Korea Astronomy and Space Science Institute

과학기술연합대학원대학교 UNIVERSITY OF SCIENCE & TECHNOLOGY

Phase Solution Analysis for the Simultaneous Dual Frequency VLBI Observations

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KVN
Korean VLBI Network
Korea Astronomy and Space Science Institute

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CONTENTS

KOREAN VLBI NETWORK

Korean VLBI Network (KVN)

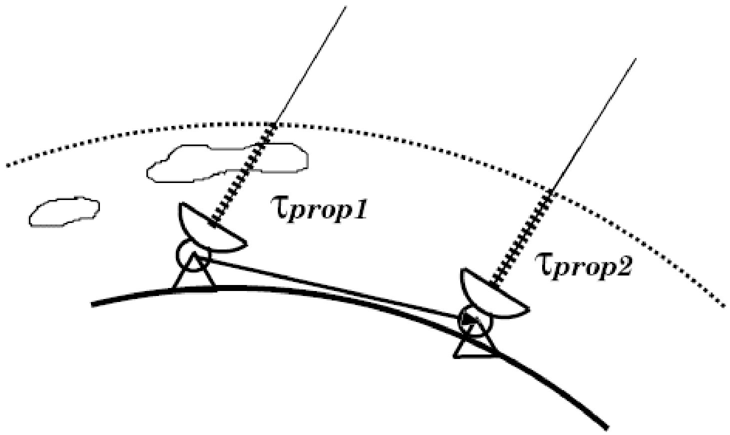
- <u>The First VLBI facility in Korea</u>
- Dedicated millimeter VLBI system
- Multi-Frequency Simultaneous Observation at 22, 43, 86, 129 GHz
- Fast switching & multi-freq. phase referencing

Difficulties in Ground-based VLBI System

- Heavy data load
- Operation & maintenance of distant stations
- Only highly bright & compact sources can be observed

But the largest difficulties come from

1. Unpredictable fluctuations in independent frequency standards
2. Highly irregular refraction effects in the atmosphere

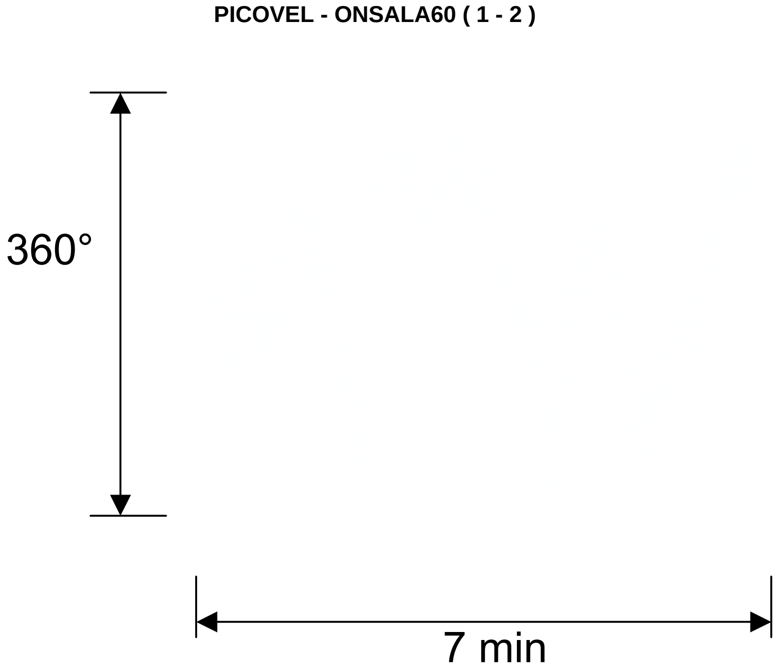


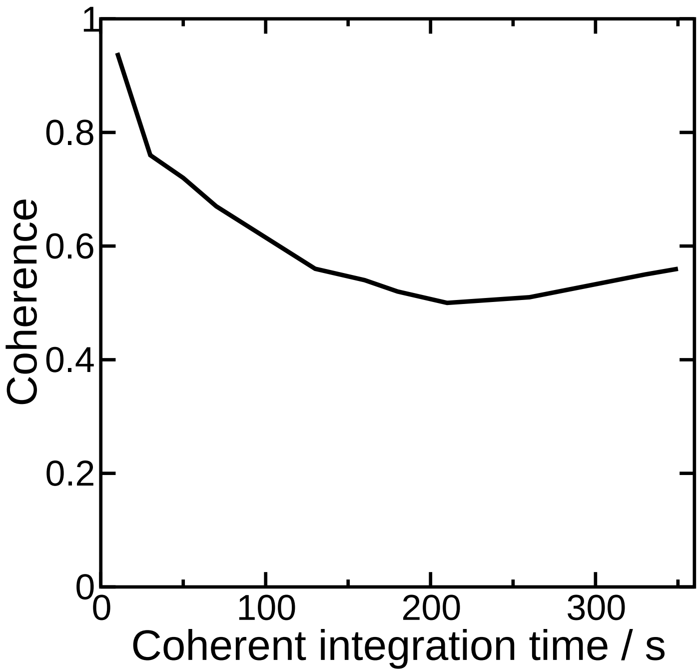
(Dr. Sasao)

Difficulties in mm-VLBI

Pico Veleta – Onsala Baseline

VLBI phase time series



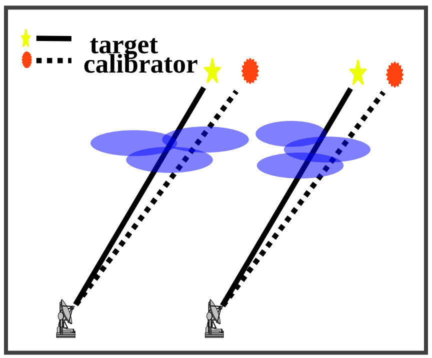


Source : BL Lac
Frequency : 86 GHz

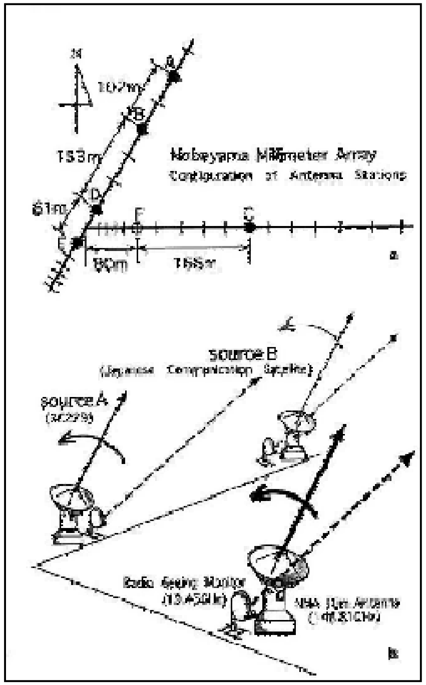
(Dr. A. Roy)

