EUROPE EXPLORES THE UNIVERSE

Marcos Bavdaž

European Space Agency (ESA)

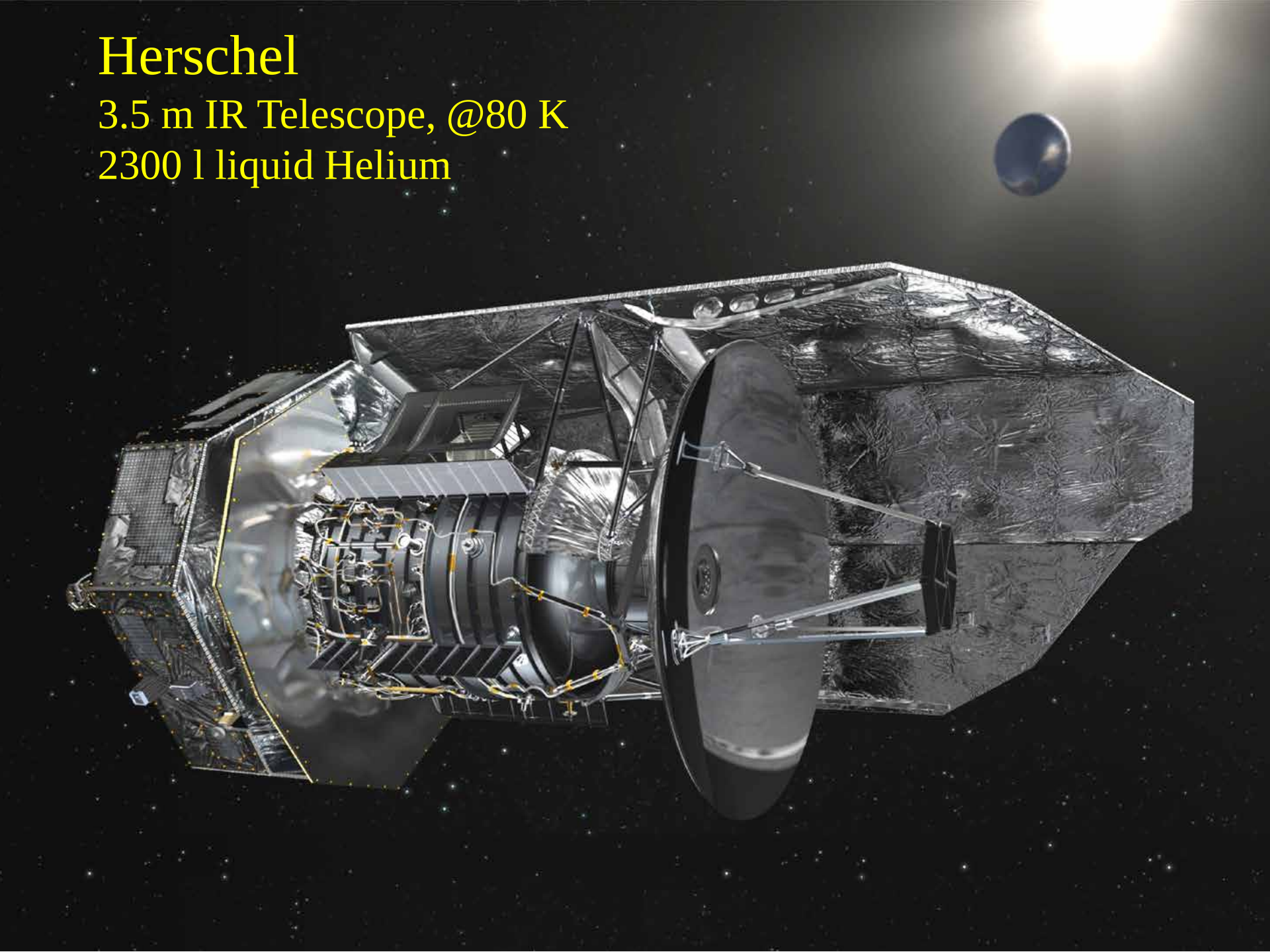
Eagle Nebula, M16
7000 lightyears away,
Temperatue 10 K (red) do 40 K (blue)
Herschel

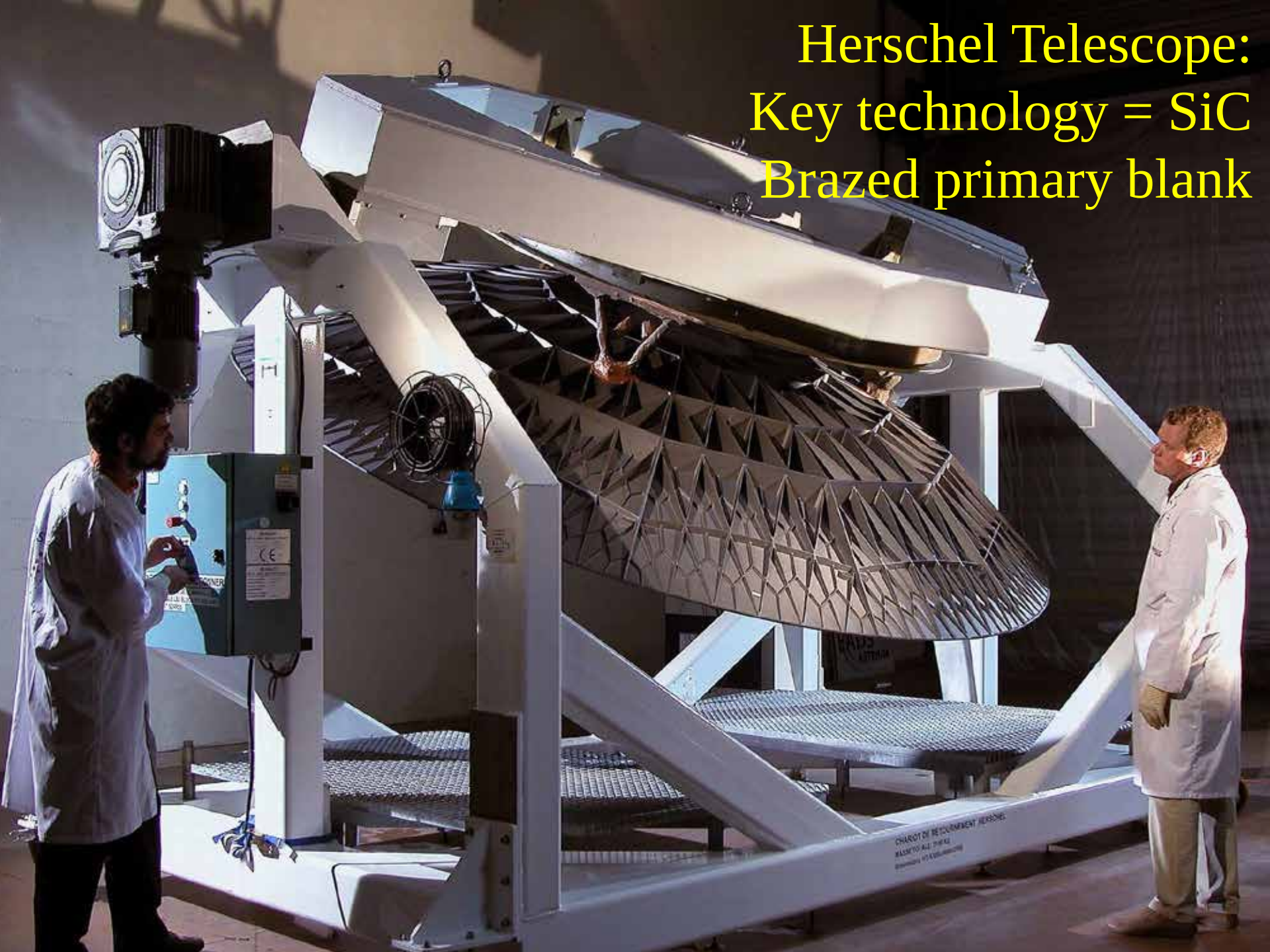
Vipava, 20 April 2017

Herschel

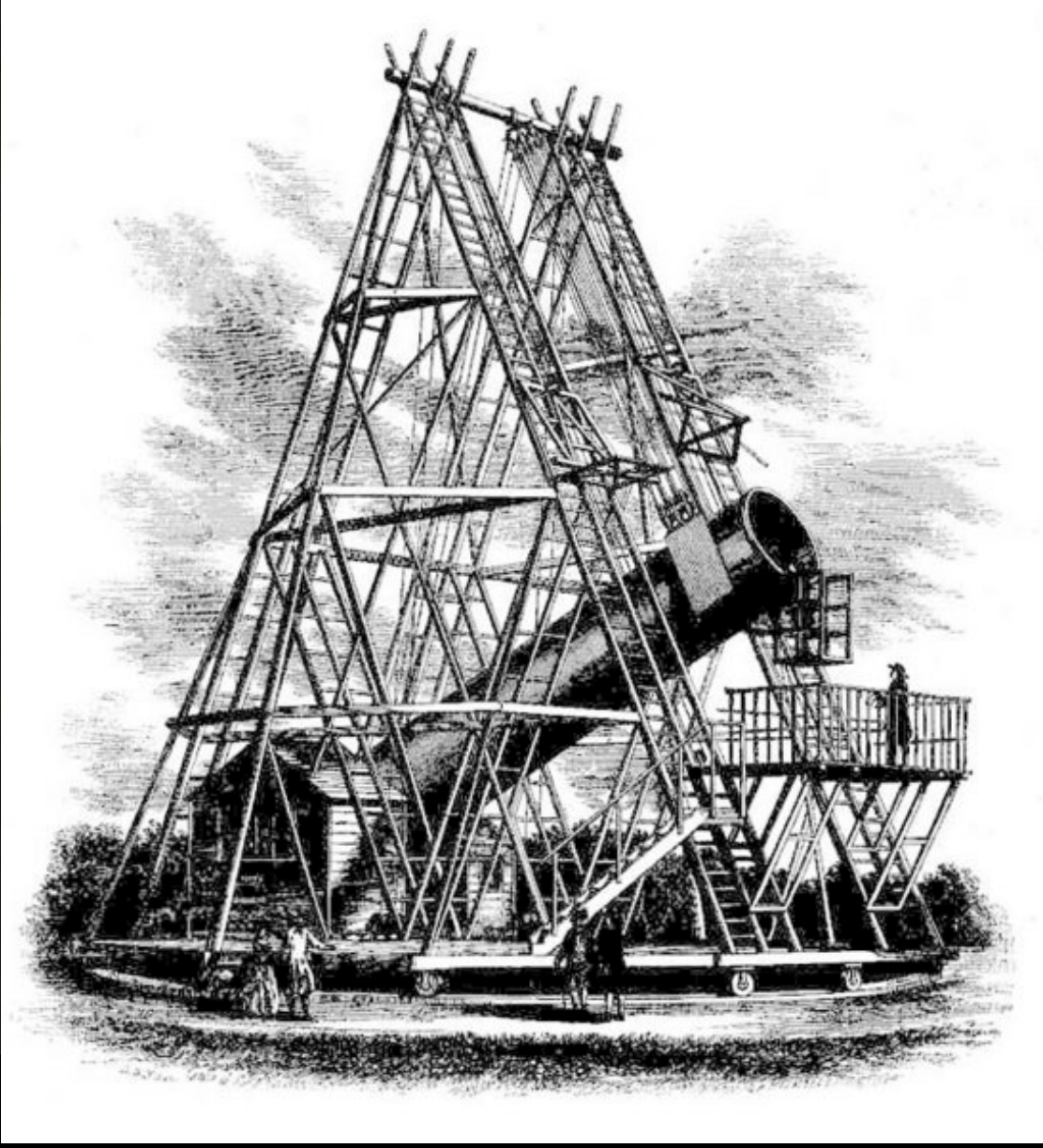
3.5 m IR Telescope, @80 K

2300 l liquid Helium

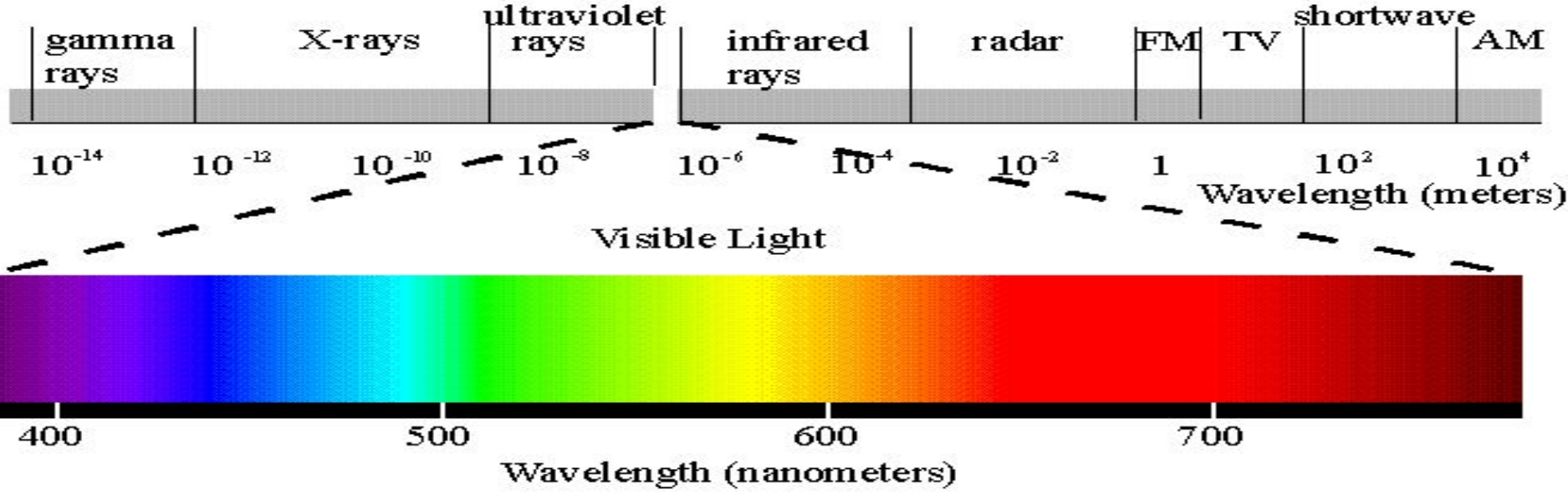


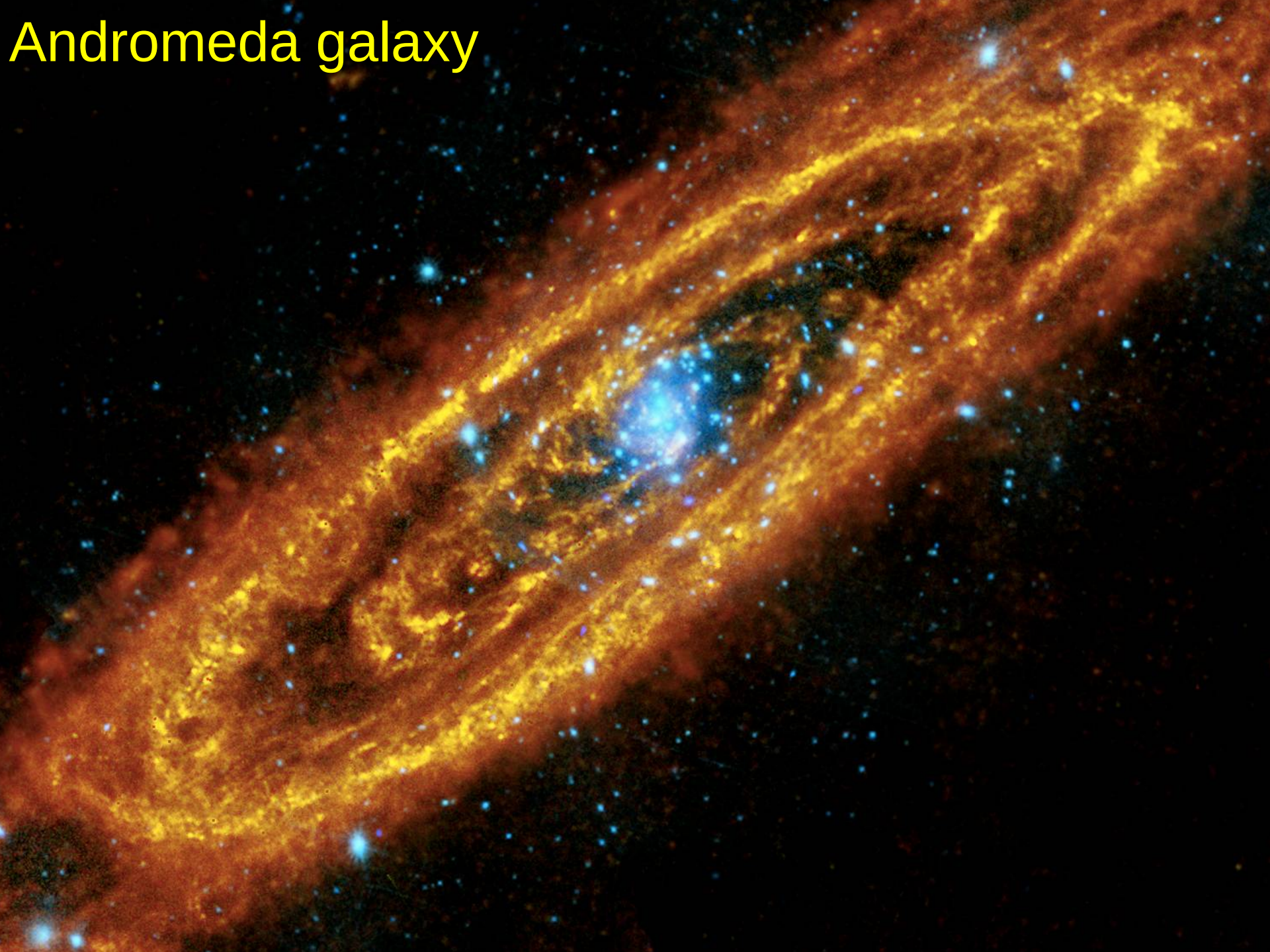

Herschel Telescope:
Key technology = SiC
Brazed primary blank

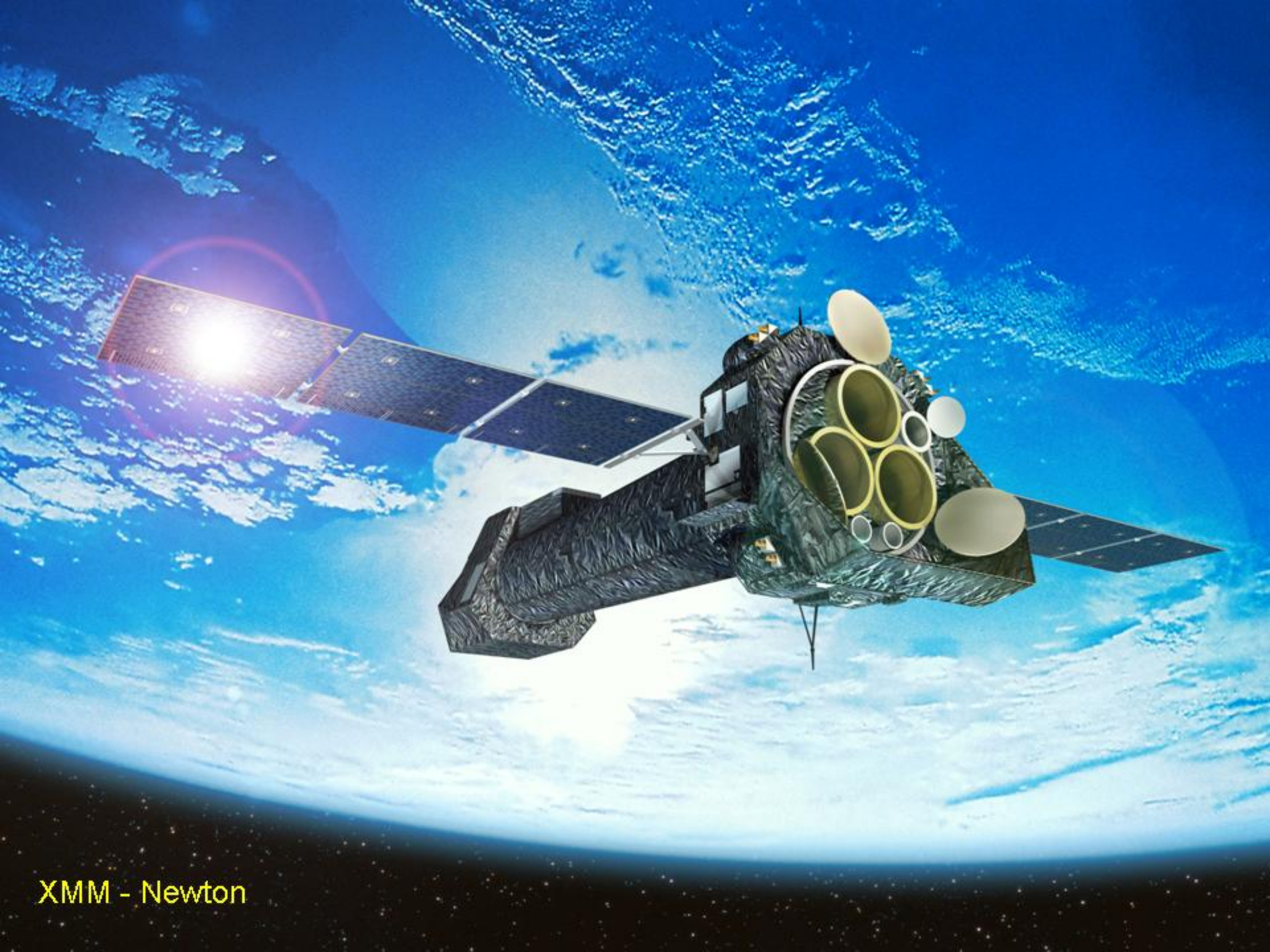
Friedrich Wilhelm Herschel,
(1738 – 1822)
German-English astronomer,
and composer
1781: discovery of Uranus



1789: large telescope (1.2 m Ø


gamma rays
X-rays
ultraviolet rays
infrared rays
radar
FM
TV
shortwave
AM
10^{-14}
10^{-12}
10^{-10}
10^{-8}
10^{-6}
10^{-4}
10^{-2}
1
10^{2}
10^{4}
Wavelength (meters)
Visible Light
400
500
600
700
Wavelength (nanometers)


