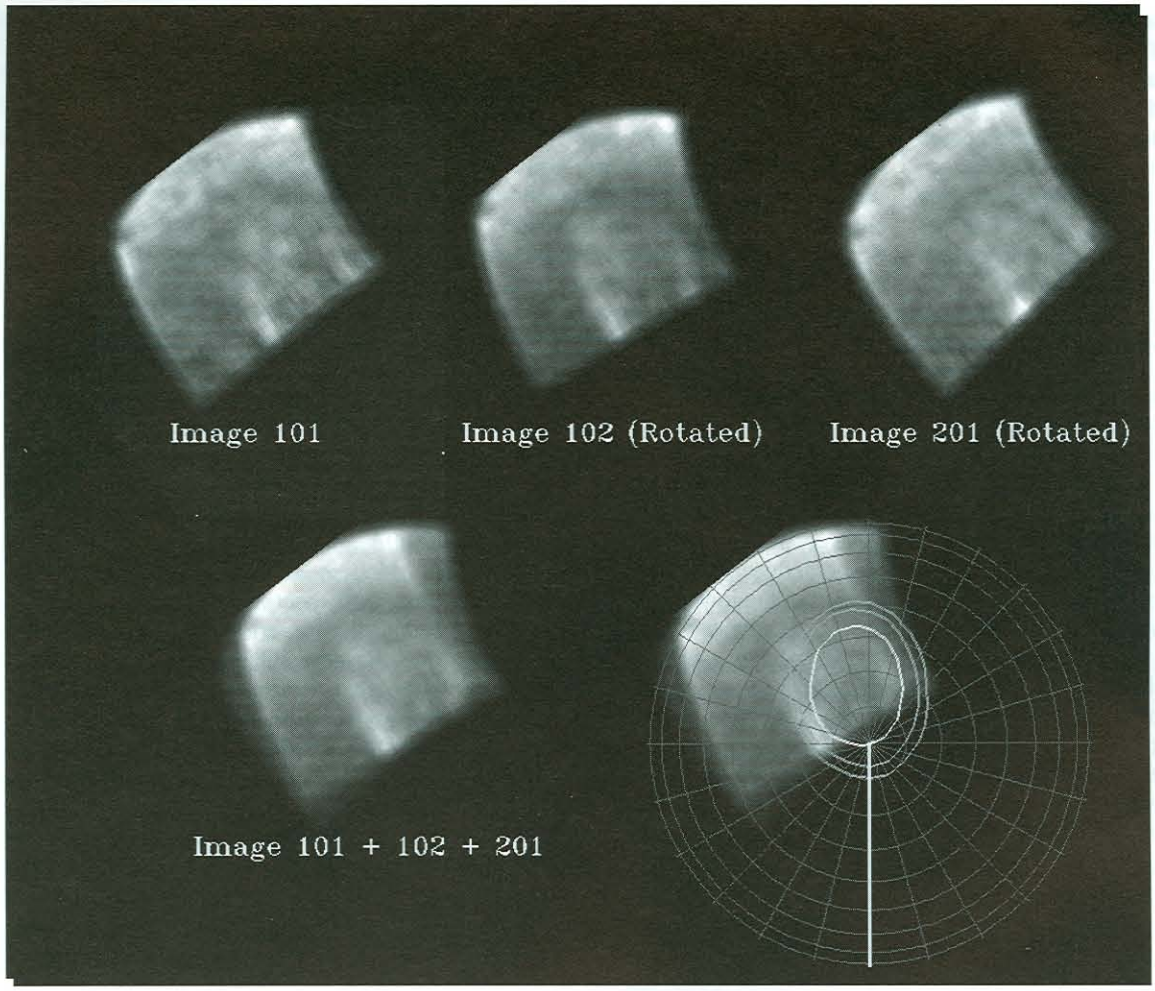
Many groups are observing Io itself and its associated plasma torus. *Francesco Paresce* described impressive new FOC direct images at 4500Å and 2900Å. The visible band images, after slight image restoration, closely matched the features visible in the Voyager pictures when the latter were degraded to a comparable resolution. This shows both the ability of the HST/FOC to image surface detail on a body only 1 arcsec in diameter and also that the surface has not greatly changed in the 13 years since the Voyager spacecraft encounters. The UV images are strikingly different, almost negatives of the visible light ones. This agrees well with a simple theory of the surface based on the properties of sulphur powder and sulphur dioxide snow. In the UV the albedo of the former is higher but this is reversed at 4500Å.

Melissa McGrath and *John Clarke* described spectral observations to investigate the properties of Io's atmosphere and the associated torus. These results show that the atmosphere must be relatively small and succeed in detecting the sulphur dioxide assumed to be present. The O^+ ion is also seen in the torus for the first time

One of the most spectacular rare events which was observed by HST was the storm in the atmosphere of Saturn which appeared in September 1990. This disturbance was extensively studied using the PC and a wide spread of filters. The results of detailed analysis and comparison with models were presented by *Reta Beebe*. The storm's appearance varied significantly in different colours which selectively high-lighted different components of the atmosphere. Analysis of these images yielded the new result that the equatorial winds appeared to decrease with altitude. The storm itself seems to have been the result of a single 'burp' from lower layers into the upper atmosphere. The recovery from this major disturbance was rapid.

