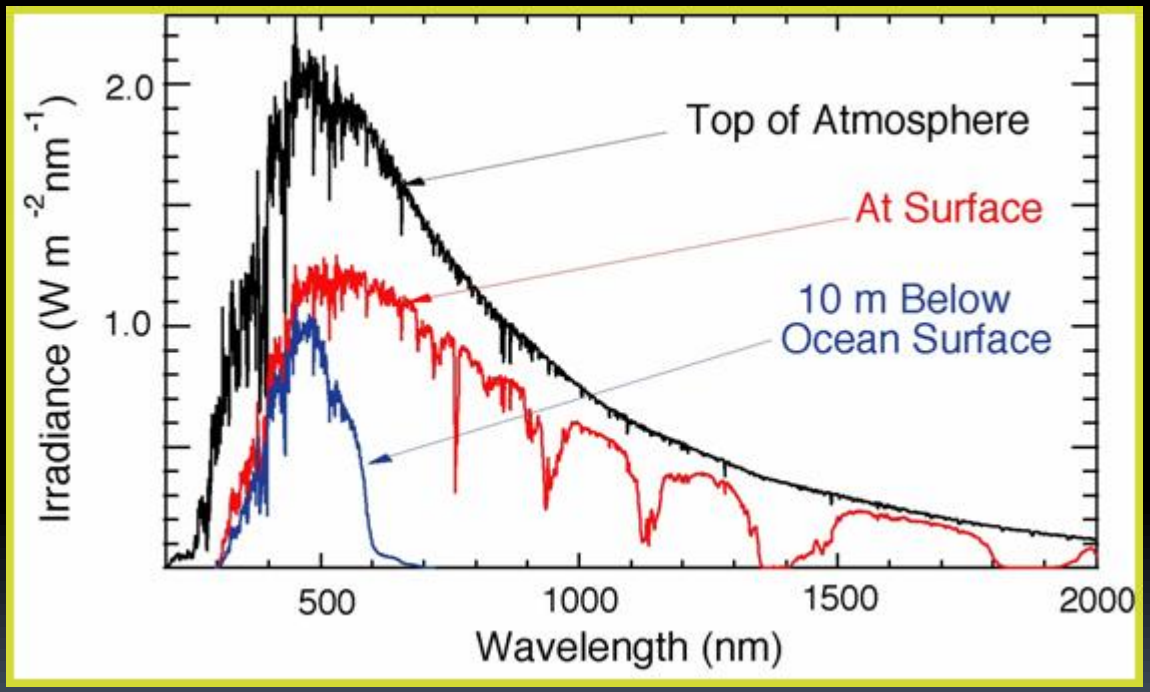
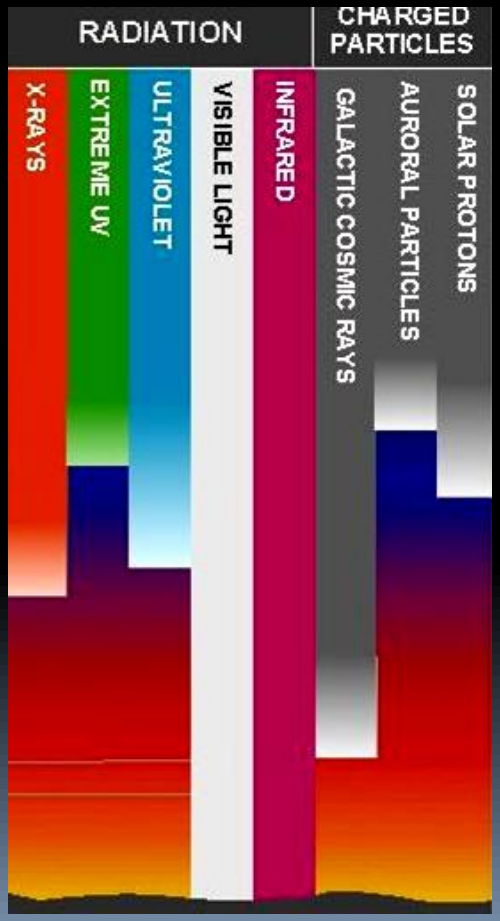
Space Science and Exploration Challenges and perspectives

Roger-Maurice Bonnet
International Space Science Institute
Institut d'Astrophysique, Paris

