Space Science
A Tool for International Cooperation

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International Space Science Institute
Bern

Main points

- What is space science?
- The main players
- Is International cooperation necessary?
- How did International Cooperation start?
- How to cooperate?
- How not to cooperate?
- The future of International Cooperation

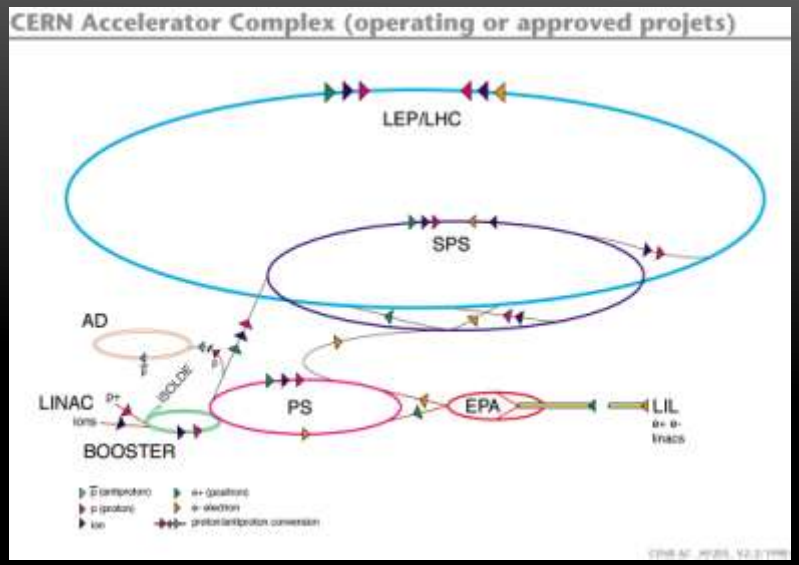
What is Space Science?

- Astronomy and fundamental physics
- Solar System exploration
- Plasma physics
- Earth sciences

Space Science is "Big Science"

Big Science


ALICE
CMS
ATLAS
LHCb


CERN Accelerator Complex (operating or approved projets)
LEP/LHC
SPS
AD
LINAC
BOOSTER
PS
EPA
LIL

Big Science

Big Science

Big Science Tianyan (天眼)

Space Science is Big Science

The main space organizations

- APSCO
- China NSSC, CAS
- Europe ESA
- India ISRO
- Japan JAXA
- Russia IKI
- Thaïland NSPO
- United States NASA

Is there any space science endeavor without IC?

- "Autonomous science" is generally not the best science!
- Science works only best when confronted to the broadest basis of knowledge!
- Science (space science) has always been, is, and will continue to be INTERNATIONAL!
- Hence, best science is dependent upon the broadest international confrontation
- Independence is a political approach, not a science approach!

What projects are concerned

- Mostly B$ projects

- Small projects also but they might be better fit to independent endeavors

Why cooperating?

- Sharing the results of science discoveries
- Some missions may be too big or too costly for one organization alone to build
- Necessary talents may not exist in the principal country
- Bringing added value and complementary expertise

Sharing the results of scientific discoveries

COMETARY SCIENCE

Dust measurements in the coma of comet 67P/Churyumov-Gerasimenko inbound to the Sun

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Critical measurements for understanding accretion and the dust/gas ratio in the solar nebula, where planets were forming 4.5 billion years ago, are being obtained by the GIADA (Grain Impact Analyser and Dust Accumulator) experiment on the European Space Agency's Rosetta spacecraft orbiting comet 67P/Churyumov-Gerasimenko. Between 3.6 and 3.4 astronomical units inbound, GIADA and OSIRIS (Optical, Spectroscopic, and Infrared Remote Imaging System) detected 35 outflowing grains of mass 10^{-10} to 10^{-7} kilograms, and 48 grains of mass 10^{-5} to 10^{-2} kilograms, respectively. Combined with gas data from the MIRO (Microwave Instrument for the Rosetta Orbiter) and ROSINA (Rosetta Orbiter Spectrometer for Ion and Neutral Analysis) instruments, we find a dust/gas mass ratio of 4 ± 2 averaged over the sunlit nucleus surface. A cloud of larger grains also encircles the nucleus in bound orbits from the previous perihelion. The largest orbiting clumps are meter-sized, confirming the dust/gas ratio of 3 inferred at perihelion from models of dust comae and trails.

Although accurate measurements of the gas loss rate from comets are possible under favorable conditions even from Earth, estimates of the dust loss rate have been more uncertain thus far. Multiparametric models are needed to extract global dust parameters from the dust features of comets (coma, tail, and trail) observed from the ground and Earth-orbiting telescopes, and it is often difficult to establish the uniqueness of these model results. Past space missions had onboard instruments devoted to the measurement of the dust flux. Because all of these missions were fast flybys, it was impossible to disentangle the dust grains coming directly from the nucleus from those reflected back by solar radiation pressure (*1*, *2*). The latter component could explain part of the excess of millimeter-sized particles, showing as a bulge of the size distribution above the fitting power law derived by the observations performed during flybys at 1P/Halley (*3*) and at short-period comets 26P/Grigg-Skjellerup, 81P/Wild 2, and 9P/Tempel 1 (*4*–*6*).

An even more severe bias could affect all estimates of dust/gas ratio obtained so far in comets. The dust/gas ratio measured in 1P/Halley was close to 2 (*3*), but this number is valid up to the largest mass of ~1 g observed by the DIDSY (Dust Impact Detection System) detector (actually, this largest-mass grain was invoked to explain the spacecraft precession-inducing impact that occurred just before closest approach). Theoretical models predict that 1P/Halley was then ejecting larger masses, and the dust/gas ratio strongly depends on the actual largest grain ejected in the coma. Because it was impossible to fix the size distribution between 1 g and the unknown largest ejected mass, we cannot exclude dust/gas values a factor of 10 higher. In this paper, we show that for comet 67P/Churyumov-Gerasimenko (67P hereafter), we can disentangle the two families of ejected grains (direct and reflected) and extract the dust size distribution up to the largest ejected grain, obtaining for the first time an accurate estimate of the dust/gas ratio.

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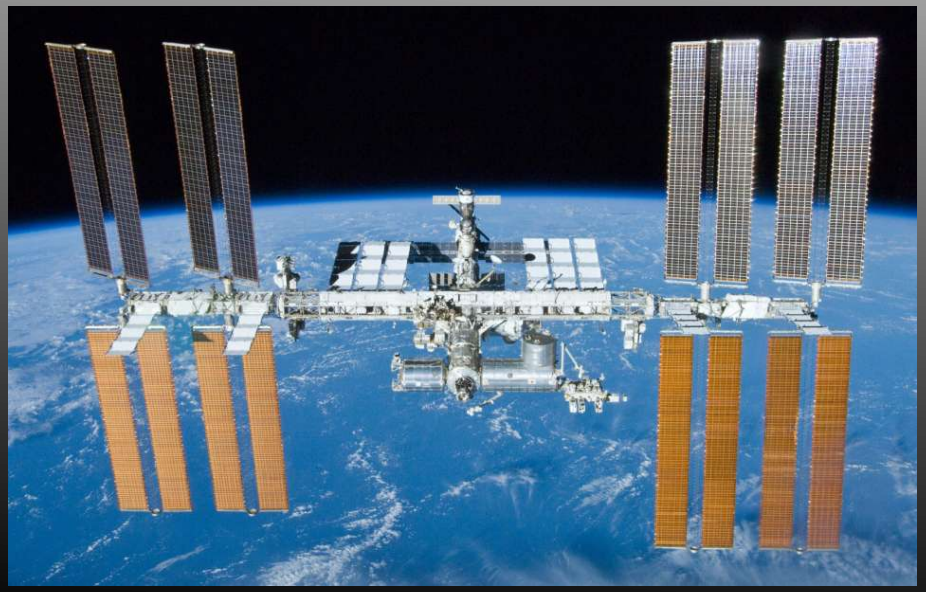
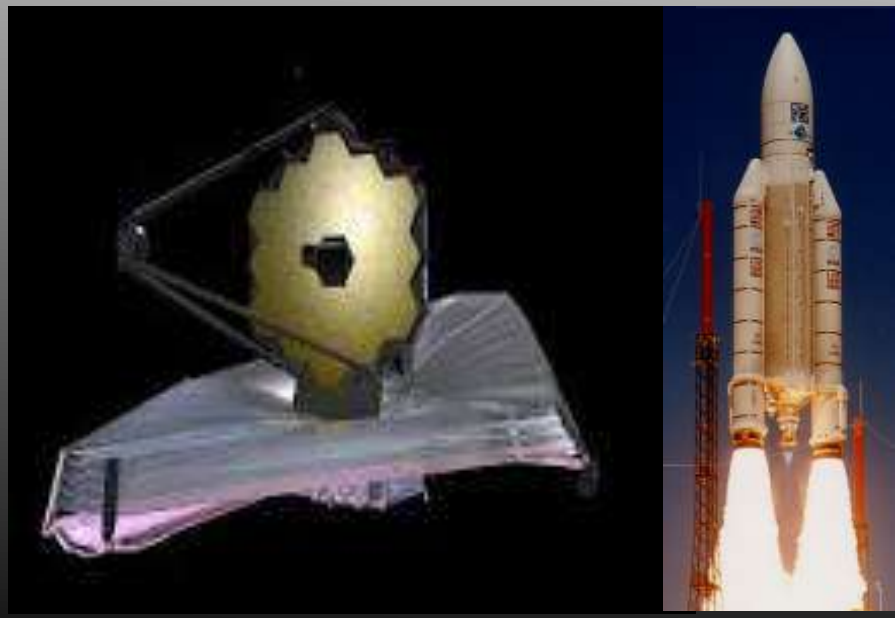
Some missions may be too big or too costly for one organization alone to build



ISS

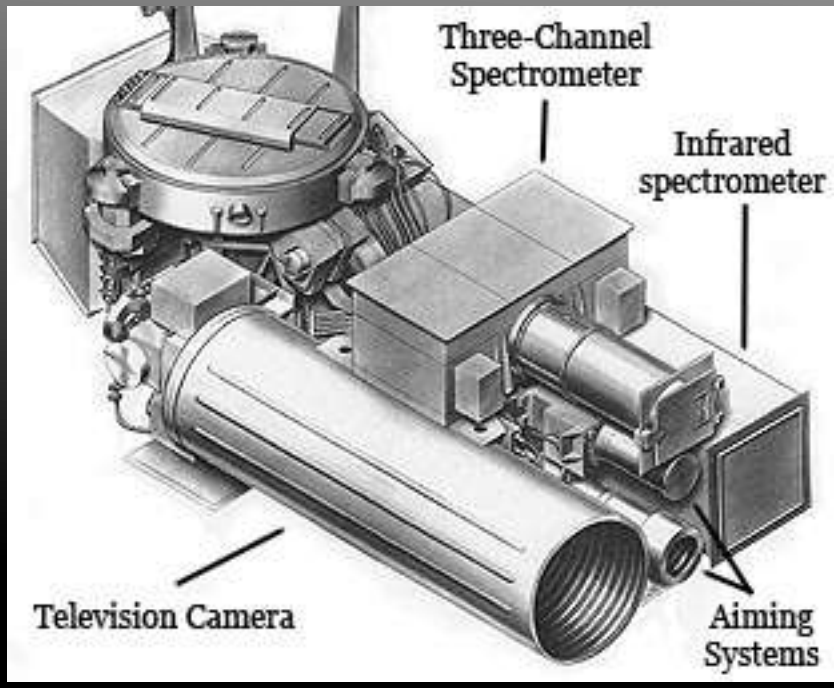


JWST

Necessary talents may not exist in the principal country

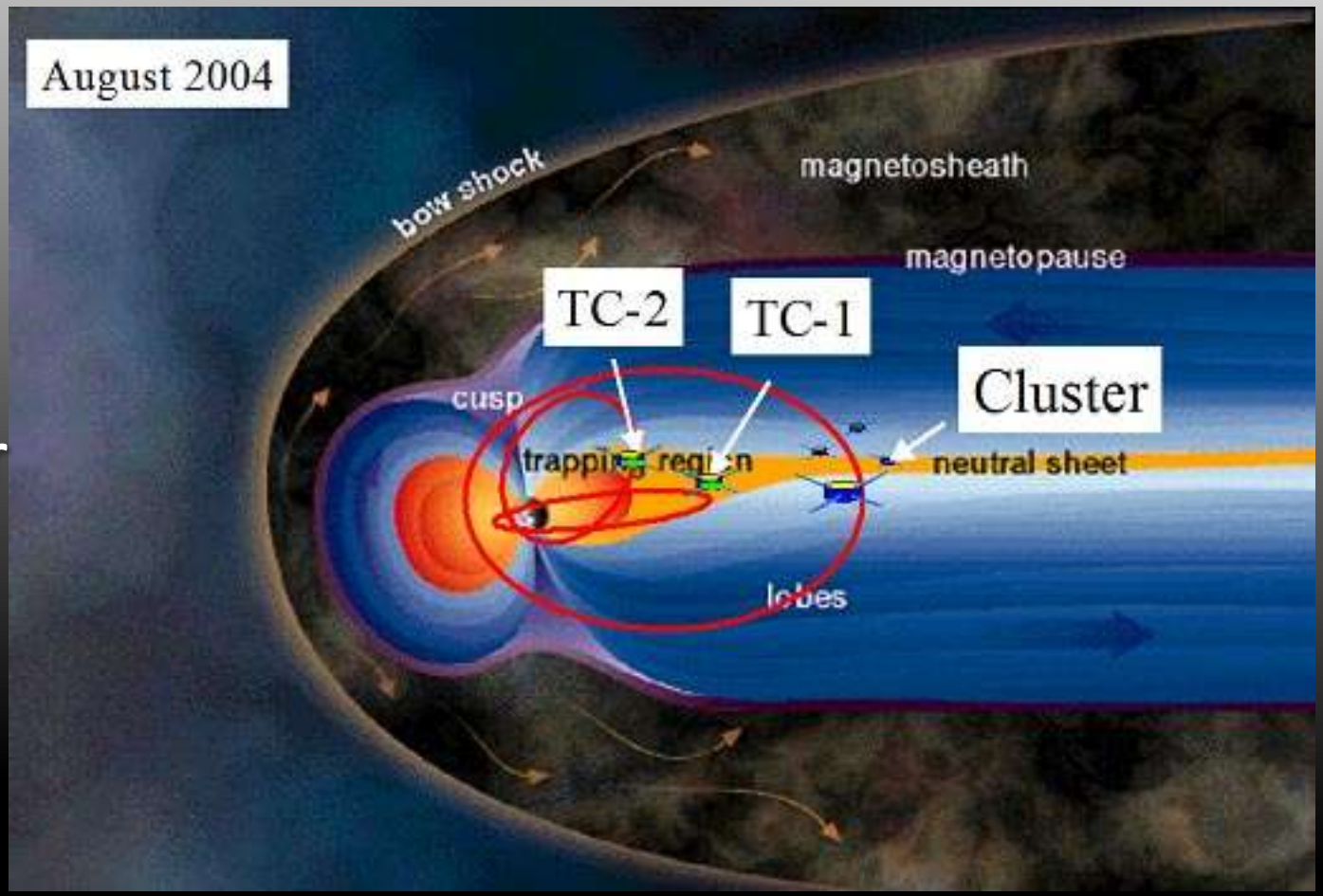
VEGA

IKS



Bringing added value and complementary expertise

- DAMPE
- Double Star
- QUANTUM



IAA Team Achievement Award 2010

How did it start?

- In the difficult context of the Cold War after the launch of Sputnik 1
- Competition was strong between the two super powers

Explorer 1

How did it start?

Soon the space and scientific community created means of cooperation:

- COSPAR
  - (Beijing-2006, Mysore-2012, Leningrad-1970, Tokyo-1968, Nagoya, 199…
- IAA (1960)
- ISSI (1995), ISSI-BJ (2013)

INTERNATIONAL
SPACE
SCIENCE
INSTITUTE

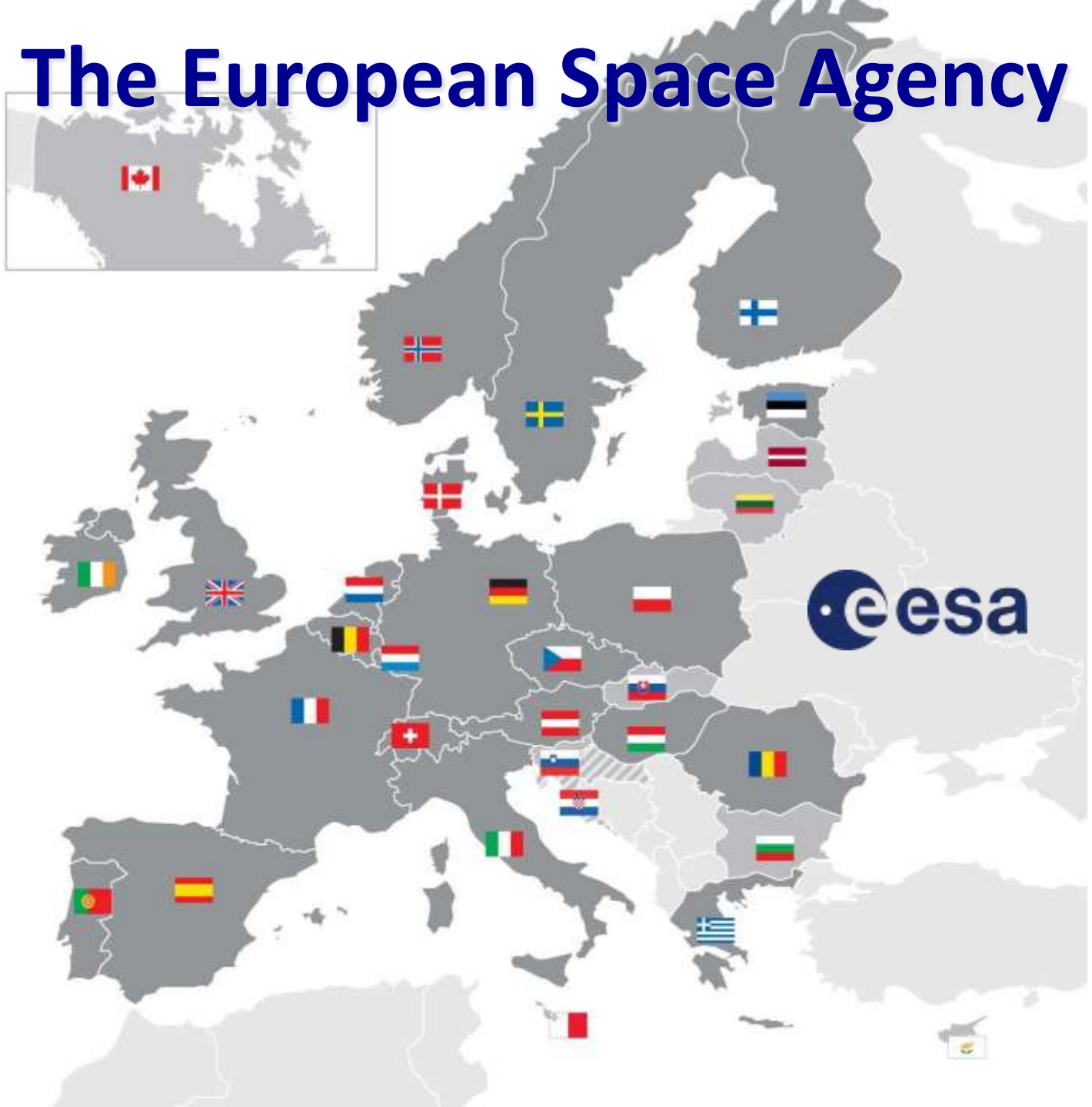
- International Teams
- Workshops
- Working groups
- Forums
- Summer Schools
- Visiting scientists

How to cooperate?

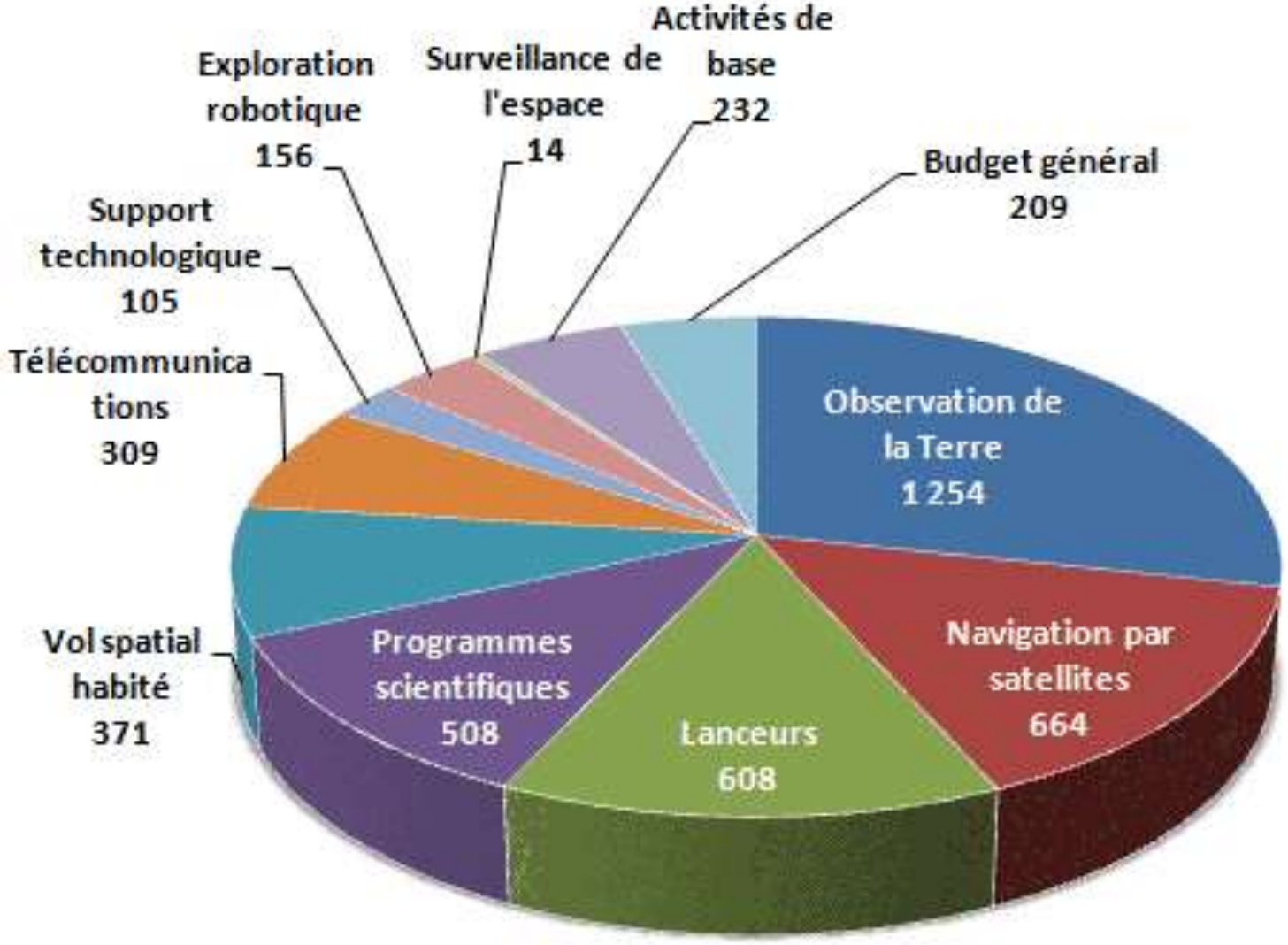
How to cooperate?

- The ESA approach
- Mutual interest through complementary contributions from the partners
- One leading partner is usually needed
- Mutual respect among the partners is a mandatory rule for a successful result
- Examples of various cooperative missions

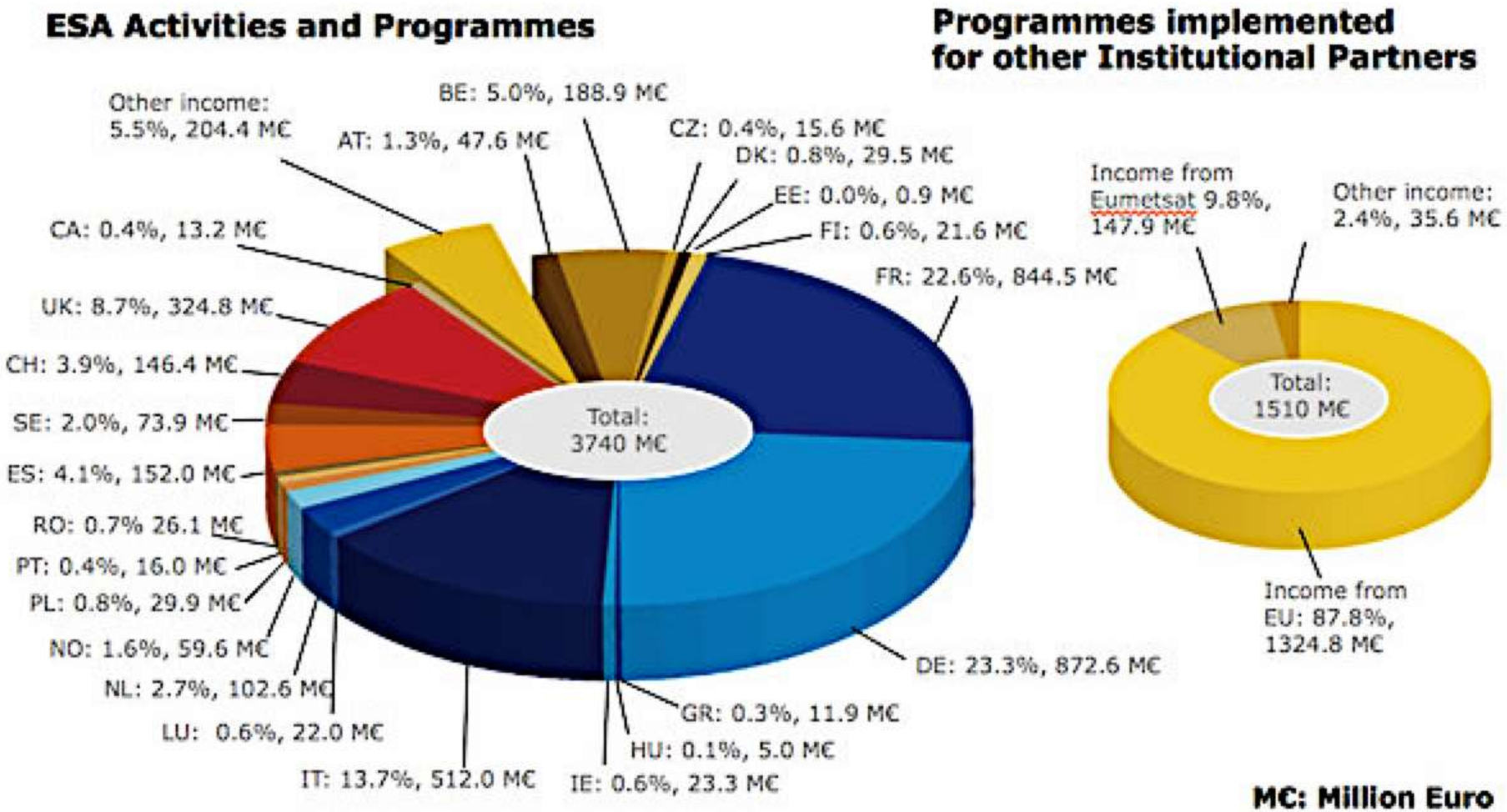
The European Space Agency



ESA Programs and respective Budgets (Billions €)



ESA Budget for 2016



TOTAL ESA BUDGET FOR 2016: 5250 M€

The ESA approach to International cooperation

- Concerns mostly missions too big for a single European nation to develop
- Share of responsibility between Member states and ESA:
  - ESA provides the common systems (Spacecraft, Launcher, in orbit operations, data delivery,
  - Member states fund all expenditures related to these parts of the scientific payload developed in their respective country
- “Coopetition”: Member states ESA contributions are in competition with their domestic activities


Council Meeting at Ministerial Level
Grand Duchy of Luxembourg, 2 December 2014

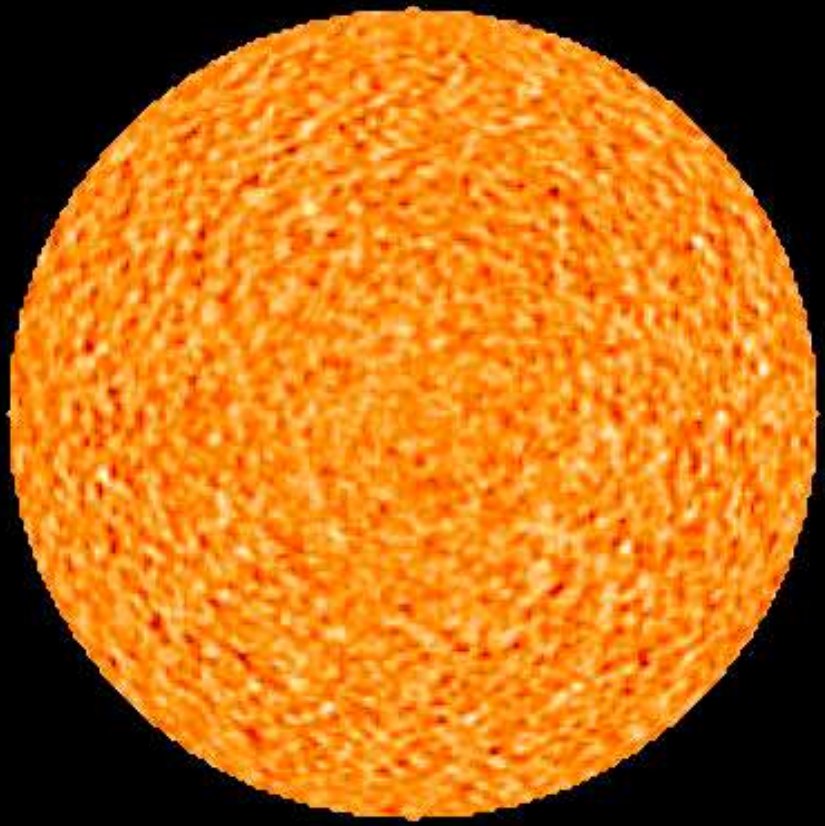
Hardware contribution
HST

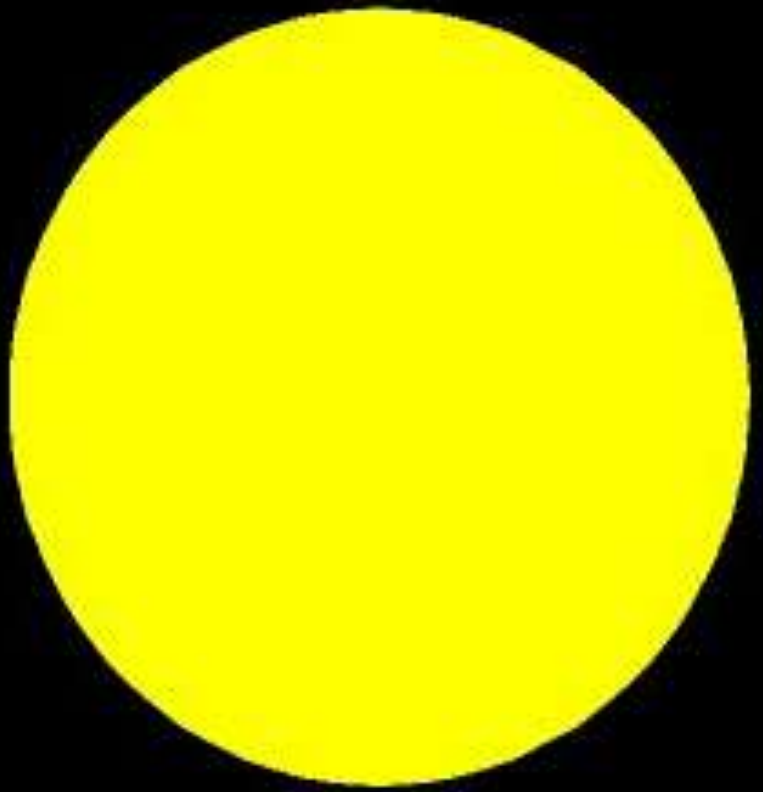
Hardware contribution
SoHO

- Joint program between the European Space Agency (ESA) and NASA.
  - An industry team led by Matra Marconi Space built SOHO in Europe. It's instruments were provided by nine European and three U.S. Principle Investigators
  - ESA: responsible for SOHO's procurement, integration, and testing
  - NASA: provided launch and mission operations (at Goddard Space Flight Center)

