Different History of Comets C/2001 Q4 and C/2002 T7?

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Motivation

C/2001 Q4 NEAT and C/2002 T7 LINEAR, are widely regarded in the literature as dynamically new comets, for the first time visiting the planetary system from the Oort Cloud. It seems, however, that in the standard model of non-gravitational (NG) acceleration [6] one of them is a dynamically new (C/2002 T7) while the other (C/2001 Q4) has visited the inner part of Solar System during the previous perihelion passage [5]. On the other hand, **both comets were included [5] into the group of five comets (together with C/1990 K1, C/1993 A1, C/2003 K4) for which** – despite of significant improvements of orbit determinations when standard model of NG acceleration is included – **some systematic deviations in the O-C** (observed minus calculated values) **time variations were detected in the NG motion (see Figure 1)**.

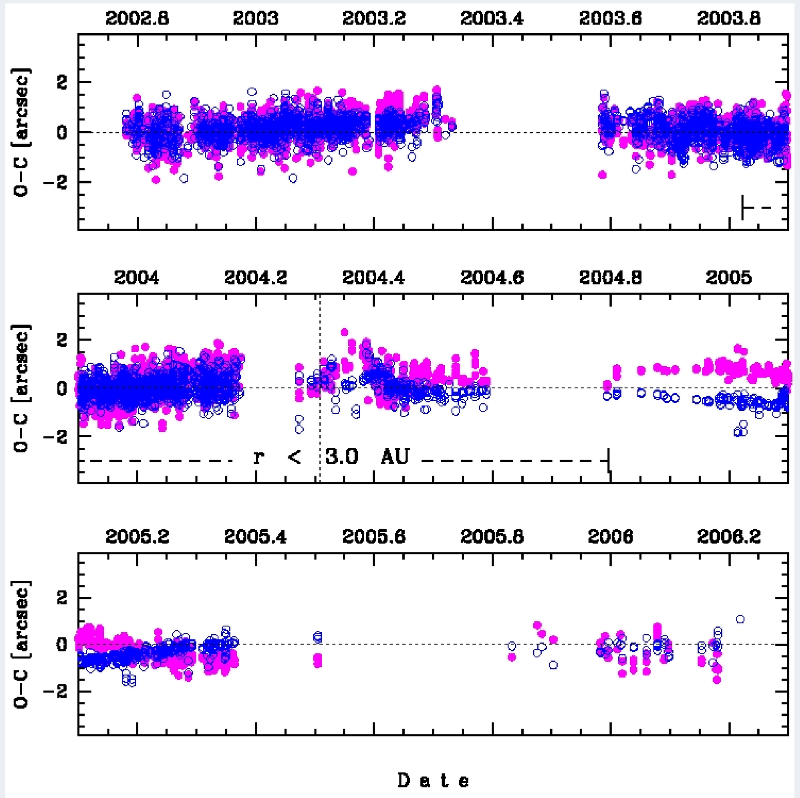


Figure 1 The O-C diagram for C/2002 T7 for the standard NG model and for all available data (model ALL+STD). The residuals in right ascension are shown as magenta dots and in declination as blue dots; the moment of perihelion passage is shown by a dashed vertical line and by dashed horizontal line are shown regions for data taken at small heliocentric distances ($r < 3.0$ AU).

New approach – data subsamples

Very long sequences of astrometric data:

- C/2001 Q4 - five years in the period from 2001 08 24 (10.1 AU from the Sun) to 2006 08 18 (8.8 AU),
- C/2002 T7 – almost 3.5 year in the period from 2002 10 12 (6.9 AU) to 2006 03 20 (8.1 AU).

Thus, for the starting osculating orbit determination we use the following types of data series:

- Data type: **ALL** – all observations.
- Data type: **DIST** – a subset of observations taken only at larger distances from the Sun. For comet C/2001 Q4 two types of distant data subsets were constructed: **DIST1** – when the observations around perihelion taken at a distance below 3.0 AU are omitted and **DIST2** where dedicated criterion based on the observed cometary unusual behavior was used [2].
- Data type: **PRE** – a subset of pre-perihelion data only.

