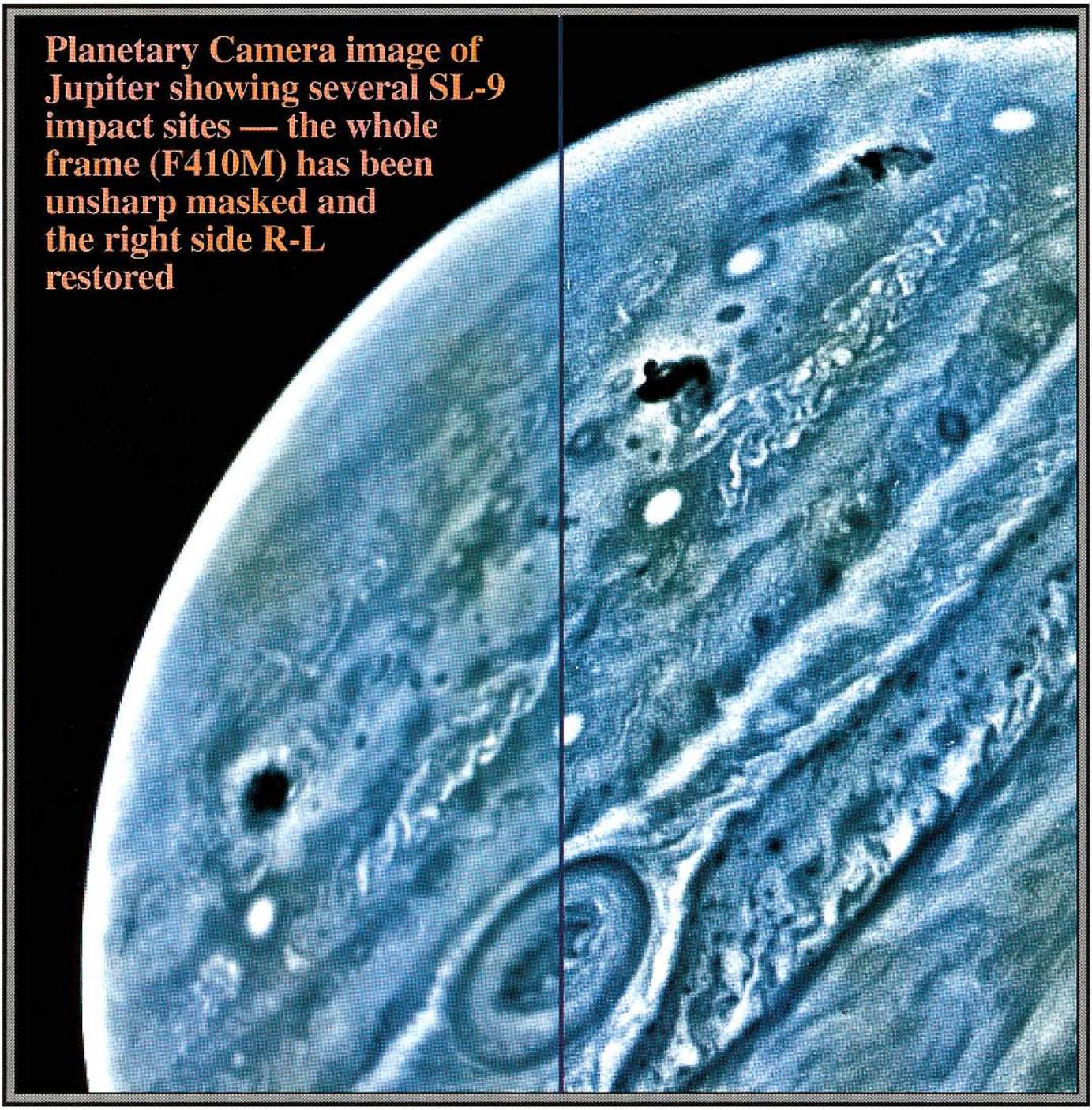
Number 22 February 1995

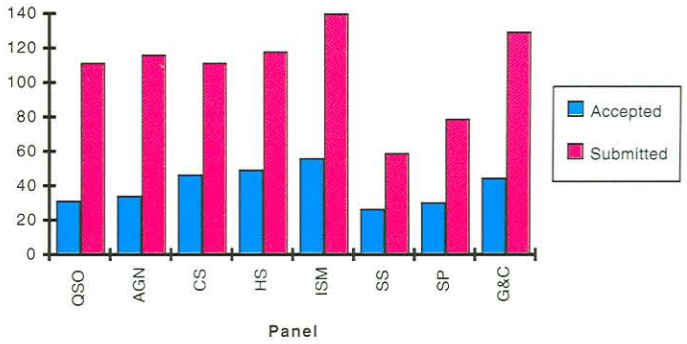
ST-ECF Newsletter

Space Telescope — European Coordinating Facility



Planetary Camera image of Jupiter showing several SL-9 impact sites — the whole frame (F410M) has been unsharp masked and the right side R-L restored

HST Cycle 5 Time Allocation

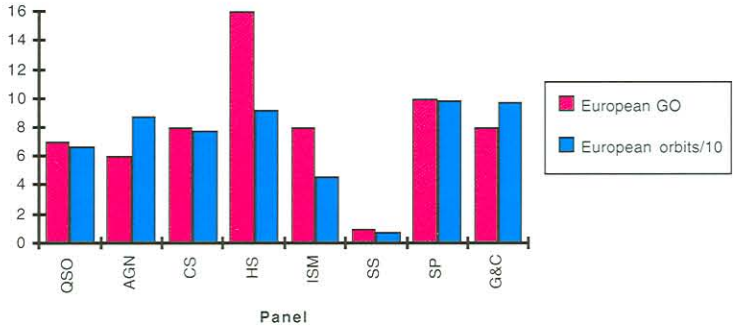


Jeremy Walsh

Following the TAC meetings described in Leon Lucy's article below, a series of Director's reviews took place to decide the final allocation. The letters to successful and unsuccessful PIs went out at the end of November and a brief overview of the statistics is presented here.

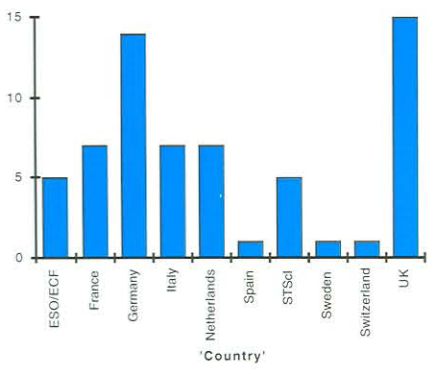
There were a total of 863 proposals for Cycle 5, including 26 parallel, 33 snapshot and 50 archive proposals (the latter US only). The requested number of orbits from the 778 GO proposals (excluding snapshot and parallel) was 14,272 and the number available 3,300; an oversubscription rate of 4.3 by orbits. In addition there was 1 Key program (100 orbits) requested and 20 target of opportunity proposals.

The final allocation was to 310 GO proposals, with 6 Snap and 36 archive retrieval. Thus the average GO allocation was 10.6 orbits. The first figure shows the breakdown of submitted and accepted proposals by TAC panel. The highest success rate in terms of number of successful proposals to number submitted was achieved by the Solar System proposers and the lowest in the area of QSOs and AGN. The largest number of successful proposals was awarded by the ISM panel (18% of total) but the largest time allocation was to Galaxies and Clusters (18.7%). The breakdown by instrument was very much as expected: WFPC 2 was the most popular instrument accounting for 162 proposals (although 47 of these also involved another instrument) and by orbits 46%; GHRS accounted for 79 proposals and 23.5% closely followed by FOS with 16%. FOC was used in 17 proposals although the majority of these were with a second instrument. There were 10 successful FGS proposals requesting just over 100 orbits.



Proposals with European GOs were well represented in the Cycle 5 allocation. There were 63 European GO proposals, of which 5 involved astronomers currently resident at STScI. There were 576 orbits of primary GO time, 26 orbits of parallel and 7 orbits of Snap allocated to European GO's. This represents 17.5% of the total number of allocated GO orbits. The centre figure shows the breakdown of accepted European GO proposals by panel and also the number of orbits allocated (divided by ten). The final figure shows the breakdown of accepted proposals by country. STScI refers only to ESA staff in Baltimore while ESO/ECF refers to proposals originating in Garching or Chile. In comparison with previous cycles Italy and UK did better whilst French PIs fared less well. Reflecting the overall statistics WFPC 2 accounted for 36 of the 63 proposals, whilst GHRS was the next most popular instrument with 19 proposals. There were 7 proposals involving two or more instruments. Four successful proposals used FOC. The average allocation was also around 10 orbits, with a large range from 1 to 31.

The hard work of turning the Phase 1 allocation into a workable Phase 2 proposal begins with staggered deadlines in February/March. Let's hope that all of the successful PIs can realise schedulable observations in Cycle 5, which starts around June 1995. Cycle 6 may well be another short Cycle (as Cycle 3) if STIS and NIC are installed in early 1997 as currently foreseen.



Reflections on the TAC

Leon Lucy

Having just learned the outcome of their Cycle 5 applications, PIs and CoIs might be curious about the operation of the Proposal Review Panels (PRPs) and the Time Allocation Committee (TAC). The following remarks are based on the author's sitting in as an ESA observer for extended periods at seven of the eight PRPs and then participating as a member-at-large on the TAC.

For this cycle, there were eight PRPs: Galaxies & Clusters, Hot Stars, Interstel-

lar Medium, Solar System, AGN, Cool Stars, Quasars, and Stellar Populations. The Stellar Population panel is new, and the previous AGN panel has been split into two: AGNs and QSOs. Each PRP comprised a chairman and seven other members, and its activities were monitored and facilitated by two STScI coordinators. In addition, other STScI staff with relevant expertise were called in as necessary to comment on questions of feasibility.

ESA had one representative on each panel. In addition, one panel chairman and one TAC member-at-large were ESA nominees. The remaining panellists, chairmen and members-at-large were selected by STScI, mostly but by no means exclusively from staff at US institutions.

Needless to say, all panellists are astronomers with significant achievements in one or more areas covered by their panels. Accordingly, for virtually every proposal, there was usually more than one panellist with research-level familiarity with the topic in question.

The task of each PRP was, first, to rank-order the proposals before them, and then, from the highly-ranked proposals, put together a scientifically-balanced core programme to be presented to the TAC. This core programme, which the TAC was expected to approve without change, was to amount to 80% of a zeroth-order estimate of the orbits available to that panel. The remaining GO orbits were allocated by the TAC from highly ranked proposals that didn't make these core programmes but which the panel chairman presented as meriting observing time.

Prior to the PRPs meeting in Baltimore, each proposal had been read by one principal and two secondary reviewers, and these three had already communicated to the STScI their preliminary grades, the average of which was therefore an initial indication of a proposal's chance of getting time. At the PRPs, each proposal was described and even argued for by its principal reviewer, supplementary remarks were added by the secondary reviewers, and then the panel as a whole discussed the proposal until the chairman judged the time appropriate to call for a vote. Typically, a proposal was discussed for 10 minutes, but for a few contentious, major proposals, the debate extended beyond 30 minutes. Even when lasting no more than a few minutes, these debates were informed, penetrating and fair-minded. In particular, panel members were scrupulous in absenting themselves or abstaining if they or an institutional colleague were PIs or CoIs on the proposal under discussion. Moreover, the merits of proposals were discussed independently of their origins (e.g., US or non-US), and the institutional affiliation of the PI was only mentioned when the in-house expertise was a relevant issue.

The oversubscription for the orbits available to GOs was by a factor 4.3. Obviously, therefore, proposals that were graded as less than excellent were not assigned time. Moreover, even from among the excellent proposals, some were assigned zero orbits and many assigned fewer orbits than requested. How such decisions were made is perhaps of interest.

A reduction below the number of orbits requested was usually proposed by the principal reviewer or the panel chairman when they sensed that a higher grade would be achieved by a more modest proposal. Although the PIs to whom this has happened might initially view such reductions as capricious or random, they were in fact done intelligently: the reduced target list or sets of filters etc. being designed to allow some, if not all, of the stated scientific goals to be achieved.

On reflection, therefore, the PI will almost certainly find that a significant investigation can still be accomplished with the reduced data set, and that the resulting publications should provide strong support for related proposals in later cycles.

Proposals that were highly rated but nevertheless got no time fell into two categories:

1) There was a competing proposal with essentially identical scientific aims and which the panel rated higher.

   In addition to avoiding duplication of effort, the constraint of producing a balanced core programme dictated that the weaker of similar proposals be assigned zero orbits. Note also that, wisely, it is STScI policy that panels are not to suggest collaborations between such competing groups; consequently, the best proposal gets all the time.

2) The project can be carried out with ground-based telescopes.

   Panel members took very seriously Bob Williams' directive that HST is a unique and valuable resource that must not be used if the same science can be achieved from the ground. Obviously, this consideration had a big impact on imaging investigations, especially those before the Galaxies & Clusters panel. Time and again the question was asked: would CFHT or NTT images suffice? If the answer was yes, the orbit allocation was zero, even if the PI and his team were themselves unlikely to get time on these telescopes.

In addition, some proposals that were perhaps intrinsically excellent received mediocre grades and so got no time. Among these were a few that were badly written or poorly argued and so did not provide the (always well-intentioned) reviewers with an adequate brief. A second category under this heading were proposals where the collective expertise of the team was perceived to be inadequate. This was rarely stated, but the opposite was. Thus, when the PI and CoIs constitute a strong group, obviously capable of making excellent use of HST data, this was remarked upon and very likely contributed to a higher grade.

How to win HST time

From the remarks made here, a few lessons can be drawn to help insure that an excellent scientific idea gets the telescope time it deserves.

- ❑ The proposal should be prepared with the appropriate template and diagrams should be of high quality.
- ❑ The scientific justification must be clearly developed in readily understood English.

  Investigators whose papers are criticized by referees for poor writing should get their HST proposals reviewed by colleagues. With a paper, one can revise and resubmit; not so with an HST proposal.
- ❑ CoIs should be selected in order that expertise is evident for all aspects of reduction, analysis and interpretation of the data.

  A non-trivial point in this regard is whether the expertise, which may have been aquired in a different branch of astrophysics, will be obvious to the relevant HST panel. If not, it should be stated.
- ❑ The proposal should explicitly justify the need for HST if this might be questioned — eg, imaging in optical bands.

WFPC 2 aperture photometry and PSF modelling

Since the WFPC 2 undersamples the PSF, aperture photometry can produce results which are competitive with profile fitting in many situations. This article reports an investigation of aperture corrections using both real data and PSF models.

Nial Tanvir†, David Robinson† & Ted von Hippel†

The wide-field chips in WFPC 2 have ~ 99.6 mas pixels which are larger than the FWHM of the point spread function (PSF). This poor sampling of WFPC 2 images means that simple stellar aperture photometry is competitive with profile fitting for moderately crowded fields. One of the problems which must be addressed with profile fitting photometry is that of allowing for variations of the PSF as a function of position on the image. The equivalent problem for aperture photometry is obtaining aperture corrections as a function of position. The aperture correction must be added to each aperture magnitude in order to account for the flux from the star falling outside the aperture. If the aperture used is large, and with WFPC 2 this means about 1 arcsec in diameter, then the aperture corrections will be both small and fairly constant. However, to obtain better signal-to-noise and hence take full advantage of the superb resolution of HST, especially in crowded fields, it is desirable to use smaller apertures.

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Photometry of NGC 2477

We have used *V* and *I*-band WFPC 2 images (filters F555W and F814W) of the open cluster NGC 2477 to explore the issue of aperture corrections. The data were acquired to investigate the white

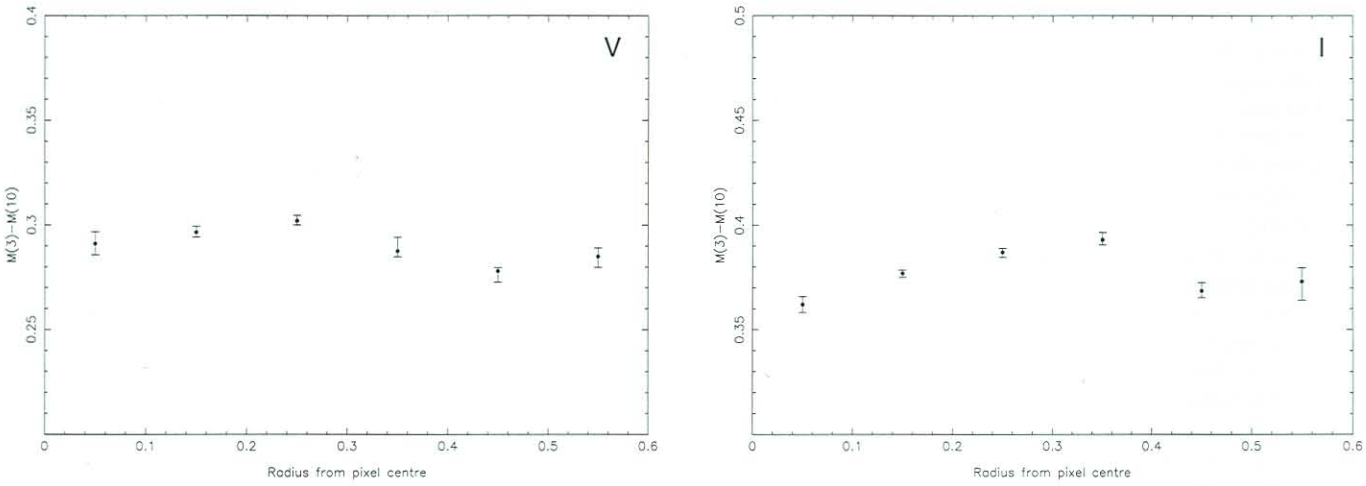

Figure 1: Plot of aperture correction as a function of the centroid position of the star within a pixel. The data for all CCDs are binned and a clipped median is found. The error bars represent the interquartile range of the clipped data, divided by the square root of the number of data values within the bin.

