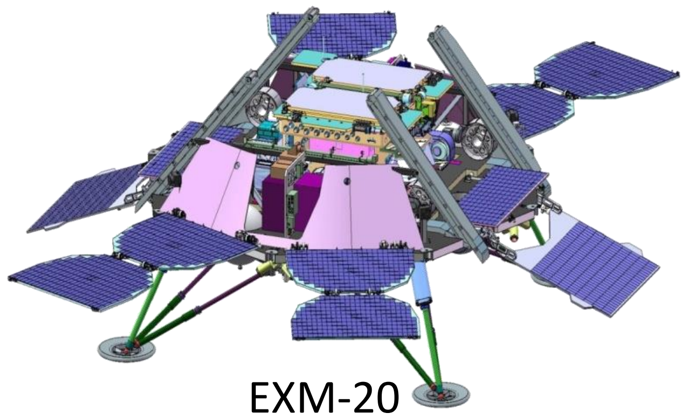
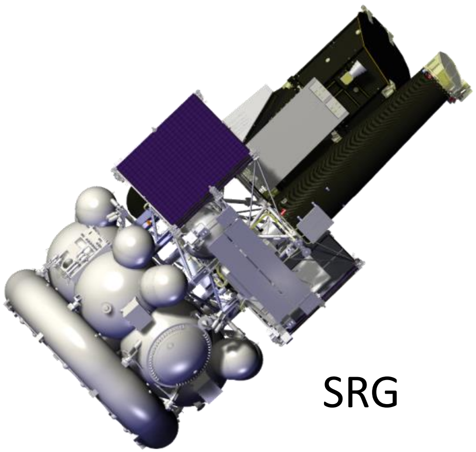
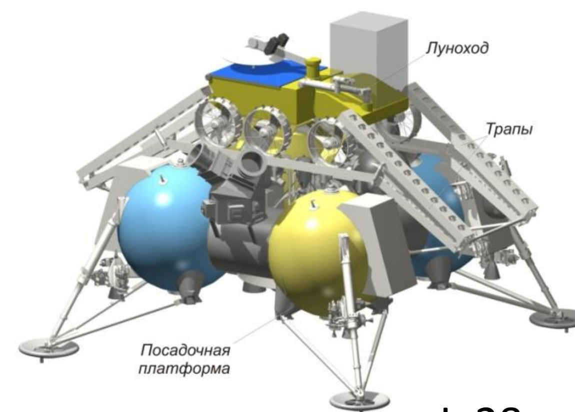
Russian Space Science Program update



EXM-20



SRG



L-28

LEV ZELENYI

RAS SPACE COUNCIL

IKI PRESIDENT

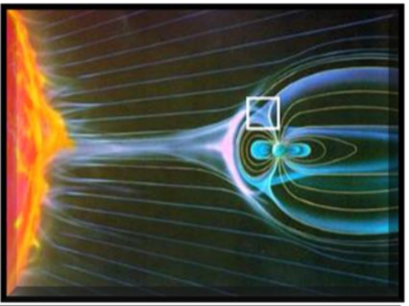
57th ESSC Plenary meeting
Amsterdam, 9-10, May, 2019

Federal space program -2016-2025
Space science division

Major directions and relative shares

space astronomy and cosmic rays (26%)

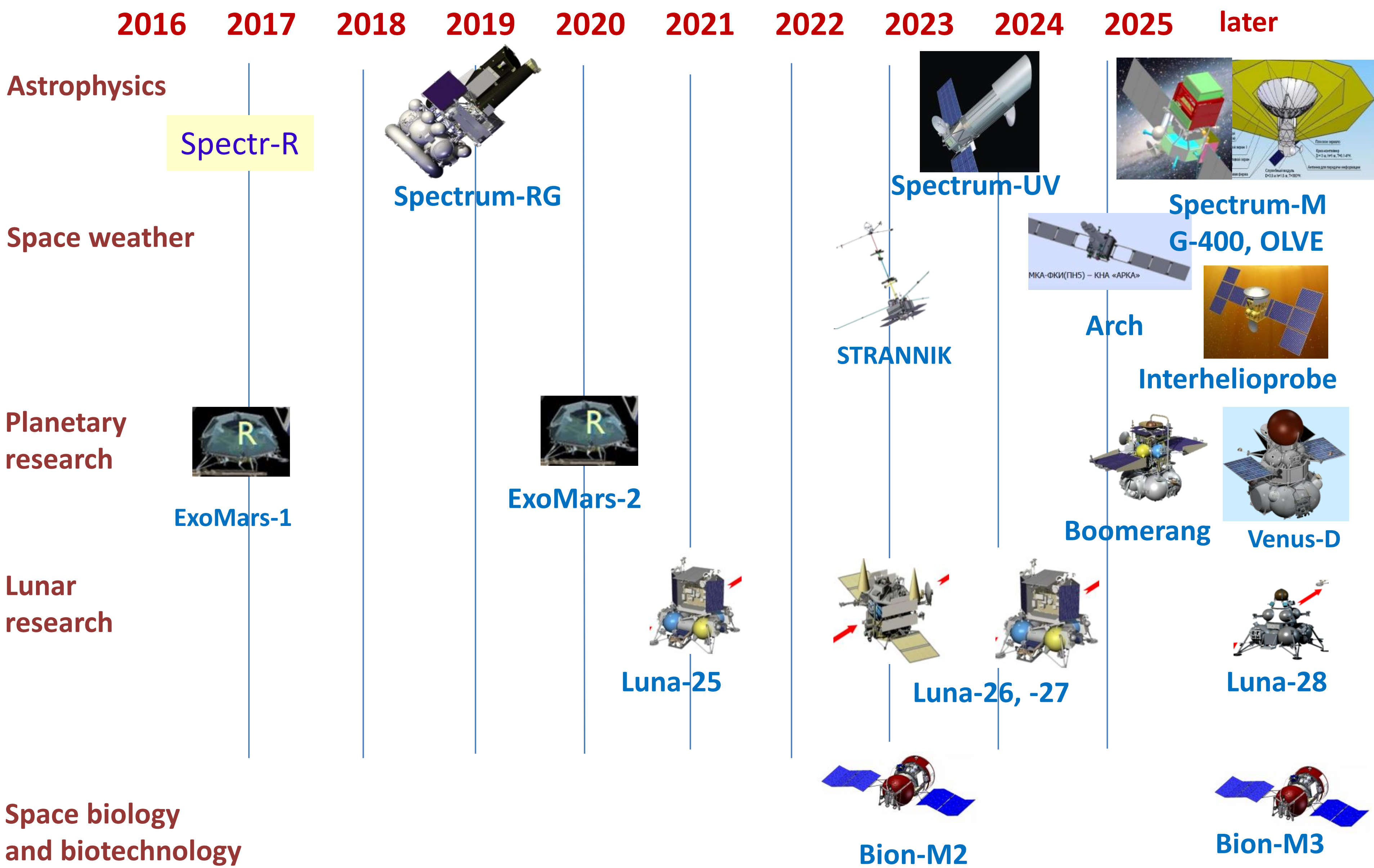
moon, planets, minor bodies of the solar system (47%)



space plasma and solar physics (13%)

basic problems of space biology and medicine (14%)

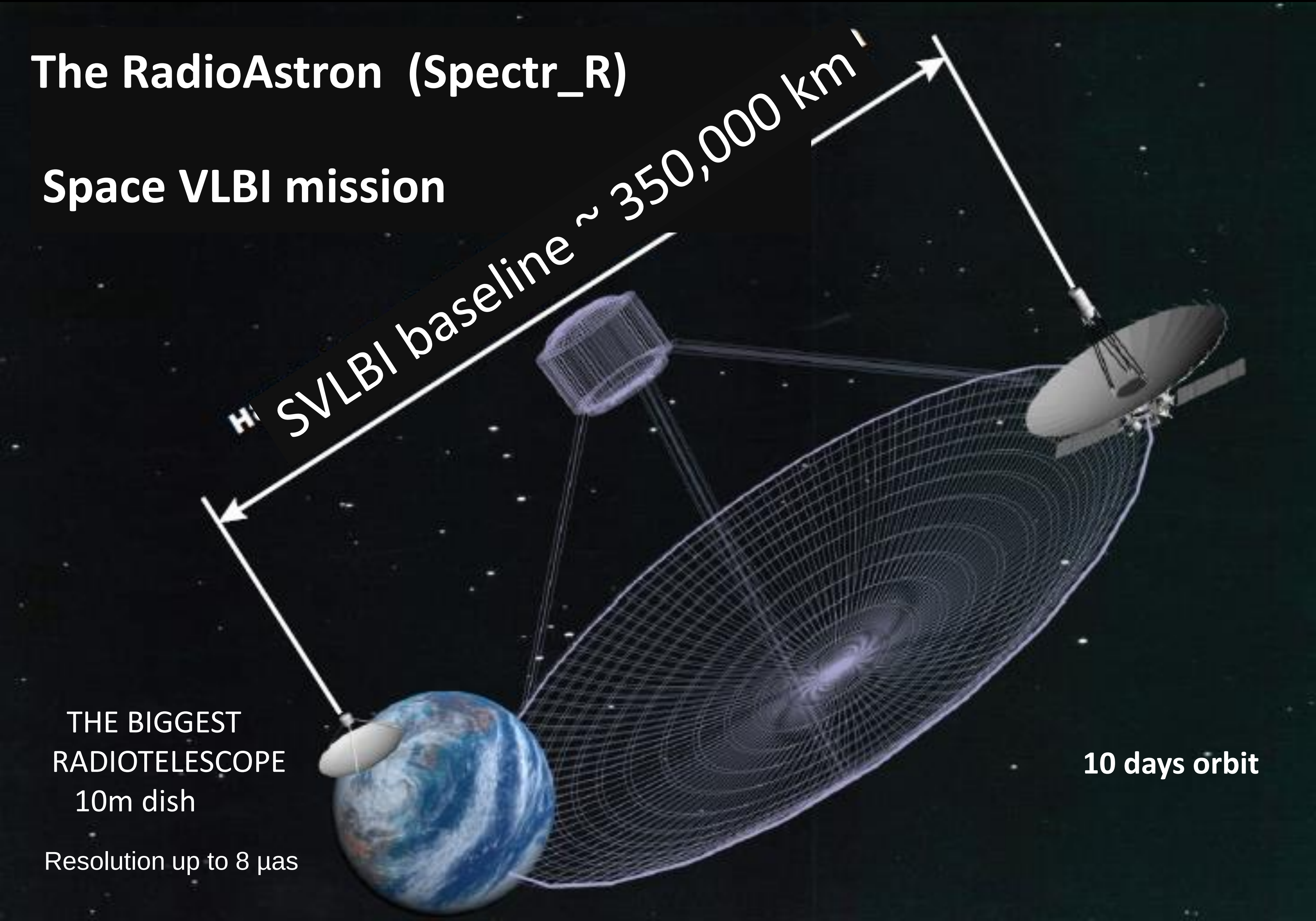
FSP-2025



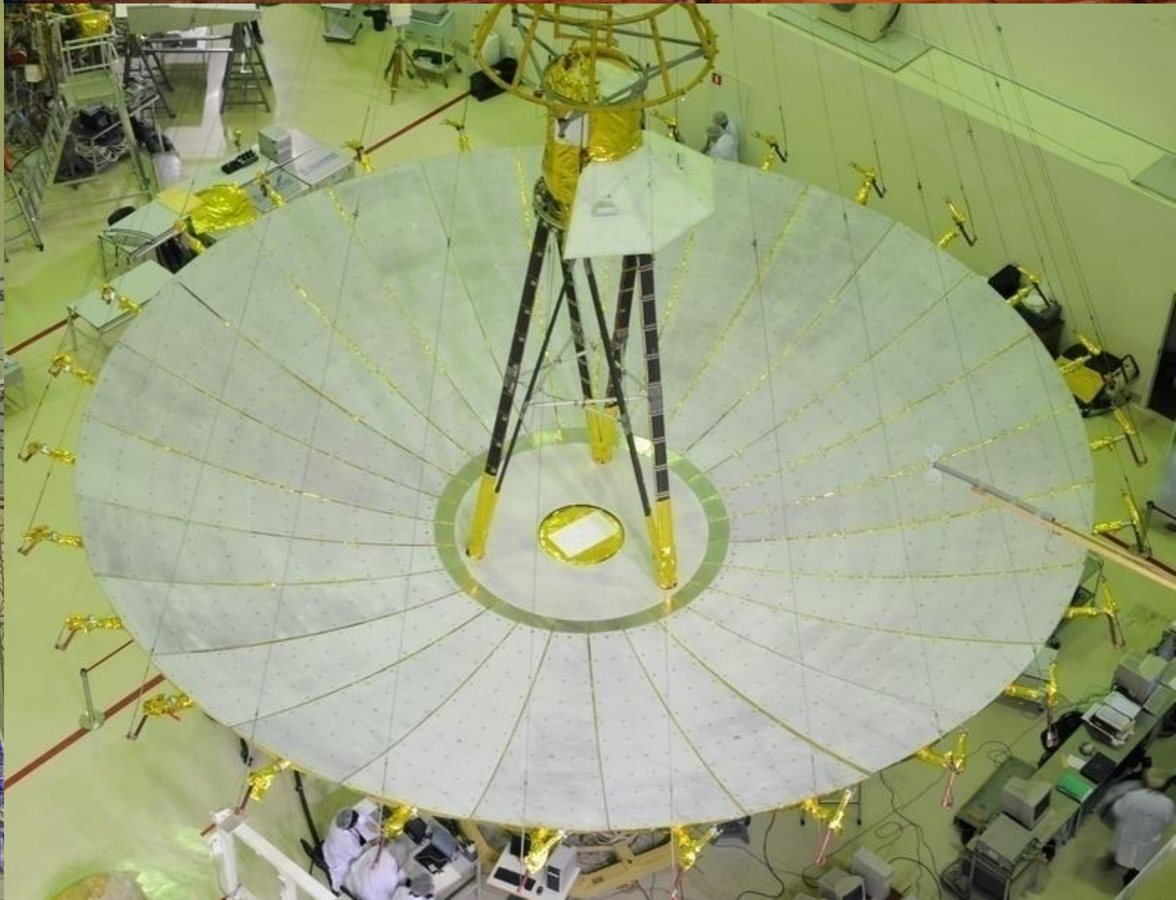
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
later
Astrophysics
Spectr-R
Spectrum-RG
Spectrum-UV
Spectrum-M
G-400, OLVE
Space weather
STRANNIK
МКА-ФКИ(ПН5) – КНА «АРКА»
Arch
Interhelioprobe
Planetary research
R
R
ExoMars-1
ExoMars-2
Boomerang
Venus-D
Lunar research
Luna-25
Luna-26, -27
Luna-28
Space biology and biotechnology
Bion-M2
Bion-M3

The RadioAstron (Spectr_R)

Space VLBI mission



Successfully launched in 2011



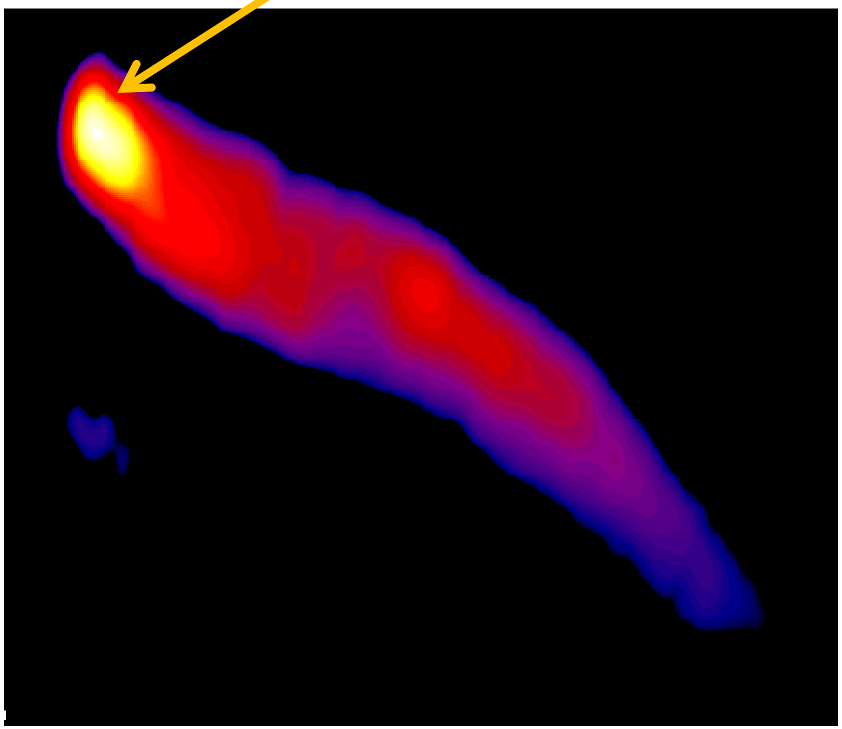
RadioAstron AGN survey: main goal

The main goal:

Measure and study **brightness temperature of AGN cores** in order to better understand physics of their emission while taking interstellar scattering into consideration.

- **Estimate brightness temperature of most compact structure(s) in the AGN jet base,**

.



SPECTR_R overcame the Earth-based T_b limit. This can not be done by going to higher frequencies on the ground;
Only Space VLBI.
Critical to test emission mechanism.

Direct T_b estimates: AGN survey completed
median ~10^{13} K, max ~> 10^{14} K

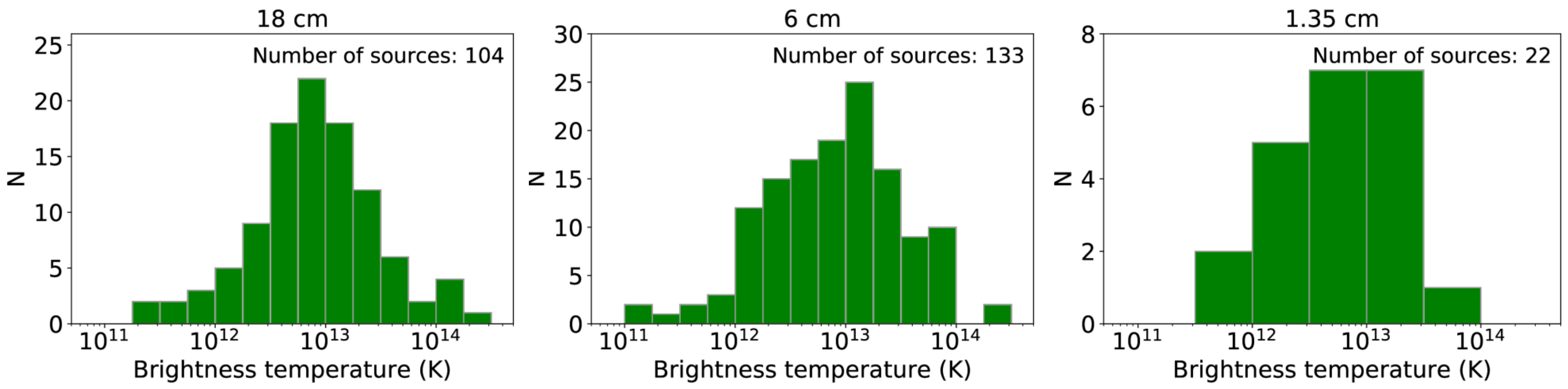
The survey is finished.

