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Estimating the velocity of the barycenter of the Solar system

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2015.05.19

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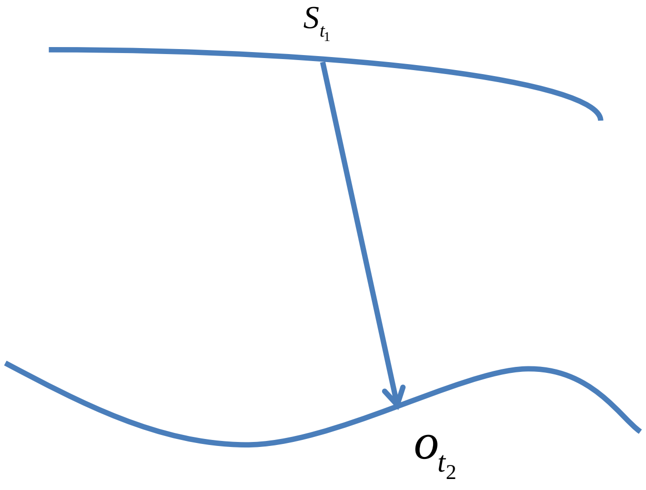
Content

Motivation

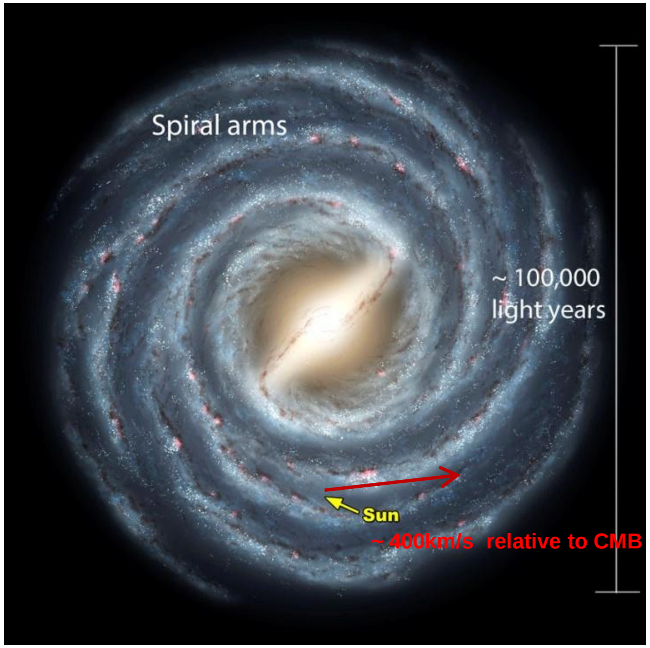
Four factors that can cause the proper motion of radio source:

1. the variation of the source structure
2. secular aberration drift caused by the acceleration of the barycenter
3. proper motion caused by the peculiar motion of the source in space
4. parallax caused by the motion of the barycenter in space



Motivation

The velocity of the barycenter in space



From:http://ds9.ssl.berkeley.edu/solarweek/MONDAY/facts.html

Motivation

The principle of the Kinematical Celestial Reference Frame:

1. model all systematical behaviors in the variation of positions of reference points
2. assume the motions of reference points as random

Taking FK5 as example, three effects should be determined:

1. Differential rotation of the Galaxy
2. Parallax correction for the motion of the Sun with respect to the local standard of rest
3. Precession

Motivation

Three questions to be addressed in this report:

1. How does the secular parallax caused by the motion of barycenter in space affect the determination of the acceleration of barycenter?

2. Can VLBI observations detect the velocity of the barycenter with respect to radio sources? If yes, to what level?

3. Should we consider the systematic variation caused by the secular parallax in VLBI data analysis?

Method and data

Secular aberration drift and secular parallax models:

$$\vec{K}_t = \vec{K}_0 - \frac{(\vec{K}_0 \times \vec{V}) \times \vec{K}_0}{d}(t - t_0) + \frac{(\vec{K}_0 \times \vec{a}) \times \vec{K}_0}{c}(t - t_0)$$

