Hubble Space Telescope

Cycle 17 GO/DD Proposal

Star Formation in Nearby Galaxies

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Scientific Category: UNRESOLVED STELLAR POPULATIONS

Scientific Keywords: STAR FORMATION, RESOLVED STELLAR POPULATIONS, STELLAR POPULATIONS IN EXTERNAL GALAXIES

Instruments: WFC3

Proprietary Period: 0

Orbit Request	Prime	Parallel
Cycle 17	110	0

Abstract

Star formation is a fundamental astrophysical process; it controls phenomena ranging from the evolution of galaxies and nucleosynthesis to the origins of planetary systems and abodes for life. The WFC3, optimized at both UV and IR wavelengths and equipped with an extensive array of narrow-band filters, brings unique capabilities to this area of study. The WFC3 Scientific Oversight Committee (SOC) proposes an integrated program on star formation in the nearby universe which will fully exploit these new abilities. Our targets range from the well-resolved R136 in 30 Dor in the LMC (the nearest super star cluster) and M82 (the nearest starbursting galaxy) to about half a dozen other nearby galaxies that sample a wide range of star-formation rates and environments. Our program consists of broad-band multiwavelength imaging over the entire range from the UV to the near-IR, aimed at studying the ages and metallicities of stellar populations, revealing young stars that are still hidden by dust at optical wavelengths, and showing the integrated properties of star clusters. Narrow-band imaging of the same environments will allow us to measure star-formation rates, gas pressure, chemical abundances, extinction, and shock morphologies. The primary scientific issues to be addressed are: (1) What triggers star formation? (2) How do the properties of star-forming regions vary among different types of galaxies and environments of different gas densities and compositions? (3) How do these different environments affect the history of star formation? (4) Is the stellar initial mass function universal or determined by local conditions?

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Target Summary:

Target	RA	Dec	Magnitude
MESSIER-085	12 25 24.0000	+18 11 28.00	
NGC-4150	12 10 33.6000	+30 24 6.00	
NGC-4592	12 39 9.0000	-00 31 33.00	
NGC-2841	09 22 2.6000	+50 58 35.00	
NGC-5128	13 25 28.9100	-43 00 18.50	
MESSIER-083	13 37 6.8000	-29 50 21.00	

Target	RA	Dec	Magnitude
MESSIER-083-POS2	13 36 46.7000	-29 52 36.00	
NGC-4214	12 15 39.2000	+36 19 37.00	
MESSIER-082	09 55 52.2000	+69 40 47.00	
R136	05 38 42.3000	-69 06 3.00	
NGC-3603	11 15 6.6000	-61 15 40.00	

Observing Summary:

Target	Config Mode and Spectral Elements	Flags	Orbits
MESSIER-085	WFC3/UVIS Imaging F225W		8
	WFC3/UVIS Imaging F336W		
	WFC3/UVIS Imaging F555W		
	WFC3/UVIS Imaging F814W		
	WFC3/IR Imaging F110W		
	WFC3/IR Imaging F160W		
	WFC3/UVIS Imaging F487N		
	WFC3/UVIS Imaging F658N		
	WFC3/UVIS Imaging F438W		
NGC-4150	WFC3/UVIS Imaging F225W		8
	WFC3/UVIS Imaging F336W		
	WFC3/UVIS Imaging F555W		
	WFC3/UVIS Imaging F814W		
	WFC3/IR Imaging F110W		
	WFC3/IR Imaging F160W		
	WFC3/UVIS Imaging F487N		
	WFC3/UVIS Imaging F438W		
	WFC3/UVIS Imaging F656N		
NGC-4592	WFC3/UVIS Imaging F225W		10
	WFC3/UVIS Imaging F336W		
	WFC3/UVIS Imaging F555W		
	WFC3/UVIS Imaging F814W		
	WFC3/IR Imaging F110W		
	WFC3/IR Imaging F160W		