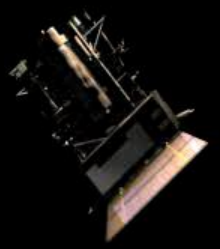
Chiaro oscuro

The solar spectrum observed from different altitudes



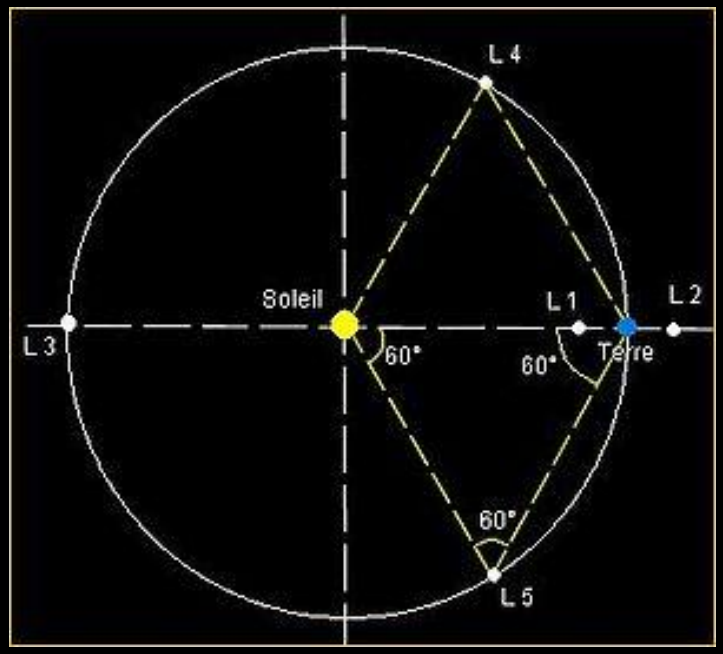


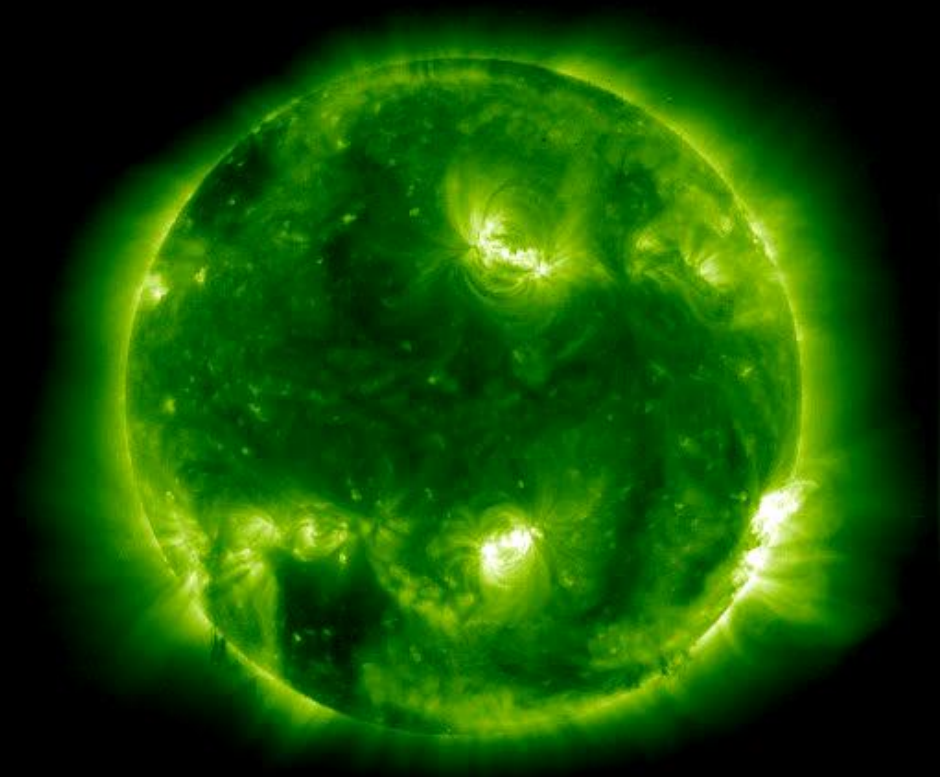
Lagrange points



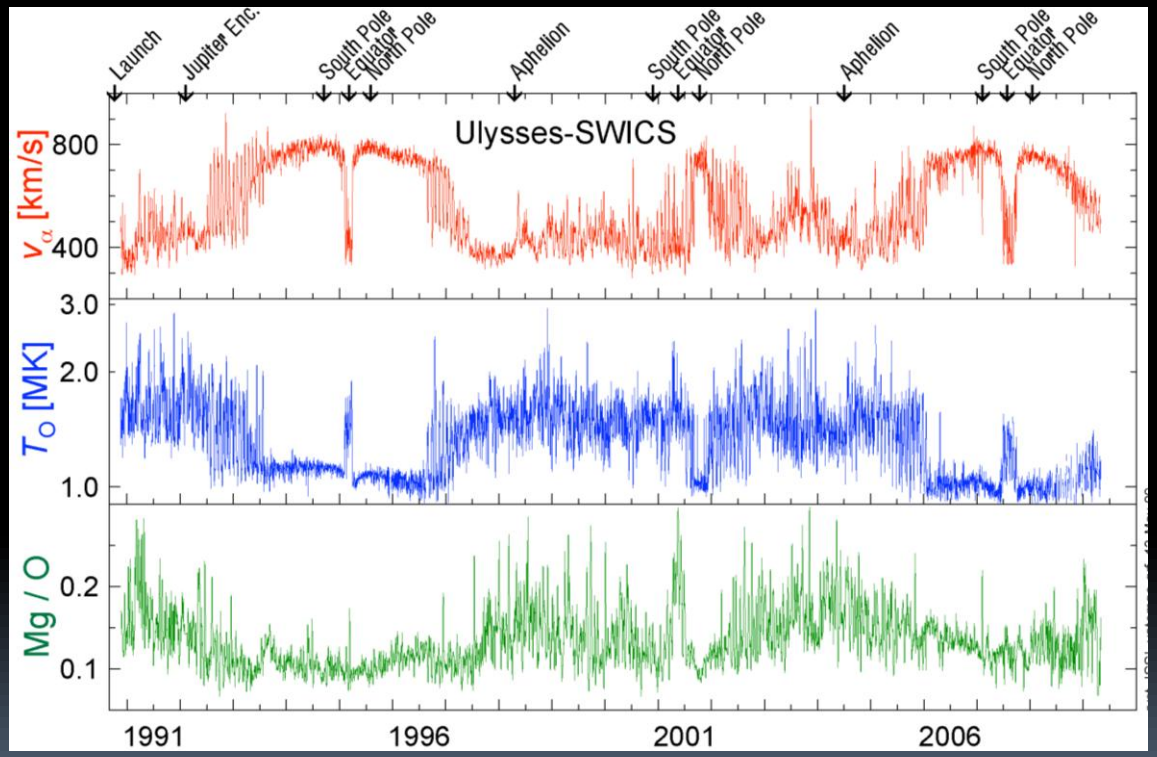
SOHO

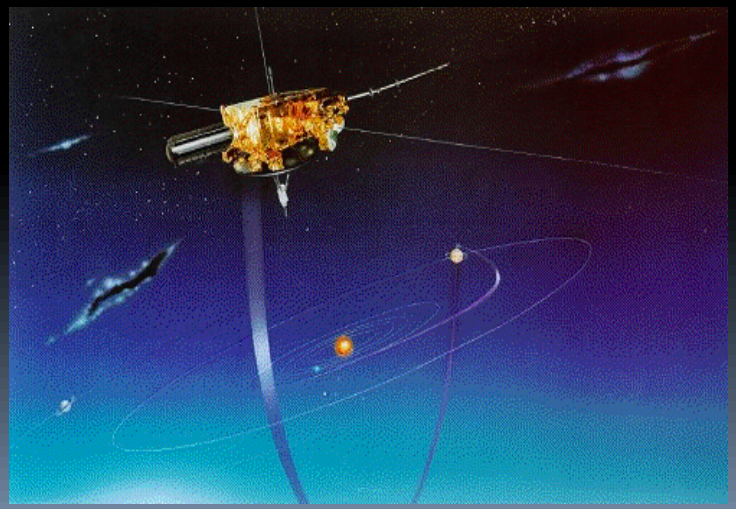
esa
ISD VisuLab

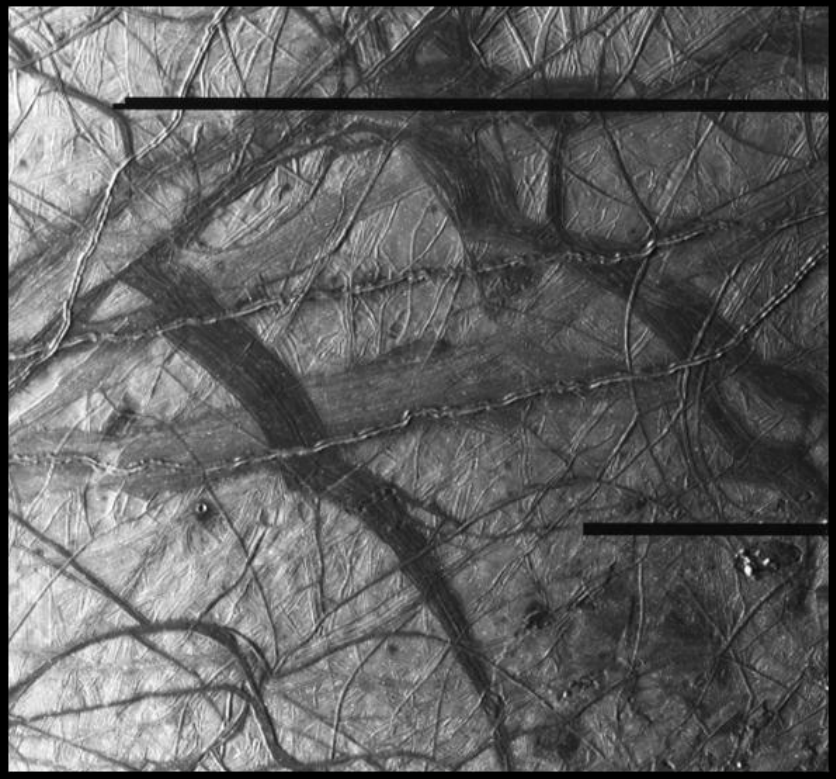




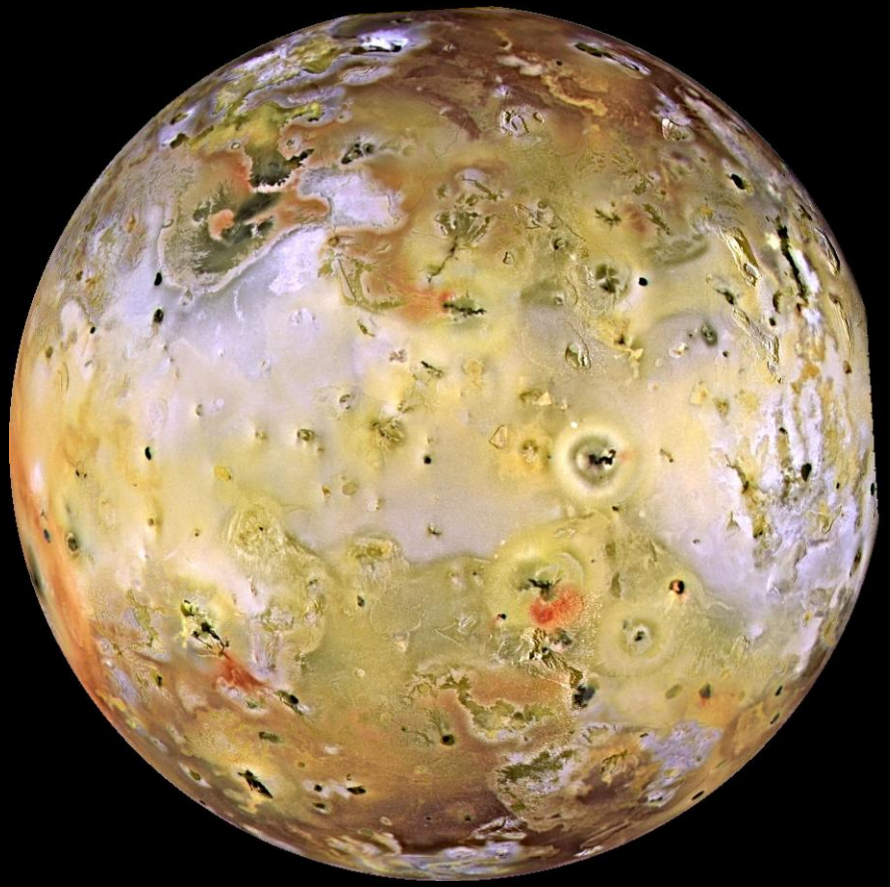
Ulysses:
Unique observing site



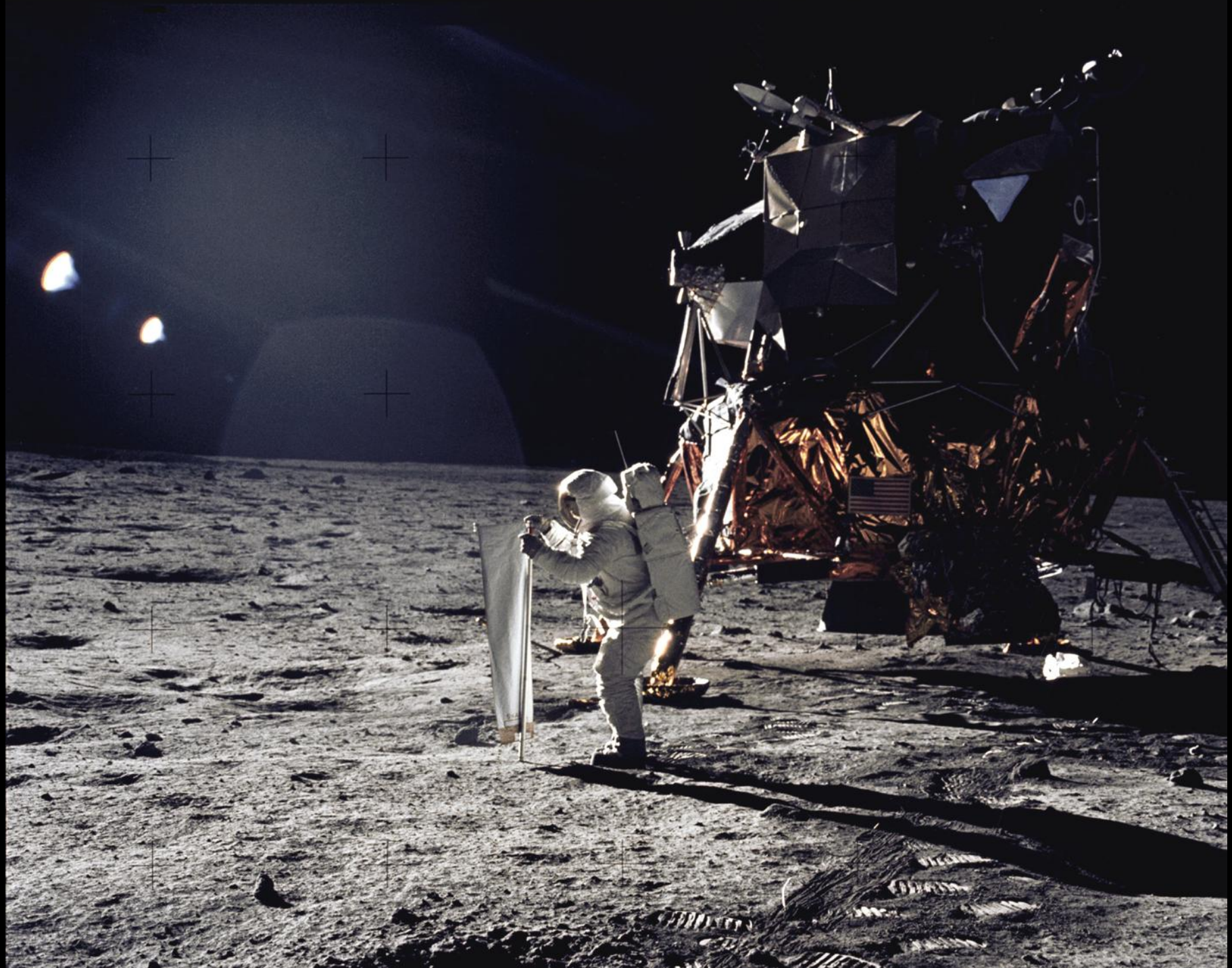


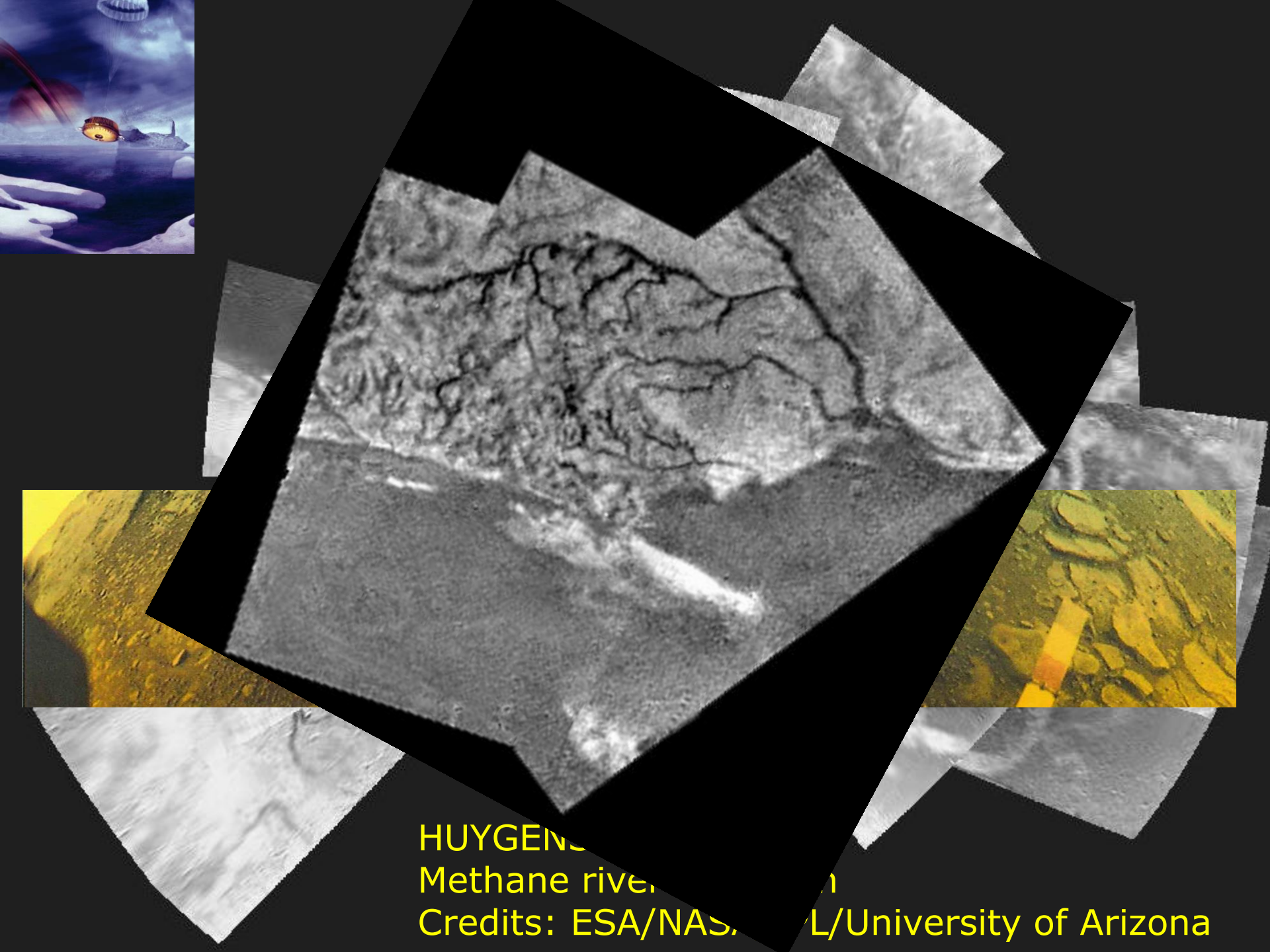


The icy surface of Europa



Extraordinary Io





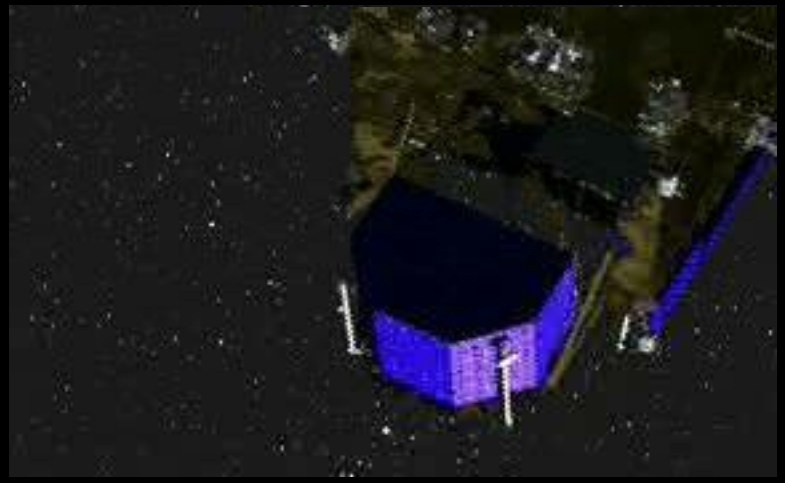
HUYGEN
Methane rive n
Credits: ESA/NAS L/University of Arizona

Landing on a comet nucleus

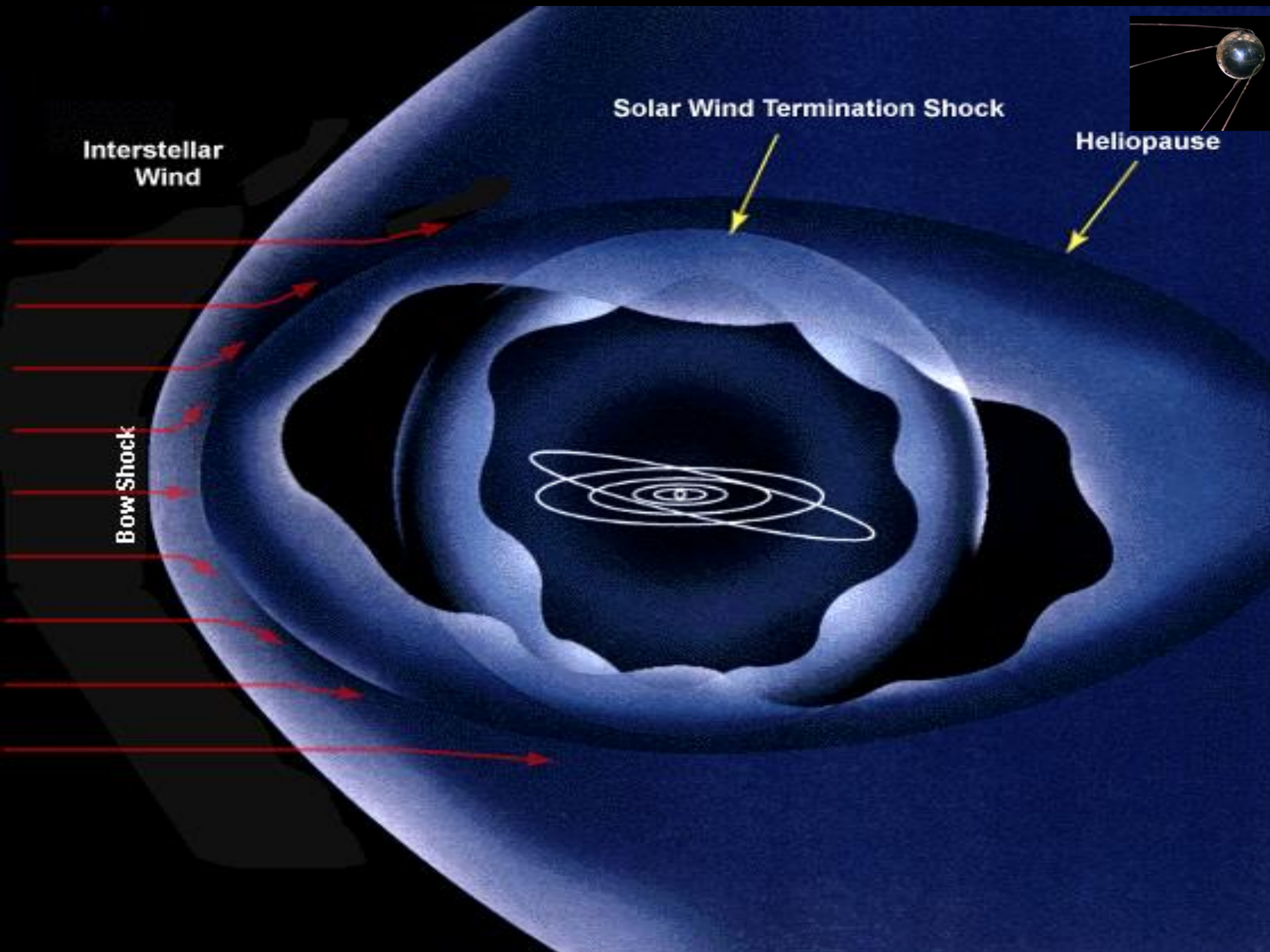
Halley's Comet nucleus
13/03/86, Giotto, ESA

Comet Hartley-2
04/11/10, Epoxi, NASA

10 November 2014



Comet
67P/Churyumov-Gerasimenko


Solar Wind Termination Shock
Heliopause
Interstellar
Wind
Bow Shock

R. Giacconi,
Nobel Prize 2002

Dr. Friedman with Aerobee rocket.

