NASA's Great Observatories
The View from HQ

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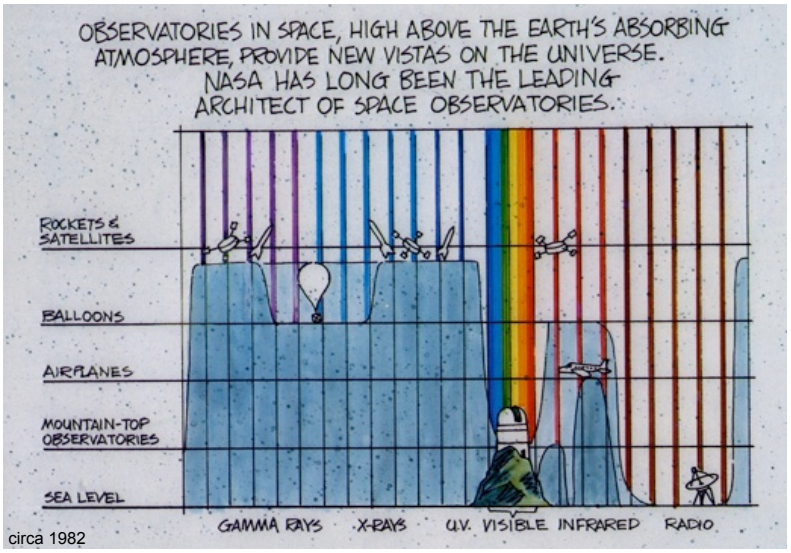
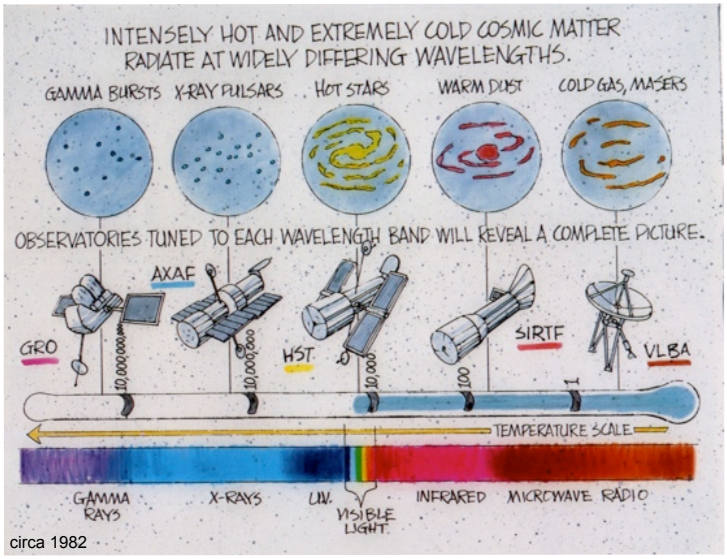
Why four of them!?



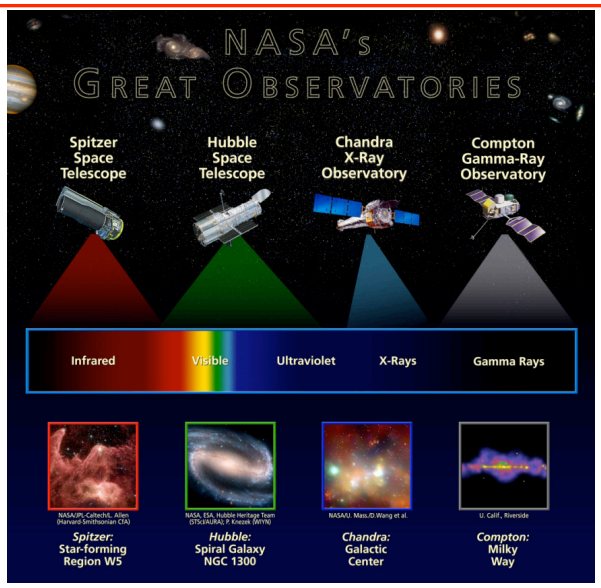
circa 1982

In *circa* 1980, this is what we wanted…



circa 1982

…and starting in 1990 this is what we got.



