WFC3: Instrument Status and Advice for Proposers and Observers

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338.06

WIDE FIELD CAMERA 3
JPL · J&T · GST · NASA/GODDARD · SWALES · MSFC
HUBBLE SPACE TELESCOPE
RTSS · STScI
MEGA · BALL · LMMS

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AAS 225TH MEETING
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SEATTLE, WASHINGTON · 4-8 JANUARY 2015
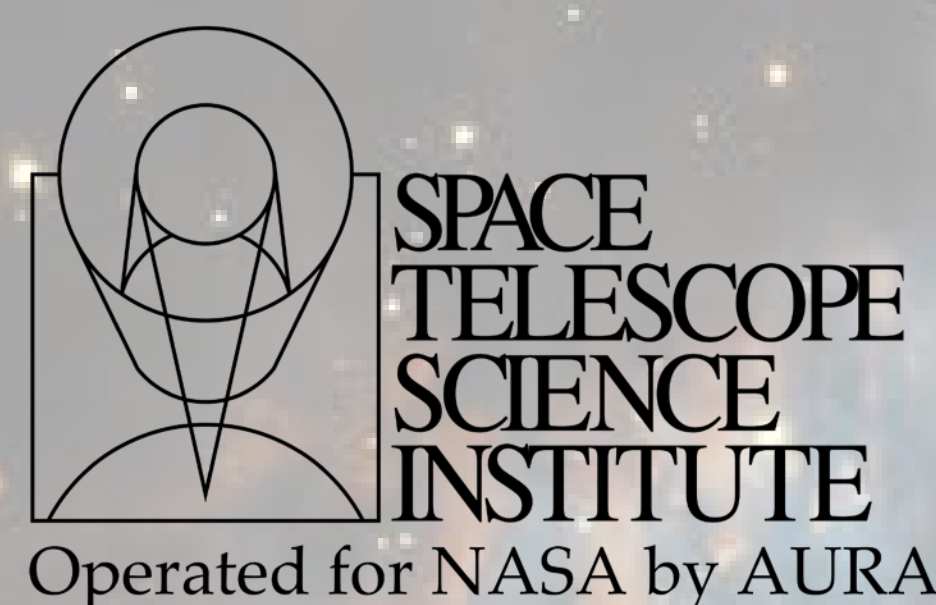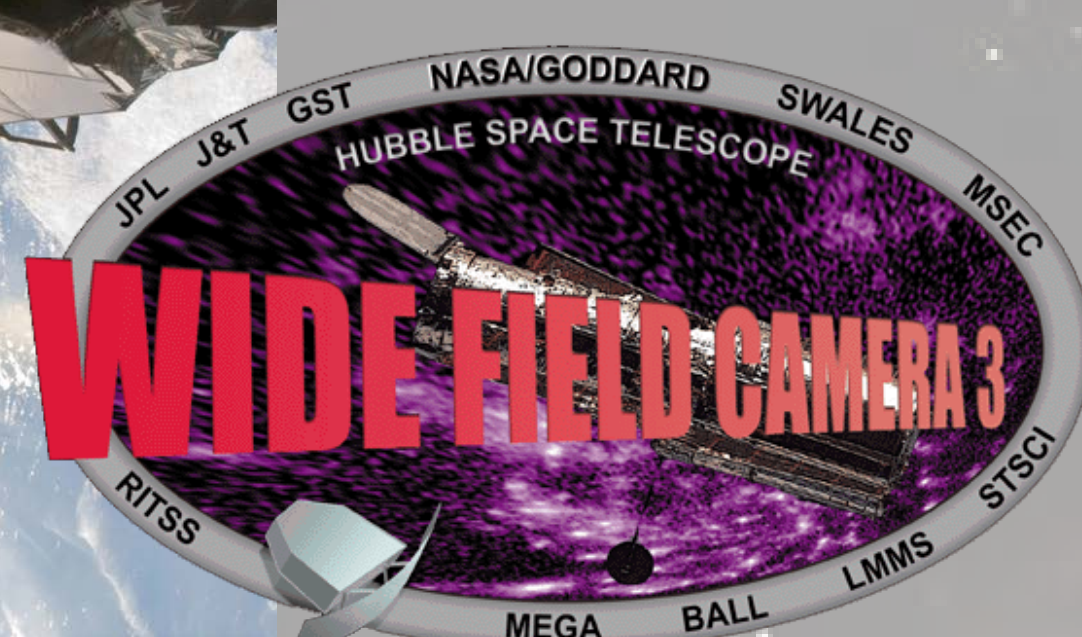
Summary

- **WFC3 continues to perform nominally.**
  - 5 Year minimum design life surpassed May 2014!
    - Kudos to GSFC, Ball Aerospace, e2V, Teledyne, and all of our contractors
  - UVIS CCD Detectors CTE declining and manageable with Post-Flash
  - IR Detector shows essentially zero evolution of its performance in flight
  - Use of Spatial Scanning technique has enhanced exoplanet spectrophotometry and precision measurements of distances to Cepheids

