29 May – 1 June 2007

European Space Agency

ESTEC, Noordwijk, The Netherlands

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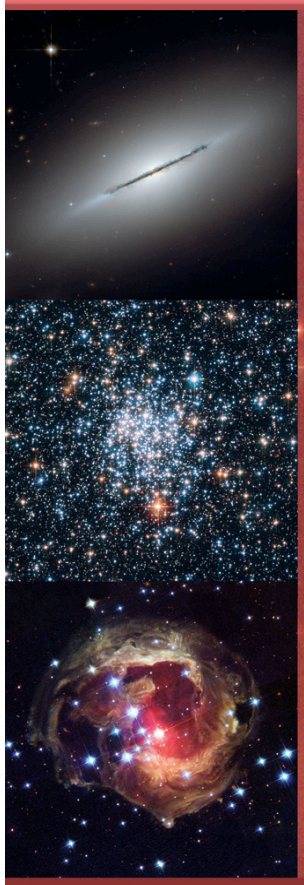
41st ESLAB Symposium
The Impact of HST on European Astronomy



The primary aim of the 41st ESLAB symposium is to review the key contribution that HST has made in all areas of astronomy and emphasise their impact on European astronomical research

ABSTRACTS

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41st ESLAB Symposium

The Impact of HST on European Astronomy

CONFERENCE ABSTRACTS

AND

LIST OF PARTICIPANTS

Session 1 - Stars, star formation, stellar populations and planets

Hot Massive Stars
(invited review)

Paul Crowther
University of Sheffield

We review the impact of the Hubble Space Telescope upon our understanding of hot, luminous stars. A few highlights are discussed, together with their impact upon European research. Optical and IR imaging have permited spatially resolved observations of young massive clusters within Local Group galaxies, such as R136, NGC3603 and Arches. These observations have also been followed up by HST, revealing unprecedented concentrations of very massive early O stars. UV spectroscopy of field Magellanic Cloud O and B type stars with FOS and STIS have provided suitable templates for interpretation of metal poor star forming galaxies at high-redshift. Spectacular imaging provides the detailed structure of ejecta nebulae from individual stars, including the Homunculus associated with Eta Carinae and M1-67 associated with a Wolf-Rayet star. Hubble has also provided an unprecedented study of giant HII regions ionized by massive stars including 30 Doradus including regions of ongoing star formation as revealed by IR imaging.

HST Spectroscopy of the Hottest White Dwarfs

Thomas Rauch
University of Tübingen

Spectral analysis needs observations of lines of subsequent ionization stages in order to evaluate the ionization equilibrium (of a particular species) which is a sensitive indicator of the effective temperature T_{eff}. Since stars with T_{eff} as high as 100,000 K have their flux maximum in the EUV wavelength range and due to the high degree of ionization, most of the metal lines are found in the UV range. Thus, high-S/N and high-resolution UV spectra are a prerequisite for a precise analysis. Consequently, we employed the Space Telescope Imaging Spectrograph aboard the Hubble Space Telescope in order to obtain suitable data. We present state-of-the-art analyses of the hottest white dwarfs by means of NLTE model-atmospheres which include the metal-line blanketing of all elements from Hydrogen to Nickel.

The Lightest and the Heaviest: key chemical tracers in the UV

Francesca Primas
ESO, Garching

The ultraviolet part of the electromagnetic spectrum of cool stars is a region extremely rich in atomic and molecular lines of several species. It offers important and unique insights on the chemical evolution of the Galaxy. Here, I will focus on the “unique” chemical tracers of this region.

UV spectroscopy of metal-poor massive stars in the SMC

Daniel Lennon
ING/IAC, La Palma

HST and STIS have provided a superb opportunity to explore the winds of hot massive stars in the nearby Magellanic Clouds. Two large programmes in particular have provided critical insight into the UV spectral morphology of massive stars in the metal-poor Small Magellanic Clouds, demonstrating with unsurpassed detail the dependence of mass-loss on metallicity. These datasets still represent the definitive UV spectral library for hot stars at low metallcity, and have been used to test spectral synthesis techniques for metal poor starbusts and high-redhshift star-forming galaxies. They have also led to a re-evaluation of mass-loss in the weak-wind regime, contributed to the on-going debate of the importance of clumping in massive star winds, and have been instrumental in constraining the wind momentum luminosity relationship (WLR) in the critical low metallicity domain. These achievments, and others, are highlighted and a number of the resulting outstanding problems are discussed.

Formation history of resolved stellar populations
(invited review)

Monica Tosi
INAF, Observatory of Bologna

The exploitation of the power and the spatial resolution of HST has allowed us to measure with good precision the individual stars of galaxies that were previously unresolved. This has enabled us to apply classical stellar evolution approaches to systems previously unreachable and has led to successful studies of the star formation histories of galaxies of different morphological types, from late to early-type galaxies, from dwarfs to giants. The current knowledge on the star formation histories of galaxies within 10 – 20 Mpc, as derived from the colour–magnitude diagrams of their resolved stellar populations, will be summarized in this talk. The impact of these results on our understanding of galaxy evolution will be discussed.

HST's view of the birth of massive stars in the Magellanic Clouds

Mohammad Heydari-Malayeri
Observatory of Paris

Accurate physical parameters and the distribution function of newborn massive stars are essential in order to shed light on their formation, which is still an unsolved problem. The rare class of compact H II regions in the Magellanic Clouds (MCs), called "high-excitation blobs" (HEBs), presents a unique opportunity to acquire this information through high-resolution near infrared and optical techniques, both imaging and spectroscopy. These compact objects (4 to 10 arcsec, or ~ 1 to 3 pc, in diameter) harbor the youngest massive stars of the OB association/molecular cloud complexes in the MCs. Since massive stars are scarce in our Galactic neighborhood, the MCs offer the advantage of having well determined distances, low overall extinction, and low metallicity. In the course of a long-term study from ground and space, our HST observations have spatially

resolved these objects for the first time. They resulted in the uncovering of the massive star birthplaces, their unknown nebular features, the distribution of their high excitation zones, and the variation of the extinction across them. In some cases our WFPC2 images revealed the exciting stars, while in other cases we could not conclusively pinpoint the exciting stars because of the relatively high and patchy extinction of those regions. Follow-up far UV spectroscopy with STIS also revealed a particularly interesting case in SMC N81, where several of its stars showed that they are O6-O8 types, but are subluminous and display astonishingly weak winds even for an SMC metallicity. We present a review of the main results so far obtained in this field.

Star formation in the Small Magellanic Cloud

Antonella Nota*, E. Sabbi, M.Sirianni, M. Tosi, J.Gallagher, L.J.Smith
**ESA/STScI, Baltimore*

The question of how the combination of low metallicity and dust content can affect the star formation processes has implications for our understanding of how stars formed in the early universe. The young star clusters in the Small Magellanic Cloud (SMC) are ideal benchmarks for this research, due to the sub-solar metallicity and much lower (1/5 solar) dust content. In addition, the close proximity of the SMC allows us to perform a detailed and accurate census of their stellar content . Using deep HST/ACS observations, we fully characterize the star formation processes in NGC 346 and NGC 602, two of the youngest star clusters in the SMC. They are located in the "bar" and the Magellanic "bridge" respectively. In both clusters we identify a rich population of pre-Main Sequence stars in the mass range 3.0 - 0.6 $M_{\odot}$, indicating that star formation in the region is recent and, possibly, still ongoing. We can infer the star formation history of these regions. In NGC 346 star formation occurred in many, likely coeval, sub-clusters. In NGC 602 we identify a primordial nucleus of star formation, and find that the feedback from the most massive stars located in the center is now triggering star formation in the periphery of the cluster. We find that the mass function of NGC 346 is in good agreement with the value derived by Salpeter for the solar neighborhood, and there is evidence of primordial mass segregation. We discuss the implications of our results for NGC 346 and NGC 602 in the context of cluster formation and evolution.

