

MeerKAT 2023 Call for Proposals

Issued: 15 March 2023 Deadline for submission of proposals: 3 May 2023, 14:00 SAST (12:00 UTC)

This Call is substantially different from previous ones in important respects. Prospective MeerKAT users are urged to first read this document carefully in its entirety.

Note: we recommend use of the Chrome browser throughout

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1 Introduction

The South African Radio Astronomy Observatory (SARAO) through this Call elicits observing proposals for MeerKAT, seeking to maximize the scientific impact of the telescope while contributing to South African scientific leadership and human capital development.

MeerKAT is a radio interferometer located in the Northern Cape province of South Africa (at 30 deg South, 21 deg East) consisting of 64 dishes with baselines of up to 8 km. Its superb sensitivity, ~2000 baselines, centrally concentrated distribution (~3/4 of the dishes are located in a 1 km diameter core), substantial field of view (~1 deg FWHM at 1.4 GHz), and unblocked aperture design, make it uniquely suited to a variety of studies.

Imaging results to date drawing on these capabilities have included the detection of low surface brightness neutral hydrogen (e.g., <u>de Blok et al. 2020</u>; <u>Healy et al. 2021</u>), high fidelity imaging of extended Galactic structures (e.g., <u>Heywood et al. 2022</u>), continuum observations exceedingly sensitive to distant star forming galaxies (e.g., <u>Mauch et al. 2020</u>) and diffuse emission in cluster environments (e.g., <u>Chibueze et al. 2021</u>; <u>Knowles et al. 2022</u>), enabling the discovery of unexpected features in radio galaxies (e.g., <u>Ramatsoku et al. 2020</u>), absorption line detections in both L and UHF bands (e.g., <u>Combes et al. 2021</u>), neutral hydrogen intensity mapping studies (e.g., <u>Wang et al. 2021</u>), efficient imaging in snapshot mode (e.g., <u>Condon et al. 2021</u>), broadband spectro-polarimetry across a large FoV (e.g., <u>Cotton et al. 2020</u>), and numerous image-plane time-domain discoveries (e.g., <u>Bright et al. 2020</u>).

MeerKAT also has a variety of non-imaging capabilities enabled by User Supplied Equipment (USE). Science projects drawing on these beamformed capabilities encompass high-precision pulsar timing (e.g., <u>Miles et al. 2023</u>), accelerated pulsar searching (e.g., <u>Clark et al. 2023</u>), and real-time detection of transients (e.g., <u>Rajwade et al. 2022</u>).

This is the 4th 'Open Time' Call for Proposals (CfP) on MeerKAT (also referred to as OT4; it is planned that future CfPs will be issued yearly in March as for OT3 and OT4). It is open to Pls with any affiliation. Compared to the OT3 CfP, we offer new technical capabilities (e.g., for pulsar/transient studies; use of S-band receivers) and proposal modes (e.g., for large and/or multi-year projects). The documentation and tools have also been updated accordingly.

It is very important that prospective proposers begin preparations early, and that they <u>contact SARAO</u> with any questions well in advance of the deadline for submission on 3 May 2023. Also, **it is essential that all instructions related to this CfP be adhered to, as non-compliant proposals will not be reviewed.** We also encourage prospective users to familiarize themselves with the general <u>guidelines on MeerKAT telescope and data access</u>.

2 Who Can Submit Proposals

Proposals submitted in response to this CfP may be led by any researcher (including postdocs and PhD students), regardless of affiliation.

The basic MeerKAT imaging data product consists of interferometric visibilities, at high rates (the 32K correlator mode yields at least 1 TB of data per hour). Also, MeerKAT has some particular characteristics that may require adaptation during processing by researchers only familiar with other radio interferometers. In the preparation of proposals, SARAO therefore encourages collaboration between new users and those who have prior MeerKAT experience.

3 Available Capabilities and Constraints

This CfP is open for **imaging and non-imaging (beamformed) projects alike**. It is expected that **at least 1750 hours of telescope time will be available through this CfP**. This refers to the amount of time to be scheduled for approved projects over a 12-month period (to start during the last third of 2023, as soon as reviews conclude).