Andromeda galaxy

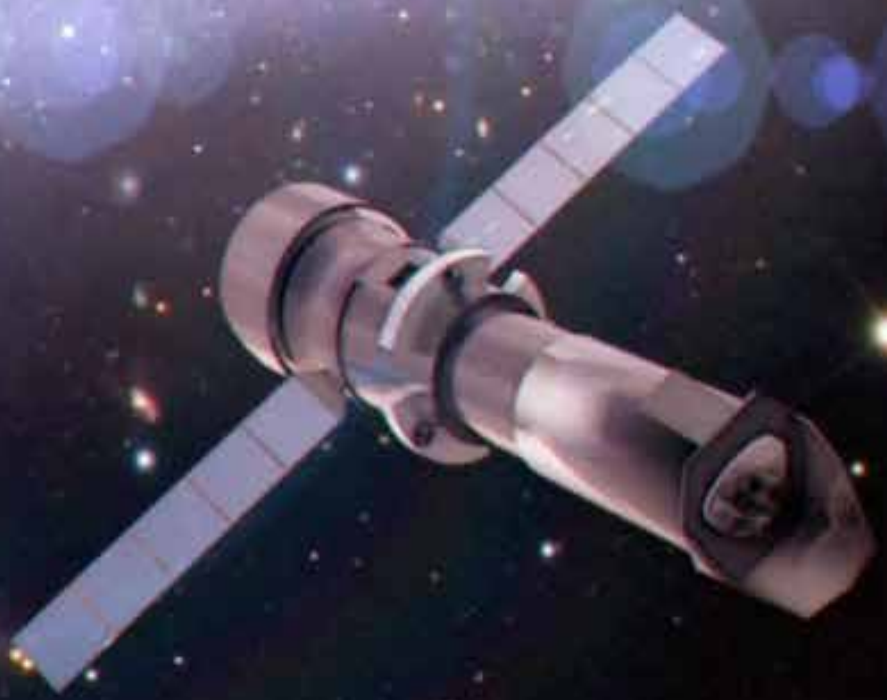

XMM - Newton

Key technology: Replicated Nickel Optics

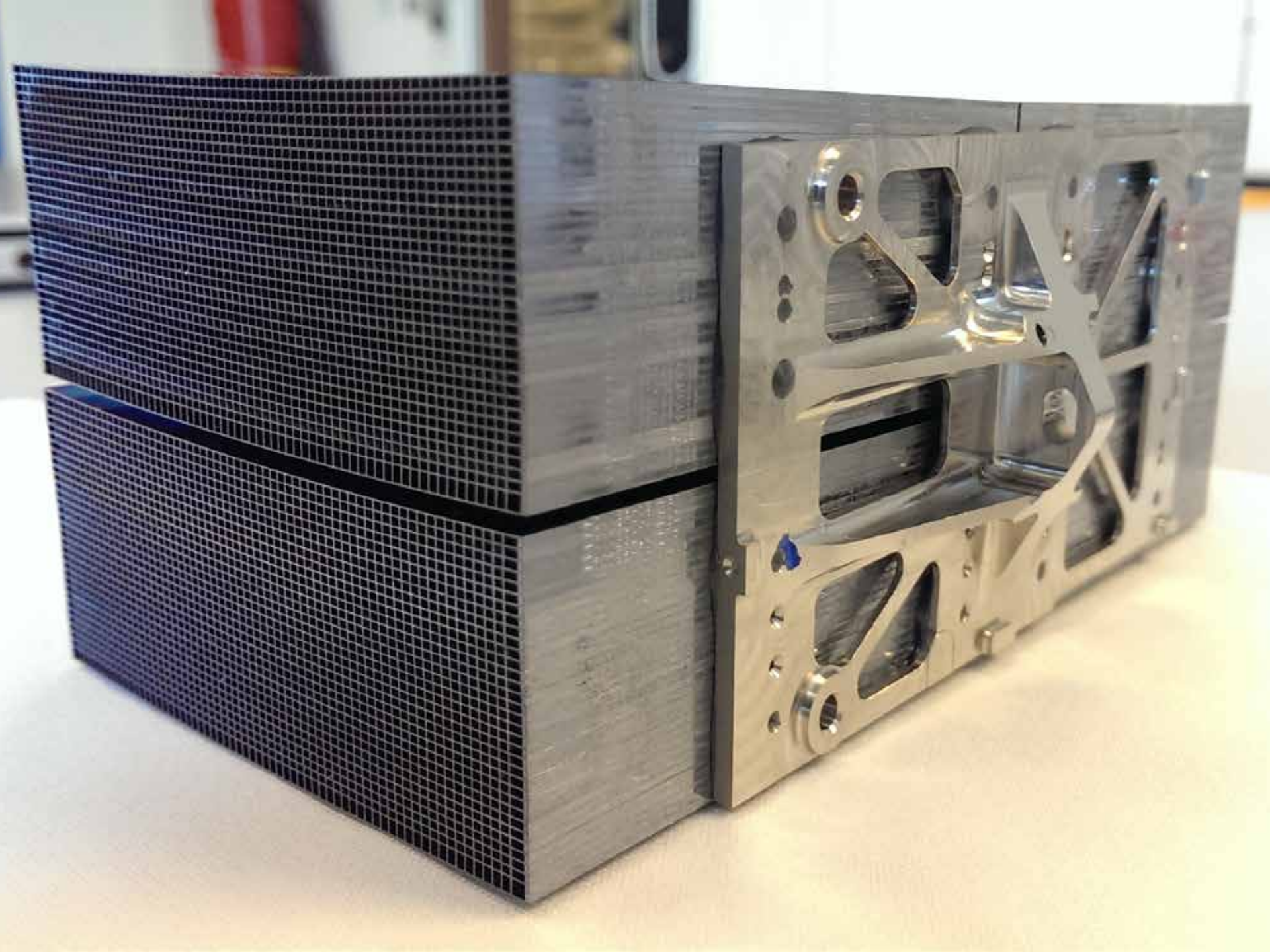
Sensitivity improvement: 100 Million times

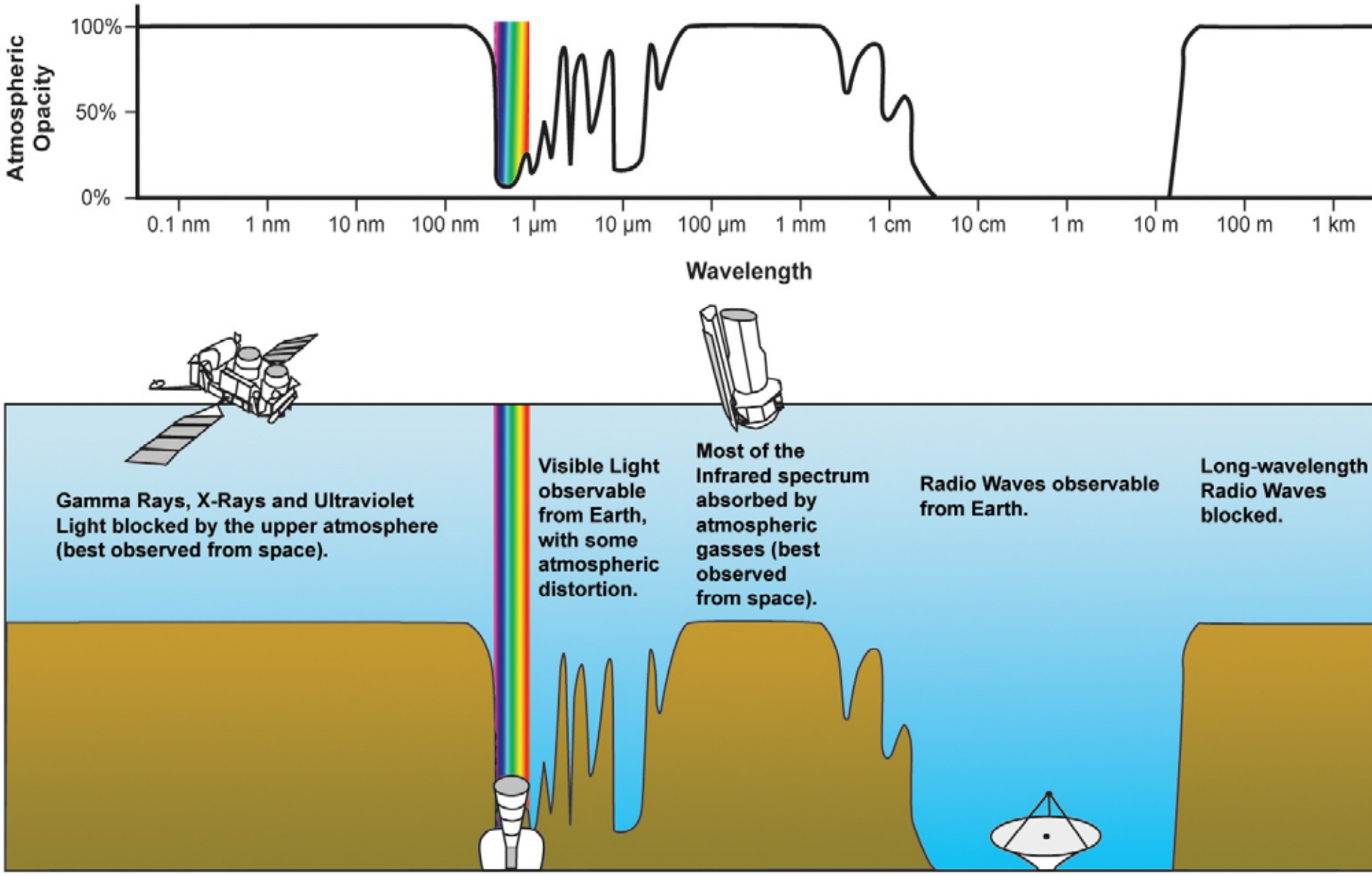
1609 ◄384 years ► 1993

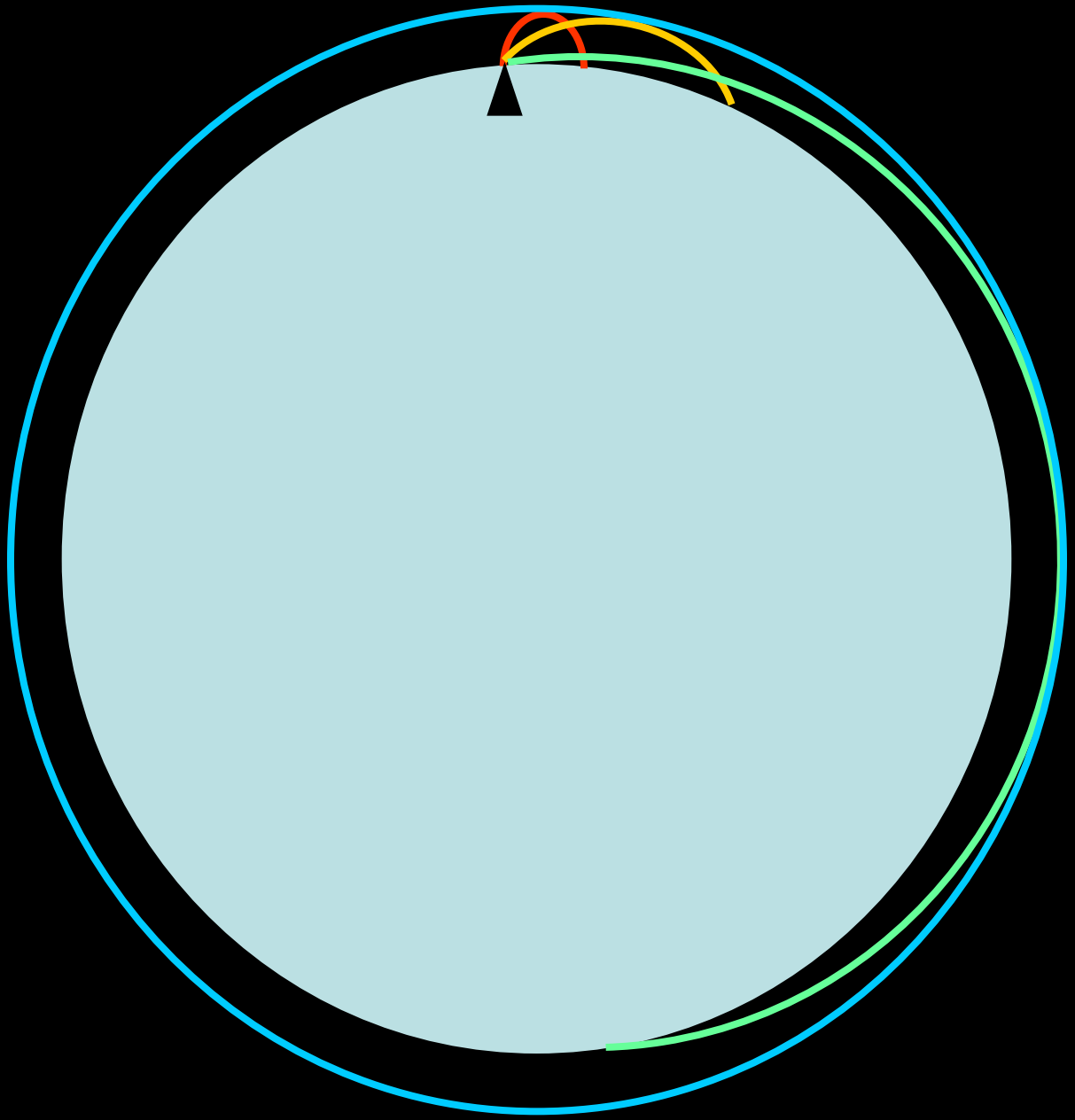
THE ATHENA+ OBSERVATORY



2nd ESA Large Class Mission
Selected 2014
Launch 2028



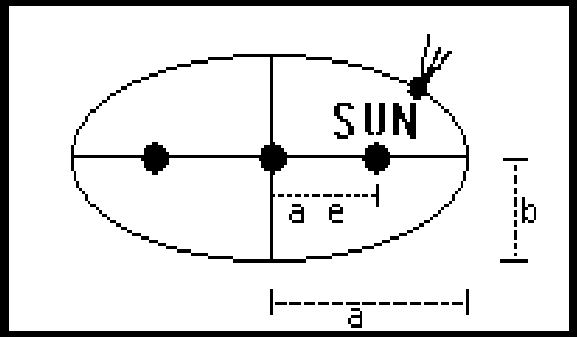

Atmospheric Opacity
100%
50%
0%
0.1 nm
1 nm
10 nm
100 nm
1 μm
10 μm
100 μm
1 mm
1 cm
10 cm
1 m
10 m
100 m
1 km
Wavelength
Gamma Rays, X-Rays and Ultraviolet Light blocked by the upper atmosphere (best observed from space).
Visible Light observable from Earth, with some atmospheric distortion.
Most of the Infrared spectrum absorbed by atmospheric gasses (best observed from space).
Radio Waves observable from Earth.
Long-wavelength Radio Waves blocked.



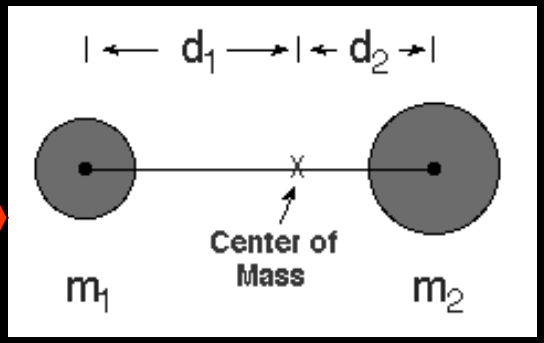
Nicolaus Copernicus
1473-1543
“De revolutionibus orbium coelestium”

Johannes Kepler
1571-1630
“Harmonices mundi”

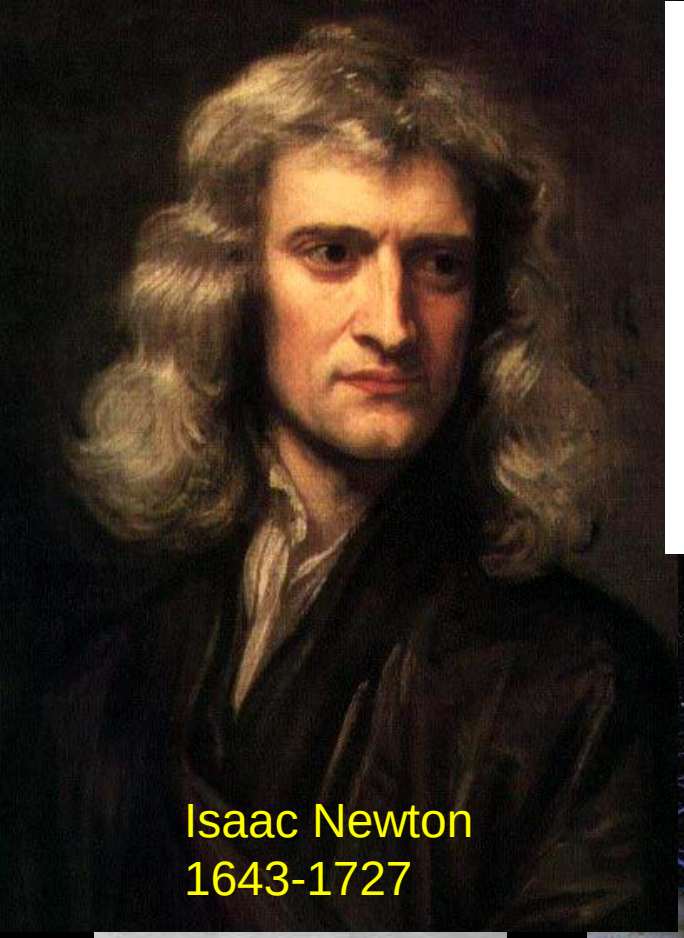
Sir Isaak Newton
1643 – 1727
“Philosophiae naturalis principia mathematica ”



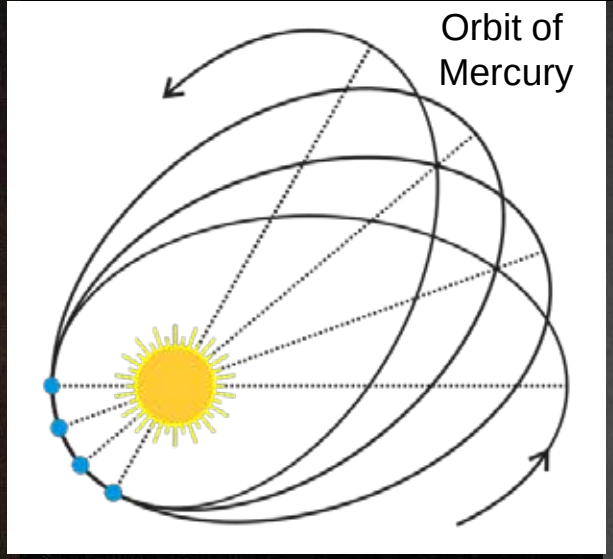
$$T_a^2/T_b^2 = R_a^3/R_b^3$$

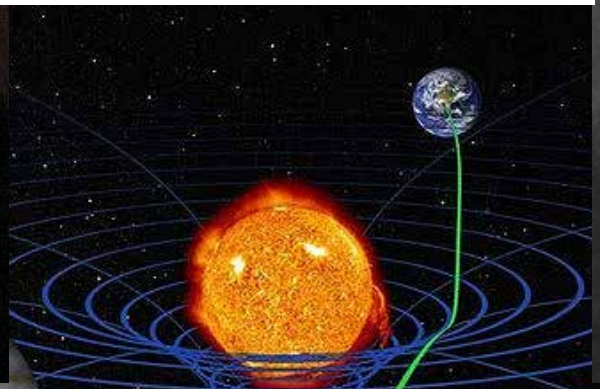


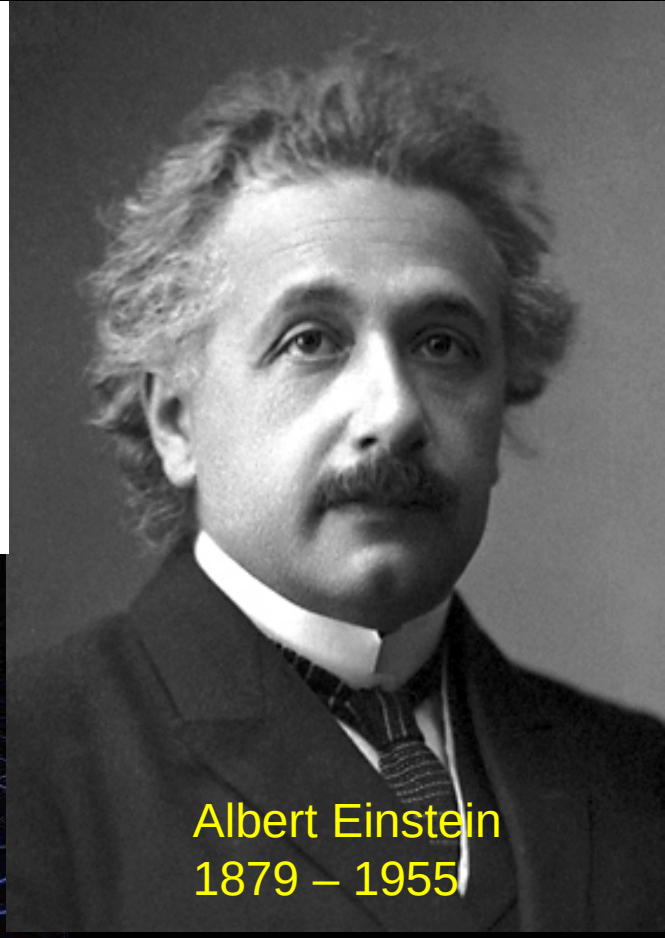
$$F = G\, m_1\, m_2/r^2$$



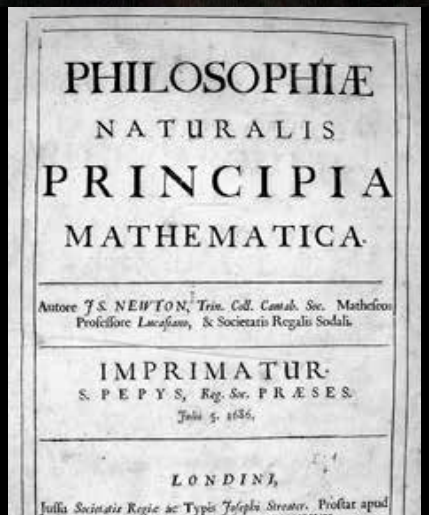
Isaac Newton
1643-1727







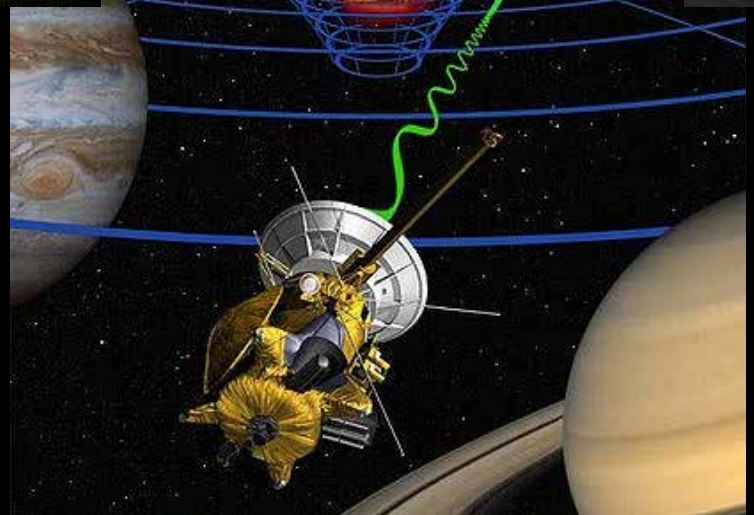
Albert Einstein
1879 – 1955


PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA

Autore *Is. NEWTON*, Trin. Coll. Cantab. Soc. Matheseos Professore Lucasiano, & Societatis Regalis Sodali.

