Introduction to the European Space Agency and its space science programme

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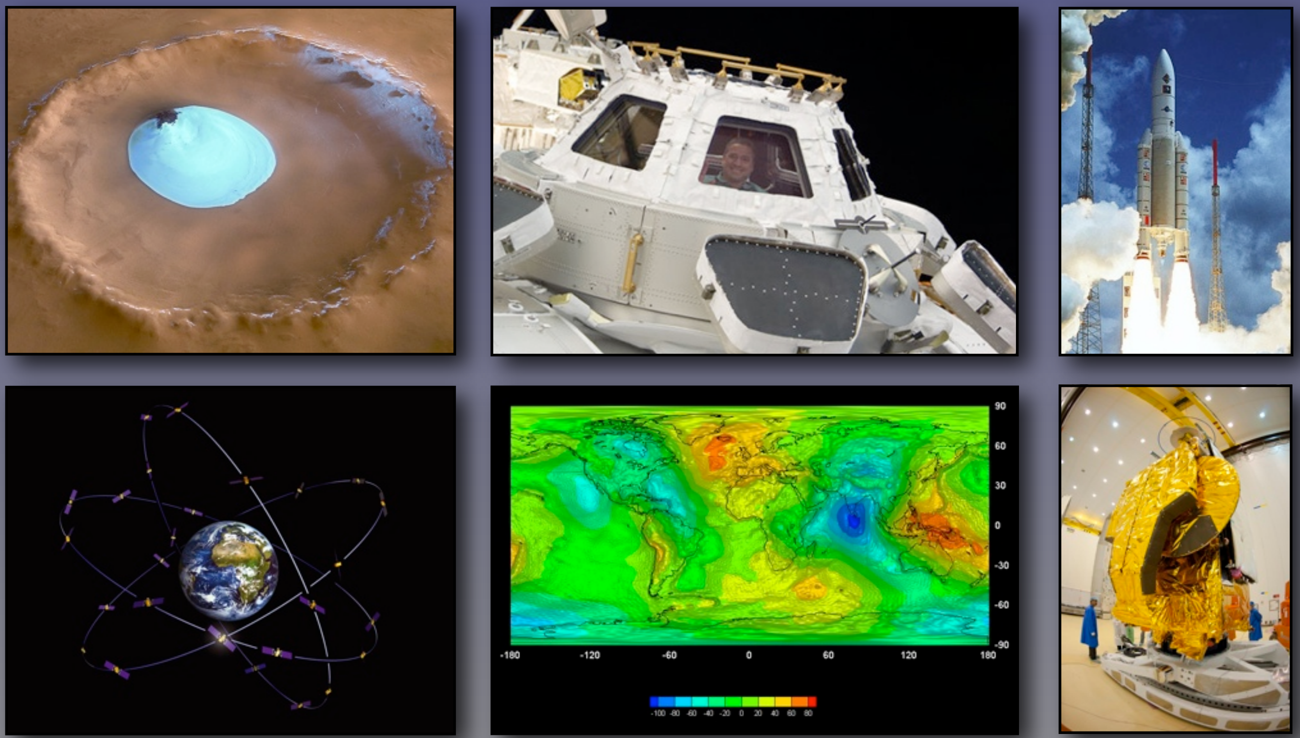
Southern Cross region with Herschel PACS + SPIRE / ESA

The European Space Agency in brief

- Intergovernmental agency
  - 18 European member states + Canada + 11 cooperating states
  - Annual budget ~ €4 billion
  - International staff ~ 2,400 + ~3,000 contractors
  - Main sites in FR, NL, DE, IT, ES, UK, French Guiana
- Six programme directorates
  - Science & Robotic Exploration
  - Human Spaceflight & Ops
  - Earth Observation
  - Telecommunications
  - Launchers
  - Navigation



A short history of ESA

- ESRO
  - European Space Research Organisation: founded in 1964
  - 10 European nations
  - Launched number of space science & technology satellites
  - ESLAB was scientific laboratory of ESRO: is ancestor of today's RSSD
- ELDO
  - European Launcher Development Organisation: founded in 1964
  - 6 European nations
  - Europa: UK Blue Streak + French Coralie + German upper stage
  - Launches from Woomera, Australia, then Kourou, French Guiana
- ESA
  - Merger of ESRO and ELDO: founded in 1975
  - 10 European nations then: now 18
  - Launched Cos-B in 1975, followed by IUE, Giotto, Exosat etc.
  - Ariane launcher programme: Ariane 1 1979, Ariane 4 1988, Ariane 5 1997

Top-level structure today

- Director General: Jean-Jacques Dordain
- Eleven directors:
  - Science & Robotic Exploration (SRE): Giménez
  - Human Spaceflight & Operations (HSO): Reiter
  - Earth Observation (EOP): Liebig
  - Launchers (LAU): Fabrizi
  - Navigation (NAV): Faivre
  - Telecomms & Integrated Applications (TIA): Vaissiere
  - Technical & Quality Management (TEC): Ongaro
  - Procurement & Legal Affairs (PFL): Morel
  - Corporate Reform (CR): Winters
  - Policies, Planning, & Control (PPC): Morsillo
  - Human Resources, Facility Management, & Informatics (HFI): Mockel

Programme directorates

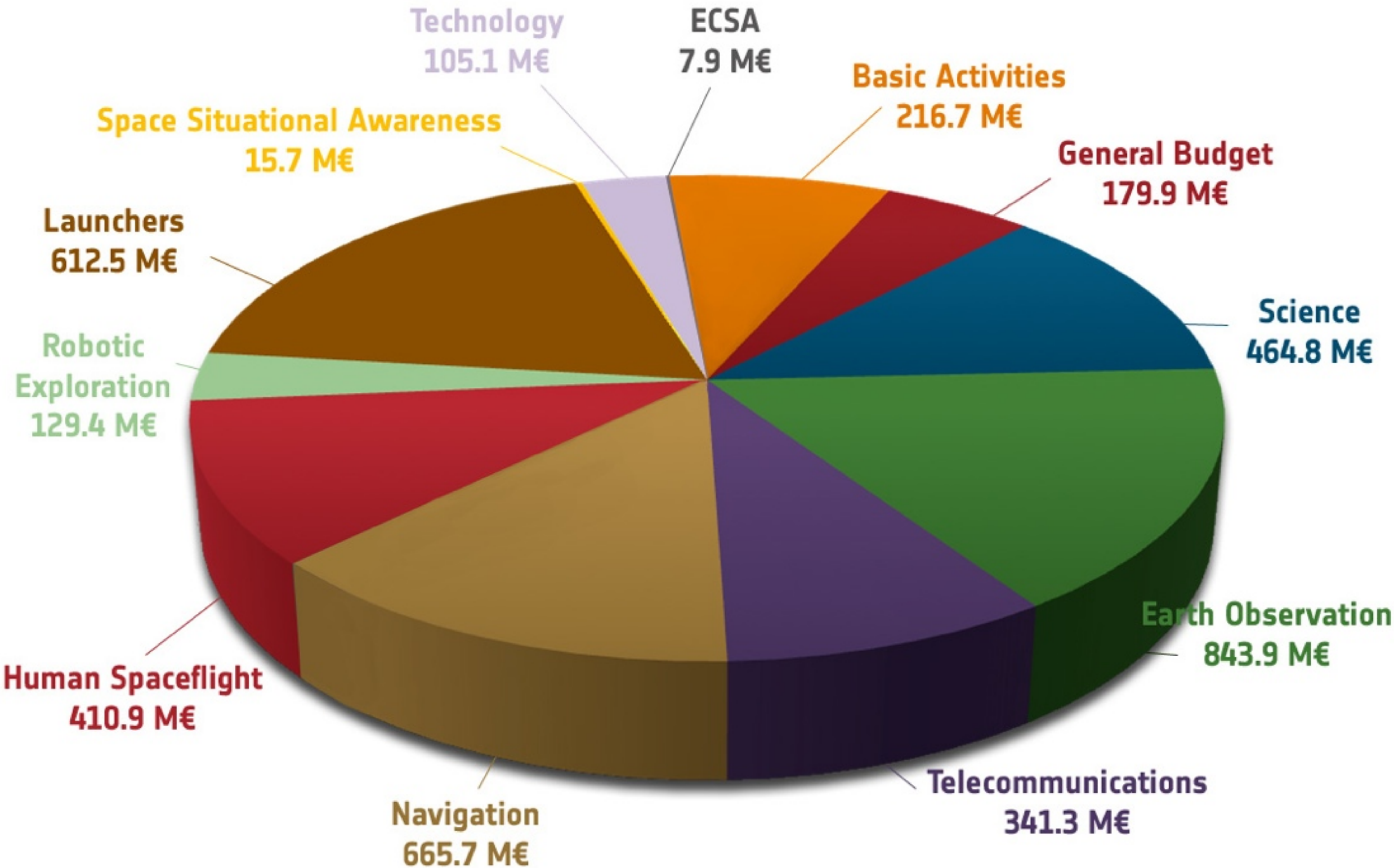
Support directorates

Funding categories

- Mandatory
  - Programmes carried out under General Budget
    - Future project studies, technology research, shared technical investments, information systems, training programme
  - Science Programme
  - Member State contributions to General Budget and Science Programme are based on GDP and thus essentially non-negotiable once overall ESA budget is fixed every 3–4 years
- Optional
  - Earth observation, telecommunications, satellite navigation, launchers, human spaceflight, robotic exploration
  - Funded on à la carte basis by Member States which want to be involved and at level they choose

Juste retour & geographic return

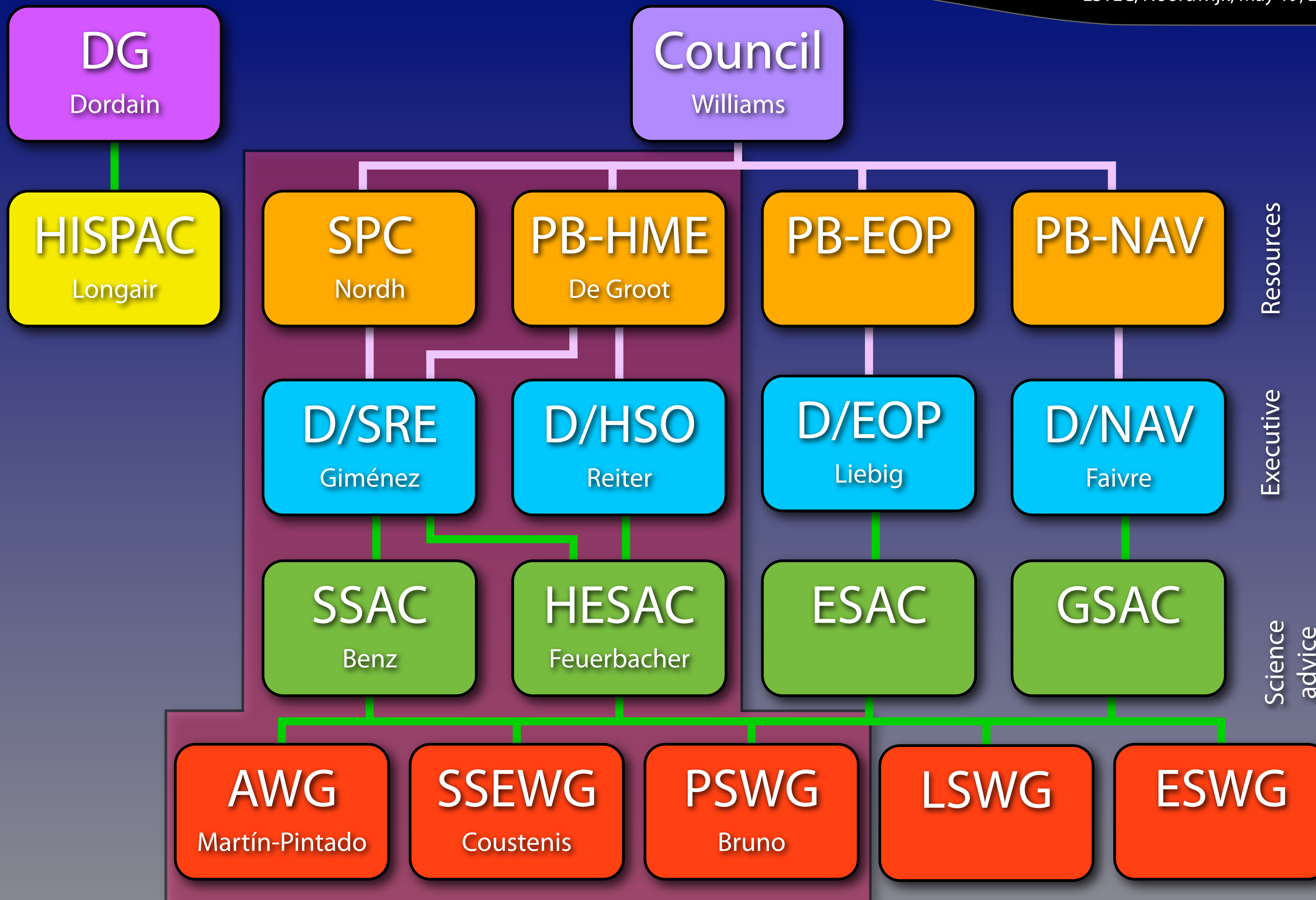
- Countries get back what they put in
  - Once ESA internal operating costs have been subtracted (~15–20%), money must be spent in the Member States in proportion to the amount contributed by that country
  - Great majority of that money goes to European industry
- Pros
  - Ensures development of appropriate industries in smaller countries
  - Overcomes concern that some countries may be subsidising others
  - Encourages investment on targeted optional programmes
- Cons
  - Can be very hard balancing individual programmes nationally
  - Does not encourage highly competitive bidding
  - Some countries against it: believe they could win more (e.g. UK)



2011 ESA budget

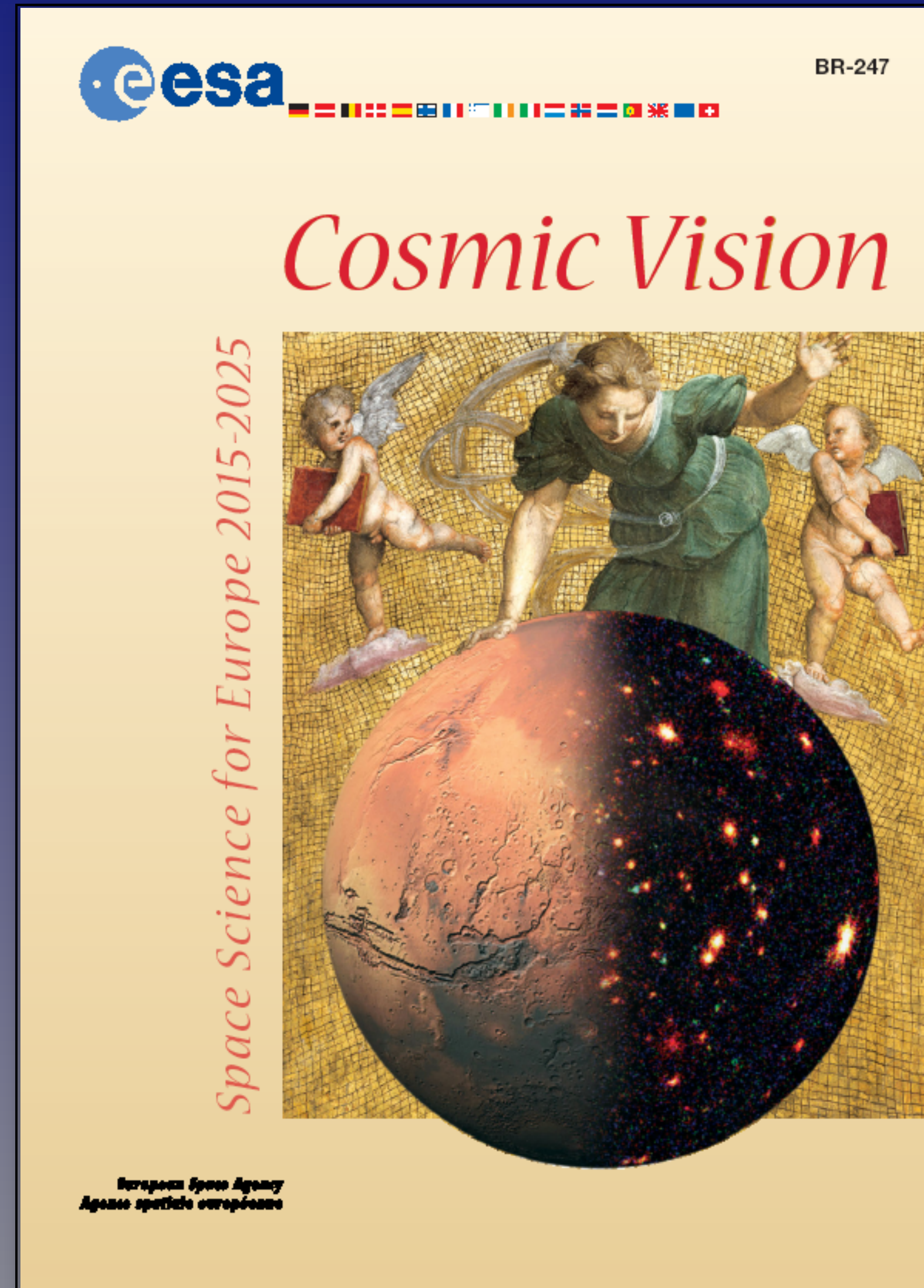
Mandatory space science programme

- Mission concepts proposed to ESA in periodic calls
- Evaluated & ranked by ESA scientific advisory structure
- Top-ranked missions studied in detail by ESA and industry for feasibility
- Missions selected for implementation based on:
  - Scientific priority
  - Projected cost
  - Technological readiness
  - Projected launch date
  - International collaboration
  - Programme balance
  - Member State priorities and financial involvement
  - (Yes, it can get complicated)


DG
Dordain
Council
Williams
HISPAC
Longair
SPC
Nordh
PB-HME
De Groot
PB-EOP
PB-NAV
Resources
D/SRE
Giménez
D/HSO
Reiter
D/EOP
Liebig
D/NAV
Faivre
Executive
SSAC
Benz
HESAC
Feuerbacher
ESAC
GSAC
Science advice
AWG
Martín-Pintado
SSEWG
Coustenis
PSWG
Bruno
LSWG
ESWG

The Cosmic Vision programme

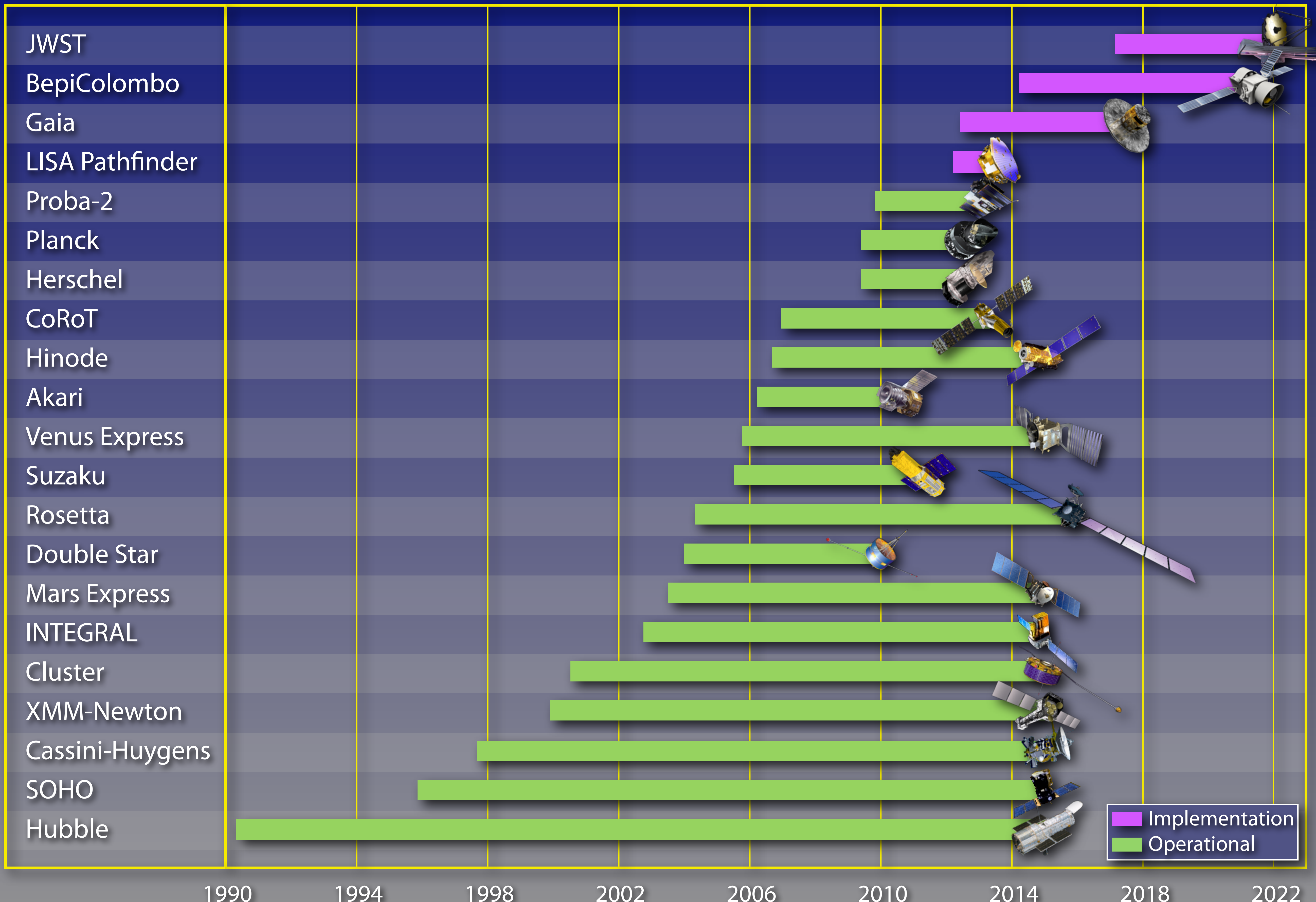
- Planets and life
  - From gas and dust to stars and planets
  - From exoplanets to biomarkers
  - Life and habitability in the Solar System
- The Solar System
  - From the Sun to the edge of the Solar System
  - Gaseous giants and their moons
  - Asteroids and other small bodies
- Fundamental laws
  - Explore the limits of contemporary physics
  - The gravitational wave Universe
  - Matter under extreme conditions
- The Universe
  - The early Universe
  - The Universe taking shape
  - The evolving violent Universe



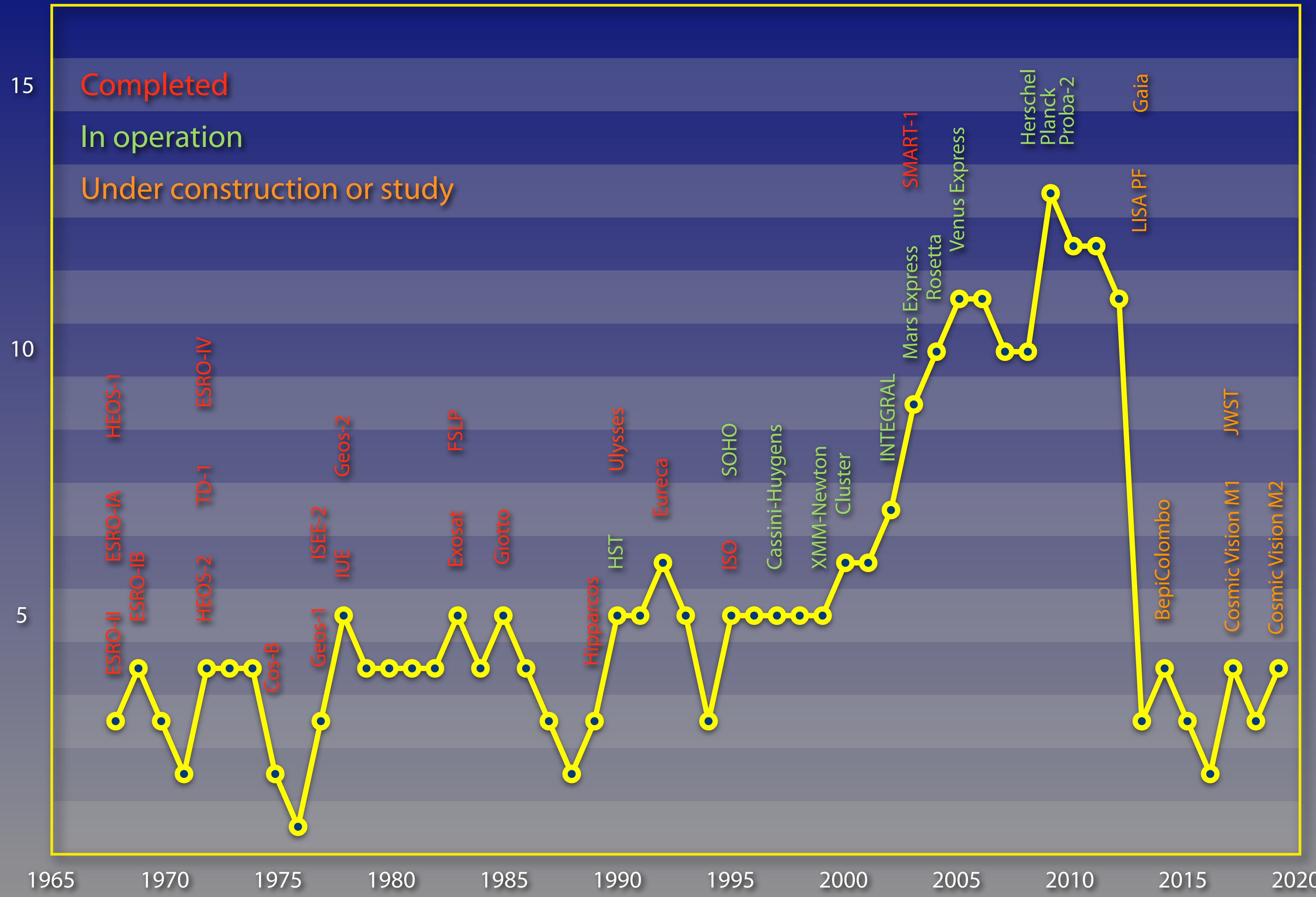
Cosmic Vision 2015–2025

- Total budget ~€3B from ESA science programme
  - Originally three AOs foreseen, ~€1B per AO (CV1, CV2, CV3)
  - Additional contributions from member states (e.g. payload) and/or international partners (e.g. USA, Russia, Japan, China, India)
- L-class missions
  - Large missions: observatories / large-scale exploration
  - ESA contribution €850M
- M-class missions
  - Medium missions: focussed science goal / experiment
  - ESA contribution originally set at €300M
  - Adjusted upwards to €450M during CV1 studies

Current ESA space science missions



History of ESRO/ESA space science missions



Operating ESA space science missions

- XMM-Newton
- Cluster
- INTEGRAL
- Mars Express
- Rosetta
- Venus Express
- Herschel
- Planck
- Proba-2

- HST (with NASA)
- SOHO (with NASA)
- Cassini-Huygens (with NASA/ASI)
- Suzaku (with JAXA)
- Akari (with JAXA) ☠
- Hinode (with JAXA)
- Double Star (with CNSA) ☠
- CoRoT (with CNES)

Future ESA space science missions

Missions in implementation

- LISA Pathfinder
- Gaia
- JWST (with NASA, CSA)
- BepiColombo (with JAXA)

CV medium missions under study

- Solar Orbiter (with NASA)
- Euclid
- PLATO
- SPICA (with JAXA)

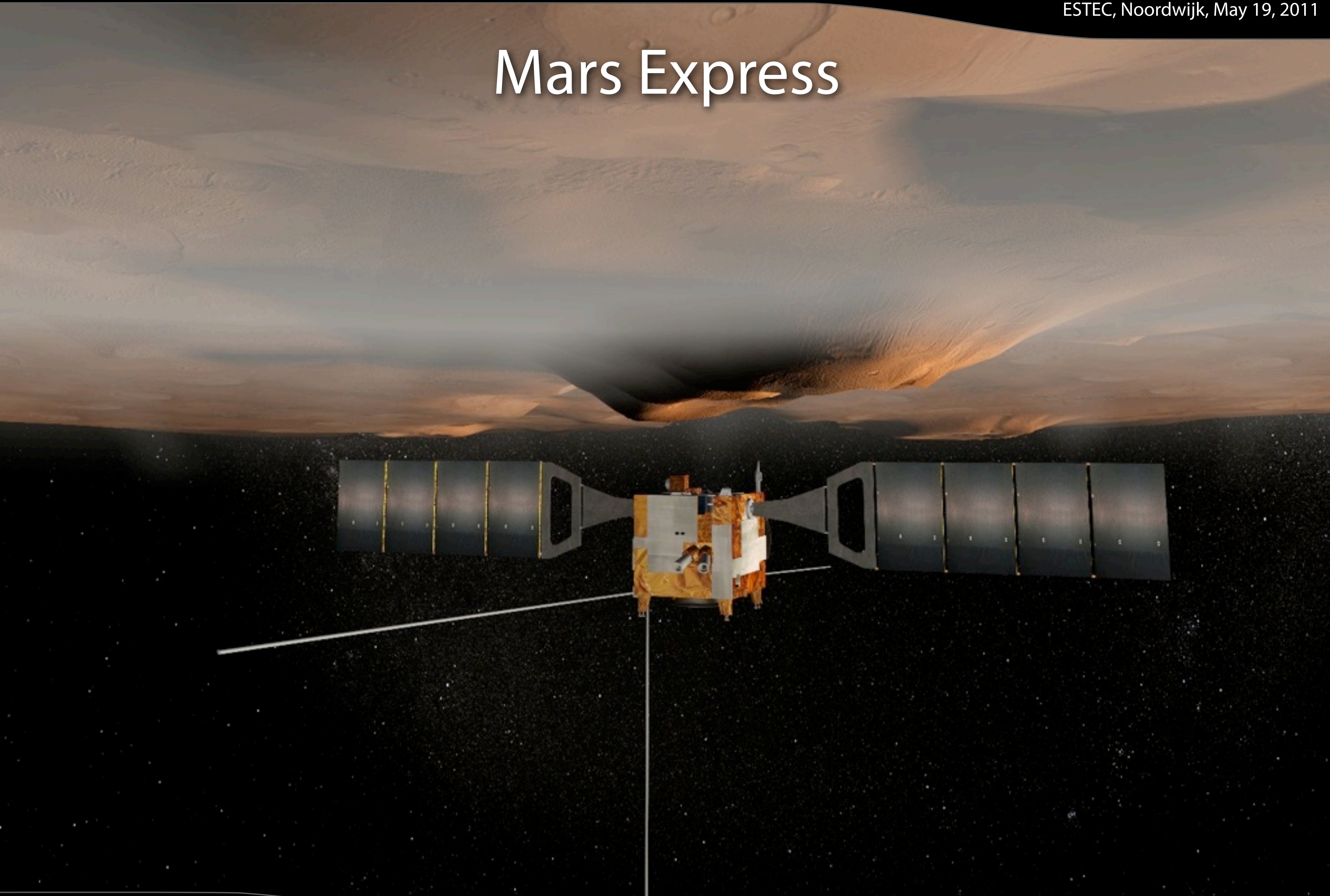
ESA-NASA ExoMars robotic exploration

- Trace Gas Orbiter + EDM
- Rover mission
- Goal: Sample Return

CV large missions under study

- X-ray Observatory
- Gravitational Waves
- Jupiter System

Mars Express



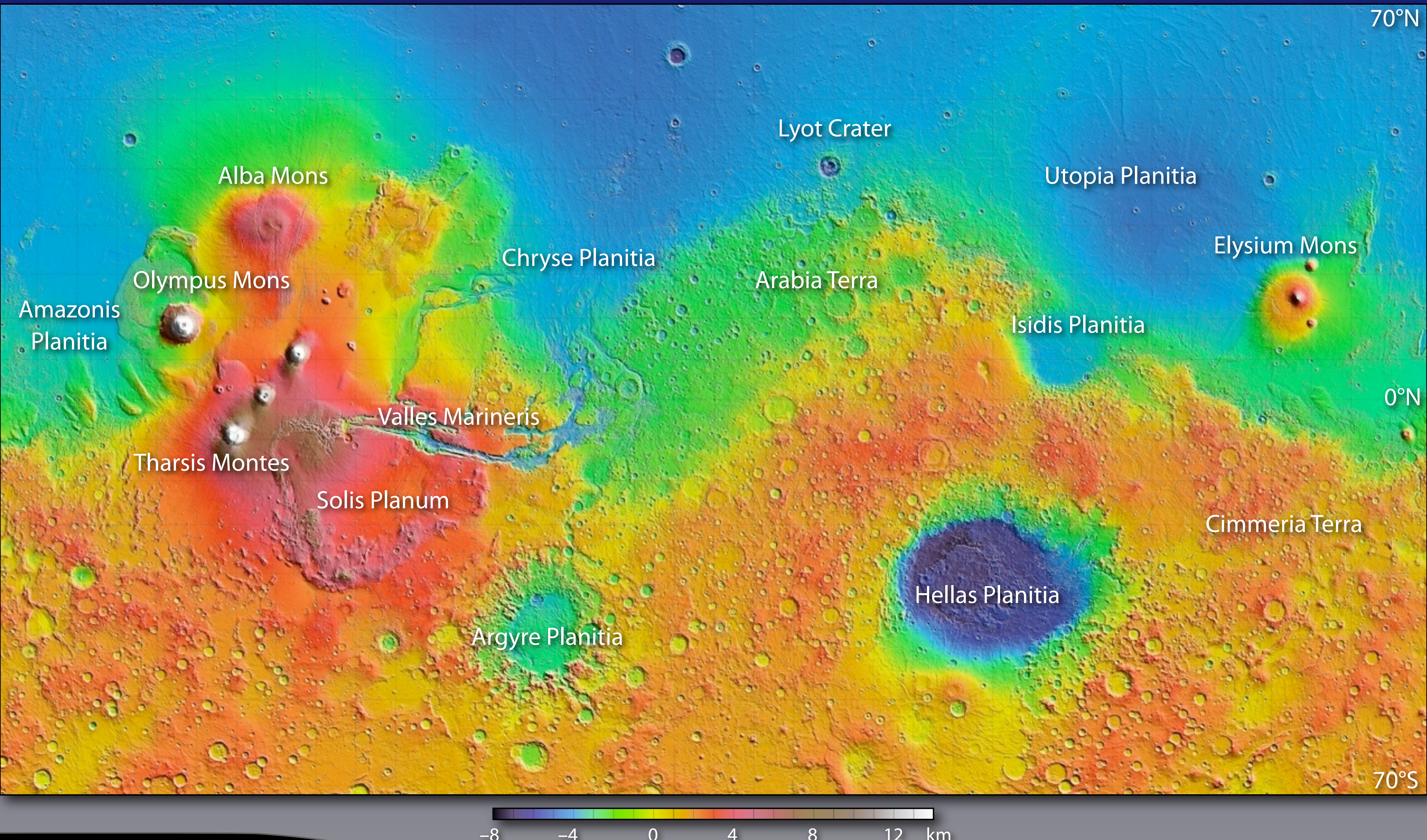
ESA Mars planetary physics mission, launched 2003

