Wide Field Camera 3: A Powerful New Imager for HST

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Origins/Purpose of WFC3

- WFC3 originated when HST's nominal observing lifetime was first extended from 2005 to 2010: conceived for installation during Servicing Mission 4, to extend and enhance HST's imaging capability
- General purpose "panchromatic" imager (200-1700 nm), being developed as a facility instrument by HST Project
  - Ball Aerospace is principal outside partner; much of the work in-house at Goddard Space Flight Center
  - Day-to-day science oversight from GSFC and STScI
  - External Scientific Oversight Committee, chaired by Bob O'Connell of U. of Virginia
- With SM4 expected in August/September of this year, WFC3 era of operation should now be 2008 → 2013+

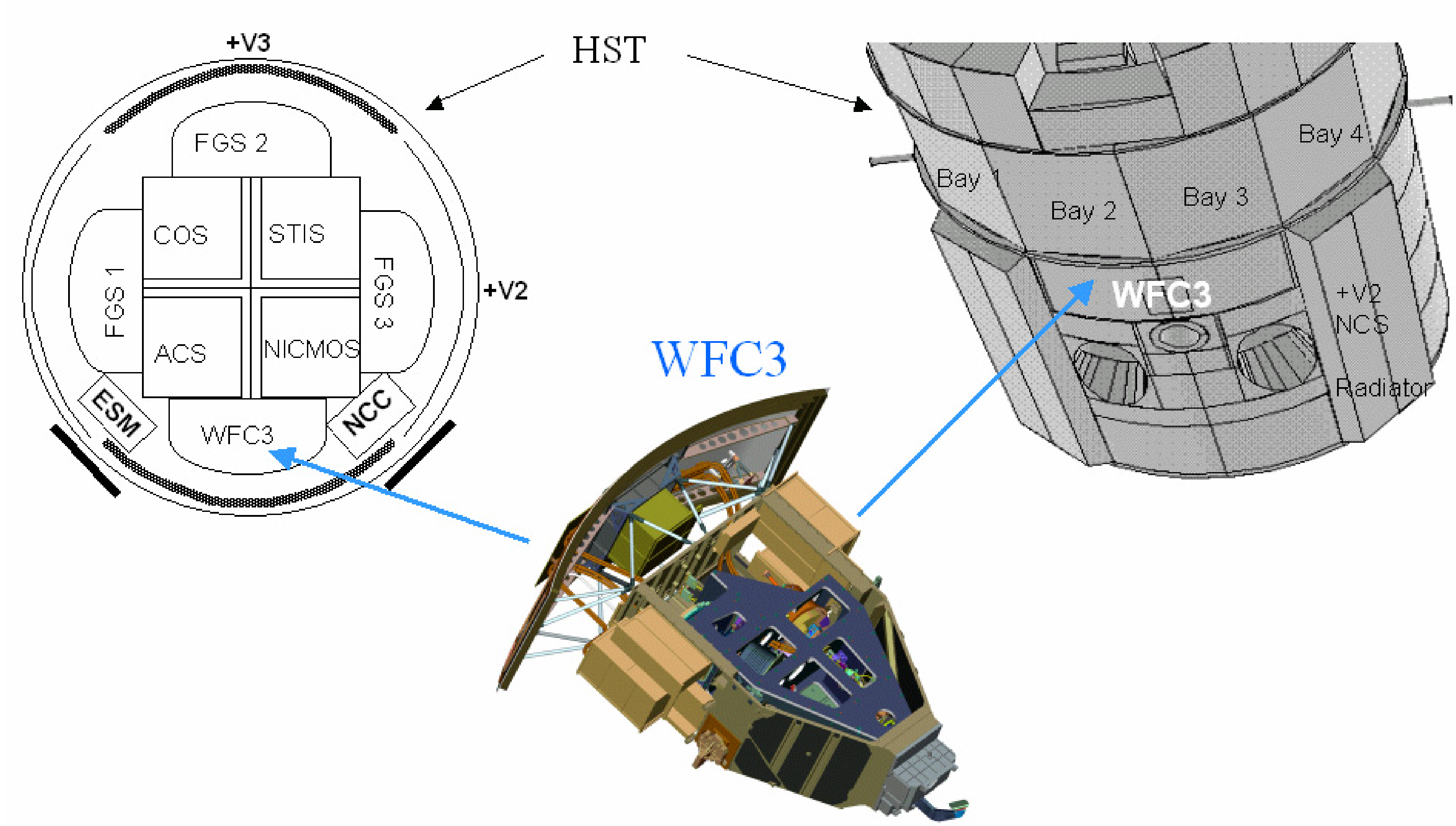
Key Aspects of WFC3

- WFC3 is a two-channel instrument – UVIS and IR – and provides a versatile imaging capability for HST
- Unique capabilities in the near-UV
  - 200 to 400 nm
- Unique capabilities in the near-IR – without cryogen or mechanical cryocooler
  - 850 to 1700 nm (though warm, HST is very powerful in this range)
- Large and diverse set of filters and grisms: 63 UVIS, 16 IR
- Complementary to I-band-optimized ACS
  - And a very capable accompaniment to ACS in the region of overlap, with more filters, fresh start with respect to radiation damage, and greater tolerance of CTE degradation

A Powerful General Purpose Imager

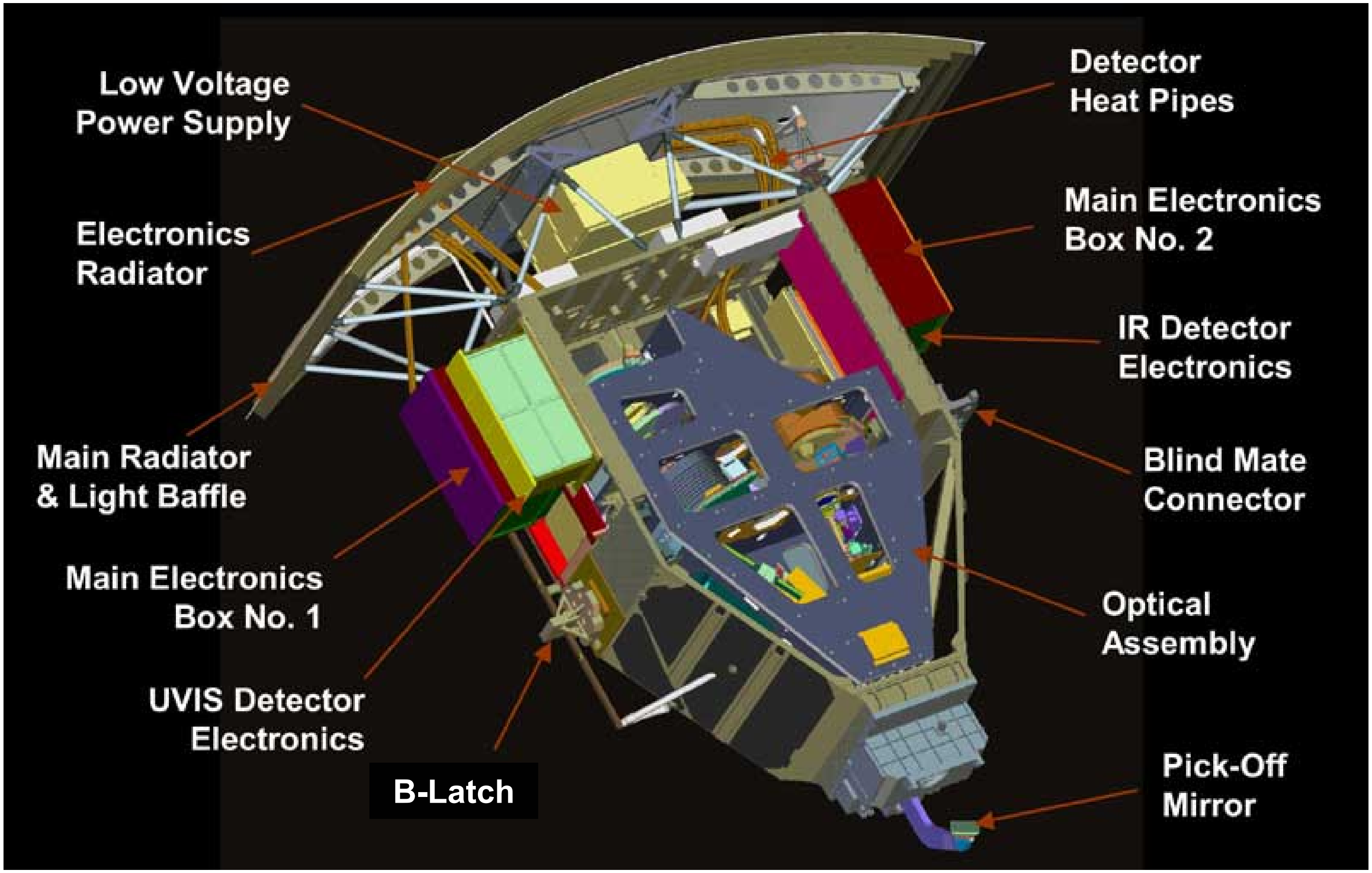
- WFC3 combines a wide wavelength coverage, high sensitivity, wide field of view, good spatial sampling, and a rich filter set
- **The result is a camera that will conduct forefront observations across the full range of astronomical investigation: from the high-redshift universe, to nearby galaxies, to local star-forming regions, to planets**
- This talk will concentrate on the hardware and its performance
- *I call your attention to Bob O'Connell's talk later today regarding the Early Release Science program of the WFC3 SOC – and look forward to hearing your ideas during the rest of the workshop*

