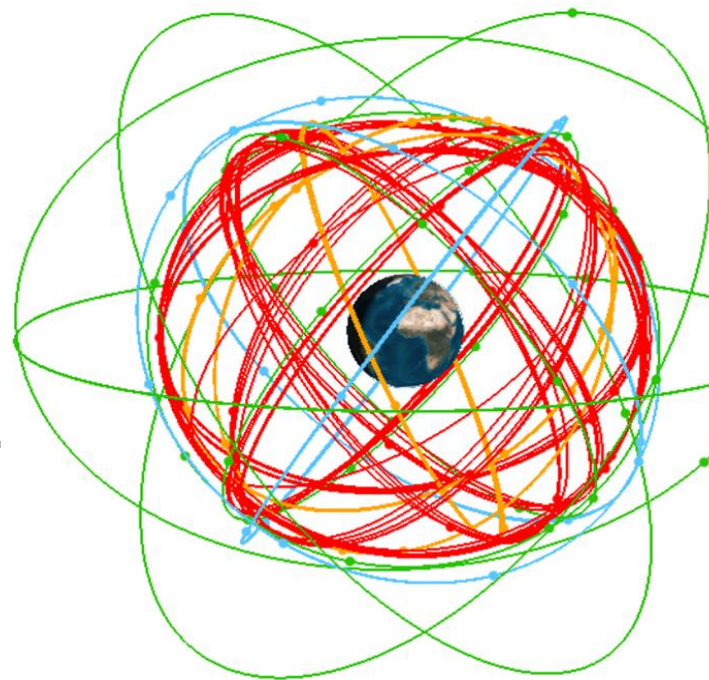


"GNSS Scientific Activities at ESA"

Dr Javier Ventura-Traveset
Head of Galileo Navigation Science Office
European Space Agency

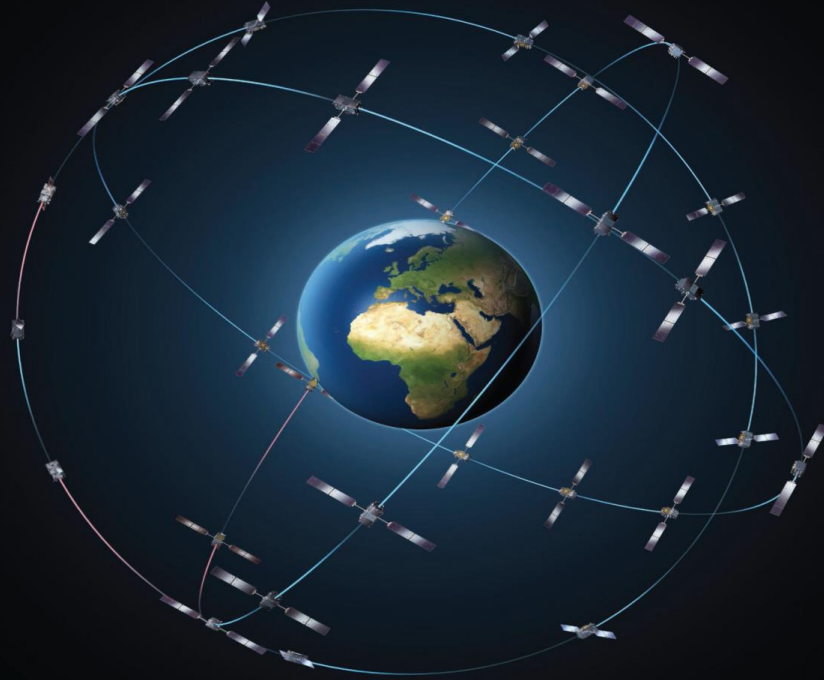
GNSS: A great Opportunity for Science

1. Over **130 GNSS satellites available with unique features for scientific exploitation**
2. Providing **Global coverage, multi-constellation, multi-frequency and long-term data availability** (decades !)
which correlates with many scientific applications.
3. A **dense network of precious GNSS data available worldwide** including several hundreds of professional receivers and **billions of smartphones and IoT sensors.**
4. Systems under **continuous technological improvements** (more stable clocks, new on-board sensors, more signals and of better quality) enhancing scientific possibilities



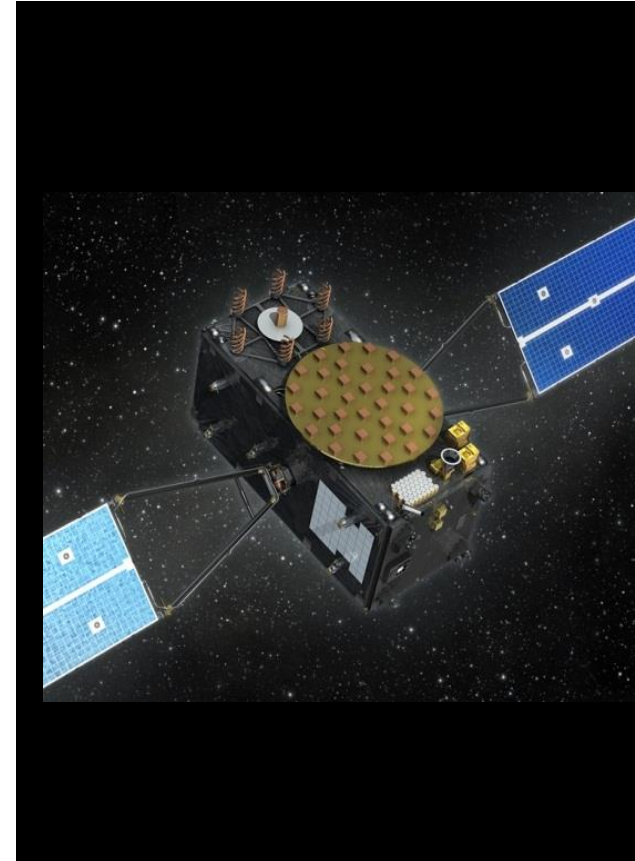
A fantastic opportunity for international Cooperation