WFC3 Infrared Background Variations

- A key design feature of the IR Channel
  → GRISMS and Wide Filters are Zodiacal background limited

- Nominal Backgrounds: 0.5 to 1.0 e-/s/pixel
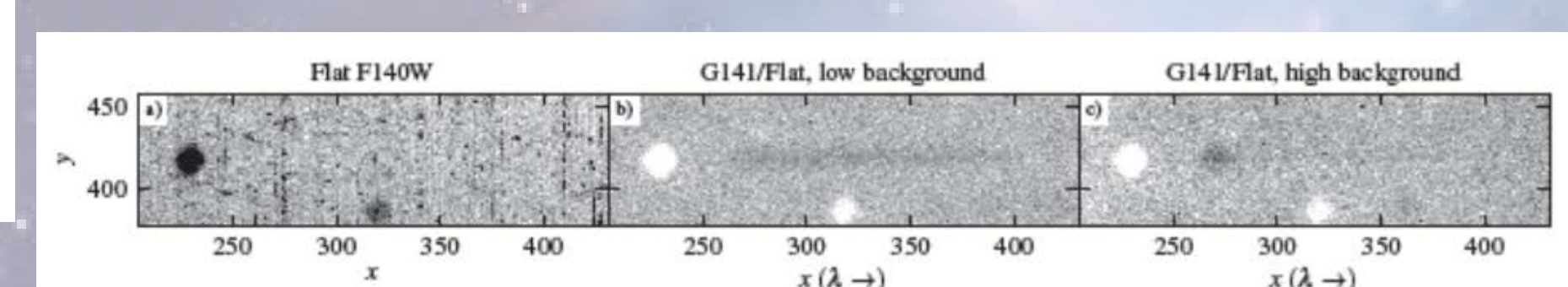 - <u>SOMETIMES</u>: brighter (up to 3 to 5e-/s) and non-uniform backgrounds are observed!
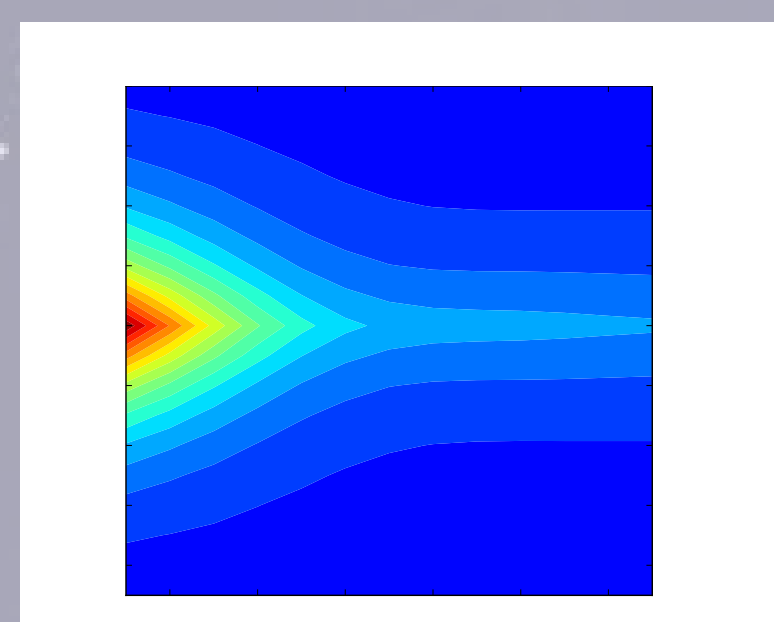
- Caused by:
  - Pointing traversing central part of zodiacal cloud
    - $i < 80°$ sun angle near ecliptic plane
  - Long dwells near bright earth limb (*i.e.* CVZ or near CVZ situations).

