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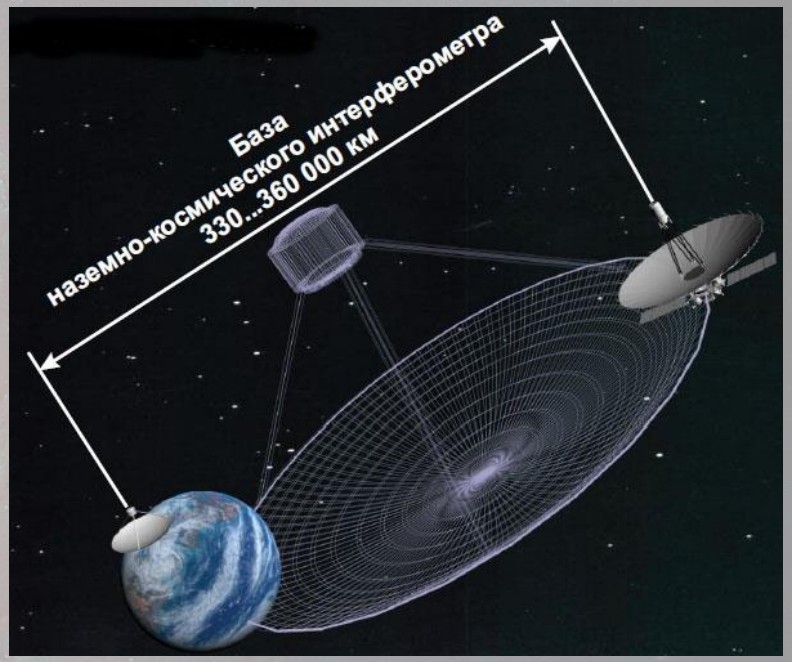
Проект Радиоастрон



Основная идея проекта - космический радиотелескоп, находящийся на орбите спутника Земли и наземные радиотелескопы образуют единый инструмент – интерферометр, эффективный диаметр которого равен расстоянию между космическим и наземными радиотелескопами.

Это позволяет достичь рекордно высокого разрешения при изучении различных космических объектов.

Запуск радиотелескопа на орбиту состоялся в июле 2011 года.

Основные задачи центра обработки проекта Радиоастрон: сбор, обработка, хранение всей информации, полученной в процессе наблюдений космическим и наземными радиотелескопами, организация информационного обмена между всеми участниками проекта.

В рамках проекта проводилась совместная работа космического и 60 наземных радиотелескопов из 20 стран мира.

В январе 2019 года, после 7 с половиной лет успешной работы, космический радиотелескоп прекратил наблюдения из-за технических проблем.

Однако, центр обработки продолжает работать и в настоящее время, так как самое ценное на сегодняшний день – это информация, накопленная в процессе наблюдений и обработки данных.

Удаленная работа - не помеха

В 2020-2021 году наша задача - создание банка данных проекта Радиоастрон, включающий в себя:

- Архив уникальных данных наблюдений объемом около 10 ПБ, который содержит информацию о 5000 экспериментах, проведенных в рамках проекта.
- Хранилище обработанных данных, служебной и вспомогательной информации.

Нашими задачами сегодня являются также:

- Структурирование служебной и вспомогательной информации обо всех экспериментах с целью проведения дальнейшего исследовательского, статистического, морфологического анализа работы проекта.
- Предоставление доступа к научным данным проекта Радиоастрон для широкого круга исследователей с целью дальнейшей обработки и переобработки имеющейся информации.

Миллиметрон

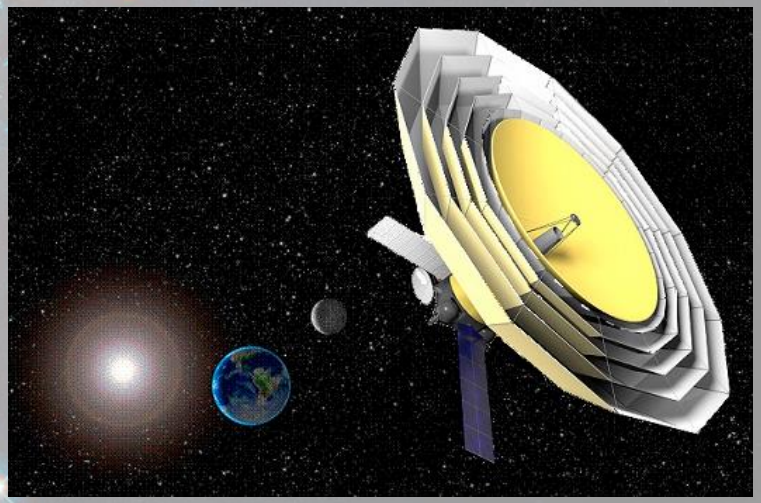
Космическая обсерватория Миллиметрон - проект Астрокосмического центра Физического института им. П.Н. Лебедева РАН.

