Australian Government

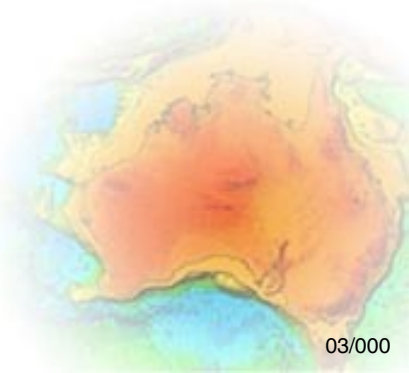
Geoscience Australia

Systematic effects the radio source motion

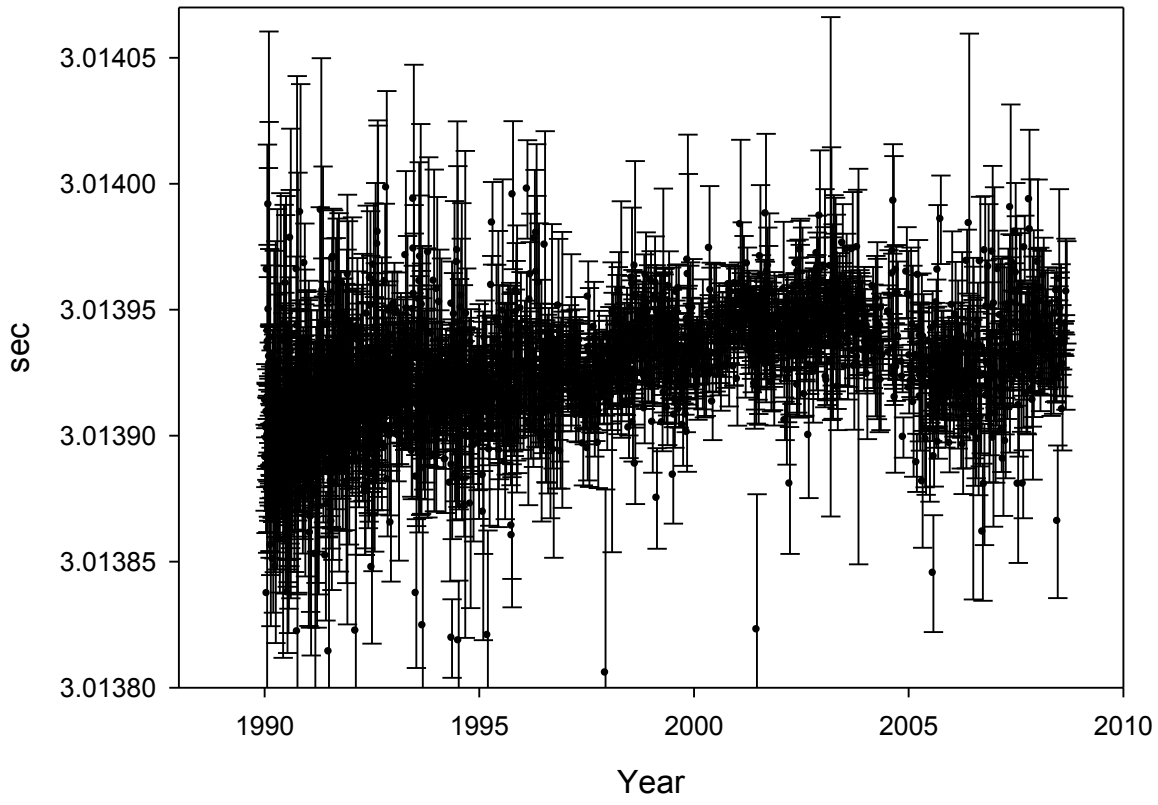
Oleg Titov

19th EVGA Working Meeting, Bordeaux,

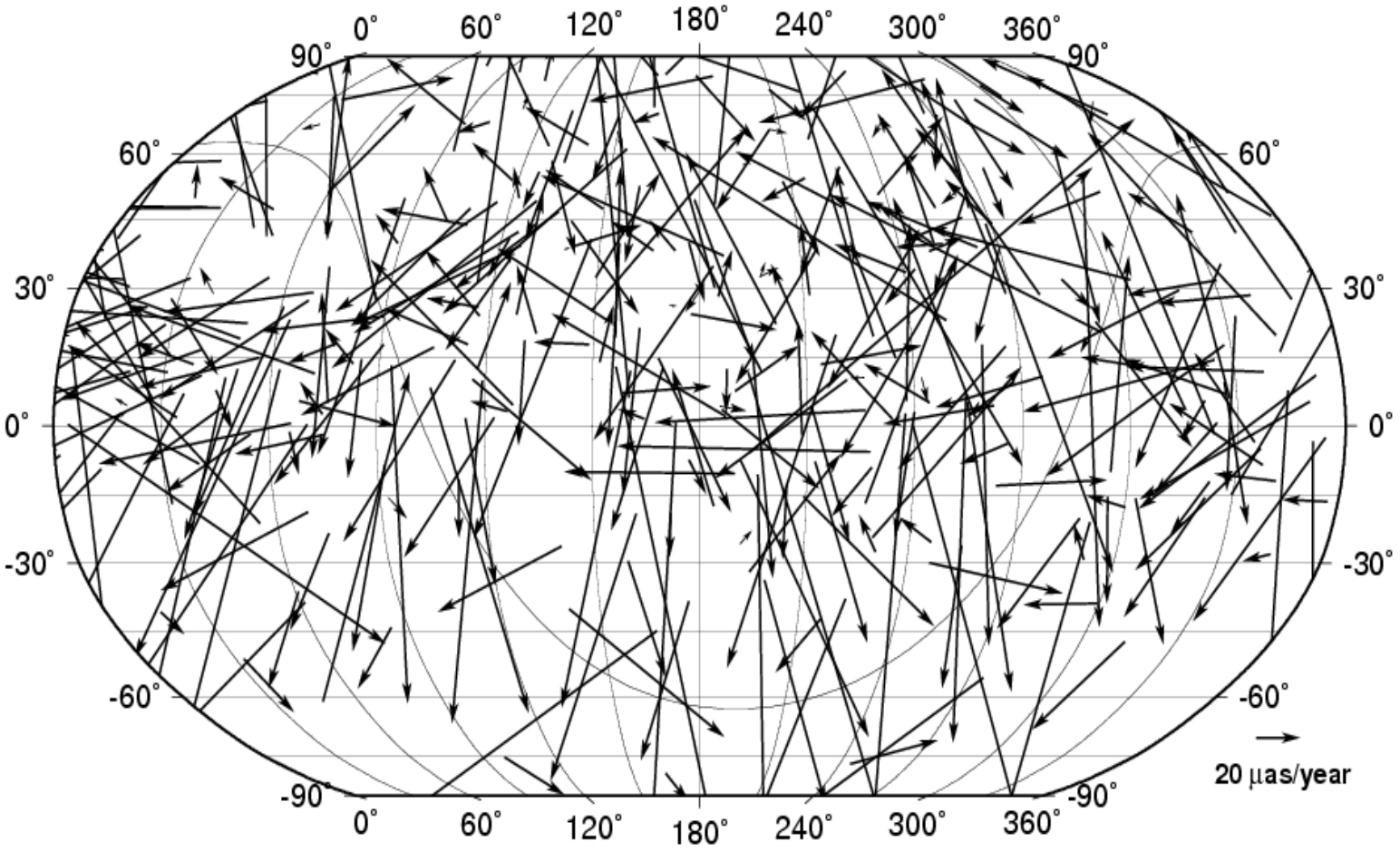
24 March 2009



4C39.25


Right ascension, 4C39.25
sec
3.01405
3.01400
3.01395
3.01390
3.01385
3.01380
1990
1995
2000
2005
2010
Year