NASA's Great Observatories - Technical

Hubble Space Telescope (HST) - Launched April 25, 1990.
-- spectroscopy, imaging, and coronagraphy
-- UV, Optical, near IR (1100Å < λ < 2.5μ)

Compton Gamma-ray Observatory (CGRO) - Launched April 5, 1991. Deorbited June 4, 2000.
-- spectroscopy, imaging
-- γ-rays (shorter than 1Å: 30 keV - 30 GeV)

Chandra X-ray Observatory (CXO, aka AXAF) - Launched July 19, 1999.
-- spectroscopy, imaging
-- X-rays (1 - 125Å, 0.1 keV - 10 keV)

Spitzer Space Telescope (SST, aka SIRTF) - Launched Aug 25, 2003.
-- spectroscopy, imaging
-- intermediate and far IR (3.6μ - 160μ)

Original Objectives: To answer the questions…

- How did the Universe form and evolve into its present form? Can we learn the basic laws of physics from this era of formation? What is H_0?
  (✓ HST, CGRO, CXO, SST)
- How did galaxies and clusters of galaxies form?
  (partly -- HST, CXO, SST. JWST will continue studies.)
- Can massive stars, or cores of galaxies form black holes? Are black holes the sources driving quasars and AGN's?
  (✓ CGRO, CXO, HST)
- How do stars form, evolve, and die? Do SNR's cause new star formation? What is the relationship between stars and gas? Are magnetic fields involved?
  (✓ HST, CGRO, CXO, SST)
- How are planets formed? How many, and what types of stars form planets? How did life start, and are we alone?
  (partly -- SST, HST. JWST will answer more.)

(✓ Done)

… but now we have new questions

As time has gone on, we have answered some of the questions posed previously, but we now have new ones…

What is the nature of dark matter? What is the nature of dark energy?

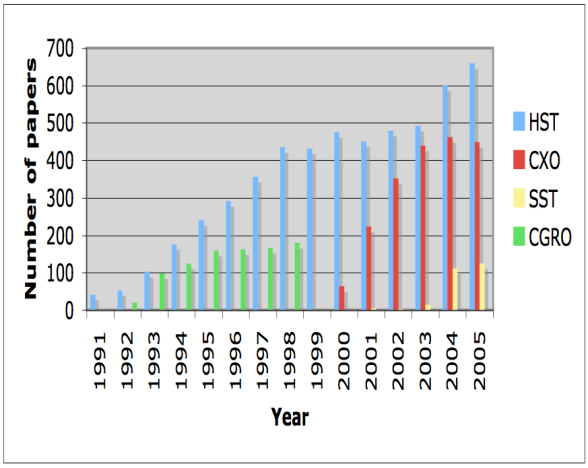
Do black holes evolve? What does their existence imply for the SFR and galaxy evolution? What are the parameters of galaxy and star formation (*i.e.* IMF)? Is there really feedback in AGNs and galaxies?

What are the origins of KBOs?; How common are they?; Do they hold implications for planetary systems beyond the Solar System? What about planetary disks?

You tell us (NASA)…

<u>The</u> Question, you know…; Life, The Universe,… Everything!…

Science Pay-off: Peer Reviewed Papers

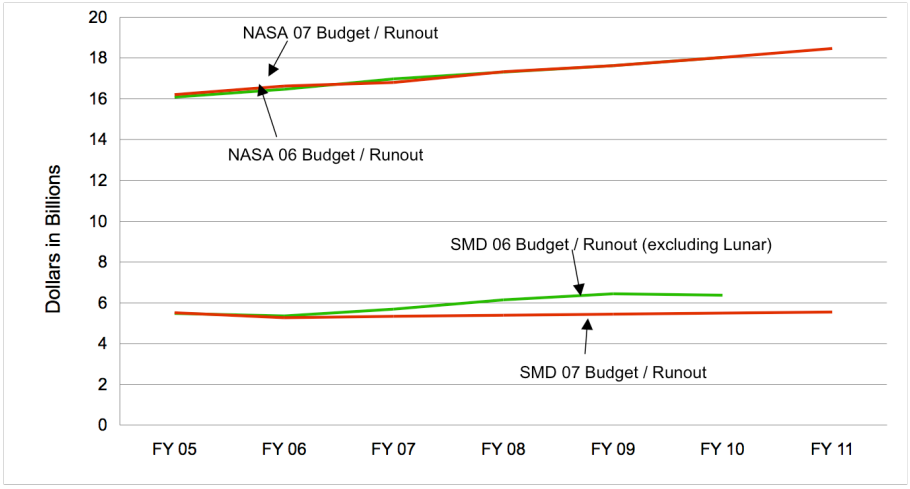


World-wide the number of peer-reviewed science papers from the three Great Observatories is over 1,200 papers a year with no indication of a decline.

