ABSTRACT
In this ISR we present the abbreviated and revised version of the proposals submitted to define the Design Reference Mission (DRM) in the development of the Wide Field Camera 3 (WFC3). These proposals include many of the areas of science identified by the WFC3 Scientific Oversight Committee (SOC) as addressable by WFC3. These areas are meant to be representative, not all-encompassing. These abstracts constitute the complete set of 43 proposals, and 40 of the proposals were subsequently processed using the baselined WFC3 ETCs of 15 February 2000. This ISR is the second in a series of ISRs to describe the process that led to the production of the proposals used in the DRM for WFC3, and the subsequent incorporation of the proposals into a representative body of science research areas that will be addressed by WFC3.

1 Introduction

As mentioned in Part I (Knezek and Hanley, 2001) of this series of ISRs, the Design Reference Mission (DRM) document provides preliminary estimates for the Hubble Space Telescope (HST) observatory resources that are required by the Wide Field
Camera 3 (WFC3) to perform its science mission successfully. These estimates have been made by (1) soliciting potential WFC3 Guest Observer (GO) observing programs from members of the WFC3 Scientific Oversight Committee (SOC), the Integrated Product Team (IPT), and the astronomical community, and (2) analyzing the usage history of other UV/optical/NIR instruments (WFPC1, WFPC2, NICMOS) in previous HST cycles and extrapolating their usage to the WFC3. This approach allowed us to compare UVIS and IR usage, to exercise the major observing modes of WFC3, and to perform early trade-offs relevant to flight software, commanding, and spacecraft operations. We have endeavored to ensure the majority of the major scientific uses of WFC3 have received adequate consideration in the early developmental stages of the instrument, and that priorities can be established for the major scientific capabilities in the event trade-offs must be considered. The DRM provided a basis for estimating data volume generation, on-board data storage requirements, and data downlink usage that will be used for sizing ground support systems (Lisse et al. 2001). Finally, the DRM provides the “science flowdown” to the instrument requirements specified in the Contract End Item Specifications (CEIS, MacKenty 2000).

Section 2 briefly covers the major scientific areas of research covered by the 43 submitted DRM proposals. Section 3 of this DRM document contains the revised and abbreviated proposals describing GO science observing programs. These revisions were requested by the chair of the SOC in July, 2000, and incorporate the final filter choices and scientific goals. They document the effort by the WFC3 SOC and the WFC3 IPT to demonstrate the capability of WFC3 to accomplish the scientific goals laid out in the WFC3 Science White Paper (eds. Stiavelli and O’Connell 2000). Proposals that were not revised are listed, but their content is not included. Section 4 contains brief conclusions.

2 Science Overview

WFC3 will be able to use its panchromatic capabilities to study a number of identified questions within NASA’s Origins theme significantly better than any previous instrument on HST. These have been detailed in the WFC3 Science White Paper (eds. Stiavelli and O’Connell 2000). In brief, the unique combination of UV/optical/NIR imaging capabilities, wide fields of view, high resolution, and high throughput, will allow scientists to address major issues in a number of areas. These areas will aide scientists in determining our “cosmic origins” through the studies of the origin and development of galaxies, stars, planets, and the chemical conditions necessary to support life. Some specific areas outlined within the DRM are described below. They have been divided among several very broad scientific categories: galactic, extragalactic (low redshift), galaxy clusters and cosmology (high redshift), stellar, and planetary.

Planetary

WFC3’s panchromaticity and extensive filter complement ensure it will be well-suited for planetary science. Within our own solar system, it can be used to study the atmospheric structures of both the inner and outer planets. It will also shed light on the sizes and properties of asteroids, Kuiper Belt Objects, and even comets. Temporal changes in comets and planetary atmospheres can also be studied. Outside our solar
system, WFC3 can address the disk-planet connection by searching for disks around galactic stars and observing Herbig-Haro objects. And it may be possible to detect earth-like planets toward the bulge of our Galaxy or even outside our Galaxy in the LMC through stellar microlensing events.

**Resolved Stellar Populations**

WFC3 will be very useful for observations of stars and stellar clusters, both within our own Galaxy and in other nearby galaxies. They will shed light on the ages and chemical evolution of stars in bars, star forming regions, and the field of Local Group galaxies. In our own Galaxy, studies of the proper motion of stars in globular clusters, as well as the white dwarf cooling sequence, and both hot and cool cluster members will lead to better determination of globular cluster ages, initial mass functions, and main sequence evolution. The star formation history of the Galactic Bulge can also be addressed by looking at the lower main sequence towards the Galactic Center and for variations in the stellar populations as a function of distance above the Galactic Plane.

**Stellar Birth and Death and the Interstellar Medium**

WFC3 can be used to image the stars, gas, and dust surrounding star forming regions in order to determine how the star formation rate depends on environmental conditions. The role played by OB stars in the star formation process can be examined, as can the frequency of very low mass stars, brown dwarfs, and super-jovian companions. Studies of supernova remnants (SNRs) will be done to determine the time evolution of supernova remnants, provide abundances to test theories of supernova nucleosynthesis yields, and study their magnetic fields and the distribution of dust within them. The morphology of proto-planetary nebulae and bipolar nebulae will be examined to determine when asymmetries in nebulae and/or stellar winds develop, and how this might be related to the location of the planetary nebulae within the Galaxy. By including both high and low mass stars, this may clues to the evolutionary link between stellar winds and the flow collimation process.

**Extragalactic (low redshift)**

WFC3 will better calibrate the distance scale through observations of Cepheid variables and post-AGB stars in the Virgo cluster and surface brightness fluctuation measurements in nearby galaxies and brightest cluster member galaxies. UV observations of nearby galaxies will be used to obtain a better understanding of galaxy morphology at wavelengths which correspond to the rest wavelengths of high-redshift galaxies recently observed with HST, and how starburst galaxies in the current epoch may provide analogues to high-redshift galaxies. The structure of starburst galaxies, and their link to merging galaxies can also be explored, as can the possible connection between some star forming clusters in merging galaxies and the current population of globular clusters. The high spatial resolution and large FOV of WFC3 is also well suited for studies of interstellar dust in external nearby galaxies, leading to insight to the diffuse ionized
medium in local star forming galaxies as well as the universality of the 2175 Å bump. Furthermore, WFC3 can provide unique capabilities in the search for low surface brightness galaxies.

**Galaxy Clusters and Cosmology (high redshift)**

WFC3 will be the instrument of choice for studies of star formation in galaxies between $z=1$ and $z=2$, the epoch when star formation is thought to have peaked. The evolution of elliptical galaxies can be traced through their UV-upturn. In the area of galaxy clusters and cosmology, WFC3 can be used to address such issues as the evolution of stellar populations within high redshift clusters and the derivation of the volume density of $z>5$ galaxies. Surveys for galaxies at redshifts $z=1-9$ can shed light on how galaxies assemble and how the Hubble sequence was established, and test CDM theories of the formation of galaxies and large scale structure in the universe. WFC3 will probe into the farthest reaches of the Universe through ultradeep imaging of “random” pieces of the sky, as a follow-on to the Hubble Deep Field. It may help determine the nature of the first luminous objects in the Universe.

### 3 DRM Proposals

#### 3.1 Original DRM Proposal Templates

In order to facilitate the interpretation of science ideas for using WFC3 to viable test programs that could be processed through an ETC, it was decided to make things as uniform as possible. Everyone who submitted a WFC3 DRM proposal was thus asked to complete a template. In addition to uniformity of the proposals, the template was designed to provide the information necessary for a WFC3 IPT member to setup a test program. This template was as follows:

1. **Title:**
2. **Author(s):**
3. **Example(s) of Existing HST Program(s):** (If you know of a similar HST program, give its ID number. Also include a journal reference if it exists.)
4. **Goal of Observation:** (few sentence summary)
5. **Scientific Justification:** (~2 paragraphs)
6. **Advantage of WFC3 over WFPC2 or ACS:** (sentence or two)
7. **Requirements:** (instrumental performance needed: S/N, filter, background, photometric accuracy, resolution, etc.)
8. **Targets:** (number, sizes, magnitudes, color, surface brightnesses; give sample ID’s)
9. **Description of observations:** (filter and exposure sequences x number of targets; include CR splits; special limiting conditions)
10. **Orbits Required:** (you don’t have to work this out; the IPT will do it. But you need to supply enough information for them to estimate the total number of orbits.)
11. Critical Requirements: (estimate which aspects are critical for success)
   [e.g., XXX=critical, XX=important, X=useful, ‘‘=not important]
   a. Faint Limiting Magnitude
   b. High Spatial Resolution
   c. Photometric Accuracy
   d. Wide Wavelength Coverage
   e. Minimal Scattered Light
   f. Large Field of View
   g. Other (please describe)

While the use of templates did aid in providing uniformity for most of the proposals,
there was significant variation in the amount of information provided to facilitate the
setup of the programs. Furthermore, the template was created before (1) the IR channel
was added, and (2) the SOC had had the opportunity to finalize a complement of filters
for both channels. Thus, it was necessary to iterate on the setup of most of the individual
programs. When possible, we gathered the needed data (spectral templates, typical
fluxes, sizes, etc.) or made the necessary calculations ourselves. If this was not possible
– for example when the final filters had to be chosen – we contacted the lead author of
the proposal for input. This resulted in the inputs and outputs that are covered in Part III
of this series of ISRs (Knezek and Hanley, 2001).