Target	Config Mode and Spectral Elements	Flags	Orbits
	WFC3/UVIS Imaging F658N		
	WFC3/UVIS Imaging F438W		
NGC-2841	WFC3/UVIS Imaging F225W		7
	WFC3/UVIS Imaging F336W		
	WFC3/UVIS Imaging F438W		
	WFC3/UVIS Imaging F555W		
	WFC3/UVIS Imaging F814W		
	WFC3/IR Imaging F110W		
	WFC3/IR Imaging F160W		
	WFC3/UVIS Imaging F658N		
NGC-5128	WFC3/UVIS Imaging F225W		11
	WFC3/UVIS Imaging F336W		
	WFC3/UVIS Imaging F438W		
	WFC3/UVIS Imaging F555W		
	WFC3/UVIS Imaging F814W		
	WFC3/IR Imaging F110W		
	WFC3/IR Imaging F160W		
	WFC3/UVIS Imaging F658N		
	WFC3/UVIS Imaging F487N		
	WFC3/UVIS Imaging F502N		
	WFC3/UVIS Imaging F673N		
	WFC3/IR Imaging F128N		
	WFC3/IR Imaging F164N		
	WFC3/UVIS Imaging F373N		
MESSIER-083	WFC3/UVIS Imaging F225W		11
	WFC3/UVIS Imaging F336W		
	WFC3/UVIS Imaging F438W		
	WFC3/UVIS Imaging F555W		
	WFC3/UVIS Imaging F814W		
	WFC3/IR Imaging F110W		
	WFC3/IR Imaging F160W		
	WFC3/UVIS Imaging F658N		
	WFC3/UVIS Imaging F487N		
	WFC3/UVIS Imaging F502N		

Target	Config Mode and Spectral Elements	Flags	Orbits
	WFC3/UVIS Imaging F673N		
	WFC3/IR Imaging F128N		
	WFC3/IR Imaging F164N		
	WFC3/UVIS Imaging F373N		
MESSIER-083-POS2	WFC3/UVIS Imaging F225W		11
	WFC3/UVIS Imaging F336W		
	WFC3/IR Imaging F110W		
	WFC3/IR Imaging F160W		
	WFC3/UVIS Imaging F438W		
	WFC3/UVIS Imaging F555W		
	WFC3/UVIS Imaging F814W		
	WFC3/UVIS Imaging F658N		
	WFC3/UVIS Imaging F373N		
	WFC3/UVIS Imaging F487N		
	WFC3/UVIS Imaging F502N		
	WFC3/IR Imaging F128N		
	WFC3/IR Imaging F164N		
	WFC3/UVIS Imaging F673N		
NGC-4214	WFC3/UVIS Imaging F225W		8
	WFC3/UVIS Imaging F336W		
	WFC3/UVIS Imaging F438W		
	WFC3/UVIS Imaging F555W		
	WFC3/UVIS Imaging F814W		
	WFC3/IR Imaging F110W		
	WFC3/IR Imaging F160W		
	WFC3/UVIS Imaging F487N		
	WFC3/UVIS Imaging F502N		
	WFC3/UVIS Imaging F673N		
	WFC3/IR Imaging F128N		
	WFC3/IR Imaging F164N		
	WFC3/UVIS Imaging F373N		
	WFC3/UVIS Imaging F656N		
MESSIER-082	WFC3/UVIS Imaging F225W		9
	WFC3/UVIS Imaging F336W		

Target	Config Mode and Spectral Elements	Flags	Orbits
	WFC3/UVIS Imaging F438W		
	WFC3/UVIS Imaging F555W		
	WFC3/UVIS Imaging F814W		
	WFC3/IR Imaging F110W		
	WFC3/IR Imaging F160W		
	WFC3/UVIS Imaging F487N		
	WFC3/UVIS Imaging F502N		
	WFC3/UVIS Imaging F673N		
	WFC3/IR Imaging F128N		
	WFC3/IR Imaging F164N		
	WFC3/UVIS Imaging F373N		
	WFC3/UVIS Imaging F656N		
R136	WFC3/UVIS Imaging F336W		21
	WFC3/UVIS Imaging F438W		
	WFC3/UVIS Imaging F814W		
	WFC3/IR Imaging F160W		
	WFC3/IR Imaging F128N		
	WFC3/UVIS Imaging F656N		
	WFC3/UVIS Imaging F555W		
	WFC3/IR Imaging F110W		
	WFC3/IR Imaging F164N		
NGC-3603	WFC3/IR Imaging F160W		6
	WFC3/IR Imaging F110W		
	WFC3/IR Imaging F127M		
	WFC3/IR Imaging F139M		
	WFC3/IR Imaging F153M		
	WFC3/IR Imaging F098M		
	WFC3/IR Imaging F128N		
	WFC3/IR Imaging F164N		
	WFC3/UVIS Imaging F656N		
	WFC3/UVIS Imaging F673N		

