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# Prediction of meteor shower associated with Comet 122P/de Vico

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We model, for a far past, a theoretical stream associated with Comet 122P/de Vico and follow its dynamical evolution until present. Selecting the modeled particles approaching to the Earth's orbit at the present, we predict the characteristics of a potential meteor shower and try to identify these particles with the meteors in three databases (photo, radar, and video). Our overall prediction is, however, negative because only the particles released from the comet nucleus before approximately 37 000 years ago are found to evolve into a collision course with the Earth and, therefore, form a possible shower. Meteoroids are known to survive a much shorter time in interplanetary space, unfortunately.

## 1 Introduction

In this paper, we deal with a potential meteoroid stream of Comet 122P/de Vico. This is a Halley-type comet with an orbital period of 74.35 years. Its osculating elements according to the JPL Small-Body Database Browser[1] are (epoch JDT = 2450280.5):

$$q = 0.659337 \text{ AU},\ e = 0.962709,$$
$$\omega = 12\overset{\circ}{.}996092,\ \Omega = 79\overset{\circ}{.}624501,\ i = 85\overset{\circ}{.}382753.$$

We model a meteoroid stream associated to this Comet and follow its orbital evolution in order to find if and when meteor showers observable from Earth could have existed. The mean shower characteristics are predicted for the period of its occurrence.

## 2 Modeling of the stream

We model a theoretical stream associated with Comet 122P/de Vico and study the dynamics of the modeled meteoroid particles. The motion of all test particles is followed with a numerical integration of their orbits. The perturbations from 8 planets are considered. We assume relatively large particles, not significantly influenced by non-gravitational effects. Therefore, non-gravitational forces are not included in the modeling. The procedure of the modeling and monitoring of test-particles dynamical evolution consists of following steps.

1. The integration of the parent body into the past over the period equal to 750 orbital revolutions of the parent body. The initial position and velocity vectors are taken from JPL ephemeris[2]. The integration is done by using integrator RA15 developed by Everhart (1985) with the Mercury package (Chambers, 1999).

2. Modeling 10 000 theoretical particles at the time of the parent body's perihelion passage obtained in the previous step. All modeled particles are assumed to have the same ejection velocity of 1/1000 of the perihelion velocity of the parent body. We assume a directionally random ejection.

3. Numerical integration of the stream particles from the moment of their ejection until present. Integrator RA15 within the Mercury package is used again. The final characteristics of 8 perturbing planets and the parent body in step (1) are taken as initial in this step.

4. The analysis of main dynamical evolutionary features of the theoretical stream.

5. The selection of the particles in orbits crossing or passing the orbit of the Earth at a distance smaller than 0.05 AU.

6. The analysis of the dynamical evolution of the Earth's orbit approaching part of the theoretical stream. If the number of these particles is sufficiently large, we predict the characteristics of a possible meteor shower associated with the studied parent body.

7. The identification of the Earth-orbit approaching particles with the actually observed meteors. The photographical (Lindblad et al., 2003), radio-meteor (Hawkins, 1963; Sekanina and Southworth, 1975; Lindblad, 2003) IAU MDC, and SonotaCo video-meteor (SonotaCo, 2009) databases are used for this purpose. The first catalogue contains the data of 4581, the second of 62 906 and the third of 64 650 double- or multi-station meteors. We used the "break-point" method suggested by Neslušan et al. (1995) (see also Tomko and Neslušan, 2012). To this end, we calculated the $D$-discriminant between the mean orbit of the predicted shower and the orbit of every real meteor.

[1] http://ssd.jpl.nasa.gov/sbdb.cg.
[2] ftp://ssd.jpl.nasa.gov/pub/eph/planets/bsp/;DE406.

