The source structure effect in broadband observations

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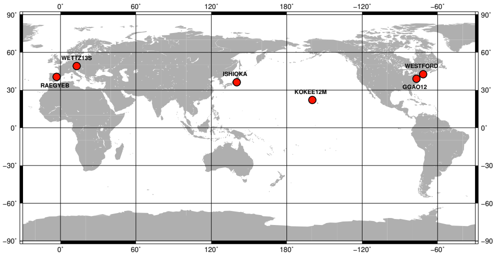
VGOS CONT17 observations

Broadband VLBI observations

- Three station networks participated in CONT17 VLBI campaign: the legacy S/X, VLBA and VGOS networks.
- the VGOS network consists of six station: GGAO12M, ISHIOKA, KOKEE12M, RAEGYEB, WESTFORD and WETTZ13S.
- The stations performed observaitons during five continuous days: December 3 – 7, 2017.
- The observations were done in the current broadband demonstration mode, recording only half of the possible channels to give a data rate of 8 Gbps instead of the possible 16 Gbps.
- The VGOS observations were correlated at the MIT Haystack Correlator.



- Preliminary data analysis has been performed at Goddard Space Flight Center, NASA and the observations now are available for public access.
- Unfortunately, one of the VGOS stations, Yebes, had a problem with hardware, so it was not included in the analysis.

Data analysis of the broadband observaitons

Software

The observations were processed by νSolve software using the embedded software using the embedded ECMAScript to treat data uniformly.

Parameterization

The baseline vectors, source positions and angles of nutation were estimated as local parameters. Station clock offsets, wet zenith delays, and atmospheric gradients were estimated as stochastic parameters (random walk model).

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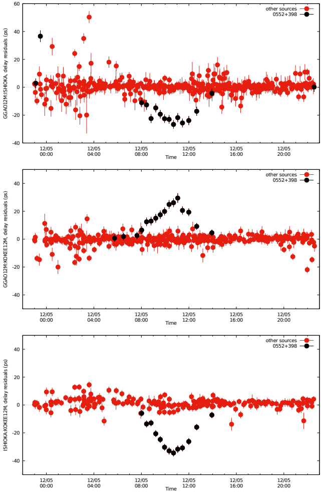
Anomalies in delay residuals, 17DEC04VG



Residuals for baselines of the stations GGAO12M, ISHIOKA and KOKEE12M.

- Anomalous residuals for 0552+398 are visible at all five VGOS session.
- The WRMS for the source, 12-13ps, are much bigger than the WRMS for a session, 2-3ps.

Two points source structure model

According to Thomas (1980), source structure affects the group delay as

$$\tau_s = \frac{Z_s \frac{\partial Z_c}{\partial \omega} - Z_c \frac{\partial Z_s}{\partial \omega}}{{Z_s}^2 + {Z_c}^2}$$

where

$$Z_c = \iint I(\vec{P}, \omega, t) \cos(\omega \frac{\vec{b}\vec{P}}{c}) d\Omega$$

$$Z_s = \iint I(\vec{P}, \omega, t) \sin(\omega \frac{\vec{b}\vec{P}}{c}) d\Omega$$

Assuming a source consist of two close points:

$$I(\vec{P}) = g_1 \delta(\vec{P} - \vec{P_1}) + g_2 \delta(\vec{P} - \vec{P_2})$$

then the source structure effect in group delay will be

$$\tau_s = -\frac{R}{f} \frac{(1+K)^2}{1 + K^2 + 2K(cos^2(2\pi R) - sin^2(2\pi R))}$$

where

$$K = g_2/g_1, g_2 < g_1$$

$$R = (\vec{b}/\lambda) P_1 \vec{P}_2$$

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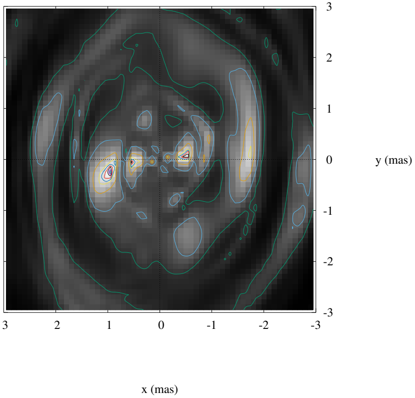
Searching initial values of the model

- The two point source structure model consists of the following parameters: an offset of the second component from the central point, (x, y), and a ratio of the amplitudes of the components, K.
- To use the least square estimation we first have to search for the initial values of the model.
- For a fixed second component position we estimated the ratio of the amplidues.
- The image shows distribution of WRMS of the source referred to the minimal WRMS, $WRMS(x, y) - WRMS_{min}$.



