Title: Array Site Reports 3

Date: Nov 13, 2014 10:45 AM

URL: http://pirsa.org/14110143

Abstract:

Status of the ARO Sub-millimeter Telescope

Arizona Radio Observatory

R.W. Freund, E. F. Lauria, G. P. Rieland, L.M. Ziurys
University of Arizona

ARO and the SMT

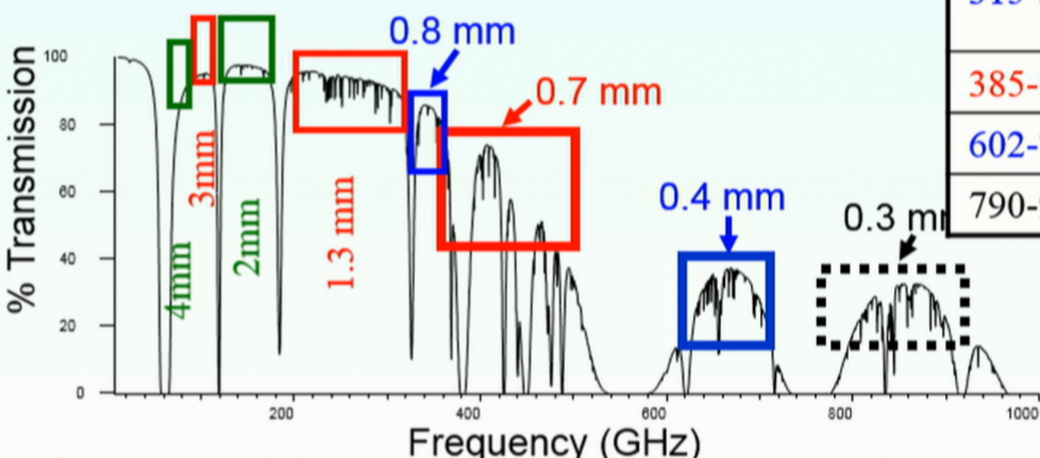
- SMT – once the Submillimeter Telescope Observatory with the Heinrich Hertz 10 m Telescope has been operating since 1993
- Located on Mt. Graham, Arizona, at 3186m (10,453 ft).
- 121 Km northeast of Tucson
- Thermally stable with CFIRP back structure & panels – 24 hour operation
- 15 µm rms surface accuracy
- η_B ~80% at 230 GHz
- Ruze limit > 1 THz capable operation

ARO Receiver Capabilities

- High-sensitivity, high-precision spectroscopy
- Covering 7 atmospheric windows between 65 GHz and 1 THz

⇒ Providing SIS receivers using two orthogonal polarization channels

- Transitioning to sideband separating mixers



ARO Receivers		
ν (GHz)	Teles.	Type
68-90	12-m	1 SSB, 2 pol replacement planned
83-116	12-m	2 SSB, 2 pol
133-180	12-m	1 SSB, 2 pol
211-275	SMT	2 SSB, 2 pol
315-365	SMT	DSB, 2 pol replacing
385-500	SMT	2 SSB, 2 pol
602-720	SMT	DSB, 2 pol
790-950	SMT	Planned

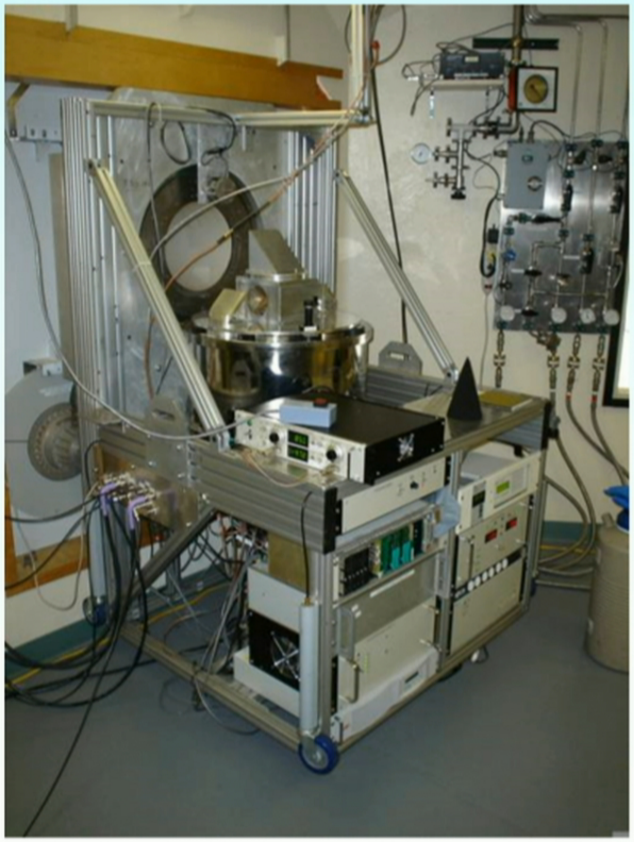
Arizona Radio Observatory

EHT Instrumentation

- Receivers - 1.3 mm & 0.8 mm
- IF Infrastructure – currently 4 to 8 GHz
- Frequency Reference and 10 MHz Distribution – new Microsemi active H-maser and Distribution Amp
- Optical Path Components – quarter-wave plates for circular polarization capability
- Backend digitizers and recorders

1.3mm Dual Polarization Sideband-Separating Receiver

- First ARO receiver using ALMA developed mixers - 2006
- Collaboration with NRAO
- RF Band: 210 – 280 GHz
- T_{rx}: 70 – 80 K (SSB)
- Mixer Class: Sideband Separating
- Polarization: dual orthogonal linear
- Polarization separation: crossed wire grids
- IF Passband: 4 – 8 GHz
- IF Bandwidth: 4 GHz
- 4 IF Channels – 16 GHz of bandwidth



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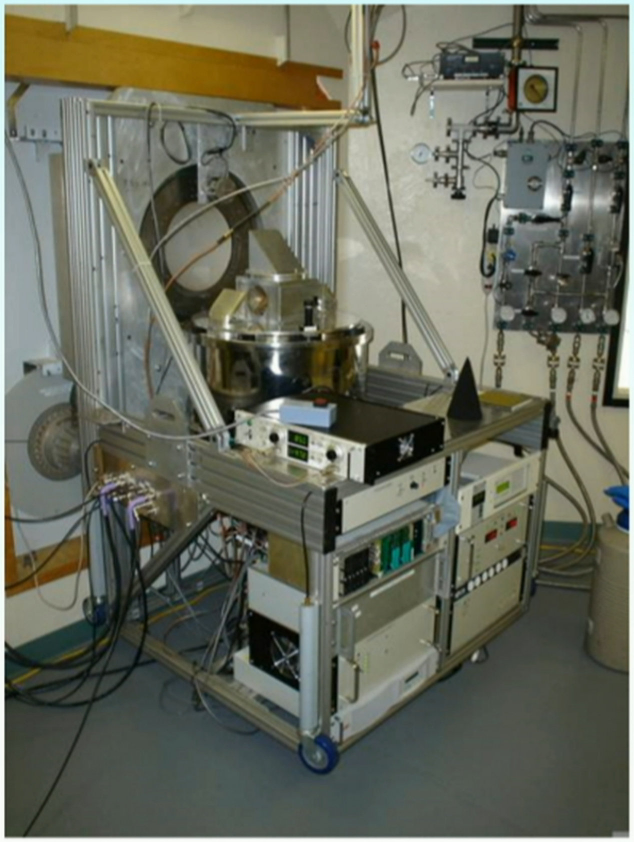
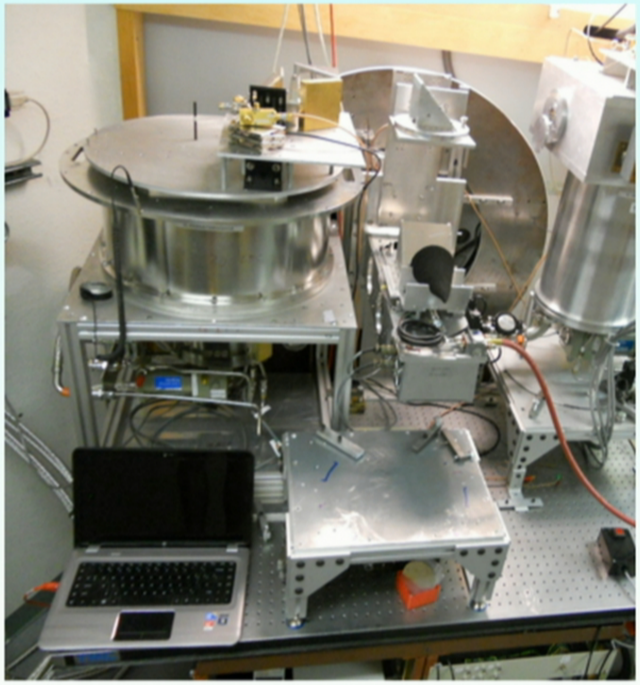


Planned Modification to 1.3 mm Receiver

- Extend IF passband to 9 GHz – simple upgrade
- Replace external cross wire grids with cooled orthomode transducers within Dewar

0.8mm Dual Polarization Double-Sideband Receiver



- ASIAA versions of SMA SIS DSB mixers – circa 2008
- RF Band: 320 – 360 GHz
- $T_{rx:}$ 70 – 90 K (DSB)
- Mixer Class: Double Sideband
- Polarization: dual orthogonal linear
- Polarization separation: crossed wire grids
- IF Passband: 4 – 6 GHz
- IF Bandwidth: 2 GHz
- 2 IF Channels – 4 GHz of bandwidth

Planned Upgrades to 0.8 mm Receiver

- Replace DSB SIS mixers with ALMA class sideband separating SIS mixers – expected 2015 (SIS device design is complete, wafers to come)
- Extend IF passband to 4 – 8 GHz
- Add additional IF channels to support full sideband separating
- Install modified mixer cartridges in 1.3 mm Rx Dewar

IF Infrastructure

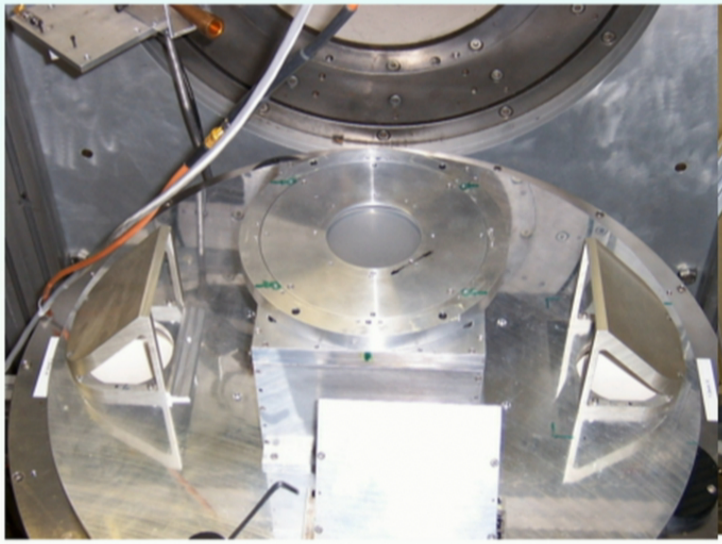
- 4 channels
- 16 GHz total bandwidth
- Current passband covers 4 – 8 GHz
- Plan to extend IF passband to 4 – 9 GHz
- Same IF capabilities for all receivers

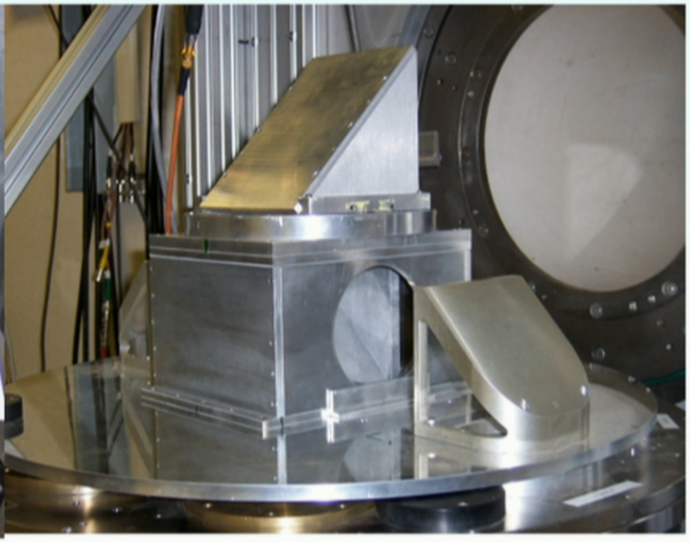
Frequency Reference

- New Microsemi (Sigma-Tau) active H-maser in its new closet – replaces the venerable Smithsonian P8
- Microsemi (Symmetricom) 6301 distribution system with 6315 - 10 MHz 12-channel amplifier modules

Optical Path Components

- Room temperature quarter ¼-wave plate
- Room temperature wire-grid polarizer, for dual circular
- Flat calibration load (reflections)





Backend digitizers and recorders

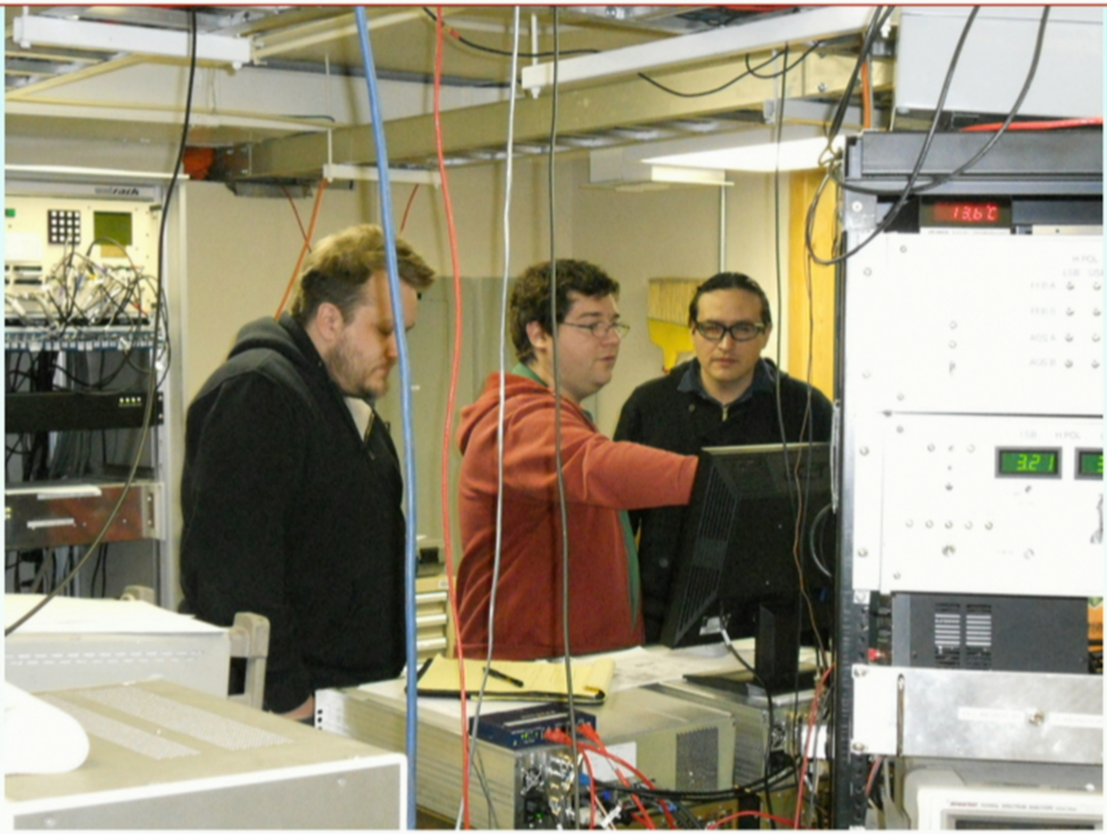
- Digital backend:

1) IF passband: 4 – 9 GHz
2) Recorded Bandwidth: 4 GHz
3) # IF Channels: 4
4) Total Recorded Bandwidth 16 GHz

- Recorders:

A Typical SMT VLBI Program

Done!



Arizona Radio Observatory

New 12-Meter on Kitt Peak

- The ALMA Project built two 12 m antennas for evaluation in 2002
- 1st call for interest in an ALMA prototype antennas (NA) – May 2010
- Acquired European antenna from ESO – Mar 23, 2013
- A replacement for the former NRAO 12-meter antenna on Kitt Peak
- Enhances longer-wavelength mm radio astronomy at the ARO
- Issues: Antenna located at the VLA site in New Mexico, approximately 650 km away, Big and Heavy: 12 m diameter, 97 tonnes
- How does one transport this object over the public highway system?

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Status of the Greenland Telescope (GLT)

Inoue, M.
Academia Sinica
Institute of Astronomy and Astrophysics
(ASIAA)

in collaboration with
SAO, MIT Haystack Observatory, and NRAO

EHT 2014, November 10-14, 2014, Perimeter Inst. For Theoretical Physics, Waterloo

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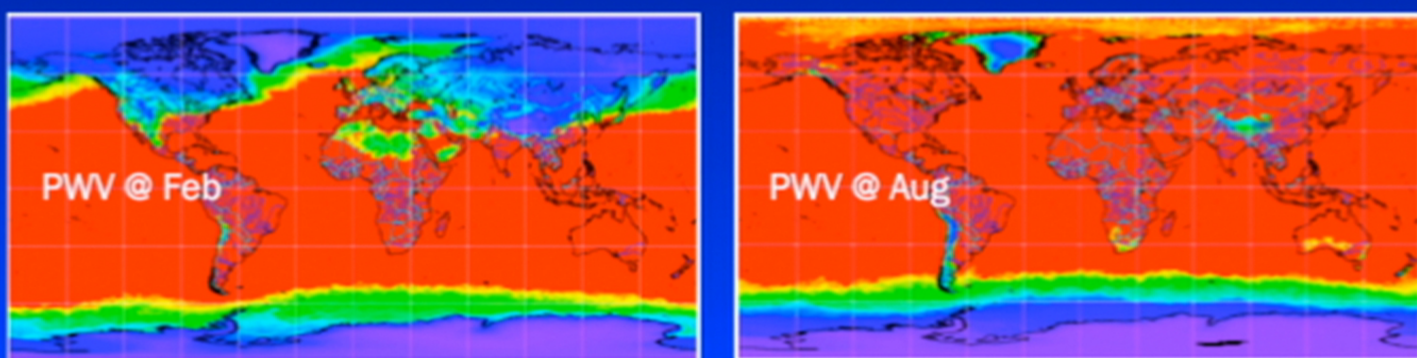
ALMA North America Prototype Antenna

Site selection

For the submm VLBI site

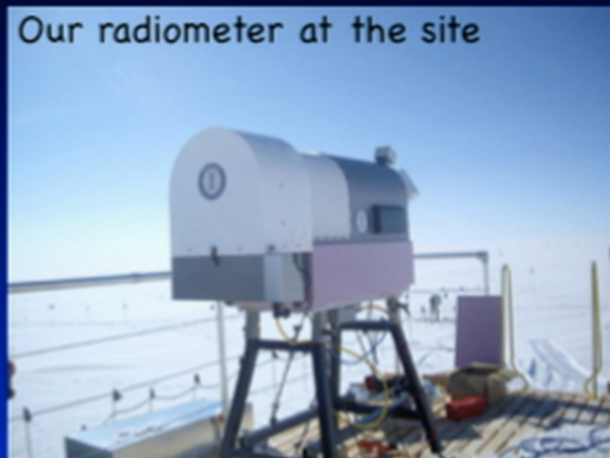
1. Low Precipitable Water Vapor (PWV)
   Low temperature/High mountain/Desert
2. Outstanding contribution to submm VLBI
3. Mutual visibility with ALMA and SMA
4. Easy to access (including infrastructures)

