In-Flight Performance of Wide Field Camera 3

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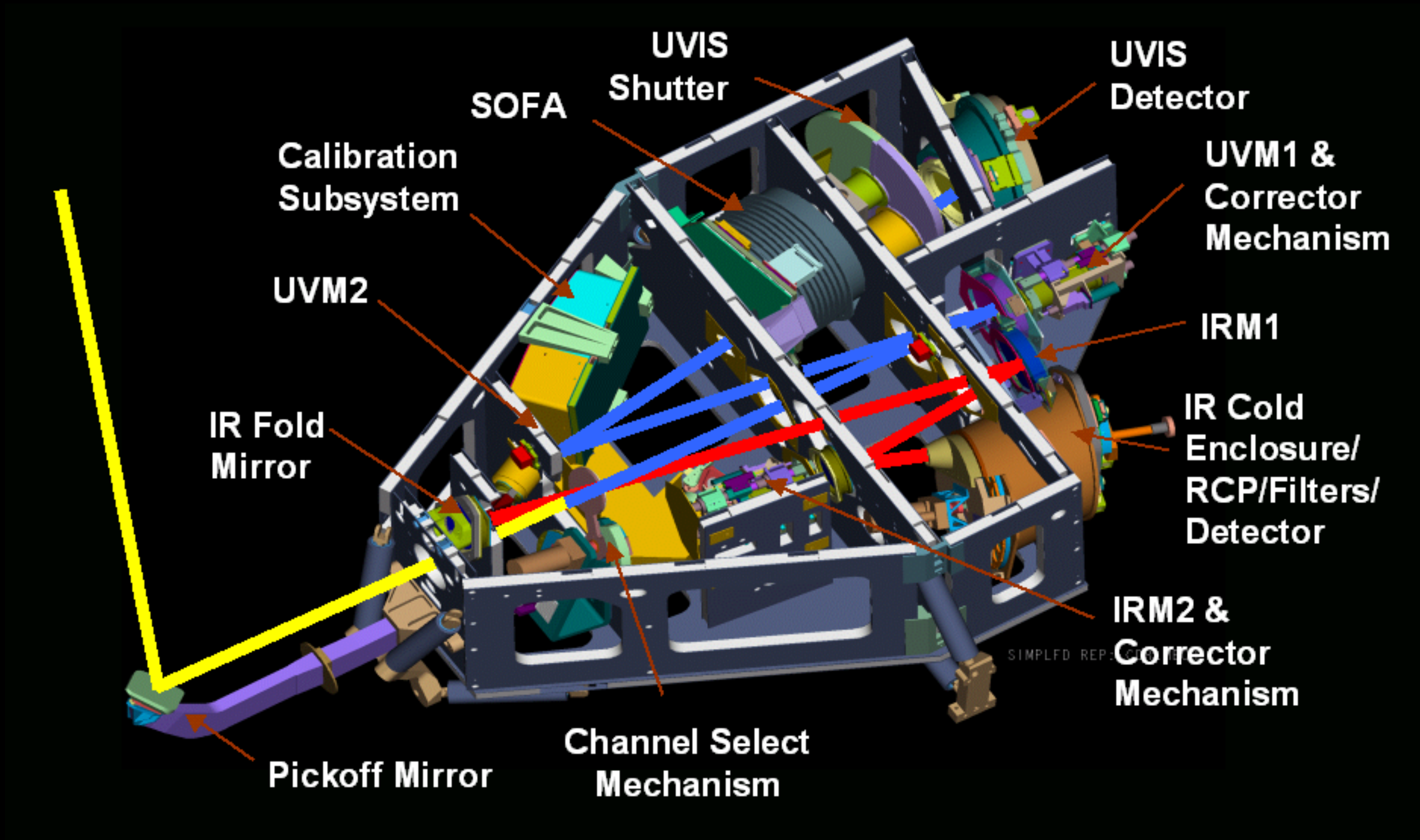
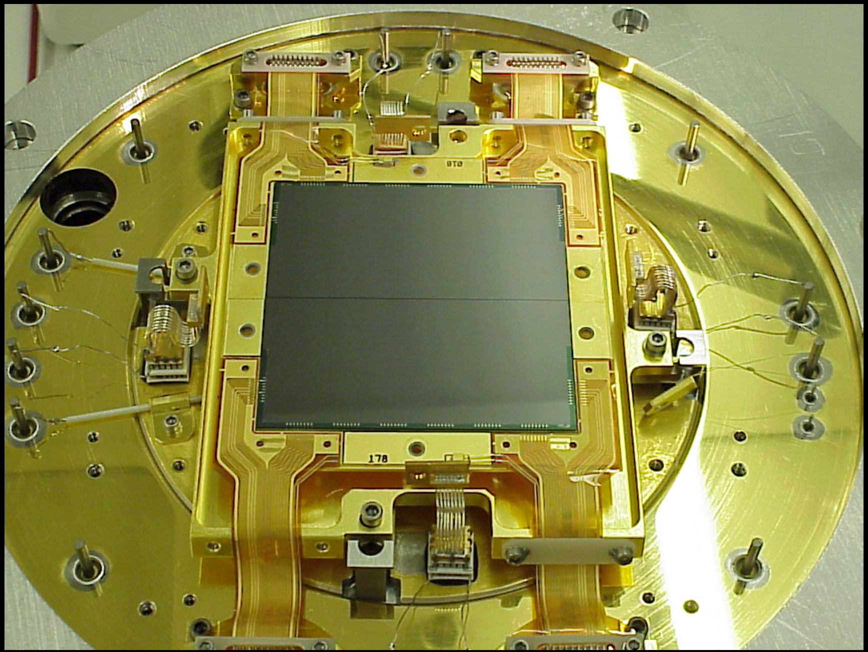
Origins/Purpose of WFC3

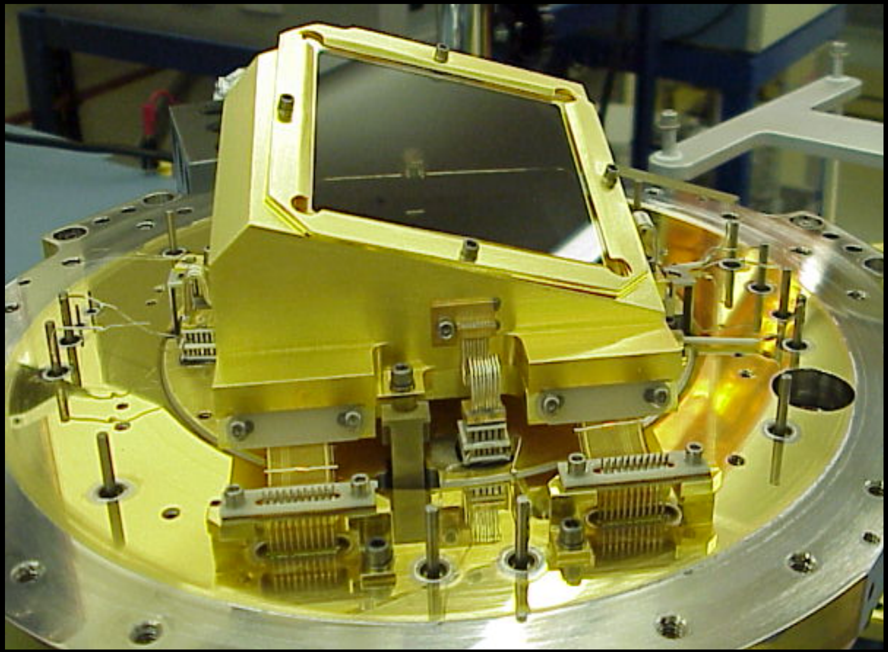
- WFC3 originated in 1997/1998 when HST's planned observing lifetime was first extended from 2005 to 2010: conceived for installation during Servicing Mission 4, to extend and enhance HST's imaging capability
- General purpose "panchromatic" imager (200-1700 nm), developed as a facility instrument by HST Project
  - Ball Aerospace was principal outside partner; much of the work in-house at Goddard Space Flight Center
  - Additional key contributions from e2v, Teledyne, Barr, Moog
  - Day-to-day science oversight from GSFC and STScI
  - External Scientific Oversight Committee, chaired by Bob O'Connell of U. of Virginia