Phase Referencing Methods

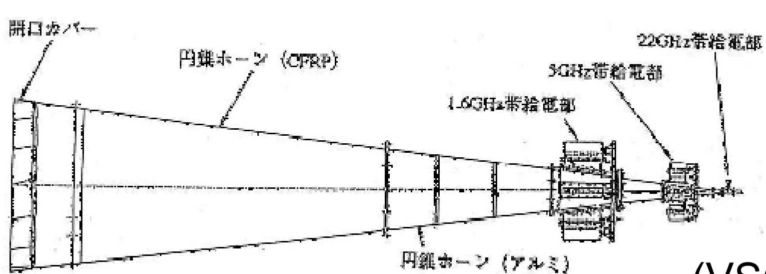
- **Fast Switching**
- **Water Vapor Radiometer**
- **Dual Beam Correction (VERA)**
- **Paired/Clustered Antennas**
- **<u>Multi-Frequency Phase Referencing</u>**



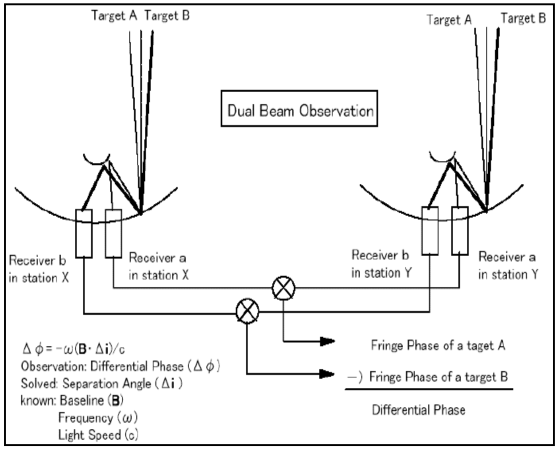
(Dr. A. Roy)



(Dr. Asaki)



(VSOP)



(VERA)

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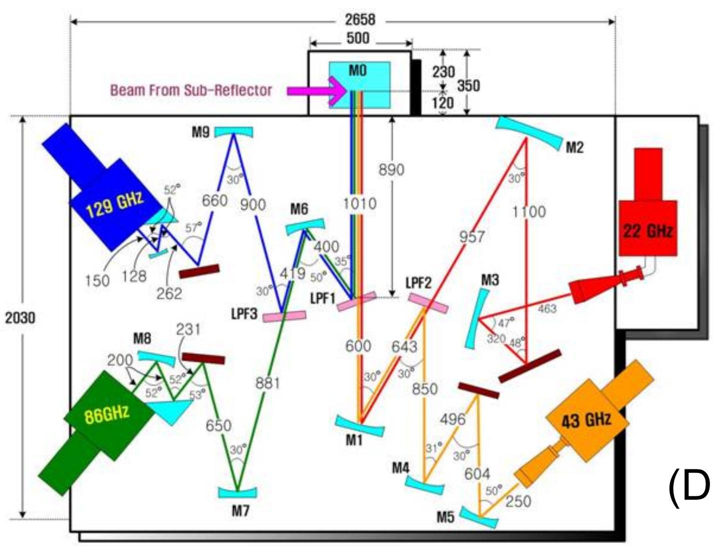
Multi-Frequency Phase Referencing

- Basic Idea
  - Using the fringe phase of a source at a lower freq. in order to calibrate the phase of the same source at higher one.
  - The *non-dispersive nature* of the water vapor-induced excess path delay in the troposphere over the wide range of radio frequency.

$$\frac{\partial \phi_{high}}{\partial t} = \left(\frac{\nu_{high}}{\nu_{low}} \right) \times \frac{\partial \phi_{low}}{\partial t}$$



(Dr. Han)

KVN Multi-Frequency Receiver (22/43/86/129 GHz)

KVN Multi-Frequency Receiver installed at Yonsei antenna receiver room

Multi-Frequency Phase Referencing

- Multi-Frequency Phase Referencing will enable mm-VLBI (Dr. Sasao)

1) to essentially resolve the reference source problem and nearly always find a reference source for a target
   ∵ target source = reference source

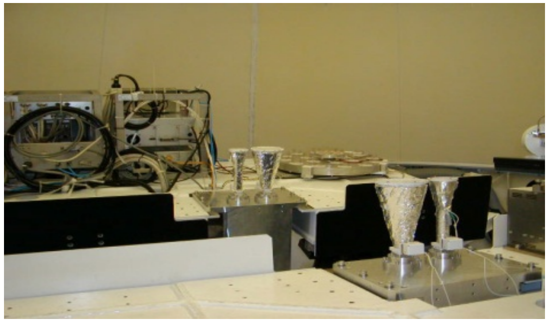
2) to get a perfect phase compensation without any loss of coherence
   ∵ sky condition is exactly same

3) to integrate mm VLBI fringes as long as a single-dish telescope does

4) to detect and image as many sources as cm VLBI does

VERA Experiment

- The first experiment with a dual-freq. simultaneous observation using VERA
- Observation
  - 2005 Apr 15 (UT 14 ~ 21 hour)
  - Bandwidth 128 MHz, LL, Dual Mode Setting
  - Target Sources
    - 22 GHz with Beam A NRAO512
    - 43 GHz with Beam B 3C345
  - **Separation Angle < 0.5 degree**



- Testing the feasibility of the multi-frequency phase referencing
- Phase solution transfer from lower freq. to higher one
- Atmospheric delay compensation between 22 & 43 GHz