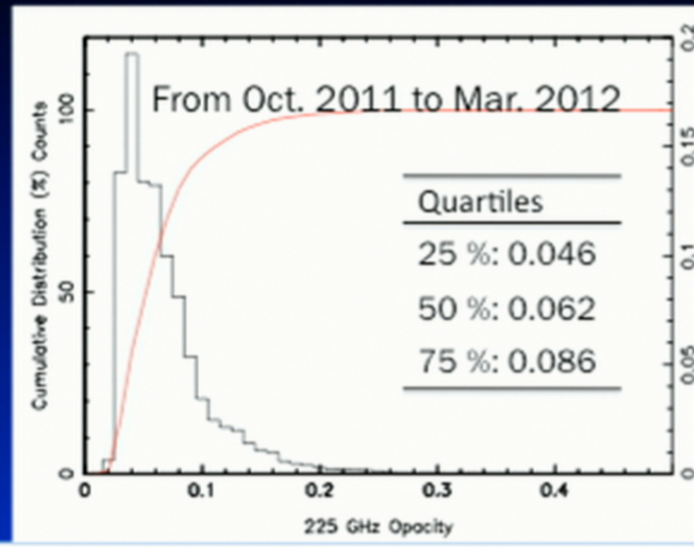


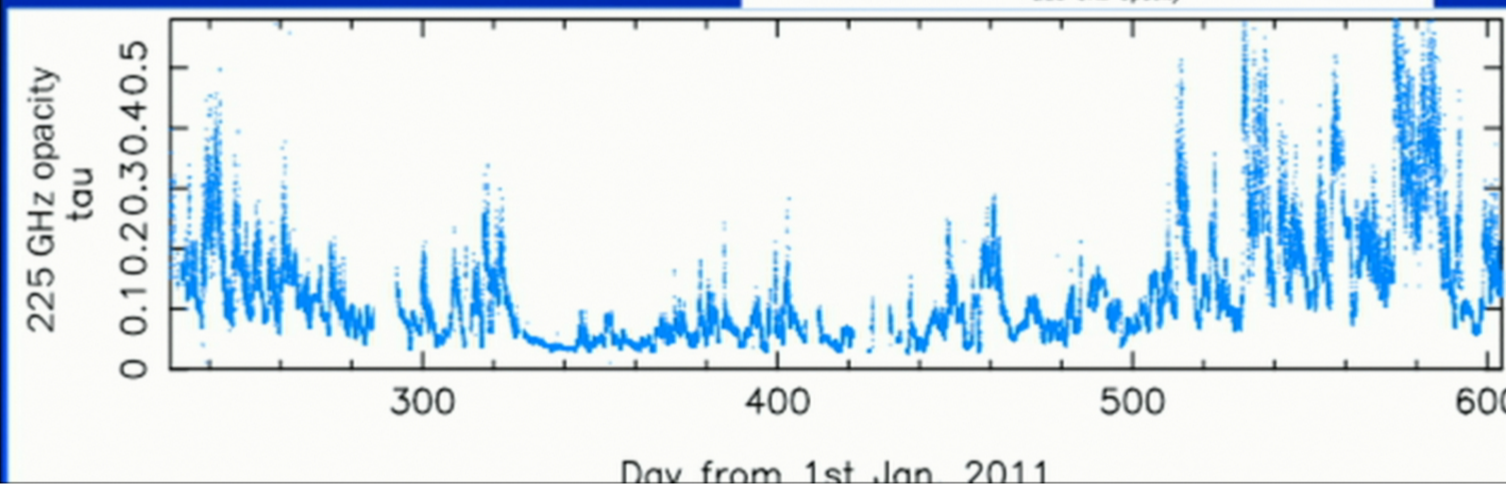
PWV > 10 mm in red color

Distribution of PWV by Terra and Aqua (NASA)

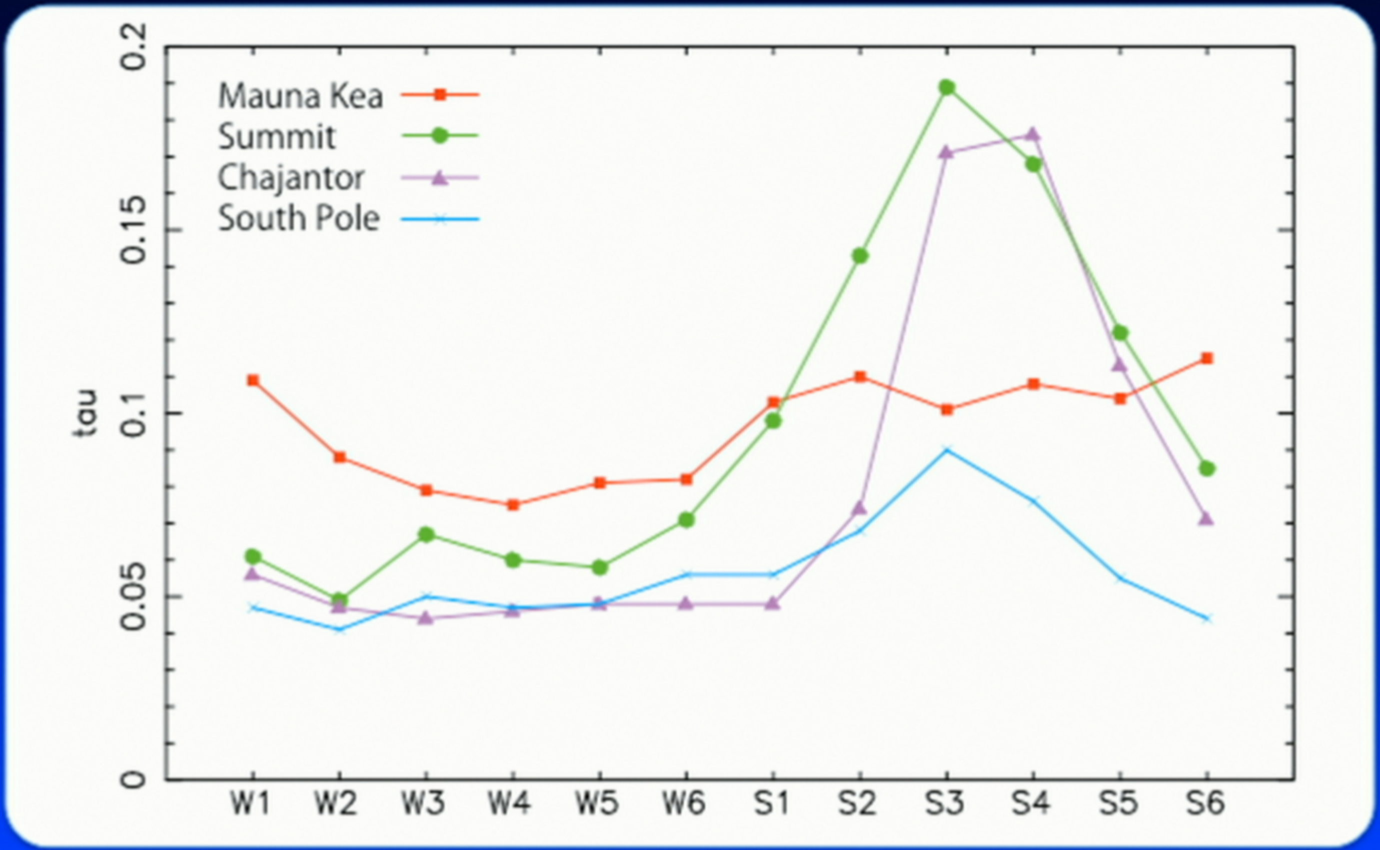
Site testing at Summit Camp







Opacity of submm site



Northern Hemisphere: November.-April; May-October
Southern Hemisphere: May-October; November-April

P. Martin-Cocher et al. 2014, SPIE 37

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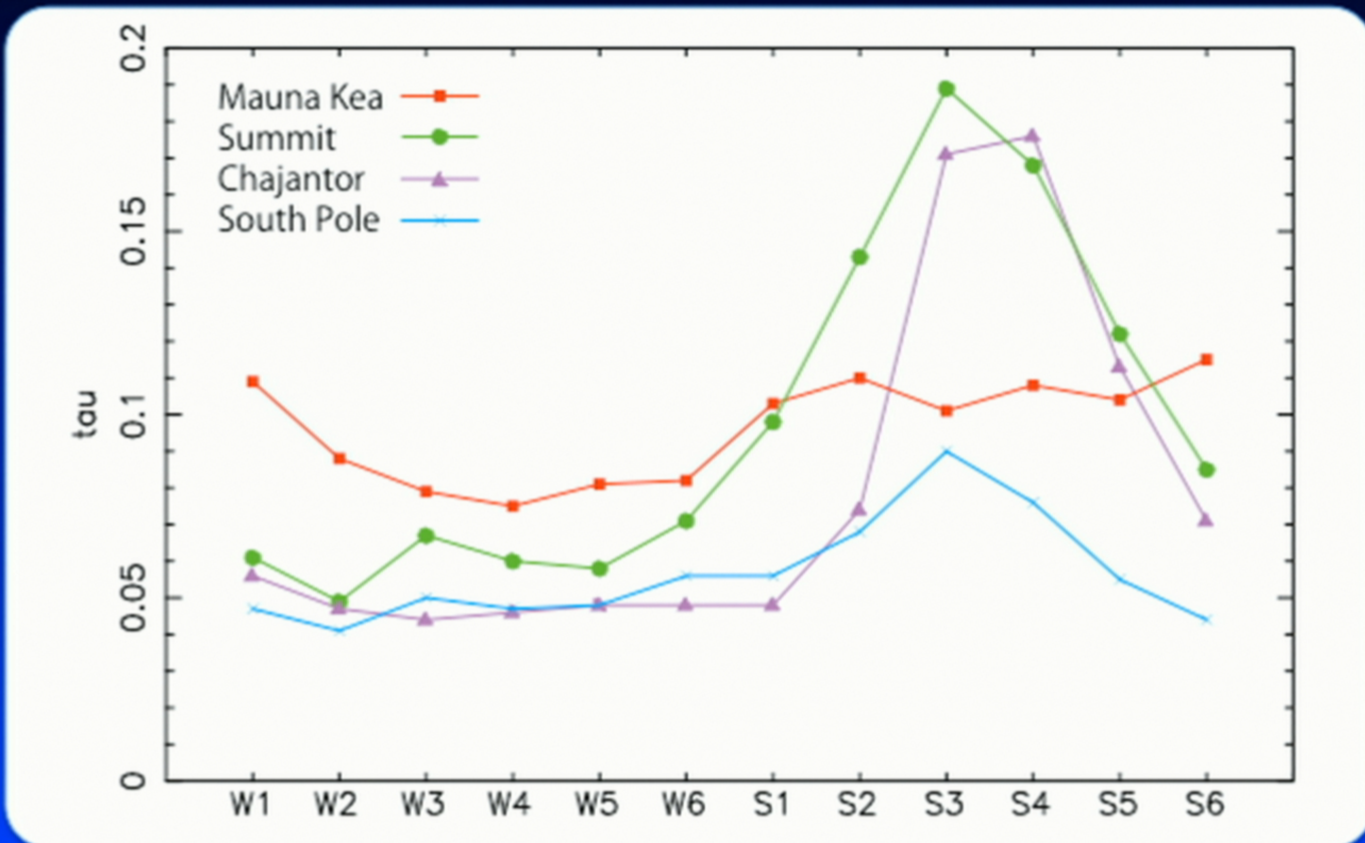

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P. Martin-Cocher et al. 2014, SPIE

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Receiver	Band (GHz)	Beams	Requirements	Source/Status
Holography Receiver	93	1 + ref	Secondary defocus, reference receiver, transmitter	SAO - Main receiver built Reference in build Optics under design
VLBI – W-Band	86	1	VLBI backend, tone injection	ASIAA
VLBI – Band 6 similar	211-275	1	VLBI backend, tone injection	Osaka Pref. Univ. Cryostat and optics: OPU/NAOJ
VLBI – Band 7	275-373	1	VLBI backend, tone injection	IRAM / ALMA type Cryostat and optics: OPU/NAOJ
350 GHz Multibeam	325-375	48	Flat focal plane	SAO - Prototype development underway
Bolometric Spectrometer	W-band - 350 GHz	Few?	Flat focal plane, pulse tube cooler	SAO/Cambridge – starting to plan technology development
THz Receivers	1.3 THz, 1.5 THz	1-7	Stable optics, good dish surface	SAO/ASIAA? – concept development

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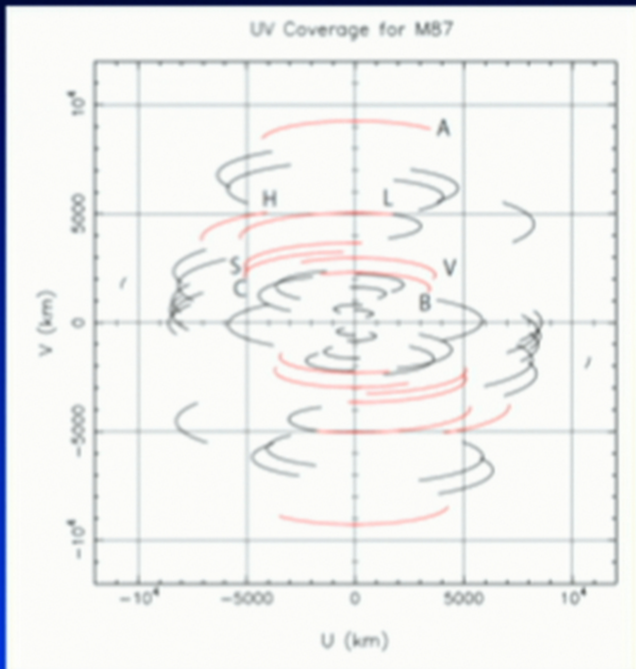
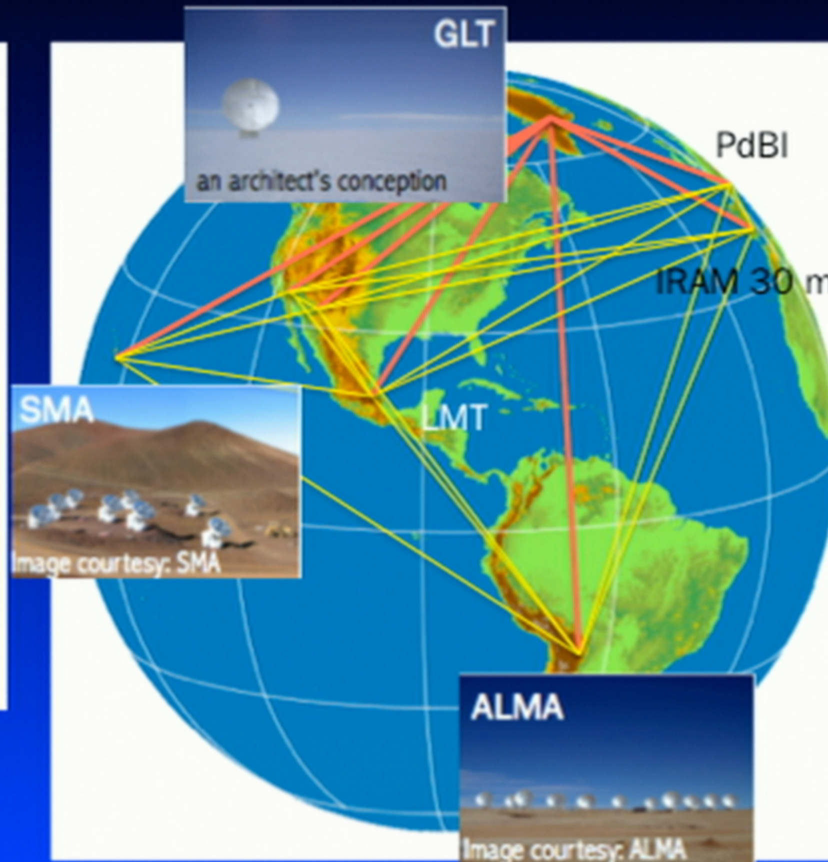
Air/Traverse Towards the Summit Station
Thule
Facilities at Summit Station

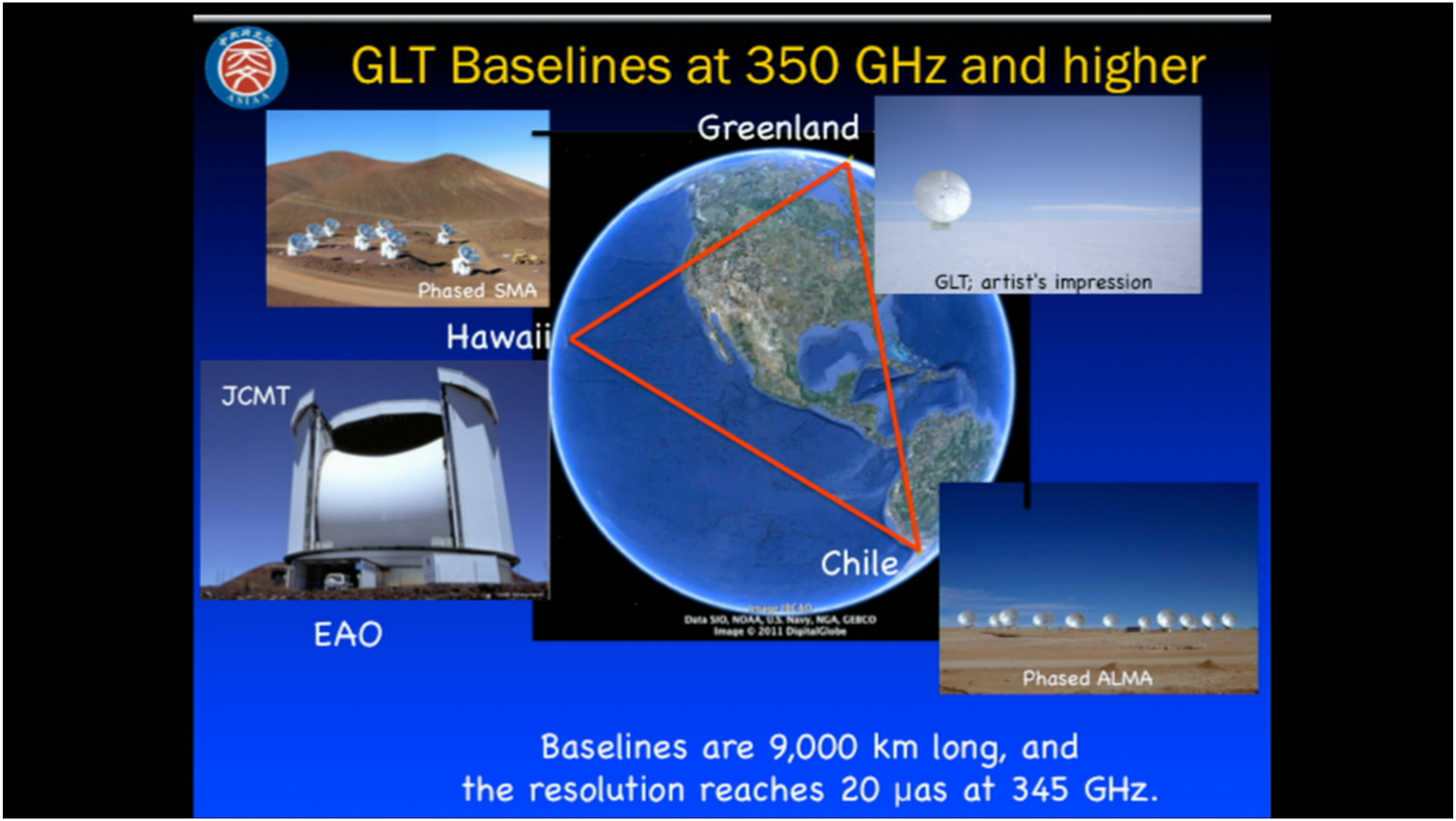
Expected uv coverage with GLT





uv coverage for M 87 with GLT, SMA, ALMA, SMT, LMT and IRAM 30m. The Baselines with GLT are shown in red.

Baselines >9,000 km provides 20 μas resolution at 345 GHz!



GLT Baselines at 350 GHz and higher
Greenland
GLT; artist's impression
Phased SMA
Hawaii
JCMT
EAO
Chile
Phased ALMA
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2011 DigitalGlobe
Baselines are 9,000 km long, and
the resolution reaches 20 μas at 345 GHz.