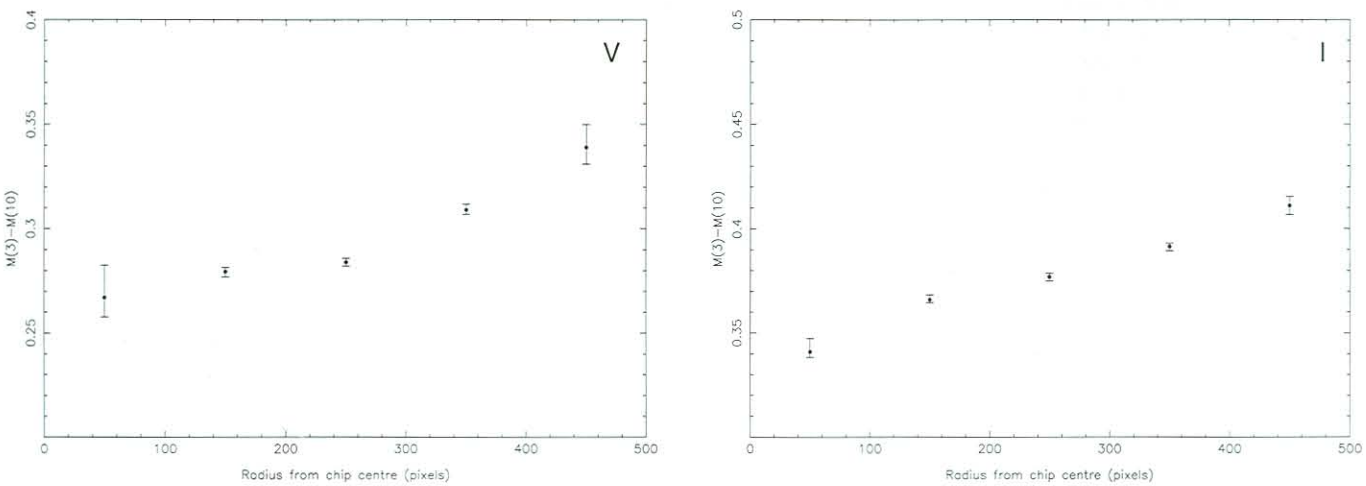

Figure 2: The aperture correction (between apertures of 3 and 10 pixel diameter) is shown to correlate with radius from the centre of each chip. A similar variation is seen in both V and I.

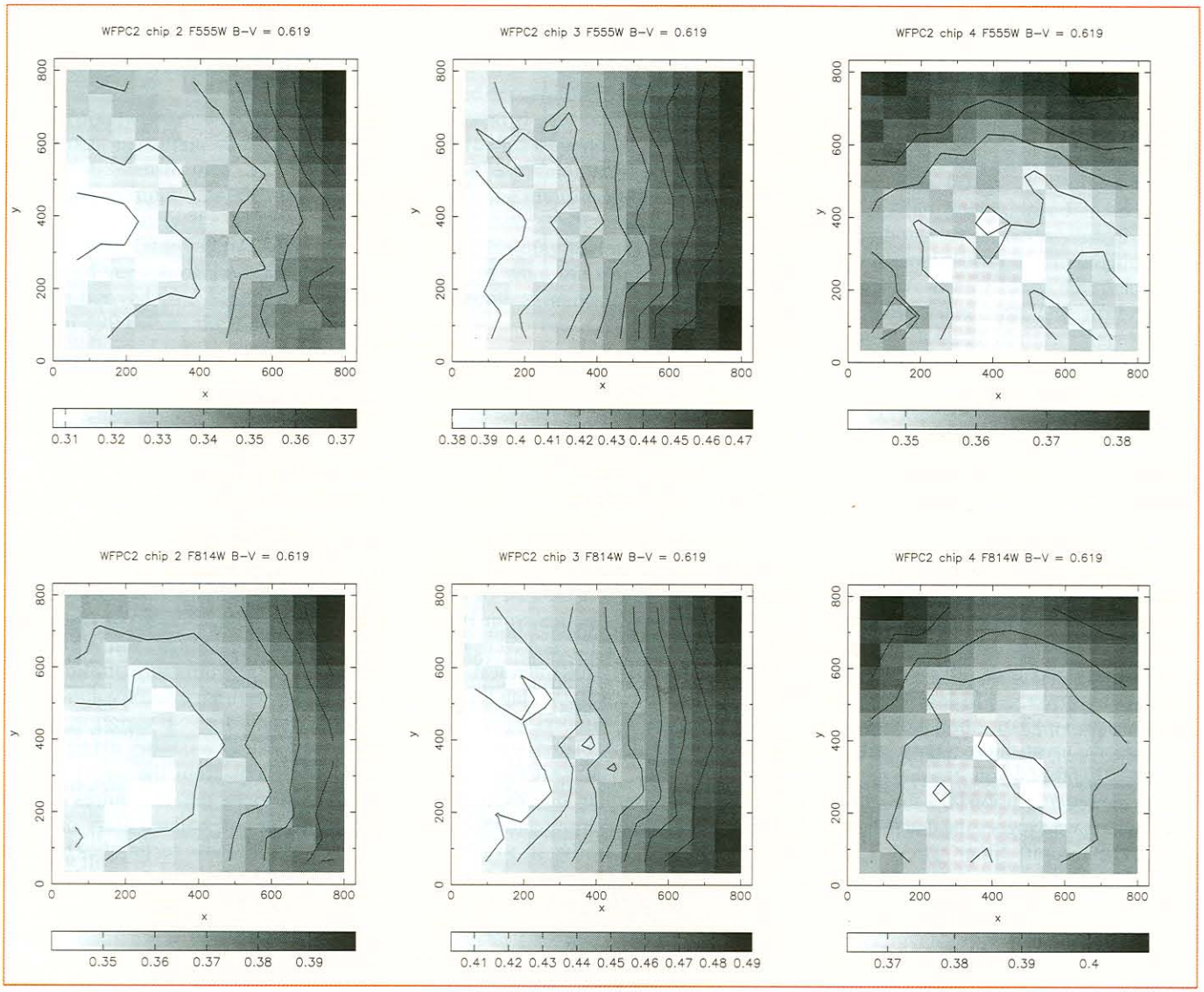

Figure 3: These maps show graphically the difference in aperture correction (3 to 10 pixels diameter) as a function of position which is predicted by TinyTim. Plots are shown for the three wide-field CCDs on WFPC 2 in each of (a–top) V-band (filter F555W) and (b–bottom) I-band (filter F814W). Contours are spaced at 0.01 magnitude intervals. Variations as high as 0.08 magnitudes are seen across individual chips, and some variation is also predicted between the chips.

dwarf cooling sequence and the low mass end of the main sequence in this cluster (von Hippel et al., in preparation). However, the large number of bright, reasonably uncrowded, stars makes these images particularly suitable for photometric experiments.

We used the PHOT routine within the IRAF implementation of DAOPHOT 2 (Stetson 1987) to obtain aperture photometry in 3 and 10 pixel diameter apertures, corresponding to 0.3 and 1 arcsec. To ensure good statistics, only stars with a s/n > 30, as determined by PHOT, were used. First we plotted the aperture corrections as a function of centroid position within a pixel (figure 1). Since the PHOT routine computes magnitudes by fractional pixel integration of counts within the circular aperture, some effect of pixelation would be expected. This figure shows that any systematic variation of aperture correction with position of stellar centroid within a pixel is ≤ 3 % for each band, even for such a small aperture. Definitive characterisation of this dependence will require further experiments.

We then proceeded to plot the aperture corrections binned as functions of various geometric parameters. The greatest correlation was seen when the corrections were plotted against the radial distance of the star from the centre of each CCD. This effect (figure 2) seems roughly linear and is in the sense that stars in the centres of the chips are somewhat sharper than those near the edge, amounting to a difference of 0.07 mag in the aperture correction. Because it is similar in both *V* and *I*, derived colours, at least, should still be reasonably accurate. This is important for studies which rely on field stars to estimate reddening.

TinyTim simulations

To investigate this further, we constructed grids of PSFs using the TinyTim v.4.0b image modelling software (Krist 1994). Each simulation consisted of 144 PSFs arranged in a 12×12 grid at 64 pixel separation. Grids were created for each of the three wide-field CCDs in both *V* and *I*. We chose to create the PSFs with no simulated 'jitter' effect, and for stars of intermediate colour ($B–V = 0.619$). Changing the colour to $B–V = -0.155$ only affected the photometry by 0.2 %.

The results of these simulations are presented in graphical form in figure 3a,b. Again we have calculated aperture corrections using PHOT, although this time the 'data' have essentially infinite signal-to-noise. It is clear that the sharper PSFs (ie, the smaller aperture corrections) are also generally found in the chip centres in these simulations. However, the apparent variations as a function of row and column, which are largely due to the tilt of each CCD in the focal plane, are rather higher than we see in the real data. Furthermore, TinyTim also predicts a variation from CCD to CCD in the sense that WF 2 should have the sharpest PSFs on average and WF 3 the broadest. The NGC 2477 data do show this effect, al-

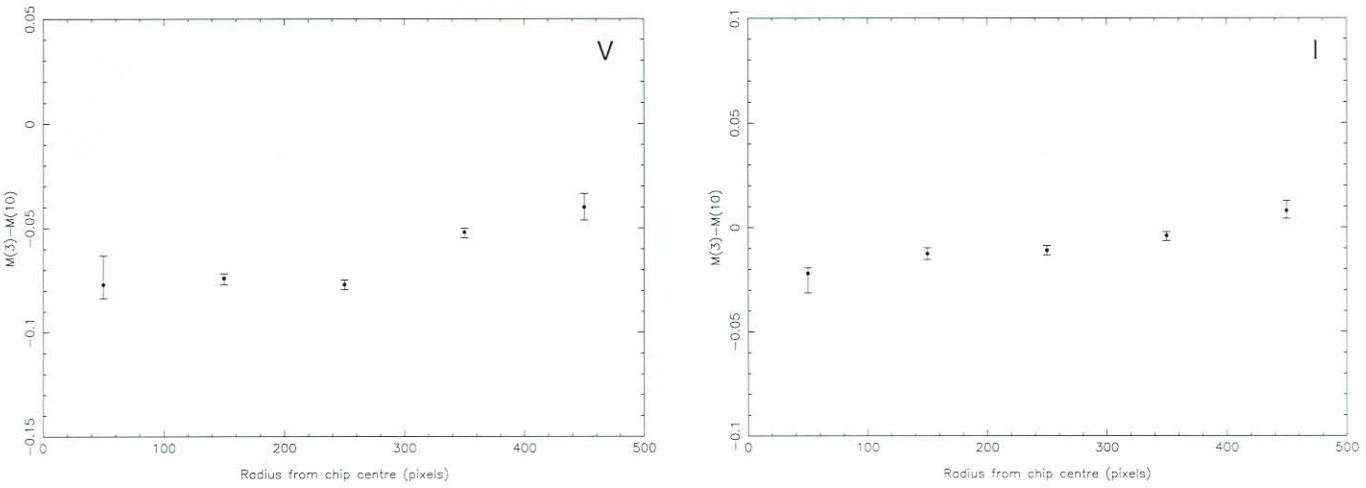

Figure 4: The radial dependence of aperture correction is reduced when the TinyTim predictions are accounted for. The residual difference between the data and the models could be explained by small focus changes which the HST experiences.

though at a lower level.

Using the TinyTim maps to correct the NGC 2477 aperture magnitudes (figure 4) shows that the variation of aperture correction as a function of radial position is considerably reduced, although is still present at a lower ~ 3 % level. Not surprisingly the TinyTim simulations on average over-correct the real data, particularly in *V*. In other words, the real data are slightly lower resolution than the simulations, which we expect to be due to factors such as spacecraft 'jitter' (Bely 1994), and focus changes produced by OTA 'breathing' (Hasan & Bely 1994) and 'desorption' (the HST focus changes slowly due to shrinkage of the telescope structure, and is readjusted when this reaches a 5μm offset.). This suggests that the 'average' aperture correction should be obtained directly off the frame even if some scheme, such as the one outlined here, is used to gauge the position dependent variations. The residual correlation with radius appears real, and might also be a consequence of an off-nominal focus position. This is further suggested by the fact that in correcting the data, we actually introduce a small correlation with column number, particularly in the case of WF 3.

The aperture correction from 10 pixels (diameter) to total is given in the WFPC 2 IDT report (Holtzman et al. 1994) as 0.09 mag for *V* and 0.08 mag for *I*. We also confirm these numbers from a small number of bright isolated stars in the NGC 2477 data. The TinyTim simulations produce similar figures out to a 30 pixel diameter aperture and the variation with position of the 10 to 30 pixel correction is only of order 0.5 % (1 σ). Whilst the simulations also predict a few percent of flux at even larger apertures, this is irrelevant providing that standard star calibration is performed consistently at the smaller apertures.

What next?

We are conducting further experiments using other WFPC 2 images in order to discover how stable these effects are with time. It is already apparent that the average aperture correction over the whole image varies between data-sets, again possibly due to the effects of jitter, breathing and longer term focus changes. We are hopeful that by modifying the focus parameters within TinyTim we can obtain simulations which much more accurately match the data. Ultimately profile fitting photometry and image deconvolution also need to account for PSF variation, and in many cases it will be difficult to characterise this from the target frames themselves given that it requires a good sample of bright isolated stars on each CCD. Thus, for these techniques too, the ability to generate realistic model PSFs will be extremely valuable.

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Image analysis using Multiresolution Transforms — new results

Fionn Murtagh, Jean-Luc Starck† & Albert Bijaoui‡

If noise were not present, astronomical images would be far more compressible, linear inverse methods would be feasible, object recognition would become a purely combinatorial problem, and so on. We describe some recent work in which we separate an image into noise and 'substantive' components.

A number of novel principles are being applied in this work. In particular, the first of the two described has been investigated only quite recently.

Taming image noise

Leaving aside noise issues related to calibration — which have not been investigated in depth as yet — noise in CCD detectors is an additive set of Poisson components with a Gaussian read-out component. This is the case for the WFPC. For the FOC, the noise is more truly Poisson. We seek to assimilate such noise into one distribution — preferably Gaussian — in order to facilitate the task of determining whether pixels and objects in the image are significant or not. Use is

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‡ Observatoire de la Côte d'Azur

made of work in the statistical literature under the heading of 'variance stabilisation' which goes back to the 1930's.

A (pixelwise) transformation of the given data is sought, such that the variance of the transformed data is constant. For Poisson input data, this transformation is essentially the square root. For Poisson plus Gaussian read-out noise, an enhanced version of the same transform can be derived (see Murtagh, Starck & Bijaoui 1994). The noise distribution of the transformed image data has constant variance, unitary by design. This is of help when we process the transformed image data in that we can control the distributional form that the noise takes.

The generalised Anscombe transformation which we use requires for validity that the pixel values be greater than about 20. With its generally low counts per pixel, FOC data is less amenable to this approach than WFPC and other CCD data. We note in passing however that a transform-based strategy is available for FOC data and will be tested later.

Highest quality measurements

When removing noise from an image, we risk doing damage to the real sources. But why bother to touch the astronomical objects at all, since noisy measurements in no way limit us later from homing in on photometric, astrometric or other relationships? Furthermore, astronomical objects usually cover small portions of the image, so if we 'protect' them in some way from our noise-removal or other operations, then we are not excluding many pixels. The protection of what we consider to be our astronomical objects is done simply with a boolean mask, called a support image. If operating at different resolution levels then this support data structure is a set of boolean images corresponding to each resolution level. The support is of immediate benefit in object finding and demarcating. It is defined from input noise properties — an astronomical object is associated with a significant pixel value.

Relative scale of objects in an image

A third idea which we have been exploring is that of multiresolution: processing which takes a range of scales into account. It is traditional in astronomy to distinguish between background, smooth extended objects, larger bright point source objects, sharply peaked detector defects and so on. Each of these classes of objects manifests itself predominantly on one or more resolution level. For a general treatment of data with some or all of these types of images, a range of resolution levels should be taken into account. We usually work with four.

Noise filtering by 'clipping' wavelet coefficients at a number of resolution scales has recently become widely employed in a number of applications. When carried out carefully, it can give considerable control over what has to be considered a delicate operation — nowhere more than in astronomical imagery.

For the multiresolution work, an important issue is what transform should be used. This may partially be answered in terms of what the transform does to an astronomical object in the image: for example, non-astronomical imagery often contains alignments and linear features while most astronomical objects are point-symmetric. For some work, we have used an efficient wavelet transform approach termed the 'à trous' transform ('with holes', due to the way the convolutions used to determine successive resolution levels are interlaced). A good deal of our current work on HST images (including simulated images to aid validation) uses a multiresolution median transform. This appears to offer an effective way of finding cosmic ray hits and detector defects, both of which can be picked out at an appropriate resolution level.

