ALMA Development in Europe

Robert Laing, ESO

• Context (Pierre Cox’s presentation)
  – ALMA Development Plan
    • Principles
    • ALMA 2030
    • Development Working Group
  – Upgrades line in ALMA Operations Budget
    • Studies (small, approval by executives)
    • Projects (large-scale, Director or ALMA Board approval)

• ESO Calls for Studies
  – 2010, 2013 studies
  – 2016 call

• Development Projects
“Studies” prepare for “Projects”

3 year cycles of studies, each led by institutes in ESO member states
- Very effective in leveraging national and EU funding

Studies
- Develop interesting ideas into preliminary concepts
- Provide detailed planning and costs for production
- Deliver small upgrades to the ALMA system
- Contribute to commissioning/deployment of an observing mode

Projects
- Deliver and commission major new capabilities for the ALMA Observatory
Outcomes of 2010 and 2013 Studies

• 2010 Studies
  - Band 5 production readiness → full production
  - VLBI → MPIfR involvement in ALMA Phasing Project
  - Band 9 sideband separation → prototype, test on APEX this year
  - Band 2+3 → science case, optics proof of concept, additional study
  - Supra-THz science, site and technology → science case, site assessment

• 2013 Studies
  - Solar observing with ALMA → Cycle 4
  - mmVLBI → GMVA selected as network for 3mm VLBI in Cycle 4
  - Digitizer upgrade → test system
  - Cryocooler → improved thermal performance for two receiver bands
  - Radiative transfer + optimization in CASA → software under test
  - Band 2+3 → system test
Design study (SRON/NOVA) 2011-2013 demonstrated prototype sideband-separating receiver based on quadrature hybrid.

Tests on APEX planned for late 2016.

Further work, also involving U Chile, on calibrated digital sideband separation (Finger et al. 2015) demonstrated excellent (average 46dB) sideband rejection using the same analogue hardware.

- Can deliver 8 GHz/sideband
- Modification of current cartridge
Band 5

- 167 – 211 GHz
  - Water in the nearby Universe (183 GHz)
  - [CII] from the first galaxies
- Production
  - NOVA + GARD + NRAO
  - 19 cartridges integrated into front ends at OSF
  - ALMA science verification in progress
  - Offered on APEX
  - On track for Cycle 5

Band 5 First Phase Closure
(uid://A002/Xa71dxb/X235, 176.3 GHz, 1924-292)

Galametz + 2016 APEX
Arp 220
Band 5 Performance

- Meets all specifications
  - Tightened noise temperature specification
  - Increased LO tuning range

<table>
<thead>
<tr>
<th>RF GHz</th>
<th>pol</th>
<th>Elevation</th>
<th>Peak Cross dB</th>
<th>eta pol + spill</th>
<th>Polarization Eff</th>
</tr>
</thead>
<tbody>
<tr>
<td>197</td>
<td>0</td>
<td>45</td>
<td>26.87</td>
<td>83.47</td>
<td>99.74</td>
</tr>
<tr>
<td>197</td>
<td>1</td>
<td>45</td>
<td>32.09</td>
<td>83.69</td>
<td>99.89</td>
</tr>
</tbody>
</table>

Meas. software version 1.0.5, Class.eff version 1.1.3
• Goals
  - 67 – 116 GHz (current Bands 2 + 3)
  - MMIC technology
  - At least 2x8GHz instantaneous bandwidth
  - No compromise on specifications

• Current study (2015-2017)
  - INAF-Arcetri + IASF Bologna; STFC/RAL; U Manchester, U Chile; NAOJ (all mostly national funding) + ESO
  - Phase A (2015): demonstrate wideband optics
  - Phase B (2016-17): full receiver demonstrator
Band 2+3 Status

• Optics
  - Phase A complete; prototypes for lens, horn and OMT mostly meet ALMA specifications across the whole band; further optimization to be done.
  - Manufacture and test of low-loss Si lenses in progress