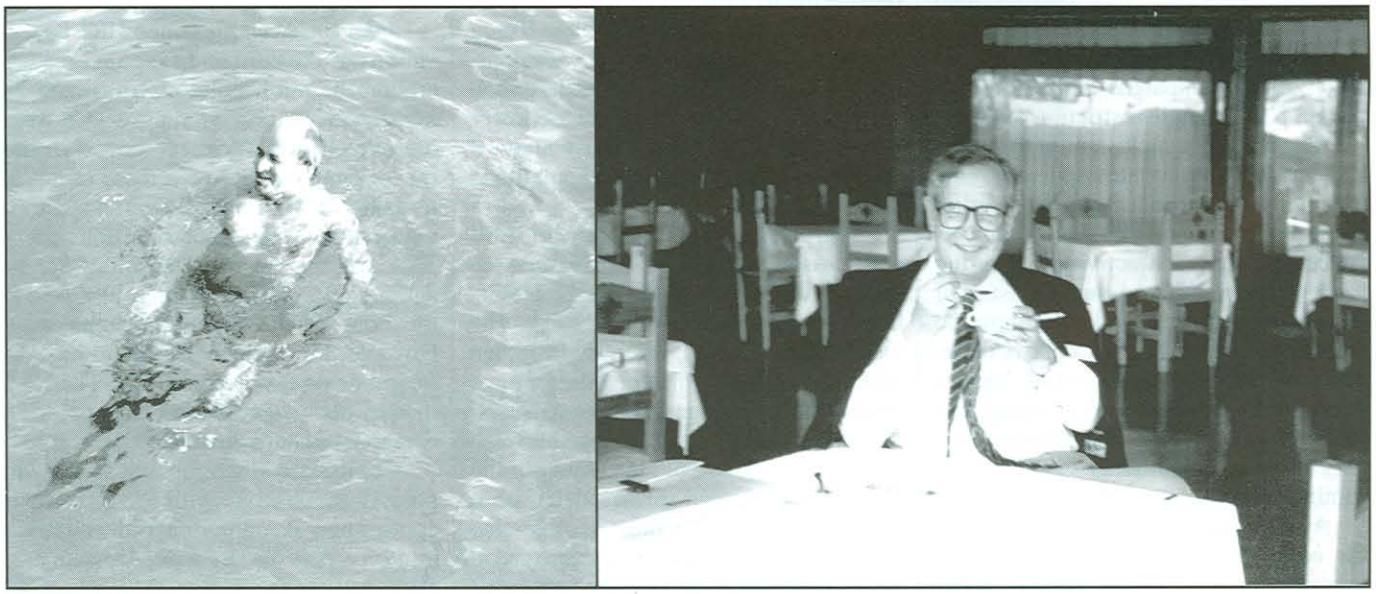
John Caldwell presented HST observations of the curious hexagonal feature around the north pole of Saturn and its associated white oval spot. These were discovered by the Voyager spacecraft and the long interval between these observations and the HST ones allows an approximate estimate of the spot's rotation period. This matches the radio period of Saturn and suggests that the spot may be linked to the core of the planet in some way. However, there are clearly also motions in longitude on faster timescales. The HST images also suggest the presence of an octagonal feature outside the hexagon.

Comets are among the most difficult objects to observe with HST as their appearance is unpredictable and their motion across the sky rapid. Despite this, HST has so far successfully observed three and observations of a fourth will have taken place before this issue is in



FOC images of the North Polar Aurora on Jupiter obtained a few hours before the Ulysses spacecraft encountered the planet. The images were taken in the 1575Å and 1508Å H_2 auroral emission bands and have been polar-projected and smoothed to show the position of the auroral emission relative to the geographic and magnetic poles of Jupiter. (J. Caldwell, B. Turgeon).

print. The angular resolution of HST is sufficient to resolve easily the jet structures in the inner coma and under favourable conditions may even be able to resolve the shape of the nucleus itself. The extended UV response also allows the spectroscopic detection of new molecular species in the coma. *Paul Feldman* reviewed HST comet observations so far. Comet Levy was selected early in the mission and proved to have a sunward pointing fan and outwardly moving large dust grains. In September 1991 Comet Hartley 2 was observed and in contrast showed a fan away from the sun. Spectroscopy of this object provided the first observations of the CO Cameron bands in the far UV. Finally WFPC observations of Comet Faye were described by *Philippe Lamy* who is using a combination of restoration and modelling techniques to try to understand the intensity distribution close to the nucleus and find small scale features.



Jeremy Mould contemplates the scale of the Universe while Gustaf Tammann, having read his Douglas Adams, relaxes in the comforting knowledge that the answer has already been computed.

