Atacama
Large
Millimeter/submillimeter
Array

EA ALMA Future Development

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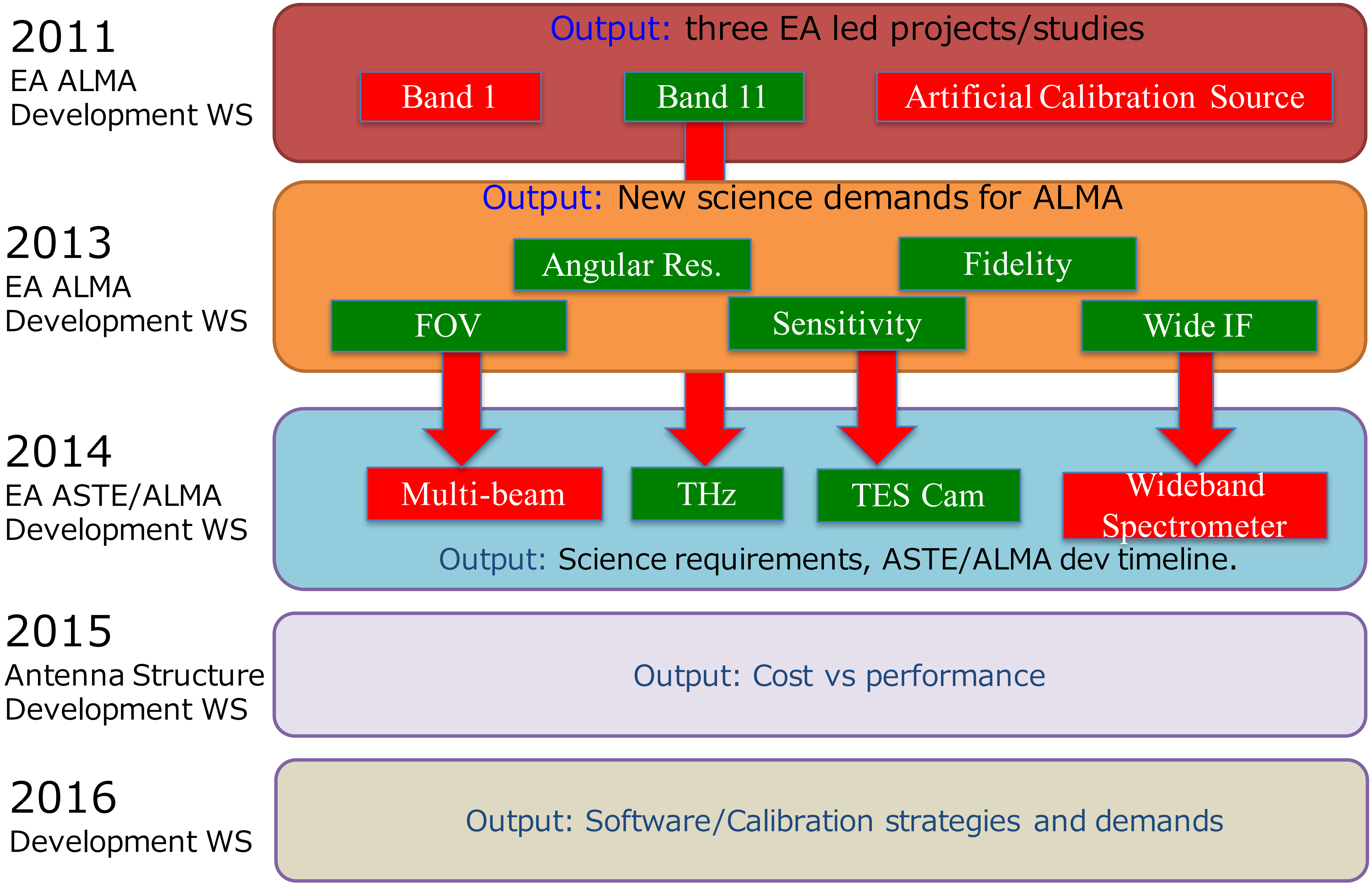
ALMA Science Advisory Committee Recommendation for 2020-2030

ALMA Science Advisory Committee has recommended the following 4 paths as a guideline for ALMA development for 2020-2030.

1. **Better archive and tools**
2. **Improving Rx with wider bandwidths**
   - Goal to correlate the entire band in one observation
3. **Longer baselines**
   - Real-time correlation (instead of VLBI techniques)
4. **Long-term research on wide-field imaging**
   - Multi-beam receivers

ALMA Future Development

- Each region has different procedure.
  - **North America and Europe**:
    - Call for development proposals
  - **East Asia**
    - Seek community input through development workshops
    - Collaborative development with NAOJ, EA partners (ASIAA, KASI, Japanese Universities/Institutes) and EU/NA partners.


2011
EA ALMA
Development WS
Output: three EA led projects/studies
Band 1
Band 11
Artificial Calibration Source
2013
EA ALMA
Development WS
Output: New science demands for ALMA
Angular Res.
Fidelity
FOV
Sensitivity
Wide IF
2014
EA ASTE/ALMA
Development WS
Multi-beam
THz
TES Cam
Wideband Spectrometer
Output: Science requirements, ASTE/ALMA dev timeline.
2015
Antenna Structure
Development WS
Output: Cost vs performance
2016
Development WS
Output: Software/Calibration strategies and demands

Current Priorities for EA ALMA

Projects

- Band 1 project (lead: ASIAA, Collaboration: NAOJ, U of Chile, NRAO, HIA)

Studies and Small Projects

- ALMA Calibration Source: Calibration at bands 3, 6, 7
- High Critical Current Density (Jc) SIS Junction Device Development and wideband receivers
- GPU Spectrometer for TP array (with KASI)

ASTE Development Project (extendable to ALMA)

- Spectrometer & Multi-beam receiver (with KASI)

Ongoing Collaboration with EU and NA

Projects

Band 5 (EU)

