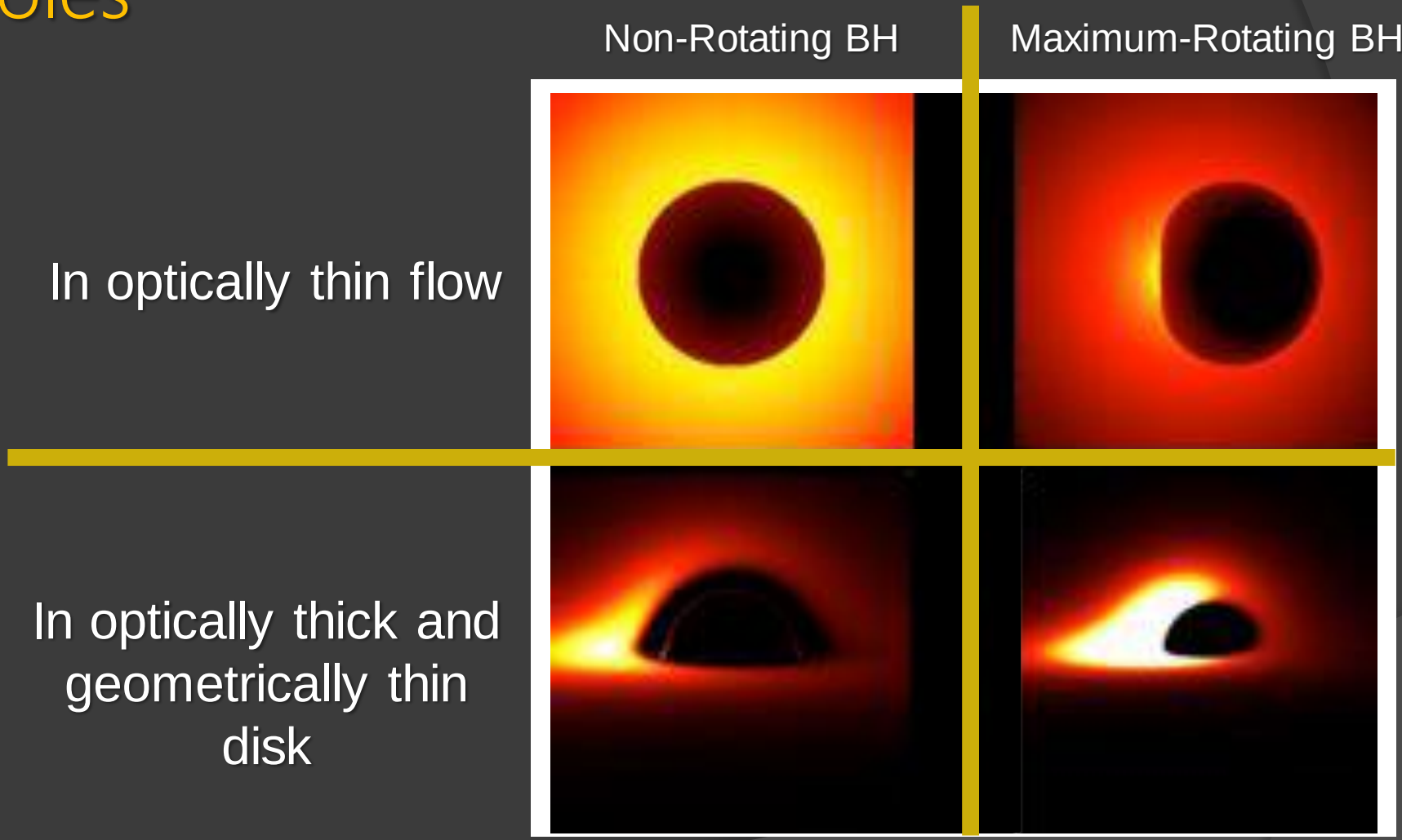
Satoki Matsushita (ASIAA)
松下 聡樹 (台湾中央研究院天文及天文物理研究所)
with help of Derek Kubo (ASIAA) & Per Friberg (EAO)

JCMT AS A STAND-ALONE SUBMM VLBI STATION

Past & Current Status of JCMT-VLBI Mode

Primary Science Target: Direct Imaging of the Shadow of Black Holes



Takahashi (2004)

Sizes of Black Holes

	Shadow Size (μasec)	Mass (10^6 Mo)	Distance (Mpc)
Sgr A*	50	4.1 +- 0.6	0.008
M87	39	6600 +- 400	17.0
M31	18	180 +- 80	0.80
M60	12	2100 +- 600	16.5
NGC 5128 (Cen A)	7	310 +- 30	4.5

Note: Here we assume $R_{shadow} \sim 5 \times R_{sch}$

Gebhardt et al. (2011)

Past mm-VLBI with JCMT

Sgr A*
Size ≈ 40 μas
(≈ 4 r_{sch})

Doeleman et al. (2008)

Vir A* (M 87)
Size ≈ 40 μas
(≈ 5 r_{sch})

Doeleman et al. (2012)

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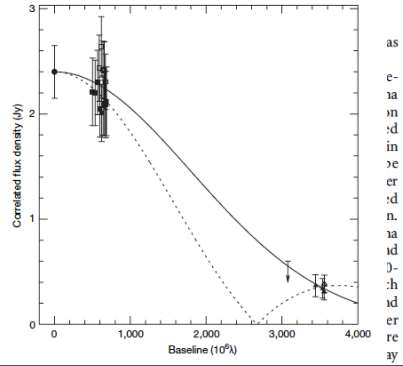
LETTERS

Event-horizon-scale structure in the supermassive black hole candidate at the Galactic Centre

Sheperd S. Doeleman[1], Jonathan Weintroub[2], Alan E. E. Rogers[1], Richard Plambeck[3], Robert Freund[4], Remo P. J. Tilanus[5,6], Per Friberg[5], Lucy M. Ziurys[4], James M. Moran[2], Brian Corey[1], Ken H. Young[2], Daniel L. Smythe[1], Michael Titus[1], Daniel P. Marrone[7,8], Roger J. Cappallo[1], Douglas C.-J. Bock[9], Geoffrey C. Bower[3], Richard Chamberlin[10], Gary R. Davis[5], Thomas P. Krichbaum[11], James Lamb[12], Holly Maness[3], Arthur E. Niell[1], Alan Roy[11], Peter Strittmatter[4], Daniel Werthimer[13], Alan R. Whitney[1] & David Woody[12]

