

# Introduction to Millimetron (Spektr-M)

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On behalf of Millimetron project team

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# Acknowledgements

Many elements of this presentation are based on existing presentations prepared by other members of the Millimetron project.

All along this presentation you will see results from work conducted by a large number of Millimetron contractors.



# Contents of the presentation

- What is Millimetron?
- General description of the Millimetron mission
- Astro Space Centre and its role in Millimetron
- Place of Millimetron in the Russian Federal Space Program
- Millimetron modes
- International cooperation



# What is Millimetron?

The idea of the Millimetron mission was expressed by **Nikolay Kardashev** in the mid 80s of the last century.



Millimetron Workshop, Paris, September 9<sup>th</sup>--11<sup>th</sup>.

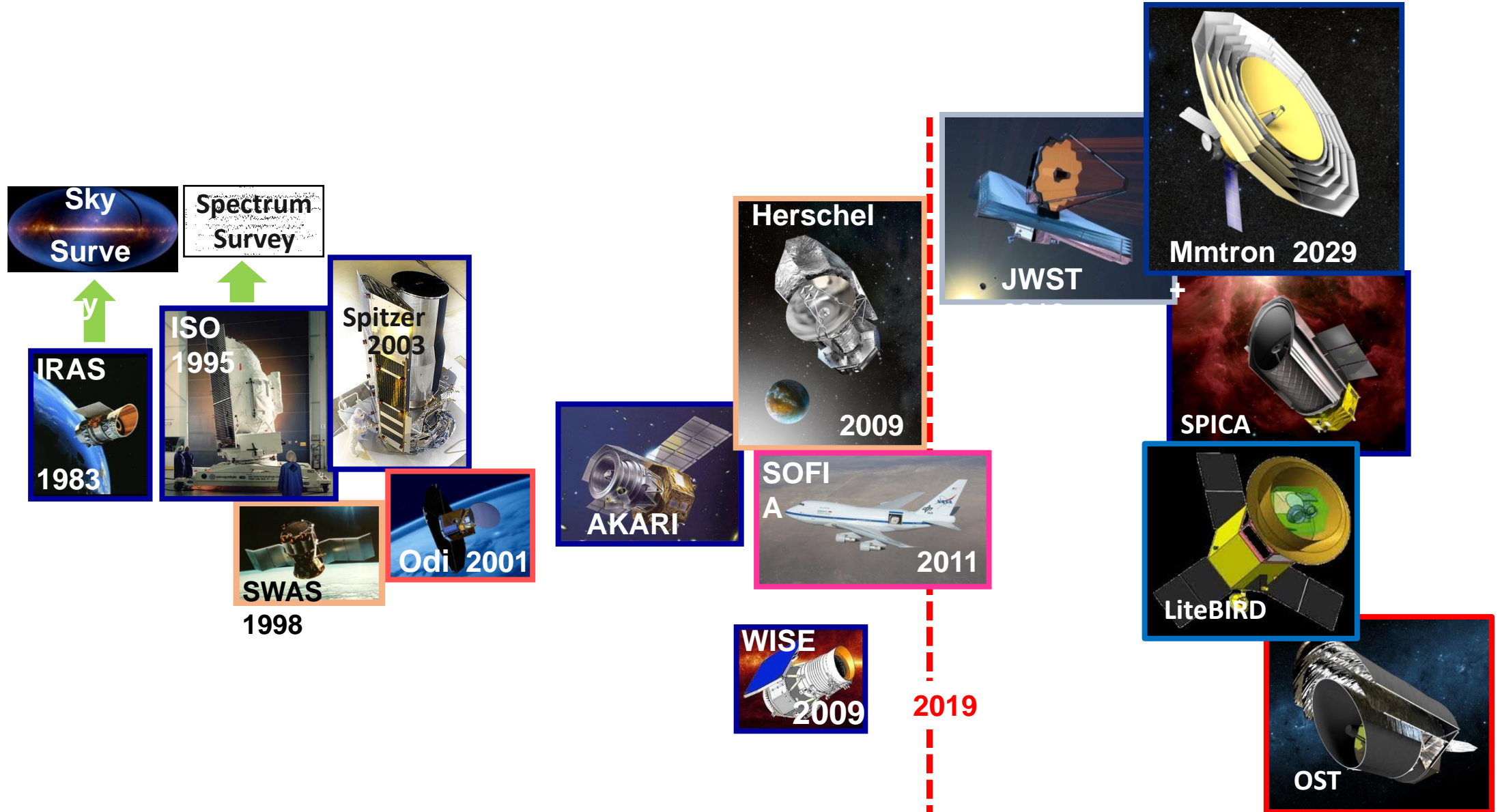


# What is Millimetron?

- The Millimetron Space Observatory, also called Spektr-M, is a large, space-based observatory, optimized for millimeter and infrared wavelengths from 0.08 to 7 mm.
- It will have greatly improved angular resolution (as a part of ground-space VLBI) and increased sensitivity (as a single cooled telescope).

