

# ALMA Development in Europe

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- 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

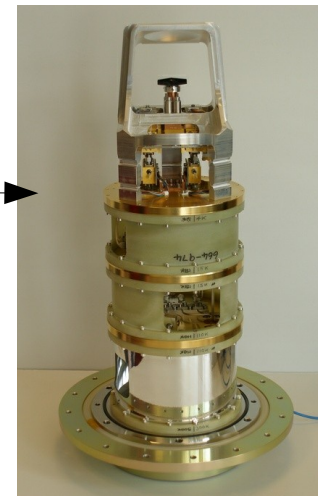
# Studies and Projects

- “Studies” prepare for “Projects”
- 3 year cycles of studies, each led by institutes in ESO member states
  - Calls in 2010, 2013, 2016
  - 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

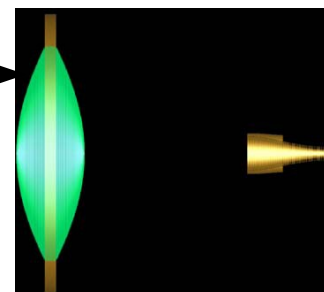
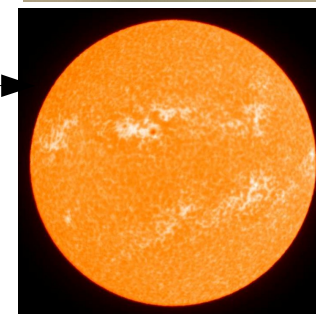
## • 2010 Studies

