Development of Wide bandwidth VLBI in Kashima

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on behalf of Kashima VLBI group

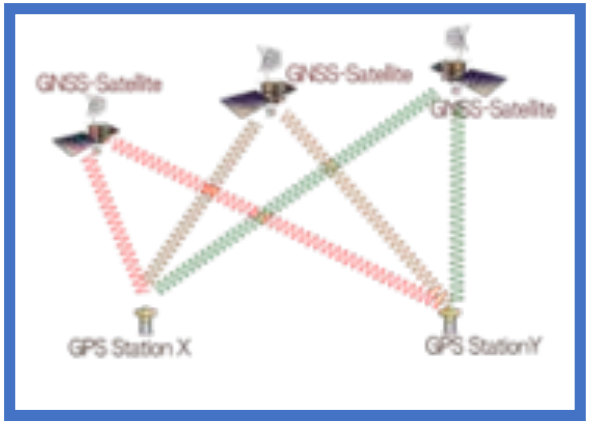
Re-definition of “second”

- Currently defined by Cs atomic clock
  - (9.2GHz,1.5x10^{-15} @NICT)
- BIPM provides UTC by the ensemble average of Cs clock around the world

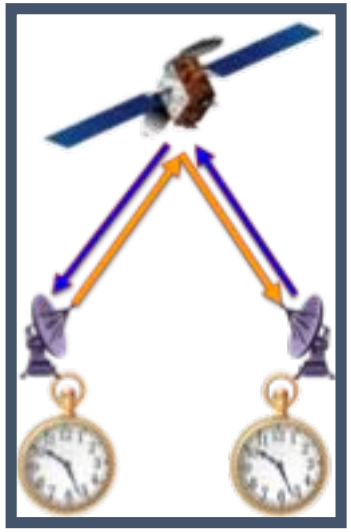
⇩

- Optical lattice clock was invented
- More accurate frequency comparison technique is required (10^{-16})

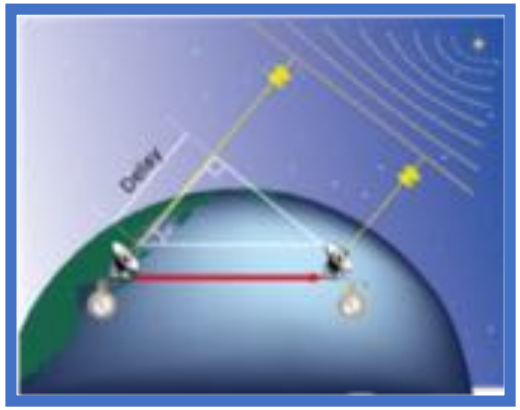
- Space Technologies over intercontinental baseline



GNSS
(Common view, PPP)



