The astrometric feasibility and accuracy of VERA

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（National Astronomical Observatory of Japan）

The requirements of the VERA correlator

- **The correlation process spends within twice observation time at most.**
  (8 hours observations, processing time within 16 hours)

- **VERA correlator process one or two narrow band width (16MHz or 32MHz) with high frequency resolution (16.625kHz) and one wide band width with low resolution (250kHz) simultaneously.**

- **The precise apriori model is needed to achieve a highly accurate measurement with phase-referencing VLBI.**

Test observations (QSO pair)

	Target	Reference	SA	PA
1	J2218-0035	3C446	2.20	125
2	J1808+4542	OU+401	1.47	90
3	J0831+0429	OJ038	2.0	50
4	NRAO512	3C345	0.5	80

Observations

- Date　2004/11/～ 2009/2
- Band　K band
- DIR2000(1Gbps, 16MHz*16) (all epoch) – VERA terminal
- DIR1000(128Mbps, 16MHz*2)（2005/5/24）– VSOP terminal

The Comparison of apriori models

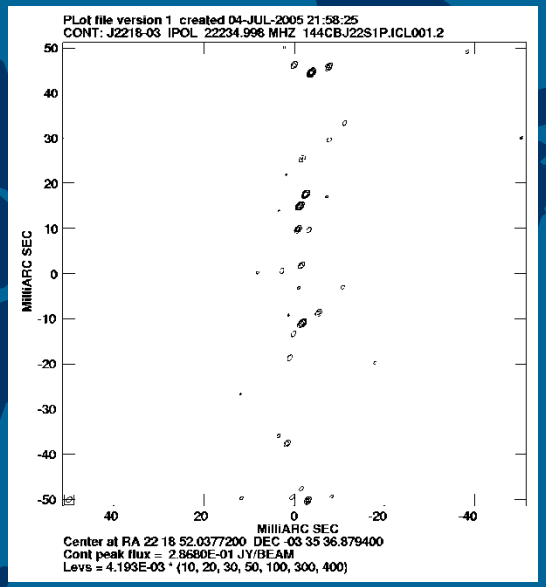
J2218-0335 phase referenced image(3C446 is reference source)

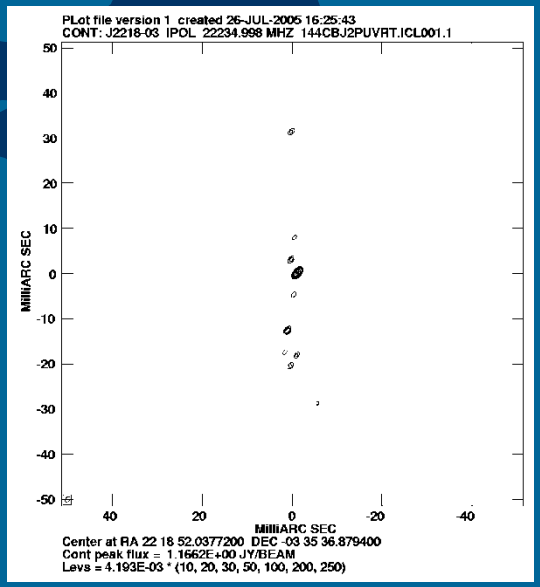
To achieve high accurate astrometry, apriori model is very important. Therefore we have checked and improved apriori models.

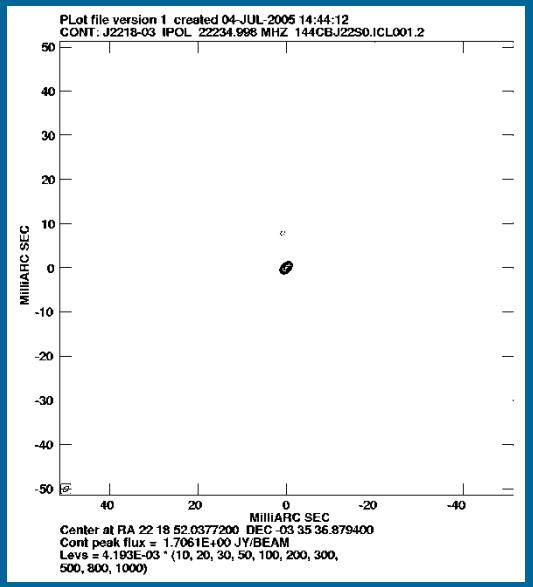
- **Two apriori models (fxcalc and DAP) developed by NAOJ have been used for VERA**

（Jike et al.2005）

- **In a result of improvement, the difference of fxcalc, DAP and CALC9 is only 10 psec(3mm), mainly due to difference of tidal model.**







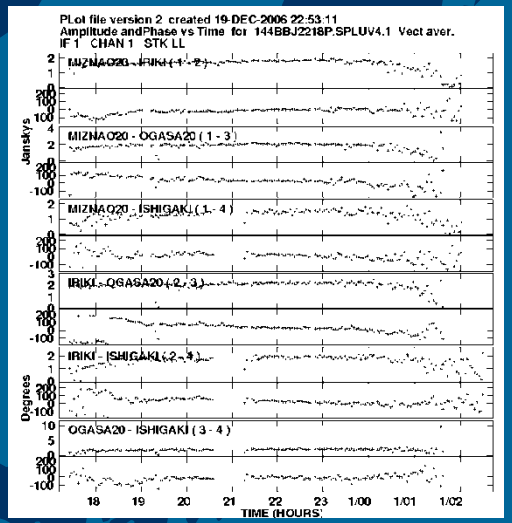
The phase referenced image with uncorrected apriori model.

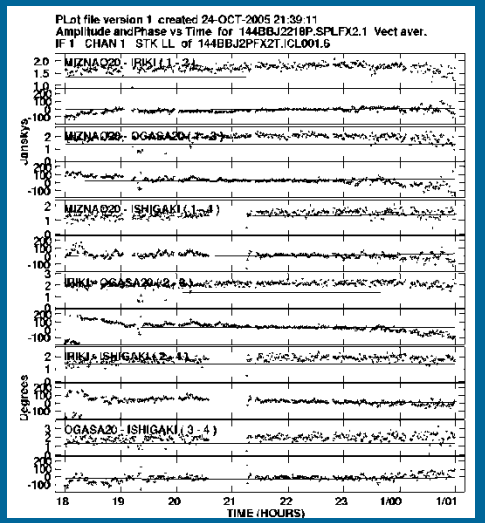
The corrected apriori model is used. The scatter of the image is improved.However a little scatter exist due to zenith atm delay offset

Self calibration is performed.