Calculate the partial derivative:

$$\frac{\partial \tau}{\partial \vec{K}_t} = -\frac{\vec{b}}{c + \vec{K}_t(V_\oplus \vec{+} \vec{\omega_2})} + \frac{\vec{K}_t \cdot \vec{b}}{c^2}(\vec{V_\oplus} + \vec{\omega_2})$$

$$\frac{\partial \tau}{\partial \vec{a}} = \frac{\partial \tau}{\partial \vec{K}_t} \cdot \frac{\partial \vec{K}_t}{\partial \vec{a}}$$

$$\frac{\partial \tau}{\partial \vec{V}} = \frac{\partial \tau}{\partial \vec{K}_t} \cdot \frac{\partial \vec{K}_t}{\partial \vec{V}}$$

Method and data

Cosmological distance:

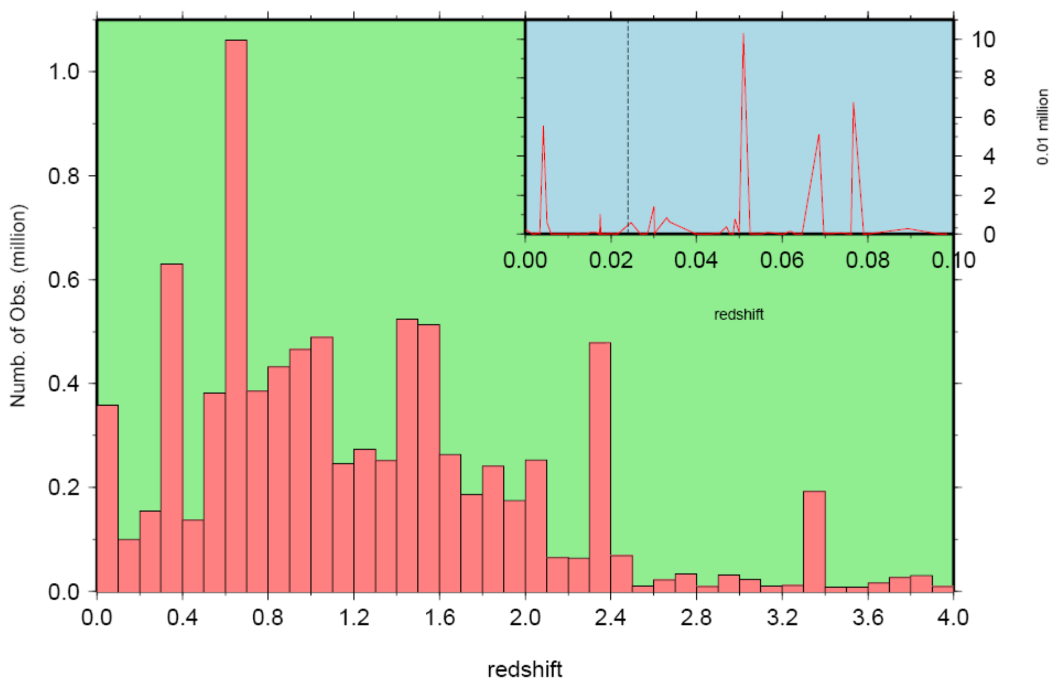
$$d_A = \frac{c[z + \frac{1}{2}(1 - q_0)z^2]}{H_0(1+z)^2}$$

Depends on the cosmological model of the Universe:

1. Deceleration parameter of the Universe
2. Hubble constant

Method and data

Observations and redshift



Number of observations as a function of redshift

1. 950 sources in the ICRF2 with redshift have about 90% of all observations.
2. redshift of most radio sources is in the range of 0.2 – 2.4
3. redshift of the order of 1 corresponds to the cosmological distance of 10 billion light-years

Method and data

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ICRF2 sources with redshift less than 0.03

Table 1: Statistic information of the radio sources with red shift less than 0.03.