The cores of most galaxies are thought to harbour supermassive black holes, which power galactic nuclei by converting the gravitational energy of accreting matter into radiation[1]. Sagittarius A* (Sgr A*), the compact source of radio, infrared and X-ray emission at the centre of the Milky Way, is the closest example of this phenomenon, with an estimated black hole mass that is 4,000,000 times that of the Sun[2,3]. A long-standing astronomical goal is to resolve structures in the innermost accretion flow surrounding Sgr A*, where strong gravitational fields will distort the appearance of radiation emitted near the black hole. Radio observations at wavelengths of 3.5 mm and 7 mm have detected intrinsic structure in Sgr A*, but the spatial resolution of observations at these wavelengths is limited by interstellar scattering[4–7]. Here we report observations at a wavelength of 1.3 mm that set a size of 37^{+16}_{-10} microarcseconds on the intrinsic diameter of Sgr A*. This is less than the expected apparent size of the event horizon of the presumed black hole, suggesting that the bulk of Sgr A* emission may not be centred on the black hole, but arises in the surrounding accretion flow.



ScienceExpress Reports

Jet Launching Structure Resolved Near the Supermassive Black Hole in M87

Sheperd S. Doeleman,[1,3]* Vincent L. Fish,[1] David E. Schenck,[1,2]† Christopher Beaudoin,[1] Ray Blundell,[3] Geoffrey C. Bower,[4] Avery E. Broderick,[5,6] Richard Chamberlin,[7] Robert Freund,[2] Per Friberg,[8] Mark A. Gurwell,[3] Paul T. P. Ho,[9] Mareki Honma,[10,11] Makoto Inoue,[9] Thomas P. Krichbaum,[12] James Lamb,[13] Abraham Loeb,[3] Colin Lonsdale,[1] Daniel P. Marrone,[2] James M. Moran,[3] Tomoaki Oyama,[10] Richard Plambeck,[4] Rurik A. Primiani,[3] Alan E. E. Rogers,[1] Daniel L. Smythe,[1] Jason SooHoo,[1] Peter Strittmatter,[2] Remo P. J. Tilanus,[8,14] Michael Titus,[1] Jonathan Weintroub,[3] Melvyn Wright,[4] Ken H. Young,[3] Lucy Ziurys[2]

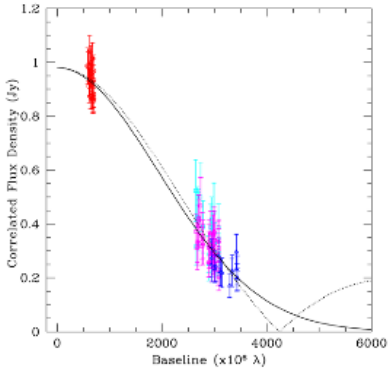
[1]MIT Haystack Observatory, Off Route 40, Westford, MA 01886, USA. [2]Steward Radio Observatory, University of Arizona, 933 North Cherry Avenue, Tucson, A [3]Harvard Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, M Department of Astronomy, University of California Berkeley, Hearst Field Annex [5]Perimeter Institute, 31 Caroline Street, North Waterloo, Ontario, Canada N2L 2 and Astronomy, University of Waterloo, 200 University Avenue West, Waterloo, [7]Caltech Submillimeter Observatory, 111 Nowelo Street, Hilo, HI 96720, USA. [8] Telescope, Joint Astronomy Centre, 660 North A'ohoku Place University Park, [9]Academia Sinica Institute for Astronomy and Astrophysics, 11F Astronomy-Ma Taiwan University, No. 1, Roosevelt Rord, Sec. 4 Taipei 10617, Taiwan, R.O.C. Observatory of Japan, 2-21-1 Osawa, Mitaka, Tokyo 181-8588 Japan. [11]The Gr Advanced Studies, Osawa, Mitaka, Tokyo 181-8588, Japan. [12]Max-Planck-Insti dem Hügel 69, 53121 Bonn, Germany. [13]OVRO, California Institute of Technolo Pine, CA 93513-0968, USA. [14]Netherlands Organization for Scientific Research 300, NL2509 AC The Hague, Netherlands.

*To whom correspondence should be addressed. E-mail: sdoeleman@haystacl

†Present address: University of Colorado at Boulder, Dept. of Astrophysical ar UCB, Boulder, CO, 80309 USA.