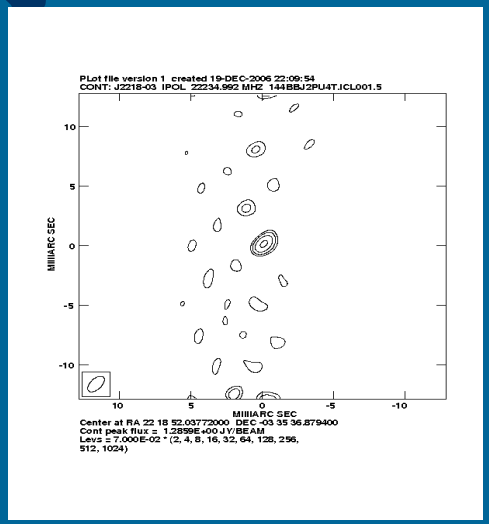
Comparison between two different apriori
Dap (by honma,hirota) Vs Fxcalc (by jike,kurayama)

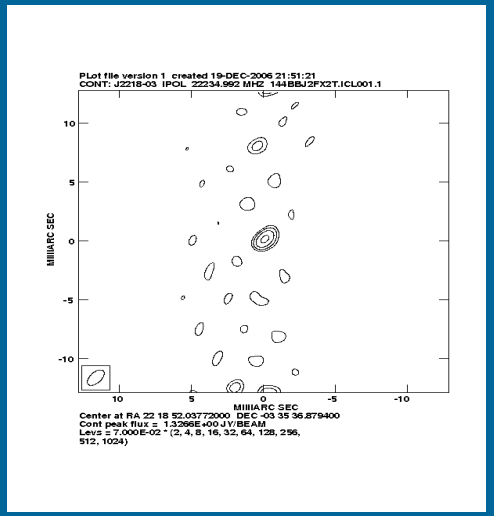
	ΔR.A (mas)	ΔDec (mas)
dap	0.1298	0.2158
Fxcalc	0.1262	0.2205
difference	0.0036	-0.0047





The difference of the total delay between dap and fxcalc is very smalll. The value is within error bar. Therefore, whichever apriori we used, it is actually not so serious .





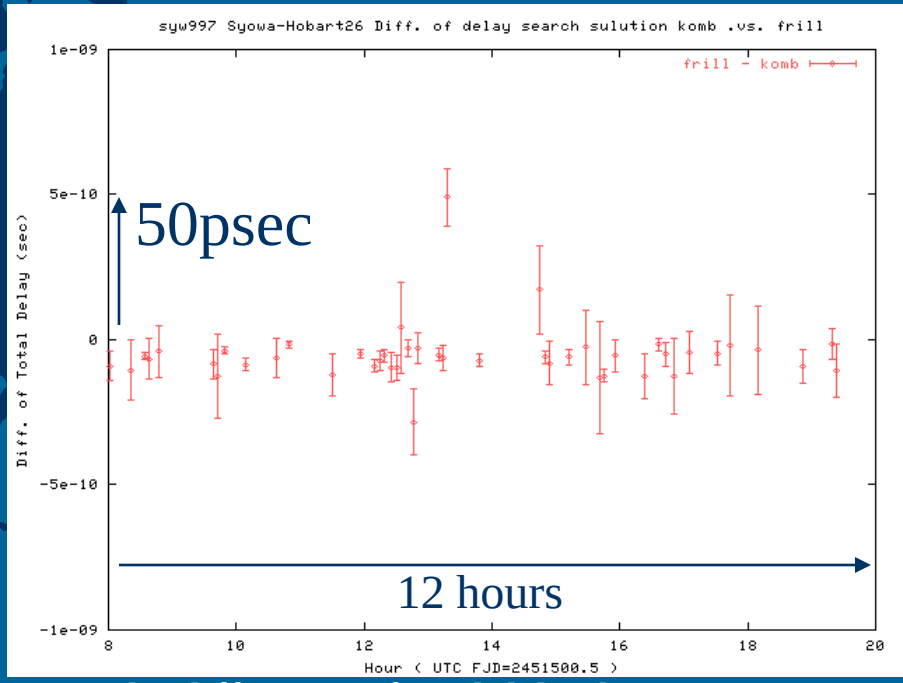
Dap

Fxcalc

The Comparison between K4 correlator and VERA 1Gbps FX correlator

To achieve high accurate astrometry and geodesy, total delay and phase is very important. Therefore the comparison between independent two correlators is needed.

- **K4 correlator developed by NICT have been used for JADE* and IVS at GSI(Geographical survey institute).**
- **VERA terminal (DIR2000,1Gbps recorder) have been used for VERA.**