A number of the papers dealing with this work are available online at URL:

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http://http.hq.eso.org/
     ~fmurtagh/
     wavelets.html
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They are also available by anonymous ftp at:

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ecf.hq.eso.org:/pub/
     fmurtagh-outgoing
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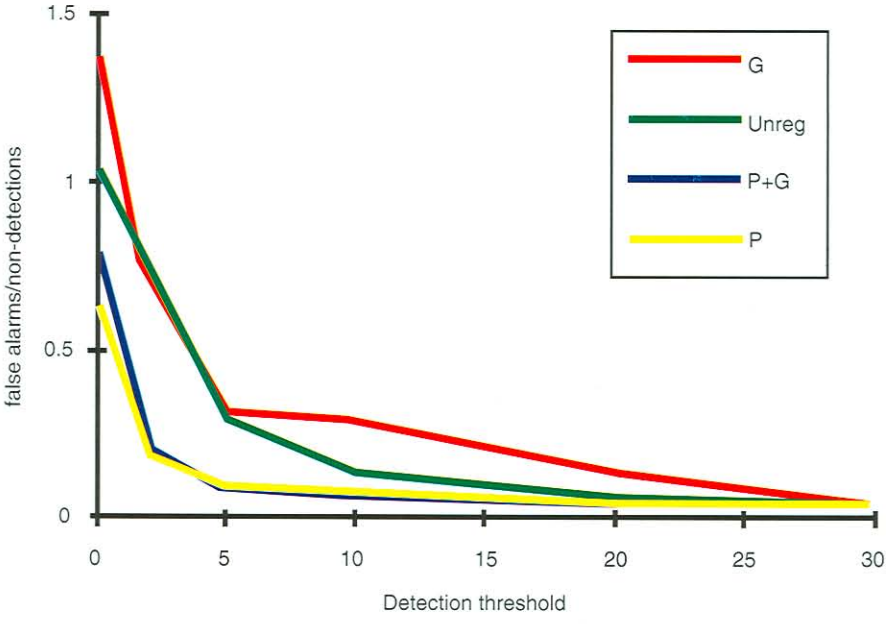
Examples of this work include the following:

- The potential of multiresolution for image enhancement was illustrated with comet images in Murtagh et al. (1993).
- A careful study of noise models (Poisson plus Gaussian, Poisson alone, Gaussian, unregularised) in image restoration is carried out in Murtagh, Starck & Bijaoui (1994). The figure illustrates the difference made by the noise model in object detection. One of the simulated globular cluster images made available in connection with the STScI Image Restoration Workshop in late 1993 was used for this experiment. The number of correct objects found, when varying the detection threshold, was clearly higher when the image was restored using the Poisson 'P', or Poisson plus readout noise 'P+G', models. The other models used were Gaussian 'G' or noise ignored 'Unreg'. Spectral filtering has been described in Starck & Murtagh (1994).
- Image compression, using a pyramidal median transform, has been found to provide compression to a few percent of the image's original size. Differenced original and compressed/uncompressed images show very limited artifacts. See Starck, Murtagh & Louys (1994).
- The multiresolution support offers an immediate definition of objects in an image. Based on this principle, an object inventory can be made. Among other advantages is a 'clean' treatment of local background. A prototype is discussed in Murtagh et al. (1994).



Plots of false alarms/non-detections for different noise models, following restoration of a globular cluster image. The number of correct objects found, when varying the detection threshold, was clearly higher when the image was restored using the Poisson 'P', or Poisson plus readout noise 'P+G', models. The other models used were Gaussian 'G' or noise ignored 'Unreg'.

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Remote STARCAT Registration & Archive User Registration forms

are available on paper in previous issues of this Newsletter or via the WWW on URLs:

http://arch-http.hq.eso.org/remote_starcat_reg_form.html

http://arch-http.hq.eso.org/arch_user_reg_form.html

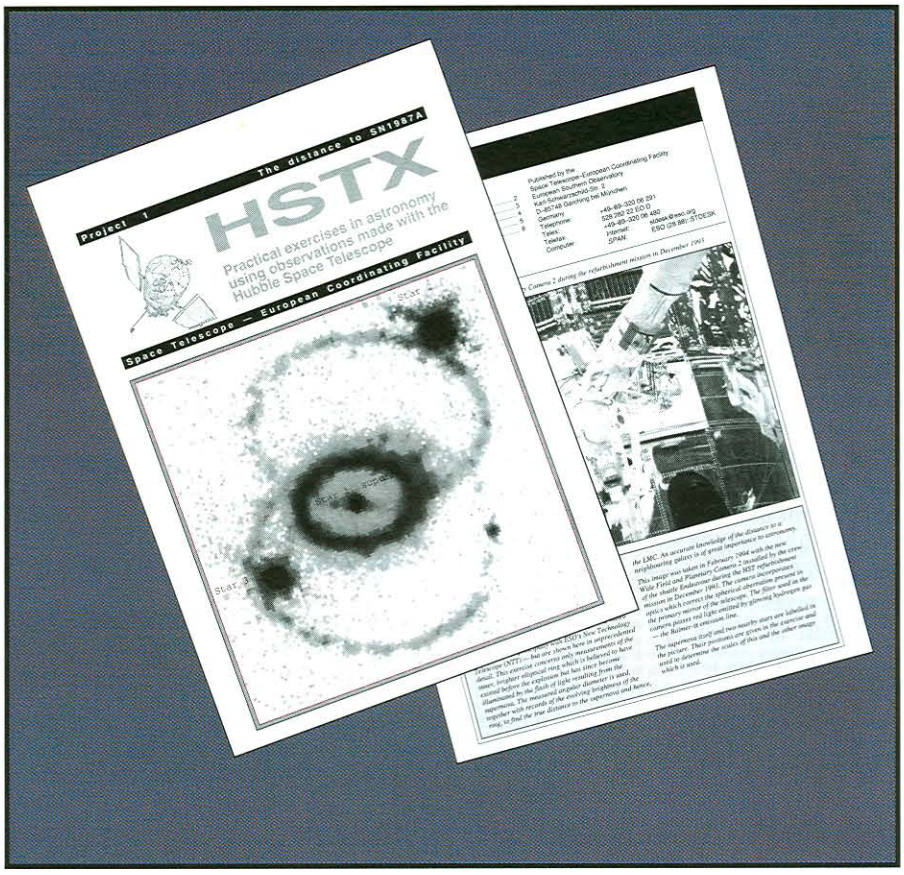
STScI NEWSLETTER

The Space Telescope Science Institute publishes a Newsletter 2–4 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)

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



Educational projects in astronomy using HST data

Robert Fosbury & Emma Fosbury†

During the summer of 1994, we prepared a prototype educational project designed for use in secondary schools and universities. The principal aim is to give students and teachers access to new data from the Hubble Space Telescope in the most convenient and exciting way. The uniqueness and profound scientific value of these data should give valuable opportunities for raising the profile of astronomy teaching and increasing the level of enthusiasm for science subjects.

Our initiative is complementary to projects underway already, eg, at the Space Telescope Science Institute in Baltimore, and aimed at the higher school levels and early university studies. Topics will be chosen which allow the student to use HST observations in a very direct way, without the need for sophisticated tools, to measure quantities of great astronomical or astrophysical importance. Our prototype, illustrated above, concerns the measurement of the distance to the Large Magellanic Cloud using observations of the size and brightness evolution of the ring which surrounds the supernova SN1987A. Another project in preparation is to measure the mass of the black hole in the nearby elliptical M87 using Faint Object Spectrograph measurements of the newly discovered gaseous disk near the core of the galaxy.

The prototype project is produced as a booklet—similar in format to this Newsletter—but future development will allow access to the material over the Internet.

These ideas were presented to the "EU/ESO Workshop on Teaching of Astronomy in Europe's Secondary Schools" recently held in Garching (25–30 November 1994) and we have already had positive responses from a number of interested teachers. We should be pleased to hear from teachers (and students) who would be willing to test our prototype and, perhaps, collaborate with us on the design and preparation of subsequent projects. Copies of the prototype may be obtained by contacting the ST–ECF.

† Pembroke College, Cambridge

The Archive column

WWW access to the HST archive

Bo Frese Rasmussen

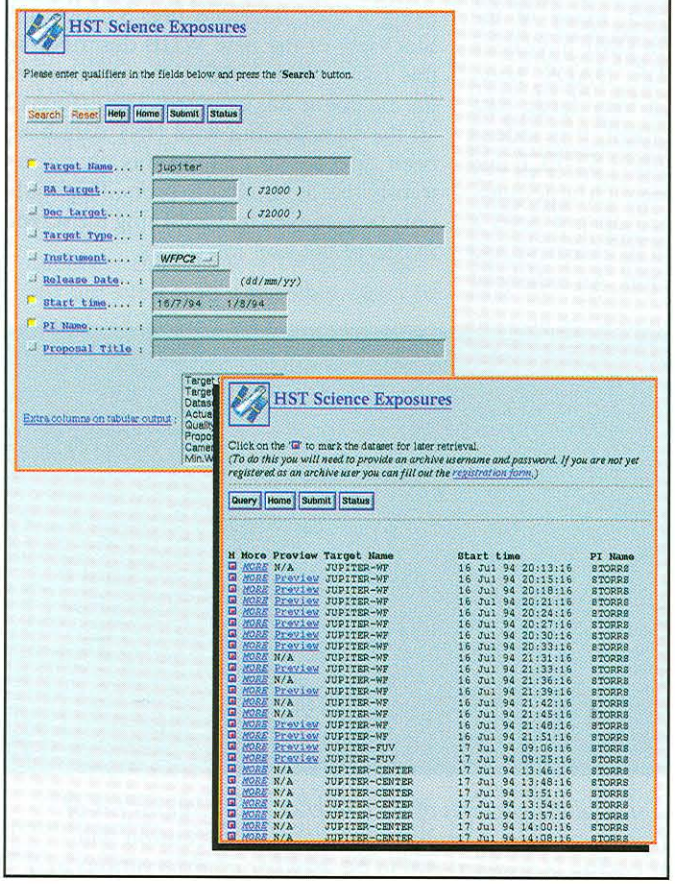
The HST archive is now available on the World Wide Web. WWW browsers, such as NCSA's Mosaic, are now becoming the interface of choice for many users when searching for information on the Internet. It was therefore a natural development for the HST archive at ST–ECF to follow this trend. This should make it easier, especially for infrequent users, to access our archive. In this way, availability is extended to a broader spectrum of users since WWW browsers now are available for almost any platform including most UNIX/X-Windows environments, MS-Windows on PC's, and on the Macintosh.

The new archive interface is available at:

`http://arch-http.hq.eso.org/HST-archive.html`

On UNIX machines the following command line can be used directly:

```
Mosaic http://arch-http.hq.eso.org/
    HST-archive.html &
```



HST Science Exposures Form.

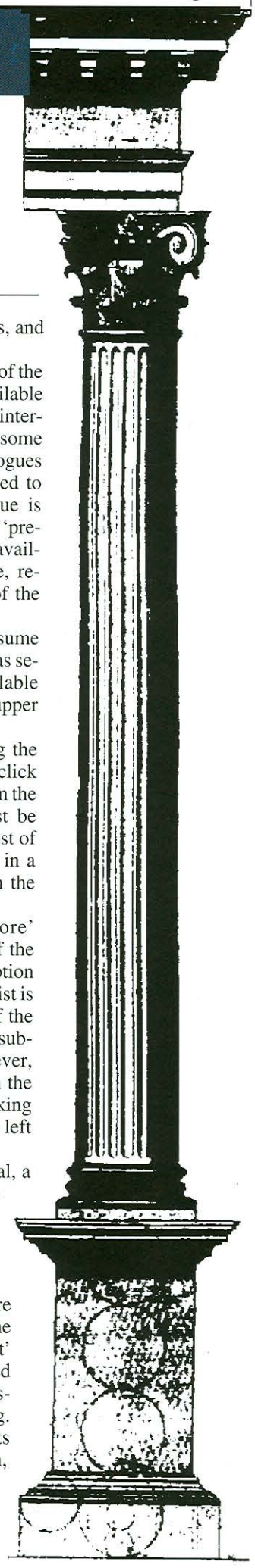
It is our goal to provide some of the more important screens now available in STARCAT in this new WWW interface. This will, however, take some time—so expect to see new catalogues and screens being regularly added to the menu. By the time this issue is delivered we should also have the 'preview' facility from STARCAT available on WWW. And, of course, retrieving HST data will be one of the possibilities.

This is how it works: Let's assume that 'HST Science Exposures' was selected from the menu of available screens. A form similar to the upper one in the figure appears.

Queries can be entered using the same syntax as in STARCAT—click on 'Help' to get a summary. When the form is filled out 'Search' must be pressed—this normally gives a list of all datasets matching the query, in a tabular presentation as shown in the lower part of the figure.

Now clicking on the 'More' hypertext link on the left side of the table will retrieve the full description of the given dataset. The tabular list is meant to provide an overview of the available data and only displays a subset of the available fields. However, the list fields that are required in the tabular list can be selected by clicking on the small toggle buttons to the left of each field in the query form.

To mark a dataset for retrieval, a click on the little red dot in the leftmost column of the tabular list is necessary. The first time around, a prompt will ask for the archive username and password. As many datasets as are needed can be marked. When the selection is complete, the 'Submit' button can be used. The marked datasets will subsequently be registered in the archive for processing. Please note that the marked datasets are remembered until submission, even if this is several days later.



Archive News

Benoît Pirenne

Almost four years of data are now available and awaiting the bright ideas of potential users. On January 1st, 1995, the archive contained over 22,000 public science observations, a significant fraction of which are from WFPC 2. Since the correction of spherical aberration, the data quality is very high and 1995 will see a rapidly increasing fraction of these entering the public domain.

Meanwhile, data processing techniques have reached maturity (deconvolution, coaddition etc...) allowing the use of them on earlier WFPC 1 and FOC data.

Table 1 presents a breakdown of science exposures (but including the photometric calibration observations) by instrument. Table 2 gives a list of all the object types observed with WFPC 2 and in the public domain from the end of 1994.

Instrument	pre-COSTAR	post-COSTAR
FOC	3067	331
FOS	3527	109
HRS	3856	1042
WFPC	7837	2538

Table 1: Pre- and post-COSTAR public datasets, by instrument.

Target class	No. public obs.
ASTROMETRIC	52
COMET SHOEMAKER-LEVY 1994	76
DARK CLOUD	5
OB ASSOCIATION	3
PHOTOMETRIC CALIBRATION	1543
PLANET JUPITER	483
POINT SPREAD FUNCTION	328
QSO	24
SPIRAL	5

Table 2: WFPC 2 public observations (as of 1st December 1994). Most of the July SL-9 WFPC2 observations became publicly available on December 1st.

New features in our user interfaces

As explained in Bo Rasmussen's preceding article, we have spent some time this last summer providing a hypertext interface to our relational database system. The result promises easier access to our catalogues via most World Wide Web browsers.

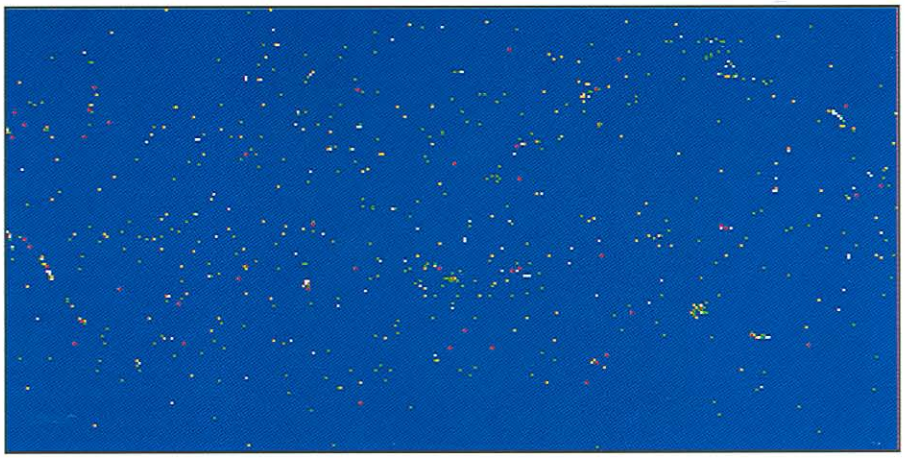
Another improvement (which will eventually be available in the WWW interface) is the multi-catalogue search capability. A STARCAT screen is invoked and queried using—typically—the 'Center' command. A database search is carried out in which all space mission catalogues available are looked up. All records matching the qualification and found in each catalogue are returned in a uniform way on the screen. This facility will be extremely useful for multi-wavelength studies and as an aid to archival research.

We are planning to build several such screens to serve many typical query situations like finding chart generation, bringing topical catalogues together (eg, all radio catalogues), etc.

The HST Archive in the DADS era

In the past few months, the Space Telescope Science Institute started the process of copying all HST data from the old 'LMSI' optical disks to the more modern 'Sony' media. The change of optical disk type was not the only driving force behind this major exercise. The main reason was the availability of an entirely new archive system known as DADS (Data Archive Distribution System). This system, which is designed to handle the data volume produced by space missions of NASA's series of 'Space Observatories' was planned a long time ago but became available only recently. In the meantime, an interim system known as Data Management Facility (DMF) was set up and helped to bridge the gap. DMF was developed as a collaboration of STScI with the ST–ECF (and later with the CADC). It proved useful in many ways, helping us all understand the problems of large data archives and gain experience in their operational aspects. In fact, many of the methods employed in the DMF have been carried over into DADS. DADS, however, is designed for a very large data throughput. At the moment, it is indeed handling about 20 GB/day! ST-ECF and CADC do not manipulate such large quantities of data and hence do not need a system like DADS with its extensive and expensive hardware setup. An enhanced version of DMF is driving ST-ECF and CADC archives: a number of changes have been made in order to, eg, read the new DADS optical disks.

The archive is, of course, not only a set of optical disks containing files. More importantly, it contains a catalogue which provides high-level but nonetheless detailed information on all aspects of any single observation. The catalogue provides pointers to the individual data files. It is stored using a relational database management system and can be examined using a user interface like STARCAT, StarView or the new WDB described in this issue. With DADS, the structure of the catalogue has changed. The efforts of all the sites dealing with HST data have been directed to making this change as transparent as possible to users. This could only be achieved by modifying the screen masks of the user interfaces.



A 2-D histogram of the spatial distribution of HST science observations (as of November 1st, 1994). The x- and y-coordinates represent right ascension and declination. The colour coding is proportional to the number of observations at a point (green->red->white).

How to get to our archive

❑ STARCAT

a. 'telnet stesis.hq.eso.org', login 'starhst', no password. select the subject of interest (eg, science) and type 'cat science'. This access is meant for those casual users not having access to a Sun workstation at their home institute.

b. Seasoned archive researchers will prefer to install the STARCAT software on their machines. To do this, just return the STARCAT site registration form in this issue. Instructions will follow. This formula will give you better access to PreView, PlotCat and Request submission features.

❑ WWW

Our Web interface is also becoming available. It will eventually provide most of the features of STARCAT. See Bo Rasmussen's article for access details.

