HUBBLE'S INSTRUMENTS AND SYSTEMS

Primary Mirror
Hubble's primary mirror is made of a special glass coated with aluminium and a compound that helps reflect ultraviolet light. The mirror is 2.4m in diameter and reflects incoming light onto the secondary mirror.

Aperture door
Hubble's aperture door can be closed if Hubble is in danger of letting light from the Sun, Earth or Moon into the telescope.

Fine Guidance Sensor (FGS)
Hubble has three FGSs onboard. Two of them are used to point and lock the telescope on the target; while the third is used for stellar position measurements, also known as astrometry.

Space Telescope Imaging Spectrograph (STIS)
Repaired during SM4, the Space Telescope Imaging Spectrograph is a versatile multi-purpose instrument taking full advantage of modern technology. It contains a camera and spectrograph and covers a wide range of wavelengths from the near infrared region into ultraviolet.

Cosmic Origins Spectrograph (COS)
COS is a third generation instrument and compliments the STIS instrument by obtain spectra in both the near and far ultraviolet. It will provide new views on the on the origin and nature of large-scale structures in the universe. It sits in the slot previously used by the COSTAR package.

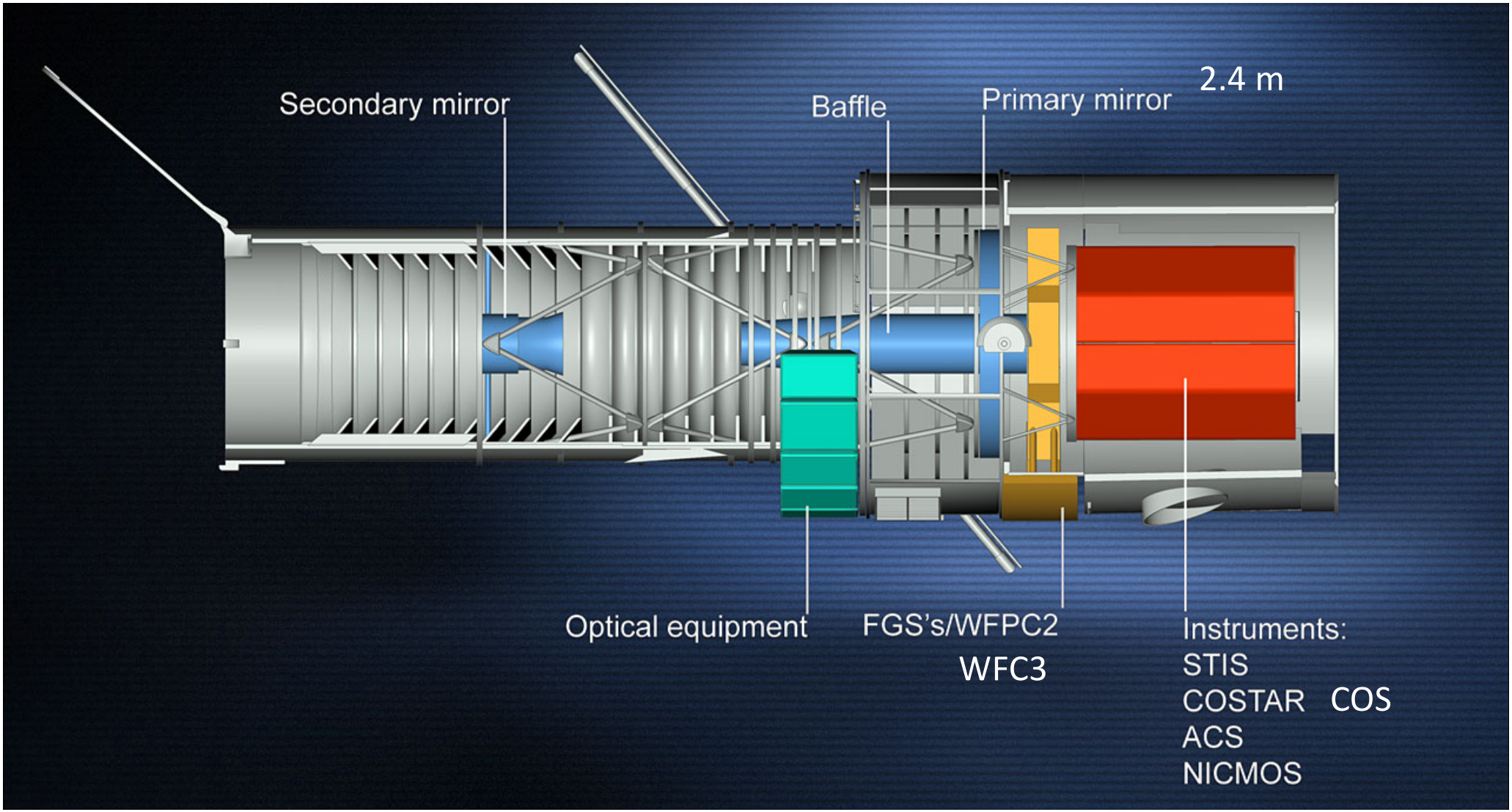
Near Infrared Camera and Multi-Object Spectrometer (NICMOS)
NICMOS is an instrument for near-infrared imaging and spectroscopic observations of astronomical targets and detects light with wavelengths between 800 to 2500 nanometres.

Advance Camera for Surveys (ACS)
Repaired during SM4, the Advance Camera for Surveys (ACS) is a second generation instrument. Its wide field of view allows it to map regions of the sky in detail and compliments the observation abilities of WFC3.

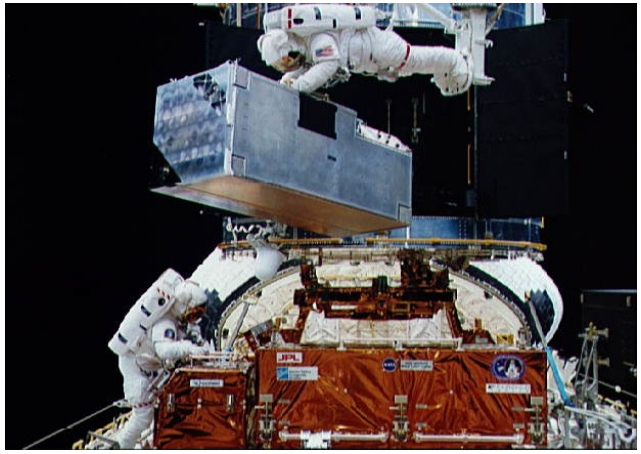
Wide Field Camera 3 (WFC3)
WFC3 is the final upgrade to the backbone of Hubble imaging and replaces WFPC2. This latest camera is panchromatic and records detailed images across a broad wavelength from the near infrared through visible and on to the near ultraviolet. It will allow scientists to see how the structure of galaxies changes at different stages in the Universe.

Support systems
Containing essential support systems such as computers, batteries, gyroscopes, reaction wheels and electronics.

