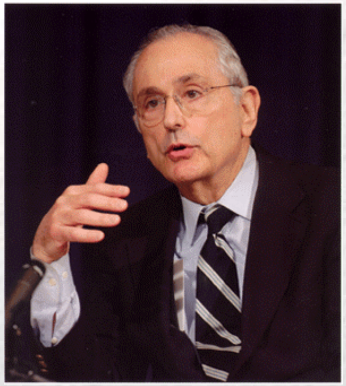
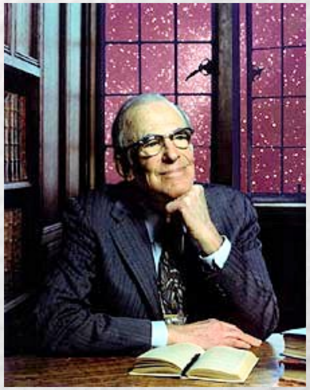
Space Telescope Science Institute

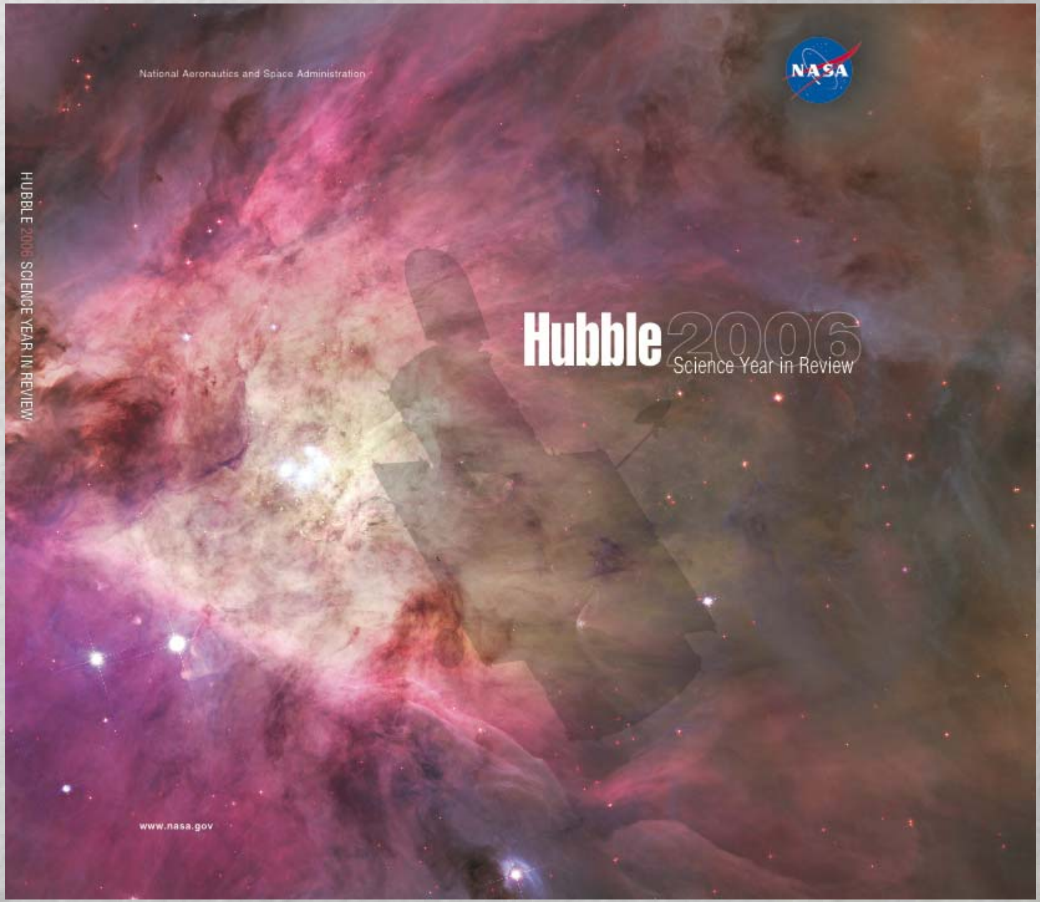
HST and JWST:
The Present and the Future
ESLAB 2007, 1 June 2007

Michael Hauser

Hubble 2006 Science Year in Review







"The Space Telescope will help solve many astronomical puzzles. The greatest excitement, however, will come when the pictures returned from the satellite reveal things no one in this generation of astronomers has dreamed of, phenomena that only the next generation will be privileged to understand."

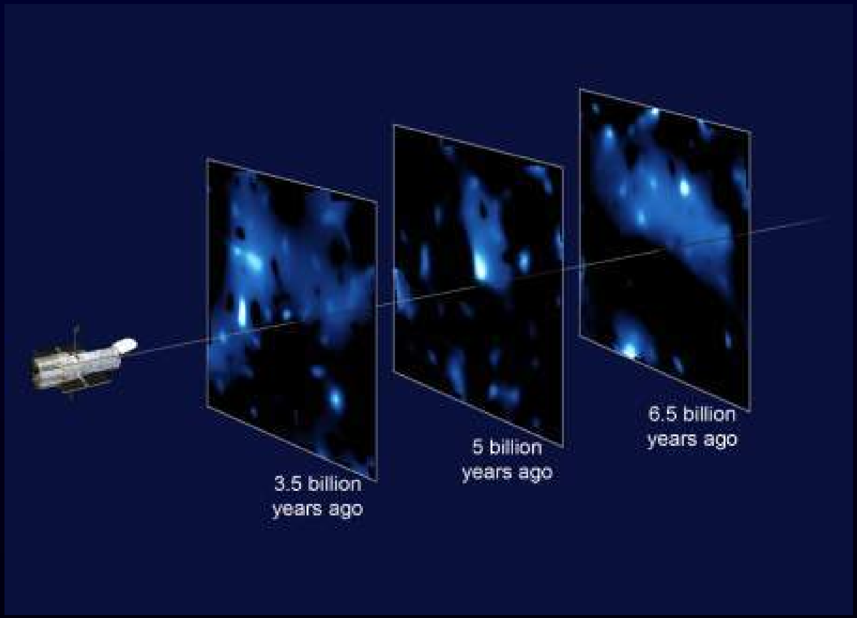
(John N. Bahcall and Lyman Spitzer, Jr., 1982, Scientific American, 247, 40)

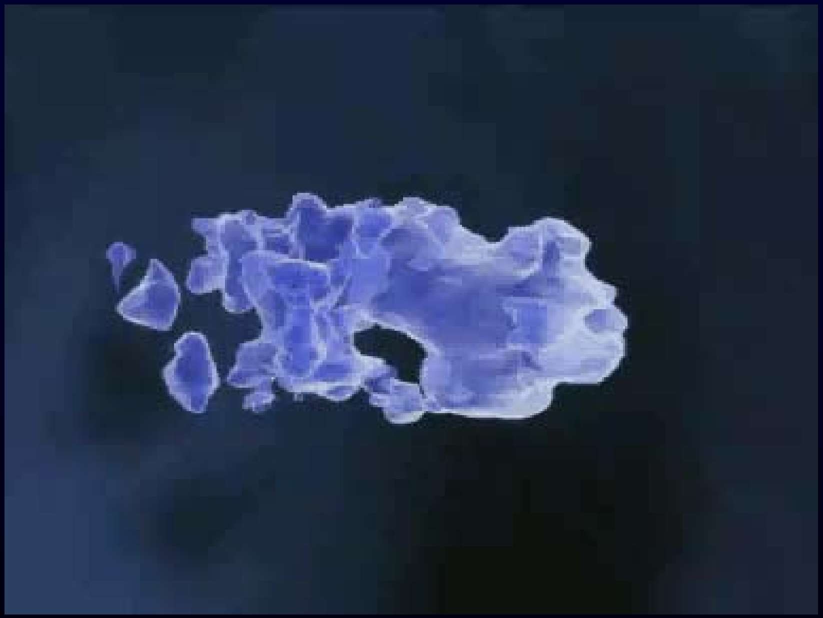
HST and JWST:
The Present and the Future

- Impact of HST
- HST Plans
- Promise of JWST
- …and Beyond

Hubble Maps the Cosmic Web of "Clumpy" Dark Matter in 3-D

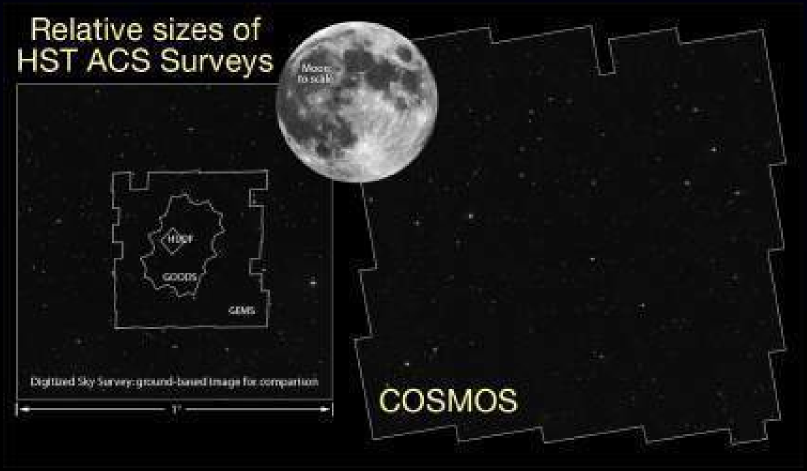
R. Massey (California Institute of Technology)





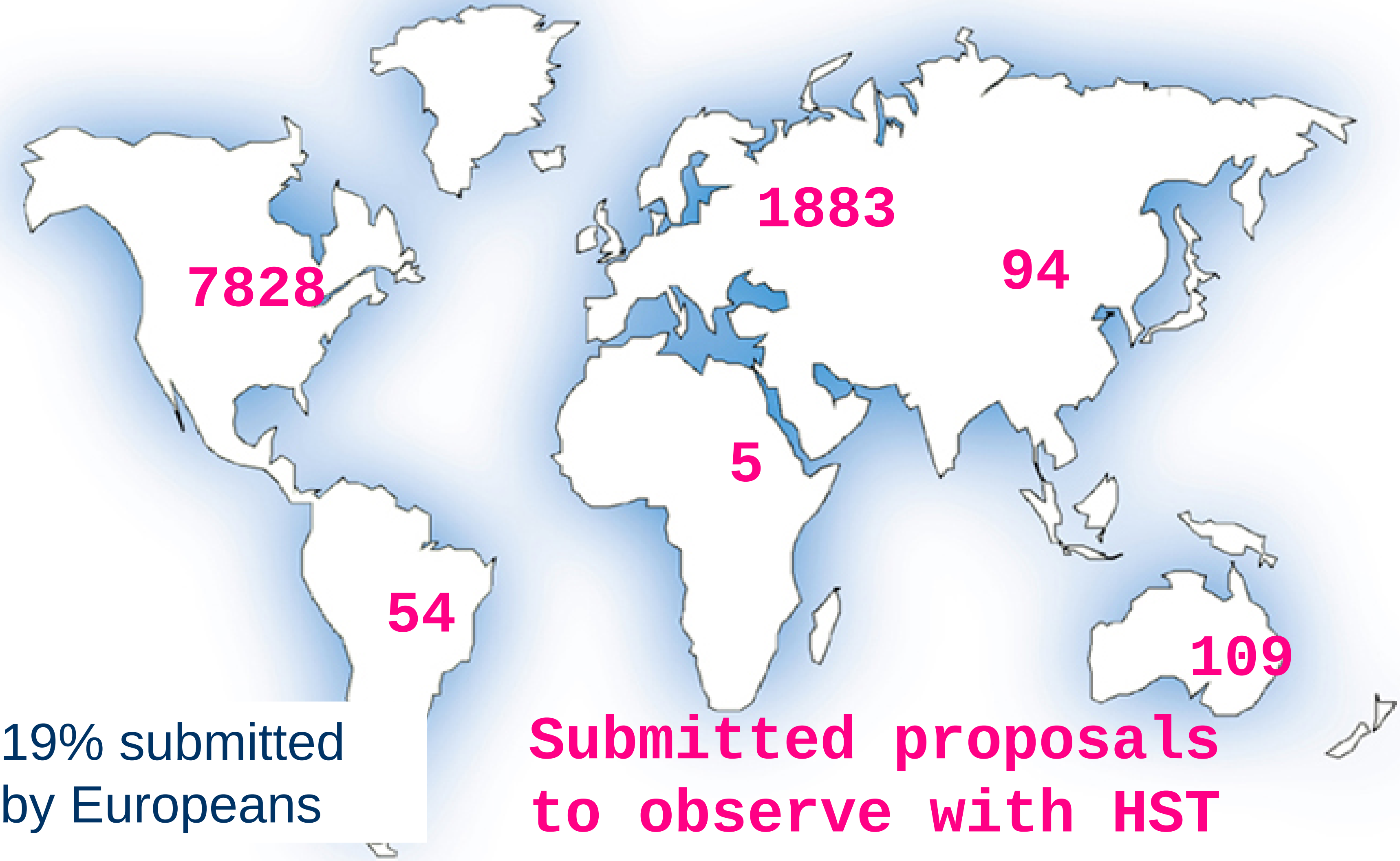
Three-Dimensional Distribution of Dark Matter in the Universe offers a first look at the web-like large-scale distribution of dark matter. This milestone takes astronomers from inference to direct observation of the dark matter “Cosmic web”. The map stretches halfway back in time to the beginning of the universe.

