ST-ECF

December 2006

NEWSLETTER

41

Future of Hubble Data

Finding Solar System Bodies

NASA Award for ST-ECF Staff

Space Telescope European Coordinating Facility

HUBBLE'S BEQUEST TO ASTRONOMY

Robert Fosbury & Lars Lindberg Christensen

Although the Hubble Space Telescope is currently in its 17th year of operation, it is not yet time for its obituary. Far from it: Hubble has been granted a new lease of life with the recent announcement by Michael Griffin, NASA's Chief Administrator, that Servicing Mission 4 (SM4) is scheduled for 2008. The purpose of this article is to reflect a little on what Hubble has already achieved and, rather more importantly, to remind ourselves what still needs to be done to ensure that the full legacy of this great project can be properly realised.

Following musings on the advantages of a telescope in space by Hermann Oberth in the 1920s and by Lyman Spitzer in the 1940s, serious studies of a "Large Space Telescope" were started by NASA in 1974. In 1976 NASA formed a partnership with ESA to carry to low Earth orbit a large optical/ultraviolet telescope on the Space Shuttle. Since its launch in 1990, and the all-important first Servicing Mission in 1993, the Hubble Space Telescope (or "Hubble" for short) has performed two supremely important and valuable functions. For scientists, it has helped to reshape our view of the Universe in ways that were beyond our imagination at the start of the 1990s. For the public, it has pioneered an intellectually — and visually! — exciting view of the scientific endeavour. It has brought astronomy, particularly in the form of spectacularly beautiful colour pictures, into homes and schools all over the planet.

Both of these impacts can be well quantified using appropriate and reliable metrics: the refereed journal publication statistics on the one hand and, on the other, the brand recognition and the huge number of press and broadcast references. Indeed, the publication numbers and scientific impact measures from Hubble have become the benchmark against which other scientific projects measure themselves.

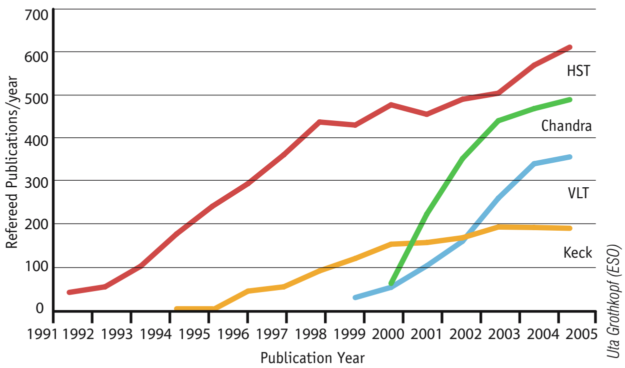


Fig 1: *Hubble's scientific productivity is illustrated by the number of refereed papers per year using Hubble, ESO/VLT, Chandra and Keck data (found with ADS as of December 2006). Also see Grothkopf et al. (2005).*

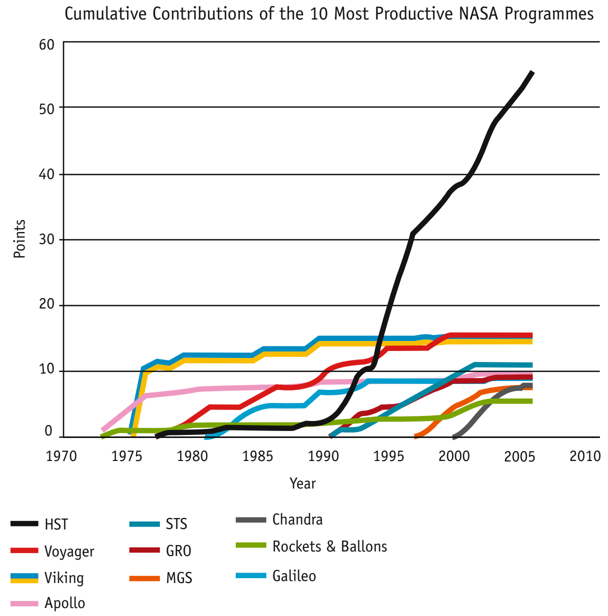
However, such endeavours do not come cheap. The total cost of the Hubble project could well exceed 9 billion US$ and its implementation has involved tens of thousands of man-years of effort. A project of this scale necessarily offers us many lessons, and it is legitimate to ask ourselves — from a scientific and operational perspective — which of them we have learned.

The use of crewed missions to launch and maintain a robotic telescope has been questioned by many. The presence of astronauts greatly inflates the cost of a spacecraft and its launch, which is why the vast majority of space science experiments are fully robotic. The lesson from Hubble, however, is that the ability to maintain and refit an observatory in space can multiply its scientific productivity and effective lifetime by large factors. Were it not for the success of Servicing Mission 1, the HST would still be regarded as the embarrassing disaster it nearly became when spherical aberration was discovered in the figure of the primary mirror. So effective were the corrections built into subsequent instruments (and applied by COSTAR to the then existing ones) that, for most people, the memory of the grim early days of the telescope has faded. Hubble is now considered to be operating close to a state of perfection. Each time the Shuttle visits Hubble and the astronauts perform their amazing ballet, the Observatory is rejuvenated by the addition of more capable instruments. As the Shuttle returns to Earth, the telescope is quickly brought back into smooth and efficient operation, providing the waiting astronomers with a more powerful Observatory far more quickly than they would have achieved with a new and untried telescope.

The great practical lesson from Hubble concerns the efficient operation of a complex observatory in low-Earth orbit for a diverse clientele of astronomers from around the world. Not only does this serve the astronomers who have won observing time in a highly competitive field, but it deposits the well-described and calibrated data into an archive that becomes publicly accessible to everybody after a year. Making the operation reliable and efficient, and performing the archiving functions in a way that enables astronomers to perform front-line scientific research using their downloads, is a truly remarkable achievement that has become the operational paradigm for other space missions and ground-based observatories such as ESO's Very Large Telescope.

We should dwell on the value of the archive since, in addition to the discoveries already made, it will become the most tangible legacy of the mission. Christian & Davidson (2006) show that space observatories (such as IUE and OAO) have their peak scientific publication rate some 4-6 years after launch. Already, papers based on Hubble archival research can be published at a higher rate than those deriving from GO or GTO programmes. Hubble has been in routine operation nearly 365 days a year at an efficiency of close to 50% for over 16 years. The resulting archive is arguably the richest collection of scientific data ever assembled. Given the cost and complexity of the Observatory, it is unlikely that it will be possible to match or exceed most of Hubble's capabilities for several decades at least. It is therefore contingent upon us to ensure that the data are freely available — and scientifically usable — in perpetuity.

There are currently three operating Hubble archives: at the Space Telescope Science Institute (STScI) in Baltimore, at ESO/ST-ECF in Munich and at the Canadian Astronomy Data Centre (CADC) in Victoria, Canada. In addition to providing robustly secure curation for the

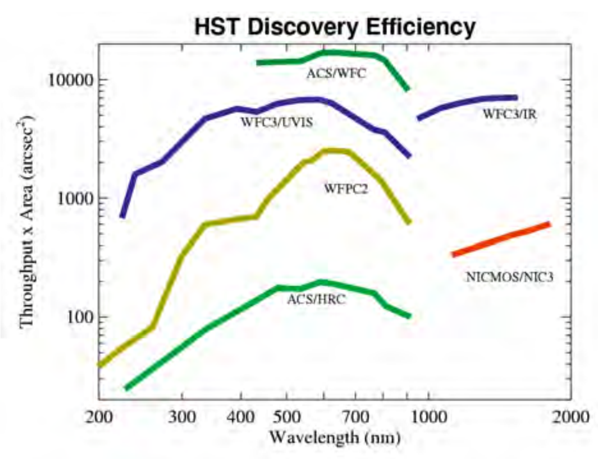


Greg Davidson Northrop Grumman Corporation

Fig 2: *The public popularity of Hubble in comparison with other NASA missions, measured as the annual number of 'most important stories' in the journal "Science News", from 1973 to 2005. Roughly 150 stories are listed every year, and a story (1 point) attributed to multiple missions or observatories is split fractionally to the different contributors. Only NASA missions are counted here and so European and ground-based contributions are unrepresented. See also Christian & Davidson (2006).*

priceless collection of all data from Hubble's nine current and past instruments, the three sites all contribute to the "intellectual property" represented by the archives and their means of access. If only one site had operated, its archive would be considerably less rich than it is now. This "friendly competition" has resulted in a number of innovations including imaging "Associations", "On-the-Fly-Calibration" and innovative user interfaces.

If SM4 is successful in 2008, Hubble will be set to continue operations for at least five years, resulting in a very substantial increase in the content and scientific value of the archives. With the two new instruments, Wide Field Camera 3 (WFC3) and Cosmic Origins Spectrograph (COS), and the possibility of a repaired STIS (that is currently dormant due to a power-supply failure), the overall "discovery



STScI

Fig 3: *Relative 'discovery efficiency' of WFC3 in the ultraviolet and infrared will increase Hubble's capability more than ten-fold. In the visible, however, the ACS will continue to reign supreme.*

efficiency" of the rejuvenated Hubble, measured as light throughput multiplied by field of view, will increase by an order of magnitude. WFC3 alone will, in the ultraviolet and near-infrared, produce more than a factor of ten increase (see Figure 3).

In terms of data volume, and very probably also in terms of scientific value, the archives are still awaiting their most important data ingest. There remains much work to be done if the repository is to be complete for posterity.

In addition to the data in what we term the "Classical Archive" — the raw and pipeline processed products — the three archive centres are collaborating on the production of higher level science data products, encapsulating more comprehensive metadata and instrument/calibration knowledge, to form the Hubble Legacy Archive (HLA — see Walsh & Hook 2006).