1st VERA Dual-Frequency Experiment

- Dual Mode Setting

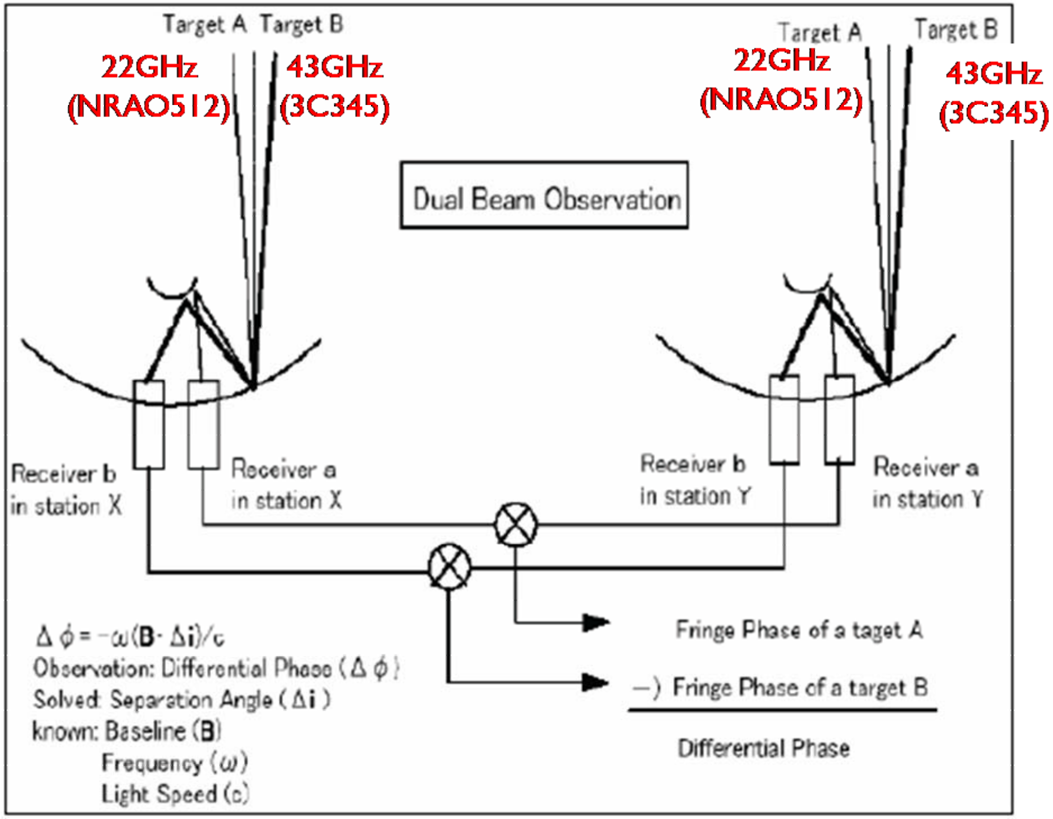
NRAO512

α=16:40:29.6

δ=+39:46:46

beam A

(22 GHz)