WFC3 Interior Configuration



CCD Detectors



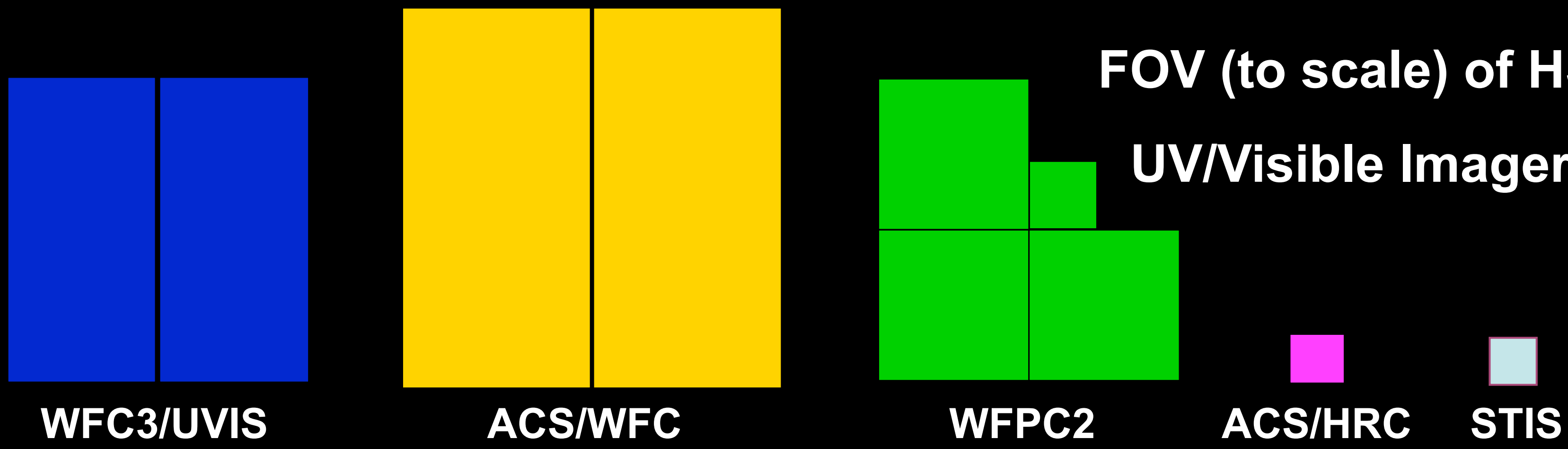


- 4K x 4K, low-noise, UV-optimized CCDs from e2v
- Camera heads built by Ball Aerospace

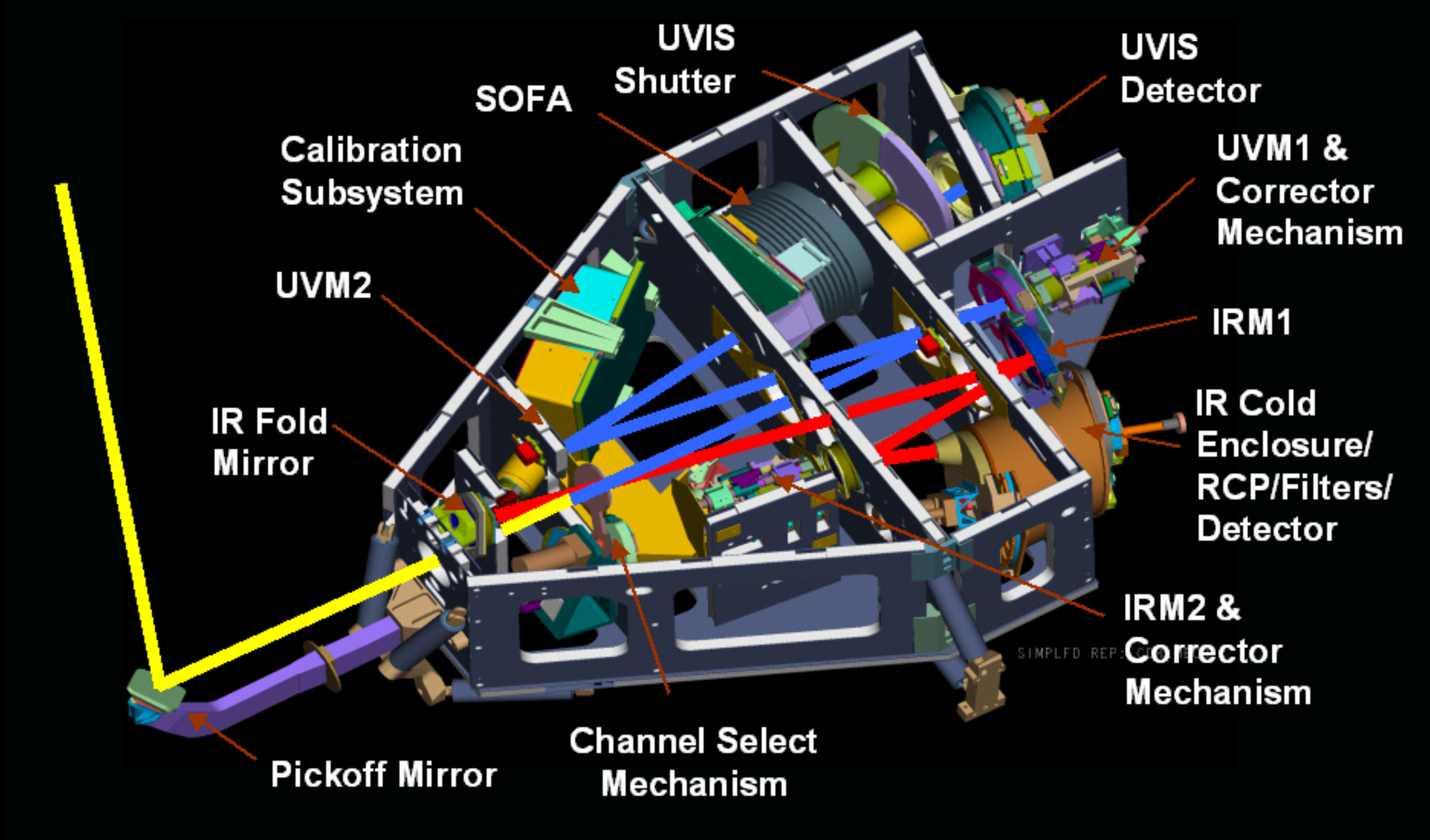
UV/Visible Channel Format Comparison of HST Imagers

Channel	Pixel Format	Pixel Scale (arcsec)	FOV (arcsec)	FOV/ WFC3
WFC3/UVIS	**4102×4096**	**0.039**	**162×162**	**1.00**
ACS/WFC	4096×4096	0.049	202×202	1.56
ARC/HRC	1024×1024	0.026	26×29	0.029
WFPC2/WF	800×800 (×3)	0.100	80×80 (×3)	0.73
WFPC2/PC	800×800	0.0455	36×36	0.051

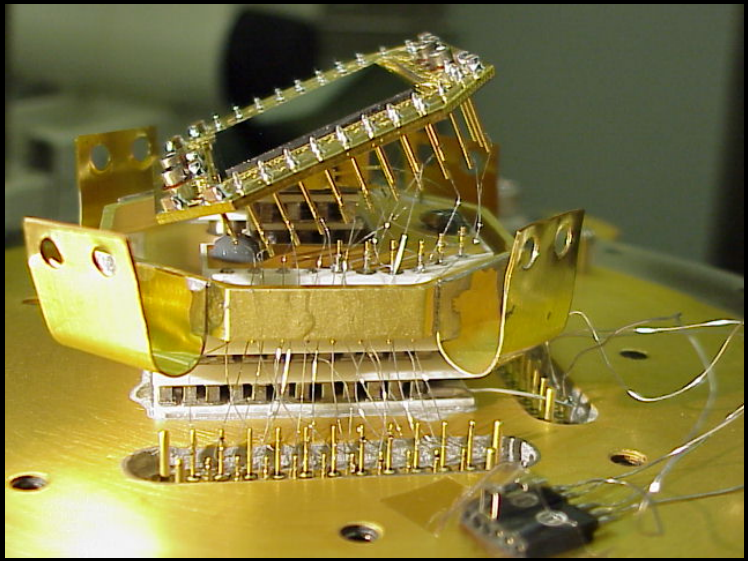
FOV (to scale) of HST UV/Visible Imagers

