ST-ECF

July 2009

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Successful Servicing of Hubble

ACS Grism Spectra Release

Slitless Spectroscopy Simulations for Euclid

Space Telescope European Coordinating Facility

THE HUBBLE SERVICING MISSION – A PERSONAL VIEW

Colleen Sharkey

Colleen Sharkey, our new Hubble Outreach Coordinator, was lucky enough to go to see the Hubble Space Shuttle mission launch from Florida and gives her personal account of the launch and the people involved. Jeremy Walsh summarises the technical achievements of the hugely successful mission in the next article.

11 May 2009: Equipped with my green badge — indicating that I am a foreign national (even though I'm a US citizen) — I was escorted to the press site at Kennedy Space Center to report on the launch of Space Shuttle *Atlantis*, whose crew would conduct Hubble's fifth servicing mission. The "Space Coast" was just as I remembered it: unforgivably hot and full of swaying palm trees and overly curious alligators. The press site was bustling with activity and packed with reporters from all corners of the world. Our only view of the action at that time was the big screen TV showing NASA's pre-launch coverage. With my colleagues from STScI, I watched with eager anticipation as the astronauts were readied for flight. NASA offered reporters the opportunity to interview astronauts from other missions. I had the pleasure of meeting Rick Linnehan, who flew on STS-109 for SM3B. A veterinarian by training, Linnehan, with his team-mate John Grunsfeld, performed three of the five spacewalks on SM3B totalling 21 hours and 9 minutes. He offered a firsthand perspective of how astronauts feel just before lift-off and emphasised just how difficult the STS-125 crew's mission would be.

Credit: NASA

Fig.1: *Space Shuttle* Atlantis *lifts off from Kennedy Space Center, en route for Hubble.*

We were invited up to a press tower to watch the launch, arguably the best view of the launch pad that a visitor can get. As the large countdown clock ticked backwards toward zero, Florida senator and former astronaut Bill Nelson joined us on the platform. Visibly nervous for his compatriots, Nelson was ever the politician, shaking hands and spreading goodwill. One of the things that struck me the most was how eerily quiet it gets seconds before launch and during lift-off. Before the clock hit zero, huge clouds of puffy white steam rose from the launch pad, three miles away from us. As the Shuttle rose, the sound travelled to us, and it was then that we felt the real power of the rockets that raised the seven astronauts toward Hubble (Figure 1). The wooden platform began to shake and I tried to ignore it so I could see *Atlantis* slip out of sight.

Credit: NASA

Fig. 2: *Hubble is successfully grappled using the Canadian robotic arm.*

After the dramatic lift-off, it was off to Goddard Space Flight Center in Greenbelt, Maryland where I met up with the ESA engineers (Figure 5) who were responsible for monitoring the solar panel drive electronics and mechanisms during SM4. The team of four, led by veteran engineer Michael Eiden worked in 12-hour shifts to ensure total coverage.

As the shifts changed in the afternoon, I got to work with both pairs of engineers each day, blogging about their areas of expertise and

Fig. 3: *Astronauts John Grunsfeld (lower left) and Andrew Feustel, perched alone on the end of the Space Shuttle* Atlantis's *remote manipulator system (robotic arm), perform the first of five STS-125 spacewalks to work on the Hubble Space Telescope, temporarily locked down in the cargo bay of the Earth-orbiting shuttle.*

the servicing mission itself (http://www.spacetelescope.org/about/history/sm4blog/).

The current (third pair) of solar arrays and electronics and drive mechanisms worked flawlessly, but the team was called upon periodically to give expert advice. Just below us in the STOCC (Space Telescope

Fig. 4: *The crew members pose for the traditional in-flight portrait on the mid-deck of* Atlantis *on mission day 10. Pictured on the front row are astronauts Scott Altman (centre), commander; Gregory C. Johnson, pilot; and Megan McArthur, mission specialist. Pictured on the back row (left to right) are astronauts Michael Good, Mike Massimino, John Grunsfeld and Andrew Feustel, all mission specialists.*

Operations Control Center), Goddard engineers were in constant communication with mission control in Houston.

NASA TV was on round the clock in our workroom and we watched every moment with cautious excitement. Would the astronauts really be able to accomplish the formidable tasks set before them? The repairs on STIS and ACS alone involved removing a total of 143 screws that were never intended to be changed-out in space. As each EVA passed, it was clear that the astronauts were incredibly well trained

Fig. 5: *The ESA Hubble team, in front of the Vertical Assembly Building (VAB) at KSC where Shuttles are connected with external fuel tanks before launch. From left to right: Lothar Gerlach, Udo Rapp, Manfred Schmid and Michael Eiden.*

and that Hubble was in good hands. With each aliveness and functionality test that STOCC reported, it was looking very promising that all SM4 goals would be met. Then came STIS. The stubborn bolt on the instrument's handrail gave astronaut Mike Massimino quite a headache but, in the end, his "brute force" paid off and he gained access to STIS and was able to make the necessary repairs. When all tasks were completed, the astronauts got some free time while nasty weather brewed in Florida.

After all mission objectives were completed, the Goddard team hosted a small celebration, during which (Goddard mission operations manager) Keith Walyus thanked each of the ESA engineers for their support. Eiden, who worked on all of the Servicing Missions, called SM4 "the most gratifying of all of them" and added, "It is a challenging job, but a dream job. The success story of international cooperation between ESA and NASA on the Hubble project for over 19 years in orbit has led to fascinating results, in my opinion unmatched by any telescope in the world. I'm extremely honoured to serve the Hubble project".

MISSION OVERVIEW

Jeremy Walsh

The fifth servicing mission to Hubble, SM4 (also known as STS-125), was a crowning achievement for the astronauts and it marks a huge increase in observational capabilities for the orbiting observatory. The installation of two new instruments and the major repair of two others (despite a stubborn bolt that refused to rotate), attests to the high level of level of preparation that NASA devoted to this mission. A letter of recognition for the outstanding achievement of the astronauts was sent to the astronauts by ESO Director General Tim de Zeeuw and the ST-ECF.

THE CREW

The seven-strong crew of *Atlantis* consisted of Scott D. Altman (Commander), Gregory C. Johnson, John M. Grunsfeld and Michael J. Massimino (both previous Hubble servicers), Andrew J. Feustel, Michael T. Good and K. Megan McArthur.

Credit: NASA

Fig. 1: *A crew member aboard the Space Shuttle* Atlantis *captured this still image of the Hubble Space Telescope as the two spacecraft slowly moved apart on May 19, after having been linked together for the better part of a week. During the week five spacewalks were performed to complete the final servicing mission for the orbital observatory.*

THE TIMELINE

EVA 1: On the first EVA day the new UV-optical and infrared camera WFC3 was installed, replacing WFPC2, which had been successfully operating since 1993. In addition the computer interface that had failed shortly before the planned SM4 launch in October 2008 was replaced.

EVA 2: The second EVA was devoted to important housekeeping activities for Hubble. Three Rate Sensor Units (RSUs), each containing two gyros for pointing and alignment, were installed followed by the first of two new battery modules.

EVA 3: The now-redundant instrument COSTAR (Corrective Optics Space Telescope Axial Replacement), flown in 1993 to correct the science instruments for the spherical aberration of the primary mirror, was removed and replaced by the new Cosmic Origins Spectrograph (COS), for spectroscopy at a resolution of up to 24 000 in the UV (1150-3200Å). Then the repair of the power supply for the Advanced Camera for Surveys (ACS) was performed. The high-resolution channel (HRC) on ACS was not restored.