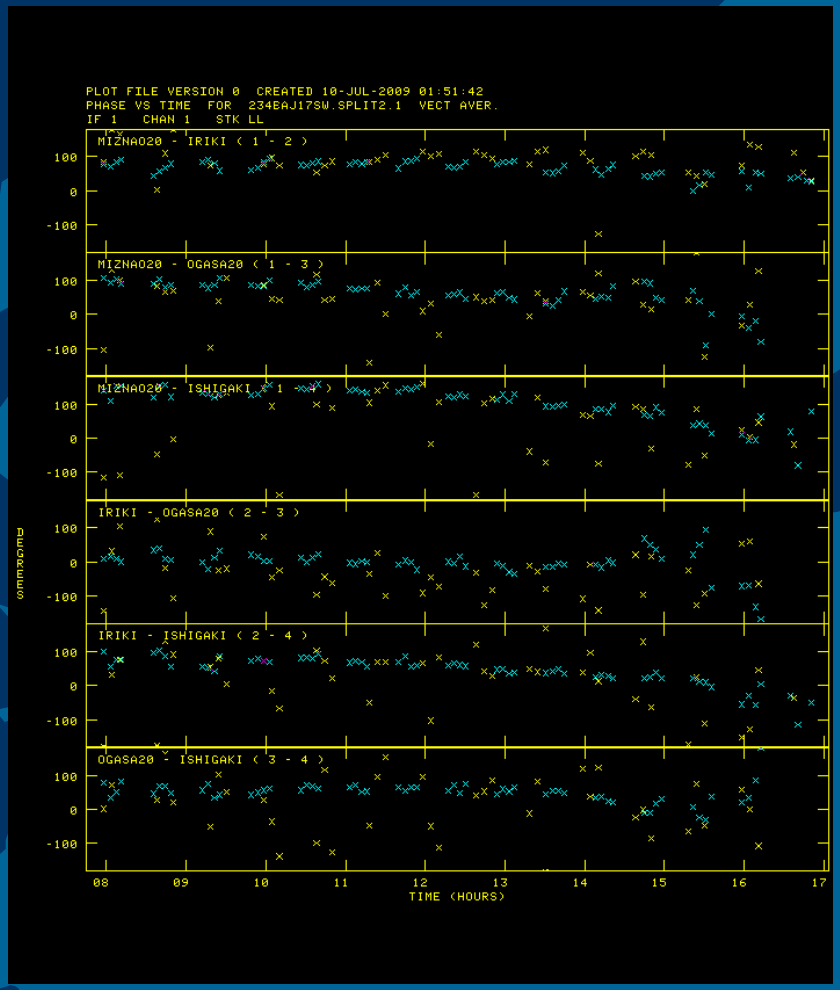


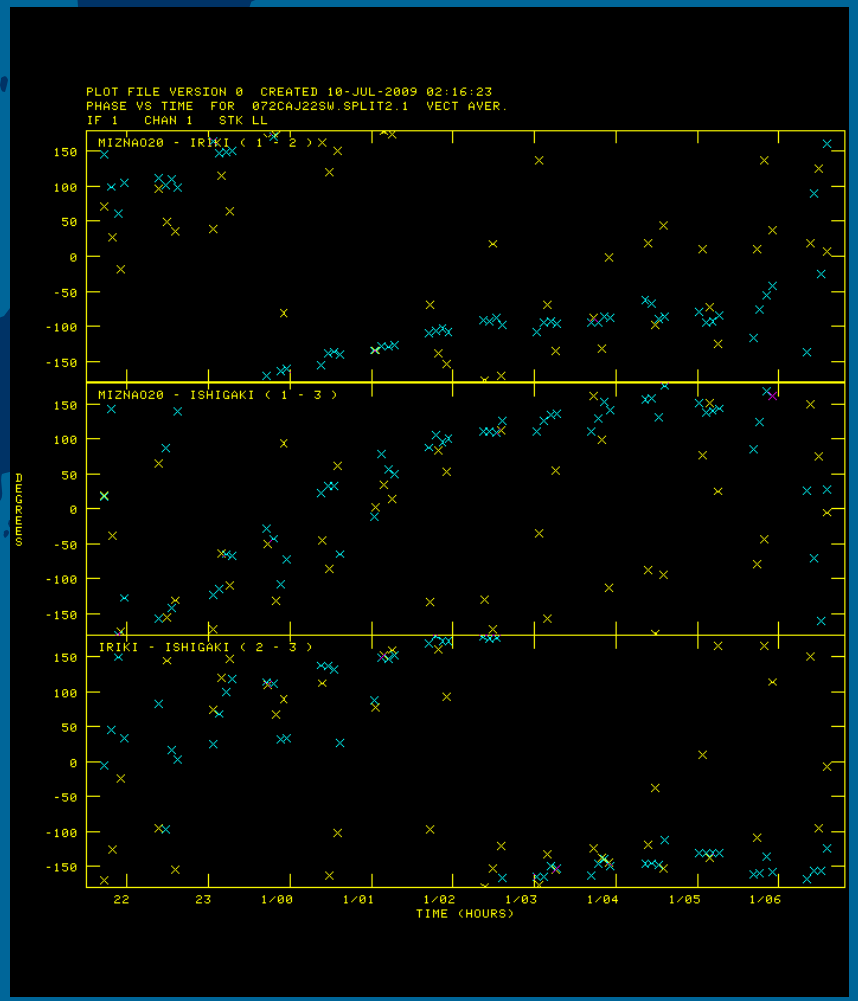
The difference of total delay between K4 correlator and VERA 1Gbps FX correlator

The difference of the total delay between K4 correlator and VERA 1Gbps FX correlator is only 50 psec(peak to peak) . This is in good agreement.

* "JApanese Dynamic Earth observation by VLBI"

Test Observations
(2 beam VS Single beam switching)



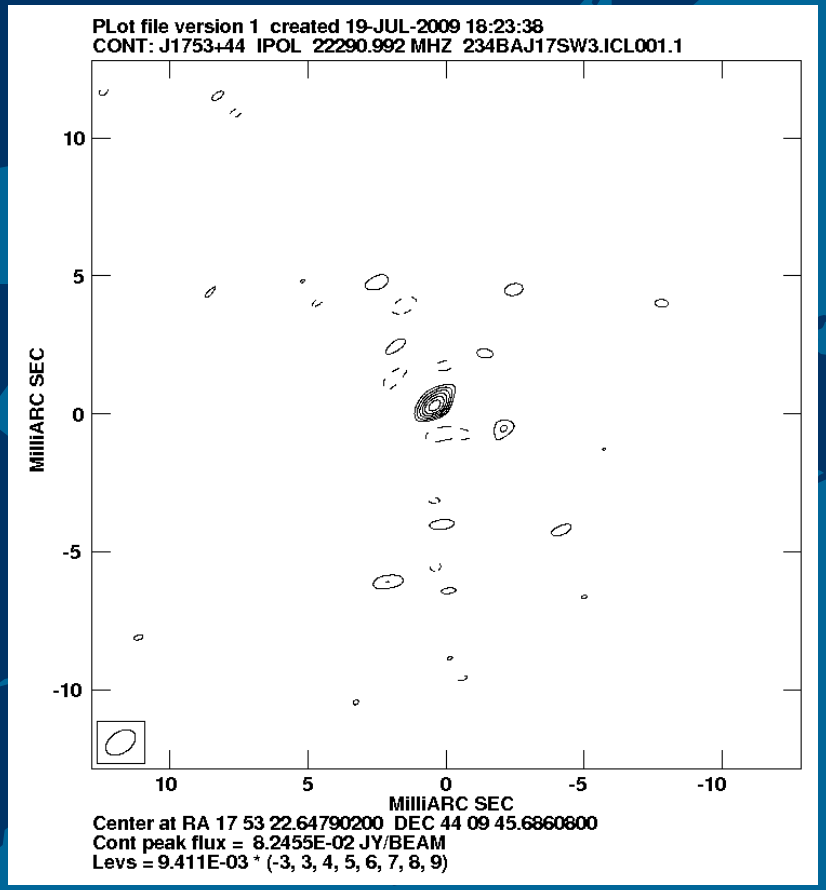


Phase referenced visibilities
J1753+4409(Target)