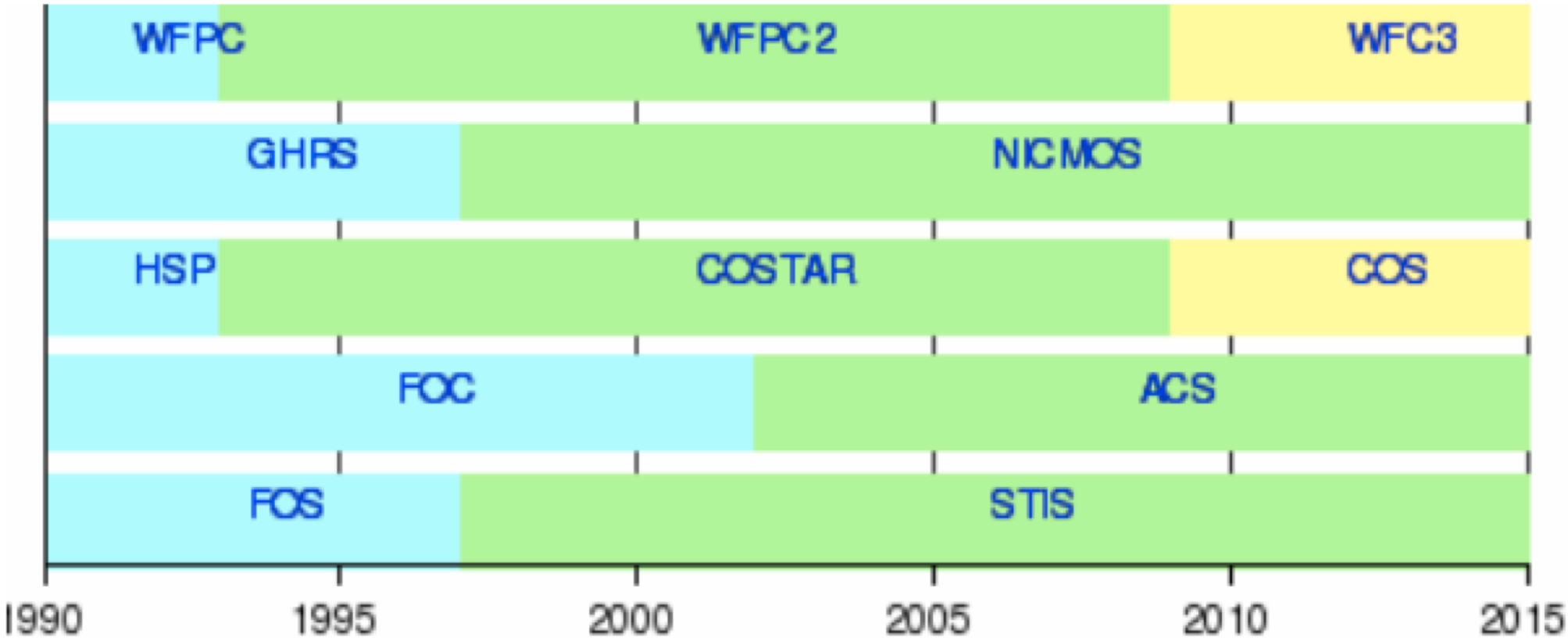
Instruments: COS, STIS, ACS, WFC3



Timeline of servicing …



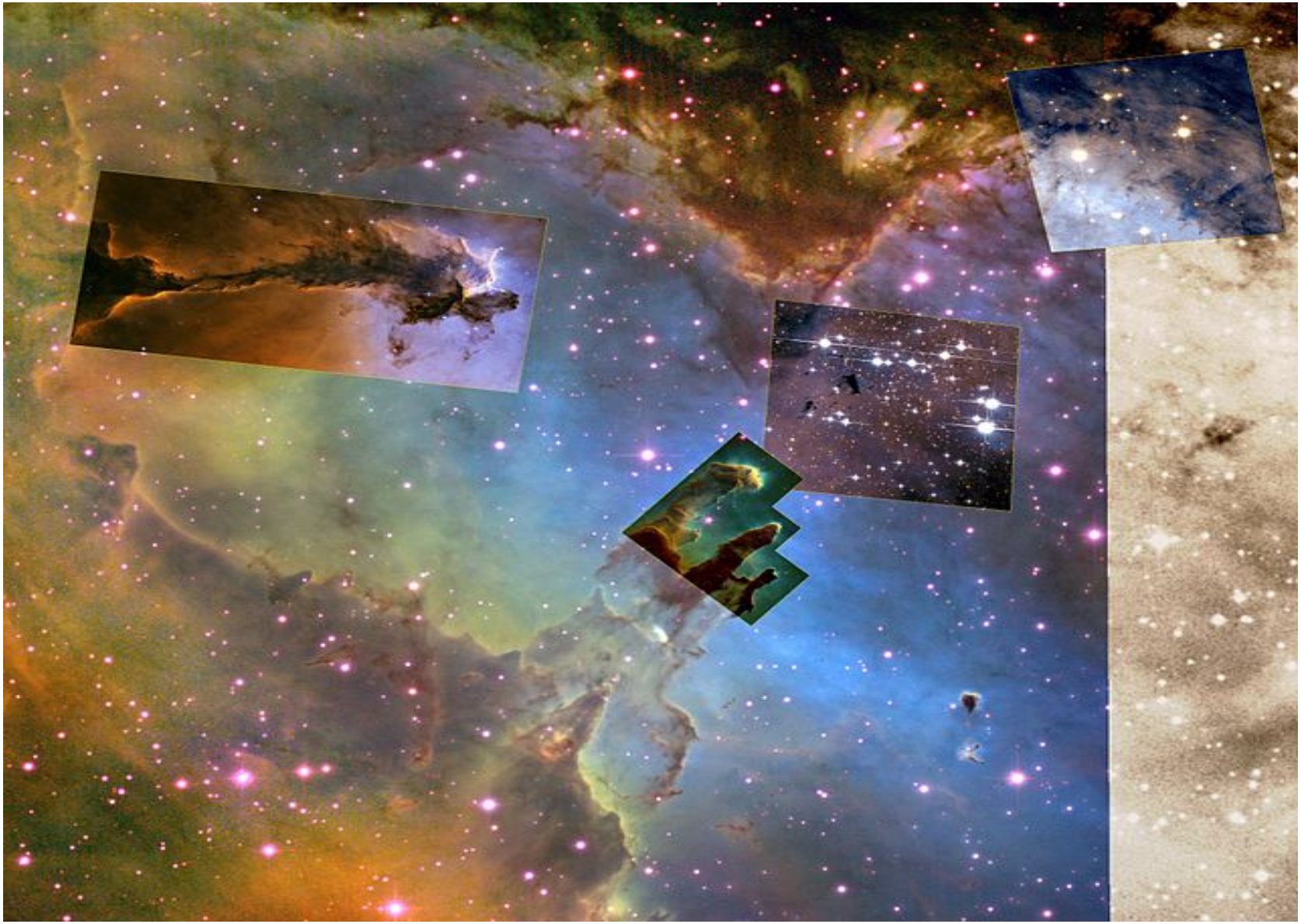
SM1: 1993 SM2: 1997 SM3: 2002 SM4: 2009



Imaging: NICMOS, ACS, WFC3

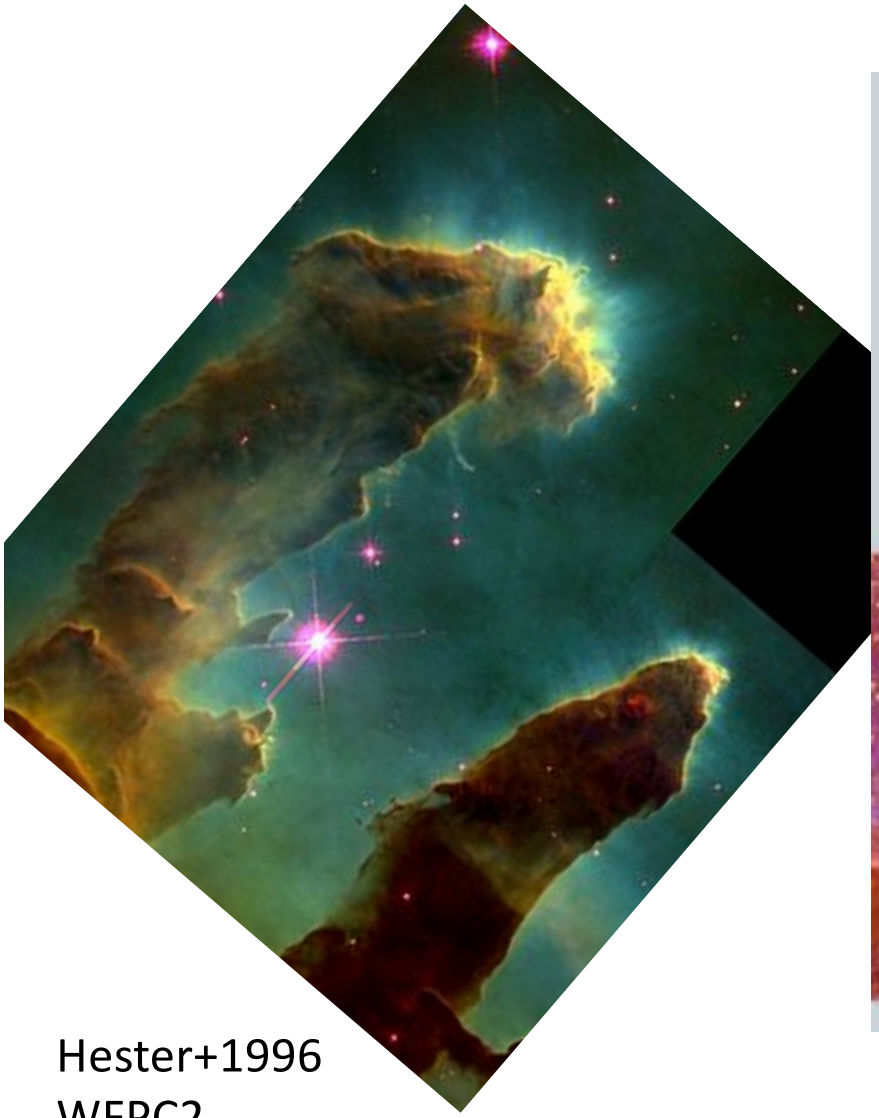
NICMOS: Near Infrared Camera and Multi-Object Spectrometer

Obscured SF: Eagle Nebula

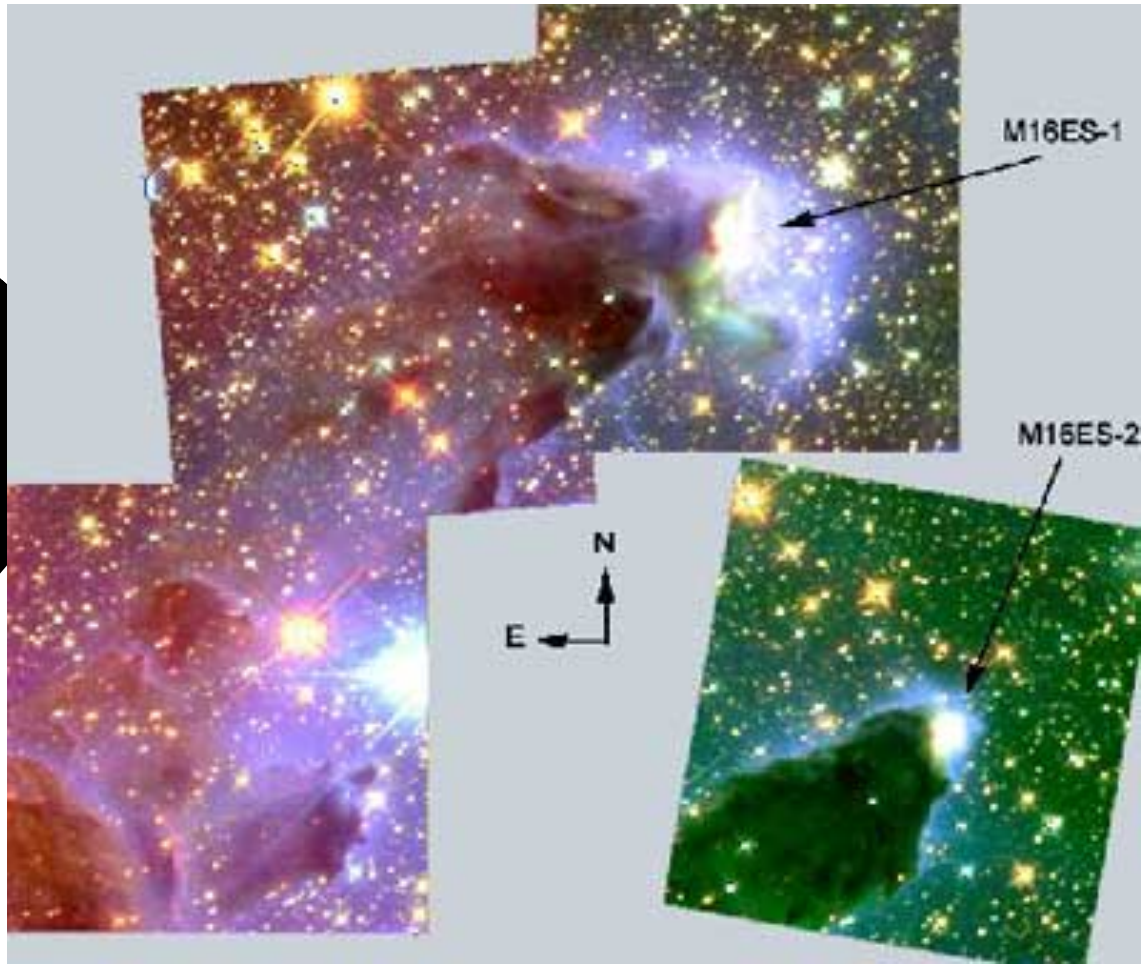


NICMOS:

Obscured SF: Pillars of Creation in the Eagle Nebula

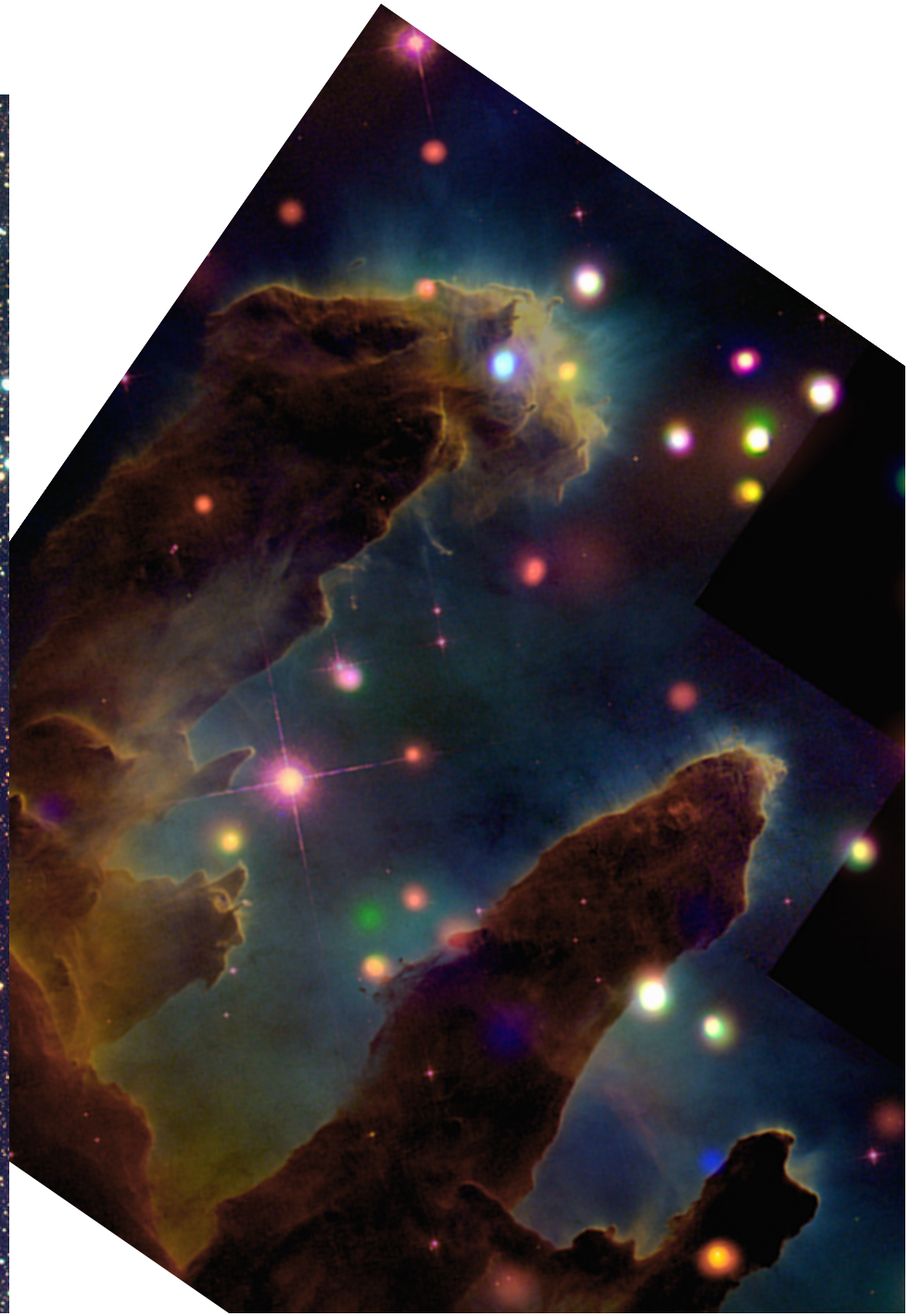


Hester+1996
WFPC2

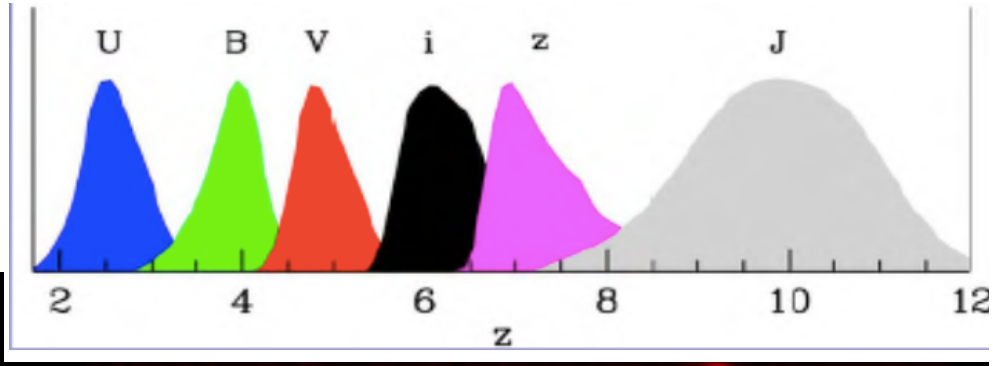


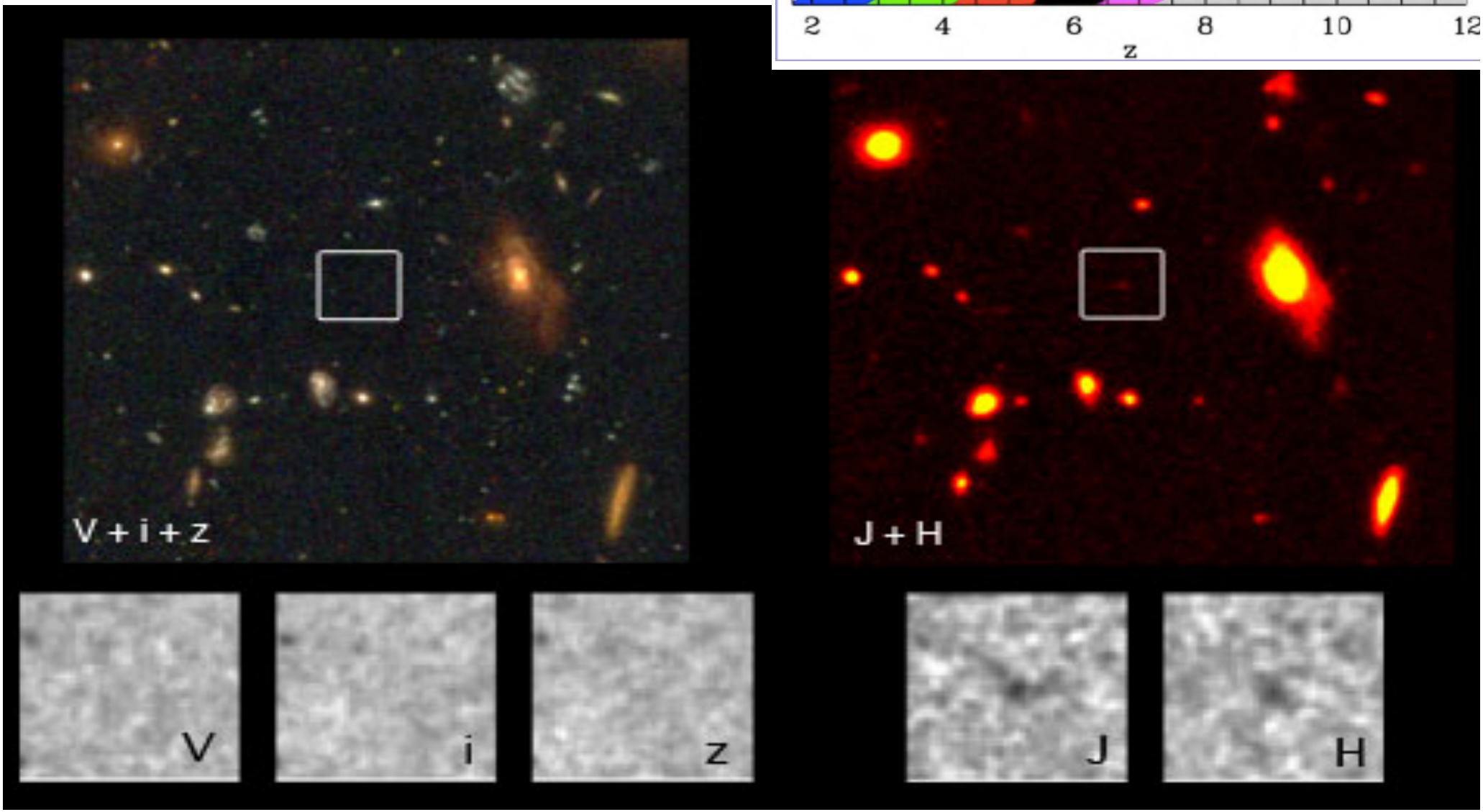
NICMOS: F110W, F160W, F222M

Thompson + 2002



NICMOS: IR UDF
z~7 galaxies





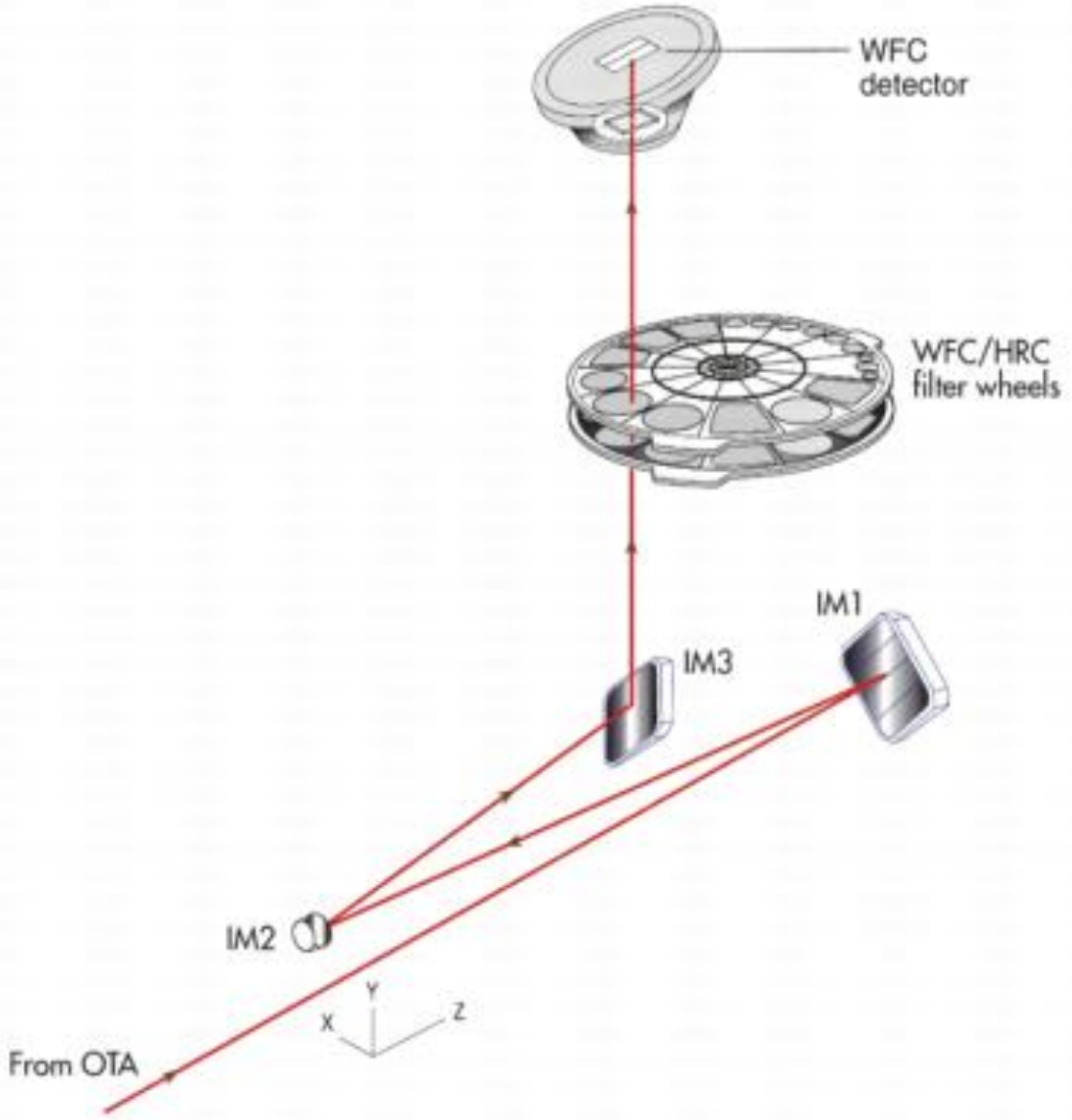
Bouwens + 2004, Thompson 2004

Lyman Break Galaxies (LBGs)

Advanced Camera for Surveys (ACS)

- Added in 2002 (SM3-B), replacing Faint Object Camera
- Wide Field optical and near infrared camera
- 3 Sub-instruments
  - **Wide Field Channel (WFC)** – optical and near-IR camera & Grism spectroscopy
  - High Resolution Channel (not operational)
  - Solar Blind Channel (SBC) FUV Imaging & Prism spectroscopy

ACS: Wide Field Camera (WFC)



Wavelength Range: 350-1050 nm

Peak efficiency at 700 nm
Optimized for optical and near IR

Mosaic of 2 CCD detectors
15 x 15 µm pixels

Plate scale 0.05”/pixel (spatial resolution)