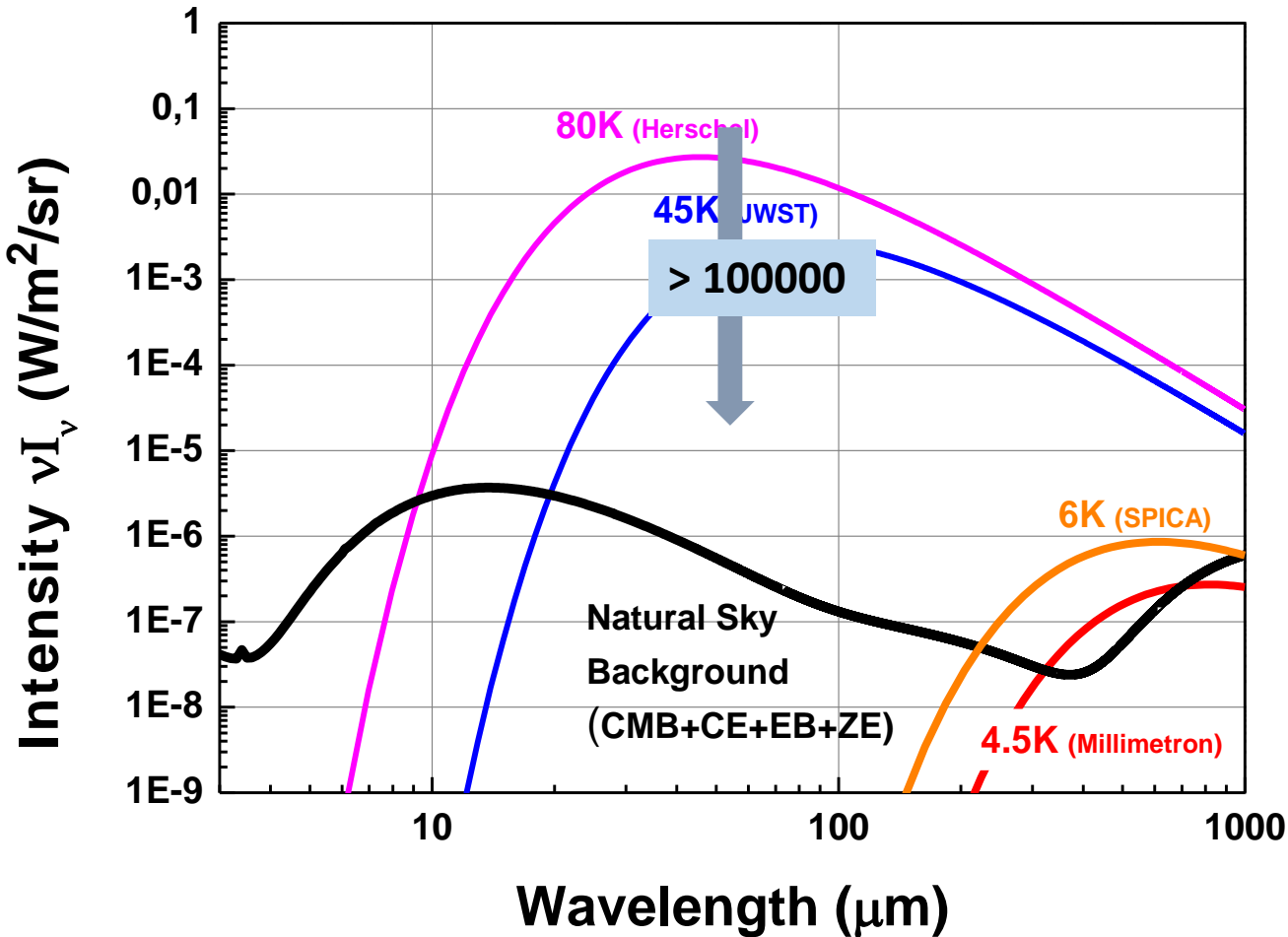


# Evolution of the FIR/Submm/Mm Instruments for Space Science





# A cooled antenna can provide 100 times more sensitivity



The intensity of the thermal self-emitted radiation falls below the limit provided by the natural sky background if the telescope is cooled to temperature  $< 10\text{K}$



Background limited  $< 300 \mu\text{m}$  if  $T_{\text{tel}} \approx 4.5 \text{ K}$





# The Millimetron Mission in one slide ...

The first 10-m deployable and cooled space sub-mm and FIR telescope.

**The mission is approved and supported by Russian Space Agency**

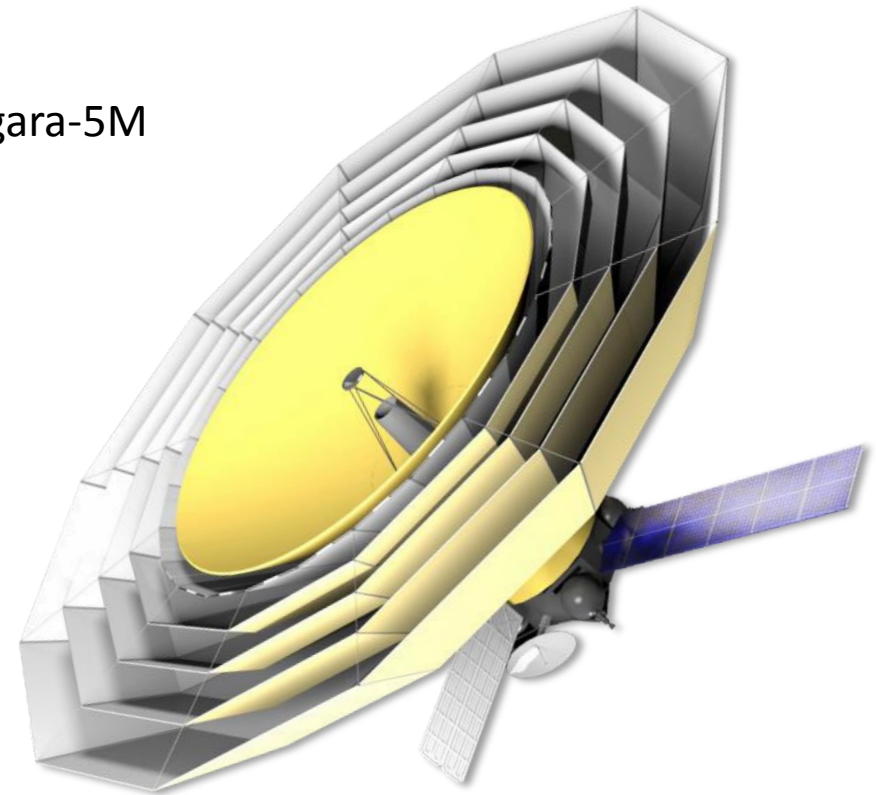
- FIR, sub-mm and mm range
- In orbit deployable and adjustable antenna
- Mechanically cooled (<10K) with post-cryo life
- Orbit around L2 Lagrange point; launch with new launcher Angara-5M
- Lifetime: 10 years; at cryo >3 years