EA contribution: Front end integration at the OSF

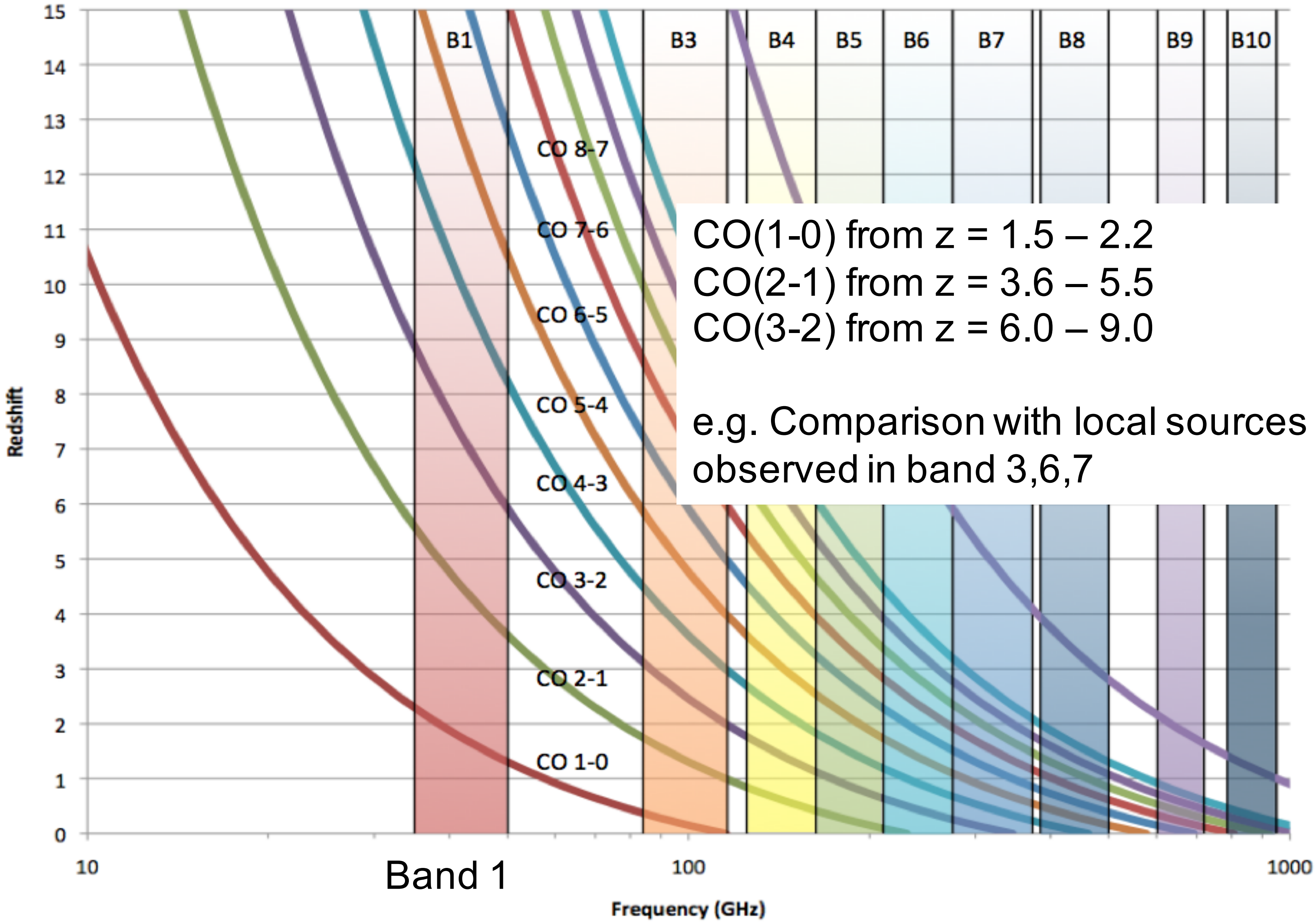
Studies and Small Projects

Band 2 (NA), Combining Band 2 and 3 (EU)

EA contribution: Optics design

Band 1 (35-50 GHz)

Band 1 Science Case
- High-z -

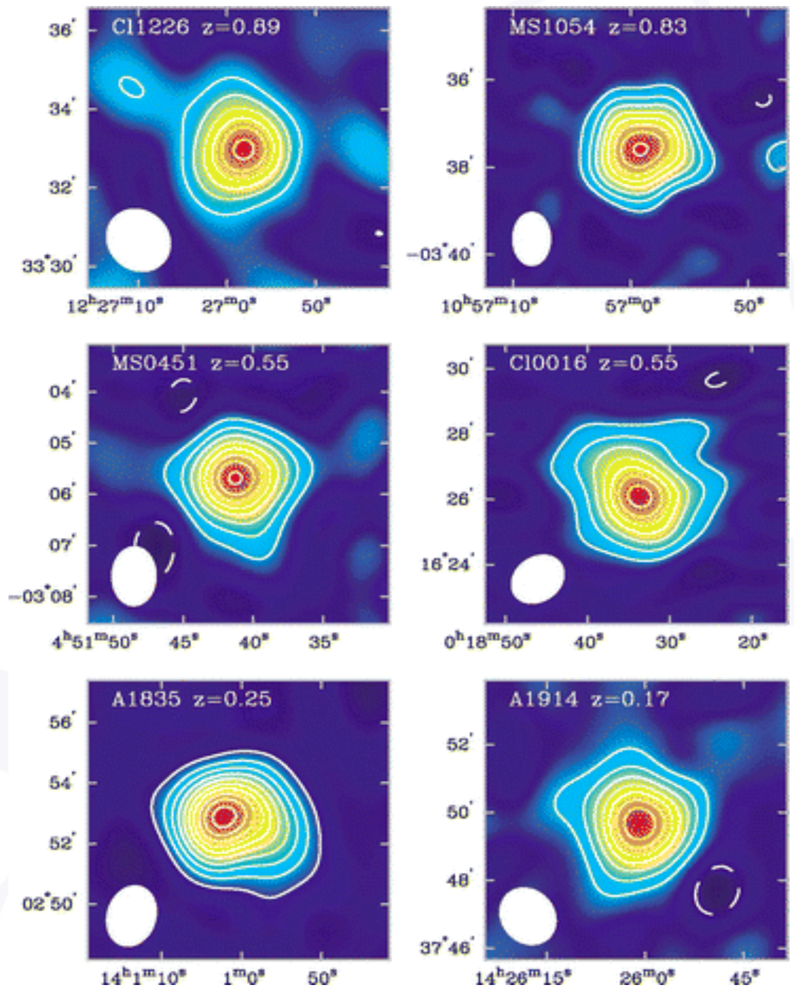


CO(1-0) from z = 1.5 – 2.2
CO(2-1) from z = 3.6 – 5.5
CO(3-2) from z = 6.0 – 9.0

e.g. Comparison with local sources observed in band 3,6,7

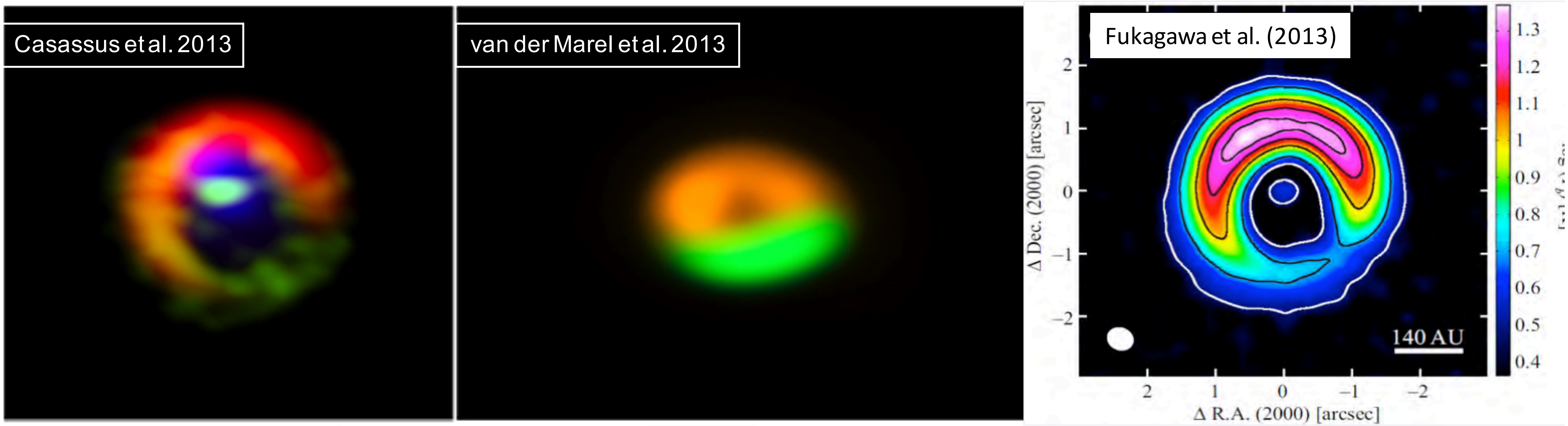
Band 1 Science Case
- SZ Effect -

- Follow-up imaging of the large clusters discovered in low resolution (~1′) surveys.
- Allows us to detect shocks, cluster mergers, ICM substructure, physical state of the ICM (electron density, temp).



SZ effect (Carlstrom et al. 2002)

Band 1 Science Case
- Protoplanetary Disks -



Dust particles emit very inefficiently at wavelengths longer than their size. Band 1 will observe large (cm size) dust particles in proto-planetary disks.