HST Subaru VLT XMM/Newton



SPACE TELESCOPE SCIENCE INSTITUTE

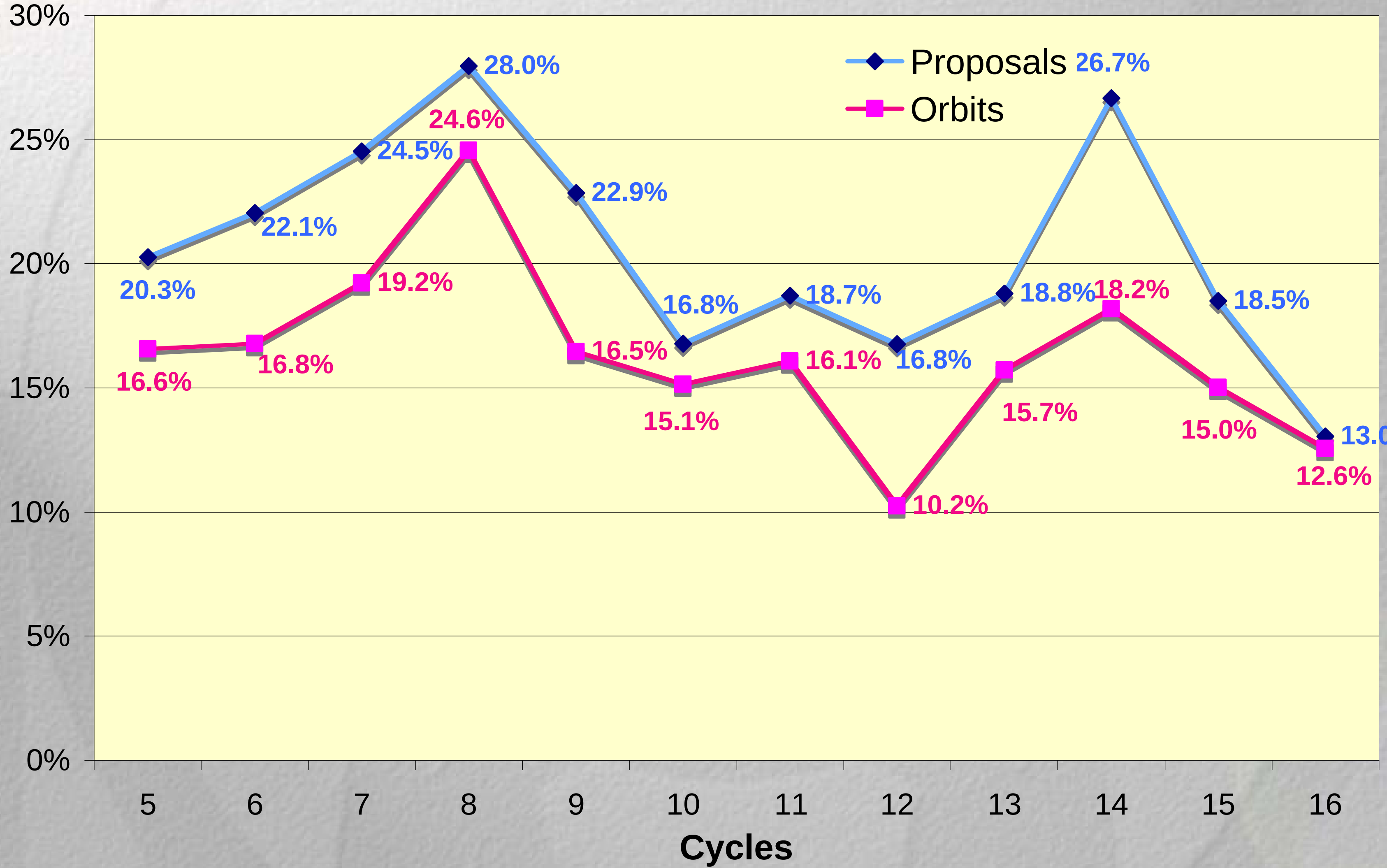
Weak-lensing survey in the COSMOS Field



19% submitted
by Europeans

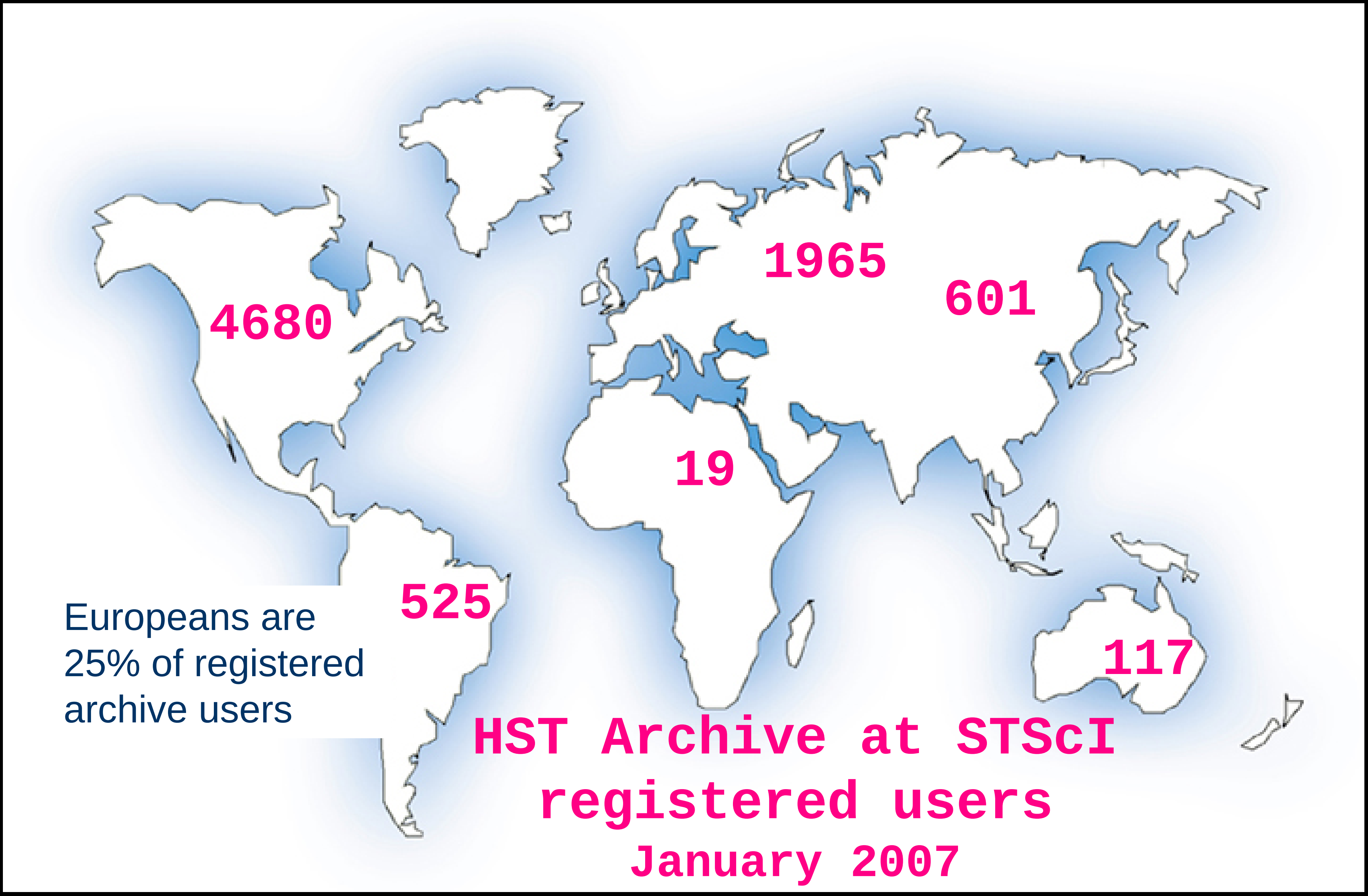
Submitted proposals to observe with HST
1997-2007