FOV 202” x 202 “

Filter wheel options

Science with ACS/WFC: Deep Wide Field Imaging

The Mice

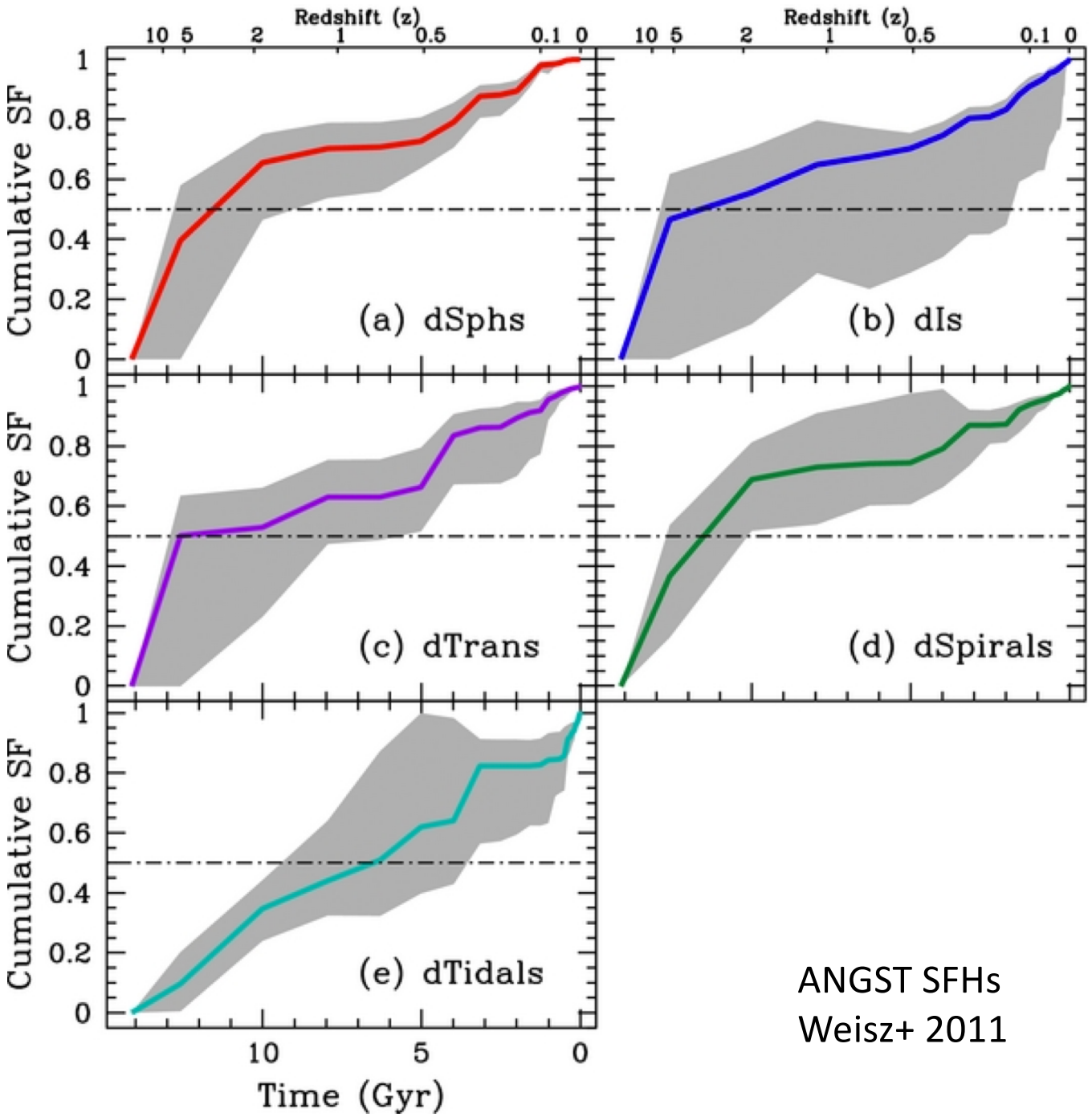
The Tadpole

ACS Nearby Galaxy Survey Treasury Program (ANGST)

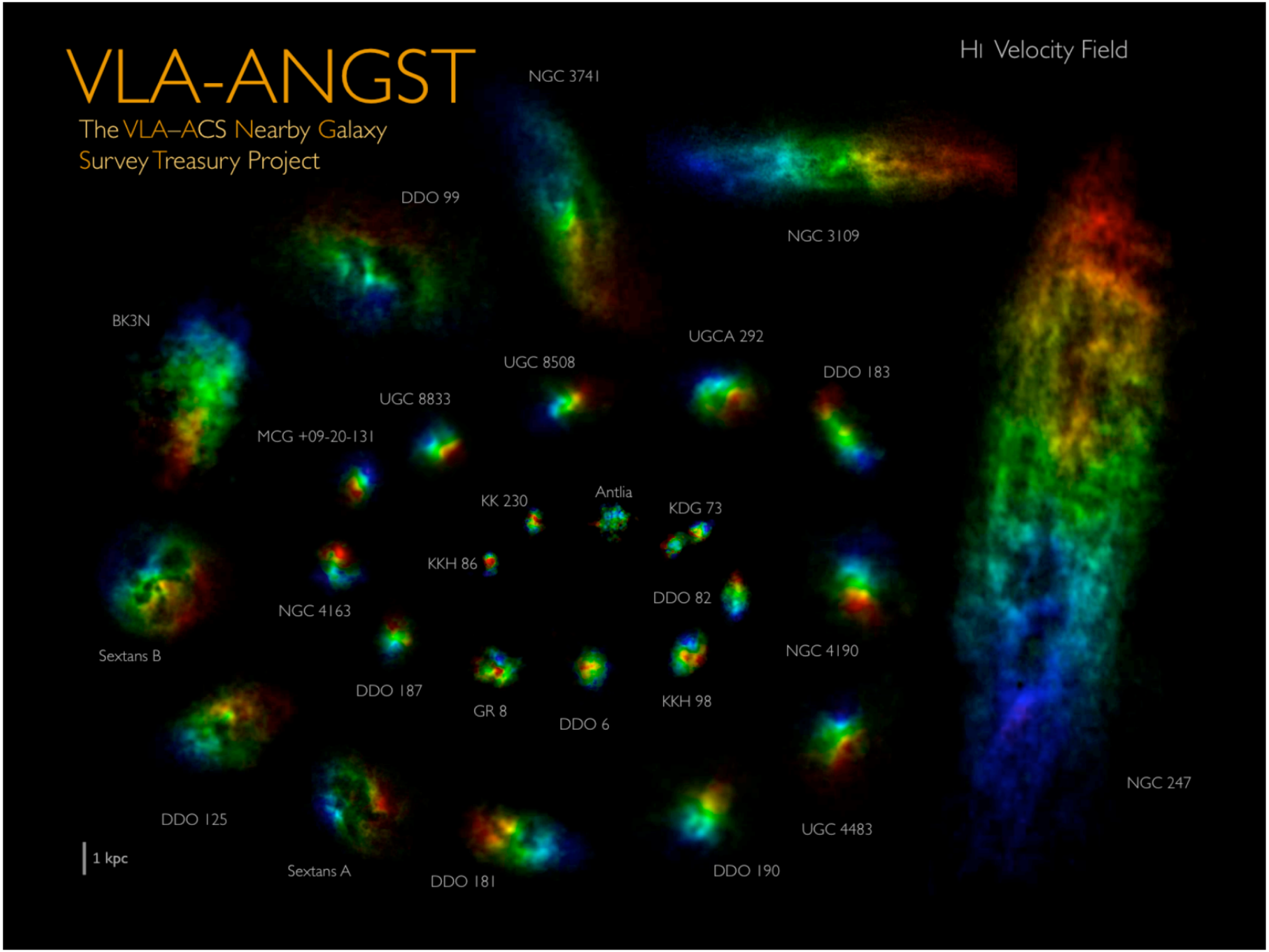
69 galaxies within the Local Volume ~ 30 Mpc - all galaxies > M33

NGC 253

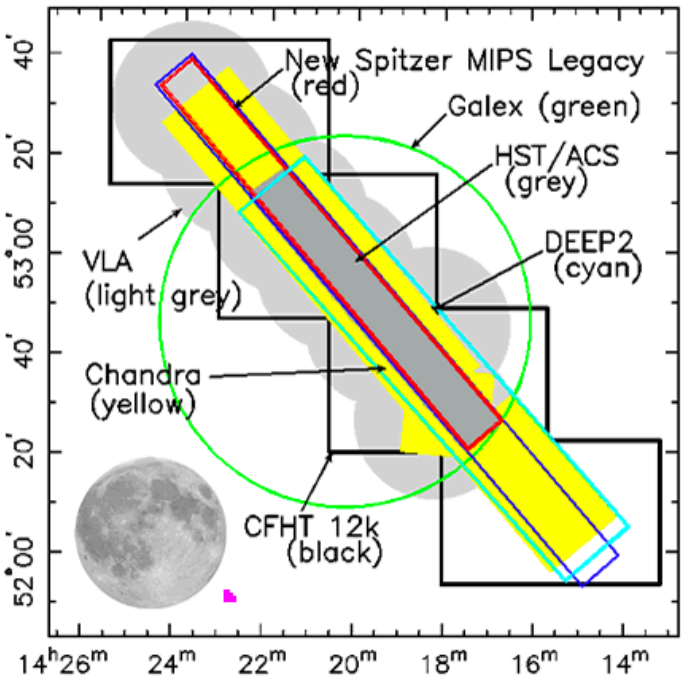
ACS Nearby Galaxy Survey Treasury Program (ANGST)



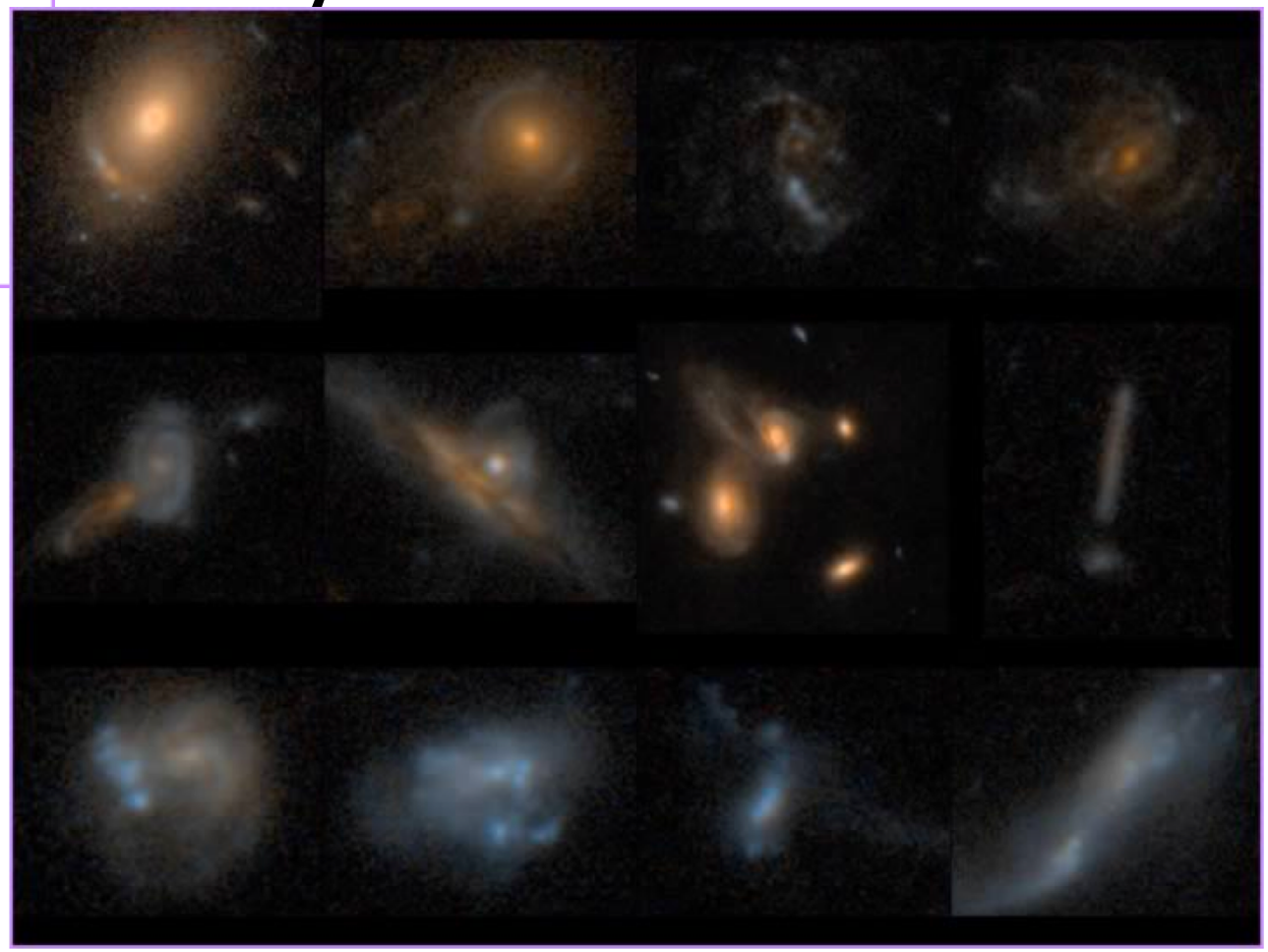
ANGST SFHs
Weisz+ 2011


VLA-ANGST
The VLA–ACS Nearby Galaxy Survey Treasury Project
HI Velocity Field
NGC 3741
DDO 99
NGC 3109
BK3N
UGCA 292
UGC 8508
DDO 183
UGC 8833
MCG +09-20-131
KK 230
Antlia
KDG 73
KKH 86
DDO 82
NGC 4163
Sextans B
NGC 4190
DDO 187
GR 8
DDO 6
KKH 98
NGC 247
DDO 125
UGC 4483
1 kpc
Sextans A
DDO 181
DDO 190