Design and testing of a Prototype Band-1 Cartridge

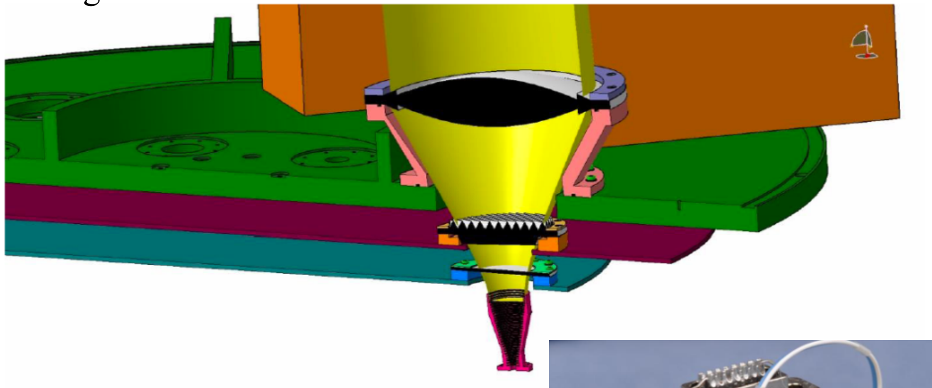
TECHNICAL HIGHLIGHTS

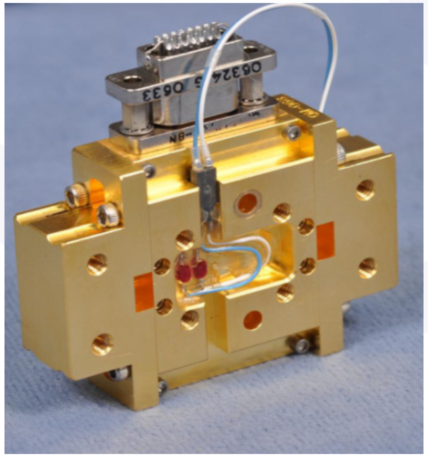
Optics

•Single room temperature lens window +Spline corrugated horn

•Lens designed by **NAOJ**

•Corrugated feedhorn design by **Univ. Chile**, one fabricated by **U. Chile** and two fabricated by outside machine shop order by ASIAA are ready for testing.





LNA

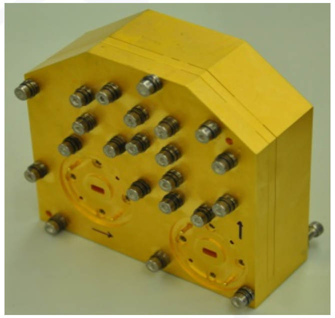
•Developed by **NRAO**

•NGST cryo3 HEMT (1st - 2nd stages) + HRL (3th - 5th stages)

•Gain = 37 – 40 dB typically

•Noise Temperature at 23K (see graph below): <18K @ full BW

OMT

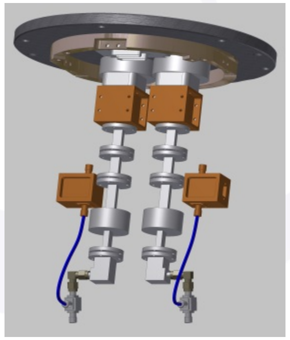


•Developed by **HIA**, Canada.

•Measured performance:

i. insertion gain = - 0.3 dB
ii. input match < -20 dB
iii. isolation < -52 dB
iv. cross polarization < - 45 dB

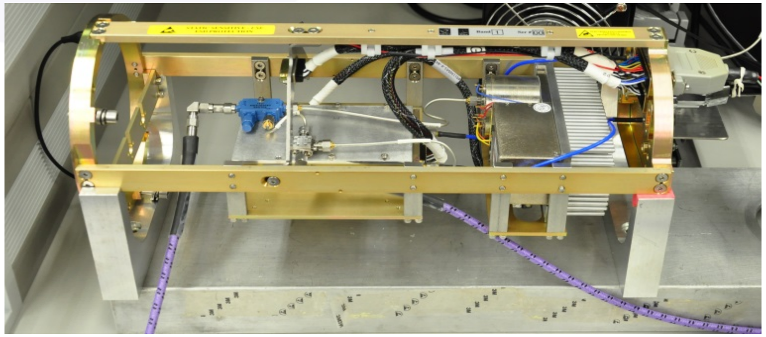
Down-converter



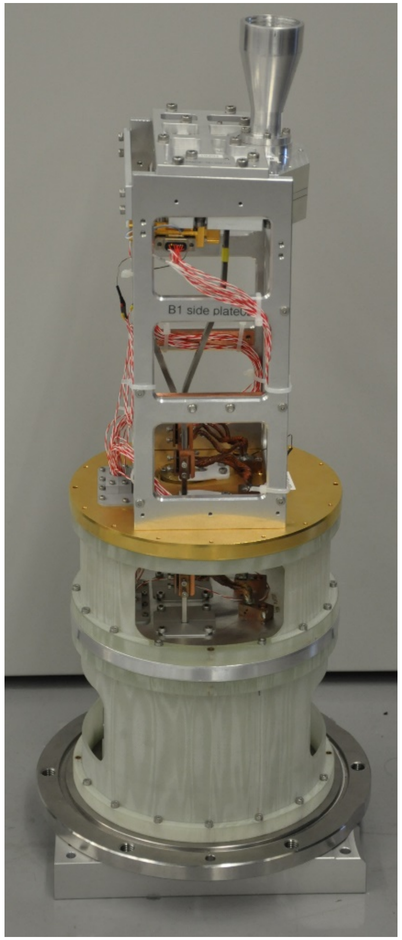
•Assembled by warm low-noise amplifier, high-pass filter, isolator, mixer and IF amplifier.

Local Oscillator

•Design similar to all the other bands: YIG-tuned transistor oscillator at 31 – 40 GHz, no frequency multiplier required.