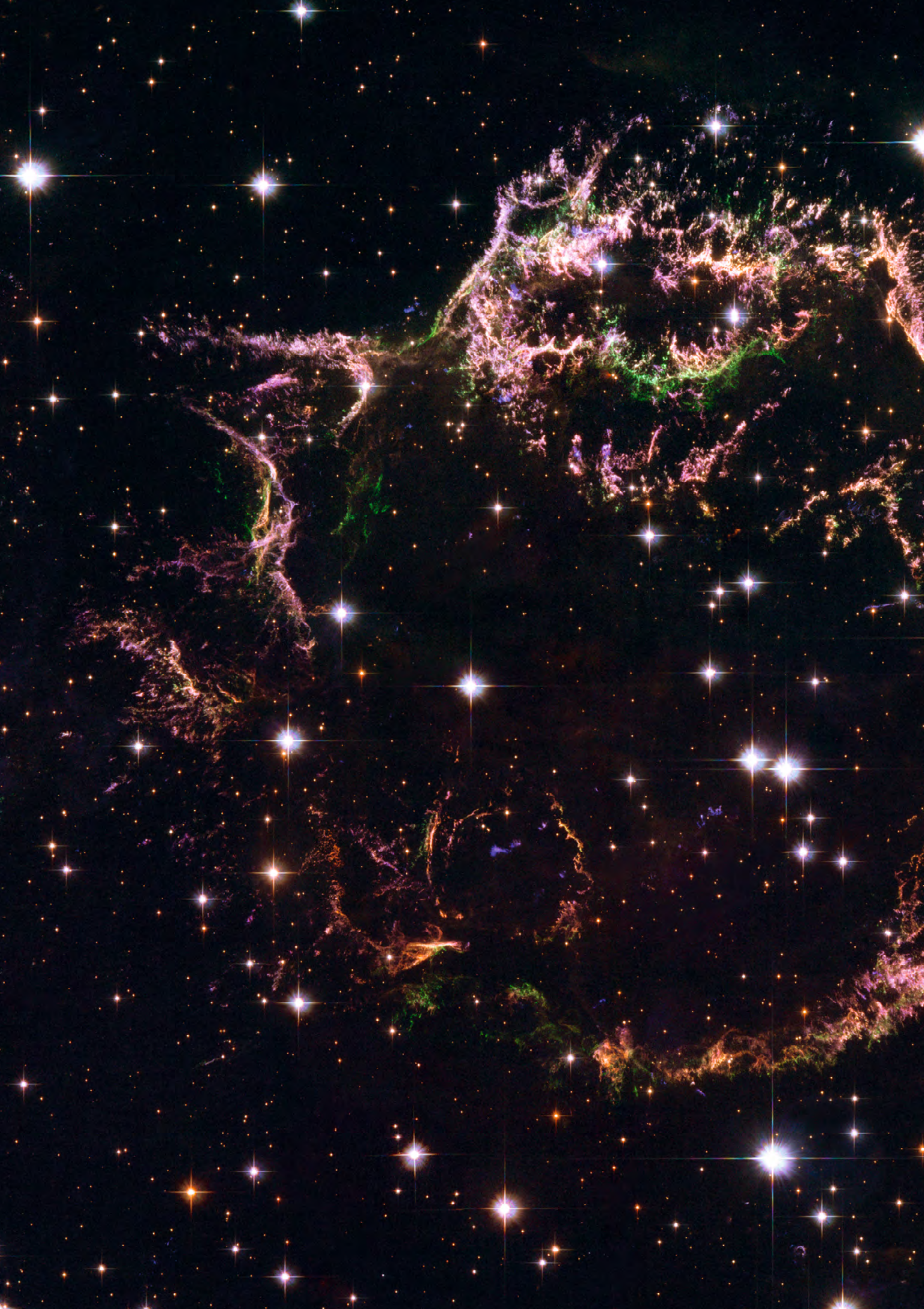
The decision to service Hubble again with the Shuttle in 2008 has opened up the vista of a very substantial future potential for the mission. There is even the possibility of an overlap of operation with the James Webb Space Telescope (JWST), a new observatory that will depend on the legacy of Hubble discoveries and, in a very practical way, on the high resolution images that will provide target coordinates for multi-object spectroscopy with ESA's NIRSpec instrument. This bright future carries implications for the operational support of the telescope and its instruments well into the next decade. It also causes us to think hard about how we can ensure that the archival legacy of this wonderful mission is complete and secure.

References

Christian, C. & Davidson G. 2006, "The Science News Metrics", in Organisation and Strategies in Astronomy 6, Ed. André Heck, Springer

Grothkopf, U. et al. 2005, "Comparison of Science Metrics among Observatories", ESO Messenger 119, 45

Walsh, J. & Hook, R. 2006, "Creating a Legacy Archive for Hubble", ST-ECF Newsletter 40, 6



NASA, ESA, and the Hubble Heritage (STScI/AURA)-ESA/Hubble Collaboration. Acknowledgements: Robert A. Fesen (Dartmouth College, USA) and James Long (ESA/Hubble)

CASSIOPEIA A [heic0609]

The colourful aftermath of a violent stellar death

The Hubble Space Telescope has provided a detailed look at the tattered remains of a supernova explosion known as Cassiopeia A (Cas A). Cas A is the youngest known remnant from a supernova explosion in the Milky Way. The image shows the complex and intricate structure of the star's shattered fragments.

The image is a composite made from 18 separate shots taken with Hubble's Advanced Camera for Surveys (ACS), and it shows the Cas A remnant as a broken ring of bright filamentary and clumpy stellar ejecta. These huge swirls of debris glow with the heat generated by the passage of a shockwave from the supernova blast. The various colours of the gaseous shards indicate differences in chemical composition. Bright green filaments are rich in oxygen, red and purple are sulphur, and blue are composed mostly of hydrogen and nitrogen.

A supernova such as the one that resulted in Cas A is the explosive demise of a massive star that collapses under the weight of its own gravity. The collapsed star then blows its outer layers into space in an explosion that can briefly outshine its entire parent galaxy. Cas A is relatively young, estimated to be only about 340 years old. Hubble has observed it on several occasions to look for changes in the rapidly expanding filaments.

In the latest observing campaign, two sets of images were taken, separated by nine months. Even in that short time, Hubble's sharp vision can observe the expansion of the remnant. Comparison of the two image sets shows that a faint stream of debris seen along the upper left side of the remnant is moving with high speed — up to 50 million kilometres per hour — fast enough to travel from Earth to the Moon in 30 seconds!

Cas A is located ten thousand light-years away from Earth in the constellation of Cassiopeia. Supernova explosions are the main source of elements more complex than oxygen, which are forged in the extreme conditions produced in these events. The analysis of such a nearby, relatively young and fresh example is extremely helpful in understanding the evolution of the Universe.

The new composite taken with the Advanced Camera for Surveys aboard the NASA/ESA Hubble Space Telescope depicts the youngest known remains of a supernova explosion: Cassiopeia A.

PHLAG: PIPELINE FOR HUBBLE LEGACY ARCHIVE GRISM DATA

Martin Kümmel, Alberto Micol, Harald Kuntschner, Jeremy Walsh & Wolfram Freudling

The ST-ECF is currently working on a pilot project to find out what is needed to build data products to form part of the future Hubble Legacy Archive. A manageable data set has been selected — spectroscopic data from Hubble's Near Infrared Camera and Multi-Object Spectrometer (NICMOS) — and software is being assembled into a "pipeline" that can take the datasets, stored in the archive, and process them to the point where they can be used for scientific analysis. The current state of the software is described.

INTRODUCTION

Together with its partners at the Canadian Astronomy Data Centre (CADC) and the Space Telescope Science Institute (STScI), the ST-ECF has started to build a Hubble Legacy Archive (HLA). More details about the background and scope of this project can be found in Walsh & Hook (2006). The main difference between the current Hubble archives and the HLA is that the HLA will contain higher-level science data products than are currently available and these will be immediately usable for scientific analysis by archive users.

The ST-ECF has supported Hubble spectroscopy in many ways through its history. Examples are projects such as the calibration lamp project (see page 20 of this Newsletter), the physical modelling approach to improve the calibration of the Faint Object Spectrograph (FOS) and the Space Telescope Imaging Spectrograph (STIS), the development of NICMOSlook, an IDL-based software tool for reducing slitless spectra from the Near Infrared Camera and Multi-Object Spectrometer NICMOS, and the full support of all slitless spectroscopic modes of the Advanced Camera for Surveys (ACS). As a natural continuation of these efforts the ST-ECF has decided to initially contribute to the HLA in the area of slitless spectroscopy. Since data taken in this observing mode are currently distributed with only basic detector-level calibration applied, offering high-level science products such as fully reduced extracted spectra would represent a big advantage to scientists.

Instrument	Disperser	Wavelength Range (Å)	Resolution (Å/pixel)	FOV (arc-second)
NICMOS/NIC3	G141	1100-19000	80.0	51 X 51
ACS/WFC	G800L	5500-10500	38.5	202 X 202
ACS/HRC	G800L	5500-10500	23.5	29 X 26
ACS/HRC	PR200L	1700-3900	20[@2500Å]	29 X 26
ACS/SBC	PR130L	1250-1800	7[@1500Å]	35 X 31
ACS/HRC	PR110L	1150-1800	10[@1500Å]	35 X 31

Tab 1: *Some Hubble slitless spectroscopic modes under consideration for the ST-ECF HLA activities and their characteristics.*

To generate high level science data and provide input to the HLA the **P**ipeline for **H**ubble **L**egacy **A**rchive **G**rism data (PHLAG) is currently being developed at the ST-ECF. PHLAG is designed to be a fully integrated pipeline that retrieves data from the Hubble archive, processes them, extracts fully calibrated spectra, and finally ingests all extraction products into the HLA.

CONCEPTS

Many Hubble instruments have, or in case of the legacy instruments had, slitless spectroscopy as one of their observing modes. The available slitless spectroscopic data covers a large wavelength range from 1150Å (ACS/SBC) to 2.5 microns (NICMOS/G206), usually at a low resolution of $\lambda/\delta\lambda \sim 200$. However, the volume of data taken in the different slitless modes varies greatly. The Hubble configurations listed in Table 1 have been chosen to be the main targets of the ST-ECF efforts for the HLA. For other modes such as STIS/G750L, STIS/PRISM or WFPC1/GRISM, either the data volume is much smaller or there is less experience within the ST-ECF, and they will be considered at a later stage of the HLA project.

Without restricting its general use for all slitless spectroscopic data, PHLAG was developed using, and is currently being first applied to, NICMOS G141 grism data.

The ST-ECF has developed two software packages for the reduction of slitless spectroscopic data, NICMOSlook (http://www.stecf.org/instruments/NICMOSgrism/nicmoslook/) and aXe (http://www.stecf.org/instruments/ACSgrism/axe/). NICMOSlook is an interactive tool developed in IDL and with many NICMOS-specific features. On the

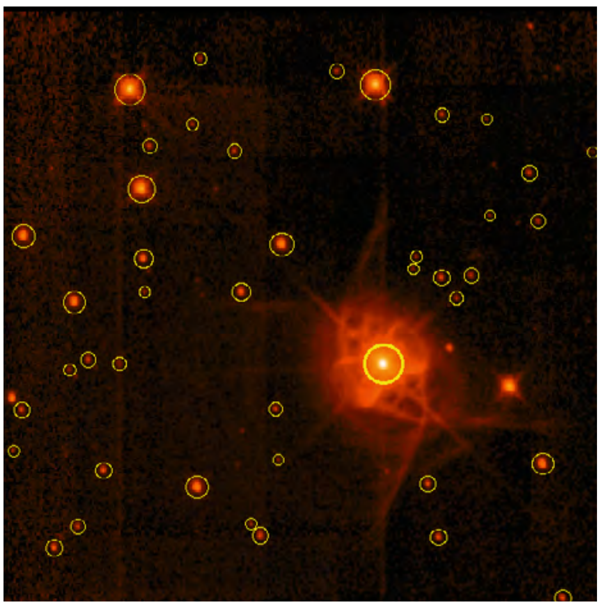


Fig 1: *MultiDrizzled direct image of the planetary nebula HB12, reduced with PHLAG. The yellow circles mark the sources detected in the object detection module. The spectra of these objects are then extracted from the slitless grism images.*

other hand, aXe is a semi-automatic data reduction system for the extraction of spectra, which has been configured and used for ACS and other, non-Hubble instruments. It was decided to use aXe as the engine of PHLAG and to enhance it with some essential NICMOS-specific features transferred from NICMOSlook.

The reduction of slitless spectroscopic data relies on the presence of direct images taken at the same sky position. This is a consequence of the lack of a framework on which to base the trace definition and the wavelength calibration. An aperture, which would define such a framework in spectroscopy with slits or masks, is not present and must be introduced for every object, using the knowledge of its position derived from an accompanying direct image (see Kümmel, Larsen & Walsh 2006). As a consequence, the processing of direct images is an integral part of PHLAG (see next Section and Figure 1).