3C345

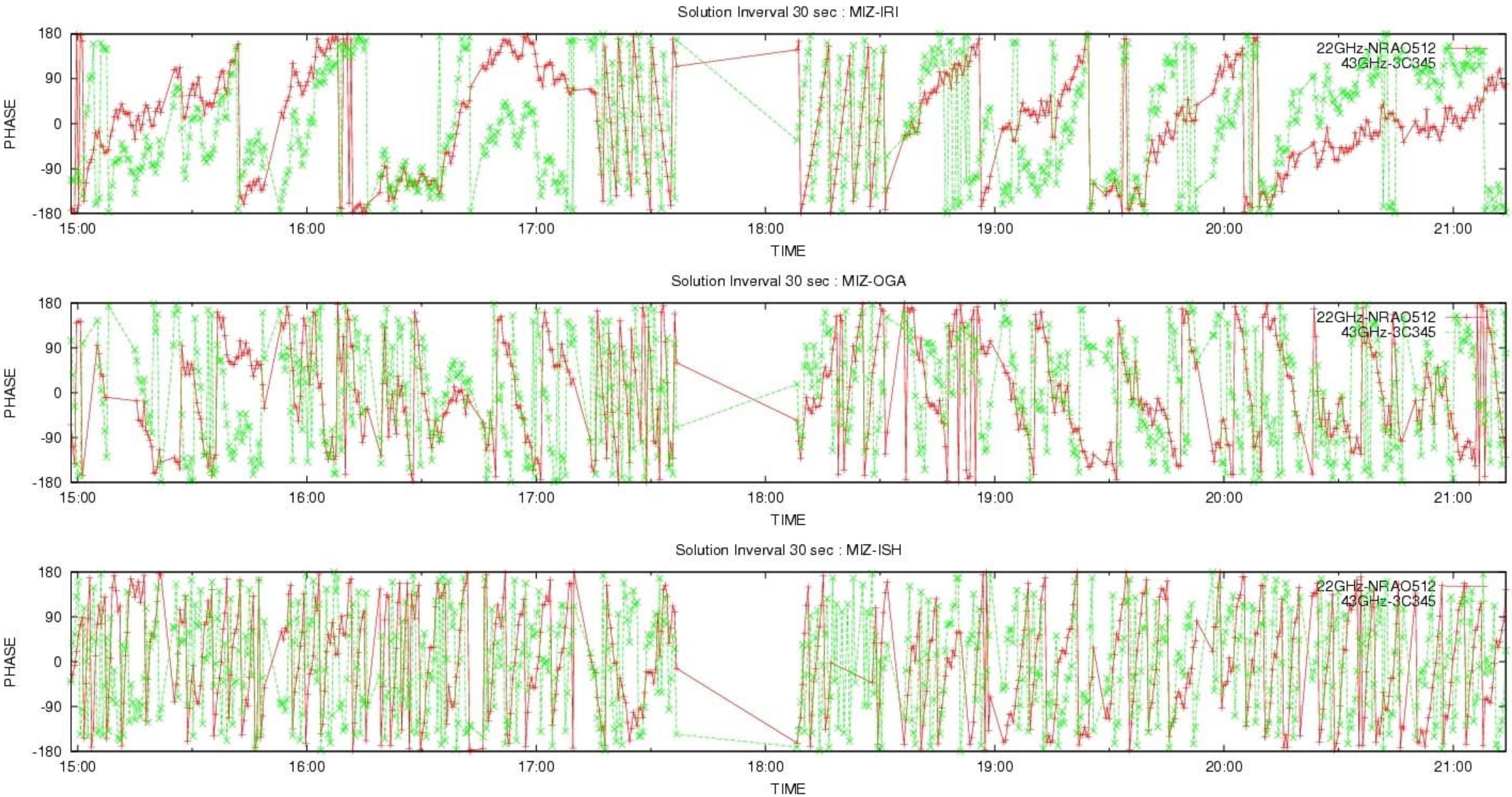
α=16:42:58.8

δ=+39:48:37

beam B

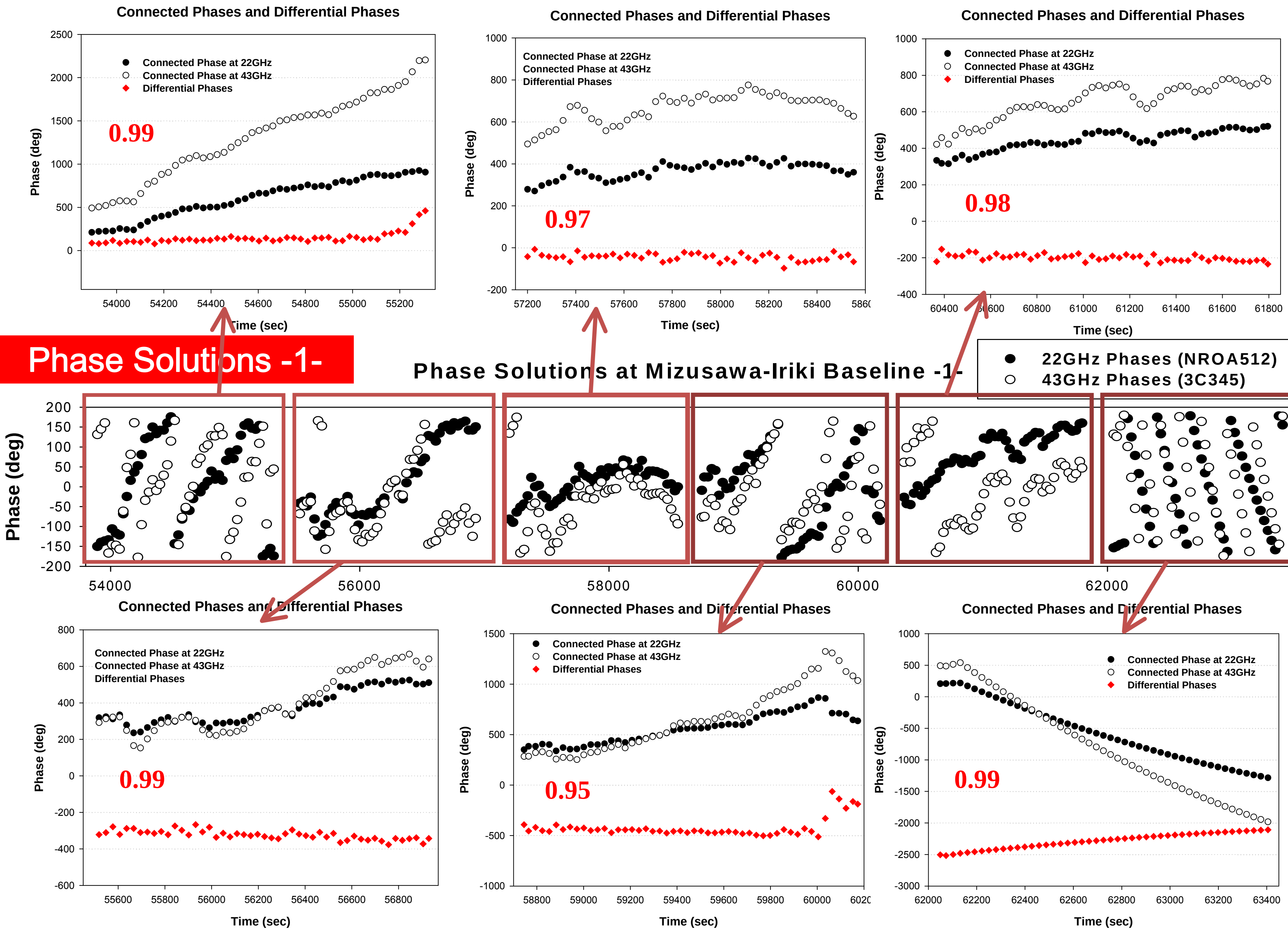
(43 GHz)

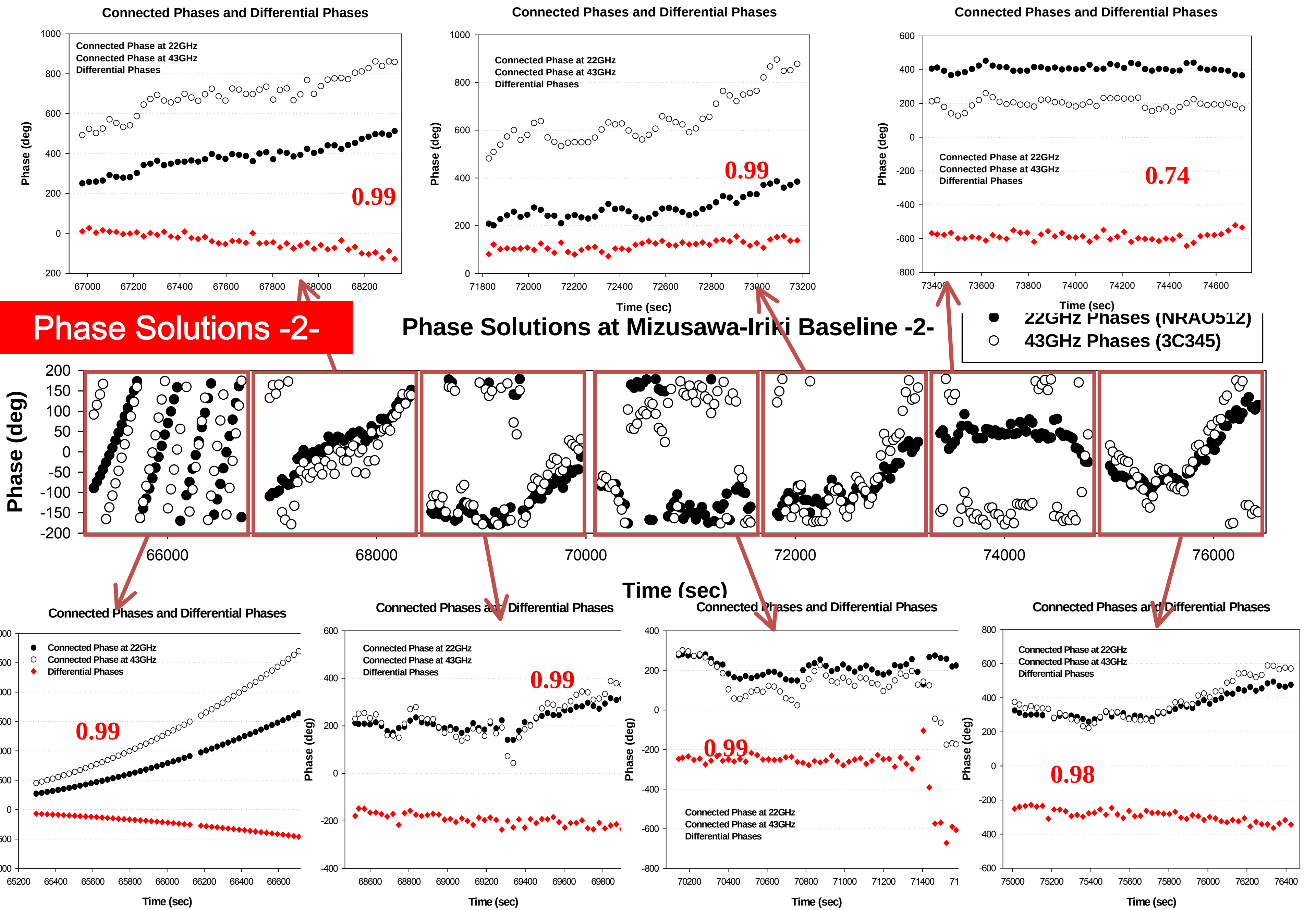
Phase Solutions with Solution interval 30sec