TWSTFT
Two way Satellite Time and Frequency Transfer



VLBI

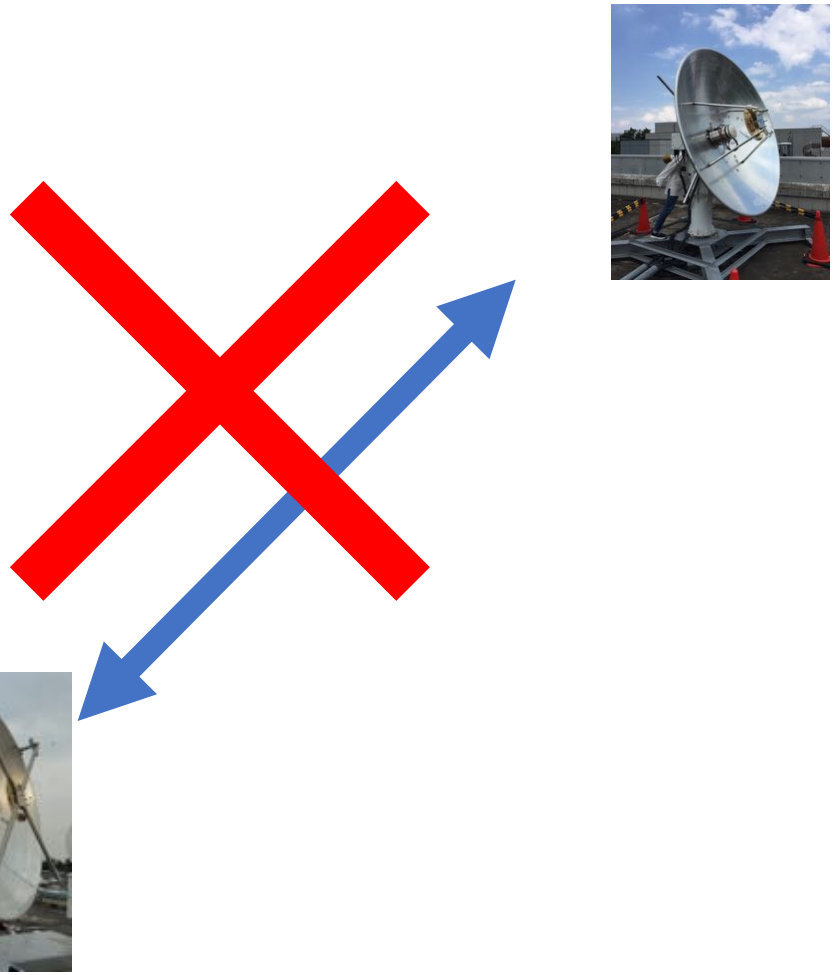
Updated broad band antennas in 2018

MARBLE1 2.4m
@ Tsukuba

MARBLE2 2.4m
@Tokyo

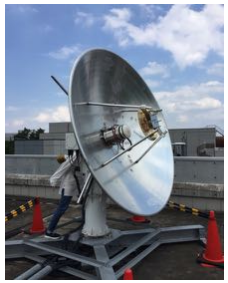
Observation strategy

VLBI is impossible
between compacts



Observation strategy

Large telescope

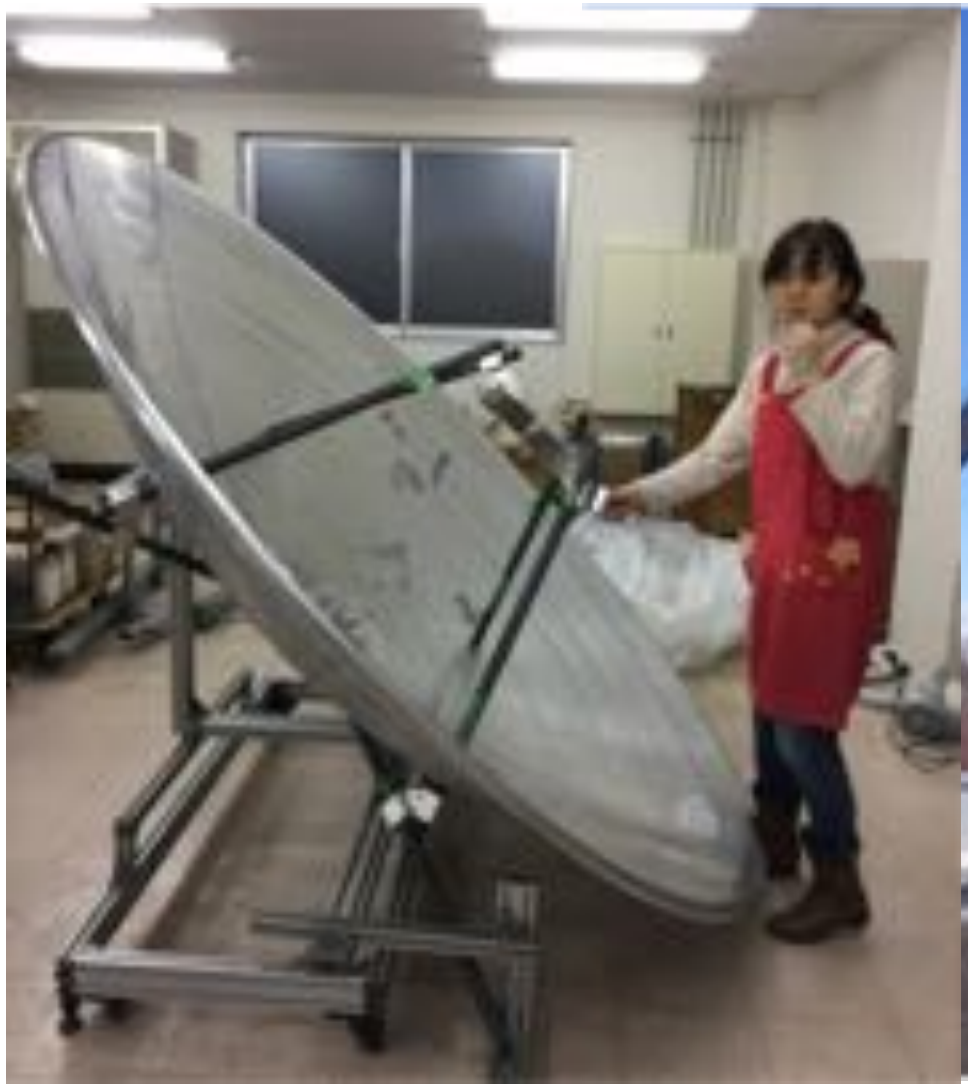


- **Advantage of the measurement**
  - Small ! Small ! Small !
  - Possible to assemble manually
  - Cost effective (~€200K/antenna wo H-maser)
  - Large telescope effect (e.g. deformation, cable delays) will be cancelled out

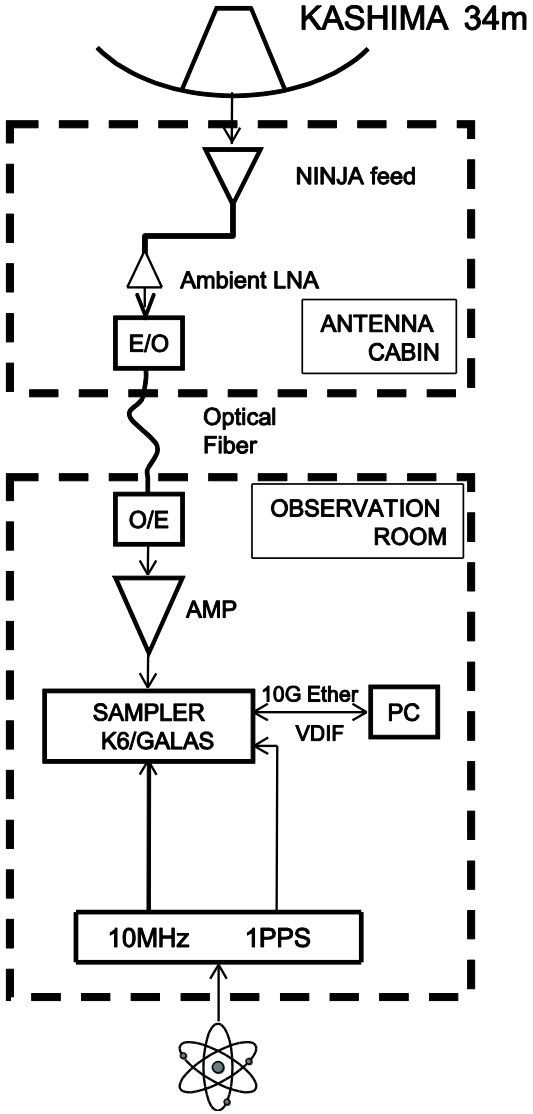
- **Disadvantage**
  - SNR ! SNR ! SNR !
    - Need large mother telescope (> 30 meter?)
    - Need broad band system

Tokyo 2016 March

Tokyo, 2016 March



Tsukuba, 2017 March


KASHIMA 34m
NINJA feed
Ambient LNA
E/O
ANTENNA CABIN
Optical Fiber
O/E
OBSERVATION ROOM
AMP
SAMPLER K6/GALAS
10G Ether
VDIF
PC
10MHz
1PPS

NICT
Kashima

- NINJA feed (3.2-15G)
  - OMT for dual polarizations
  - Two ambient LNAs
  - 2RF signals transfer via single fiber with the wavelength division multiplexing (WDM)

RF-Direct Sampler, K6/GALAS

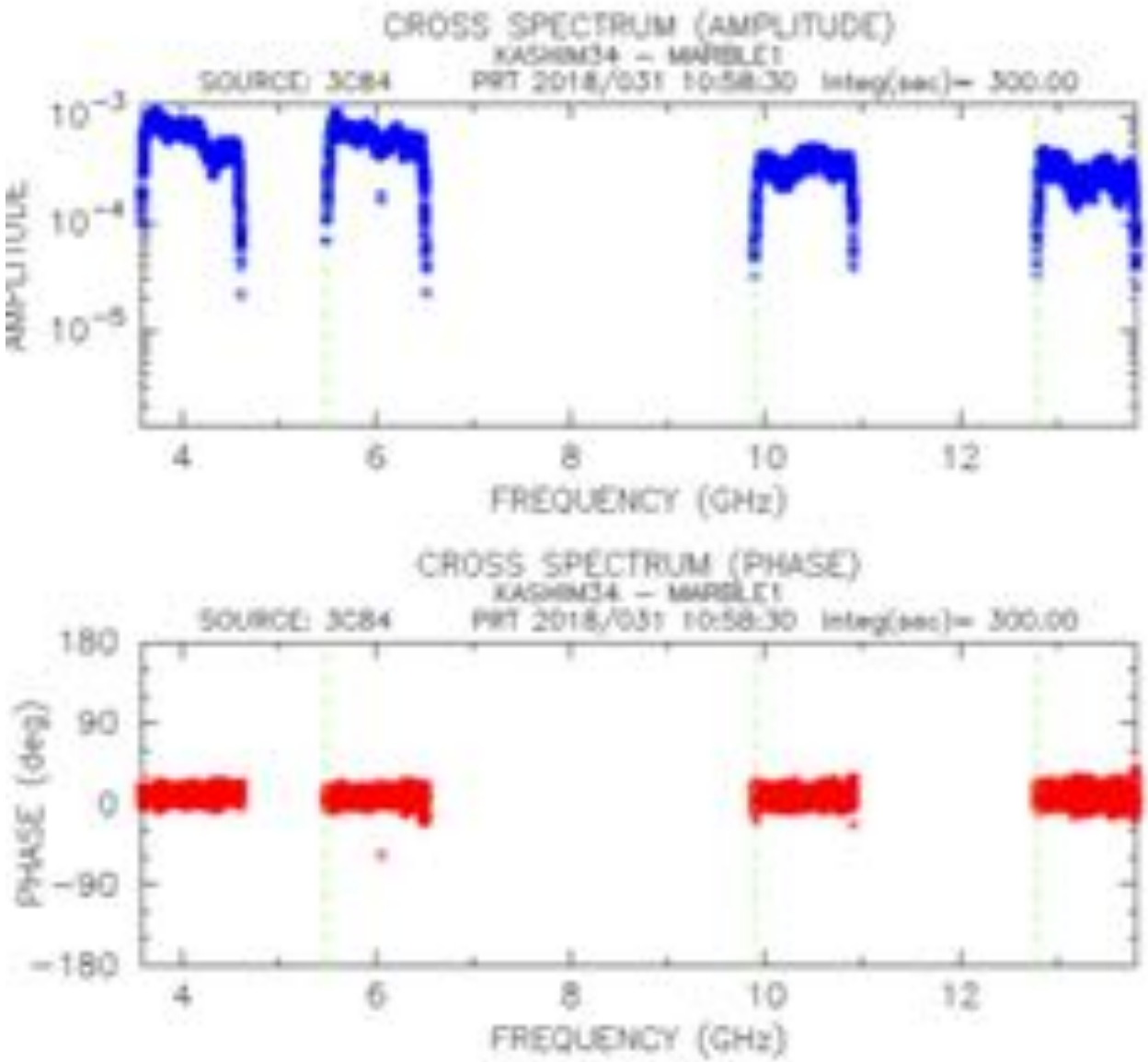
Input Freq. Range	**0.1** to over **20 GHz**
Sampling Rate	**16384 MHz**, **3bit**
Input port	**4** analog inputs
Data mode	**8 DBBC** channels (1GHz bw.)
Output Port	10GBASE-SR, 4port
Data rate	8192 Mbps/port