WFC3's Destination



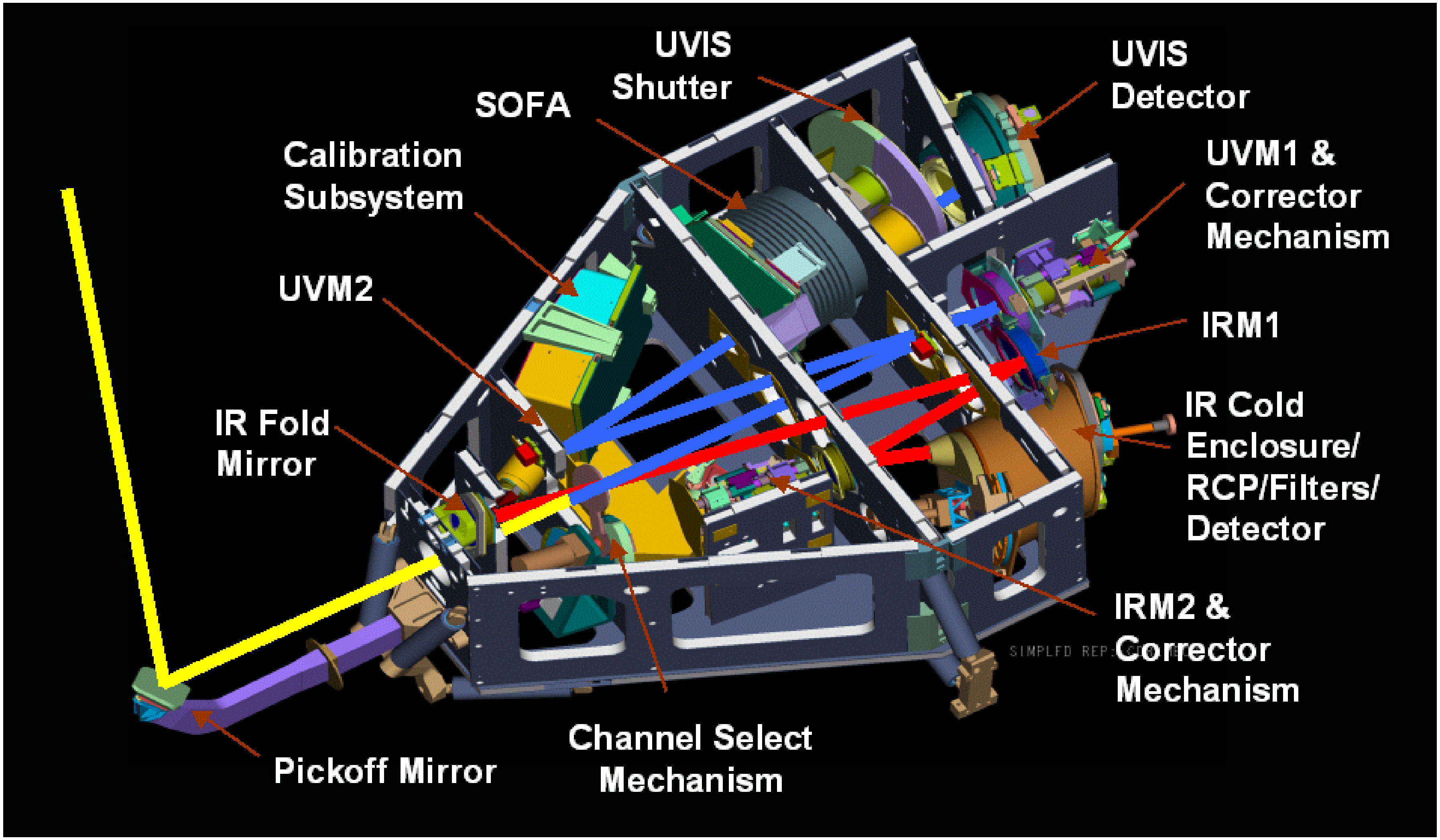
WFC3 will replace the extraordinarily successful but aging WFPC2 in its radial instrument bay

Overall WFC3 Configuration

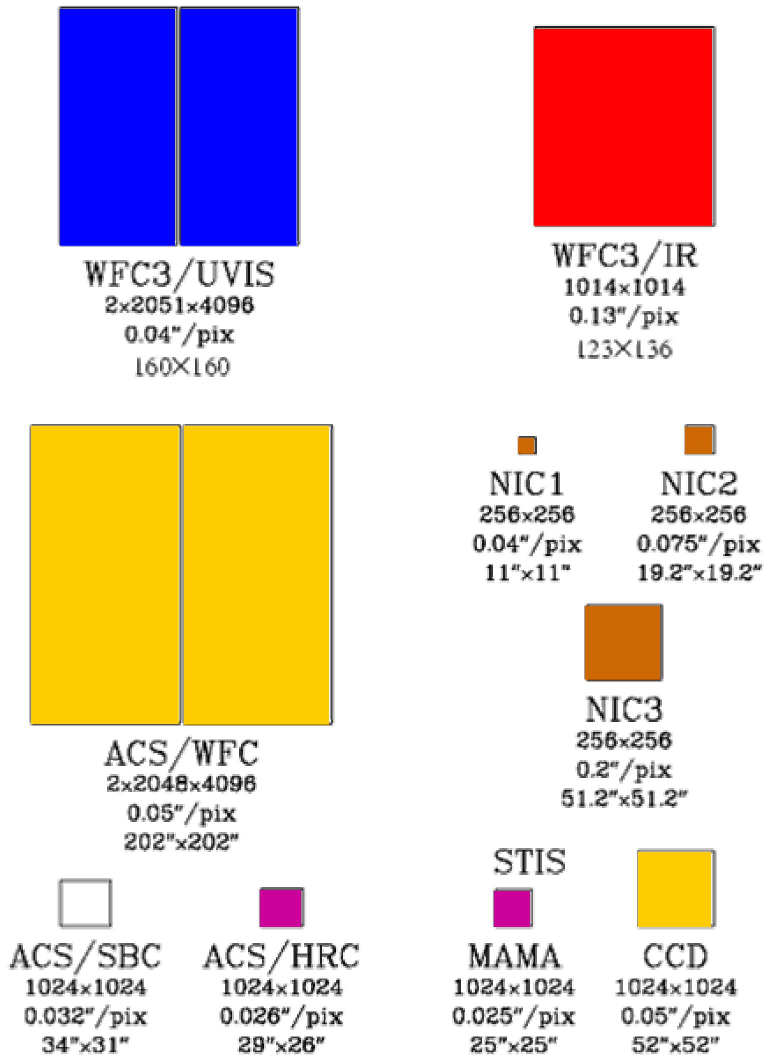


Dimensions: 2.3m x 2m x 1m   Weight: ~410kg

WFC3 Interior Configuration



Fields of View of Post-SM4 HST Imagers – To Scale



Comparing FOV Only:

NUV:

- WFC3 > 33 x ACS/HRC
- WFC3 > 40 x STIS/NUV

Visible:

- WFC3 = 0.64 x ACS/WFC

Near-IR:

- WFC3 = 6.4 x NICMOS/NIC3
- WFC3 > 40 x NICMOS/NIC2

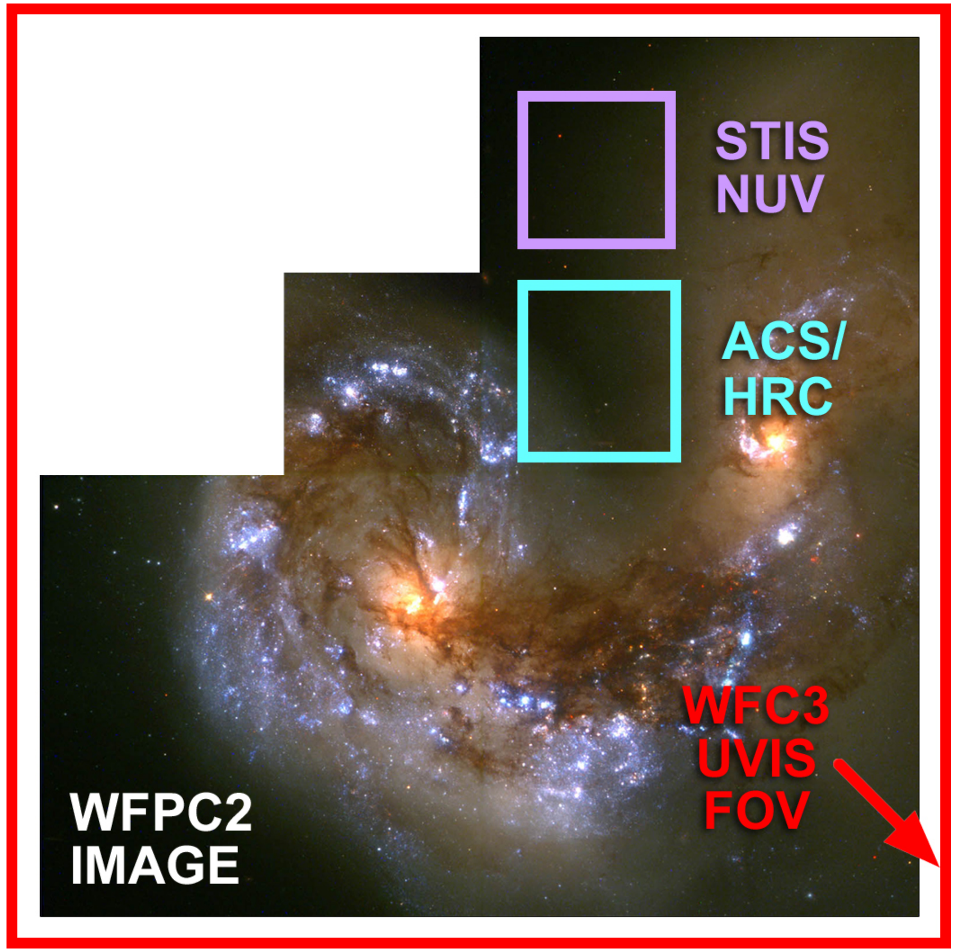
Survey efficiency further augmented by NUV/NIR sensitivity advantages

UVIS Channel Summary

Key Properties

- 200 – 1000 nm
- 4K x 4K CCD mosaic (two 2K x 4K UV-optimized CCDs)
- 0.04” x 0.04” pixels, 162” x 162” field of view

