Direct estimation of the Solar acceleration using geodetic/astrometric VLBI observations

Minghui Xu, Guangli Wang & Ming Zhao
Shanghai Astronomical Observatory, CAS

7, Mar, 2012
Madrid, Spain
7th IVS General Meeting

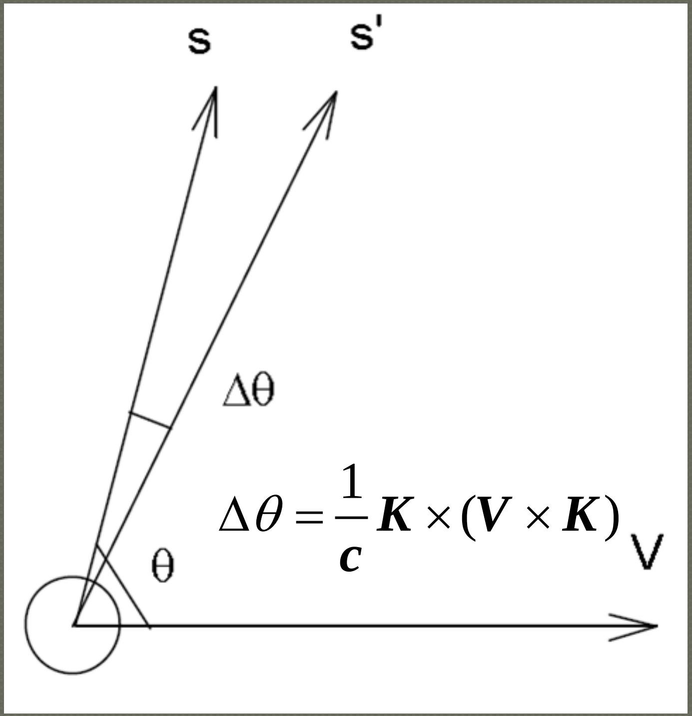
Contents

Introduction (1/2)

- The Sun accelerates as it travels in the Galaxy which causes the secular aberration drift.
- This effect has the similar nature of the physical proper motion with the magnitude of up to 4-5 uas/yr .
- Proportional to time
  30 years ➡ more than 100uas

It affects the ICRF systematically!

(Eubanks et. al. 1995, Sovers et. al. 1998, Perryman et. al. 2001, Kovalevsky 2003, Kopeikin & Makarov 2006, Titov 2011)



$$\Delta\theta = \frac{1}{c}\boldsymbol{K} \times (\boldsymbol{V} \times \boldsymbol{K})$$

Introduction (2/2)

- The relationship between this effect and the Solar acceleration

$$\vec{k}_t = \vec{k}_0 + \frac{1}{c}\vec{k}_0 \times \left(\vec{a} \times \vec{k}_0\right)\left(t - t_0\right)$$

This is the classical form.

One assumption here is the acceleration is a constant in these 30 years.

Two methods(1/2)

- "Global solution"

-The acceleration was estimated as a three dimension vector and a global parameter

-The partial equation:

$$\frac{\partial \tau}{\partial \vec{a}} = -\frac{1}{c^2}\left[\vec{b}_0 - \left(\vec{b}_0 \cdot \vec{k}_0\right)\vec{k}_0\right](t - t_0)$$

Two methods(2/2)

- “Time-series solution”

-Step 1: the time-series of the velocity adjustment of the observer

$$\frac{\partial \tau}{\partial \vec{V}} = -\frac{1}{c^2}\left[\vec{b}_0 - \left(\vec{b}_0 \cdot \vec{k}_0\right)\vec{k}_0\right]$$

-Step 2: obtain the linear trend from the time-series by least square

The estimation of the acceleration and the velocities was realized by the USER_PARTIAL, a function of the Calc/Solve software.

Data

A global set of VLBI data:

• from 1980.4 to 2011.10, more than 7 million observations

•4632 24-h sessions: 1) duration > 18 hours
2) the length of longest baseline > 3000km

Generally, the parameterization is the same as the routine VLBI data analysis. But some strategies were different for time-series solution.

Results

- Global solution

Three components in the Galactic coordinate system:

(7.47±0.46, 0.17±0.57, 3.95±0.47) mm/s/yr

Divided the entire set of VLBI data into fours groups and estimated the acceleration with the same analysis configuration, respectively.

