Russian Space Science Program update

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


Astrophysics
Spectr-R

Space weather
Spectrum-RG

Planetary research
ExoMars-1

ExoMars-2

Luna-25

Luna-26, -27

Bion-M2

Space biology and biotechnology
Bion-M3

Spectrum-UV

STRANNIK

Spectrum-M

G-400, OLVE

Interhelioprobe

Boomerang

Venus-D

Luna-28
The RadioAstron (Spectr_R)
Space VLBI mission

THE BIGGEST RADIOTELESCOPE
10m dish
Resolution up to 8 μas

SVLBI baseline ~ 350,000 km
10 days orbit
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 $\sim 10^{13}$ K, max $\sim > 10^{14}$ 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 $\mu$as.

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 ??

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![Histograms of Brightness Temperature](image)

- **18 cm**: Number of sources: 104
- **6 cm**: Number of sources: 133
- **1.35 cm**: Number of sources: 22

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**Axes:**
- X-axis: Brightness temperature (K)
- Y-axis: Number of sources

**Legend:**
- Green bars indicate the distribution of brightness temperatures for different wavelengths.
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
Mass~12kg
SOLAR WIND AS A TURBULENCE LABORATORY
ADVANTAGES OF "IN SITU" MEASUREMENTS

TURBULENT CASCADE

PUMPING

INERTIAL RANGE

\[ \log E(k) \]

\[ \log k \]
TURBULENCE PROPERTIES AT KINETIC RANGE

INERTIAL RANGE
KOLMOGOROV TYPE SPECTRUM

PROTON DEMAGNETIZATION SCALE ≈ 1000 km

STEEP SPECTRUM DISSIPATION INTERVAL

PREVIOUS EXPERIMENTS
Air show MAKS2009

AGREEMENT -August 18, 2009,
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 $\geq 3$ million active galactic nucleus

• 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.
April 25, 2019
LAUNCH - June 21, 2019

Proton-M

DM-3 buster
WORLD SPACE OBSERVATORY – ULTRAVIOLET

launch 2025

Geosynchronous orbit, $i=40^\circ$
Launcher “PROTON”

RUSSIA + SPAIN
World Space Observatory – Ultraviolet (Spectr – UF)

- 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.

Telescope T-170M under construction
Primary mirror of the T-170M telescope

Optics is being manufactured at Lytkarino Optical Plant.
The WSO-UV Core Program


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 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 H2O, O2, 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
The first measurements of Ultra-High Energy cosmic rays from space ($10^{20}$ eV)

LOMONOSOV satellite
MOSCOW UNIVERSITY

$S_{\text{eff}} \sim \text{km}^2$

Launched 2016 from the new eastern cosmodrom “VOSTOCHNYI”
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

Mars 96
Phobos 88
Phobos Grunt

1960
1970
1980
1990
2000
2010
2020

US
Mariner 3, 4
Mariner 6, 7
Mariner 8, 9
Viking

Mars Observer
MGS, MRO
MCO, MSL
Mars Odyssey
MERs
Phoenix

Non-US
1M, 2M
M69
Mars 2, 3
Mars 4, 5, 6
Phobos

Mars 96
Nozomi
Mars Express
Phobos-Grunt

MOM
ExoMars

2020 Rover
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
Trace Gas Orbiter

CH₄, volcanic gases

Rover at landing scientific platform

Drilling Systematic surface observations

2016

2020

eesa

EXOMARS
NOMAD
High resolution occultation and nadir spectrometers
Atmospheric composition (CH₄, O₃, trace species, isotop) dust, clouds, P&T profiles

UVIS (0.20 – 0.65 μm) \( \lambda/\Delta \lambda \approx 250 \)
IR (2.3 – 3.8 μm) \( \lambda/\Delta \lambda \approx 10,000 \)
IR (2.3 – 4.3 μm) \( \lambda/\Delta \lambda \approx 20,000 \)

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) \( \lambda/\Delta \lambda \approx 20,000 \)
IR (Fourier, 2 – 25 μm) \( \lambda/\Delta \lambda \approx 4000 \) (so)/500 (N)
Mid IR (2.2 – 4.5 μm) \( \lambda/\Delta \lambda \approx 50,000 \)

FREND
Collimated neutron detector
Mapping of subsurface water

Background image: CH₄ map, Mumma et al, Science 2009
Global Dust Storm

- 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

High resolution stereo camera on Mars Express image taken in April 2018, ESA/DLR/FU Berlin
$\text{H}_2\text{O}$, HDO and D/H observations

- Increase of densities
- Uplifting to higher altitudes
- Fast phenomenon
No detection of methane

O. Korablyev & A.C. Vandaele and ACS & NOMAD Science Team
TGO FLIGHT TO MARS
MEASUREMENTS OF RADIATION DOSES

The radiation dose received by astronauts during flight to Mars and back is almost equal to the integral dose acceptable for the entire carrier.

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

Data from 250 days of mapping, 20% of the planned mapping stage
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 cameras
- **ISEM**
  Infrared spectrometer at Rover mast
- **CLUPI**
  Microscope-camera
- **WISDOM**
  Subsurcaue 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**
  Radoscience.
- **PK**
  Dust studies.
- **M-DLS**
  Laser spectrometer
- **FAST**
  Fourier spectrometer
- **MGAK**
  Gas Chromatography.
- **ADRON-EM**
  Neutron spectrometer
- **HABIT**
  Meteo studies
4 Candidates sites were recommended:

- Oxia Planum
- Mawrth Vallis
- Aram Dorsum
- Hypanis Vallis
ExoMars TGO
Proton, Orbiter, Two Russian instruments ASC и FREND

ExoMars Rover
Soil study along the Rover way

Mars-SR
2 Proton, Mars SR, Mars investigation

Mars-Lander
Proton, Rover, Mars Lander

Boomerang
(Phobos-Soil-2)
Proton, Phobos SR, Phobos investigation

PHASE-A
...

Orbiter

ESA contribution

Under discussion

THE FIRST STAGE

ROSCOSMOS MARTIAN PROGRAM

2016

2020

2026-2027

ExoMars Rover
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)

- 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
Goals of the 1\textsuperscript{st} 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 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
Main landing site
69.55°S 43.54°E

Reserved landing site
68.77°S 21.21°E

https://doi.org/10.1134/S0038094617030029
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

- Landing platform
- Track of lunokhod
- Monopole antennas
INTERACTION OF GCR WITH THE LUNAR SURFACE

Measurements at the Lunar surface
albedo neutrons
Gamma quants
radio emissions

GCR (protons) → Neutrons → Gamma-quants → Radioemission
ROBOTIC ASSEMBLAGE OF COSMIC RAY FACILITY

With the total mass $\sim 10$ tonn
RECORDING GEOMETRICAL FACTOR
300 $\text{m}^2$ стер2

GALACTIC COSMIC RAYS

INFORMATION MODULE

MODULES “NEITRONYI” ASSEMBLED

NEUTRON ALBEDO

GAMMA RADIO

PERMAFROST
VENUS PLANS (>2028)

**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):

- **Orbiter**: Polar 24 hour orbit with a lifetime greater than 3 years—

- **Lander** (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
BION M1

SCIENTIFIC GOALS

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