3.1 Proposal types and time limits

• Regular

Individual Regular proposals (the only type available through the OT3 CfP) are limited to a maximum request of 125 hours, including calibration and slewing overheads, to be fully scheduled within a 12-month period. The maximum time on-source for the science target(s) is 100 hours.

• Large

Any proposal that requests more than 125 hours is a Large proposal. The maximum time request for a Large proposal is 2500 hours.

• Multi-year

Projects may be submitted through this CfP that must or may have to be scheduled over more than 12 months, *up to a period of 4 years*. Such Multi-year proposals will have to indicate and justify their overall time request *as well as* the request for the 12 months specifically covered by this CfP cycle.

Any proposal that *requires* observations over more than 12 months for scientific reasons (e.g., a monitoring project) is of Multi-year type. In addition, any Large proposal that requests more than 500 hours is also Multi-year because of scheduling

constraints: individual successful OT4 proposals will be limited *at most* to 500 hours in the 12-month observing cycle covered by this CfP.

For example, a monitoring project that requests 10 hours per year over 4 years is Multi-year but not Large (and although it does not exceed 125 hours it is not Regular because it cannot be scheduled during a 12-month period); a monitoring project that requests 40 hours per year over 4 years exceeds 125 hours and is therefore both Large and Multi-year; a project that requests 150 hours is Large, but need not, inherently, be Multi-year (if it could be scheduled within a 12-month period); while any project that requests more than 500 hours in total is both Large and Multi-year.

3.1.1 Large proposals and pilot studies

Large requests will have to be exceptionally well motivated in all respects. This includes the clear demonstration of their feasibility. As noted in the <u>MeerKAT telescope use guidelines</u>, Large projects "have to first demonstrate technical and/or scientific feasibility through the successful completion of smaller pilot studies. Depending on the details, such projects might be deemed to have already demonstrated readiness by comparison to prior successful suitably analogous projects".

In the context of the current CfP, Large proposals must clearly demonstrate that the above requirement has been met. If not, the authors should rather consider submitting a Regular proposal that may be a pilot for a future Large proposal.

3.1.2 Multi-year proposals and future CfP cycles

Multi-year proposals (including those that are also Large) submitted through this CfP will contain Science Cases and time requests for the overall project, including specific requests for the first 12 months of the project. However, *successful proposals will be awarded time through the current CfP only for the first 12-month cycle.* In order to continue thereafter, the proposals will have to be resubmitted and evaluated against all proposals received in response to future CfPs.

3.2 Bands/receivers

- UHF: digitized band of 544–1088 MHz (RF band of approximately 580–1015 MHz);
- L band: digitized band of 856–1712 MHz (RF band of approximately 900–1670 MHz);
- S band: any of 5 sub-bands (S0–S4), each digitizing an 875 MHz-wide band, can be selected within the 1750–3500 MHz range.

L band and UHF are suitable for full-Stokes polarimetric work (although there are limitations for wide-field polarimetry as noted in the documentation).

The newer <u>S-band capability</u> is offered in shared-risk mode, with a limit of 16 hours of observing time (including overheads) for proposals requesting it.

Individual proposals can request the use of multiple bands (note that in some tools UHF is referred to as U-band).

3.3 Correlator modes and USE backends

3.3.1 Correlator modes for imaging observations

- 4K: 4096 channels across the digitized band;
- 32K wide: 32,768 channels across the digitized band;
- <u>32K narrow</u>: 32,768 channels across 1/8 (107 MHz; NE107) or 1/16 (54 MHz; NE54) of the digitized band (*these modes are available only for L band*).

3.3.2 USE for beamformed observations

The following User Supplied Equipment backends are available for a variety of beamformed time-domain applications:

- PTUSE: Pulsar Timing USE (for pulsar timing and single-beam searching)
- FBFUSE: Filterbanking Beamformer USE (generating up to hundreds of independently steerable beams)
- APSUSE: Accelerated Pulsar Search USE (to record, and in limited circumstances do off-line processing of, multi-channel fast-sampled time series produced by FBFUSE)
- TUSE: Transient USE (for real-time searching/studies of transients, alongside FBFUSE)

These backends have many options (e.g., channelization and sample times) and constraints that *must* be understood first by consulting the relevant <u>USE technical documentation</u>. Then, any team contemplating submitting a proposal using *any* of these backends **must** consult with the relevant contact point(s) indicated in the documentation for a technical evaluation. In addition, any proposal requesting any USE backend **must** contain at least one experienced user of the relevant backend(s) who also has the ability to access the collected data.