GALILEO SPECIALLY SUITED FOR SCIENCE



GALILEO SPECIALLY SUITED FOR SCIENCE

1. Two on-board clock technologies, including Highly stable PHM atomic clocks
2. Robust modulation schemes, large BW and low noise (e.g. E5-AltBOC);
3. Laser Retro Reflectors present on all Galileo satellites;
4. Galileo satellites' revolution period avoids Earth rotation resonances: Stable Galileo orbits without manoeuvres;
5. Radiation monitors in a number of satellites;
6. Two Galileo satellites placed in an eccentric orbit (e.g. excellent source for Fundamental Physics tests).
7. High Accuracy Services available soon
8. Metadata information publicly available for Galileo IOC and FOC satellites



Galileo Satellite Metadata and recent Updates

The **European GNSS Service Centre** (GSC) has provided **updated Galileo Satellite Metadata (April 2019)**:

- Metadata for **Galileo satellites 18 to 26** (L9 and L10) now included
- update of the **Mass, Centre of Mass** and **ANTEX Reference Frame coordinates** for all the others

The **following Metadata information is now available** for all Galileo in-orbit satellites:

- Geometry, dimensions, materials and reflectivity;
- Mass and Centre of Mass (COM);
- Antenna Reference Point (ARP);
- Phase Centre Offsets (PCO) for E1, E5a, E6 and E5b signals;
- Laser Retro Reflector Location; and
- Attitude laws.

<https://www.gsc-europa.eu/>



European
Global Navigation
Satellite Systems
Agency

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European GNSS Service Centre

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APPLICATIONS](#)

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GALILEO HELP DESK

OUR EXPERTS WILL PROVIDE ANSWERS
TO YOUR QUESTIONS, INCIDENTS AND PRODUCTS REQUESTS



GALILEO SYSTEM STATUS

CLICK FOR SATELLITE
INFORMATION AND NOTIFICATIONS

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[GALILEO SATELLITE METADATA](#)

[GALILEO COMPATIBLE DEVICES](#)

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GSTI



Galileo Satellite Metadata

7th GNSS / GALILEO Scientific Colloquium, 4-6 Sept 2019



Scientific and Fundamental Aspects of GNSS / Galileo

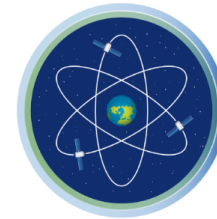
7th International Colloquium

Organised by ESA and ETH University, Zurich in Sept 2019

This bi-annual colloquium brings together members of the International scientific community involved in the use of Galileo and other GNSS in their research. The various possibilities to use GNSS satellites for scientific purposes are reviewed in detail during 3 days.

7th GNSS / GALILEO Scientific Colloquium - Sept 2019

1. About **200 participants** from **25 countries**;
2. A total of **134 technical presentations**;
3. Full coverage of **all identified GNSS scientific fields** with a great scientific return;
4. A selected number of papers will appear on the **Journal of Applied Science** for a **dedicated issue on GNSS Science**.