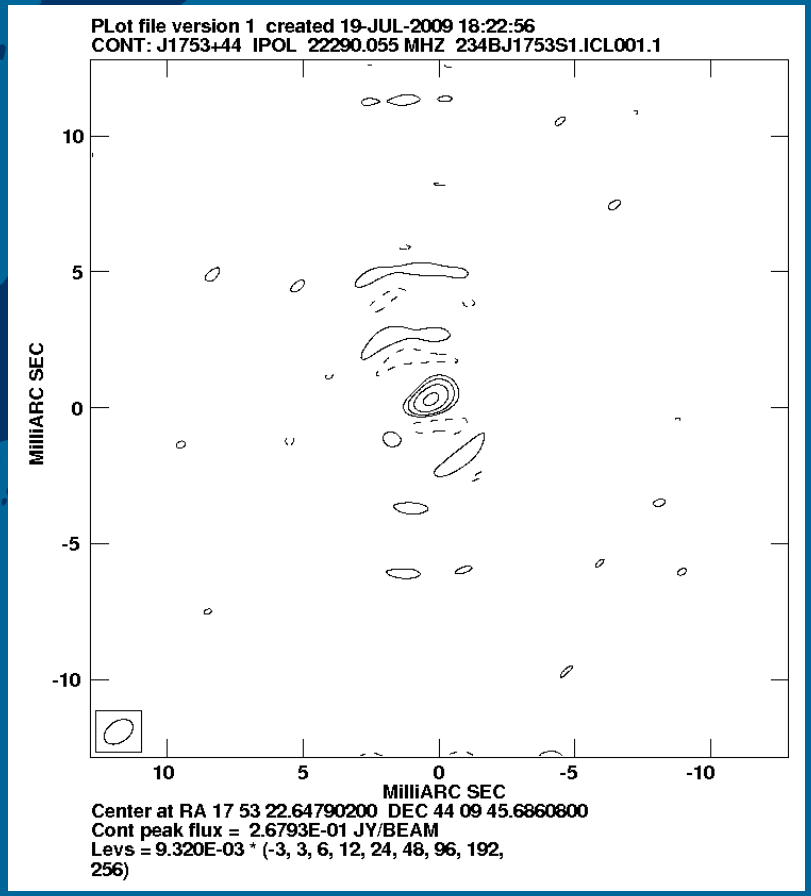
Phase referenced visibilities
J2218-03（Target）

Yellow: Single beam ,Blue : 2beam

Test Observations
(2 beam VS Single beam switching)



J1753+4409（Switching）
Peak Flux: 82.5 mJy

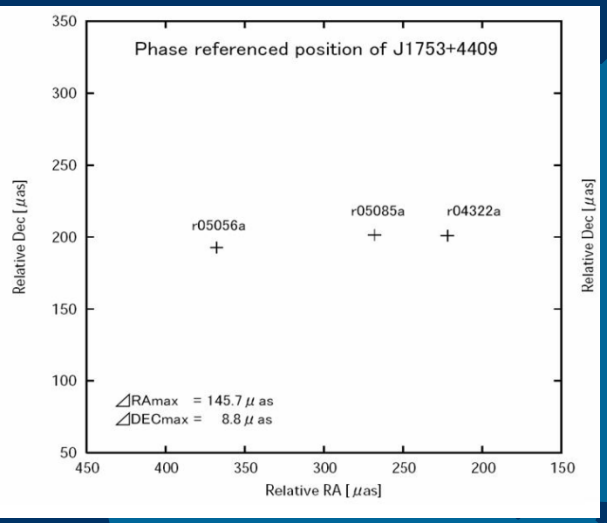


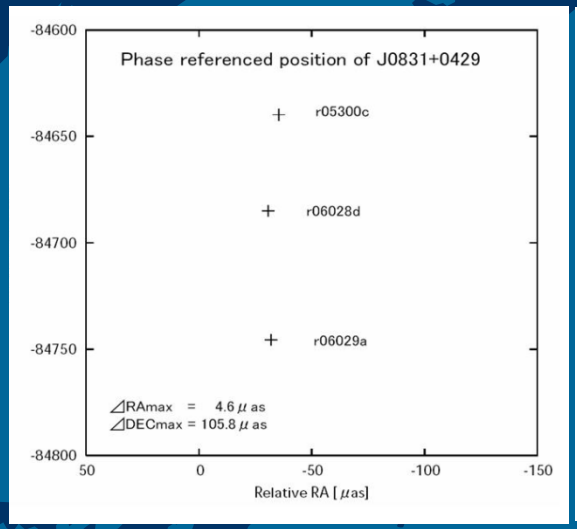
J1753+4409（2beam）
Peak flux：267.9 mJy

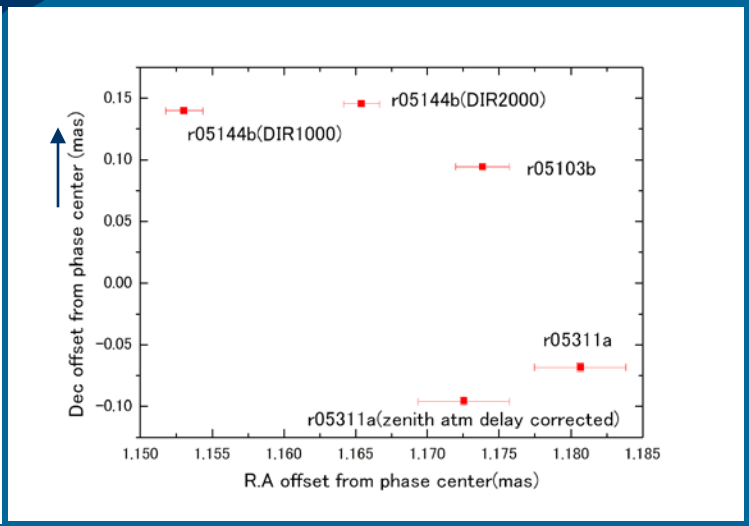
Position difference between 2beam and switching
RA. 118±50μas、Dec. -4.45±50μas（2beam-switching）

Test Observations (Astrometry)

・By way of checking apriori models and correlator system, astrometric observations are considerabl







OU+401&J1753+4409　　OJ038&J0831+0429　　3C446&J2218-0335

The accuracy of the direction of R.A is very high(about 10μas）.But the direction of Dec is a little bad. Mainly due to apriori model error and zenith atm delay offset?. The directions of offsets may be dependent on PA.

1. **To more improve the astrometric accuracy , improvement and verification of geophysical models (ex., plate motion, ocean tide loading, non-tidal ocean loading, etc.) are considerable.**
2. **Moreover, we have to estimate the atmospheric zenith delay offset and apply the most accurate geophysical models.**