Additionally, APSUSE availability for projects selected through this CfP is limited, owing to its need for previously approved large projects. *In the aggregate*, approved projects requesting APSUSE will be limited to *recording* data from no more than 100 hours of observations.

Note also that the TUSE backend is used in commensal mode alongside most MeerKAT observing projects. Unless a proposal explicitly requests the use of TUSE for its key science goals, or justifies why its use by others in commensal mode would clash with core science goals and should be excluded, such commensal use will generally proceed by default.

3.4 Target-of-Opportunity requests

Regular ToO requests are for transient targets/events that could reasonably be predicted to occur within the observing span associated with the current CfP, i.e., that could be **triggered within a 1 year period expiring by September 2024**. *Any request for a Multi-year ToO project must be exceptionally well justified* (e.g., directly connected to predicted event rates). Rare enough events for which reasonable prediction of rates cannot be supported should be proposed under Director's Discretionary Time. Furthermore, a compelling ToO *proposal addresses a narrow object class with well-defined science goals.*

3.5 Proposals connected to ongoing MeerKAT LSPs

As of this CfP, all 8 MeerKAT Large Survey Projects (LSPs) are ongoing, although some will reach their 5-year term by 2024. Proposals that could be considered an extension of ongoing LSPs in general will not be accepted through this CfP. Any potential exceptions **must** be <u>discussed with</u> and *approved* by SARAO well in advance of the submission deadline. It is also recommended that any other proposals that may be closely linked to ongoing LSPs be first <u>discussed with SARAO</u>.

3.6 Non-standard modes

Some capabilities that prospective MeerKAT users may be familiar with using at other telescopes may not currently be available on MeerKAT (e.g., particular noise-diode firing schemes, solar observations), or may have MeerKAT-specific implementations that could impact the attainment of some science goals.

Users considering potentially non-standard observing modes or those not yet commissioned for regular use **must** discuss their plans with SARAO well in advance of the submission deadline to evaluate suitability for the current CfP. In case of doubt, please <u>contact SARAO</u>.

3.7 Data products

The official imaging data products provided by SARAO to MeerKAT users consist of visibilities with basic flagging, calibration solutions and reports.

Continuum and spectral image cubes are also automatically generated by the Science Data Processor (SDP) pipeline for *some* observations. These are primarily generated for quality assessment purposes but have already been shown to be useful for *some* science investigations. Proposers are encouraged to learn about the <u>power and limitations of SDP</u> <u>pipeline products</u>, and as relevant consider the feasibility of using these for specific science applications.

In any case, proposals submitted under this CfP must address the feasibility of achieving their science goals on the basis of analyzing the relevant data products, which for most current MeerKAT imaging projects are the visibilities. Beamformed projects, as noted in <u>Section</u> <u>3.3.2</u>, must in addition demonstrate that their team has the expertise required to collect the data.

3.8 Documentation on MeerKAT capabilities

Prospective proposers are directed to documentation on telescope capabilities and constraints on the <u>External Service Desk Knowledge Base</u>. Any questions should be addressed to <u>SARAO</u> well in advance of the submission deadline.

4 Determining Targets for Observation and Time Requests

MeerKAT observing projects are approved to address specific science goals, alongside the targets/fields and integration time/modes required to achieve those scientific objectives. Newly proposed projects may not unduly clash with the specific science goals of ongoing large projects.

Note that it is entirely possible to have multiple projects observing some of the same targets, to address different science goals. For instance, a project with a large sample of targets selected according to well-defined criteria may happen to observe one galaxy that is the specific focus of a separate project with distinct aims observing the same galaxy with a different integration time and/or using different telescope modes.

In order to not unduly clash with active large projects, prospective proposers should become at least passingly familiar with them (see <u>Section 4.1</u>).

4.1 Approved projects and existing datasets

All approved MeerKAT Large Survey Projects (LSPs), Open Time (OT), and Director's Discretionary Time (DDT) projects are <u>listed here</u>.