ESA proposal acceptance fraction

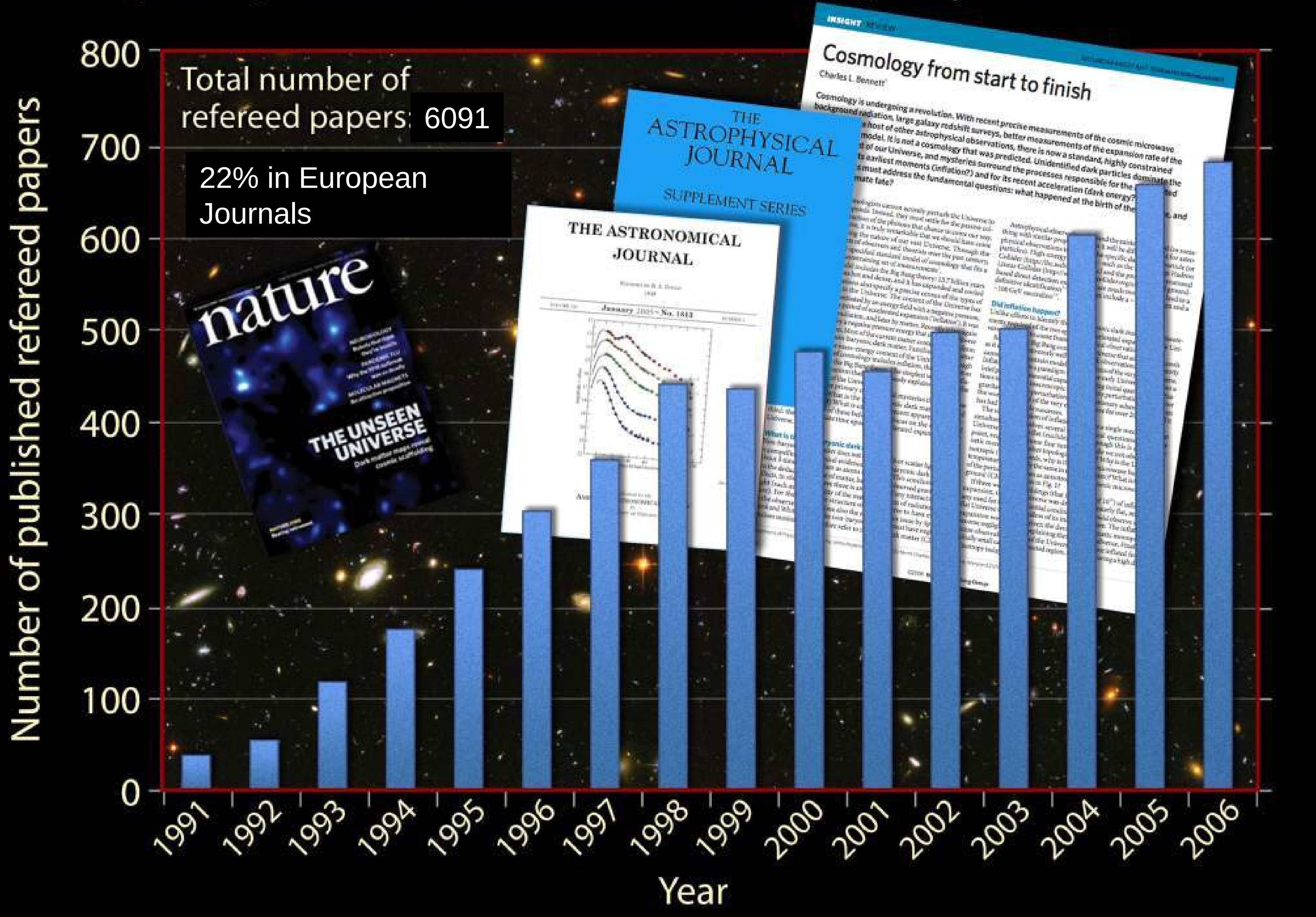


ESA astronomers in Cycle 16

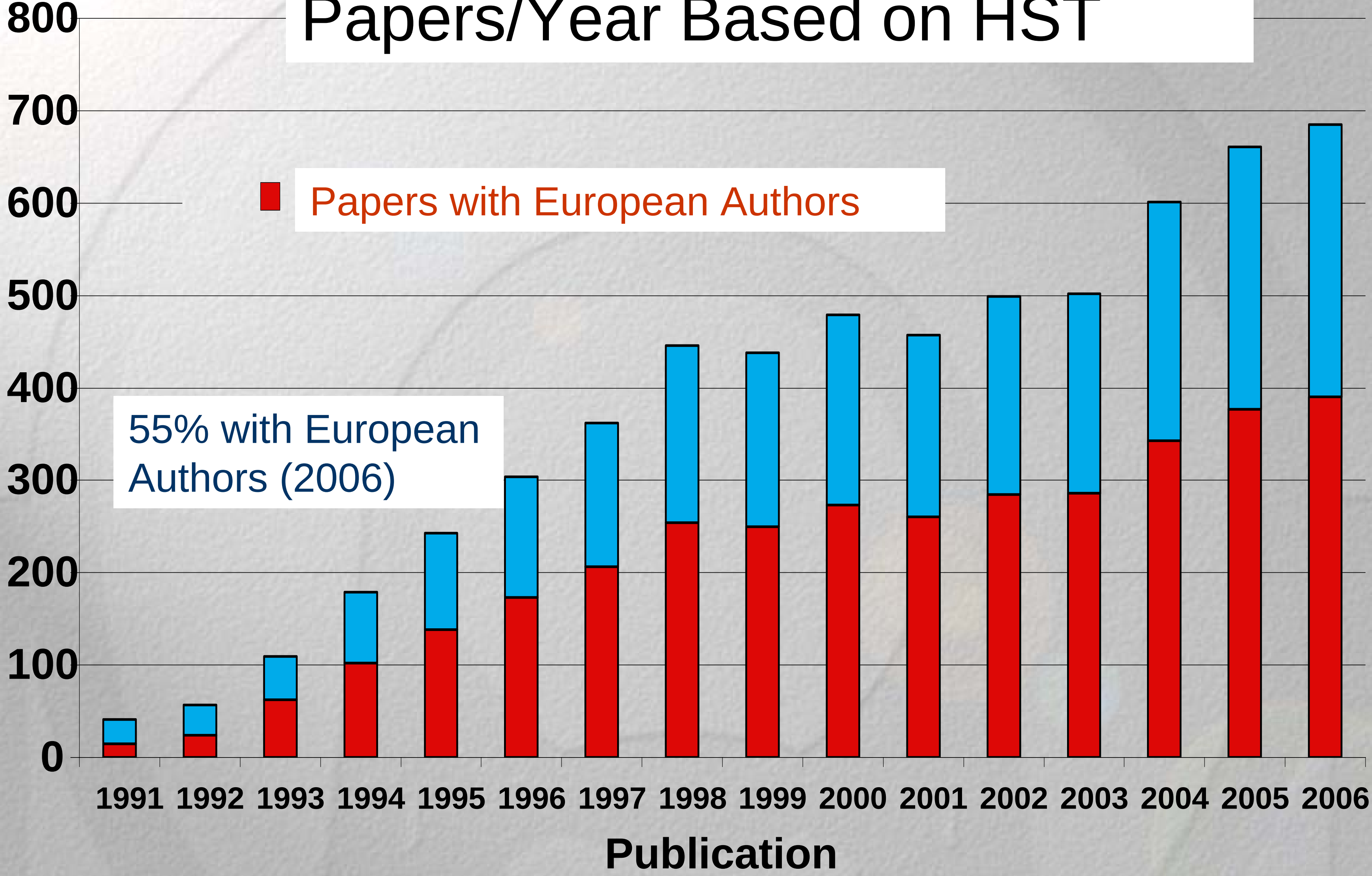
- ESA acceptance fraction: 13% for proposals and 12.6% for orbits
  - 176 ESA CoIs   149 Unique ESA CoIs
  - ESA CoIs are 19% of Total CoIs and 20% of Unique CoIs
- ESA CoIs are involved in
  - 40% of total GO Orbits
  - 40% of Snap programs and 46% of the Snap Orbit Allocation
  - 18% of the AR programs have at least 1 ESA CoI


4680
1965
601
19
525
117
Europeans are
25% of registered
archive users
HST Archive at STScI
registered users
January 2007

Papers generated from HST data per year



Number of Refereed Papers/Year Based on HST



European Hubble Fellows

Pawel	**Artymowicz**	**Konrad**	**Kuijken**
Gaspar	**Bakos**	**Peter**	**Lundqvist**
Amy	**Barger**	**Darren**	**Madgwick**
Niccolo	**Bucciantini**	**Barbara**	**Mochejska**
Paul	**Callanan**	**Klaus**	**Pontoppidan**
Marcella	**Carollo**	**Simon**	**Portegies Zwart**
Roelof	**de Jong**	**Michael**	**Rauch**
Jurg	**Diemand**	**Chris**	**Reynolds**
Marijn	**Franx**	**Marco**	**Spaans**
Mauro	**Giavalisco**	**Tomaso**	**Treu**
Eva	**Grebel**	**Glenn**	**van de Ven**
Rafael	**Guzman**	**Frank**	**van den Bosch**
Coel	**Hellier**	**Roeland**	**van der Marel**
Jarrod	**Hurley**	**Pieter**	**van Dokkum**
Rob			
Inge			
Christian	**Knigge**	**Lifan**	**Wang**
		Janet	**Wood**

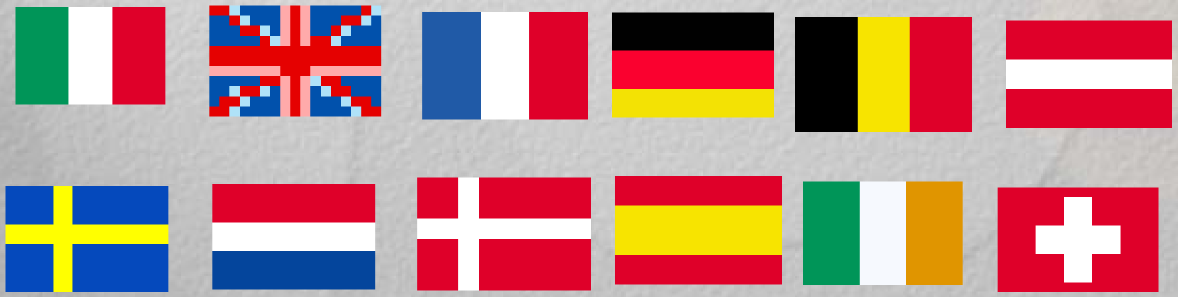
35 European Fellows out of 201 total

STScI Summer Student Program

- Students participate with STScI staff in research
- Steady increase in non-US participation since 1994
  - 13 in 2006, 61 total since 1994
  - Citizens of 18 countries, mostly European
- Of those prior to 2004, most have become graduate students, then professional scientists
  - Marco Sirianni (1995 participant) now ESA staff member serving as Head of STScI ACS/WFPC2 Team

ESA Participation at STScI

- 63 total individuals
  - 15 currently on ESA staff
  - 7 former ESA staff currently on AURA staff
- 12 countries



HST Tools for Observatory Operations

- Digital Sky Survey (DSS)
  - Used globally by observatories and amateurs
    - 1.1 M requests from 143 countries, 7/06-1/07
- Observation scheduling software (SPIKE)
  - FUSE, VLT, Subaru, SIRTF, Chandra, German Space Operations Center, EUVE, ASCA, XTE
- Proposal preparation and submission SW (APT)
  - SOFIA
- Pipeline data processing SW (OPUS)
  - FUSE, Spitzer, Integral, Chandra, Gemini, Chandra, BeppoSAX

Bringing along the public and educators….

- Share the excitement
- Inspire the next generation
- Increase scientific literacy
- Maintain support for astronomical research
- Satisfy long-standing human curiosity

STScI Office of Public Outreach (OPO)

Each functional area derives its effort from the science and leverages the work of other areas.

OPO collaborates with other mission EPO programs to leverage resources and meet common goals.

Penetration into Culture

The new power of images (in German)

Celestial harmony

Teaching English in Japan

Webby Awards: "Oscars of the Internet" (NY Times)

And the 2007 winner for Science is…

HUBBLESITE

Awarded by the International Academy of Digital Arts and Sciences

WINNER
2007 WEBBY AWARDS

PEOPLE'S VOICE WINNER
2007 WEBBY AWARDS

HST 17th Anniversary of Launch

Carina Nebula

Hubble Heritage

NASA, ESA, N. Smith (University of California, Berkeley), and The Hubble Heritage Team (STScI/AURA)
Hubble Space Telescope ACS/WFC • STScI-PRC07-16a

HST Future Plans

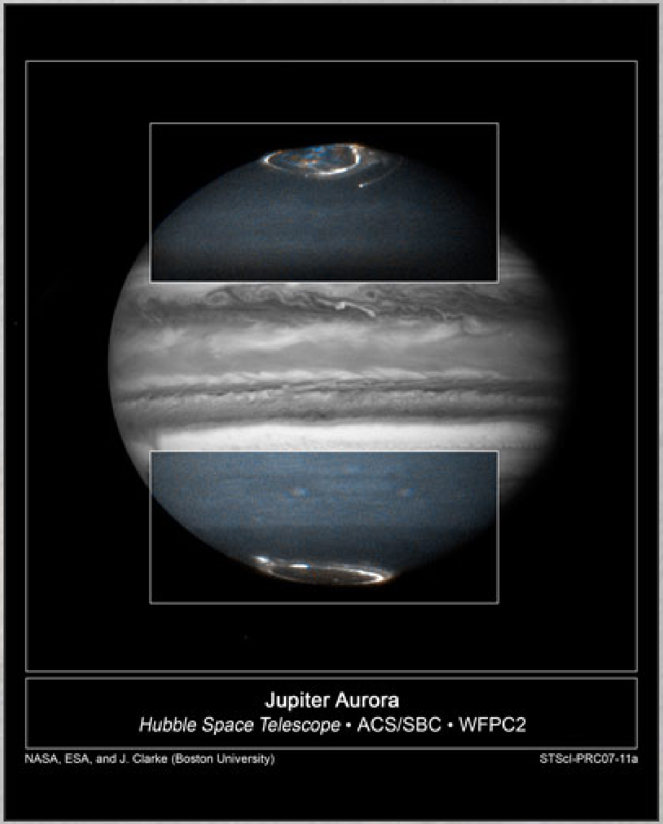
- Fifth Servicing mission (SM4) scheduled for September 2008

"*We are going to add a shuttle-servicing mission to the Hubble Space Telescope to the shuttle's manifest to be flown for before it retires.*" Mike Griffin, NASA Administrator, 31st October, 2006

- Flight operations extended to April 2014
- Cycle 16 will continue until SM4
- ESA role beyond 2010 under discussion
- AURA/STScI contract for science operations extended to 2016

Current Hubble Instrument Status

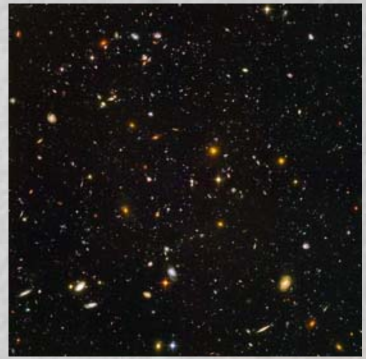
- Wide Field/ Planetary Camera 2 (WF/PC2)
  - Installed December 1993; operating well
- Near Infrared Camera and Multi-Object Spectrometer (NICMOS)
  - Installed February 1997, cooling system installed March 2002; operating well
- ***Fine Guidance Sensors (FGS)***
  - ***FGS2r and FGS3 degrading;*** FGS1r operating well
- ***Space Telescope Imaging Spectrograph (STIS)***
  - Installed February 1997; ***currently disabled***
- ***Advanced Camera for Surveys (ACS)***
  - Installed in March 2002; SBC operating well
  - ***WFC and HRC currently disabled***

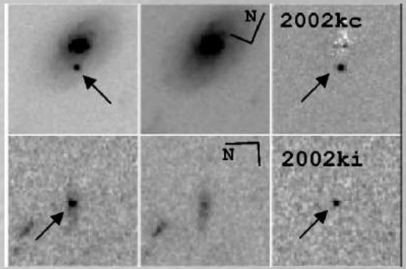


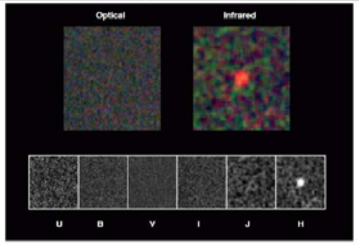
SM4 MISSION GOAL: Six working, complementary instruments for the first time since 1993; Hubble at its Apex.

