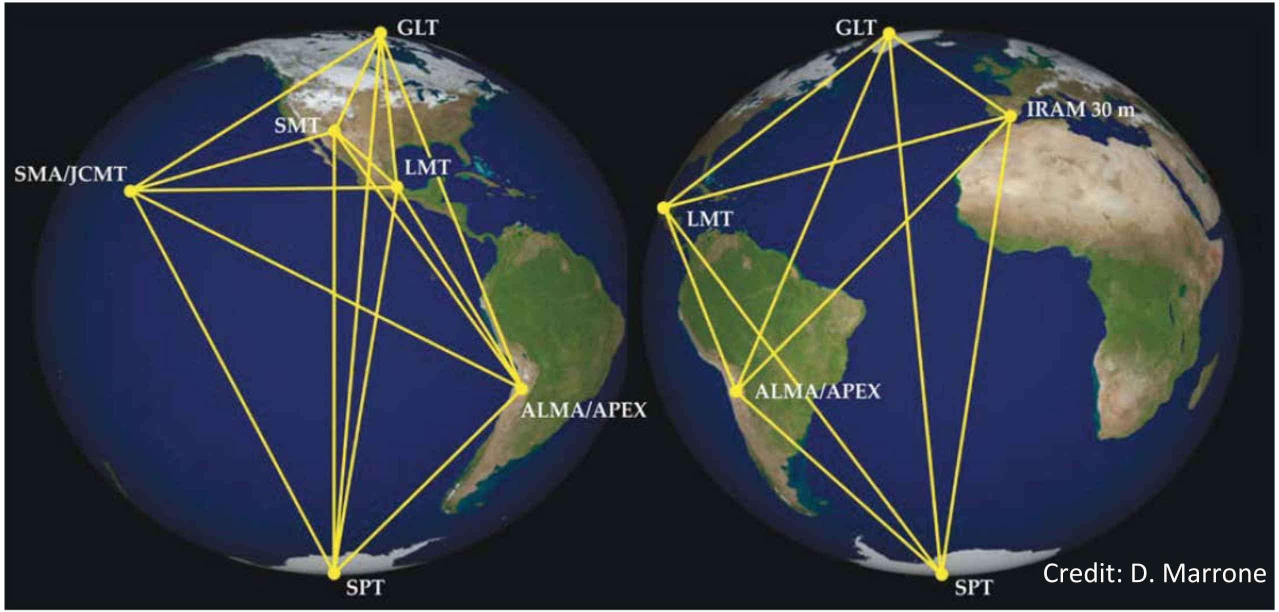
East ASIA VLBI Network Observations at 230 GHz

Kenta Fujisawa (Yamaguchi univ.)
on behalf of Asada-san and EAVN -hi- collaboration

Introduction

Event Horizon Telescope (230 GHz)



One sessions / yr: End of March
Each session: ~ 5 day within 10 days slots
Open sky policy
Host institute: EHTC
Due for the proposal: ~ April 20th (propose to ALMA)

Further Possible expansion of EHT

Table 2: Current and planned stations for 1.3 mm VLBI. EA contributions are shown in bold.

Stations	Location	Diameter [m]	SEFD [Jy]	Status
ALMA 37	Chile	37 × 12	100	2017 -
APEX	Chile	12	3600	operational
GLT	Greenland	12	7800	2018 (planned)
IRAM 30m	Spain	30	1400	operational
JCMT	Hawaii	15	4700	operational
LMT	Mexico	32	1400	operational
NOEMA	France	15	5200	operational
SMA	Hawaii	8 × 6	4000	operational
SMT	Arizona	10	11000	operational
SPART	Japan	10	10000	2018? (planned)
SPT	South Pole	10	9000	operational
SRAO	Korea	6	40000	2018? (planned)

1. KVN at 230 GHz with FPT?
2. Balloon - Borne VLBI led by ISAS/JAXA
3. Re-activate ASTE for VLBI ?
4. Seek the process to use ACA ?

Two important direction for mm/submm VLBI community in EA

a. Participate/contribute to global efforts (e.g., EHT and GMVA)
   - KVN participate GMVA
   - JCMT is one of the initial stations of EHT
   - GLT started to participate EHT and GMVA from this year
   - Approved ALMA CY7 EHT projects: Koyama+ Mrk501

b. Do unique things as (regional) efforts
   - KVN is unique VLBI array observable at 86 and 129 GHz with FPT
   - NRO45m at 86 GHz led by Imai-san and Niinuma-san
   - We (will) have JCMT and GLT at (86) and 230 GHz

EAVN at 86 GHz, 230 GHz and even higher?

EA mm/submm White Paper

White Paper on East Asian Vision for mm/submm VLBI:

Toward Black Hole Astrophysics down to Angular Resolution of 1 R_S

Editors

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Experiences 230 GHz VLBI with EA stations

1. JCMT became stand alone station.
2. GLT started to participate EHT observations since 2018, and got fringes
3. SPART experiments have already demonstrated mm-VLBI feasibility of SPART telescope in 2015

⇒ We are ready to start regional coherent efforts to form 230/(86 GHz) array

Observations

The first EAVN -hi- test observations

- Date: 2019 March 18, 19
- Duration: UT11-18, 7 h each day
- Frequency range: 230200 – 232248 MHz*
- Stations: GLT-12m, SPART-10m, SNRAO-6m
- Sources: M87, 3C345, 1633+382, 3C371, 1928+738, N6251, Mrk501, CO2-1 sources for verification purpose
- Weather: Cloudy (SPART), Fine (GLT)

System Setup

	GLT 12 m	SRAO 6 m	SPART 10 m
SEFD	4 900 Jy	78 000 Jy	18 000 Jy
Start Freq.	230.200 GHz	230.200 GHz	230.200 GHz
Bandwidth	2 048 MHz	1 024 MHz	512 MHz
Polarization	Dual circular	Single circular	Single linear
Recorder	R2DBE Mark6	R2DBE Mark6	ADS3000+ OCTAVE

Preparation for each site

GLT

Observations ~ -30 degree

Wen-Ping Lo, Kevin Koay, and Keiichi Asada at the site

- ALMA-NA prototype 12 m

- 3 receivers (86, 230 and 345 GHz)

- 64 Gbps system with
  4 x Mark6 + 4 x R2DBE

- Phase stability test for receiver with tone injection
  before and after the observations

  ASD ~ 10^{-14} @ 1 sec

- Monitoring reference signal with respect to OCXO

  ASD ~ 10^{-13} @ 1 - 10 sec

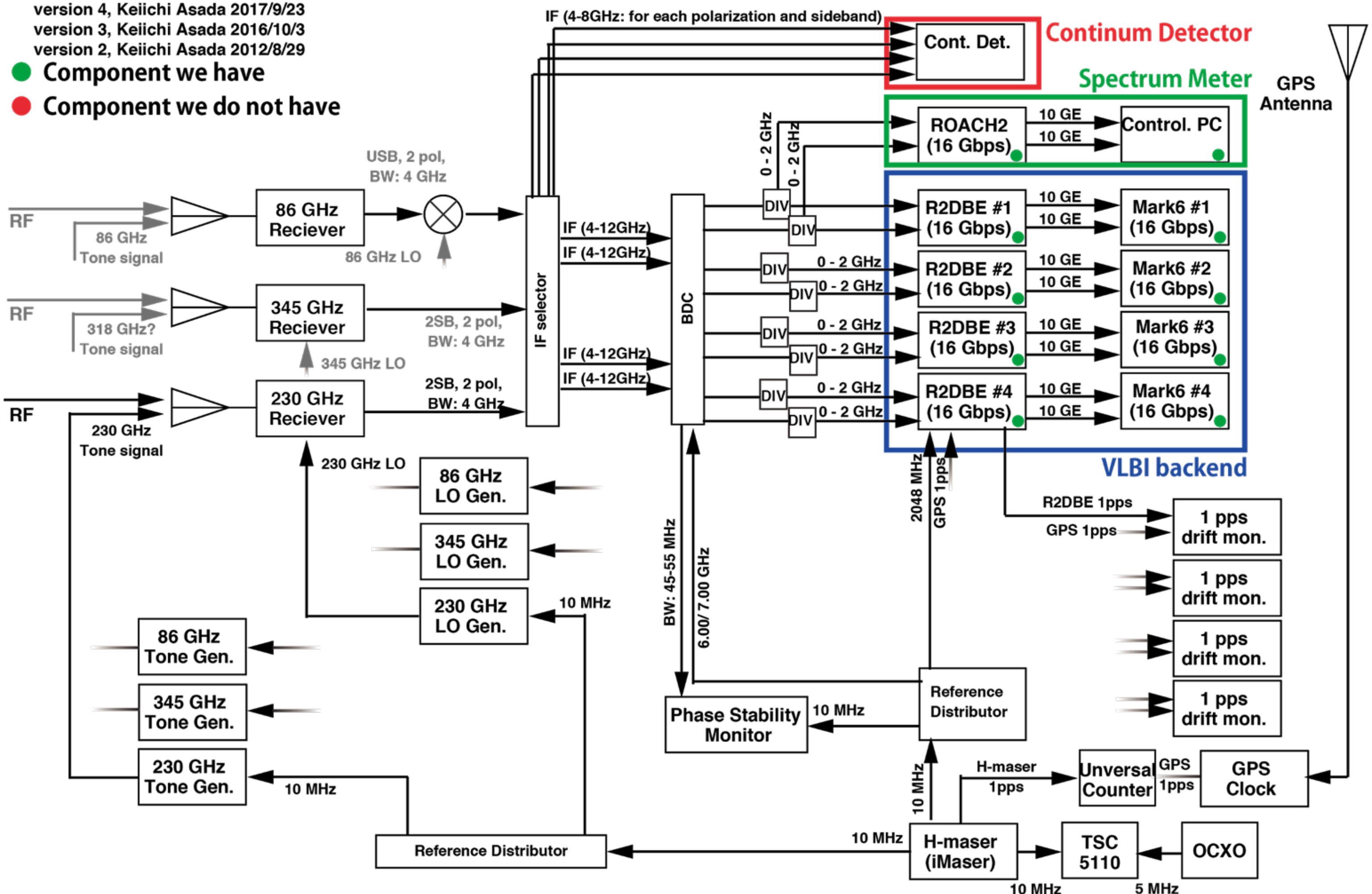
- Detection of Fringe for GMVA campaign 2019
  (just after the EAVN -hi-)

