The need of space exploration

A. Sadovski

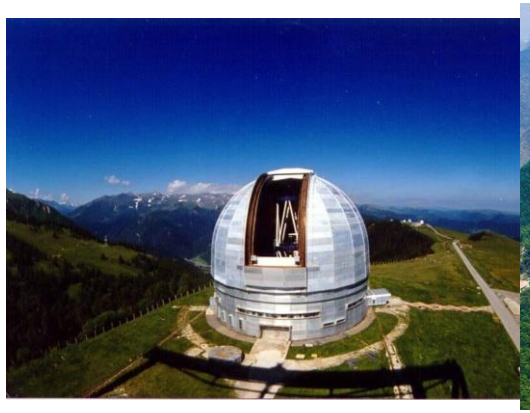
Scientific secretary

Space Research Institute (IKI)

ИКИ

ИНСТИТУТ КОСМИЧЕСКИХ ИССЛЕДОВАНИЙ РАН

For the space explorations we need to leave the Earth

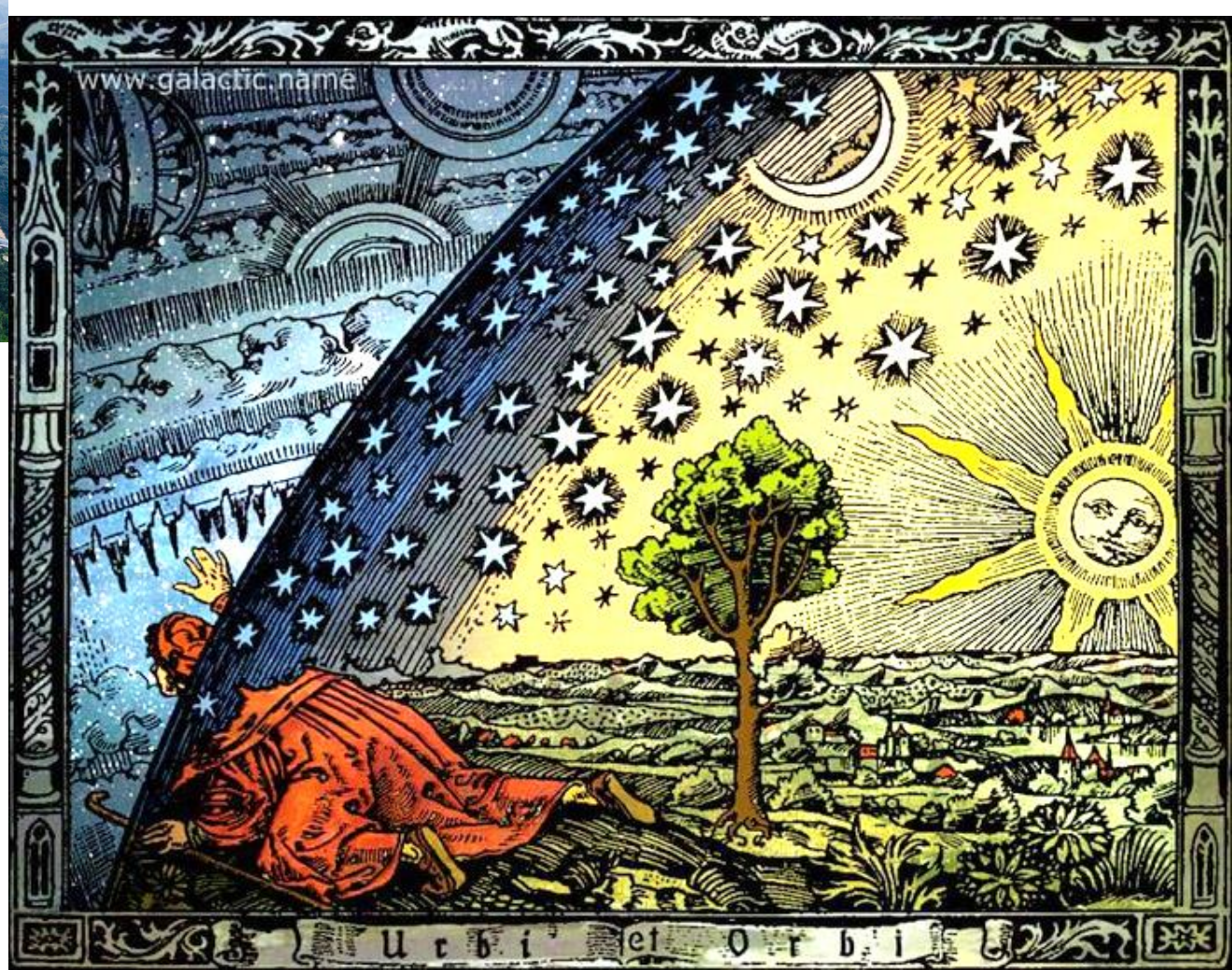


Telescope BTA (6м)

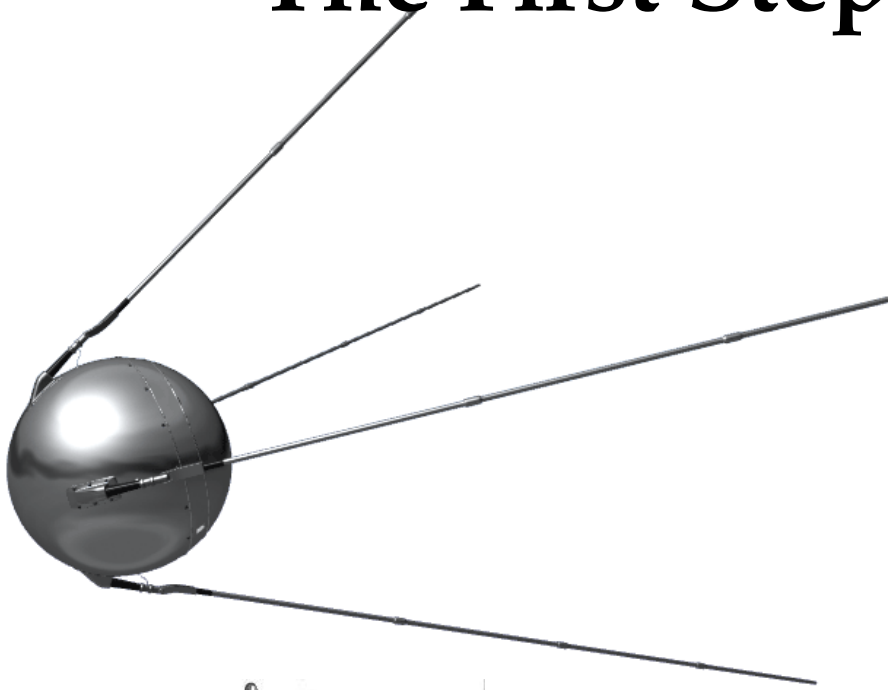
FAST (500 м)

VLT (8м, ESO)

Effelsberg (100 м)

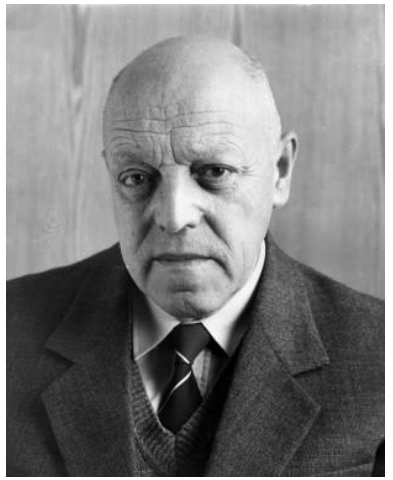


The First Steps and the First Discoveries

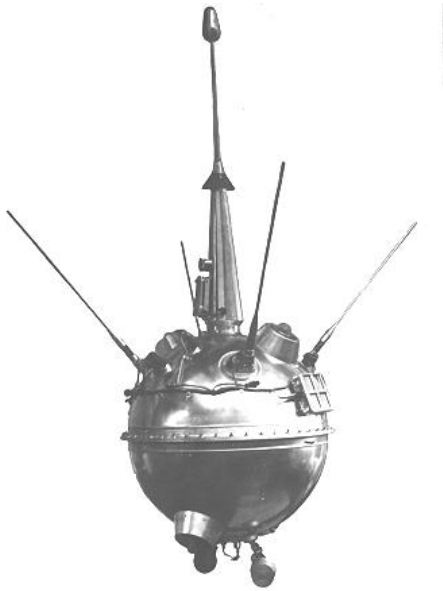


1957 First Satellite –
the first scientific instrument

1959 First lunar mission
1961,1962 First missions to Mars and Venus

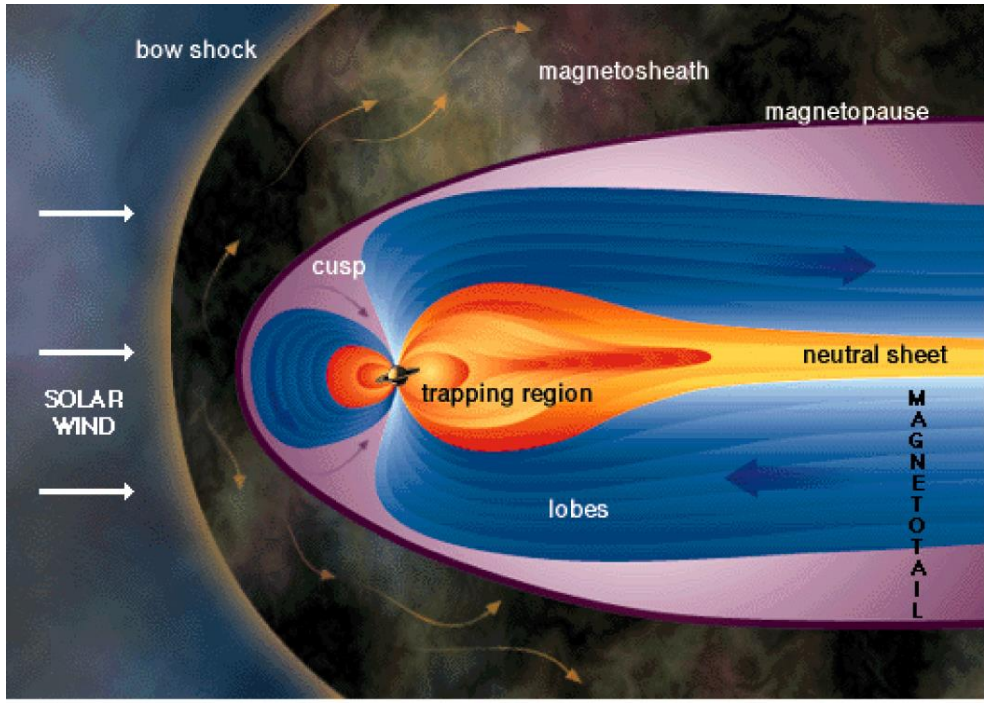


K.I. Gringauz

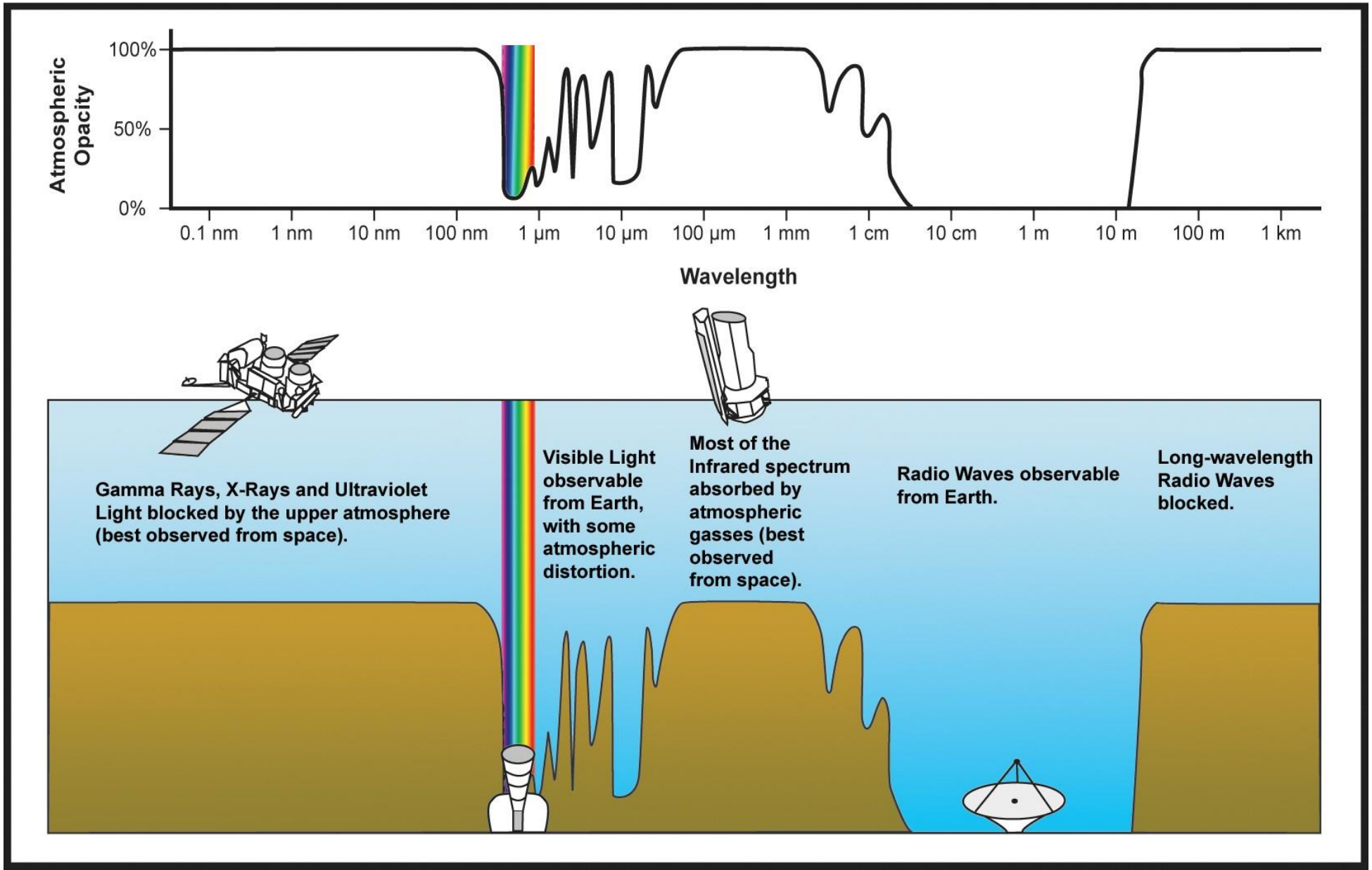


- Radiation belts
- Solar wind
- Plasmapause

The very beginning of
the space plasma science

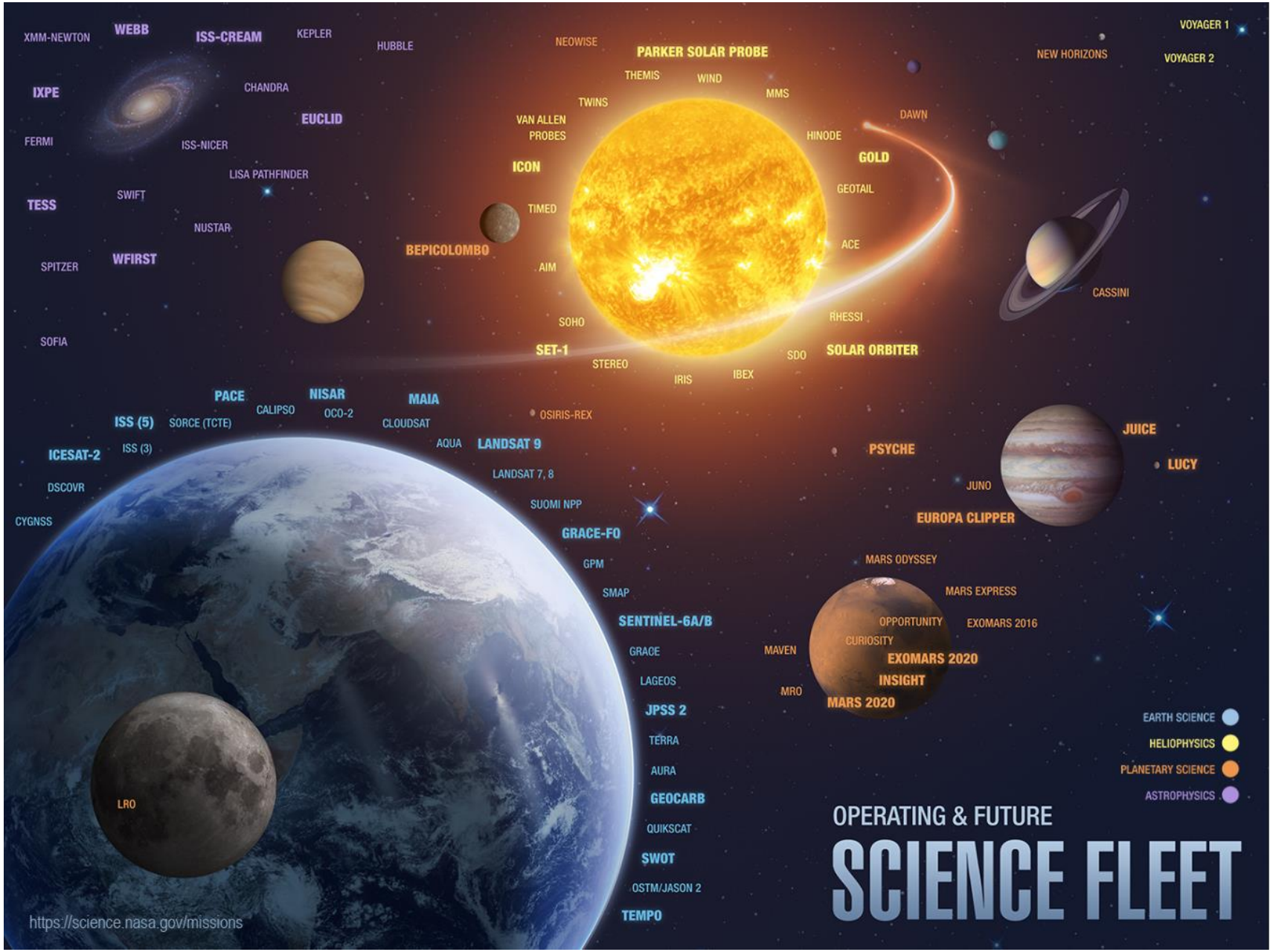


Electromagnetic Radiation

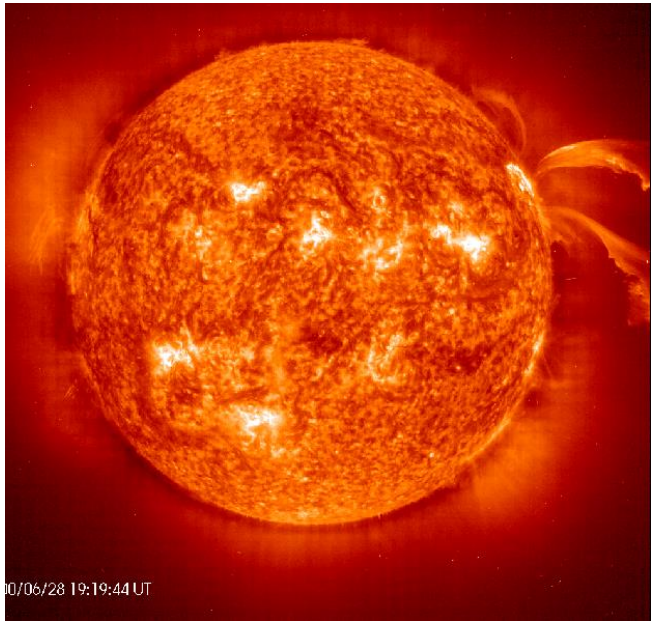


- Cosmic Rays
- Gamma Flashes
- Relativistic objects
- Dust
- Microwave Radiation
- AGN
- Star Birth Regions

The Space Fleet Today

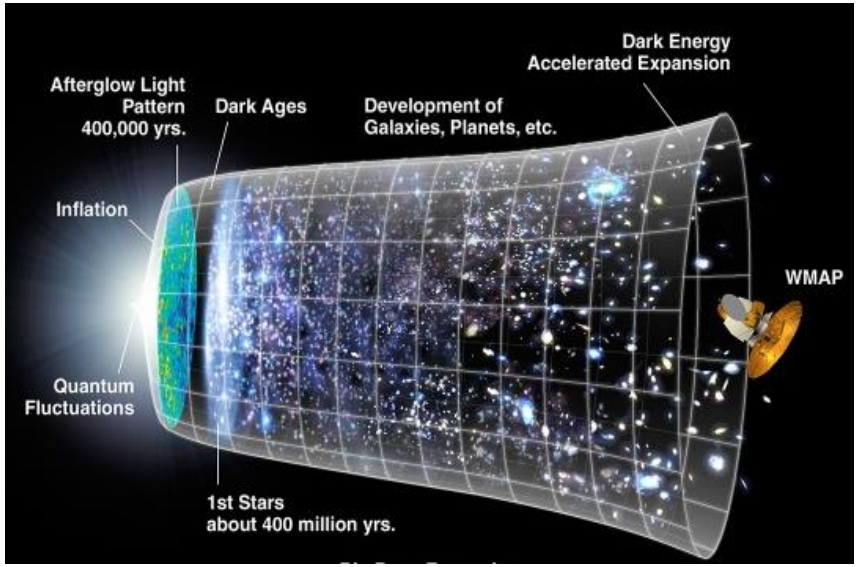


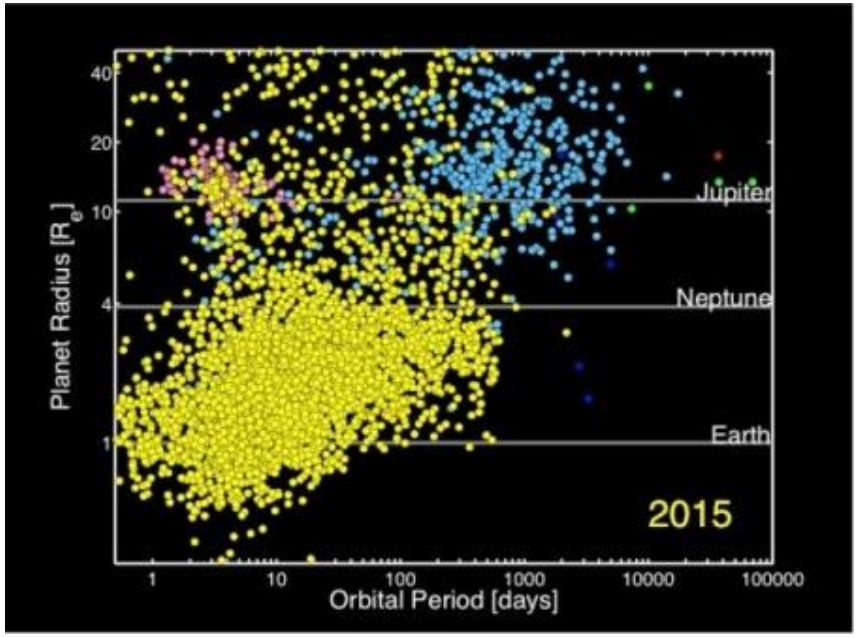
New Space for XXI



New Science

- New physics and cosmology
- Life and extraterrestrial life
- Earth as space ecosystem
- Space exploration