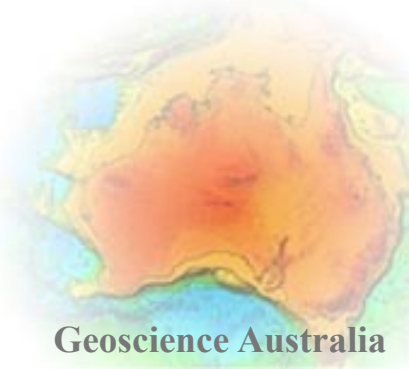
Apparent proper motion



Apparent proper motions look random

Search for systematic has been done (Gwinn, Eubanks et al. 1997; MacMillan 2003)

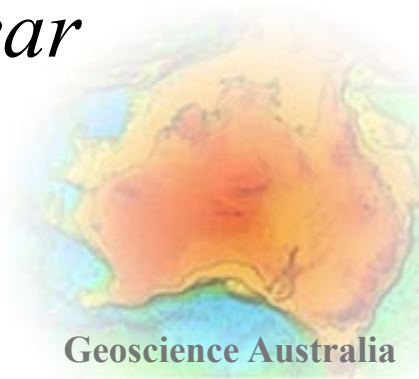
Motivation – detection of the secular aberration drift – 4 μarcsec/year (many authors)



Acceleration of the Solar system due to the Galaxy rotation

Expected acceleration directed towards the centre of the Galaxy
(RA= 270º, DE = -30º)
with magnitude $a = V^2/R$

$$a = 2 \cdot 10^{-13}\, km/\sec^2 \rightarrow \mu = 4\, \mu as/year$$



Systematic proper motions

$L = 1$

electric

harmonic

Secular aberration drift (dipole)

Acceleration of the Solar system barycentre?

$L = 2$

electric

&

magnetic

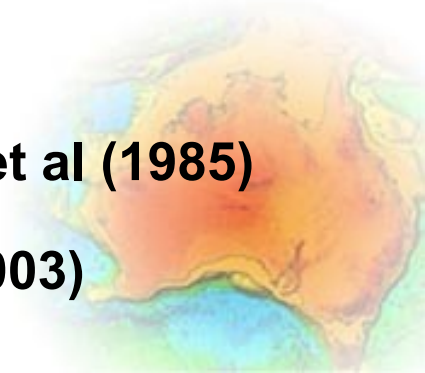
Primordial gravitational waves

Anisotropic expansion of the Universe

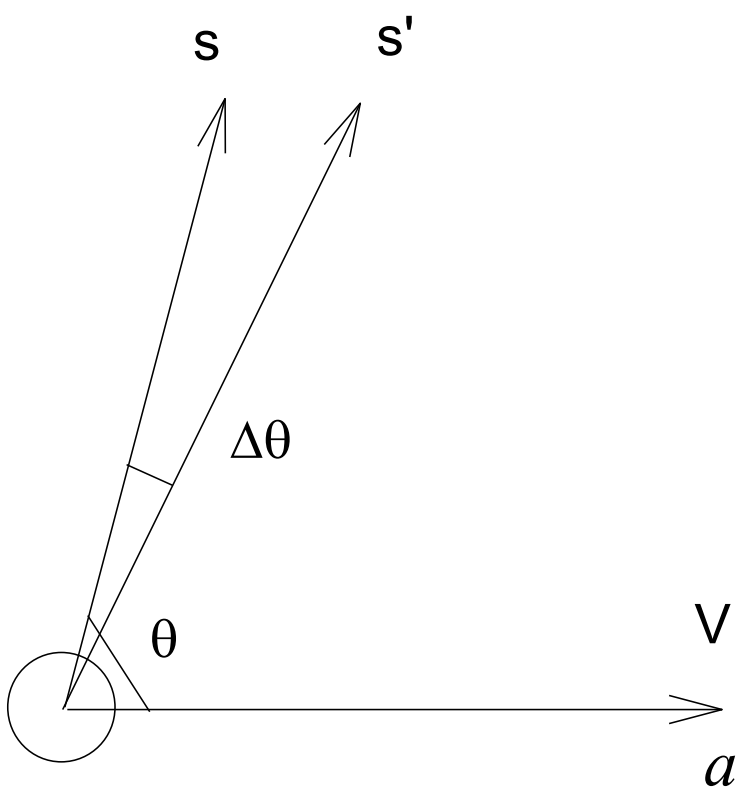
(quadrupole)

Kristian and Sachs (1966), Ellis et al (1985)

Gwinn et al (1997); MacMillan (2003)



Secular aberration and drift



$$\Delta\theta = -\frac{V}{c}\sin\theta$$

$$\Delta\theta + \mu\Delta t = -\frac{V + a\Delta t}{c}\sin\theta$$

$$\mu\Delta t = -\frac{a\Delta t}{c}\sin\theta$$

$$\mu = -\frac{a}{c}\sin\theta$$

Global VLBI solutions

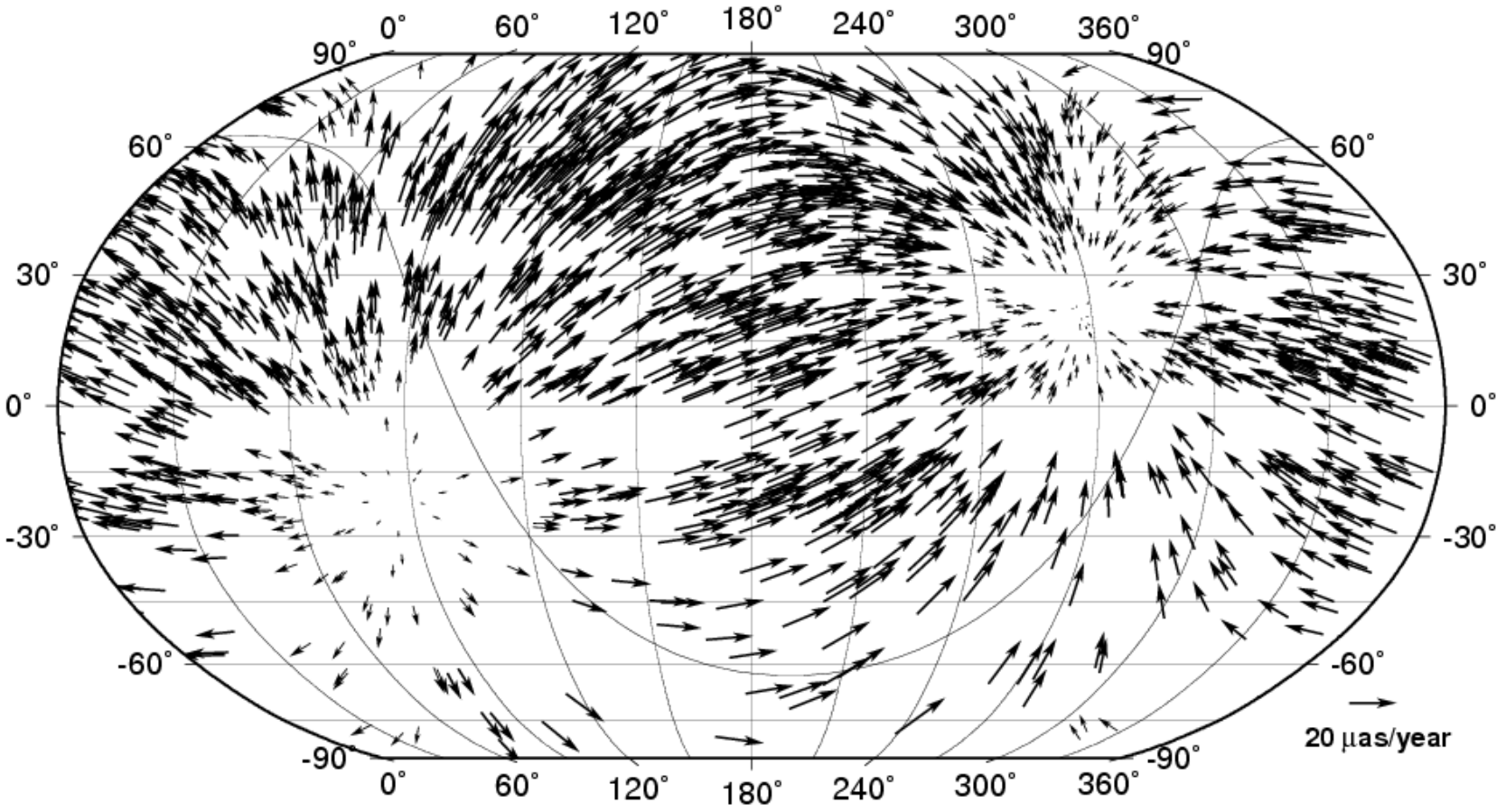
The effect of secular aberration drift can be estimated from analysis of a global set of VLBI data