- Out of 249 observed AGNs in 3000 experiments: 164 were detected in about 1/3 of segments at 18 and/or 6 and/or 1.3 cm up to the longest projected spacing of 350,000 km.
- Highest formal resolution is achieved for 0235+164, OJ287, 3C279 at about **10 μas.**

AGN cores are found to be at least 10 times brighter than predicted and observed before. (from 10^{13} to more than 10^{14} K)

Discovery of ultracompact regions of extreme brightness requires to reconsider our understanding of Galaxy emission and jet acceleration ::

magnetic reconnection and/or relativistic protons ??



Space VLBI: Prospects and Lessons

There are many more bright objects on the sky than conservatively expected. Moreover, the scattering was found to be both our friend and enemy.

➢ (Very) long baselines, long wavelengths:

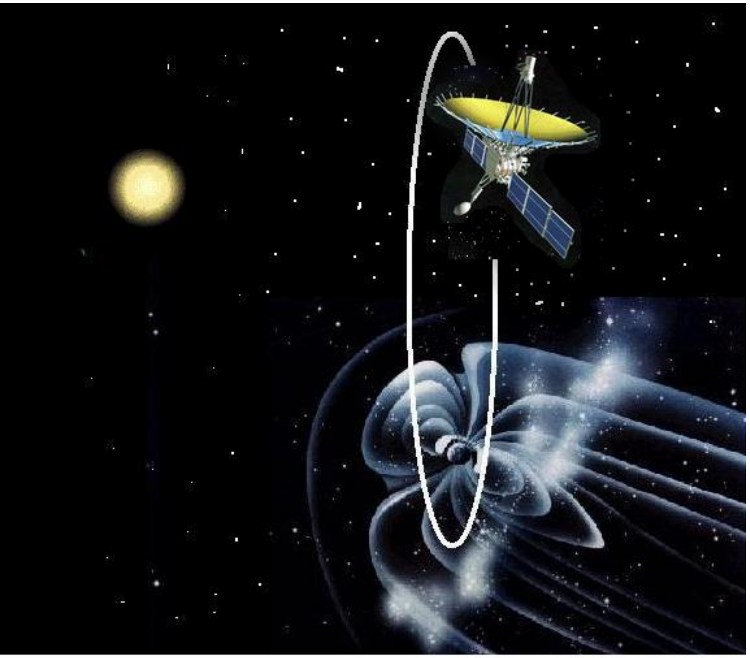
Scattering properties of the interstellar medium can be studied in unprecedented details as well as help to reveal intrinsic structure. Cheap and large space telescope

➢ MM wavelengths:

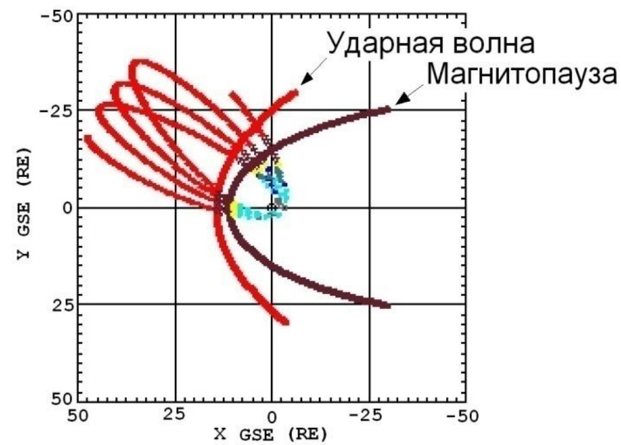
Apparent case to attack event horizon: overcome absorption, film the rapidly changing galactic center, study SMBHs in nearby active galaxies. Still, careful with the scattering.
The Millimetron is being developed by the Astro Space Center.

Whatever we do, should measure polarization. It is a strong and detectable tracer of magnetic field.

SPECTR-R
LOCAL MEASUREMENTS: PLASMA-F



MONITORING OF SOLAR WIND TURBULENCE with unprecedented resolution 32 msec !!



Russia, UKRAINE, Chehia, Slovakia Greece , Kirgizia, China

Solar CR Monitor

– SW ANALYZER

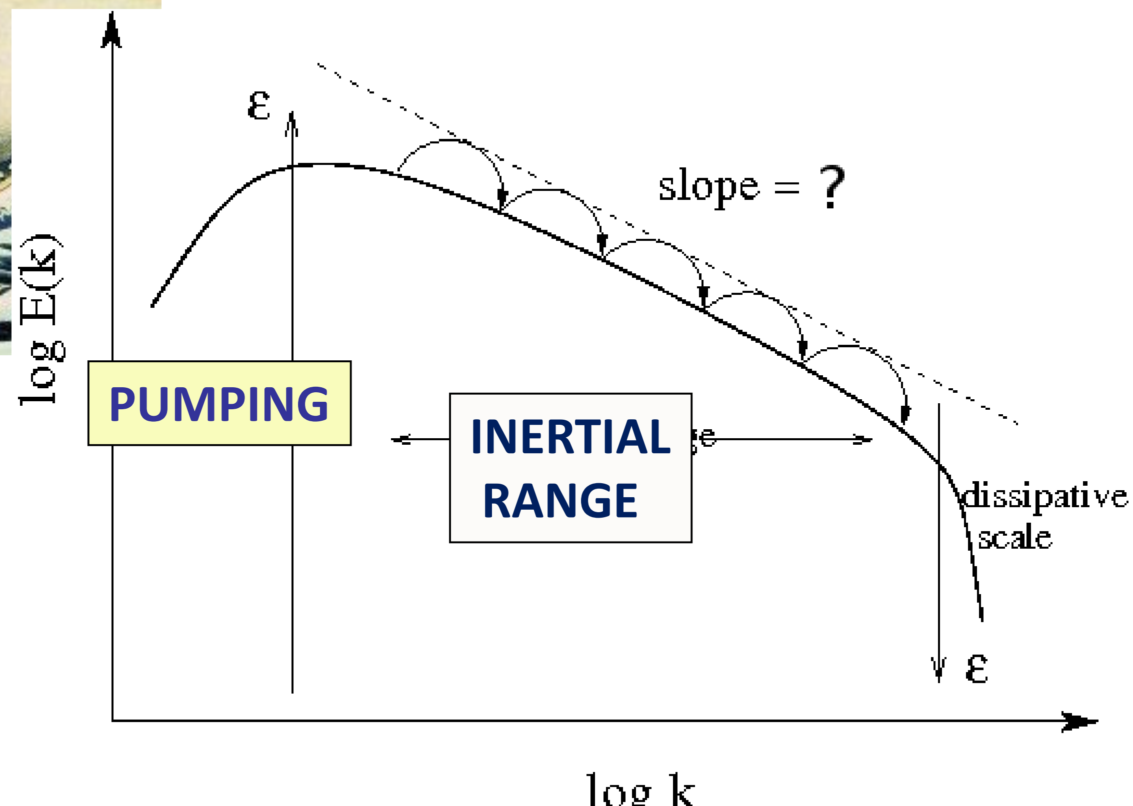
Data Collection system

Mass~12kg

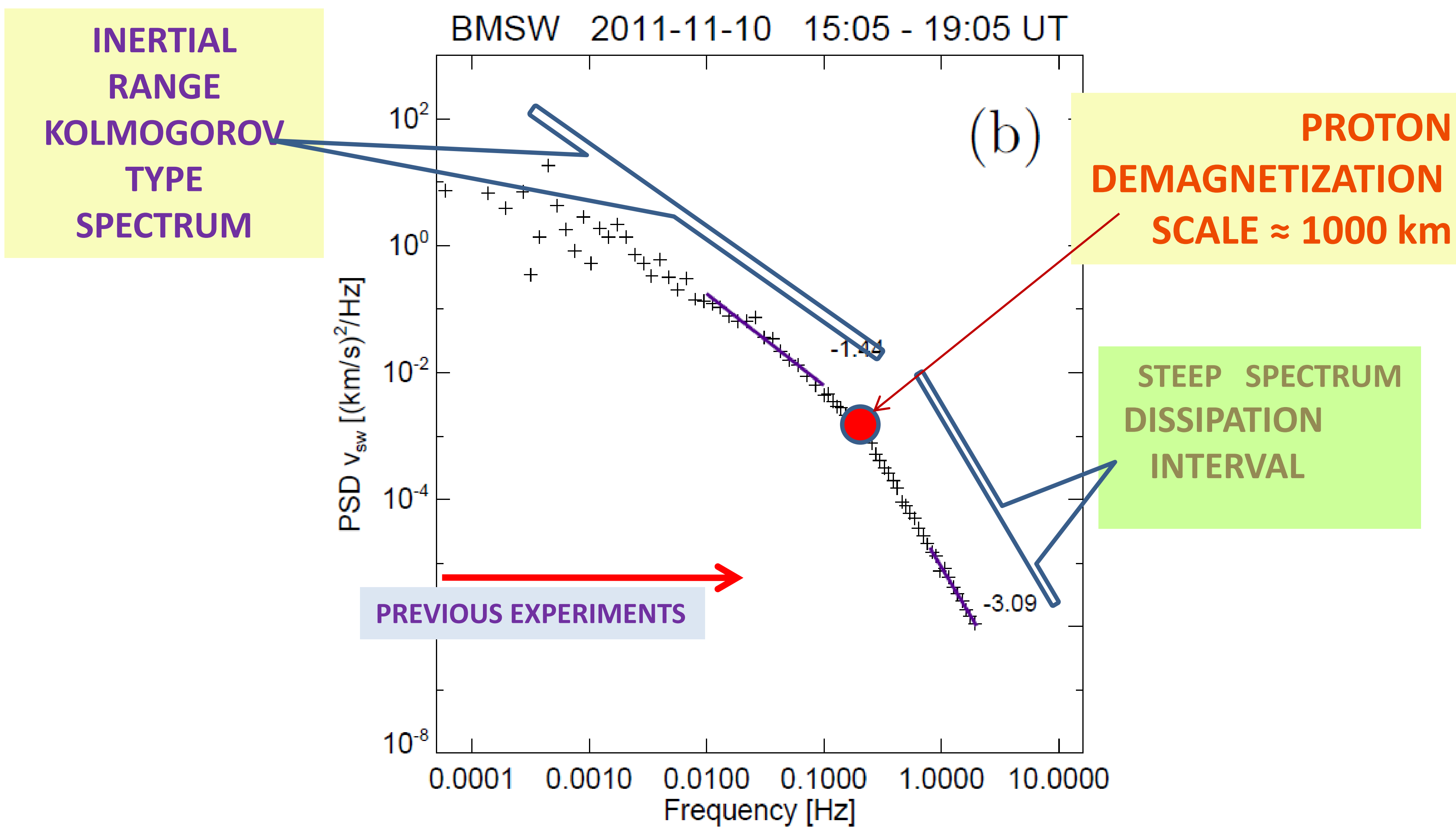
SOLAR WIND AS A TURBULENCE LABORATORY

ADVANTAGES OF "IN SITU" MEASUREMENTS

TURBULENT CASCADE



TURBULENCE PROPERTIES AT KINETIC RANGE

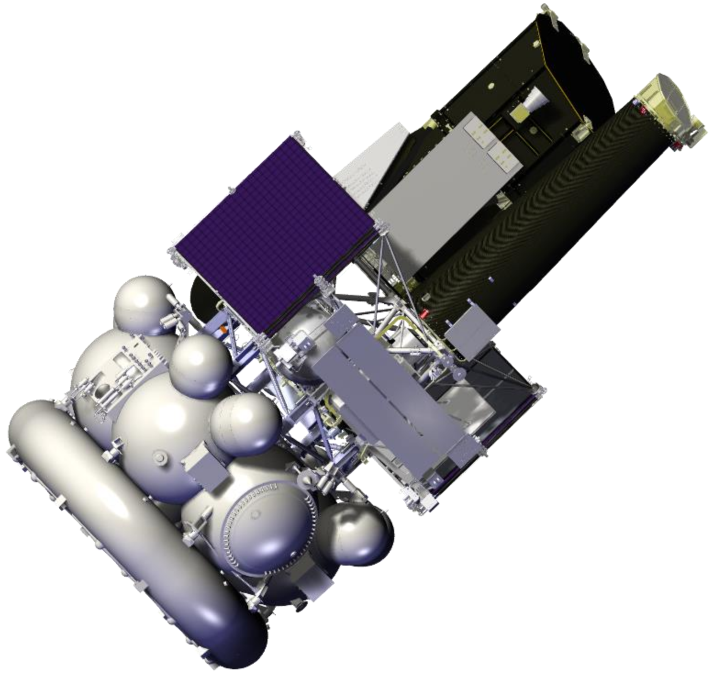


SRG

Air show MAKS2009

AGREEMENT -August 18, 2009,

SPEKTR-RG (SRG)

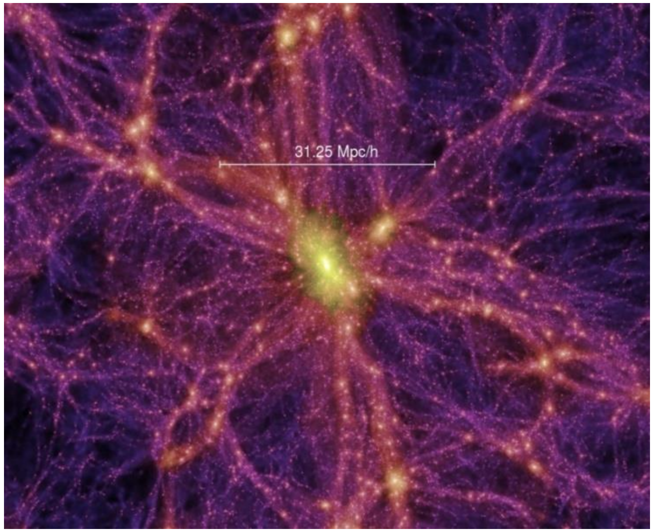


- **e-ROSITA** (MPE, DLR, GERMANY), **0.5–10 KeV**
- **ART-XC** (IKI @ VNIIEF, ROSCOSMOS, MSFC/NASA, USA), **6–30 KeV**

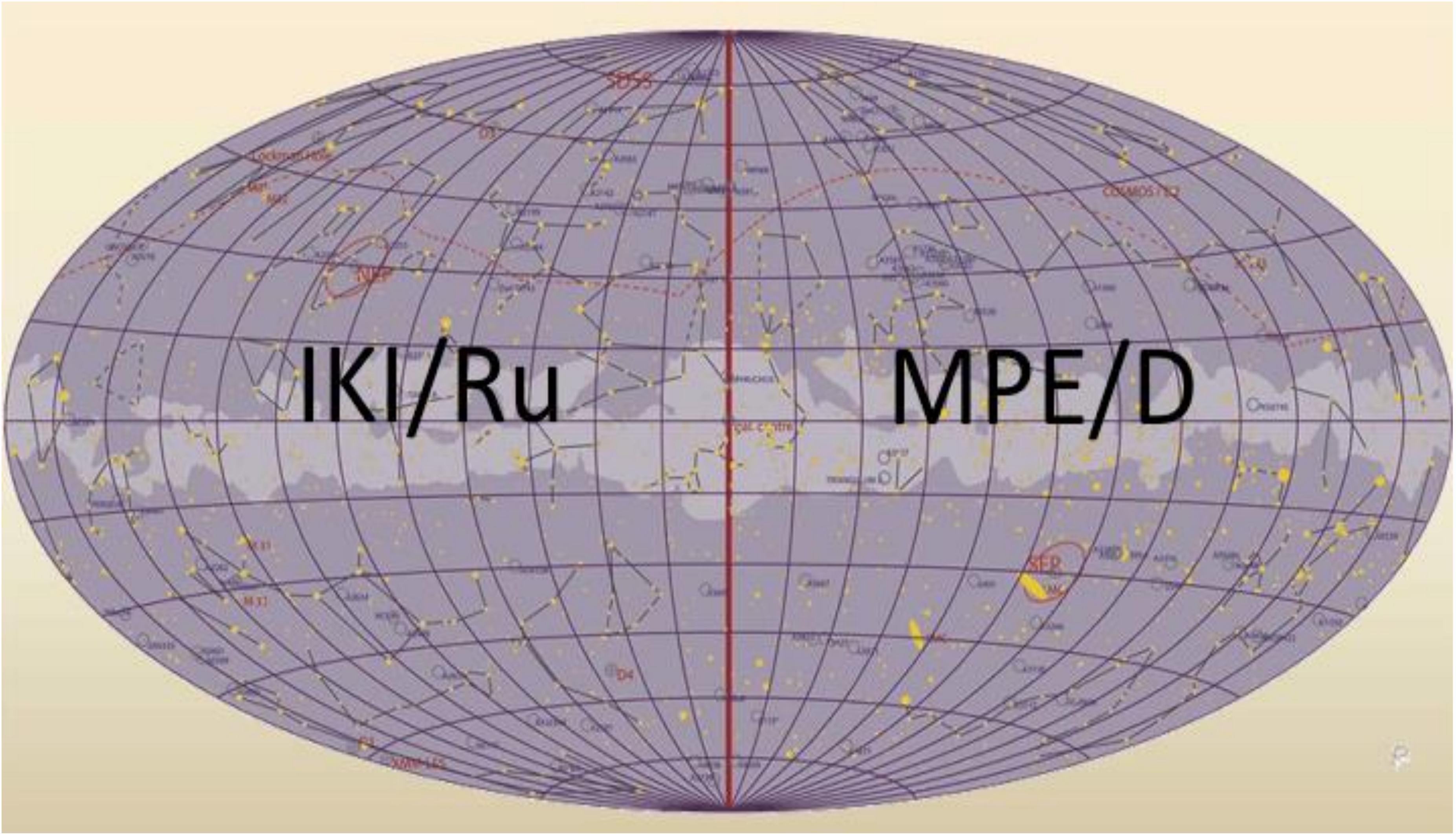
4 Years—ALL SKY SURVEY
3 Years-- **POINTED OBSERVATIONS OF THE MOST INTERESTING GALAXY CLUSTERS AND AGNS.**

SCIENTIFIC GOALS OF THE SRG ALL-SKY SURVEY:

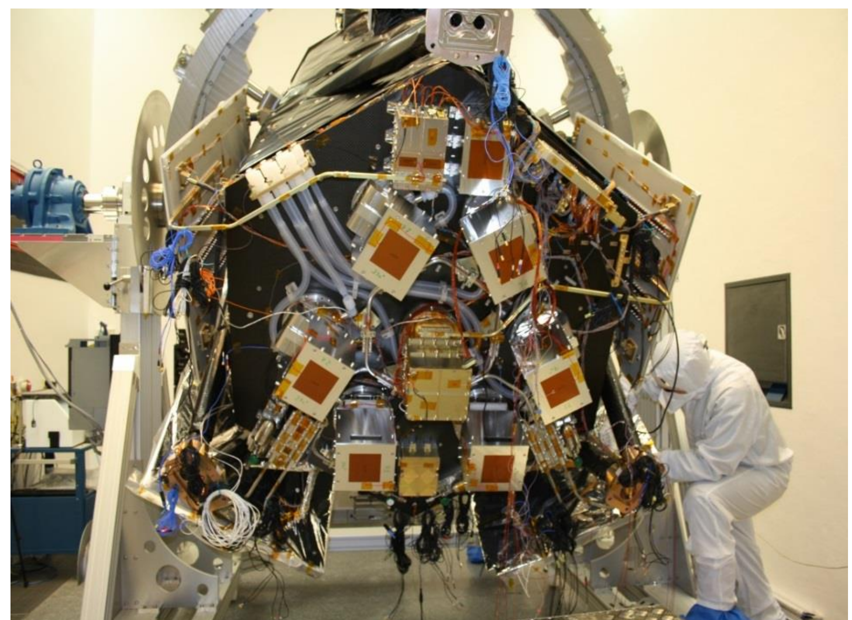
- **study of the large-scale structure of the universe ⇒ with 100 000 galaxy clusters**
- **study of the growth and cosmological evolution of supermassive black holes in the universe ⇒ with sample ≥3 million active galactic nucleus**



