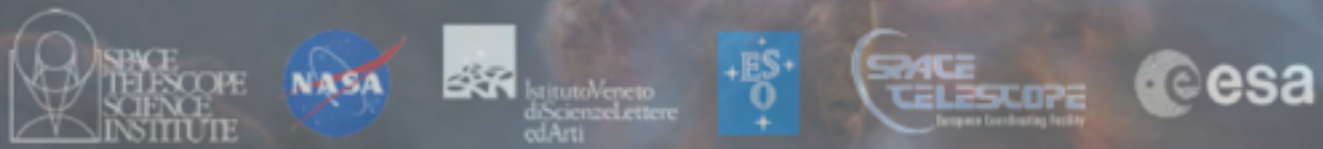
Future Prospects



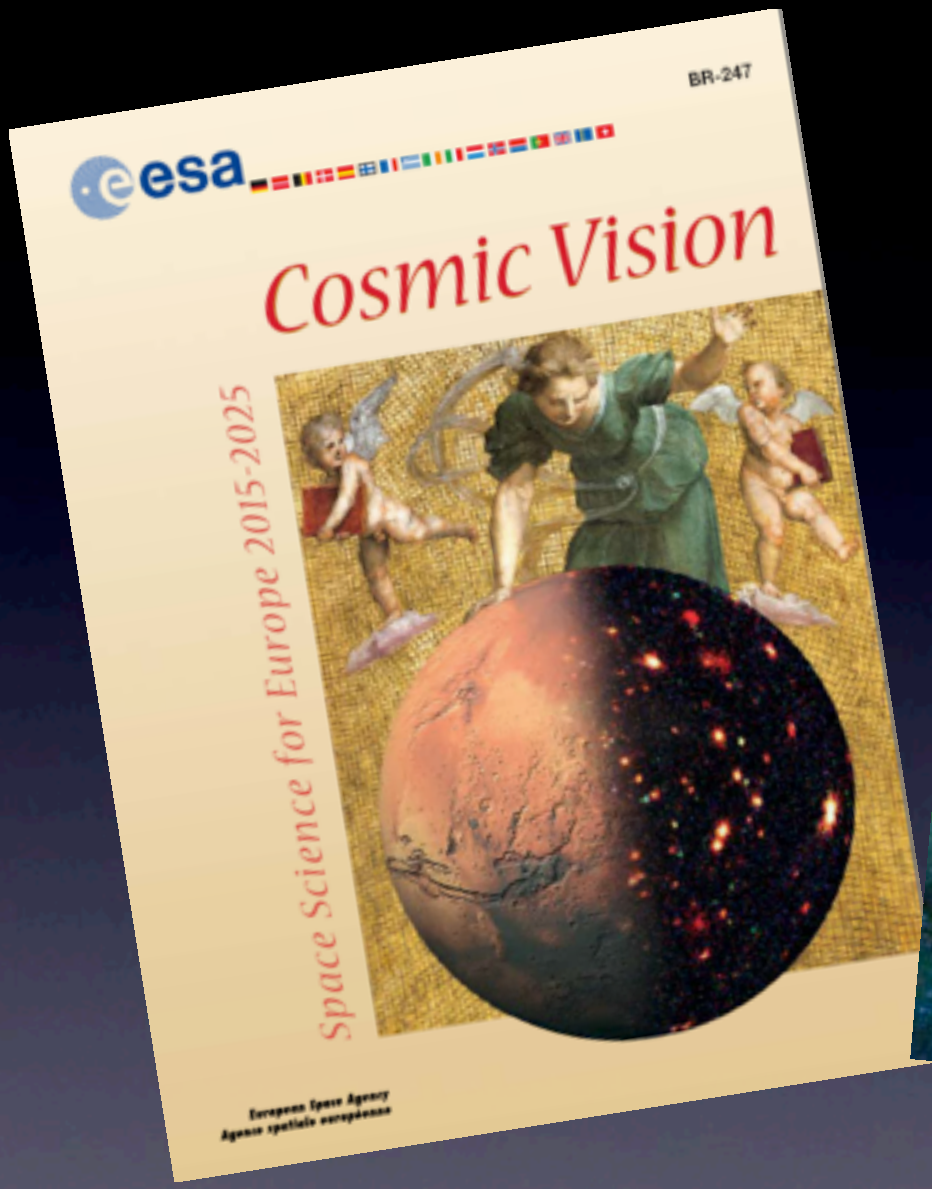
Science with the Hubble Space Telescope - III
two decades and counting

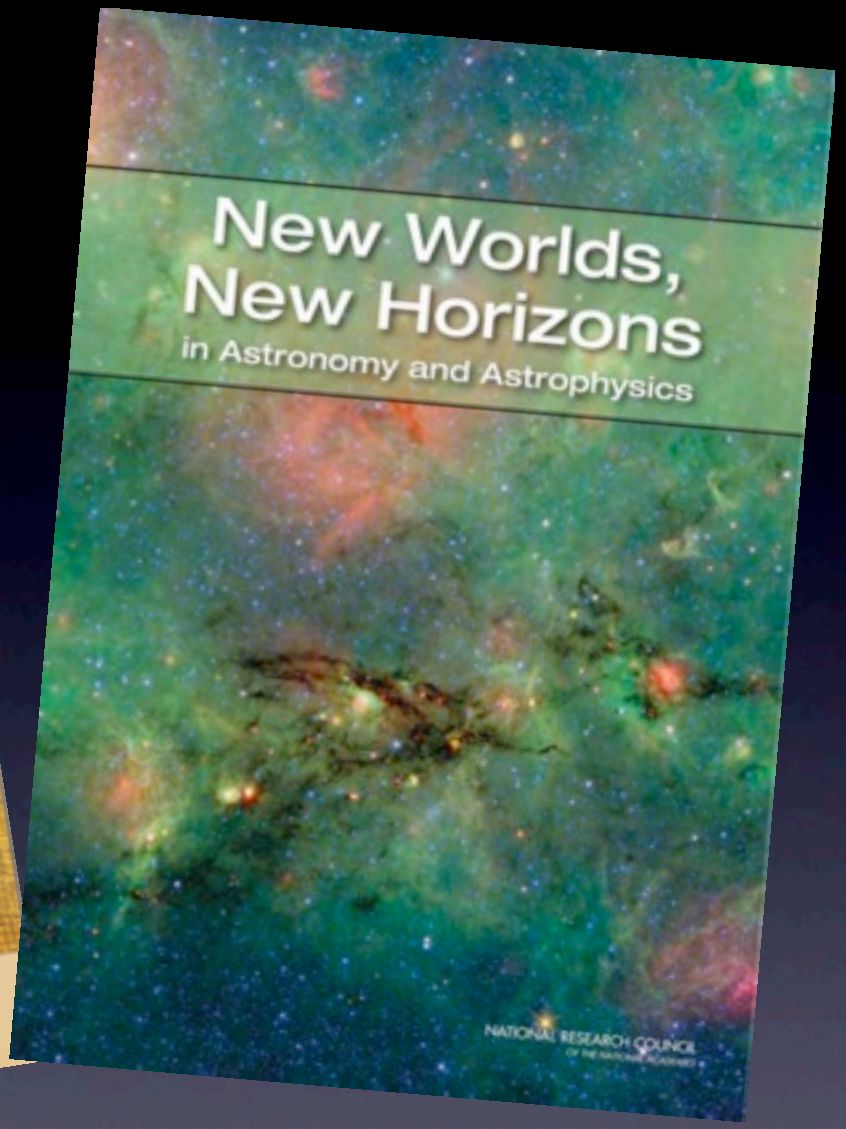
October 11-14, 2010

Matt Mountain
Space Telescope Science Institute

Future Prospects - what does a "post-HST" world look like?

- As both *"Comic Vision"* and *"New Worlds, New Horizons"* have shown - these are exciting times, though both accept "the present", both also make assumptions about the future that may not be valid
- For 400 years observational astrophysics has been photon-limited: though we are making a "detour" into wide-area surveys (which is fine)
- To make significant progress beyond this decade will unfortunately take significant investments
- Governments have other interests, and we need to recognize this or go the way of "particle physics"
- Investments in space technologies are not driven by science - its important to understand this, or go the way of "particle physics"
- Consequently models of collaboration across communities will be come increasingly important, *"The truest sign of insanity is doing the same thing again and again expecting a different result....."* *(how many times are we going to propose planet finders and separately, large UV/O telescopes - for example?)*
- Can we find common ground, which also inspires a new generation?
  - the formation of the Universe and the Search for life
  - take a technology leap, but one that mirrors "other interests"
  - collaboration rather than competition is the key for 21st Century Space Science


BR-247
esa
Cosmic Vision
Space Science for Europe 2015-2025
European Space Agency
Agence spatiale européenne


New Worlds,
New Horizons
in Astronomy and Astrophysics
NATIONAL RESEARCH COUNCIL

How did the Universe originate and what is its made of?


BR-247
esa
Vision
How did the Universe originate and what is its made of?
Trace the the life cycles of matter in the Universe along its history
Space Science
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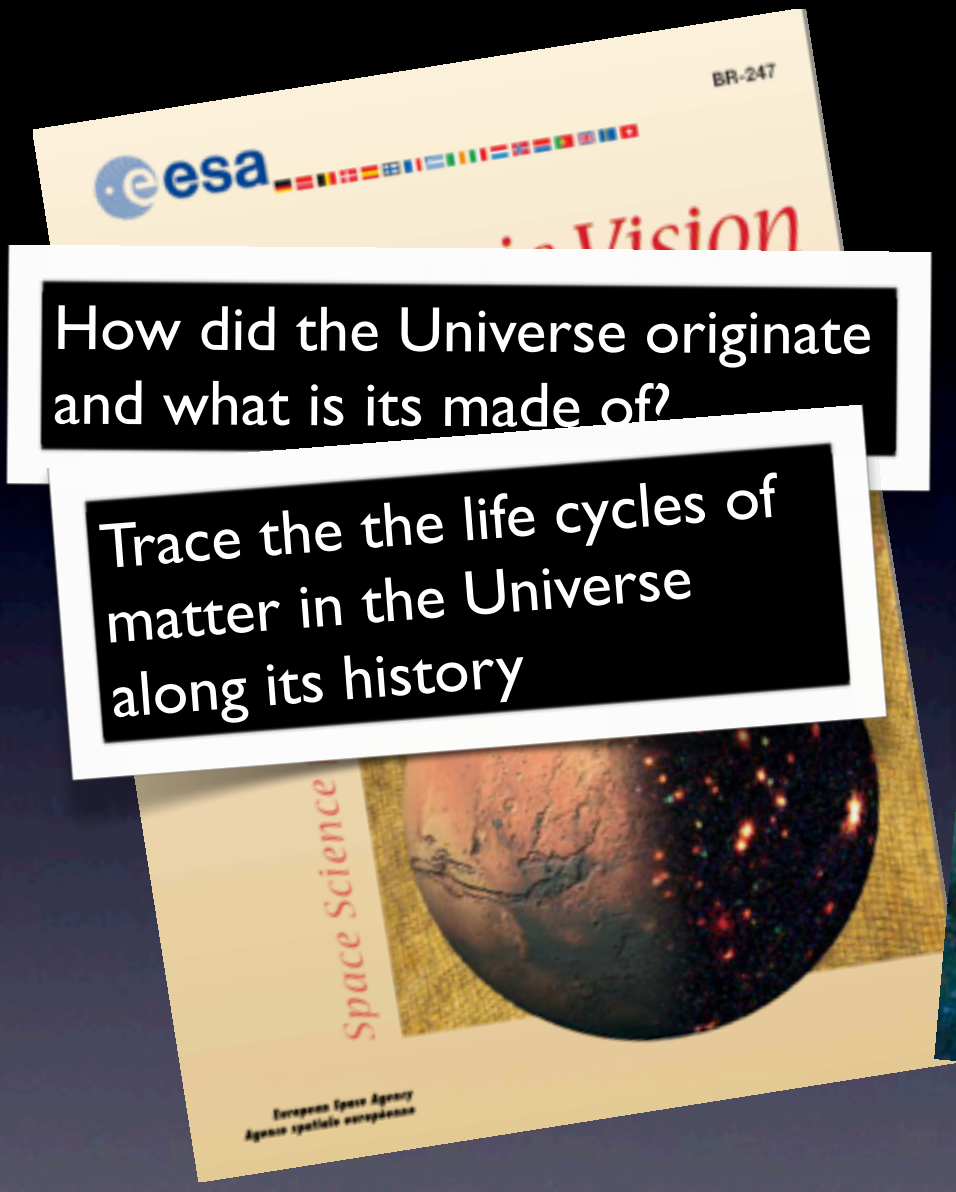
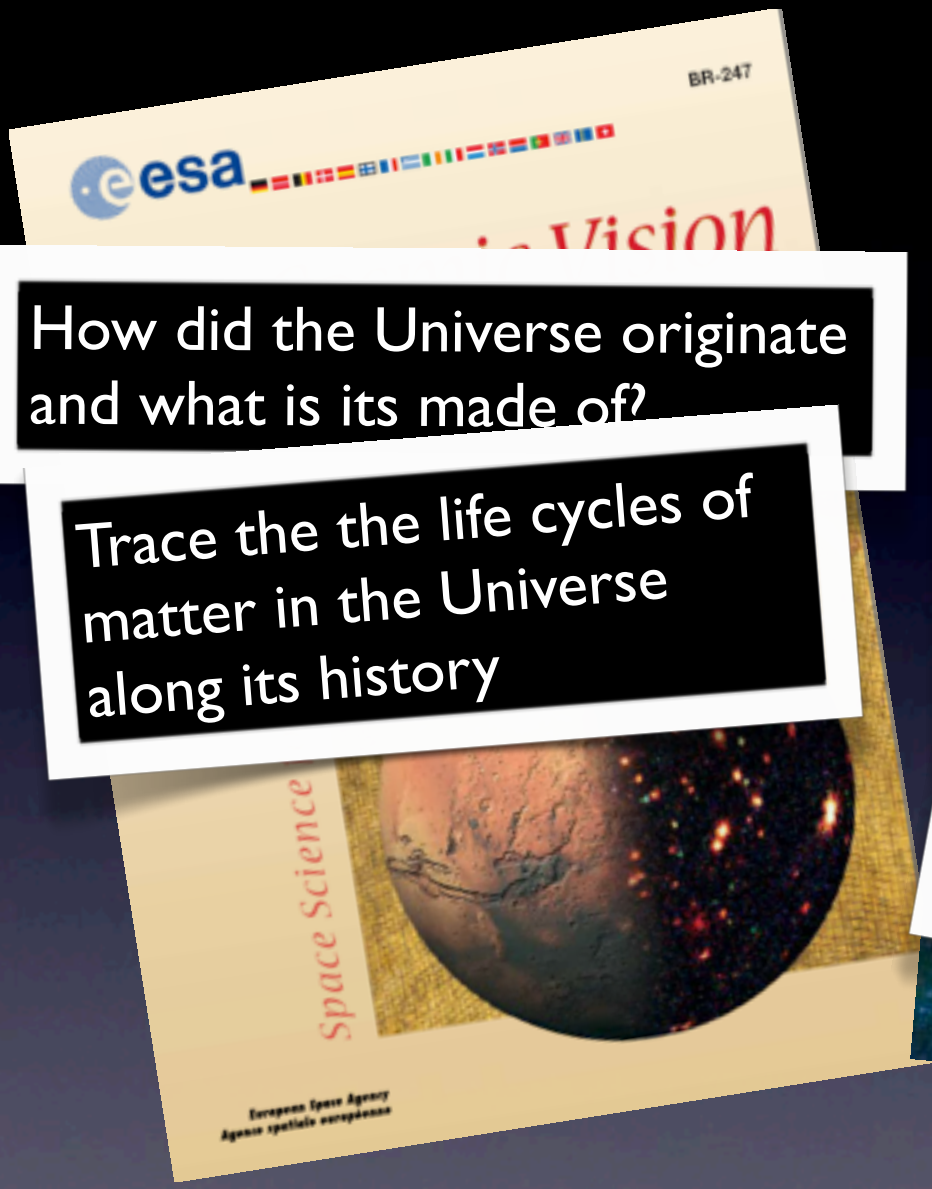


How did the Universe originate and what is its made of?

Trace the the life cycles of matter in the Universe along its history

Galaxies Across Cosmic Time:

How do Baryons cycle in and out of galaxies, and what do they do while they are there?



