Hubble Space Telescope

STUC Meeting – April 25, 2013

K. Sembach

Accounting for only 1/2% of NASA's Budget

The Hubble Space Telescope is:

- The most scientifically productive observatory in history
- Synonymous with science excellence
- A universally recognized NASA "brand"
- A role model for fair science selection

- Changing the field of astrophysics
- Rewriting science textbooks
- Reaching millions of students in all 50 states
- Inspiring the public and enriching our culture

23rd Anniversary Image

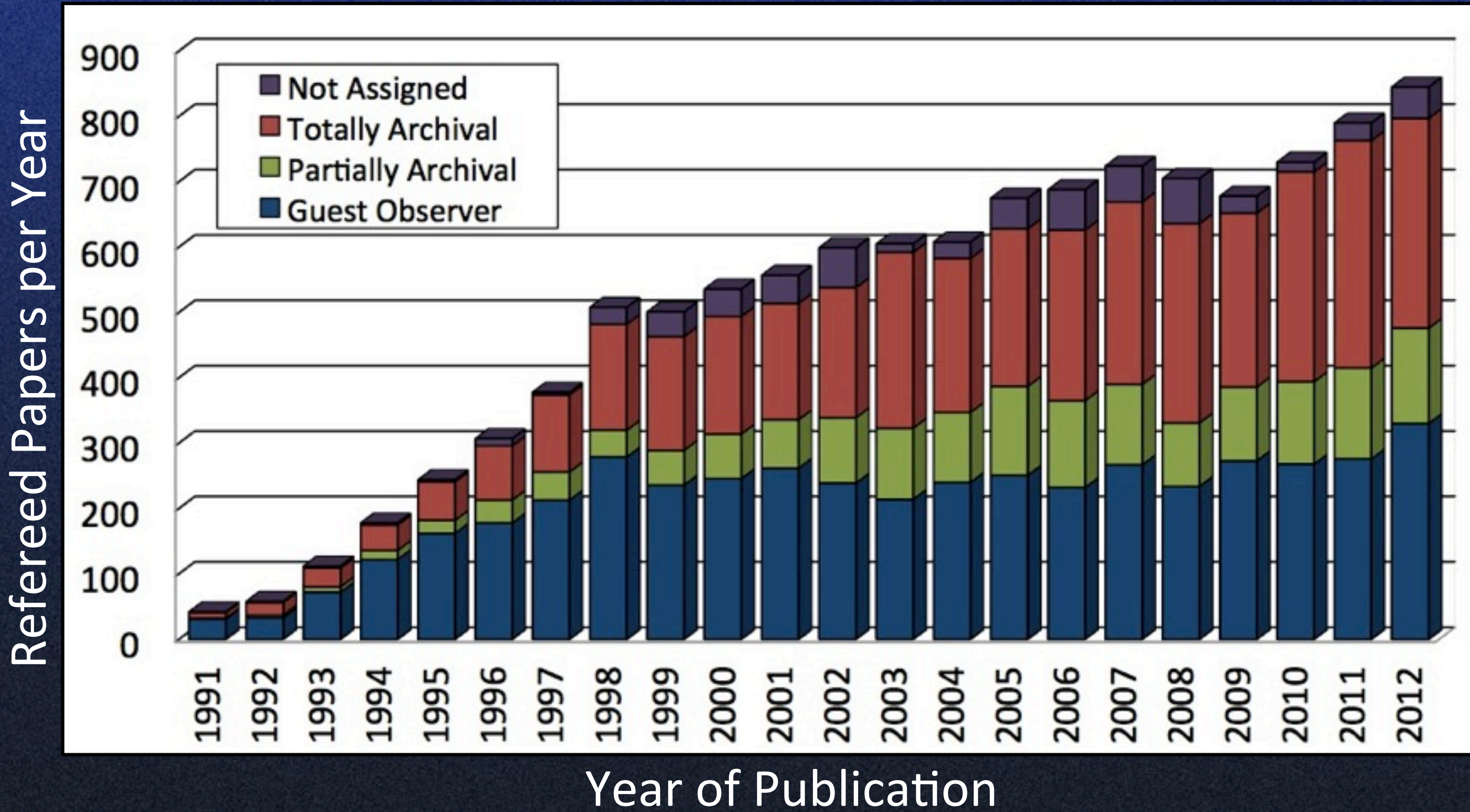
23rd Anniversary Image

Comet ISON

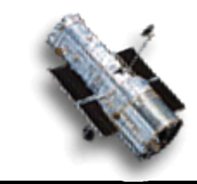

Comet C/2012 S1 ISON April 10, 2013
HST WFC3/UVIS
NASA and ESA
STScI-PRC13-14a

HST Science Output is Higher Than Ever

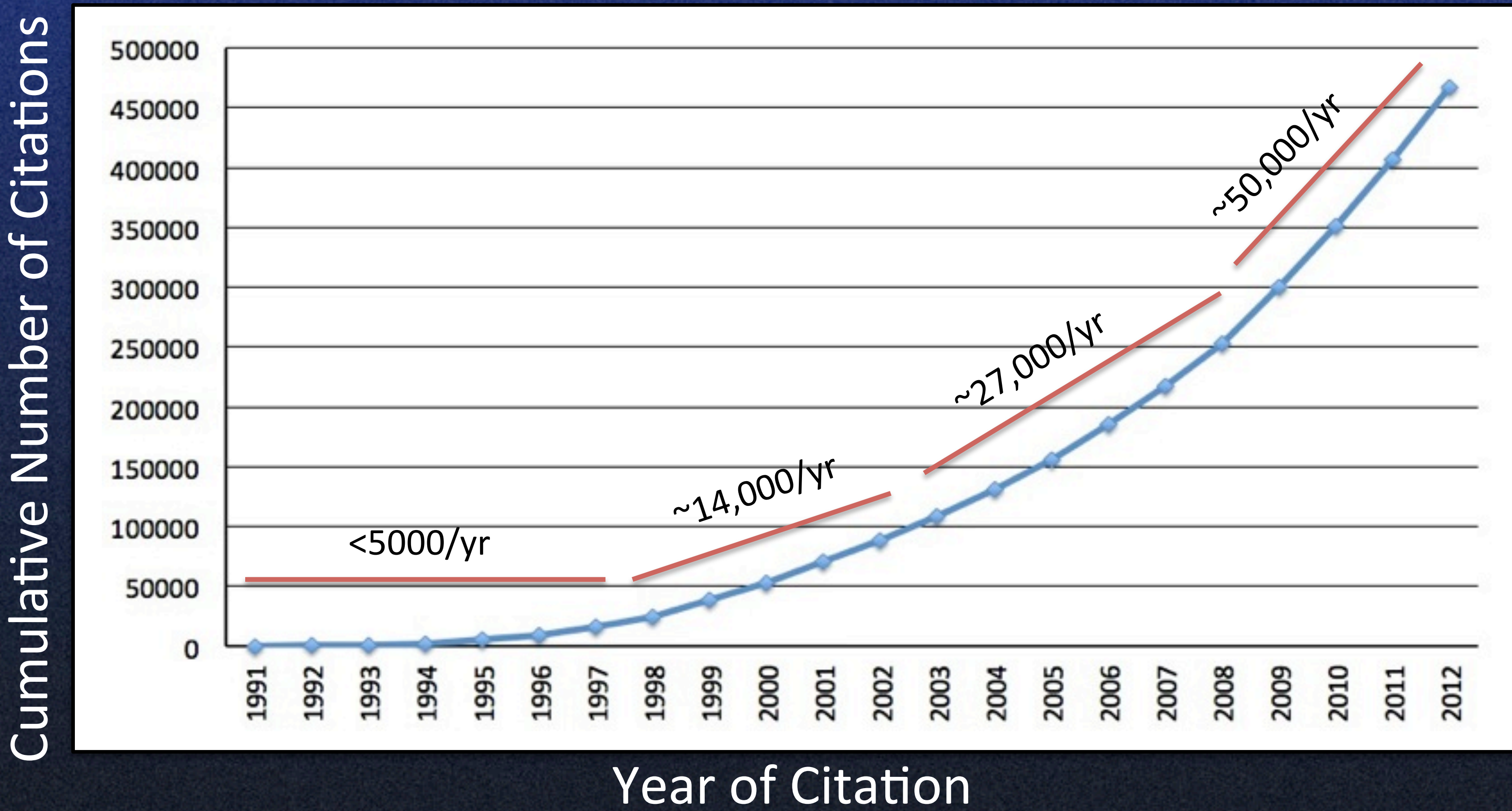
- 11,297 refereed science papers based on HST data to date
- 845 papers in 2012 was highest output ever



Hubble Citations are Increasing Exponentially

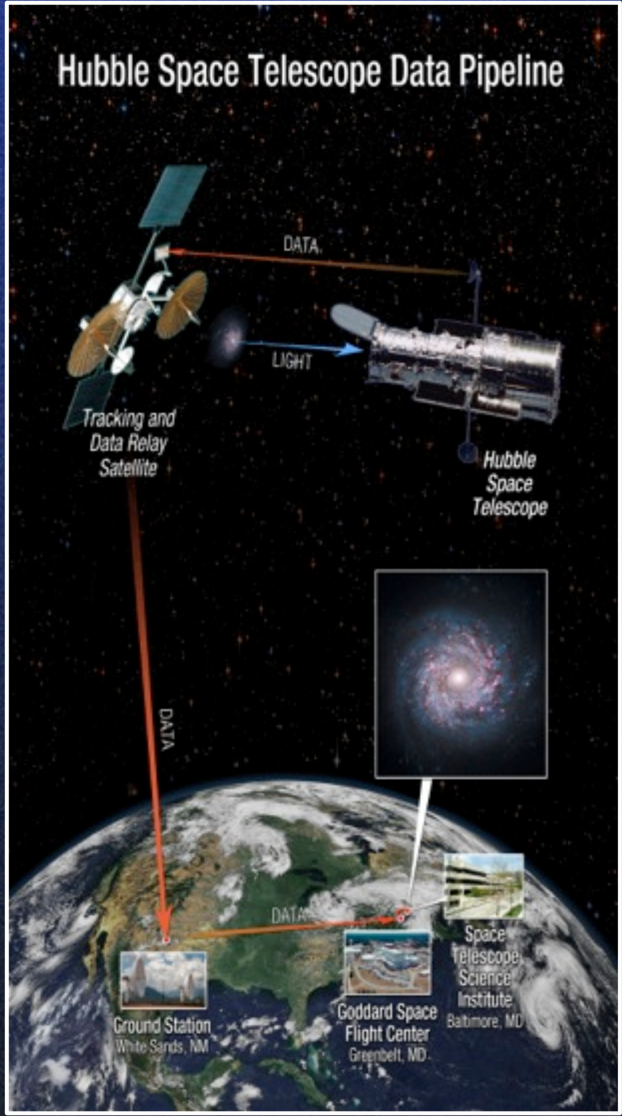


- >470,000 citations to refereed HST papers (1990-2012)
- 33 papers have >500 citations; 264 papers have >200 citations
- Typical paper more than 5 years old has ~50 citations



Current Status

- All science instruments are performing well.
  - ACS, COS, FGS1r, STIS, and WFC3 are in use
- Scheduling efficiency is ~85 orbits per week for first 31 weeks of the cycle.
- 100,000th WFC3 exposure occurred this week.
  - Part of the CLASH program (CLJ1226+3332, F275W image)
- Multi Cycle Treasury program observations conclude in Cycle 20.
  - Summer is busy period for these programs
- Mid-February observatory safing event
  - Solar array slew anomaly (minor)
  - No observations for about 5 days, with a net loss of 57 orbits
  - Most of those have been rescheduled and executed, with a few pushed out to Jan-Mar 2014



Long Range Plan
Status through calendar ending 05/05/13

Cycle	Orbits	Diff from Mar 31
18	24	-21
19	69	-17
20	1732	-333
21	12	-0
Total	1837	-371

Visits not in current plan	Orbits	Diff
Unschedulable	28	-2
No plan windows	67	-45
C20 misc	66	-8
Total not in plan	161	-55

Instrument	Orbits	Diff
WFC3	1022	-233
COS	30	-53
ACS	292	-51
STIS	229	-30
FGS	5	2
Total	1857[(1)]	-369

C19 snaps	621	-5
C20 snaps	964	-25
Total snaps	1585	-30

Cycle 17 orbits completed on March 3, 2013
Cycle 18 orbits complete in July 2013

1. Some programs have more than one prime science instrument.

Long Range Plan
Progress of MCT, Large, & Treasury Programs

Multi-Cycle Treasury	Total alloc	Exec/sched by 05/05/13	Planned before 9/30/13	Planned 10/1/13+	Comment
Dalcanton	834	778	54	2	Finishes 10/13
Faber/Ferguson	750	689	61	0	Finishes 08/13
Postman	474	448	26	0	Finishes 07/13
Riess (ToO)	202	175	1	0	26 unplanned