The WFC3 UVIS channel will extend high-sensitivity, large-format imaging at HST’s sharp angular resolution to the near UV



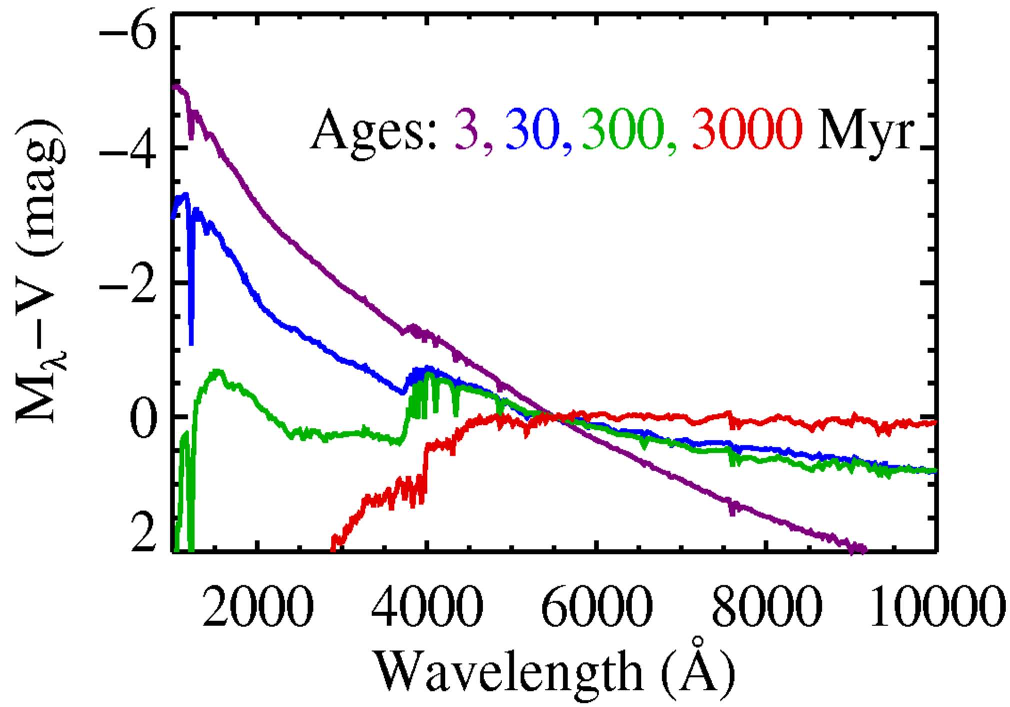
Relative fields of view of HST’s NUV imagers

UVIS Channel Science Goals

The UVIS channel will be particularly well suited to the study of:

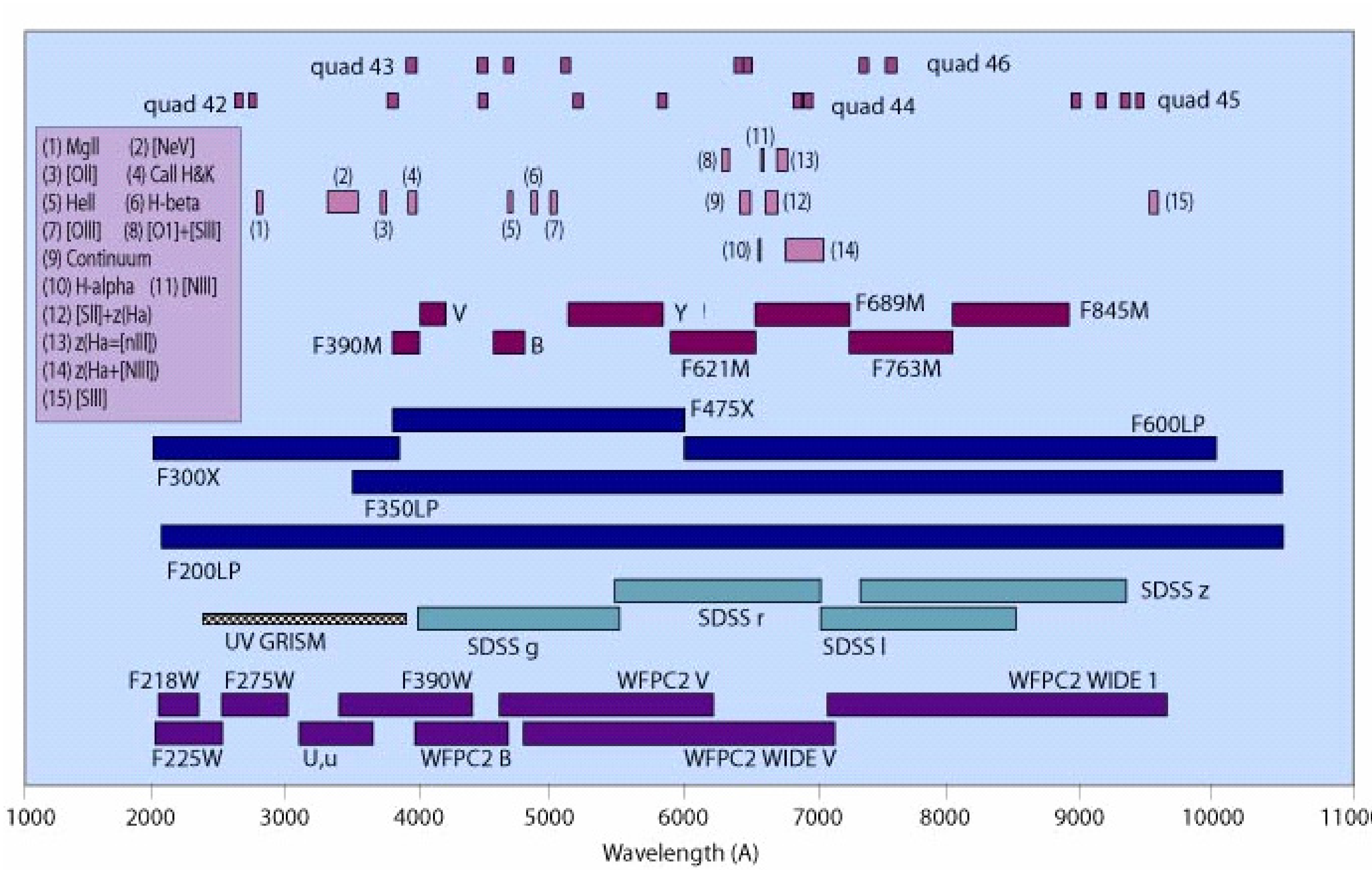
- Star formation history of galaxies (see figure at right)
- Chemical enrichment history of galaxies
- Ly α dropouts at z = 1 – 2.
- It will also probe one of the darkest spectral regions of the natural sky background (~200 nm).

NUV Observations Probe Age of Stellar Populations

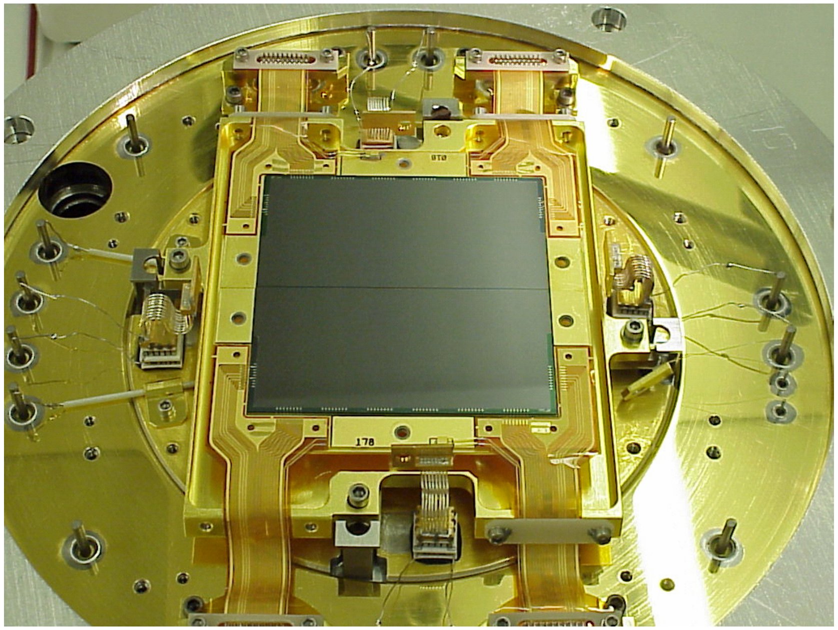


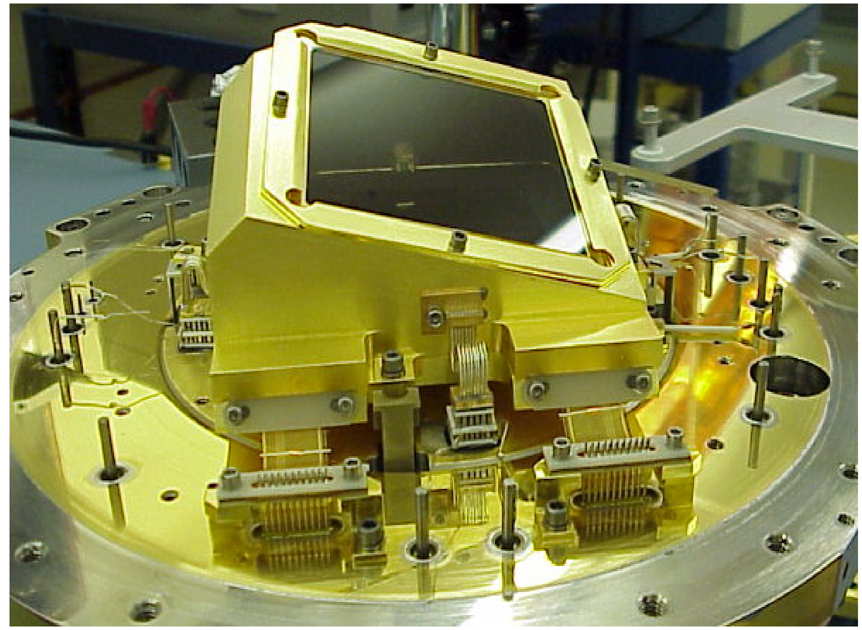
- It will also complement the IR channel by resolving at low redshift the processes (e.g. star formation in galaxies) seen in a more integrated way in the IR channel at high redshift.