Thule Air Force Base in Greenland

Timeline

- NSF Call for Proposal: 12.2010
- Antenna awarded to ASIAA/SAO: 04.2011
- Antenna inspection: 04.2011
- Antenna power-up, surface check: 07.2011, 01.2012
- Antenna retrofit evaluation: 11.2011 – 03.2012
- Antenna pointing test: 06 – 08. 2012
- Disassembly in Socorro: 09 – 12. 2012
- Antenna retrofitting for cold: 09.2012 – 12.2014
- Antenna to Greenland (Thule): 07. 2015
- Antenna full functioning test (Thule): 10.2015 – 02.2016
- GLT First light in Thule: 01.2016
- GLT VLBI observations in Thule: 2016-2018
- Antenna to Greenland Summit: 03.2018
- GLT Operational on Summit: 10.2018

The main facility


Current Status of ALMA and
the Long Baseline Campaign
Satoki Matsushita
(ASIAA, Taiwan)

Current Status

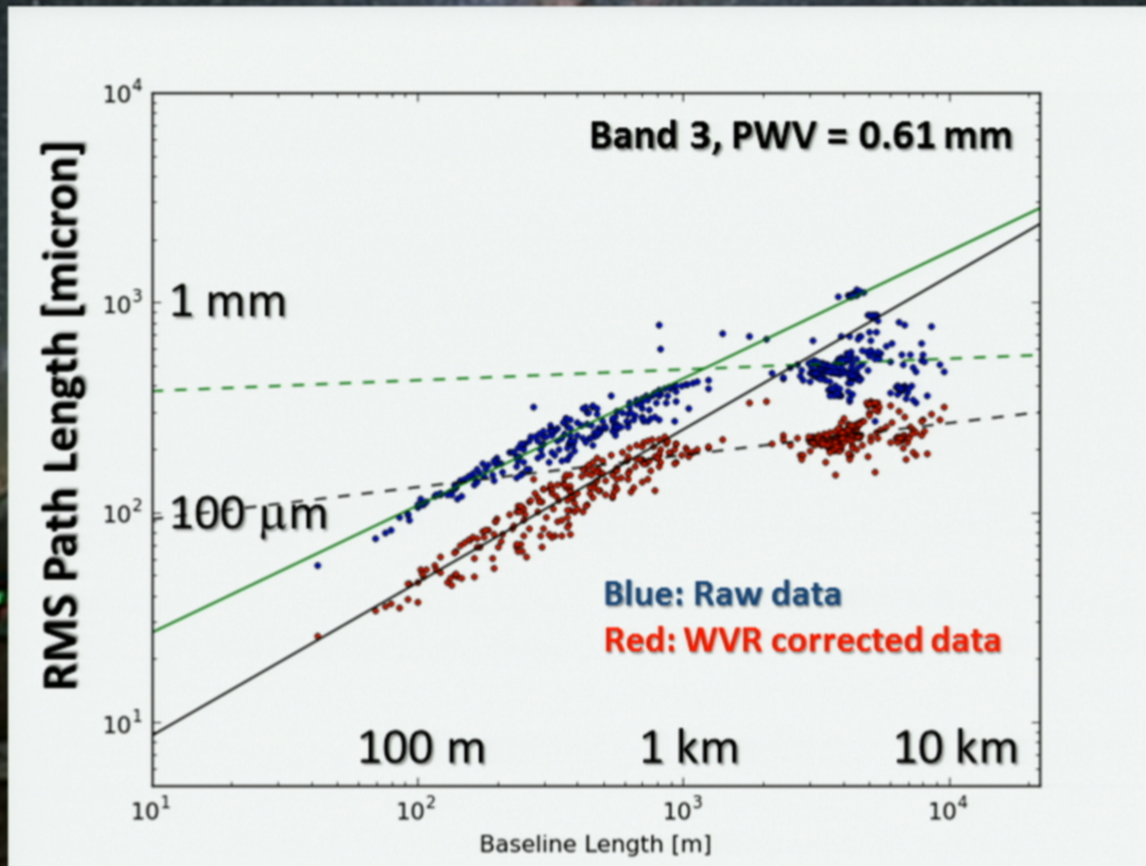
- Construction phase finished.
- Number of Antennas at the high site:
  - 64 Antennas (as of Nov.12, 2014)
    - 52 x 12-m Antennas
    - 12 x 7-m Antennas
- Current Cycle:
  - Cycle 2 (continue till Oct. 2015)


Long Baseline Campaign
• Purpose:
– Test the longest baseline (= 15 km).
• Dedicated Campaign:
– 2014 Sep. 1 – Nov. 30.

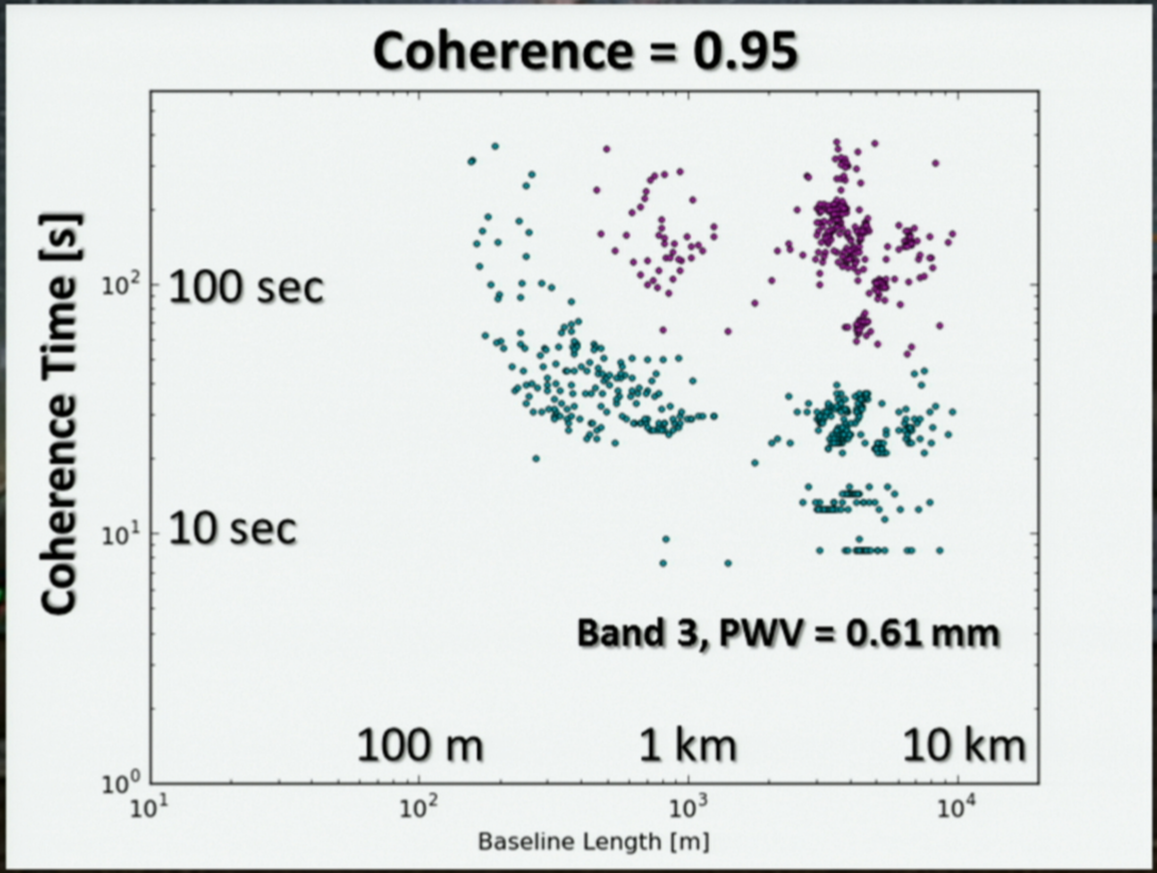

地図
航空写真
27
Purico
Complex
Google
地図データ ©2014 Google, Mapcity 画像 ©2014 TerraMetrics
利用規約

地図
航空写真
ASTE
APEX
Purico Complex
15 km
Google
地図データ ©2014 Google, Mapcity 画像 ©2014 TerraMetrics
利用規約

Spatial Structure Function



Coherence Time



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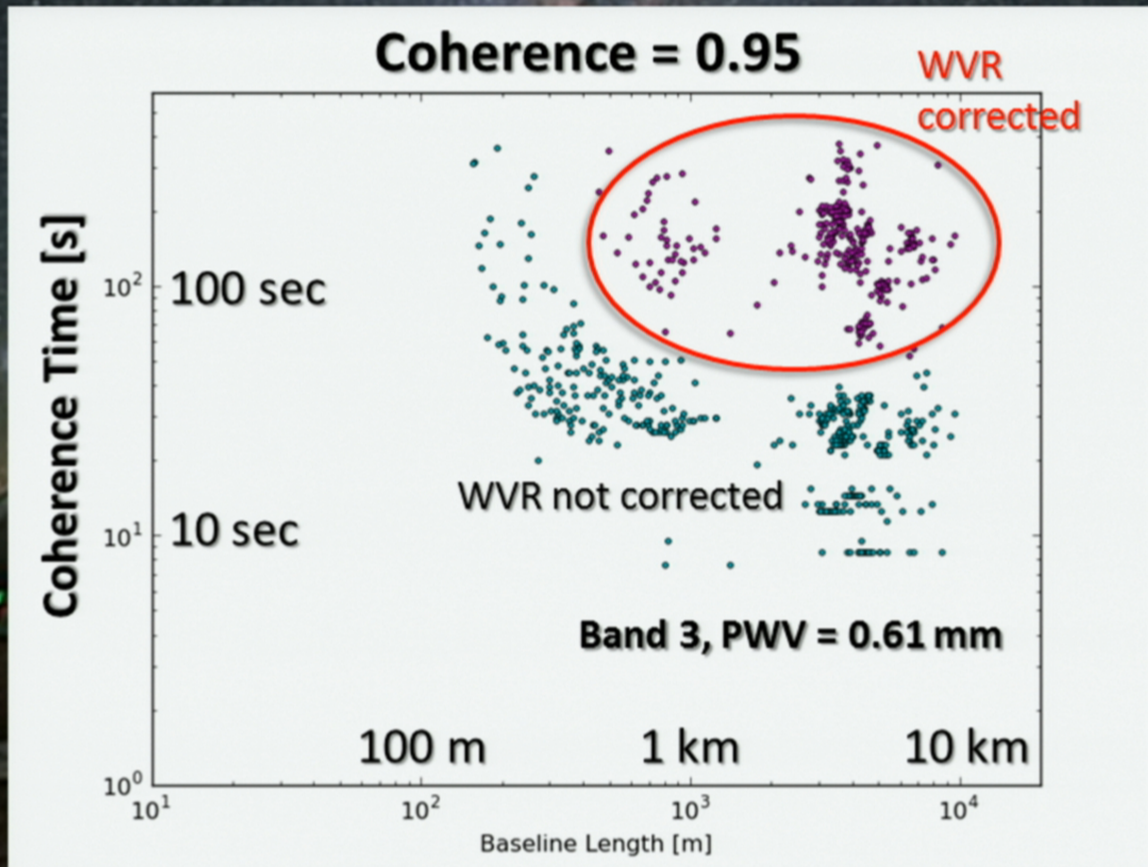
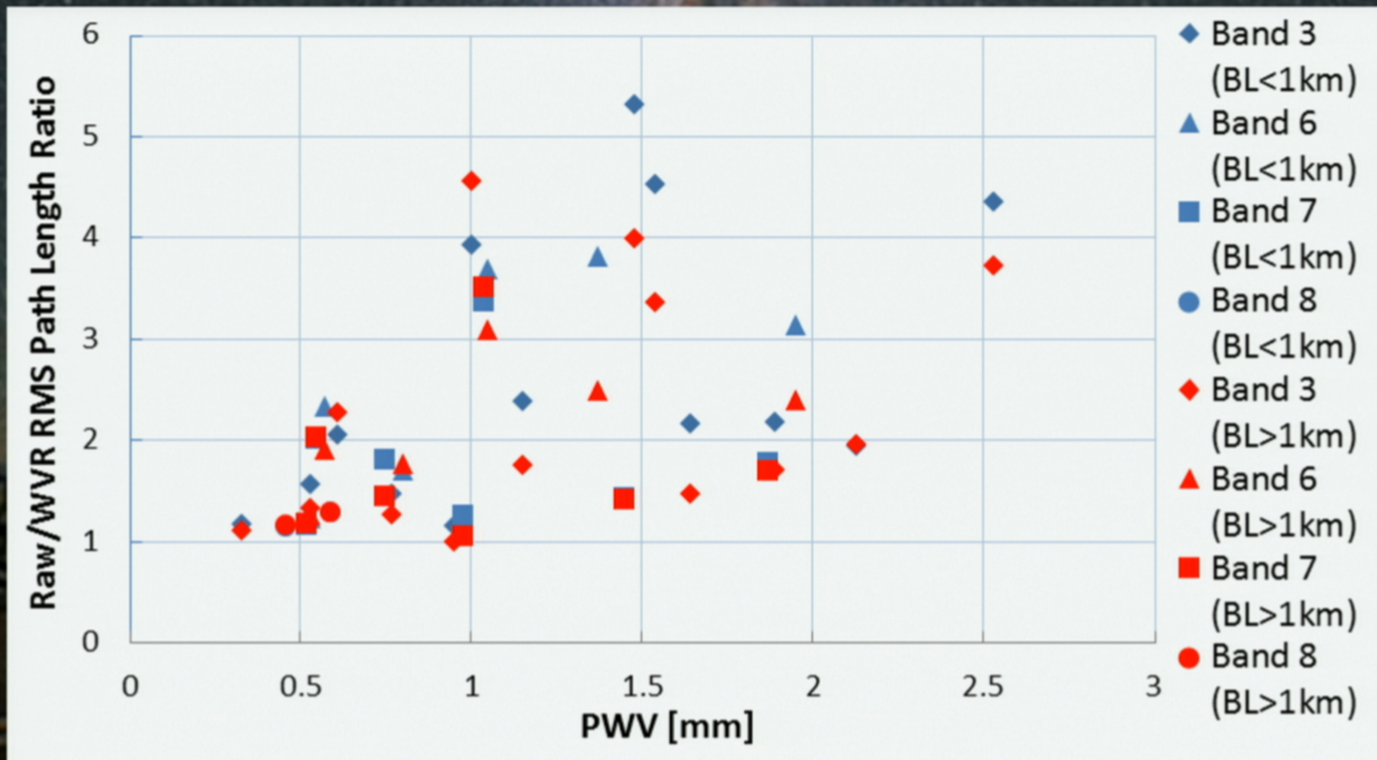
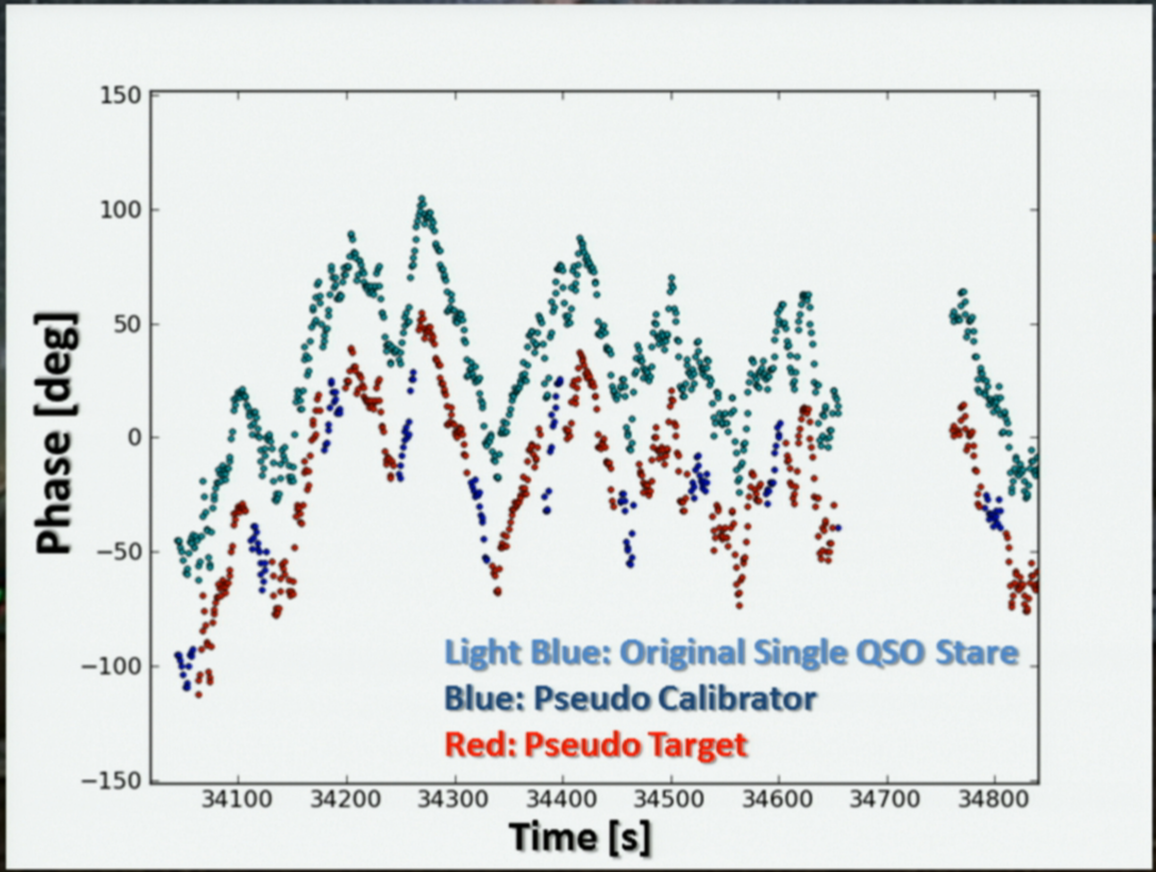


WVR Efficiency



Fast Switching Simulation



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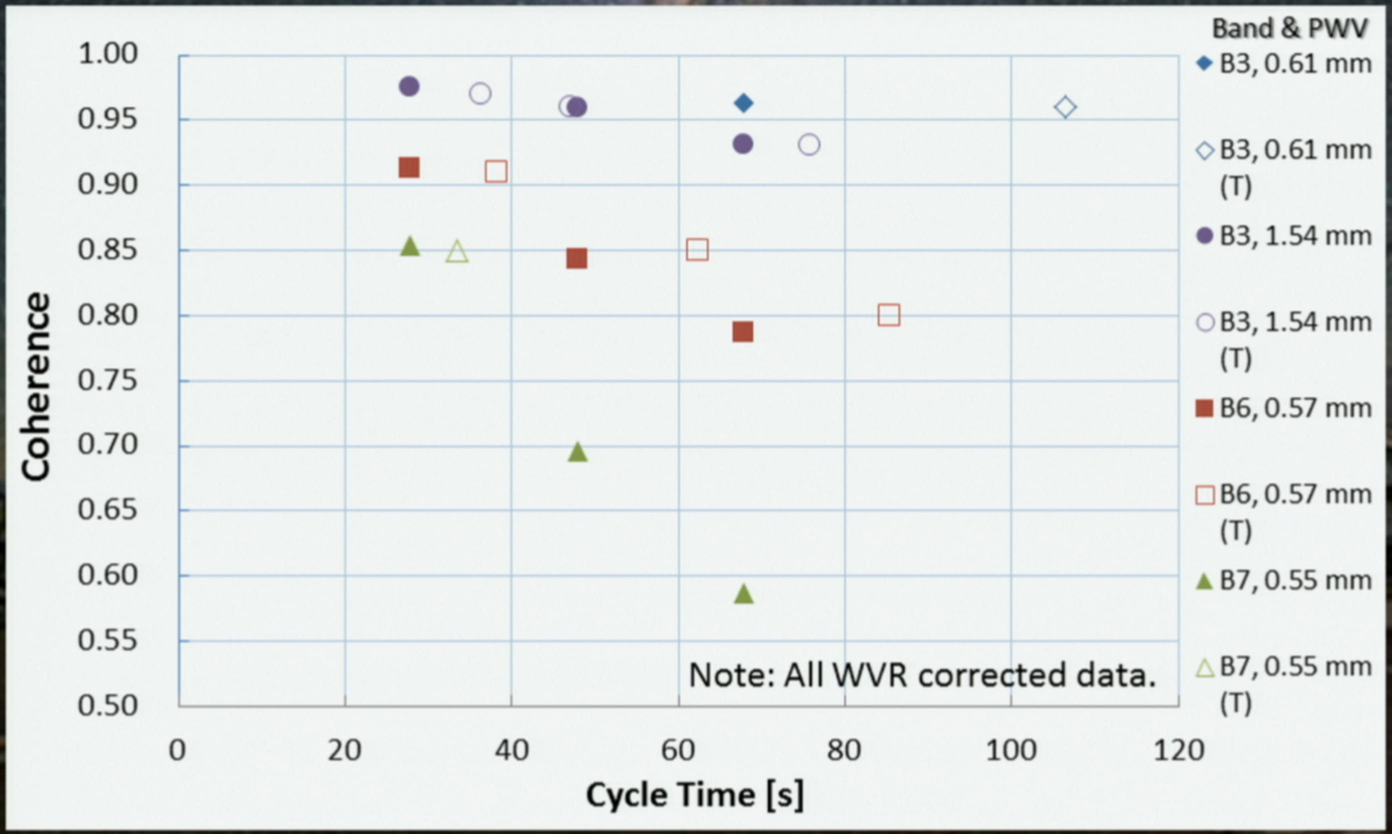