C18/19 Large	Total alloc	Exec/sched by 05/05/13	Planned before 9/30/13	Planned 10/1/13+	Comment
Van Dokkum	248	247	1	0	Finished 04/13
Heckman	119	109	10	0	Finishes 05/13

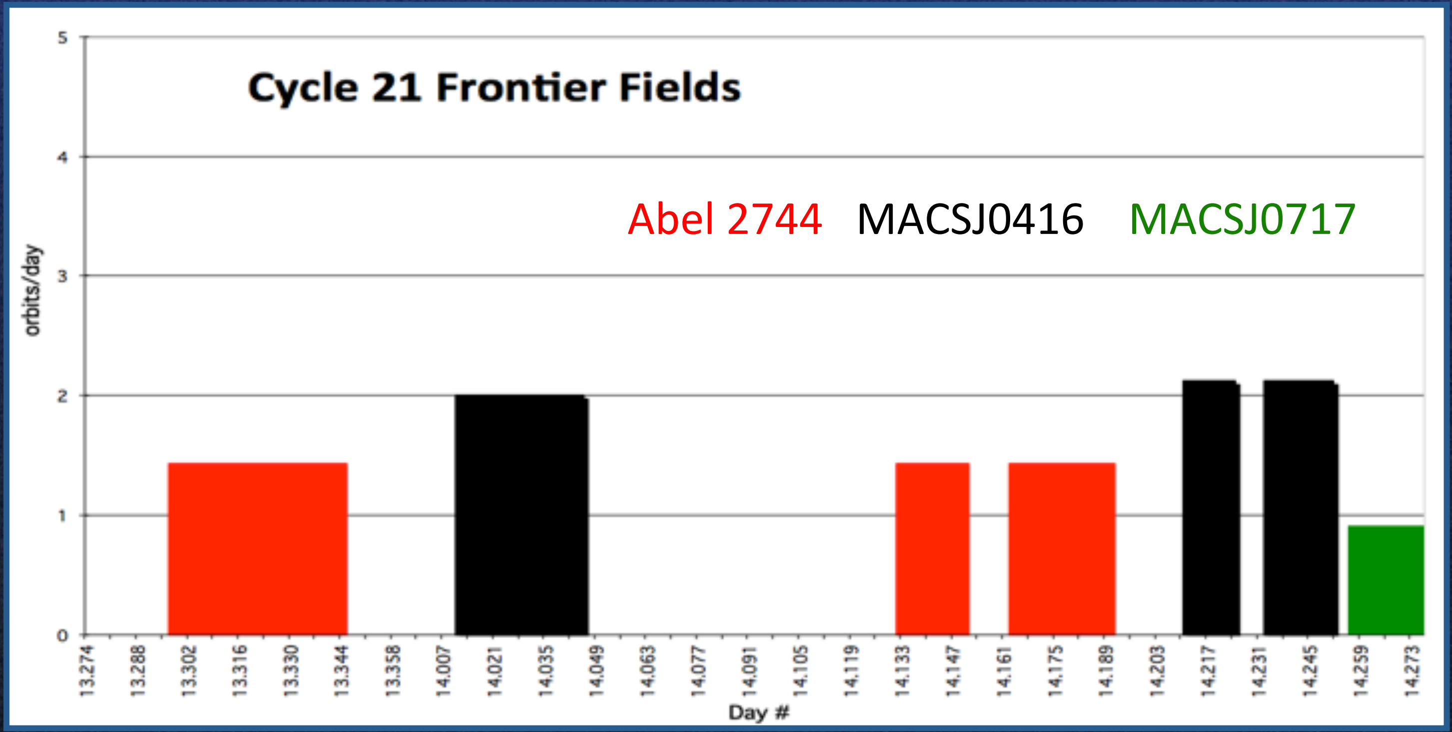
Long Range Plan
Cycle 20 Large & Treasury Programs

C20 Large & Treasury	Total alloc	Exec/sched by 05/05/13	Planned before 9/30/13	Planned 10/1/13+	Not yet in plan
Bean	60	44	16	0	0
Bedin	120	60	60	0	0
Cushing	125	28	57	40	0
Gaensicke(1)	122	106	41	20	83
Gladders	107	51	38	18	0
Kirshner (ToO)	100	38	5	5	52
Riess	112	30	45	37	0
Sabbi	60	30	30	0	0
Sahu	64	20	36	8	0

1. Total orbits > allocation due to extra visits to set flags and check for bright objects.

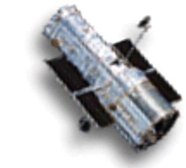
Long Range Plan
Frontier Fields

- Schedulers have been working with the Frontier Fields Implementation Team to determine how best to schedule the 6 field pairs (140 orbits each) over the next three years.
- There is no timing overlap between the two Cycle 21 targets.
- Initial analysis of possible conflicts with Cycle 21 Large /Treasury Programs has begun, but final analysis awaits TAC recommendations.



WFC3 Status

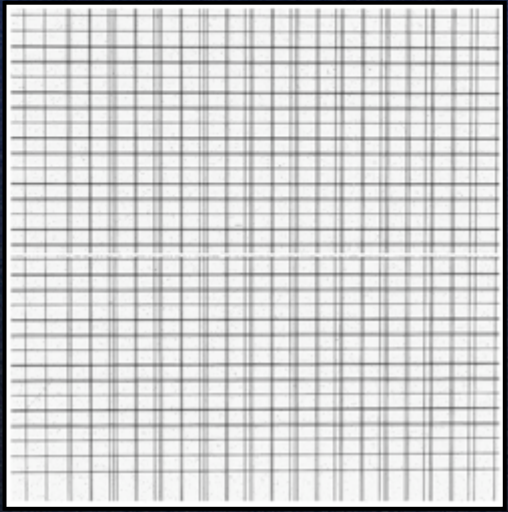
(J. MacKenty and the WFC3 Team)



- WFC3 is operating nominally
  - Photometric zero points remain stable to <0.3% (UVIS) and <0.5% (IR)
  - Quality in-flight flat fields are available in both channels
  - Improved UV flats are being worked this year

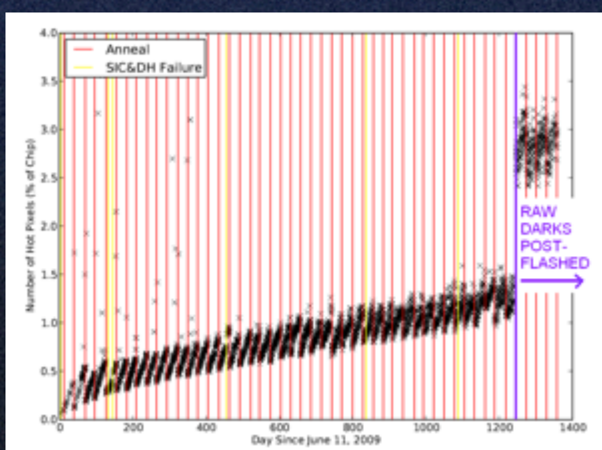
- IR image persistence exposure history tracking is available for all WFC3/IR images
  - Downloads from MAST with estimates of persistence levels in each pixel
  - Manual identification of "bad actors" to aid scheduling

- Spatial scans supported for Cycles 20 and 21
  - Increased potential for exoplanet transit observations
  - Astrometric precision better than FGS
    - Parallax to ~25-30 micro-arcsec
  - Key calibration activities:
    - IR zero-points of Vega
    - Multiple scans to test/improve flat fields



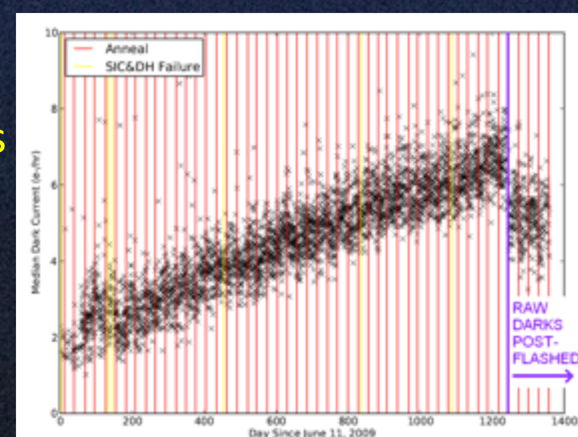
WFC3 Post-Flash

- Post-Flash
  - Initiated March 2012 and first used for GO observations in August 2012
  - Addition of ~10-12 e- dramatically improves transfer for small charge packets (~100-1000e-) → e2v mini-channel works!
  - User specifies desired number of additional electrons (1-20e-)
- Charge trailing still significant for larger packets
  - Post-Observation correction by deconvolution w/ Anderson-Bedin algorithm modified from ACS implementation
    - *ALPHA* Release March 2013 (Fortran code via www; OPUS in FY14)
- Interesting impact on Dark Calibration → moving to PF Darks
  - Also impacts existing flat fields (Omega Cen derived) at 0.3-0.4% level

