1mm VLBI Call for Proposals: Cycle 4

22 March 2016

Introduction

The National Radio Astronomy Observatory (NRAO) invites proposals for 1mm Very Long Baseline Interferometry (VLBI) using the phased output of the Atacama Large Millimeter/submillimeter Array (ALMA (http://www.almaobservatory.org/)) and the Event Horizon Telescope (EHT (http://www.eventhorizontelescope.org/)) during ALMA Cycle 4. Up to 5% of ALMA Cycle 4 observing time is available for VLBI, shared between 1mm and 3mm. *Note that the EHT without phased ALMA is not being offered as part of this Call.*

The submission deadline for 1mm VLBI proposals is Thursday, 28 April 2016, at 23:59 UT.

An overview of phased ALMA and the EHT is provided below, and further technical information to support proposal preparation is available at the Proposal Preparation (https://science.nrao.edu/observing/call-for-proposals/1mm-vlbi-cycle4/proposal-preparation) link above, and at the EHT web page for 1mm VLBI with ALMA and the EHT (http://eventhorizontelescope.org/proposal.html) .

The same proposal (including scientific and technical justification) must be submitted in response to this Call for Proposals as that submitted to the ALMA Cycle 4 Call (http://almascience.org/proposing/call-for-proposals) to request phased ALMA. Proposal preparation is therefore through the ALMA Observing Tool (OT (https://almascience.nrao.edu/proposing/observing-tool)), which requires registration through the ALMA Science Portal beforehand. The ALMA OT Quickstart Guide (http://almascience.org/documents-and-tools/cycle4/alma-ot-quickstart) provides more information on how to use OT. Proposers will then submit a PDF copy of their full ALMA Cycle 4 proposal through the 1mm VLBI Proposal Submission (https://science.nrao.edu/observing/call-for-proposals/1mm-vlbi-cycle4/proposal-submission/) website by the above deadline. Additional information on proposing to ALMA may be found in the ALMA Cycle 4 Proposer's Guide (http://almascience.org/proposing/proposers-guide) .

Proposers who need assistance with proposal preparation or have questions regarding the Call should contact NRAO staff via the NRAO Helpdesk (https://help.nrao.edu/) . To submit a helpdesk ticket with 1mm VLBI-related questions, login to the NRAO Helpdesk, select "Submit a Ticket", select the "General" option for Telescopes, and then select the "General Queries" department. If you do not already have a user account on the NRAO Science Portal, you must create one before logging into the NRAO Helpdesk.

The ALMA Phasing Project

The ALMA Phasing Project (APP) has provided the hardware and software necessary to phase up the ALMA dishes to form a single station for VLBI. It is an international collaboration led by MIT Haystack Observatory, including contributions from NRAO, MPIfR, ASIAA, NAOJ, University of Concepción, Harvard-Smithsonian

CfA, and Onsala Space Observatory. It has been funded by the ALMA North America Development Fund, the NSF Major Research Instrumentation Program, and associated cost sharing partners. For ALMA Cycle 4 the phasing system is offered using Band 3 (λ~3mm) with the Global 3mm VLBI Array (see the semester 2016BCall for Proposals (https://science.nrao.edu/observing/call-for-proposals/2016B/vlba-hsa-vlbi-proposals)) and Band 6 (λ~1.3mm) with the EHT (this Call for Proposals). In the future, other ALMA Bands (e.g., λ~0.85mm) may also be available. The maximum bandwidth that can be output from the phasing system is 7.5GHz. The fringe spacing on a baseline from ALMA to Mauna Kea (JCMT, SMA) is ~30μas at λ~1.3mm. Further technical information about phased ALMA may be found in the ALMA Cycle 4 Technical Handbook (http://almascience.org/documents-and-tools/cycle4/alma-technical-handbook/) .