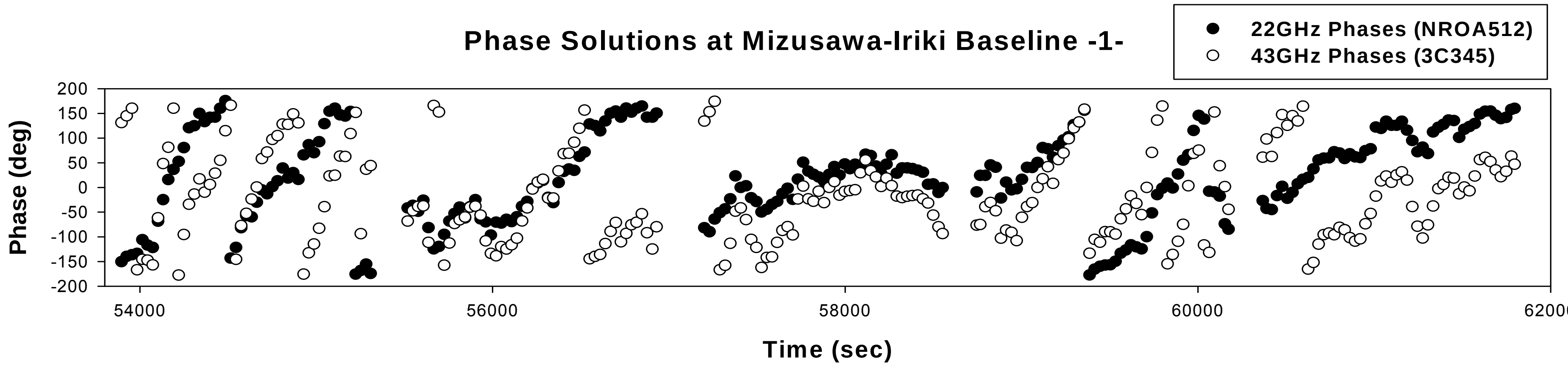
Red lines ~ 22GHz (NRAO512) Grean line ~ 43GHz (3C345)

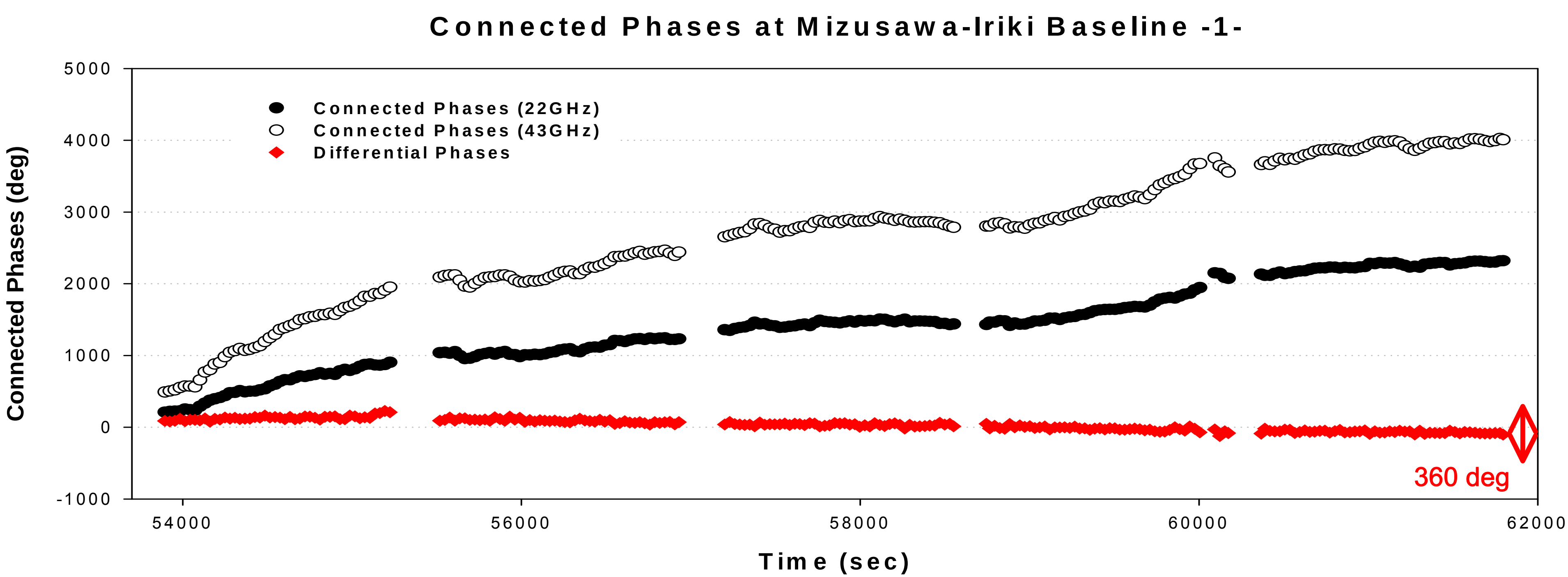
Phase Solutions -1-



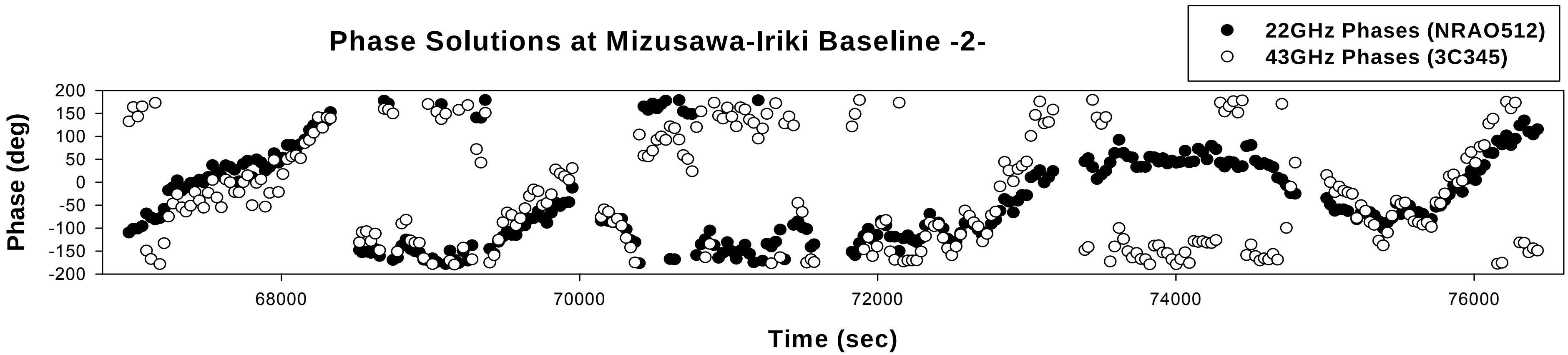

Phase Solutions -2-
Phase Solutions at Mizusawa-Iriki Baseline -2-
22GHz Phases (NRAO512)
43GHz Phases (3C345)
Phase (deg)
Time (sec)
Connected Phases and Differential Phases
Connected Phase at 22GHz
Connected Phase at 43GHz
Differential Phases
0.99
0.99
0.74
0.99
0.99
0.99
0.98