Supernovæ and interstellar medium

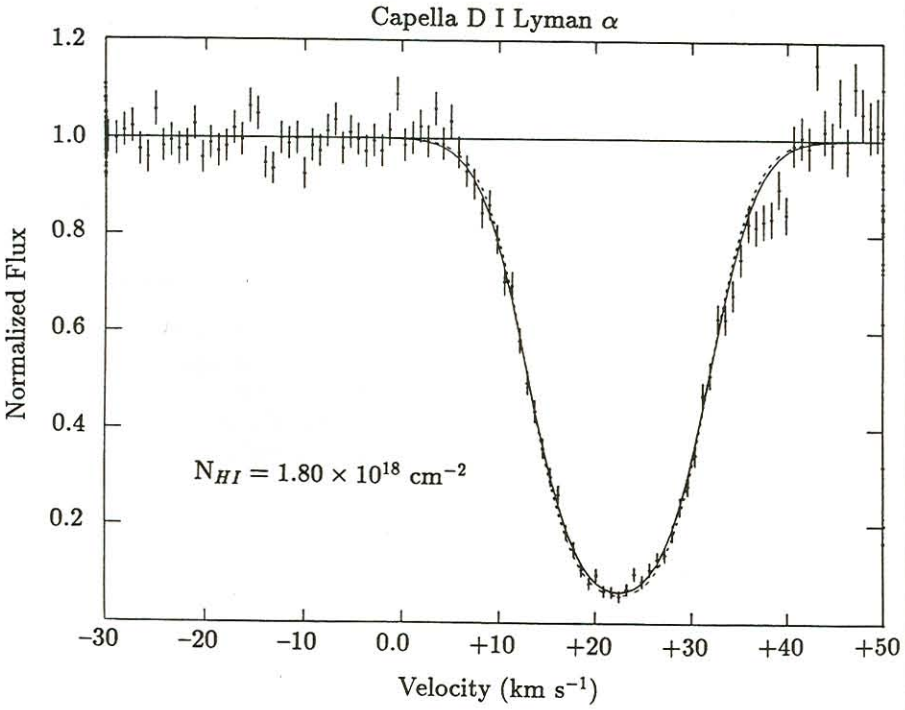
The potential for studying the ISM with the HST spectrographs is enormous. There is a huge list of resonance lines and lines from low-lying states that can be observed in the UV: including those from exotic elements like Ga, Ge, Kr etc. *Blair Savage* first described the use of sight-lines to bright, nearby stars. Working from a solar abundance corrected column density/velocity plot, the behaviour of different atomic species as a function of velocity gives a fascinating picture of the depletion of elements by dust formation in different ISM components. Differential depletions of 2.5 dex between oxygen and nickel can be seen.

He described recent work by Spitzer and Fitzpatrick which brings to fruition some of the pioneering predictions by Spitzer in 1956 on the nature of the hot Galactic corona. The widths of the highly ionized species like C IV, Si IV and S III cannot be thermal and could represent the infall of Galactic fountain gas, the slower gas having cooled and recombined.

From a sample of 16 extragalactic sight-lines it appears that 44% of the sky is covered with metal-line clouds having high or very high velocities.

GHRS observations of the binary system Capella obtained near quadrature give us a breathtaking view of what this spectrograph can do at 3.5 km/sec resolution when presented with a sufficient number of photons. *Jeff Linsky* described studies of the local interstellar medium—within the star's 12.5 pc distance—with the particular objective of obtaining a high quality measurement of the Deuterium/Hydrogen ratio. The random errors in such a measurement are small but Linsky is careful to assess the full range of systematic errors which could arise from an incorrect assumption about the intrinsic stellar line-profile. The local atomic $(D/H)_{LISM}$ ratio is 1.65×10^{-5} for this line of sight, with $\pm$ 6% random and –17 to +6% systematic error. Galactic evolution calculations indicate that the primordial value of this ratio, $(D/H)_p$, lies in the range $(1.5–3) \times (D/H)_{LISM}$. Comparing this with the standard Big Bang nucleosynthesis models implies that $\Omega_B h_{50}^2 = 0.06–0.08$.

Linsky points out, however, that this is not necessarily equivalent to saying that the universe is open!



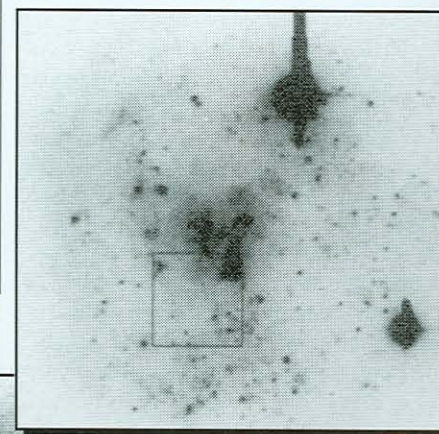
GHRS spectrum of the D I Lyman-α line profile in Capella (± 1 σ error bars). (Linsky)

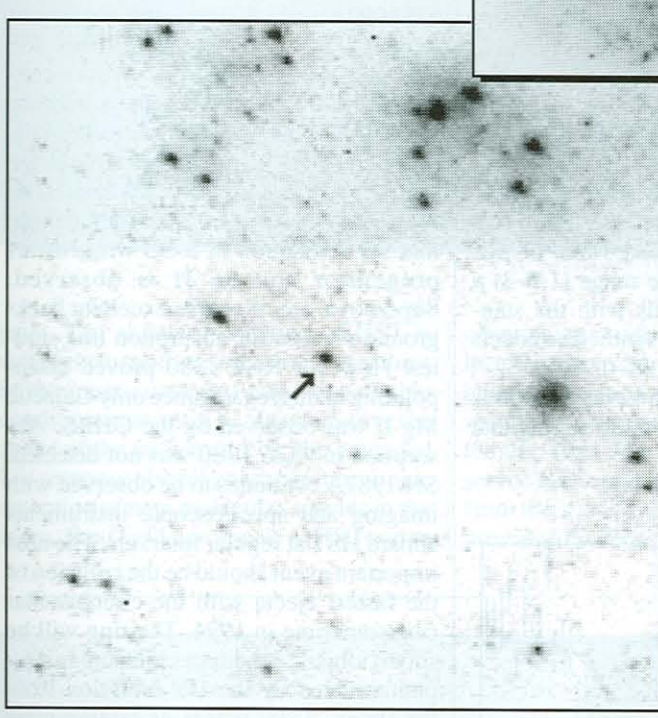
HST has already committed two SINS—that is Supernova Intensive Studies. Unfortunately, the brightest supernova for four hundred years (SN 1987A of course) erupted some years before the launch of HST. However, important imaging and spectroscopy remain to be performed. The aim of the SINS programme is to obtain early imaging and UV spectroscopy of bright supernovae soon after detection. In a feat of organization, *Bob Kirshner* obtained FOS spectra of SN 1992A only 5 days after maximum light in January of this year. This 13th magnitude type Ia supernova was discovered in NGC 1380 and is unusual in being a double detonation event where the burning wave steepens as it moves through the atmosphere. The spectrum has been modelled and shows the typical abundance mix for detonation of a CO white dwarf progenitor and no H is observed. Supernovæ are of course excellent background sources for absorption line studies. However NGC 1380 proved disappointing in this regard since only Galactic Mg II was observed by the GHRS. Absorption in NGC 1380 was not detected. SN 1987A continues to be observed with imaging and spectroscopic instruments aboard HST at regular intervals. The next important event should be the collision of the fastest ejecta with the circumstellar ring sometime in 1994. The ring will be shock ionized by direct collision and re-photoionized by the UV emission from the shock. Some words of caution were offered about using a single supernova to determine the distance to a galaxy since spectral differences occur among supernovæ of the same class which alters the absolute magnitude—they are after all not such perfect standard candles.