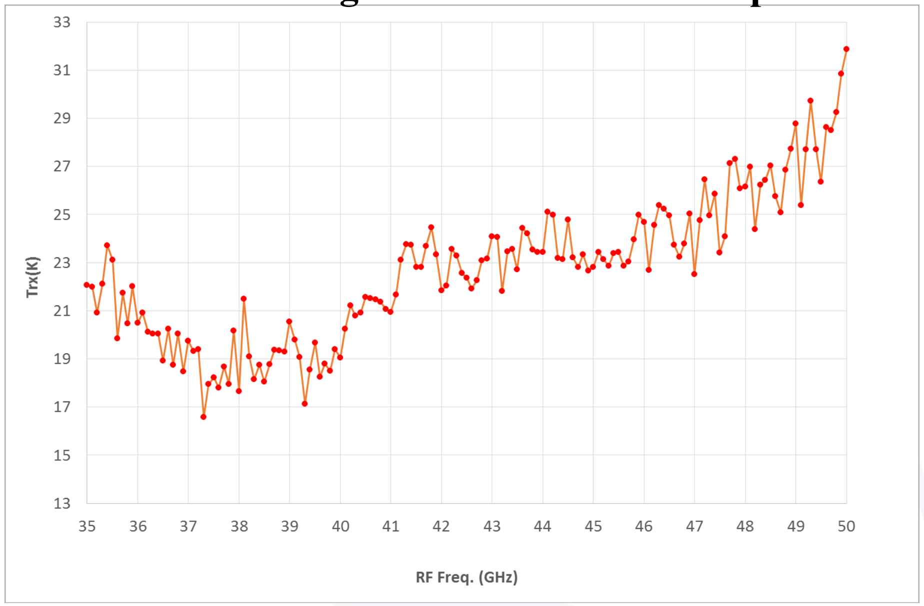


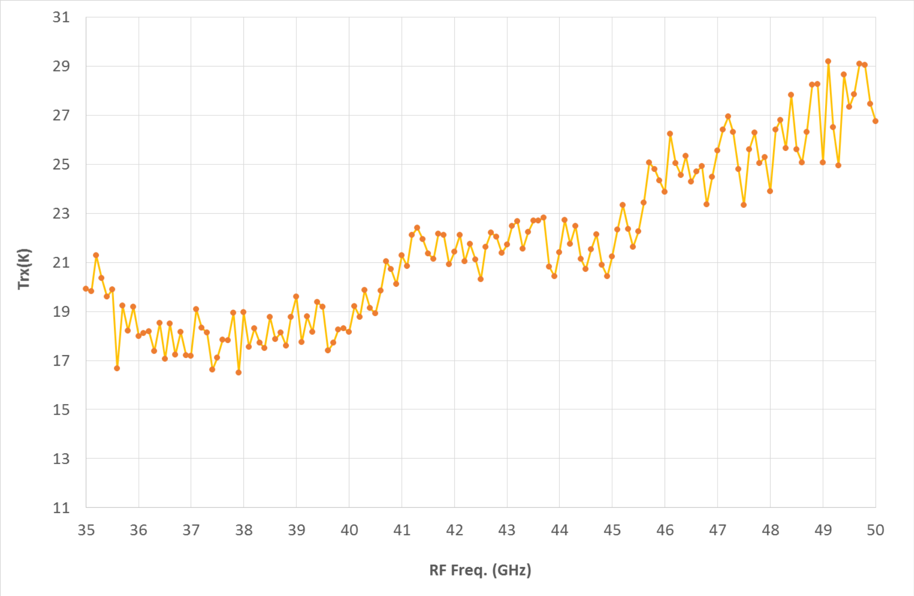
Band 1 Cartridge Result



Band 1 Cold
Cartridge Assembly

Band 1 Warm
Cartridge Assembly





Band 1 Status

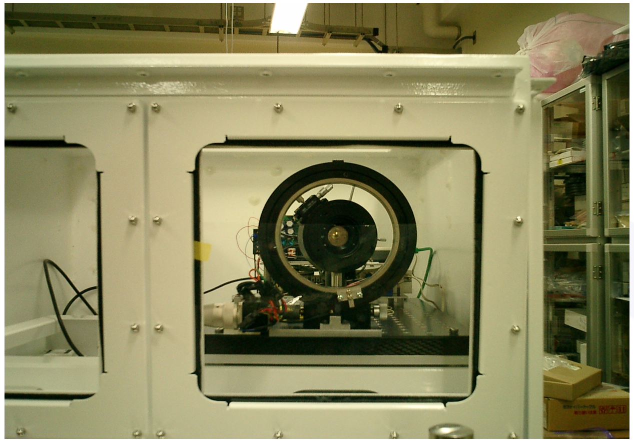
- CDR and project review were held on Jan 19-20, 2016 at ASIAA in Taiwan
- CDR completed, pre-production phase can be initiated. Final document being prepared.
- Positive ASAC reaction on science case
- <u>Board approval for production (May, 2016)</u>
- Manufacturing Reediness Review will be held in late 2016
- Array Integration and Verification in 2019

Artificial Calibration Source

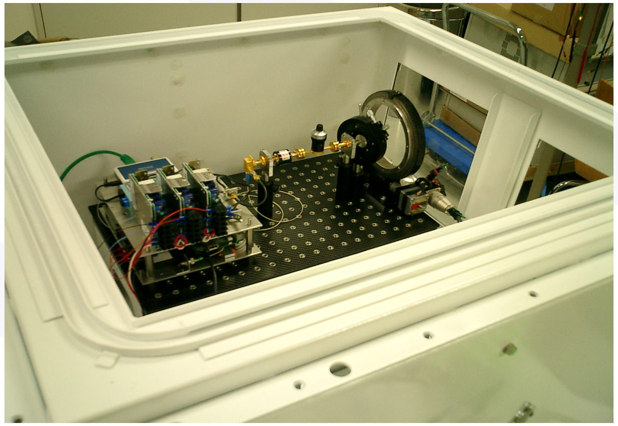
Artificial Calibration Source

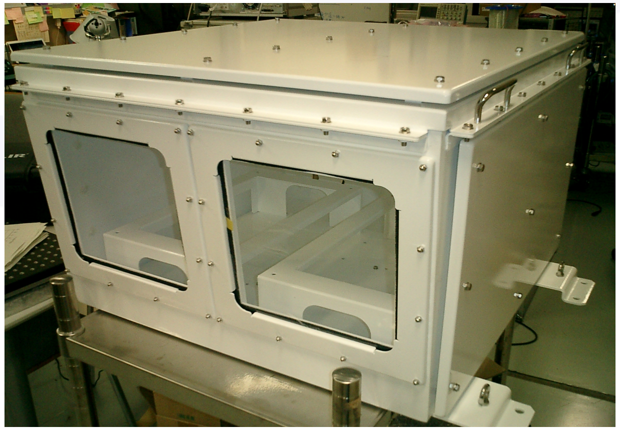
- Lead: Hitoshi Kiuchi (NAOJ)
- Original idea by R. Hills
- Used for calibration purposes
  - Provide a signal for interferometric holography measurements of antenna surface
  - Provide a source of known polarization for calibration
  - Provide a high S/N source to help measure e.g. coherence, phase stability, switching time, stability and sideband ratio.

Artificial Calibration Source



Front face

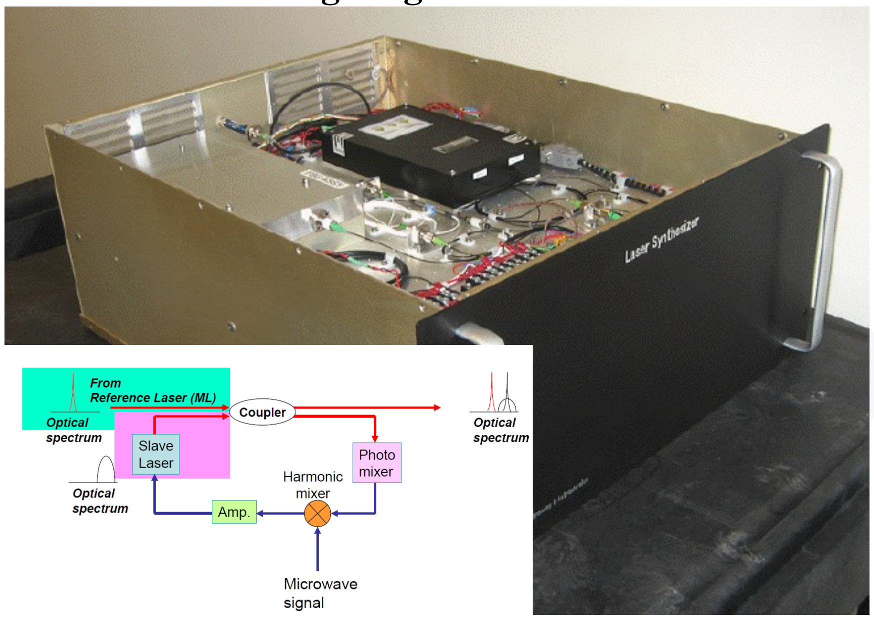




Artificial Calibration Source

- 100GHz frequency range source has been delivered, and will begin testing in Q4 2016.
- 230/345GHz being developed and will be delivered by 2018.