- 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



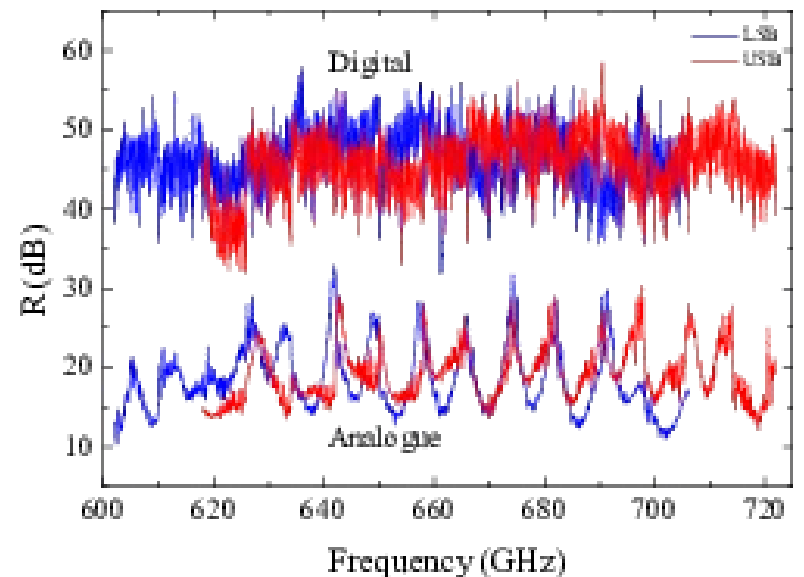
## • 2013 Studies

- 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



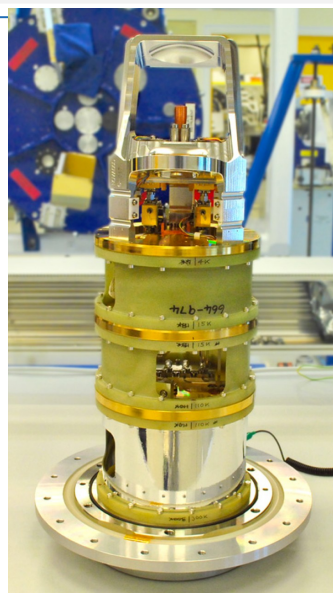
# Band 9 Sideband Separation

- 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

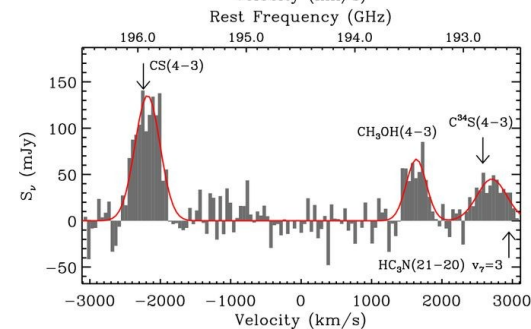
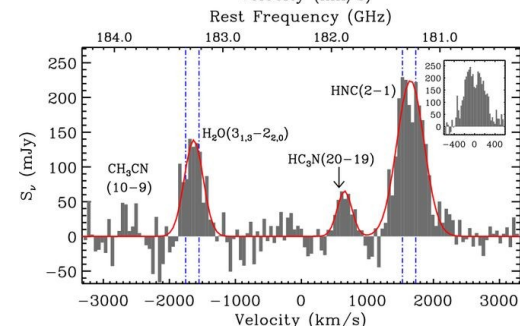
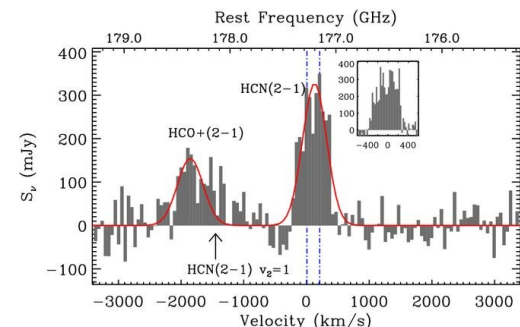
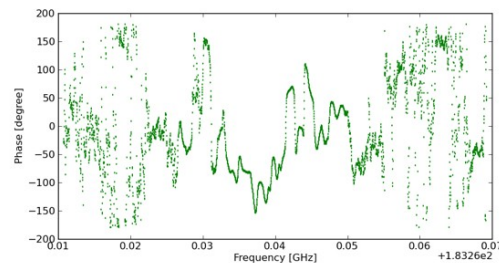
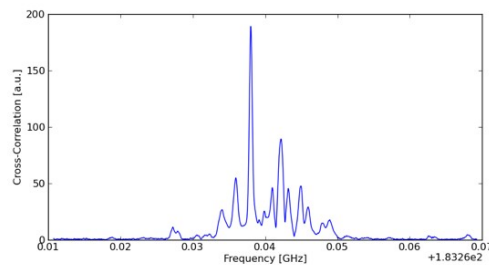
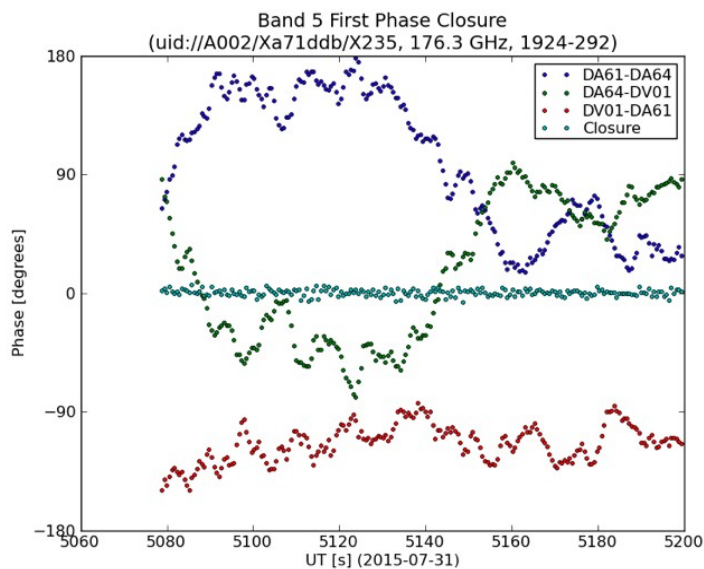


# Band 5

- 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 1st Fringe (DA64-DV01) at AOS, baseline ~ 1km, OMC1 H<sub>2</sub>O Maser 183.3 GHz



