



# The Future Evolution of ALMA

The ALMA Development Program

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## Board Resolution

- The ALMA Board has charged the project to develop a long term ALMA Development Plan in consultation with the international astronomy community. The plan should set out the scientific context for transformational science with ALMA in 2020, in the era of for example JWST, ELTs and SKA, and the developments necessary to achieve this vision. The ALMA Board views this plan as having the utmost strategic priority, and is coordinating its development across the entire ALMA partnership.



# The Process

- The idea is to do something similar to the Gemini Aspen process...
- Develop a scientific context document that says where ALMA should try and be scientifically in 2020
  - i.e. in the era of JWST, ELTs and SKA
- This should be a pan-chromatic perspective driven by where we see the science going
  - perspective should incorporate ALMA's appeal to non-sub-mm/mm specialists
- The resulting science perspective should inform the ALMA Board on the direction of technological R&D needed to allow ALMA to remain a transformational instrument well beyond 2020
- As such the process should be informed about the technical possibilities and their possible timescales – for example
  - All receiver bands – relatively easy
  - More antennas – simple but expensive
  - Wide field imaging utilizing focal plane arrays – difficult and expensive
- Produce an agreed long term development plan



# The Process

- Stage One: Preliminary Report
  - The process of generating the ALMA Development Plan should be led by the JAO Project Scientist and the ASAC (with support from the Executives)
- Stage Two: Regional Input
  - Preliminary report distributed to Executives and used for any necessary regional activities
- Stage Three: Implementation Plan
  - The JAO and the Executives meet to develop an implementation plan
  - Plan is presented to the ALMA Board for review
  - Agencies decide which components of the plan they wish to pursue
- Stage Four: Implementation
  - Board agrees a long term (five year?) program of work and associated funding
  - JAO solicits a call for proposals from the Executives to carry out the plan
  - JAO recommend a program of work to the ALMA Board



# Current Level 1 Science Requirements

- 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.
- 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.
- The ability to provide precise images at an angular resolution of 0.1". Here the term precise image means accurately representing 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. These requirements drive the technical specifications of ALMA.



# Future Directions

- Can classify developments into three broad areas:
  - **Restoring Capabilities** that were once envisaged but were dropped either during or prior to rebaselining
  - **Improving The Baseline System** by upgrading or replacing sub-systems
  - **Transformational Upgrades** that require replacing a large amount of the existing hardware and possibly a long term R&D program, but that radically transform ALMA's capabilities
- Need a science perspective and context for all of these



# Restoring Capabilities

- Scope was removed both prior to and during rebaselining
- An obvious Development Program activity is to replace this missing scope
- Just because they were once dropped, does not mean we should automatically plan to add them back in
  - The science context for ALMA in 2020 has to justify it
- Key items are:
  - Missing Receiver Bands: Band 1, Band 2, completing Band 5
  - More subarrays
  - VLBI capability



# Restoring Capabilities

- Antennas
  - It is very unlikely that additional antennas will ever be part of the Development program
  - However a science perspective on the case for additional antennas would nevertheless be very useful
  - Think about this problem from two perspectives
    - The case for a more antennas to improve image fidelity & collecting area
    - The case for more antennas to guarantee that we have a minimum of 50 antennas in operation all the time



# Improving The Baseline System

- There are many likely improvements that could be made to the baseline system as technology improves
- An incomplete list is
  - Receiver upgrades: improved sensitivity and stability of the cartridges as improved mixers become available.
    - Requires an ongoing technology development activity.  
Improvements may be feasible at all Bands.
  - LO upgrades: improvements to the LO systems to improve the phase stability of the system



# Improving The Baseline System

- WVR upgrades: as we learn more about phase correction a next generation WVR system may well be desirable
- Polarimetry: developing a dedicated deployable polarimetry systems with rotating waveplates
- Keeping the correlator data: the correlator have very high time resolution, but we can't presently keep the raw data
- Software upgrades:
  - improve data taking efficiency
  - new algorithms
  - improved heuristics
  - ???



# Transformational Upgrades

- Upgrades that are very expensive and require a long term R&D program would have to have a big payback
- Possible examples of this would be:
  - Increasing the continuum sensitivity of ALMA by taking in the entire atmospheric window
    - Requires detector development, new DTS, new correlator
    - Are the gains enough to justify this?
  - Simultaneous observations are multiple frequencies
    - Requires new DTS, LO upgrades, possibly new cryostat, new correlator (or bandwidth tradeoff)
    - Is this worth it, or are the differential S/N issues too limiting?



# Transformational Upgrades

- Focal Plane arrays
  - Huge R&D project
  - Not clear what is actually possible (would need considerable R&D/study to scope out what may be possible)
  - New Receivers, new DTS, new correlator
- 200 micron ALMA
  - Even though the antennas are falling off and the transmission is not as good as the highest peaks, the huge collecting area makes this an interesting idea to consider IMHO
  - Would need Band 11, LO, possible antenna upgrades TBD?



# Transformational Upgrades

- New ways of thinking...
  - Should the ALMA partnership be considering ALMA science in a more holistic way?
  - For example should some of the projects that do surveys to find sources for ALMA follow-up be considered as fair game for the ALMA development program?
  - Or should these issues remain regional ones?