An Overview of HST Instrument Capabilities After SM4

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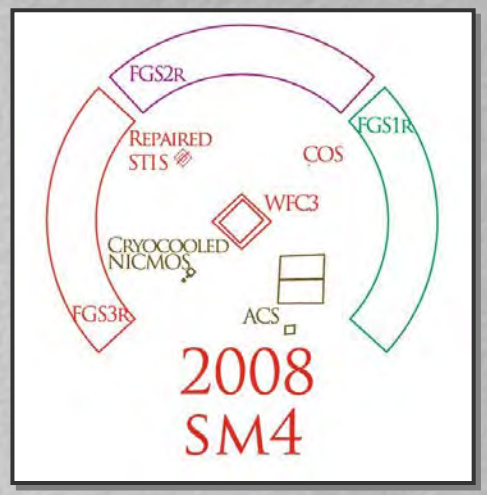
HST Instrument Timeline

- **WFPC2**
  - Installed in December 1993 during SM1
  - Replaced WF/PC-1
- **STIS**
  - Installed in February 1997 during SM2
  - Replaced GHRS
- **NICMOS**
  - Installed in February 1997 during SM2
  - Replaced FOS
  - Cooling system installed in March 2002 during SM3B
- **ACS**
  - Installed in March 2002 during SM3B
  - Replaced FOC
- **WFC3**
  - To be installed in late 2008 during SM4
  - Replaces WFPC2
- **COS**
  - To be installed in late 2008 during SM4
  - Replaces COSTAR

Post-SM4 Instrument Complement

New: WFC3 and COS
Existing: NICMOS, FGS, ACS, and STIS



Overview of Key Capabilities

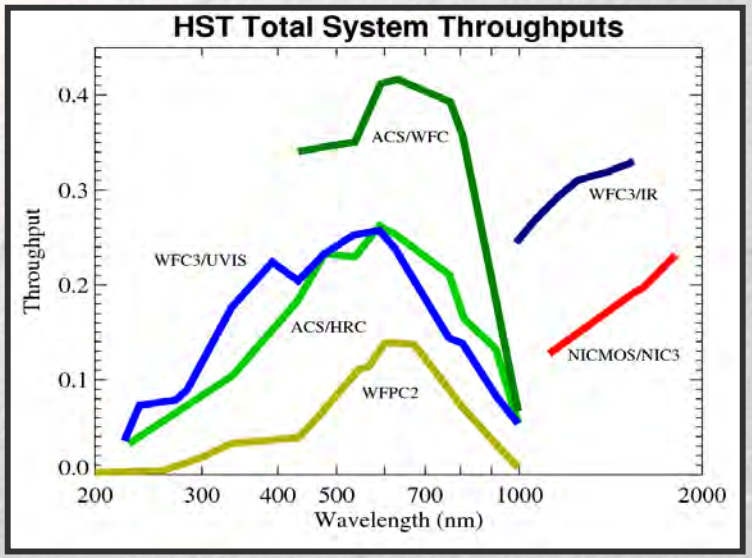
ACS
- High throughput wide-field visual imaging (WFC)
- High resolution imaging from far-UV to near-IR (SBC and HRC)
- UV/optical coronagraphy and polarimetry
- UV prism spectroscopy and optical grism spectroscopy