  Stability should be fine for GLT

VLBI Observational Signal

version 5, Keiichi Asada 2019/1/30
version 4, Keiichi Asada 2017/9/23
version 3, Keiichi Asada 2016/10/3
version 2, Keiichi Asada 2012/8/29

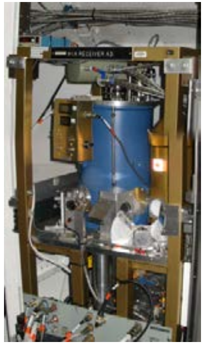
- Component we have (green dot)
- Component we do not have (red dot)



R2DBEs at receiver cabin

Mark6s

JCMT

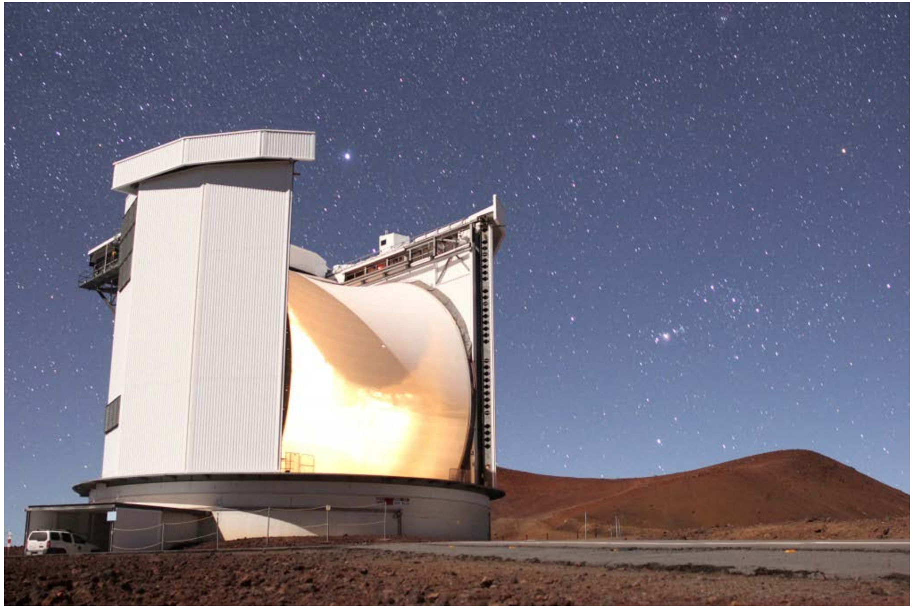


RxA:
Retired June 23, 2018

Namakanui (GLT spare):
Commissioning

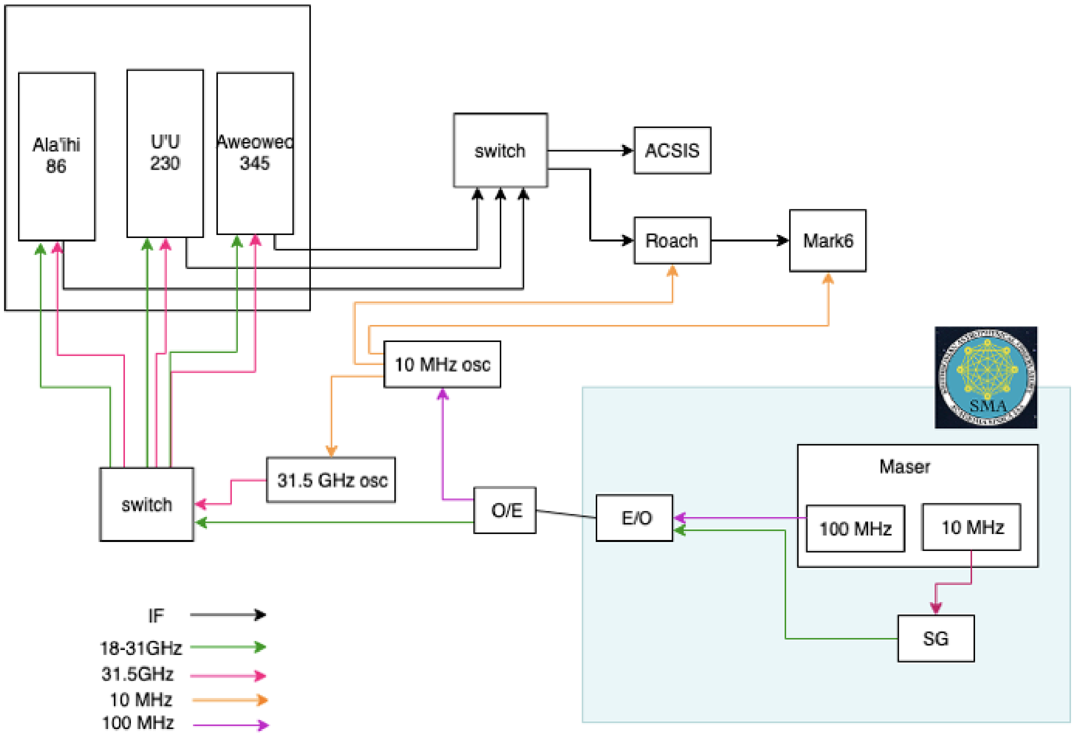
Diameter: 15m
Location: Maunakea summit, Hawaii
(3 receiver cartridge (86. 230, 345 GHz))