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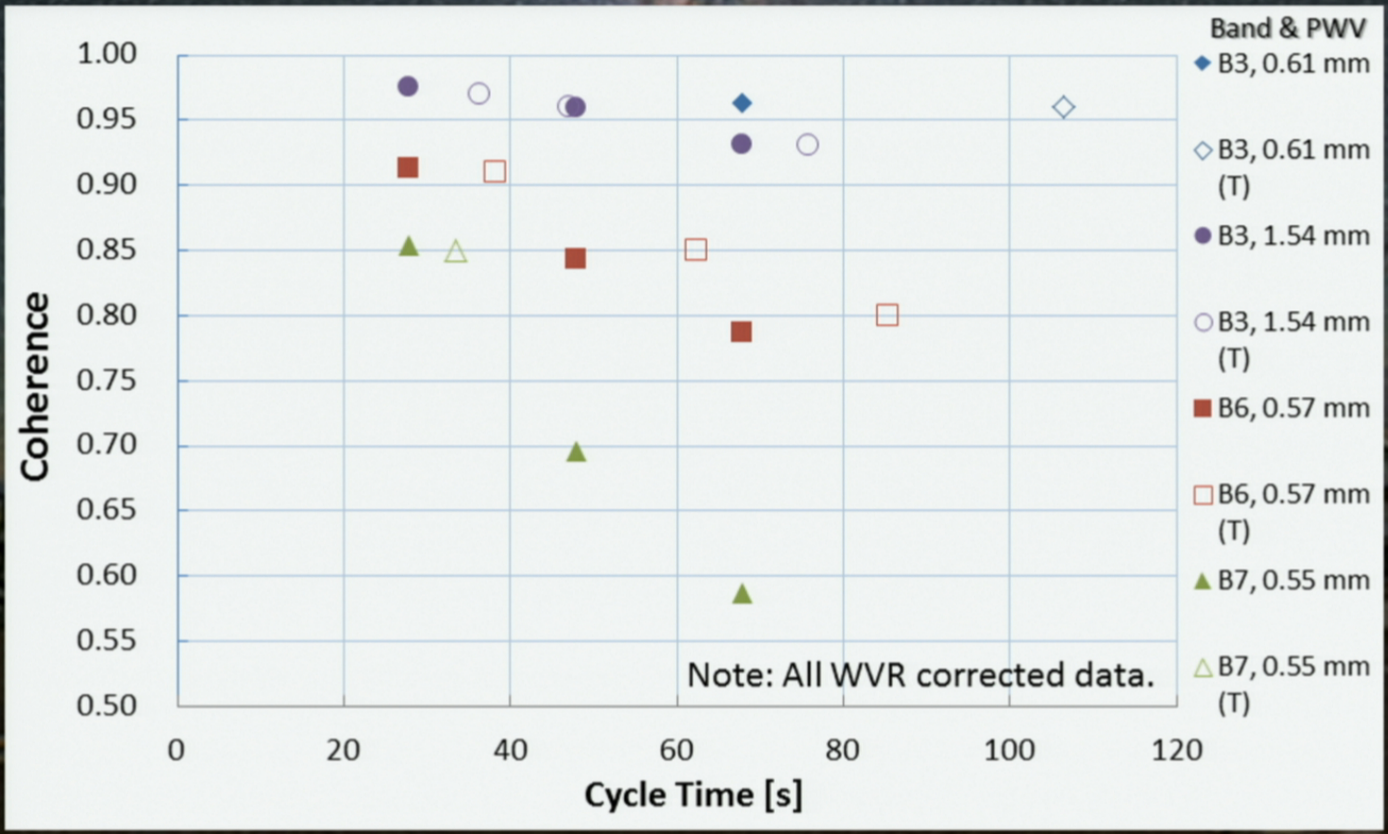
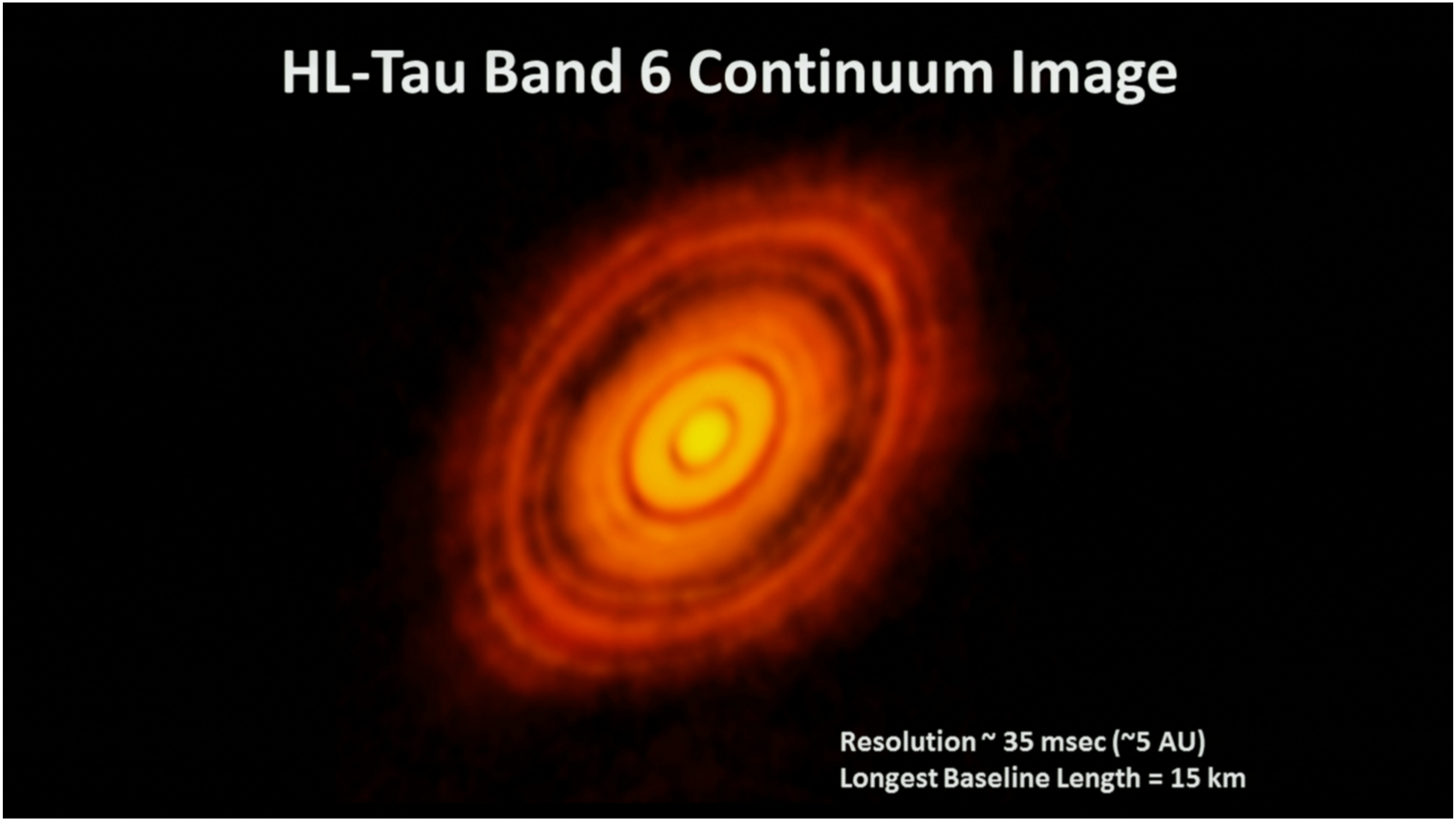
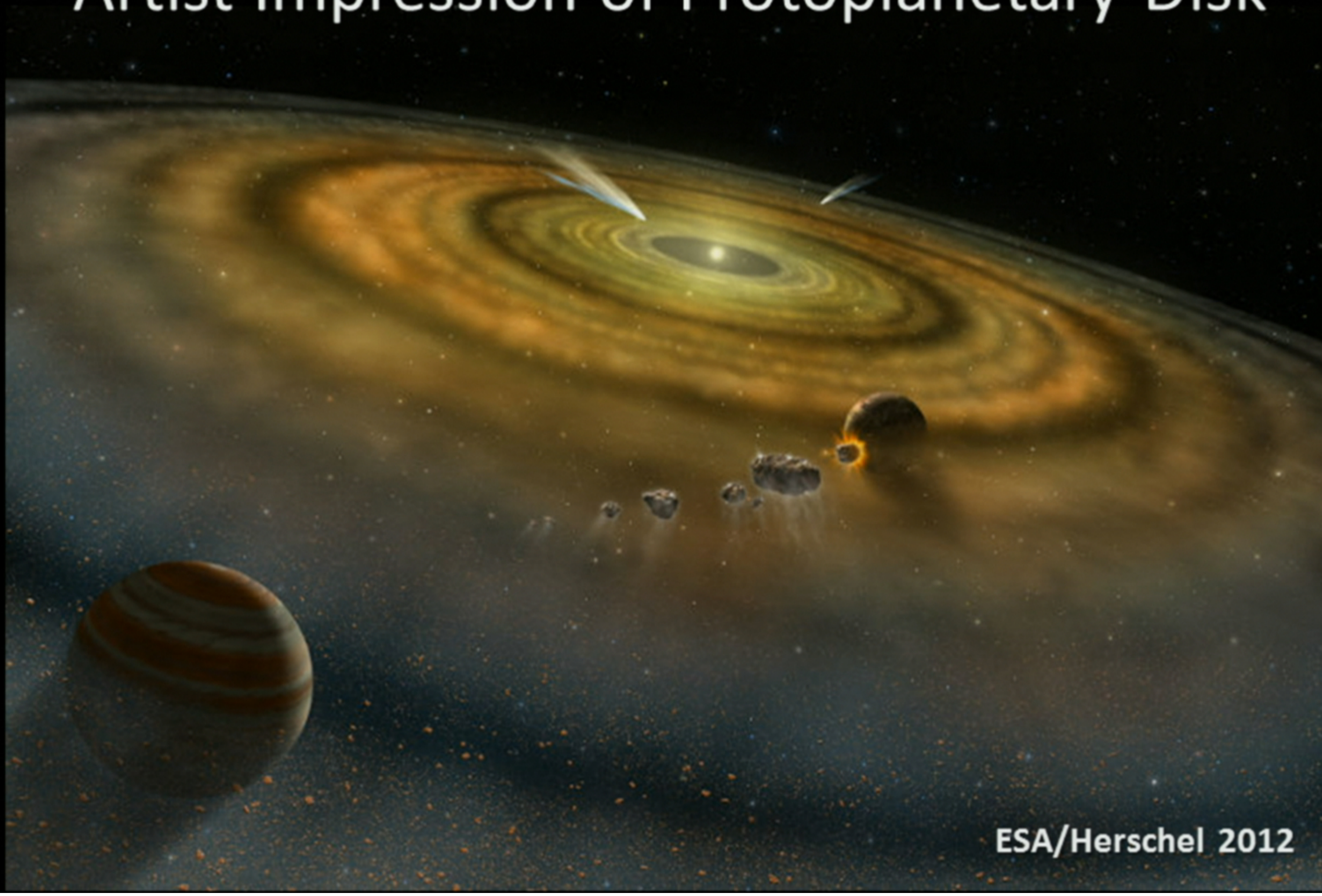



HL-Tau Band 6 Continuum Image
Resolution ~ 35 msec (~5 AU)
Longest Baseline Length = 15 km

Artist Impression of Protoplanetary Disk




INTERSTELLAR
NOVEMBER 7

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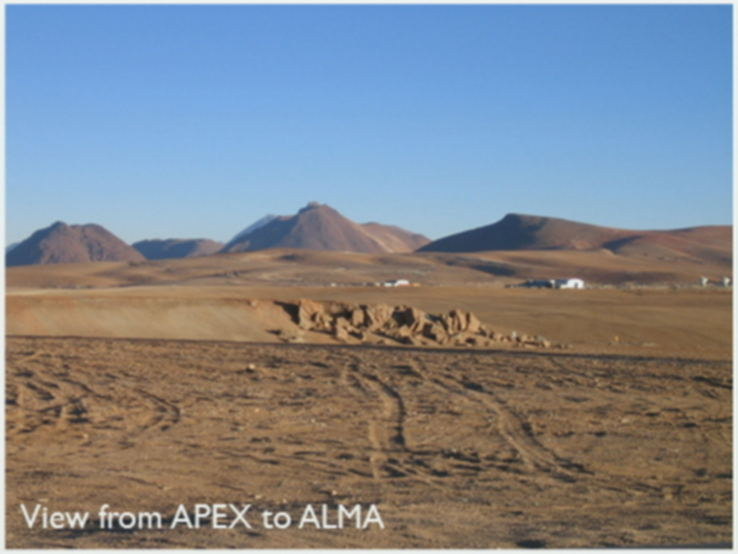
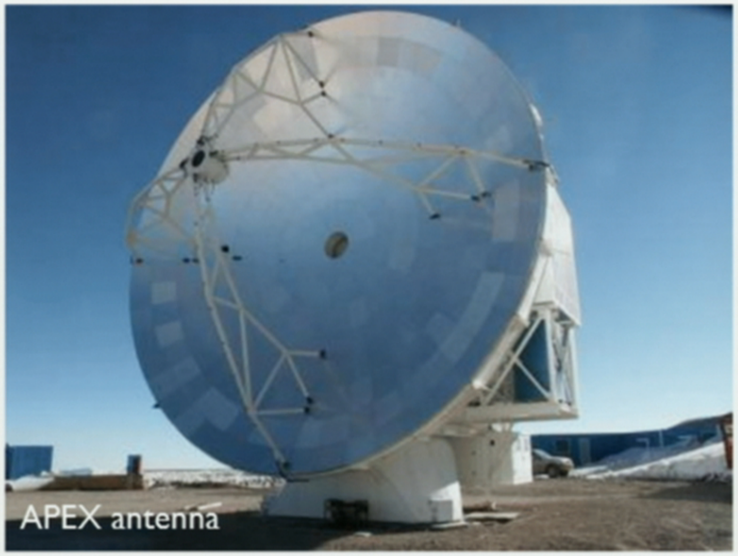
APEX Background





APEX: • Atacama Pathfinder Experiment

• Partners:	MPIfR (50%), Onsala (23%), ESO (27%)
• Design:	Modified ALMA prototype VERTEX antenna, 12 m diam
• Inauguration:	Sep 2005
• Altitude:	5100 m
• Heterodyne Rx:	213 to 275, 267 to378, 358 to 506, 1250 to1390 GHz

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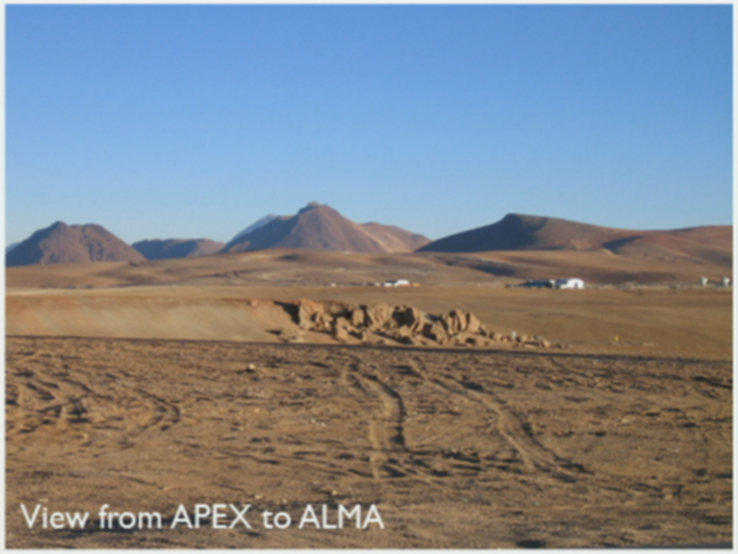

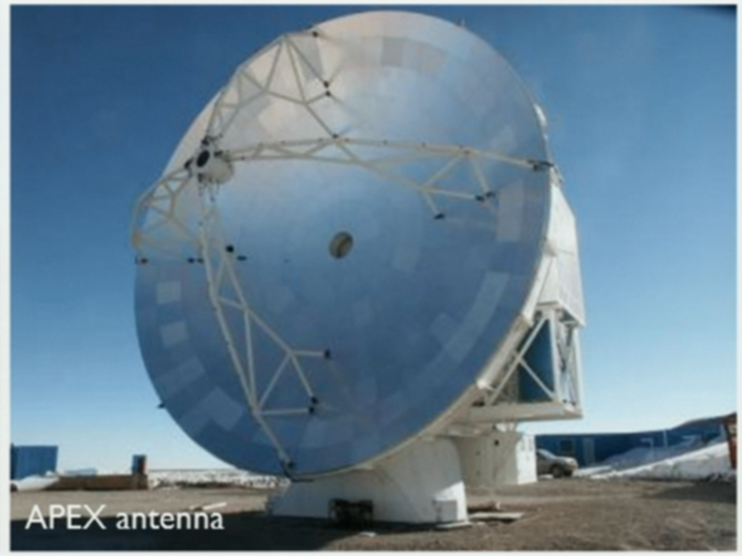

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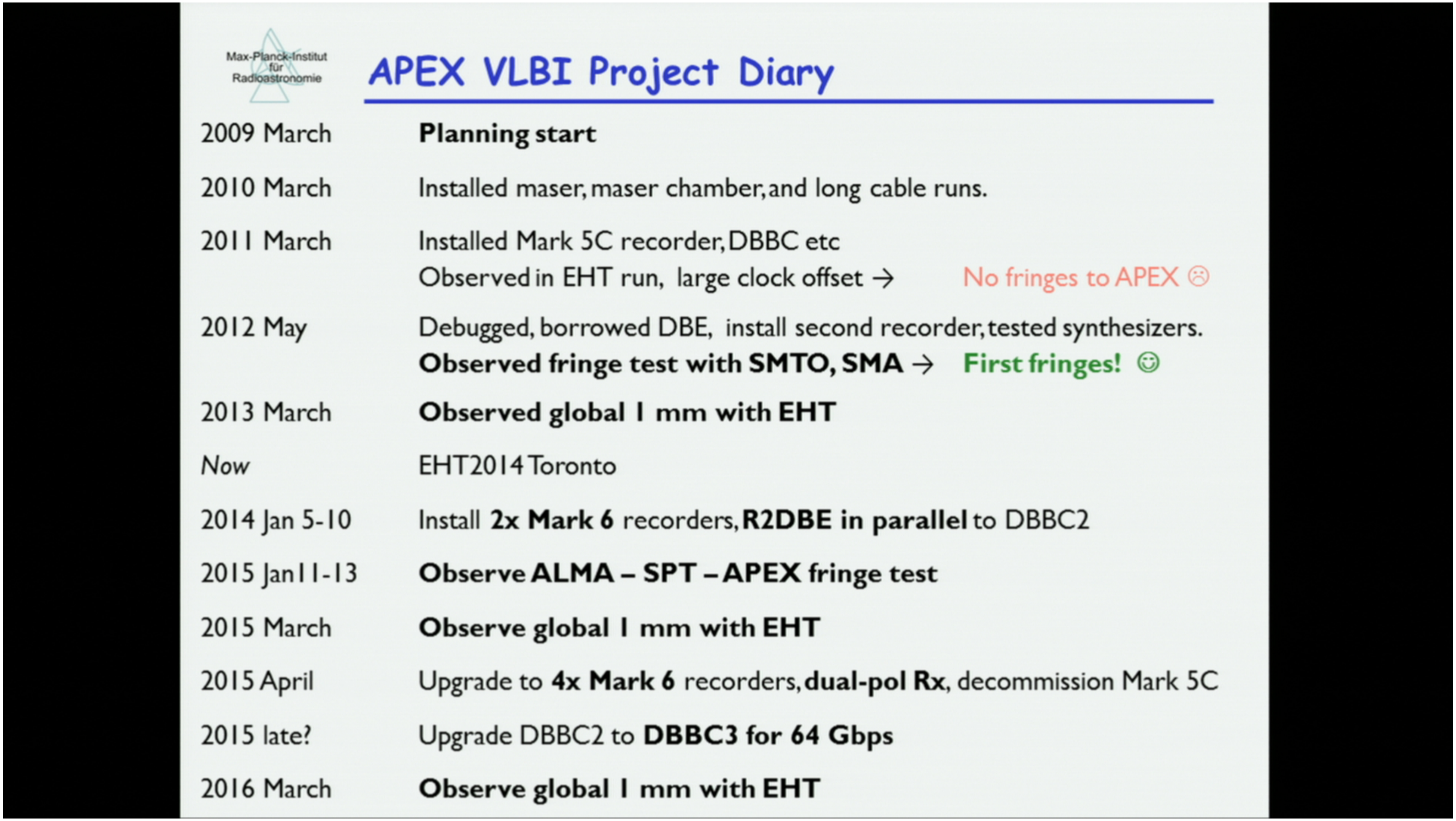
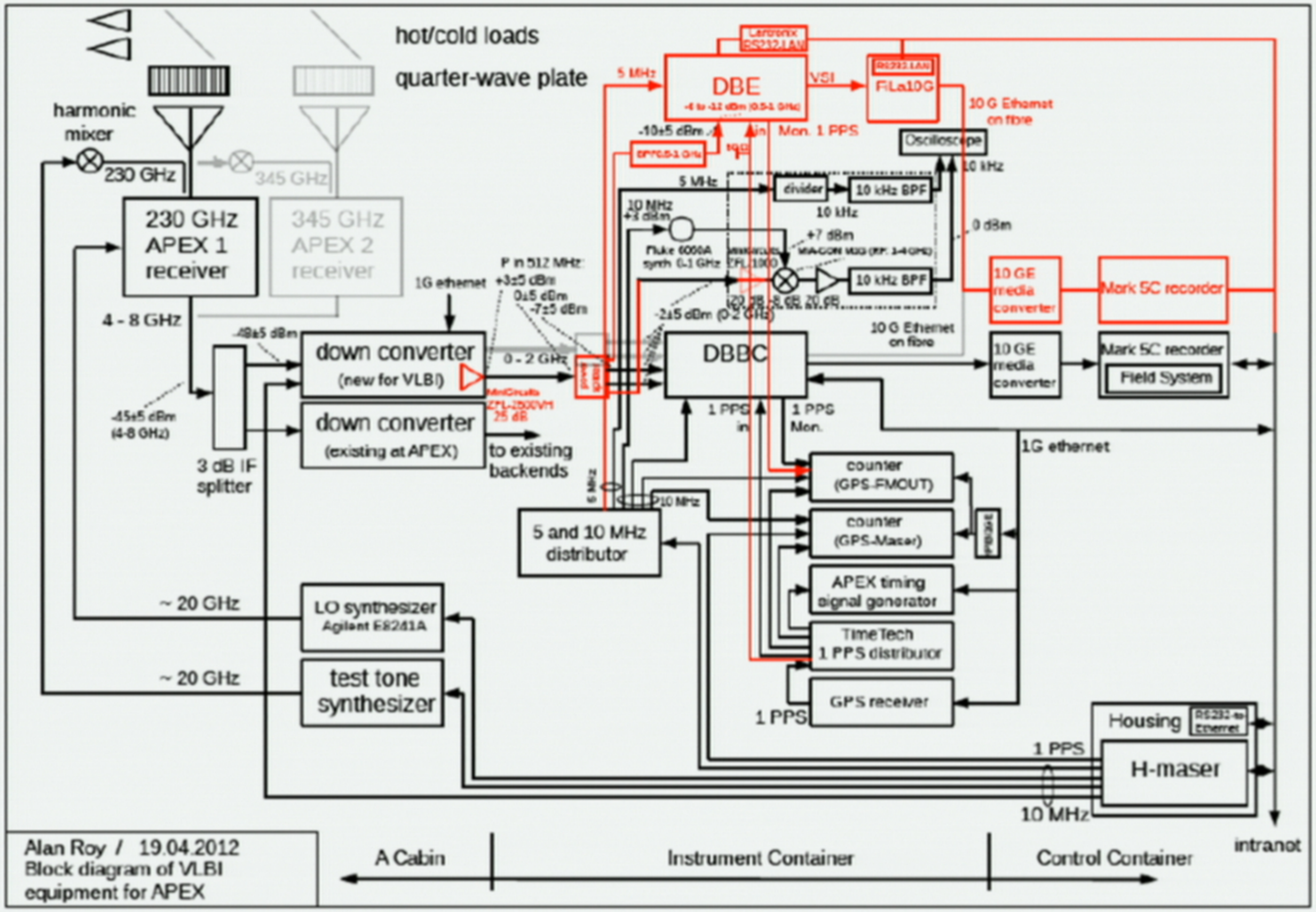