Это будет 10-метровый космический телескоп, запущенный на расстояние 1,5 миллиона километров от Земли в противосолнечном направлении и предназначенный для исследования различных объектов во Вселенной в миллиметровом и инфракрасном диапазонах длин волн. Запуск 2025+

- Более подробную информацию о проекте

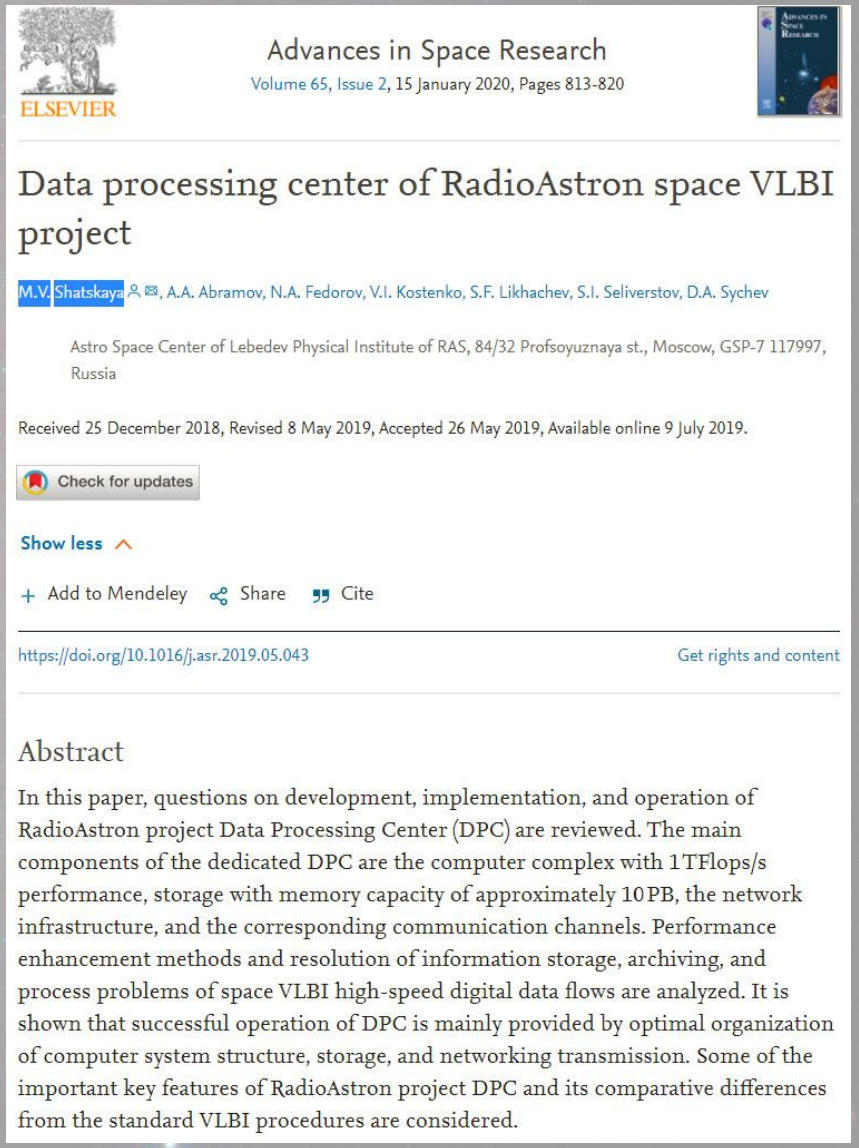
можно посмотреть на сайте http://millimetron.ru

Задачи центра обработки ММ аналогичны проекту Радиоастрон. Однако, ожидается поступление беспрецедентного для подобных проектов количества информации. В настоящее время нами прорабатываются исходные данные для центра обработки проекта Миллиметрон.



