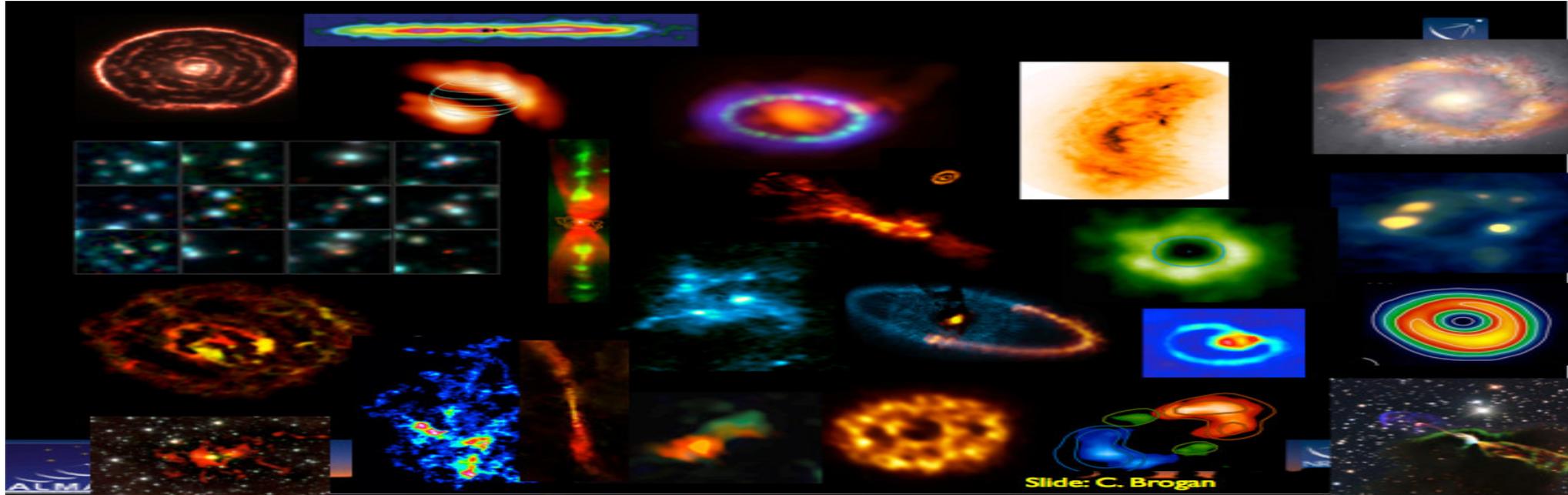


# Summary on Status of NA Development Projects and Studies



## A Short Overview

Al Wootten



Atacama Large Millimeter/submillimeter Array  
Karl G. Jansky Very Large Array





# ASAC Recommended Development Paths

- **Finish the Scope of ALMA** (B1 + B2 + B5 receivers, VLB capability)
  - Detailed in **ALMA Scientific Specifications and Requirements** (ALMA-90.00.00.00-001-B-SPE)
- **ALMA2030**
  - 1. Improvements to the ALMA Archive: enabling gains in usability and impact for the observatory.
  - 2. Larger bandwidths and better receiver sensitivity: enabling gains in speed.
  - 3. Longer baselines: enabling qualitatively new science.
  - 4. Increasing wide field mapping speed: enabling efficient imaging.

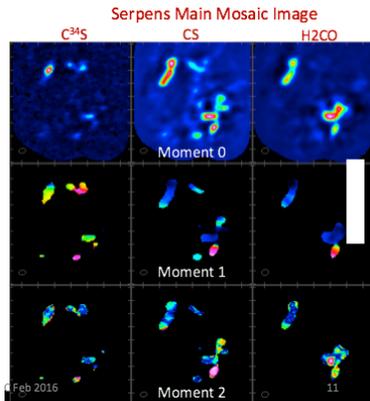
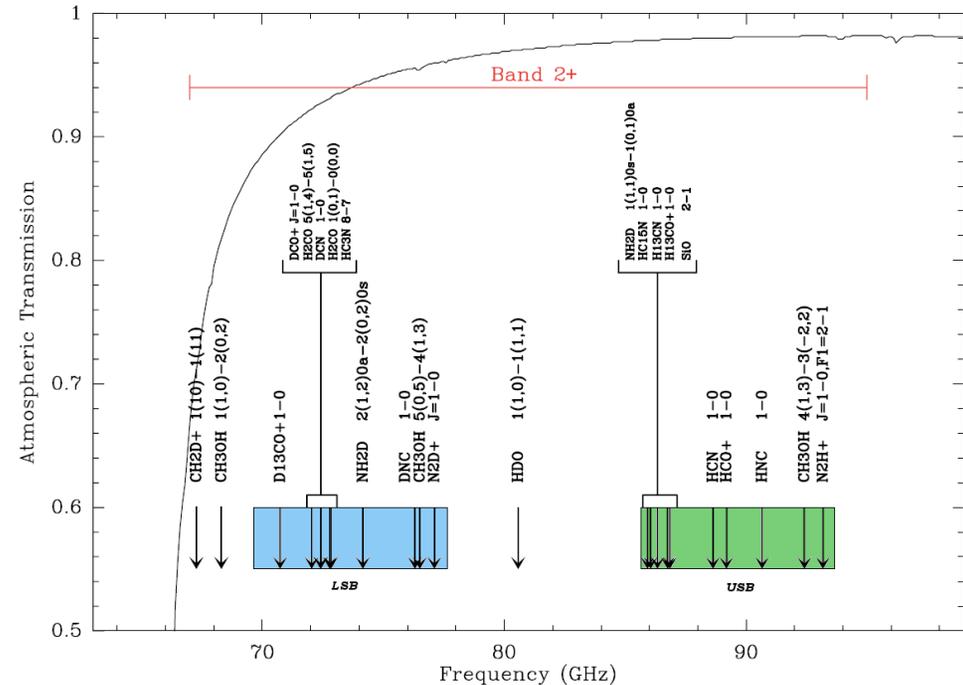


