## 2.9 Science IPT

During October-December, Science IPT activity concentrated on ALMA calibration, imaging, operations, and configuration considerations. Specific focus lay upon the final revision of the draft ALMA Science Requirements document, preparation of the ALMA Calibration Strategy Plan, completion of the Design Reference Science Plan, construction of an Operations Plan in concert with the Operations Group, including how the plan described in Chapter 6 of the Project Plan might be improved, and also how the ALMA Science Center will operate. During this period a transition occurred in EU Project Scientist from Ewine van Dishoeck to Tom Wilson. Brian Butler left the ALMA Science IPT at the beginning of the period.

Joint NA/EU Science IPT staff and Calibration Group telecons were held monthly, and the weekly NA Science IPT telecons continued, beginning their sixth year (Agendas and notes for all meetings are available; this period's include telecons on 7, 14, 20 (Science IPT), 28 October; and 11, 18 (Science IPT) and 25 November and on 2 December. During these telecons, progress on action items is tracked toward meeting milestones and assignments (new action items) are made to assure their timely completion. One Level 2 Milestone scheduled during October-December 2003 has been postponed owing to its Lead, Brian Butler, departing close upon the heels of another key figure, Stephane Guilloteau. A recovery plan was implemented and the Calibration Strategy is expected to be complete by 2003-Dec-31. There was one level 3 milestone met during the period and one of Level 3 and below was deferred owing to departure of the responsible party.

*Scientific Advisory Committees*

The Science IPT arranged the agenda, minutes and telecon for the monthly ASAC telecons (held on 12 November and on 3 December 2003; agendas and minutes in ALMAEDM). The Science IPT supported the ASAC as it developed its report presented to the ALMA Board in Santiago on 4 November 2003. The Science IPT also made the report available to other IPTs through general announcement and placement upon the ALMAEDM web site. The Science IPT leads attended the ALMA Groundbreaking ceremony and publicized it through dissemination of a web page of photographs from the event, a collected booklet of speeches given at the ceremony, and an article for the Executive Newsletters. The Science IPT assisted the ASAC, after its request, through suggestion of specific charges which might be given to the ASAC from the ALMA Board. Related to the ASAC are the ALMA North America Science Advisory Committee (ANASAC) group and European Science Advisory Committee (ESAC) also held telecons. In conjunction with the ANASAC and NRAO, the NA Science IPT planned a town meeting to be held at lunchtime on January 8, 2004 during the American Astronomical Society meeting in Atlanta. Planning commenced for a general North American ALMA Science Meeting to be held at the University of Maryland conference center on 14-15 May 2004. These meetings, and the plans for the ALMA proposal review process were the subject of an ANASAC telecon held 10 October.

**Science Requirements**

The ALMA Scientific Requirements was submitted as draft ALMA-90.00.00.00-002-A during the last quarter. Some final changes were made to the document during the present quarter. The Science Requirements document provided standards against which, for example, plans for the ALMA correlator critical design review, held in early October, could be compared. Wootten attended the Correlator CDR as a member of the Committee and provided the comments in the Committee report on how the correlator would meet the science goals of ALMA.

**Design Reference Science Plan**

The Design Reference Science Plan was completed and presented to the project in December. Pseudo-proposals were collected for 4 themes and 21 sub-themes from the ESO proposal and from topics addressed at the 1999 ALMA Conference in Washington. The Design Reference Science Plan attracted over 113 proposals from 75 scientists. After an initial assessment by the ASAC in early September 2003, additional DRSP's in missing subthemes were received by mid-October, bringing the total number of DRSP entries to 128. The results were collected into web-accessible format, and also placed into a worksheet format for easy statistical study. Virtually all of them have been reviewed by ASAC members and their comments have been circulated back to the authors for replies and further updates. These updated versions form Version 1.0 of the DRSP.

