# WFPC2 Status and Plans

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STUC Meeting – 12 April 2007

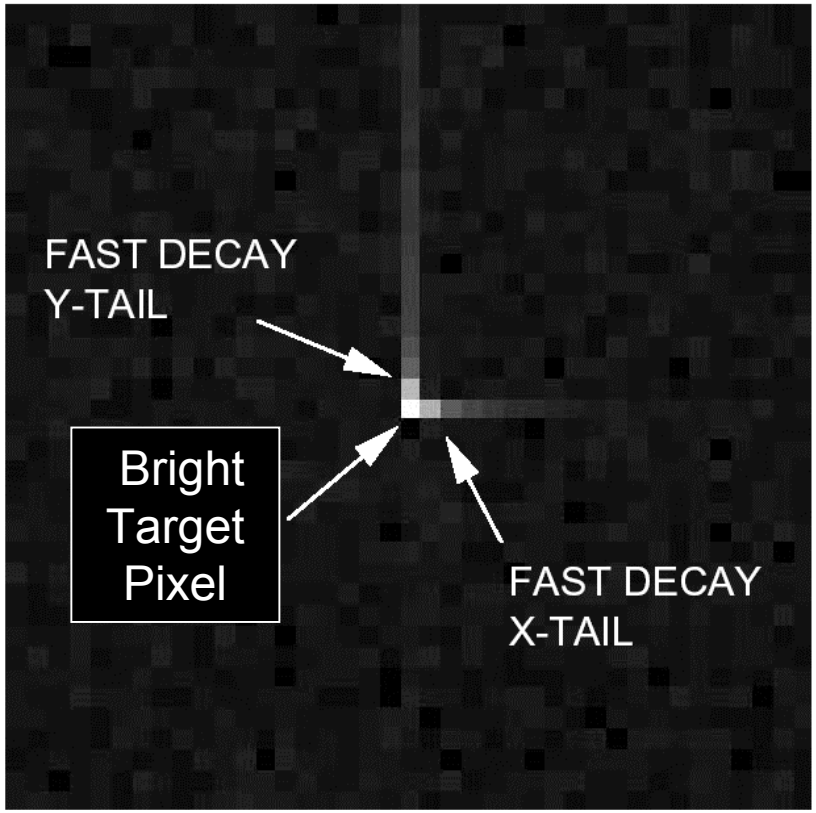
# ***WFPC2 Status***

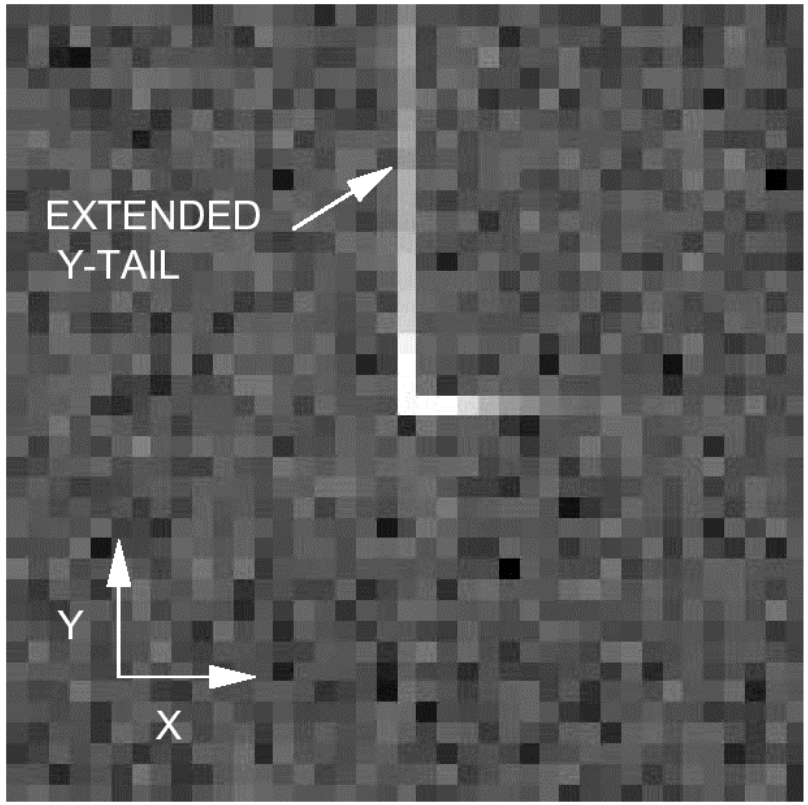
- Launched Dec. 1993
- ~15 yrs old by end of Cycle 16
- Continues to operate well
- Liens on performance:
  - CTE from radiation damage
  - WF4 CCD anomaly

# ***Charge Transfer Efficiency (CTE)***

- Charge is trapped during exposure and readout of image by defects in CCD Silicon
- Trapping sites increase over time due to on-orbit radiation damage
- Impacts:
  - Charge is lost from image
  - Detected counts & photometry is low
  - Larger losses farther from readout amplifier (high Y)
  - Background light reduces loss (pre-fills traps)
  - Tails are seen on bright pixels as charge released

CTE causes brief trapping (and release) of charge during image read-out. Charge is moved out of the image and becomes lost….