# NA Development Program



## Current Project Overview

- New alma Band (2+) provides new science: access to redshifted CO 'desert' and deuterated light molecules
- Fiber optic connection ALMA to JAO improves PI data delivery
- B3 upgrade delivers improved TP stability
- Recently delivered ADMIT and CARTA projects for improved archive use
- ALMA Phasing Project

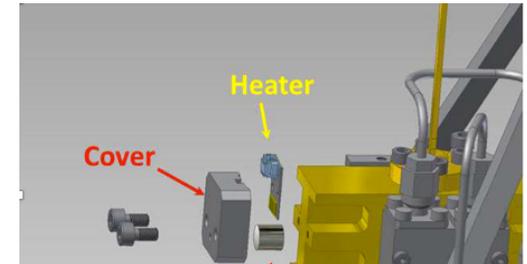


ADMIT products are delivered with data packages, also archived (currently independently)

## Design & Testing of a Prototype 67-95GHz Cartridge



Fiber Optic Project



Band 3 CCA Heater Installation for Deflux Operation

**Three Projects continue during FY2017.**



# Other Projects and Contracts

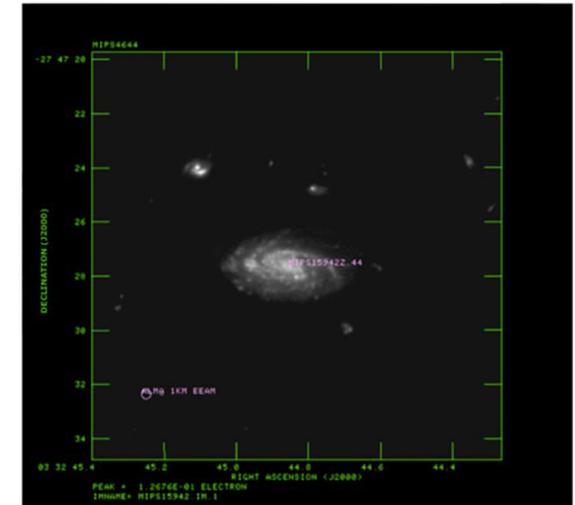


- Previous Cycles

- Band 5 LOs: Delivered; B5 obs to begin Cyc5
- Band 1 LNAs: Being delivered under NAOJ contract; obs begin 2019.

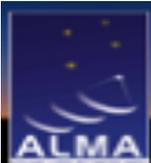
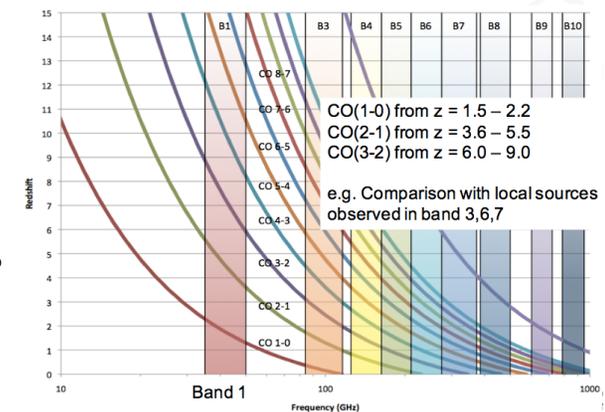
- New Cycle: Closed 30 Jan 2017

- Seven proposals were received
- Thirty-six investigators from nine institutions in the U.S. and Canada
- Five of the proposals focused on advanced hardware and two on advanced techniques.
- Proposals are now being refereed



LIRG Galaxy at  $z=0.44$

Band 1 Science Case  
- High- $z$  -



## Cycle 1

The first call for ALMA Development Studies (Cycle 1) was reported in eNews

<https://science.nrao.edu/enews/5.6/index.shtml#almadev>.

77 investigators associated with 26 institutions responded to the Call with a total of 21 Study Proposals, of which the following 8 were funded.

<b>Cycle 1 Study Title</b> <i>(hover for linked reports)</i>	<b>PI</b>	<b>Notes</b>
<a href="#">Second Generation Receiver for ALMA Band 6 (Study continues into Cycle 2)</a>	Anthony R. Kerr (NRAO)	
<a href="#">Ultra-wideband quantum limited amplifiers for receiver frontends</a>	D. Woody (Caltech)	
<a href="#">Design Study for Production of the Band 2 Cartridges</a>	Eric Bryerton (NRAO)	Study has become a Cycle 2 ALMA Development Project: <i>Design and Testing of a Prototype Band-2 Cartridge</i> (PI: K. S. Saini)
<a href="#">A Visualization Portal for ALMA Data</a>	E. Rosolowski (UBC-Okanagan)	Study has become a Cycle 2 ALMA Development Project: <i>The Next Generation ALMA Viewer</i> (PI: E, Rosolowsky)
<a href="#">Millimeter/Submillimeter VLBI with ALMA</a>	Jeff Kern (NRAO)	Study was associated with an ALMA Development Project now reaching realization: <i>The ALMA Phasing Project</i> (PI: S. Doleman, MIT)
<a href="#">Unleashing Large Dataset Science</a>	Lee Mundy (Univ. Maryland)	Study has become a Cycle 2 Development Project: <i>ALMA Data Mining Toolkit: ADMIT</i> (PI: Lee Mundy)
<a href="#">Increasing the ALMA Data Rate</a>	B. Glendenning (NRAO)	NOTE: Study proposal was withdrawn
<a href="#">ALMA Band 1 Receiver Development Study</a>	P.T.P. Ho (ASIAA)	Study has become an ALMA Development Project led by East Asia, in collaboration with North America and Universidad de Chile

## Cycle 2

The second call for ALMA Development Studies (Cycle 2) was reported in eNews Feb 2014:

<https://science.nrao.edu/enews/7.3/index.shtml>

9 submissions were received from 8 PIs with teams totaling 41 investigators from 17 institutions; 6 funded.