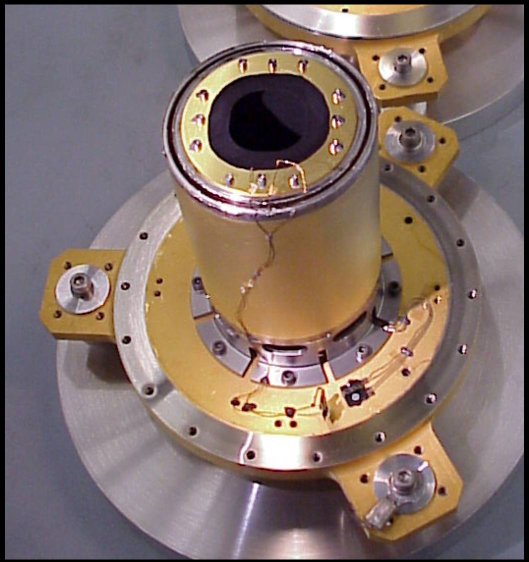


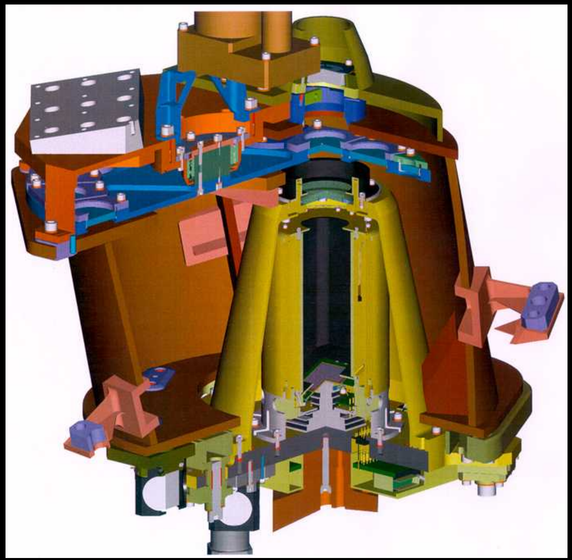
WFC3 Interior Configuration



IR Detectors



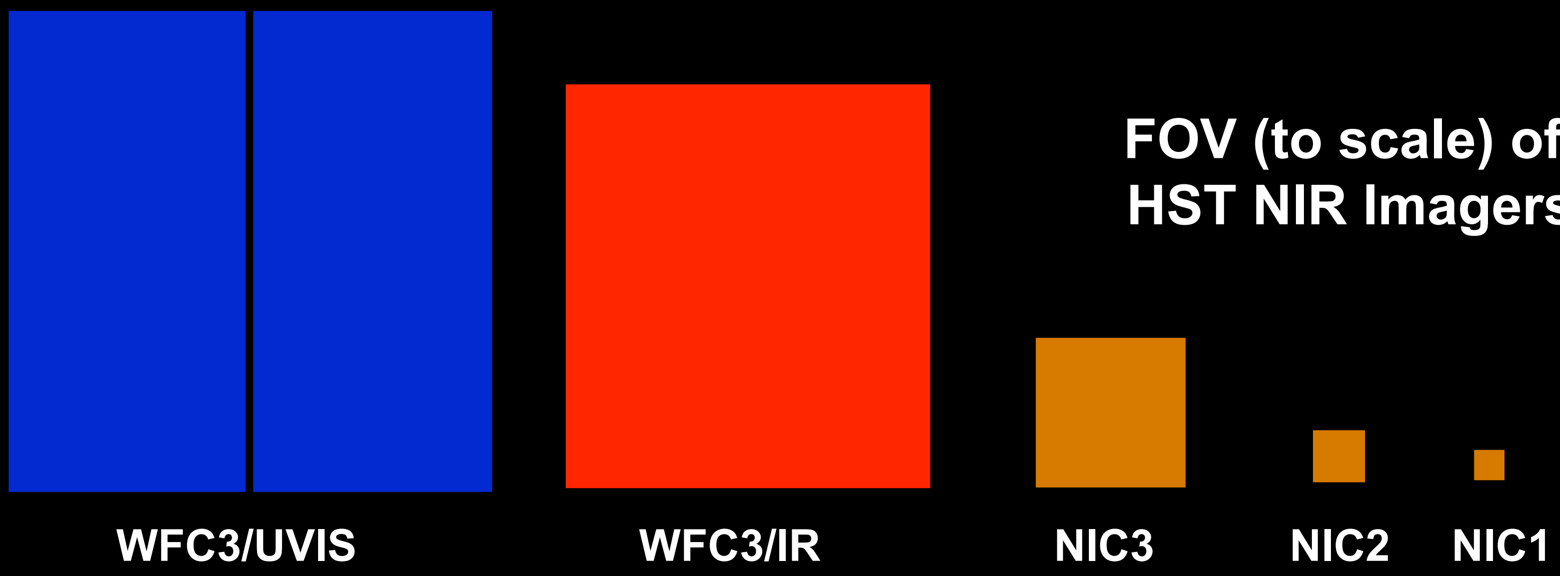




- The novel 1.7 micron cutoff wavelength of the IR array (left), developed by Teledyne Imaging Sensors (formerly Rockwell Scientific), permits low-dark-current operation at a temperature of 145 K, achievable with thermo-electric cooling alone.
- The development program was WFC3's biggest technical challenge, but in the end yielded a few "just in time" gems.

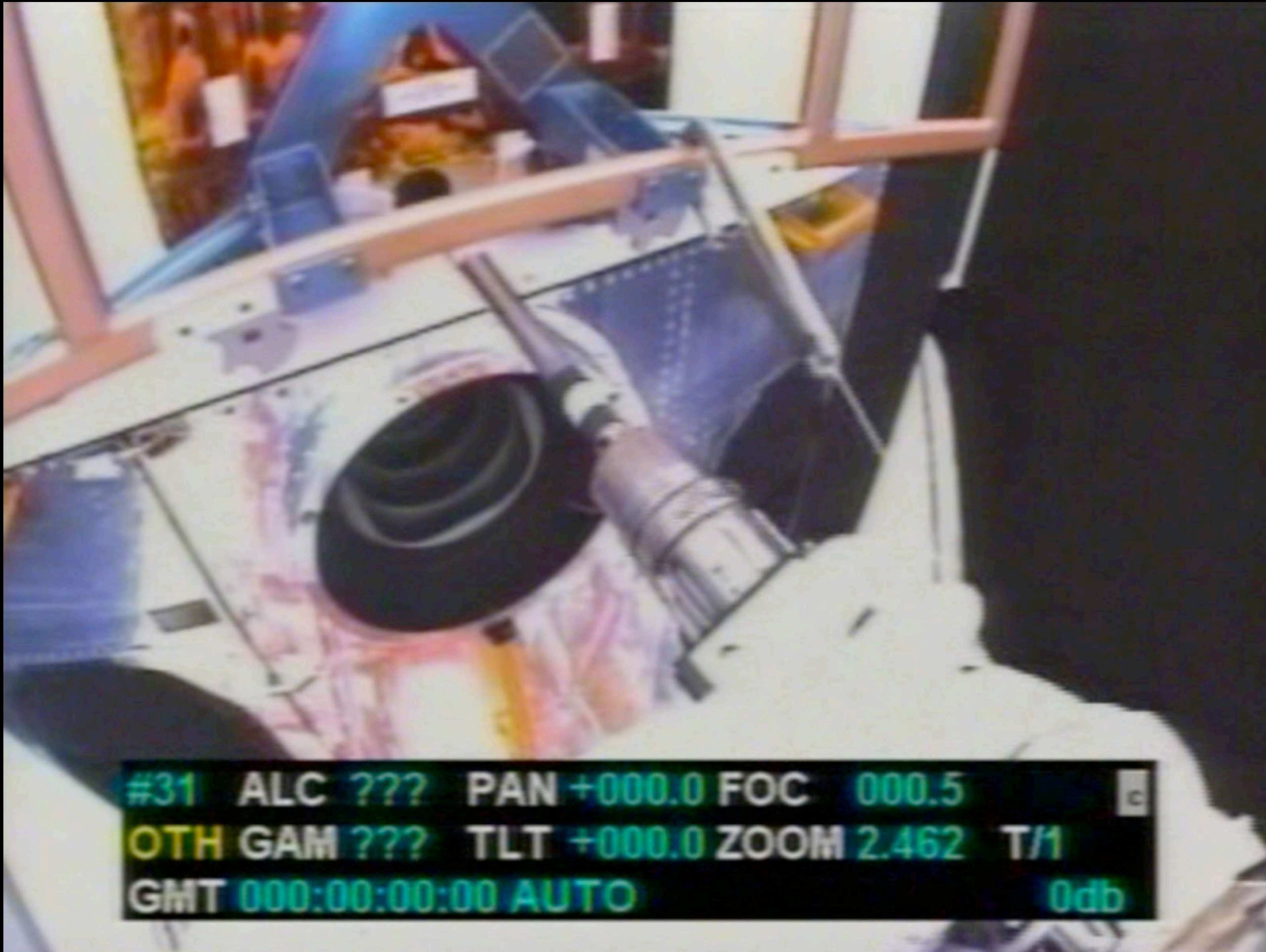
Infrared Channel Format Comparison of HST Imagers