Photonic signal generator: MZM-LS

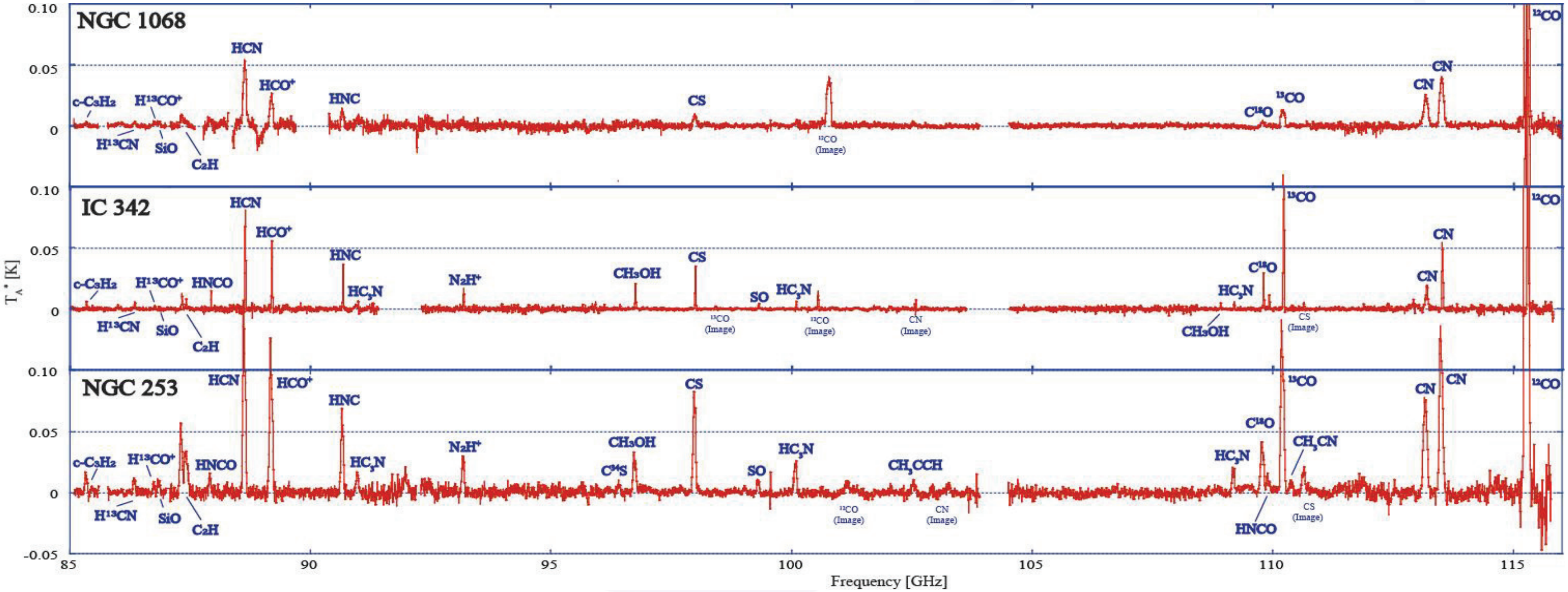


ACS acceptance at OSF

High Critical Current Density SIS Junction Device Development
and
Ultra Wideband Receivers

Wideband Receivers: Science Case

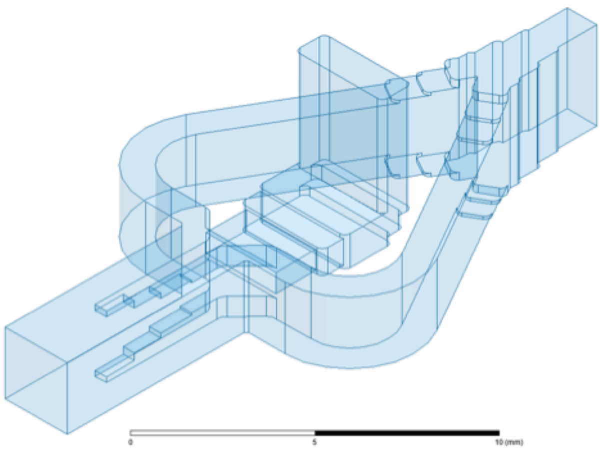
Rich in molecular lines, from 85 – 115 GHz. Wide freq coverage is essential.

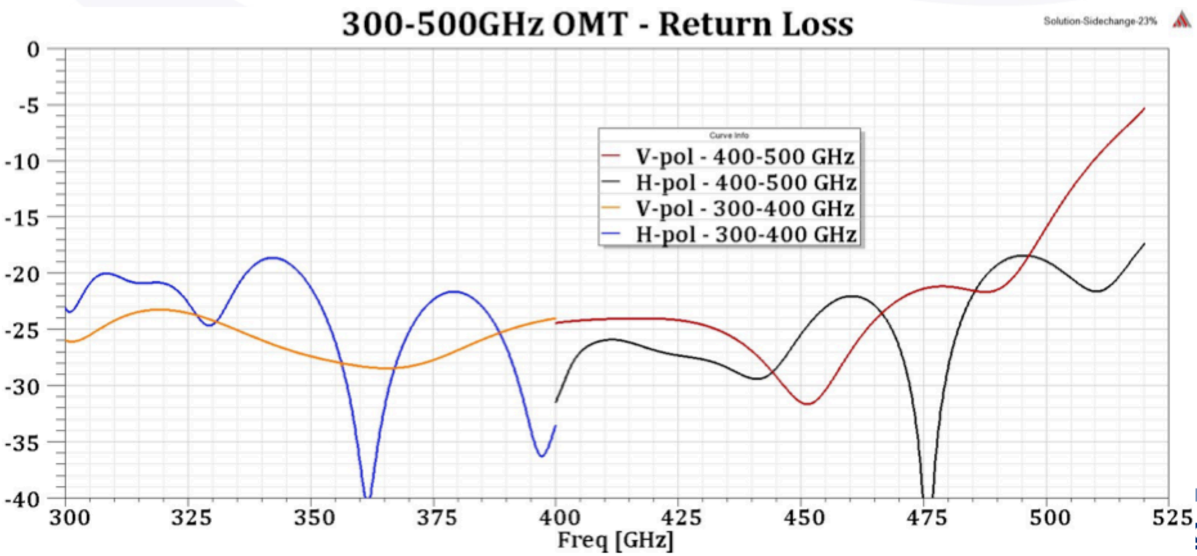


Takano et al. (2013)

Expanding the RF

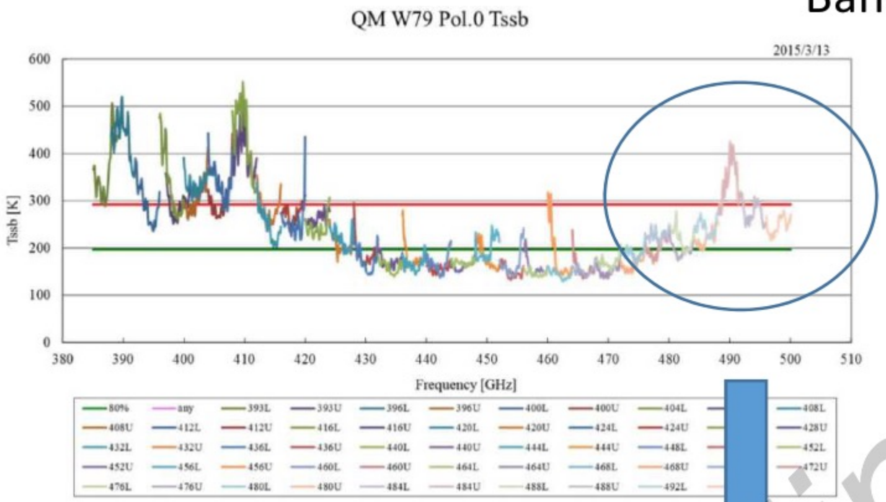
- Initial studies for passive components ongoing
  - Orthomode transducer (OMT) for 300-500 GHz [Osaka Prefecture University]
  - Wideband corrugated horn [A. Gonzalez (NAOJ)].
- High Jc junctions (~30kA/cm^2)
  - RF bandwidth to be increased substantially for Ultra-wideband receivers
  - Required for THz receivers
- Development and implementation of aluminum nitride (AlN) barriers for SIS devices