Cycle 2 Study Title	PI	Notes
<a href="#">Advanced Solar Observing</a>	T. Bastian, NRAO	Study has resulted in ALMA offering solar observations in Cycle 4 Observations
<a href="#">2nd Generation Band 10 Receiver</a>	A. Kerr, NRAO	
<a href="#">Community Science Tool Development</a>	A. Leroy, NRAO	
<a href="#">2nd Generation Band 6 Receiver</a>	A. Kerr, NRAO	
<a href="#">Millimeter Camera</a>	S. Claude, NRC-Herzberg	
<a href="#">Calibration Refinements for ALMA Imaging</a>	T. Wilson, NRL	

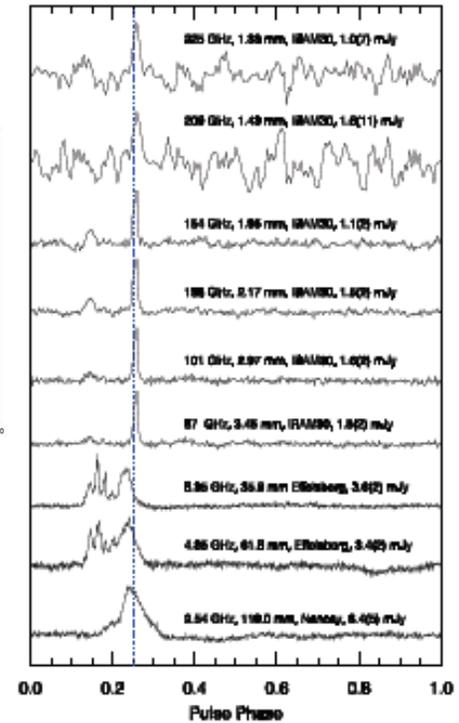
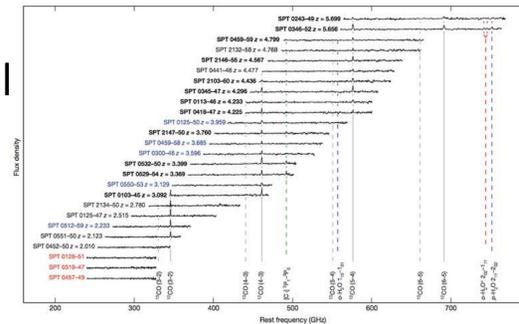
# NA Development Program

## Cycle 3 Study Overview

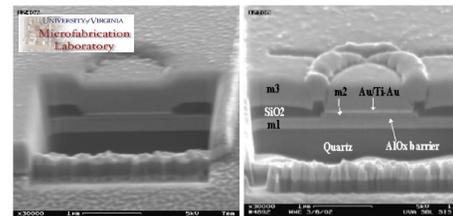
Focus on ALMA2030 science improvements:

- Correlator upgrade:
  1. Delivering more channels, higher spectral resolution and wider bandwidth
  2. Next generation correlator
- Maximizing point source sensitivity, spatial resolution
  1. Extending VLB phasing to B7, optimize phasing, data reduction
  2. Enable a phased ALMA for pulsars & transients
- Improved data use
  1. Improved calibration through atmospheric spectral features
  2. Data cube visualization enhancements
- Increased sensitivity
  1. 2nd generation receiver mixer studies

Spectral Resolution & Bandwidth Upgrade of the ALMA Correlator



Below, UVA SiO<sub>2</sub> evaporation (left) versus SiO<sub>2</sub> sputtering (right)



Galactic Center magnetar at mm  $\lambda$

**Seven Cycle 3 Studies underway.**

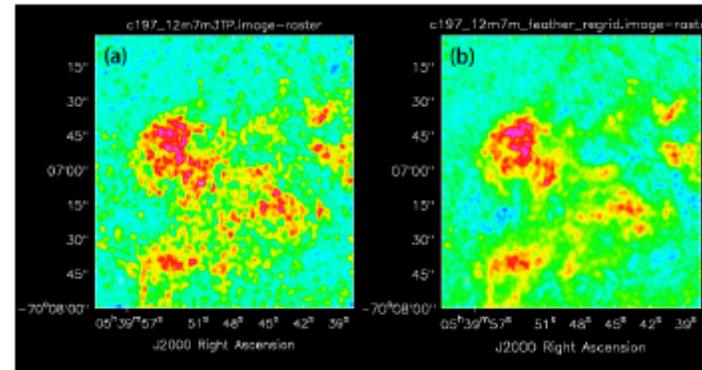
# NA Development Program



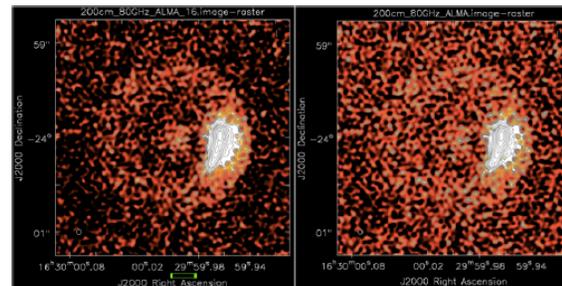
## Cycle 4 Study Overview

Acting on ALMA2030 vision:

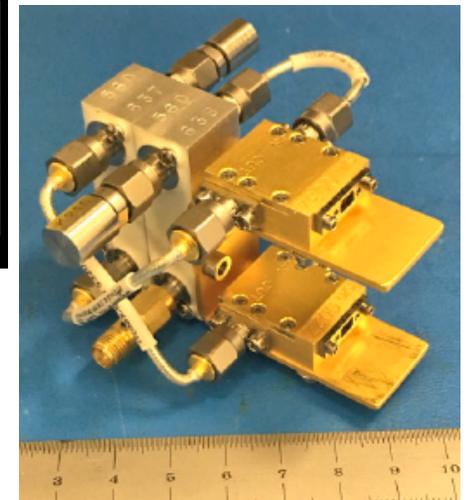
- Increasing receiver sensitivity, bandwidth
  1. Upgraded ALMA B3 mixer block
  2. 2<sup>nd</sup> generation SIS receiver development
- Expanding ALMA's processing bandwidth
  1. Upgrade of Backend Antenna Article to match correlator upgrade
- Improved data use
  1. Improved interactive CLEAN
  2. Improved imaging with combined arrays
- Maximizing point source sensitivity and resolution
  1. Weak source and spectral line VLBI



Total Power Map to Visibilities (TP2VIS)  
a) Joint deconvolution b) Current mode



A protoplanetary disk simulation: r: current bandwidth l: upgraded 2x BW.



Development of 2<sup>nd</sup> Generation SIS Receivers for ALMA: Prototype balanced B6 amplifier 4-12 GHz

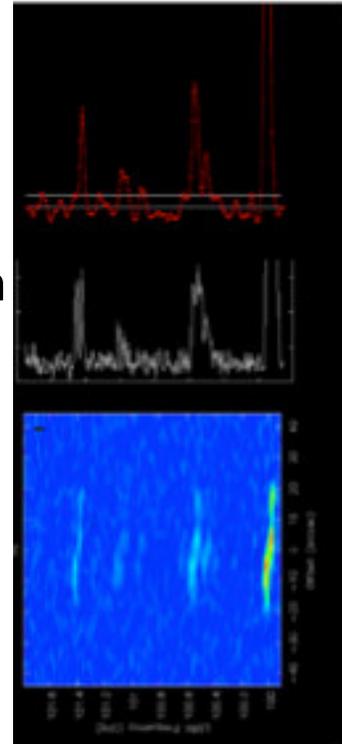
**Six Cycle 4 Studies underway.**



# Gains in ALMA Usability and Impact



- Enhanced data access and usability
  - Three current NA **Projects**, one NA **Study** move in this direction  
*Hardware or Software:*
    - AOS-JAO fiber connection (HW: NA, JAO, ESO) ADMIT line view
      - Improved connectivity, data flow to ARCs
    - ADMIT data miner (SW: Mundy, PI, U. Md, U. Illinois)
      - Archival spectral line data characterized for all lines
    - CARTA data visualizer (SW: Rosolowsky, PI, U. Alberta)
      - Replaces CASA viewer with enhanced functionality
    - Feature Extraction and Data Cube Visualization through Topology (SW: Rosen, U. S. Florida)
      - New visualization tools for data cubes