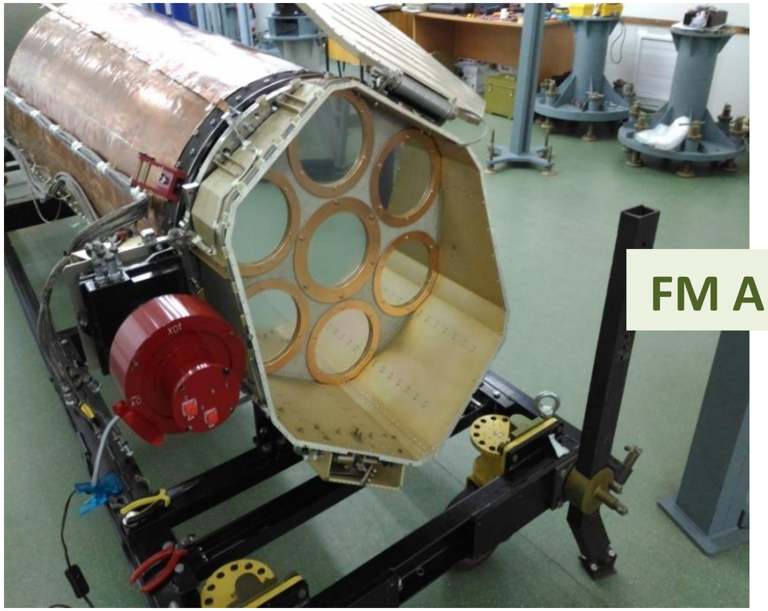
SRG

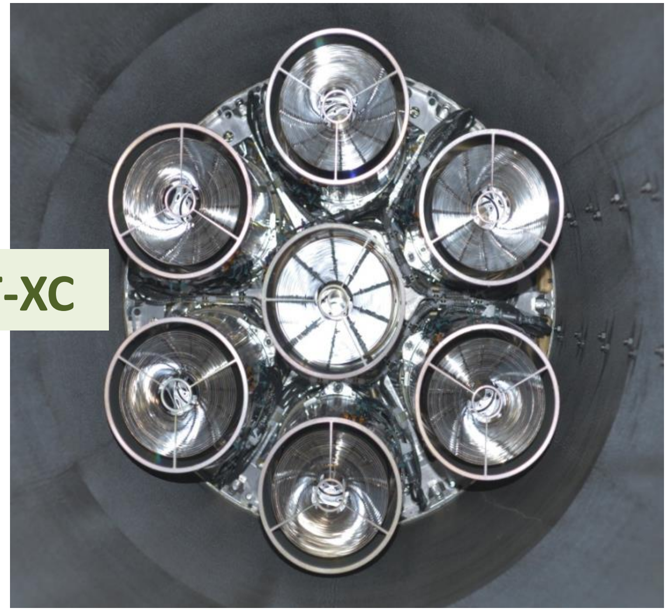


SRG



SRG





FM ART-XC

SRG

SRG

April 25, 2019

Volga-Dnepr
Волга Днепр

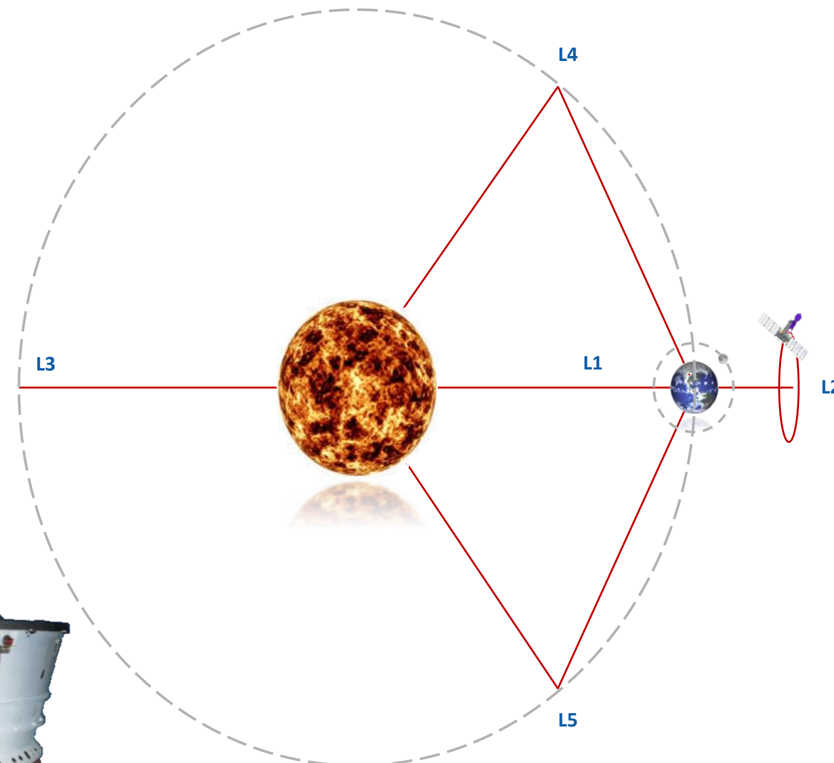
epr
ПР129-2
НПО
С. А. Лавочкина

ПР129-2

LAUNCH -June 21, 2019

Proton-M

DM-3 buster



WSO - UV

WSO-UV

Geosynchronous orbit, i=40^o
Launcher “PROTON”

WORLD SPACE OBSERVATORY – ULTRAVIOLET

launch 2025

РОСКОСМОС

ИНАСАН
Институт астрономии РАН

UNIVERSIDAD COMPLUTENSE MADRID

RUSSIA
+ SPAIN

World Space Observatory – Ultraviolet (Spectr – UF)

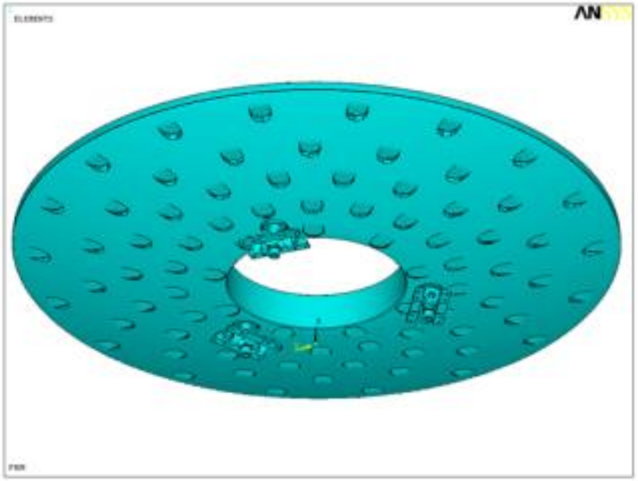
Telescope T-170M under construction

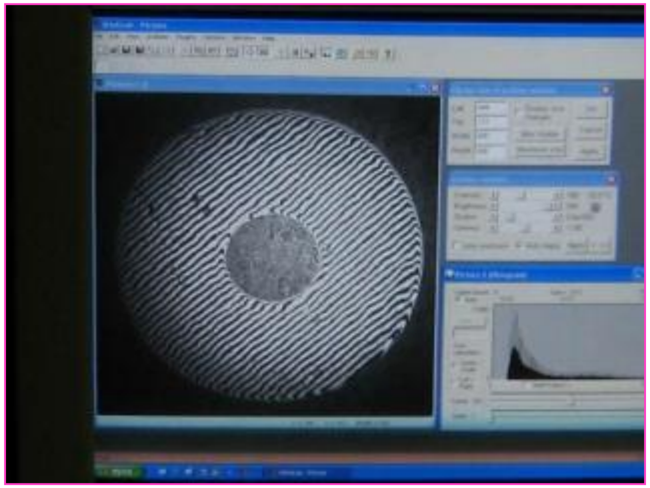
•International space observatory for UV spectral range (>100 - 320 nm).
•The WSO-UV is equipped with a 170 cm telescope and scientific instruments: UV–imagers and 3 spectrometers (resolving power 1000 - 55000).

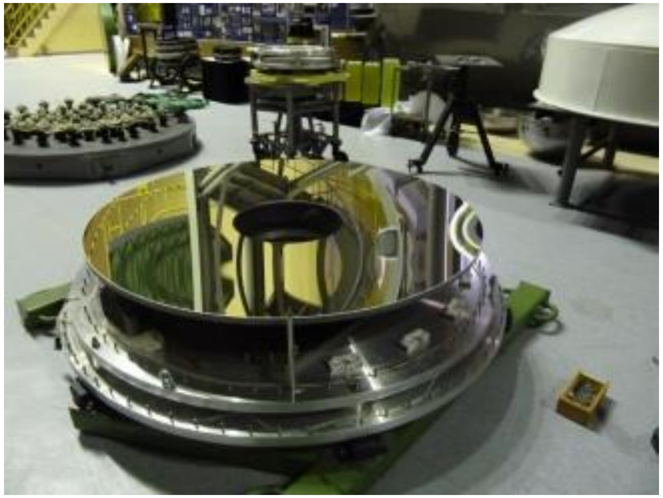
SCIENTIFIC GOALS

- The Cosmic Web (history of reionization, search for baryons).
- Stellar physics - activity of stars
- The early evolution of stars and role of UV in the evolution of the young planetary disks and astrochemistry in UV field.
- Atmospheres of (exo)planets.

Primary mirror of the T-170M telescope



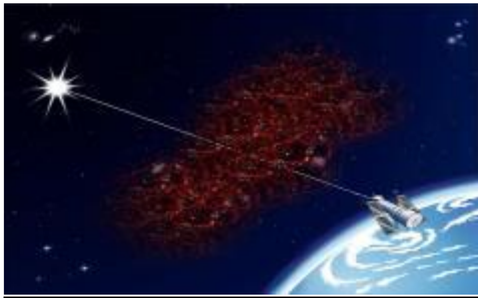




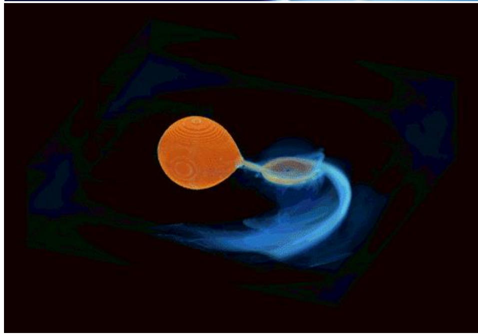
Optics is being manufactured at Lytkarino Optical Plant.

The WSO-UV Core Program

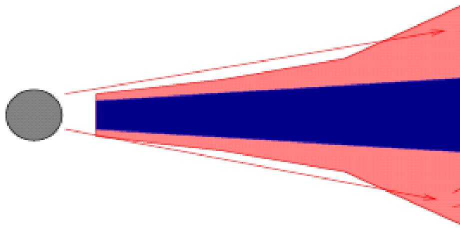
I. Chemical evolution of the Universe. Missing baryons problem. Formation and evolution of galaxies.



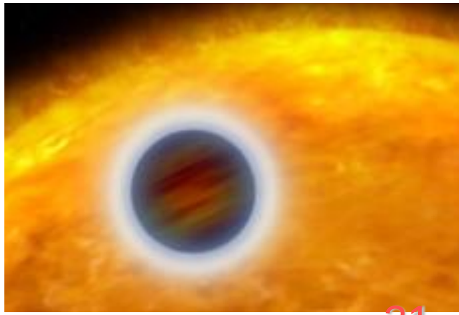
II. Physics of compact objects and stars (accretion processes onto AGN, NS, BH etc., mass loss from massive stars, physics of WD etc.).



III. Evolution of the young planetary disks and astrochemistry in UV field.



IV. Atmospheres of (exo)planets.



Star formation patterns in galaxies

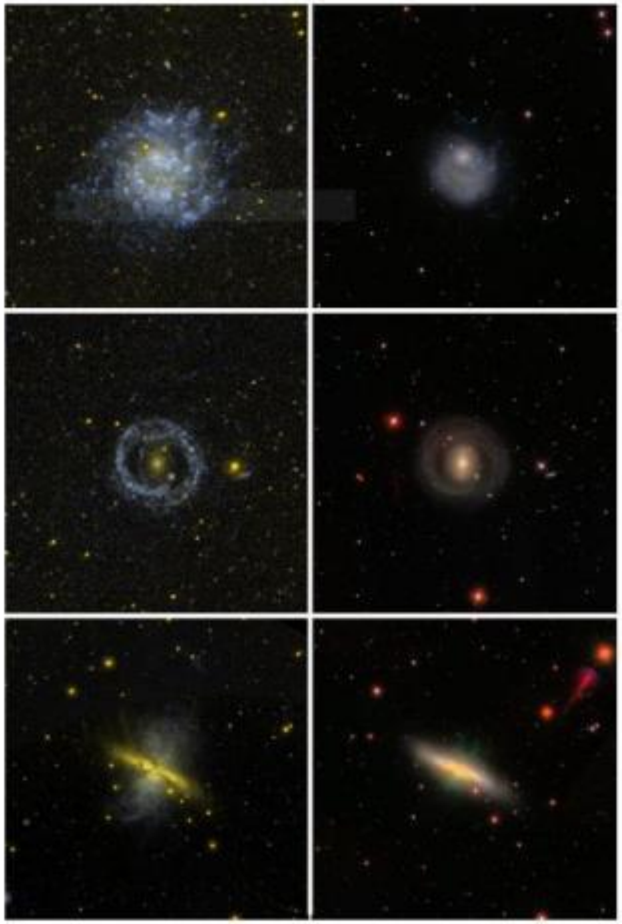
UV visual

Fig. 1 *GALEX* (*left*, FUV: *blue* and NUV: *yellow*) and optical (*right*, on the same scale) color-composite images of selected objects examplifying the power of UV imaging for revealing young stellar populations. In particular, examples of dwarfs and tidal dwarfs inconspicuous in the optical are also shown, near bright galaxies. From the *top*: NGC 4656, M81, and M101

UV visual

Fig. 2 *GALEX* (*left*) and optical (*right*) color-composite images giving typical examples of: extended UV-disks (*top*, NGC5474), UV-emitting rings around early-type galaxies (*middle*, the SB0/a galaxy NGC5701) and halo UV emission (*bottom*: M 82, see Hoopes et al. 2005)

GALEX



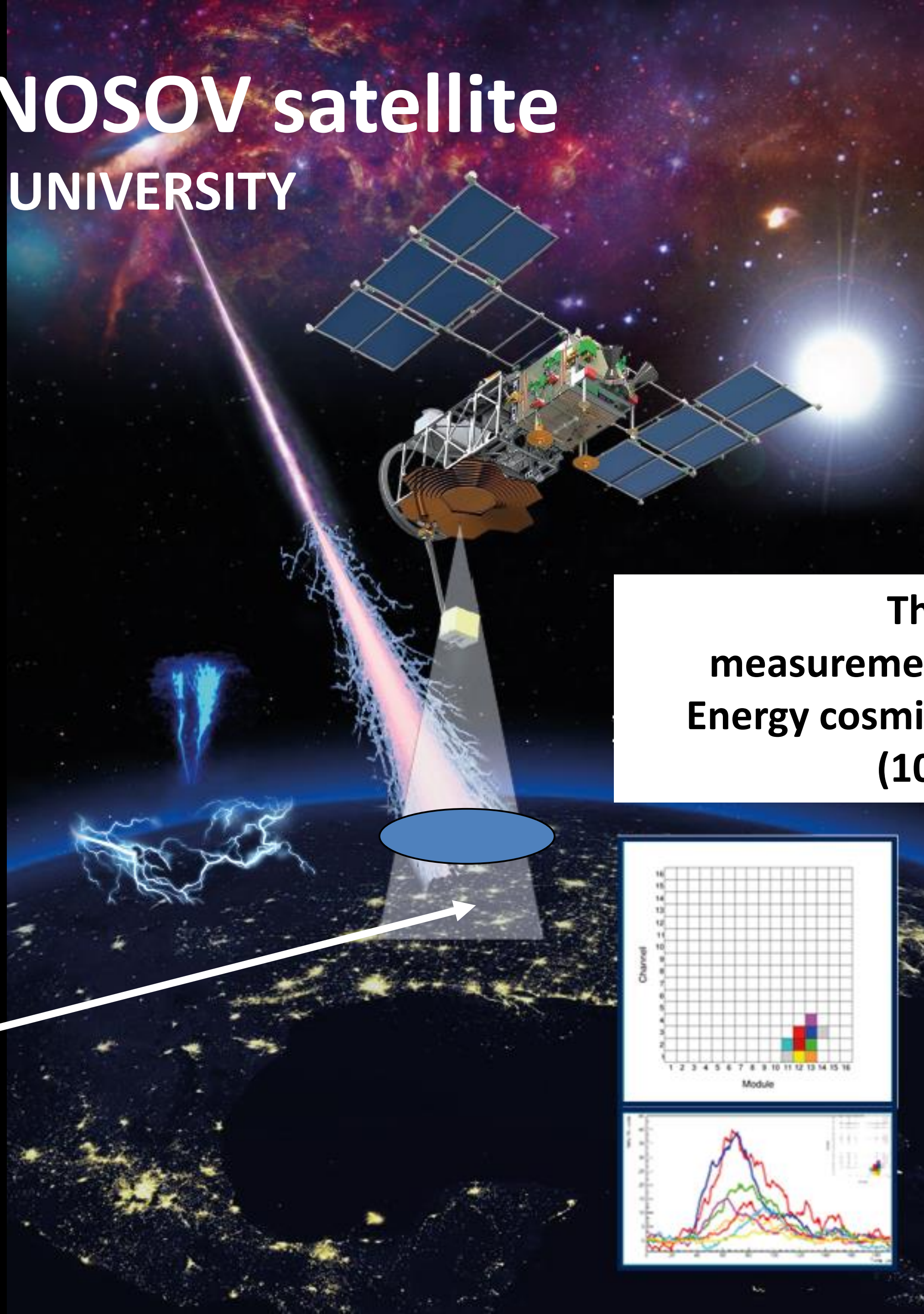
UV images of galaxies reveal amazingly new features of star formation.