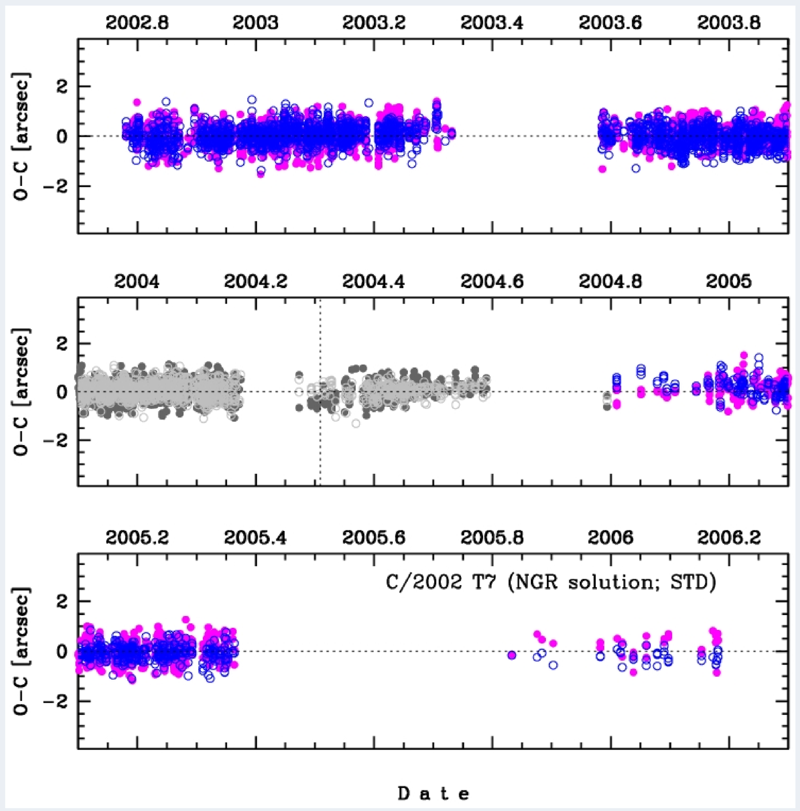


Figure 2. The O-C diagram for C/2002 T7 for two separate NG models of a standard acceleration derived for two complementary data sets. Residuals of NG model based on DIST data sets (observations taken when comet was further than 3.0 AU from the Sun) are shown in magenta and blue dots (residuals in right ascension and declination, respectively). The other NG model – not used in this analysis – was derived for the remaining data and residuals are shown in grey and light grey dots.

New approach

We examine the past evolution of both comets by exploring a grid of 3/4 × 3 models using different criteria of astrometric data compilation as well as different models of NG acceleration, $a_i = A_i \cdot h(r), i = 1, 2, 3$, where A_i's are NG parameters fitted to data and the dimensionless function $h(r)$ takes one of the forms:

- **STD** based on water sublimation [6]

$$g(r) = 0.1113\,(r/2.808)^{-2.15}\left[1 + (r/2.808)^{5.093}\right]^{-4.6142}$$

- **GEN** generalized $g(r)$ with fitted parameters

$$g^*(r) = \alpha\,(r/r_0)^{-m}\left[1 + (r/r_0)^n\right]^{-k}$$

- **YAB** based on CO sublimation [7]

$$f(r) = \frac{1.0006}{r^2} \times 10^{-0.07395(r-1)} \cdot \left(1 + 0.0006 r^5\right)^{-1}$$

Different forms of NG force do not solve the problem of trends in O-C diagrams taken for complete astrometric data sets. The reason lies in unusual activity of both comets at small perihelion distance that is impossible to be modeled with single set of 3 or 4 NG parameters determined from the entire data set.

Method of calculations

- For each comet we construct a dedicated grid of 9/12 independent starting osculating swarms of 5 000 orbits (VC orbits well-fitted to data); each swarm is based on different subsets of positional data and different dependence of NG acceleration on the heliocentric distance.
- Next, we follow numerically each VC orbit in the swarms one orbital revolution to the past taking into account planetary and Galactic perturbations and checking for all known stellar perturbers [1][3]. **This method allows us to obtain the orbital elements and their uncertainties at the previous perihelion passage** (more details one can find in [5] & [4]).

Results in short

- Generalized $g(r)$-like function seems be more adequate to describe the NG effects than the standard $g(r)$-function in the motion of both comets but we were able to estimate only two parameters: scale distance r_0, and the exponent m. Results are summarized in Figure 3 and are in agreement with [2].
- The greatest change in the previous perihelion value relative to that obtained in the standard approach results from the type of data subset used for the NG orbit determination. The form of the dependence of NG acceleration on heliocentric distance is of the secondary importance for both investigated comets in this context (see Figure 4).