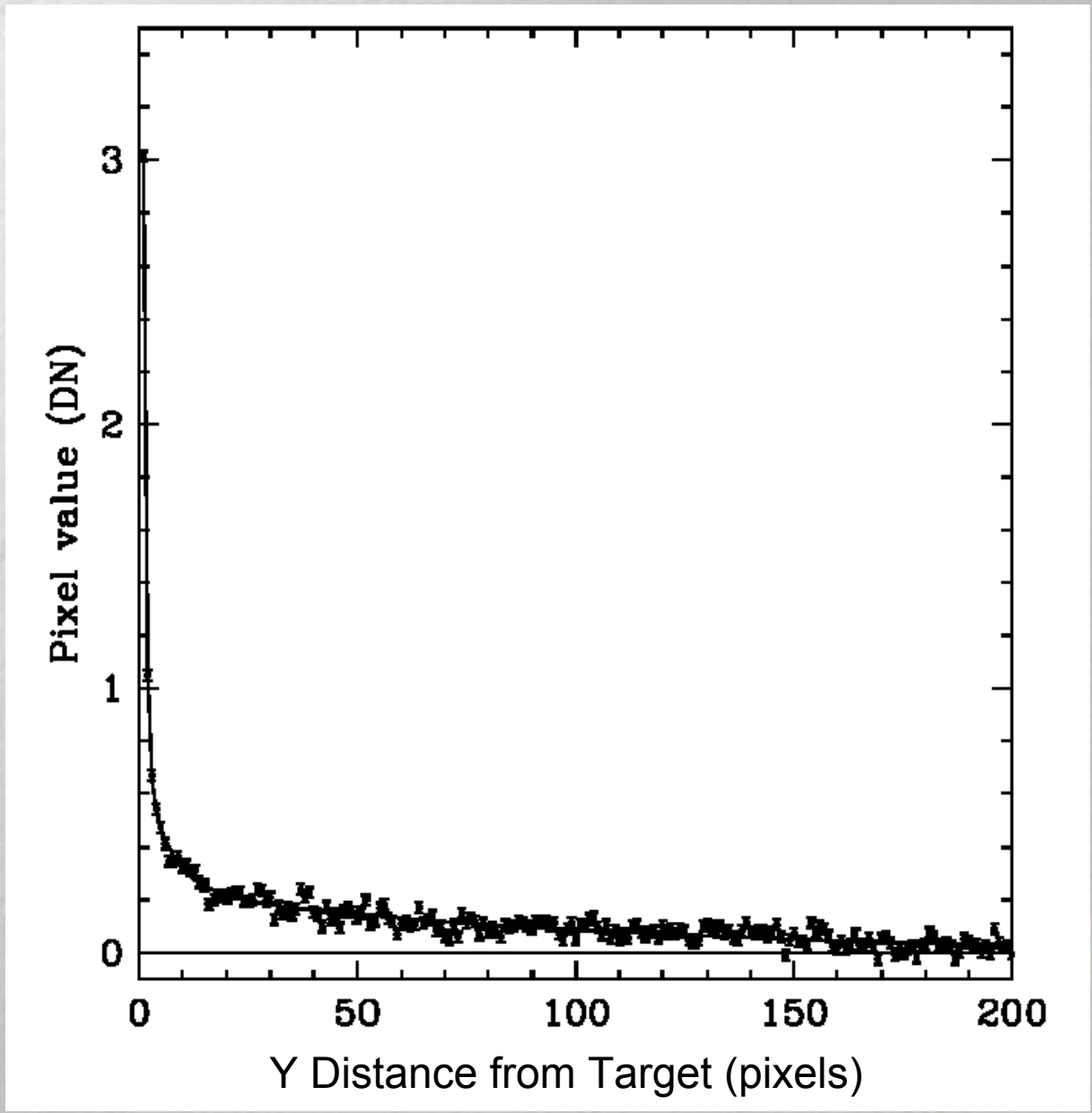


Example of “tail” on 310 DN target caused by CTE effect.

Tail contains 9% of the total counts.

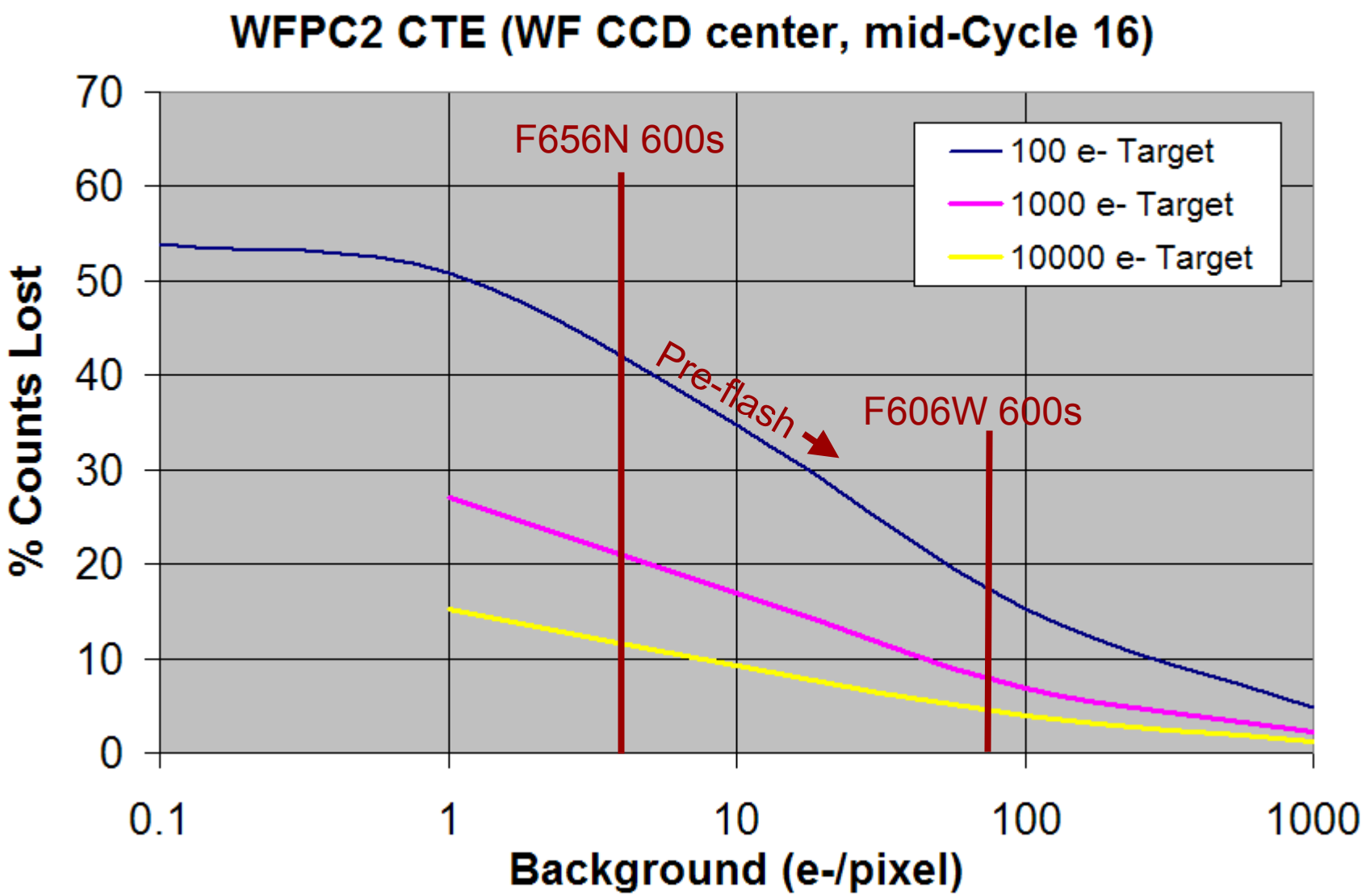
(Data from 2002; Gain 7)