Launch 2 December 1995

Probing the Sun's interior





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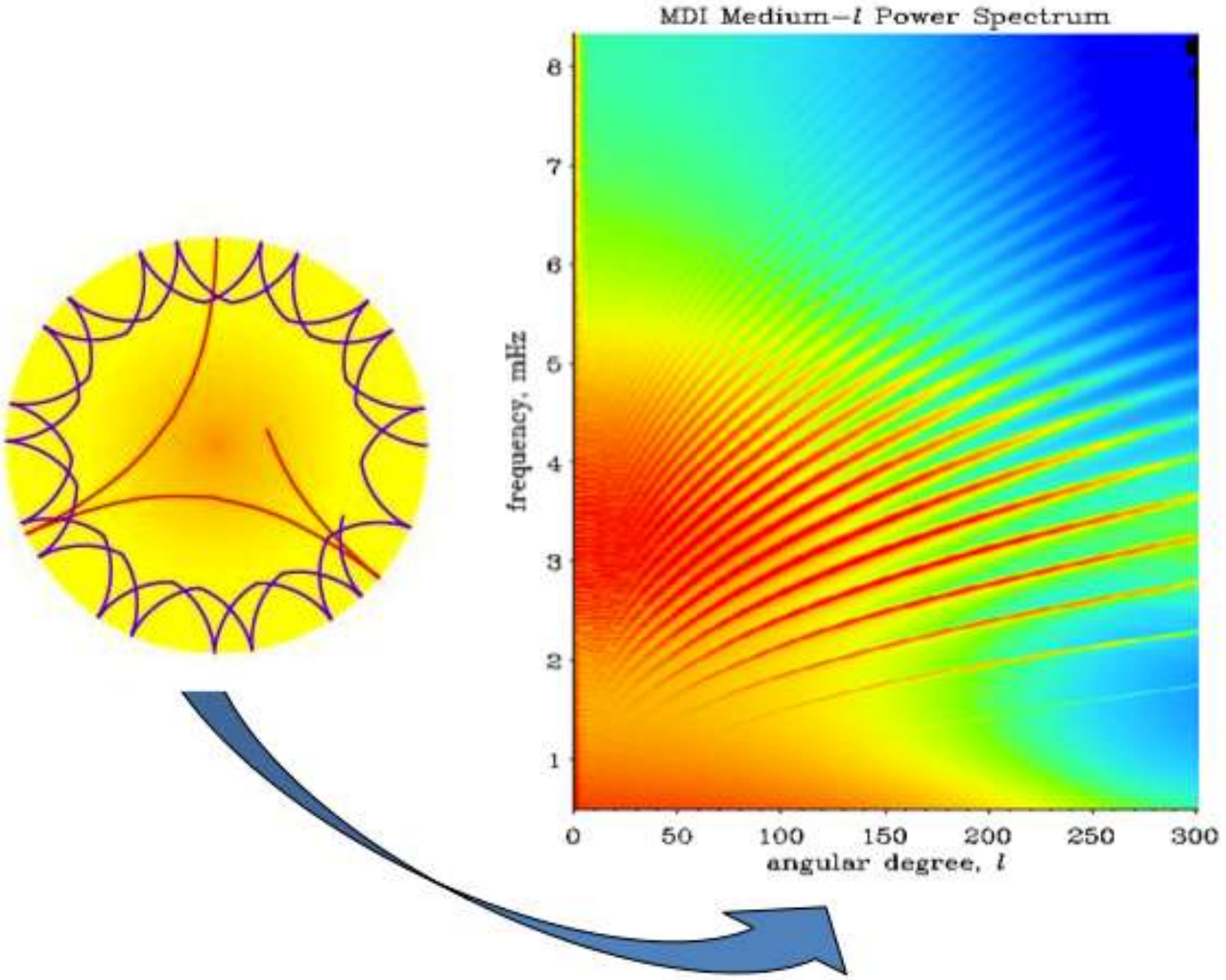
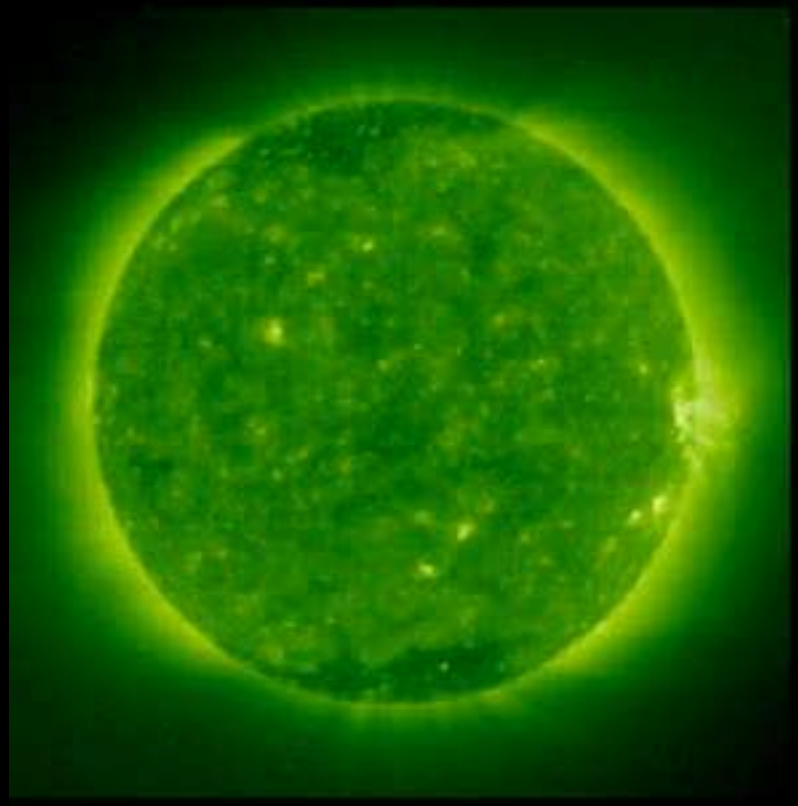
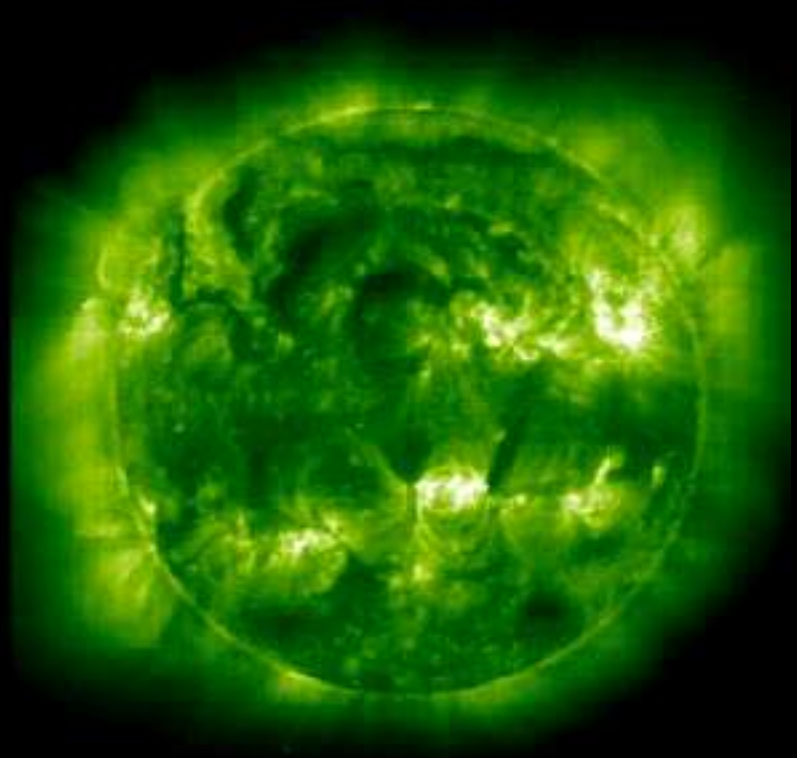