Planetary Nebulae and their central stars in the Magellanic Clouds

Eva Villaver*, L. Stanghellini, R. A. Shaw
**STScI/ESA, Baltimore*

Low- and intermediate-mass stars, after experiencing heavy winds at the end of the Asymptotic Giant Branch (AGB) phase, leave behind a core that is below the Chandrasekar mass limit. This core eventually illuminates the stellar remnant giving birth to a planetary nebula (PN). The final mass reached by the central star of a PN depends mainly on the stellar mass during the main sequence phase and on the mass-loss during the AGB phase. Mass-loss during the AGB phase has a strong dependency on metallicity, as it is thought to be driven mainly by dust and thus low-metallicity stars with dust-driven winds are expected to lose smaller amounts of matter. In the last decade HST has allowed us to extend late stellar evolution studies to nearby galaxies where the effect on the environment can be quantified. We present the first observational evidence from PNe progenitors for reduced mass-loss rates in a lower metallicity environment: the Large Magellanic

Cloud. HST's spatial resolution allows us to resolve the central star from its nebula (and line-of-sight stars) at the distance of the LMC, eliminating the dependency on photoionization modeling in the determination of the stellar flux. We find an average central star mass of 0.65±0.07 $M_{\odot}$ in the LMC, higher than the one reported in the literature for both white dwarfs and the central stars of PNe in the Galaxy. If significant, this higher average central star mass in the LMC can be understood in terms of a metallicity dependency on mass-loss rates during the AGB, since the LMC has on average half the metallicity of the Galaxy. Moreover we find differences in the SMC and LMC central star mass distributions, with the SMC sample lacking an intermediate-mass stellar population (0.65 $M_{\odot}$). We discuss the differences in the star formation history between the clouds and the mass-loss rate dependence on metallicity as possible explanations for the observed differences.

Visiting Hubble in orbit
(invited review)

Claude Nicollier
ESA/EPFL, Lausanne

Following its launch in 1990, the Hubble Space Telescope has been visited four times by Space Shuttle crews to exchange failed or degraded components and upgrade systems and scientific instruments. A fifth servicing mission is now planned for the end of 2008. This presentation will describe the servicing philosophy of the orbiting observatory and a brief narrative of the four close encounters so far. It will also explain the challenge of working on a complex space system while spacewalking and in the absence of gravity. An attempt will be made to explain the reasons for the remarkable success of these on-orbit interventions so far.

A (long) look at neutron stars with HST

Patrizia Caraveo
INAF-IASF, Milan

Easy to spot at radio wavelengths, neutron stars are harder to detect in X rays, and even harder at optical wavelengths. The radio pulsar sample of 2,000 shrinks to <100 in X-rays and to 10 in the optical. The paucity of the optical detections is mainly due to the neutron stars' small size, lack of atmosphere and high surface temperature, all of which conspire to render them faint optical emitters. Notwithstanding the detection challenge, the study of neutron stars' optical emission is an important tool to secure their identification and to understand the emission mechanisms at work. Both goals have been pursued by HST, which has played a key role in the study the optical emission from the vast majority of the neutron stars currently known at optical wavelengths. Its angular resolution has been instrumental in measuring the stars' proper motions and parallactic displacements, while its spectral coverage, as provided over the years by the different instruments available at the telescope, allowed for the assessment of the stars' spectral shapes. With the recent discoveries of yet more types of neutron stars, the contribution of HST promises to remain an allimportant one for the understanding of the richly diversified neutron star family.

The HST contribution to Pulsars' Astronomy

Roberto Mignani
UCL-MSSL, Dorking

While neutron stars are the brightest sources in the gamma-ray sky, in the optical domain they are very faint and the search for their counterparts is a difficult task relying upon the most powerful telescopes. After the seminal work carried out from the ground with the ESO telescopes, HST has lead the study in the field of pulsars's optical astronomy yielding nearly all the identifications achieved since 1990. In this talk, I will review the major HST contributions in the optical studies of pulsars and their relevance for neutron stars' astronomy.

Probing exotic populations in globular clusters with the HST

Francesco Ferraro
University of Bologna

HST high-resolution observations of the central region of Galactic globular clusters have shown the presence of a large variety of exotic stellar objects whose formation and evolution may be strongly affected by dynamical interactions. In this talk I review the main properties of two classes of exotic objects: the so-called Blue Stragglers stars (BSS) and the recently identified optical companions to Millisecond pulsar (MSP). Both these objects are invaluable tools to investigate the binary evolution in very dense environments and are powerful tracers of the dynamical history of the parent cluster. The study of BSS and MSP companions has highly benefited from the combination of HST and wide-field/spectroscopic ground-based observations, thus, representing a clean example of the synergy between ground-based and space facilities.

The stellar mass function in globular clusters

Guido De Marchi
ESA, Noordwijk

Globular clusters in our own Milky Way formed at redshift z~5 or more, when the physical conditions of the environment, such as pressure, density, temperature and chemical composition, were very different from those found in current star forming regions. The end product of this massive star formation is a stellar initial mass function (IMF) that holds the secret to the making of stars in the primeval universe. Over time, under the effects of stellar evolution and dynamical interactions, the stellar IMF of globular clusters has evolved to become what we can now accurately measure with the HST down to very small masses near the Hydrogen burning limit. But how does this present mass function compare with the original IMF and what can we learn from it about star formation at high redshift? I will report on the discovery of a surprising correlation between the shape of the current mass function of globular clusters and their central concentration, which suggests that our understanding of their dynamical evolution might not yet be complete.

Atmospheres and Evaporation of Extrasolar Planets
(invited review)

Alain Lecavelier
IAP, Paris

Today, more than 200 extra-solar planets have been identified. Among those, few of them transit their parent stars. This configuration allows the observation of the planet atmospheric constituents which imprint their signatures in the spectrum of the host star during the transit. Using exclusively HST, this technique led to the detection of absorption features in the deep atmosphere of HD209458b as well as the detection of its escaping upper atmosphere. The measurements in the deep atmosphere, together with few upper limits, give strong constraints on the atmospheric structure, in particular on the presence of clouds. Concerning the upper atmosphere, the discovery made with the HST that HD209458b has an extended atmosphere of hydrogen triggered new theoretical studies on the evaporation of Hot-Jupiters. The subsequent detection of Oxygen and Carbon at very high altitude also shows that the escape mechanism must be an hydrodynamical blow-off of the atmosphere. Recently, with HST again, the detection of excited Hydrogen in the upper atmosphere confirmed the suspected very high temperatures driving the evaporation of these Hot-Jupiters. It is clear that, although this had not been anticipated at the time of its launch, HST is a major contributor to our present understanding of the atmospheres and the evaporation of extra-solar planets.

Resolved High Contrast Observations of Debris Disks: The HST Legacy

Mark Clampin
NASA/GSFC, Greenbelt

Prior to HST, Beta Pictoris was the only debris disk resolved at visible. High contrast imaging with the NICMOS and ACS coronagraphs has significantly enhanced our understanding of these systems. We will discuss the formation and evolution of planetary systems in the context of the debris disks, and show how resolved observations of debris disks have progressed our understanding of both the properties of the dust disks and the planetary systems within the disk.

Early phases of protoplanetary disk evolution

Inga Kamp
ESA/STScI, Baltimore

It is widely accepted that planetary systems form from protoplanetary disks, and observations of the dust reveal significant grain growth over timescales of a few million years. However, we know little about the gas processing in the first 10-20 Myr of disk evolution. This is the phase where protoplanetesimals form and accrete into planetary cores. One outstanding question is whether gas dispersal is coeval with the formation of planetesimals. If the gas dispersal would preceed the dust evolution, the formation of gas giant planets through the standard coreaccretion scenario would be impeded. This talk will focus on HST's contribution to our understanding of disk dispersal processes and disk structure in early phases of disk evolution.

T Tauri Jets and the Angular Momentum Problem

Deirde Coffey*, F. Bacciotti, T. Ray, J. Eisloffel, J. Woitas
**INAF, Observatory of Florence*

The role of jets from young stars in the star formation process is still a crucial open issue in modern astrophysics. The existence and properties of atomic jets and molecular outflows can help explain several aspects of the process, including the extraction of the excess angular momentum from the star/disk system. The exact nature of the accelerating engine, however, is still unclear. Long standing observational difficulties lie in the fact that young stars are often heavily embedded and, due to the relatively small spatial and temporal scales, understanding physical properties of the jet requires high angular resolution data. A recent major breakthrough has been the detection of gradients in Doppler shift of 10-20 km/s transverse to the axis in jets from more evolved, optically visible T Tauri stars. These results were recently reported based on HST long-slit spectroscopic observations in the optical and near ultraviolet domains (Bacciotti et al. 2002; Woitas et al. 2005; Coffey et al. 2004, 2007). When interpreted as jet rotation, under the assumption of steady ejection, the derived values of the specific angular momentum imply that the jet is indeed the major agent for extracting the amount of angular momentum from the system necessary to allow for accretion to proceed at the observed rate. In addition, the jet poloidal and toroidal velocities indicate that the flow lines have a launching radius of between 0.1 and 2-3 AU, i.e. they have been ejected from the disk, thus acting as a powerful discriminant between models of jet generation (Bacciotti et al. 2002; Anderson et al. 2003; Ferreira et al. 2006). Concurrently, we have used HST spectroscopic data, with the slit placed along the flow axis, to conduct optical diagnostic studies of these atomic flows. The derived physical parameters were used to measure the mass flux, a crucial parameter in models for jet launching. Assuming the Doppler gradients do indeed represent rotation signatures, these results, in tandem with mass flux determinations, provide valuable constraints on models for magneto-centrifugal jet launching, and provide long awaited observational backing for the proposed theory of jets as extractors of angular momentum from protostellar systems.