Phobos and Mars

Image taken in 2010
Latest series of Phobos fly-bys in January 2011

Mars Express HRSC / ESA / DLR / FU Berlin (G. Neukum)

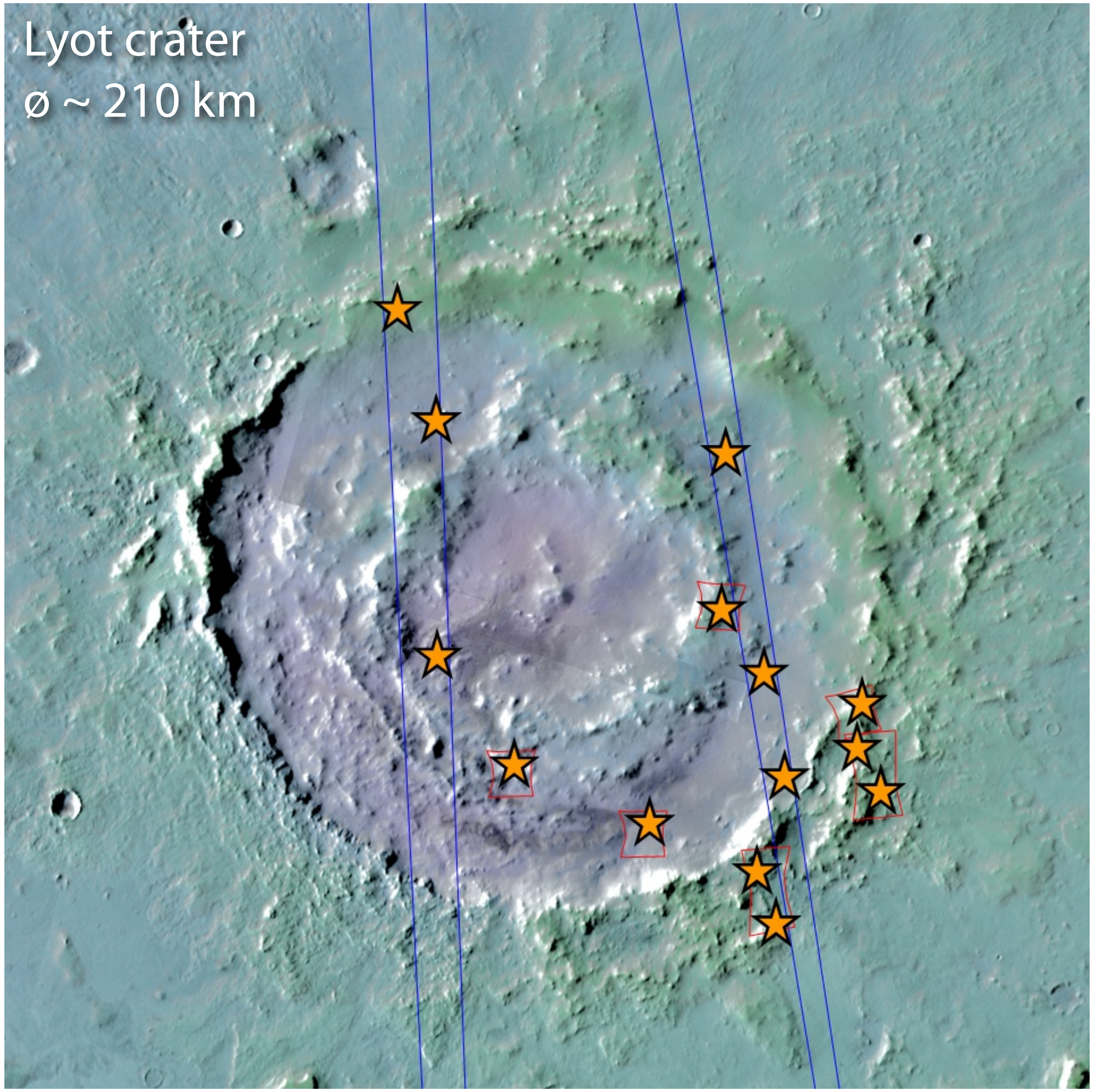
Altimetry of Mars



Mars Orbiter Laser Altimeter, MGS / NASA

Wet era on early Mars was global

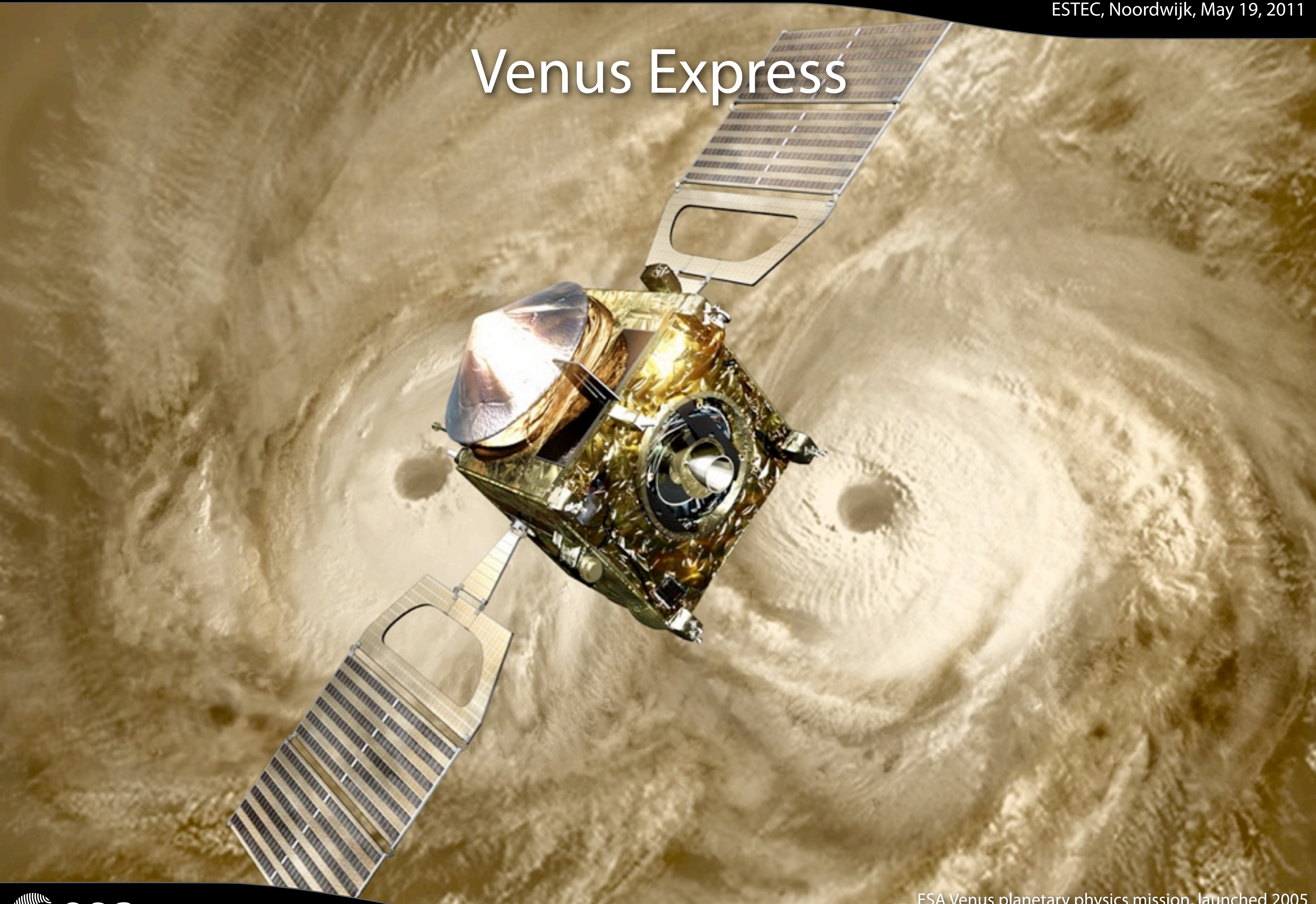
- Many small outcrops of hydrated silicates in ancient southern highlands
- Northern lowlands younger, ancient crust covered by 0.1–few km layer of volcanic and processed sediments
- Search in northern craters shows identical hydrated silicate deposits under sediments
- Both hemispheres altered by water ~4 billion yr ago, prior to volcanic activity on northern Tharsis plateau



MEX OMEGA scans | MRO CRISM observations | Hydrated minerals detected

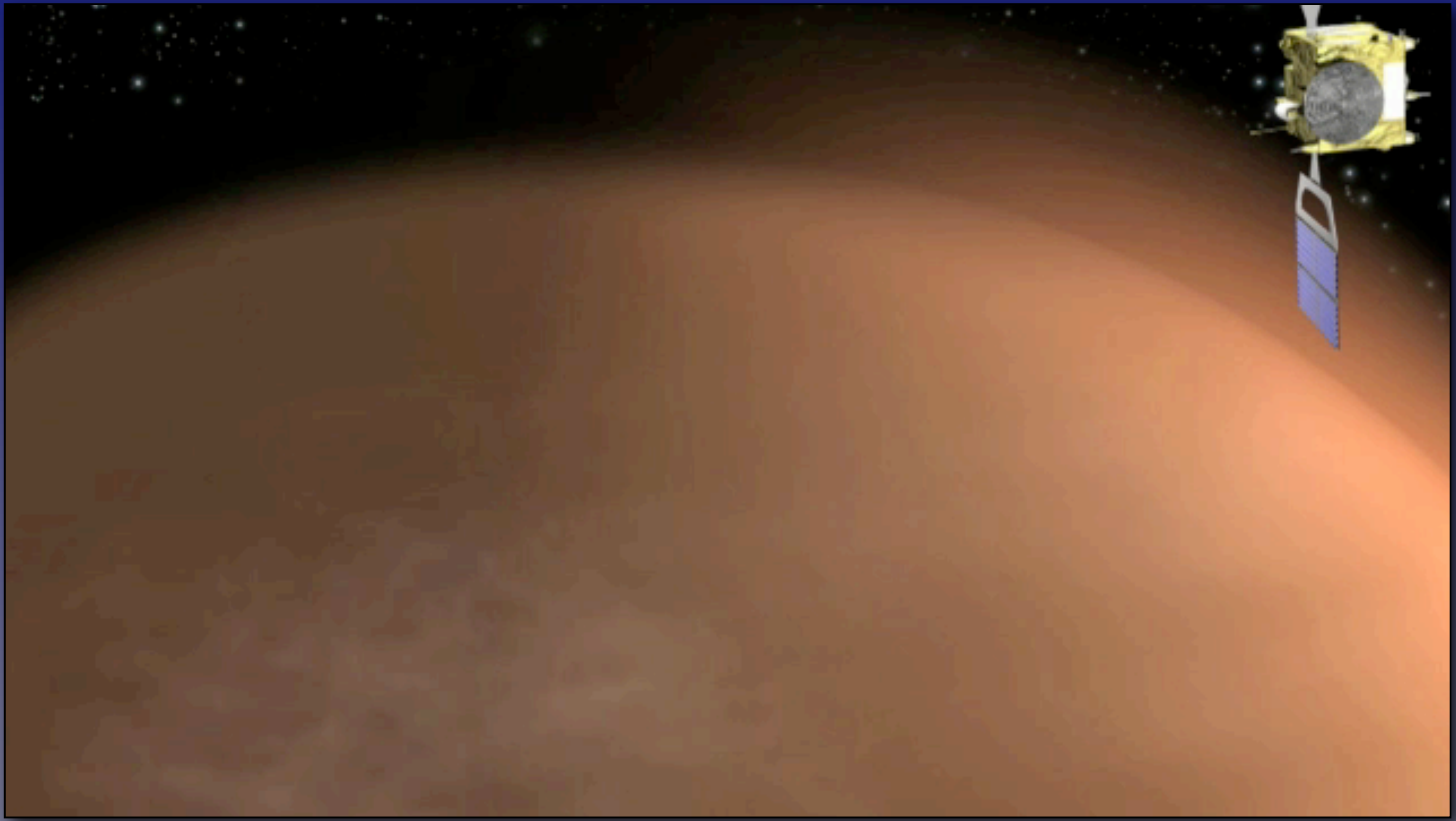
Carter et al. (2010, Science)

Venus Express



ESA Venus planetary physics mission, launched 2005

Atmospheric density via torque technique



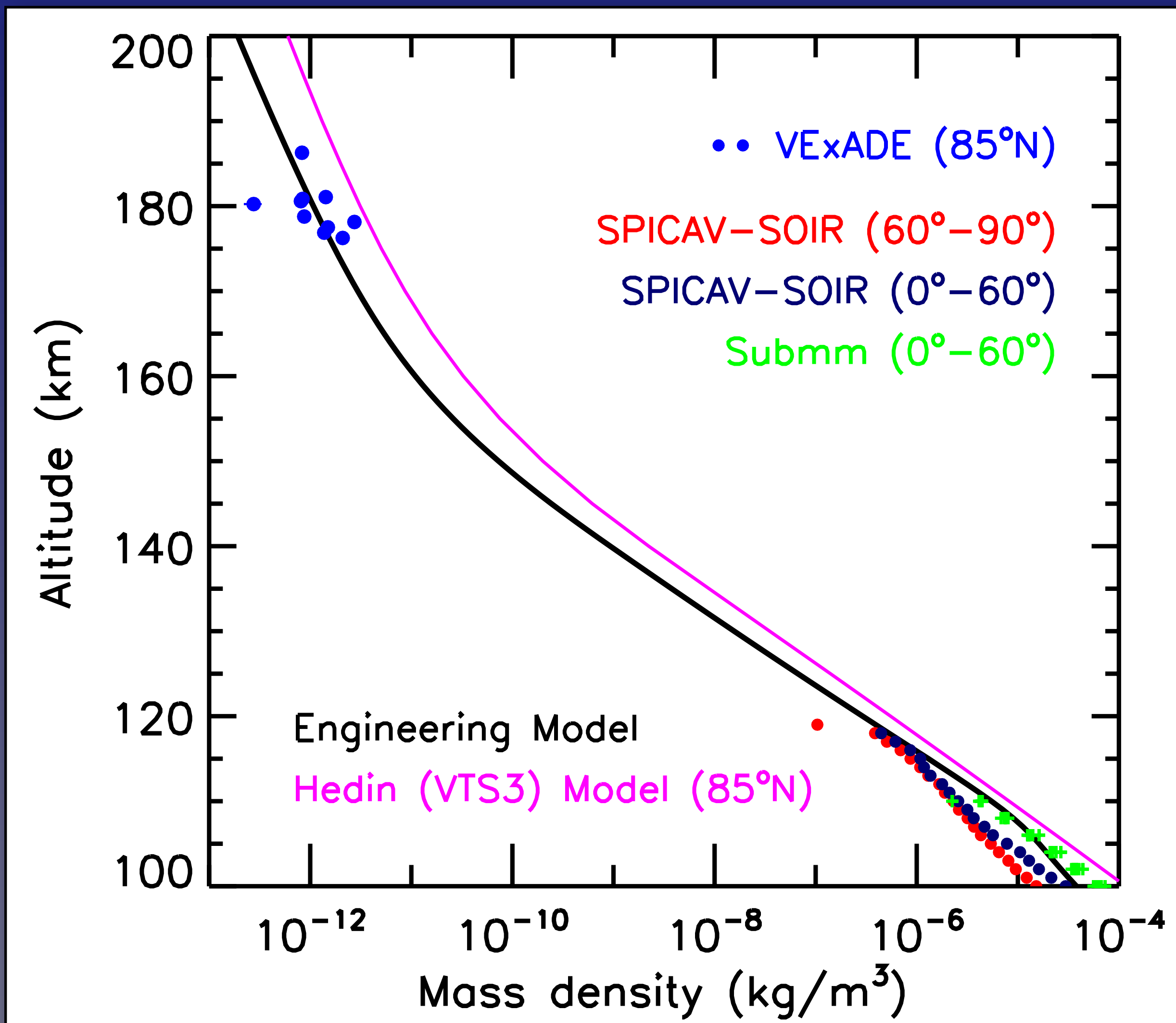
Techniques for measuring upper atmospheric density:

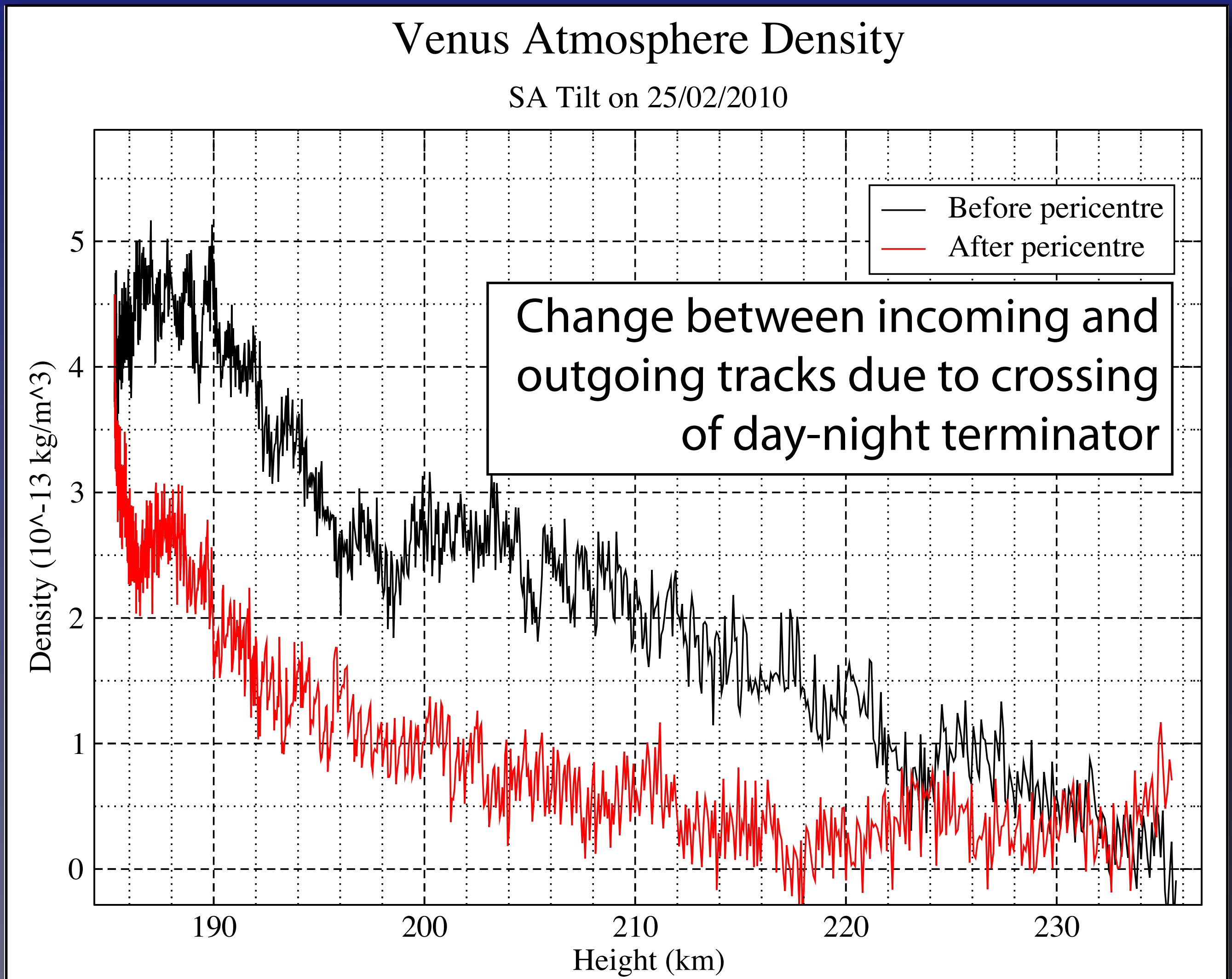
Traditional: monitor small orbital perturbations via radio signals at ground stations

New: orient solar arrays so as to create torque and monitor reaction wheels

Very sensitive: works up to ~220 km altitude at Venus

Application of torque technique to VEX





Technique works down to densities of ~10^{-13} kg m^{-3} ⇒ ~220 km altitude at Venus

Sampling rate 8 Hz yields results on ~ 1 sec timescale ⇒ ~10 km horizontal scale at 10 km s^{-1}

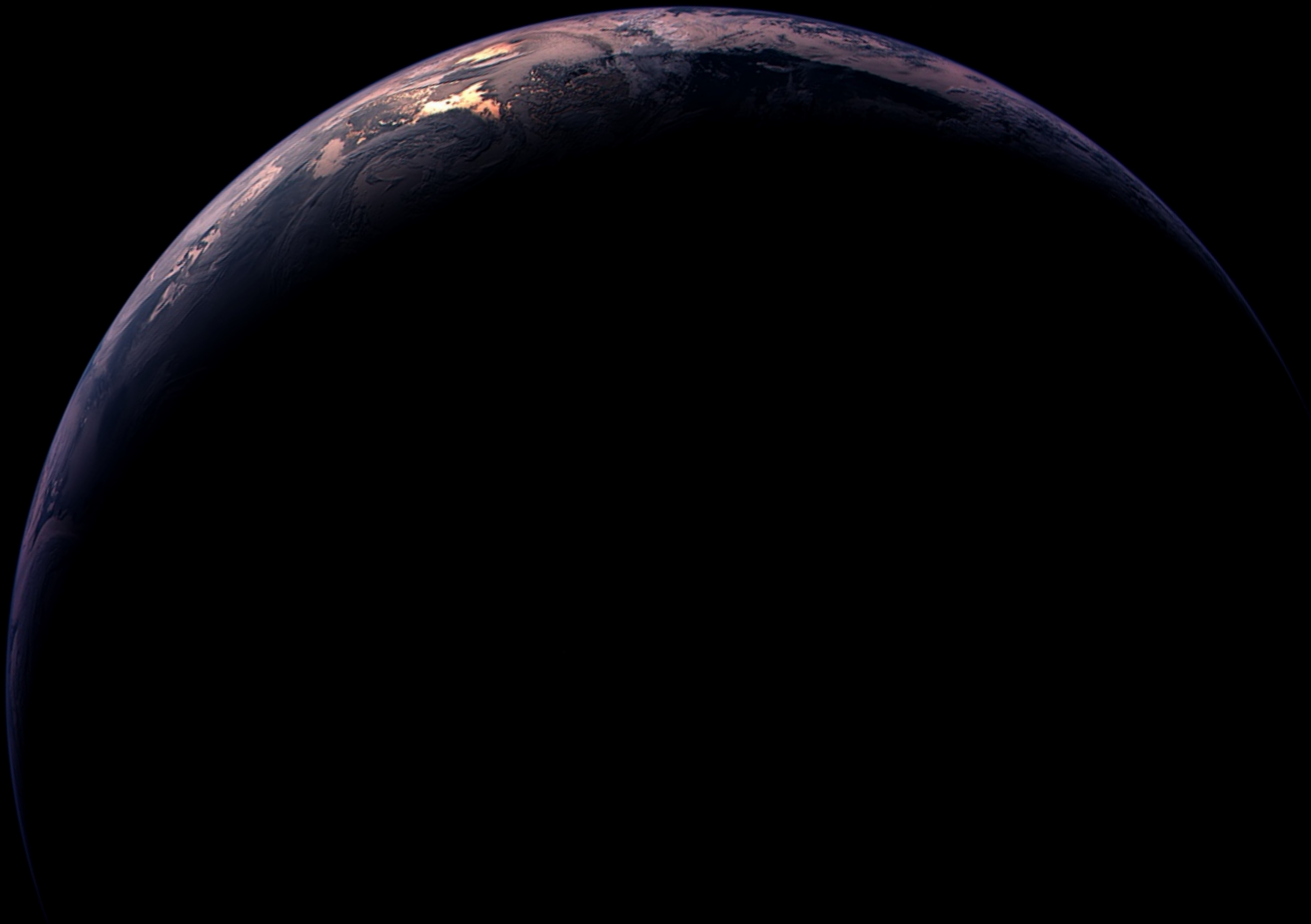
Vertical sensitivity ~1–2 km, but most fluctuations detected are related to horizontal variations

Rosetta

Asteroid (21) Lutetia flyby:
July 10, 2010

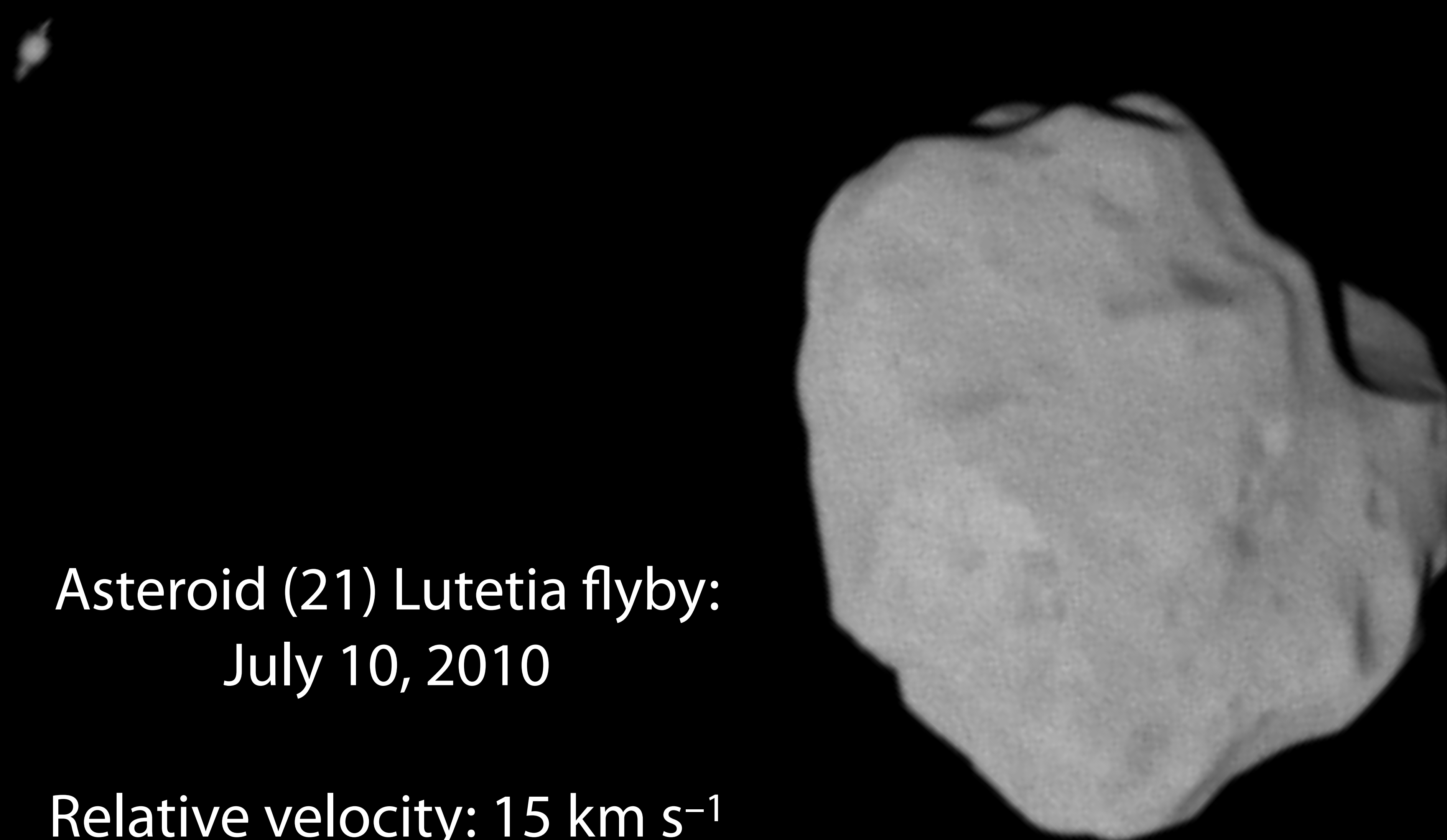
Relative velocity: 15 km s^{-1}
Closest approach: 3162 km

ESA comet orbiter and lander, launch 2004, arrival at Comet 67P/Churyumov-Gerasimenko in 2014



Final Earth fly-by by Rosetta, November 2009 / ESA

Lutetia and Saturn



Asteroid (21) Lutetia flyby:
July 10, 2010

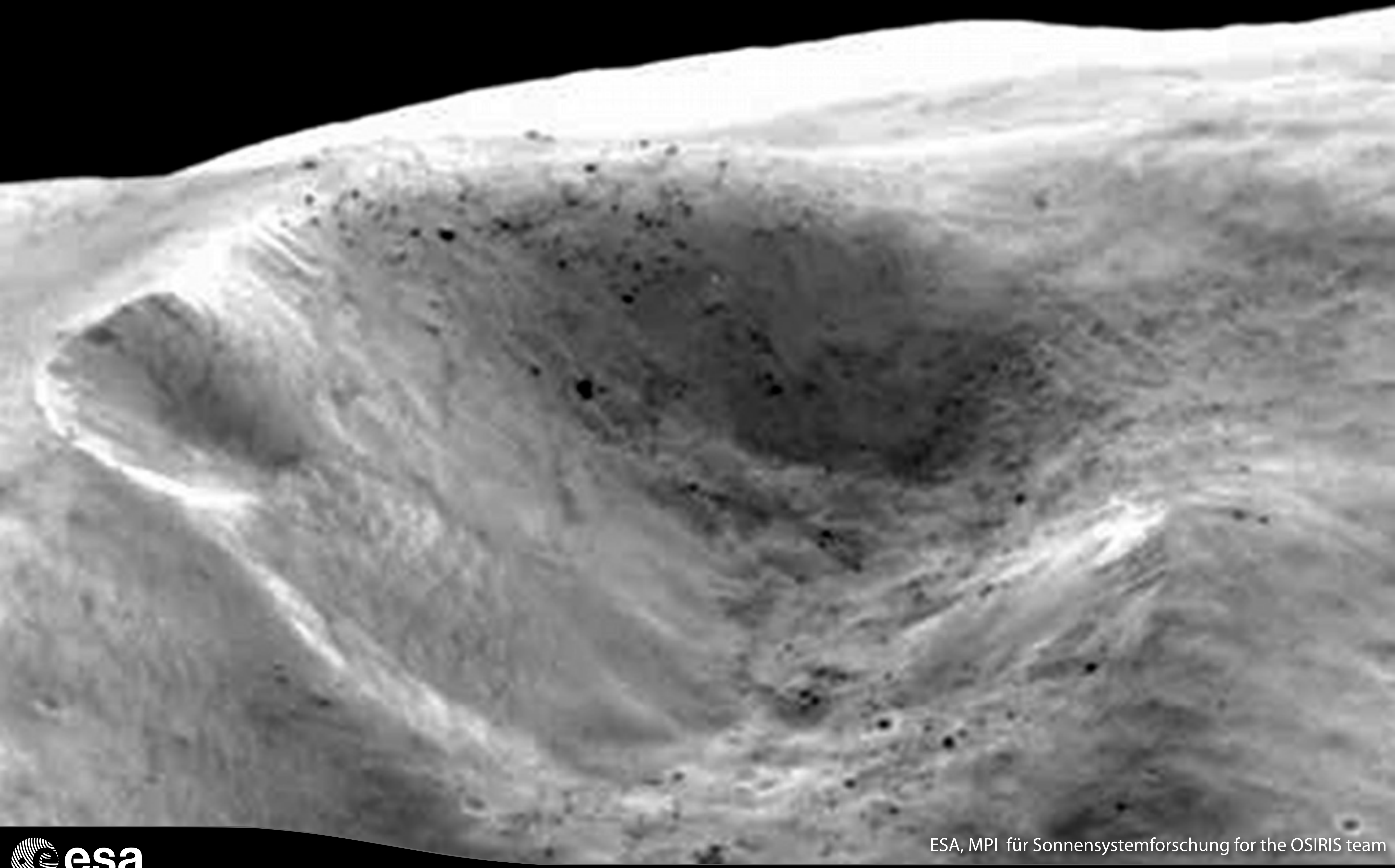
Relative velocity: 15 km s^{-1}
Closest approach: 3162 km