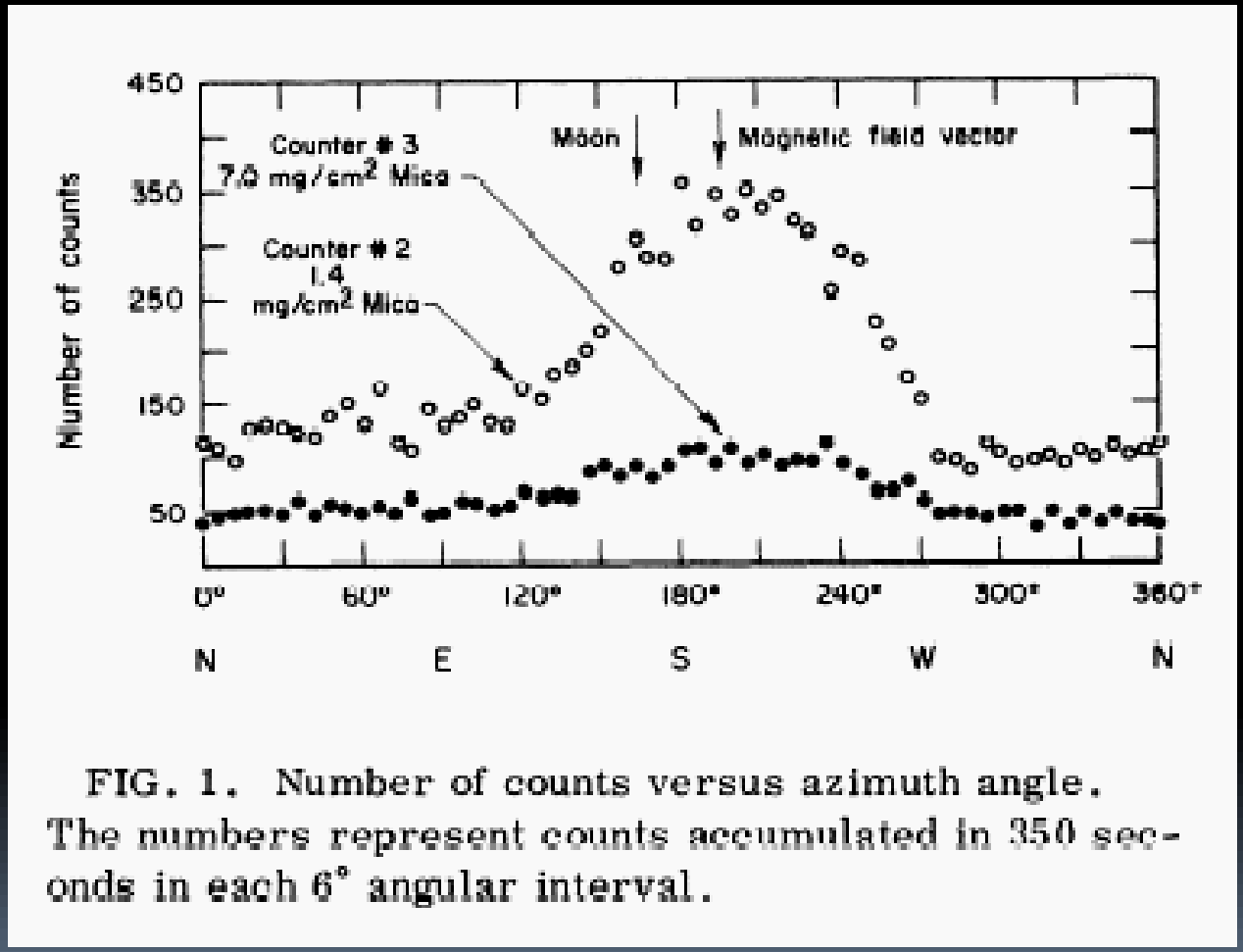
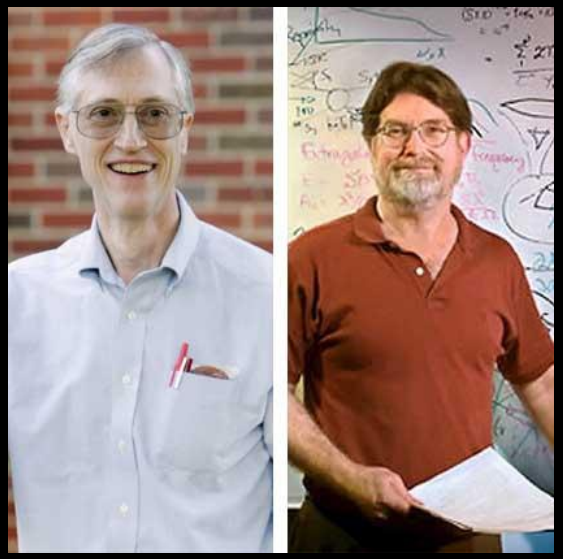
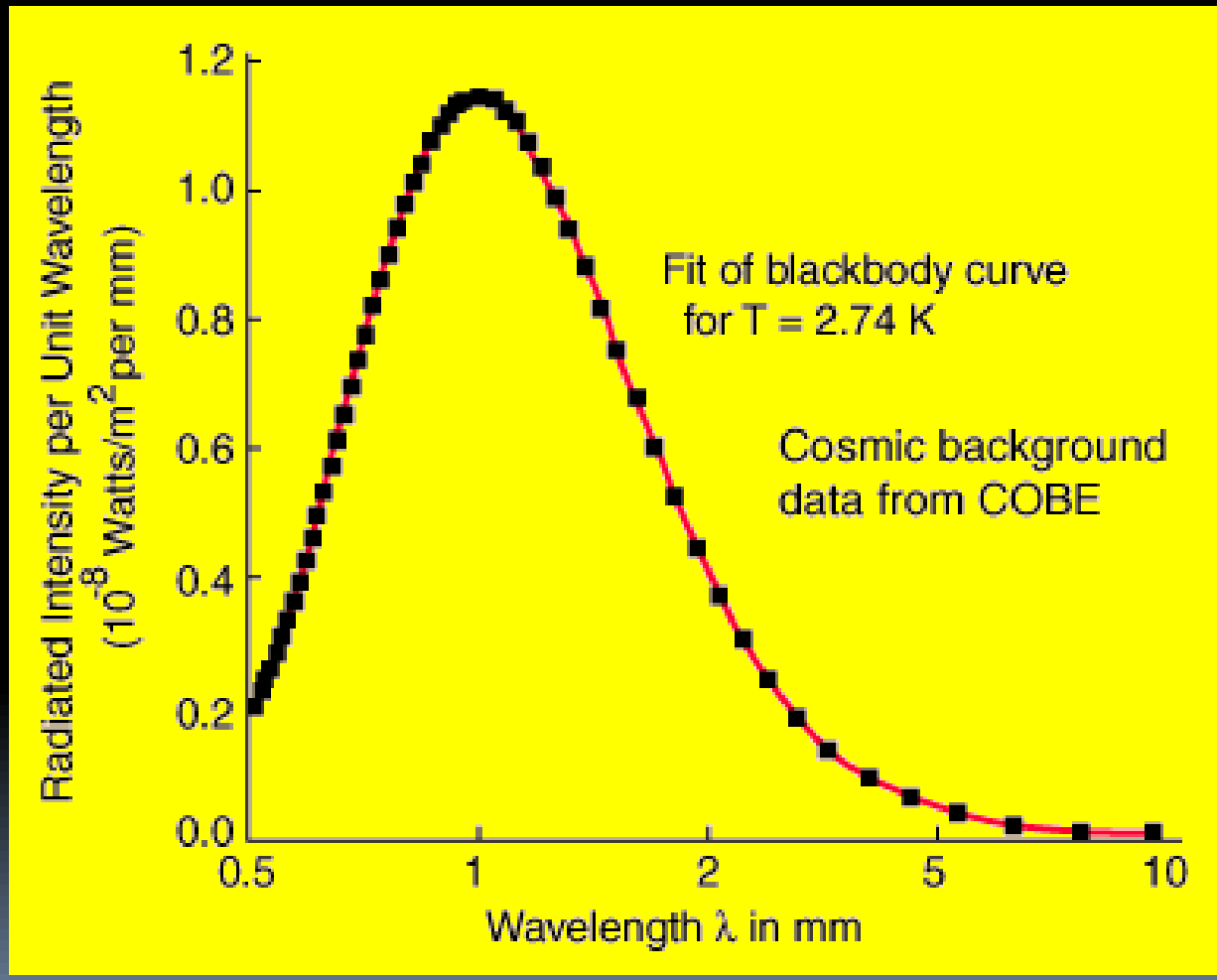


FIG. 1. Number of counts versus azimuth angle. The numbers represent counts accumulated in 350 seconds in each 6° angular interval.