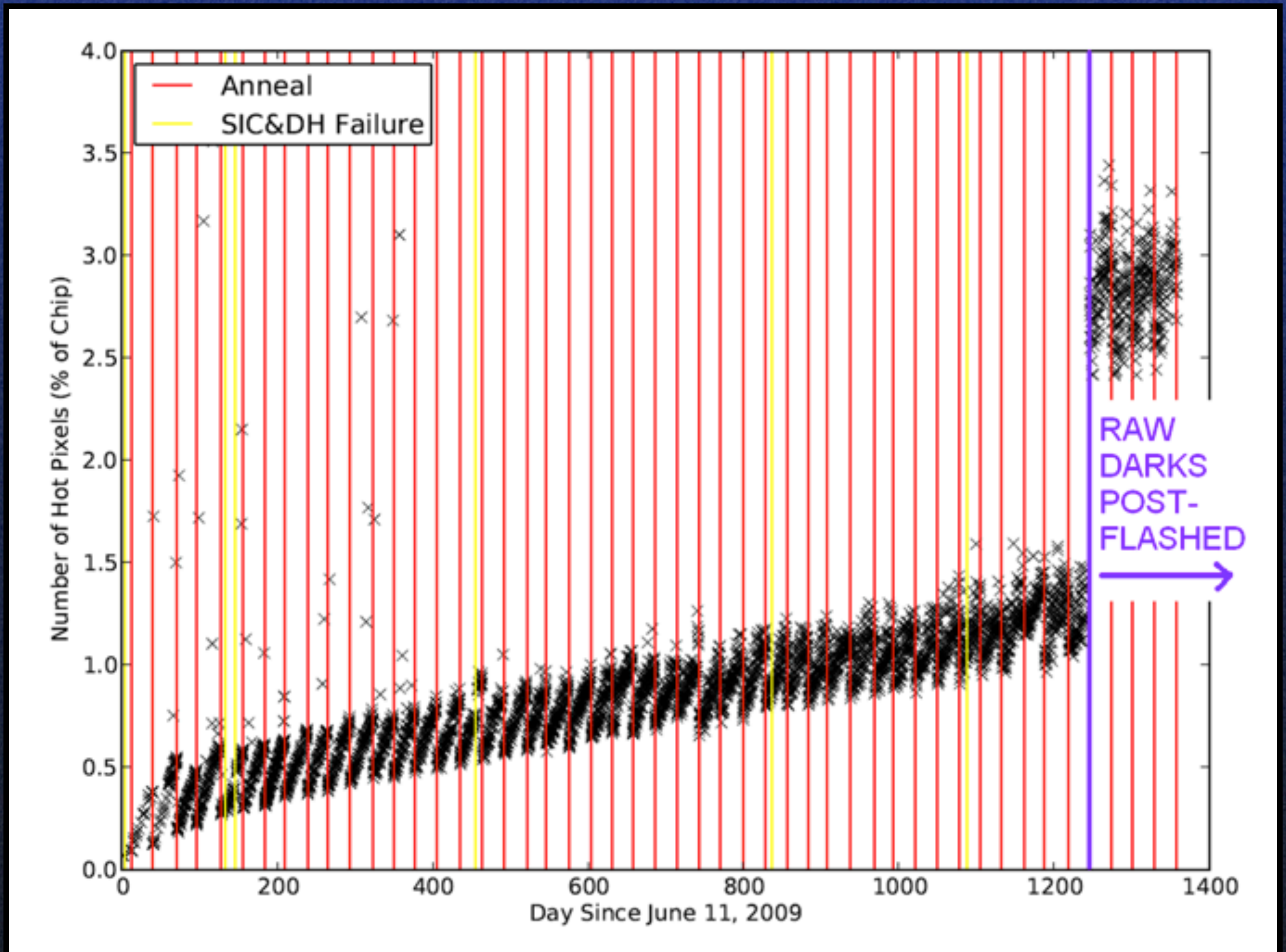


← More hot pixels

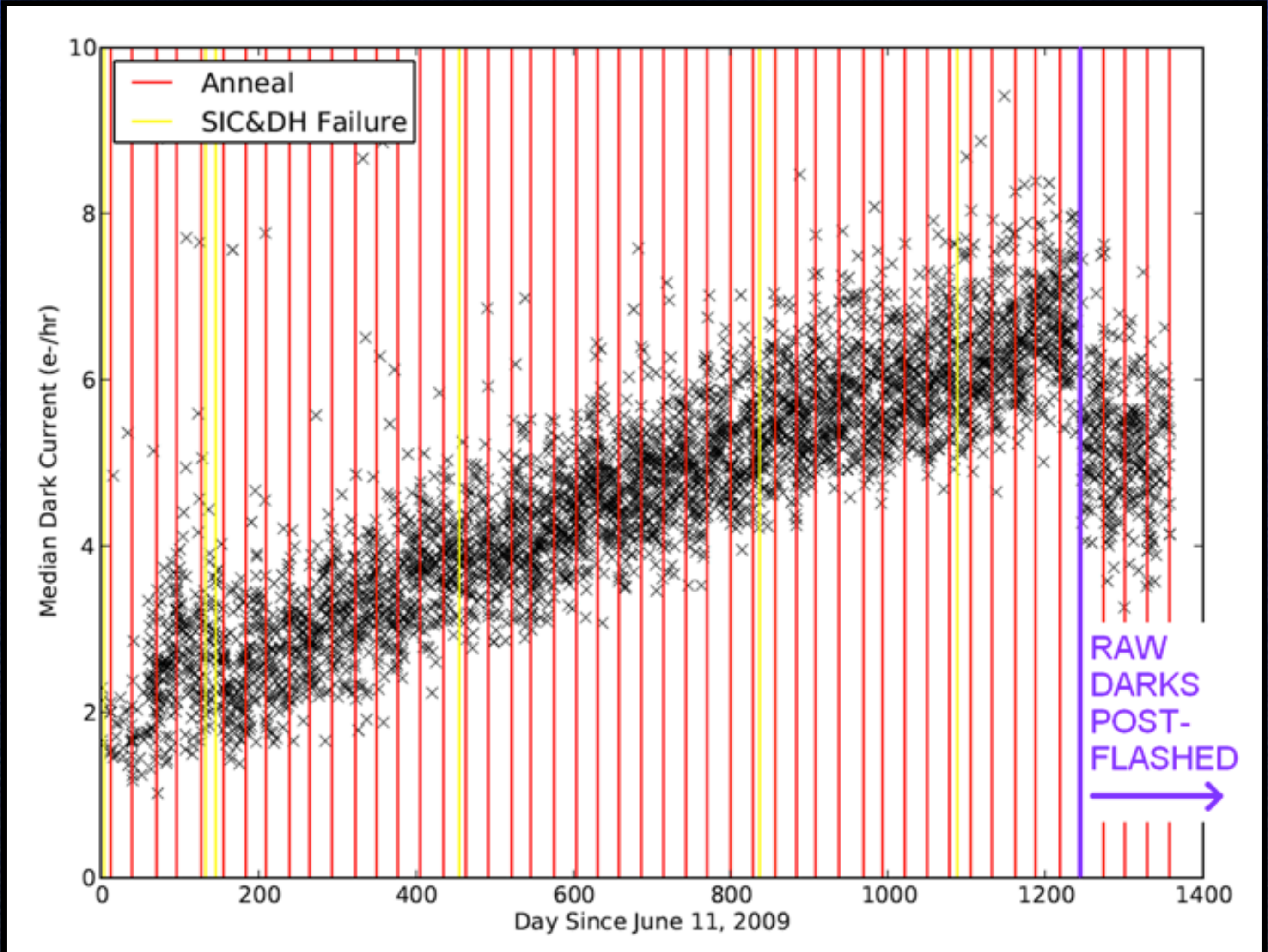
Less bulk dark →



Post-Flash Reveals Hot Pixels

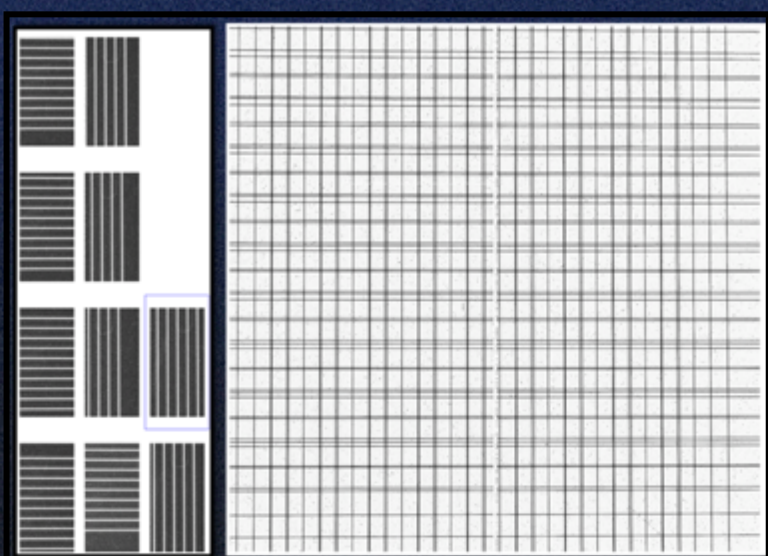


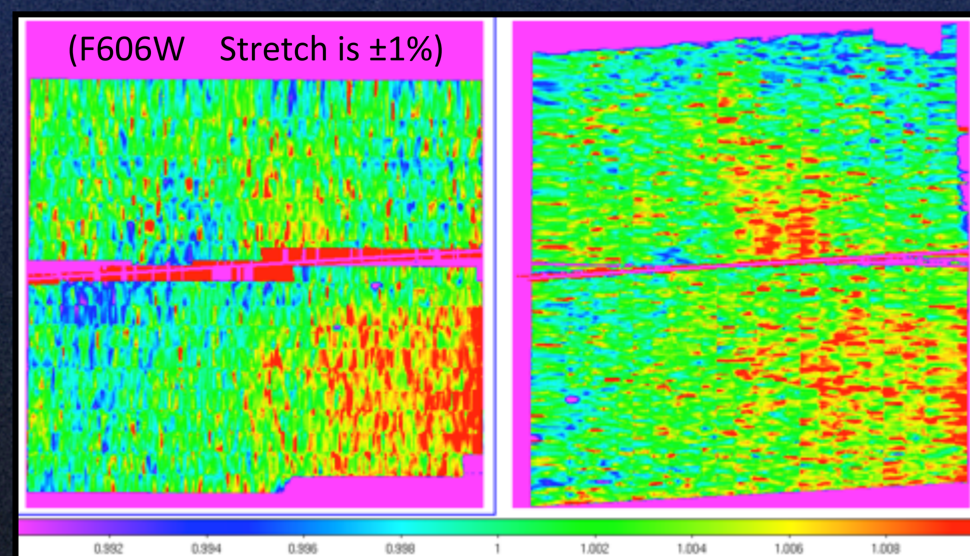
Post-Flash Suppresses Diffuse Bulk Dark



WFC3 Spatial Scans

- Spatial Scans are working well
  - Successful GO science programs (*e.g.* Deming et al 2013 ApJ)
  - Riess & Casertano program getting <<60 micro-arcsec relative astrometry
  - Vega zero-point data appears to be good at 1-2% level
  - APT visualization implemented and released
  - For Cycle 21, FGS controlled spatial scans now available at 4.8 “/sec (*viz* 1”/s)
  - Co-added zig-zag scans enable independent test of flat fields and a path to improve UV flats



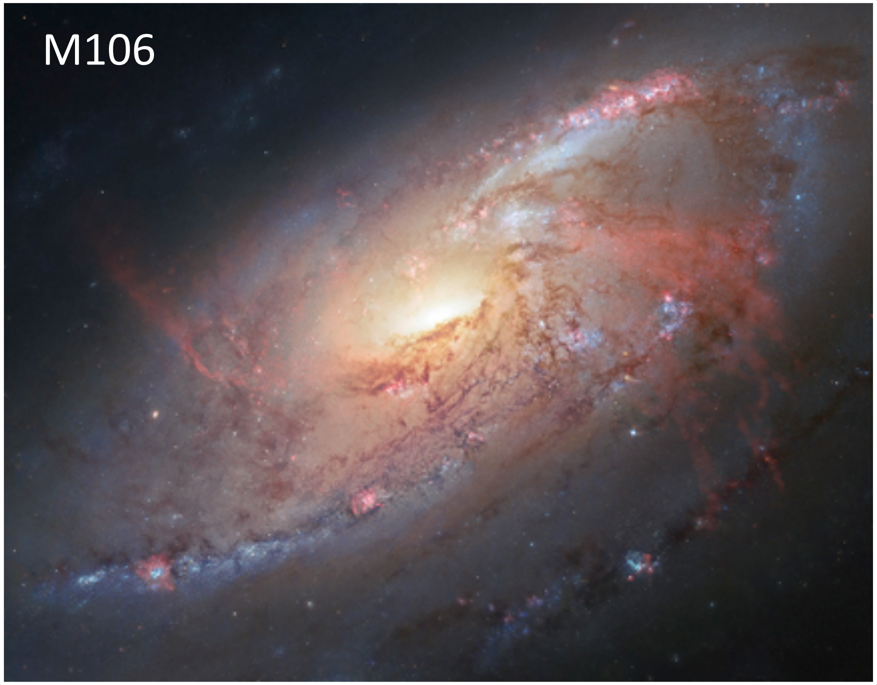


ACS Status

(N. Grogin and the ACS Team)

- ACS/WFC and ACS/SBC channels are both working well. The repaired ACS has now been in operation for nearly 4 years.

- The last major upgrade to CALACS pipeline calibration has been performing smoothly for nearly a year now, providing CTE-rectified data products with corrections for all post-SM4 electronic artifacts (crosstalk, bias-striping, and bias-shift).



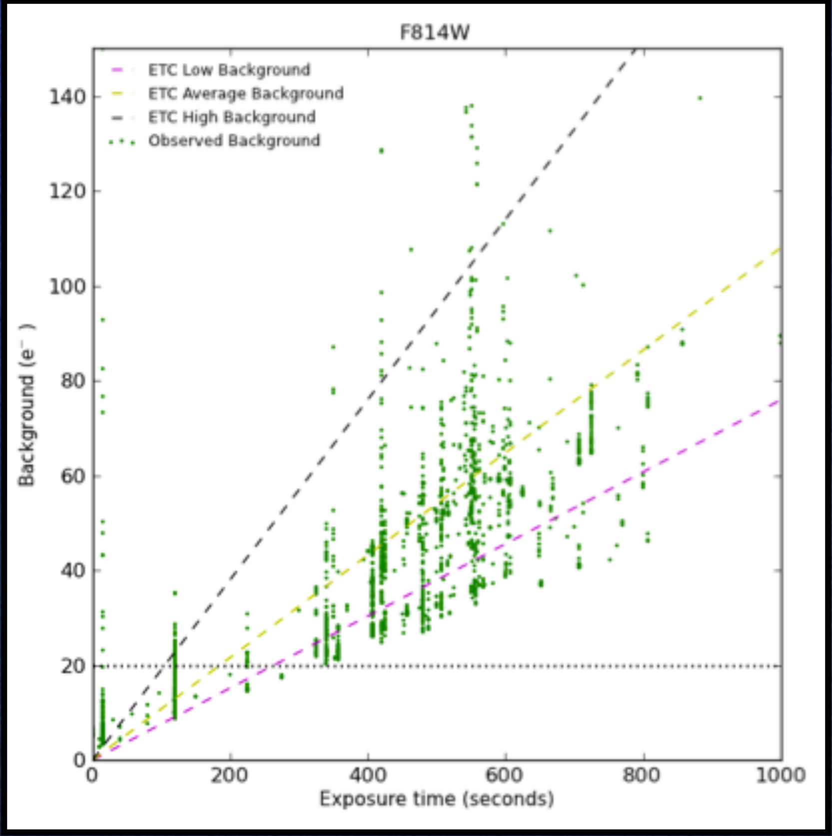
- Preparations are underway to support enhanced ACS/WFC calibrations for the HST Frontier Fields.
  - These calibrations will be incorporated into CALACS for the benefit of the broader ACS user community.