3724 (3554) daily VLBI sessions since 1980
~ 28 years
~ 4.3 million of observations in total (9% since 2007)
~ 1500 radio sources

Direct adjustment (one-step) to reduce the source structure effect; OCCAM

the amplitudes of spherical harmonics are estimated directly from time delays $\tau \rightarrow$ A(1), A(2), A(3);
MacMillan (2003)

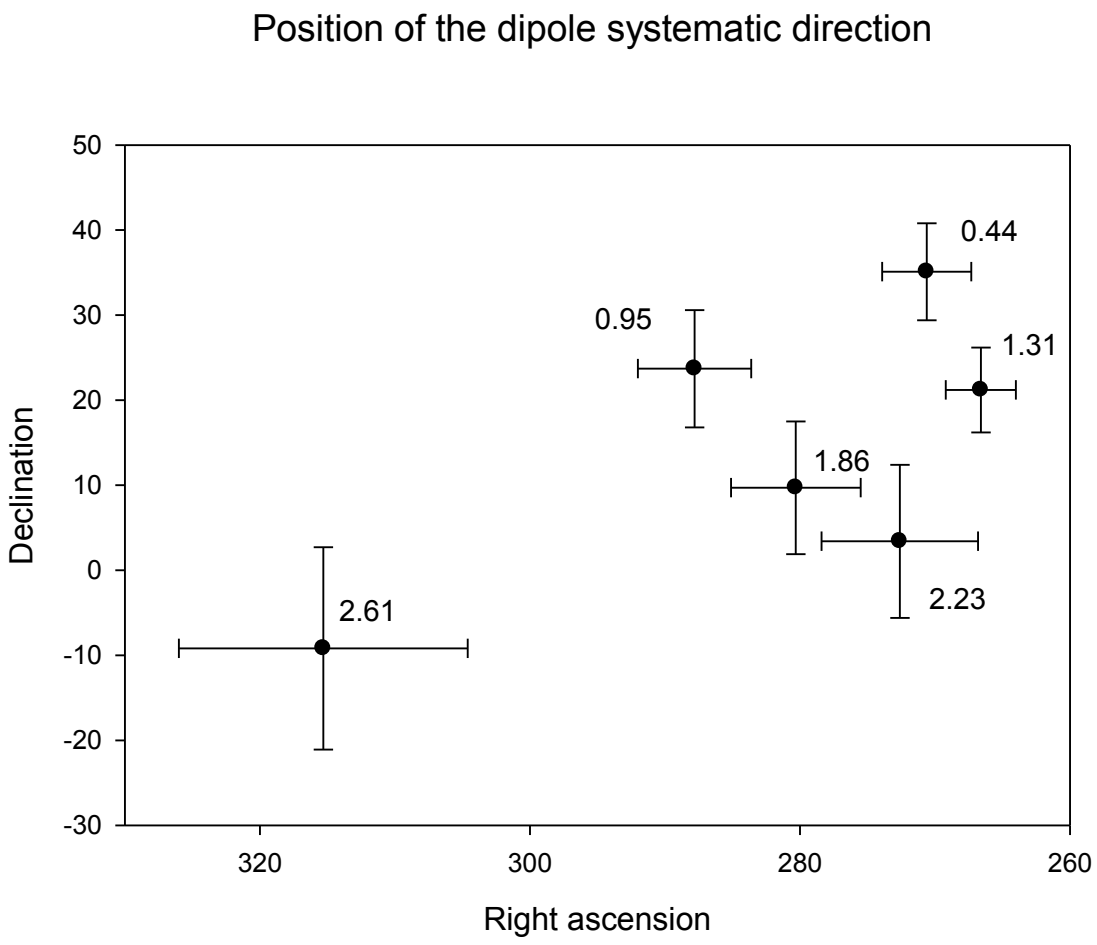
Dipole systematic for all sources

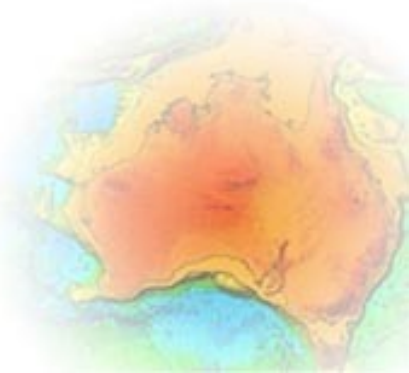


Dipole (L=1) harmonic estimates

Range of z	0<z<0.7 357	0.5<z<1.5 468	All 1530	1.0<z<3.0 542	1.5<z<3.0 312	z>1.7 287
mean z	0.44	0.95	1.31	1.86	2.23	2.61
Acceleration magnitude (μas/year)	23.1 +/- 1.5	18.9 +/- 1.2	21.8 +/- 1.0	15.9 +/- 1.2	15.5 +/- 1.6	15.4 +/- 2.0
RA(deg) DE (deg)	270.6 +/- 3.3 35.1 +/- 5.7	287.8 +/- 4.2 23.7 +/- 6.9	266.6 +/- 2.6 21.2 +/- 5.0	280.3 +/- 4.8 9.7 +/- 7.8	272.6 +/- 5.8 3.4 +/- 9.0	315.3 +/- 10.7 -9.2 +/- 11.9