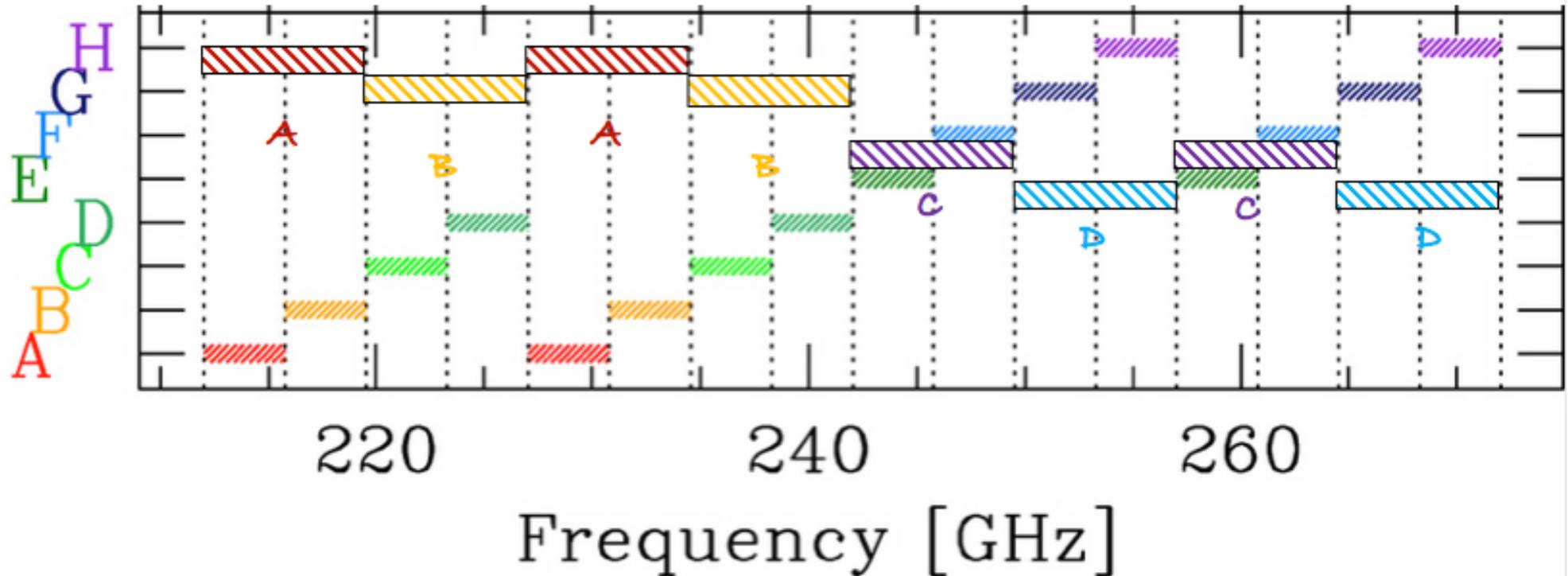
# Increased spectral grasp: Speed gain



- Increased bandwidth, resolution
  - Spectral Resolution/Bandwidth Correlator Upgrade (HW: Lacasse, NRAO)
    - New chips provide 8x channels, 4bit mode, double bandwidth to current correlator
      - Higher continuum, spectral line sensitivity
      - Broader frequency range for redshift or astrochemical searches
    - Velocity resolution improved, important for lower frequencies
  - Digital Correlation and Phased Array Architectures (HW: Weintroub, SAO)
    - New correlator design eventually replacing baseline correlator using modern architecture



# Upgraded Correlator, IF, Halves Spectral Search Settings

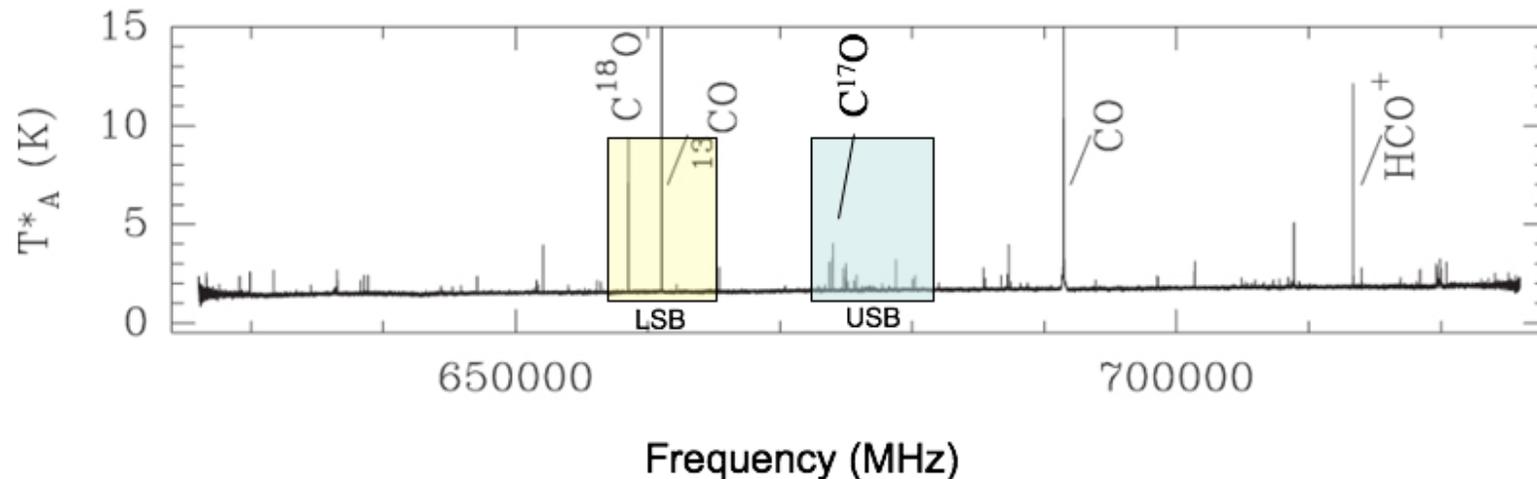


Upgraded ALMA Correlator needs *only four* settings to cover Band 6; currently *eight* tunings (Lettered, left) are needed to cover the frequencies of the [C II] line at redshifts of 6 to 8 in the ALMA ASPECS spectral scan of the Hubble UltraDeep Field.

Adapted From Walter et al. 2016



# Upgraded Correlator Nets More Lines



- Many CO isotopomers fall within a part of the Herschel HEXOS spectral scan in a portion of ALMA Band 9 (611-720 GHz) showing the spectral grasp of the current baseline correlator (8 GHz x 2 polarizations) compared to that from the upgraded correlator (2 x 8GHz x 2 polarizations). From Tahani et al. 2016.
- For high resolution, ALMA's current configuration provides 58 MHz spectral windows, only  $\sim 70$  km/s at 300 GHz. With the correlator upgrade, one could achieve the same resolution over  $\sim 550$  km/s.

# Increased sensitivity: Speed gain

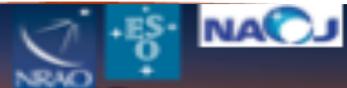


- Receiver Upgrades

- ALMA Band 1 Production (EA+NA+UCh HW: Kemper, ASIAA)
  - Under way, expected availability on ALMA 2019
- ALMA Band 2 Prototype (NA EA HW: Saini, NRAO)
  - Built, Preliminary design review ca April 2017
- ALMA B5 Full Production (ESO, NA HW: Chalmers, SRON NRAO)
  - Los delivered, Being installed on ALMA, planned available Cycle 5
- 2nd Generation ALMA Band 6 receiver (HW: Kerr, NRAO)
  - Report available
- 2nd Generation ALMA Band 10 receiver (HW: Kerr, NRAO)
  - Report available

- Technological Advances

- Advanced Materials & On-wafer Chip Evaluation (HW: Lichtenberger, U. Va.)