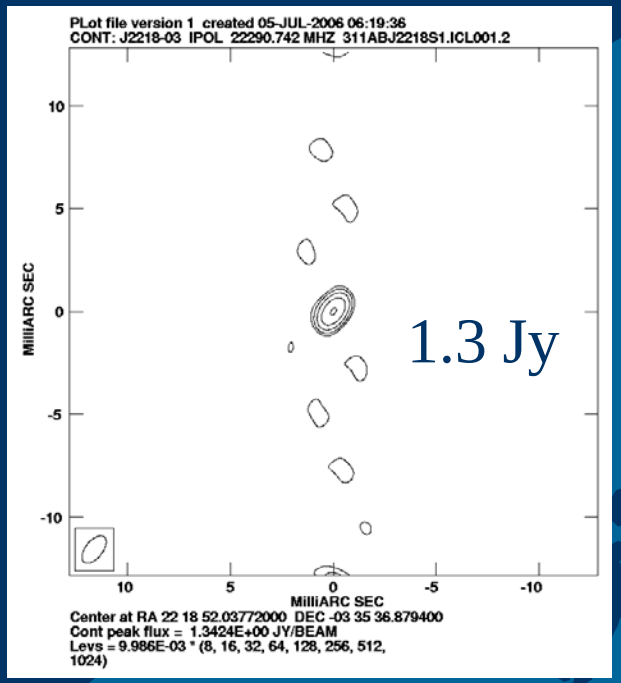
Several question

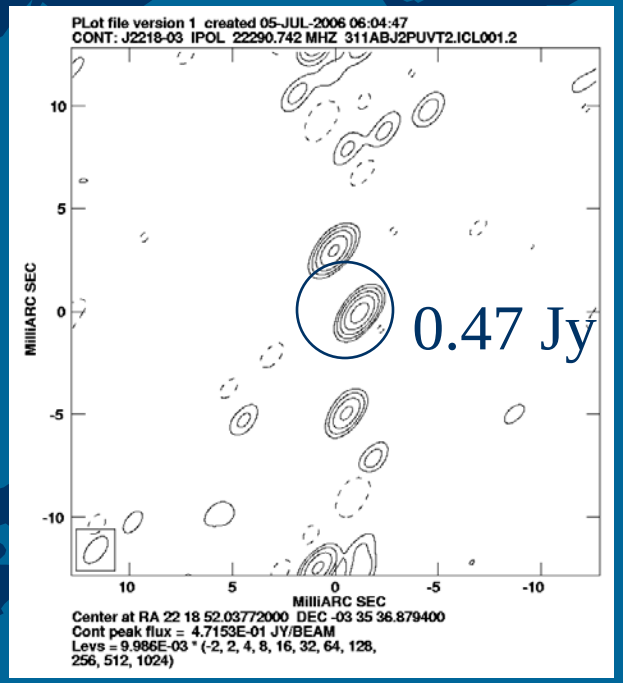
1) What? short period phase fluctuations
（10 min～1 hour）to distort image

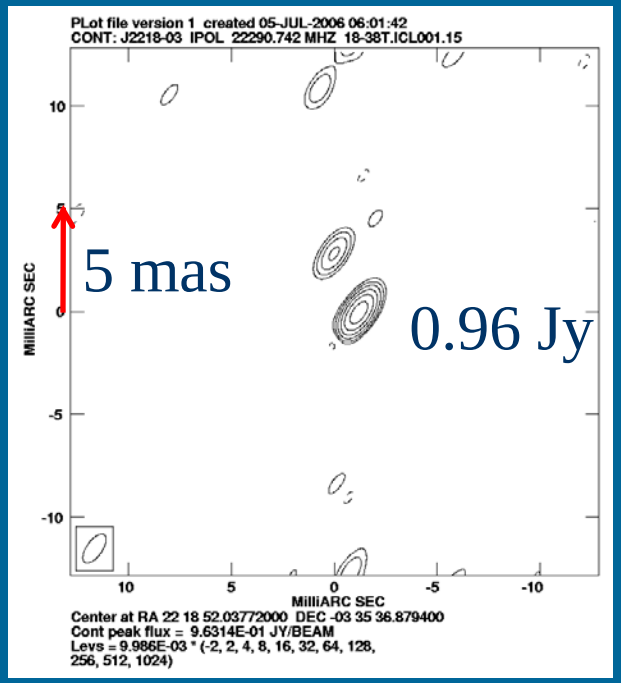
2) Why? the astrometric accuracy toward Dec is more worse than toward R.A.

3) Are directions of offsets dependent on PA or RADEC?

Short period phase fluctuations（10m～1h）to distort image
(Target Images J2218-0035、R05311A)







Not phase reference
Fring search
Selfcal image

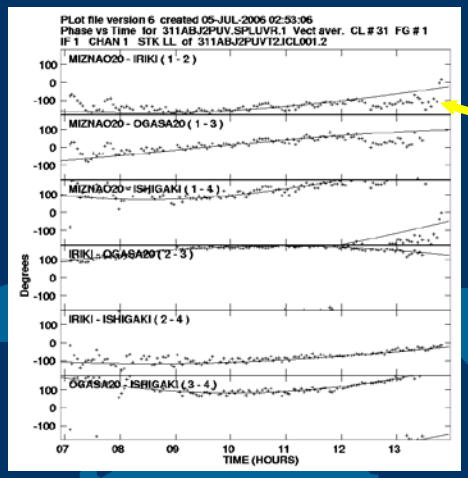
Phase referenced image
Zenith atm delay offset
is not applied

Phase referenced and Zenith atm
Delay offset compensated image
(MIZ 0.1nsec、IRK 0.06 nsec offset)

To compensate zenith atm delay, peak flux has improved by the twice.
however peak flux is 70% compared with self cal image
⇒Need to check phases to be phase referenced.

Short period phase fluctuations（10m～1h）to distort image

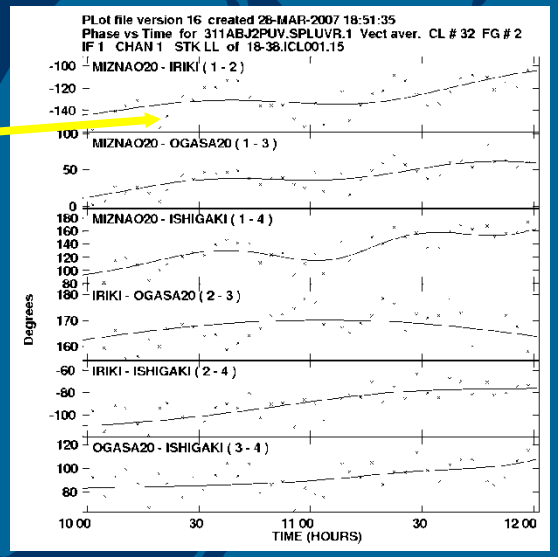
（Target J2218-0335 (r05311a) phase to be compensated）