The Event Horizon Telescope

The Event Horizon Telescope is a 1.3 mm VLBI array whose primary goal is to observe and image nearby supermassive black holes with sufficient angular resolution to resolve the hot material just outside the black hole event horizon. The EHT network currently consists of telescopes in the US, Mexico, Chile, western Europe, and the South Pole that together provide a resolution of better than 30μas. To provide the sensitivity required to observe sources at such fine detail, EHT partners have developed ultrawide-bandwidth instrumentation and correlation facilities capable of handling very high data rates. For ALMA Cycle 4, the EHT is offering a limited amount of array time to enable new science programs that can make use of the EHT in conjunction with the APP.

Proposal Review Process

All proposals requesting both phased ALMA and EHT time will undergo review through the normal ALMA proposal review and time allocation process, as well as being reviewed by the EHT consortium. The final 1mm VLBI observing schedule will comprise proposals of the highest scientific and technical merit that are also able to fit into the VLBI session given its scheduling constraints.

Proposal Preparation

Observing Capabilities

Telescopes

The EHT + phased ALMA 1mm VLBI array is expected to comprise the following millimeter-wave telescopes: the Submillimeter Array (SMA), the James Clerk Maxwell Telescope (JCMT), the Submillimeter Telescope (SMT), the Atacama Pathfinder Experiment (APEX), the South Pole Telescope (SPT), the Large Millimeter Telescope Alfonso Serrano (LMT), the IRAM 30m telescope, an antenna from the Northern Extended Millimeter Array (NOEMA at Plateau de Bure), and phased ALMA.

For Cycle 4 VLBI observations at 1mm (Band 6), ALMA will be operated as a phased array comprising between 31 and 37 phased 12-m antennas. The effective collecting area will therefore be approximately equivalent to a single 67 to 73-m diameter antenna with a gain of 1.03 K/Jy and an SEFD of ~100 Jy. To maximize phasing efficiency, baselines between phased antennas will be restricted to ~1km and correlated 1-mm flux densities on 1-km baselines must be ≥500mJy.

Antenna positions and SEFDs are given at the EHT web page for 1mm VLBI with ALMA and the EHT (http://eventhorizontelescope.org/proposal.html) , for proposers wishing to perform uv-coverage or other

simulations. Proposers should assume this array in considering uv-coverage, sensitivity, and other technical aspects, although all available telescopes (which may be more or fewer than those listed) will be used during the 1mm VLBI observing session. Note that only VLBI observing including phased ALMA may be requested at this time. *The EHT without phased ALMA is not being offered as part of this Call.*

Sky Coverage and Scheduling Considerations

The performance of the phased arrays (SMA and ALMA) will degrade at low elevation, and other elements of the 1mm VLBI array have elevation limits determined by the local terrain. Soft limits on the declination range that can be observed with the array are -45 deg < δ < +45 deg. Proposers should consult the EHT web page for 1mm VLBI with ALMA and the EHT (http://eventhorizontelescope.org/proposal.html) for plots of target visibility as a function of declination and VLBI station.

There may also be scheduling constraints at some of the VLBI stations. For example, the performance of some of the telescopes degrade during the daytime, and so do not observe after sunrise. In addition, some of the telescopes may have other programmatic constraints. While there are no formal restrictions on the target RAs that can be requested in this Call, proposers should be aware that all these scheduling constraints will be taken into account when developing the approved VLBI program.

The 1mm VLBI session dates are not yet fixed, but are likely to be in March or April, 2017.

Frequencies Supported

A single tuning covering 226.1 to 230.1 GHz will be available at all 1mm VLBI stations, supporting continuum science only. At ALMA, this is provided by two 1.875GHz bands centered at 227.1 and 229.1GHz. The other stations will be tuned to fully overlap these two bands. In addition, phased ALMA will output two 1.875GHz bands centered at 213.1 and 215.1GHz. When ALMA is operated as a VLBI station, all ALMA standard interferometry data products are also created by the ALMA correlator, providing the equivalent of a standard single-field interferometry observation of the target field for all four of the above bands. Further information about the phased ALMA system is available in the ALMA Cycle 4 Technical Handbook (http://almascience.org/documents-and-tools/cycle4/alma-technical-handbook/).