3.2 Current DRM Proposals
Once the filter lists had been finalized and the 40 proposals that could be set up to run
through the UVIS and/or IR ETCs had been processed, the results were presented to the
WFC3 SOC. At that juncture in time the chair of the SOC requested that the DRM
proposal authors revise and update their proposals to reflect any changes in scientific
goals and objectives. These updates could include changes due to the finalized filter lists,
indications from the results of the first ETC processing that there needed to be
modifications to target numbers, flux limits, etc., or revised goals and objectives based on
the most up-to-date knowledge of the scientific capabilities of WFC3. The SOC agreed
that only the broad overall scientific goals and objectives would be published. It is these
revised proposals that are included in the next section. For the few proposals where no
revision was received, the proposal number, title, and author(s) are listed, but all other
information is listed as “not received”. For each proposal the following information is
provided:

1. Title:
2. Author(s):
3. Example(s) of Existing Program(s):
4. Goal of Observation: (few sentence summary)
5. Need for WFC3

It should be remembered that these revisions were written after the results that are
discussed in Parts I and III (Knezek and Hanley, 2001) of this series of ISRs were already
completed. Thus, there may be occasional discrepancies between the stated goals and
objectives of a particular proposal and the actual inputs and outputs listed elsewhere.
However, this is rare since the majority of the revisions were done to reflect the final filter list, and the final filter list was used in the ETC processing.

### 3.3 Individual Proposals

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**PROGRAM: 101**

**TITLE:** Cepheid Observations in Virgo Clusters

**AUTHOR:** B. Whitmore

**EXAMPLE OF EXISTING PROGRAM:**

5397 (Mould et al., cycle 4)

**GOAL OF OBSERVATION:**

The determination of the distance scale of the universe continues to be one of the fundamental questions in astronomy, important both for understanding the most basic physical characteristics of astronomical objects (e.g., their size and mass) and for a determination of the age of the universe. One of the primary tools in this quest is the measurement of Cepheid variables for galaxies at the distance of the Virgo cluster or slightly beyond. In fact, roughly 1000 orbits have been awarded over the lifetime of HST to pursue this question. ACS and WFC3 will continue this important work and provide the opportunity to extend the range of the technique a factor of roughly 2 (representing a volume increase of roughly a factor of 10).

The goal for this program is to measure the light curve of 50 Cepheid variables in five Virgo Cluster spiral galaxies in order to determine the distance to the cluster using the period-luminosity relation. Two colors (V and I) are required to provide an estimate of the reddening corrections, and hence the extinction correction.

**NEED FOR WFC3:**

This is one of the backup mode proposals (i.e., designed to ensure that at a minimum WFC3 can make the key observations that WFPC2 was capable of). However, WFC3 will provide better spatial resolution over a wider field than possible with WFPC2, and hence will provide more candidate Cepheids. This program can also be done by ACS.

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**PROGRAM: 102**
TITLE: Ultradeep Imaging (i.e., HDF or HDF-S)

AUTHOR: B. Whitmore

EXAMPLE OF EXISTING PROGRAM:

HDF = 6337
HDF-S = 8058, 8073, 8074, 8075, 8076

Hubble Deep Field South. For details see:


GOAL OF OBSERVATION:

Deep HST images, such as the Hubble Deep Fields (North and South), have opened up a new frontier by allowing us to examine the morphologies of galaxies at high redshift, and to identify galaxies in the process of formation at redshifts as high as 4 or 5. The goal for this program is to obtain the deepest image possible of a "random" piece of the sky. Four filters are used to provide photometric redshifts in order to identify high redshift candidates (i.e., the U dropout galaxies where the Lyman break has been redshifted redward of the F300W filter response). The number counts will be used to test various cosmological models and the sizes and morphology of galaxies will be used to study their evolution.

NEED FOR WFC3:

This is one of the backup mode proposals (i.e., designed to ensure that at a minimum WFC3 can make the key observations that WFPC2 was capable of).

A critical part of the success of the HDF was the use of the F300W filter to identify high Z candidates by determining which galaxies were "U-dropouts". The much higher QE of the WFC3 (a factor of 9) will make this much more efficient than was possible with WFPC2.

This program will also be much more efficient than possible with ACS. While the QE in the UV is much higher for the HRC on ACS, the field of view is very small (30" X 30"). Hence the discovery efficiency is roughly a factor of 40 better than ACS.

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PROGRAM: 103

TITLE: Multi-wavelength Observations of the Young Clusters in Merging Galaxies

AUTHOR: B. Whitmore
EXAMPLE OF EXISTING PROGRAM:

ID = 5962

GOAL OF OBSERVATION:

The discovery of young, ultraluminous, compact star cluster in NGC 1275 by Holtzman et al. (1992, AJ, 103, 691) was the catalyst for what has become a major HST industry, observations of young star cluster. These clusters have all the attributes expected of young globular clusters. While these "super star clusters" are most prevalent in merging galaxies (e.g., Whitmore and Schweizer, 1999, AJ, 118, 1551) they are also found in starburst galaxies in general, as well as in barred galaxies. Perhaps the most exciting thing about this field is that the young star cluster may allow us to study the formation of globular clusters in the local universe, rather than forcing us to guess how they formed 12 billion years ago.

The goal of the program is to determine whether the ultraluminous, compact star clusters found in merging galaxies are protoglobal clusters. An important requirement of the project is the ability to separate the stars from the clusters in order to determine the initial cluster luminosity function and the sizes of the clusters. This requires the highest possible spatial resolution over the entire field of view.

NEED FOR WFC3:

This is one of the backup mode proposals (i.e., designed to ensure that at a minimum WFC3 can make the key observations that WFPC2 was capable of).

WFC3 will provide better spatial resolution over a wider field than possible with WFPC2, and hence will provide much better discrimination between individual stars and clusters. This is required in order to determine the luminosity function for the clusters and the sizes of the clusters, which are the primary goals of the program.

Also, the youngest clusters have not had time to clear away the dust, making it difficult to determine the luminosity function (and other properties) for clusters < 5 Myr old. Observations in J and H will largely surmount this problem.

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PROGRAM: 104

TITLE: Distance Estimates from Surface Brightness Fluctuations of Nearby Galaxies in the Optical and Infrared

AUTHOR: B. Whitmore
EXAMPLE OF EXISTING PROGRAM:

Tonry (7453)

Tonry article in "The Extragalactic Distance Scale", STScI symposium series #10.

GOAL OF OBSERVATION:

The surface brightness fluctuation method developed by John Tonry has become one of the leading contenders in the distance measurement business. The high spatial resolution of HST increases the SBF signal, and makes this method particularly useful, especially at longer wavelengths (i.e., Tonry says is 30 times better at H compared to I). The high spatial resolution also makes it easy to remove globular clusters and background galaxies, which is the first step in the process. The technique uses the pixel-to-pixel variations in counts due to the finite number of stars in each pixel to make the measurement. Hence, the technique is quite sensitive to any sources of pixel-to-pixel variance, such as read noise, the quality of the flat-field, focus variations, under-sampling, hot pixels, and PSF spatial variability across the CCD fields. We also note that this dataset can be used to determine distances using the peak of the globular cluster method which provides an independent measurement.

The goal of the project is to determine distances (and the Hubble constant), based on the Surface Brightness Fluctuation (SBF) method. The targets consist of 20 calibrator and 40 brightest cluster galaxies. The primary observations will be made using the H filter, with a few observations in I to determine color corrections and compare with past measurements.

NEED FOR WFC3:

This is one of the backup mode proposals (i.e., designed to ensure that at a minimum WFC3 can make the key observations that WFPC2 was capable of).

The surface brightness fluctuation method works roughly 30 times better at H than at I, hence the IR channel of WFC3 provide a unique capability for this project.