Phys. Rev. Letters, 1962

J. Mather & G. Smoot, Nobel Prize 2006

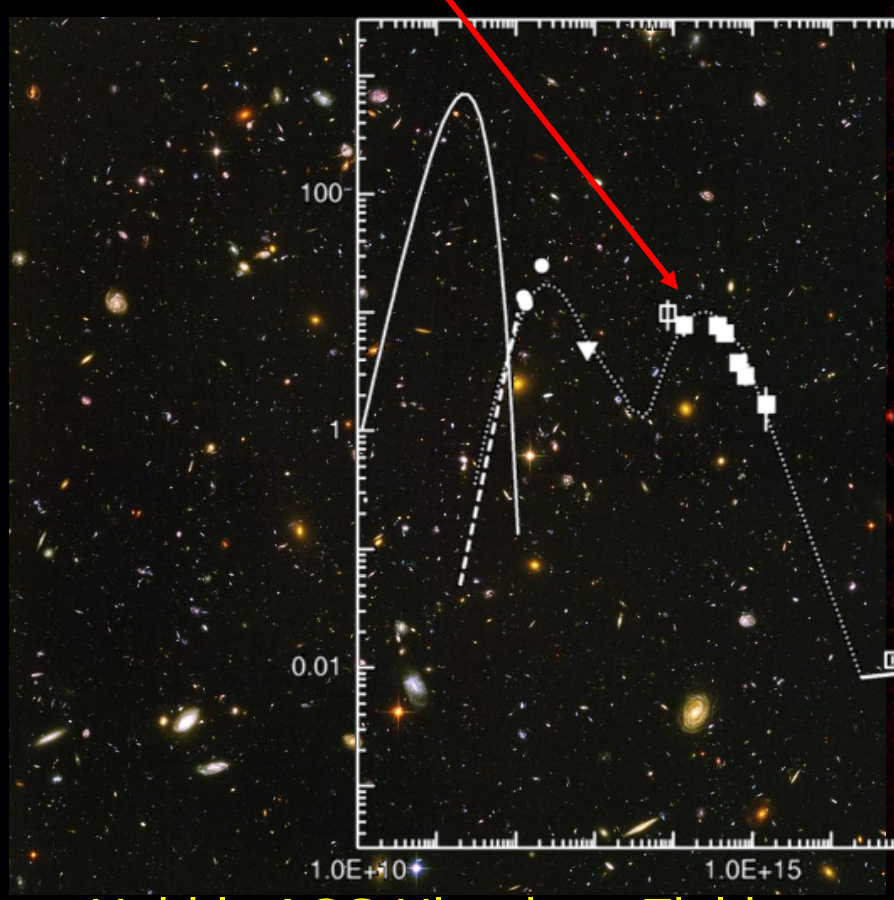


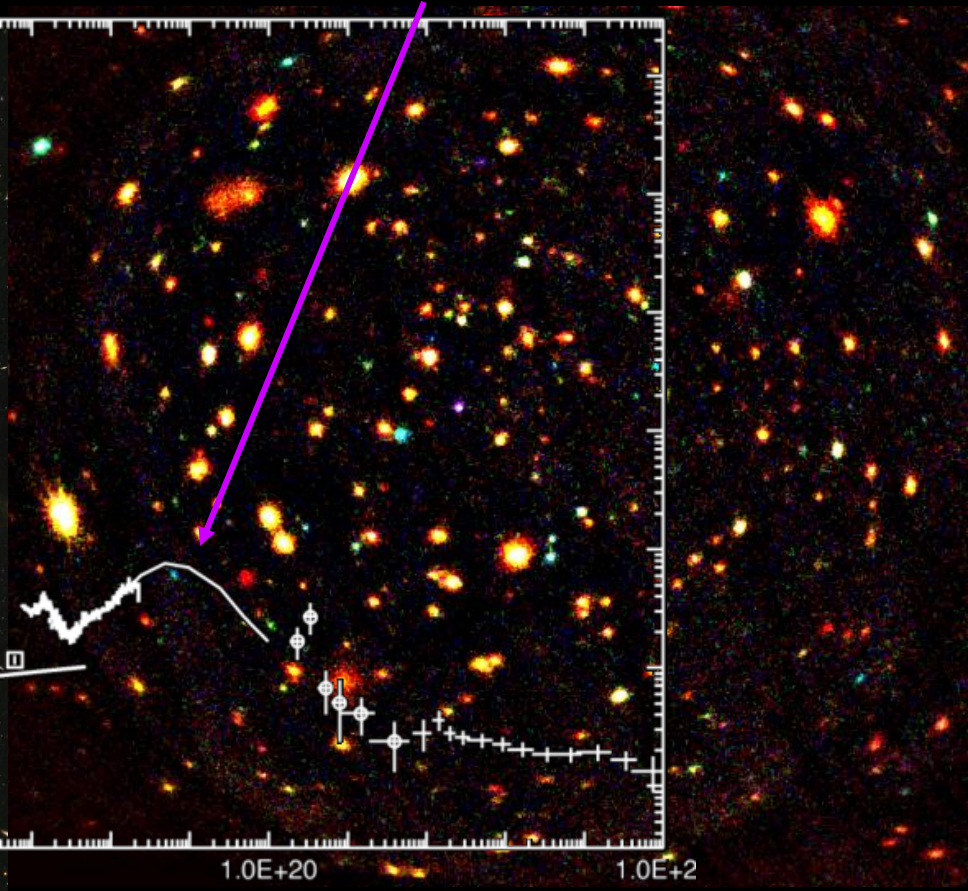


Continuous spectrum of the Universe

The 6,000 K Universe:
Stars

The 1,000,000 K Universe:
Black Holes + Hot Gas





Hubble ACS Ultradeep Field

XMM-Newton 1 Msec Field

Credit: G. Hasinger

Grand Questions

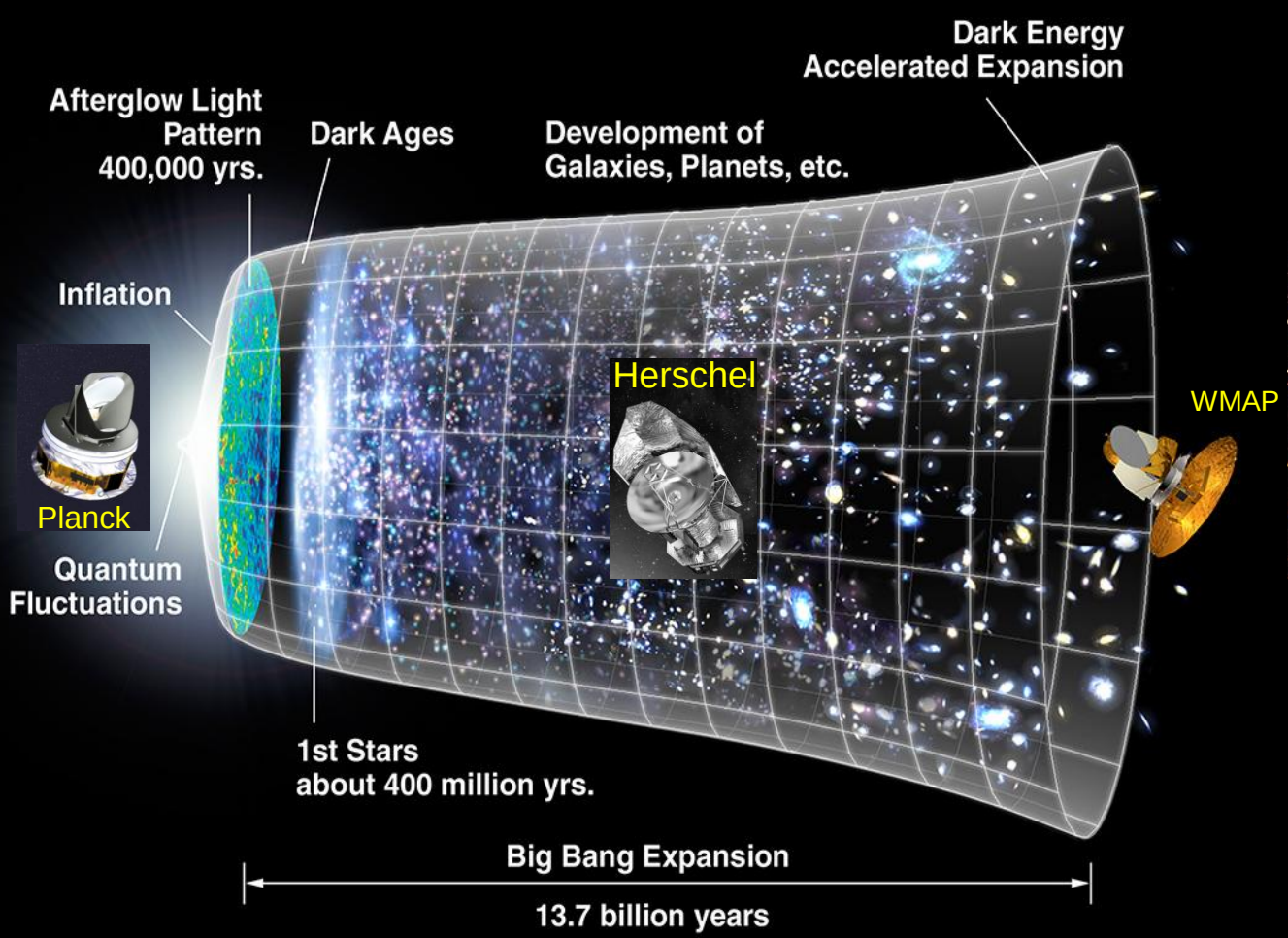
1. Understanding the Universe. How did it began? How is it evolving?
2. Are we alone?
3. Understanding the Solar System. How did it begin? How is it evolving?
4. Will the Earth remain an hospitable home for humanity in the future?
5. What could the future hold for humans in space?

Understanding the Universe

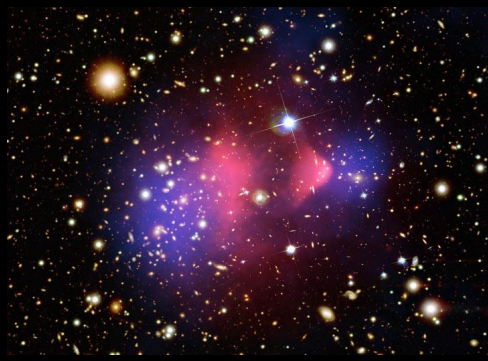
How did it began?

How is it evolving?

How did it begin?