Editting by Izumi



The JCMT. Image Credit: William Montgomerie

JCMT



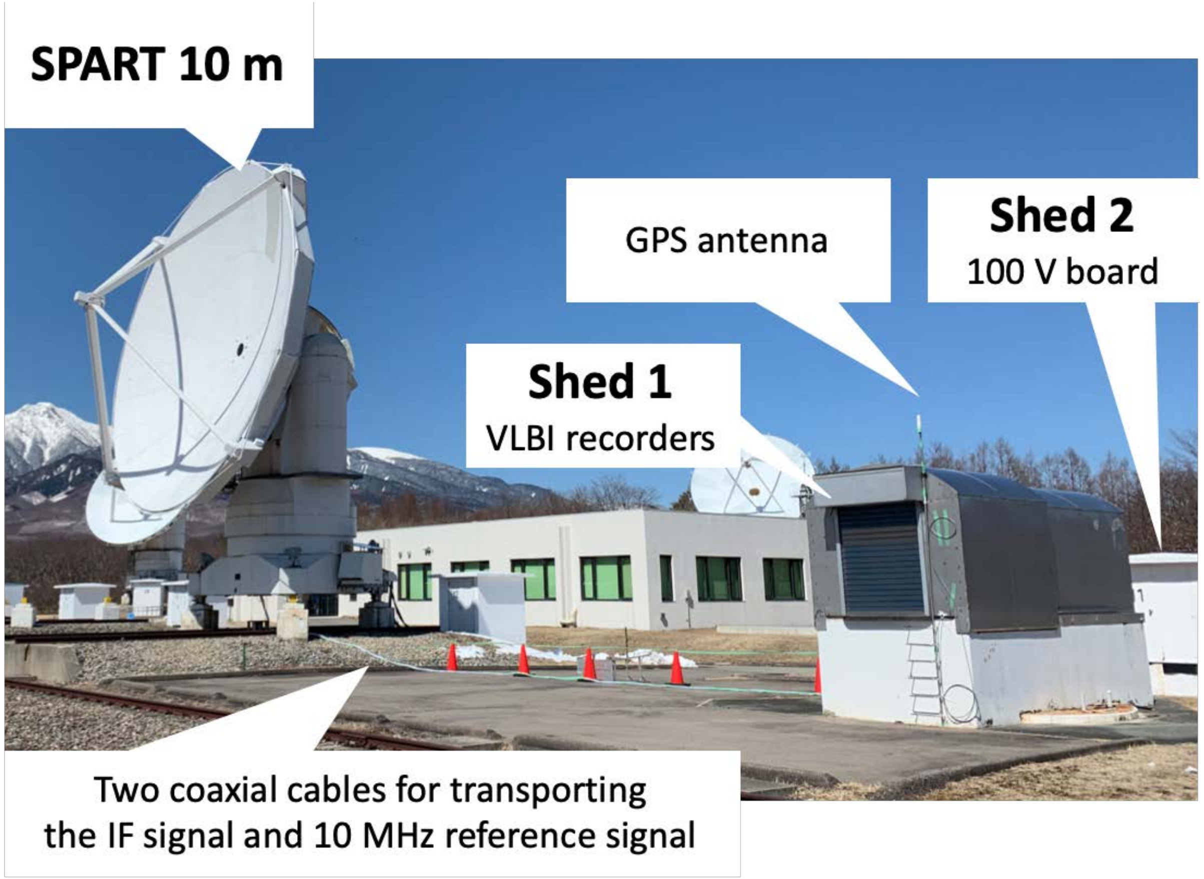
Ala'ihi
86
U'U
230
Aweowed
345
switch
ACSIS
Roach
Mark6
10 MHz osc
31.5 GHz osc
switch
O/E
E/O
Maser
100 MHz
10 MHz
SG
SMA
IF
18-31GHz
31.5GHz
10 MHz
100 MHz

SPART 10 m
Solar Planetary Atmosphere Research Telescope

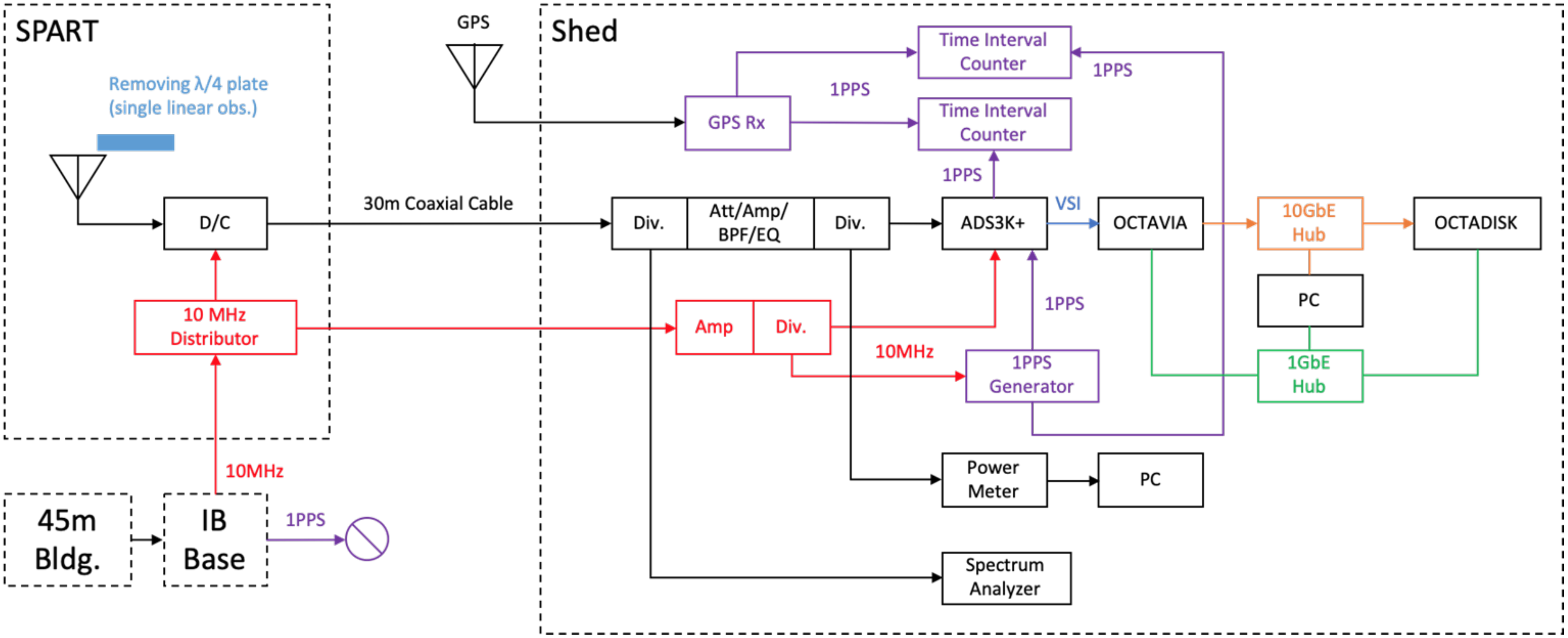
- Operated by Osaka Prefecture University, Japan
- One of the antennas of the former Nobeyama Millimeter Array
- Normally observing solar planets and others at 230 GHz as a single dish
- VLBI system temporarily installed:
  - The system of Yamaguchi 32-m was disassembled and transported to SPART

SPART 10 m

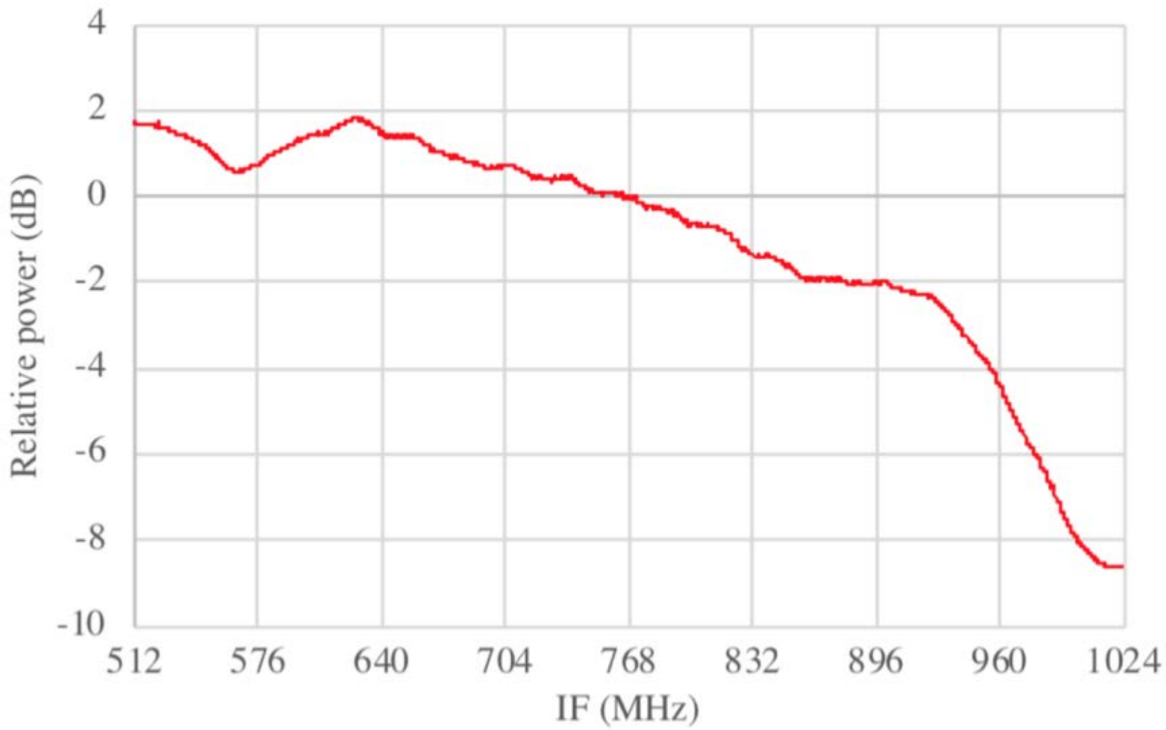
- VLBI system installed in Shed 1
  - GPS antenna tied on a laundry pole
- Two coaxial cables connecting SPART and Shed 1, transporting the IF and 10 MHz signals