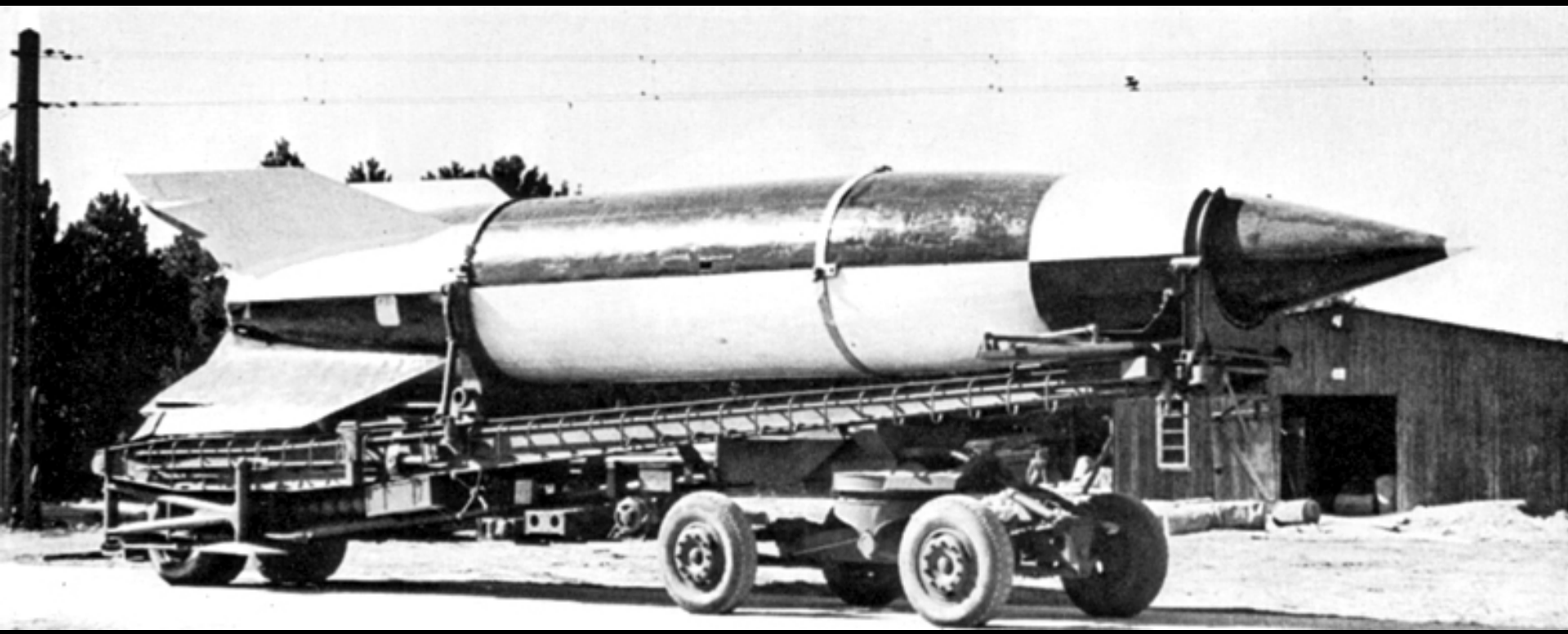
IMPRIMATUR.
S. PEPYS, Reg. Soc. PRÆSES.
Julii 5. 1686.

LONDINI,



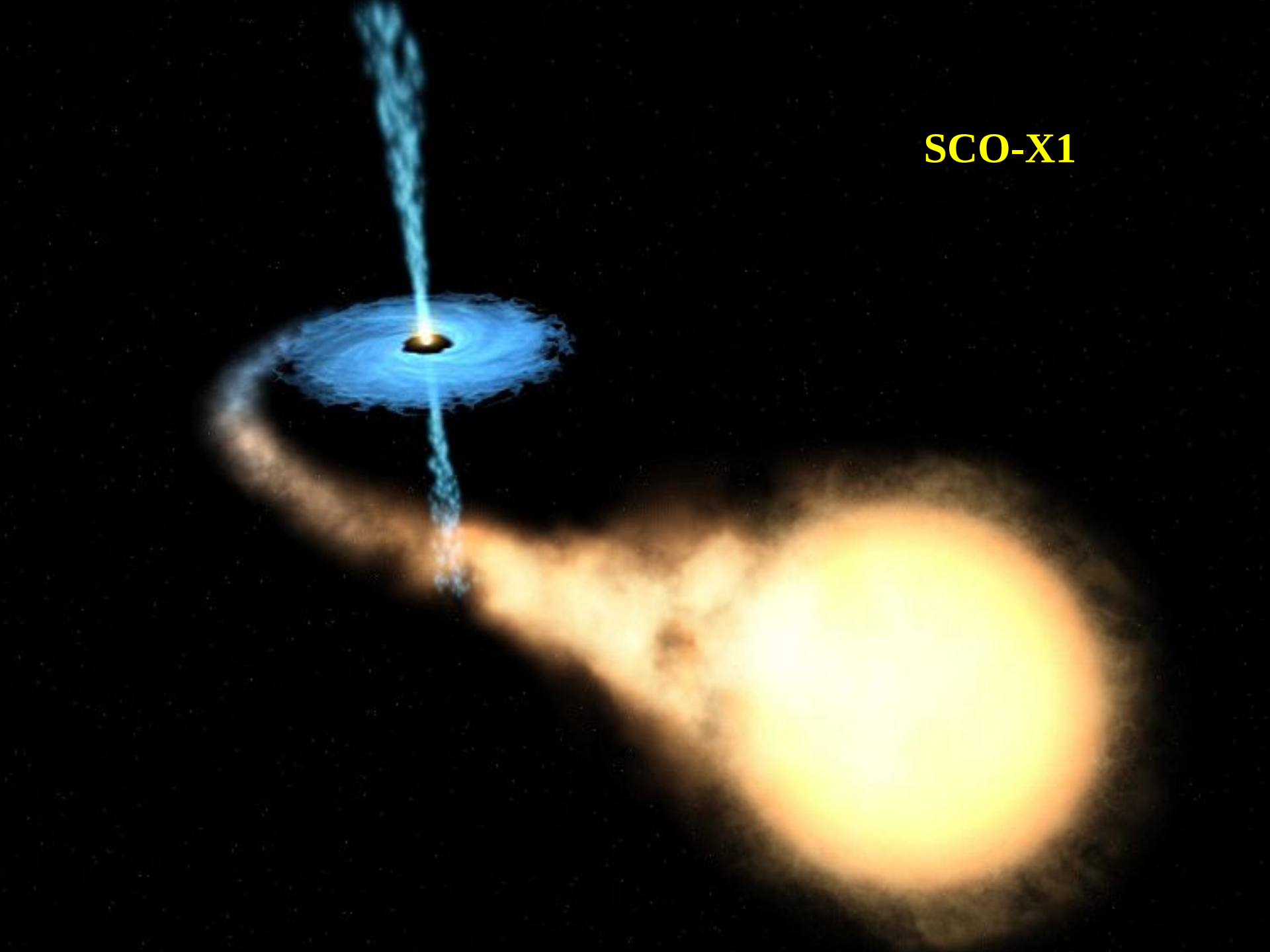
General relativity theory
(1916)

Geiger counters on V2



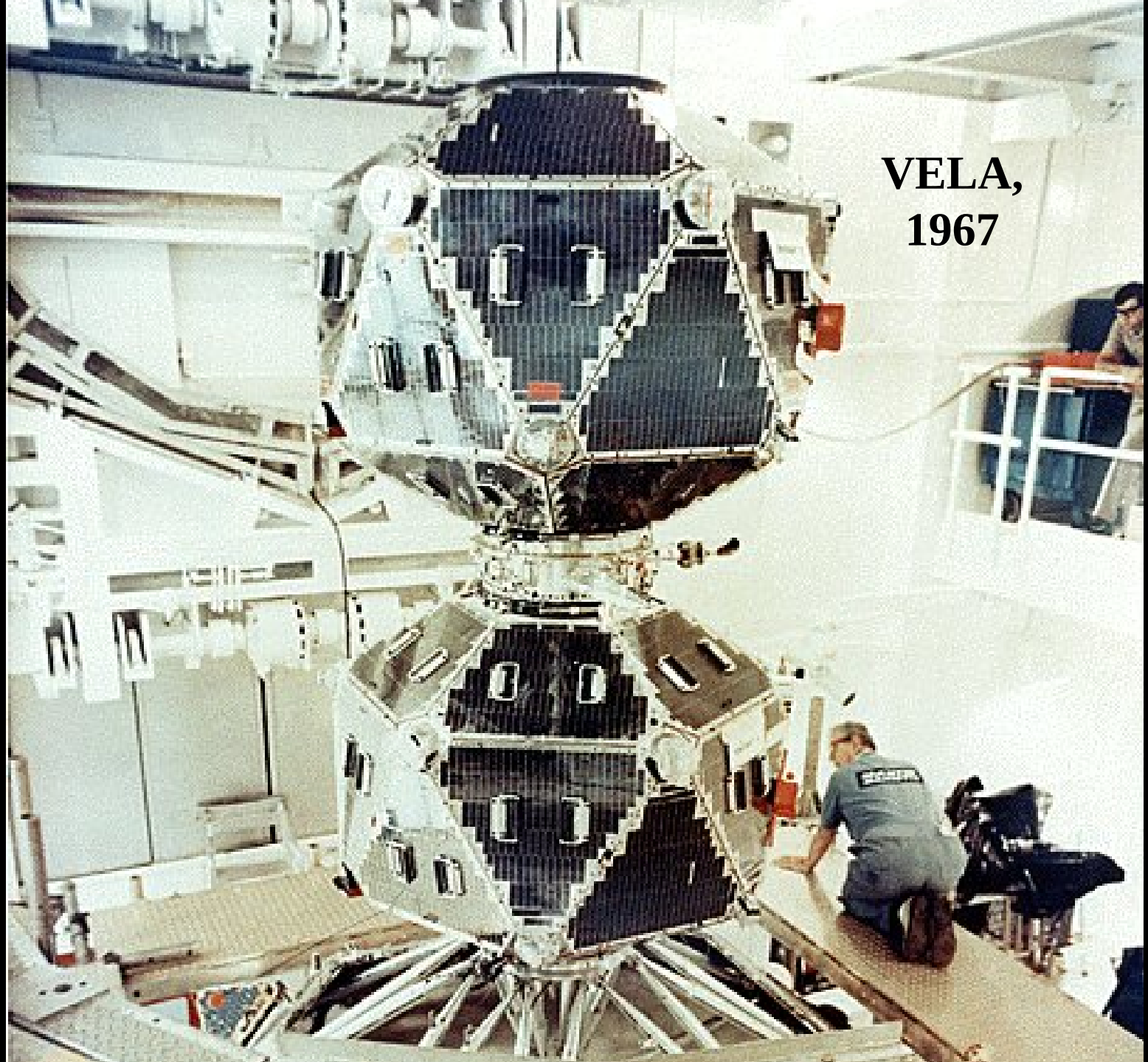
First observation of X-rays in space, 1949

AEROBEE, 1962


SCO-X1

Riccardo Giaconi (born 1931 in Genoa, I)
John Hopkins (USA), ESO (D)
Discovery of cosmic X-ray sources

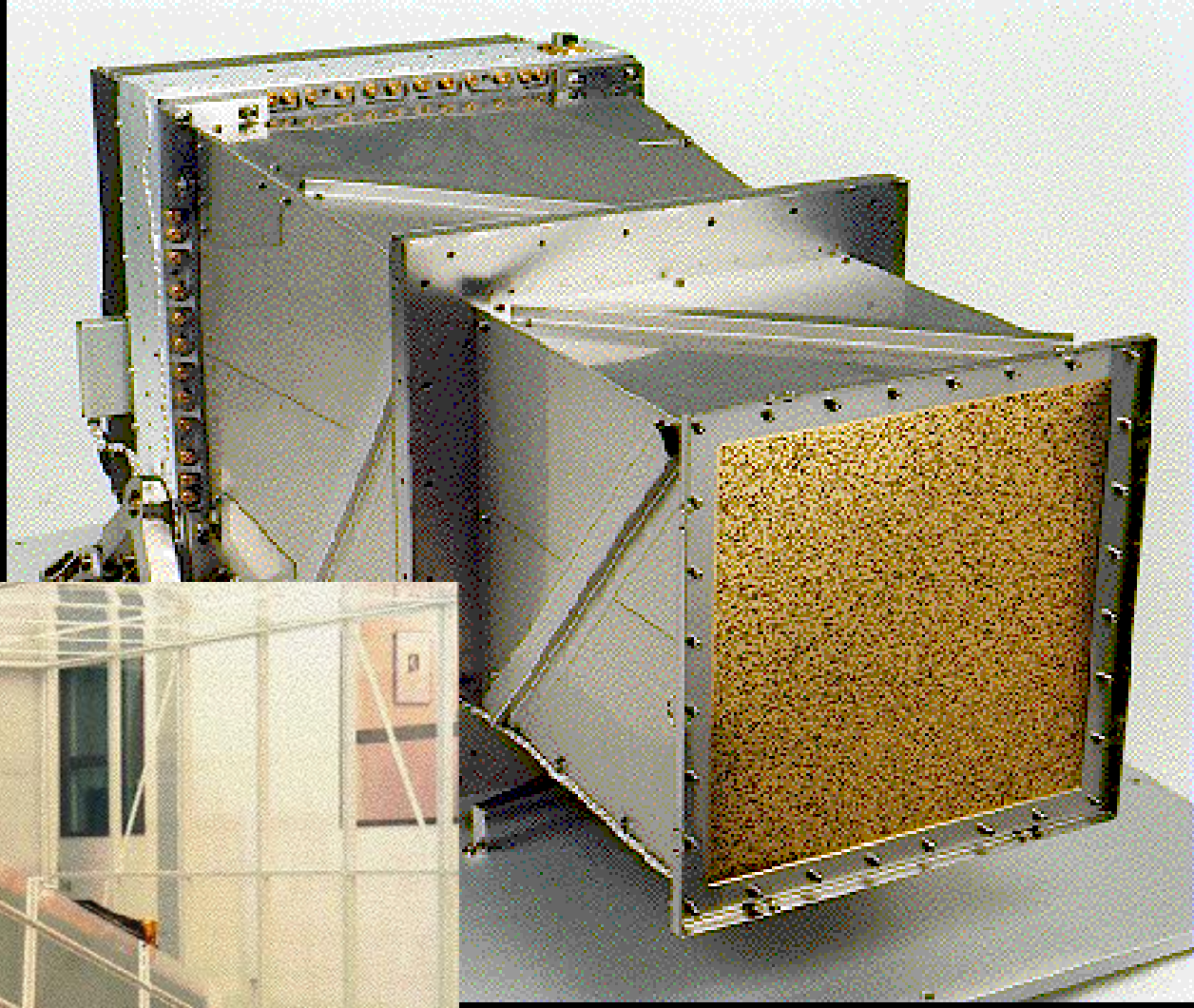
Nobel Prize in Physics in 2002

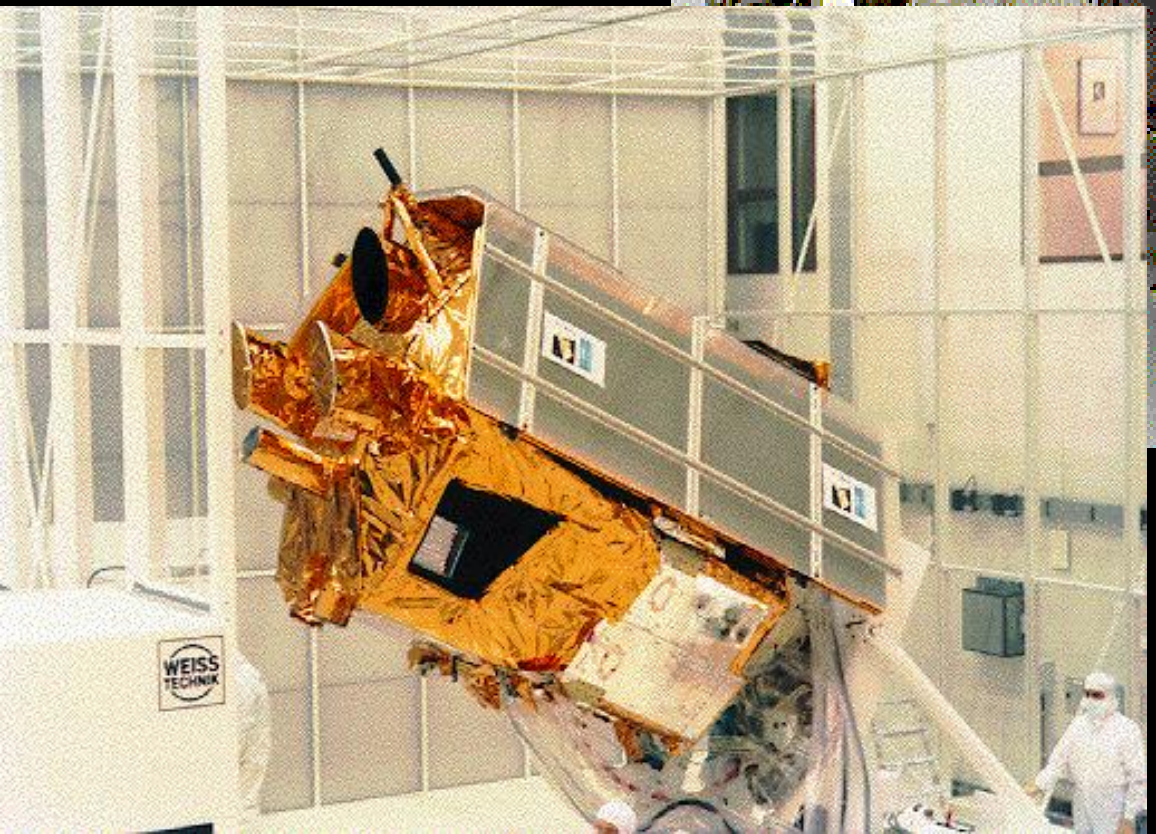

VELA,
1967

02 July 1967, at 14:19 UTC:
VELA 3 and 4 detected a flash of gamma radiation,
unlike any known nuclear weapons signature.

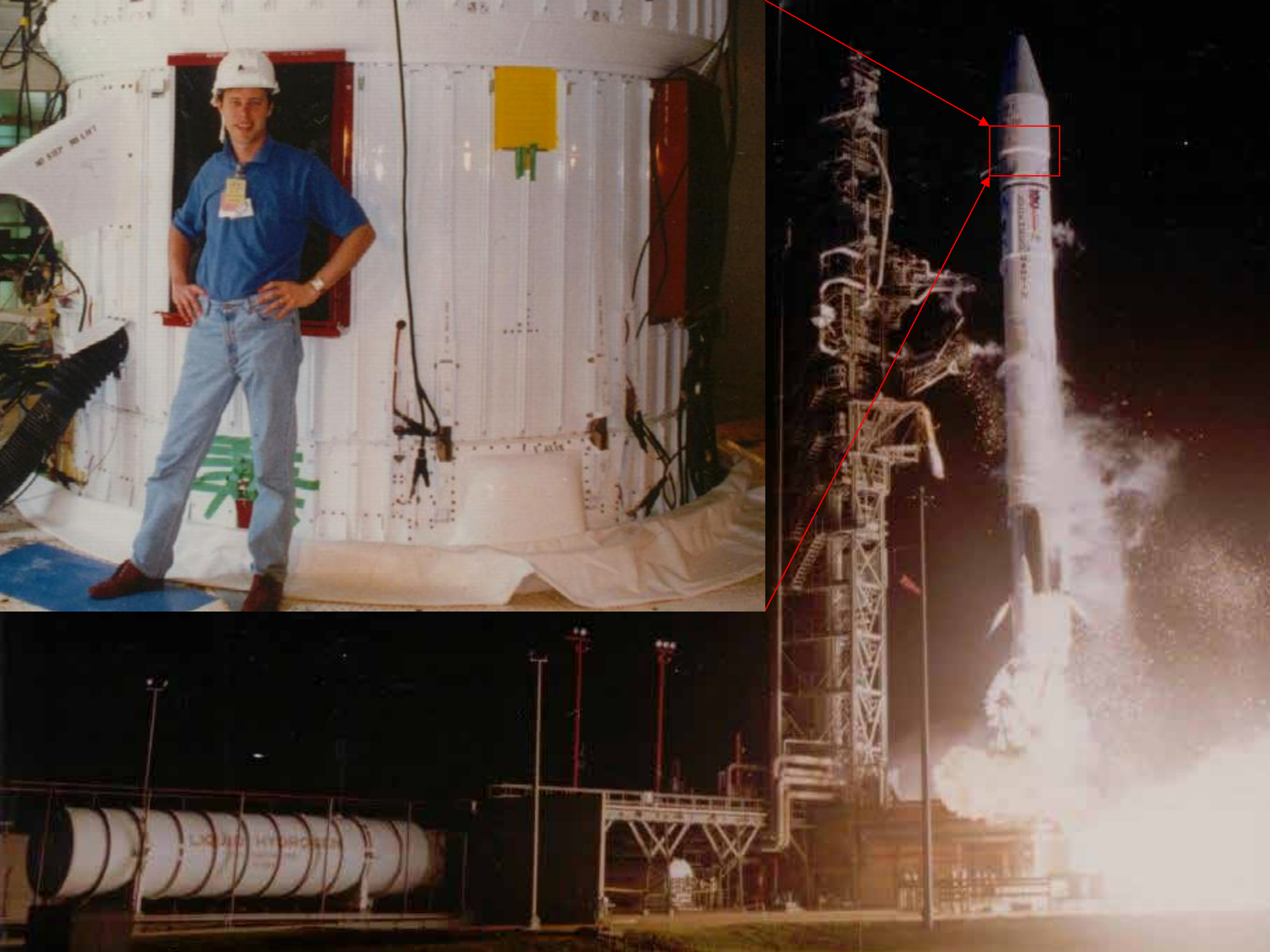
Declassified and published in 1973,
"Observations of Gamma-Ray Bursts of Cosmic Origin"

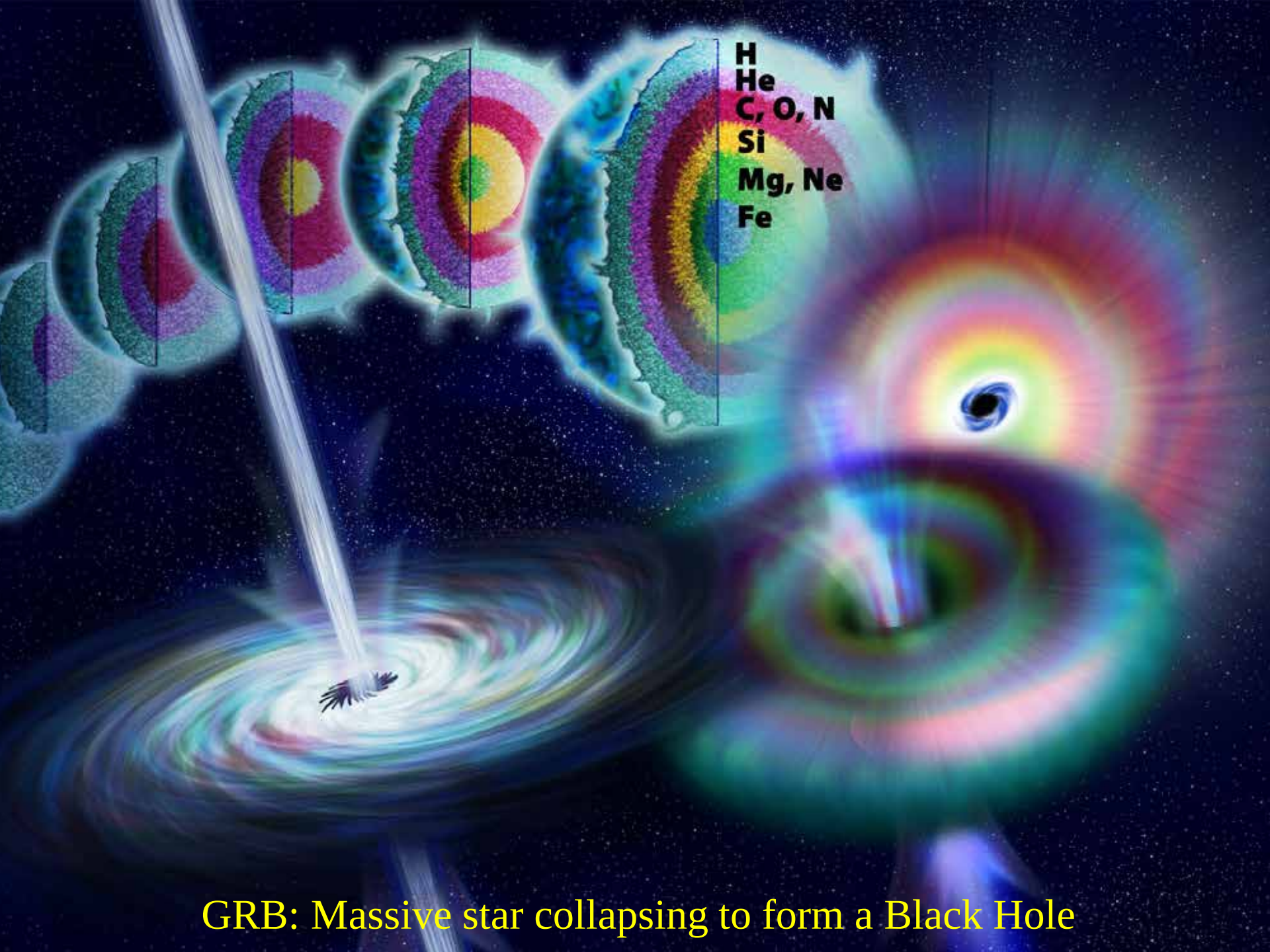
Wide Field Camera
On
BeppoSAX
(1996 – 2002)