- <u>Inclusion of He I 10830Å line within the passbands of G102, G141, F105W, F110W</u>
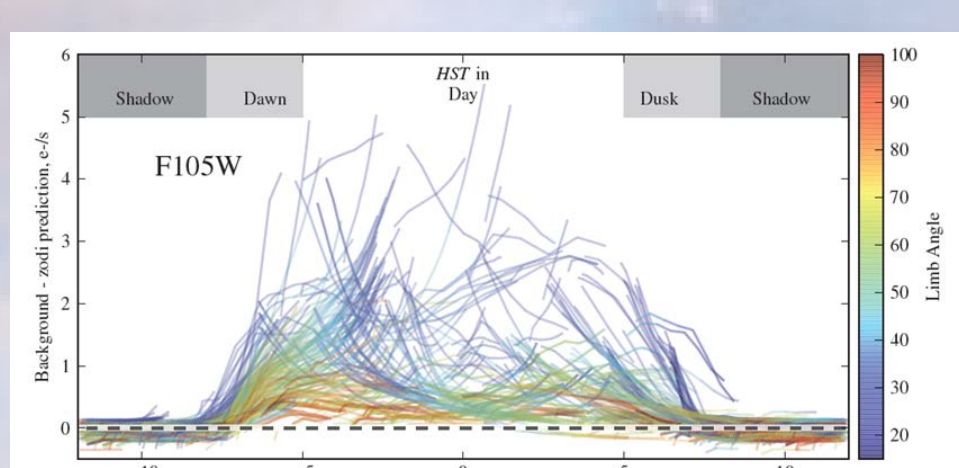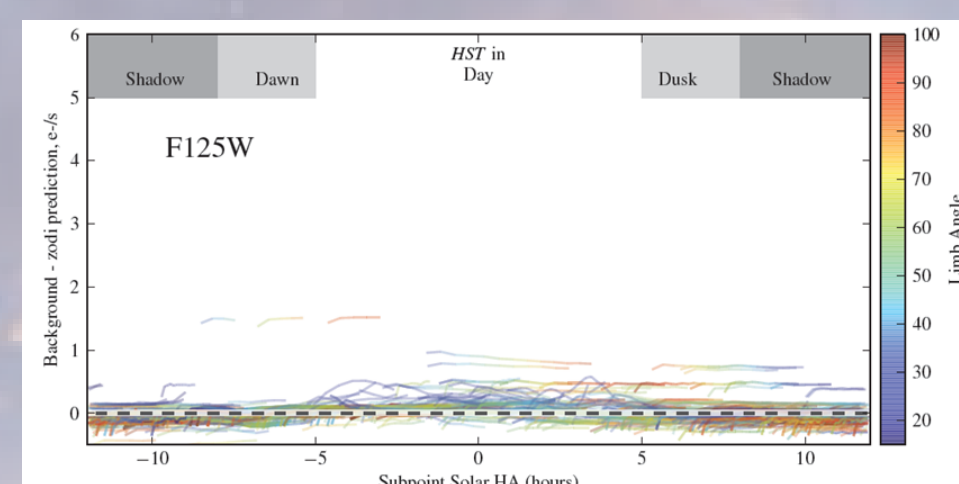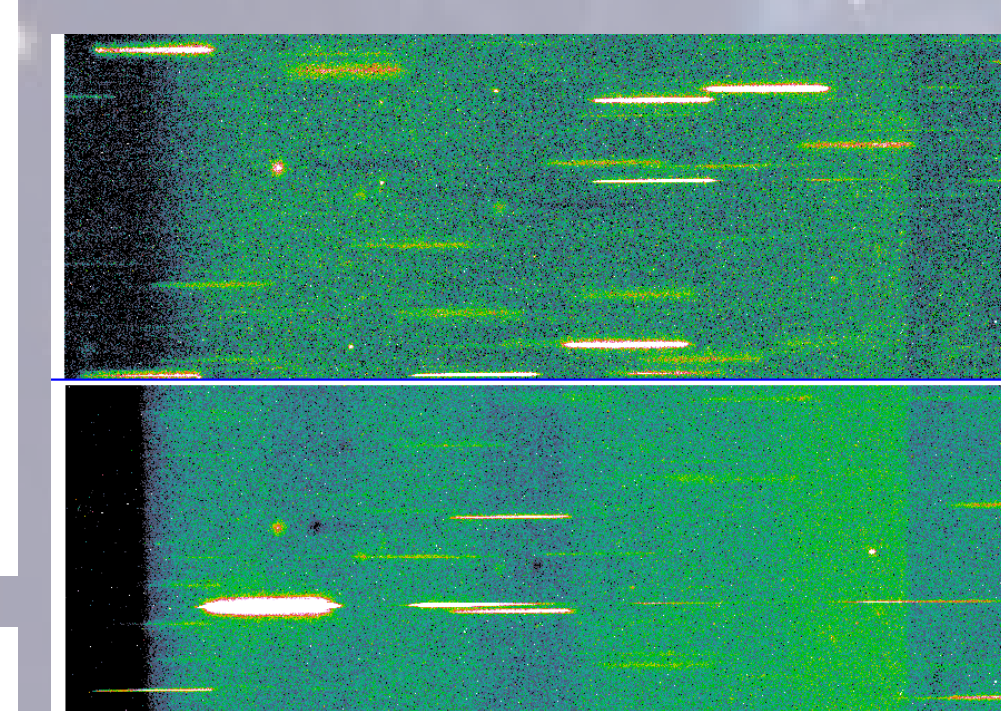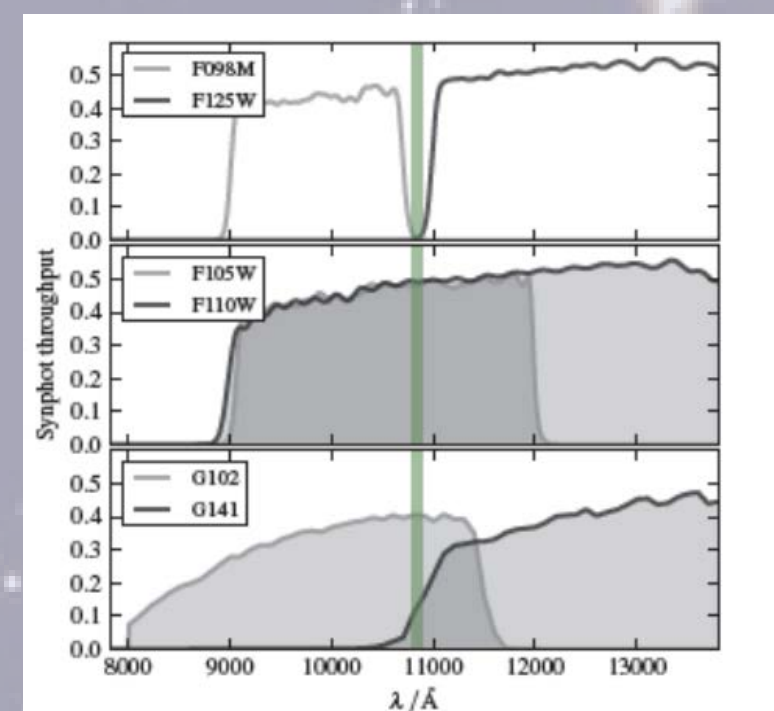
Above (left): Variation in G141 background seen between two exposures.
Above (right): Instantaneous background in F125W and F105W as function of orbital position and limb angle (color coded).
Below: He I 10830Å line seen in silhouette due to dust particles on CSM mirror.