How to retrieve HST data.

a. Register as an archive user. Although retrieving HST data does not incur costs to the person submitting the request, operator work is still needed at our site. Therefore, we need to know who is retrieving data. To register, please fill out and return the form 'archive user registration' available via the WWW (see box on page 8) or, on paper, in earlier issues of this Newsletter.

b. Mark observations and submit request. Use STARCAT or our Web interface to 'mark' observations of interest. If you are using a local version of STARCAT, 'ReqTool' is available and allows you to select various file types, alternative data distribution media, etc. When done, use the 'submit' command to send the list of files to retrieve to our archive center. Note: FTP data retrievals are subject to a monthly quota of about 100MB per user.

c. Wait for the completion of the request service. A message is automatically sent when the request is processed. The message contains instructions on where to find the files (if an FTP transfer was requested). The delay is typically a couple of hours and depends essentially on the size of the request. We are investigating means of accelerating the service.

New catalogues

The ROSAT observation log was introduced in our database. It contains 3460 entries with Preview images attached.

A new version of the ZCAT catalogue (redshift survey) has also been made available. It now contains entries for over 50,000 galaxies.

Accessing HST data and information — a human engineering challenge

Rudolf Albrecht

The STARCAT user interface to the HST European Data Archive has been working well for several years now. It is a very powerful and versatile tool, allowing access not only to HST data, but also to the ESO (and the CFHT) archives, as well as to a multitude of astronomical catalogues. At the ST–ECF we have been using STARCAT to do mass retrievals involving many thousands of data sets.

Recently, we were alerted to the fact that operating STARCAT from the outside, through a telnet remote session, was much more difficult. We investigated and identified several reasons for this. Some of the reasons were simple, like the fact that some hardware/software setups on remote machines provided default window configurations which were not ideally suited for STARCAT; some of the STARCAT command philosophy is still VAX-oriented (for example terminating input with CTRL-Z); the STARCAT cursor, which is red at the ST–ECF, maps black in some systems and thus becomes invisible if the window background is also dark. This depends on the setup of the client system and is outside of our control.

However, the more important reasons have to do with human engineering. STARCAT has, over the years, expanded to encompass all archive facilities at ESO/ST–ECF. This means that for the first-time user (or the non-expert user) the information threshold required to operate STARCAT is too high. This is especially true for users who enter STARCAT through the World Wide Web: most Web browsers can be operated in a very easy, almost playful manner; being then dumped into a STARCAT session is too much of a contrast. Also, it did not help that the session always started with the most general STARCAT screen: just getting to the HST part of STARCAT required issuing keyboard commands. Many users became frustrated and gave up.

We recently developed an interface to the archive which is based on HTML (Hypertext Markup Language) and which makes the HST archive accessible through all Web browsers which support forms (such as *Mosaic*, *Netscape* or *Lynx*). The advantage of this approach is that the interface can be operated by anybody who knows how to operate a Web browser: in other words almost everybody who has a computer. Another advantage, as seen from the ST–ECF, is the fact that the archive interface client software (ie, the Web browser) is available at most sites and does not have to be supported by the ST–ECF. In the past we have, because of manpower limitations, experienced problems supporting off-site implementations of the STARCAT client software on platforms from multiple vendors. A small disadvantage is the fact that there are several different Web browsers, some of them sensitive to 'dialects' of HTML, so we have to make sure that the interface runs on all of them.

The Web-based user interface to the HST archive does not eliminate the need for STARCAT. In the first place not everybody has access to graphics workstations or terminals, some users still have straight ASCII terminals. Although the Lynx browser circumvents this limitation to some extent, STARCAT is still required for sophisticated retrievals. For instance, setting up a batch procedure which searches the HST and ESO archives and provides output in MIDAS table format cannot be done with the Web-based interface.

At the time of this writing we are going through an internal evaluation of the access procedures to the HST archive. By the time you read this there should be an implementation which takes most of the above considerations into account. Please help us by trying out these tools and letting us know about your experiences with them. Both the Web and the STARCAT interfaces are accessible through the ST–ECF Home Page on the World Wide Web, URL

```
http://ecf.hq.eso.org/ST-ECF-
    homepage.html
```

The Web based interface is called 'quick look data browser', and is easily accessible from the ST–ECF home page. The intention is to 'catch' customers for archival research by giving them an easy way to find out whether there are HST observations of their favourite targets. STARCAT can be accessed through the 'HST Information and Data' section.

Image retrieval using free-text queries

Using text from the observing proposal to select archive data.

Fionn Murtagh

It is not in general easy to make a meaningful characterisation of images in an archive. A pragmatic solution to this problem is to make use of the textual information which accompanies each image.

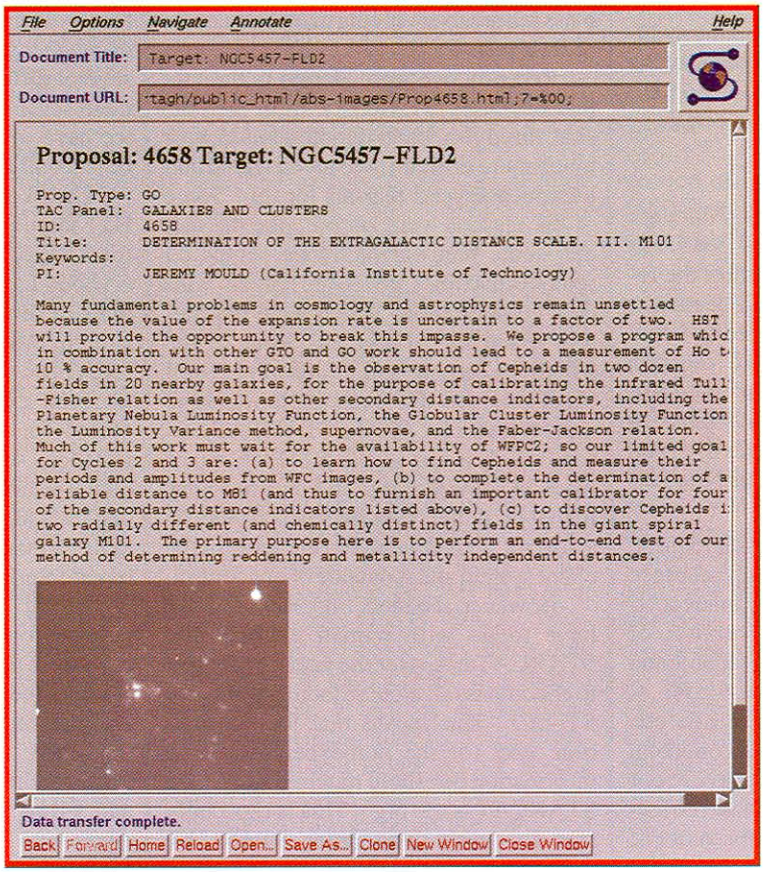
A prototype system has been constructed for application to the HST archive which, around the end of September 1994, contained about 60,000 1- and 2-dimensional images. The set of available observing proposals (cycles 1–4, GO and GTO; and cycle 5 GTO) numbered 2006. These provided a convenient body of text to characterise the images. A proposal is an advance statement of what the image is supposed to contain and this forms the basis of a working hypothesis.

More than one image is usually related to a proposal. For instance, a snapshot survey of protoplanetary nebulæ requested, and obtained, 100 images at different pointings.

For an initial prototyping phase, we concentrated on WFPC 1 images, taken before HST's refurbishment in December 1993. Each such image is of dimension 1600×1600 and is about 10.5 MB in size. However, many of these have a preview version which is binned and compressed (using a wavelet H-transform) to 800×800 which is convenient to store on-line. When using these, we further reduced their size and converted them to GIF format in order to allow them to be viewed using a World-Wide Web browser such as *Mosaic*. The final image is around 200×200 (20 kB).

About 4340 unique images were finally selected and 2362 preview images were found to be available. We excluded multiple images with the same pointing but with different exposure times or filters simply to cut down on the processing involved in this prototype. Generally, non-existence of a preview image means that the proprietary period of one year is still running. We also ignored all images classified for calibration purposes.

We used WAIS (Wide-Area Information Server) to index the observing proposal text, having first created an HTML file from the proposal with a link to any accompanying images. Then, accessing WAIS via Mosaic provided a list of 'hits' resulting from a free-text query.



Text (proposal abstract) and inlined image(s) found when using a free-text search. This is one approach to content-based image retrieval.

Each item in this ranked list corresponded to a proposal. Clicking on any such item provided the text of the proposal and the associated images which were displayed.

This approach is quite feasible for the quick and easy delivery of information. It is not computationally demanding. Displaying 100 WFPC images with the Mosaic browser, even if they are highly compressed, does, however, take a short while. This approach to information delivery is flexible in that the user's request is expressed in free-text. The figure shows the result in the case of a particular proposal. The query term used was 'extragalactic distance scale'. The prototype version set up is accessible at URL:

`http://ecf.hq.eso.org/~fmurtagh/hst-navigate.html`

This is a workable approach to the task of content-based image retrieval. The image contents are assessed using the available text information. In the future, we plan to upgrade this system with more modern versions of WAIS which allow fielded searching. Constraints on the query — such as before or after certain dates, or within certain wavelength ranges — are supported in a user-friendly fashion. Newer versions of WAIS also more clearly and more correctly support boolean queries and multiple source files. We will also investigate more thoroughly the advantages of multiple data-type support, ie, where the WAIS indexer is told to associate a text file with an image file and, if desired, a sound file or a plot file.

Another more challenging project looms on the horizon. This is to integrate HST archive images with text from other sources, for example the published astronomical literature, eg, online abstracts of major astronomical publications, available at:

`http://adswww.harvard.edu/abstract_service.html`

Distributed information delivery tools which are widely available allow us to think about image retrieval — from the HST archive and from other large image databases — in new ways. These client-server tools have already caused a revolution in work practices since centralised data repositories are no longer needed. We can look forward to the era of natural language man-machine interfaces for helping us select what we really need.

Photometric restoration methods applied to the Hamburg Quasar Monitoring (HQM) project

The application of image restoration methods developed at the ST–ECF may allow more valuable photometric information to be extracted from a large volume of CCD imaging of gravitational lens systems. Some initial results are presented.

Jochen Schramm† & Richard Hook

A large photometric monitoring program in the optical has been carried out since 1989 by the gravitational lens group in Hamburg (eg, Borgeest & Schramm 1993). The primary goal is the detection of microlensing events in a sample of 100 principal targets (quasars) and the derivation of time delay values in the known cases of multiply lensed quasars. Later, an additional sample of approximately 300 quasars and blazars were added to fill gaps during observations caused by weather or inaccessibility of the main targets.

Since May 1989—and during a test phase in 1988—regular observational campaigns of mostly 3 to 5 nights were undertaken at the 1.23m telescope of the German Spanish Astronomical Centre on Calar Alto, operated by the Max Planck Institute for Astronomy. The aim was to observe this sample every three to five weeks. For each measurement of one point in the lightcurve a CCD exposure of 500sec was used to reach a typical intensity value of >10,000e⁻ for an object of 18.5mag. By measuring the quasar's intensity with respect to several reference stars on the CCD frame, a photometric error of 0.02mag could be achieved on average. A second exposure of typically 100sec is taken to verify the datapoint. During the last five years, nearly 10,000 data points have been obtained yielding a variety of very interesting lightcurves.

The scale of approximately 0.5arcsec/pixel (During the last five years we have used different CCD cameras with pixel sizes between 20 and 27 microns) at the 1.23m telescope led us to believe that it was not possible to measure the individual magnitudes of multiple objects with angular distances less than 2.5arcsec. The mean seeing at the 1.23m telescope of 1.2arcsec did not allow this either. Thus the very interesting cases of multiple gravitational lensing like the 'Einstein Cross' 2237+0305, the 'Clover Leaf' 1413+117, the 'Triple Quasar' 1115+080 or 'ESO GL1' 0142-100 could not be resolved in the HQM program and only photometric values integrated over all multiple images could be given.

Nevertheless, more than 250 data points from the Einstein Cross have been observed, more than 120 from the Clover Leaf and more than 100 each from the Triple Quasar and ESO GL1.

The derivation of time delay values or typical microlensing features in the lightcurves is one of the main goals of gravitational lens groups. Especially for the Einstein Cross, many attempts have been made with telescopes under exceptional seeing conditions to resolve the individual lightcurves. Several authors (eg, Corrigan et al., 1991) published measurements showing marked changes in the magnitudes of the images. However, longer series of connected data points have not been obtained. To measure individual photometric values only seeing conditions of significantly better than an arcsec were used.

With new photometric image restoration methods (Lucy 1994, Hook & Lucy 1994), the observational dataset of the multiple lenses obtained within the HQM program may again become important. If these deconvolution procedures, under photometric stability restrictions, are able to resolve even the CCD images from the 1.23m telescope a very much larger number of data points becomes available giving renewed hope for the very early aims of the HQM program even for these complicated objects. It was with this plan that a series of experiments with the application of ST–ECF restoration software to HQM data was started and this article reports some early results.

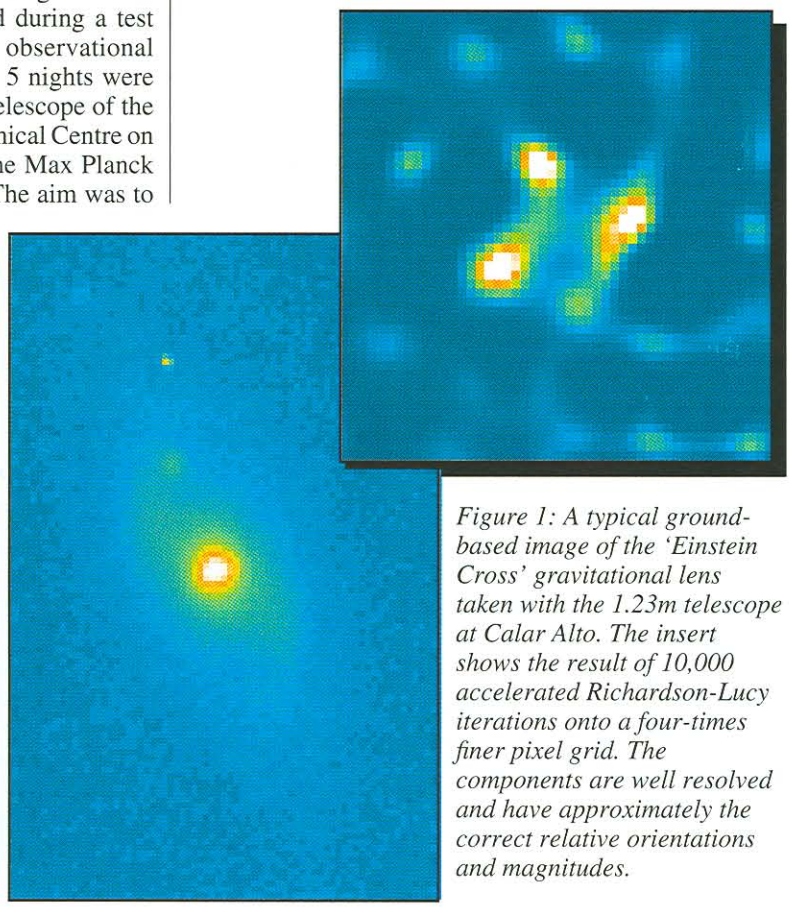


Figure 1: A typical ground-based image of the 'Einstein Cross' gravitational lens taken with the 1.23m telescope at Calar Alto. The insert shows the result of 10,000 accelerated Richardson-Lucy iterations onto a four-times finer pixel grid. The components are well resolved and have approximately the correct relative orientations and magnitudes.

As a first experiment, an attempt was made to find out whether typical images—where the object tends to be extended but not resolved—could be effectively resolved by applying the Richardson-Lucy restoration method with the additional features (acceleration and sub-pixellation) which have been incorporated into the ST–ECF version. Work by Lucy (Lucy 1992) has shown that, given adequate signal-to-noise, super-resolution may be achieved on typical well-exposed ground-based CCD images

† Hamburger Sternwarte

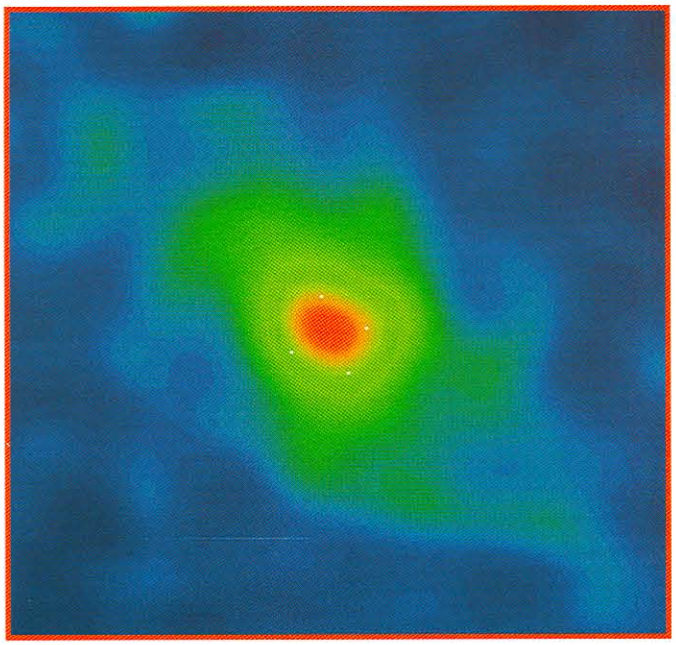


Figure 2: The result of a two-channel 'PLUCY' restoration of another similar HQM image of the Einstein Cross. The four components, at specified positions, appear as delta functions and the second, smooth, channel represents the underlying galaxy and its nucleus.

of multiple point-source objects but that impractical signal levels are required to gain much more than a factor of two. A marginal example is the image of the Einstein Cross shown in figure 1. This was taken in 1.65arcsec seeing using the 1.2m telescope on Calar Alto. The pixel size is 0.46arcsecs/pixel. The insert shows the result of 10,000 accelerated iterations of the Richardson-Lucy method onto a pixel grid four times finer than the raw data. Clear resolution is achieved and all four components appear at approximately their correct orientations and relative brightness. However, as expected, there are some artifacts and the background has completely broken up into small speckles.

It is one thing to achieve super-resolution and quite another to get good photometry of the components. However, the PLUCY program (Lucy 1994, Hook & Lucy 1994), which uses a two channel approach in which one channel is regularized using an entropy term and the other has designated point-sources at (known) positions, appears suitable for this work and is what we have used. An example of such a restoration of the Einstein Cross is shown in figure 2. The four components appear as single-pixel 'spikes' and the background galaxy, including the nucleus, is modelled by a smooth surface.

