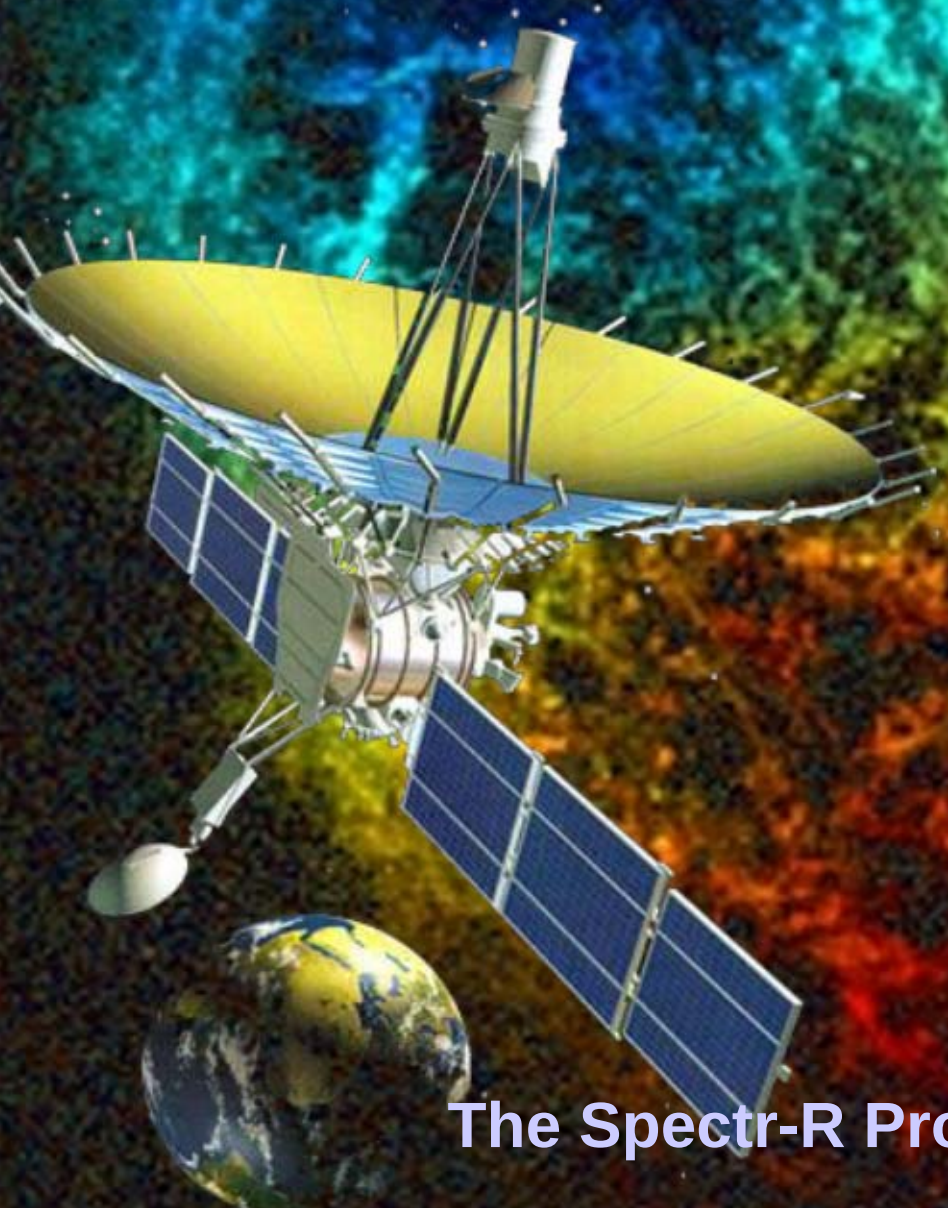
P.N. Lebedev Physical Institute
Astro Space Center
Russian Academy of Sciences

S.A. Lavochkin Association, Roscosmos

RADIOASTRON

The Ground – Space Interferometer:
“radio telescope much larger than the Earth”



The Spectr-R Project

http://www.asc.rssi.ru/radioastron/

High-Resolution HI 21 cm Mosaic of M 33 galaxy

GENERAL OUTLINE

The RadioAstron Space Observatory (the Spectr-R project) equipped with 10-m mirror antenna, is dedicated to investigate a structure of various objects in the Universe at centimeter and decimeter wavelengths with an angular resolution of up to a few millionth of arcsec (i.e., millions time better than human eye's resolution).