CCD Charge Transfer Efficiency Decline Mitigation Options

- The WFC3/UVIS CCD detectors experience an inevitable decline in charge transfer efficiency due to radiation damage in the space environment

- Results in Loss of S/N for faint sources; charge trailing; photometric & astrometric errors

- Observers have several options to mitigate and correct for CTE decline:

  1) Sources placed near the readout amplifiers in the corners are less impacted

  2) Post-Flash (i.e. Background Enhancement)
     - Recommended *option* for Cycle 20+
     - 10-12 e- per pixel restores most CTE (~80%)
     - Benefits: recovers faint sources, better darks
     - Cost: increased effective noise from 3.1e- to 4.6e-

  3) Post-Observation Corrections
     - Pixel Based Charge Transfer Model (Anderson&Bedin)
     - Benefits: Restores trailed charge to correct locations
     - Limitation: Cannot recover lost S/N
     - Available for post-processing at http://www.stsci.edu/hst/wfc3/ins_performance/CTE/
   - To be included in OPUS pipeline in mid-2015

WFC3 Spatial Scans

Spatial Scans allow the light from astronomical objects to be trailed across the WFC3 detectors in a predictable and repeatable manner during exposures at rates up to 4.8 arc seconds per second (FGS control) and 7.8 "/s (GYRO control).