ESA, MPI für Sonnensystemforschung for the OSIRIS team

Closest approach to Lutetia at 3162 km

ESA, MPI für Sonnensystemforschung for the OSIRIS team

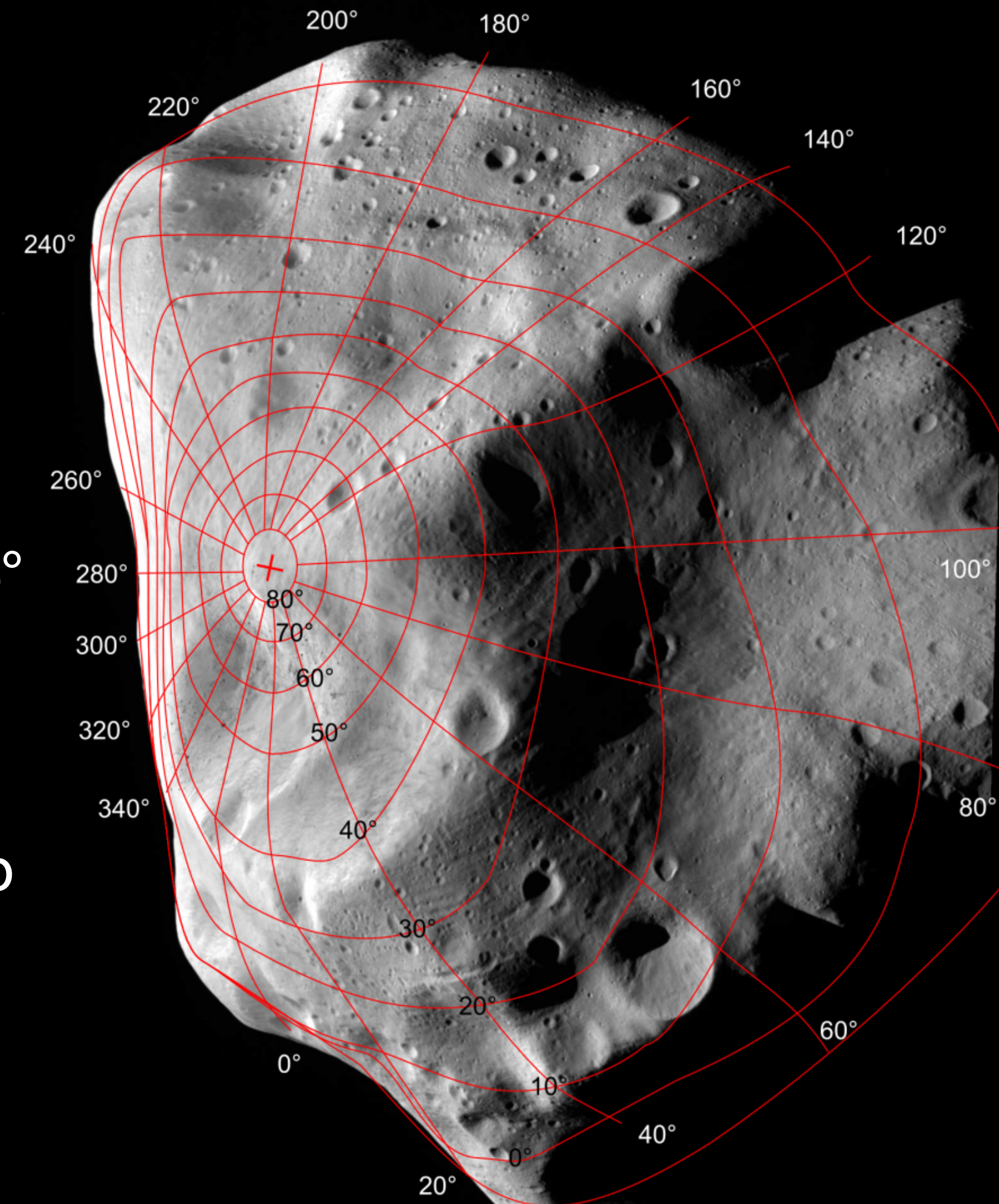
Landslides and boulders



ESA, MPI für Sonnensystemforschung for the OSIRIS team

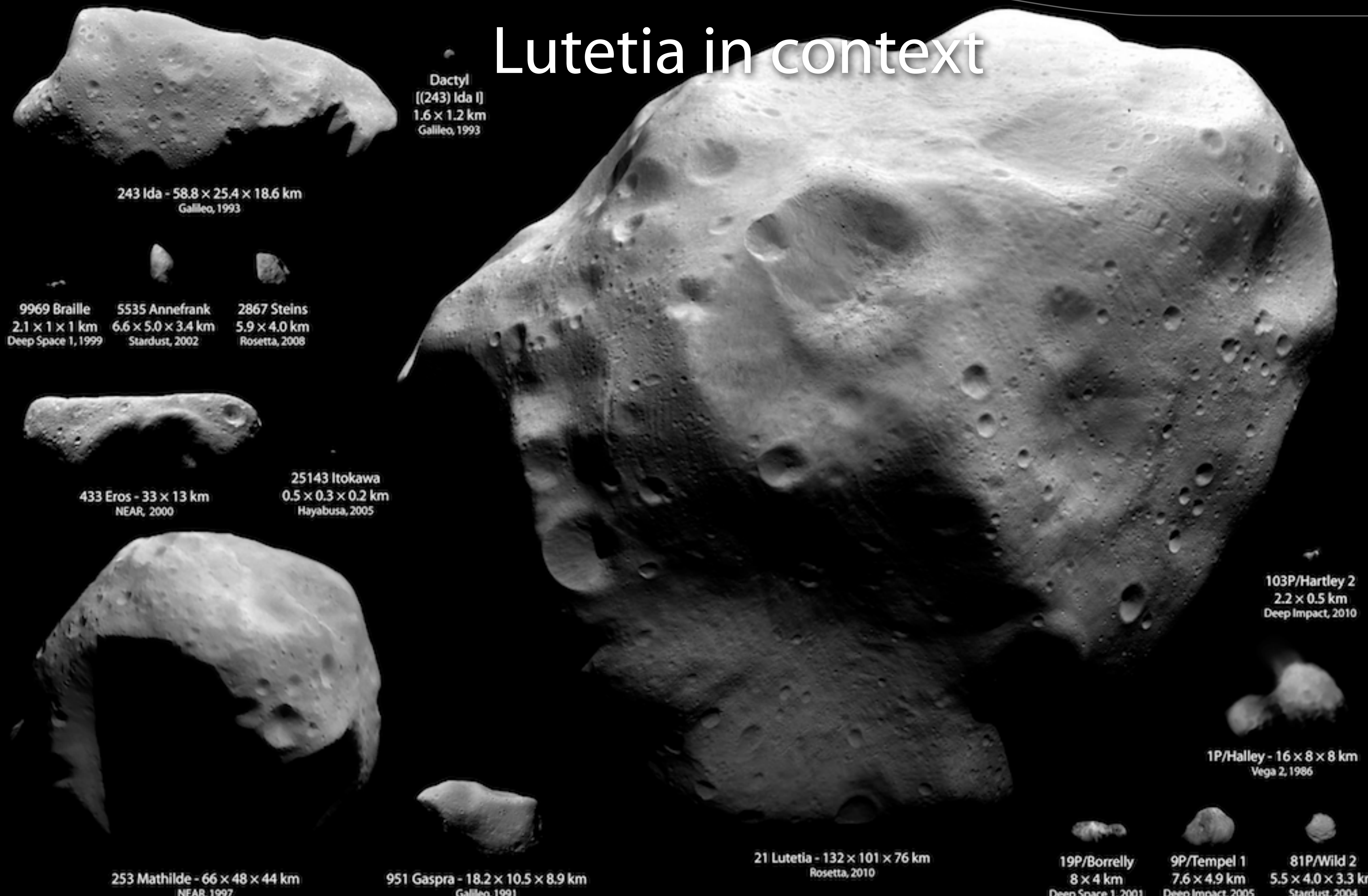
Preliminary science results

- Dimensions: 123 x 103 x 93 km
- Volume: $5 \pm 1 \times 10^5$ km^3
- Mass: 1.65×10^{18} kg
- Density: 3.3 ± 0.6 g cm^{-3}
- Spin period: 8.168270 ± 0.000001 hr
- Spin axis: $\alpha = 51.8 \pm 0.4°$, $\delta = +10.8 \pm 0.4°$
- Albedo: P(V) = 0.185
- Colour: Grey (very)
- Surface covered by regolith ~600m deep
- Many geological features: craters, faults, fractures, scarps, ridges, grooves, gullies, pit-chains, landslides



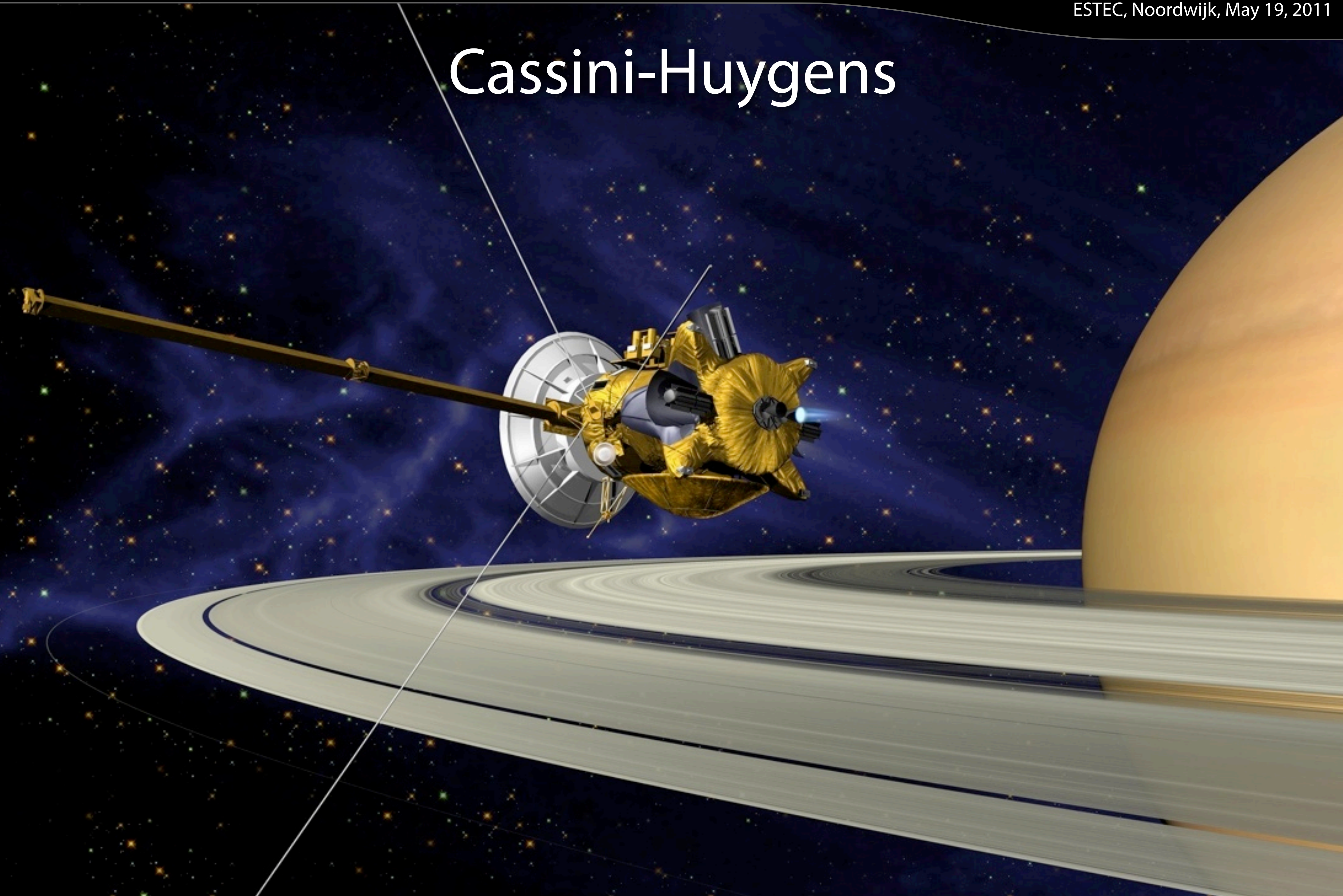
ESA, MPI für Sonnensystemforschung for the OSIRIS team

Lutetia in context



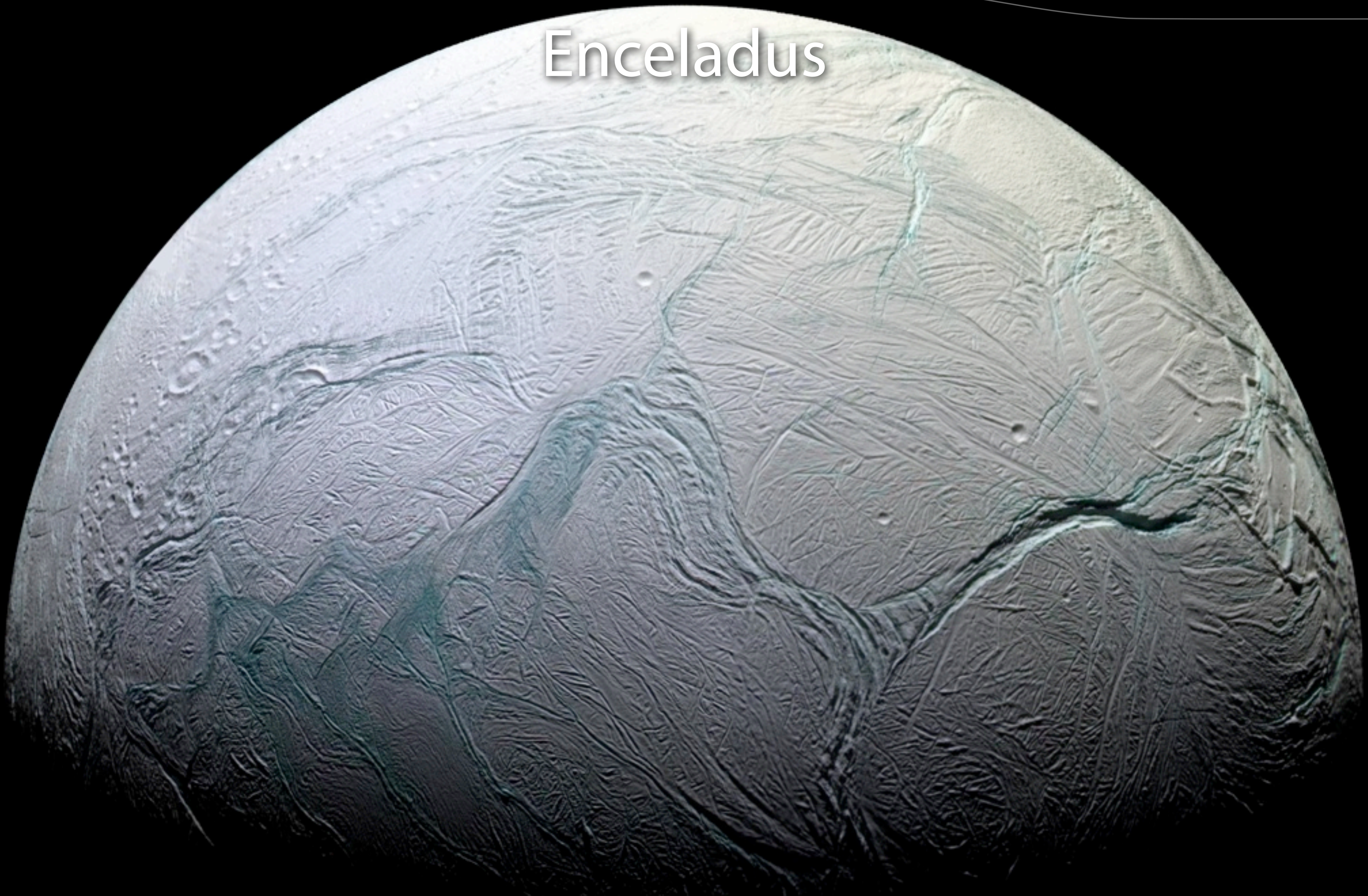
Adapted from montage by Emily Lakdawalla, The Planetary Society

Cassini-Huygens



NASA / ESA / ASI mission to Saturn system and Titan in particular, launched in 1997

Enceladus



Cassini-Huygens, NASA / ESA / ASI

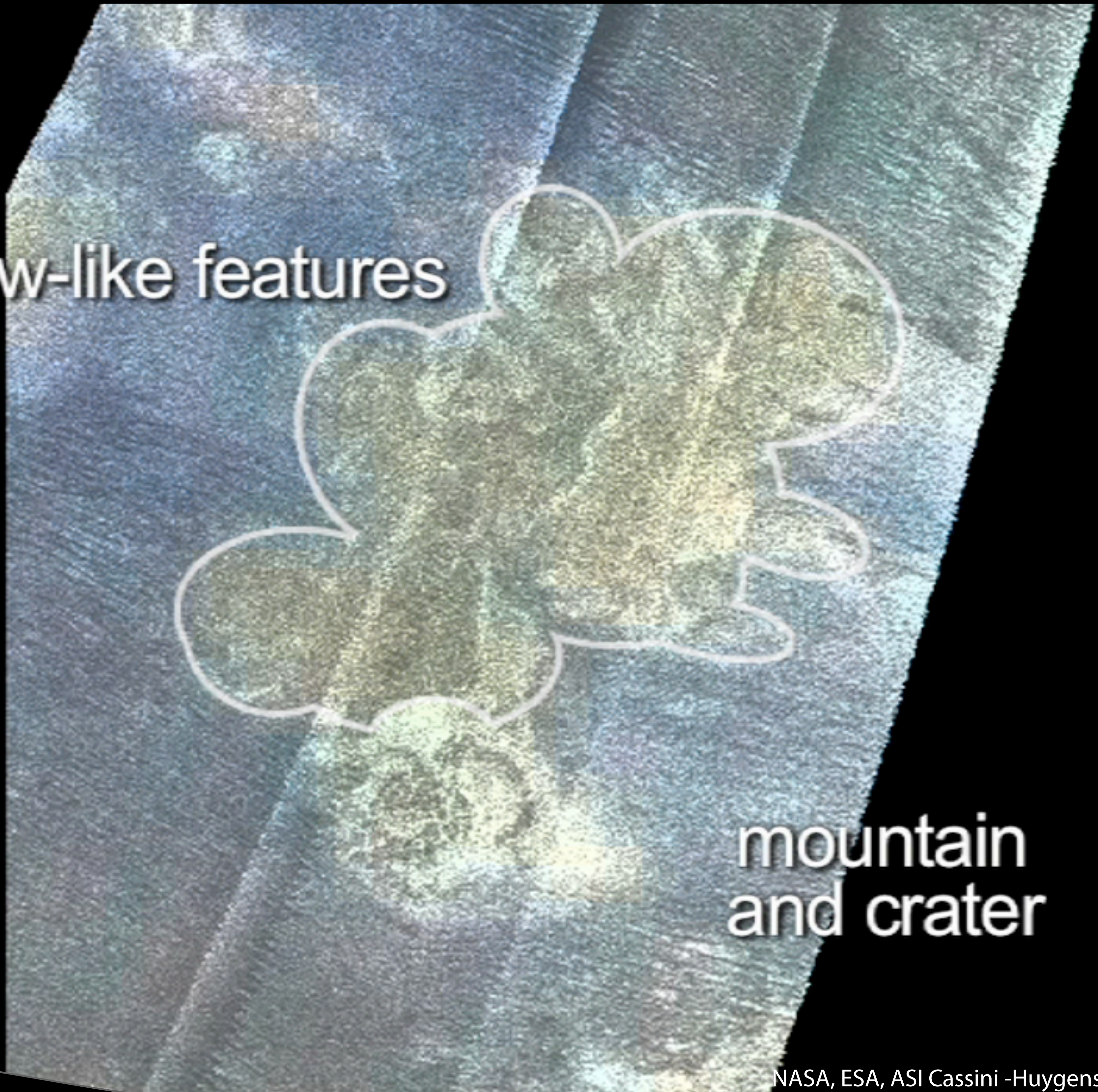
Enceladus water plumes

Cassini-Huygens, NASA / ESA / ASI

Aurorae on Saturn

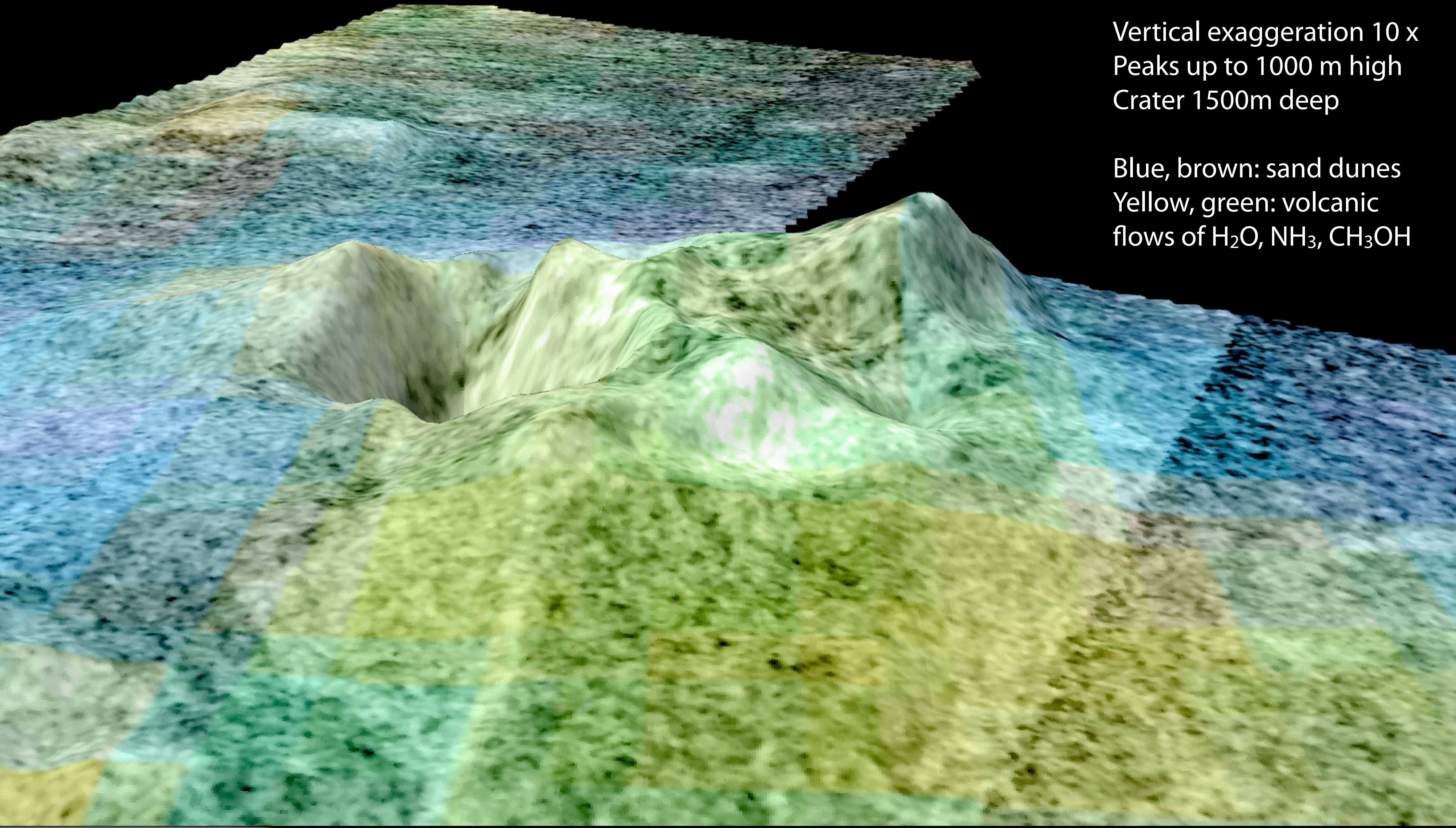
Cassini visible light images from 2009 / NASA, JPL, Space Science Institute

Sotra Facula: cryovolcano on Titan?



NASA, ESA, ASI Cassini -Huygens / Kirk et al. 2010, AGU

Sotra Facula: cryovolcano on Titan?

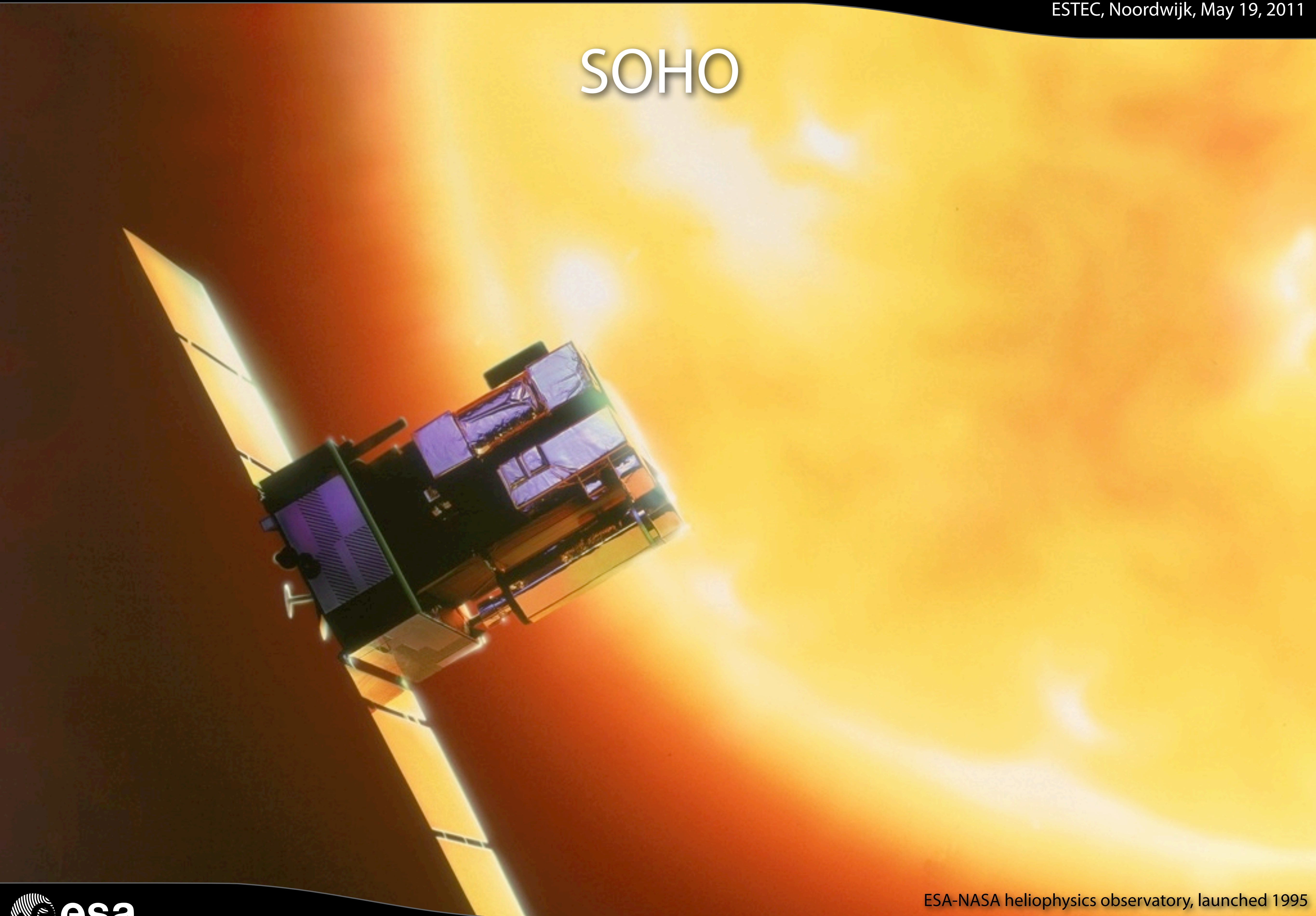


Vertical exaggeration 10 x
Peaks up to 1000 m high
Crater 1500m deep

Blue, brown: sand dunes
Yellow, green: volcanic flows of H_2O, NH_3, CH_3OH

VIMS imaging spectroscopy + radar altimetry / NASA, ESA, ASI Cassini-Huygens / Kirk et al. 2010, AGU

SOHO

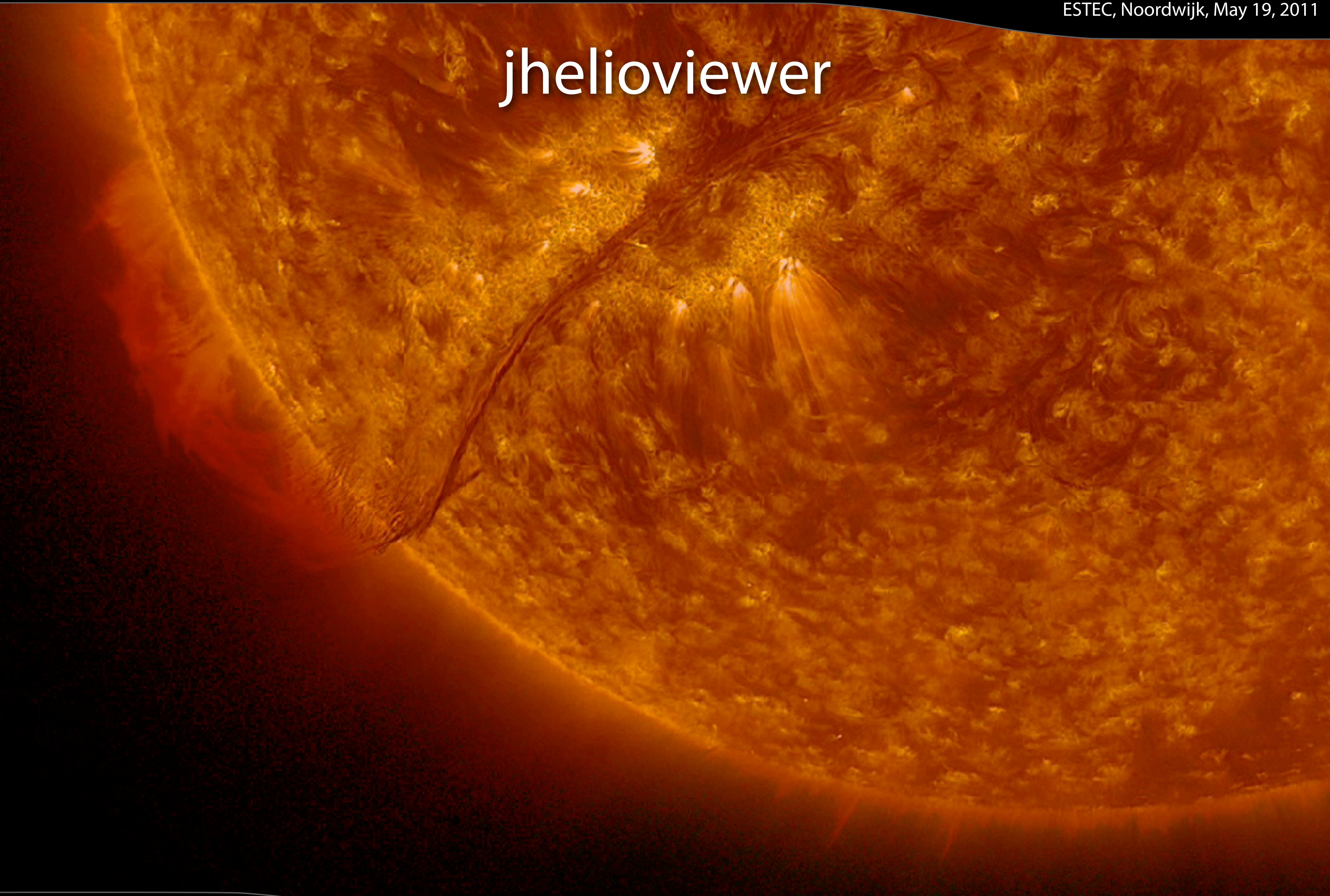


ESA-NASA heliophysics observatory, launched 1995

Partial solar eclipse, January 4, 2011

Image taken by Thierry Legault near Muscat, Oman

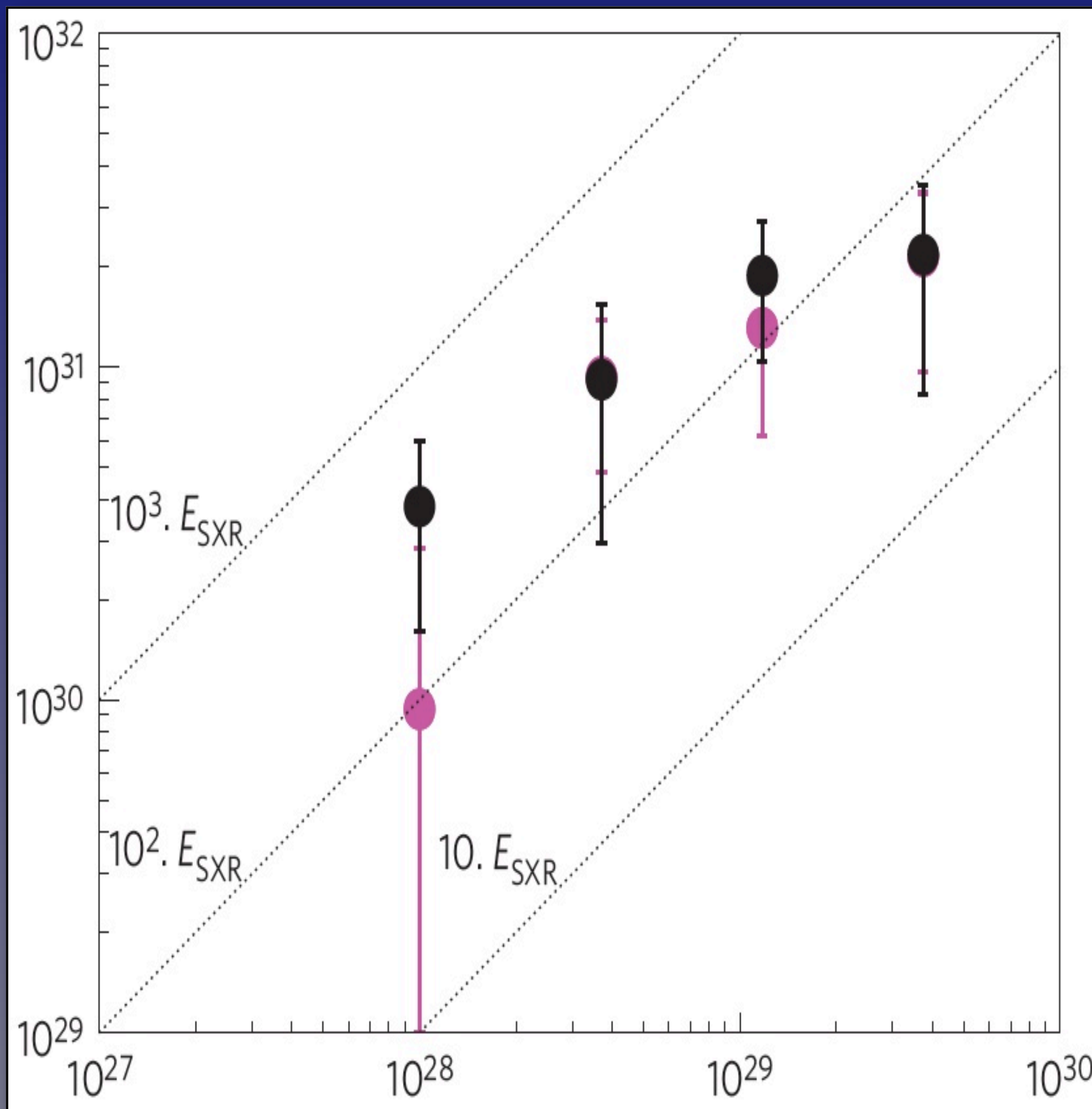
jhelioviewer



NASA SDO AIA data visualised by ESA jhelioviewer open source software: available at www.jhelioviewer.org

Contribution of flares to total solar irradiance

Total radiated flare energy (ergs)