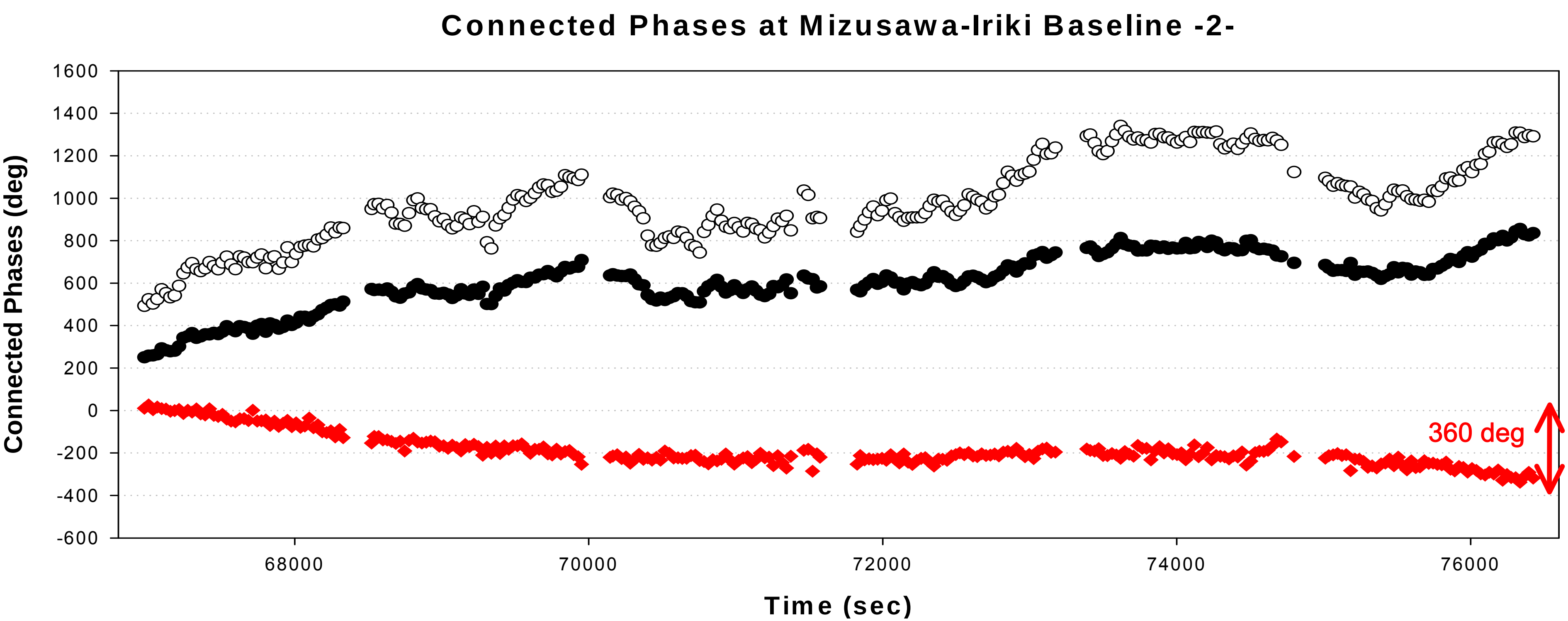
Phase Solutions at Miz-Iri baseline -1-





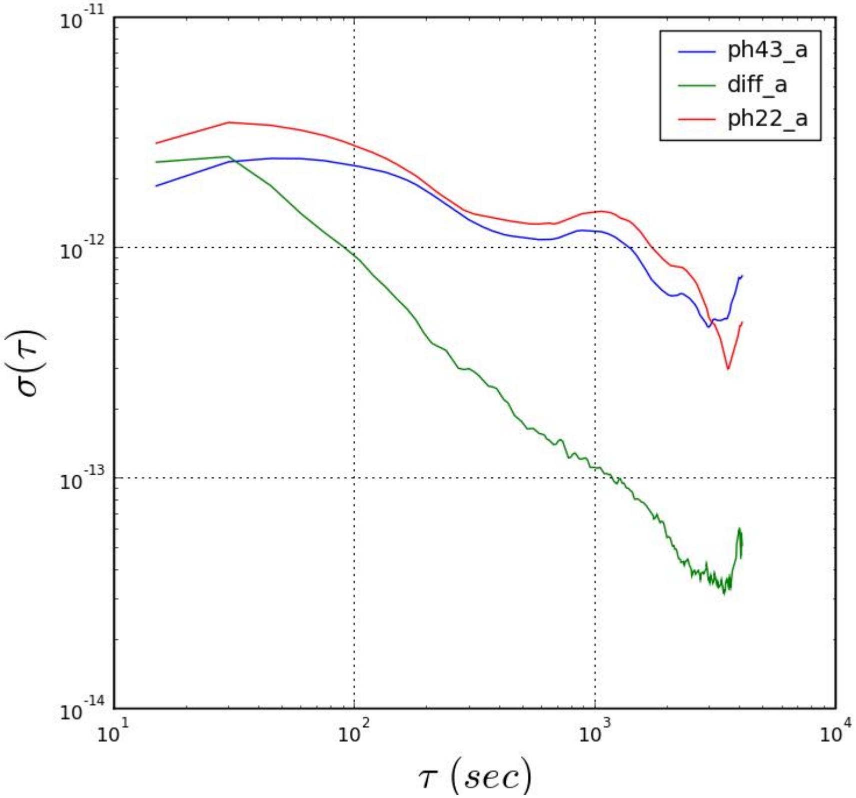
Phase Solutions at Miz-Iri baseline -2-



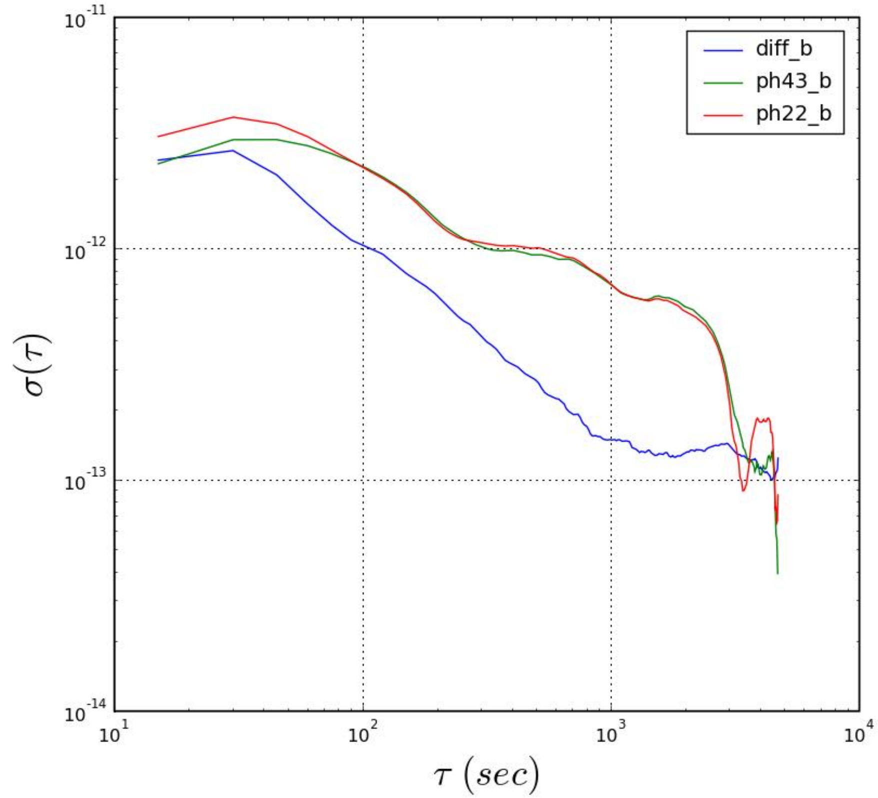


ALLAN STANDARD DEVIATION

Allan standard variations -1-



Allan standard variations -2-



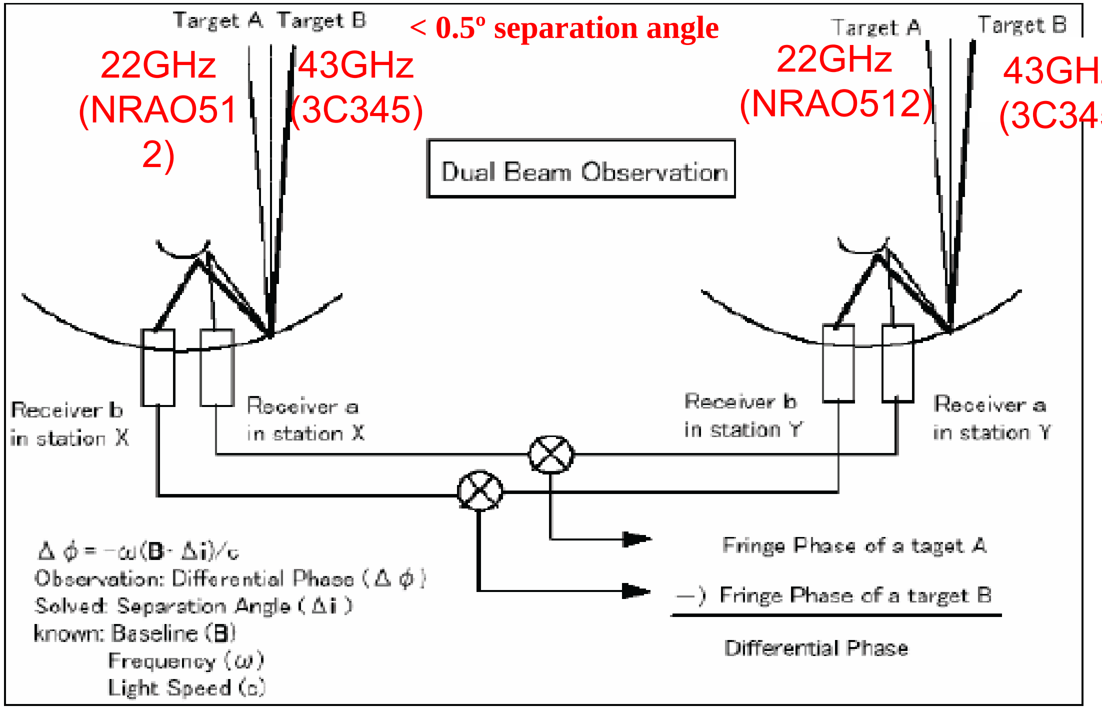
- Both of fringe phases at 22 & 43 GHz show a typical behavior of the phases in VLBI, which is the flicker freq. noise for short time scale and white phase noise for a longer time scale

