March 2018

ASAC Report to the ALMA Board

M. Aravena, H.J. van Langevelde (excused), J. Kim, K. K. Knudsen (remotely), K. Kohno, D. Marrone, R. Neri (remotely), G. Novak, N. Sakai (excused), E. Schinnerer (chair), S. White (deputy chair), & C. Wilson

General considerations

Since the last face-to-face meeting, Prof. Dan Marrone and Prof. Nami Sakai have joined ASAC while Prof. Munetake Momose has left ASAC. We would like to thank him for his many contributions to ASAC's efforts. Dr. Stephen White has been approved by the ALMA Board as the NA deputy ASAC chair.

The ASAC face-to-face meeting was held at the JAO, Santiago, Chile, on February 26th and 27th, 2018, with ten ASAC members present (Roberto Neri and Kirsten Knudsen remotely via videoconferencing) and two sending apologies due to other commitments (Prof. Huib van Langevelde and Prof. Nami Sakai). In addition, the ALMA Director Dr. Sean Dougherty, Deputy Director Dr. Stuartt Corder, and Observatory Scientist Dr. John Carpenter were present, as well as the three regional Project Scientists (Drs. Leonardo Testi and Al Wootten in person, Dr. Daisuke Iono via videoconferencing). The liaison of the ALMA Board Science Committee, Prof. Karin Öberg, joined for the discussion of permanent charge #4 and ad-hoc charge #2, and Dr. Crystal Brogan (NRAO) attended to present the correlator upgrade project.

ASAC appreciates the timely delivery of all the documentation and several presentations for this meeting prior to the meeting itself, which aids in ASAC's preparations and, when possible, gathering of feedback from the regional SACs. The clear responses from both the JAO and the ALMA Board to the ASAC report from the previous meeting were also welcome; such clarity allows ASAC to better understand the concerns involved and to provide meaningful advice.

John Carpenter presented a summary of recent science highlights, including a gallery of results from the first completed "large" project, the survey of protostellar disks. The spectacular images of diverse circumstellar environments were striking and will demonstrate the power of ALMA observations when ready for publication. In addition, the puzzling linear polarization properties of the HL Tau disk provide strong constraints on models for such disks. There continue to be more detections of CO and CII at high redshifts, tightly constraining the evolution of galaxies in the early universe. Another significant milestone was the first delivery of Band 5 science data. ASAC continues to be impressed by the release of wonderful science justifying the promise of ALMA's capabilities.

Eva Schinnerer's term as ASAC chair ends in June 2018, and vacancies are also arising for deputy chairs for East Asia and Europe. ASAC voted to nominate Stephen White (NA) to become the next ASAC chair, Kotaro Kohno as the EA deputy chair, and Kirsten Knudsen as the EU deputy chair.

ASAC welcomes the arrival of Dr. Sean Dougherty as the new ALMA Director, and would like to take this opportunity to recognize Dr. Stuartt Corder for his invaluable service as Acting Director during the interim period.

ASAC would like to thank the Observatory Scientist and JAO staff for their support of the meeting, including extensive videoconferencing activity. This support was essential for the participation of the remote members and the smooth running of the face-to-face meeting.

Permanent Charge #1. **Assessment of the performance of ALMA scientific capabilities: The ASAC shall indicate what information is required from the Joint ALMA Observatory (JAO) to perform this assessment.**

Recommendations/Issues:

- ASAC welcomes the changes to EOC planning intended to improve performance and efficiency in the development of new capabilities. ASAC believes that it would be valuable to receive regular updates on planned EOC activities in a formalized manner at its face-to-face meetings.
- ASAC notes the disruption to early operations in Cycle 5 (in particular affecting data quality assessment) caused by the simultaneous introduction of a large number of new software tools with a slow learning curve. ASAC recommends that ALMA avoid such disruption in the future by a more structured and better-designed approach to releasing critical tools.
- ASAC would like to hear an update on the outcome of the investigation of the data processing flow by the DMG lead at the earliest possible occasion.
- ASAC appreciated the detailed description of the options for spectral scans. ASAC notes the concern in the ALMA community regarding the slow implementation of more efficient spectral scan methods. ASAC recommends that the spectral scan capabilities be optimised and implemented with the shortest possible time frame, as there is a need for this capability from several communities (both galactic and extragalactic).
- At the face-to-face meeting, ASAC was disappointed not to hear an update from the mmVLBI team on the Cycle 4 data. ASAC was pleased that a report made available soon after the face-to-face meeting indicates that ALMA performed well and data reduction is underway. ASAC would like to receive an update on mmVLBI status and progress in time for its next face-to-face meeting.