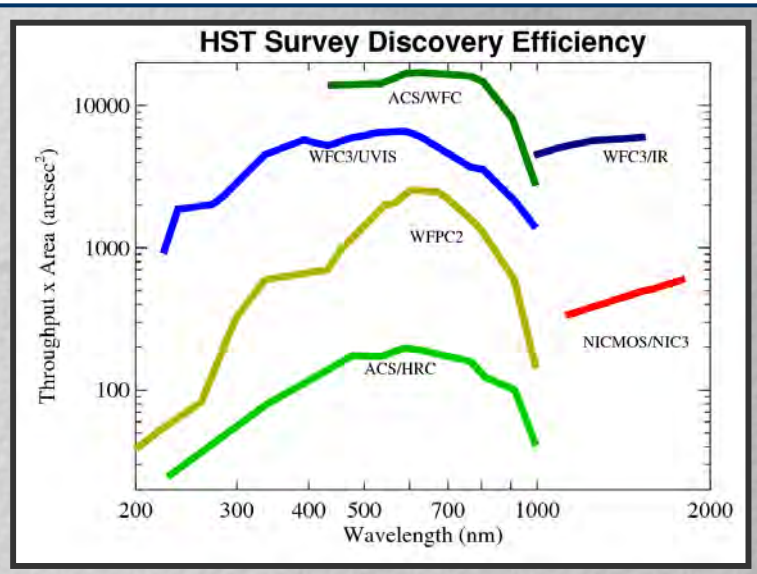
WFC3
- High throughput, panchromatic wide-field imaging from 200 nm to 1.7μm
- Wide range of narrowband filters
- UV and IR grism spectroscopy

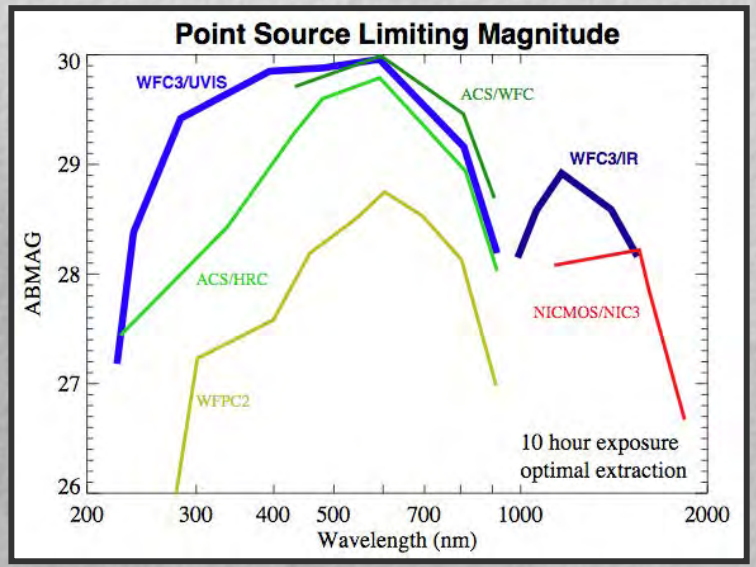
STIS
- High resolution (R ~ 110,000) and medium resolution (R ~ 45,000) FUV and NUV echelle spectroscopy of point sources
- UV/optical long slit spectroscopy of point sources and extended sources
- Coronagraphic imaging and spectroscopy

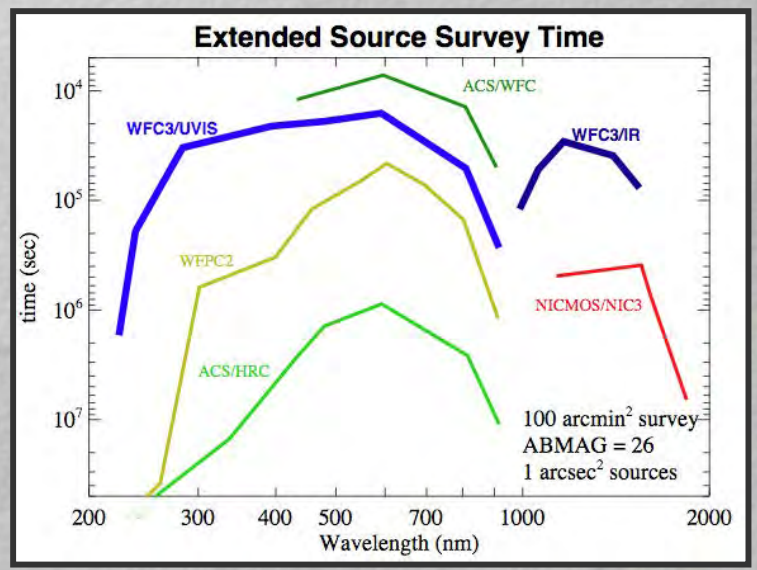
COS
- High throughput FUV (115-200 nm) and NUV (170-320 nm) point source spectroscopy at moderate resolving power (R ~ 20,000)