Dipole systematic

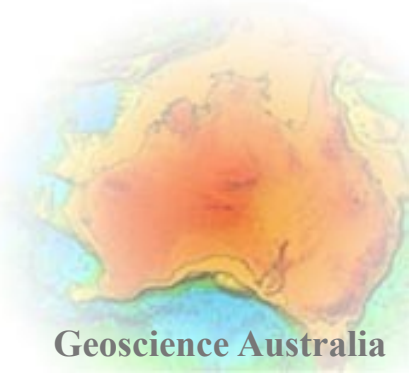




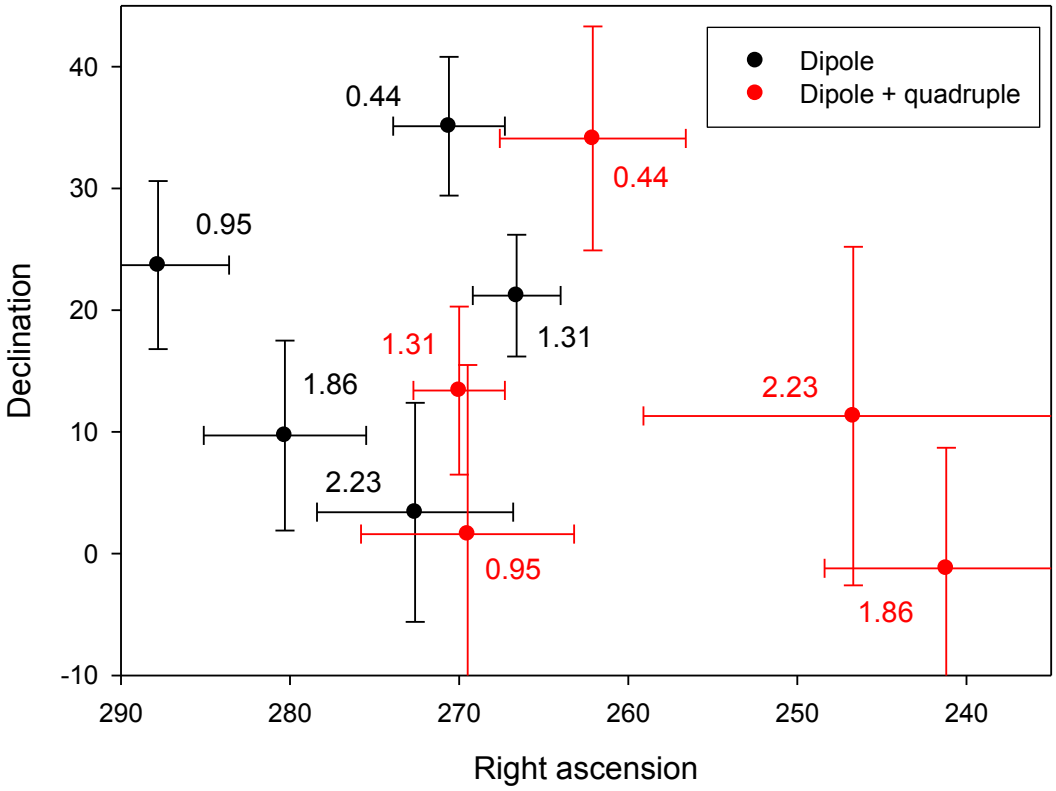
Possible physical interpretations of the effect

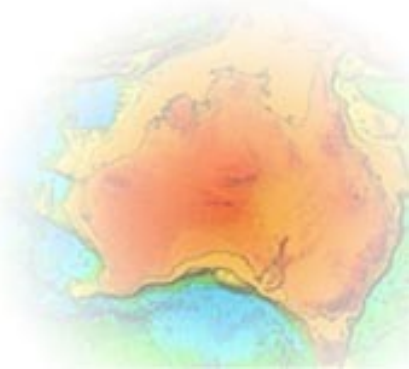
- Large mass near Solar system
- The Universe is not isotropic