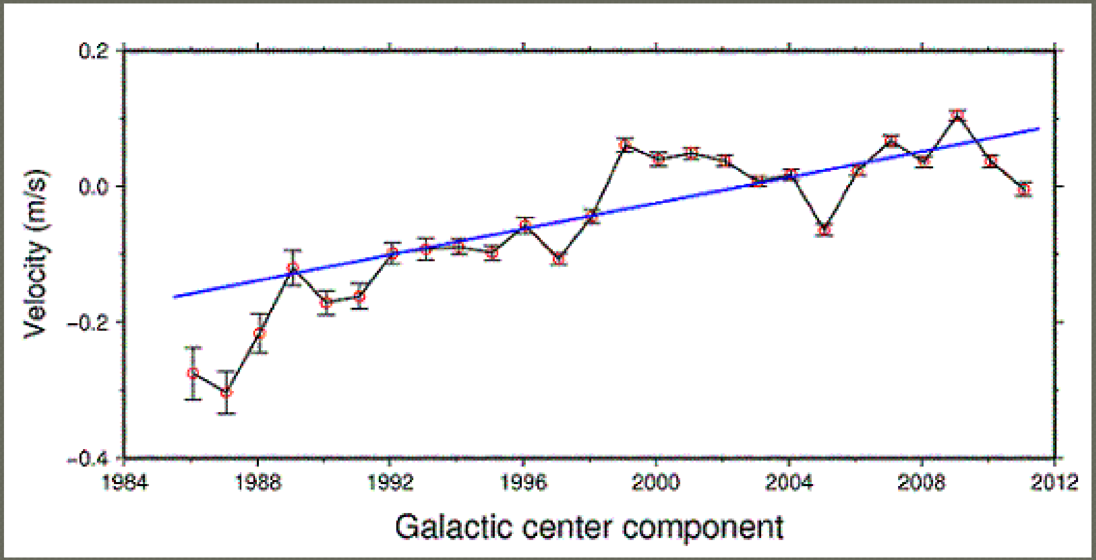
Num. of session	X(Galactic enter)	Y	Z(Galactic pole)
3474	7.44±0.53	0.63±0.67	3.27±0.54
3474	7.28±0.53	-0.12±0.66	3.93±0.53
3474	7.22±0.53	0.06±0.66	4.55±0.54
3474	7.86±0.53	-0.41±0.67	3.98±0.54

Notes. All sessions are sorted and numbered in time order. Then the first group does not contain the sessions whose number are 4n+1; the second group does not contain the sessions whose number are 4n+2; ..., and so on.

Results

- Time-series solution

The velocity was estimated once a year and then the linear trend was fitted.

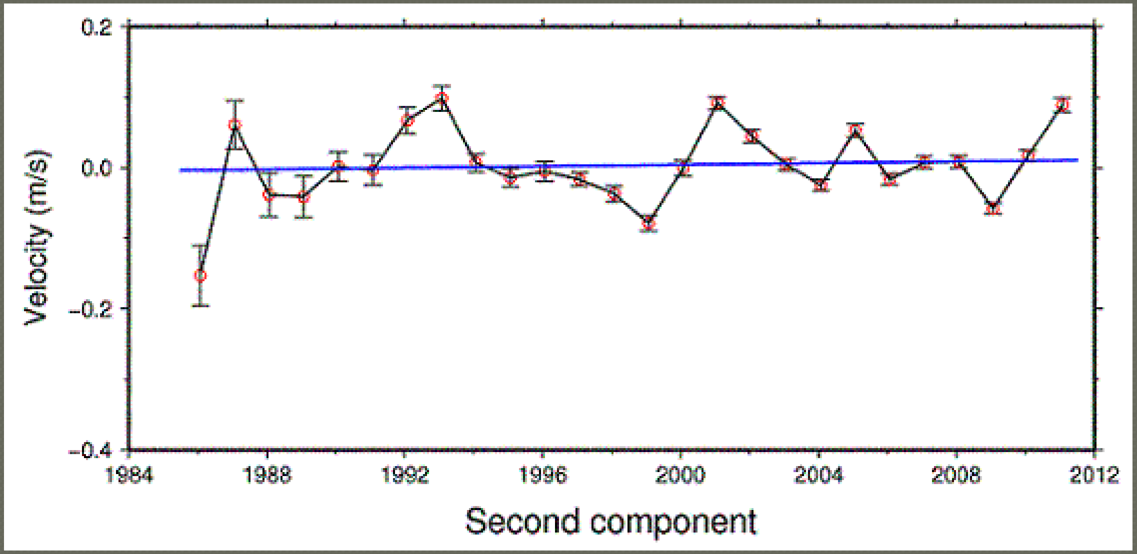


The galactic center component is 9.10±1.74 mm/s/yr.

Results

- Time-series solution

The velocity was estimated once a year and then the linear trend was fitted.