ACS Post-Flash and CTE Corrections

- Phase II support for CTE-mitigating WFC post-flash has now been incorporated into APT.

- GOs with Cycle 20 programs meriting post-flash for CTE mitigation have been alerted.
  - Charge transfer efficency losses are severe for exposures with low sky backgrounds (<20 e^-).
  - Plan to alert Cycle 21 GOs well before Phase II deadline

- Cycle 20 Post-flash calibration exposures have now been combined into a high-S/N reference frame delivered to CDBS.

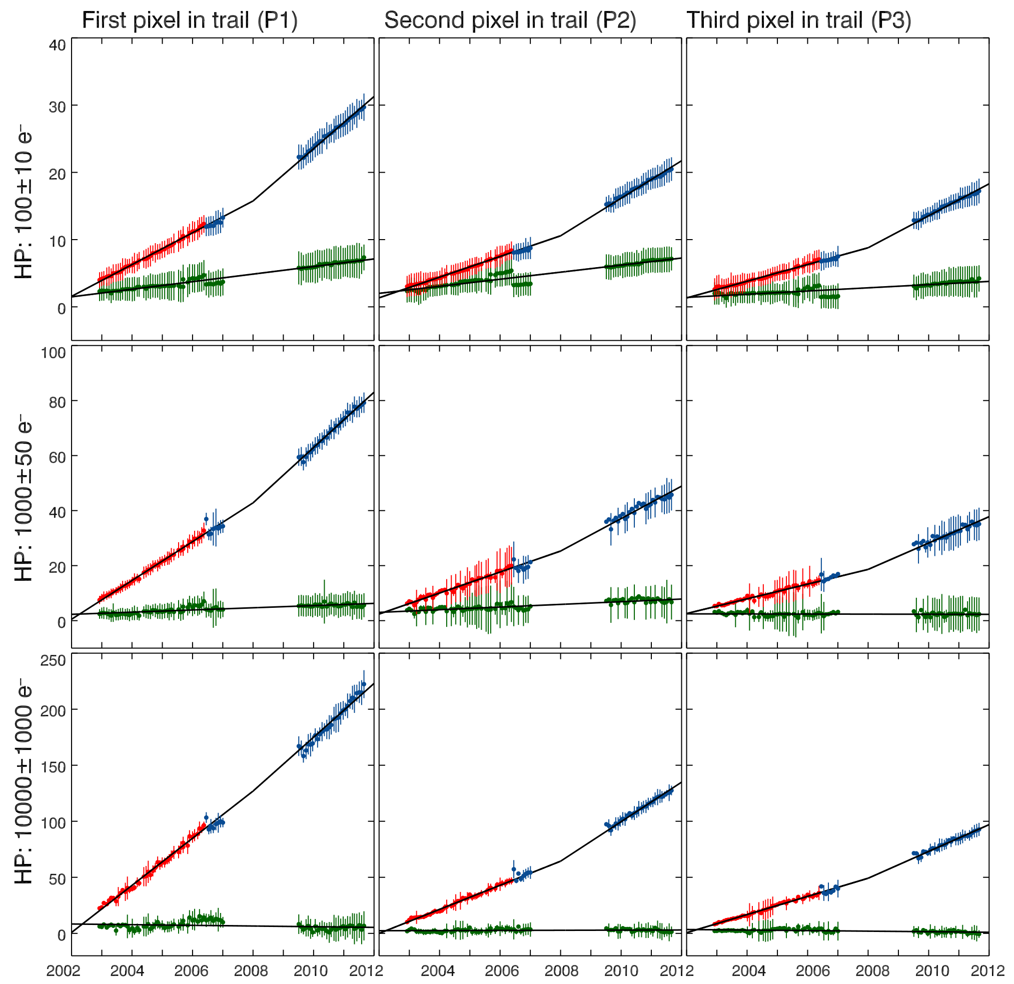


- ACS Exposure Time Calculator (ETC) recently updated to alert users when WFC low-background conditions may cause poor CTE.

- On-line WFC photometric CTE correction calculator now available via ACS Team website (http://www.stsci.edu/hst/acs/performance/cte/ctecorr.py).

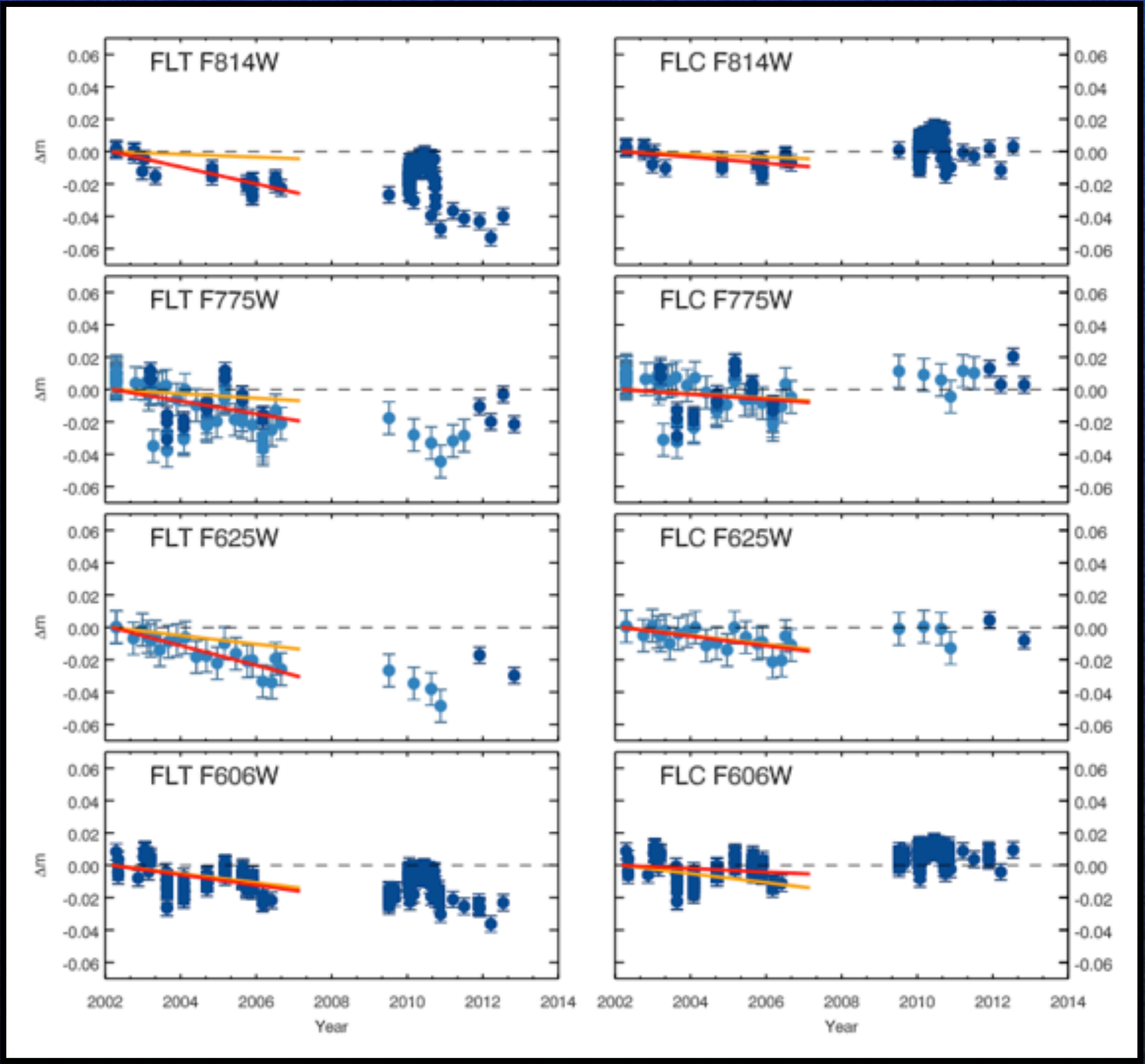
ACS/WFC Long-Term Monitoring

- CTE
  - Degradation characterized across entire 11 year lifetime of ACS/WFC
  - See Ubeda & Anderson Instrument Science Report ACS2012-03



Evolution of number of electrons in the first, second, and third upstream pixels in the CTE trail as a function of time. The black lines represent linear fits to the empirical data. The red and blue symbols correspond to _FLT dark frames (uncorrected) and the green symbols correspond to _FLC dark frames (corrected).

ACS/WFC Long-Term Monitoring



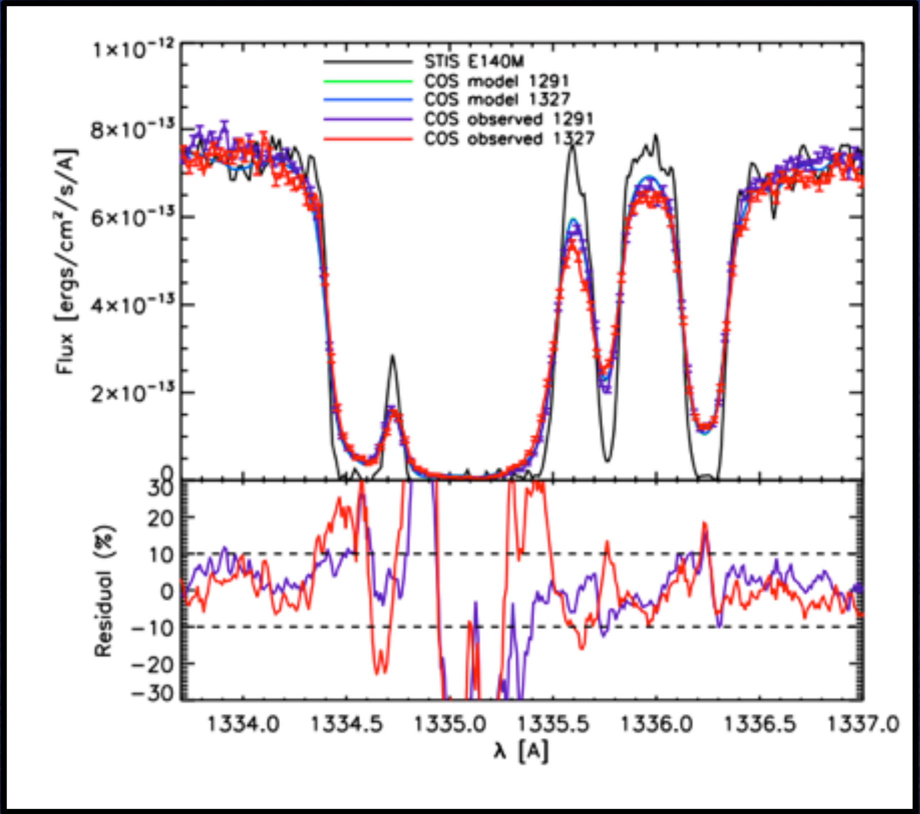
- Filter Sensitivities
  - Highly stable since SM4
  - See Instrument Science Reports by Bohlin et al. (ACS2011-03) and Ubeda & Anderson (2013-01)

Magnitude residuals as a function of time for filters F814W, F775W, F625W, and F606W. Dark blue symbols correspond to deep observations (exposure time > 300 sec) and short exposures are shown in light blue. The orange line represents the pre-SM4 fitting using the standard white dwarf stars from ISR ACS 2011–03. The red line is the best fit of the 47 Tucanae study.