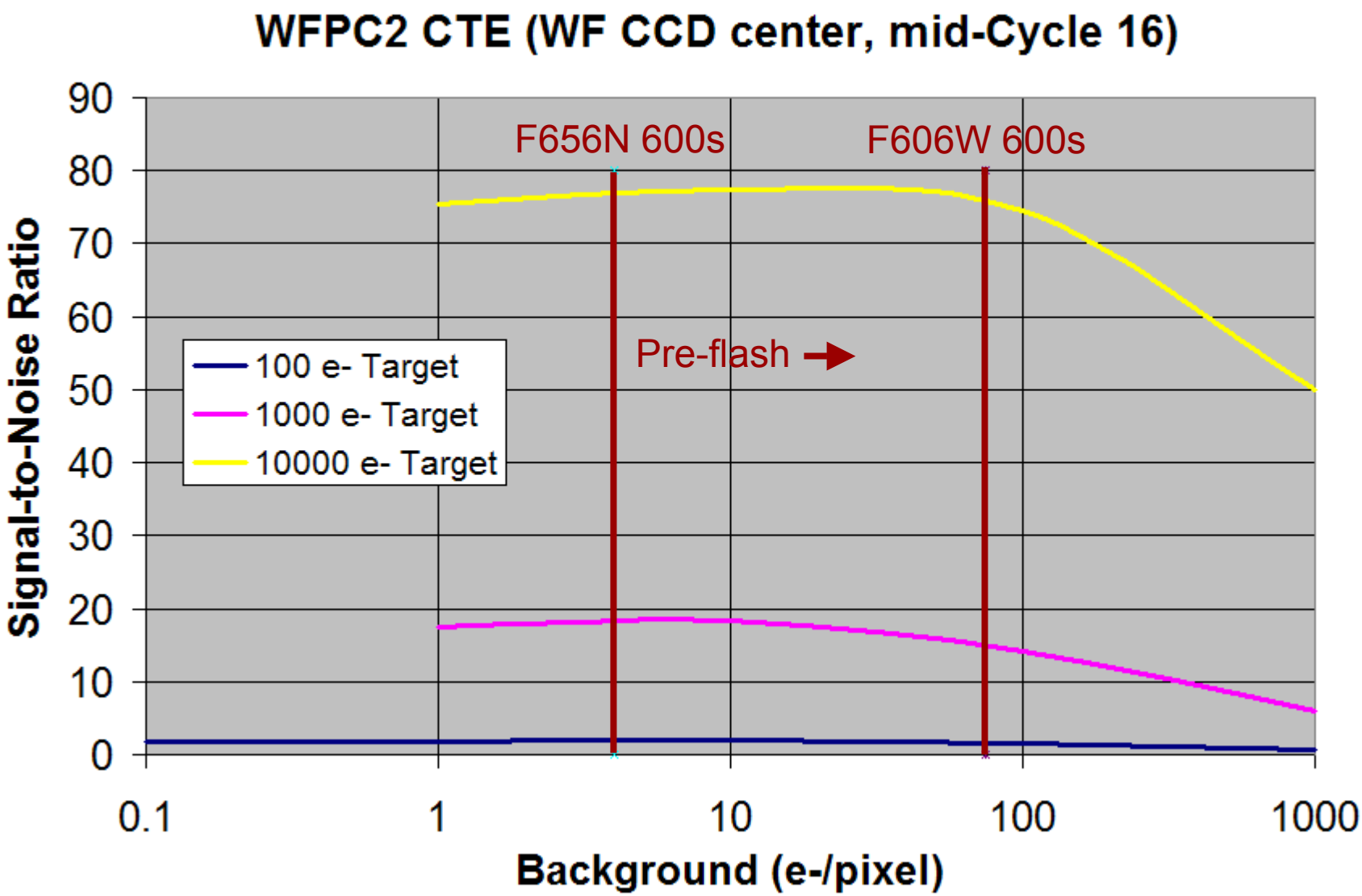
# *CTE vs.Target Brightness & Background*

- Bright targets lose smaller fraction of counts
- Sky background tends to “pre-flash” exposures – fills traps -- reduces CTE.
- Typical broad band filter images have high background -- CTE losses 5% to 20%.
- UV & narrow band filters – low background -- CTE losses up to ~60% are possible.
- Extended targets have less CTE – leading edge pre-flashes CCD during read-out.
- Pre-flashing with internal lamps -- reduces CTE but adds background noise.

CTE losses depend on background… illustration w/ typical backgrounds…



Pre-flash does not help SNR… illustration w/ typical backgrounds…



# *CTE: Mitigate During Observation*

- Move discrete targets closer to CCD amplifier -- near (x,y)=(1,1) corner
  - Reduces CTE by factor ~4
  - Only possible for small single targets
- Pre-flash image with internal lamp
  - Reduces CTE but adds noise
  - Photometric errors reduced
  - SNR generally not improved

# *CTE: Calibrate After Observation*

- Correction equations available for point sources
- Corrects photometry as function of position on CCD, epoch, target brightness, & sky background
- No corrections available for extended targets, though effects thought to be smaller.

# *CTE: Calibration Projects*

Continue annual monitoring on Omega Cen.

New data on background dependences – Omega Cen with various filters and pre-flash levels.

Update point source correction equations (Dolphin, Whitmore, etc.) – CTE correction as function of epoch, target brightness, and sky background (do ASAP).

Calibration outsource proposal (PI=Dolphin) approved in Cycle 16. Provides independent update of point-source CTE corrections.

# *CTE: Calibration Projects (2)*

New studies of CTE effects on extended targets:

- Use orphaned ACS calibration orbits (few dozen orbits).
- Observations of galaxies (HDF field, Abell cluster) to study CTE effects vs. epoch, brightness, background, etc.

# *CTE: Calibration Projects (3)*

Continue work towards image-based correction of CTE effects:

- Difficult but high-value project.
- If successful, provide CTE-corrected product in pipeline (in addition to current products).

# ***WF4 CCD Anomaly***

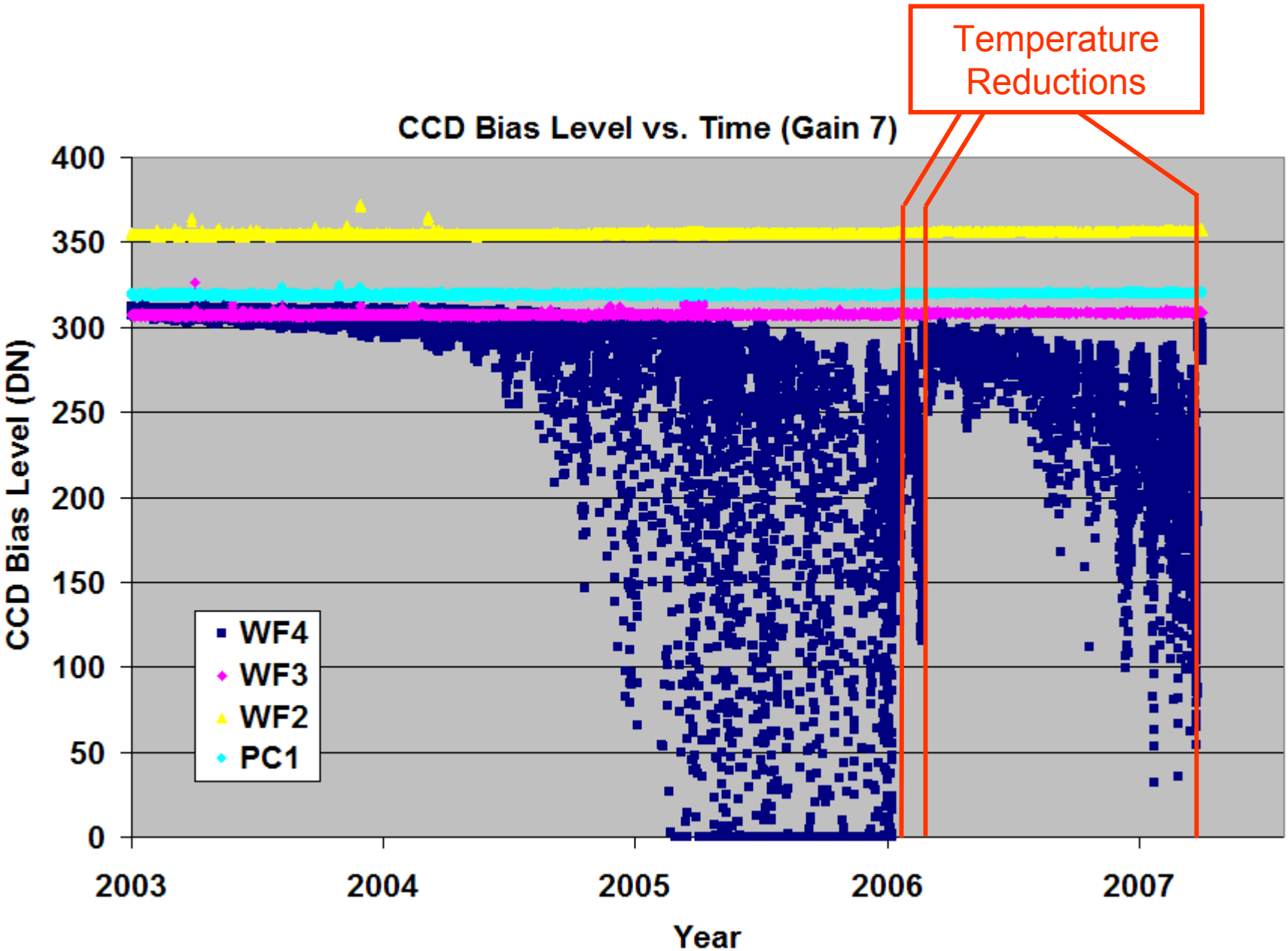
- Anomaly in WF4 CCD amplifier gain
- Hyper-sensitive to temperature
- CCD gain is low & varies ~10 minutes
- Impacts:
  - CCD bias level goes low
  - Photometric counts too low (5%-70%)
  - Faint (<1 DN) horizontal streaks
- Other CCDs unaffected