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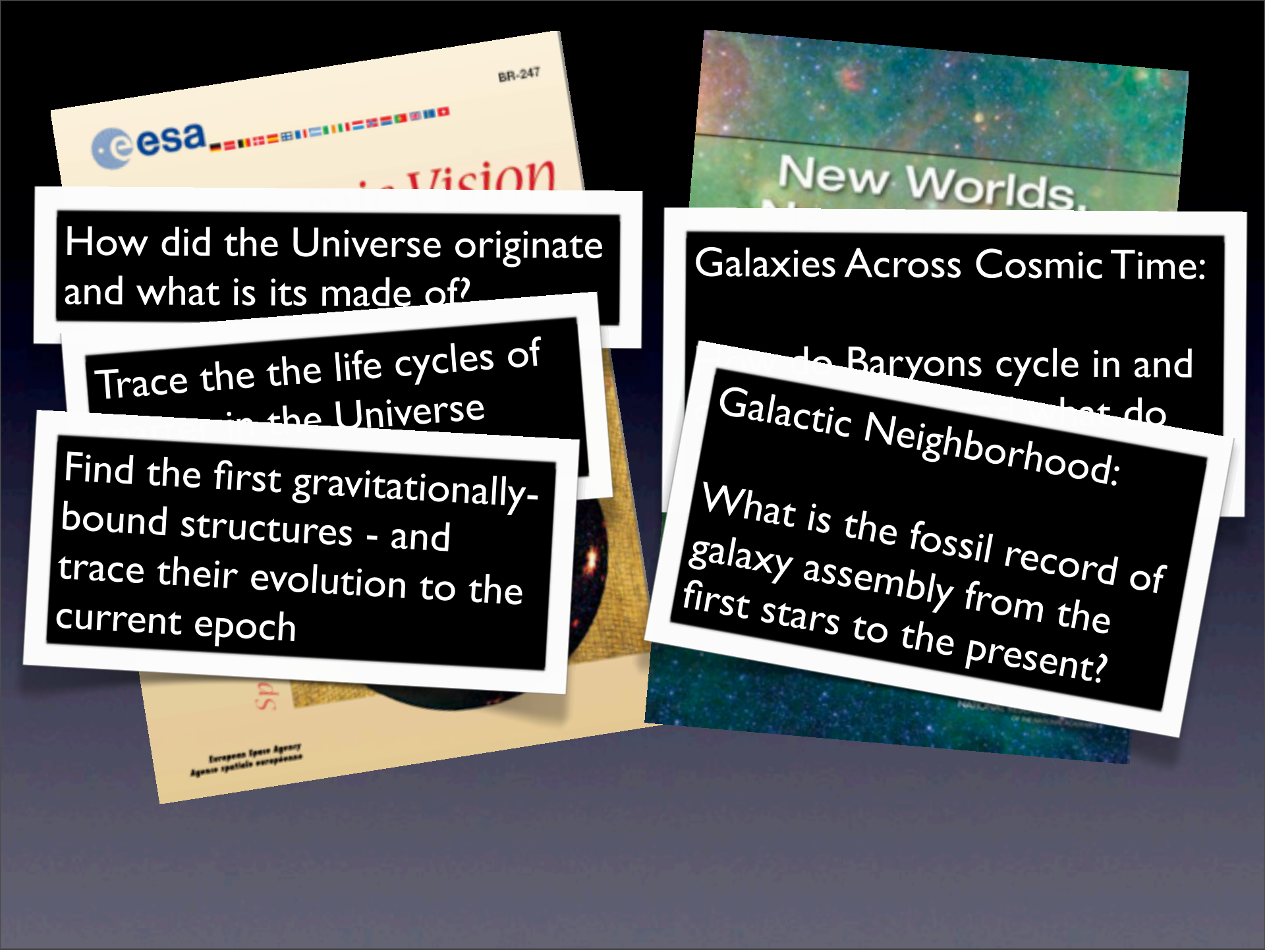
Galaxies Across Cosmic Time:

Baryons cycle in and

Galactic Neighborhood:

What is the fossil record of galaxy assembly from the first stars to the present?


BR-247
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BR-247
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Planetary systems and starformation:
Do habitable worlds exist around other stars, and can we identify the telltale signs of life on an exoplanet?

How did the Universe originate and what is its made of?

Trace the the life cycles of in the Universe

Find the first

What are the conditions for planet formation and the emergence of life?

Search for planets around starts other than the Sun, looking for biomarkers in their atmospheres and image them

Galaxies Across Cosmic Time:

Baryons cycle in and

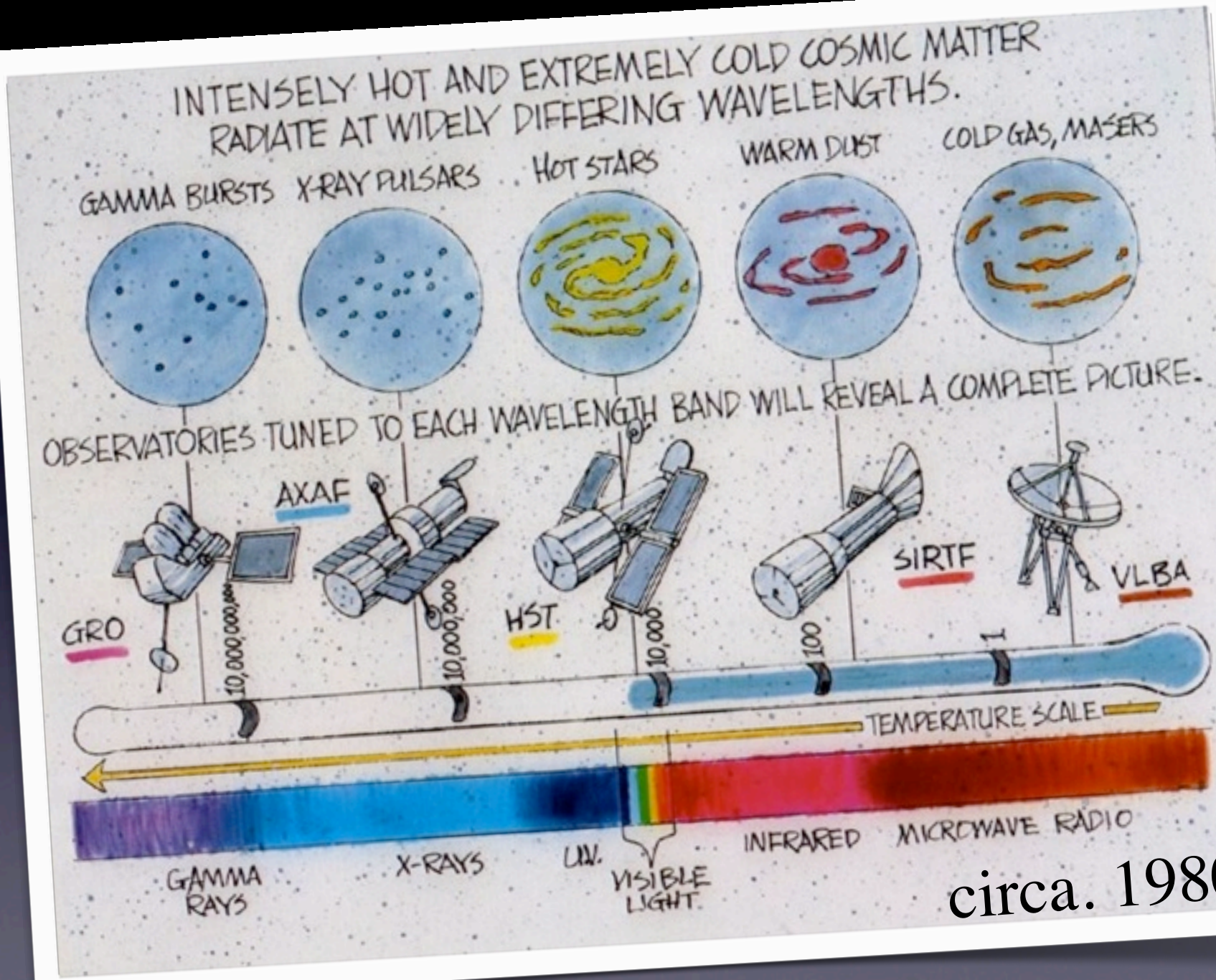
Galactic Neighborhood:

Planetary systems and starformation:

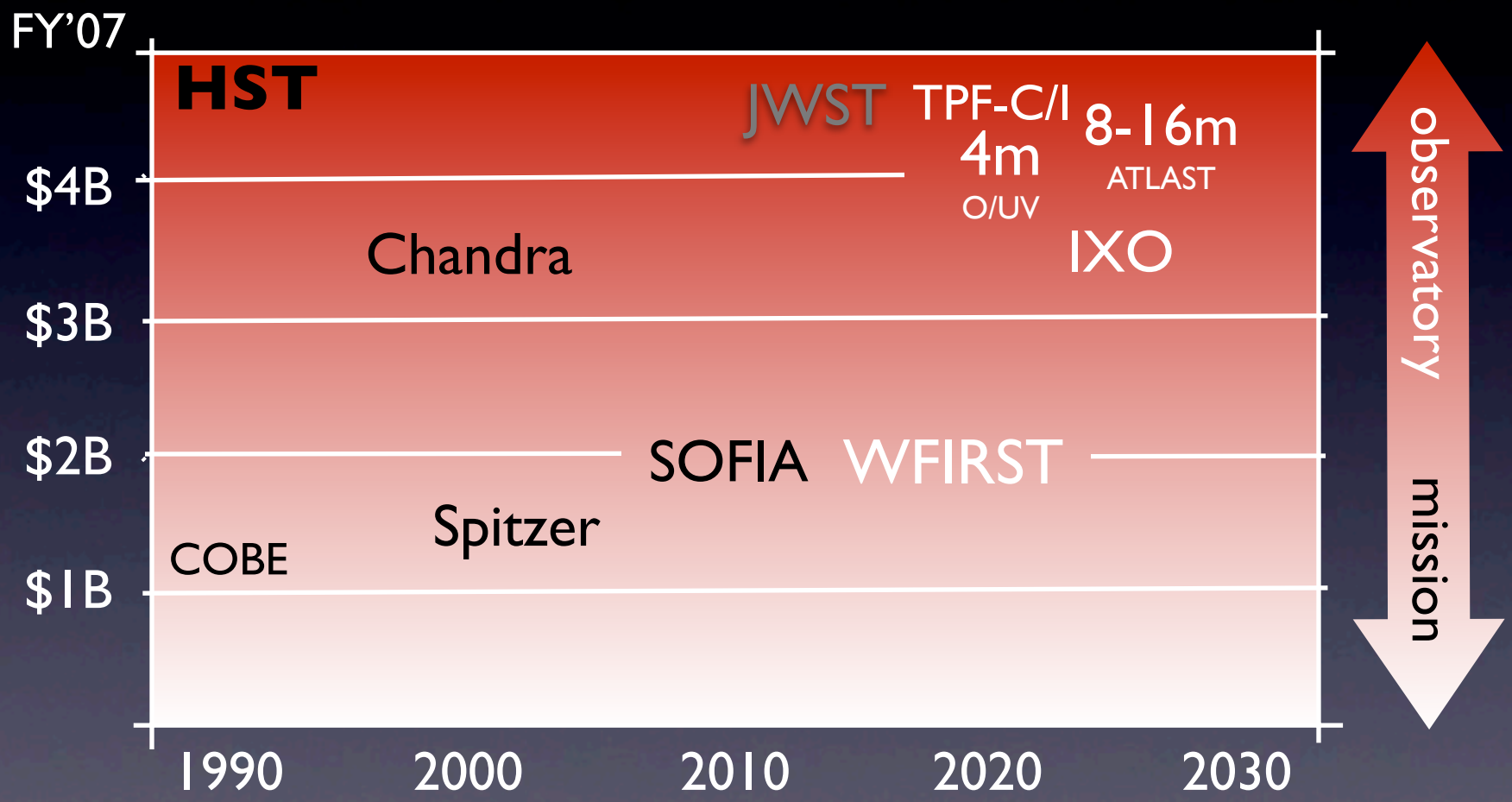
Do habitable worlds exist around other stars, and can we identify the telltale signs of life on an exoplanet?

"As civilization's universal state emerges, its people become blinded by 'the mirage of immortality'… the citizens of such universal states [and particularly their astronomers] in defiance of apparently plain facts…are prone to regard [their situation], not as a night's shelter in the wilderness, but as the Promised Land, the goal of human endeavors."

The Clash of Civilizations and Remaking of World Order, Samuel P. Huntington


INTENSELY HOT AND EXTREMELY COLD COSMIC MATTER RADIATE AT WIDELY DIFFERING WAVELENGTHS.
GAMMA BURSTS
X-RAY PULSARS
HOT STARS
WARM DUST
COLD GAS, MASERS
OBSERVATORIES TUNED TO EACH WAVELENGTH BAND WILL REVEAL A COMPLETE PICTURE.
GRO
AXAF
HST
SIRTF
VLBA
10,000,000,000
10,000,000
10,000
100
1
TEMPERATURE SCALE
GAMMA RAYS
X-RAYS
U.V.
VISIBLE LIGHT
INFRARED
MICROWAVE
RADIO
circa. 1980

NASA flagship cost and 'expectations'



huge competition for the few slots in the top-right corner

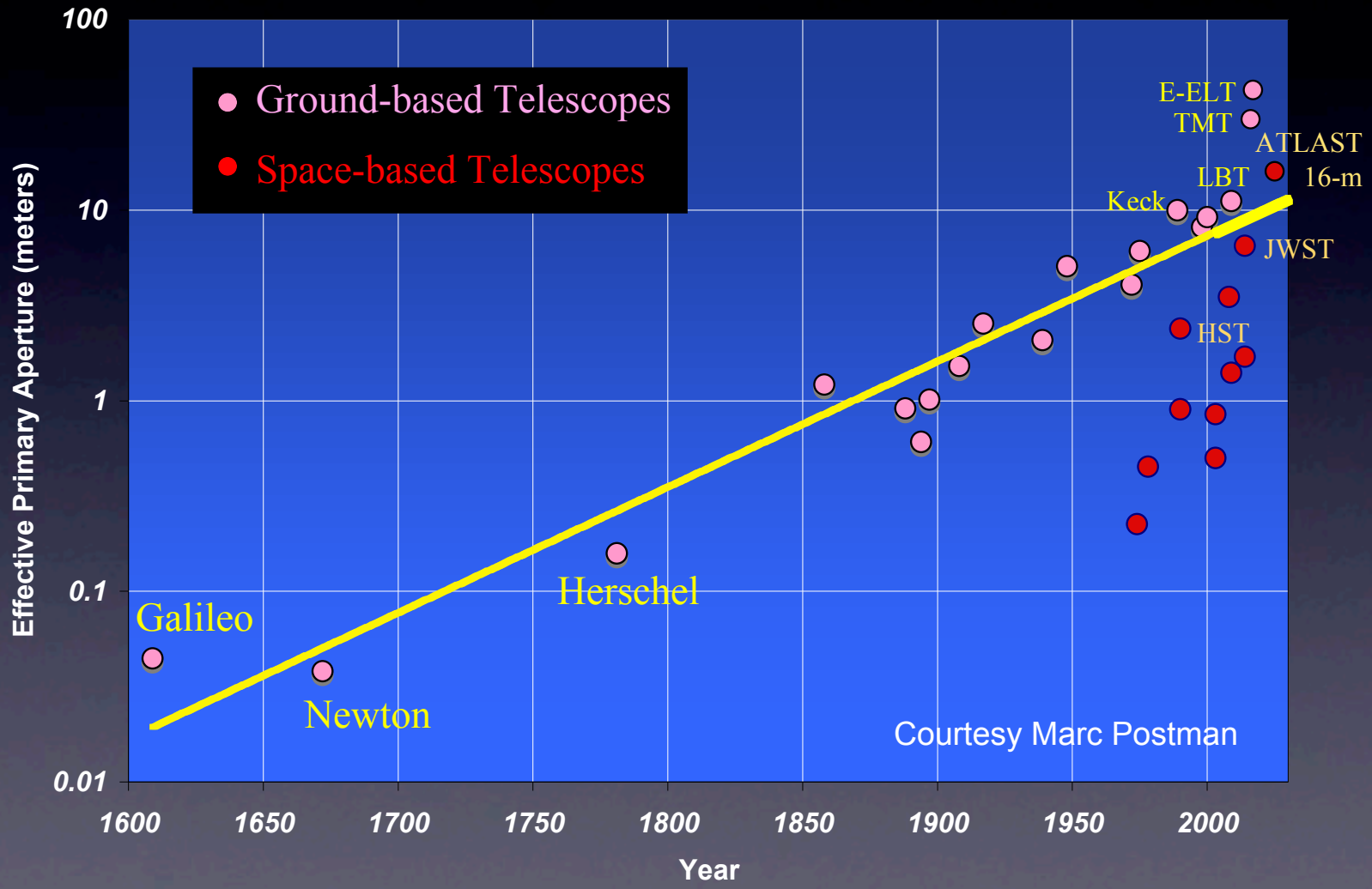
observational astrophysics will continue to be photon limited

$$\frac{\text{Signal}}{\text{Noise}} \propto \frac{\text{Telescope Diameter}}{\text{Image size}} \times \sqrt{\frac{QE_\lambda}{B_\lambda}}$$

QE = detector quantum efficiency	~ 100%
B = sky, telescope background	~ low in space
Image size, over large FOV	~ small in space

hence there is a continuing and compelling case for large apertures in space

Over 400 hundred years telescope aperture driven by science and technological maturity



Primary Telescope Aperture vs. Time

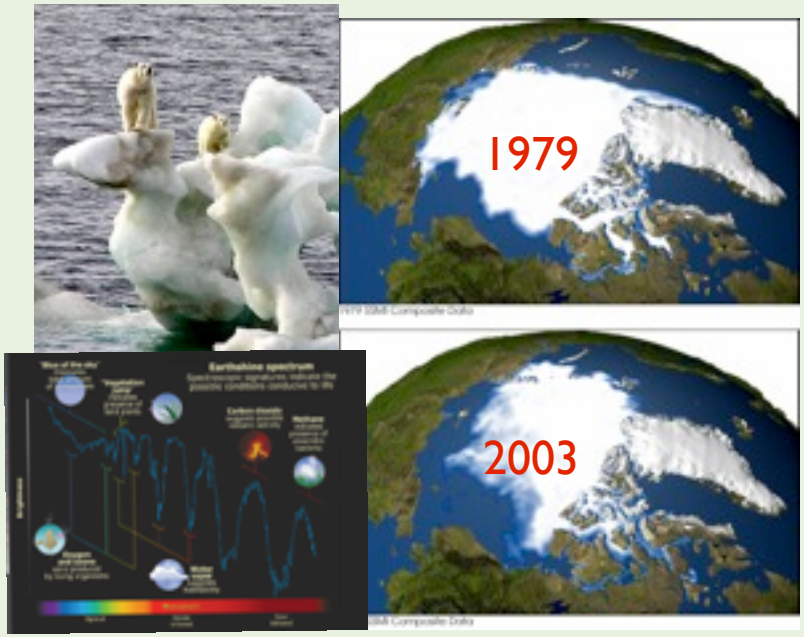
We need …the right balance between manned space exploration and robotic space exploration. We need to manage the balance between looking up and looking down…

