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Radio Source Instability in the Analysis of VLBI Data

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Abstract

The source position time series for many of our frequently observed sources show systematic variation of as much as 0.5-1.0 mas due mainly to source structure changes and observing network changes. In our standard geodetic solutions, we only estimate global source position from data from all observing sessions. If these effects are not modeled, they produce corresponding systematic variations in estimated Earth orientation parameters (EOP) at the level of 0.02-0.04 mas in nutation and 0.01-0.02 mas in polar motion. We discuss two strategies for handling source instabilities: 1) estimate the positions of all unstable sources for each session they are observed and 2) estimate spline parameters chosen to fit the specific variation seen in the position time series. The second strategy improves VLBI EOP and nutation accuracy by reducing the biases and wrms differences between independent measurements from the simultaneous CORE-A and NEOS-A networks.

1. Introduction

In our standard geodetic solutions, we have generally ignored source structure effects and only estimate a single global source position for each source using its entire observing history. However, estimation of source position time series shows that many sources have significant systematic position variation that can be as much as 0.5-1.0 mas. This position variation is due to source structure changes and to the effect of observing sources with structure with networks consisting of different baselines. If these variations are not modeled, their effects will propagate into systematic effects on Earth orientation and nutation estimates. In this paper, we consider two ways of handling sources with significant position instabilities: 1) estimate the position of such sources for each session in which they were observed or 2) estimate global spline parameters chosen to fit the observed systematic variations of the position time series.

2. Source Position Time Series

We generated source position time series for 653 sources that were observed in 4017 experiment sessions from August 1979 until October 2005. For this paper, we concentrated on sources that were classified as unstable by Feissel-Vernier [2003]. Of the set of 107 geodetic sources, which includes the most frequently observed sources in the geodetic VLBI observing program, 23 sources were classified as unstable. Several of these sources show clear systematic linear or nonlinear variation. To illustrate how large the apparent source position variation of sources can be, we show the time series for 4C39.25 and 2145+067 in Figures 1 and 2. Fey et al. [1997] studied 4C39.25 and found consistency between the astrometric position time series and the evolution of the position of source components in VLBA and Mark III images. They observed that the apparent motion in right ascension was decreasing quadratically and that the motion should stop around

1997.7. However, one can see from Figure 1 that the astrometric position has continued to change.

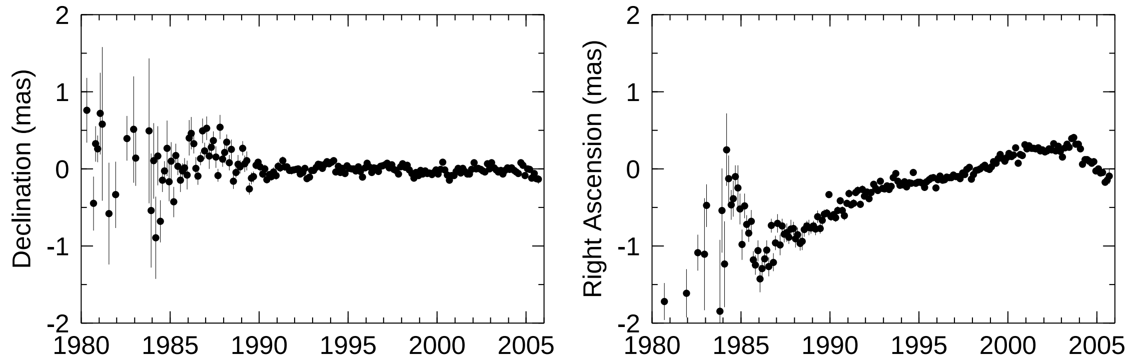

Figure 1. Radio source position time series in right ascension and declination for 4C39.25. Positions shown are 1.5 month averages

