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THE ADVANCED CAMERA FOR SURVEYS

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RESUMEN

La cámara avanzada para muestreos (ACS en sus siglas inglesas) es un instrumentos de tercera generación del Telescopi Espacial Hubble (HST), que incluye tres cámaras: la cámara de Gran Campo (WFC), la cámara de alta resolución (HRC) y el Canal ciego solar (BSC). La cámara preferida para la mayoría de los programas se espera que sea la cámara de Gran Campo, como ya ha mostrado el Ciclo 11 de propuestas del HST. La cámara de Gran Campo ($3'.4 \times 3'.4$) posee una alta eficiencia (45% en 7000 Å) y cubre todo el rango espectral desde 3700 a 11000 Å. Su escala de $0.05''$/pixel muestrea críticamente la mitad del patrón de difracción del HST en 5000 Å. Una gran parte de las 500 órbitas del tiempo garantizado de la ACS se usarán para observar cúmulos masivos de galaxias a z entre 0.2 y 1.25. Nuestros objetivos científicos incluyen cartografiar la distribución de materia oscura en dichos cúmulos, el estado de su evolución y la detección e identificación de galaxias hasta $z \sim 6$.

Las capacidades del HST para el estudio del universo lejano se van a ver aumentadas en un orden de magnitud una vez concluya con éxito la instalación de la ACS en marzo del 2002. La ACS tendrá un amplio e inmediato impacto en muchas áreas de la astrofísica. Asimismo, dejará un legado científico duradero, proporcionando objetivos para telescopios como el GTC durante muchos años.

ABSTRACT

The Advanced Camera for Surveys is a *Hubble Space Telescope* (*HST*) third generation instrument that includes three cameras: the Wide Field Camera (WFC), the High Resolution Camera (HRC), and the Solar Blind Channel (SBC). The camera of choice for most imaging programs is expected to be the WFC, as the Cycle 11 round of *HST* proposals has shown. WFC is a wide field ($3.4' \times 3.4'$), high throughput camera (45% at 7000 Å), covering the spectral range 3700–11000 Å. It has a 0.05 arcsec/pixel scale, which half critically samples the *HST* point spread function at 5000 Å. A large part of the 500 orbits included in the ACS GTO program will be used to observe massive galaxy clusters at $0.2 < z < 1.25$. Our science goals include mapping the cluster dark matter distribution, studying the evolution of cluster galaxies and the detection and identification of galaxies at $z \sim 6$.

The capabilities of the *Hubble Space Telescope* for the study of the distant Universe will be increased by an order of magnitude after the successful installation of the Advanced Camera for Surveys in 2002 March. ACS will have an immediate high impact on many areas of astrophysics, but will also leave a long-lasting scientific legacy, providing targets for telescopes such as the GTC for many years to come.

Key Words: **INSTRUMENTATIONS: CAMERAS**

1. INTRODUCTION AND TECHNICAL CHARACTERISTICS

The Advanced Camera for Surveys (ACS, Ford et al. 1995) includes three channels (Woodruff & Cahill 1998, see also Figure 1): the Wide Field Camera (WFC), the High Resolution Camera (HRC), and the Solar Blind Channel (SBC).

The WFC is a wide field ($3.4' \times 3.4'$), high throughput camera (45% at 7000 Å), covering the spectral range 3700–11000 Å. It has a 0.05 arcsec/pixel scale, which half critically samples the *HST* point spread function at 5000 Å. The HRC has a smaller field of view, $26'' \times 29''$, and is optimized for difraction-limited imaging, with an 0.027 arcsec/pixel plate scale. It covers the spectral range 2000 to 11000 Å and has a high near-UV throughput, 29% at 2500 Å. The SBC is a far-UV camera with a 6% throughput at 1216 Å and a $26'' \times 29''$ field of view. The ACS has been described in detail elsewhere (Ford et al. 1998, 2001). More information and updates can be obtained at http://acs.pha.jhu.edu (the ACS team website).

