EUROPE EXPLORES THE UNIVERSE

Marcos Bavdaž
European Space Agency (ESA)

Eagle Nebula, M16
7000 lightyears away,
Temperature 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)
Andromeda galaxy
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
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”

\[ \frac{T_a^2}{T_b^2} = \frac{R_a^3}{R_b^3} \]

\[ F = G \frac{m_1 m_2}{r^2} \]
Isaac Newton
1643-1727

Albert Einstein
1879 – 1955

Orbit of
Mercury

General relativity theory
(1916)
Geiger counters on V2

First observation of X-rays in space, 1949
Discovery of first extra-solar X-ray source: SCO-X1
Riccardo Giacconi (born 1931 in Genoa, I) John Hopkins (USA), ESO (D)

Discovery of cosmic X-ray sources

Nobel Prize in Physics in 2002
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"
02 July 1967: VELA 3 and 4 detected a flash of gamma radiation

GRB: Massive star collapsing to form a Black Hole
ESA’s Columbus laboratory
Herman Potočnik (1892 - 1929)  
(pseudonym Hermann Noordung)  
Slovene rocket engineer
International Space Station (ISS)
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
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
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

Navigation*
17.6%, 1010.8 M€

Launchers*
18.9%, 1088.4 M€

Space Science
8.9%, 513.1 M€

Human Spaceflight & Robotic Exploration
11.0%, 633.0 M€

Telecom & Int. Appl.*
5.6%, 319.0 M€

Associated with General Budget
3.9%, 222.3 M€

Technology Support*
2.0%, 114.3 M€

Space Situational Awareness
0.3%, 15.1 M€

Prodex
0.8%, 47.2 M€

Basic Activities
4.1%, 234.8 M€

European Cooperating States Agreements
0.1%, 5.5 M€

Earth Observation*
26.9%, 1543.3 M€

SL: 0.1%, 3.4 M€

*includes programmes implemented for other institutional partners
ESA’s Fleet Across the Spectrum

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.

- **Herschel**: Unveiling the cool and dusty Universe
- **JUST**: Observing the first light
- **Gaia**: Surveying a billion stars
- **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
- **Integral**: Seeking out the extremes of the Universe

**Lisa Pathfinder**: Testing the technology for gravitational wave detection
Ariane 5 Launch Zone (ZL3), Kourou, 14 May 2009: launch Herschel and Planck
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
Afterglow Light Pattern 400,000 yrs.

Dark Ages

Development of Galaxies, Planets, etc.

Dark Energy Accelerated Expansion

Inflation

Quantum Fluctuations

1st Stars about 400 million yrs.

Big Bang Expansion

13.7 billion years
Higgs boson: candidate event
Composition of the universe

- Dark Matter: 25%
- Free Hydrogen and Helium: 4%
- Neutrinos: 0.3%
- Heavy Elements: 0.03%
- Stars: 0.5%
- Dark Energy: 70%
EUCLID
Mapping the geometry of the dark Universe
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.
Huygens
14 January 2005: ESA’s Huygens probe lands on Titan
ESA: First landing on a world in the outer Solar System

Horizon at 88.5°

6 13 cm 240 cm

5 15 cm 4 85 cm

8 3 2 1
ROSETTA
ROSETTA’S JOURNEY

- Launch
- 1st Earth flyby
- Mars flyby
- 2nd Earth flyby
- 3rd Earth flyby
- Asteroid Steins flyby
- Asteroid Lutetia flyby
- Nominal mission end
- Enter deep space hibernation
- Exit deep space hibernation
- Comet closest to the Sun
- Philae landing
- Arrival at comet
- Rendezvous manoeuvres
- Rosetta's journey
- Comet orbit

Timeline:
- 2 March 2004 (Launch)
- 4 March 2007 (1st Earth flyby)
- 25 February 2007 (Mars flyby)
- 13 November 2007 (2nd Earth flyby)
- 5 September 2008 (Asteroid Steins flyby)
- 13 November 2009 (3rd Earth flyby)
- 10 July 2010 (Asteroid Lutetia flyby)
- 6 August 2011 (Enter deep space hibernation)
- 29 January 2014 (Exit deep space hibernation)
- 6 August 2014 (Arrival at comet)
- 12 November 2014 (Philae landing)
- 13 August 2015 (Comet closest to the Sun)
- 31 December 2015 (Nominal mission end)
Rosetta's ROSINA instrument finds Comet 67P/Churyumov-Gerasimenko's water vapour to have a significantly different composition to Earth's oceans.

The measurements were taken 8 Aug - 5 Sep 2014.

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), chondritic meteorites from the Asteroid Belt (grey), comets originating from the Oort cloud (purple) and Jupiter family comets (pink). Comet 67P/CG, a Jupiter family comet, is highlighted in yellow. ◆ = data obtained in situ ◇ = data obtained by astronomical methods.
M = 1:1,000,000,000

Sun: 1.5m
Earth: 13mm
Jupiter: 150mm

Earth-Sun: 150m
Earth-Jupiter: 500m
Neptun: 3km
Alpha Centauri: 400,000km
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!

In our galaxy:
Human radio transmissions travelled this distance

250 000 light years