Submillimeter Array Advisory Committee Report

July 19, 2014

Summary

The 2014 meeting of the Submillimeter Array Advisory Committee was preceded by *The First Decade of Discovery* scientific meeting, an impressive showcase of SMA and related science. The SMA continues to attract excellent scientists who use the array to advance studies of a wide range of topics. SMA data are playing an increasing role in ALMA proposals, showing that the utility of the SMA in the ALMA era is strong. The Committee sees a very healthy collaboration between the CfA and ASIAA in operating and supporting the observatory.

Many of the Committee's comments relate to increasing the SMA's visibility and impact. A mix of individual and collaborative large observing projects is healthy and needed. The Committee suggests that approximately 20%, but no more than 40%, of time go to large projects; approximately 20% of the time go to short programs refereed on a timescale much shorter than a semester; and the balance be assessed and scheduled in the customary way. Whatever the exact divisions in time, the TAC should keep a high priority on assigning time to complete projects in good time even if this limits the total number of projects in any one semester. Improving the archive's usability will help capitalize on the SMA's results, inside and outside the CfA.

Overall, the instrument's performance, reliability, technical development, and operation are very good. Proper maintenance of the telescopes is important, especially as the instrument ages. Erosion in observatory staffing is having an impact on science productivity and observatory operation; replacing site technical staff and bringing the Observatory up to its usual complement of postdoctoral scientists must be high priorities. In looking to the future, the Committee strongly suggests building the Observatory's capabilities in digital signal processing (DSP).

1. Introduction

The Submillimeter Array (SMA) Advisory Committee met in Cambridge, Massachusetts from June 9-13, 2014. Committee members C. Gammie, M. Guelin, A. Harris (Chair), K. Menten, R. Plambeck, and J. Turner were all present. Science results from the array was the topic of the conference "The Submillimeter Array: First Decade of Discovery," held on the two days before the Committee meeting, followed by presentations on technical and operational matters at the Harvard-Smithsonian Center for Astrophysics on the two following days.

2. The First Decade of Discovery

The First Decade of Discovery meeting was an impressive showcase of SMA science. Astronomers from around the world, many presently or formerly associated with the CfA or ASIAA, presented talks and posters covering a wide range of topics. Scientific highlights of the meeting were talks on star and planet formation, observations of external galaxies with an emphasis on systems at high redshift, and work on our Galactic center at a variety of spatial scales. Other talks covered time-domain, planetary, millimeter-wave very long baseline interferometry, and evolved stars. The review talks were generally excellent and comprehensive, and many were delivered by young scientists. It was an exciting meeting that showed the interplay of SMA data with other observatories and theory, and was an excellent prelude to the Committee's visit.

3. Current status

a) Scientific strengths and program balance

The SMA fulfils a strong observatory's goal of uniting a group of scientists around an instrument and a set of shared scientific goals. Its instrumental assets provide a focus for strong scientific engagement, particularly in star and planet formation, within the CfA and ASIAA. Participation of many students, SMA post-doctoral fellows, National fellowship scholars, and the engagement of a new young Harvard faculty member shows the draw of the instrument. The Committee imagines that this attraction extends to excellent young scientists at institutions associated with ASIAA.

The Committee saw a very healthy collaboration between the CfA and ASIAA in operating and funding the observatory. Researchers within the CfA, ASIAA, and in the broader communities in which they are embedded gave strong talks in the SMA ten-year conference. Technical collaborations, which began with early work fabricating receivers and antennas, have now moved to increasingly equal partnerships on the superconducting mixers that are at the heart of SMA receivers and on the high speed digital signal processing used in the next-generation SWARM correlator.