Total prime orbits: 110

Scientific Justification

Not required.

Description of the Observations

The primary goal of this proposal is to observe star formation in a wide range of environments in the local universe in order to determine how star formation is triggered, how it is regulated through feedback, and the degree to which it is universal. These different environments dictate the need for a range in observing strategies. The targets are therefore broken into the following four groups: 1) S0 galaxies in the Virgo Cluster, 2) nearby "quiescent" galaxies, 3) nearby "starbursting" galaxies, 4) and local young star clusters. While the observing strategies vary considerably for these four groups, we provide a degree of commonality by observing with the same seven broad-band filters (F225W, F336W, F438W, F555W, F814W, F110W, F160W), plus a narrow-band Hα filter, whenever feasible.

1) S0 galaxies in the Virgo Cluster: The goal of these observations is to measure the star cluster formation history back to $\sim$ 10 Gyr, and to use this as a fossil record of the assembly history of two S0 galaxies known to have recent star formation. For clusters younger than $\sim$ 1 Gyr, we will quantify merger-induced star formation, both temporally and spatially, by studying substructure (including young cores and globular clusters) as a probe of star formation history and mass assembly. A 'pixel-by-pixel' analysis combining NUV, optical, NIR and narrow-band Hβ photometry, will enable us to accurately quantify the age, mass and spatial distribution of young stars in the target galaxies. Internal substructure and young stellar populations have been clearly detected for the two program galaxies by previous work (e.g. using SAURON and GALEX). We will leverage off an extensive body of existing corollary data in the UV, optical, infrared and radio for these galaxies.

	F225W	F336W	F438W	F487N	F555W	F656N or F658N	F814W	F110W	F160W	total
M 85	3200	1700	1900	2000	1300	2000	2000	2000	2000	~8 orbits
N 4150	3200	1700	1900	2000	1300	2000	2000	2000	2000	~8 orbits

2) Nearby "quiescent" galaxies: The goal is to measure the current and recent star formation in normal star forming galaxies. An important sub-theme is to study the properties of young star clusters, where most star formation occurs. More specifically, we will determine how universal the processes of star and star cluster formation are (e.g., are the Schmidt law, cluster size and mass functions, and fractions of star formation in clusters/field the same in different environments). In addition we will explore various triggering mechanisms such as propagating star formation. Seven broad-band filters will be used to simultaneously solve for age, extinction, and metallicity using a maximim likelihood algorithm and a variety of population synthesis models (e.g., Bruzual & Charlot, Starburst99, etc). Hα observations will also be taken to help characterize the most recent star formation (i.e., in the past 10 Myr).

The exposure times are designed to reach $S/N = 5$ for a 10 Myr cluster with $M_v = -4$ and a typical extinction $A_V = 0.5$ in most of the bands. In a few cases (e.g., F160W observations in the more distant galaxies) we are not able to reach this design goal, but are generally within about one magnitude. We impose boundary conditions of 500 seconds at the low end (i.e., we can go deeper than the design goal without costing much time) and 6000 seconds at the high end (in the regime where additional exposure time only allows us to go slightly deeper).