We are currently assessing the sources of error in this approach and the dependencies on different aspects of the data, such as the strength of the background (much greater in R-band exposures when compared to B), the seeing and the relative brightness of the objects. Some of these factors appear to limit the accuracy but the results are still valuable and a more detailed investigation will be described in a later issue.

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Corrigan, R.T., et al., 1991. AJ, 102, 34
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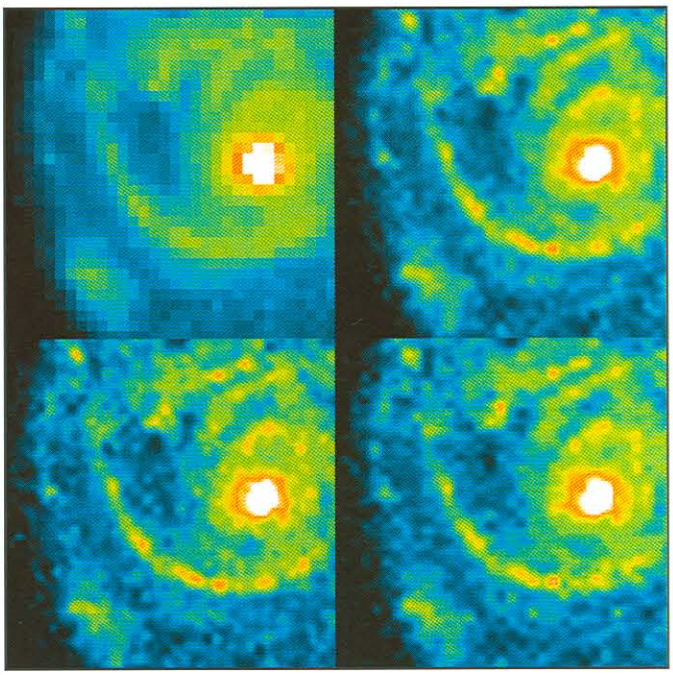
Lucy, L.B., 1994. in "The Restoration of HST Images and Spectra–II" R. Hanisch & R. White (eds), p79
Lucy, L.B., 1992. AJ, 104, 1260

The combination of substepped WFPC 2 images

The following group of three articles deal with the important question of the optimum use of the Wide Field and Planetary Camera—whose CCD arrays undersample the HST point-spread function. The practice of obtaining multiple images with sub-pixel offsets can recover spatial resolution and improve the signal-to-noise as well as cope simultaneously with cosmic ray event and hot pixel identification and removal.

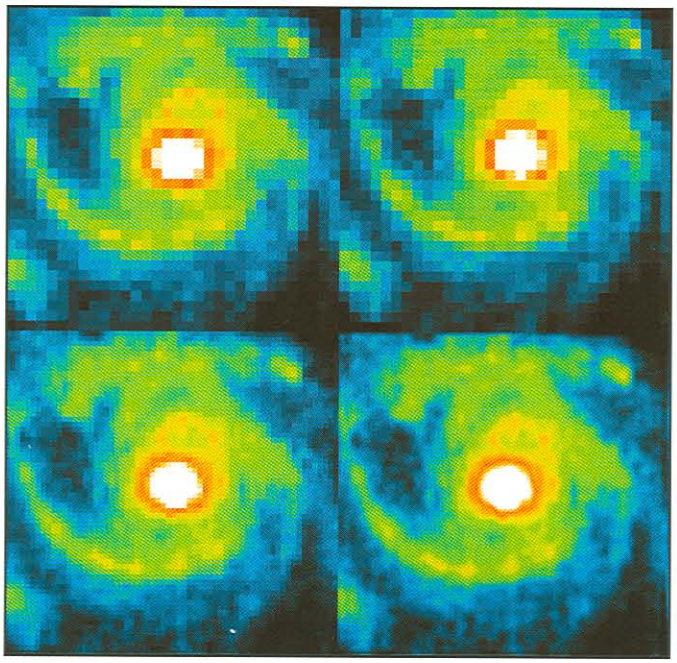
Mark Dickinson† & Robert Fosbury

The CCD arrays in the aberration-corrected WFC 2 and PC 2 undersample the image supplied by the HST Optical Telescope Assembly (OTA) by factors of about four and two respectively at a wavelength of 500 nm. Although images resulting from single pointings of the telescope suffer a consequent loss of resolution and astrometric precision, there are substepping strategies—giving a sampling frequency which is higher than that resulting from the pixel spacing of the CCD—which are remark-



The Lucy-Hook, 40-iteration combination (see the following article by Richard Hook) of a foreground spiral (estimated redshift a few tenths) in the cluster image described here. The panels show: upper left—one of the four input frames at the original WFC 2 pixellation, upper right—the combination of all four sub-images and, lower pair—combinations of independent pairs of sub-images. The pixellation of the combinations is a factor of four finer that the originals.

† Space Telescope Science Institute



The POCS combinations (see the following article by Hans-Martin Adorf) of the same spiral. In this case, the upper two panels are the two input frames at WFC 2 pixellation. The lower-left panel shows the POCS-combination and the lower-right has been interpolated onto a grid another factor of two finer. The lower-right panel should be compared with each of the two lower panels in the previous figure.

ably successful in capturing the full potential of the incoming image. Indeed, due to the low background brightness per pixel in space telescope images and the necessity to take multiple images for the purpose of cosmic ray event detection, the large pixels of the array can offer—without compromising the eventual resolution—an advantage in photometric performance over a Nyquist-sampling instrument.

These issues are discussed in some detail in the report "The Future of Space Imaging" (ed. R Brown, 1993) and the references therein. Software for combining subpixel stepped images, which utilises the Lucy iterative algorithm, has been described by Hook & Lucy (1993). In the following two articles, both this method and a new, complementary approach (POCS) are described. Their applications are illustrated using an extensive set of WFPC 2 data which allows us, by comparing independent subsets, to make critical assessments of the stability and reality of features on different scales in the processed images. A fourth article, by Wolfram Freudling, discusses a strategy for obtaining data in an optimum way for coping with both cosmic ray and hot pixel artifacts.

The data set used for these experiments consists of an extremely deep WFPC 2 observation of the field around the $z = 1.206$ radio galaxy 3C 324, which is situated in a fairly rich cluster of faint galaxies. Ground-based infrared and optical imaging identified a large population of extremely red (R–K ~ 6) objects near the radio source. Such red galaxies are uncommon—although not unknown—in blank-field surveys, but have colours consistent with those expected for relatively unevolved elliptical galaxies at the radio galaxy redshift. The HST images confirm that these are indeed mostly normal E/S0s and also provide detailed morphologies for literally thousands of other faint galaxies down to the detection limit of R ~ 29. Many of these have peculiar and complex morphologies. While the faint galaxies are generally well resolved by HST—which provides kpc-scale imaging at all redshifts—they are nevertheless quite small and the undersampling introduced by the 100 mas WFC 2 pixels is a frustrating limit on efforts to elucidate their structure.

In all, 32 single-orbit exposures were obtained through the F702W filter, giving a total exposure time of 18 hours. The telescope pointing was offset four times in a small diamond pattern with sides of 500 mas. These offsets were carefully arranged so that a given point on the sky would be imaged at four different subpixel positions in order to permit experimentation with the type of image combination techniques discussed here. At each pointing, 8 exposures were obtained, making cosmic-ray rejection straightforward. The effect of applying each of the combination methods to WFC data is shown in the accompanying figures. This is a foreground spiral which we estimate to be at a redshift of a few tenths and the result illustrates well the gross undersampling and the effectiveness of the recovery.

Even the PC pixel scale is not entirely adequate to properly sample the HST point-spread function. Moreover, although it might seem greedy to ask for super-resolution beyond the already outstanding capabilities of the telescope, the stability and well-behaved nature of the point spread function encourage us to consider possibilities for deconvolution. For objects with adequate signal-to-noise, we can hope to identify and 'sharpen' structure at very fine scales, perhaps revealing new morphological details.

In our image, the radio galaxy itself provides an intriguing test of this possibility. 3C 324 is a textbook example of the 'alignment effect': the tendency for the optical (ie, rest-frame UV) continuum of powerful, high redshift radio galaxies to share the orientation of the radio source axis. The physical origin of this alignment is not yet understood. A variety of models have been proposed, including scattering of anisotropically emitted light from AGN, and star formation induced by the passage of the radio source through ambient gas in and around the host galaxy. In the PC image (only a small subcomponent of the radio galaxy is shown in the article by Richard Hook), the aligned continuum breaks up into a chain of compact, high surface brightness clumps, each with galaxy-like luminosity in its own right. The algorithm illustrated in the accompanying article not only offers the opportunity to improve the sampling of the PC image by taking advantage of the pixel substepping, but also generates a deconvolved image which can provide new information about the sub-kpc details of the radio galaxy morphology. This is illustrated by the figure in the Hook article, where both deconvolved and reconvolved sums of a portion of the radio galaxy are shown. In the deconvolved image, some of the clumps exhibit interesting substructure, and some filamentary 'bridges' appear in the more diffuse inter-clump regions. Some sanity check on the reality of these features can be obtained by examining sums/deconvolutions generated from half of the data (two of the four independent telescope pointings). While some of the fine details change, the overall structure reproduces well. It appears that when the signal-to-noise is reasonably high, modest deconvolution can indeed reveal new details even in PC images. The structure of the radio galaxy is presently being analysed and its significance for models of the alignment effect investigated (Dickinson et al. 1995, in preparation).

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The Lucy-Hook coaddition code

The generalised coaddition method may be used directly to combine sub-stepped WFPC 2 data onto a finer grid. The method allows the option of resolution and contrast enhancement or the choice of a conservative, re-convolved, output. The technique is simple and easy to apply and all the tools are currently available in standard data analysis systems. Tests with very deep WFPC 2 imaging data of excellent quality show that these methods can be very effective and allow fine scale features to be studied better than on the unprocessed images.

Richard Hook

In an earlier article (Hook & Lucy 1993) we explained how the generalised co-addition extension of the standard Richardson-Lucy iterative restoration method could also be used to combine sub-stepped, undersampled multi-frames. At that stage no suitable data were available for testing the method and we used simulations. With the arrival of excellent deep WFPC 2 images which are shifted by fractions of a pixel between exposures we have data which are an ideal test case for the method. Here we describe such combinations of subsets (one from both the PC and the WFC) of deep images of a distant ($z = 1.2$) radio galaxy and an associated galaxy cluster. More details of these impressive data are given in the introductory article.

The input data for the experiments consist of four PC and WFC images. These were each derived from eight separate exposures at the same pointing which have been already summed and had cosmic rays removed using standard techniques. In addition, the numerous hot pixels in the frame have been suppressed before the combination. Small subsets of the PC images, covering a region about 1 arcsecond square and including a bright feature with peculiar morphology, are shown in the left-hand column on the opposite page. A small subset of the WFC data at the same pointing and showing a bright, foreground, spiral is shown at the top-left of the image shown in the introductory article by Dickinson & Fosbury. In this case the undersampling is more severe than the PC and the region shown covers about 3.2 arcsec in each direction. This is again just one of four shifted images used in the combinations.

Because of the severe undersampling of the WFPC 2, we wish to combine the input images onto a pixel grid which is four times finer in both x and y. The first steps are to generate suitable point-spread-functions on this fine grid, one each for the PC and WFC, using the familiar TinyTim software (Krist 1994). We then also block replicate the data images onto the same fine grid. Note that no interpolation or other re-sampling method is applied to the data. The shifts between the input frames have been measured (see the adjacent article by H-M Adorf) and these shifts are then applied to the PSFs so that there are finally four PSFs for each camera—one for each data frame. It is assumed that the PSF images on the fine grid are adequately sampled for this shifting and interpolation to introduce no significant artifacts. The PSFs must be shifted in the same direction as the relative displacements of the images, this may seem counter-intuitive but is simply a result of the effect of the convolutions within the Lucy method.

When the four data images and their matching PSFs for both cameras are prepared, the combination is done using the standard co-addition code we have described before (stsdas.contrib.acoadd in STSDAS and COADD/IMAGE in the IMRES context of MIDAS). Depending on the data and the features of interest one may either attempt super-resolution by using the restored output or use the 'conservative' result obtained by reconvolving with the PSF after restoration to convergence. The latter gives a result very similar to that produced by the POCS method described in the next article.

The centre column on the facing page shows the restored PC combinations after ten iterations. The second image down from the top was obtained from all four input images. Those immediately above and below it show the results from combining only two of the four images. Comparison of these allows an immediate assessment of the reliability of the structure in the combined image. The bright features are in general the same but fainter structure, which is affected significantly by the differing noise in the input frames, differs between the two. Such knowledge is very useful in interpreting the results and is encouraged as a general way of assessing the validity of features in combined images when there are adequate numbers of independent input images. However, such partial combinations only have half of the signal and spatial sampling coverage and hence can be expected to be pessimistic indicators of the quality of the combination of all the input data.

In earlier articles on coaddition we have stressed that the reconvolution of (converged) restored images with the PSF results in an image which should be less affected by the noise and artifacts which appear when super-resolution is attempted. The images down the right-hand column on the facing page show such re-convolved results from the PC, again bracketed by partial combinations, using only two of the four frames. In these cases 100 iterations were performed before the reconvolution. Although the contrast and resolution are somewhat lower than in the ten iteration restorations, the structure seen is very similar and also similar to that seen in the POCS combinations described in the next article.

When we move from the PC to the WFC the sampling becomes worse by more than a factor of two and hence the value of sub-stepping as a technique for reconstructing fine-scale structure becomes greater. The images of the spiral in the introductory article show how well this can work when there is good signal-to-noise. The size of the original pixels is obviously comparable with the width of the spiral arm of the galaxy. The image at the upper-right is a 40-iteration combination of all four input subsets. The pixellated appearance is much suppressed and considerable new fine-scale structure appears. The two images at the bottom show the results of doing identical processing using independent halves of the data. The bright structures agree excellently — for example the distribution of intensity along the conspicuous spiral arm — even when such structure is not at all apparent in the input single frames.

Reference

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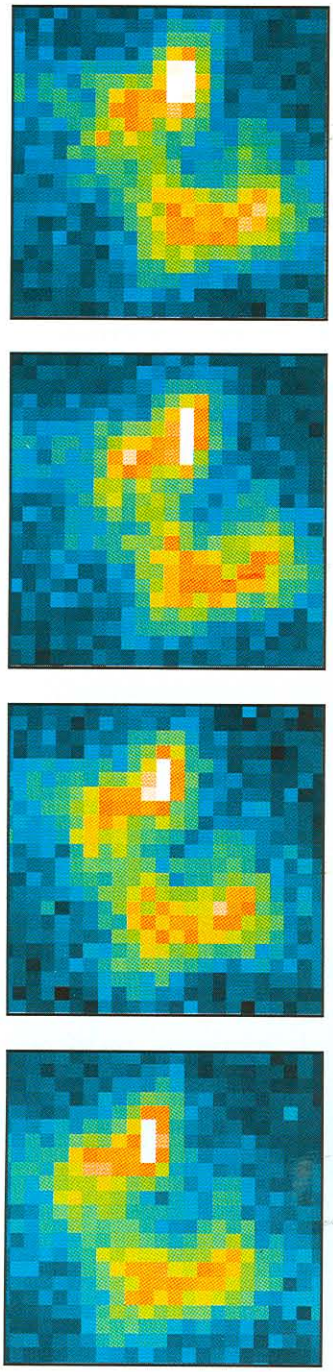
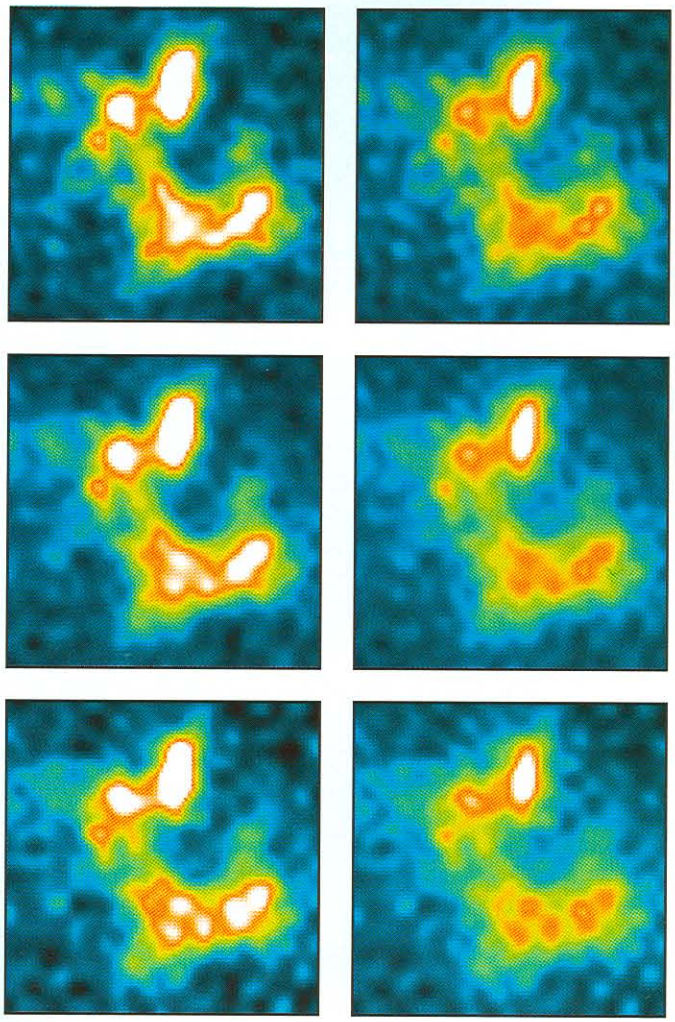


Original PC 2 sub-frames.

The Lucy-Hook combination of four sub-frames of a small section of the PC 2 data described by Dickinson & Fosbury in the introductory article. The PC 2 pixel scale (left column) is 0.046 arcsec and so each panel is just 1 arcsec square. The two upper right and two lower right combinations are independent and can be compared to assess the reality of features.