PHLAG is intended to deliver HLA products within the next two years. Achieving results within such a short time is only possible by designing and developing PHLAG to be very flexible and lean, using existing technology and software (such as PyRAF, SExtractor and MultiDrizzle) wherever possible. PHLAG is built as a series of modules, which allows a convenient spread of responsibility amongst several developers. The pipeline is implemented in Python (www.python.org), a fast and convenient scripting language which contains interfaces to all necessary external packages.

THE MODULES OF PHLAG

The inputs to PHLAG are calibrated datasets as provided from the current Hubble archive. The final products of PHLAG are reduced, VO-compatible slitless spectra stored in an HLA archive.

As in the case of conventional near-infrared imaging, repeated, "dithered'' slitless observations of a target field usually exist. Combining and co-adding the spectra from different images requires high precision in the relative astrometry of both the slitless spectroscopic and direct images. For Hubble data such a precision can only be guaranteed within a so-called "visit'', a period during which Hubble is continuously locked on the same guide stars. The association of images taken during the same visit therefore forms the natural data unit on which to run PHLAG.

PHLAG consists of a series of modules that each perform a certain reduction step on the data. It is possible to run one dataset (association) through all the modules as well as to run several, or all, existing associations through a set of selected modules.

- **Preparation**: In this step the data are prepared for pipeline reduction. The direct images are grouped according to the filter. The "best" filter is chosen, which is the filter whose images cover the area of the slitless spectroscopic images and offers the greatest depth for a selection of spectroscopic objects. Finally, every slitless image is paired with the direct image in the "best" filter that was obtained with the smallest positional difference. The set of direct image — slitless image relationships created here is an essential input to the spectral extraction.
- **Data Retrieval**: This step copies the data from a staging area to a work area for the data reduction. The staging area provides all the on-the-fly-calibrated images of an instrument mode.
- **Image Combination**: To prepare for the object extraction, the images in the "best" filter are combined to create a deep direct image. This is done using the MultiDrizzle software (Koekemoer et al. 2006).
- **Object Detection**: The object detection software SExtractor (Bertin & Arnouts 1996) is run on the combined direct image. The spectra of all detected sources will be extracted from the slitless images. Figure 1 illustrates the final products of the direct image processing in PHLAG, the MultiDrizzled filter image (of the planetary nebulae HB12) and the objects detected in SExtractor. Conservative parameter settings are used, and the prime aim is to detect all objects that also have detectable spectra in the slitless images.
- **Background Subtraction**: A global background is subtracted from the slitless images. If possible, the background image is constructed from the data itself. Otherwise an appropriate pre-fabricated background image is selected.
- **Spectral Extraction**: The spectrum extraction package aXe (see Kümmel et al. 2006) is used to extract the object spectra from the slitless images. aXe determines a local background around every object to remove any residual sky background. As shown in Figure 3 for one spectrum in the dataset of HB12, the flatfielded two-dimensional spectral stamp images extracted from the individual

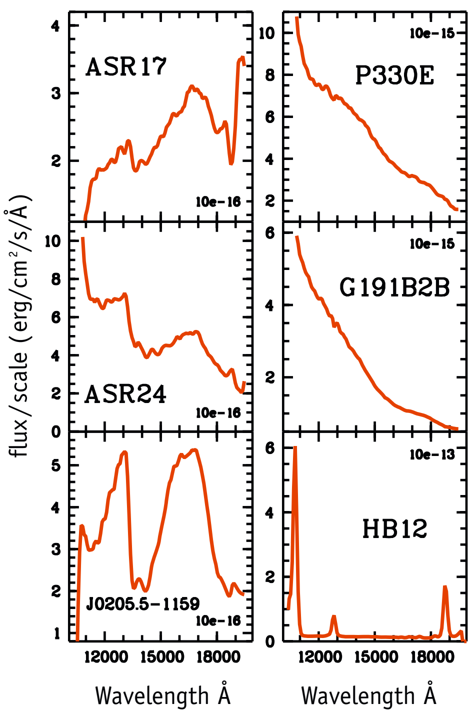


Fig 2: *Spectra of bright objects as reduced by PHLAG. The individual scale factor is given in the plots. The left column shows the spectra of two brown dwarfs in NGC 1333 (upper panels) and the field dwarf standard J0205.5-1159 (lower panel). The full dataset, reduced with NICMOSlook, is published in Greissl et al. (2006). The spectra of three standard stars are shown in the right column. The solar analogue star P330E (upper panel) is followed by the white dwarf G191B2B, which is a flux standard (middle panel). The lower panel displays the spectrum of the planetary nebula HB12.*

grism images are co-added using the aXedrizzle technique (Kümmel et al. 2004). Finally, deep one-dimensional spectra are extracted from these combined two-dimensional spectral images. For each spectrum, an estimate of the contamination caused by neighbouring objects is derived using the photometric information from the direct images (see Walsh et al. 2006).

- **Visualization**: This module uses the tool aXe2web (http://www.stecf.org/instruments/ACSgrism/axe/axe2web.php, Walsh & Kümmel 2004) to create browsable webpages from the extraction products. The webpages show the extracted spectra of every object, the available astrometric and photometric information and two-dimenional images from the direct and the deep grism stamp images. While this module will not be routinely run in the final production pipeline, such a convenient tool for data and data quality assessment is very important during the development phase of the pipeline.
- **Quality Control**: Consistency checks are performed, eg, between the photometry from the direct image and from the spectroscopy. Spectra with quality problems are either flagged or discarded.
- **Metadata**: The spectra are post-processed and prepared for ingestion into the HLA archive. Metadata are collected (object positions, extraction geometry) or derived (signal-to-noise estimates for the spectra). To ensure compatibility with the Virtual Observatory, we closely follow the rules and recommendations of the IVOA Spectral Data Model (http://www.ivoa.net/Documents/latest/SpectrumDM.html) in the selection of the metadata.
- **Data Ingestion**: This last module inserts the fully reduced, quality controlled and VO-ready spectra into the HLA archive.

STATUS AND OUTLOOK

The development of PHLAG was started early in 2006. Currently, almost all modules are already implemented and PHLAG produces high quality spectra. Figure 2 shows a selection of bright objects reduced from different datasets with PHLAG. Further improvements to the data quality are expected from an optimisation of the fairly large set of control parameters and the results from trend analysis.

The remaining pipeline modules will be finished within the next few months. The HLA database to distribute the reduced spectra will be designed on a similar timescale. We hope that an initial release of HLA products produced by PHLAG will be available in summer 2007. The latest information and news concerning PHLAG and HLA can be obtained from the ST-ECF HLA website www.stecf.org/archive/hla.php

References

Bertin E. & Arnouts S. 1996, A&A, 117, 393

Koekemoer, A.M., Fruchter, A.S., Hook, R.N., Hack, W. & Hanley, C. 2006, in "The 2005 Calibration Workshop", eds. Koekemoer, A., Goudfrooij, P., & Dressel, L., 423

Kümmel, M., Walsh, J.R., Larsen , S.S. & Hook, R.N. 2004,"Drizzling and the aXe Slitless Spectral Extraction Software", ST-ECF Newsletter, 36, 10

Kümmel, M., Larsen, S.S., & Walsh, J.R. 2006, in "The 2005 Calibration Workshop", eds. Koekemoer, A., Goudfrooij, P., & Dressel, L., 85

Greissl, J., Meyer, M.R., Wilking, B.A., et al. 2006, "HST/NICMOS Observations of NGC 1333: The Ratio of Stars to Sub-stellar Objects", astro-ph/0611501

Walsh J.R., Kümmel, M. & Larsen, S.S. 2006, in "The 2005 Calibration Workshop", eds. Koekemoer, A., Goudfrooij, P., & Dressel, L., 79

Walsh, J.R., & Hook R.N. 2006, ST-ECF Newsletter 40, 6

Walsh, J.R. & Kümmel, M. 2004,"Comfortable Visualisation of ACS Spectra", ST-ECF Newsletter 35, 9

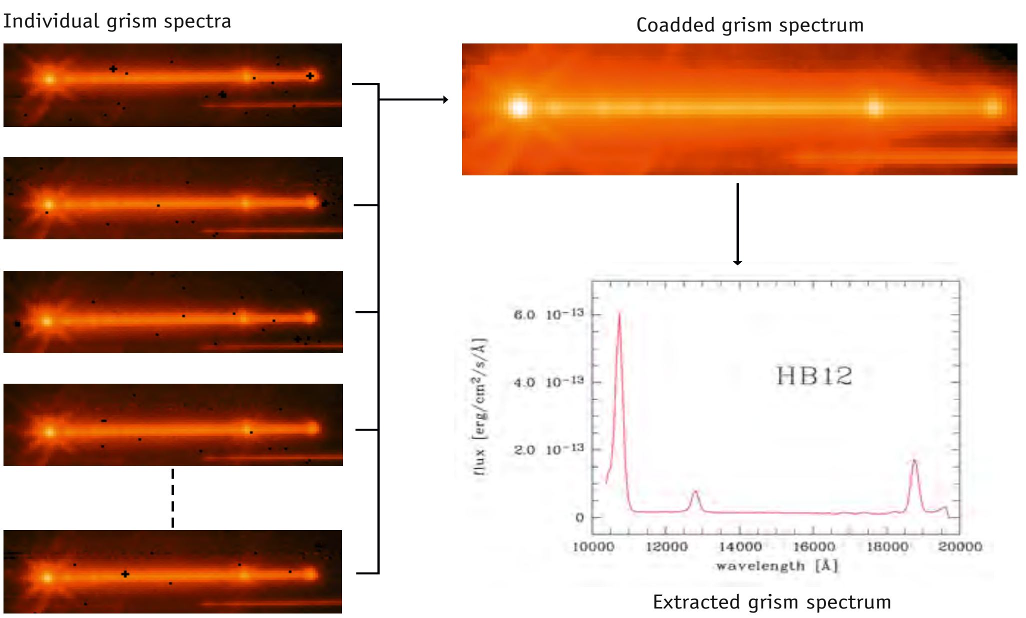
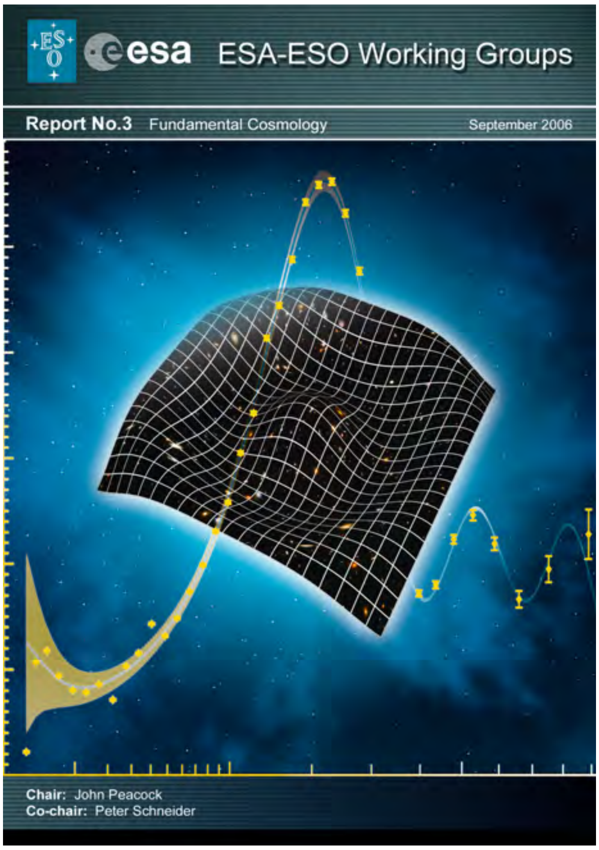


Fig 3: *aXe extraction process for HB12. The flatfielded two-dimensional grism stamp images are shown on the left. The two-dimensional stamp images are co-added to a deep two-dimensional grism image using the aXedrizzle technique (upper right). With aXedrizzle, the numerous bad pixels are masked out using weight images. The final, deep spectrum (lower right) is extracted from the co-added two-dimensional grism image.*

ESA-ESO TOPICAL SCIENCE WORKING GROUPS

Wolfram Freudling



The European Southern Observatory and the European Space Agency, as the two European organisations with major astronomy programmes, collaborate on a number of activities. To help with their joint science planning, the ST-ECF has been asked to organise joint ESO-ESA working groups on specific science topics that are, or will become, issues of strategic importance to both organisations. The purpose of these working groups is to recommend, for some selected fields of astronomy, how ESO and ESA, both separately and together, can optimize the exploitation of current and planned missions, and how the agencies can collaborate in the planning of future missions. In September 2006, the most recent of the working groups, on Fundamental Cosmology, concluded their work and issued their final report. This and previous reports (this Newsletter, edition 39, page 12, December 2005) are available at http://www.stecf.org/coordination/esa_eso/ and printed copies can be requested from Britt Sjöberg (bsjoeber@eso.org).

The third ESA-ESO bilateral meeting took place at the ESO Headquarters in Garching on 25-26 October 2006 to plan future activities. Representatives of ESO, ESA and their science advisory bodies discussed the implications of the working group recommendations. The main results of the meetings are:

- The key recommendations of the working groups on Extra-Solar Planets are being taken into account by the planning bodies of the organisations.
- The recommendations of the Alma-Herschel working group will be followed up by a study group to propose specific implementations.
- Issues raised by the working group on Fundamental cosmology will be considered by the agencies.
- Several new working groups will be organised in the next few years. The first of them will be on Galactic Structure and will start work in early 2007.

Both ESO and ESA agreed that their collaboration will become even more important in the future and they are resolved to continue the bilateral discussions.

NASA, ESA, and the Hubble Heritage Team (STScI/AURA)-ESA/Hubble Collaboration. Acknowledgement: B. Whitmore (Space Telescope Science Institute) and James Long (ESA/Hubble).

A FERTILE COLLISION [heic0615]

The Universe is an all-action arena staging some of the slowest evolving dramas known to mankind. The Advanced Camera for Surveys (ACS), onboard Hubble, provides the “sharpest ever” view of the Antennae galaxies — seemingly a violent clash between two once isolated galaxies, but in reality a fertile marriage. As the two galaxies interact, billions of stars are born, mostly in star clusters. The brightest and most compact structures are called super star clusters.

The two spiral galaxies first collided a few hundred million years ago making the Antennae galaxies the nearest and youngest example of a pair of colliding galaxies. Nearly half of the faint objects in the Antennae are young clusters containing tens of thousands of stars. The orange blobs to the left and right of the image centre are the cores of the original galaxies and consist mainly of old stars criss-crossed by filaments of dark brown dust. The two galaxies are dotted with brilliant blue star-forming regions surrounded by glowing hydrogen gas, shown in pink in the shot.

The image allows astronomers to distinguish better between the stars and super star clusters created after the collision of two spiral galaxies. By age dating the clusters in the image, astronomers find that only about 10% of the newly formed super star clusters in the Antennae will live to see their ten millionth birthday. The vast majority of the super star clusters formed during this interaction will disperse, with the individual stars becoming part of the smooth background of the galaxy. It is, however, believed that about a hundred of the most massive clusters will survive to form regular globular clusters, similar to those in our Milky Way.

The Antennae galaxies take their name from the long antenna-like “arms” extending far out from the galaxies’ nuclei, best seen by ground-based telescopes. These “tidal tails” formed during the initial encounter of the galaxies some 200 to 300 million years ago. They offer a glimpse of what may happen when the Milky Way collides with the neighbouring Andromeda galaxy in several billion years.

This Hubble view of the Antennae galaxies portrays a violent clash between the two galaxies, which has resulted in a fertile marriage and billions of star births.

SOLAR SYSTEM BODIES IN HUBBLE OBSERVATIONS

Diego Sforna & Alberto Micol

Finding astronomical data that include solar system targets is often a tricky problem. Because such objects move with time the usual name-resolving servers, such as NED and SIMBAD, cannot be used in these cases. Even with the help of a detailed ephemeris it is far from easy to find the appropriate datasets.

In order to help Hubble archive researchers, the ST-ECF has developed a new user interface specifically tailored to search for solar system bodies. Using the Skybot service from the Institut de Mécanique Céléste et de Calcul des Ephémérides, (IMCCE, see http://www.imcce.fr/), we could precompute, and store in a database, the names of solar system objects (with the exception of comets) that happened to fall, whether by design or serendipitously, in the field of view of an observing Hubble camera. It then became easy to offer astronomers a search engine through which they could specify the name of a solar system body and then find Hubble observations that were likely to include it, in a similar manner to that already used for galactic and extragalactic objects. This article describes how the system works, including both the user interface and the machinery behind the scenes, and explains how certain Virtual Observatory formats and conventions were used.

INTRODUCTION

Astronomical archives cannot normally support solar system researchers effectively. Finding observations in science archives that could be used to study a certain class of solar system objects, at least in the realm of the Hubble archive, has been almost impossible up to now. Even the simple question, "Which observations contain the object called Vesta?" cannot be answered exhaustively. Partial answers to this question would rely on *a priori* knowledge by a principal investigator and whether the name of the object (eg, Vesta) was in the text of the proposal, or, better, in the target name field in the catalogue. But what about those serendipitous observations that happened to unexpectedly collect photons from a solar system body? This could happen for parallel observations or for observations by instruments with a large field of view. The key to this long standing problem is now available to us, thanks to the efforts of the IMCCE. A database of precomputed ephemerides has been compiled, sampled at intervals of ten days, for more than 300,000 known solar system bodies including planets, satellites and asteroids. Comet ephemerides are not yet part of the IMCCE database, although they are planned for the future, so our service cannot currently be used to query for them.

The IMCCE Skybot service provides sufficient accuracy to be used to discover which solar system bodies are actually in the field of view of any archived Hubble observation. By querying the Skybot service for each of the Hubble science observations, we could build our own

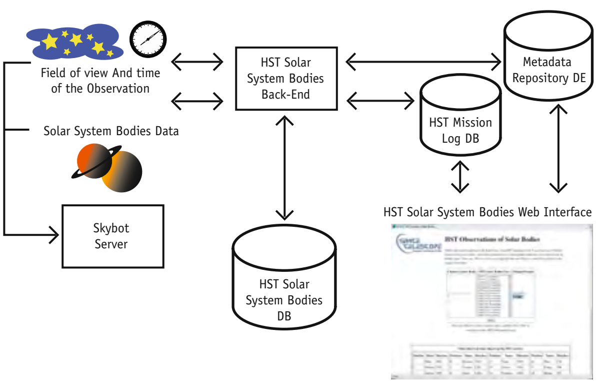


Fig 1: *Block diagram of the Hubble Solar System Bodies system*

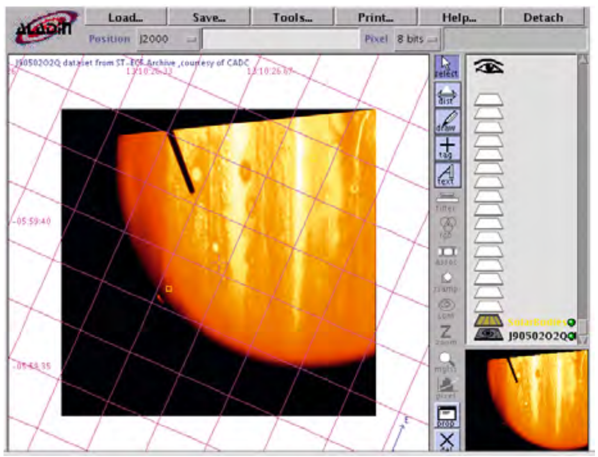


Fig 2: *Ganymede emerging from behind the limb of Jupiter*

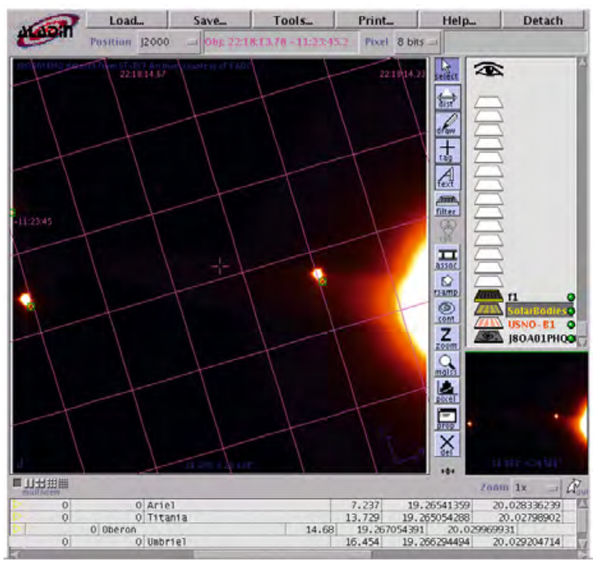


Fig 3: *Uranus observation showing some of the satellites*

database of those solar system bodies actually observed by Hubble. On top of this we built a search engine that immediately gives access to the list of all detected solar system bodies, and allows the user to query the database by both solar system body properties or Hubble instrumental characteristics such as instrument name or filter. Interested users can find the service on the ESO/ST-ECF Archive web site: http://archive.eso.org/archive/hst/solarbodies/. In the following sections we describe how the system has been implemented.

DATA PREPARATION

Archive users may wish to issue a query similar to: “Which Hubble dataset contains the solar system object X?”, but the IMCCE Skybot service can provide an answer to the question “Which solar bodies are present in the field of view of the dataset Y?”. To make it possible for our users to search for solar system bodies in the Hubble archive, we had to assemble the following two main elements:

1. A backend system that could query Skybot for each archived Hubble dataset and store the results in a database with a one-to-many relation between dataset and solar system object.

2. A frontend system to provide access to the solar system bodies database for users.

To achieve this, an additional preparatory step was necessary: we had to gather accurate spatial and temporal positions and extents for each observation. There was also the added complication that many Hubble observations (often referred to as associations) are actually composed of multiple single observations. The current nature of the Hubble archive means that no products are stored on disk and instead the process of On-The-Fly Reprocessing (OTFR) generates the products on demand. This meant that we could not gather precise information on the field of view of each single observation directly from the products themselves as this would have required us to run OTFR on the entire archive. Furthermore, the existing Hubble database does not provide easy access to the necessary information at the required level of precision for all instruments, instrument modes, and observer-selected instrument configuration choices. The way out was to use the existing repository of observation previews (generated at CADC and mirrored to the ST-ECF) and to set up a pipeline to scan through them and extract the required metadata. The results were then stored in a new database table. Later we actually made the scanning process for WCS information part of the mirroring software so that metadata of any new preview is immediately available. In addition to the spatial coverage metadata another table is also filled with temporal extent information at the same time.