**Scientific and Fundamental
Aspects of GNSS**

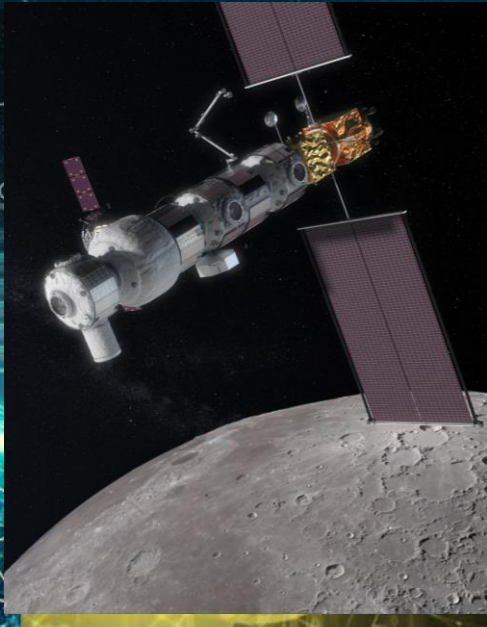
7th International Colloquium



Earth Science & Space Weather



Space Science



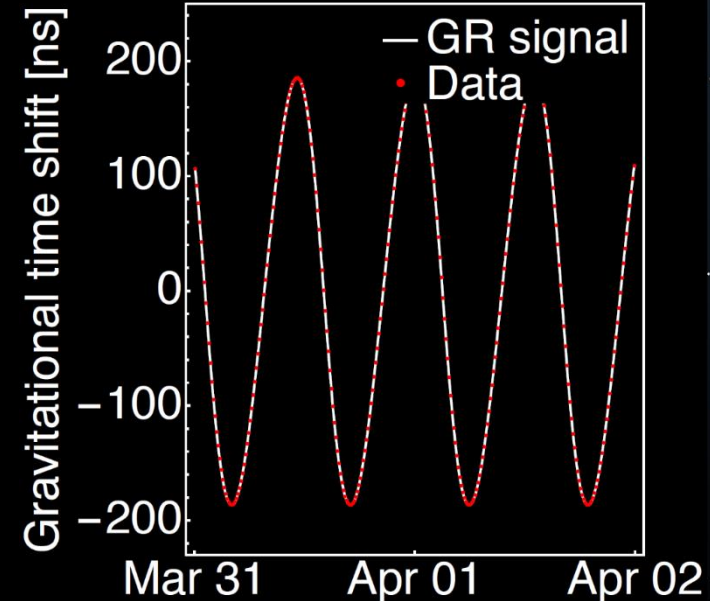
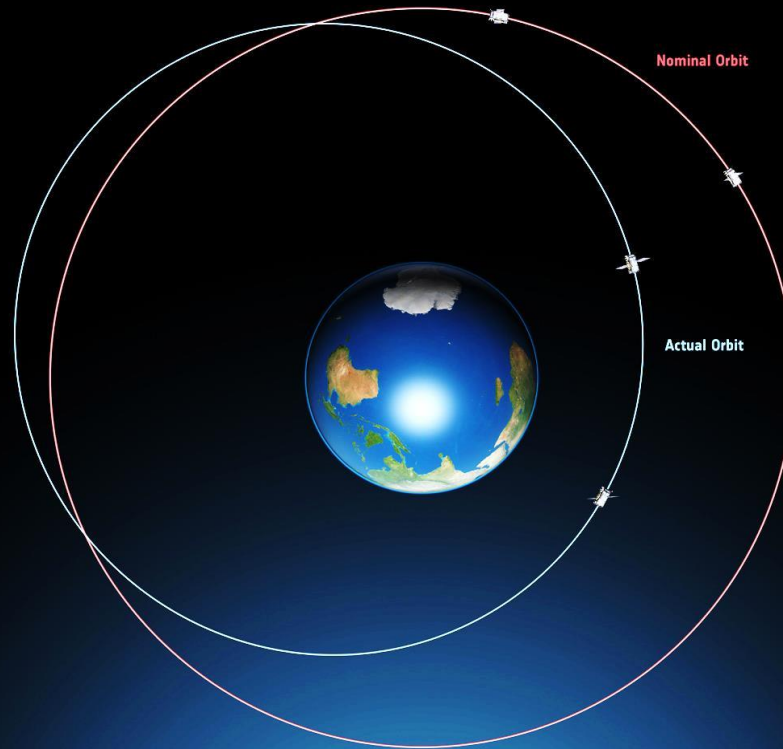
Metrology



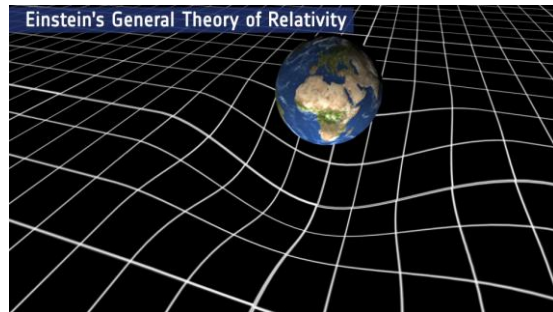
Fundamental Physics



GALILEO ECCENTRIC SATELLITES WITH ACTIVE PHM CLOCKS AND VERY PRECISE ORBITS



Most accurate measurement ever of the **General Relativity**
Gravitational Red-shift (Best measurement in over 40 years)