EVA 4: Repair of the Space Telescope Imaging Spectrograph (STIS) was accomplished. This activity, which occupied the whole EVA, proved to be the most demanding of any ever performed by astronauts on Hubble.

EVA 5: The last spacewalk was again devoted to renewal of basic Hubble components that will continue the functioning of the telescope for at least the next five years: a second set of batteries, a refurbished Fine Guidance Sensor (FGS) unit and some New Outer Blanket Layer (NOBL) thermal insulation material. This is expected to be the last time that astronauts “touch” Hubble before it makes a controlled re-entry into the atmosphere sometime in the 2020s.

AFTER THE MISSION

Hubble has been in a period of extensive testing and check-out since SM4. So far all instruments appear to be performing well. There has been little observation activity since a period of a few weeks must be allowed for the new instruments to out-gas and any gaseous pollutants brought by the Shuttle to dissipate. There was a recorded high bias on one of the STIS CCD amplifiers, which has been investigated but is not causing concern. A safing event in WFC3 was caused by a temperature sensor being below the low limit and was traced to the electronics being colder than the normal operating temperature since they had not been turned on for long. So far all the new and repaired instruments are performing well and the many Servicing Mission Orbital Verification (SMOV) activities are ramping up. Over the coming weeks and months the first images and spectra will be taken and a press release is currently scheduled for the beginning of September.

ERRATUM

The picture on page 14 of the last ST-ECF Newsletter was inadvertently labelled incorrectly. The cluster shown is really Abell 1703 at z=0.26, corresponding to a distance of about 3 billion light-years.

Credit: NASA, ESA, and J. Maíz Apellániz (Instituto de Astrofísica de Andalucía, Spain)

HUBBLE CAPTURES OUTSTANDING VIEWS OF MAMMOTH STARS [HEIC0822]

Two of our Galaxy's most massive stars have been scrutinised in an impressive view by the NASA/ESA Hubble Space Telescope. They have, until recently, been shrouded in mystery, but the new image shows them in greater detail than ever before.

The image shows WR 25 and Tr16-244, located within the open cluster Trumpler 16. This cluster is embedded within the Carina Nebula, an immense cauldron of gas and dust that lies approximately 7500 light-years from Earth.

ST-ECF ACS/WFC GRISM SAMPLE RELEASE

Martin Kümmel, Piero Rosati, Harald Kuntschner, Marco Lombardi, Jonas Haase, Richard Hook, Felix Stoehr, Jeremy Walsh, Alberto Micol & Robert Fosbury

A first sampler of 1235 slitless spectra, obtained with Hubble's Advanced Camera for Surveys and the G800L grism, was extracted from two NICMOS parallel pointings in the Chandra Deep Field South area and released into the Hubble Legacy Archive in May 2009. Spectral extraction was performed with the aXe software and all spectra were visually screened for quality control. A release of the entire ACS slitless dataset is planned for the end of 2009. The availability of a large number of extracted ACS grism spectra in the HLA opens the door to many interesting scientific applications.

INTRODUCTION

As the latest part of a continuing effort to enhance the content of the Hubble Legacy Archive (HLA) with highly processed data products that significantly facilitate the scientific exploitation of the Hubble data, the ST-ECF has recently released a sampler of ACS/WFC extracted grism spectra. This follows the full release of NICMOS grism spectra in 2008 (Freudling et al. 2008). The ACS sample release (http://stecf.org/archive/hla/) includes 1235 science-ready one- and two-dimensional spectra that were individually validated. It forms part of HLA Data Release 3, which contains many other new data products and interface enhancements (see http://hla.stsci.edu/). The spectra were extracted from two parallel pointings, using ACS/WFC in slitless mode with the G800L grism, during the NICMOS Hubble Ultra Deep Field (HUDF) observations. The two fields (denoted UDFNICP1 and UDFNICP2) lie to the south and west of the GOODS-South field, in the Chandra Deep Field South (Figure 1), one of the most-studied regions of the sky with a very rich multi-wavelength dataset from space and ground observatories.

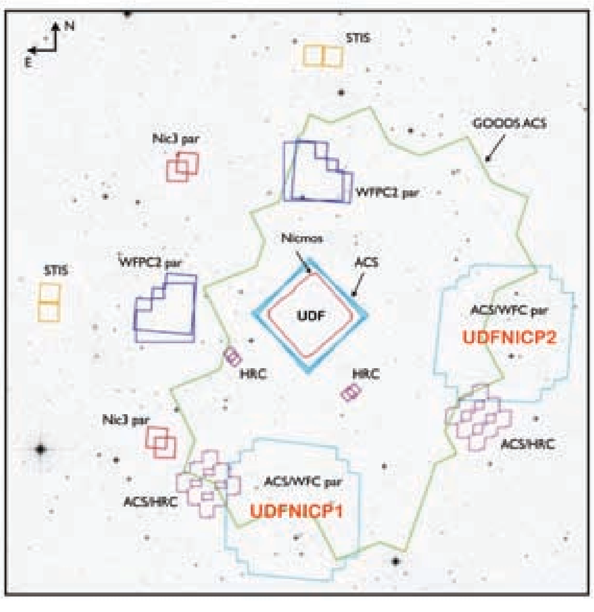

Fig. 1: *Chandra Deep Field South region, covering a region about 25 arcminutes across, centered on the Hubble Ultra Deep Field. The GOODS ACS coverage and a number of Hubble primary and parallel pointings are indicated, including the NICMOS parallel fields P1 and P2 observed with G800L grism and subject of the HLA sample release.*

DATA RELEASE CONTENT

This is the first step towards a release into the HLA of extracted spectra from the entire ACS grism data set. ACS G800L grism pointings in the Hubble archive were first grouped into data associations, following pre-defined rules on sky position, roll angle and availability of direct images. The PHLAG pipeline (Kümmel et al. 2008) was then used for the end-to-end data processing, which included data preparation and retrieval from the archive, MultiDrizzle image combination (Koekemoer et al. 2002), object detection with SExtractor (Bertin & Arnouts 1996) on associated direct images, and spectral extraction on the dispersed combined images with aXe, the software developed by the ST-ECF (Kümmel et al. 2009) to reduce slitless mode data from Hubble. aXe was used for the NICMOS grism spectral extraction and has recently been further developed to deal optimally with ACS spectra. Supporting metadata are generated for each data product, then extracted spectra undergo a quality control process, where a high quality selection of spectra is retained, before they are ingested into the archive. In addition, several methods were used to refine and then quantify the absolute flux calibration of the spectra (e.g. by checking the consistency with integrated fluxes in a given ACS/WFC filter), the wavelength calibration using spectral templates and the astrometric accuracy of the target.