The <u>projects dashboard</u> provides a view of all science observations done to date. Also, the <u>data archive search interface</u> (which includes functionality such as a cone search) can be used to list useful information about all science observations done (and in some cases approved) with MeerKAT (e.g., integration times and receiver/correlator modes, and whether those data are publicly available).

Note that the data collected for many projects are already public, and some projects have issued curated <u>data releases</u> which may be used for further science exploitation.

Apart from LSPs, substantial active large projects include: SARAO Legacy Surveys of the Galactic plane and of the Magellanic Clouds (all done at L band with the 4K mode of the correlator); some other SARAO Science Verification (SSV) datasets; and MPIfR-led Galactic plane surveys. Prospective proposers are encouraged to <u>learn more about these projects</u>.

Any questions regarding the status of existing MeerKAT datasets and how they might relate to the submission of new proposals can be addressed to <u>SARAO</u> in advance of the submission deadline.

4.2 Time requests

The type and number of targets/fields requested in a proposal, along with the observing mode, must be suitably addressed in the context of the Science Case.

In addition, all time requests must be justified by appropriately motivated sensitivity calculations. To assist, a variety of <u>sensitivity calculators</u> are available.

5 Components of Proposal

All complete proposals consist of three (3) mandatory sections (cover sheets; Science Case containing scientific & technical justification; data analysis/management plan). Important information on these components follows in the remainder of this section.

5.1 Cover sheets

These are to be completed directly through the <u>proposal submission system</u>, which contains instructions. Both attachments noted in the following sections are also submitted through the proposal submission system.

The cover sheets include fields for information such as proposal title and abstract, broad proposal scientific category (to assist SARAO with reviews), team details, telescope modes, source lists, and overall time requested. Multi-year proposals must also indicate the time requested for the 12-month period explicitly covered by this CfP. <u>Tools are available</u> to assist with the completion of some of these items (e.g., sensitivity calculators; observing run simulation tools, including selection of suitable calibrators and estimated slew time).

5.1.1 Proposal for PhD thesis?

If the proposed project is to form a core component for the PhD thesis of a listed PI/co-PI, this should be indicated under Team Details. Otherwise, this field should be answered No.

5.1.2 Status of previous related projects

If any key member of the current proposal team (including, but not limited to, the PI and technical lead) has been a key member of any previous MeerKAT Open Time or DDT project that is closely *related* to the new proposed project, a brief status update **must** be included for up to the 3 most relevant projects.

If the project has already resulted in any publication, provide paper title(s) and standard bibliographic information; optionally, also add a sentence about the contents of the paper(s). If paper(s) have been submitted or are in *advanced* states of preparation, indicate so and outline the main results (and any technical issues if relevant). Otherwise, indicate the current status, and as relevant any issues – especially as they might connect to the current proposal (e.g., data analysis).

5.1.3 Pilot results for Large projects

As noted in <u>Section 3.1.1</u>, a Large project **must** first have retired technical and/or scientific risk via prior pilot studies/results. This **must** be indicated in the body of the proposal and a summary *must* be included in the cover sheets.

5.1.4 Integration times: per target, and overall

The cover sheets now require an indication of requested integration time per target, exclusive of overheads, as well as overall proposal time request including overheads. In addition, Multi-year proposals require an indication of the overall time request for the 12-month cycle covered by this CfP.

5.2 Science Case: scientific justification & technical justification

This section consists of one pdf document (maximum size 10 MB) using font size no smaller than 11 pt and with standard margins. Any abstract, relevant figures/tables, and references must be included within its page limit. **The page limit for the Science Case is:**

- Three (3) pages for Regular or (only) Multi-year proposals
- Four (4) pages for Large proposals

There can be no explicit identification of team members within this document, as it will be reviewed in dual-anonymous fashion. In addition, refrain from style that indirectly identifies teams – e.g., instead of 'As we have shown in Author et al. (2021)', write rather 'As shown by Author et al. (2021)', or better yet 'As shown in [Ref. #]'. Note that anonymization does *not* preclude teams from incorporating their prior work in proposals where relevant, it rather requires careful attention to how this is done.