THE DATABASE

The Hubble Solar System Bodies database stores the data retrieved from the Skybot Server and makes them immediately available. However, the drawback is that this approach does not provide the most up-to-date information. If knowledge of the ephemeris changes, or an additional solar system body becomes available in the ephemerides database, then all the Hubble observations would need to be reprocessed to take care of such a change. To allow selective reprocessing, the records in the database are flagged with the version of the IMCCE Ephemerides Database from which they have been retrieved.

BACKEND LAYER

The backend layer automatically takes care of adding new Hubble observations to the Hubble Solar System Bodies Database. In order to perform its job, the backend layer needs two pieces of information:

1. Characterisation of observations: we now use two new characterisation tables to gather spatial and temporal information about each individual observation.

2. Solar system body ephemerides: these are not locally available but obtained through the IMCCE Skybot service. A spatial-temporal cone search interface provides metadata for all the solar system bodies falling in a specified space-time region. The Skybot standard VO interface (VOTable output) made it easy to develop interfaces and handle the resulting data.

The backend system is a Java application (JVM 1.4.2) using the Savot VOTable parser and the Sybase Jconnect. Communication with the Skybot server is through the HTTP protocol, with the Skybot output VOTable being read from a local Java URL object.

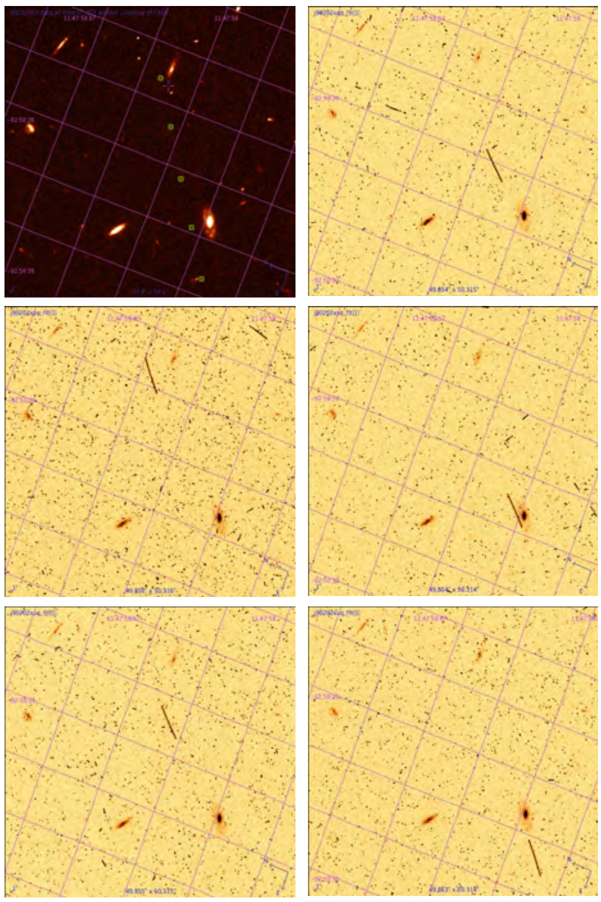


Fig 4: *A minor planet moving across a set of Hubble ACS images. The preview at the upper left (courtesy of CADC) shows the drizzled image of an ACS association (J90202010) with the expected Skybot positions of 2005GD51 plotted on top. The other images show the object moving across the component single exposures. In the drizzling process, the reprocessed solar system body is treated as a spurious cosmic ray and removed.*

WEB INTERFACE

After the backend has completed its job the data can be retrieved through the web interface. The main ESO/ST-ECF archive web interface [WDB] has been enhanced for VO compatibility and can now also provide the results of user queries in VOTable format. From the HTML result it is possible to access the archive data request screen or the data preview system. For an imaging observation, the CDS Aladin (http://aladin.u-strasbg.fr/aladin.gml) applet is used to display the preview image and overplot the Skybot expected position of the solar bodies.

CONCLUSIONS

We have added a new interface to the Hubble archive that is specifically tailored to solar system body research. The resources required to put this new service into operation were quite modest thanks to the use of pre-existing services, both internal (VO Metadata Repository) and external (Skybot Server at IMCCE). In addition the preparation of the necessary infrastructure blended in quite naturally with the general effort of organising a VO-characterisation of the ST-ECF Hubble archive and, as a final byproduct our database of temporal and spatial characteristics of each observation was enhanced. The use of VO technologies (VOTable standard) also eased the seamless integration of the various components.

Without the Hubble Solar System Bodies service the only option for users interested in solar system bodies was to search for a object by name in the target description field of the standard Hubble Science archive interface (http://archive.eso.org/wdb/wdb/hst/science/form). This approach usually leads to very limited results as the names assigned are often arbitrary, incomplete or missing completely. The introduction of the Hubble Solar System Bodies service solves all these problems. At the time of writing (October 2006), from a total of 400,000 Hubble individual observations, 20,000 have been found to contain at least one solar system body. In that set, a total of 36,500 traces of 600 distinct solar system bodies are available to the community via this novel service.

ACKNOWLEDGMENTS

We are grateful to the Institut de Mécanique Céléste et de Calcul des Ephémérides (IMCCE) for providing a remarkable and unique service to the community. Please note that any use of the IMCCE data requires the IMCCE agreement (http://www.imcce.fr/page.php?nav=en/site/copyright.php).

References

Berthier, J., Vachier, F., Thuillot, W., Fernique, P., Ochsenbein, F., Genova, F ., Lainey, V. & Arlot 2006, in ASP Conf. Ser., Vol. 351, ADASS XV, ed. C. Gabriel, C. Arviset, D. Ponz, & S. Enrique (San Francisco: ASP), 367

Sforna, D. & Micol, A. 2005, in ASP Conf. Ser., Vol. 347, ADASS XIV, ed. P. Shopbell, M. Britton, & R. Ebert (San Francisco: ASP), 257

STAFF UPDATE

Jeremy Walsh

It has been all change in the archive group over the last few months. Both Italian members of the archive group have left, Alberto Micol on 30th September and Diego Sforna on 31st October. This spate of departures has prompted a re-examination of the role of the archive in the ST-ECF activities. One foreseen future element of change will be to serve high level science products as part of the Hubble Legacy Archive initiative. The archive, however, continues to retain an Italian flair as Marco Lombardi began as archive scientist from 1st December 2006. The other archive position is expected to be filled in January.

ALBERTO MICOL

Alberto left to take up a permanent ESA position as archive systems engineer in the Science Operations and Data Systems Division at the European Space Astronomy Centre (ESAC) in Villafranca, Spain. He has been at the ST-ECF since April 1996 and was the mainstay of the ST-ECF archive. Currently he knows as much as anyone about its inner and outer workings. However, in his new position he will continue to work on the Hubble archive, at least for the foreseeable future. Indeed since his move to Madrid we have seen him so often that we are all wondering if he has really left. At least we had a farewell party for him.

DIEGO SFORNA

Diego joined the archive group in April 2003 and has been working mostly on the archive frontend. He was snared by ESO to work on their archive, which also houses the Hubble archive, so that he will continue to have close involvement with the ST-ECF. As his new office is just around the corner from the ST-ECF wing, we see him regularly.

MARCO LOMBARDI

Marco has held both an ESO studentship and fellowship and lately worked in the ESO Visiting Astronomers Section (VISAS). He will be responsible for scientific leadership of the archive but, given his penchant for software development, he will also partake in archive development. Marco's research interests are in gravitational lensing and also the structure of dusty molecular clouds.

FLIES IN A SPIDER'S WEB: GALAXY CAUGHT IN THE MAKING [heic0614]

New Hubble images have provided a dramatic glimpse of a large, massive galaxy being assembled as smaller galaxies merge. Although this was thought to be the way galaxies grew in the young Universe, unprecedented Hubble observations of the radio galaxy MRC 1138-262, nicknamed the "Spiderweb Galaxy", have shown dozens of star-forming satellite galaxies in the merging process.

In nature, spiders earn our respect by constructing fascinating, well-organised webs in all shapes and sizes, but the beauty masks a cruel, fatal trap. Analogously, Hubble has found a large galaxy 10.6 billion light-years away from Earth, stuffing itself with smaller galaxies caught like flies in a gravity-web. The galaxy is so far away that astronomers see it as it looked in the early stages of the Universe, only three billion years after the Big Bang.

The Hubble image portrays the Spiderweb Galaxy lying at the centre of an emergent galaxy cluster, surrounded by hundreds of other galaxies from the cluster.

Reaching much deeper than ever, Hubble offers a detailed view of the merging process. Galaxies can be seen as they are sucked into the Spiderweb at speeds of several hundred kilometres per second, from distances of more than a hundred thousand light-years around it.

Radio telescopes have shown that jets of fast particles are being spewed out from the centre of the Spiderweb Galaxy with enormous energies. Such jets are believed to be produced by a massive black hole deeply buried in the system's core. This black hole "spider" feeds on the infalling galaxy "flies" while it continues to disgorge the jets.

The Hubble image offers a unique real-world example for testing theoretical models of massive galaxy formation. Despite the complexity and clumpiness of the Spiderweb agreeing with qualitative predictions of such models, a surprising feature of this galaxy is the presence of several faint small linear galaxies embedded within the merging structure.

The Spiderweb Galaxy *This image is a composite of many separate exposures made by the ACS instrument on the Hubble Space Telescope using several different filters. It shows the Spiderweb Galaxy sitting at the centre of an emergent galaxy cluster, surrounded by hundreds of other galaxies from the cluster.*

NASA, ESA, George Miley and Roderik Overzier (Leiden Observatory, the Netherlands)

COMMUNICATION OF THE "PLUTO AFFAIR"

AN INSIDER'S PERSPECTIVE

Lars Lindberg Christensen

As the newly appointed press officer for the International Astronomical Union I had to build up a press office at the IAU General Assembly in Prague. As a result I witnessed the development of one of the most publicly visible astronomical stories of 2006, perhaps of the decade — the re-classification of Pluto as a dwarf planet.

The 2006 General Assembly of the International Astronomical Union was a General Assembly like no other. Many different interesting scientific topics were discussed — from Near-Earth objects to galaxy evolution across the Hubble time. But there was one issue that was by far the most hotly debated in the corridors at the Prague Congress Center, and also took most of the media limelight — how to define a "planet". This apparently non-scientific issue obviously has some strong cultural roots and a very high public visibility.

The planet definition debate that took place at the IAU 2006 General Assembly was clearly the "hottest topic" in many years, if not in the entire history of the IAU. It is naturally unfortunate that the many other pieces of interesting science were somewhat overshadowed during the intense planet definition discussion, but it is not possible to control the media.

RATIONALE FOR A PLANET DEFINITION

There was no scientific definition of a planet when Pluto was discovered in 1930. The ancients thought of "planets" as "wanderers" or moving lights in the sky, and more recently astronomers have considered them simply as bodies orbiting the Sun, but there seemed little reason to define more precisely what a "planet" really was, as it seemed that very little ambiguity could arise.