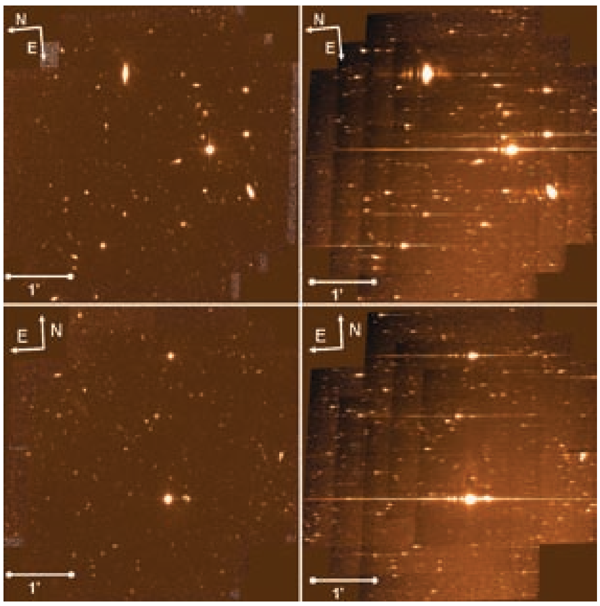

Fig. 2: *UDFNICP1 (top) and UDFNICP2 (bottom) fields: Right: combined G800L grism image (~18 ksec); Left: corresponding direct image obtained combining F606W+F775W+F850LP exposures (up to 60 ksec).*

The combined direct and dispersed images of the two fields are shown in Figure 2, where the level of contamination due to spectral overlap and multiple orders can be appreciated. Each field is the combination of two data associations. The ACS G800L grism provides a wavelength range of 0.55-1.05 μm, with a dispersion of 40Å/pixel and a spectral resolution of ~100Å (FWHM) for point-like sources.

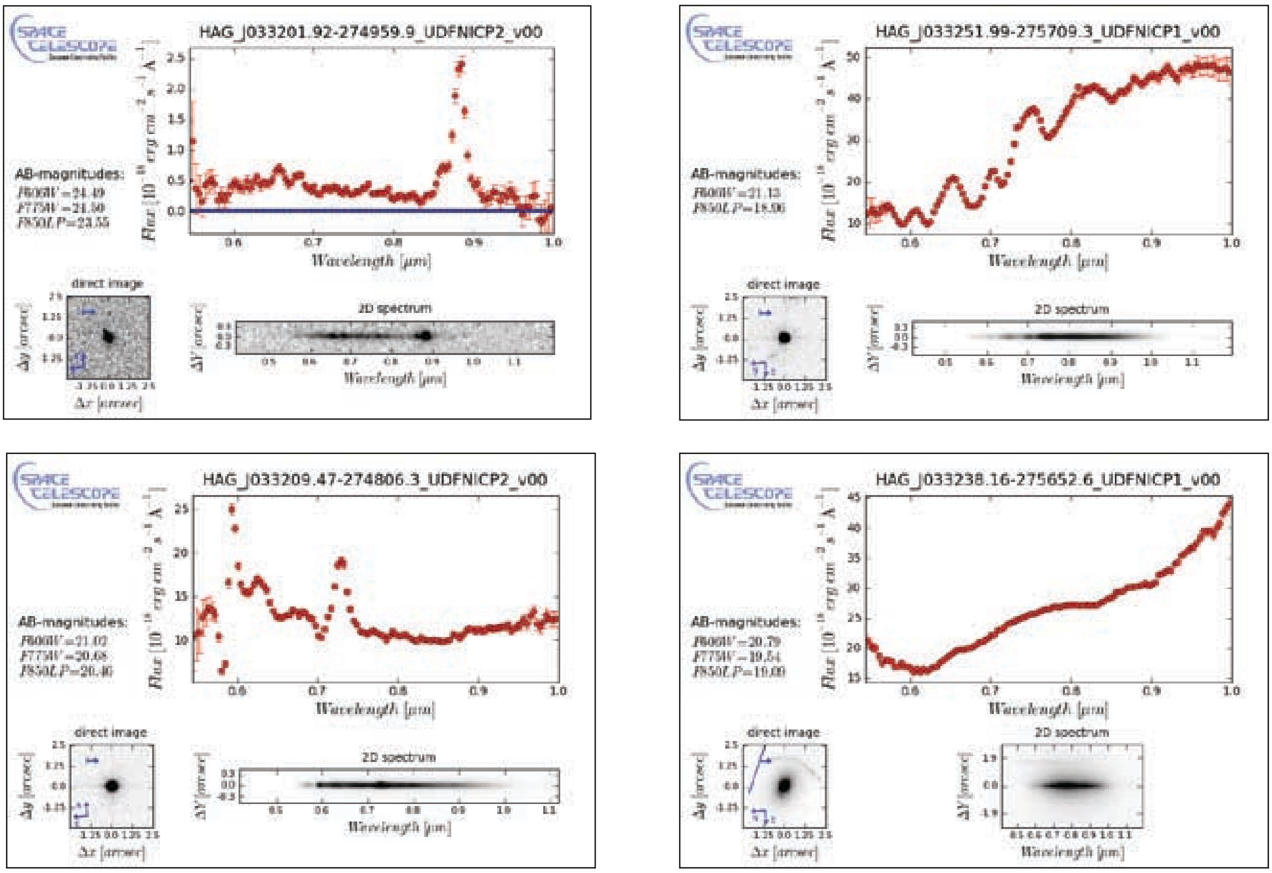

Fig. 3: *Examples of ACS grism spectra extracted with aXe as shown in the previews included in the sample release. Top left: a low-redshift starburst galaxy; top right: an M-star; bottom left: a broad-absorption line QSO identified as a Chandra X-ray source (Szokoly et al. 2004); bottom right: a bright elliptical galaxy (z=0.617) with a prominent gravitational arc (Blakeslee et al. 2004) that is clearly detected in the two-dimensional spectrum (see Figure.4).*

All data products can be retrieved via the ST-ECF HLA archive interface (http://hla.stecf.org) or the STScI HLA portal (http://hla.stsci.edu). For each target a cut-out of the undispersed image, a two-dimensional spectrum (position versus wavelength) and a one-dimensional integrated spectrum of the target, all in VO-compatible FITS files with related metadata in FITS keywords, are returned. A visual summary of all data products is given on a preview page for each target and this is also available from the archive (in PNG format). Some examples are shown in Figure 3, which includes two emission line objects, an M-star and a bright elliptical galaxy with a prominent gravitational arc (described in Blakeslee et al. 2004), which is well seen in the two-dimensional image and whose redshift is still not known. A further analysis of this system is shown in Figure 4.

The number of spectra in the pre-release was small enough so that each spectrum could be inspected visually. In this visual quality control process ~40% of the spectra were discarded, primarily because of excessive contamination from nearby sources, but also because of the presence of deviant pixels, either saturated or lying near the edges of combined chips. By retaining several spectra, which although contaminated to some level can still provide useful information on the nature and redshift of the source, this process led to the selection of the 1235 spectra. The availability of thousands of ESO/VLT fully reduced spectra, publicly released as part of the ESO-GOODS programme (Vanzella et al. 2008), allows interesting comparisons between ACS grism spectra and higher resolution multi-slit spectra. An example is shown in Figure 5 for a range of galaxy types at z~1. It is clear that, while the low resolution of ACS G800L spectra makes it difficult to detect narrow lines, the ability to reproduce the spectral shape is quite remarkable, which opens up the possibility of obtaining redshifts