Chandra

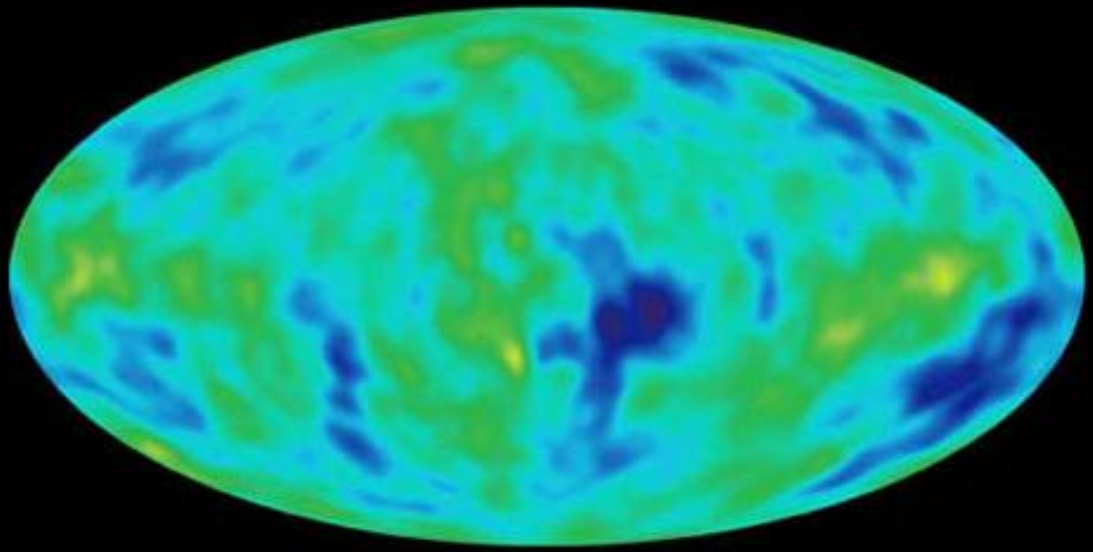


Dark **Matter**

HST

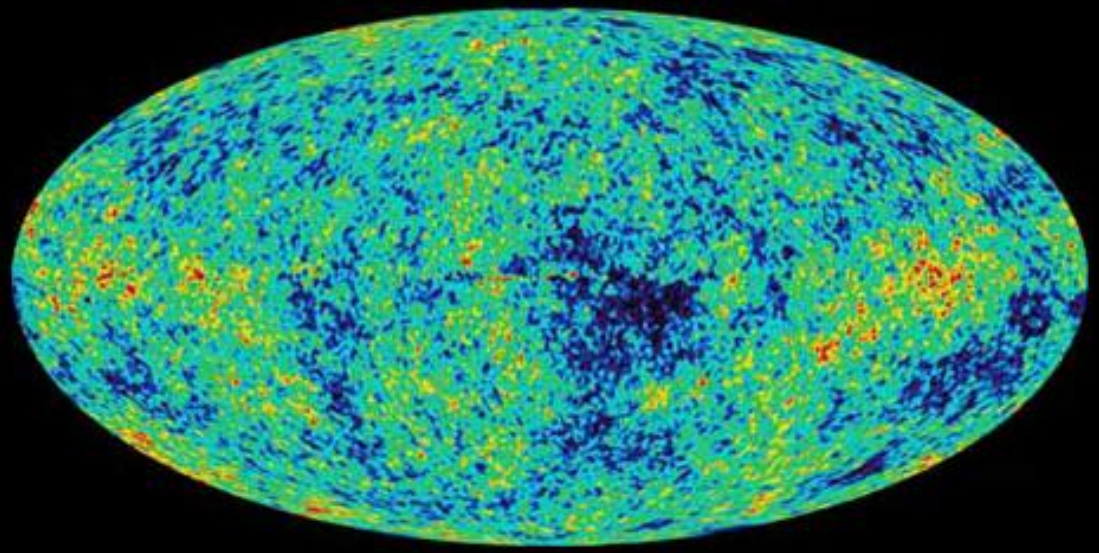
NASA/WMAP Science Team

The first lights

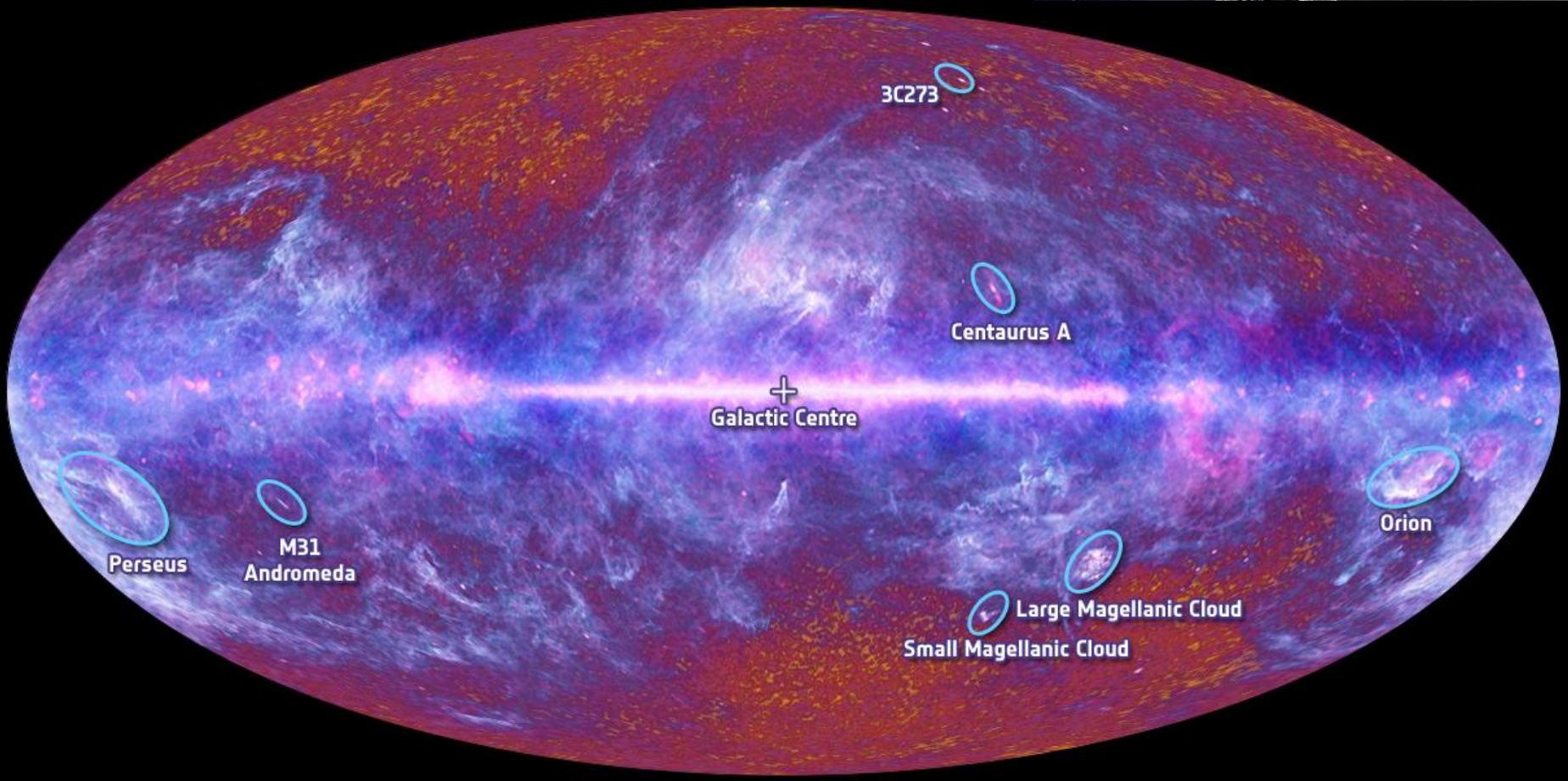


COBE

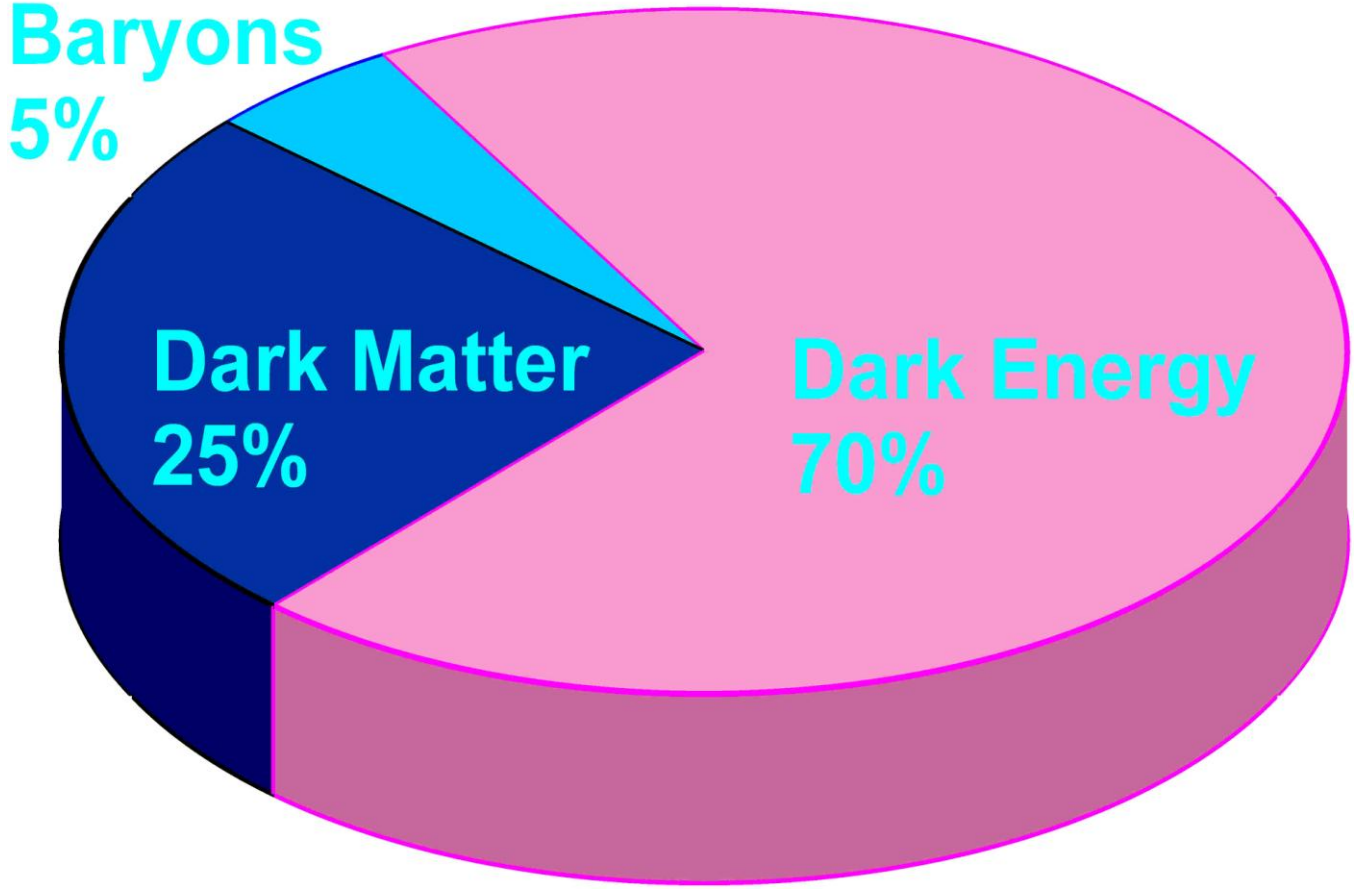
WMAP



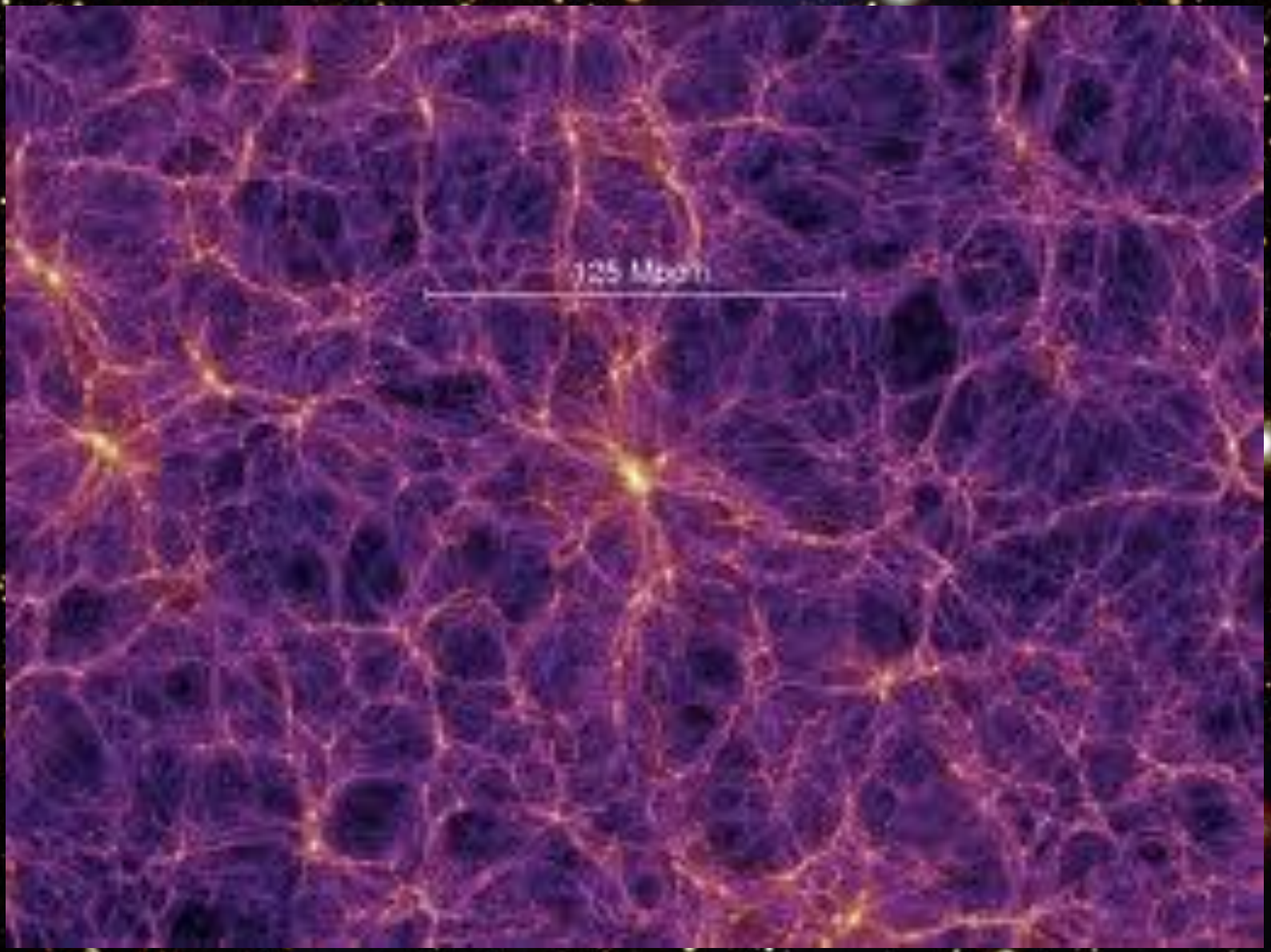
Planck's Universe



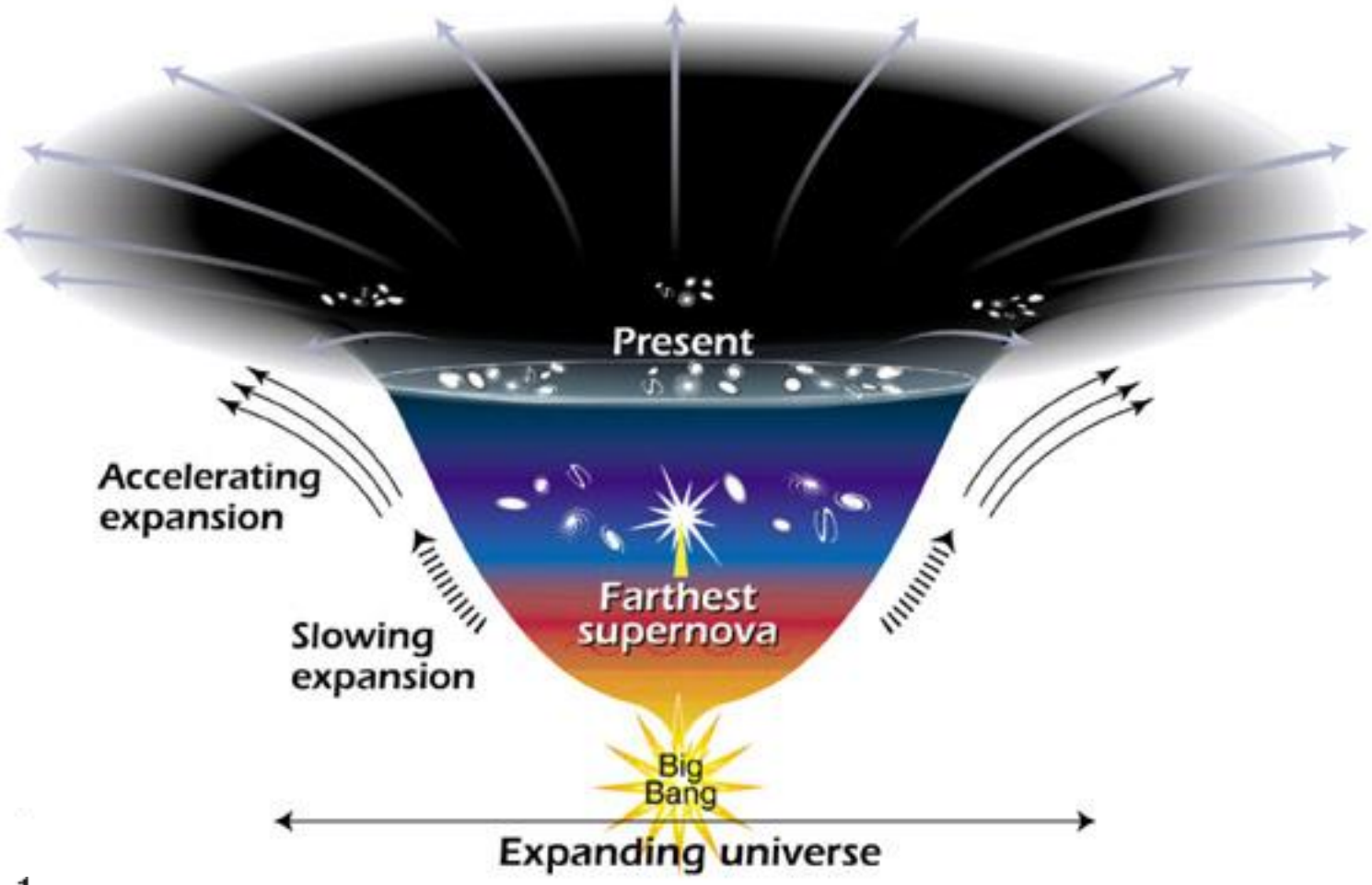
The known and the unknown of the Universe



Dark matter



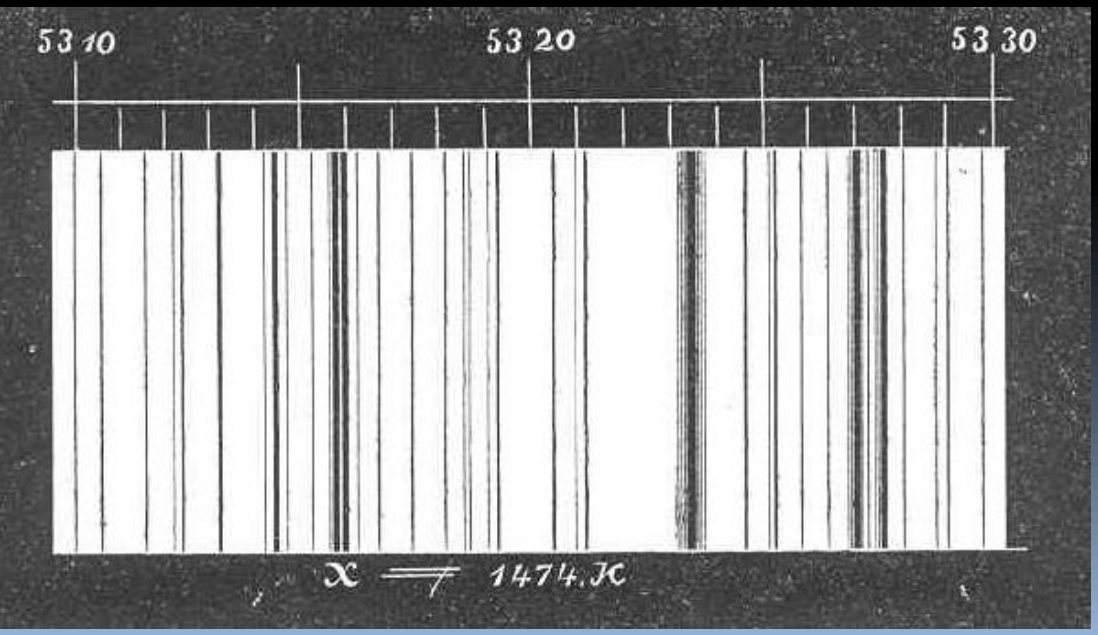
How did it evolve?

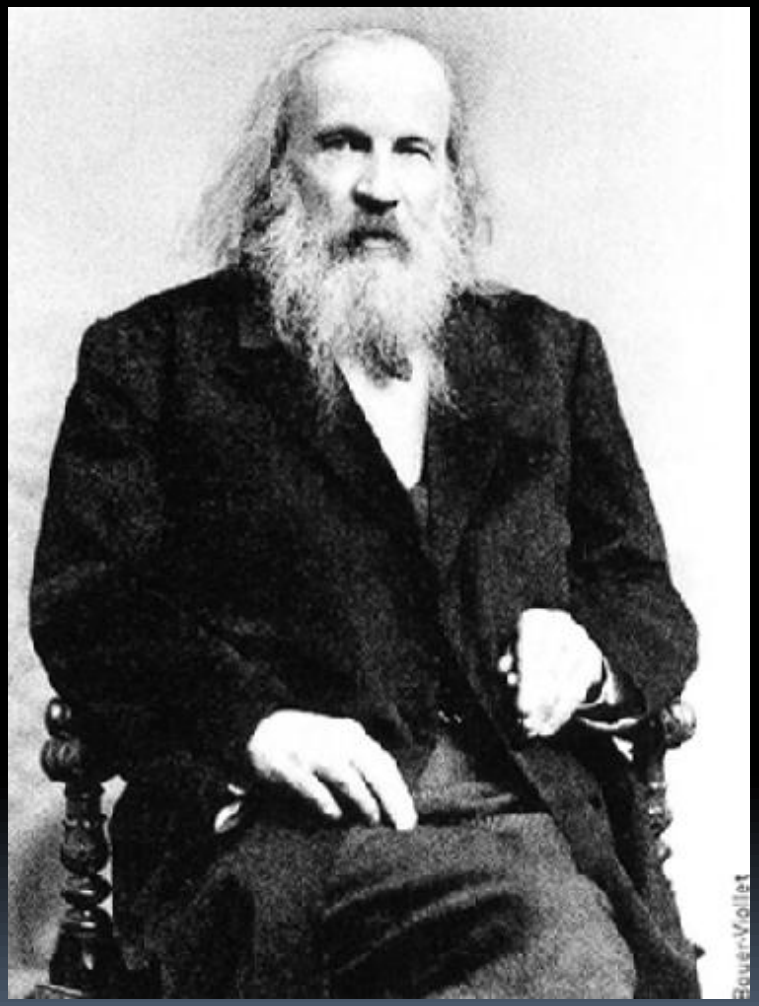


$$R_{ij} - \frac{1}{2} g_{ij}.R = \chi T_{ij} + g_{ij}.\Lambda$$

Coronium?

Newtonium?





D. Mendeleïev, 1902

”Why not?”

Murray Gell’Mann

Petr Horava

The search for darkness

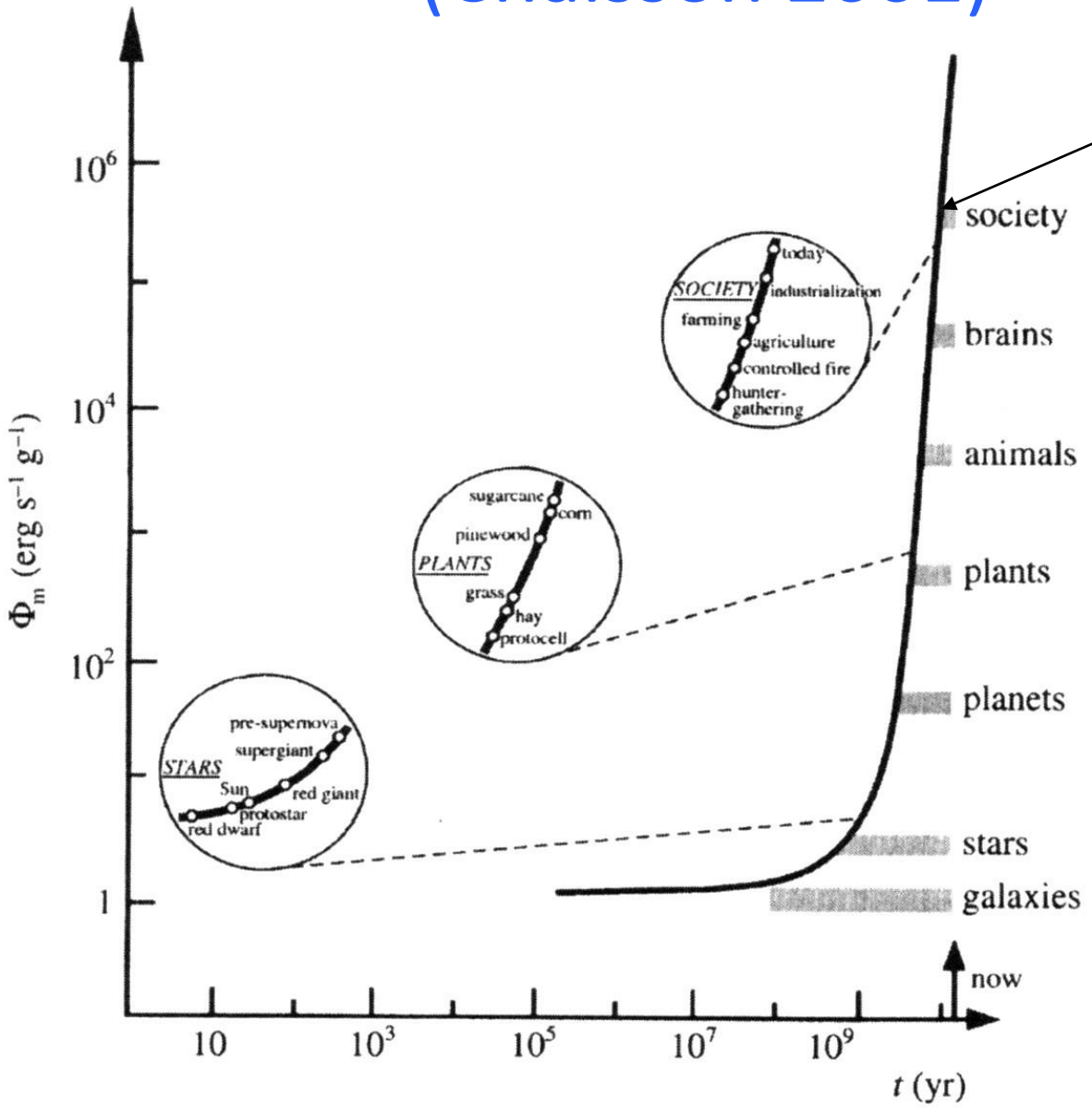
WFIRST

EUCLIDE

Core of Galaxy NGC4261 HST · WFPC2

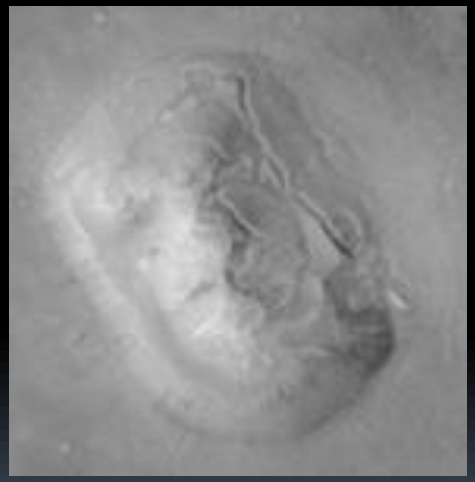
PRC95-47 · ST ScI OPO · December 4, 1995
H. Ford and L. Ferrarese (JHU), NASA