Source name	Num. of Obs.	Num. of Sess.	First obs.	Last obs.	Red shift
M81	2207	77	1993.06.02	2009.10.07	0.000113
CEN-A	72	8	1990.08.06	2002.05.14	0.001825
M84	667	28	1996.08.07	2009.10.07	0.003392
M104	40	14	1995.06.14	2005.06.30	0.003416
3C274	55681	1646	1986.03.12	2014.04.29	0.004283
NGC1052	5851	257	1988.01.15	2014.04.15	0.005037
2254-367	19	4	2002.01.31	2004.05.12	0.006011
NGC4261	79	3	1996.08.07	2007.01.24	0.007378
NGC6500	32	4	1996.08.07	2002.05.14	0.010017
NGC3894	120	7	1994.08.12	2000.08.30	0.010751
1333-337	189	5	2008.01.23	2013.12.11	0.012465
1343-601	22	4	2003.09.04	2004.05.12	0.012916
NGC5675	85	10	1996.08.07	2000.05.22	0.013252
1718-649	93	22	1990.08.06	2008.07.22	0.014428
NGC0262	981	26	1996.05.15	2010.04.12	0.015034
NGC0315	869	22	1996.05.15	2004.06.21	0.016485
NGC5141	8	2	1999.04.28	2004.05.08	0.017379
3C84	10208	282	1979.08.04	2013.07.18	0.017559
0147-076	18	8	1994.06.30	2005.06.01	0.017666
0056-572	36	8	1989.04.09	2003.10.28	0.018000
0125+628	81	1	2006.08.30	2006.08.30	0.018300
0131-522	417	66	1990.09.27	2014.04.22	0.020000
UG01841	45	2	1999.09.27	2004.03.03	0.021258
0651+410	230	7	1996.06.07	2004.06.01	0.021562
NGC3862	274	17	1996.10.29	2004.05.27	0.021718
NGC6251	5825	211	1997.08.27	2014.03.24	0.024710
2201+044	42	1	2007.06.26	2007.06.26	0.027000
2152-699	23	7	1990.08.06	2003.11.04	0.028273
NGC1218	1071	36	1996.08.07	2010.05.17	0.028653

1. 29 sources in the ICRF2 have redshift less than 0.03

2. Taking the value of solar velocity as 400km/s, the parallax effect for a source with redshift less than 0.03 is larger than 1 uas/yr

Method and data

1. Calc/Solve, USER_PARTIAL
2. Routine Global solution
3. 1980.04 – 2013.04 VLBI 24hr observations
   about 8.1 million observables

Result

Estimate the solar velocity when correcting the aberration effect caused by the solar acceleration

Direction	Estimates (km/s)	Uncertainty (km/s)
X	-7.49D3	1.02D3
Y	-9.06D3	7.98D2
Z	-1.14D4	1.15D4

(in Equatorial coordinate system)

Acceleration ($mm \cdot s^{-1} \cdot yr^{-1}$)			Velocity (km/s)		
X	Y	Z	X	Y	Z
-3.78	-7.37	-1.68	-358.6	80.3	-43.2

Taking the acceleration from Xu et al. (2012) for correction and the velocity from Fixsen et al. (1996) for comparison

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Result

Estimate the acceleration and the velocity of the barycenter at the same time

(in Equatorial coordinate system)

	Direction	Estimates	Uncertainty
Velocity (km/s)	X	-5.12D3	1.15D3
	Y	-3.86D3	8.68D2
	Z	-1.22D4	1.39D4
Acceleration (mm/s/yr)	X	-3.21	0.45
	Y	-7.07	0.42
	Z	1.05	0.72

Taking the acceleration from Xu et al. (2012) and the velocity from Fixsen et al. (1996) for comparison

Acceleration $(mm \cdot s^{-1} \cdot yr^{-1})$			Velocity (km/s)		
X	Y	Z	X	Y	Z
-3.78	-7.37	-1.68	-358.6	80.3	-43.2

Conclusion and discussion

1. Existing VLBI data covering about 34 years only have the capacity to constraint the solar velocity to about 10000 km/s, which is much larger than it is expected to be.
2. The systematic variation caused by the relative motion between radio source and barycenter is negligible for the determination of the barycentric acceleration.
3. The variation in position of radio source should be dominately caused by the source structure.
4. Gaia is observing and will observe many more quasars with a wide range of redshifts, so that the motion of the barycenter can be studied.
5. The relationship between the cosmological distance and the astrometric distance of an extragalatic object may then be studied as well.

Thank you very much!

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