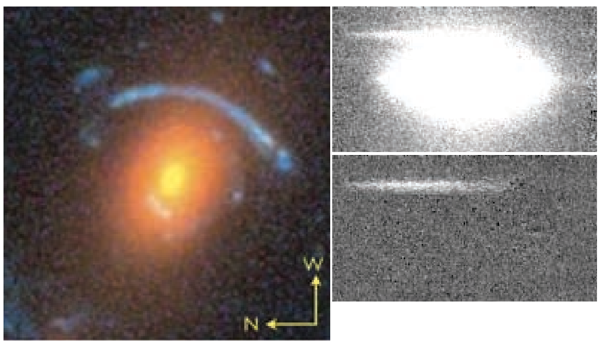

Fig. 4: *Left: Colour composite image (ACS/WFC B_{435} V_{606} i_{775} from Blakeslee et al. 2004) of the elliptical galaxy HAG_J033238.16-275652.6_UDFNICP1 and the associated multiply-lensed system (see bottom right in Figure 3). Right: two-dimensional ACS grism spectrum (top) and with lens galaxy subtracted (bottom). The spectrum of one of the high surface brightness regions of the arc (B_{435}~ 25.5) is clearly visible.*

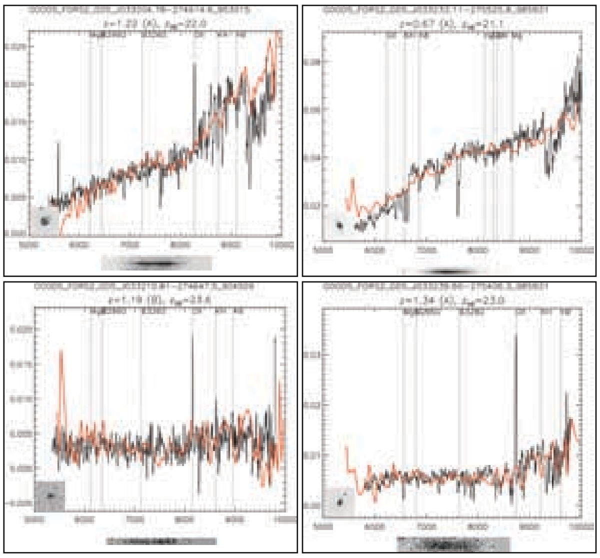

Fig. 5: Comparison between ACS grism spectra (red curves with two-dimensional cutouts at the bottom) and spectra obtained with VLT/FORS2 with the 300I grism (R~600).

for large samples of spectra via spectro-photometric techniques, a method already exploited in ACS grism observations of high-z galaxies and supernovae.

FUTURE PLANS

The full ACS slitless release is planned for the end of 2009 and is expected to contain approximately 40 000 spectra, extracted from about 150 ACS G800L datasets randomly distributed on the sky away from the galactic plane (see Kümmel et al. 2008). As visual inspection of the whole sample will no longer be an option, we have explored ways of using automatic classification with machine-learning techniques. The idea is to first train an algorithm with a small number of visually inspected spectra using measured values such as the estimated contamination fraction, the signal-to-noise ratio and the magnitude and the position of the maximum of light on the two-dimensional spectrum. In a second step the remaining spectra could ideally be classified automatically and a relatively small number of selected spectra for which the classification is uncertain would be flagged and then passed on for additional visual inspection. The goal is to use this two-step process to achieve a high fraction of correct classifications without the need for unreasonable numbers of visual inspections.

Besides working towards the release of the entire ACS grism dataset in the HLA, we are engaged in exploring the scientific niches afforded by the slitless mode of ACS. This sample release, being focused on deep grism observations in an area with a vast range of publicly available advanced data products, is particularly suited for this purpose.

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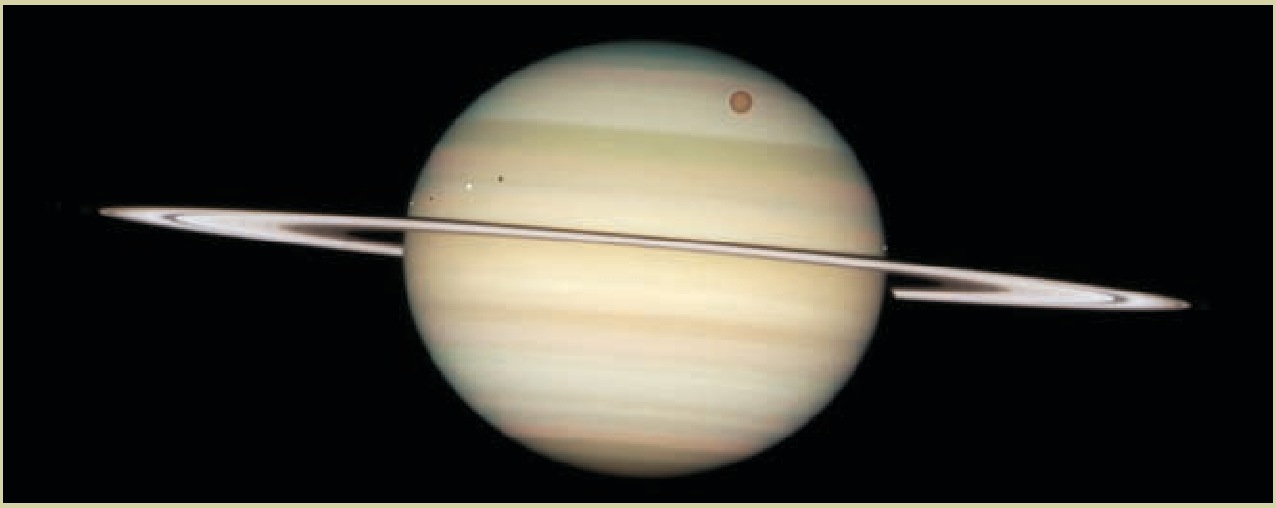
FOUR OF SATURN'S MOONS PARADE BY THEIR PARENT [HEIC0904]

On 24 February 2009, the NASA/ESA Hubble Space Telescope captured a photo sequence of four moons of Saturn passing in front of their parent planet. The moons, from far left to right, are the white icy moons Enceladus and Dione, the large orange moon Titan, and icy Mimas. Due to the angle of the Sun, they are each preceded by their own shadow.



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

NEWS FROM THE HUBBLE ARCHIVE

Jonas Haase & Felix Stoehr

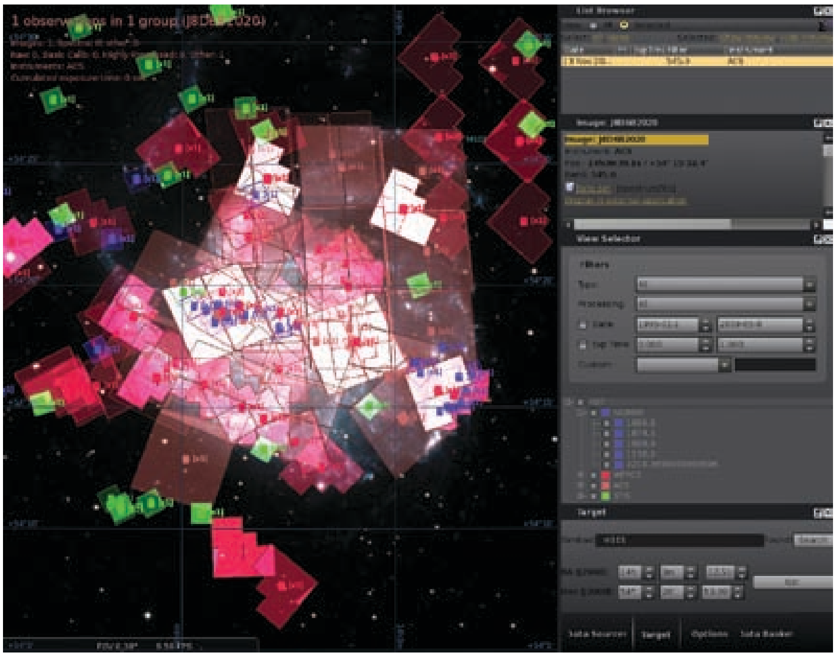


Fig. 1: *Footprints of Hubble observations of the region of the spiral galaxy M101, visualised using the VirGO visual archive browsing tool.*

UPDATES ON THE HUBBLE CACHE

Work continues on the new Cache system for the Hubble archive that was described in the last Newsletter. And as part of our efforts to try to provide the best possible service for our users we continue to make changes to the archive system in order to improve the speed and reliability. More importantly we strive to keep the Hubble data available in the best possible state to make direct scientific exploitation as productive as possible.