Capabilities. ASAC was presented with the progress on the "Extension and Optimization of Capabilities" (EOC). ASAC appreciates the progress on this, and in particular that there is a priority plan for the EOC towards Cycles 7 and 8 (such as the data processing throughput, long baselines for Band 7, TP, and the implementation of the polarization capabilities). The progress on the polarization capabilities includes a range of aspects, and it is important that these become standard modes as soon as possible; ideally this will include polarization capabilities for ACA stand-alone observations. In March 2016, ASAC provided input, as requested, on the 5-yr plan for EOC, including what ASAC viewed as important developments of capabilities for the scientific output. To follow-up on the implementation of this plan, ASAC would like to have insights and clear feedback on the progress of this 5-yr plan. Aside from being able to follow the process, relevant feedback and information to the ASAC is also essential to ensure that the knowledge is sustained and made available for new ASAC members. Thus, ASAC would like to regularly receive an update that presents the status of the main items planned for implementation, as this allows the committee to track progress and ensures that all members have similar information.

Cycle 4 millimeter VLBI (mmVLBI) campaign. ASAC was disappointed not to receive an update on the mmVLBI progress at the face-to-face meeting, but subsequent to that meeting an update was provided to the committee. Without timely updates, ASAC is unable to provide informed feedback on the value of this important capability and its future potential. The update subsequently provided suggests that at least the ALMA component of the campaign was successful, which is gratifying to hear, and we look forward

to seeing further results from both Cycle 4 and 5 campaigns. Also ASAC notes that GMVA released the correlated mmVLBI data to the PIs in January 2018 while EHT foresees a release in April/May 2018.

Data processing workflow. ASAC is very concerned about the major problems caused by the introduction of the new pipeline software and observing tools at the beginning of Cycle 5. This has caused significant delays in the QA2 process and PI data delivery. For future situations of such large changes, it is very important to have much better prepared implementation plans and to be prepared for reversion - this goes not only for the pipeline, but for any implementation that could cause such significant delays in the data flow. ASAC is happy to see that the data flow and throughput is being investigated by the DMG lead and looks forward to hearing an update at the earliest opportunity. Priorities for the data processing workflow were presented for Cycles 7 and 8 (high frequency, sessions, polarization as a standard mode, and 'combined array'), and ASAC supports these priorities.

Spectral scan capabilities. ASAC was informed of the investigation of more efficient spectral-scan capabilities that are based on three different methods. Of these methods, one is already operational and a second is ready for implementation (the final option is still in an early stage of testing). ASAC was requested to address the question "What are the primary use cases and science requirements for spectral scans?" with the clarification that this will determine whether to optimize time/speed, simultaneous *uv* coverage, relative flux accuracy between tunings, etc. ASAC notes that the primary use cases span a wide range of topics, from single, compact sources to more complex extended sources, as well as both galactic and extragalactic sources. For **extended sources** (e.g., galactic star-forming regions), high-*z* lensed sources, and high angular resolution studies (e.g., nuclear regions of nearby galaxies), a **near-simultaneous *uv*-coverage is important.** If the *uv*-coverage differs significantly across the spectral scan, the relative measurements of the flux might be biased between different regions of the source or sensitivity may need to be sacrificed to obtain a common beam shape. In the cases where **lines from relatively faint sources** are being sought, for example redshift determination of high-*z* galaxies, sensitivity is key, and thus **optimising the speed/time is important**. In case of line surveys, a uniform sensitivity across the band is required. As a general comment, ASAC notes that there is a strong concern in the ALMA community that more efficient spectral scan methods still have not been implemented. ASAC recommends that the spectral scan capabilities be optimised and implemented with the shortest possible time frame, as there is a need for this capability from several communities (both galactic and extragalactic).