- The differential phases are inversely proportional to τ, that means the effect of atmospheric fluctuation is effectively removed.

2nd VERA Dual-Frequency Experiment

- Confirming of using different LO effects at 22 & 43 GHz
  - Position switching
  - Freq. fixed for beam A & beam B
  - [if any] Source structure & L.O. effects will be discriminated

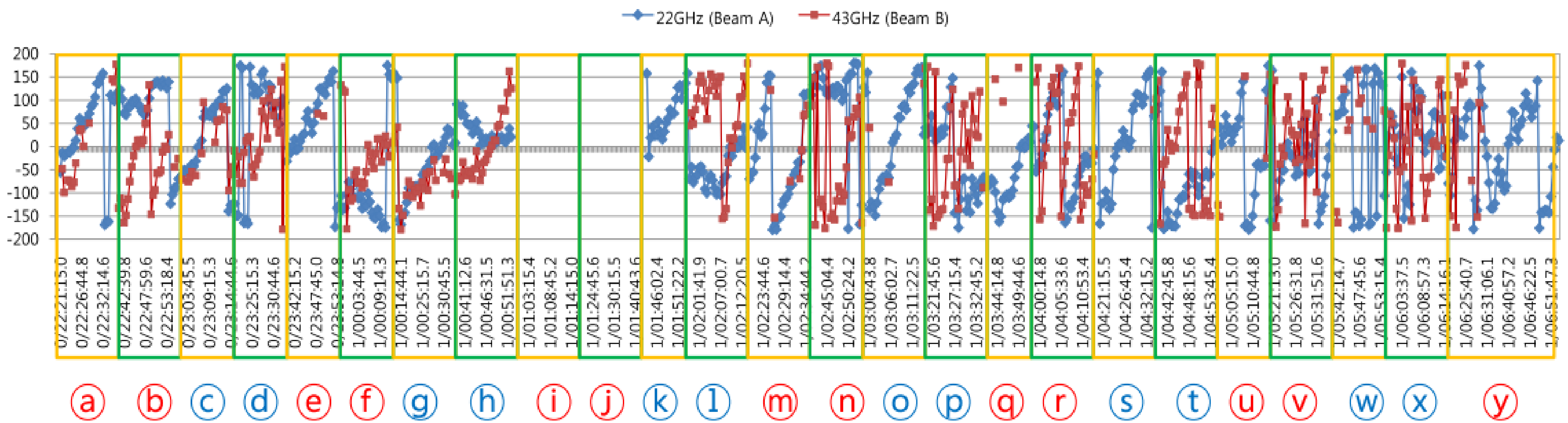
- Beam A : 3C345 → NROA512 → 3C345 → NRAO512 → …
  Beam B : NROA512 → 3C345 → NRAO512 → 3C345 → …