COS Status

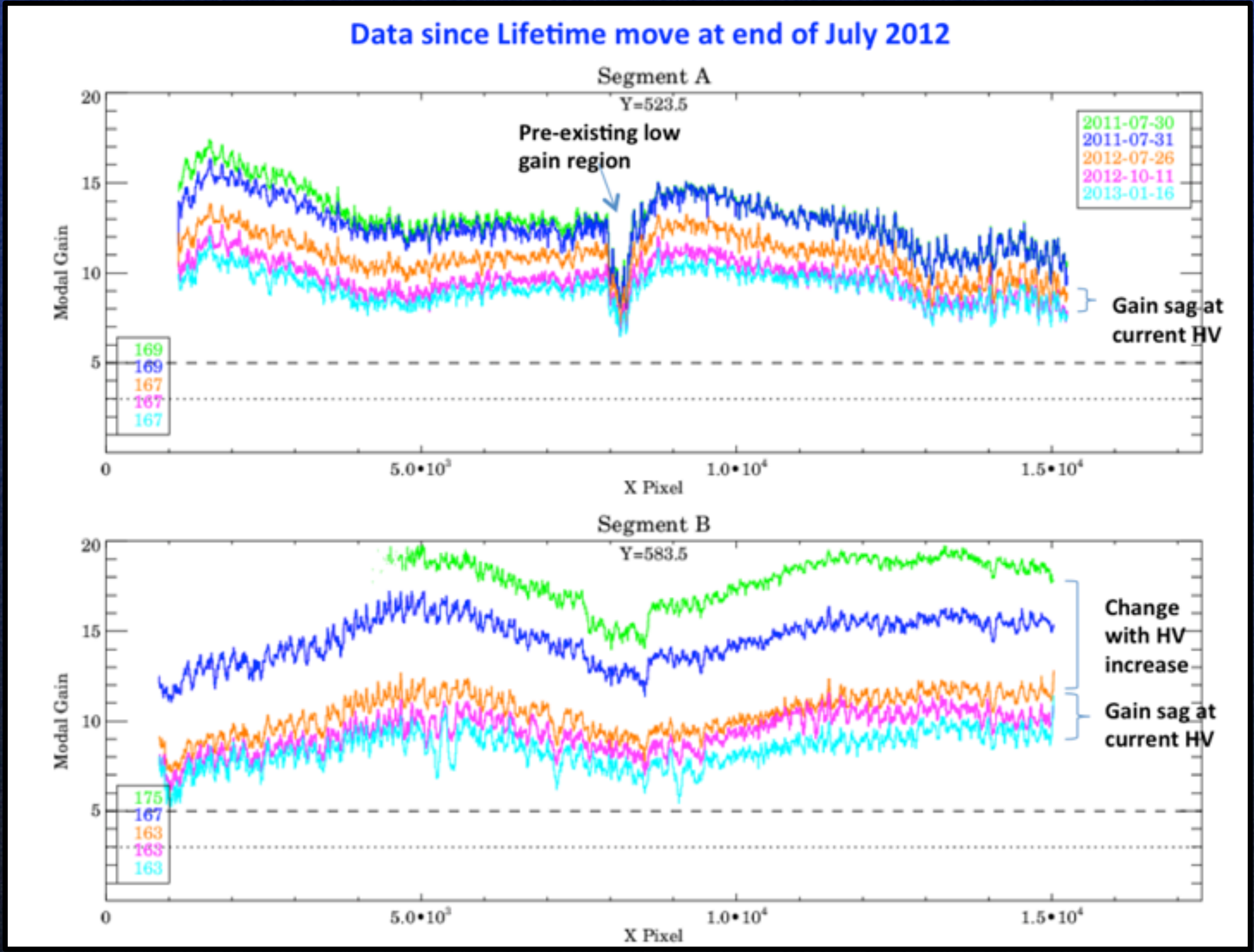
(A. Aloisi and the COS/STIS Team)

- COS is performing well at its new detector lifetime position.
  - Position move made in July 2012
- FUV spectral resolution is ~ 90% of that at original position.
- New set of model LSFs computed at new FUV position.
  - Excellent agreement with observations
  - Theoretical LSFs soon to be released to the community

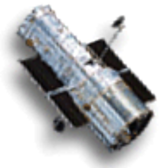


http://www.stsci.edu/hst/cos/performance/spectral resolution/

COS Gain Sag Trending

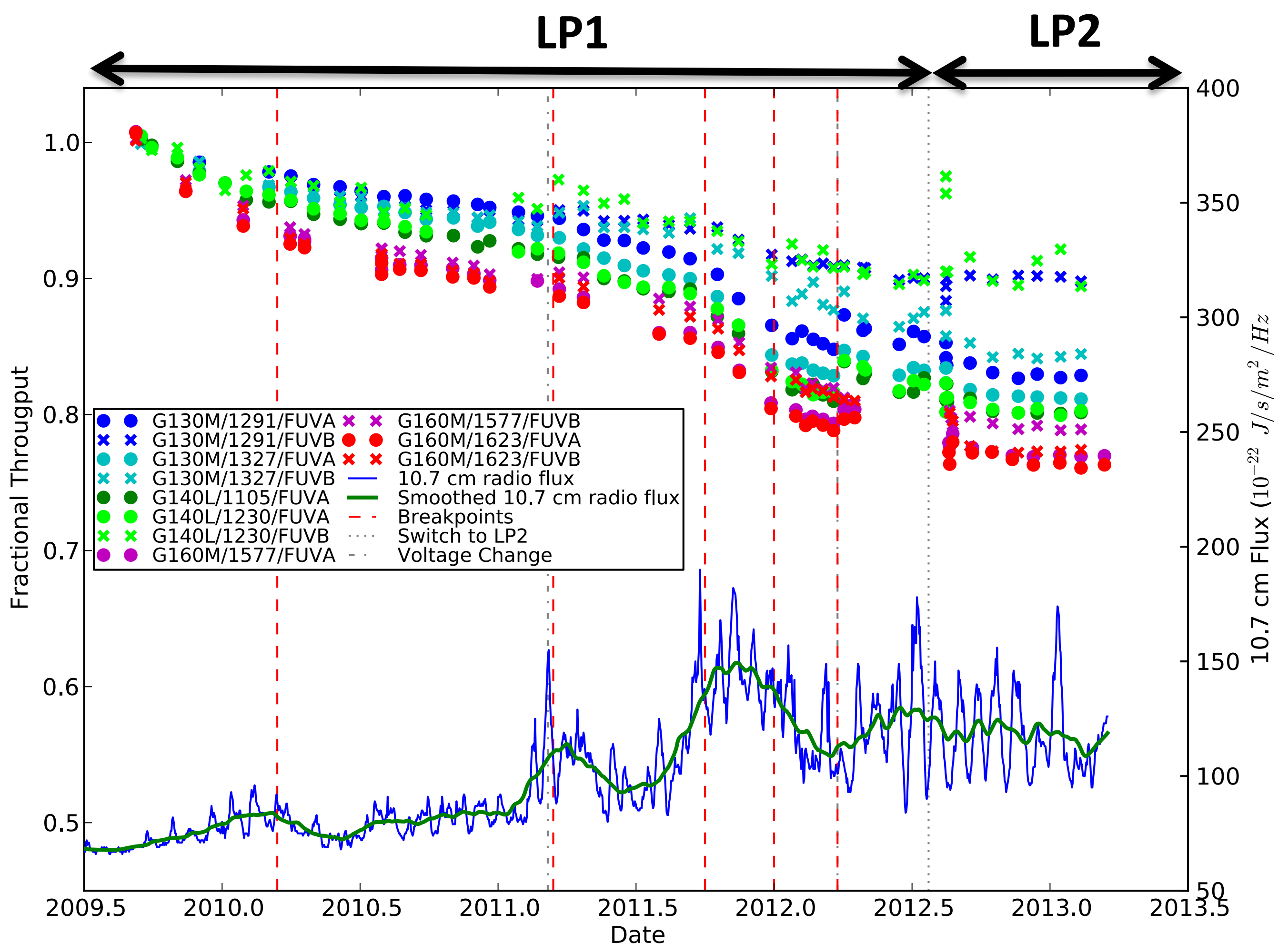


COS Gain Sag Trending



- Routine observations at the new COS FUV position started at the lowest HV possible for good data quality in order to prolong lifetime by extracting less charge with time.
- Modal gain decreases with usage (gain sag)
  - Spectral resolution degradation sets in at modal PHA ~ 5
  - Localized sensitivity loss sets in at modal PHA ~ 3
- We will soon need to increase the operational HV on Segment B to avoid degradation of data quality (currently targeting mid-June 2013).
- With regular HV increases every 6-8 months, we should have an additional ~ 2.5 years of operations at current lifetime position.
- Mandatory usage of all FP-POS settings is helping to spread the damage of the Lyα holes around on Segment B.

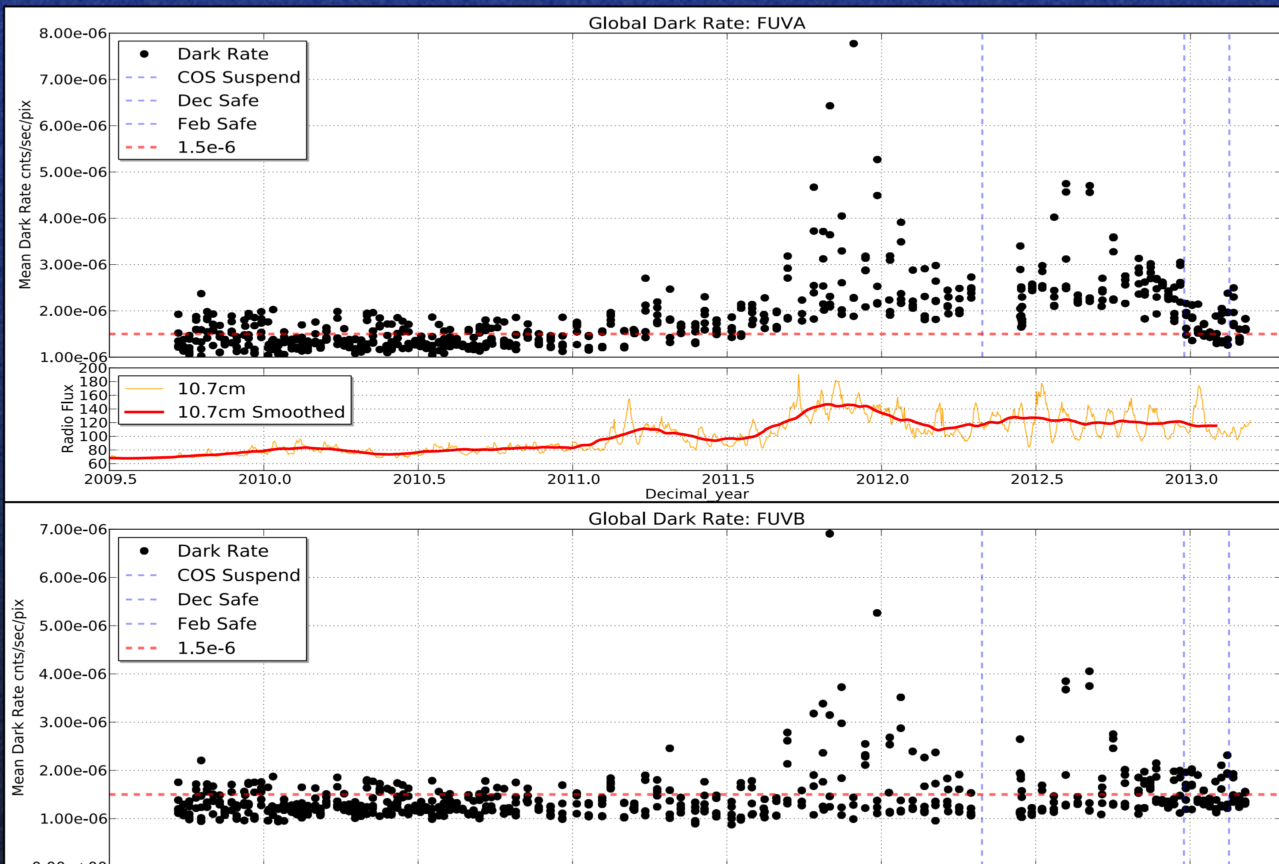
COS FUV Sensitivity Trending



COS FUV Time Dependent Sensitivity

- COS FUV sensitivity showed a steep drop in late 2011 (up to 20% per year), coincident with period of very high solar activity (curves at the bottom: green is smoothed version of the blue curve).
- Subsequent decline much more modest (4% to 6% per year).
- HV increase on segment A in March 2012 caused a small (~2%) increase because data at lower HV were affected by gain sag.
- Latest TDS break appeared shortly after moving to new position (LP2).
- Currently, TDS trends have flattened out again (2-3% per year) and are at this point almost wavelength independent.

COS FUV Dark Rate



Segment A: Increase in scatter and baseline rate

Solar cycle analogue; 10.7 cm radio flux

Segment B: Increase in scatter only with no corresponding baseline increase

- Overall dark rate, 2D structure, and distribution of pulse heights continue to evolve with time.
- There is a correlation with solar cycle, though behavior is different for Segment A and B.
- Segment A dark rate mysteriously reset to 2009 values, 2D structure, and PHD after Dec 2012 HST safing (no such change seen after either the Apr 2012 COS suspend or the Feb 2013 HST safing).

STIS Status
(A. Aloisi and the COS/STIS Team)

- STIS/MAMA and STIS/CCD channels are working well. The repaired STIS has now been in operation for nearly 4 years.