PROGRAM: 105

TITLE: Identifying Stars in a Globular Cluster Using Proper Motions

AUTHOR: B. Whitmore

EXAMPLE OF EXISTING PROGRAM:
GOAL OF OBSERVATION:

Determining the hydrogen-burning limit at the lower end of the main sequence is a fundamentally important, but very difficult observational problem, due to serious field-star contamination. It is possible to identify the field stars by doing careful astrometry of the stars in a globular cluster, if sufficiently high spatial resolution is available.

Observations will be made in V and I, separated in time by a few years in order to determine cluster members in a globular cluster based on proper motions. The primary goal is to determine the luminosity function of the cluster stars, especially the low-mass end.

NEED FOR WFC3:

This is one of the backup mode proposals (i.e., designed to ensure that at a minimum WFC3 can make the key observations that WFPC2 was capable of). WFC3 will provide better spatial resolution over a wider field than possible with WFPC2, and hence will provide more accurate astrometry to a fainter level than possible with WFPC2. This program can also be done by ACS.

PROGRAM: 106

TITLE: Search for Disks Around Stars

AUTHOR: B. Whitmore & C. Burrows

EXAMPLE OF EXISTING PROGRAM:

5700 - Burrows

GOAL OF OBSERVATION:

The discovery of disks around nearby stars has provided new insight into the formation of stars, and perhaps of more public interest, the formation of planets. The goal of this program is to observe the circumstellar disk around Beta Pic (a V= 3.9 mag star) in more detail, and to detect new examples of this phenomenon in order to increase the sample and begin making comparative studies of circumstellar disks in general. The success of this program requires careful design and construction of the camera in order to minimize scattered light.

NEED FOR WFC3:
This is one of the backup mode proposals (i.e., designed to ensure that at a minimum WFC3 can make the key observations that WFPC2 was capable of). WFC3 will provide better spatial resolution over a wider field than possible with WFPC2, and hence will provide more accurate astrometry to a fainter level than possible with WFPC2. This program can also be done by ACS.

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PROGRAM: 201

TITLE: WFC3 Observations of Herbig Haro Objects

AUTHOR: A. Walker & S. Heathcote

EXAMPLE OF EXISTING PROGRAM:


GOAL OF OBSERVATION:

Herbig-Haro (HH) objects, consisting of a complex system of radiative shock waves, are caused by the violent interaction of highly collimated supersonic outflows from newborn stars and the interstellar medium. Study of these flows, via imaging of the structures in a variety of diagnostic emission lines, then repeating the observations to assemble measurements over a temporal baseline of a few years, determines both the structure and kinematics of the HH objects. The phenomenon may occur for all newborn stars and be an integral part of the star and planetary system formation process, thus an understanding of the complex HH fluid dynamics will be a necessary part of understanding the birth processes of stellar systems.

NEED FOR WFC3:

The higher QE expected for WFC3, when compared to WFPC2, especially in the UV, opens up the possibility of obtaining images in a number of additional shock diagnostic lines. No other space facility, on HST or otherwise, has the combination of both visual and IR sensitivity, high spatial resolution, and the combination of specialist filters, that allow this program to be carried out. Diagnostics of particular importance are: MgII 2800A, CII] 2325A, [Ne IV] 2423A, [OIII] 3727A, [OII] 5007A, [OI] 6300A, Halpha, [NII] 6584A, and [SII]6717+31A. Imaging in the first four of these lines was essentially not feasible with WFPC2 even had filters been available. The higher QE and lower RON also means that it will be possible to get adequate S/N at 0.04"/pix resolution, while the WFPC2 observations have largely been limited to the 0.1"/pix resolution of the WF chips by the low surface brightness of the objects. In the near IR the availability of filters for both members of the [FeII]1.26,1.64 micron doublet (only one line was covered by
NICMOS) permits the extinction to be measured allowing accurate reddening corrections to be applied to the fluxes of the optical and near UV lines. Imaging through one or more broadband filters in the near IR can be used to search for close binaries amongst the energy sources and to probe the structure of associated disks and reflection nebulae. This requires the detection of faint extended structures adjacent to, often, very bright point sources.

PROGRAM: 202

TITLE: The Age of the LMC Bar

AUTHOR: A. Walker & K. Olsen

EXAMPLE OF EXISTING PROGRAM: TBD

GOAL OF OBSERVATION:

The spatial distribution of LMC clusters as a function of age, and two recent studies of field color-magnitude diagrams of the LMC Bar, have led to the idea that the Bar is a young feature, with age < 1 Gyr. However other color-magnitude work suggests that the Bar may contain stars as old as 6-8 Gyr, but this is not certain. There does appear to be a significant fraction of 4 Gyr old stars that are not present in LMC disk fields, and which might signal the formation epoch of the Bar. To resolve this discrepancy we propose to observe ten fields aligned parallel to the minor axis of the Bar, and to extract the star formation histories implied by the color-magnitude diagrams. This will map the distribution of orbits of the 4 Gyr population and determine their relationship to the Bar. The observations will thus directly address the question of how the Bar relates to the LMC as a whole, and will be an important ingredient in understanding aspects of the formation and evolution of Magellanic Systems.

NEED FOR WFC3:

The Bar fields are very crowded and preclude ground-based photometry. The small pixels (0.04 arcsec) of WFC3 are an advantage over WFPC2, which has this resolution only for the PC channel. Observing with the Washington C filter is essential for disentangling the effects of age and metallicity, thus although ACS could observe in the V and I passband, it does not contain the Washington C filter.

PROGRAM: 203

TITLE: Ages and Abundances of M31 Open Clusters
AUTHOR: A. Walker & K. Olsen

EXAMPLE OF EXISTING PROGRAM: TBD

GOAL OF OBSERVATION:

A study of the stellar populations of M31, and a direct comparison to those in our own galaxy, is a pre-requisite for deciphering which formation scenario is applicable to M31. An integral part of this process is measuring possible age and abundance gradients in the M31 stellar disk, and placing limits on its age. This will be achieved by selecting a sample of 15 open clusters with a variety of ages, estimated on the basis of already existing integrated colors, and then producing their color magnitudes from observations in UBV filters. Observations through the four filters specified will allow disentanglement of age and metallicity effects in the presence of reddening.

NEED FOR WFC3:

This program requires very deep photometry ($V = 28$) and high spatial resolution to enable measurement of stars in the crowded clusters down to the luminosity of the Sun. We will measure reddening using the UBV combination of filters, which requires sensitivity at a wavelength of 300 nm. WFC3 is unique in offering the combination of ultraviolet sensitivity and the ability to do accurate, high resolution stellar photometry to very faint limits.

PROGRAM: 204

TITLE: Detection of Earth-Like Planets through Planetary Microlensing

AUTHOR: M. Dopita

EXAMPLE OF EXISTING PROGRAM:

Not received.

GOAL OF OBSERVATION:

Not received.

NEED FOR WFC3:

Not received.
PROGRAM: 205

TITLE: Origin of the Elements: Ejecta-dominated Supernova Remnants

AUTHOR: J. Hester, J. Morse, & P. Knezek

EXAMPLE OF EXISTING PROGRAM:

Cas A: GO-7406: Fesen, PI
   (see DRM Program 212)
SN1987A: SINS Survey: Kirshner, PI
E0102-7219: GO-6052: Morse, PI
SNR0540-69.3: GO-7340: Morse, PI

GOAL OF OBSERVATION:

The goal of these observations is to map the UV-optical line emission from shocked or
photoionized filaments of stellar ejecta in spatially resolved supernova remnants in order
to study the spatial distribution, ionization structure, and time evolution of the knots.
Such data are crucial for modeling the observed emission that ultimately lead to
abundance estimates that test models of supernova nucleosynthesis yields.

NEED FOR WFC3:

Only WFC3 has the combination of the large field of view and the extensive complement
of needed narrowband filters necessary to complete this program.

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PROGRAM: 206

TITLE: Wide-Field UV Imaging of Nearby Galaxies

AUTHOR: J. A. Frogel, R. Windhorst, & R. O'Connell

EXAMPLE OF EXISTING PROGRAM: TBD

GOAL OF OBSERVATION:

The rest frame wavelength at which we observe distant, young galaxies is in the blue or
ultraviolet region of the spectrum. For example, at redshifts of z about 4, any observation
at a wavelength of 1.2 microns or shorter corresponds to a rest frame wavelength which,
for nearby objects, lies shortward of the atmospheric cutoff. Yet, if we are to understand
the formation and early history of these distant and young objects, we have to know
"where they are headed", i.e. what do the nearby, aged, descendents of these objects look like. The necessary ultraviolet imaging observations have to be made from above the atmosphere. Our goal is to use the unique wide field UV imaging capabilities of WFC3 to study a large sample of representative spiral galaxies in the nearby universe and attempt to understand how galaxies get from a z of 4 or greater to a z of about 0 in 12 billion years. The UV light is essentially for matching up observations of the near and far. And, paradoxically, stars that are both very young and very old are expected to be the prime contributors to the UV light.