Planetary atmospheres issues for UV studies

- Hot oxygen coronae of terrestrial planets atmospheres;
- Aurora and hot hydrogen coronae of giant planets;
- Rarefied H_2O, O_2, and O atmospheres of icy moons embedded in the magnetosphere of the giant planets;
- Neutral tori in the Jupiter and Saturn systems;
- Coma of comets;
- The atmospheres of exoplanets

LOMONOSOV satellite
MOSCOW UNIVERSITY

Launched 2016
from the new
eastern
cosmodrom
“VOSTOCHNYI”



The first measurements of Ultra-High Energy cosmic rays from space (10^{20} eV)

S_{eff} ~ kkm2

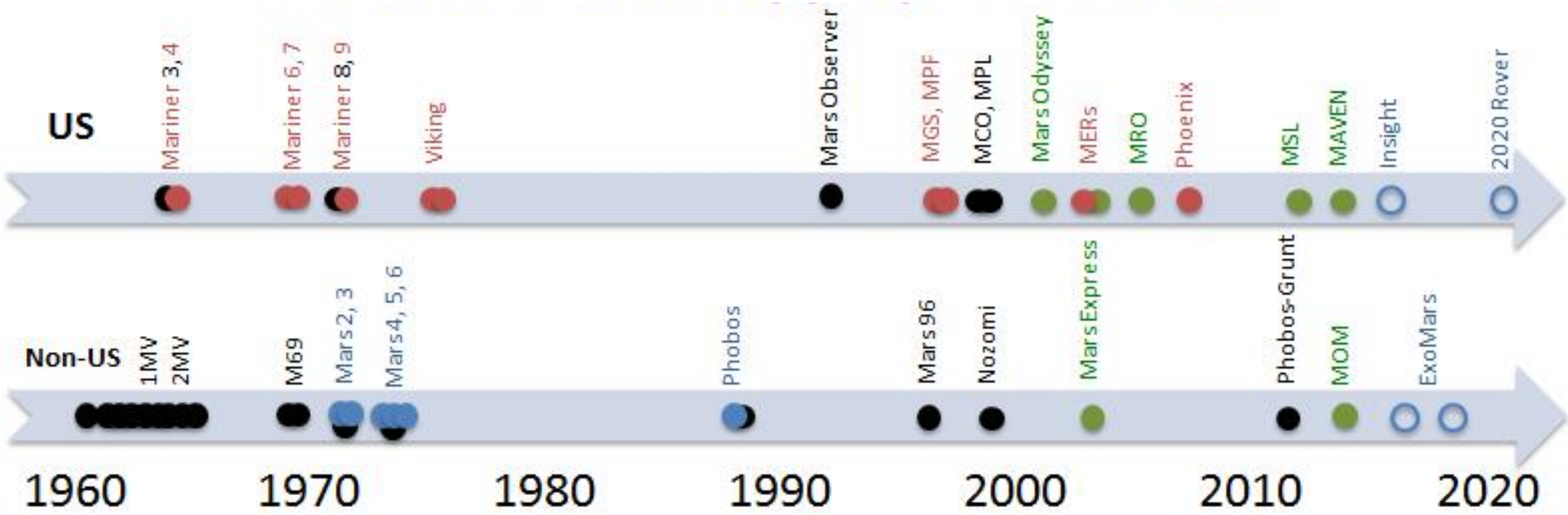
SOLAR SYSTEM EXPLORATION MISSIONS

- **EXOMARS** (ESA-ROSCOSMOS) **2016, 2020**
- **LUNAR PROGRAM** **2021-2024**
- **PHOBOS SR** **2025++**
- **VENERA-D (Roscosmos+NASA)** **2028+**

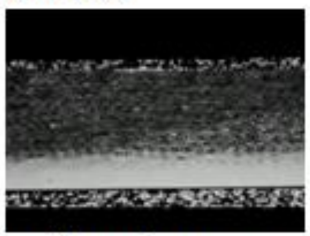
Projects beyond the Federal Space Program 2025

- **LUNAR MISSIONS L28-L30**
- **MARS SR**
- **Near Earth Asteroid**

HISTORY OF MARTIAN EXPEDITIONS



1960-1973 early attempts: 13 unsuccessful USSR launches

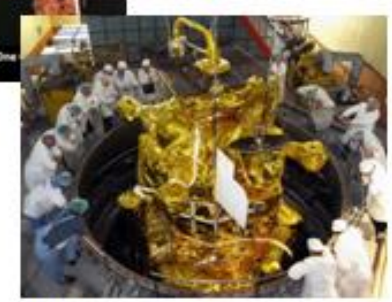



Mars 3 and the surface image

Mars 5 orbiter

Phobos 88

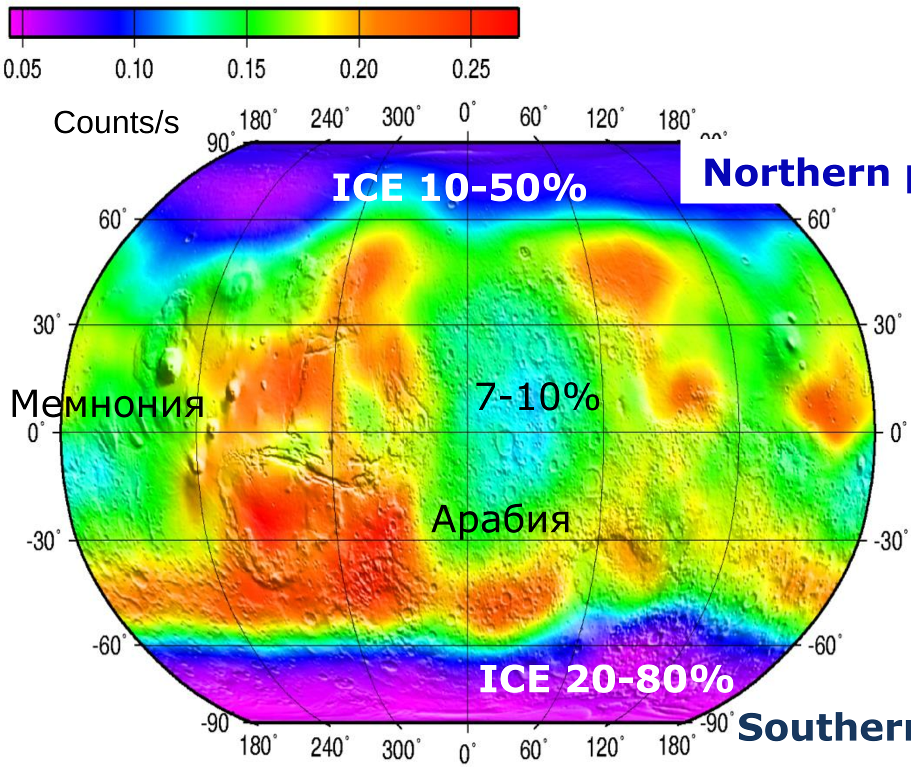
Mars 96

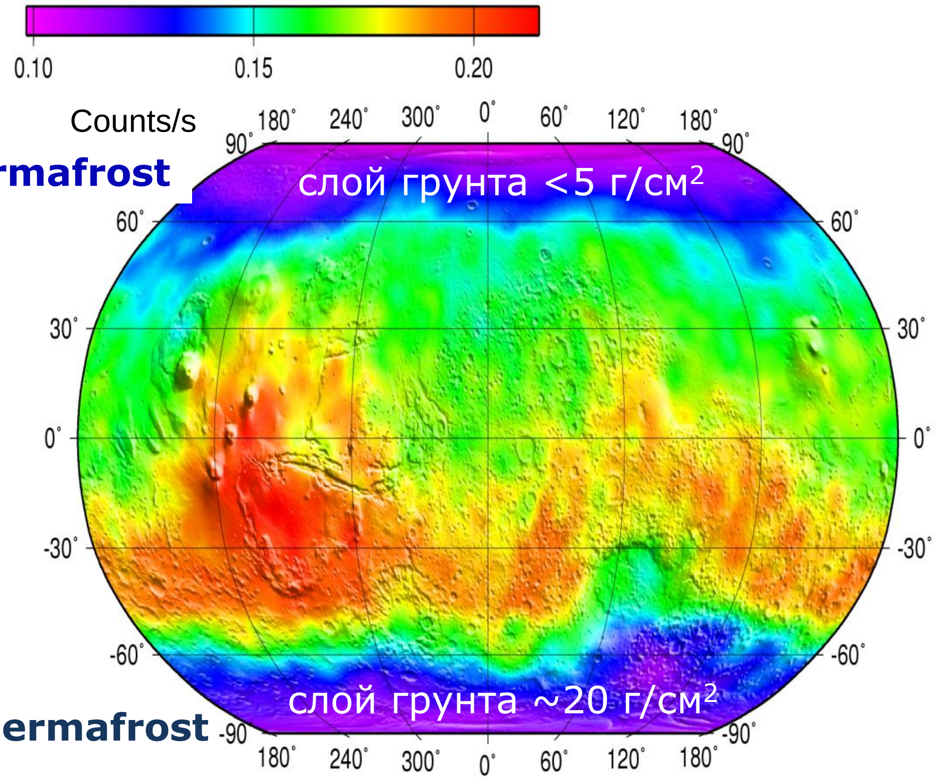


Phobos Grunt

MARTIAN WATER

HEND: mapping of epithermal neutrons emission from Mars





Epithermal neutrons

Fast neutrons at 0.4 – 2.0 MeV

RUSSIAN INSTRUMENT HEND ONBOARD NASA MISSION MARS_ODYSSEI REVEALED MARTIAN PERMAFROST WITH A HIGH ABUNDANCE OF WATER ICE


EXOMARS
esa
РОСКОСМОС
2016
2020
Trace
Gas
Orbiter
HCl
H2O
CO2
SO2
H2S
HBr
HF
CH4,
volcanic
gases
Rover
at landing
scientific
platforma
Drilling
Systematic
surface
observations

NOMAD

High resolution occultation and nadir spectrometers

Atmospheric composition (CH_4, O_3, trace species, isotop) dust, clouds, P&T profiles

UVIS (0.20 – 0.65 μm)	$\lambda/\Delta\lambda$ ~ 250	SO	Limb	Nadir
IR (2.3 – 3.8 μm)	$\lambda/\Delta\lambda$ ~ 10,000	SO	Limb	Nadir
IR (2.3 – 4.3 μm)	$\lambda/\Delta\lambda$ ~ 20,000	SO		

CaSSIS

High-resolution camera

Mapping of sources; landing site selection

ACS

Suite of 3 high-resolution spectrometers

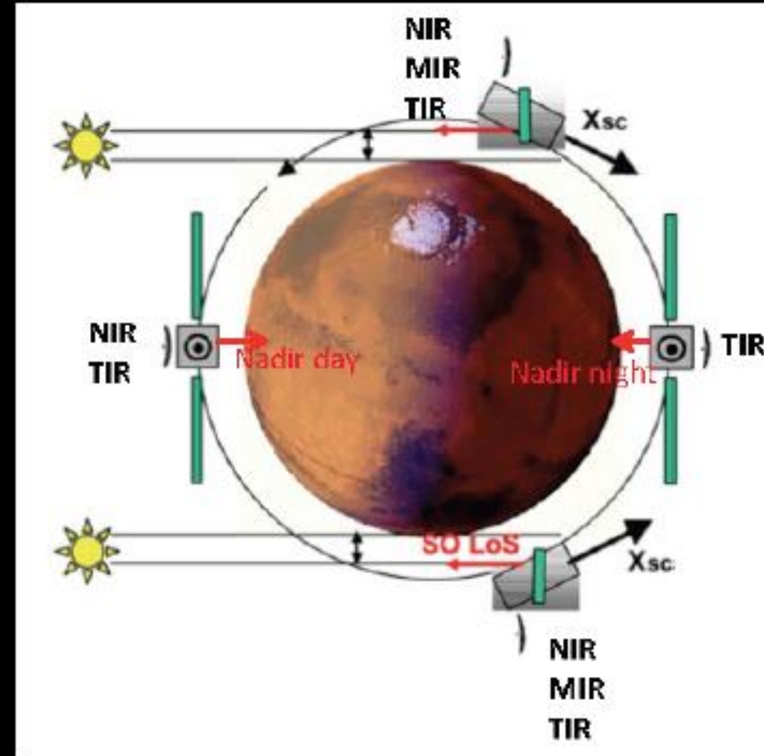
Atmospheric chemistry, aerosols, surface T, structure

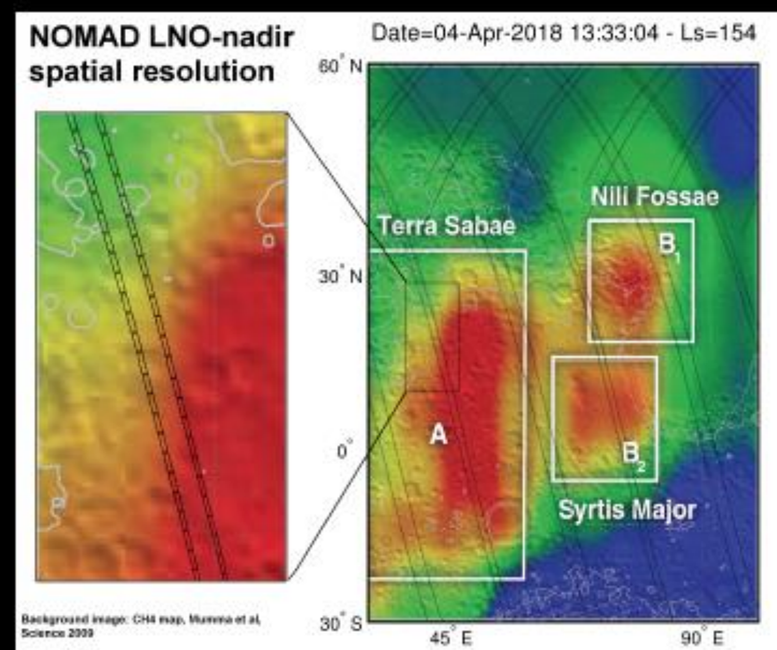
Near IR (0.7 – 1.7 μm)	$\lambda/\Delta\lambda$ ~ 20,000	SO	Limb	Nadir
IR (Fourier, 2 – 25 μm)	$\lambda/\Delta\lambda$ ~ 4000 (SO)/500 (N)	SO		Nadir
Mid IR (2.2 – 4.5 μm)	$\lambda/\Delta\lambda$ ~ 50,000	SO		

FREND

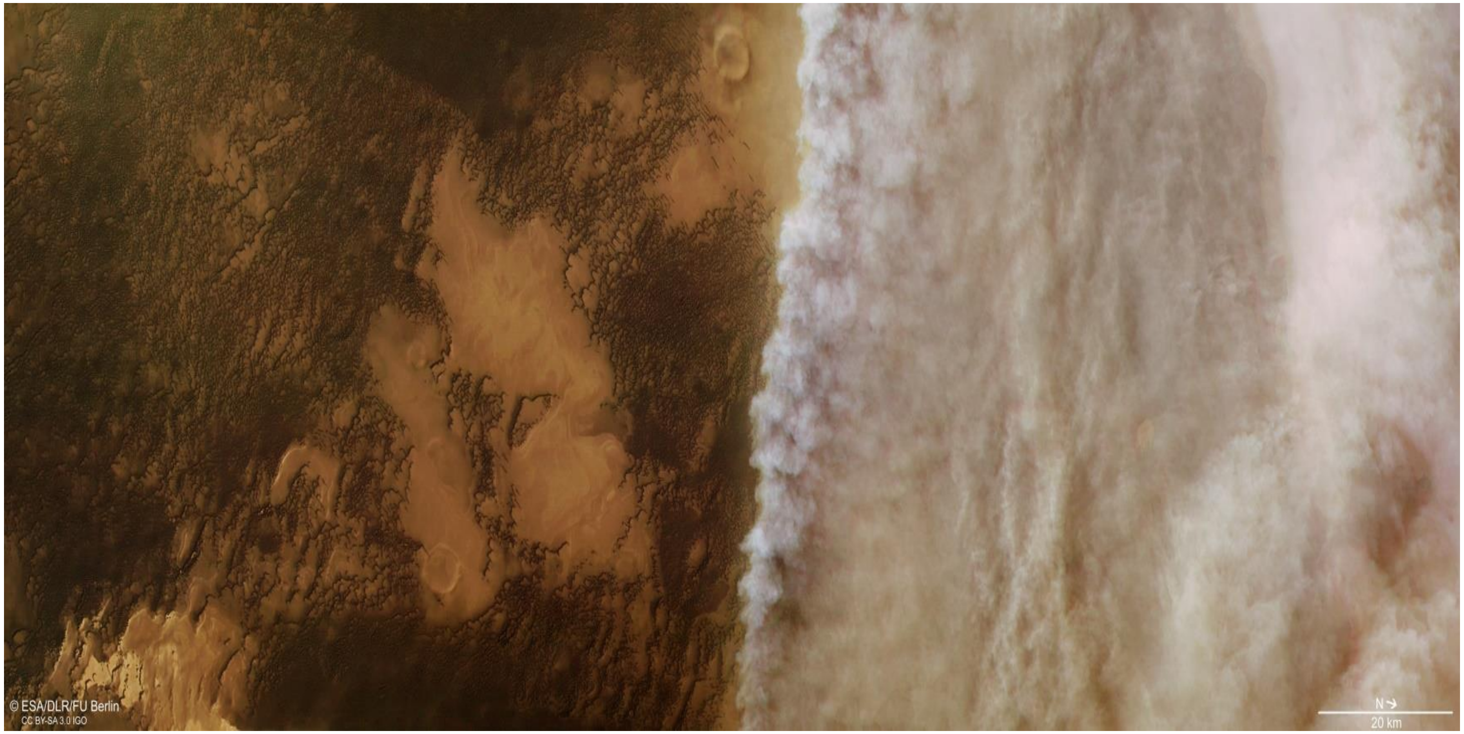
Collimated neutron detector

Mapping of subsurface water





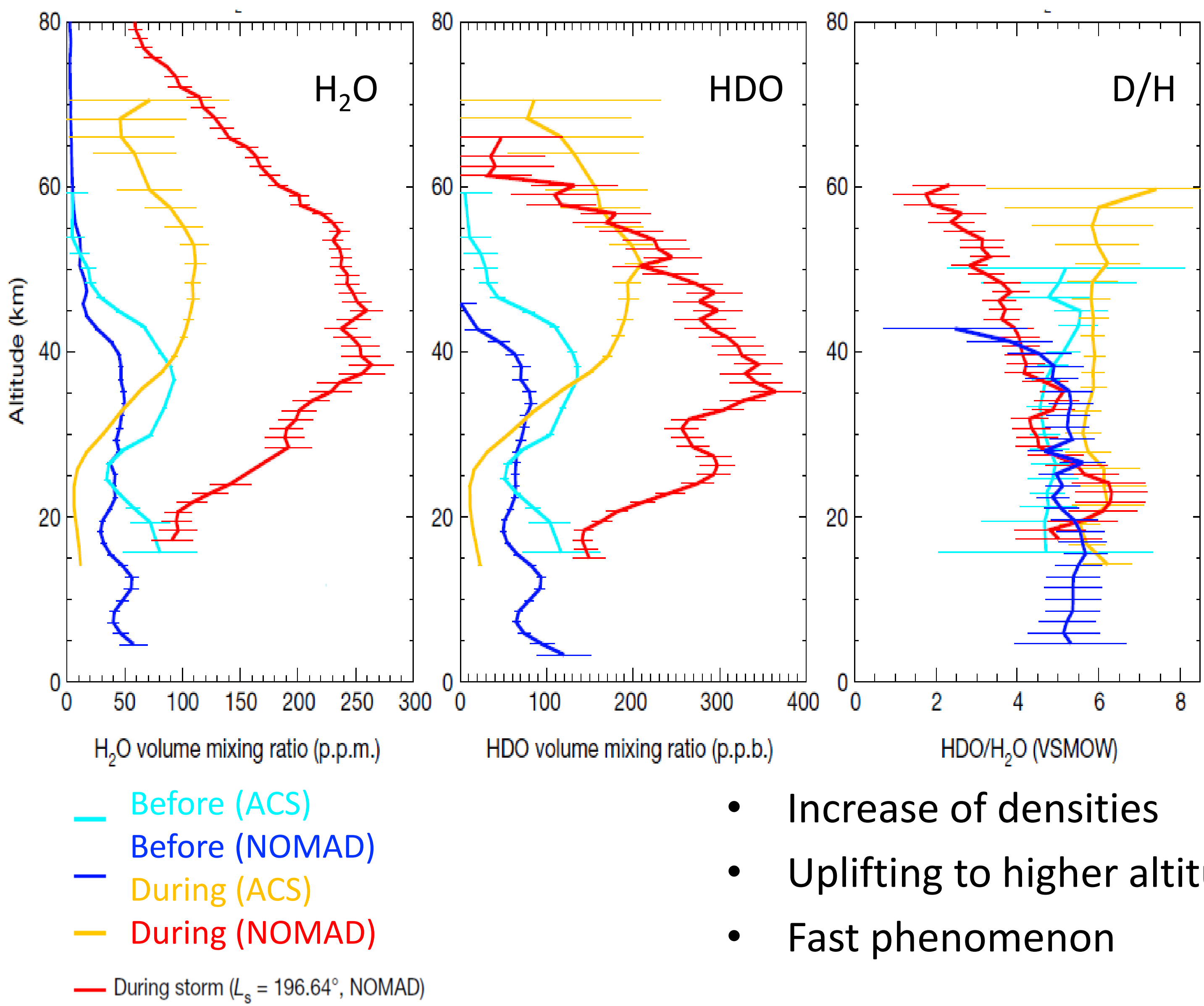
Global Dust Storm



High resolution stereo camera on Mars Express image taken in April 2018, ESA/DLR/FU Berlin