Comets and CMEs

The solar corona as seen from SOHO

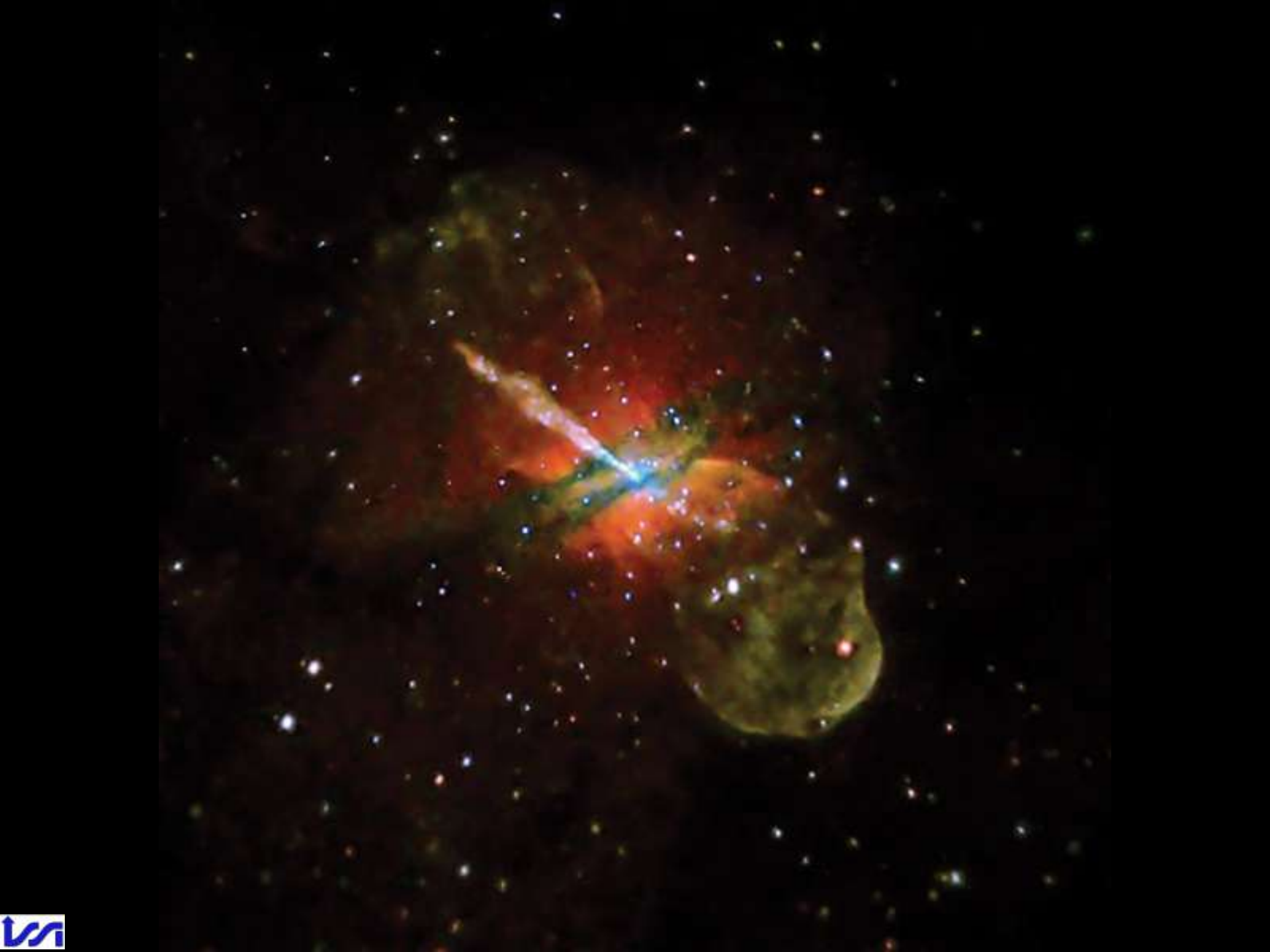




Complementarity

XMM-Newton ESA

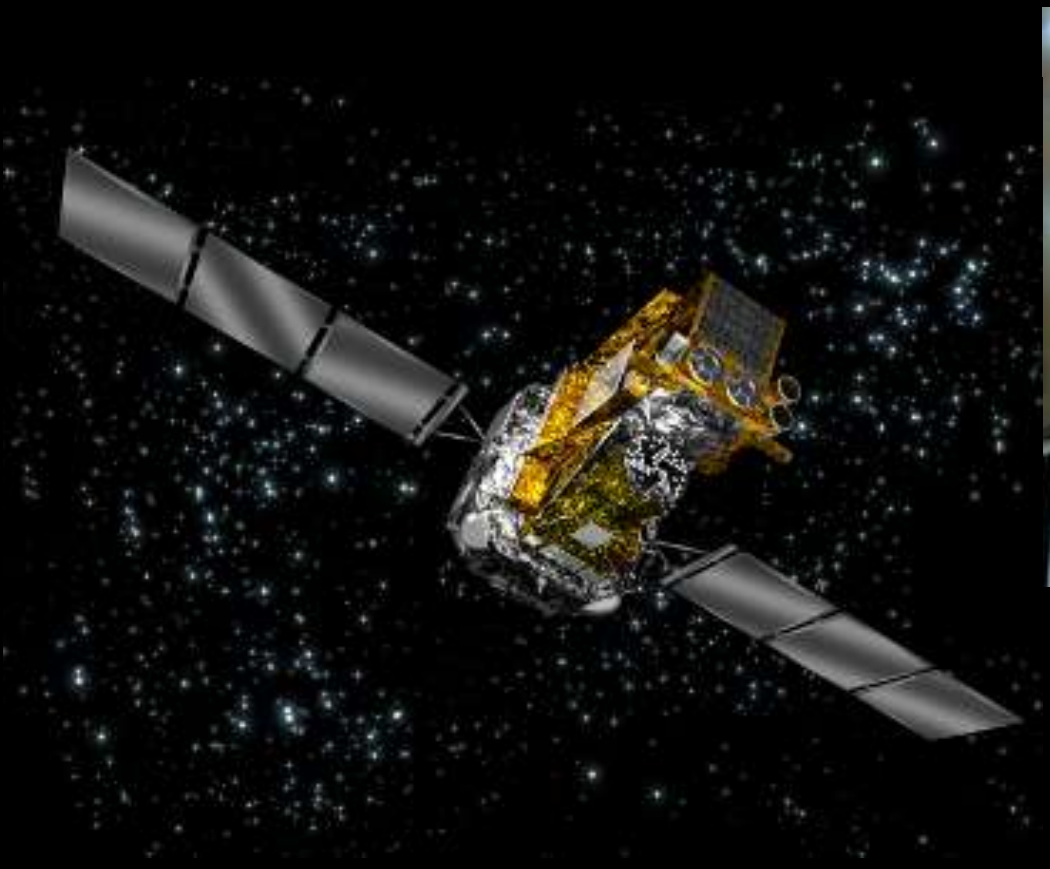
Chandra- NASA



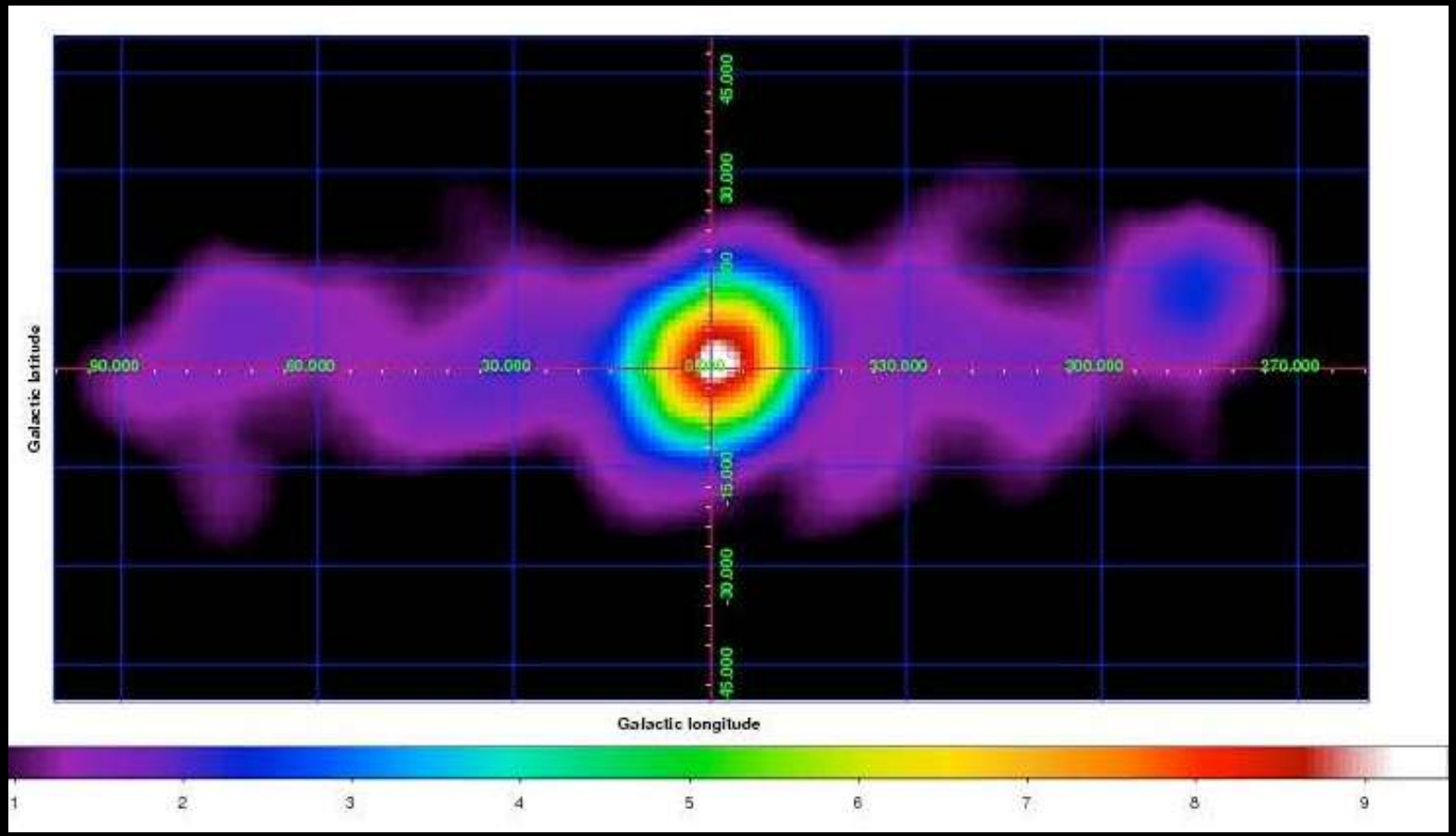
Multilateral agreements

INTEGRAL (ESA-Russia-NASA)