Channel	Pixel Format	Pixel Scale (arcsec)	FOV (arcsec)	FOV/ WFC3
WFC3/IR	**1014×1014**	**0.13**	**123×136**	**1.00**
NICMOS/NIC3	256×256	0.200	51×51	0.155
NICMOS/NIC2	256×256	0.075	19×19	0.022

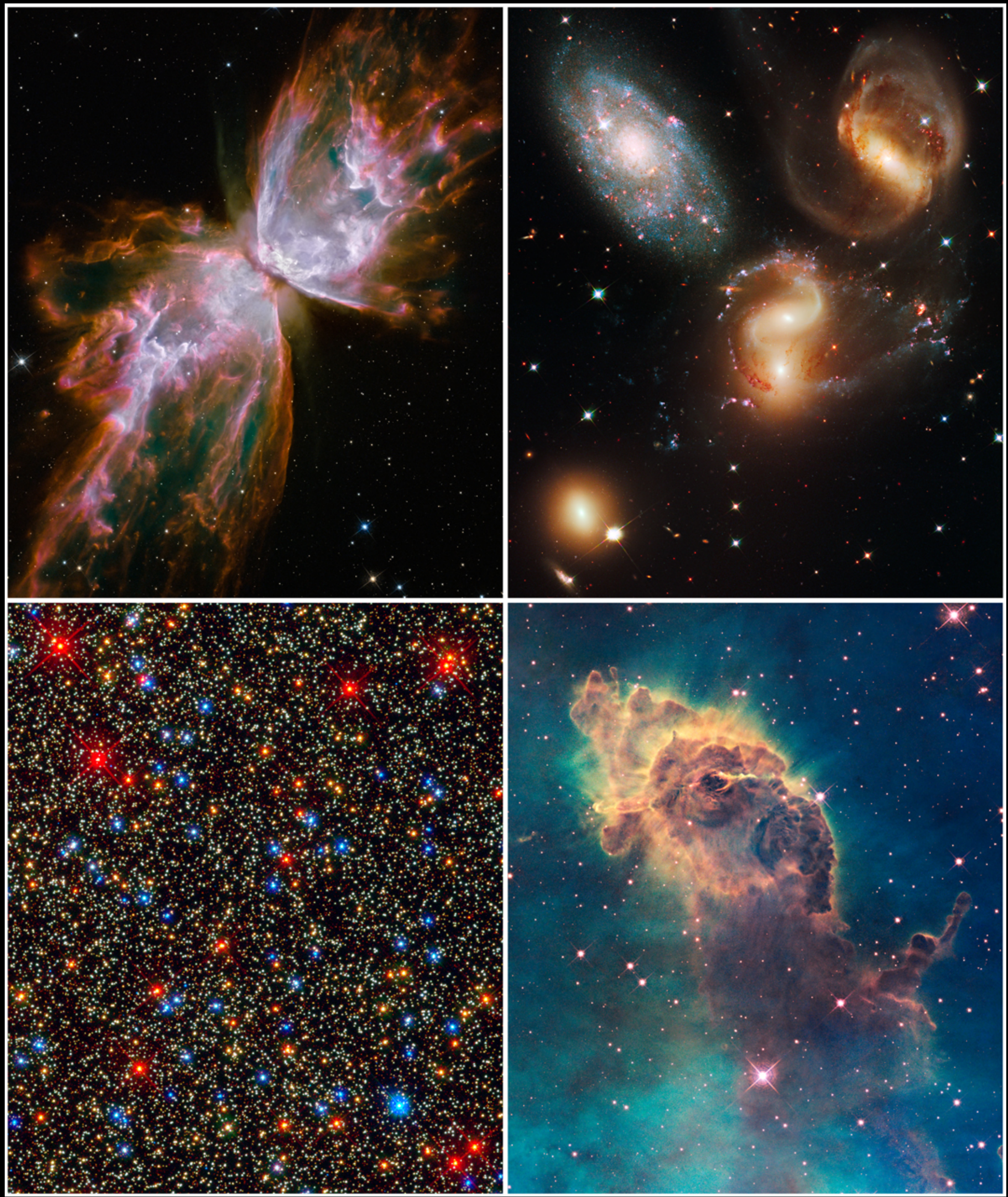


FOV (to scale) of HST NIR Imagers

Ready to Go


#31 ALC ??? PAN +000.0 FOC 000.5
OTH GAM ??? TLT +000.0 ZOOM 2.462 T/1
GMT 000:00:00:00 AUTO 0db

WFC3 Heading In



Early Release Observations

SMOV Results in a Nutshell

- Instrument operating completely nominally (mechanisms, electronics, thermal control) – all redundant systems on primary side
- Image quality excellent, in good agreement with ground test
- Detectors performing very well
- *Throughput 5-15% higher than ground test predictions*

Image Quality

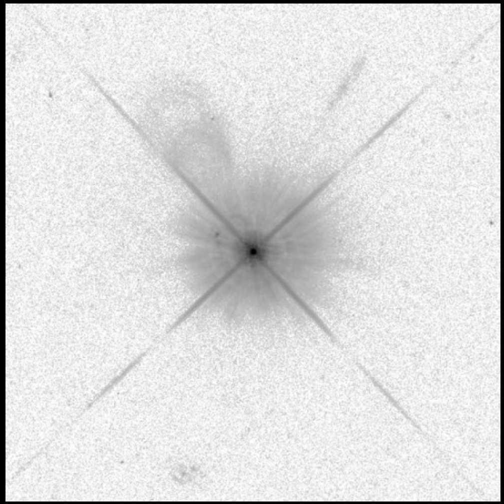
Encircled energy appropriate to an HST imager

UVIS:

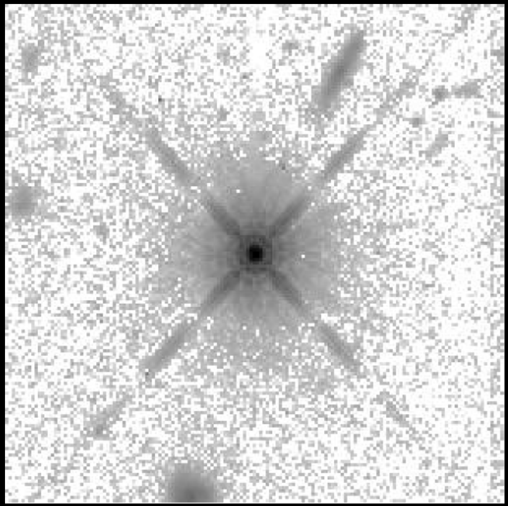
- ~79% in 0.25 arcsec diam at 633nm
- Same in UV (finer diffraction limit; more scatter)