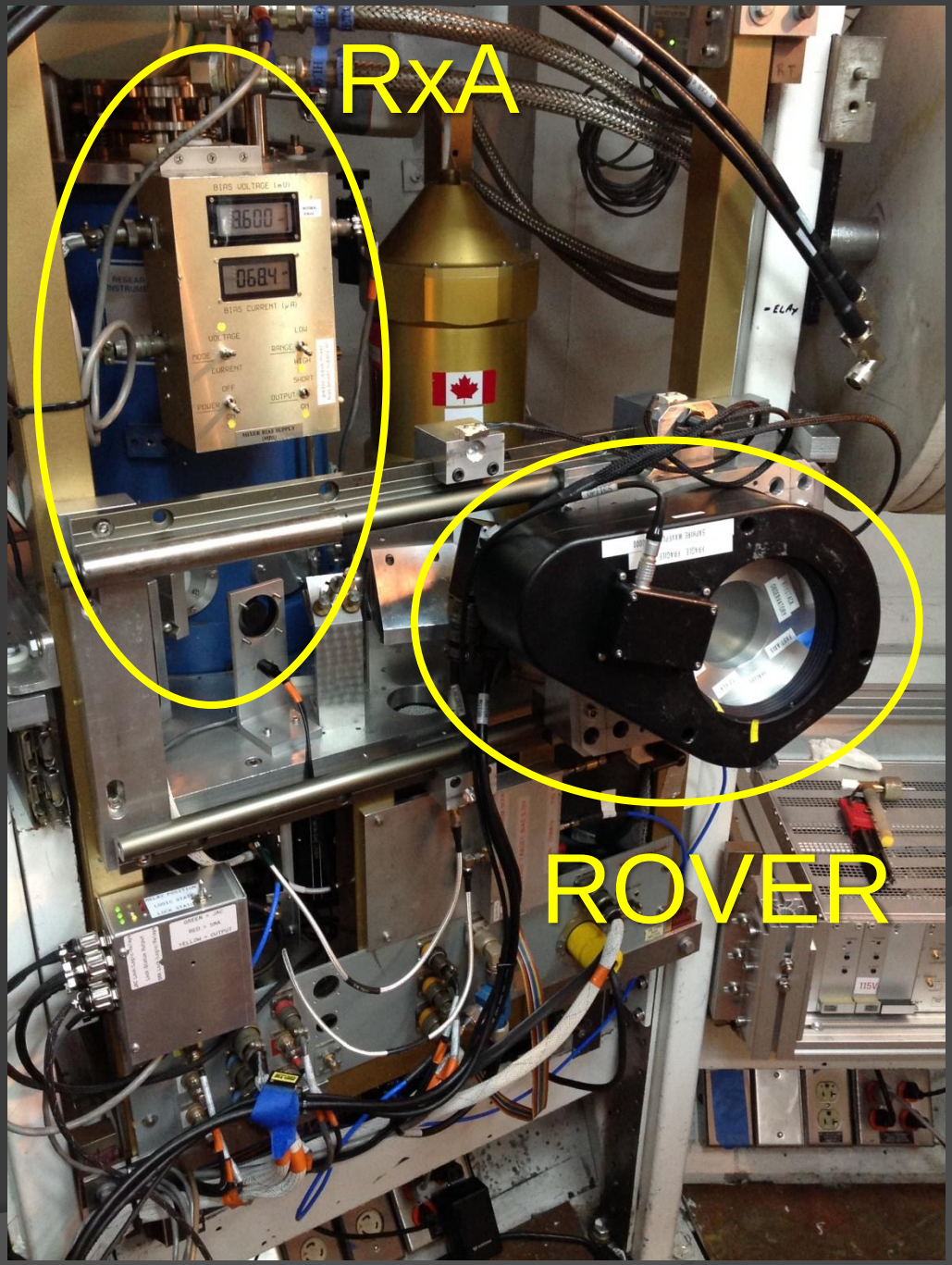
Approximately 10% of active galactic nuclei exhibit relativistic powered by accretion of matter onto super massive black hole measured width profiles of such jets on large scales agree wit collimation, predicted structure on accretion disk scales at the not been detected. We report radio interferometry observation

scales for extragalactic jet sources. High-resolution radio interferometry of these sources at cm wavelengths is limited by optical depth effects that obscure the innermost accretion region. For these reasons, it remains unclear if jet formation requires a spinning black hole (5, 6), and if so, whether jets are more likely to be formed when the orbital angular momentum of the accretion flow is parallel (prograde) or anti-parallel (retrograde) to the black hole spin (7, 8). To address these questions, we have assembled a Very Long Baseline Interferometry (VLBI) array operating at a wavelength of 1.3 mm, the Event Horizon Telescope (9), where AGN become optically thin, and



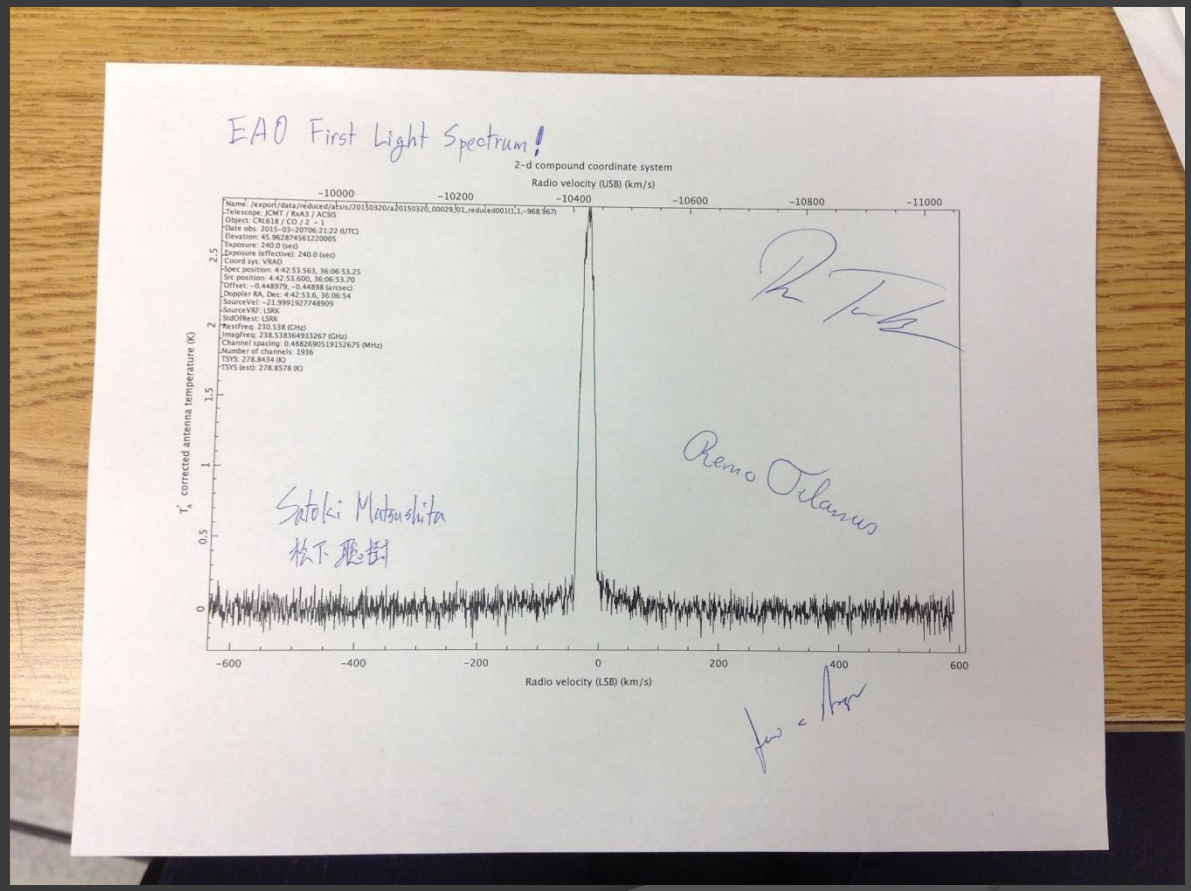
RxA

- The oldest receiver in JCMT.
- Need to fill liquid nitrogen and liquid helium constantly.
- LO can be locked using both JCMT generated and SMA generated reference signals.
- Recently upgraded to the SMA 230 GHz SIS mixer.
- ROVER is a polarizer to create circular polarization signal for RxA.