# *Mitigate Impact by Reducing WFPC2 Operating Temperature*

- Reduce WF4 camera head circuit temp. to avoid very low bias & blank images.
- Adjust temp. colder by 1 deg C every 6 mos. to keep-up with progressing hardware failure.
- Three temp. reductions successful so far (Jan. & Feb. 2006, Mar. 2007).
- Need 2 or 3 more reductions before SM4; sufficient adjustment range should exist.
- Monitor camera (image quality, optical alignment) for any adverse side-effects.

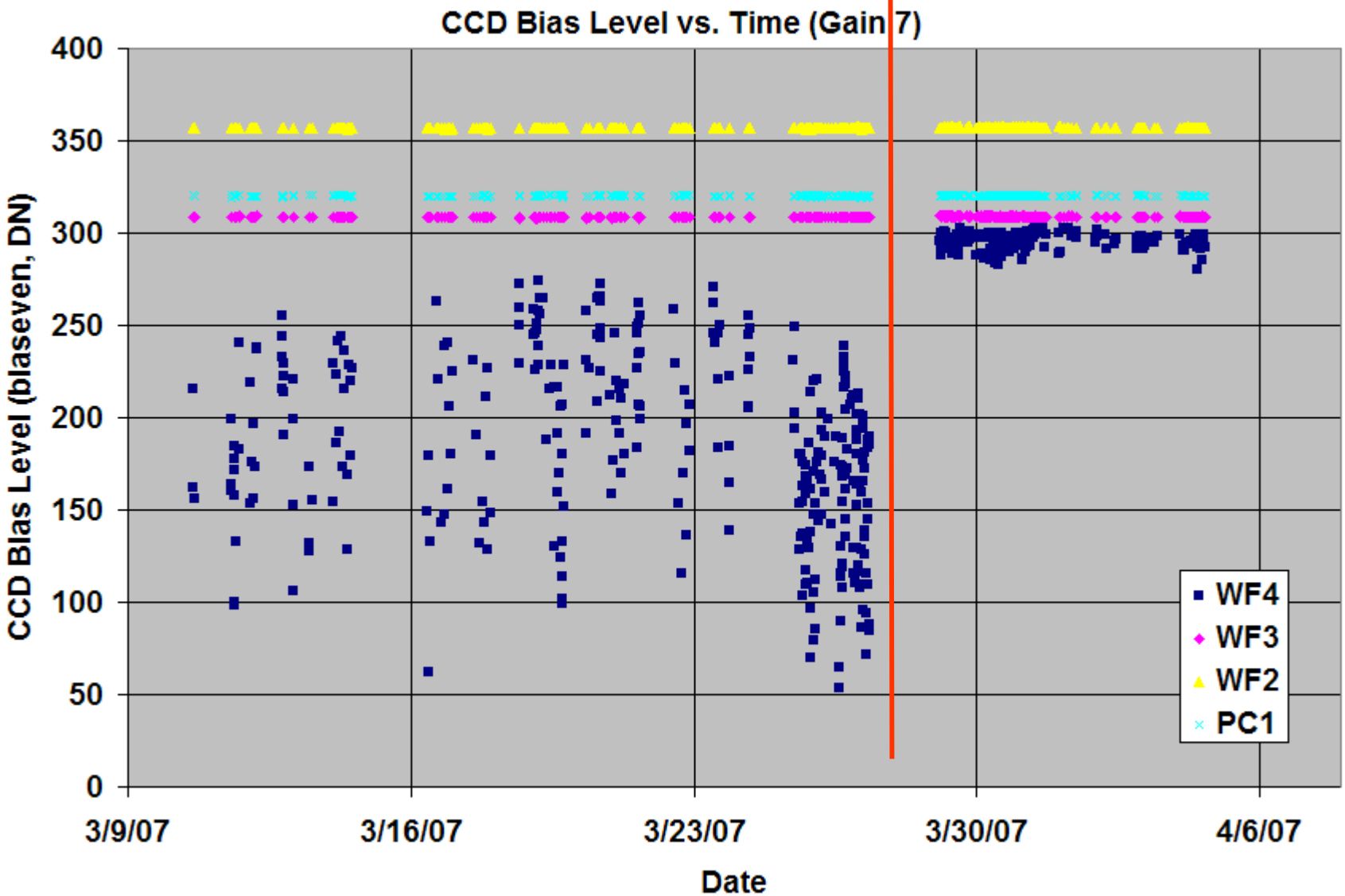
# *Mar. 27, 2007 Temperature Reduction*

- WF4 restored to near-normal operation
- Image quality unchanged:
  e.g. PC1 PSF FWHM before 1.74 +/- 0.03 pixels;
  after 1.75 +/- 0.02 pixels
- Change in CCD positions ~0.1 pixel
- No adverse effects seen after 3 temperature reductions – believe we can keep WF4 CCD alive until SM4




(each point = 1 image)

March 27 Temperature Reduction




(each point = 1 image)

