DETERMINATION OF FCN PARAMETERS FROM DIFFERENT VLBI SOLUTIONS, CONSIDERING GEOPHYSICAL EXCITATIONS

Jan Vondrák & Cyril Ron, Astron. Inst. CAS, Prague

Outline:

- ♦ Introduction, motivation;
- ♦ Short description of the method;
- ♦ Data used;
- ♦ Results;
- ♦ Conclusions.

Astronomical Institute of the Czech Academy of Sciences

Introduction, motivation:

- ♦ Dominant part of nutation is caused by external torques, excerted by the Moon, Sun, and planets;
- ♦ Excitations by geophysical fluids (atmosphere, oceans) play much smaller role, but they are now detectable by VLBI;
- ♦ Rapid changes of amplitude & phase of the free term (FCN) occur near the epochs of geomagnetic jerks (rapid changes of the second time derivatives of intensity of geomagnetic field), as recently shown by *Malkin (J. Geodyn. 2013)*;
- ♦ We developed a method of determining FCN parameters (period, Q-factor), considering these effects *(Vondrák & Ron, A&A 2017)*;
- ♦ Here we apply this method to several VLBI solutions and models of geophysical excitations, and compare the results.

Short description of the method:

- We use Brzezinski's broad band Liouville equations to integrate numerically the influence of geophysical excitations, and compare the results with observed celestial pole offsets (CPO):
  - To this end, we use standard atmospheric and oceanic excitations from different sources;
  - The effect of geomagnetic jerks is modeled by impulse-like excitation functions whose amplitudes are determined to yield the best agreement with observations.
  - Observed CPO are corrected for the difference between the FCN parameters as used in standard IAU model of nutation and the estimated ones, to account for resonance effects;
- We find FCN parameters that yield the best fit between integrated and observed CPO values, using standard least-squares estimation.

Brzeziński's broad-band Liouville equations in celestial frame:

$$\ddot{P} - \mathrm{i}(\sigma'_C + \sigma'_f)\dot{P} - \sigma'_C\sigma'_f P =$$

$$= -\sigma_C\left\{\sigma'_f(\chi'_p + \chi'_w) + \sigma'_C(a_p\chi'_p + a_w\chi'_w) + \mathrm{i}\left[(1+a_p)\dot{\chi}'_p + (1+a_w)\dot{\chi}'_w\right]\right\}$$

where

- P is the motion of spin axis in celestial system;
- σ_C is the Chandler frequency in terrestrial frame;
- σ'_C, σ'_f are Chandler and FCN frequency in celestial frame;
- χ'_p, χ'_w are pressure and wind terms of excitation in celestial frame;
- $a_p = 9.200\times10^{-2}$, $a_w = 2.628\times10^{-4}$ are numerical constants.

Mathews-Herring-Buffet transfer function (nonrigid/rigid Earth model) is used to account for the difference between FCN parameters (s_2) as used in standard IAU model of nutation and the estimated one:

$$T_{MHB}(\sigma) = \frac{e_R - \sigma}{e_R + 1} N_0 \left[1 + (1+\sigma) \left(Q_0 + \sum_{j=1}^{4} \frac{Q_j}{\sigma - s_j} \right) \right]$$

where e_R is the dynamical ellipticity of the rigid Earth, σ is nutation frequency (in ITRF), N, Q are constants and s_j are resonance frequencies [cpsd] for

1. Chandler wobble - CW ($P_{ter.} \approx$435 d);
2. Retrograde Free Core Nutation - RFCN ($P_{cel.} \approx$430 d);
3. Prograde Free Core Nutation - PFCN ($P_{cel.} \approx$1020 d);
4. Inner Core Wobble - ICW ($P_{ter.} \approx$2400 d).

→ $s_2 = \sigma'_f / 6.30038 - 1$ [cpsd] in terrestrial frame.