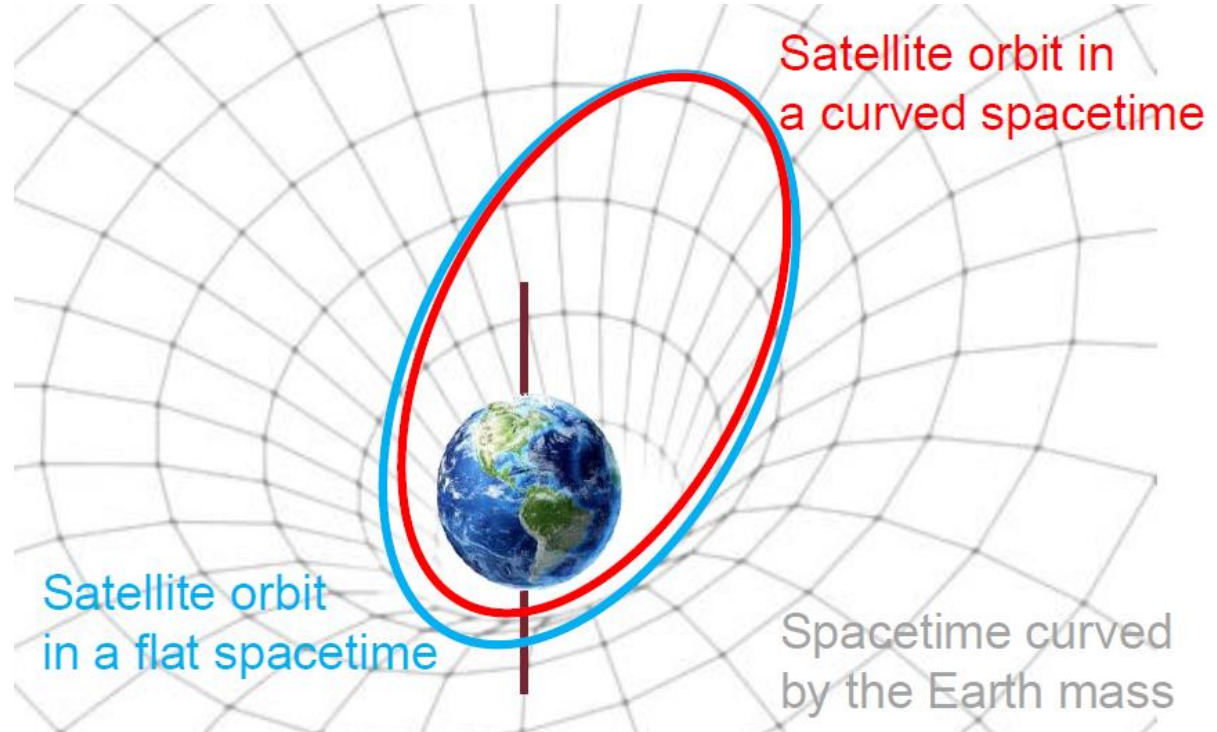
Measurements of Galileo orbit geometry deformations caused by general relativity

Orbit effects

Schwarzschild

Lense-Thirring

De Sitter (Geodetic precession)

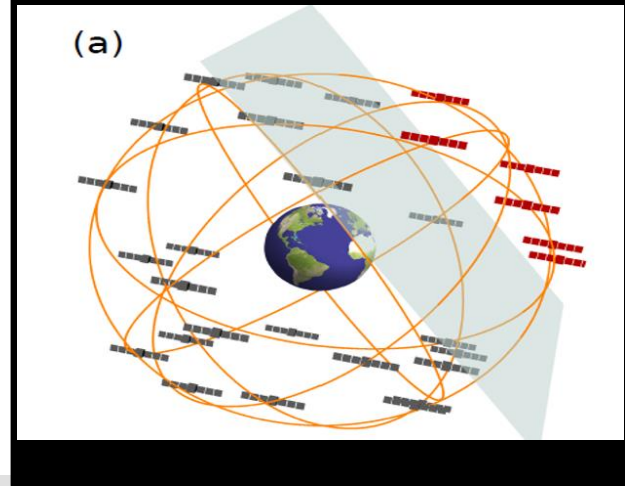


Source: **Wroclaw University (Polland) of Environmental and Life Science**

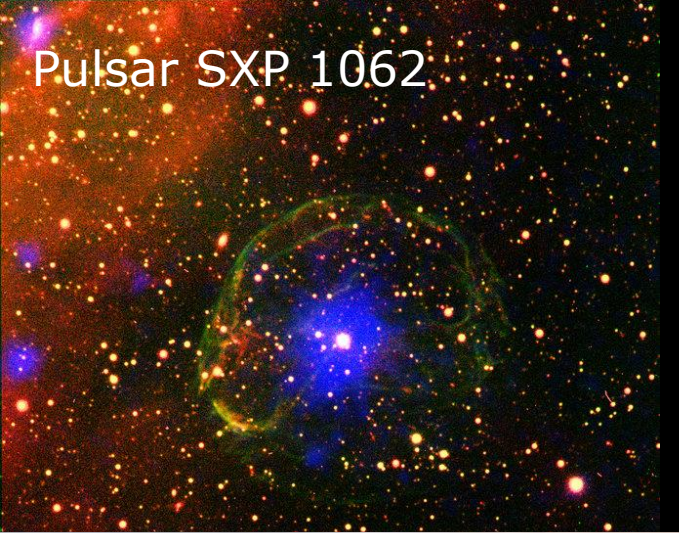
Search for dark matter with atomic clocks on board Galileo

- Some of the theories about Dark Matter suggest this could consist of ultra-light scalar fields, forming topological defects and producing space-time variation of fundamental constants.
- **The large network of atomic clocks and electromagnetic links from the Galileo constellation could act as a gigantic detector of 60000 km of aperture to search for DM.**

Source: SYRTE, CNRS, Royal Belgium Observatory



Pulsar SXP 1062



'PulChron' generating a Pulsar pulsar-based timing system

PulChron aims to demonstrate the effectiveness of a pulsar-based timescale for the generation and monitoring of satellite navigation timing in general, and Galileo System Time in particular



