# Space VLBI Mission "RadioAstron"

# Announcement of Opportunity — 5

*for the period 1 July 2017 – 30 June 2018*

Proposals Due: 23 January 2017, 23:59 UT

# Contents

# 1 Summary

The space VLBI Mission "RadioAstron," led by the Astro Space Center (ASC) of the Lebedev Physical Institute, provides a range of specific and unique capabilities for detecting and imaging sources of cosmic radio emission at the highest angular resolution. The optimal utilization of these capabilities relies on the construction and execution of a balanced scientific program for the Mission. The scientific program of RadioAstron consists of three major parts: the Early Science Program (ESP), Key Science Program (KSP), and General Observing Time (GOT) projects. The Early Science Program, which finished in June 2013, explored the main scientific capabilities of RadioAstron observations and paved the way for the subsequent KSP and GOT programs.

RadioAstron KSP observations commenced in July 2013. The KSP is aimed specifically at focusing on the areas of strongest scientific impact of RadioAstron and ensuring a long-lasting scientific impact for the Mission. KSP observations within the AO-1 period were carried out between July 2013 and June 2014, inclusive, and had a shared-risk nature since a number of observing modes were not fully tested by the ASC.

In AO-5, as in the previous AOs, proposals are invited for the RadioAstron Key Science Program *and* General Observing Time experiments, to be submitted by **23 January 2017** to the Mission, and to ground radio telescopes required for the specific observations by their respective proposal deadlines. AO-5 observations will be performed between July 2017 and June 2018 inclusive. Any team that wants to continue their project is required to submit a new proposal for the AO-5 period. Proposers are strongly encouraged to consult the main operational documents including the "RadioAstron User Handbook[1]."

This document describes the main goals and the general requirements and criteria for the AO-5 RadioAstron projects, outlines the process of proposing, selection and operation of the projects and the relationships between individual teams and the RadioAstron Mission.

# 2 RadioAstron Mission Overview

RadioAstron is a space VLBI Mission aimed at achieving the highest angular resolution of radio observations at centimetre wavelengths through ground-space interferometric measurements on baselines of up to $\sim 360,000$ km. The Mission consists of a 10-metre space-borne radio telescope (SRT) operating at wavelengths of 92, 18, 6.2, and 1.2–1.6 cm and supported by a range of ground-based facilities (see details in § 2.2). Basic parameters of the SRT and RadioAstron observations are summarized in Table 1

RadioAstron provides observations of radio sources at ultra-high angular resolution, with ground–space baselines of up to 360,000 km, reaching a resolution of about 7 microarcseconds at a wavelength of 1.3 cm. These observations enable accurate measurements of structural properties and evolution on sub-milliarcsecond scales in galactic and extragalactic radio sources. At intermediate baselines, high quality imaging of radio sources with moderate resolution can be obtained for objects located near the orbital plane or observed near perigee passages of the satellite.

[1] http://www.asc.rssi.ru/radioastron/documents/rauh/en/rauh.pdf

Table 1: Basic Parameters of RadioAstron Space Radio Telescope (SRT): for more details see the RadioAstron User Handbook.