Surveys
AEGIS: ACS/Nicmos
PI : Marc Davis
Cycle 13: 10134



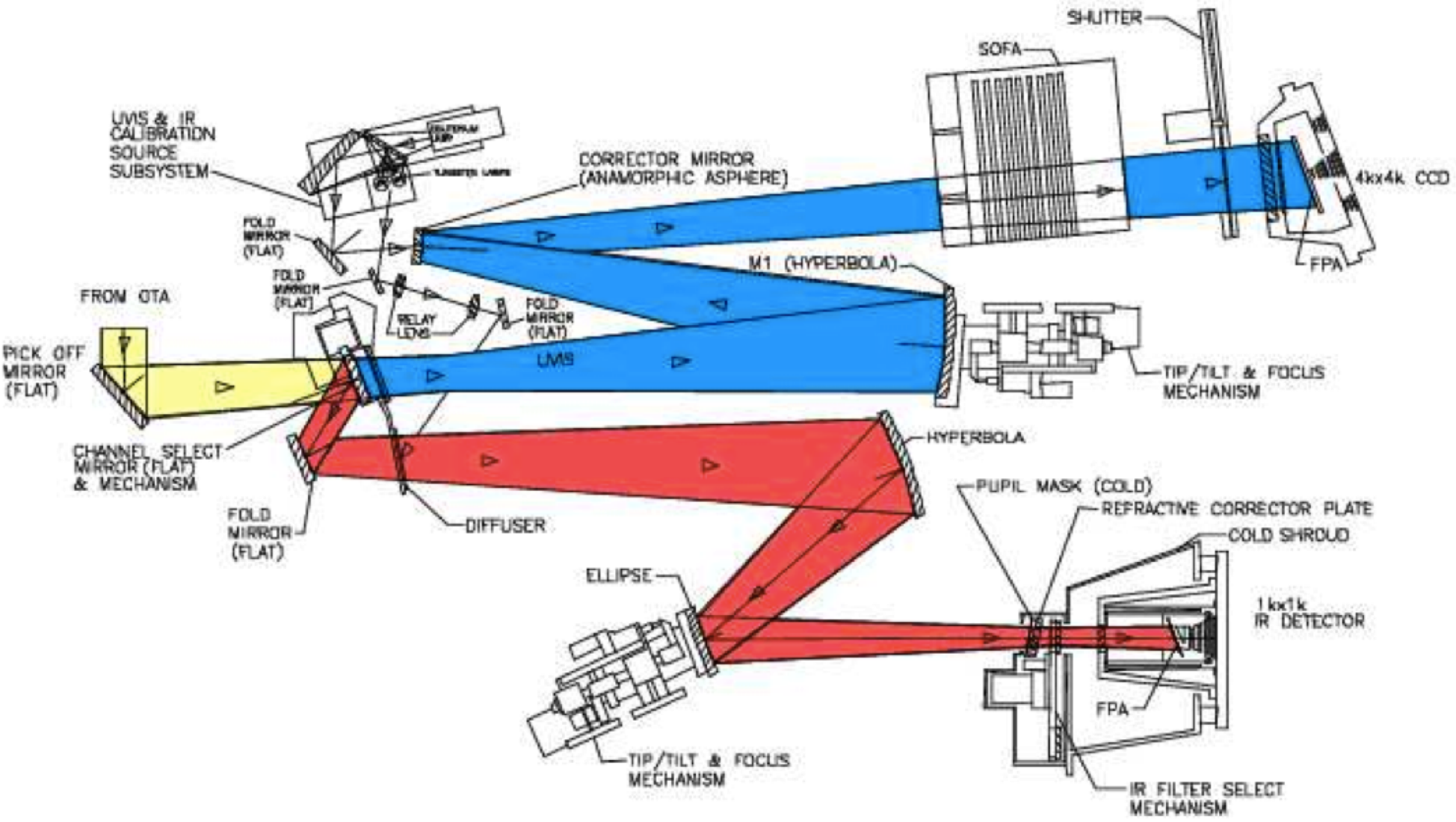
Evolution and assembly
of galactic disks



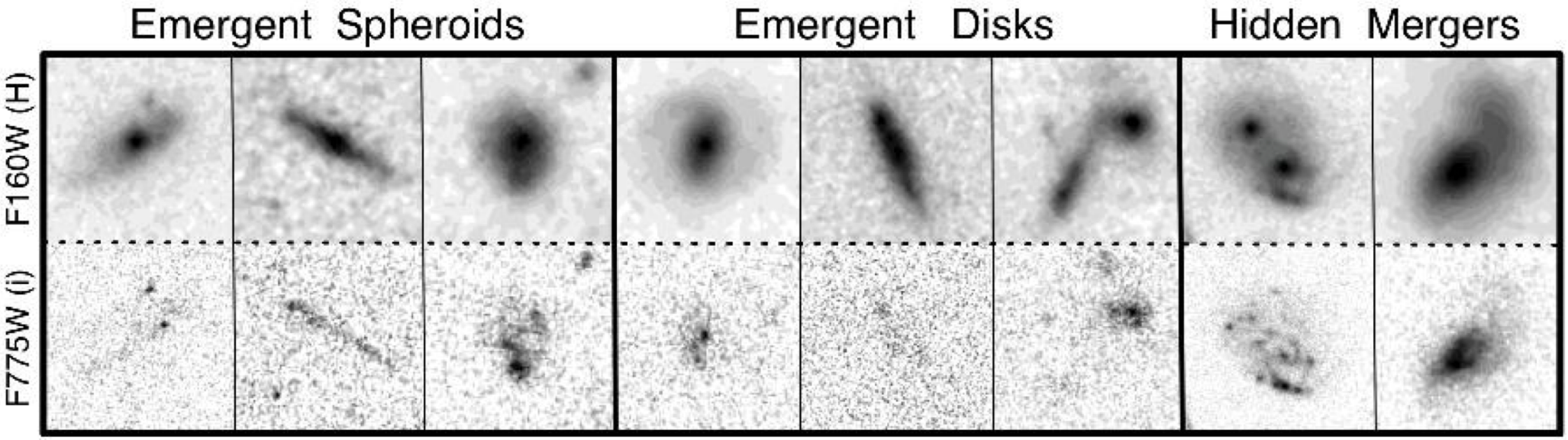
Wide Field Camera 3 (WFC3)

- Installed in 2009 SM4
- NUV, Visible, **NIR** – broader range of wavelengths than ACS (panchromatic)
- 1 UVIS girsm, 2 IR grisms: slitless spectroscopy
- Often used in tandem with ACS
- 2 channels: filters
  - UVIS : 200-1000 nm, pixel size 0.04”/pixel 2 CCDs
    FOV 162 x 162 “ (35x over HRC)
  - NIR : 800-1700 nm pixel size 0.13”/pixel HgCdTe
    FOV 123 x 137 “ (15-20 x over NICMOS)

Wide Field Camera 3



Cosmic Noon (1<z<3): CANDELS

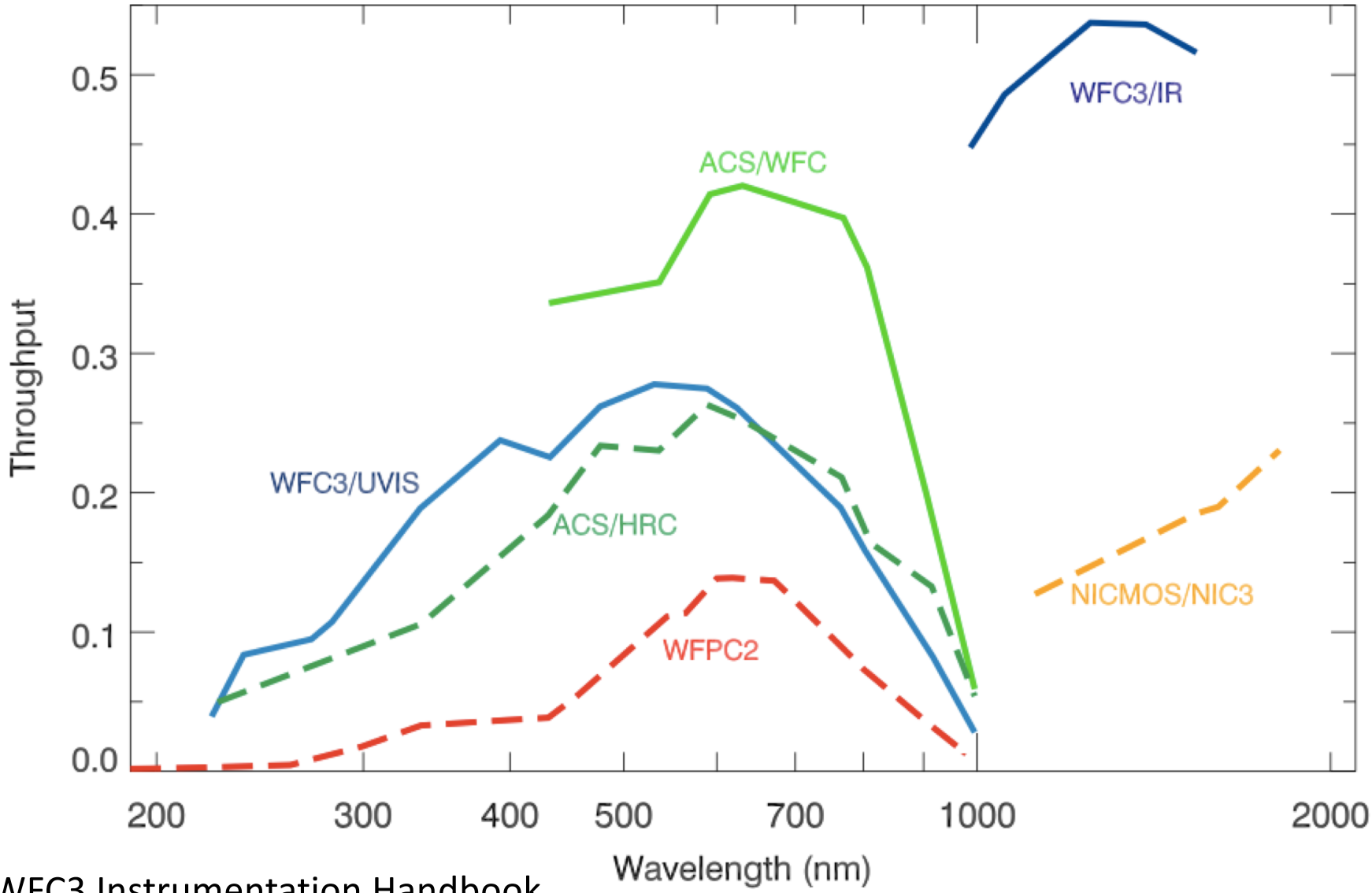


Comparison of 4-orbit F775W- and 2-orbit F160W-band images of selected galaxies in the UDF, highlighting the advantages of using WFC3 to study distant galaxy structure.