• LNA
  - MMIC amplifiers (NGC 30nm process), designed by U Manchester; collaboration with Caltech
  - Packaged amplifiers now being tested
  - Results currently embargoed, but very promising across the whole band
Goals

- Larger bandwidth
- Lower power dissipation
- Better reliability
- Faster calibration

Study

- U Bordeaux
- 2013-2016
- Conceptual design, DSP modelling, ASIC design, test
- Close connections to NRAO correlator upgrade study
<table>
<thead>
<tr>
<th>Present configuration</th>
<th>New configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Digitizer</strong></td>
<td></td>
</tr>
<tr>
<td>2 POL x 4 x [2 GHz]</td>
<td>2 POL x 2 x [12 GHz]</td>
</tr>
<tr>
<td>4 GSPs</td>
<td>24 GSPs</td>
</tr>
<tr>
<td>3 bits</td>
<td>3 or 4 bits</td>
</tr>
<tr>
<td><strong>Optical fiber</strong></td>
<td></td>
</tr>
<tr>
<td>2 POL x 4 x [2 GHz]</td>
<td>2 POL x 4 x [4 GHz] or [8 GHz]</td>
</tr>
<tr>
<td>10 Gbps</td>
<td>10 Gbps</td>
</tr>
<tr>
<td>12 WL</td>
<td>24 or 48 WL (3b) or 32 or 64 WL (4b)</td>
</tr>
<tr>
<td><strong>Correlator</strong></td>
<td></td>
</tr>
<tr>
<td>2 POL x 4 x [32 x 62.5 MHz]</td>
<td>2 POL x 4 x [32 x 125 MHz]</td>
</tr>
<tr>
<td>125 MSp&lt;</td>
<td>250 MSp&lt;</td>
</tr>
<tr>
<td>2 bits</td>
<td>2 bits</td>
</tr>
</tbody>
</table>

B Quertier, U Bordeaux
Software

- **Data analysis software**
  - External plugin to CASA
  - Optimization algorithms, automatic line identification, radiative transfer
  - Builds on earlier, externally funded work
  - Köln, Copenhagen, Leiden

- **Integrated Alarm System**
  - Allow Array Operators to monitor the ALMA system efficiently
  - ESO internal study with extensive JAO input
  - ALMA Memo 600
2016 Call for Studies

• Examples
  - Hardware and software upgrades
  - Advanced techniques
  - Research and Development

• Focus on implementation of ALMA 2030
  - Emphasize ultra-wide bandwidths to improve spectral range and continuum sensitivity ...
  - ... but do not exclude new ideas coming from the community

• Fund studies to be led by external groups
  - Support from ESO/ALMA staff
  - Leverage national or EU funding if possible
  - Evaluation process (ESO + ESAC/STC) and criteria as for earlier calls

• Deadline September 5th
Future Strategy

- Complete current major projects
  - Band 5

- Complete studies that deliver direct benefit
  - Solar and VLBI observing modes
  - Optimization of cryostat performance
  - Data analysis software
  - Antenna performance enhancements (internal)

- Framework then set by ALMA2030/Dev WG

- New studies

- Projects arising from current studies might include:
  - Band 9 sideband separation
  - Band 2(+3) components
  - Integrated Alarm System
  - Enhanced digital system
ALMA Developers' Workshop

May 25 – 27 2016, Gothenburg

• Objectives
  - Review current and previous development studies
  - Discuss priorities identified by the community
  - Solicit new ideas for ALMA development

• Targeted at European ALMA community
  - Good attendance from other ALMA partners and JAO

• Presentations on-line at

  http://www.chalmers.se/en/centres/GoCAS/Events/ALMA-Developers-Workshop/Pages/Programme.aspx

• See also Band 2+3 workshop contributions at

  http://www.chalmers.se/en/centres/GoCAS/Events/ALMA-Bands2and3-Workshop-2016/Pages/Programme.aspx