| | | | | | |
|---|---|---|---|---|---|
| **Satellite Overview** | | | | | |
| Launch mass | $m_{\rm sat}$ [kg] | 3660 | | | |
| Lifetime | $\tau_{\rm Mission}$ [yr] | 7.5 | | | |
| Main reflector diameter | $D_{\rm ant}$ [m] | 10 | | | |
| Pointing accuracy | $\sigma_{\rm p}$ [arcsec] | 10 | | | |
| Slew rate | $\Delta_{\rm slew}$ [deg/s] | 0.35 | | | |
| **Nominal Orbit** | | | | | |
| Perigee height | $H_{\rm p}$ [km] | 400 – 65,000 | | | |
| Apogee height | $H_{\rm a}$ [km] | 265,000 – 360,000 | | | |
| Orbital period | $P_{\rm orb}$ [day] | 8.2 – 9.5 | | | |
| Orbital eccentricity | $e$ | 0.59 – 0.96 | | | |
| Orbital inclination | $i$ [deg] | 0 – 75 | | | |
| Argument of perigee (AOP) precession | $\dot{\omega}$ [deg/yr] | 40 | | | |
| **Observing System** | | | | | |
| Polarisation | | Dual Circular (LCP, RCP) | | | |
| Continuum bandwidth | $B_{\rm c}$ [MHz] | $2 \times 16$ | | | |
| Spectral channels per IF | $N_{\rm chan}$ | 16 000 000 | | | |
| Observing band | [GHz] | 0.3 | 1.6 | 5 | 22 (wide) |
| SEFD | [kJy] | 13.4 | 2.8 | 11.6 | 40 |
| Bandwidth | $B$ [MHz] | 16 | 2×16 | 2×16 | 2×16 |
| Angular resolution[1] | $\theta_{\rm min}$ [$\mu$as] | 530 | 100 | 35 | 7 |
| Baseline sensitivity[2] | $\sigma_{\rm n}$ [mJy] | 14 | 3 | 5 | 16 |
| Image noise[3] | $\sigma_{\rm m}$ [mJy/beam] | 0.3 | 0.06 | 0.1 | 0.3 |

[1] – Fringe spacing for $H_{\rm a} = 350,000$ km.
[2] – Noise on the baseline between RadioAstron and the Green Bank Telescope (GBT) for an integration time of 300 sec and a single polarisation 16 MHz channel.
[3] – Image noise is calculated for a continuum, dual polarisation observation, with a bandwidth of 32 MHz per polarisation and a total integration time of $\tau_{\rm obs} = 1$ hr. Participating ground telescopes: Effelsberg, Jodrell Bank, GBT, and the VLBA.

## 2.1 "Spektr-R" satellite

The space radio telescope is mounted on the "Spektr-R" satellite. The general technical characteristics of the satellite are described in the RadioAstron User Handbook. The scientific payload of the satellite consists of a 10-metre antenna, four feed and receiver/backend systems for operating at 1.2–1.6, 6.2, 18, and 92 centimetre wavelengths, a data formatter, a data transmission module and a hydrogen maser frequency standard. Data are provided in dual-circular polarisation, in continuum and spectral line modes, with a total bandwidth of up to 32 MHz per polarisation (at 92 cm, the maximum bandwidth is 16 MHz per polarisation).

## 2.2 Ground Facilities

There are a number of different ground facilities participating in operation, tracking, data transfer and observations with the radio antenna on board Spektr-R. These include the Flight Control Center (FCC) at the Lavochkin Association; the Deep Space Network Communication (DSNC) antennas in Ussurijsk and Bear Lakes employed for the uplink and telemetry communications with the satellite; the Satellite Tracking Station (STS) in Pushchino, Russia, and Green Bank, USA, used for telemetry and data acquisition from the Spektr-R satellite and radio antenna; the laser ranging stations (LRS) used for orbit determination measurements; and the ground radio telescopes (GRTs) taking part in Very Long Baseline Interferometry (VLBI) observations with the Spektr-R antenna (hereafter, RadioAstron observations). VLBI methods are being utilized to determine the space craft state vector for orbit reconstruction.

## 2.3 Mission Organisation

The RadioAstron Mission is headed by the Astro Space Center (ASC) of the P.N. Lebedev Physical Institute in Moscow, Russia. The Spektr-R satellite operations are supported by the Russian Space Agency (RSA) “Roscosmos” and conducted by the Lavochkin Association (LA) in Chimki, Russia. Orbit determination measurements and analysis are performed by the Ballistics Group at the Keldysh Institute of Applied Mathematics (KIAM) in Moscow. Data from the SRT are received at the Pushchino STS operated by the ASC and the Green Bank STS operated by the GBO. The data from the SRT are recorded in the RadioAstron Data Format (RDF) specially developed for the Mission operations. Data correlation from RadioAstron observations is conducted at the RadioAstron Correlator Facility designed and operated at the Data Processing Department of the ASC. The MPIfR-DiFX software correlator and the EVN software correlator at JIVE (SFXC) are also being used to correlate RadioAstron experiments, for details see § 2.5. Block time commitments to RadioAstron observations are being organized or considered at many GRT facilities, for details see § 2.4.