From an instrumental point of view, one of the SMA's strengths has been high-resolution imaging of dust continuum around 350 GHz, something that no other observatory has been capable of until ALMA was commissioned. The SMA also has the ability to make high-

resolution polarimetric observations to explore magnetic fields. Its wide bandwidth brings not only high continuum sensitivity but also enables simultaneous observations of many different molecules to explore the physical, chemical, and dynamical state of luminous regions. Its large field of view, compared to those of ALMA and other mm/sub-mm interferometers, makes it particularly suited for the mapping of extended sources. A large field of view and broad bandwidth allows it to contribute strongly to planetary observations. The SMA is also a critical part of the Event Horizon Telescope (EHT), with the long baseline to Hawaii essential for imaging the region very close to the Milky Way galaxy's central black hole.

The topics of the SMA's scientific programs continue to be appropriate to the instrument's strengths. As a measure of success, the publication rate is consistently high, with refereed publications above 80 per year without signs of slowing. Impact, as measured by citations, is high but could be higher, as discussed later in this report.

The role and utility of the SMA in the early ALMA years is strong. ALMA will ultimately dominate for highest-sensitivity, highest-resolution millimeter and submillimeter interferometry, but it will never be able to do everything for everyone. The SMA's particular strengths will continue for some years to come, becoming more apparent as ALMA shows its strengths and limitations in data throughput and imaging, particularly for extended sources. Scientific topics where the SMA is strong will gain importance and visibility, and scientists working with the SMA will be positioned to be natural leaders. The SMA is a facility that can provide far more flexibility with more rapid turnaround to try out ideas than ALMA. Scientists associated with the SMA have used both the SMA and ALMA for their research. Already in the first rounds of ALMA proposals SMA data have motivated and strengthened ALMA proposals. The observatory provides deep technical expertise in hardware and software that can advance the field of submillimeter science on many fronts, including participation in ALMA development proposals that will enhance ALMA. The SMA group is a prominent part of the national core group of experts in instrument development. Student and young scientist involvement in the SMA provides training for the next generation of observers that few other instruments can equal. Finally and importantly, the SMA is and will remain the sole truly sub-mm interferometer covering the entire northern sky.

b) Observatory operation

Erosion in observatory staffing is having an impact on science productivity and observatory operation. The Committee notes with some concern that the number of postdoctoral fellows associated with the array will drop from 6 to 3. While the proximate cause of this was temporary funding problems brought on by US national politics, postdoctoral scholars are very productive elements of the observatory, and returning to normal staffing levels as soon as possible is important. Technical support in Hawaii has reached critically low levels, which impacts the array's operating efficiency. The Committee urges the observatory to refill positions for two technicians with skills in electrical and mechanical hardware as soon as possible. The loss of mechanical engineering expertise at the site has had serious implications for operation, as seen with the difficulties related to mechanical damage of the elevation lead screw drives. Quickly engaging outside experts in failure analysis could mitigate delays and risk in future major failures.

Although mechanical problems have hindered full array operation, the array seems to be recovering from those. Overall, the array runs very well. The receivers, electronics, and computer systems perform impressively. The prime technical goal of the past few years has been a push to broader bandwidth, and that has been very successful. Increasing bandwidth remains a high priority for the Receiver Lab, which has achieved impressive results. The new digital correlator system, SWARM, is showing great promise, and the Committee congratulates the team for bringing it on line so quickly, even at half speed. Perfection is the enemy of good, and SWARM in its present state adds considerable observing capability. The digital group's production of the Phringes phased array electronics has gone quickly as well, allowing the SMA to participate in the EHT VLBI experiment. The Committee's concerns about gradual mechanical degradation were largely but not entirely dissipated by discussion with the observatory staff. Particularly as the observatory ages it is important to provide sufficient funding for maintenance and necessary upgrades within the base budget. The Committee stresses the importance of keeping 8 antennas in operation. Dropping from 8 to 7 antennas, which has been common over the last 2 years, reduces the SMA's imaging speed by cutting the number of baselines by a quarter.