Max-Planck-Institut für Radioastronomie
APEX VLBI Project Diary
2009 March
Planning start
2010 March
Installed maser, maser chamber, and long cable runs.
2011 March
Installed Mark 5C recorder, DBBC etc
Observed in EHT run, large clock offset →
No fringes to APEX ☹
2012 May
Debugged, borrowed DBE, install second recorder, tested synthesizers.
Observed fringe test with SMTO, SMA →
First fringes! ☺
2013 March
Observed global 1 mm with EHT
Now
EHT2014 Toronto
2014 Jan 5-10
Install 2x Mark 6 recorders, R2DBE in parallel to DBBC2
2015 Jan 11-13
Observe ALMA – SPT – APEX fringe test
2015 March
Observe global 1 mm with EHT
2015 April
Upgrade to 4x Mark 6 recorders, dual-pol Rx, decommission Mark 5C
2015 late?
Upgrade DBBC2 to DBBC3 for 64 Gbps
2016 March
Observe global 1 mm with EHT

APEX VLBI Block Diagram



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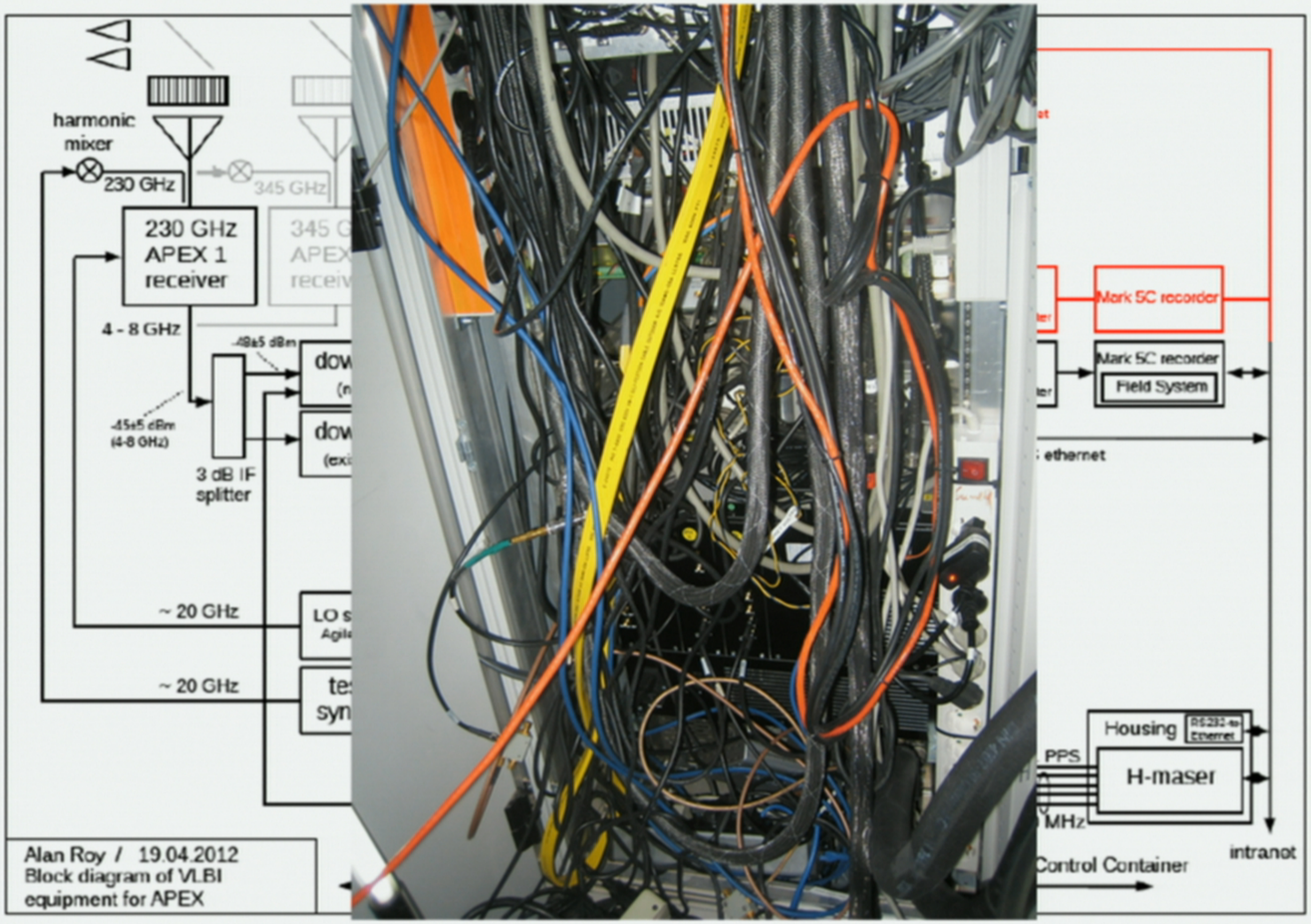

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Special Aspects: Pressurized Recorders

Recorder pressure housing

200 hPa above ambient
→ pressure altitude = 3000 m

Liquid cooled (1.5 kW cooling capacity)

Disks keyed by microcontroller after pressure exceeds threshold

Space for 2 recorders + 4 modules

Manufacturer: Reichert GmbH, Bonn
Price: ~ 20 kEUR to replicate

To be replace with He6 disks + Mark 6 in Jan 2015

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Special Aspects: Data Transmission over Optical Fibre

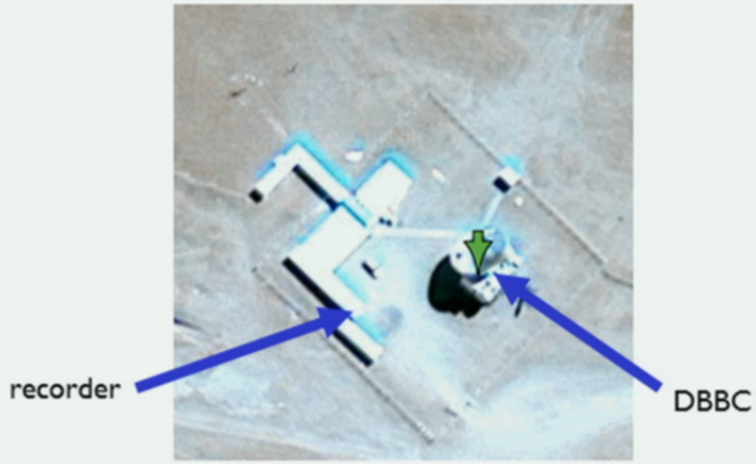


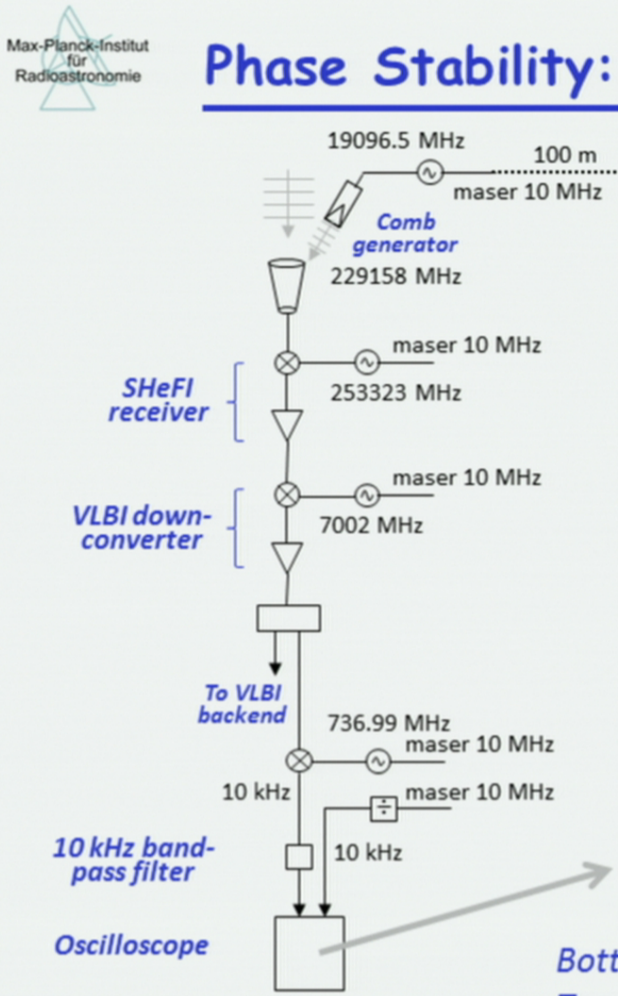
Figure 3 Picture of the FILA10G board. On the right side the 10 GBit optical connectors can be seen.

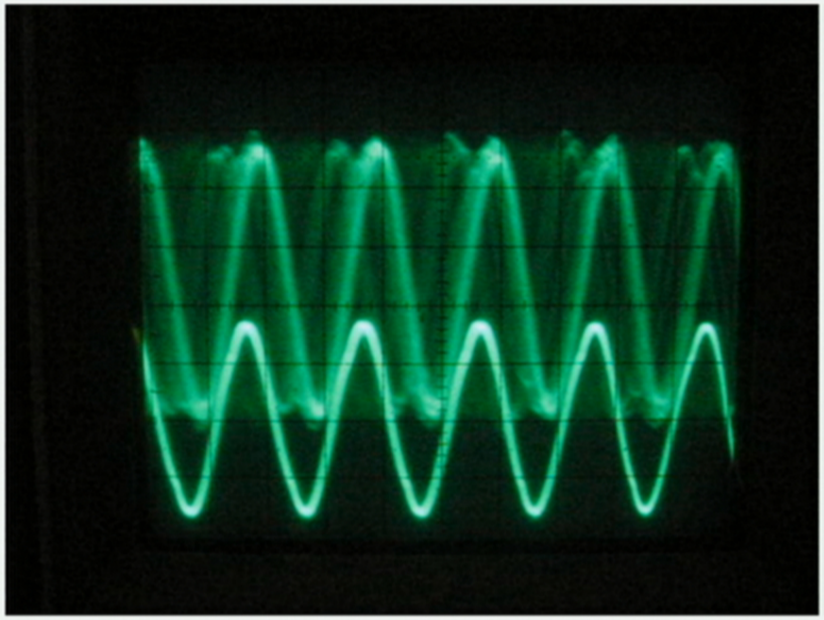
FiLa 10G card
Input: 64 LVDS pairs (2x VSI)
Output: 10 GE optical
Transceiver: XFP SR (300 m) 850 nm

Optical fibre: 100 m, OM3, 50/125 um, LC connectors

10 GB ethernet fibre-copper media converter (Glapper)

Phase Stability: Coherence Check at 230 GHz





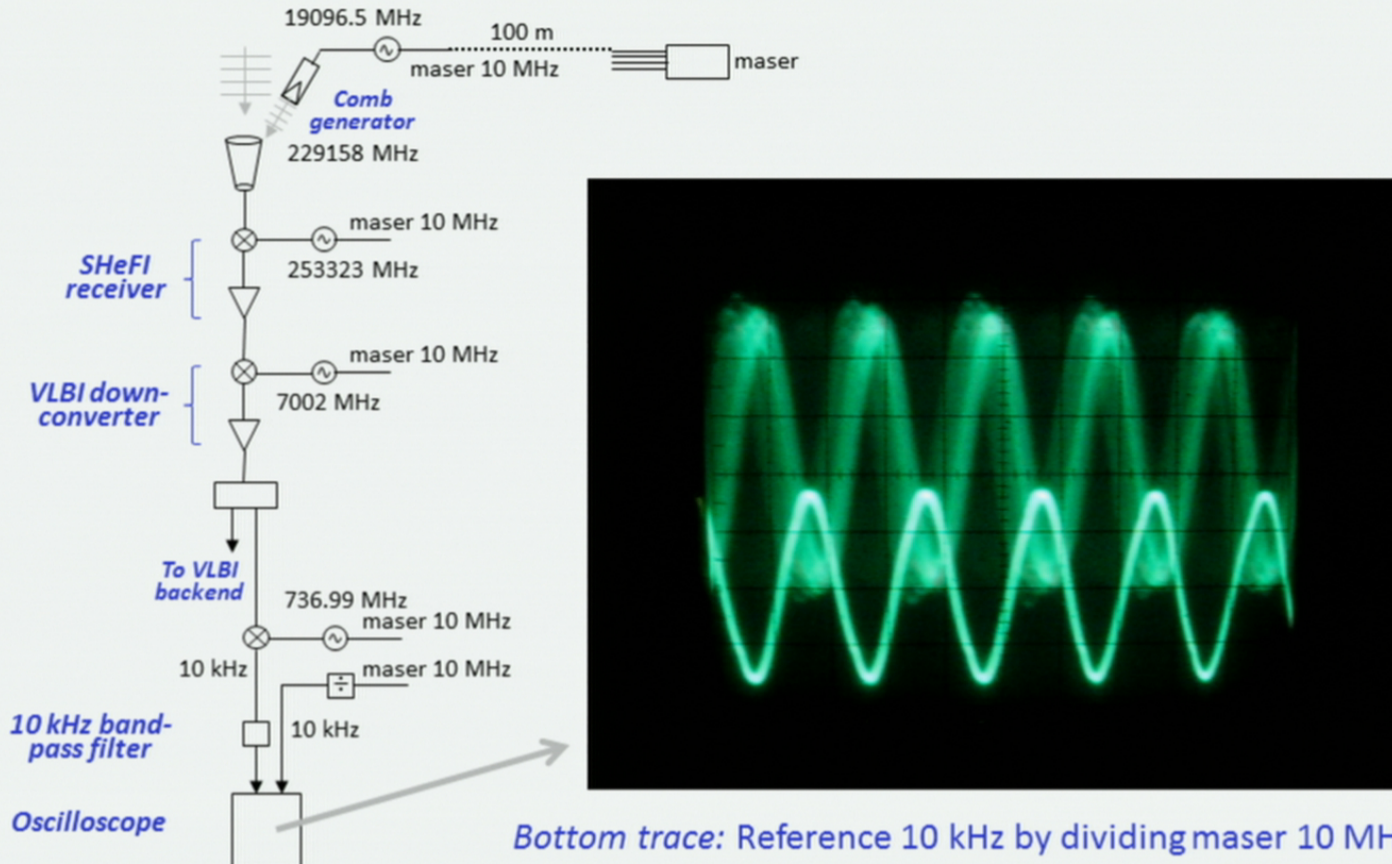
Bottom trace: Reference 10 kHz by dividing maser 10 MHz

Top trace: Tone injected at 230 GHz and mixed to 10 kHz

Movie taken at APEX 2013mar21 during setup for VLBI run

Max-Planck-Institut für Radioastronomie

Phase Stability: Coherence Check at 230 GHz



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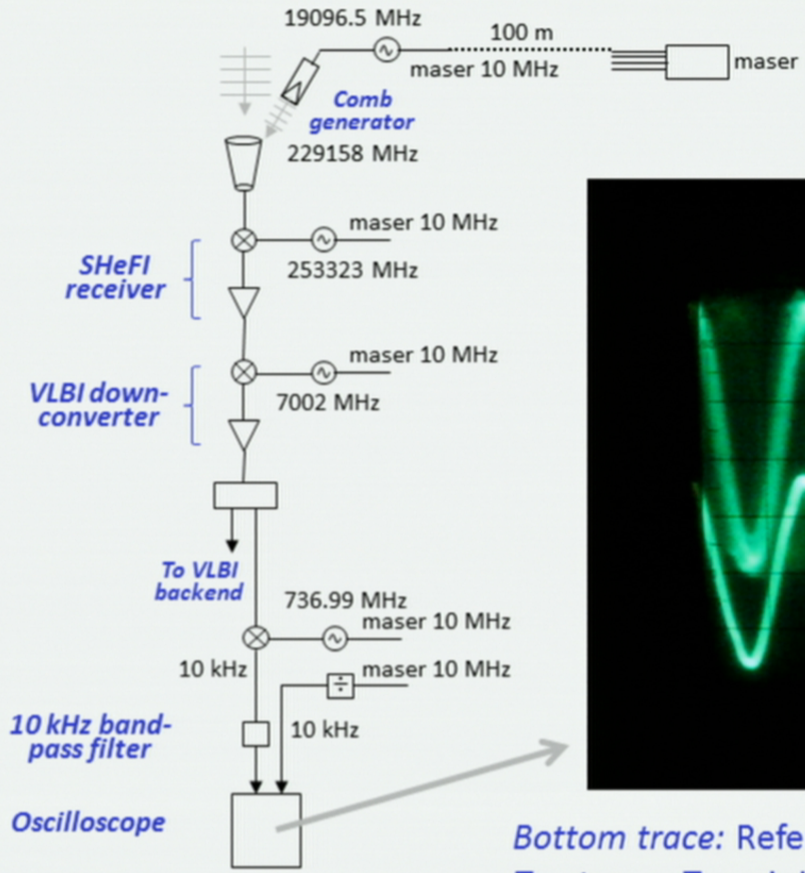