## **Two operation modes:**

Space-VLBI at 0.3 – 7 mm

Single dish at 0.08 – 3 mm

- Step forward with respect to earlier missions
- Sensitivity:  $10^{-22}$  W/m<sup>2</sup> for spectroscopy and 0.5  $\mu$ Jy
- for photometry (single dish)
  
- **Spacecraft bus and instruments in Phase-A**
- **Antenna in Phase-B**
- **Launch date : 2029**



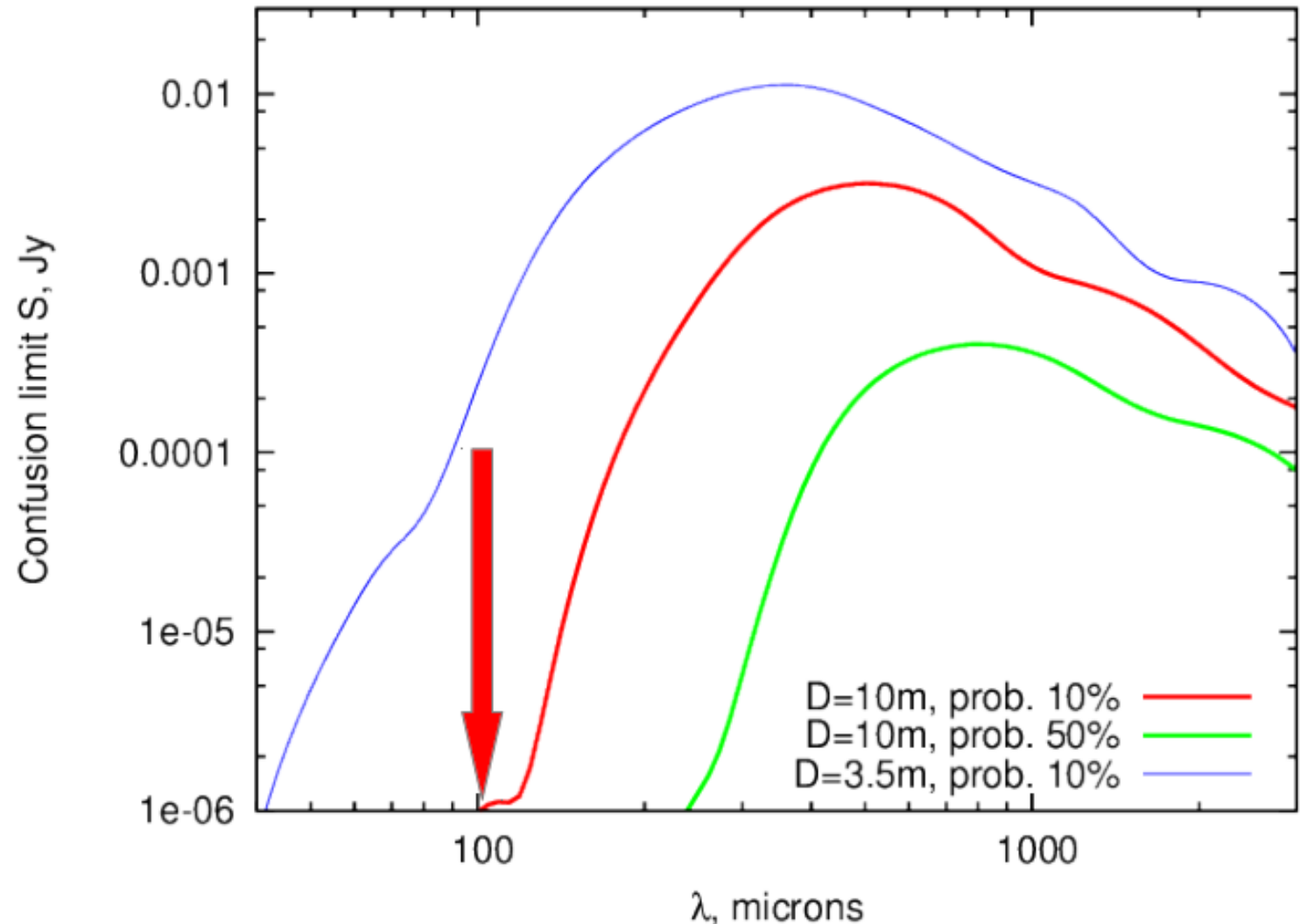




# A single 10 m antenna beats the confusion limit in FIR

Definition: for sources with flux density  $>S$  the probability to have indistinguishable sources is  $P$ .

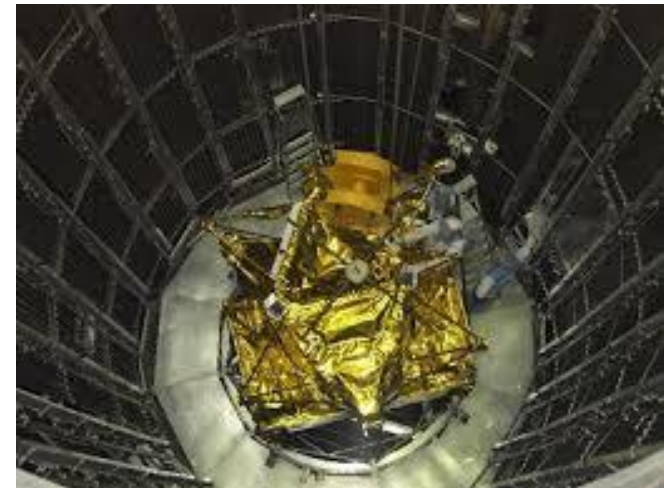
Data from Bethermin et al. 2011 **model counts used.**