Permanent Charge #2. Assessment of the technical aspects of the ALMA system performance: ASAC shall indicate what information is required from the JAO to perform this assessment.

Recommendations/Issues:

- ASAC recommends further investigation of the sources of 12m array idle time and efforts to minimize this idle time.
- ASAC notes that the data backlog situation is still far from ideal. ASAC is particularly concerned about the large fraction (~15%) of data that was overdue (> 30 days) at the end of January 2018, as well as the long tail of delivery times for projects (e.g. pipeline-processed data that is delivered > 40 days after being fully observed). ASAC recommends development of a contingency plan for

the rest of this cycle that could support the ongoing efforts to minimize the backlog in the longer term.

- ASAC is concerned that the ACA observing queue is again likely to run out of projects during Cycle 5. ASAC recommends development of a long-term solution to this problem, particularly if Cycle 6 proposals do not provide a sufficient increase in time requests.
- ASAC reiterates the importance of collecting feedback from the PIs of the Large Programs in order to use their experience to improve the efficiency and success of these kinds of projects.

System performance. ASAC welcomes the continued efforts and good progress made in Cycle 5 so far to achieve relatively high observing efficiencies (>65% on average; goal: 80%). However, the overall system performance is still far from ideal. In particular, ASAC is concerned that large amounts of time in the 12m array have been idle in Cycle 5 (5-16%). ASAC recommends investigation of this issue and encourages efforts to bring these idle times to zero (set as a goal by JAO). These are critical for the productivity of the observatory.

QA2 process/data delivery backlog. ASAC values the progress made to reduce the data backlog during the last year, the efforts to improve the pipeline data workflow, and the goal to process and deliver 90% of the data within 30 days from observation. However, ASAC is concerned that there is still a significant data processing backlog (~400 datasets) for Cycle 5. This will likely increase with the forthcoming observations during this cycle when more compact arrays are used during the best weather months, which will also increase the observing efficiency. Along these lines, it is noted that part of the reduction of the Cycle 4 backlog was aided by the significant weather downtime in the winter. Given these concerns, ASAC recommends development of a contingency plan for this cycle that could support the ongoing efforts to minimize the backlog in the longer term. Furthermore, ASAC is worried that there is still a long tail of pipeline and manually processed projects that were only delivered after 40 and 60 days, respectively. While these correspond to a minor fraction of projects, and ASAC recognizes the conflict between processing the bulk of the standard observations and paying attention to outliers such as these, ASAC wonders if partial data delivery would be appreciated by the waiting PIs.

ACA observing. ASAC is concerned about the status of the ACA observing queue, which is again expected to run out of projects to observe in Cycle 5 in most LST ranges. The JAO presented a solution for the current cycle, consisting of resurrecting the ACA 7m array portion of ACA+12m projects that did not fit into the 12m array schedule. While this solution might ameliorate the current situation, it is unclear whether this will completely solve the problem. ASAC suggests developing additional ideas for Cycle 5 including, for example, the possible resurrection of timed-out Cycle 4 projects.

In addition, a couple of longer term solutions were discussed apart from the ones suggested by the JAO. It was recognized that the lack of projects in certain LST ranges was at least partly due to the relatively small variety of observing modes that can be performed with ACA standalone (for example, high-frequency and polarimetry observations are not an ACA standalone option). Similarly, the lower ACA sensitivity does affect the interest in high-z science with ACA standalone. Expanding the portfolio of observations that are offered with ACA standalone and further increasing the large project threshold for this array could help to reduce the under-subscription, although possibly at the expense of increasing the data backlog due to the “non-standard” nature of the data. Other possible options that were also discussed,

included: (i) performing community legacy projects (analogous to ESO public surveys) with input from the community (where members of the community would provide manpower to calibrate data, and thus not affect the backlog); (ii) having a separate deadline for ACA standalone ~1-week after the main ALMA deadline; or (iii) having a separate call and deadline for ACA standalone, ~6 months after the April deadline.

Feedback from large programs. ASAC recognizes the significant investment of resources and observing time devoted to large programs. Thus, ASAC reiterates the importance of collecting feedback from the PIs of these programs to look for ways to improve the execution of such programs.