Astronomical Institute of the Czech Academy of Sciences

Data used (1986.0-2018.5):

- Celestial pole offsets data in 1-day steps:
  - IERS C04 combined solution;
  - IVS combined solution;
  - Solution by Bundesamt fuer Kartografie und Geodaesie (BKG);
  - Solution by Goddard Space Flight Center (GSF);
  - Institute for Applied Astronomy (IAA);
  - Observatoire de Paris (OPA);
  - U.S. Naval Observatory (USN).
    - All data filtered to contain periods between 10 and 6000 days,
    - For FCN parameters different from the values used in IAU2000 model of nutation, these are further corrected by using MHB transfer function.

Data used (cont.):

- ♦ **Atmospheric and oceanic excitations:**
  - ♦ **No atmospheric and oceanic excitations;**
  - ♦ **NCEP/NCAR atmosphere with IB correction (representing a simple oceanic model), in 6-hour steps;**
  - ♦ **ESM GFZ atmosphere + ocean, in 3-hour steps.**
    - ♦ **All data, originally given in terrestrial frame, were re-calculated into celestial frame, centered and smoothed to contain only periods longer than 10 days.**

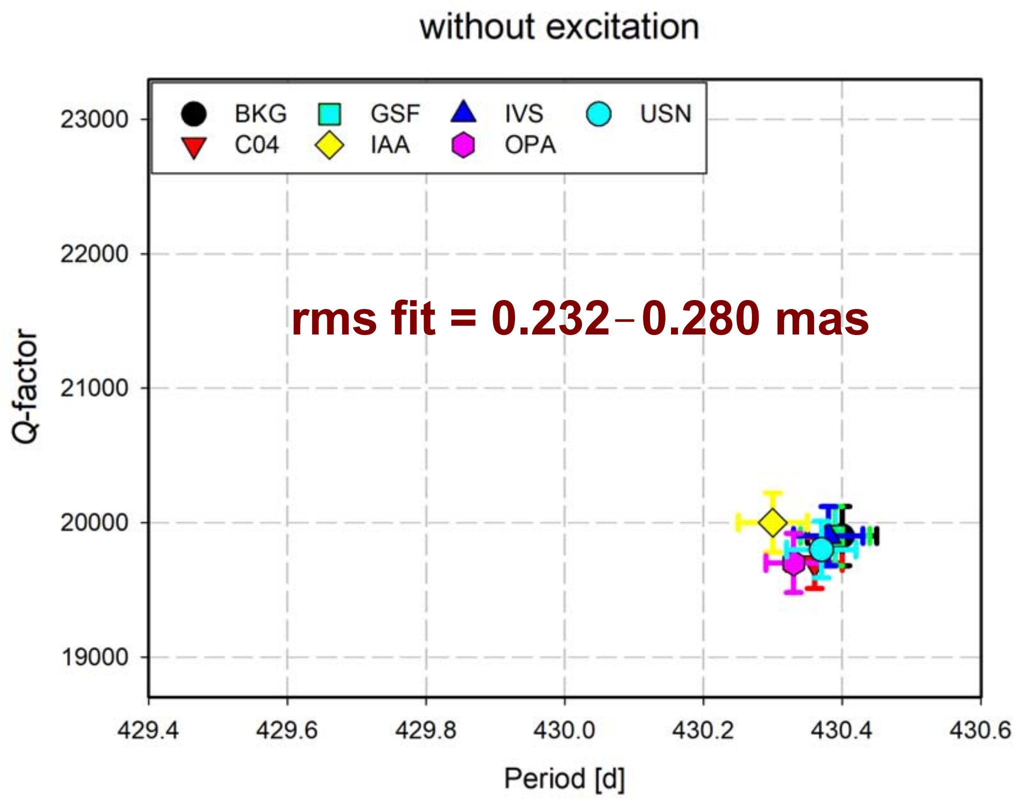
Data used (cont.):