c) Development for SMA Fellows and Predocs

The Committee very much enjoyed meeting a group of SMA Fellows and Predocs, mentored by a number of faculty advisors, over lunch. An interest for many, at varying levels of detail, was "getting under the hood" with interferometry. Some of the Predocs and especially Fellows saw their time at the SMA as a way to become familiar with or expert in interferometry as part of a career path. Understanding how to get involved with interferometry without taking too much focus away from analyzing and publishing SMA data, tasks that were seen as their chief responsibilities, was the main barrier to becoming more involved. One possibility is for SMA staff to suggest potential projects once a semester or so. Providing suggestions of this kind will help define sensible projects for those without sufficient experience to do so themselves; it will also set the scope of realistic projects. Individuals independently raised questions or ideas (e.g. improving the archive) that resonated with a fair number of others in the room; it seemed that finding a forum to allow peers and near-peers to share experiences would be valuable. The Observatory might promote this by experimenting with supporting gatherings of those concerned. An offer that the Fellows could organize occasional "Fellows parties" to bring the younger scientists together is valuable, and the Observatory should provide reasonable financial support to encourage the interaction. The goal would be to allow those interested to share their experiences and to forge connections between those with common interests, as well as a perhaps anonymized conduit to feed concerns back to Observatory management.

4. Recommendations and observations for the future

a) Increasing the SMA's impact; distribution of observing time

As in previous years, the Committee again states its recommendation to better balance the distribution of observing projects and time allocations. A mix of individual and large projects is healthy and needed. Large projects, if chosen well, will have higher impact than many small ones.

While some of the highest-visibility results from the SMA have been the integrated effort from small programs, the overall impact would be higher had these studies been united as coherent bodies of work. As a measure of this, although the SMA's publication rate is impressively high, its citation number (13,282 citations to 570 refereed papers by 272 unique first authors at the time of the visit) is only moderately high when compared with the citations for individual prolific senior authors. To the extent that citation numbers represent impact, the SMA can do better.

The SMA's citation history shows the value of larger projects: of the 18 papers with 100 or more citations, about half come from SMA participation in multi-instrument, multi-institution projects even though the small-project papers dominate the number of publications. Developing focused strong projects that lay groundwork or provide complementary data for ALMA and other "data factories" will give CfA and ASIAA staff advantages for other proposals and will increase the Observatory's impact.

The Committee recommends that approximately 20%, but no more than 40%, of time go to large projects. The lower limit, somewhat less than a quarter, is sufficient to have impact and allow evaluation during an exploratory period without dominating the observing program; the upper cap, somewhat less than half, preserves priority for the more flexible smaller projects. A key element is to identify the person who will lead each project, someone whose scientific interests are directly aligned with the project. This person must have the time necessary to complete the project. We suggest that the possibility of leading such a project could attract SMA Fellows, with the proposal part of a fellowship application.

Proposals for large projects must be refereed by topical experts to ensure that the investment is worthwhile. Establishing a referee path parallel to the usual one, as has been the case so far, seems to work well, but augmenting reports for the regular TAC is another. In any case, the TAC must be in the loop to enable coordination. Large project proposals must be announced in advance of the proposal calls to allow the TAC and proposers to adapt to the priority that a large project will have in given LST ranges. The proposals need thorough technical vetting and resolution of problems before they start. A modest data management plan that identifies intermediate milestones is important to ensure that the project is on track to produce reasonable results in a reasonable amount of time. These milestones may also be useful in setting proprietary data periods if the project can be divided into sub-parts. Project management must be geared to get data and results out as quickly as possible.

These comments covered large projects, but one of the SMA's strengths is its flexibility and ability to tackle projects at the individual PI scale. Such programs range from exploratory to small samples. The present TAC process works well for these. The Committee also examined the Director's Discretionary Time (DDT) and Targets of Opportunity (TOO) programs, which run well.

To build on the SMA's advantages of flexibly scheduling small projects, the committee suggests an additional path to short programs refereed on a timescale much shorter than a semester. These would allow quick confirmation of other results, brief tests of ideas for larger proposals at

the SMA and elsewhere in time to align with proposal deadlines elsewhere, and similar programs. The latter proposals can be rather loosely refereed since the time investment is small. This path would be less than, say, 20% of the observing time in a given semester. The idea is to draw users with a kind of advertised Director's Discretionary Time path to data (the rapid track would logically accommodate some or many of the proposals currently run through the DDT process). This would be a clear and positive contrast with e.g. the ALMA data timescale.