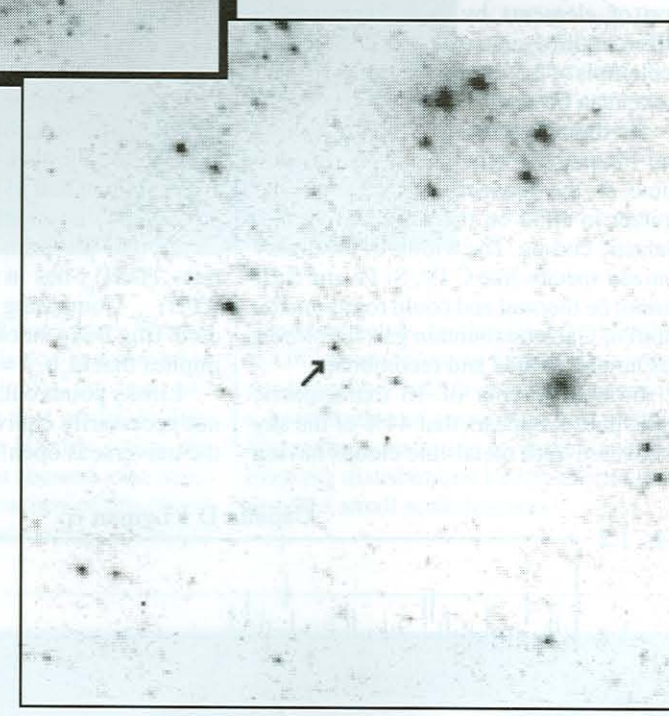
According to *Nino Panagia* the ring around SN 1987A appears to be a real ring and is remnant stellar ejecta from the earlier phases of the progenitor star. It was photoionized by the initial burst of high energy photons and is now recombining. The Carbon, Nitrogen and Oxygen abundances in this material are much enhanced above solar and the material was probably ejected during the red supergiant phase. Measurement of the diameter and inclination of the ring (assumed circular) from the well publicized FOC image allows the

distance to the supernova to be determined from the absolute radius of the ring estimated from consideration of the variation of UV emission line fluxes. The distance estimate is in excellent agreement with other distance determinations. The ring is thought to have originated when the wind from the blue supergiant collided with the non-spherically symmetric wind from the red supergiant. The central source seen on the HST images is definitely resolved and is expanding at a velocity similar to that indicated by the early absorption line widths (6500 km/s).

One of the key programmes for which it was considered that HST would make fundamental advances was determination of the cosmological distance scale and measurement of H_0. The spherical aberration has severely dented this programme but for the closer galaxies there is still the possibility of measuring their distances from the period-luminosity relation of the Cepheids. For IC 4182, *Nino Panagia* and his collaborators obtained a series of 20 sets of B, V, R images over a period of 47 days and detected 27 Cepheids with periods ranging from 4 to 42 days. The V magnitudes of the stars are 23–25 and for very small reddening to this galaxy the distance modulus is 28.47 ± 0.05 mag. A type Ia supernova occurred in this galaxy in 1937 and was well observed to have a V magnitude at maximum light of 8.55. The derived absolute V magnitude of SN 1937C was –19.92 ± 0.10. Using this calibration of type Ia supernovæ enables the Hubble constant to be determined by examining data for many type I supernovae. A low value of 45 ± 9 km/s /Mpc is derived.







A Cepheid variable captured at two different phases with the WFC (lower pair). The field in IC 4182 is identified in the 200-inch photograph above. (Panagia)

Organizing a scientific workshop outside your own Institute is a challenging experience. Many of the basic facilities which one is used to having at hand (conference room, workstations, computer links, telephone lines, unlimited stationery supplies...) suddenly become an issue or are just out of reach. This fact is only partially compensated by other attractions, described and illustrated elsewhere in this Newsletter, which are not generally available either in Garching or in Baltimore. Nonetheless, thanks to the determined efforts of the Local Organizing Committee and to the generosity of the several co-sponsors, it seems that both the scientific work and the social events unrolled rather smoothly, to judge by the positive (in some cases enthusiastic) comments we continue to receive. It would be impractical, if not impossible, to name all the contributors to the success of this Workshop, but we would like to especially express our gratitude to the Local Organizers, Ignazio Porceddu and Angelo Poma, for their constant and invaluable support, to the Regione Sardegna for its substantial financial contribution, to the Provincia di Oristano for an unforgettable feast at Tharros and, last but not least, to the secretaries of the Workshop, Britt, Christina, Loretta and Sheryl, who were seduced by the mirage of two weeks of paradise and found themselves instead cloistered into a sort of hell!

Piero Benvenuti & Ethan Schreier

Stars and stellar populations

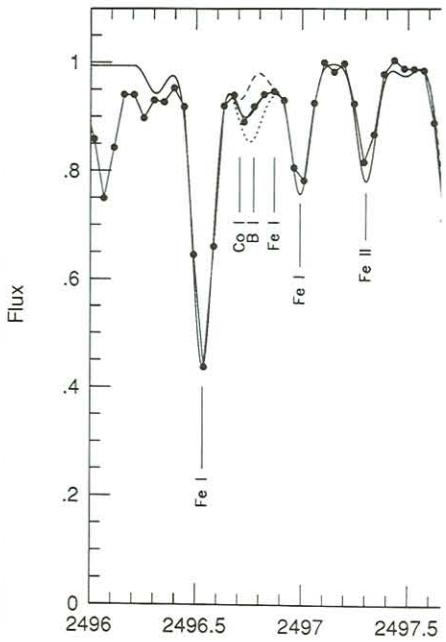
Hot stars play an important rôle in galactic evolution and enrichment of the interstellar medium through their prodigious winds and later as type 2 supernovæ. Detailed theoretical work by the Munich group, reported by *Rolf-Peter Kudritzki*, now enables good models of the spectra of hot stars to be made so that the essential parameters of the stars, their winds and abundances can be determined. NLTE modelling of $\sim 10^5$ metal lines together with hydrodynamic treatment of the atmospheres enables radii, masses and luminosities to be derived. Masses from wind modelling are more accurate than those from determining log *g* from hydrogen lines. Since most metal lines occur in the UV, spectra from space at high resolution are required. A programme has begun on spectroscopy of LMC and SMC hot stars and first results—obtained only within the last few weeks—were reported. An O3 star, Sk–68 137, was observed with FOS and was found to have an effective temperature of 60,000 K and a wind terminal velocity of 3,400 km/s. The radius was determined as 14 $R_\odot$ and the metallicity as $0.25 \times$ solar. Using these stars as distance indicators gives good agreement with other distance measurements for the LMC. After the correction of spherical aberration by COSTAR, this study could be pushed to V ~ 20 mag. stars, thus including many local group galaxies.

χ Lupi is a bright (V = 3.9) double lined Bp star with very peculiar surface abundances. For example, 99% of its Hg is in the form of ^{204}Hg, and the abundance of this isotope is 10^5 times the solar value. *David Leckrone* speculated whether such surface abundances are typical and reflect the diffusion process taking place in the atmosphere or reflect some real peculiarities in the local interstellar medium from which the stars formed. The spectra are overflowing with lines mostly of iron-group elements, and spectrum modelling is underway, although it will be years before even these few spectra have been fully fitted. The excellent relative wavelength accuracy offered by GHRS has enabled refinement of atomic data for more poorly known species. A plot of abundance *vs.* atomic number shows that the heavy elements are more strongly enhanced over solar abundances at high Z. It appears that the diffusion processes within the star may enhance the iron-peak elements in a way that mimics nucleosynthesis. An absorption line of gold was detected in this star indicating enough of the precious metal to finance a few HST's.

The transition regions of late type stars can show remarkably high ionization species such as N V and C IV. The upper regions of the atmosphere are heated either by magnetic fields or acoustic waves. *Jeff Linsky* described GHRS spectra of the line profiles of many emission lines in the giant stars Capella (G binary system) and γ Dra (K5) which show line shifts between species of differing ionization. The line wings are enhanced with the blue wing more pronounced for higher ionization lines than the red wing. This effect can be understood in terms of transport of energy in flux tubes. The gas is heated as it rises up the flux tube (blue shift) and cools as it descends (red shift). The density of the emitting gas is about $10^{10.6}$/cm^3 but there is a scatter of a factor five in the values from individual species suggesting that the atomic data may not be very reliable for these physical conditions.

Although the HSP is to be removed to make way for COSTAR there is a niche for some unique science to be performed with this photometer based on its very high time resolution (10 μsec). Optical pulsars have a very short period so the high time resolution enables small details of the pulse profile to be studied. The Crab Pulsar was observed by *Joseph Dolan* in the UV (1680–2920Å) and visible (4000–7000Å). In the visible, 2.7×10^6 photons were collected (individually!) and in the UV, some 50,000. The light curves are similar in shape in the UV and optical although the UV leading edge of the main pulse is not exactly in phase with that in the optical; the UV and visible pulses arrive simultaneously within 1 millisecond. No evidence was found for variations in pulse height or separation as a function of time suggesting that each pulse comes from a different pole which does 'know' about the other. There is evidence that the flux increases into the UV rather than turning over as expected from extrapolation of visible and X-ray data.

Doug Duncan described GHRS spectroscopy of three low metal abundance halo stars (–2.7 < [Fe/H] < –1.1) in order to measure boron abundances to complement ground-based visible work on lithium and beryllium. Re-analysing some of the recent ground-based data with the new model atmospheres used in the boron analysis (this changed the adopted gravity to which the Be abundance is particularly sensitive), the derived B/Be ratio of 10 (+4/–3) is equal to the minimum value expected if these elements are synthesised in cosmic ray spallation reactions in the ISM. This conclusion is consistent with the observed linear relationship between these elements and [Fe/H]. He argues that there is consequently no conclusive evidence for another source for the light elements such as an inhomogeneous Big Bang.



Observed and synthetic spectra of HD 140283 ([Fe/H] = –2.64) showing the fit to the B I line near 2496Å. (Duncan)

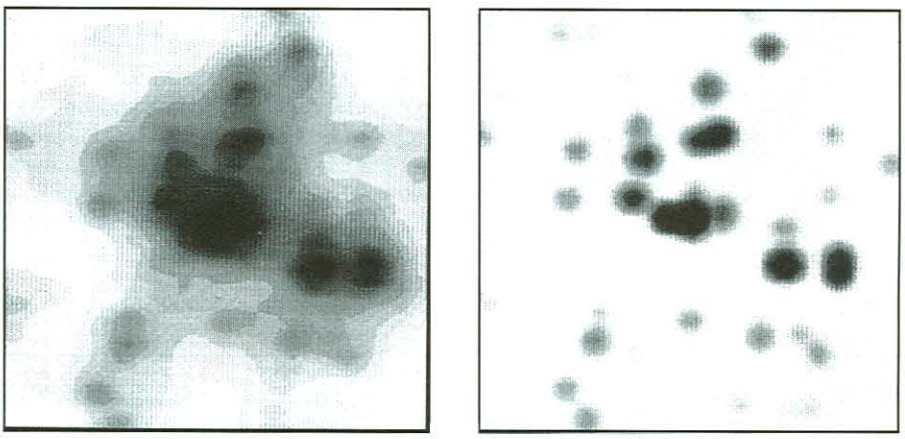
WFC observations of the Galactic bulge through Baade's window reach a limit of fainter than V = 23 and show clearly the main-sequence turn-off. With a metallicity of $Z \approx 0.01$ ($0.5 \times$ solar), it looks like an old population similar to the globular clusters. *Jeremy Mould* showed that the Bahcall-Soniera Galactic model

can fit the observed luminosity function with the 15 × enhanced bulge adopted as one way of fitting the rotation curve. There is no evidence for an initial mass function different from that derived in the solar neighbourhood.

The "Hubble Constant" key programme is designed to measure the value of H_0 to an accuracy of 10%. Mould, in one of the first reports of the progress of the work, described the use of some of the secondary distance indicators. The best of these, with a remarkable self-consistency, seem to be the measurements of small-scale surface brightness fluctuations in early-type galaxies and the planetary nebula luminosity function observations. The Tully-Fisher relationship and the type Ia supernova 'standard candle' results showed considerably greater scatter when compared with the others. The calibration of all of these distance indicators is weak and so we still don't know the scale. No 'preliminary' H_0 is going to be squeezed out of these guys!

The programme contains a list of objects going out as far as Virgo and Fornax but they are starting with M81 which can be observed with HST in very much the same detail as the LMC can from the ground. With 18 epochs of 20 min exposures over a year, they are sensitive to Cephieds down to V ≈ 23.5 and with periods greater than 10 days. Photometry is being carried out from the unrestored data but deconvolved images are used as a check for contamination. The observations are being used to calibrate several distance indicators. Reaching the Virgo Cepheids will be a real step forward but this may well take three years starting from Cycle 4.

There were two presentations on the nature of the R136 complex in 30 Doradus. *Sally Heap* showed a splendid PC picture of the 47 stars in the 2 arcsecond aperture of the GHRS centred on R136a. After making a careful a spectroscopic distinction between the three brightest stars which are Wolf-Rayet objects (WN with strong HeII λ1640Å) and the remaining early O stars, she was able to put tight constraints on the age of this cluster which is the only known resolved starburst core. It has to be greater than about 2.8 Myr to get the WN stars and less than 5 Myr to avoid having late O stars. The mass range of the stars in this aperture is 9–110 $M_\odot$ with the extraordinary result that the initial mass function has a positive slope (top-heavy in massive stars). *Eliot Malumuth* investigated this IMF over a larger part of the PC field and showed that, while the slope is negative over the cluster as a whole, there is a gradual flattening towards the centre. The question of incompleteness at the fainter magnitudes is being investigated using image synthesis techniques. There are now 450 stars in the region with measured UBV magnitudes making 30 Dor a splendid quantitative template for the study of more distant starburst regions.



A V-band picture of R136a taken with the PC. The field corresponds to the 2 × 2 arcsec aperture of the GHRS. The raw data are on the left while the right hand frame shows a reconstruction using the derived photometry and positions convolved with the un-aberrated PSF. (Heap)

The blue stragglers are thought to be primordial binaries and, as such, would be destroyed in the cores of the densest globular clusters. But they *are* found in high concentration clusters so what are they and why are they so concentrated in the cores? NGC 104 (47 Tucanæ) is the archetypal relaxed cluster. *Francesco Paresce* showed the FOC UV photometry and objective prism spectroscopy of its core. It contains a 10^{34} erg/s X-ray source, eleven millisecond pulsars (six of which are binaries) and 21 centrally concentrated blue stragglers. Is 47 Tuc teetering on the edge of a collapse or has it just emerged from a core bounce? Binaries provide a good clue.

Paresce has a good candidate for the X-ray source (X0021.8) identification: a star with U = 20.9 but a rising flux into the far-UV, characterised by a 20,000K blackbody. It is variable at 140 nm by 1.5 mag in a few hours and is the only variable in the core.

Luciana Bianchi sketched the results of the large precursor ground-based and IUE programme on the nature of the brightest stars in M31. One of the aims of the recent FOS UV spectroscopy is to test the dependence of stellar wind velocity on metallicity which is observed when comparing massive stars in the Galaxy and the LMC. The fitting of model profiles to the strong lines yields an estimate for the mass loss rate which appears, like in the LMC, to be lower than in the Galaxy. This, together with the LMC-like extinction law, suggests that M31 may have undergone just a single burst of star formation rather than the more continuous process that we see in our galaxy. Having seen the R136 story though, Sally Heap pointed out that these luminous 'stars' may indeed be multiple objects in which case the profile fitting could lead to erroneous mass loss rates.

α Orionis is an M supergiant whose UV spectrum displays many strong absorption and emission lines. *Kenneth Carpenter's* poster showed the strong and broad absorption lines which arise from molecules, principally CO, and atoms at a temperature of 500K whilst the emission lines from low ionization species, such as Fe II, S I and O I, arise in the chromosphere. The Fe II lines are fluorescently pumped by Lyman-α. A real continuum was measured at 1200Å which is thought to be formed in the chromosphere.

η Carinae and its associated nebula, the Homunculus, has alredy been the subject of a published HST observation but new images, taken with the PC by *Dennis Ebbets* at different wavelengths, show unprecedented detail down to the resolution limit of the PC. η Carinae itself is seen to consist of a bright source and four maxima which show fair agreement with the positions of the Speckle sources discovered from the ground. From profile fitting, the individual sources appear to be extended so are most probably knots illuminated by the central supermassive star. The outlying condensations generally show numerous small (~ 0.25 arcsec) condensations with no evidence of alignments or organization. However the N condensation to the north-east shows six condensations strung out in a well-collimated line. Comparison with ground-based images allows the proper motions of these condensations along the jet to be measured. There is a suggestion of uniformerly decelerated motion of these knots.

The study of the small-scale structure of planetary nebulæ is one to which HST is well suited and the size and ionization structure of globules is of considerable interest in understanding the origin and evolution of planetary nebulæ and for

photoionization processes in general. NGC 6164/5 is a large nebula with two large bright lobes, one of which was imaged by *Glen Mackie* using the WFC. There is much structure visible with striations and wisps and many condensations whose size is in the range 10^{15-16} cm. The condensations are typically crescent-shaped with the tails pointing away from the central ionizing star. In contrast, for NGC 6853, where a linear reolution of 4.5×10^{14} cm is achievable with HST, no condensations were found. However there are small scale structures concentric with the central star.

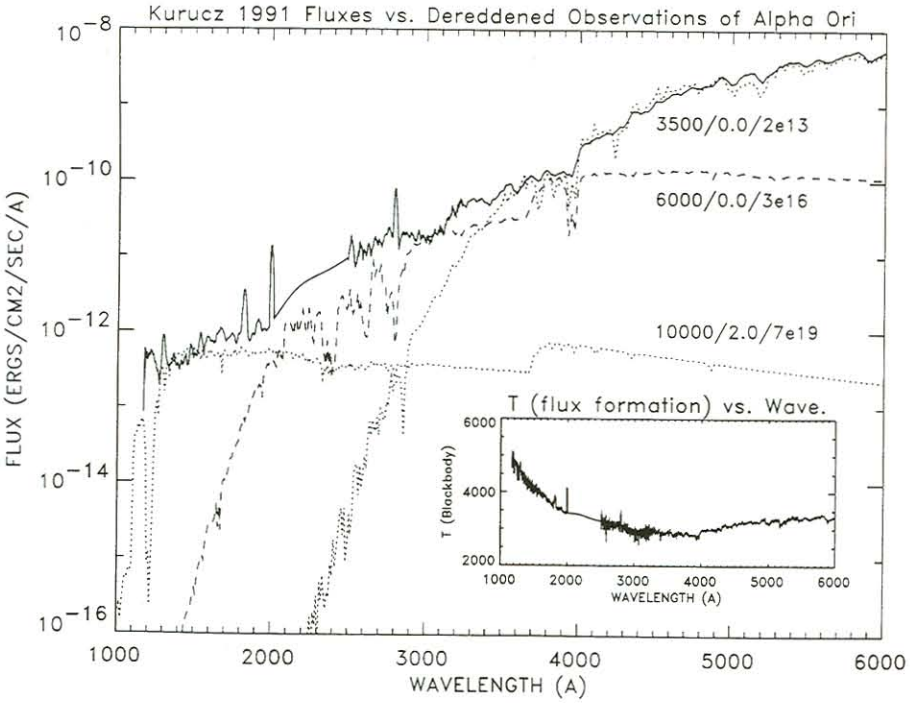
X-ray bursters have been located in the cores of some globular clusters and some 10 are known. Ground-based imaging is hindered by the severe crowding in these regions so the search for optical candidates should be facilitated by HST imaging. Once likely candidates have been pin-pointed, follow-up spectroscopy can be performed. *Bruce Margon* has searched for UV excess objects in NGC 6712, 47 Tuc, and NGC 1851. NGC 6712 shows an obvious X-ray candidate within the error box but its luminosity is rather low. In 47 Tuc, a possible candidate has been identified but there is risk of chance superposition by one of the blue stragglers which have been discovered with FOC imaging.

Ground-based CCD images have been compared with PC images of the globular cluster M15 in V and R to quantify the sensitivity and advantages of HST data. The aperture photometry was done using only the total counts in the cores of the aberrated HST images, whilst DAOPHOT2 was used for the ground-based images. The comparison, by *Sergio Ortolani* and *Fionn Murtagh* shows that HST data provides better photometry and completeness than the ground-based data. On the ground-based CCD image 160 stars were found whilst 913 were found on the HST PC image in the same field.

X-ray Nova Muscæ has a 10.5 hour period and UV and optical spectroscopy were obtained with FOS from 1500 to 4800Å. A poster by *Fuhua Cheng* presented the spectrum which shows a strong 2200Å feature and dereddening reveals a power law with slope $\alpha = 0.3$, typical of a canonical accretion disk. The derived lower limit to the mass of the central compact object (perhaps a black hole) is 10 $M_\odot$ and the distance is 8 kpc. No cooling front predicted for accretion disk instability models was observed.

GHRS spectra of the active dwarf star AU Mic were obtained by *Bruce Woodgate* in rapid readout mode around the lines of Lyman-α and Si III. A series of twelve 30 min sequences were obtained in an effort to detect the impulsive phase of a flare as the protons propagate down and excite H by charge exchange, emitting in the Lyman-α line. The predicted observational result should be an enhanced red wing to the Lyman-α line and since this phenomenon may be short-lived, high time resolution spectra are necessary. One flare was encountered just before an observing session and a significant enhancement was indeed observed in the red wing. The enhancement lasted 3.2 sec and a 6 σ detection was made. The implied energy of the proton beam is 10^{30} erg/s and such beams may play an important rôle in the dynamics of flares.

The HSP has proved that it is capable of useful scientific results as demonstrated by very high time resolution, high frequency resolution (long time sampling) and good repeatability. The dwarf nova Z Chamaeleontis was observed by *Jeffrey Percival* every four days or so over a period of 6 months in the UV (1550Å centred filter). Using maximum entropy reconstruction, the surface brightness of the accretion disc was modelled from its decline in brightness from normal outburst. The mass accretion rate is about 3×10^{-10} $M_\odot$ /yr. An occultation of a 12th magnitude star by Saturn and its rings was also observed by HSP. The orbital motion of HST causes a spacecraft parallax effect which produces a curlicue path of the occulting star across Saturn although resolutions of a few km on Saturn are achievable. Occultation events were recorded across the azimuthally varying Keeler Gap which will supplement Voyager 1 data on this feature whose dynamical cause is not yet understood.



The spectrum of α Ori. Scaled Kurucz model flux distributions are compared with observed dereddened UV and optical flux measurements. The insert shows the variation of the flux creation temperature with wavelength in the far-UV.

STScI NEWSLETTER

The Space Telescope Science Institute publishes a Newsletter at regular intervals (3-4 times per year). The STScI Newsletter contains information of interest to proposers, including updates on the status of the HST and its instruments. Subscriptions are available at no cost to all interested scientists; requests to be added to the mailing list should be sent (by regular or electronic mail) to the User Support Branch at the following address:

User Support Branch
Space Telescope Science Institute
3700 San Martin Drive
Baltimore, MD 21218
USA

E-mail: scivax::usb (SPAN)
usb@stsci.edu (Internet)
usb@stsci (Bitnet/Earn)

Requests should also specify whether the subscriber wishes to receive future Calls for Proposals.

News

Contents

Changes to the ST–ECF electronic information services

Until recently we used a VAX/VMS bulletin board system for our STINFO information service and this was described in detail in earlier Newsletters. This system provided up-to-date information about HST and other news items by allowing remote users to login to an ECF machine and run a bulletin board program. Unfortunately, we have found that this software does not work reliably under the newest versions of VMS and we have decided to move the service. It is now implemented as part of the 'news' system on one of the ESO UNIX machines.

Although the software is different, the old access routes may still be used. You may login to the machine STESIS (DECnet name: STESIS = 28.99 = 28771, Internet address: stesis.hq.eso.org = 134.171.8.100) using the username STINFO and will then be connected automatically to the UNIX host supporting the new system. Alternatively you may access the latter machine directly by making an Internet connection (normally using the 'telnet' command) to the machine stinfo.hq.eso.org=134.171.8.4 and then logging in as 'stinfo' (no password). If you cannot access either SPAN (DECnet) or Internet (TCP/IP) then you may also connect via the public packet switching data networks (X.25) to the number 0262 458900924 which will also connect you to the same machine where you may again login as 'stinfo'.

We have retained the STDESK account for receiving mail enquiries and the addresses given in earlier Newsletters remain valid. We welcome any comments about how these services may be improved.

Finally we should like to stress that ST-ECF Internet connections, and those of ESO as a whole, are now routed to all external Internet hosts through a fast link supplied and maintained by ESA. This has reduced our dependency on low-throughput Deutsche Bundespost connections and provides much better links to most sites. However, if you are having problems connecting to us please let us know and we will endeavour to help you.

Richard Hook

We should like this Newsletter to reach as wide an audience of European astronomers as possible. If you are not on the mailing list but would like to receive future issues, please write to the editor stating your affiliation.

Contacts at ST–ECF

Head: P. Benvenuti
Tel., +49–89–320 06 290
Computer: PBENVENU

Science Data and Software: R. Albrecht
Tel., +49–89–320 06 287
Computer: RALBRECH

Science Instrument Information: R.A.E. Fosbury
Tel., +49–89–320 06 235
Computer: RFOSBURY

Hot-line and information Computer: STDESK (for e-mail)
STINFO (for bulletin board)

Editor: Robert Fosbury

Typeset with Apple® Macintosh™
Printed by Royal Media Werbgesellschaft mbH, Ottobrunn

Published by the
Space Telescope–European Coordinating Facility
European Southern Observatory
Karl-Schwarzschild-Str. 2
D–8046 Garching bei München
Germany
Telephone: +49–89–320 06 291
Telex: 528 282 22 EO D
Telefax: +49–89–320 06 480
Computer: *Internet:* user@eso.org
SPAN: ESO (28.88)::USER
UUCP: user@eso.uucp
Bitnet/EARN: user@dgaeso51.bitnet

esa SPACE TELESCOPE
ESO
European Coordinating Facility