LOVELL TELESCOPE IN UK

Supporting multi-messenger Astronomy with Galileo

By equipping a number of Galileo satellites with light Gamma Ray Burst (GRBs) detectors we could identify the location on neutron merger stars event with 100-1000 more precision (sub-degree level) than with current existing technologies

Source: Max Planck Institute of Extraterrestrial Physics & University of Munich (Germany)

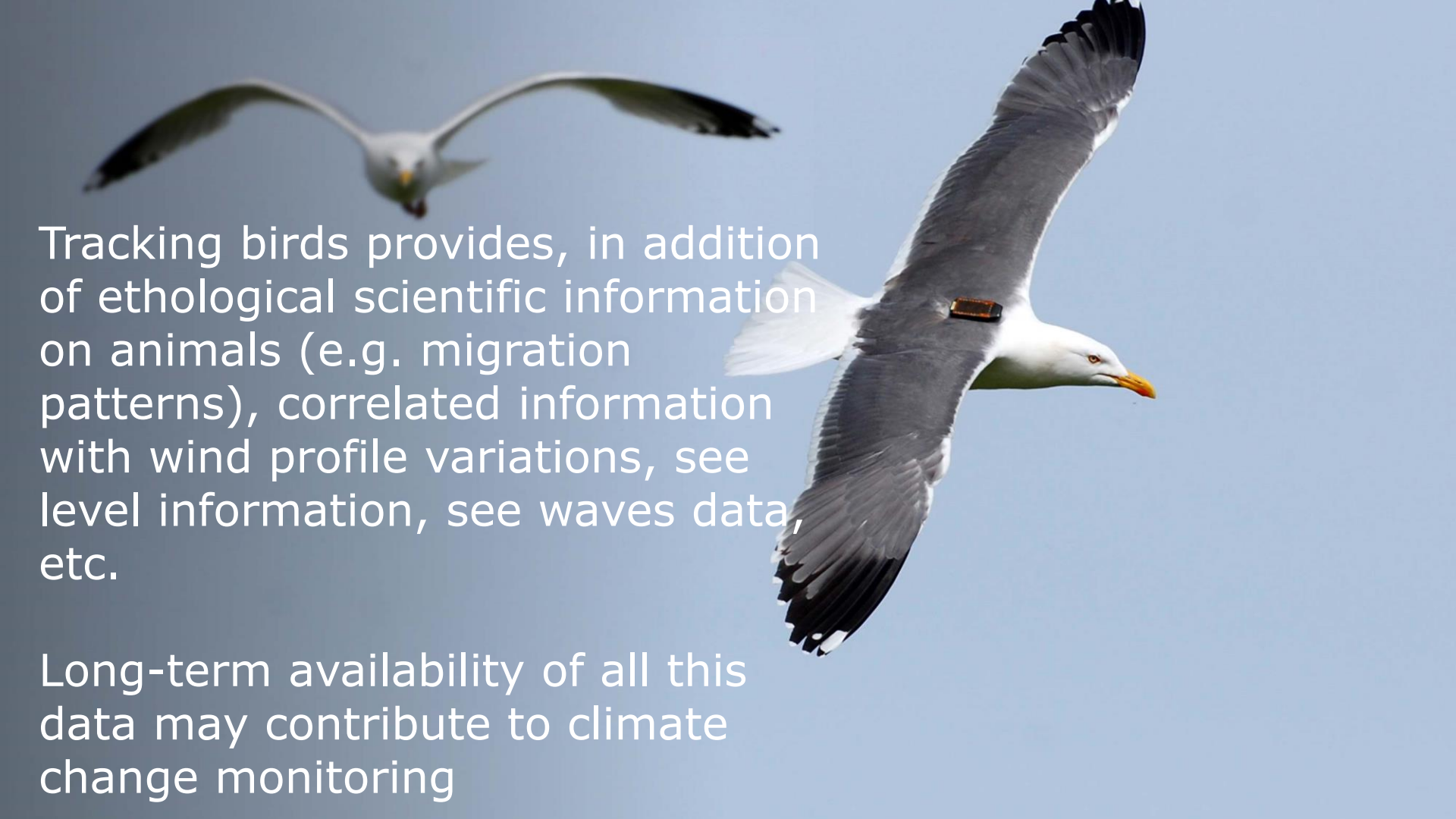


Use of GNSS in support to Climate Change Monitoring and earth science

- **Enhancements on GNSS Radio-occultation & GNSS-R**
- **Weather Monitoring & Collaborative GNSS Crowdsourcing**
- **Exploiting GNSS sensor in trains for weather estimation**
- **IoT, climate monitoring and GNSS**
- **Possibilities of Artificial Intelligence technologies**
- **GNSS big-data and earth monitoring**
- **Animal tracking and climate change information**