- Continuing to refine parameters for pixel-based CTE correction to STIS CCD data
  - Currently in the process of characterizing the time dependence of CTE

- Working on adapting the stand-alone ACS pixel-based CTE correction tool for use with STIS CCD data

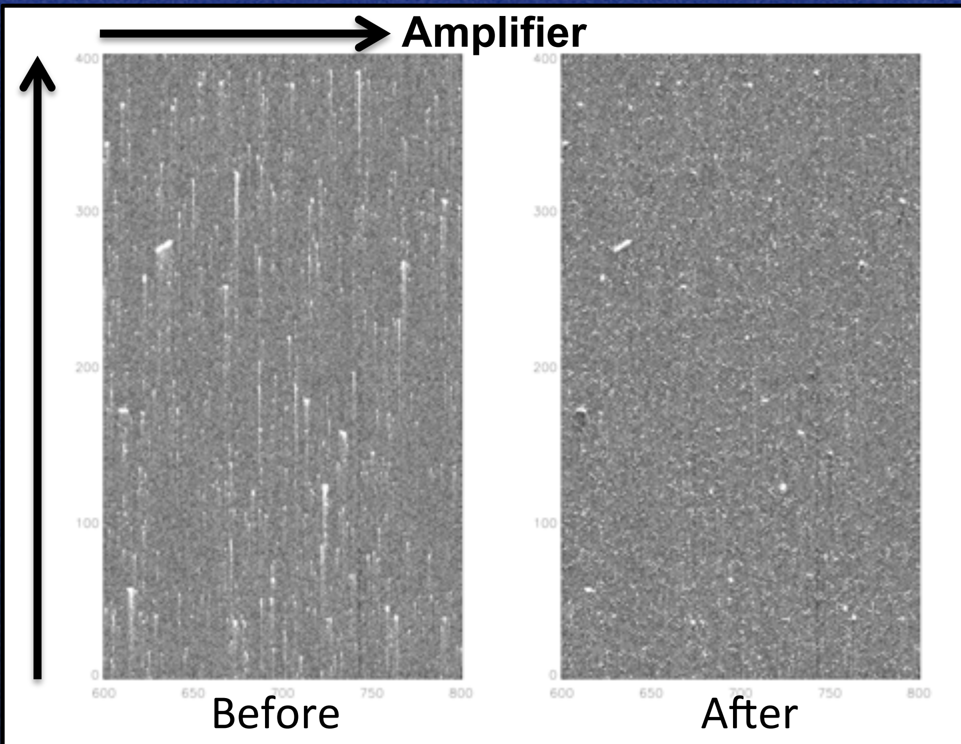
- Comparing subarray versus full-frame images to evaluate effect of CCD readout speed on CTE
  - Understanding this will allow improved pixel-based CTE corrections for subarray data, and might provide information about the impact of timing changes on CTE.

STIS CTE – Possible Studies

- Evaluating science benefits of possible CCD readout changes
  - Since STIS CCD can be read from either end of detector, doing a parallel split readout (Amp D + Amp A) would reduce maximum transfers by 50% for the lower ½, although at a cost of increased read noise (from 5.6 e^- to 8.5 e^-) due to noisier amplifier (A) on bottom of detector.
  - Doubling readout speed might improve CTE from current ~ 0.999 to 0.9999, but it is unclear if this can be done without a noise penalty.
- Charge injection strategies may exist, but a compelling science need has not yet been identified.

It is doubtful at this point that we can scientifically justify extensive hardware testing, so pixel-based CTE correction still remains the most promising way to mitigate STIS CTE effects.

STIS Charge Transfer Reconstruction



Single Dark Frame Correction

Left: Trails from warm pixels and cosmic rays are clearly seen extending away from the amplifier.

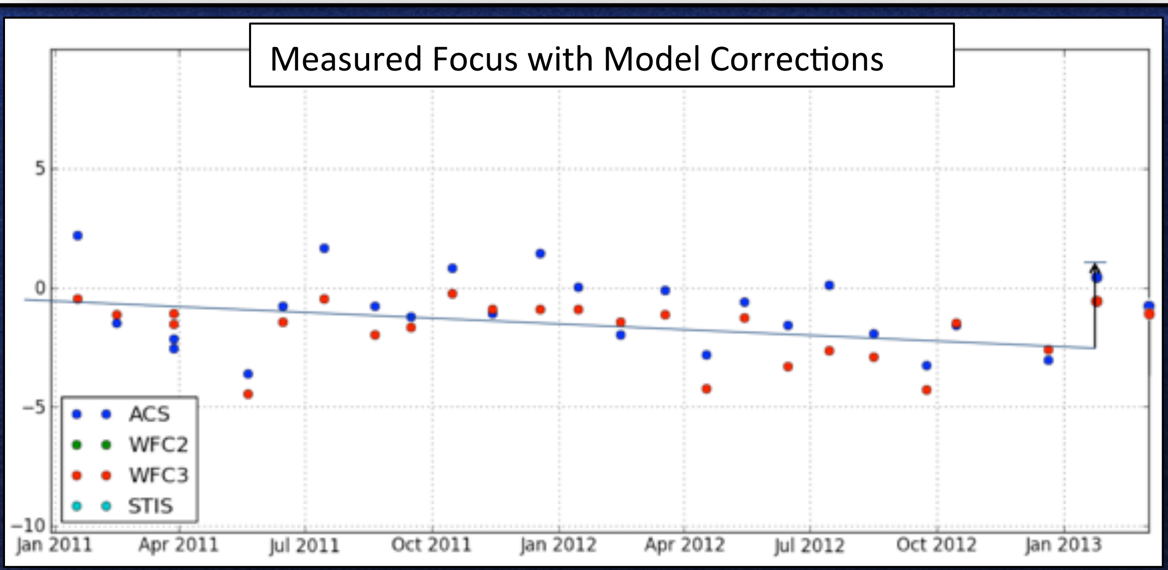
Right: Same area of the detector with a pixel-based CTE correction implemented through the PixCteCorr Pyraf routine.

Some increase in background noise occurs in corrected image, but this is compensated for by removal of hot pixel tails

- Next step will be to test some science cases to quantify improvements in S/N and limiting flux levels
  - Necessary to first remove herringbone electronic noise pattern (~ 3.6 e^-) before correction

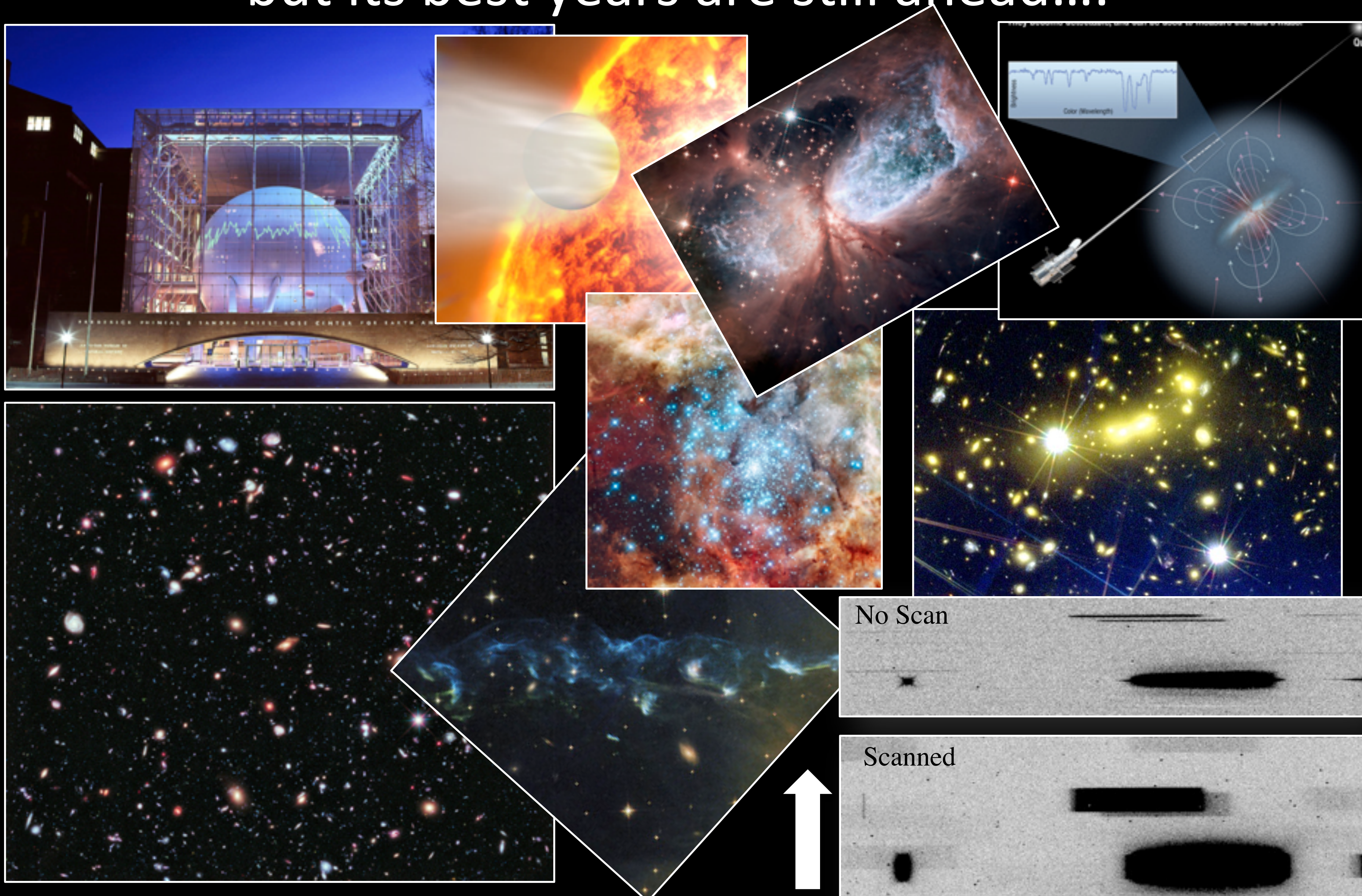
HST Focus Adjustment

(M. Lallo and the Telescopes Team)



- Linear fit to the focus determinations since refocusing in July 2009 (SMOV4) predicted -2.4 +/- 1.4 microns of defocus January 24, 2013 (for WFC3).
- A +3.6 micron despace of the Secondary Mirror was commanded on January 24th. We expected to put the Secondary +1.2 microns from best focus for WFC3 UVIS (1.5 microns from best focus for ACS WFC).
- Phase retrieval analysis of the standard monitoring observations have since shown temperature-model-corrected mean focus of WFC3 to be equivalent to –0.68 microns at the Secondary Mirror (Jan 26) and –1.1 microns (Mar 4). ACS was found to be +0.54 microns (Jan 26) & –0.81 microns (Mar 4). 1 sigma errors are approx. +/- 1.5 microns.
- Results thus far are consistent with commanding of the Secondary Mirror away from the Primary by the intended amount.

Hubble may be 23 years old, but its best years are still ahead....



Sequestration is Making an Impact

Ability to hold conferences is reduced.

Travel and conference participation is being limited.

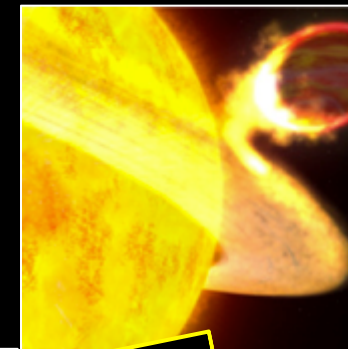
E/PO activities are being curtailed.

Travel for STScI colloquia is no longer supported.

Weekly press releases with amazing scientific discoveries reach more than 100 million people per year

Will this continue? Or will Hubble's science voice fall silent?