This Plan has 4 themes (Galaxies, Star- and Planet Formation, Stars and their Evolution, Solar System) and 21 sub-themes. For each sub-theme, a leader was appointed, chosen from the Science IPT, ASAC, ESAC or ANASAC, including observers from Japan and Chile. These leaders were free to enlist the help of other scientists in the community. ASAC, ESAC and ANASAC members were encouraged in general to involve their communities, although no formal `open call' was made. The (sub-)leaders were asked to use the science cases described in the ESO document as a guideline, but there was no requirement to follow them in detail. Spontaneous submission of programs by astronomers from the community were also accepted, including (sub)topics which were not in the earlier ALMA science compendia. The final list of programs can be found at http://www.strw.leidenuniv.nl~joergens/alma

A single set of sensitivities was used for estimating all integration times. Authors were instructed to use the calculator on the ESO ALMA Web at:

http://www.eso.org/projects/alma/science/bin/sensitivity.html

The formulae used in this program are given in ALMA memo 393 by Guilloteau (Figure 1) and take into account that the highest frequency observations will only be done under the best weather conditions. The time estimates do NOT include overheads, nor any downtime due to weather and/or technical problems. Detailed estimates of the overheads due to fast switching have been made by Holdaway (ALMA memo 403 and Calibration Plan), and result in a loss of about 20 % in sensitivity due to the time spent on

the calibrator and slewing as well as decorrelation. This translates in a time loss of at least 30% to reach the same sensitivity on source. Additional time losses due to amplitude, bandpass, focus, delay and polarization calibrations have to be added. The fraction of time lost due to weather (either opacity, phase stability or winds out of specification) is estimated to be at least 10%. Thus, the current DRSP including overheads will take at least 4 yr. Some conclusions, based upon the initial DRSP, were presented to the ASAC in September and were included in the previous Quarterly Report.

As suggested by the ASAC, future upgrades of the DRSP may contain a greater amount of technical detail to be specified in the observing proposals. These include:

- accounting for realistic observing overheads in the time estimates
- estimating data rates required by each project
- quantifying the time required for ACA and single-dish imaging
- specifying in detail the mosaicking patterns required
- detailing the correlator set-up
- establishing the flux calibration requirements for each proposal
- clarifying in detail how polarization projects will be observed and calibrated, both with and without use of the quarter wave plate at 345 GHz

In addition, once Japan has officially joined the project and its contributions are confirmed, DRSPs which make use of the additional receiver bands should be added.

The ASAC also recommends that a similar document be prepared which covers typical proposals expected during interim science from 2007--2012 when only a limited number of antennas will be available.

One ALMA Science memo was published in the period:
*ALMA Memo 475* Observing Stars & Extrasolar Planetary Systems with ALMA Bryan Butler, Alwyn Wootten, & Bob Brown

**Calibration**

The Calibration Strategy for ALMA will be finished in its draft form at the beginning of the next quarter. In twelve major sections, all elements of ALMA calibration will be addressed. For each, a description of the calibration technique will be provided, along with a description of hardware required and a note of the budgeted allocation for this hardware, with references. For each, the frequency of the calibration observation and the dependence of frequency upon wavelength will be discussed. Quantities to be archived will be detailed (along with the rate), and it will be noted which systems will need to access them. If a particular calibration device involves another IPT, the need for an ICD

will be noted and all ICDs required tabulated. Furthermore, for each technique there will be a note of what further tests and/or development is required, with a recommended implementation plan.

Tests of the semitransparent vane amplitude device installed at the IRAM 30m telescope will be concluded, with observations of astronomical targets, early during the next quarter. A memo on passband calibration will be published during the first quarter of 2004. It is expecteded that a set of procedures will be available shortly.

As a result of discussions on phase calibration, one memo has been published:

*ALMA Memo 478* Distance to Possible Calibration Sources as a Function of Frequency for ALMA Bryan Butler

**Configuration, Antennas**

The main activity in this quarter centered on interaction with the Operations Group members of the Science IPT, to achieve a model for the configuration of ALMA during the Early Science period.