L=2 to be added

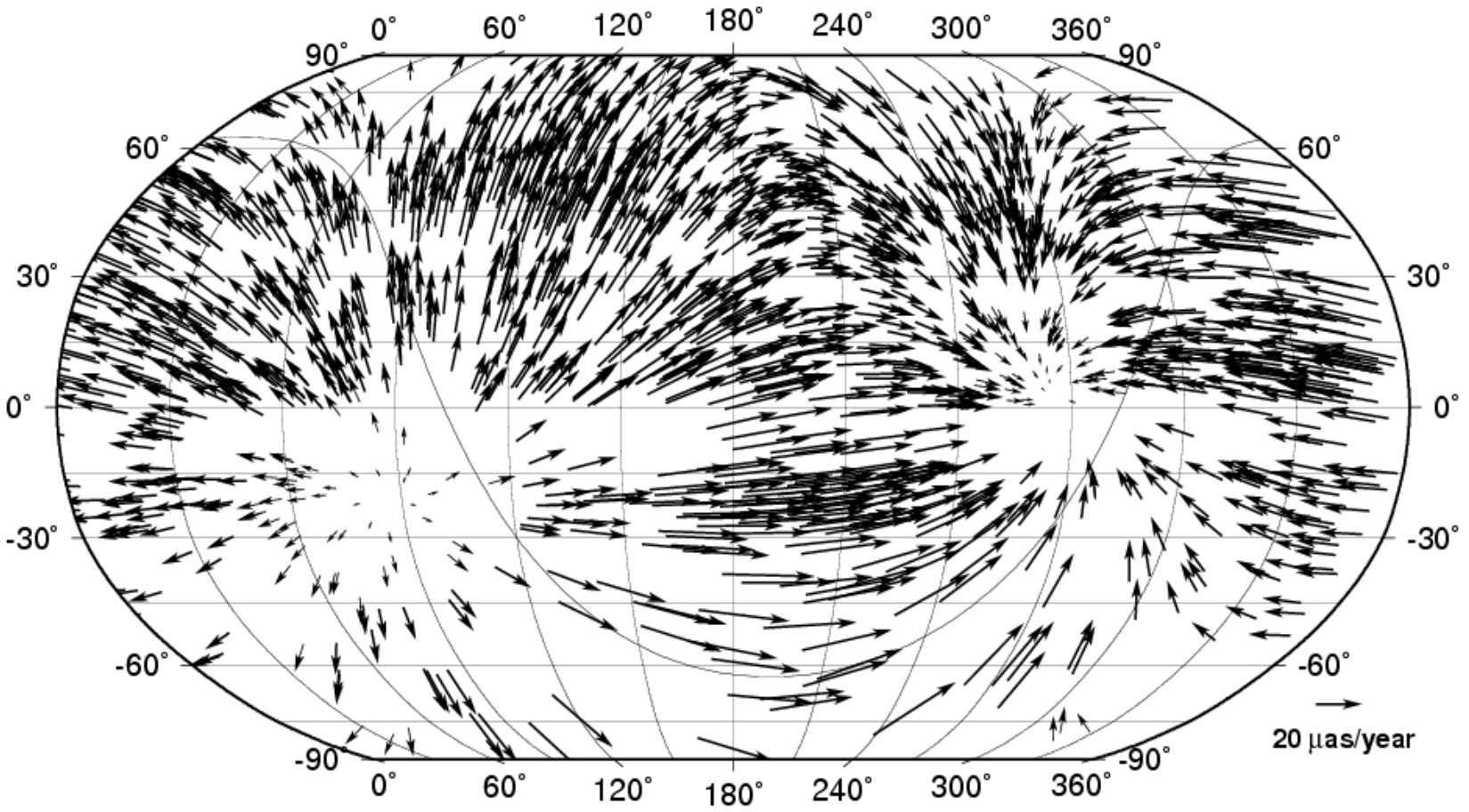


Focal position of the dipole systematic effect

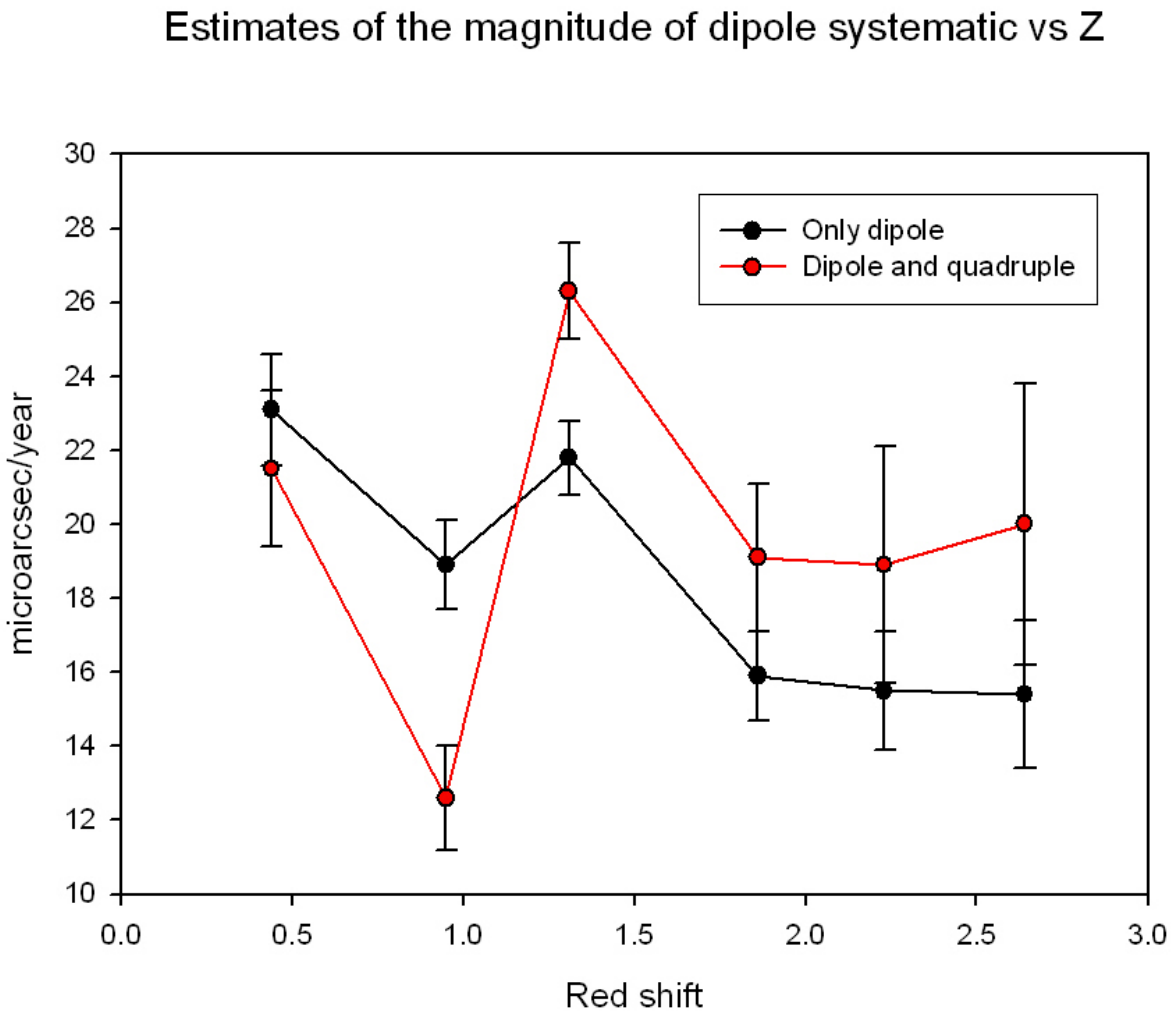


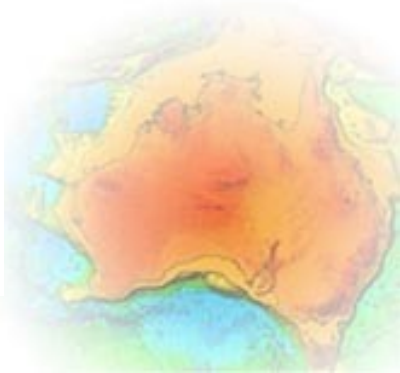


Dipole and quadruple systematic for all sources