NEED FOR WFC3:

Nearby, well-studied galaxies are large. If one considers a representative sample of all galaxy types, the range in angular size for such a sample would typically be between 2 and 6 arc minutes. Thus, to properly observe these nearby galaxies an instrument with both high UV sensitivity and wide field of view is needed. WFC3 has both of these abilities. In particular, the areal coverage of its high sensitivity UV CCD will be more than an order of magnitude greater than the high resolution UV camera on ACS. This unique advantage of WFC3 over any existing or planned HST instrument will allow it to make major contributions in the understanding of the birth and evolution of galaxies.

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PROGRAM: 207

TITLE: Direct Determination of Metallicities in Nearby Galaxies: Breaking the Age-Metallicity Degeneracy.

AUTHOR: A. Saha & J. Holtzman

EXAMPLE OF EXISTING PROGRAM:

Not possible with current instrumentation.

GOAL OF OBSERVATION:

Nearby galaxies that are resolved into stars can tell us about the history of star formation and chemical evolution. Photometric techniques applied to the brighter stars have been widely used for studying stars that are too faint for spectroscopic methods. The color-magnitude diagrams (CMDs) that are observed can now be synthesized from stellar evolution models, and star formation histories and coarse chemical evolution analyses are being done using such methods. However, age and chemical composition information gleaned from such methods are degenerate -- i.e. changes in the CMD from age effects can be compensated for by altering the assumed chemical composition. A direct measurement of the abundances of the brighter stars is thus desirable for breaking this degeneracy. Such direct measures of the abundance can also be used to search for very
metal poor stars in a systematic way, and can shed light about the relative occurrence of such stars, and thus their role in shaping the early histories of galaxies.

A photometric CaII K-line index is used to photometrically measure star by star abundances of the brighter stars, using on- and off-band imaging with special filters. The narrow K-band filter is especially sensitive for low metallicities, allowing metallicity discrimination at [Fe/H] = -4.0 for K stars.

**NEED FOR WFC3:**

The K-line filter, which measures the CaII K line (the strongest metal line in the visible part of the spectrum and thus the best probe at low metallicities), has not been available with any other instrument on board HST. The observations proposed here cannot be done before WFC3 is flown. Therefore this will be a UNIQUE capability for WFC3. This feature is in the blue part of the spectrum (393.3 nm), where the sensitivity of the imagers on HST prior to WFC3 has been poor.

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**PROGRAM: 208**

**TITLE:** Evolution of Distant Cluster Galaxies in the Restframe Ultraviolet

**AUTHOR:** R. O'Connell

**EXAMPLE OF EXISTING PROGRAM:**

Dressler: 5378, 6480  
Dickinson: 5468, 5967

**GOAL OF OBSERVATION:**

The goal of the program is to study the evolution of stellar populations in distant clusters of galaxies by obtaining imaging/photometry in restframe UV wavelengths.

**NEED FOR WFC3:**

This program is based on UV observations of multiple early type galaxies in the centers of clusters of galaxies. The only instrument other than WFC3 with suitable UV sensitivity is the ACS High Resolution Camera. However, the cores of clusters are much larger than the 26x26" field of view of ACS/HRC. For this kind of program WFC3 offers a gain of over 30x in efficiency. This program cannot be undertaken with ground-based telescopes.

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PROGRAM: 210

TITLE: Tracing the Evolution of Elliptical Galaxies: The UV-upturn up to Intermediate Redshifts

AUTHOR: C. M. Carollo

EXAMPLE OF EXISTING PROGRAM:


GOAL OF OBSERVATION:

Elliptical galaxies are known to show an UV upturn that becomes more pronounced as the metallicity of the system increases. However, there are reasons to expect that the UV upturn may depend on age as well, increasing as the population becomes older. Age and metallicity effect are hard to disentangle in z=0 galaxies; probing the UV upturn in giant ellipticals with a lookback time of ~4-5 Gyrs, i.e. at z~0.4-0.5, promises to assess the origin and evolution of the UV upturn and thus substantially clarify the star formation history of the massive spheroidals.

NEED FOR WFC3:

WFC3 offers a unique opportunity to achieve the science goals. The program requires UV observations with high sensitivity over a large field of view so as to image several cluster ellipticals in a single exposure. ACS/HRC could typically observe only one galaxy at a time making the program unpractical. WFPC2 does not have the required sensitivity to detect the upturn over a range of metallicities at the redshift of interest.

PROGRAM: 211

TITLE: UV Color Gradients in Elliptical Galaxies

AUTHOR: R. O'Connell

EXAMPLE OF EXISTING PROGRAM:

O'Connell 7438 (STIS Far-UV Color Gradients)

GOAL OF OBSERVATION:

Study changes in UV-optical colors in nearby elliptical galaxies in order to trace metallicity/age structure.
NEED FOR WFC3:

This program is based on UV observations of nearby elliptical galaxies to large radii (several arcminutes) from their centers. The only instrument other than WFC3 with suitable UV sensitivity is the ACS High Resolution Camera. However, the field of view of the ACS/HRC is much too small (26") for this application. WFC3 offers a gain of over 30x in efficiency. This program cannot be undertaken with ground-based telescopes.

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PROGRAM: 212

TITLE: Survey of the Crab Nebula

AUTHOR: J. Hester & P. Knezek

EXAMPLE OF EXISTING PROGRAM:

Program 5206


GOAL OF OBSERVATION:

A complete survey of the Crab Nebula will be conducted in both lines and continuum emission. Emission line imaging will be employed to study the ionization structure of the filaments. Particular emphasis is placed on imaging in three ionization states of oxygen, as well as imaging in He II and the [Ne V] line at 3426 Angstroms. Polarization observations in line free continuum bands will be used to study the small-scale structure of the magnetic field, to look for spectral index variations within the Crab, and to characterize the distribution of dust within the filaments. The nebula will be observed at two epochs to study the temporal evolution of the filaments.

NEED FOR WFC3:

Only WFC3 has the combination of the large field of view and the extensive complement of needed narrowband filters necessary to complete this program.

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PROGRAM: 214
TITLE: Absolute Age of Globular Clusters from the White and Brown Dwarf Cooling Sequences

AUTHOR: F. Paresce

EXAMPLE OF EXISTING PROGRAM:


GOAL OF OBSERVATION:

Determine a robust lower limit to the age of the universe by determining the age of a globular cluster directly without uncertain assumptions on distance, reddening, dredge-up, convection etc. by accurately measuring the white dwarf cooling sequence turn-over luminosity and by identifying and measuring the luminosity of the brightest cluster brown dwarfs. The combined uncertainties in these two methods should correspond to a few percent uncertainty in globular cluster ages, a level which would seriously constrain the remaining cosmological parameters.

NEED FOR WFC3:

To detect faint, cool ( Te < 2000K ) stars such as old white and brown dwarfs, it is absolutely crucial to work in the 0.8-1.5 micron range where their luminosity has a peak and where the steam and methane features have their maximum contrast with the continuum. Moreover, in order to distinguish them from faint background galaxies in the magnitude range 27< V < 30 requires construction of an accurate two-color diagram. Theory shows that the most discriminating colors are B, V, I and J. Finally, measuring faint stars near the half-light radius of a globular cluster requires high spatial resolution to resolve them from MS stars and especially a large enough FOV to maximize the area covered in one image and, thus, the chances of detecting them. ACS and WFPC2 have no IR sensitivity and NICMOS has too small a FOV at the required spatial resolution. This program can be done only with WFC3.

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PROGRAM: 215

TITLE: Atmospheric Structures of the Outer Planets - UV, Visual and IR Imaging

AUTHOR: J. Trauger

EXAMPLES OF EXISTING HST PROGRAMS:

Not received.
GOAL OF OBSERVATION:

Not received.

NEED FOR WFC3:

Not received.