INTErnational Gamma-Ray Astrophysics Laboratory

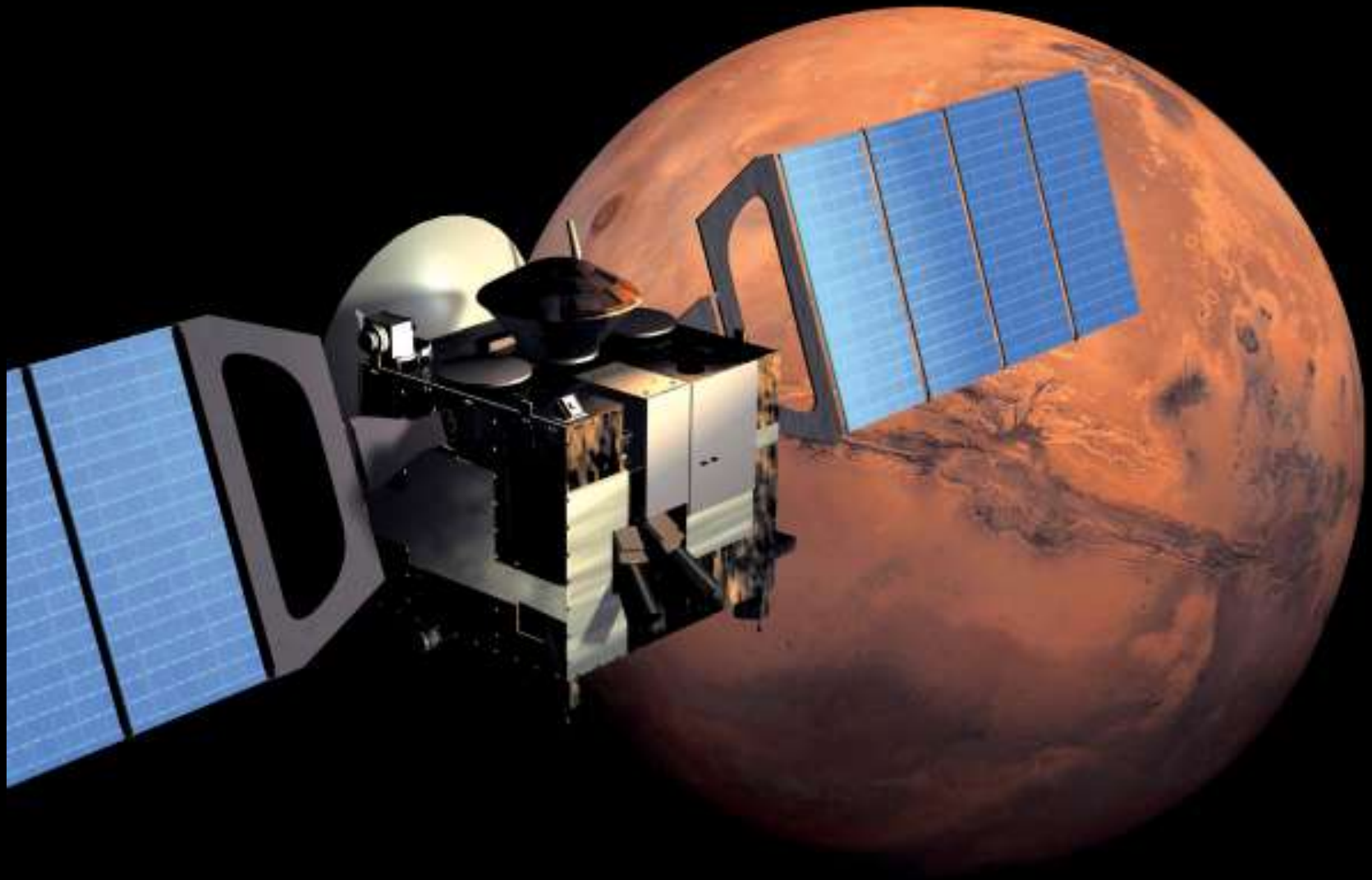


INTEGRAL

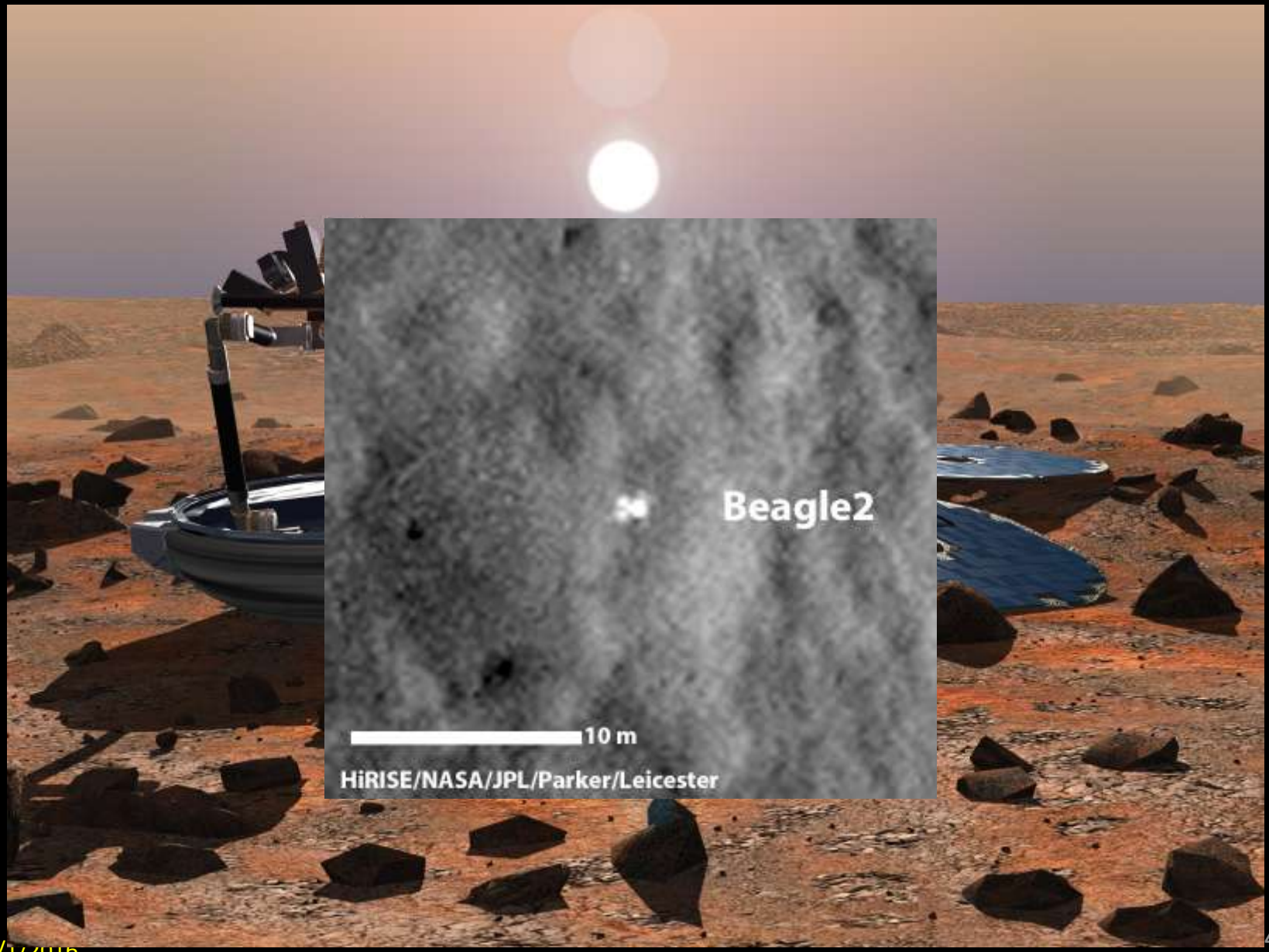


Spatial distribution of the 511 KeV positron annihilation emission in the galactic center