- Northern latitudes: layers at 25-40 km altitude appear
- Mid latitudes: always many layers and lot of dust; at higher altitude during GDS
- Southern latitudes: dust layers move to higher altitudes

H_2O, HDO and D/H observations

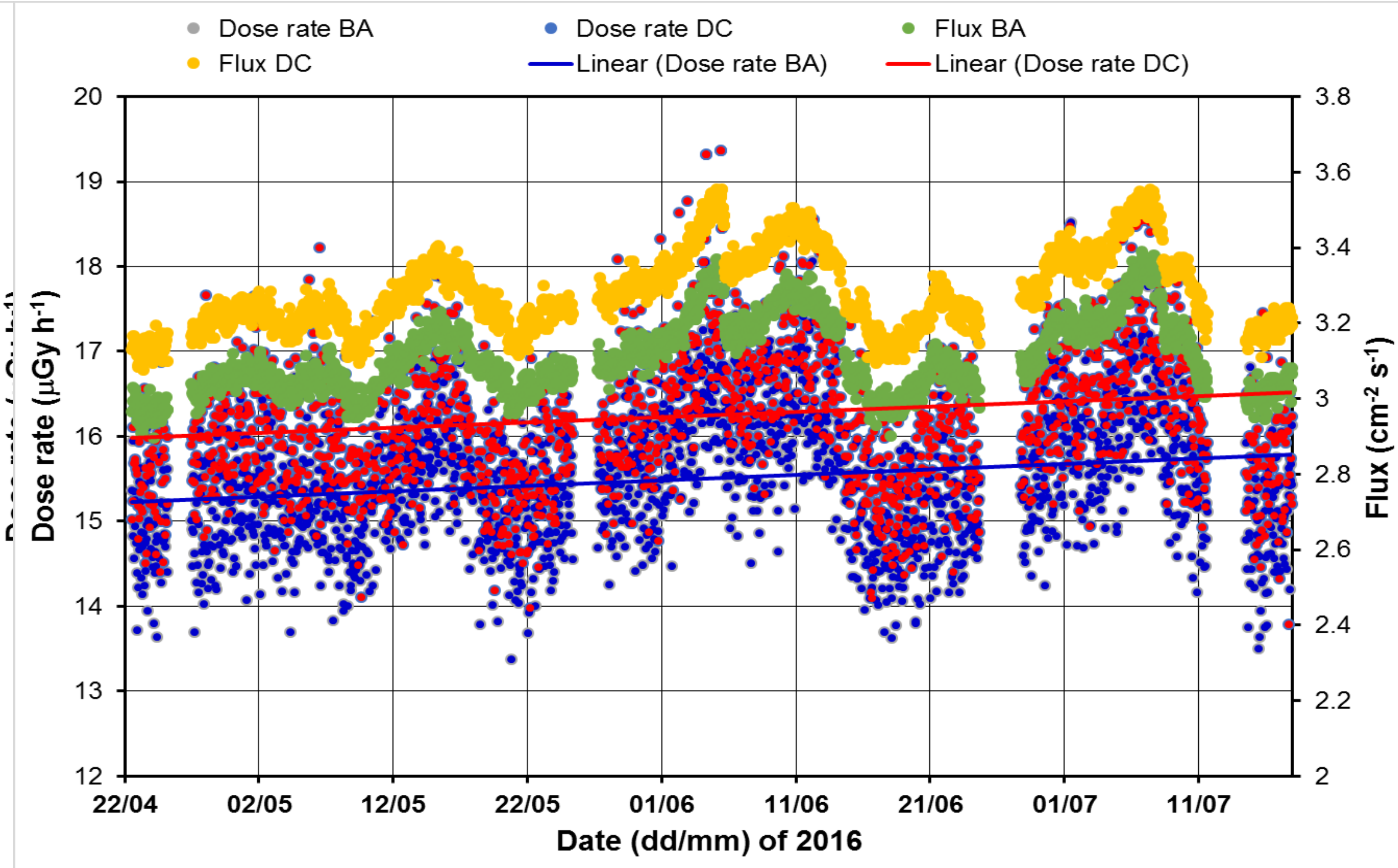


- Increase of densities
- Uplifting to higher altitudes
- Fast phenomenon

No detection of methane

O. Korablev & A.C. Vandaele
and ACS & NOMAD Science Team

TGO FLIGHT TO MARS
MEASUREMENTS OF RADIATION DOSES



Liulin-MO

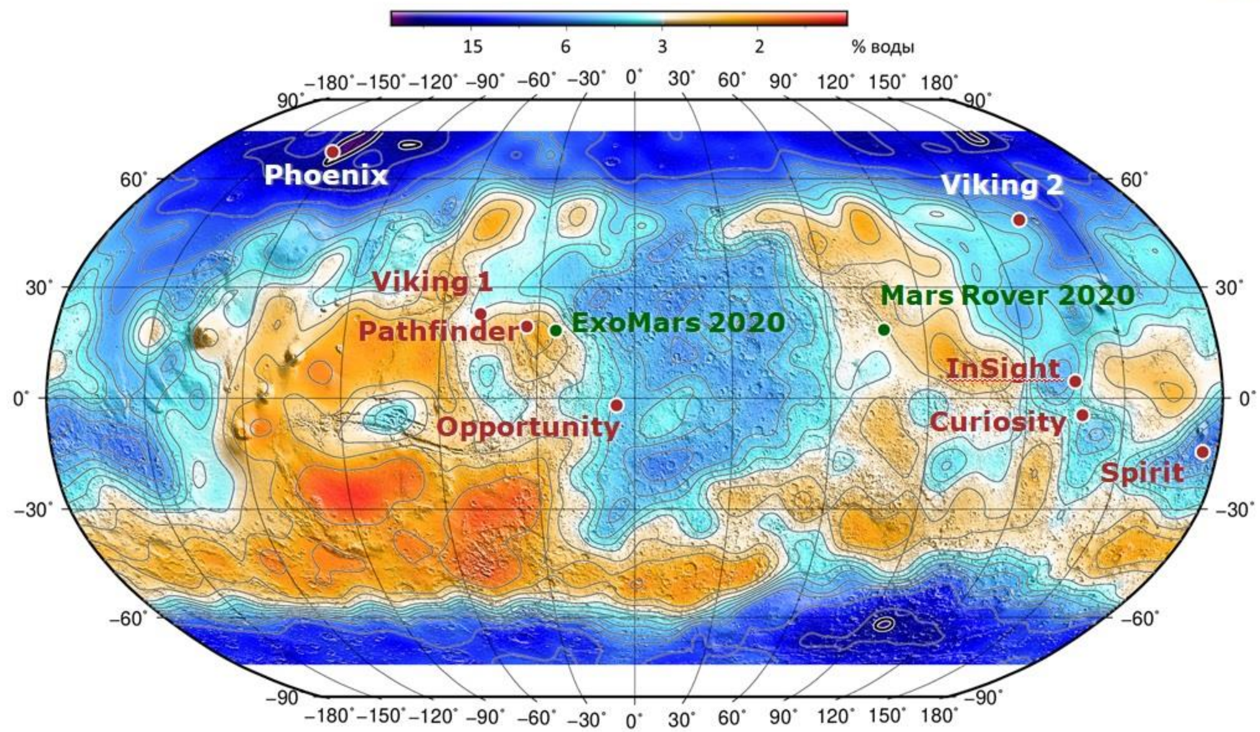
perpendicular detectors B(A) and D(C)

RADIATION DOZE RECEIVED BY ASTRONAUTS DURING FLIGHT TO MARS AND BACK IS ALMOST EQUALL TO THE INTEGRAL DOZE ACCEPTABLE FOR THE ENTIRE CARRIER

E X O M A R S

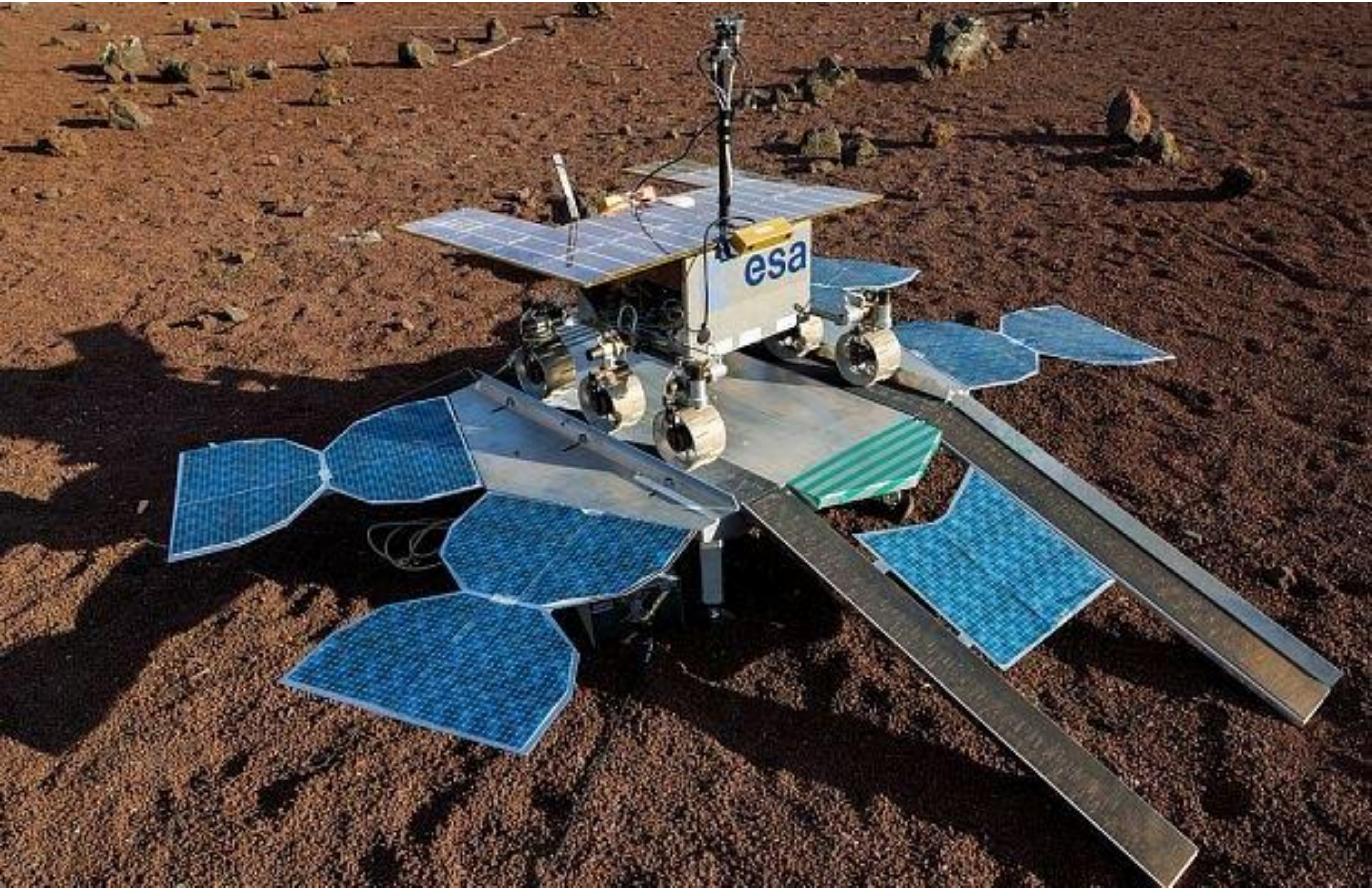
ExoMars 2016 Science Working Team Meeting #17
incorporating SOWG #19

FREND ИКИ



Data from 250 days of mapping, 20% of the planned mapping stage

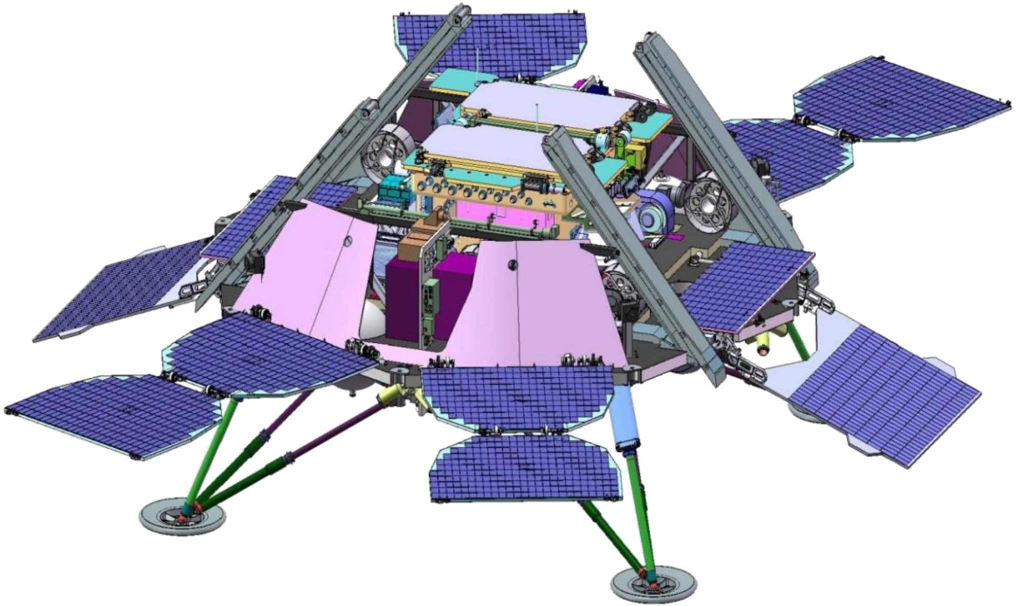
SPATIAL RESOLUTION OF FREND (~40 km) (DUE TO COLLIMATORS) IS TEN TIMES BETTER THAN THE RESOLUTION OF HEND (400km)


esa

ExoMars – 2020 Surface Platform

Scientific objectives:

- Context imaging
- Long term climate monitoring and atmospheric investigations
- Studies of subsurface water distribution at the landing site
- Atmosphere-surface volatile exchange
- Monitoring of radiation environment at the landing site
- Study of Internal Mars structure (geophysics)



ExoMars-2020 Scientific Payload

Pasteur Rover

Mobile Rover to study surface composition and search for biosignatures.

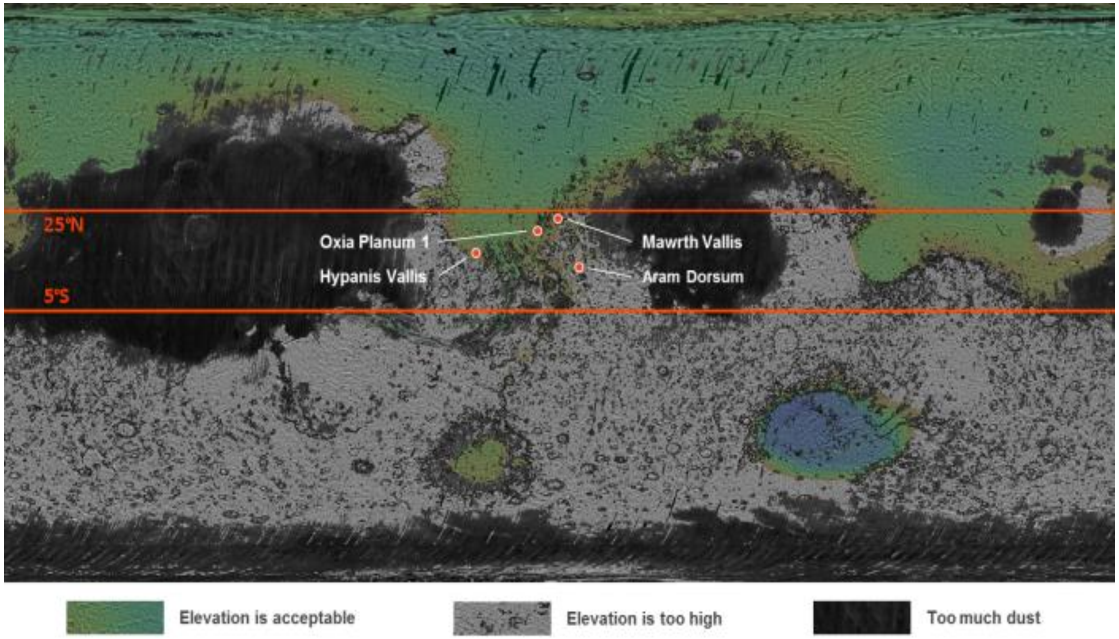
- **PanCam** — Set of 3 cameras at Rover mast. Stereo pair and high-resolution camers
- **ISEM** — Infrared spectrometer at Rover mast
- **CLUPI** — Microscope-camera
- **WISDOM** — Subsurcae radar
- **ADRON-RM.** — Passice neutron spectrometer
- **Ma_MISS** — Spectrometer at Tover drill
- **MicrOmega** — IR spectrometer
- **RLS** — Raman spectrometer
- **MOMA** — Gas Chromatography, Laser desorption

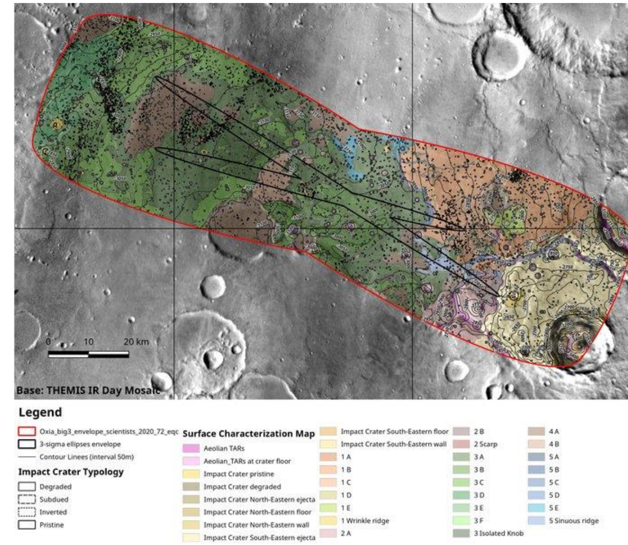
Surface Platform

Long-lived stationary platform with scientific suite to study environment at the landing site.