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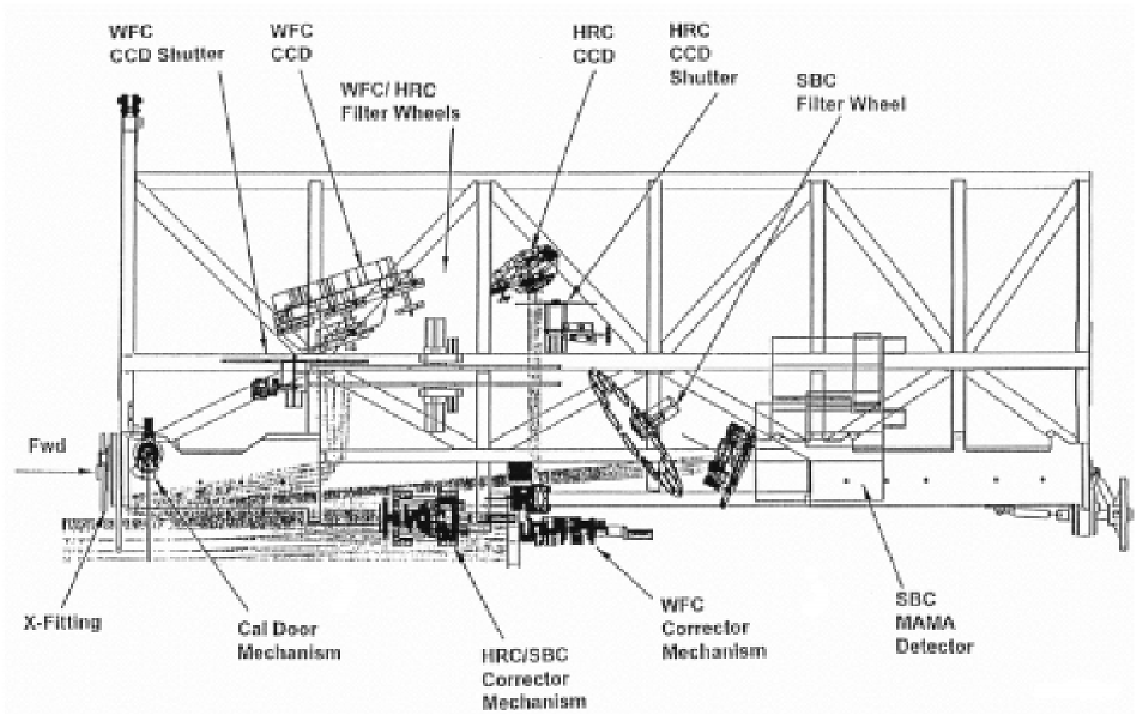

Fig. 1. The layout of the ACS optical bench.

The WFC is the instrument of choice for most galaxy evolution programs, and was the *HST* instrument with most observing time requested and awarded in the last *HST* Cycle 11 proposal round. WFC has been optimized for observations at ∼8000 Å (see Figure 2), a spectral range greatly affected by atmospheric emissions from the ground but crucial to the study of high z objects. Its very high throughput, 44% at 6000 Å, is 3–5 times higher than that of WFPC2. This has been achieved through the use of silver-coated optics and high quantum efficiency (QE), back-illuminated CCDs. The pixel scale is half of that of WFPC2, and the area ∼2 times larger. All these improvements combined make WFC more than ten times better than WFPC2 for survey-type imaging.

The WFC complement of filters includes some of the broad band filters used by WFPC2 (F555W, F606W, and F814W) but also the Sloan Digital Sky Survey *griz* filter set (Leviton et al. 1998). These filters divide the spectral range available to the ACS in almost equal-width regions with very little overlap, which makes then very useful for photometric redshift estimation. A visible grism will add a low resolution ($R \sim 100$) spectroscopic capability, which is expected to be useful for objects with emission lines because of the low background on the *HST*.

2. ACS PIPELINE AND ARCHIVE

The goals of the ACS GTO science data pipeline are processing and extracting scientific information from the ACS GTO data in a consistent way with as little human intervention as possible. The images are calibrated using CALACS, corrected for geometric distorsion (which, caused by the position of the ACS in the focal plane of the *HST*, is much larger than for WFPC2), grouped and aligned if necessary, and combined using the DRIZZLE software package. The following stage involves creating a detection image, running SExtractor to detect and obtain photometry of faint sources, and feeding the corresponding photometric catalogs into the BPZ software package, which produces photometric redshift estimates for galaxies using a Bayesian procedure (Benítez 2000). As a last step, the pipeline products, both images and catalogs, are archived in the ACS GTO data archive.

3. GTO SCIENTIFIC PROGRAM

The highest fraction of the ACS GTO orbits, about 60%, will be devoted to the study of galaxy and cluster evolution (Postman et al. 1998; Illingworth et al. 2001). Table 1 shows how these orbits will be distributed among different subprograms.