Recent improvements include:

- The NICMOS calibration pipeline has undergone significant changes, introducing the use of the same software that is going into the NICMOS recalibration effort at the Space Telescope Science Institute. At this point all the NICMOS data in the Hubble Cache should be in the newest possible state.

- In the same vein we are shadowing the WFPC2 recalibration and have revamped the WFPC2 calibration pipeline. All WFPC2 data is now available in the usual WFPC2 waivered FITS format (extensions .d0f.fits/.c0f.fits) and also as multi-extension FITS (.d0m.fits/.c0m.fits).

- Sub-products, which are produced by the ACS and NICMOS calibration procedure for more exotic observation modes are now available from the archive as well.

- The preview system has been overhauled. All previews shown in the Hubble archive interface and in Aladin are now a direct product of the Cache software and should be a significant improvement over the old offering.

- New SSAP and SIAP servers for VO access have been installed at http://stecf.org/hst-vo/hst_ssa and http://stecf.org/hst-vo/hst_sia. These serve almost all Hubble science frames and, in addition, Hubble Legacy Archive imaging products will also be available in the near future. At the time of writing frames from the live instruments ACS, WFPC2, NICMOS and STIS are available. Note that the old HLA SSAP server is still accessible at the new location of http://stecf.org/hst-vo/hla_ssa and now allows access to both NICMOS and ACS grism spectra. Figure 1 shows Hubble observations of M101 visualised using the VirGO archive browsing tool.

THE IMMEDIATE FUTURE

The ESO/ST-ECF Hubble archive is finishing its preparations for serving data from the new COS and WFC3 instruments that were successfully installed during Servicing Mission 4. For the users this will be visible through a new archive interface. This interface is based on a wider set of metadata collected through the Cache system and will allow the user to query using a much larger range of scientifically interesting parameters.

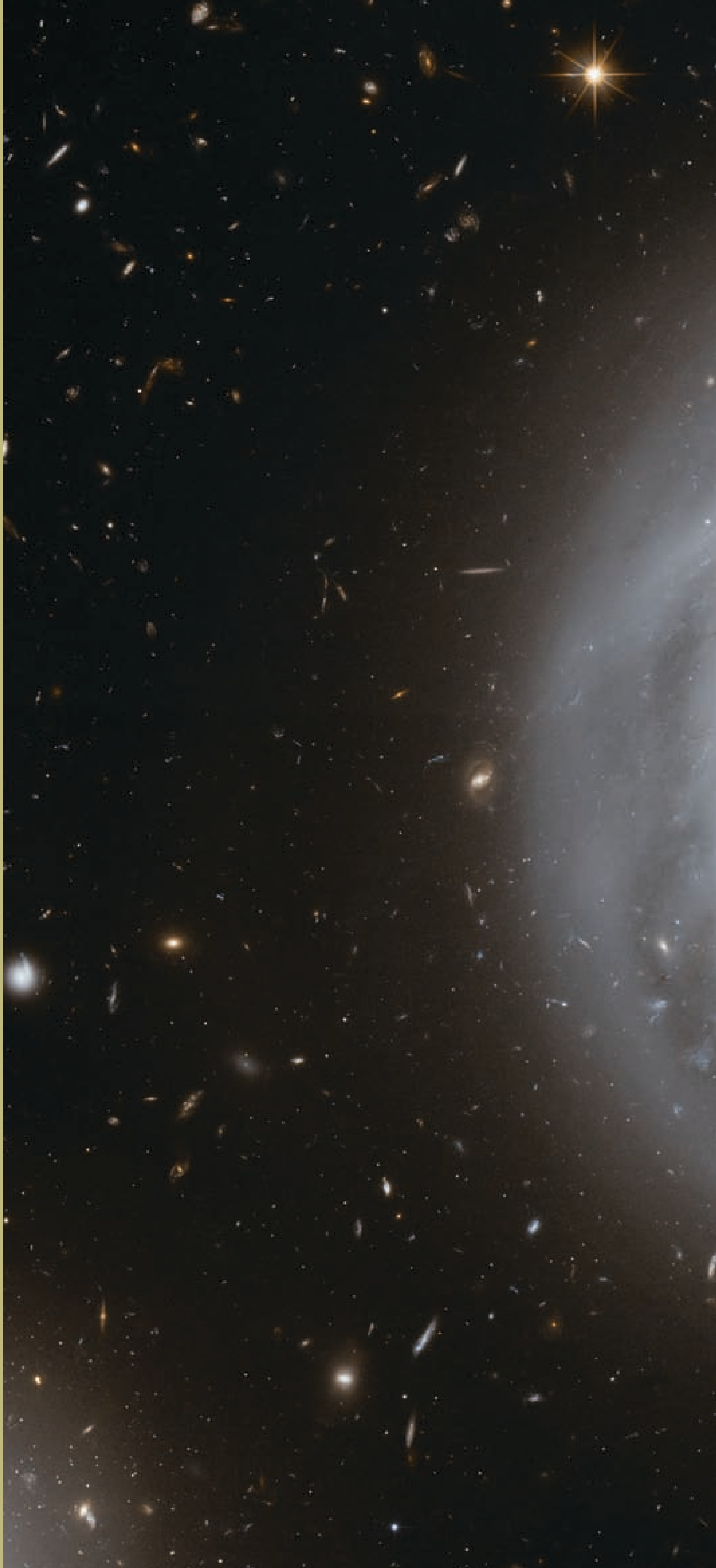
It also makes it possible to explore new approaches for astronomical archive search: A search interface which offers some of functionality of the well-known general purpose search engines on the web is currently undergoing first tests and will appear for a public trial in the near future.

EXCEPTIONALLY DEEP VIEW OF STRANGE GALAXY
[heic0901]

The Coma Galaxy Cluster, in the northern constellation of Coma Berenices, the hair of Queen Berenice, is one of the closest very rich collections of galaxies in the nearby Universe. The cluster, also known as Abell 1656, is about 320 million light-years from Earth and contains more than 1000 members. The brightest galaxies, including NGC 4921 shown here, were discovered back in the late 18th century by William Herschel.

The galaxies in rich clusters undergo many interactions and mergers that tend to gradually turn gas-rich spirals into elliptical systems without much active star formation. As a result there are far more ellipticals and fewer spirals in the Coma Cluster than are found in quieter corners of the Universe.

NGC 4921 is one of the rare spirals in Coma, and a rather unusual one — it is an example of an “anaemic spiral” where the normal vigorous star formation that creates a spiral galaxy’s familiar bright arms is much less intense. As a result there is just a delicate swirl of dust in a ring around the galaxy, accompanied by some bright young blue stars that are clearly separated out by Hubble’s sharp vision. Much of the pale spiral structure in the outer parts of the galaxy is unusually smooth and gives the whole galaxy the ghostly look of a vast translucent jellyfish.