Such resolution is achievable for the radio interferometer consisting of a space telescope orbiting with an apogee of up to 350,000 km, and largest ground based radio telescopes.

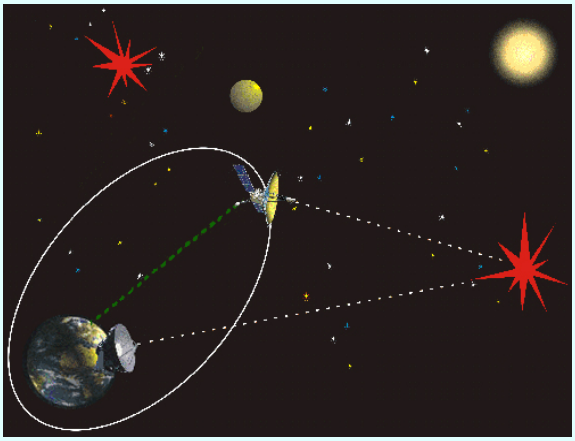
The Spectr-R project has been included in the Federal Space Program of Russia for 2006-2015.

A super high angular resolution – the key parameter of this project

Due to the very long baseline close to the Earth-to-Moon distance, the ground-space interferometer RadioAstron is able to determine radio sources dimensions, their structures, proper motions and distances, as well as spectral and polarization imaging, - up to tens time better than achievable for the ground based radio interferometers.

The orbit of the RadioAstron gravitationally perturbed by the Moon has the following parameters:

Perigee radius:	≥10,000 km
Initial inclination:	51.6^0
Average apogee radius:	350,000 km
Average period of revolution:	9.5 d



The ground-space radio interferometer (artist's view)

Band	P	L	C	K
Frequencies (MHz) of observations	327	1665	4830	18392-25112
Bandwidth (MHz) for each polarization	4	32	32	32
Fringe size (μas) [base line 350 000 km]	540	106	37	7,1 -10
Min. cor. flux (mJy) [RMS with EVLA, 300 s integration time]	10	1,3	1,4	3,2

Basic parameters of the Space Radio Telescope

SCIENTIFIC PROGRAM

The main scientific goal of the mission is to investigate a variety of astronomical objects with an unprecedented angular resolution up to several millionth of arcsec.

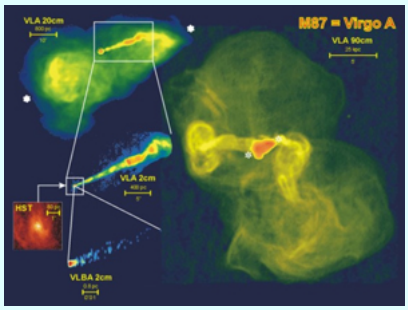
The resolution achievable by RadioAstron would permit an investigation of the following targets of great interest of modern astrophysics:

- ❖ A study of the central engine of Active Galactic Nuclei (AGN) close to the events' horizon of the supermassive black hole, via their structure and emitting nuclear regions dynamics, and, also, their spectra, polarization and variability.
- ❖ Parameters of the cosmological model, dark matter and dark energy in the Universe determined by means of the redshift dependence of the AGN parameters, and, also, by effects of gravitational lensing.
- ❖ Structure and dynamics of the star formation regions by the maser and megamaser spectral line emission.
- ❖ A structure of the star mass black holes, neutron and possible quark stars in our Galaxy (particularly, by the "interstellar interferometer" method), and determination of their proper motions and parallaxes.
- ❖ Structure and distribution of the interplanetary and interstellar matter by the investigation of fluctuations of the visibility function scintillation of pulsars.
- ❖ Construction of a high precision celestial coordinate frame.
- ❖ Development of a high precision model of the Earth gravitation field, and General Relativity tests by means of the precision redshift measurements.