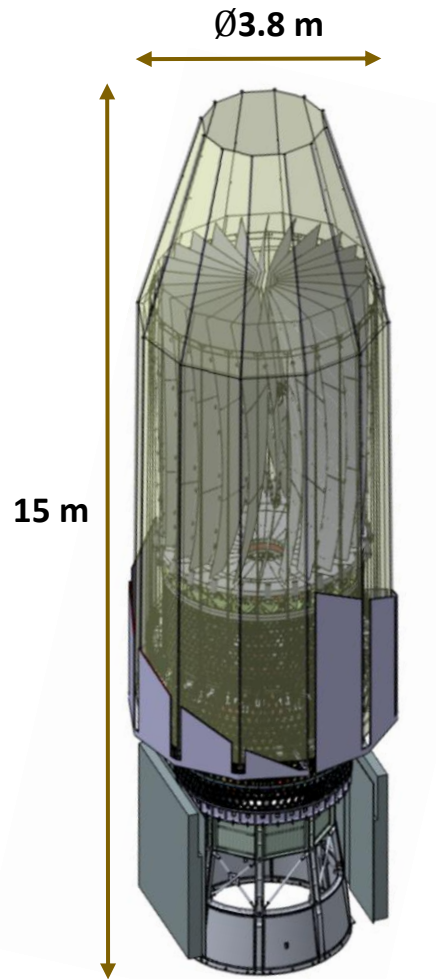
# Millimetron Spacecraft “Navigator-M”

- The space platform is based on the “Navigator” spacecraft, which was used by Spektr-R (Radioastron) and Spektr-RG (SRG) with upgrading of the basic systems (guidance and pointing, stabilization, power supply, radio links).
- The modified space platform to be called “Navigator-M”.
- Development is to start 2023, by Lavochkin Association, Moscow.

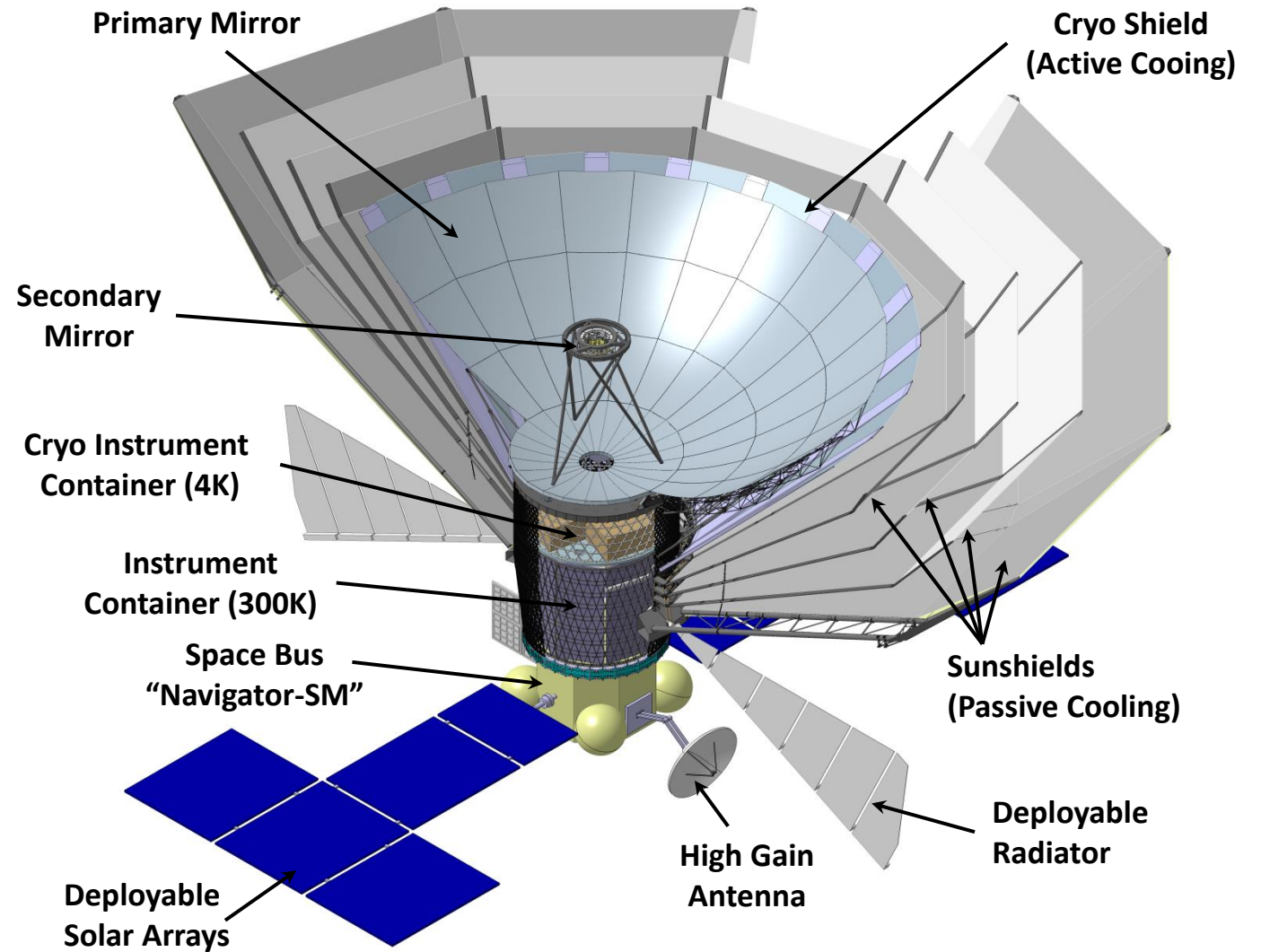




# Millimetron Payload Concept



Launch configuration







# Millimetron PI Institute

ФЕДЕРАЛЬНОЕ ГОСУДАРСТВЕННОЕ  
БЮДЖЕТНОЕ УЧРЕЖДЕНИЕ НАУКИ

Физический  
ИНСТИТУТ



имени  
П.Н.Лебедева

РОССИЙСКОЙ АКАДЕМИИ НАУК

Ф И А Н

- The **Astro Space Centre** is a part of the oldest physical institute of Russian Federation – **P. N. Lebedev Physical Institute (LPI)**.
- The **Astro Space Center (ASC )** of *P. N. Lebedev Physical of Russian Academy of Sciences* was **founded in 1990** for fundamental research in astrophysics
- Our primary goal are space telescopes projects: **Radioastron (mission 2011 to 2019)** and **Millimetron**.





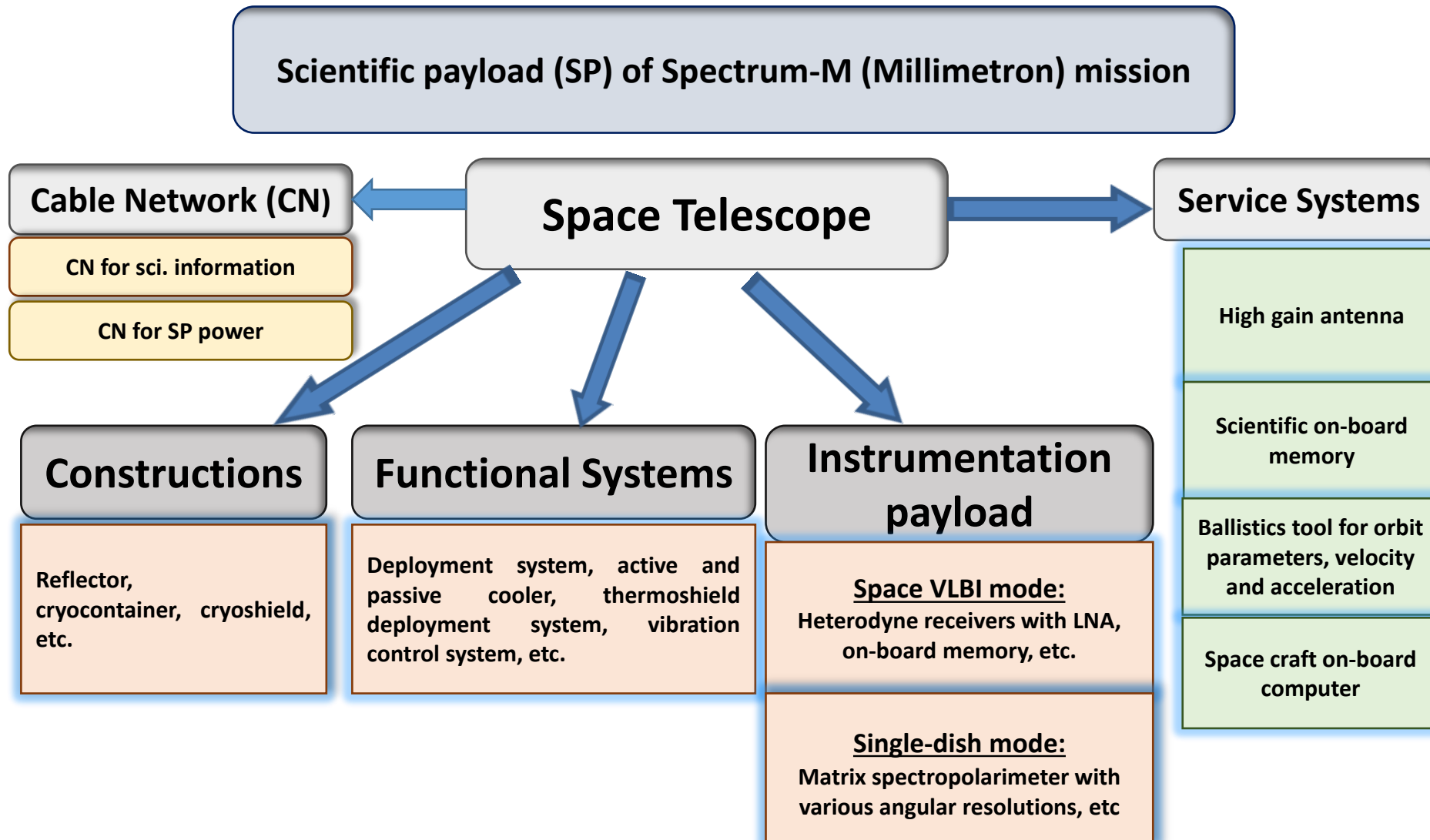
# ASC and Millimetron Mission

**Astro Space Centre of P. N. Lebedev Physical Institute of RAS is responsible for:**

- Define and produce requirements specifications
- Implementation of the **phase control**.
- Integration of scientific instrumentation



# Work Breakdown Structure of Millimetron Mission







# ASC Contractors

ASC signed contracts with the following organizations and institutions:

<b>Russian Space Systems Corp.</b>	Development of high informational system of transfer of on-board data
<b>Information Satellite Systems Corp. (ISS Reshetnev)</b>	Development of deployable antenna.
<b>Research Centre "Ares"</b>	Development and manufacturing high-precision panels for the antenna.
<b>Special Design Bureau of Inst. Of Radioelectronics</b>	On-board VLBI heterodyne receivers
<b>Special Design Bureau "Contact-Technology"</b>	Equipment for a tracking station, on-board memory
<b>Company "Vremia- Ch"</b>	Development and manufacturing of on-board masers
<b>Lavochkin Association</b>	Manufacturing of space-bus "Navigator-M"



# Place of Millimetron in the Russian Space Federal Program

- Roscosmos (Russian: Роскосмос), is a state corporation responsible for the wide range and types of space flights and cosmonautics programs for the Russian Federation.
- The **Federal Space Program (FSP)** of Russia developed by Roscosmos is approved by Russian Government and is a **state law of Russian Federation**.
- “Millimetron” was included in FSP 2016-2025 and expected to be continued in FSP 2026-2035.



# Place of Millimetron in the Russian Space Federal Program

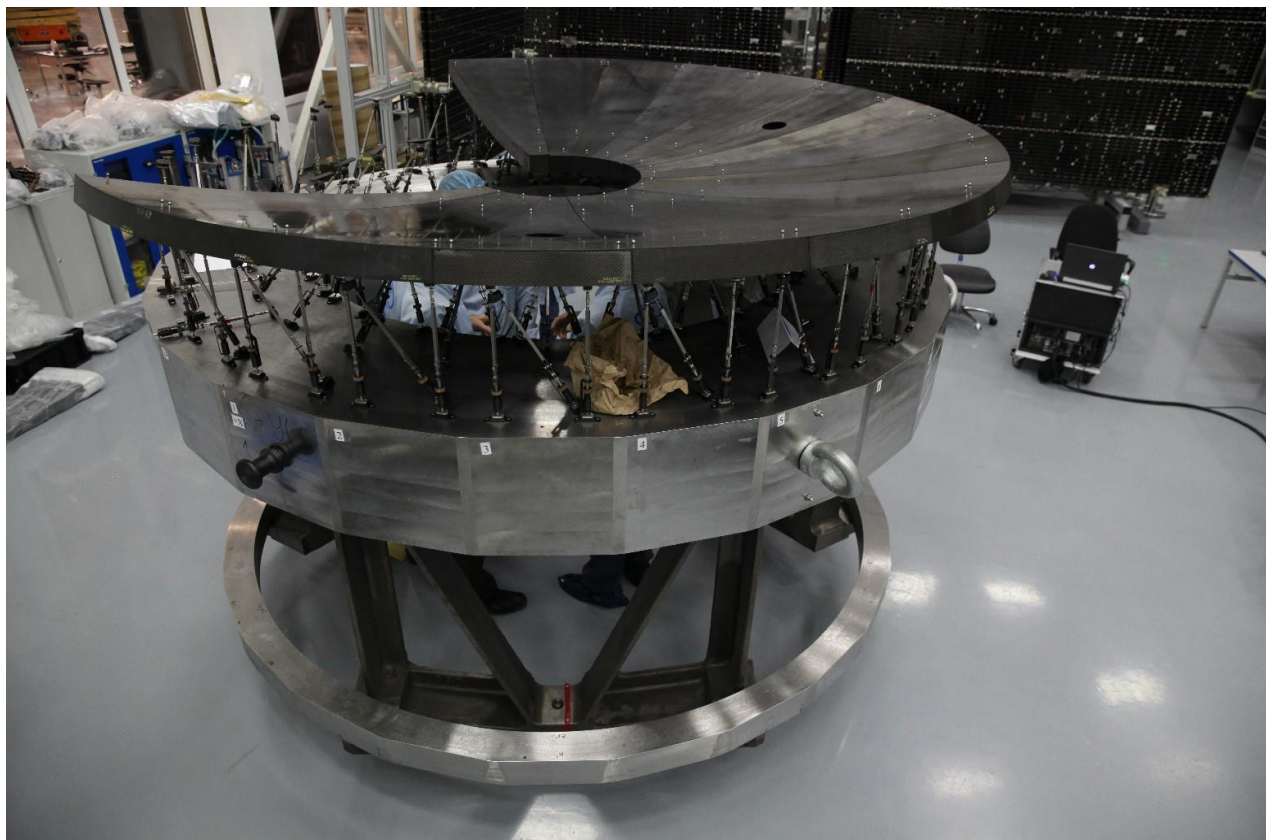
According to FSP the state contract between Roscosmos and ASC was signed in 2016, and Roscosmos will pay all expenses for:

- **Antenna**
- **Cryo-container**
- **Space bus (Navigator-M)**
- **VLBI instruments**
- **Rocket/launch (Angara-5)**
- **Ground support and mission control**
- **Data center**





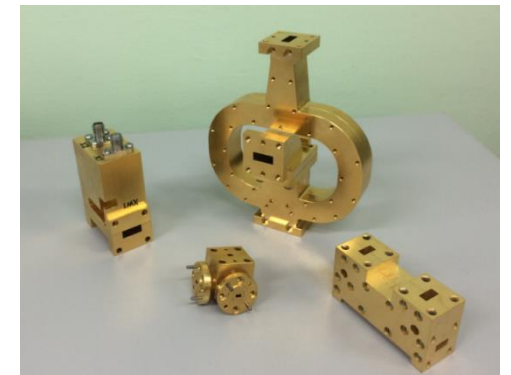
# Antenna Mock-Up (ISS-Reshetnev, Russia, 2018)





# Preliminary Science Payload of Millimetron

- 1) **Space-VLBI receivers (S-VLBI): 0.3 - 7 mm**
- 2) **Mmtron Heterodyne Instrument for the Far-Infrared (MHIFI): 60 - 600  $\mu\text{m}$**
- 3) **Short-wave Array Camera Spectrometer (SACS):**
  - **Camera:** 4 bands: **70, 125, 230, 375  $\mu\text{m}$**
  - **Spectrometer:** long slit grating spectrometers: **50 - 450  $\mu\text{m}$**
- 4) **Long wave-Array Camera Spectrometer (LACS):**
  - **Camera:** 4 bands: **0.4, 0.7, 1.2, 2.3 mm**
  - **Spectrometer:** the FTS: **0.3 - 3 mm**







# Modes of the Millimetron mission

- **VLBI mode** – investigation of late Universe (10...20% of total observational time). Orbit, start with L2 followed by near-Earth highly elliptical orbit (TBC)
- **Single –dish mode** -- investigation of early Universe (80—90% of total observational time) and Origins of Life environment

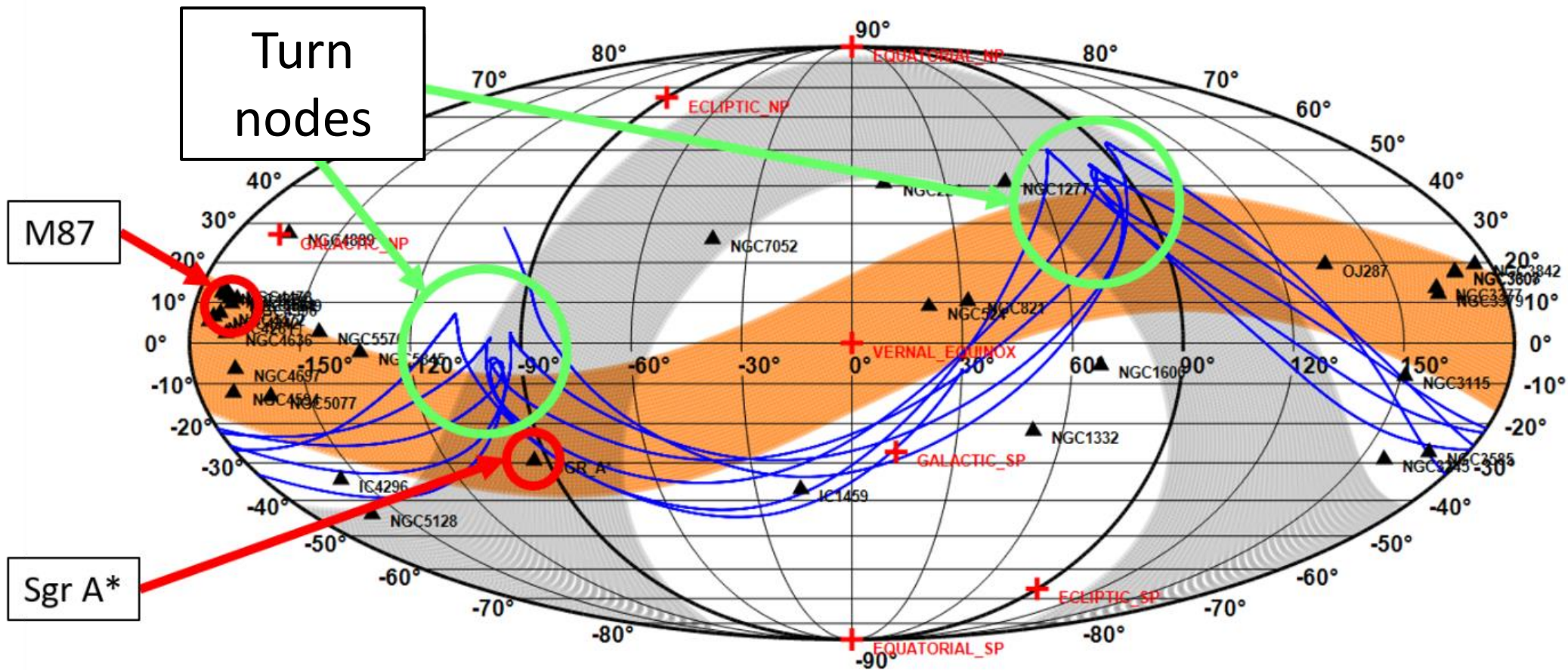


# Millimetron VLBI Science

EQUATORIAL MOLLWEIDE PROJECTION  
EPOCH: J2000  
FLUX LIMIT: 0

▲ BH\_CANDS\_0.88MM  
+ REFERENCE POINTS

■ ECLIPTIC ZONE FROM: -15° TO: 15°  
■ GALACTIC ZONE FROM: -20° TO: 20°  
■ MILLIMETRON START: 2023-06-16.5 STOP: 2028-09-19.5