Permanent Charge #3. Assessment of the science outcomes from ALMA: Statistics on publications, citations, press releases, web sites, etc. collected by the Executives shall be collated by the JAO, and analyzed by the ASAC.

Recommendations/Issues:

- ASAC would like to receive an update on how the improved collection of demographic data has been working at its next face-to-face meeting.
- ASAC reiterates that it would be good to separately break out SV data when tracking publication data. It understands that using the same scientific categories for both the publication statistics and the proposal review is non-trivial; however, this would be very helpful for tracking the impact of the different categories (as defined in the proposal review).
- ASAC would like to review the publication statistics and archival use on a yearly basis at its spring face-to-face meeting.

ALMA publications. ASAC received a summary of the ALMA publication statistics up to the end of 2017, and a summary on the use of archival data. ASAC is pleased to see the continued excellent output of publications over a wide variety of science topics. The super-linear increase in publications per year suggests that ALMA produces exciting results. About three-quarters of all publications use data from ALMA Band 6 or 7 (with roughly equal share between the two bands). Publications utilizing Band 3 data contribute about $1/6^{th}$, while Band 9 is used in $1/12^{th}$ of all publications to date. The recommended upgrade of receivers as part of the ALMA2030 roadmap is in line with the relative importance of the bands indicated by the publication distribution.

The median time between data delivery and first publication has slightly increased to about 16 months. This is not unexpected as both the average observing time per project and ALMA's capabilities have increased over the cycles, leading to richer datasets that would be expected to require more processing. It is worth pointing out that three years after data delivery more than 80% of all projects have at least one publication.

Archival data use. ASAC is also pleased to see the continued interest in the community to use archival data. In 2018 the volume of downloaded public data has doubled compared to previous years. The number of files downloaded is roughly constant back to Cycle 2 data, and science products (delivered since Cycle 1) are more than twice as popular as raw data. Up to now about one quarter of publications use archival data, with most of these publications relying on archival data alone. Similarly two-thirds of all projects result in two or more publications. The ALMA archive should become a major resource for science and

an important channel for amplifying ALMA's scientific output; the current trend confirms this potential.

Statistics. In addition to band-split publications, it would be useful to have graphs illustrating the statistics of publications for different array configurations. This information would allow ASAC (and ALMA) to understand which bands and configurations are most successful in leading to publications and which bands and configurations should be reviewed. ASAC re-iterates its request that publications from the SV (Science Verification) data should be broken out separately.

Permanent Charge #4. Recommendations of ways to maximize ALMA's scientific impact: This includes review of the scientific effectiveness of the Proposal Review Process after each Proposal cycle.

Recommendations/Issues:

- ASAC believes that it is too risky to implement the distributed peer review model at this time, given the fact that the proposed model has never been tested as the primary time allocation system at any major observatory.
- ASAC recommends to improve the current review system to make it sustainable, rather than adopt the proposed new distributed model. Specific suggestions are given that should help to reduce the workload of the review panel members.

The viability of the proposed distributed peer review model for ALMA -- The committee recognizes the fact that it is a challenge for the JAO to sustain the current proposal review system, both from the perspective of reviewer workload and of cost. ASAC appreciates the presentation of a detailed investigation of the distributed peer review (DPR) model, which aims at resolving this problem. However, from the viewpoint of science outcomes (i.e., getting the best science on the telescope), ASAC believes that it is too risky to implement the DPR model at this time given the fact that DPR has never been tested as the main time allocation system at any major observatory.

There are a number of open questions and concerns regarding the DPR including: (1) *impact and acceptance within the community*: it is unclear how the DPR will affect the number of ALMA proposals submitted, and raises issues for faculty with numerous ALMA-oriented PhD students; (2) *confidentiality*: it is not clear how confidentiality will be maintained, given the dramatically larger number of reviewers; (3) *loss of current reviewing contributions/expertise from outside the ALMA PI pool*: such as other wavelengths and theory; and (4) *robustness against potential biases*: a face-to-face meeting provides an opportunity to mitigate biases (e.g., language, scientific breadth, etc.) that the DPR lacks. In addition, regional balance of reviewers cannot be easily controlled in the DPR and the impact of this change remains unclear.