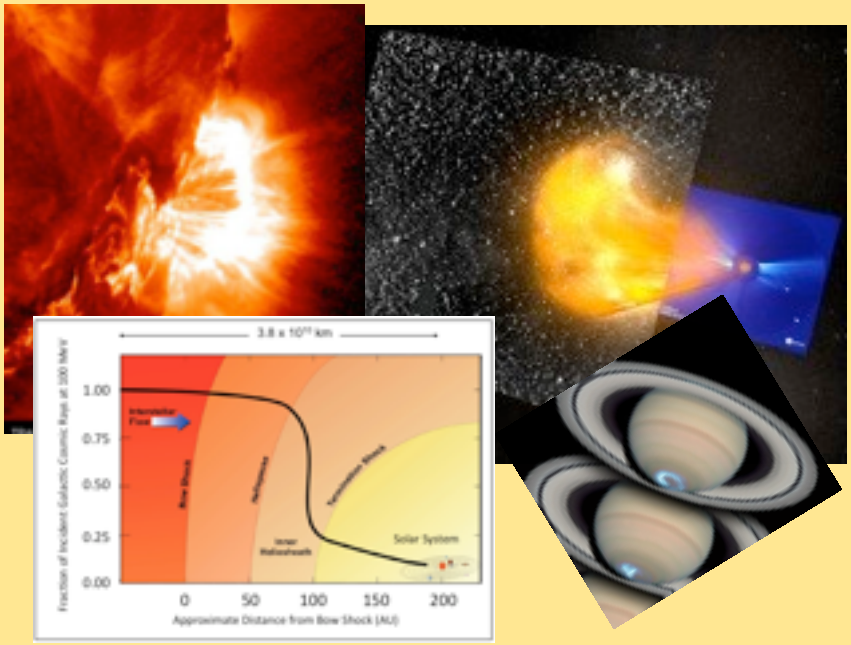
Dr. John Holdren, US Presidential Science Advisor

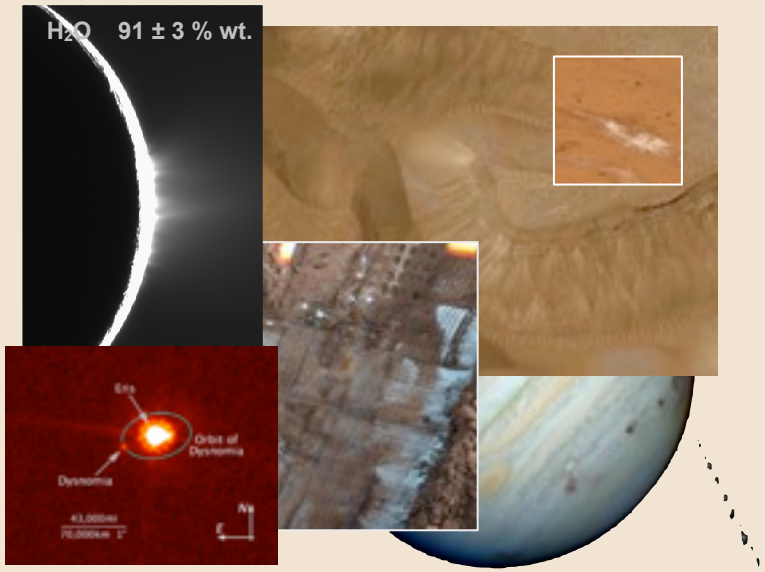
We need some of the bright people in Particle Physics and Astronomy to move into solving some of the more relevant problems we face..

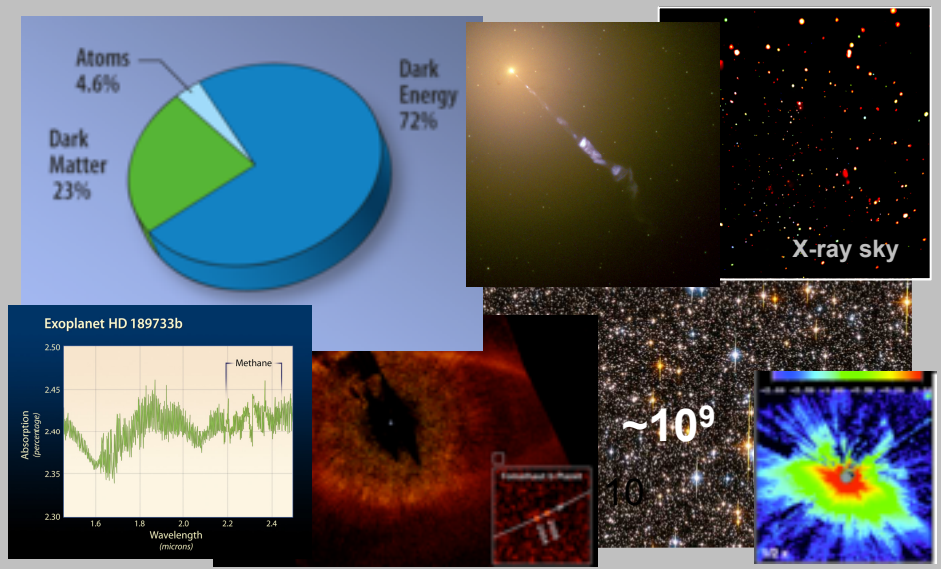
Sir David King , Chief Scientific Adviser to HM Government, 2000 - 2008

we have learnt a lot in the last 40 years from space









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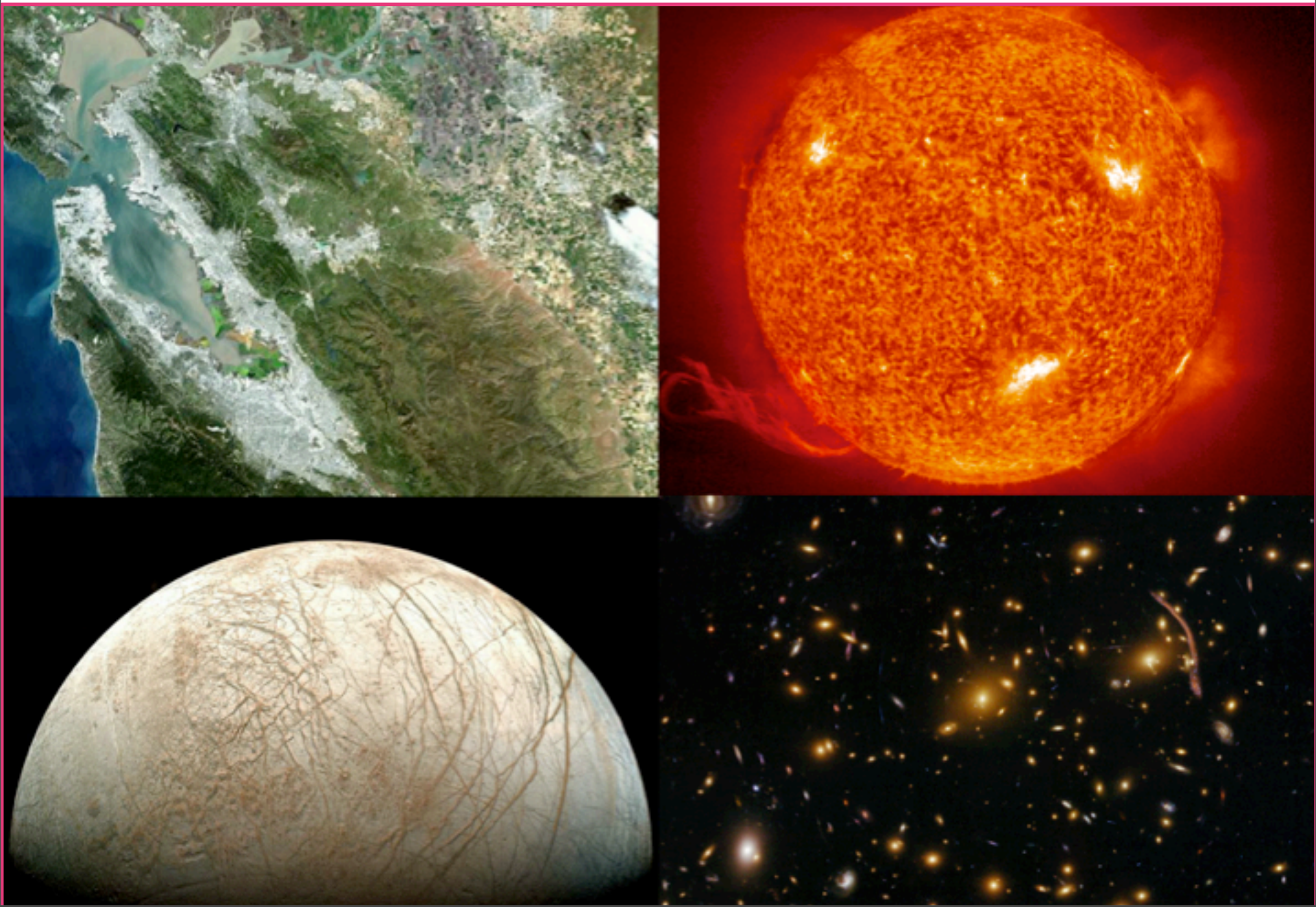
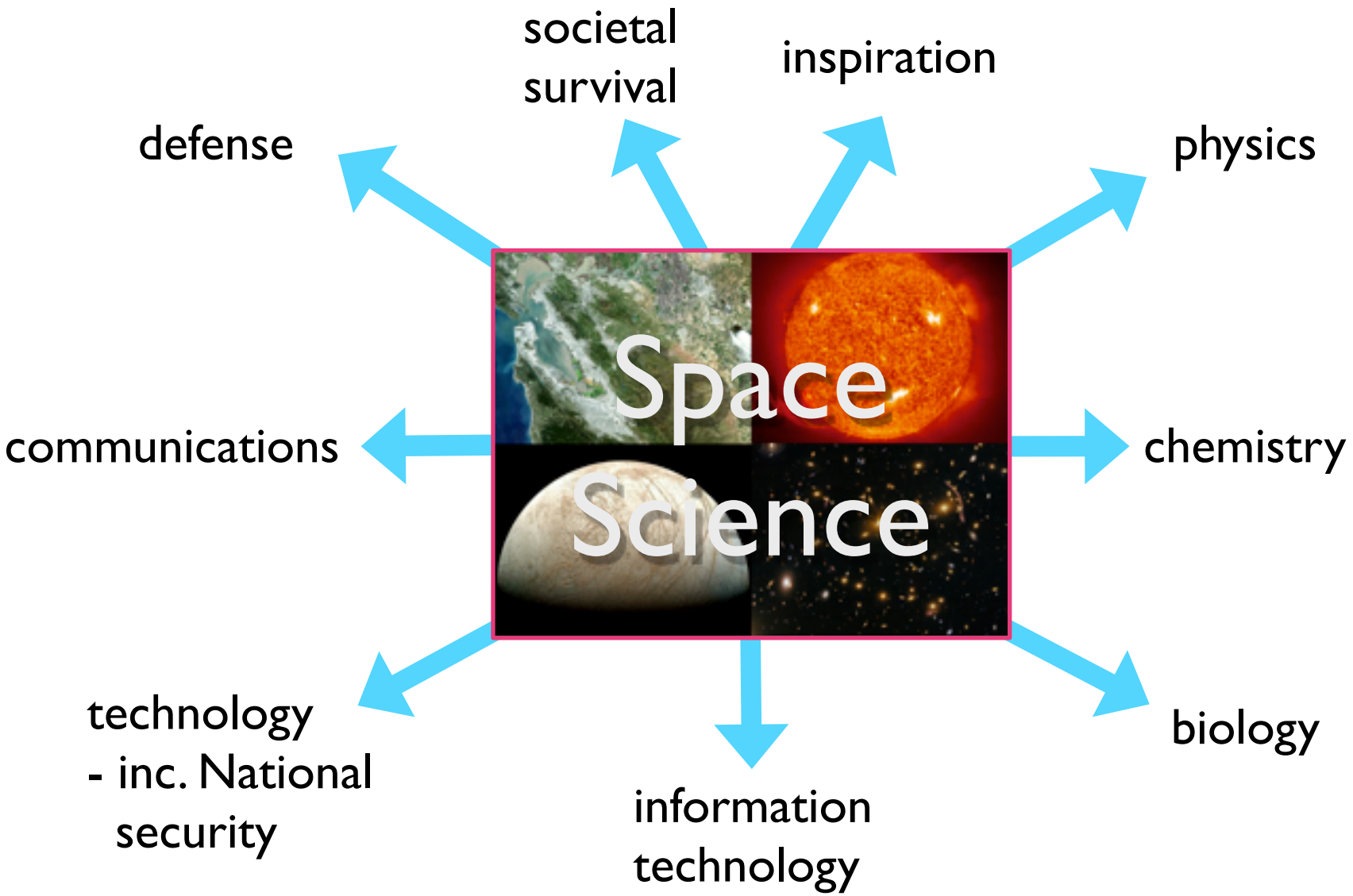
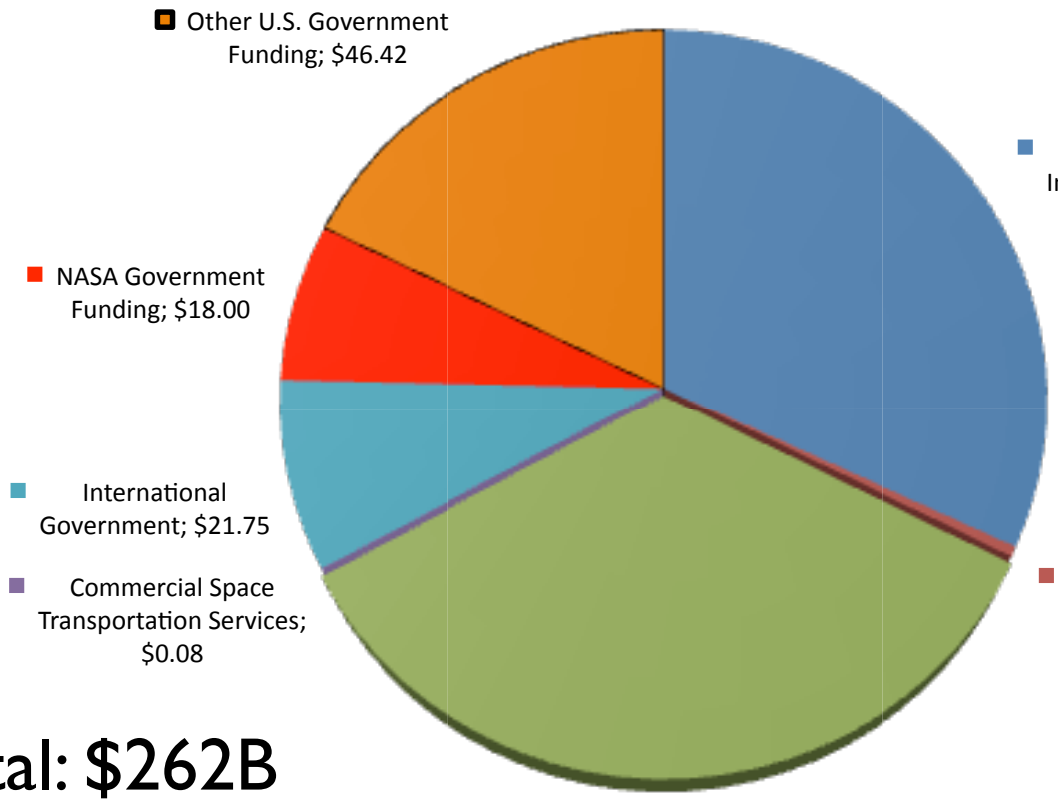


Lessons Learned from 40 years of space science:
SPACE science impacts other sciences & societal activities



The Space Foundation honors SM4 Team with *2010 Achievement Award*

Global Space Activity - source Space Foundation



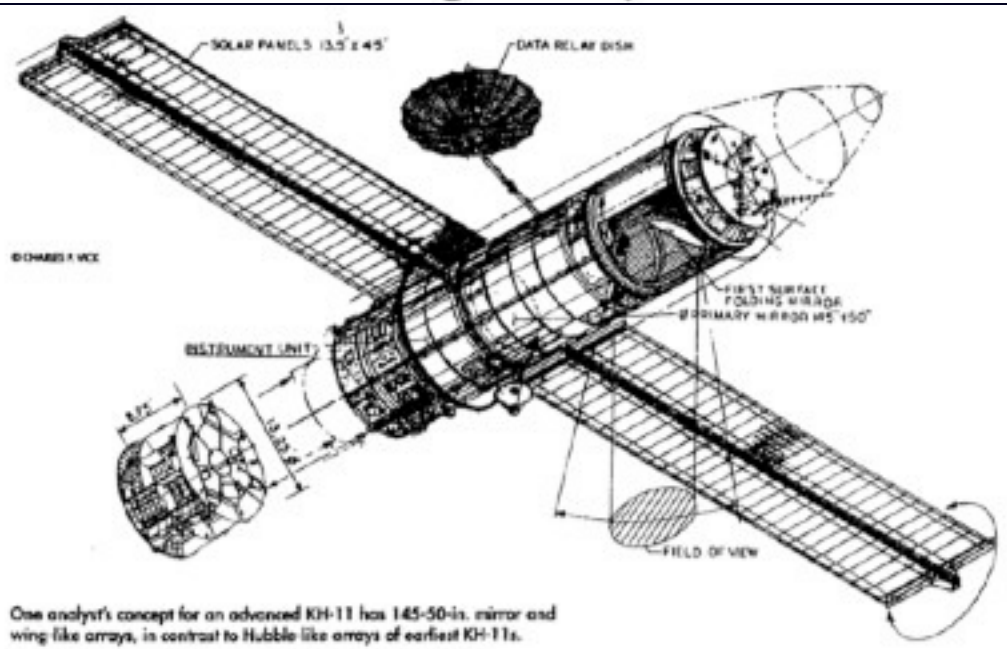
Total: $262B

NASA + ESA Science ~ 2.5%

Space Science has always built on investments made "elsewhere"

HEADLINE NEWS

Advanced KH-11 Broadens U.S. Recon Capability



One analyst's concept for an advanced KH-11 has 145-50-in. mirror and wing like arrays, in contrast to Hubble like arrays of earliest KH-11s.

24 AVIATION WEEK & SPACE TECHNOLOGY/JANUARY 6, 1997

The two main contractors that built the telescope had allegedly extensive experience building this kind of spacecraft - but not much is known publicly about these programs.