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PROGRAM: 216

TITLE: Ejecta from Old Stellar Objects, Part I - Optical and IR Imaging

AUTHOR: B. Balick

EXAMPLE OF EXISTING PROGRAM: Related, but not particularly similar programs are 6117, 6353, 6502, 6565, 6816, 7423, 7840

GOAL OF OBSERVATION:
Planetary nebulae (PNe) and their precursors, proto PNe (pPNe) show a vast array of shapes, from circular to elliptical and bipolar. Within these large-scale morphologies lies a host of very symmetric yet complex filaments and jet-like structures, all of which require a very effective collimator to be present (for a color montage see: http://www.astro.washington.edu/balick/WFPC2/plneb.pdf). A stellar mechanism for shaping the flows was never predicted, and attempts to explain the phenomenon post-facto are numerous though largely conjectural. A handful of NICMOS and deep red WFPC2 images show that the shapes are imposed during the pPNe phase. Therefore we plan to observe a carefully selected set of bright, nearby pPNe using WFC3 in order to probe the structure of PNe in a statistical sense, to try to understand when and how the asymmetries in the nebula and/or its stellar winds develop. We will map the morphologies of these nebulae in the [FeII]1.644 micron lines excited by shocks, broadband IR colors, the permitted line of Halpha, and the forbidden line of [NII]. The immediate goal is to identify the collimator that structures the nebular flows, and to ascertain how the collimated flows interact with older ejecta. We will utilize existing complementary data in the literature to see how the geometry and collimation mechanism of outflows depend on the age and mass of the central star.

NEED FOR WFC3:

The critical physical size scales for shocks and ionization fronts are 10^{15} cm, which corresponds to 2 pixels on the WFC3 at typical distances. We will be able to work usefully at the diffraction limit of the telescope throughout most of WFC3’s observable IR window that will be crucial if the differences on the various images are to be compared and exploited over the full image of the nebula.

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EXAMPLE OF EXISTING PROGRAM:

Related, but not particularly similar programs are 6501, 6502.

GOAL OF OBSERVATION:

Our objective is to merge the proposed observations with studies of the LBV eta Car (in related HST proposals) in order to probe the kinematics of bipolar collimation mechanisms in the resolved outflows of low- and high-mass stars. The HST results will be used to constrain detailed 2.5- and 3-D MHD models being developed by Matt, Balick, and Winglee, Garcia-Segura et al, and Frank and Mellema specifically to understand the evolutionary link between stellar evolution and flow collimation processes.

NEED FOR WFC3:

0. Using a series of long and short exposures at various ORIENTs we hope to be able to probe the structures of the nebula deep into the regions of the nucleus. For this excellent linearity and dynamic range are essential. The nuclear regions will be observed in three different ORIENTs so that the bright diffraction spikes of the PSF can be treated as non-repeating events and removed ("roll deconvolution"). Also, the diffraction rings, which scale in size linearly with wavelength, might also be identifiable and removable with some effort.

1. The critical size scales are $10^{15}$ cm, which correspond to 2 pixels in the visible spectrum to about 1 pixel longward of about 1 micron.

2. Of almost equal importance is the addition of wide field imaging in [FeII] at 1.6 microns.

3. WFPC2 efficiency through the F375N filter was only 0.8%, and the observations below would not have been feasible. Thanks to recent improvements in CCDs at 3700A, WFC3 should be a factor of 5 - 8 more efficient over a large field.

Advantage over ACS: WFC3 operates well with the F375N filter. Note: STIS has a F375N filter for the imaging CCD (3% overall efficiency), but its FOV is just 28 x 50 arcsec.
TITLE: WFC3 Grism Survey for Faint Compact Emission Line Objects at z=0.7-2

AUTHOR: R. A. Windhorst

EXAMPLE OF EXISTING PROGRAM:

HST P5985, P6610, P7459, P8388

GOAL OF OBSERVATION:

Use WFC3 to systematically search for faint compact Ly-alpha emitting objects, that are isolated, in groups, filaments and/or in clusters at z ~ 0.7--2. This will be done through blue and red WFC3 grism surveys that cover 2000--10,000 A. The goal is to find large numbers of subgalactic sized objects at z~0.7—2 to constrain the LF of galaxies and its evolution over this epoch, and so directly constrain CDM theories of galaxy formation (c.f. Pascarelle et al. 1996, Nature, 383, 45).

NEED FOR WFC3:

Must go down to 2000 A, and so cover Lya in the critical range z=0.7—2 where the universal star formation rate peaks, which cannot be done with the ACS.

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PROGRAM: 219

TITLE: The Universality of the 2175 A Dust Bump

AUTHOR: D. Calzetti & B. Whitmore

EXAMPLE OF EXISTING PROGRAM:

Similar only in scope, not in technique: GO-5349, P.I.: L. Bianchi

Publications related to the 2175 A bump:

Publication that describes the method at optical wavelengths:

GOAL OF OBSERVATION:

Determine the presence/absence and measure the depth of the 2200 A bump in external nearby, foreground spiral galaxies using background galaxies down to V~22-23. The project requires observing local spiral galaxies, seen almost face on (e.g., NGC6744,
M81, M83, M100). Background galaxies will be observed at a range of wavelengths through the interarm and arm regions, together with control fields. Observations from the UV through the I bands will provide a measure of the total opacity and of the presence and depth of the 2200 A bump. The goal is to determine whether dust in external galaxies is like the "Milky-Way" dust, a key ingredient to understand restframe UV observations of high-z galaxies. Background galaxies with V~22-23 correspond to the typical galaxy at z~0.3. An observing wavelength of 2000 A corresponds to restframe ~1500 A, which is contributed by star formation in the background galaxy. We will use the fact that star formation was a factor ~2-3 larger at z~0.3 than at present times to ensure that a statistically significant sample of background galaxies will be collected.

NEED FOR WFC3:

The capability of UV imaging (< 3000 A) over a large FOV is unique to WFC3 and essential for the success of this program, which requires observing in the UV a statistically significant number of background galaxies seen through a foreground nearby galaxy. In addition, the high UV sensitivity combined with high angular resolution are key to discriminate background galaxies from HII regions residing in the foreground galaxy. UV observations are not possible from the ground, and none of the current/future HST instruments has a large-field capability in the UV.

PROGRAM: 220

TITLE: Hot Stars in Globular Clusters

AUTHOR: R. O'Connell

EXAMPLE OF EXISTING PROGRAM:

GO 6804, 6607, 5969, 5903. Others.

GOAL OF OBSERVATION:

To study the properties of stars in globular clusters with temperatures over 10000 K, especially the hot horizontal branch and related phases of advanced stellar evolution.

NEED FOR WFC3:

This program involves searching the fields of relatively nearby globular clusters for UV-bright stars. The objects of interest have luminosities near or above that of the horizontal branch, so that instrumental sensitivity is not a limiting factor. Instead, the globulars are generally considerably larger in area than the field of view of any HST instrument. The efficiency of the program therefore is in direct proportion to the field of view. Since the WFC3 field is 38x larger than that of the ACS High Resolution Camera, it offers
compelling advantages for this program. Requirements for UV access and high spatial resolution (to eliminate image crowding) mean that ground-based telescopes cannot undertake this program.

PROGRAM: 222

TITLE: An Optical-Near-IR Medium Deep Survey

AUTHOR: C. M. Carollo

EXAMPLE OF EXISTING PROGRAM:

GO 5369, 5370, 5371, 5372, 5971, 6802, 6609
[Im et al. 1999 ApJ 510, 82 (on MDS data);
 Driver et al. 1998 ApJL 496, L93 (on HDF data)]

GOAL OF OBSERVATION:

While the very first galaxies probably formed at very high redshift, z>5, a large fraction of the stars in galaxies today formed a redshift of order 1 or less. Unfortunately, even at these low redshifts optical observations probe wavelengths different from those at which low redshift galaxies are typically studied. The dependence of morphology on the rest frame wavelength makes it extremely difficult to derive solid results on the evolution of a particular population unless the same rest wavelength is adopted in the comparison. Moreover, even for low redshift galaxies one benefits from multiwavelength data so as to be able to disentangle the effect of dust and stellar populations. A four-filters parallel imaging survey with WFC3 is optimal to properly study the morphological (and size) evolution of galaxies with cosmic time.

NEED FOR WFC3:

The optical part of the program could be done with ACS. However, WFC3 offers the unique possibility to carry out the near-IR part of this program that requires high spatial resolution over a large field of view.