Proposed improvements to reduce the workload in the ALMA proposal review -- The committee suggests to increase the number of panels to reduce the number of proposals assigned to each reviewer. A specific plan is described as follows. Suppose there are 1650 proposals and 150 reviewers. If we have 6 reviewers per panel and everyone reads all proposals, then each panel will have 66 proposals and there will be 25 panels. Maintaining the triage of bottom 25%, this means ~50 proposals to discuss during the face-to-face meeting. At 5 proposals per hour, it takes 10 hours: a 2-day meeting will be enough for the face-to-face

meeting. A possible option is to do consensus reports afterwards. The present average, 70 - 80 non-triaged proposals in 2 days, implies 1.25 days of discussion in the proposed plan above.

If reviewers serve for 2 years, it is necessary to recruit 75 new reviewers and 13 new panel chairs each year (versus 50 and 6 per year in the current model). It would need 25 technical secretaries per year (versus 18 now). A possible alternative here is to do half the panels in the first two days in a week (i.e., Monday-Tuesday), another half in the next two days (Wednesday-Thursday), and then have a panel meeting for large programs (Friday). This plan has another possible feature: if reviewers served for 2 years with a 1-year break, then each year the group of reviewers would be new; e.g., panels will have fresh eyes on re-submitted proposals.

Further considerations on the reviewer recruitment -- ASAC recognizes that the JAO has already made intensive efforts to increase the pool of potential reviewers. ASAC further encourages the JAO to find additional paths, such as an example from ESO, where a database of panel member candidates gets input from the members of the Users Committee of the names of potential reviewers collected from the community.

ASAC also discussed the possibility of non-traveling reviewers as an option to mitigate the workload. In fact, there could be some people who have difficulty to travel abroad even for a few days due to personal circumstances (e.g., needing to take care of their parents or children, having a heavy duty in universities, etc.). Having a short (a few hours) telecon during the face-to-face meeting with non-traveling reviewers can help to build consensus in a panel. Although it would be impractical to have a telecon if non-traveling reviewers on a single panel are distributed across the whole 3 regions, some grouping of the non-traveling reviewers or having two separate short telecons could be an option.

Permanent Charge #5. Reporting on operational or scientific issues raised by the wider community as communicated by the three regional Science Advisory Committees (ANASAC, ESAC and EASAC).

Recommendations/Issues:

- ASAC would like to receive an up-date on the helpdesk and in particular the requests for proprietary period extensions at its next face-to-face meeting in October 2018.

No other issues under this charge were raised at this meeting.

Permanent Charge #6. Assessment of the scientific impacts of the ALMA Development Program, and particularly of new projects that are proposed.

Recommendations/Issues:

- ASAC recommends the implementation of the proposed first phase of the correlator upgrade project (higher spectral resolution and data rates) as an important step towards improving ALMA's capabilities. ASAC is aware that further development projects in support of the

correlator upgrade project will likely be proposed in the near future.

- ASAC recommends the Hardware-in-the-Loop (HiL) project, noting its ability to provide support both for the correlator upgrade project and also for future EOC activities. ASAC suggests that work on the HiL be started as early as possible. ASAC notes that additional resources will be required to maintain the HiL project.
- ASAC recommends the implementation of both the proposed EU development projects on the Band 2 vacuum lens and the Band 2 component optimization. ASAC views both efforts as critical towards a successful implementation of Band 2 receivers on the array.
- ASAC plans to comment on the proposed metrics to evaluate the scientific value of a narrow-band Band 2 versus a wide-band Band 2+3 receiver (that it received before submitting thhis report) and expects to provide input on the scientific evaluation of the up-coming Band 2 (+3) decision.
- ASAC does not recommend to pursue the proposed re-imaging project in its present form, but suggests that such an effort be re-considered in view of current limits on pipeline data processing.

