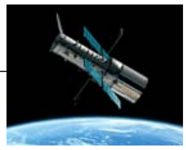
May 2004

ST-ECF Newsletter

The Bug Nebula, NGC 6302, is one of the brightest and most extreme planetary nebulae known. This Hubble image is composed of two WFPC2 (Wide Field and Planetary Camera 2) exposures: a 610 second exposure through an H-α filter (shown in blue) and a 470 second exposure through an ionized nitrogen filter (shown in red). The nitrogen (red colours) is especially abundant in the outer regions where the gas is coolest.

Image courtesy ESA/NASA and Albert Zijlstra

HST News and Status



Jeremy Walsh

A fortnight before the Cycle 13 Phase 1 deadline at the end of January 2004 the NASA Administrator, Sean O'Keefe, announced that there would be no more servicing missions to Hubble. The news was greeted with surprise in the HST community and there has been widespread reaction. Given the findings of the Columbia Accident Investigation Board, which mandated extensive changes and restrictions before return to shuttle flight, this should perhaps not have come as a shock. Subsequently O'Keefe asked Admiral Gehman, the chair of the Columbia Board for his opinion. As a result of his comments, and pressure within the US Senate, a very distinguished US National Academy of Sciences Board has also been convened to present a report on options for continuation of Hubble's life and will report in a few months. After much defence of HST excellence (the HST Daily Report reminds us that "HUBBLE SPACE TELESCOPE — Continuing to collect World Class Science") and discussions, the options for a robotic servicing mission have now been raised and publicly backed by NASA. Some form of robotic mission would certainly be required to achieve NASA's stated goal of attaching a booster to enable a controlled re-entry of Hubble. This is essential as an un-controlled re-entry poses a significant risk to life on the ground. Left to itself atmospheric drag would result in Hubble re-entry in about ten years. Options to include gyroscopes and battery replacements in such a mission are under discussion. Possibly this mission could even carry an instrument — WFC3 would be easier to install than COS, which entails opening the aft-shroud bay doors. Initial reports are that space robotic systems are more advanced than some had expected and most of the core technology already exists.

Obviously the lifetime of Hubble is now a heightened issue and steps to preserve its current capabilities are being sought. The first to take effect is the cancellation of all uncoordinated parallel programmes. The reason is that data transmission through the high gain antenna results in wear on the electronic components. Two gyro mode is under development and will be tested on-board within a year. It appears likely that Hubble can work quite well with only two gyros. The main problems are larger jitter, resulting in elliptical point spread functions which would render some programmes impossible, and much stronger constraints on target acquisition and availability which lead to complex scheduling and lower efficiency. Meanwhile HST is doing prime science with three gyros. The fourth gyro displays a high bias but is thought to be a reliable replacement when one of the others stops functioning. Since the new gyros (installed in the last two servicing missions) appear to be more reliable than the ones used in the first decade of the mission, there is optimism that HST can survive on at least two gyros for another two years or so. Every day that passes without a gyro failure leads to a revised lifetime estimate longer by about one-third of a day!

The Hubble Time Allocation Committee (TAC) met in the week of 22 March, only 57 days after the proposal deadline and the results were announced within a week of the end of the TAC meeting. European astronomers kept up their share of allocated time, being awarded 15.7% by orbits and 18.8% by proposal number. Two ESA PI proposals were among the 10 Large and Treasury proposals accepted. There was no change to the TAC process as a result of the cancellation of HST servicing missions but probably by the next TAC in early 2005 some contingency plans will have to be in place to deal with the eventuality of two gyro mode. Some creative thinking will be required to optimize the science from Hubble until there can be renewal of components.

Staff Arrivals

Richard Hook

Paolo Padovani joined the ST-ECF in December 2003 as an Astrophysical Virtual Observatory (AVO) Scientist and manager of the AVO Work Area 1 (Science). His main research interests are active galactic nuclei at all wavelengths, radio sources, blazars and unified schemes, and multiwavelength surveys. Paolo spent the past six years in Baltimore as an ESA Archive Scientist at the Multimission Archive at STScI.

Science from the Astrophysical Virtual Observatory

Paolo Padovani on behalf of the AVO Project Team

The second Astrophysical Virtual Observatory (AVO) science demonstration was held during an AVO Science Working Group meeting in January 2004 at ESO. This "First Science" event showed that AVO tools have evolved beyond the demonstration level to become respectable research tools. The AVO is now enabling astronomers to reach into new areas of parameter space with relatively little effort.

Background

The breathtaking capabilities and ultra-high efficiency of new ground and space-based observatories have led to a data explosion calling for innovative ways to process, explore, and exploit these data. The Virtual Observatory (VO) is an innovative, evolving system that allows users to interrogate multiple data centres in a seamless and transparent way using new international standards for data access and mining protocols. The VO initiative is a global collaboration of the world's astronomical communities under the auspices of the recently formed International Virtual Observatory Alliance (IVOA).

The Astrophysical Virtual Observatory (AVO) project is conducting a research and demonstration programme on the scientific requirements and technologies necessary to build a VO for European astronomy. The AVO has been jointly funded by the European Commission (under the Fifth Framework Programme [FP5]) with six European organizations participating in a three year Phase-A work programme. The partner organizations are ESO in Munich, ESA, AstroGrid, which is funded by PPARC as part of the United Kingdom's E-Science programme, the CNRS-supported Centre de Donneés Astronomiques de Strasbourg (CDS), the TERAPIX Astronomical Data Centre at the Institut d'Astrophysique in Paris, the University Louis Pasteur in Strasbourg and the Jodrell Bank Observatory of the Victoria University of Manchester. As a coordinated effort, the IVOA partners are holding demonstrations of new VO capabilities on an annual basis.

AVO prototype

The AVO recently held a Science Working Group meeting and related demonstration on January 27-28 2004 at ESO. On the technical side, the demonstration revolved around the AVO prototype. This is an evolution of Aladin, developed at CDS, and has become a varied set of software components, provided by AVO and international partners, which allows relatively easy access to remote data sets, manipulation of image and catalogue data, and remote calculations in a fashion similar to remote computing. The prototype is enabled by the VO infrastructure and interoperability standards that are being developed by all the VO projects under the auspices of the IVOA.

Science demonstration

The AVO science demonstration this year dealt with an extragalactic case on obscured quasars, centred around the Great Observatories Origins Deep Survey (GOODS) public data, and a galactic scenario on the classification of young stellar objects.

New features, compared to last year's demonstration (ST-ECF Newsletter 33), included the support of spectroscopic data, with direct links between imaging and spectral data of the same sources, seamless and transparent access to scientifically validated products from the ISO and XMM-Newton archives, usage of new standards (Simple Image and Simple Spectrum Access), and new tools (SpecView, Hyper-z, VOPlot, and a cross-matching service).

The demonstration was truly multi-wavelength, using heterogeneous and complex data covering the whole electromagnetic spectrum. These included: MERLIN, VLA (radio), ISO (spectra and images) and 2MASS (infrared), USNO, ESO 2.2m/WFI and VLT/FORS (spectra), and HST/ACS (optical), XMM and Chandra (X-ray) data and catalogues.