- **TSPP** — Set of 4 cameras
- **BIP** — Computer
- **MTK** — Meteo studies
- **RAT-M** — Radiometer
- **MAIGRET** — Magnetometer
- **SAM** — Seismometer
- **LARA** — Radioscience.
- **PK** — Dust studies.
- **M-DLS** — Laser spectrometer
- **FAST** — Fourier spectrometer
- **MGAK** — Gas Chromatography.
- **ADRON-EM** — Neutron spectrometer
- **HABIT** — Meteo studies

SELECTION OF THE LANDING SITE FOR EXM-2020





4 Candidates sites were recommended:

- **Oxia Planum**
- **Mawrth Vallis**
- **Aram Dorsum**
- **Hypanis Vallis**

ROSCOSMOS MARTIAN PROGRAM

THE FIRST STAGE

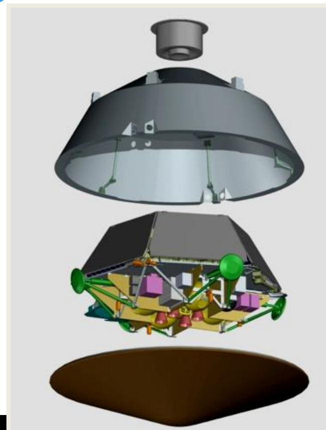
2016

ExoMars TGO

Proton, Orbiter,
Two Russian instruments
ASC и FREND

Orbiter

2020



ExoMars Lander

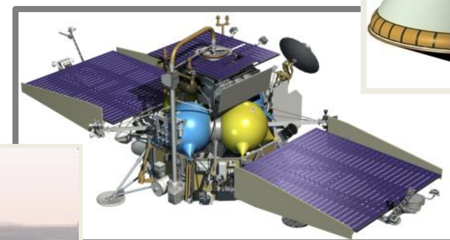
Proton,
Rover, Mars
Lander

ExoMars Rover

Soil study along
the Rover way

Mars-Rover

2026-2027

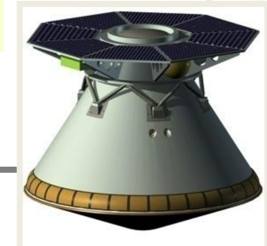


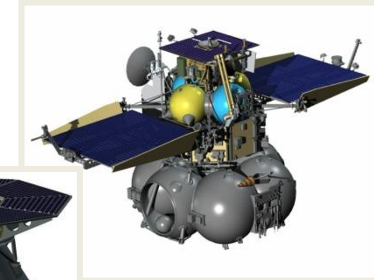
Boomerang

(Phobos-Soil-2)

Proton,
Phobos SR, Phobos
investigation

PHASE-A
…





Mars-SR

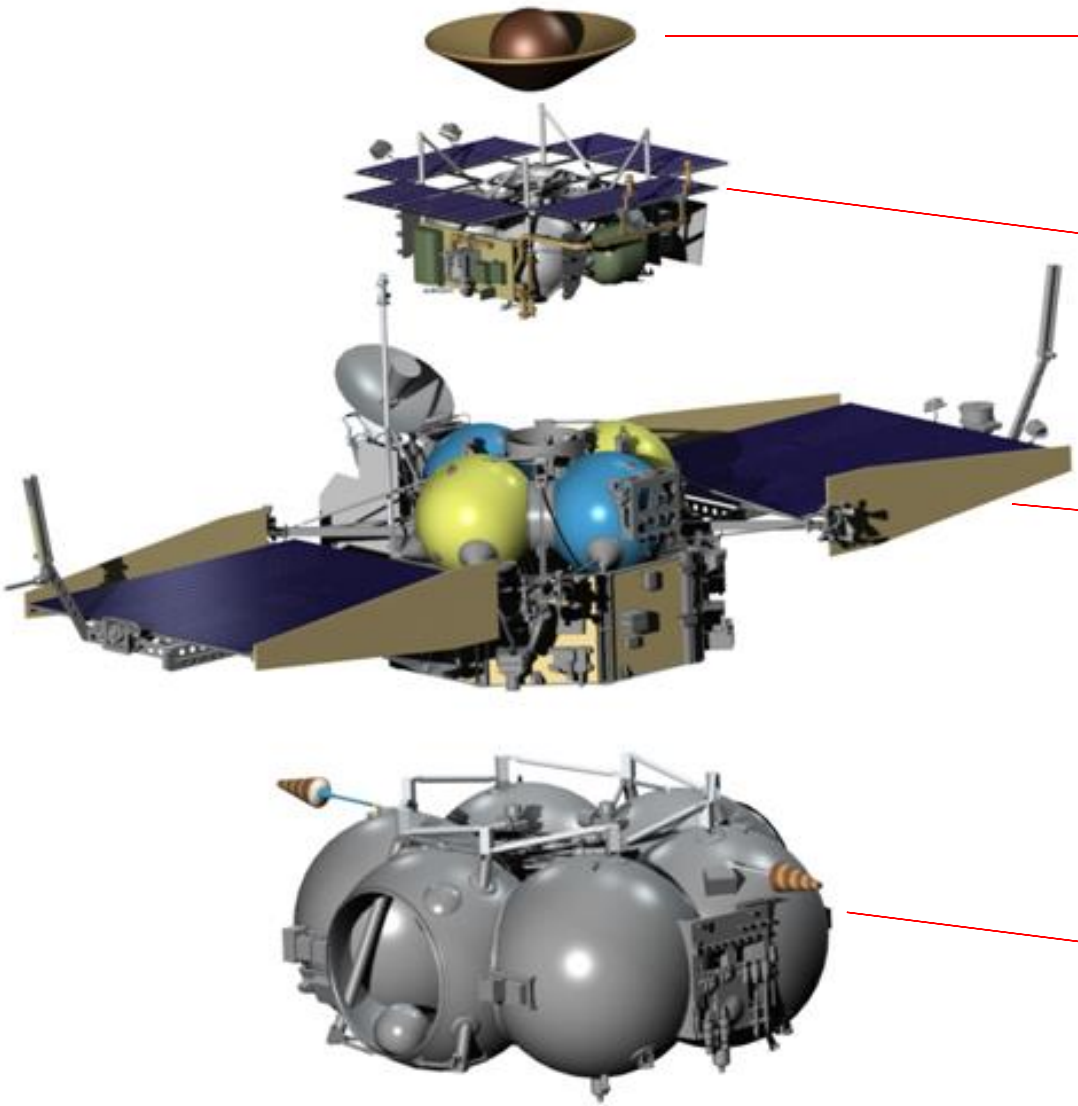
2 Proton,
Mars SR,
Mars investigation

Under
discussion

ESA contribution

BOOMERANG=PHOBOS SR2

ELEMENTS OF THE PHOBOS SR




INVESTIGATION AND EXPLORATION
OF LUNAR POLAR REGIONS
REGOLITH - DUST- PERMAFROST-- VOLATILES

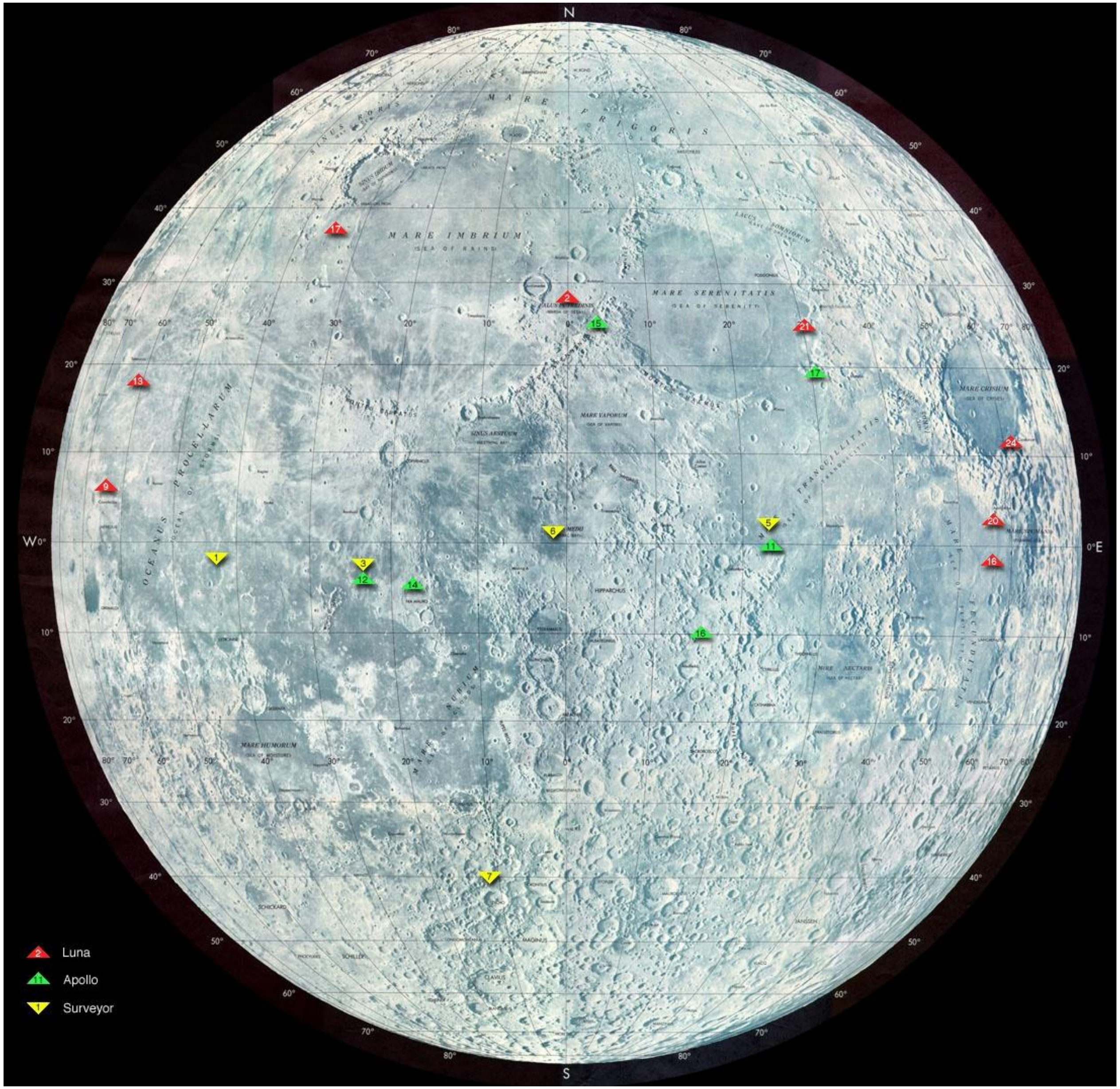
US – USSR LUNA SPACE RACE OF 60-ies and 70-ies

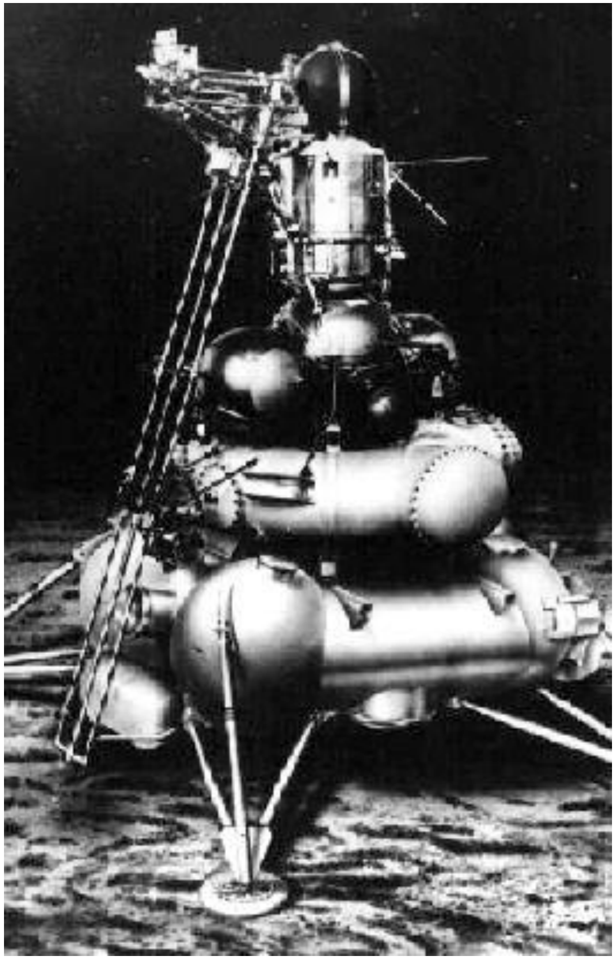
SOVIET
LUNNICS

USA
APPOLLOS

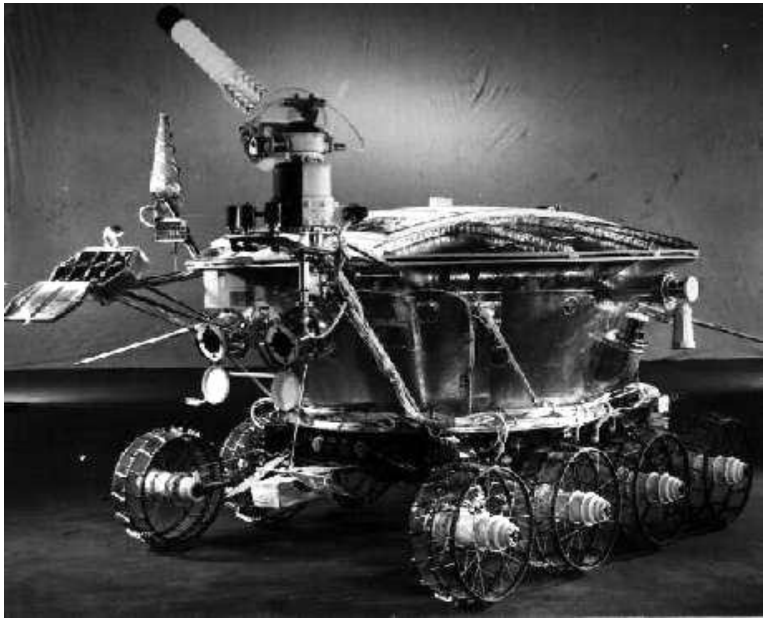
USA
SURVEYORS

MOSTLY
EQUATORIAL
AND MID LATITUDE
MOON
HAVE BEEN
STUDIED





LUNA-24 (1976)



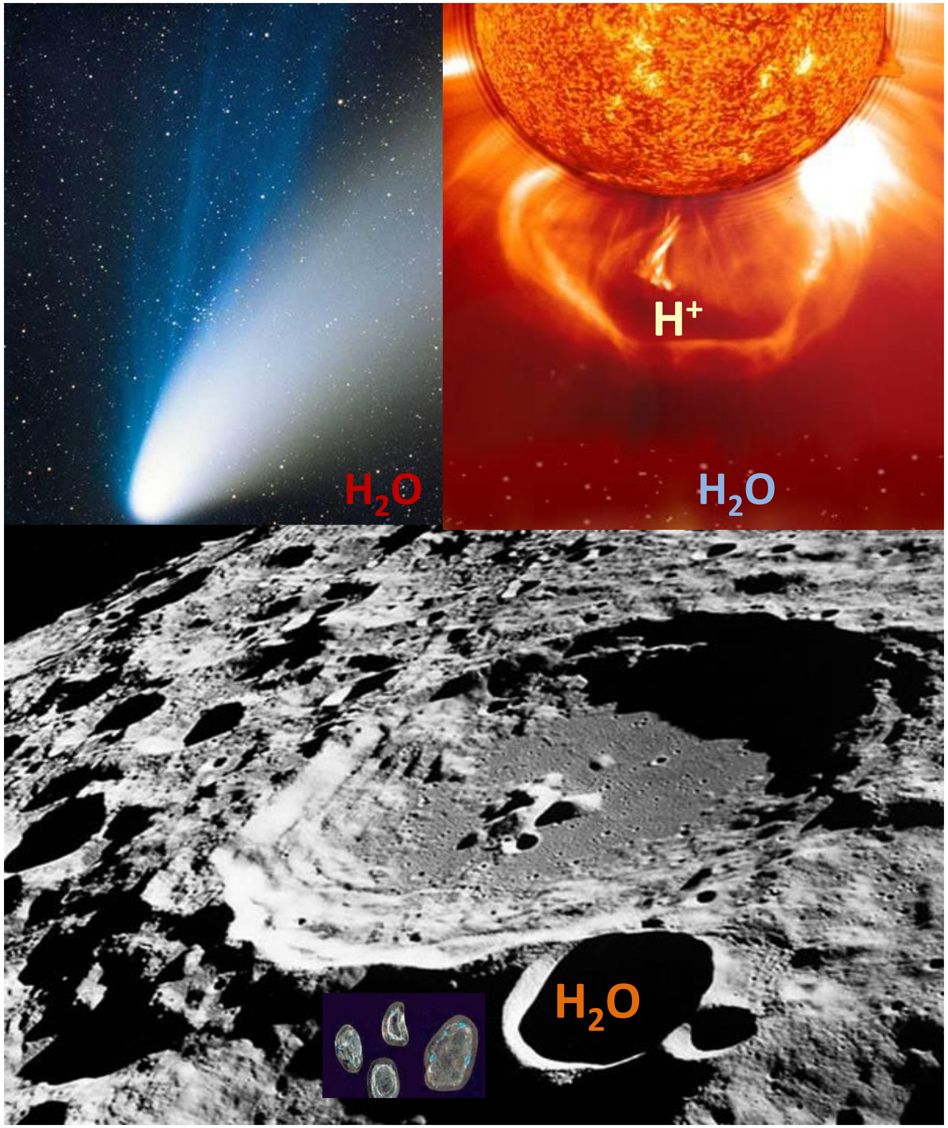
LUNOCHOD- 1 (Luna -17)