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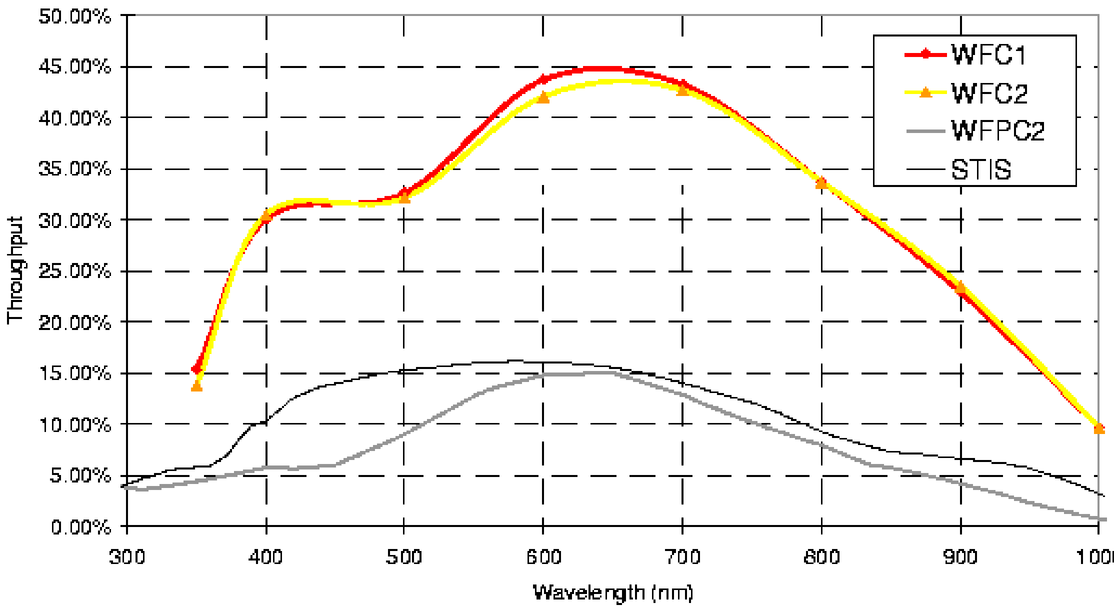

Fig. 2. The expected net throughput for the WFC, including the *HST* OTA. The corresponding WFPC2 and STIS values are shown for comparison.

The rest of the orbits are spread into several programs, including the study of massive black holes in early-type galaxies, observations of QSO host galaxies, coronagraphic searches for planets and disks around nearby stars, and a Solar System subprogram, which includes studies of Jovian satellites, comets, and searches for Kuiper Belt objects.

3.1. *Evolution of galaxy clusters at $z \sim 1$*

The ACS will obtain multicolor imaging of the central 1.5 Mpc of several distant clusters in the redshift range $0.75 < z < 1.27$. One of the main goals of this program is to establish the dependence of morphological composition and star formation properties of the cluster galaxies as a function of radius and local density. It also intends to explore the relationship between substructure, kinematics, and morphology, and strongly constrain the galaxy merger frequency and the origins of elliptical and S0 galaxies. The sample of clusters includes the two most distant, spectroscopically confirmed superclusters and will significantly increase the baseline over which evolutionary effects can be studied.

3.2. *Cluster lensing: dark matter and high z galaxies*

This subprogram has two main goals: to determine the dark matter distribution of massive galaxy clusters and to observe the high redshift universe using these clusters as powerful cosmic telescopes. Deep *griz* imaging of a sample of low z (0.2–0.4) clusters will yield a large sample of lensed background galaxies with reliable photometric redshifts. By combining strong and weak lensing constraints with the photometric redshift information, it will be possible to measure precisely the cluster dark matter distribution with an unprecedented combination of high spatial resolution and area coverage, avoiding many of the uncertainties that plague ground-based studies and giving definitive answers about the structure of massive dark matter haloes.

In addition, cosmological parameters can be constrained in a largely model-independent way using multiply lensed objects because of the dependence of the Einstein radius on the distance to the source.

We can also expect to detect several highly magnified drop-out galaxies behind the clusters up to $z \sim 6$ or higher, thanks to the presence of the high throughput SDSS "z" filter (F850LP). The combination of *HST* resolution and the high magnification in such lensing clusters will allow us to study these objects in considerable detail. Or, if such $z > 6$ sources are intrinsically faint, lensing may provide the only practical means of their detection prior to even more sensitive telescopes and instruments in the future.

We shall also obtain the best information to date on the giant arcs already known in these clusters, making possible detailed, pixel-by-pixel studies

TABLE 1

GALAXY AND CLUSTER EVOLUTION ACS GTO SCIENCE PROGRAMS

Program	Orbits
Low-z Gravitational Lensing Survey	43
Cluster evolution at $z \sim 1$	165
Formation of high-z Radio Galaxies	51
The Nature of Galaxies at $z > 4$	16
Field Galaxies in Deep IR Fields	18
Total	293

of their star formation rate, dust distribution, and structural components, including spiral arms, out to a redshift of around $z \sim 2.5$ in several passbands.

4. UPDATE

The Advanced Camera for Surveys was launched aboard the Space Shuttle *Columbia* (STS-109) on 2002 March 1, just a few weeks after this conference concluded. It was successfully installed aboard the *HST* a few days later and, after going through several testing procedures, obtained the so called Early Release Observations at the beginning of April that include two pairs of interacting galaxies, UGC 10214, or the "Tadpole" and the "Mice", and the "Cone" and the "Omega" nebulae. These stunning pictures were made public on 2002 April 30 and analysis shows that the performance of the ACS WFC is even better than expected.

5. CONCLUSIONS

The capabilities of the *Hubble Space Telescope* for the study of the distant Universe will be increased by an order of magnitude after the successful installation of the Advanced Camera for Surveys in 2002 March. The ACS will have an immediate high impact on many areas of astrophysics, but will also leave a long-lasting scientific legacy, providing targets for telescopes such as GTC for many years to come.

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