WFC3 F160W-band images are critical for revealing the true stellar mass distribution of these galaxies, unbiased by young stars or dust extinction.

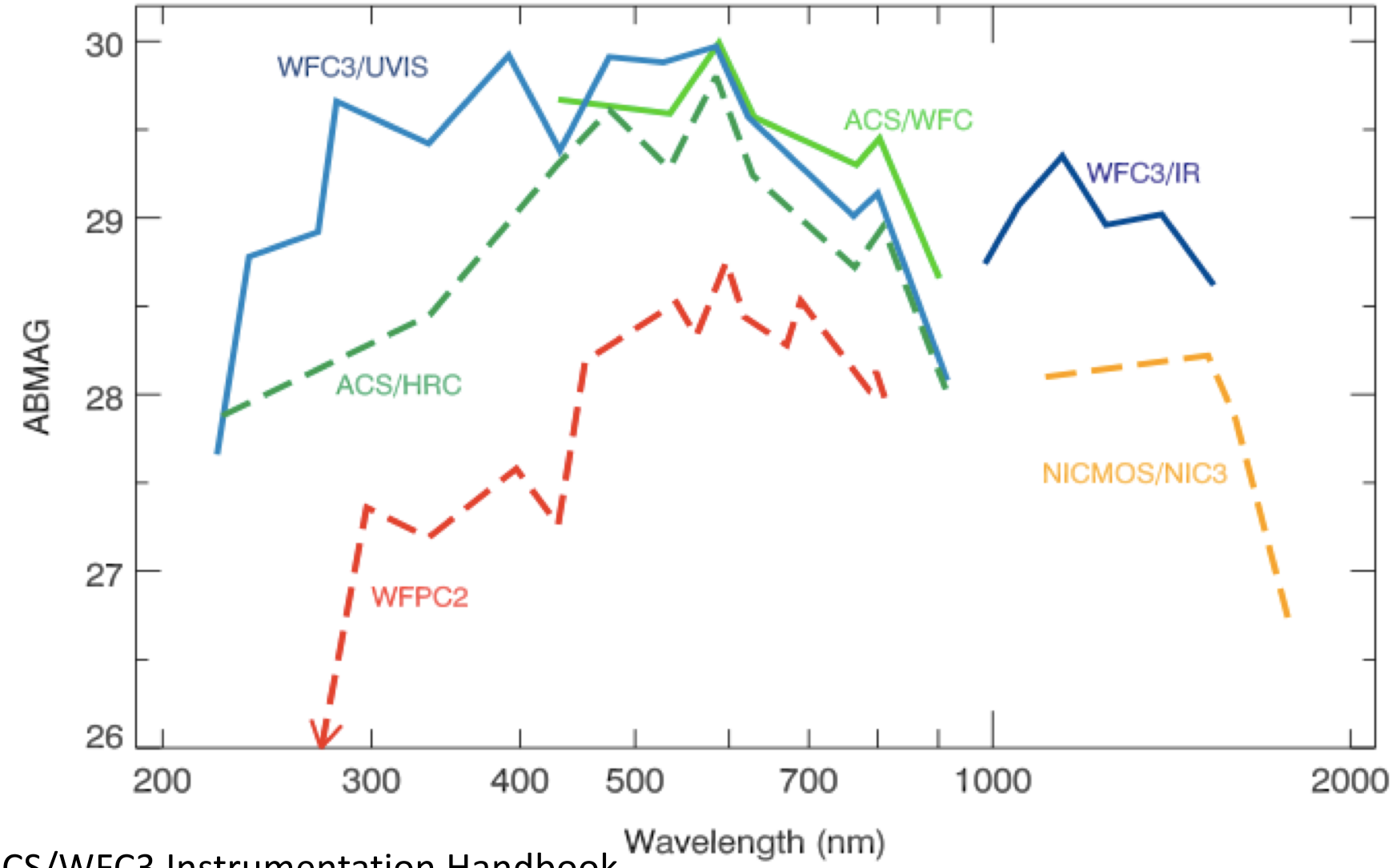
Throughput

Figure 2.1: *HST* total system throughputs as a function of wavelength.



ACS/WFC3 Instrumentation Handbook

Figure 3.4: Limiting point-source magnitudes reached by optical/infrared *HST* imaging instruments in 10 hours. (WFC3/UVIS performance has declined slightly from the early on-orbit level shown here due to increasing CTE losses.)



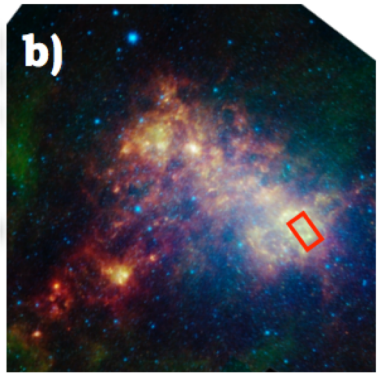
ACS/WFC3 Instrumentation Handbook

WFC3 vs ACS

- Redundancy is intentional – in case of failure and expectation of lifetime (V band F606W is similar)
- Overlap ~ 3700-1000 Å
- FOV : 162 x 162 (WFC3) vs 202 x 202 (ACS)
- WFC3 is preferred if angular resolution matters more than field of view (finer pixel size than any instrument at optical wavelengths)
- ACS is more sensitive (higher throughput) > 400 nm: so use if need greater sensitivity in the red
- **BUT** ACS has lower CTE and higher # hot pixels (1.8%) – issue for astrometry, faint sources (older by 7 yrs)

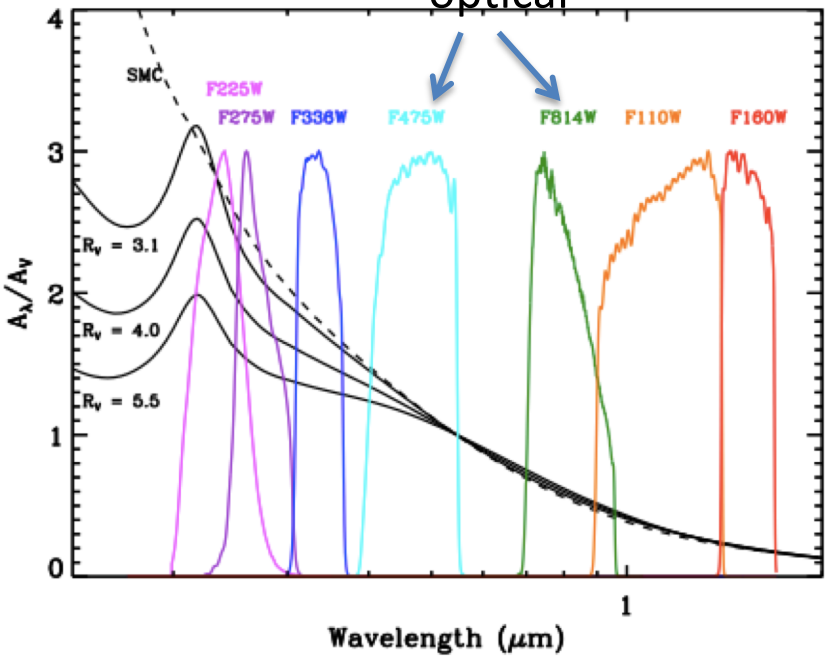
A New View of Dust at Low Metallicity: The First Maps of SMC Extinction Curves

Sandstrom HST GO 13659



[Fiters]

ACS optical



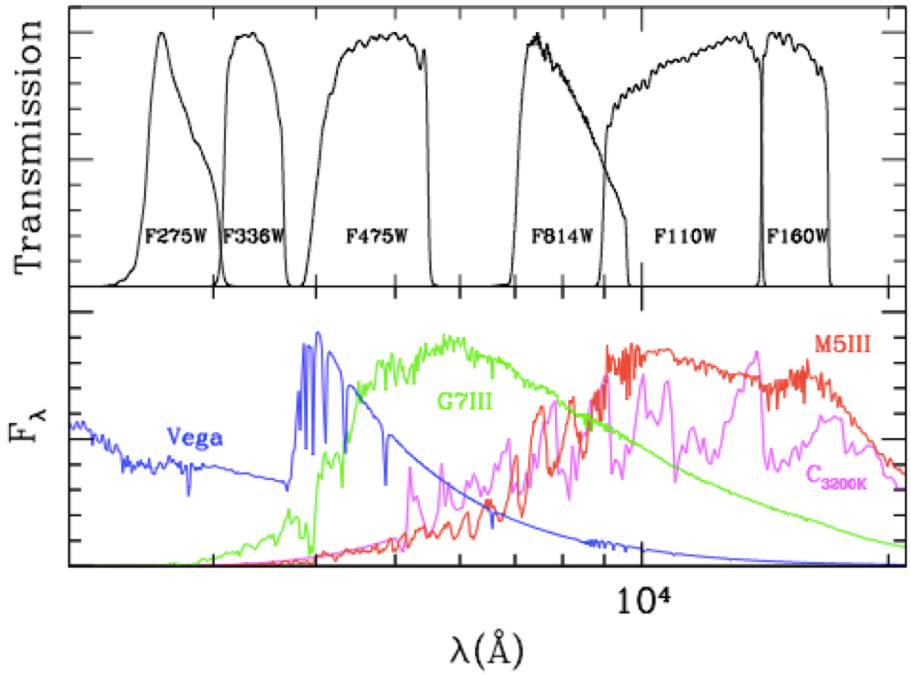
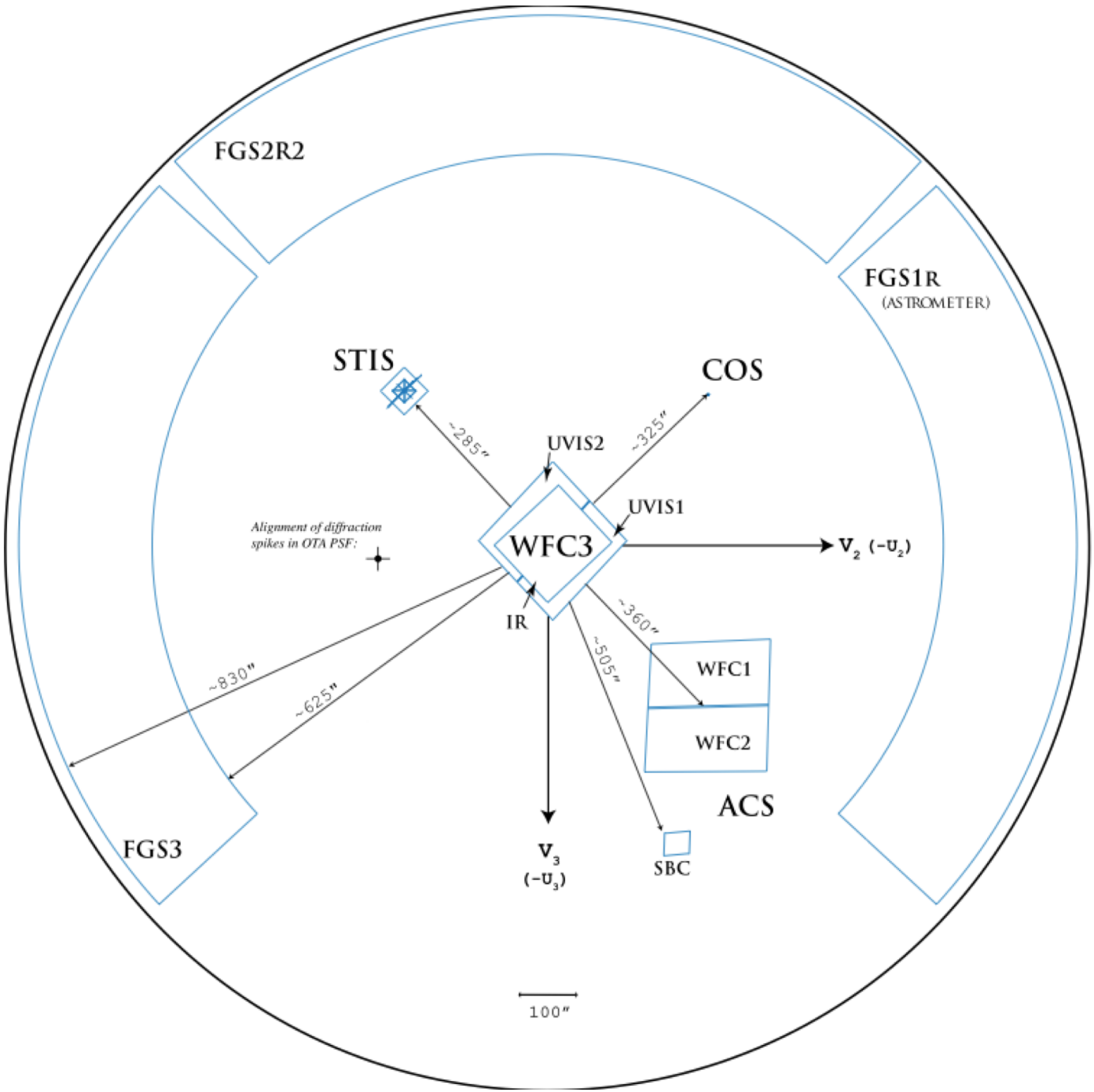
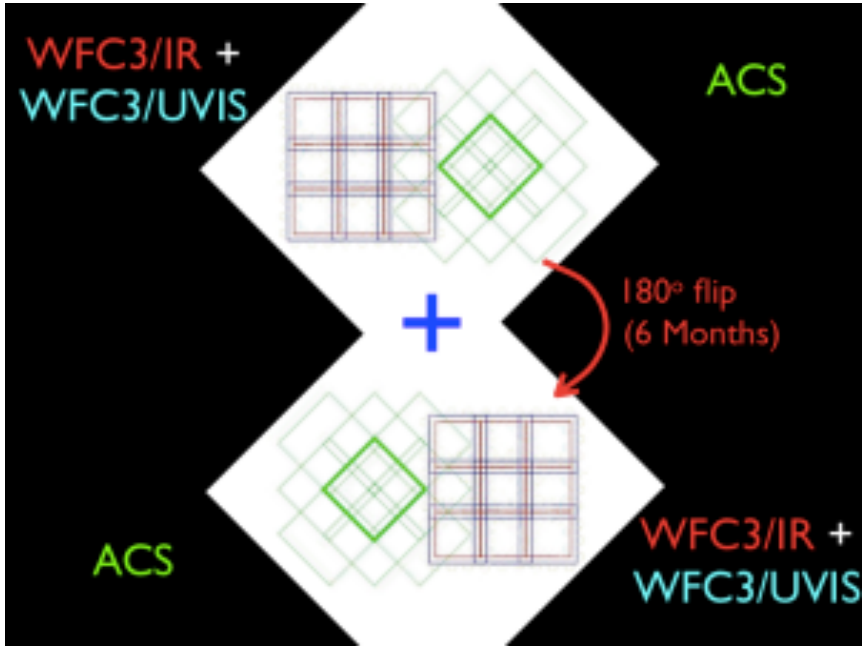