# *WF4 CCD Anomaly: Correcting Photometry*

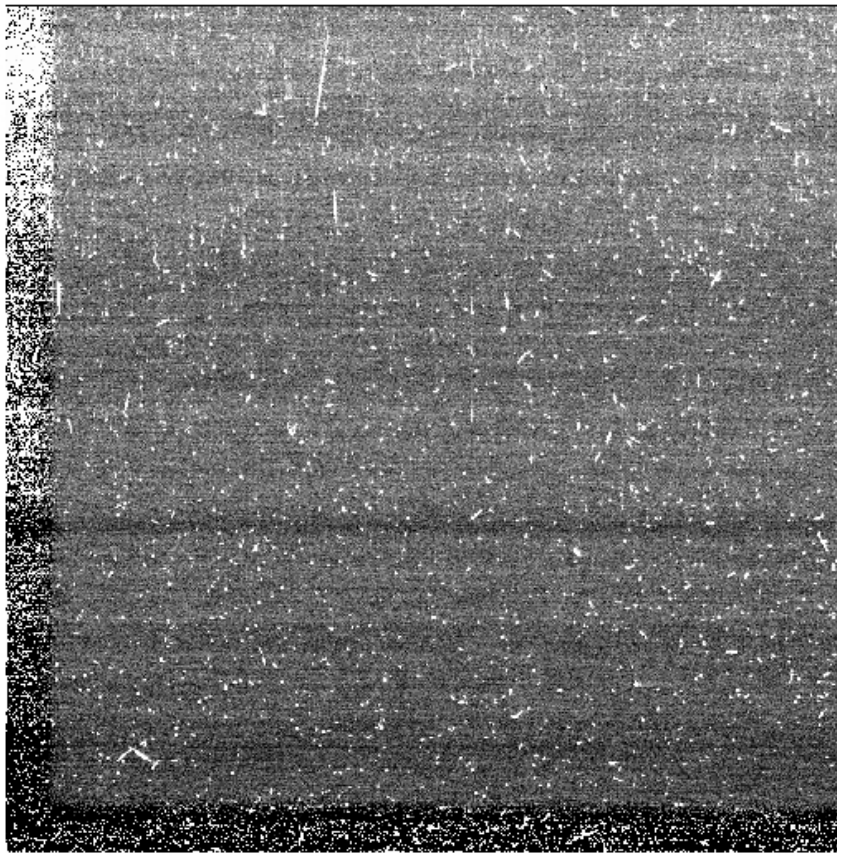
- Photometry can be up to 70% too low.
- Photometric anomaly well-characterized as function of bias level and pixel value.
- Can correct photometry to ~few% accuracy.
- Plan to install image-based WF4 photometric corrections in WFPC2 pipeline ~Fall 2007.

# *WF4 CCD Anomaly: Removing Background Streaks*

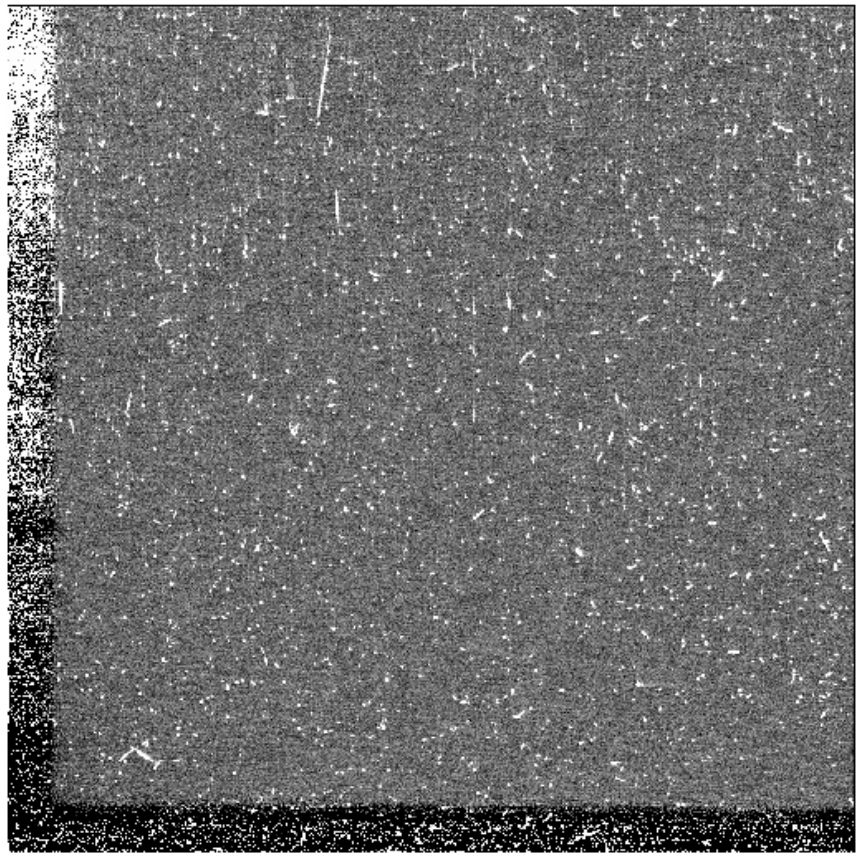
- Two concepts for correction scheme
  – spatial filtering
  – use blank columns to derive streak pattern
- Stand-alone repair script available (filtering)
- Consider adding streak repair to WFPC2 pipeline ~Winter 2008.

*Filtering to remove WF4 streaks…*

*Before*



*After streak filtering*



# ***WFPC2 Plans***

- Closeout Projects
- Cycle 15+16 Calibration Observations
- Changes since last STUC meeting
- New plans (new items in blue)

# *Closeout Projects*

Calibrations:

1. WF4 Anomaly (high priority; underway)
2. CTE Corrections (high priority; underway)
3. Global HST Photometric Accuracy (med. priority)
4. Photometric Zeropoints (med. priority)
5. Low-Light Flats for Broadband Filters (med. priority)
6. Red-Leaks in Blue/UV Filters (med. priority)
7. Narrow Band & Ramp Filters (outsourced to O'Dell)

# *Closeout Projects (2)*

Pipeline / Software:

1. WF4 photometry repair in Pipeline (high priority; underway)
2. WF4 streak repair in Pipeline (med. priority)
3. WFPC2 associations / drizzle products for proprietary GO data?? (via HLA?, med. priority)

# *Closeout Projects (3)*

Documentation:

1. Website clean-up (high priority; underway)
2. WFPC2 Data Handbook (high priority)
3. WFPC2 Instrument Handbook (high priority)
4. WFPC2 Archive User's Guide (med. priority)

# *Cycle 15+16 Calibration Observations*

Routine Monitors and Calibrations:

- Phase II proposals submitted and executing for all 8 programs.
- Need to augment for SM4 delay – add ~6 months of observations.

Closeout Calibrations:

- Phase IIs submitted and executing for 3 programs: WF4 Anomaly, CTE Background Dependence, Ramp and Narrow Band Filters.
- Need Phase IIs for 8 programs: Extended Target CTE, Full Moon Earth Flats, Photometric Closeout, Photometric Zero Points, Red Leaks, Red Filters, Polarizers, Geometric Distortion.

# *Changes and New Plans*

Significant changes since last STUC presentation:

- WFPC2 now main visible camera on HST
- WFPC2 will be ~40% of Cycle 15+16 science program
- Emphasis shifted from “improving archival value” to “supporting current observers” over near-term
- Calibration goals changed from “take cal. data and put in archive” to “provide best possible calibration for Cycle 15 & 16 WFPC2 data.”
- WFPC2 staffing increased from 1.5 to 5.2 FTEs
- SM4 delayed from Dec. 2007 to Sept. 2008 – must support WFPC2 for longer time

# *New plans for User Support & Documentation*

WFPC2 importance increased after ACS failure…

- WFPC2 User Support lead assigned (Ron Gilliland).
- WFPC2 help procedures reviewed & streamlined.
- Instrument scientists assigned to review Cycle 16 phase II proposals.
- New web document on WFPC2 observation strategies (dithering advice, etc.).
- New “Cookbook” on drizzling WFPC2 data (ready ~1 month).