Evolution of the structures of the Universe (Chaisson 2001)



Dissipatives structures of increasing complexity

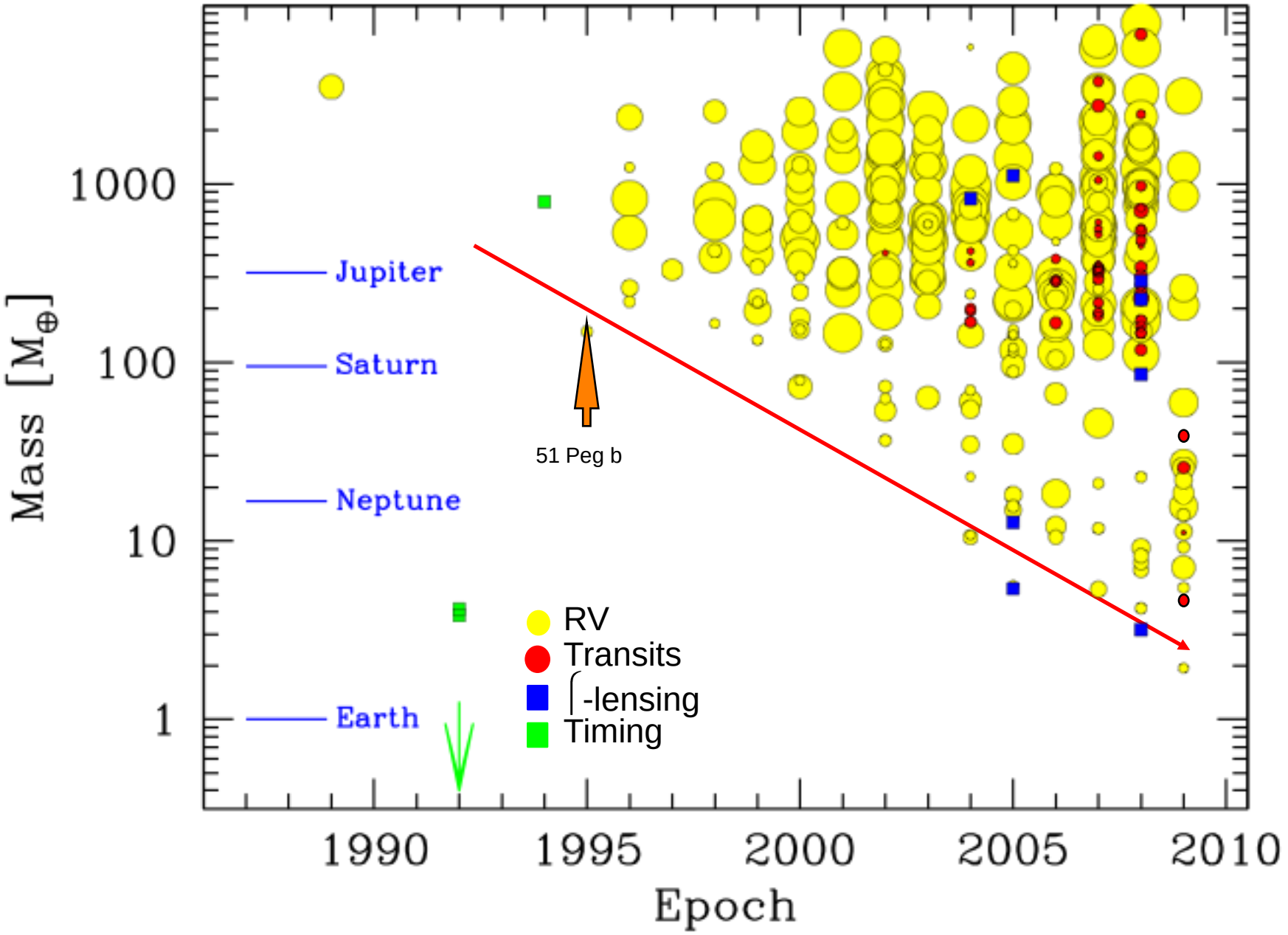
Are we alone?

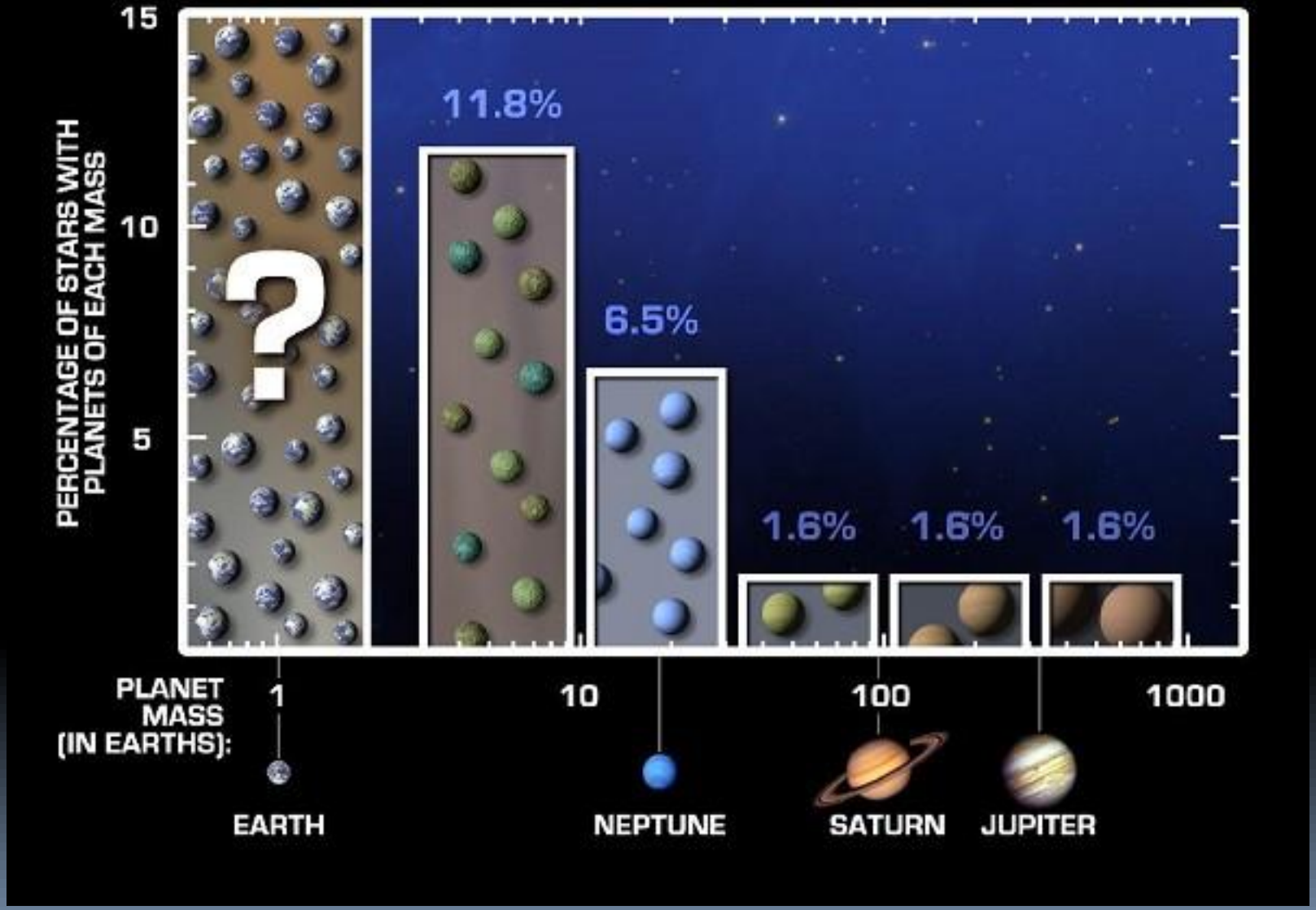


ALH-84001

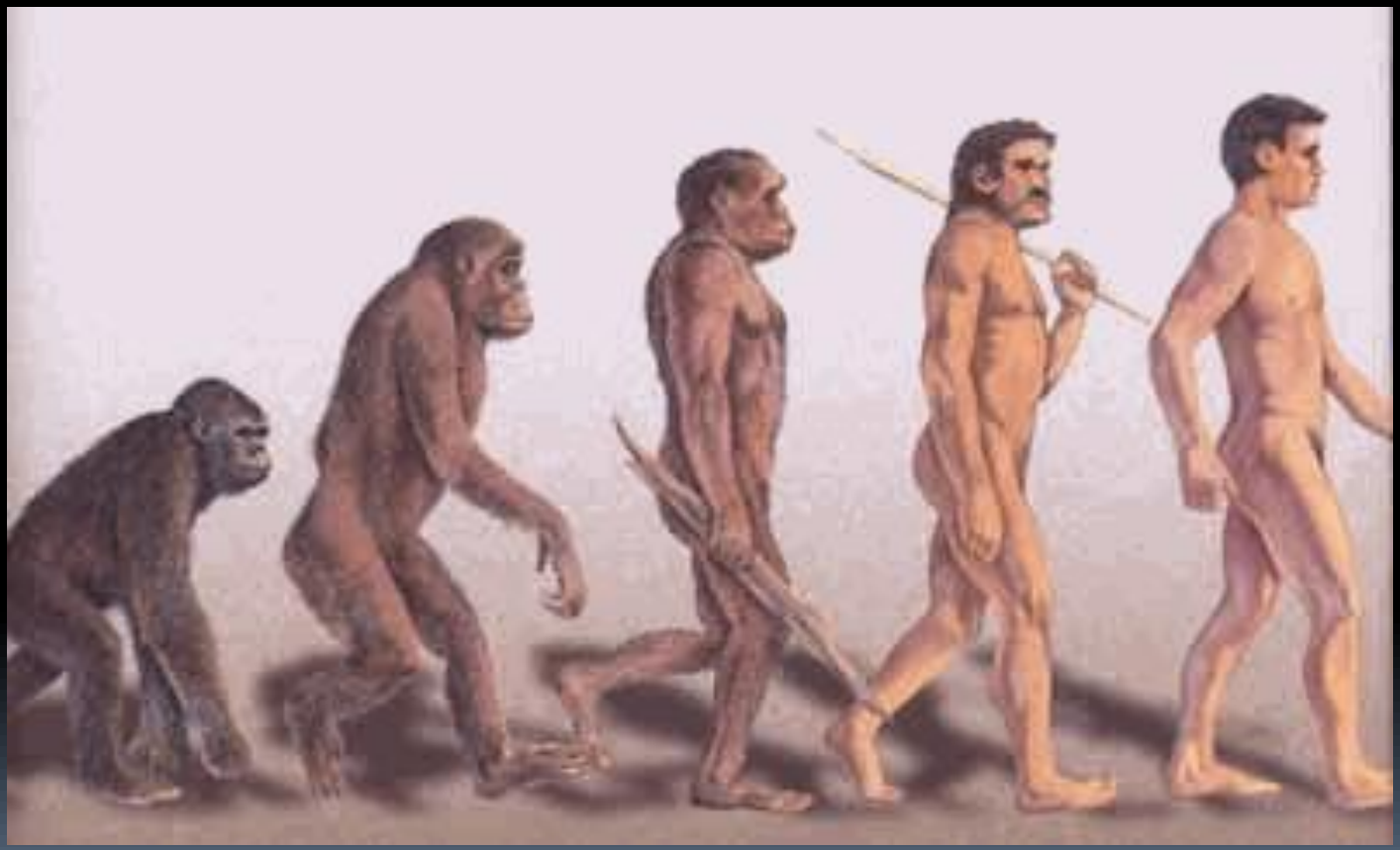
Extra solar planets

(S. Udry, 2010)




PERCENTAGE OF STARS WITH PLANETS OF EACH MASS
15
10
5
?
11.8%
6.5%
1.6%
1.6%
1.6%
PLANET MASS (IN EARTHS):
1
10
100
1000
EARTH
NEPTUNE
SATURN
JUPITER

Evolution to modern humans and terrestrial inteligence



3 My (57.3s) | 2 My (38.2s) | 1 My (19.1s) | 100 000 y (1.91s) | Now


Я.Б. ЗЕЛЬДОВИЧ
Избранные труды

Simulation of an Earth like planet at 10 light Years, observed with a 150 km array hypertelescope of 150 mirrors of 3 m

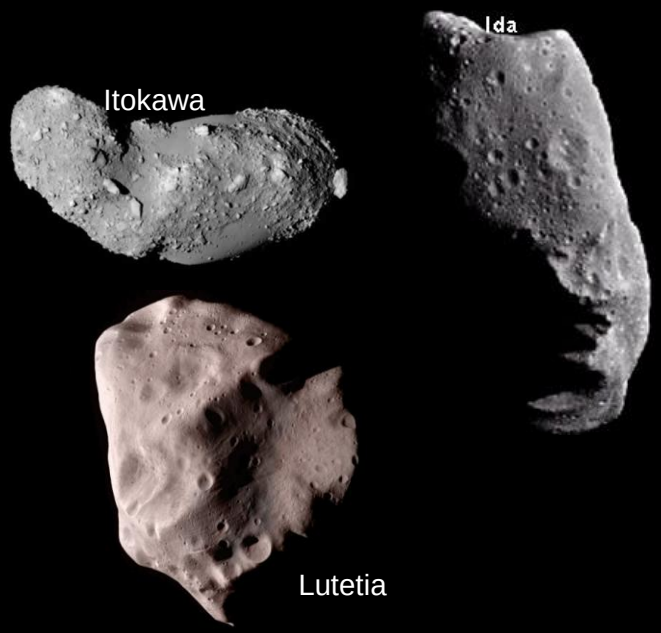
Understanding the Solar System

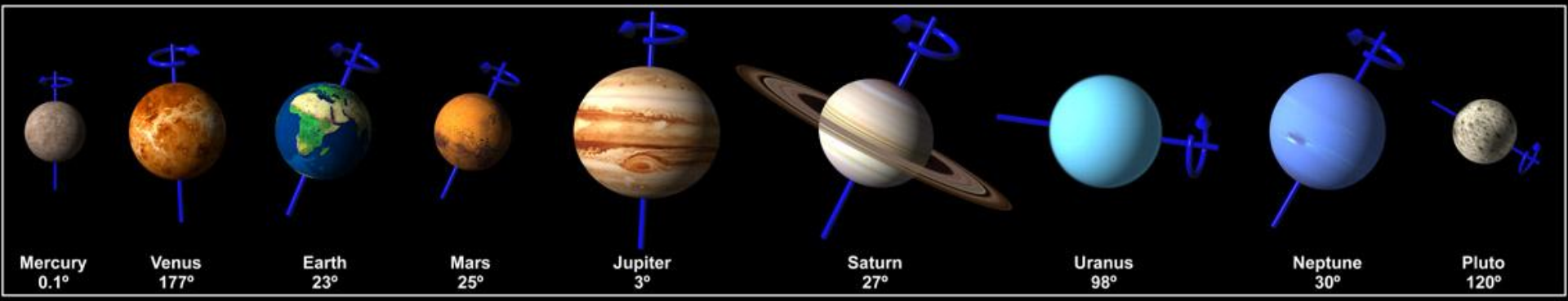
How did it begin?