Batteries+Gyros+FGS = Sustained HST Lifetime

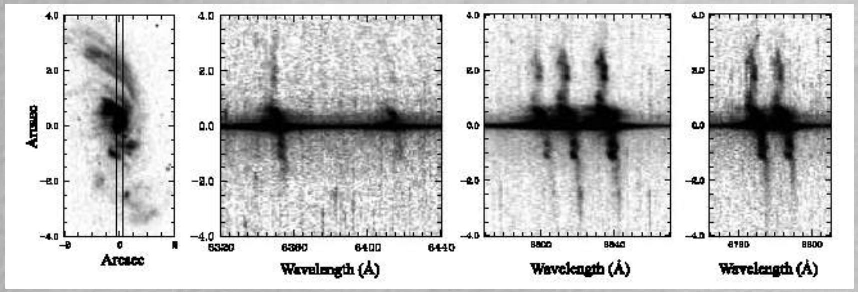
WFC3+ACS = Most powerful imaging ever

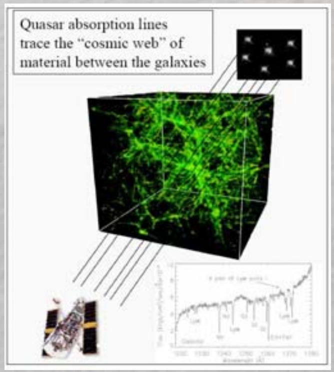


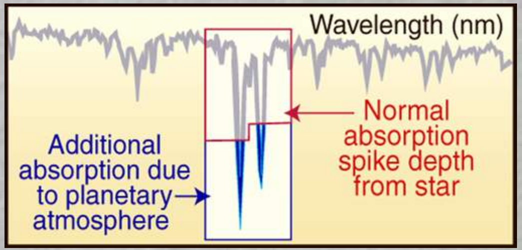




COS+STIS = Full set of tools for astrophysics







COS Science Themes

- What is the large-scale structure of matter in the Universe?
- How did galaxies form out of the intergalactic medium?
- What types of galactic halos and outflowing winds do star-forming galaxies produce?
- How were the chemical elements for life created in massive stars and supernovae?
- How do stars and planetary systems form from dust grains in molecular clouds?
- What is the composition of planetary atmospheres and comets in our Solar System (and beyond)?

WFC3 Science Themes

- What are dark energy and dark matter?
- How and when did galaxies first assemble?
- How universal are the processes of star formation in galaxies?
- How do stars evolve, and what is their distribution of masses?
- How does star-formation and planetary disk formation depend on environmental conditions?
- What is the composition of planets, comets, and minor planets in our Solar System (and beyond)?

SM4 Shuttle Plan

- HST on Shuttle Atlantis on September 11, 2008
  - Final Atlantis mission
- Contingency rescue mission with Shuttle Discovery
  - Recommended by Columbia Accident Investigation Board

SM4 Crew

Scott Altman

Greg Johnson

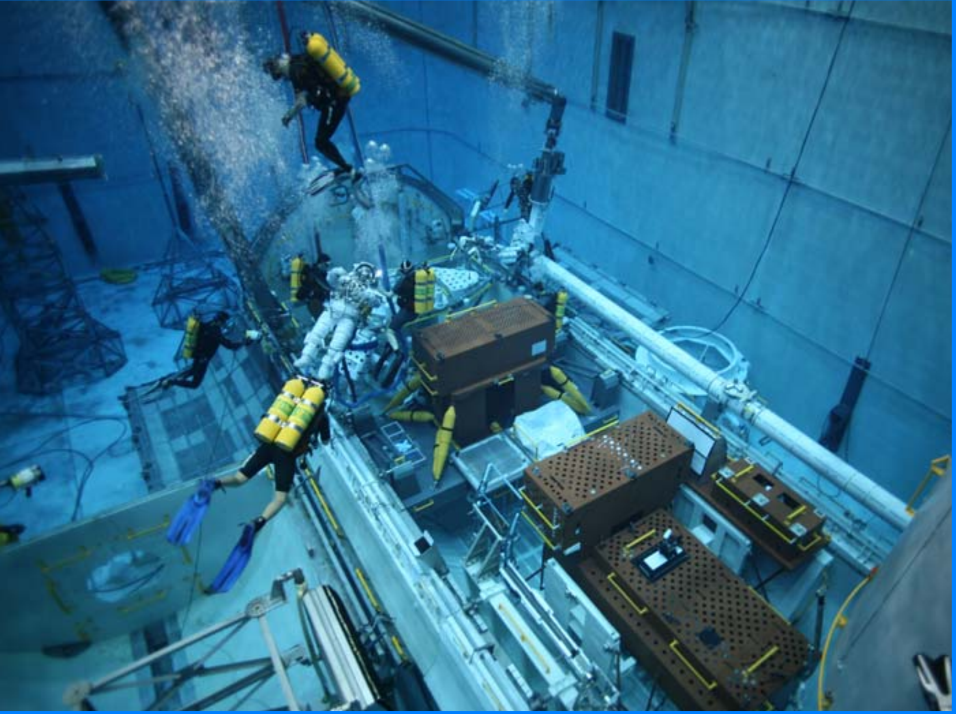
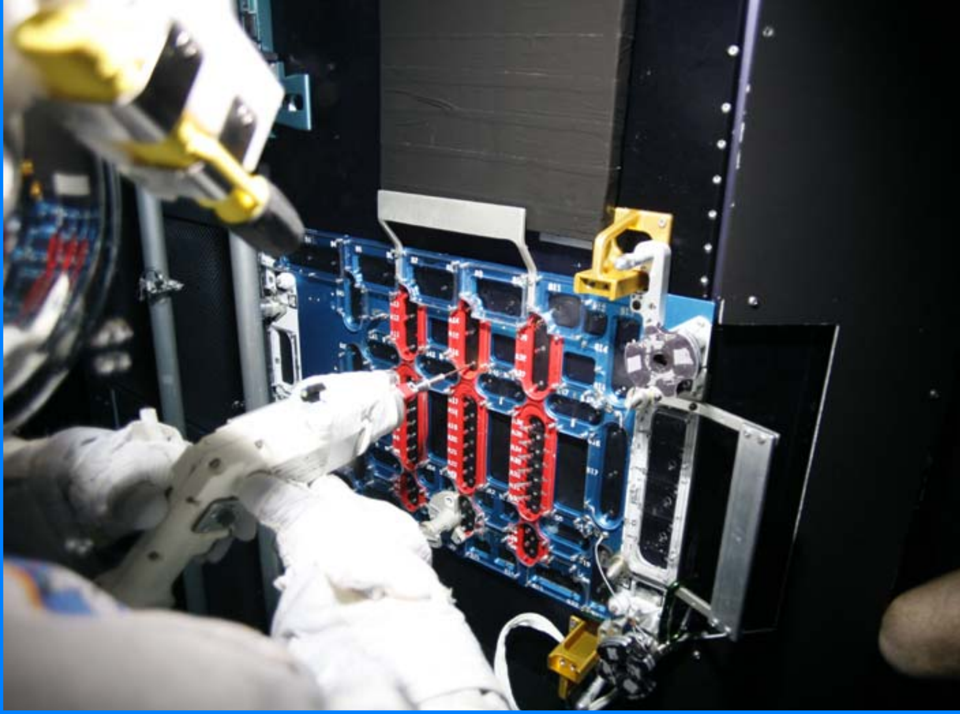
Megan McArthur

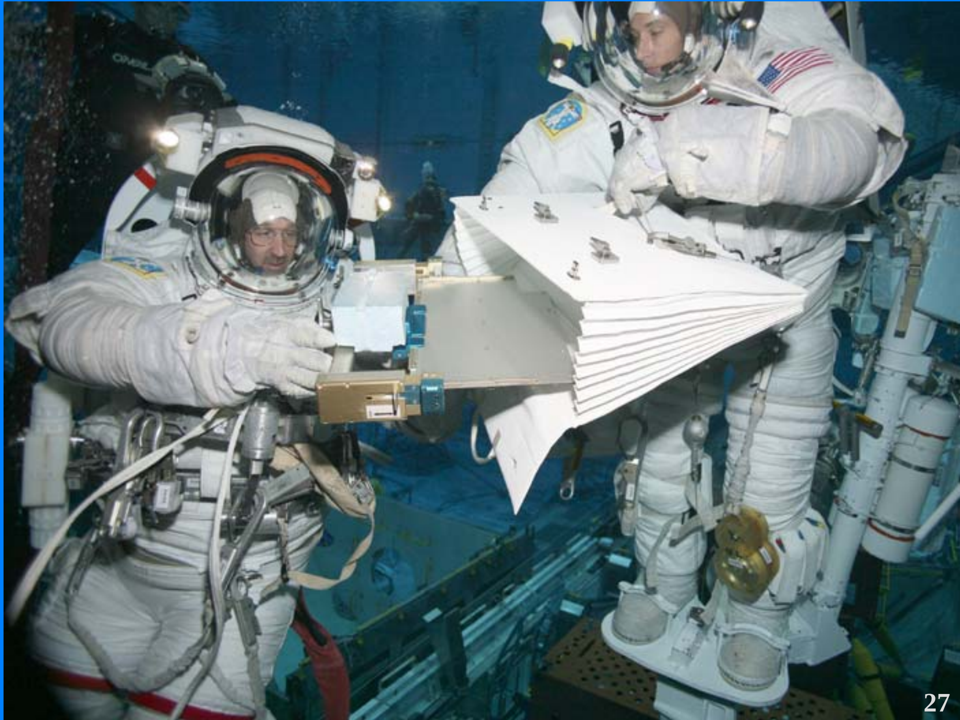
John Grunsfeld

Drew Feustel

Mike Good

Mike Massimino



SM4 Instrument Priorities and Contingencies

- Formal discussions in the NASA Project will begin mid-June
- WFC3 and COS are top priority
  - Contingency: If time for only one, STUC and STScI recommend WFC3
- Instrument repairs: secondary instrument priority
  - Project preparing to repair both STIS and ACS (ACS still requires NASA approval)
    - ACS repair for WFC. HRC may also become operable
    - SBC will continue operations with or without CCD repair
  - Contingency: If time for only one repair, STUC and STScI to make recommendations to NASA

THE NEW YORK TIMES **EDITORIALS/LETTERS** FRIDAY, MAY 3, 2002

The Hubble Achievement

It seems hard to believe that we have already grown used to seeing images from the Hubble Space Telescope in the dozen years since it was first launched. But the startling pictures released this week from a newly restored Hubble are a reminder that we had, in fact, begun to take for granted our ability to peer into deep space, an ability no generation of humans has ever possessed before. In a sense, these new images, produced with cameras and power sources that were added or rejuvenated during a space shuttle flight in March, feel something like learning to see all over again. They remind us what an astonishing chapter of astronom-

the real wonder appears. Beyond the uniformity of the naked-eye universe, there is this other universe, the one Hubble discovers with astonishing clarity. This is a place full of discordant objects, of cataclysmic disturbances. Galaxies devour each other. Stars form in infernos of gas and dust and light. And they do so against the backdrop of a sky that is almost unimaginably deep.

For what the Hubble cameras show us, especially in their new incarnation, is time itself. The distance of the distant objects in these images is measured as much by their relative youth, by how far back in time we must peer to see them, as by

It has taught us to see the properties of a universe humans have been able, for most of their history, to probe only with their thoughts.