# *New Calibration Plans*

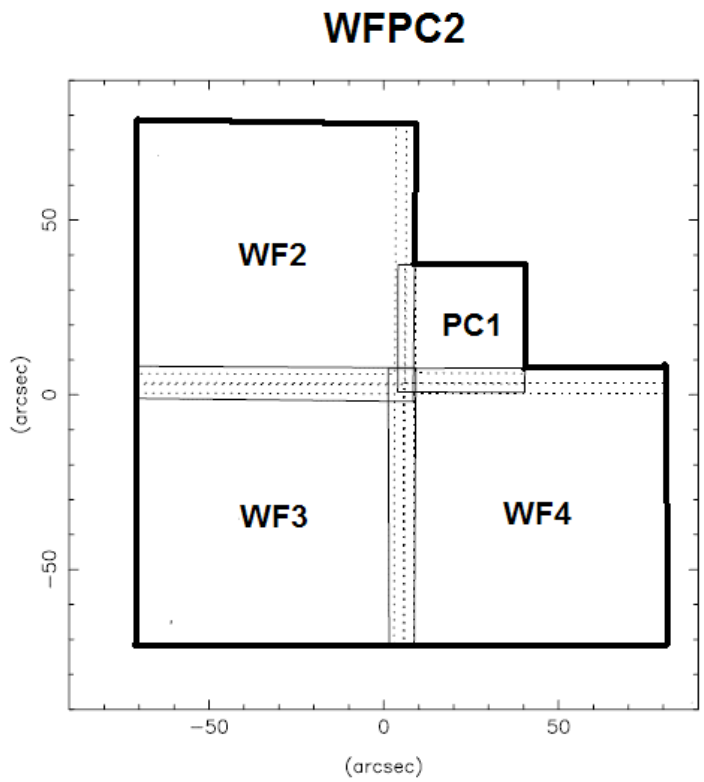
- CTE
  - update correction equations ASAP
  - expand study of extended target CTE
- WF4 anomaly
  - photometric corrections in WFPC2 pipeline
  - additional temperature reductions planned
- Astrometry studies to support / improve drizzling
  - update distortion & offset tables
- Review Cycle 16 GO pool & augment cal plan as needed

# Appendix

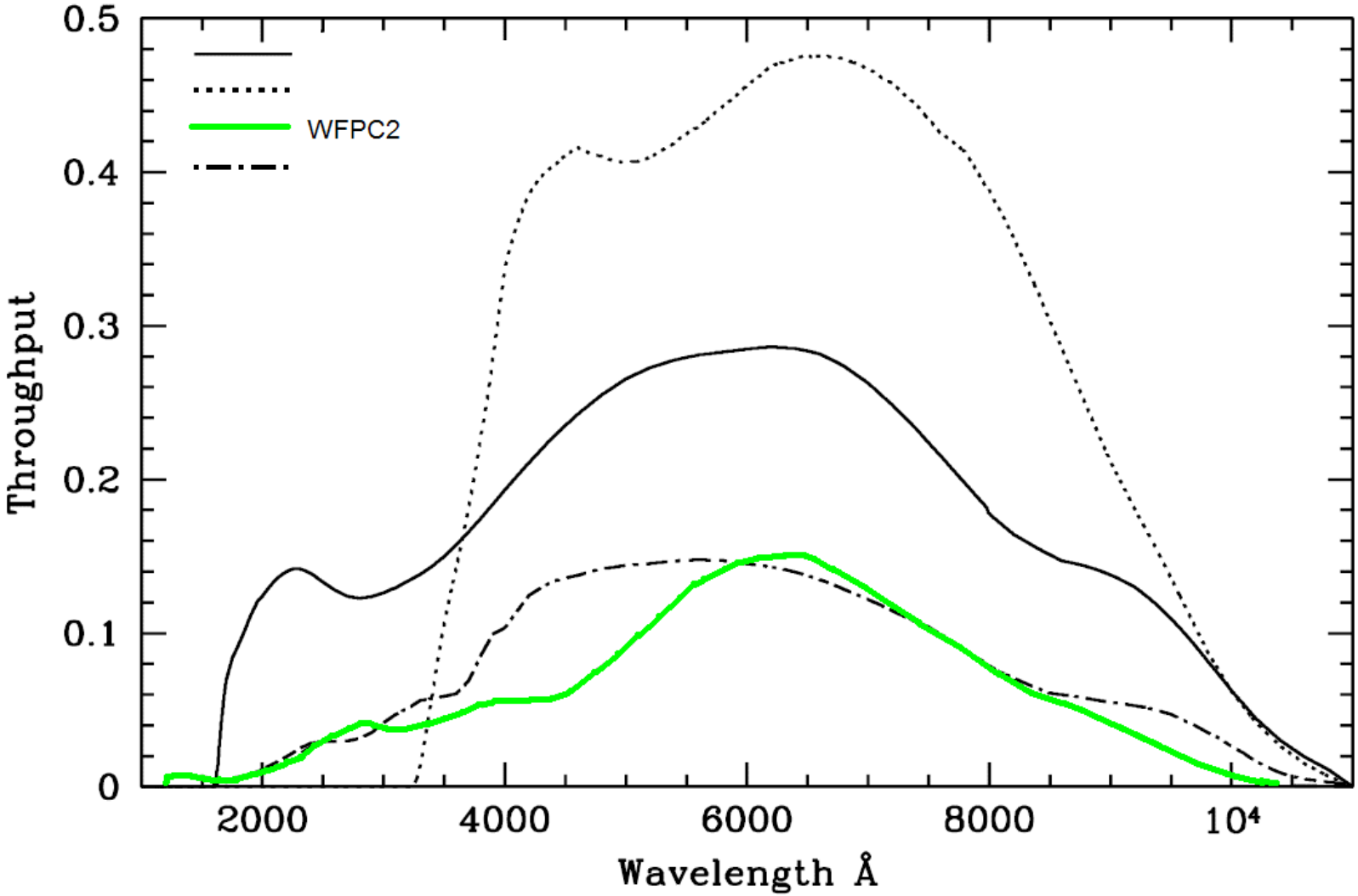
# *WFPC2 Basic Properties*

| | WFPC2 | | ACS | |
|---|---|---|---|---|
| | WF | PC1 | WFC | HRC |
| Field-of-View | 3x75”x75” L-shape | 34”x34” | 202”x202” | 29”x26” |
| Pixel Size | 0.1” | 0.046” | 0.05” | 0.027” |
| Resolution (FWHM, dithered) | 0.12” | 0.07” | 0.07” | 0.05” |
| Saturation | 53000e- | | 80000e- | 140000e- |
| V mag limit ($5\sigma$, F606W, 1 orbit, w/ overheads, CTE) | 26.95 | | 28.43 | |