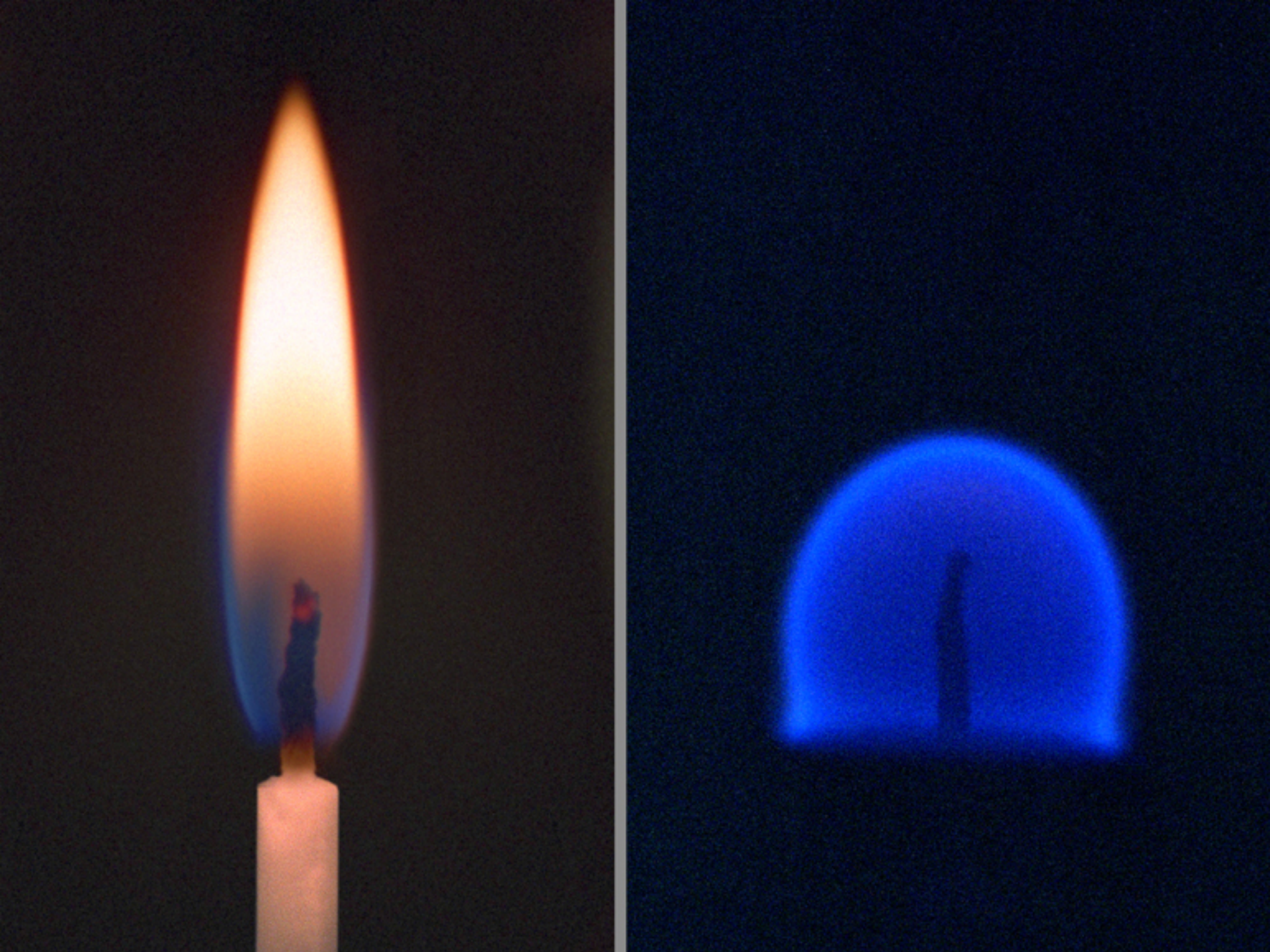
Bruno Rossi Prize,
1998





GRB: Massive star collapsing to form a Black Hole

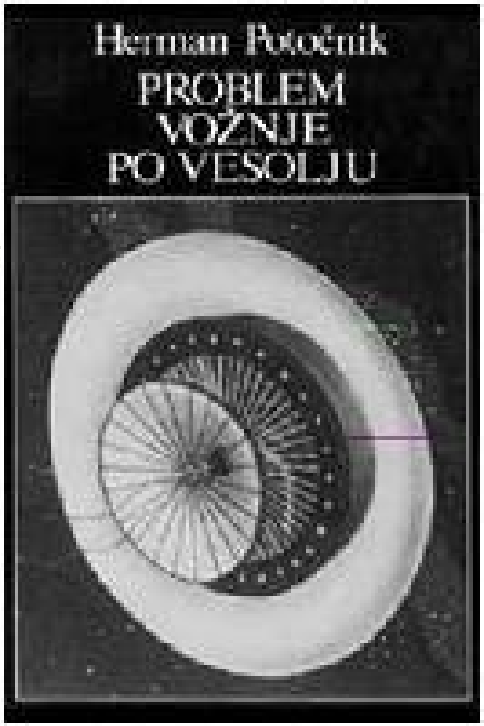
ESA’s Columbus laboratory

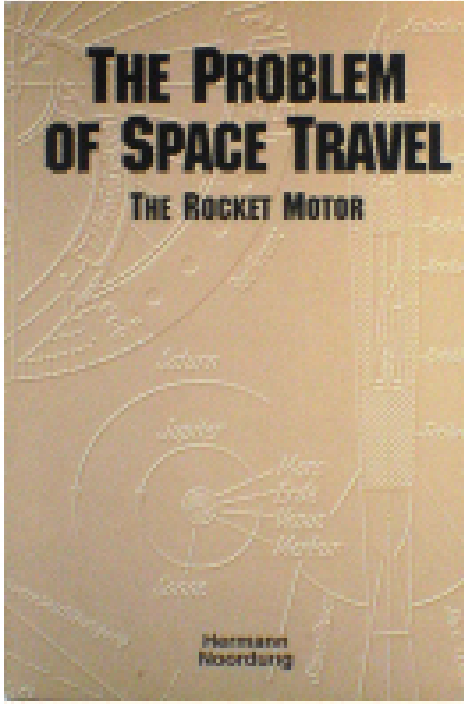


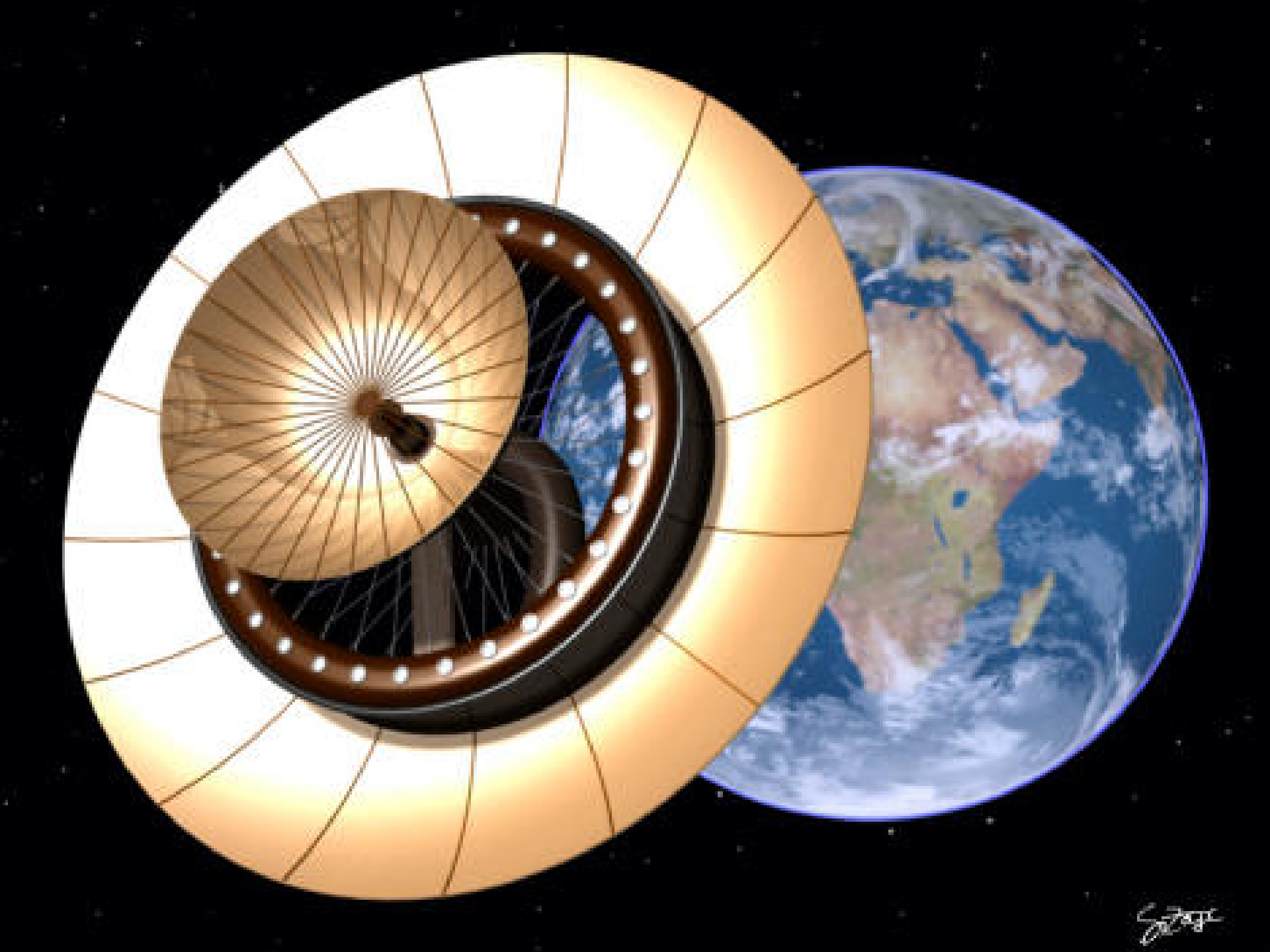
Herman Potočnik (1892 - 1929)
(pseudonym Hermann Noordung)
Slovene rocket engineer


Hermann Noordung
Das Problem der Befahrung des Weltraums
Der Raketen-Motor
Eine leichtfaßliche Darstellung der größten technischen Zukunftsfrage der Menschheit
Richard Carl Schmidt & Co. / Berlin

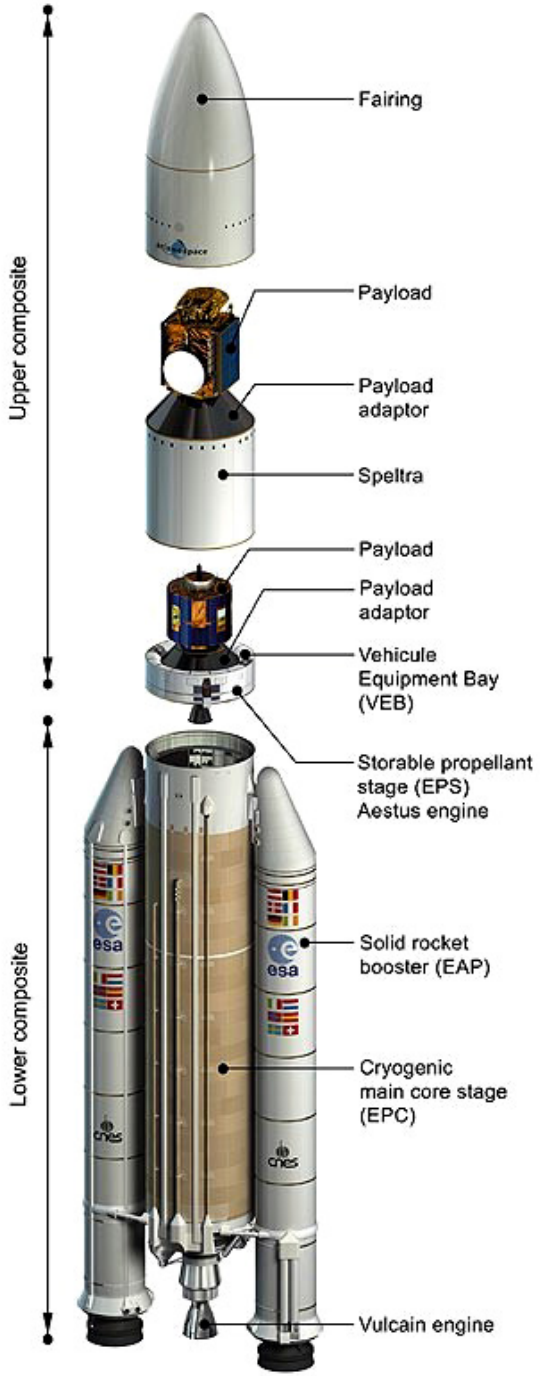

Г. НООРДУНГ
ПРОБЛЕМА ПУТЕШЕСТВИЯ В МИРОВОМ ПРОСТРАНСТВЕ


Herman Potočnik
PROBLEM VOŽNJE PO VESOLJU


THE PROBLEM OF SPACE TRAVEL
THE ROCKET MOTOR
Hermann Noordung



International Space Station (ISS)


Upper composite
Lower composite
Fairing
Payload
Payload adaptor
Speltra
Payload
Payload adaptor
Vehicule Equipment Bay (VEB)
Storable propellant stage (EPS) Aestus engine
Solid rocket booster (EAP)
Cryogenic main core stage (EPC)
Vulcain engine

H=57.7m
M=777t


1960: European Launcher Development Organisation (ELDO)
1962: European Space Research Organisation (ESRO)
1975: ELDO+ESRO → European Space Agency (ESA)
2016: Slovenia becomes Associated Member of ESA

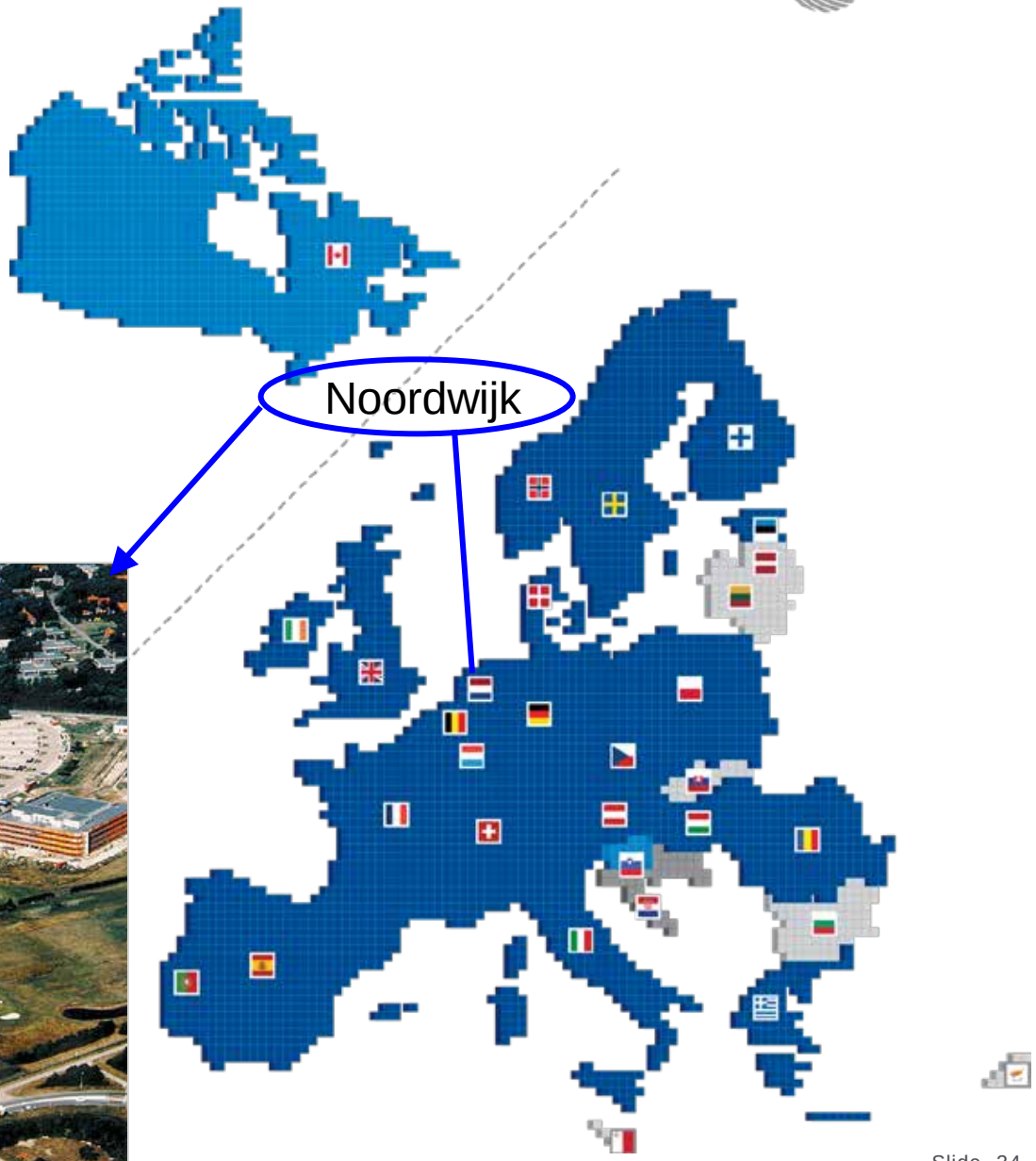
Purpose of ESA

"To provide for and promote, for exclusively peaceful purposes, cooperation among European states in **space research** and **technology** and their **space applications.**"

Article 2 of ESA Convention

Member States

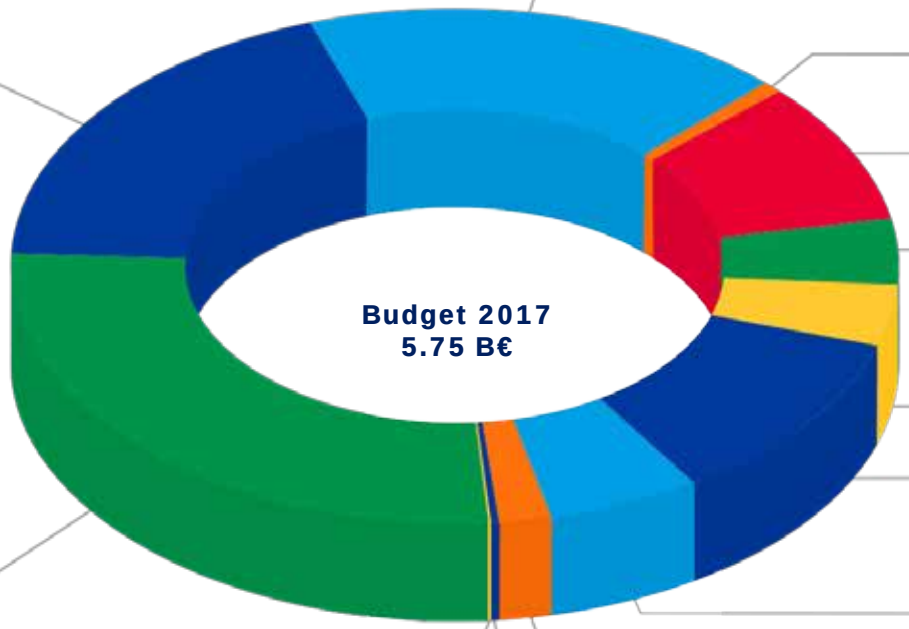
ESA has 22 Member States: 20 states of the EU (AT, BE, CZ, DE, DK, EE, ES, FI, FR, IT, GR, HU, IE, LU, NL, PT, PL, RO, SE, UK) plus Norway and Switzerland.



ESA budget for 2017: by domain (total: 5.75 B€)

Population: 500 Million
→ ESA: 11.50 €/person/year
→ Space Science: 1 €/person/year

SL: 0.1%, 3.4 M€



Navigation*
17.6%, 1010.8 M€

Launchers*
18.9%, 1088.4 M€

B€: Billion Euro

M€: Million Euro

***includes programmes implemented for other institutional partners**

Earth Observation*
26.9%, 1543.3 M€

European Cooperating States Agreements
0.1%, 5.5 M€

Prodex
0.8%, 47.2 M€

Space Science
8.9%, 513.1 M€

Basic Activities
4.1%, 234.8 M€

Associated with General Budget
3.9%, 222.3 M€

Human Spaceflight & Robotic Exploration
11.0%, 633.0 M€

Telecom & Int. Appl.*
5.6%, 319.0 M€

Technology Support*
2.0%, 114.3 M€

Space Situational Awareness
0.3%, 15.1 M€

→ ESA'S FLEET ACROSS THE SPECTRUM

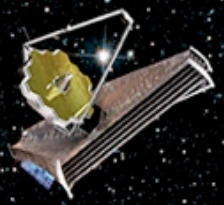
esa

Thanks to cutting edge technology, astronomy is unveiling a new world around us. With ESA's fleet of spacecraft, we can explore the full spectrum of light and probe the fundamental physics that underlies our entire Universe. From cool and dusty star formation revealed only at infrared wavelengths, to hot and violent high-energy phenomena, ESA missions are charting our cosmos and even looking back to the dawn of time to discover more about our place in space.