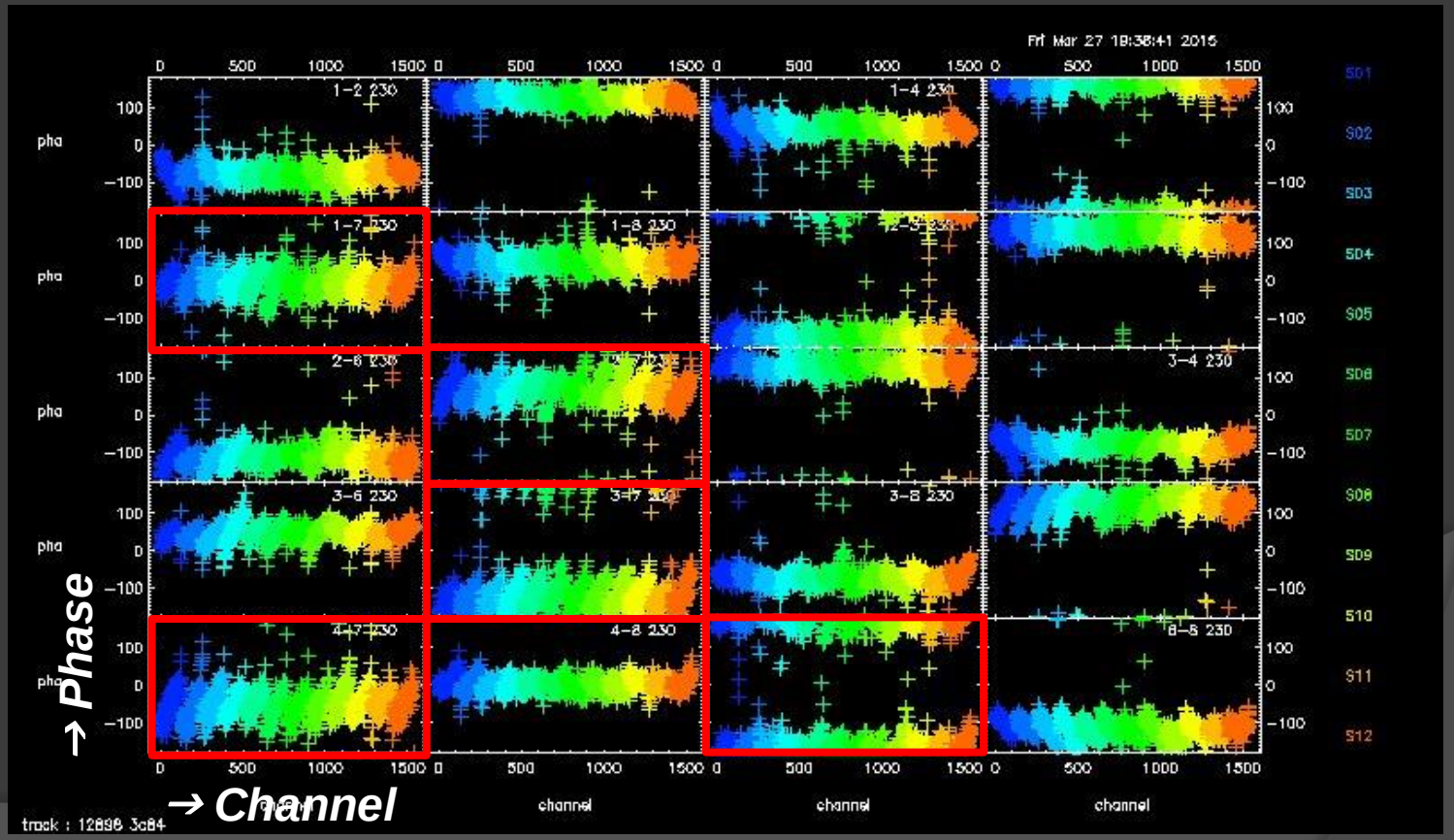
Re-Start of JCMT/RxA

- JCMT was totally shut down before it moved to EAO.
- Re-started from Mar.1, 2015.
- Successfully obtained the first light with RxA as EAO on Mar.19, 2015!



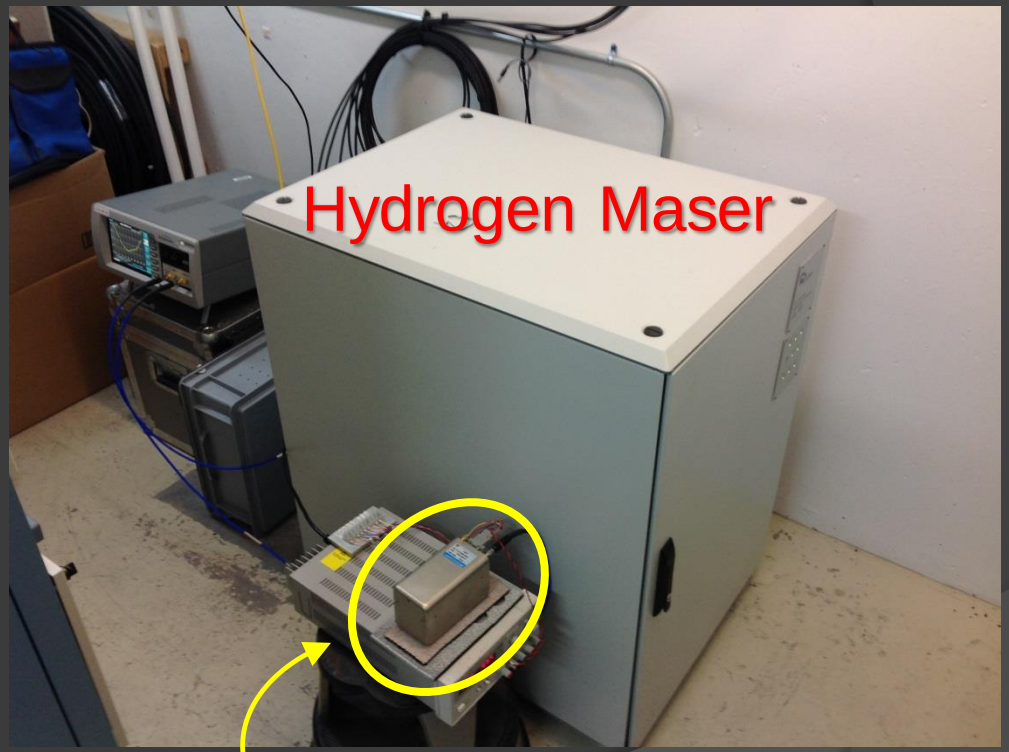
Re-start of JCMT/eSMA

- Successfully obtained the first fringe between JCMT and SMA on Mar. 21, 2015!