Figure 3: The WFC3 and ACS filters we will use in this project compared to extinction curves (left) and stellar spectra (right). The full seven band coverage of the SED allows us to separate the effects of reddening, including the bump, and changes in stellar properties.

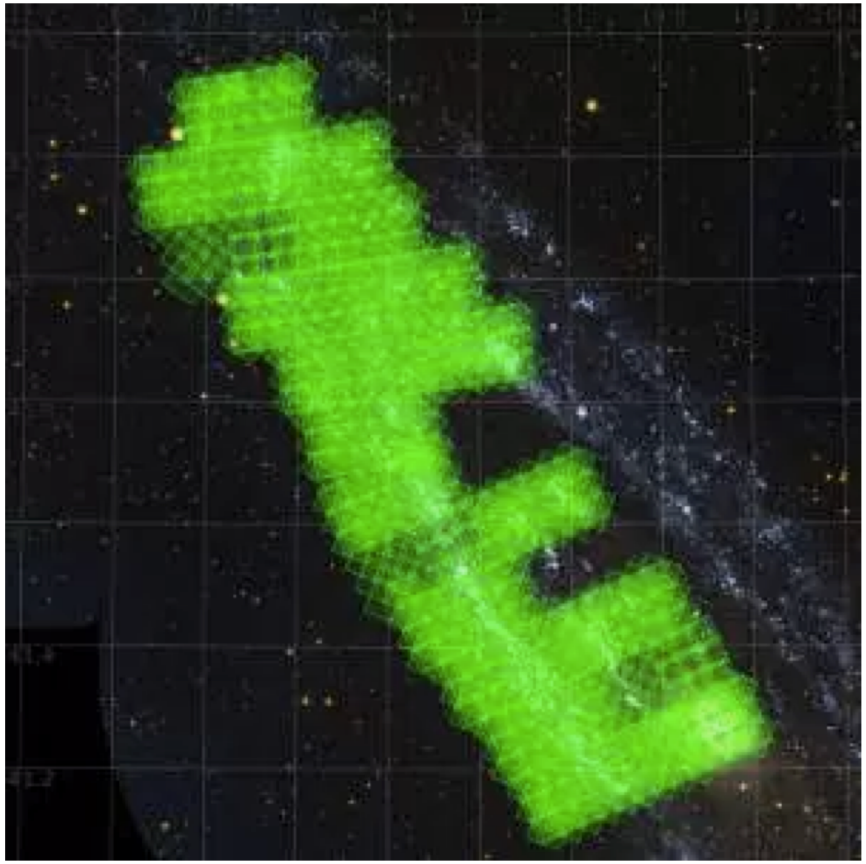
HST focal plane after SM4

Can use ACS/WFC and WFC3 in coordinated parallel – separated by 360”

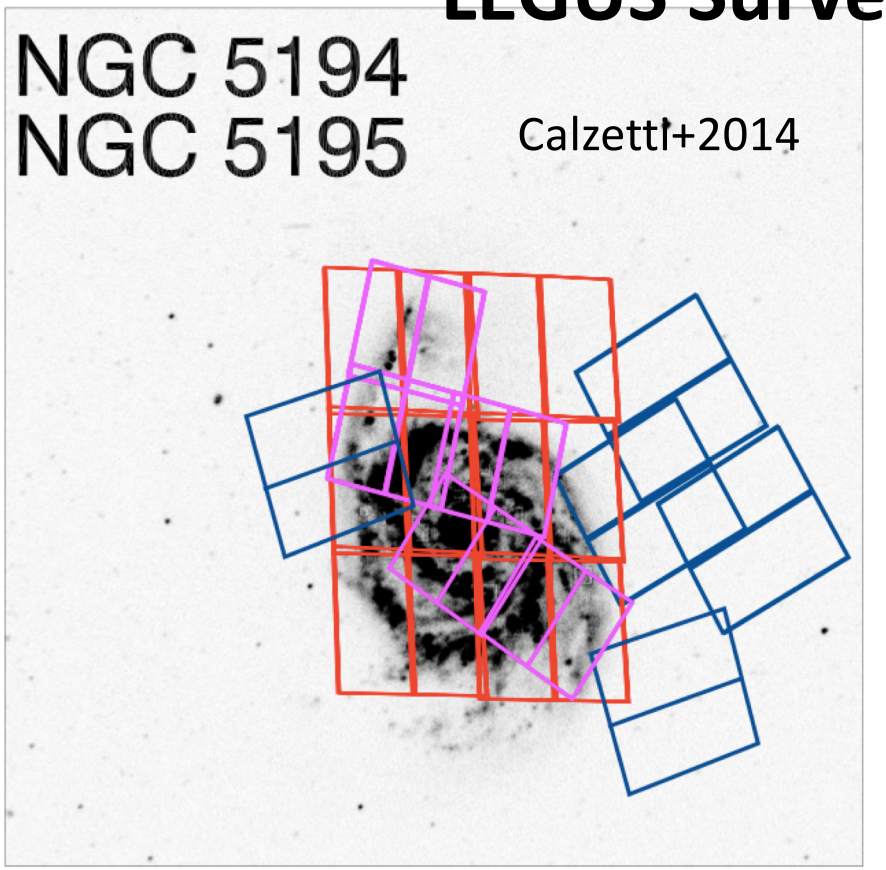




PHAT



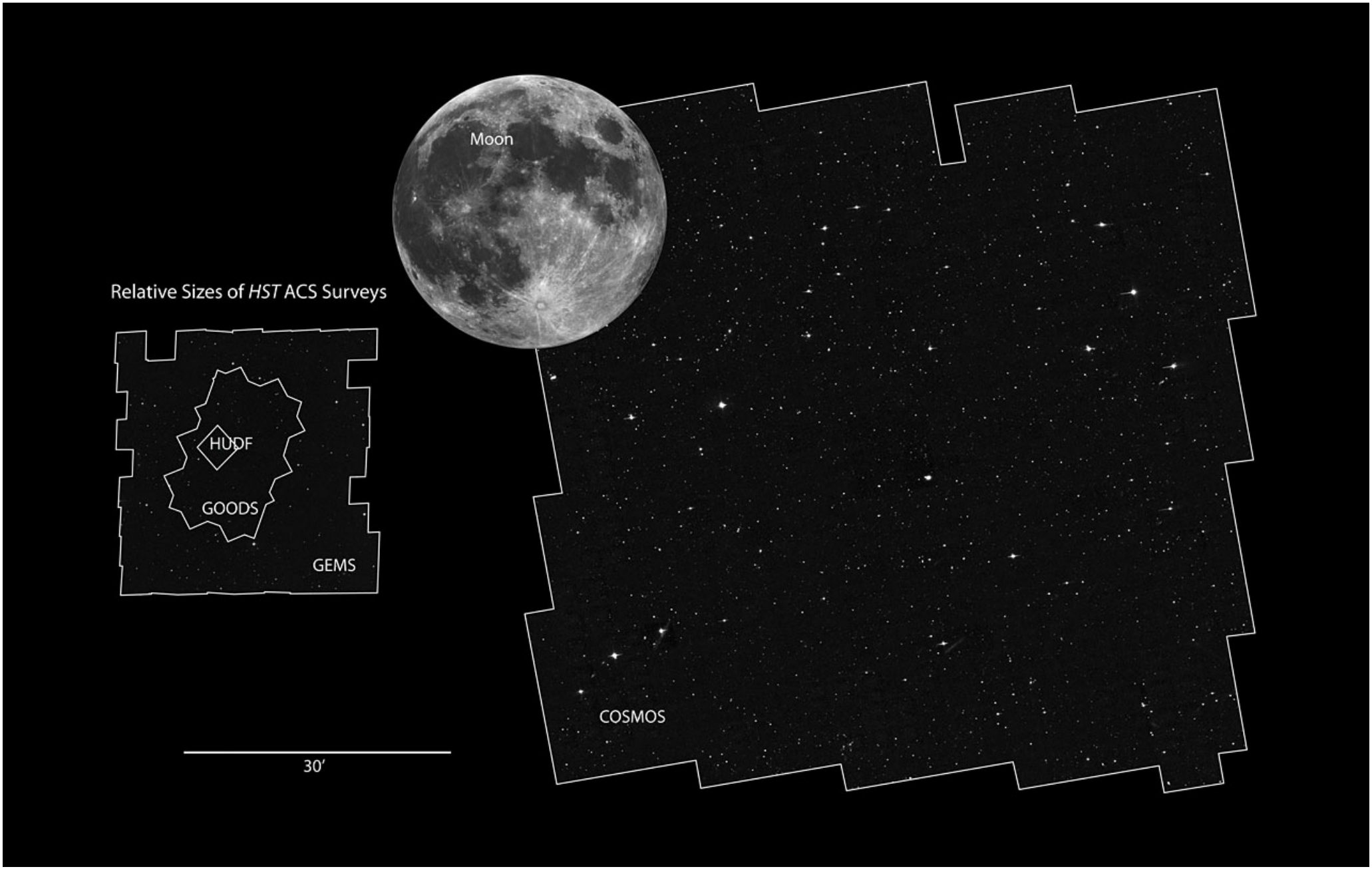
LEGUS Survey



Survey Science with ACS & WFC3

- **COSMOS**: ACS 640 Orbits. 2 square degree
  - Study galaxy and large scale structure evolution
  - morphologies > 2 million galaxies < 100 pc resolution
- **CANDELS**: WFC3 (NIR) + ACS parallel. 88 Orbits
- **3D-HST**: 88 orbits cover CANDELS field with WFC3 Grism observations
- **AEGIS:** ACS, Nicmos – 126 Orbits