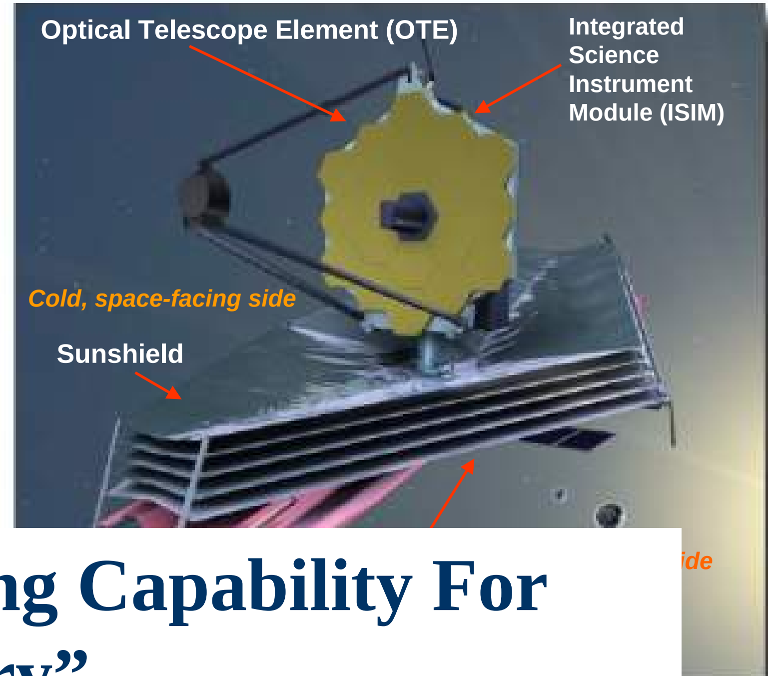
The James Webb Space Telescope - looking beyond Hubble

Michael Hauser
Space Telescope Science Institute
June 1, 2007

James Webb Space Telescope (JWST)

Organization

- Mission Lead: Goddard Space Flight Center
- International collaboration with NASA, ESA & CSA
- Prime Contractor: Northrop Grumman Space Technology
- Instruments:
  - Near Infrared Camera (NIRCam) – Univ. of Arizona
  - Near Infrared Spectrograph (NIRSpec) – ESA
  - Mid-Infrared Instrument (MIRI) – JPL/ESA
  - –
- Operat
- Deploy meter primar
- Cryogenic temperature telescope and instruments for infrared performance
- Launch June 2013 on an ESA-supplied Ariane 5 rocket to Sun-Earth L2
- 5-year science mission (10-year goal)

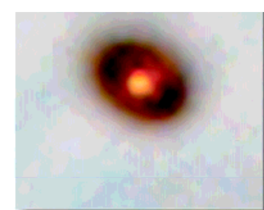


"NASA Adding Docking Capability For Next Space Observatory"

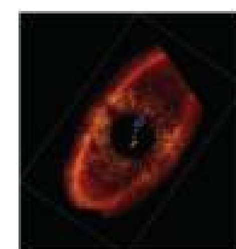
Space News, 23 May 2007

End of the dark ages: First light and reionization

The assembly of galaxies



Birth of stars and proto-planetary systems



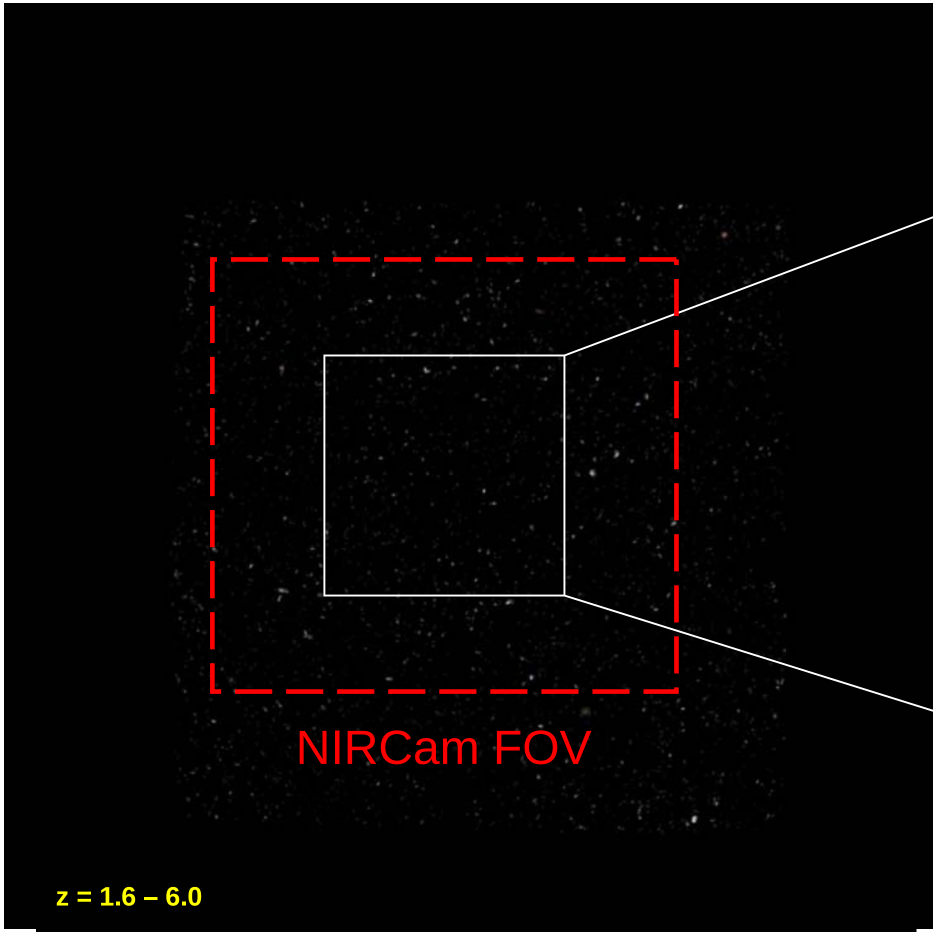
Planetary systems and the origin of life

www.JWST.nasa.gov

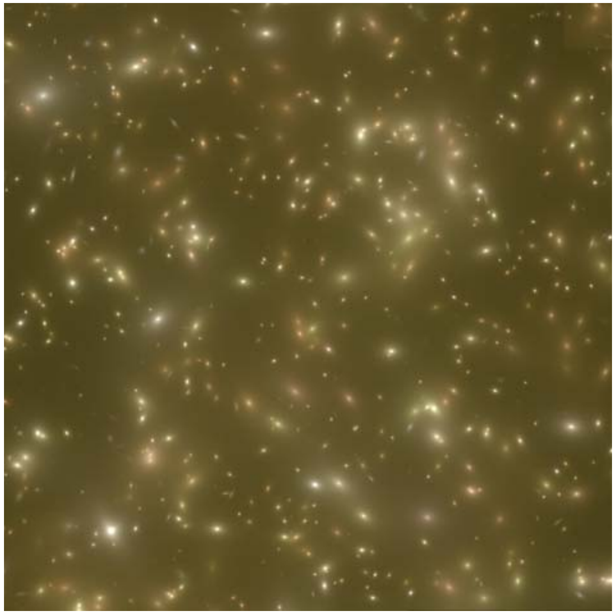
Why do we need a large, cold space telescope?

Probing the Early Universe in the Infrared with a 6m Space Telescope

HST Ultra Deep Field



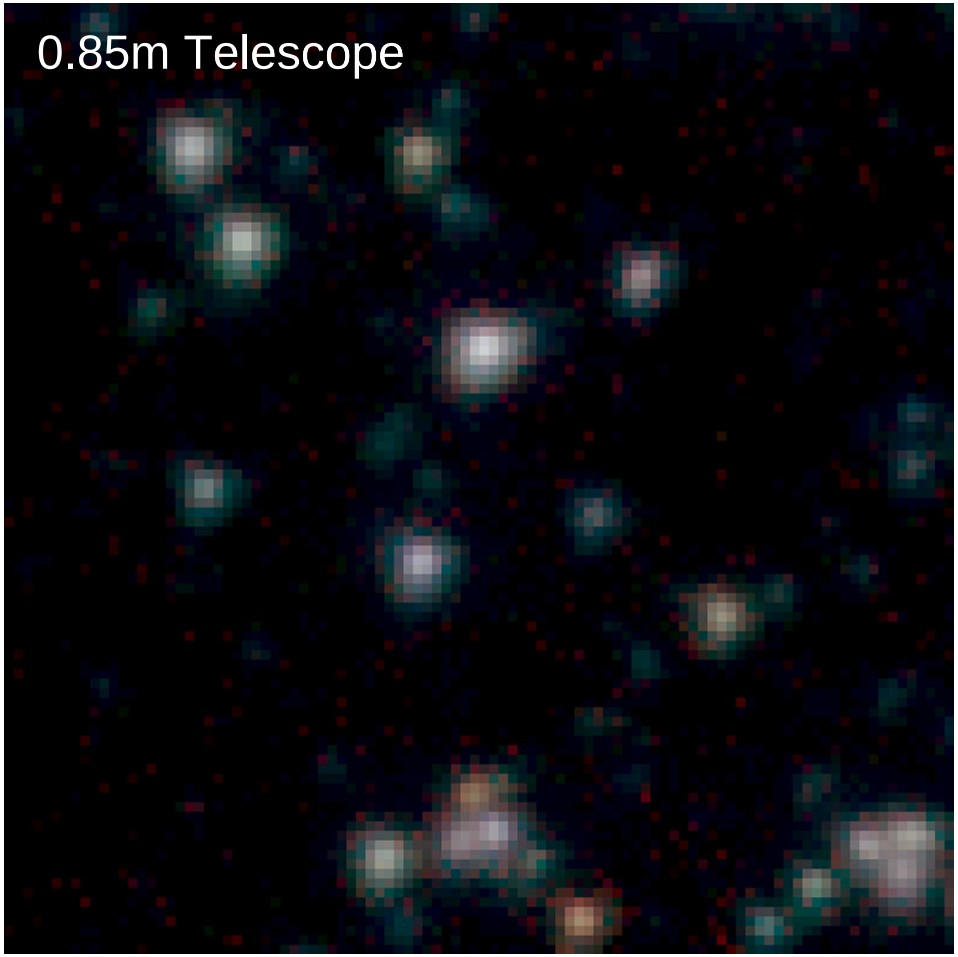
1,000,000 seconds integration with HST



z = 1.6 – 6.0 JWST simulation, 10,000 seconds per infrared band, 2.2μm, 3.5μm, 5.8μm

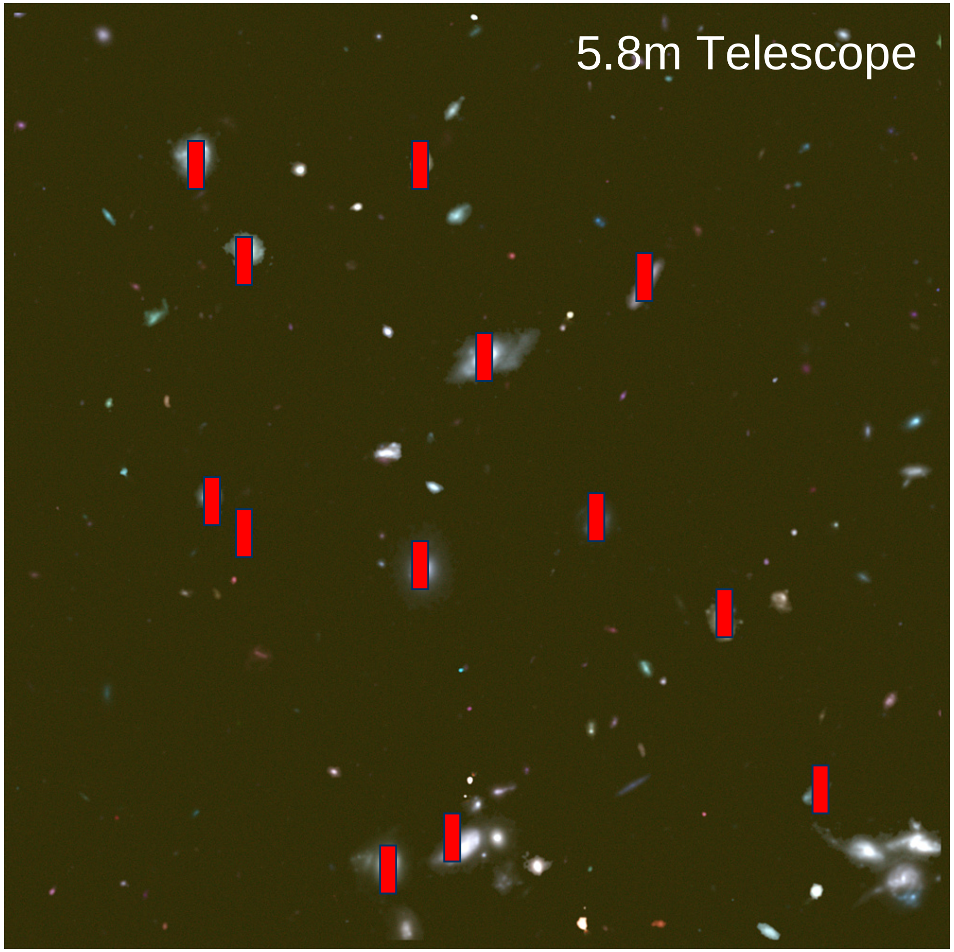
JWST-Spitzer Space Telescope image comparison