VLBI Reference Signal

- Hydrogen Maser
  - Located at the vault of the SMA building.
  - It is for both SMA and JCMT VLBI.
  - This signal is sent to JCMT via SMA Antenna 5 IF2 (high frequency IF) backend.
  - When high frequency IF is in use for the normal SMA operation, the Hydrogen Maser signal cannot be used for JCMT.

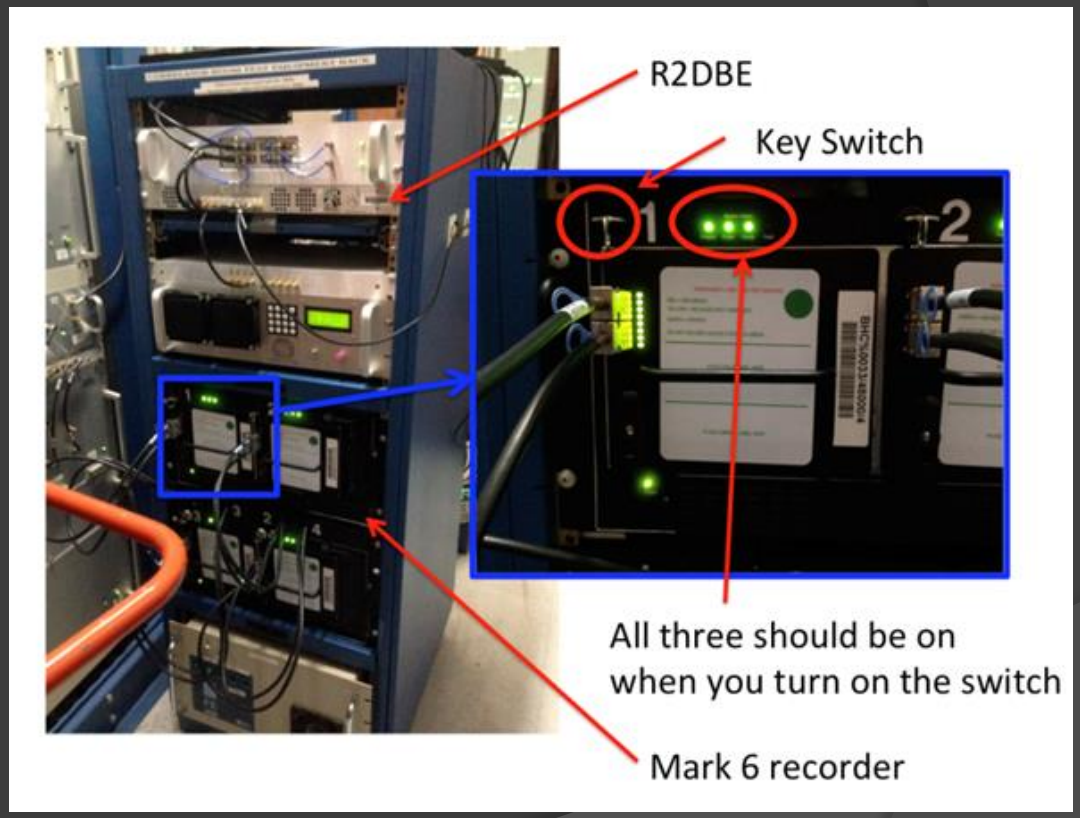


Location of Hydrogen Maser

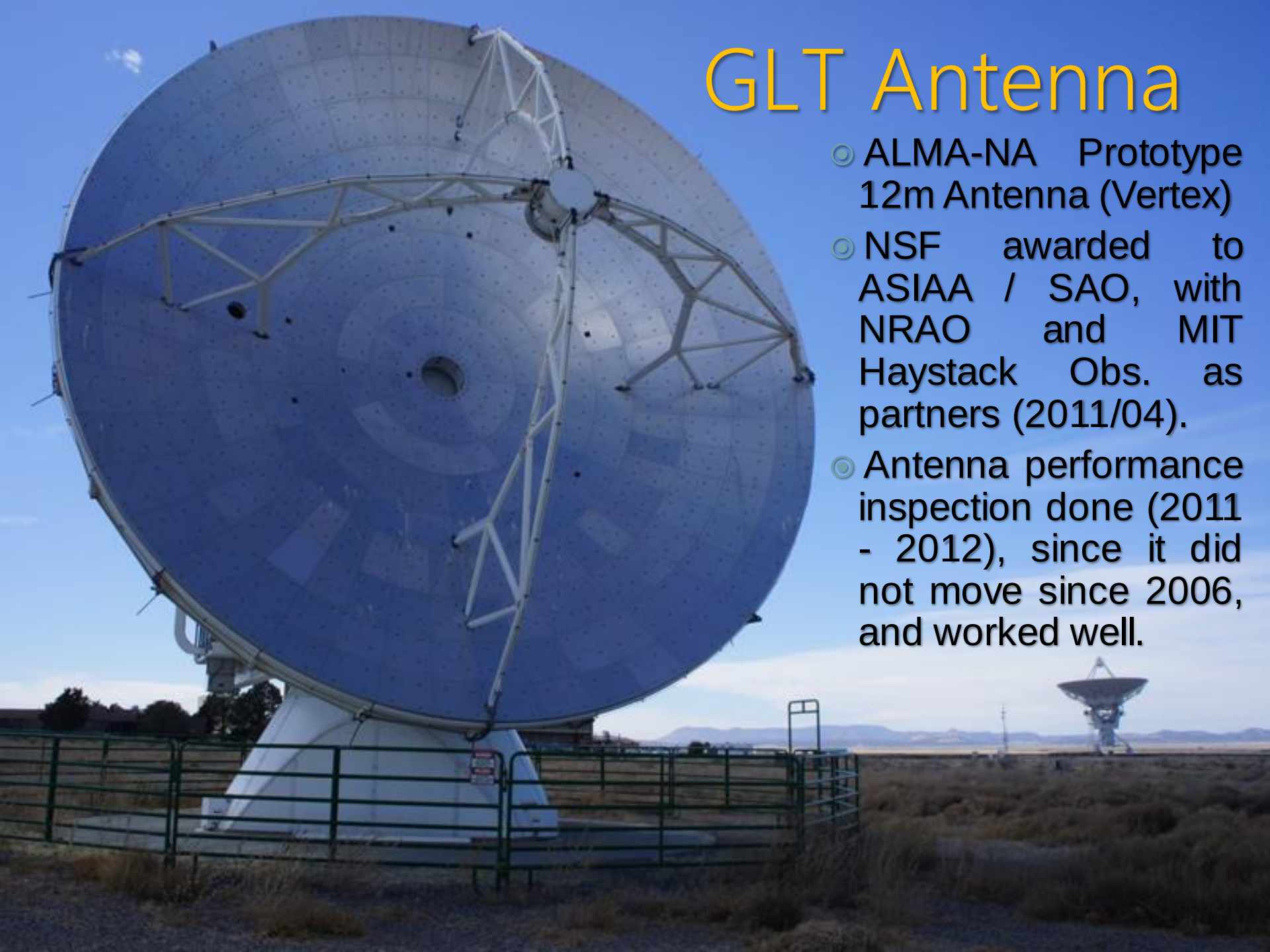
Mar.17, 2015

VLBI Backends

- R2DBE (Roach 2 Digital Back End) & Mark 6 recorder have been used for the latest EHT / ALMA 2015 & 2016 observations.