T&F VLBI Observation

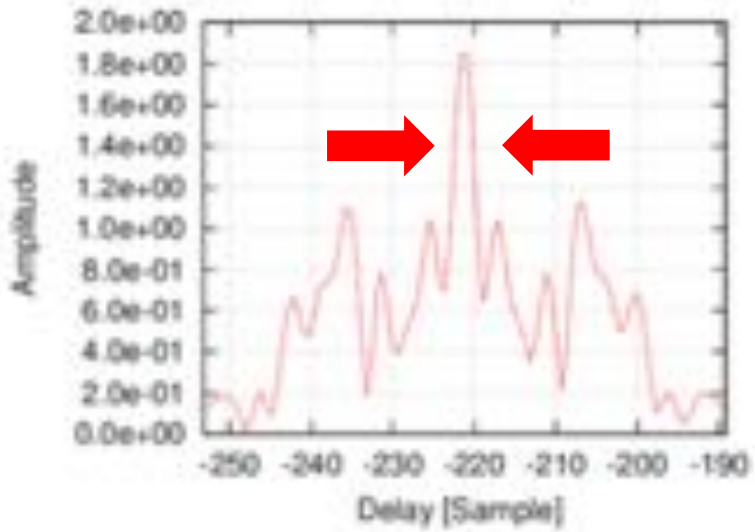
- Stations:
  - Kashima(34m), Tsukuba(2.4m), Tokyo (2.4m)
- Frequency allocation:
  - 3.6-5.5-9.9-12.8GHz, four 1GHz bandwidth
- Experiments:
  - ICRF sources mostly over 1Jy flux density
  - 1200 scans / observation
  - 60-70 TB / station

Needle fringe over 10GHz BW (GV18031 session)

Kashima34- Compact #1

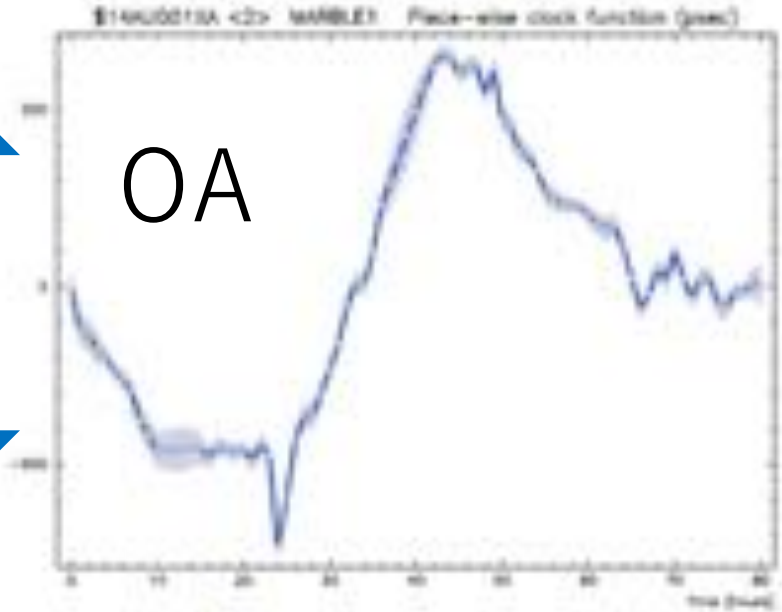


70ps

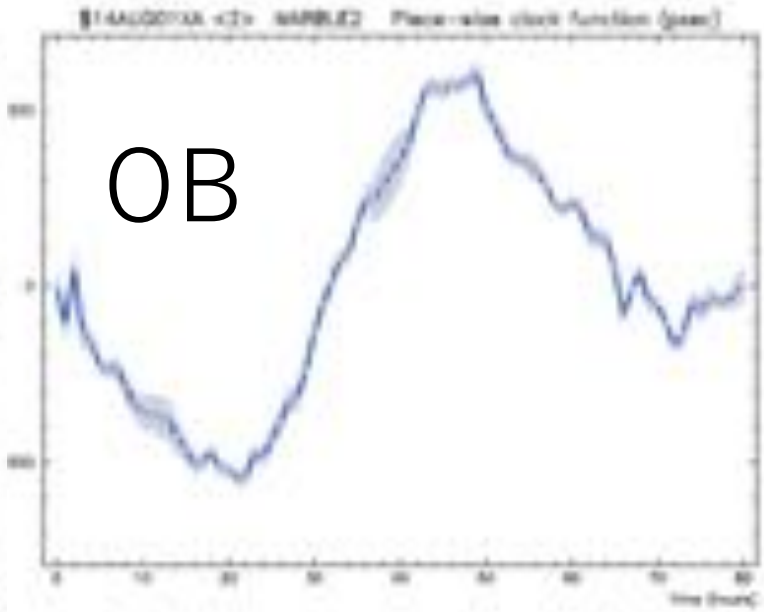


Synchronized clock variation +- 500ps

1ns



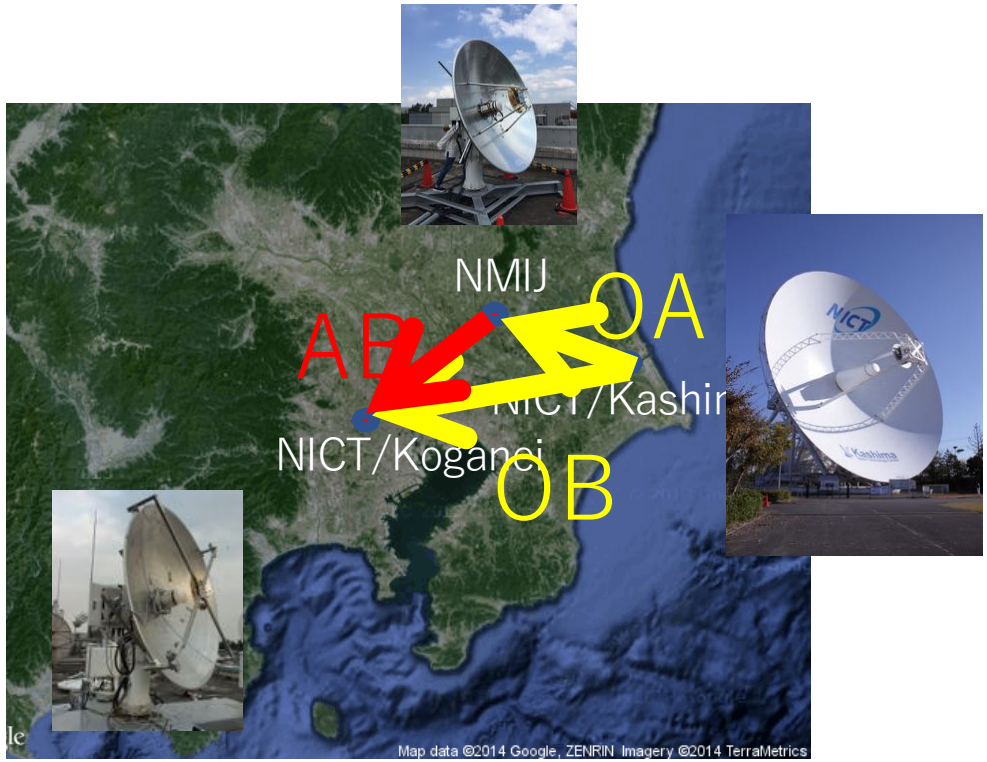
Kashima 34m - #1 compact ant



Kashima 34m - #2 compact ant

It may be caused by 34 m

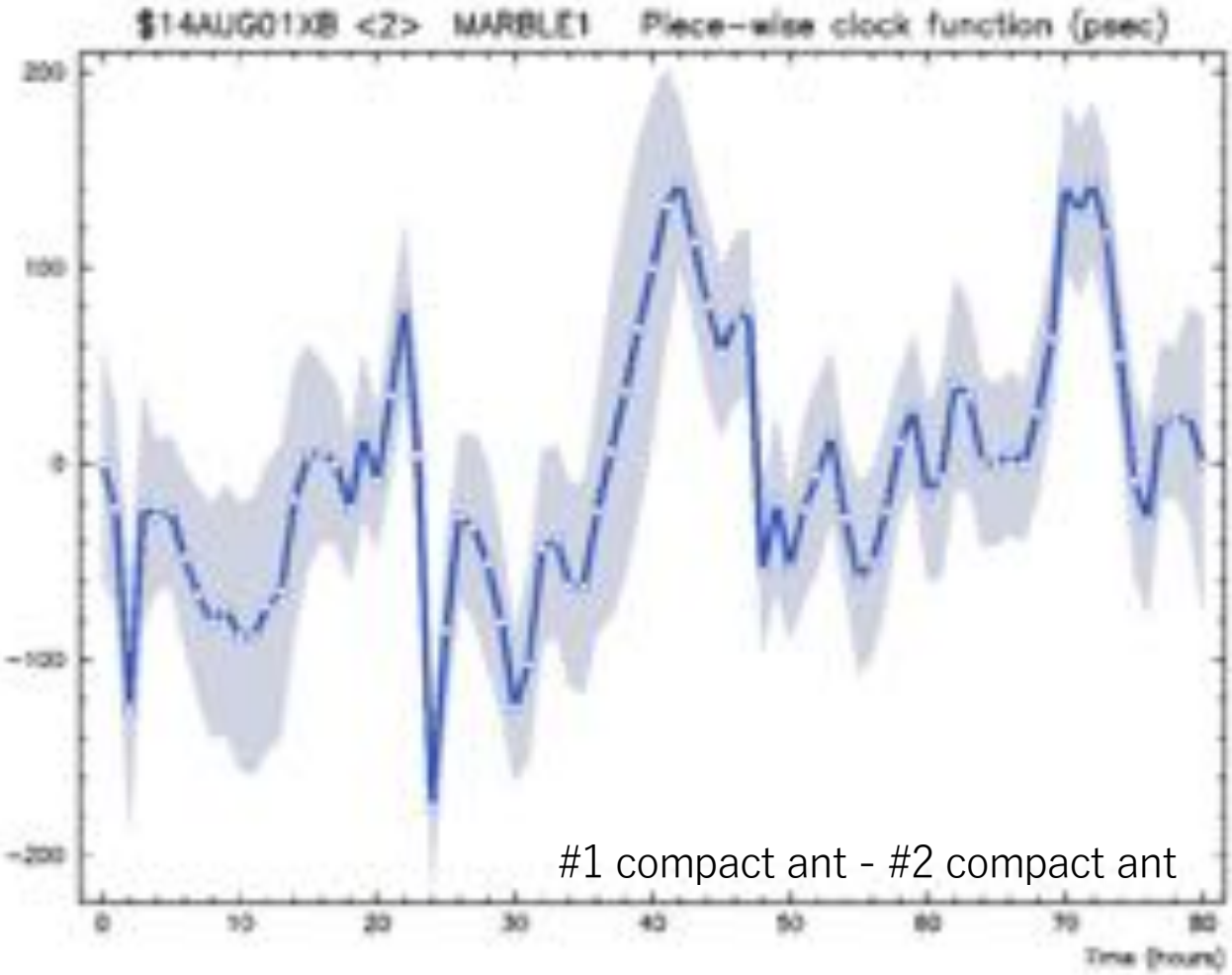
Epoch conversion of delay model



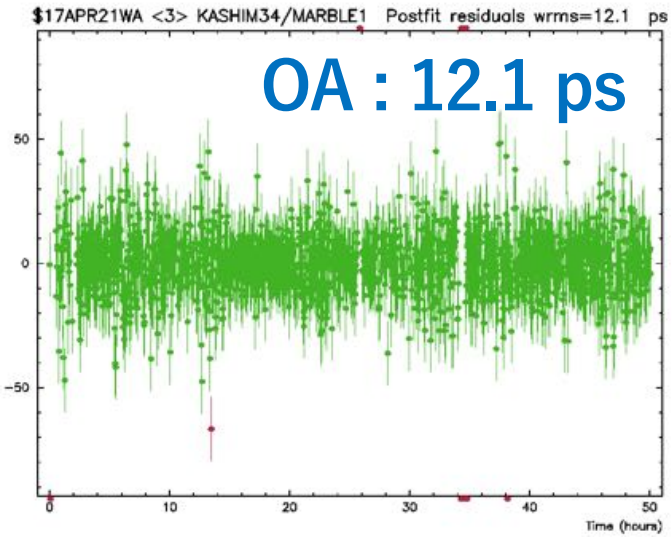
$$\tau_{\mathrm{AB}} = \tau_{\mathrm{OA}} - \tau_{\mathrm{OB}} - \dot{\tau}_{\mathrm{AB}} \times \tau_{\mathrm{OA}}$$

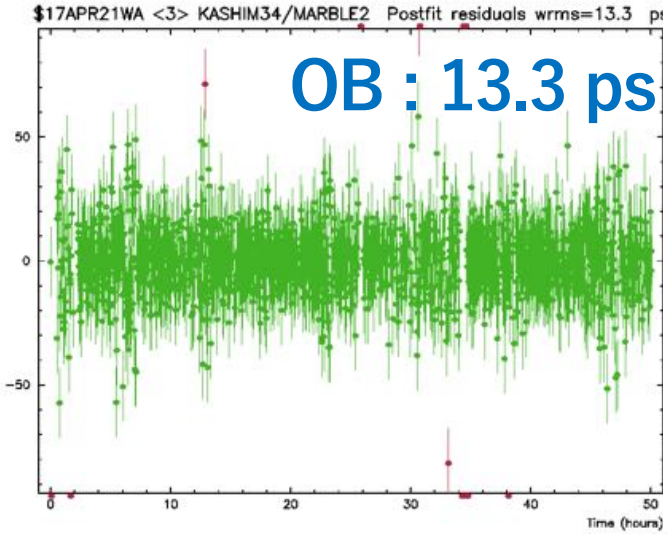
2nd , 3rd order should be taken into account for longer baseline !

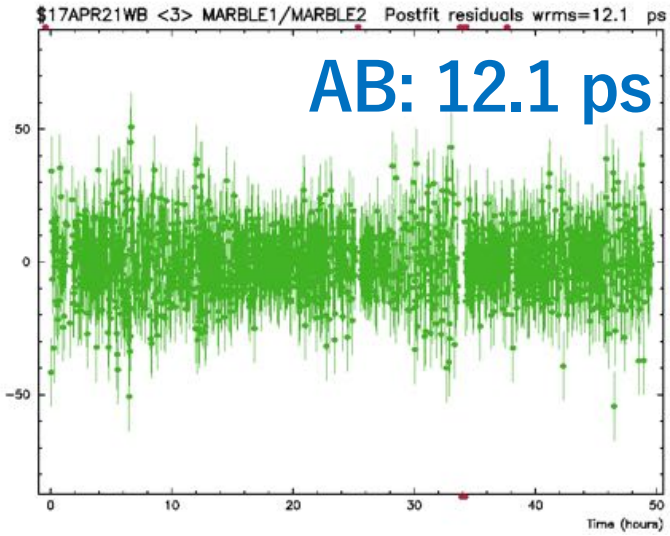
After epoch conversion +- 100ps

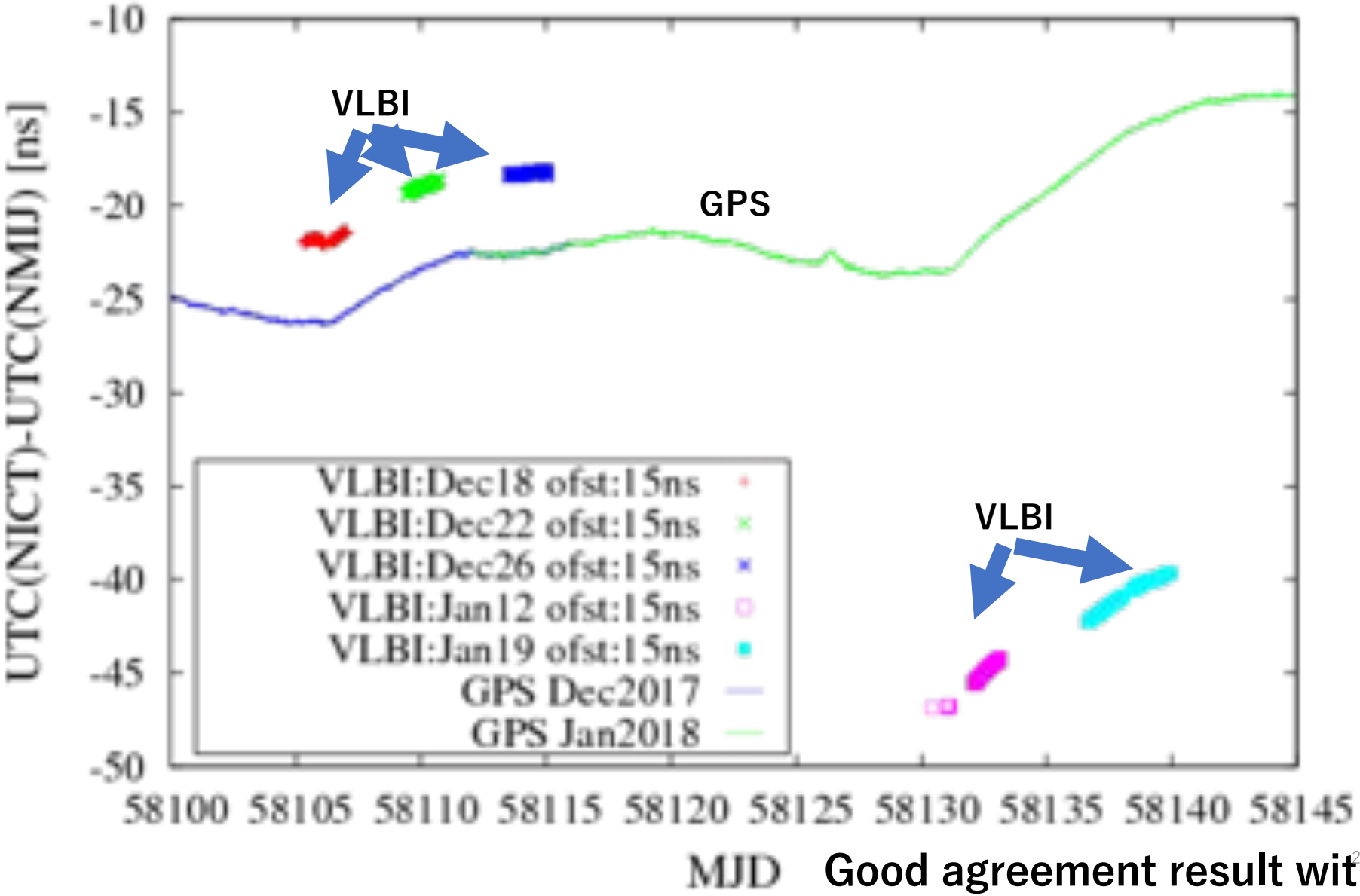


Residual delay









Good agreement result with GPS

Long baseline T&F by VLBI between INAF-INRIM and NICT

Kashima, 2018 May
NICT
MARBLE1 has transported to Bologna

ionosphere + source structure + polarization

- We carried out the long baseline observation with Hobart12 of university of Tasmania and Onsala13NE of Onsala space observatory since 2016.