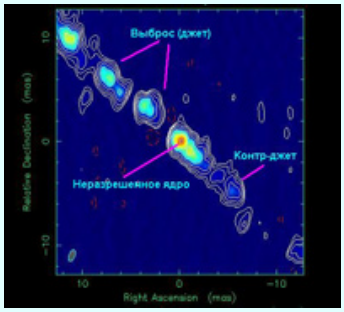
OBSERVATIONS FEATURES

- A ballistic forecast of the orbit evolution allows choice of an optimal time for observations of any specific area on the sky. Such forecast could be used to prepare a long time-scale schedule of scientific observations.
- Every source chosen for observations is investigated first with medium angular resolution (e.g., when the satellite is near the perigee, or when on the source direction is close to the plane of the satellite's orbit). Only after this preliminary investigation, and if there are still unresolved details in the image, could high resolution observations be performed.
- The user can choose observations either in one band (and get both, left and right, circular polarizations), or any two of the available bands - 1.35, 6.2, 18 and 92 cm (but get only one of two circular polarization).
- In the case of the multi frequency synthesis (MFS) in the 1.35 cm band, the frequency of the receiver can be cyclically switched between standard values (18.39, 19.35, 20.31, 21.27, 22.23, 23.19, 24.15 and 25.11 GHz). For spectral observations of the red-shifted sources (megamasers) at frequencies 22.136, 22.168, 22.200, 22.232 GHz, the frequency of the receiver can be tuned in the range of up to 1500 km/s.

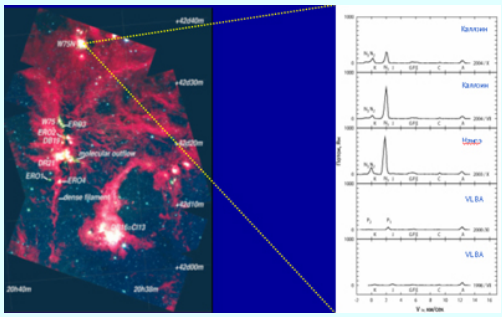
RADIOASTRON's TARGETS



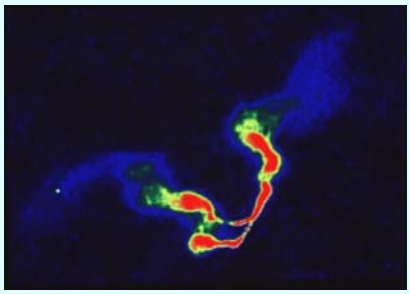
A set of different scale radio images of giant E-galaxy M 87



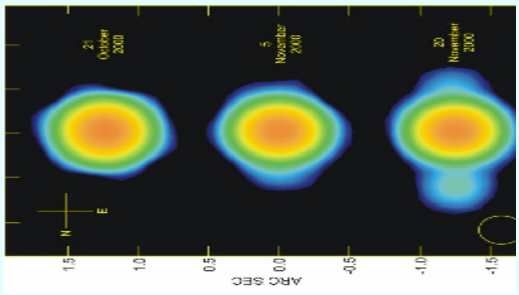
The nucleus and jets from radio galaxy Cen A (VSOP, 6 cm)



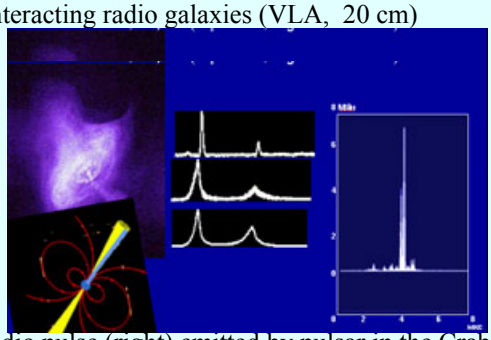
A burst of the OH maser emission in the star-forming region W75N