IR:

- 56% in 0.25 arcsec diam at 1.0
- 46% in 0.25 arcsec diam at 1.6



F625W, ~20x20 arcsec, 6 dex log stretch



F160W, ~20x20 arcsec, 6 dex log stretch

UVIS Detector Has Low Read Noise and Dark Current

- Read noise is ~3.1 e- rms for all four readout amps
- Median dark current <3 e-/pixel/hr
  - Higher than ground test and slowly growing, but still negligible
  - Hot pixel tail slowly growing with radiation damage

- *These low values are particularly valuable for WFC3 with its fine sampling (0.039”/pixel) and its emphasis on UV and narrowband observing → low sky counts*

IR Dark Current and Read Noise Slightly Improved vs. Ground Test

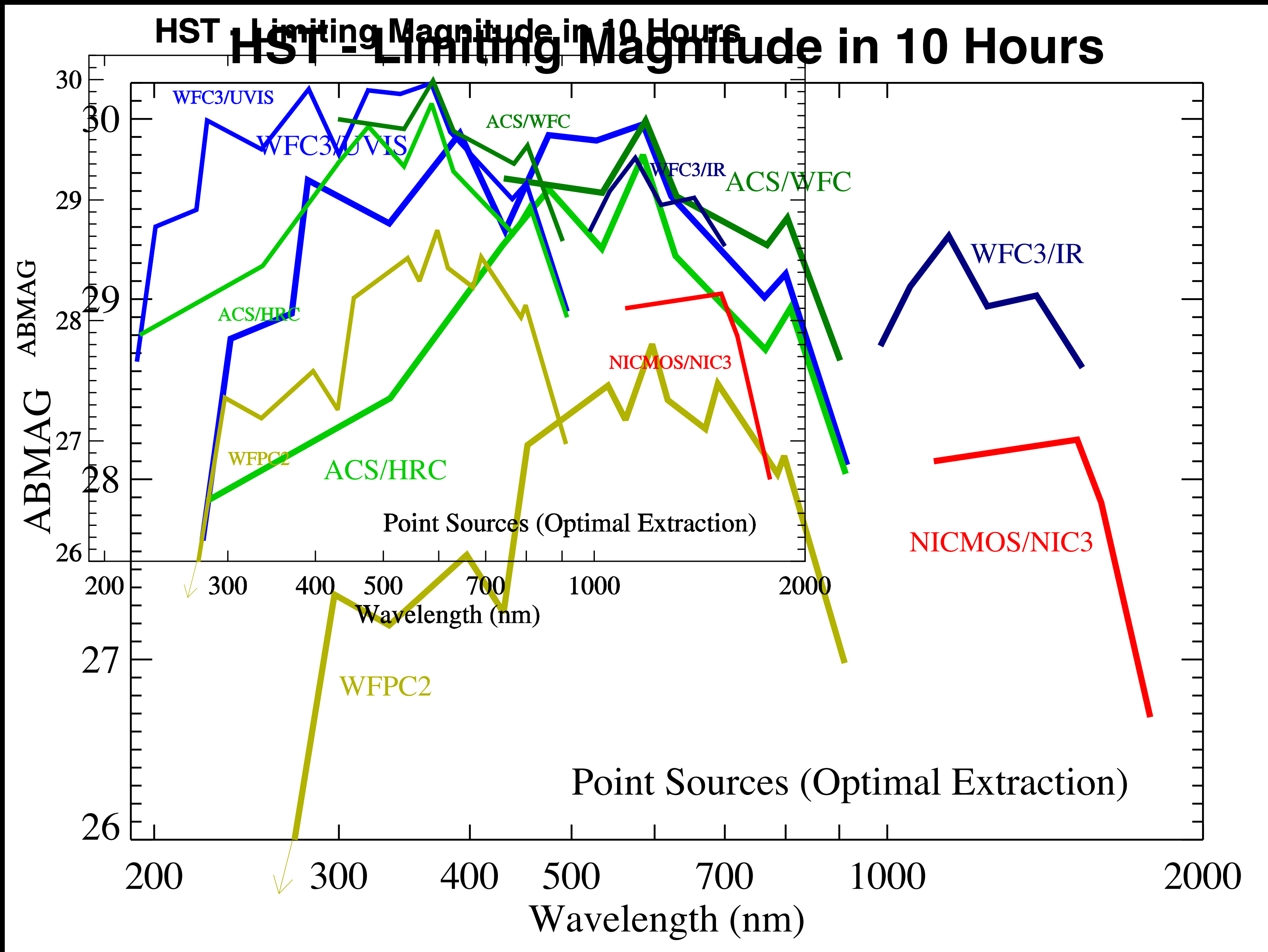
- Median dark rate ~0.05 e/pix/s, only 0.6% of pixels above spec of 0.4
- Effective noise reading up the ramp is actually a bit lower in flight than in thermal-vac for long exposures: (average of the 4 quadrants shown)

# of Reads	3	8	15	
Effective noise (e- rms; SMOV)	19.6	16.0	12.4	***Flight***
Effective noise (e- rms; thermal-vac)	20.8	17.8	14.6	***Ground***

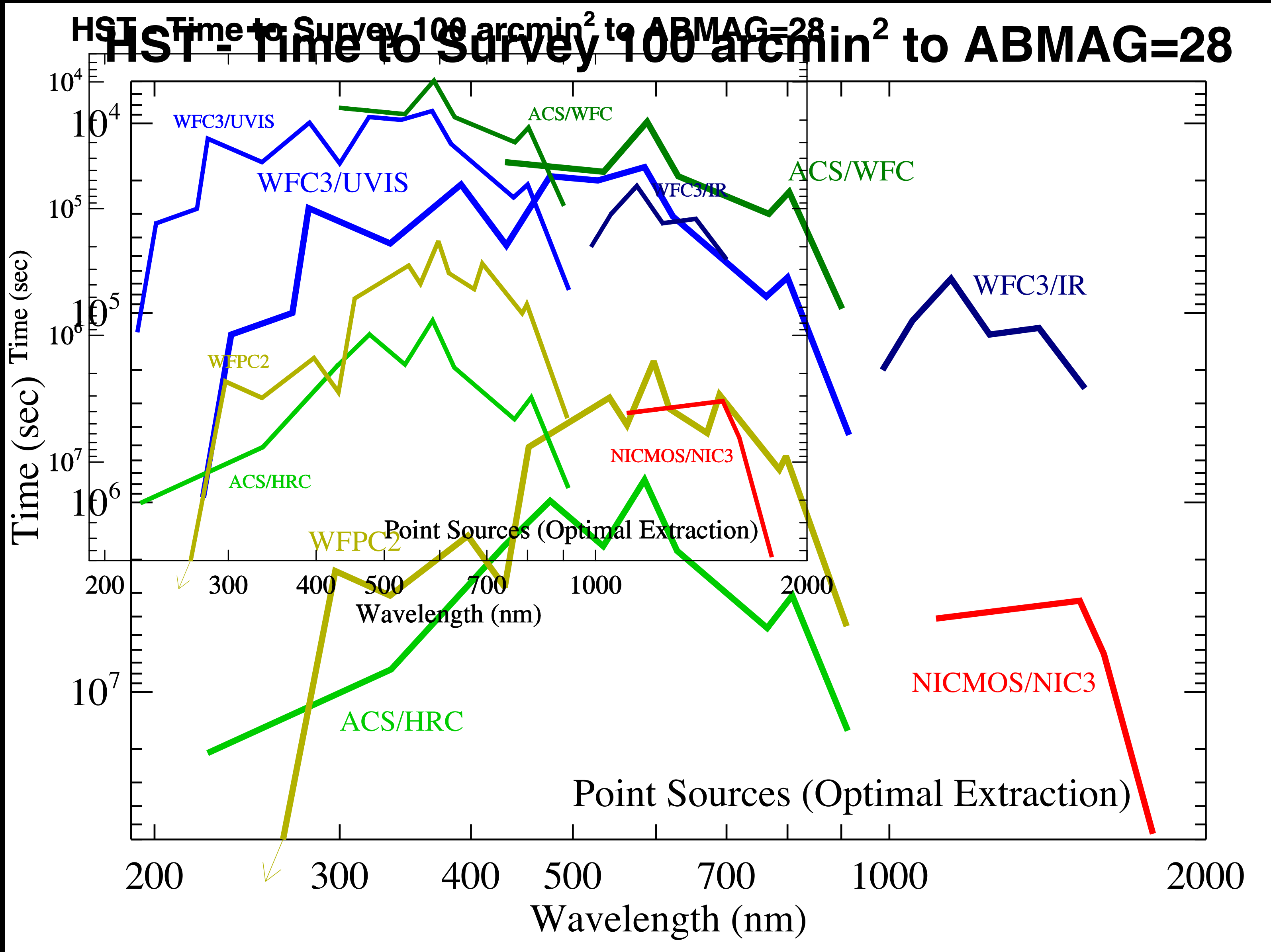
- *Combining read noise with excellent dark current, very well satisfies goal of being zodiacal-background-limited for long exposures in broad bands (zodi rates from a few tenths to >1 e-/pix/s)*