Astrophysics Division
Operating Missions Status

	Launch/EOM	Mar	Apr	May	STATUS
HST (Extended)	4-25-90 2010	G	G	G	Battery charge tests on-going:analysis complete by July. Battery 2 tested with similar results to #6 (slight increase in capacity)
Rossi XTE (Extended)	12-30-95 2-28-09	G	G	G	
FUSE (Extended)	6-24-99 9-30-08	G	G	G	
Chandra (Extended)	7-19-99 7-19-10	G	G	G	
XMM-Newton (Extended)	12-9-99 9-30-10	G	G	G	
HETE-2 (Ext-Extended)	10-8-00 12-31-05	G			
WMAP (Extended)	6-30-01 9-30-09	G	G	G	
Integral (Extended)	10-17-02 9-30-10	G	G	G	
GALEX (Extended)	4-28-03 9-30-10	G	Y	Y	FUV detector 'short" in channel, similar to last year's event started 3/30. Team cycling HV to recover operation.
Spitzer (Prime)	8-25-03 5-25-06	G	G	G	Safe mode occurred 5/8 when star tracker saturated on v. bright object (V~1.8) Recovery finished up 5/12 without incident. Bright object checking instituted. 51 hrs.
GP-B (DA mode)	4-20-04 8-30-05	G	G	G	
Swift (Prime)	11-20-04 9-30-10	G	G	G	Swift in safe mode May 5-7 due to star tracker anomaly (cause understood)
Suzaku (Prime)	7-9-05 9-30-10	G	G	G	

FY06 *vs.* FY07 Budget Comparison



Follow the Money - FY07 NASA Budget ($M)

	FY 05	FY 06	FY 07	FY 08	FY 09	FY 10	FY 11
Total NASA	**$16,196.4**	**$16,623.0**	**$16,792.3**	**$17,309.4**	**$17,614.2**	**$18,026.3**	**$18,460.4**
Science	$5,501.6	$5,253.7	$5,330.0	$5,383.1	$5,437.1	$5,491.5	$5,546.4
Solar System Exploration	$1,720.5	$1,582.3	$1,610.2	$1,598.6	$1,840.4	$1,899.6	$1,846.7
Astrophysics	$1,474.9	$1,507.9	$1,509.2	$1,500.9	$1,307.9	$1,276.1	$1,309.7
Earth-Sun System	$2,306.2	$2,163.5	$2,210.6	$2,283.7	$2,288.9	$2,315.8	$2,390.0
Exploration Systems	$2,209.3	$3,050.1	$3,978.3	$3,981.6	$4,499.8	$5,055.9	$8,775.1
Constellation Systems	$422.3	$1,733.5	$3,057.6	$3,067.6	$3,612.9	$4,083.8	$7,698.4
Exploration Systems R & T	$898.9	$692.5	$646.1	$632.2	$605.1	$679.2	$764.6
Human Systems R & T	$888.1	$624.1	$274.6	$281.8	$281.8	$292.8	$312.1
Aeronautics Research	$962.0	$884.1	$724.4	$731.8	$732.4	$722.8	$722.7
Space Operations	$7,114.4	$6,869.7	$6,234.4	$6,680.4	$6,442.3	$6,242.9	$2,896.7
Space Shuttle	$5,049.2	$4,777.5	$4,056.7	$4,087.3	$3,794.8	$3,651.1	$146.7
International Space Station	$1,591.3	$1,753.4	$1,811.3	$2,200.3	$2,255.6	$2,197.1	$2,360.8
Space and Flight Support (SFS)	$473.9	$338.8	$366.5	$392.8	$392.0	$394.7	$389.2
Inspector General	$31.3	$32.0	$33.5	$34.6	$35.5	$36.4	$37.3
Cross-Agency Support Programs	$377.8	$533.5	$491.7	$497.9	$467.1	$476.8	$482.2
Education Theme	$178.9	$162.4	$153.3	$152.4	$153.1	$154.0	$153.3
Advanced Business Systems (IEMP)	$0.0	$156.3	$108.2	$106.9	$73.8	$78.5	$80.6
Innovative Partnership Programs	$198.9	$214.8	$197.9	$205.5	$206.2	$209.7	$212.9
Shared Capability Assets Program	$0.0	$0.0	$32.2	$33.1	$33.9	$34.7	$35.5

Budget Comparison by Theme

	FY06	FY07	FY08	FY09	FY10	FY11	Total Changes
Total Science							
FY 06 President's Budget, excluding Lunar	5,341.7	5,684.2	6,132.0	6,436.8	6,370.7		
FY 07 President's Budget	5,253.7	5,330.0	5,383.1	5,437.1	5,491.5	5,546.4	
Changes	-88.0	-354.2	-748.9	-999.7	-879.2		-3,070.0
Earth-Sun Systems							
FY 06 President's Budget	2,063.6	2,081.2	2,132.2	2,359.0	2,324.8		
FY 07 President's Budget	2,163.5	2,210.6	2,283.7	2,288.9	2,315.8	2,390.0	
Changes	99.9	129.5	151.5	-70.2	-9.0		301.8
Solar System Exploration							
FY 06 President's Budget, excluding Lunar	1,765.9	2,071.5	2,460.5	2,582.7	2,639.2		
FY 07 President's Budget	1,582.3	1,610.2	1,598.6	1,840.4	1,899.6	1,846.7	
Changes	-183.6	-461.4	-861.9	-742.4	-739.6		-2,988.8
Astrophysics							
FY 06 President's Budget	1,512.2	1,531.5	1,539.4	1,495.0	1,406.7		
FY 07 President's Budget	1,507.9	1,509.2	1,500.9	1,307.9	1,276.1	1,309.7	
Changes	-4.3	-22.3	-38.5	-187.2	-130.6		-382.9