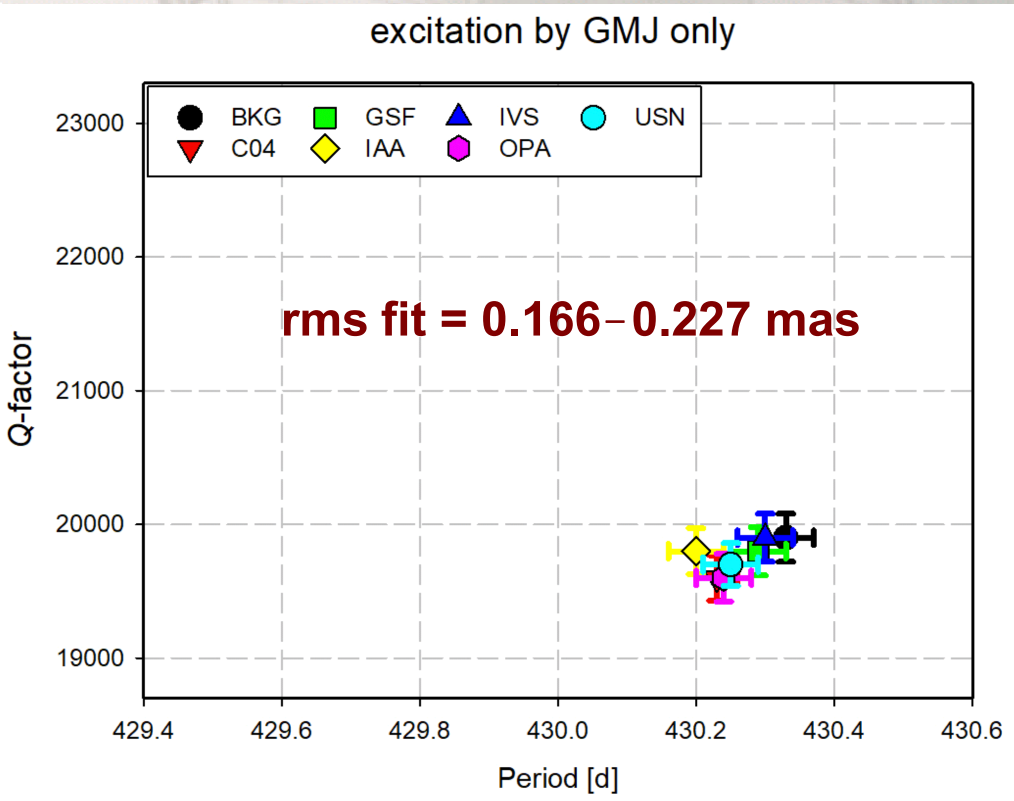
- ♦ **Geomagnetic jerks (GMJ):**
  - ♦ **Eight epochs of GMJ, found in literature, are used:**
    - ♦ **1991.0, 1994.0, 1999.0, 2003.5, 2004.7, 2007.5, 2011.0, 2014.0;**
  - ♦ **The amplitudes *a* of bell-shaped excitations, centered around these epochs and lasting 200 days, are estimated from the fit to observations. The excitations have the form**

$$\chi'_{GMJ} = \frac{a}{2}\left[1 + \cos\frac{2\pi(t - t_0)}{200}\right]$$

Results:

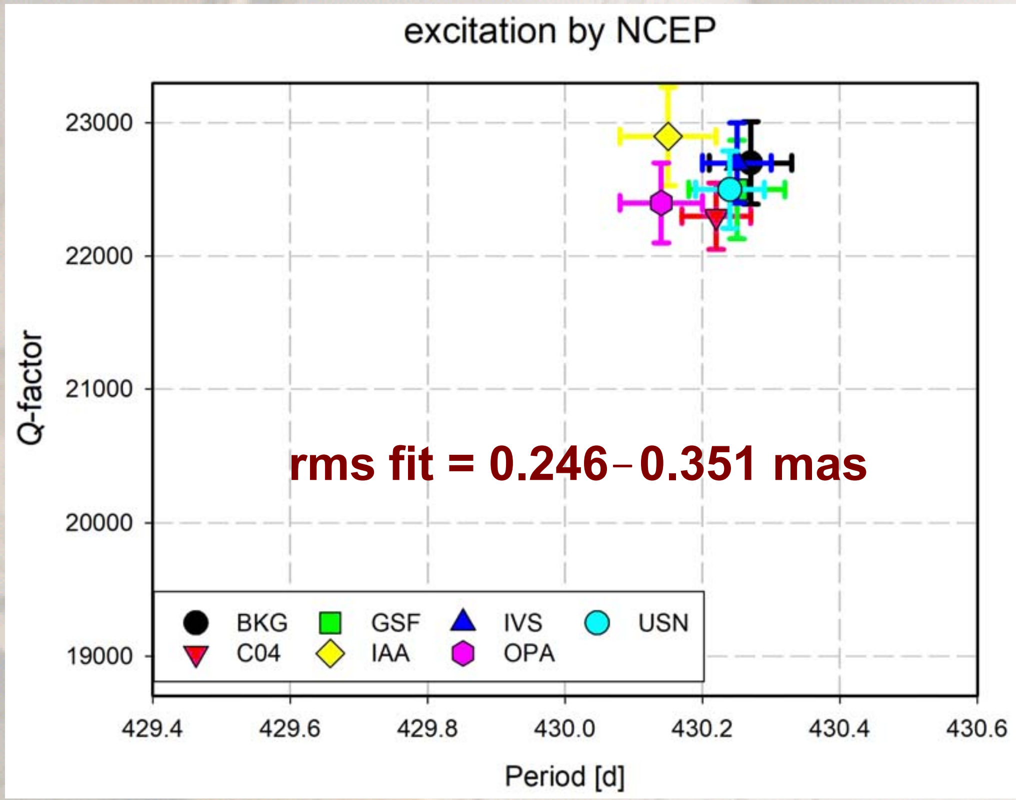
without A+O excitations

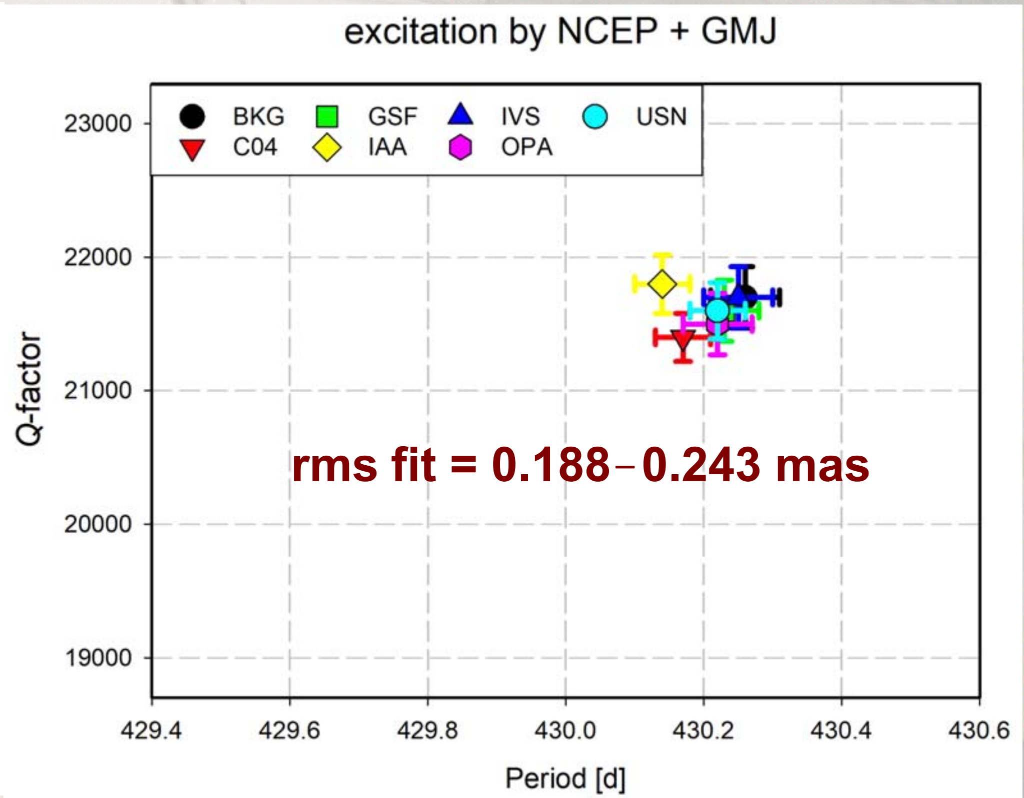




Results:

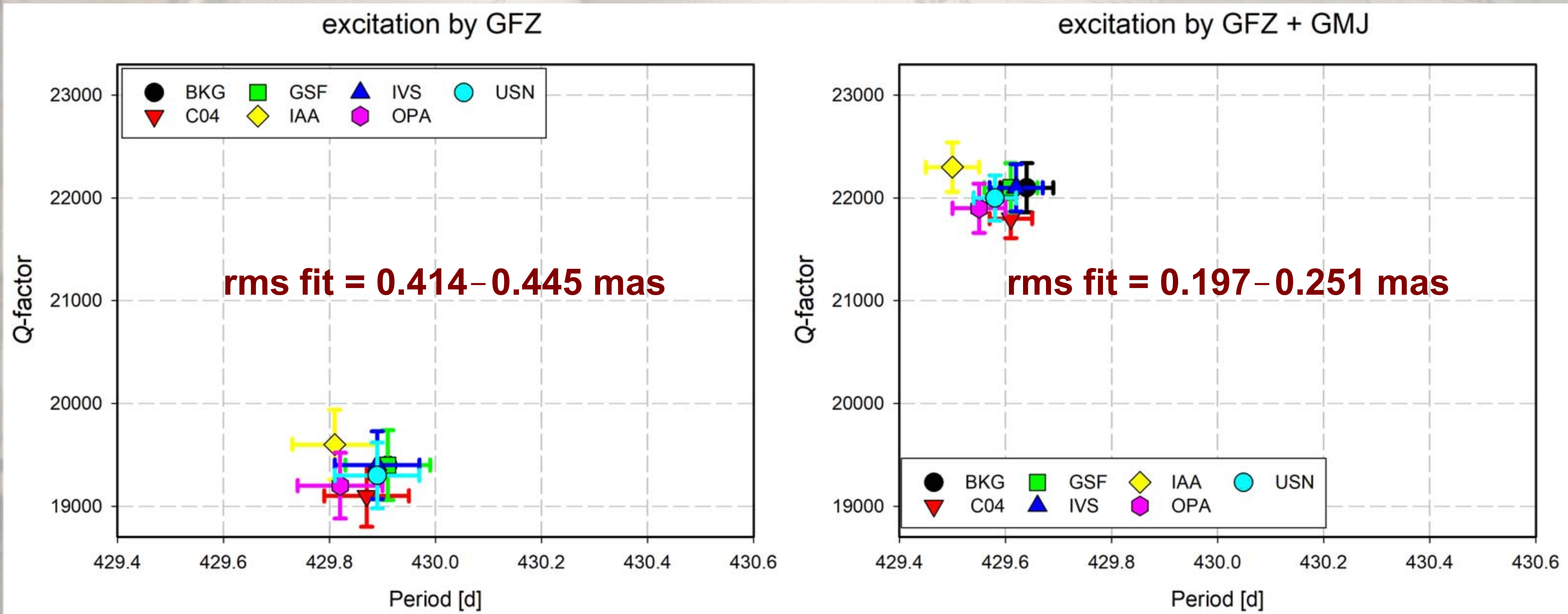
Excitations NCEP IB





Results:

Excitations EMS GFZ



Astronomical Institute of the Czech Academy of Sciences

Conclusions:

- ♦ All results based on different VLBI solutions agree at the level of their formal uncertainties, if the same excitation model is used;
- ♦ The best rms fit to observations is always obtained with IERS C04 solution;
- ♦ Different models of excitation yield values of FCN parameters whose differences often exceed their formal errors
  - ♦ Quite surprisingly, the best fit is obtained when atmospheric and oceanic excitations are neglected;
- ♦ Inclusion of GMJ effect always improves the fit, the most significant improvement occurs in case of EMS GFZ excitations, but
  - ♦ in some cases it brings about relatively large changes of FCN parameters, exceeding their formal errors.