Session 2 - Nearby galaxies, bulges, spheroids and galaxy formation

Stars and stellar systems
(invited review)

Alvio Renzini
INAF, Observatory of Padova

Great surprises have been revealed by HST/ACS observations of some of the most massive globular clusters in the Milky Way: multiple main sequences and subgiant branches and extremely complex horizontal branches. Such massive clusters appear to host multiple stellar populations, with different ages, metallicities, and — most embarrassingly — very different Helium content, making their formation a real puzzle. Moving out, extensive HST observations of Magellanic Cloud globular clusters have allowed to accurately age-date them, while ultradeep ACS observations of the the spheroid, disk, and stream of M31 have revealed a very complex scenario, apparently much different from our picture of the Milky Way. Jumping to high redshift, it will be reported how ACS in imaging and grism mode has provided morphologies, redshifts and ages of early-type galaxies all the way to z~2. With European astronomers having played a key role in many such discoveries, the invaluable HST/VLT synergy will also be emphasized.

Young massive star clusters in the era of the Hubble Space Telescope

Richard de Grijs
University of Sheffield

The Hubble Space Telescope (HST) has been instrumental in the discovery of large numbers of extragalactic young massive star clusters (YMCs), often assumed to be proto-globular clusters (GCs). As a consequence, the field of YMC formation and evolution is thriving, generating major breakthroughs as well as controversies on annual (or shorter) time-scales. In this talk, I review the long-term survival chances of YMCs, hallmarks of intense starburst episodes often associated with violent galaxy interactions. I address the key question as to whether at least some of these YMCs can indeed be considered proto-GCs, which in turn are believed to be among the fundamental galactic building blocks. In the absence of significant external perturbations, the key factor determining a cluster's long-term survival chances is the shape of its stellar initial mass function (IMF). It is, however, not straightforward to assess the IMF shape in unresolved extragalactic YMCs. I also discuss the latest progress in worldwide efforts to better understand the evolution of and disruption processes affecting entire cluster populations, predominantly based on HST observations. I conclude that there is an increasing body of evidence that GC formation appears to be continuing until today; their long-term evolution crucially depends on their environmental conditions, however.

High Resolution imaging of nearby Super Star Clusters

Marco Sirianni* and the ACS Science Team
**ESA/STScI, Baltimore*

The superb spatial resolution of the optical and near IR instruments on board of HST has allowed a real breakthrough in the study of the nearby super star clusters (SSCs). We present the study of the SSCs in nearby starburst galaxies (NGC 1569, NGC 1705 and NGC 4214) performed using the High Resolution Channel of ACS. The real morphology and structured nature of these SSC is revealed in great detail and allow us to revise structural parameters like the radial luminosity profile that contains evidence of the formation process of the cluster.

The Central Regions of Early-Type Galaxies

Andres Jordan
ESO, Garching

The ACS Virgo and Fornax cluster surveys present homogeneous HST/ACS observations of 143 early-type galaxies and their globular cluster systems in the Virgo and Fornax clusters. I will briefly describe these surveys and will present some of their recent results, concentrating on the properties of the central regions of galaxies. I will show that on small angular scales, galaxies are found to exhibit a gradual progession from a light “deficit” (cores) to a light “excess” (stellar nuclei), while on larger scales the brightness profiles of galaxies are accurately described by Sersic models. I will also discuss a new relation between stellar nuclei, supermassive black holes and their host galaxies. Our observations suggest that a generic by-product of galaxy formation might be the creation of a central massive object - either a supermassive black hole or a compact stellar nucleus - that contains a mean fraction ~0.2% of the total galactic mass.

HST Observations of Extragalactic Star Clusters and Resolved Stellar Populations

Søren Larsen
University of Utrecht

It is difficult to overestimate the significance of HST's contribution to studies of extragalactic star clusters. Prior to the launch of HST, little was known about young star cluster populations beyond the Local Group. HST observations have been instrumental in establishing two key results: 1) massive, globular cluster-like objects are still forming in many starburst and merger galaxies, and 2) the majority of early-type galaxies have experienced several globular cluster formation episodes, as reflected in the bimodal optical colour distributions of their globular cluster systems. However, it is now also evident that massive star clusters form in more quiescent environments, such as spiral and dwarf galaxies with elevated levels of star formation. These results have made it clear that the formation of globular star clusters was not a consequence of unique conditions present only in the early Universe, but is continuing to the present day. Measurements of structural parameters for such clusters, combined with ground-based high-dispersion spectroscopy, have provided dynamical constraints on their masses. I will give an overview of what HST imaging has taught us about star

cluster formation in different environments, and give a preview of what may be still to come. In particular, HST imaging allows spatially resolved imaging of stellar populations and star clusters well beyond the Local Group, and colour-magnitude diagrams of massive star clusters are now within reach. Such data can provide crucial tests of models for the evolution of massive stars, as well as on the relation between formation histories of individual stars and star clusters in different galaxies. The combination of optical/UV sensitivity and high spatial resolution offered by HST is ideally suited for such studies, and will remain unequalled for the foreseeable future.

The stellar populations of M31
(invited review)

Annette Ferguson
Institute for Astronomy, Edinburgh

M31, our nearest large galactic neighbour, offers an ideal laboratory for studying in exquisite detail the processes which drive the formation and evolution of typical spiral galaxies. Over the past 5 years, our view of this oft-considered quiescent galaxy has been revolutionized as a result of wide-field photometric and spectroscopic surveys from the ground, as well as deep pencil beam studies with HST. Through the dedication of more than 400 orbits, the Advanced Camera for Surveys has played a particularly important role in establishing the detailed properties of the stellar populations in the outer regions M31. When interpreted in combination with ground-based results, a surprising yet compelling picture of a galaxy with a rather violent past has emerged. In this talk, I will highlight recent results from studies of the resolved fossil stellar populations in the outskirts of M31 and conclude by discussing how this highly desirable combination of ground and space-based data is now being used to probe the assembly history of other galaxies within the Local Group and beyond.

Variable stars in "nearby" galaxies

Gisella Clementini
INAF, Observatory of Bologna

Variable stars are powerful tools for the definition of the astronomical distance scale and to trace stellar populations of different age in galaxies. Results will be presented on variability surveys in a number of stellar systems that range from Galactic to extragalactic globular clusters (NGC2419, the SMC, Fornax and M31 globular clusters), to one of the most remote galaxies resolved in stars: IZw18. All these studies were made possible in large part either by the exploitation of the HST archive or by proprietary observations awarded with the WFPC2 and the ACS.

New HST/ACS Insights into the Evolution of Star-Forming Dwarf Galaxies with Extreme Properties of Cosmological Relevance

Alessandra Aloisi
ESA/STScI, Baltimore

I will report results of four HST/ACS studies of nearby star-forming dwarf galaxies with particularly extreme properties, namely SBS1415+437, IZw18, NGC4449, and NGC1569. Deep broad-band imaging yields high-quality color magnitude diagrams (CMDs) of the resolved stars that can be used to infer the star formation history (SFH), as well as the distance through the TRGB-method, AGB brightness or Cepheid variability. Chemically unevolved systems, like IZw18 or SBS1415+437, represent the closest analog to primordial galaxies in the early universe and, as such, offer the best place where to study star formation in a pristine environment. Some of these objects could also turn out to be "young" galaxies in the local universe (e.g., the controversial case of IZw18), but our results so far do not support this interpretation. Starbursts like NGC1569 or NGC4449 were a recurrent mode of star-formation in the past. We can study the SFH of these galaxies and the connection to the phenomena (e.g., galaxy interactions) that triggered their starburst directly from our data. In particular, NGC1569 is the strongest and closest starburst in the nearby universe, and NGC4449 is a so-called global starburst with a widespread star-formation activity. Galaxies like these closely resemble Lyman Break galaxies at high redshift (z~3), and represent the perfect laboratory where to characterize the effects of those processes (e.g., merging and accretion) intimately connected to the formation and evolution of galaxies in the early universe.