Astrophysics: Content of FY07 Budget

	FY06	FY07	FY08	FY09	FY10	FY11
FY 07 President's Budget	1,507.9	1,509.2	1,500.9	1,307.9	1,276.1	1,309.7
Navigator	145.5	128.1	170.6	276.9	261.6	347.0
SIM	117.0	98.5	139.0	236.2	222.5	302.2
Keck Interferometer / Single Aperture	9.6	10.2	9.6	8.4	7.0	7.0
TPF	3.4					
Corporate / Other	15.5	19.4	22.0	32.3	32.1	37.8
James Webb Space Telescope	364.0	443.1	492.6	380.9	353.0	305.0
Hubble Space Telescope	268.6	336.7	302.2	161.4	120.3	138.5
Development	166.5	216.2	178.9	55.0	45.4	45.7
Operations and Data Analysis	87.0	102.0	106.0	97.0	68.0	85.0
Corporate	15.1	18.5	17.3	9.4	6.9	7.8
Stratospheric Observatory for Infrared Astronomy (SOFIA)	48.0					
Gamma-ray Large Space Telescope (GLAST)	125.9	85.4	25.2	28.8	29.3	30.4
Discovery (Kepler / Corporate)	137.5	100.8	69.9	13.8	13.4	13.0
Explorer (Universe)	85.4	67.6	86.1	56.7	19.0	4.6
WISE	69.7	53.9	71.7	44.8	8.8	4.3
Swift, Suzaku	10.9	10.0	9.5	8.6	9.1	
Corporate	4.8	3.7	4.9	3.3	1.1	0.3
Universe Research	305.8	306.6	309.2	297.4	288.9	259.6
Research and Analysis	65.1	54.4	54.0	56.0	53.9	55.9
Chandra	58.4	63.0	65.1	64.7	65.1	65.0
Spitzer	74.3	76.6	75.7	71.7	66.4	35.9
Other Missions / Data	68.1	71.2	70.8	59.2	58.4	59.2
Balloons	22.8	24.5	25.8	28.5	28.8	29.0
Corporate / Other	17.1	16.9	17.8	17.3	16.3	14.6
ISSC (Herschel / Planck)	13.0	19.6	23.6	38.9	38.5	36.3
Beyond Einstein	14.1	21.2	21.4	53.0	152.2	175.4

But what makes *these* Observatories great?

Each mission is individually excellent, but what makes them *truly* great, is the fact that they are *complementary*. They have archives: this makes the data accessible to *all* US astronomers, and are the legacy to the world. Total change in the way astronomy has been done in the last 16 years.

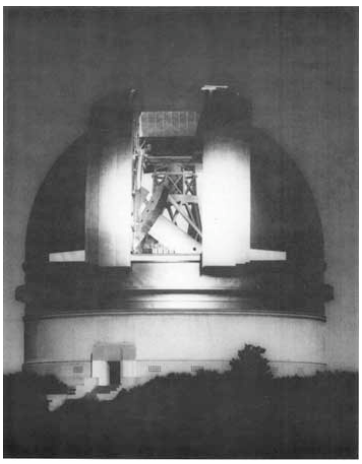
We have the privilege to work at a time when we can actually answer some of the age-old science questions, and this is impossible to conceive of the advances over the last decade without these missions. They are part of the culture.

We are now to the point where scientifically we *cannot* be parochial about the wavelengths we study. Also,we must think in an ecumenical way - *if one mission does well, they (we) all do well.*

…In the Lake Wobbegong phrase, "*All our children are above average*".

Back up

Just to get a feel for numbers…



- Palomar was conceived in the 1930's and constructed in the 1940's.
- Built using a $6M grant from the Rockefeller Foundation: in FY06 funds this is ~$86.9M: this is NOT life-cycle-costs!
- NOT a public asset: owned by Caltech.
- No instruments or data analysis included in the cost.

A happy story of Government funding!

- When proposed in the early 1970's the cost was estimated to be $76M.
- The final cost on completion in 1978 was ~$78.4M (RY) (This is now $276.6M in FY06!)

- We got it right!
  - Why?
    - No "new" technology
    - Ground-based
    - THE priority instrument of the decade