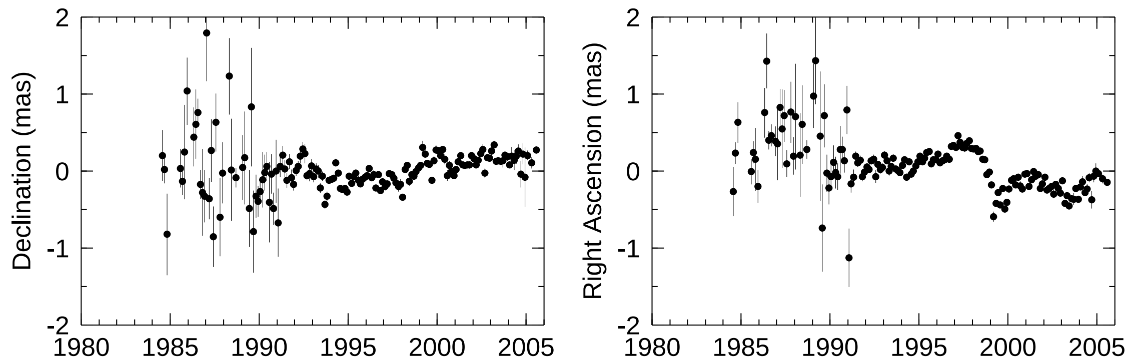

Figure 2. Radio source position time series in right ascension and declination for 2145+067. Positions shown are 1.5 month averages

3. Strategies for Modeling Source Position Instabilities

Ideally, one would derive source structure corrections from radio source images of an unstable source and then apply the corrections in the geodetic analysis. However, source image histories are generally not complete and it is a significant effort to correctly register the image of a quasar and to identify its stationary core. For this paper, we have used a more practical approach. We have identified unstable sources from position time series and then modified the estimation strategy to correct the effect of the instabilities. Here, we considered 3 estimation strategies:

A. Estimate all source positions as global parameters based on observations of all sources over all epochs of observation (conventional strategy).

B. Estimate positions for all 105 sources classified as unstable by Feissel-Vernier [2003].

C. Estimate spline parameters to fit nonlinear variations of 8 geodetic sources (0014+813, 0528+134, 1739+522, 2145+067, 2234+282, 2243-123, 4C39.25, and 3C446) among the 23 unstable geodetic sources identified by Feissel-Vernier [2003] and estimate only an offset and rate for 3 other sources (OK290, 0955+476, and 2126-158) with rates greater than 30 μas/yr. For the remainder of the 23 sources, positions were estimated as global parameters.

4. Effect of Source Position Variations

If source position instabilities are not modeled, the residual apparent source motion will be absorbed in estimates of other parameters. Figures 3 and 4 show the effect on nutation in obliquity using estimation strategies B and C rather than the conventional strategy A. These difference plots have a similar systematic variation, although the weighted root mean square (WRMS) scatter for the B-A differences (60 μas) is significantly greater than for the C-A differences (26 μas) since so many source positions (105) are being estimated as arc parameters. The differences $\delta\epsilon(t)$ in both plots appear to have a variation with an amplitude of about 25 μsec at a period that is close to the 18.7 year nutation period.

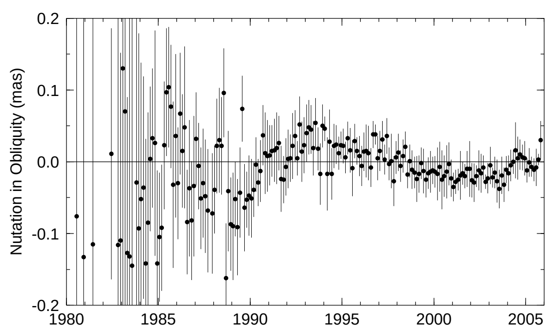

Figure 3. Effect on nutation in obliquity estimates when strategy B is used instead of A. For clarity, 1.5 month averages of the A-B differences are plotted

5. Determining the Best Estimation Strategy

One way of evaluating different stategies of parameter estimation is to look at baseline length repeatabilities. In Figure 5 and 6, we compared the repeatabilities from site position solutions using the three estimation strategies discussed in this paper. The repeatabilities using strategy B were worse than the conventional approach A and slightly better using stategy C, but only by at most 0.5 mm. These tests appear to show that the terrestrial reference frame is not very sensitive to these choices of estimation approach.

To assess the EOP accuracy of the different estimation strategies, we compared the EOP and nutation estimates from simultaneous independent VLBI networks. We used the set of 80 simultaneous CORE-A and NEOS-A experiments during the period 1997-2000. Table 1 summarizes the statistics of these differences. The strategy B of estimating for each session the positions of all

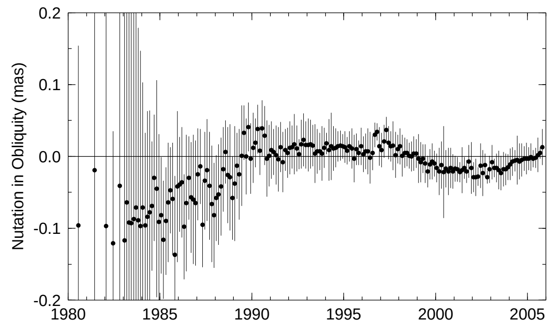

Figure 4. Effect on nutation in obliquity estimates when strategy C is used instead of A. For clarity, 1.5 month averages of the A-C differences are plotted