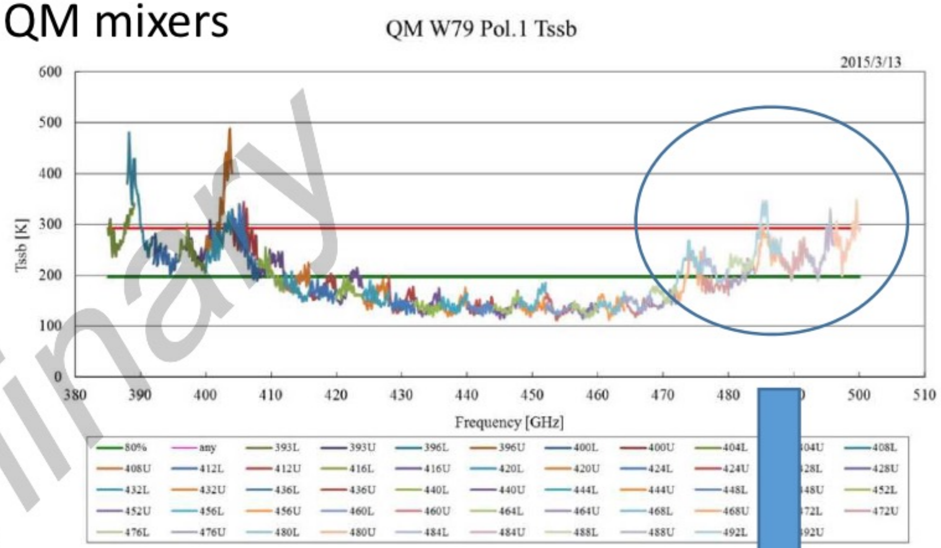




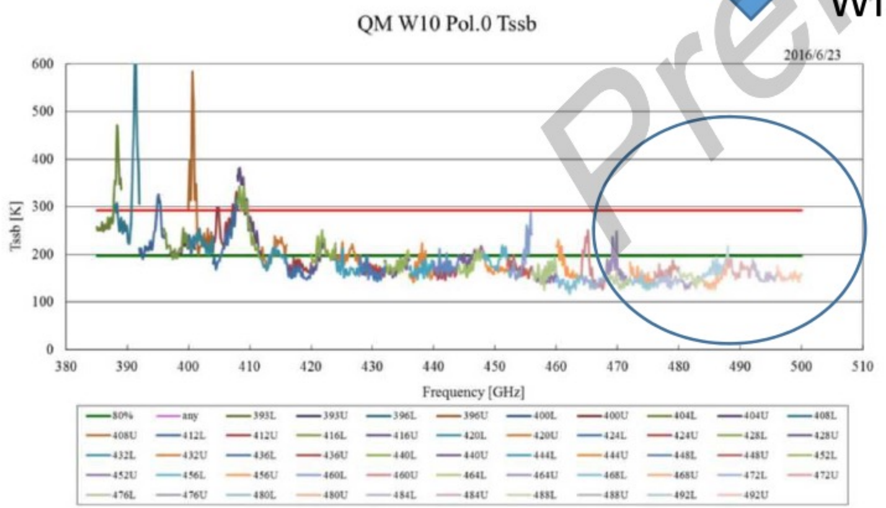
Noise Improvements Using High Jc SIS Junction

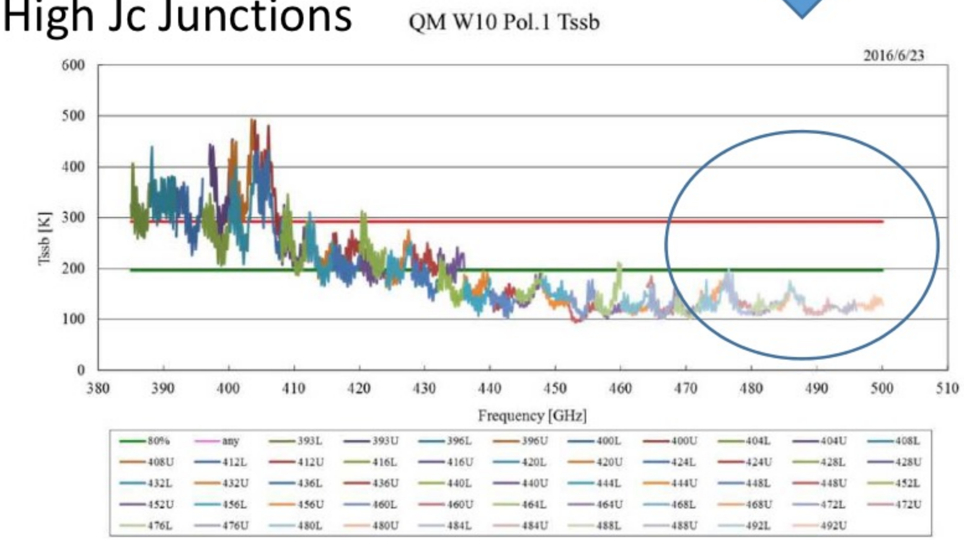
Band 8 QM mixers





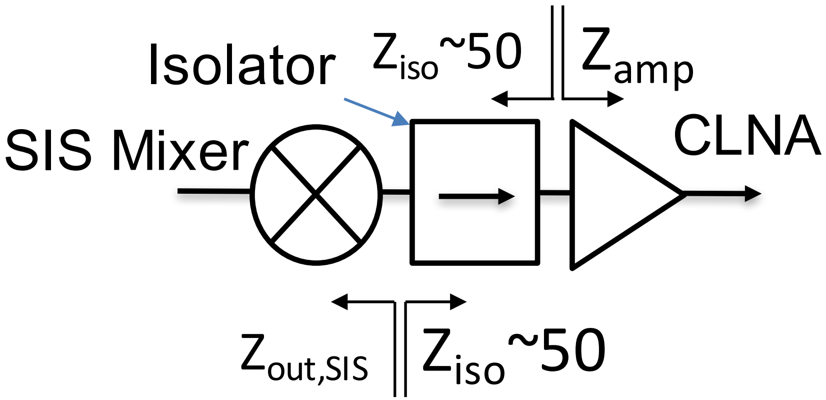
With High Jc Junctions



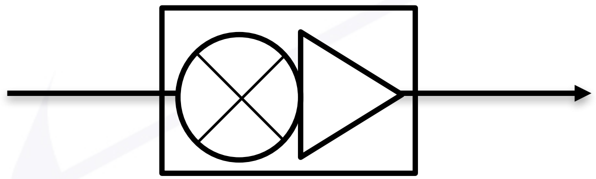


What limits IF bandwidth in currently existing Rx

Conventional modular approach



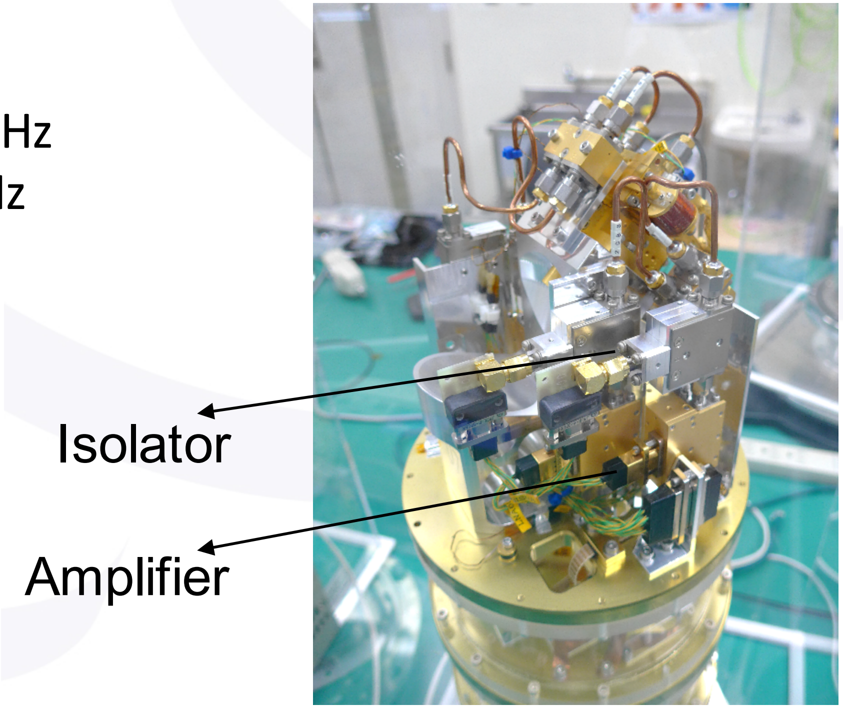
Mixer configuration in the future



Passive IF components : 4-8 GHz, 4-12 GHz
Low noise amplifier: 1-12 GHz, 4-20 GHz

◇Advantage
-"Artificially" compensate better matching between SIS mixer and IF amp.
-Stable operation