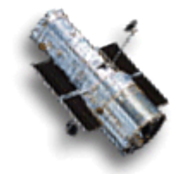
Atmospheres of planets orbiting other stars



Most distant objects ever seen

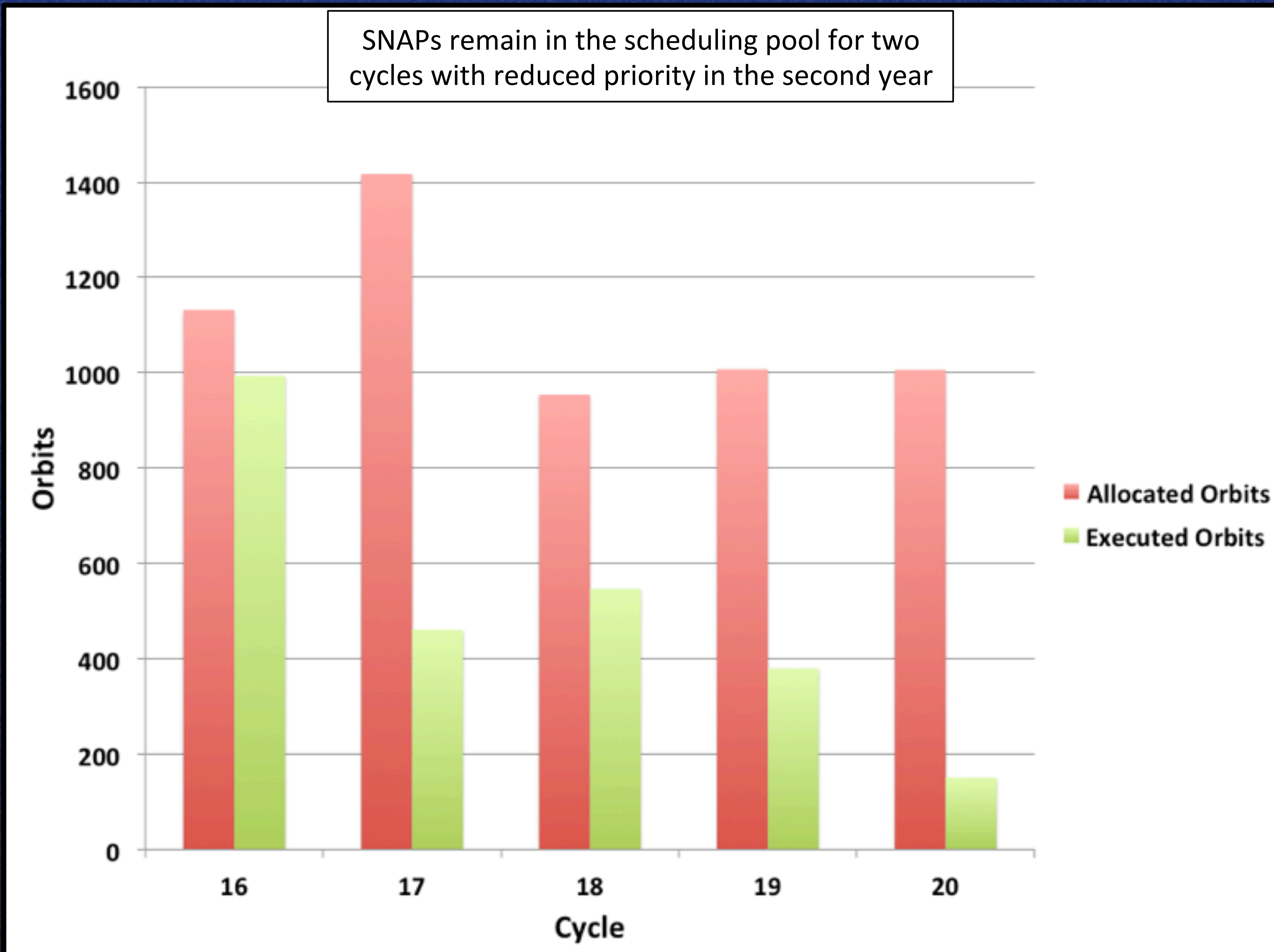
Mysterious Dark Energy And Dark Matter

SNAPs – An Overview

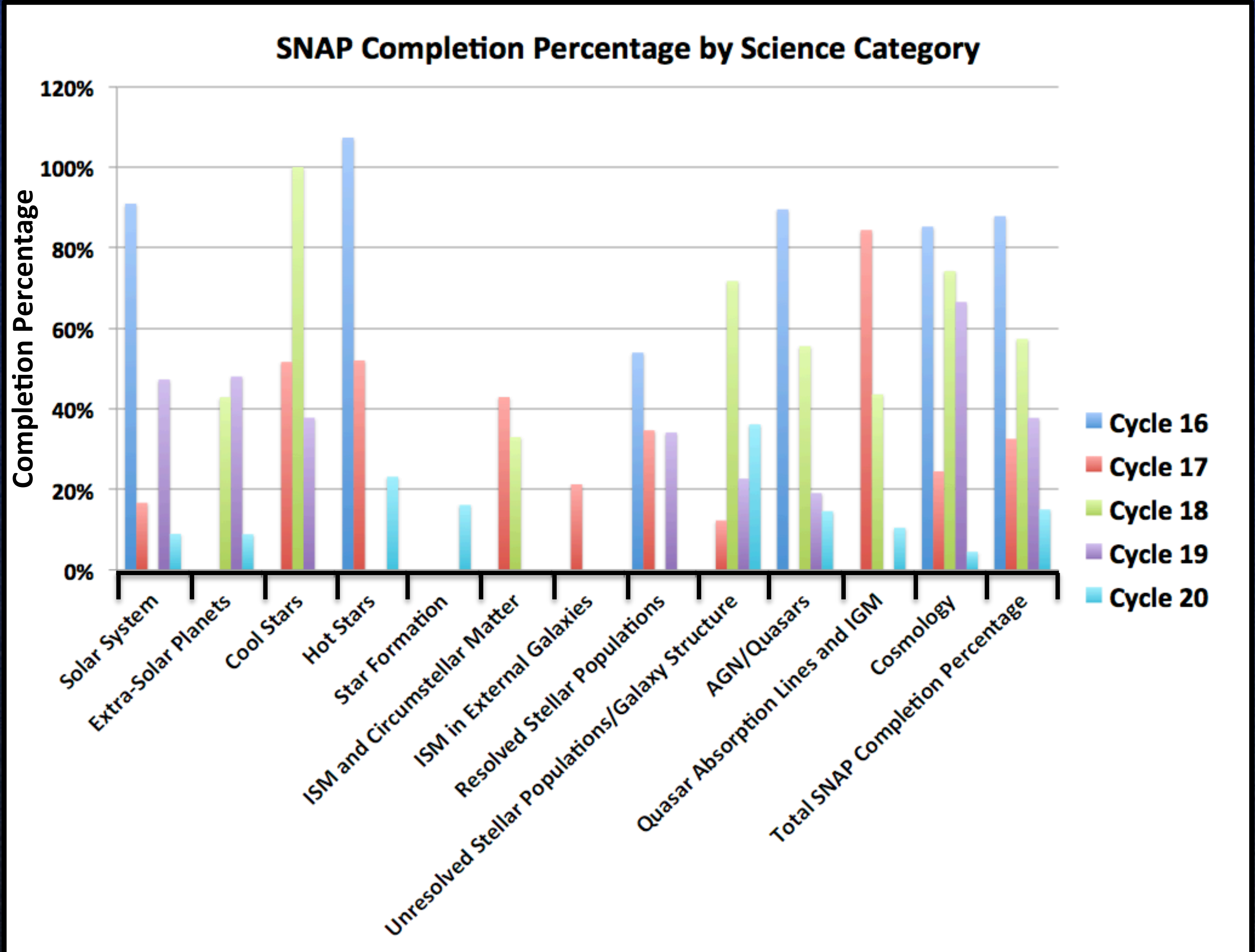


- Snapshot (SNAP) programs consist of separate, short observations with typical durations (including overheads) of 45 minutes or less
  - No special scheduling constraints (e.g., CVZ or ORIENT)
  - No ACS/SBC, no COS imaging, and no STIS/MAMA imaging
  - COS and STIS/MAMA spectroscopic SNAPs limited to 150 per cycle
  - No COS or STIS moving targets
  - No SNAPs for moving targets interior to the orbit of Jupiter
  - Moving target SNAPs must have schedulability of 1 month or more
- SNAPs are used to fill holes between "prime" observations in the observing schedule that would otherwise be unused
  - Typically 7-10 SNAPs per weekly calendar
- We typically allocate 1000 SNAP orbits per cycle through TAC/panel process
  - Need to have large, diverse pool of opportunities spread across the sky
  - Expect to complete 30-40%, averaged across SNAP pool
  - Cycle 18 (57%); Cycle 19 (38%); Cycle 20 (15% so far)