**A dedicated panel of GNSS and Climate change was held during
the ESA GNSS Scientific Colloquium**

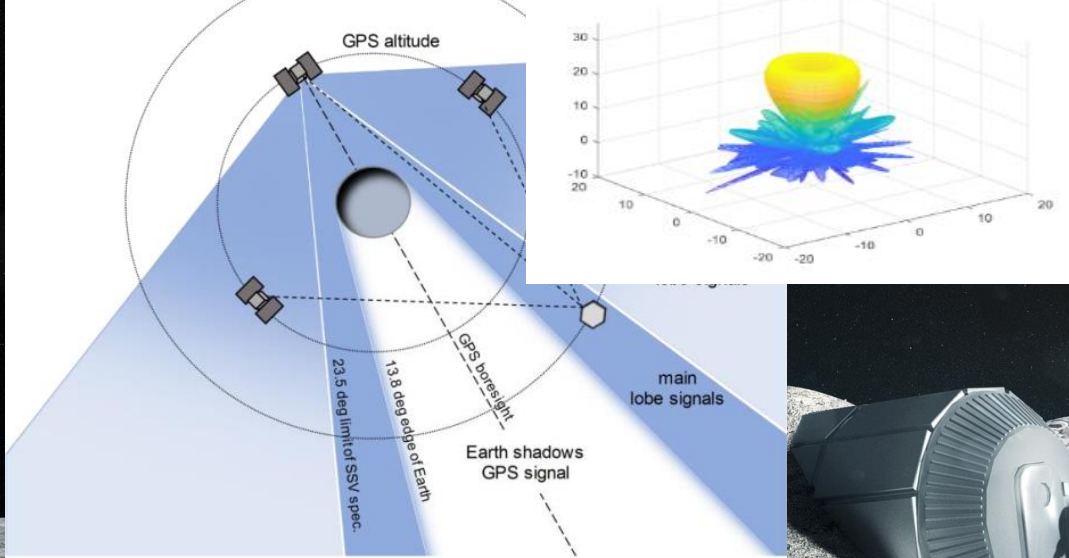




Tracking birds provides, in addition of ethological scientific information on animals (e.g. migration patterns), correlated information with wind profile variations, sea level information, sea waves data, etc.

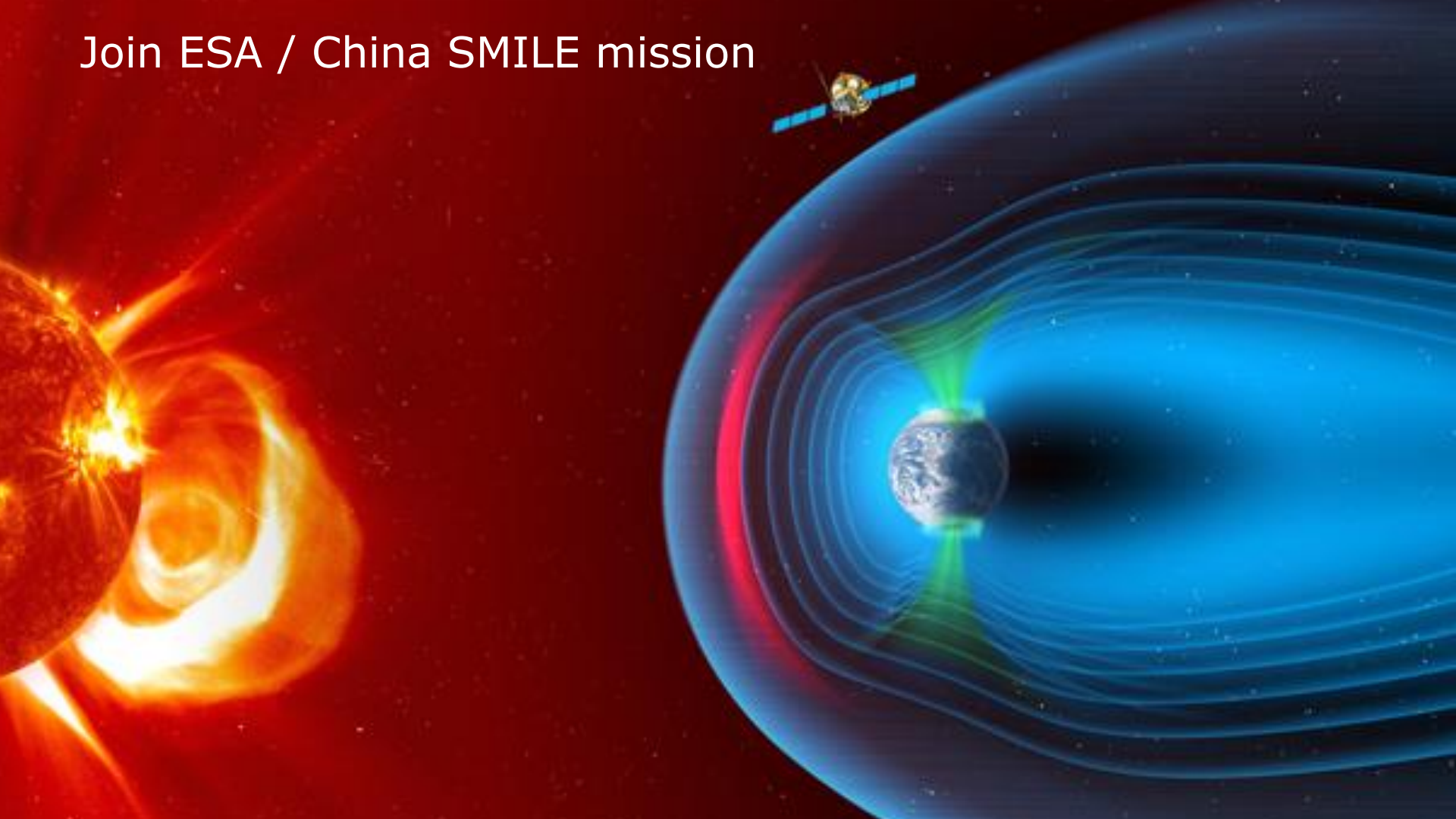
Long-term availability of all this data may contribute to climate change monitoring