Публикации

В 2020 году вышла статья “Data processing center of Radioastron space VLBI project” в высокорейтинговом научном журнале “Advances in Space Research”



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Data processing center of RadioAstron space VLBI project

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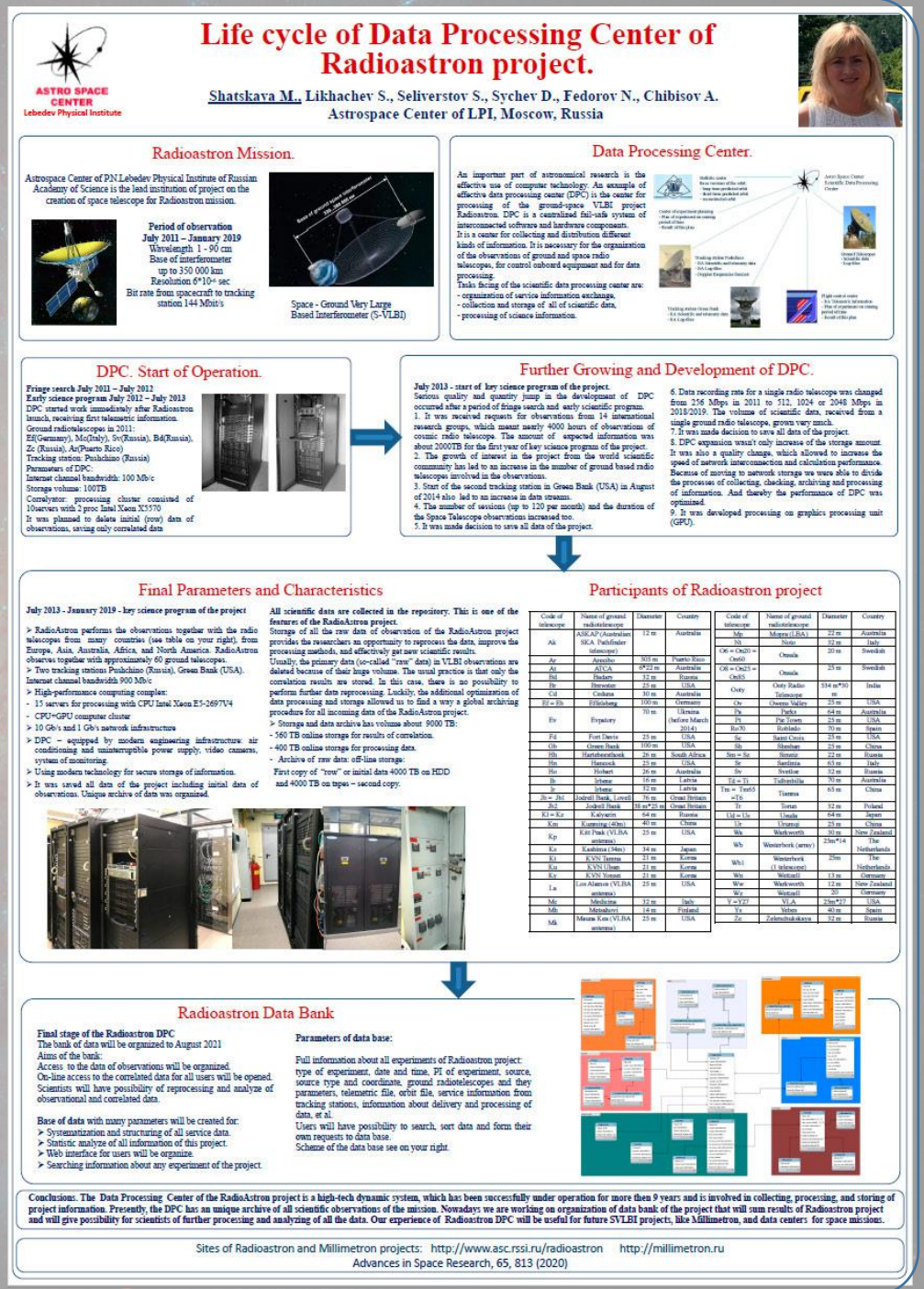
Abstract

In this paper, questions on development, implementation, and operation of RadioAstron project Data Processing Center (DPC) are reviewed. The main components of the dedicated DPC are the computer complex with 1 TFlops/s performance, storage with memory capacity of approximately 10 PB, the network infrastructure, and the corresponding communication channels. Performance enhancement methods and resolution of information storage, archiving, and process problems of space VLBI high-speed digital data flows are analyzed. It is shown that successful operation of DPC is mainly provided by optimal organization of computer system structure, storage, and networking transmission. Some of the important key features of RadioAstron project DPC and its comparative differences from the standard VLBI procedures are considered.

Конференции

На международной конференции COSPAR 2020 (committee on space research), проходившей в формате он-лайн, был представлен доклад на тему: «Жизненный цикл центра обработки научной информации проекта Радиоастрон».



Life cycle of Data Processing Center of Radioastron project.

ASTRO SPACE CENTER
Lebedev Physical Institute

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Astrospace Center of LPI, Moscow, Russia

Radioastron Mission.