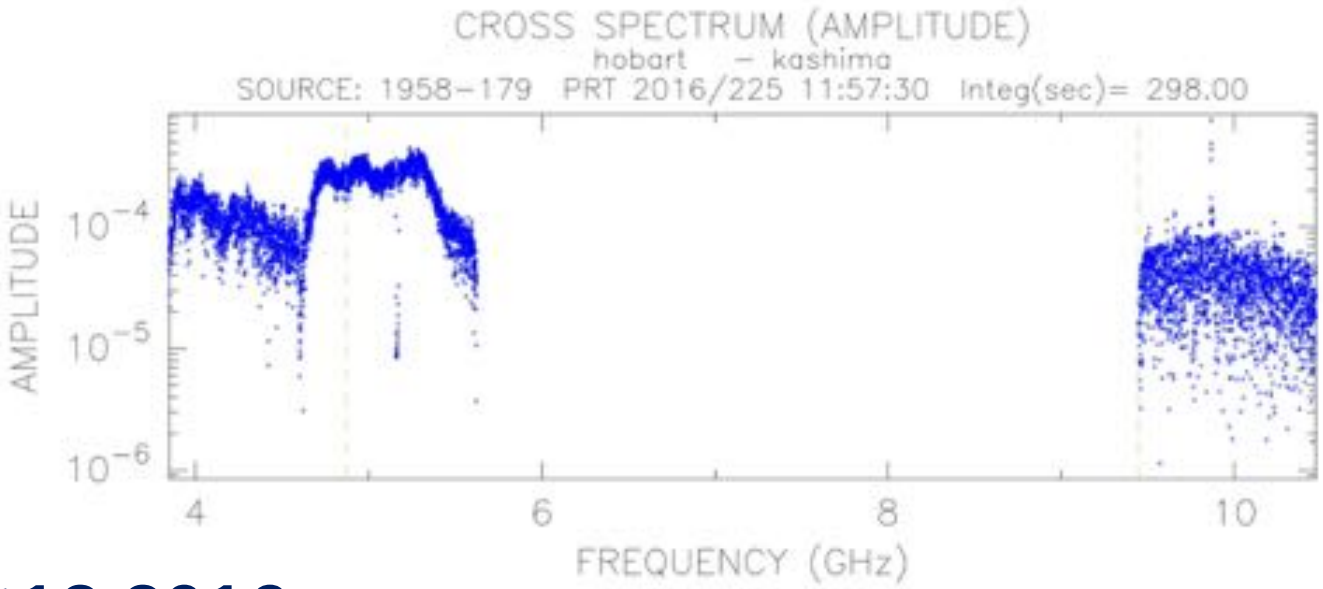
The wideband bandwidth synthesis

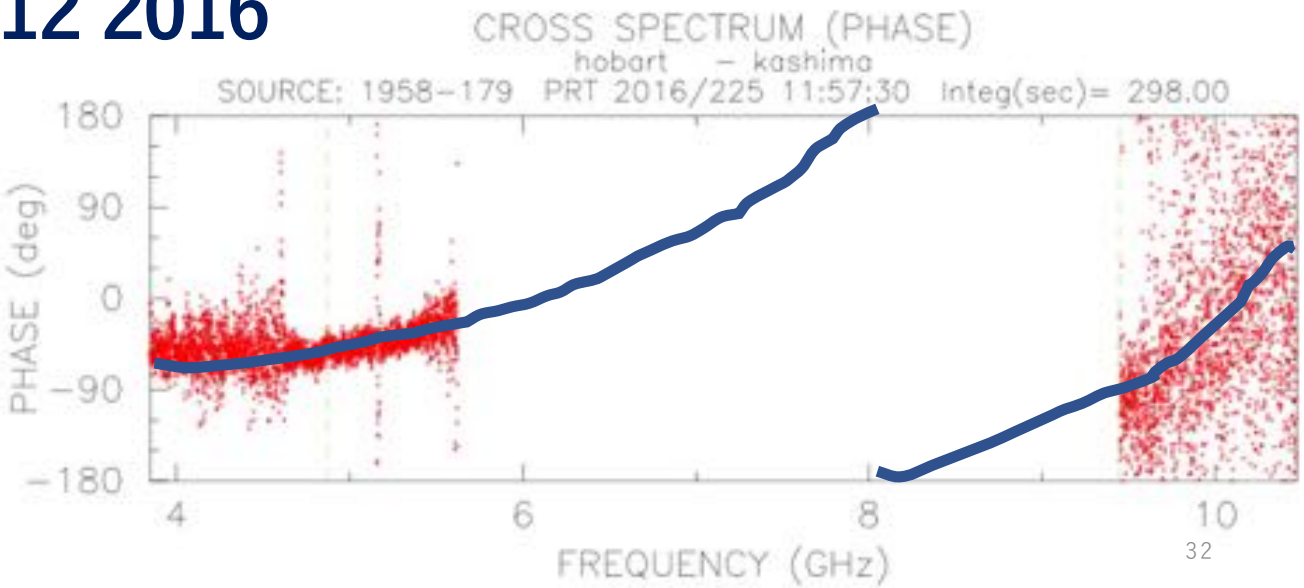
- **Take strong radio source scan as a phase reference**
  1. inter-band delay correction
  2. inner-band phase correction

- **Ionospheric delay correction.**
  - The dTEC is estimated by the LSQ

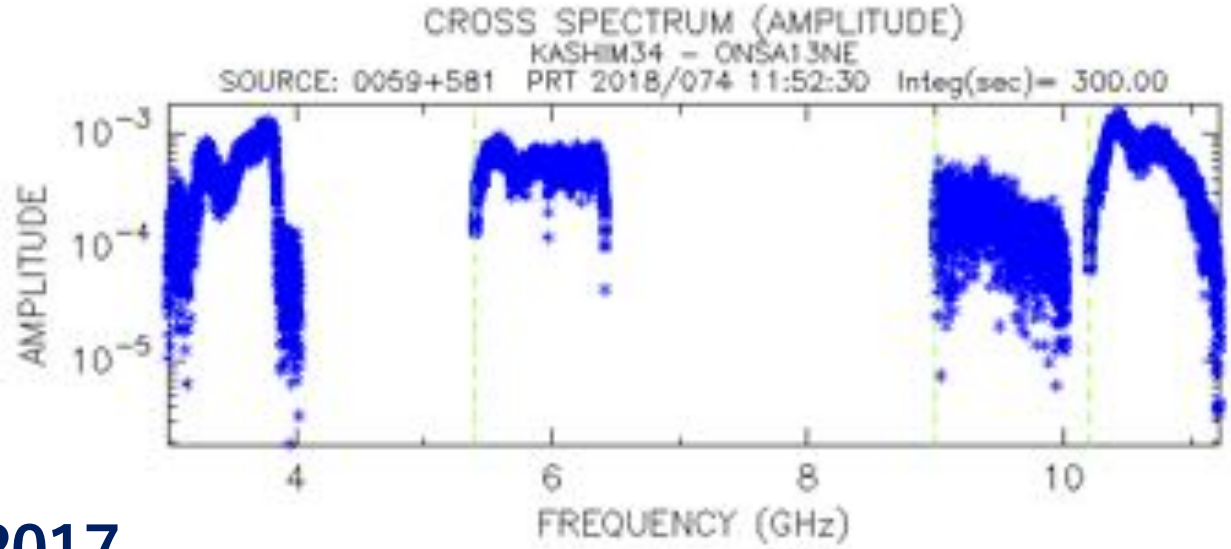
Kondo & Takefuji, RadioScience, 2016

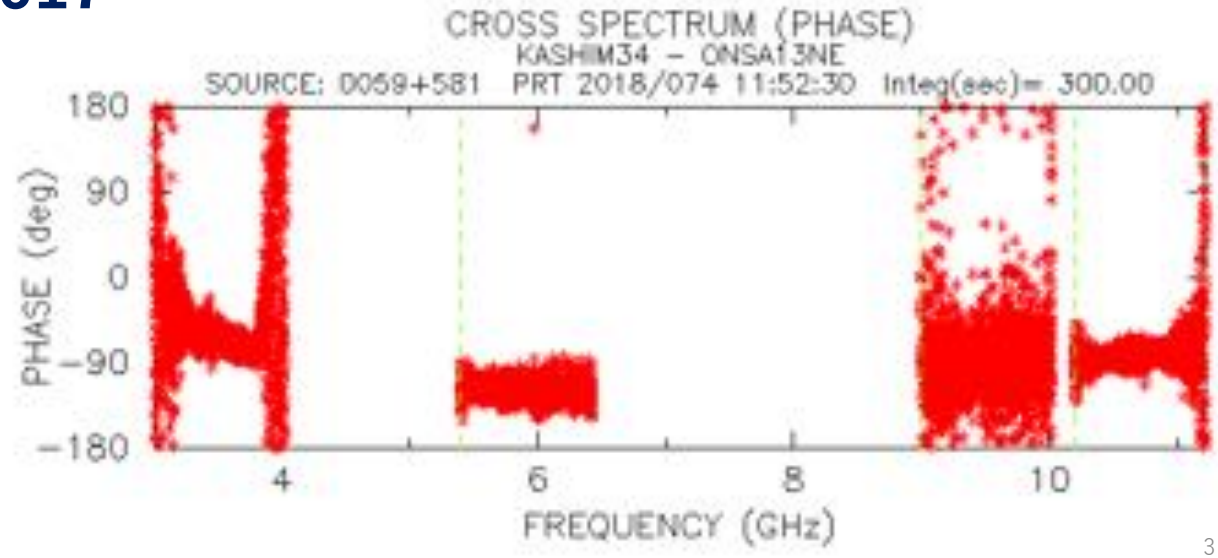
cross-spectrum of Kashima34-Hobart12 2016