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HEADLINE NEWS

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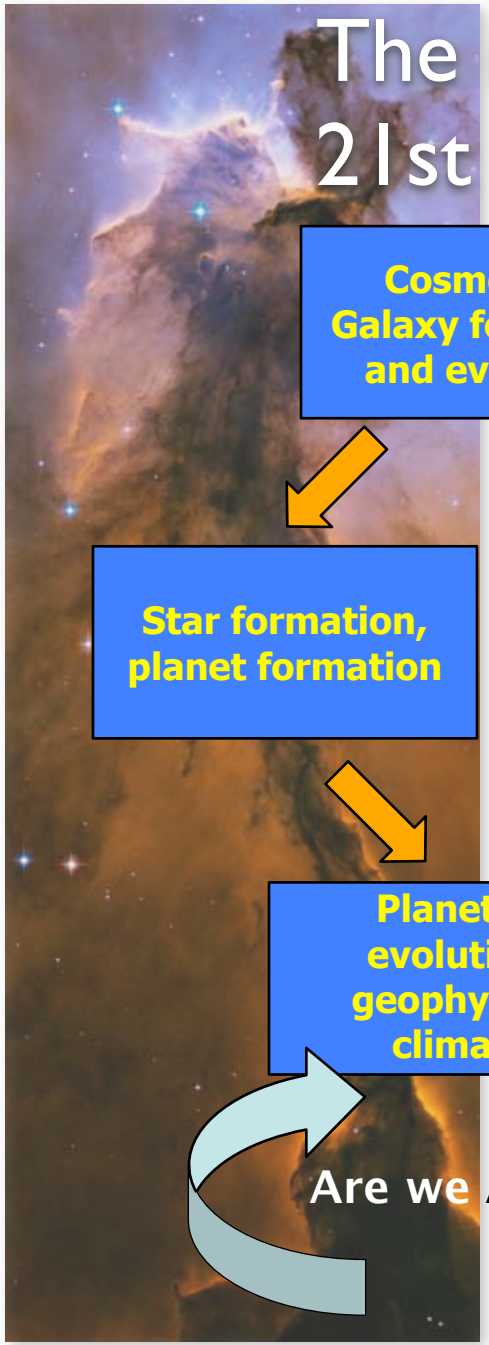
"How [have] we in astronomy come so far? … By standing on the shoulders of military/ industrial giants. … These larger scale efforts have been central to our success. … Where military or industrial support did not exist and we had to go ahead on our own, progress has been much slower."

Martin Harwit,
March 1999


Do we understand the threats to our national security
and global sustainability?
- have we the tools to enable informed and timely decisions?
Can we causally relate the conditions during the Big Bang
to the emergence of RNA and DNA?
- how did the Universe originate and what is its made of?
- how unique was our occurrence; are we alone?

The inter-connectedness of 21st Century space science



Cosmology, Galaxy formation and evolution

Fundamental Physics & Chemistry

Origin of life

Interstellar chemistry

Molecular interactions

Star formation, planet formation

Feedback mechanisms

Biological Evolution

Planetary evolution, geophysics, climate

Sustaining life

Environmental Feedback

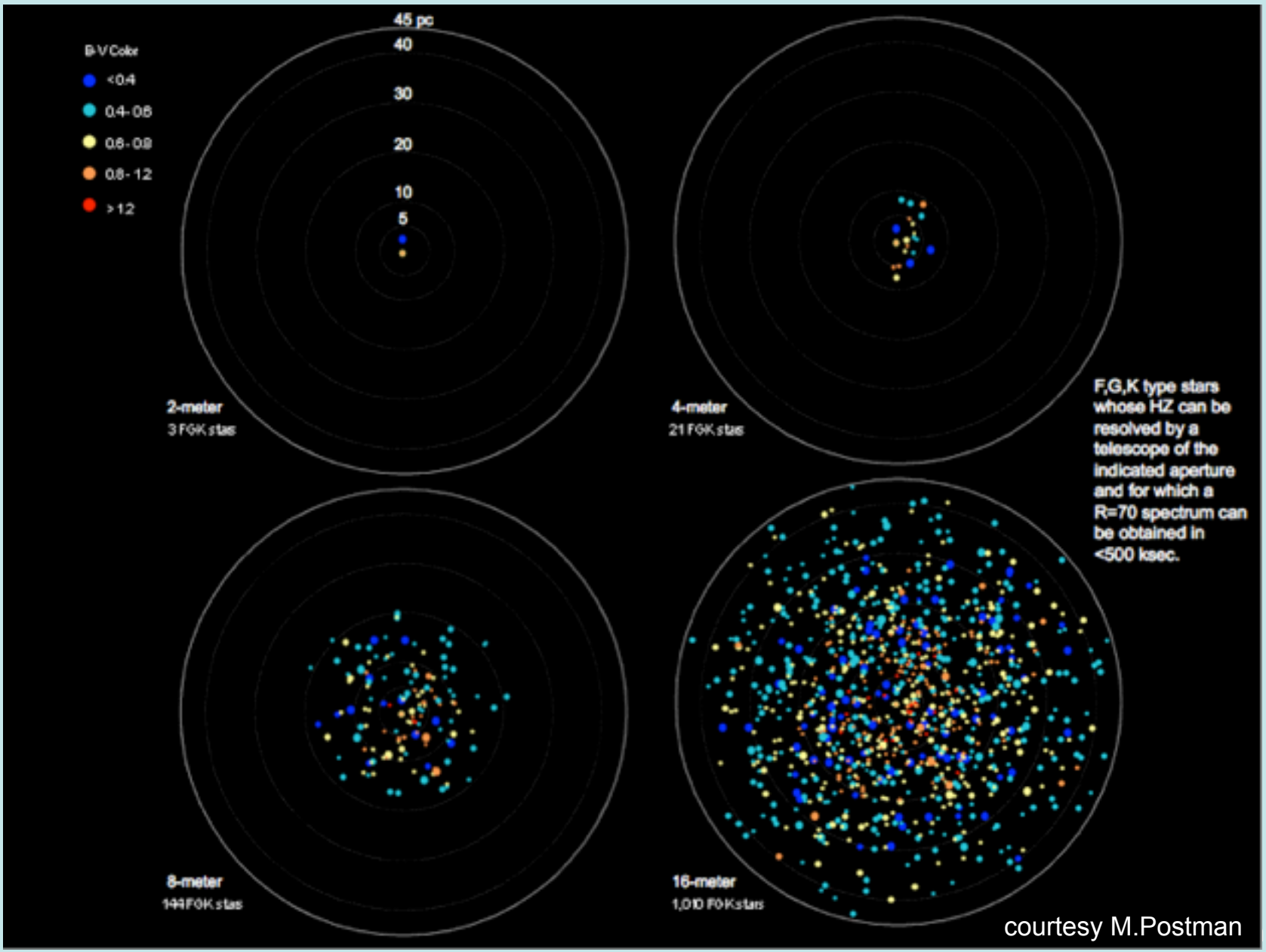
Are we Alone?

Habitable worlds

Is life sustainable?

courtesy Neill Reid

Can we find a find life in the solar neighborhood?



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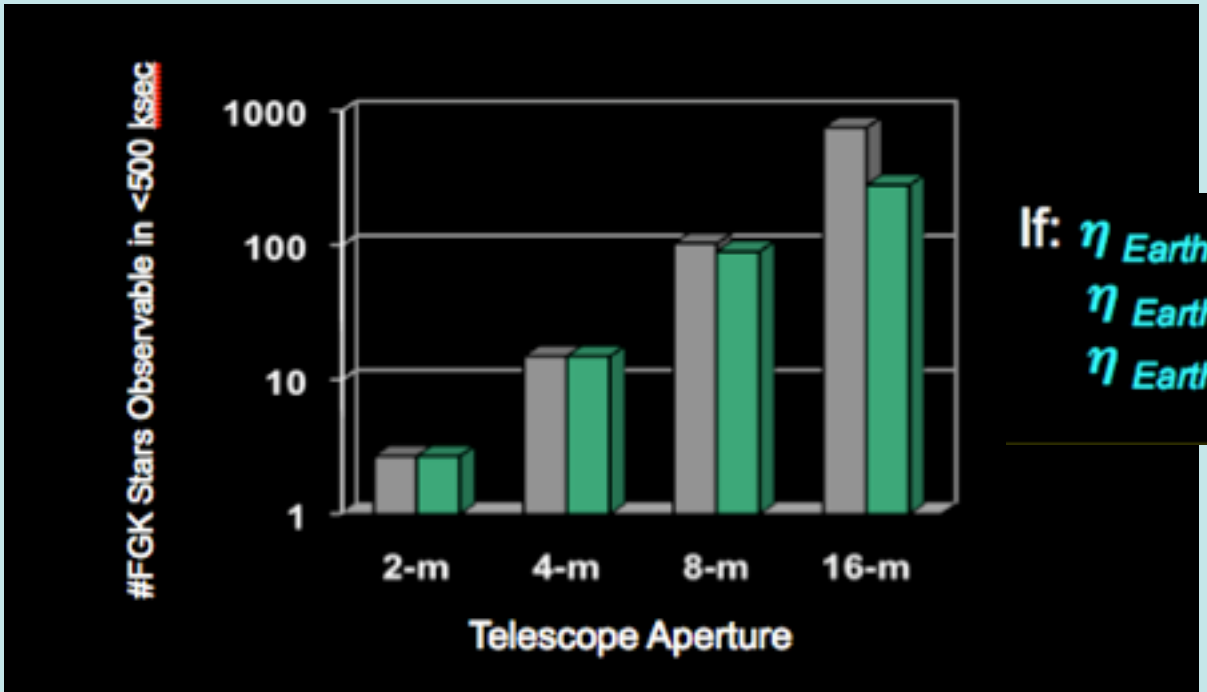
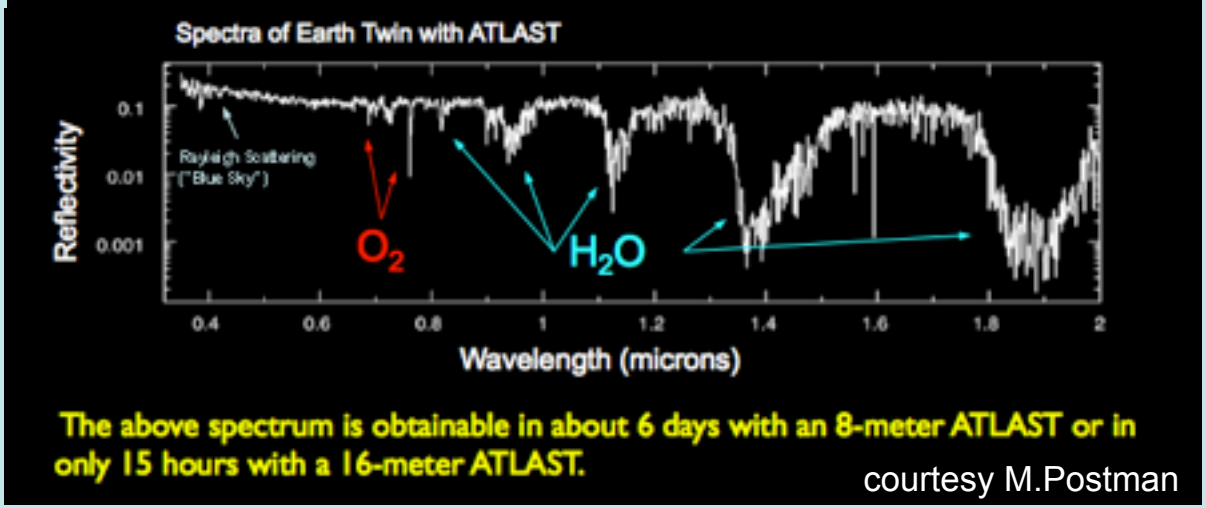


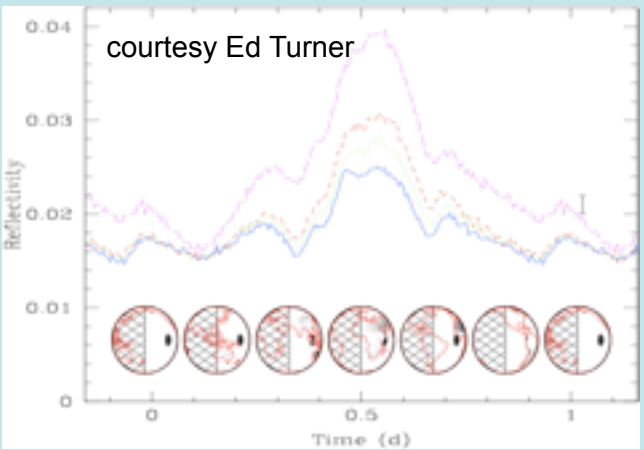


courtesy M.Postman

We require spectra of ~30 m_v sources

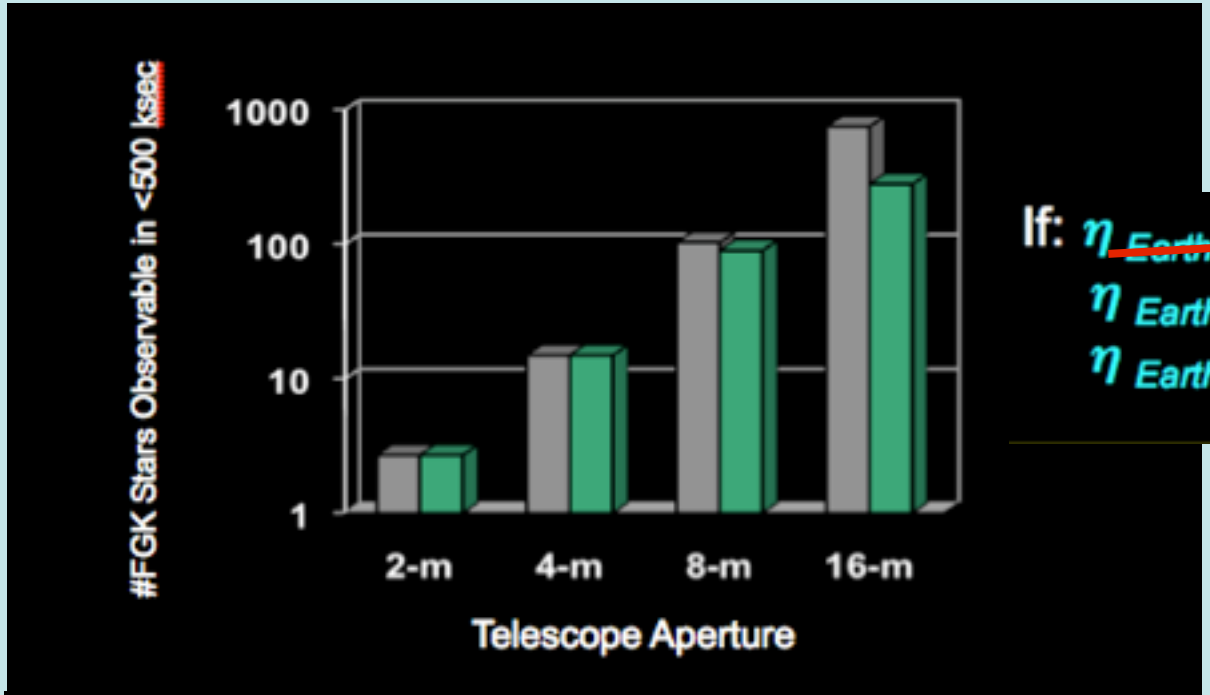
If: $\eta_{Earth} \times f_B \sim 1$ then $D_{Tel} \sim$ 4m
$\eta_{Earth} \times f_B < 1$ then $D_{Tel} \sim$ 8m
$\eta_{Earth} \times f_B << 1$ then $D_{Tel} \sim$ 16m

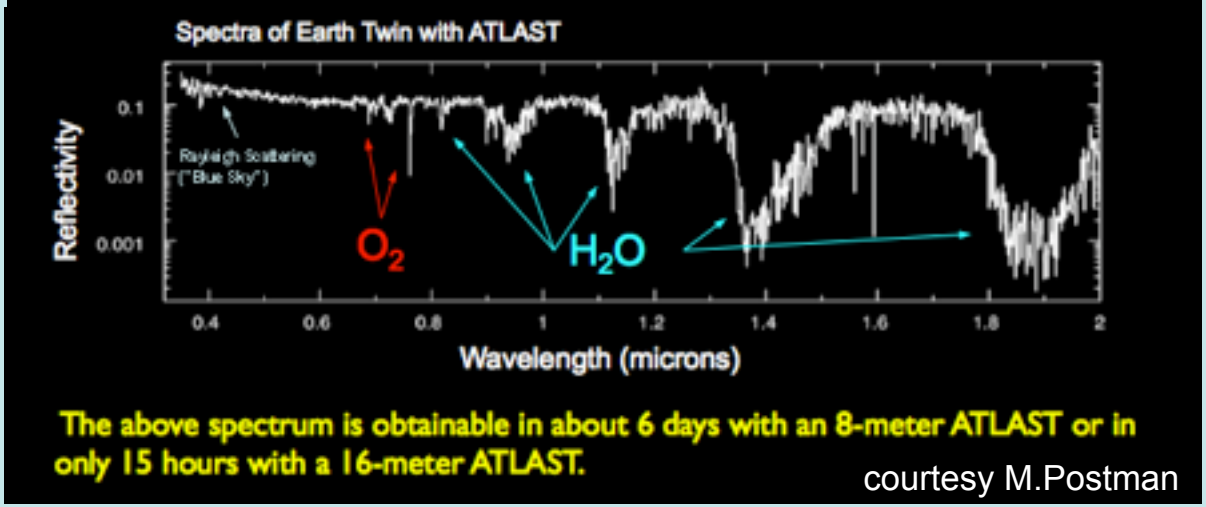
Exo-planet remote sensing



continents and vegetation can been "seen" though variability, if D = 8m ~ 16m

Can we find a find life in the solar neighborhood?