Scientific operations of the RadioAstron Mission are conducted by the ASC and the radio interferometric networks. The RadioAstron International Science Council (RISC), which is comprised of representatives from the ASC, major GRT facilities, and the radio astronomical community, provides overall policy definitions for the Mission, and discusses scientific issues and priorities.

## 2.4 Ground Radio Telescope observing requests

Separate proposal(s) for the required ground support need to be submitted by RadioAstron teams to appropriate ground facilities. Consult GRTs' announcements for proposing opportunities, proposal due dates, etc. The mission encourages proposers to apply for the ground telescope time as early as possible so that planning of RadioAstron experiments can be done the most efficiently.

At the same time, the RadioAstron Mission has reached a special agreement with a number of telescopes which can be requested directly within a RadioAstron AO-5 proposal. These telescopes have committed to co-observing with RadioAstron outside of their respective VLBI network time commitments. All of these telescopes perform various experiments during the year and will accommodate observing with RadioAstron following successful RadioAstron proposals within their local constraints. Technical details for these telescopes can be found on their web sites or in

the EVN status table `http://www.evlbi.org/user_guide/EVNstatus.txt`. The list of the telescopes, supplemented by specific notes, includes:
**Svetloe 32-m (Sv), Badary 32-m (Bd), Zelenchukskaya 32-m (Zc):** Available observing bands: L, C, K.
*Actual availability for AO5 observations is not yet clear, subject to financial constraints of the IAA which will be clarified in late 2017.*
**Irbene 32-m (Ir)**: Available observing bands: L, C.
**Robledo 70-m (Ro):** Available observing bands: L, K. Primarily a satellite tracking facility but can be used for RadioAstron experiments within the Spanish host country time option *if a proposal has a Spanish Co-I.* L-band (and, possibly, K-band) is only available in LHC polarization.
**Yebes 40-m (Ys)**: Available observing bands: C, K.
**Sardinia 64-m (Sr):** Available observing bands: P, L, K.
**Noto 32-m (Nt):** Available observing bands: P, L, C, K.
**Medicina 32-m (Mc):** Available observing bands: L, C, K.
**Torun 32-m (Tr)**: Available observing bands: L, C, K.
**Urumqi 26-m (Ur), Shanghai 25-m (Sh)**: Available observing bands: L, C, K.
**Tian Mai 65-m (T6)**: Available observing bands: L, C.
**HartRAO 26-m (Hh)**: Available observing bands: L, C, K.

Proposers requiring a large number of ground telescopes simultaneously, e.g., for imaging observations, are advised to apply for time through the EVN, global-VLBI, VLBA (LBO), KVN, or LBA proposal routes.

## 2.5 RadioAstron correlators

**ASC correlator:**
The default correlator for RadioAstron data is the ASC correlator. However, teams can propose to correlate RadioAstron data on another correlator.

**MPIfR-DiFX correlator:**
In order to request the MPIfR-DiFX correlator in the RadioAstron and respective ground proposals, the team should contact the correlator representative in advance and get an approval from the correlator (see Appendix B).

**EVN software correlator at JIVE:**
The EVN software correlator at JIVE can be requested directly from JIVE within a proposal for EVN / global-VLBI observations in support of the RadioAstron project.

# 3 Key Science Program

It is expected that observations with RadioAstron will provide substantial advances in a number of areas of astrophysical research, for both galactic and extragalactic objects.

In order to optimise the scientific output of RadioAstron observations, the ASC and RISC have identified several specific “key science” areas where RadioAstron observations are expected to provide unique and ground-breaking results.