Astrospace Center of P.N.Lebedev Physical Institute of Russian Academy of Science is the lead institution of project on the creation of space telescope for Radioastron mission.

Period of observation
July 2011 – January 2019
Wavelength 1 - 90 cm
Base of interferometer
up to 350 000 km
Resolution 6*10^-6 sec
Bit rate from spacecraft to tracking station 144 Mbit/s

Space - Ground Very Large Based Interferometer (S-VLBI)

Data Processing Center.

An important part of astronomical research is the effective use of computer technology. An example of effective data processing center (DPC) is the center for processing of the ground-space VLBI project Radioastron. DPC is a centralised fail-safe system of interconnected software and hardware components.
It is a center for collecting and distribution different kinds of information. It is necessary for the organization of the observations of ground and space radio telescopes, for control onboard equipment and for data processing.
Tasks facing of the scientific data processing center are:
- organization of service information exchange,
- collection and storage of all of scientific data,
- processing of science information.

DPC. Start of Operation.

Fringe search July 2011 – July 2012
Early science program July 2012 – July 2013
DPC started work immediately after Radioastron launch, receiving first telemetric information.
Ground radiotelescopes in 2011:
Ef(Germany), Mc(Italy), Sv(Russia), Bd(Russia), Zc (Russia), Ar(Puerto Rico)
Tracking station: Pushchino (Russia)
Parameters of DPC:
Internet channel bandwidth: 100 Mb/c
Storage volume: 100TB
Correlyator: processing cluster consisted of 10servers with 2 proc Intel Xeon X5570
It was planned to delete initial (raw) data of observations, saving only correlated data

Further Growing and Development of DPC.

July 2013 - start of key science program of the project.
Serious quality and quantity jump in the development of DPC occurred after a period of fringe search and early scientific program.
1. It was received requests for observations from 14 international research groups, which meant nearly 4000 hours of observations of cosmic radio telescope. The amount of expected information was about 2000TB for the first year of key science program of the project.
2. The growth of interest in the project from the world scientific community has led to an increase in the number of ground based radio telescopes involved in the observations.
3. Start of the second tracking station in Green Bank (USA) in August of 2014 also led to an increase in data streams.
4. The number of sessions (up to 120 per month) and the duration of the Space Telescope observations increased too.
5. It was made decision to save all data of the project.
6. Data recording rate for a single radio telescope was changed from 256 Mbps in 2011 to 512, 1024 or 2048 Mbps in 2018/2019. The volume of scientific data, received from a single ground radio telescope, grows very much.
7. It was made decision to save all data of the project.
8. DPC expansion wasn't only increase of the storage amount. It was also a quality change, which allowed to increase the speed of network interconnection and calculation performance. Because of moving to network storage we were able to divide the processes of collecting, checking, archiving and processing of information. And thereby the performance of DPC was optimized.
9. It was developed processing on graphics processing unit (GPU).

Final Parameters and Characteristics

July 2013 - January 2019 - key science program of the project

- RadioAstron performs the observations together with the radio telescopes from many countries (see table on your right), from Europe, Asia, Australia, Africa, and North America. RadioAstron observes together with approximately 60 ground telescopes.
- Two tracking stations Pushchino (Russia), Green Bank (USA).

Internet channel bandwidth 900 Mb/c

- High-performance computing complex:
- 15 servers for processing with CPU Intel Xeon E5-2697V4
- CPU+GPU computer cluster
- 10 Gb/s and 1 Gb/s network infrastructure
- DPC – equipped by modern engineering infrastructure: air conditioning and uninterruptible power supply, video cameras, system of monitoring.
- Using modern technology for secure storage of information.
- It was saved all data of the project including initial data of observations. Unique archive of data was organized.

All scientific data are collected in the repository. This is one of the features of the RadioAstron project.
Storage of all the raw data of observation of the RadioAstron project provides the researchers an opportunity to reprocess the data, improve the processing methods, and effectively get new scientific results.
Usually, the primary data (so-called "raw" data) in VLBI observations are deleted because of their huge volume. The usual practice is that only the correlation results are stored. In this case, there is no possibility to perform further data reprocessing. Luckily, the additional optimization of data processing and storage allowed us to find a way a global archiving procedure for all incoming data of the RadioAstron project.

- Storage and data archive has volume about 9000 TB:
- 560 TB online storage for results of correlation.
- 400 TB online storage for processing data.
- Archive of raw data: off-line storage:

First copy of "raw" or initial data 4000 TB on HDD and 4000 TB on tapes – second copy.