New Physics in Space

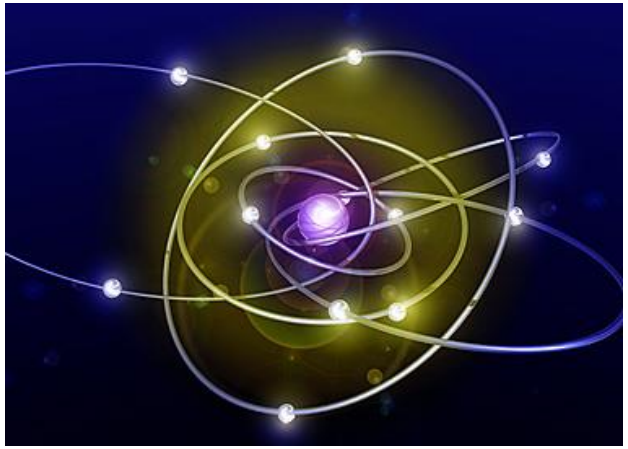
Our civilization (beginning of XXI) based on the physical discoveries in XIX and XX

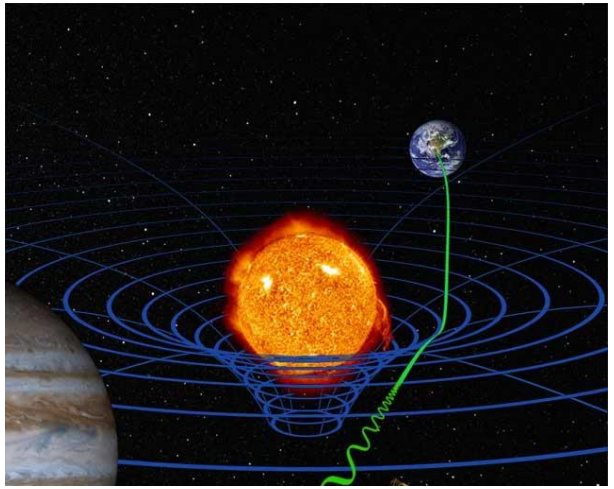
- Electromagnetic theory
- Relativistic physics
- Quantum theory

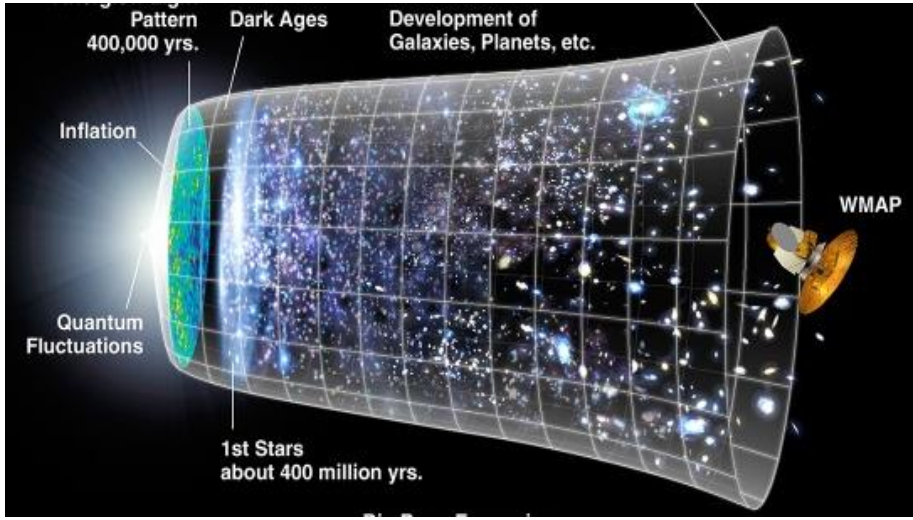
The next step is possible only from new unknown physical laws

The first steps:

- Dark matter and dark energy
- Cosmological theories
- Experimental check of the elementary particles theories

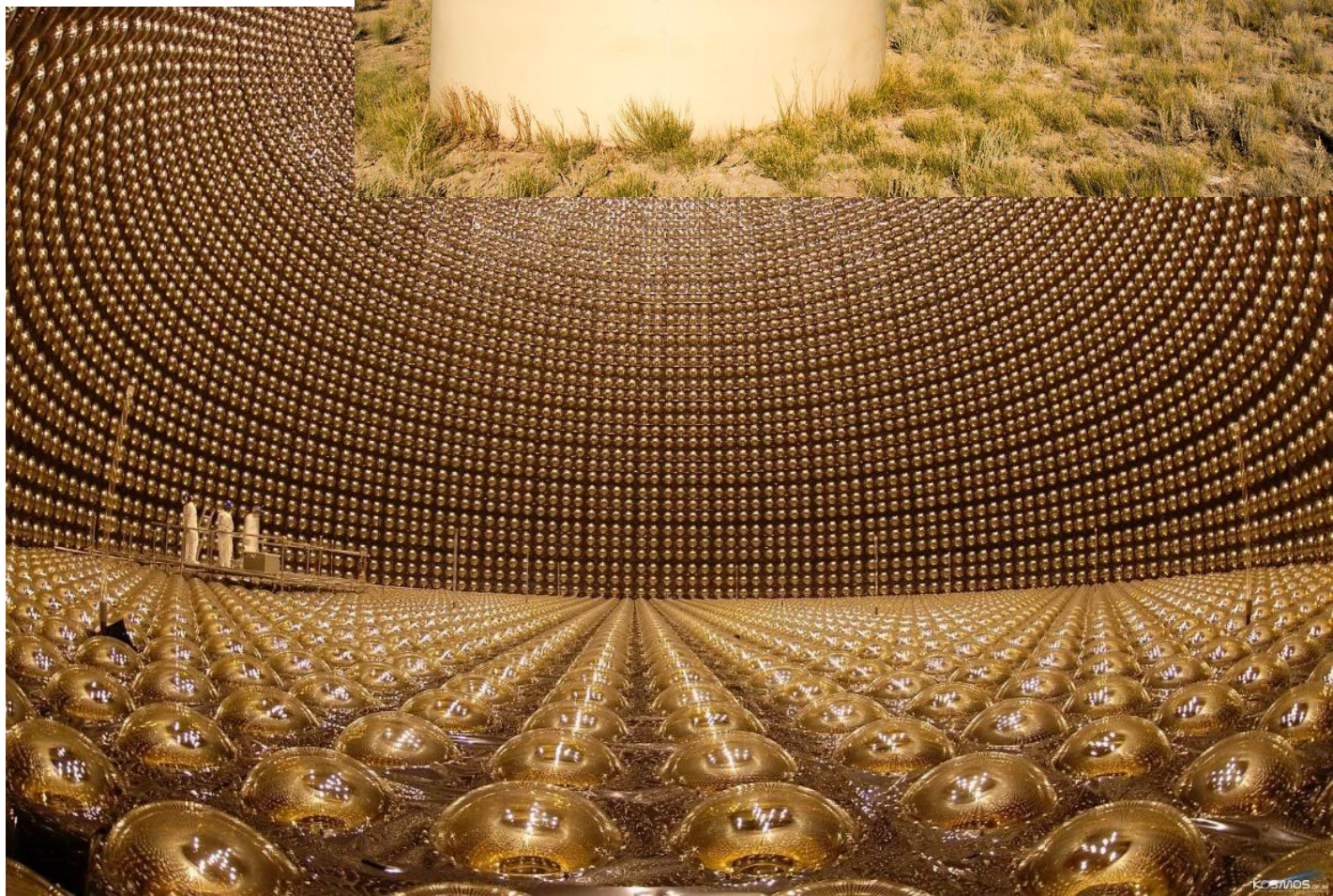






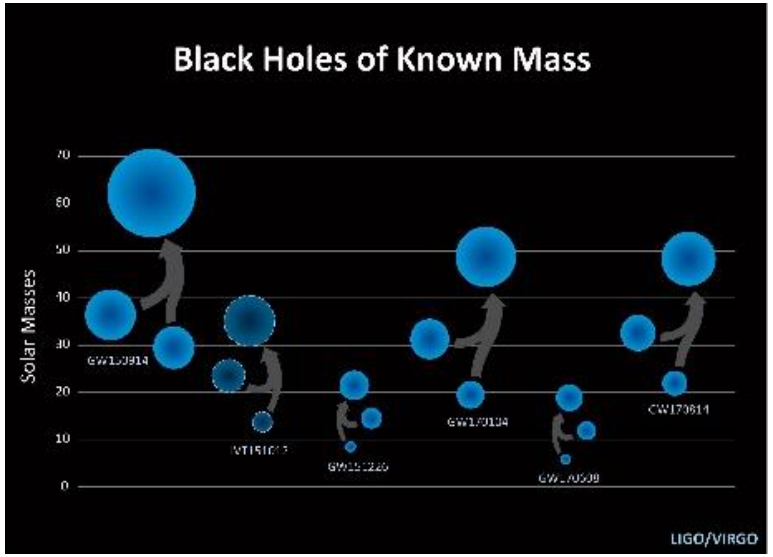
Four(?) Types of Radiation

- Electromagnetic - photons
- Space rays – particles (mainly protons)
- Neutrinos

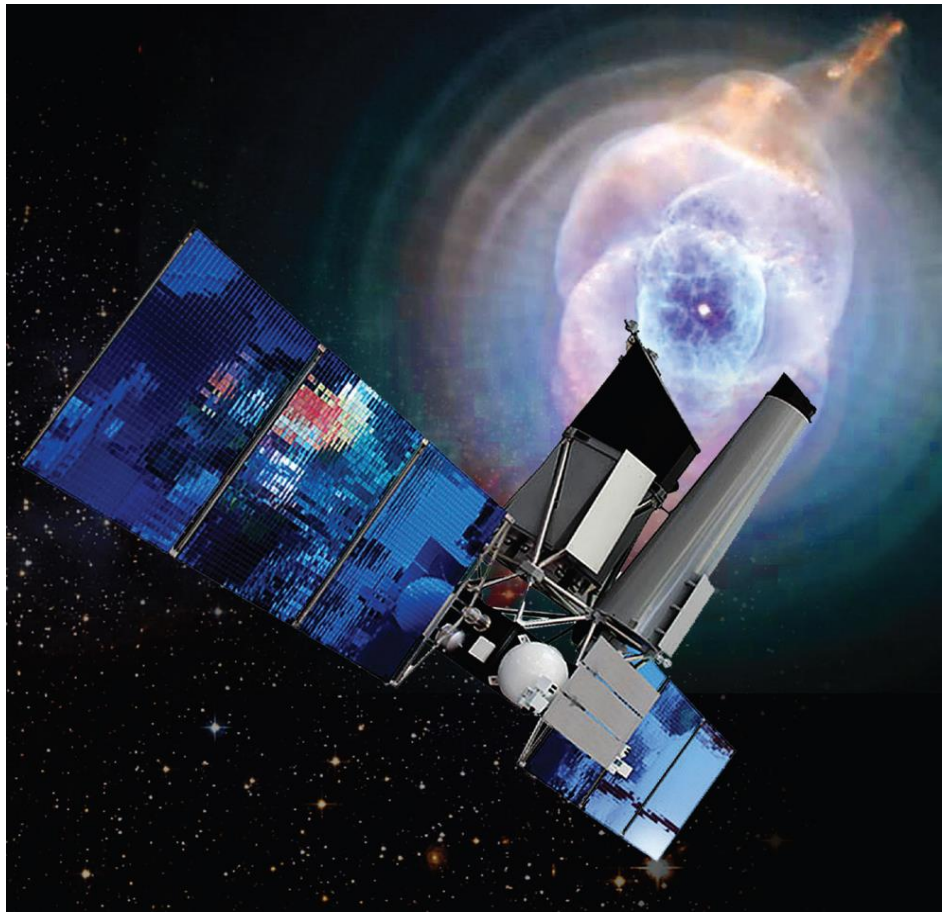


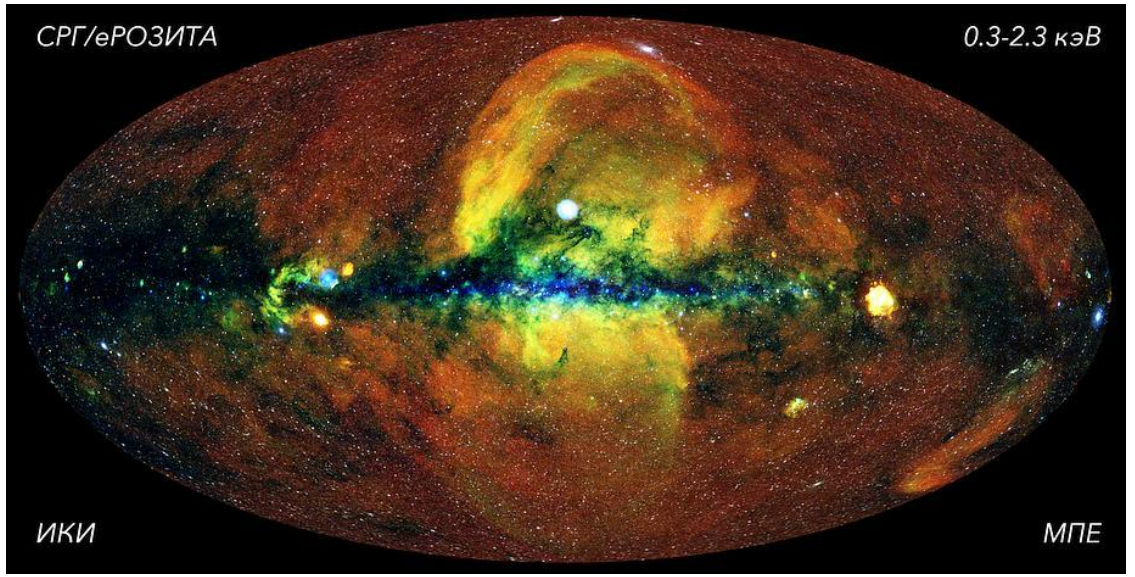
All-wave Astronomy

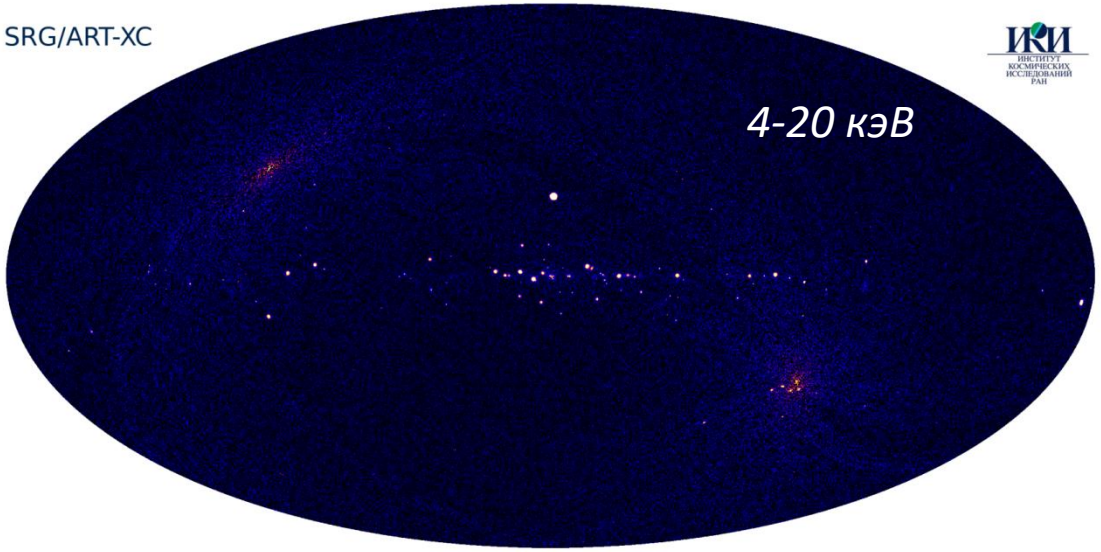
- Telescopes
- Space telescopes
- Neutrinos
- Gravitational waves astronomy



Spektr-RG (SRG)





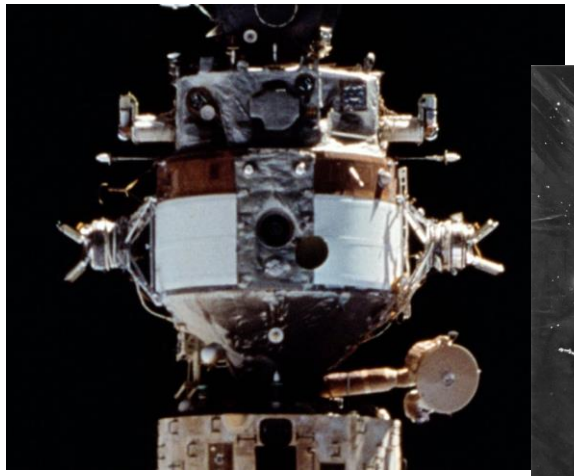


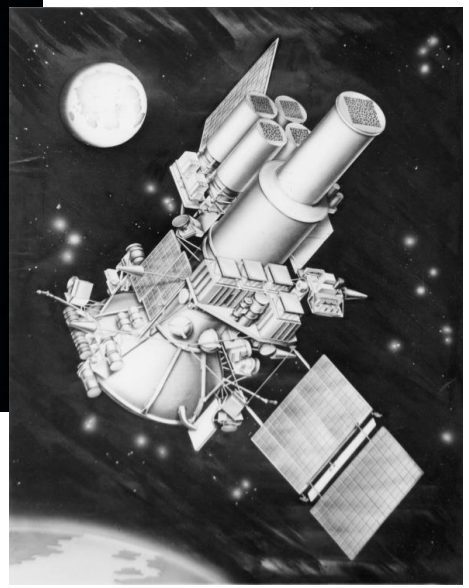
Two X-ray telescopes

eROSITA (Germany) and ART-XC (Russia)

In Search of New Physics

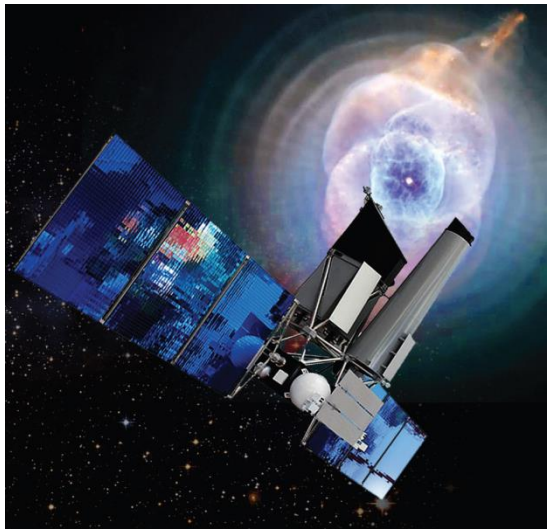
- The most energetic objects in the Universe – neutron stars, black holes
- Dark matter and dark energy