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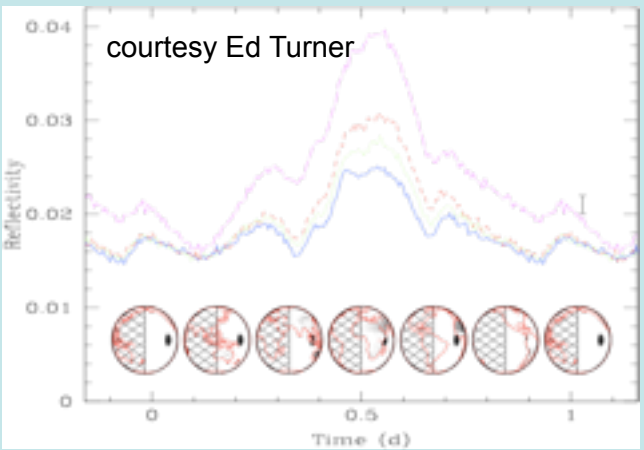

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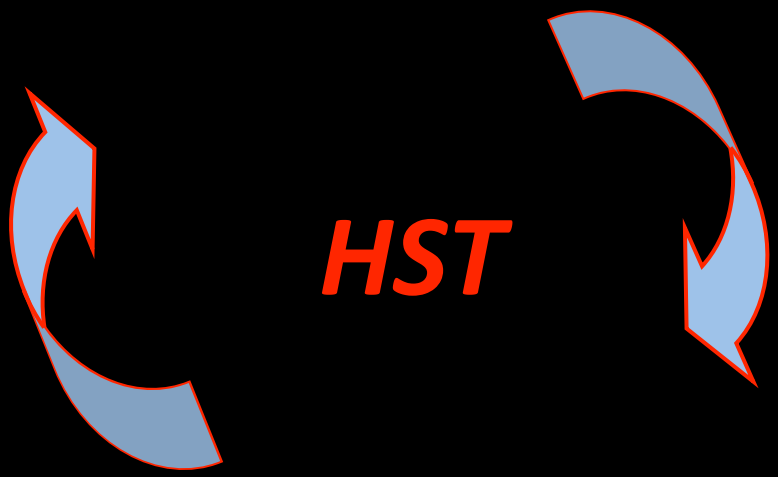
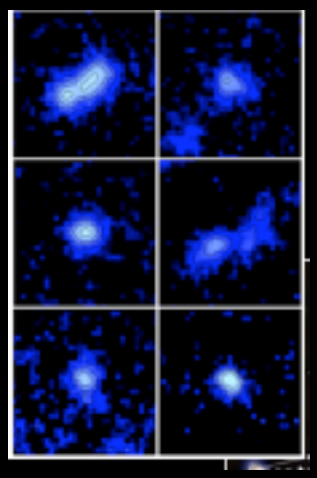
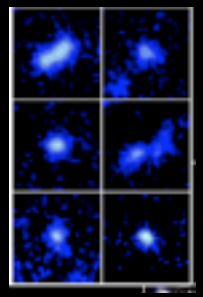
understanding galaxy formation and evolution……

galactic archaeology

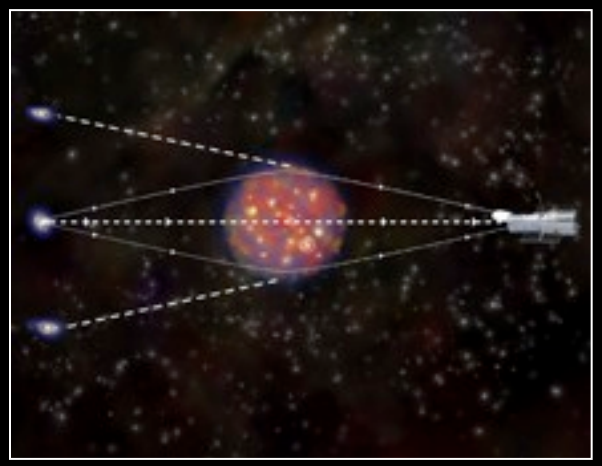


direct observation





understanding galaxy formation and evolution……



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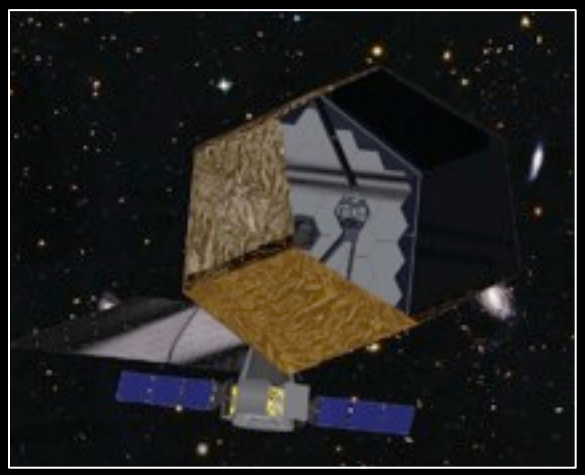

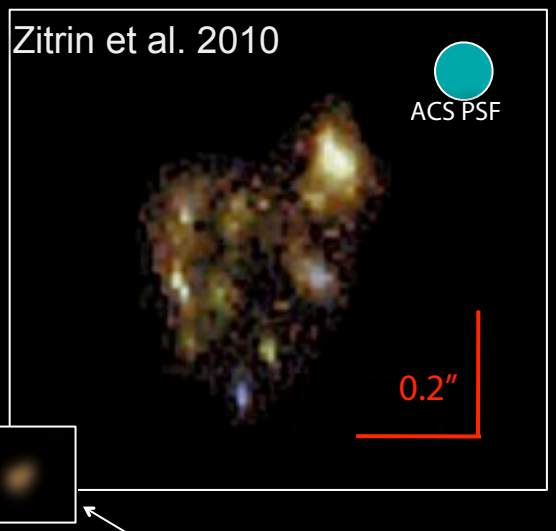

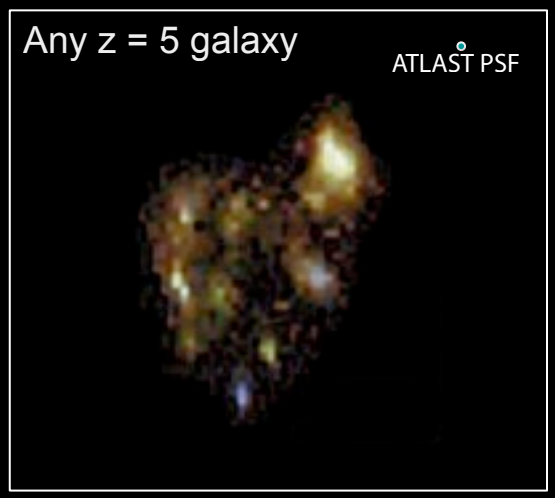

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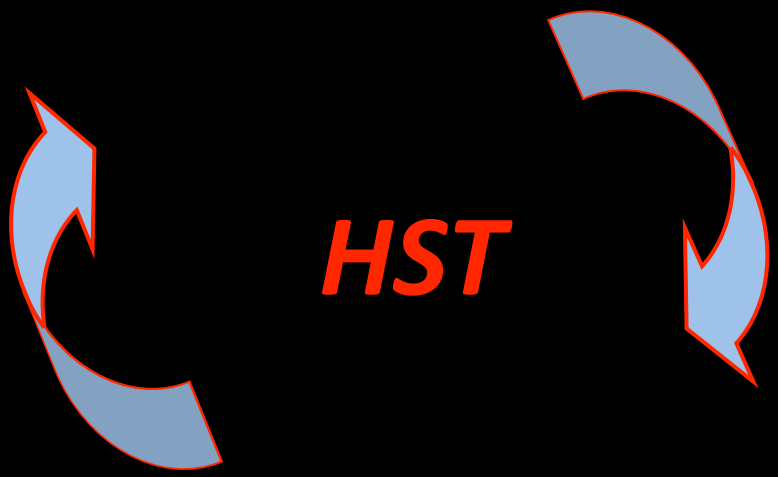

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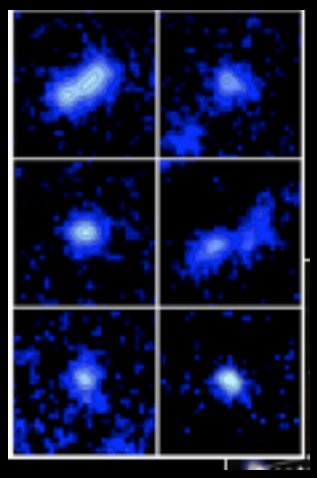

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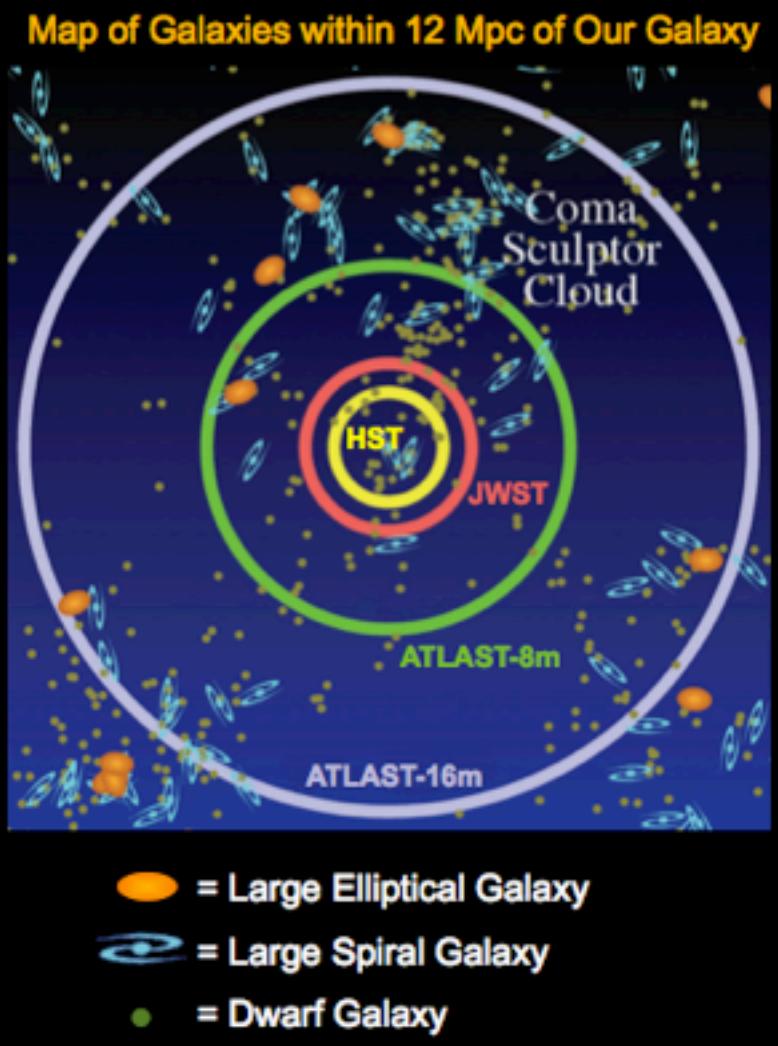


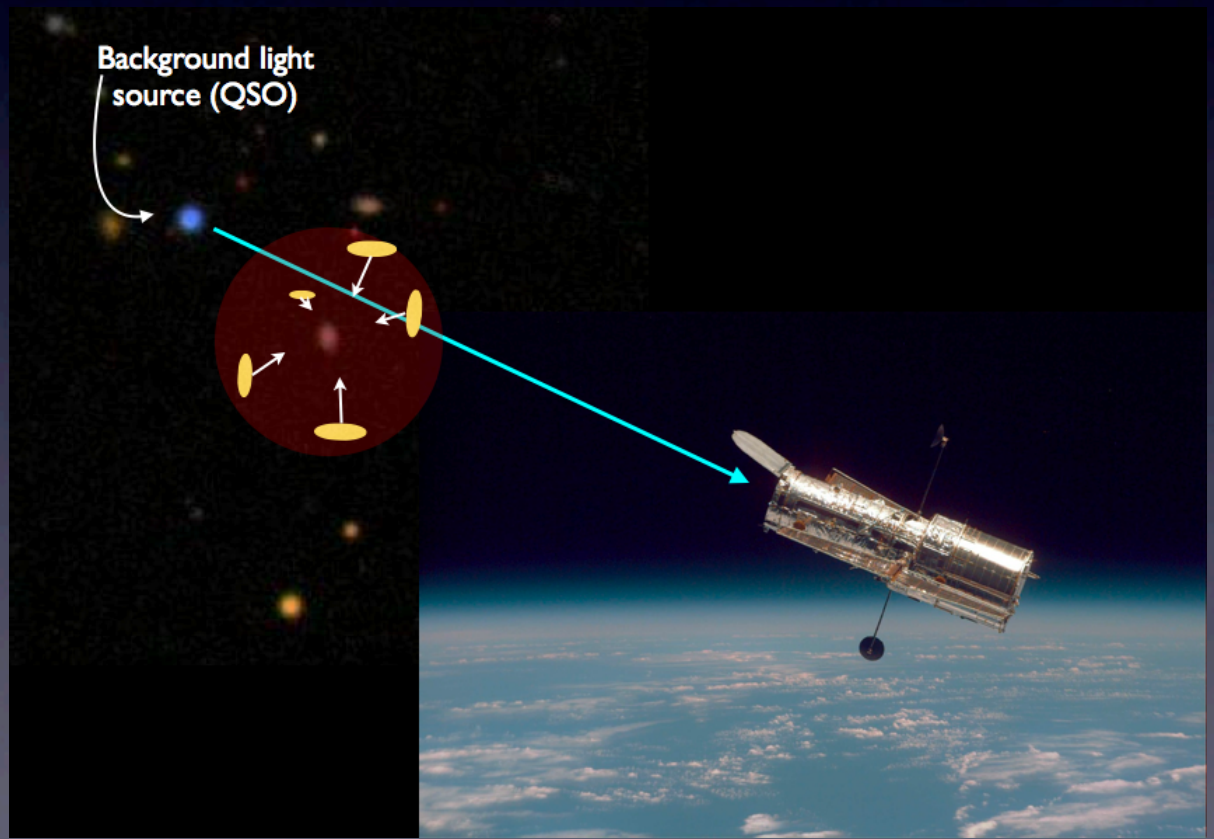
Circles in the figure to the left show the distance out to which an individual solar type star can be detected with a space telescope of indicated size. ATLAST will be able to detect individual stars in the main sequence in nearby giant Elliptical galaxies – providing a major breakthrough in our understanding of how galaxies assemble their stars. No other planned facility will have this capability.

courtesy M.Postman

COS Opens New Science Possibilities

Example: J. Tumlinson Cycle 17 program

- *"How Galaxies Acquire Their Gas"*
- 43 galaxy/quasar pairs, 134 orbits



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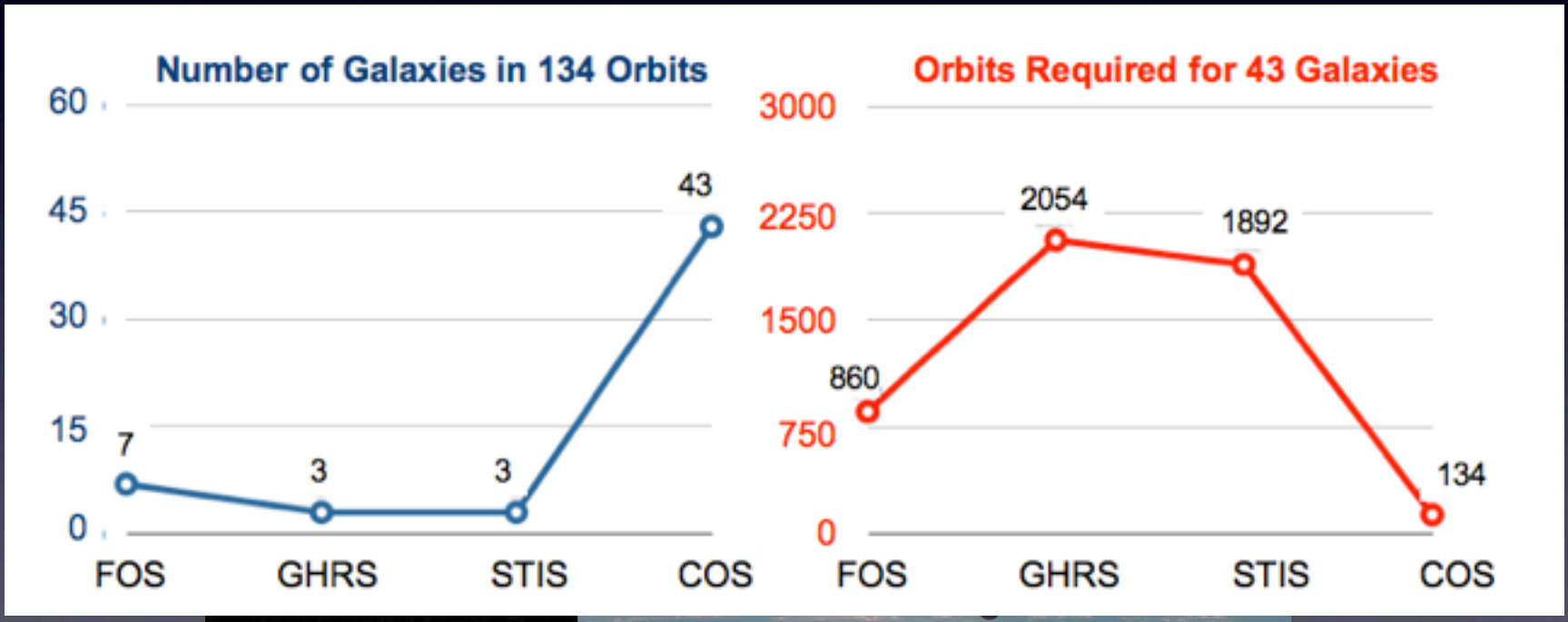