Resolved stellar populations of nearby galaxy halos

Marina Rejkuba
ESO, Garching

I will present the results of the ACS HST based study of the resolved stellar populations in the outer halo of the nearest easily observable giant elliptical galaxy NGC 5128. The broad metallicity distribution function (MDF) of the upper red giant branch stars in the ACS outer halo field is compared with the MDF obtained in other regions of this galaxy. The width and the radial gradients of the MDF are compared to predictions of elliptical galaxy formation and evolution models. NGC 5128 is a dominant member of the nearby Centaurus A group of galaxies, which harbours a large number of dwarf spheroidal galaxies. The results of the studies of the resolved stellar populations of dwarf companions of NGC 5128, using the optical HST imaging complemented with ground based near-IR data, are used to investigate the environmental dependence of star formation histories at the low luminosity end of the galaxy luminosity function.

The nature of bulges and spheroids
(invited review)

Tim de Zeeuw
University of Leiden

Much world-wide effort is devoted to the study of the formation and evolution of galaxies, ranging from observations of the most distant objects in the early Universe to detailed analysis of the motions of individual stars in the Milky Way, combined with theoretical work and numerical simulations. Hubble imaging and spectroscopy combined with ground-based integral-field spectroscopy make it possible to measure the motions and physical properties of stellar populations in nearby galaxies, and to determine the properties of the supermassive black holes in their centres. The observations reveal a fascinating diversity of properties. The stellar and gaseous kinematics and the line-strength distributions provide the intrinsic shape of the galaxies, their orbital structure, the mass-to-light ratio as a function of radius, the frequency of kinematically decoupled cores, the masses of nuclear black holes, the role of nuclear star clusters, and the relation between orbital structure and the age and metallicity of the stellar populations. This "fossil record" provides key insight into the galaxy formation process. The talk will summarize recent results in this area, and will include a brief forward look.

M/L Evolution and Formation Redshift of Elliptical Galaxies

Roeland van der Marel*, P. van Dokkum, A. van der Wel
**STScI, Baltimore*

I will discuss our understanding of the M/L evolution of elliptical galaxies, and the implied formation redshifts, based on both the Fundamental Plane and detailed dynamical modeling. Both approaches rely heavily on the availability of high-quality HST imaging. To start out I will present the results of a homogenized analysis of Fundamental Plane studies published in the past decade, both for galaxies in clusters and for those in the field. Then I will show how more direct insight on M/L evolution can be obtained by the detailed dynamical modeling of spatially resolved rotation velocity and velocity dispersion profiles. I will focus on our Keck/LRIS data for a sample 25 early-type galaxies in three clusters at $z \sim 0.5$. To interpret these data we used HST photometry and constructed Jeans equation solutions for oblate axisymmetric systems with f(E,Lz) distribution functions. This yields M/L_B for each galaxy, as well as the correlation between M/L_B and velocity dispersion. This result can be compared to the correlation for 60 galaxies in the local Universe, which have previously been modeled in similar detail, to determine the M/L evolution. I will also present the first results of applications of this approach to field galaxies in the Chandra Deep Field South at $z \sim 1$. This methodology not only yields new insights into M/L evolution, but also into the rotation rate of early-type galaxies, and its evolution with redshift. I will discuss all the results in the context of popular models of early-type galaxy formation.

Nuclear Star Clusters across the Hubble Sequence

Torsten Böker
ESA, Noordwijk

Over the last decade, HST imaging studies have revealed that the centers of most galaxies are occupied by compact, barely resolved sources. Based on their structural properties, position in the fundamental plane, and spectra, these sources clearly have a stellar origin. They are therefore called "stellar nuclei" or "nuclear star clusters" (NCs). NCs are found in galaxies of all Hubble types, suggesting that their formation is a process that is intricately linked to galaxy evolution. Interest in NCs increased recently due to three independent and contemporaneous studies (Rossa et al. for spiral galaxies; Wehner & Harris for dE galaxies; and Cote et al. for elliptical galaxies) which concluded that NC masses obey similar scaling relationships with host galaxy properties as do supermassive black holes. I will review these and related studies and discuss their implications for NC evolution and the possible connection to supermassive black holes.

Connecting photometry with integral-field kinematics in Early-type galaxies

Jesus Falcon Barroso* and the SAURON team
ESA, Noordwijk

I will review the current status of our photometric follow-up of the representative sample of early-type galaxies in the SAURON project. The photometric dataset comprises both HST and deep ground-based imaging in the F555W and F814W filters, allowing us to trace the stellar light from the nuclei to the outermost regions of these galaxies. This data together with the 2D kinematic information provided by the SAURON and OASIS integral-field spectrographs is the ideal tool to study the relationship between kinematic and photometric features (i.e. KDCs, inner disks, etc.). In this contribution I will focus on the correlations between central and global properties and the morphological characterization of the different kinematical structures.

Detecting the progenitor stars of supernovae in HST images

Stephen J. Smartt
Queen's University, Belfast

The HST archive is a rich source of deep and multi-colour images of galaxies in the nearby Universe, and this legacy will be useful for decades to come. These images resolve much of the massive stellar populations, and most of the large late-type spirals within 20 Mpc have been observed. When a core-collapse supernova explodes in these galaxies, we can attempt direct detection of the progenitor star. During Cycles 10-15 we have had target-of-opportunity status on HST to directly detect the massive progenitor stars of nearby supernovae in archive images. We have detected the progenitors of six type II-P showing them to be red supergiants with initial masses close to the theoretical limit for core-collapse (8 $M_{\odot}$). We have set robust upper luminosity and mass limits on another 12 progenitor stars (from type II-P, and Ib/c) supernovae. I will review the results from our work, and others in the field, that is constraining stellar evolutionary theory and limiting SN explosion models. It appears that faint SNe which have been thought to come from black-hole forming SNe are more likely to have low mass progenitors. I will present direct constraints on the progenitors of typc Ib/c SNe which are related to gamma-ray bursts.

Galaxy formation and evolution
(invited review)

Simon Lilly
ETH, Zurich

The HST has a had a very large impact on the study of distant galaxies. This has greatly exceeded (I believe) most pre-launch expectations, largely because of the strong evolution in the intrinsic surface brightnesses of galaxies. I will briefly review some highlights of this progress and argue that HST has been most powerful when used in combination with other facilities on the ground and in-space. A good example of this is the current international COSMOS program (the largest HST survey to date) where Europeans are making major contributions with the ESO VLT and ESA XMM-Newton. I will present some recent results from COSMOS, and will conclude by previewing this same synergy that will exist in the future between JWST, ALMA and the E-ELT.

Tracing Galaxy Evolution in Clusters and Groups at z > 1

Simona Mei
Observatory of Paris, Meudon

Observing galaxies in groups and filaments before they enter the environs of massive clusters provides important clues to the processes driving galaxy evolution. We present new results from recent ACS/HST observations in five galaxy groups around the central two clusters in the Lynx Supercluster region at z=1.3. We discuss the environmental differences in morphology, colors and distribution of the group galaxy population as compared to that of the two central clusters, and the ACS GTO Intermediante Cluster Survey.

Galaxy formation, halo substructure and reionization
(invited review)

Piero Madau
University of California, Santa Cruz

The development of primordial inhomogeneities into the non-linear regime and the formation of the first astrophysical objects within dark matter halos mark the transition from a simple, neutral, cooling universe — described by just a few parameters — to a messy ionized one — the realm of radiative, hydrodynamic, and star formation processes. It is an early generation of extremely metal-poor massive stars and/or seed accreting black holes in subgalactic halos that may have generated the ultraviolet radiation and mechanical energy that reheated and reionized most of the hydrogen in the cosmos. In this talk I will summarize the impact of the HST on studies of the dawn of galaxies and the lessons recently learned from supercomputer simulations of galaxy halos.