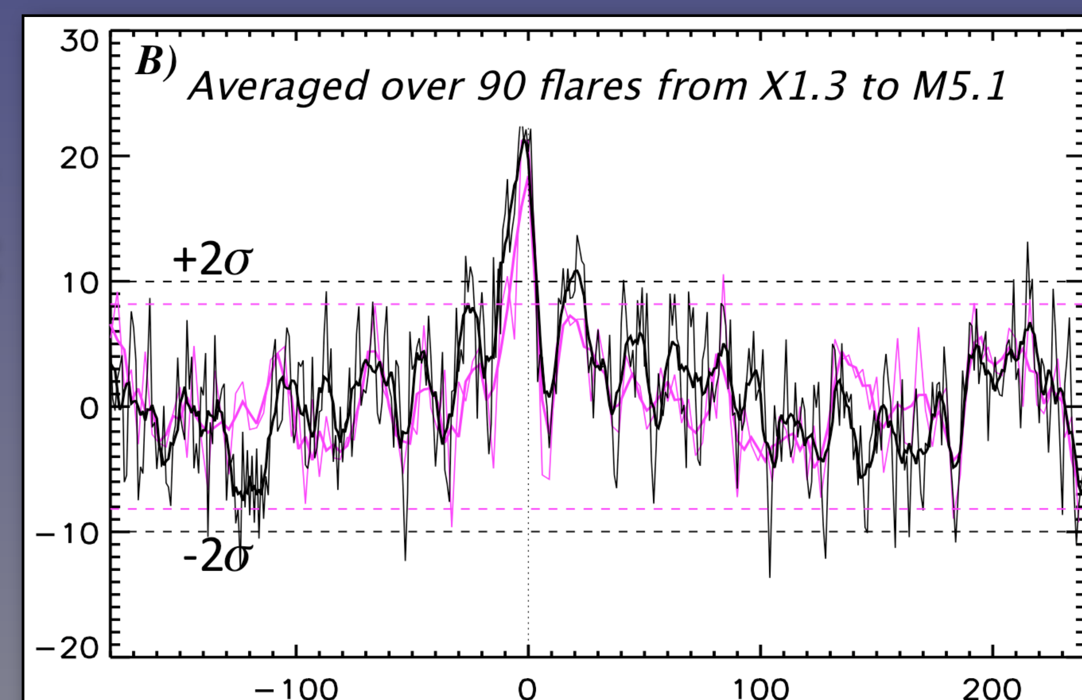


Mean soft X-ray energy (ergs)

UV/visible flux in flares exceeds that from soft X-rays by ~ 100

Flare class	# of flares	TSI increase
X10–X1.3	42	~ 25 ppm
X1.3–M5.1	90	~ 22 ppm
M5.1–M1.6	267	~ 7 ppm
M1.6–C4	1477	~ 4 ppm

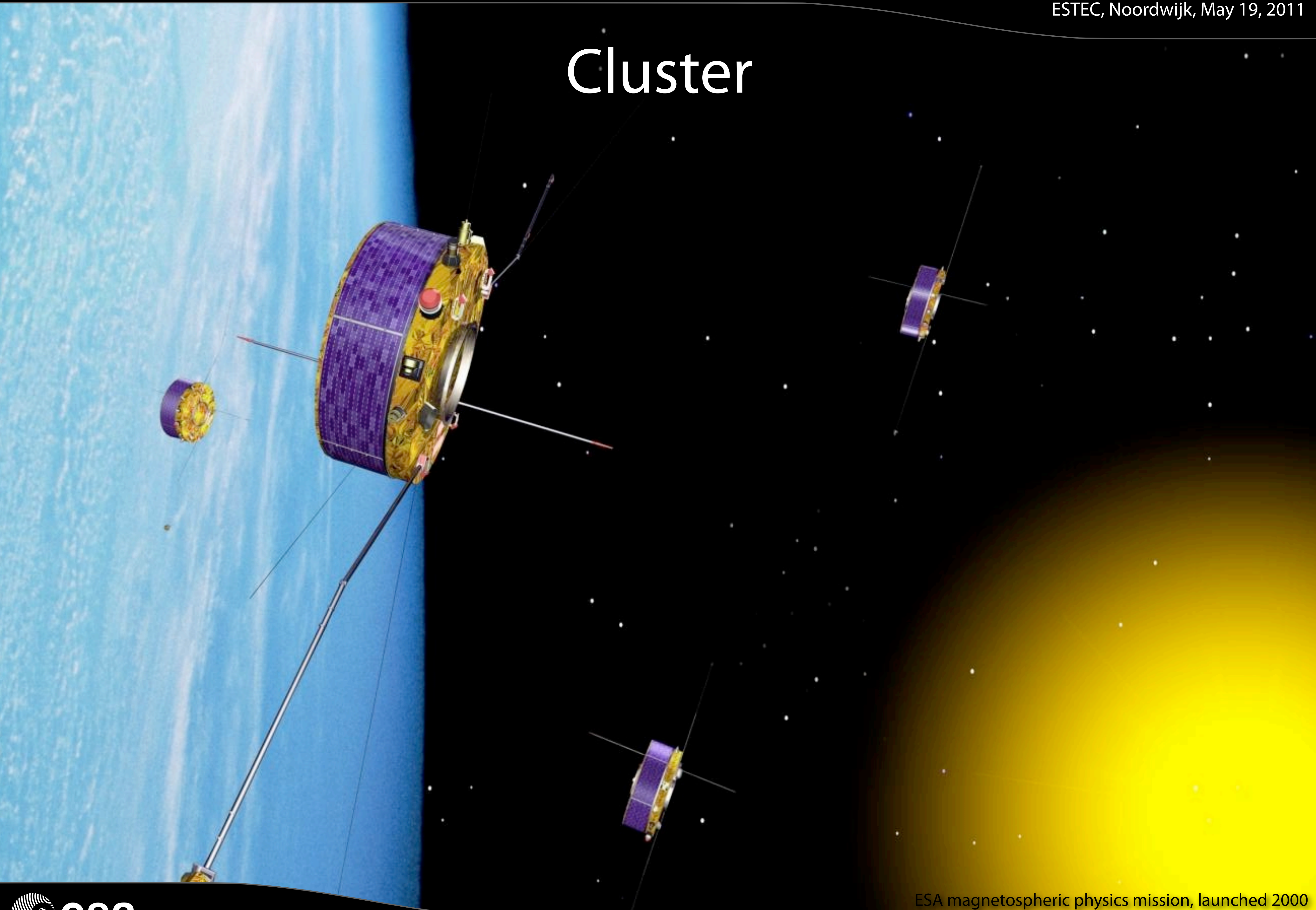
TSI variation (ppm)



Time relative to flare onset (mins)

ESA-NASA SOHO VIRGO radiometers PMO + DIARAD / Kretzschmar et al. 2010, Nature Physics

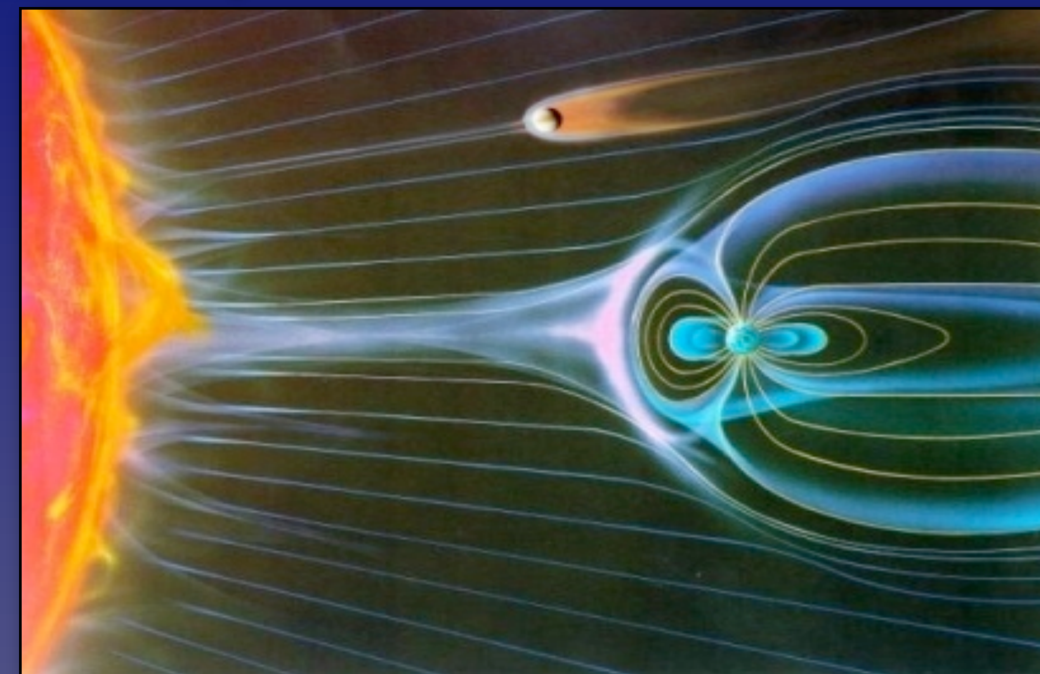
Cluster

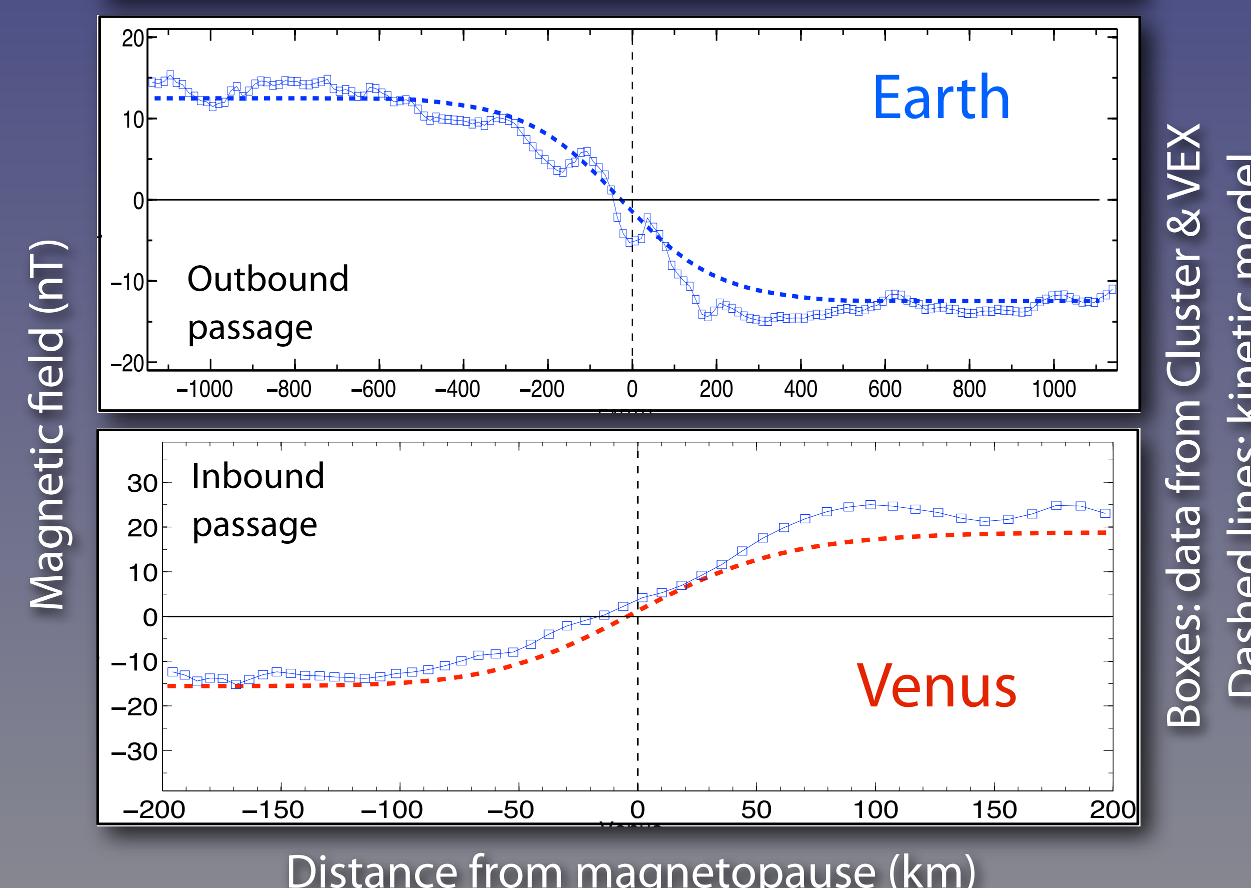


ESA magnetospheric physics mission, launched 2000

Understanding solar-planetary interactions

- Combined Cluster-VEX study of magnetopauses at Earth and Venus on June 27, 2006
- Earth:
  - Boundary between magnetic fields of solar wind and Earth; 1500 km thick
  - Physics dominated by terrestrial plasma
- Venus:
  - Induced magnetopause; 200 km thick
  - Physics dominated by solar wind plasma
- More mass and momentum transfer at Venus than at Earth
- Better understanding of principles governing magnetopause physics





Analysis using kinetic model of magnetopause / Echim et al. 2010, PSS, in press

Hubble Space Telescope

NASA-ESA UV-optical-near-IR astrophysical observatory, launched 1990, last servicing May 2009

20 years of Hubble: star formation in Carina

NASA-ESA HST WFC3 optical ([O III], [N II], [S II]) / M. Livio & Hubble 20th Anniversary Team

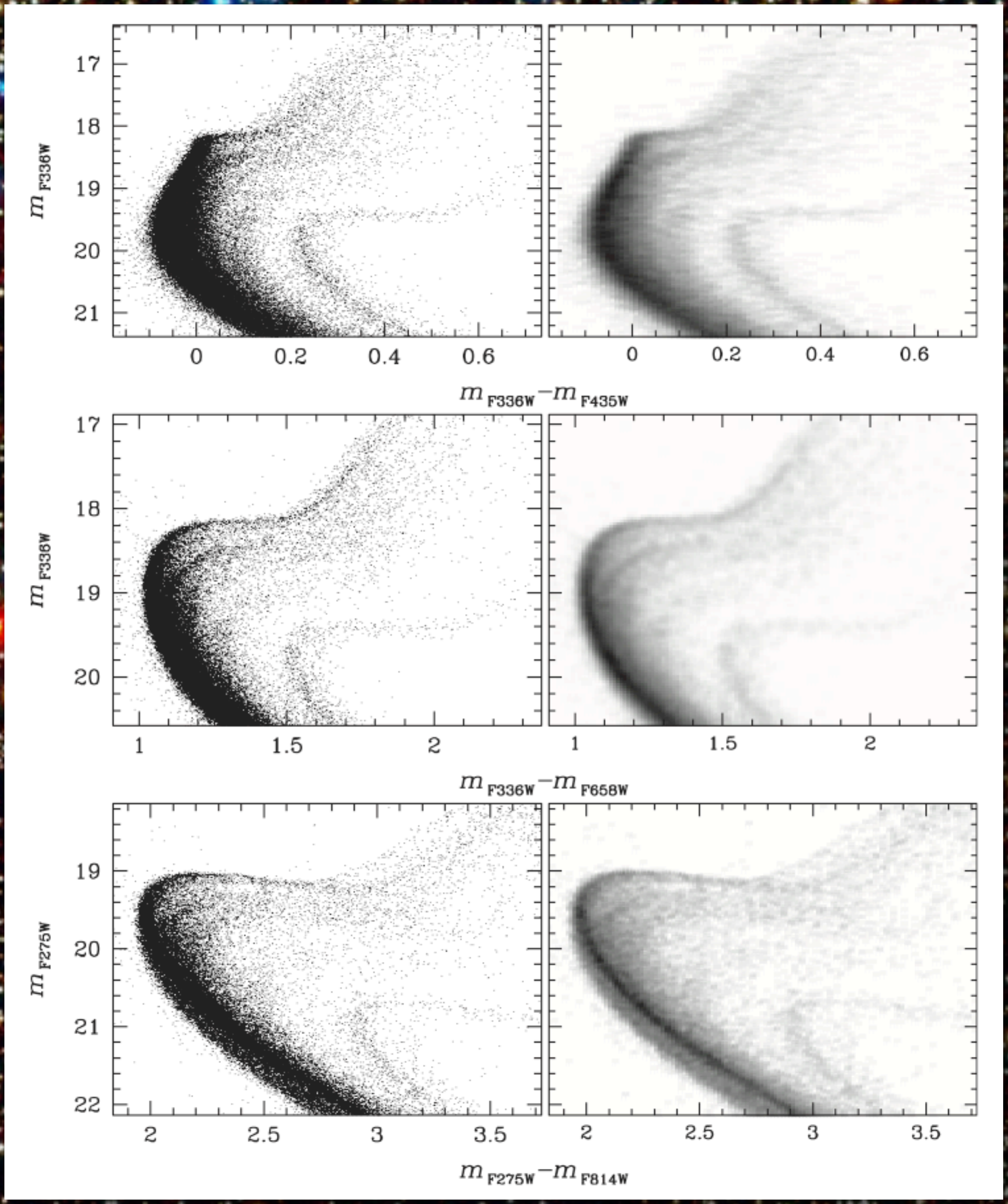
HST imaging of ω Cen

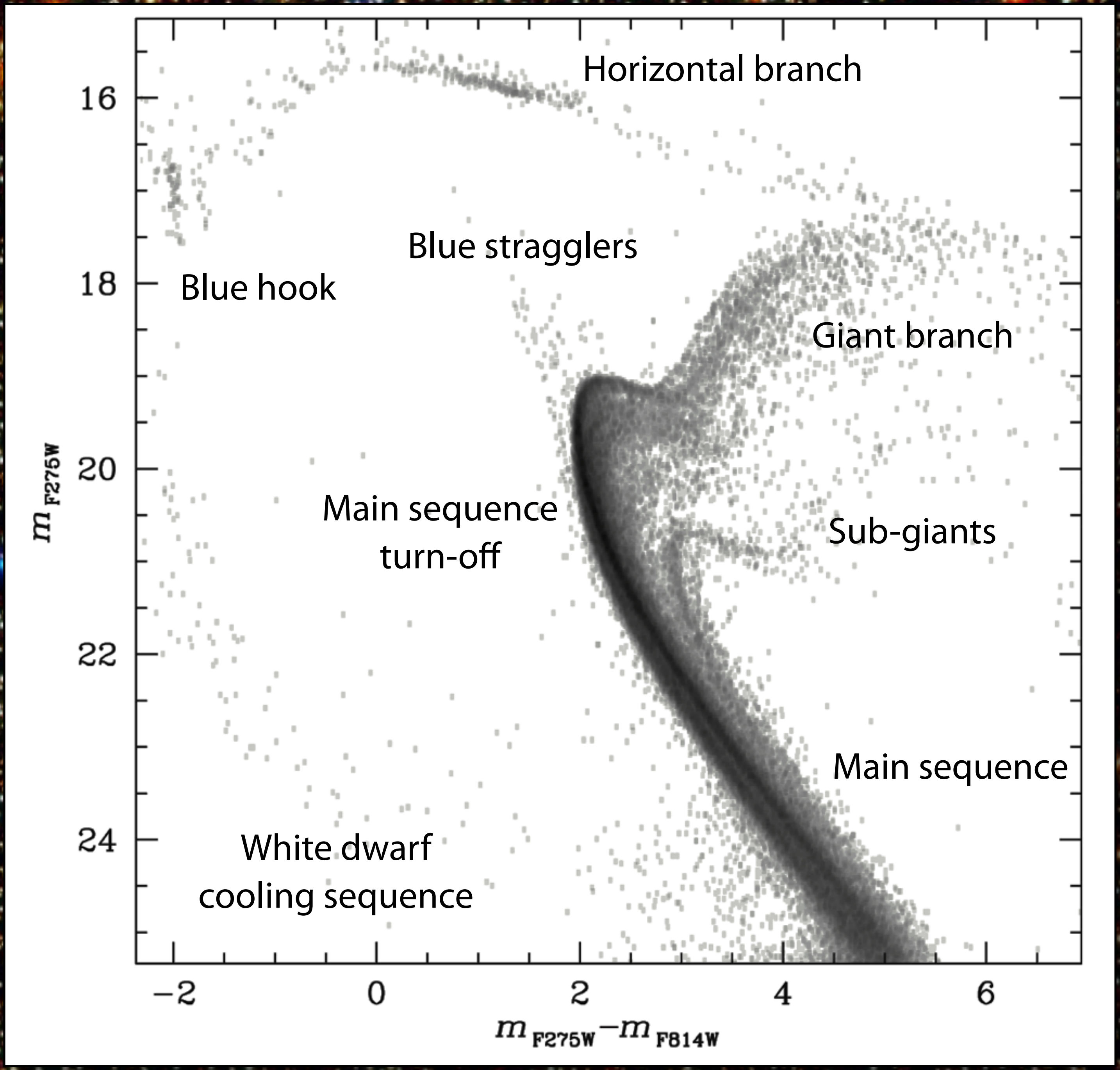
NASA, ESA / HST ACS + WFC3 imaging

The Hertzsprung-Russell diagram

NASA, ESA / Anderson, van der Marel, Bacon, Estacion

WFC3 + ACS photometry of ω Cen



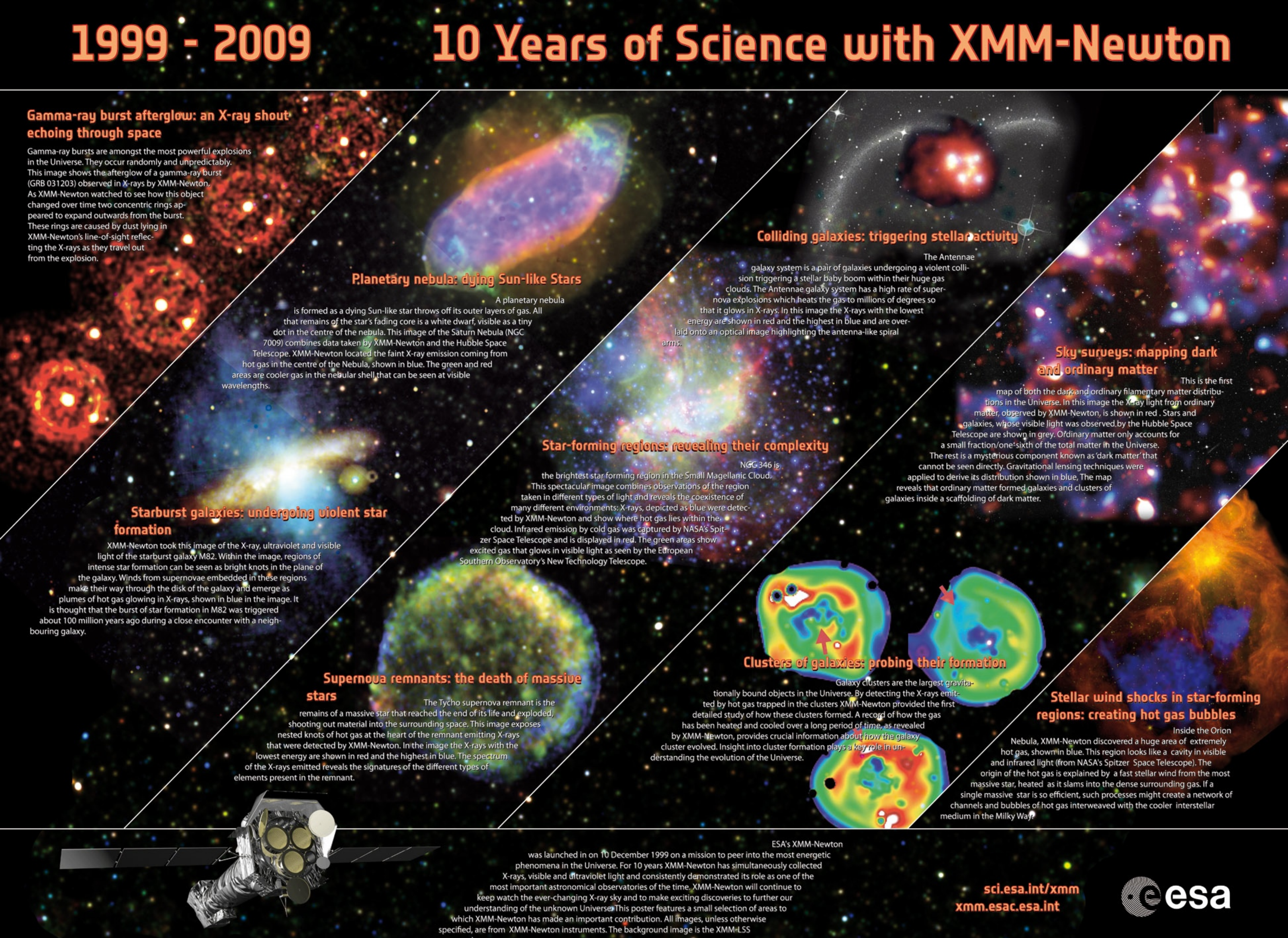


Significant substructure in colour-magnitude diagrams (multiple main sequences, sub-giant branches, etc.) give credence to model of ω Cen as disrupted dwarf galaxy rather than GC

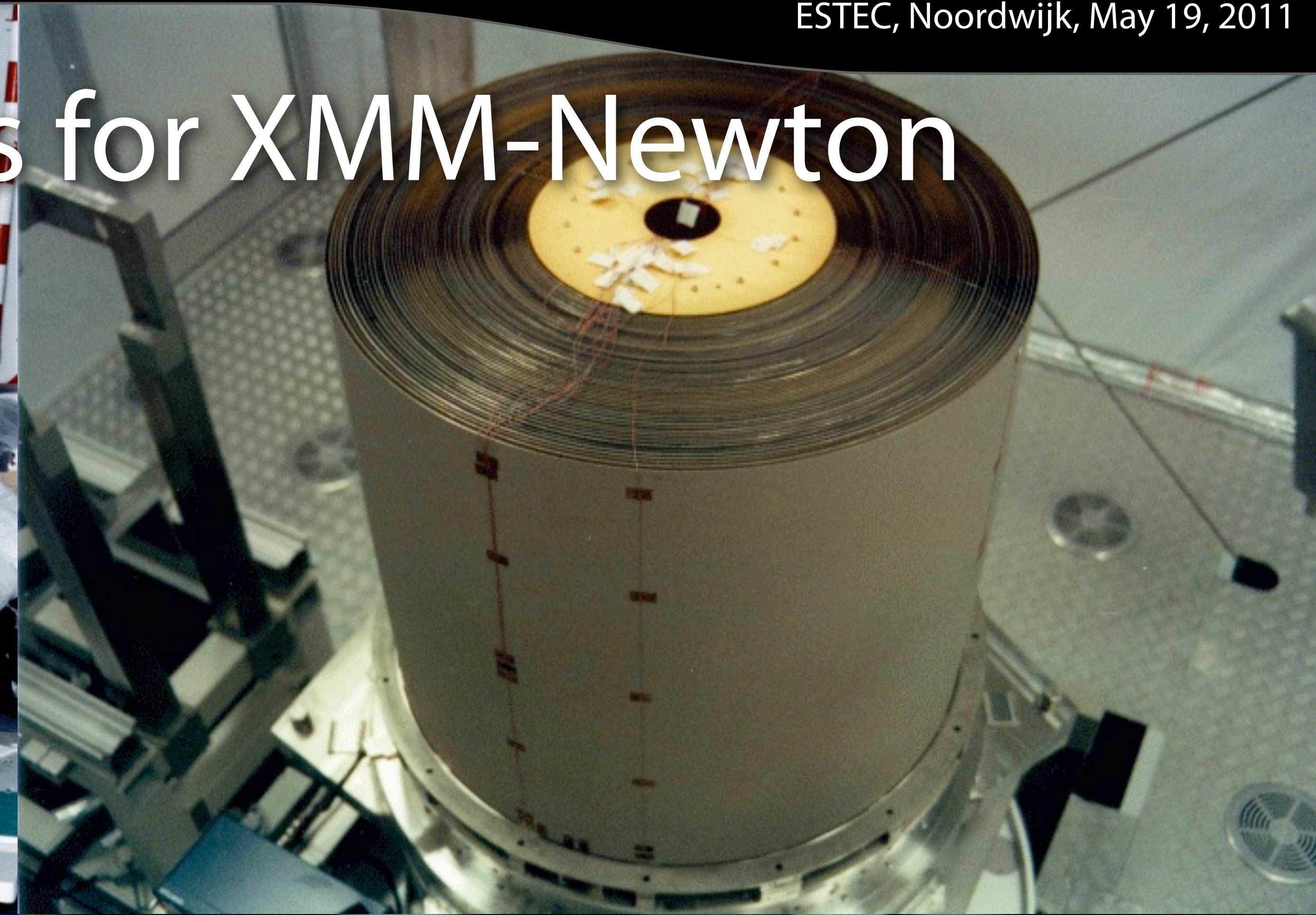
Bellini et al. 2010,, AJ

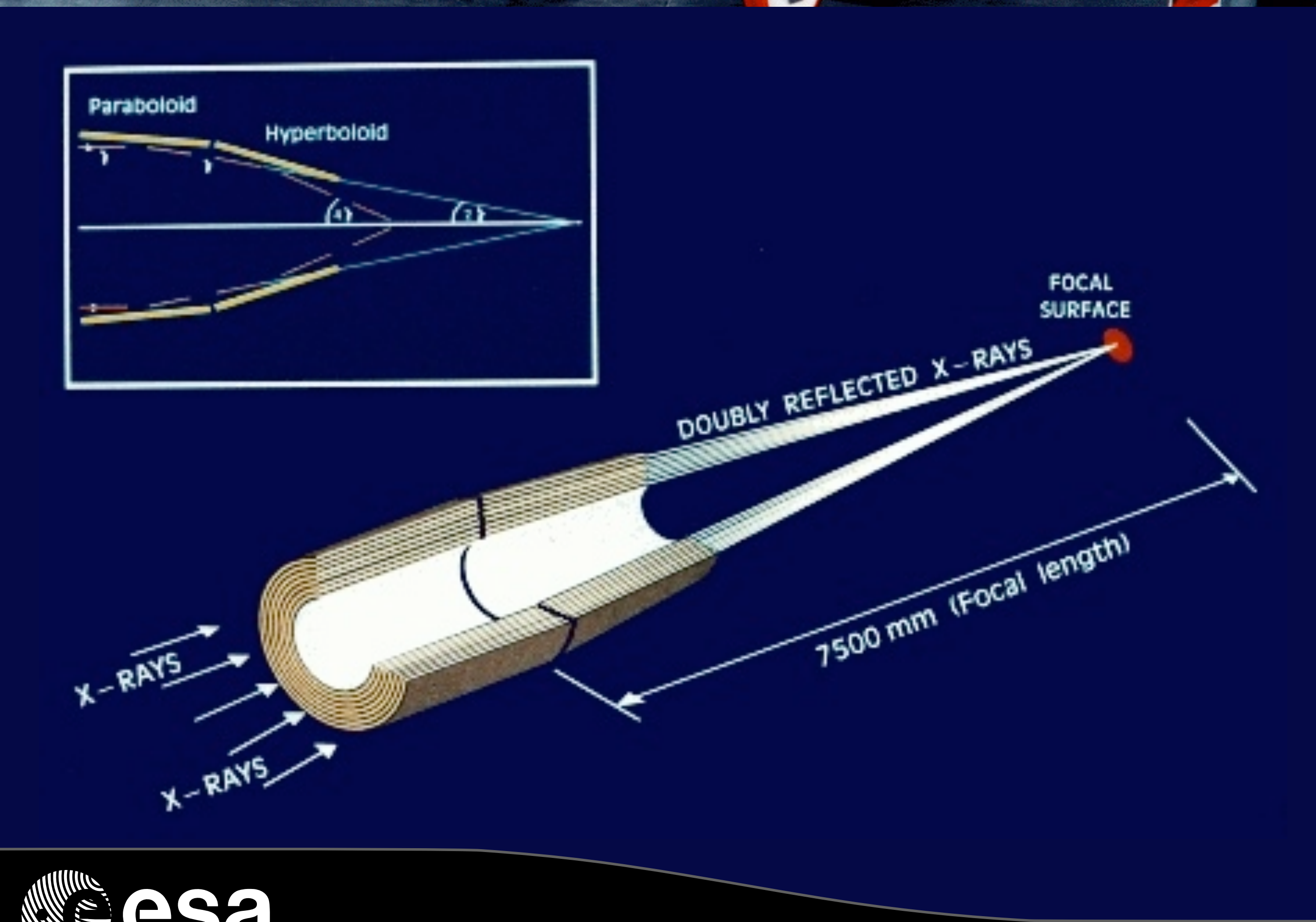
XMM-Newton

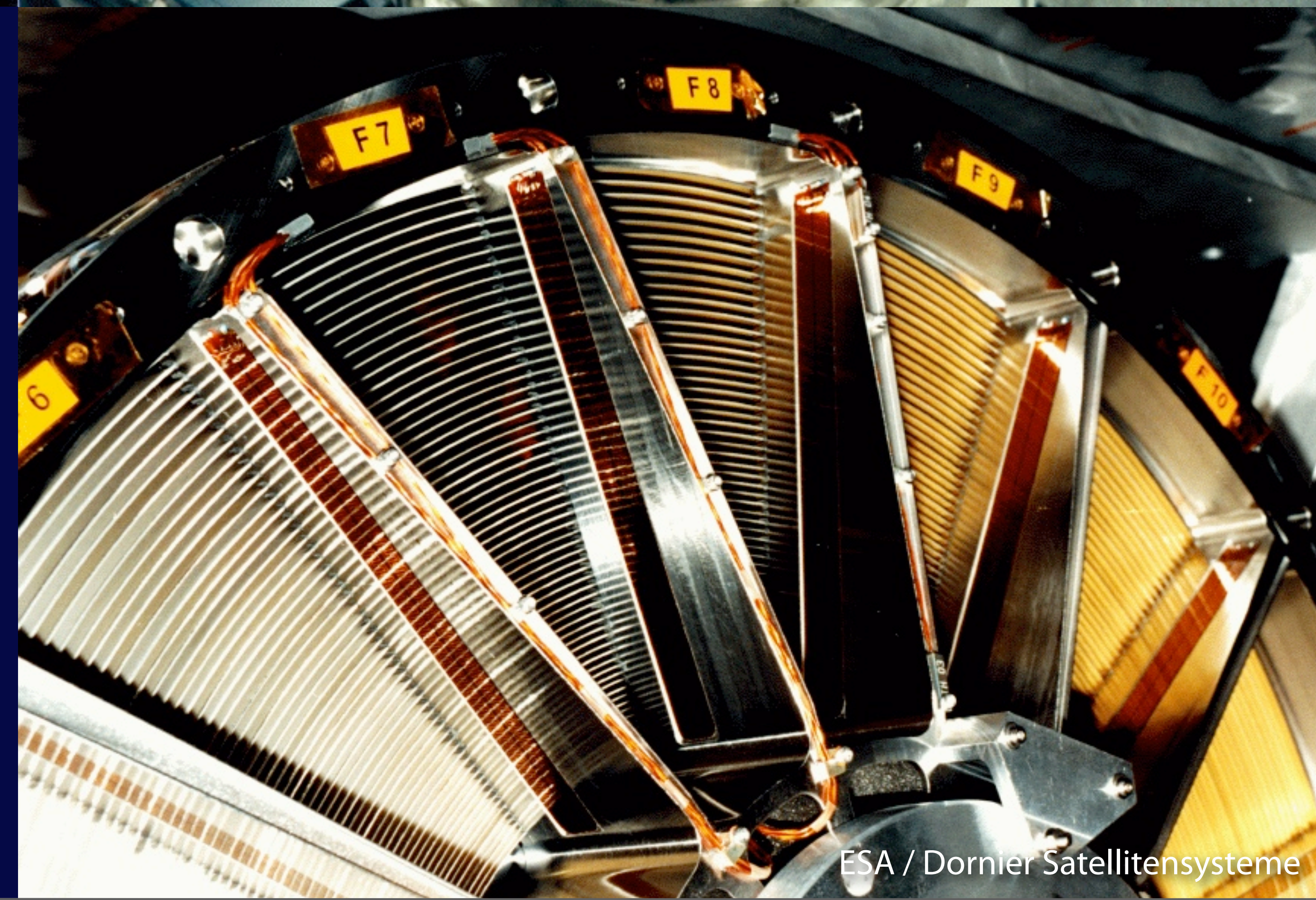
ESA X-ray astrophysics observatory, launched 1999