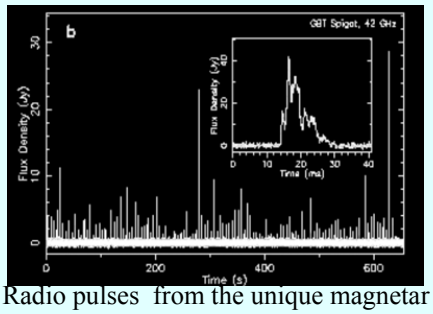
3C 75: radio image of the interacting radio galaxies (VLA, 20 cm)



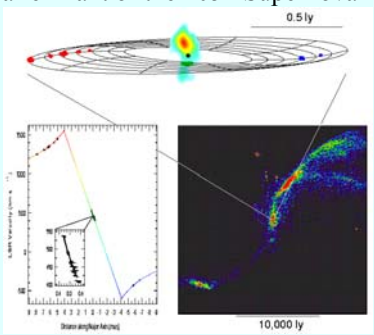
Rapid development of the microquasar Cyg X-1 image (NRAO, VLA, 6 cm)



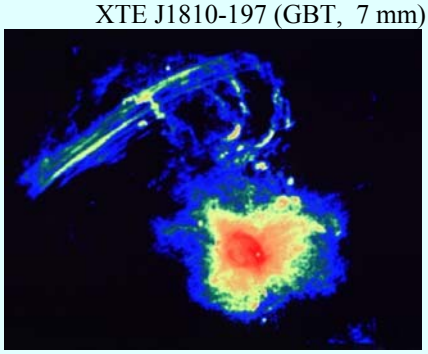
Giant radio pulse (right) emitted by pulsar in the Crab Nebula, a remnant of the 1054 Supernova



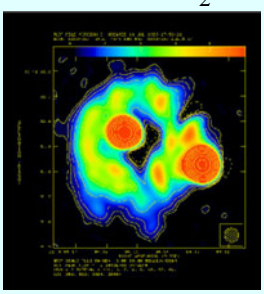
Radio pulses from the unique magnetar XTE J1810-197 (GBT, 7 mm)



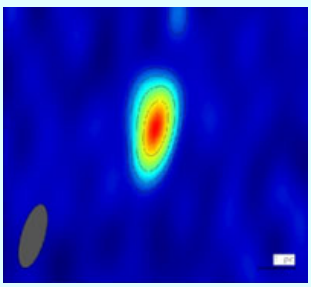
The rotation curve of galaxy M 106, obtained from 1.35 cm H_2O maser line observations



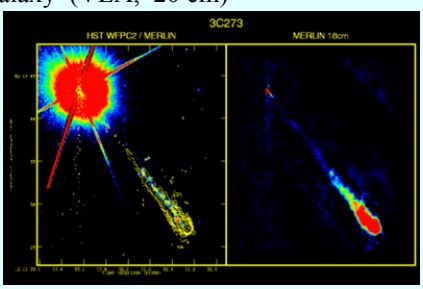
A fine filamentary structure of the central part of our Galaxy (VLA, 20 cm)



Radio image of the gravitational lens B0218+357 (VLA+MERLIN, 6 cm)

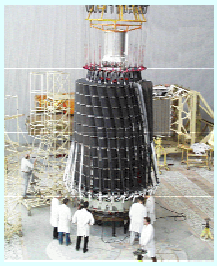


Gamma-ray burst GRB 030329: radio afterglow (VLBA, 8.4 GHz)