1’x1’ region in the UDF – 3.5 to 5.8 μm



Spitzer, 25 hour per IR band

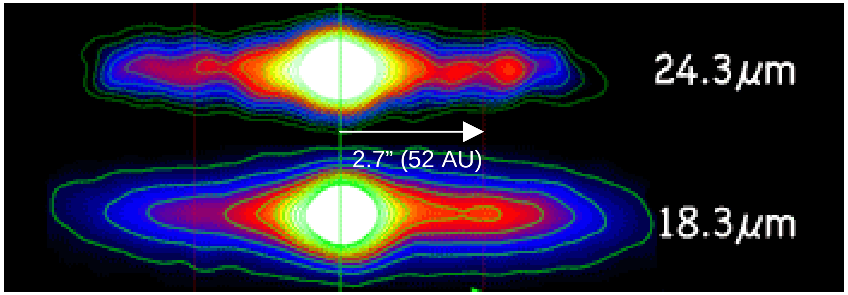
(GOODS collaboration)



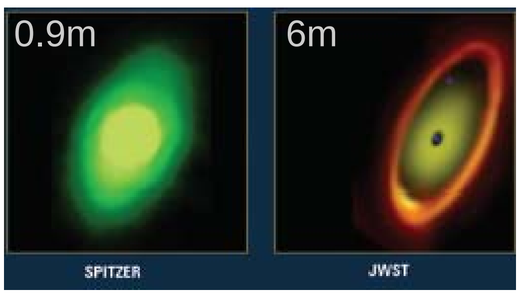
JWST, 1000s per band (simulated)

IR multi-spectral data now possible

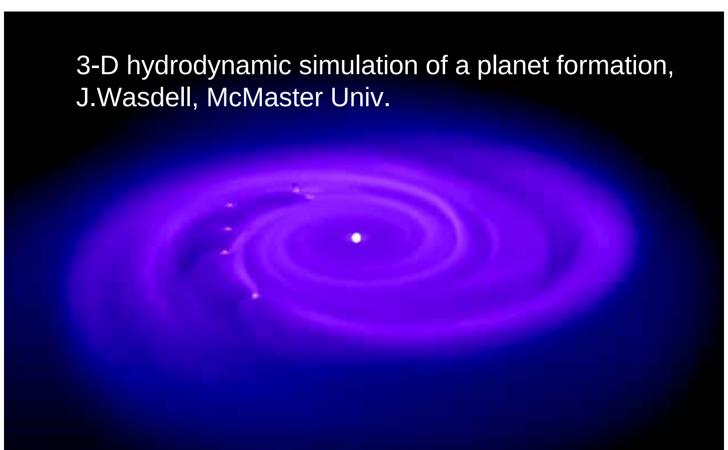
Thermal infrared observations of “nascent” planetary systems



Several nights on Gemini 8m Telescope,



Fomalhaut (SST): Stapelfeldt et al 2004



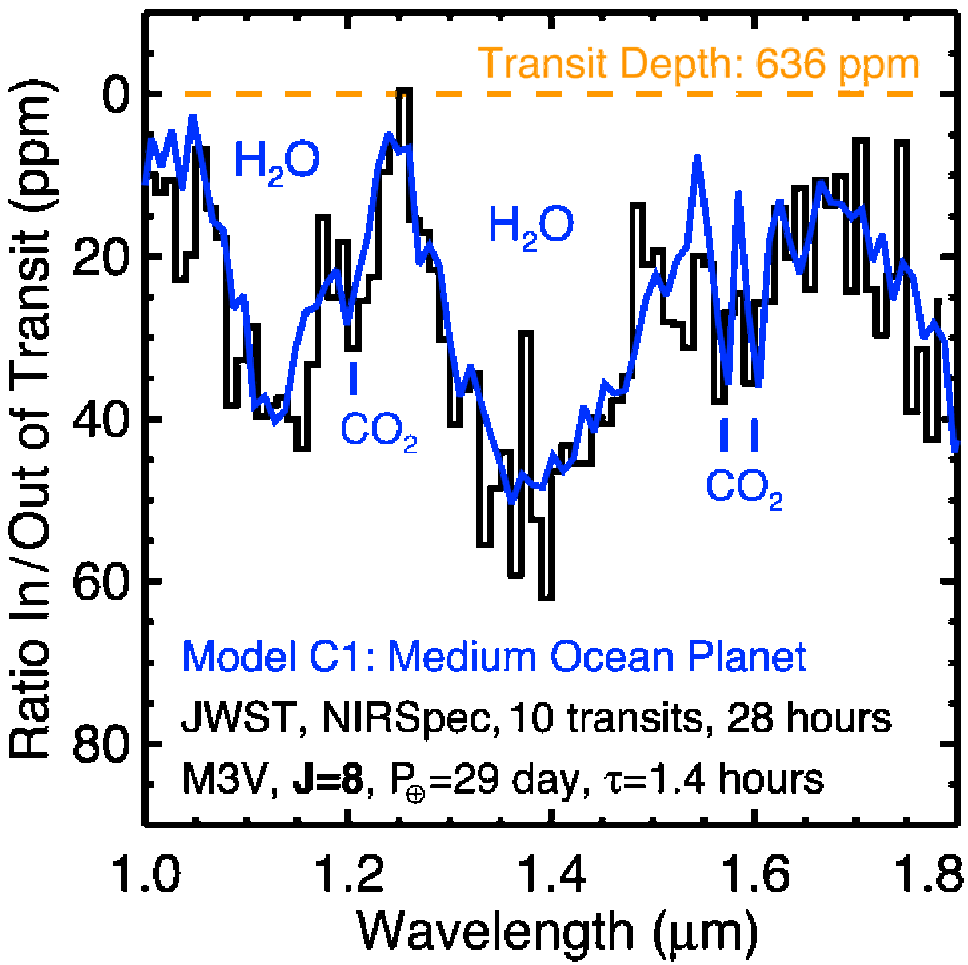
Groundbased 8m thermal infrared imaging of one of few debris disks observable today (around Beta Pictoris) shows spatial structure in these systems during the era of heavy bombardment (Gemini Observatory).

Recent observation by Spitzer have shown that protoplanetary disks are both extremely common yet varied

20% of solar-type stars may have debris disks

Theoretical framework for planetary systems are advancing rapidly – the structure of debris disks is a key diagnostic

Transit Spectrum of a Habitable Ocean Planet

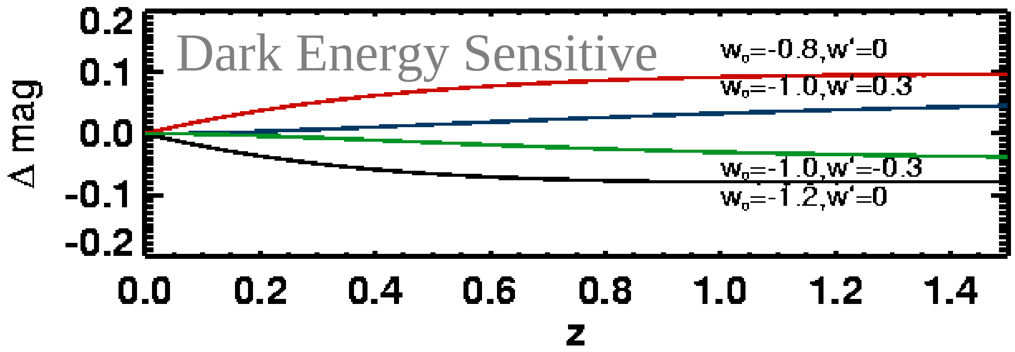


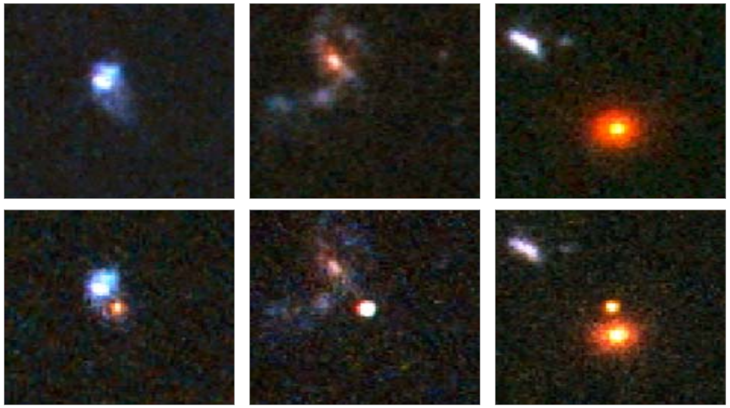
Model: Ehrenreich et al. (2006)

JWST Simulation: Jeff Valenti, STScI.

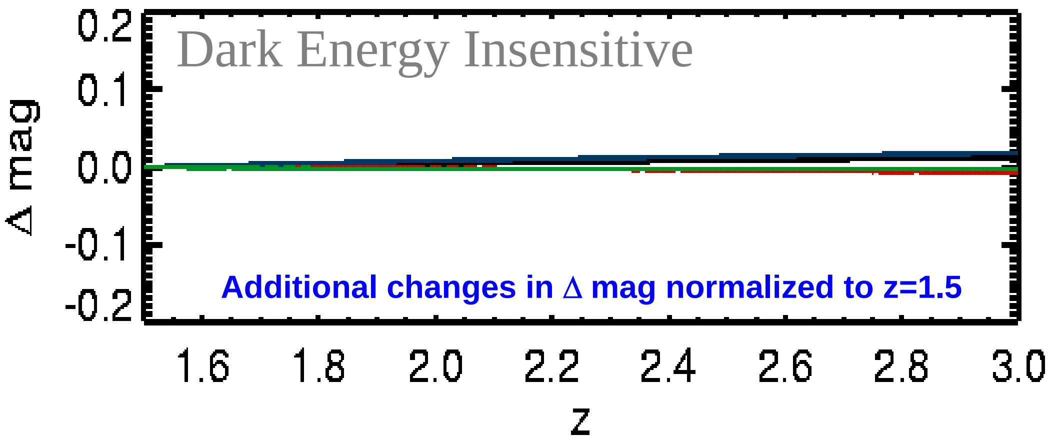
- JWST may detect water
  - Small star → less dilution
  - Lines are 0.005% deep
  - Need 1 billion photons
  - Very precise calibration
- Gliese 581 (M3V, J=6.7)
  - b: 5.4 days, 15.6 $M_{\oplus}$
  - c: 12.9 days, 5.1 $M_{\oplus}$
  - d: 83.4 days, 8.3 $M_{\oplus}$
  - Size? Temp? Atmosphere?
- Find one that transits…
  - 6000 M dwarfs with J<10
  - Habitable → 11% transit
  - Up to 70 transits for J<10

Calibrating the 21st Century's distance scale and Dark Energy





Differing dark energy (DE) parameters would show changes in luminosity-distance ~ 10% in the DE dominated Universe. Subtle SNe 1a evolutionary effects are difficult to untangle observationally.



In contrast, observing SN in the dark matter dominated Universe (z > 1.5), any *additional* changes due to DE in the luminosity-distance normalized to those determined at z = 1.5, become small (~1%), so possible SNe1a evolutionary effects become observable with JWST.