Imaging Throughput and Discovery Efficiency









Imaging Considerations

- **Far-Ultraviolet (<200 nm)**
  - WFC3 has no far-ultraviolet imaging capability.
  - ACS/SBC is more sensitive and has more filters than STIS FUV-MAMA.
- **Near-Ultraviolet (200 nm - 350 nm)**
  - WFC3/UVIS has superior field of view compared to ACS/SBC, ACS/HRC, and STIS/NUV-MAMA.
  - WFC3/UVIS has superior throughput compared to ACS or STIS.
  - ACS/HRC (SBC) has 44% (25%) smaller pixels than WFC3/UVIS.
- **Optical (350 nm - 1.0 μm)**
  - ACS/WFC has wider field of view than WFC3/UVIS.
  - ACS/HRC has smaller pixels than WFC3/UVIS.
  - WFC3/UVIS has highest extended source sensitivity and survey efficiency below 400 nm.
  - ACS/WFC has highest extended source sensitivity and survey efficiency above 400 nm.
  - WFC3/UVIS has highest point source sensitivity below 450 nm.
  - WFC3/UVIS and ACS/WFC have comparable point source sensitivity at 450-600 nm.
  - ACS/WFC has slightly higher point source sensitivity above 600 nm.
- **Near-Infrared (800 nm - 2.5 μm)**
  - WFC3/IR has superior throughput and much larger field of view compared to NICMOS.
  - WFC3/IR wavelength coverage ends at 1.7 μm, shortward of the 2.5 μm cutoff for NICMOS/NIC2 and NIC3.
  - NICMOS/NIC1 and NIC2 have smaller pixels than WFC3/IR.

Other Imaging Considerations

- **Coronagraphy**
  - WFC3 has no coronagraphic capabilities.
  - ACS/HRC optical imaging coronagaph is superior to STIS coronagraph.
  - NICMOS/NIC2 imaging coronagraph operates at IR wavelengths.
  - STIS aperture bars allow spectroscopic coronagraphy.
- **Polarimetry**
  - WFC3 has no polarimetric capabilities.
  - ACS/HRC and WFC have imaging polarimetry with 0˚, 60˚, and 120˚ relative polarization angles.
  - NICMOS/NIC1 and NIC2 have imaging polarimetry with 0˚, 120˚, and 240˚ relative polarization angles.
- **Miscellaneous**
  - Older ACS and STIS CCDs suffer more charge transfer efficiency loss than the new WFC3/UVIS CCDs.
  - WFC3 has excellent PSF properties due to its on-axis optics.

Imaging at Near-Ultraviolet Wavelengths
(200 nm - 350 nm)

	WFC3/UVIS	ACS/HRC	STIS/NUV-MAMA
FOV area (arcsec^2)	160”x160” (25600)	29”x26” (754)	25”x25” (625)
Broadband throughput @ 230, 330 nm	0.07, 0.18	0.05, 0.10	0.026, 0.002
Pixel scale (arcsec)	0.039	0.027	0.025
Number of pixels	4k x 4k	1k x 1k	1k x 1k
Read noise (e^-)	3	4.7	None
Dark current	$5.0x10^{-4}$ (e^-/pix/s)	$5.8x10^{-3}$ (e-/pix/s)	$1.4x10^{-3}$ (cnt/pix/s)
Number of filters	13 10 full-field, 3 quad	6 3 full-field, 3 UV polarizers*	9 8 full-field (inc. 2 neutral density), 1 quad neutral density

*These polarizers are optimized for the UV and the ACS/HRC field of view but can in principle be used with the ACS/WFC in the optical.

