



# **Hubble Space Telescope**

**Tom Brown**

**STUC Meeting – October 20, 2016**

# Summary

Crab Nebula • M1



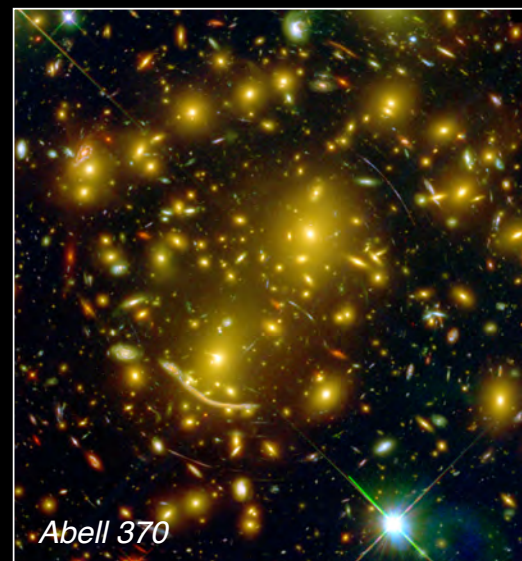
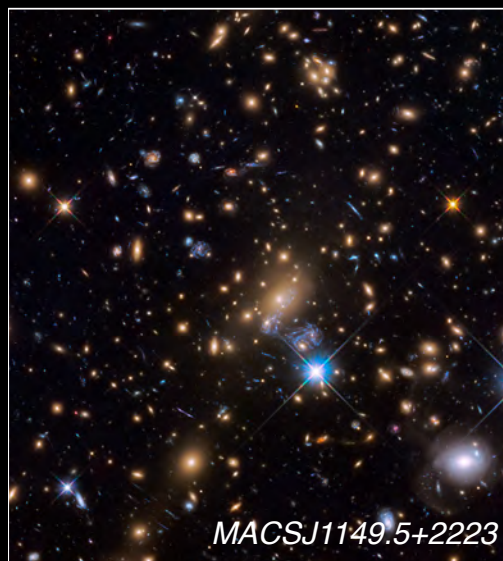
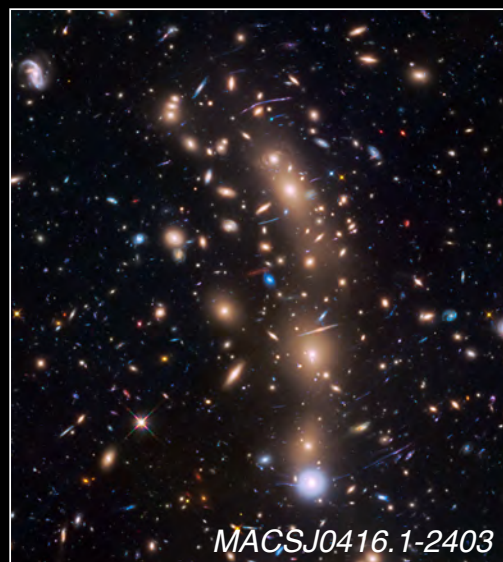
Hubble  
Heritage

NASA and ESA • HST ACS/WFC • STScI-PRC16-26a

- All science instruments and subsystems are functioning well
  - Decision made to stay in 3-gyro mode as long as possible (3-3-3-1-1)
  - Instrument teams busy with standard support and calibration but looking for improvements and expanded capabilities
- Cycle 24
  - TAC met 5-10 June, notifications 24 June
  - Phase II & budget deadline was 21 July
  - Cycle 24 officially began on 1 October
  - Exoplanet & Juno programs prominent
- Observing efficiency remains excellent
  - C23 avg 85 orbits/week and 51% efficiency
  - New “schedule gap” pilot program executing
- HST Contract Extension
  - 1 July 2016 to 30 June 2021
  - Senior Review feedback very positive

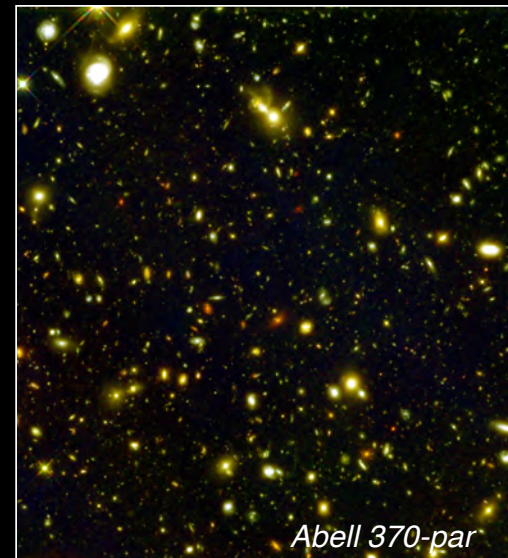
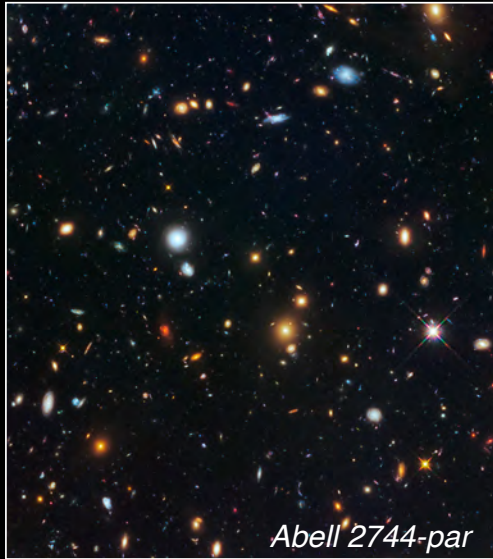


# Frontier Fields Completed





# Frontier Fields Completed



# Frontier Fields Completed

Last two fields (Abell S1063, Abell 370) completed 11 Sep 2016

## Frontier Fields Visit Status Page

[How To Use This Page](#)

■ Observed 
 ■ Scheduling 
 ■ Long Range Planning 
 High Level Science Products (full-depth mosaics)

		2013			2014												2015												2016									
	Progress	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
ABELL-2744	<a href="#">100.0%</a>	WFC3	WFC3						ACS	ACS	ACS																											
ABELL-2744-HFFPAR	<a href="#">100.0%</a>	ACS	ACS						WFC3	WFC3	WFC3																											
MACSJ0416.1-2403	<a href="#">100.0%</a>				ACS	ACS						WFC3	WFC3	WFC3																								
MACSJ0416.1-2403-HFFPAR	<a href="#">100.0%</a>				WFC3	WFC3						ACS	ACS	ACS																								
MACSJ0717.5+3745	<a href="#">100.0%</a>	ACS												ACS	ACS	ACS			WFC3	WFC3																		
MACSJ0717.5+3745-HFFPAR	<a href="#">100.0%</a>	WFC3												WFC3	WFC3	WFC3			ACS	ACS																		
MACSJ1149.5+2223	<a href="#">100.0%</a>		WFC3					ACS							WFC3	WFC3	WFC3				ACS	ACS																
MACSJ1149.5+2223-HFFPAR	<a href="#">100.0%</a>		ACS					WFC3							ACS	ACS	ACS			WFC3	WFC3																	
ABELL-S1063	<a href="#">100.0%</a>													ACS													ACS	ACS					WFC3	WFC3				
ABELL-S1063-HFFPAR	<a href="#">100.0%</a>													WFC3													WFC3	WFC3					ACS	ACS				
ABELL-370	<a href="#">100.0%</a>																																			WFC3	WFC3	WFC3
ABELL-370-HFFPAR	<a href="#">100.0%</a>																																			ACS	ACS	ACS

V1.0 high-level HST data products released for all but Abell 370 epoch 2


V0.5 Abell 370 epoch 2 – 3 Oct 2016

V1.0 Abell 370 epoch 2 - by 31 Oct 2016

V2.0 for all clusters - by 15 Dec 2016

Lensing models done for 2 clusters.

Next 2 in Feb 2017, then last 2 in Sep 2017.