A simple physical model for young galaxies in the early Universe

Gianfranco De Zotti*, J. Mao, A. Lapi, G.L. Granato, L. Danese
**INAF, Observatory of Padua*

The onset of star formation in the early Universe is investigated by exploiting the high-redshift observations of Lyman-break galaxies (LBGs) and Lyα emitters (LAEs). Simple physical recipes for the evolution of the star formation rate and of dust extinction in protogalaxies are shown to reproduce the UV luminosity functions of LBGs and of LAEs at high-z. We argue that LBGs contributing to the observed luminosity functions reside in galactic halos in the mass range $10^{10}\,M_\odot \leq M_h \leq 10^{12}\,M_\odot$, while LAEs are confined within a narrower range around $10^{11}\,M_\odot$. The stellar masses of LBGs span the range $10^8\,M_\odot \leq M_\star \leq 10^{10}\,M_\odot$. In massive galaxies, endowed with large star formation rates, the extinction increases rapidly so that they shine as UV and Lyα emitters only for a short fraction of their life and are much more easily detected as sub-millimeter sources. The X-ray luminosity of LBGs is expected to be dominated by high mass X-ray binaries and supernova remnants, although some level of nuclear activity should be present. Finally, we show that the IGM can be completely re-ionized at redshift $z \approx 6$ - 7 by massive stars shining in proto-galactic spheroids with halo masses of a few $10^{10}\,M_\odot$ to a few $10^{11}\,M_\odot$, showing up as faint LBGs with $-17 \geq M_{1350} \geq -20$, without resorting to any special stellar Initial Mass Function.

Session 3 - Deep fields, AGN, Black holes and radio galaxies

The host galaxy properties of powerful radio sources across cosmic time
(invited review)

Robert Fosbury
ST-ECF, Garching

The powerful extragalactic radio sources are believed to mark the most massive galaxies at every epoch. Using a combination of sensitive observational techniques covering different regions of the electromagnetic spectrum, both the stellar and interstellar properties of these host galaxies are now being investigated in detail. This talk reports some results from two major observing programmes. Restframe UV-optical spectroscopy and polarimetry of a sample of radio galaxies at $z \sim 2.5$ using the VLT and the Keck telescopes has provided high quality measurements of the Lyman-α to H-α region from which the spatial, kinematic and chemical properties of the ISM are being investigated. A comprehensive Spitzer survey of 69 radio galaxies from $1 \leq z \leq 5.2$ and supported by archival HST imaging and other observations, are being used to construct SED covering a wide wavelength range which includes the restframe optical and NIR spectrum. This enables reliable estimates to be made of the galaxy stellar masses from the restframe H-band stellar emission. The derived stallar luminosities imply stellar masses of 10^{11} - 10^{12} $M_{\odot}$ even at the highest redshifts. The rather complete SED that we can compile for some of the sources enables us to clearly disentangle the bolometric stellar from the total AGN luminosity.

A new view of the origin of the radio-quiet/radio-loud dichotomy?

Alessandro Capetti*, B. Balmaverde
**INAF, Observatory of Turin*

Using archival HST observations of nearby early-type galaxies we have found evidence that the radio-loud/radio-quiet dichotomy is directly connected to the structure of the inner regions of their host galaxies in the following sense: 1) Radio-loud AGN are associated with galaxies with shallow cusp in their light profiles; 2) Radio-quiet AGN are only hosted by galaxies with steep cusps. We recently extended our analysis to a sample of nearby Seyfert galaxies hosted by early-type galaxies. We found that their brightness profiles show the presence of a steep nuclear cusp, as expected for these radio-quiet AGN based on our previous findings. This extends the validity of the connection between brightness profile and radio-loudness to AGN of far higher luminosity. Since the brightness profile is determined by the galaxy's evolution, through its merger history, our results suggest that the same process sets the AGN flavour. This provides us with a novel tool to explore the co-evolution of galaxies and supermassive black holes, and it opens a new path to understand the origin of the radio-loud/radio-quiet AGN dichotomy.

The bright and dark sides of Malin 1

Renzo Sancisi*, F. Fraternali
**INAF, Observatory of Bologna*

Malin 1 is a highly unusual disk galaxy characterized by an enormous, HI rich and extremely low surface brightness disk. It has long been considered as a prototype giant, dark matter dominated LSB. Two recent studies, one based on an archival Hubble I-band image and the other based on a re-analysis of existing VLA HI observations, throw a new light on this enigmatic galaxy and on its dark/luminous matter properties.

Cluster lensing with Hubble

Jean-Paul Kneib
LAM-CNRS, Marseille

I will review in my presentation the major contribution of Hubble in the field of cluster lensing. Hubble sharp eyes easily reveals the numerous faint galaxies that are distorted and magnified by the massive clusters. By modeling the multiple images and the weakly sheared galaxies a very aurate (dark matter) mass map of clusters can be computed. Complementing the lensing measurements with other techniques like X-ray or dynamical estimates, allow an in-depth understanding of cluster physics and the contribution of the different mass components. Furthermore, massive clusters are acting as natural lenses and thanks to them, Hubble could studied in details some examples of the most remote galaxies of the Universe. Ultimately, Hubble observation of massive clusters may lead to purely geometrical constraints of Cosmology.

HST observations of gravitationally lensed QSOs

Jean-Francois Claeskens*, D. Sluse and J. Surdej
**IAGL, University of Liege*

When a foreground massive galaxy lies near the line-of-sight of a more distant quasar, it acts as a gravitational lens and the observer may see several (mostly 2 or 4) amplified but distorted images of the background QSO. The typical angular separation between the images varies from a few tenths of an arcsec to a few arcsec. In case the alignment is sufficiently good, the extended QSO host galaxy may also be lensed into a so-called Einstein Ring. Thanks to its sharp view, HST has significantly improved our knowledge of tens of such gravitational lens systems in several aspects: 1) the excellent derived astrometry of the unresolved QSO images; 2) the detection of the lensing galaxy very close to the bright QSO images; 3) the detection of faint NIR or optical rings. Altogether, these observations yield improved constraints on the mass distribution of the lens galaxy and help, for example, in studying the evolution of the mass-to-light ratio, and to reconstruct the undistorted, thus real, shape of the QSO host galaxy. We shall illustrate this with one of the most spectacular lensed quasar: RXS J1131-1231 (Sluse et al. 2006; Claeskens et al. 2006).

Study of quasar host galaxies combining HST/ACS images and VLT spectra

Gèraldine Letawe*, Y. Letawe, P. Magain
**University of Liege*

We present the results of a study of the host galaxies of a few bright low resdshift quasars, based on a combination of high resolution HST/ACS images with deep VLT spectra. Using a version of the MCS deconvolution algorithm specially adapted to HST images, the light from the central point source can be efficiently removed, which allows us to study the environment of the quasar down to 100 pc from the center. In a similar way, the spectra can be separated into a quasar contribution and a spatially resolved slit spectrum of the host galaxy. Combining the images and spectra allows one to carry out a detailed analysis of the immediate environment of the quasar: stellar content, excitation and ionization state of the gas, dynamics, etc. Up to now, this method has been applied to six quasars, including the peculiar HE0450-2958 (Magain et al. 2005, Nature 437, 381), for which no host galaxy could be detected.

Local Lyman alpha emitters studies and their relevance to high redshift ones

Daniel Kunth
IAP, Paris

The Lyman α line is an important diagnostic of star formation and and activity in galaxies. However the analysis of Lyα is complicated due to the resonant nature of the line and the consequent radiative transfer effects. On the oter hand, the pronounced progress on very high redshift galaxies (z >3) in the last few years is largely based on Lyα detection while redshift confirmations almost also exclusively depend on Lyα. It is likely that the importance of Lyα will remain also when JWST is launched and the next generation of 30 meter (or larger) ground based telescopes have their first light. High spectral resolution studies of local starburst galaxies with the HST have shown that the Lyα properties are quite complex. This line is sometimes seen in absorption or in emission and in the latter case a P-Cygni profile is conspicuously observed, indicative of a large scale outflow of neutral gas. Hydrodynamical models have been able to qualitatively predict the observed profiles assuming that, as a star cluster ages, a wind develops that allows Lyα to escape . Moreover, HST imaging obtained with the ACS has revealed that a substantial fraction of the Lyα photons are diffused far away from the emissive knots. Since the importance of Lya for tracing large scale structure, correlation functions, and galaxy formation is recognized one should clearly identify under what circumstances a galaxy shows detectable Lyα. Hence, Lyα will remain a very important probe of the distant universe for the foreseable future, and is therefore imperative to acquire a better understanding of what mechanisms regulate our ability to detect this line. I shall review the last results obtained in this area from both an observational point of view (local starbursts) and from the most recent modelling codes.