- Brought by MIT Haystack Observatory.
- Located at the SMA correlator room.



Future of JCMT-VLBI Mode: East Asian Submm-VLBI



GLT Antenna

- ALMA-NA Prototype 12m Antenna (Vertex)
- NSF awarded to ASIAA / SAO, with NRAO and MIT Haystack Obs. as partners (2011/04).
- Antenna performance inspection done (2011 - 2012), since it did not move since 2006, and worked well.

GLT Antenna Disassembly

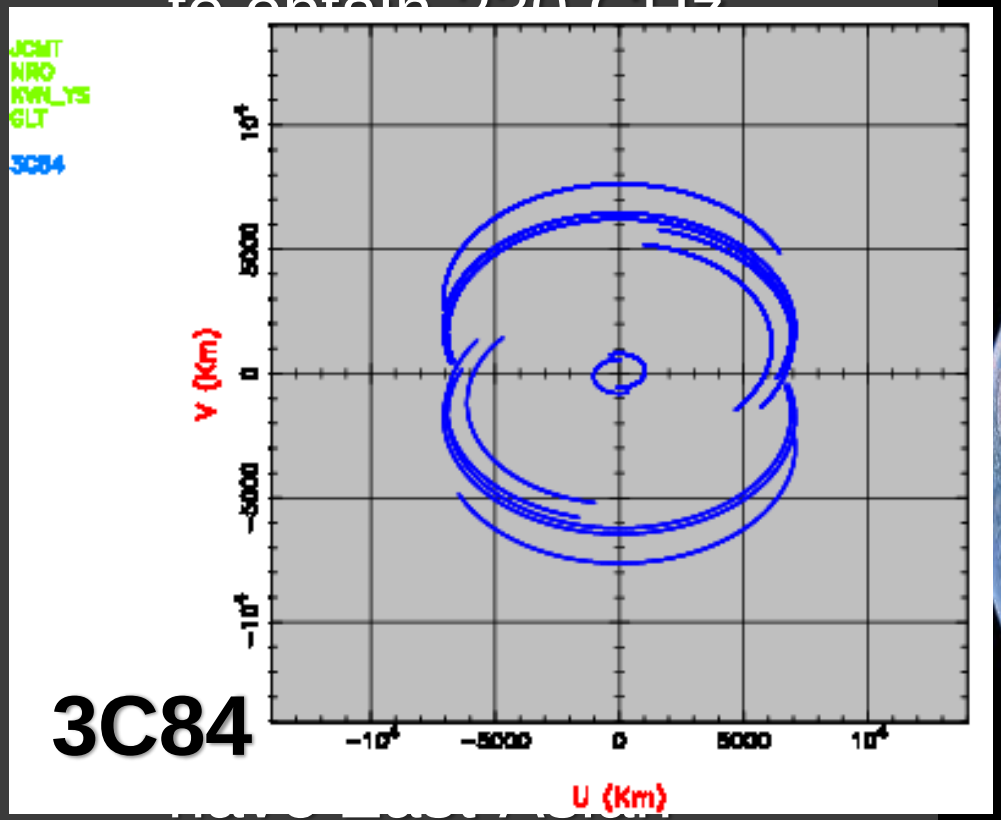
- Totally disassembled at VLA site. (2012/12)