◇Drawback
- Limited bandwidth
- Large size

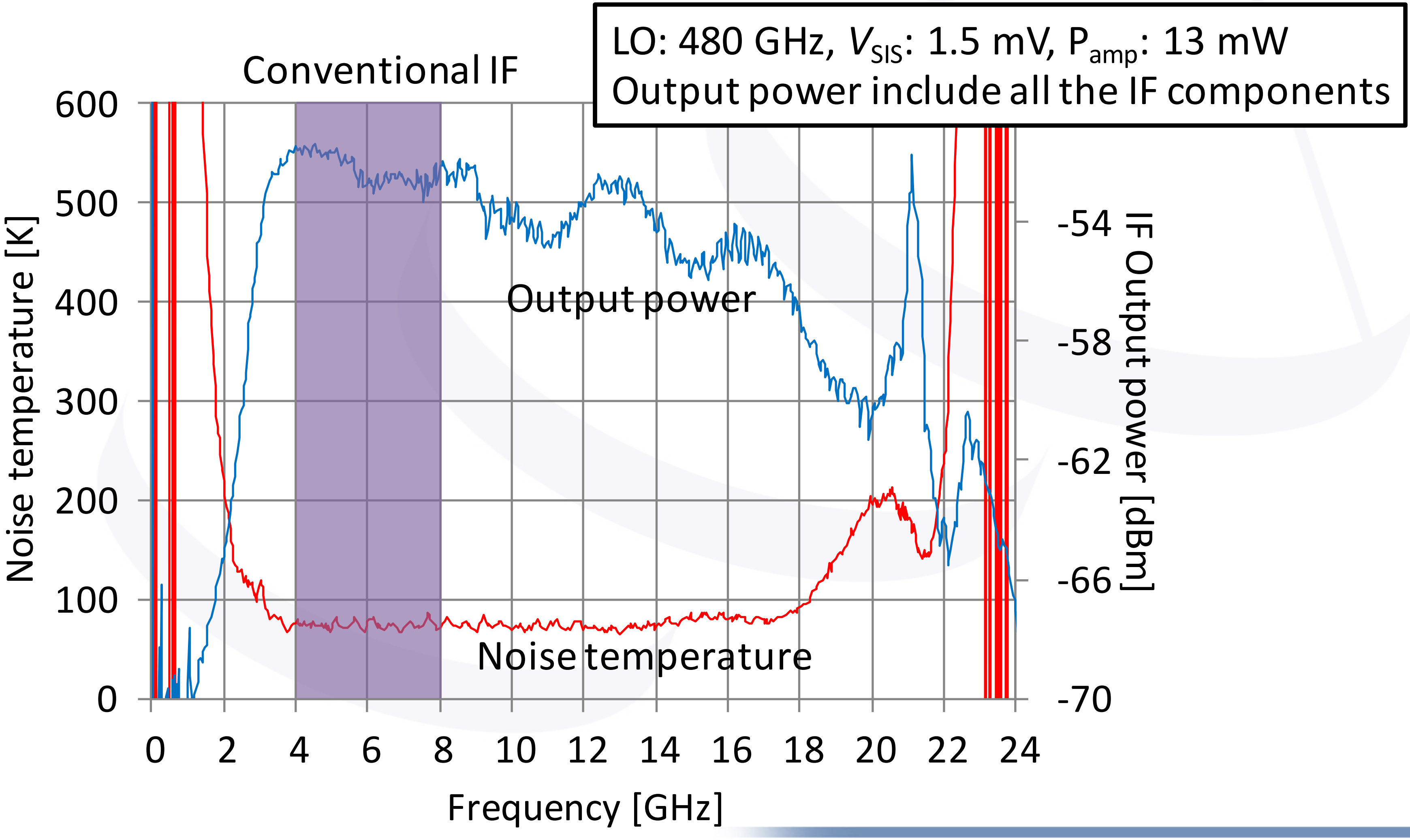


Band 8 receiver

Work done by T. Kojima (NAOJ)

Preliminary test result of the Wideband IF Receiver

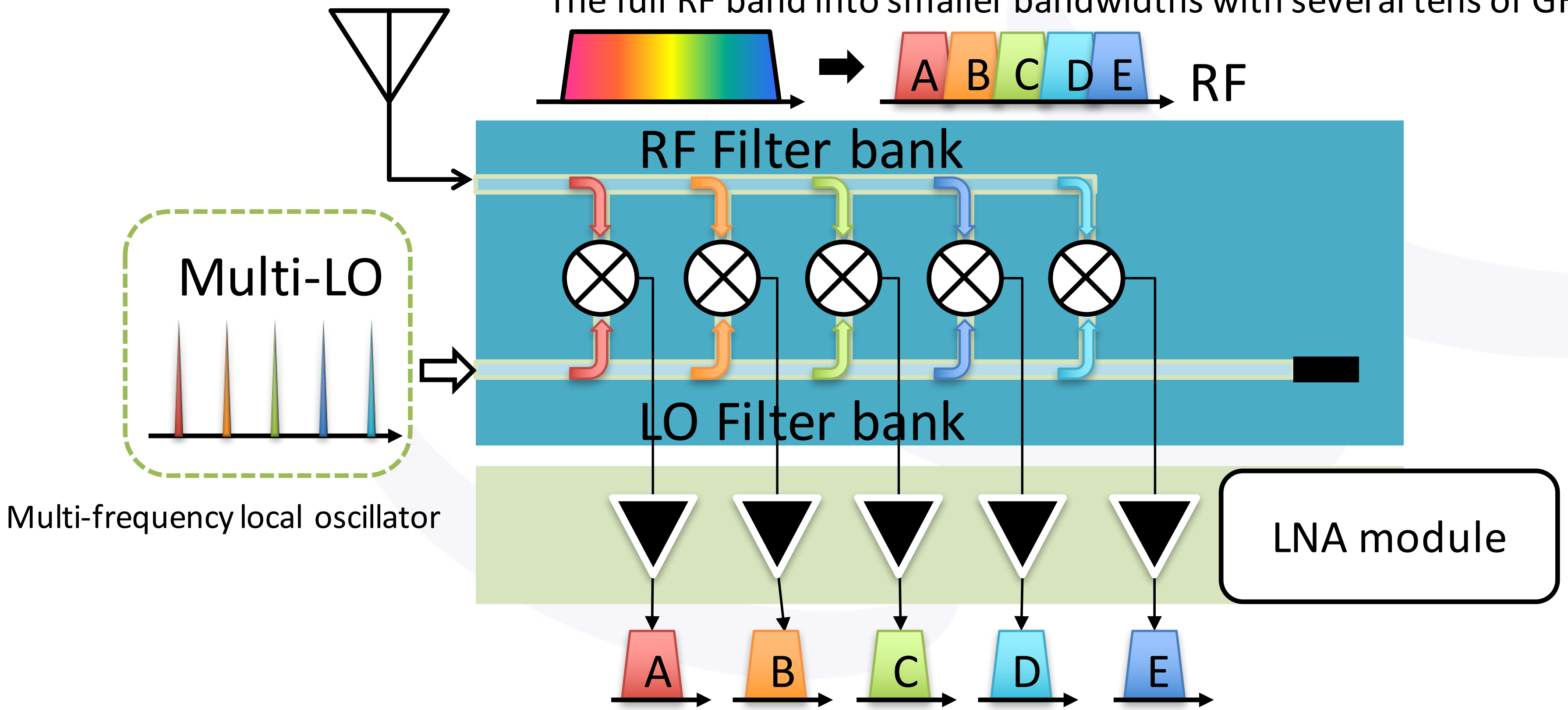
-Response of the SIS mixer over 2-22 GHz
-Very flat noise over 2.5-19 GHz



Instantaneous observation bandwidth > 100 GHz

- Advantage in terms of development: SIS mixers can be tuned for particular channel.
- Disadvantage: Very complex receiver system