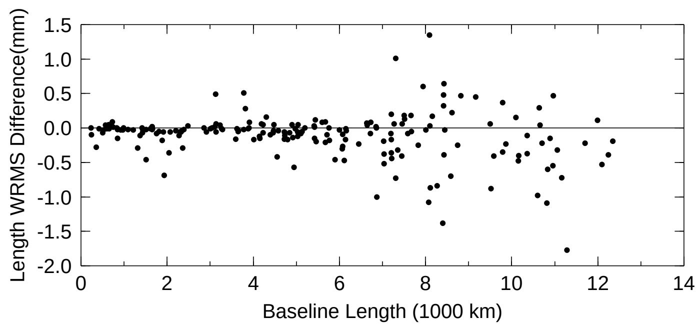

Figure 5. Improvement in baseline length wrms repeatability with strategy C compared with A in the sense wrms(A)-wrms(C)

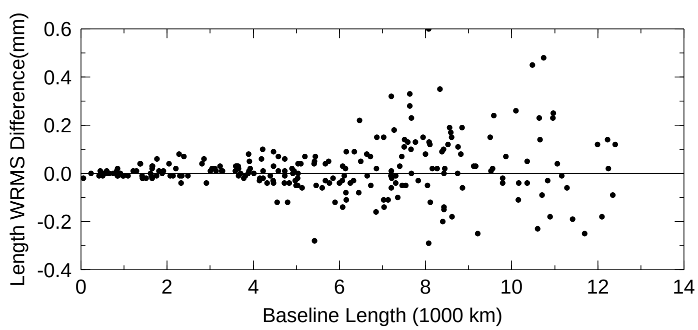

Figure 6. Improvement in baseline length wrms repeatability with strategy B compared with A in the sense wrms(A)-wrms(C)

sources classified as unstable by Feissel-Vernier [2003] leads to WRMS and bias differences that are mostly larger than the standard strategy A (except for X-pole). Strategy C yields smaller biases and WRMS differences for most components than the conventional approach A.

Table 1. NEOS-A minus CORE-A simultaneous session differences

Parameter	A		B		C	
	WRMS	Bias	WRMS	Bias	WRMS	Bias
X-pole (μas)	221	55±15	203	31±15	207	32±15
X-pole rate (μas/d)	523	25±49	556	54±51	511	30±49
Y-pole (μas)	154	12±12	153	28±13	152	18±12
Y-pole rate (μas/d)	556	-78±45	558	-79±47	542	-70±45
UT1 (μs)	8.9	1.1±0.6	9.3	2.4±0.6	9.1	2.2±0.6
UT1 rate (μs/d)	19.2	-4.4±1.8	19.3	-3.8±1.9	18.6	-4.1±1.8
Psi (μas)	376	152±29	374	143±32	375	153±29
Eps (μas)	142	39±11	159	50±12	138	30±11

6. Conclusions

The position time series of many of the radio sources observed by geodetic networks have significant systematic variations. These variations can be nonlinear and can have large linear rates. We found that estimation of additional position parameters for unstable sources improves the internal accuracy of EOP and nutation estimates. Estimation of spline parameters for a subset of 11 of the 105 sources identified by Feissel-Vernier [2003] yields better accuracy than estimation of all 105 unstable source positions as arc parameters (estimated for each experiment session). Not modeling the instability of these sources appears to lead to a cyclic variation in estimates of nutation in obliquity that has a period close to the 18.7 year nutation period. In this paper, we mainly considered the effect of the most frequently observed sources, which are the 107 sources in the geodetic observing catalog. In the future, we will examine the stability of sources not currently in the geodetic catalog. In weekly R1 sessions over the last two years, we have been monitoring the positions of candidate sources not in the current catalog. We plan to use this information combined with previous source position histories to add new stable sources to the geodetic catalog and remove unstable sources.

7. Acknowledgements

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References

[1] A. L. Fey, "The Proper Motion of 4C39.25," Astron. J., Vol. 114, No. 6, 2284-2291, 1997.

[2] M. Feissel-Vernier, "Selecting Stable Extragalactic Compact Radio Sources from the Permanent Astrogeodetic VLBI Program," Astron. Astrophys.,Vol. 403, 105-110, 2003.