- **Enables:**
  - Significantly increased S/N observations – especially for infrared spectroscopy of bright sources (*e.g.* exo-planet transits)
  - Higher precision astrometric measurements orthogonal to the scan direction (measurements to <30 micro-arc seconds)
  - Opportunity to observe brighter sources (especially with the IR detector– 0th mag achieved with Grism in -1 order)
  - Flat field verification and improvement of mid-spatial frequency residuals in near UV CCD flats
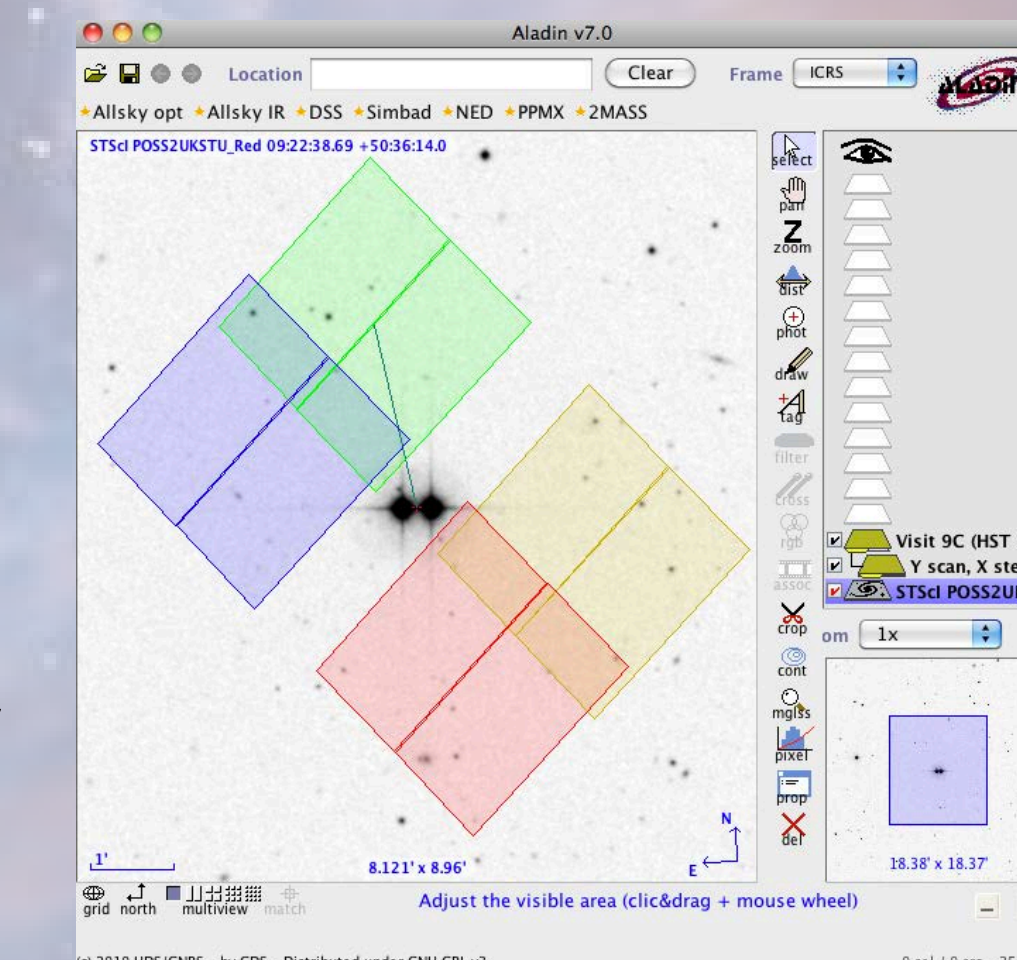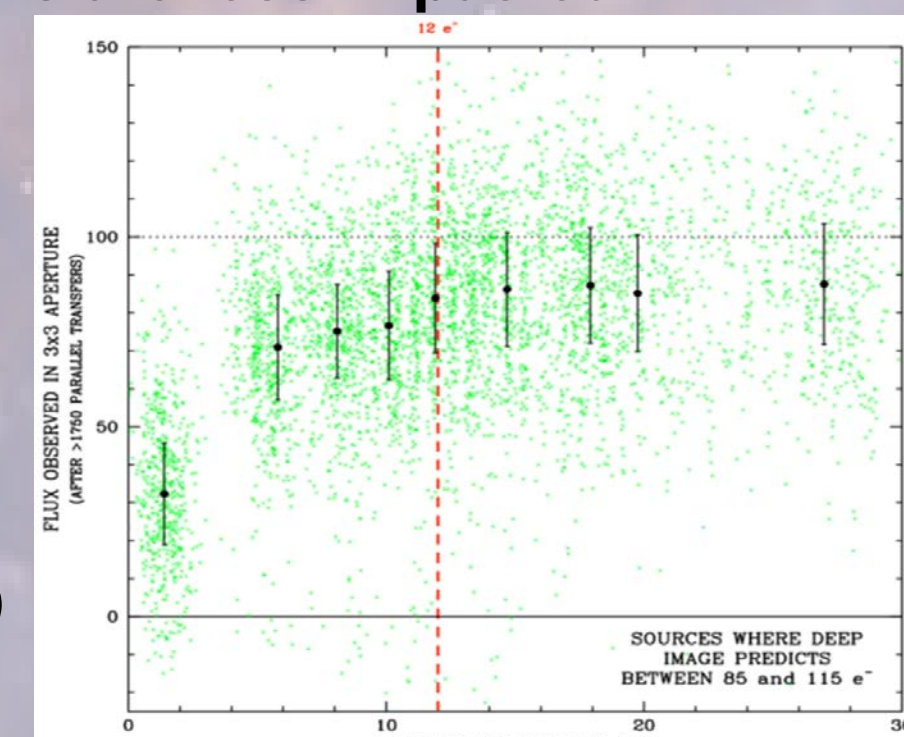
Imaging, PSF $\sigma_0 = 0.01$ pix
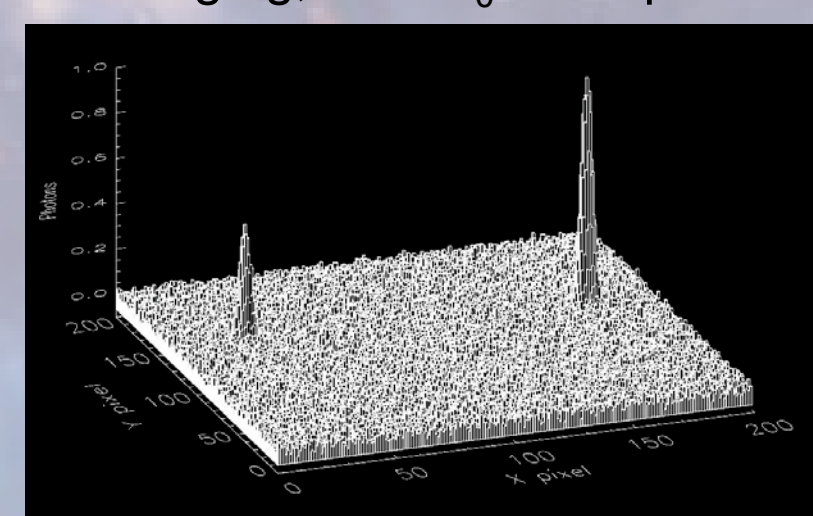
Scanning, $\sigma_0 = 0.01/\sqrt{N}$ samples pix