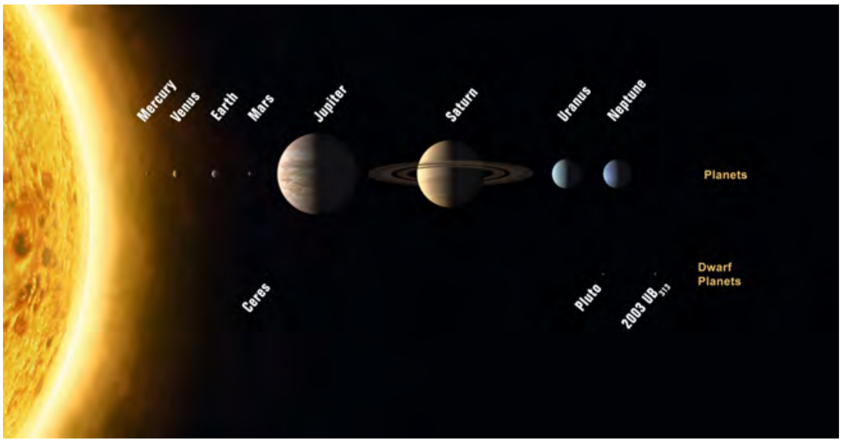
However, with the advent of modern telescopes, it was discovered that Pluto belongs to a vast population of small solar system objects in the Kuiper belt. Such recent discoveries have prompted astronomers

International Astronomical Union/Robert Hurt (SSC)

Fig 1: *An historic moment? The crucial vote that passed IAU GA XXVI Resolution 5A and so reclassified Pluto as a dwarf planet. Image Credit: International Astronomical Union/Robert Hurt (Spitzer Science Center)*

2001	The American Museum of Natural History decides to leave Pluto out of their scaling walk. The story hits the news and becomes a high profile item.
2003-2005	Discovery of large trans-Neptunian objects including Sedna and Eris.
2004-2005	The first IAU Planet Definition Committee outlines a few different possible definitions of a planet.
27.06.2006	Appointment of an IAU Press Officer.
01.07 2006	Second IAU Planet Definition Committee meets in Paris and decides on a definition.
27.07 2006	Recommendation for public communication.
01.08.2006	First Resolution draft approved by the IAU Executive Committee.
14.08.2006	The XXIVth IAU General Assembly starts.
15.08 2006	Draft Resolution Press release under embargo to press.
16.08.2006	Press release embargo is lifted. Press briefing.
18.08.2006	IAU Division III Business Meeting.
22.08.2006	Executive Committee plenary discussion.
24.08.2006 08:00	Press release: "Final Resolution ready for voting".
24.08.2006 ~ 15:40	Resolution 5A is passed, 5B is not passed. Pluto is defined as a dwarf planet.
24.08.2006 16:21	Press release: "Result of the IAU Resolution votes".
04.09.2006	A petition with almost 400 signatures protesting against the decision is delivered to the IAU.

Tab 1: *An approximate timeline of the events around the "planet definition" decision*



Credit: International Astronomical Union/Martin Kornmesser (ESA/Hubble)

Fig 2: *New Solar System — 8 planets and 3 dwarf planets.*

to reconsider the definition of what makes a planet a planet. It was therefore proposed that the term planet should be properly defined, and that the definition should reflect our current understanding of the Solar System.

THE EVENTS

An approximate timeline of the events around the "planet definition" decision is outlined in the table opposite. The IAU Resolution 5A implies that a planet in our Solar System (extrasolar planets are specifically not included in this definition) is a celestial body that is in orbit around the Sun and has sufficient mass to become nearly round (due to its self-gravity), and dominates its orbital zone dynamically. The actual interpretation of this definition — especially whether a given body is round enough and dynamically important enough — will have to be discussed by the appropriate IAU body as each new case arises. The Resolution also defines a dwarf planet in our Solar System to be a celestial body with sufficient mass to assume a nearly round shape, but not dynamically dominant in its orbital zone. Resolution 5A had the immediate effect that Pluto was re-classified as a dwarf planet along with Ceres and Eris (formerly known as 2003 UB313).

The new definition of a planet has — as predicted — provoked strong reactions from both the public and the astronomical community that still persist months after the General Assembly. Any decision on a topic of this magnitude and importance will inevitably generate a barrage of negative reactions. The current opposition is, in other words, unavoidable. Judging from the ongoing public and internal communication the main resistance against IAU XXIV Resolution 5 seems to stem from a vocal minority of astronomers.

CRISIS COMMUNICATION

Before the General Assembly we had to choose just how open to be with the scientists, press and public during the process of deciding on the new definition of a planet.

An internal working paper written before the General Assembly predicted: "The planet issue has the potential to become an historic event of epic proportions. It may become the hottest astronomy story of the year, or even the decade. It has the potential to change history. Seeing this as a potential historic event, do we fulfil our public duty and inform the world about the process and the decisions openly, or do we keep quiet to protect the slow and thoughtful scientific work process?"

It was already clear that we were dealing with a very special situation. Shortly afterwards the situation around the "planet definition" debate was declared a crisis in recognition of the possible negative effects that an improper public communication could have.

In crisis communication there are some general rules see Christensen (2006) for more on this topic. The main thing is not to react too hastily and let the outside world dominate your decisions. Be proactive rather than reactive. Some guidelines apply:

- Communicate internally first to avoid internal confusion and enable all involved to work towards the global goal.
- Plan ahead as early as possible.
- React as quickly as possible – the timescale is usually counted in minutes and hours.
- Be available via cell phones, email etc.
- Be credible and fact-based in the external communication.
- Apply analytic working methods.
- Be transparent, open and honest.
- Be ready to compromise several times along the way in order to achieve the global goal at the end of the process. This point is notoriously difficult to accept as it goes against normal management practice.

WORST CASE SCENARIOS

As we were planning for the "planet-crisis" we considered a series of worst case scenarios:

1. Lack of communication

- A polarised "Them and Us" situation could arise in the media: The press (and public) are largely held outside the process and are not properly informed leading to a public outcry over the secrecy of discussions among senior cigar-smoking astronomers in a "closed club".
- Leading opinion-makers from cultural, art and religious backgrounds will speak publicly against "this lab-coat nonsense", and create a global surge of protests. Possible political intervention? Demonstrations? Violence?

2. Communication is too simplistic

- The issues around the Resolution are communicated widely, but its tentative/draft character is omitted in the public communication. In the end a Resolution is not passed and the press and public feels led astray. The IAU comes out looking bad.

3. Broad disagreement

- The majority of the community disagrees. Resentment? Demonstrations?
- The majority of the public disagrees. Resistance to the redefinition of the "labelling" of the Solar System, and the modification of geography books. Resentment? Demonstrations?

4. Perception of anti-Americanism

- Pluto's status will change from "planet" to "dwarf planet", creating a feeling of anti-Americanism on the part of the US (as the IAU is seen by some as a predominantly European organisation).
- Under political pressure, or spontaneously, NASA or the US planetary science community may develop its own categorisation for objects in the Solar System — such as developing the "ice dwarf" category using criteria other than those proposed by the IAU.
- The American Astronomical Society may be asked to develop policies on this and related issues that provide "American" alternatives to the "European" ones of the IAU.
- US astronomers may be lobbied (for example, by the Planetary Society) to withdraw from the IAU as individual members.
- An individual member or members of Congress (possibly from Arizona) might be lobbied to move for the US to withdraw from the IAU at a national level.
- To generate ammunition for political lobbying, the Planetary Society may conduct a poll of the US public on the status of Pluto.
- The New Horizons team may perceive that a change in Pluto's status will weaken its funding status, and lobby the IAU Executive or members for any change in Pluto's status to be delayed (or, if it is changed, reversed).
- The family of Clyde Tombaugh may protest against Pluto's change in status.
- Flagstaff Observatory is likely to maintain its current displays and materials about Pluto.
- New Mexico State University may continue to refer to Pluto as a planet and Clyde Tombaugh as its discoverer.
- US book publishers, planetariums and generators of online content may be slow to change their current material on Pluto and its discovery, if they change it at all. They may do this spontaneously: they may also be lobbied to do so.
- Individual schools in the US may be slow to change what they teach about Pluto and its discovery, if they change it at all.

Fig 3: *The GA 2006 pressroom at a time of hectic activity. The episode was later included in Jenny Hogan's (left) blog on nature.com.*

After considering these four hypothetical scenarios the IAU Executive Committee decided to make the process leading to a Resolution as open as possible. Fortunately none of the scenarios played out as visualised above, although scenario four came closest with protests from part of the American astronomy community.

LESSONS LEARNED

Many interesting lessons were learned in the press office, especially about the practicalities of setting up a well-functioning pressroom in response to the crisis, but also about the complex ways that information is transmitted from scientists to the press.

Once the IAU Executive Committee — IAU's highest body — had made the decision to propose the new definition of a planet the whole issue was somewhat like having two bombs waiting to explode. The first bomb was the public reaction to changes in the worldview — adding or subtracting planets to the Solar System — and the second was the internal tension within the scientific community — due to differences of opinion and the appointment of some selected experts to work on the definition. Our job was to try to minimise the negative effects for the IAU and for astronomy, and to maximise the benefits from the two explosions. These explosions themselves were probably unavoidable, but we could at least make sure that the bombs were thrown in a certain direction rather than exploding in our faces.

For the first explosion — the public bomb — damage control consisted of keeping the process as open as possible and informing the press about each step of the process as it took place — including the first Resolution draft and the ongoing debate. As many as thirty journalists had already signed up weeks before the meeting and it was well known among science journalists that the definition of a planet was going to be discussed, suggesting a strong outside interest that spoke forcibly for an open communication strategy. It would not have been possible to keep the planet definition debate out of the press. By issuing press releases all the relevant information was delivered, and press and public speculation was minimised, although not completely eliminated.

It is difficult to speculate how the image of the IAU or the astronomical community might have been affected if a more closed form of public communication had been chosen. It is more than likely that the — not always constructive — messages from many prominent and outspoken astronomers would have reached the press. The open communication did avert most of the potential criticism that the planet definition process took place as closed discussions among senior astronomers.

With respect to the second bomb, the strong reaction from the scientific community was somewhat underestimated by most of the Executive Committee and the Press Officer. The majority of us also did not anticipate the significant changes to Resolution 5 that took place during the General Assembly. With 20-20 hindsight, the draft aspect of Resolution 5 could have been stressed more in the initial press release. The "inreach" aspect — sharing the draft Resolution earlier with the community (especially Divisions I and III) could perhaps have been given more emphasis, but this was difficult for two reasons:

1. The Executive Committee feared that the Resolution text would leak to the entire community and to the public, without the Executive Committee and the Planet Definition Committee having a chance to add the necessary scientific context, historical background and interpretation.
2. The Resolution itself was drafted shortly before the General Assembly, and practical considerations made it difficult to initiate discussions with the hundreds of members of Division I and III (collecting emailing lists etc).

OUTCOME

The planet definition affair has definitely had some negative effects. Astronomers and scientists in general have been publicly portrayed as being in disagreement, arguing and, at times, even being childish in their discussions. The positive side of this is that astronomers and scientists have appeared as human beings and far from their usual "lab-coat" image. The IAU has also been publicly accused of being a body that only represents a fraction of astronomers.

In my opinion the positive effects, however, outweigh the negative by far. One of the most important outcomes of the public communication from the General Assembly is that the public today has a much better knowledge of the Union and its mission as the authority on fundamental astronomical issues. The enormous public interest in the planet definition story is perhaps best illustrated by the large number of cartoon jokes/caricatures appearing in the international newspapers. It is the first time in many years to my knowledge that any scientific topic has penetrated so deeply into the public conscience. The effect of this is very significant. Scientific issues are usually notoriously difficult to get on the front pages (although astronomy usually stands a better chance than most other sciences). The value of this is — despite the unavoidable negative effects described above — enormous.