## 3.1 Key science areas

Primary areas of RadioAstron observations will include studies of active galactic nuclei, the vicinity of supermassive black holes, relativistic flows, galactic and extragalactic masers, the physics and dynamics of pulsars, relative astrometry, the interstellar medium, gravitation and general relativity.

These key science areas may be particularly attractive for engagement within the RadioAstron KSP experiments, although KSP experiments can be proposed for any relevant field of radio astronomical measurement in which RadioAstron observations may break new scientific ground and bring significant progress in our understanding of cosmic phenomena.

## 3.2 Scope of the KSP

The Key Science Program of RadioAstron serves four basic goals:

1. The KSP should deliver important science for the Mission through coherent investigations that are unlikely to be carried out as comprehensively through the General Observer program.
2. The KSP should provide a legacy for the Mission by addressing fundamental astrophysical problems and exploiting the areas of astrophysics where RadioAstron offers unique scientific capabilities.
3. The KSP should have high visibility within the astrophysical and space science community.
4. The KSP should establish tangible benchmarks and reference points for future space VLBI developments.

## 3.3 General scientific criteria for KSP

Projects identified as key scientific objectives of RadioAstron will be selected according the following criteria:

1. KSP projects address fundamental and currently unanswered questions in astrophysics or fundamental physics.
2. KSP projects represent science which is either unique to RadioAstron or synergetic with other studies, but in which RadioAstron plays a key role.
3. KSP projects address scientific questions which excite the broader astrophysical and space science communities.

## 3.4 KSP Experiments and KSP Teams

KSP observations within the AO-5 period are expected to utilize about 1/2 of the total available observing time, with the actual fraction depending on proposal pressure.

KSP teams are expected to include people with knowledge of the Mission prepared to provide tangible contributions to Mission operations.

KSP teams should demonstrate their capability to commit resources necessary for the timely and successful completion of their programs and publication of the results of their KSP observations. The KSP teams should also be committed to operate in close contact with the ASC.

KSP teams should be prepared to be involved in the design of observations and to contribute to the development of data reduction and analysis applications.

KSP teams should assume shared responsibility for the timely processing, publishing, and publicising of scientific results obtained from key science observations.

In some cases, and based on evaluation of individual KSP proposals, the ASC or RadioAstron Program Evaluation Committee (RPEC) may suggest the addition of an ASC representative to the proposal team to provide extensive support in order to ensure the timely and successful delivery of science from the KSP observations.

# 4 General Observing Time (GOT)

General Observing Time observations within the AO-5 period are expected to utilize about 1/2 of the available observing time, depending on proposal pressure. While the GOT programs are required to achieve important scientific results, they might be more focused on addressing specific science questions in the study of specific target(s). The GOT teams do not have to include people with extensive knowledge of the Mission (although they are strongly advised to include someone with good VLBI experience) and need not provide contributions to Mission operations.

The amount of observing time requested in a single GOT proposal is limited to 100 hours. Time requests in excess of this amount will be considered only for Key Science Programs. The Mission will take the responsibility of scheduling the accepted GOT projects, for both the space and the ground segments of the schedule. If considered necessary, the Mission may appoint a contact/support scientist who will contribute to dealing with technical, calibration, and data processing aspects of the observations.

# 5 AO-5 Observing Opportunities

AO-5 observations may be requested for any subject that can be addressed with RadioAstron, not limited to the areas described in section 3.1. All operational and observational modes of RadioAstron will be made available for AO-5 observations. If necessary, special technical and logistical arrangements for observations can be proposed, based on consultations with the ASC and participating ground facilities. Generic RadioAstron observing modes are summarized below and described in detail in the RadioAstron User Handbook.

## 5.1 ESP, AO-1,2,3,4 RadioAstron observations

In order to prevent possible proposal duplications, we advise RadioAstron proposers to check the list of RadioAstron targets from the ESP, AO-1,2,3,4 programs[2]. You can also consult the archive of RadioAstron observing schedules[3], AO-1 projects[4], AO-2 projects[5], AO-3 projects[6], and AO-4 projects[7].