•DE mission concepts propose to average 1000's of SNe Ia at 0<z<1.5 to measure the eq. of state of DE

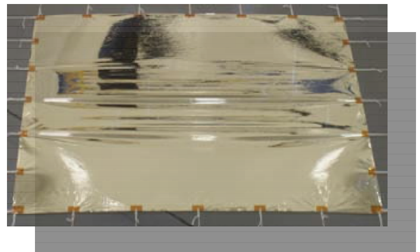
Will rely on our ability to detect and calibrate possible SN Ia evolution to ~1%

•Need to break the degeneracy between DE and SN evolution at z = 2~3

• Such observations require flux measurements at H>25 & K>27 mag, where JWST is unique. JWST should be able to measure 100's of such SNe Ia
(Riess and Livio,2006)

Technology Milestones

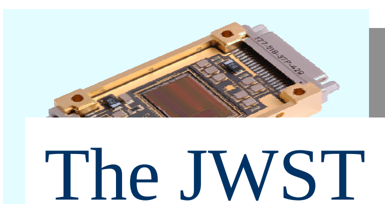
Near Infrared Detectors
April 2006



Sunshield Material
April 2005

Mid-IR Detectors
July 2005

Primary Mirror
Segment Assembly
June 2006



The JWST Non-Advocate Review Team considers the TNAR, and subsequent activities, to have demonstrated that the TRL-6 criteria for all 10 enabling technologies have been met…

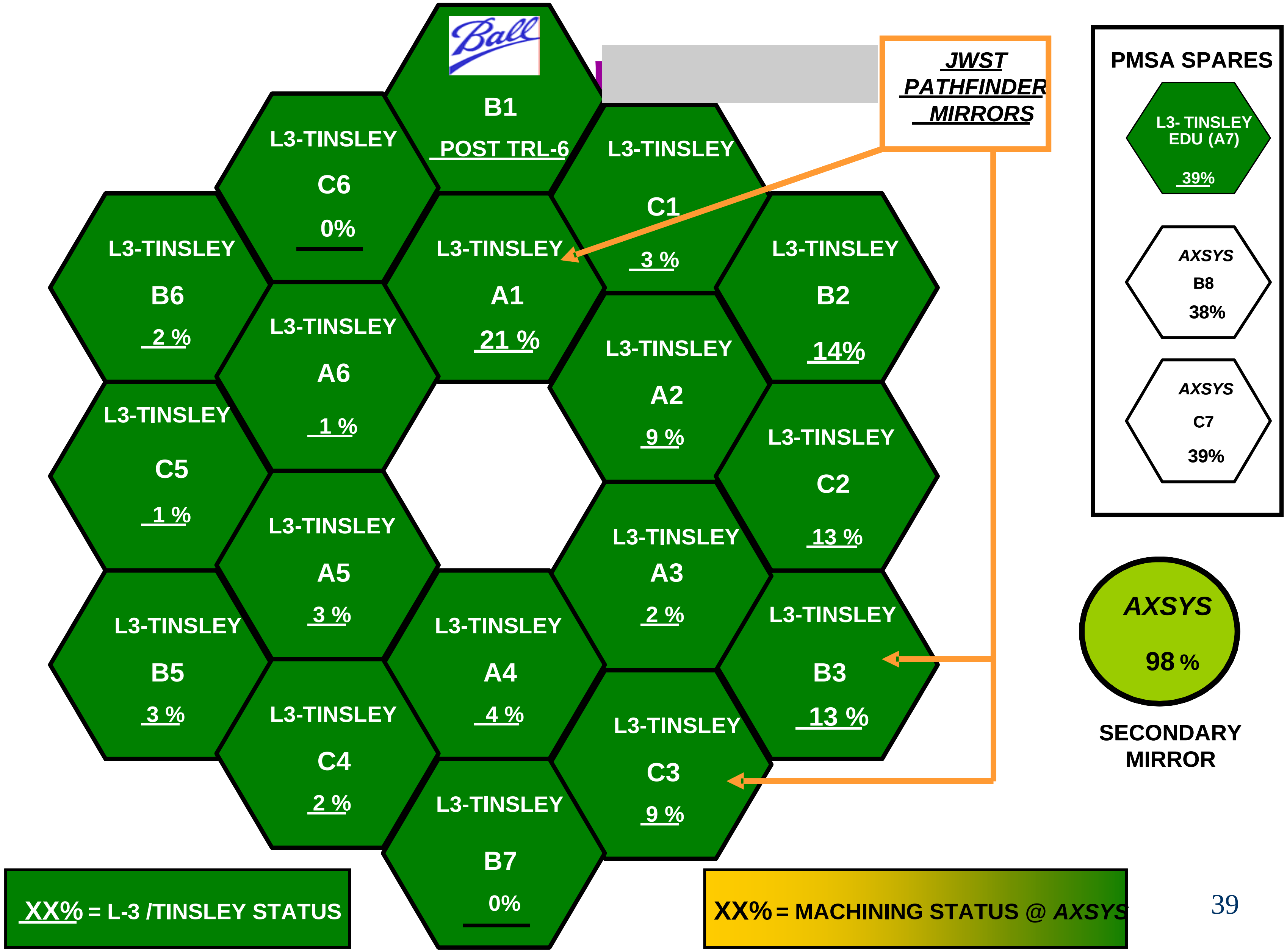
23 March 2007

Large Precision Cryogenic Structure
November 2006

Wavefront Sensing & Control
December 2006

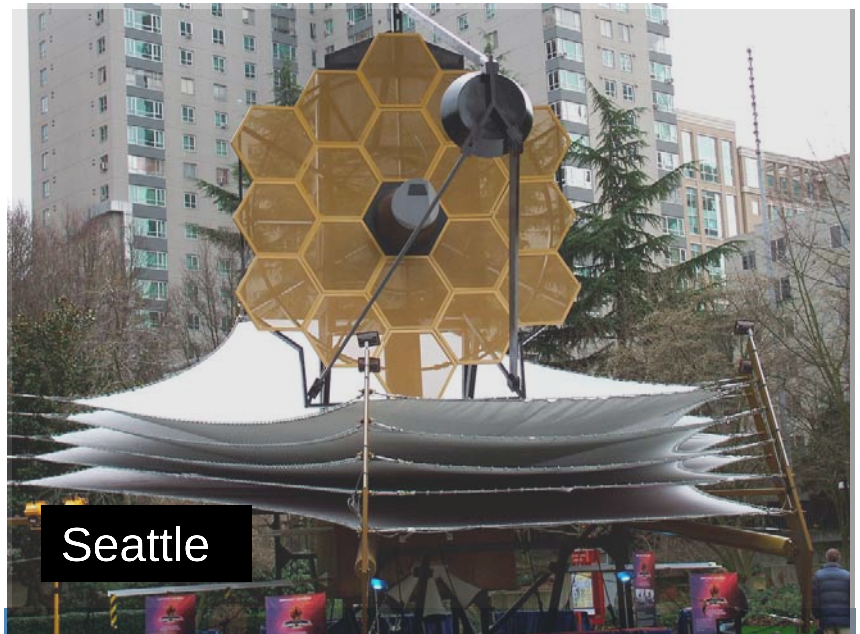
Cryocooler
December 2006

JWST Mirror Status



Sunshield Evolutionary Pathfinder (EPF) with all 5 Layers Installed

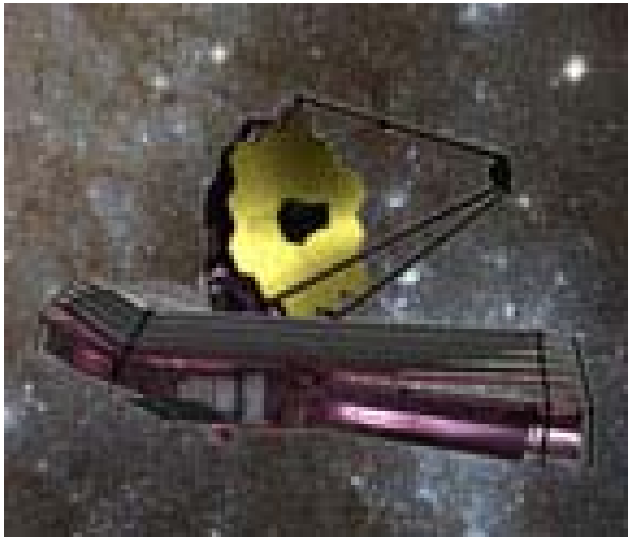
JWST—Gold at the end of the rainbow!



September 24-27, 2007

Marriot Starr Pass,
Tucson, Arizona

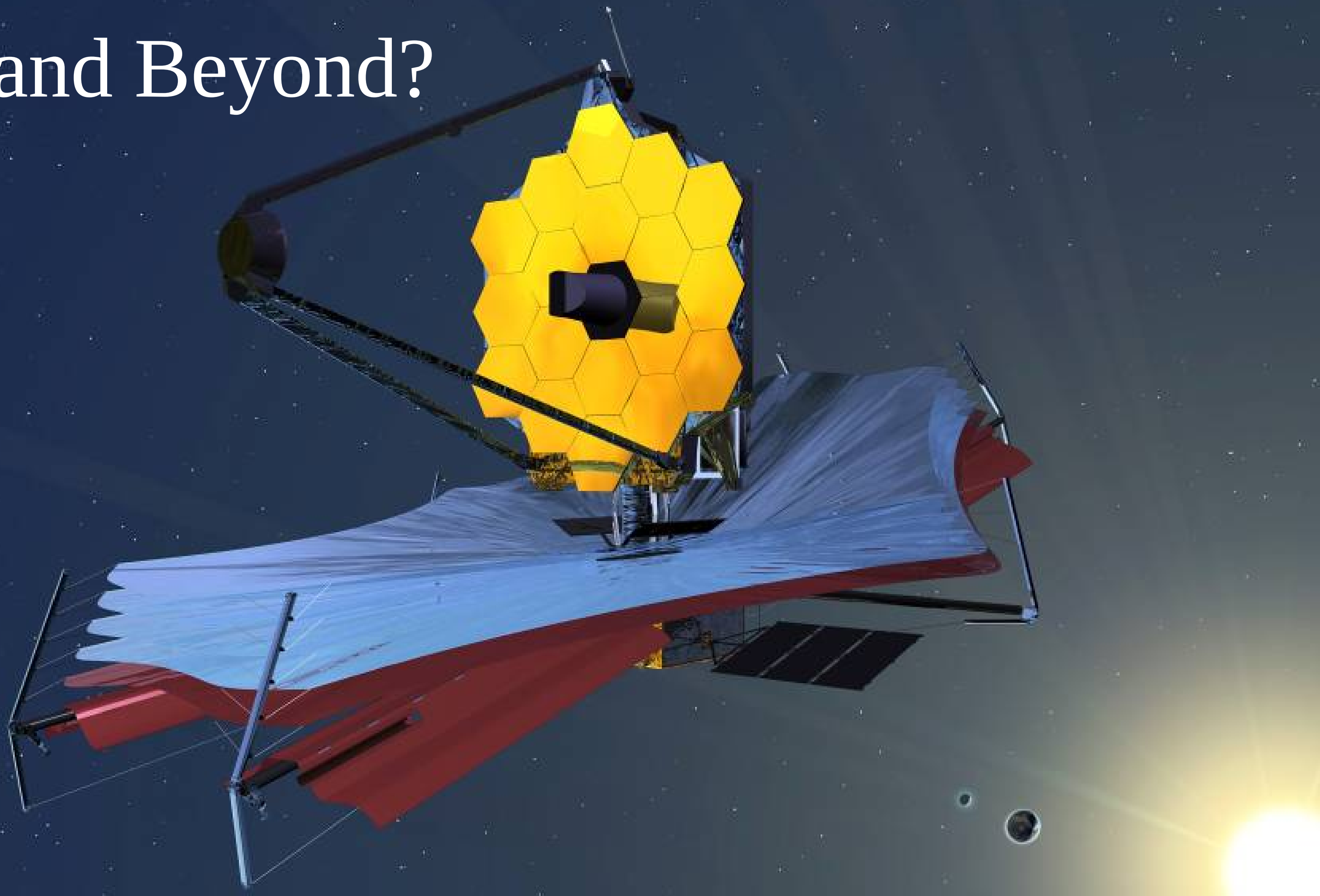
http://www.stsci.edu/institute/conference/jwst2007



“Flagship” space observatories such as HST, Chandra, and Spitzer have achieved remarkable democratization of world-class research away from a few prosperous institutions (such as that of Edwin Hubble himself).