Imaging at Optical Wavelengths
(350 nm - 1.0 μm)

	WFC3/UVIS	ACS/WFC	ACS/HRC
FOV area ($arcsec^2$)	160”x160” (25600)	202”x202” (40804)	29”x26” (754)
Broadband throughput* @ *V*, *I*, *z*	0.26, 0.14, 0.08	0.41, 0.36, 0.20	0.23, 0.16, 0.13
Pixel scale (arcsec)	0.039	0.049	0.027
Number of pixels	4k x 4k	4k x 4k	1k x 1k
Read noise (e^-)	3	5	4.7
Dark current	$5.0x10^{-4}$ (e^-/pix/s)	$2.6x10^{-3}$ (e^-/pix/s)	$5.8x10^{-3}$ (e-/pix/s)
Number of filters	49 32 full-field, 17 quad	27 12 full-field, 15 ramp	21** 13 full-field, 3 polarizers, 5 ramp

* Average throughput in a 10 nm bandpass at the pivot wavelength (V = F606W; I = F814W; z = F850LP)
**Some of these filters cover only the ACS/HRC field of view but can in principle be used in the ACS/WFC.

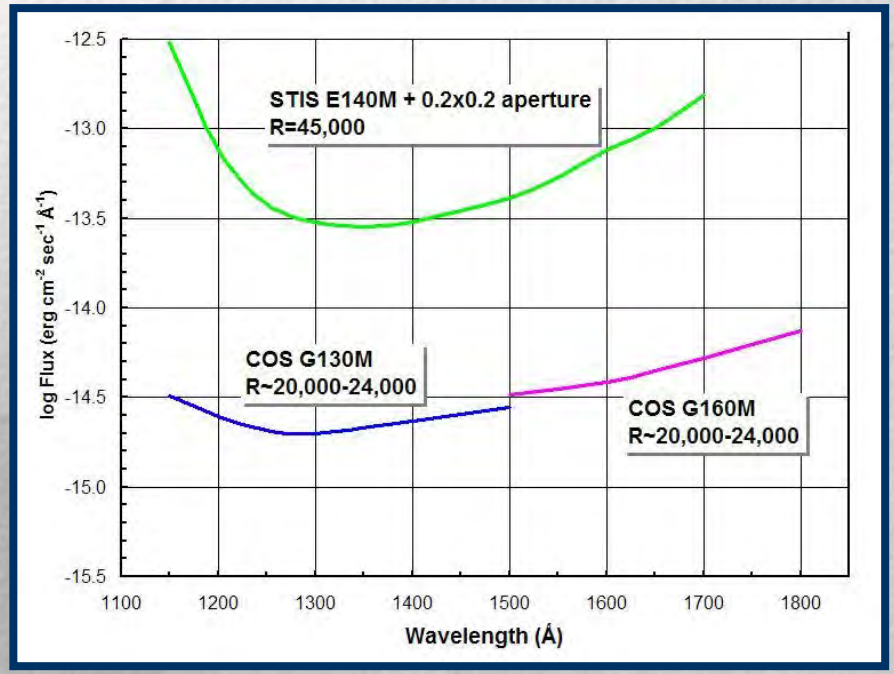
Imaging at Near-Infrared Wavelengths
(800 nm - 2.5 μm)

	WFC3/IR	NIC3	NIC2	NIC1
FOV area ($arcsec^2$)	123”x136” (16728)	51”x51” (2601)	19”x19” (361)	11”x11” (121)
Broadband throughput @ 1.1, 1.6 microns	0.29, 0.33	0.13, 0.20	0.14, 0.20	0.12, 0.18
Wavelength range	0.8-1.7 μm	0.8-2.5 μm	0.8-2.5 μm	0.8-1.8 μm
Pixel scale (arcsec)	0.128	0.200	0.075	0.043
Number of pixels	1k x 1k	256 x 256	256 x 256	256 x 256
Read noise (e^-)	16	29	26	26
Number of filters	15	16	19 16 standard, 3 pol.	19 16 standard, 3 pol.