- ~2.5% pixels flagged as “bad” – low QE, high dark, unstable, open

Performance Metrics vs. Other HST Imagers



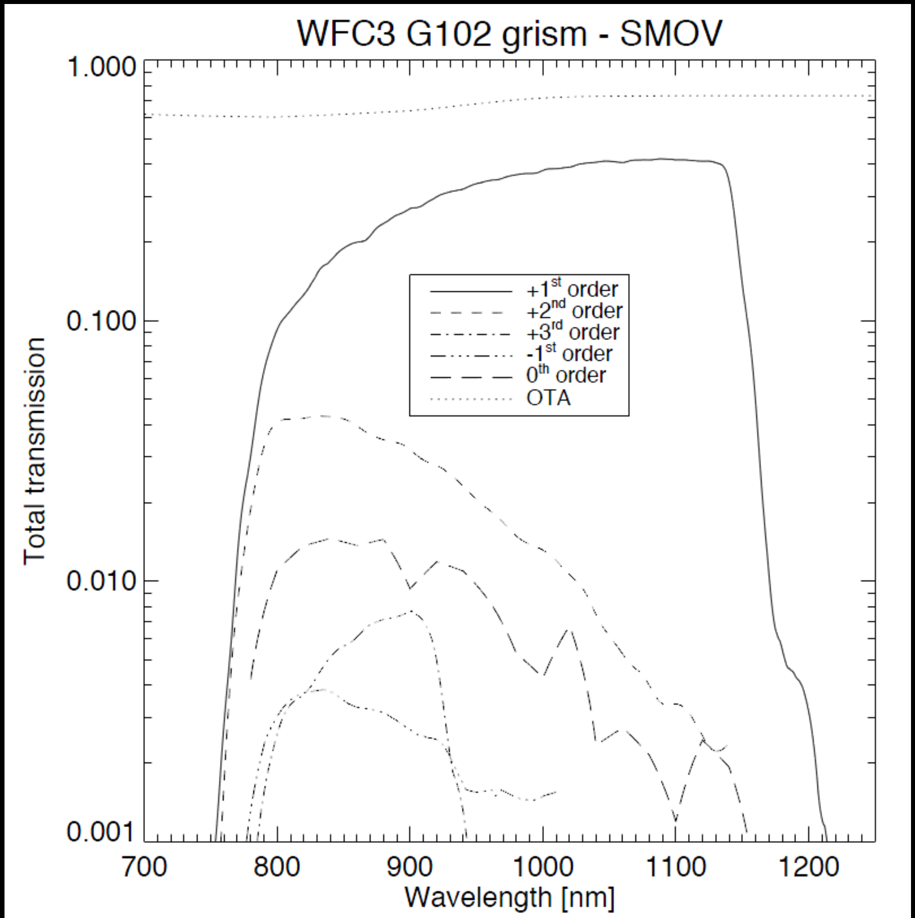
Performance Metrics vs. Other HST Imagers (2)

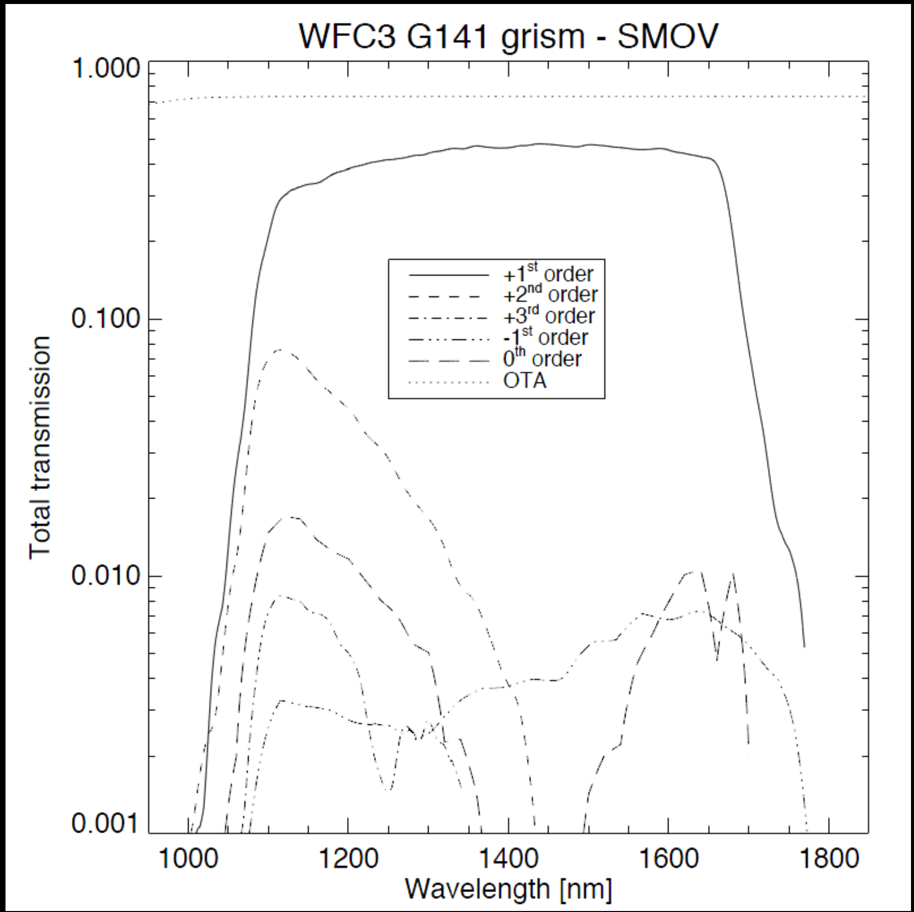


Very Exciting Capability –
Slitless Spectroscopy with WFC3's IR Grisms

- G102 (0.8 – 1.1µm; R ~ 210)
- G141 (1.1 – 1.6µm; R ~ 130)