Pulsar X-1 gamma-spectrometer
Mir-Kvant, 1987-2001
Granat, 1989-1999

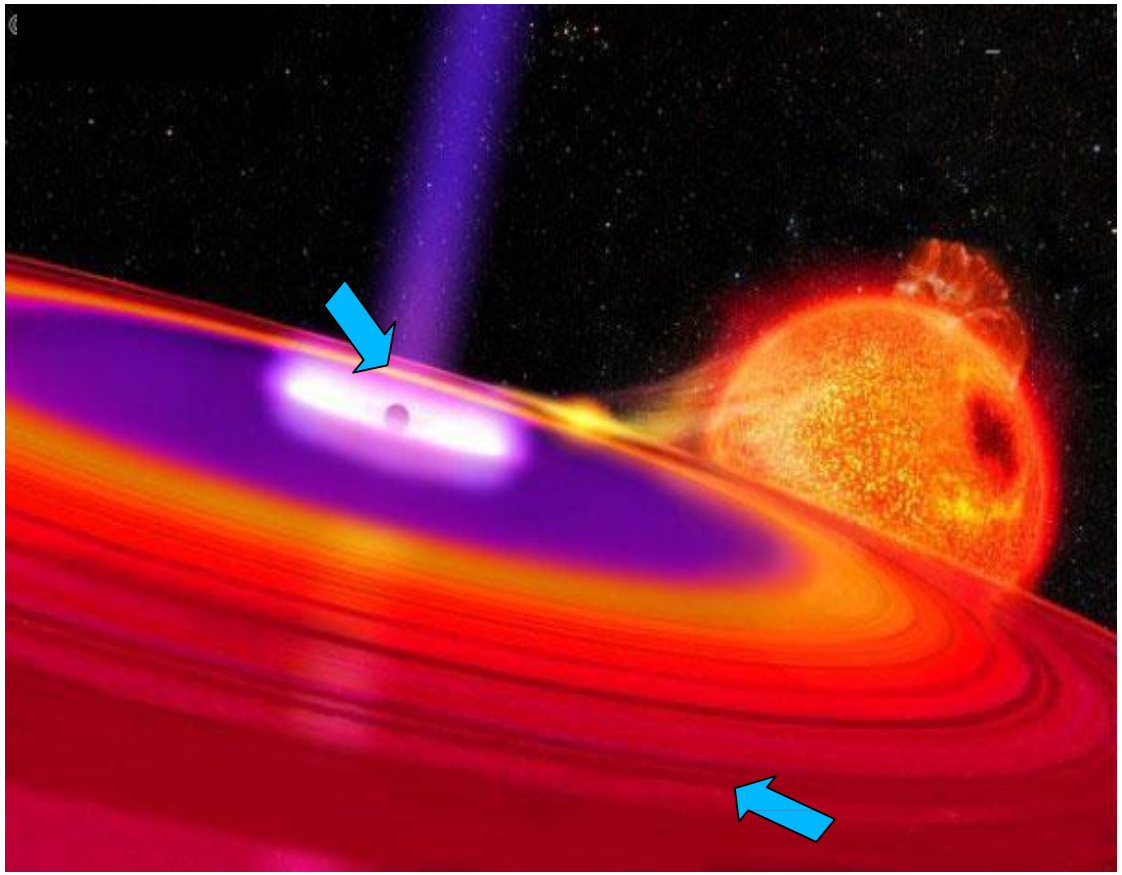
MBH, MBH-2,
2022,
ISS



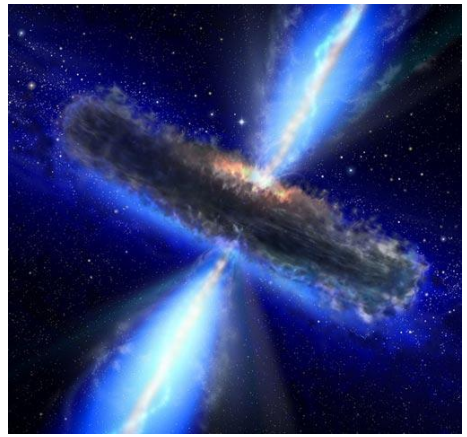
Spectr-RG, 2019

Gamma-400/ Spectr-L
Galaxy map/X-ray navigation

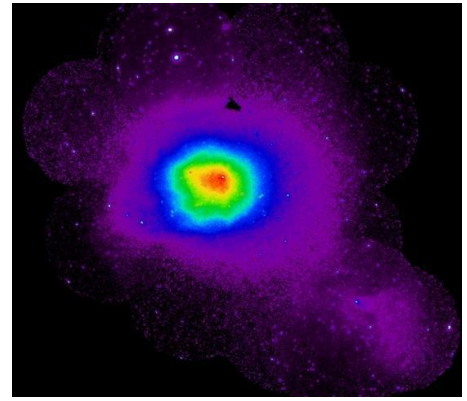
X-rays sources



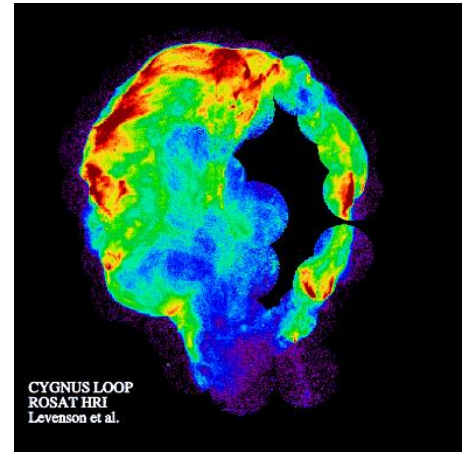
AGN – massive black holes



Galaxies clusters



Interstellar medium



Accretion power in astrophysics: black holes and neutron stars

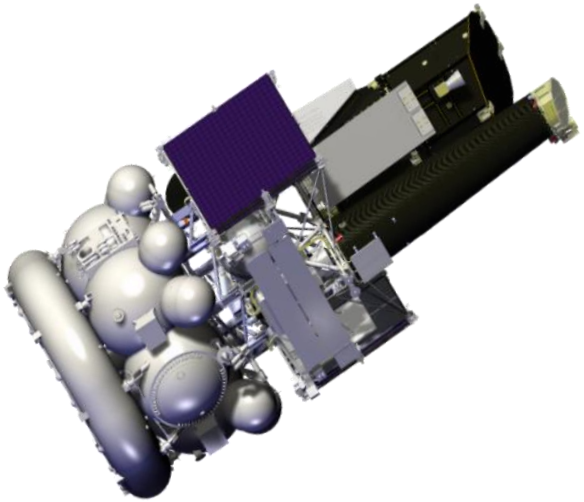
For neutron star ($R = 10$ км) $\Delta E_{acc} \sim 10^{20} m$ erg

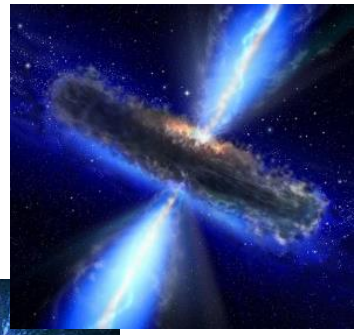
Thermonuclear reaction $\Delta E_{nuc} = 0,007 mc^2 \sim 6 \cdot 10^{18} m$ erg

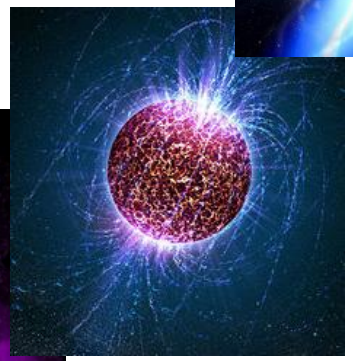
New Physics in space

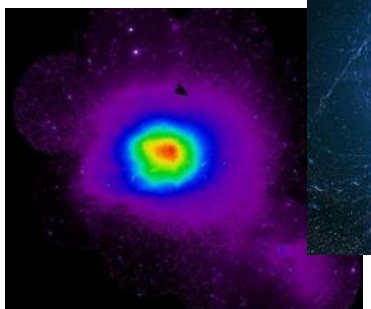
Спектр-РГ 2019

рентгеновский телескоп



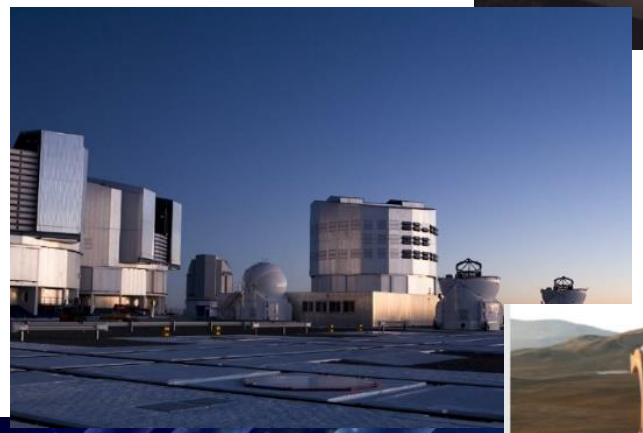


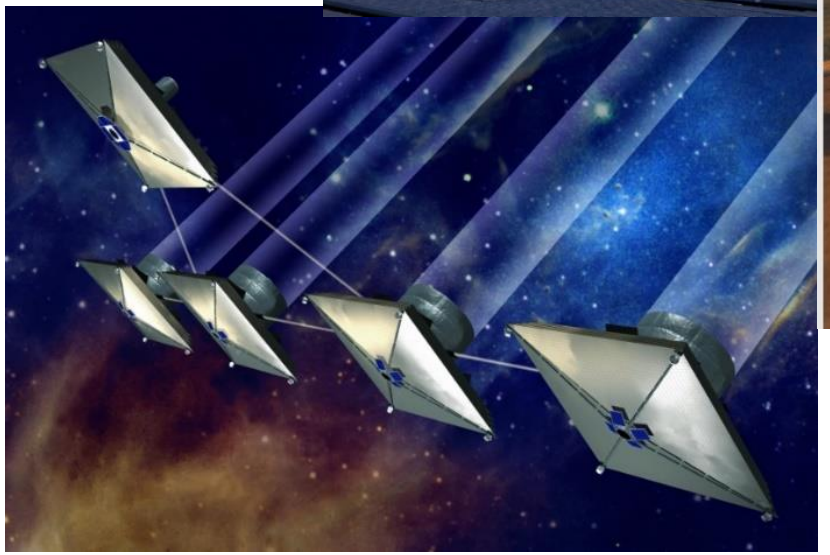


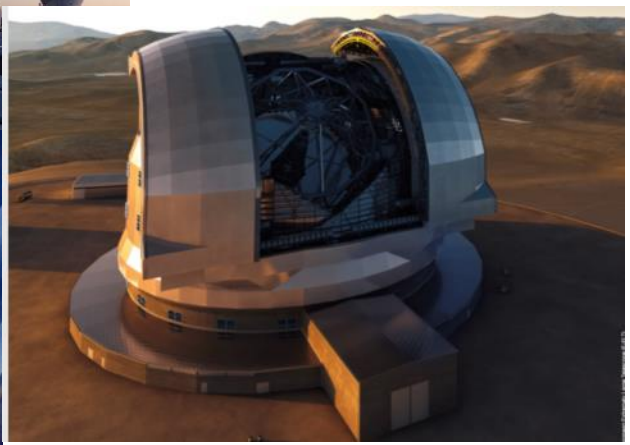


Next step

- systems of interacting space and earth telescopes





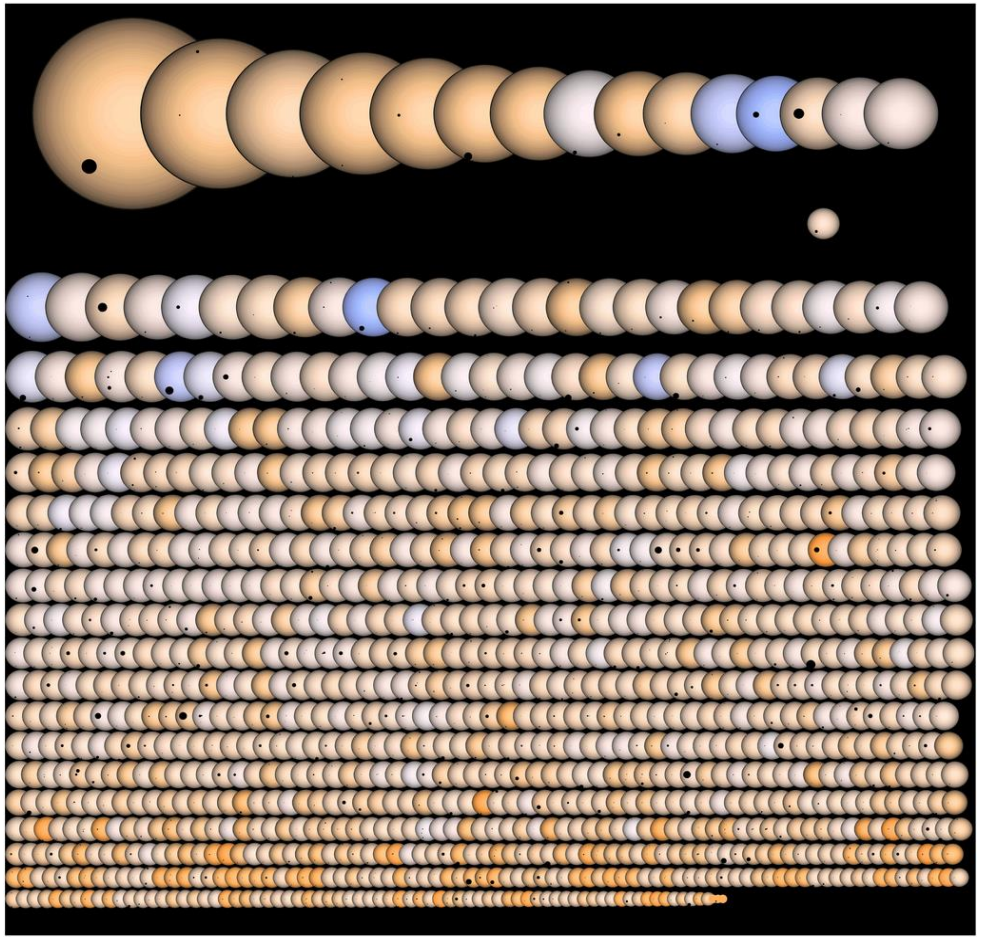


In search for Life - Exoplanets

I. Shklovskiy

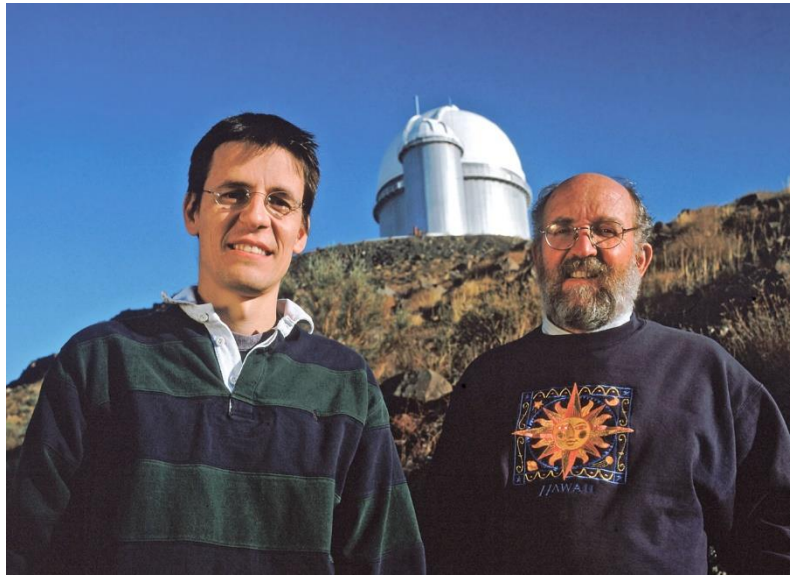
About unique life in the Universe.

M.: 1976.



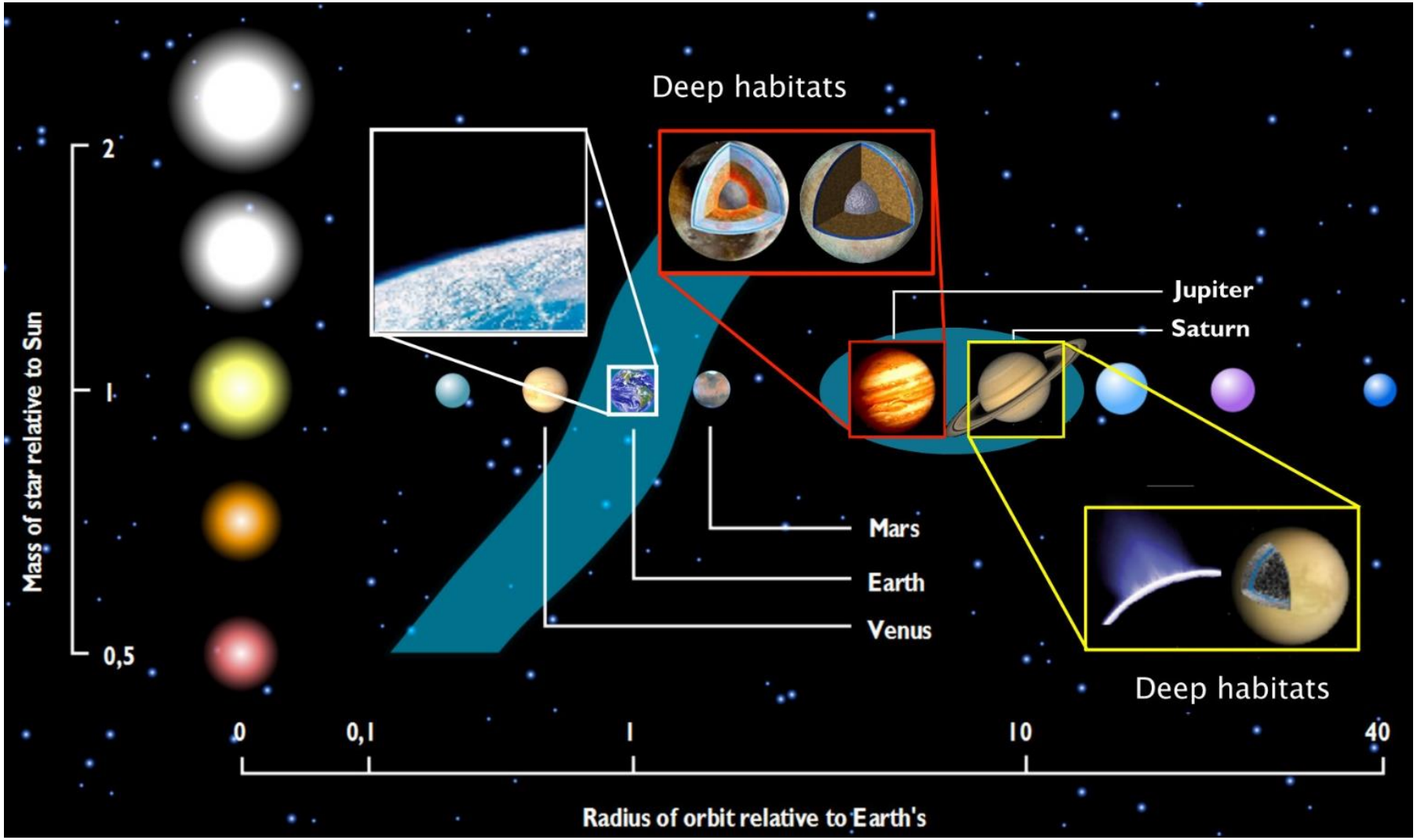
Kepler planets (part)

The first exoplanet with normal star (51 Pegasus b)
Michel Mayor and Didier Queloz



$$N = N_{Star} \times f_p \times n_e \times f_{life} \times f_i \times f_c \times L$$

Solar system habitability



Necessary elements

- Water
- Element of Periodic table
- Energy
- Time

- Atmosphere
- Tectonics
- Gravitation
- Magnetic field

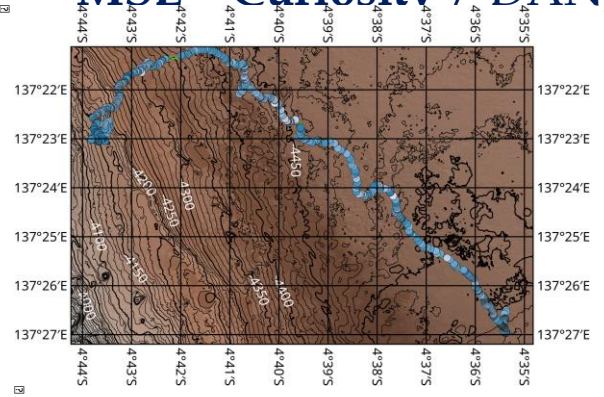
Mars – climate and trace of life

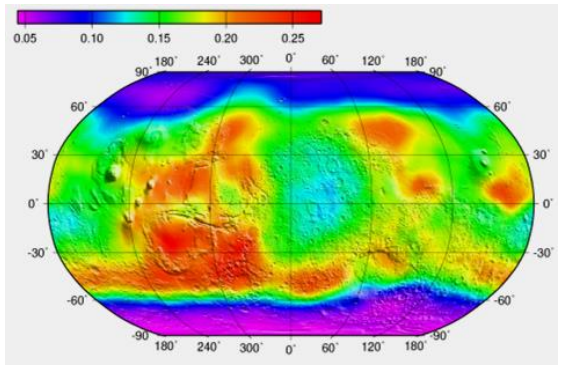
Mars-Odyssey / HEND, **2001**

Mars-Express / OMEGA, SPICAM, PFS, **2003**

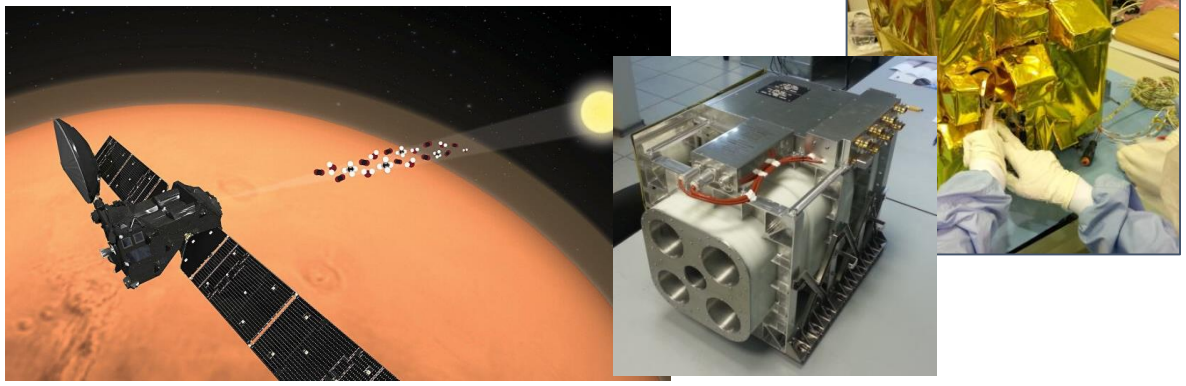
Spirit, Opportunity/ Mossbauer spectrometer, **2003**

MSL – Curiosity / DAN, **2011**





Exomars TGO, **2016**



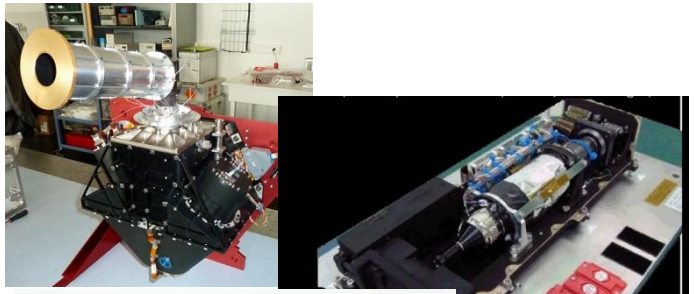
Exomars, 2022

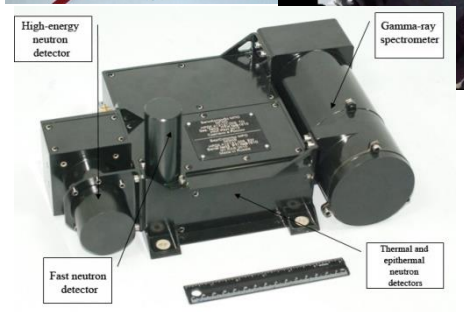
- European rover on the Russian platform
- 13 scientific devices (11 Russian and 2 European) on platform
- 2 Russian scientific devices on rover