Science results

The extragalactic scenario resulted in the discovery of about 30 new optically faint, obscured quasar candidates, the so-called QSO 2, an improvement of a factor of 4 when compared to the nine such sources previously identified in the GOODS fields. By going about 3 magnitudes fainter than previously known objects we are sampling a region of redshift — power space so far un-

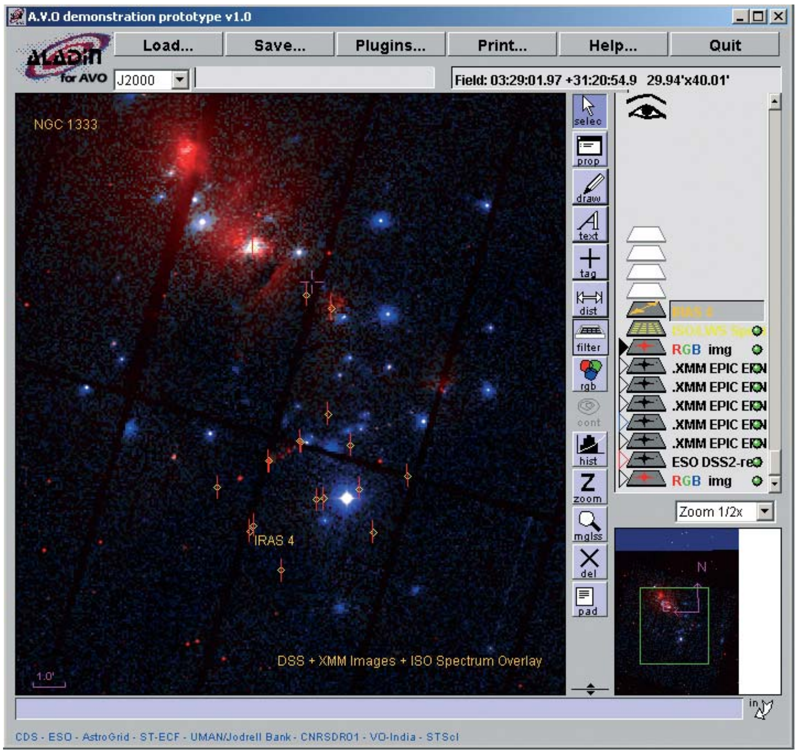
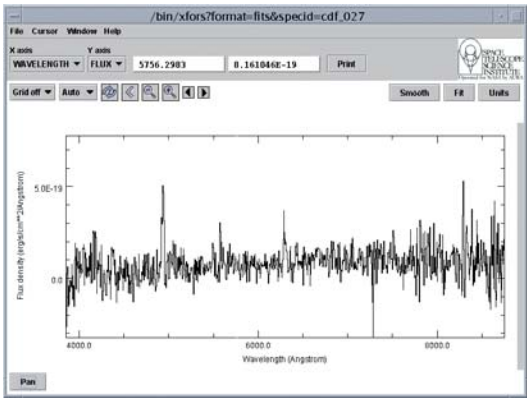


Fig 1: Composite optical (red — DSS2) and X-ray (blue — XMM Newton) image of the star-forming region NGC 1333. Symbols denote sources with infrared spectra taken with ESA's ISO.



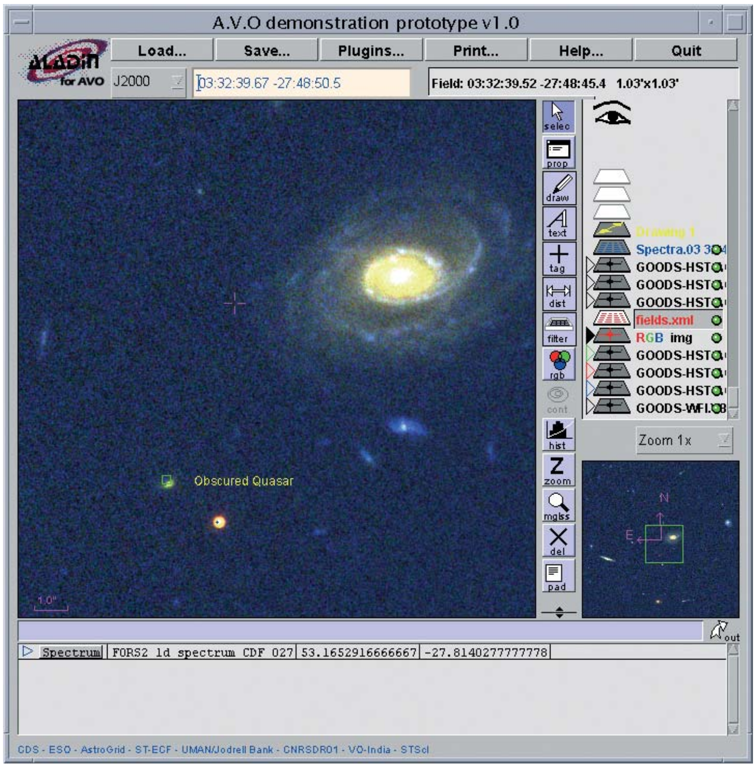


Fig 2: Example of the direct links between imaging and spectral data: an obscured quasar selected via its X-ray (Chandra) properties, imaged by the HST/ACS (right), and identified through an ESO/ VLT FORS2 spectrum (above). The great majority of the new candidates are too faint to be classified even by the VLT or Keck.

reachable with "classical" (ie, non-VO) methods. The inferred QSO 2 surface density is much larger than current estimates and predictions. A paper describing these results has been submitted to Astronomy & Astrophysics. The demonstration showed that AVO is already starting to do cutting-edge science by allowing the exploitation of astronomical data beyond the classical identification limits. Astronomers are quickly moving beyond the era when source identification was done by taking a spectrum with a telescope, into an era when classification is achieved by using all the multiwavelength information available.

Using the AVO prototype

The AVO prototype used during the demonstration can be downloaded from the AVO Web site at: http://www.euro-vo.org/twiki/bin/view/Avo/SwgDownload. This page also contains detailed instructions on how to reproduce the AVO science demonstration (both the extragalactic and galactic scenarios). We encourage astronomers to download the prototype, test it, and also use it for their own research. For any problems with the installation and any requests, questions, feedback, and comments you might have please contact the AVO team at twiki@euro-vo.org. It should be noted that this is still a prototype: although some components are pretty robust some others are not.

Conclusions

The second AVO demonstration has shown that the AVO is mature enough to produce science results by exploiting astronomical data beyond classical identification limits (R < ~25). The paper that came out of it represents the first significant published science result that has been fully enabled via end-to-end use of VO tools and systems.

The AVO Phase-A will end on October 31 2005. The main AVO commitments before then are: to produce a Science Reference Mission, that is a definition of what the AVO should be when fully implemented (Phase B); to complete the definition of its science requirements; to complete the description of the data, archive interoperability and the necessary database technologies needed for a full implementation; and finally, to deliver the last AVO demo in January 2005. Work is well under way in all of these areas.

After Phase-A, the project will move towards the EURO-VO, which is the full-fledged 4-year European VO programme.

Acknowledgments

The AVO was selected for funding by the Fifth Framework Programme of the European Community for research, technological development and demonstration activities, contract HPRI-CT-2001-50030.

References

- *AVO Home Page: http://www.euro-vo.org/*
- *AVO Science Working Group Meeting 2004: http://www.euro-vo.org/twiki/bin/view/Avo/SwgMeeting04*
- *AVO Prototype Download: http://www.euro-vo.org/twiki/bin/view/Avo/SwgDownload*
- *International Virtual Observatory Alliance: http://www.ivoa.net/*

Supernova blast bonanza in nearby galaxy

European Space Agency, NASA & Peter Anders (Göttingen University Galaxy Evolution Group, Germany)

The nearby dwarf galaxy NGC 1569 is a hotbed of vigorous star birth activity which blows huge bubbles and super-bubbles that riddle the main body of the galaxy. The galaxy's vigorous 'star factories' are also manufacturing brilliant blue star clusters. This galaxy had a sudden and relatively recent onset of star birth 25 million years ago, which subsided about the time the very earliest human ancestors appeared on Earth.