Credit: NASA, ESA and K. Cook (Lawrence Livermore National Laboratory, USA)

SLITLESS SPECTROSCOPIC SIMULATIONS FOR EUCLID WITH AXESIM

Piero Rosati, Martin Kümmel, Jeremy Walsh, Paolo Franzetti (INAF-IASF Milan), Andrea Cimatti (Università degli Studi di Bologna), Bianca Garilli (INAF-IASF Milan), Gianni Zamorani (INAF-Osservatorio Astronomico di Bologna), Marco Scodeggio (INAF-IASF Milan) & Hugo Rivera (INAF-IASF Milan)

Euclid is a proposed medium-class dark energy space observatory mission selected for assessment by ESA within the Cosmic Vision 2020 programme. The current concept includes a spectroscopic channel operating in slitless mode to carry out a survey covering half of the sky. The ST-ECF is involved in end-to-end sky simulations using the aXeSIM software, with the goal of quantifying the performance of the spectrograph, verifying science requirements and guiding the instrument development.

INTRODUCTION

As part of the ESA Cosmic Vision 2015-2025 programme, the medium class mission Euclid, designed to map the geometry of the dark Universe, was selected for further definition and assessment in November 2007. Euclid will carry out an imaging and a spectroscopic survey of the extragalactic sky covering 20 000 square degrees with the principal goal of constraining the nature of dark energy and measuring its energy density using a number of cosmological probes, primarily baryonic acoustic oscillations (BAO) and weak lensing.

Euclid is the result of the merging of two dark energy-related mission concepts, both selected by ESA in the context of the Cosmic Vision plan: “SPACE: the Spectroscopic All Sky Cosmic Explorer” (principal investigator: A. Cimatti) and “DUNE: the Dark Universe Explorer” (principal investigator: A. Refregier). These missions proposed to explore the Universe out to $z\sim2$ by obtaining, respectively, a three-dimensional map of the (visible) Universe with near-infrared slit spectroscopy to $H=22$ mag_{AB} (from which BAO can be measured) and a reconstruction of the (dark) matter mass distribution using weak lensing tomographic techniques from optical/near-infrared imaging to ~24 mag_{AB}. The current Euclid concept therefore allows a powerful combination of different cosmological probes, those depending on the universal geometry (BAO and possibly Type-Ia supernovae, whose requirements are still under study) and those based on the growth of structure (weak lensing, cluster counts and redshift distortions). Such independent physical constraints are not only the best way to control systematics and break degeneracies among cosmological parameters, but by probing both the texture and the dynamics of the Universe they also open up new ways to test general relativity and modified-gravity theories on cosmological scales. In addition to the primary goal of the mission, the Euclid imaging and spectroscopic data set will have a superb legacy value and will allow a broad range of astrophysical issues to be addressed.

To define the science requirements and assess the feasibility of the Euclid mission, ESA has appointed a Euclid Study Science Team (ESST) that also coordinates a number of working groups spread throughout the community, which are currently studying different aspects of the mission. This assessment phase is scheduled to end in December 2009 when a “Euclid Yellow Book” will be presented to the ESA advisory structure for the down-selection process in the Cosmic Vision programme, with a foreseen launch to L2 before the end of the next decade.

SIMULATING SPECTROSCOPIC SLITLESS OBSERVATIONS

The current Euclid design includes a 1.2 m telescope with optical and near-infrared imagers, as well as a near-infrared spectroscopic channel. The latter originally used digital micromirror devices (DMDs) as a novel approach to provide multi-slit spectroscopy from space. However, more recently, due to programmatic and technical constraints, a slitless near-infrared spectrograph was chosen as the baseline. A European consortium led by A.Cimatti, in coordination with ESA, is currently developing the design. In order to study the performance of a slitless spectrograph and to drive the requirements on the various instrument parameters based on scientific needs, realistic sky simulations are essential, especially because of the significant effect of overlapping spectra (Kümmel et al. 2009). The ST-ECF is engaged in this collaboration and is providing its expertise and software tools, particularly aXeSIM (Kümmel et al. 2007, 2009, see also http://www.stecf.org/software/slitless_software/axesim/), which forms the core of sky simulations. The main goal of this activity is to test different instrument configurations and assess the performance of the spectrograph in extracting the largest possible sample of uncontaminated

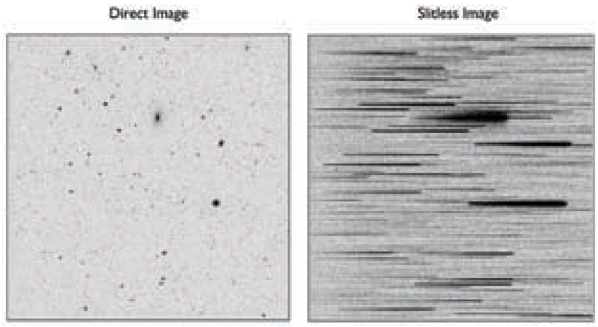


Fig. 1: *Example of a simulated sky patch (16 x16 arcminutes, ~1/4 of the spectrograph field of view) with Euclid using the aXeSIM software. The direct image is to the left and the dispersed slitless image to the right (1500s exposure, spectral resolution R=400).*

spectra from which redshifts can be measured. To this end, in collaboration with IASF-Milan, we have built an end-to-end simulator around aXeSIM that allows detailed comparisons of spectrograph performance with the expected scientific goals. The scientific requirements of the BAO experiment are expressed in terms of the accuracy with which the dark energy equation of state parameters can be measured, this essentially depends on the survey volume and number of measurable redshifts, as well as their accuracy. Typically, dark energy-driven slitless surveys from space require 10^8 redshifts at $0.5<z<2$, with a redshift accuracy of $\sigma_z\sim10^{-3}$. In slitless mode, with a wavelength range of 0.9-2 μm, the galaxy sample is dominated by H-α emitters with $<z>\sim1$. When compared to the multi-slit case, the sensitivity (for the continuum) is significantly reduced, and so is the redshift measurement success rate due to overlapping spectra and the difficulty in identifying low equivalent width lines. An example of the aXeSIM Euclid simulations is shown in Figure 1, where the effect of overlapping spectra can be appreciated.

