VLBI astrometry:
IAA CRF solution

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IAA CRF activity

• QUASAR VLBI data processing software
• Global VLBI data processing for source positions
• Optimal defining sources selection
• Systematic differences between CRF realizations
• Galactic aberration
• Source positions time series
QUASAR features

• Reduction parameters
  – Most calculations done according to the IERS Conventions (2010)
  – Various options

• Single and multi session estimations

• Estimation options
  – Various parameters can be estimated
  – Every parameters can be global, arc or stochastic
  – Every parameters can be estimated as polynomial trends

• Least Square Collocation method

• Stochastic signal of clock-offset and WZD
  – Mean correlation function
  – Individual variance values for each station
Global Solution Parameters

- **Global:**
  - RA, DE
  - Stations coordinate and velocities
  - Antenna offset
  - Galactic aberration parameters

- **Arc**
  - Earth orientation parameters ($X_p, Y_p, UT1-UTC, X_c, Y_c$)
  - Linear trend of wet zenith delay
  - Troposphere gradient east and north
  - Quadratic trend of station clock offset

- **Stochastic**
  - Stochastic component of WZD
  - Stochastic component of clock offsets
Constraints

- no-net-rotation for 212 defining sources ICRF1
- no-net-rotation/translation for positions and velocities of 15 stations (BR-VLBA, FD-VLBA, FORTLEZA, HN-VLBA, KP-VLBA, LA-VLBA, MATERA, NL-VLBA, ALGOPARK, WESTFORD, WETTZEELL, HARTRAO, KOKEE, NYALES20, ONSALA60)
- Not estimated sources observed less than 15 times and stations velocities of less than one year observation period (soft constraints)
- Sum of clock offsets is equal to zero in one session
- Soft constraint for EOP for sessions with low geometry
- Equal stations velocities for stations on same site
IAA global solution for ICRF2

- 4404 VLBI sessions
- Aug 1979 - Jan 2011
- 6721880 delays
- 132 stations (15 with discontinuous motion)
- 3493 radio sources
Comparison of CRF catalogue with the ICRF2

<table>
<thead>
<tr>
<th></th>
<th>Mean Sigma, mas</th>
<th>WRMS vs ICRF2, mas</th>
</tr>
</thead>
<tbody>
<tr>
<td>RA</td>
<td>0.2</td>
<td>0.05</td>
</tr>
<tr>
<td>DE</td>
<td>0.2</td>
<td>0.07</td>
</tr>
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</table>
Source positions formal errors vs number of observations chart
Source positions formal errors vs number of observations chart
International VLBI Service web site


ftp://ivs.bkg.bund.de/pub/vlbi/ivsproducts/CRF/

iaa2006a.crf
iaa2007a.crf
iaa2007b.crf
iaa2008a.crf
iaa2009a.crf
iaa2011a.crf
iaa2012a.crf
iaa2014a.crf
Estimation of Solar system acceleration from VLBI

1. With fixed source positions the acceleration:
   \[ a_x = -1.9 \pm 0.2 \cdot 10^{-1}^\circ \text{ m/s}^2, \]
   \[ a_y = -4.2 \pm 0.2 \cdot 10^{-1}^\circ \text{ m/s}^2, \]
   \[ a_z = -0.2 \pm 0.4 \cdot 10^{-1}^\circ \text{ m/s}^2. \]

2. With estimation of source positions:
   \[ a_x = -1.5 \pm 0.2 \cdot 10^{-1}^\circ \text{ m/s}^2, \]
   \[ a_y = -4.4 \pm 0.2 \cdot 10^{-1}^\circ \text{ m/s}^2, \]
   \[ a_z = -0.1 \pm 0.4 \cdot 10^{-1}^\circ \text{ m/s}^2. \]

- Calculation was performed by the global adjustment of the VLBI data
- The estimated value of acceleration vector \( a = (4.7 \pm 0.5) \cdot 10^{-1}^\circ \text{ m/c}^2, \alpha = 288^\circ \pm 5^\circ, \delta = 0^\circ \pm 5^\circ \) significantly differs from the theoretical one but comparable with the other results.
- Results presented at 20th EVGA Meeting & 12th Analysis Workshop, March 29 - 31, 2011
Optimal defining sources selection

- Given catalogue RA, DE, arbitrary catalogue ra, de.
- Rigid rotation transformation model
  \[
  \begin{align*}
  dRA_i &= RA_i - ra_i \\
  dDE_i &= DE_i - de_i \\
  dRA_i &= A_1 \tan(RA_i) \cos(RA_i) + A_2 \tan(DE_i) \sin(RA_i) - A_3 \\
  dDE_i &= A_1 \sin(RA_i) + A_2 \cos(RA_i)
  \end{align*}
  \]
- Least Square for A1, A2, A3 estimation
  \[
  C = \frac{\partial(dRA, dDE)}{\partial A}; N = C^T C; A = N^{-1}b
  \]

\[
\sigma_A = \sigma_0 \text{tr}(N^{-1})
\]

Inaccuracy of positions part

Geometry part
Algorithm

1. For each catalogue in analysis:
   • Triple loop over all sources in order to find the best trio what gives minimum to the $q$, thus obtain optimal set for $N=3$
   • Search over all remaining sources in order to minimize $q$ for $N+1$ sources
   • The sequence of source sets obtained and parameter $q$ as function of number of sources in the set
   • For all catalogues that function has a minimum in the $N_k$ point.
2. Take the common part of the “minimum” sets $N_k$
3. Make 1. and 2. for both global solution $\sigma_{RA}, \sigma_{DE}$ and time series and obtain common set
Comparison of IAA list, and 380 sources OPA list, set of defining sources ICRF1 and combined set.
IAA core sets in comparison with the OPA set
Systematic differences ICRF2(752) $\Delta \delta$, uas
Source positions estimations

• Global solution for mid-point position
• Estimate one source position with fixed all another sources
  – minimize the session set of sources effect
  – loose constraints or NNR-minimal constraints give differs results
Source positions variations 2145+067

α

δ
Radio source proper motion solutions

<table>
<thead>
<tr>
<th>Source</th>
<th>Nobs</th>
<th>Epoch</th>
<th>Position</th>
<th>Proper motion (mas/(10y))</th>
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<tr>
<td></td>
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<td></td>
<td>$R_0$</td>
<td>$SR_0$</td>
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ICRF3 solution under way

• BIG session vs LSC
  – sharing method affect source position
  – inversion of BIG matrices
• Sources with only one-base observations
• Cable-calibration issues for several stations
• Sources for NNR-constraints
• Low geometry sessions
• Low observations sources