For once, a large fraction of the demographic segment of people inattentive to science was exposed to science. A small-scale poll among friends and family found that everyone had heard of the Pluto story and most even offered an opinion about it. This is an important consequence and should not be underestimated.

In terms of public communication it is vital that the current high awareness of the Solar System is used to promote scientific issues. There is great potential to use this debate to teach about the Solar System, that it is still in formation, about debris, about asteroids, about dwarf planets, Kuiper Belt objects, trans-Neptunian objects, planets and more. This is a great opportunity to teach that science is not static, and that when new discoveries are made, science must change. In the longer term the increased awareness of the IAU due to the "Pluto Affair" can be used to further the interest in the International Year of Astronomy 2009.

The re-classification of Pluto as a dwarf planet should not be seen as a demotion. Pluto is now the prototype for a whole new class of objects. Pluto is a swan, not an ugly duckling, and we should all celebrate that it has finally been placed in a class of its own. After all Pluto is still Pluto, and what we decide to call it changes nothing on Pluto itself.

ACKNOWLEDGEMENTS

I would like to thank the pressroom team for their dedication, hard work and good spirits during the General Assembly! I would also like to thank the Executive Committee and the Definition of a Planet Committee, especially Richard Binzel, for the incredible amount of hard work they put into the planet definition debate and the various topics dealing with communication. ESO and the ESO Public Affairs Department deserve especial thanks as they partly sponsored the loan of a large fraction of the pressroom equipment and partly sponsored and arranged the transport of the IAU exhibition.

References

Lars Lindberg Christensen 2006,"Hands-on Guide for Science Communicators", Springer, New York

NASA AWARD FOR ST-ECF STAFF

"In recognition of painstaking efforts to provide maximum scientific value to HST data using precision laboratory spectral measurements and physical instrument modelling techniques."

Michael Griffin – NASA Administrator (signed)

So reads the citation on a prestigious award granted by NASA to six members of a transatlantic collaboration that brought together their skills in instrument modelling and laboratory excellence to significantly improve the calibration of UV spectroscopy from Hubble. The team consisted of three members of the ST-ECF's former Instrument Physical Modelling Group: Michael Rosa, Florian Kerber and Paul Bristow (Figure 1), and three members of the Atomic Spectroscopy Group at the National Institute of Technology and Standards (NIST) in the USA: Joseph Reader, Gillian Nave and Craig Sansonetti (Figure 2). The award was made following a suggestion from the HST Project (see Niedner 2005), at Goddard Space Flight Center (GSFC), and was presented to representatives of each team during a ceremony in the summer of 2006 (Figure 3).

BACKGROUND – A NEW APPROACH TO CALIBRATION

On several previous occasions the ST-ECF Newsletter has reported in detail on a long-term effort to apply advanced techniques of calibration to spectrographic data from Hubble instruments. Originally discussed as "Predictive Calibration Strategies" (Rosa 1995, 1997a,b) these methods have in subsequent reports been referred to as "Model based calibration", "Advanced Calibration" and "Instrument Modelling". The complementary laboratory work has become known as "The Lamp Project". They are all based on the application of physical first principles to instrument calibration, in combination with a thorough and critical assessment of the laboratory calibration data on which Hubble's wavelength standards were based.

The model based calibration concept mapped very well into the grand vision of rigorously operating great observatories for maximum scientific return (Giacconi 2005, particularly the section "Intellectual Development" on page 21). Therefore, in 1998 the extension of the ESA/NASA Memorandum of Understanding on Hubble added funds for three posts for the specific task of creating the so-called final archives for selected suites of Hubble data using the advanced calibration methodology (Benvenuti 1998).

Fig 1: *The European part of the NASA award winning team, the group at ST-ECF: Florian Kerber, Michael Rosa, Paul Bristow (left to right).*

Group Leader Michael Rosa summed up the advantages of this approach as follows: "Calibration based on instrument models has been demonstrated to provide better accuracy than empirical methods, but in addition it also provides a real understanding of the instrument that enables one to maintain it at maximum performance and quickly diagnose any deviations."

INSTRUMENT PHYSICAL MODELLING AND LABORATORY CHARACTERISATION

The studies performed in the ST-ECF Instrument Physical Modelling Group for the re-calibration of the blue-side Faint Object Spectrograph (FOS, see Kerber & Rosa 2000 and Rosa et al 2002) and those for sophisticated modelling of the Space Telescope Imaging Spectrograph (STIS) high resolution echelle modes made it clear that the laboratory ground truth for the UV wavelength calibration lamps on Hubble was insufficient. Calibration of Hubble instruments relied exclusively on the fundamental work by Reader et al. (1990). This Pt-Ne atlas was published in support of operations of the Goddard High Resolution Spectrograph (GHRS), which was a pure UV instrument and had a Pt-Ne lamp. Combined UV-visible instruments such as the FOS and STIS use a Pt/Cr-Ne lamp for wavelength calibration. Quite naturally the Pt-Ne atlas, which does not contain any Cr lines, is not adequate for these instruments and the large number of Cr lines emitted by a Pt/Cr-Ne lamp could not be used for the calibration of Hubble spectrographs. The model based wavelength calibration for FOS and STIS data easily revealed significant systematic errors in pipeline calibration for those instruments based on the classical polynomial fit technique to sparse or even erroneous standard line measurements.

Therefore, substantial effort was invested into getting hold of the FOS lamps actually flown (Kerber & Wood 2004) and flight spares for STIS. These hollow cathode lamps of the Pt/Cr-Ne variety, as well as pure Pt-Ne and Cr-Ne lamps were assessed critically and with utmost precision for their actual spectral output at the National Institute of Technology and Standards, Gaithersburg, USA, (NIST, Kerber et al. 2003). As a result, significantly improved wavelength standards were derived, including the ubiquitous lines of Cr and the modifications that the Pt and Ne spectra suffer from the presence of Cr ions. The data are available for the HST project and UV spectroscopy in general — space and ground alike — a total of over 5000 lines (Sansonetti et al. 2004).

Receiving this award from NASA also highlights the continuing contributions that NIST's high-resolution spectrometers can make towards the solution of important problems. Participation in this project has enabled NIST to develop its expertise further in Fourier transform spectroscopy in the vacuum ultraviolet and in the use of phosphor storage image plates to replace standard photographic plates. It has provided a rewarding link between laboratory work at NIST and the most current international work in astronomy.

The impact of these new high quality standards in combination with the advanced calibration concept of instrument model based 2D echelle dispersion relations on the STIS MAMA 130H spectra of interstellar lines towards galactic stars can be judged from our report on science impact (Kerber et al. 2005).

THE NASA PUBLIC SERVICE GROUP ACHIEVEMENT AWARD IN PERSPECTIVE

The NASA award specifically acknowledges that the instrument modelling approach and its success is not specific to any instrument but can be applied to a large variety of astronomical instruments. It is therefore no surprise that instrument modelling, originally developed for ESO's high-resolution spectrograph UVES (Ballester & Rosa 1997), and having been "to space" is now coming full circle. The NASA award winning methods — instrument modelling combined with state of the art laboratory measurements — are currently applied to the calibration of the latest spectrographs for the VLT, the Cryogenic IR Echelle Spectrometer (CRIRES) and X-Shooter (eg, Bristow et al. 2006). And these are only stepping stones towards the development of advanced calibration schemes for the extremely demanding instruments foreseen for a European ELT. On the other hand, hoping for a successful Servicing Mission 4, a revitalised STIS and in particular the semi-slitless spectroscopy with COS will benefit from further developments in the model based support of calibration for the space based UV range. To this end the ST-ECF is already engaged in a project, jointly funded by NASA and ESA and conducted in collaboration with NIST, STScI and the COS IDT, to characterise the performance and lifetimes of the calibrations lamps of COS.

Fig 2: *The US part of the NASA award winning team, the group at NIST: Joseph Reader, Gillian Nave and Craig Sansonetti (left to right).*

Fig 3: *Edward J. Weiler (GSFC Center Director) and Colleen Hartman (Deputy Associate Administrator, Science Mission Directorate, NASA Headquarters) present the award to the representative of the European Team (Florian Kerber) at a ceremony in summer 2006.*

References

Ballester, P. & Rosa, M.R. 1997, "Modeling Echelle Spectrographs", A&AS, 126, 563

Benvenuti, P. 1998, "ESA-NASA agreements on HST and NGST", ST-ECF Newsletter, 25, 2

Bristow, P., Kerber, F., Rosa, M. R., Pirard, J.F., Siebenmorgen, R. & Käufl, H.-U., 2006, "Model based wavelength calibration for CRIRES", SPIE, Volume 6270, 58

Giacconi, R., 2005, "An Education in Astronomy", Ann.Rev.Astron.Astrophys., 43, Issue 1, 1

Kerber, F., & Rosa, M.R. 2000, "Rectification of FOS wavelength scales", ST-ECF Newsletter, 27, 4

Kerber, F., Rosa, M.R., Sansonetti, C., & Reader, J. 2003, "STIS Calibration – Spectral Characterization of Pt/Cr-Ne Hollow Cathode Lamps", ST-ECF Newsletter, 33, 2

Kerber, F., Rosa, M R., Nave, G., Reader, J., Sansonetti, C., Bristow, P. & Lercher, G., 2004, "New Insights from the ST-ECF Lamp Project", ST-ECF Newsletter, 37, 5

Kerber, F., Bristow, P. & Rosa, M.R. 2005, in "The 2005 HST Calibration Workshop", A.M. Koekemoer, P. Gooudfrooij and L. L. Dressel eds., 309

Niedner, M. F. Jr 2005, ST-ECF Newsletter, 35, 2

Reader, J., Acquista, N., Sansonetti, C.J. & Sansonetti, J.E. 1990, "Wavelengths and intensities of a platinum/neon hollow cathode lamp in the region 1100-4000 A", ApJS, 72, 831Rosa, M.R. 1995, in "Calibrating and Understanding HST and ESO Instruments", ed. P. Benvenuti, ESO Conf Proc., ESO, Garching, 43

Rosa, M.R. 1997a, "Predictive Calibration using Instrument Models", ST-ECF Newsletter, 24, 14

Rosa, M.R. 1997b, "Physical Modelling of Scientific Instruments", in "Astronomical Data Analysis Software and Systems VI" ASP Conference Series, Editors: Gareth Hunt and H. E. Payne, 125, 411

Rosa, M.R., Alexov, A., Bristow, P. & Kerber, F. 2002, "FOS Blue-side spectroscopic data recalibration", ST-ECF Newsletter, 29, 9

Sansonetti, C. J., Kerber, F., Reader, J. & Rosa, M. R. 2004, "Characterization of the Far-ultraviolet Spectrum of Pt/Cr-Ne Hollow Cathode Lamps as Used on the Space Telescope Imaging Spectrograph on board the Hubble Space Telescope", ApJ Suppl., 153, 555