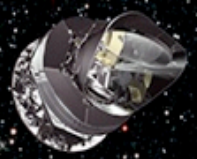
gaia
Surveying a billion stars

herschel
Unveiling the cool and dusty Universe

jwst
Observing the first light



planck
Looking back at the dawn of time



euclid
Probing dark matter, dark energy and the expanding Universe

hst
Expanding the frontiers of the visible Universe

xmm-newton
Seeing deeply into the hot and violent Universe

lisa pathfinder
Testing the technology for gravitational wave detection

microwaves
sub-millimetre
infrared
optical
ultraviolet
x-rays
gamma rays

integral
Seeking out the extremes of the Universe

esa

EXPLORATION

European Space Agency


Ariane 5 Launch Zone (ZL3), Kourou,
14 May 2009: launch Herschel and Planck

PLANCK

Looking back to the dawn of time

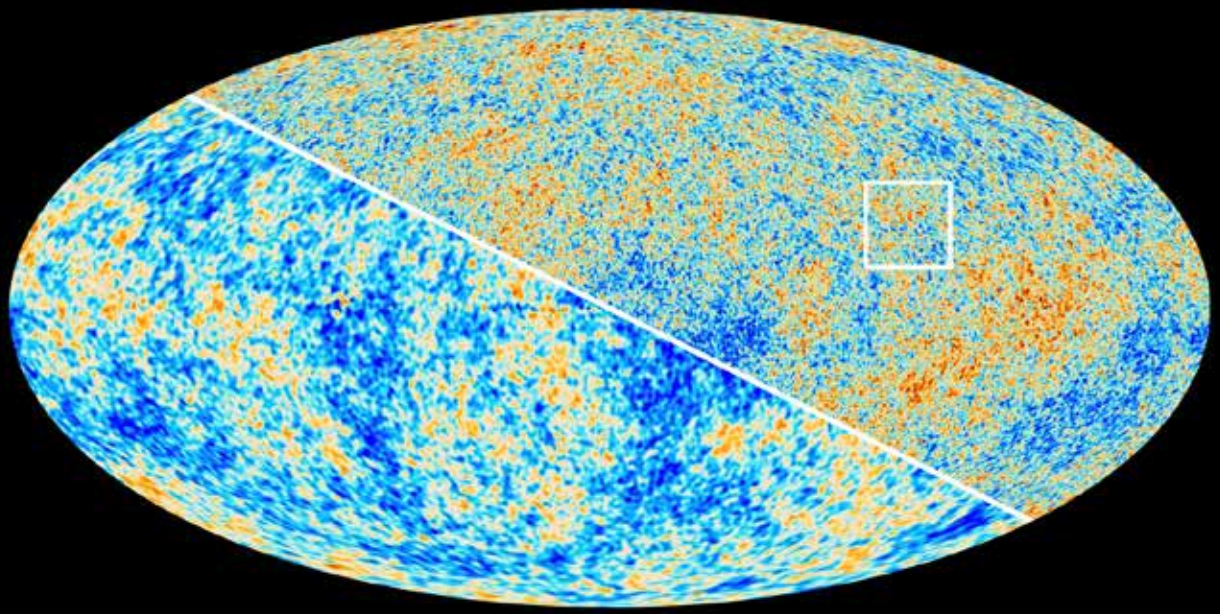
Planck, ESA's time machine, is Europe's first mission that will look at the very edge of the observable Universe by studying the cosmic microwave background, the relic radiation of the Big Bang.

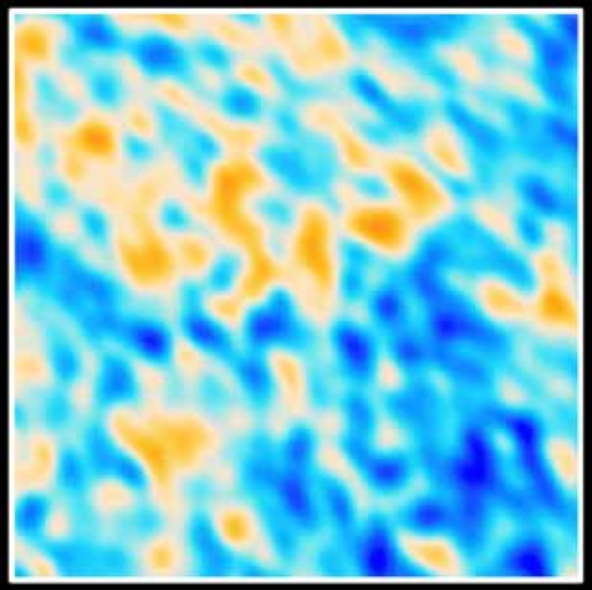
This radiation, which permeates space in all directions, is our direct link to the birth of the Universe. It carries a picture of the cosmos as it was about 300 000 years after the Big Bang, or about 14 thousand million years ago, when light started to travel freely in space.

The third and most advanced space experiment of its kind, the Planck telescope will measure tiny variations in the temperature of the cosmic microwave background with the highest-ever precision. These variations will reveal the fingerprints left by the 'seeds' of the structures, such as galaxies, that we observe in our Universe today. With its sensitivity, Planck will reveal much more about the infant Universe than any mission has done so far.

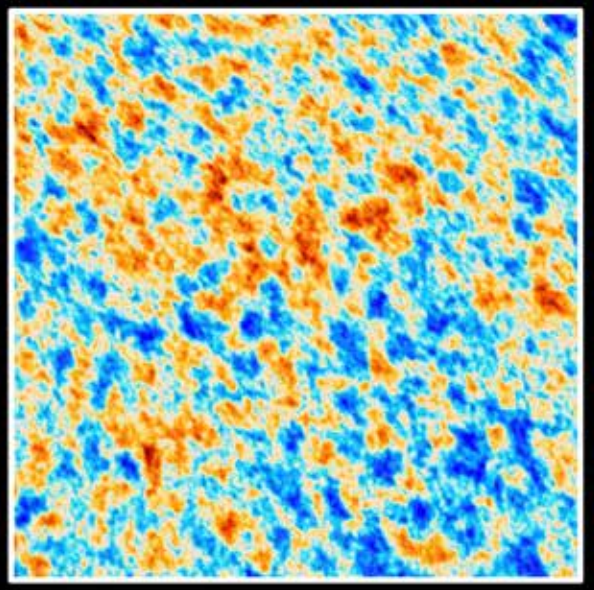
Planck will help determine the properties of the Universe with great accuracy: its geometry, the total density of normal and dark matter, the total amount of atoms in the Universe, and the nature of dark energy.

The Cosmic Microwave Background as seen by Planck and WMAP

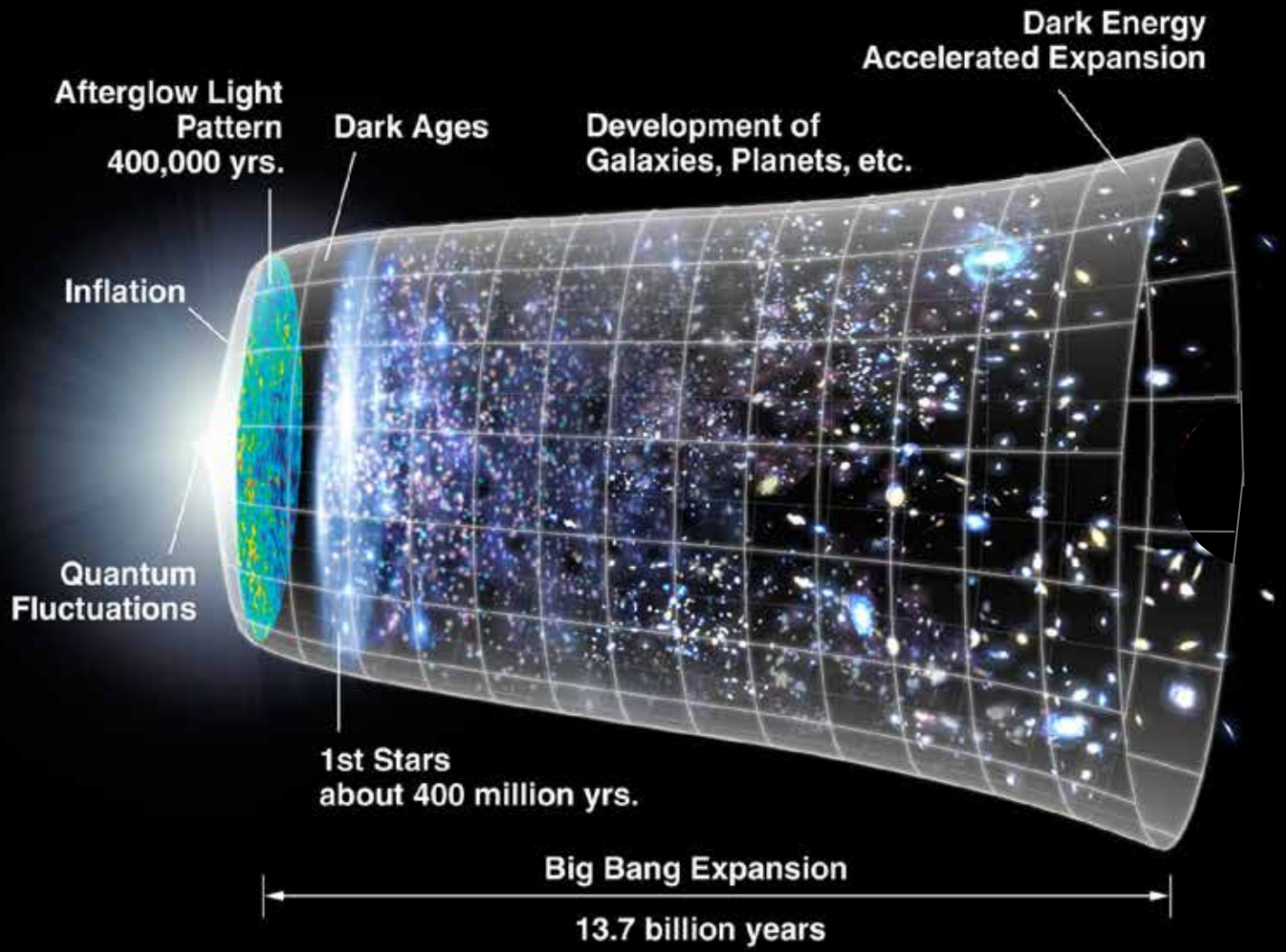


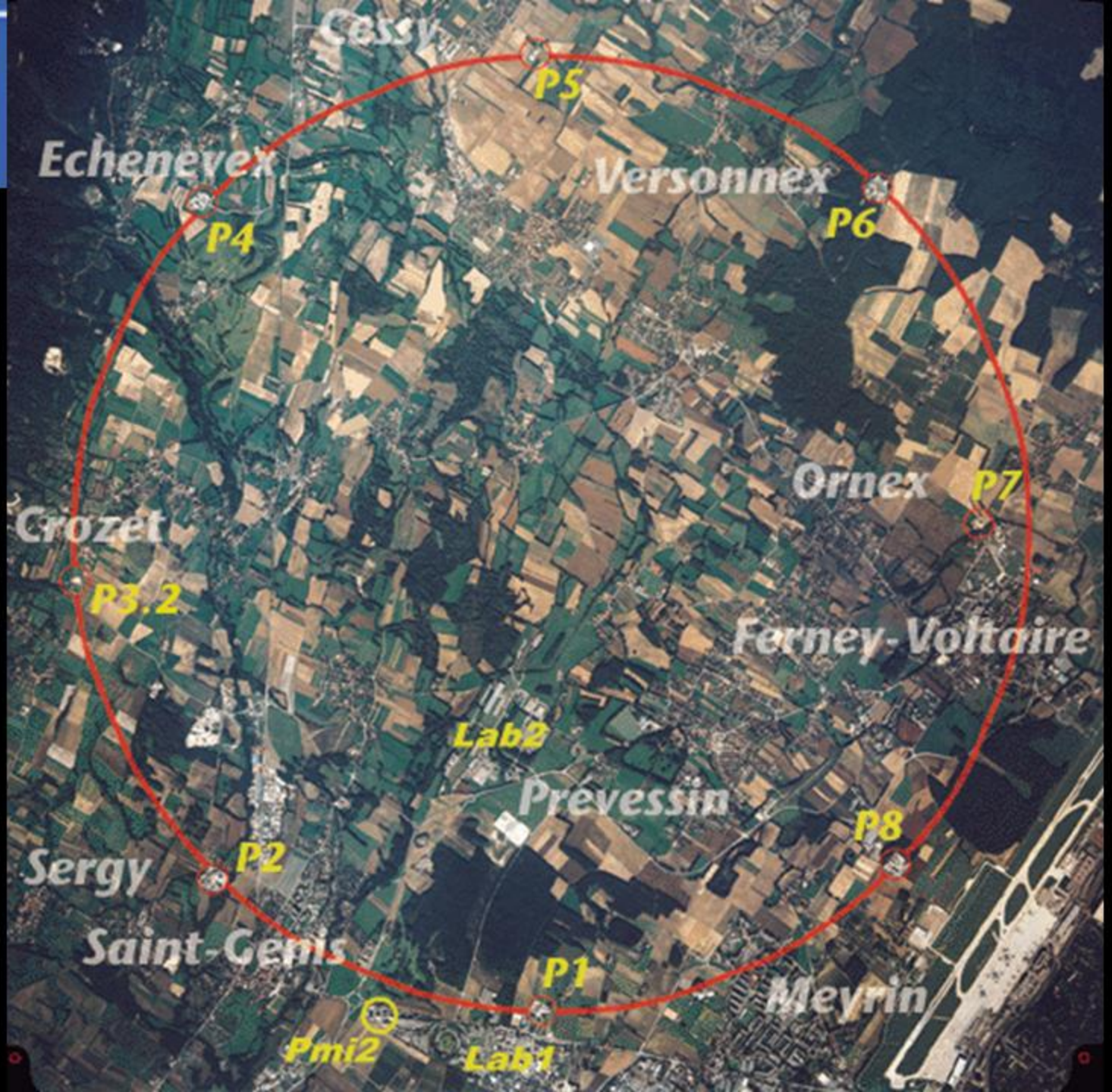


WMAP

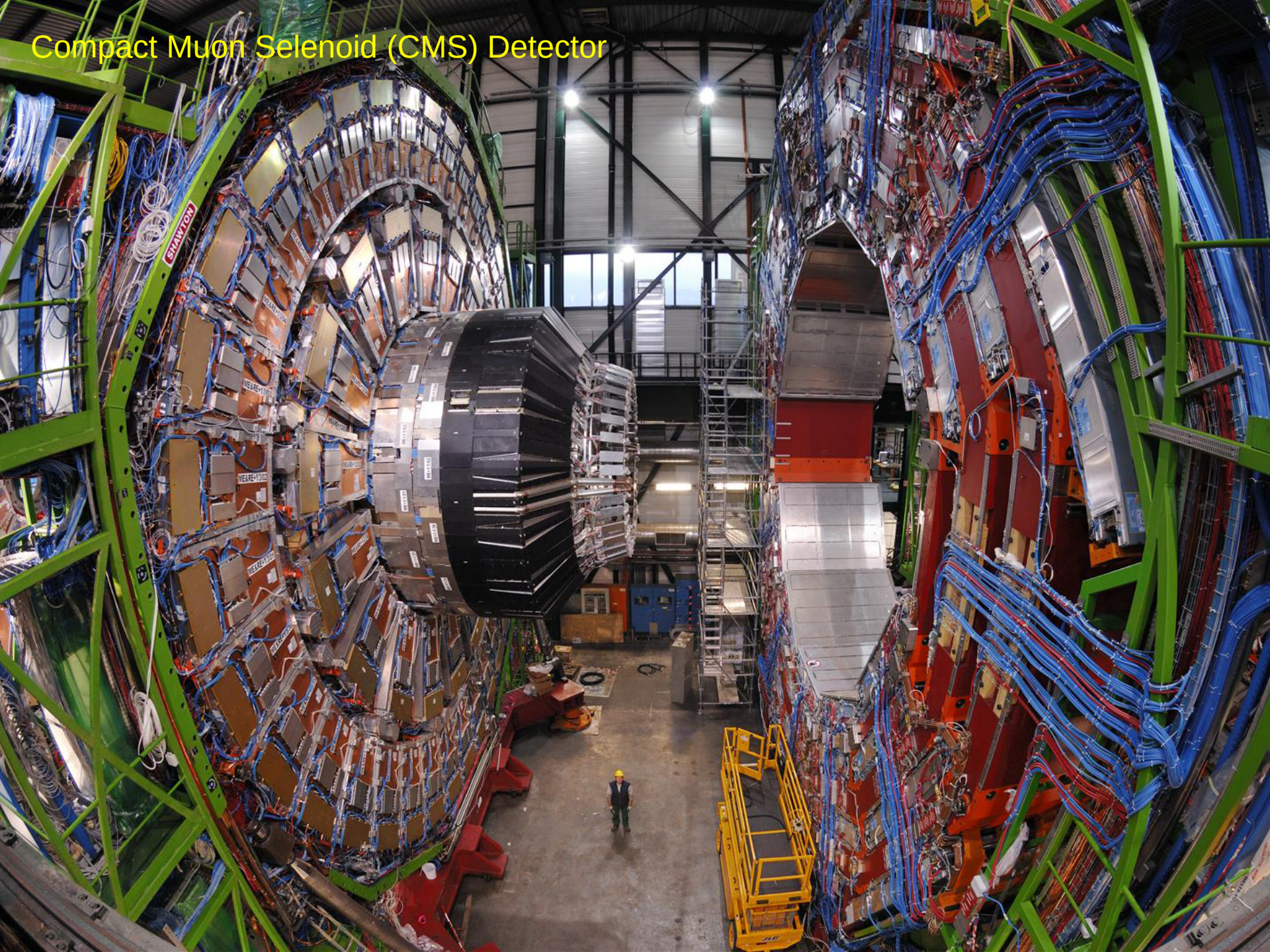


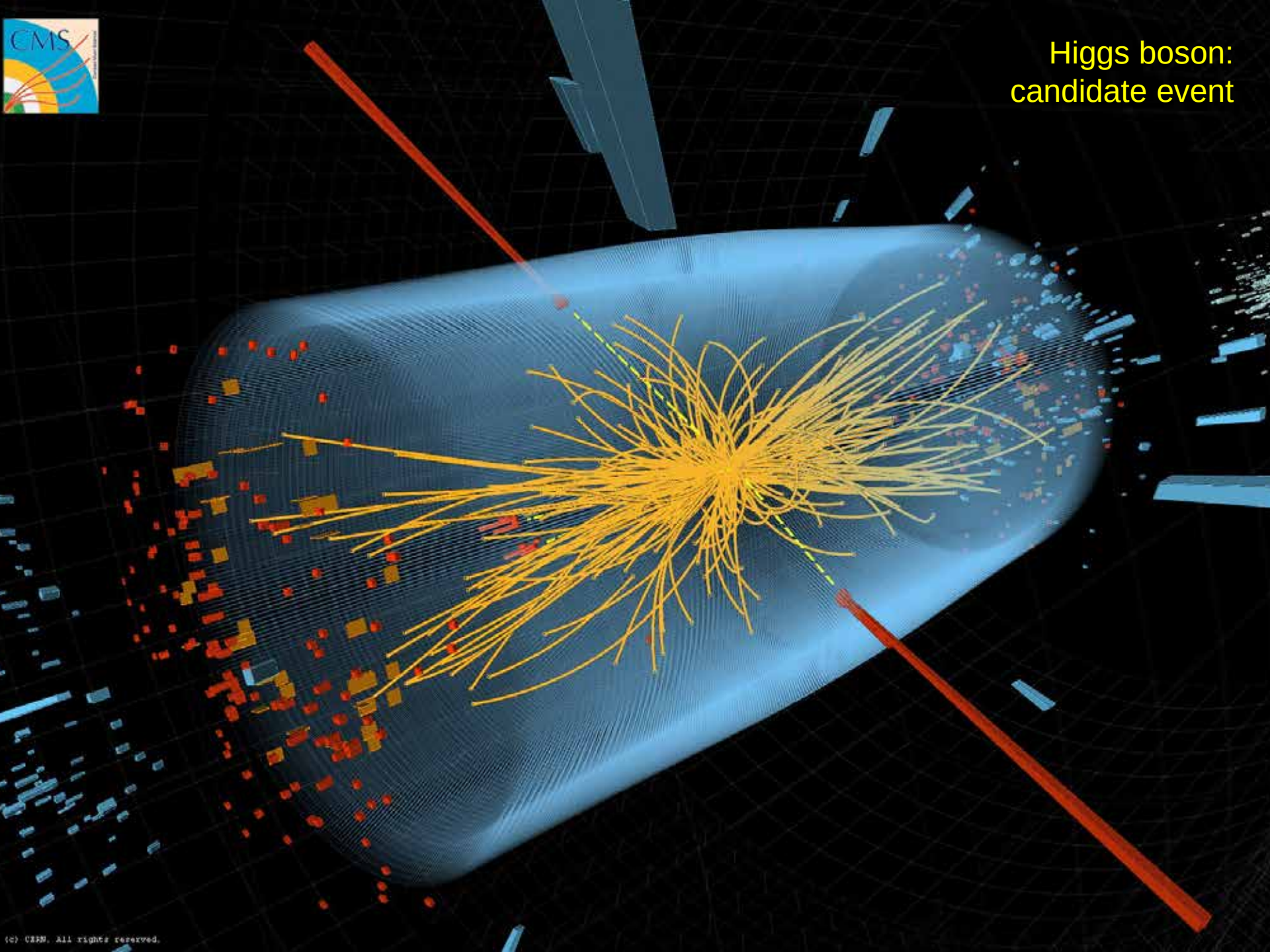
Planck


Dark Energy
Accelerated Expansion
Afterglow Light
Pattern
400,000 yrs.
Dark Ages
Development of
Galaxies, Planets, etc.
Inflation
Quantum
Fluctuations
1st Stars
about 400 million yrs.
Big Bang Expansion
13.7 billion years

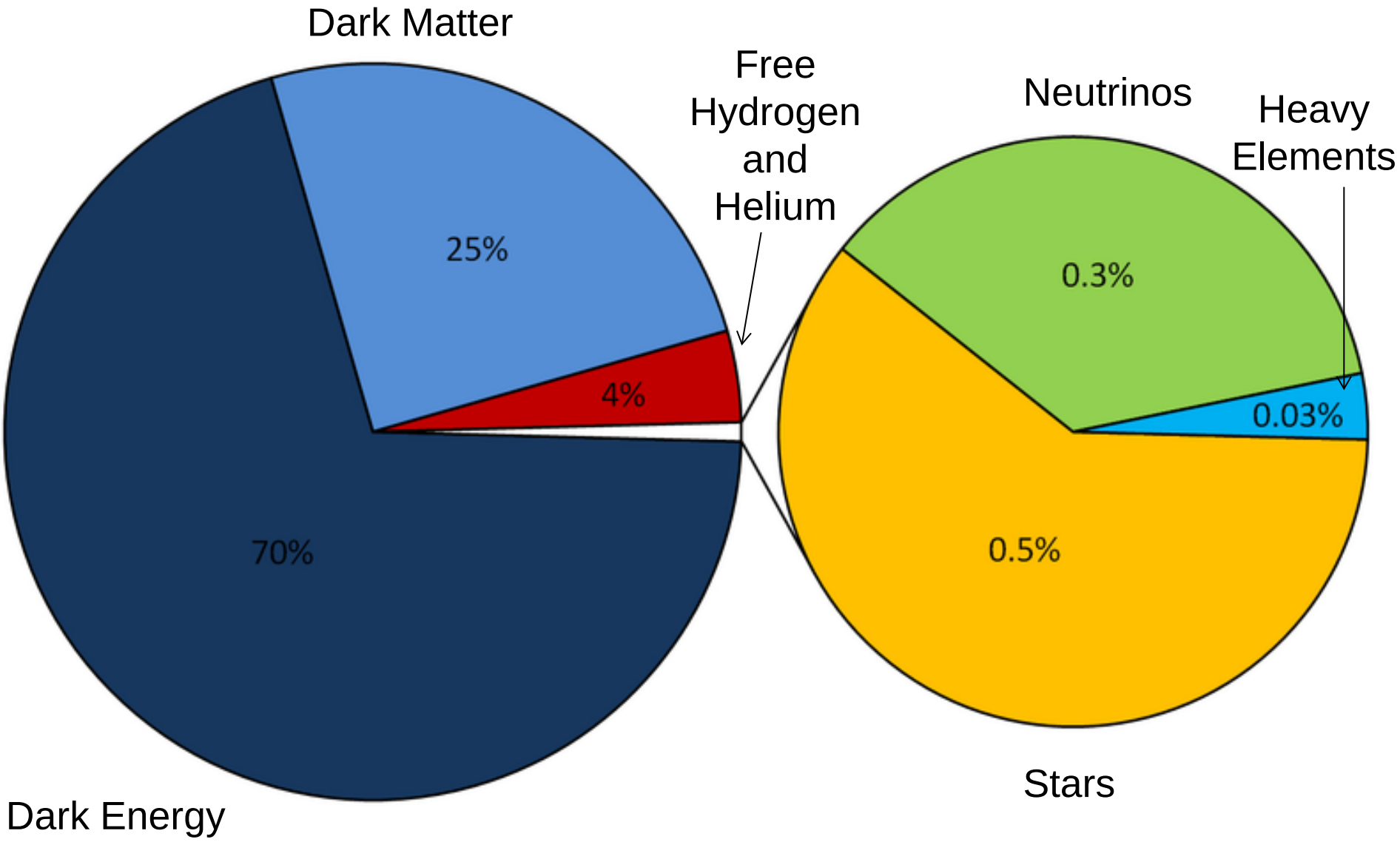

Cessy
P5
Echenevex
P4
Versonnex
P6
Ornex
P7
Crozet
P3.2
Ferney-Voltaire
Lab2
Prévessin
P8
Sergy
P2
Saint-Genis
P1
Meyrin
Pmi2
Lab1


Large Hadron Collider, CERN

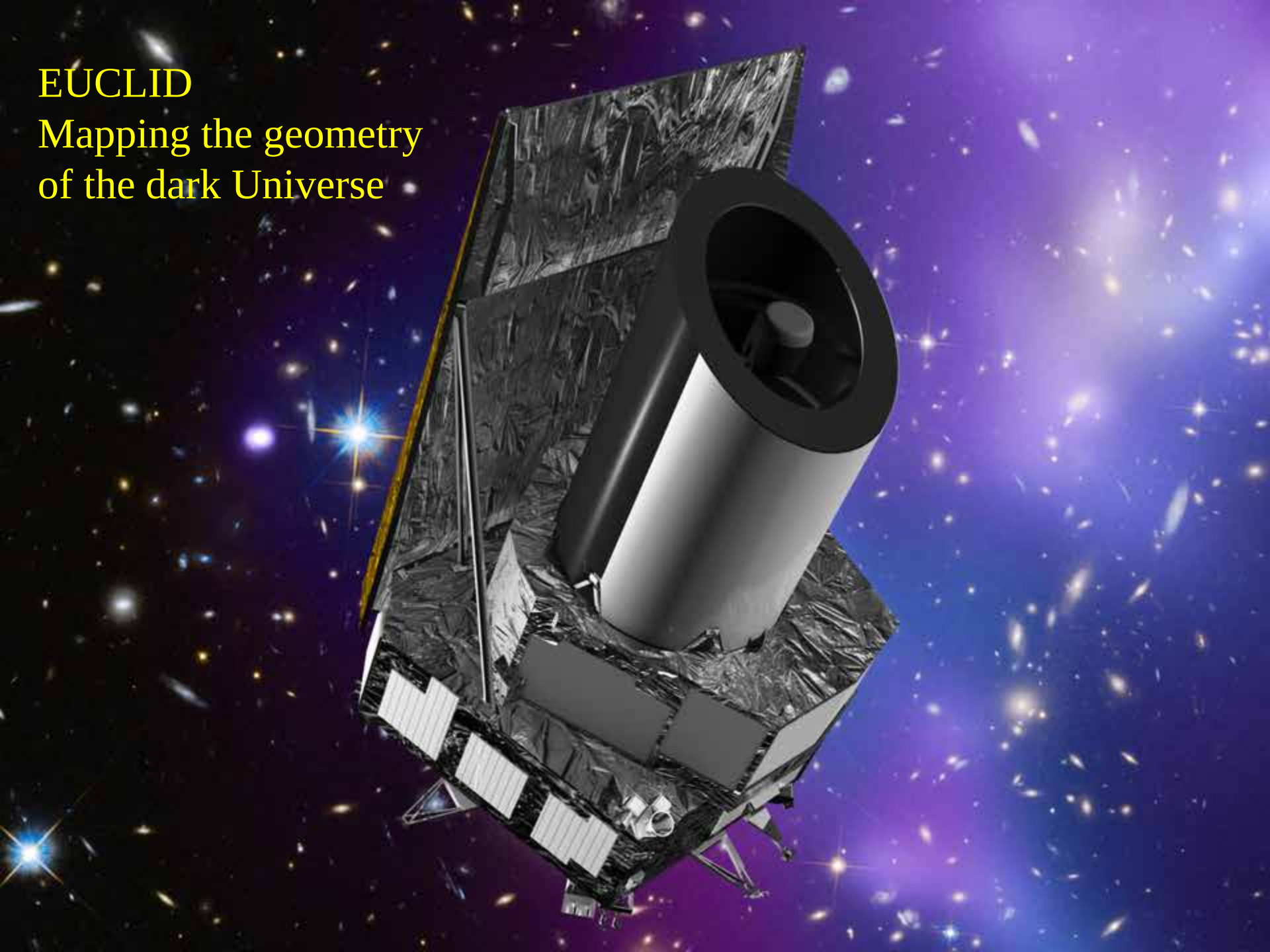

Compact Muon Selenoid (CMS) Detector

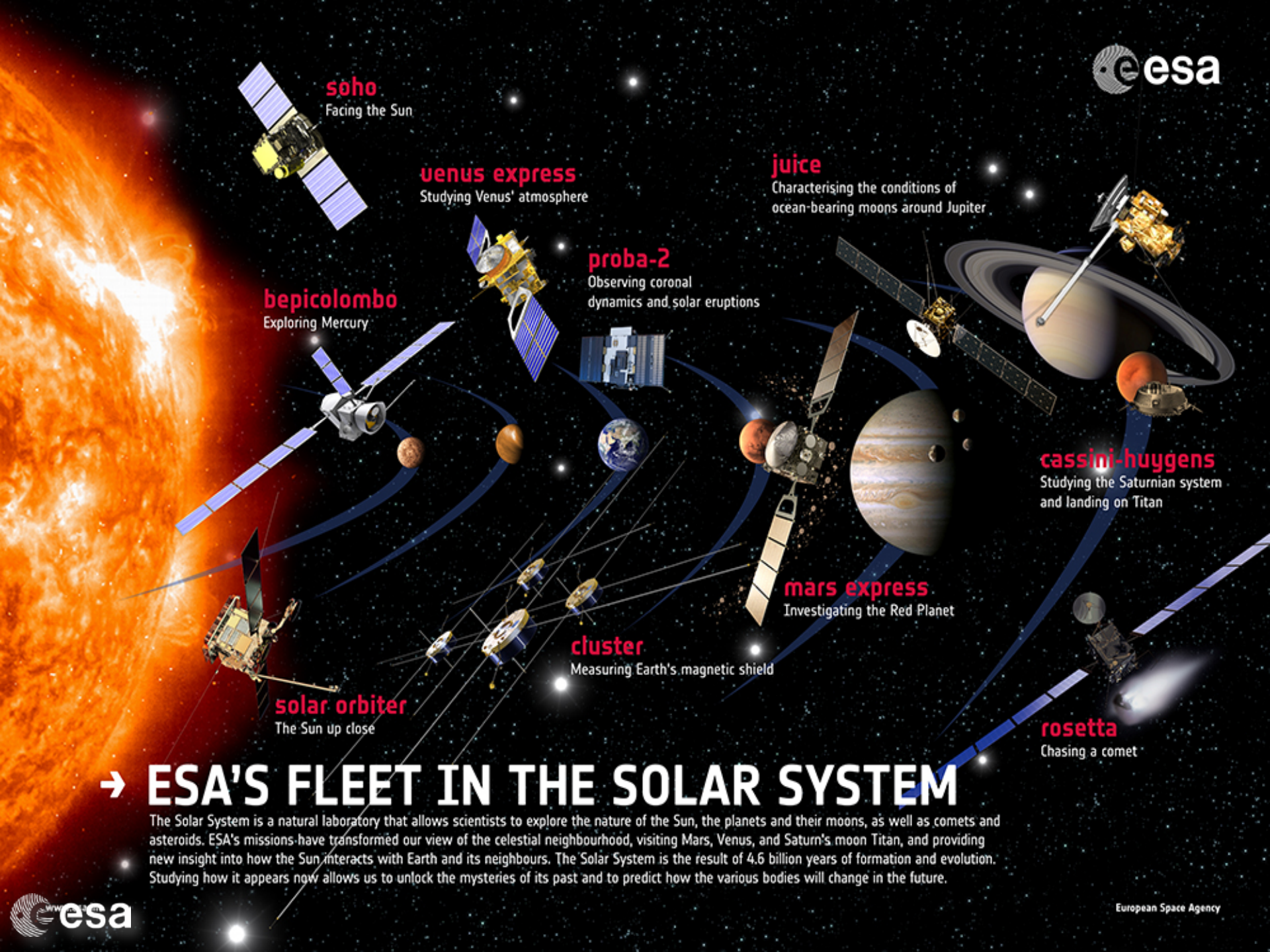

CMS
Higgs boson:
candidate event
(c) CERN. All rights reserved.

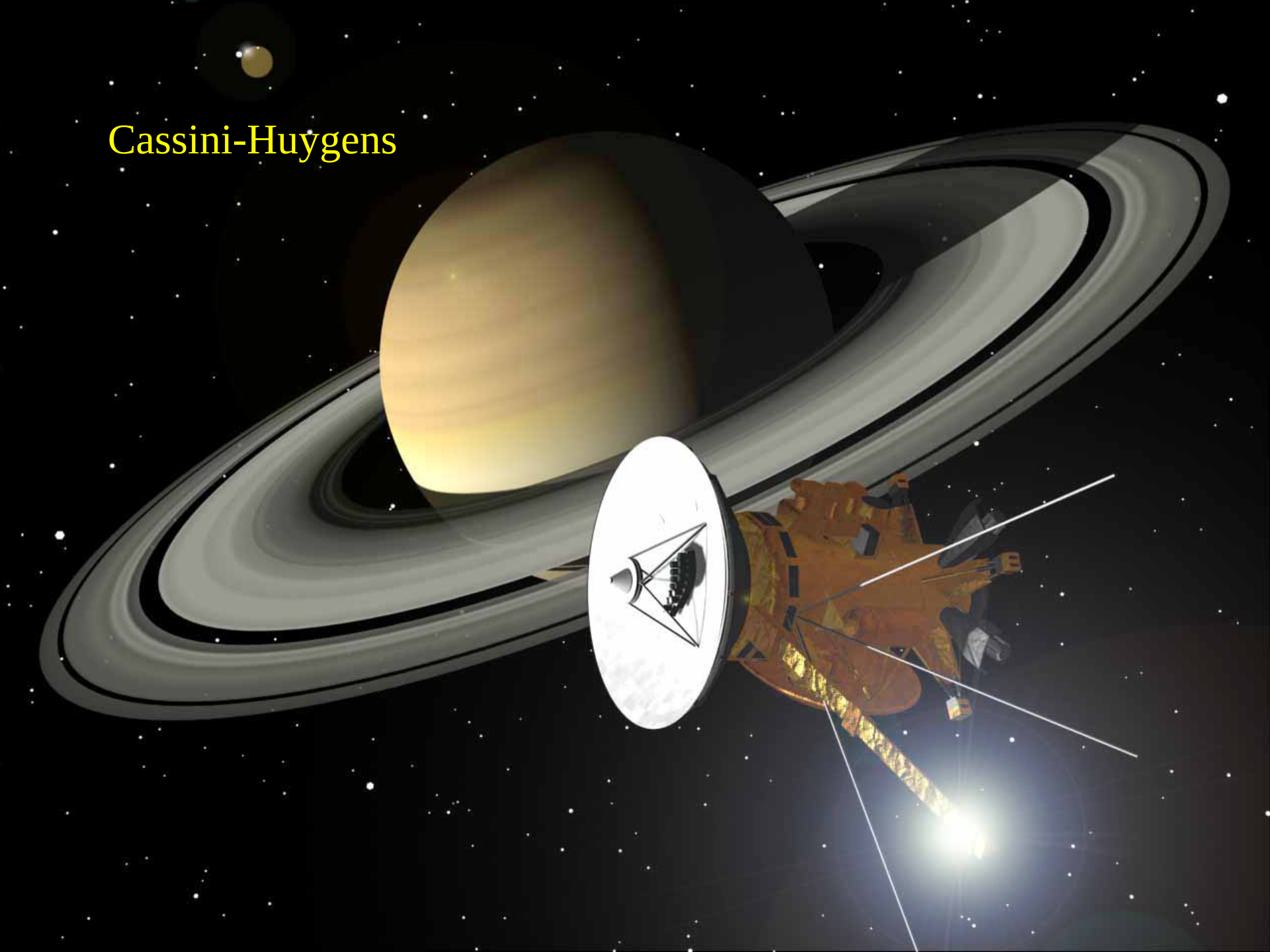
Composition of the universe



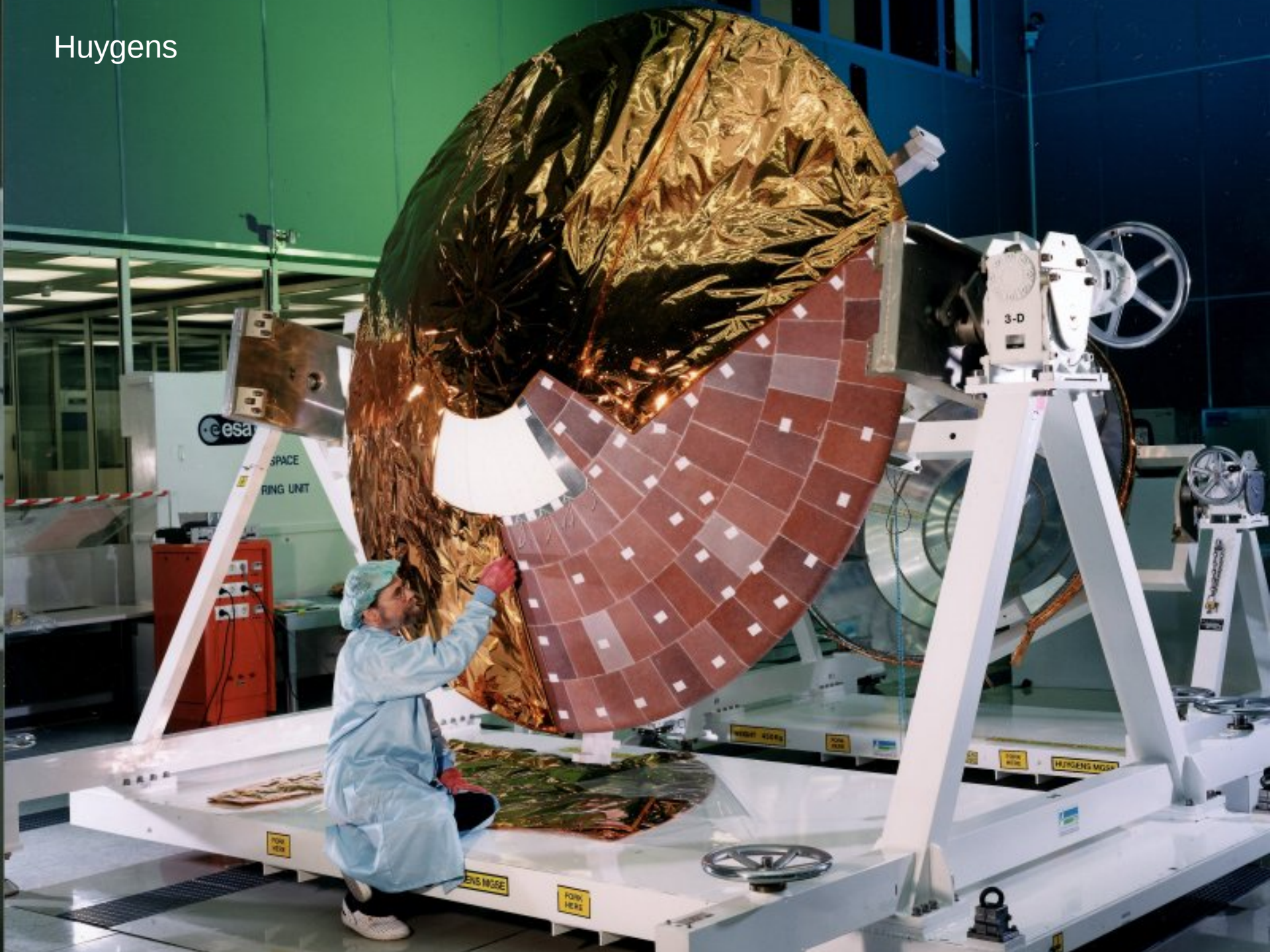
EUCLID
Mapping the geometry of the dark Universe



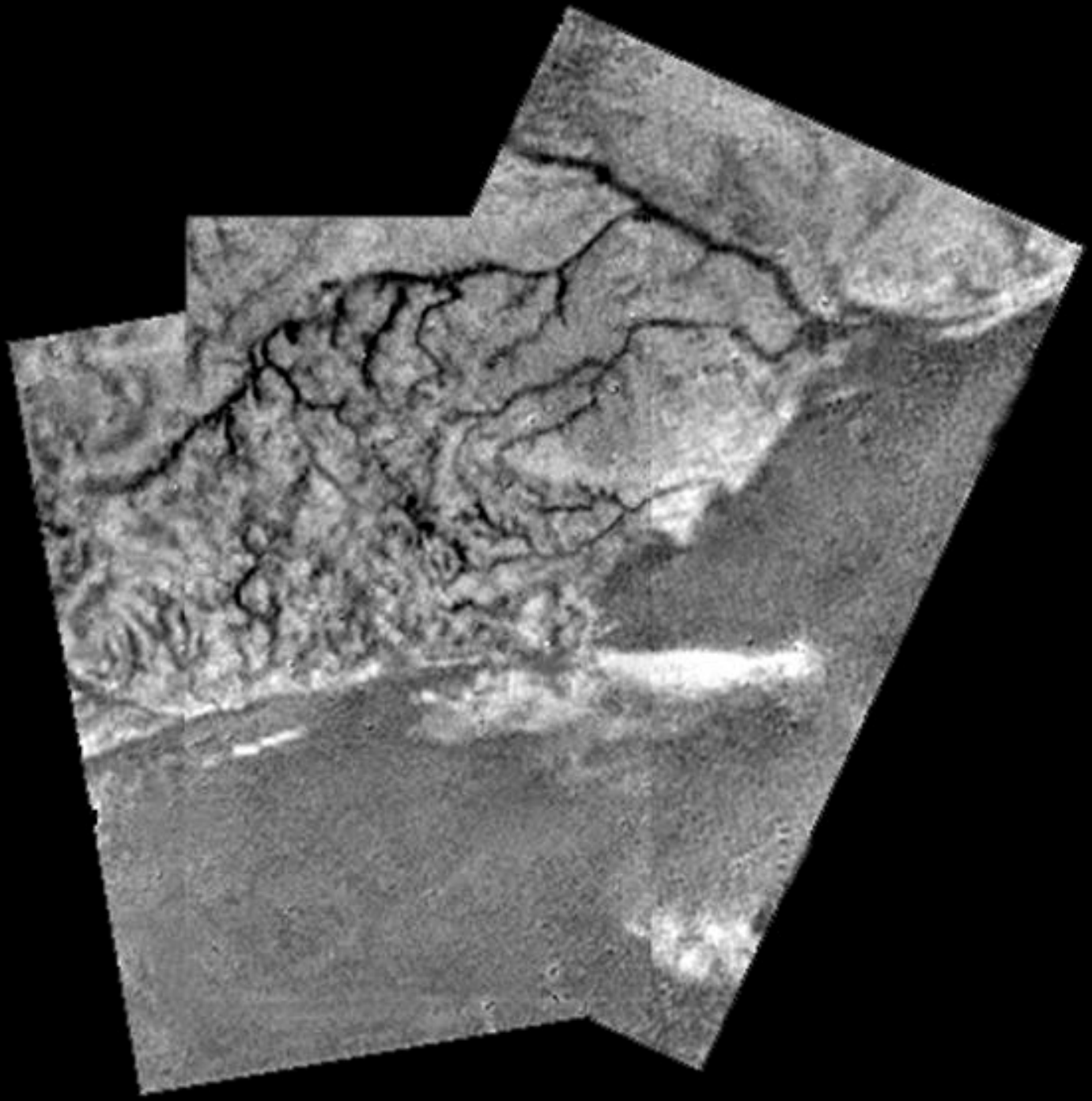

esa
soho
Facing the Sun
venus express
Studying Venus' atmosphere
proba-2
Observing coronal dynamics and solar eruptions
bepicolombo
Exploring Mercury
juice
Characterising the conditions of ocean-bearing moons around Jupiter
cassini-huygens
Studying the Saturnian system and landing on Titan
mars express
Investigating the Red Planet
cluster
Measuring Earth's magnetic shield
solar orbiter
The Sun up close
rosetta
Chasing a comet
→ ESA'S FLEET IN THE SOLAR SYSTEM
The Solar System is a natural laboratory that allows scientists to explore the nature of the Sun, the planets and their moons, as well as comets and asteroids. ESA's missions have transformed our view of the celestial neighbourhood, visiting Mars, Venus, and Saturn's moon Titan, and providing new insight into how the Sun interacts with Earth and its neighbours. The Solar System is the result of 4.6 billion years of formation and evolution. Studying how it appears now allows us to unlock the mysteries of its past and to predict how the various bodies will change in the future.
esa
European Space Agency


Cassini-Huygens

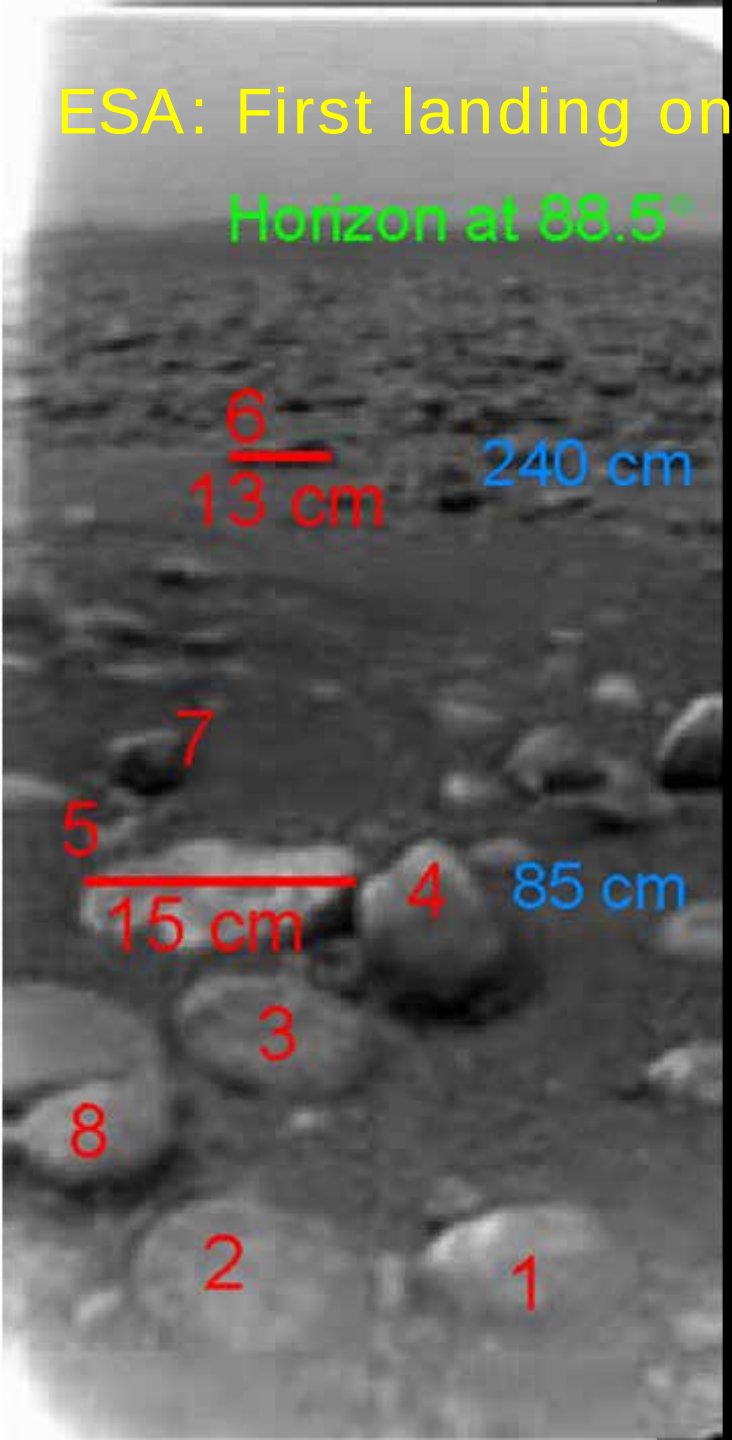
Huygens

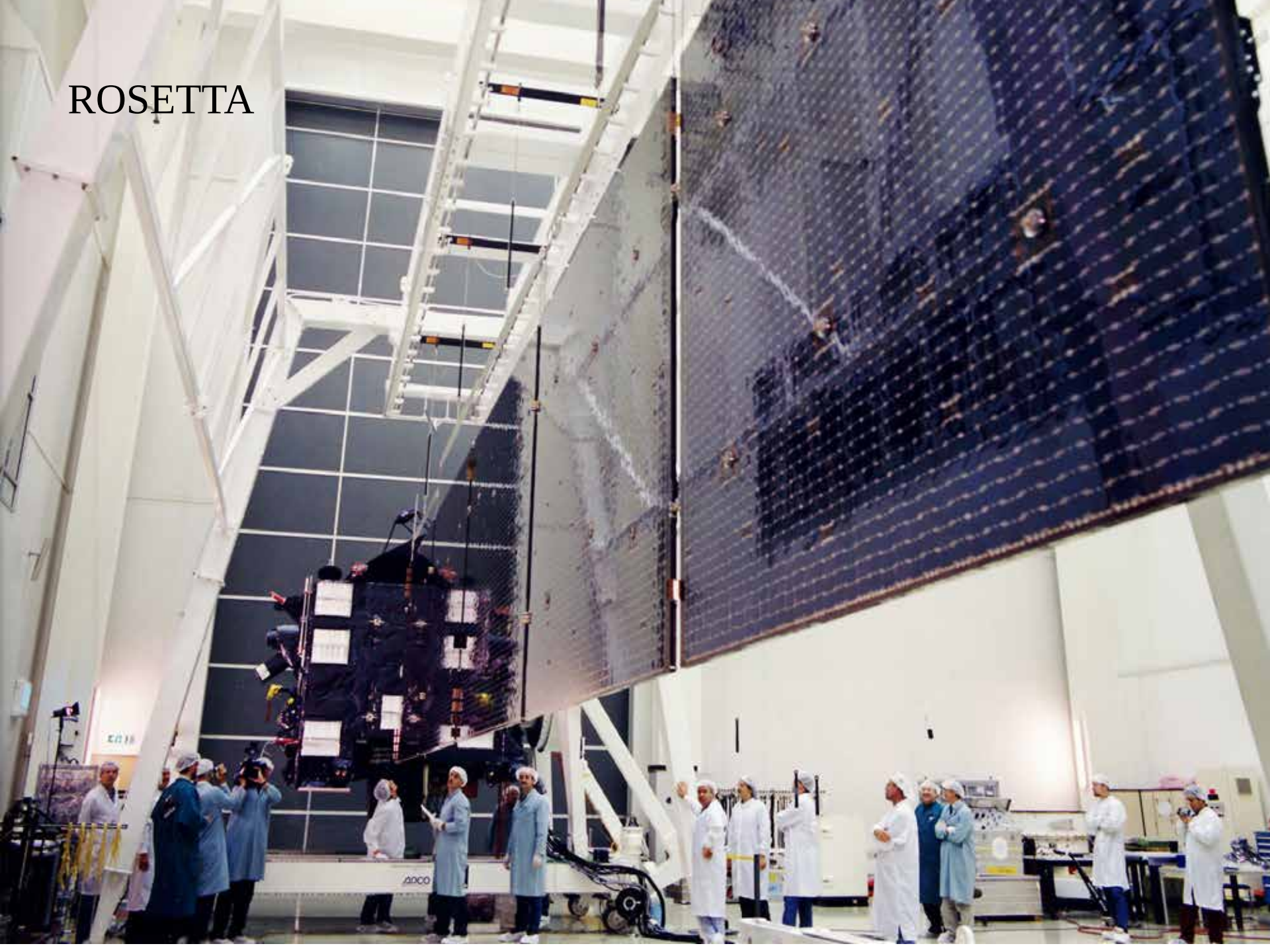



14 January 2005:
ESA’s Huygens probe
lands on Titan



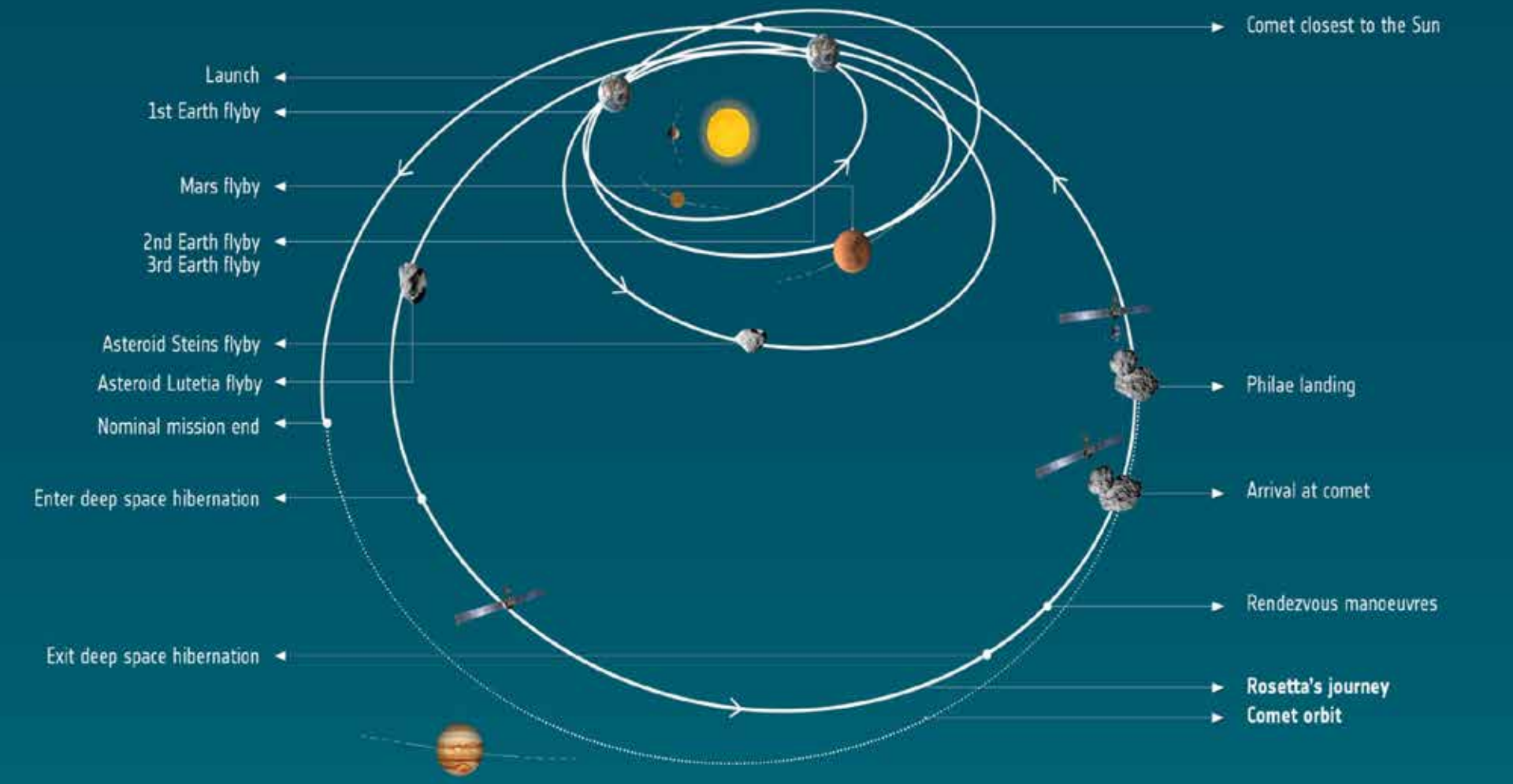
ESA: First landing on a world in the outer Solar System

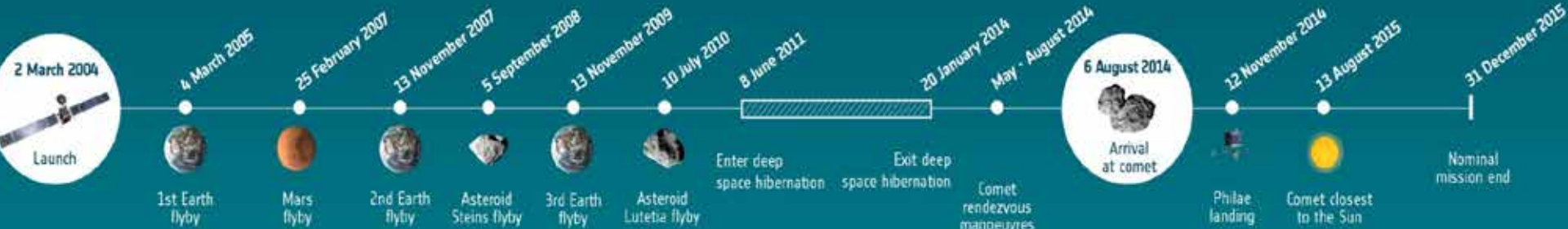


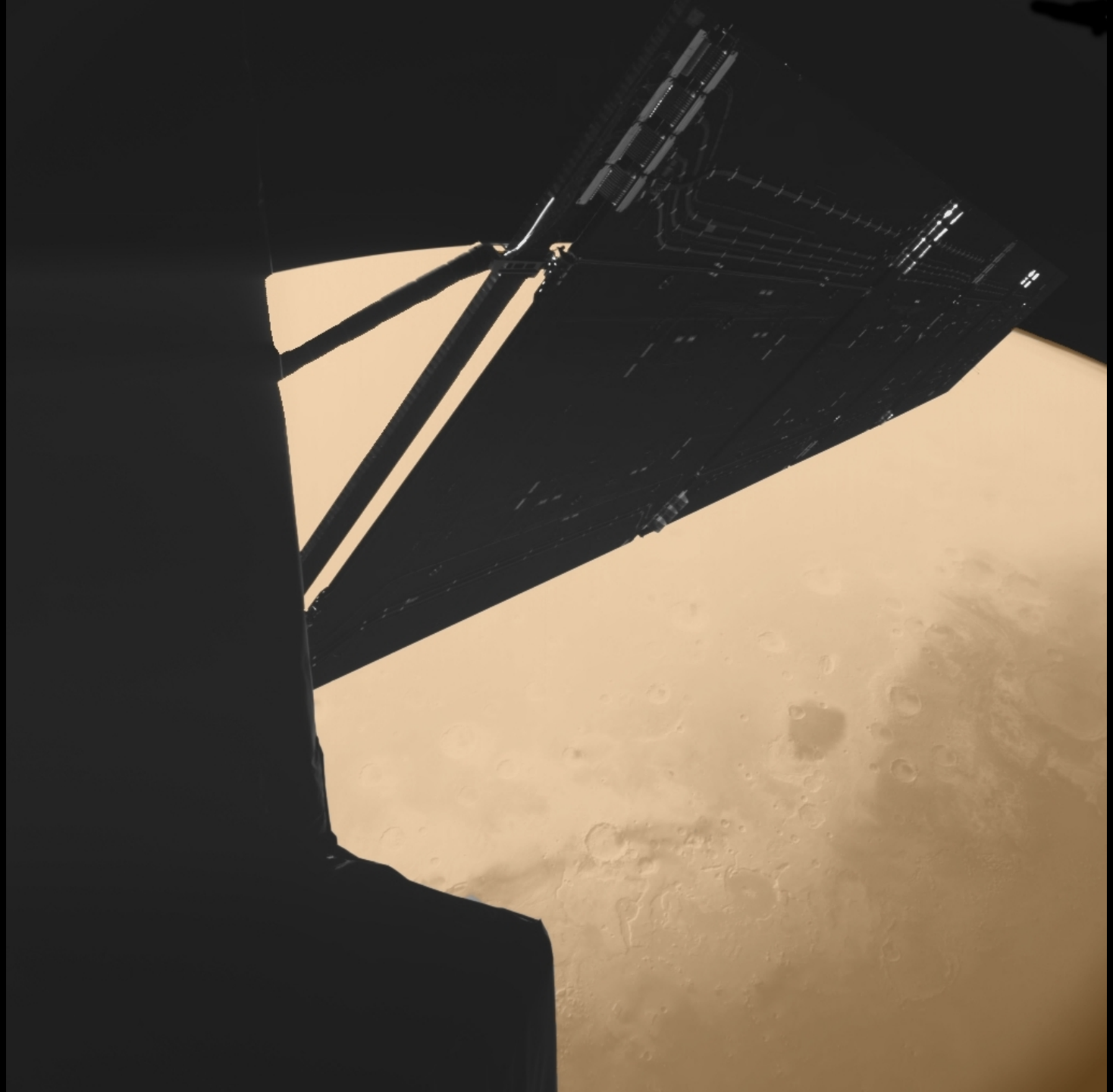

ROSETTA

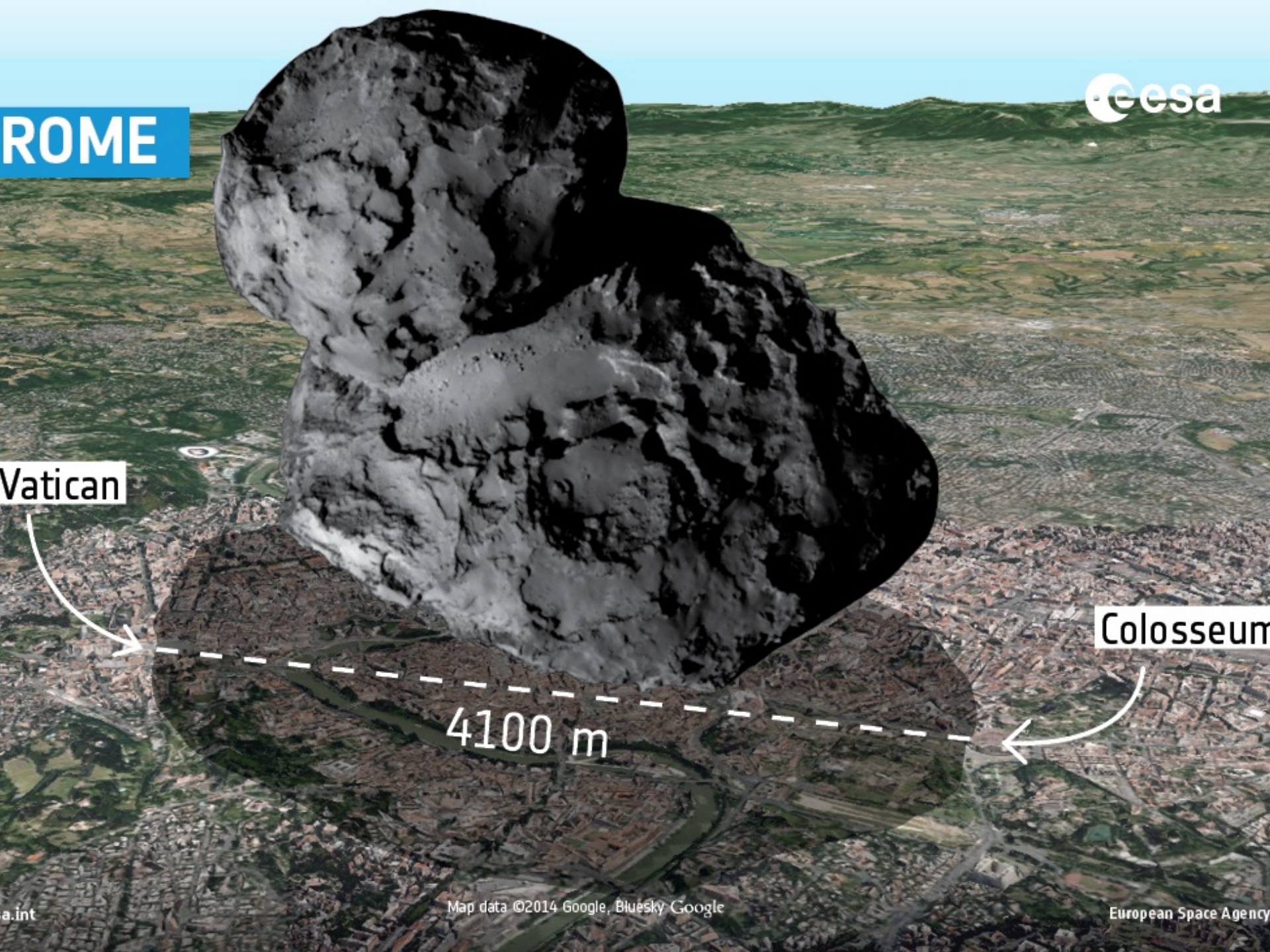
ROSETTA'S JOURNEY

esa

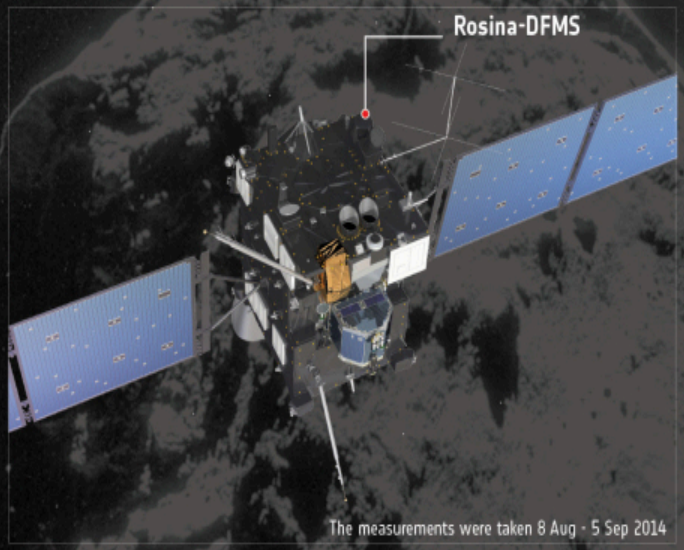


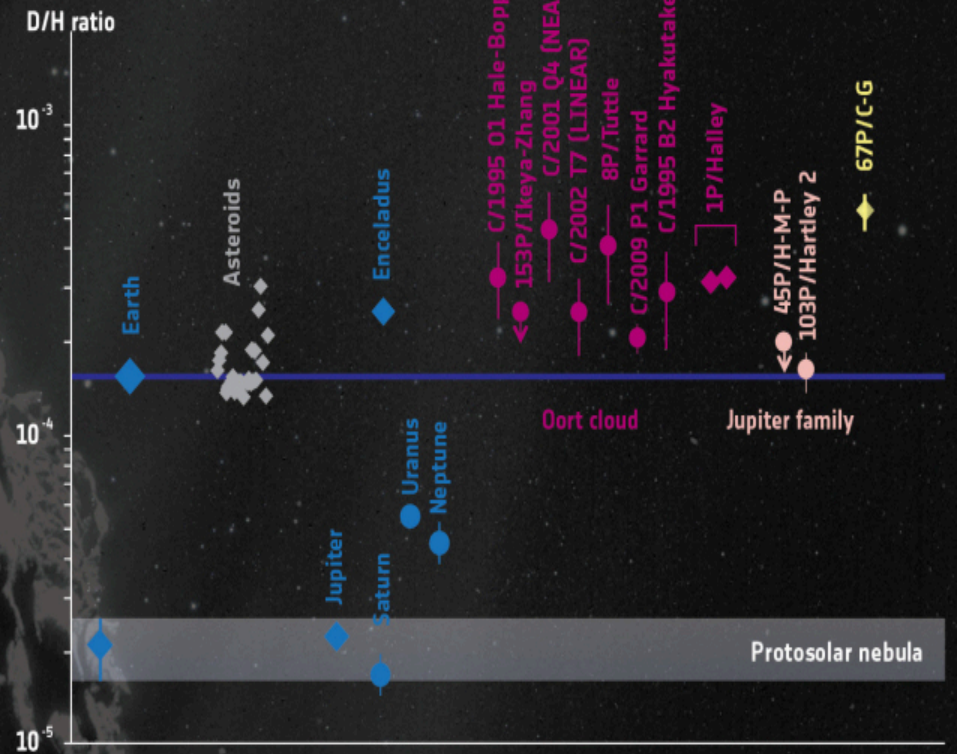




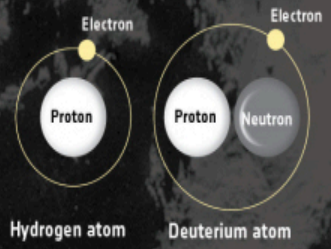

ROME
esa
Vatican
Colosseum
4100 m
Map data ©2014 Google, Bluesky Google
European Space Agency

Rosetta's ROSINA instrument finds Comet 67P/Churyumov-Gerasimenko's water vapour to have a significantly different composition to Earth's oceans.





The ratio of deuterium to hydrogen in water is a key diagnostic to determining where in the Solar System an object originated and in what proportion asteroids and comets may have contributed to Earth's oceans



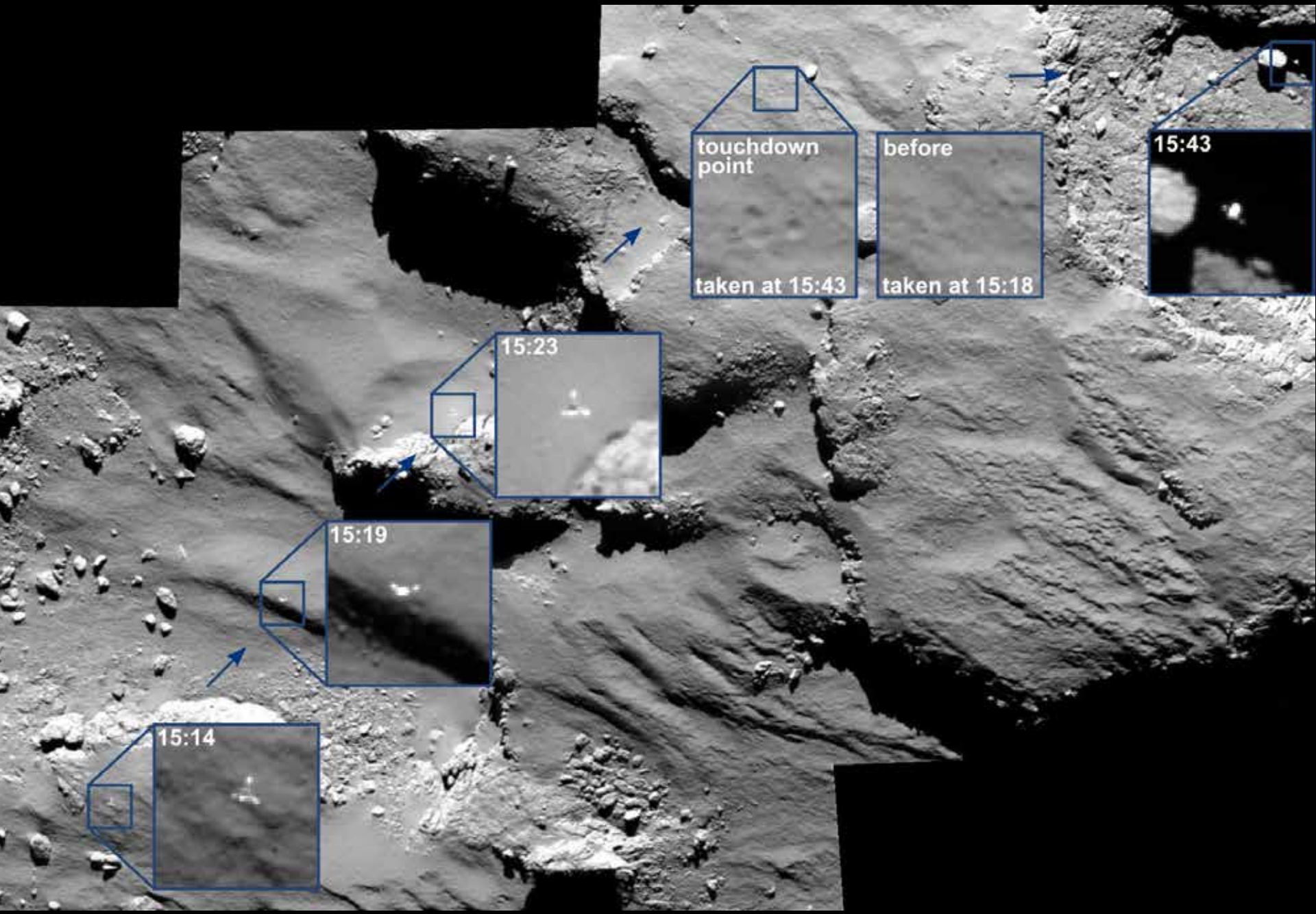
D/H ratio for different Solar System objects, grouped by colour as planets and moons (blue), chrondritic meteorites from the Asteroid Belt (grey), comets originating from the Oort cloud (purple) and Jupiter family comets (pink). Comet 67P/C-G, a Jupiter family comet, is highlighted in yellow. ◆ = data obtained in situ ● = data obtained by astronomical methods

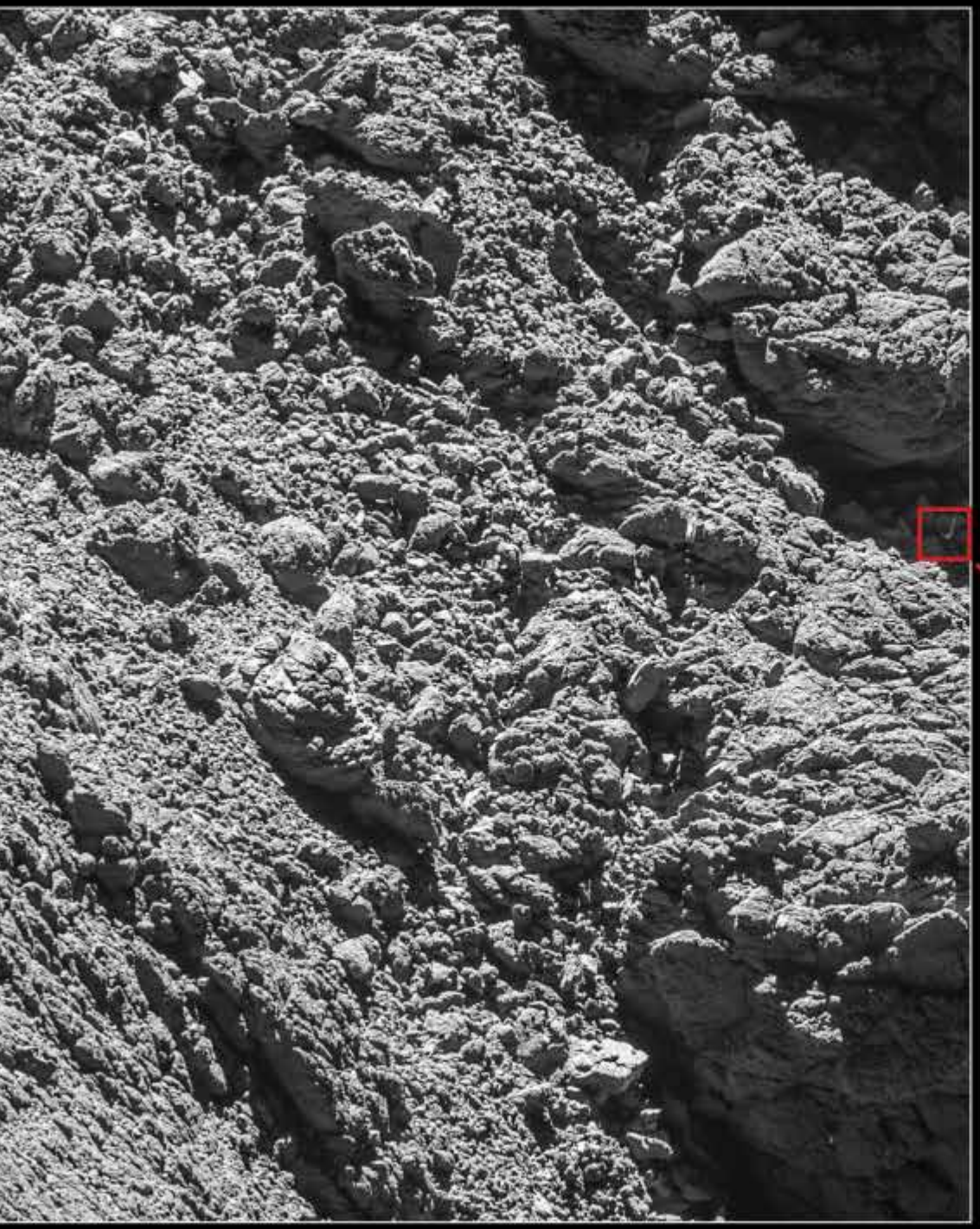
www.esa.int

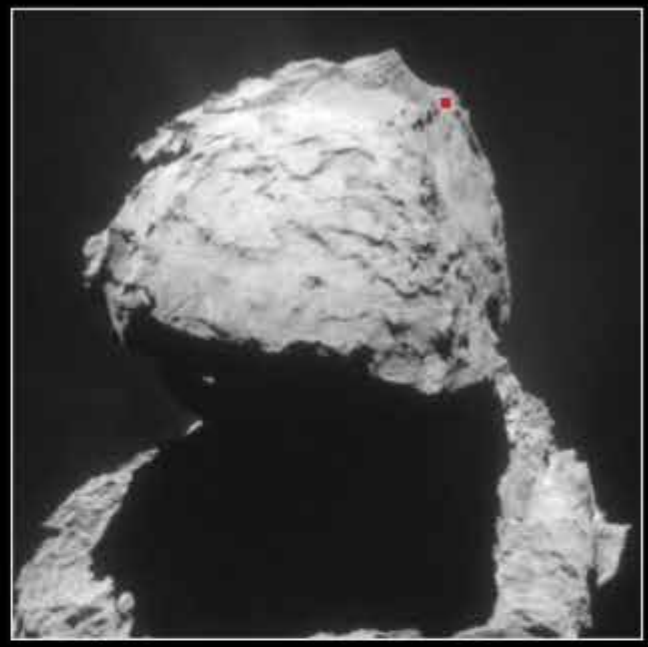
Spacecraft: ESA/ATG medialab; Comet: ESA/Rosetta/NAVCAM; Data: Altwegg et al. 2014 and references therein.

European Space Agency


PHILAE


touchdown point
taken at 15:43
before
taken at 15:18
15:43
15:23
15:19
15:14





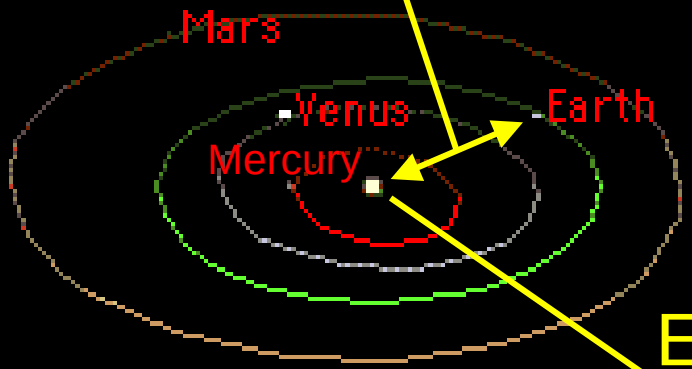
M = 1:1.000.000.000

Sun: 1.5m

Earth: 13mm

Jupiter: 150mm

Earth-Sun: 150m

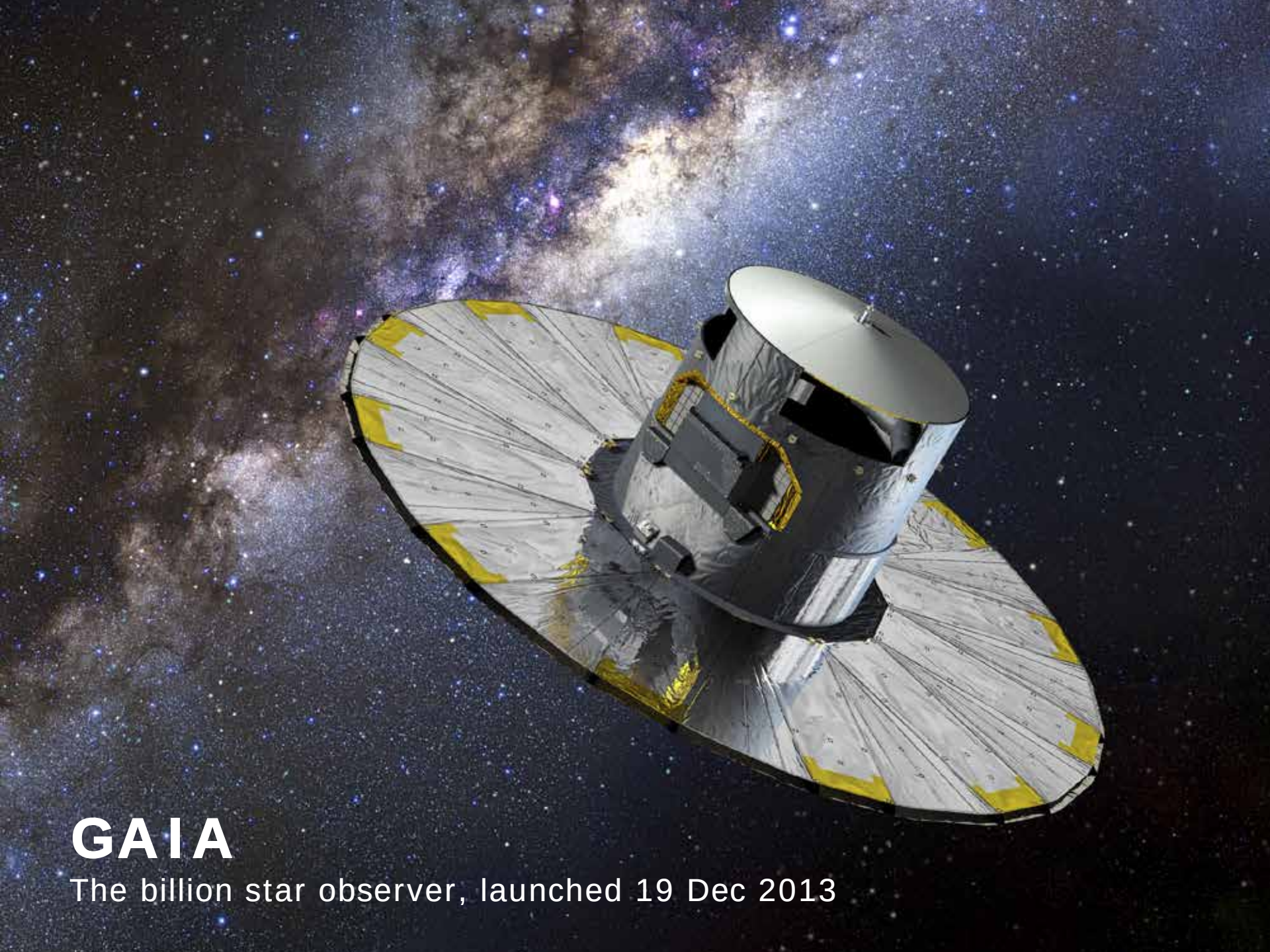


Earth-Jupiter:
500m

Neptun: 3km

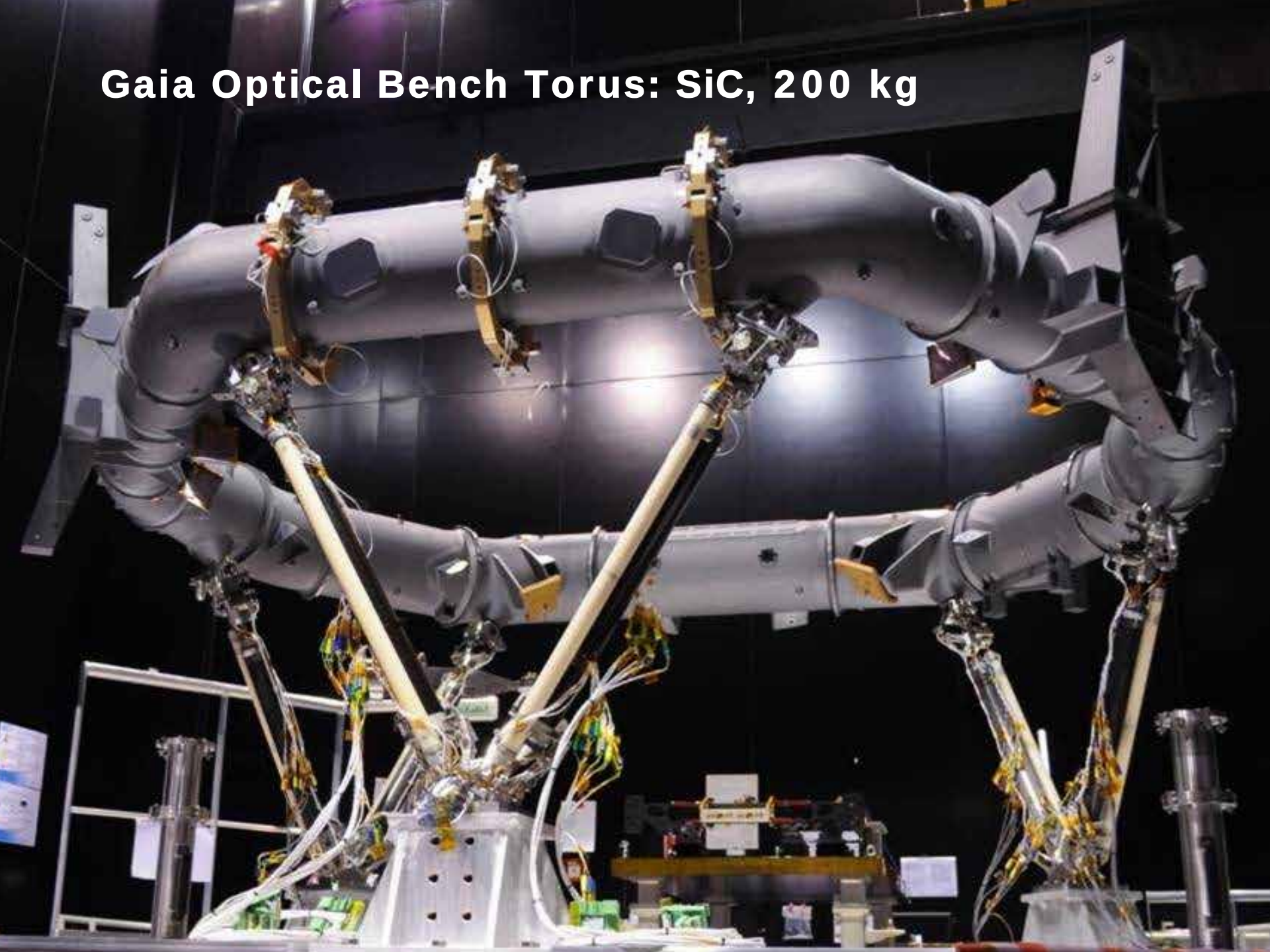
Alpha Centauri: 40000km

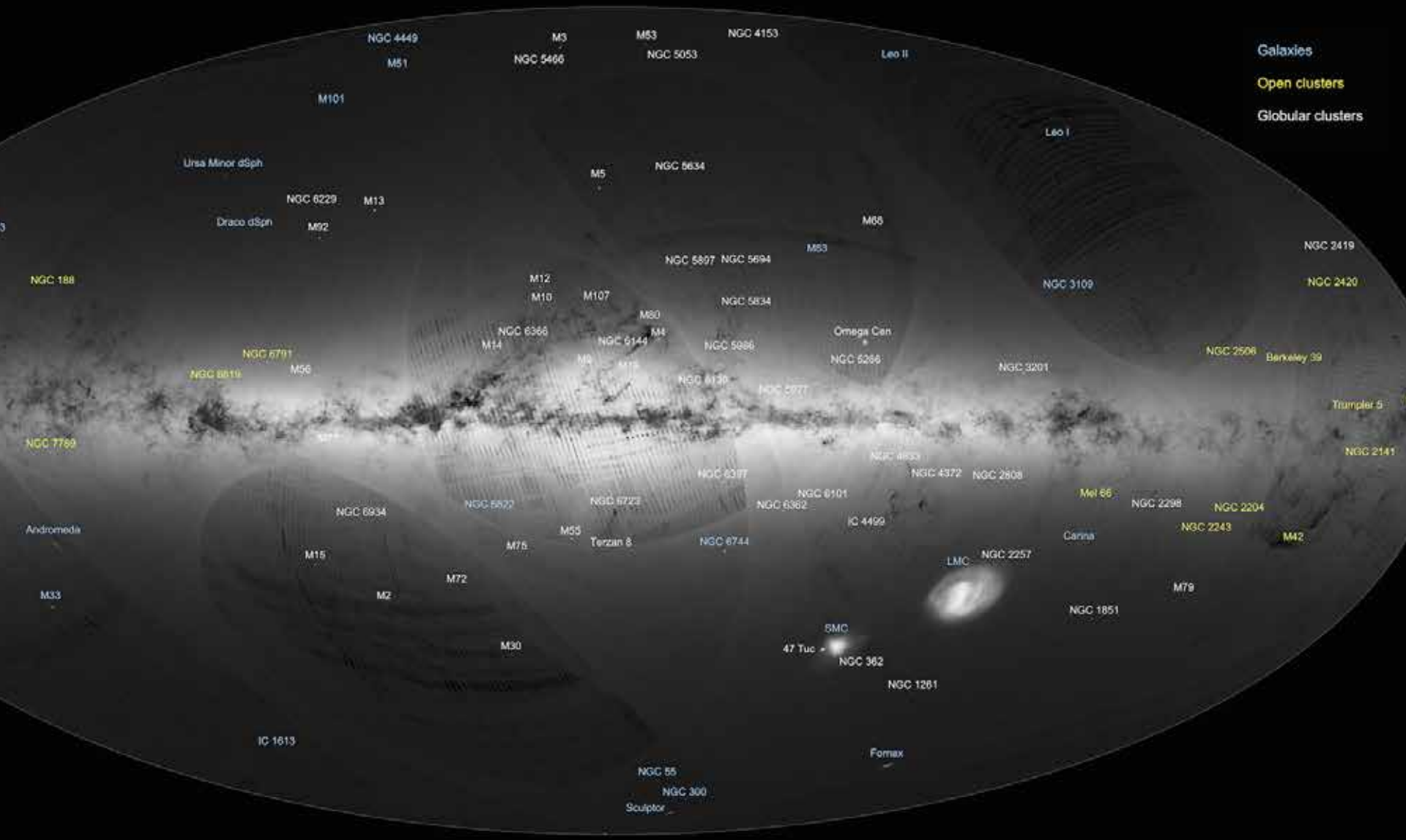
Jupiter



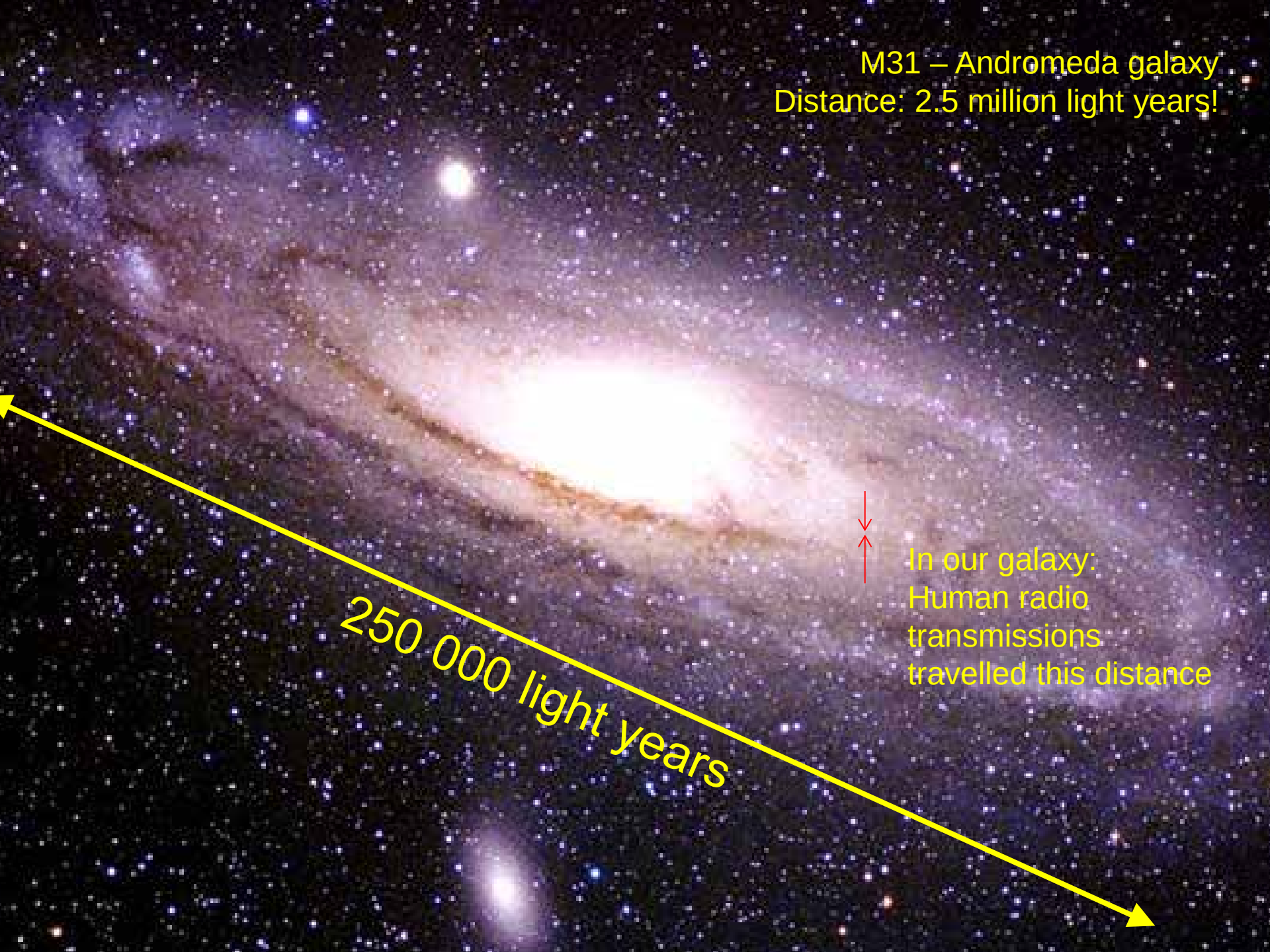
GAIA

The billion star observer, launched 19 Dec 2013


Gaia Optical Bench Torus: SiC, 200 kg



GAIA: all-sky view of stars in our Galaxy and neighbouring galaxies


M31 – Andromeda galaxy
Distance: 2.5 million light years!
250 000 light years
In our galaxy:
Human radio
transmissions
travelled this distance