The bubble structure in this new image, taken with the NASA/ESA Hubble Space Telescope, is sculpted by the galactic super-winds and outflows caused by a colossal input of energy from collective supernova explosions that are linked with a massive episode of star birth.

The bubble-like structures seen in this image are made of hydrogen gas that glows when hit by the fierce winds and radiation from hot young stars and is racked by supernovae shocks. The first supernovae blew up when the most massive stars reached the end of their lifetimes roughly 20-25 million years ago. The environment in NGC 1569 is still turbulent and the supernovae may not only deliver the gaseous raw material needed for the formation of further stars and star clusters, but also actually trigger their birth in the tortured swirls of gas.

Oxygen and carbon discovered in exoplanet atmosphere 'blow-off'

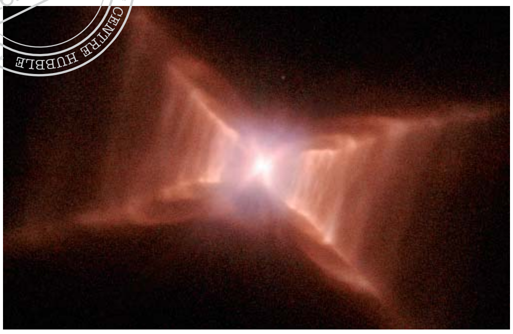
European Space Agency and Alfred Vidal-Madjar (Institut d'Astrophysique de Paris, CNRS, France)

This artist's impression shows an extended ellipsoidal envelope — the shape of a rugby-ball – of oxygen and carbon discovered around the well-known extrasolar planet HD 209458b.

An international team of astronomers led by Alfred Vidal-Madjar (Institut d'Astrophysique de Paris, CNRS, France) observed the first signs of oxygen and carbon in the atmosphere of a planet beyond our Solar System for the first time using the NASA/ESA Hubble Space Telescope.

The atoms of carbon and oxygen are swept up from the lower atmosphere with the flow of escaping atmospheric atomic hydrogen — like dust in a supersonic whirlwind — in a process called atmospheric 'blow off'.

The remarkable Red Rectangle: stairway to heaven?



NASA/ESA, Hans Van Winckel (Catholic University of Leuven, Belgium) and Martin Cohen (University of California, USA)

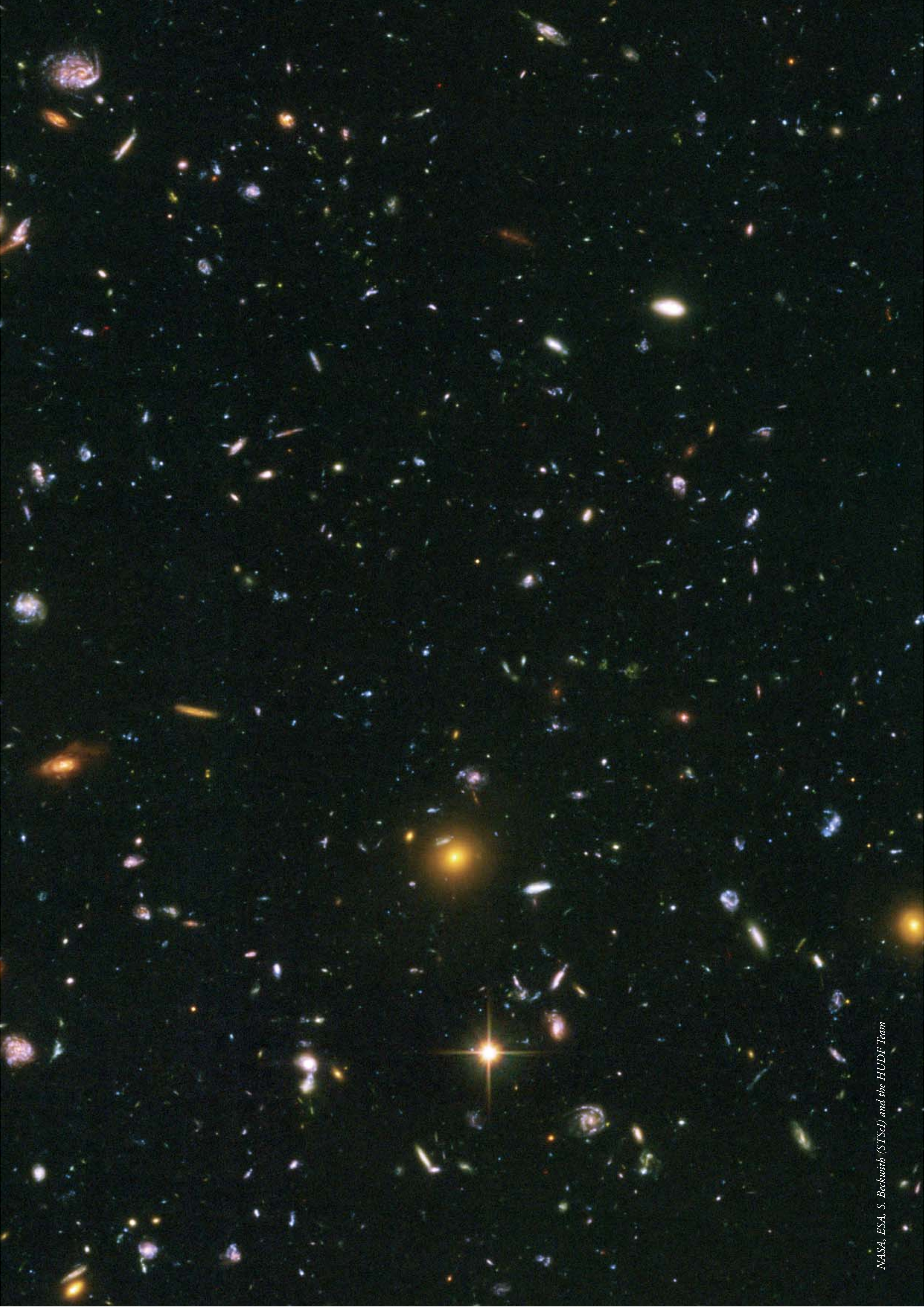
This image, taken with the NASA/ESA Hubble Space Telescope, reveals startling new details of one of the most unusual nebulae known in our Galaxy. Catalogued as HD 44179, this nebula is more commonly called the "Red Rectangle" because of its unique shape and colour as seen with ground-based telescopes.

Hubble has revealed a wealth of new features in the Red Rectangle that cannot be seen by ground-based telescopes looking through the Earth's turbulent atmosphere. Details of the Hubble study were published in the April 2004 issue of The Astronomical Journal.

Hubble Ultra Deep Field released

Richard Hook

The Hubble Ultra Deep Field data release occurred on schedule on 9 March 2004. The release was coordinated between STScI (Baltimore), ST-ECF/ESO (Garching) and CADC (Victoria) and went very smoothly despite huge interest from both the scientific community and the public. The ST-ECF contributed software and was responsible for the reduction of the data, including grism spectroscopy, from the Hubble ACS HRC instrument. This work, and the algorithmic development it prompted, is described in the accompanying articles. The picture shown here covers about half of the primary ACS/WFC field and was created from the final mosaiced data in the BViz bands.