+ VLA, Chandra, Galex, Spitzer, Scuba2, CFHT, MMT


Moon
Relative Sizes of *HST* ACS Surveys
HUDF
GOODS
GEMS
COSMOS
30′

Abstract Outline

Facts

Problem

Goal

Proposed Strategy/Solution

Importance of Solution

Broader Impact

A New View of Dust at Low Metallicity: The First Maps of SMC Extinction Curves

Sandstrom HST GO 13659

In order to constrain basic dust physics and anchor the interpretation of both UV/optical extinction and IR emission at low and high redshifts, we propose seven-filter photometry of a key region in the Small Magellanic Cloud (SMC). Via a cutting-edge technique demonstrated to work in M31 we will use these data to construct the first ever maps of the extinction curve shape (Rv), 2175 Angstrom bump strength, and dust column (Av) across a low metallicity environment. These maps will allow us to (1) measure the true distribution of extinction curves in the SMC, which is frequently used as a template for low metallicity extinction; (2) rigorously test whether PAHs are the carriers of the 2175 Angstrom extinction feature; and (3) place the estimation of dust masses from IR emission in low metallicity systems on a firm empirical and observational footing. Dust regulates the structure and evolution of interstellar medium (ISM) and shapes the optical and ultraviolet emission of galaxies. Its emission at infrared and mm wavelengths represents a powerful tool to probe the ISM out to the highest redshifts. Understanding the physics and interpretation of dust absorption and emission as a function of metallicity is critical to a vast range of science and mapping key dust properties is a new application, uniquely possible with UV through NIR imaging from HST. As such, we expect this program to have wide ranging scientific impact.

Problem/Importance

Proposal/Goal

Proposed strategy/Solution

Importance of Solution

Why HST & Broader Impact

A New View of Dust at Low Metallicity: The First Maps of SMC Extinction Curves

Sandstrom HST GO 13659

Qualifiers:

In order to constrain basic dust physics and anchor the interpretation of both UV/optical extinction and IR emission at low and high redshifts, we propose seven-filter photometry of a key region in the Small Magellanic Cloud (SMC). Via a cutting-edge technique demonstrated to work in M31 we will use these data to construct the first ever maps of the extinction curve shape (Rv), 2175 Angstrom bump strength, and dust column (Av) across a low metallicity environment. These maps will allow us to (1) measure the true distribution of extinction curves in the SMC, which is frequently used as a template for low metallicity extinction; (2) rigorously test whether PAHs are the carriers of the 2175 Angstrom extinction feature; and (3) place the estimation of dust masses from IR emission in low metallicity systems on a firm empirical and observational footing. Dust regulates the structure and evolution of interstellar medium (ISM) and shapes the optical and ultraviolet emission of galaxies. Its emission at infrared and mm wavelengths represents a powerful tool to probe the ISM out to the highest redshifts. Understanding the physics and interpretation of dust absorption and emission as a function of metallicity is critical to a vast range of science and mapping key dust properties is a new application, uniquely possible with UV through NIR imaging from HST. As such, we expect this program to have wide ranging scientific impact.

A Search for Extended Stellar Galactic Halos
HST Proposal 7552. Cycle 7 Dennis Zaritsky

Several lines of evidence (ground based observations of NGC 5907; the apparent large fraction of Galactic dark matter accounted for by MACHOS) suggest that galactic halos consist primarily of stellar type objects out to radii of at least several tens of kpc. Further investigation of this claim is critical in constraining the properties of dark matter and the nature of galactic halos. We propose to use HST archival images of random edgeon field spiral galaxies in the F814W filter to trace the extended stellar light around disk galaxies. HST data provides two key advantages for this study: {1} the background surface brightness at 8000Angstrom is about 2 mag fainter than for ground based images; and {2} the contamination by foreground stars is effectively eliminated because HST resolution enables one to study relatively distant galaxies, which have fewer superposed stars because of their small angular extents. Both of these advantages will enable us to map the extended light to the unprecedented level of 28 mg2 at 8000Angstrom. If the data and model of Sackett Etal {1994} are correct, we will map the extended emission, and hence the stellar halo, to a vertical distance above and below the plane that is at least twice as large as ever before.

Facts

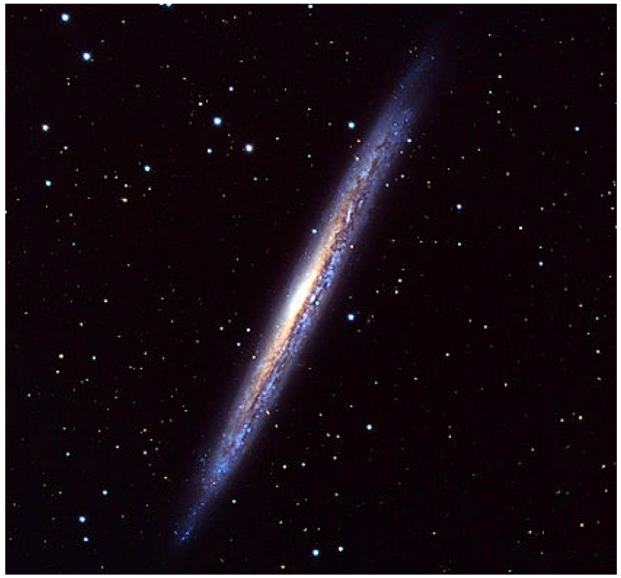
Problem

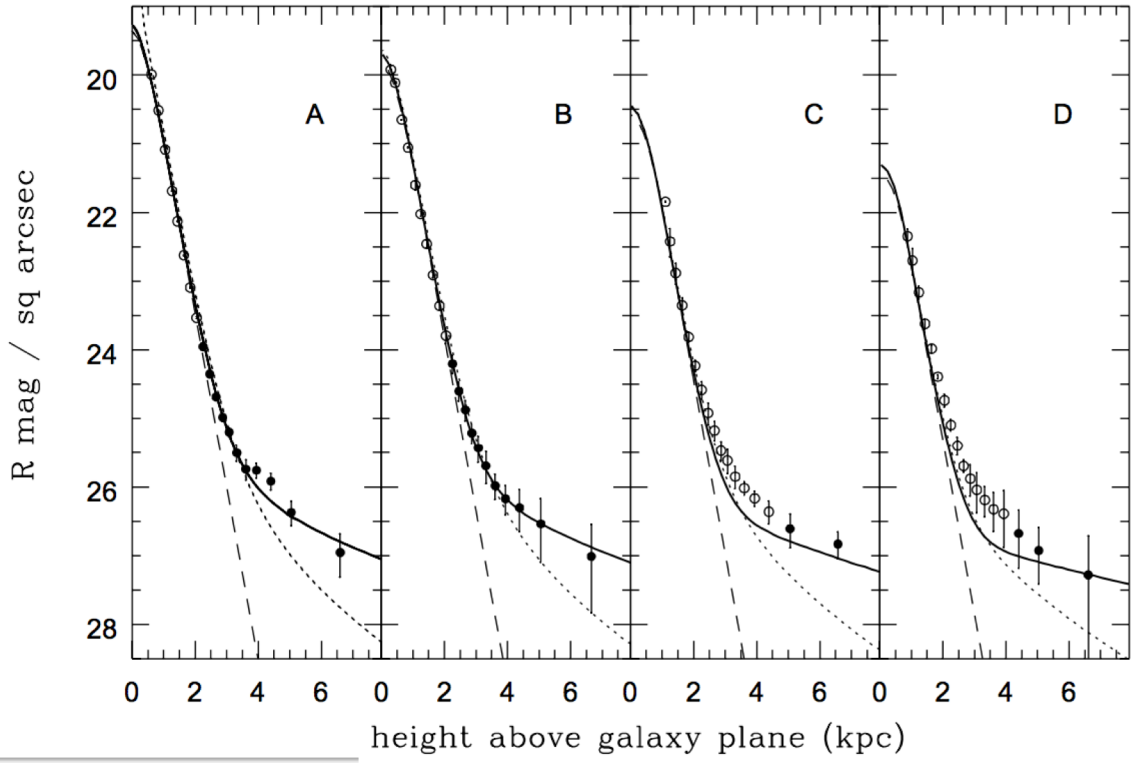
Goal

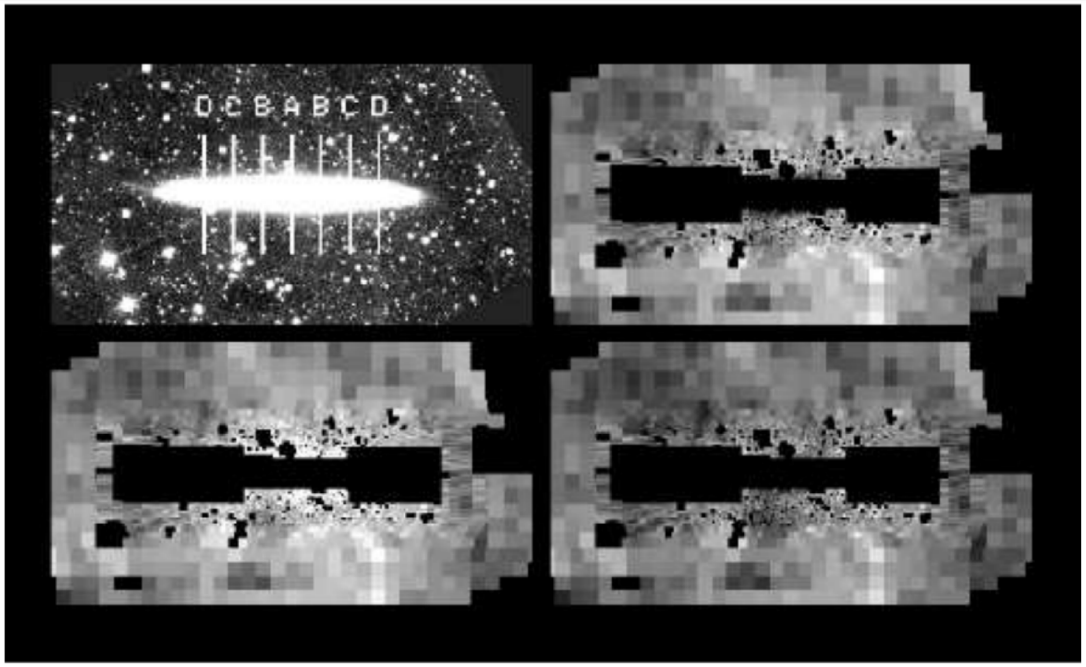
Proposed Strategy/Solution

Importance/Broader Impact

Sackett + 1994







Jay Gabany & David Martinez-Delgado

NGC 5907