The Evolution of Active Galactic Nuclei
(invited review)

Günther Hasinger
MPE, Garching

The X-ray sky is dominated by a diffuse extragalactic background radiation, which our team, together with others, was able to resolve almost completely into discrete sources using the X-ray satellites ROSAT, Chandra and XMM-Newton - we observe the growth phase of the population of supermassive black holes throughout the history of the Universe. Indeed, the mass distribution of black holes in local galaxies is well traced by the evolution of the accreting black hole luminosity function. However, the maximum of high- luminosity objects occurs significantly earlier in the history of the universe (at redshifts 2-3), than that of low-luminosity objects, which have a peak at redshifts below unity. This antihierarchical evolution, which in the meantime has also been confirmed in other wavebands, is similar to the down- sizing effect observed in the optical galaxy population and is most likely connected to the AGN feedback influencing galaxy evolution. At the end I will advertise a new X-ray survey to be performed with the Russian SRG satellite, among others carrying the eROSITA telescope.

The HST view of low luminosity active galactic nuclei

Marco Chiaberge
STScI, Baltimore

We have studied a sample of local low luminosity AGN composed by LINERs, Seyferts and low luminosity radio galaxies, which have been imaged with the Hubble Space Telescope. We find faint unresolved nuclei in a significant fraction of the objects. The nuclear emission is as low as 10^{-8} times the Eddington luminosity, indicating extremely low radiative efficiency for the accretion process. The nuclei show a dichotomy as far as their radio loudness is concerned, and best separate in a plane in which the L_{Opt}/L_{Edd} is plotted against the nuclear radio loudness. Our results show that the best chance of investigating RIAF processes in the IR-to-UV spectral region is to observe (at the resolution provided by HST) the nuclei of unobscured Seyferts of the lowest luminosity, as well as a sub-class of LINERs. In all other objects other radiation processes dominate. In a sample of 132 LLAGN we identify 8 objects in which we predict the radiation from a RIAF can be directly detected.I will show the nuclear SED of NGC4565, a low-luminosity Seyfert galaxy which does not show nuclear absorption in the optical-UV. Its SED is completely different from that of all other AGN, and may represent the first case in which optical emission from an ADAF-like process is directly observed in an AGN.

Supermassive black holes
(invited review)

David Axon
RIT, Rochester

We will discuss the current status of three key areas of supermassive black hole (SMBH) research. Firstly, what do we know about SMBH masses in AGN and their relationship to galaxy properties. Secondly, the observational consequences of the assembly of galaxies and SMBH via mergers, and finally new directions in investigating the growth of SMBH via gas accretion Under the umbrella of these three broad themes we will discuss the controversy surrounding the observed relations between inferred SMBH and the host galaxy properties and the importance of SMBH gravitational kicks and spin flips for the observed properties of AGN.

Which is the fundamental relation between BH masses and their host spheroids?

Alessandro Marconi*, L. Hunt
**University of Florence*

One of the major contributions of HST has undoubtedly been the discoveries and measurements of the masses of many supermassive black holes in nearby galaxies. Such measurements have allowed the discovery of many scaling relations between BH mass and structural parameters of the host spheroid such as stellar velocity dispersion and luminosity. These relations have had an enormous impact in our understanding of galaxy evolution and of the importance of AGN activity and feedback on the host galaxy. However there is still a fundamental question which remains unanswered. Of the many BH-spheroid relations which is the fundamental one? In this talk I will briefly discuss BH-spheroid scaling relations, their biases and accuracy and I will present a simple, fully analytical method which allows us to combine BH-spheroid and fundamental plane relations. I will then be able to disentangle the fundamental BH-spheroid relation from those which are just a consequence of the fundamental plane relation. I will show that a definitive answer is not possible only because the errors on the correlation slopes are large, but only by assuming that the BH-sigma relation is the fundamental one is it possible to explain all the other relations matching both slope and intrinsic dispersions well within observational errors.

HST's Deep Imaging Surveys: Watching the Universe Evolve
(invited review)

Hans-Walter Rix
MPIA, Heidelberg

Using the “wedding cake” of imaging surveys in the extended Chandra Deep Field South (UDF, GOODS, GEMS) as an example, I will illustrate how HST has been able to lead the revolution in understanding how galaxies assembled and black holes grew. In particular, I will show for which aspects HST's key strengths were pivotal: sensitivity, spatial resolution, color imaging, photometric precision and broad wavelength coverage. As an outlook, I will show the enormous potential that WFC3 has to enable the next leap.

The HST/ACS Coma Cluster Treasury Survey

David Carter* on behalf of the HST Coma Treasury Team
**John Moores Univ., Liverpool*

The ACS Coma cluster survey is an HST treasury program to survey 740 sq arcmin of the cluster. Coma is the nearest dense environment, and provides the opportunity to study the effect of the cluster environment upon the formation and evolution of galaxies. The key science drivers for the survey are: 1) The structure of the dwarf galaxies, including scaling laws, nuclear structure and morphology, to compare with hierarchical and evolutionary models of their formation. 2) Stellar populations from colors and color gradients, and how the internal chemical evolution of galaxies is affected by interaction with the cluster gaseous and galaxy environment. 3) The effect of the cluster environment upon morphological features, disks, bulges and bars, by comparing these structure in the Coma sample with field galaxy samples. 4) Identification of dwarf galaxy samples for further study with the new generation of multi-object and integralfield spectrographs on 8-10 metre class telescopes such as Keck, Subaru, Gemini, and GTC. I will present initial results from the survey, observations will be about 70% complete by the time of the symposium.

Evidence for a Population of Massive and Old Galaxies at High Redshifts

Bahram Mobasher*, T. Wiklind
**ESA, Villafranca*

We present results from a search for massive and evolved galaxies at $z > 5$ in the Great Observatories Origins Deep Survey (GOODS) field. Combining HST (ACS), VLT (ISAAC) and Spitzer (IRAC) photometric data, we develop a colour selection technique to identify candidates for evolved and massive galaxies at high redshifts. The colour selection is primarily based on locating the Balmer Break, using the K-band and 3.6 micron bands. Over an area of 10x16 arcmin^2, we find 11 candidates with redshifts in the range $5 < z < 6.5$, dominated by an old stellar population with ages 0.2-1.0 Gyr and stellar masses in the range 0.5-5 x 10^{11} $M_\odot$. The majority of the stars in these galaxies are formed at $z > 9$ and the current star formation activity in these systems is a few percent of the early star formation rate. We find the comoving number density of galaxies at $z \sim 5$ with a stellar mass > 10^{11} $M_\odot$ to be 4 x 10^{-5} Mpc^{-3}, with a stellar mass density of 8 x 10^6 Mpc^{-3}. The discovery of such massive and evolved galaxies when the Universe was ~1 Gyr old implies that conversion of baryons to stars proceeded much more efficiently in the early Universe than it does today. If confirmed, this discovery poses serious challenge for current scenarios for formation of galaxies.

Deriving properties of Lyman Break Galaxies at z~3-5 using HST/VLT/Spitzer data

Tommy Wiklind
ESA/STScI, Baltimore

The derivation of global properties of galaxies is difficult in general, and even more so when the galaxies in question are distant. One approach is to apply stellar population synthesis models and determine the galaxy properties from the best-fit set of parameters. This method has now reached a

level of sophistication that allows us to ascertain the characteristics of galaxy population with a relatively high degree of confidence. Since there are many different physical parameters needed to describe the stellar population and its evolution, it is necessary to have a sufficiently large set of observed data to perform the fit. For high redshift galaxies, it is necessary to obtain optical, near-infrared and mid-infrared data in order to characterize the stellar population. This kind of studies has only recently become possible by combining HST data with ground-based and Spitzer data. Here we present an analysis of the properties of Lyman break galaxies from the GOODS South field. In particular, we study B-, V- and i-band dropouts, cross-correlated with a K-band selected catalog. While the overlap between the two catalogs only constitute 10% of the Lyman break galaxies, it allows us to derive the physical properties (stellar mass, age and star formation history, as well as photometric redshift when needed), with a high degree of confidence. Our results show that for this subset of LBG's, the galaxies span a surprisingly large range of properties, both in terms of stellar mass and and star formation history.