SPART VLBI System



SPART Bandcharacteristics



SPART Preparation

SPART Preparation

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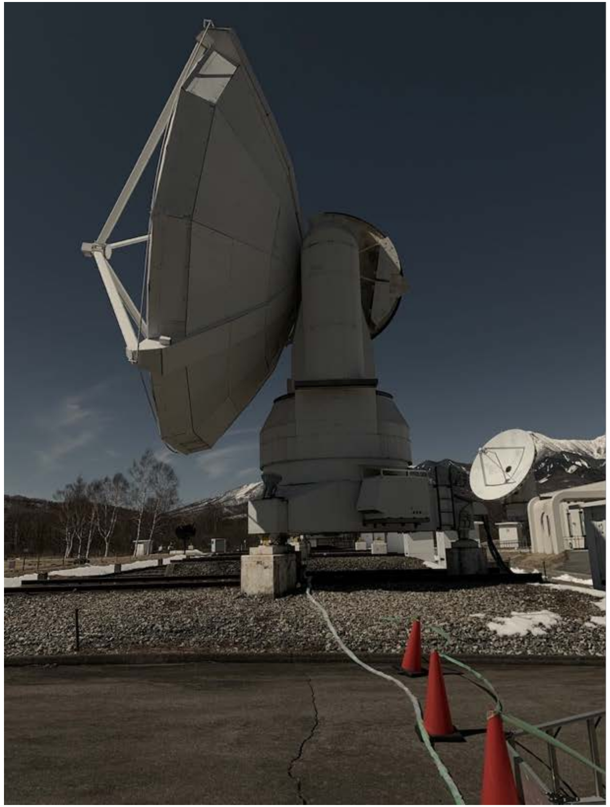
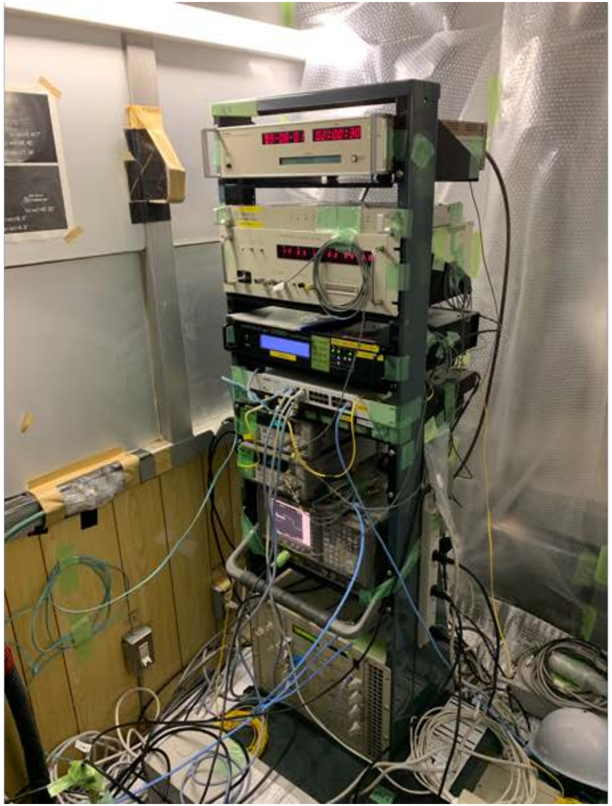


SPART Preparation

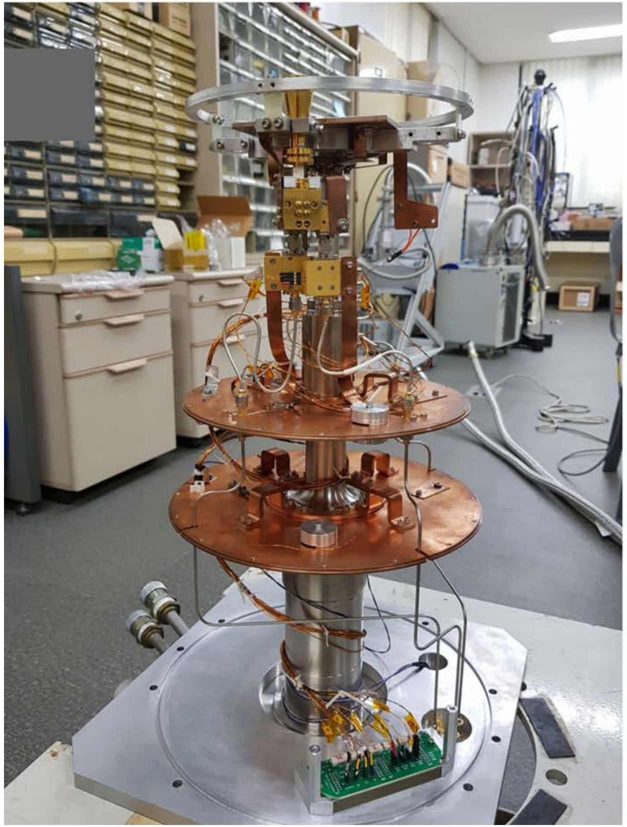

SPART Preparation

SRAO

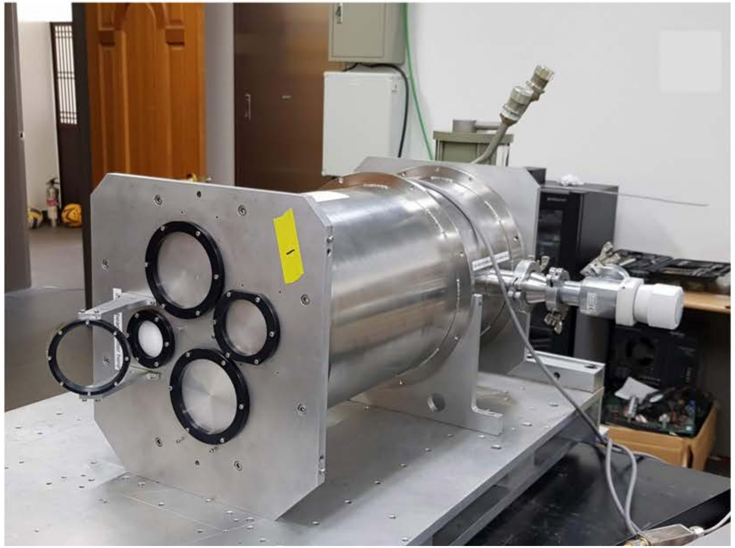
- Inaugurated: 2002
- Aperture: 6.1 m
- Sub-reflector: 61 cm
- Cassegrain focus
- 230-GHz band receiver
- Beam size: 45''
- Aperture efficiency: 49%

Image:
Workshop "mm-VLBI with SRAO" held in Sep. 2015. Participants from SNU, KASI, NAOJ, ASIAA, Yamaguchi U, Osaka Pref. U.

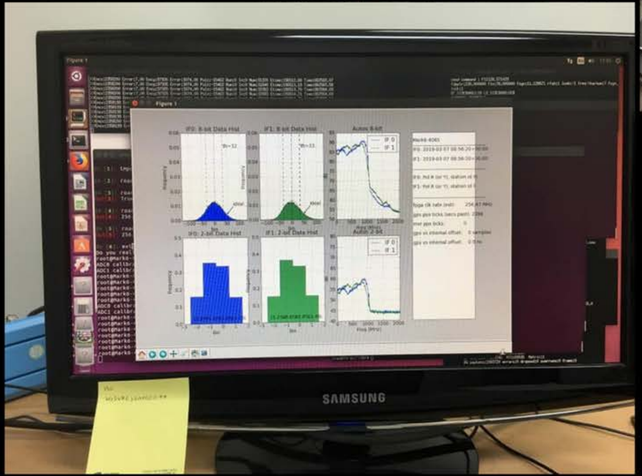
The new SRAO 230-GHz band receiver

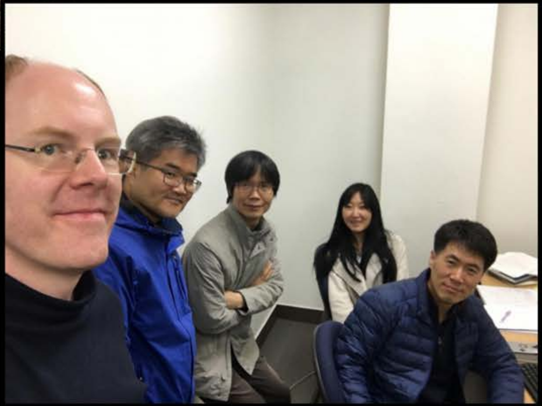


- Previously at CARMA
- Frequency range: 215 – 265 GHz
- Bandwidth 1 GHz
- Left & right hand circular polarization
- Receiver temperature ~60 K