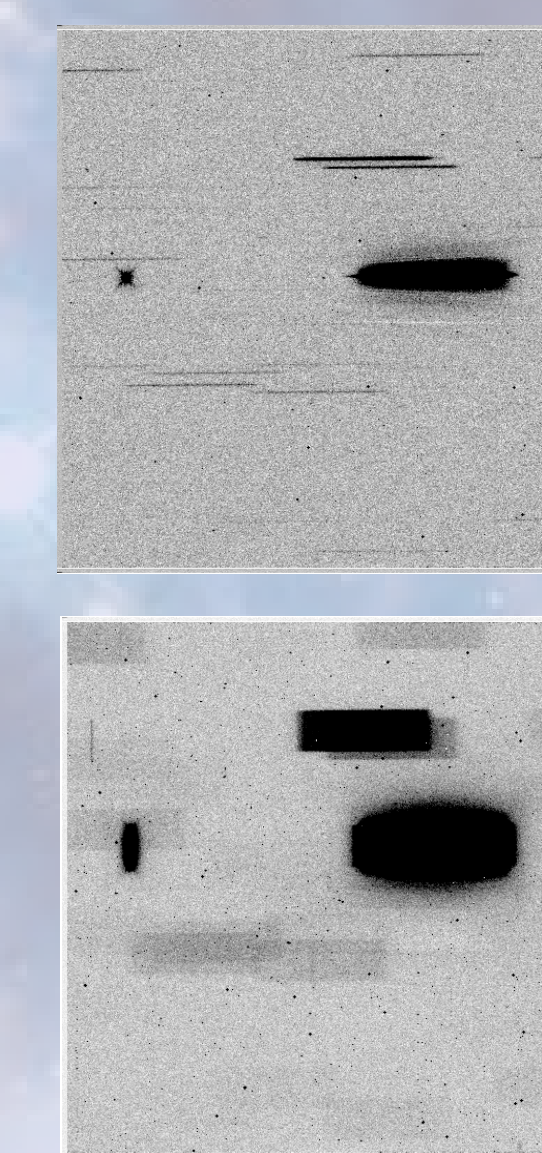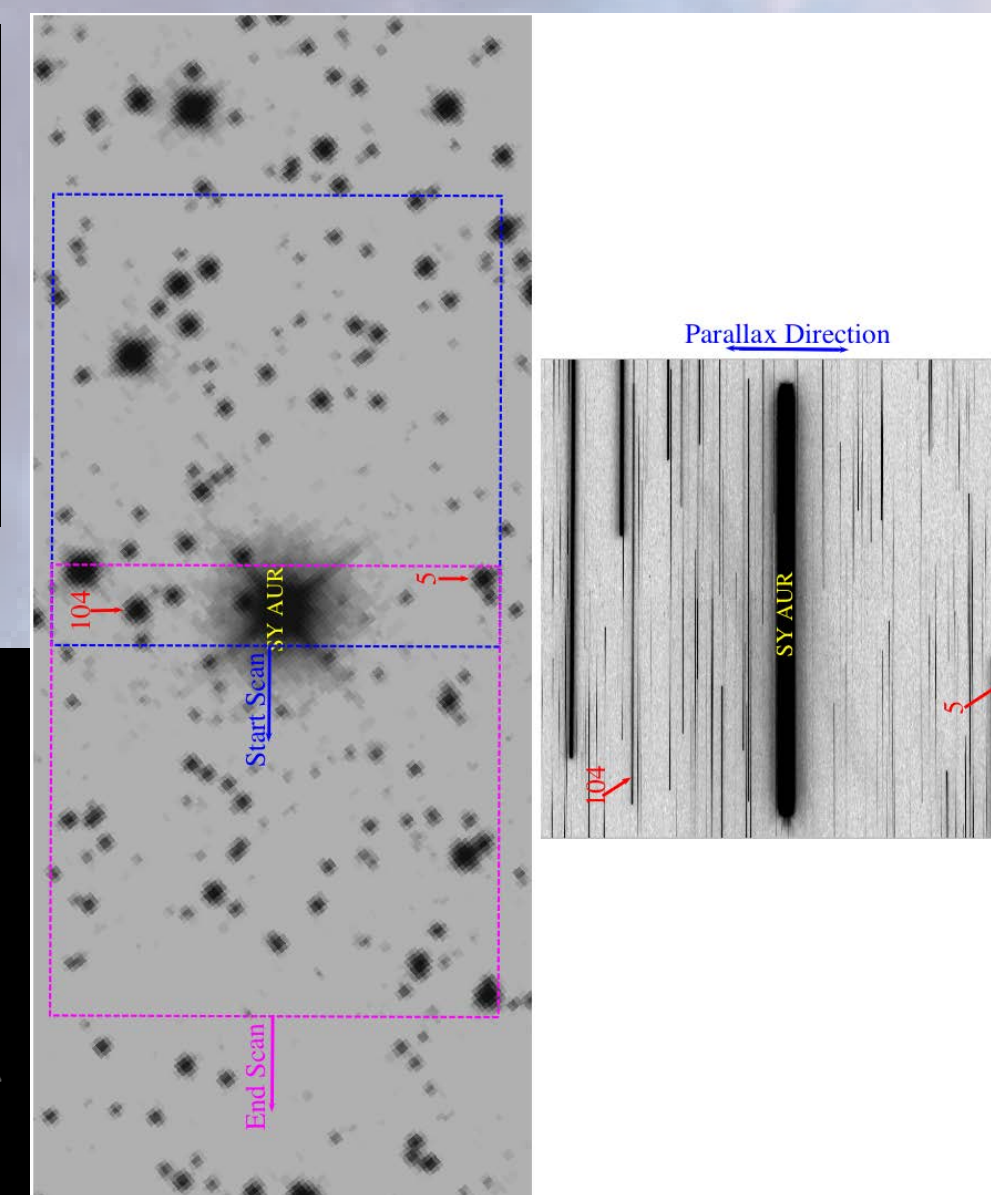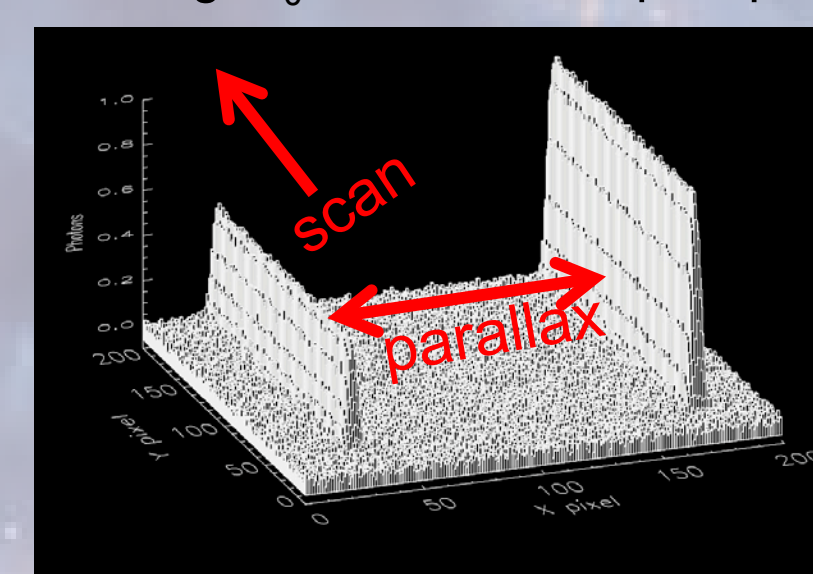
- *Left:* IR Grism Spectra (Stationary and Scan)
- *Right:* Astronomer Proposal Tool now supports and visualizes scans.
- *Below:* Superposition of multiple scans of a pair of bright stars provides path for improved correction of 3-5% mid-spatial frequency residuals in UV flat fields.