UVIS Filter Complement



CCD Detectors





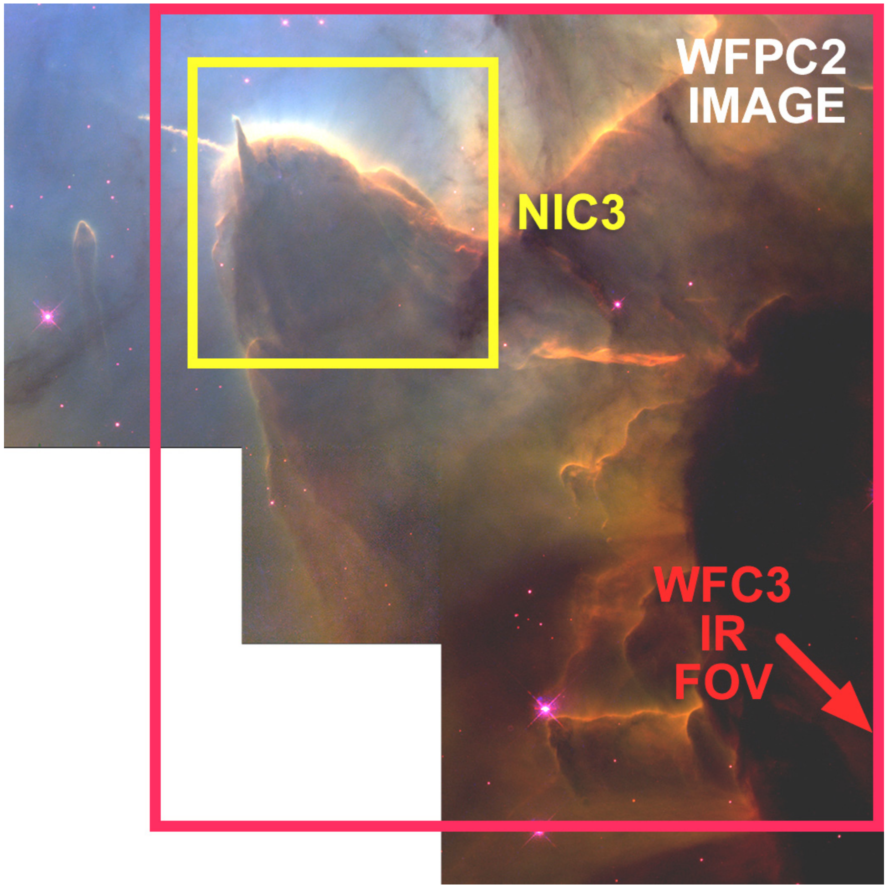
- The WFC3 CCDs, developed by e2v (formerly Marconi) are shown mounted on their TEC cooler (left) and with their inner thermal radiation shield installed (right); a vacuum cover and window completes the assembly.
- ***The end-to-end read noise for the flight CCDs and electronics is 3 e- rms for all four readout amplifiers.***

IR Channel Summary

Key Properties

- 800 – 1700 nm
- 1K x 1K HgCdTe array with 1.7 micron cutoff
- 0.13” x 0.13” pixels, 123” x 136” field of view
- zodiacal-background-limited sensitivity in broadband filters

The WFC3 IR channel will provide a 10-30+ x increase in survey speed vs. NICMOS + cryocooler, with finer angular resolution and improved stability, photometric accuracy, and cosmetics.



Relative fields of view of HST’s IR imagers

IR Channel
Sampling Advantage vs. NIC3

The WFC3 IR channel offers a significant advantage in spatial sampling vs. NIC3

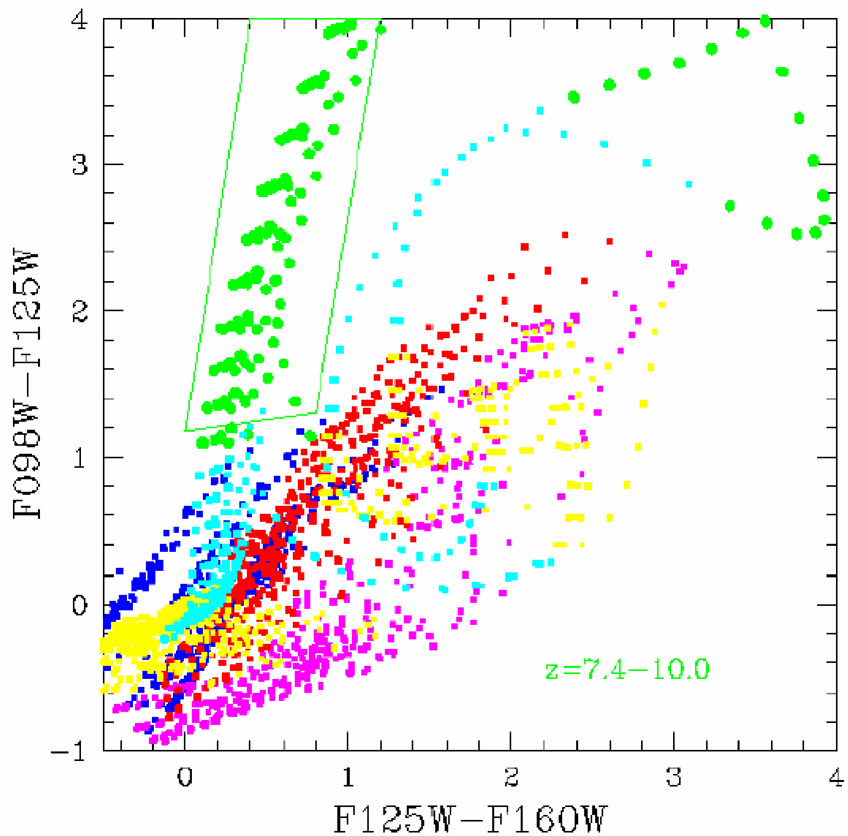
- NIC3 severely undersamples the HST PSF in the WFC3 0.8-1.7 μm range (NIC1/2 better sampled, but negligible field)
  - Combined with large intrapixel sensitivity variations, leads to large effects on NIC3 photometry vs. position
- WFC3 IR is also undersampled, but less so (0.13” vs 0.205”)
  - FWHM ranges from ~1-1.3 pixels across the band
  - Modern high-QE detector has much lower intrapixel sensitivity variations, producing more uniform photometric response
- WFC3 thus offers real resolution advantages as well in wide field surveys, e.g. in tracing galaxy morphologies to higher redshift

IR Channel Science Goals

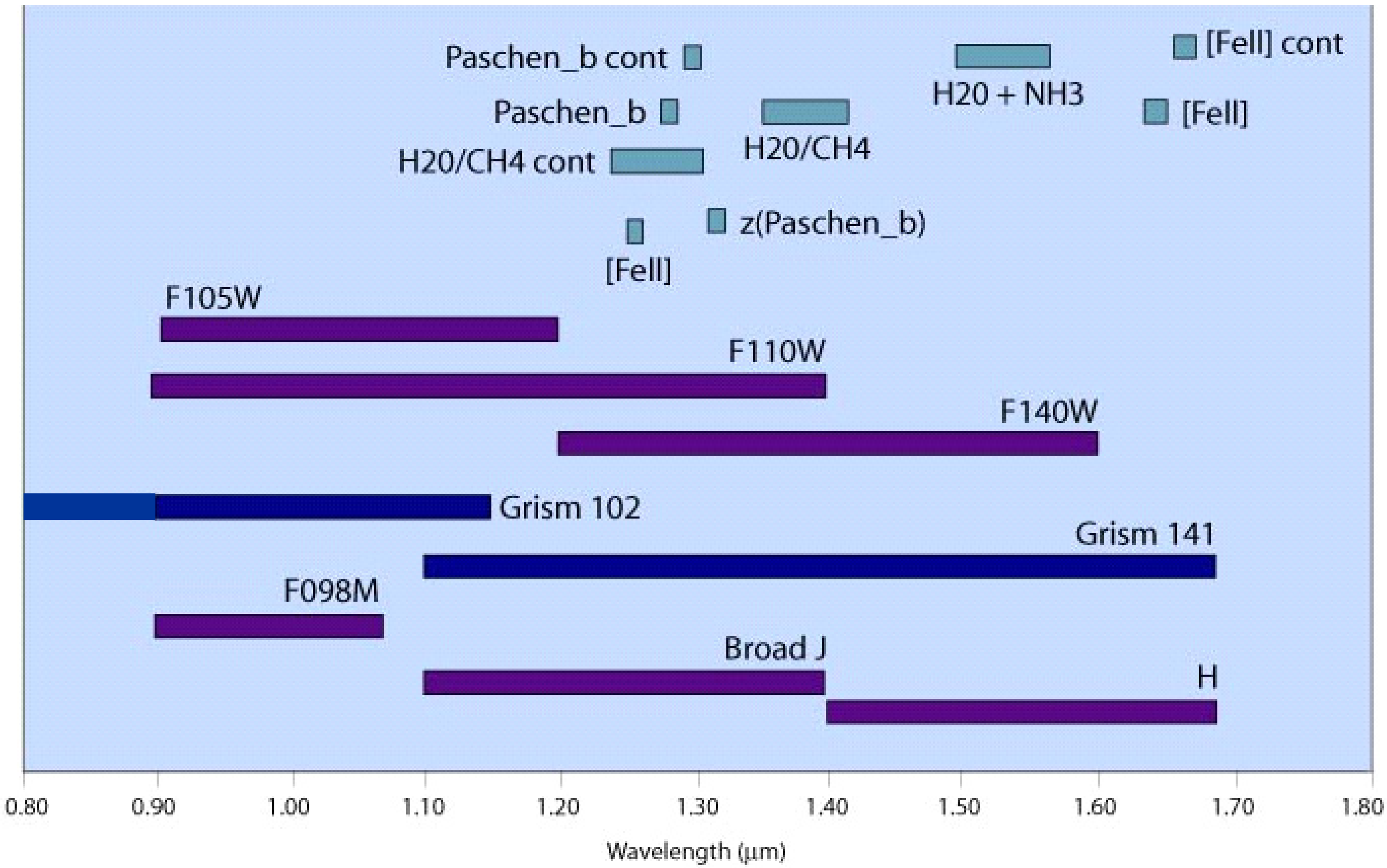
The IR channel will take advantage of the dark IR sky in space to study:

- Type Ia supernovae and the accelerating universe (cf. Riess and Livio 2006)
- High-redshift galaxy formation (high-z dropouts) – note the strong NIR color-color discrimination of high-z galaxies in the figure at right
- Sources of cosmic re-ionization
- Dust-enshrouded star formation
- Water and ices in the solar system.