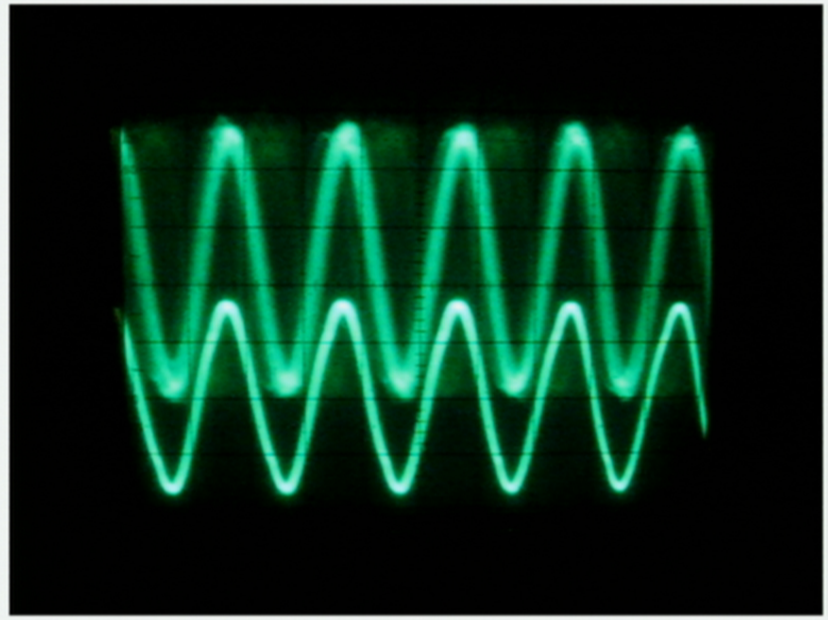

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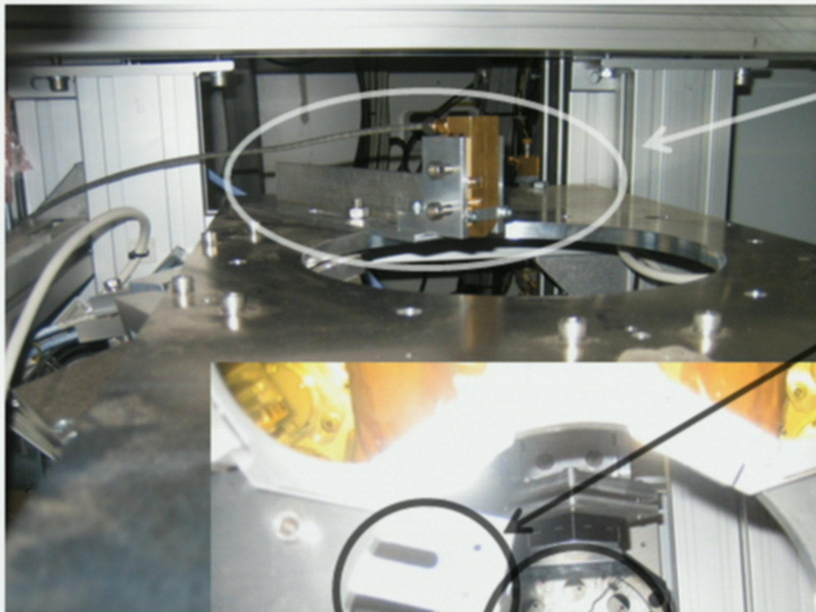
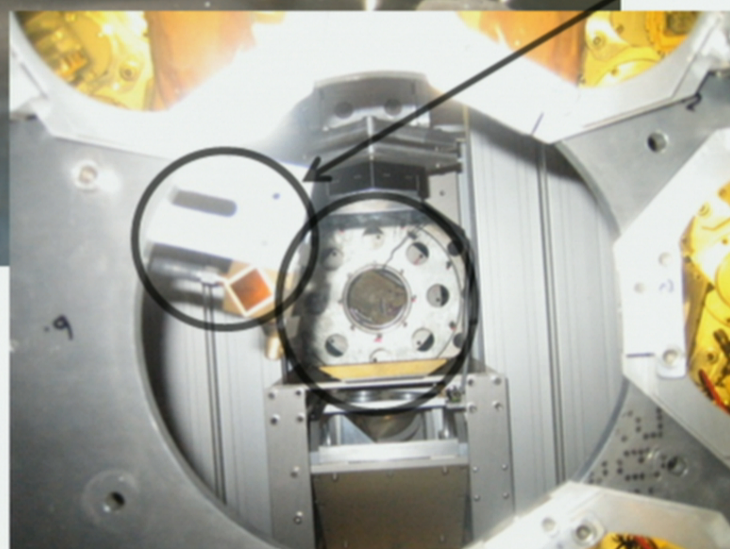
Phase Stabilization: Tone Injection

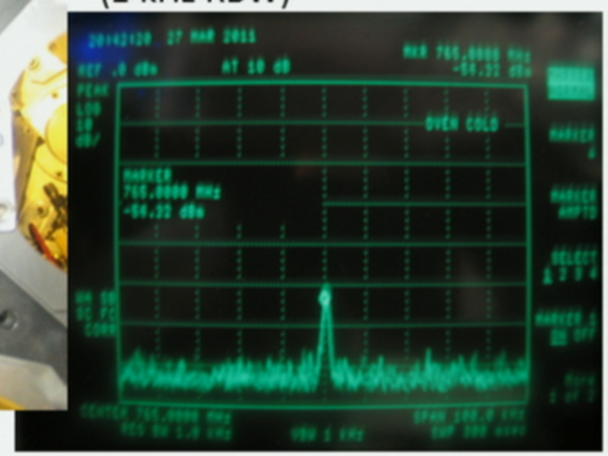


Comb Generator mounted in SHeFI for tone injection during observing

View from SHeFI up along beam showing beam blockage by comb generator as mounted when observing



Tone at VLBI downconverter output as used during observing (1 kHz RBW)



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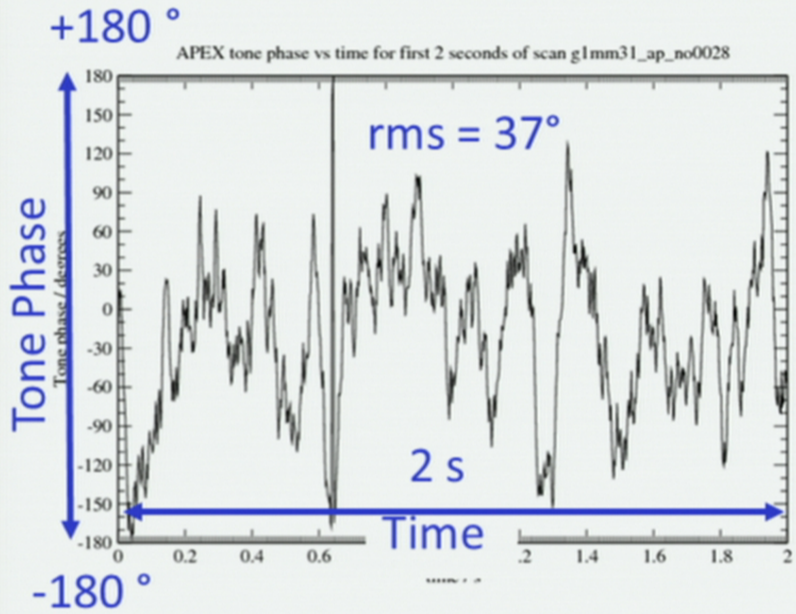
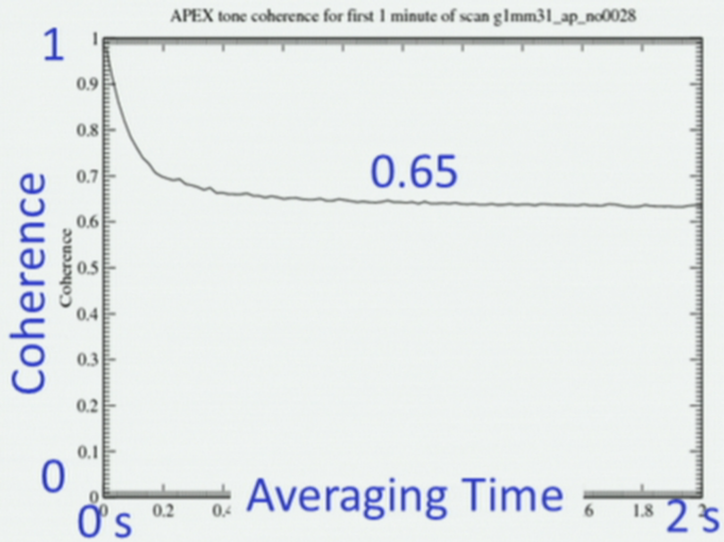
Phase Stabilization: Tone Extraction at Correlator





Phase vs time shows rapid phase fluctuations,
Requires correlation with 0.02 s integration time to permit phase correction.

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VLBI Observing at APEX

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Upgrades Coming to APEX

DBBC2 Firmware

- PFB 2000 MHz clock, 16 chan x 62.5 MHz **to match ALMA**
- Single channel mode, 2048 MHz sample clock **to match R2DBE**

Available: 2014 December

Dual Pol Receiver (April 2015)

230 GHz band, 4-12 GHz IF, **dual pol, phase stable**

Convert to circular with QWP

Mixer by IRAM, design/construction: Heyminck & Leinz (MPIfR)

Installation : 2015 March early

Optical alignment, pointing: 2015 March late

Available: 2015 April

Mark 6 Recorders (January - April 2015)

Install 2x Mark 6 for max **32 Gbps** 2015 Jan (use 2x 8 Gbps)

Upgrade to 4x Mark 6 for max **64 Gbps** 2015 Apr (use 2x 8 Gbps)

Jan '15 Fringe Test ALMA-SPT-APEX: Freq structure

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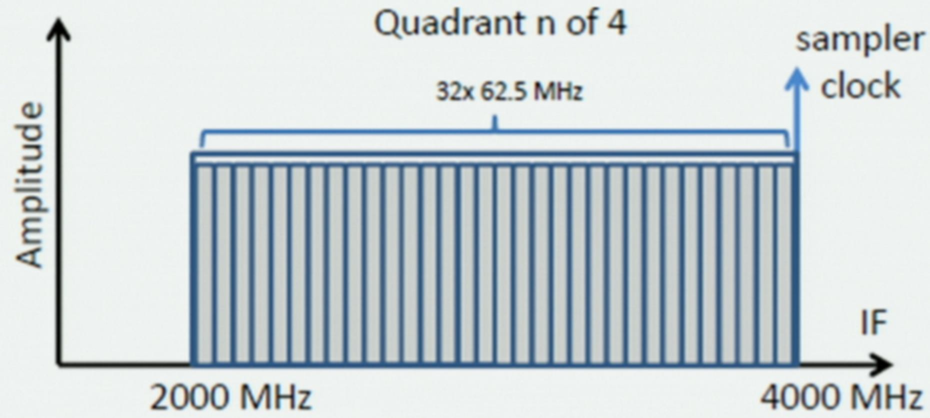
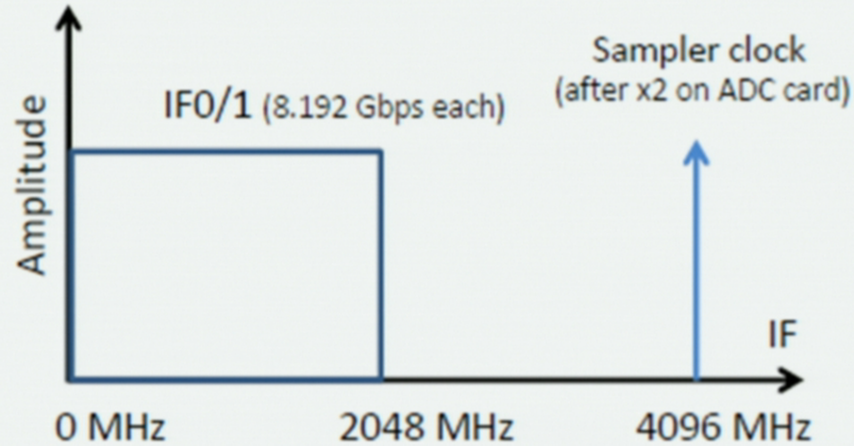
ALMA

South Pole Telescope (R2DBE)



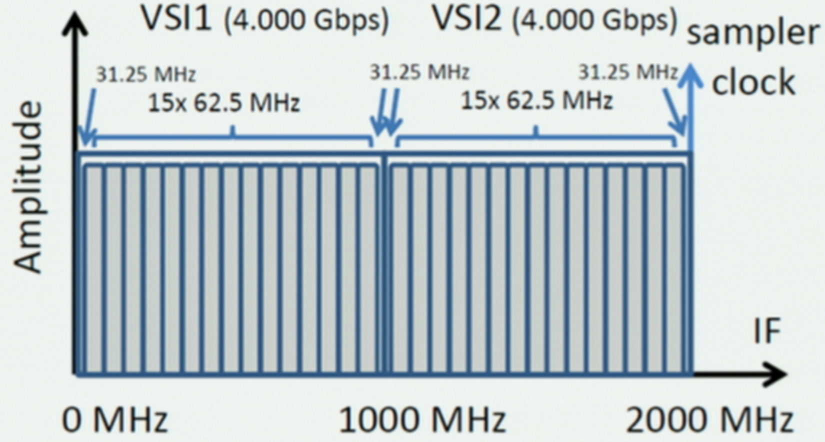


Jan '15 Fringe Test ALMA-SPT-APEX: Freq structure

APEX DBBC:

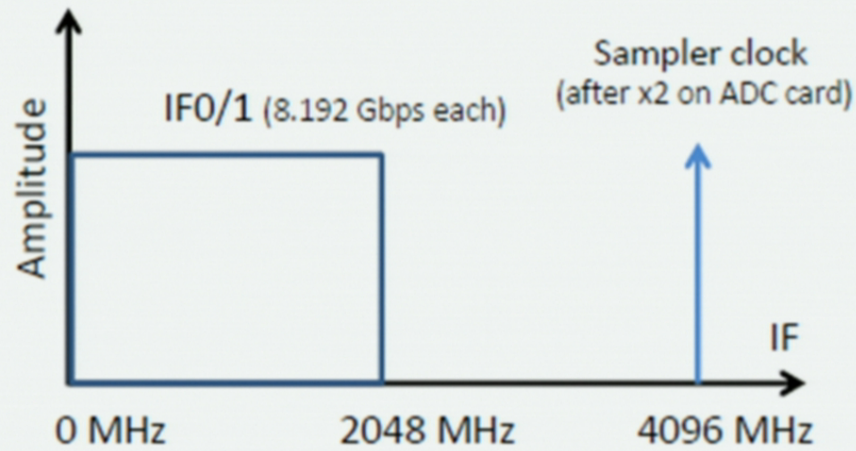
PFB matches ALMA:

+



APEX R2DBE:

matches SPT:



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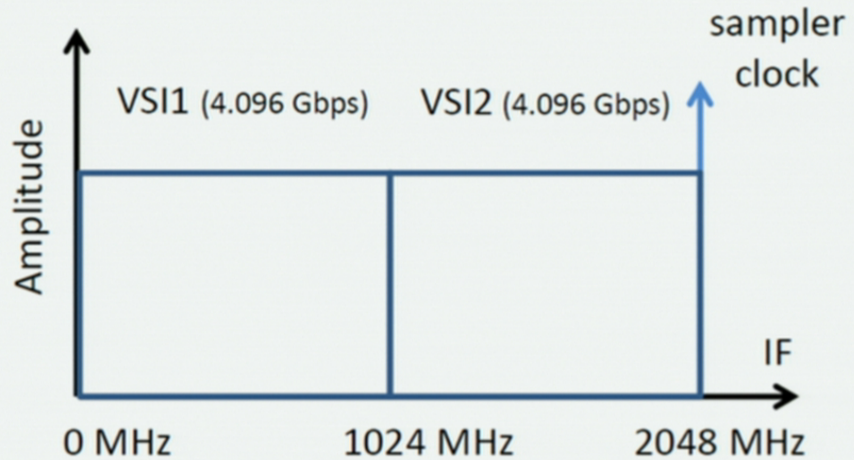
March 2015 Global 1 mm: APEX Freq Structure

DBBC :

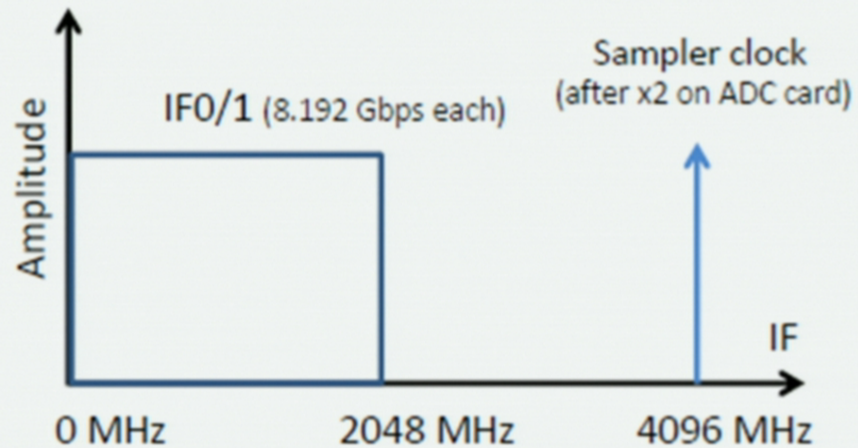
2x 1 ch almost matches EHT:



+

R2DBE:

matches EHT:



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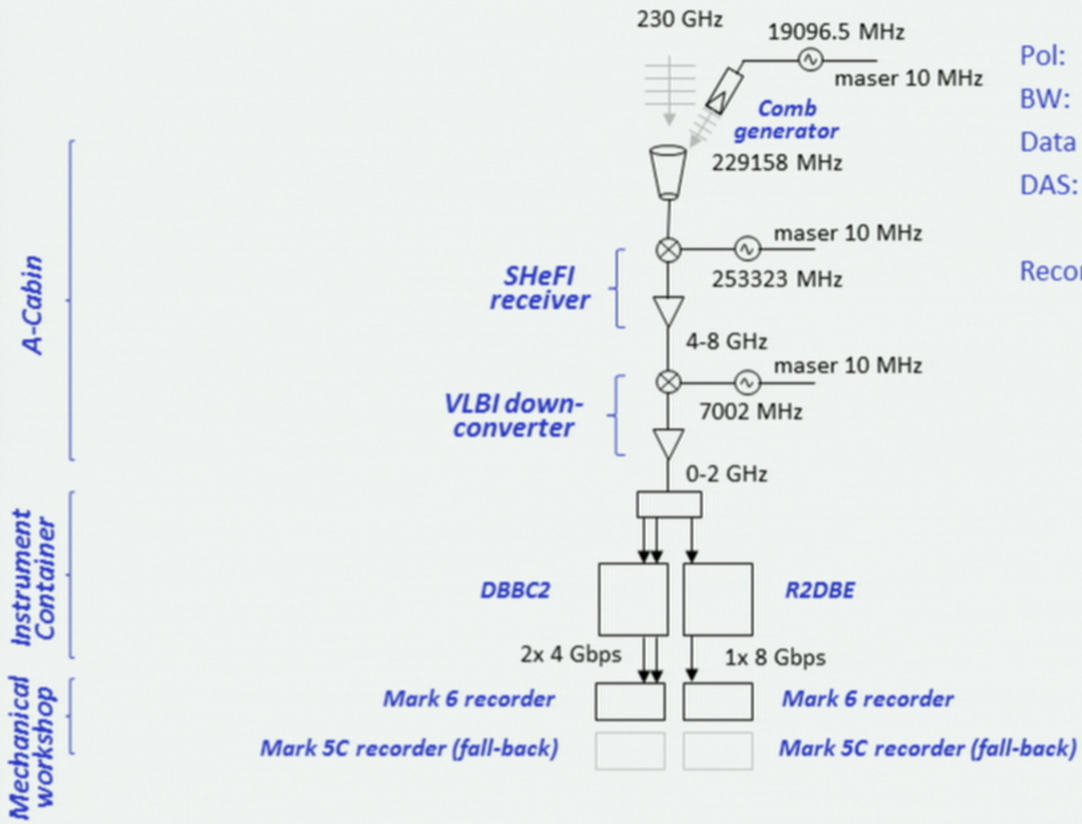
APEX Status: Nov 2014 | Jan | Mar | Apr '15 | Mar '16

2x Mark 6 + R2DBE



Pol:	Single
BW:	**2048 MHz**
Data rate:	**8 Gbps (x2 redundant)**
DAS:	DBBC2 PFB to **match ALMA**
	R2DBE 1 chan to match SPT
Recorder:	**Mark 6 (2x)**
	Mark 5C (backup)