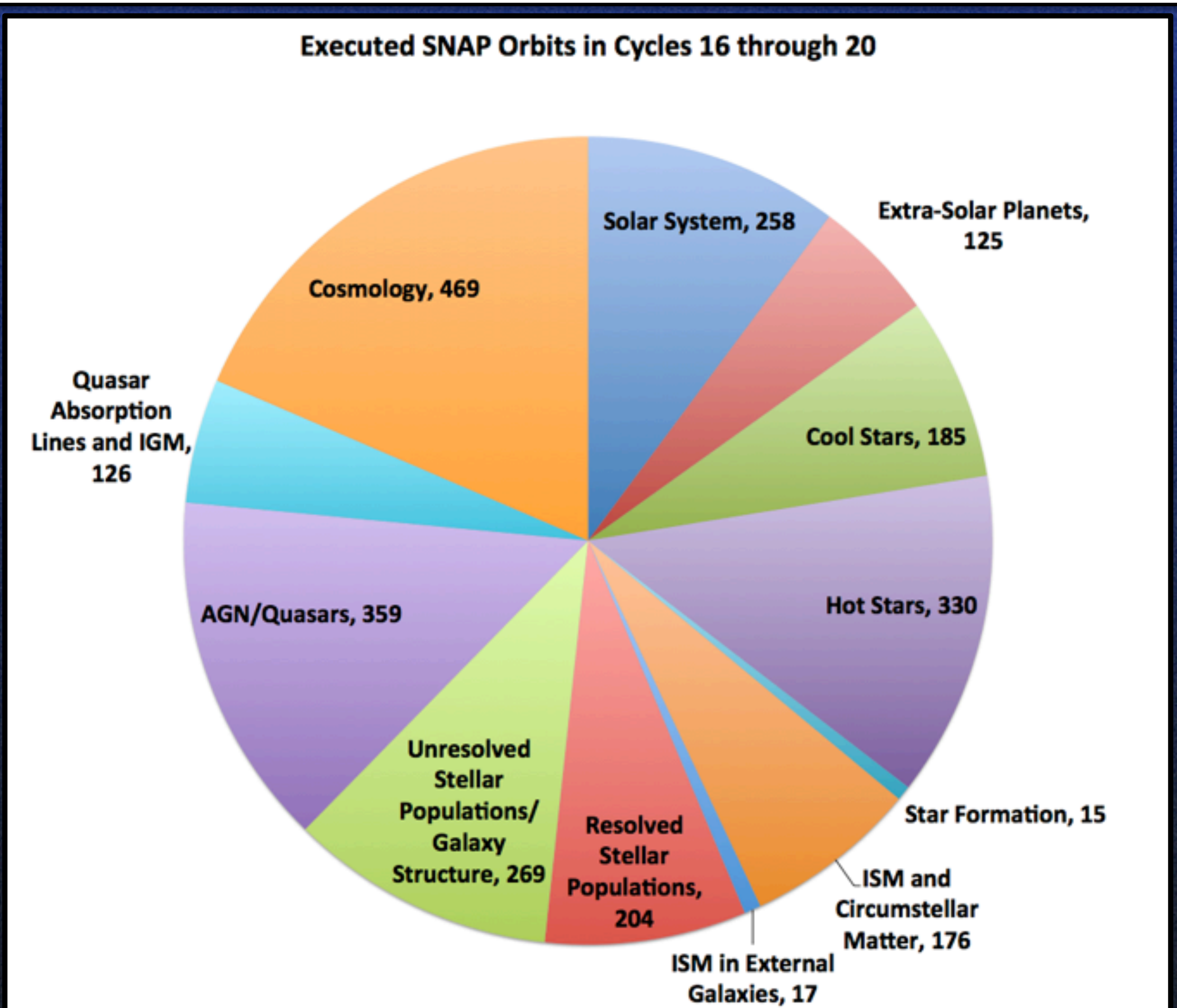
SNAP Orbit Allocations and Executions



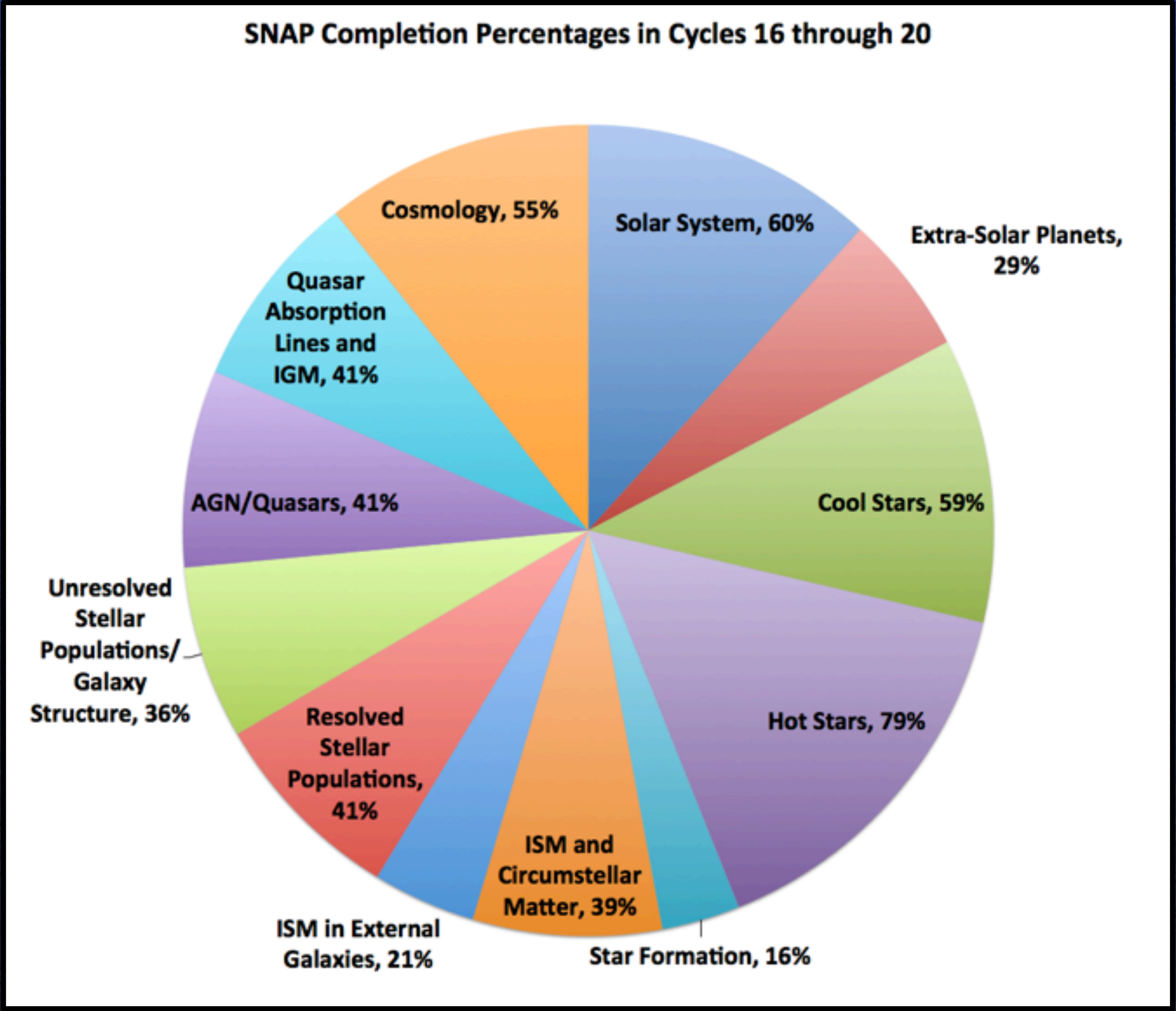
SNAP Completion Percentage by Science Category and Cycle



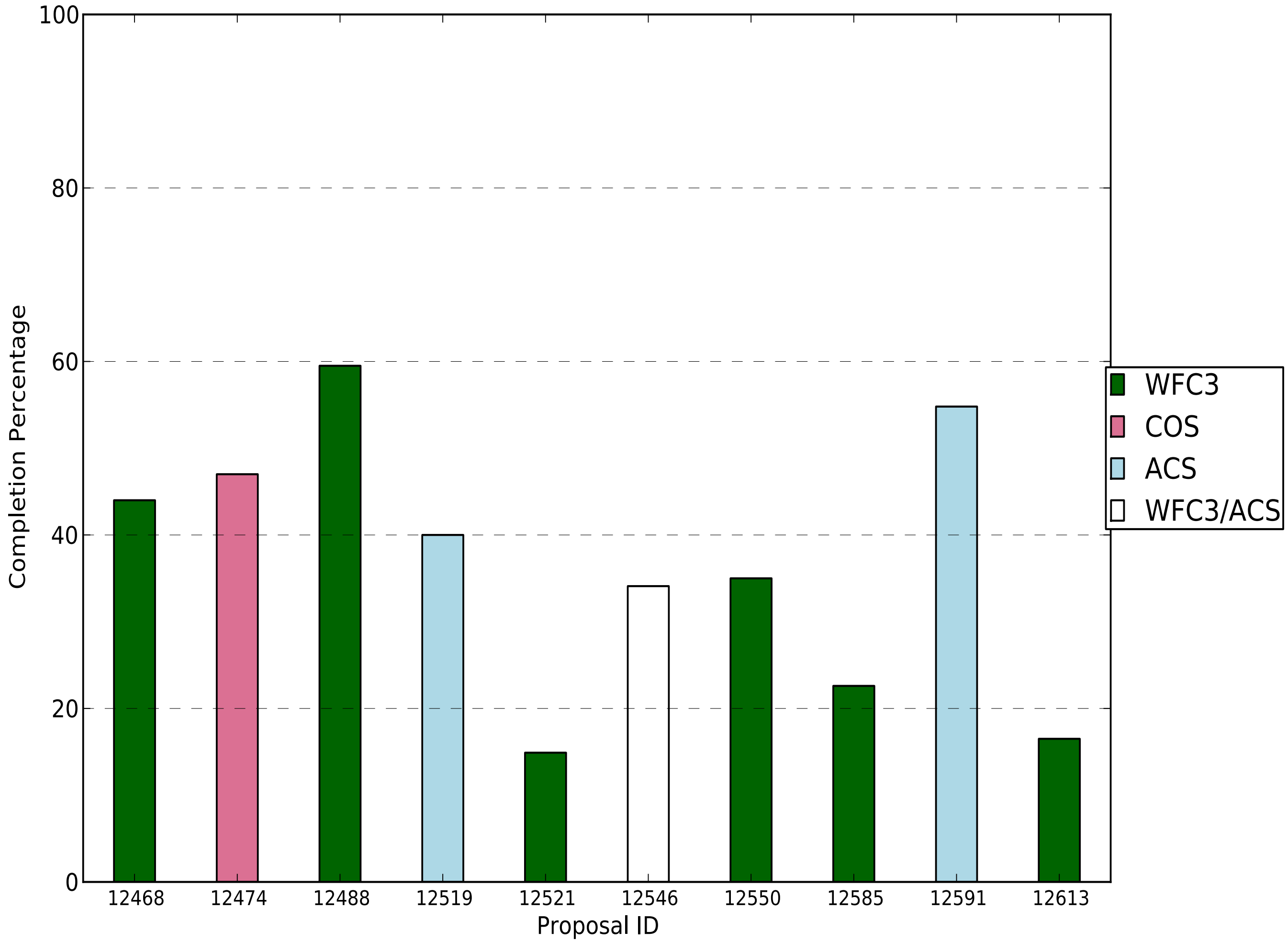
SNAP Orbits Executed in Cycles 16-20



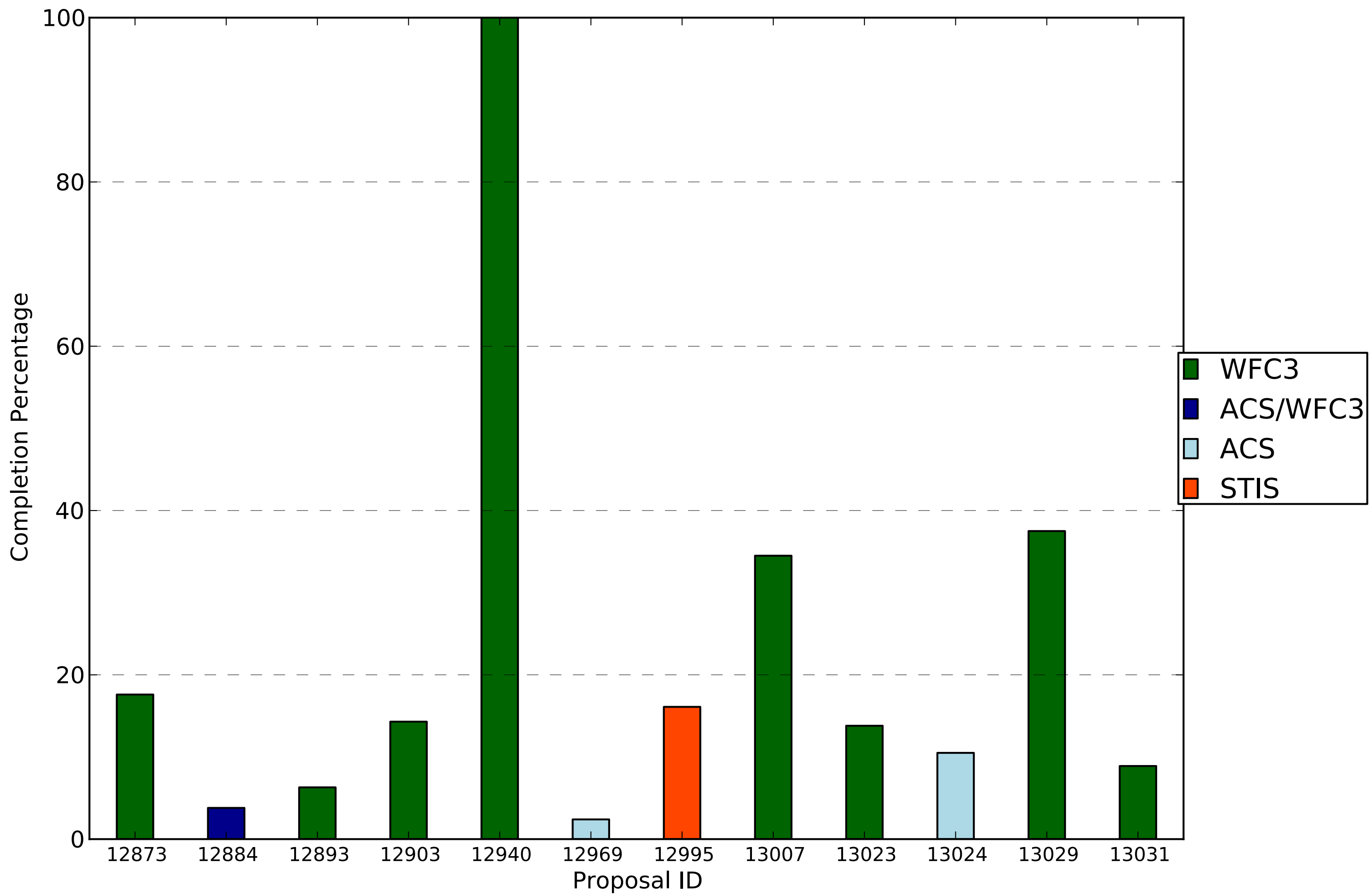
SNAP Completion Percentages by Science Category in Cycles 16-20



Cycle 19 SNAP Completion Percentages



Cycle 20 SNAP Completion Percentages



Cycle 19 SNAP Programs

- 12468 (Noll): How Fast Did Neptune Migrate? A Search for Cold Red Resonant Binaries12488
- 12519 (Sahai): Newly Discovered LMC Preplanetary Nebulae as Probes of Stellar Evolution
- 12521 (Liu): The Frequency and Demographics of Dual Active Galactic Nuclei
- 12546 (Tully): The Geometry and Kinematics of the Local Volume
- 12550 (Apai): Physics and Chemistry of Condensate Clouds across the L/T Transition
- 12585 (Petty): Physical Structures of the Most Luminous IR Galaxies Discovered by WISE at z>1.6
- 12591 (Gallo): A Chandra/HST Census of Accreting Black Holes and Nuclear Star Clusters
- 12613 (Jahnke): Are Major Galaxy Mergers a Significant Mechanism to Trigger MBH Growth at z=2?

Cycle 20 SNAP Programs

- 12873 (Biller): Search for Planetary Mass Companions around the Coolest Brown Dwarfs
- 12884 (Ebeling): A Snapshot Survey of The Most Massive Clusters of Galaxies
- 12893 (Gilliland): Study of Small and Cool Kepler Planet Candidates with High Resolution Imaging
- 12903 (Ho): The Evolutionary Link Between Type 2 and Type 1 Quasars
- 12940 (Massey): The Unevolved Massive Star Content of the Magellanic Clouds
- 12969 (Garnavich): Probing the Local Environments of Type Ia Supernovae
- 12995 (Johns-Krull): Testing Disk Locking in the Orion Nebula Cluster
- 13007 (Armus): UV Imaging of Luminous Infrared Galaxies in the GOALS Sample
- 13023 (Chiaberge): Universe in Transition: Powerful Activity in the Bright Ages
- 13024 (Mulchaey): Public Snapshot Survey of Galaxies Associated with O VI and Ne VIII Absorbers
- 13029 (Filippenko): A Snapshot Survey of the Sites of Recent, Nearby Supernovae
- 13031 (Grundy): Testing Collisional Grinding in the Kuiper Belt