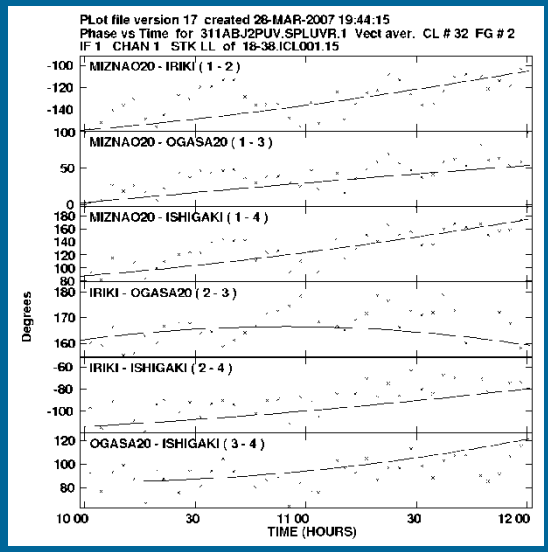
Short phase fluctuations

10:00-12:00 expand

MIZ 0.1nsec+IRK 0.06 nsec
Zenith atm dellay offset applied



Model = all components

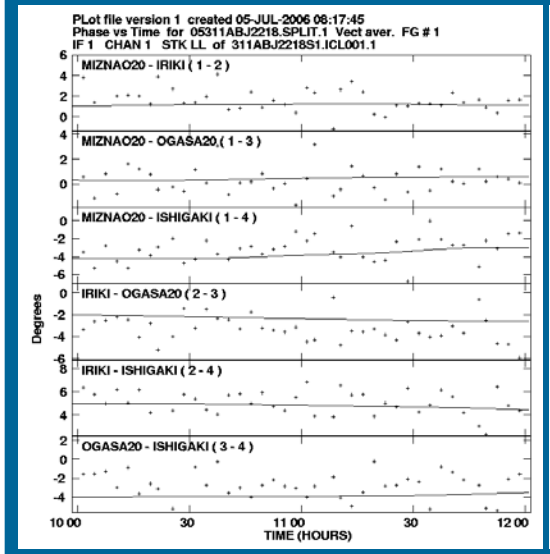


Model = only center

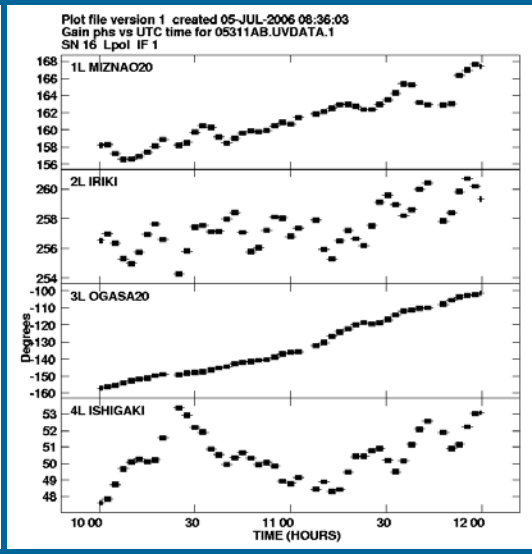
1) Short period phase fluctuations distort image
2) Closure phase is stable as point source.
3) 2beam calibration table is stable.

4) Is it impossible to compensate short period phase fluctuations using zenith atm delay of GPS data?
⇒Need to WVR, QSO pair obs hourly and improve accuracy of GPS measurement

5) What are causes?
1. Time interval for fringe search ?
2, Accuracy of measurement of short atm fluctuations using GPS ⇒next page
3, Method of analysis?



Only fringe search (1beam)