IR Color-Color Identification of High-z Galaxies



IR Filter Complement

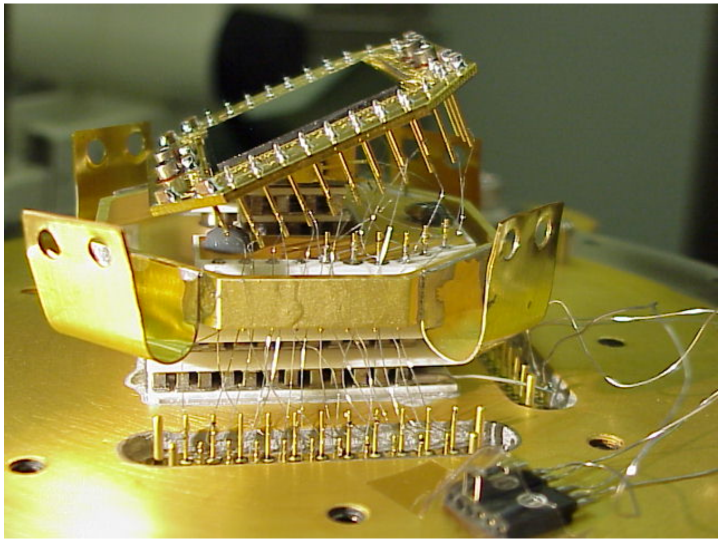


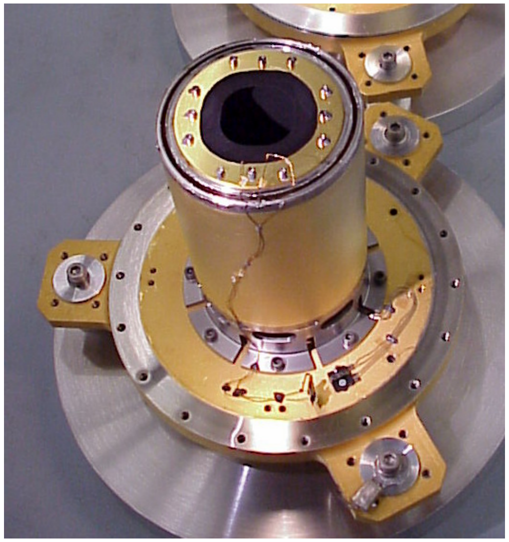
Slitless Spectroscopy with WFC3 Grisms

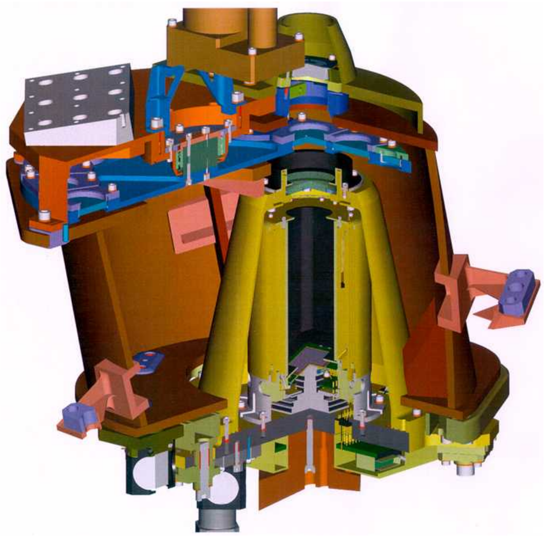
WFC3 offers low-resolution, wide-field slitless spectroscopy with grisms in the NUV and NIR

- NUV grism – WF/PC1 spare optic; very complex output (lots of orders), will be a bit tricky to use
- NIR grisms – clean, efficient first order spectra; lots of potential, e.g. for spectroscopy of faint, high-z supernovae
- *I call your attention to Harald Kuntschner's talk later today for details of the WFC3 grisms and their performance*
- As well as the associated poster from the ST-ECF team regarding their valuable software simulation tools for grism spectroscopy

IR Detectors





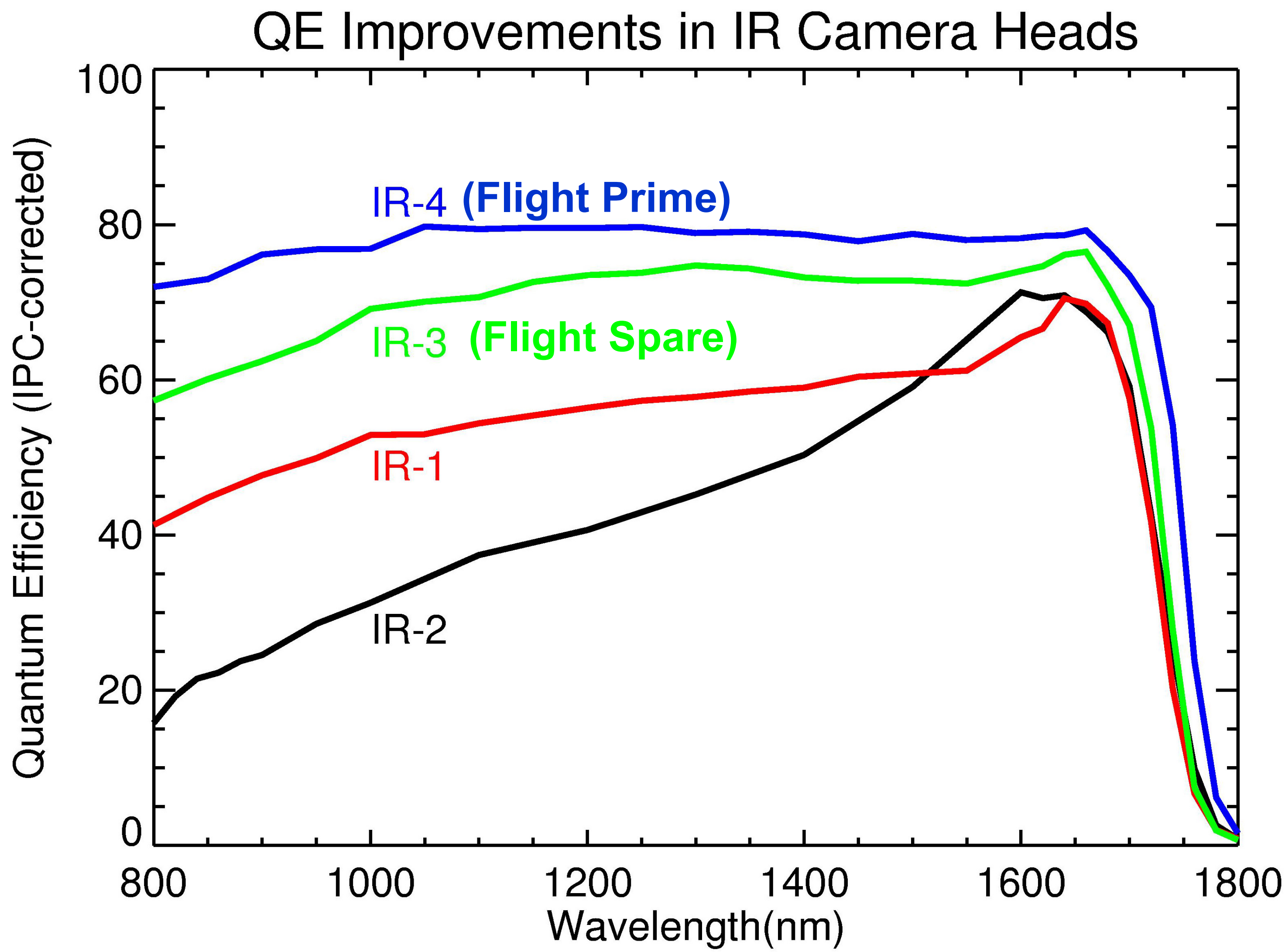


- The novel 1.7 micron cutoff wavelength of the IR array (left), developed by Rockwell Scientific (now Teledyne Imaging Sensors), permits low-dark-current operation at a temperature of 145 K, achievable with thermo-electric cooling alone.
- A cooled inner shield (center) within the detector housing (right) helps to minimize the thermal background radiation incident on the array.