	F225W	F336W	F438W	F555W	F658N	F814W	F110W	F160W	total
N 4592	1000	1000	1000	6000	1300	6000	2000	2000	~10 orbits
N 2841	1000	500	500	500	2000	2000	6000	6000	~7 orbits

3) Nearby "starbursting" galaxies: Many of the goals here are similar to those described for item 2 above. However, we will also take advantage of the high rates of star formation, and corrresponding strong nebular emission lines, to study a number of physical processes (e.g., shock parameters, gas pressure, ionization parameters, star formation rates, abundances, etc.) which are important for triggering and regulating star formation. Using the models of Kewley & Dopita (2007), we will quantify the energetics and the stellar energy feedback in the nucleus and the ISM of the observed galaxies, and we will identify outflows and supernova remnants in order to calculate both the local and global energy balance in the galaxies. We are interested in the role of feedback in a variety of galactic physical and metallicity environments, and in particular, the determination of the efficiency parameter for feedback. Note that two positions are taken for M83, an inner position including the nucleus and an outer location where star formation is more quiescent.

(Broad Band)

	F225W	F336W	F438W	F555W	F814W	F110W	F160W	total
NGC 5128	1000	500	500	500	800	1600	4000	~4 orbits
M 83 (in)	800	500	500	500	900	1600	4000	~4
M 83 (out)	800	500	500	500	900	1600	4000	~4
NGC 4214	500	500	500	500	500	700	3000	~3
M 82	500	500	500	500	500	500	900	~2

(Narrow Band)

	F373N	F487N	F502N	F658N or F656N	F673N	F128N	F164N	total
NGC 5128	3600	2800	3000	800	1200	1300	2600	~7 orbits
M 83 (in)	3600	2800	3000	800	1200	1300	2600	~7
M 83 (out)	3600	2800	3000	800	1200	1300	2600	~7
NGC 4214	1000	2000	700	700	2800	1300	2600	~5
M 82	3600	2800	3000	800	1200	1300	2600	~7

4) Local young star clusters (R136 in 30 Dor): The goal of these observations is to accurately determine the IMF of R136 down to the H-burning limit ($\sim 0.1\,M_\odot$). This requires deep imaging with both UVIS and NearIR channels in order to detect and measure the lowest mass objects, which are in their pre-Main Sequence phase. The most suitable bands for this task are F814W and F160W, since the $I - H$ colour provides a large baseline that is particularly useful for estimating the mass of the pre-MS stars by comparing their position in the CMD with theoretical evolutionary sequences. Another consideration is the nebulosity which gives rise to widely varying and patchy absorption. Multi-band photometry must then be used to properly estimate the extinction towards individual objects. This requires the availability of two filters across the Balmer discontinuity (in our case F336W and F438W), combined with measurements in two other filters at longer wavelengths (F555W and the F814W). Finally, in order to measure the accretion rate of pre-MS stars, deep Hα (F656N) exposures will be taken. The matching continuum will be derived from the neighbouring F814W and F555W bands. For compatibility with the rest of the program, short (1000 sec) exposures in F110W, F128N (Paβ) and F164N [FeII] will also be taken, the latter to probe shock fronts.

	F336W	F438W	F555W	F656N	F814W	F110W	F128N	F160W	F164N	total
R 136	12000	5000	5000	10000	10000	1000	1000	8000	1000	~21 orbits

NGC 3603: While many of the goals are similar to those for R136, the much higher extinction for this target compromises some of the measurements at short wavelengths. However, the proximity of the cluster provides the opportunity to use strong H2O bands in the IR which arise in very cool stars to allow spectral classification of M, L, and T dwarfs. By using four colors, we can produce reddening-free indices that can be used even in moderately embedded clusters. The exposure times are designed to reach a depth sufficient to determine the mass function down to 10 $M_{Jupiter}$, hence allowing us to characterize the mass function below the stellar mass limit.

	F656N	F673N	F098M	F110W	F127M	F128N	F139M	F153M	F160W	F164N	total
N 3603	1000	1000	2000	500	2000	1000	2000	2000	500	1000	~6 orbits

PHASE II DETAILS

More detailed observing strategies will be worked out in phase II, and will be tailored to each specific target. However, here are a few general considerations.