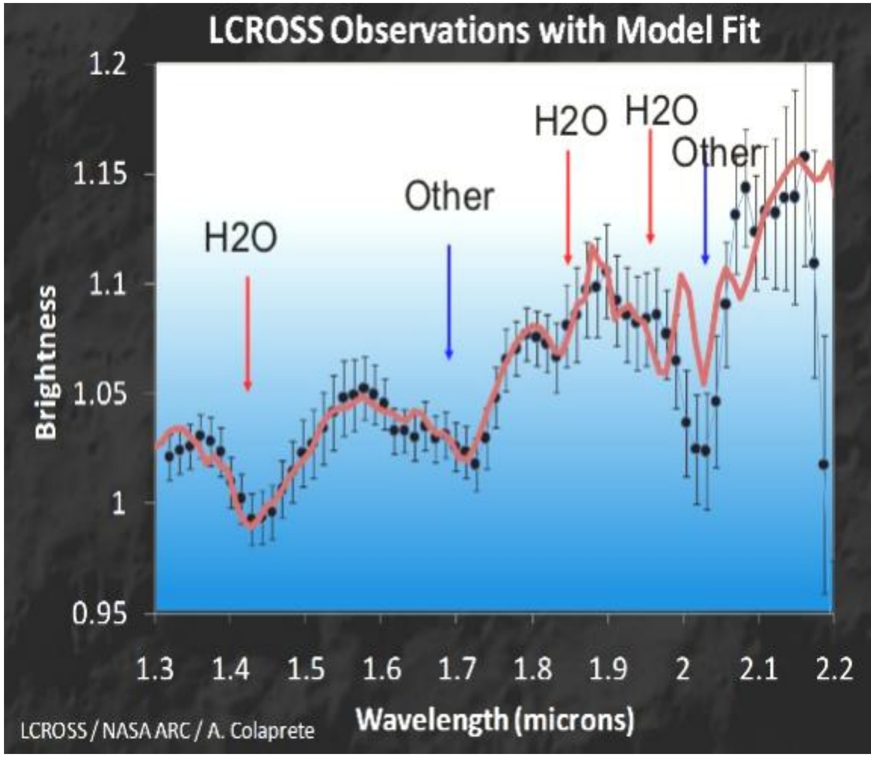
LUNA 16, 20, 24

- First Farside images
- 3 successful sample deliveries
- 2 LUNOCHODS

Problems of Moon exploration in the XXI century

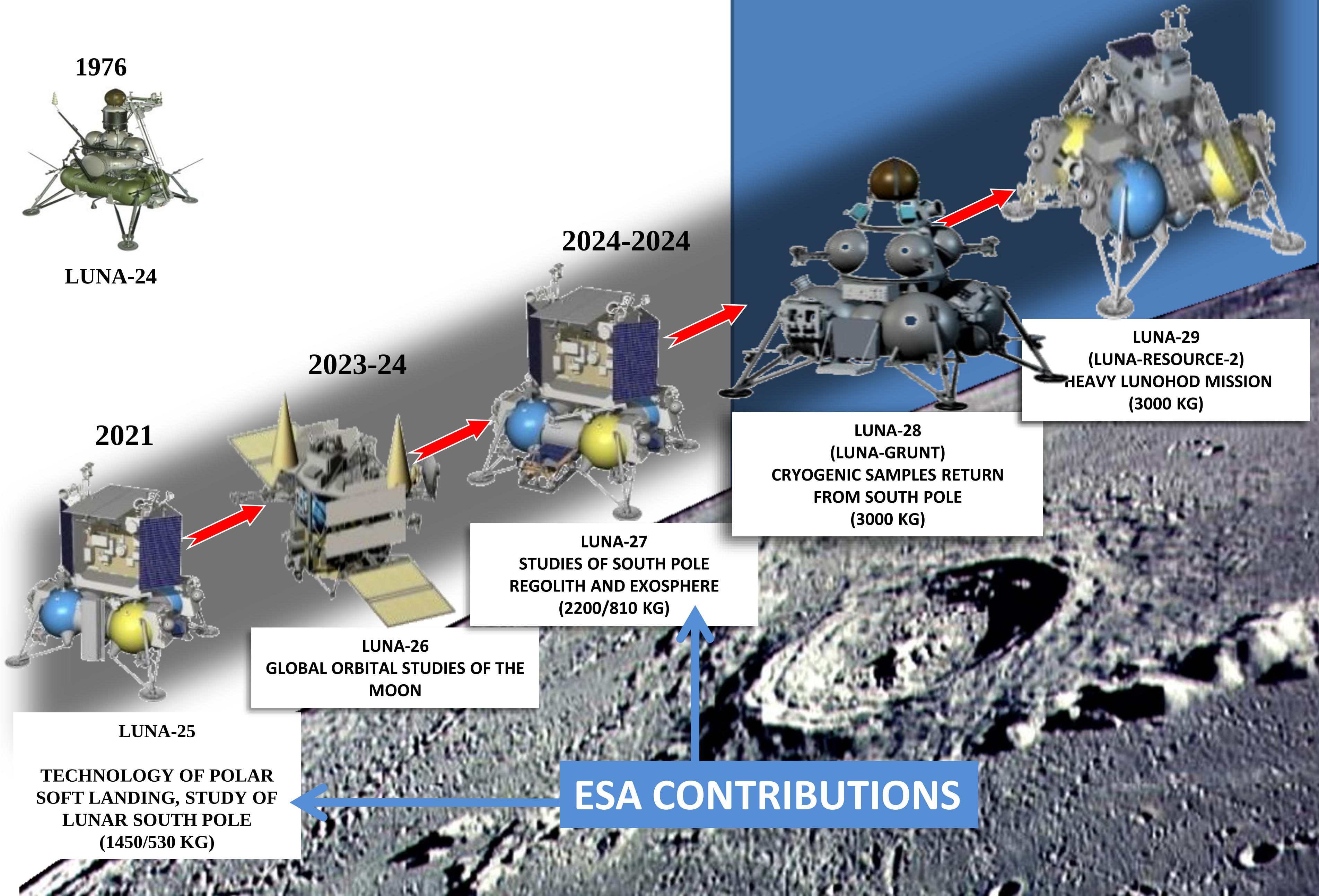
ORIGIN: Water&Volatiles in Polar regions





WATER ICE IN POLAR REGIONS

LUNAR PROGRAM



Goals of the 1st stage of Russian lunar robotic missions: SCIENCE INVESTIGATIONS + PRECURSOR TO EXPLORATION

Goal 1: Study of mineralogical, chemical, elemental and isotopic content of regolith and search for a volatiles in regolith of polar areas of the Moon.

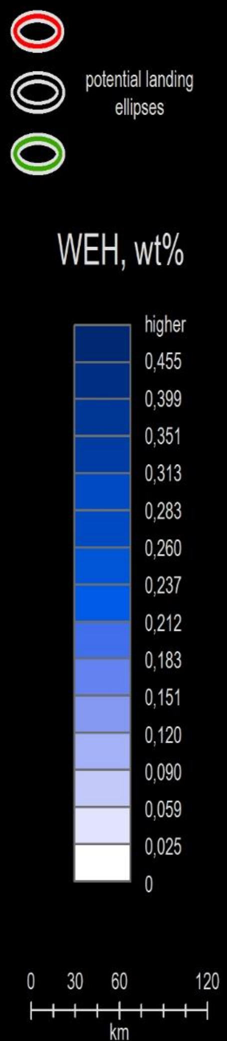
Goal 2: Study of plasma, neutral and dust exosphere of Moon and interaction of space environment with Moon' surface at poles.

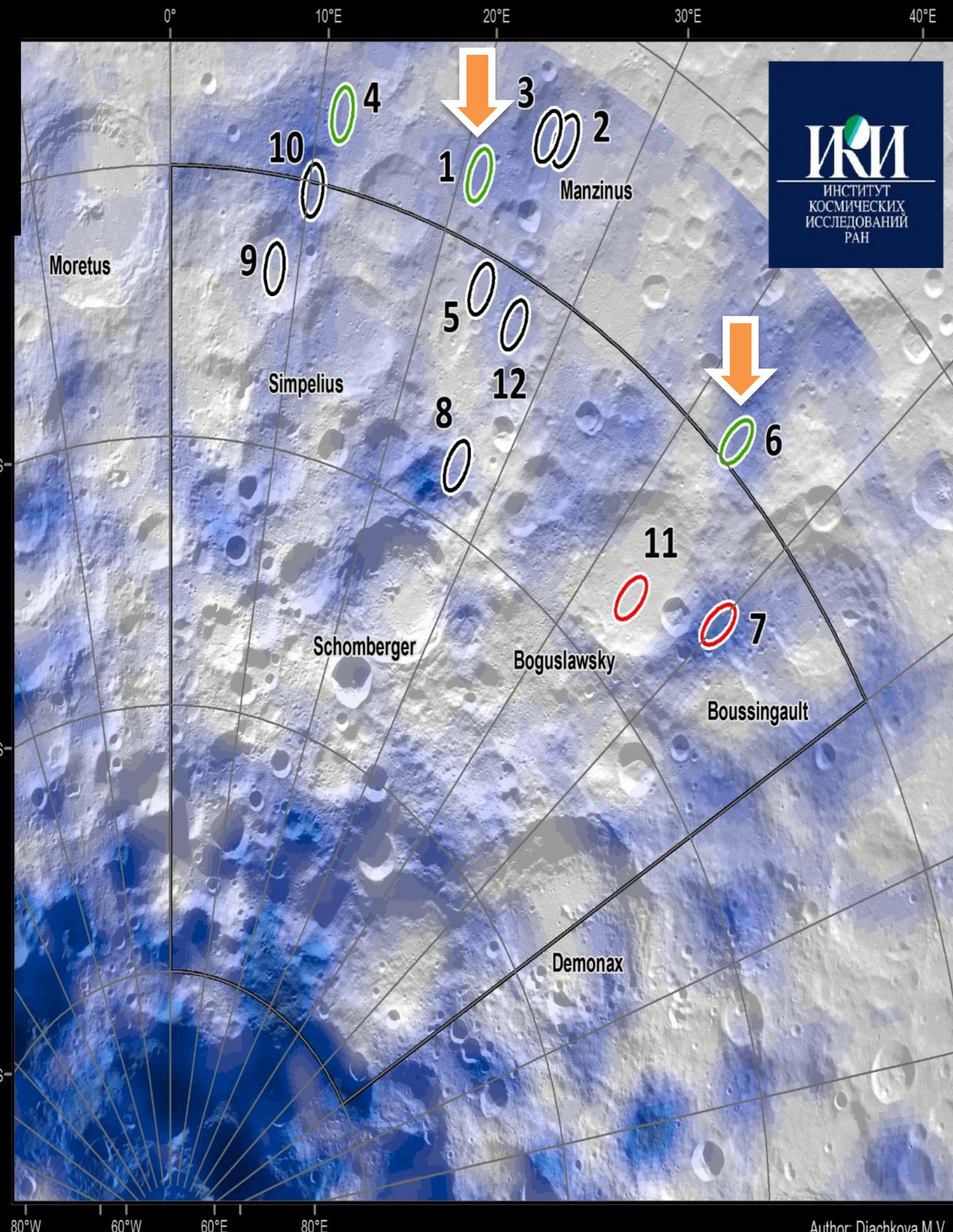
Goal 3: Study dynamic of daily processes at lunar poles, including thermal property variations of subsurface layers of regolith and evolution of hydratation and volatiles.

Goal 4: Study of inner structure of the Moon by seismic, radio and laser ranging methods.

Goal 5: Preparation for future exploration of the Moon

LUNA-25 MISSION SELECTION OF LANDING SITE





Main landing site

69.55°S 43.54°E

Reserved landing site

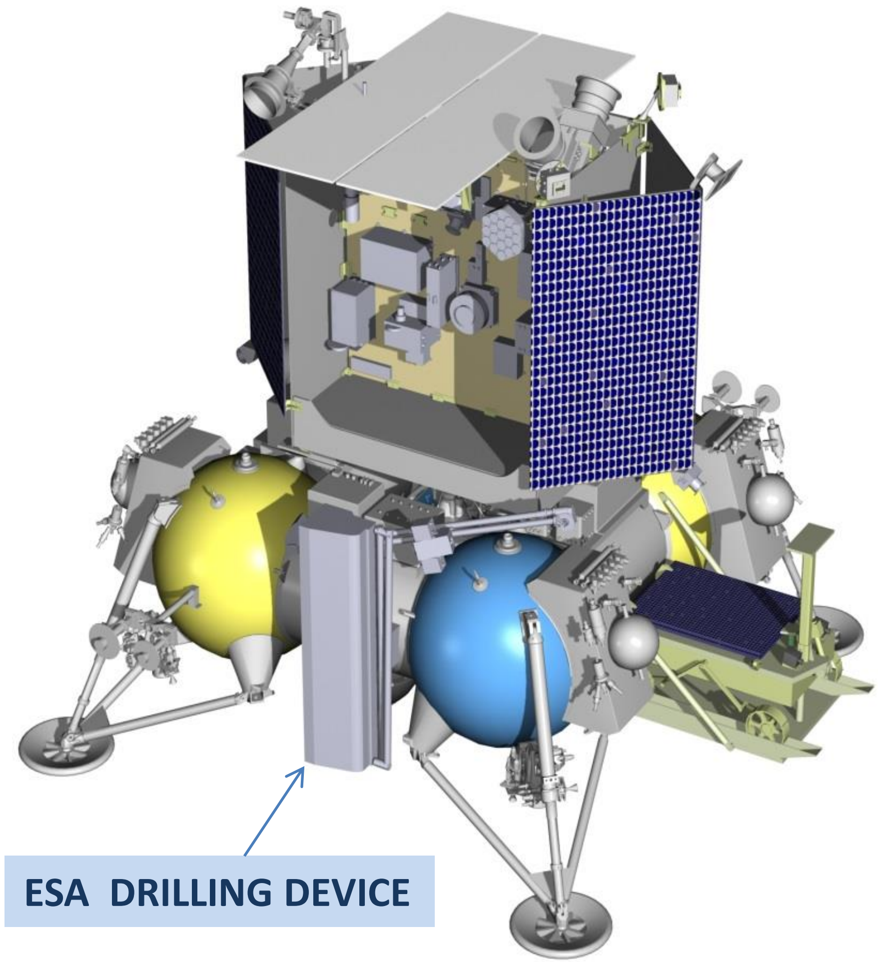
68.77°S 21.21°E

Djachkova, M.V., Litvak, M.L., Mitrofanov, I.G. et al. Sol Syst Res (2017) 51: 185.

https://doi.org/10.1134/S0038094617030029

EGU 2018

Luna-27 LANDER



Technology:

- *High precision landing and hazard avoidance*
- *Pole-orbiter UHF radio link tests and experience*
- *Cryogenic drill testing and validation*

Science:

•Mechanical/thermal/compositional properties of polar regolith within 2 meters

•Water content and elements abundance in the shallow subsurface of the polar regolith

•Plasma, neutral and dust exosphere at the pole

•Seismometry and high accuracy ranging

Dust on the Moon

Dust particles above Moon surface have three types of origins:

- high speed micrometeorites,
- secondary particles after micrometeorites soil bombardment,
- Levitating dust particles due to electrostatic fields

- **VERY DANGEROUS**

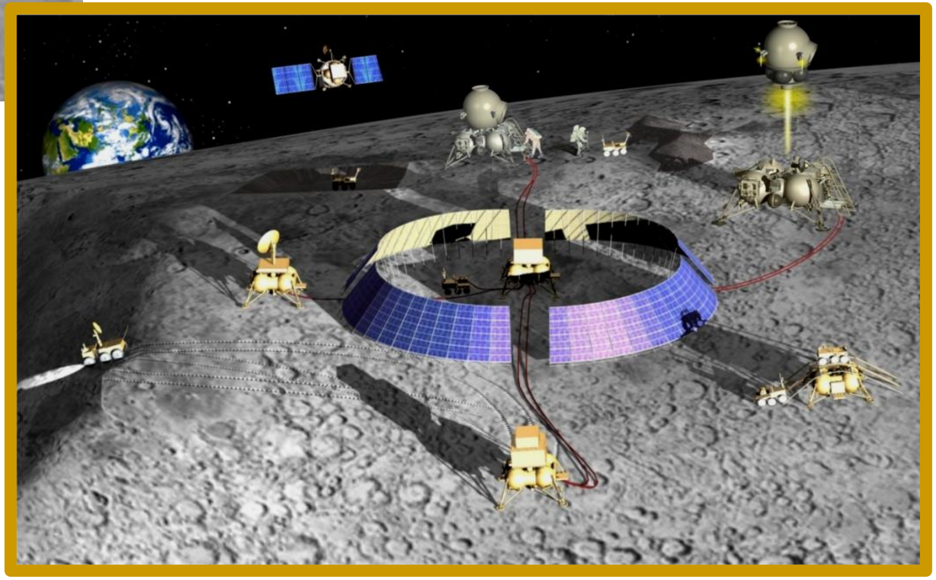
AND TOXIC SUBSTANCE !

Synergy of Martian and Lunar programmes

Lunar Base (Lunar village)

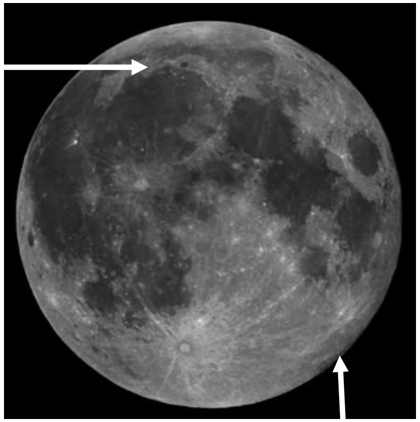
What humans can do there except the survival ?

- RADIOASTRONOMY
- SUBMILLIMETER ASTRONOMY
- OPTICAL ASTRONOMY
- X-RAY AND GAMMA ASTRONOMY
- ASTROPARTICLE OBSERVATIONS (COSMIC RAYS)



FUTURE LUNAR OBSERVATORIES

- *Absence of clouds*
- *Absence of atmospheric perturbations*
- *Possibility of continuous observations*
- *Possibility of long expositions-slow motions of stars*

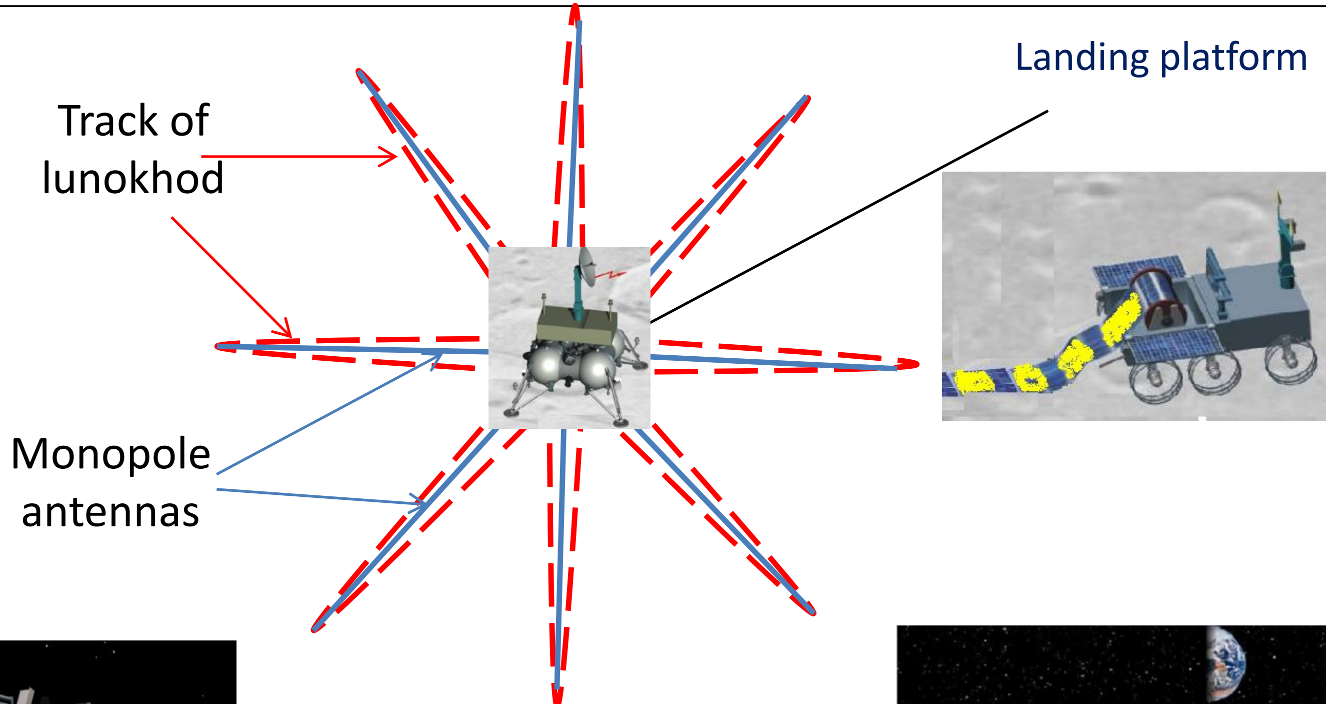


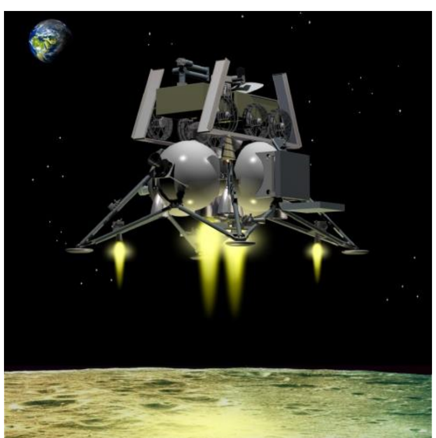
RADIO TELESCOPE AT THE DARK SIDE
PROTECTION FROM THE EARTH"s
RADIOSPAM-
DREAM OF ASTRONOMERS