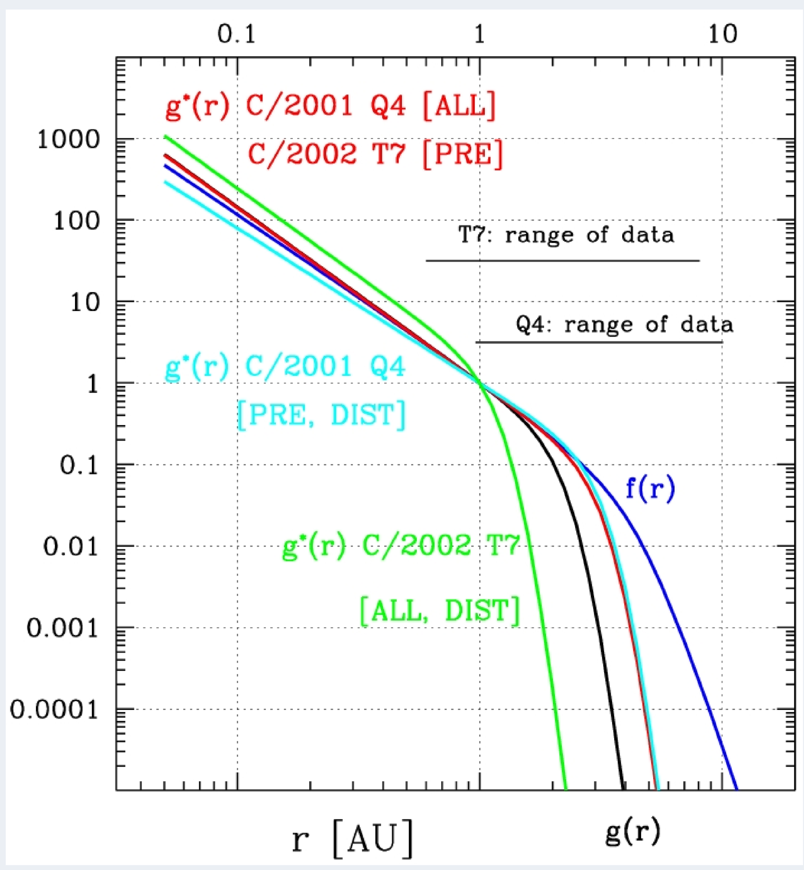
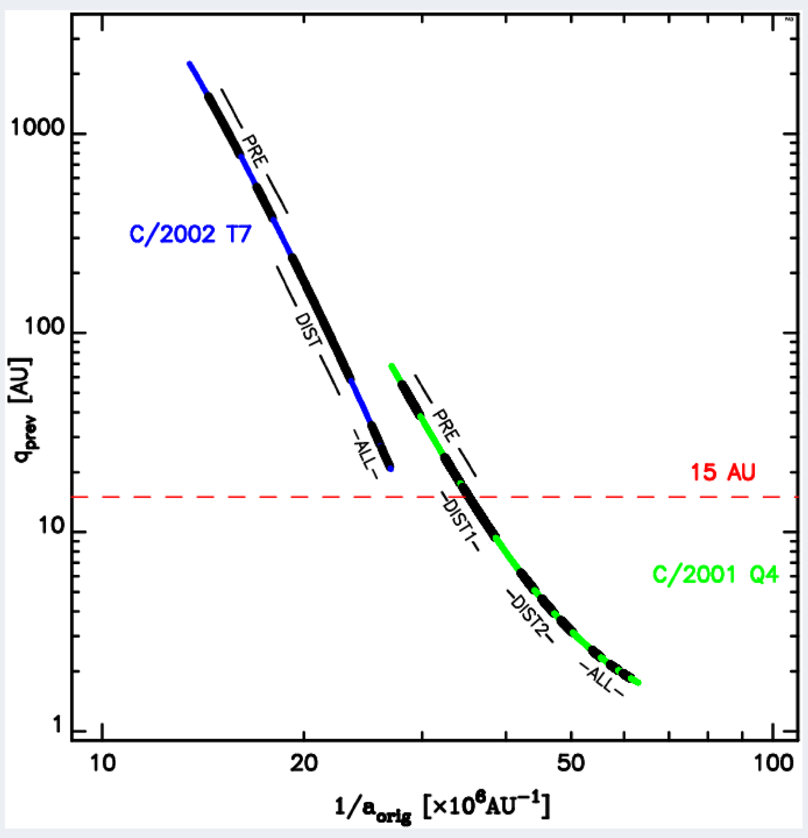