Members of the Science IPT also participated in the Antenna Call for Proposals, providing comment on the antenna specification and other documents. At a Science IPT telecon on 11 November; discussion on antenna specifications document included study assignments on science implications for various specific specifications. Comments, including simulation results on the effects of the lower acceleration values requested in the revised specifications, were delivered to the JAO and are available at NA Science IPT telecon agenda of 18 Nov, where further discussion ensued. An ancillary memo was submitted to the ALMA Memo Series:

*ALMA Memo, Rejected.* Notes on Axis Intersection for MMA Antennas Bryan J. Butler

**Site Characterization**

The Site Characterization group kept the flow of data from the site coming through the austral winter. Two memos summarized site characterization data:
*LAMA Memo 801* Joint Distributon of Atmospheric Transparency and Phase Fluctuations at Chatnantor Larry D'Addario and Mark Holdaway

*DRAFT LAMA Memo 803* Simulation of Atmospheric Phase Correction Combined with Instrumental Phase Calibration Using Fast Switching. M. A. Holdaway and L. D'Addario.

**Organization, interaction with other IPTs**

A monthly telecon continues for the whole Science IPT, and there is a weekly telecon of the NA Science Team. Topics under intense discussion continue to center on the calibration plan, discussed in several telecons of the Calibration Group. In addition,

several discussions on Operations and on imaging, particularly with respect to amplitude stability, were held.

Science IPT was represented at the AMAC meeting by van Dishoeck, who made presentations on the Science IPT and on the Design Reference Science Plan. Wootten and van Dishoeck both represented the Science IPT at the Board meeting in Santiago in November and at the subsequent ALMA Goundbreaking ceremony.

The Science IPT held discussions with the FE IPT on tests of calibration devices. A plan for further tests was conveyed, including the design of the design of the amplitude calibration device described in ALMA Memo No. 461. Implementation of this device in the Array was sought by way of a change request.

The Science IPT participates in the Operations Group. Version E of the Operations Plan was written as of the end of December, for further iteration toward an end of the year submission to the Project.

A major activity has been construction of the Calibration Plan, some details of which are described above.

Stability issues for the system were also discussed at the telecon preparatory to a telecon with SE and FE on 13 November. At the latter telecon specifications were agreed between the three IPTs. At a later meeting of the Change Control Board, gain stability specifications were adopted. For the ALMA system, gain stability must not be worse than one part in $10^{-3}$ in one second. On the total power antennas, system gain stability must be better than 4 parts in$10^{-4}$ $s^{-1}$ total. Sramek noted that the Systems group would then settle on an allocation of 7 parts in $10^{-4}$ $s^{-1}$ to front end and same to back end. Out of 80 ALMA needs four receiver packages which meet this specification. It was noted that good polarization measurements require better than five parts in $10^{-4}$ $s^{-1}$ over five minutes gain stability as in the original draft specification.

Loosened phase stability specifications proposed by D'Addario express more pessimism about schemes for removing atmospheric phase instabilities than those expressed by the Science IPT. Fast switching simulations, much more elaborate than any heretofore designed, were carried out by Holdaway in coauthorship with D'Addario. These simulations have been published in draft form and details continue to be worked out. However, the bottom line is that past estimates of the efficacy of fast switching in removing atmospheric phase components are supported. The new simulations show that if good a good high frequency calibrator net can be established, fast switching at the target frequency works quite well, even compared to switching to a low frequency band. Water vapor radiometry will correct phase variations on one second scales; on shorter scales coherence will be lost. The Science IPT continues its efforts to convince skeptics that the WVR system will work as intended, and to the specifications advertised by the WVR team and the Science IPT.

**Meetings, Outreach and Public Education**

van Dishoeck presented an informal ALMA update at Caltech, where she has spent the quarter. Wilson attended a workshop 'IRAM in the ALMA/Herschel/PLANCK era' at IRAM. Wootten assembled copies of talks given at the ALMA Groundbreaking ceremony into a pamphlet; he wrote an article on the event for the NRAO Newsletter.