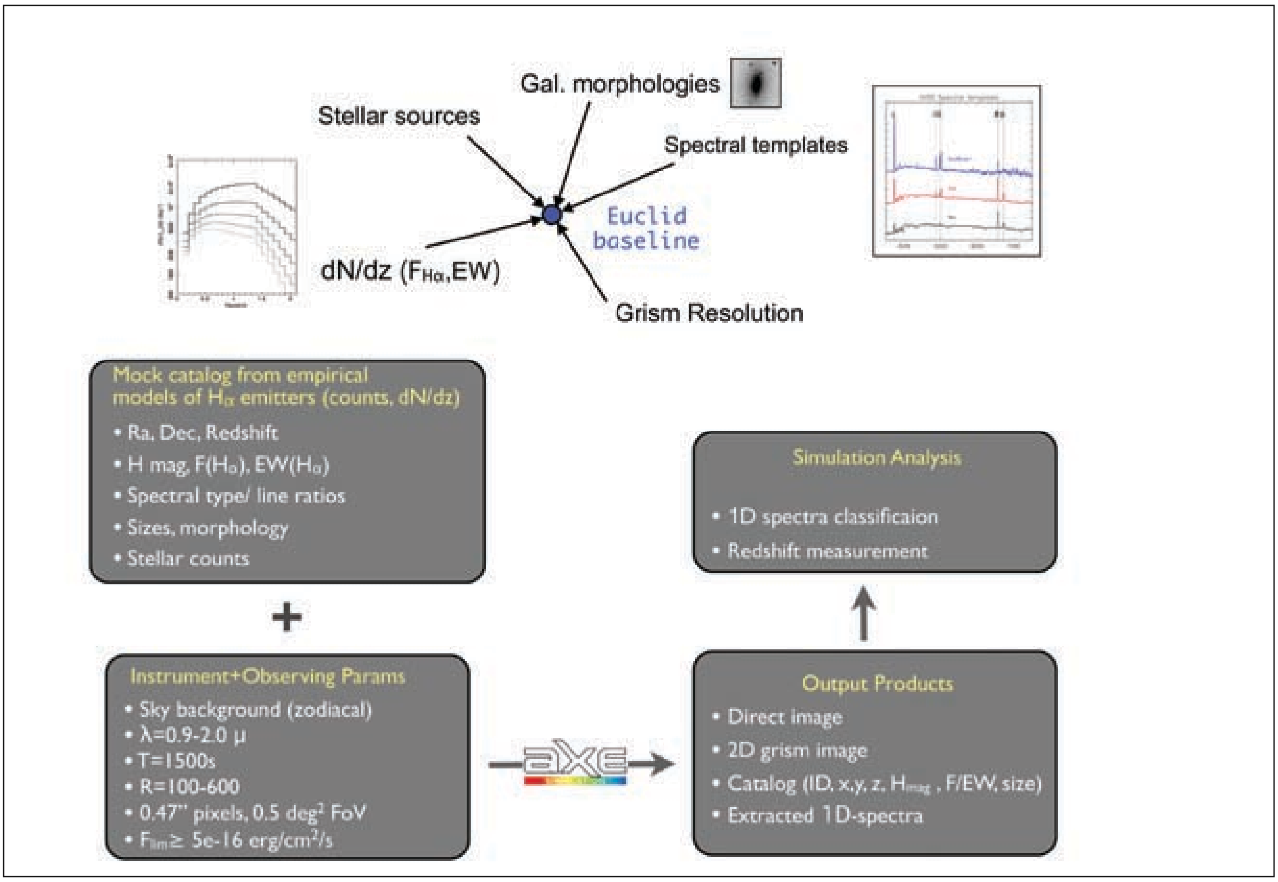


Fig. 2: *Workflow of the end-to-end slitless simulation for Euclid with a range of input components (top).*

In Figure 2 we sketch the workflow of end-to-end sky simulations. A large set of simulations has already been produced to explore different instrument configurations (grism resolutions, multiple rolls and blocking filters), to ultimately optimise the survey strategy and to test the instrument model for the exposure time calculator. A key parameter estimated from simulations is the actual redshift yield per square degree. To this end, the extracted one-dimensional spectra produced by aXeSIM are analysed with the EZ software, developed by Fumana et al. (2008), to identify emission lines and measure redshifts in an automated fashion, thus providing the redshift success rate and redshift error as a function of limiting line flux and equivalent width. These are critical inputs for the Euclid Cosmology Working Group, which studies how the slitless experiment can meet the scientific requirements.

FUTURE PLANS

aXeSIM simulations have proved to be an essential component of the current assessment study of the BAO experiment with the slitless survey with Euclid and have led to the optimisation of the near-infrared spectrograph design. We are working to make these simulations as realistic as possible, using an empirical approach based on observations from large area surveys from the ground such as COSMOS as well as from the slitless mode of Hubble. In the present Euclid configuration a DMD-based slit spectrometer remains an option, subject to technological readiness. We therefore plan to quantitatively assess the overall impact of the slitless mode on the full range of science cases by comparing simulated spectra with those obtained in multi-slit mode and hence provide a solid basis on which to discuss the balance between technological complexity and science return. The results of this activity will be reported to the ESST and will be included in the Euclid Yellow Book due at the end of this year.

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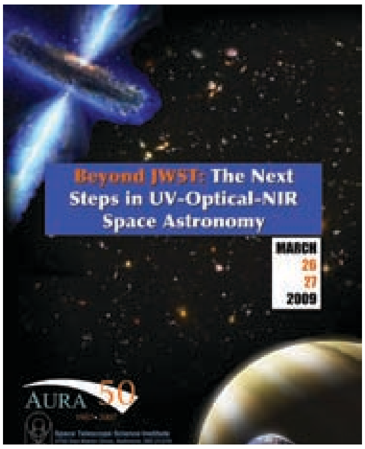
BEYOND JWST: A WORKSHOP AT STSCI

Piero Rosati



The workshop "Beyond JWST: The Next Step in UV-Optical-NIR Space Astronomy", held at STScI on March 26-27, was an opportunity to look 25 years into the future, think boldly about the next scientific frontiers and consolidate visions for future large space telescope facilities at a time when ground-based extremely large telescopes are nearing their construction phases. Ambitious science cases were presented ranging from exoplanets to the first stars in the Universe and cosmology. These require space telescopes with diameters of 8 metres or more and complex instrumentation. Several mission concept studies were presented with plans for affordable key technological developments over the next two decades. A summary of the workshop and links to further information have been posted at:
http://www.stsci.edu/institute/conference/beyondjwst

Among the mission concepts described, Marc Postman presented the status of the Advanced Technology Large Aperture Space Telescope (ATLAST), a NASA-funded strategic mission concept study for the next generation of space observatories working over a wavelength range stretching from the UV to the near-infrared. With a primary mirror of 8 to 16 m (Figure 1), ATLAST will have a sensitivity three orders of magnitude greater than Hubble and an angular resolution up to ten times better than JWST.

The science enabled by such technological advances in space stretches our imagination to the limit: from the detection of biosignatures in Earth-like exoplanets to detailed studies of stellar populations well beyond the Local Group. On cosmological scales, one could map across cosmic time the physical and chemical properties of both galaxies and the surrounding diffuse intergalactic medium with UV-optical high resolution/sensitivity absorption spectroscopy with a high density of sightlines. This sort of facility would also allow a big leap in the high-precision mapping of the dark matter distribution on galaxy and cluster scales, via strong lensing techniques, using hundreds of multiple images in many systems to resolve low-mass subhalos.

There is no doubt that such ambitious projects will require the engagement of the international community at large and will benefit greatly from the technological and scientific experience gained during the development and operation of forthcoming facilities such as JWST and the E-ELT.