NASA, ESA, S. Beckwith (STScI) and the HUDF Team

Reducing the Hubble Ultra Deep Field ACS HRC Data

Jeremy Walsh, Martin Kümmel & Søren S. Larsen

The STScI Director's time devoted to the Hubble Ultra Deep Field (HUDF) in the Chandra Deep Field South (CDFS) exploited all the possible parallel opportunities available with Hubble. As well as the primary field of the Advanced Camera for Surveys (ACS) Wide Field Channel (WFC), part of which is reproduced in this Newsletter on page 6-7, there were parallel data obtained with the ACS High Resolution Channel (HRC), NICMOS, WFPC2 and STIS. The ACS HRC was used in its auto-parallel mode. In this case, because the HRC and WFC share the same filter wheels, the filters used by the WFC dictate those in use by the HRC in parallel. Since the primary science was set by the WFC and its B (F435W), V (F606W), i (F775W) and z (F850LP) filters, the HRC was exposed in the UV (F220W), V (F555W), methane band (narrow band centred at 8920Å, F892N) filters and the G800L grism.

Since the ST-ECF is responsible for support of the ACS grism and prism modes, it seemed natural for us to attempt to reduce this data. After some negotiation we agreed not only to reduce the G800L data but also the HRC direct images through the three other filters, to extract all the spectra from the images and to make the resultant data products public at the same time as the release of the HUDF WFC and NICMOS parallel data. The field of the HRC is small (about 28 arc-seconds square) and would not be expected to contain very many objects. The positions of the HRC auto-parallel observing positions on the GOODS image and relative to other HUDF fields is shown on the figure on the back page of the last ST-ECF Newsletter, No. 35, 2004. Nevertheless there were four hundred orbits (840 ks) of HRC data in total, of which 300 ks was slitless spectroscopy. Since the HUDF campaign had to be split between two sets of roll angles of the spacecraft, this implied that there would not be one HRC Hubble Ultra Deep Field but two, and in addition the 4 degree range in roll angle of the each campaign gave rise to a shift of about half an HRC field. The resulting combined images only achieve the full exposure over about half the HRC field as can be seen in Figure 1.

Reducing the images

For the two roll angles, the sets of F220W, F555W and F892N images were reduced using the ACS pipeline to produce bias-subtracted, gain corrected and flat fielded images. These were cleaned of cosmic-rays and other defects and drizzled into a single image using the MultiDrizzle task of the IRAF/STSDAS software package. Although there were very many images to combine (56,48 for F220W, 57,52 for F555W and 152,124 for F892N at the two epochs) the small size of the HRC images (1024x1024 pixels) made it feasible to run the MultiDrizzle combination on a standard SunBlade 1000 workstation. Since the fields were small and there were no bright objects — only in one field was there an object bright enough to confidently align single images — we had to trust in the excellent pointing of HST to provide our image alignment. By examining combinations of several images taken on a given day, it was clear that there were no large shifts to deal with, so we were confident that the final images were not significantly smeared. For a subset of the frames where the alignment could be checked with a single bright object, we did note a small, time-dependent shift in the alignment of the individual images. The maximum amplitude is about one HRC pixel, and is presumably due to differential velocity aberration between the WFC and HRC apertures. Since we had no way to test for such offsets for the entire dataset it was not possible to apply any empirical correction, but we are currently investigating the possibility of modelling and applying a correction for the effect of differential velocity aberration on parallel exposures.

Figure 1 shows one of the fields, the one resulting from the September-October 2003 campaign (roll angles 310-314 degrees) in the V band. The F220W field essentially only shows a detection of the brightest object (the disk galaxy at the top of the field). The F892N image shows detection of some of the other objects but no obvious emission line objects without continuum in the V band, such as Lyman-α emitters in the redshift range 6.27 to 6.40.

Reducing the slitless spectroscopy

In order to extract the slitless spectra it is necessary to know the position of the object on the direct image giving rise to the spectrum. This position is required by the aXe software developed at the ST-ECF (http://www.stecf.org/software/aXe/index.html), which was used as the basis of the slitless spectroscopy extraction. The F555W image was ideal for this purpose and a catalogue of objects was created using SExtractor. The two catalogues (one for each epoch) contained 39 and 70 objects respectively. We had never attempted to extract such weak spectra from stacks of so many low signal-to-noise images before. One approach would be to extract all the available spectra from each individual image and then combine the 1D extracted spectra. Since there were many pixels affected by cosmic rays and partial coverage of spectra caused by the different field coverage, we decided to try out a more radical approach. For the predicted position of each spectrum expected from the position of the direct image, a sub-image would be cut out and rectified to a long slit spectrum with wavelength and position offsets perpendicular. The transformation and combination of the spectra from each image was accomplished with the drizzle software, now with a transformation to an image with an X-axis in Ångstroms and a Y-axis in arc-seconds. The HUDF HRC was used as a prototype for this approach, so we were somewhat nervous we might not be able to achieve the full reduction before the deadline of the HUDF public release.

The article by Martin Kümmel in this Newsletter describes the method of drizzle combination of the slitless spectra. Once the deep drizzle-combined spectrum of an object had been formed it was extracted using an aXe task. However, since each spectrum is now a long slit spectrum, there are many other tasks in the major astronomical software packages which could be used for the extraction step. Now that the data have been publicly released we can see some of the advantages of this approach of drizzle combination of spectra and this has led us to think that perhaps it could be used more generally for the combination of spectra from other spectrometers.

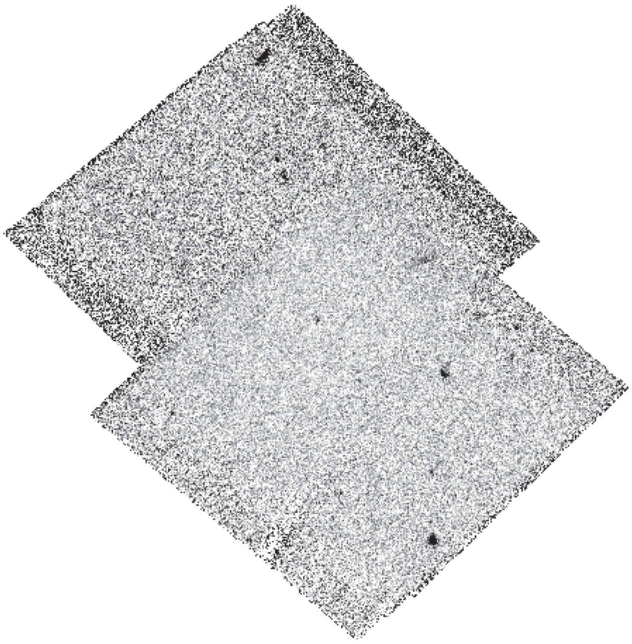


Fig 1a: ACS/HRC HUDF F555W parallel image combination from the first epoch of observations in September and October 2003.

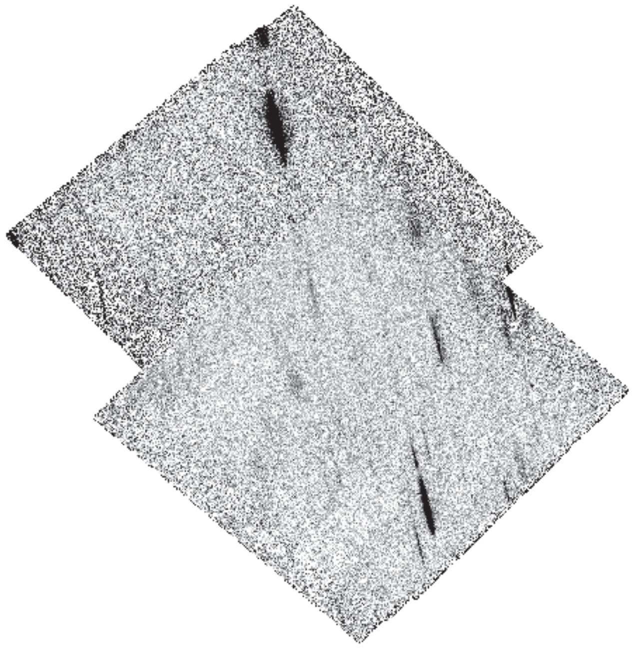


Fig 1b: The matching G800L grism image of the same field.

The catalogues derived from the V band HRC images were sufficient to extract the spectra of most objects. However, there were some spectra at the edges of the field where we could not establish a wavelength scale since the object giving rise to the spectrum lay outside the HRC field. Since the fields of both HUDF HRC parallel images are situated in the GOODS CDFS area, the GOODS images and catalogues could be used to provide the positions of these objects. In addition, since the HRC catalogue was established in the V band, red objects, in particular V dropouts, would not be contained in this list. Fortunately the GOODS dataset includes deep z-band images which could be used to provide the required coordinates of red objects in the HRC fields. Aligning the GOODS V band image to the HRC V band drizzled combination allowed accurate relative positions for the direct objects in the frame of the HRC to be derived. Although the spectra were extracted with the HRC V detected objects and the GOODS objects combined, the extracted spectra were presented in two sets, primarily because the HRC-based ones were totally HUDF derived.

Presenting the data

Despite developing the technique of drizzle combination on the actual HRC data itself, we managed to finish the extraction of the spectra in good time for the public release deadline of 9th March 2004. Since a FITS table containing multiple spectra is not a very user-friendly product for an observer unfamiliar with slitless spectroscopic data, we decided to present the data through a series of Web pages (http://www.stecf.org/UDF/HRCpreview.html). The aXe2web tool (described in the last ST-ECF Newsletter) was used to produce browsable spectra and a 'Spectrum Selector' was constructed which enables the user to click on the position of source on the direct image of the HRC field and to bring up the extracted spectrum of that object. We viewed this presentation of the data as a move in the direction of Virtual Observatory provision of well-defined public datasets.

The HRC autoparallel data resulted in eight final drizzled images (three filters and grism at two epochs) and a total of 182 spectra. The brightest object whose spectra was presented was m_{AB} (F555W) = 18.7 and the faintest beyond m_{AB} (F555W) = 27.5. There weren't any major surprises among the spectra, such as Lyman-α emitters at redshift beyond 7, but there was a V dropout object which, from its spectrum, appears most probably to be a dwarf star. The spectra are among the deepest available in the spectrum range 7000-9500Å which is a difficult region from the ground on account of the strong and variable atmospheric emission.

We were encouraged that within a feasible time we could combine hundreds of ACS slitless spectral images and extract their spectra (even while developing the reduction tools). We are therefore contemplating reducing some other HST public datasets in a similar manner and releasing them to the community.

Drizzling and the aXe Slitless Spectra Extraction Software

Martin Kümmel, Jeremy Walsh, Søren Larsen & Richard Hook

The Advanced Camera for Surveys (ACS) on the Hubble Space Telescope offers slitless spectroscopy as one of its observing modes. Over the wavelength range 5500 to 10500Å the G800L grism provides spectra with a resolution of 40Å/pixel and 24Å/pixel on the Wide Field Channel (WFC) and High Resolution Channel (HRC), respectively. The ACS slitless spectroscopy mode is especially effective due to the low, stable and homogeneous background from space. The G800L grism has been extensively used in parallel programmes such as the Hubble Ultra Deep Field (HUDF), HRC Parallels (see http://www.stecf.org/UDF/) and the the ACS Pure Parallel Lyman-α Emission Survey (APPLES, PI James Rhoads, http://www-int.stsci.edu/~rhoads/apples.html) and also for primary observations such as Grism-ACS Program for Extragalactic Science (GRAPES, with PI Sangeeta Malhotra; see http://www-int.stsci.edu/~san/Grapes/, and Pirzkal et al. 2004 for more details) and spectroscopic follow-up of high redshift supernovae (Riess et al. 2004).

The ST-ECF is responsible for the support of the spectroscopic modes of ACS. This support provides wavelength and flux calibration and the aXe software package to extract and visualise slitless spectroscopy data from the ACS. The aXe Spectral Extraction Software in its current version (aXe-1.3, see http://www.stecf.org/software/aXe/) is part of the IRAF/STSDAS software package and has been extensively described in earlier Newsletter articles (see Pirzkal et al. 2001, Pirzkal et al. 2003 and the aXe manual http://www.stecf.org/software/aXe/Manual_1.30.pdf). In this article we concentrate on describing a new reduction technique which uses drizzling (Fruchter & Hook 2002) to combine slitless spectral data. This reduction scheme has been used in a preliminary version to reduce the HUDF HRC Parallel data (see http://www.stecf.org/UDF/HRCpreview.html). We are currently working on a final version which will form the main extension to aXe to be released as aXe-1.4 in Summer 2004.

aXe

The aXe spectral extraction software was designed to extract large numbers of spectra from ACS grism images in an unsupervised way. As data input aXe needs a grism image, a corresponding direct image and a catalogue which lists the objects detected on the direct image. Driven by the object catalogue the various aXe tasks extract wavelength and flux calibrated 1D spectra for each object from the grism image.

An ACS data set usually consists of several images on the same sky region with only small shifts (dithers) between them. One way to derive the coadded spectrum of an object from such a data set is to coadd the 1D spectra extracted from each image to form a combined, deep spectrum. This approach, however, has several drawbacks:

• The data must be (non-linearly) rebinned twice, once when extracting the spectrum from the image and again when combining the individual 1D spectra

• A complex weighting scheme is required to flag the number and contribution of cosmic ray affected pixels in the combined spectral element arising from the summation in the cross-dispersion direction as well as the relative exposure per spectral element

• Low level information on the cross dispersion profile is lost when many 1D extracted spectra are combined to a deep spectrum. Also problem detection and error tracking is more difficult on a 1D than a 2D spectrum

For cosmic ray affected pixels, a convenient correction method is replacing them with the average (or median) value derived from the whole data set at the corresponding position. This approach was used in the reduction of the thousands of spectra extracted from the GRAPES data of the HUDF (Pirzkal et al. 2004). But this procedure skews the signal-to-noise ratio of the affected pixels. Moreover the standard tools to replace CR rejected pixels (eg, MultiDrizzle) work on the basis of geometrical distortion models and do not take into account dispersing elements and their field dependent wavelength solution, which would require a different, non standard model for ACS slitless spectroscopy.

aXe and drizzling

To circumvent the drawbacks mentioned above we extended the aXe reduction scheme such that for each object a coadded, deep 2D spectral image is formed from all the 2D spectra in the individual images. The final, deep 1D spectrum is then extracted from this combined 2D spectral image. The method of combining the individual 2D spectra was to use the drizzle software (Fruchter & Hook 2002), available in IRAF/STSDAS. Drizzle is the standard technique for combining Hubble images. It has the advantage that it preserves photometry and resolution and can handle weighting of input images according to the statistical significance of each pixel. This is the first implementation of the drizzle code to combine spectral data, and the technique presented here can also be applied in other reduction packages for spectral data. The advantages of this technique as applied to slitless spectra can be summarized:

• Regridding to a uniform wavelength scale and a cross-dispersion direction orthogonal to the dispersion direction is achieved in a single step

• Weighting of different exposure times per pixel and cosmic-ray affected pixels are correctly handled through the drizzle weights

• There is only one linear rebinning step to produce a 2D spectrum. The 1D spectrum can be extracted simply by summing the source flux in the cross-dispersion direction without additional binning

• The combined 2D spectra can be viewed to detect problems and the deep spectra can reveal lower level features which were subsumed in the 1D spectra