## 5.2 Generic Observational Constraints

A detailed description of the RadioAstron technical capabilities and observational constraints can be found in the RadioAstron User Handbook.

Due to a requirement to cool down the high gain antenna drive, science teams should plan for about 50 % overhead of observing time due to cooling if their experiment lasts for longer than two hours.

## 5.3 Orbit correction expected in 2017

An orbit correction is planned for July 2017. The long term orbit prediction provided for the AO5 period is made assuming that the correction is implemented as planned. An improved long-term orbit prediction will be available only after the correction is performed. The RadioAstron mission will do everything possible to minimize the loss of observing time in July and August due to the correction and will work with the science teams to update the planning of experiments after a more accurate orbit prediction after the correction becomes available — in August 2017.

## 5.4 Main Observing Modes of RadioAstron

RadioAstron can provide several main types of observations, depending on the instrumental setup and the specific configuration of the ground facilities. KSP and GOT programs may request any of these observational modes or propose for a specific design and configuration of the observations. The main standard observing modes are summarised below and described in more detail in the RadioAstron User Handbook.

### 5.4.1 Visibility Tracking

Visibility tracking with RadioAstron provides basic measurements of interferometric visibilities within a range of baseline lengths and (typically) a narrow sector of position angle in the visibility plane. This mode is envisaged primarily for survey observations and measurements of size and brightness temperature of compact radio sources. Observations in this mode would be normally

[2] http://www.asc.rssi.ru/radioastron/documents/ra_obs_summary.pdf
[3] http://www.asc.rssi.ru/radioastron/schedule/sched.html
[4] http://www.asc.rssi.ru/radioastron/news/newsl/en/newsl_20_en.pdf
[5] http://www.asc.rssi.ru/radioastron/news/newsl/en/newsl_24_en.pdf
[6] http://www.asc.rssi.ru/radioastron/news/newsl/en/newsl_28_en.pdf
[7] http://www.asc.rssi.ru/radioastron/news/newsl/en/newsl_30_en.pdf

made covering different projected spacings and need to be supported by at least three (one large and two medium) ground antennas. The imaging capability of RadioAstron observations will generally be limited in this mode, even with a larger number of ground telescopes employed.

### 5.4.2 Orbital Plane Imaging

For targets lying close to the plane of the Spektr-R orbit, imaging quality is enhanced by the crossing of the ground–space and ground–ground baseline tracks. For such objects, orbital plane imaging can be employed effectively to provide robust imaging capabilities up to the highest achievable resolution. These observations need to be supported by a large number of ground telescopes, in order to provide better coverage and redundancy of the $(u, v)$-sampling. The strong evolution of the Spektr-R orbit will enable orbital plane imaging for a substantial fraction of the sky over the lifetime of the mission, but the optimum time periods for such experiments need to be determined in advance in order to successfully plan and prepare the observations.

### 5.4.3 Perigee Imaging

Perigee imaging will be possible for approximately 20% of the orbital period of Spektr-R and will cover space–ground baselines of up to $\sim 50,000$ km. Perigee imaging requires support from a large number of ground telescopes and will yield good quality images at intermediate resolution.

### 5.4.4 Pulsar Observations

Pulsar observations are performed in a standard mode, with the pulse calibration ("P-cal") and noise diode systems turned off, and in some circumstances the automatic gain control disabled. Pulsar mode correlation is supported by the ASC correlator, which can accommodate many baselines, high spectral resolution, narrow pulse gates, and dedispersion. Multiple pulse gates and single-pulse correlation are also available. The DiFX and SFXC correlators can also support pulsar gating/binning during correlation.

### 5.4.5 Polarisation Observations

RadioAstron can observe in a dual polarisation mode in the 92, 18, and 1.2–1.6 cm bands: for more details refer to the RadioAstron User Handbook. Successful polarisation imaging experiments with high quality polarisation calibration are made and published by science teams at L and K bands.