Recording Rate and Polarization Products

In Cycle 4, all partner telescopes will record 2-bit samples of both polarizations in each band for a total of 32 Gbps. The recorded VLBI data from all stations will be shipped to the EHT facilities (Haystack Observatory and MPIfR Bonn) for correlation. At ALMA, the polarizations are linear (X and Y), while circular polarizations (L and R) are used at the other sites. The ALMA observations will therefore include additional calibration to allow conversion of the ALMA X/Y data to equivalent L/R in post-correlation processing (see Marti-Vidal et al. 2015 (http://publications.lib.chalmers.se/publication/225757)). Note that correlation of full polarization is required even for Stokes I continuum science goals.

While the EHT has carried out polarimetry in the past, polarimetry with phased ALMA is scheduled to be commissioned in Spring 2016 and is offered with the caveat that the results of the commissioning are not known at the time of this Call.

Sensitivity and Target Flux Densities

The phasing mode offered for Cycle 4 requires the phase-up of the array to be performed directly on the science target. Science targets are therefore limited to sources with correlated 1-mm flux densities of ≥500mJy on 1-km baselines and having sufficient flux density on intercontinental baselines to allow self-calibration on timescales of 10 seconds (~50mJy). Note that these sensitivity requirements correspond to source brightness temperatures of a few x10^8K on 5000km baselines. Proposers should be aware that this array is therefore sensitive only to non-thermal emission. Further information on the SEFDs of individual telescopes can be found at the EHT web page for 1mm VLBI with ALMA and the EHT (http://eventhorizontelescope.org/proposal.html) .

Calibration Overhead

Phased ALMA data need full-polarization correlation even for Stokes I continuum science goals, for the reasons described above; it is therefore necessary to calibrate the ALMA polarization leakage terms. To do this, the polarization leakage calibrator for any individual science target must be observed over an hour angle range of at least 3 hours to sample a range of parallactic angles. The overall observing efficiency on the science target within this 3 hour block is expected to be ~25%, with the remaining 75% of the time taken up with ALMA-specific, single dish, and VLBI calibrations. Proposers should request the full amount of time needed to perform their science observations, including calibration overhead.

Proposal Technical Justification

The technical justification for a 1mm VLBI proposal should be used to specify how the technical set-up enables the proposal's scientific goals to be met. For VLBI proposals it is entered as free-format text in the ALMA OT (maximum 4000 characters). It should include the following:

- Explain the reason for using the 1.3mm band (ALMA Band 6).
- Specify whether the science goal is Stokes I continuum or continuum polarimetry. Note that all polarization products must be requested whether or not the science goal includes polarimetry.
- Give the expected flux densities of the targets on (a) 1km baselines and (b) 5000km baselines.
- Specify the VLBI calibrators to be observed, and their expected flux densities. These should include calibrators for determining delays, bandpass, and instrumental polarization leakage and polarization angle.
- Justify the sensitivity required to achieve the science goal. For non-imaging experiments, justify the required baseline sensitivity.
- Specify the required on-source integration time to achieve the required sensitivity, and the total observing time including overhead. Include considerations such as uv-coverage needed for precision imaging. Please also verify that the time request on the proposal cover page is consistent with that specified here.
- Note whether the imaging is expected to be sensitivity limited, dynamic range limited, or both. Describe any potential imaging issues expected (e.g., due to nearby strong sources, complex source structure, etc.).
- Note any other special technical considerations with either the set-up or the data processing.

Proposers are encouraged to use the following cues to structure their technical justification:

- Frequency/band:
- Polarization science goal:
- Target flux densities:

- Calibrators:
- Sensitivity:
- Observing time:
- Imaging:
- Other:
