Plan for VLBI observations of close approaches of Jupiter to compact extragalactic radio sources in 2014-2016

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JOURNÉES 2013, Ecole Normale Superieure, Paris, France
16 September 2013

Estimation of the PPN-parameter γ from the VLBI observation of close approaches of Jupiter to quasars

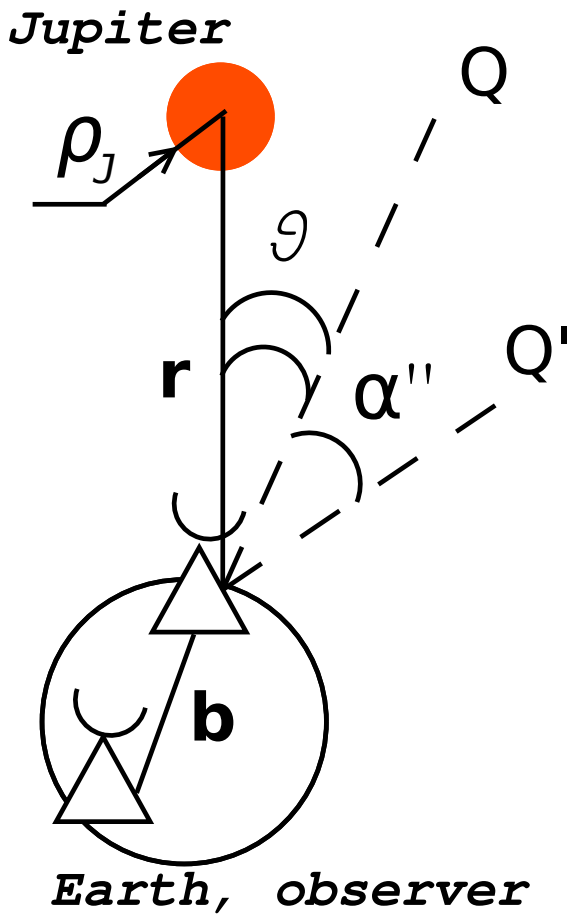
- VLBI observations have been used for testing of general relativity with the close approaches of Jupiter to compact extragalactic radio sources (quasars)
  First attempt to test by Jupiter to quasar 0201+113 in 1988, at angular distance 3'.5. (H.Schuh et al, 1988, AJ, 129, 299)

- The experiment by S. Kopeikin and E. Fomalont on 8 September 2002. Observations of the close approach of Jupiter to the quasar J0842+1835 at angular distance of 3'.7 (E.Fomalont and S.Kopeikin, 2003, AJ,598,704)

- Experiment OHIG60 on 18 November 2008. The close approach of Jupiter to the quasar 1922-224 at angular distance of 1'.2 during 12 hours.

Jupiter is the best planet for observations

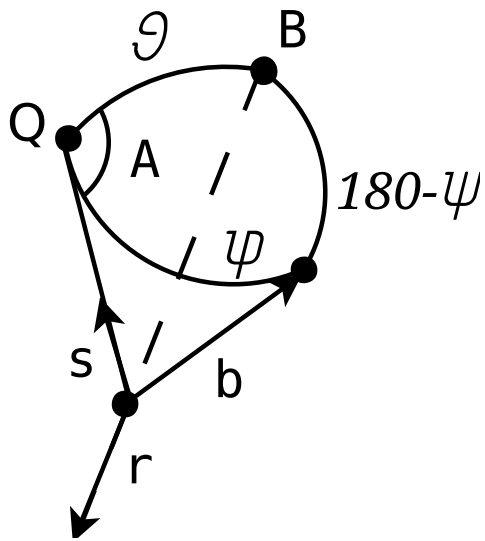
- Apparent size of Jupiter is $\rho_J = 20''$ (minimum impact parameter)
- Mass of Jupiter M_J, it's the most massive planet
- The fastest apparent motion among big planets leads to the largest number of events
- light deflection
  $\alpha'' = \frac{2GM}{c^2 r} \frac{\sin\theta}{1-\cos\theta}$
  θ - impact parameter



Estimation of the PPN-parameter γ from the VLBI observation

$$\tau_{grav} = \frac{(\gamma+1)GM}{c^3} \ln \frac{r_1+(\vec{r_1},\vec{s})}{r_2+(\vec{r_2},\vec{s})} = -\frac{(\gamma+1)GM}{c^3}\frac{b\cos\varphi}{r} +$$

$$+\frac{(\gamma+1)GM}{c^3 r}\frac{b\ \sin\varphi\sin\theta\cos A}{1-\cos\theta} + \text{small terms}$$



$$\tau_{group} = \frac{\tau_{grav} - \frac{\vec{b}\cdot\vec{s}}{c}(1-\frac{(1+\gamma)GM}{c^2 r}+\ldots)}{1+\frac{1}{c}(\vec{s}\cdot(\ldots))} = \frac{\tau_{GR}+\ldots}{1+\frac{1}{c}(\vec{s}\cdot(\ldots))}$$

for GR $\gamma = 1$

Einstein 1916 $\alpha_{clas.} = \frac{4GM}{c^2 R} = \frac{2GM}{c^3}[\ln \frac{r_1+(\vec{r_1},\vec{s})}{r_2+(\vec{r_2},\vec{s})} + \frac{(\vec{b}\cdot\vec{s})}{r}] \cdot \frac{c}{b\ \sin\varphi|\cos A|}$

Quasar 1922-224 in 18 November 2008

1922-224 $\alpha_{2000.0} = 19^h25^m39^s$

$\delta_{2000.0} = -22°19'35''$

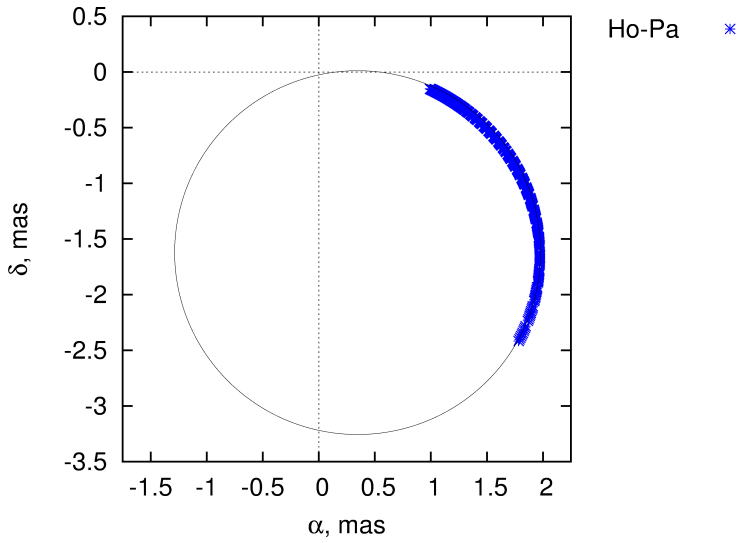
top $\frac{\alpha''}{|cosA|} = \frac{2GM}{c^2 r}\frac{\sin\theta}{1-\cos\theta}$

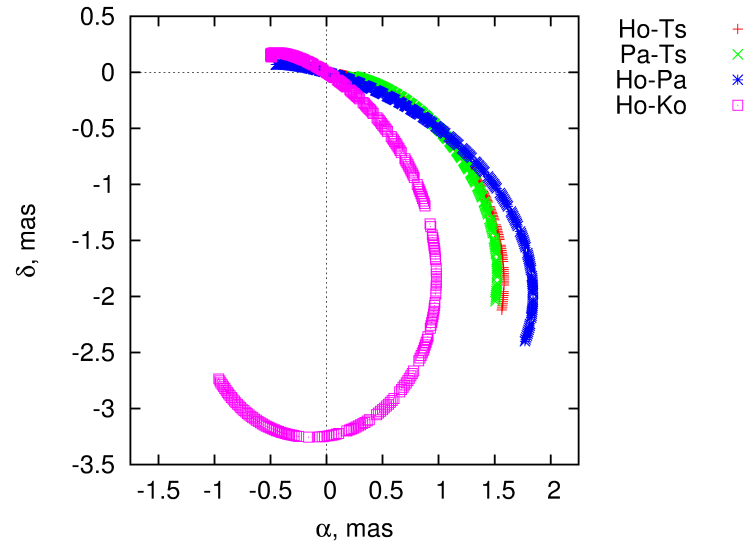
lower $\alpha'' = \frac{2GM}{c^2 r}\frac{\sin\theta|\cos A|}{1-\cos\theta}$

Hobart26, Tsukub32, Kokee, Parkes

4 baselines have good group delays

Hobart26-Tsukub32,
Parkes-Tsukub32,
Hobart26-Parkes,
Hobart26-Kokee





Data of quasars with which will of closely approaches of Jupiter in 2014-2016

quasar	date	θ''	Flux (mJy)	$\frac{\alpha''}{\cos A}$ (mas)	small terms (ps)
0846+184	28.08.2014	45	?	6.0	8.5
0918+167	09.02.2015	30	?	12.8	39.1
0912+171	24.05.2015	39	?	7.7	14.2
0920+168	08.06.2015	37	?	7.8	14.8
1109+070	26.03.2016	26	~ 200	14.5	50.1
1101+077	09.04.2016	20(8)	~ 150	16(46)	142(503)

deflection light $\alpha_{clas.} = \frac{4GM}{c^2 R}$

small terms in τ $\pm \frac{2GM}{c^3} \frac{b^2}{R^2}$

maximum measuring of small terms is calculated for $b \approx 6 \cdot 10^3$ km

Table of visibility for 0920+168 on 08.06.2015

stations/UT	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Angular distance	166	170	148	126	104	83	64	48	41	46	61	79	100	121	143
Badary	+	+	+	+	+	+	+	+	+	+	+	+	+		
Svetloe				+	+	+	+	+	+	+	+	+	+	+	+
Zelenchuk				+	+	+	+	+	+	+	+	+	+	+	+
Medicina						+	+	+	+	+	+	+	+	+	+
Yebes							+	+	+	+	+	+	+	+	+
Seshan25	+	+	+	+											
OV-VLBA	+	+	+											+	+
FD-VLBA	+	+												+	+
Pietown	+	+												+	+
LA-VLBA	+	+												+	+
NL-VLBA	+												+	+	+
KP-VLBA	+	+												+	+
HN-VLBA											+	+	+	+	+
BR-VLBA	+	+	+											+	+
MN-VLBA	+	+	+	+	+										
SC-VLBA												+	+	+	+
Kokee	+	+	+	+	+										
Hartrao						+	+	+	+	+	+	+	+	+	+
Tsukub32	+	+	+	+	+	+	+	+	+						
Parkes	+	+	+	+	+	+	+	+							
N_scan	12	12	12	12	12	12	12	13	13	13	13	13	13	13	13
N_obs	501	424	180	180	174	135	180	187	140	100	140	187	240	607	607

Flux=50mJy, **SNR**=20/15 (X/S), **Rate**=10^6 byte/s, $\mathbf{Num_{Chanels}}$=14,

$\mathbf{N_{scan}} = 3600/\mathbf{scanlen}$, $\mathbf{N_{obs}} = \mathbf{N_{base}} \times \mathbf{scanlen}$

Plan for future VLBI observations

- for GR $\gamma = 1$
  $\sigma\gamma = 2 \cdot 10^{-4}$ by VLBI (Lambert, Gontier, 2009, A&A, 493, 317),
  $\sigma\gamma = 2 \cdot 10^{-5}$ by Cassini (Bertotti, et. al, 2003, Nature, 425, 374)

  We are going to evaluate parameter γ with accuracy
  $\sigma\gamma = 10^{-3}$ for a single experiment

- Flux density for the quasars marked with '?' needs to be measured. We have observed them at session CRF76 on 19-20, August 2013. This session included large telescopes: Parkes, DSS45 and Hobart26 to measure flux density of these 4 quasars.

- We are going to submit proposal for several networks (IVS, VLBA, LBA) to observe these events.

Thank you for your attention!