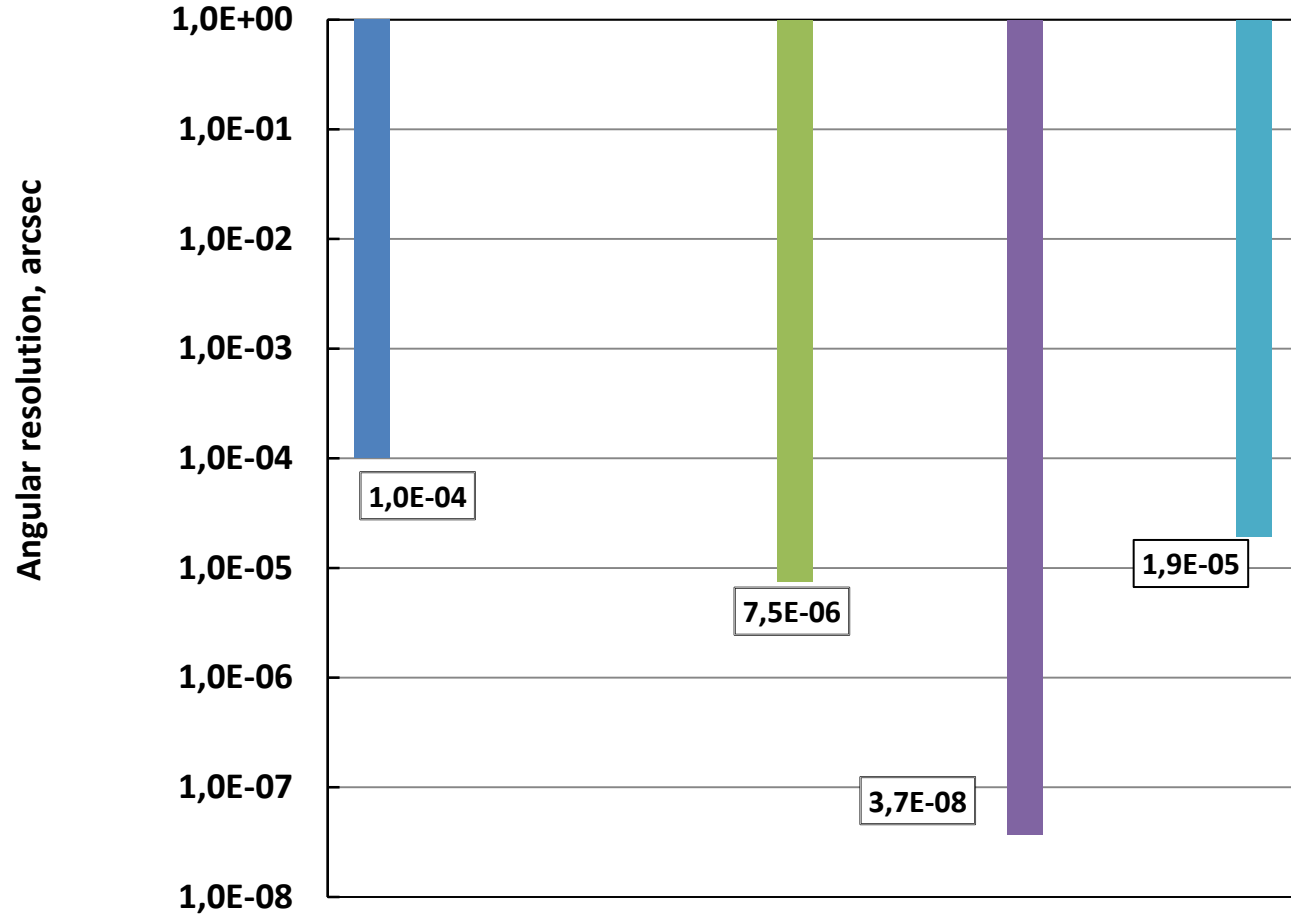


The geocentric equatorial Mollweide projection and the track of Millimetron observatory for 5 years. The blue curve is the Millimetron track. The orange bar is an ecliptic region of  $\pm 15^\circ$ . The gray bar is the  $\pm 20^\circ$  region at the Galactic equator. Black triangles correspond to the sources. Turn nodes - the moment of the passage of Millimetron of the upper (north) pole of the halo orbit when the speed along the Z axis changes its sign.

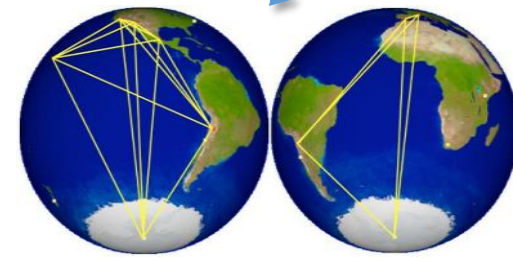
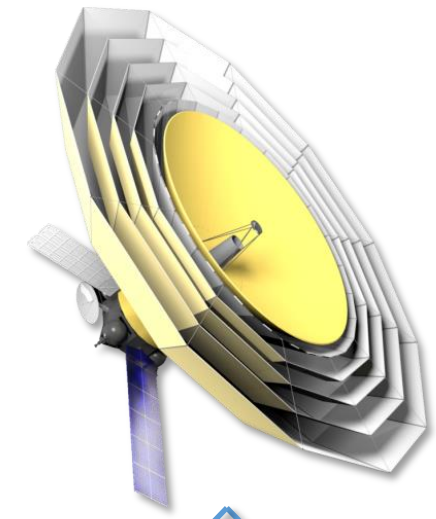




# Angular Resolution



- VSOP
- Radioastron
- Millimetron
- EHT



**Global mm-VLBI**



**ALMA**

The 10-m telescope located at the L2 Lagrange point and working in Space-VLBI mode can increase angular resolution  $\approx 100$  times ( $\approx 10^{-8}$  arcsec).



# Importance of International Cooperation

- Ambitious and exciting scientific objectives Millimetron mission needs the best on-board scientific payload in the world.
- Complexity of Millimetron mission. Astro Space Centre won't be able to provide all of the necessary scientific payload.
- Timely development and testing of onboard scientific equipment will ensure the reliability of the space mission and avoid a shift in the launch date of the mission.

**The uniqueness of scientific tasks  
dictates the uniqueness of equipment!**



# International Cooperation

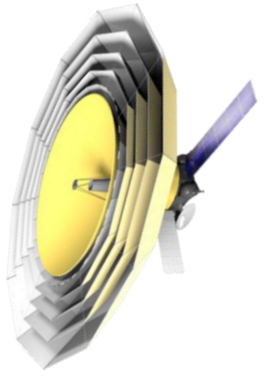
1. Millimetron is included into Russia-China Program on Cooperation in Space 2018-2022
2. MoU with Shanghai Observatory (SHAO, China)
3. Inter-agency agreement with Italian Space Agency (ASI) on LACS

## **On instrumentation development:**

1. MoU with Onsala observatory (Sweden, Chalmers University)
2. MoU with Observatoire de Paris (LERMA, France)
3. MoU with Purple Mountain Observatory (PMO, KLRA, China)
4. MoU with KASI (South Korea). Inter-agency agreement in preparation



# Summary

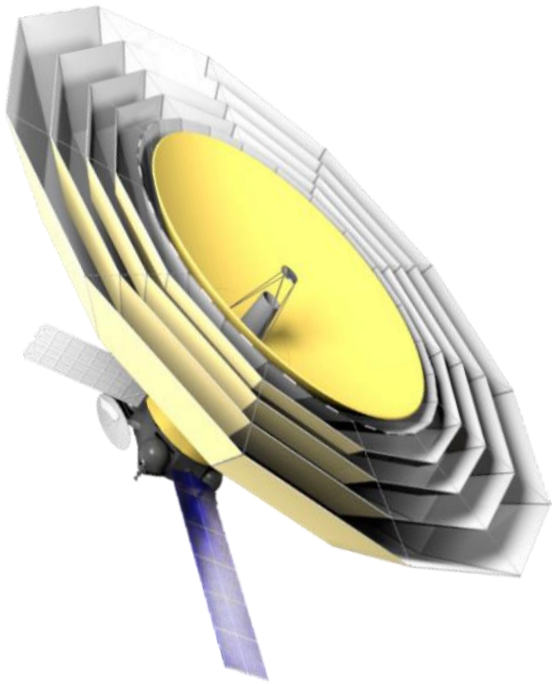


- The project is **fully supported** by Russian Space Agency and included in the Russian Federal Space Program.
- **Millimetron** is the next step of space based astronomy. As a single dish and space-ground VLBI observatory in mm, sub-mm and FIR it will provide **unprecedented sensitivity** and **highest** angular resolution.
- The capabilities of **Millimetron** mission will bring the astrophysical research to a new high level and enable revolutionary discoveries in the understanding of the evolution of the Universe and development from stars to life





# Thank you!



Millimetron Workshop, Paris, September 9<sup>th</sup>--11<sup>th</sup>.



ROSCOSMOS



ASC LPI