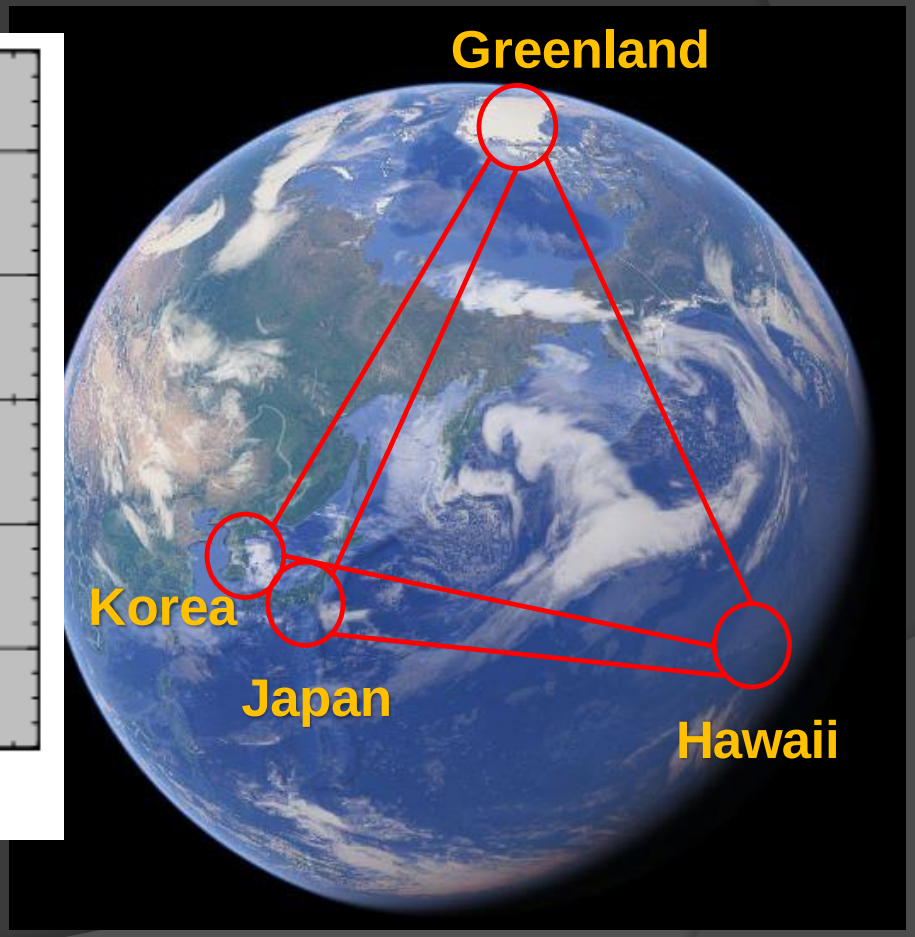
GLT Antenna Retrofit

- Retrofit finished.
- Now testing servo/gear system at Norfolk (VA, USA).
- Antenna will be shipped to Greenland (Thule) this July from Norfolk.

East-Asian Submm-VLBI Network

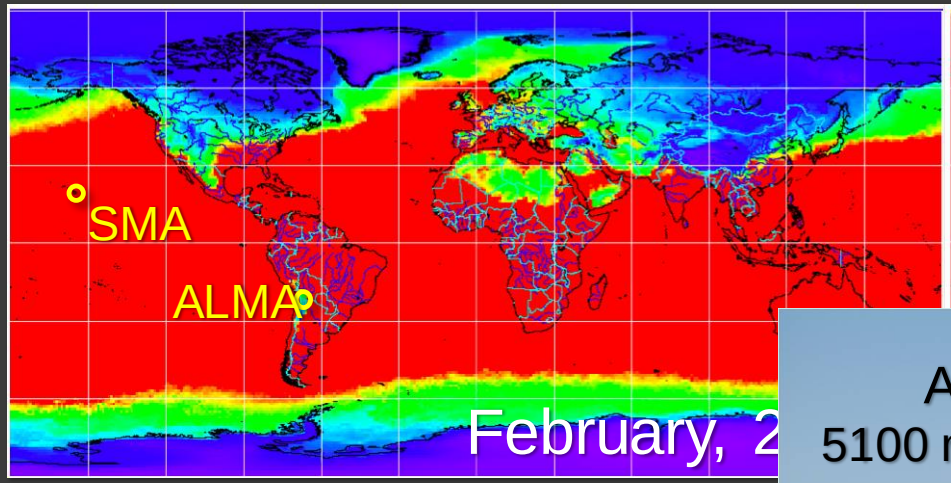
- Japan have succeeded to obtain 230 GHz
  Submm-VLBI network.





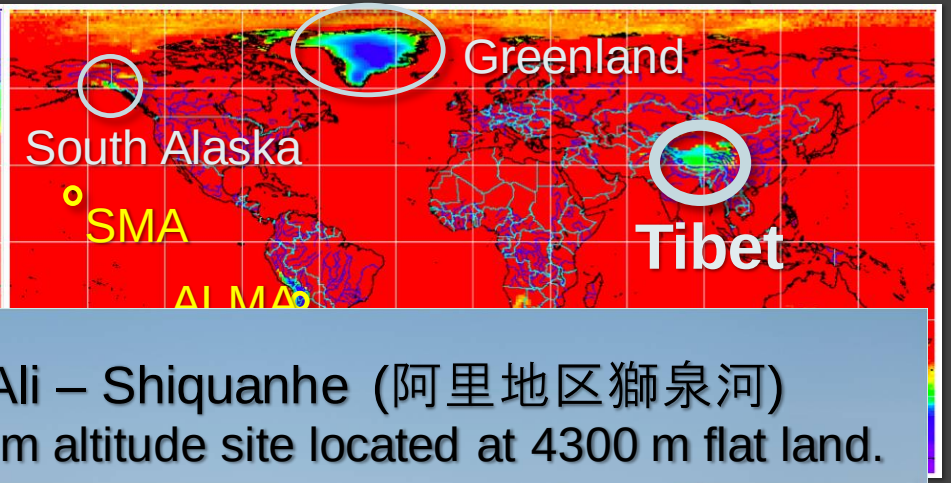
New Submm-Site in EA

Winter in the North, Summer in the South



NASA Aqua & Terra/MODIS Satellit

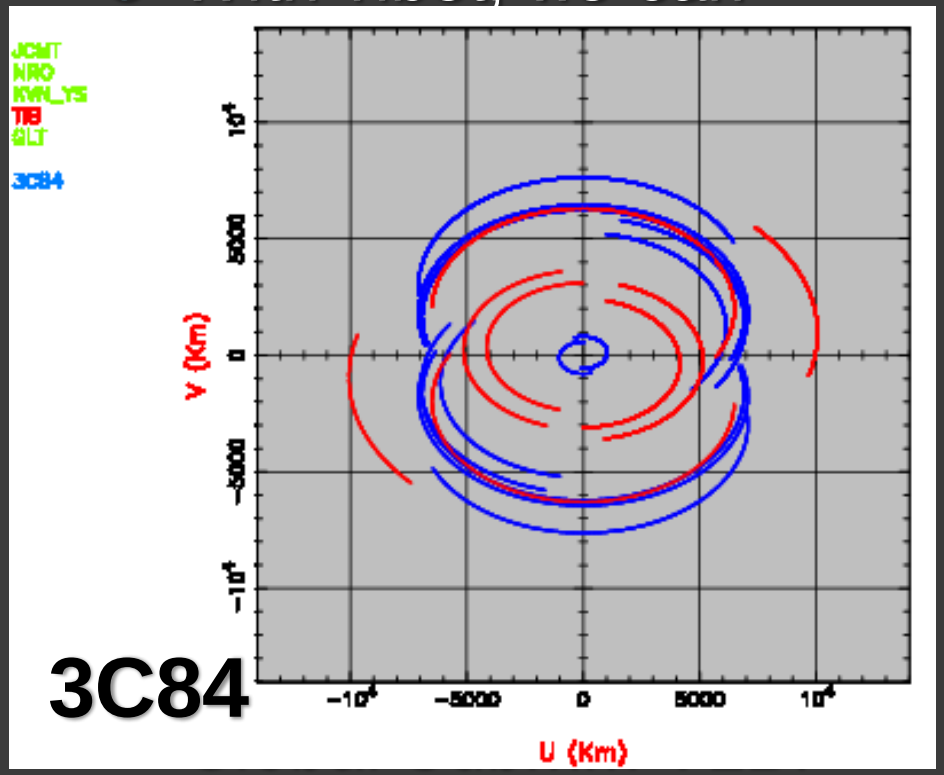
Winter in the South, Summer in the North