1999 - 2009
10 Years of Science with XMM-Newton
Gamma-ray burst afterglow: an X-ray shout echoing through space
Gamma-ray bursts are amongst the most powerful explosions in the Universe. They occur randomly and unpredictably. This image shows the afterglow of a gamma-ray burst (GRB 031203) observed in X-rays by XMM-Newton. As XMM-Newton watched to see how this object changed over time two concentric rings appeared to expand outwards from the burst. These rings are caused by dust lying in XMM-Newton's line-of-sight reflecting the X-rays as they travel out from the explosion.
Planetary nebula: dying Sun-like Stars
A planetary nebula is formed as a dying Sun-like star throws off its outer layers of gas. All that remains of the star's fading core is a white dwarf, visible as a tiny dot in the centre of the nebula. This image of the Saturn Nebula (NGC 7009) combines data taken by XMM-Newton and the Hubble Space Telescope. XMM-Newton located the faint X-ray emission coming from hot gas in the centre of the Nebula, shown in blue. The green and red areas are cooler gas in the nebular shell that can be seen at visible wavelengths.
Colliding galaxies: triggering stellar activity
The Antennae galaxy system is a pair of galaxies undergoing a violent collision triggering a stellar baby boom within their huge gas clouds. The Antennae galaxy system has a high rate of supernova explosions which heats the gas to millions of degrees so that it glows in X-rays. In this image the X-rays with the lowest energy are shown in red and the highest in blue and are overlaid onto an optical image highlighting the antenna-like spiral arms.
Sky surveys: mapping dark and ordinary matter
This is the first map of both the dark and ordinary filamentary matter distributions in the Universe. In this image the X-ray light from ordinary matter, observed by XMM-Newton, is shown in red . Stars and galaxies, whose visible light was observed by the Hubble Space Telescope are shown in grey. Ordinary matter only accounts for a small fraction/one-sixth of the total matter in the Universe. The rest is a mysterious component known as 'dark matter' that cannot be seen directly. Gravitational lensing techniques were applied to derive its distribution shown in blue. The map reveals that ordinary matter formed galaxies and clusters of galaxies inside a scaffolding of dark matter.
Star-forming regions: revealing their complexity
NGC 346 is the brightest star forming region in the Small Magellanic Cloud. This spectacular image combines observations of the region taken in different types of light and reveals the coexistence of many different environments: X-rays, depicted as blue were detected by XMM-Newton and show where hot gas lies within the cloud. Infrared emission by cold gas was captured by NASA's Spitzer Space Telescope and is displayed in red. The green areas show excited gas that glows in visible light as seen by the European Southern Observatory's New Technology Telescope.
Starburst galaxies: undergoing violent star formation
XMM-Newton took this image of the X-ray, ultraviolet and visible light of the starburst galaxy M82. Within the image, regions of intense star formation can be seen as bright knots in the plane of the galaxy. Winds from supernovae embedded in these regions make their way through the disk of the galaxy and emerge as plumes of hot gas glowing in X-rays, shown in blue in the image. It is thought that the burst of star formation in M82 was triggered about 100 million years ago during a close encounter with a neighbouring galaxy.
Clusters of galaxies: probing their formation
Galaxy clusters are the largest gravitationally bound objects in the Universe. By detecting the X-rays emitted by hot gas trapped in the clusters XMM-Newton provided the first detailed study of how these clusters formed. A record of how the gas has been heated and cooled over a long period of time, as revealed by XMM-Newton, provides crucial information about how the galaxy cluster evolved. Insight into cluster formation plays a key role in understanding the evolution of the Universe.
Supernova remnants: the death of massive stars
The Tycho supernova remnant is the remains of a massive star that reached the end of its life and exploded, shooting out material into the surrounding space. This image exposes nested knots of hot gas at the heart of the remnant emitting X-rays that were detected by XMM-Newton. In the image the X-rays with the lowest energy are shown in red and the highest in blue. The spectrum of the X-rays emitted reveals the signatures of the different types of elements present in the remnant.
Stellar wind shocks in star-forming regions: creating hot gas bubbles
Inside the Orion Nebula, XMM-Newton discovered a huge area of extremely hot gas, shown in blue. This region looks like a cavity in visible and infrared light (from NASA's Spitzer Space Telescope). The origin of the hot gas is explained by a fast stellar wind from the most massive star, heated as it slams into the dense surrounding gas. If a single massive star is so efficient, such processes might create a network of channels and bubbles of hot gas interweaved with the cooler interstellar medium in the Milky Way.
ESA's XMM-Newton was launched in on 10 December 1999 on a mission to peer into the most energetic phenomena in the Universe. For 10 years XMM-Newton has simultaneously collected X-rays, visible and ultraviolet light and consistently demonstrated its role as one of the most important astronomical observatories of the time. XMM-Newton will continue to keep watch the ever-changing X-ray sky and to make exciting discoveries to further our understanding of the unknown Universe. This poster features a small selection of areas to which XMM-Newton has made an important contribution. All images, unless otherwise specified, are from XMM-Newton instruments. The background image is the XMM-LSS survey mosaic.
sci.esa.int/xmm
xmm.esac.esa.int
esa

X-ray mirror shells for XMM-Newton

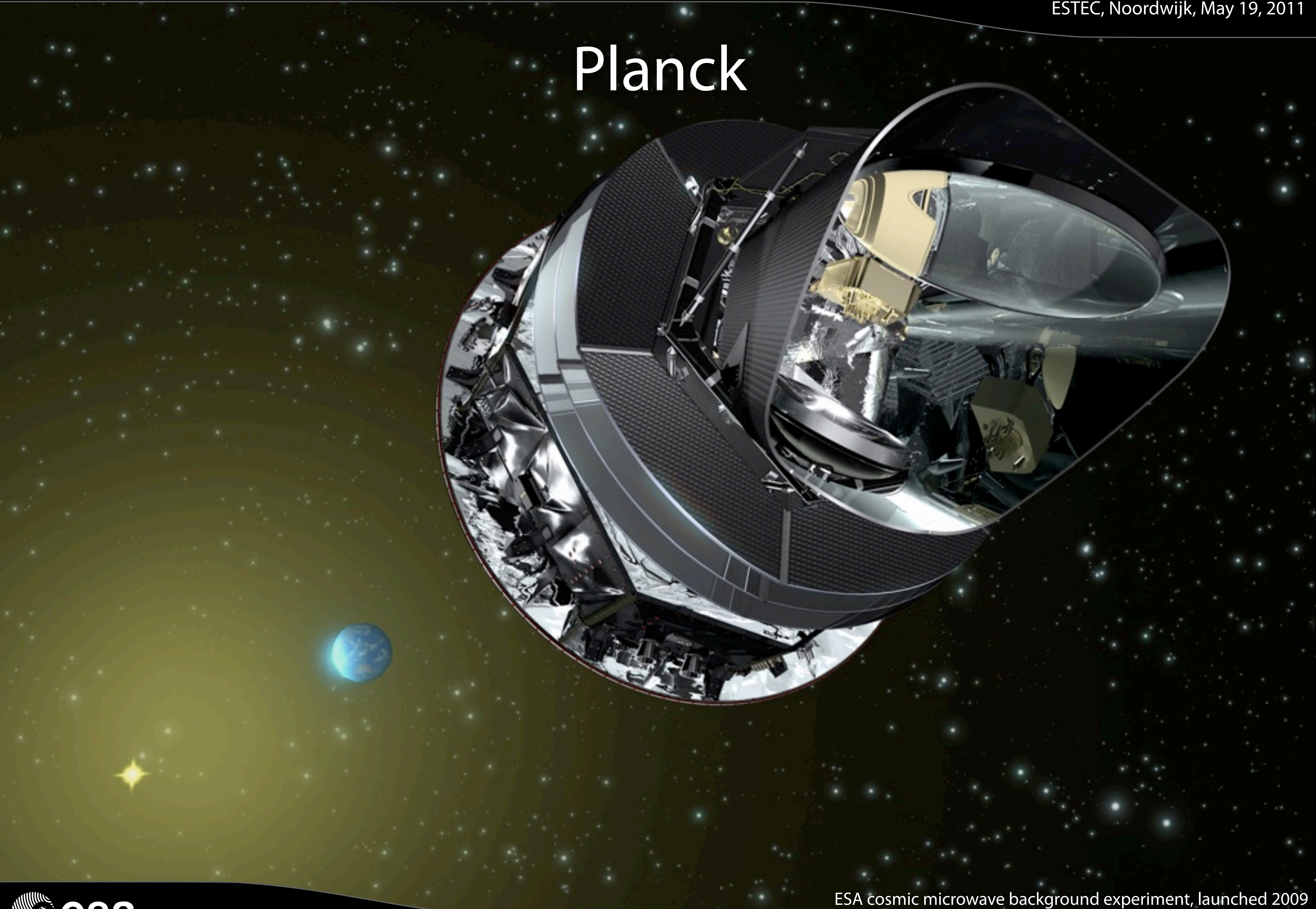






ESA / Dornier Satellitensysteme

Planck



ESA cosmic microwave background experiment, launched 2009

Planck: an off-axis telescope

Focal plane feed horns for instruments

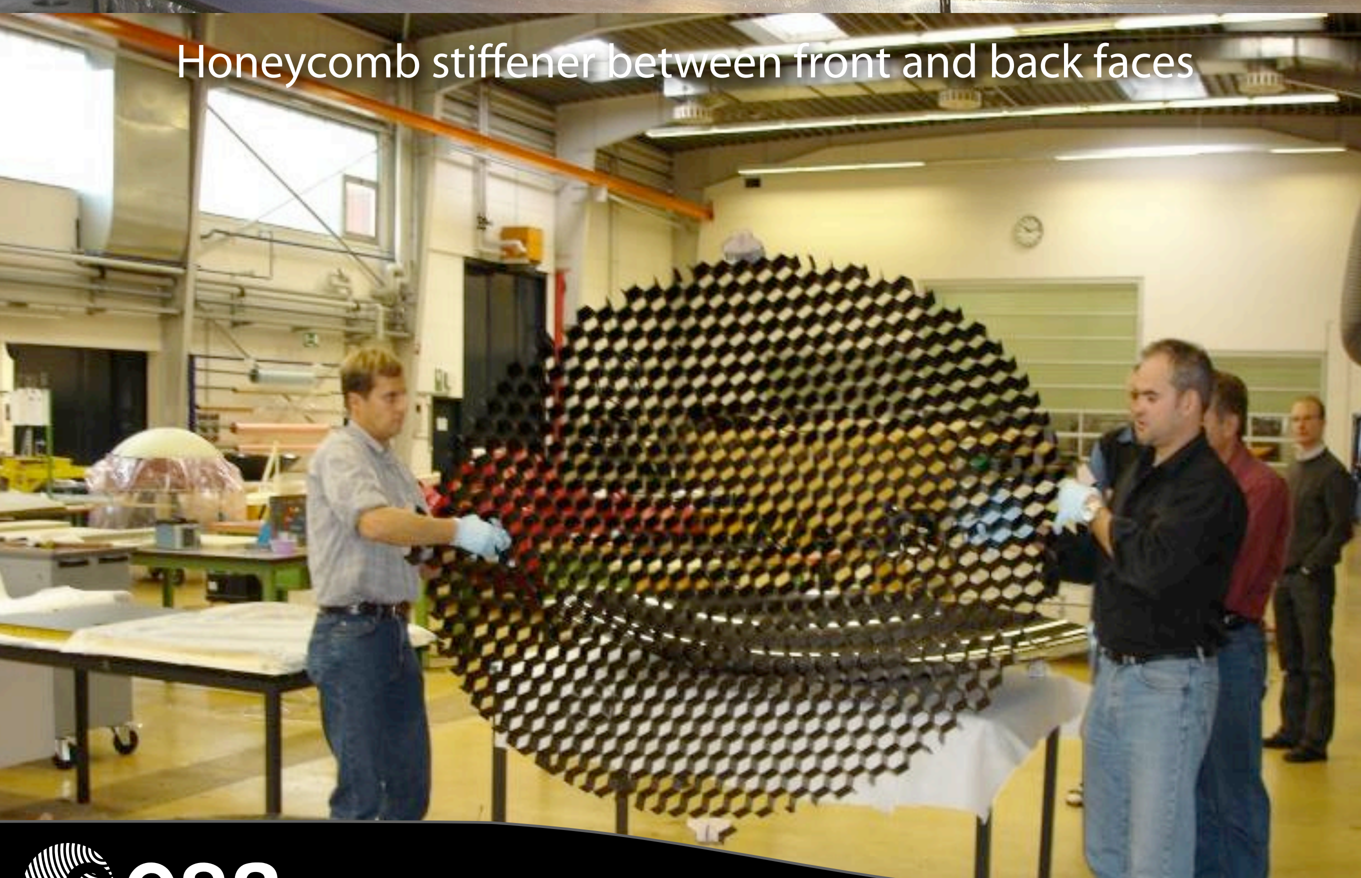
ESA / EADS-Astrium, Danish Space Research Institute

Planck CFRP secondary reflector manufacturing

Carbon fibres laid by robot on steel mandrel

Finished front sheet removed from mandrel

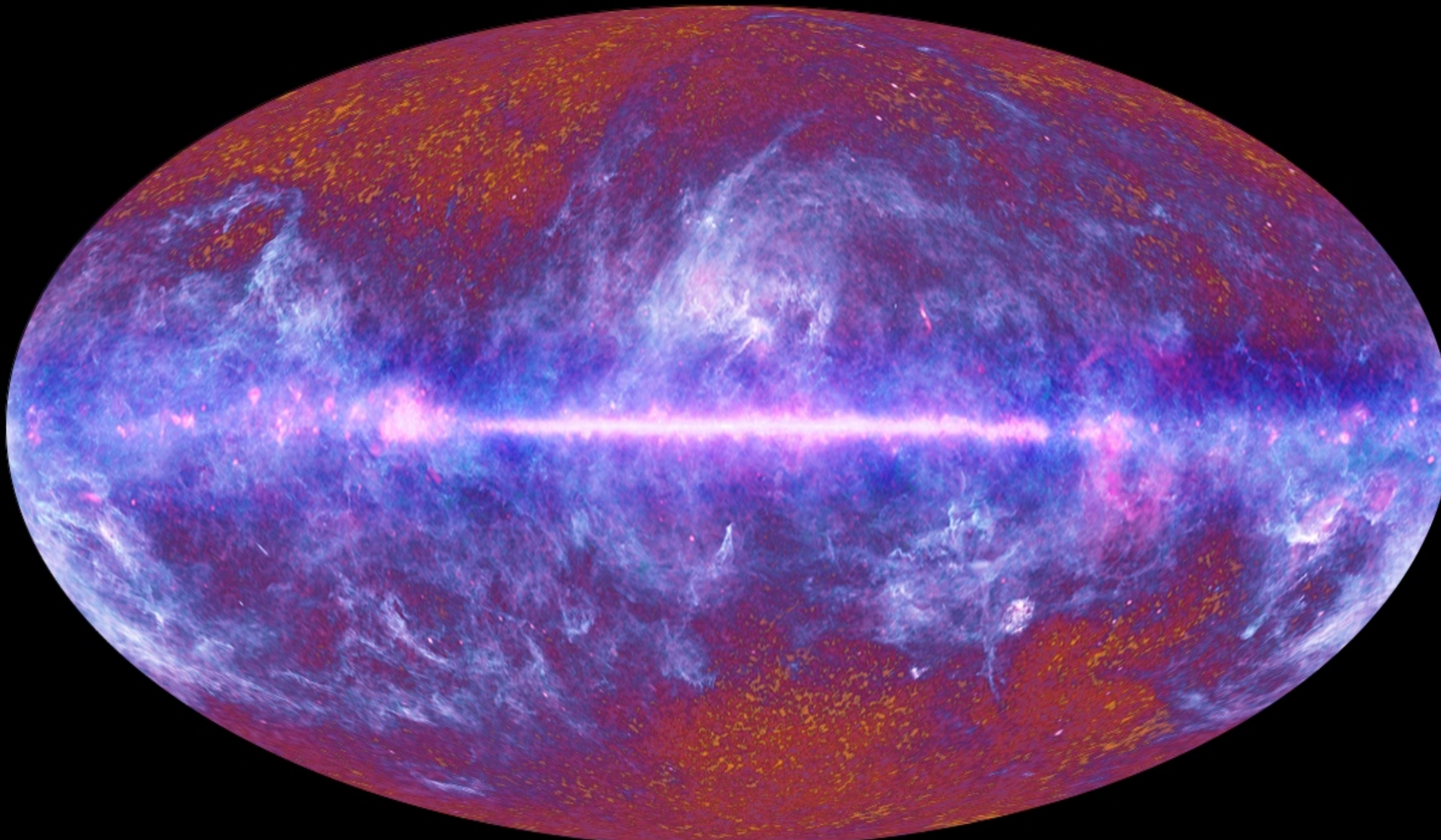
Honeycomb stiffener between front and back faces