PROGRAM: 223

TITLE: The Search for Low Surface Brightness Objects with WFC3

AUTHOR: M. Disney & P. Knezek
EXAMPLE OF EXISTING PROGRAM: None

GOAL OF OBSERVATION:

Much of optical astronomy is surface brightness limited. For instance, most local galaxies may simply be too dim to detect from the ground even with a 10m telescope, while high-z objects are further affected by the \((1+z)^{-4}\) cosmic dimming that may dominate deep imaging programs such as the HDF. In space, particularly in the NIR, the sky is much darker, and very blue, whereas galaxies are generally red. The improved contrast is such that WFC3 should detect galaxies that have a blue surface brightness of \(\mu(B)=35\ \text{mag/arcsec}^2\), i.e. dimmer by \(-7\) magnitudes (a factor of \(~1000\)) than the dimmest galaxies detected so far. We propose to image the recently discovered 21-cm sources with no optical candidates, as well as other candidate low surface brightness galaxies.

NEED FOR WFC3:

This program requires imaging in H-band over large fields of view. Only WFC3 offers this possibility.

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PROGRAM: 224

TITLE: Post-AGB Stars in the Virgo Cluster

AUTHOR: H. E. Bond

EXAMPLE OF EXISTING PROGRAM:

Not received.

GOAL OF OBSERVATION:

Not received.

NEED FOR WFC3:

Not received.

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PROGRAM: 225
**TITLE:** A WFC3 study of faint galaxies at redshifts z~1-12: A direct test of theories of Formation and Evolution Galaxies and Structure

**AUTHOR:** C. M. Carollo, R. Windhorst, & J. A. Frogel

**EXAMPLE OF EXISTING PROGRAM:**

HST P5308, P5985, P6610, P7459, GO/DD 6337, 8058, 8073, 8074, 8075, 8076, GTO 7235

**GOALS OF OBSERVATION:**

Despite the recent progress in our knowledge of the high redshift Universe, we have only begun exploring the nature and distribution of galaxies at redshifts between 1 and 5. These studies require better redshift accuracy than allowed by the by now classical broadband Lyman-break search techniques and efficient ways of selecting candidate objects with strong emission lines. The scientific objectives of this program are: (1) Detect several hundred Ly-alpha emitters and absorbers in the range 1 <= z <= 6.5 and Lyman dropouts for 2.2 <= z <= 12, and study their luminosity function and evolution; (2) Determine accurate photometric redshifts (sigma(z) <= 0.02-0.04) for several thousand faint field galaxies (m_AB <= 28 mag), and their clustering and spectral evolution as a function of Hubble type; (3) Determine the epoch of assembly and formation of massive spheroidal stellar systems by estimating ages for several dozen old and luminous ellipticals at z ~ 1-2; and (4) identify and study galaxy candidates at z ~ 5-12.

**NEED FOR WFC3:**

The requirement of large FOV and high sensitivity in the entire wavelength range of WFC3 is essential for this program. This project cannot be performed with ACS or WFPC2, since they do not have the required medium-band filters, and their linear ramp FOV is far from being large enough.

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**PROGRAM: 226 & 227**

**TITLE:** The Near-IR Luminosity Function of Globular Cluster Main Sequences and of the Galactic Bulge

**AUTHOR:** J. A. Frogel

**EXAMPLE OF EXISTING PROGRAM:**
GOAL OF OBSERVATION:
How does a gas cloud fragment into stars in different environments? Is the mass spectrum that results from fragmentation different in dense globular clusters from what it is in the general field of the Galactic disk or halo? Do the mass distributions depend on the metal abundance of the parent cloud? Is there a cut-off to the mass function? In order to answer these questions we propose to use wide field near-IR imaging capabilities of WFC3 to determine luminosity functions of several types of stellar assemblages. We will study young disk clusters, old globular clusters - both in the bulge and halo - and in the Galactic bulge itself. For each of these type of stellar groups there exists a range in chemical abundances. We will compare our derived luminosity functions with stellar models to convert luminosity to mass and then compare the results with what has been observed in the solar neighborhood. We will search for differences in mass functions that might depend on both Galactic environment and metallicity.

NEED FOR WFC3:

The significant gain for this program of WFC3 over NICMOS is that fact that the areal coverage of WFC3 will be nearly two orders of magnitude greater than it is for NIC2. In order to achieve the goals of this program stellar luminosities must be measured to a precision of no worse than a few percent. NICMOS detectors have large intra-pixel sensitivity variations and the NIC3 camera is greatly under sampled. Thus the accuracy that can be achieved with WFC3 will be significantly greater than that possible with NICMOS. Also, WFC3-IR is expected to have significantly greater QE than the NICMOS chips.

PROGRAM: 227 (see DRM 226)

TITLE: (see DRM 226)

AUTHOR: J. A. Frogel

EXAMPLE OF EXISTING PROGRAM:
(see DRM 226)

GOAL OF OBSERVATION:
(see DRM 226)

NEED FOR WFC3:
(see DRM 226)

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PROGRAM: 228

TITLE: Near-Infrared Imaging of Regions of Star Formation in the Large Magellanic Cloud

AUTHOR: D. DePoy & J. A. Frogel

EXAMPLE OF EXISTING PROGRAM: TBD

GOAL OF OBSERVATION:

Because of their nearness the Magellanic Clouds present us with a unique laboratory in which we can study star formation. We propose to carry out an extensive survey of a region of the LMC that is rich in molecular gas and most likely to be harboring extensive regions of low mass star formation, similar, for example, to the rho Oph complex in the Milky Way. Because of obscuration, a search for these regions and a sensitive study of their content cannot be done optically. Observations in the near-IR, however, can be extremely useful as has been demonstrated by observations of this type of regions in the Milky Way. The survey we are proposing will detect main sequence stars down to K type.

NEED FOR WFC3:

This project cannot be carried out with NICMOS because of its small field of view. WFC3-IR has nearly two orders of magnitude greater areal coverage. Even so, we will still need to obtain deep images of more than 100 separate fields in J and H. The need for wide fields of view and high accuracy photometry makes this project prohibitive even for the new generation of large ground based telescopes with AO.

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PROGRAM: 229

TITLE: Nearby Starbursts and Their Connection with the High-z Luminous Galaxies

AUTHOR: C. M. Carollo

EXAMPLE OF EXISTING PROGRAM: TBD

GOAL OF OBSERVATION:

High luminosity starbursts are spectacular cosmic events which often involve high concentrations of gas and dust, and often huge amounts of energy (and sometimes mass).
A thorough understanding of the origin, properties, and evolution of starbursts is an essential part of studying galaxy evolution in general. A detailed optical plus NIR WFC3 study of a sample of nearby starburst and post-starburst galaxies spanning a vast range in properties will push one step further our understanding of many of the fundamental issues that still remain open about the origin, physics and evolution of starbursts.

**NEED FOR WFC3:**

WFC3 offers unique capabilities in the near-IR thanks to the combination of sensitivity, angular resolution and large field of view. A small fraction of the observations could be done competitively with ACS/WFC. However, WFC3 offers decisive advantages in the blue and provides the required narrow band filters over the full field of view.

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**PROGRAM: 230**

**TITLE:** Determination of Cometary and KBO Sizes Using WFC3

**AUTHOR:** C. Lisse, P. Lamy, & A. Cochran

**EXAMPLE OF EXISTING PROGRAM:**

5312 (Cochran et al., Cycle 4)
7916 (Lamy et al., Cycle 7)
6956 (Brown et al., Cycle 8)

**GOAL OF OBSERVATION:**

Use WFC3 HST observations to determine a comet’s/KBO’s size (assuming an albedo and a phase function), its shape, and its rotation period by measuring its projected cross section (and color) as a function of time. Such observations will greatly improve the meager knowledge we currently have on the planetesimals that populate the Oort cloud and Kuiper Belt and contribute to our understanding of the formation and early evolution of the solar system. If there is any cometary activity, advantage will be taken of the high spatial resolution of the WFC3 to clearly distinguish the nucleus from the surrounding coma, as has been done for 8 previous HST comets. The magnitude of the nucleus/KBO will be measured at eight different times in order to construct a light curve, from which we can derive the shape and rotation period (assuming an albedo and scattering phase function). Observations will be made through several filters (some combination of U, B, V, R, I, J, H depending on the comet’s brightness) to obtain color information. A deep search for the faint end of the KBO population, using the improved capabilities of the WFC3 arrays, will also be performed. This search will also find a number of near-Earth and main-belt asteroids.

**NEED FOR WFC3:**
Cometary nuclei and KBO’s have the highest contrast vs the interplanetary background in the R and I bands, depending on the bodies’ color. The larger FOV, smaller pixels, and higher QE at R and I for the WFC3 will greatly improve the camera’s sensitivity to smaller cometary nuclei and KBO’s, and dramatically increase the number of KBO objects imaged versus the WFC2. Improved WFC3 radiation hardness in the detectors will greatly simplify the interpretation of the faint end of the KBO size distribution, which has been dominated by systematic uncertainties due to cosmic rays in past programs with the WFC2. The improved QE at R and I makes this work more attractive to do with the WFC3 than the ACS, as well as the possibility of using the optimized WFC3 B and U response to make the first KBO detections in these bands.

PROGRAM: 231

TITLE: Pixel Microlensing of M87

AUTHOR: J. Silk & E. A. Baltz

EXAMPLE OF EXISTING PROGRAM: TBD

GOAL OF OBSERVATION:

Monitor M87 for microlensing events in the infrared. Analysis of event rate and timescale distribution will allow us to determine the nature of the lenses, in particular whether they are normal stars in M87, dark objects in the M87 halo, or even dark objects in the Virgo cluster halo. Two colors are required to check achromaticity.

NEED FOR WFC3:

The combination of H band and large field is crucial, as the surface brightness fluctuations from AGB stars are optimized and the large field of ACS makes the experiment feasible. This means that one can perform an experiment that is not feasible with WFPC2, ACS or NICMOS.

PROGRAM: 232

TITLE: The Nature of the Diffuse Ionized Gas in Local Star-Forming Galaxies

AUTHOR: D. Calzetti

EXAMPLE OF EXISTING PROGRAM:
GOAL OF OBSERVATION:

This project aims at determining the distribution and excitation of ionized gas in low-redshift actively star forming galaxies, by measuring variations in the ratio between [FeII](1.64 microns) and Paschen-beta line emission. In order to remove effects of dust obscuration, observations of either the Paschen-alpha line or the [FeII](1.26 micron) line are a requirement for the success of the observing program. J and H broad band filters are also required to sample the galaxy stellar population. A systematic study, over a statistically meaningful sample of galaxies, of the nature of the diffuse gas, and its relation to star formation is long overdue. Understanding how star formation, once triggered, evolves within a galaxy will have profound impact on understanding the evolution of the high-redshift star-forming galaxies. This project uses the IR channel of the WFC3.

NEED FOR WFC3:

This IR project requires the unique combination of wide field and high angular resolution of WFC3-IR that neither HST-NICMOS nor ground-based facilities (even with AO) can provide. Nebular emission from nearby galaxies typically extends over 1-3 arcmin, perfectly matched to the WFC3-IR FOV. High angular resolution, together with the low IR background and stable PSF provided by HST, will allow us to detect and sample extended filaments and structures of ionized gas.

PROGRAM: 233

TITLE: A Search for High-z Emission Line Objects with WFC3-IR Grisms

AUTHOR: J. A. Frogel, P. McCarthy, & P. Osmer

EXAMPLE OF EXISTING PROGRAM: None

GOAL OF EXISTING PROGRAM:

We propose to conduct a search for high redshift emission line objects with WFC3 and its grisms. This survey will be more sensitive than any existing optical and IR survey and have several unique advantages over them. 1) The grisms span a factor of two in wavelength space. 2) The background in space is exceptionally low in this spectral region. 3) Interstellar - and possibly intergalactic - extinction is significantly lower in this spectral region than in the optical - between factors of 2 and 6 relative to that in V. The search can completely cover the range in z space between about 0.9 and 8 with no break and with 3 strong emission lines always present except that for some short intervals there will only be two strong lines. Aside from its sensitivity, the approach we propose
will address the question of what effect, if any, does intergalactic dust have on the observed space density of quasars and, in particular, is dust responsible for the observed drop in quasar space density for $z \geq 3.5$ where extinction by damped Ly-alpha systems may begin to seriously affect optical searches. We also note the possibility of finding distant galaxies with strong emission lines: all wavelengths between H alpha and H gamma will be present for nearly the entire range in $z$ that we will be able to survey.

**NEED FOR WFC3:**

On NICMOS the grisms are used with NIC3. The areal coverage of WFC3-IR will be more than a factor of 10 greater than that of NIC3, greatly extending the size of discovery space. In addition, the IR detectors for WFC3 will have substantially higher QE and uniformity that those in NICMOS. Also, NIC3 is still not quite in focus which even in grism mode reduces somewhat its sensitivity for point sources. Finally we point out that this type of survey would be impossible to carry out from the ground because of the sky background falling on the detectors in slitless grism mode.

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**PROGRAM: 234**

**TITLE:** Determination of Asteroidal Size and Surface Composition Using WFC3

**AUTHOR:** A. Storrs, C. Lisse, B. Zellner, & F. Vilas

**EXAMPLE OF EXISTING PROGRAM:**

6481 (Zellner et al. Cycle 6)
6559 (Storrs et al. Cycle 6)
7443 (Mccarthy et al. Cycle 7)

**GOAL OF OBSERVATION:**

Use WFC3 HST observations to determine the size, shape, rotational pole, surface variegation, and presence of companion objects for a variety of large main-belt asteroids. This will be done by measuring the projected cross section (and color) as a function of time. Such observations will greatly improve the meager knowledge we currently have on the planetesimals that populate the asteroid belt and contribute to our understanding of the formation and early evolution of the solar system. The asteroid will be imaged at five consecutive orbits in order to construct a complete map of the surface (most main belt asteroids rotate with periods of 5-7 hours). Observations will be made through several filters (F439W, F606W, F814W, F953N in the UVIS camera, and F110W, F124W, F145M, F171M, and F187N in the NIR camera, if available) in order to isolate the continuum and 1 and 2 micron silicate bands. The presence of a 0.7 micron water of hydration feature will be determined for C type asteroids. This search will be sensitive to the presence and composition of any companion bodies (satellites).
NEED FOR WFC3:

The silicate bands have the highest contrast in the NIR. The larger FOV, smaller pixels, and higher QE at these wavelengths for the WFC3 will greatly improve the camera’s sensitivity to surface features on large bodies, and dramatically increase the number of companion objects imaged versus the WFC2. The ability to image in the NIR using the same instrument with no time delay makes this work more attractive to do with the WFC3 than NICMOS/NCS.

PROGRAM: 235

TITLE: Star Formation History of the Galactic Center

AUTHOR: D. Figer & B. Whitmore

EXAMPLE OF EXISTING PROGRAM: TBD

GOAL OF OBSERVATION:

The Galactic Center contains an active star formation region with rather unique conditions compared to elsewhere in the Galaxy. In fact, the strong magnetic field, large turbulent velocities, and strong tidal field, may be more akin to the properties in starburst nuclei or merging galaxies. Such environments may have an elevated lower mass cutoff, such as has been suggested for the Galactic Center. A deep survey of the Galactic Center will directly measure the lower mass cutoff and IMF slope, directly testing the hypothesis that the former is greater than 1 Msun, and the latter is relatively flat.

The proximity and stellar content of our own Galactic Center make it an ideal testing ground for ideas concerning inner bulge formation. This closest example of an inner bulge contains features common to a large number of galaxies, i.e. active ongoing star formation and an ancient component; unfortunately, intervening dust blocks our view and has led to the odd situation that nearby inner bulges are more completely studied than our own. Understanding the formation mechanism of our own Galactic Center is an important stepping stone to understanding bulge formation (and galaxy formation) in other galaxies.

The goal is to construct color-magnitude diagrams which can be used to infer the star formation history of the Galactic Center.

NEED FOR WFC3:

The IR channel of the WFC3 provide a unique capability which is required for the success of this program, since only in the IR can we penetrate the dust toward the Galactic Center.
PROGRAM: 236

TITLE: Searches for Brown Dwarfs in Star-Forming Regions

AUTHOR: K. Noll, B. Whitmore, & P. Knezek

EXAMPLE OF EXISTING PROGRAM: TBD

GOAL OF OBSERVATION:

All-sky surveys will have increased the number of known brown dwarfs into the thousands by the advent of WFC3. However, because objects in the field are of unknown age it is impossible to determine the initial mass function (IMF) for brown dwarfs without making uncertain assumptions. In star-forming clusters, however, it is possible to constrain the ages of observed objects. By searching for and finding brown dwarfs and very low mass stars in nearby clusters of known age it will be possible to determine the IMF in the brown dwarf mass range. This will allow us to address several basic questions such as:

- do substellar objects contribute significantly to the mass of the galaxy?

- is there a continuum of objects through the brown dwarf mass range?

- conversely, is there evidence for a break in the mass distribution; evidence of multiple formation processes operating in the substellar mass range?

- do environmental factors, such as the presence of massive stars, affect the IMF?

The goal of this project is to perform a statistically significant search for brown dwarfs in several nearby star forming regions such as Taurus. Very-low-mass stars and brown dwarfs will be identifiable by their optical-infrared colors. The initial mass function at masses near and below the substellar mass limit will be determined from these observations.