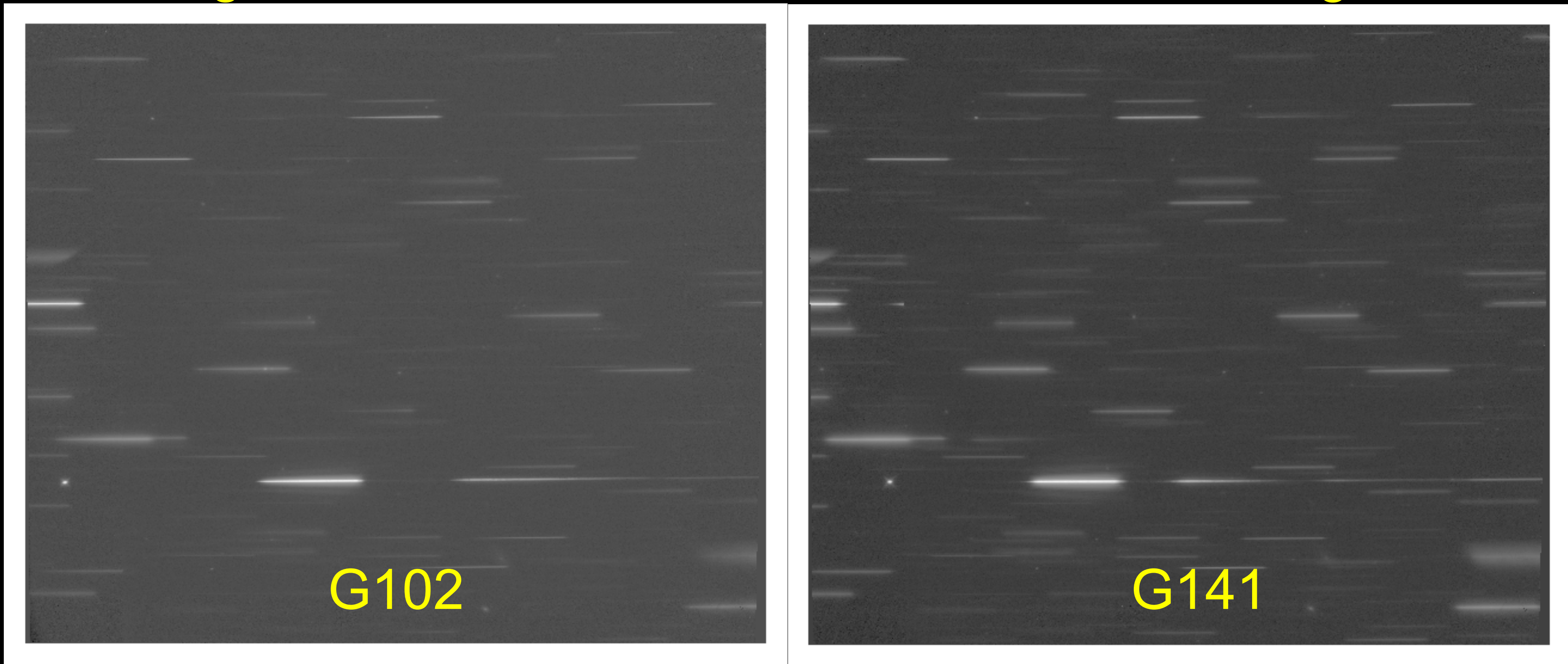
Very high end-to-end throughput





IR Grism Images from GOODS Field

- SOC did a very nice demonstration project in ERS program
  - Two orbits in each grism
- Straughn et al. showed a number of emission-line galaxies

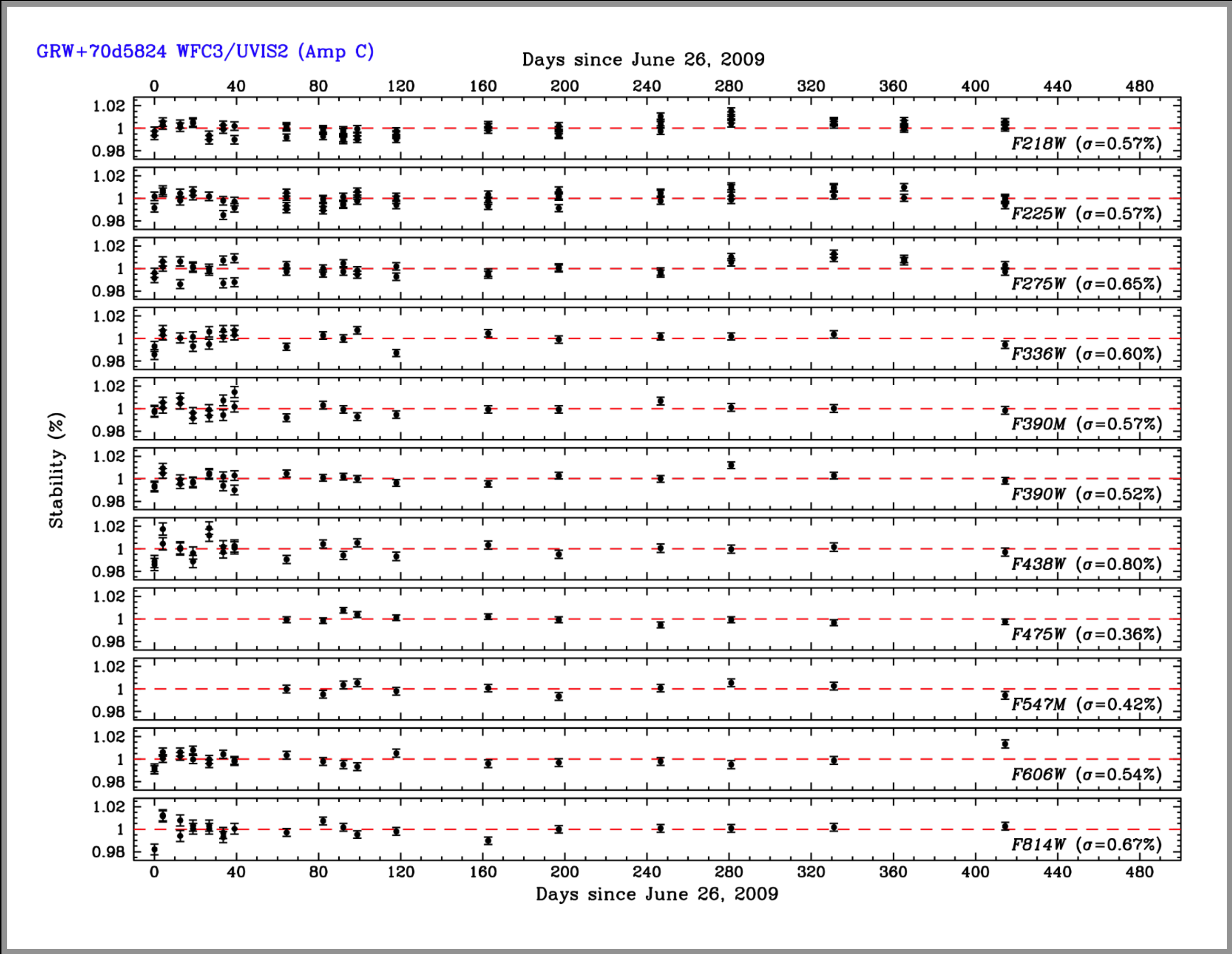


- Community has definitely noticed this capability
- *20% of prime GO orbits in Cycle 18 selection to IR grisms*

Photometric Stability

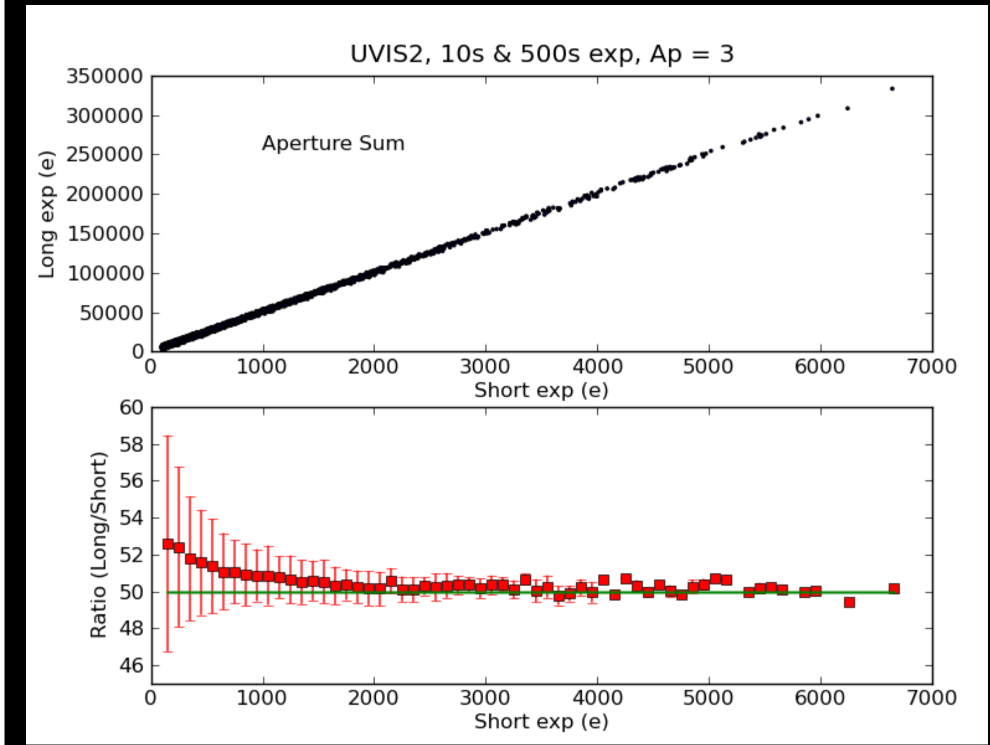
- Photometric stability has been excellent
- UVIS: ~0.3% rms on bright standard stars over 15 months
- IR: ~0.5% rms in similar monitoring
- No discernible trend in either channel
- Few % QEH issue intrinsic to these CCDs completely controlled in flight using lamp flash protocol developed in lab test in the year before launch