Participants of Radioastron project

Code of telescope	Name of ground radiotelescope	Diameter	Country
Ak	ASKAP (Australian SKA Pathfinder telescope)	12 m	Australia
Ar	Arecibo	305 m	Puerto Rico
At	ATCA	6*22 m	Australia
Bd	Badary	32 m	Russia
Br	Brewster	25 m	USA
Cd	Ceduna	30 m	Australia
Ef = Eb	Effelsberg	100 m	Germany
Fr	Evpatory	70 m	Ukraina (before March 2014)
Fd	Fort Davis	25 m	USA
Gb	Green Bank	100 m	USA
Hh	Hartebeesthoek	26 m	South Africa
Hn	Hancock	25 m	USA
Ho	Hobart	26 m	Australia
Ir	Irbene	16 m	Latvia
Ir	Irbene	32 m	Latvia
Jb = Jb1	Jodrell Bank, Lovell	76 m	Great Britain
Jb2	Jodrell Bank	38.m*25 m	Great Britain
Kl = Kz	Kalyazin	64 m	Russia
Km	Kunming (40m)	40 m	China
Kp	Kitt Peak (VLBA antenna)	25 m	USA
Ks	Kashima (34m)	34 m	Japan
Kt	KVN Tamna	21 m	Korea
Ku	KVN Ulsan	21 m	Korea
Kv	KVN Yonsei	21 m	Korea
La	Los Alamos (VLBA antenna)	25 m	USA
Mc	Medicina	32 m	Italy
Mh	Metsahovi	14 m	Finland
Mk	Mauna Kea (VLBA antenna)	25 m	USA

Code of telescope	Name of ground radiotelescope	Diameter	Country
Mp	Mopra (LBA)	22 m	Australia
Nt	Noto	32 m	Italy
On = On20 = On60	Onsala	20 m	Swedish
On = On25 = On85	Onsala	25 m	Swedish
Ooty	Ooty Radio Telescope	534 m*30 m	India
Oy	Owens Valley	25 m	USA
Pa	Parkes	64 m	Australia
Pt	Pie Town	25 m	USA
Ro70	Robledo	70 m	Spain
Sc	Saint Croix	25 m	USA
Sh	Shanhai	25 m	China
Sm = Sr	Simeiz	22 m	Russia
Sr	Sardinia	65 m	Italy
Sv	Svetloe	32 m	Russia
Td = Ti	Tidbinbilla	70 m	Australia
Tm = Tm65 =Tr	Tianma	65 m	China
Tr	Torun	32 m	Poland
Ud = Us	Usuda	64 m	Japan
Ur	Urumqi	25 m	China
Wa	Warkworth	30 m	New Zealand
Wb	Westerbork (array)	25m*14	The Netherlands
Wb1	Westerbork (1 telescope)	25m	The Netherlands
Wz	Wettzell	13 m	Germany
Ww	Warkworth	12 m	New Zealand
Wz	Wettzell	20	Germany
Y =Y27	VLA	25m*27	USA
Ys	Yebes	40 m	Spain
Zc	Zelenchukskaya	32 m	Russia

Radioastron Data Bank

Final stage of the Radioastron DPC
The bank of data will be organized to August 2021
Aims of the bank:
Access to the data of observations will be organized.
On-line access to the correlated data for all users will be opened.
Scientists will have possibility of reprocessing and analyze of observational and correlated data.

Base of data with many parameters will be created for:
- Systematization and structuring of all service data.
- Statistic analyze of all information of this project.
- Web interface for users will be organize.
- Searching information about any experiment of the project.

Parameters of data base:

Full information about all experiments of Radioastron project: type of experiment, date and time, PI of experiment, source, source type and coordinate, ground radiotelescopes and they parameters, telemetric file, orbit file, service information from tracking stations, information about delivery and processing of data, et al.
Users will have possibility to search, sort data and form their own requests to data base.
Scheme of the data base see on your right.

Conclusions. The Data Processing Center of the RadioAstron project is a high-tech dynamic system, which has been successfully under operation for more then 9 years and is involved in collecting, processing, and storing of project information. Presently, the DPC has an unique archive of all scientific observations of the mission. Nowadays we are working on organization of data bank of the project that will sum results of Radioastron project and will give possibility for scientists of further processing and analyzing of all the data. Our experience of Radioastron DPC will be useful for future SVLBI projects, like Millimetron, and data centers for space missions.

Sites of Radioastron and Millimetron projects: http://www.asc.rssi.ru/radioastron http://millimetron.ru

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Удалёнка – что осталось за кадром).

В этот непростой период, во время многочисленных вебинаров, семинаров, совещаний у меня нашлось немного времени для рукоделия и творчества. Этот уютный пледик я связала собственными руками.

Спасибо, что дочитали до конца)!