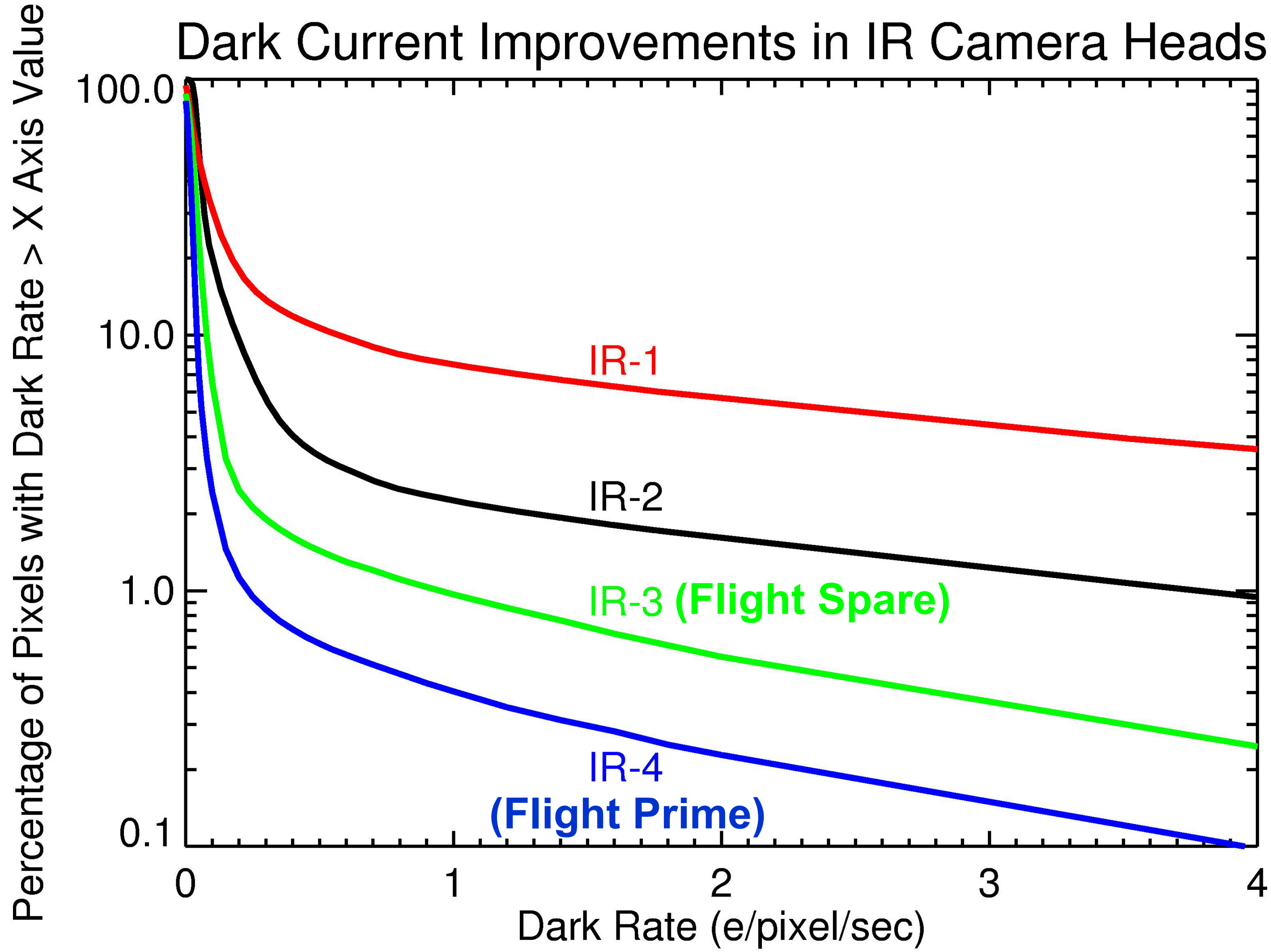
Tremendous Advances in IR FPA Performance During the WFC3 Program

- WFC3 HgCdTe arrays are grown by MBE process on CdZnTe substrates
- Early FPAs were illuminated through the CdZnTe substrate, which transmits down to 800nm
- WFC3 "live" radiation testing revealed a luminescence from the substrates that would have compromised the detector background rate in orbit
- Fortunately, Rockwell/Teledyne were just then developing a process for removing the CdZnTe substrates
- Early parts of this design were unable to combine high QE with good dark current
- **The final WFC3 lot yielded some "just-in-time" gems**

Substrate-Removed IR FPAs Deliver Dramatically Improved QE



Recent Substrate-Removed FPAs Deliver Excellent Dark Current As Well



Cumulative histogram shown at left.

Mean dark rate for >99.5% of pixels is only 0.022 e/pix/s.

Read noise (16 reads up the ramp) = ~15e rms.

Recent Highlights of WFC3 Development

Thermal-Vacuum Test #2 (July-Oct 2007)

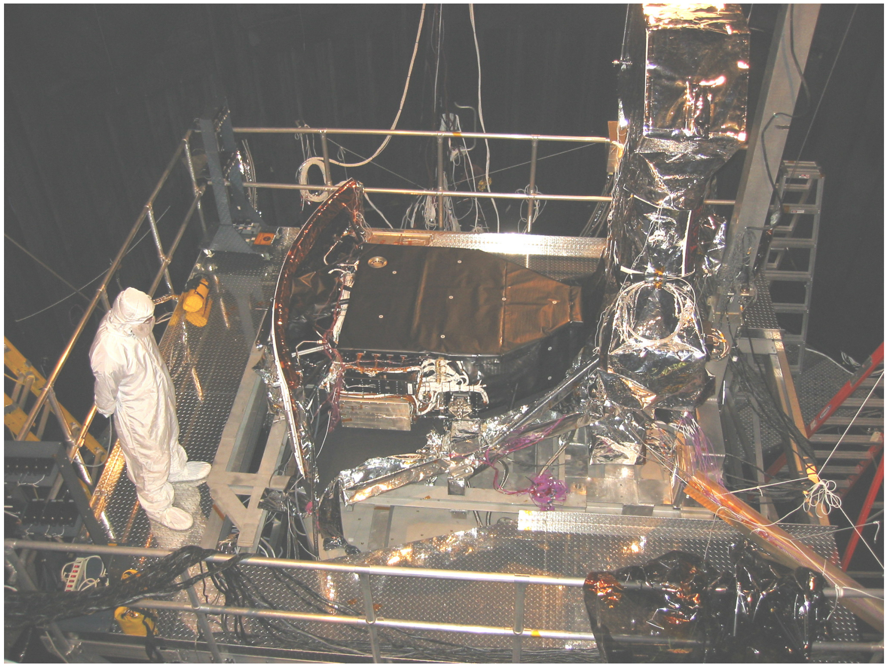
- Extensive engineering checkout of all WFC3 systems
- Validated thermal performance and thermal model
- Confirmed excellent optical performance
- Yielded baseline science calibration with flight-like detectors, though not the final flight units

Post-Thermal-Vac Activities

- Corrected the small number of hardware issues in T-V #2
  - Tweaked the TEC control circuitry for the detectors
  - Replaced tungsten lamps in the internal cal system with more robust versions
- ***Completed and installed the intended flight detectors***
- ***Buttoned up the instrument for final testing/calibration***

WFC3 Integrated for Thermal-Vac #2

The fully assembled instrument.



Setting up in vacuum chamber with HST optical simulator.

In-Flight Performance Predictions

Baseline science calibration provides a firm basis for estimating in-flight performance of the instrument

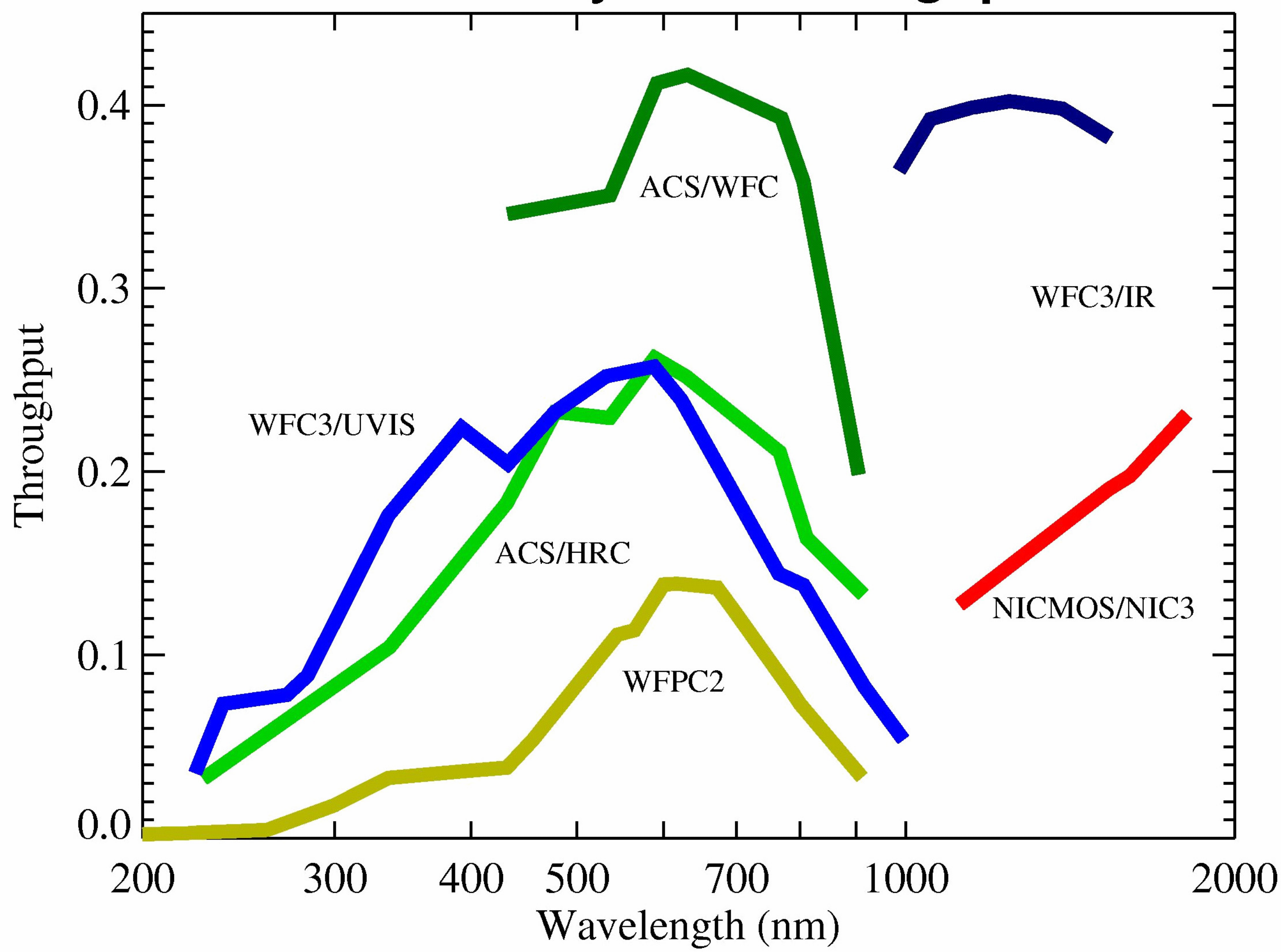
- Scale T-V #2 data by relative performance of flight detectors vs. the earlier units
- Combine with standard models of HST OTA throughput, PSF, sky backgrounds