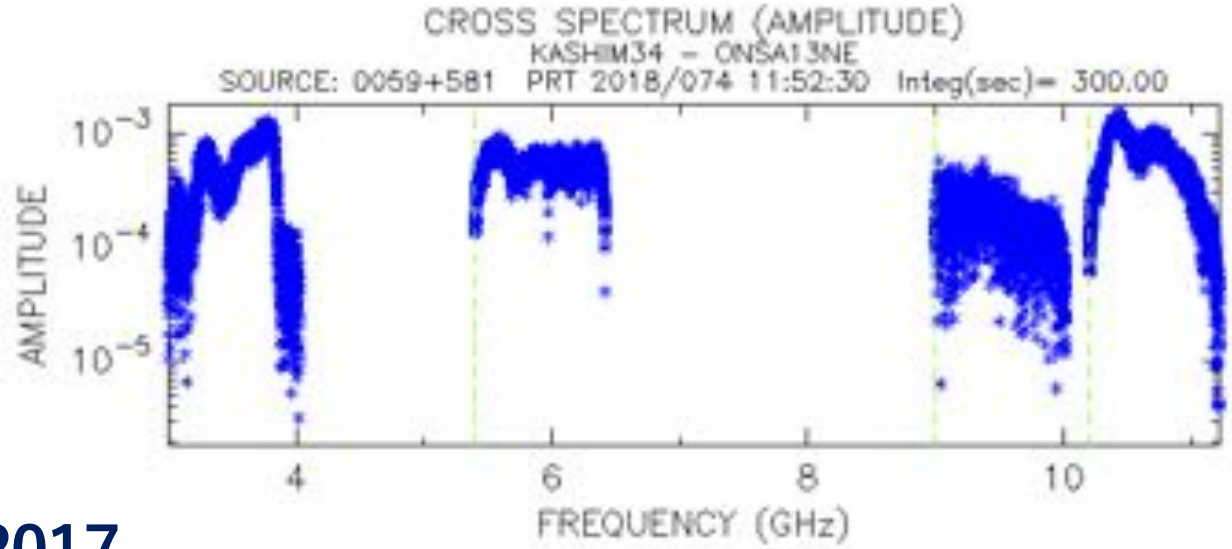


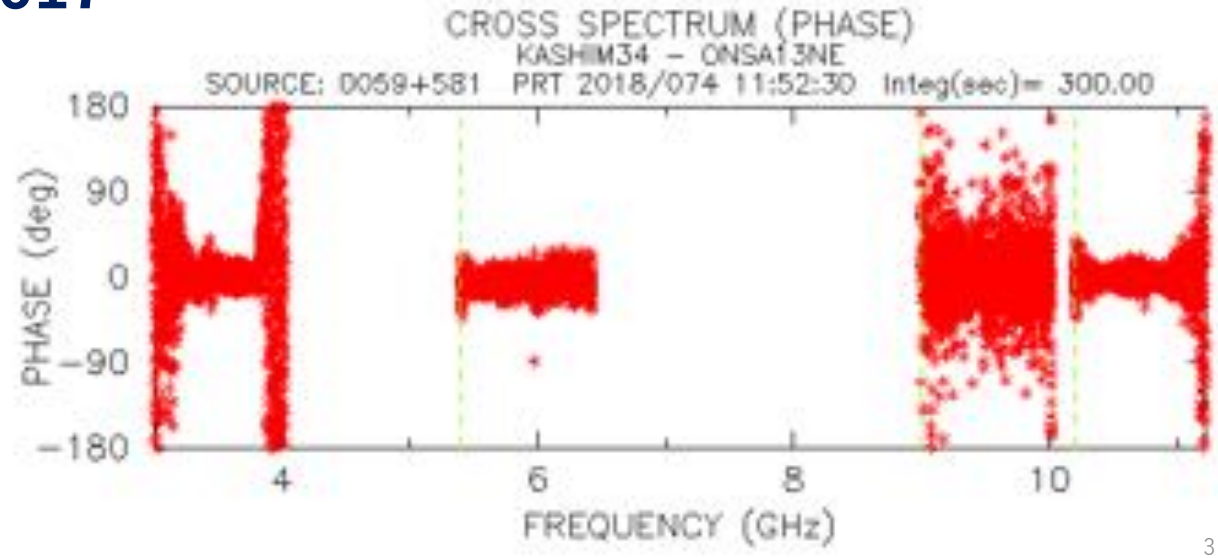
cross-spectrum of Kashima34-Onsala 2017



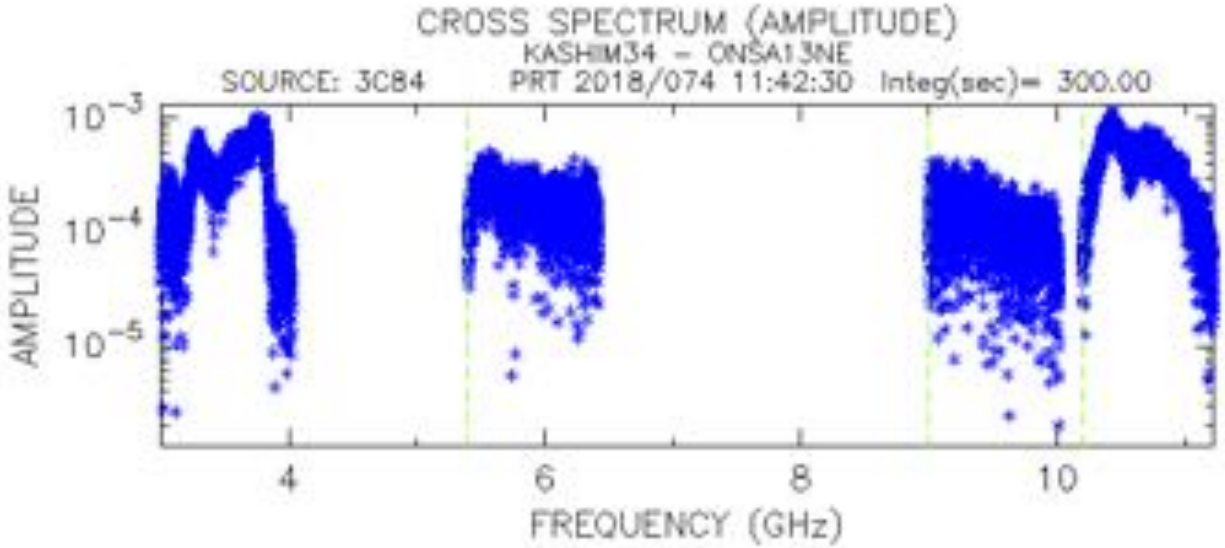


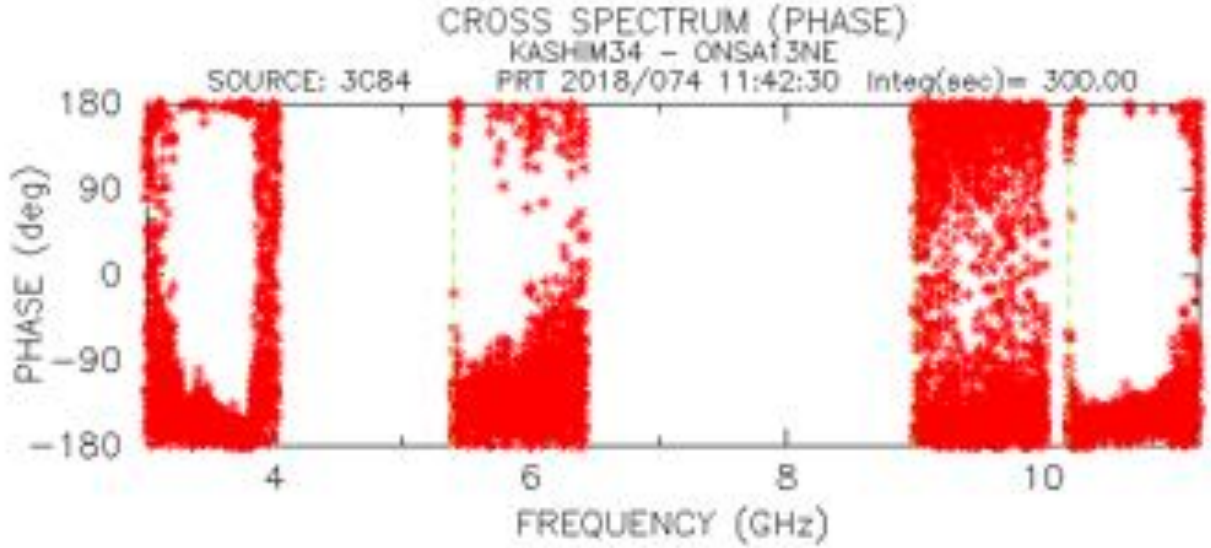
cross-spectrum of Kashima34-Onsala 2017



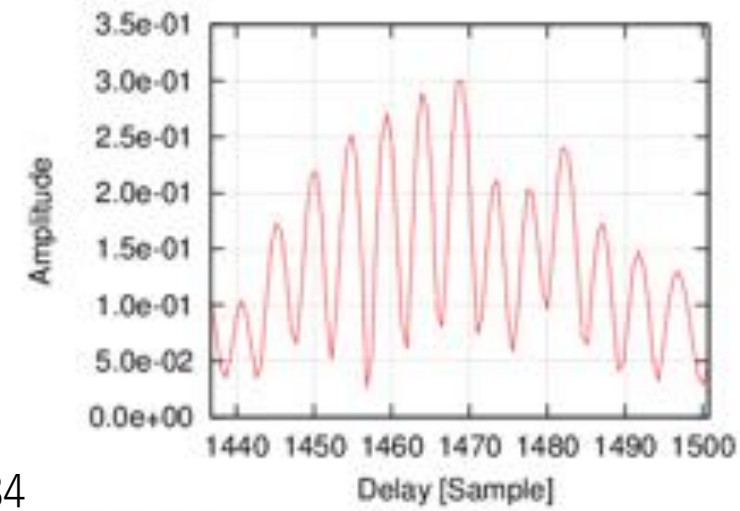


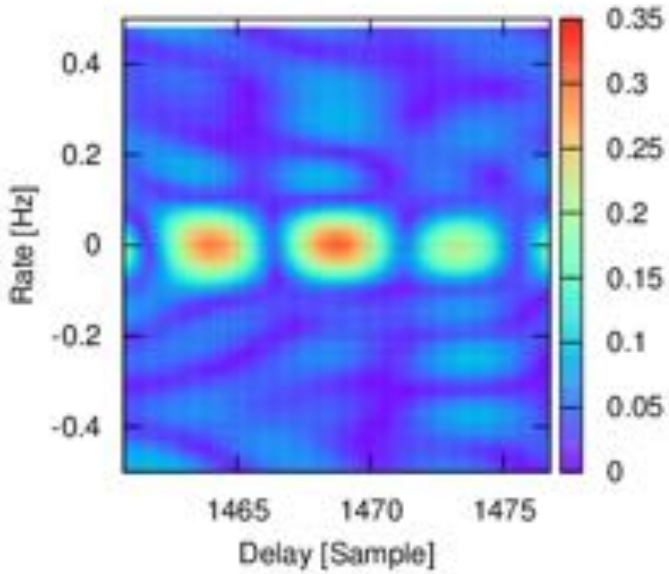
W.r.t large structure source 3C84, the wbws has failed.
Inversely speaking, may we know the source structure from the phase?