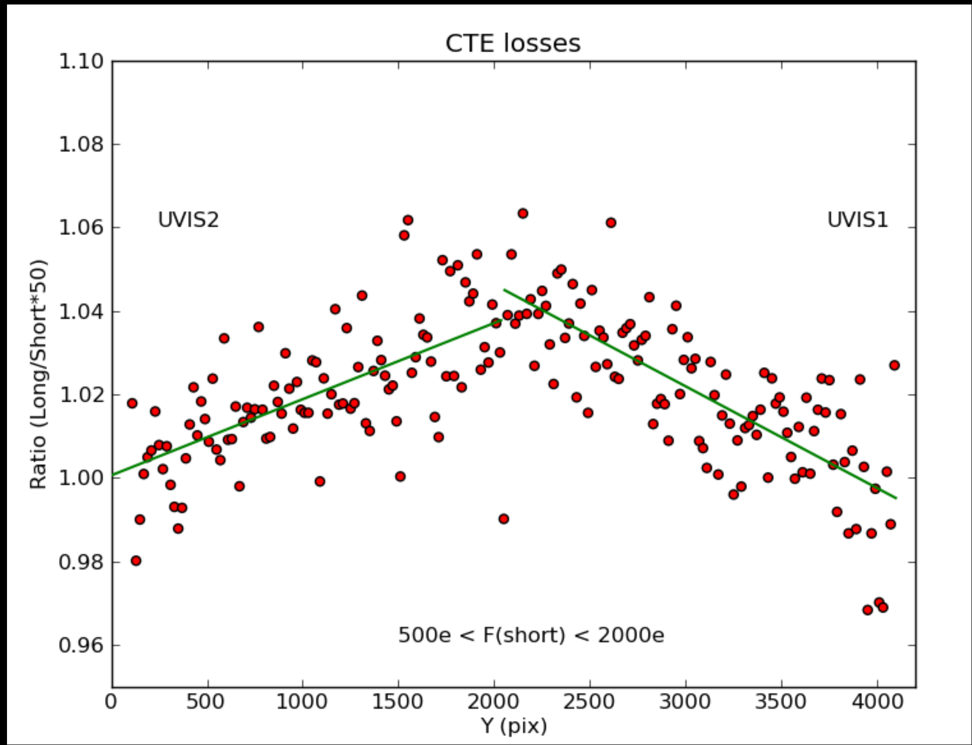
Photometric Stability – UVIS



CTE Degradation

- Compare signal levels in long vs. short exposures (left)





- Deficit in short exposures tracks linearly with rows from readout – classic signature of parallel CTE loss

CTE Degradation (2)

Expected effect, but strength 2-3x stronger than ACS loss at same point in mission – expected comparable

- Probable contributor is greater strength of SAA at solar minimum when SM4 occurred vs. solar max of SM3B
  - STScI examining HST CCD histories to look for such modulation
  - Recent preprint by Massey suggests ACS CTE degradation also has been worse recently
  - Rate of degradation should slow as solar activity picks up

What to do about it?

- WFC3 offers a potentially useful charge injection capability; being evaluated as part of Cycle 18 cal program
  - >10,000 e- of "fat zero" at the cost of 15 e- rms noise
  - Periodic line injection option may provide significant benefit
- Pixel-based correction algorithms (e.g. Anderson, Massey) have also shown significant promise

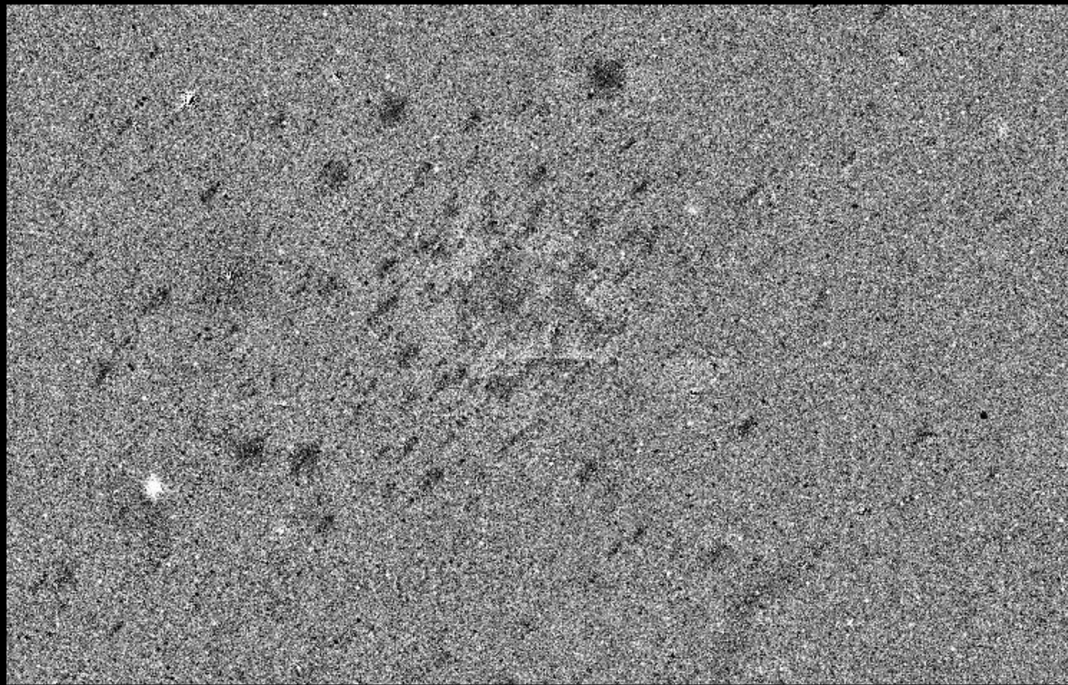
IR Persistence

Image persistence is a well known feature of HgCdTe arrays

- <1/2 x full well, very small, essentially gone by next orbit
- Strongly saturated sources can linger for hours

- STScI taking manual scheduling steps to avoid worst such situations
- Developing tools to enable removal

- *Be alert to this issue*



Deep field exposure following bright star cluster

IR Rate-Dependent Response

"Reciprocity failure", "count-rate non-linearity", "Bohlin effect": fewer counts out per photon in at low input rates

- Smaller effect than for NICMOS (which showed 3-6%/dex), but still present
- Lab measurements on flight spares: 0.3 – 1.0% /dex
- In-flight measurements comparing cluster observations with ACS, NICMOS:
  - 1.1% /dex (ISR WFC3 2010-07, A. Riess)
- Attempting WFC3-only determination using varying Earth limb background

Information Resources

At STScI WFC3 site: www.stsci.edu/hst/wfc3

- WFC3 Instrument Handbook, v. 2.1
- WFC3 Data Handbook
- Instrument Science Reports

Happy observing!

Scare from IR Spots

First few months after launch, dark spots appeared in IR sky

- Found to be on Channel Select Mechanism fold mirror, not detector
- Large particles, localized coating problem?
- Fortunately, appears to have stopped – no new obvious features since January, 2010