Phase 1 Correlator Upgrade Project -- Phase 1 of the upgrade to the correlator, with an increase in spectral channels of a factor of 8, will provide a major improvement in ALMA's capabilities independent of other hardware changes (e.g. receivers). It will provide the ability to measure velocities as low as 10 m/s in Galactic sources including prestellar cores, protostellar cores, and protoplanetary disks. It will allow ALMA to fully exploit the current bandwidth at high spectral resolution, thus speeding up spectral scans by factors of order 4. By providing the velocity resolution necessary to measure motion in disks at lower frequencies where opacity is lowest, it should greatly impact planet formation studies.

ASAC recognizes that there will be a significant loss of observing time during the implementation of Phase 1 of the correlator upgrade, and that this will be a concern to the community. However, ASAC feels that the resulting improvement in capability justifies the gap in observations, and notes the measures taken by ALMA to minimize downtime and prepare for possible difficulties during the installation. ASAC recognizes that the Hardware-in-the-Loop project (see below) is an important part of planning to achieve maximum efficiency and minimum downtime in the upgrade. Furthermore, ASAC is aware that further development projects in support of the correlator upgrade project will likely be proposed in the near future.

Hardware-in-the-loop (HiL) project -- The HiL project is an upgraded simulation platform that will serve as a test bed for hardware upgrades. It reduces the testing time of new hardware and it is expected to allow more time for science programs. ASAC highly recommends the HiL project, not only because the HiL project is an essential component for the efficient installation of the upgraded ALMA 64-antenna correlator, but also because it is potentially useful for a variety of future EOC activities beyond Cycle 8. ASAC also notes that a delay in the implementation of the HiL project might potentially have an impact on the schedule of the phase 1 of the correlator upgrade project, and recommends the earliest possible start for HiL project to minimize competing demands for required personnel. ASAC was assured that the extra resources required to maintain the HiL project would not be a significant drain on the JAO, but this needs to be tracked.

ALMA Band 2 cartridge -- ASAC received an update on the progress of the Band 2 receivers including the PDR report of the Band 2+3 cartridge. ASAC was happy to see that there is now a clear path forward for a Band 2 receiver, which has as its goal to use the best technical solutions available. The two proposed EU development projects for Band 2 allow for achievement of this goal, with all partners having the option to participate. The proposed scheme in which some technical decisions are to be taken at a Gateway review as part of the production process does carry some extra risks. ASAC learned that a document exists describing the comparison matrix to be used to assess and decide on the final Band 2 performance and received this document before the submission of this report. ASAC plans to comment on this document by its next telecon. ASAC expects to provide scientific input on the final decision between a narrow-band or wide-band solution for the LNAs for Band 2.

ALMA re-imaging study -- The EU re-imaging development proposal seeks to provide a homogeneous and more complete set of image products in the ALMA archive by re-imaging data from Cycles 0-4 using the Cycle 5 imaging pipeline. The related EU development study presents an extensive analysis of a number of aspects of the current archiving process, as well as science cases and the results of re-imaging tests. The study notes that ~15% of ALMA publications make use of archival data, and makes the argument that improved archive products would enhance the scientific output of ALMA. ASAC agrees with this argument, as noted in our ALMA 2030 Development documents. However, the re-imaging proposal fails to take into account a number of properties of the current pipeline that will affect its results:

- Data from Cycles 0, 1 & 2 are not suitable for the Cycle 5 imaging pipeline because it requires the presence of metadata describing the sensitivity of the observation, taking into account features such as spectral averaging in the correlator and spectral window merging. Without these metadata the CLEAN threshold is not set correctly by the pipeline. These important metadata are not available in datasets acquired prior to Cycle 3.
- In addition, the pipeline is optimized for the >40-antenna arrays used in the current cycle and does not work well with the smaller arrays used in Cycles 0 & 1.

The topic of archive content raises another issue that needs to be addressed for longer-term usage. Currently the data are imaged in each channel in one spectral window as long as the resulting image cube is not so large (> 30 GB) as to be difficult to load on modern computers. However, most of the image cubes in the archive are filled with channel planes that contain only noise and thus do not add any real value. Instead of simply archiving every channel that is mapped, more sensible choices would make the archive more useful. ASAC acknowledges that this is not a simple change, but notes that intelligent software capable of such choices is desirable in the long term. The relevance of this topic for the re-imaging study is that the value of adding to the archive more large but almost entirely empty spectral cubes representing a single spectral window in each project probably needs more thought.