Images in optics and radio of the first detected quasar 3C 273

THE SPACE RADIO TELESCOPE



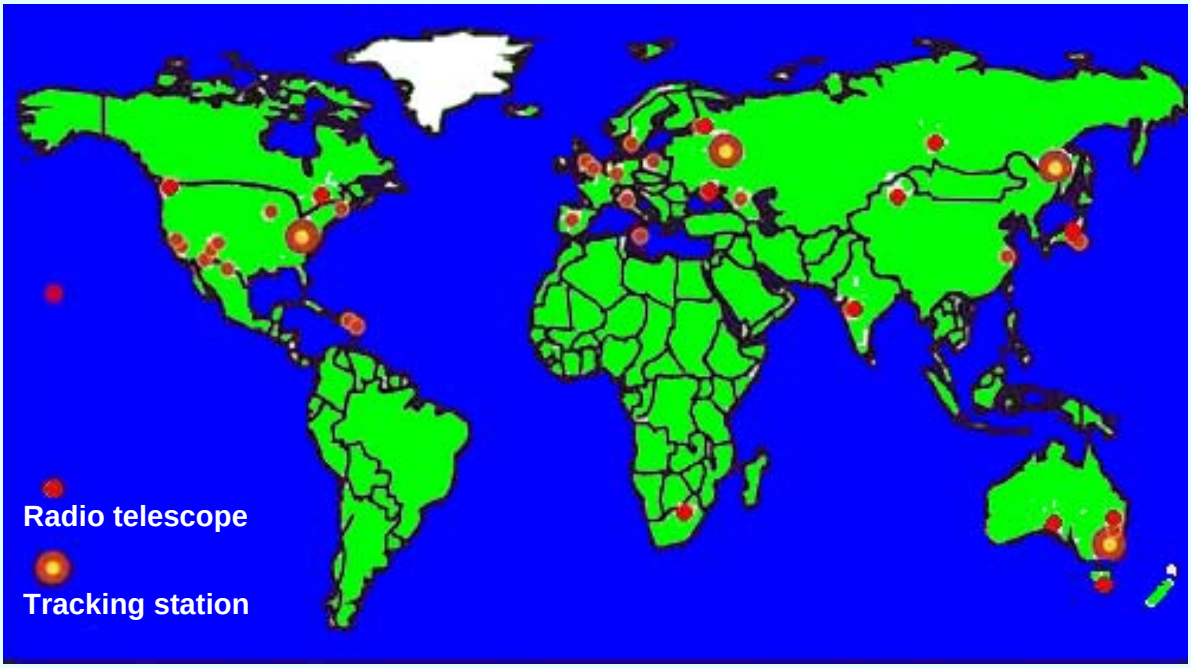
At the folded state

At the deployed state

With space service module "Navigator"