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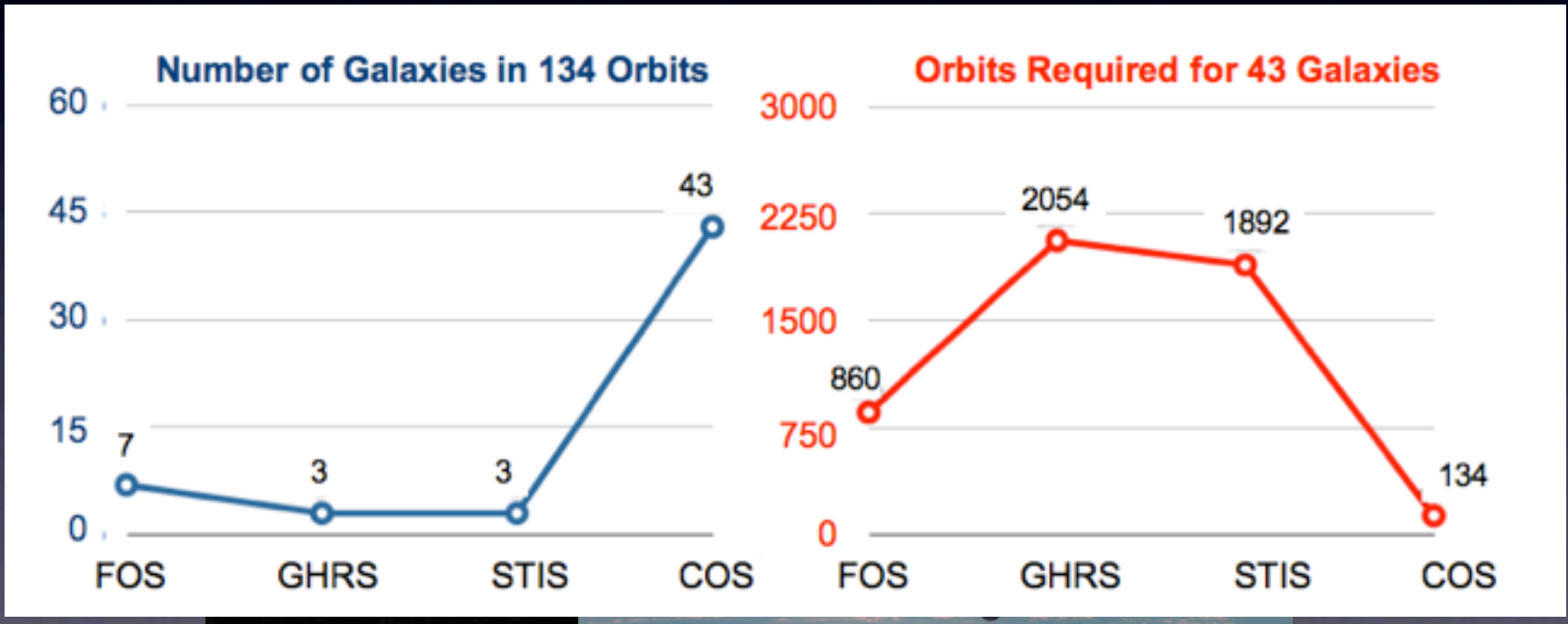
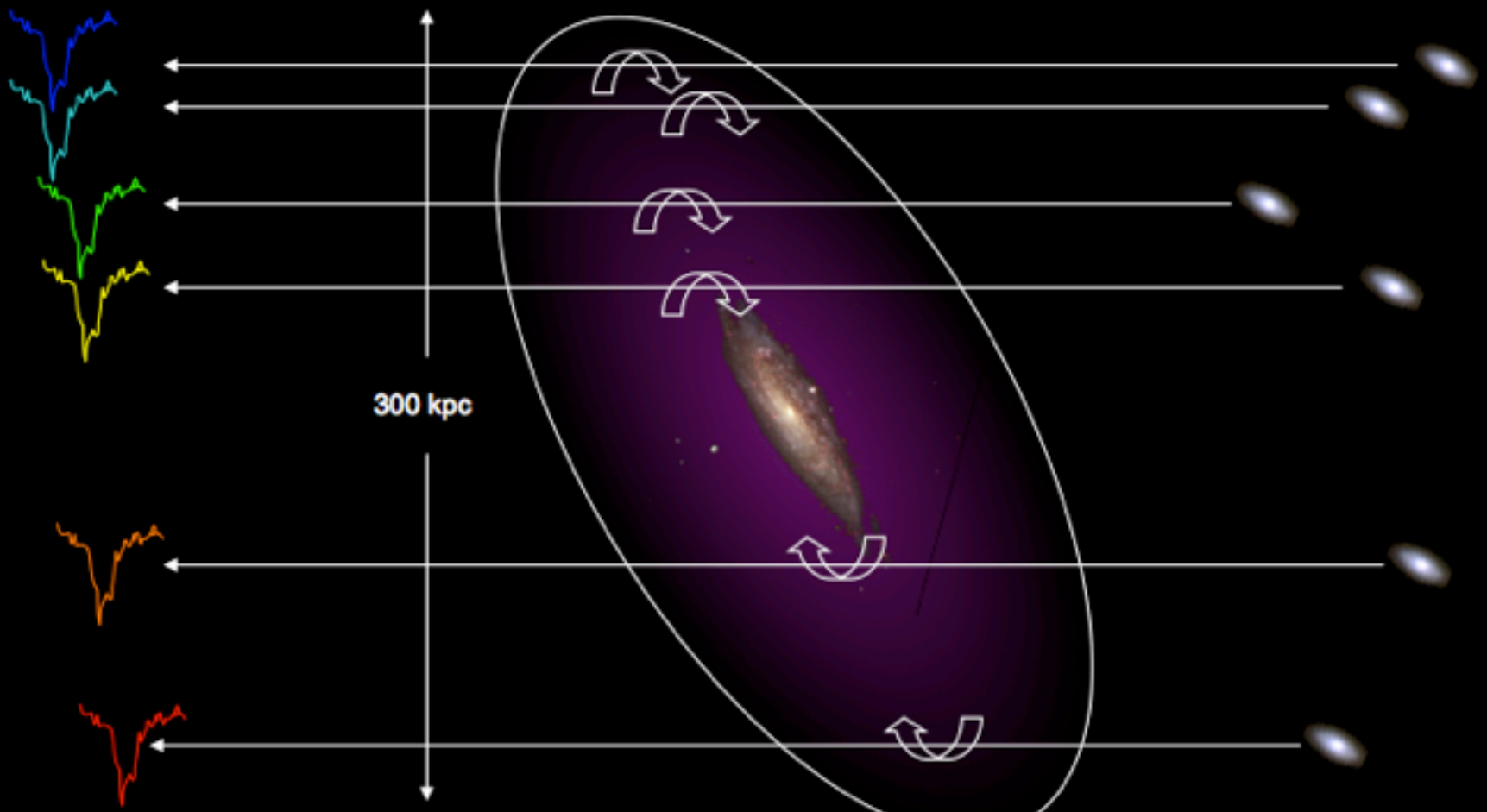


But we are still orders of magnitude away for doing full IGM tomography of all galaxy types

Enabling IGM Tomography and "Modern" Galaxy Evolution with 8m ~ 16m O/UV Telescope



Absorption features from gas in the foreground galaxy's halo are superposed on the spectra of the background galaxies, enabling the direct determination of the halo mass within the radius probed by the light beam.

Light from several background galaxies can be used as probes of the galactic halo of a foreground galaxy

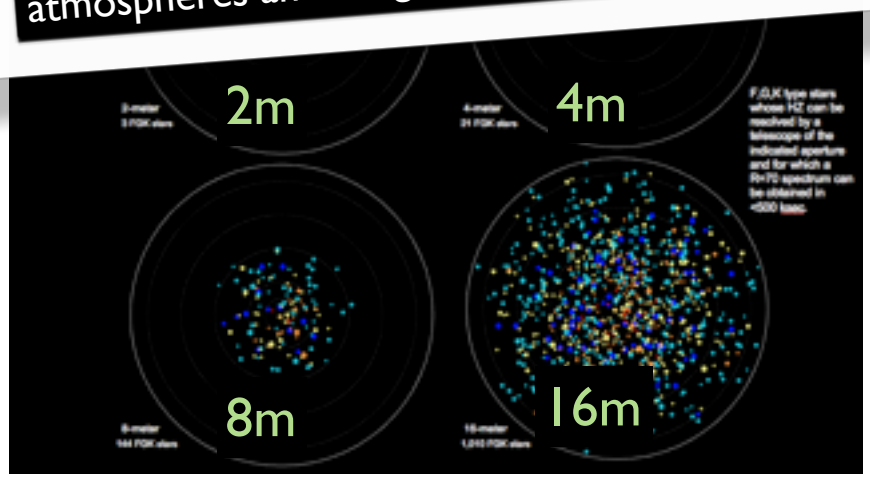
courtesy M.Postman

Astrophysics we can't do today,

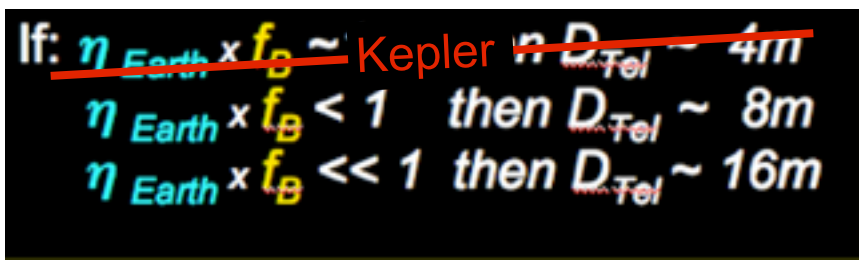
nor will we be able to do in the JWST era

What are the conditions for planet formation and the emergence of life?

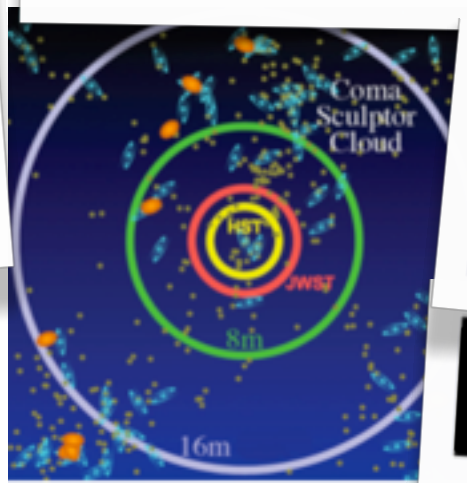
Search for planets around starts other than the Sun, looking for biomarkers in their atmospheres and image them



Number of observable candidate stars in our solar neighborhood as a function of telescope diameter



How did the Universe originate and what is its made of?



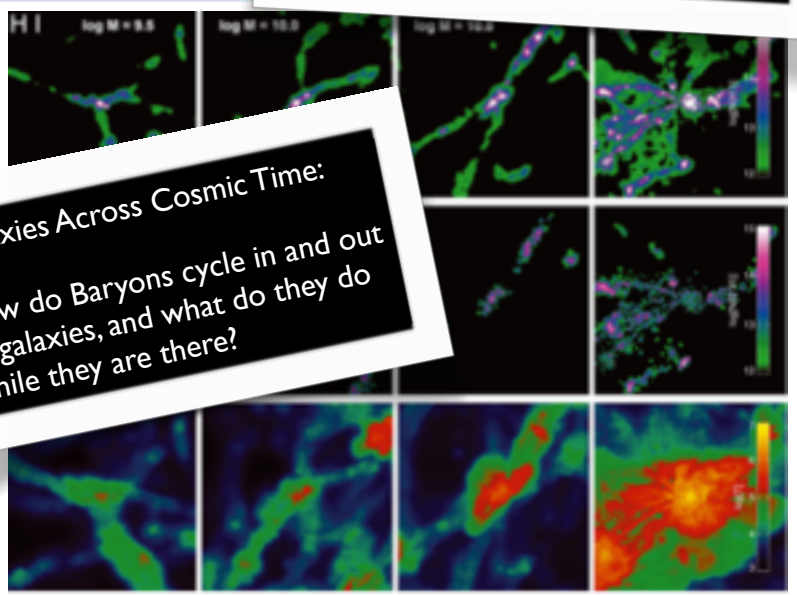
Galactic Neighborhood:

What is the fossil record of galaxy assembly from the first stars to the present?

Find the first gravitationally-bound structures - and trace their evolution to the current epoch

Galaxies Across Cosmic Time:

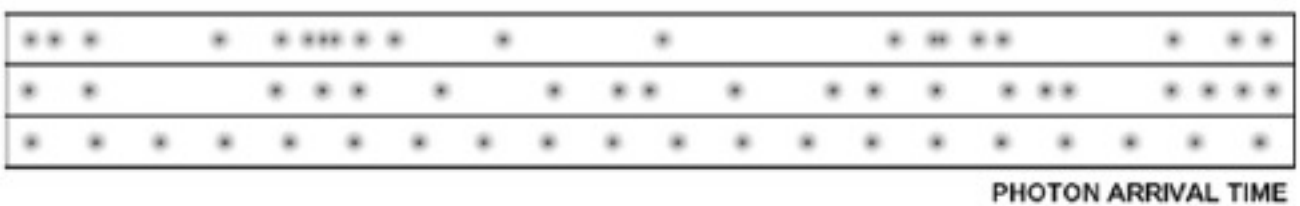
How do Baryons cycle in and out of galaxies, and what do they do while they are there?



Large Apertures enable new modes of observational astrophysics

: using photons more efficiently

The struggle for information from faint astrophysical sources pushes inexorably for larger telescopes



"bunched" – thermal (BB)

"anti-bunched" – non-thermal

"uniform" - maser emission

Measuring individual photon statistics and correlation functions within streams of photons reveals *directly the* physics of the emission source

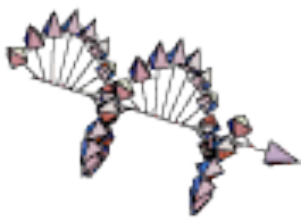
However $D_{Telescope}$ > 8m see Dravins (2007)

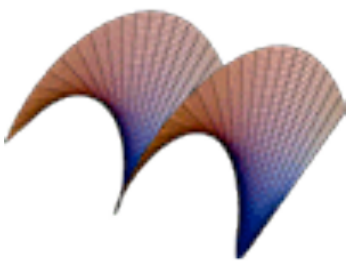
Narrabri stellar intensity interferomer circa 1970 (R.Hanbury Brown, R.Q.Twiss et al.,)

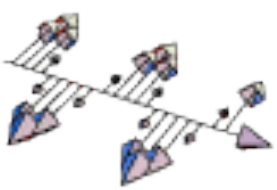
Photon Orbital Angular Momentum

Spin

POAM







Although polarization enables only two photon-spin states, photons can have many orbital-angular-momentum eigenstates, allowing single photons to encode much more information.

Harwit, ApJ 597, 1266 (2003)

“Big Science” Models

Instrument Team 1

Instrument Team 2

Instrument Team 3

Distinct multi-disciplinary teams

“Big Science” Models

Instrument Team 1

Instrument Team 2

Instrument Team 3

Distinct multi-disciplinary teams

Explorer or M/S class missions

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Instrument Team 1

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Distinct multi-disciplinary teams

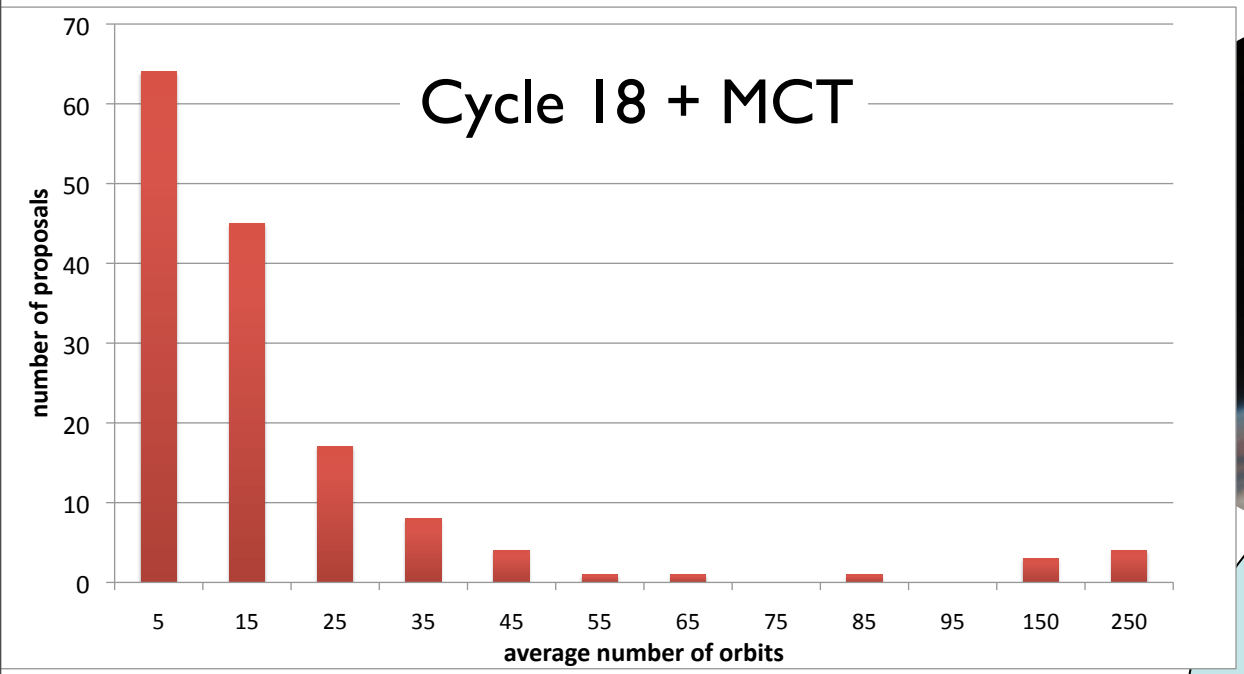
Explorer or M/S class missions

Great Observatories

diverse sustainable communities ~8,000

“Giaconni Model”