- Precision of centroiding of bright stars is 0.01 pix (400 μas)
- Scans over several 1000s pixels → factor of >10 better (reaching ~25 μas)
- Exceeds FGS precision and complements GAIA capabilities
- Successful measurement of Cepheid parallax to ~2 kpc (with 5 kpc possible)
  - See Riess, Casertano, Anderson, MacKenty, Filippenko 2014 Ap.J. 785,161 (arXiv:1401.0484)

Coming in 2015

- **PSF Libraries**
  - Interpolated grids for most frequently used filters using Jay Anderson's models
  - Extracted PSFs of reasonably bright and isolated stars (>10^7 sources) from archive
- **Time dependent UVIS zero points**
  - Unexplained small decline (0.2-0.4%/year) in 400-700nm throughput will be corrected in Synphot
- **Improved IR persistence model**
  - Models incorporating additional parameters (see ISRs by Knox Long)
  - STScI now provides a predicted residual image for every WFC3/IR observation within 7 days of your observations http://archive.stsci.edu/predps/persist/search.php
- **Prototype IR Grism software for crowded fields/multiple roll angles**
  - Together with the JWST and WFIRST, we are exploring options for improved Grism analysis software (ideas and suggestions most welcome!)

Ongoing & Improved Instrument Calibrations

- UVIS Photometry
  - Tracking ~0.2-0.4% annual decline in visible (not UV or IR) throughput.
  - Independent solutions for UVIS CCD detectors available at http://www.stsci.edu/hst/wfc3/analysis/uvis_2_chip (available in the OPUS pipeline and MAST archive mid-2015).
- UVIS Astrometry
  - Two-dimensional corrections for photo-lithographic pattern in place.
  - Filter specific corrections for top ten filters (remainder over 2015/16).
  - Improves residuals to ~1 mas rms (~2 mas without filter specific calibration).
- UVIS Darks improved by use of Post-Flash (better discrimination of hot pixels).
  - Monthly darks plus daily hot pixel tracking coming 1st QT 2015
- IR Linearity and Persistence
  - Studies in Cycles 21&22 to understand impacts of charge trapping on precision photometric observations of bright sources and impact of the very brightest sources
- UVIS Shutter Blade selection now available for short exposures
  - Permits observer to obtain best possible PSF (*i.e.* less vibration)

Program Title	Ext. Orbits	Int. Orbits	Program Title	Ext. Orbits	Int. Orbits
UVIS anneal	0	85	WFC3/UVIS contamination monitor	18	0
UVIS bowtie monitor	0	130	UVIS Shutter Characterization	3	1
UVIS CCD daily monitor	0	637	Photometric repeatability of scanned direct imaging	4	0
UVIS CCD un-flashed monitor	0	140	WFC3 UVIS & IR photometry**	21	0
UVIS post-flash monitor	0	44	WFC3 IR observations of red CALSPEC stars**	3	0
UVIS CCD gain stability	0	18			
IR dark monitor	0	95	WFC3 IR grisms wavelength calibration stability and calibration	4	0
IR linearity monitor	0	9	WFC3 IR grisms flux/trace calibration stability and calibration	4	0
IR gain monitor	0	16	WFC3 IR grism wavelength calibration stability and calibration	2	0
UVIS CTI monitor (EPER)	0	12	WFC3 UVIS grism flux calibration**	2	0
UVIS CTE monitor (star cluster)	6	0	UVIS Pixel-to-Pixel QE Variations via Internal Flats Monitor	0	51
WFC3/UVIS CTE in subarrays	0	42	UVIS internal flats	0	13
Characterization of UVIS traps with CI**	0	36	IR internal flats	0	18
Refining the persist. model in the IR detector	12	12	CSM monitor with earth flats	0	200
Short term persistence	3	3	Astrometric Validation of WFC3/UVIS filters	18	0
Persist. after worst actors**	0	50	High precision calibration of WFC3/UVIS geometric distortion (CAL-13929)	10	0

Abstract

The Wide Field Camera 3 continues as the most used HST instrument after over five productive years in space. We summarize its basic performance characteristics including our analysis of its stable and time variable calibrations. Key recent improvements in our calibrations and instrument characterizations will be discussed including the development of improved libraries of Point Spread Functions, better models of persistence in the infrared detector, and advances in our understanding of sources of variable infrared backgrounds. Basic calibration improvements include the adoption of a CCD specific QE curve for the UVIS channel together with improved flat fields, an ongoing effort to include more filter elements with high precision astrometric calibration, and a time dependent calibration of the UVIS photometric zero points. Recent lessons learned regarding the use of the spatial scan technique to enable extremely high precision photometric and astrometric measurements will be presented. The calibration program for Cycle 22 will also be summarized
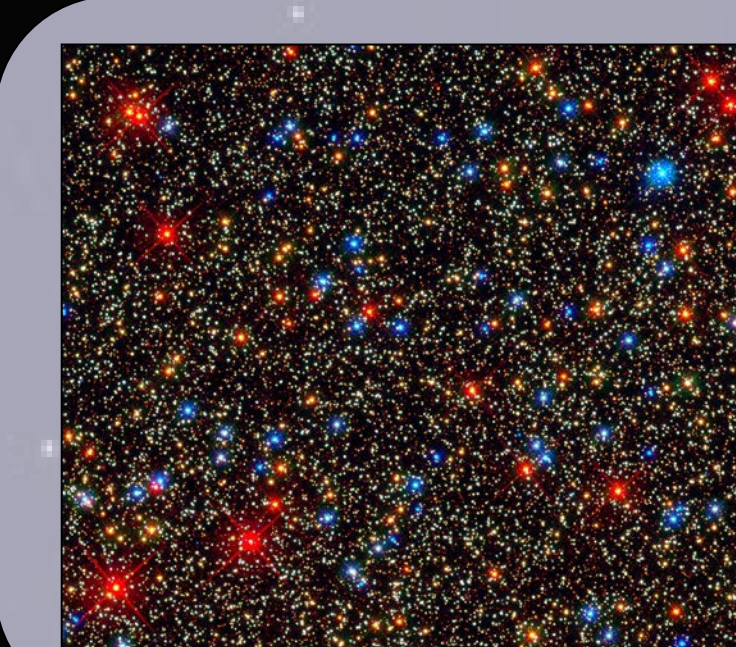
Additional Information:
http://www.stsci.edu/hst/wfc3
http://www.stsci.edu/hst/wfc3/documents/ISRs
Note: this and all WFC3 AAS meeting posters since 2010 are available at
http://www.stsci.edu/hst/wfc3/documents/meeting_posters/
Questions and Support: help@stsci.edu