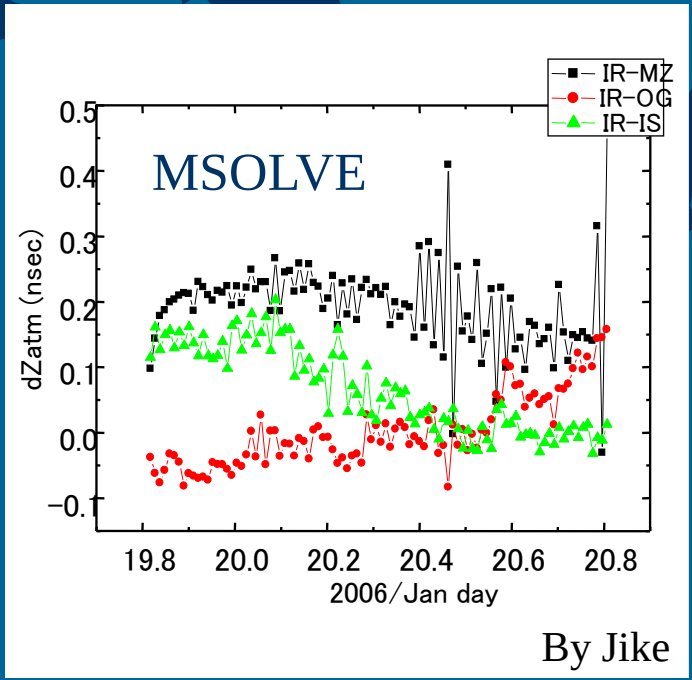
2beam cal table

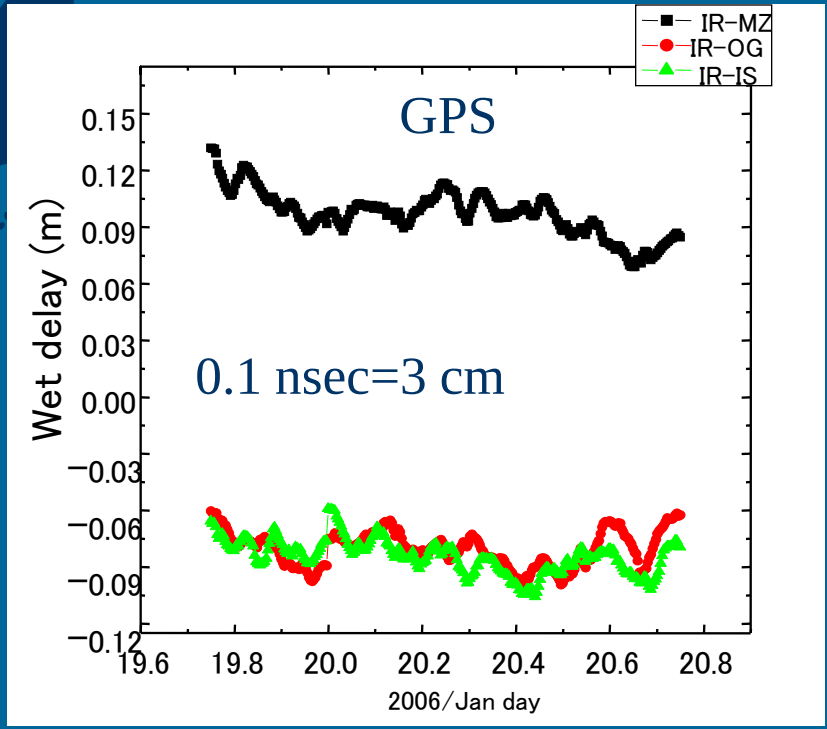
Method of zenith atm delay compensation

MSOLVE(geodetic VLBI by NAOJ) VS GPS

The sequence of atm analysis for VERA

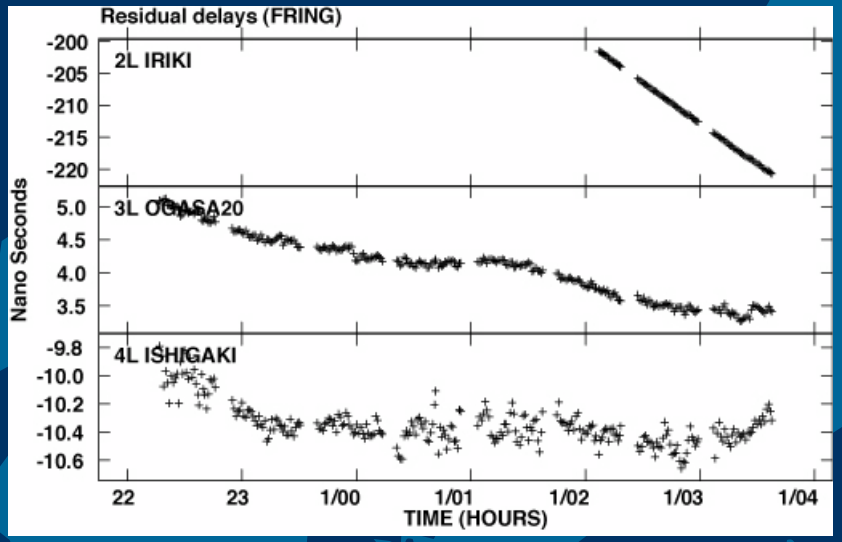
· GPS data + zenith atm delay offset which are applied to reference to phase variation and image qualities.



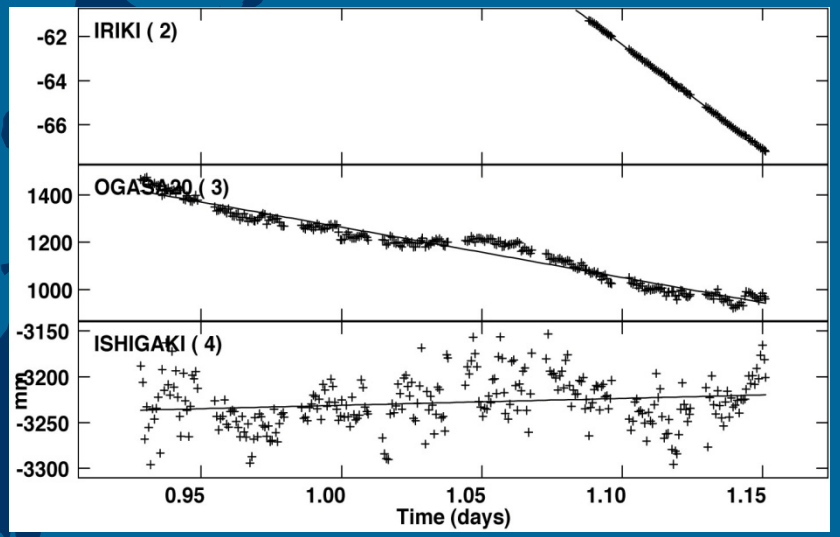


The aspects of short and long phase variations are different between MSOLVE and GPS

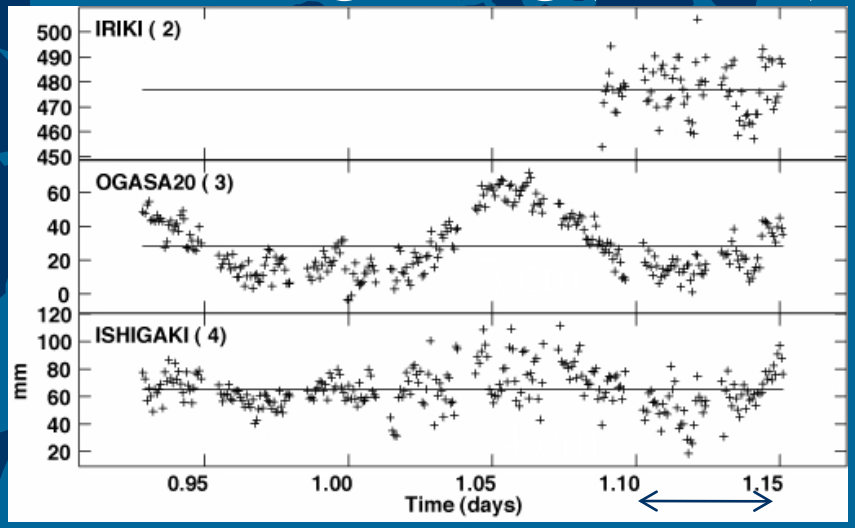
Zenith atm delay（Phase Fitting)



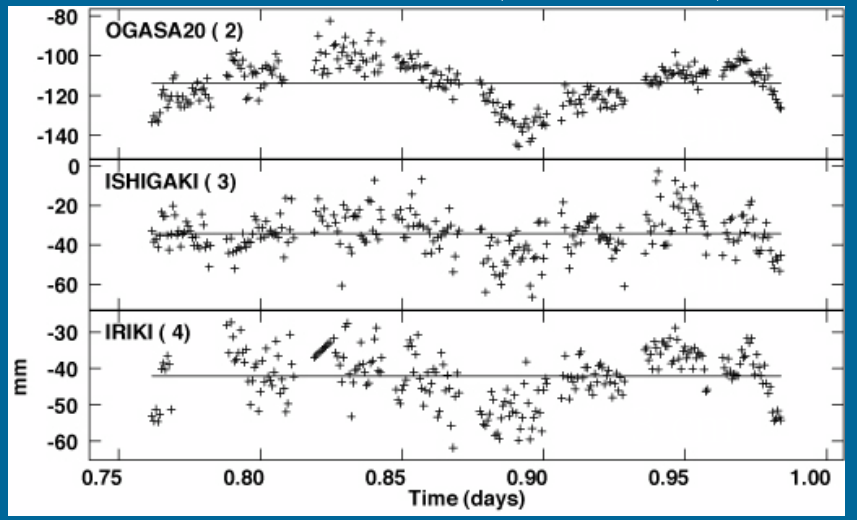
Fringe fitting (r05354c)



Clock (r05354c)