Estimated parameters of the model

	Number of obs.		WRMS for 0552+398 (ps)		Model parameters		
session	Usable	Used	Model:off	Model:estimated	K	x(mas)	y(mas)
17DEC03VG	134	132	13.6	2.8	0.385	0.900	-0.128
17DEC04VG	118	118	13.5	2.3	0.352	0.930	-0.223
17DEC05VG	138	137	13.8	2.6	0.390	0.900	-0.105
17DEC06VG	90	90	15.2	3.2	0.384	0.905	-0.098
17DEC07VG	149	149	13.3	2.8	0.378	0.911	-0.155

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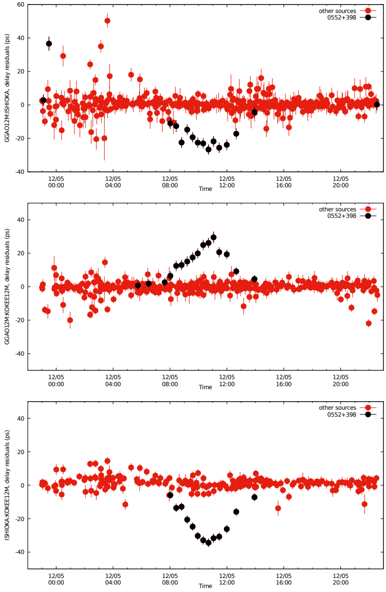
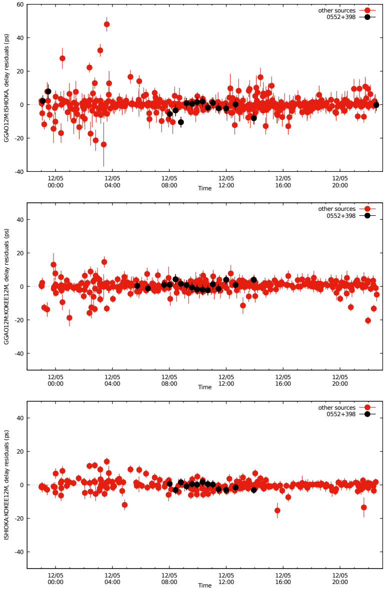
Residuals after the model has been applied



Residuals without the source structure model.



Residuals after the model was applied.

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Multiple points source structure model

For multiple points soure structure model the brightness distribuition can be written as

$$I(\vec{P}) = g_0\delta(\vec{P} - \vec{P_1}) + \sum_{i=1}^{N} g_i\delta(\vec{P} - \vec{P_g})$$

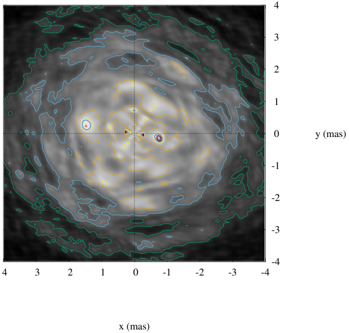
and the source structure effect in group delay

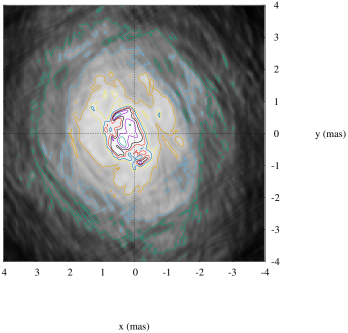
$$\tau_s = -\frac{1}{f}\frac{\sum_{i=1}^{N} k_i \sin 2\pi R_i \sum_{i=1}^{N} k_i R_i \sin 2\pi R_i + (\sum_{i=1}^{N} k_i \cos 2\pi R_i + 1)\sum_{i=1}^{N} k_i R_i \cos 2\pi R_i}{1 + [\sum_{i=1}^{N} k_i \sin 2\pi R_i]^2 + [\sum_{i=1}^{N} k_i \cos 2\pi R_i]^2 + 2\sum_{i=1}^{N} k_i \cos 2\pi R_i}$$

where

$$k_i = g_i/g_0,\, g_i < g_0$$
$$R = (\vec{b}/\lambda)\vec{P_i}$$

Searching initial values of the model





Model parameters

K	x(mas)	y(mas)
0.2992	-0.7615	-0.1313
0.1896	0.4328	-0.3126

Frequency dependent source structure model

The multiple points soure structure model with components that have different spectral indexes:

$$I(\vec{P}) = g_0\delta(\vec{P} - \vec{P_1}) + \sum_{i=1}^{N} g_i\delta(\vec{P} - \vec{P_g})$$

and

$$g_i = r_i(\frac{\omega}{\omega_0})^{\alpha_i}$$

The source structure effect in group delay

$$\tau_s = \frac{T_1}{Z^2} + \frac{T_2}{Z^2}$$

where

$$T_1 = -\frac{1}{2\pi f}[\sum_{i=1}^{N} \beta_i k_i \sin 2\pi R_i + \sum_{i=1}^{N}\sum_{j=i+1}^{N} k_i k_j(\beta_i - \beta_j)\sin 2\pi(R_i - R_j)]$$

$$T_2 = -\frac{1}{f}[\sum_{i=1}^{N} k_i R_i \cos 2\pi R_i + \sum_{i=1}^{N} {k_i}^2 R_i + \sum_{i=1}^{N}\sum_{j=i+1}^{N} k_i k_j(R_i + R_j)\cos 2\pi(R_i - R_j)]$$

$$Z^2 = 1 + \sum_{i=1}^{N} {k_i}^2 + 2[\sum_{i=1}^{N} k_i \cos 2\pi R_i + \sum_{i=1}^{N}\sum_{j=i+1}^{N} k_i k_j \cos 2\pi(R_i - R_j)]$$

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Conclusions

The effect of source structure is directly visible in the broadband observaitons.

Taking into account source structure effects will be necessarry for analysis of VGOS obervations.

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Thank you for your attention!