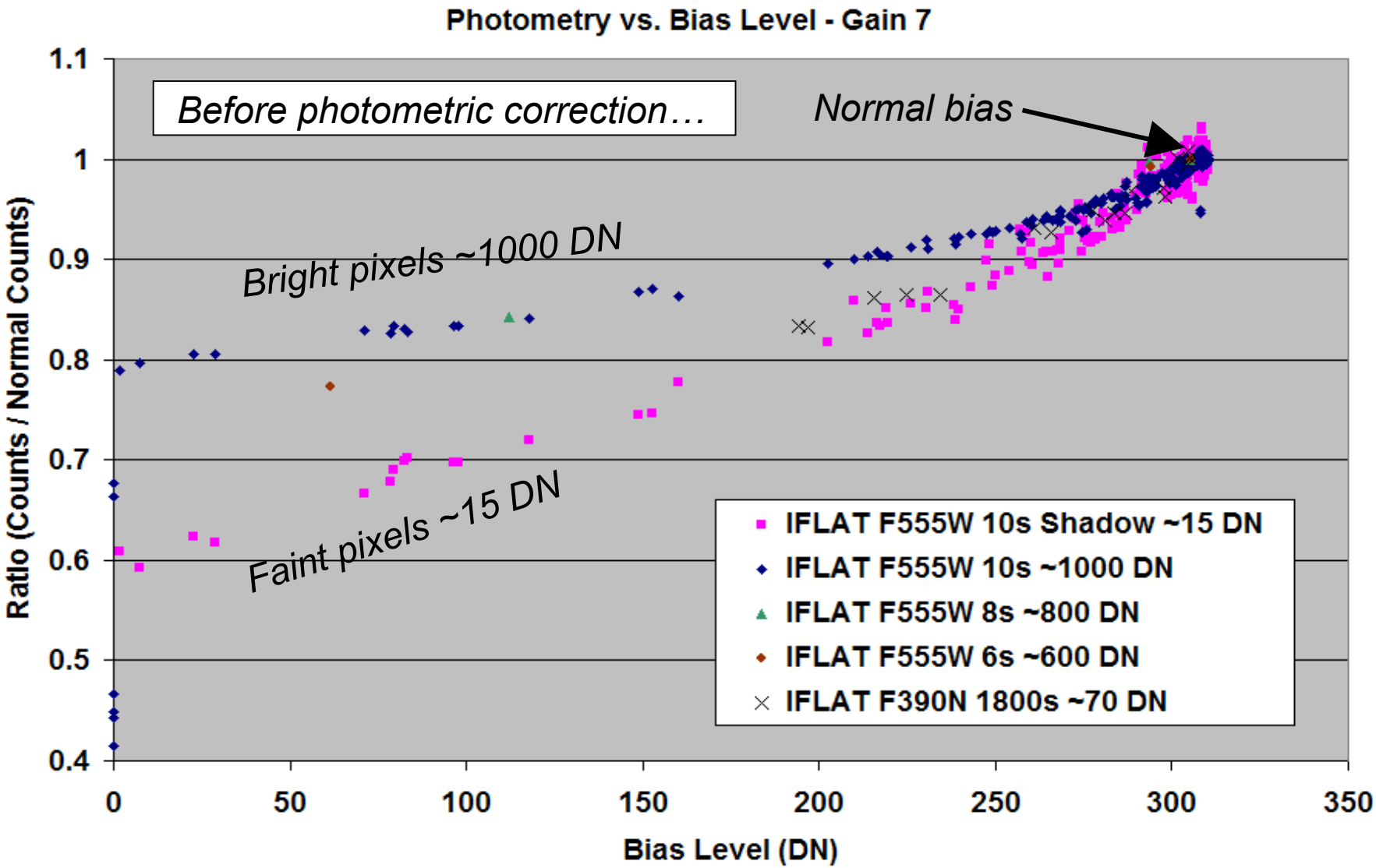
# *WFPC2 Field-of-View*



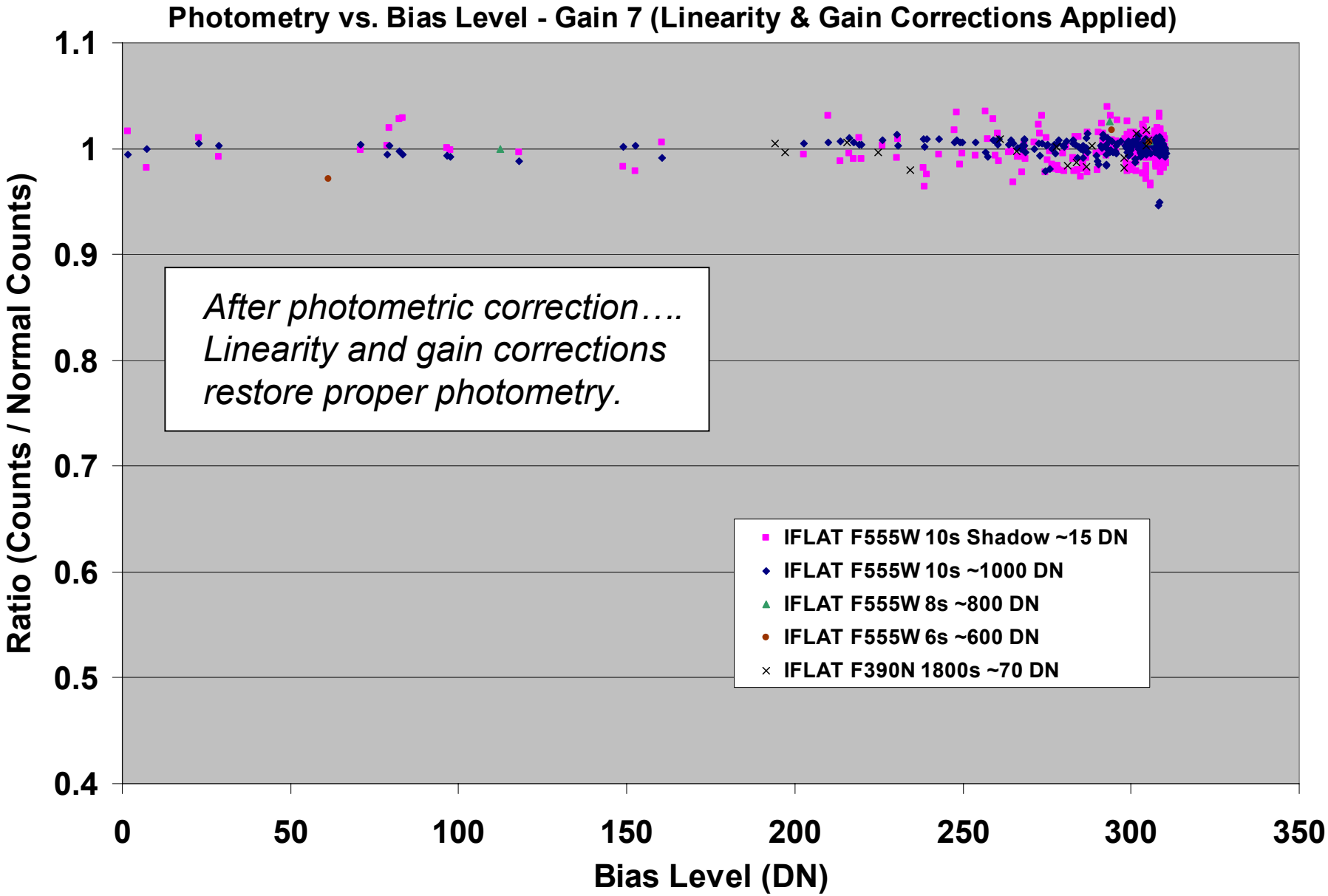
# WFPC2 + HST Throughput



# WF4 Photometric Corrections: Before…



# WF4 Photometric Corrections: After…



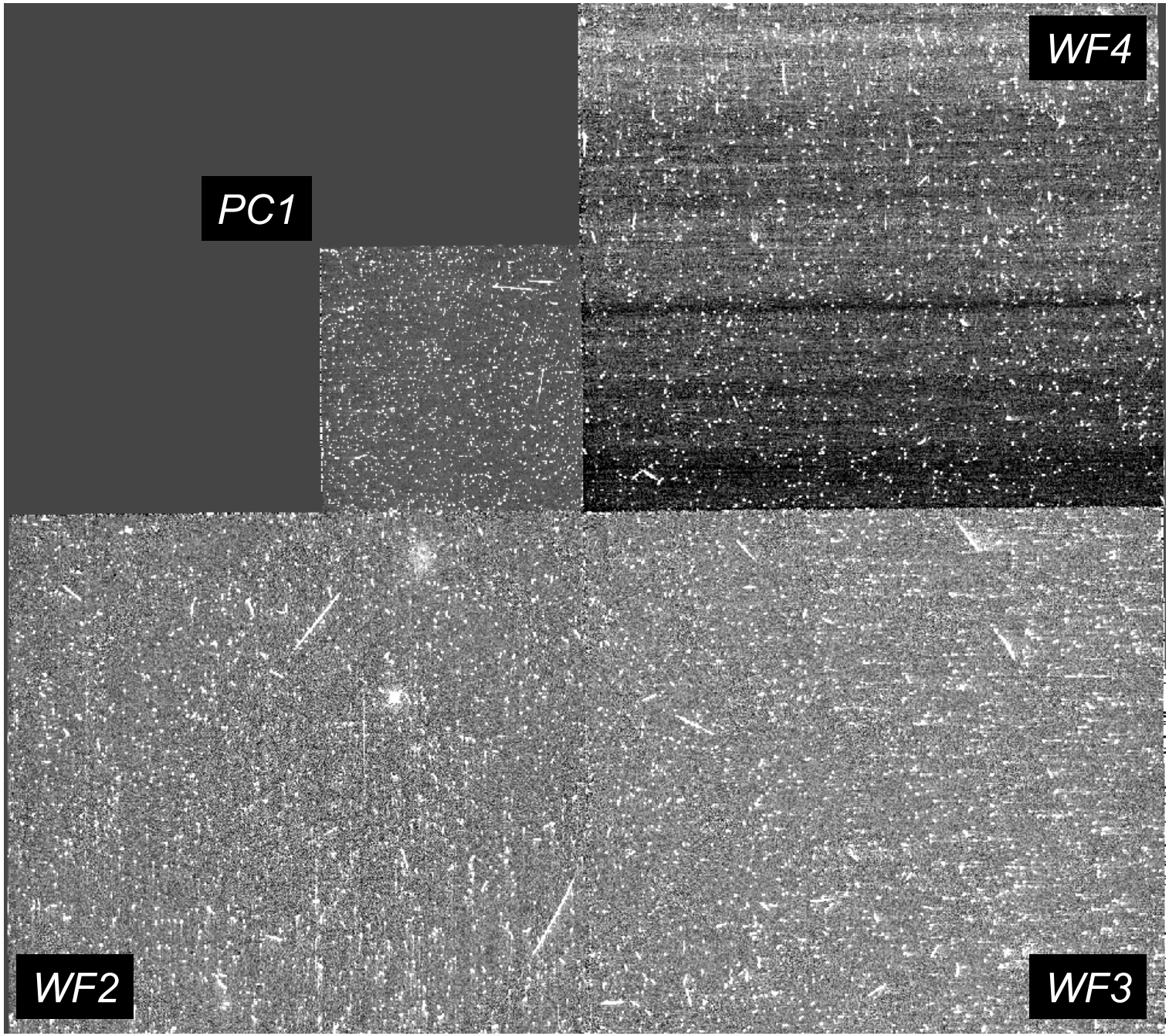
Low Bias Image Example

8/25/2005

F439W, 700s

Stripes in WF4.

+/- 0.5 DN



*Closeout Project Details from Oct. 2006*

# *WF4 Anomaly*

- Monitor health of WF4
- Keep WF4 functioning: Perform temperature adjustment in Jan. 2007, possibly also Aug, 2007.
- Document work on temperature adjustments & their impact.
- Derive and document photometric corrections.
- Impacts ~20% of images by numbers; science impact 6%?
- Has indirect impact on many areas of calibration.
- Committed to do.  0.5 FTE yr.

- Software tasks to correct photometry and background streaks.
- Pipeline-based corrections.
- Requires work from software / pipeline groups.
- High priority.  0.3 FTE yr.

# *CTE Studies*

- CTE is greatest single lien on WFPC2 data quality, accuracy, and ease of use.
- Existing CTE correction equations derived prior to 2002. Re-derive corrections for entire mission.
- Simplify CTE corrections – currently 3 sets of corrections that often give different results.
- Image based corrections? Greatly simplify future archival use / improve accuracy if corrections were made in pipeline. Valuable asset for other instruments – WFPC2 good test bed – long history and large CTE.
- Impacts ~80% of data to some degree.
- High priority; 0.6 FTE yr.

## *HST Global Photometric Accuracy*

- Compare photometric scales of past / current instruments.
- Study long-term trends in HST throughput (especially UV).
- WFPC2 has 14 year overlap with other instruments.
- Medium priority; 0.2 FTE yr.