GNSS & Space Exploration



1. Development of multi-constellation Space Receivers
2. Detailed Analysis on GNSS moon achievable performances
3. System studies for possible GNSS enhancements / augmentations
4. International cooperation

Join ESA / China SMILE mission

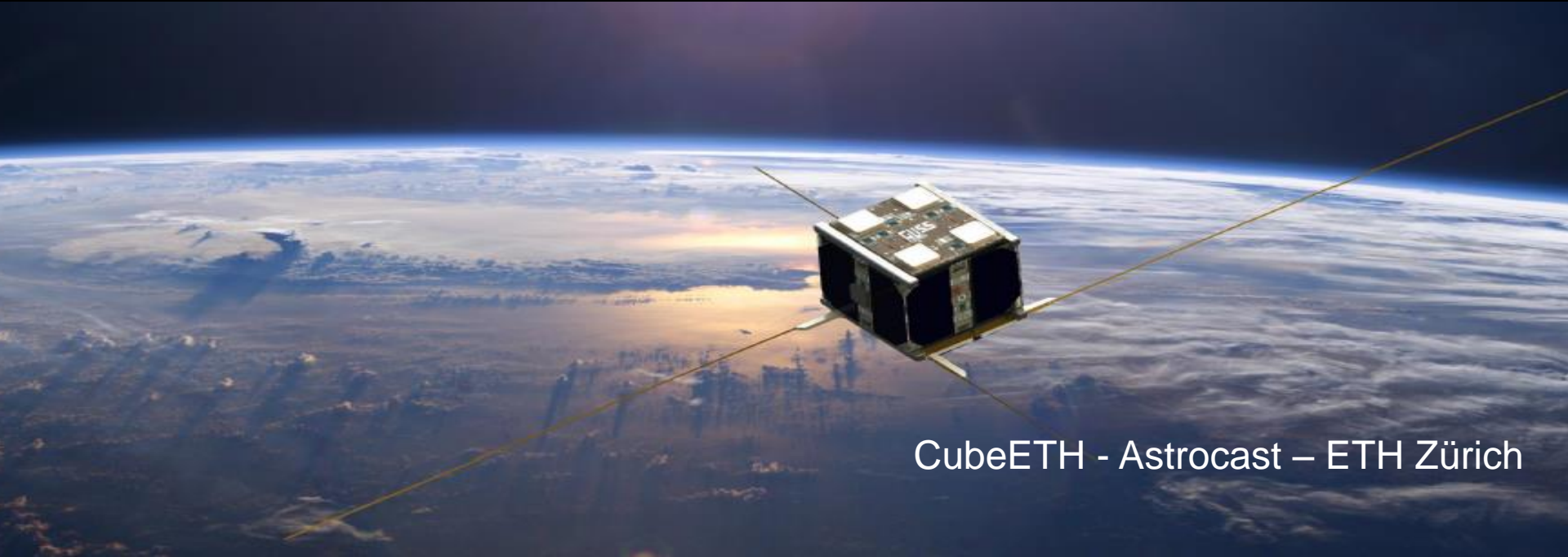


GNSS Science Support Centre at ESA



Our Mission: to provide a world-wide reference **Science Exploitation and Preservation Platform** that fosters **international collaboration** across Science Domains, through the provision of information and processing services based on **GNSS assets**.

Establishing a close cooperation with Universities

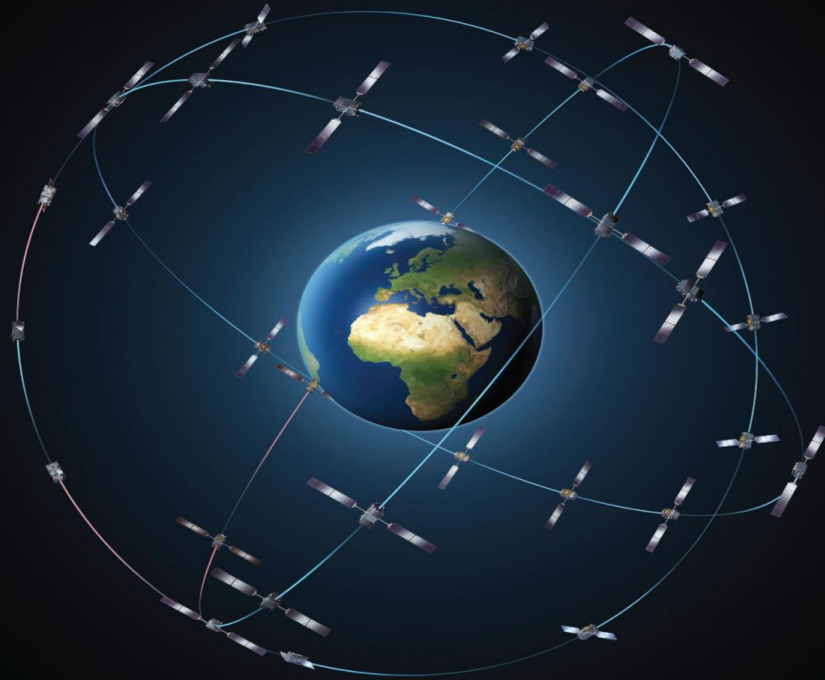


CubeETH - Astrocass – ETH Zürich

To our knowledge first ever space mission exploiting GALILEO, GPS, GLONASS, BEIDOU and the QZSS



Thank you !