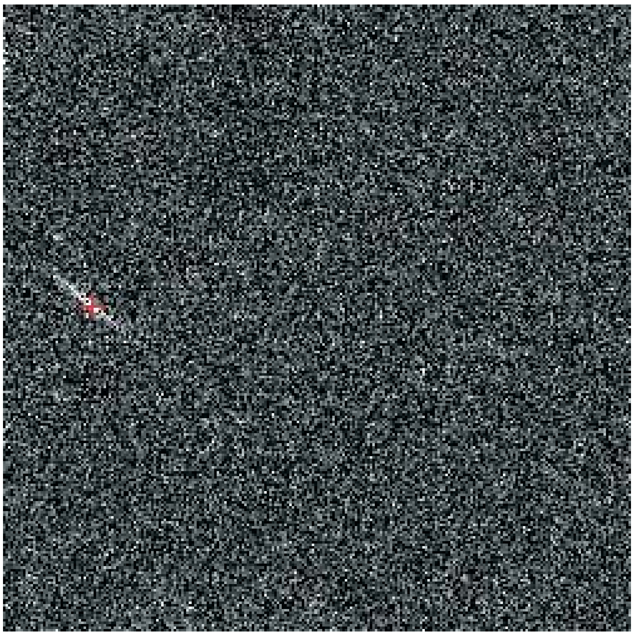


Fig 1: Spectrum of the object J033253.28-274934.8 (marked with a red cross) on one of the individual grism images (j8m840bwq_flt) in the HUDF HRC Parallels dataset.

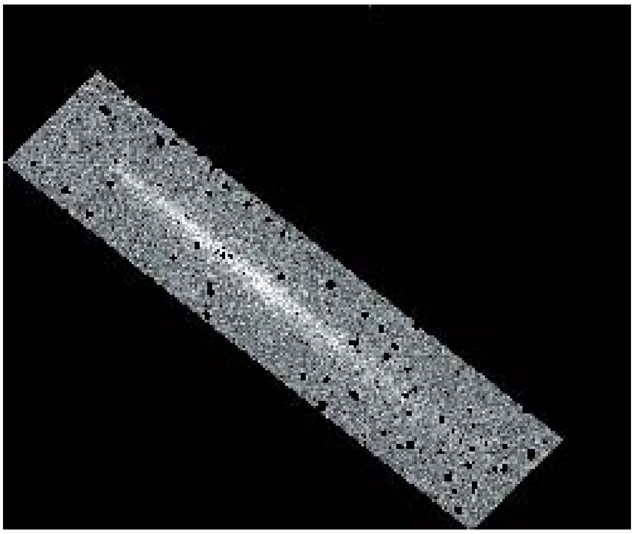


Fig 2: Individual stamp image of J033253.28-274934.8 extracted from the image in Figure 1.

• Standard tools can be used to extract the 1D spectrum from the 2D one and weighting can be applied (eg, optimal extraction)

Those advantages come at the expense of greater complexity of the reduction and significantly larger processing time.

To illustrate this scheme Figures 1 to 4 highlight the main steps to compute the combined 2D spectral image for the object J033253.28-274934.8, a relatively bright (m_{AB}(F555W) = 22.8) QSO observed in the HUDF HRC Parallel programme. Figure 1 shows the spectrum of J033253.28-274934.8 marked with a red cross on one of the individual grism images (j8m840bwq_flt). Following the normal aXe procedure, fully flat fielded and wavelength flagged Pixel Extraction Tables (PETs) were derived for all images that cover, wholly or partially, the object spectrum. A PET is an internal data transport format within aXe: it is a binary table which lists the pixel positions and values within a given aperture surrounding the trace of the spectrum values. The information about the assigned wavelengths of the individual pixels is also held in the PET. The PETs were converted to 2D spectral 'stamp' images (in FITS). Figure 2 shows the stamp image for the QSO as derived from the input _flt image in Figure 1.

To create the coadded, deep 2D spectral images, the drizzle task within STSDAS was used. For the dozens of grism stamp images of the QSO from the single grism images, transformation coefficients were derived to drizzle the individual 2D spectra onto a single, common output image. The transformation coefficients are computed so that the combined drizzle image resembles an ideal long slit spectrum with the dispersion direction parallel to the x-axis and cross-dis persion direction parallel to the y-axis. Moreover, the wavelength scale (in Å/pixel) and the pixel scale in the cross-dispersion direction (in arcsec/pixel) are the same for all the drizzled spectra. Figure 3 shows the drizzled grism stamp image derived from that displayed in Figure 2. In Figure 4 the final coadded 2D spectrum for the J033253.28-274934.8 as derived from the HUDF HRC Parallels data is shown. For this image, 112 PETs with a total exposure time of 124 ksec were combined. In both Figures 2 and 3 the 'holes' resulting from the discarded cosmic ray-affected pixels are clearly visible.

The wavelength scale as well as the pixel scale in the cross-dispersion direction can be chosen by the user with keyword settings in the aXe configuration file. For the undersampled WFC data in particular this offers the possibility to enhance the image resolution (both in the wavelength direction and the cross-dispersion direction) if the data were taken with subpixel stepping.

Extraction of deep spectra from drizzled images

Figure 5 shows the deep 1D spectrum extracted from the coadded 2D spectrum shown in Figure 4. The 1D extraction was done using aXe tasks. To finally extract the 1D spectrum from the deep 2D spectral image any longslit extraction program can be used. aXe also offers tools to perform this reduction step with an adapted configuration file that takes into account the modified spectrum of the drizzled images (ie, orthogonal wavelength and

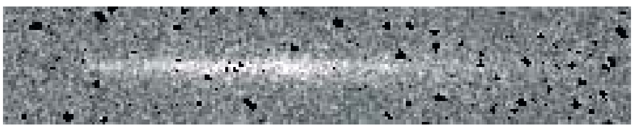


Fig 3: Drizzled stamp image derived from the image shown in Figure 2. Here and in Figure 2 the holes created by discarding bad pixels and cosmic ray affected pixels are clearly visible.

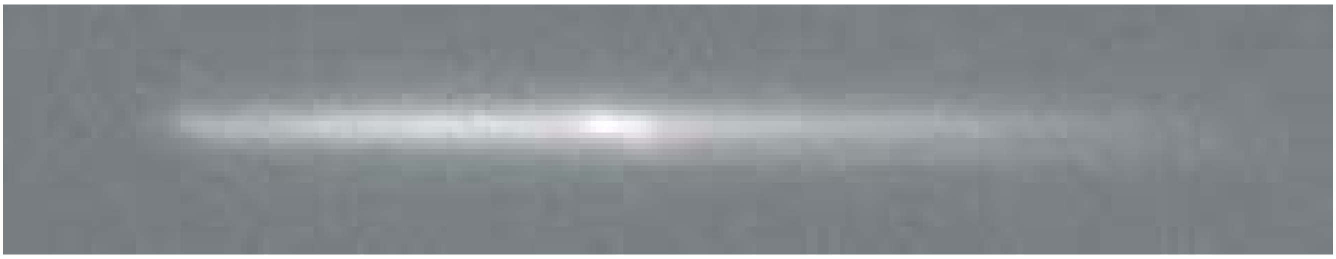


Fig 4: Final, coadded 2D spectrum of J033253.28-274934.8 derived from the whole HUDF HRC Parallel data set. The wavelength scale is 24Å/pixel, and the pixel scale in the cross-dispersion direction is 28mas/pixel.

cross-dispersion and the Å/pixel and arcsec/pixel scales). For the extraction of the 1D spectra (Figure 5) from the 2D drizzled images (eg, Figure 4) aXe applies a weighting scheme which take into account the variations in signal-to-noise ratio provided by the drizzle weights. The differing weights are a consequence of the variations in the exposure time within the 2D drizzled image (since not all images are guaranteed to cover the whole spectrum) and by the flagged cosmic rays. Within each set of pixels that is coadded to a final spectral element, the weight assigned to an individual pixel is proportional to its relative exposure time. While the irregular coverage of the total field of view makes exposure time weighting a necessity, this first application of weights within aXe opens the door for the implementation of more refined weighting schemes such as optimal extraction (Horne 1986) in future aXe releases.