### 5.4.6 Spectral Line Observations

Observations are performed in a standard mode having the pulse calibration system turned off. Correlation by software correlators can be done with a very high spectral resolution, where justified. The spectral line mode is available on all the RadioAstron-capable correlators and was successfully tested and used already to correlate spectral line RadioAstron experiments at the ASC and SFXC correlators.

#### 5.4.7 Monitoring Observations

Monitoring observations with RadioAstron will be feasible in principle, however they are expected to be limited in practice by the seasonal variations of the Sun-related orientation constraints and the rapid and strong evolution of the Spektr-R orbit. Engaging in such observations will require careful design and planning, if the desired monitoring period is longer than about 4 months.

#### 5.4.8 Transient Phenomena Observations

Observations addressing transient phenomena can be proposed as triggered observations for specific types of target objects. All such proposals must be submitted for the general AO-5 proposal deadline of 23 January 2017.

Within given visibility constraints, best efforts will be made to schedule RadioAstron observations of transient phenomena within 48 hours after a trigger is approved by the RadioAstron scheduler together with schedulers of required GRTs.

#### 5.4.9 Target of Opportunity Observations

During the entire AO-5 period, target of opportunity (ToO) requests will be considered by the Mission within the Director's Discretionary Time. In order to submit a RadioAstron ToO proposal, the standard RadioAstron proposal template as well as submission e-mail address should be used (e-mail address: *ra_submit@asc.rssi.ru*, subject: "ToO proposal"). It is expected that up to several percent of the total time might be used for the ToO observations.

## 6 Assistance to Proposers

Proposers of AO-5 experiments are advised to consult the RadioAstron Mission documents which describe the main characteristics of the satellite, list the main modes and capabilities of RadioAstron observations, and discuss specific constraints arising from inclusion of an orbiting antenna in VLBI observations. Further help and consultation on the issues and areas not covered in these documents can be sought at the ASC, using the contact details provided in Appendix B.

### 6.1 RadioAstron Mission Website, Documents, and Newsletter

Complete information about the current status, scientific results, and technical developments of the Mission are available from the RadioAstron website[8]. A description of the RadioAstron observational capabilities, including technical specifications of all available observational modes is given in the "RadioAstron User Handbook[9]". Information about observations conducted by RadioAstron can be found in the observations status summary[10]. Updates on the Mission status are provided by the RadioAstron Newsletter[11], distributed by e-mail. A list of RadioAstron

[8] http://www.asc.rssi.ru/radioastron/
[9] http://www.asc.rssi.ru/radioastron/documents/rauh/en/rauh.pdf
[10] http://www.asc.rssi.ru/radioastron/documents/ra_obs_summary.pdf
[11] http://www.asc.rssi.ru/radioastron/news/news.html

publications[12] is maintained on the RadioAstron website.

### 6.2 Simulation Software

The RadioAstron simulation software `FakeRat` provides a facility for simulating the $(u, v)$-coverages of RadioAstron observations and determining the optimal ground array support and time periods for specific observations.

The software `FakeRat` is based on the package `FakeSat`, originally developed by David Murphy (JPL). `FakeRat` is currently implemented for the LINUX operating system. The main modification from the original `FakeSat` software is the introduction of the satellite orbit in tabular form. This is required because a Keplerian orbit treatment does not apply for the Moon-perturbed orbit of RadioAstron. Other modifications concern specific operational constraints of the Spektr-R spacecraft. The `FakeRat` package and its user's guide can be obtained at the RadioAstron server[13].

To help proposers to plan RadioAstron observations, the ASC has produced a set of simulated all-sky $(u, v)$-coverage plots[14].

If you need help in order to estimate visibility constraints for AO-5 observations of a target of your interest, feel free to contact the RadioAstron scheduler at *ra_sched@asc.rssi.ru*.