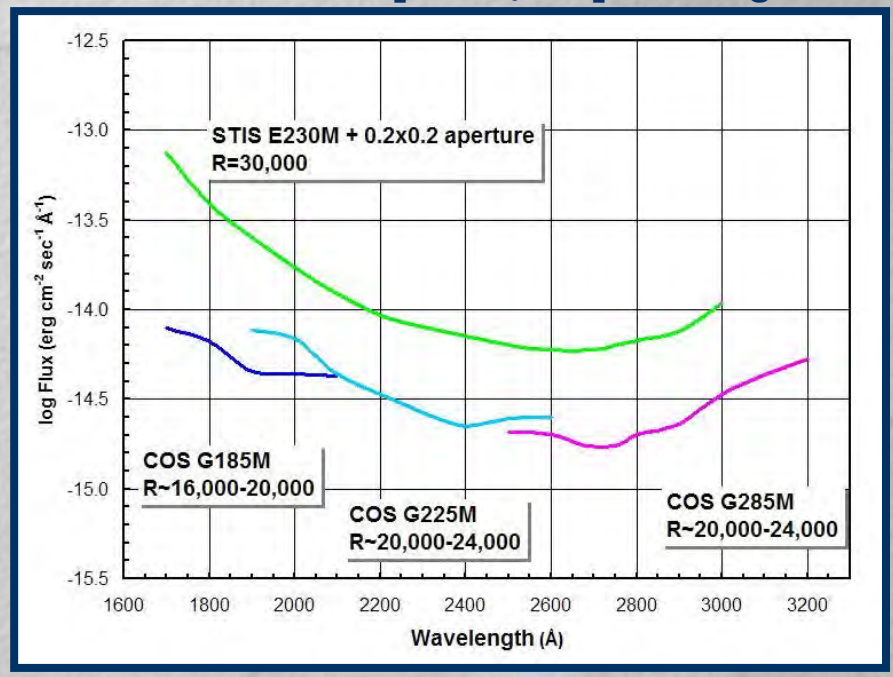
COS and STIS Limiting Fluxes

S/N = 10 in 3600 sec (no backgrounds)

FUV: 0.08 Å [R~20,000] binning



NUV: 0.12 Å [R~20,000] binning



COS: 2.5” primary science aperture (PSA) throughput ~100%.
STIS: 0.2”x0.2” aperture average throughput ~63% (FUV) and 75% (NUV).

Slit/Aperture Spectroscopy Considerations

- **General**
  - COS excels at moderate resolution spectroscopy of faint point sources.
  - STIS excels at high resolution UV echelle spectroscopy of bright point sources.
  - STIS UV modes have about 20x the spatial resolution of COS (0.05” vs. 1”).
  - STIS 1st order and PRISM UV observations extend 25” in the cross dispersion direction for observation of multiple or extended targets.
  - COS has two science apertures (primary and bright object), both 2.5” in diameter.
  - STIS has multiple narrow slits of varying lengths and a range of neutral density filters.
- **Far-Ultraviolet (<180 nm)**
  - COS has ~10x the throughput and up to ~70x the observing speed of STIS.
  - COS has an advanced micro-channel plate detector with significantly lower backgrounds than the STIS/FUV-MAMA.
  - COS and STIS low dispersion gratings offer no significant advantage in observing speed over COS medium resolution gratings for point sources.
- **Near-Ultraviolet (180 nm - 320 nm)**
  - COS/NUV-MAMA is expected to have lower background rates than the STIS/NUV-MAMA.
  - COS medium resolution gratings have greater sensitivity than STIS echelles, but cover only ~10-12 nm in each exposure compared to ~80 nm for STIS E230M.
- **Optical (350 nm - 1.0 μm)**
  - COS has no optical or IR spectroscopic capabilities.
  - STIS has optical/near-IR longslit (52”) spectroscopy with spatial resolution of 0.1”.