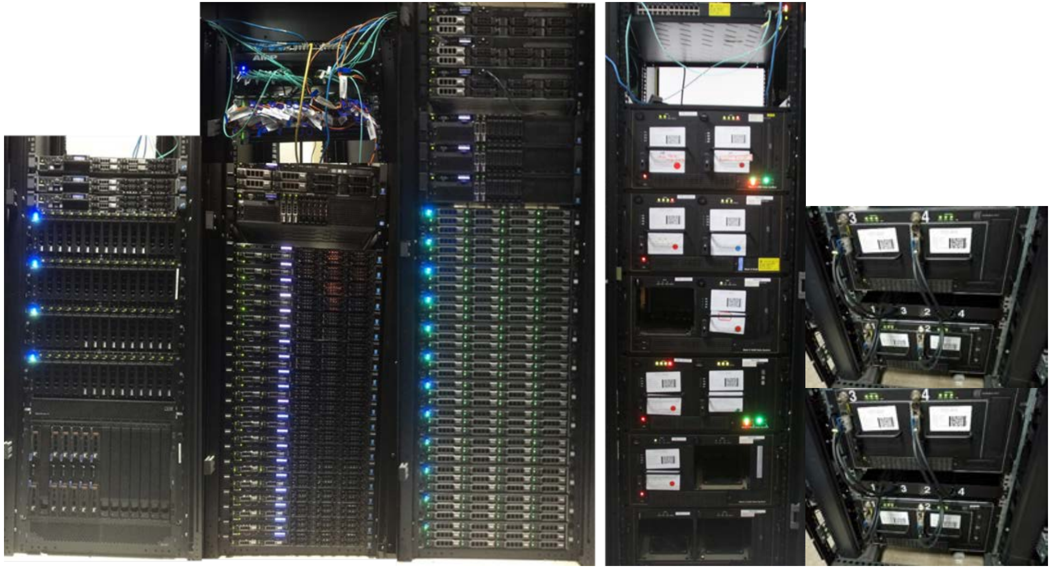
First VLBI run with SRAO
March 18+19, 2019





Correlations

Correlator	DiFX-**2.6.1**
Post processing	HOPS-**3.20**



SHAO DiFX correlator

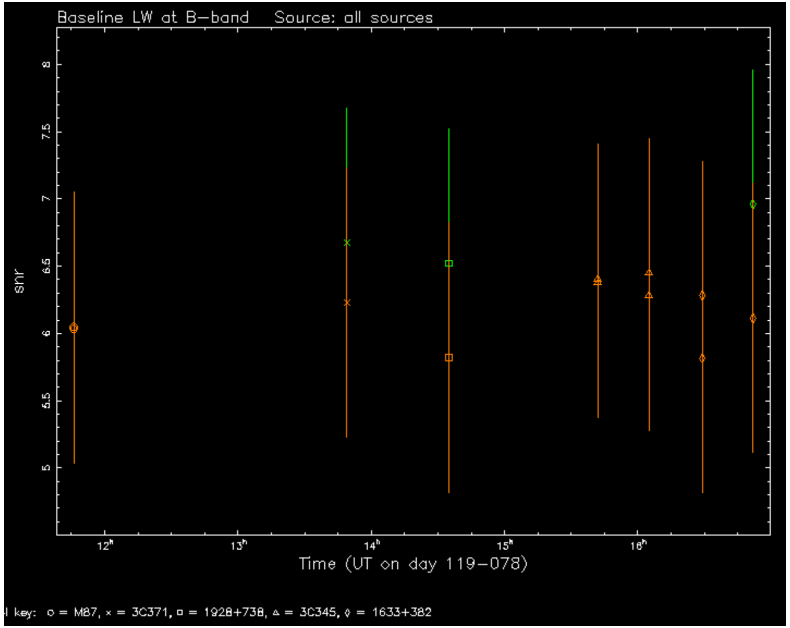
Status of correlation

- ✓ Data transfer:
  Diskpacks (GLT, SPART, arrived), Internet (SRAO, arriving)
- ✓ Pre-correlation:
  Raw data format of each station (GLT, SPART) was confirmed with detections of CO-line spectrum data.
- ✓ Correlation:
  Using ZOOM band to extract the same frequency bands from each station, GLT-SPART (512MHz), GLT-SRAO (1024MHz), SPART-SRAO (512MHZ)
  Split the band into multiple 32MHz BW for larger delay search window and incoherent averaging.

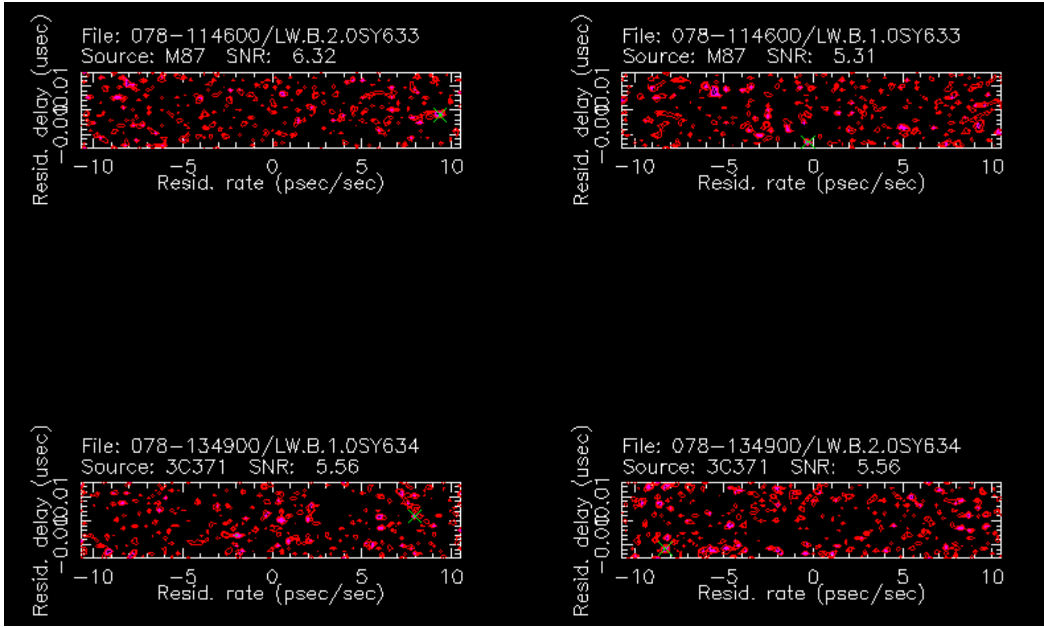
Status of correlation

Limited SNR!

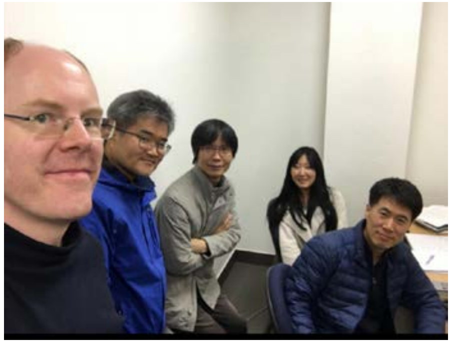
Coherent fringe search



Incoherent fringe fitting



The first VLBI experiments at 230 GHz



That was a great first step for us,
while no fringe were detected so far.

Contents for Discussion Session

Set up 1. Simple BH shadow case

Input image: Simple BH shadow model from Bubu

Noise:

Thermal Noise: Yes

Systematic Noise: No

BW: 2 GHz

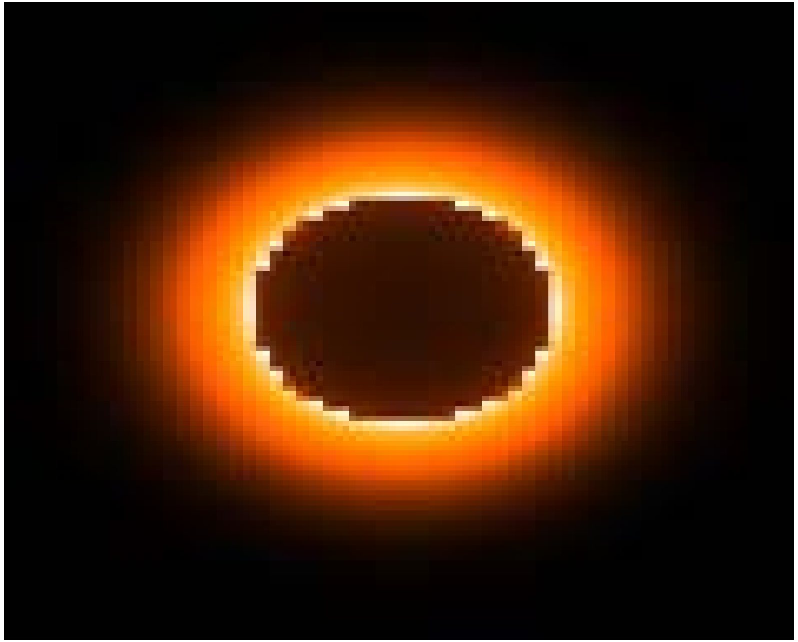
Duration: Full Track

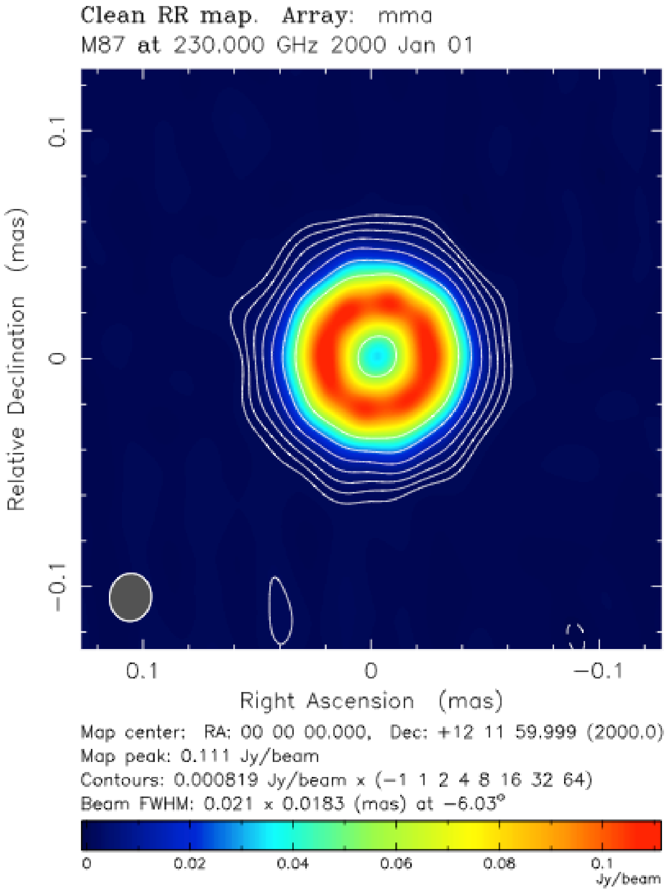
(12° (EL) to 12° (EL))

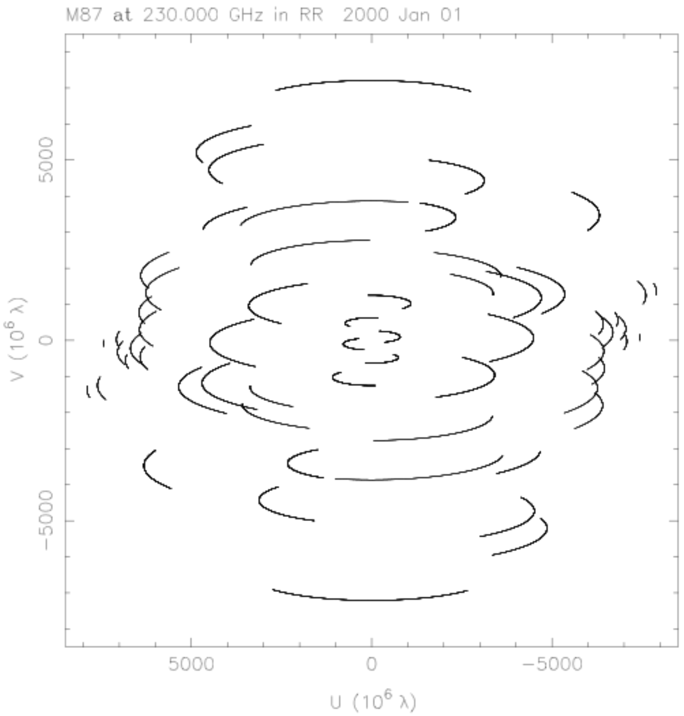
Data: Generated with UVCON (AIPS)