Coating of finished reflector at Calar Alto Observatory

ESA / EADS-Astrium, Danish Space Research Institute

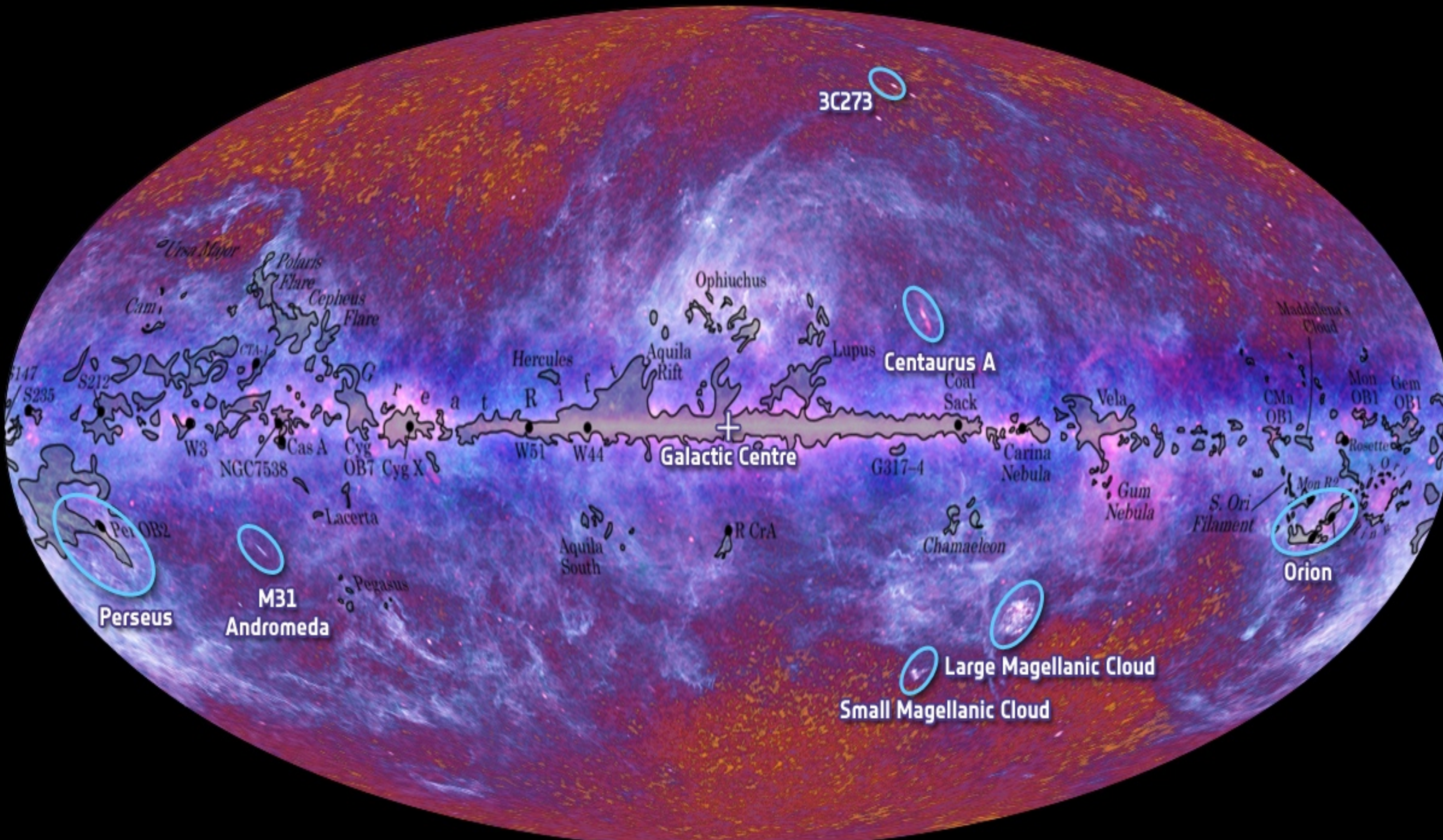
Planck all-sky image



Released July 5, 2010

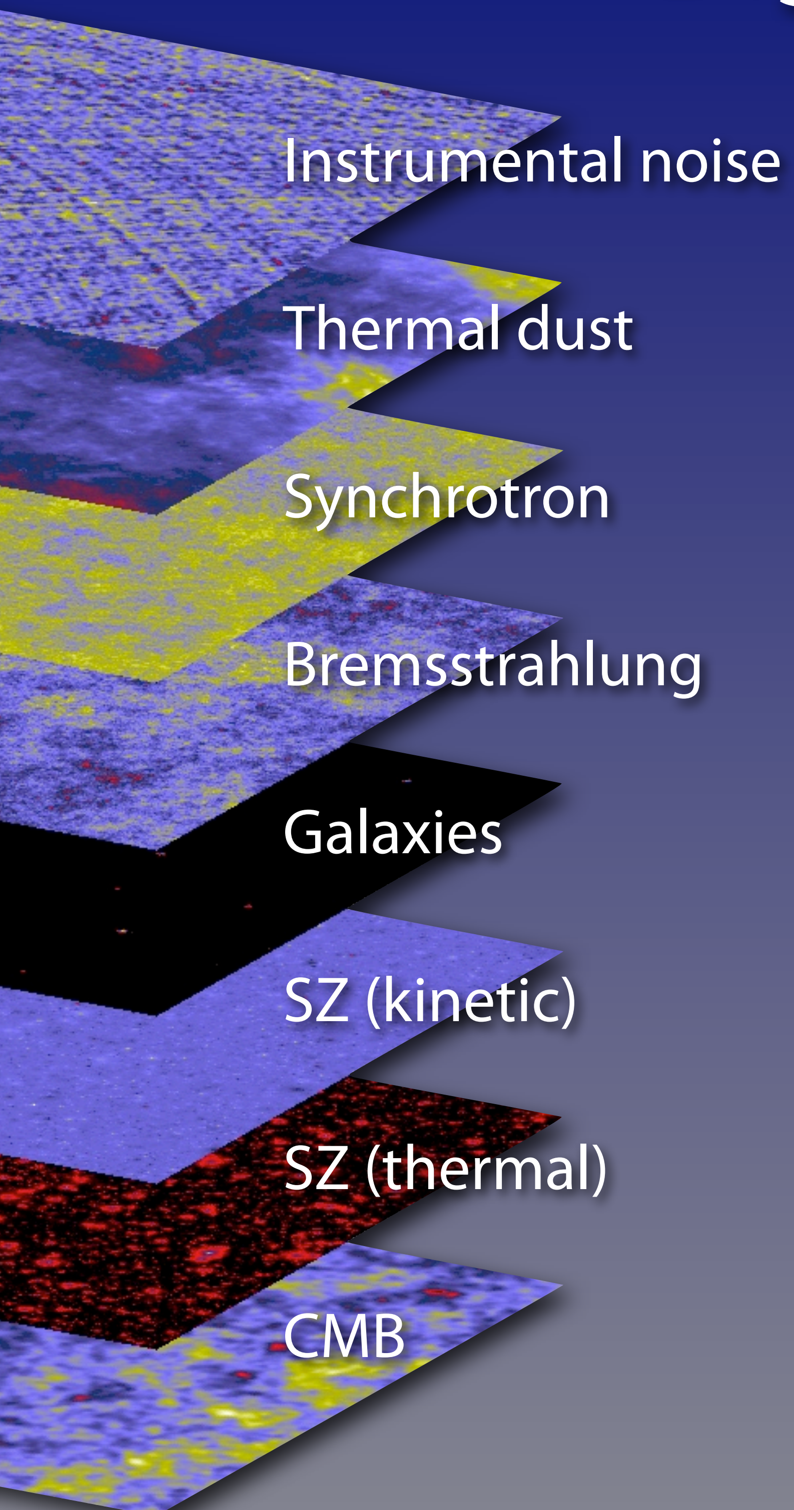
ESA / LFI & HFI consortia

Planck all-sky image

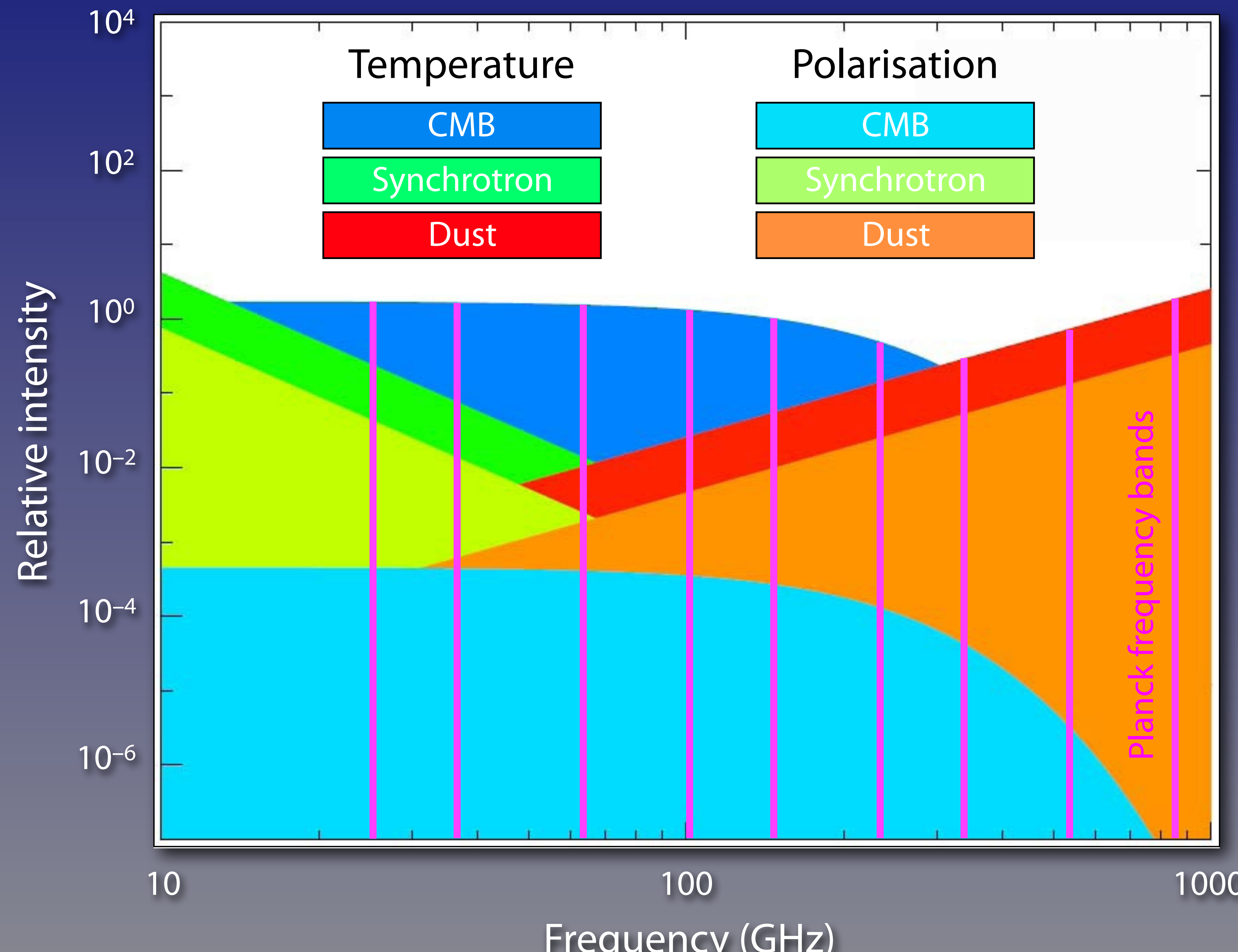


Released July 5, 2010

Digging down to the CMB



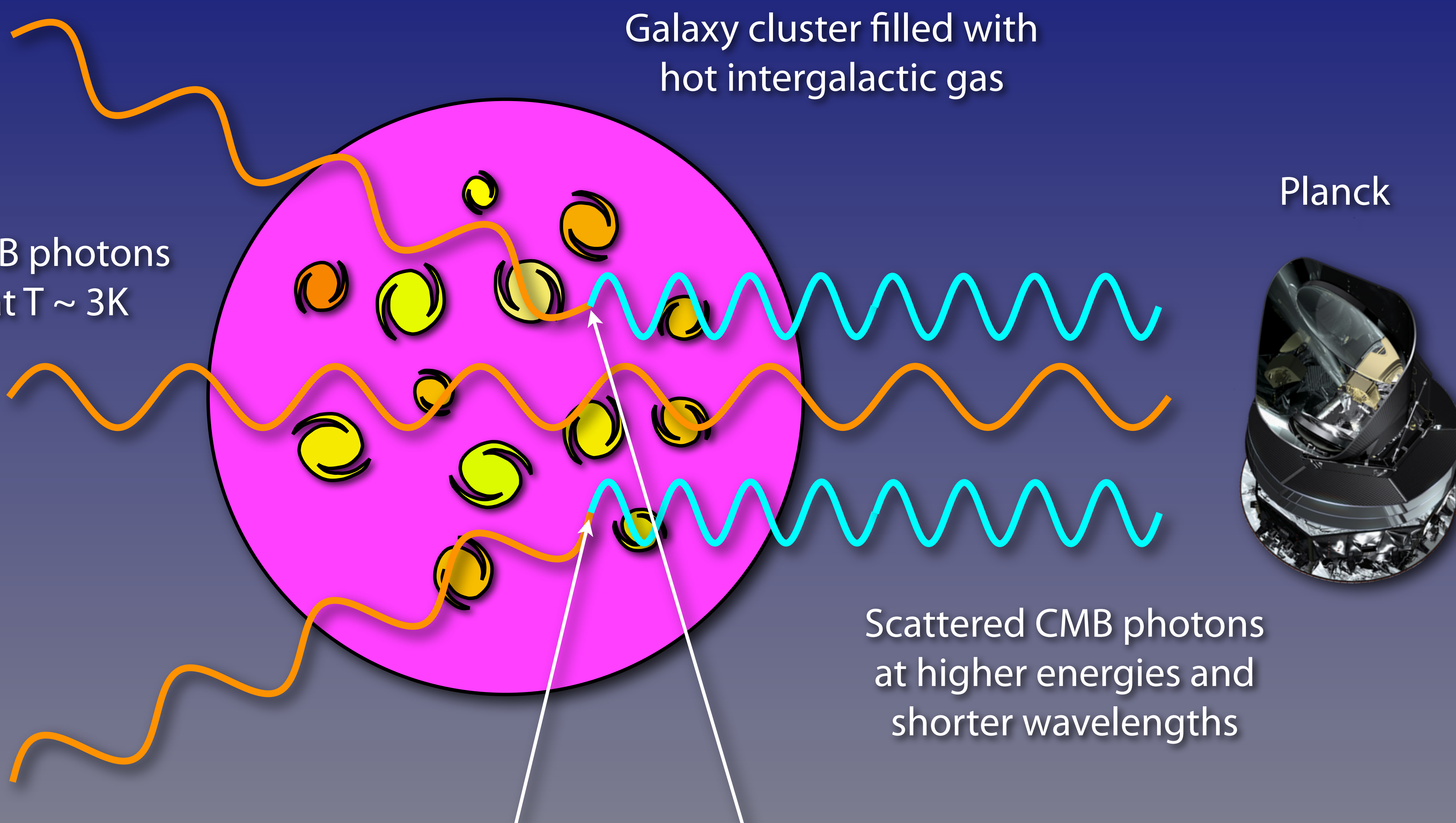
Adapted from Bouchet & Gispert



Original figure courtesy Lauranne Fauvet

Sunyaev Zel’dovich effect

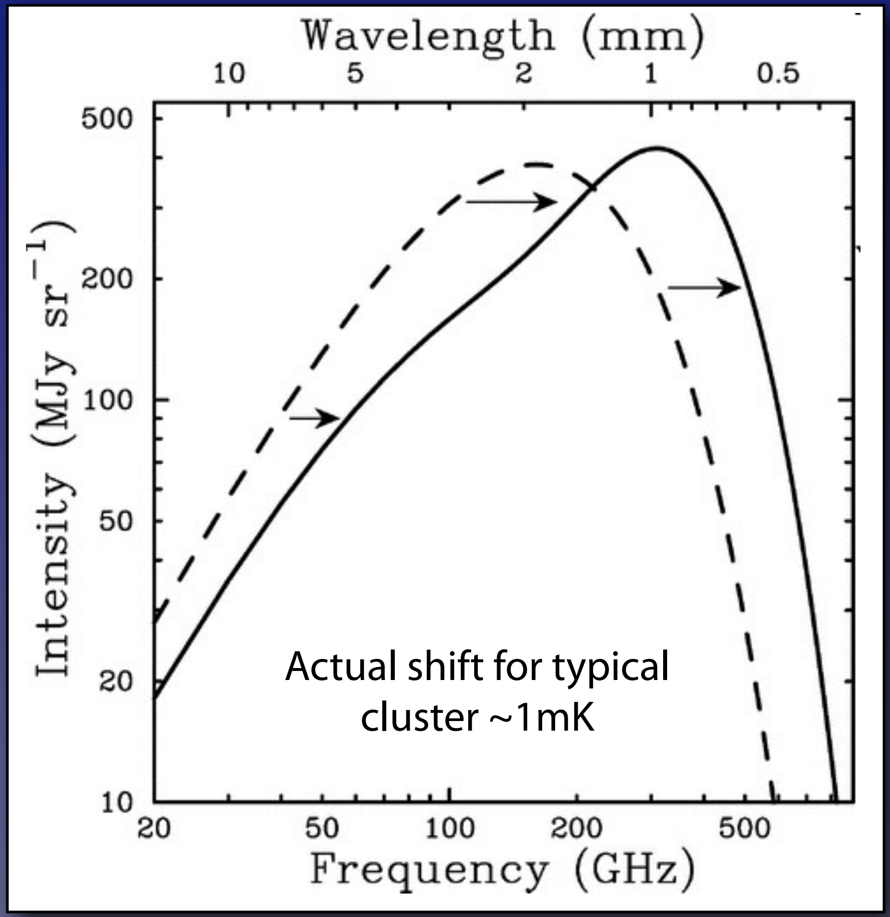
Cosmic Microwave Background



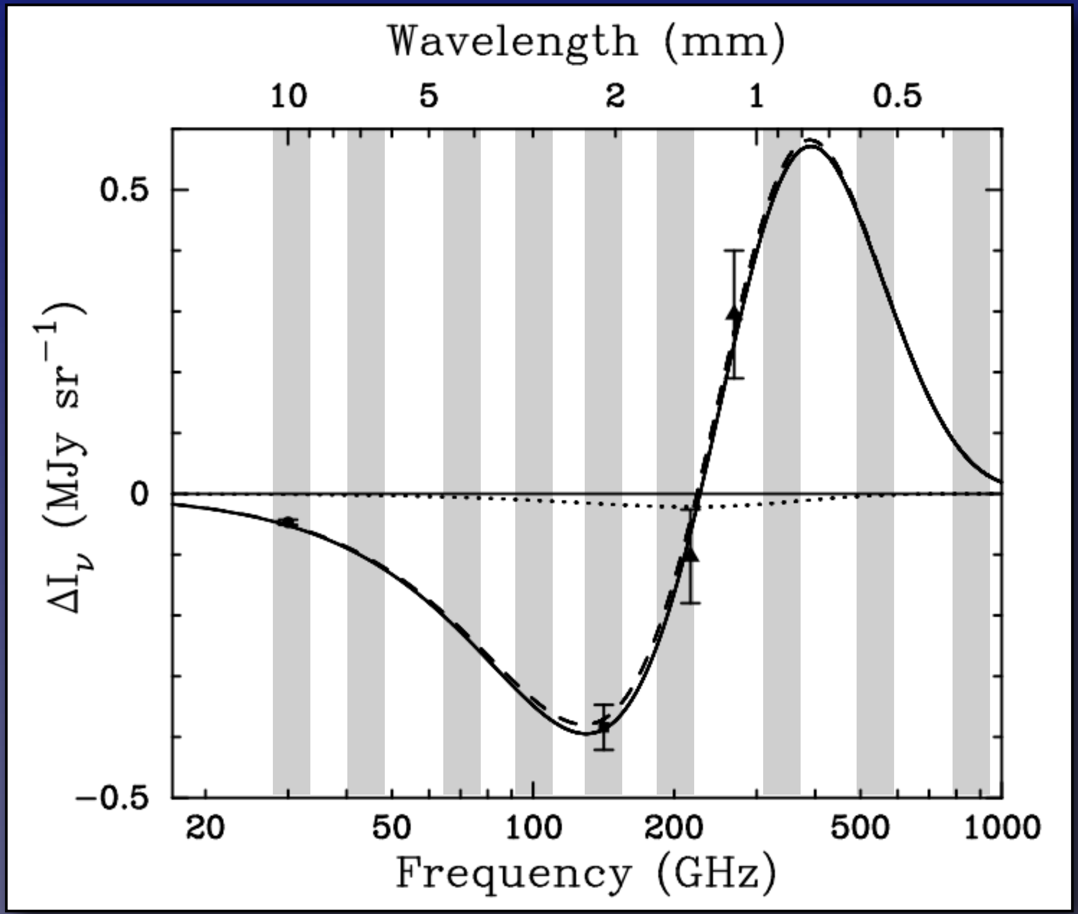
Inverse Compton (inelastic) scattering
of CMB photons by energetic electrons
(roughly 1% of CMB photons scattered)

Detecting galaxy clusters via the SZ effect

Simulation for fictional cluster (1000x more massive than normal): Carlstrom et al. 2002, ARA&A

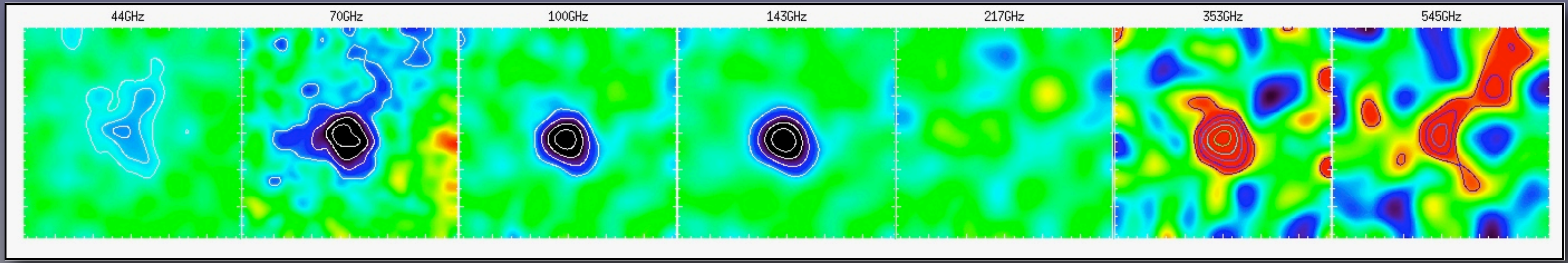


CMB photons scattered to higher frequencies by high energy electrons in galaxy clusters



SZE effect on Abell 2163: Carlstrom et al. 2002, ARA&A

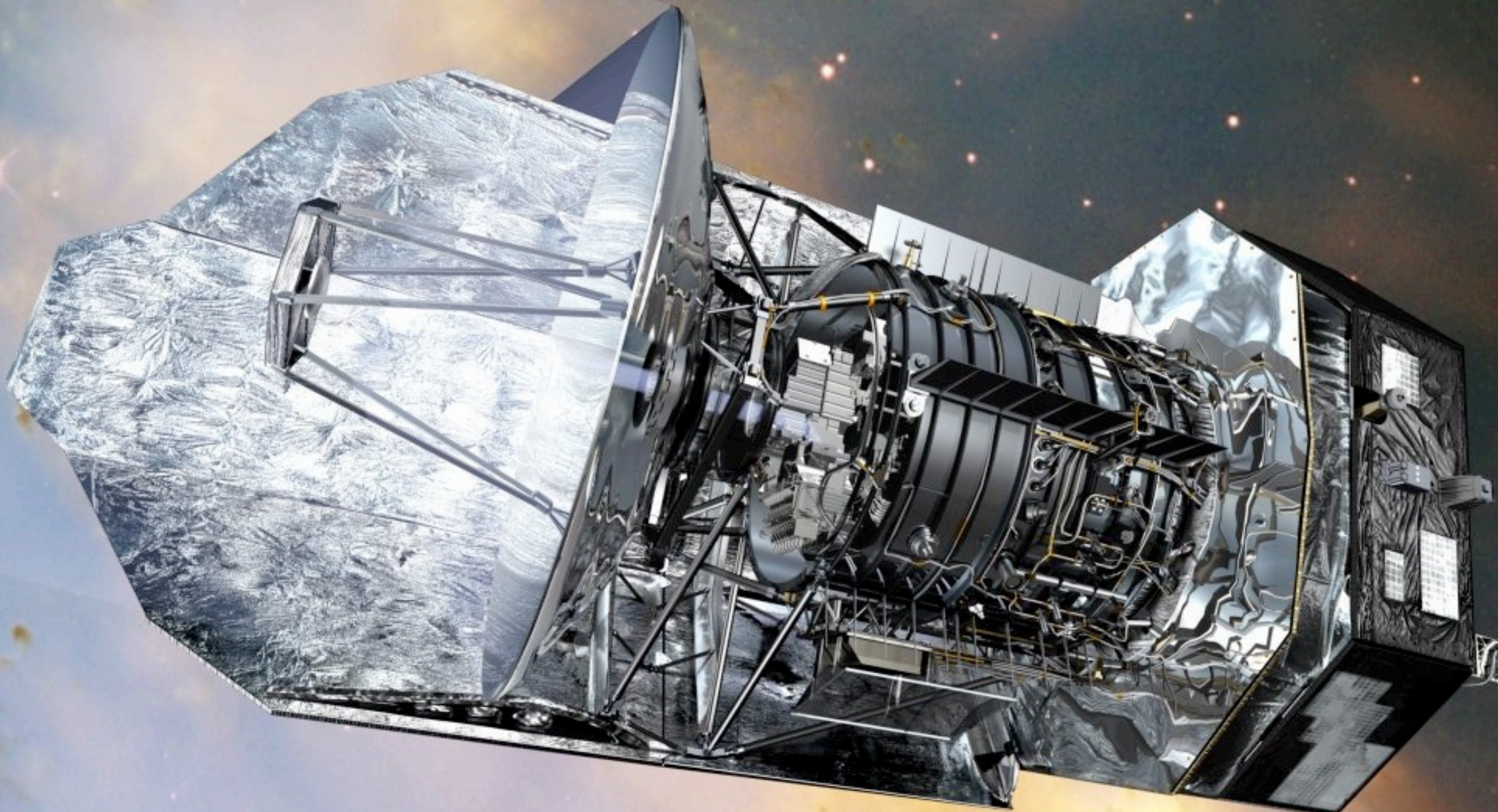
In Planck bands, leads to lower flux at low frequencies, higher flux at higher frequencies



Sunyaev-Zel'dovich effect as seen on Abell 2319 with Planck

ESA / LFI & HFI consortia

Herschel Space Observatory



ESA far-infrared astrophysics observatory, launched 2009

Herschel silicon carbide M1 fabrication

ESA / Boostec, Opteon, CSL

Brazed Herschel M1 with front face stiffeners

ESA / Boostec, Opteon, CSL

Machined Herschel M1

ESA / Boostec, Opteon, CSL

Complete Herschel observatory

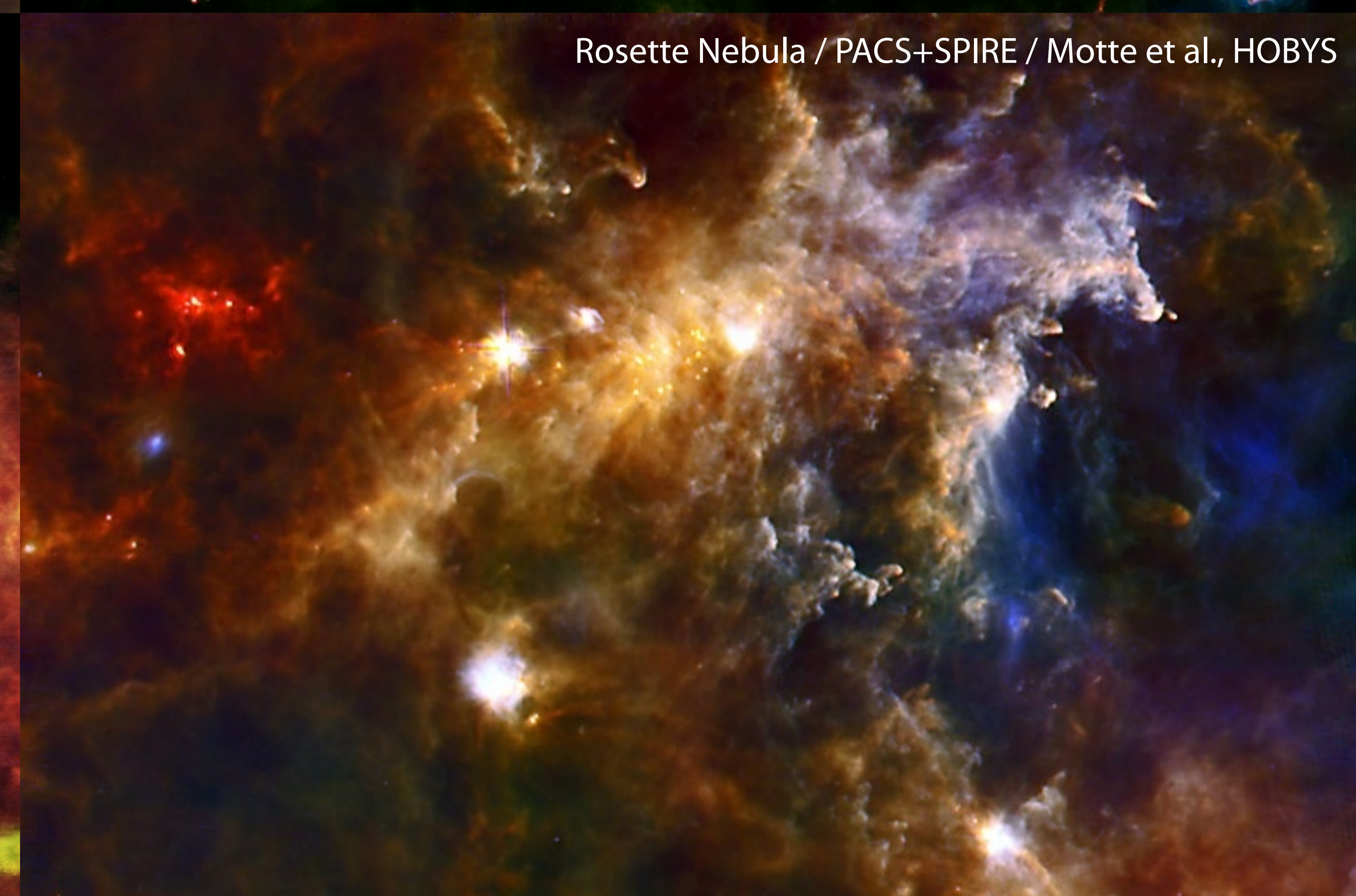
ESA / EADS Astrium, Boostec, Opteon, CSL, Zeiss

Galactic star-forming regions with Herschel

RCW120 / PACS+SPIRE / Zavagno et al., HOBYS

Galactic plane towards Aquila / PACS+SPIRE / Molinari et al., HiGAL

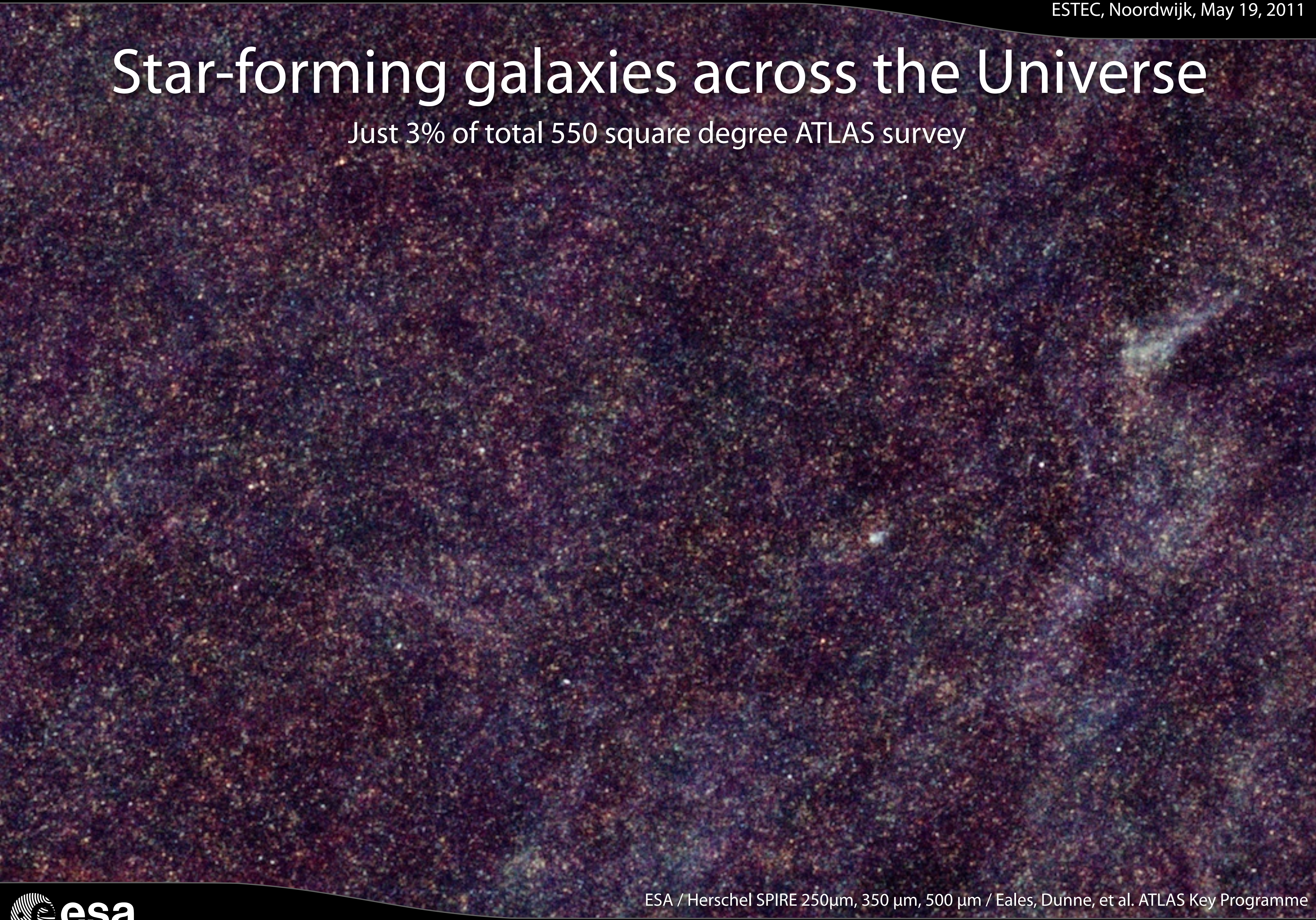
Galactic plane towards Vulpecula / PACS+SPIRE / Molinari et al., HiGAL



Rosette Nebula / PACS+SPIRE / Motte et al., HOBYS

Star-forming galaxies across the Universe

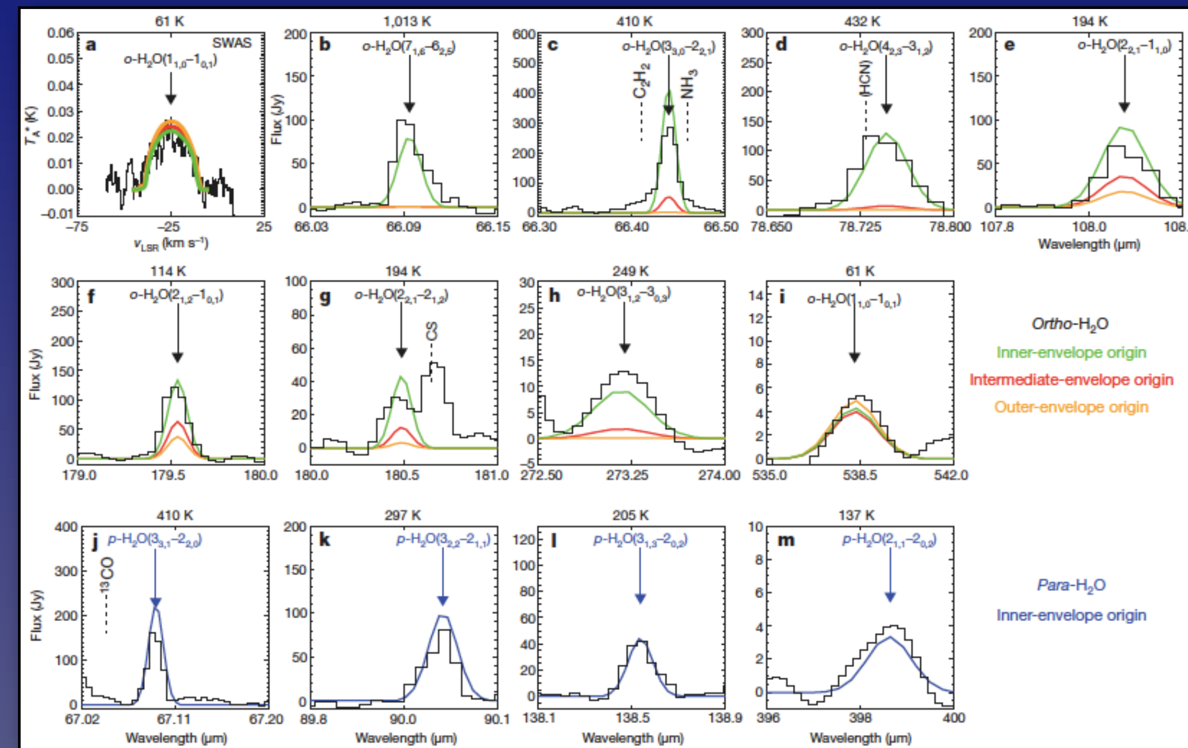
Just 3% of total 550 square degree ATLAS survey



ESA / Herschel SPIRE 250µm, 350 µm, 500 µm / Eales, Dunne, et al. ATLAS Key Programme

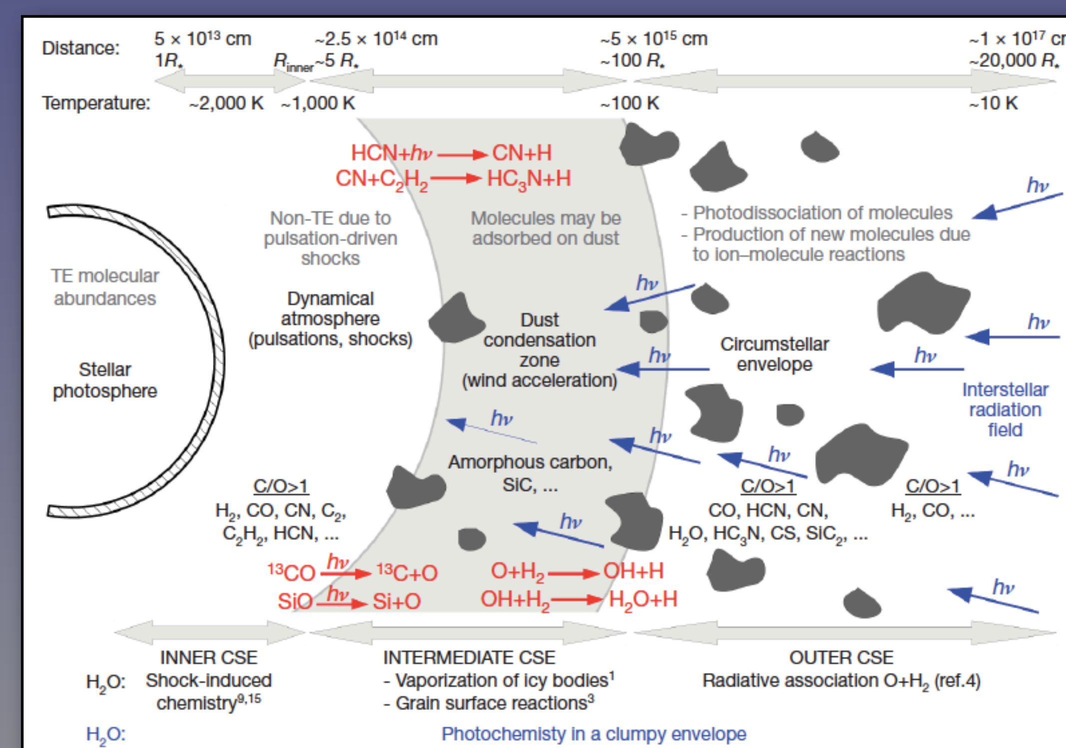
Water vapour detected around IRC+10 216

PACS + SPIRE 160 + 250 + 350 µm



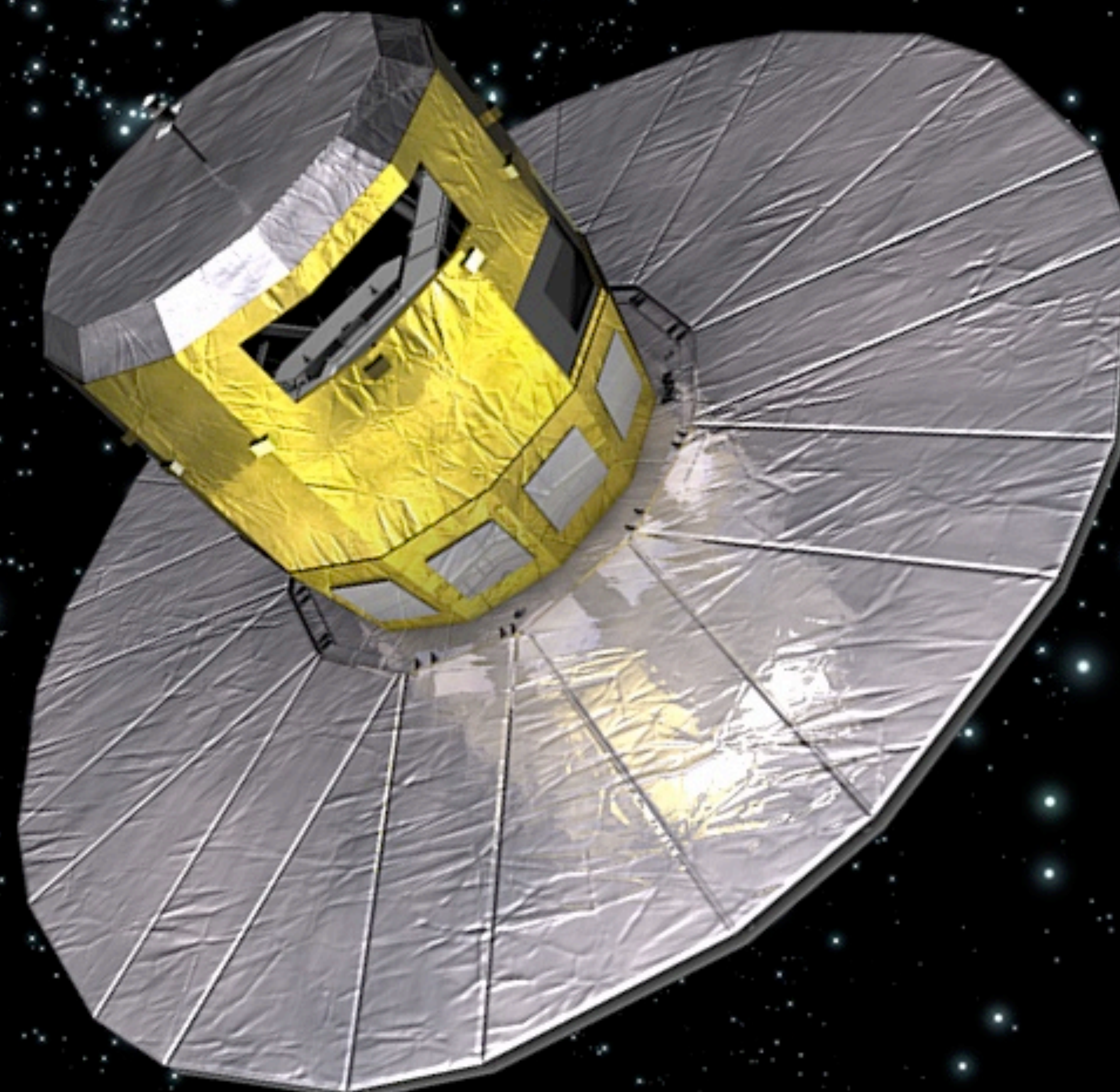
PACS + SPIRE spectroscopy
Many ortho and para H_2O lines seen

- IRC+10 216 (CW Leo) is a carbon-rich AGB star
- No H_2O expected, but seen by SWAS
- Hypothesis: evaporating comets, planets?
- Herschel sees many H_2O lines, T_{ex} up to 1000 K
- Must be warm water in central, sooty core
- Likely due to external UV-induced photo-chemistry in clumpy circumstellar envelope



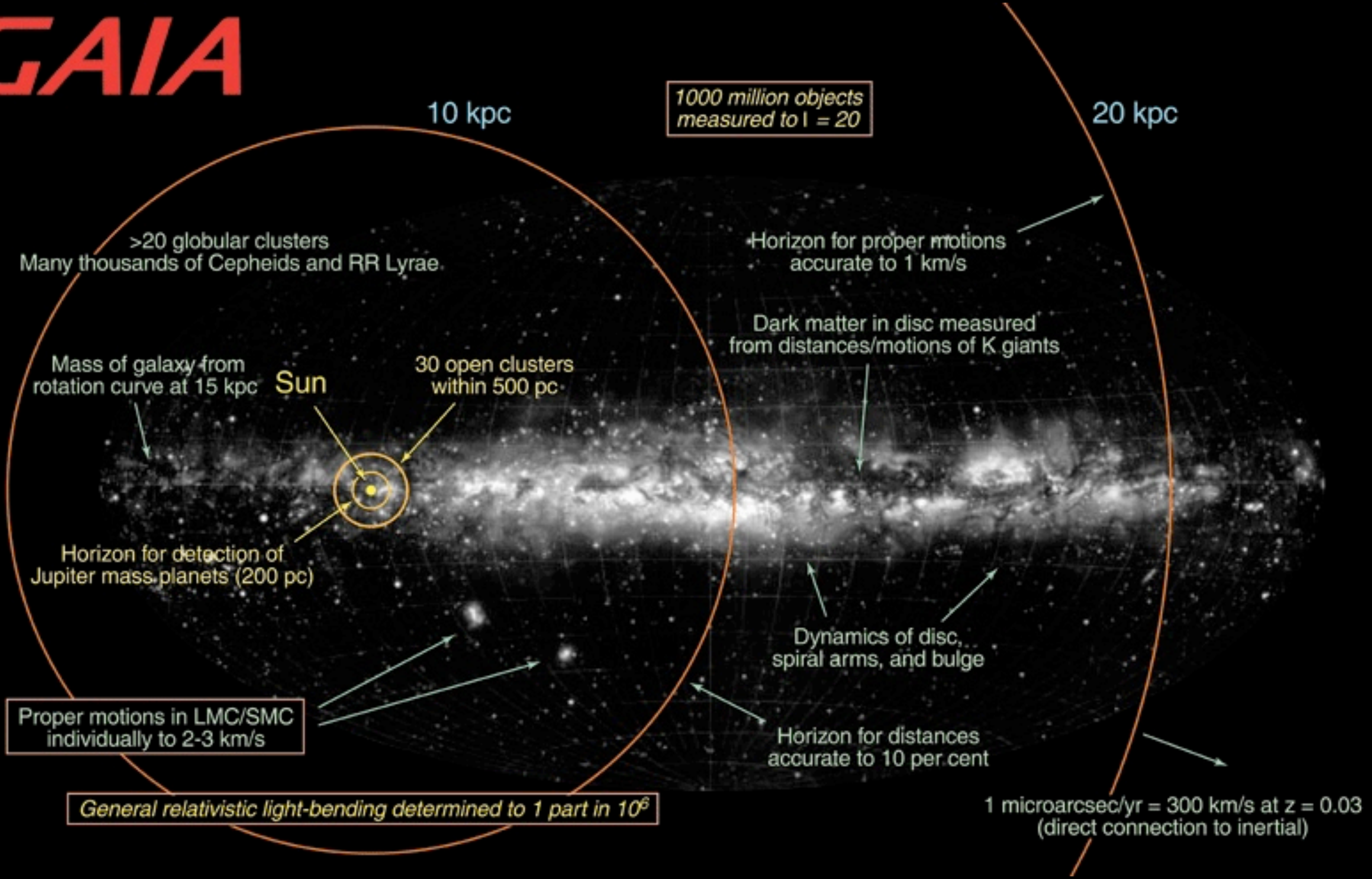
Decin et al. (2010, Nature)