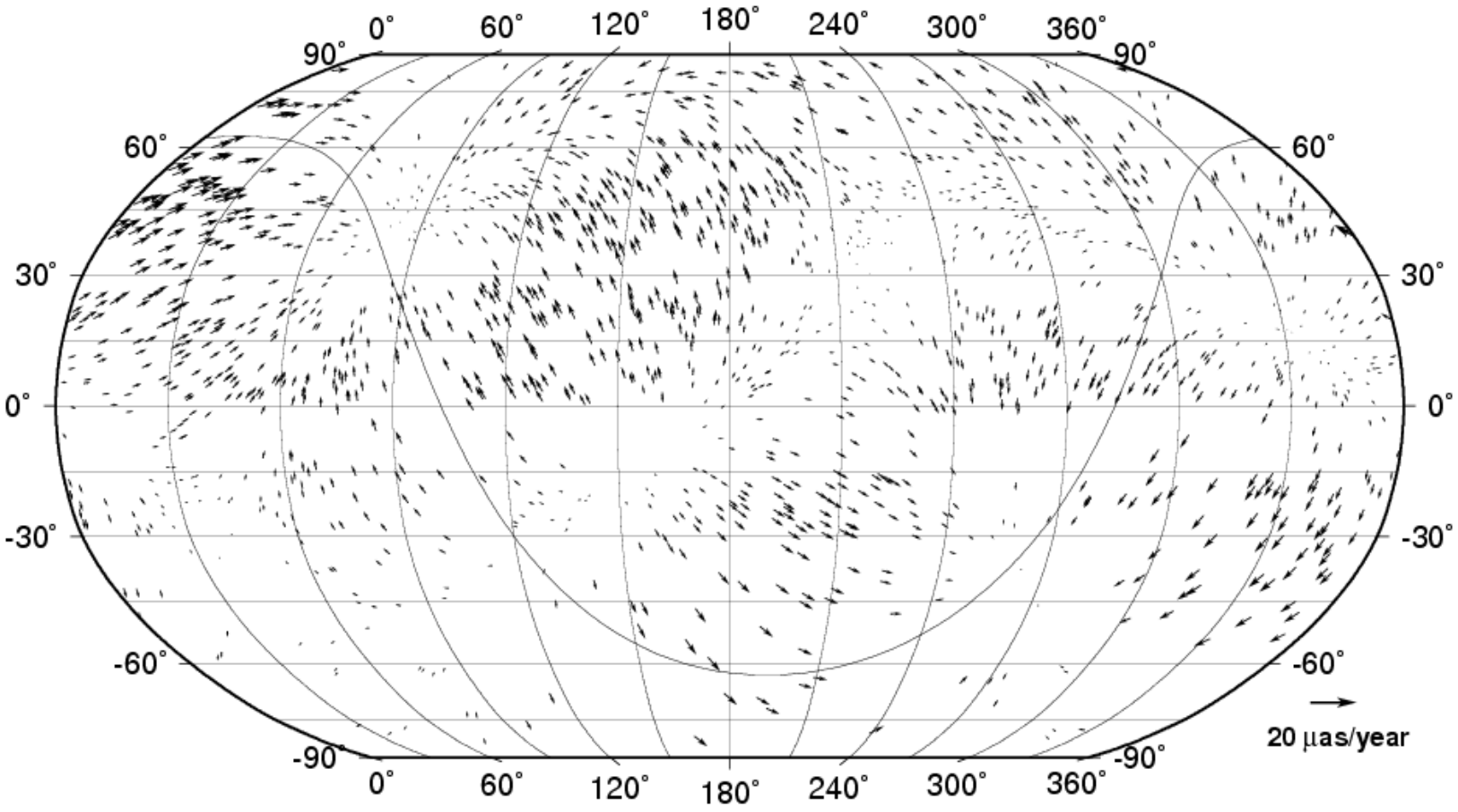


Dipole effect vs red shift

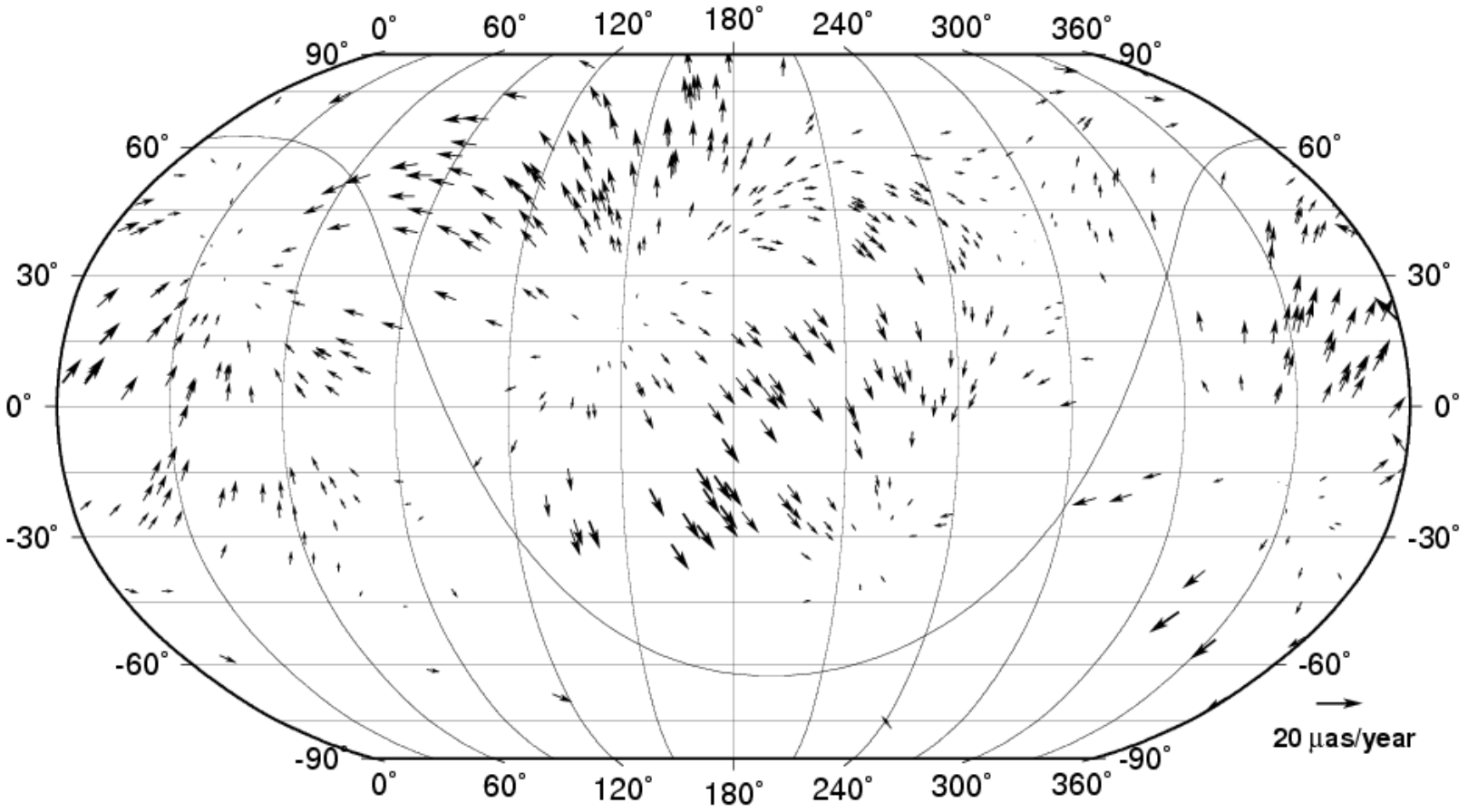




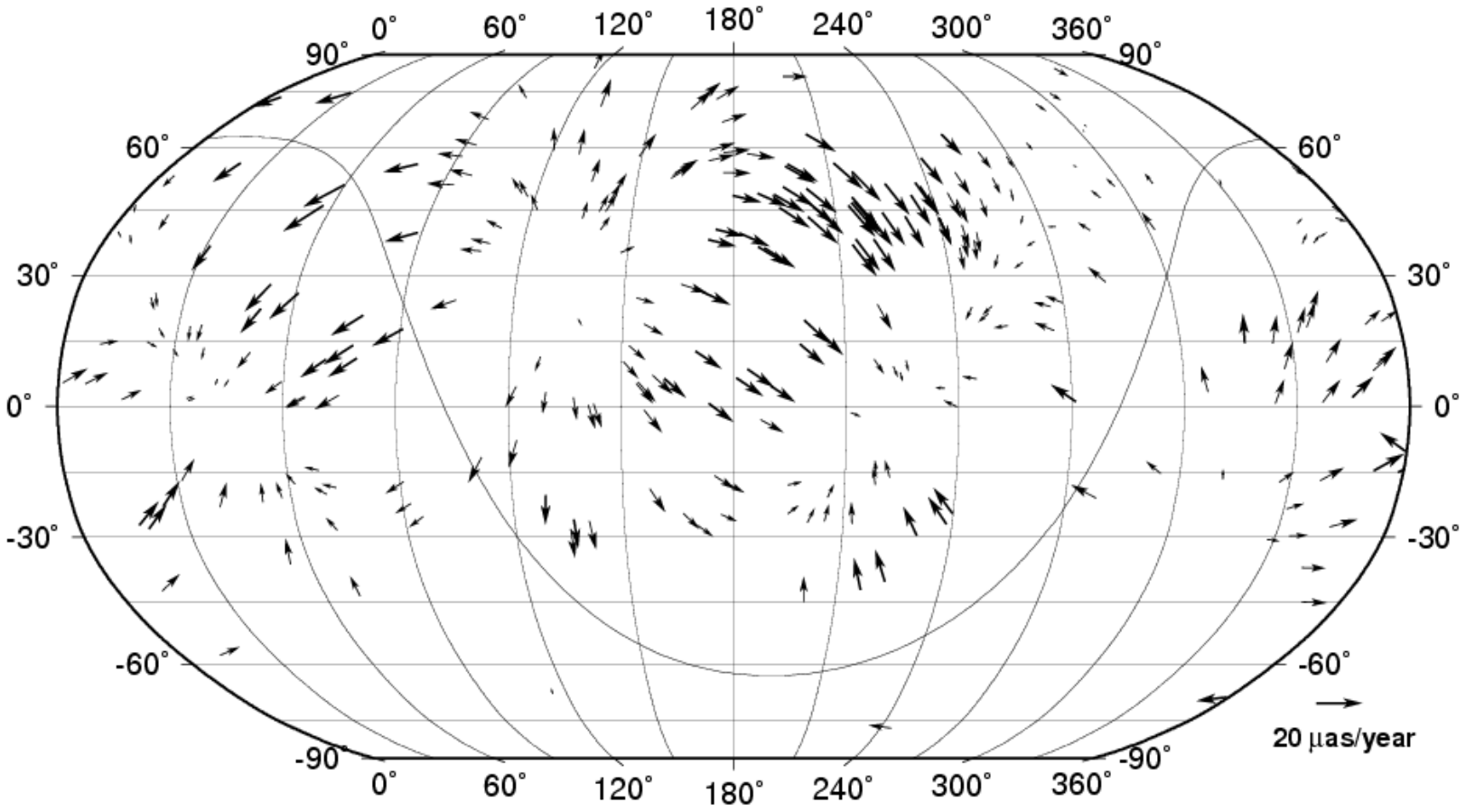
Quadrupole systematic for all sources



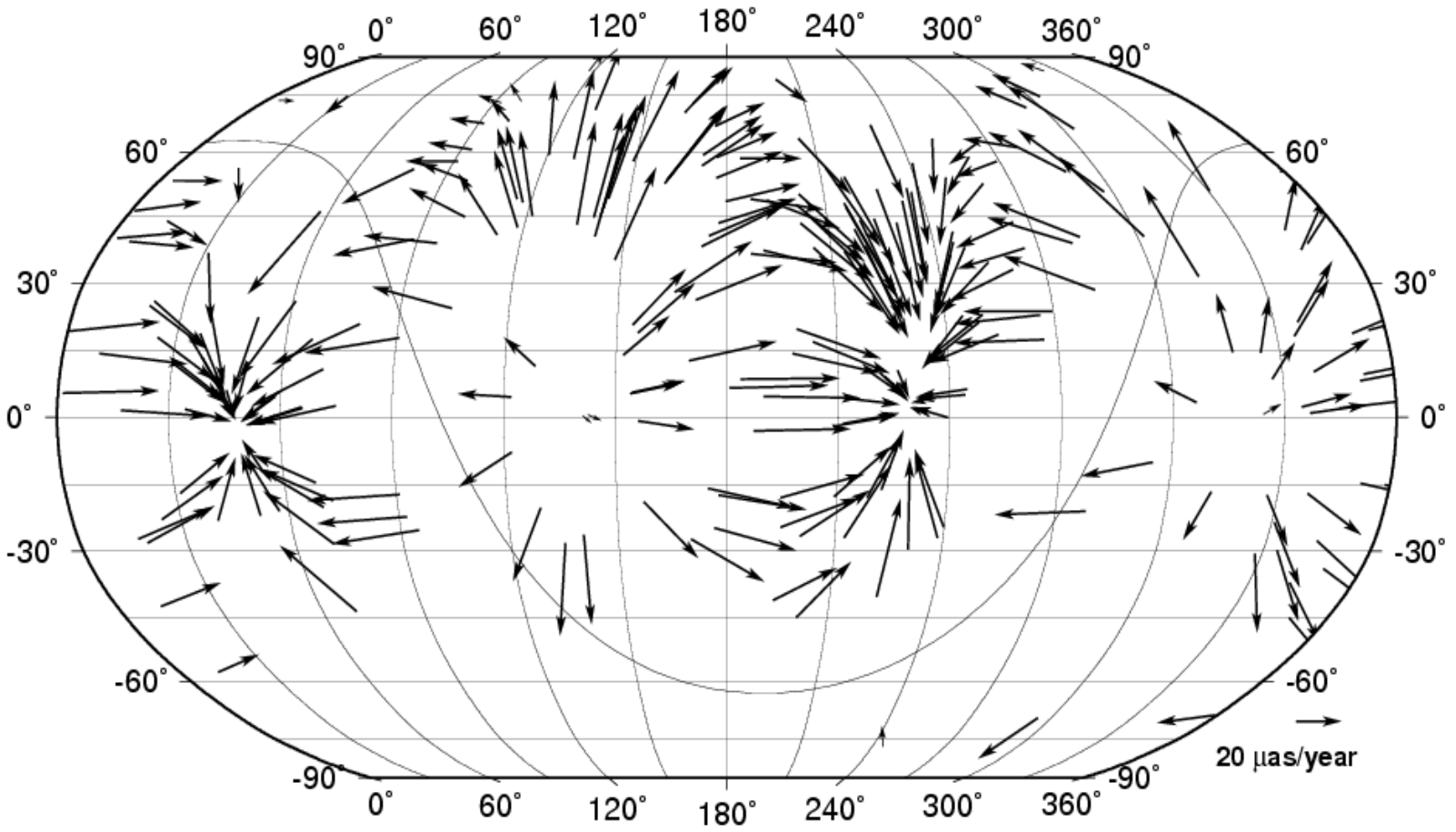