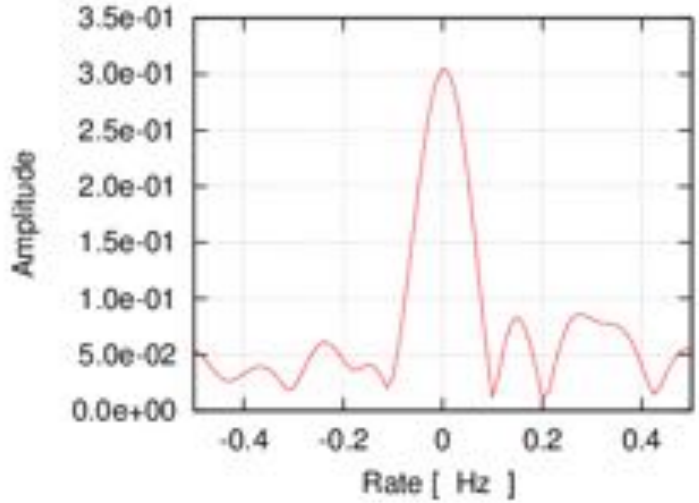


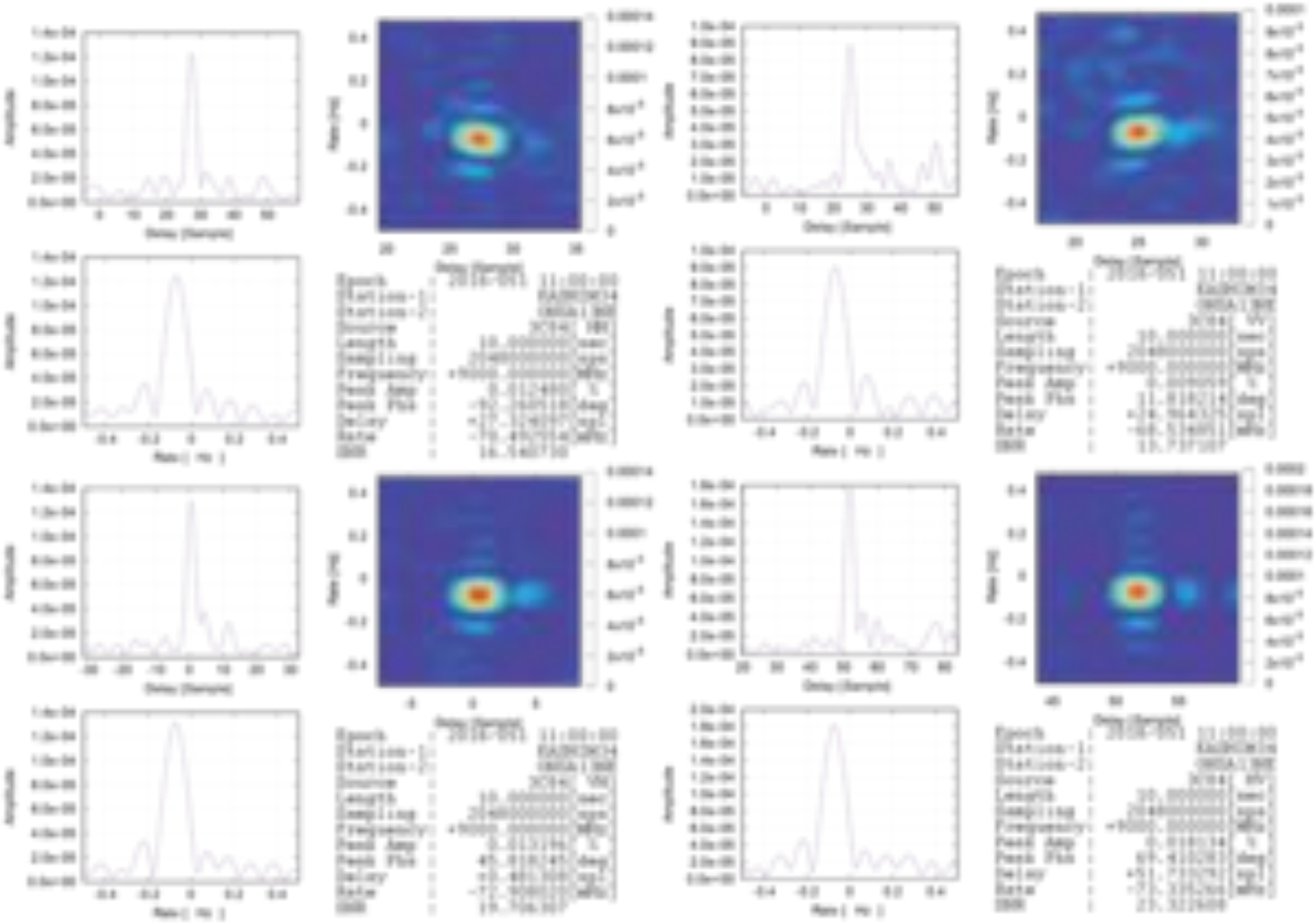


Failed wbws case, 3C84








```
Epoch     : 2018/074 11:20:00
Station-1:           KASHIM34
Station-2:           ONSA13NE
Source    :      3C84     [  W]
Length    :     10.000000[sec]
Sampling  :  32768000000[sps]
Frequency: +3000.000000[MHz]
Peak Amp  :     30.560328[ % ]
Peak Phs  :  -131.657724[deg]
Delay     : +1468.741455[spl]
Rate      :     +3.208923[mHz]
SNR       :      9.198161
```