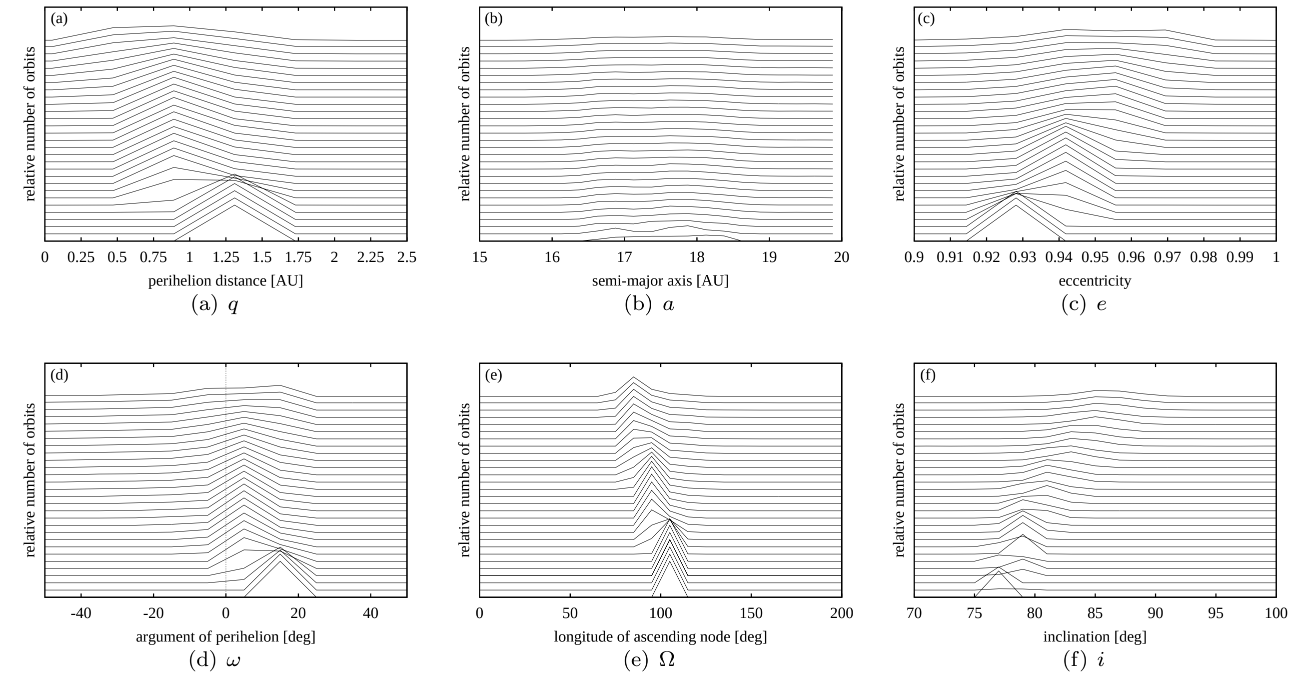



*Figure 1* – The evolution of orbital elements of a theoretical meteoroid stream associated with Comet 122P/de Vico. The stream is modeled for the time of the Comet's perihelion closest to 750 times its current orbital period ago. The bottom curve illustrates the distribution at that time. The higher curves show the behavior of the stream at successive 2000-year intervals. The top curve corresponds to the present distribution.

*Table 1* – Mean orbital characteristics of the individual filaments (Fil) of the Comet's meteoroid stream predicted to appear as meteor showers in the Earth's atmosphere. The following symbols and abbreviations are used: Br, branch of the shower; $n$, number of filament members; $t_{\max}$, time of maximum acivity; $q$, perihelion distance; $a$, semi-major axis; $e$,eccentricity; $\omega$, argument of perihelion; $\Omega$, longitude of ascending node; $i$, inclination; $\alpha_{\rm geo}$ and $\delta_{\rm geo}$, equatorial coordinates of the geocentric radiant; $V_{\rm geo}$ and $V_{\rm hel}$, geocentric and heliocentric velocity.

| Fil | Br | $n$ | $t_{\max}$ | $q$ (AU) | $a$ (AU) | $e$ | $\omega$ | $\Omega$ | $i$ | $\alpha_{\rm geo}$ | $\delta_{\rm geo}$ | $V_{\rm geo}$ (km/s) | $V_{\rm hel}$ (km/s) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | N | 6 | Sep 27.57 | 0.437 | 16.8 | 0.975 | 279.°2 | 184.°4 | 80.°4 | 26.°8 | +48.°1 | 47.9 | 41.3 |
| 2 | N | 5 | Dec 20.11 | 1.010 | 18.7 | 0.946 | 72.°3 | 87.°0 | 84.°0 | 127.°1 | −30.°5 | 48.5 | 41.3 |
| 3 | S | 997 | Jun 23.77 | 0.981 | 18.3 | 0.961 | 212.°2 | 92.°2 | 85.°6 | 317.°0 | +41.°6 | 48.8 | 41.2 |
| 4 | S | 23 | Feb 19.43 | 0.642 | 17.2 | 0.963 | 285.°8 | 150.°8 | 84.°3 | 293.°2 | −65.°2 | 49.3 | 41.7 |

## 3 The predicted stream

The theoretical meteoroid stream associated to Comet 122P/de Vico was modeled for several perihelion passages in the past. We present results from our model starting from 750 orbital periods ago, i.e., from about 55 790 years before present.

The evolution of orbital elements of this theoretical stream is illustrated in Figure 1. In the first few thousand years, we see the peaks corresponding to the initial parameters. Plot (e) shows an interesting evolution occurs for $\Omega$, the longitude of the ascending node, which changes by a few degrees about every 20 000 years. A permanent rise of the inclination $i$ is seen in plot (f).