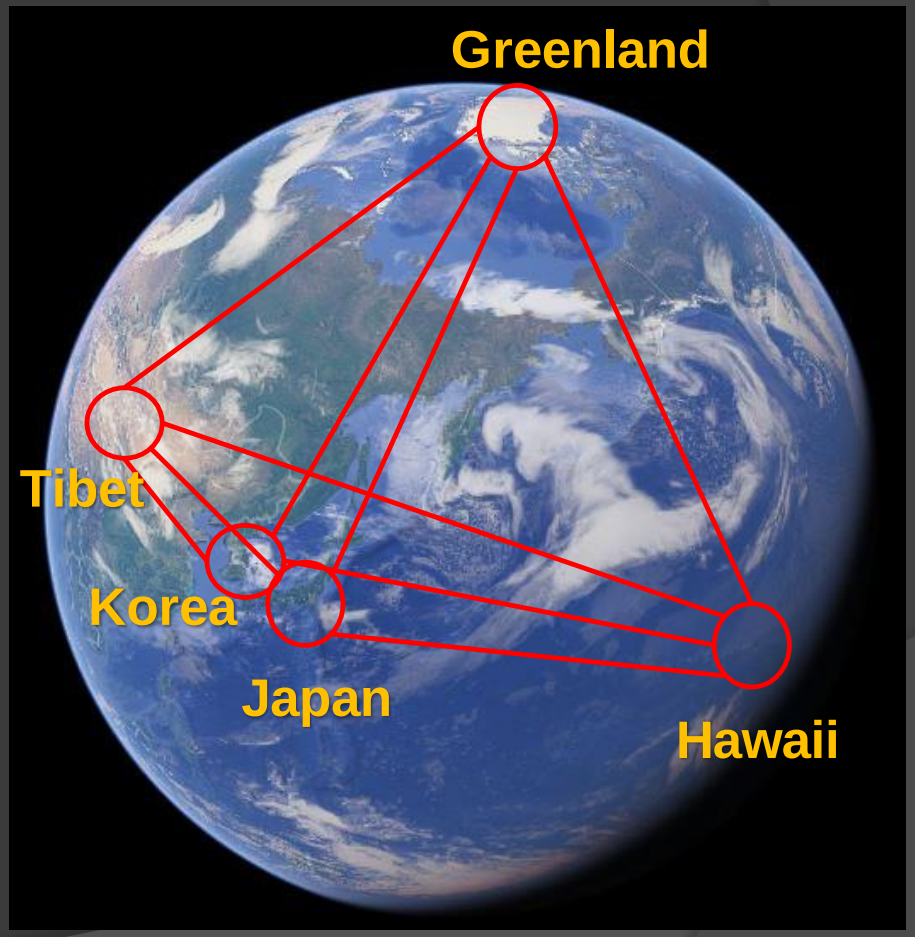
- Tibet is the obvious
  - Japanese group did s
  - EACOA site survey w
    - Mainly for optical telesc submm telescopes.
  - There are many fla linked-arrays, in addition to single dish telescopes.

East-Asian Submm-VLBI Network

- With Tibet, we can



Network.



Making JCMT as a Stand-Alone VLBI Station

Problems for JCMT VLBI

- JCMT stand-alone VLBI has never been done.
  - Reference signal, backends, and some of the cables are shared with the SMA.
    - This is a historical reason, since the VLBI mode is using the eSMA mode system.
    - Currently, reference and IF signals sent out via SMA Antenna 5 IF2 (high frequency IF) backend.
  - Reference (H-Maser) belongs to MIT & ASIAA.
  - Backends belong to MIT.
    - There is no VLBI backends that belong to SMA or JCMT.
    - Not clear whether MIT supports EAO VLBI activities (we hope they will support us).
  - No signal injection system for JCMT.
    - JCMT-VLBI mode always work with SMA, so always check fringes with SMA.
  - No VLBI receivers other than 230 GHz. (3-Cartridge dewer will help A LOT!)

Confliction with SMA

- JCMT VLBI needs to use 1 IF backend to send out the reference signal to JCMT, and receive the IF signal back to SMA.
  - If SMA is in the use of
    - 2 frequency mode,
    - 1 frequency mode with the wide band (4 GHz BW) mode,

    then we cannot use JCMT VLBI mode.
  - If SMA is in the use of
    - 1 frequency mode with the narrow band mode, then OK.
- The most popular SMA observation modes are the first 2 modes, so it is almost hopeless to use JCMT as a stand-alone VLBI station, independent from the usual SMA operation under this configuration.

How to avoid this problem?

- Use eSMA mode and VLBI together with SMA.
  - Fringe check can be done before VLBI, so very convenient.
  - Need to obtain both JCMT and SMA observation time. (i.e., need to submit proposals to both observatories)
  - Need extensive help of the SMA scientists and engineers in both Hawaii and Cambridge.
- Move H-Maser, backends, & recorders to JCMT.
  - Need extensive re-cabling, new designs for making reference signals, etc.
- Use available cables to send the reference signal directly to JCMT
  - Under discussion with ASIAA / JCMT / SMA engineers.

Summary

- JCMT VLBI mode is working well even after JCMT moved to EAO.
- JCMT VLBI mode is highly relying on SMA.
- There is a confliction with the SMA normal operation.
- To avoid this, it needs special technical consideration, which is under discussion with ASIAA / JCMT / SMA engineers.

⇨ We are pushing JCMT to be a stand-alone VLBI station for the future EA Submm VLBI.