Will quickly present those performance predictions here

- See associated poster for a more leisurely look
- See STScI Cycle 17 and WFC3 web sites for similar information (e.g. Instrument Handbook)
- Use WFC3 Exposure Time Calculator to estimate performance for your intended application

WFC3 Greatly Enhances NUV/NIR Performance of Observatory

HST Total System Throughputs

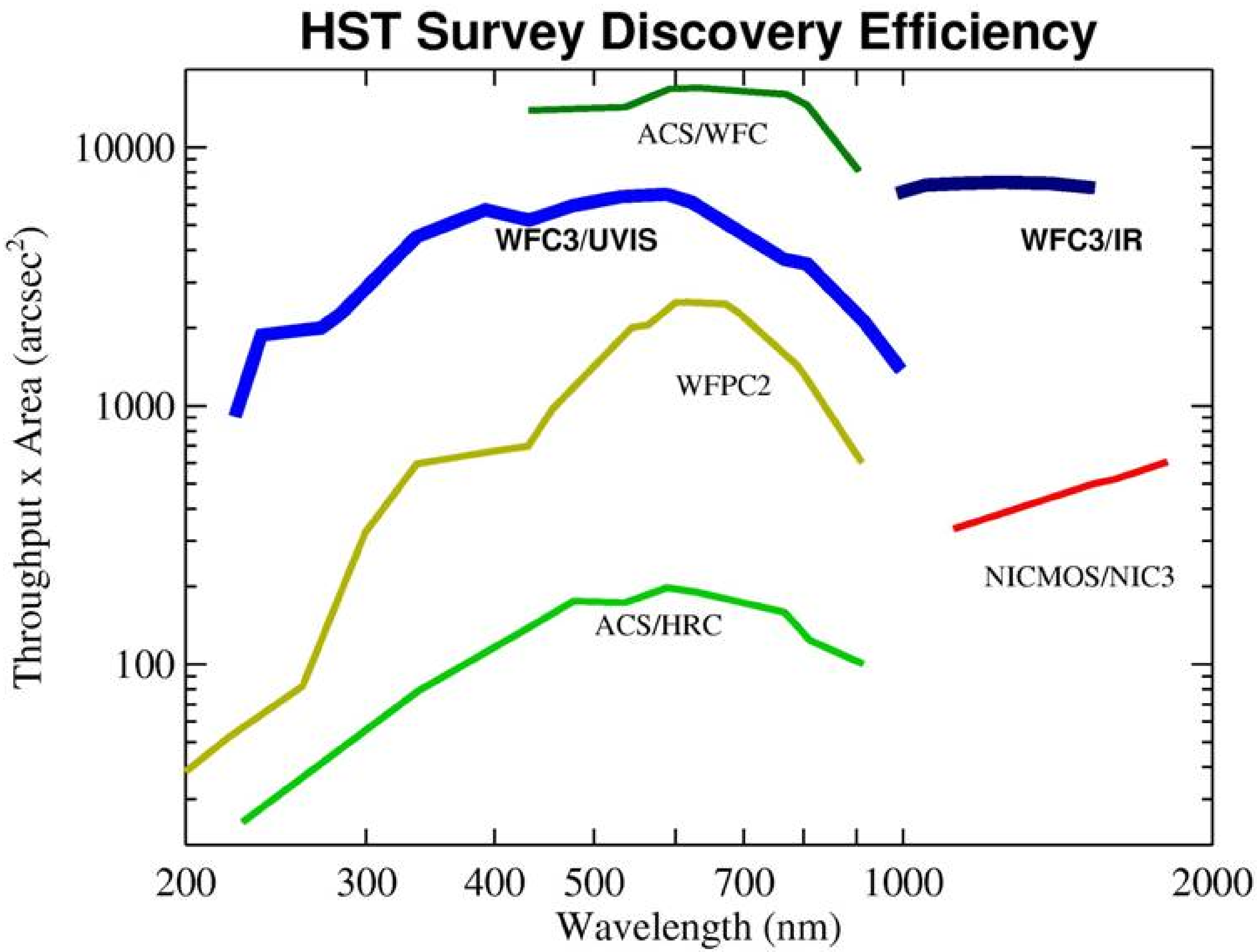


Curves connect midpoints of available broadband filters.

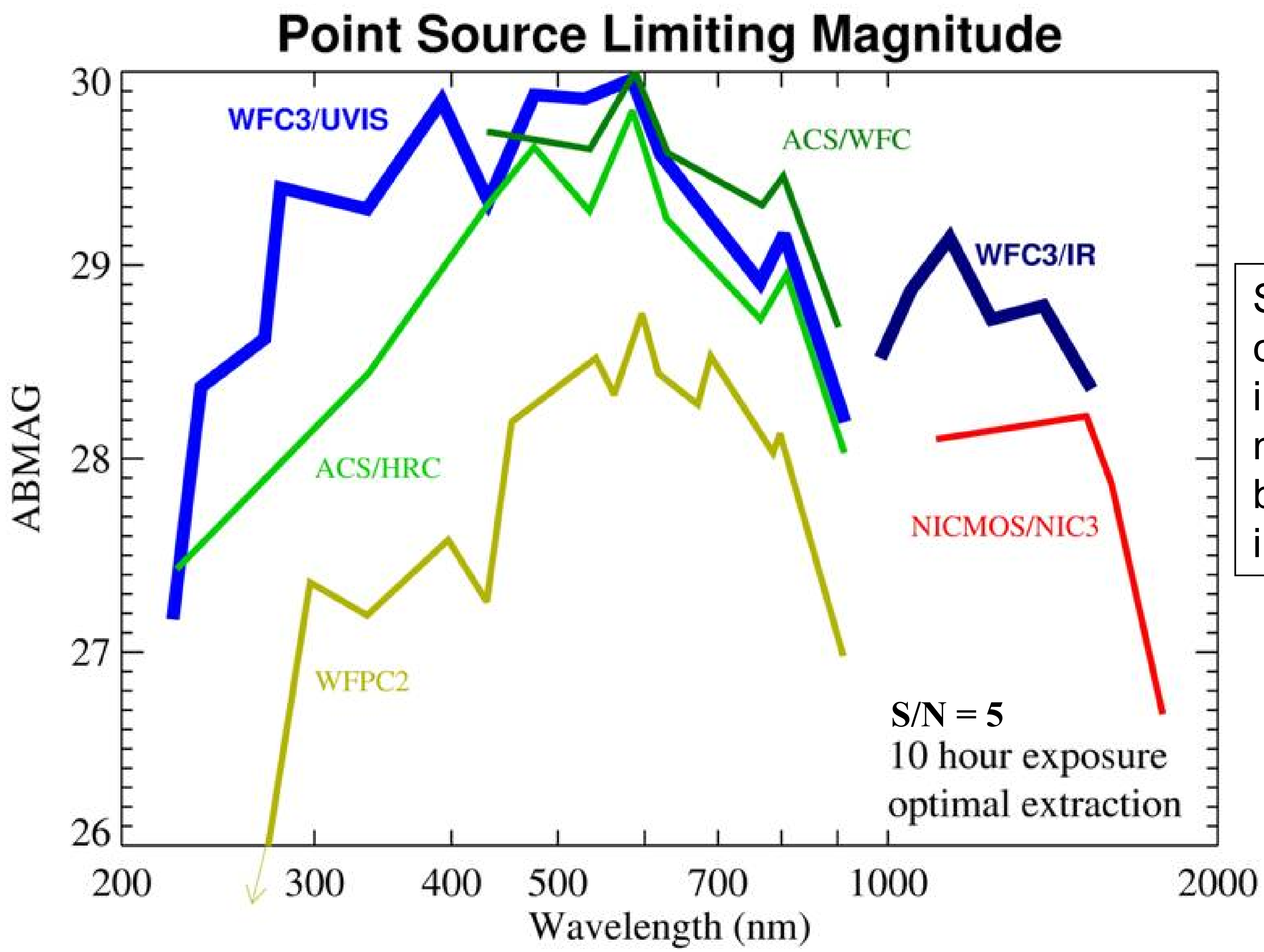
WFC3/UVIS and ACS/HRC throughputs have been scaled down by >1 quantum yield shortward of 340nm.

There are actually more e- per detected photon than shown here.