Astronomical test observations in Pushchino

GROUND RADIO TELESCOPES AND TRACKING STATIONS



THE LAUNCH AND GROUND SUPPORT

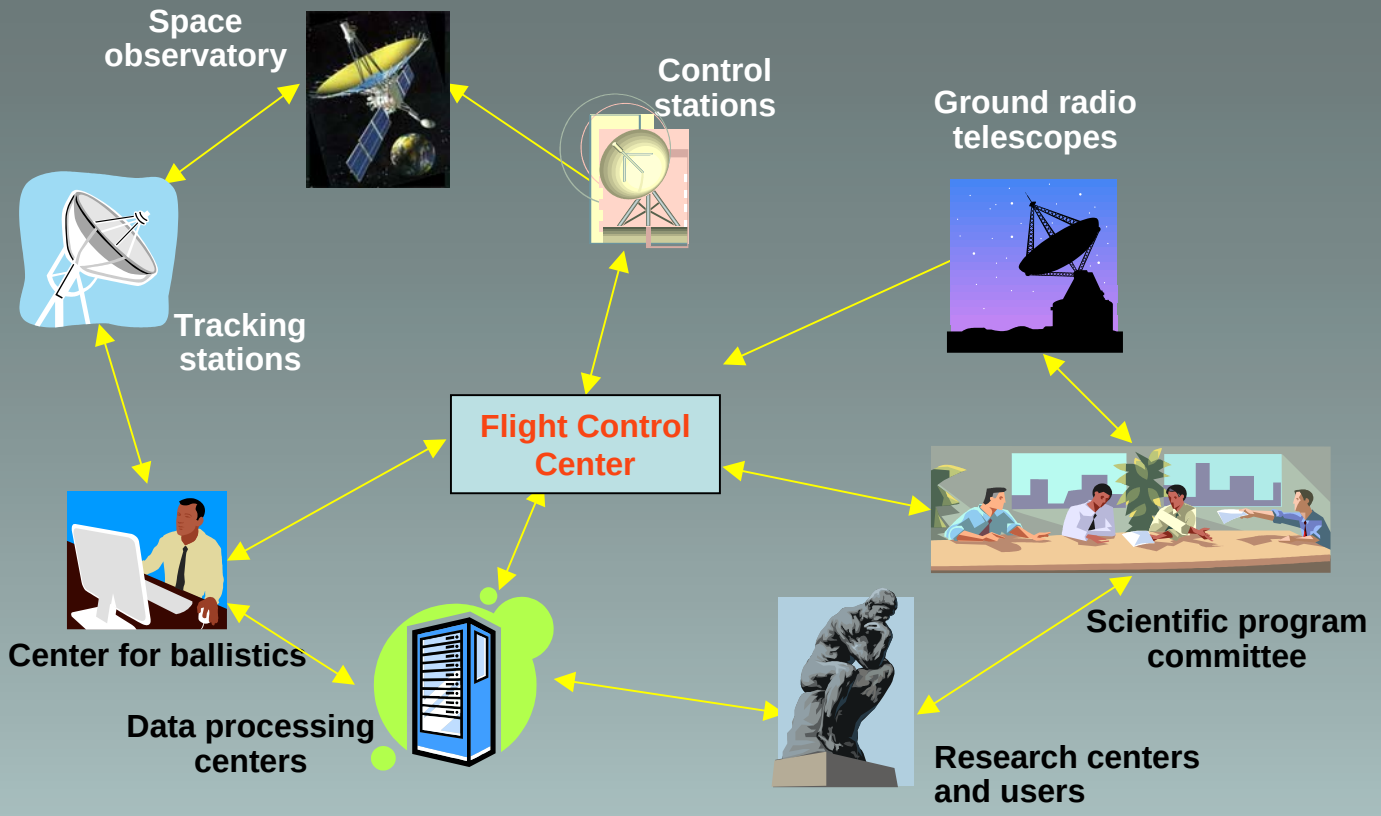
The launch has been scheduled for November 2009, and will be carried out by the "Zenith" launcher and "Fregat" additional booster.

The observatory's lifetime is planned to be about 10 years.

The synchronization and scientific data reception will be carried out by tracking stations located in Russia, Europe, the USA and Australia.

Control stations: at the Bear Lakes near Moscow, and near Ussuriysk City on the Far East of Russia.

The observatory control and data processing



The collaborators of the project:

- **International cooperation under supervision of the RadioAstron International Scientific Council (RISC), 16 countries.**
- **Astro Space Center of the P.N. Lebedev Physical Institute, RAS (including Pushchino and Kalyazin Radio Astronomy Observatories)**
  - Development of the scientific program
  - Scientific payload and ground system
  - Data processing center
  - International collaboration management
- **S.A. Lavochkin Association, Roscosmos**
  - Space Radio Telescope design
  - Satellite service module “Navigator”
  - Booster “Fregat”
  - Participation in the ground segment
- **M.V. Keldysh Institute for Applied Mathematics, RAS**
  - Ballistic support
  - Participation in the scientific program development
- **P. Sternberg Astronomical Institute, Moscow State University**
  - Participation in the scientific program development
- **Russian Institute of Space Device Engineering, Roscosmos**
  - Command space-ground radio link
  - On-board scientific and phase transfer up-down link (VIRK)
- **Special Bureau for Design and Technology “Luch”, and JSC “Plastic” (Syzran’)**
  - Carbon-fiber reinforced parts for SRT
- **Experimental Design Bureau “Mars”, Roscosmos**
  - On-board control and attitude equipment
- **Space Research Institute, RAS**
  - Plasma and magnetic space experiment PLASMA-F
- **Design Bureau of the Power Engineering Institute, Roscosmos**
  - Control station “Bear Lakes”
  - Ground radio telescope in Kalyazin (jointly with ASC)
- **Institute of Applied Astronomy, RAS**
  - Ground radio telescopes of the QUASAR network
- **Design Bureau of the Institute of Radio Engineering and Electronics, RAS**
  - On-board receivers
  - The SRT feed system
- **JS Company “Vremya Ch” (Nizhny Novgorod)**
  - On-board H-maser frequency standard

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