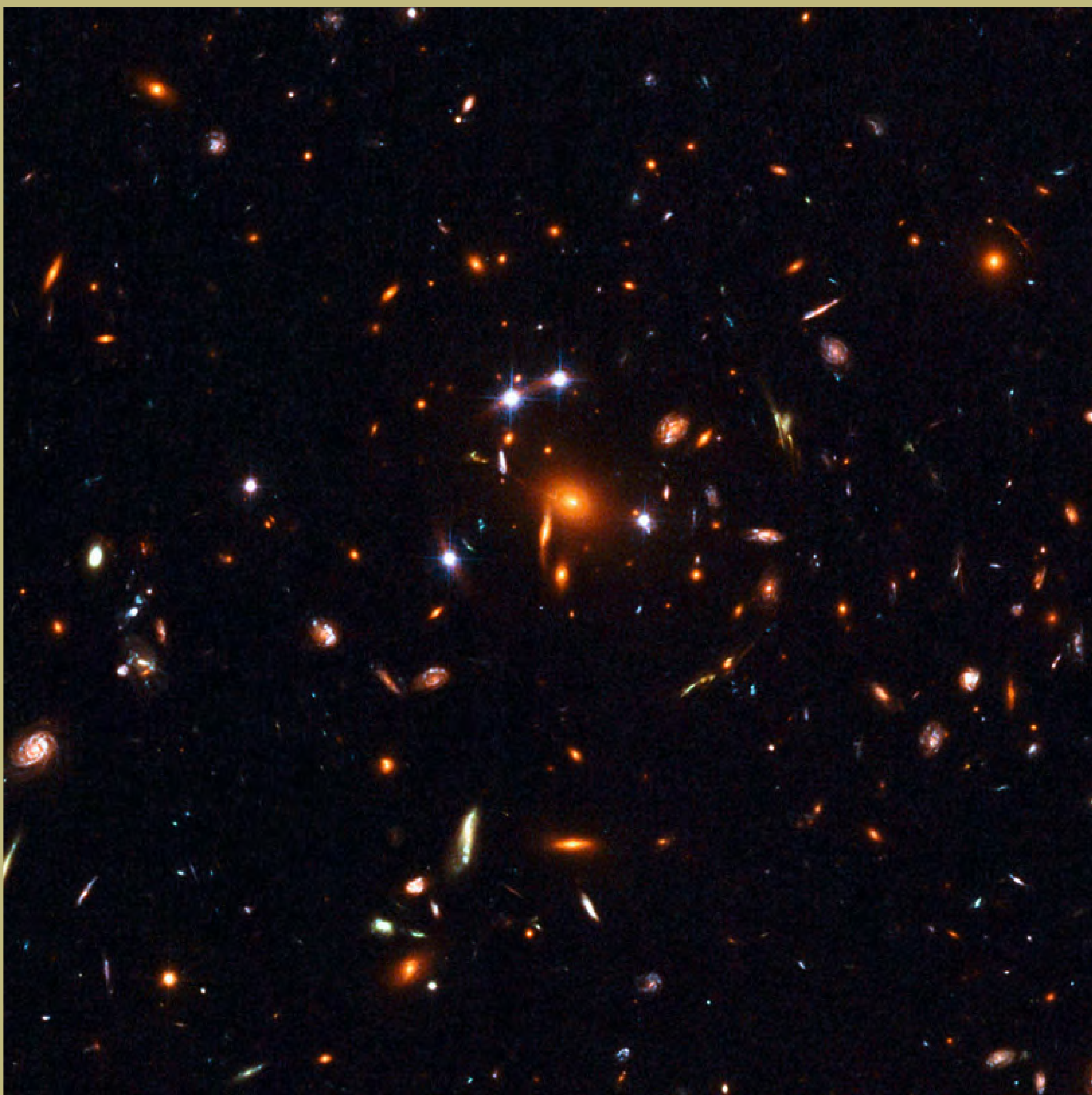
HUBBLE CAPTURES A 'FIVE-STAR' RATED GRAVITATIONAL LENS [heic0606]

The NASA/ESA Hubble Space Telescope has captured the first-ever picture of a distant quasar lensed into five images. In addition the image holds a treasure of lensed galaxies and even a supernova.

The unique feature in a new image taken with the NASA/ESA Hubble Space Telescope is a group of five quasar images produced by a process called gravitational lensing, in which the gravitational field of a massive object — in this case, a cluster of galaxies — bends and amplifies light from an object — in this case, a quasar — farther behind it.

Although other multiply lensed quasars have been seen before, this newly observed "quintuple quasar" is the only case so far in which multiple quasar images are produced by an entire galaxy cluster acting as a gravitational lens.

The background quasar is the brilliant core of a galaxy. It is powered by a black hole, which is devouring gas and dust and creating a gusher of light in the process. When the quasar's light passes through the gravity field of the galaxy cluster that lies between us and the quasar, the light is bent by the space-warping gravity field in such a way that five separate images of the object are produced surrounding the cluster's centre. The fifth quasar image is embedded to the right of the core of the central galaxy in the cluster. The cluster also creates a cobweb of images of other distant galaxies gravitationally lensed into arcs.



European Space Agency, NASA, Keren Sharon (Tel-Aviv University) and Eran Ofek (CalTech). Acknowledgements: Davide de Martin (ESA/Hubble).

THE INTERNATIONAL YEAR OF ASTRONOMY 2009

Lars Lindberg Christensen

The International Astronomical Union (IAU) has taken the initiative to celebrate the year 2009 as the International Year of Astronomy (IYA2009): a global celebration of astronomy and its contributions to society and culture. The aim is to stimulate worldwide interest, not only in astronomy, but in science in general, with a particular slant towards young people.

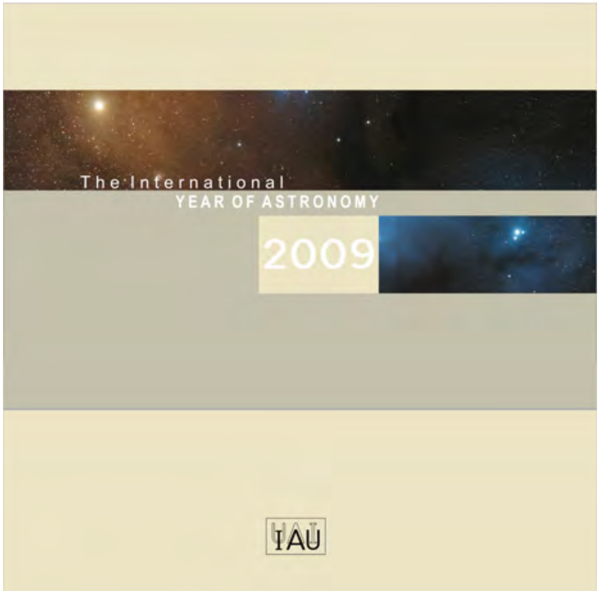
Today we live in what may be the most remarkable age of astronomical discovery in history. One hundred years ago we barely knew of the existence of our own galaxy of stars — the Milky Way. We now know that many billions of galaxies make up our Universe and that it, in turn, originated approximately 14 billion years ago. One hundred years ago we had no means of answering the centuries old question: are there other solar systems in the Universe? Today we know of over 200 planets around other stars in our Milky Way. One hundred years ago we studied the sky using only optical telescopes, the human eye and photographic plates. Today we observe the Universe with telescopes with advanced digital detectors, both on the Earth and in space, that are sensitive to high-energy gamma rays through to low frequency radio emission. Our view of the Universe is now more fully polychromatic than ever before.

The year 2009 will be the 400th anniversary of Galileo Galilei's remarkable discoveries that changed astronomy forever. He turned one of his telescopes to the night sky and saw mountains and craters on the Moon, a plethora of stars invisible to the naked eye and moons around Jupiter. IYA2009 will mark the monumental leap forward that followed Galileo's first use of the telescope for astronomical observations, and portray astronomy as a global endeavour that unites astronomers in an international, multicultural family of scientists working together to find answers to some of the most fundamental questions ever asked. IYA2009 is, first and foremost, a series of activities for people all around the world. It aims to convey the excitement of personal discovery, the pleasure of sharing fundamental knowledge about the Universe and our place in it and the value of scientific culture.

The majority of IYA2009 activities will take place on several levels: locally, regionally and nationally. Several countries have already formed national committees to prepare activities for 2009. These committees are collaborations between professional and amateur astronomers, science centres and science communicators. At the global level the IAU will play a leading role as a catalyst and coordinator. While the IAU will organise a small number of truly global or international events such as the Opening and Closing Events, the main activities will take place at the national level and will be coordinated by the IYA2009 National Nodes in close contact with the IAU.

The IYA 2009 is based on a resolution that was adopted by the UNESCO General Conference in 2005. With a confirmation by the General Assembly of the United Nations in 2007, the IYA will be able to benefit fully from an endorsement by the highest international body.

More information (including a PDF brochure and a sign-up sheet for an e-mail Newsletter) is available at: http://www.astronomy2009.org/



CONTENTS

ST-ECF

Head
Robert A.E. Fosbury
+49-89-320 06 235
Robert.Fosbury@stecf.org

Advanced Data Products
Jeremy R. Walsh
+49-89-320 06 248
Jeremy.Walsh@stecf.org

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

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

Websites
http://www.stecf.org
http://www.spacetelescope.org

Telephone
+49-89-320 06 291

Telefax
+49-89-320 06 703

Hot-line (email)
stdesk@stecf.org

Email
<user>@stecf.org

ST-ECF Newsletter

Editor
Richard Hook, Richard.Hook@stecf.org

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

Layout, illustrations and production
Martin Kornmesser,
Lars Lindberg Christensen &
Raquel Yumi Shida

Printed by
TypeSet, München

Published by
ST-ECF

SERVICING MISSION 4 [heic0618]

Hubble's huge contributions to science and culture have only been possible as a result of regular upgrades and enhancements to the telescopes's instrumentation and other engineering systems, as described in the article on page two of this Newsletter.

With the decision by NASA's Administrator, Michael Griffin, to proceed with the launch of a fifth Servicing Mission to upgrade the telescope in 2008, a crew of NASA astronauts and a huge support team will undergo two years of training in preparation for the mission.

Despite the Columbia Space Shuttle disaster in 2003 and the absence of a safe haven for the crew, NASA's approval for the 11-day mission will not only ensure that Hubble can function for perhaps as much as another ten years, it will also increase its capabilities significantly in key areas.

Once launched, the space shuttle will follow an orbit tilted 28.5 degrees to the Earth's equator on a path that will ensure that the space vehicle will rendezvous with Hubble around two days after launch in an orbit 589 km above the Earth.

There are planned to be five spacewalks during the flight, the astronauts will install two new scientific instruments: the Cosmic Origins Spectrograph (COS) and the Wide Field Camera 3 (WFC3). Each has advanced technology sensors that will dramatically improve Hubble's potential for discovery and enable it to observe the faint light from the youngest stars and galaxies in the Universe.

Other upgrades will include the installation of several pallets in the shuttle's cargo bay: the Super Lightweight Interchangeable Carrier (SLIC), the Orbital Replacement Unit Carrier (ORUC), the Flight Support System (FSS) and the Multi-use Logistic Equipment Carrier (MULE).

With such a dramatic increase in its science capabilities, Hubble is expected to continue to penetrate the most distant corners of space and reveal further new results.

***Cover image** [heic0617]: Hubble has returned to the intriguing object V838 Monocerotis many times since its initial outburst in 2002 to follow the evolution of its light echo. This new image from September 2006 provides the most astonishing view of V838 Mon to date. This previously inconspicuous star underwent an outburst early in 2002, during which it temporarily increased in brightness to become 600,000 times more luminous than our Sun. Light from this sudden eruption is illuminating the interstellar dust surrounding the star, producing the most spectacular "light echo" in the history of astronomy.*

***Image Credit**: NASA, ESA and H. Bond (STScI)*