Galametz + 2016 APEX  
Arp 220



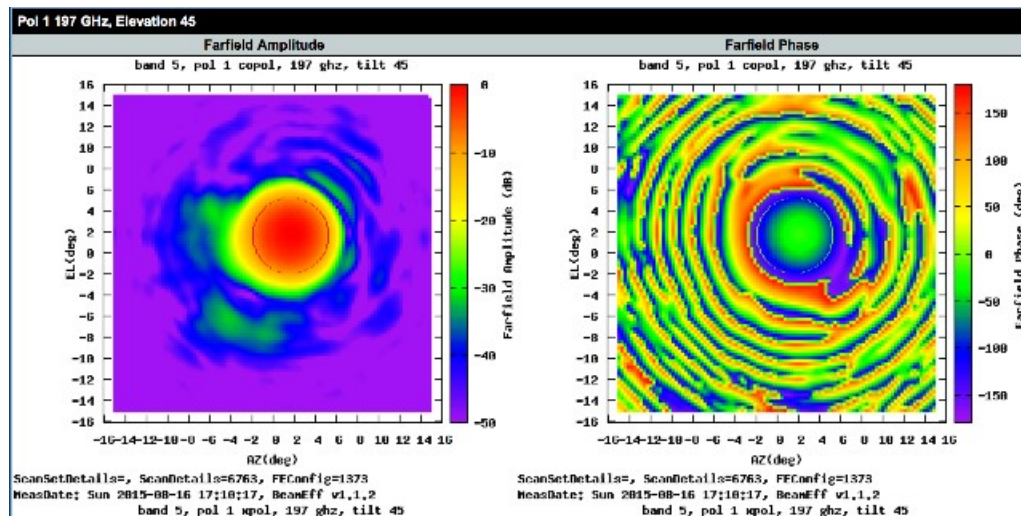
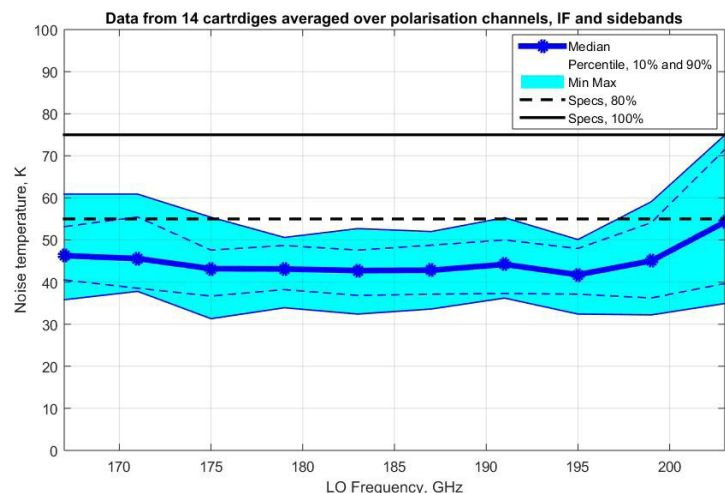
# Band 5 Performance

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

**Polarization Efficiency Band 5**

RF GHz	pol	Elevation	Peak Cross dB	eta pol + spill	Polarization Eff
197	0	45	26.87	83.47	99.74
197	1	45	32.09	83.69	99.89

*Meas. software version 1.0.5, Class.eff version 1.1.3*



# Band 2+3

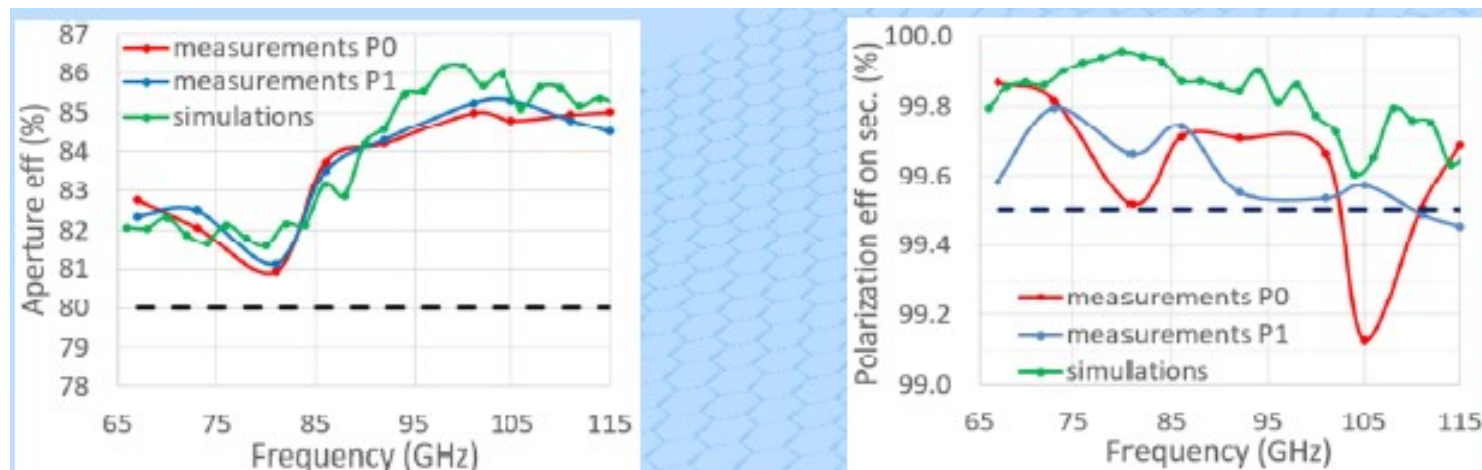
- Goals
  - 67 – 116 GHz (current Bands 2 + 3)
  - MMIC technology
  - At least 2x8GHz instantaneous bandwidth
  - No compromise on specifications
- Current study (2015-2017)
  - INAF-Arcetri + IASF Bologna; STFC/RAL; U Manchester, U Chile; NAOJ (all mostly national funding) + ESO
  - Phase A (2015): 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