Long exposures will be made up of many 20 min images with a small dithering pattern to improve the PSF sampling. In some cases, short exposures (e.g., 30 sec) will also be taken to recover bright stars that would otherwise saturate, especially for nearby bright star clusters (e.g., R136 in 30 Dor, NGC 3603). We have done a detailed duplication check and there are several galaxies for which we could use ACS observations (e.g., NGC 2841, M83, M82) to save a few orbits. In phase II we will decide whether this savings is worth the various

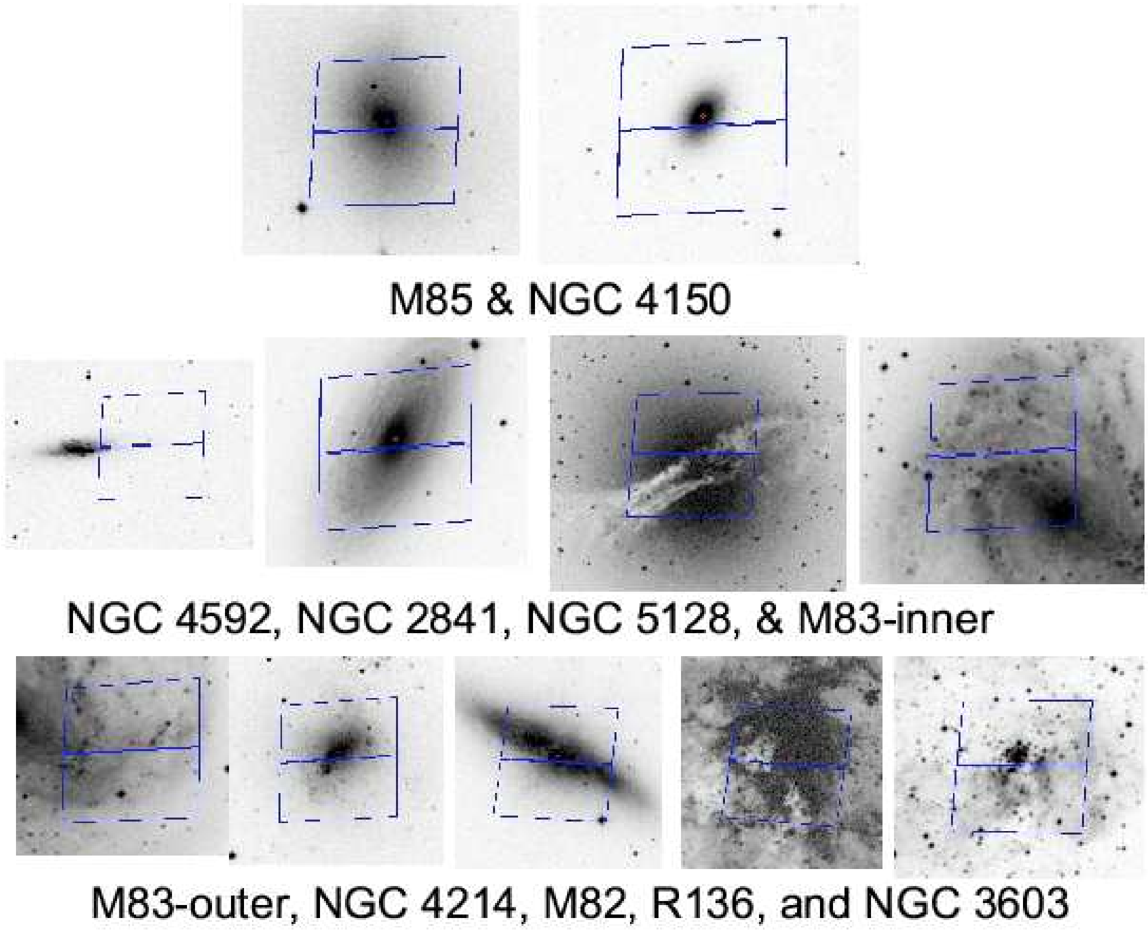

Figure 1: A mosaic of the proposed pointings.

difficulties and compromises to the scientific utility of the dataset (e.g., the images would not be oriented and aligned exactly the same, hence some objects would be lost around the edge.) In addition, we will append ACS parallel observations to some fields (e.g., R136 in 30 Dor) in phase II.

Figure 1 shows a mosaic of the various pointings.

Special Requirements

Coordinated Observations

Justify Duplications