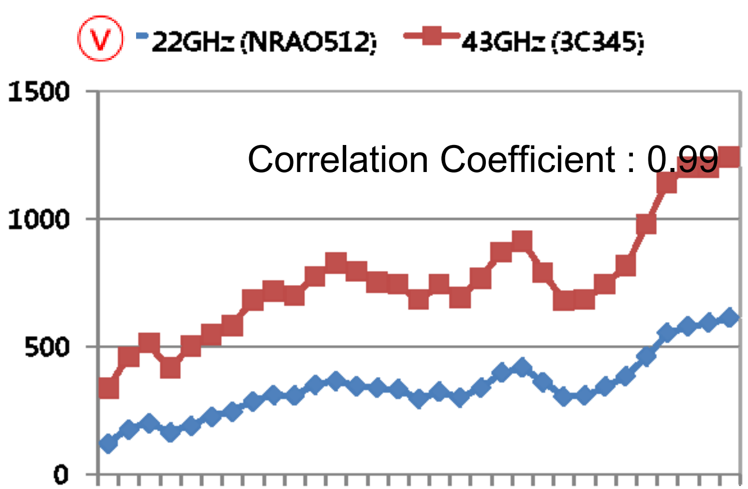


2nd VERA Dual-Frequency Experiment

22GHz (Beam A) : 3C345
43GHz (Beam B) : NRAO512

22GHz (Beam A) : NRAO512
43GHz (Beam B) : 3C345





- We were not able to get fringe phases of NRAO512 at 43 GHz (yellow scans) because it was not bright enough at this frequency.

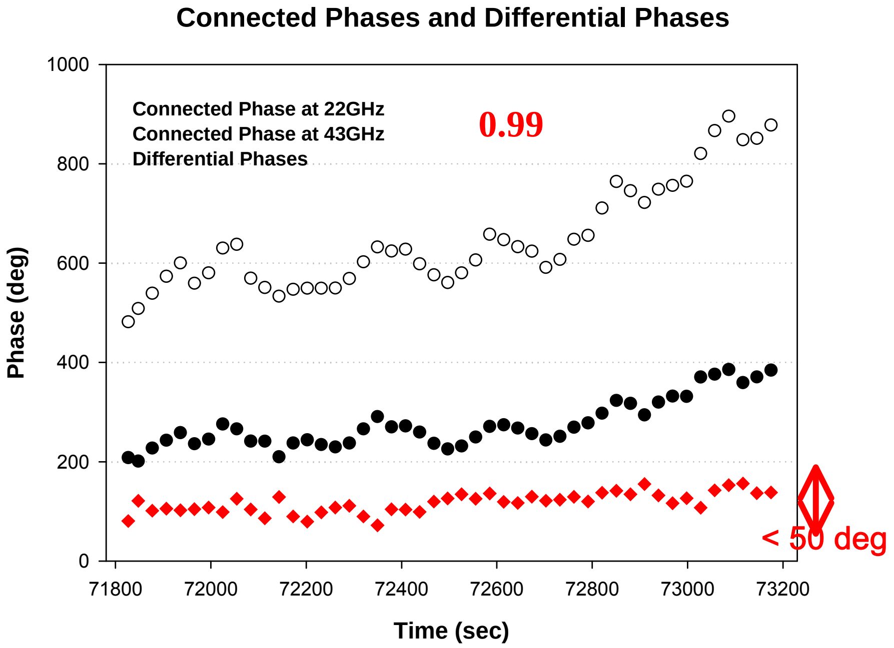
- However, the other scans which are NRAO512 (22GHz) and 3C345 (43GHz) were observed and showed the repeatability of these experiments very well.

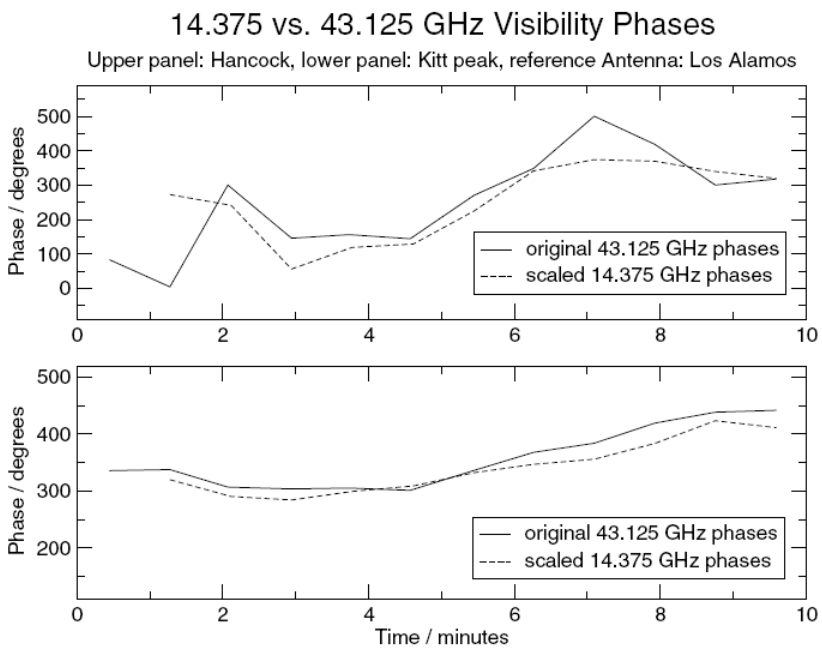
DISCUSSION & SUMMAY

- VLBI phases are suffering from many of effects such as, troposphere, ionosphere, sec Z effect, source structure, uncertainties of the source/station coordinates , clock offsets and instrumental delays and so on.
- We made a dual-frequency simultaneous observation at 22 & 43 GHz using VERA and analyzed phase solutions to test the feasibility of multi-frequency phase referencing for KVN.
- From the 1st experiment, we found some drift/sinusoidal tendency at differential phases. We have investigated what kind of effect could cause such a specific tendency.

DISCUSSION & SUMMAY

Multi-freq. Phase Referencing vs Fast Frequency Switching





23 min

10 min

(Middelberg et al)

- Good possibility of Multi-freq. phase referencing technique with a strong correlation of phases at different frequencies

DISCUSSION & SUMMAY

- The performance of multi-freq. phase referencing in KVN is expected to be much higher than this experiment because of using same source

- VLBI Imaging at higher freq. will be able to have a good chance with multi-freq. phase referencing
  - AGNs : Core shift, accretion, jet formation, black-holes etc…
  - Masers : multi-line observation, environmental studies of evolved stars etc…

- Multi-freq. phase referenced observation between KVN + VERA is near at hand.

- Multi-frequency phase referencing in KVN is feasible

- The correlation between different frequencies of KVN is expected to be better than this experiment ($\rho > 0.96$)