Planets researches

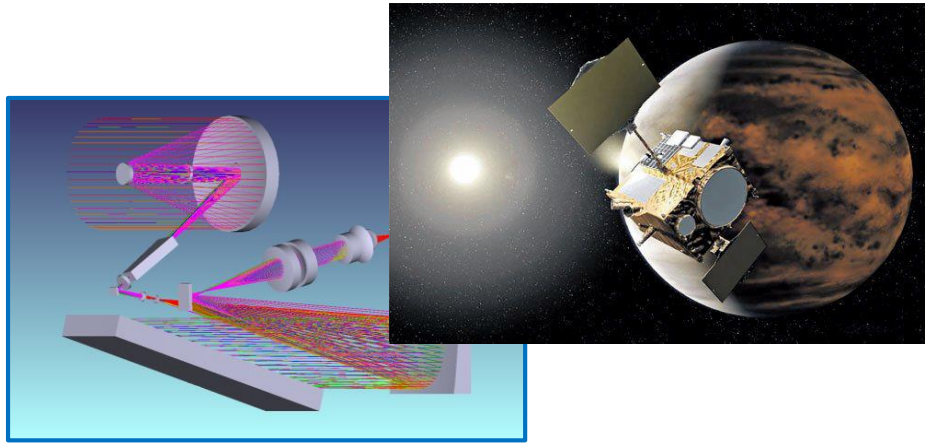
Mercury
Bepi-Colombo 2018-2025

PHEBUS, MSASI, MGNS

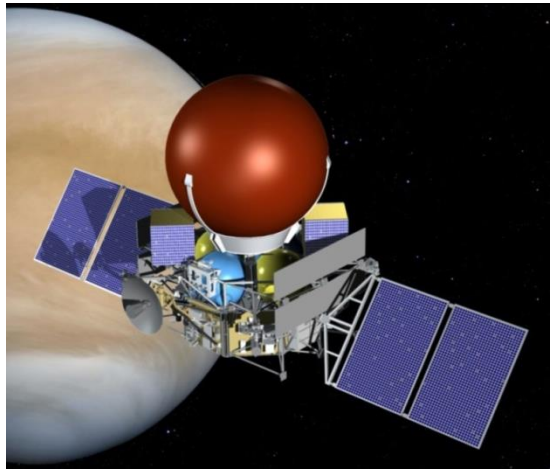




Venus
Indian mission
Schukrayaan – VIRAL 2024



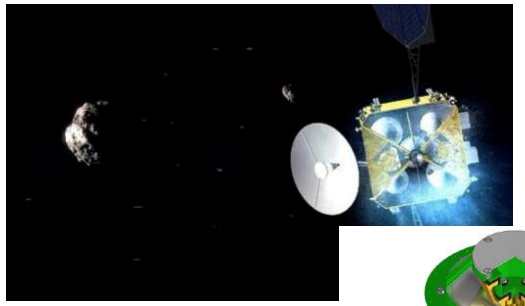
Venera-D 2028-2030



Mars and asteroids

???

ZhengHe, 2024, China

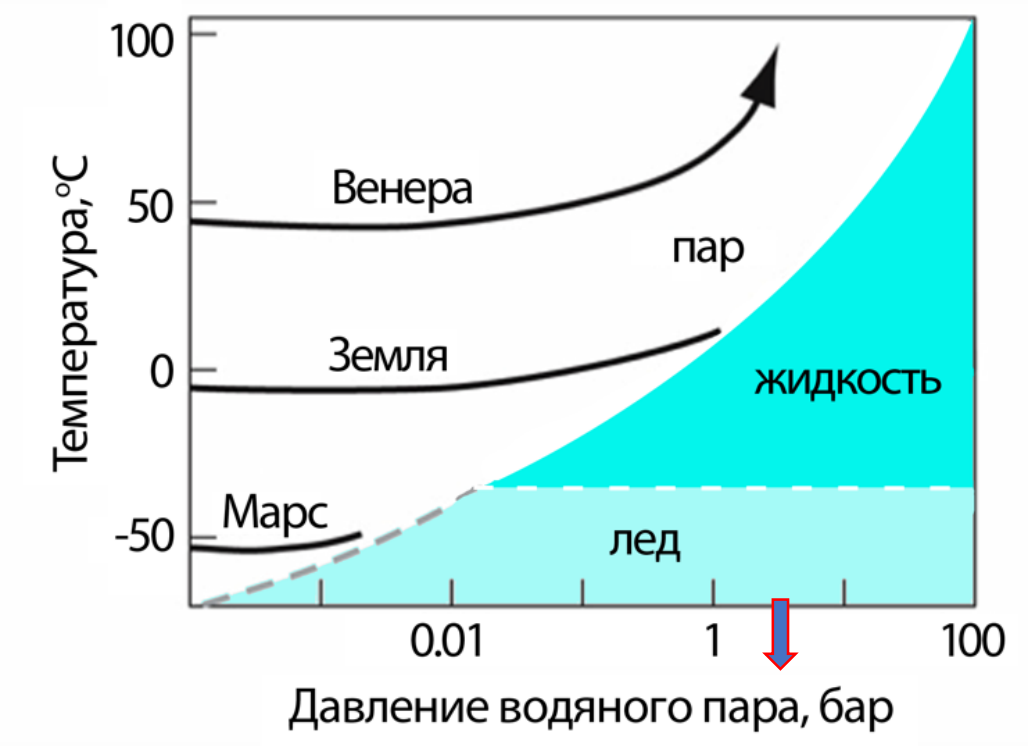


	Distance from the Sun, a.u.	Mass, Earth masses	Atmospheric gases
Mercury	0,39	0,052	Na, He
Venus	0,72	0,81	CO_2, N_2
Earth	1	1	N_2, O_2, (CO_2, H_2O)
Mars	1.52	0,11	CO_2, N_2, (H_2O)

	P (surface), Bar	Surface temp., K (average)	Greenhouse effect, K
Mercury	10^{-16}	440	0
Venus	92	735	**500**
Earth	1	289	**39**
Mars	0,006	214	**4**

Different Paths of Earth-type Planets

Investigations of Solar System give us understanding of the Earth climate system

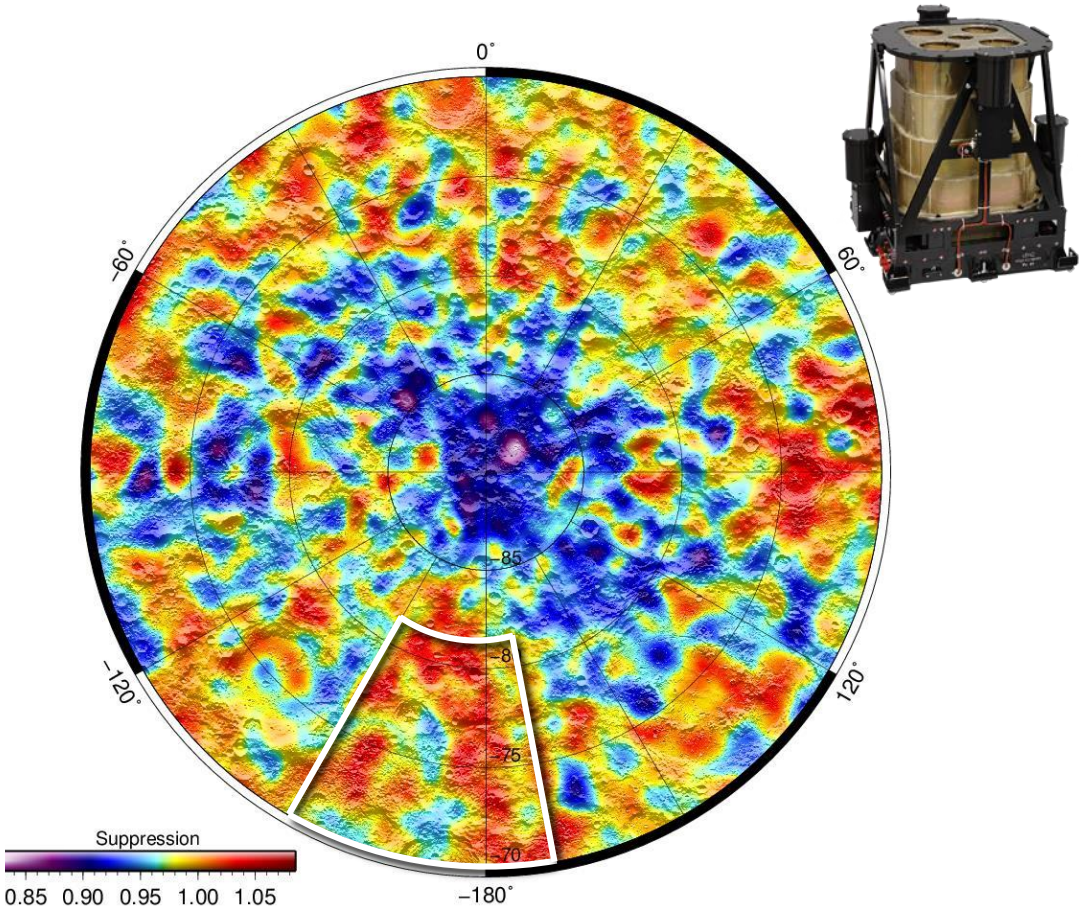


Venus: all water in atmosphere, temperature grows catastrophically
(+500гр – greenhouse effect)

Earth: Oceans
(+40гр – greenhouse effect)

Mars: ice

Moon of XXI century



LEND/LRO, 2009

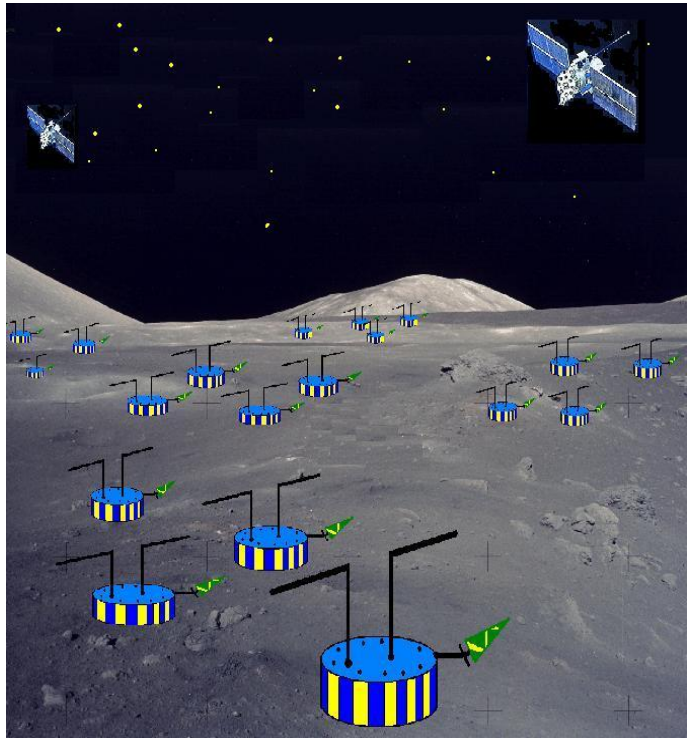
- water
- Lunar poles as the base

Luna-25, 2023…

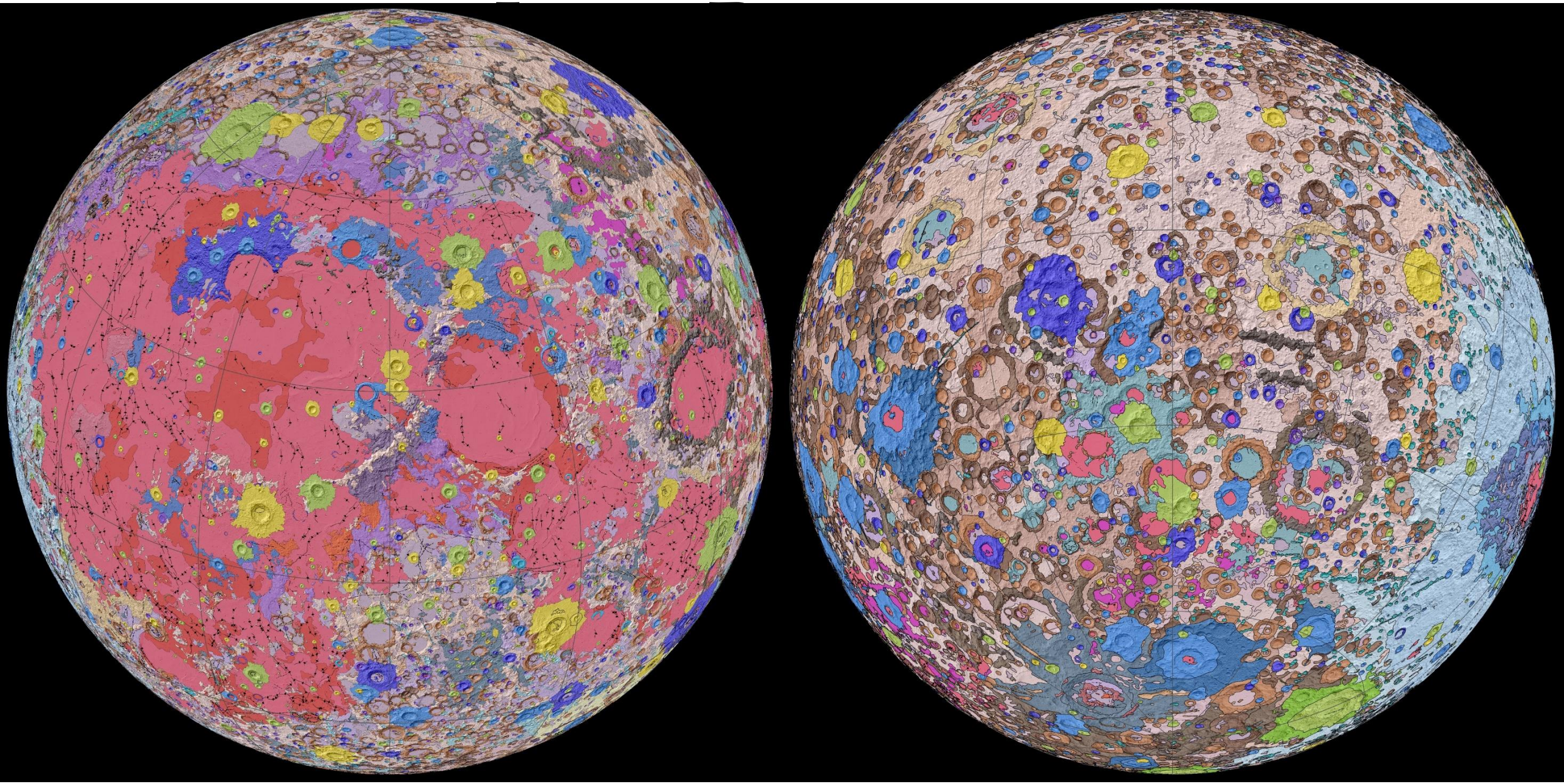
- Landing in near-pole region
- Exosphere
- Ice and regolith composition

Observatory on the Moon

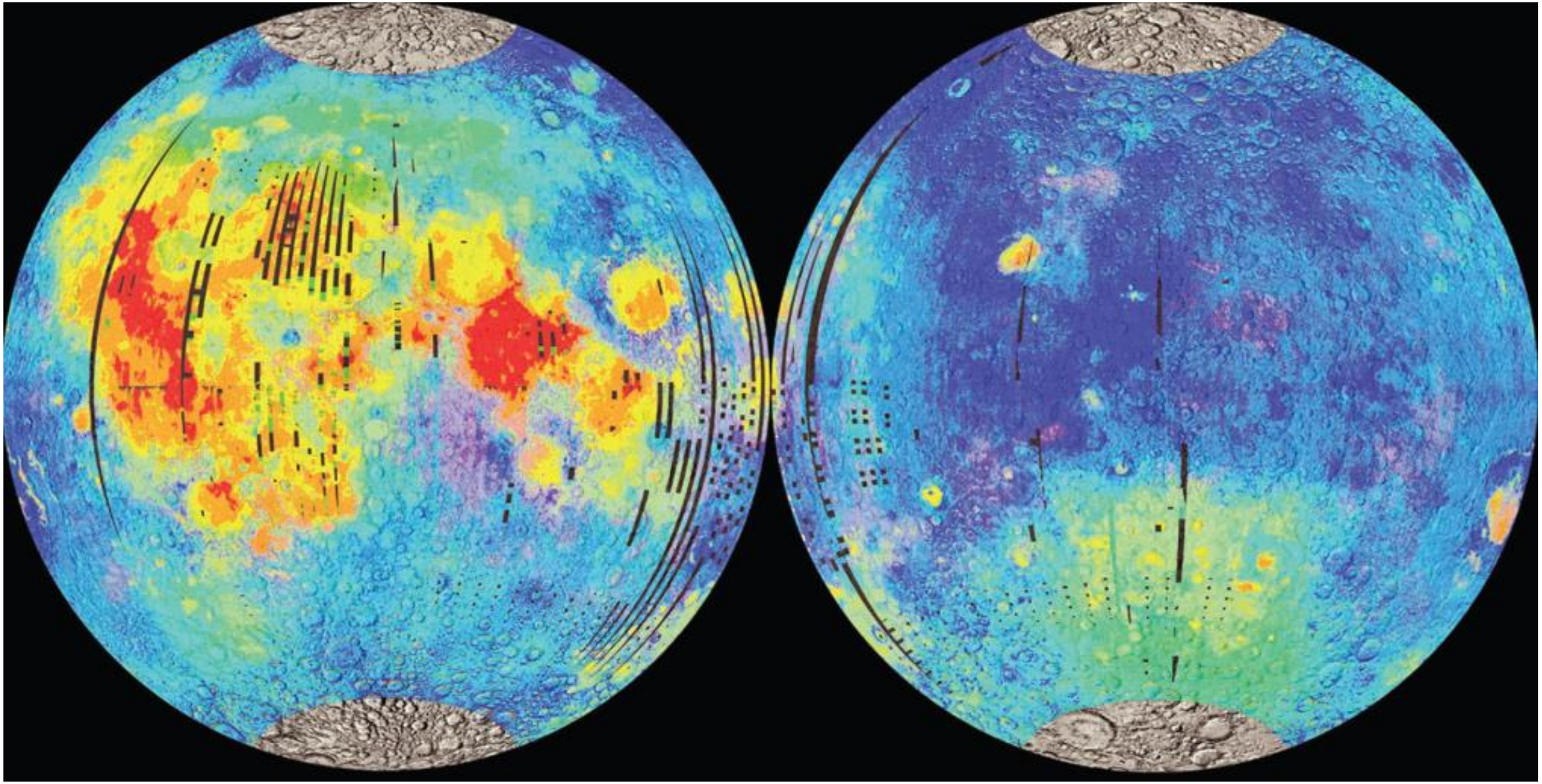
- No clouds
- No atmosphere
- Continuous observations
- Long expositions – slow moving if stars



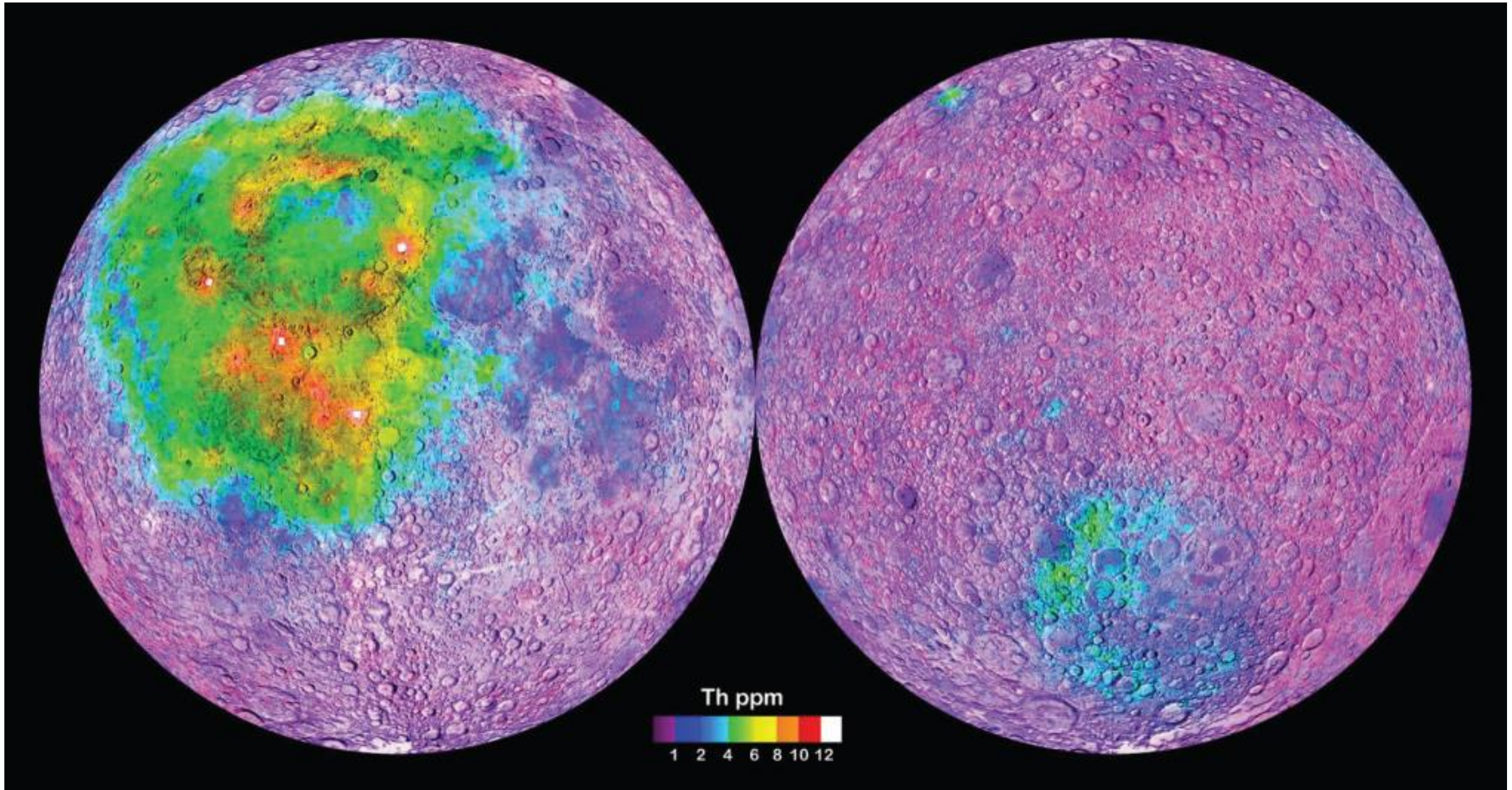
Radio-telescope on the dark-side is the possibility to prevent the Earth effects (the main problem for radioastronomy)