APEX Status: Nov 2014 | Jan | Mar | Apr '15 | Mar '16

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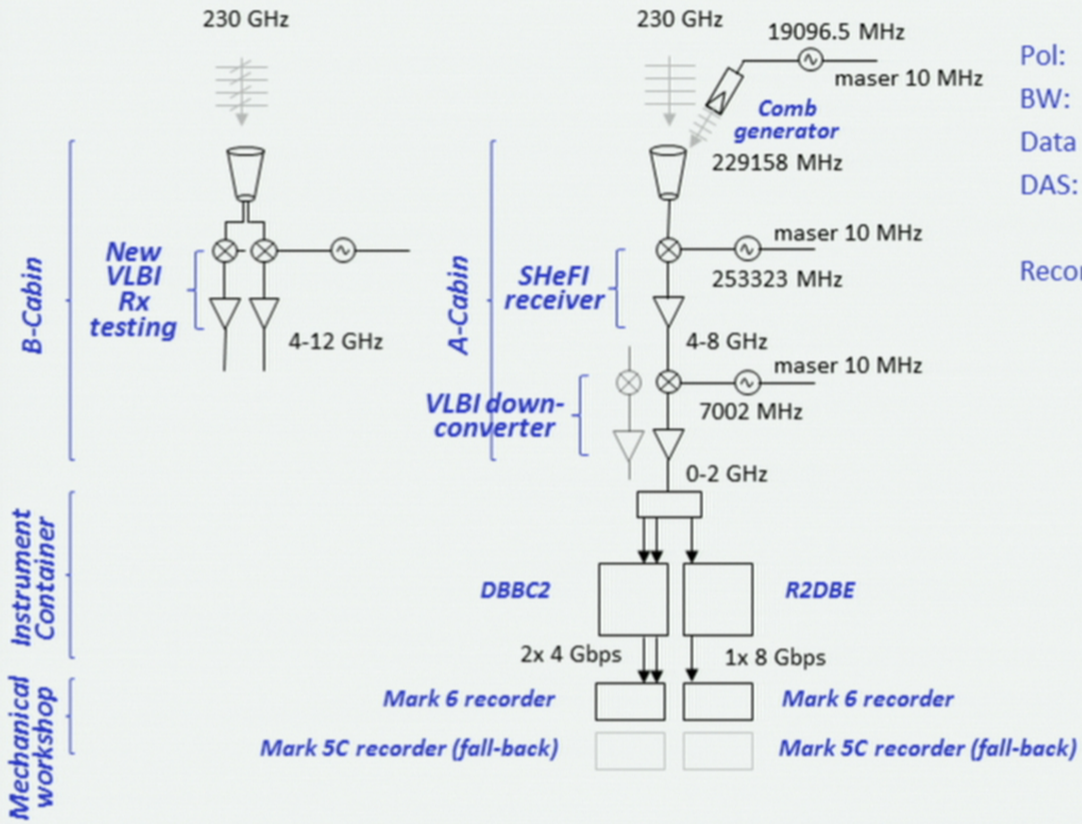
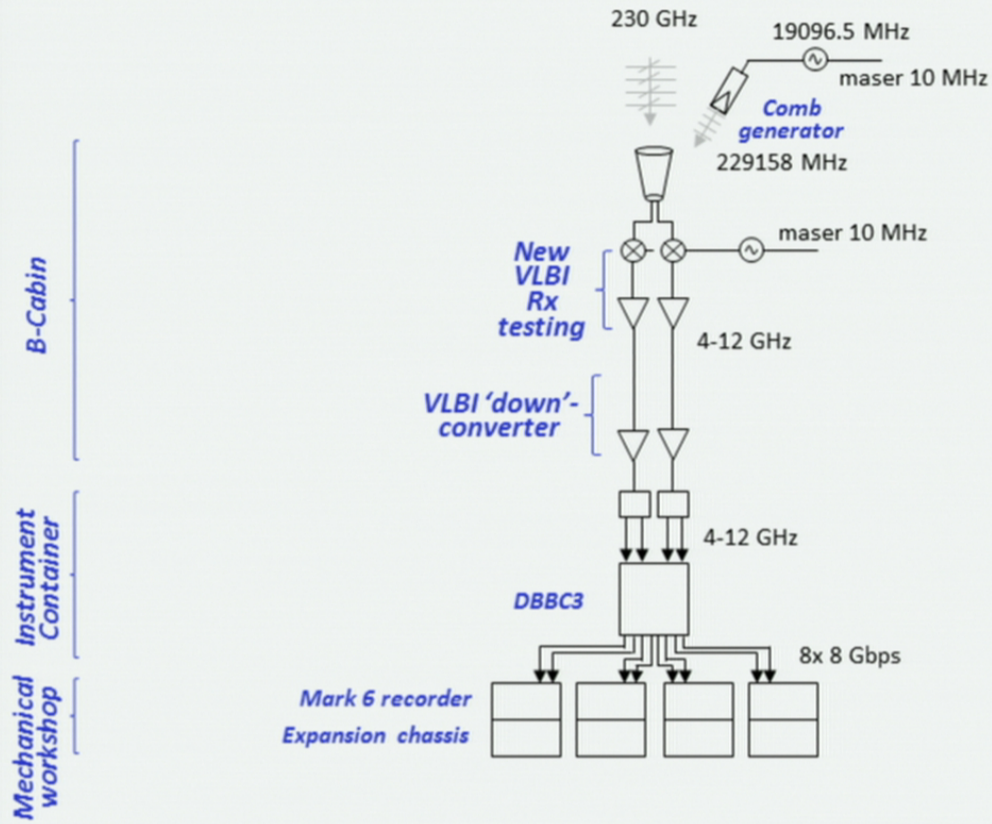
DBBC firmware for 1 chan



Pol:	Single
BW:	2048 MHz
Data rate:	8 Gbps (x2 redundant)
DAS:	DBBC2 **1 ch matches R2DBE**
	R2DBE (parallel)
Recorder:	Mark 6 (2x)
	Mark 5C (backup)

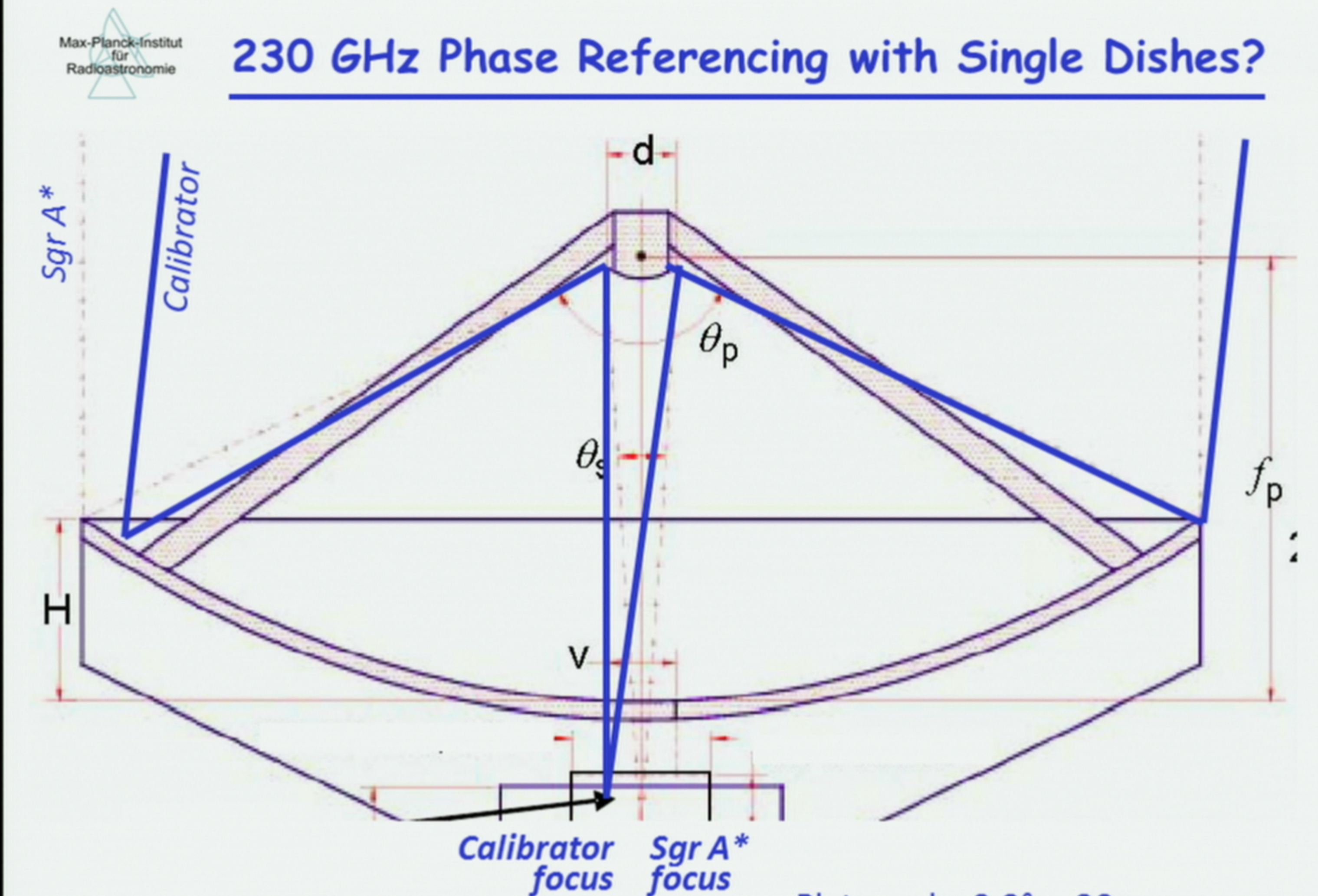
APEX Status: Nov 2014 | Jan | Mar | Apr '15 | Mar '16

4x Mark 6 + DBBC3



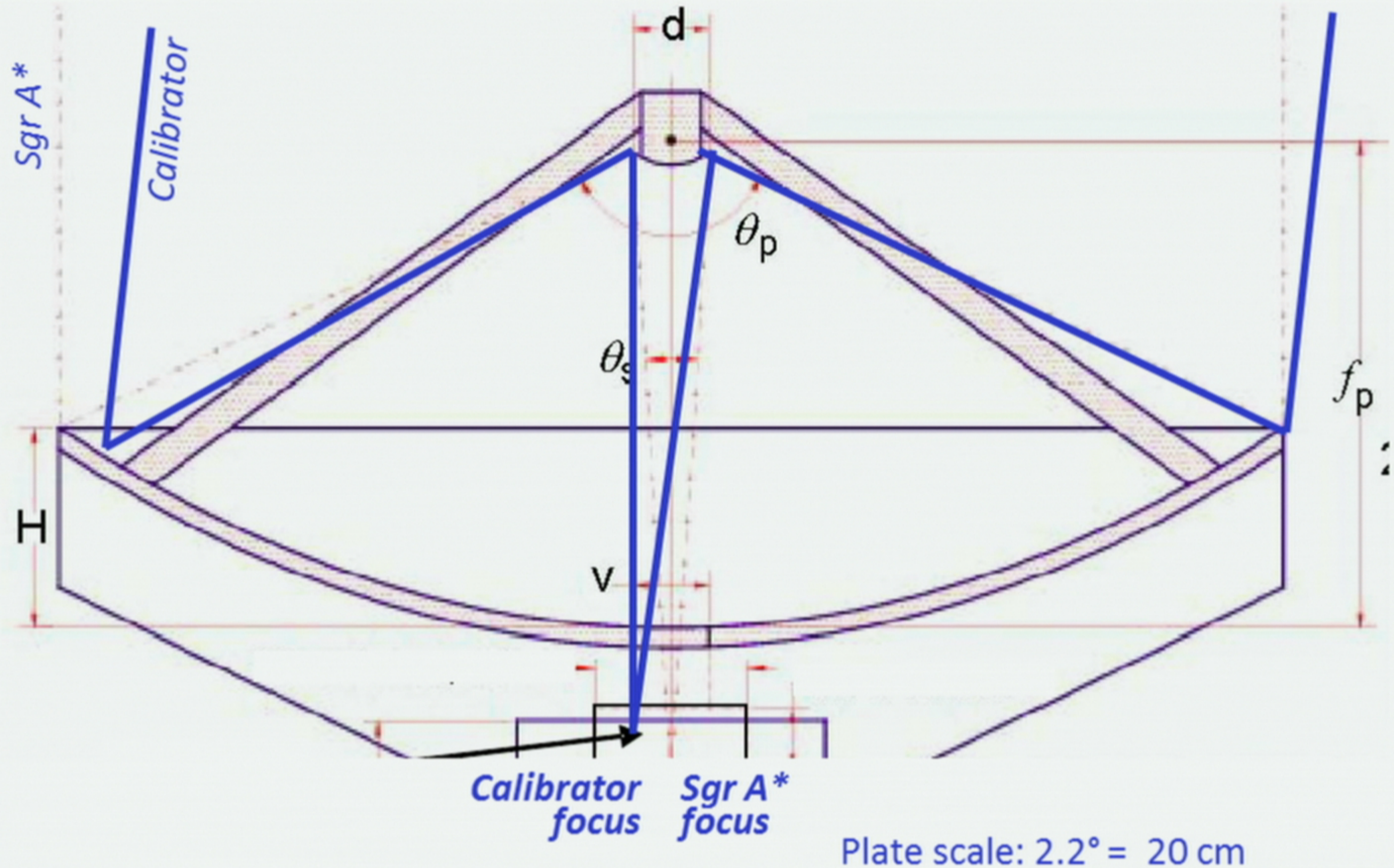
Pol:	Dual
BW:	8192 MHz / pol
Data rate:	**64 Gbps (32 Gbps / pol)**
DAS:	**DBBC3**
Recorder:	Mark 6 **(4x)**

230 GHz Phase Referencing with Single Dishes?



Base Figure: Carter et al. 2007 ALMA Front-End Optics Design

230 GHz Phase Referencing with Single Dishes?



Base Figure: Carter et al. 2007 ALMA Front-End Optics Design

230 GHz Phase Referencing with Single Dishes?

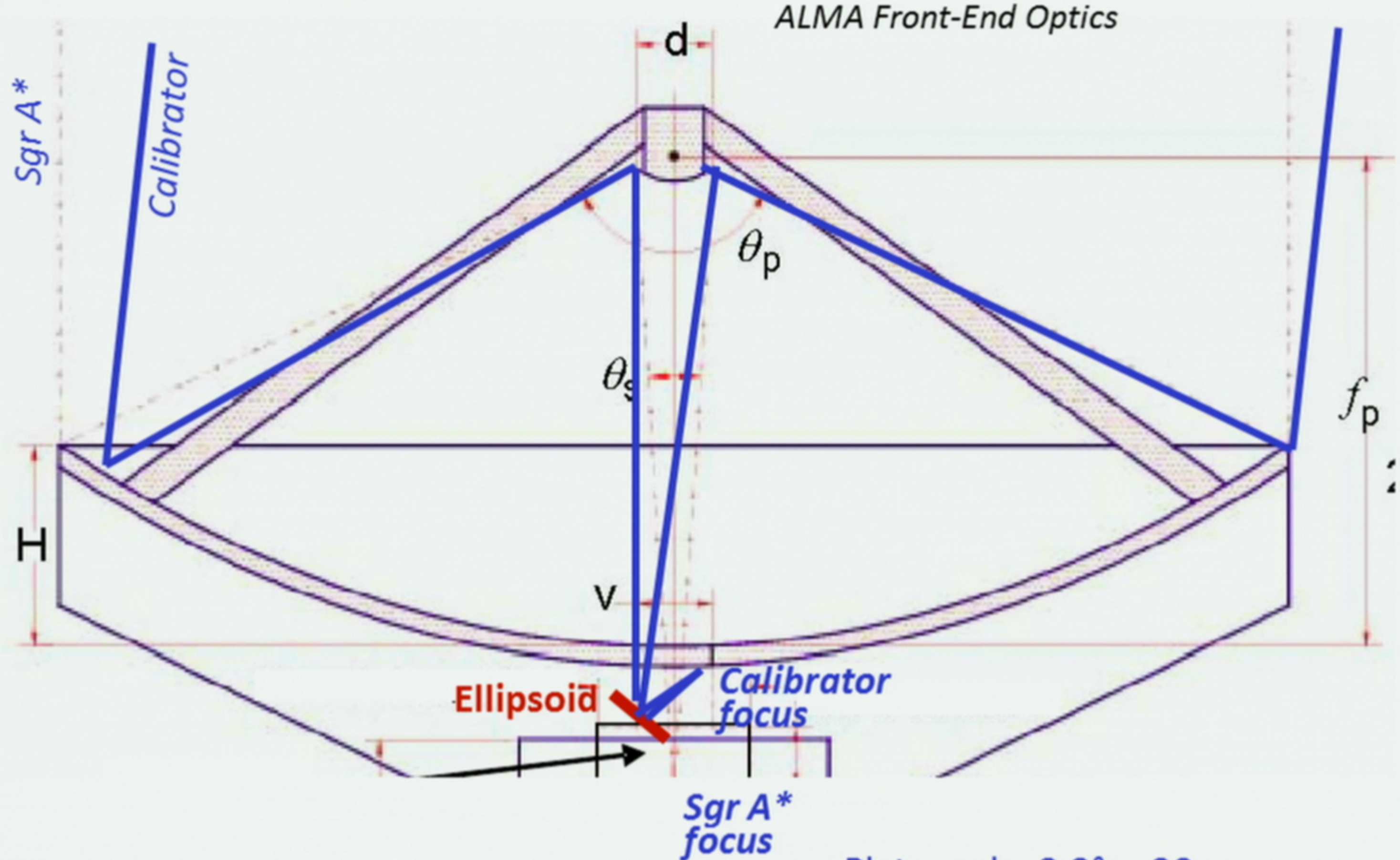


Plate scale: 2.2° = 20 cm

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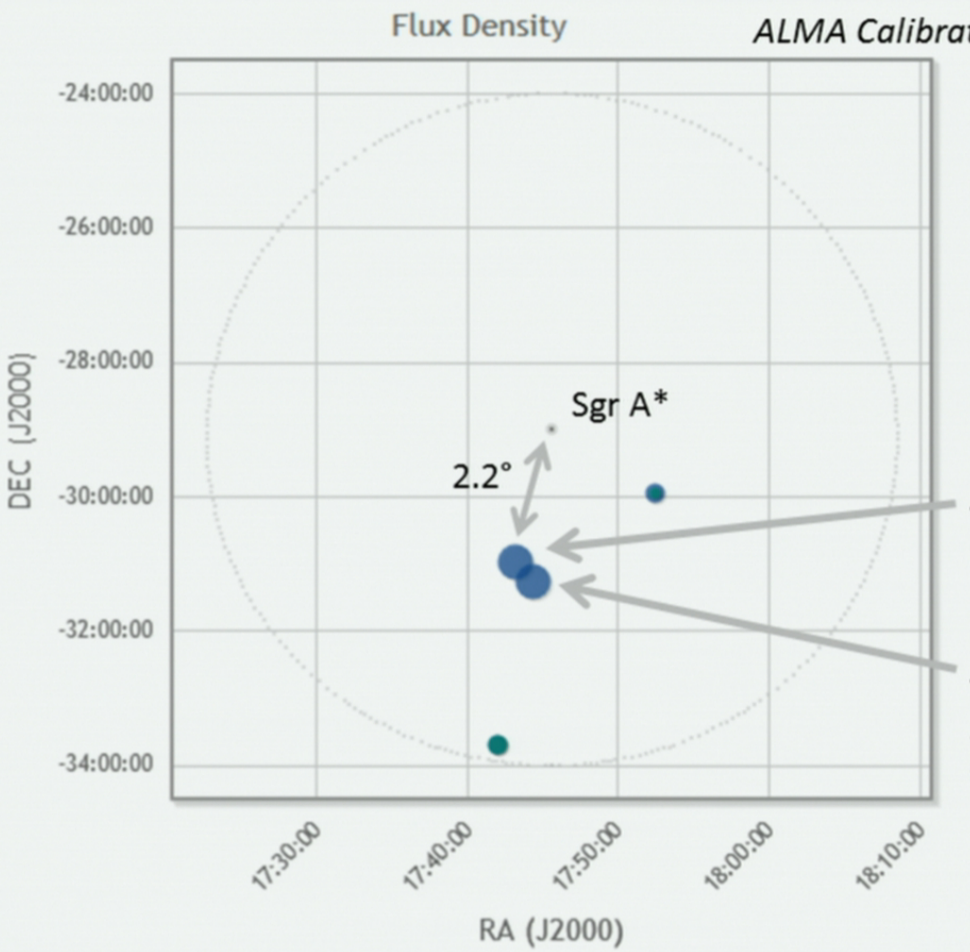
Calibrators near Sgr A*

*ALMA Calibrator Database; 5° around Sgr A**



J1744-3116
520 mJy @ 111 GHz

J1743-3058 = IVS B1740-309
ALMA: 520 mJy @ 104 GHz
VLBA: 110 mJy @ 24 GHz
(Petrov 2011)

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Summary APEX Capability

Now:	4 Gbps recording rate, single pol
Jan 2015	1x R2DBE + DBBC2 + 2x Mark 6
Mar 2015	1x R2DBE + DBBC2 + 2x Mark 6
Mar 2016	DBBC3 + 4x Mark 6 + new Rx
After:	64 Gbps recording, dual pol
	→ 4x sensitivity improvement

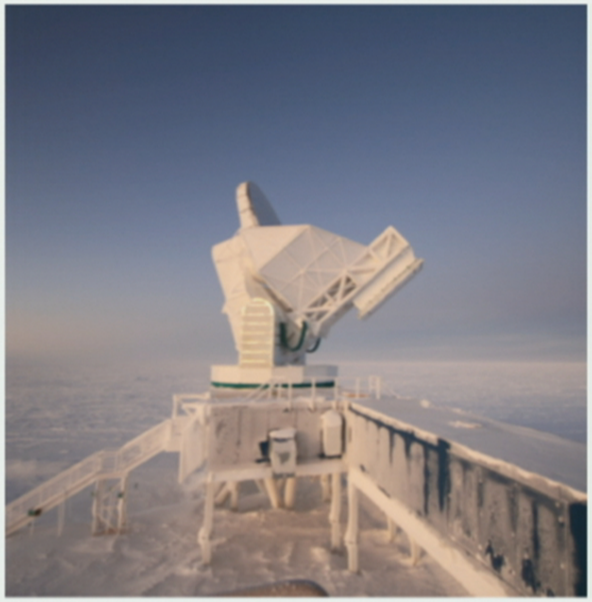
EHT Site Status:
South Pole Telescope

Dan Marrone
University of Arizona

Co-Is: John Carlstrom, Shep Doeleman
Project team:
- Chris Greer, Junhan Kim, Chi-hanh Ngyuen, Rita Ezeugwu
    - Robert Freund, Gene Lauria, George Reiland, David Forbes (Arizona)
- Jonathan Weintroub, Laura Vertatschitsch, Rurik Primiani, John Test, Edward Tong (CfA)
- Chris Beaudoin, Jason SooHoo, Alan Rogers, Geoff Crew, + (Haystack)
- Paul Ho, Derek Kubo, Ming-tang Chen (ASIAA)
- Erik Leitch (Chicago), SPT Team