Combination of first two sub-frames.

Combination of all four sub-frames.

Combination of second two sub-frames.

10-iteration combinations.

100-iteration combinations, re-convolved with PC 2 PSF.

1 arcsec

POCS image combination

'Dithered' WFPC 2 data sets consist of two or more frames which are shifted with respect to each other by fractions of a pixel. These undersampled multiframes may contain information at high spatial frequencies which is recoverable by special combination methods. An algorithm of this kind based on 'projections' has successfully been applied to multiple WFC 2 observations of a cluster of distant, faint galaxies in order to construct a high-resolution image.

Hans-Martin Adorf

Several HST science programmes, such as the morphological classification of distant galaxies, while they require a large field of view, benefit from the highest achievable spatial resolution (Dressler et al. 1994). Due to the narrow core of the HST point-spread function, objects with fine spatial detail are undersampled by the coarse WFC 2 detector pixels. High spatial frequencies present in the data are aliased with lower frequencies, and are therefore unrecoverable from an individual frame.

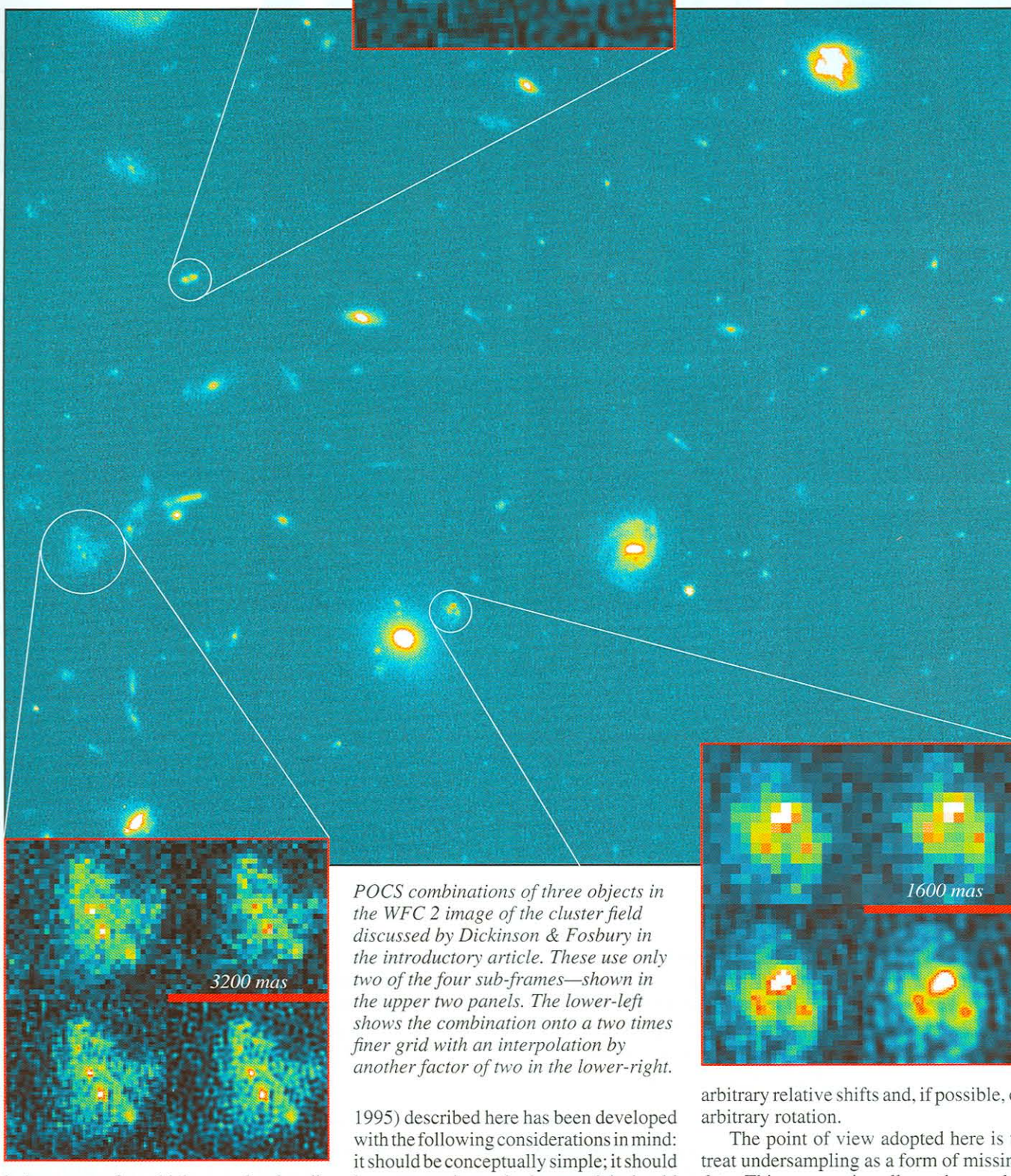
However, specialised combination algorithms can use 'dithered' observations to perform frequency unaliasing and produce high-resolution images with spatial detail up to the diffraction limit of the telescope optics.

A POCS-based method

The reconstruction of a high-resolution image from undersampled multi-frames is a typical inverse problem and no computationally feasible, direct solution is known so far which can also handle missing data.

The combination algorithm (Adorf 1995) described here has been developed with the following considerations in mind: it should be conceptually simple; it should be conservative and robust; and, it should only recover high spatial frequency components, but not amplify them as a fully-fledged restoration does (see the accompanying article by Richard Hook). The method should obey or enforce the non-negativity constraint of real images. Considering the frequency of cosmic ray hits and hot pixels, it should be tolerant towards missing data. Since the WFPC 2 point-spread function (PSF) is spatially variable and difficult to assess on the sub-pixel level, it should not require PSF-knowledge. Finally, the algorithm should work with two or more dithered frames of arbitrary relative shifts and, if possible, of arbitrary rotation.

The point of view adopted here is to treat undersampling as a form of missing data. This perspective allows the combination algorithm to be modelled on a POCS-based method developed for inter-



POCS combinations of three objects in the WFC 2 image of the cluster field discussed by Dickinson & Fosbury in the introductory article. These use only two of the four sub-frames—shown in the upper two panels. The lower-left shows the combination onto a two times finer grid with an interpolation by another factor of two in the lower-right.

polating irregularly sampled time series (Adorf 1993).

Conceptually, the POCS combination algorithm works as follows. Each observed low-resolution frame is upsampled without interpolation. In the case of a two-fold upsampling, this means that every other row and column remains empty. This operation preserves knowledge about missing data, eg, due to hot pixels. A high-resolution estimate of the image to be reconstructed is shifted such that it registers with the first upsampled frame. Data values, wherever they are known, are copied into the estimate, which is subsequently shifted such that it registers with the second upsampled frame. Then again values are copied wherever known. If further upsampled observational frames exist, they are treated accordingly. Then the process starts over again with the first upsampled frame.

The non-negativity constraint and a bandpass constraint is applied at least once in every round. When enough observational data points are available, the frequency limit of the bandpass filter corresponds to the diffraction limit of the telescope-camera combination. Otherwise, a bandpass filter may be used which has at most as many degrees of freedom as there are good data pixels in all data frames combined. In this case, not all of the undersampling will be removed.

This iterative algorithm provably converges provided there is a solution at all. The proof relies on the fact that all the operations described above are 'projections onto convex sets' (POCS) in the linear space of images.

Observational strategies

All HST proposers who wish to obtain the highest possible spatial resolution with WFPC 2 should consider requesting dithered observations. Clearly any combination method can work only on data with sufficient signal-to-noise, so that the signal at high spatial frequencies is not totally dominated by noise. As a minimum, two fractionally shifted observations are necessary to apply either of these methods. However, due to undersampling, difficulties have to be expected with cosmic ray hit detection.

A safer way is to ask for two or more sets of observations. Each set should consist of at least two observations with the same pointing, which serve to detect cosmic ray hits. Recovery is most robust if the offset between the sets is (n+1/2) pixels in the x- and y-directions. It is helpful if n is at least a few so that residual hot-pixels can be identified and removed. Accurate fractional offsets are achievable by the HST pointing system. For more information, see the following article by Wolfram Freudling.

Which algorithm to choose?

The two combination methods described here are complementary. If the aim is some resolution and contrast enhancement then the Lucy-Hook algorithm would be the best choice. This is particularly valuable for image sections having good signal-to-noise such as the spiral galaxy shown in the introduction. However, a conservative and more computationally efficient method (it also requires less computer memory in the present implementations) which doesn't need a PSF, would be the POCS scheme. This is very robust and free of the artifacts which appear in Lucy-based restorations at higher numbers of iterations. When trying to extract all the information from a WFPC image it is probably advisable to try both.

"As remarkable as these images of systems at high redshift are, they point up the need for…higher resolution. …Substepping… would dramatically increase the detail in these very high redshift systems…"

Alan Dressler (1994)

Application

The POCS-combination algorithm was applied to the dithered WFPC 2 observations of the galaxy cluster described in the introductory article by Dickinson & Fosbury. Due to current software restrictions, only two of the four sets of five images each with different pointings were used. Each set had previously been co-added with cosmic rays removed.

The resulting two 512×512 pixel frames were registered using a cross-correlation technique (Adorf 1995)—which does not require the presence of point sources—and then combined into a single 1024×1024 pixel image using 40 iterations of the POCS-algorithm (see figure). The output frame was further interpolated by a factor of two in both dimensions (not shown) in order to enhance the visibility of fine spatial structures. The inserts in the figure show close views of several galaxies with multiple components. Each insert displays the two input subframes in its top panels, the POCS-reconstruction in the lower left panel, and the interpolated POCS-reconstruction in the lower right panel.

The second illustration in the introductory article shows a spiral galaxy for comparison with the Lucy-Hook reconstruction. Note that the apparent horizontal and vertical alignment of the structural features in the spiral arms as seen on the input frames has completely vanished in the high-resolution reconstruction.

As can be seen, in each case the combined high-resolution image reveals fine spatial structure difficult to discern on the two undersampled frames individually. Also the contrast in the high resolution image is increased compared to the coarsely sampled frames.

Software

The POCS-algorithm has been implemented in the Interactive Data Language (IDL) for the case of two dithered frames. It will eventually be made available via anonymous FTP. Experimental code for hot pixel detection is also available. At this early development stage, astronomers wishing to use the POCS-algorithm should contact the ST–ECF for assistance in applying the POCS code to WFPC 2 data.

Since the POCS code is implemented on a very high level, it should be easily portable into other image processing systems, provided that the building blocks such as fractional shifting, upsampling, enlargement (ie, upsampling with sinc-interpolation), bandpass filter generation, image operators on masked data, crosscorrelation, peak-detection etc. already exist.

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Dressler, A., Oemler Jr., A., Sparks, W.B., Lucas, R.A., 1994. "New images of the distant, rich cluster CL0939+4713 with WFPC 2", *Astrophys. J. Lett.* **435**, L23–L26

WFPC 2 hot pixels and image restoration

...Suggesting a strategy for designing WFPC 2 observations for resolution recovery and cosmic ray and hot pixel artifact removal.

Wolfram Freudling

A common cosmetic defect of CCD chips used in astronomy is the presence of 'hot pixels', ie, isolated pixels with very large dark currents. If this enhanced dark current is constant, normal dark image subtraction will correct for hot pixels and the only residuals left are the effect of enhanced Poisson noise at their positions. For WFPC 2, the situation is more complicated because hot pixels are mostly cleared by the contamination procedure which is carried out once about every 4 weeks. Subsequently, hot pixels with a dark current of more than 100 e^-/1000 sec appear with a rate of about 60 pixels/month at the current operating temperature of –88°C.

As an example, the left figure shows a median of four dark exposures, each of 1800 sec, right after a decontamination and the right figure shows a similar dark taken before the next decontamination. Normally, if the dark frame closest in time to the science observations is used for dark current subtraction, the hot pixels should be removed to first order. It often happens, however, that these dark current frames become available only after the pipeline calibration, and therefore it is necessary to recalibrate. If exposures are dark current limited, this recalibration can be done with superdarks which are averages of dark frames taken over a period of time. In that case, hot pixels have to be treated separately. Such a special treatment can range from identification by eye and simple interpolation of the flux in the affected pixel (eg, with IRAF task 'imedit') to masking of pixels for image restoration or model fitting.

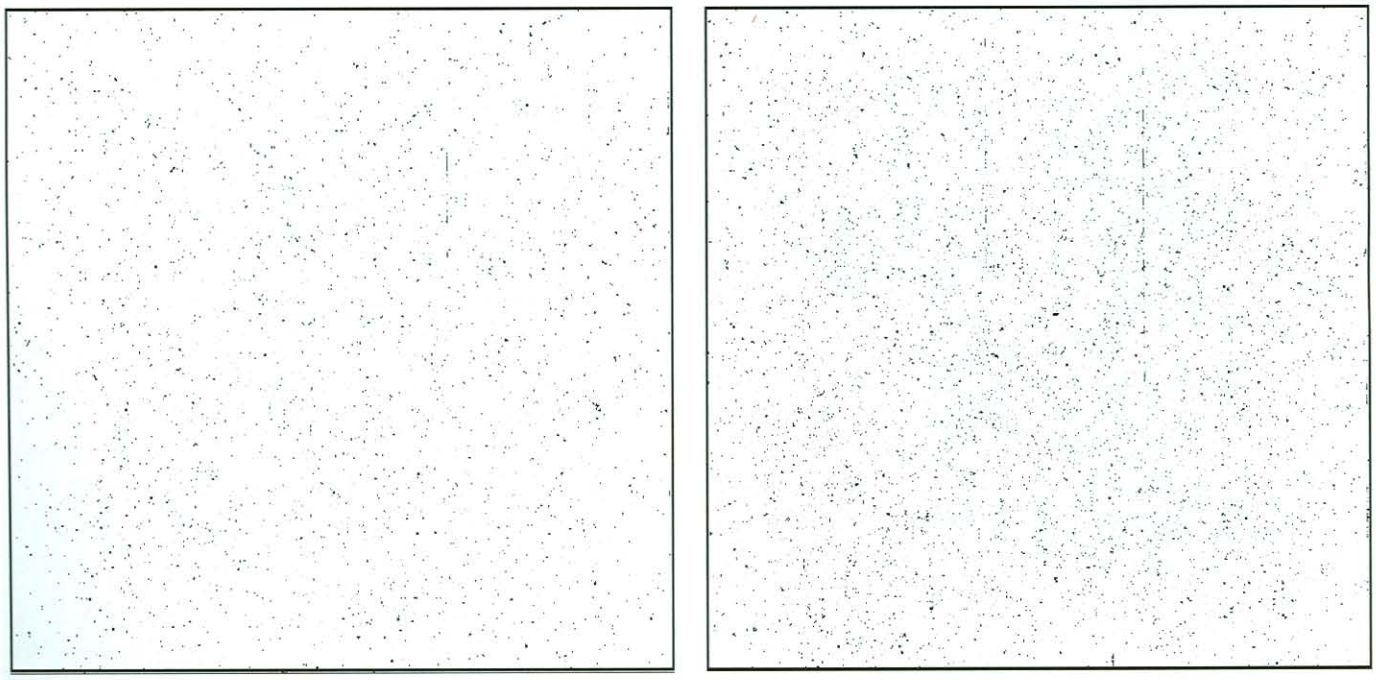
All of these strategies will result in a local degradation of the images. Since the state of the hot pixels depends on the time of observations within a decontamination cycle, the exact number and position may not be known in advance of a given observation. For programs which could suffer from the effect of such hot pixels, it is therefore advisable to slightly shift the camera between single exposures of a regular cosmic ray split. The shift should be large enough to separate the position of the hot pixels of the different exposures, ie, about 10 pixels. If this shift is done by an integer number of pixels, the images can be aligned later by a simple integer pixel shift and hot pixels can be treated similar to cosmic ray hits (eg, with the 'CRREJ' routine in the stsdas.wfpc package.)

Both the three WFC CCDs and the PC CCD substantially undersample the PSFs of the telescope. Some of the resolution lost by the undersampling can be recovered by shifting the field of view between the separate exposures of the CR split by a non-integer multiple of the pixel size. Such shifted images can be combined using the algorithms described in the preceding articles. Many science programs carried out with WFPC 2 profit from additional spatial information. In order to avoid the effects of hot pixels in such an approach, an integer number of pixels can be added to the subpixel shifts to arrive at total shifts of say 10.5 pixels. Hot pixels on observations carried out in such a mode can then be treated as cosmic ray hits and, eg, be identified and removed as suggested by Freudling (1995). Note that the alternative strategy to remove CR hits from the images at each position separately through median filtering of registered images at that position fails to remove hot pixels.

To summarize, appropriate observing strategies can be employed to allow the treatment of hot pixel on the WFPC 2 chips in a way similar to cosmic ray hits. Such strategies are equally suited for the case where shifts between images aim at resolution enhancements of the undersampled images and where such a resolution enhancement is not needed or justified by the s/n ratio.

Reference

Freudling, W., 1995. PASP, in press.
(See also ST–ECF Newsletter 22, 8)



Medians of four dark frames taken with WFPC 2 on June 16/17(left) and July 4, 1994. Both images contain a significant number of unremoved cosmic ray hits. The different number of bright pixels reflects the build-up of hot pixels in that period. The relevant decontamination dates were June 13 and July 10.

Electronic access to HST information III — WAIS

The Wide Area Information Servers (WAIS) system is a networked full-text retrieval system. It offers natural language access to its information bases. Returned documents are relevance ranked with respect to the query. Several WAIS servers are now operational, which provide a wealth of information about HST, the STScI and the ST–ECF.

Hans-Martin Adorf

WAIS, the Wide Area Information Servers, is possibly the most profound development on the Internet of the past decade. Together with its cousins Gopher and the World Wide Web, WAIS has helped to transform the Internet from a network for remote computing via remote login, to a network for communication and publication. *Information networking* has supplanted computer networking as the primary reason for expanding the Internet (Peters 1994).