Scientific results using the ACS grism mode

Norbert Pirzkal*, S. Malhotra, J. E. Rhoads, J. Walsh, C. Xu, and the GRAPES and PEARS teams
**STScI, Baltimore*

The Wide Field Channel (WFC) of the Advanced Camera for Survey (ACS) offers a low resolution (R~100), slitless spectroscopic observing mode. While some care must be taken to reduce such datasets, one can obtain spectra to very faint magnitudes using only a few HST orbits. We have thus used the ACS grism mode in the Grism ACS Program for Extragalactic Science (GRAPES) to provide spectra of the Hubble Ultra Deep Field (HUDF). Using 40 HST orbits, GRAPES obtained spectra of sources with continuum levels as low as I(AB) ~27, i.e. for about 30% of HUDF sources. This has allowed us to spectroscopically identify many stars and emission line sources at both moderate redshifts ($0.3 < z < 2$) and at high redshifts ($4 < z < 7$). GRAPES has since been supplemented by a larger program, Probing Evolution And Reionization Spectroscopically (PEARS), which used 200 HST orbits to obtain slitless spectroscopy of faint sources in the GOODS-N and GOODS-S fields. We present the nature and the peculiarities of ACS slitless spectroscopy data and show a few of the scientific results which have been made possible with these data.

The role of HST in the study of near- and mid-IR-selected galaxies

Karina I. Caputi
ETH, Zurich

Because of their unique quality, HST data constitute an invaluable complement for IR/millimetre surveys conducted with other major facilities, such as VLT, Spitzer or the future Herschel and ALMA. In this talk, I will present some of the main results obtained on the evolution of near- and mid-IR-selected galaxies in the GOODS fields, and discuss the role of HST data in the identification and study of these galaxies. I will focus on the analysis of the sources making the nearand mid-IR luminosity functions at different redshifts, and discuss jointly the evolution of star formation and stellar-mass growth with cosmic time.

Large Scale Structure and Galaxy Evolution in COSMOS

Nick Scoville* and the COSMOS team
**CalTech, Pasadena*

The COSMOS survey is the largest cosmology survey done with HST, imaging 2 square degrees with ACS. I will describe the key considerations which led to the design of the survey and its multi-wavelength data and then present exciting new results on large-scale structures detected in the dark matter from weak lensing and in the galaxy distributions.

Session 4 – HST, H_0 and dark energy

HST and JWST: the Present and the Future
(invited review)

Michael Hauser
STScI, Baltimore

The Hubble Space Telescope (HST) has had a transformative impact on science, the science community, and the public around the world. As HST completes its 17th year of operations, NASA is preparing to send astronauts to service Hubble a fifth time, refurbishing critical systems, installing a new generation of powerful instruments, and possibly repairing instruments that have currently failed. This mission is planned to extend Hubble's operational life until 2014, potentially overlapping the initial operations of the James Webb Space Telescope (JWST). I will review the impact and status of HST and the promise of JWST.

Enabling Science with the Hubble Legacy Archive

Helmut Jenkner*, W. W. Miller III, B. Whitmore
**STScI/ESA, Baltimore*

The Hubble Space Telescope (HST) has the potential to provide excellent scientific data for several more years. But as the conclusion of the HST mission draws nearer, interest will turn increasingly to the analysis of archival data and to the establishment of the true legacy archive of this mission. The research community already retrieves three times more data from the Hubble Data Archive than is put in, indicating that HST data are used for purposes beyond their original intent. Much information remains to be gleaned from the archive, especially as holdings grow and larger statistical and correlative studies can be carried out. A large number of diverse science cases, spanning all areas of astrophysics, could be accomplished and enabled by improvements to the existing system. This improved archive, the Hubble Legacy Archive, will be an essential research resource for many years, if not decades. We present the plan for the implementation of significant enhancements to the Hubble Data Archive that will prepare it for legacy use and provide major new science capabilities. The focus will be on higher-level data products than are available now, including fully calibrated and combined images, image cutouts, and object catalogs. All data products will be immediately available on disk, eliminating the latency of queued data delivery. This capability will make HST data easier to obtain, combine, and compare with data from other space missions and with ground-based data. Image headers will be updated with improved astrometric information, greatly reducing the 1-2 arcsecond errors that frequently affect current pipeline products and that compromise astrophysically essential comparisons with other data. A generalized space-time "footprint" service will be available, allowing users to determine quickly whether, and for how long, a particular region of the sky has been observed with HST. High-level products associated with the requested region of the sky will be immediately available for browsing or downloading. As a consequence of these enhancements, all Hubble data will become accessible through standard Virtual Observatory interfaces, thereby increasing its utility and access throughout the international astronomical community.

Evolution of galaxies from mass selected samples
(invited review)

Marijn Franx
University of Leiden

Traditional studies of galaxy evolution have focussed on luminosity selected samples at various redshifts (from low to high). Here we present results from studies based on mass selected samples, from z=0 to z=3, and highlight the differences between the luminosity selected samples.

HST and the Value of the Hubble Constant
(invited review)

Gustav A. Tammann*, A. Sandage, A. Saha
**University of Basel*

An early HST proposal included A. Sandage, A. Saha, F.D. Macchetto, N. Panagia, and the writer (ApJ, 653, 843). The aim was to determine Cepheid distances to galaxies which had produced a SNIa. The resulting mean SNIa luminosity was then to be inserted into the tight Hubble diagram of spectrum-normal SNeIa out to 30 000 km s-1 in order to calibrate the large-scale value of H_0. Two galaxies were observed with WFC, six more with WFPC2. The data were reduced with DoPHOT with an improved zero-point. The determination of Cepheid distances became more complicated because their period-luminostiy relation is not universal. P-L relations of the Galaxy (for high-Z Cepheids) and LMC (for low-Z Cepheids) were calibrated and applied to the respective galaxies with interpolation for intermediate values of Z. The possibility of a second parameter (Y?) cannot be excluded. Augmented by Cepheid data in the literature, the mean luminosity of SNeIa becomes then $M_V = -18.46 \pm 0.04$. This inserted into the Hubble diagram of SNeIa yields $H_0 = 62.3 \pm 1.3$ (random). The difficulty with Cepheids calls for confirmation. Tip of the Red-Giant branch distances, independently calibrated by RR Lyr stars in 24 galaxies, confirm the mean Cepheid distances of 18 galaxies to within 0.03 ± 0.03. Additional TRGB distances define a local value of $H_0 = 61.7$ (out to 12 Mpc). The mapping of the expansion field is carried further out by Cepheids and by Tully-Fisher distances to the UMa and Virgo clusters, and is eventually linked through local SNeIa to the cosmic expansion of distant SNeIa. The value of $H_0 \sim 62$ holds on all scales.

Recent Progress on the Cepheid Distance Scale with HST

Lucas Macri
NOAO, Tucson

I will present an overview of several programs carried out with HST in recent years to improve our understanding of the Cepheid Distance Scale and measure the value of the Hubble Constant with increased accuracy and precision. In particular, I will focus on ACS and NICMOS observations of Cepheids in the "maser galaxy" NGC 4258.

Universe expansion
(invited review)

Adam Riess
STScI/JHU, Baltimore

The expansion rate and its evolution must be empirically determined for our Universe to reveal its composition, scale, age, and fate. The Hubble Space Telescope is unique in its ability to measure the keystones of cosmic expansion, distant type Ia supernovae and Cepheid variables in their hosts. In 1998, high-redshift SNe Ia provided the first and only direct evidence for an accelerating Universe and the existence of dark energy. More recently, ACS and NICMOS on HST have become tools to calibrate the Hubble diagram of SNe Ia with modern data and to extend its reach to $z > 1$ when cosmic expansion was still decelerating. New measurements from HST are providing new clues about the nature of the mysterious dark energy.

Posters – All sessions

Tracking the distribution of Star Formation in galaxies up to z~1

J. Ruyman Azzollini*, J. E. Beckman, L. Gutierrez
**IAC, La Palma*

In this poster we present the methodology we have implemented in order to study the spatial distribution of Massive Star Formation in galaxies. To do this, we are analysing samples of nearby galaxies and also galaxies in a range of redshifts extending up to z~1. We use data from the GOODS survey on HST supplemented by other data which enable us to span the wavelength range from FUV to NIR, (GALEX, SDSS, and other sources). The aim is to develop a methodology which can be used to help decide between different basic models of galaxy formation using the spatial distribution of star formation within galaxies as the test parameter. In situ knowledge of the star formation distribution as a function of redshift is a valuable counterpart to population synthesis studies which at best integrate this kind of information over long periods.