This is the only section that may contain the scientific and technical justification for the proposal, in a self-contained fashion – it is the only section that the science reviewers will be asked to consider (e.g., they will not review the cover sheets and its abstract). The following considerations apply:

i. *This document should be written for an astronomer who is not an expert in the sub-field* (e.g., it may be assumed that the reviewer has expertise in some continuum science if they are reviewing such a proposal, but particular expertise should not be assumed on, say, galaxy clusters or star forming galaxies).

ii. The **scientific justification** portion should provide context for the science goal(s) being proposed, and it should be explicit (no generalities) as to what it aims to achieve science-wise, and also how the proposed observations, if successful, will do so. Why are these interesting questions to address, and how does the proposed work advance on the current state of the art? Previous relevant work on the topic, regardless of telescope used, should be noted. Also indicate why you're proposing to do this work on MeerKAT: e.g., is it the most suited instrument available for this investigation?

iii. The **technical justification** portion should make a clear connection between the specific science goals to be achieved and the observing request (e.g., flux density or flux density per synthesized beam solid angle limits, target(s), areal coverage, number of visits – which in turn quantitatively drive the overall requested time). The <u>RFI environment</u> should be taken into consideration as relevant. *Also, any requested integration period of less than 8 seconds or night-time observations must be justified.*

This section should also succinctly note the time(s) requested on-source for the science target(s) as well as overall request including overheads, band(s)/mode(s)/USE backend(s) to be used, and identity of the source(s)/field(s) to be observed. For large source lists, only the criteria need to be indicated here. Calibration plans should be outlined as relevant. *If the default overhead fraction of 25% is not selected in the cover sheets, this section must note the expected fraction, backed up by Observation Planning Tool simulations.*

As relevant, note additional requirements (e.g., dynamic range) and discuss possible constraints (for instance, bright sources in the field, and how they'll be dealt with – e.g., by addressing direction-dependent effects – if they might otherwise impact attainment of the science goals).

For **Multi-year proposals**, time requests should be clearly stated and justified for both the overall project and the 12-month cycle explicitly covered by this CfP. For **Large projects**, relevant findings from prior *pilot studies* should be incorporated into the proposal; also, due consideration should be given to the matter of *scalability* (what would be impact on science return if substantially less than the full time request could be awarded).

As noted in <u>Section 3.4</u>, **Target-of-Opportunity requests** must be narrowly tailored. Apart from addressing the specific science goals, proposals with ToO classification have to address in this section predicted event rates (reasonably expected to be triggered within a 1 year period), provide a sense of their brightness, and the triggering criteria, including what facilities will generate them.

5.3 Data analysis/management plan

This (non-anonymized) section consists of a **1-page** pdf document. It will not be shared with the science reviewers, but will be used to help assess the feasibility of the proposed project.

Turning large amounts of MeerKAT data into science can be challenging. A proposal with a compelling Science Case but an unrealistic or unclear data analysis management plan is unlikely to be ranked highly overall.

In this section the proposers should outline their intended analysis plan and indicate the resources that they have at their disposal for the relevant tasks. These resources include:

i. Personnel with the necessary expertise. The role of named key team members, both technical and scientific, should be outlined, and relevant experience with MeerKAT data analysis if any (and data collection/access for any requested USE) should be noted. Other team members need not be noted here.

ii. Software. The data reduction and analysis plan must be outlined in sufficient detail to provide confidence that the required outcomes can be achieved. The implications of any software (e.g., pipelines) still under development must be addressed.

iii. Hardware. It's important to note whether access to the required tools and computing resources has been secured (and if not to make a timely plan to do so). This will also have been outlined in the cover sheets.

In this context (especially for larger/more challenging projects), it may not be sufficient to state that the data will be processed at 'X institute'; rather, the proposers should seek to make quantitative estimates of their storage and compute requirements, and indicate either that they already have access to those specifically required resources, or outline how they reasonably intend to acquire them.

Note that the contents of this section of the proposal (addressing in detail how data will be turned into science) are distinct from what needs to be included in the technical justification section of the Science Case (<u>Section 5.2</u>), and they will be reviewed differently (<u>Section 6</u>).

As noted in <u>Section 3.1.1</u>, **Large proposals** will have to be exceptionally well motivated in all respects. This includes the clear demonstration of their *readiness* to deliver the proposed science at scale. Is it critical that this be *comprehensively* addressed in the data analysis/management plan section of the proposal.