How is it evolving?

The Solar System diversity and commonalities

- Sizes
- Moons
- Craters
- Rings
- Volcanoes
- Magnetism
- Atmospheres
- Water



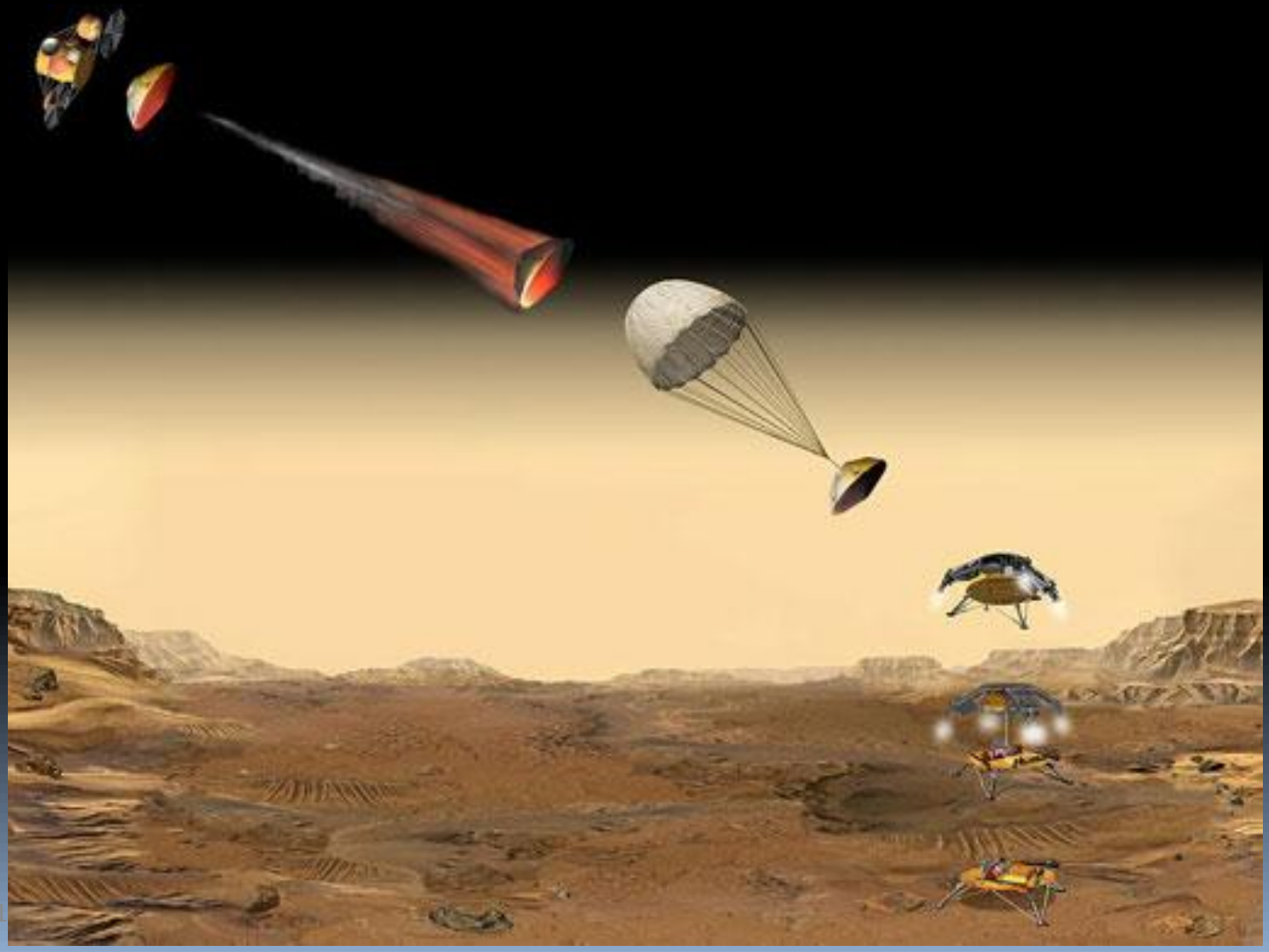


Obliquity of the Nine Planets

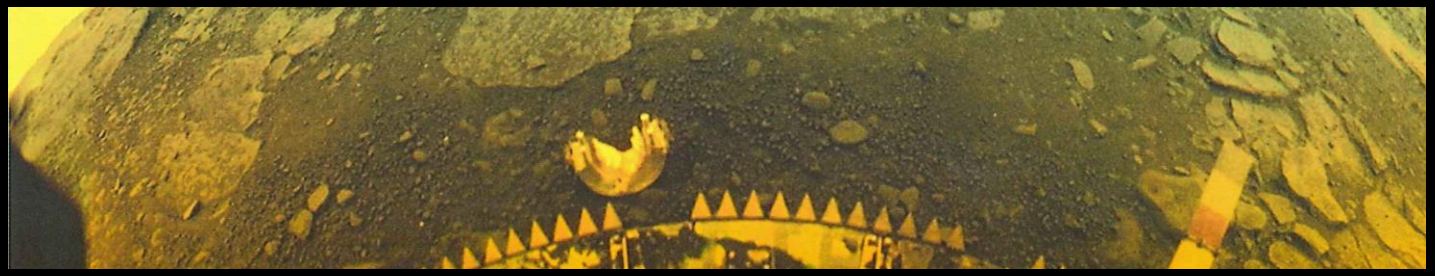
History book of the Solar System

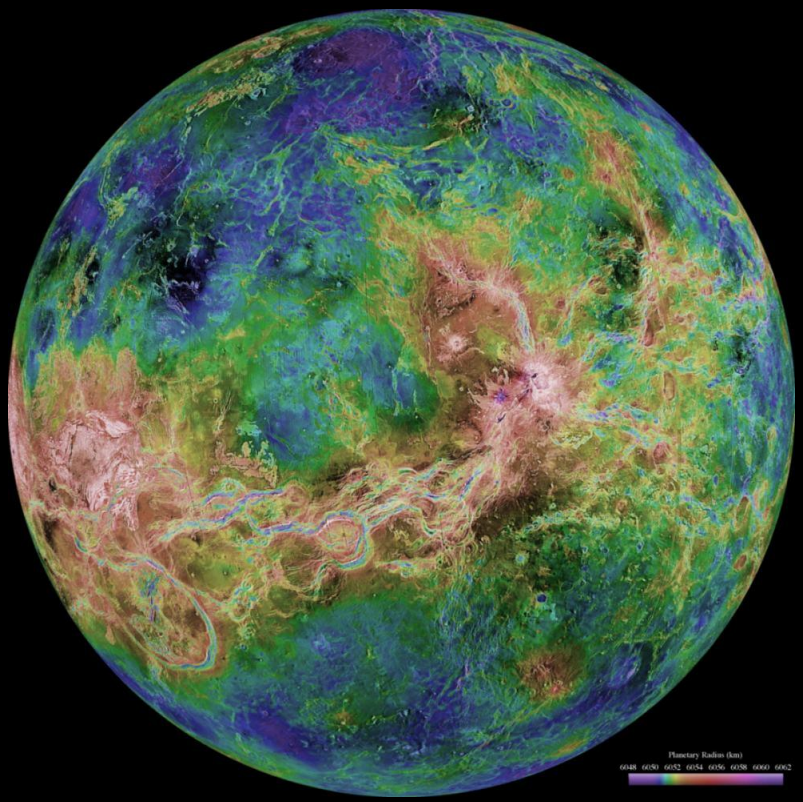
Returning samples to Earth

Essential for a proper understanding of what is happening in our neighborhood



Venus





esa

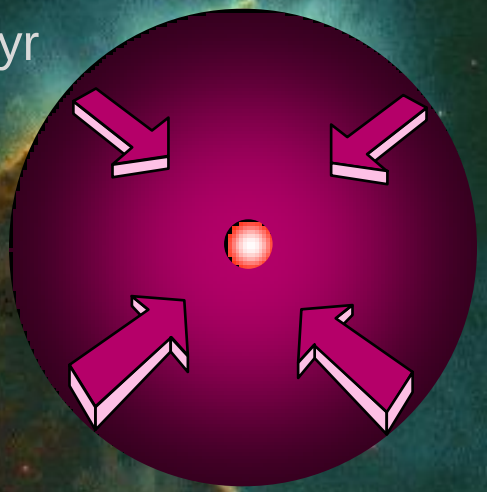
Venus Sample Return

Assessment Study Report

SCI(98)3 June 1998

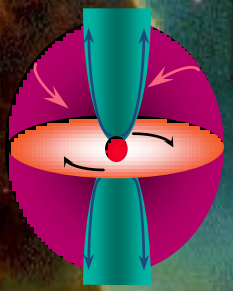
The formation of planetary systems

10^4 yr



Collapsing cloud

Disk & Jet

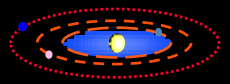


10^6 yr

Protoplanetary system

10^8 yr

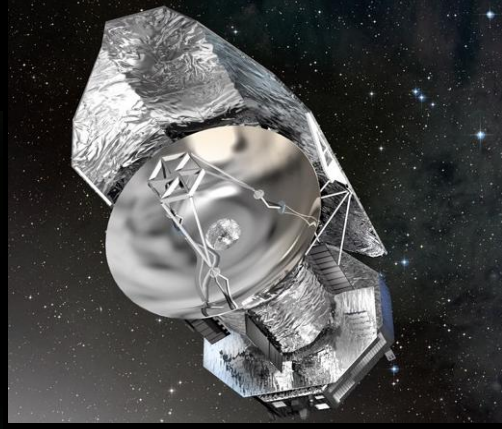
Planetary system



10^9 yr

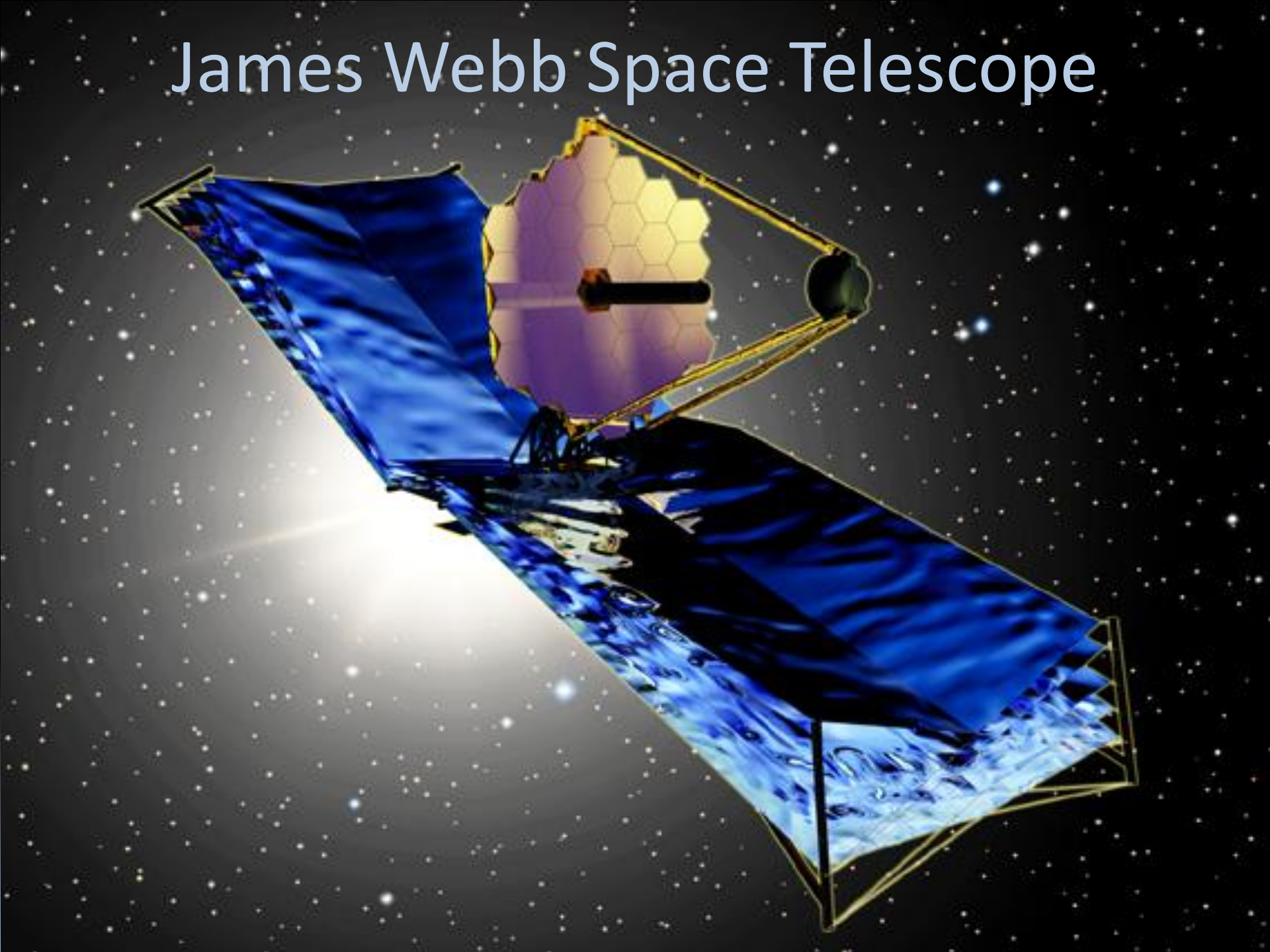
2009: Herschel

ESA’s largest space telescope

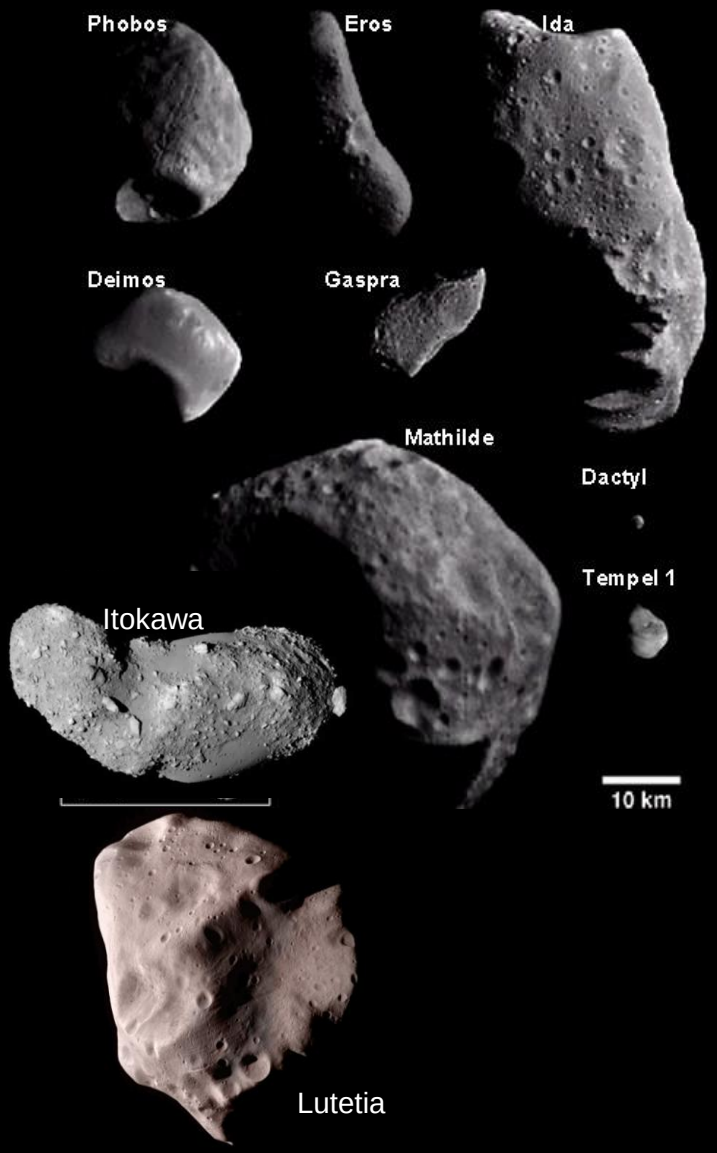


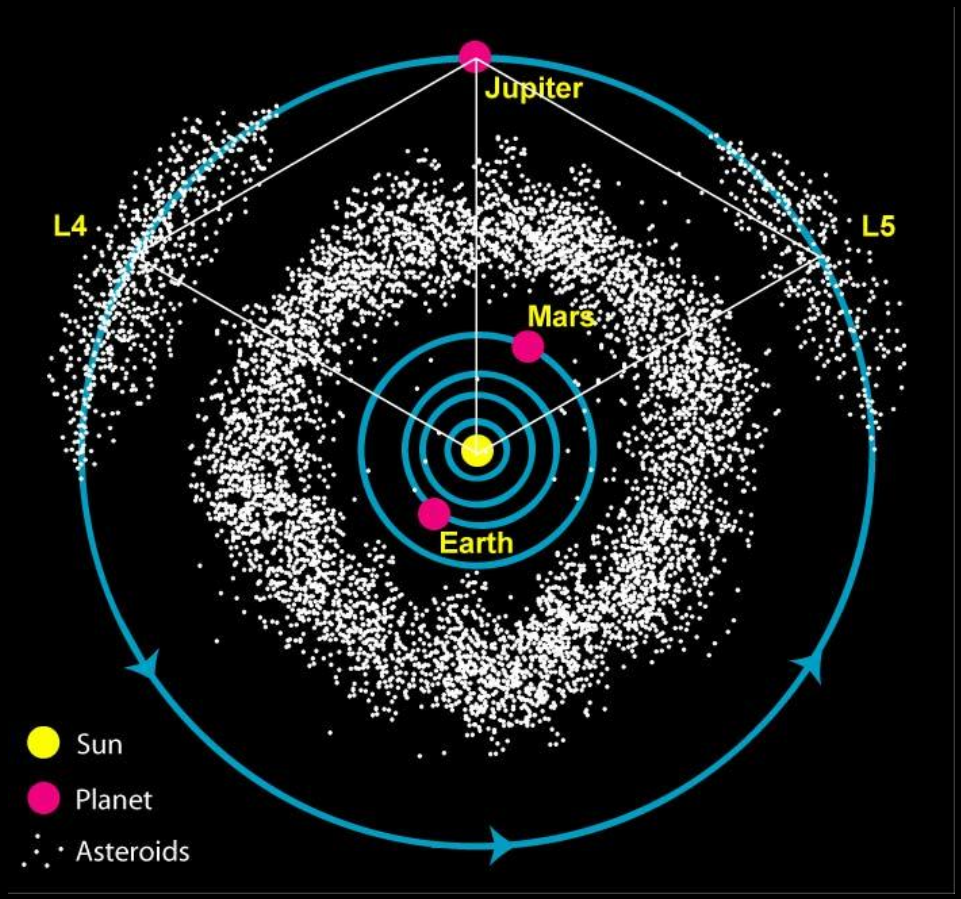
Herschel forces a complete review of stars formation models. There will be a ’’before and an after’’ Herschel(Laurent Vigroux, Oct.2010)

James Webb Space Telescope



Asteroids: understanding the “genome” of the Solar System

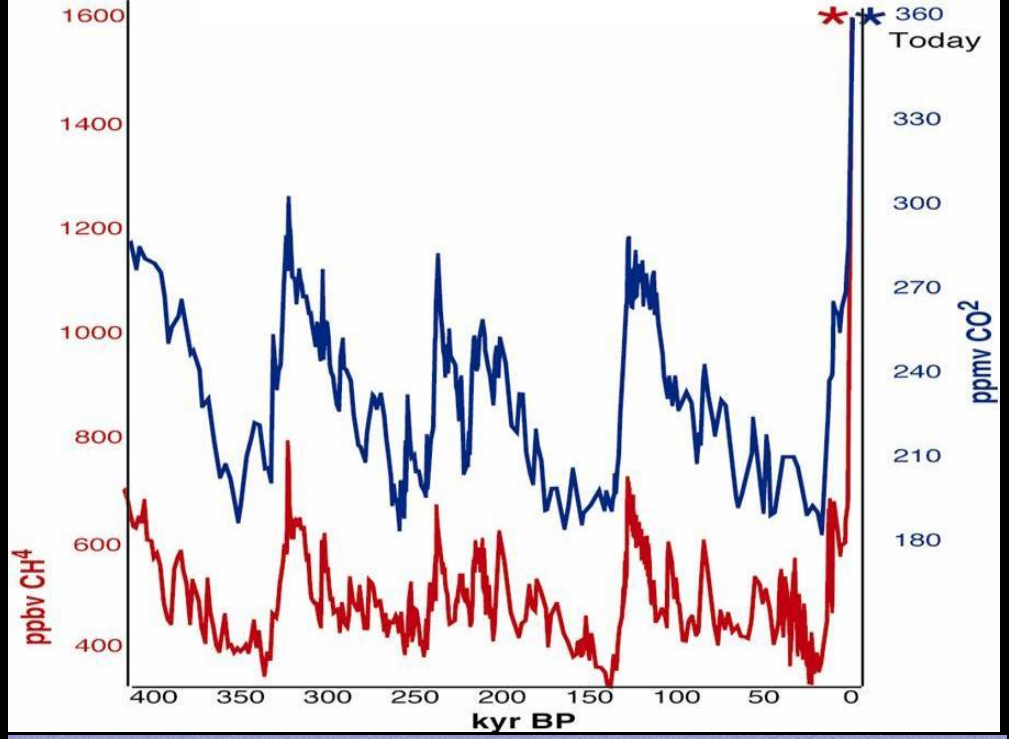


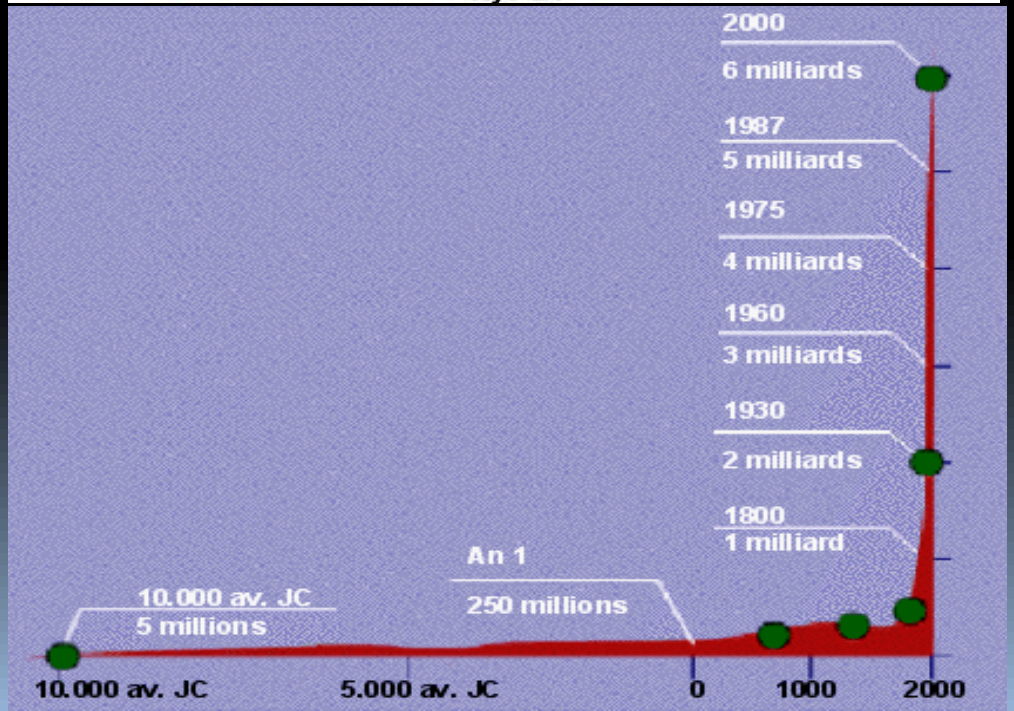


The Earth

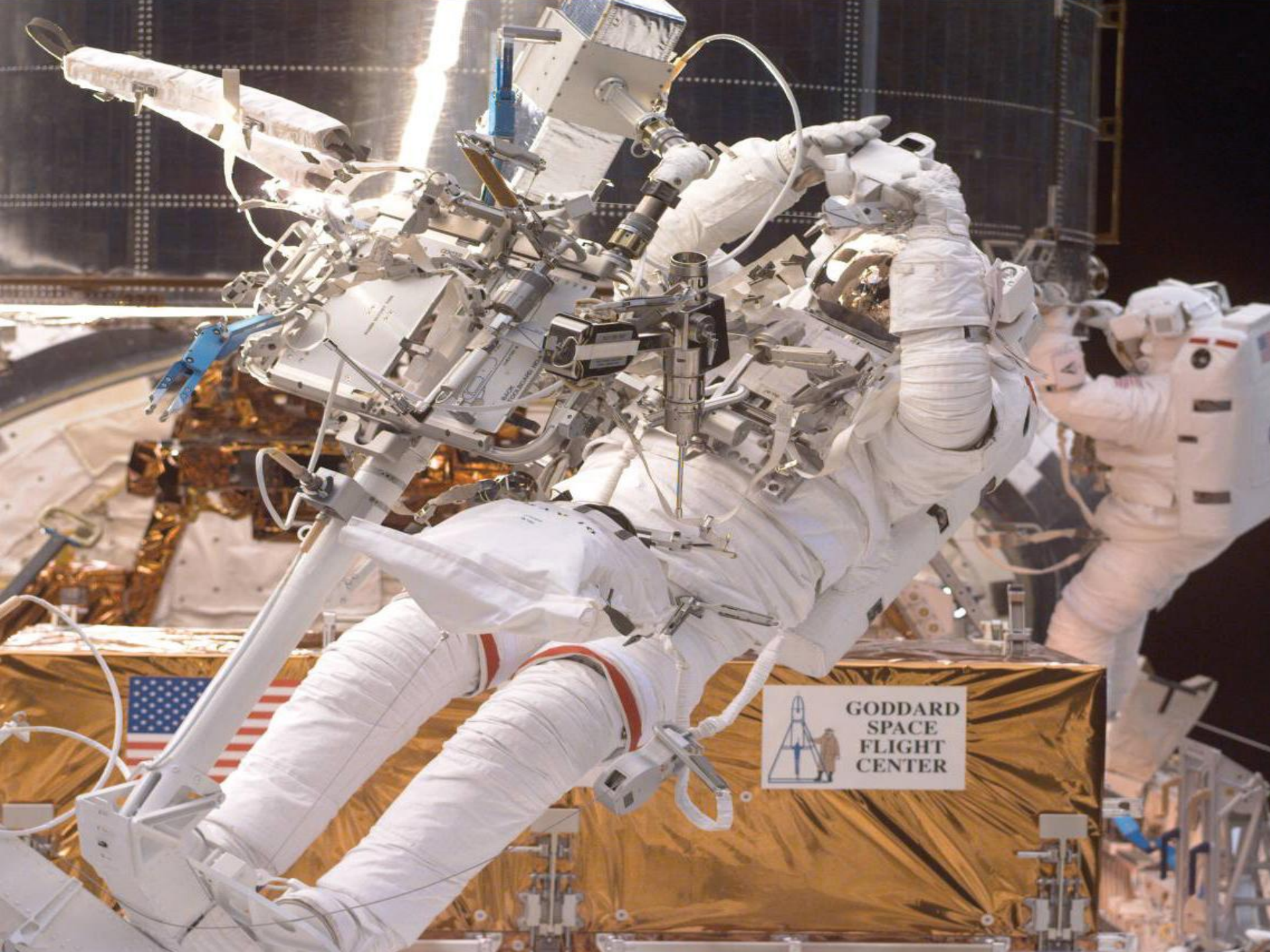

Will it remain a hospitable home for humanity in the future?

Will it remain a hospitable home for humanity in the future?


1600