# Longer Baselines Enable Qualitatively New Science

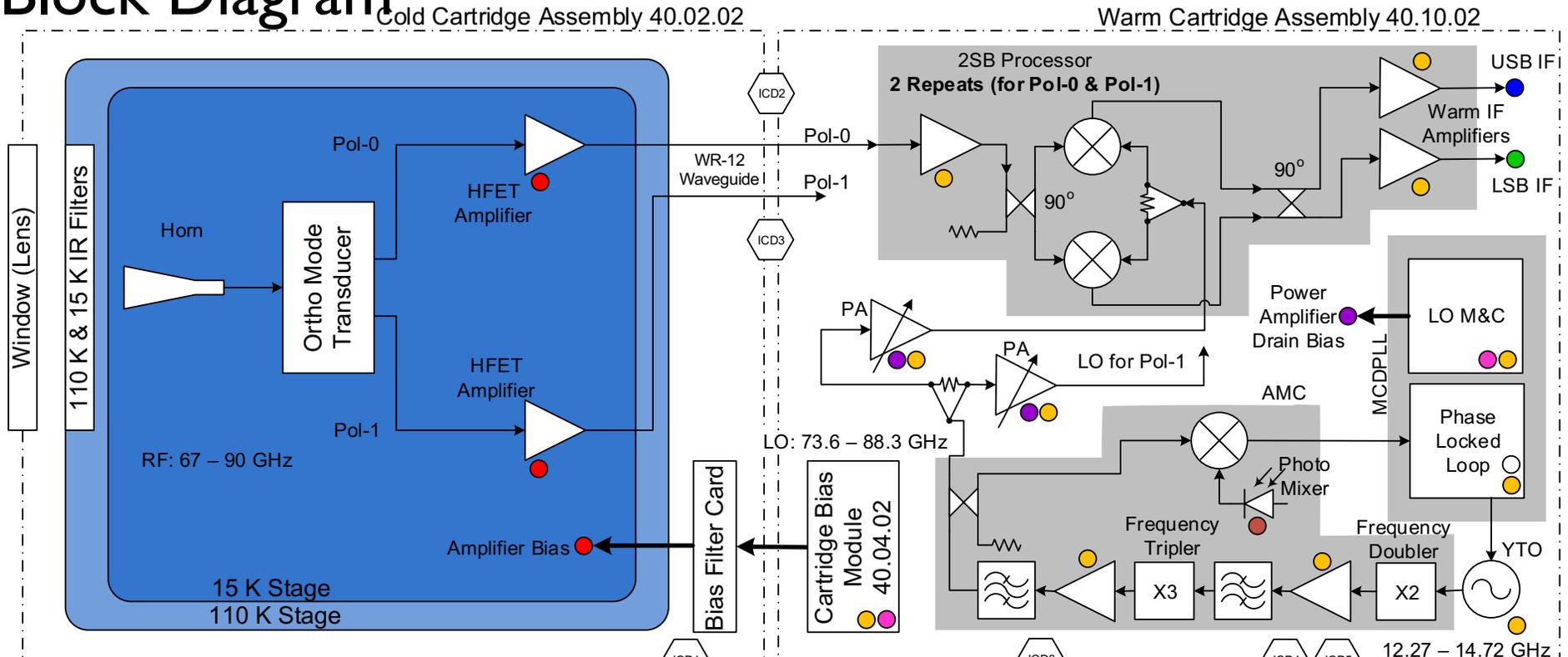
- VLB arrays
  - ALMA Phasing Project (NA, ESO, EA HW/SW: Doeleman, MIT +)
    - Offered for Cycle 4 (1 Oct 2016=30 Sept 2017)
  - ALMA Phasing System Extensions and Enhancements (HW/SW: Matthews, MIT and others)
    - VLBI capability for B7, spectral lines
  - Pulsars, Magnetars and Transients with Phased ALMA (SW: Cordes, Cornell and others)
    - Phased array software for temporal monitoring
- Connected element array extension
  - Strategic Goal for current Studies