Quadrupole for sources 1<z<3



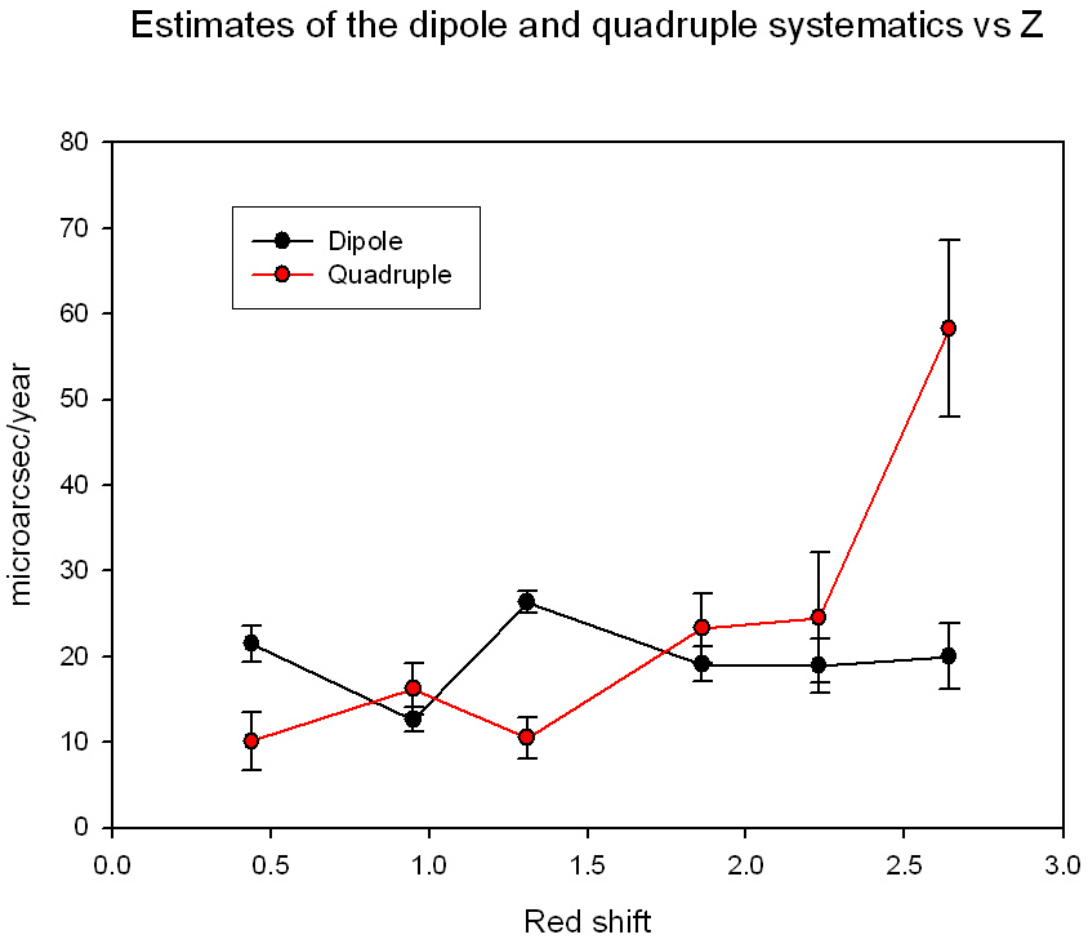
Quadrupole for sources 1.5<z<3

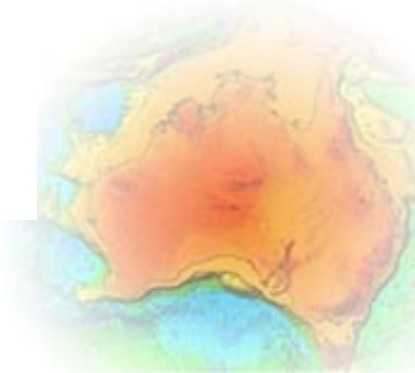


Quadruple for sources z>1.7



Dipole and quadruple vs Z





Quadrupole effect (interpretation)