WAIS (Fullton 1993, Murtagh 1994) is an operational networked information retrieval system, which allows the user to search quickly through vast amounts of on-line full-text information. It generally accepts natural (English) language queries; some servers in addition offer Boolean query capabilities. The WAIS search process uses a heuristic similarity measure to find documents which appear relevant to the query issued. Multiple distributed databases can be simultaneously searched, and results are automatically merged. Relevant documents or portions thereof can be fed back to further guide the search.

WAIS is a significant development (Wells 1992) putting into the public domain much of the technology for full-text search and retrieval, which had previously been available only in commercial information retrieval systems, such as ITMS (Adorf & Busch 1988).

Notable WAIS databases

Within the larger scientific community, astronomers were among the first to realise the potential of WAIS after its initial release. Consequently there exists already a bewildering number of WAIS-searchable databases relevant to astronomy and astrophysics. The AstroWeb listing (Adorf 1995) currently lists about 40 of them, and the number is steadily growing.

HST, STScI and ST–ECF related databases

The STScI, the ST–ECF, and Arizona State University currently maintain about a dozen WAIS databases directly related to HST. They cover past HST observing proposals, current and past HST weekly timelines, HST status reports, WFPC 1 images (Murtagh 1995), the STScI's HST data handbook, STScI's user manuals, HST-related publications, the ST–ECF Newsletter (partly), the ST–ECF software library, the ST–ECF World Wide Web files, and the HST-specific Usenet newsgroup (see Box 2 for details).

> WAIS is the best developed and most widely implemented text searching mechanism on the Internet.
>
> *Don Wells, 1992*

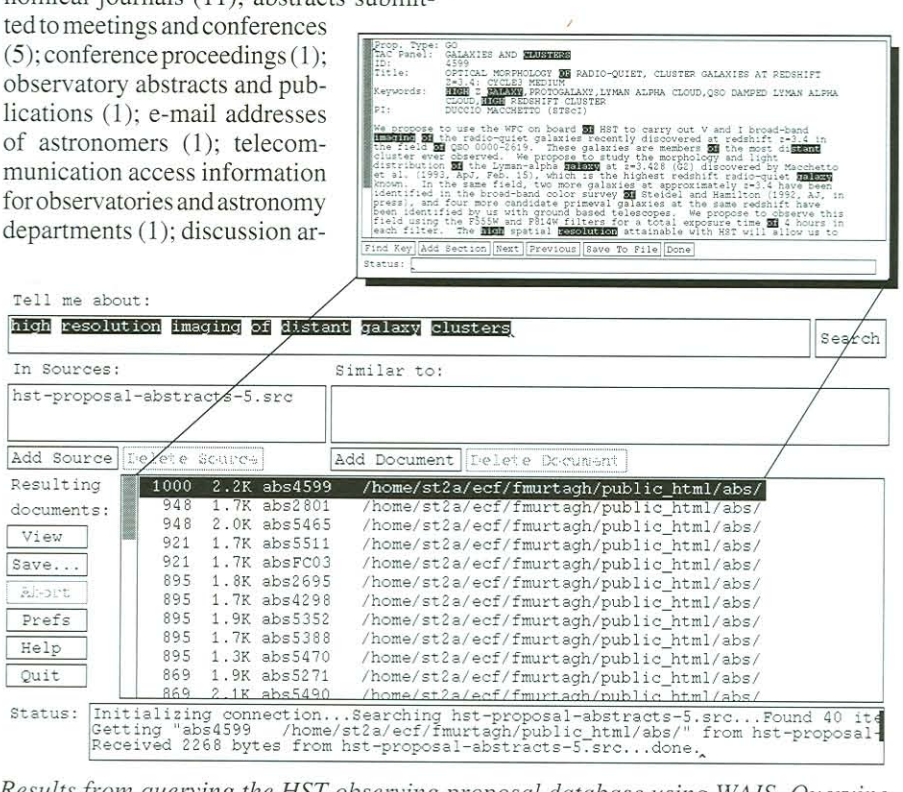
Other astronomical databases

These information resources are complemented by other valuable astronomical WAIS databases. Here is a selection (figures in parentheses indicate my current counts): preprint lists (3); on-line newsletters (2); abstracts of major astronomical journals (11); abstracts submitted to meetings and conferences (5); conference proceedings (1); observatory abstracts and publications (1); e-mail addresses of astronomers (1); telecommunication access information for observatories and astronomy departments (1); discussion archives (2); astronomical CD-ROM catalogues (1); job offerings (1); space missions (1); astronomical Internet resource listings (1); and numerous others. See Box 2 for details of some of these sources.

Unfortunately there is still no path to a convenient and general on-line access to the precious Astronomy & Astrophysics Abstracts database. This issue was raised quite some time ago (Adorf & Busch 1988). While a proprietory database system was recommended at the time, these days one would presumably use a WAIS or Z39.50 search engine underneath a WWW user interface, as exemplified by the Astrophysics Data System (ADS, Accomazzi et al. 1995).

How does WAIS work?

WAIS, jointly developed by Apple Computer, Thinking Machines, Dow Jones, and KPMG Peat Marwick, operates according to the familiar client-server con-



Results from querying the HST observing proposal database using WAIS. Querying the database wais://ecf.hq.eso.org/hst-proposal-abstracts-5 for "high resolution imaging of distant galaxy clusters" reveals GO proposal number 4599 "Optical morphology of radio-quiet, cluster galaxies at redshift z = 3.4" as top-ranked proposal, closely followed by GO/AM proposal 2801 "Imaging the arc in the galaxy cluster 2244-02 by R. Sterner.

cept. The WAIS system consists of four components: client software, a unique communications protocol, server software including a search and a retrieval engine, and, most importantly, a database (see Box 1 for a glossary of WAIS terms).

The *client* acts as the user interface to WAIS. The user formulates a free-format text query which the client transmits to the appropriate server via the WAIS communications *protocol*. The latter is an extension of the Z39.50-1988 protocol for computer-to-computer information retrieval (Obraczka et al. 1993; Lynch 1994) developed by the ANSI-accredited US National Information Standards Organization (NISO) for serving the library, publishing, and information services communities.

Upon receipt of a query a *server* searches the requested database for relevant documents using a pre-computed inverted index. WAIS servers have some built-in knowledge of the English language including a stemming algorithm, but presently do not really 'understand' the language. They rather rely on statistics to find 'relevant' documents. The simple, yet surprisingly efficient search engine supplied with the free WAIS distribution matches occurrences of words (or word stems) in the query with words (or stems) in the documents, and tallies a score for each document based on the number of 'hits'. The underlying assumption is that, if a document has many words in common with the query, the document is probably relevant. The relevance is increased if query and document in question share rare words. As a result, a list of document identifiers is returned to the requesting client in ranked order of relevance to the query.

Given the list of relevant document identifiers, the user operating the client may now request the server to send a copy of a desired document. They may then feed back one of these documents (or a portion thereof) for further guiding a second round search.

A large number of WAIS *databases* (over 500) have been officially registered: more than 40 in astronomy alone. An unknown, but presumably fairly large, number of unregistered WAIS servers are working 'behind the scenes', supplying seamlessly integrated search engines underneath the surface of point-and-click client interfaces to the WWW. Such WAIS-based WWW search engines are in operation eg, at the ST–ECF, the STScI, the CADC, and the CEA (Center for EUV Astrophysics).

WAIS vs. Gopher and WWW?

Each of these information retrieval and presentation systems are client-server based. In Gopher (Adorf et al. 1993), searches are possible, but no relevance ranking is performed. Also Gopher permits the querying of only one database (index) at a time. In the WWW (Adorf 1994b) searches may be carried out by using forms and scripts, or by invoking WAIS directly.

These days the WWW is getting the lion's share of praise and use as a distributed document system. The choice appears to be to use a WWW client as front-end interface for information presentation and linking, and to use a WAIS search engine for document discovery and retrieval in the background.

Accessing existing WAIS databases

WAIS client software

WAIS clients run on a wide variety of machines, from UNIX-based X-windows systems and character terminals, to MS-DOS and Macintosh microcomputers. Most users interact with WAIS databases through a graphical user interface (GUI, see figure), but command line interfaces (CLIs) are also occasionally useful (see eg, Adorf 1993, 1994a).

A number of public domain sources for WAIS client software are available on the Internet (see Box 3).

Accessing WAIS from WWW clients

Most WAIS users will not need any special WAIS client software, since direct WAIS support is built-in into most modern WWW clients. A Uniform Resource Locator (URL) of the generic form `wais://host.domain:port/database?keyword` accesses the WAIS server identified through its IP address and port, and queries the specified WAIS database using the given keyword. Several keywords can be concatenated using the plus sign ('+'). The port defaults to 210 and may be omitted. For instance, `wais://anarky.stsci.edu/astroweb+HST+Hubble+Telescope` queries the AstroWeb database at the STScI for all entries related to HST.

While certainly convenient, WWW clients usually do not cater for relevance feedback, nor do they allow the querying of more than one database in a single query. An exception to the rule is the

1. Glossary of WAIS terms

Database
A collection of documents (or a dash-separated collection of text paragraphs) on a server. It is described by a source file and automatically indexed by the indexer.

Document identifier
A special unique string created by the document indexer for document retrieval or relevance feedback. Document identifiers point to documents.

Directory of servers (sources)
A database that helps to find source files of databases and serves them. A directory of registered servers is (still) maintained at Thinking Machines Corporation (URL: wais://quake.think.com/directory-of-servers). Another slightly different one is maintained at CNIDR (wais://cnidr.org/directory-of-servers).

Document indexer
A program that ingests a database of documents and produces a source file, a catalogue of indexed files, and, most importantly, an inverted index based on the contents of the database. Some English language stemming operations are usually performed. Stop words from a predefined list, or words with an exceedingly high frequency are excluded from indexing. A synonym list may be used.

Inverted index
A dictionary of all words (or word stems) which occur in a database together with pointers to the relevant documents. The index is used by the retrieval software to rapidly find the documents which match a query.

Question structure
A file used by some client programs to store the state of a query for later re-use. It includes the sources asked, the user's query string together with any relevant documents, and might store the last list of results. Clients usually may store several such question structures.

Relevance feedback
A technique which allows quite precise searches without requesting the user to explicitly formulate a detailed query. The user can select all or part of a retrieved document and use it as a refined query to get all 'similar' documents.

Server
A program that listens for incoming queries and invokes a search engine which searches a database using the associated inverted index. It also interfaces to the retrieval engine which delivers requested documents.

Source
An ASCII text file containing access information about how to contact a WAIS database via the Internet (ie, host IP name or number, port number, and database name) together with a text description of the database content. The contact information is used by the client. The free text is indexed by 'directory of servers' services, which may be queried to obtain source files. The description of a known source can usually be retrieved by issuing a question mark or 'help' as query to the corresponding database.

2. Important WAIS databases

HST related sources at the STScI

HST status reports
HST daily status reports which include sections on: activities scheduled and accomplished, flight operations summary, activities scheduled for next reporting period, anomaly status, significant forthcoming event (wais://www.stsci.edu/hst-status)

HST weekly timeline
Weekly Timeline files for current year's HST observations, ie, the timeline_* files in observer/weekly_timeline directory on STEIS (wais://www.stsci.edu/hst-weekly-timeline)

HST related sources at the ST–ECF

ST–ECF Newsletter
ST–ECF Newsletter starting with #20. Each page is stored as a separate postscript file (wais://ecf.hq.eso.org/stecf-newsletter)

ST–ECF Newsletter index
titles and authors in the ST–ECF Newsletter from #11 to #20, ie, May 1989 to August 1993 (wais://ecf.hq.eso.org/stecf-newsletter-index)

HST literature
local copy of the bibliography of HST related references maintained by Sarah Stevens-Rayburn, STScI Library (wais://ecf.hq.eso.org/hst-literature).

HST observing proposals cycles 1 to 5
all HST observing proposal abstracts for Observing Cycles 1 to 5 (currently only GTO entries for Cycle 5); (wais://ecf.hq.eso.org/hst-proposal-abstracts-5)

HST observing proposals without PI names
all HST observing proposal abstracts for Observing Cycles 1 to 4 with PI names removed (wais://ecf.hq.eso.org/hst-observing-proposals-noPI)

WFPC observing proposals with preview images
WFPC related proposal abstracts for cycles 1 through 4, GO and GTO; and cycle 5 GTOs (wais://ecf.hq.eso.org/hst-wfpc-im-text)

HST Data Handbook (the "One-Book")
describes HST datasets produced by any instrument. It includes information about how to read tape files, how to determine whether data should be recalibrated, how to understand and solve potential problems with the data, etc. Appendixes explain how to use StarView, STSDAS, and STEIS (wais://ecf.hq.eso.org/hst-one-book)

ST–ECF World Wide Web
all files (HTML and other formats) in the WWW directory tree at the ST–ECF (wais://ecf.hq.eso.org/stecf-www)

HST related source at ASU

sci.astro.hubble Usenet newsgroup archive
archive of material posted to the sci.astro.hubble Usenet newsgroup, maintained by Paul A. Scowen, Department of Physics & Astronomy, Arizona State University (wais://wfpc3.la.asu.edu/sci.astro.hubble)

Other astronomical sources of note

AstroWeb Internet resource listings
comprehensive listing of astronomical resources on the Internet (Adorf 1995) collected by the AstroWeb consortium (wais://anarky.stsci.edu/astroweb)

STScI STEP Preprint Database
bibliographic listing of astronomy and astrophysics preprints received at the Space Telescope Science Institute library during the last two years, including *all refereed HST papers.* At any one time, STEP comprises approximately 5000 references (wais://marvel.stsci.edu/stsci-preprint-db).

STScI OLDSTEP preprint listing
bibliographic listing of astronomy and astrophysics preprints received at the Space Telescope Science Institute library prior to the last two years. OLDSTEP presently includes approximately 14,000 references (wais://marvel.stsci.edu/stsci-old-preprint-db).

NRAO RAPS preprint listing
a bibliographic listing of astronomy and astrophysics preprints received in the Charlottesville library of the National Radio Astronomy Observatory from 1986 forward (wais://annie.cv.nrao.edu/nrao-raps).

IOA preprint listing
bibliographic listing of astronomy and astrophysics preprints received at the Insitute of Astronomy, Cambridge, UK (wais://cast0.ast.cam.ac.uk/prelocal)

ADS astronomical abstracts
the experimental WAIS interface to the ADS (Astrophysics Data System) collection of astronomical abstracts. (See http://adswww.harvard.edu/abs_doc/wais/ for detailed information on this service.) The database contains abstracts from over 200 journals, publications, colloquia, symposia, proceedings, and internal NASA reports. Abstracts start in 1975, and are current through approximately six months ago. Field searches, (nested) boolean expressions, partial words, and literal expressions are possible (wais://adswais.harvard.edu/abstracts).

STELAR astronomical abstracts
abstracts of 10 leading astronomical journals (AJ, A&A, A&AS, A&AR, ApJ, ApJS, JGR, JGRS, MNRAS and PASP)provided by the STELAR project (Van Steenberg *et al.* 1992; Warnock *et al.* 1992) of NASA's Astrophysics Data Facility (ADF); the underlying RECON system database contains abstracts from as early as the mid-1960's (wais://ndadsb.gsfc.nasa.gov/abstracts)

NASA RECON abstracts
over 200,000 abstracts from the Scientific and Technical Aerospace Reports (STAR) for the years 1990 through 1992 and from the International Aerospace Abstracts (IAA) of the NASA RECON database for the years 1990 through 1992 (wais://nova.sti.nasa.gov/recon)

NASA SCAN abstracts
abstracts from NASA's Selected Current Space Aeronautics (SCAN) database (wais://nova.sti.nasa.gov/NASA-CURRENT-SCAN)

NOAO Newsletter
latest issues (1 June 1992 and later) of the Newsletters of the US National Optical Astronomy Observatory (wais://pandora.tuc.noao.edu/noao-news)

CEA publications and abstracts
publications and abstracts of papers issued by the Center for EUV Astrophysics, Berkeley, CA (wais://www.cea.berkeley.edu:8000/pubindex)

ST–ECF software library
all source code and documentation files in the ST–ECF software library (wais://ecf.hq.eso.org/stecf-sw-library)

IAU circulars
contains Astronomical Circulars of the International Astronomical Union, beginning with number 5828, 6 July 1993 (wais://www.stsci.edu/iau-circulars)

Union List of Astronomical Series, 2nd edition
bibliographical information for publications of astronomical observatories and research institutions (wais://www.stsci.edu/stsci-ulas-db)

Directories of servers

TMC directory of sources
directory of registered WAIS sources maintained at Thinking Machines Corporation (wais://quake.think.com/directory-of-servers); note that several sources listed there are outdated and no longer operational

CNIDR directory of sources
directory of registered WAIS sources maintained at the Clearinghouse for Networked Information Discovery and Retrieval (wais://cnidr.org/directory-of-servers)

NASA directory of sources
directory of NASA related WAIS sources (wais://ndadsb.gsfc.nasa.gov/NASA-directory-of-servers)

ST–ECF directory of sources
directory of a collection of astronomy & astrophysics related WAIS sources maintained at the ST–ECF (wais://ecf.hq.eso.org/INFO)

EINet MacWAIS/MacWeb pair, where one client invokes the other if needed.

WAIS server software

WAIS servers have been implemented on UNIX, VMS and, recently, on MS-DOS. For Apple Macintoshes, Apple Computer offers AppleSearch, an offspring of Apple's involvement in the initial WAIS effort. Also for WAIS server software some public domain sources are available on the Internet (see Box 3).

WAIS products with extra features and full support are now commercially available from WAIS, Inc. (http://www.wais.com), which was founded by many of the original WAIS developers. Commercial WAIS servers are being used by large organisations, including NASA and the US Environmental Protection Agency.

Although WAIS, Inc. does sell commercial servers, they continue to provide other freely redistributable tools (see ftp://ftp.wais.com/pub/freeware; Europeans should try ftp://nic.funet.fi/pub/networking/services/wais first).

Further information

A good starting point for further information about WAIS is the WAIS-FAQ (frequently asked questions) document (ftp://rtfm.mit.edu/pub/usenet-by-group/news.answers/wais-faq/getting-started or http://www.cis.ohio-state.edu/hypertext/faq/usenet/wais-faq/getting-started/faq-doc-4.html).