## *Improve Photometric Zeropoints*

- Accuracy ~2% in visual and red; only 3% to 4% in blue.
- Analyze additional standards & standard fields.
- Impacts ~45% of images.
- Medium priority; 0.3 FTE yr.

# *Low Light Flats for Broadband Filters*

- Existing broadband filter flats are combination of ground test data and on-orbit illumination corrections derived from narrow-band filters.
- Directly derive flats for broadband filters:
- Sky flats: large archive of images available.
- Full moon Earth flats: earth illuminated by full moon provides correct brightness for direct broadband flats. (Effort needed from scheduling group.)
- Impacts ~94% of images.
- Medium priority; 0.4 FTE yr.

## *Red-Leaks in Blue and UV Filters*

- Red-leaks not well calibrated on-orbit.
- Evaluate spatial variations and any long-term changes.
- Impacts ~35% of images.
- Medium priority; 0.2 FTE yr.

## *Narrow Band and Ramp Filters*

- Possibility that filters change in space environment due to chemistry processes.
- Evaluate central wavelengths, band widths, throughputs.
- Some evidence for 5% - 10% photometry errors in ramps.
- Impacts ~4% of images.
- Medium priority; 0.5 FTE yr.

# *Documentation*

- Instrument Handbook final version. Last full version 2004; only short updates since then.
- Data Handbook final version. Current version is Jan. 2002.
- Website Clean-up. Convert from “work in progress” to “final document.” Remove out-of-date / redundant / wrong material. Improve accessibility and usability. Sensible paths to material vs. historical accidents.
- Summary document “The WFPC2 Experience.” Single document summarizing history and issues from archival user point-of-view.
- High + medium priority tasks; 0.4 + 0.4 FTE yr.