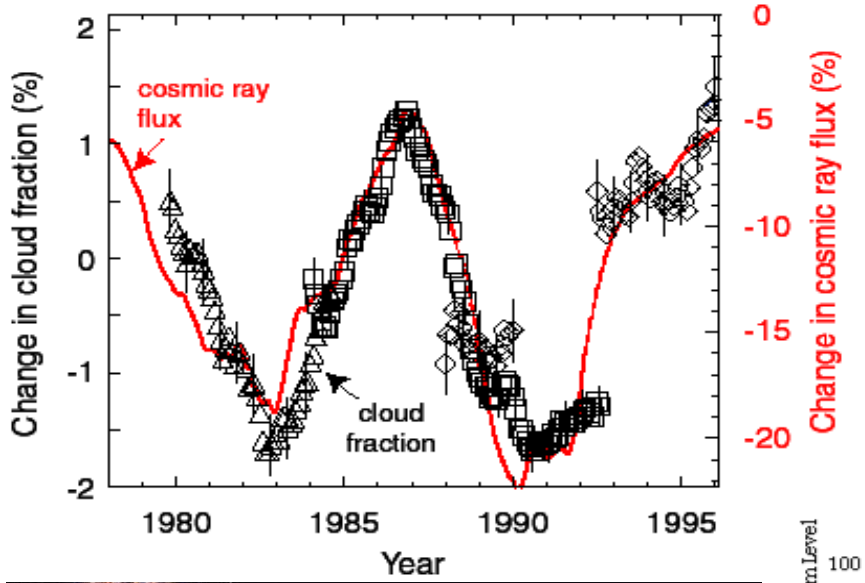
Yellow: low-Ti basalts; red: high-Ti basalts (Crawford, 2015)



Th concentration (Crawford, 2015)

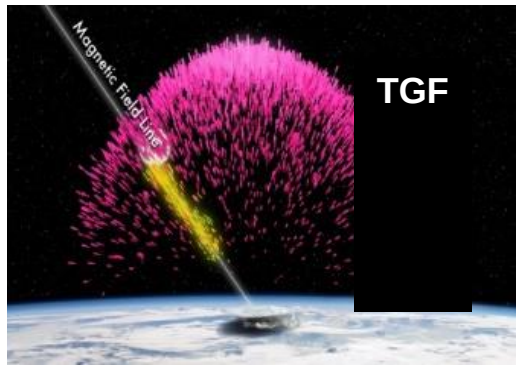


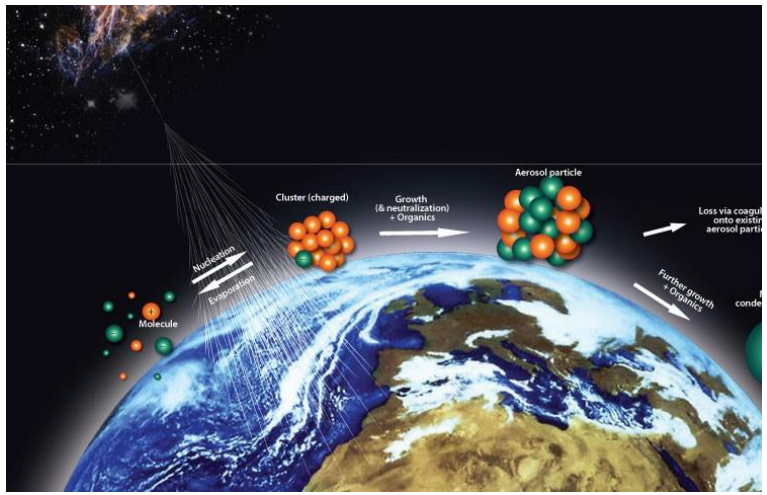
Galactic Cosmic Rays Influence

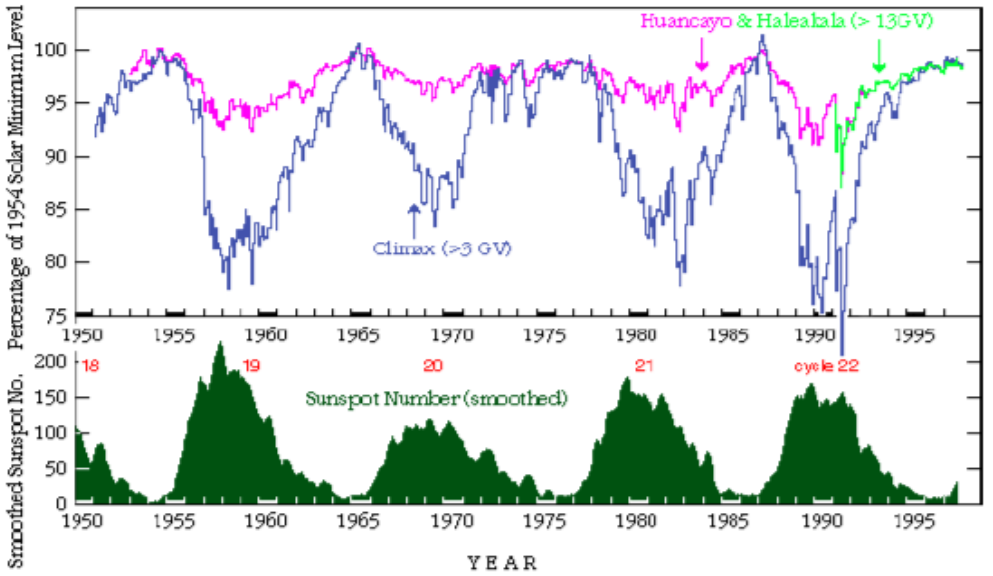


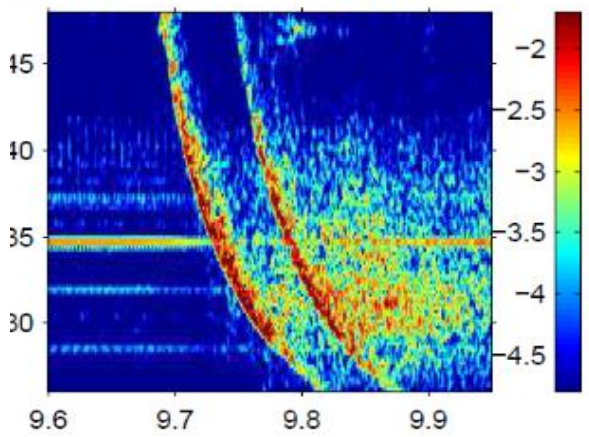
- Intensity depends on the solar activity
- Correlation between flux and cloudness

Thunderstorms - atmosphere





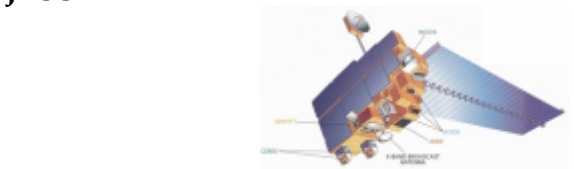


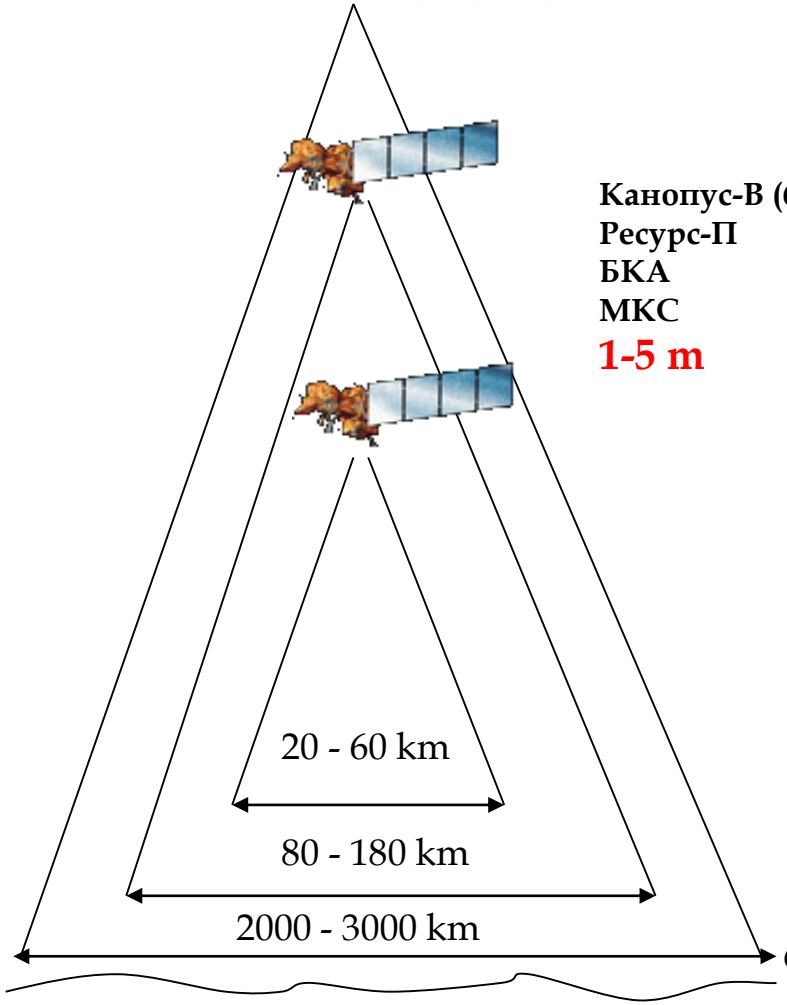


The main data sources

NOAA, Terra, Aqua, NPP, JPSS1
Метеор-М (МСУ-МР)
Канопус-В ИК
Meteosat,
Himawari-8
Электро-Л
Proba-V
Sentinel-3
Sentinel-5
100 m - 2 km

Landsat 4,5,7,8
Sentinel-1A/B
Sentinel-2A/B
Метеор-М (КМСС)
Ресурс-П (КШМСА)
Канопус-В (6 КА)
EOS-1 (Hyperion)
10-50 m





Канопус-В (6 КА)
Ресурс-П
БКА
МКС
1-5 m

Green – Russian satellites systems

Mainly focused on using Russian and publicly available foreign data

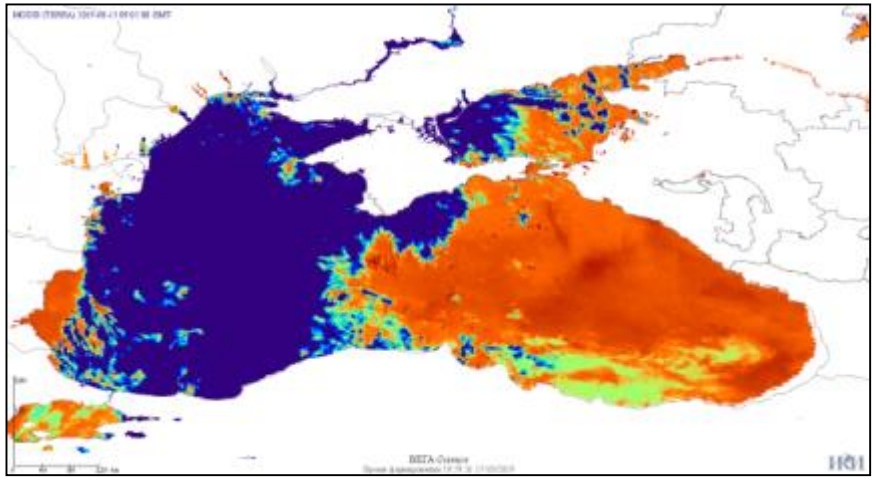
The system receives information from Russian and foreign satellite data centers for collection, processing and archiving centers.

Supports data from more than 40 satellite systems

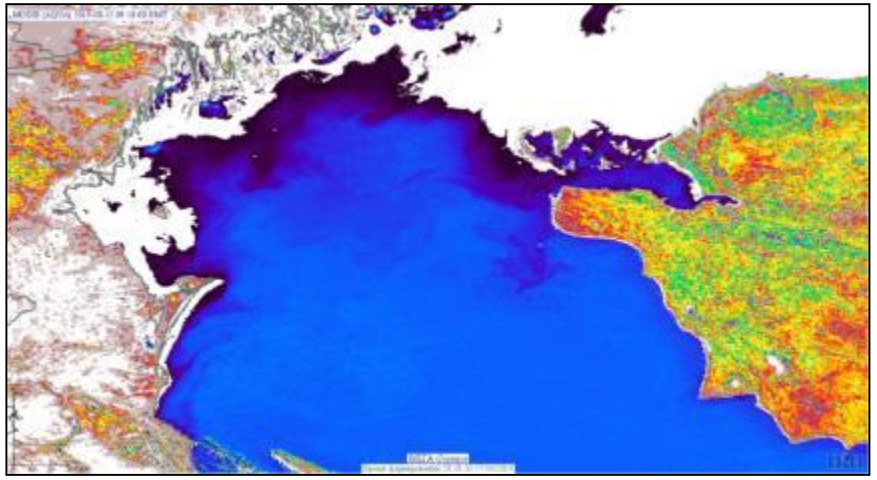
Enables operation with data of more than 30 types of observation devices

The depth of archives reaches 35 years

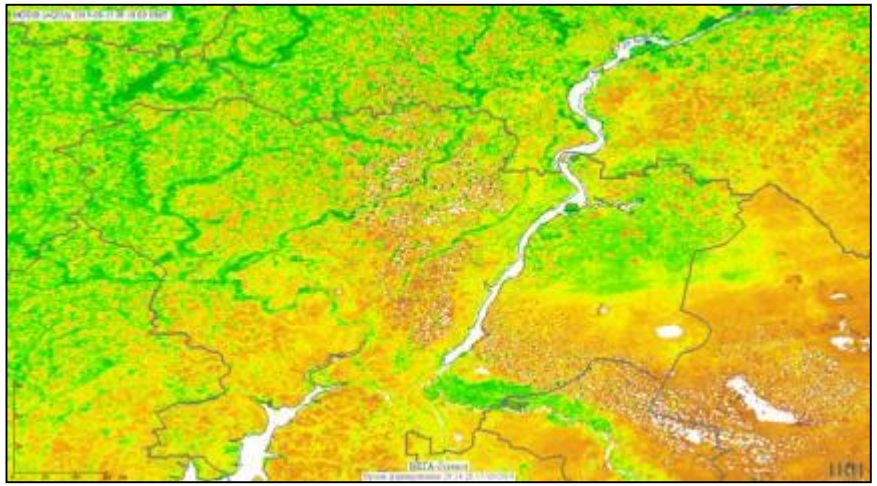
Examples of Level 2 products
(session fields of different physical characteristics and indices)



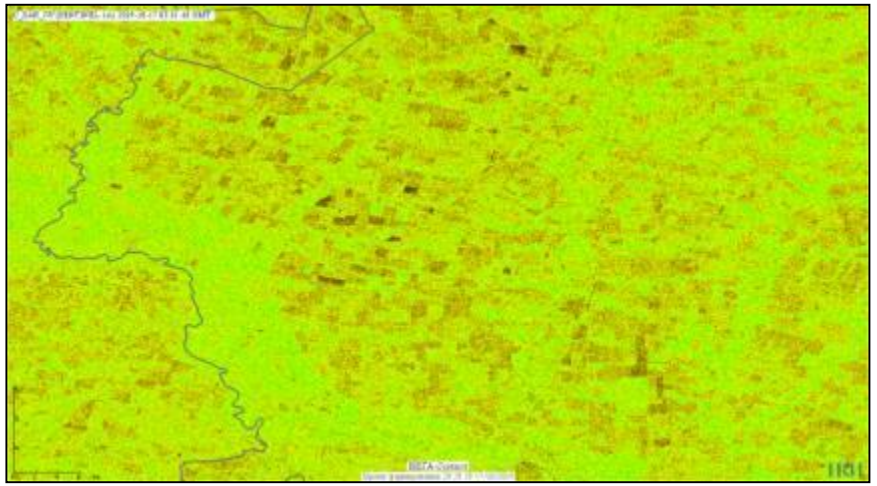
Temperature of sea surface



Index FAI



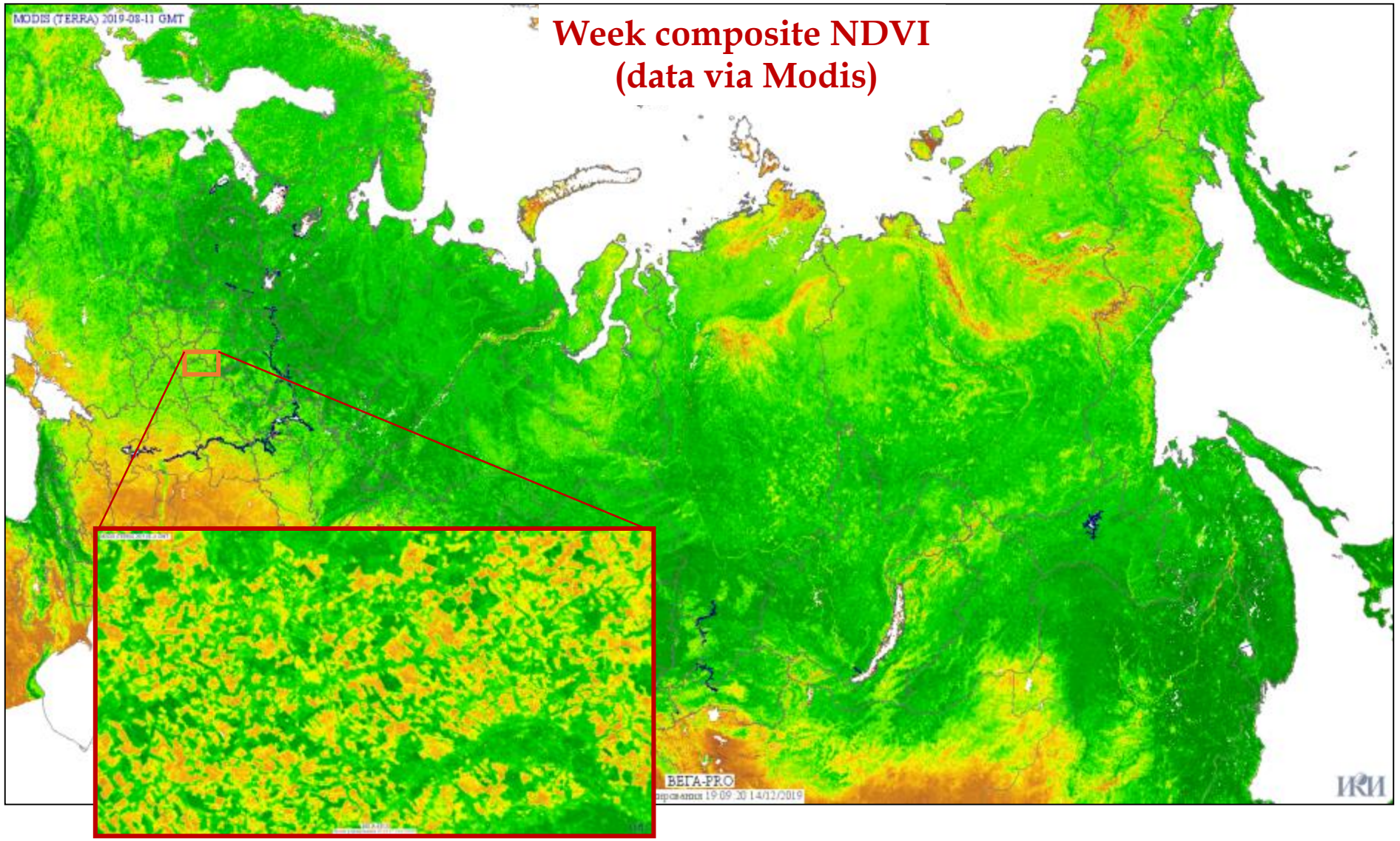
Vegetation index NDVI



Radar vegetation index NRVI

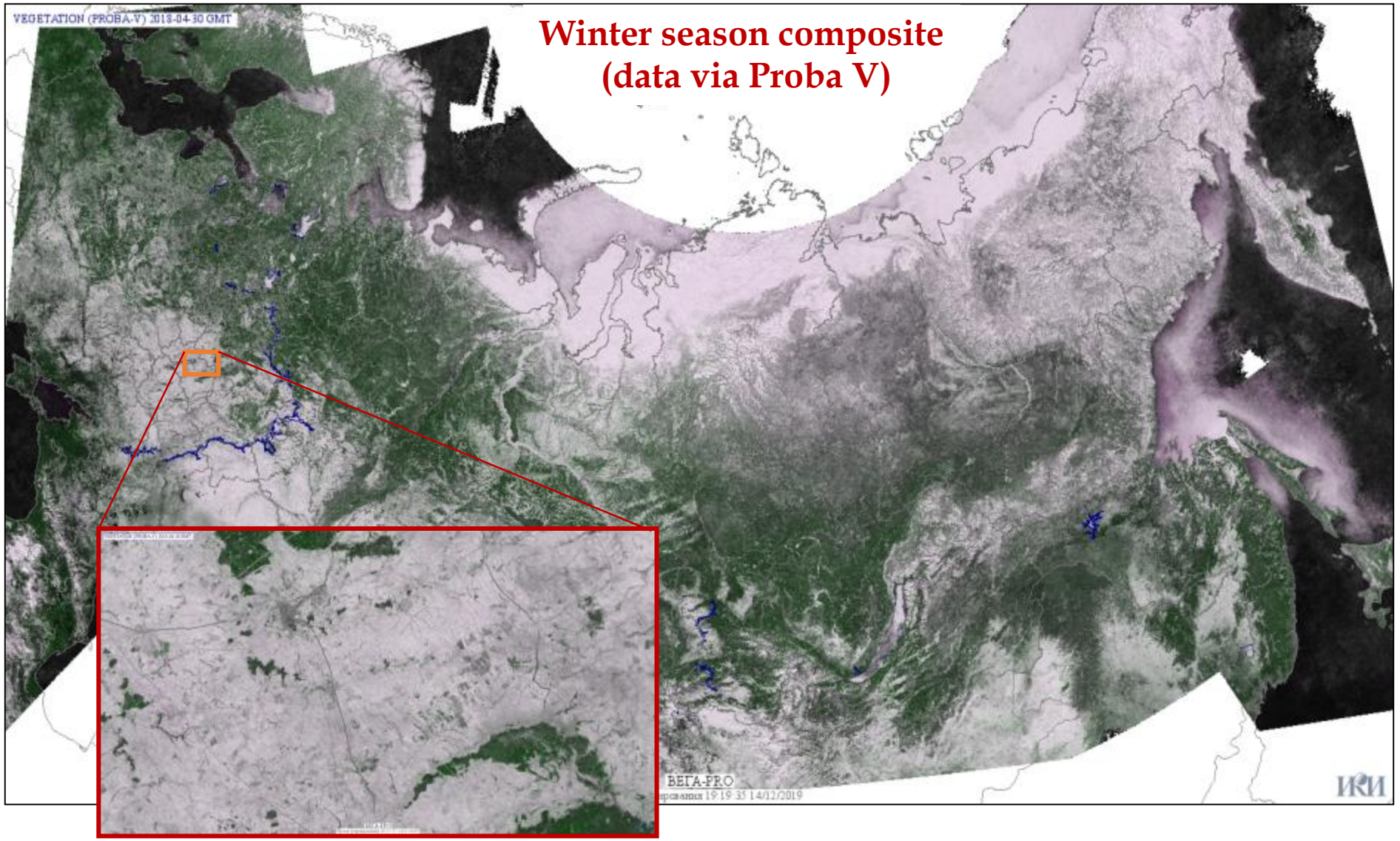
The overwhelming number of Level 2 products is generated dynamically, online

Example of cloud-free composite image with Aqua/Terra (MODIS) (250 m)



Cloud-free composite images at a resolution of 250-500 m
are created for different observation periods: season, month, week, day.