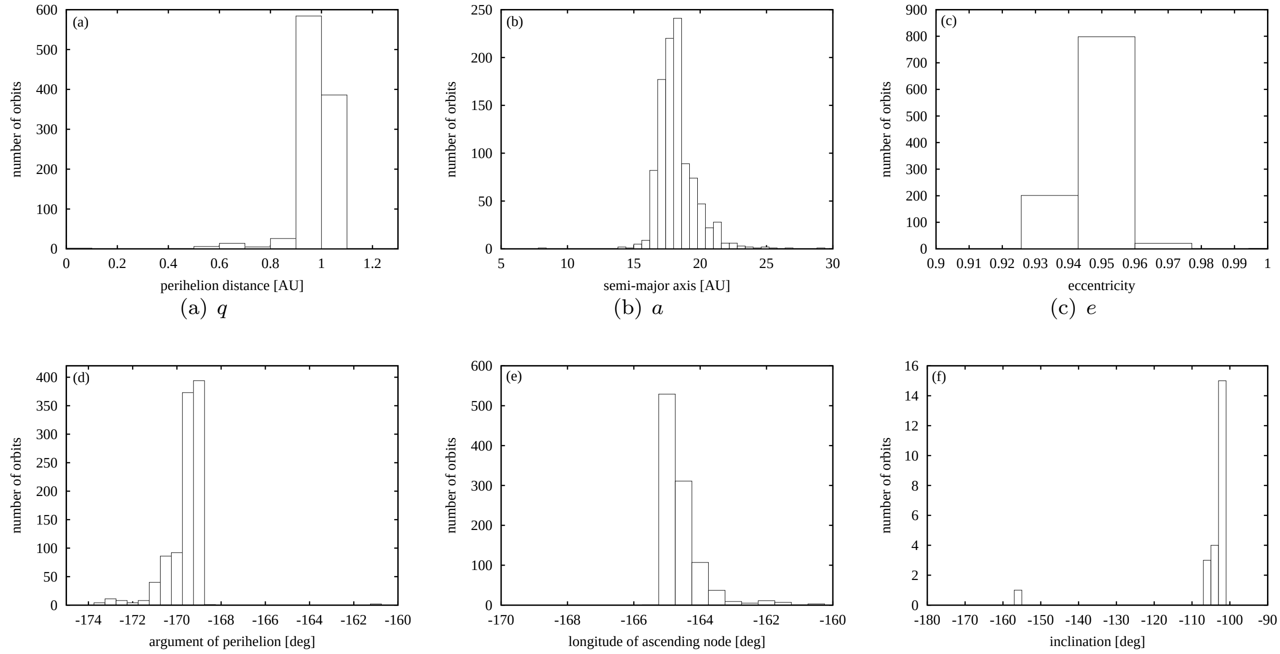
In determining how many particles approach the orbit of the Earth within 0.05 AU, we found two branches. A lesser populated northern branch is represented by 12 particles and a more populated southern branch by 1023 particles, from a total number of 10 000 particles.

In Figure 2, the distribution of the orbital elements of the southern branch is illustrated.

Analyzing the radiants, four separate radiant areas, corresponding to four distinct stream filaments, are found (Figure 3, filaments F1–F4). We determined the mean radiant and the other characteristics for each of these filaments. The mean characteristics of the separate radiant areas are listed in Table 1.

We failed to identify theoretical particles with real meteors. No apparent break point in the dependence of the selected number on the $D$-discriminant was found.

We also modeled the theoretical streams for other ejection times. Specifically, we considered of 500, 250, 100, and 50 orbital periods before present. The closer we come to the present time, the fewer Earth-orbit approaching particles occurred. Finally, there were no Earth-orbit approaching particles for ejection times 100 and 50 orbital periods before present.




(a) $q$ (b) $a$ (c) $e$

(d) $\omega$ (e) $\Omega$ (f) $i$

*Figure 2* – The distribution of orbital elements of the southern Earth-orbit approaching part of theoretical stream associated with Comet 122P/de Vico.

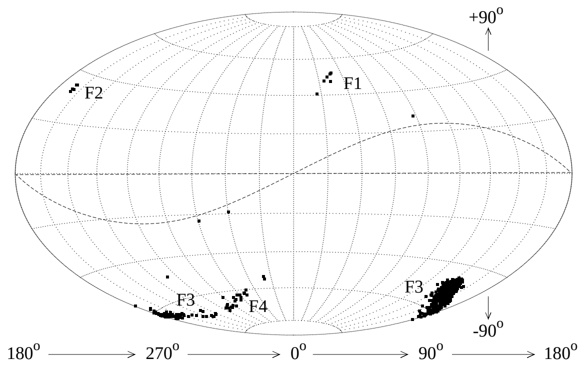



*Figure 3* – Positions of radiants of the theoretical stream's particles moving currently in orbits, in which they can approach the Earth's orbit within 0.05 AU. The stream is split into four filaments with four distinct radiant areas. The radiants are shown in a Hammer projection of the sky. The equatorial coordinate frame is used. The sinusoid-like curve is the ecliptic.

## 4 Conclusions

Our study of the dynamics of meteoroid particles representing the stream associated with Comet 122P/de Vico shows that the planetary perturbations changed a quite large number of the particles to orbits approaching the orbit of the Earth. In more detail, these particles can hit our planet concentrated in four filaments. The radiants of two filaments are predicted on the southern sky where a relatively low number of real meteors has been detected.

It appears that Comet 122P/de Vico would associate a meteor shower observable on the Earth only if its meteoroids were able to survive an extremely long period (about 55 000 years) orbiting the Sun. The orbits of the particles younger than approximately 37 000 years are found to clearly not evolve to the vicinty of the Earth's orbit.

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