Kristian and Sachs (1966) – proper motions in general relativity

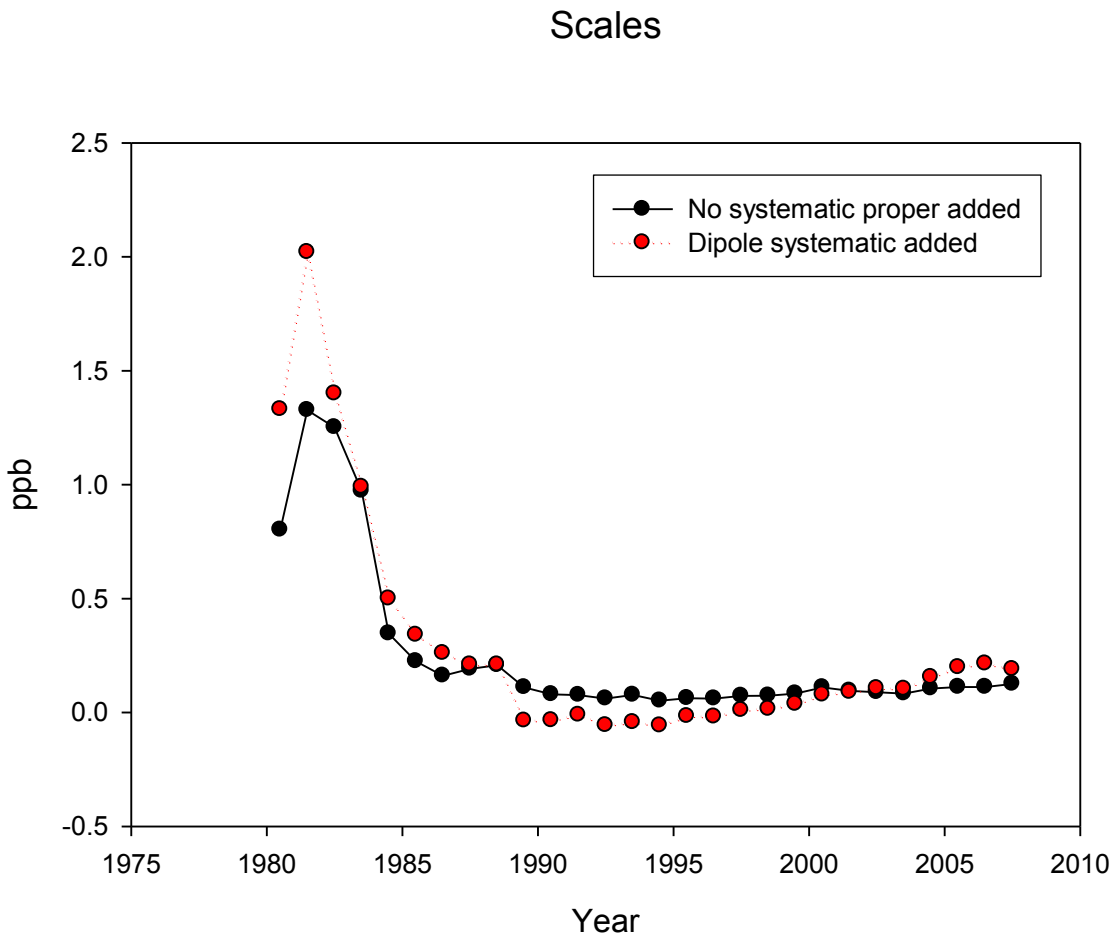
$$\frac{de^{\mu}}{dt} = h^{\mu\nu}[e^{\beta}\sigma_{\nu\beta} +$$

$$+\frac{c}{H_0}\left\{z + z^2\left(\frac{1-q_0}{2}\right)+\ldots\right\}\left\{e^{\beta}\sigma_{\gamma\beta}u_{\gamma\nu} - e^{\beta}E_{\nu\beta} + \frac{1}{2}e^{\beta}e^{\gamma}(u_{\nu\beta\gamma} - \varepsilon_{\nu\beta\lambda}H_{\gamma\lambda}) + e^{\beta}e^{\gamma}e^{\lambda}\sigma_{\nu\gamma}\sigma_{\beta\lambda}\ldots\right\}]+\ldots$$

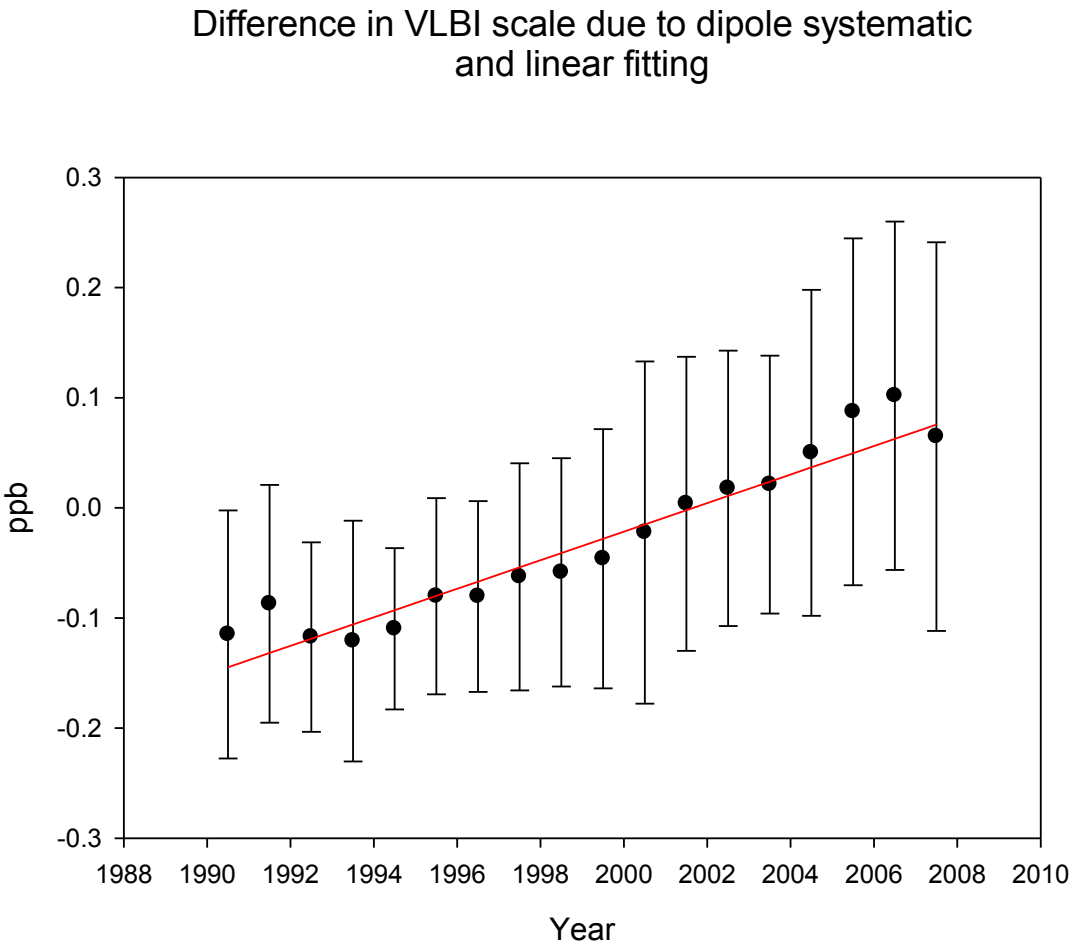
Another test for the cosmologic model

Ellis et al. “ the major problem is that neither the distortion nor the proper motions are likely to be measurable in practice in the foreseeable future” (“Ideal physical cosmology”, 1985).

Effect on the TRF scale



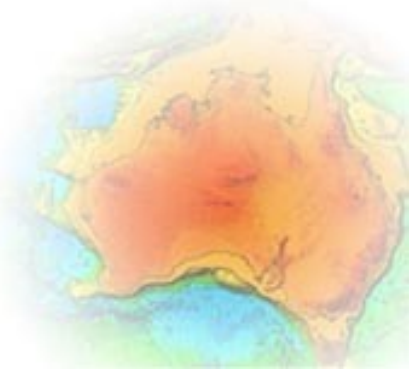
Effect on the TRF scale



0.013 +/- 0.001 ppb/year

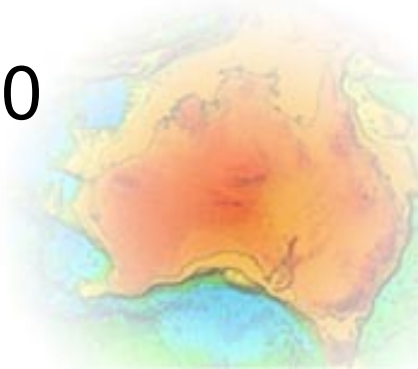
0.083 +/- 0.006 mm/year

1.7 mm for 20 years



Conclusion

- Dipole effect ~20 μas/year for different groups of radio sources – independent on Z
- Quadrupole effect – increases with Z??
- More quasars δ<-40
- More observations of quasars δ<-40
- More red shifts to be measured for δ<-40



Thank you!