Example of cloud-free composite image with Proba V (100 m)

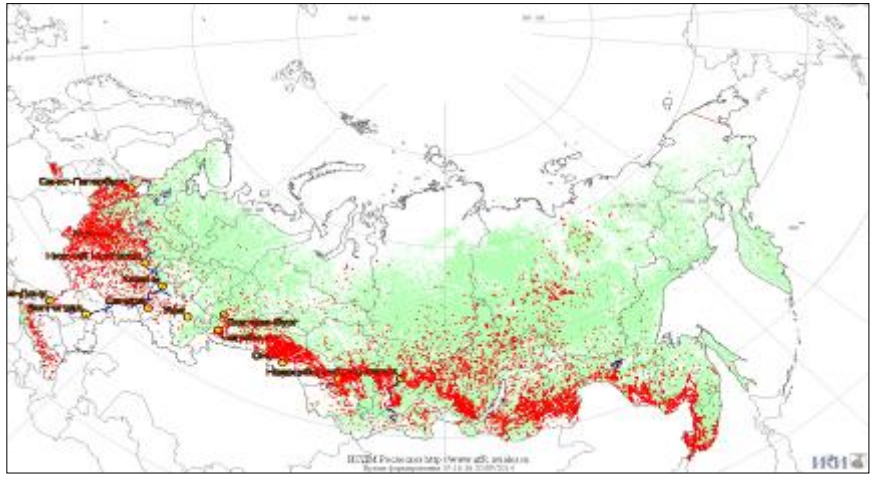


Cloud-free composite images at a resolution of 50-100 m
are created for different observation periods: season, month, week, day.

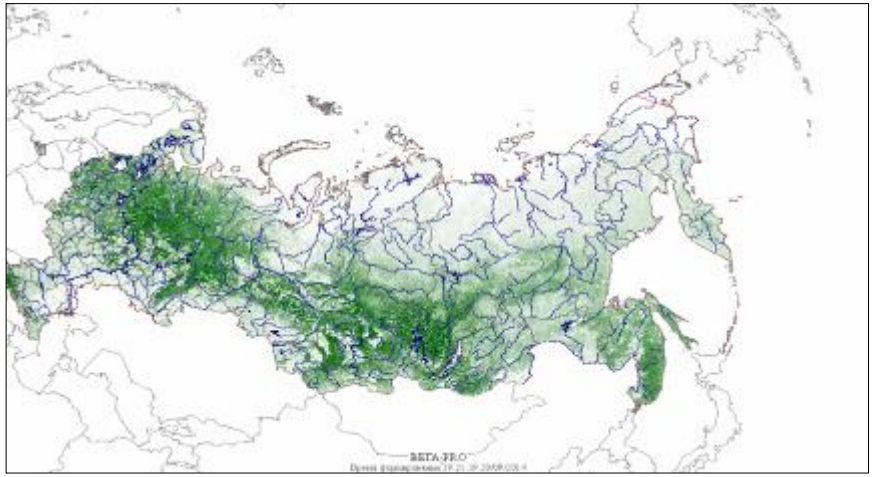
Level 4 products
(different thematical products)

**Maps of the vegetation cover in Russia.
Updated annually.**

**Maps of the dominant tree species.
Updated annually.**



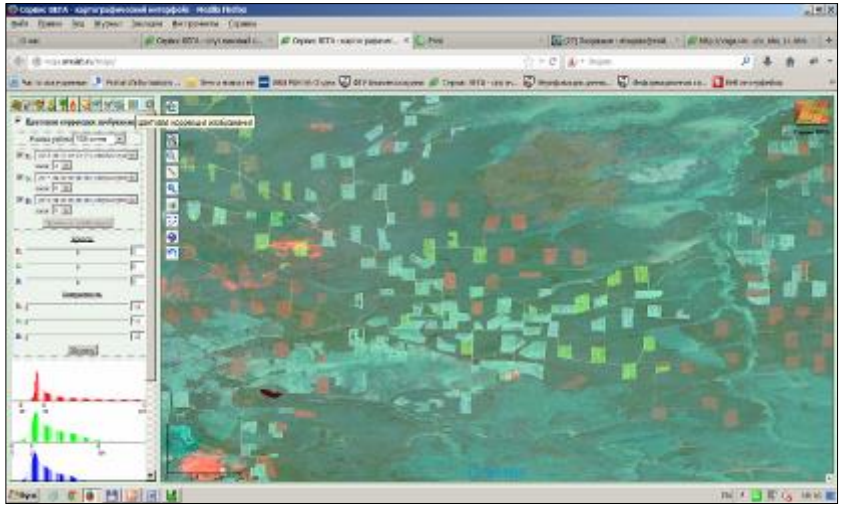
**Information on forest natural fires and their consequences.
Updated daily**



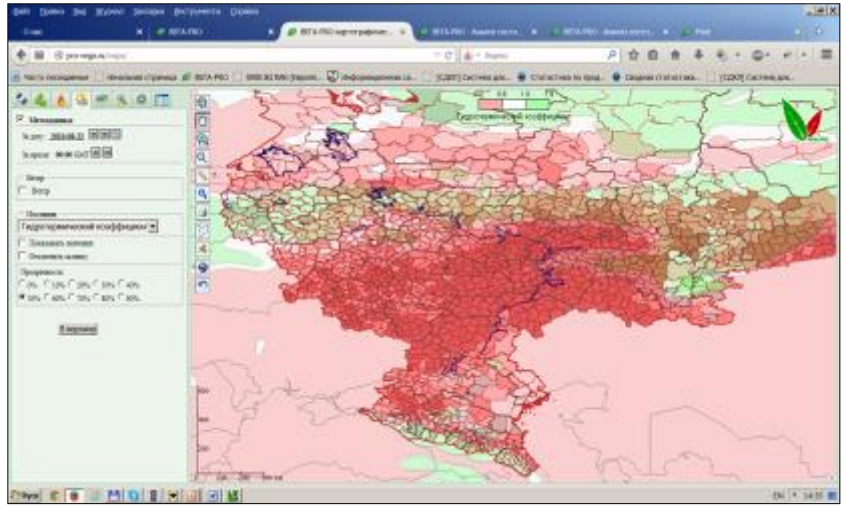
**Trunk wood stocks.
Updated annually.**

ИКИ

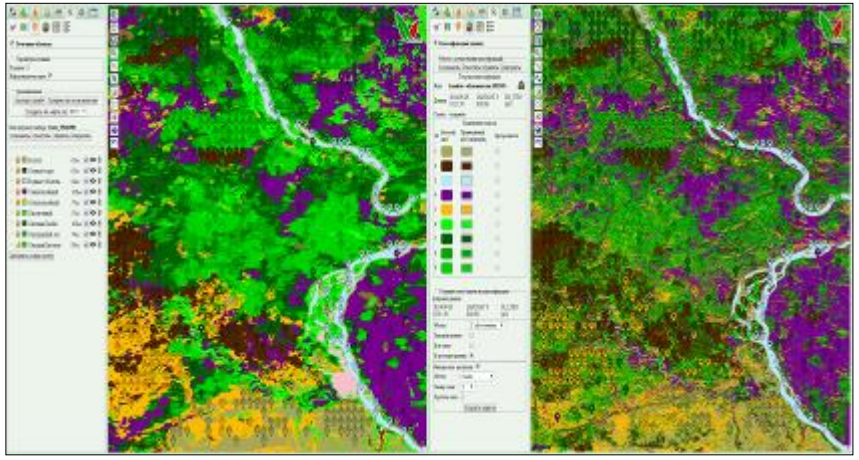
Examples of instruments



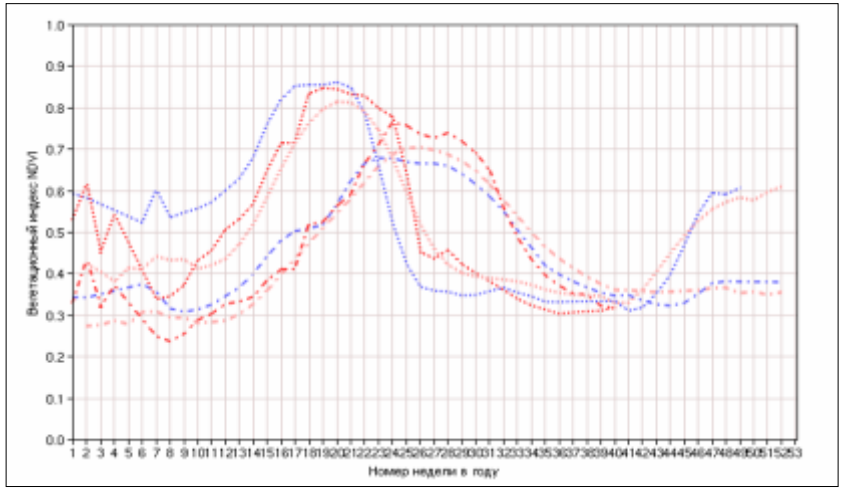
Analysis of multitemporal data



Joint analysis of different information



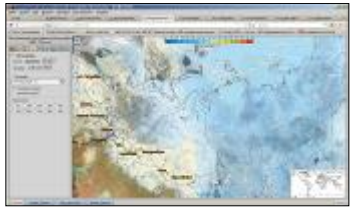
Data classification

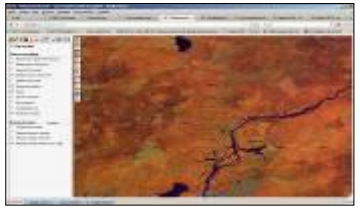


Temporal data analysis

Examples of systems

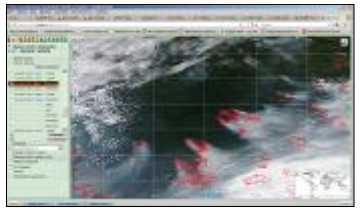
System of work with remote hydrometeorological monitoring data (ИС НИЦ «Планета» Росгидромета)

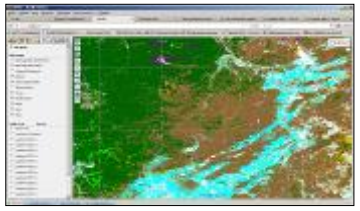




System of complex remote forest monitoring of Primorsky Krai (ИС Вега-Приморье)

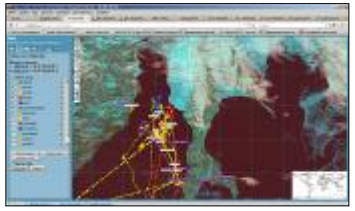
Remote monitoring of forest fires and their consequences (ИСДМ-Рослесхоз)





Agricultural monitoring (ИС Вега-Geoglam)

Monitoring system for aquatic biological resources (ОСМ Росрыболовства)

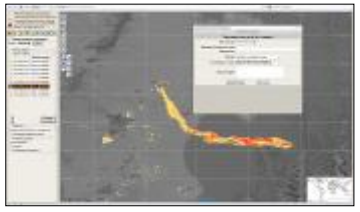


Global agricultural monitoring system development (ИС Вега-Pro)

Agricultural Census Remote Control System (МСКД ВСХД Росстат)

The System of Remote Study of the Border Seas of Russia (ИС Sea The See)

Remote Agrometeorological Monitoring System (ИС Вега-Агрометеоролог)

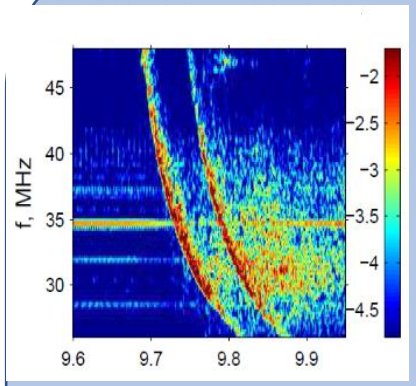


Volcanic activity monitoring system in Kamchatka and the Kurils (ИС VolSatView)