CLEAN: Difmap

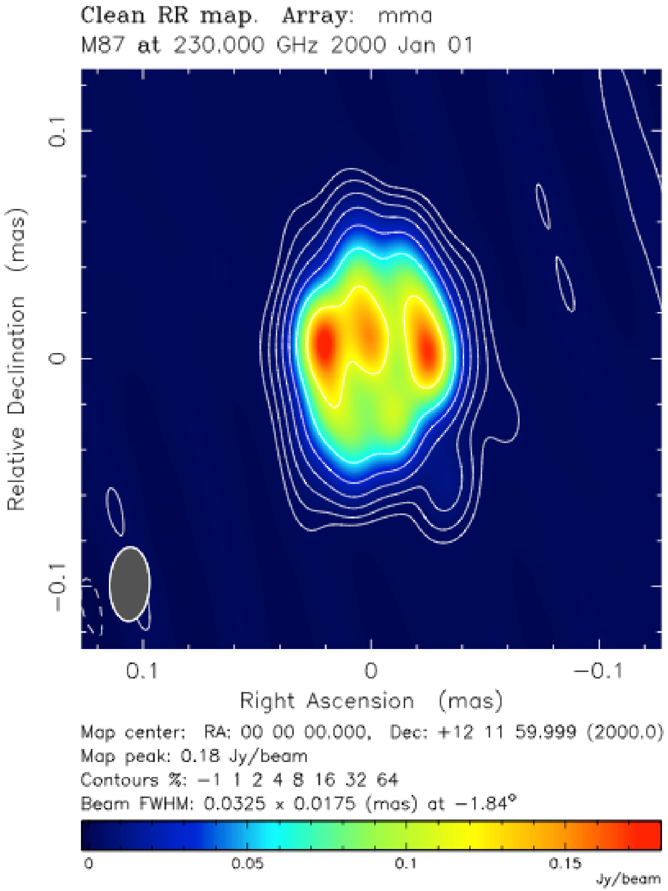
All process done manually

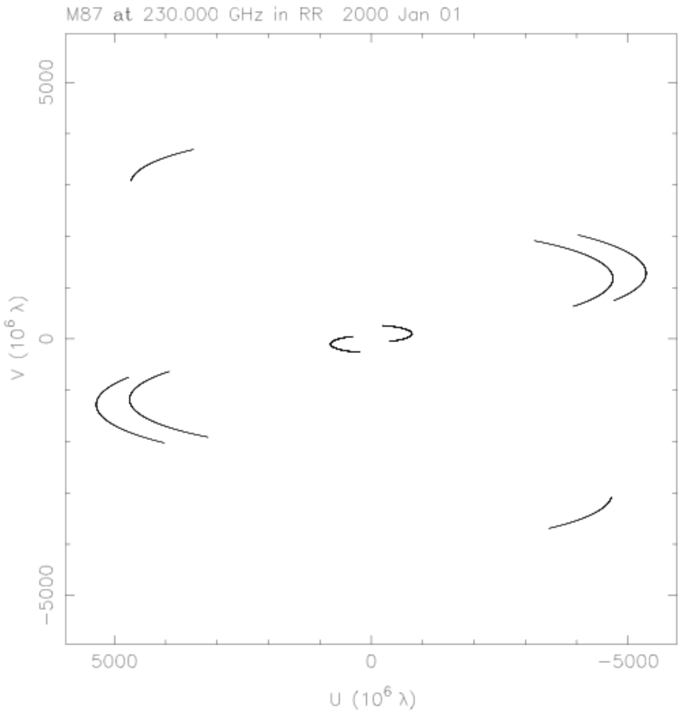




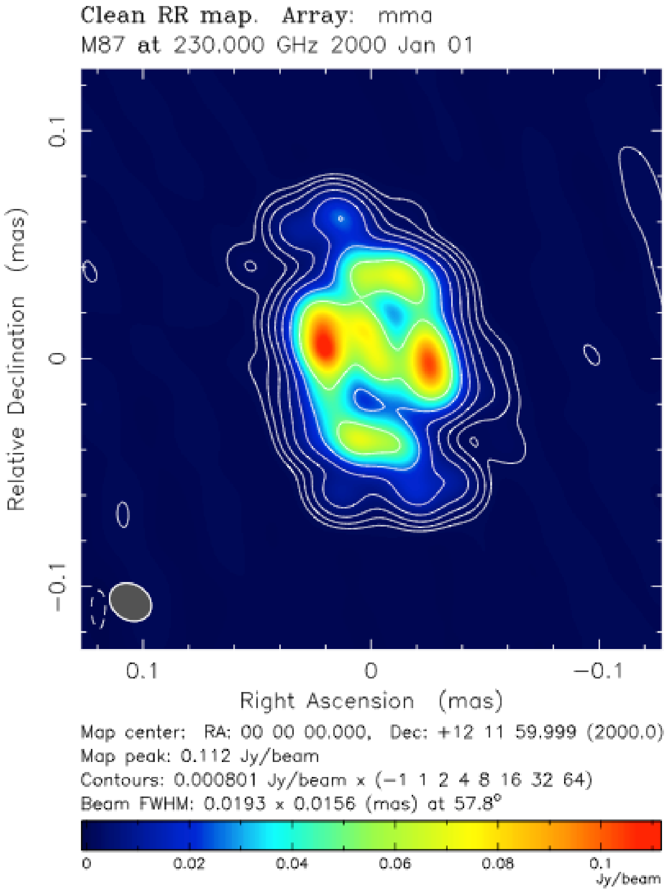


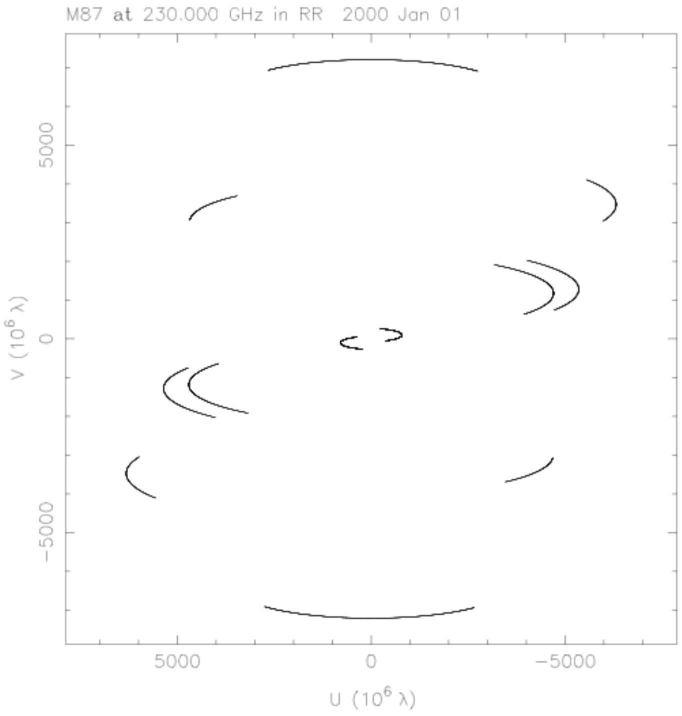
GLT+JCMT+SPART+SRAO
+PICO+NOEMA +ALMA+APEX
+SMA+SMTO+LMT