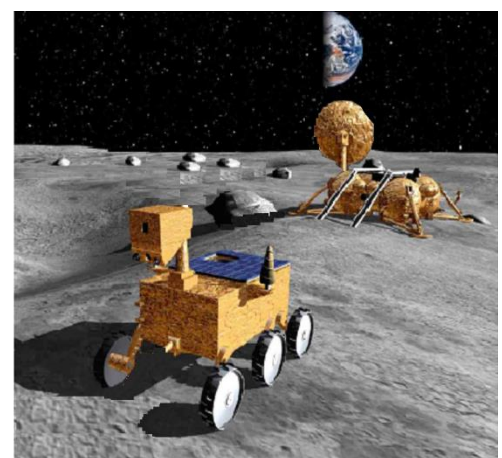
MOON PROVIDES EXCELLENT CONDITIONS FOR:

- **RADIOASTRONOMY**
- **SUBMILLIMETER ASTRONOMY**
- **OPTICAL ASTRONOMY**
- **X-RAY AND GAMMA ASTRONOMY**
- **ASTROPARTICLE OBSERVATIONS (COSMIC RAYS)**

The radio cluster at Moon: its development

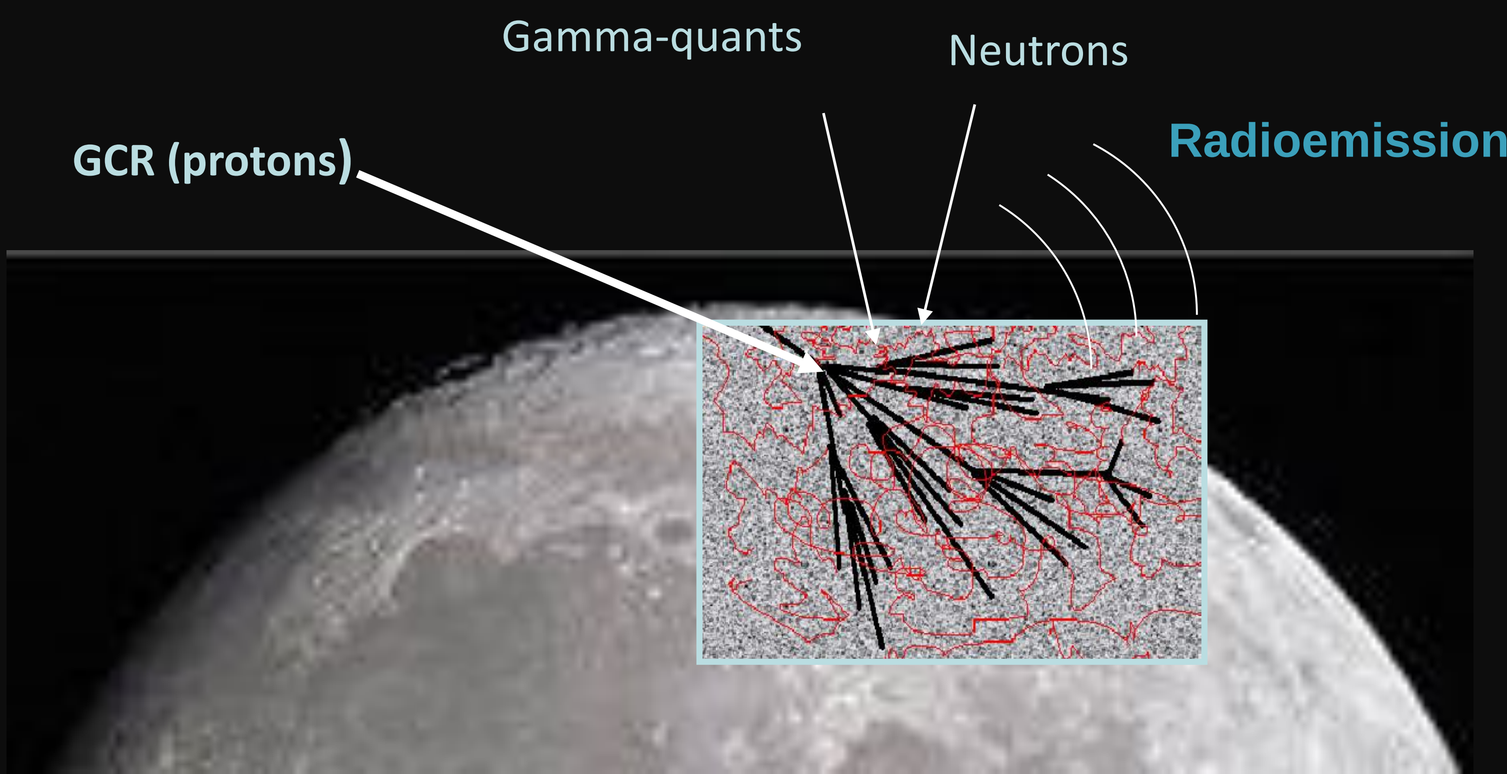




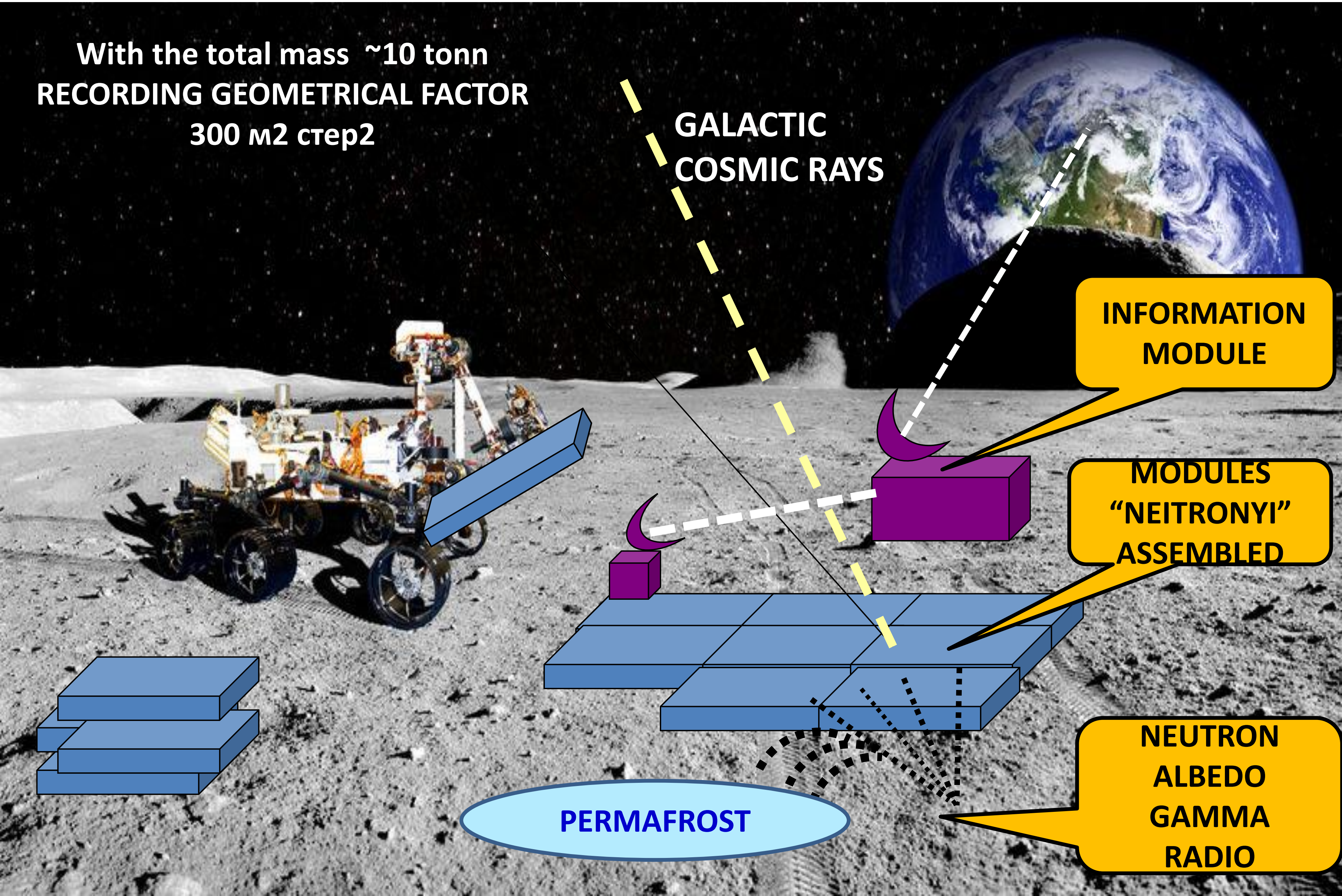


INTERACTION OF GCR WITH THE LUNAR SURFACE

Measurements at the Lunar surface
albedo neutrons
Gamma quants
radio emissions



ROBOTIC ASSEMBLAGE OF COSMIC RAY FACILITY



VENUS PLANS (>2028)

Venera-D
Roscosmos/IKI – NASA
Joint Science Definition Team

Artist concept of the joint mission to Venus with
Venera-D orbiter and Lander
and Venus Atmospheric Maneuverable Platform (VAMP)

Orbiter:

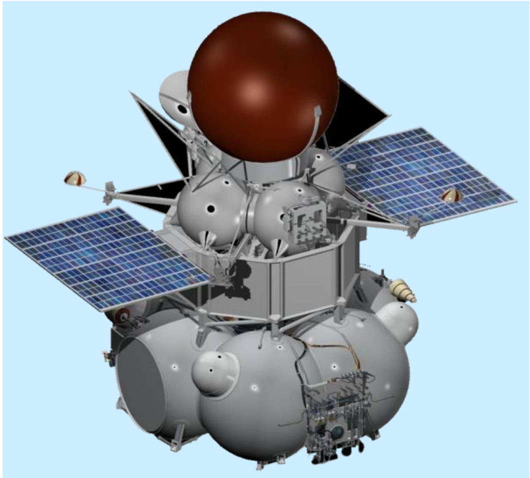
- **Study of the dynamics and nature of super-rotation, radiative balance and nature of the greenhouse effect;**
- **Characterize the thermal structure of the atmosphere, winds, thermal tides**
- **Measure composition of the atmosphere; study the chemistry of clouds**

Lander:

- **Perform chemical analysis of the surface material**
- **Study of interaction between the surface and atmosphere;**
- **Perform direct chemical analysis of the cloud aerosols;**
- **Search for volcanic and seismic activity; search for lightning**

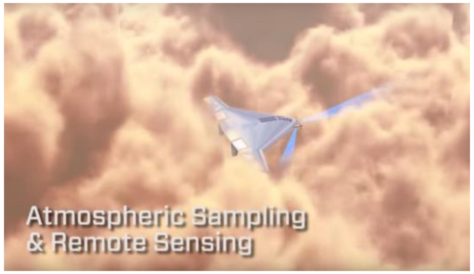
Baseline elements (Roscosmos):

- <u>Orbiter</u> : Polar 24 hour orbit with a lifetime greater than 3 years—
- <u>Lander</u> (VEGA-type, updated) 2+ hours on the surface (one hour to conduct baseline science and one hour of margin)

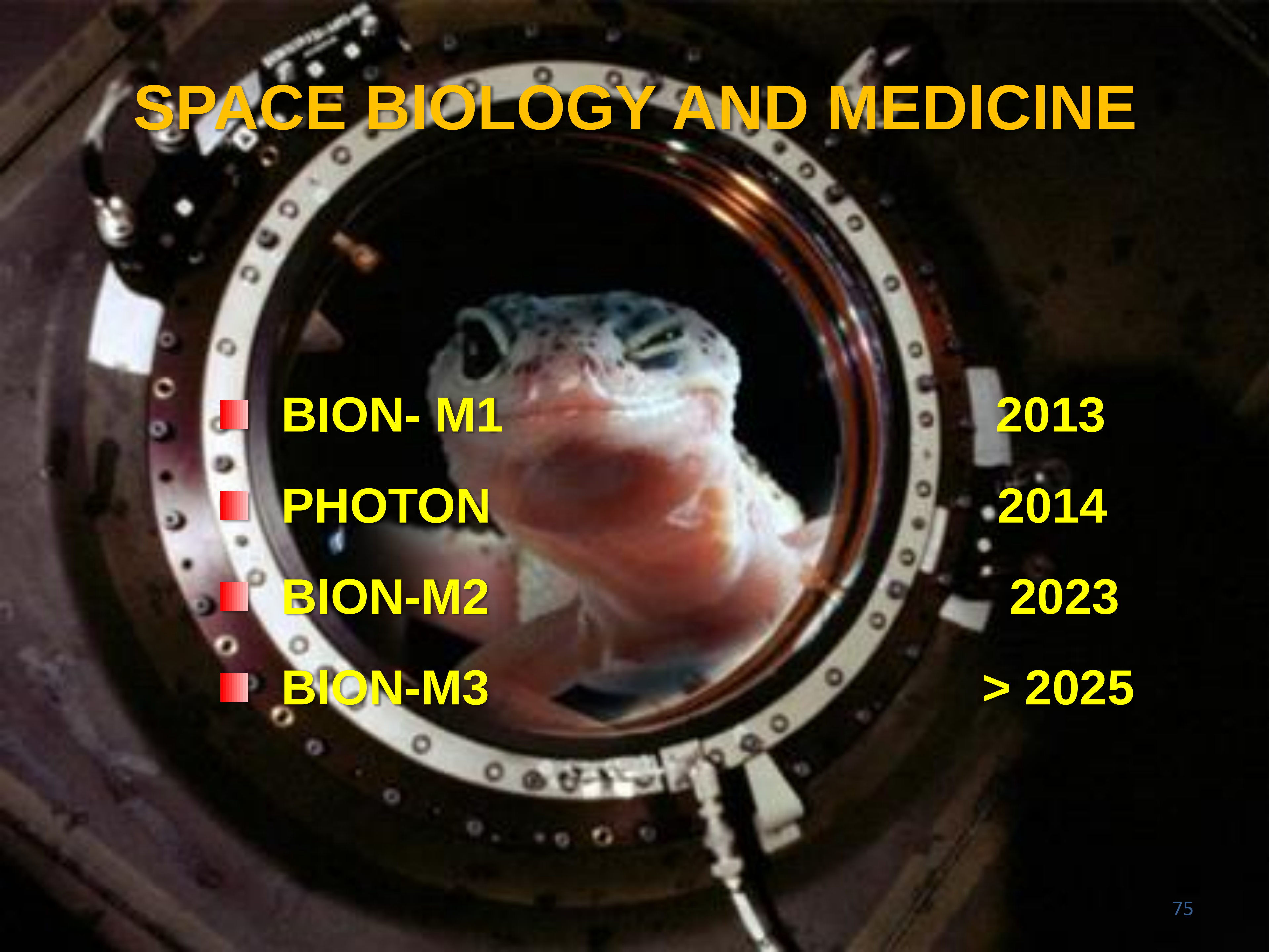


Components discussed as a potential augmentations:

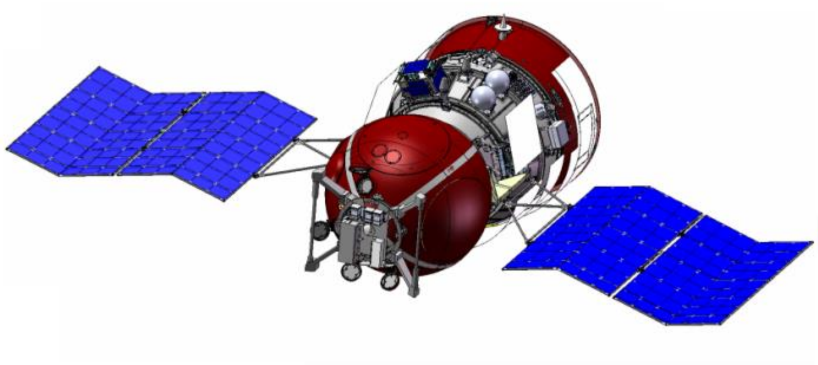
- Free flying aerial platform and balloons (NASA)
- Sub-satellite (Roscosmos)
- Long live stations (NASA)



BIOLOGICAL INVESTIGATION ON BOARD UNMANNED SPACECRAFT


SPACE BIOLOGY AND MEDICINE
BION- M1 2013
PHOTON 2014
BION-M2 2023
BION-M3 > 2025
75

BION M1



SCIENTIFIC GOALS

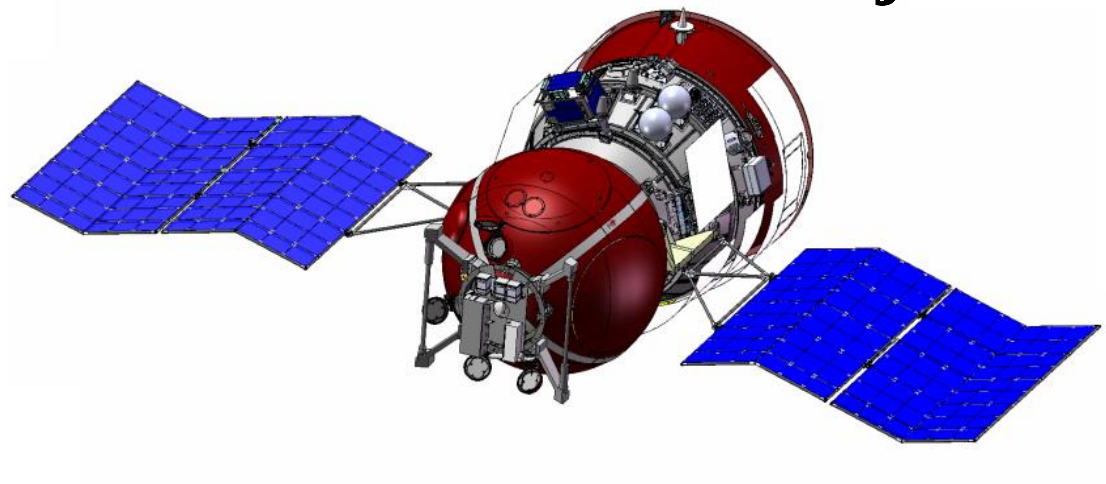
Studies of hostile space environment on biological materials and living species in space flight s (duration up to 45 days).

Meteorite experiment

The purpose of the Meteorite experiment was to verify whether microorganisms embedded in meteorite and asteroid type materials could survive their exposure to outer space and dense layers of Earth's atmosphere

It was demonstrated that out of different microorganisms only spore-forming bacteria *Carboxydocella ferrireduca* and *Bacillus pumilis* survived the exposure. These bacteria were embedded in a «meteorite» containing glauconite, i.e., iron potassium phyllosilicate mineral, characterized by low thermal conductivity whereas other microorganisms were placed in magnetite samples having higher thermal conductivity.

BION-M 2 Project



Main task:

Comprehensive study of combined biological impact of increased space radiation levels and weightlessness on organism and its separate functional systems at cell and molecular levels.

Planned launch date– **2023**

Flight duration– **30 days**

Orbital height– **800-1000 km**

Hardware will be similar to the one at BION-M 1 but modified after flight tests.

N=75

Bioobjects – mice C57bl, insects, plants, cell cultures, microorganisms


THANKS
FOR
YOUR
ATTENTION