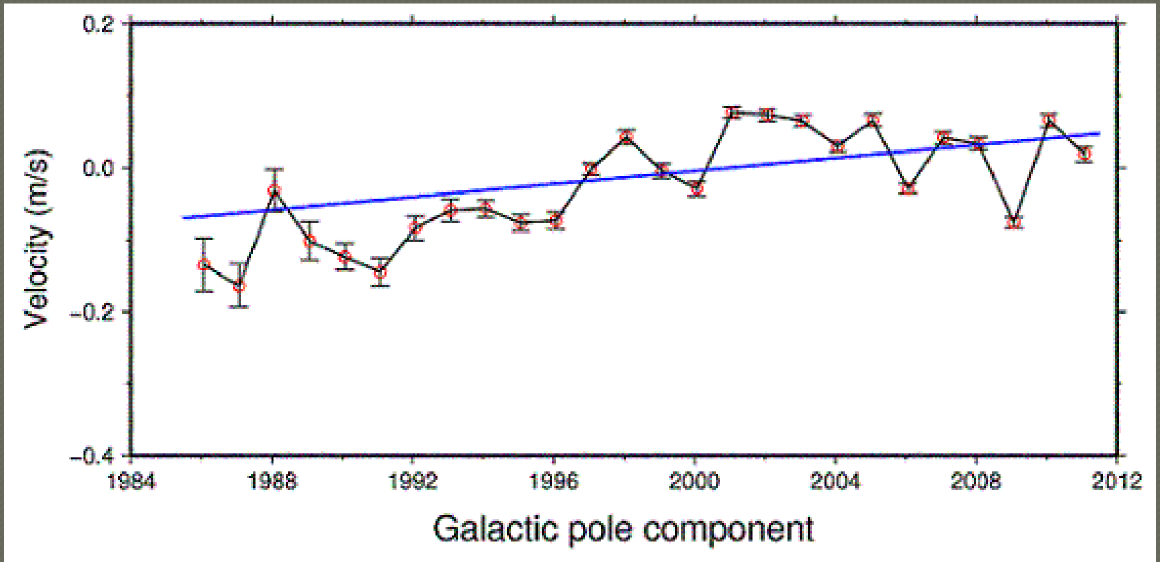


The second component is 0.56±1.60 mm/s/yr

Results

- Time-series solution

The velocity was estimated once a year and then the linear trend was fitted.



The Galactic pole component is 4.53±1.88 mm/s/yr

Comparison (1/3)

- Global solution vs. time-series solution

  (7.47±0.46, 0.17±0.57, 3.95±0.47) mm/s/yr

  (9.10±1.74, 0.56±1.60, 4.53±1.88) mm/s/yr

- This comparison shows that results of two methods are consistent:

  •The result of the global solution shows much better accuracy.
  •The result of time-series solution shows the velocity variation in detail.

The estimate of the global solution was chosen as the final value.

Comparison (2/3)

- Our estimate vs. Titov's estimate

Through post fitting the coordinate time series of the 497 radio sources, (Titov et al., 2011) obtained the acceleration vector (6.4 $\pm$1.5uas/yr, $\alpha = 263^0 \pm 11^0, \delta = -20 \pm 12^0$)

Representing this result in the same unit as our result:

(8.3$\pm$2.2, 1.3$\pm$2.2, 0.9$\pm$1.6) mm/s/yr

•Our result (7.5 $\pm$0.5, 0.3$\pm$0.6, 4.0$\pm$0.5) mm/s/yr

- Differences:

•The Galactic pole components are significant different.
•The other two components of our result are a little smaller than those of Titov
•The accuracy of our result is much better.

Comparison (3/3)

- Our estimate vs. Galactic potential model

  •The galactic center component can be obtained based on the mass model of Galaxy (Paczynski 1990, Dehnen & Binney 1998)

  •For example, to correct the period derivative of the pulsars, (Zakamska & Tremaine 2005) used the Galactic acceleration $2.0\times10^{-10}\,m/s^2$

- Our estimate vs. the latest result

  • Based on BeSSeL survey, (Brunthaler et al. 2011) gave the best values of the Solar galactic radius 8.3±0.23kpc and Solar velocity 251.25 ± 7km/s.

  •Then the acceleration of the sun toward the Galactic centre has the amplitude $2.5\times10^{-10}\,m/s^2$

  Our estimate of this component: $2.4\times10^{-10}\,m/s^2$

Future work

- The third component:

•It has almost the same amplitude as the component of Galactic center

•It is larger than the expected acceleration of the Z oscillation perpendicular the Galactic plane (Gould & Vandervoort 1972, Cox 2000)

•It points to the Galactic pole

How to explain it?

Thank you for your attention.