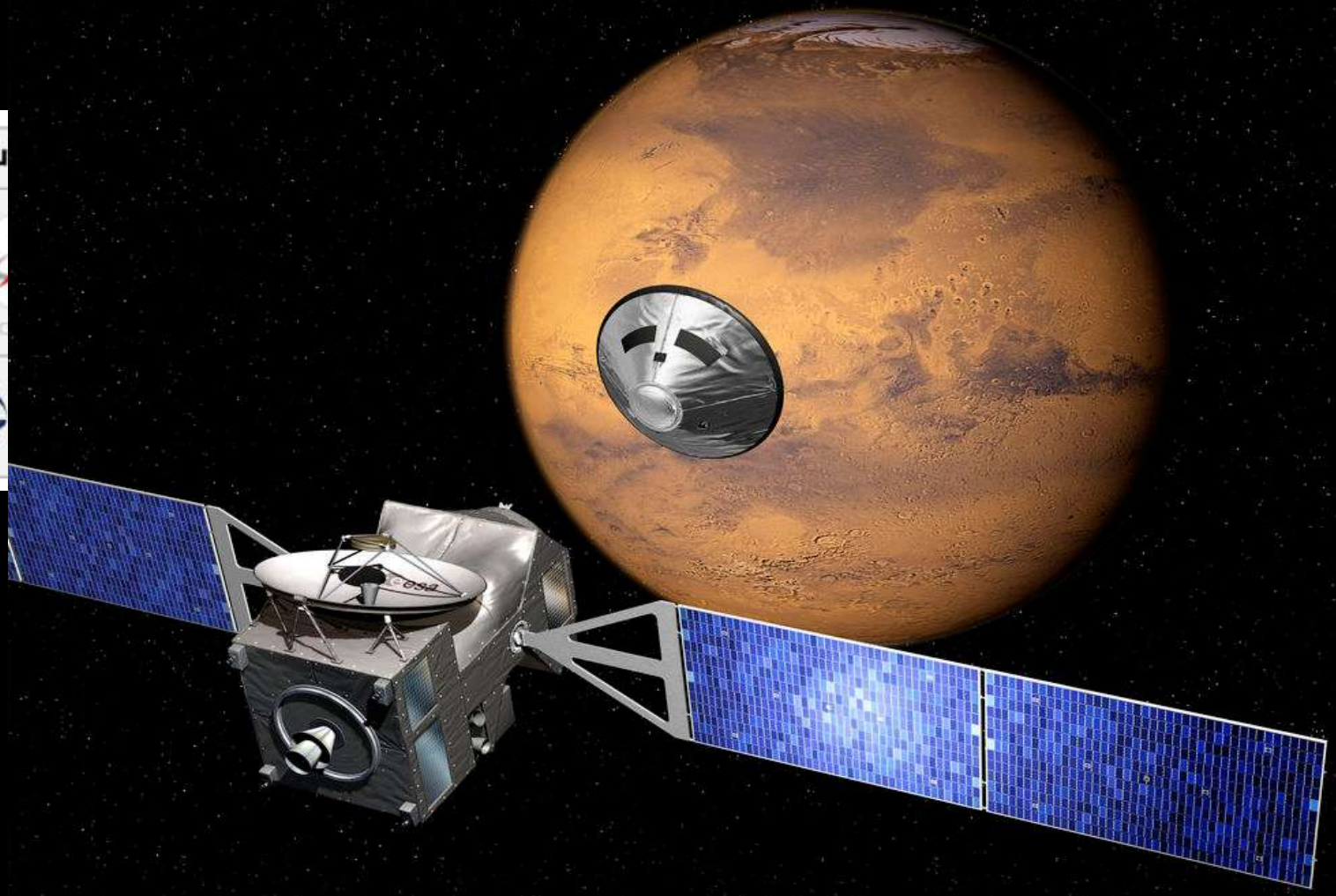
Mars Express and Beagle 2



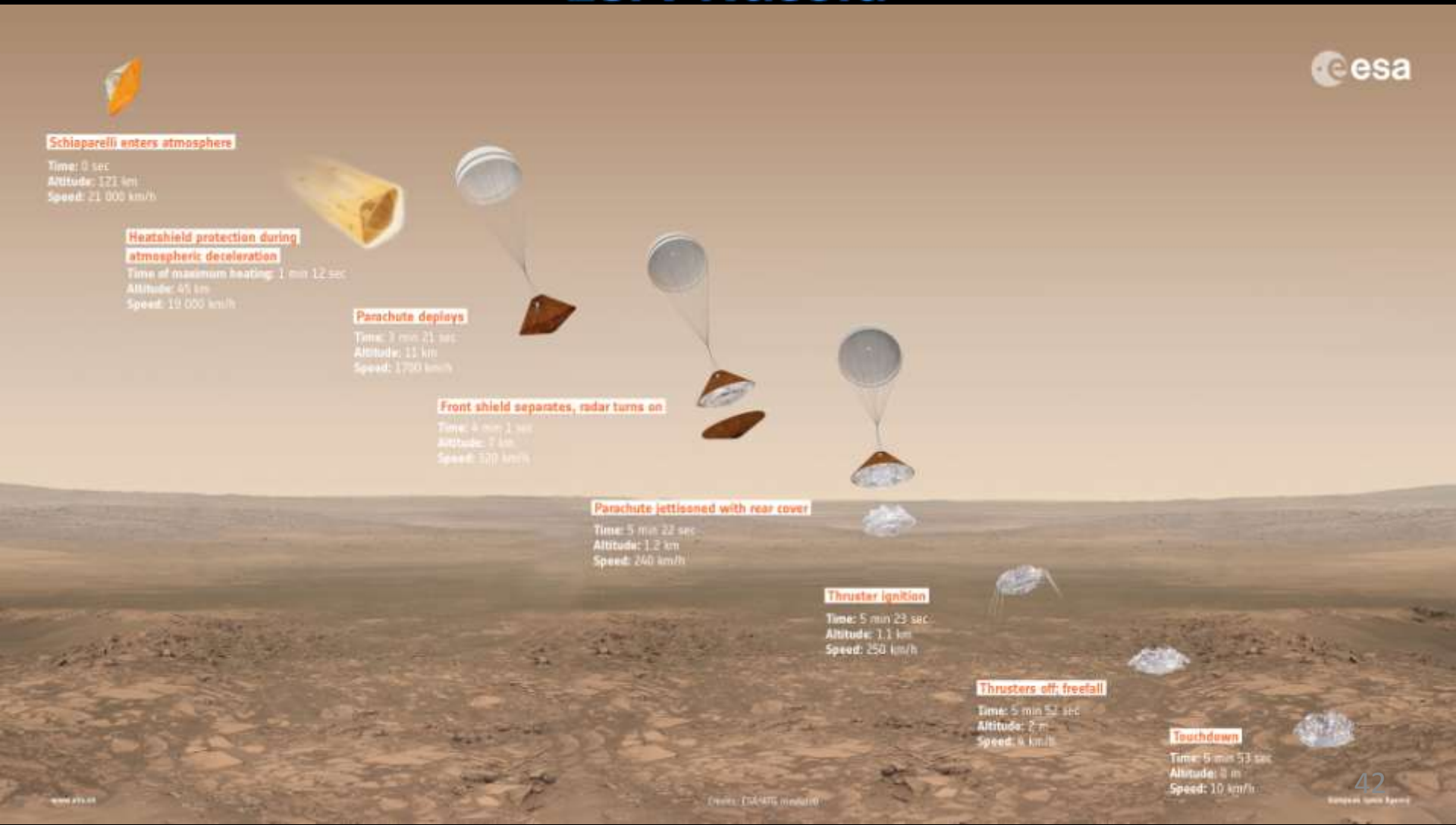
Mars Express and Beagle 2



ExoMars
ЭкзоМарс
ESA-Russia

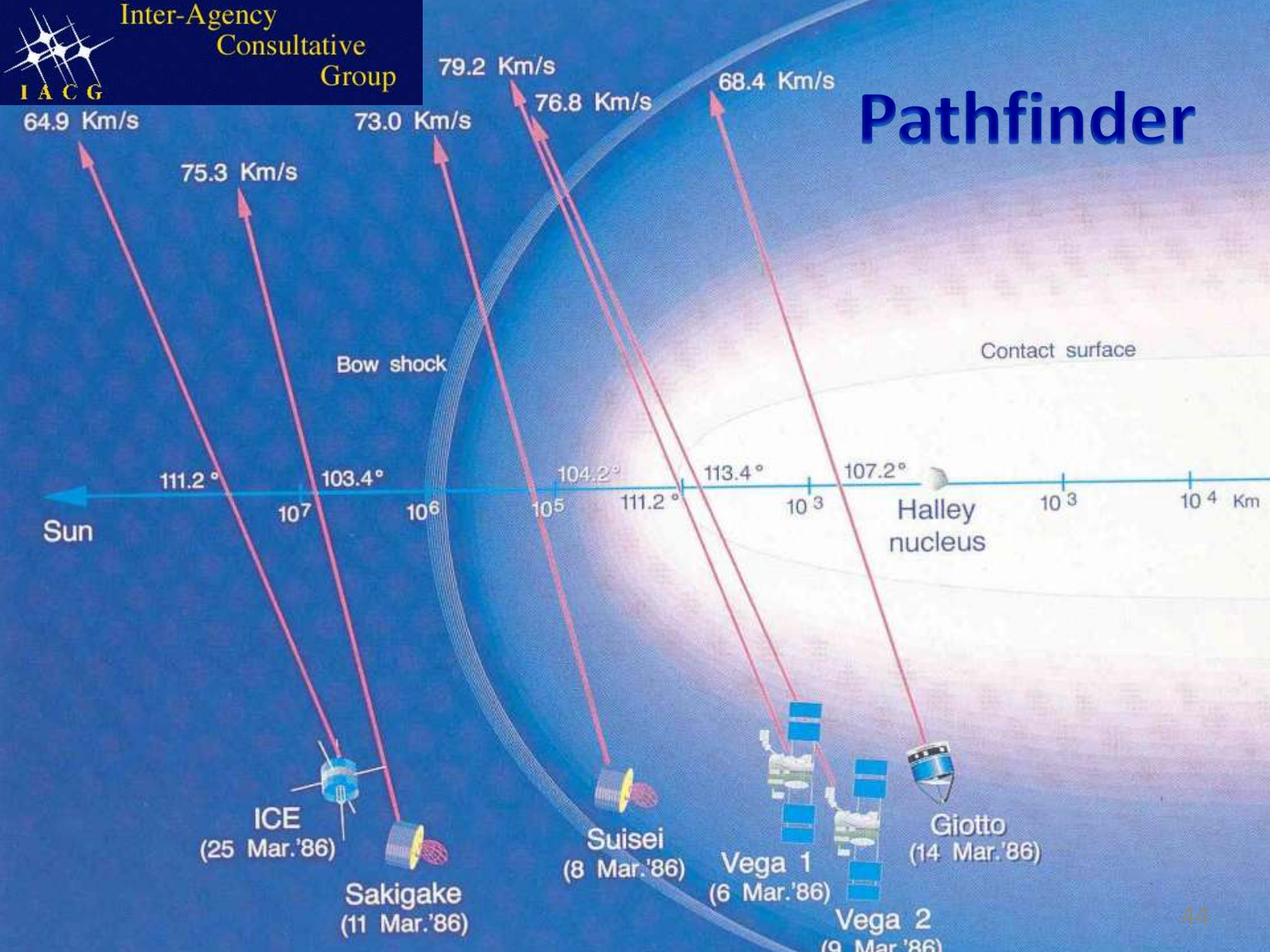


ExoMars
ЭкзоМарс
ESA-Russia



Cooperation through coordination

- **Giotto-Halley pathfinder concept**
- **ILWS**
- **Earth sciences**


Inter-Agency
Consultative
Group
I A C G
64.9 Km/s
75.3 Km/s
73.0 Km/s
79.2 Km/s
76.8 Km/s
68.4 Km/s
Pathfinder
Bow shock
Contact surface
111.2 °
103.4 °
104.2°
111.2 °
113.4 °
107.2°
Sun
10 7
10 6
10 5
10 3
10 3
10 4 Km
Halley
nucleus
ICE
(25 Mar.'86)
Sakigake
(11 Mar.'86)
Suisei
(8 Mar.'86)
Vega 1
(6 Mar.'86)
Vega 2
Giotto
(14 Mar.'86)


International Living With a Star
SCIENCE
CHARTER
ORGANIZATION
MISSIONS
NEWS
PRESENTATIONS
HISTORY
CONTACTS
IACG

ILWS Charter

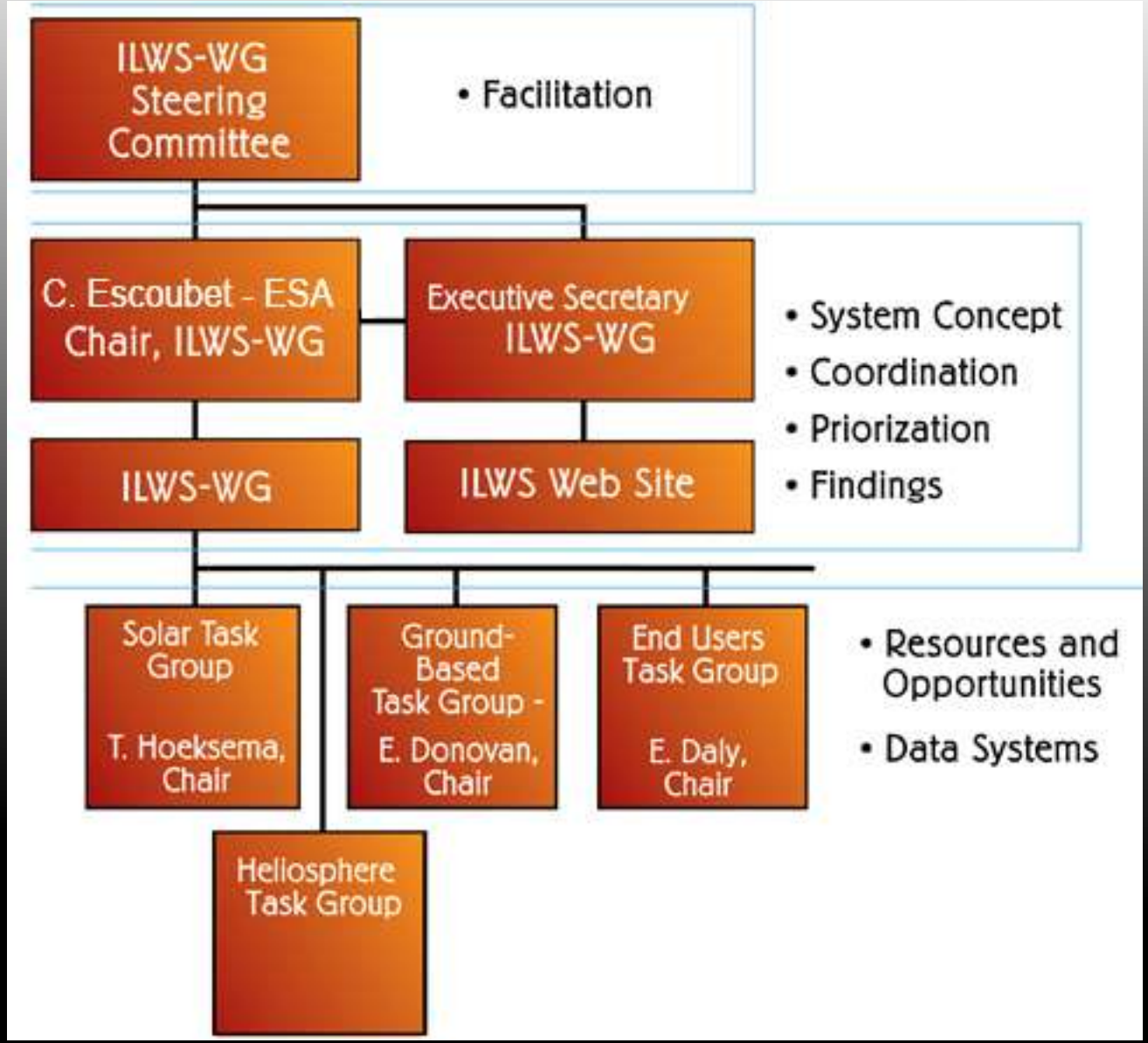
- **Stimulate, strengthen, and coordinate space research to understand the governing processes of the connected Sun-Earth system as an integrated entity.**
- **Objectives**

  To stimulate and facilitate:

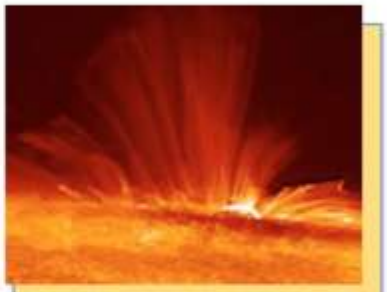
- **Study of the Sun-Earth connected system as a system and its effect which influence life and society.**
- **Synergistic coordination of international research in solar-terrestrial physics, including all relevant data sources as well as theory and modeling.**
- **Collaboration among potential partners in solar-terrestrial space missions.**
- **Effective and user driven access to all data, results, and value-added products.**

ILWS: Member Agencies

Organization



Solar Missions



GOES

PROBA-2

HINODE

RHESSI

CORONAS -FOTON

SDO

SOHO

SOLAR ORBITER

ELEKTRO-L

ADITYA

PICARD

PROBA-3

TRACE

SOLAR-C

SolACES

SOLAR PROBE+

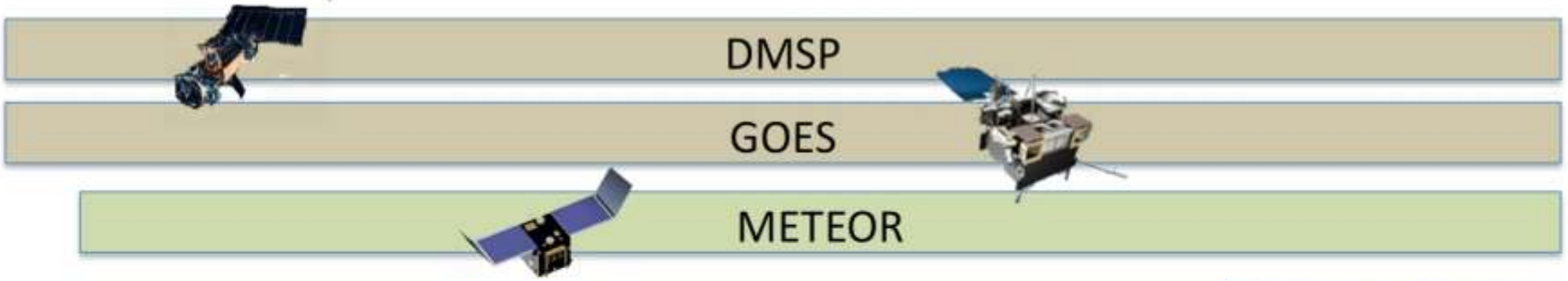
STEREO

INTERHELIOPROBE

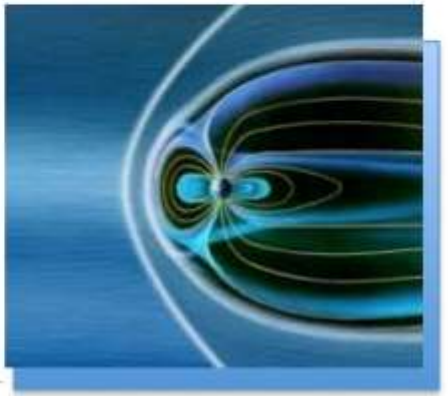
Sunrise

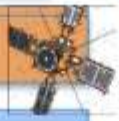
2009 2012 2015 2018 2021

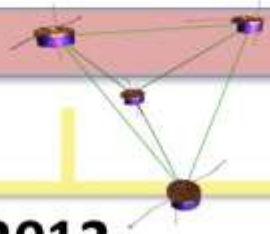
CNSA CSA CNES ESA ISRO JAXA NASA USA (other) RFSA Other