GNSS Scientific Fields at this ESA Colloquium

Earth Science and Space Weather:

- E01 Geodesy / Precise positioning
- E02 Geodynamics, geophysics and oceanography
- E03 Global tectonics
- E04 Reference frames
- E05 Ionosphere / space weather
- E06 Troposphere / climatology
- E07 Disaster monitoring
- E08 Gravity field
- E09 GNSS remote sensing, GNSS reflectometry

Fundamental Physics:

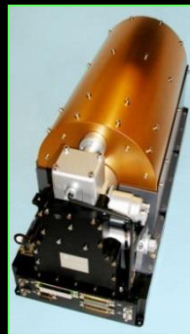
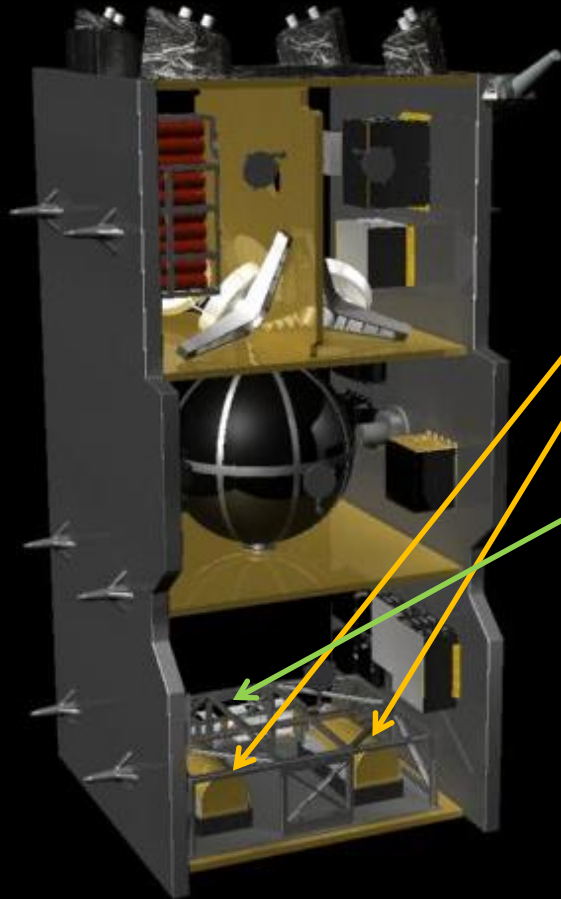
- P01 Test of General Relativity and alternative theories
- P02 Fundamental constants
- P03 Relativistic reference frames
- P04 Relativistic positioning
- P05 Astrometry, VLBI, pulsar timing
- P06 Quantum technologies for positioning and timing
- P07 Gamma Ray Burst detection and GNSS
- P08 GNSS and dark matter

Space-Time Metrology:

- M01 Atomic clocks for space and ground-segment
- M02 Galileo timing system
- M03 Time scales and time transfer
- M04 Inter-satellite links
- M05 Precise orbit determination
- M06 High-precision clocks in receivers

Space Service Volume and transversal activities

- T07 Space service Volume navigation
- N01 Signal processing
- N04 Sensors, hybridization for science
- N06 Animal tracking / Migrations
- T01 GNSS Big Data for science / scientific data archives
- T04 Cubesats and UAVs for GNSS science
- T05 Software receivers / low-cost SDR platforms
- T06 GNSS science and education



Passive Hydrogen Maser

The most stable and accurate

→ Looses no more than 0.5 ns in 12h,

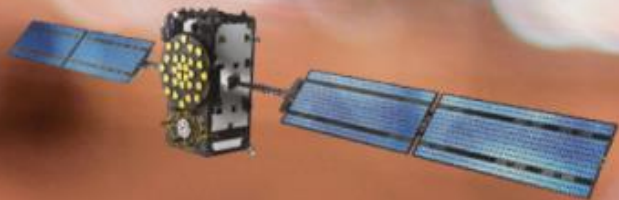
→ Frequency Stability $\sim 10^{-14}$ / day



Rubidium

→ Looses 3s in 1 million of years

All Galileo satellites include
Highly stable PHM clocks
(with 2 placed in eccentric orbit)



GALILEO will soon provide High Accuracy Services (decimetre)

SHAPING EUROPE'S COMPETITIVENESS.

A great Opportunity also for Science !!

#USEGALILEO



European
Global Navigation
Satellite Systems
Agency