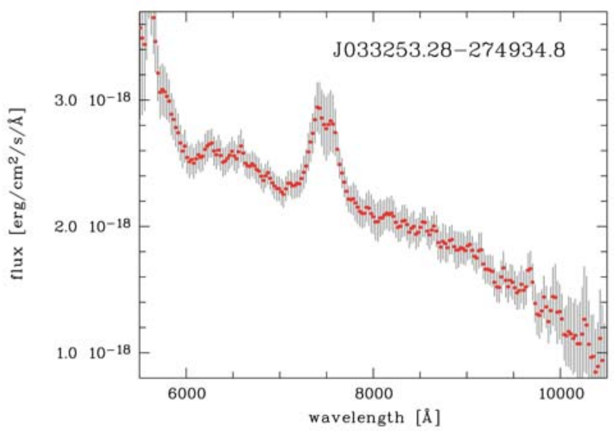


Fig 5: 1D spectrum of J033253.28-274934.8 extracted from Figure 4.

Release of aXe-1.4

In a pilot study, the new reduction scheme was applied to reduce the data from the HUDF HRC parallels. The results can be seen on the preview webpages of the ACS HRC Parallel data at: http://www.stecf.org/UDF/HRCpreview.html. With this study, the feasibility and the power of the new reduction scheme was proved. We are currently working to implement this scheme as a set of new aXe tasks. Those new tasks will form the major part of the extension to aXe, which will be released as aXe-1.4 in Summer 2004.

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"Simplicity" at Spacetelescope.org – A web scheme for science communication

Lars Lindberg Christensen, Lars Holm Nielsen (freelance) & Erik Nordström Andersen (freelance)

Designing any web site is far from trivial. Designing web sites that are both user friendly and easy to maintain is a real challenge.

Here we describe the ideas behind Spacetelescope.org, the new public and press web site for the NASA/ESA Hubble Space Telescope in Europe, and the general structure and workings of Simplicity, an innovative scheme for producing web sites which we developed to build Spacetelescope.org.

Simplicity provides an efficient alternative to existing commercial content management systems and is free for everyone to use. A more detailed description can be found at:
http://www.spacetelescope.org/projects/web

The web was not a fad...

A recent billboard advertisement read "The web wasn't just a passing fad". No one would argue with that statement. In science communication the web is one of the most frequently used ways of distributing popular information about science to the media, the public and decision makers today. Although the web is still more of a 'professional medium', it is also increasingly a layman's tool. For several years the web has been the preferred tool for journalists to conduct story research and therefore a proper web site must be a very high priority for any public information office.

Fig 1: The front page for spacetelescope.org.

The European outreach and education office for both the Hubble Space Telescope and the James Webb Space Telescope, the Hubble European Space Agency Information Centre (HEIC), has existed since 1999 to disseminate public information about these two missions. More details about our work can be found on the web at: http://www.spacetelescope.org/about_us

At HEIC we see the web as an excellent tool for the distribution of outreach products and for product archiving (as a repository), while also providing a service that is available at any time as well as a search engine for the rapid retrieval of relevant material. The most critical issue for us is time management — an efficient outreach office needs to spend most of its time producing material, and very little time on actually distributing it.

Early in 2004 we began designing our new web site and we naturally wanted to exploit the positive features of the web and to produce a web site that fulfilled our particular needs for efficiency. We quickly realized that the need to reduce manpower consumption for web maintenance was a general one and we extended our methodology into a general scheme for building efficient web sites. A scheme we now offer to the community.

The result of our efforts is the new public and press web site for the NASA/ESA Hubble Space Telescope in Europe and the web scheme Simplicity that combines ease of use for visitors with a simple and effective strategy for maintenance.

Put yourself in the place of others

Targeting a website to its primary customers is essential to make it successful, and the front page of a web site is undoubtedly the most important page of all. In our preparations for an effective front page we devised a so-called "Front page priority matrix" where we collected an overview of different target groups. The importance of different elements on the page was assessed — with us trying to imagine the preferences of the target group in question. Following this we gave each of the groups effective weights calculated from how big a target group they represent and from their 'importance' (as judged by our own particular criteria).

The study of this matrix led to the following conclusions:

- A simple page overview is the most important.
- News must have top priority.
- Hubble images have to be prominent.
- We can't allocate excessive space for flash animations.
- We can't allocate excessive space for design components.

We ended up with the design for the front page seen in Figure 1. For us this is the compromise between

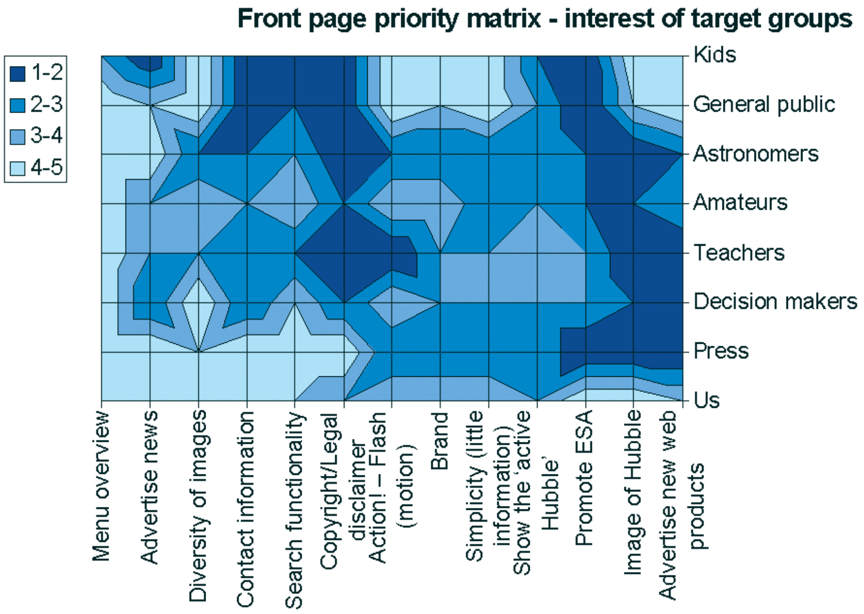

Fig 2: An assessment of the importance of different elements on the front page — with us trying to imagine the preferences of the target group in question. The higher the score (lighter colour), the higher priority an element has for a given target group. The scores in this chart are folded with the effective weight of the target groups, and the final result is a priority of the elements on the front page.

efficiency, searchability, science, visual appeal, 'action' and overview that we think caters for the needs of most target groups and the most important users.

For Spacetelescope.org there were three main areas of focus in the planning phase. Firstly to plan the functionality of the web site, then to plan the sitemap — ie, the structure (files and directories) and finally to plan file formats and sizes for images and videos — ie, the structure of the metadata.

Anyone implementing a web site using the Simplicity scheme that is described below will need to go through the same three planning steps and to commit one or two days to set up and adapt the Perl scripts to specific needs.

Some of the main features of the finished Spacetelescope.org site are:
- The complete collection of ESA and NASA Hubble images
- Huge volumes of animations and films (~35 GB)
- Optimal image quality (best available tiff/jpeg files, sizes up to 250 MB)
- Interactive flash applications and
- Last, but not least, a well-functioning hardware, software and network infrastructure.