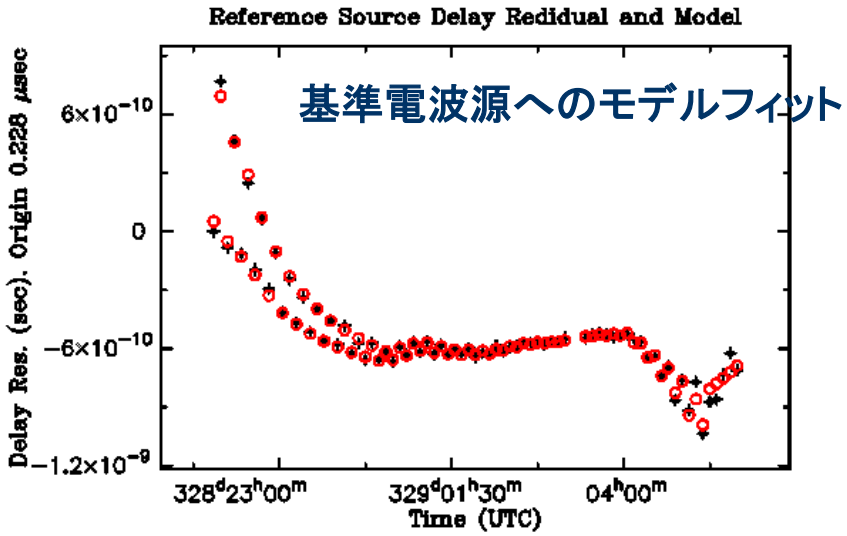
ATM (r05354c) 60m

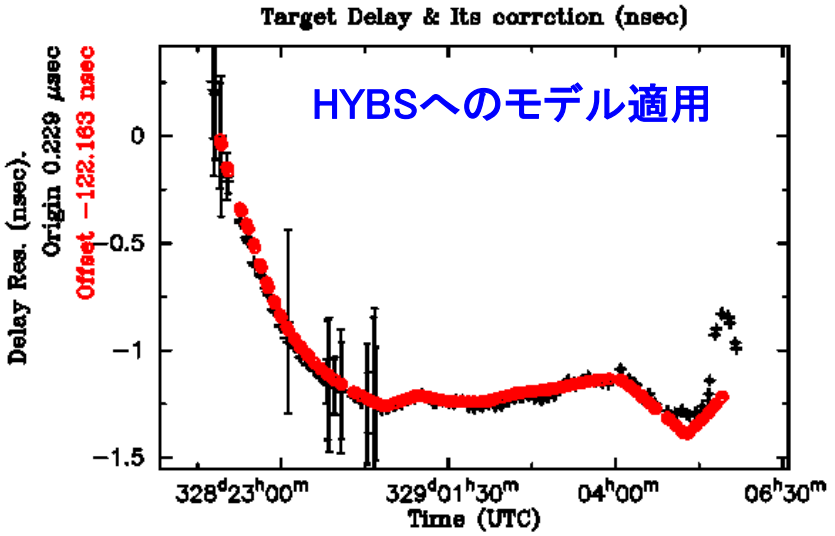


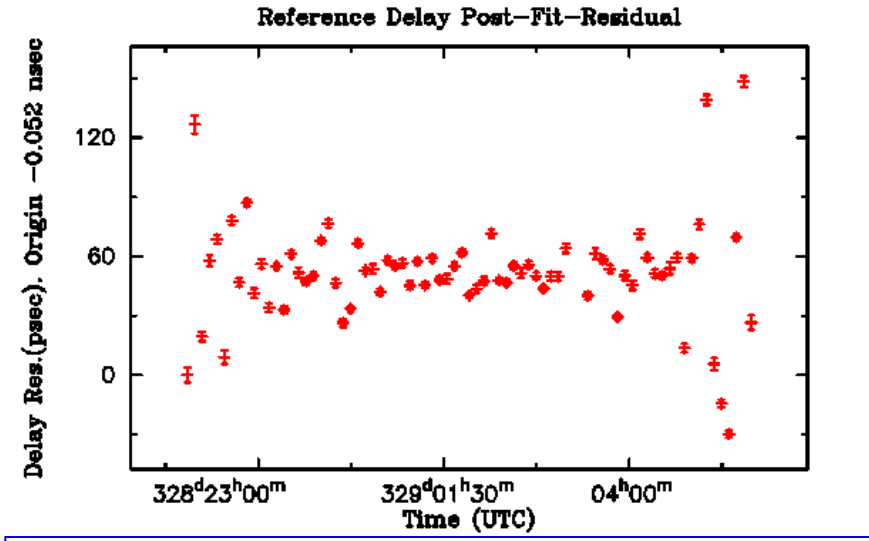
ATM (r06053b)

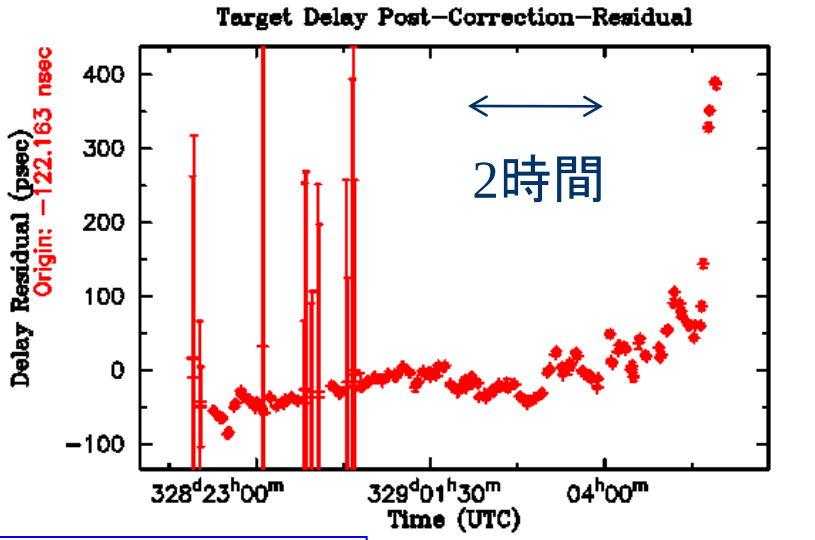
By imai

2005/11/25 鹿島34–つくば32基線









$$\tau = \tau_0 + \dot{\tau}(t - t_0) - \tau_{atm,x}\, fm(El_x) + \tau_{atm,y}\, fm(El_y)$$

Why? the astrometric accuracy toward Dec is more worse than toward R.A.

Problems and situations

- An aspect of long phase variation is different between SOLVE and GPS
- Accuracy is limited to 100μas（QSO pair、maser at several pc）due to lack of the accuracy of estimation of zenith atm delay ?
- In case of near maser sources > also source structure ?（Orion、S-Crt、ρOph by hirota, nakagawa, imai et al. ）

Other Status

- Accuracy of apriori have attained to several mm (comparison to calc 9)
- VLBA astrometry have been attained to 10 micron accuracy toward (Xu et al . 2006 , Hachisuka et al. 2006）

Studying

- Comparison between Geometric observation and image optimization method. (Honma et al in preparation)
- Studying the new method of geometric observations. (Jike in this conf)

Summary

- 1-Gbit recording system and correlator are used regularly. The good results of astrometry have been obtained.
- The accuracy of the direction of R.A is very high(about 10μas).
- The two questions have been discussing and studying.