GAIA

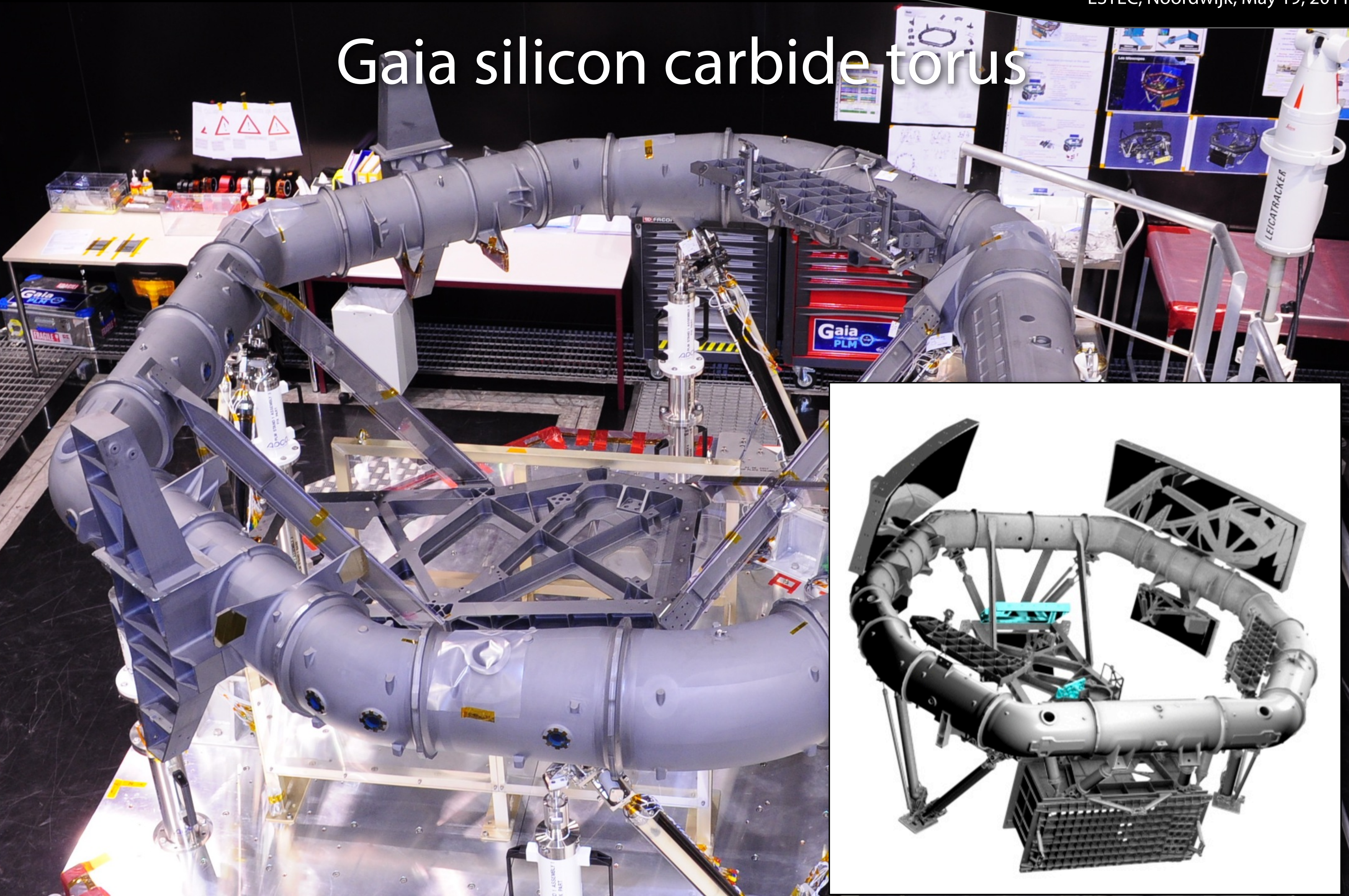


ESA precision astrometry mission, scheduled launch 2012

GAIA


10 kpc
1000 million objects measured to I = 20
20 kpc
>20 globular clusters
Many thousands of Cepheids and RR Lyrae
Horizon for proper motions accurate to 1 km/s
Dark matter in disc measured from distances/motions of K giants
Mass of galaxy from rotation curve at 15 kpc
Sun
30 open clusters within 500 pc
Horizon for detection of Jupiter mass planets (200 pc)
Dynamics of disc, spiral arms, and bulge
Proper motions in LMC/SMC individually to 2-3 km/s
Horizon for distances accurate to 10 per cent
General relativistic light-bending determined to 1 part in 10^6
1 microarcsec/yr = 300 km/s at z = 0.03
(direct connection to inertial)

Gaia silicon carbide torus

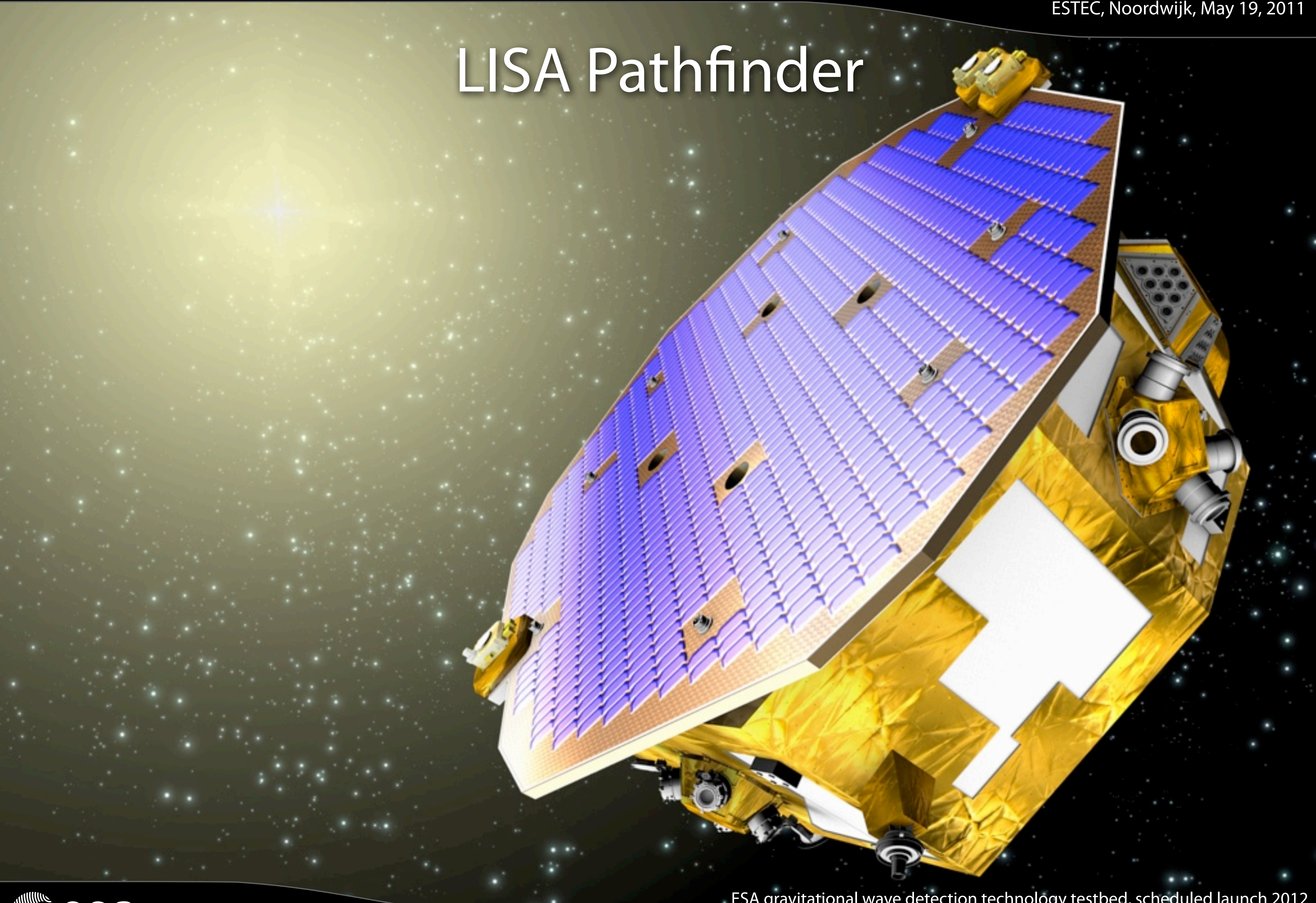


ESA / Boostec

One of the two Gaia primary mirrors

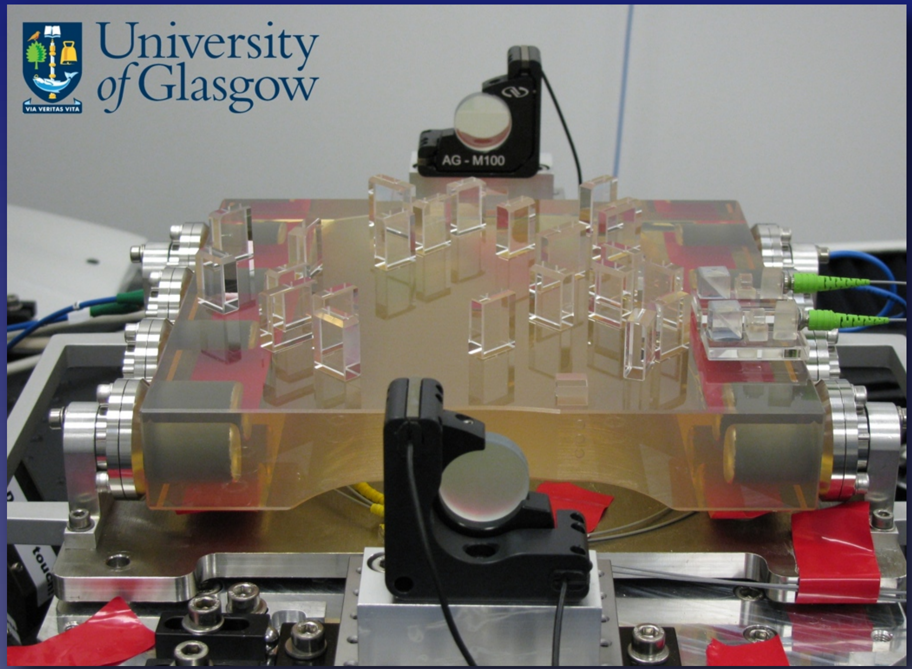
ESA / EADS Astrium, Boostec, Sagem - REOSC, Schunk Kohlenstofftechnik

LISA Pathfinder

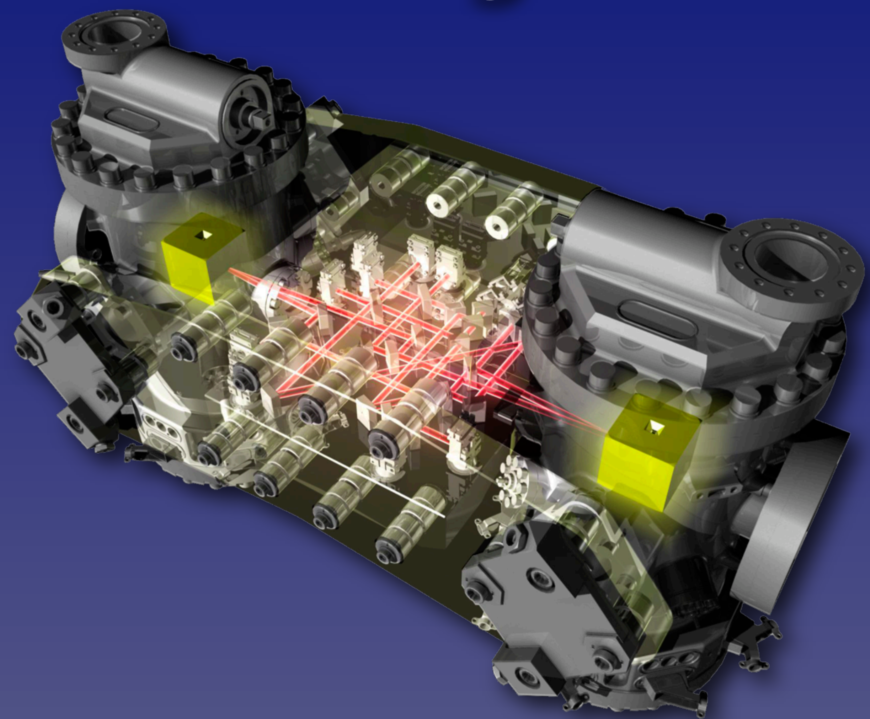


ESA gravitational wave detection technology testbed, scheduled launch 2012

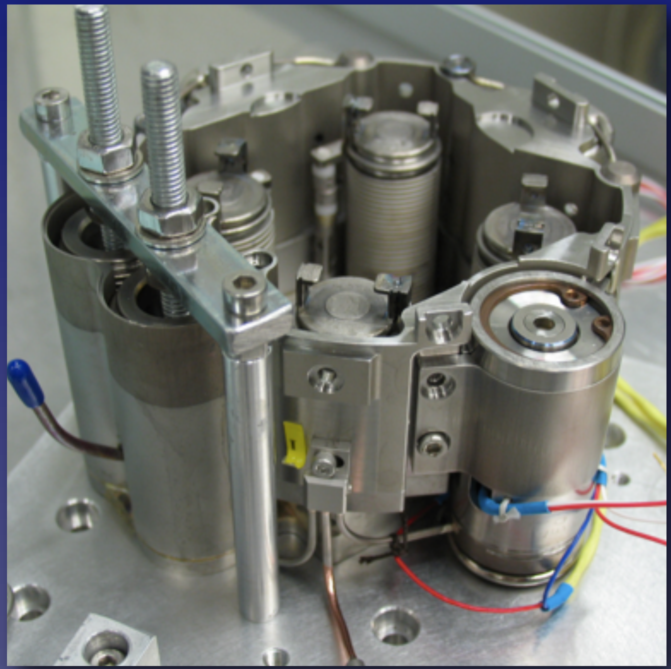
LISA Pathfinder flight hardware



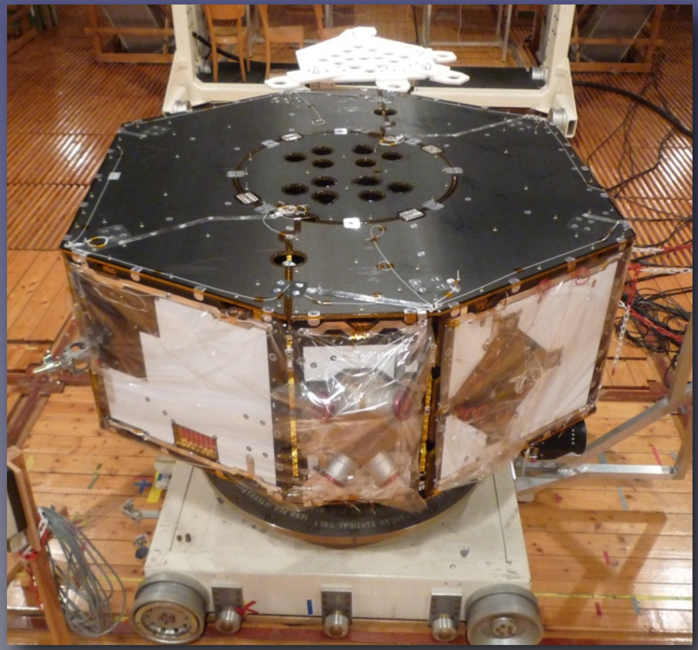
Optical bench



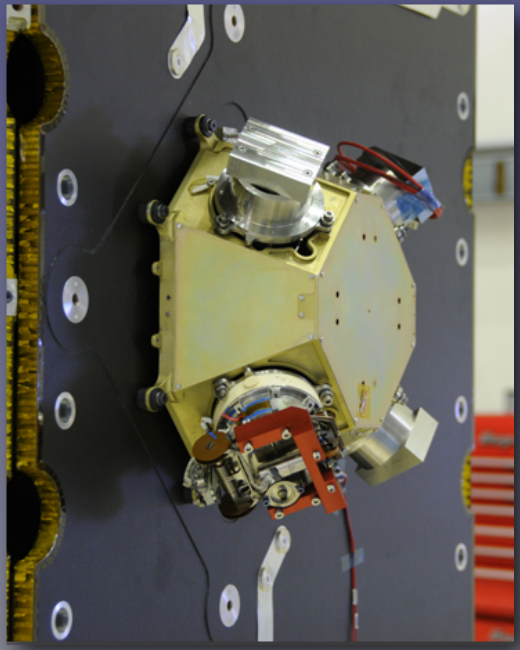
LISA Technology Package (LTP)



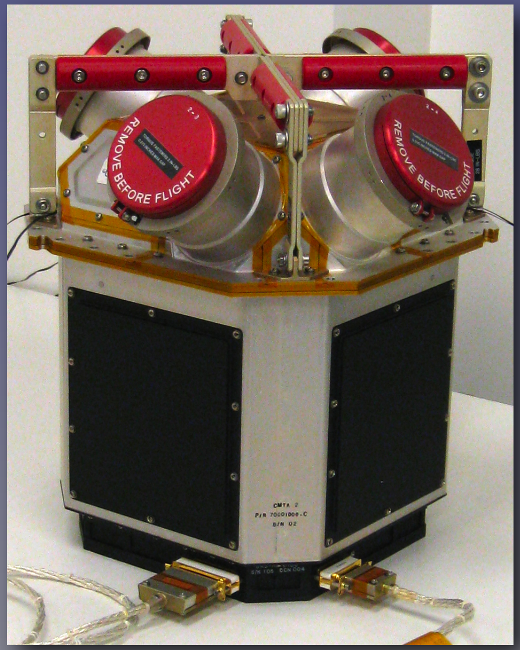
Test mass caging mechanism



Spacecraft EM testing



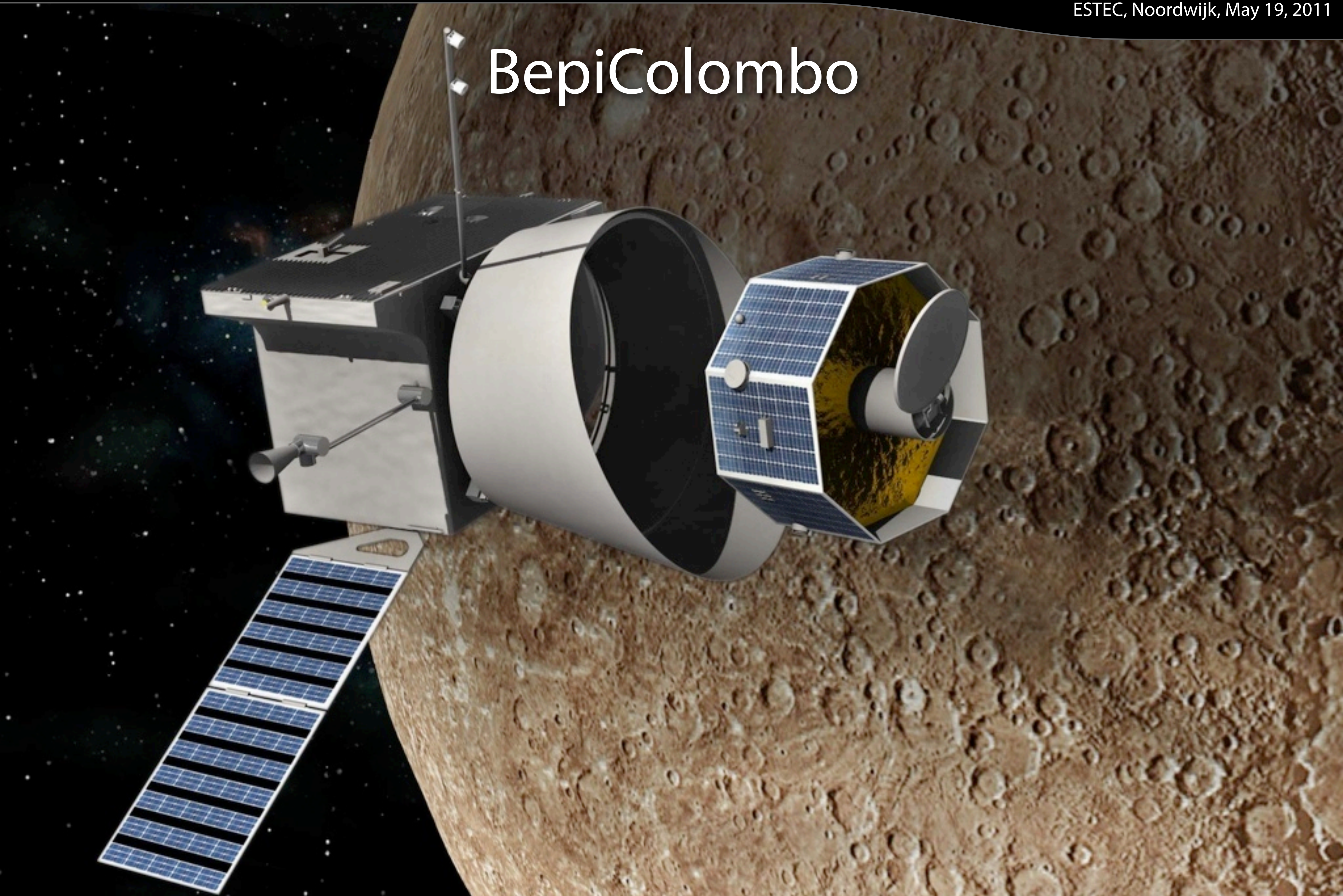
ESA slit FEEP



NASA colloidal thruster

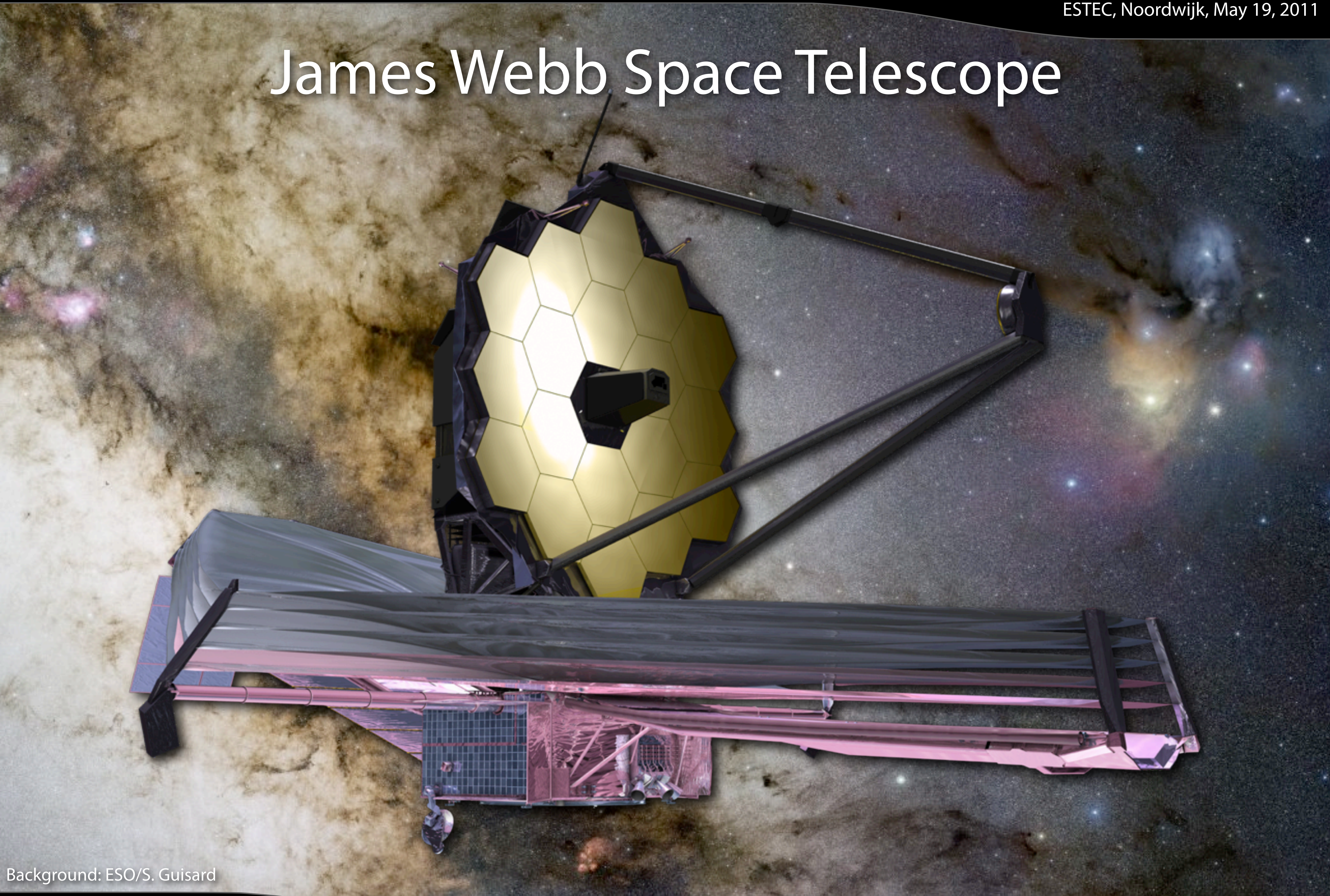
VEGA rocket motor tests

BepiColombo



ESA-Japan Mercury planetary science mission, scheduled launch 2015

James Webb Space Telescope

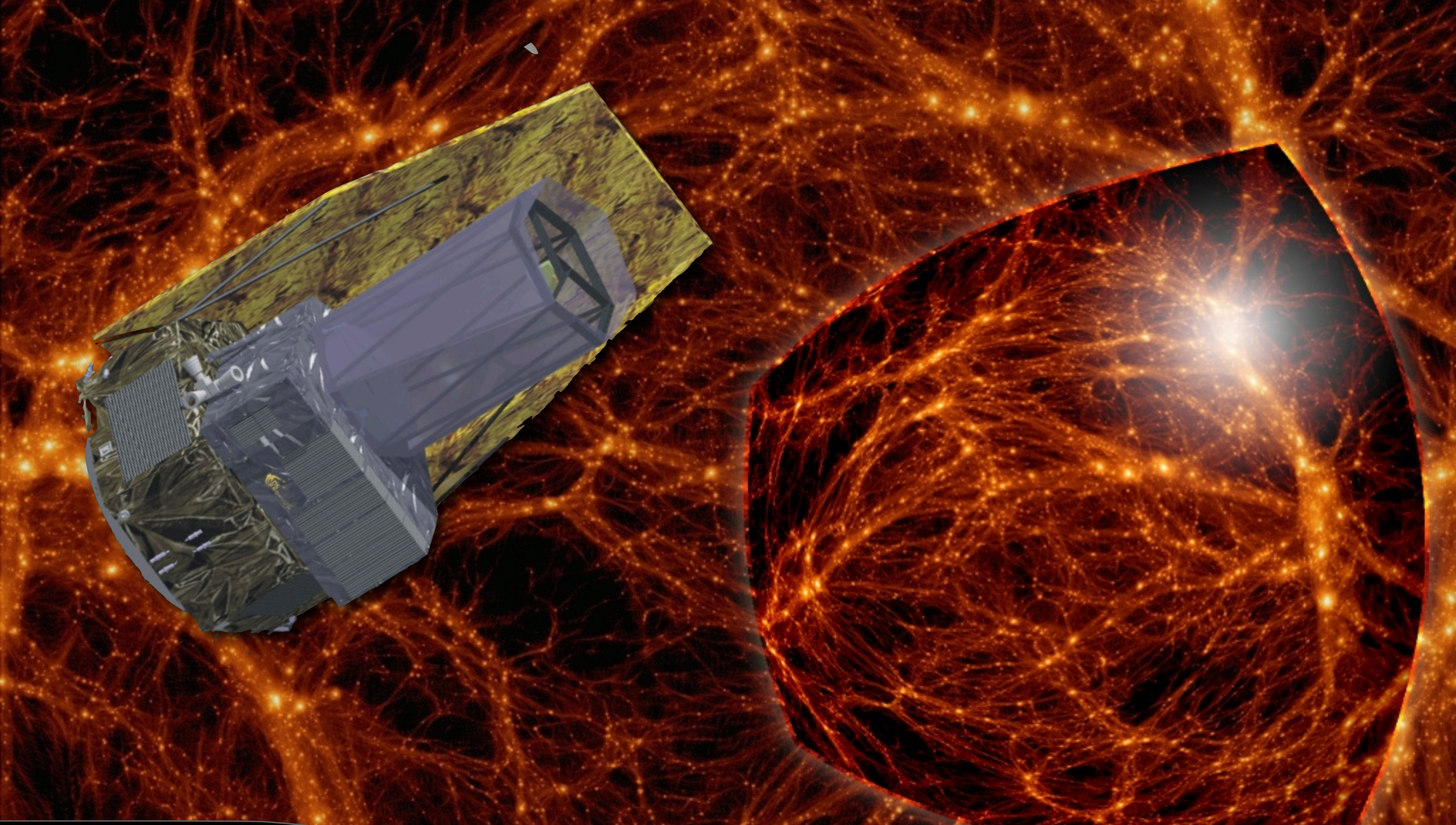


Background: ESO/S. Guisard

NASA-ESA-CSA optical-infrared astrophysics observatory, scheduled launch 2017?

Euclid

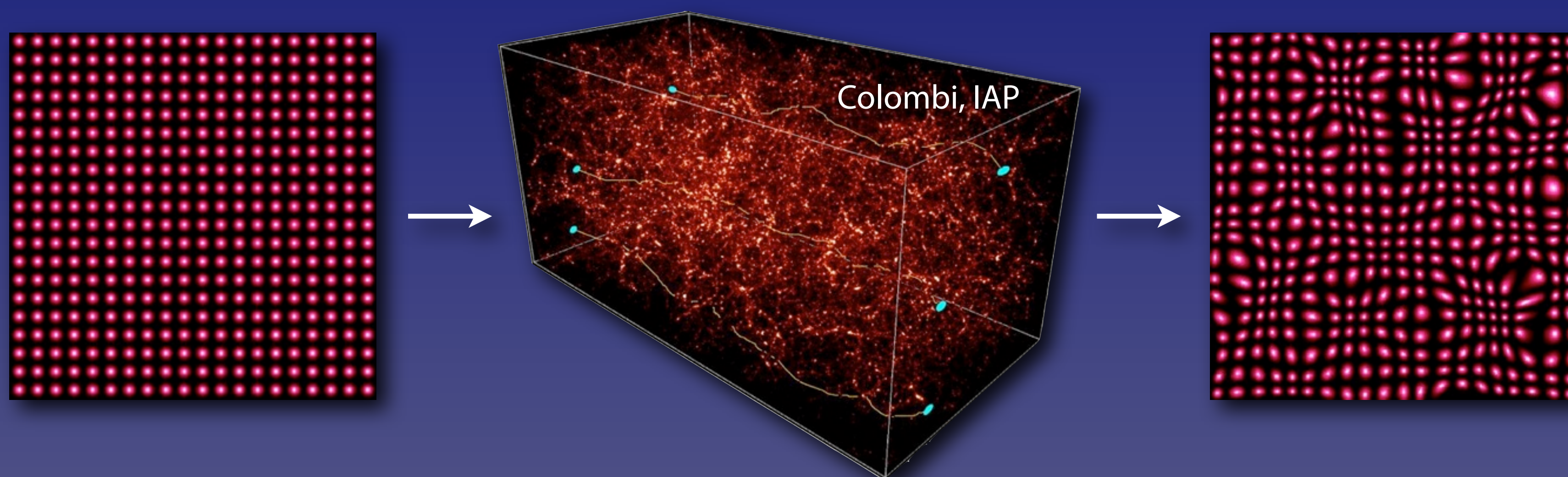
Cosmic Vision M-mission



ESA dark Universe astrophysics survey mission, possible launch 2018

Multiple probes of evolving cosmic structure

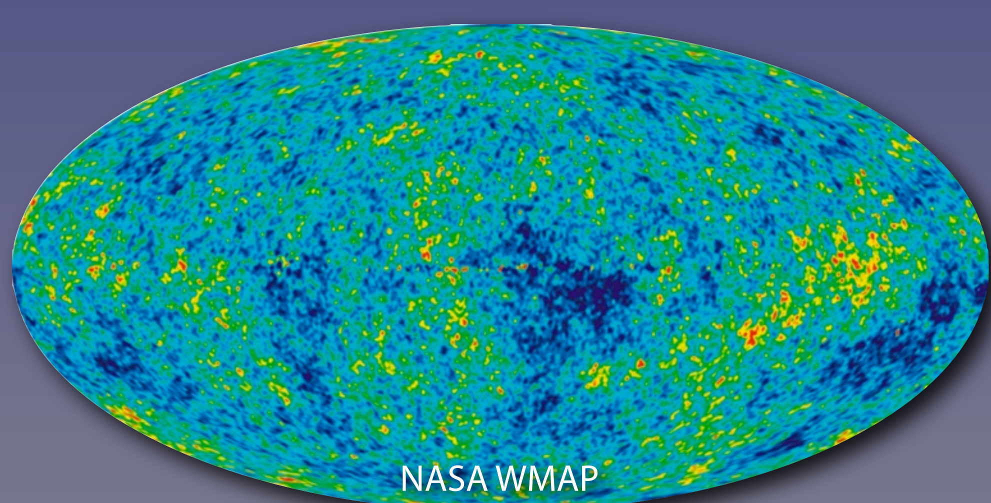
Weak lensing

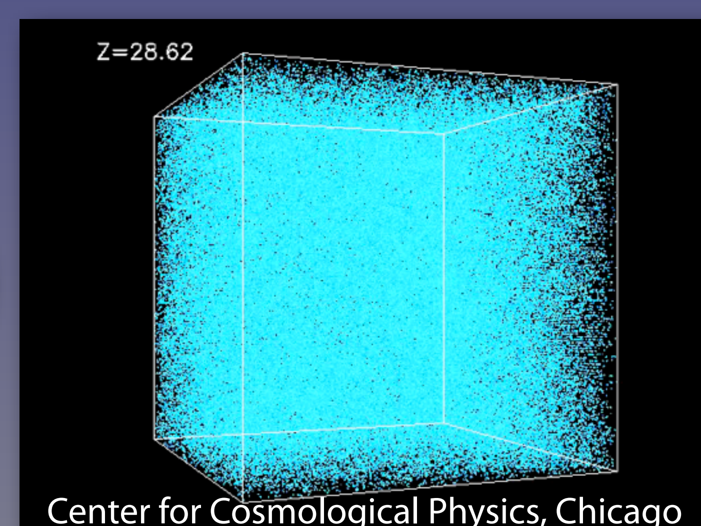


Galaxy shapes systematically distorted by intervening matter (baryonic and dark)

Wide-field, high-resolution visible imaging measures shear; near-IR imaging photometry measures photo-z's for lensed galaxies

Baryon acoustic oscillations





Initial structure imprinted on Universe at recombination has characteristic scale; follow its evolution as standard ruler to present epoch (now ~ 150 Mpc)