Figure 3 Different forms of NG function, $h(r)$, vs. heliocentric distance, r, investigated here (see section New approach). Standard $g(r)$ are shown by black curve, Yabushita function $f(r)$ by blue. Green, cyan and red curves represent the best derived $g(r)$-like functions for comets C/2001 Q4 and C/2002 T7 for different types od data.

Figure 4 Relations of the previous perihelion distance vs the original semi-major axis for C/2001 Q4 NEAT (green curve) and C/2002 T7 LINEAR (blue curve). The black parts of NEAT curve show ranges of values determined in four investigated types of data sets (PRE, DIST1, DIST2, ALL) and black parts of LINEAR curve show the ranges of values derived in three types of data sets (PRE, DIST and ALL).



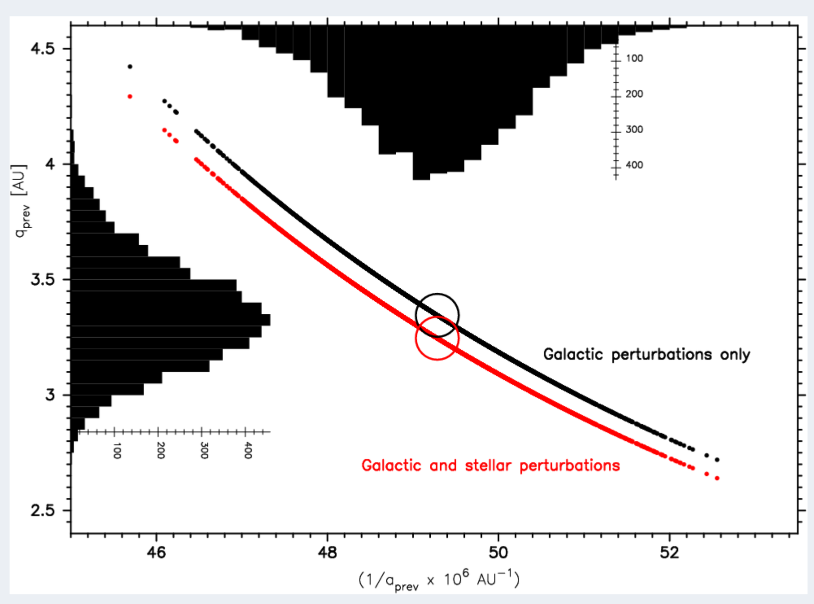


Figure 5 The dependence of the previous perihelion distance vs the reciprocal of the previous semimajor axis for C/2001 Q4 (DIST2 variant with the standard NG model). Each dot in the central part of figure represents individual cometary orbit from the swarm of 5 000 VC orbits propagated to the previous perihelion (∼3 million years back in time). Results of two different calculations are shown: without stellar perturbations (the central upper plot) and with stellar perturbation included (the lower one). The centers of the big circles define the positions of the respective nominal orbits. For the variant without stellar perturbations boundary distributions of $1/a_{prev}$ and q_{prev} are also plotted.

- **Only comet C/2002 T7 passed far beyond the planetary system during its previous perihelion passage while C/2001 Q4 was probably well inside the Saturn orbit at previous perihelion passage (see Figure 4)**.
- The small displacement of the central plots presented in Figure 5 is quite representative for the whole grids of models analyzed here. Thus, we are convinced that known stars do not influence our conclusions on the dynamical history of both investigated comets by any means.

References

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Main conclusions

- For these comets (having long sequences of positional data) the safest method for the previous perihelion determination is to exclude data within time intervals where some local outbursts were reported.
- We recommend the non-gravitational models based on data taken at larger perihelion distance as more appropriate for the previous perihelion estimations for C/2001 Q4, and for C/2002 T7 – those based on pre-perihelion data set. These models suggest that C/2001 Q4 passed previous perihelion closer than 6-7 AU from the Sun so it is dynamically old, whereas C/2002 T7 – at the distance larger than 400 AU and is dynamically new comet since it jumped over the Jupiter-Saturn barrier during the last orbital revolution.