1400
1200
1000
800
600
400
ppbv CH4
360
Today
330
300
270
240
210
180
ppmv CO2
400 350 300 250 200 150 100 50 0
kyr BP


2000
6 milliards
1987
5 milliards
1975
4 milliards
1960
3 milliards
1930
2 milliards
1800
1 milliard
An 1
250 millions
10.000 av. JC
5 millions
10.000 av. JC
5.000 av. JC
0
1000
2000

What could the future hold for Humans in space?


GODDARD
SPACE
FLIGHT
CENTER


1990-2010:
Hubble 20 years in orbit

International Space Station






Conclusions (1/2)

- 50 years after Sputnik1, space has become an essential element of our life and for our survival,
- We enter an era of globalization and space systems are global by nature,
- International cooperation is therefore crucial to ensure that all the elements of the essential space network are at the disposal of all humans

Conclusions (2/2)

- Most of the Grand questions will find an answer through the continuous progress in our understanding of the fundamental laws of nature.
- The rigorous scientific approach finds its purest applications in our attempts to answer these Grand questions. It offers a unique example to those who by ignorance, or arrogance. or personal interest claim that science is wrong.
- Uncertainty and progress have always characterized science
- The grand questions offer an arena for educating the public at large in the value of rigorous scientific reasoning, constantly leading to more discoveries and also to skepticism, both being an integral part of scientific progress and understanding


Thank You!