Requirements for Simplicity – the web scheme

Technically the general web site scheme behind Spacetelescope.org was built to satisfy several requirements.

Firstly it will produce user-friendly web sites that are easy to navigate, have consistent, attractive designs and are extremely fast for the customers. In today's information overloaded society it is crucial to provide search capabilities that enable the user to sift through the vast amounts of information swiftly and receive an instant response to each query.

Secondly the technology behind the site juggles huge data files — images and videos — (from 10s to 1000s of MB) in archives containing thousands of items each represented in up to 15-20 different formats (eg, thumbnails, wallpaper, originals etc. for the images), without impeding function or maintenance.

Thirdly the maintenance of the web system is extremely easy. Design changes are made in just one place so that the web master is not forced to manually update hundreds of pages. Structural changes such as the addition of new archives are also possible with relatively small changes to the scripts.

Finally, the website is relatively 'CPU light' and can, on standard server hardware, handle many concurrent visitors.

Components of the web scheme

Apart from the data itself (images, videos etc.) Simplicity consists of three main components:
- Dreamweaver templates for the 'wrapping' of the design
- Perl scripts to execute various search and display queries
- Excel, or comma separated, files for the metadata, or information, attached to images, news stories, videos, posters etc.

Dreamweaver MX is used to edit the html-scripts. Dreamweaver is a simple and visual commercial editor that enables the easy editing of web pages, and also provides a template scheme. The templates define editable areas of a web page, making it possible to keep a consistent design on all web pages. Any changes made to a template will cascade to all web pages that are based on it, and so design changes need only to be made in one place. To further ease the maintenance load, so-called nested templates are used, which are templates based in turn on another template. This makes it possible to define the global design of the website in one template and create templates for the different sections based on this global template to hold the individual section design items and menus.

Archives

One of the pillars of the Simplicity scheme is the concept of "archives". An archive can be any collection of data and metadata (images and information). The content of an archive can be for-

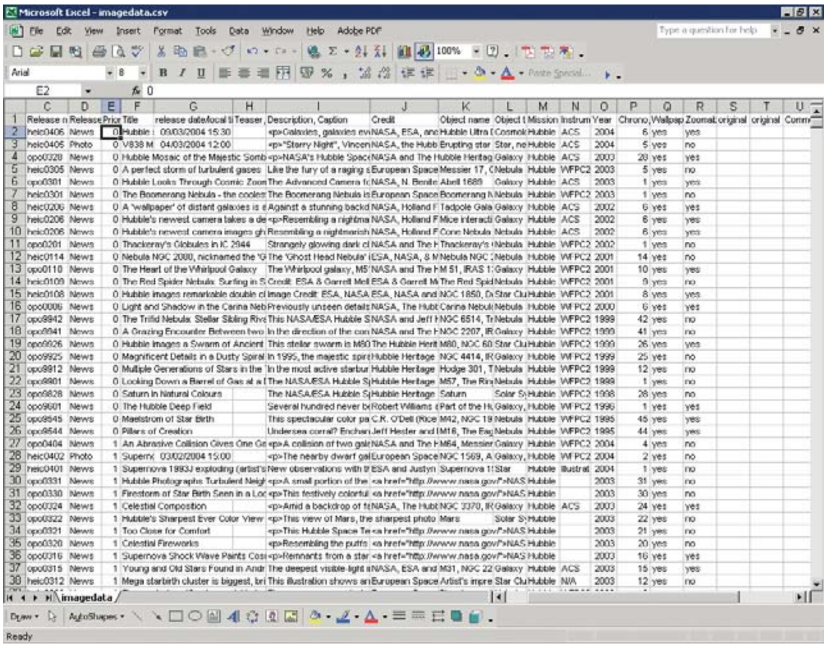

Fig 3: The archive metadata are stored in Excel files (in reality comma-delimited text files). These files hold all the data for each news item, image and video and are edited with Microsoft Excel (or any column-based editor).

matted in any way that is needed, and in different ways in the different parts of the website.

Instead of using off-the-shelf database solutions that have problems dealing with huge files, a large maintenance overhead and a potentially slow response time, the choice for Simplicity fell on lightweight Perl scripts as the 'engine' to create the dynamic web content.

In Simplicity the Perl scripts search and show excerpts of the archive metadata that are stored in Excel files (in reality comma-delimited text files). These files hold all the data for each news item, image and video and are edited with Microsoft Excel (or any column-based editor). The metadata include the object ID (for instance the image filename), title and caption. Excel, although not traditional for this type of work, has maintenance-friendly features such as spell checking and is familiar and easy to use.

The Perl scripts can format the data/metadata content of the archives in many different ways and also make refined searches possible. Other features are also built into the Perl scripts:

- Publishing at a pre-determined time
- Generating static html pages for the data and metadata contents that are changed rarely (news, images, videos etc.)

Search functions are provided through a freely available search engine called "ht://Dig" that indexes all web pages on a regular basis, and can be customized to fit into the overall design. Furthermore a freely available link-checker can be implemented into the scheme to make sure that all links on the web site are valid.

Pros and cons

Why choose a 'home-made' low-tech solution over one of the many content management systems[1] (CMS) on the market? A CMS can certainly be adapted to most common user demands, such as ease of maintenance and a consistent design, but when it comes to performance and handling of huge image files, we believe most CMS fail.

In science communication there is an extreme need for flexibility, and this implies the fully autonomous control of a web scheme and its technical maintenance and flexibility to quickly adapt to new ideas. Most CMS do not provide this. In addition most CMS do not provide the lightning fast response needed.

On the down side Simplicity is not a foolproof scheme. No web system is ever 100% foolproof, but our scheme is probably more open to error, especially when used by non-technical staff. Simplicity is also not a multi-user system, in the sense that only one person at a time can edit the page design, or update the individual metadata files. In a normal outreach office none of these issues should present major worries as it is usually staffed with technical personnel and there is no need for workflow control, approval control and version tracking.

As a happy side effect, the construction of Simplicity (including the implementation of Spacetelescope.org with all its data and metadata) only required three man-months of work, compared to an estimated two or three times longer for off-the-shelf CMS (with less functionality). Some of this time was naturally invested in an integral knowledge of the scheme which in the long run will contribute towards a reduced total cost of ownership. The total implementation costs were about 13 kEuro.

Simplicity's low-tech solution has already proven its performance capability. Spacetelescope.org is running on a single Apache web server and was able to cope with 2.3 million hits per day (50-60 requests/sec peak load) and the delivery of up to 180 GB of data per day during the first weeks of operation.

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[1] A CMS is a large database driven tool that helps to structure information in the form of text, images and animations and place it on the web in a predefined way.

V838 Monocerotis revisited: Space phenomenon imitates art

HUBBLE
European Space Agency Information Centre

"Starry Night", Vincent van Gogh's famous painting, is renowned for its bold whorls of light sweeping across a raging night sky. Although this image of the heavens came only from the artist's restless imagination, a new picture from the NASA/ESA Hubble Space Telescope bears remarkable similarities to the van Gogh work, complete with never-before-seen spirals of dust swirling across trillions of kilometres of interstellar space.

This image, obtained with the Advanced Camera for Surveys on February 8, 2004, is Hubble's latest view of an expanding halo of light around a distant star, named V838 Monocerotis (V838 Mon). The illumination of interstellar dust comes from the red supergiant star at the middle of the image, which gave off a flashbulb-like pulse of light two years ago. V838 Mon is located about 20,000 light-years away from Earth in the direction of the constellation Monoceros, placing the star at the outer edge of our Milky Way galaxy.

Credit: NASA, the Hubble Heritage Team (AURA/STScI) and ESA

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