# ALMA Band 2 Receiver Prototype

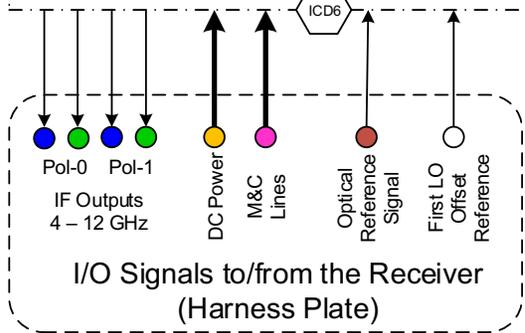


## Block Diagram



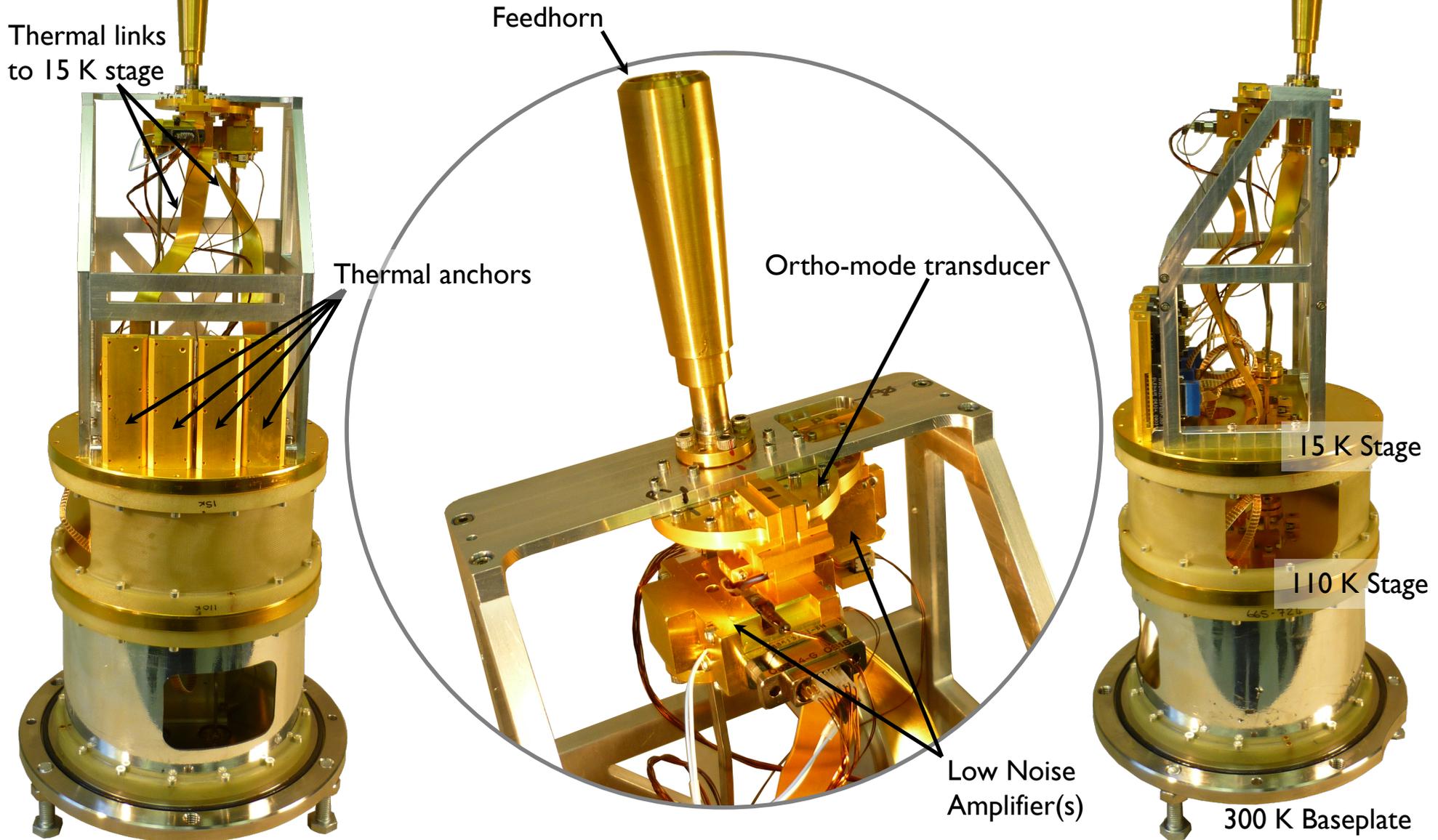
**INTERFACES**

ICD1 Cold Cartridge Assembly to ALMA Cryostat	ICD4 FE LO to BE Photonics LO
ICD2 Cold Cartridge Assembly to Warm Cartridge Assembly	ICD5 Cold Cartridge Assembly to IF Switch Subsystem
ICD3 Cold Cartridge to Bias Module	ICD6 Warm Cartridge Assembly to Harness Plate