South Pole Telescope

PI: John Carlstrom
10m telescope at geographic pole
Primary science:
Cosmology through CMB/SZ

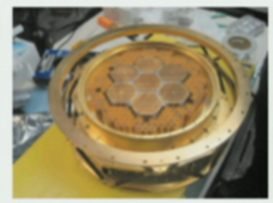


SPT-SZ Camera (1st Generation):

- 2007 – 2011
- 960 pixels, 1 deg^2 FOV
- 95, 150, 220 GHz

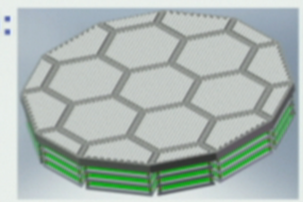
SPT-pol Camera (2nd Generation):

- 2012 – 2015
- 1600 detectors, 1 deg^2 FOV
- Dual-polarization 95 & 150 GHz



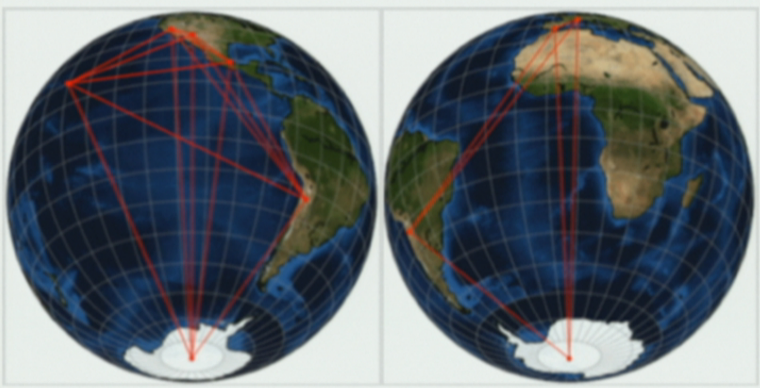
SPT-3G Camera (3rd Generation):

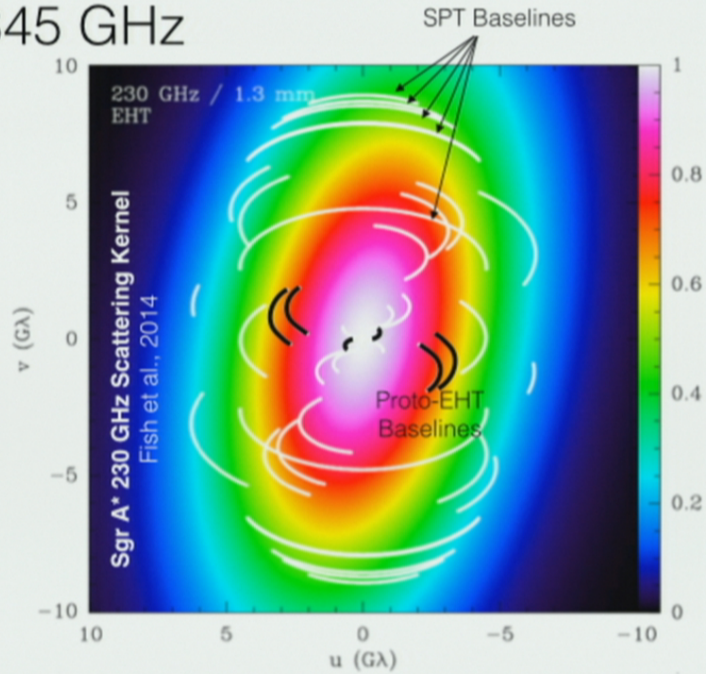
- 2016 – 2020
- 15k detector mm camera, 2.4 deg^2 FOV
- Dual-polarization 95, 150, 220 GHz



Uniqueness of South Pole

- Overlap with all available stations at all times
- Longest time series
- Excellent 345 GHz site
- Longest baselines: >12Gλ at 345 GHz
- Favored by scattering screen





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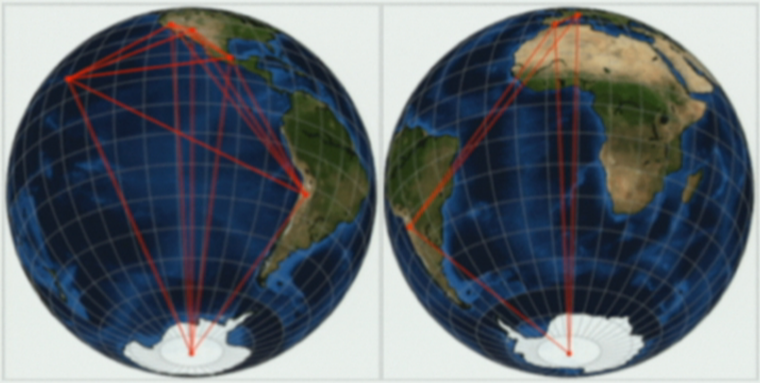
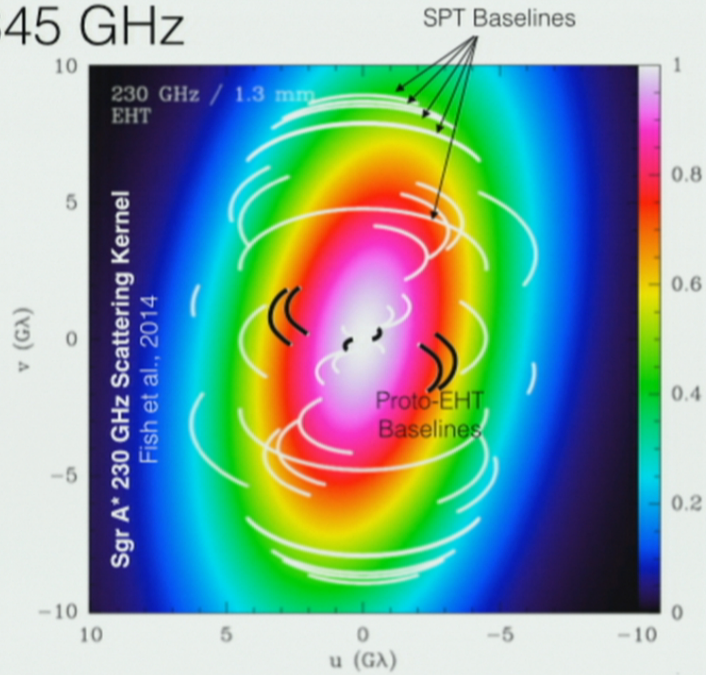
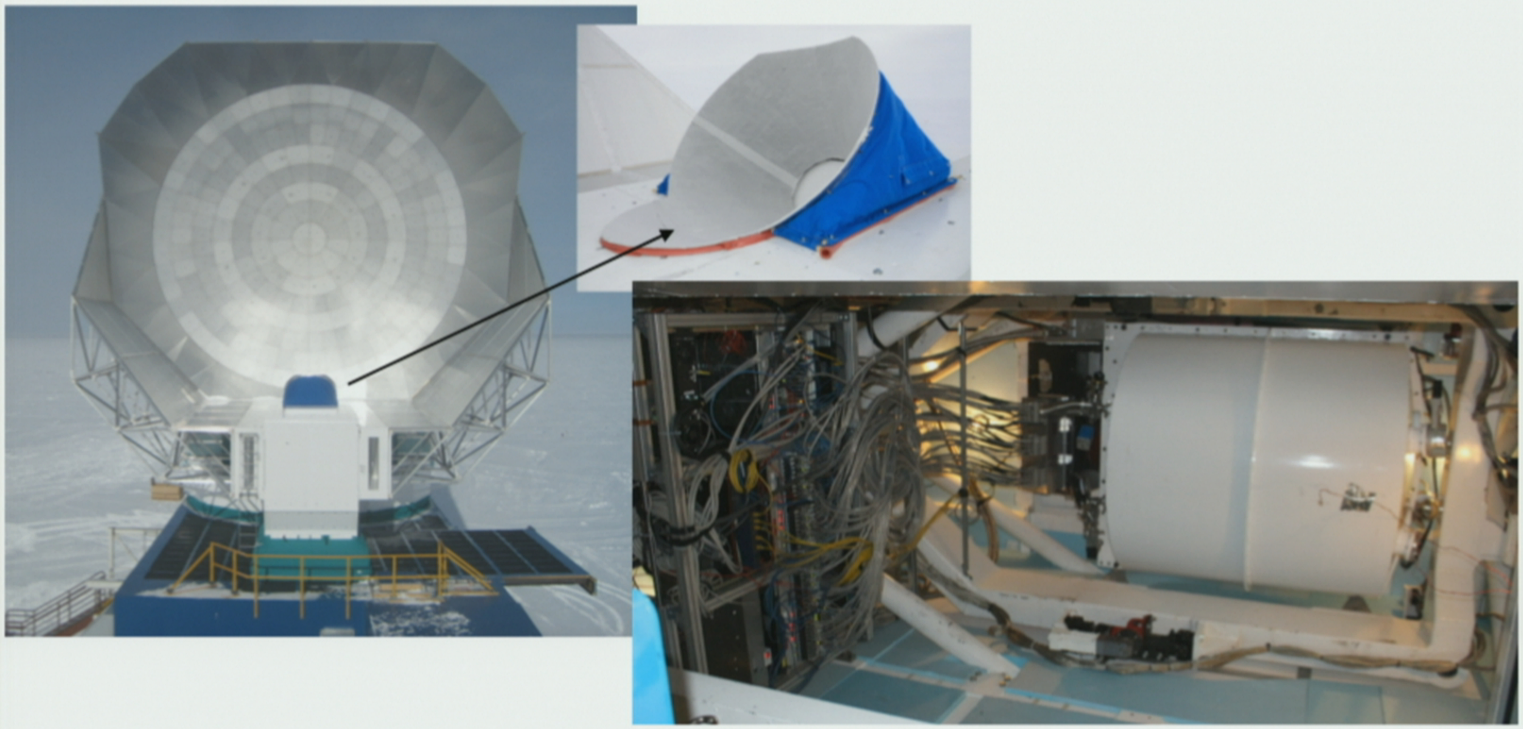




Uniqueness of South Pole

- SPT is not an observatory!
  - Single instrument, single observing program, no proposals!
  - Not much space, very little relevant equipment/infrastructure



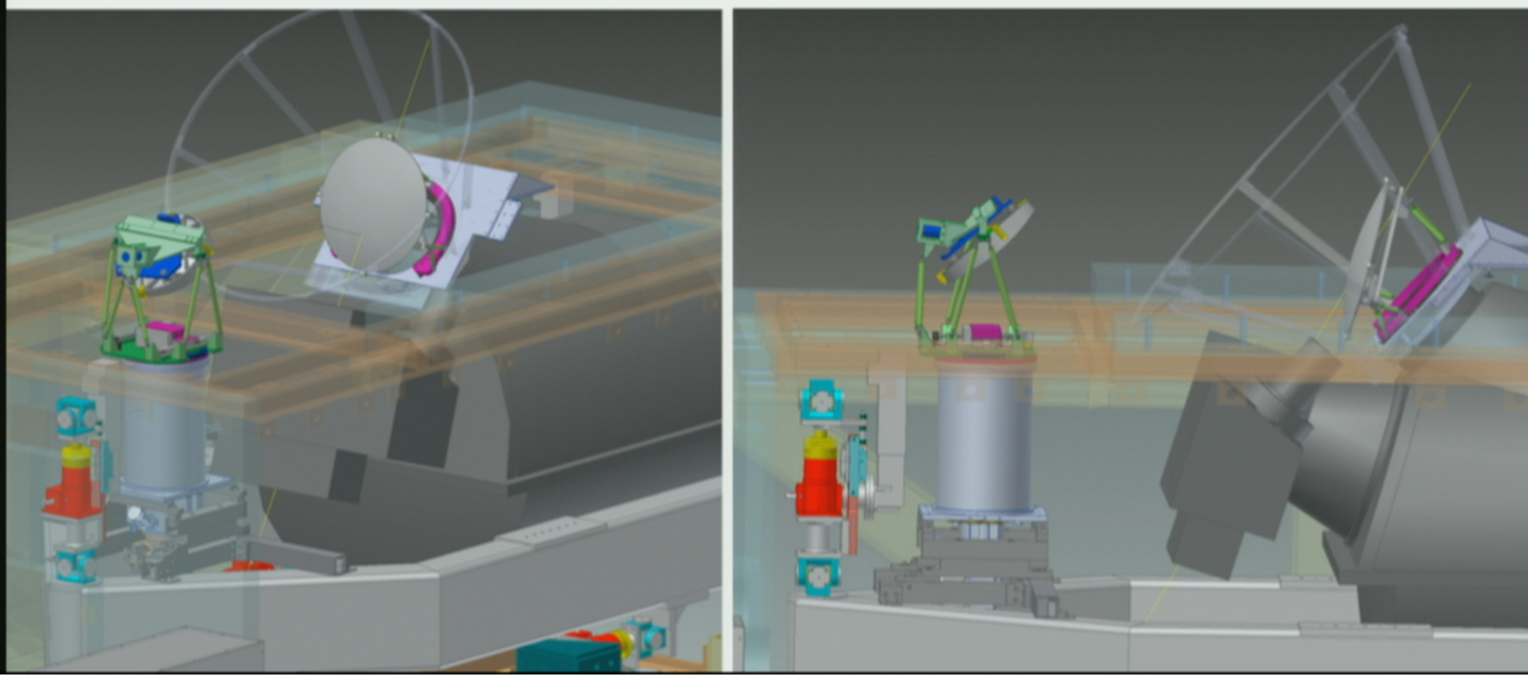

SPT Challenges
PERIMETER
INSTITUTE
EXIT

SPT Challenges

- Compact space
  - Install receiver, illuminate without major disruptions to SPT cosmology instruments
- Lack of on-site expertise and test equipment
  - Minimize complexity (fixed-tuned operation)
- Cold!
  - Phase stability of LO/IF transmission
  - Environment for maser

SPT Design

- Single-purpose heterodyne receiver and backend
- Annual VLBI override of cosmology experiment
- Stay out of the way of SPTpol/SPT3g

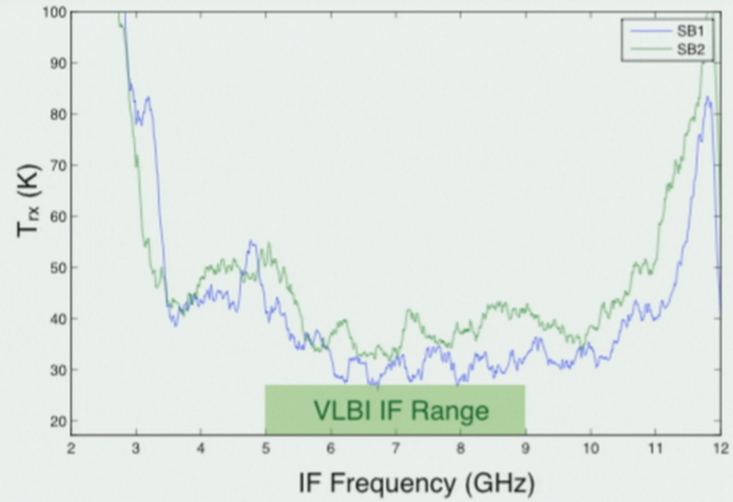


SPT Receiver

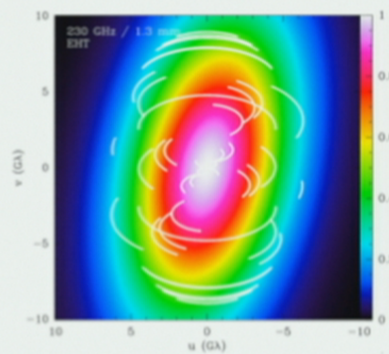
- 230 GHz:
  - Dual polarization
  - Sideband separating
  - ALMA mixers
  - To be installed Dec/Jan
- 345 GHz:
  - Dual polarization/sideband separating
  - Confocal with 230 GHz, selected by tertiary mirror
  - Mixers developed by ARO/NRAO
  - Install Dec 2015

SPT Status

- 230 GHz:
  - T_{rx} = 40K (SSB) or less
  - !!



- Atmosphere contributes 21K at Sgr A* el (30deg)
- Mirrors: 15/12/23um (Tert/Sec/Pri) - 93% Ruze Eff
- SEFD (50th %ile weather): 4200 Jy
  - SMT: 13000 Jy
  - Phased SMA/CARMA: 4000-8000 Jy
  - LMT (2015): 2000 Jy?
  - ALMA: 100 Jy



SPT Status

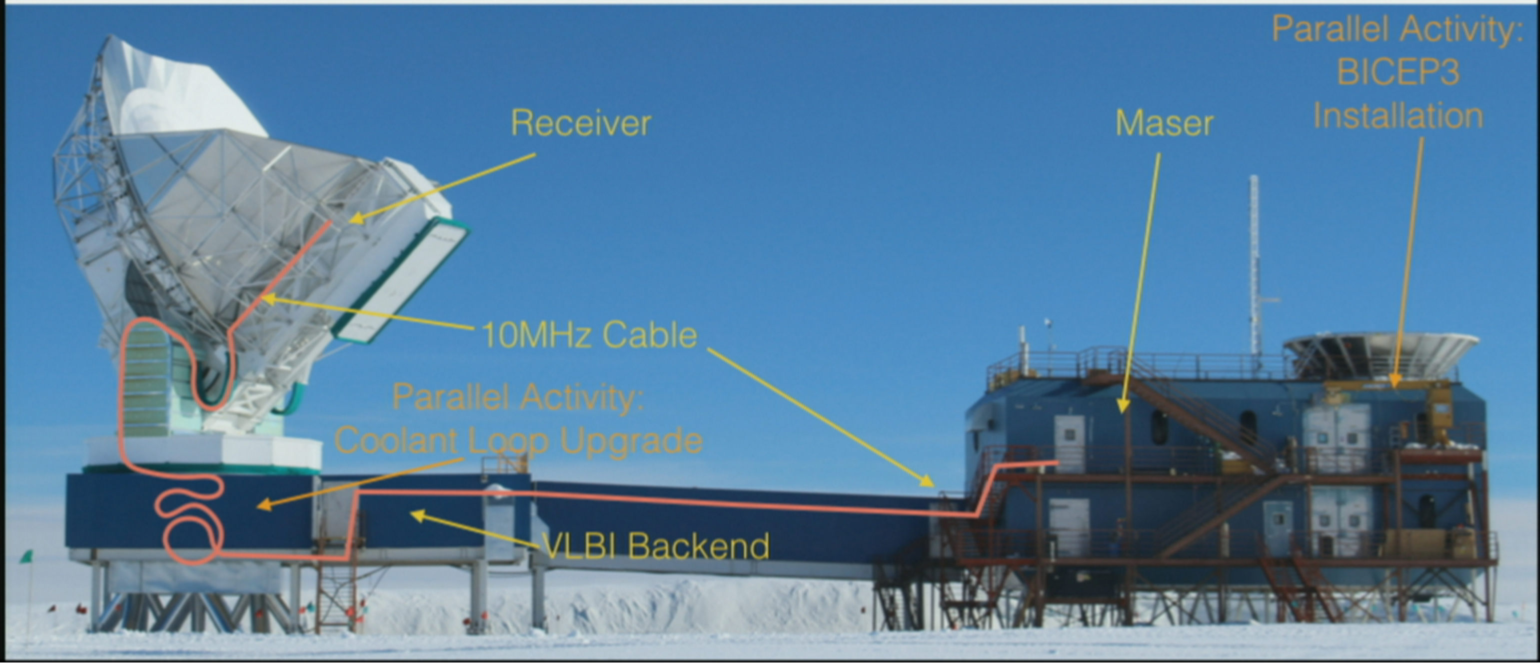
- Backend
  - R2DBE developed from scratch, tested, shipped
    - (Vertatschitsch, Primiani, Weintroub)
  - Downconverter developed, tested, shipped
    - (Rogers, Beaudoin, Eckert)
  - Tone injection prototype developed, tested, shipped
    - (Test, Weintroub)
  - Mark6 Recorders shipped
- Maser
  - T4Science iMaser3000
  - Loan from ASIAA

SPT Status

Shipping deadline:
In CA by Nov 3

SPT Installation

- 13 crates, 7000 pounds shipped to SP
- Maser in NZ, other crates there or following
- To be at pole by Dec 6 (with first team)



SPT Installation

- Dec 2014:
  - Receiver & backend installation, testing
  - DPM, Kim, Greer, SooHoo
- Jan 2015:
  - VLBI testing: APEX/ALMA
  - DPM, Kim, Greer, Freund, Beaudoin, Leitch
- March 2015:
  - First science campaign