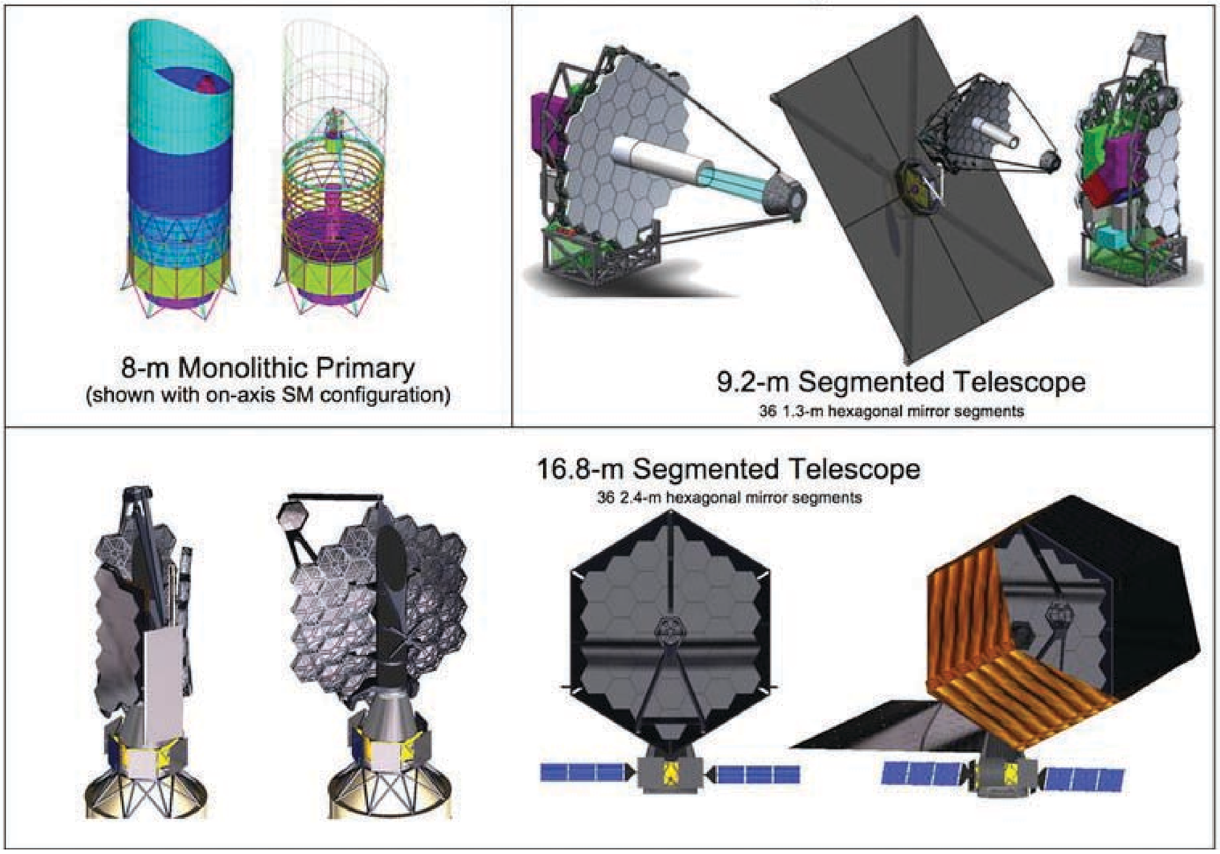


Fig. 1: *Artist's concepts of possible designs for ATLAST (see http://www.stsci.edu/institute/atlast).*

RUDOLF ALBRECHT

Robert Fosbury

Credit: Österreichisches Weltraum Forum

Rudi Albrecht retired from his ESA position at the ST-ECF in the middle of 2008. Following the selection by ESA of ESO as the host of the new organisation, Rudi had joined in 1984 as one of the first recruits.

He came with considerable experience in astronomical image processing, software engineering and, most especially, he had already worked closely with Riccardo Giacconi during the early days of setting up the Space Telescope Science Institute in Baltimore. As a member of the ESA Faint Object Camera Investigation Definition Team (IDT), he had another direct connection with the Hubble project. This familiarity with the modus operandi of both NASA and ESA remained an asset to the ST-ECF over the years, allowing the group to work effectively within the rather formal space project structures necessary to fly systems that worked.

As Piero Benvenuti's deputy, Rudi was in charge of the pioneering data analysis work at the ST-ECF and he started the still continuing process of establishing and operating the European Hubble Archive. This became the seed from which the current, massive, ESO archive grew.

One of Rudi's characteristics that will be well-remembered by a number of ST-ECF staff is his ability to persuade people to jump out of flying aircraft attached somehow to a parachute. In the later years, he also joined his wife, Katalin, as a qualified balloon pilot. Down on the ground he was a keen marathon runner as well as a collector of an impressive range of vintage vehicles of all kinds.

We all believe that it was entirely a coincidence that Austria finally joined ESO at the time that Rudi left!

HUBBLE CELEBRATES 19TH ANNIVERSARY WITH FOUNTAIN OF YOUTH [HEIC0906A]

This brilliant image, courtesy of NASA/ESA's Hubble Space Telescope and its long-lived WFPC2 camera, is a fitting 19th anniversary tribute to the workhorse space observatory.

This interacting group contains several galaxies, along with a "cosmic fountain" of stars, gas and dust that stretches over 100 000 light-years. Resembling a pair of owl's eyes, the two nuclei of the colliding galaxies at the top can be seen in the process of merging. The bizarre blue bridge of material extending down from the northern component looks as if it connects to a third galaxy but in reality the lower galaxy is in the background and not connected at all. The blue "fountain" is the most striking feature of this galaxy troupe and it contains complexes of super star clusters that may have as many as dozens of individual young star clusters in them.

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

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
Colleen Sharkey
+49 89 320 06 306
csharkey@eso.org

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

Websites
www.stecf.org
www.spacetelescope.org

Phone
+49 89 320 06 291

FAX
+49 89 320 06 703

Hotline (e-mail)
stdesk@stecf.org

E-mail
<user>@stecf.org

ST-ECF Newsletter

Editor
Richard Hook, Richard.Hook@stecf.org

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

Layout & Illustrations
Martin Kornmesser
Anika Bombik

Production Coordination
ESO ePOD

Printed by
TypeSet, München

Published by
ST-ECF/ESO ePOD

NEW ARRIVALS

Colleen Sharkey is the new Hubble Space Telescope Outreach Coordinator/Public Information Officer for ESA, based at the ST-ECF/ESO. She takes over Hubble outreach responsibilities from Lars Lindberg Christensen who has moved up to be the head of the ESO education and Public Outreach Department (which now includes the Hubble outreach). Originally from the US, Colleen worked at NASA's Jet Propulsion Laboratory during some of the centre's most exhilarating times. Writing about NASA's missions to Mars, she collaborated closely with scientists and engineers on many projects including the Mars Exploration Rover mission (MER), Mars Reconnaissance Orbiter mission (MRO) and Mars Science Laboratory (MSL). While at JPL, she was privileged to attend the 2005 launch of the Mars Reconnaissance Orbiter, but the launch of *Atlantis* for SM4, described in this Newsletter, was her first Shuttle launch experience.

Before joining the ESA/ESO team in February 2009, Colleen worked as the associate director of communications at Occidental College, the Californian alma mater of U.S. President Barack Obama.

Kim Nilsson joined the ST-ECF in April 2009 as the new Hubble Astronomer. Kim was an ESO student for two years while completing her PhD at the Dark Cosmology Centre in Copenhagen, Denmark, in 2007. After her PhD she went to the Max Planck Institute for Astronomy in Heidelberg, Germany, as a post-doctoral fellow. Kim's work has so far been focused on understanding high-redshift galaxies, more specifically so-called Lyman-alpha emitters. She is a Swedish national.

Cover image: *The remote manipulator arm of Space Shuttle Atlantis lifts the Hubble Space Telescope from the cargo bay moments before the the orbital observatory is released during the hugely successful Servicing Mission 4. Credit: NASA.*