ASAC therefore does not recommend proceeding with the re-imaging proposal in its current form. The archive may benefit from reprocessing of data from Cycles 3 & 4, but sensible choices should be made about the products provided. In particular, the re-imaging team needs to involve the pipeline team in developing any new concept for re-imaging in order to ensure that the proposal is compatible with the operation and capabilities of the pipeline.

Ad-hoc Charge #1. ASAC assess whether ALMA's level one science goals have been met and whether the proposed new fundamental science drivers as stated in the ALMA Development Roadmap are appropriate.

Recommendations/Issues:

- ASAC find the statement that the three original science goals have essentially been achieved is defensible.

ASAC believes that the three original level-one science goals have *essentially* been achieved. They are reproduced here for reference:

- *Goal 1*: The ability to detect spectral line emission from CO or C+ in a normal galaxy like the Milky Way at a redshift of $z = 3$, in less than 24 hours of observation.
- *Goal 2*: The ability to image the gas kinematics in a solar-mass protostellar/ protoplanetary disk at a distance of 150 pc (roughly, the distance of the star-forming clouds in Ophiuchus or Corona Australis), enabling one to study the physical, chemical, and magnetic field structure of the disk and to detect the tidal gaps created by planets undergoing formation.
- *Goal 3*: The ability to provide precise images at an angular resolution of 0.1″. Here the term "precise image" means an accurate representation of the sky brightness at all points where the brightness is greater than 0.1% of the peak image brightness. This requirement applies to all sources visible to ALMA that transit at an elevation greater than 20 degrees.

Numerous publications now effectively address these level-one science goals. Examples are:

- ALMA has imaged "normal" (defined as locally typical) galaxies in [CII] at redshifts of $z > 4$ in Band 7, and in both CO and [CII] in $z > 3$ (gravitationally lensed) galaxies. [*Goal 1*]
- Keplerian disks have been imaged around protostars in nearby molecular clouds at a distance of 150 pc and CO observations have demonstrated the gas kinematics. [*Goal 2*]
- Multi-wavelength polarization observations of the HL Tau disk have been made by ALMA and shown to constrain dust properties and the magnetic field geometry in this disk. [*Goal 2*]
- The goal of precise imaging is satisfied by the high-fidelity, high-resolution (0.03") HL Tau disk continuum image produced during the long baseline campaign [Goal 3], revealing gaps that likely result from planet formation. [*Goal 2*]

Ad-hoc Charge #2. Deeper Assessment of the scientific motivation for 2-year versus 3-year configuration schedule.

Recommendations/Issues:

- From the perspective of science outcomes, ASAC continues strongly to prefer a 2-year configuration schedule. ASAC finds that a 2-year configration schedule will serve a broader range of science themes. In addition, a 2-year schedule is better suited to the needs of graduate students and has a smaller impact on the ability to complete A-ranked proposals that carry over to the next observing cycle.

- Recognizing that tradeoffs in capabilities must be made, ASAC recommends prioritizing (1) long baseline configurations and (2) high frequency observations in compact configurations during the June/July/August period of good weather, in alternate years of a 2-year cycle. These priorities should be reviewed in a few years to see if they are consistent with ALMA's evolving capabilities, the science opportunities, and proposal pressure.
- ASAC would like to see the final optimized configuration schedule for the 2-year plan, including an assessment of the completion likelihood of grade A projects, at a future meeting.

ASAC renewed their discussion of the question of a 2-year versus a 3-year configuration schedule for ALMA. Feedback was also solicited from the EASAC, the ESAC, and the ANASAC. The ASAC reviewed the materials submitted by the Observatory Scientist, which included the distribution of requested weather bands and configurations as a function of LST and science category in Cycle 5. ASAC certainly understands the scheduling constraints imposed by the prevailing weather patterns on the altiplano. ASAC finds that the need to use the best weather months (June/July/August) for either high frequency observations (in relatively compact array configurations) or for the longest baseline configurations (at a variety of frequencies) was scientifically more compelling than the argument to use a significant amount of this time for intermediate (0.1-0.3") configurations. The ASAC feels that community interest in observing at the highest frequencies is not yet at the level that it could be and that this lower level of interest may be linked to the difficulties in proposing for and then obtaining high quality data in these severely weather-challenged bands. Emphasizing the compact configurations at this time will allow the community to gain more experience and expertise in the high frequency capabilities with ALMA.