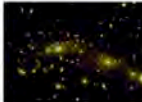
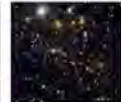


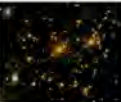


Barbara A. MIKULSKI ARCHIVE FOR SPACE TELESCOPES

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### The Hubble Space Telescope Frontier Fields

Abell 2744    MACSJ0416.1-2403    MACSJ0717.5+3745    MACSJ1149.5+2223    Abell S1063    Abell 370

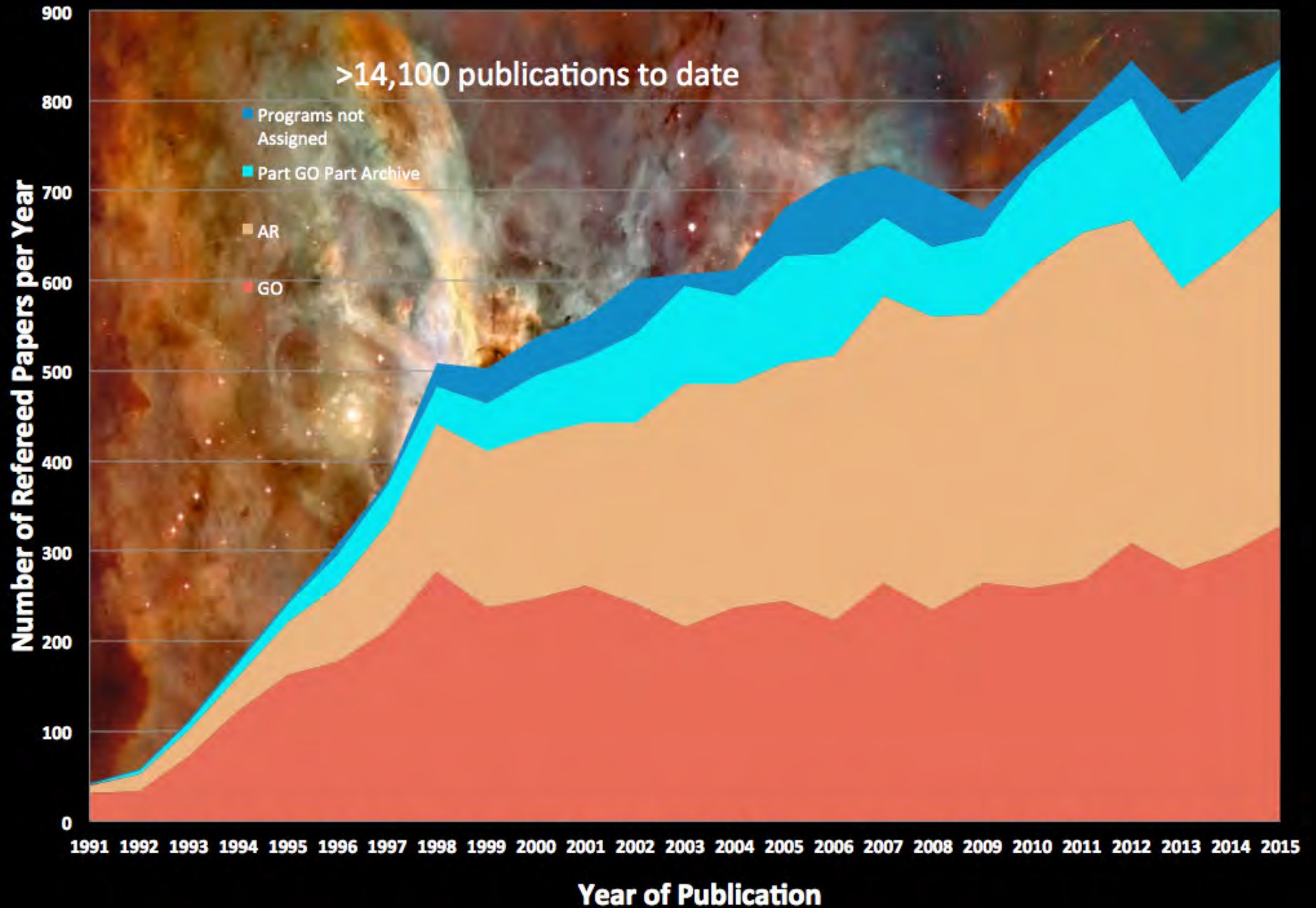
This is the primary Archive website for accessing all data from the Hubble Space Telescope Frontier Fields program, a new initiative of six deep fields centered on strong lensing galaxy clusters drawn from [Abell et al. \(1989\)](#) and the MACS survey ([Ebeling et al. 2001](#)), in parallel with six deep "blank fields" adjacent to these clusters. Please refer to the [Frontier Fields project website](#) for more general information about the project. We provide here a variety of products, including:

- [Observational data products \(images and catalogs\)](#)
- [Lens models provided by the community](#)

Also please visit the [Spitzer Frontier Fields website](#) for access to all the Spitzer data on the Frontier Fields.



# Hubble Science Productivity Remains High



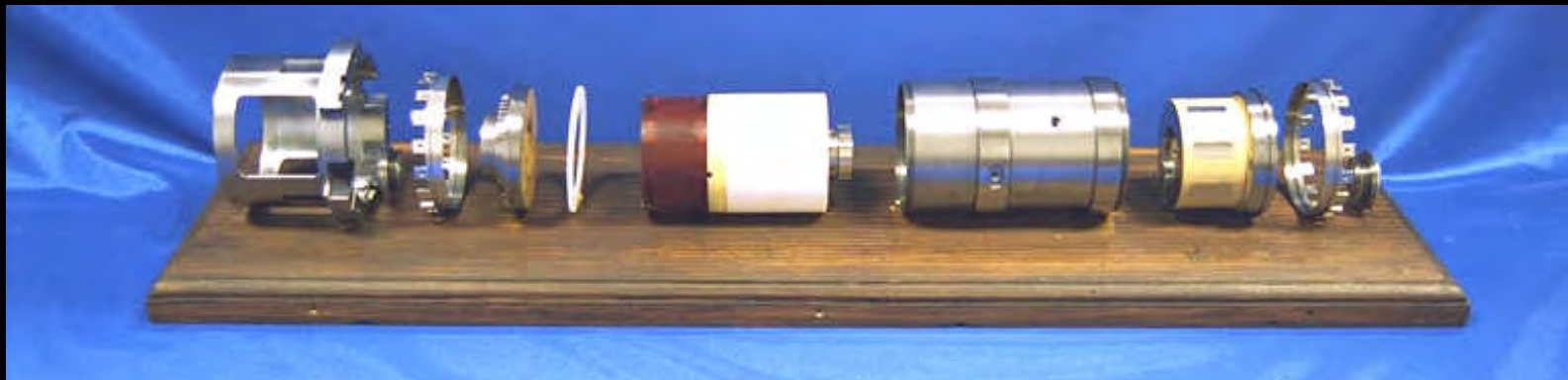
# Recent Safing Events

- STIS suspended on 19 June 2016 while passing through the South Atlantic Anomaly
  - Consistent with Single Event Upset
  - Recovered 21 June 2016 with no issues
- HST payload safed due to lockup of Science Instrument Command & Data Handler (SIC&DH) on 31 July 2016
  - Similar to other lockups over the years
  - Recovered & returned to science in record time of 18h 41m



# Reduced Gyro Mode

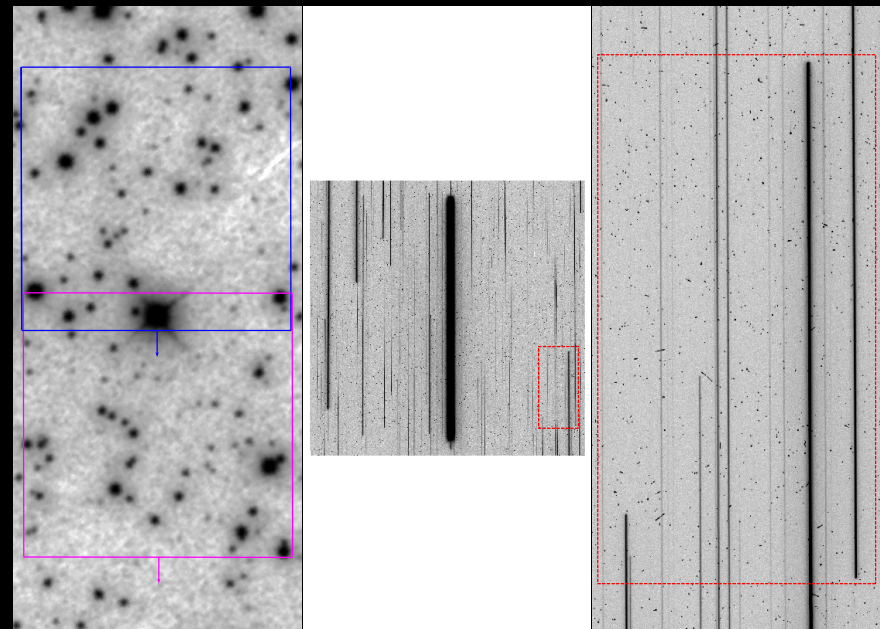
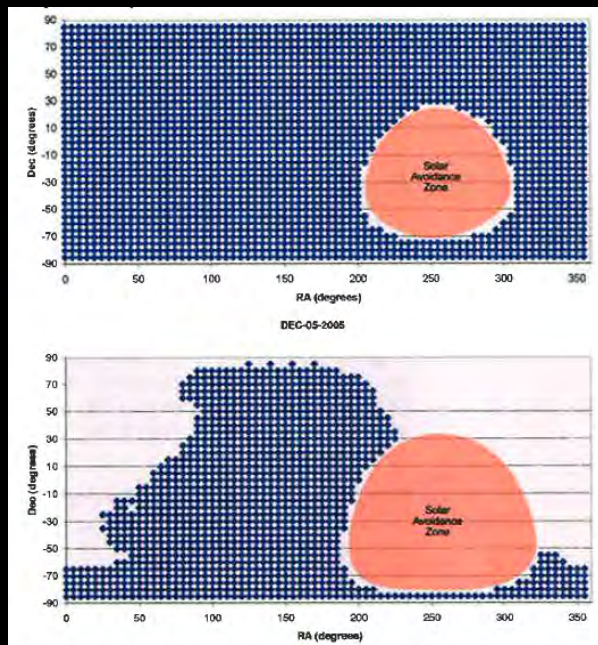
- By late 2015, STScI and GSFC were leaning toward early entry into RGM
- In June 2016, STScI and GSFC reviewed science and engineering impacts – no reason for early entry
- Remain in 3-gyro mode until 2 are left, then drop to 1-gyro mode (3-3-3-1-1)