“Big Science” Models



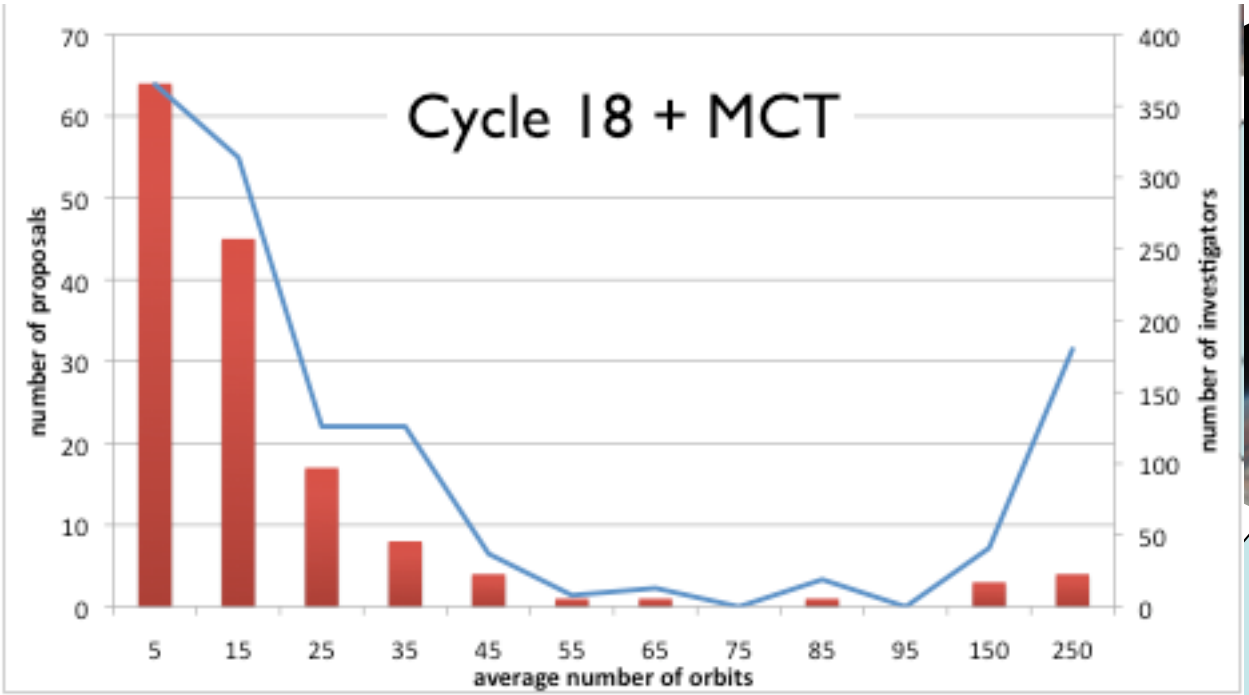
Great Observatories

diverse sustainable communities ~8,000

enables science at all scales

“Giaconni Model”

“Big Science” Models



number of supported investigators

Great Observatories

diverse sustainable communities ~8,000

“Big Science” Models

Instrument Team 1

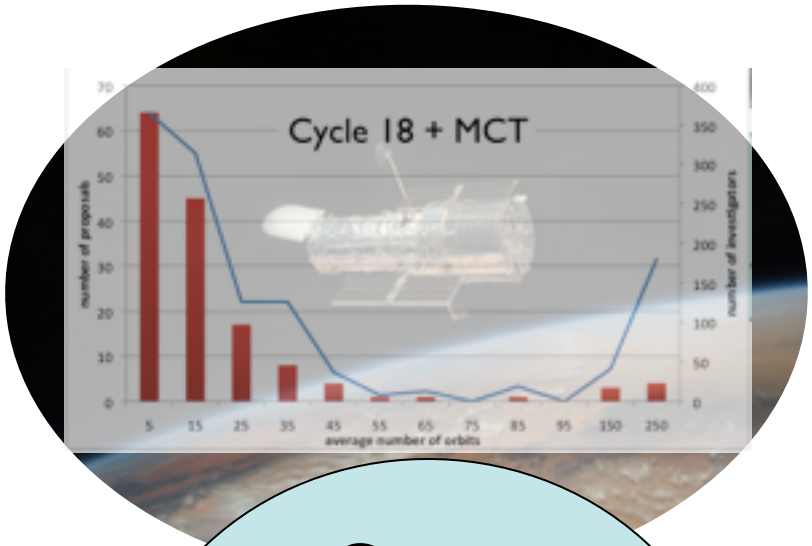
Instrument Team 2

Instrument Team 3

Distinct multi-disciplinary teams

Explorer or M/S class missions

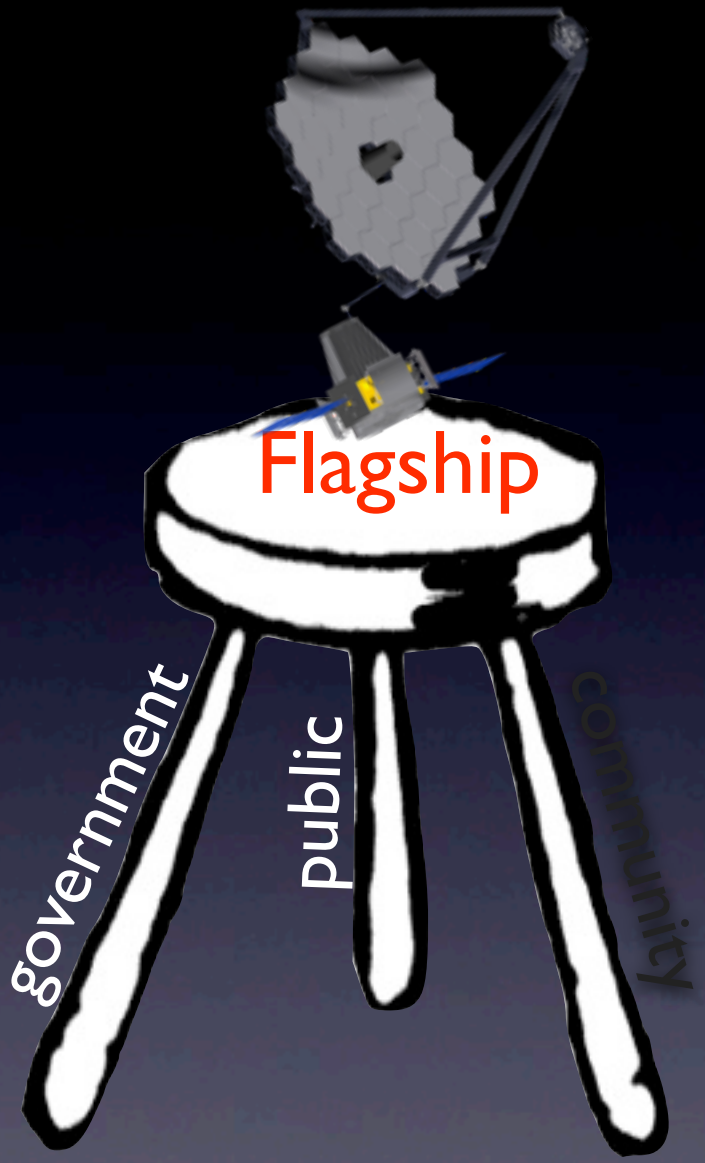
A few “winners”, many “losers”

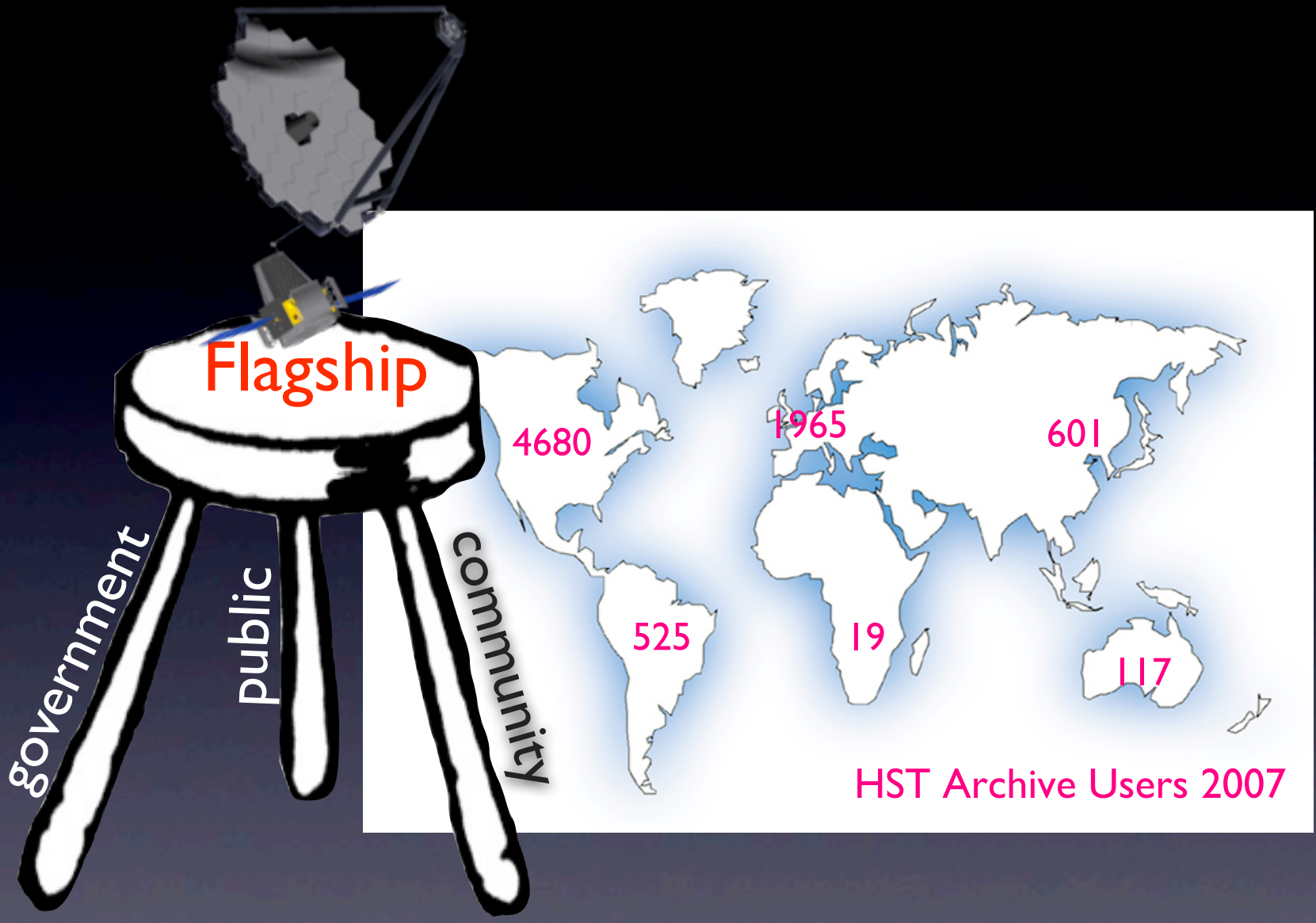


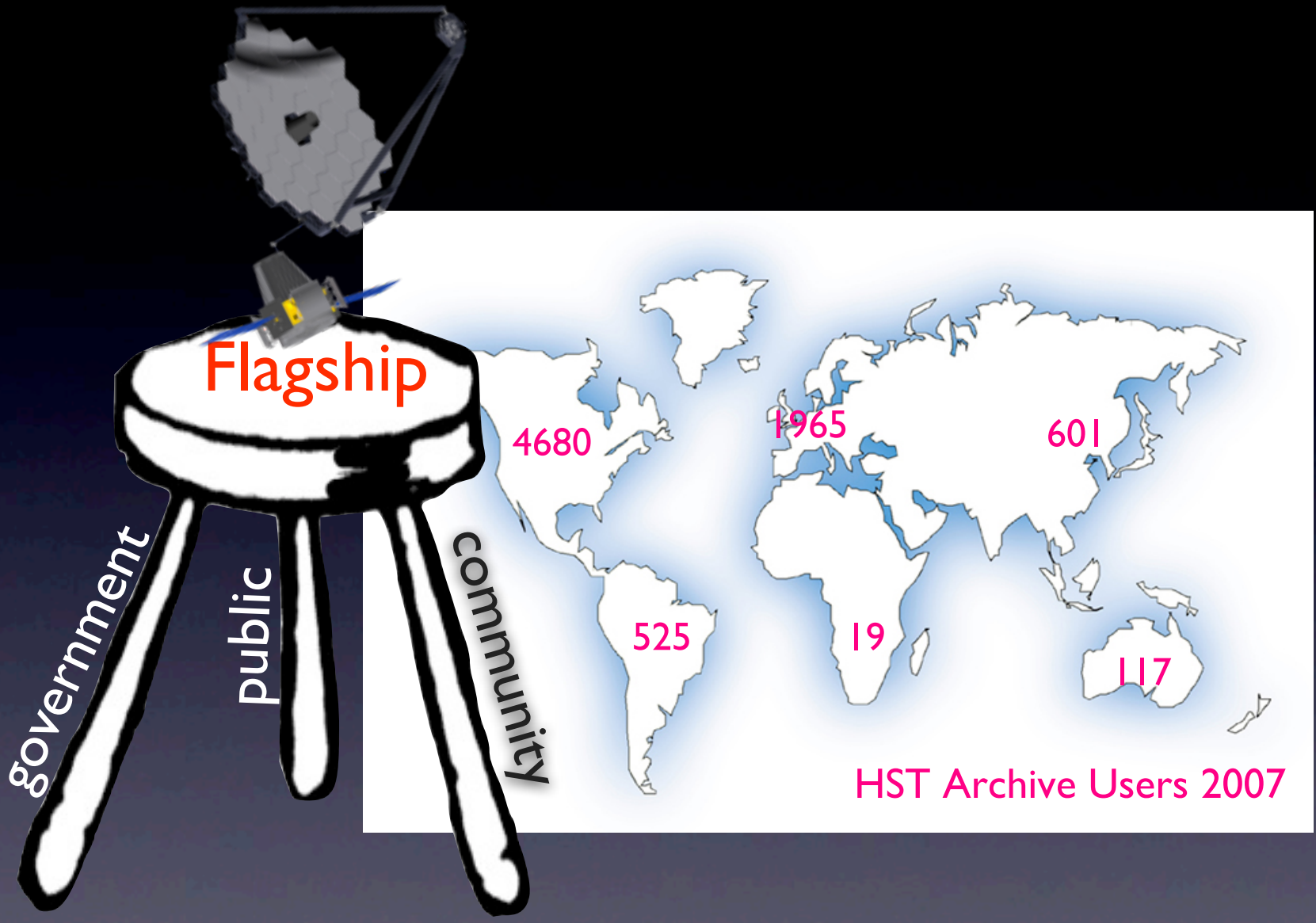
Great Observatories

diverse sustainable communities ~8,000

*Many “winners”, **but** whole fields can be “losers”*

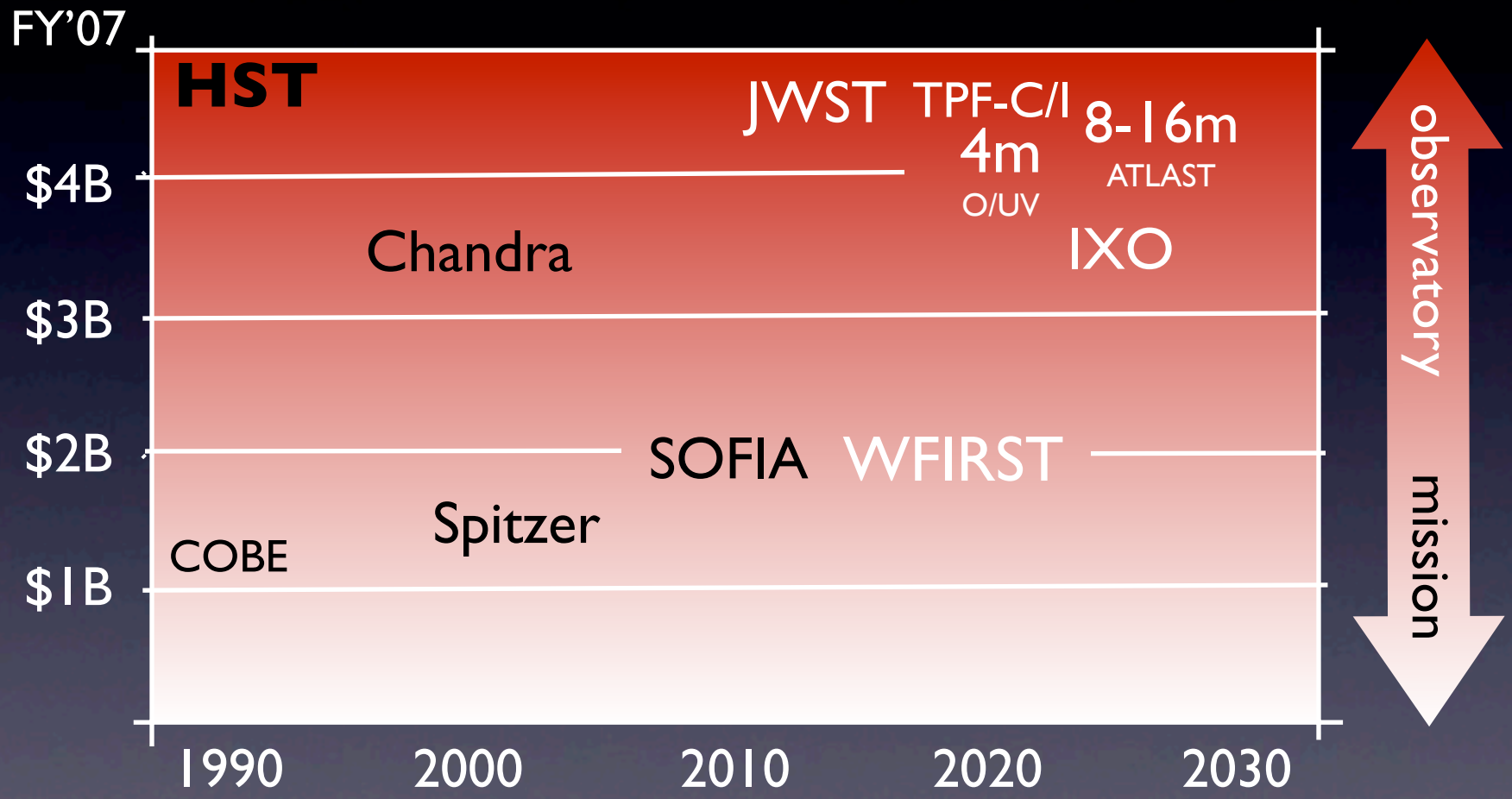

Flagship
government
public
community


Flagship
government
public
community
4680
1965
601
525
19
117
HST Archive Users 2007