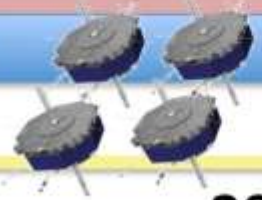


Magnetospheric Missions









2009 2012 2015 2018 2021

CNSA CSA CNES ESA ISRO JAXA NASA USA (other) RFSA Other

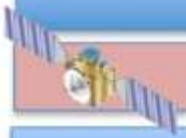
New Horizons

Cassini/Huyghens

Juno

Planetary Missions

Mars Odyssey



Mars Express

Mars Reconnaisance Orbiter

Maven

Mangalyaan

Mangalyaan-2

Trace Gas Orbiter

Venus Express

Akatsuki

Messenger

Bepi Colombo

2009 2012 2015 2018 2021

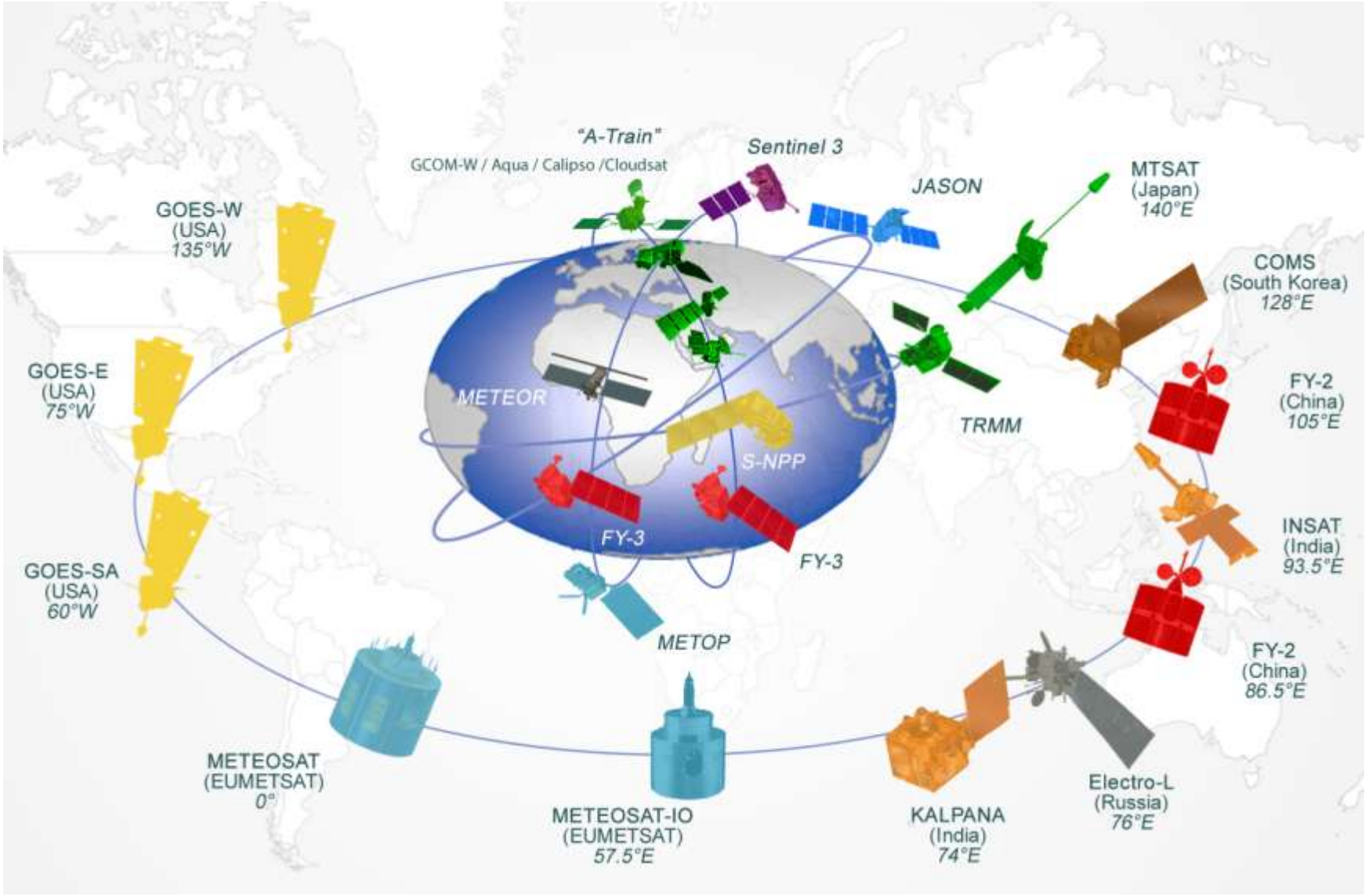
CNSA CSA CNES ESA ISRO JAXA NASA USA (other) RFSA Other

The special case of Earth observation satellites

CEOS Background

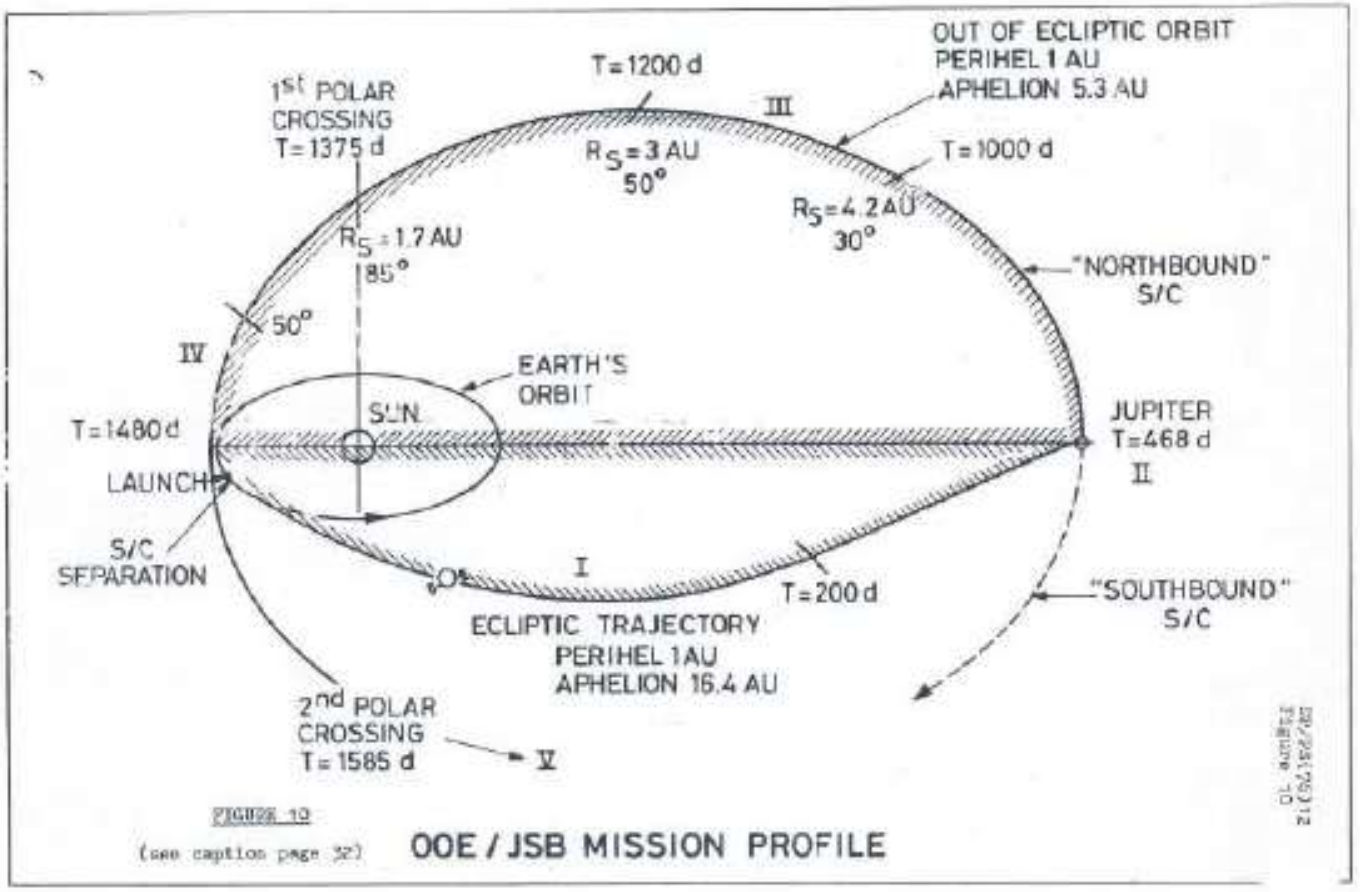
- Optimize the benefits of spaceborne Earth observations through cooperation in mission planning and development of compatible data products, formats, services, applications & policies;
- To serve as a focal point for international coordination of space-related Earth observation activities;
- To exchange policy and technical information to encourage complementarity and compatibility among spaceborne Earth observation systems and the data received from them.

WIGOS


"A-Train"
GCOM-W / Aqua / Calipso /Cloudsat
Sentinel 3
JASON
MTSAT
(Japan)
140°E
GOES-W
(USA)
135°W
COMS
(South Korea)
128°E
GOES-E
(USA)
75°W
METEOR
TRMM
FY-2
(China)
105°E
S-NPP
INSAT
(India)
93.5°E
GOES-SA
(USA)
60°W
FY-3
FY-3
METOP
FY-2
(China)
86.5°E
METEOSAT
(EUMETSAT)
0°
METEOSAT-IO
(EUMETSAT)
57.5°E
KALPANA
(India)
74°E
Electro-L
(Russia)
76°E

How not to cooperate

ISPM
Original concept



Europe,
from dependent became leader!

International Space Station

Conclusions

Some general rules

- International cooperation should be the tool for the development of an optimum worldwide program for the benefit of space science.
- Programs of the different agencies should be complementary to one another and not compete, while allowing a healthy overlapping.
- Agencies should exercise fairness, restraint, and respect for one another in the process of establishing and/or modifying their programs.
- Reciprocal access to one another's facilities should be the norm, and scientific exchange of data should be encouraged.
- Hardware cooperation should be based on mutual advantage and clear technical and management interfaces.
- Coordination among separate projects should be implemented whenever possible.
- Fair acknowledgment of the contribution of the other parties should be recognized and publicized.
- Upholding international agreements should have priority.

Some general rules

- The formulation of global road maps, involving the present set of space nations plus those which appear on the scene becomes everyday a pressing evidence
- However the technology transfer (ITAR) issue requires new approaches
- Some space agencies are not necessarily in full support of such an approach, which deprives them of their freedom and ability to keep a certain control
- However, can they maintain global control because of their own idiosyncrasies and national pride?
- A new system of governance must nevertheless be established particularly in Earth sciences

Future of International cooperation

- International cooperation in space science is a must
- It can only expand, including all space fairing nations and all talents from all nations
- Reciprocity between partners should be the rule
- Coordination of missions is easier to implement and should face no difficulties

Thanks