### 6.3 Consultation and Contact with the Mission

For specific questions not addressed by the online documentation, consultation can be sought from the ASC. The contact for general consultations is the RadioAstron Science and Technical Operations Group (RSTOG) (see Appendix B). To facilitate the communication between the teams and the ASC, each approved AO-5 experiment will be assigned a specific contact person within the RSTOG.

## 7 Proposal Preparation

This document solicits proposals for the AO-5 period of the RadioAstron Mission.

### 7.1 The AO-5 Period

This RadioAstron Announcement of Opportunity covers the fifth period of the RadioAstron operation, following the completion of the RadioAstron Early Science Program, AO-1,2,3,4 periods. It runs from July 2017 to June 2018, inclusive, and includes both KSP and GOT proposals. The AO-5 proposal deadline is 23 January 2017, 23:59 UT. It is expected that subsequent announcements of opportunity for RadioAstron will be issued once per year with a proposal submission deadline around the end of January each year.

[12] `http://www.asc.rssi.ru/radioastron/publications/publ.html`

[13] `http://www.asc.rssi.ru/radioastron/software/soft.html`

[14] Available from `http://www.asc.rssi.ru/radioastron/ao-5/AO5_allsky_uvplots_pu_and_gb.pdf`

### 7.2 Eligibility for Proposing

There are no restrictions imposed on the nationality or affiliation of primary investigators and co-investigators of AO-5 RadioAstron proposals.

### 7.3 Proposal Content and Submission

RadioAstron proposals must contain a cover sheet section and a scientific justification. The scientific justification submitted to the Mission may not exceed six/four pages for KSP/GOT proposals, respectively, including figures, tables and references. The accompanying cover sheet must be filled out using the template form provided[15].

Proposals for RadioAstron AO-5 KSP and GOT experiments are expected to: (a) describe the main scientific goals of the project, (b) present a concise scientific justification for investigations proposed, (c) present the methodology for analysis and interpretation of RadioAstron data, (d) provide estimates of required and expected parameters of visibility data and resulting images, and (e) demonstrate the technical feasibility of the observations proposed for AO-5 (addressing, if necessary, all specific technical issues arising in connection to the observations including identification of suitable dates and times). KSP proposals are additionally required to (f) review the team capacities to execute the timely completion of the project and publication of results, (g) provide an estimate of the overall observing time required for completion of the project if the full experiment is intended to be carried over several AO periods.

Scientific justification(s) and cover sheet(s) submitted separately to the ground segment of the observations proposed should comply with the rules of respective telescopes and interferometric networks.

The RadioAstron AO-5 proposals should be submitted by e-mail to RadioAstron Mission (e-mail address: *ra_submit@asc.rssi.ru*, subject: “AO5 proposal”) by **23 January 2017, 23:59 UT** as a pdf file attached to an e-mail. Submissions to ground facilities requested to participate in projects should be made in compliance with the submission rules and deadlines of the respective facilities.

## 8 Review and Scheduling of AO-5 projects

The RISC has formed a review panel to grade all proposals received — the RadioAstron Program Evaluation Committee (RPEC). Proposals submitted for AO-5 observations with RadioAstron will be reviewed separately by the RPEC and the requested ground facilities.

### 8.1 Technical Review

The technical review by the RSTOG will address the technical feasibility of proposals, covering the issues of instrumental and satellite constraints, scheduling restrictions, and logistical limitations of the proposed observations. The RSTOG technical reviews will be made available to the RPEC and the program committees of ground facilities requested for the observations.

[15] http://www.asc.rssi.ru/radioastron/ao-5/radioastron_ao5_proposal_template.tex

### 8.2 Scientific Review

The scientific review by the RPEC will provide an assessment of scientific novelty, relevance, and merits of the research goals, methodological foundations of analysis and interpretation, and feasibility of achieving the research goals with the observations proposed. The review will further investigate cases of potential conflict and overlap between different proposals. Based on the results of these review actions, recommendations for data sharing may be made.