The Usenet newsgroup comp.infosystems.wais discusses WAIS developments. The WAIS FAQ is regularly uploaded to this group. The World Wide Web page http://info.cern.ch/hypertext/Products/WAIS/Sources/NewsGroupRelated.html provides a list of WAIS servers that serve up some or all of a Usenet newsgroup.

Another way of finding information about WAIS is to access the World Wide Web Worm (http://www.cs.colorado.edu/home/mcbryan/WWWW.html), a resource discovery tool which maintains an index to virtually all top-level WWW resources in the Internet.

Outlook

The last few years have witnessed a huge increase in electronic information exchange. Several professional scientific societies in the United States and Europe are now seriously exploring the impact of electronic archiving and the distribution of scientific material.

The Elsevier science publishing house has recently made its complete Science Catalogue available under the WWW, featuring all journals, books, major reference works and electronic products of all Elsevier Science imprints. Elsevier maintains the impressive number of 34 WAIS sources for searching its various databases.

The ACM (Association for Computing Machinery) reportedly has outlined a comprehensive plan for changing the nature of its publication methods, proposing print-on-demand, pay-per-view, and profiling to automatically inform a member about the existence of an article that matches his/her professional interests.

The AAS has outlined its long term plans for electronic publishing (Boyce 1992). With the existence of on-line abstracts of astronomical journals, the planned build-up of electronic preprint servers, and the imminent advent of full-text versions of astronomical journals — an experimental on-line version of one issue of the Astrophysical Journal Letters is in the works—free-text search tools such as WAIS will become increasingly important in astronomy. And the HST-project has already a good stake in this development.

3. WAIS client and server s/w

The following software has been used at the ST–ECF at one time or another:

freeWAIS
This is the current distribution of free WAIS client and server software for UNIX systems, available at CNIDR (Clearinghouse for Networked Information Discovery and Retrieval). Current CNIDR releases are called freeWAIS, to help reduce confusion, freeWAIS provides Boolean searches, stemming, etc. (http://cnidr.org/welcome.html and ftp://ftp.cnidr.org/pub/NIDR.tools/freeWAIS-0.3.tar.Z)

freeWAIS-sf
This is a much improved and recommended version of freeWAIS featuring a redesigned query processing which permits, among other things, fieldwise indexing and retrieval (http://ls6-www.informatik.uni-dortmund.de/freeWAIS-sf/index.html). For a comparison of the freeWAIS search engine and the one used by the ADS project, see http://adswww.harvard.edu/pubs/adass-94/asias/.

wais-8b5.1
This used to be the main distribution of WAIS client and server software for UNIX systems (ftp://ftp.think.com/wais/wais-8-b5.1.tar.Z) and is still in operation at many sites. It has been superseded by freeWAIS and freeWAIS-sf.

Wais for Mac
This free Macintosh WAIS client is available from WAIS, Inc supports both WAIS and the new Z39.50 commercial servers (ftp://ftp.wais.com/pub/freeware/mac/wais-for-mac-1.2-alpha.sea.hqx). It has superseded WAIStation for the Mac.

MacWAIS
EINet MacWAIS is a shareware product (30 US$) of the MicroComputer Corporation (MCC). It is currently one of the best available Mac clients and cooperates with EINet MacWeb (ftp://ftp.einet.net/einet/mac/macwais1.29.sea.hqx or http://galaxy.einet.net/EINet/MacWAIS.html)

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The new European Science Foundation Network

The European Science Foundation (ESF) supports 'Scientific Networks'. These are collaborations which usually extend over a 3 year period. The ESF funding is used for organizing workshops, travel and work visits. A coordinating committee of around 10 oversees the evolution in Network activities.

A Network entitled "Converging Computing Methodologies in Astronomy" has been given the green light for a 3 year period starting in January 1995. The motivation for this project encompasses objectives such as the following:

- surveys potentially produce large quantities of data, which must be interpreted and summarized in appropriate ways;
- working with large image databases—HST for example—poses new challenges for accessing appropriate image data, with limitations on applicability of strategies which have proved successful in other disciplines;
- methods such as data fusion (eg, based on images of different resolutions, or associated bibliographic and image data), fuzzy object characterization, multiresolution transform approaches, and massively parallel algorithms, have been prototyped, and larger-scale field testing is now needed;
- large-scale catalogue data sets must be cross-correlated and linked with other forms of data such as bibliographic and image.

The Network will develop methods and take them into a range of practical environments. The topics mentioned comprise various 'emergent technologies'. The ever-growing quantities of data provide an immediate justification—and a requirement—for making use of the best-available methodologies.

The coordinating committee of the Network is comprised of: M.C. Maccarone (chair), IFCAI, Palermo; F. Murtagh (secretary), ST–ECF; A. Bijaoui, Observatoire de la Côte d'Azur, Nice; V. Di Gesù, DMA, Palermo; A. Heck, Observatoire de Strasbourg; M.J. Kurtz, Center for Astrophysics, Cambridge; P. Linde, Lund Observatory; R. McMahon, Institute of Astrophysics, Cambridge; R. Molina, University of Granada; and E. Raimond, NFRA, Dwingeloo.

Information on this Network will be available on the Web at http://http.hq.eso.org/conv-comp.html

Fionn Murtagh

The ST–ECF Web

Fionn Murtagh

The ST–ECF Web area has undergone a face-lift recently. Much of the same material as before can be obtained there but access is easier. The address is http://ecf.hq.eso.org/ That is all you need, although the longer form, with ST-ECF-homepage.html tagged on, is also perfectly valid.

While the logo will be further improved at some point, the decision was taken to minimize graphical material in the 'entrance' pages. European network speeds are often not good and network routing may cause very uneven response.

A regularly updated 'Priority Information' statement will signal noteworthy changes. A new scheme to alert interested users of any significant changes in the Web area is under test, and we hope to announce it shortly.

Public relations images are made available on the ST–ECF Web. With a very successful HST, these press release images and text are occurring more frequently than before and create wide interest.

Under 'Observer Information', some new items are the instrument homepages at STScI for the scientific instruments on board HST. These provide current information and background on the instruments. The new instruments—STIS and NIC—to be fitted during the 1997 Servicing Mission have their own homepage. Observing proposal abstracts can be searched using free text queries. The list of published and preprint HST articles, from the STScI Library, is also available for free text searching here. Observation scheduling information can be browsed using a link to the PRESTO system. This allows the progress of a specific proposal to be monitored.

The HST Archive is accessible through the ST–ECF Web area. Under Information and Data, there is a list of HST-related meetings including pointers to the two forthcoming conferences on calibration. This information area also includes a copy of the recent Dressler Committee letter on 'HST and Beyond'.

Comments on the contents of the ST–ECF Web area are welcome at any time.

AstroWeb — Internet resources for astronomers

The AstroWeb database is the most complete collection of astronomical Internet resources world-wide. It comprises well over 1100 pointers to observatories and societies, telescope schedules, meteorological information, conferences, publications, data archives, software and other information services. The AstroWeb pages have become the most accessed items in WISE, the ST–ECF's WWW-based information system.

Hans-Martin Adorf[1], Daniel Egret[2], André Heck[3], Robert Jackson[4], Anton Koekemoer[5], Fionn Murtagh[1], Don Wells[6]

The AstroWeb database

The amount of astronomical information easily accessible on the Internet has grown explosively over the past year, largely driven by the World Wide Web (WWW, Adorf 1994a) which has greatly facilitated access and transfer of textual and image data. It has been recognised for quite some time that the wealth of distributed information would benefit from some organisational structure.

During 1993 several people had individually started to collect interesting astronomical Internet resources, only to quickly realise that the only way to proceed was to merge the different, partially overlapping collections into a single, comprehensive database–the birth of the AstroWeb consortium (Adorf et al. 1994, Jackson et al. 1994a, 1994b, 1995). Its currently seven members (identical to the authors) are located at five different institutions in Europe, the United States, and Australia.

Their primary product, the AstroWeb database, comprises records for FTP, Gopher, Telnet, USENET Newsgroups, WAIS, and WWW resources, uniquely specified by their respective Uniform Resource Locators (URLs). Many resources are augmented by a paragraph of descriptive text; some descriptions already contain links to other entries. If known, the e-mail address of the resource's maintainer is stored in the record. As added value, each record is classified by a consortium member according to one or more of ~25 categories, such as observatory, instrument, abstract, software or people.

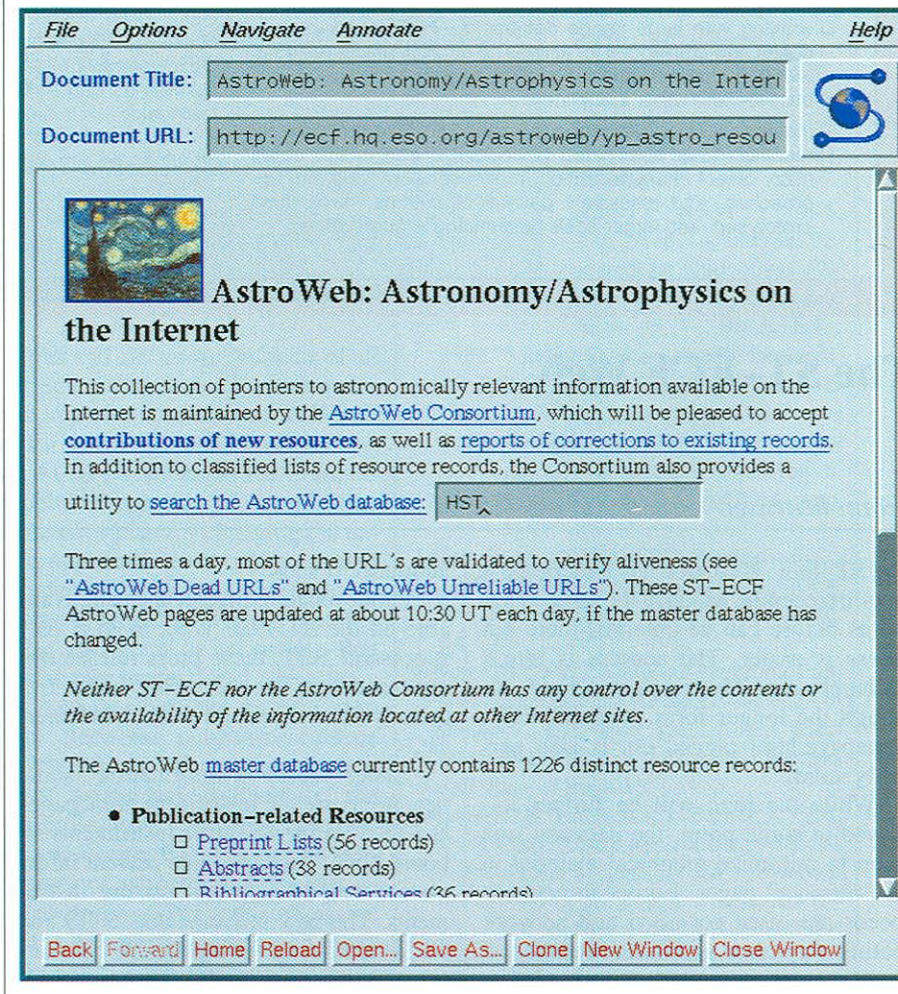
The AstroWeb collection complements the recent annotated compilation of Internet resources by Andernach, Hanisch & Murtagh (1994). Being of general interest and being the most complete collection available, the AstroWeb database pages have become the most popular items in WISE, the ST–ECF's WWW-based information system.

Structure and organisation

The current AstroWeb set-up consists of a master database maintained at the STScI. In a highly dynamic environment such as the WWW, it is important to regularly check the validity of the database entries. Three times a day a demon probes the primary URLs of all records (except Telnet URLs), and labels 'dead' or 'unreliable' entries in the database.

From the master database different renderings are automatically derived on a daily basis. For instance, the ST–ECF presentation of the database (http://ecf.hq.eso.org/astroweb/yp_astro_resources.html) is terse, permitting quick transfer and reference (suitable for European networks with relatively low bandwidths). The STScI presentation (http://www.stsci.edu/net-resources.html), on the other hand, includes the descriptive text, and is more suitable for initial browsing of the database content. Categories and resource owners are usually not displayed, but hidden in HTML comments, which can be viewed in the HTML source, if necessary.

At a size of well over 1100 entries it is



The ST–ECF's top-level WWW page (http://ecf.hq.eso.org/astroweb/yp_astro_resources.html) of the AstroWeb database.

[1]ST–ECF, [2]CDS, [3]Strasbourg Astronomical Observatory, [4]CSC/STScI, [5]MSSSO, [6]NRAO

mandatory that the AstroWeb database is searchable. There are two possibilities: after downloading the entire database one may use the simple text matching facility built into most, if not all WWW clients; or one may use a WAIS index (see Adorf 1994b) maintained at the STScI, which indexes all the information in the AstroWeb database, including the categories, URLs, and owner's e-mail address.

HST related resources in AstroWeb

For illustration we briefly inspect the current content of the AstroWeb database related to HST, ST–ECF and STScI.

Searching the database for 'HST or Hubble' retrieves more than 25 records, including pointers to STScI, ST–ECF, the Space Telescope electronic information system (STEIS), remote proposal submission (RPS), STSDAS, PSF modelling software, all three HST archives, HST public relations images, two newsgroups, the STScI's preprint database (and a gravitational lensing conference).

Similarly, searching the database for 'stecf or ecf' finds more than 30 pointers to ST–ECF related information, including WISE, the ST–ECF Newsletter, the HST archive, and all ST–ECF staff.

Finally, searching for 'STScI' reveals 35 records including pointers to STScI received preprints, STScI authored preprints (searchable abstracts), PASP abstracts, and IAU circulars.

Submission of new records

The AstroWeb consortium welcomes new contributions. To this end it provides a WWW entry form for entering new records (http://fits.cv.nrao.edu/www/astroweb/aref.html). Similarly there are entry forms for requesting modifications to existing records, for entering a personal anchor, and for reviewing recently submitted records, all accessible from the top-level AstroWeb page. Each entry or modification request is reviewed by a consortium member and, upon acceptance, added manually to the database in order to ensure continued quality.

Future developments

Several future developments are conceivable, apart from continuing to collect more Internet resources. For instance, it would be very helpful, if the AstroWeb database were internally fully cross-referenced. Also some community involvement is currently being considered in order to complete and improve the resource descriptions. In any case the AstroWeb consortium welcomes suggestions by all database users (e-mail to astroweb@nrao.edu).

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ESO

esa SPACE TELESCOPE European Coordinating Facility

Calibrating and Understanding HST and ESO Instruments

ESO / ST–ECF Workshop
ESO, Garching, April 26–28, 1995

Space and Ground-based Observatories have followed different approaches to the problem of monitoring, calibrating and understanding their Scientific Instruments. However, with the increasing complexity of the new Ground-based Instrumentation, this cultural and operational gap is gradually disappearing. This Workshop, starting from a review of the level and effectiveness of the calibration procedures which are currently adopted by the refurbished HST and by the ESO main Instruments, is aimed at highlighting the remaining differences and will provide guidelines for the development of operational procedures and software tools to be used in the VLT era. The core programme will include invited reviews followed by round-table discussions; a limited number of contributed papers / posters will also be selected.

Main Topics: HST Instruments after the M&R Mission
ESO/La Silla Instruments
VLT and VLTI Instruments
Current and Future Major Observatories
Software environments

Scientific Organizing Committee: D. Baade (ESO), P. Benvenuti (ESO/ST-ECF), J. Bergeron (ESO), S. D'Odorico (ESO), K. Freeman (MSSO), P. Grosbøl (ESO), H. Hensberge (Koninklijke Sterrenwacht van België), M. Mountain (NOAO), M. Rosa (ST-ECF), E. Schreier (ST ScI), H. Schwarz (ESO Chile), J. Spyromilio (ESO), J. Wampler (ESO)

Local Organizing Committee: P. Benvenuti, R. Gilmozzi, F. Murtagh, M. Peron, B. Sjöberg, J. Spyromilio

Further information: WWW URL http://http.hq.eso.org/calconf.html

Contact Address: Britt Sjöberg, European Southern Observatory, Karl-Schwarzschild-Str. 2, D-85748 Garching, Germany, Tel.: +49-89-32006-291, Fax: +49-89-32006-480, E-mail: calconf@eso.org

Registration Deadline: 3 March 1995

Registration Fee: DEM 80.00 payable at the workshop. The fee includes a free copy of the Proceedings published by ESO

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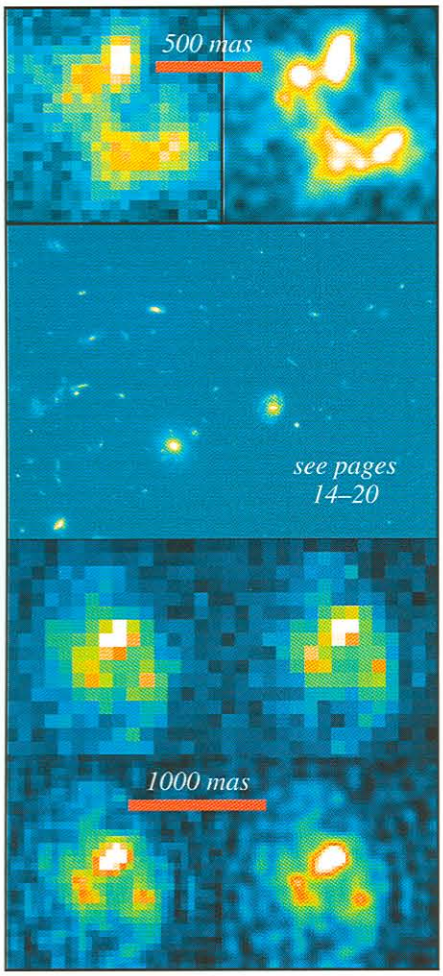

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We should like this Newsletter to reach as wide an audience of interested astronomers as possible. If you are not on the mailing list but would like to receive future issues, please write to the editor stating your affiliation.

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