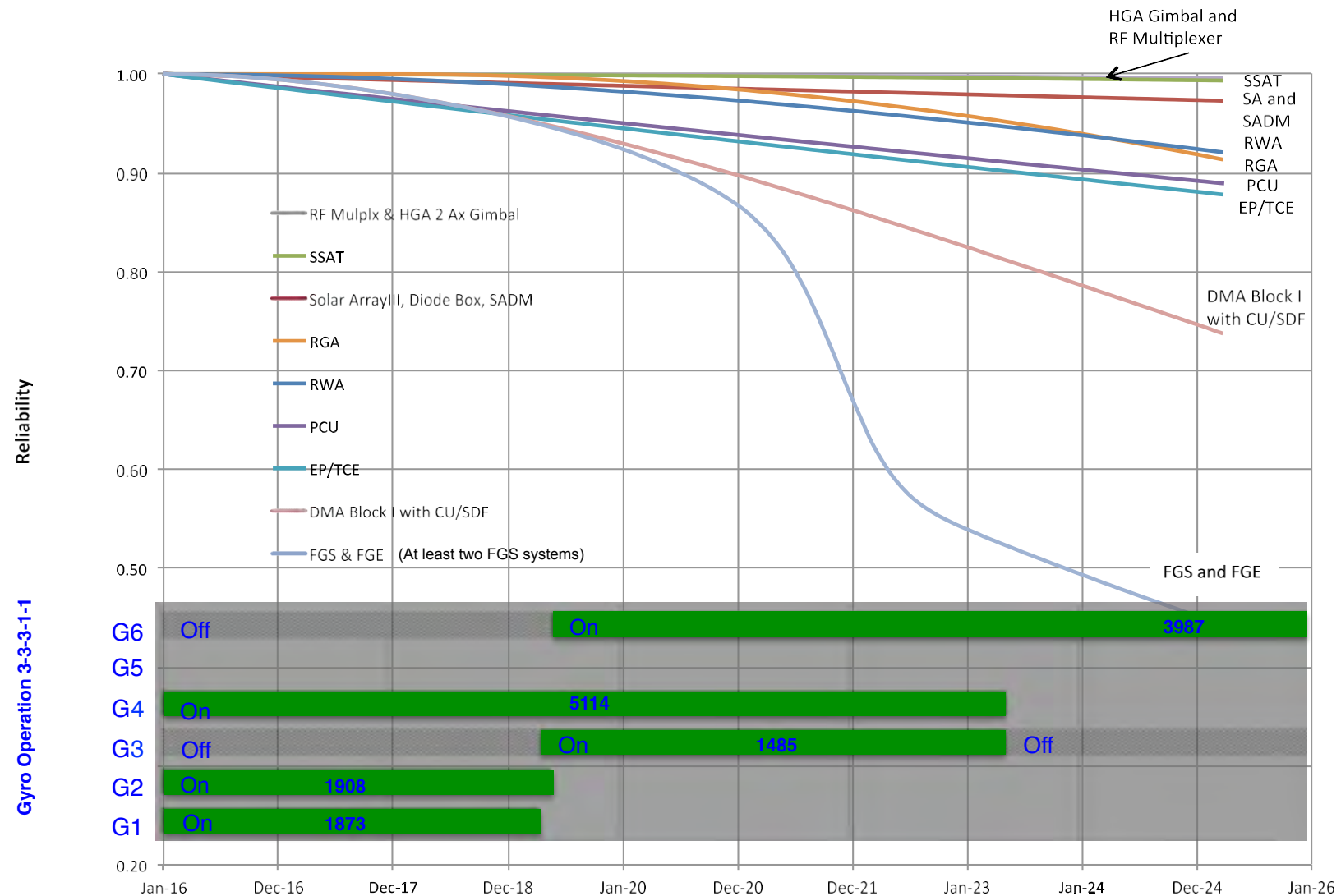


# RGM – Science Impact from STScI

- ~25% reduction in science productivity (MacKenty & RGM working group)
- Loss of efficiency (scheduling ~85 orbits/week to ~73 orbits/week, increased acquisition time, increased acquisition failures, decreased field of regard, orientation restrictions)
- Reduced science capabilities and opportunities (ToOs, spatial-scanning astrometry with WFC3/UVIS, spatial-scanning spectroscopy with WFC3/IR, coordinated parallels, Solar System objects)



# RGM – Engineering Impact from GSFC/HSTP

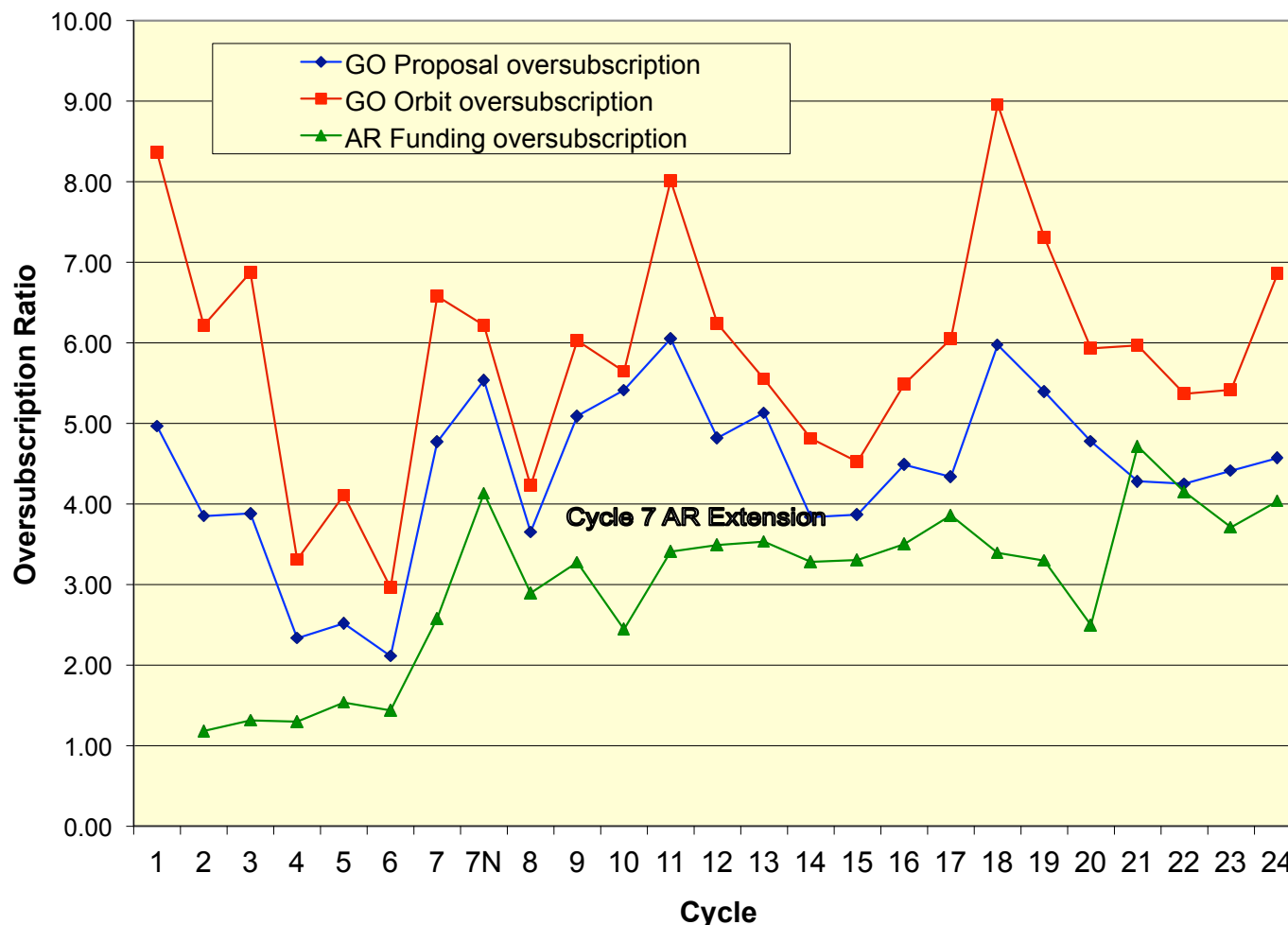


FGS systems are limiting factor, and entry into RGM would incur additional Coarse Track cycling that would shorten FGS lifetimes (FGS3 definitely, FGS2R2 probably not, and FGS1R perhaps)

# Demand for Hubble Observing Time Remains High

Cycle 24 began 1 October 2016

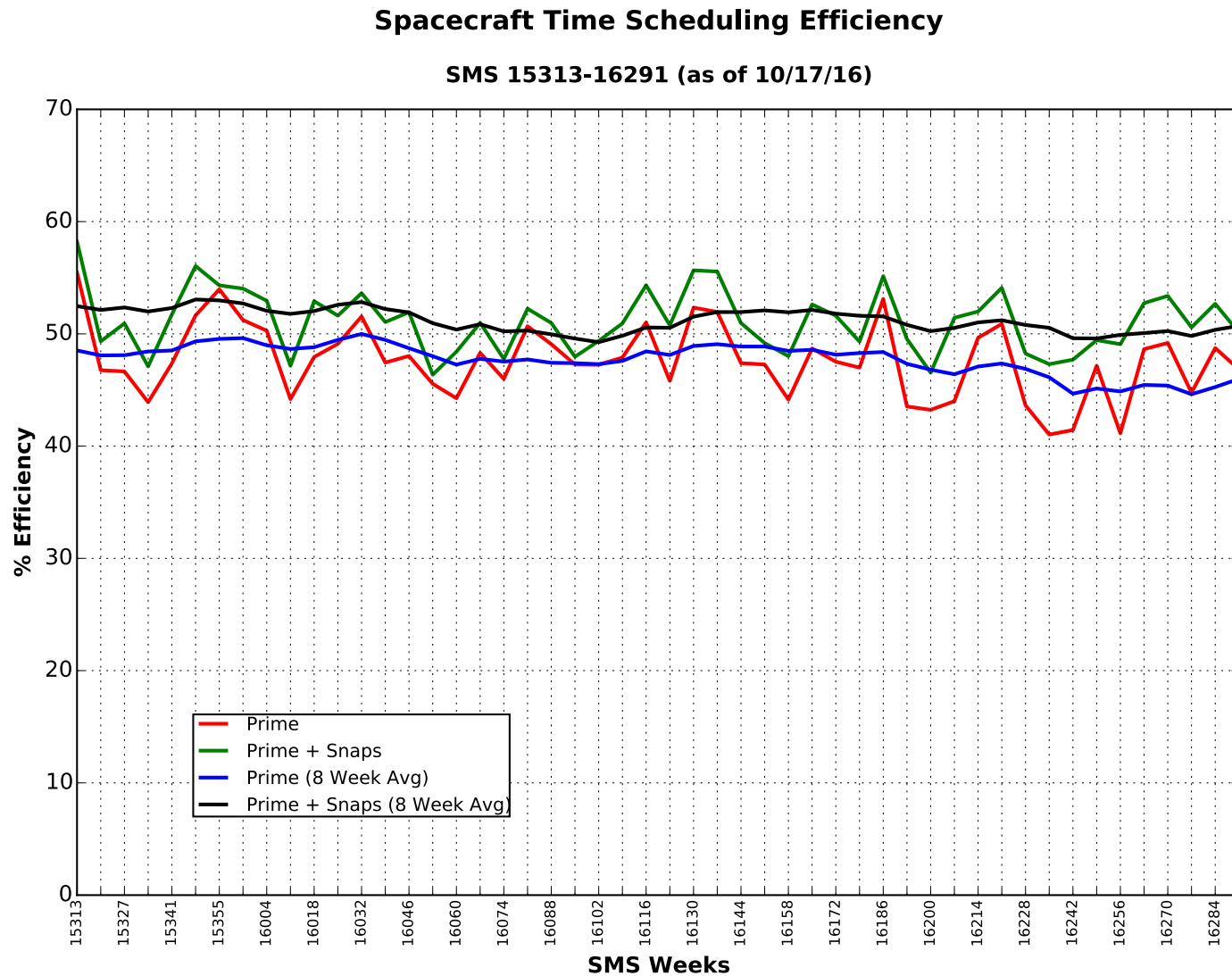
## Over-subscription by Cycle



Also: Mid-cycle submissions have increased (52 submitted for 30 September deadline)



# Hubble Scheduling Efficiency Remains High

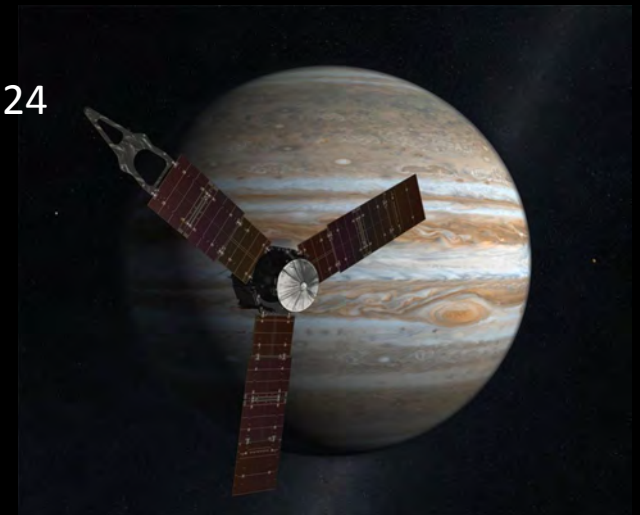


# Long Range Plan: Highlights

- Cycle 24 LRP was released on August 18, 2016.
  - Began October 1, 2016
  - Some observations started early due to under-subscription in summer 2016
- Cycle 23 averaged 84.8 orbits/week over 52 weeks of cycle
  - Consistent with other post-SM4 cycles (84.0 orbits/week since Cycle 17)
  - Contributors to high scheduling rate:
    - Flexible mix of science accepted by TAC
    - Larger-than-normal “tail” (material originally planned past 10/1/16)
      - Allowed flexible visits to be pulled forward to fill weekly schedule gaps
- Previous Cycle Completeness:
  - Cycle 20, 21: completed in late 2015
  - Cycle 22: 13 orbits remain, completes in January 2018 (astrometry)
  - Cycle 23: 550+ orbits remain, planned into fall 2017

# Long Range Plan: Cycle 24 Issues

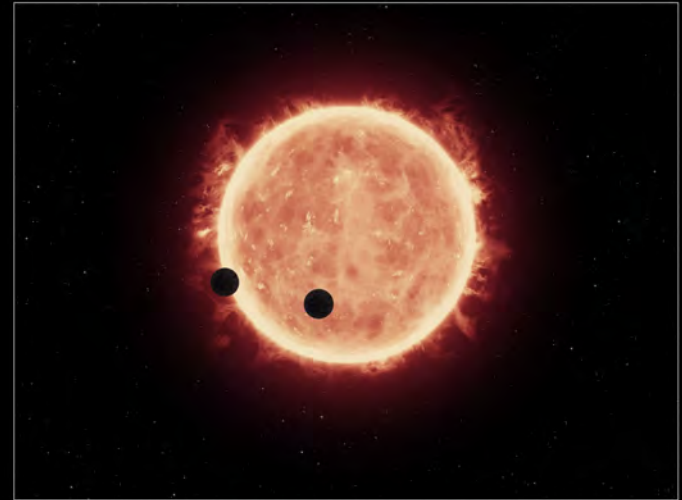
- Large amount of material accepted by Cycle 24 TAC
  - HST always accepts enough science for a “tail” into next observing cycle
    - Provides a flight-ready pool of visits as new cycle is incorporated
  - Nominal tail is 600-800 orbits
  - As in Cycle 23, Cycle 24 tail is large - 1000+ orbits
  - Extra material helps the overall scheduling
  - Downside is that more science is planned late in Cycle 24
- Solar System observations
  - Juno-coordinated (3 programs, 204 orbits)
  - Cassini-coordinated (25 orbits)
  - OPAL - Outer Planet Atmosphere Legacy (29 orbits)
  - Plus other smaller programs
- Original Cycle 24 LRP - numerous scheduling conflicts between these programs
  - working with PIs to resolve them
  - Particularly difficult to resolve Juno conflicts due to limited opportunities
  - Jupiter/Juno observations start in late November, when it emerges from solar exclusion





# Long Range Plan: Cycle 24 Issues

- Exoplanets:
  - >830 orbits awarded in Cycle 24 – much more than previous cycles
    - Approximately same number were awarded in Cycles 21-23 combined
    - Large program (14634, PI Sing) is spread over two cycles
  - Most have very tight period/phase constraints
    - Exoplanets planned during the *definitive spacecraft ephemeris* time-frame (<10 weeks) generally have relatively stable windows
    - But those with several-minute tolerances planned in the *predictive spacecraft ephemeris* time-frame (>10 weeks) have unstable/unreliable plan windows
  - Because constraint windows are not accurate past ~10 weeks, the LRP group cannot accurately plan exoplanet science throughout the cycle
  - Solution: manual intervention
    - The LRP group will view upcoming opportunities every 2 – 3 weeks and move exoplanet science forward, assuming they are flight-ready
  - Opportunities will be scarce once the Juno observations begin



# Current state of the operational LRP

- complete through calendar ending 10/30/16.

Cycle	Orbits
22	13
23	468
24	3595
Total	4076

C23 snaps	734
C24 snaps	934
Total snaps	1668

Instrument	Orbits
WFC3	1513
COS	881
ACS	668
STIS	1061
FGS	1
Total	4124*

Visits not in current plan	orbits
unschedulable	99
no plan windows	0
Not LRP ready	48
C23 misc	69
C24 misc	243
Total not in plan	459

\* Some programs have more than one prime SI.

## Cycle 22 Large/Treasury programs

<b><i>Program</i></b>	<b>Total alloc</b>	<b>Exec/sched by 10/16/16</b>	<b>Planned before 9/30/17</b>	<b>Planned after 10/1/17</b>	<b>comment</b>
<b>Benneke</b>	<b>124</b>	<b>114</b>	<b>10</b>	<b>0</b>	

## Cycle 23 Large/Treasury programs

<b><i>Program</i></b>	<b>Total alloc</b>	<b>Exec/sched by 10/16/16</b>	<b>Planned before 9/30/17</b>	<b>Planned after 10/1/17</b>	<b>comment</b>
<b>Apai</b>	<b>112</b>	<b>58</b>	<b>18</b>	<b>0</b>	<b>36 not in LRP</b>
<b>Bedin</b>	<b>66</b>	<b>66</b>	<b>0</b>	<b>0</b>	<b>completed</b>
<b>Borthakur</b>	<b>100</b>	<b>92</b>	<b>8</b>	<b>0</b>	<b>Finished by Dec</b>
<b>Coe (ToO)</b>	<b>190</b>	<b>105</b>	<b>68</b>	<b>0</b>	<b>17 not in LRP</b>
<b>Deming</b>	<b>111</b>	<b>97</b>	<b>14</b>	<b>0</b>	<b>Finished by Feb</b>
<b>Kirshner (ToO)</b>	<b>100</b>	<b>48</b>	<b>4</b>	<b>0</b>	<b>46 not in LRP</b>
<b>Lehner</b>	<b>93</b>	<b>93</b>	<b>0</b>	<b>0</b>	<b>completed</b>
<b>Papovich</b>	<b>130</b>	<b>120</b>	<b>10</b>	<b>0</b>	<b>Finished by Mar</b>
<b>Peterson</b>	<b>74</b>	<b>74</b>	<b>0</b>	<b>0</b>	<b>completed</b>
<b>Siana</b>	<b>48</b>	<b>48</b>	<b>0</b>	<b>0</b>	<b>completed</b>



## Cycle 24 Large/Treasury programs

<b><i>Program</i></b>	<b>Total alloc</b>	<b>Exec/sched by 10/16/16</b>	<b>Planned before 9/30/17</b>	<b>Planned after 10/1/17</b>	<b>comment</b>
<b>Benneke</b>	<b>78</b>	<b>0</b>	<b>38</b>	<b>40(*)</b>	<b>exoplanets</b>
<b>Bielby</b>	<b>96</b>	<b>6</b>	<b>90</b>	<b>0</b>	
<b>Dalcanton</b>	<b>108</b>	<b>0</b>	<b>54</b>	<b>54</b>	
<b>Grodent</b>	<b>151</b>	<b>0</b>	<b>151</b>	<b>0</b>	<b>Juno</b>
<b>Kallivayalil</b>	<b>164</b>	<b>24</b>	<b>106</b>	<b>34</b>	
<b>Roman-Duvall</b>	<b>101</b>	<b>15</b>	<b>75</b>	<b>11</b>	
<b>Shkolnik</b>	<b>118</b>	<b>0</b>	<b>96</b>	<b>22</b>	
<b>Sing</b>	<b>498</b>	<b>19</b>	<b>119</b>	<b>360(*)</b>	<b>2-cy exoplanet</b>
<b>Suzuki (ToO)</b>	<b>46</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>2-cy ToO</b>

**\* - visits not planned here; "in the bullpen" until the LRP can pull them forward**

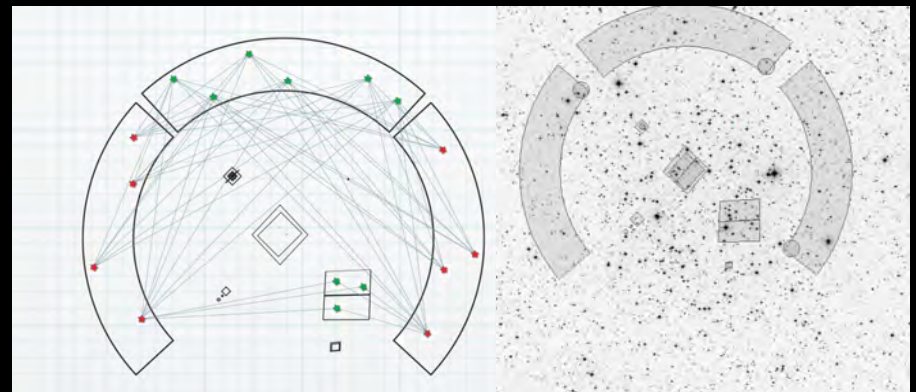
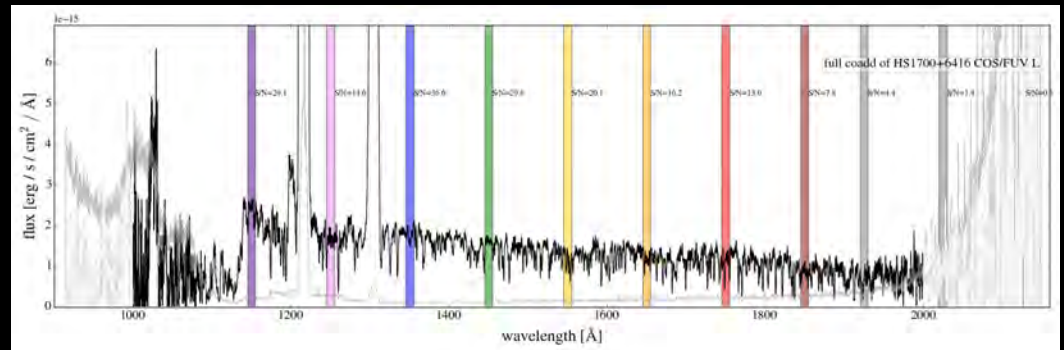
# Expanding calibration and capabilities

Teams are very busy with standard calibrations and support

- see upcoming presentations from instrument team leads

Future efforts include:

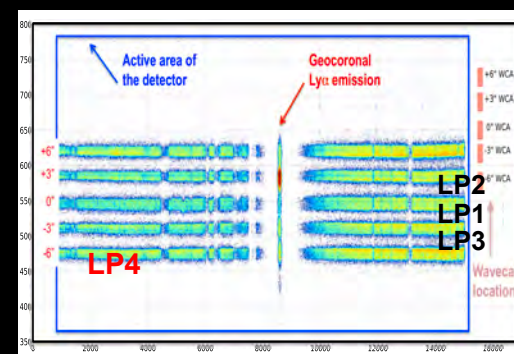
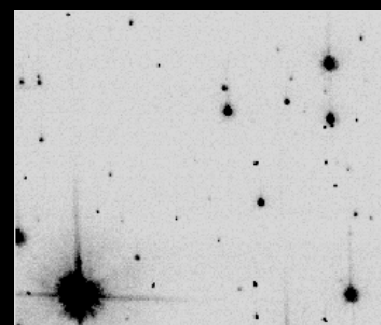
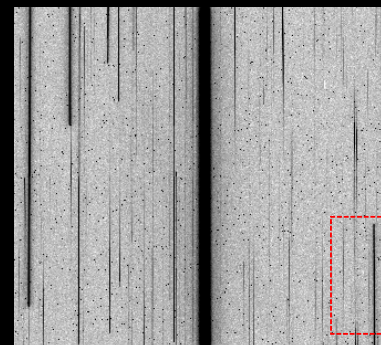
- Refresh and expand Hubble Spectroscopic Legacy Archive
  - Refresh COS FUV
  - Add COS NUV
  - Add STIS
- Refine astrometric calibration
  - Astrometry Working Group (M. Fall et al.)
    - Update Guide Star Catalog with Gaia positions
    - Update Hubble Source Catalog with Pan-STARRS and Gaia (see HSC talk by B. Whitmore)
    - Propagate updated astrometry into HST archive
  - Improve focal plane model tying instruments to FGS



# Future efforts of SI teams

- Possibilities for refining existing calibration, expanding science capabilities, and managing lifetime:

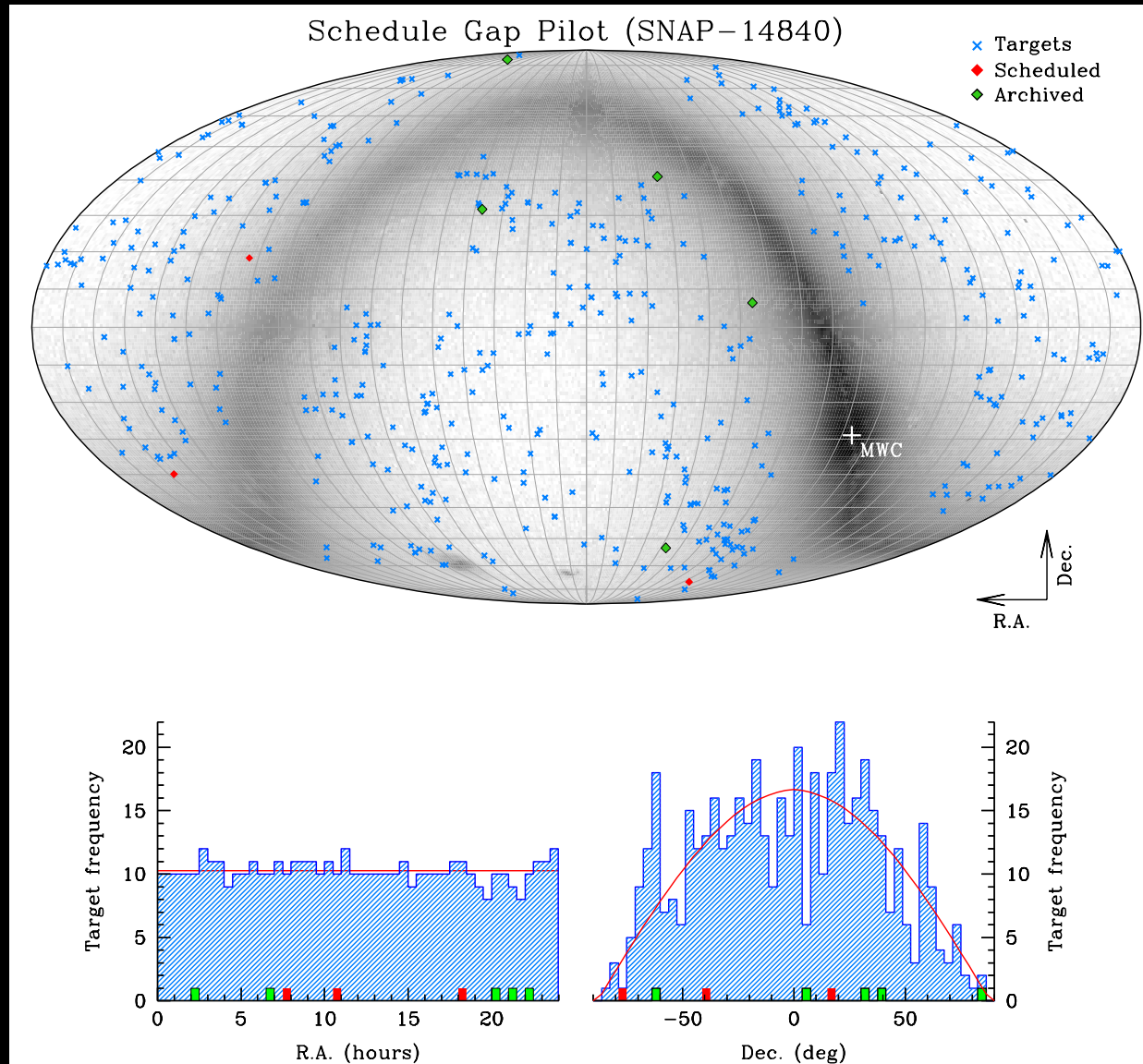
- STIS spatial-scanning spectroscopy
  - H echelles, 2048x2048 MAMA format, smallest aperture
- STIS R=200,000 spectroscopy
  - in progress – see Sabbi presentation
- WFC3 fringing correction
  - synergy with work on JWST
- WFC3/IR up-the-ramp fitting revisions
  - Currently bringing 2<sup>nd</sup> generation WFC3/UVIS CTE correction to ACS
- ACS 3<sup>rd</sup> generation CTE correction
  - G800L crossed with polarizers
- COS G140L – new position for central wavelength
  - puts 1280/FUVB wavelengths onto FUVB
  - Reduces detector area for background-limited observations
- COS lifetime position 5 and beyond
  - See upcoming Oliveira & MacKenty presentations
- GO calibration programs remain underutilized option





# Schedule Gap Pilot Program

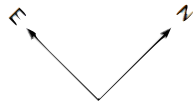
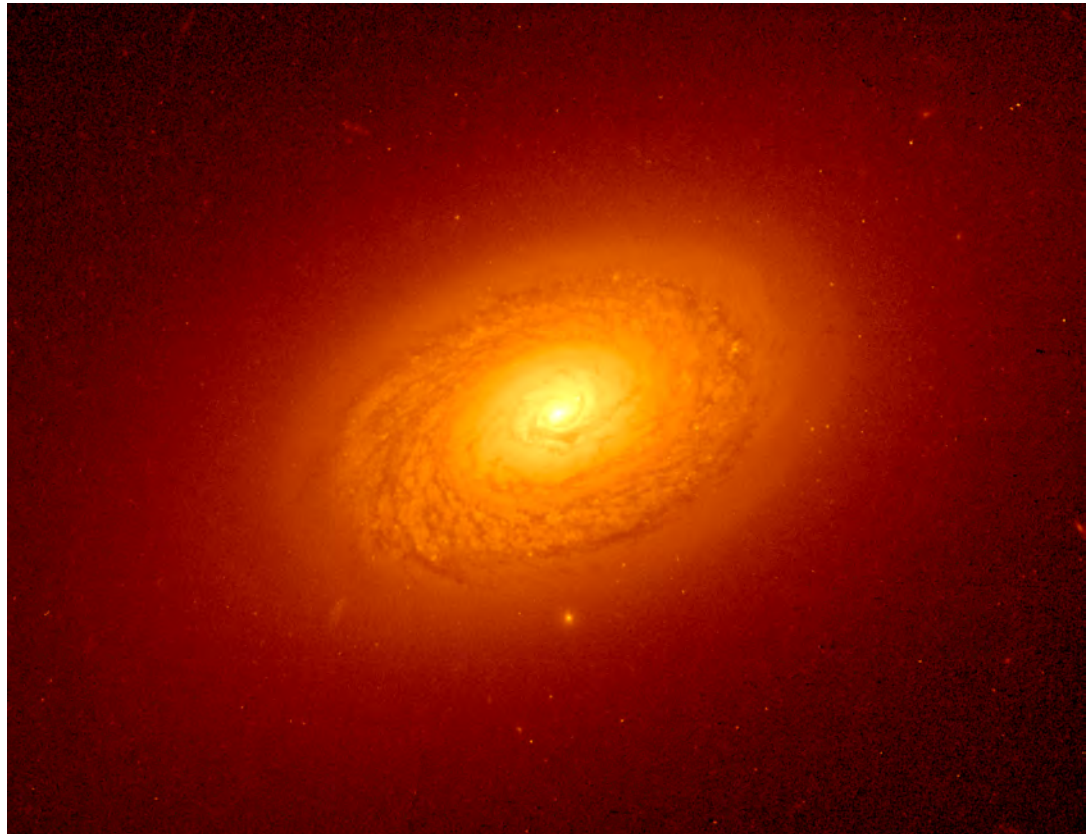
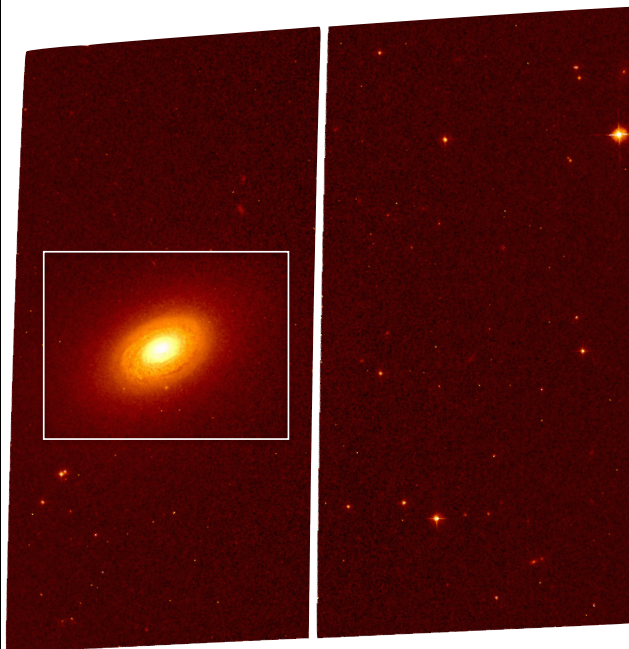
- Scheduling team works to fill every available orbit, but narrow windows remain unused
- Began pilot (14840) to see if useful observations could be scheduled
- Two dithered 337s ACS/WFC/F606W exposures
- 500 galaxies from NGC catalog (no star clusters)
- Assigned to A. Bellini (ACS team)
- Currently proprietary



# Schedule Gap Pilot Program

NGC 940

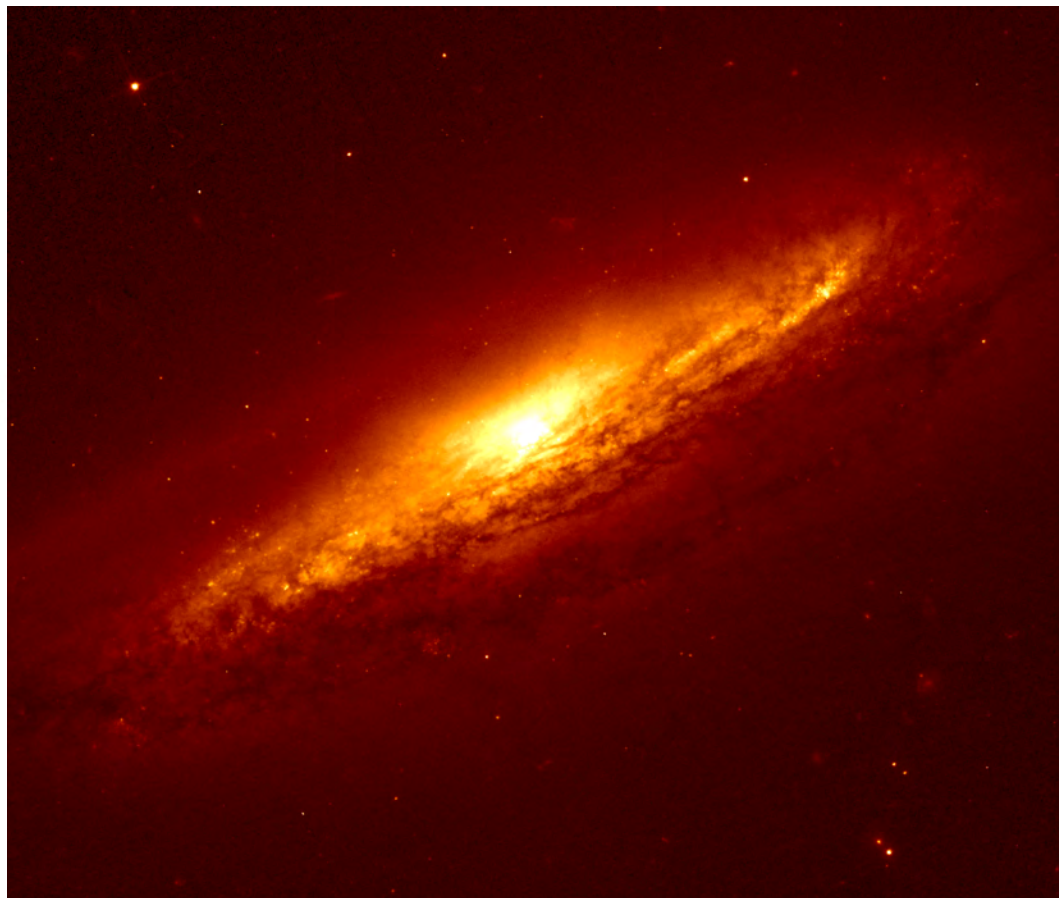
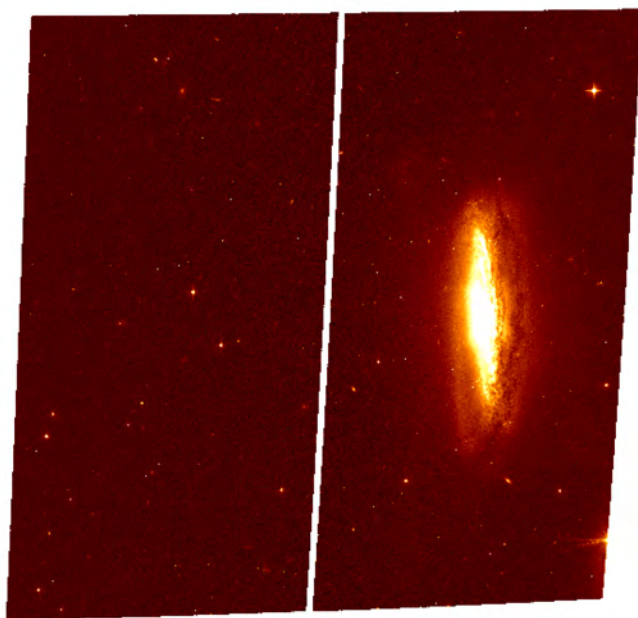
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Trgt ID: 50  
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Dec.: +31:38:29.0  
Obs.: 2016-10-05



# Schedule Gap Pilot Program

IC 5084

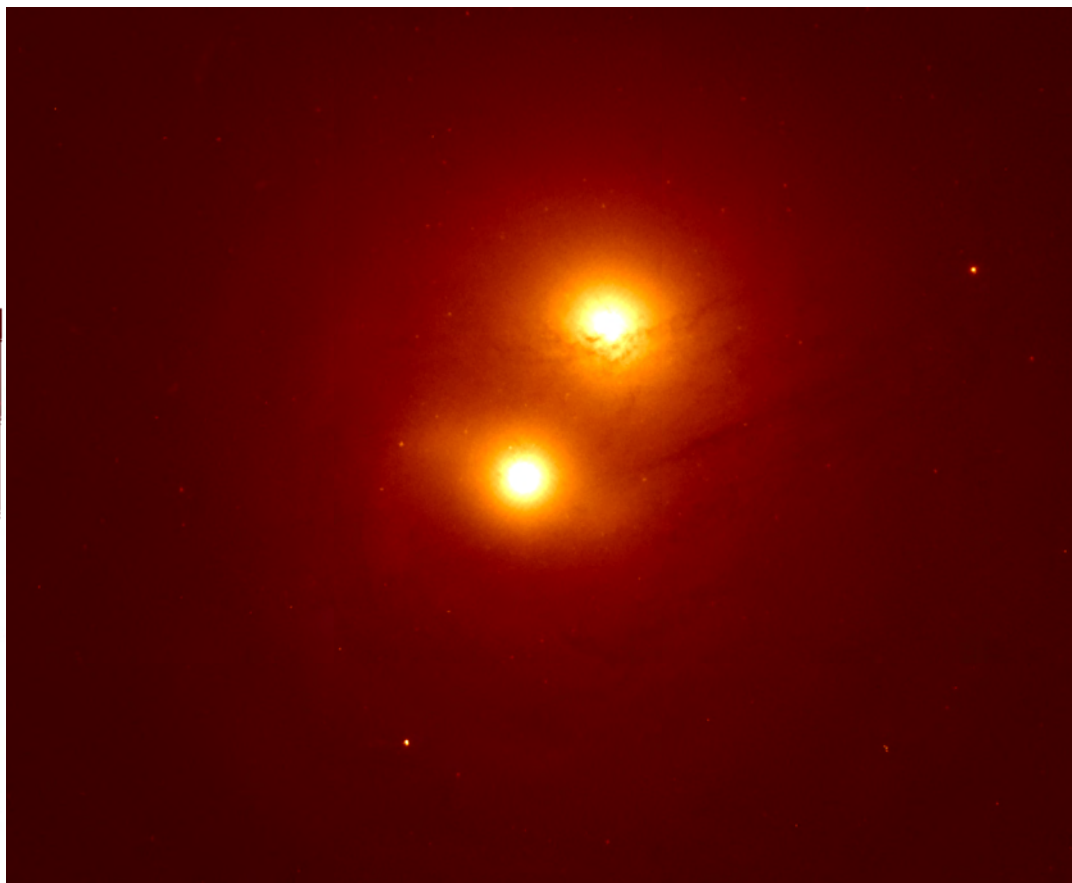
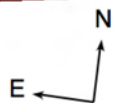
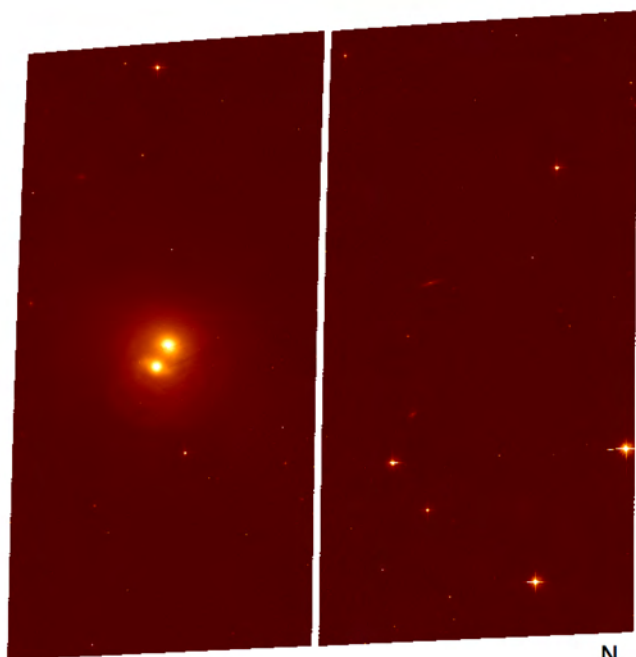
V mag: 12.0  
Trgt ID: 432  
R.A.: 21:09:14.4  
Dec.: -63:17:23.0  
Obs.: 2016-10-08



# Schedule Gap Pilot Program

IC 442

V mag: 12.9  
Trgt ID: 137  
R.A.: 06:36:11.9  
Dec.: +82:58:08.0  
Obs.: 2016-10-12

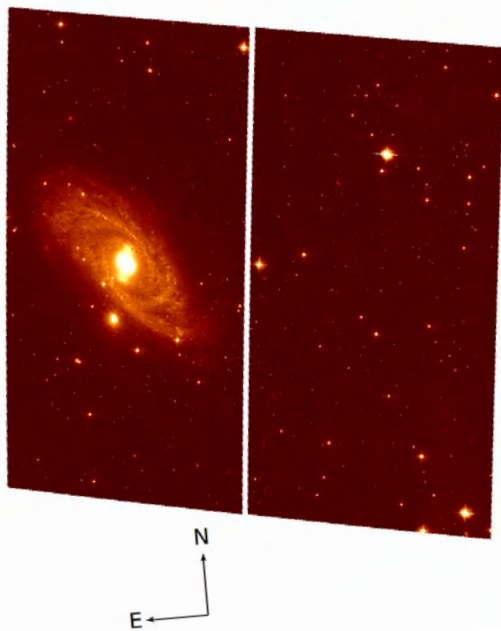




# Schedule Gap Pilot Program

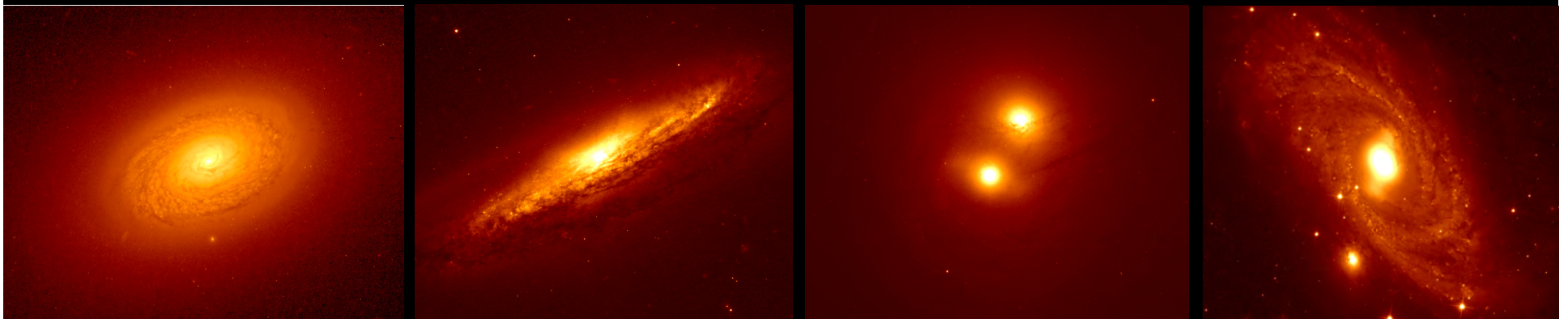
NGC 6906

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Trgt ID: 419  
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Dec.: +06:26:40.0  
Obs.: 2016-10-16



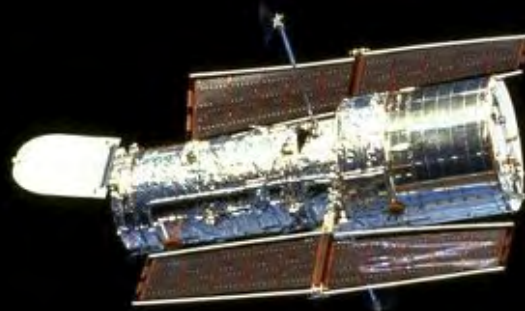
# Future gap targets

- Two short exposures in a single filter (minimum visit duration) that are dithered (artifact removal) and use ACS/WFC (no WFC3 CSM usage)
- Large pool of targets ( $>200$ ) isotropically distributed on the sky (maximum schedulability)
- No proprietary period and no GO grants
- Increase scientific value of archive
- Targets that benefit from optical space-based imaging
- Special call to community? Addendum to mid-cycle call? STUC provides suggestions?
- Employ same external peer review system as mid-cycle call?



# HST Contract Extension

- Incorporates the common 2020+ vision.
- Five year extension from 1 July 1 2016 to 30 June 2021 (two month slip from original expectation)
- WFIRST moves to its own contract in Jan 2017
- MAST moves from grant to HST contract in Jan 2017
- DDRF now a flat 2% - not tied to performance metric

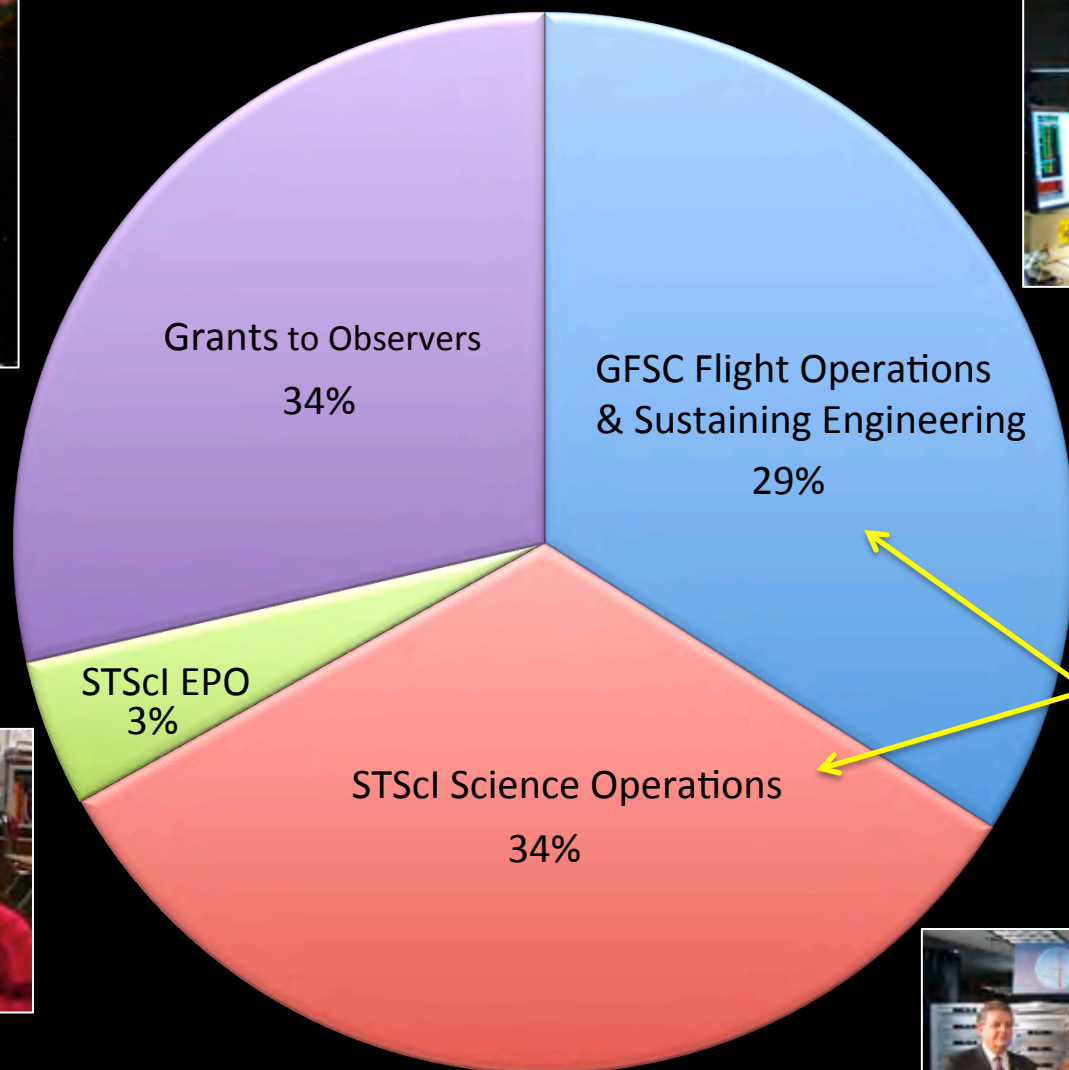




# HST Budget (\$97.3M in President's FY17 budget)



Cy20 – \$30.1M  
Cy21 – \$28.6M  
Cy22 – \$28.6M  
Cy23 – \$28.9M  
Cy24 – \$31.6M



Operations staffing  
is half the size it  
was 10 years ago



We expect FY18 – FY22 to return to \$98.3M/year.

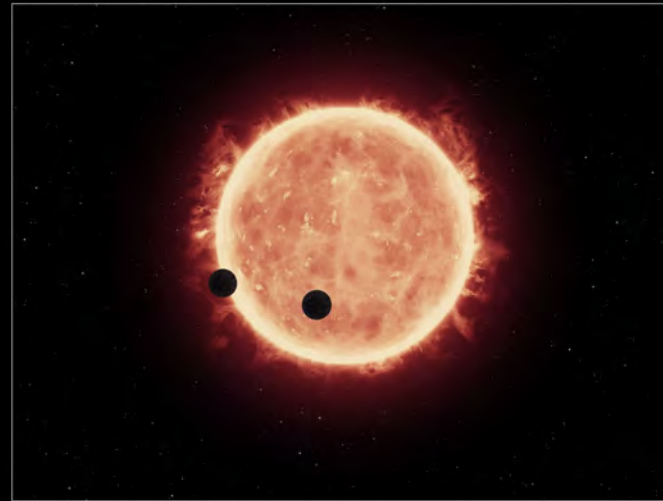
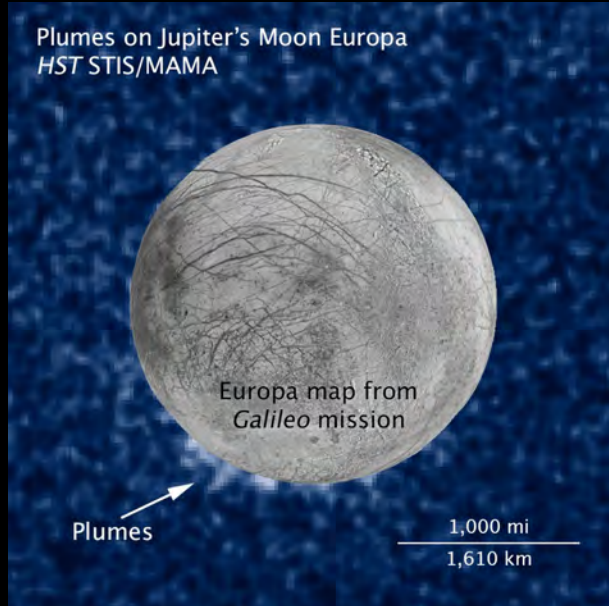


# NASA Senior Review Final Report – 31 May 2016

- FY16 \$98.3M ... FY17 \$97.3M ... FY18-FY20 \$98.3M
- Excellent progress toward 2014 Primary Mission Objectives (PMOs)
  - Next review: “higher level” PMOs with broader representation of user community
- Praised scientific output of observatory and archive
- Noted improvements in observatory efficiency
- Stressed need to maintain GO/AR funding
  - Wants to see a task force examining purchasing power of grants
- Continue maximizing science return
  - Continue replacing IRAF
  - Next review: strategic plan showing resource allocation, staffing, risk posture, dependencies, scientific goals, and productivity metric
- Next review should be a delta review



# Hubble still going strong



Artist's View of Planets Transiting Red Dwarf Star in the TRAPPIST-1 System  
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