WFC3 Offers >10x Increase in Discovery Efficiency (Throughput x FOV)



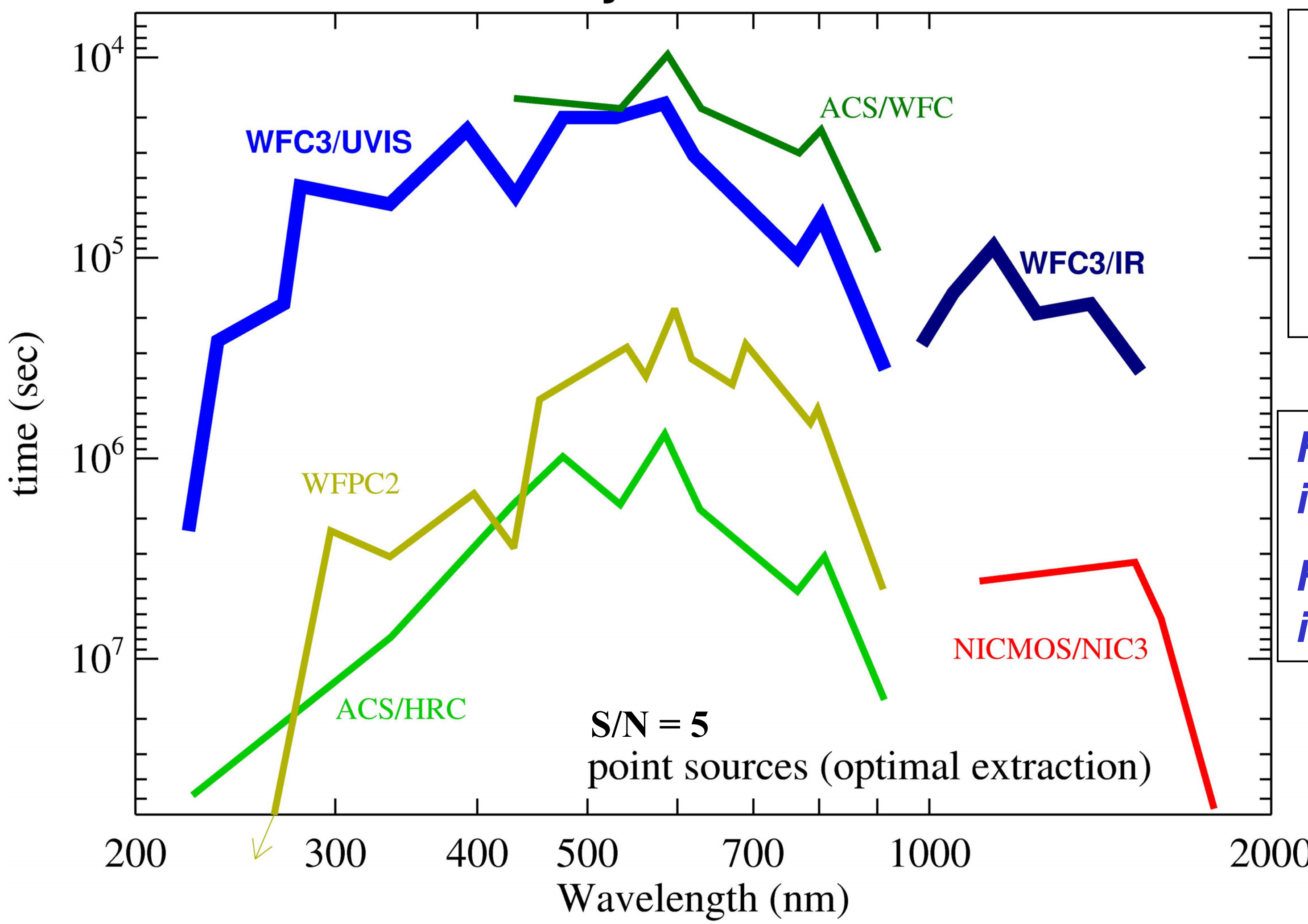
WFC3 Offers Increased Point Source Sensitivity in the NUV/NIR



Sensitivity calculation includes detector noise, typical sky background, and image sharpness.

And Greatly Increased Point Source Survey Speed in the NUV/NIR

HST - Time to survey 100 arcmin^2 to ABMAG=28

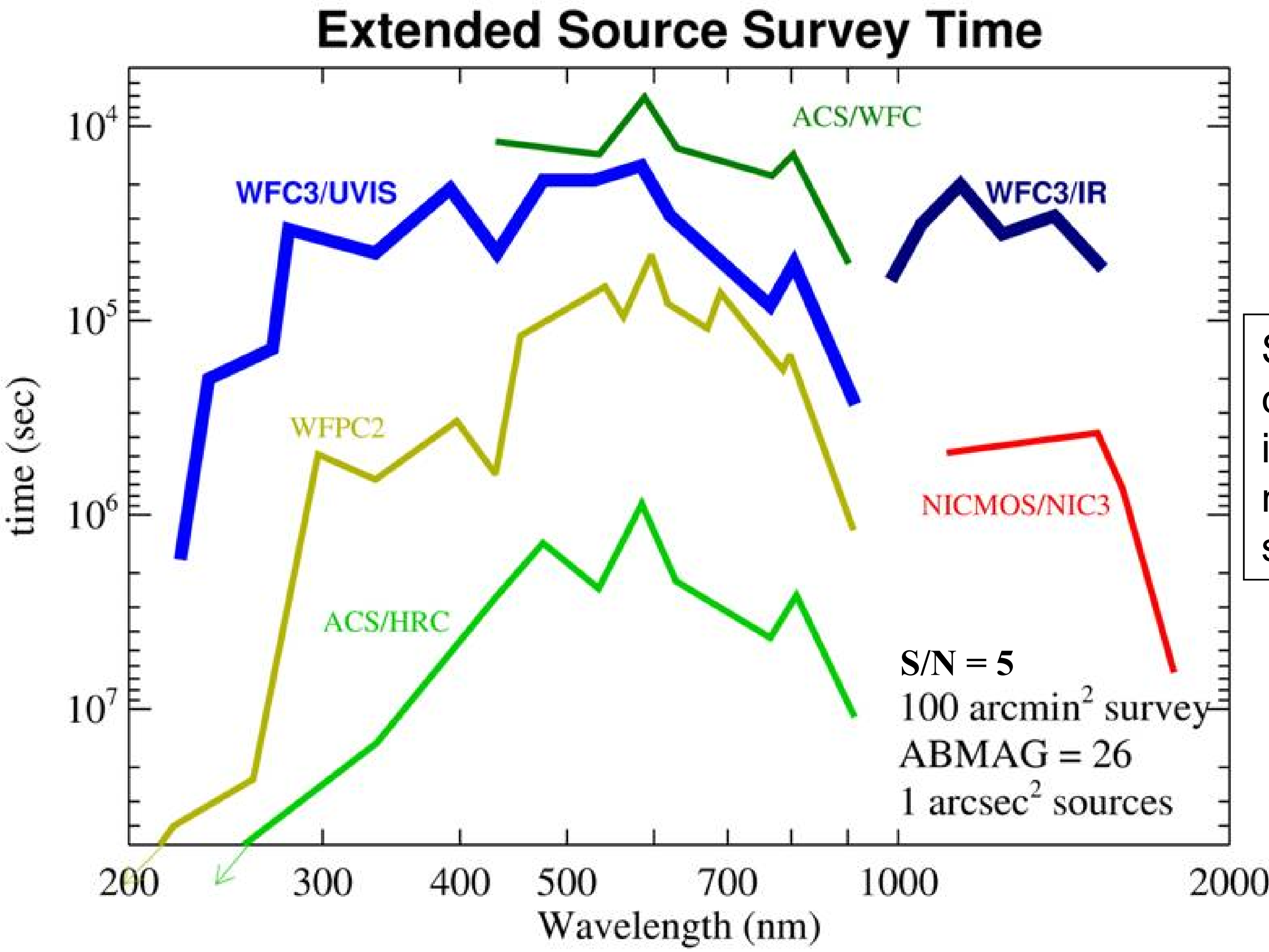


Sensitivity calculation includes detector noise, typical sky background, and image sharpness.

Factors of 30-100 in the NUV.

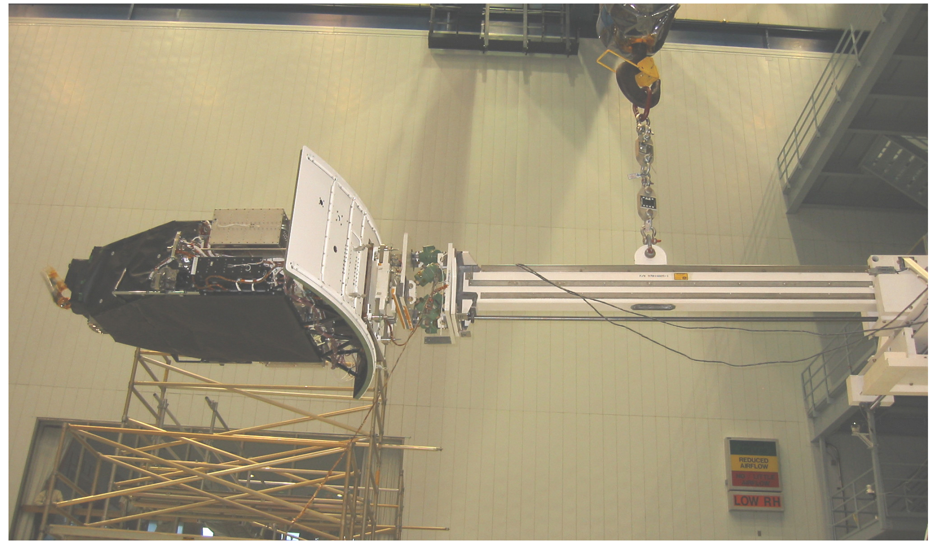
Factors of 10-30 in the NIR.

WFC3 Offers >10x Extended Source Survey Speeds in the NUV/NIR



Sensitivity calculation includes detector noise and typical sky background.

WFC3 Integration and Test Program Is Nearing Completion



An early flight of WFC3.

To a successful fit check in the HST Hi-Fidelity Mechanical Simulator.

Principal Remaining Pre-Installation Activities

- Completion of EMI/EMC testing (going well)
- VEST/SMGT (electrical/commanding checkouts with HST systems – preliminary runs were successful)
- **Thermal-Vac #3** – February/March; exercise the instrument in its final flight configuration and carry out the detailed ground science calibration with the flight detectors
- Delivery to HST Project – early April
- Integrated SMGT and System Compatibility Checks
- Ship to KSC
- ***Launch!***