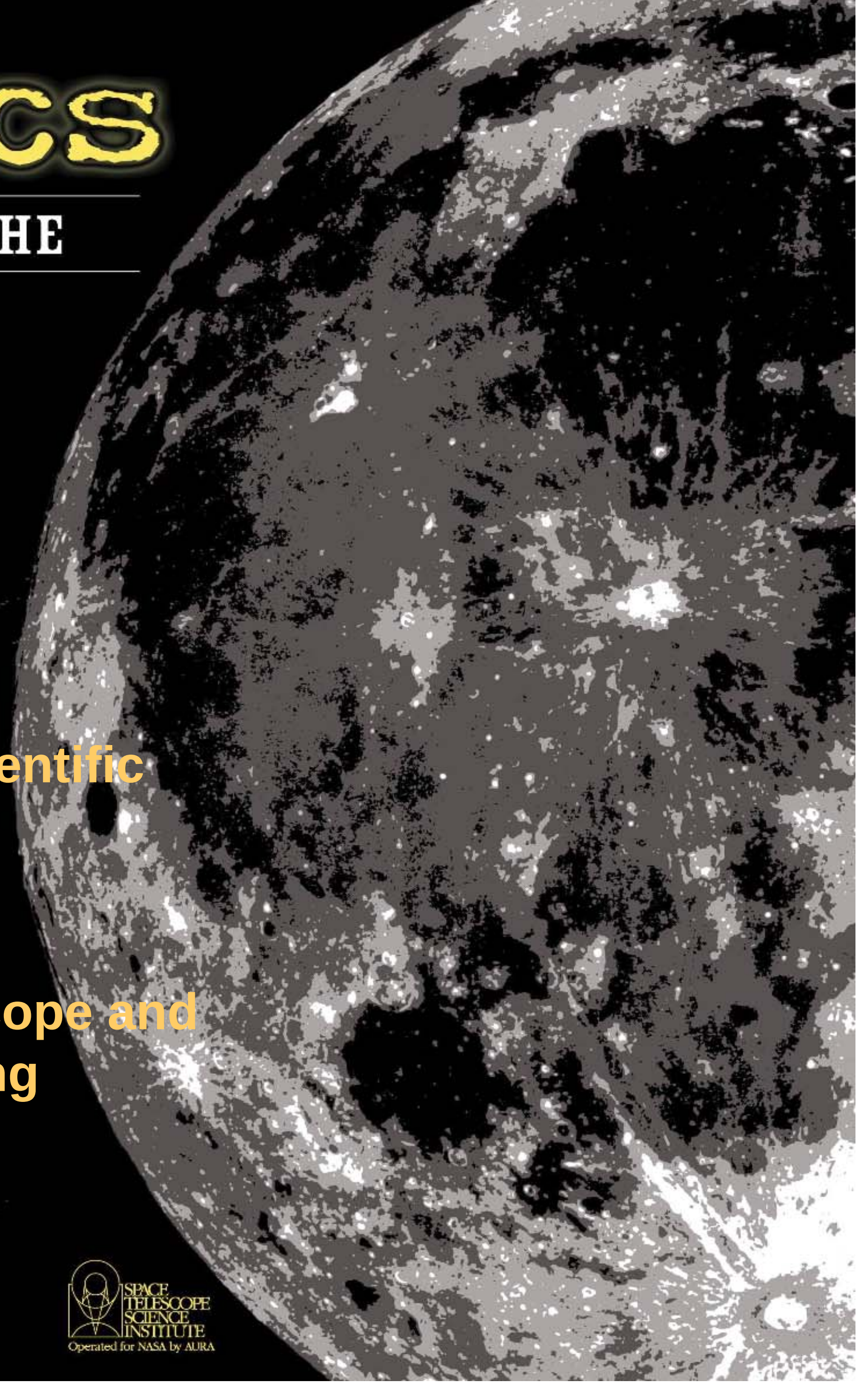
Crucially, time is allocated by the community through peer review, transforming major space observatories into ***community-lead and community accountable research facilities**,* that are engaging a broad community in revolutionizing our view of the Universe. *JWST will be run the same way, and serve a similar community of over 7,000 astronomers world-wide*

…..and Beyond?



ASTROPHYSICS
ENABLED BY THE RETURN TO THE
MOON

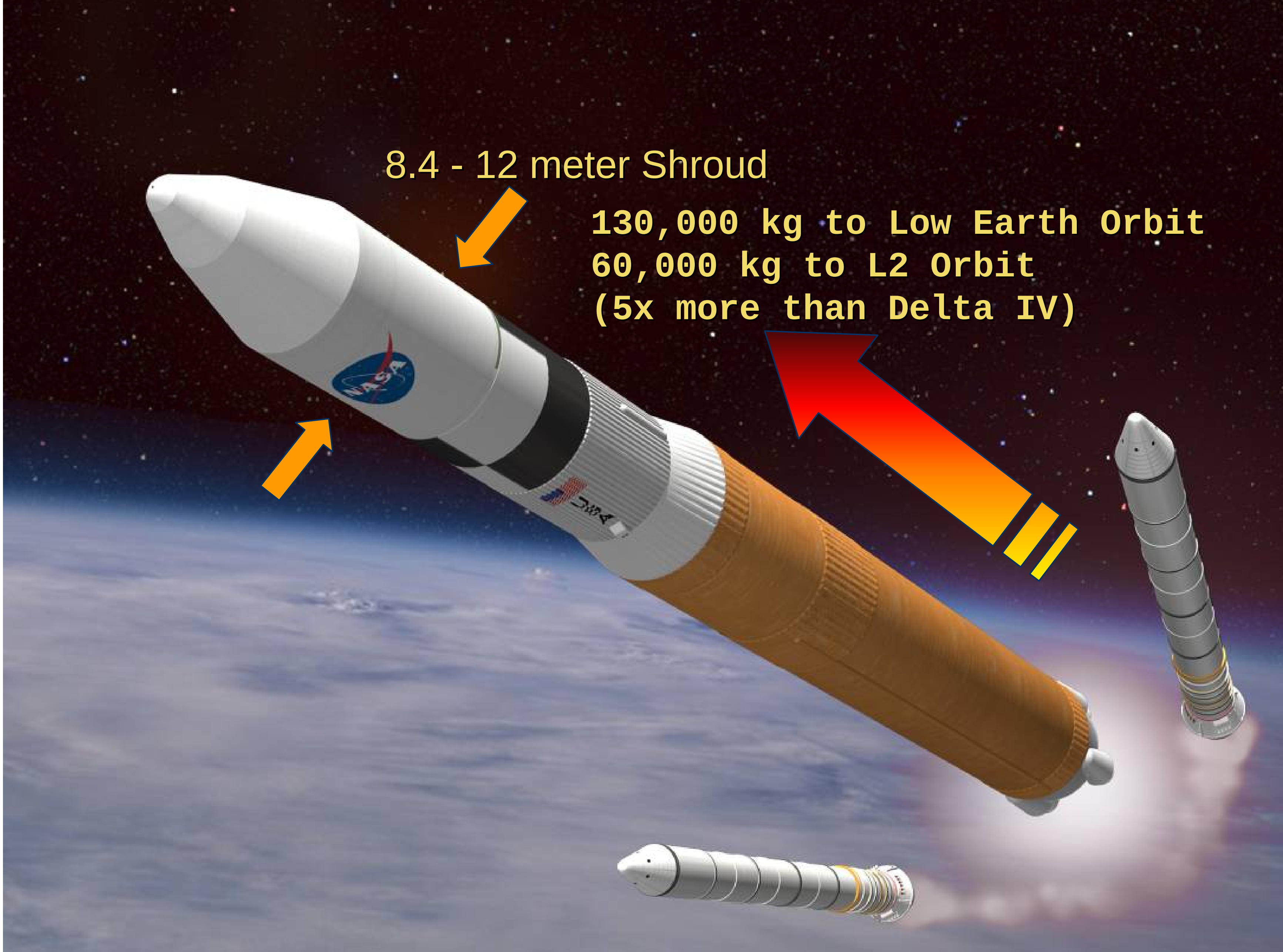
NOV 28-30, 2006



1. An exciting and sustaining scientific vision
2. A subsidized launch and transportation system,
3. The ability to re-new the telescope and instruments through a servicing infrastructure

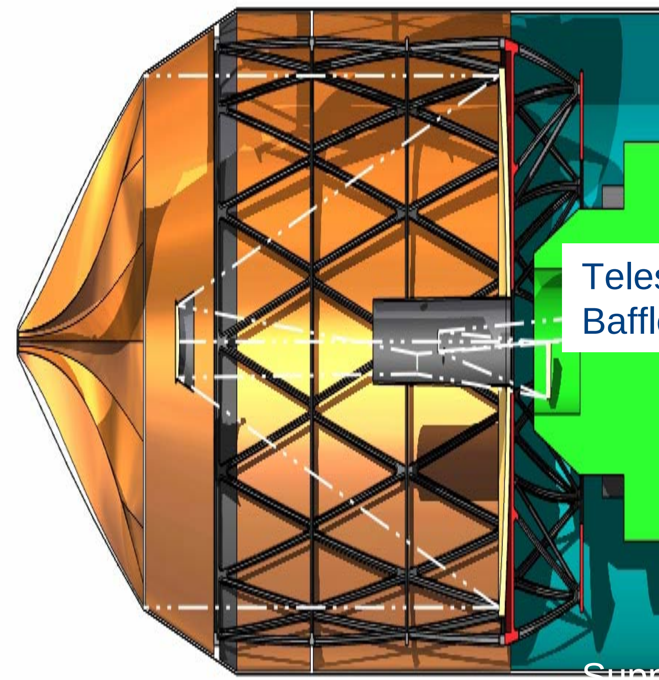
SPACE TELESCOPE SCIENCE INSTITUTE
Operated for NASA by AURA

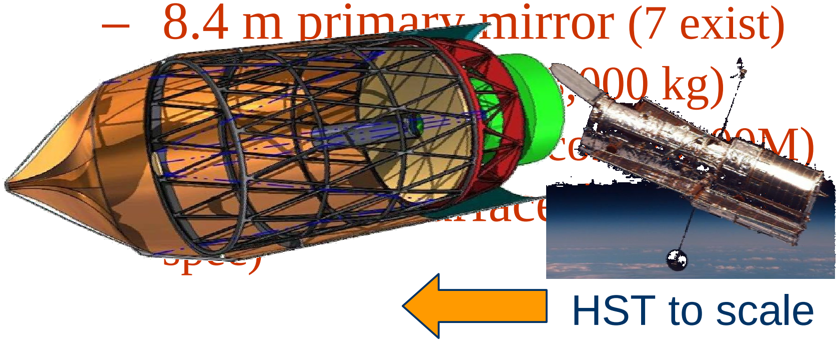
Ares V Cargo Launch Vehicle



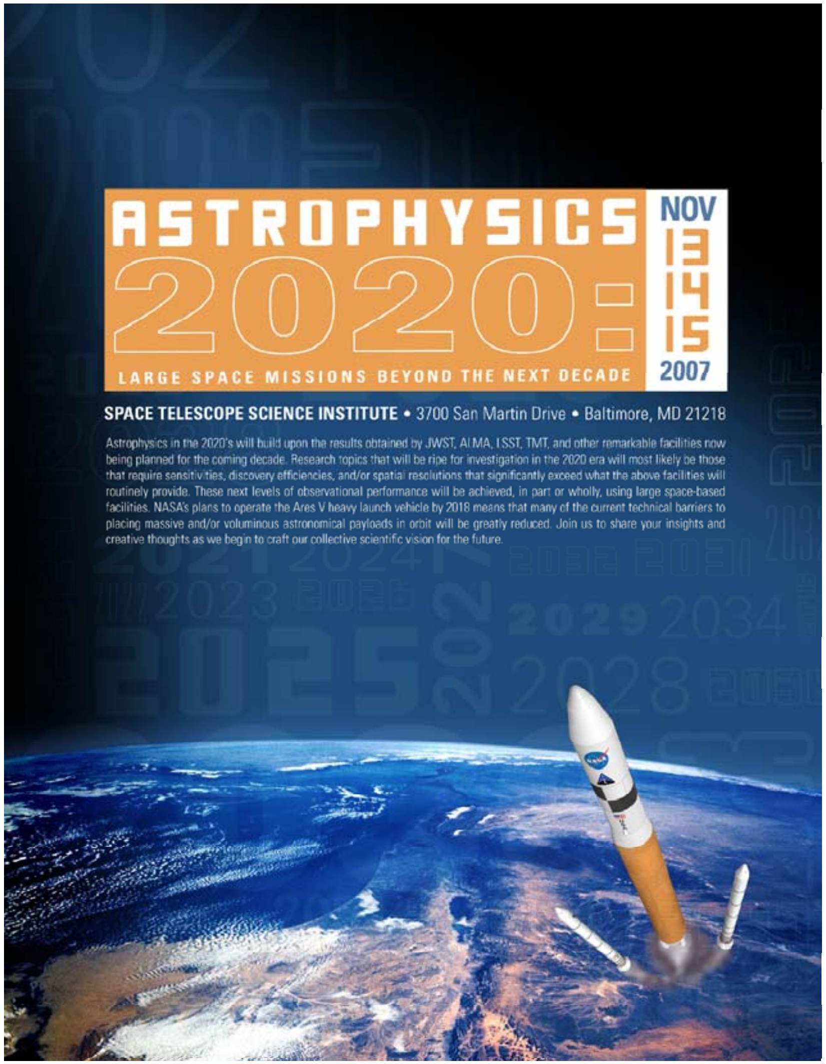
Design Concept

- 6 to 8 meter Monolithic Telescope with full baffle tube can fit inside the dynamic envelope of Ares V 8.4 to 12 meter shrouds. (larger sizes if asymmetric aperture is used)
- Reduce cost (& risk) by using existing ground-based telescope mirror technology.
  - A 6 - 8 meter 175 mm thick meniscus primary mirror can survive Ares V launch.
  - 8.4 m primary mirror (7 exist)





Astrophysics 2020: Large Space Missions Beyond the Next Decade



November 13-15, 2007, STScI

Summary

- HST has had a great impact on European astronomy (in a broad sense) —FACT
- HST will continue to have a great impact on European astronomy (in a broad sense)—a fearless prediction
- JWST will have a great impact on European astronomy (in a broad sense) —an even more fearless prediction