Having suggested a number of interlocking small and large projects, the Committee also strongly recommends that the TAC should keep a high priority on assigning time to complete projects in good time even if this limits the total number of projects in any one semester.

b) Technical developments

The Committee discussed the SMA's choices of receiver bands. It was wise, even if disappointing, to drop operation at 690 GHz despite heroic efforts and significant results. The Committee strongly endorses a 210–270 dual polarization receiver as highest priority, both for observations with the SMA alone and with the EHT. The high frequency limit is important for dust continuum emission and molecular lines. Sensitivity to lower frequencies in the band is desirable but should not be a design driver. The Committee notes that while only part of the Receiver Lab's activities directly affect the SMA, the Receiver Lab and its collaboration with ASIAA on SIS devices is world-class, and maintaining the excellent staff is a benefit to the SMA, the CfA, and ASIAA.

In looking to the future, the Committee strongly suggests to building the Observatory's capabilities in digital signal processing (DSP). In the near term completing and upgrading the SWARM correlator is a critical priority. Bandwidth expansion past the current SWARM would be natural. Receiver development is leading in this direction, and further digital work would enable this expansion. In a broad view, DSP is an essential element in all modern instrumentation, whatever the wavelength, and a strong DSP group will be an asset for both the CfA and ASIAA.

c) Partnerships

The CfA-ASIAA partnership continues to prosper and mature, most visibly in the technical realm, but in science as well. Adding other partners could benefit both the CfA and ASIAA without jeopardizing their relationship. Exploring sales of time is interesting, but funding should be tied to specific benefits to the SMA (e.g. specific postdocs, staff, or equipment upgrades). It is important to ensure that the cost of the time would be accurately assessed. A clear understanding between the Observatory management, the buyer, and the TAC about how the time is to be awarded and scheduled is absolutely necessary.

d) Archive

Improving the archive is important for capitalizing on the SMA's results, inside and outside the CfA. Authors are more likely to use and cite results when they are able to apply data to their own papers. This is another potential way to increase the impact of the SMA. The Committee believes that a basic archival database, possibly with a simple data retrieval utility, could be provided largely by refocusing the effort that goes into the current archive. Given that reductions

are done to provide basic quality assurance, it seems that much of the effort needed in producing an archive is already being done, with the only additional work being to upload raw and calibrated data files, and to provide reasonably calibrated images in FITS format. The largest new task would be in getting observation metadata into searchable form to allow straightforward searches for sources and frequencies. A combination of metadata, quick-look reductions, and raw data will enable interested users to identify sources of interest and to pursue more extensive reductions on their own without further support. Enhancing the current archive should not draw significant effort from supporting completion of existing programs, however.

e) The Event Horizon Telescope

The EHT is a high scientific priority project with the potential for fundamental discoveries. The SMA has a crucial geographic role in the most important task: imaging the event horizons of the black holes at the center of our and other galaxies. The SMA technical staff can continue to play significant roles in instrumentation and data reduction. EHT needs should have high priority within observatory planning, especially in hardware development, but should not be the main driver.

f) Strategic planning

The 2009 Committee on the Future of the SMA, chaired by Dr. Giovanni Fazio, produced an insightful and valuable report some 5 years ago. We encourage the CfA to reform a similar committee to produce a strategic plan with a five to ten year horizon within the next few years. On that timescale ALMA's capabilities for different types of projects, the needs of time-domain astronomy, practical goals for wider receiver and correlator bandwidth, and the SMA's maintenance needs will be much clearer. A strategic plan will provide valuable perspective for the staff and scientists who will be considering their effort relative to the SMA. Reliability to allow high-quality imaging for rapid response and program completion could be a dominant concern. In that case adding a ninth antenna to allow full operation with one antenna out for service (as is the case for the VLA) or failure might be desirable.