Atmosphere researches

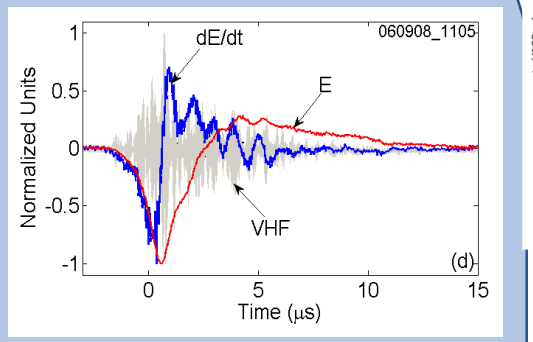
CHIBIS

TIPP



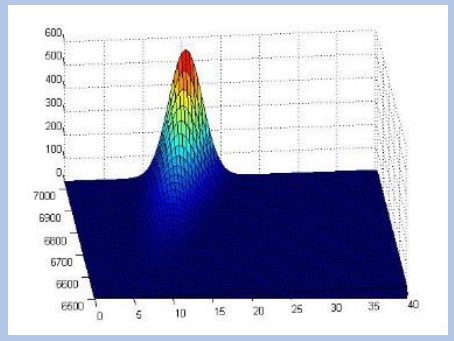
Trans-Ionospheric Pulse Pair

NBP

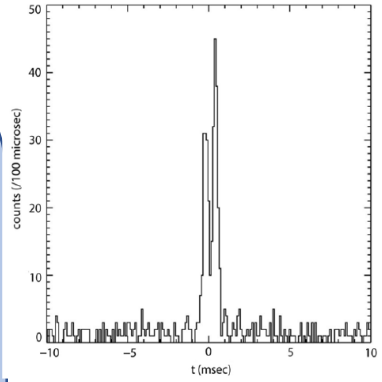


Narrow Bipolar Pulse

CID



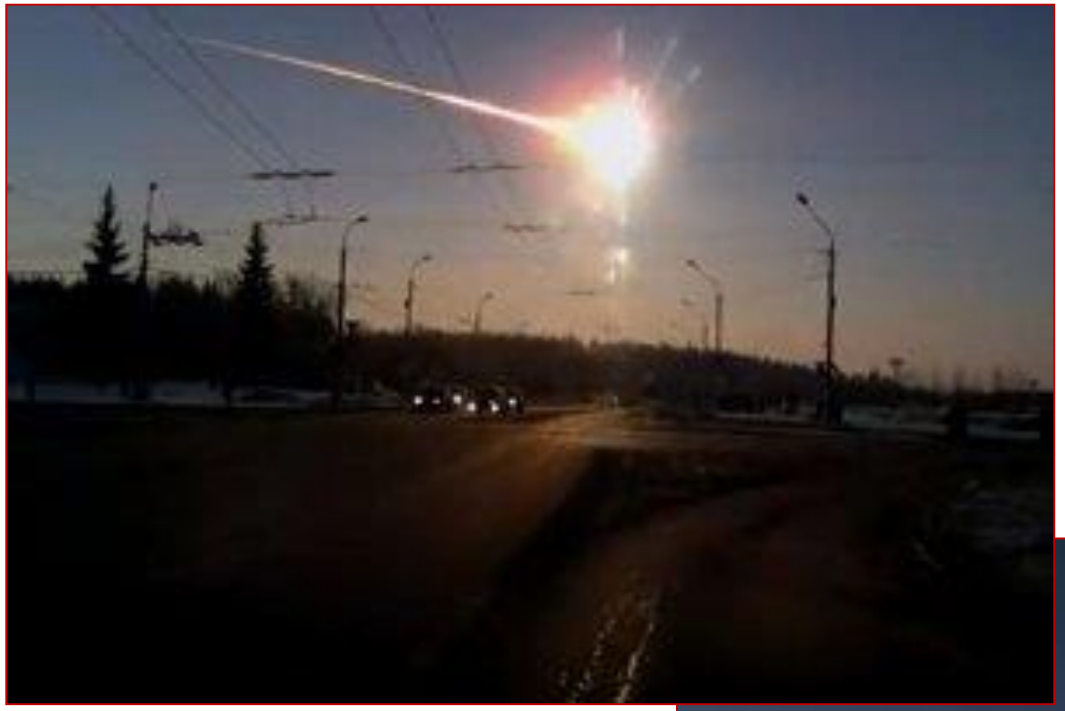
Compact Intracloud Discharge



TGF

Terrestrial Gamma-Flash

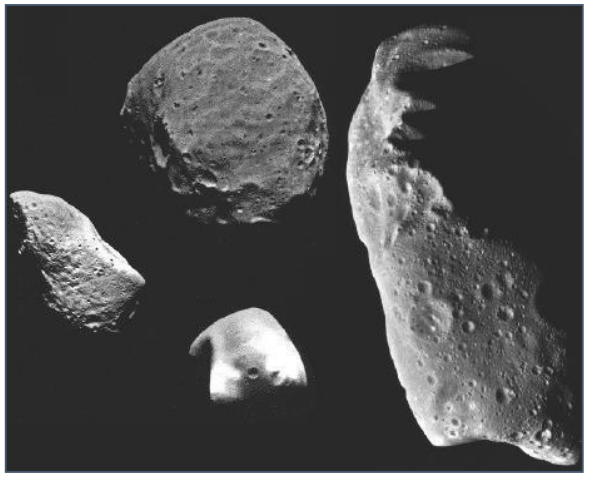
Chelyabinsk Meteorite,15 February 2013



Craters on the Different Solar System Objects

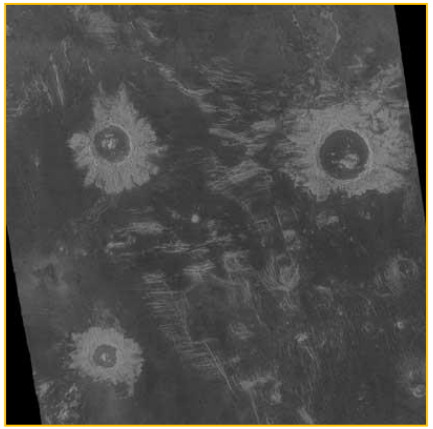
Moon

Mercury

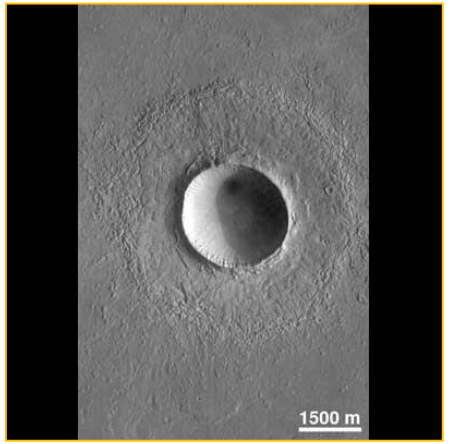


Asteroids

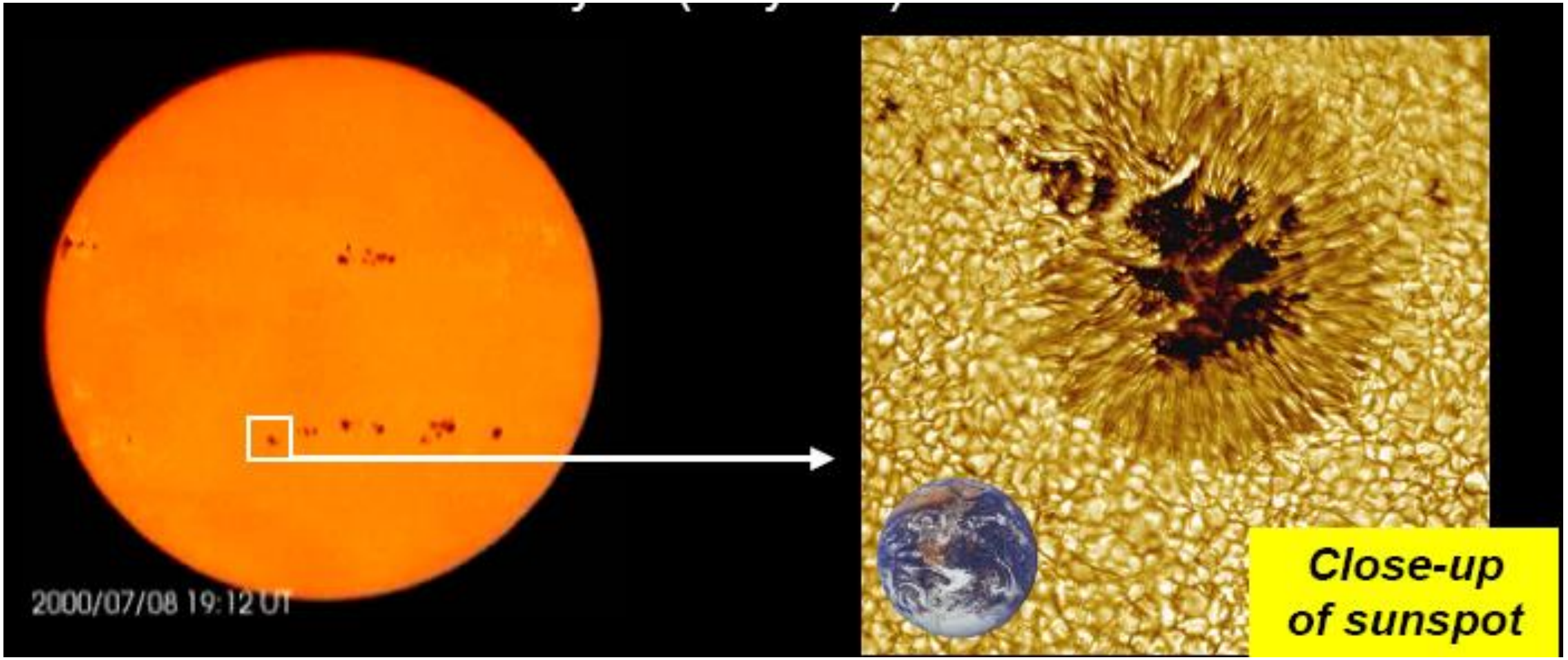
Venus



Mars

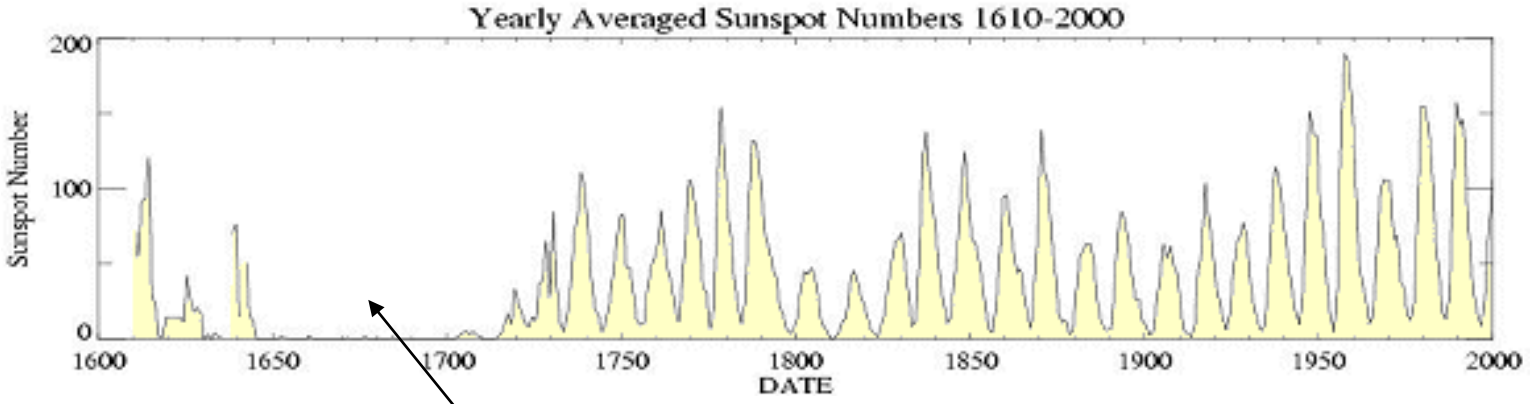


Sunspots

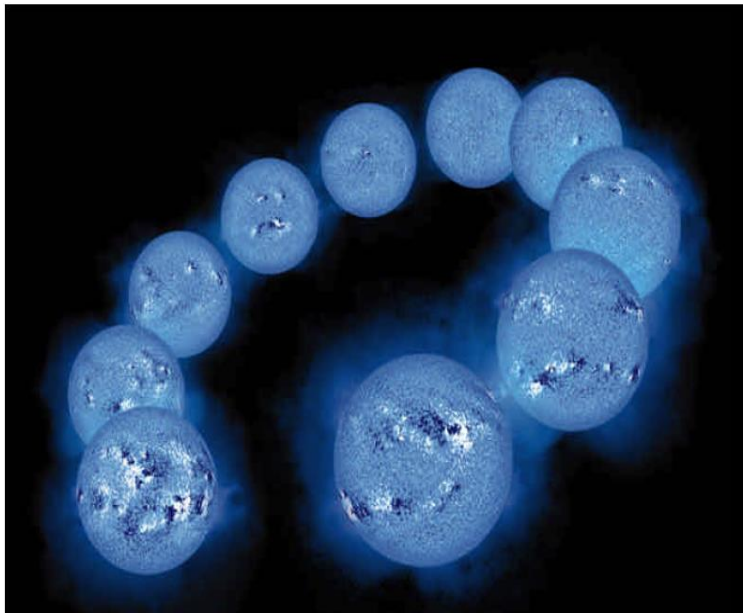


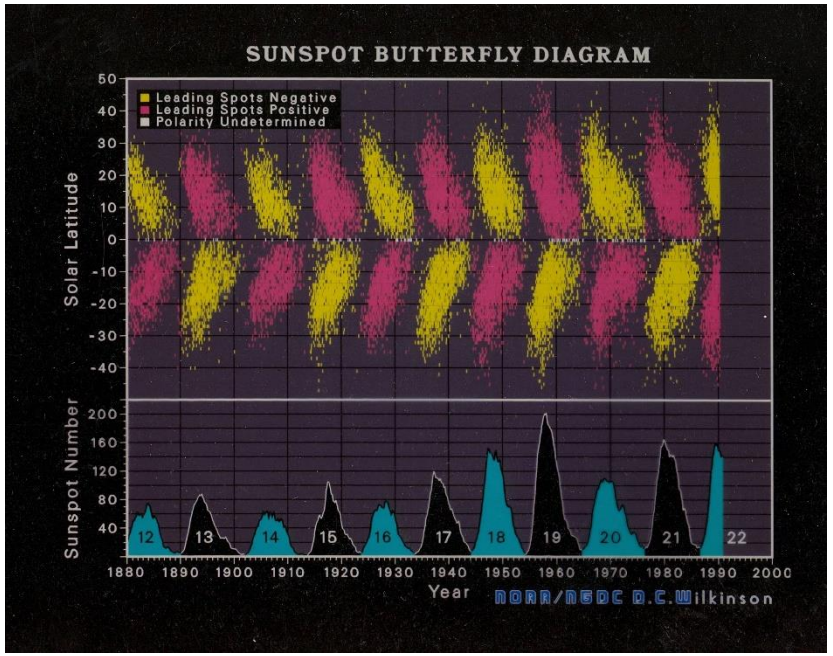
Size ≥10'' (7250 km)
Big spot ~35 000 км.
Magnetic field 2000-4000 G
T = 4500 K

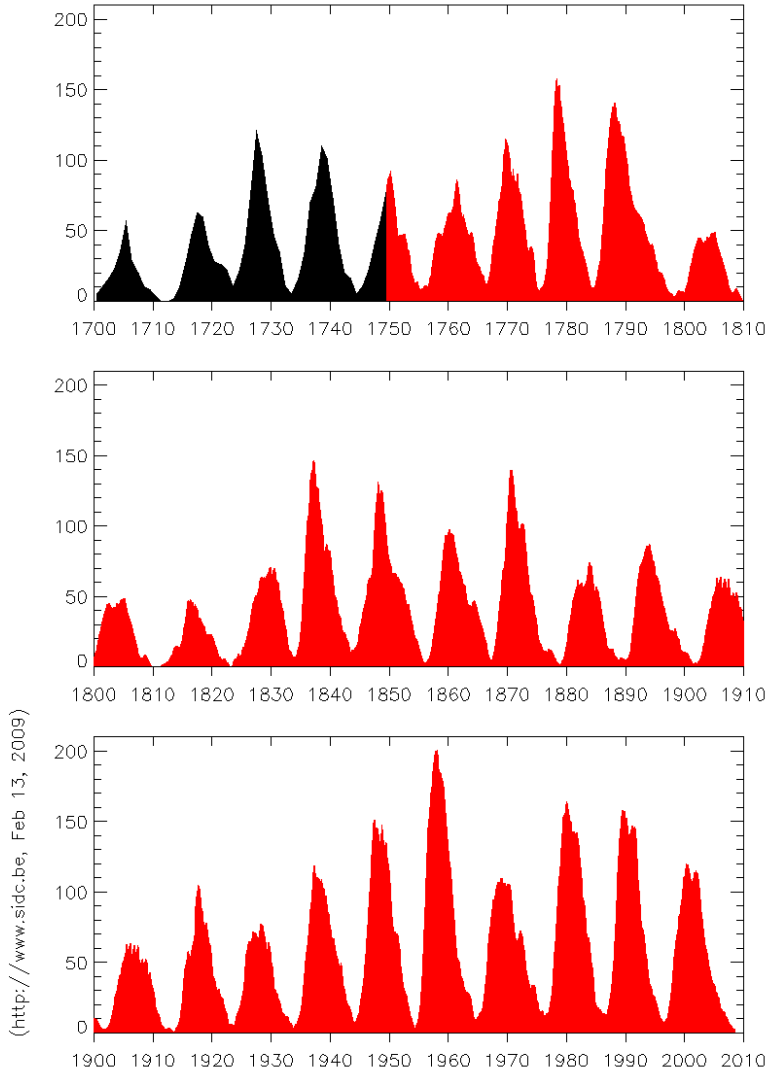
Solar cycle



Maunder Minima
(1640-1710 гг.)

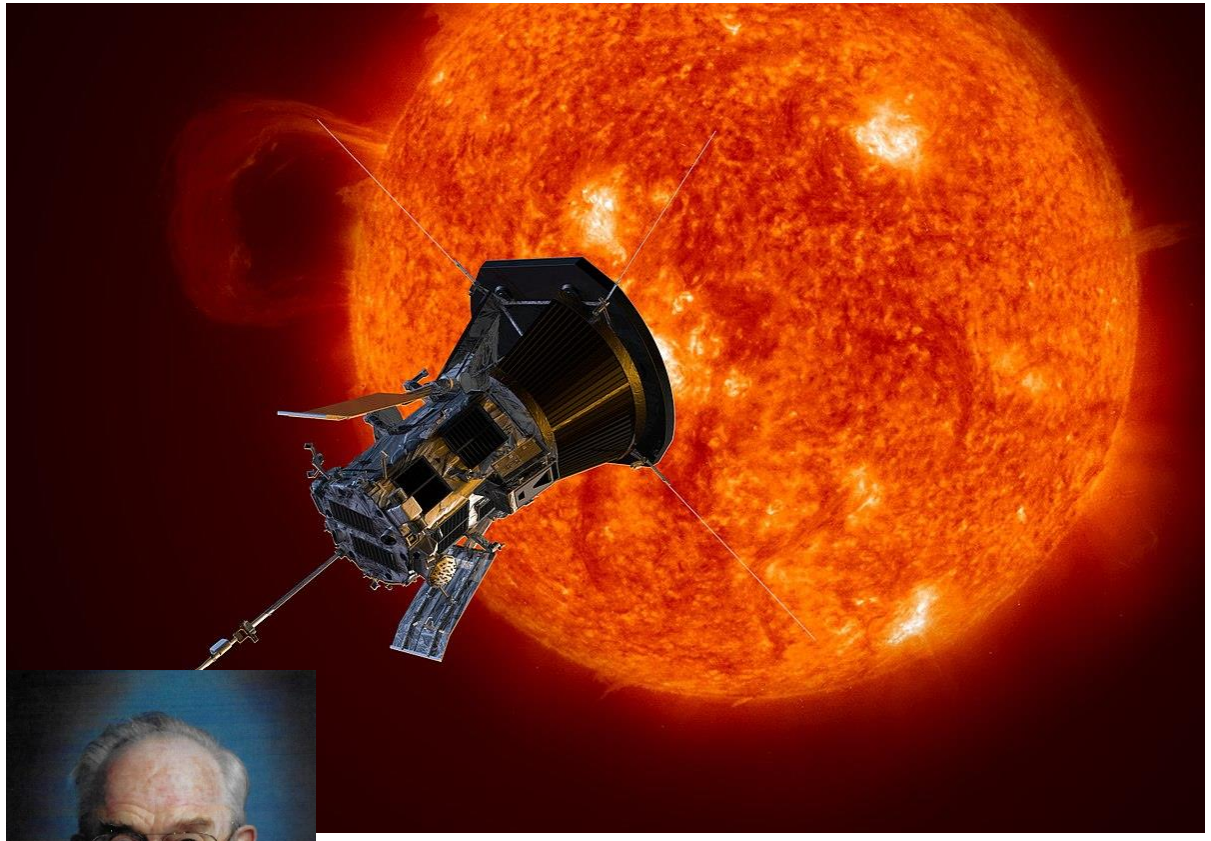


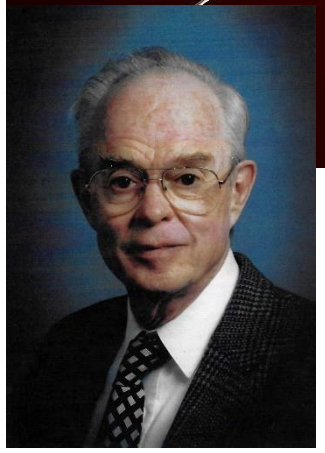




Spots for different periods

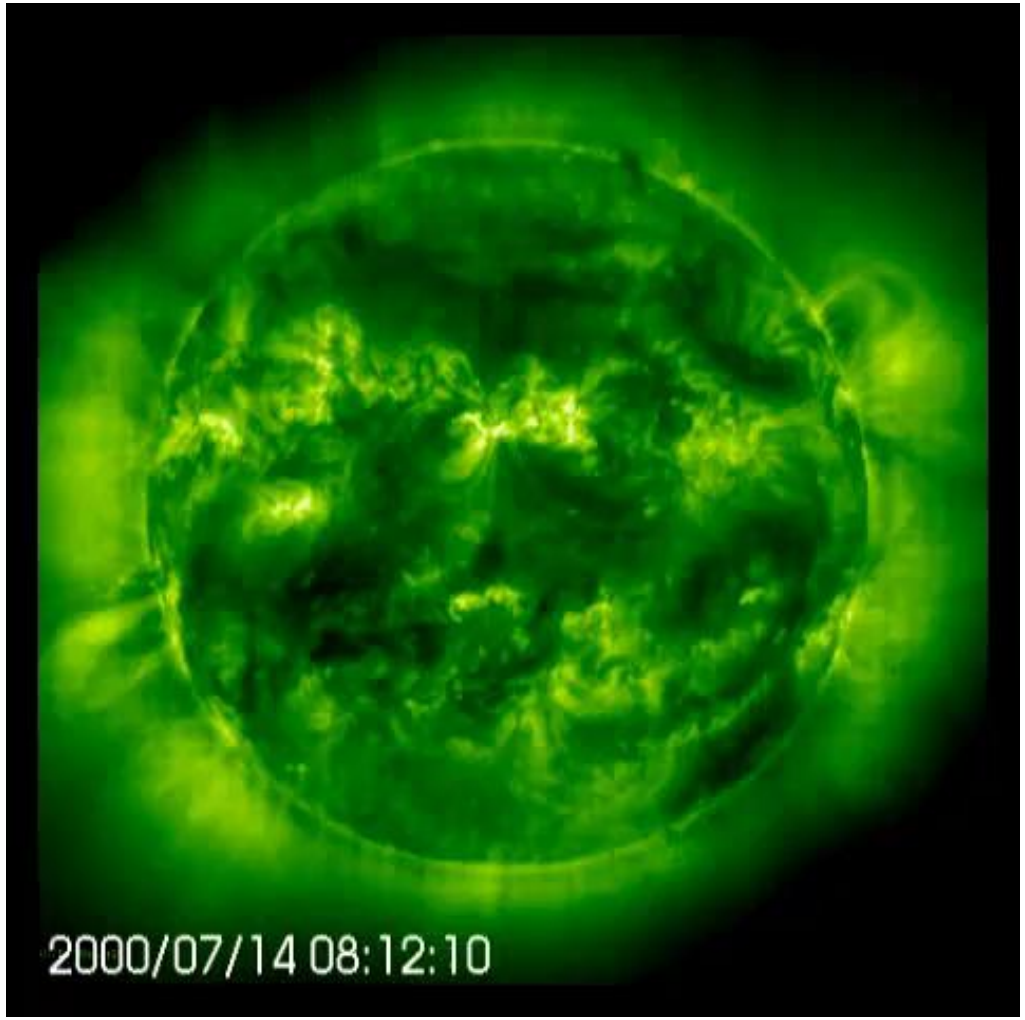
Parker





Solar Orbiter

Solar Flares

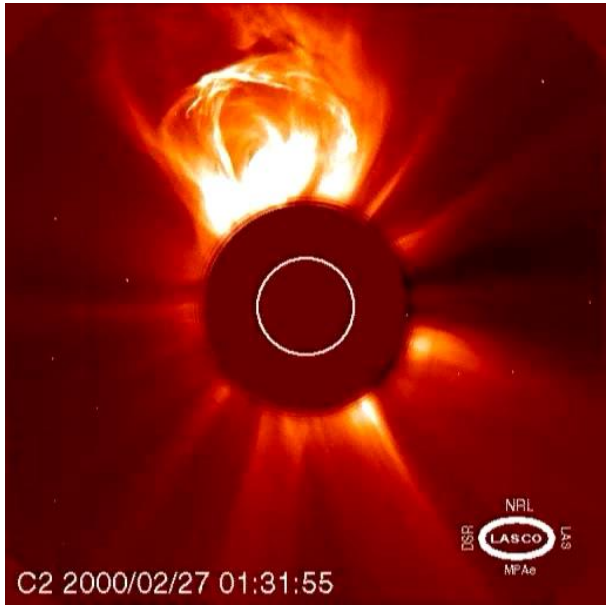


Venera, Skylab (70th); HINITORI, SMM, GOES (80th); CGRO, GAMMA-1, GRANAT, Yokhoh, GOES (90th); YOKHOH, RHESSI, Coronas-F, INTEGRAL, TRACE, SOHO, GOES (00-ые); HINOBE, STEREO, Coronas-Photon (2009), SDO, IRIS…

Energy 10^{32}-10^{33} erg in 100-1000 s.

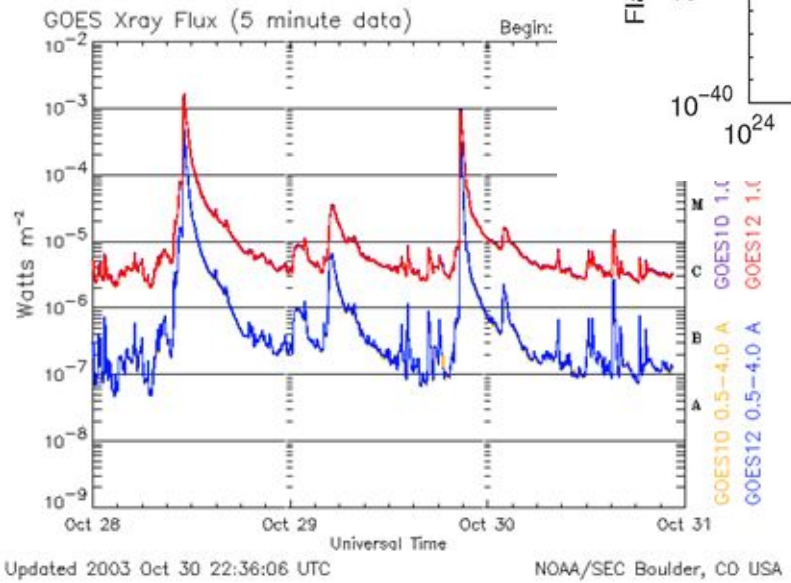
10%-50% in accelerating particles.

Coronal mass ejections



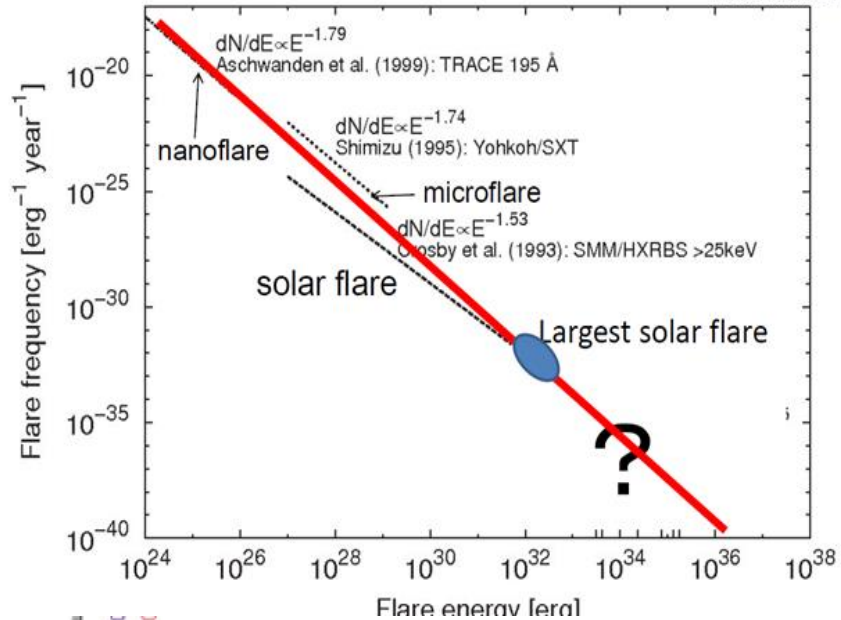
Flares: X-ray Classification

Class	Intensity (erg cm^{-2} s^{-1})	I (W m^{-2})
B	10^{-4}	10^{-7}
C	10^{-3}	10^{-6}
M	10^{-2}	10^{-5}
X	10^{-1}	10^{-4}

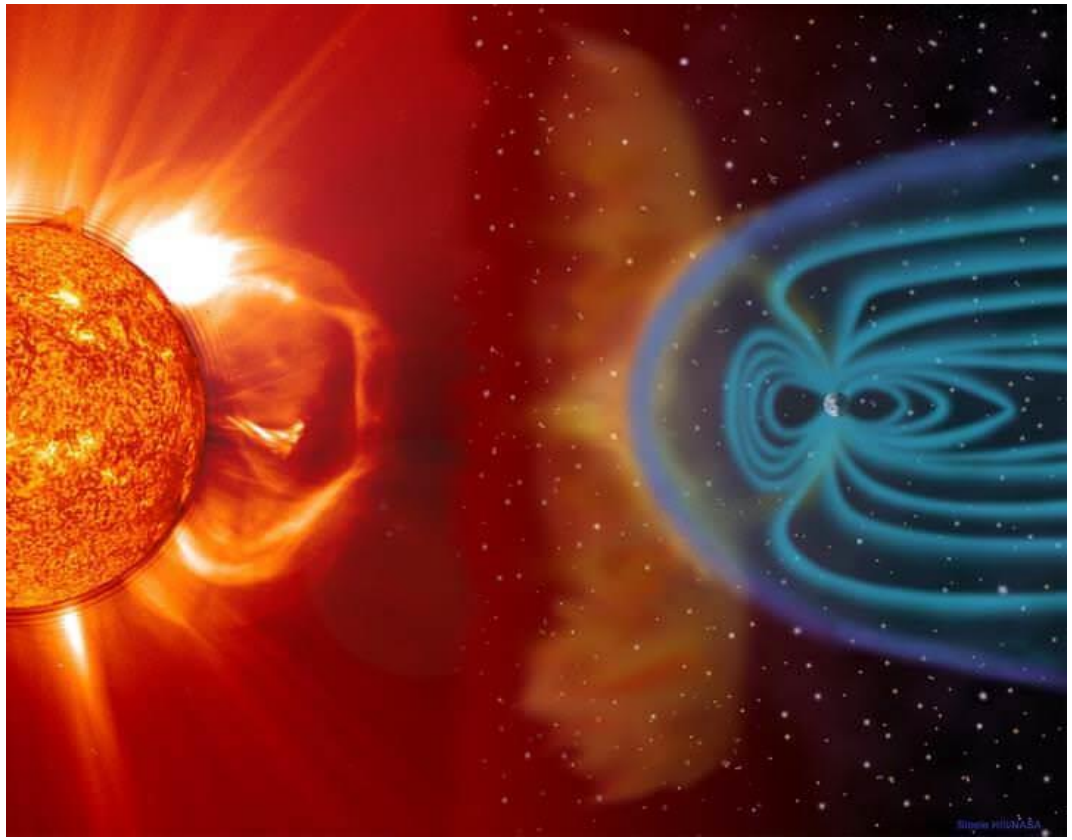


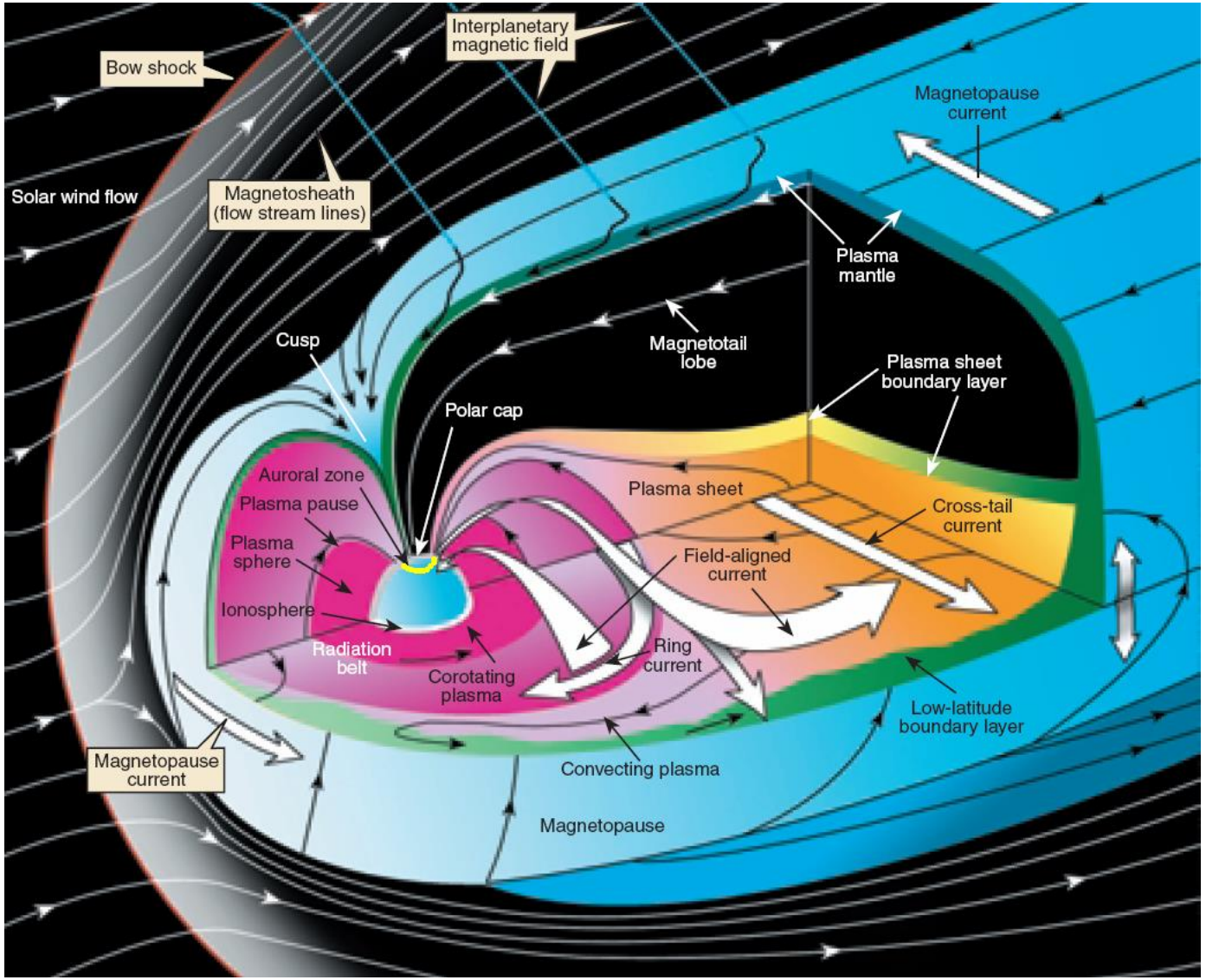
Comparison of statistics between solar flares/microflares and superflares

Shibata et al. 2013



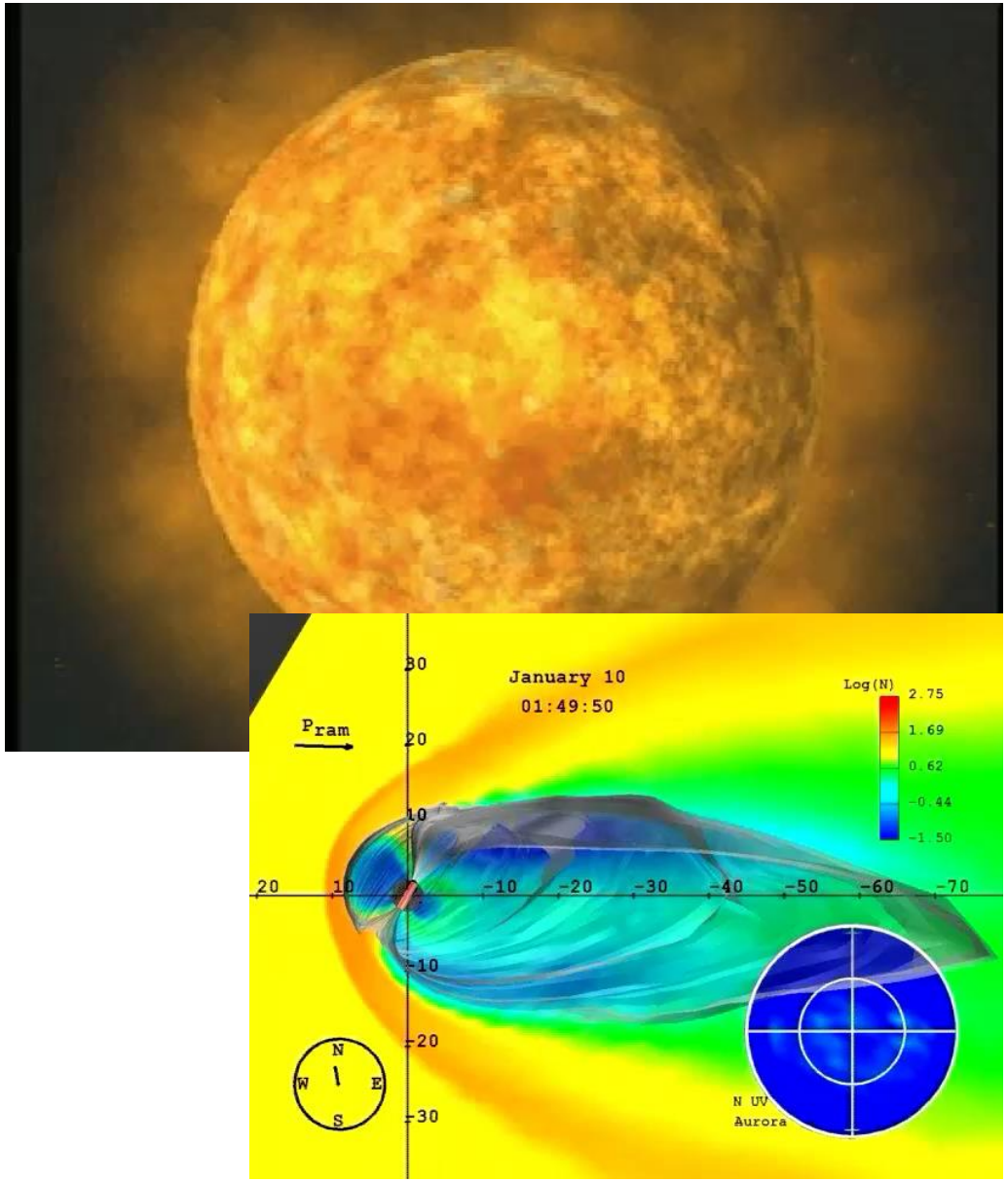
Earth magnetosphere

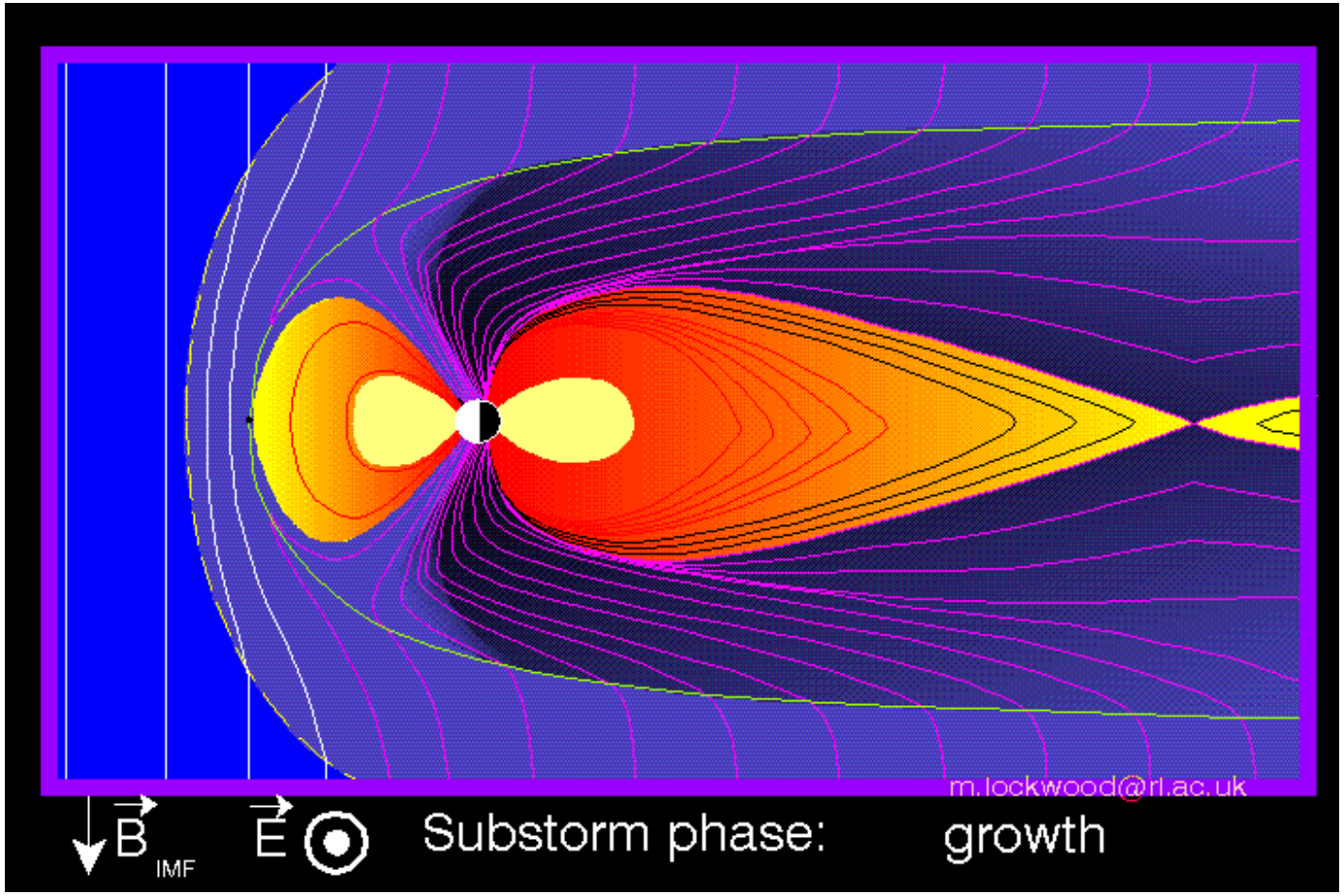




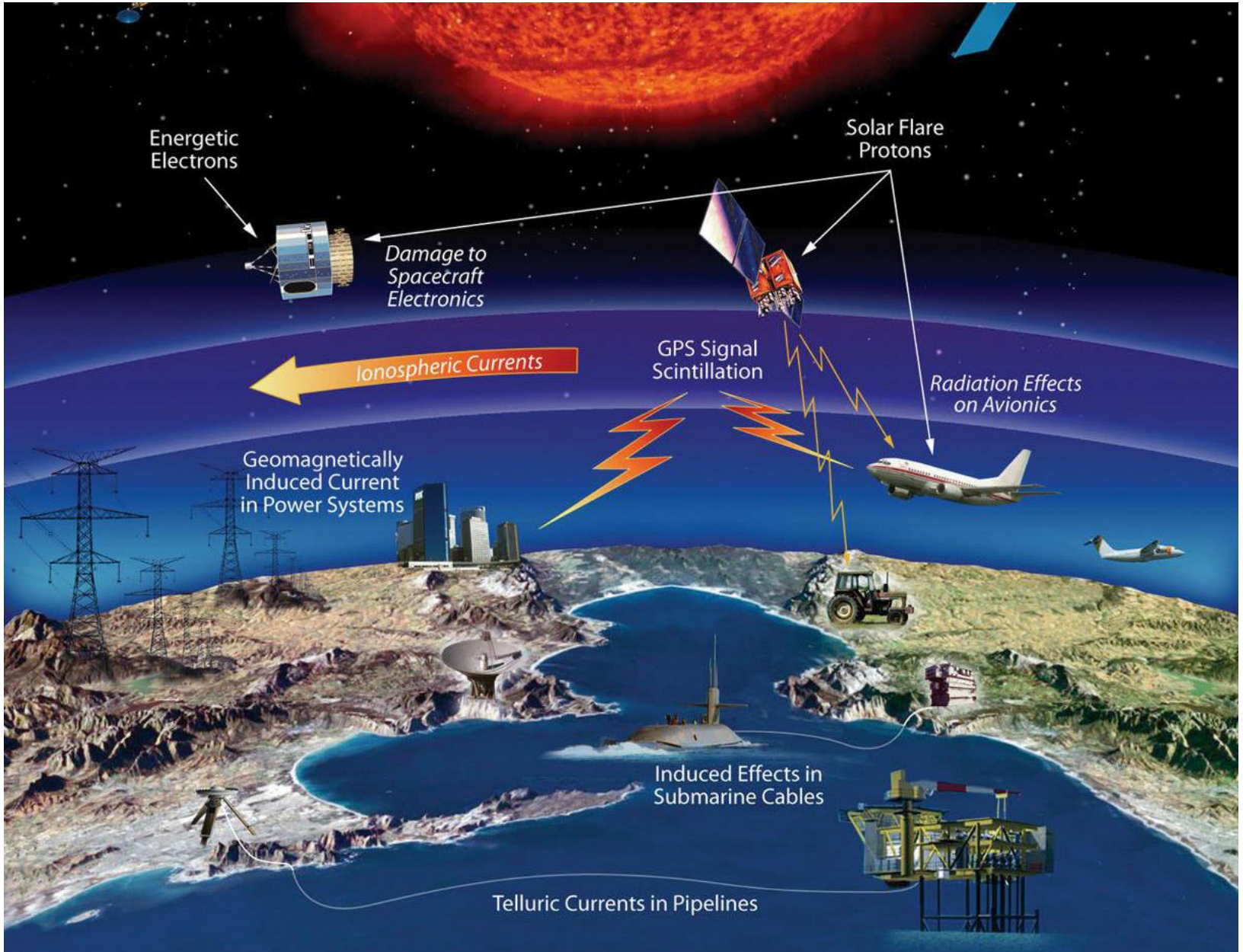
Aurora Borealis

Magnetic Storms and Substorms





Space Weather



Space exploration

Natural human expansion

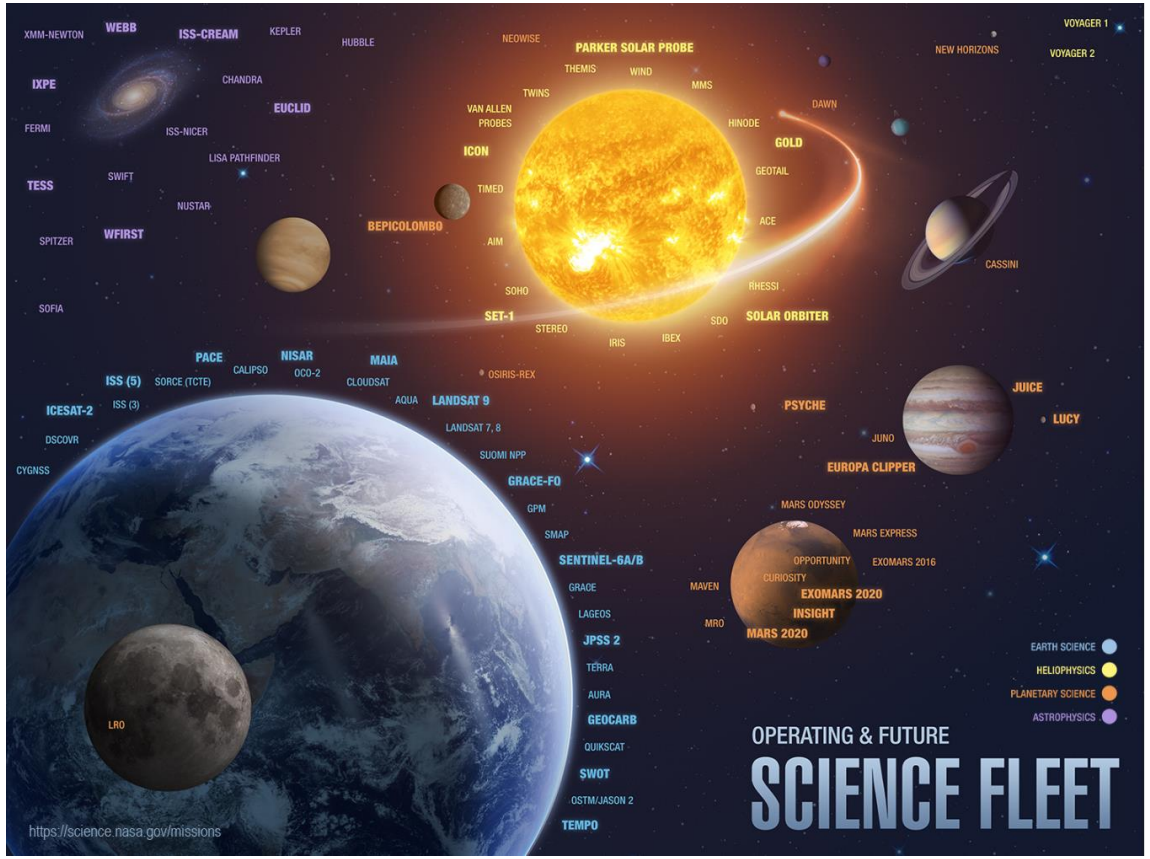
Siberia expansion begins 500 years ago,
but made the new quantum leap only in XIX and XX centuries

Civilization energy

- Beginning XX 30 EJ/year
- Beginning XXI 450 EJ/year
- Beginning XXII ?
- Solar energy beyond the atmosphere 3000 EJ/year

New energy sources – new space physics

But using this energy
is possible only in space



Continuing of space exploration