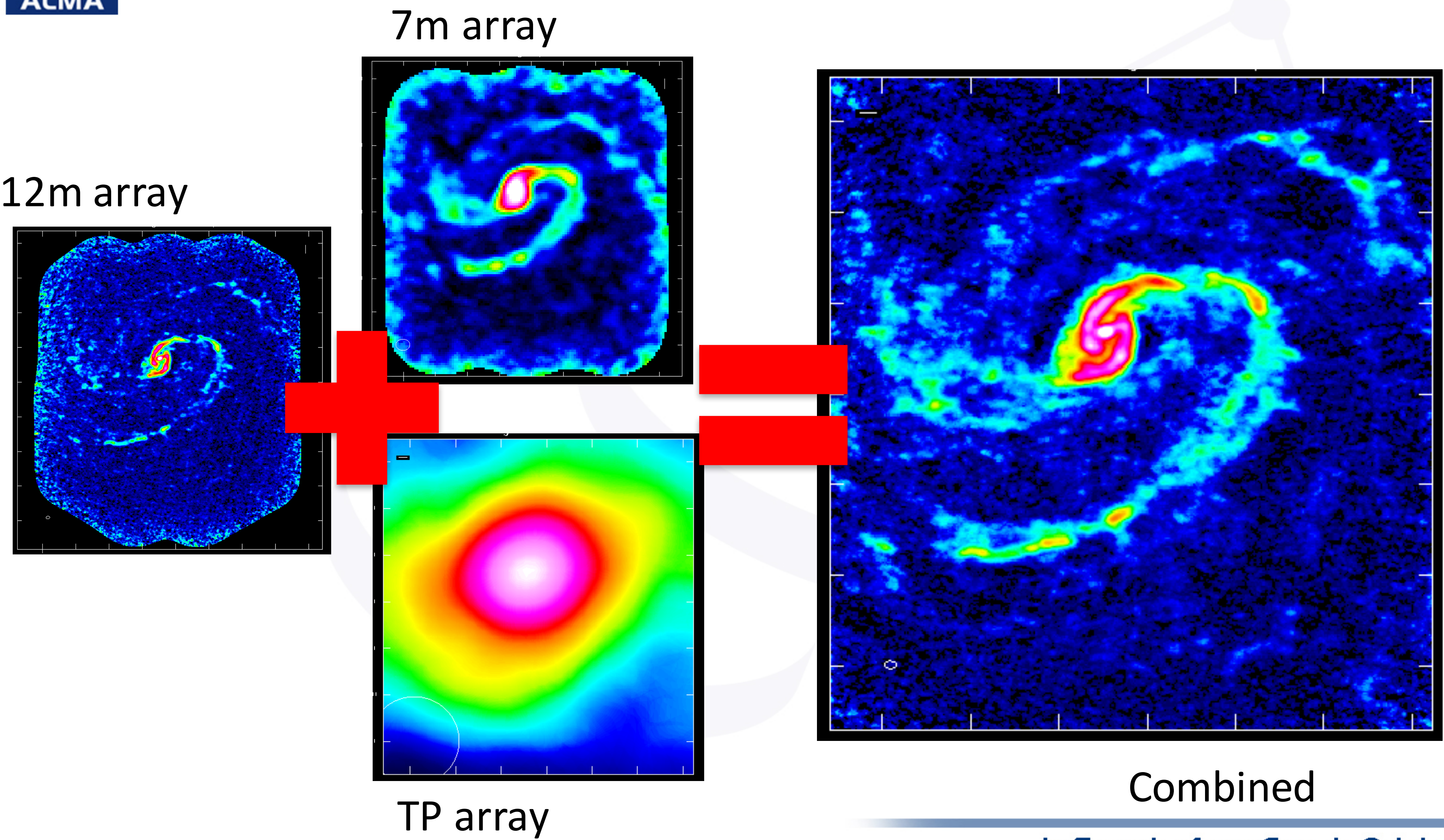
The full RF band into smaller bandwidths with several tens of GHz.



The down-converted signals can be simultaneously amplified with dedicated similar IF amplifiers.

GPU Spectrometer for TP Array

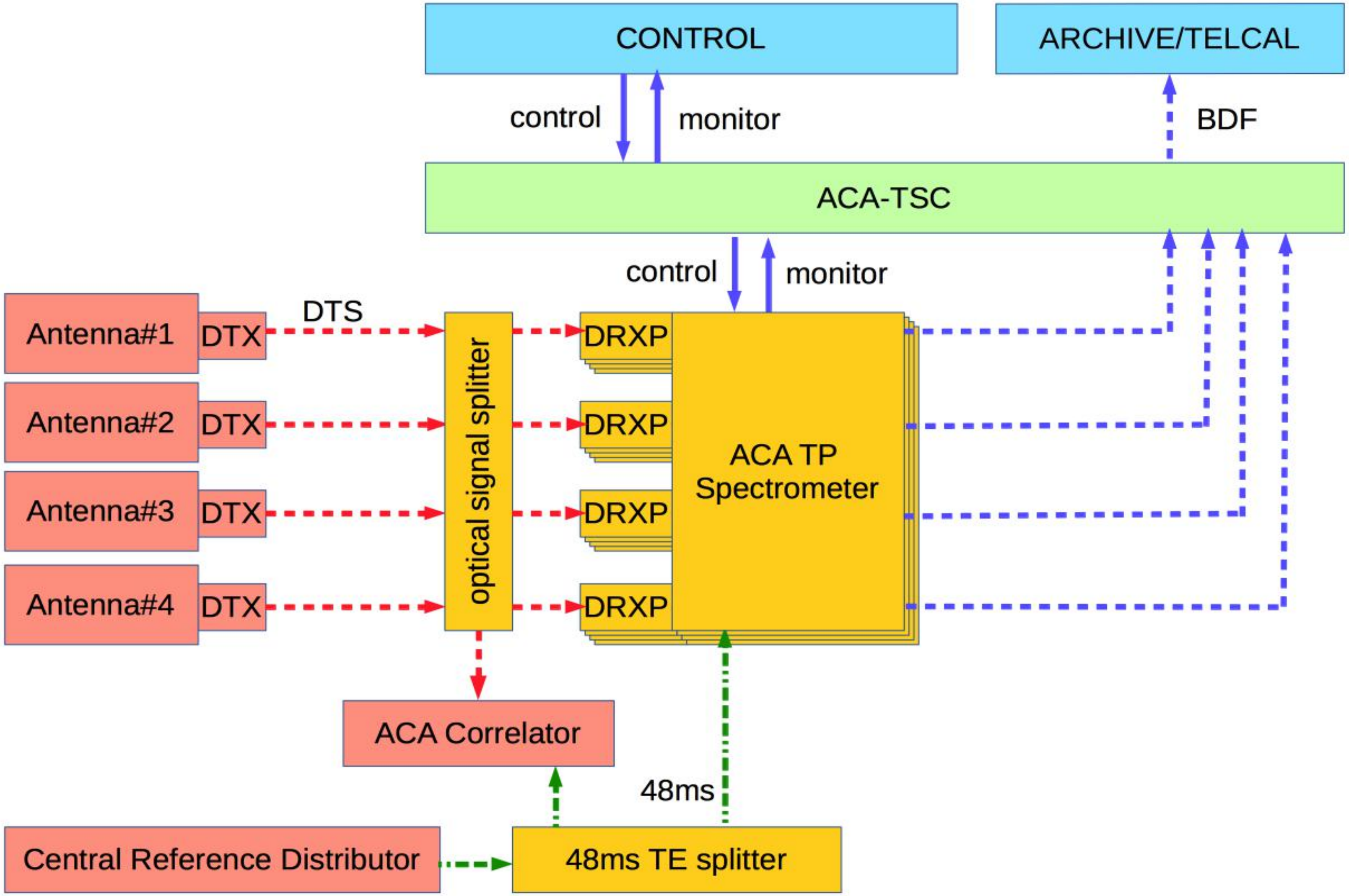
Scientific Importance of the ACA



Scientific Importance of the new TP Spectrometer

- Scientific Advantage
  - Higher sensitivity (by eliminating sensitivity loss due to re-quantization)
  - High accuracy (by allowing 32-bit quantization)
- Operational Advantage
  - Improvements in efficiency (by separating 7m with TP array)
  - Simple architecture
- Specs will be the same as the ACA correlator

Specifications



ASTE Development

Collaboration within EA ALMA

- Spectrometer: J. Kim (KASI)
- Band 7/8 receiver: J.W. Lee (KASI)
  - Single pixel (2017 -)
  - Multi pixel (2019 -)
- TES Camera (270-350GHz camera): T. Oshima (NAOJ)

Collaboration with Universities

- FMLO: Y. Tamura, A. Taniguchi (U. Tokyo)
- 230 GHz receiver: T. Sakai (UEC)
- THz receiver: S. Yamamoto (U. Tokyo)
- DESHIMA (On-chip Filterbank Spectrometer): A. Endo (Delft)

Summary

- Projects
  - Band 1
- Studies and Small Projects
  - ALMA Calibration source
  - High Jc SIS junction device and wide bandwidth receivers
  - GPU spectrometer for TP array
  - Optics design
- ASTE development project (connected to ALMA)