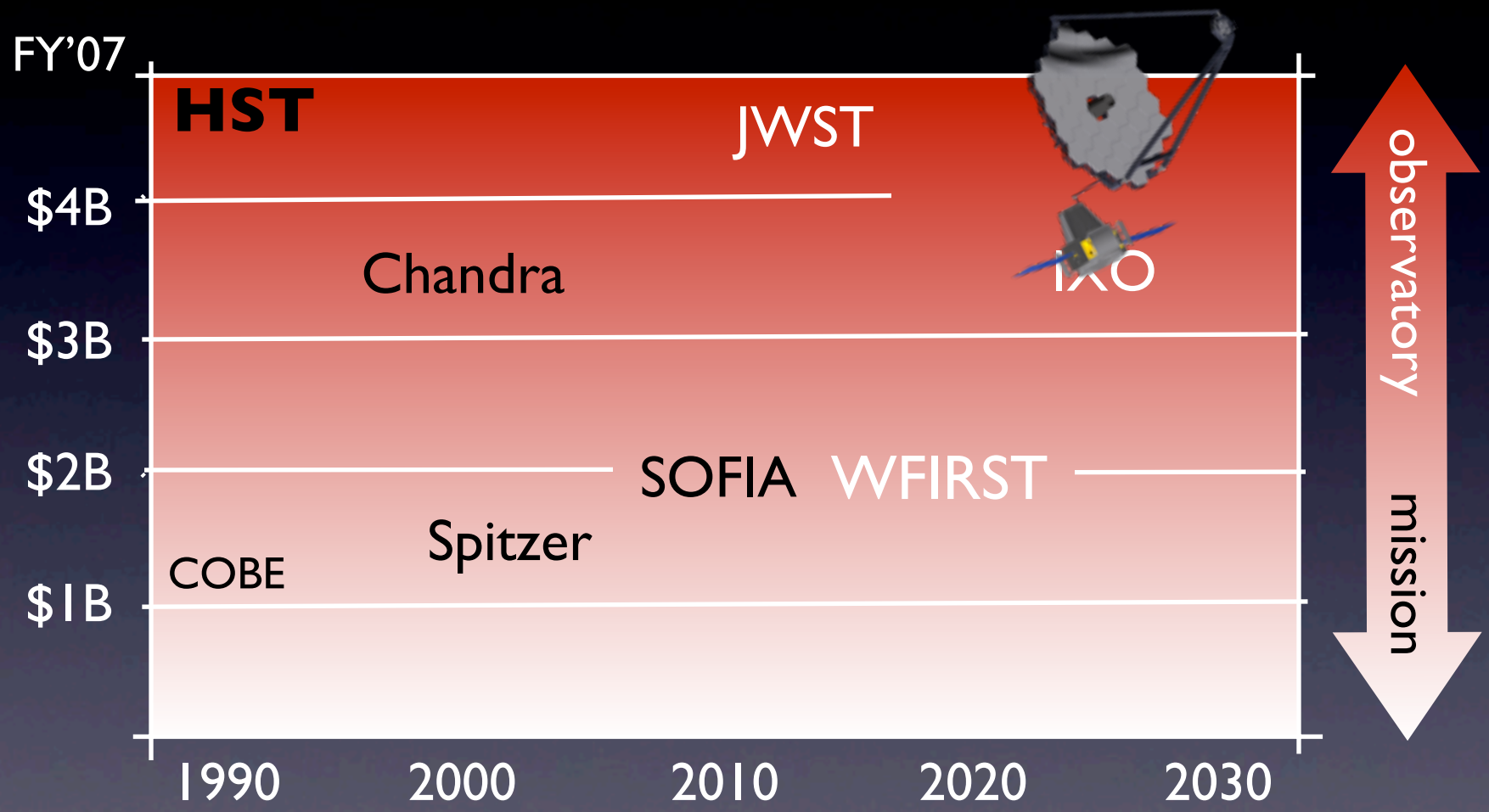
Lesson 1: *The truest sign of insanity is doing the same thing again and again expecting different result* - build a broad scientific consensus

Space Telescope costs and 'expectations'



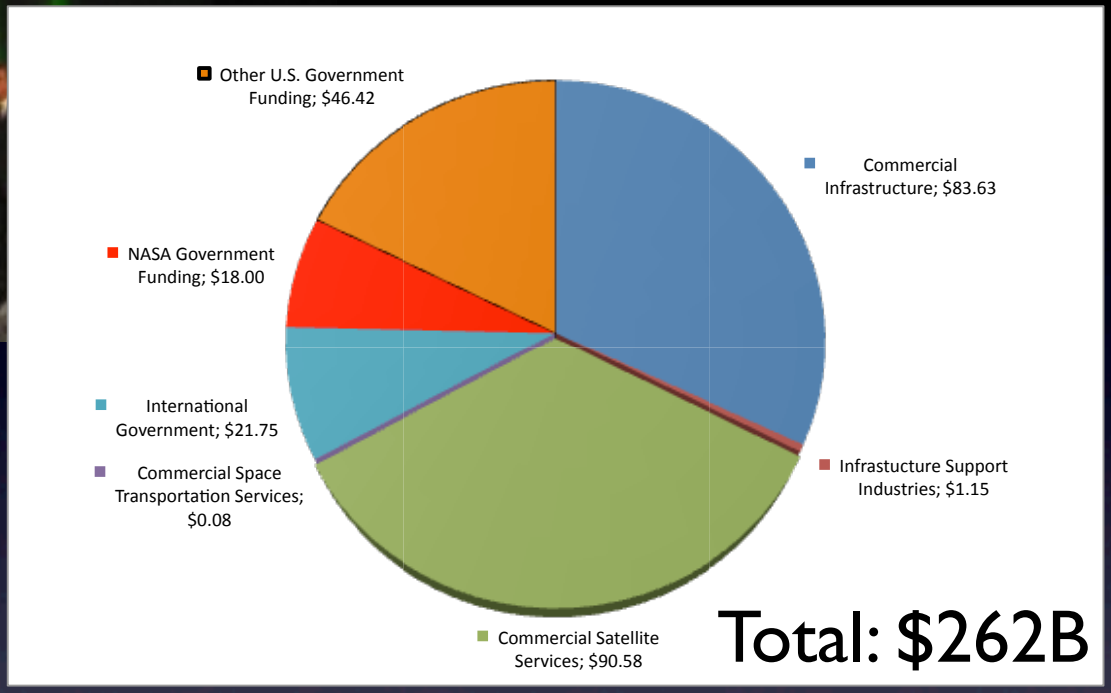
huge competition for the few slots in the top-right corner

Space Telescope costs and 'expectations'



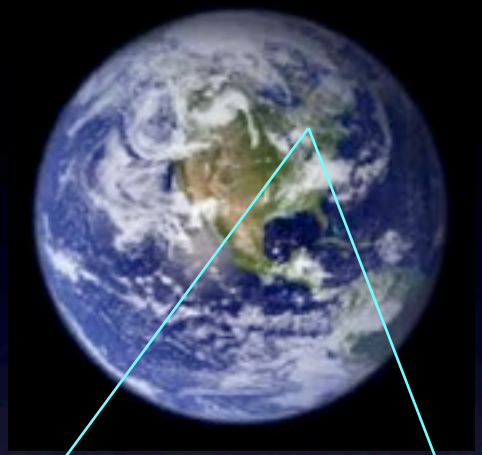
huge competition for the few slots in the top-right corner

Global Space Activity - source Space Foundation



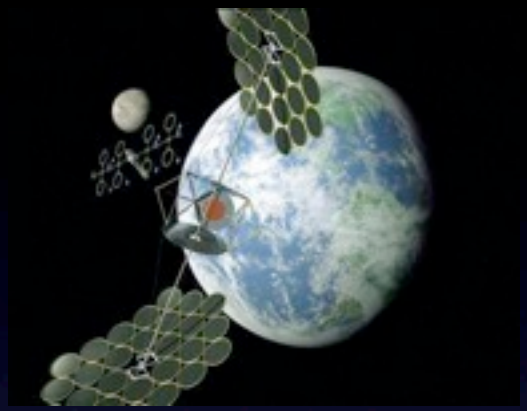
Lesson 2: Space science will not, and perhaps even NASA may not, significantly influence investments in future space infrastructure - so build partnerships

Space Science is probably not the only constituency that wants large space based imaging technologies

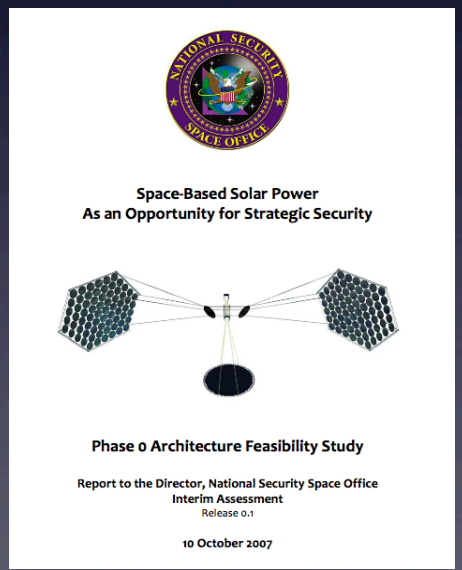


Geostationary orbit persistent surveillance

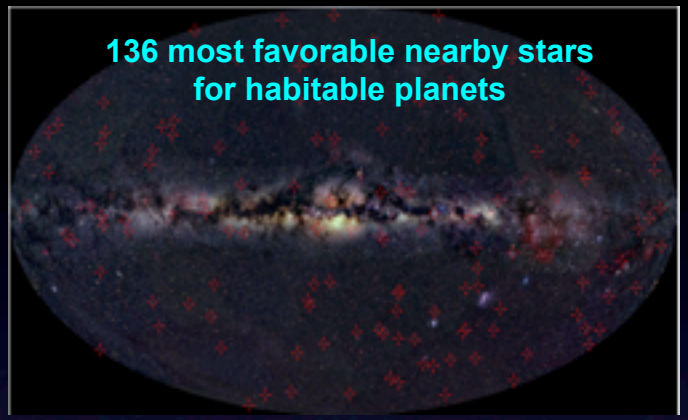
National & Environmental Security



Solar collectors in space



Energy



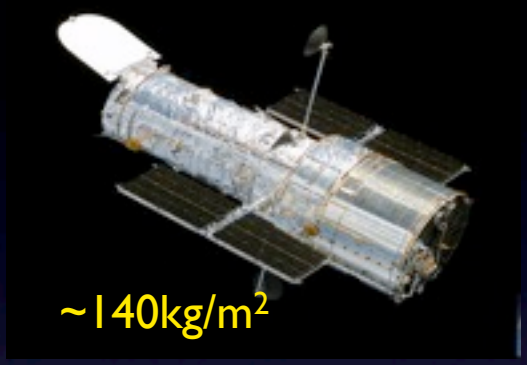
"I would like to see a reconnaissance of the planetary systems around the nearest 100 stars."

Carl Sagan, 1994 (paraphrase)

Are we alone?

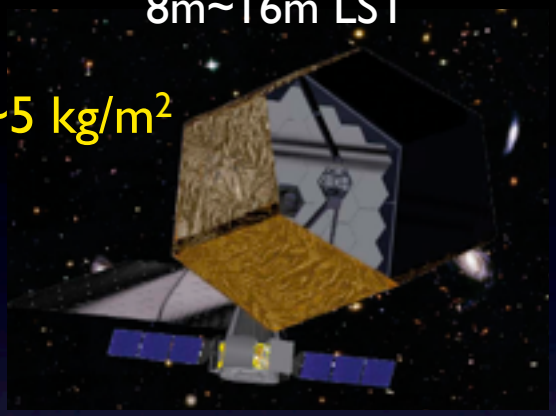
Lesson 3: lead by example

HST 2.4m



JWST 6.5m

8m~16m LST



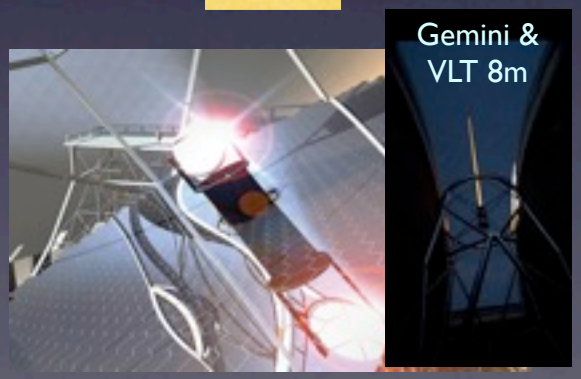
Passive control

Active control

Fully active and adaptive control

Palomar 5m

Keck 10m



E-ELT/TMT 30m~40m


theguardian
weekend edition
The Hubble Space Telescope has brought about a visual revolution, more significant than any recent work of art in transforming the way we see ourselves and the cosmos. And shouldn't we be starting to admit that it was more important than Apollo? The moon missions were based on Newtonian science and confirmed a Newtonian model of the universe (planets in orbit, trajectories, everything very mechanical). The Hubble has revealed to the eye a cosmos that is far more poetic, mysterious, and fluid.
Jonathan Jones
1 February 2010

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Dov'è il mio Hubble?

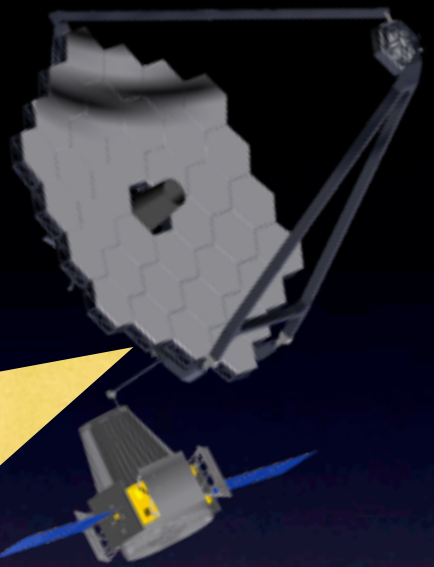
The Challenge for the second decade of 21st Century space science

6.5m ~ $5B (FY10)

2.4m ~ $5B (FY10)

The Challenge for the second decade of 21st Century space science

2020



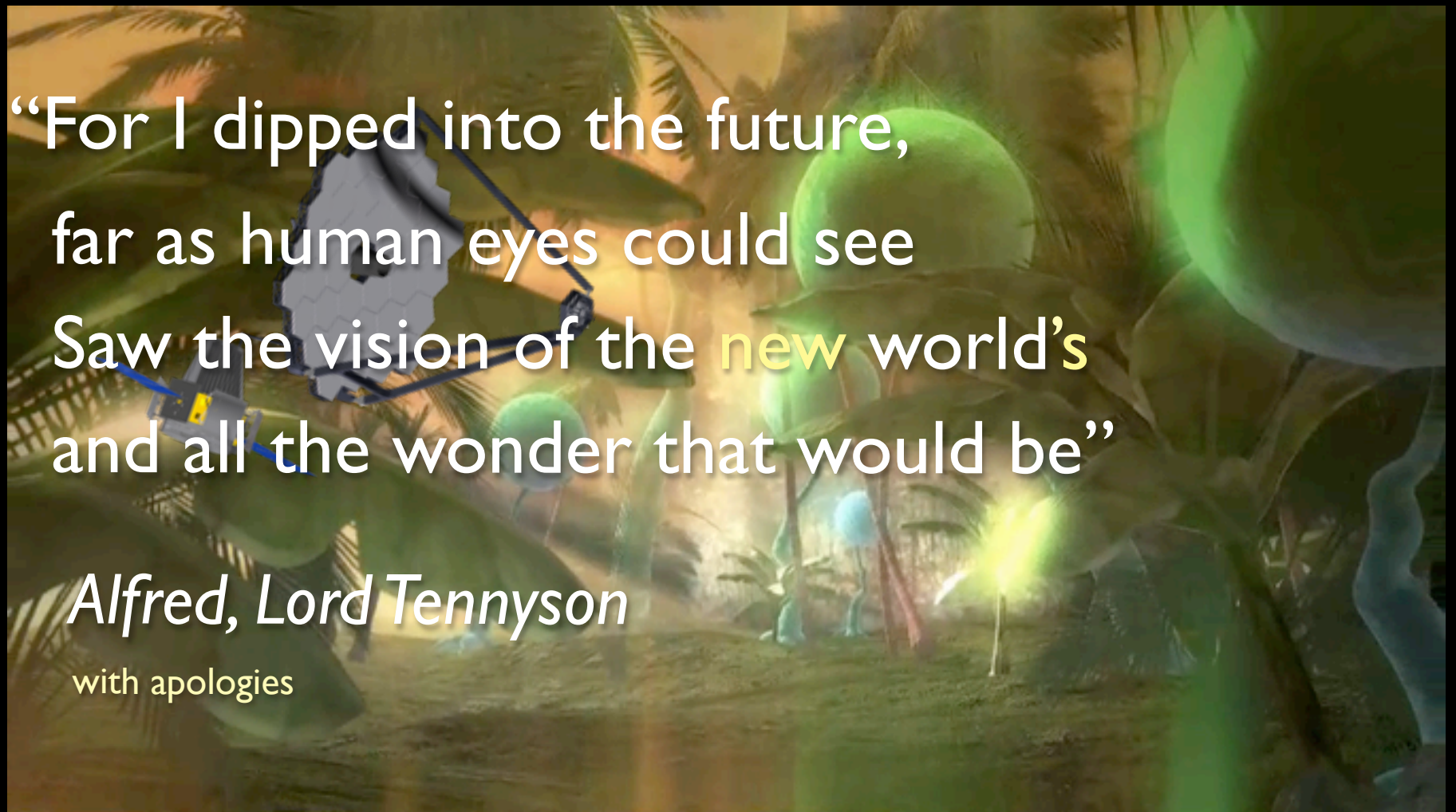
16m ~ $5B (FY10)

6.5m ~ $5B (FY10)

2.4m ~ $5B (FY10)

"We choose to [do] this ... and do the other things, not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills..."

President J. F. Kennedy, Rice University, 1962


"For I dipped into the future,
far as human eyes could see
Saw the vision of the new world's
and all the wonder that would be"
Alfred, Lord Tennyson
with apologies

back-up