Spectroscopy at Ultraviolet Wavelengths

	COS/FUV	COS/NUV	STIS/FUV	STIS/NUV
Spectral coverage (Å)	1150 - 1775 (M) 1230 - 2050 (L)	1700 - 3200	1150 - 1700	1600 - 3200
Effective area (cm^2) at 1300Å (FUV), 2500Å (NUV)	2800 (M) 2400 (L)	900 (M) 750 (L)	400 (M) 1700 (L)	350 (M) 900 (L)
Resolving power ($\lambda/\Delta\lambda$) H	N/A	N/A	114,000	114,000
M	20,000 - 24,000	16,000 - 24,000	10,000 - 46,000	10,000 - 30,000
L	2400 - 3500	1500 - 2800	1000	500
Number of pixels along dispersion	32768	1024	1024 (2048)	1024 (2048)
Background (cts/resel)	4.3×10^{-5}	1.9×10^{-3}	350×10^{-5}	17×10^{-3}
Background equivalent flux (erg cm^{-2} sec^{-1} $Å^{-1}$)	$(0.5\text{-}8) \times 10^{-18}$	$(1.3\text{-}3.8) \times 10^{-16}$	20×10^{-18}	13×10^{-16}

Slitless Imaging Spectroscopy

- **Ultraviolet (< 350 nm)**
  - ACS/SBC has PR110L and PR130L prisms (125 - 180 nm) with R ~ 100.
  - STIS /NUV-MAMA has PRISM (115 - 300 nm) with R ~ 2500 to 10.
  - ACS/HRC has PR200L prism (170 - 390 nm) with R ~ 59.
  - WFC3/UVIS has G280 grism (200 - 500 nm) with R ~ 125.
- **Optical (350 nm - 1.0 μm)**
  - WFC3/UVIS has G280 grism (200 - 500 nm) with R ~ 125.
  - ACS/WFC and HRC have G800L grism (550 - 1050 nm) with R ~ 100.
- **Near-Infrared (800 nm - 2.5 μm)**
  - WFC3/IR has G102 grism (0.9 -1.15 μm) with R ~ 200, and G140 grism (1.08 - 1.7 μm) with R ~ 140.
  - NICMOS/NIC3 has G096 grism (0.8 - 1.2 μm), G141 grism (1.1 - 1.9 μm), and G206 grism (1.4 - 2.5 μm), all with R ~ 200.

COS Spectral Modes

Grating	Spectral Range (nm)		Resolving Power ($\lambda/\Delta\lambda$)	Detector
	Full	Per tilt		
FUV Channel				
G130M	115 - 145	30	20,000-24,000	FUV-MCP
G160M	140 - 175	37	20,000-24,000	
G140L	123 - 205	>82	2500-3000	
NUV Channel				
G185M	170 - 210	3 x 3.5	16,000-20,000	NUV-MAMA
G225M	210 - 250	3 x 3.5	20,000-24,000	
G285M	250 - 300	3 x 4.1	20,000-24,000	
G230L	170 - 320	(1 or 2) x 39.8	1550-2900	

STIS Spectral Modes

Grating/ Prism	Spectral Range (nm)		Resolving Power ($\lambda/\Delta\lambda$)	Detector	Cross Dispersion Plate Scale (“/pixel)
	Full	Per tilt			
First Order Gratings					
G140L	115 - 173	58	935 - 1440	FUV-MAMA	0.024
G140M	115 - 174	5.5	11,500 - 17,400		0.029
G230L	157 - 318	161	500 - 1005	NUV-MAMA	0.024
G230M	164 - 317	9	9110 - 17,500		0.029
G230LB	168 - 317	138	615 - 1135	CCD	0.051
G230MB	164 - 319	15.5	5550 - 10,335		
G430L	290 -570	280	530 - 1040		
G430M	302 - 561	28.6	5330 - 10,270		
G750L	524 - 1027	503	535 - 1170		
G750M	545 - 1020	57	4870 - 9950		
Echelle					
E140M	115 - 170	55	46,000	FUV-MAMA	0.029
E140H	115 - 170	21	114,000		
E230M	157 - 310	80	30,000	NUV-MAMA	
E230H	165 - 300	26.7	114,000		
PRISM					
PRISM	115 - 300	195	2500 - 10	NUV-MAMA	0.029