Mass Estimations of Supermassive Black Holes in Brightest Cluster Galaxies

Elena Dalla Bontà*, L. Ferrarese, J. Miralda-Escude', L. Coato, E. M. Corsini, A. Pizzella
**University of Padova*

To define the upper end of the supermassive black hole (SBH) mass function, we observed a sample of three Brightest Cluster Galaxies (BCGs), Abell 1836-BCG, Abell 2052-BCG, and Abell 3565-BCG, with the Advanced Camera for Surveys (ACS) and the Imaging Spectrograph on board the Hubble Space Telescope. For each target galaxy we obtained high-resolution spectroscopy of the Halpha and [NII]6583 emission lines at three slit positions, to measure the central ionized-gas kinematics. ACS images in three different filters (namely, F435W, F625W, and FR656N) were used to determine the optical depth of the dust, stellar mass distribution near the nucleus, and intensity map. We present SBH mass estimates for two galaxies which show regular rotation curves and strong central velocity gradients, and an upper limit on the SBH mass of the third one. For the SBHs of Abell 1836-BCG and Abell 3565-BCG, we derived $M_O=4.8^{+0.8}_{-0.7} \times 10^9 M_\odot$ and $M_O=1.3^{+0.3}_{-0.4} \times 10^9 M_\odot$ at 1 sigma confidence level, respectively. Abell 1836-BCG harbours the largest SBH mass to have been dynamically measured to-date. For the SBH of Abell 2052-BCG, we found $M_O \leq 7.3 \times 10^9 M_\odot$.

Diffuse ionized gas halos seen with HST

Ralf-Juergen Dettmar*, J. Rossa, M. Dahlem
Astronomical Institute, Bochum

The presence of extraplanar diffuse ionized gas in spiral galaxies is a result of the mass exchange between regions of massive star formation in the disk and the halo. Its distribution and ionization

constrains global models of the interstellar medium. We present new results on the ditribution of H^+ in the disk-halo interface of four edge-on spiral galaxies observed with ACS and compare this high resolution images with other tracers of gaseous halos such as the X-ray emitting hot phase or cosmic rays.

Advanced calibration using physical instrument models: FOS, STIS and beyond

M. Rosa, P. Bristow, **Florian Kerber***
**ESO, Garching*

The Space Telescope European Co-ordinating Facility (ST-ECF) in close collaboration with the European Southern Observatory (ESO) has pioneered the use of physical instrument models in instrument calibration and data analysis applications. In contrast to the traditional empirical methods, such as fitting of polynomials to irregularly and scarcely distributed data points or the subsequent sequential, linear analysis of dispersion and distortion solutions in 2D spectroscopy, the physical model based approach can make full use of of the engineering information fed into the design and construction of the instrument(s). The high predictive power of the model based dispersion solutions for FOS and STIS very early on demonstrated the inadequacy of the wavelengths line lists in use for the calibration lamps flown. In a fruitful collaboration with the Atomic Spectroscopy Group at the US National Institute of Standards and Technology we have been able to produce very much improved wavelength standards for these Pt/Cr-Ne lamps. The superior performance of the new dispersion solutions, based on instrument models verified against the new Pt/Cr-Ne line list (Sansonetti et al. 2004), have been validated on demanding scientific data. Meanwhile, the experience gained in the HST project with the above described methodology has been transferred to the ground. Lately, the physical model based approach has been successfully applied to spectrographic instruments for the ESO VLT: CRIRES (in the 1-5 μu IR domain) and X-shooter (UV to NIR). Further laboratory work in support of the operations of the Cosmic Origins Spectrograph is currently underway. All these efforts to provide the best possible calibration to HST spectrographs will also directly benefit the ST-ECF activities towards a Hubble Legacy Archive.

HST WFPC2 and ACS View of Star Forming Regions in the Magellanic Clouds

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The Magellanic Clouds (MCs) offer extremely rich samples of resolved low-mass stars (below 1 $M_\odot$) in the act of formation that has not been explored sufficiently yet. These pre-main sequence (PMS) stars provide a unique snapshot of the star formation process, as it is being recorded for the last 20 Myr, and they give important information on the low-mass Initial Mass Function (IMF) of their host stellar systems. Studies of young, rich clusters like 30 Doradus in the Large Magellanic Cloud (LMC) or NGC 330 in the Small Magellanic Cloud (SMC) are crowding limited, even at the angular resolution facilitated by HST in the optical. To learn more about low-mass PMS stars in the MCs, one has to study less crowded regions like young stellar associations. We present results from earlier observations with WFPC2, and more recent ones with ACS of star forming associations in the MCs concerning the discovery and classification of their PMS populations. We discuss the

characteristics of these stars in comparison with samples in our Galaxy, their spatial distribution, which shows a clumpy behavior of clustered star formation in these regions, and their age distribution as indication of sequential star formation events. This study aims at a comprehensive collection of substantial information on the most recent low-mass star formation and the low-mass IMF in the MCs. The discussed different regions, which have been selected optimizing a combination of criteria, namely crowding, nebular contamination, and background confusion in comparison to other regions in the Local Group, exhibit the extraordinary variety in conditions of star formation, included in the stellar associations of the MCs, as seen through their low-mass PMS populations.

A preliminary budget for the ionizing photons in HII regions of M51

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Using high-resolution images from ACS/HST, we have analyzed a set of HII regions located on one of the spiral arms of the galaxy NGC 5194 (part of M51), with deprojected distances to the galactic center between 5 and 11 kpc. Associated with these regions, a set of point sources responsible for the ionization of the gas was identified. The absolute magnitudes of these sources were determined in the broadband filters BVI and the values indicate that the sources are generally clusters, not single stars. The local extinction in each region was estimated and, for regions with enough sources, the extinction law was determined. The extinction law so calculated gives, on average, a value for $R_V \sim 3.3$ very similar to the Galactic value. The estimated total visual extinction ranges from 0.82 to 3.24, with a mean value of 1.57, consistent with the range of values reported by Calzetti et al. (2005) for M51. The Lyman continuum flux produced by the ionizing clusters was estimated, as well as the Halpha flux that should be produced if the gas were ionized in ideal conditions. We have compared this calculated Halpha flux with the measured extinction-corrected Halpha flux. This procedure puts a threshold to the missing Lyman photons, which have either been directly extinguished before down-conversion to Halpha, or have escaped entirely from the HII region. The mean value for the fraction of missing photons is ~0.85. Assuming that all of the missing Lyman flux is due to the effective Lyman continuum extinction (A_{Ly}), the value of A_{Ly} ranges from 0.8 to 3.7 (mean ~2.1). These maximum values are already too small to be explained except by a highly inhomogeneous gas and dust density distribution. On the other hand, assuming that ~50% of the Lyman continuum simply escapes (Oey & Kennicutt 1997; Relaño et al. 2002; etc.), the mean value of A_{Ly} would be between 0.33 and 0.71. Here again only a highly inhomogenous model can account for the values.

Near-UV morphology of Low Luminosity AGNs with ACS-HRC of HST

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The physical processes operating in the central regions of Low Luminosity AGN are still nowadays a matter of debate. Its ionizing source could either be a low efficiently accreting super-massive black hole, as well as a massive star cluster. It is thought now that a large fraction of LINER (which are the most common LLAGN) host actually a true active nucleus. On the other hand there are

examples of galaxies with a central ionizing massive star cluster. In a number of objects both processes may coexist and play a similarly important role in the galactic nuclei evolution. In order to disentangle both possible contributions we have constructed a sample of 40 LLAGN imaged at the near-UV with HST. The very high spatial resolution of ACS-HRC and WFPC2 will allow us to estimate the presence of unresolved nuclear point-like sources that could be attributed to an AGN, as well as to determine the frequency of nuclear and circumnuclear stellar clusters in LLAGN. We also plan to complement this observations with optical and near-IR archival HST data, in order to carry on a more detailed study of the stellar cluster population in the most interesting objects and to compare our results with a similar previous study for Seyfert galaxies (Muñoz Marin et al., 2007; in press).

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