Thus, consistent with the recommendations in the October 2017 ASAC report, ASAC strongly recommends a 2-year configuration schedule for ALMA. ASAC recommends prioritizing long baseline and high frequency observations during the June/July/August period of good weather in alternate years of a 2-year cycle. This recommendation is consistent with ASAC's long-term priorities of implementing ALMA's most unique capabilities, which are high angular resolution and high frequency. These priorities should be reviewed in a few years to see if they are consistent with ALMA's evolving capabilities, the science opportunities and proposal pressure.

ASAC has identified some detailed scientific cases that support this recommendation. One of the strong scientific cases for observing at high frequency in the compact configurations is nearby galaxies. In particular, observations of atomic carbon in Band 8 are best suited to compact rather than intermediate configurations. Atomic carbon is important as an alternative tracer of molecular gas and also a tracer of photon-dominated regions. Another nearby-galaxy science case is to observe CO(6-5) to trace the warm molecular gas. Again, compact configurations will be very useful, although C43-4 and C43-5 look promising for very bright sources such as Arp 220.

Another strong scientific case for high frequency observations in the compact configurations comes from high-redshift galaxies. Observations of [OIII] at $z \approx 7$ in Band 8 probe this important line (known to be strong in low metallicity galaxies in the local Universe) near the Epoch of Reionization. Some recent ALMA observations suggest that the [OIII] emission can be extended over regions of ~1". [CII] imaging of normal star-forming galaxies at z=1-2 in the peak epoch of cosmic star formation fall in Band 9 or 10

and will benefit from the maximum sensitivity available with compact configurations. In addition, the 0.2-0.5" resolution available in the configurations and bands is a good match to the 1-2" sizes of galaxies at these redshifts.

ASAC considered the effect of this recommendation on ALMA's ability to observe high-mass star forming regions and the Galactic Center, which are best positioned for observations in the same June/July/August period. The sample configuration schedule prepared by the Observatory Scientist visits all configurations except for C43-1 (the most compact) and C43-7 (the largest "intermediate" configuration) during the period May 15-Sept 1 at least once over the two year cycle. ASAC feels that this configuration coverage should provide sufficient opportunities for observing high-mass star formation targets at whatever frequencies were required.

ASAC also feels strongly that a 2-year configuration schedule would better suit the needs of Ph.D. students (who can have programs as short as 3 years duration). The 2-year configuration schedule also offers the advantage that a higher fraction of the A-ranked proposals that are not completed in their first observing cycle will have a chance to be completed in the subsequent observing cycle, whereas the delay in completion may be much longer in a 3-year cycle (assuming that guidelines would be changed to allow A-ranked proposals to be held over for 2 years if needed).

It is clear that the ability to complete either high-frequency or long baseline observations in the following observing cycle is likely to be nearly impossible in any of the configuration schedules that were presented. However, with a 2-year configuration cycle, the maximum gap between a configuration being offered is only 1 year, compared to the possibility of a 2-year gap if ALMA adopts a 3-year configuration cycle. ASAC is concerned that having too long a delay in the opportunity to get ALMA data for a particular project could lead to a loss of interest in using ALMA in communities that might be particularly strongly affected by the 3-year configuration cycle.

ASAC understands that a final optimized 2-year configuration schedule would likely be quite similar to one of the two options presented by the Observatory Scientist. In order to reduce time lost to reconfiguration and provide more flexibility for intermediate-length configurations, ASAC considers that it would be acceptable to omit the largest configuration (C43-10) in the year in which ALMA is in compact configurations for high frequency observations in June/July/August. An alternative that may be worth considering is retiring the smallest of the long baseline configurations (C43-8) while making C43-7 a little bigger and C43-9 a little smaller, ending up with 9 configurations instead of 10 but being able to visit all 9 configurations every year.

ASAC would like to see the final optimized configuration schedule for the two-year plan, including an assessment of the completion likelihood of grade A projects, at a future meeting.