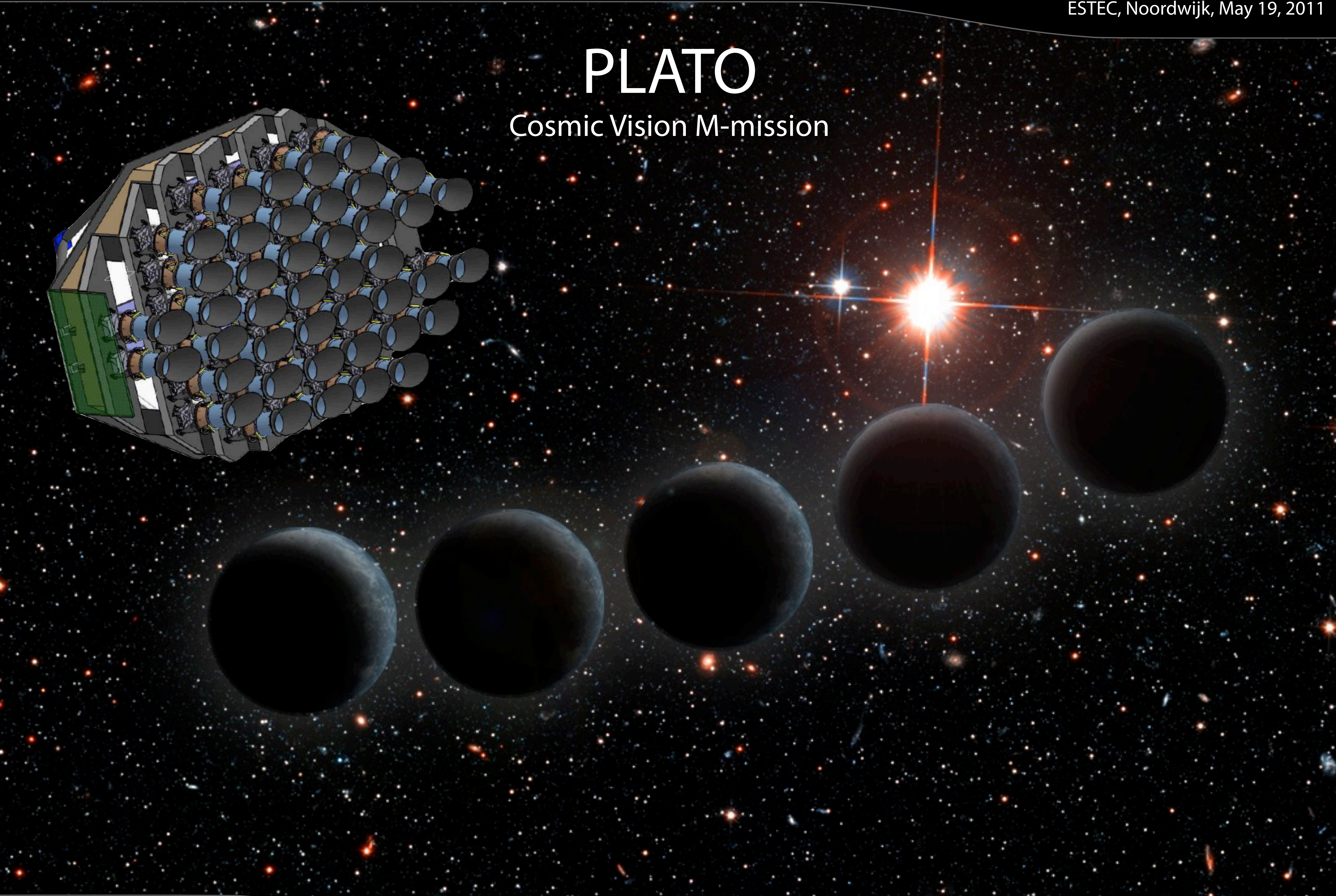
Near-IR spectroscopy provides accurate redshifts and 3D maps

Euclid aims to conduct these measurements over half of sky

Combined with Planck data, would yield dark energy parameters w to ~1% and w_a to ~ 10%

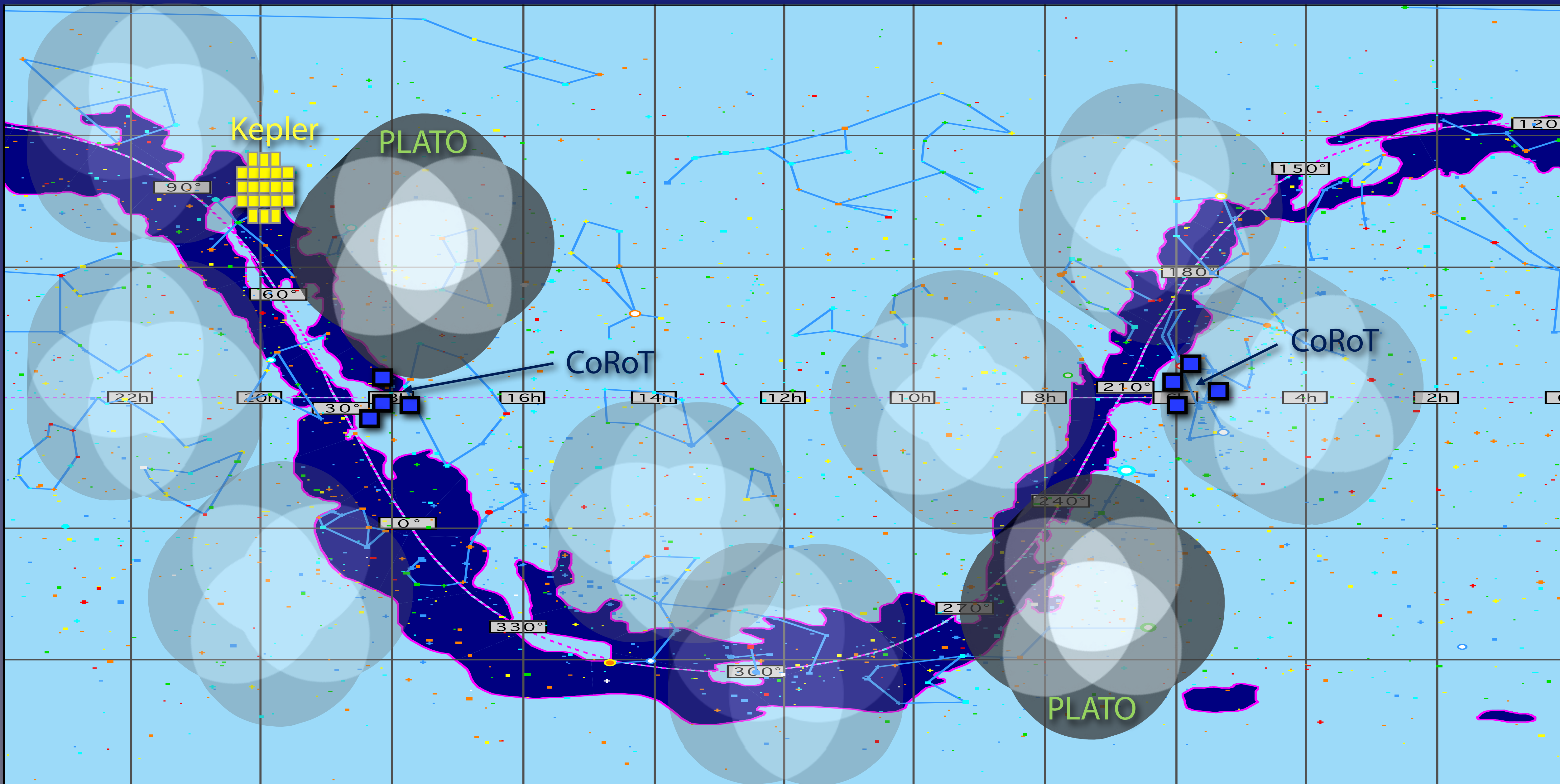
PLATO

Cosmic Vision M-mission



ESA transiting rocky planet discovery and characterisation mission, possible launch 2018

Proposed PLATO sky coverage



Wide field, (relatively) shallow survey yields bright sources for radial velocity and asteroseismology follow-up

Dark: long duration fields (~ 2 & 2 years)
Light: short duration fields (~ few months)
Optimisation of survey strategy ongoing

PLATO Optimisation Advisory Team, courtesy Catala et al.

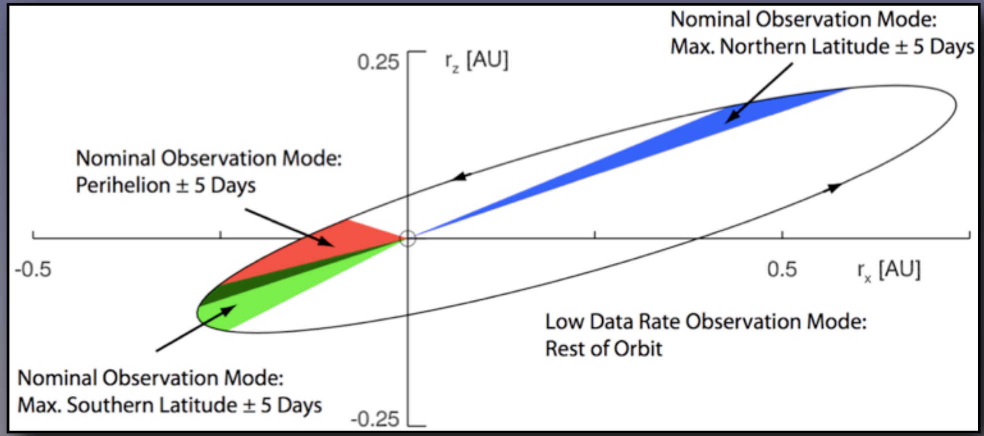
Solar Orbiter

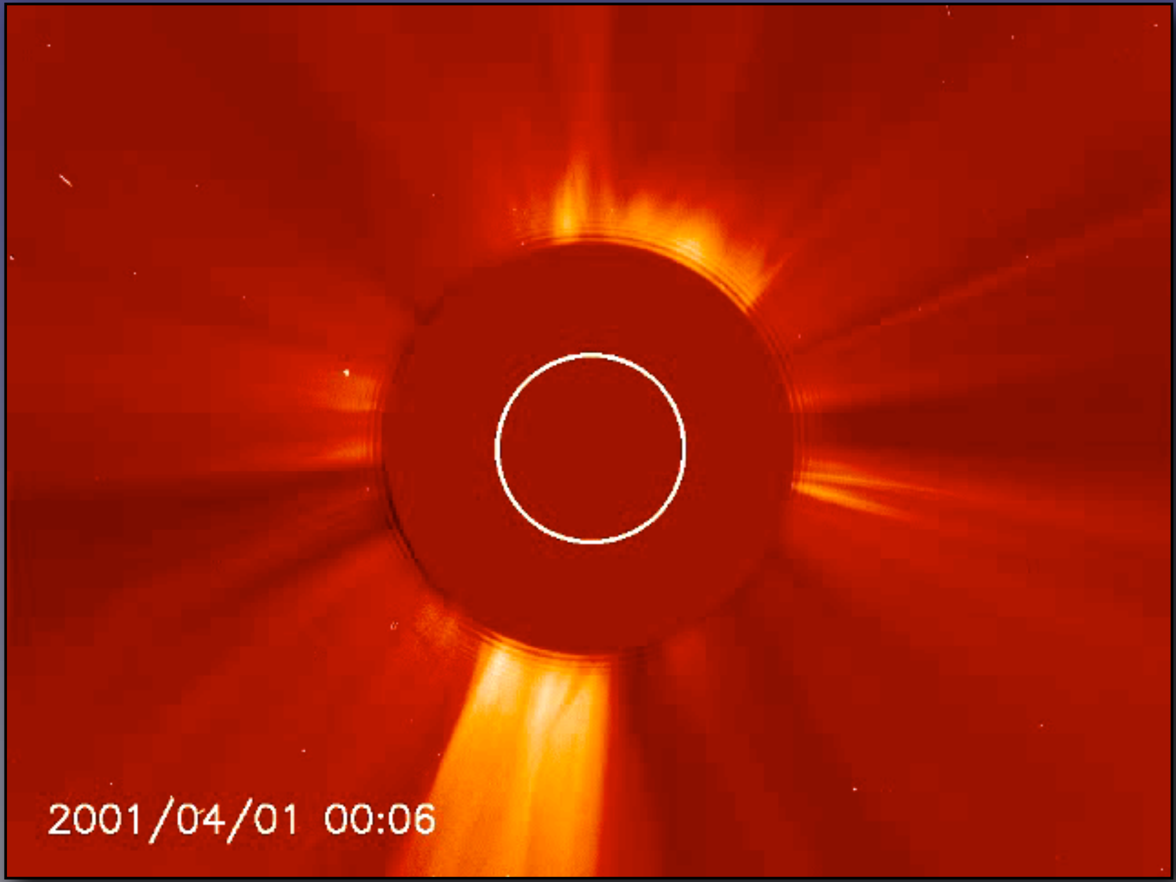
Cosmic Vision M-mission

ESA-NASA inner heliosphere mission, possible launch 2017

Solar Orbiter science goals

- How does the Sun create and control the heliosphere?
  - How and where do solar wind plasma and magnetic field originate in corona?
  - How do solar transients drive heliospheric variability?
  - How do solar eruptions produce energetic particle radiation that fills the heliosphere?
- Mission architecture:
  - In-situ & remote sensing in to 0.3 AU and latitudes up to 30°

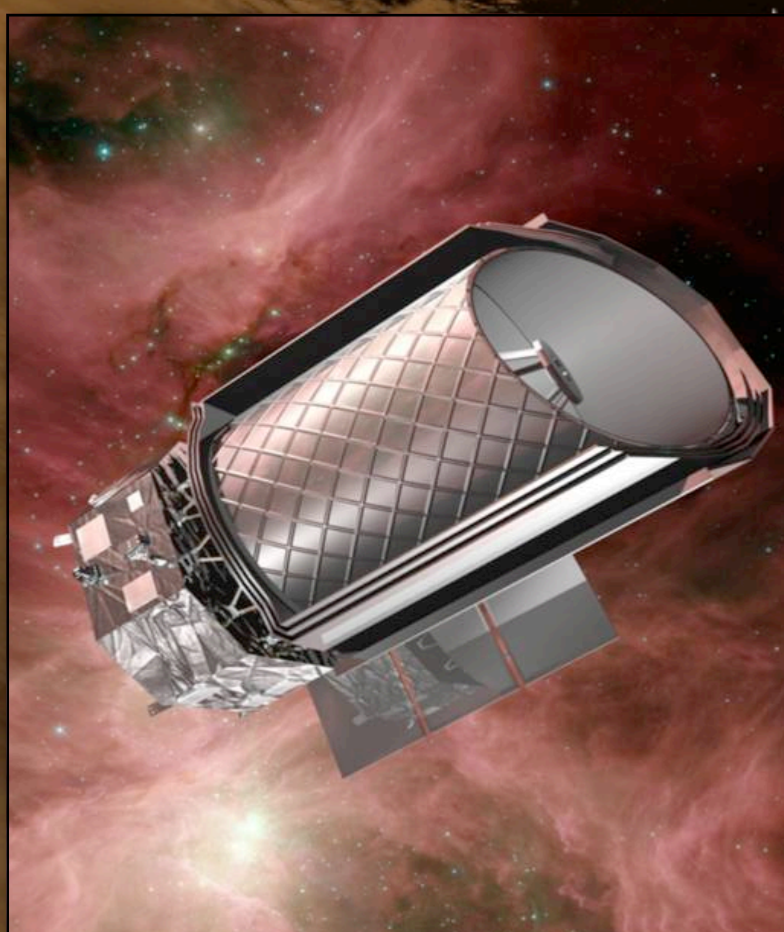




ESA-NASA SOHO LASCO C2, April 2001

SPICA

Cosmic Vision mission-of-opportunity

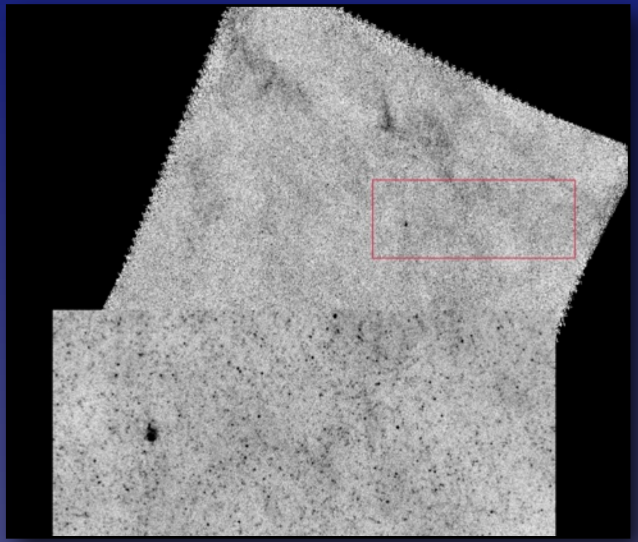


JAXA-led mid-, far-IR cryogenic observatory, possible launch 2018+

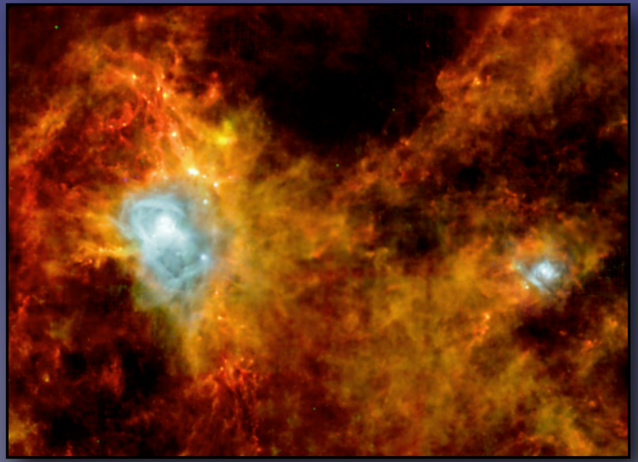
SPICA: beyond Herschel

- 3–3.5m mid, far-IR observatory
  - JAXA-led mission
  - 5–210 μm wavelength range
  - Imaging, spectroscopy, coronagraphy
- Key improvement over Herschel:
  - Actively cooled to ~ 6K
  - Much lower background
  - Much more sensitive
- Likely European contributions:
  - Telescope assembly
  - SAFARI IR FTS instrument
    - Imaging and spectroscopy 34–210μm, 2 x 2 arcmin FOV

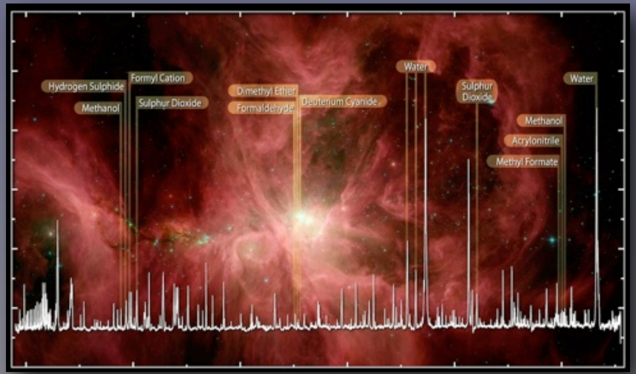
Much better than these!



Deep-field Herschel SPIRE 250μm image, Eales et al.



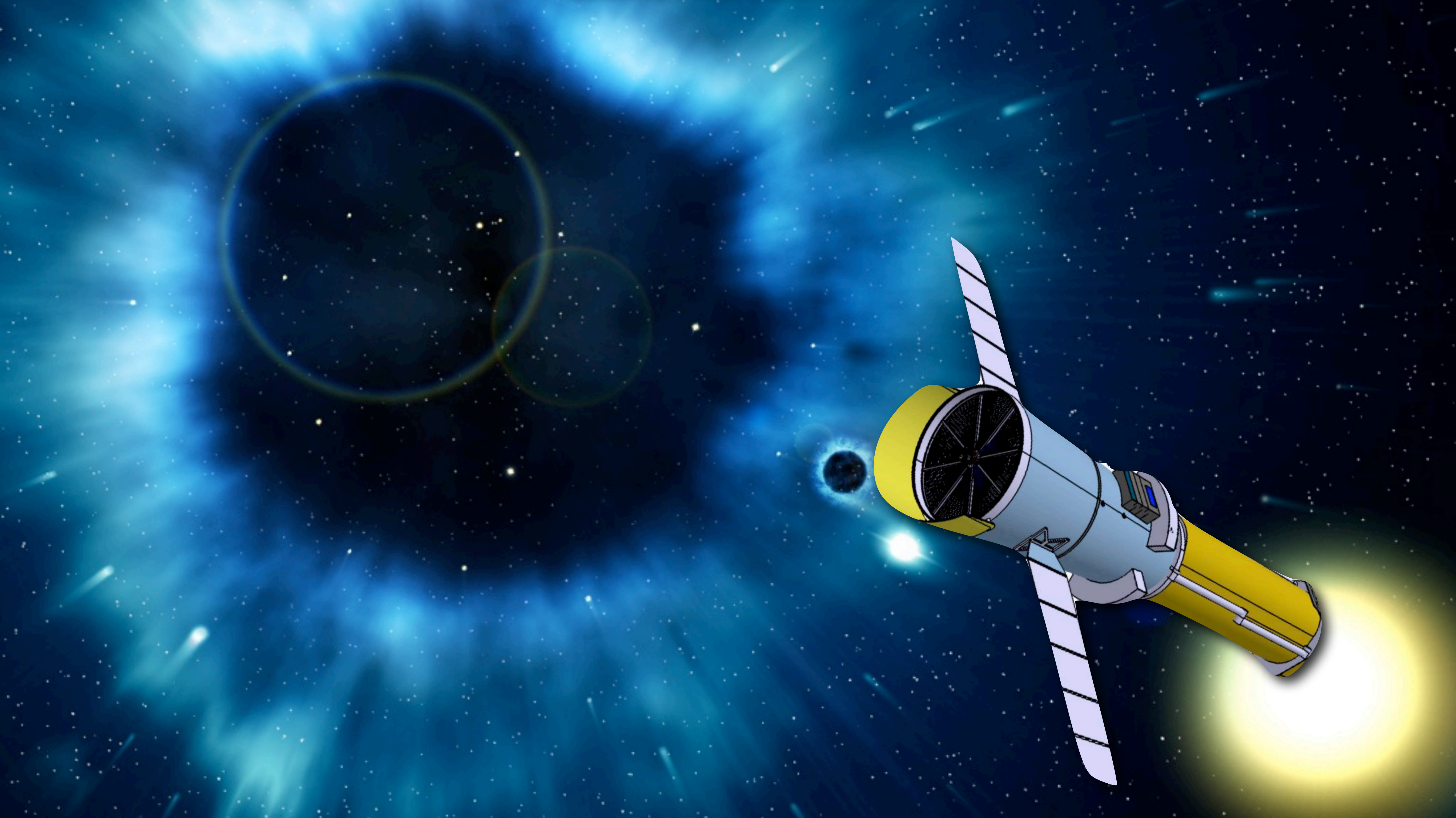
Herschel PACS+SPIRE image in Aquila, André et al.



Herschel HIFI spectrum of Orion, Bergin et al.

X-ray Observatory

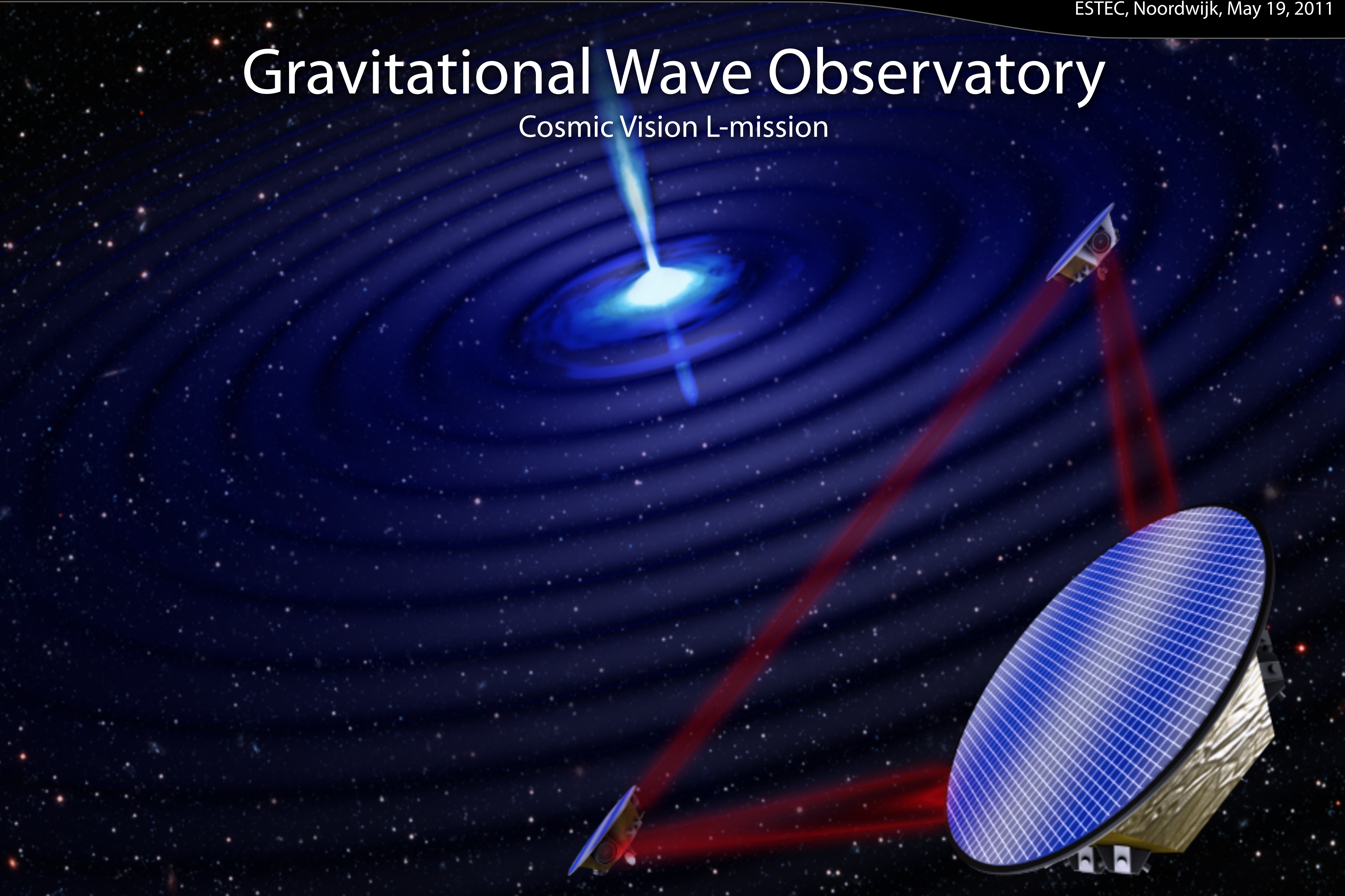
Cosmic Vision L-mission



ESA-JAXA-(NASA?) X-ray astrophysics observatory, possible launch 2020

Gravitational Wave Observatory

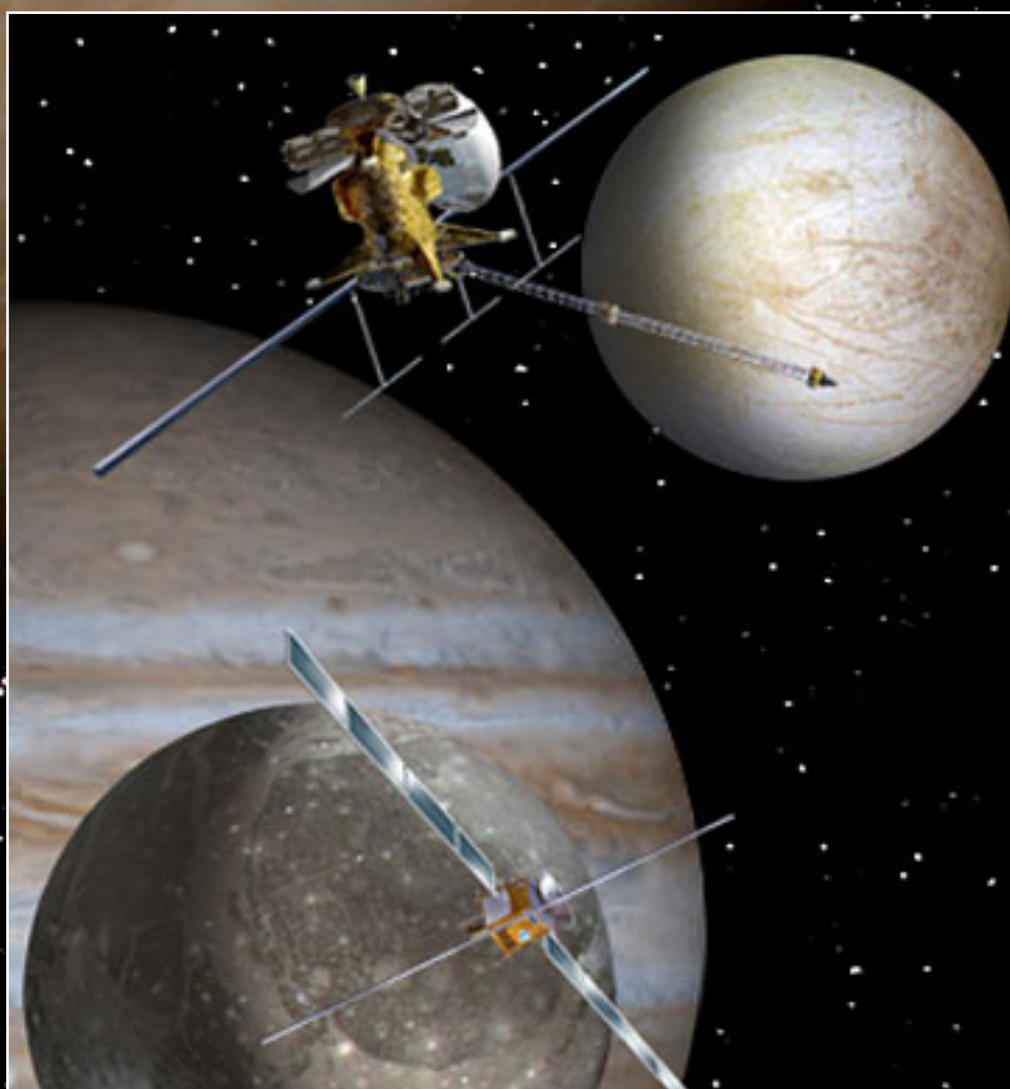
Cosmic Vision L-mission

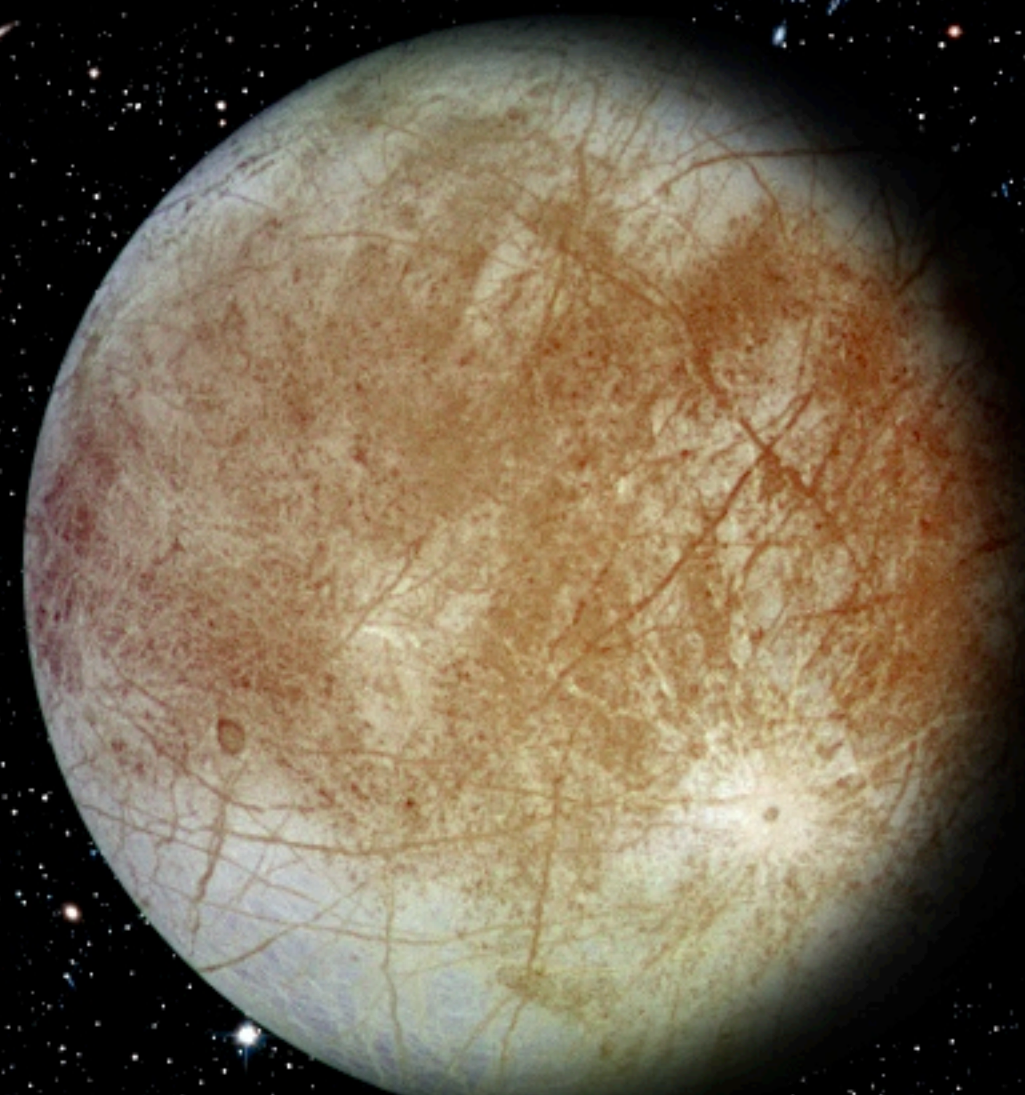


ESA-(NASA?) gravitational wave observatory, possible launch 2020

Jupiter System Mission

Cosmic Vision L-mission





ESA-(NASA?) outer planet mission, orbiter to Europa and Ganymede, possible launch 2020

Closing thoughts

- ESA has a robust space science mission portfolio
  - 17 (15) ESA-led or ESA-partner missions in operation
  - 4 in implementation, 9 under study (Cosmic Vision + ExoMars)
- Some concern about lack of “small” missions
  - Traditionally done by ESA member states
  - Survey community to judge scientific need for small ESA missions
- International collaboration
  - Many current missions are made with partners: often vital
  - Concern about robustness of programme when partner defaults
- Co-operation with ground-based facilities vital
  - Gaia, Euclid, & PLATO all have key ground-based components
  - Joint roadmaps and strategies (e.g. ASTRONET) required