6 Review of Proposals

All valid proposals received under this CfP will be evaluated on the merits of their Science Case and feasibility. Large proposals will receive particular scrutiny. In addition, proposals that form a core component for the PhD thesis of South African-based students, or that build South African capacity for Key Science with SKA1, will be advantaged compared to otherwise similarly meritorious proposals.

First, different sections of proposals will be reviewed in a non-conflicted manner as follows:

i. The full Science Case (<u>Section 5.2</u>) will be reviewed by anonymous domain experts in dual-anonymous fashion (i.e., the reviewers will not have explicit knowledge of the identity of the proposing teams), according to guidelines provided by SARAO.

ii. The technical justification portion of the Science Case, data analysis/management plan (<u>Section 5.3</u>), and as relevant past performance on previous closely related projects (<u>Section 5.1.2</u>), will be reviewed by SARAO, with input from external experts as needed.

These reviews will inform the assessment of the overall feasibility of the proposed project.

A Review Panel appointed by the SARAO Managing Director will then incorporate the above inputs and recommend to the MD a rank-ordered list of proposals suitable for scheduling on MeerKAT, together with other recommendations as relevant (e.g., partial time allocations).

Depending on the number of **Large proposals** received and their aggregate time pressure for the 12-month observing cycle explicitly covered by this CfP (i.e., the fraction of overall observing time for the current cycle requested by Large proposals), a second stage of panel review may be implemented by the SARAO MD, in order to select an appropriately balanced science program.

After taking into account other relevant constraints (e.g., pressure for particular LSTs or night-time observing), SARAO will group proposals into three classes: A (will be observed); B (may be observed); C (will not be observed). Specific time allocations for A- and B-rated proposals pertain to observing time to be scheduled during the 12-month cycle covered by this CfP (as noted in <u>Section 3.1.2</u>, Multi-year proposals allocated initial time through this CfP will need to be resubmitted and evaluated against all proposals received in response to future CfPs). Following this, all PIs will receive feedback on the disposition of the proposals.

Suitable sections of the cover sheets of approved projects may be made public.

7 Timelines

This CfP is being issued on 15 March 2023.

All <u>documentation and tools</u> required to prepare proposals in response to the CfP are available as of this date.

Proposals may be submitted on the submission system until 12:00 UTC on 3 May 2023.

Successful proposals will start being scheduled on MeerKAT as soon as the review process is completed and communication on outcomes is provided to PIs. This is expected to happen in the last third of 2023.

8 Proprietary Periods

By default, the data associated with any project approved under this CfP will have a proprietary period of 12 months, counting from the date of last data collection for the project during the 12-month cycle explicitly covered by this CfP. After the proprietary period expires, the visibilities, and data cubes produced automatically by the SDP pipeline if any, will become freely available through the MeerKAT data archive interface. Relevant beamformed data will also become available at that time.

Approved projects that form a significant component of the thesis work of PhD students may be considered by SARAO for proprietary periods of up to 18 months.

Note that SARAO does not guarantee the storage of either visibility data or any associated image cubes substantially beyond the proprietary period of the observations. Teams may wish to arrange their own storage should they see longer term value in retaining the data.

9 Publications and Acknowledgements

We request that authors inform SARAO of refereed papers accepted for publication, or theses, that include MeerKAT data. These will be added to the <u>MeerKAT ADS Library</u>.

Such publications should contain the following acknowledgement statement:

The MeerKAT telescope is operated by the South African Radio Astronomy Observatory, which is a facility of the National Research Foundation, an agency of the Department of Science and Innovation.

Publications making use of the S-band receivers should in addition contain the acknowledgement statement provided in the <u>S-band capability</u> page; while publications making use of any User Supplied Equipment (USE) should also contain the relevant acknowledgement statements provided in their <u>technical pages</u>.

10 Contact Information

Any questions pertaining to the current MeerKAT Call for Proposals should be addressed to SARAO as soon as possible in advance of proposal preparation/submission by raising a ticket on the <u>SARAO External Service Desk</u>. Feedback on the documentation and tools associated with this CfP is also welcome.