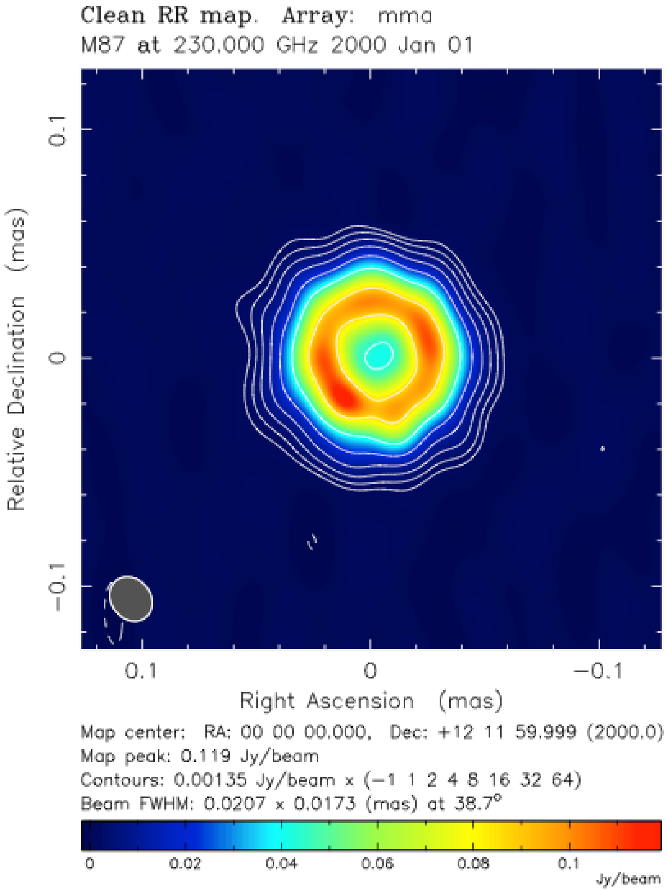
GLT+JCMT+SPART+SRAO

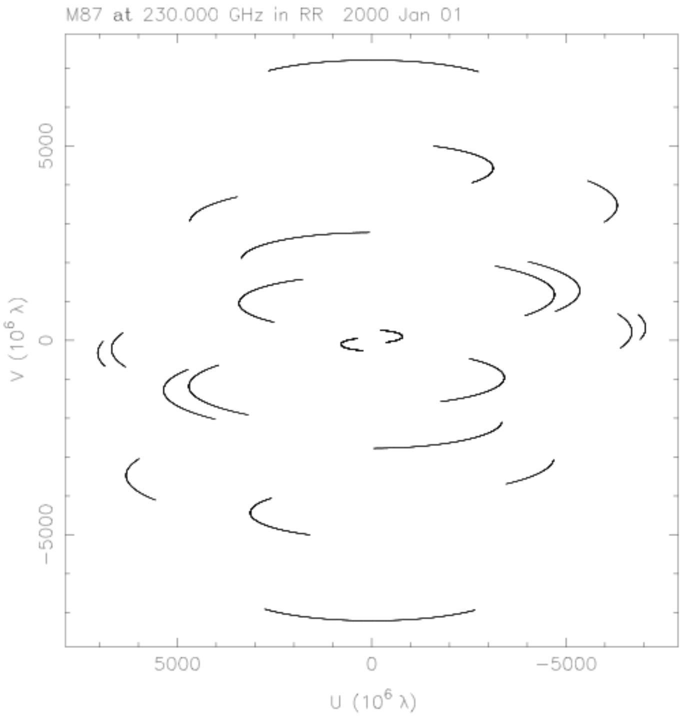




GLT+JCMT+SPART+SRAO

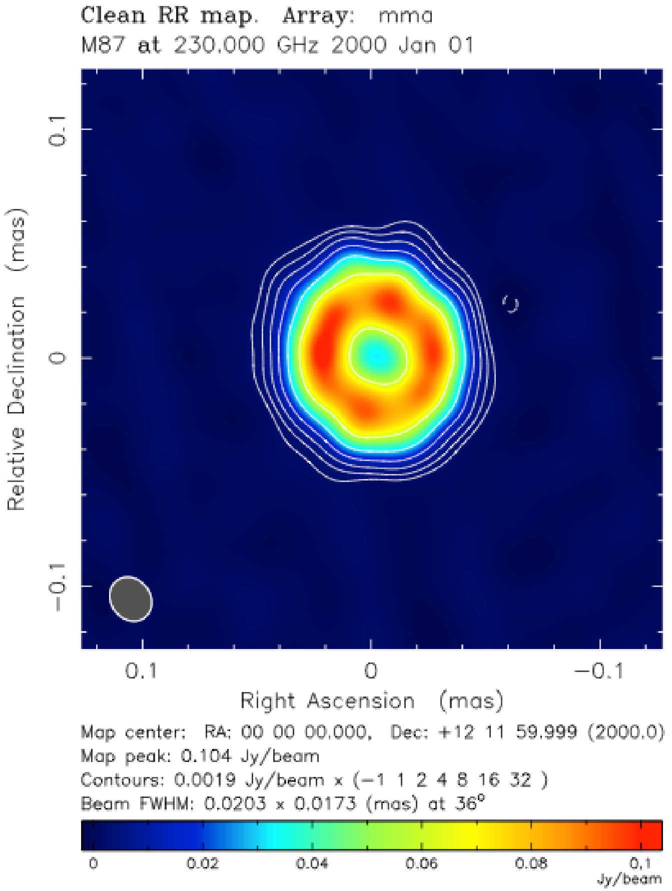
+ALMA

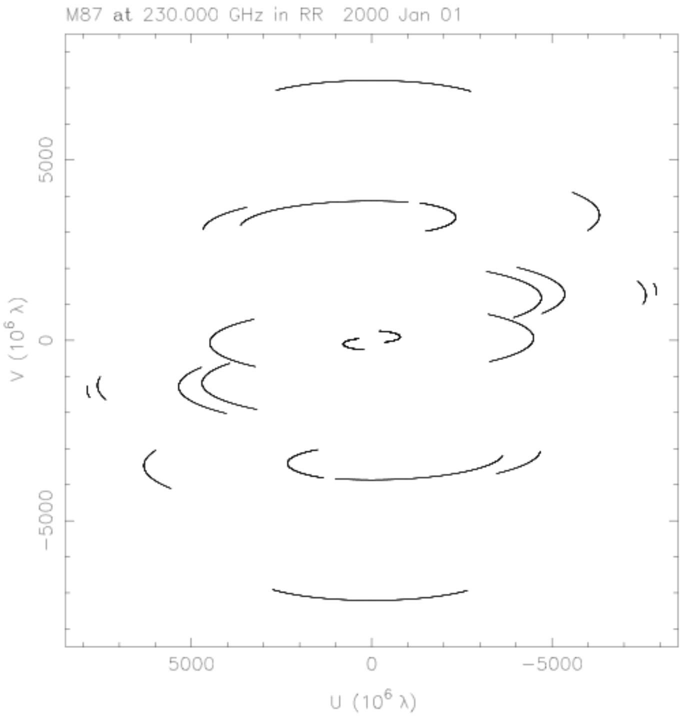




GLT+JCMT+SPART+SRAO

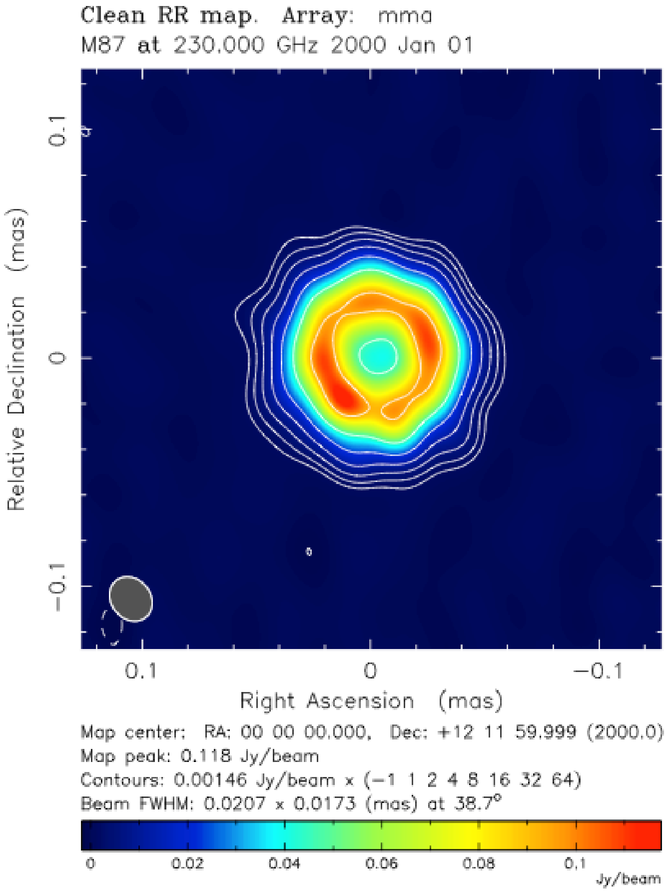
+ALMA +SMTO

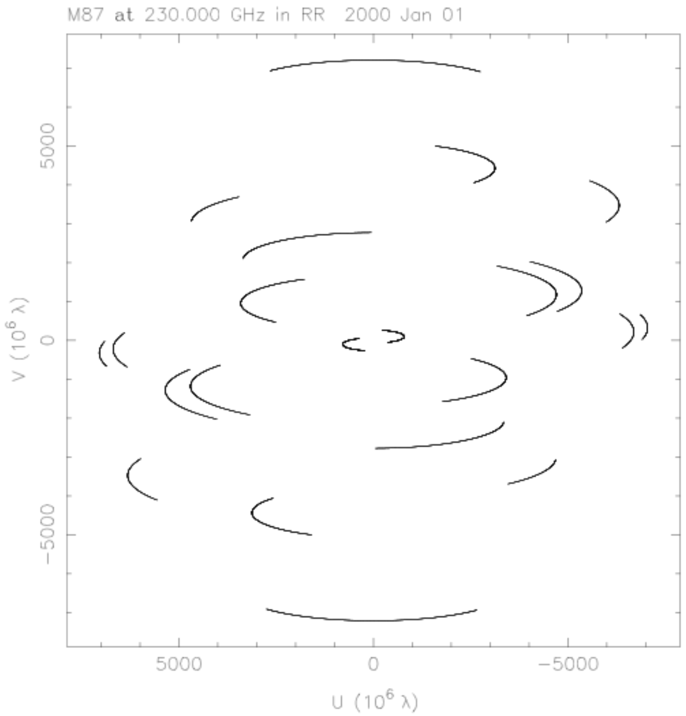




GLT+JCMT+SPART+SRAO

+ALMA +LMT





GLT+JCMT+SPART+SRAO

+APEX +SMTO

	Peak [Jy/beam]	Rms [Jy/beam]	DR	chi2
GLT+JCMT+SPART+SRAO	0.118	0.00069	171	1.13
GLT+JCMT+SPART+SRAO+ALMA	0.118	0.00027	442	1.17
GLT+JCMT+SPART+SRAO+ALMA+SMTO	0.119	0.00045	264	1.14
GLT-JCMT-SPART-SRAO-APEX-SMTO	0.118	0.00049	243	1.13
GLT-JCMT-SPART-SRAO-APEX-LMT	0.118	0.00063	187	1.29
FULL	0.111	0.00027	407	1.25

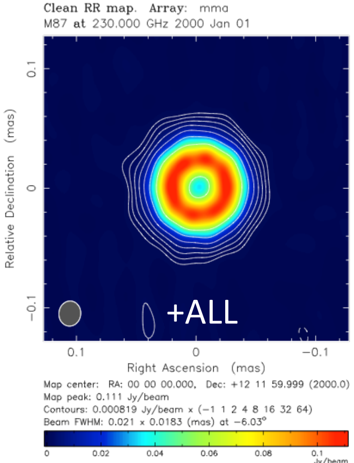
1. Simple BH shadow case

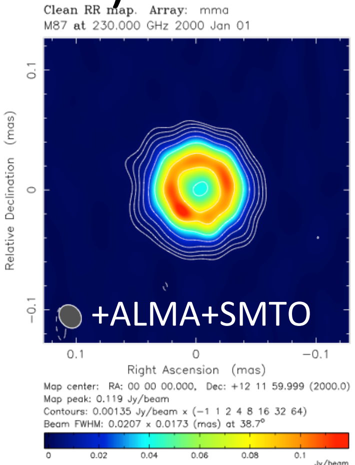
Tentative summary for BH shadow imaging

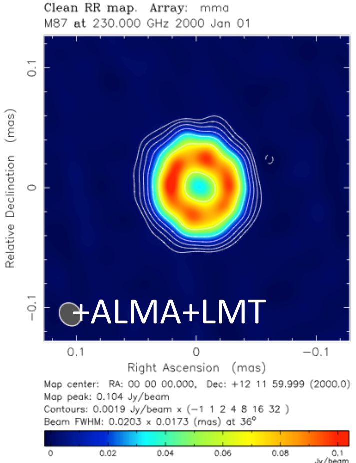
(1). We need EAVN (GLT-JCMT-SPART-SRAO) + Chile + LMT or SMA

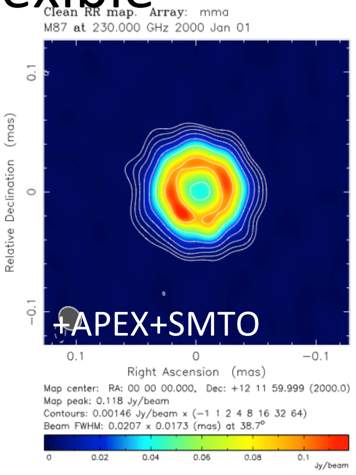
(2). ALMA may not be crucial for imaging

EAVN hi + ASTE (or ACA) +SMTO may be sufficient and flexible



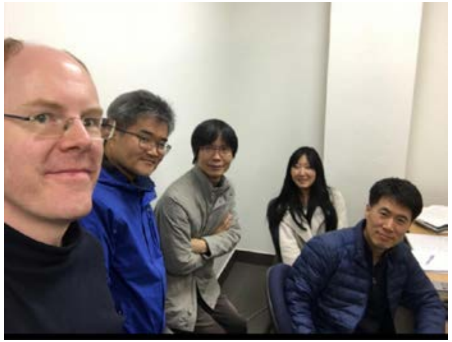






Where are we?

The first VLBI experiments at 230 GHz



That was a great first step for us,
while no fringe were detected so far.

No Fringes between GLT - SPART so far?

CO2-1 was detected with GLT and SPART -> sky signal is there

Two possibilities?:

1. Low sensitivity ?

2. Stability of system was not sufficient ?

1. Low sensitivity?

SEFDs: GLT 5300, SPART 18000Jy

Effective BW: 512 MHz

Integration time: 10 sec

Fringe sensitivity: 965 mJy for 7 sigma (551 mJy for 4 sigma)

Could be challenging? Marginal even for strong QSOs.

2. Phase stability?

Let's check stabilities

1. Let's make sure the purity of reference signals with 1 Hz resolution

2. Let's try to conduct tone injection test

3. Let's make sure the stability of frequency standard

Points for discussions

How we can detect the first fringes

- Participation of JCMT
- Increase the BW from 512 to 2048 GHz
- Spend more time for QSOs, not for RGs
- Phase stability tests
- More challenges

How we can extend

- Participate to EHT with keeping regional efforts

- ACA/APEX? KVN?

- other stations? SMTO, KP, LMT?