### 8.3 Ranking of the RadioAstron Proposals

After completion of the technical and scientific review by the RPEC, the AO-5 proposals will be ranked according to the combined strength of their scientific merits and technical feasibility. Based on the final ranking of the proposals by the RPEC, scheduling recommendations of the Mission will be determined and communicated to the teams and (if requested) to the ground facilities requested to participate in the RadioAstron observations.

### 8.4 Scheduling

The final decision on the scheduling of observations will be based on a joint ranking of the respective proposals by the RPEC and the program committees of the ground facilities requested for the observations — similar to the process for "global" VLBI projects. Joint approval by the Mission and the participating ground facilities is a pre-requisite for an observation to be scheduled. In all other cases, scheduling decisions will be made on the basis of negotiations between all parties involved.

The teams will receive the results of the technical and science evaluation as well as the final ranking from the RadioAstron Mission by March 2016.

Scheduling of RadioAstron observations is undertaken by the Mission on a month-by-month basis, with teams to be notified in advance of their observations being conducted.

## 9 Data Rights

Any science team awarded RadioAstron observing time will have exclusive rights, within a specific proprietary period, to all interferometric data products and SRT scientific data arising from their observations, with the exception of any data to be shared with another team. Groups can suggest data sharing in their proposals and/or the RadioAstron Program Evaluation Committee (RPEC) may recommend it.

### 9.1 Proprietary Period

A 12 month proprietary period from the release by the correlator of the final observation of a project will be allocated by the Mission for all data products produced at the ASC correlator from the observations. ToOs will have a 6 month proprietary period. For RadioAstron data obtained from the observations and correlated at other correlator facilities, the 12 month rule will apply unless other arrangements have been negotiated between the team, the respective correlator facility, and the ASC.

In exceptional circumstances, an extension of the proprietary period may be requested by the teams and will be considered by the Mission.

## 9.2 Data Archive

RadioAstron users have password protected access to results of correlation of their RadioAstron experiments from the Astro Space Center archive facility `sftp://archive.asc.rssi.ru`. After the expiration of the proprietary period, RadioAstron data will be made publicly available from the archive.

# Appendix

## A Acronyms and Abbreviations

| | |
|---|---|
| AGN | Active Galactic Nuclei |
| AO | Announcement of Opportunity |
| ASC | Astro Space Center |
| Co-I | Co-Investigator |
| DSNC | Deep Space Network Communication |
| ESP | Early Science Program |
| EVN | European VLBI Network |
| FCC | Flight Control Center |
| GBO | Green Bank Observatory |
| GBT | Green Bank Telescope |
| GOT | General Observing Time |
| GRT | Ground Radio Telescope |
| KIAM | Keldysh Institute of Applied Mathematics |
| JIVE | Joint Institute for VLBI in Europe |
| JPL | Jet Propulsion Laboratory |
| KSP | Key Science Program |
| KVN | Korean VLBI Network |
| LA | Lavochkin Association |
| LBA | Long Baseline Array |
| LBO | Long Baseline Observatory |
| LCP | Left-hand Circular Polarisation |
| LRS | Laser Ranging Station |
| PI | Principal Investigator |
| RCP | Right-hand Circular Polarisation |
| RDF | RadioAstron Data Format |
| RISC | RadioAstron International Science Council |
| RPEC | RadioAstron Program Evaluation Committee |
| RSA | Russian Space Agency |
| RSTOG | RadioAstron Science and Technical Operations Group |
| SCS | Satellite Command Station |
| SEFD | System Equivalent Flux Density |
| SFXC | EVN software correlator at JIVE |
| SRT | Space Radio Telescope |
| STS | Satellite Tracking Station |
| ToO | Target of Opportunity |
| UT | Universal Time |
| VLBA | Very Long Baseline Array |
| VLBI | Very Long Baseline Interferometry |
| WSRT | Westerbork Synthesis Radio Telescope |

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