NEED FOR WFC3:

Brown dwarfs are many magnitudes brighter in the infrared than at optical wavelengths, hence the IR channel of the WFC3 provides a unique capability that will be required for the success of this program.

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TITLE: Very Low Mass Luminosity Function in Young Clusters

AUTHOR: E. Young

EXAMPLE OF EXISTING PROGRAM: TBD

GOAL OF OBSERVATION:

The goal of this program is to survey a number of young star clusters in intermediate width infrared filters and to identify the lowest mass members. The infrared water and ammonia features are prominent in the atmospheres of cool stars and substellar objects and can be used to unambiguously identify the lowest mass population in the cluster. The strength of these features is very temperature sensitive, and these observations can be used to determine spectral types of even extremely faint objects. This survey will be sensitive to both isolated and companion low mass objects. Coupling these results with pre-main sequence evolutionary tracks will lead to a determination of the Initial Mass Function (IMF) in these clusters.

NEED FOR WFC3:

The success of this program relies on a number of unique capabilities of WF3. The spectral coverage, sensitivity, and wide field of view are all required to conduct this investigation. One of the key temperature discriminators in very low mass stars is the 1.45 micron water vapor band. These observations must be done in space since the 1.45 micron spectral region is badly corrupted by telluric water vapor absorption. Although appropriate filters exist on NICMOS, they are only present on Camera 1 which only has a 12” field of view. The sensitivity of WF3 is also critical for the success of this investigation. Although it might be possible to do ground-based observations in the wings of the water vapor band, WF3 will have unparalleled sensitivity since it will not suffer from the atmospheric OH background. Since this investigation is searching for the very lowest mass objects in these clusters, this sensitivity is essential.

The wide field of view combined with the improved sensitivity of WF3 means that we will be able carry out this program 100-200 times faster than with NICMOS.

PROGRAM: 238

TITLE: Mars Surface and Atmospheric Studies Using WFC3

AUTHOR: J. Bell, M. Wolff, & P. James

EXAMPLE OF EXISTING PROGRAM:
GOAL OF OBSERVATION:

Use WFC3 HST observations of Mars to: (1) Quantify the abundance and spatial/temporal distribution of atmospheric ozone and water vapor; (2) Determine the opacity, composition, and time variability of atmospheric aerosols (dust, water ice, CO$_2$ ice), including the growth and evolution of dust storms and other atmospheric disturbances; (3) Monitor the seasonal and interannual variations of surface and atmospheric volatile transport, especially in the polar regions; and (4) Detect and map the distribution of specific surface mineralogies. These goals will be met using narrow- and medium-band imaging from the UV through the near-IR, timed to most effectively sample the seasonal and diurnal timescales of a wide range of phenomena. These observations will provide direct information on the current Martian climate, including the transport of water vapor and CO$_2$ among different planetary reservoirs and the radiative effects of dust and other aerosols. They will also provide indirect information on the past Martian climate, through models of the formation of oxidized or hydrated surface minerals. In addition to these purely scientific goals, the observations will also provide support for ongoing NASA Mars spacecraft missions by providing complementary synoptic measurements at UV and near-IR wavelengths that are not being studied by any current or planned NASA instruments, and at a spatial scale that cannot be achieved using groundbased telescopes.

NEED FOR WFC3:

WFC3 offers three primary advantages over other instruments for Mars work: First is UV spectral imaging capability, in order to obtain high resolution information on the spatial distribution of atmospheric ozone and water ice clouds. Second is the ability for near-simultaneous imaging in the UVIS and near-IR using the same instrument, allowing contiguous spectral coverage across the mineralogically-important silicate bands in the 1 micron and 2 micron regions. Third is the higher spatial resolution and higher QE of WFC3 compared to other instruments, greatly improving the camera’s sensitivity to small surface features and/or weak spectral contrast on Mars. An additional advantage would be provided by the ability to perform high spatial resolution NIR spectroscopy with the WFC3 grism, if a grism is eventually incorporated into the baseline WFC3 design.

PROGRAM: 239

TITLE: The Structure of Starburst Galaxies

AUTHOR: D. Calzetti
EXAMPLE OF EXISTING PROGRAM:

GO-8234, Calibrating Star-Formation with the Metal-Rich Starburst Galaxy M83 (NGC5236), P.I. D. Calzetti

GOAL OF OBSERVATION:

This is a study of the spatial and temporal structure evolution of bursts of star formation, of their link with the host galaxy and, ultimately, of the connection between low and high redshift galaxies. The feedback mechanism between the starburst and the host galaxy’s interstellar medium produces a highly inhomogeneous environment that determines the appearance, duration, and evolution of the starburst. The goal of this observation is to obtain UV, optical, and IR broad-band and optical narrow-band [OII](3727 A), H-beta, [OIII](5007 A), H-alpha+[NII](6584 A), and [SII](6730 A) images of nearby starburst galaxies with z<=0.022. The broadband images sample the stellar populations and its dust reddening. The narrowband images map the distribution of photoionized and shocked gas and of the gas reddening, in and beyond the region of star formation. H-alpha emission and broadband colors of stellar clusters provide age maps, to investigate the temporal and spatial evolution of the starburst. We will investigate the variations of the physical conditions across the bursting regions and the spatial extent of the optically visible burst. The starburst phenomenon will be therefore placed in a proper context within the host galaxy. The impact of this study is beyond the investigation of the structure of local starburst galaxies. Starbursts may be the prevalent way to form stars in a galaxy, and may have had a predominant role in the evolution of primeval galaxies (Steidel, Adelberger, Giavalisco, Dickinson & Pettini 1999, ApJ, 519, 1; Madau, Ferguson, Dickinson, Giavalisco, Steidel & Fruchter, 1996, MNRAS, 283, 1388). Understanding the evolution of bursts of SF will ultimately shed light on the evolution of galaxies.

NEED FOR WFC3:

The main target of this project is to obtain line emission images and broad-band UV and IR imaging over a large FOV (to sample extended filaments and structures of ionized gas and to discriminate young from old stellar populations). Existing HST-UV instrument do not have either the sensitivity (WFPC2 or ACS-WF) or the large field of view (STIS or ACS-HRC) required for the success of this project. In addition, the complement of optical narrow band filters available on HST is either insufficient for the project (ACS) or does not cover the redshifted wavelengths (WFPC2) needed to probe extragalactic targets. In the IR, the combination of high-angular resolution and large FOV is crucial for the project. This proposal cannot be carried out from the ground because it requires high angular resolution to resolve spatial structures and stellar populations within galaxies, and low background in the IR, in addition to a stable PSF.

PROGRAM: 240
TITLE: Ultraviolet Parallel Survey

AUTHOR: J. MacKenty

EXAMPLE OF EXISTING PROGRAM: None

GOAL OF OBSERVATION:

Obtain moderately deep near UV observations of a more than 100 fields together with B and R band observations of the same fields. These observations will provide an improved measurement of the evolution of the high star formation rate galaxies since z~1 and a source catalog of objects with excess UV (e.g. blue dwarf galaxies, low redshift QSOs, and white dwarf stars).

NEED FOR WFC3:

WFC3 offers much greater sensitivity in the near UV than WFPC2 and greater area than ACS at wavelengths < 300nm. Discovery efficiency should be at least 10 times high than either predecessor science instrument.

4 Conclusions

A representative set of example proposals has been written for both the UVIS and IR channels of WFC3. This set consists of 43 individual proposals, 40 of which were actually translated into estimated exposure times and numbers of HST orbits using the WFC3 Exposure Time Calculator. Overall, these proposals broadly cover the anticipated areas of astronomy where WFC3 will have a significant scientific impact. These areas include the solar system, galactic stars and the interstellar medium, resolved stellar populations, galaxies in the Local Universe, and the Universe at high redshifts. Results of the translation of these proposals into actual exposure times, as well as statistics on the usage of filters, binning, subarrays, different gains, etc., within the proposals have helped to establish the scientific priorities of WFC3, determine instrument capability trade-offs, and understand the data volume requirements of the instrument.

Acknowledgements

The WFC3 SOC and Science IPT would particularly like to thank those astronomers in the astronomical community not directly involved in WFC3 who took the time to participate in writing one or more proposals. Those individuals are Chris Burrows, Steve Heathcote, Knut Olsen, Jon Morse, Darren DePoy, Phillipe Lamy, Anita Cochran, Edward Baltz, Pat Osmer, Alex Storrs, Ben Zellner, Faith Vilas, Don Figer, Keith Noll, Jim Bell, Mike Wolff, and Philip James.
References