**ALMA Band-2 Receiver**  
 67 - 90 GHz  
 Top Level Block Diagram  
 Revised 18 Mar 2016

# ALMA Band 2 Cold Cartridge Prototype

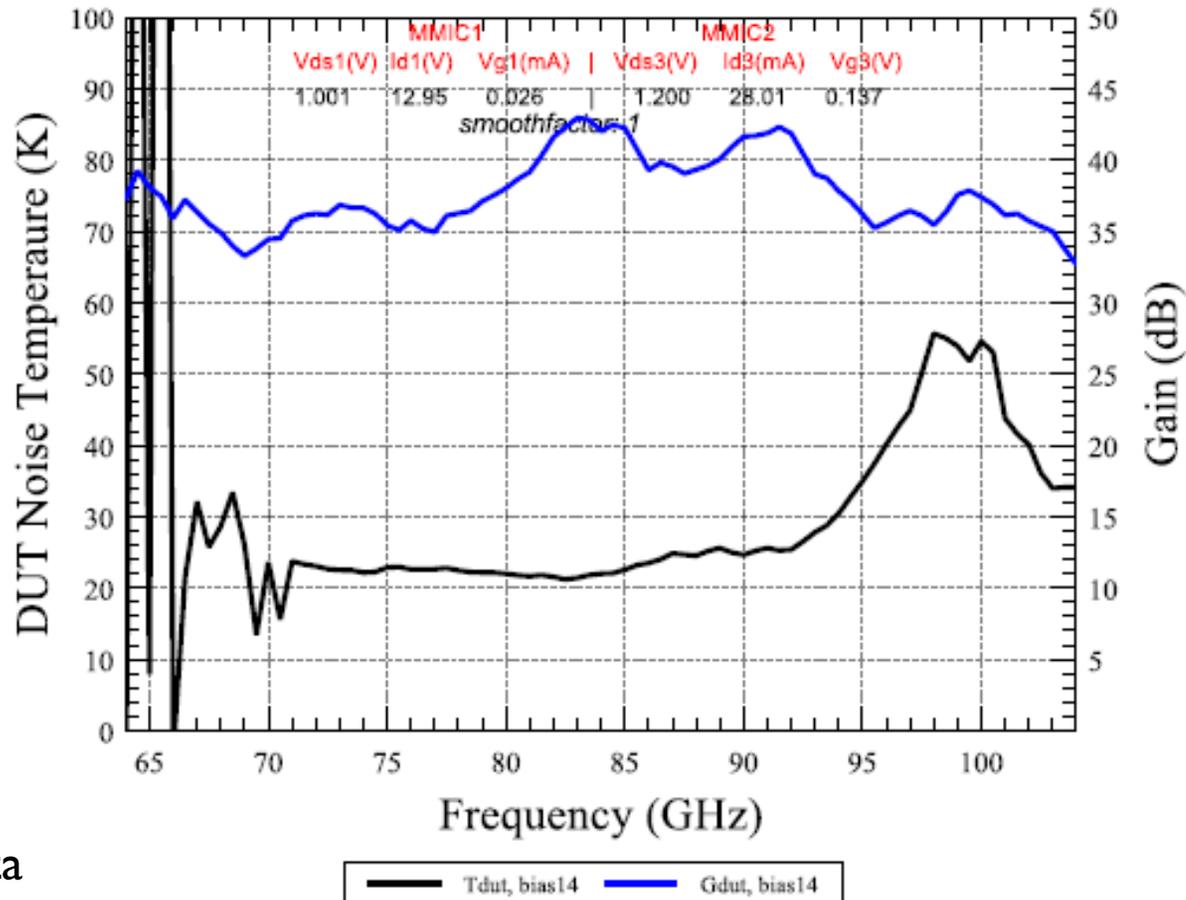


# ALMA Band 2 Prototype Project



## Example CRAL MMIC based CLNA Noise Results

Minimum Td<sub>ut</sub> with Associated Gain



CLNA Data  
CRAL Block #3

# ALMA Band 2 Prototype Project



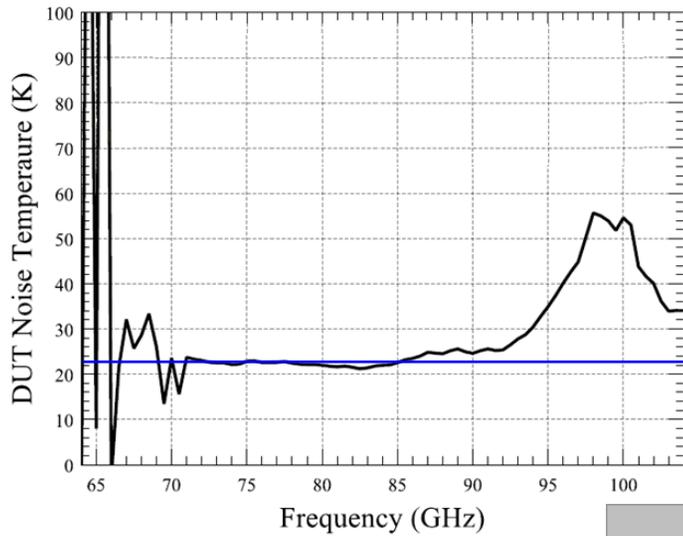
## Rx NT estimation with HDPE-Lens and 15 K IR filter

Band 2 Receiver stage	Gain	Cumulative Gain to preceding stage	Noise Figure	Noise Temperature	Tequivalent
Lens/Window (room temperature)	-0.1 dB	0.0 dB	0.1 dB	8.9 K	8.9 K
IR Filters	-0.1 dB	-0.1 dB	0.1 dB	1.4 K	1.5 K
Feedhorn (15 K)	-0.1 dB	-0.3 dB	0.1 dB	0.3 K	0.4 K
OMT	-0.1 dB	-0.4 dB	0.1 dB	0.3 K	0.4 K
E-Band Amplifier (15 K)	35.0 dB	-0.5 dB		27.0 K	30.0 K
Waveguides, feed-thru and BPF	-4.0 dB	34.5 dB	4.0 dB	453.6 K	0.2 K
W-Band Amplifier (room temperature)	14.0 dB	30.5 dB	3.5 dB	371.6 K	0.3 K
2 SB Downconverter	-12.0 dB	44.5 dB	12.0 dB	4454.7 K	0.2 K
Warm IF Amplifier	30.0 dB	32.5 dB	2.0 dB	175.5 K	0.1 K
<b>Total</b>	<b>62.5 dB</b>				<b>41.9 K</b>

# ALMA Band 2 Prototype Project



## Rx NT Estimation with Si-Lens and 15 K IR filter removed



LNA Noise Temperature ~ 23 K

Band 2 Receiver stage	Gain	Cumulative Gain to preceding stage	Noise Figure	Noise Temperature	Tequivalent
Lens/Window (room temperature)	-0.1 dB	0.0 dB	0.1 dB	4.4 K	4.4 K
IR Filters	-0.1 dB	-0.1 dB	0.1 dB	0.7 K	0.7 K
Feedhorn (15 K)	-0.1 dB	-0.1 dB	0.1 dB	0.3 K	0.4 K
OMT	-0.1 dB	-0.2 dB	0.1 dB	0.3 K	0.4 K
E-Band Amplifier (15 K)	35.0 dB	-0.3 dB		23.0 K	24.8 K
Waveguides, feed-thru and BPF	-4.0 dB	34.7 dB	4.0 dB	453.6 K	0.2 K
W-Band Amplifier (room temperature)	14.0 dB	30.7 dB	3.5 dB	371.6 K	0.3 K
2 SB Downconverter	-12.0 dB	44.7 dB	12.0 dB	4454.7 K	0.2 K
Warm IF Amplifier	30.0 dB	32.7 dB	2.0 dB	175.5 K	0.1 K
<b>Total</b>	<b>62.7 dB</b>				<b>31.4 K</b>

# Immediate Future



- **Projects**

- NA Call closed 30 Jan; Projects being refereed. Next: Follow many steps in Principles of ALMA Development, probably to Board late 2017.

- **Studies**

- NA: New Call 1 March 2017. Total of \$3M expected to be available.
- Two categories of proposals are included in this call:
  - General Studies (funded for 1 year up to \$200,000 per individual award) and
  - Strategic Studies (funded for 2 years up to \$400,000 per individual award). Strategic Studies is a new proposal category that applies to in-depth studies directly aligned with the development priorities currently identified by the ASAC in the "Road Map for Developing ALMA" document (increasing throughput, improving mapping efficiency, improving spatial resolution and improving archive performance).





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