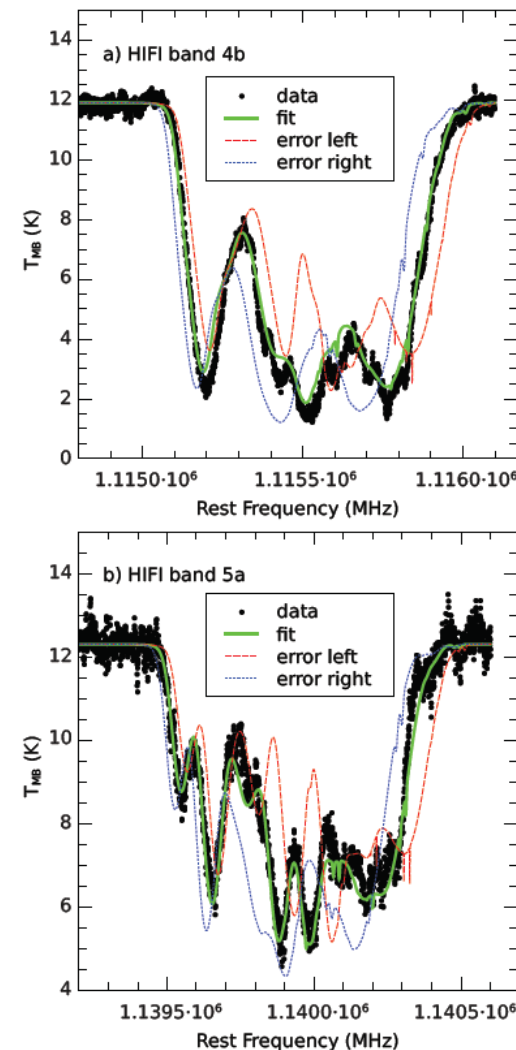
- Goals
  - Larger bandwidth
  - Lower power dissipation
  - Better reliability
  - Faster calibration
- Study
  - U Bordeaux
  - 2013-2016
  - Conceptual design, DSP modelling, ASIC design, test
  - Close connections to NRAO correlator upgrade study

# Possible back-end + correlator upgrade

Suppressing analog IF stages & doubling correlator BW

	Present configuration	New configuration
Digitizer	<ul style="list-style-type: none"> <li>• 2 POL x 4 x [ 2 GHz ]</li> <li>• 4 GS<sub>ps</sub></li> <li>• 3 bits</li> </ul>	<ul style="list-style-type: none"> <li>• 2 POL x 2 x [ 12 GHz ]</li> <li>• 24 GS<sub>ps</sub></li> <li>• 3 or 4 bits</li> </ul>
Optical fiber	<ul style="list-style-type: none"> <li>• 2 POL x 4 x [ 2 GHz ]</li> <li>• 10 G<sub>bps</sub></li> <li>• 12 WL</li> </ul>	<ul style="list-style-type: none"> <li>• 2 POL x 4 x [ 4 GHz ] or [ 8 GHz ]</li> <li>• 10 G<sub>bps</sub></li> <li>• 24 or 48 WL (3<sub>b</sub>) or 32 or 64 WL (4<sub>b</sub>)</li> </ul>
Correlator	<ul style="list-style-type: none"> <li>• 2 POL x 4 x [ 32 x 62,5 MHz ]</li> <li>• 125 MS<sub>ps</sub></li> <li>• 2 bits</li> </ul>	<ul style="list-style-type: none"> <li>• 2 POL x 4 x [ 32 x 125 MHz ]</li> <li>• 250 MS<sub>ps</sub></li> <li>• 2 bits</li> </ul>

- 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>

