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Prediction of evolution of meteor shower associated with comet 122P/de Vico

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Abstract. We deal with a theoretical meteoroid stream of the comet 122P/de Vico. For five perihelion passages in the distant past, we model a theoretical stream and follow its dynamical evolution until the present. We predict the characteristics of potential a meteor shower approaching the Earth's orbit and we make also the identification of the particles of the predicted shower with the real 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 are found to evolve into a collision course with the Earth and, therefore, form a possible shower. Many meteoroids do not survive such a long time in interplanetary space.

Key words: comets – meteoroids – meteors

1. Introduction

Similarity between the orbits of a comet and meteoroids was described by several authors. The first relationship between meteoroids and comets were established by G.V. Schiaparelli more than 150 years ago ("Obituary", 1911). The first computer search for meteoroid streams was made by Hawkins and Southworth (1958) 50 years ago. Since that time, many investigators have studied a cometary or asteroidal origin of meteoroid streams. We can usually observe only the meteors in the Earth's atmosphere originating from the bodies, the orbit of which crosses the orbit of our planet.

Comet 122P was discovered by de Vico in Rome on February 20, 1846 (de Vico, 1846). An independent discovery was made by William C. Bond (1846) on February 26 of the same year. The orbit, which was determined from the first observations, was similar to that of comet 5D/Brorsen, also discovered in 1846 (Astronomische Nachrichten, 1846,Vol. 23, Nr. 556, pp. 61-62). More detailed calculations showed that this is not the same comet. The calculations showed that Brorsen's comet has a period of 5.6 years whereas the period of de Vico's comet is ≈ 75 years. De Vico's comet was observed until May of 1846 and then not seen again until 1995, when it was observed between September 1995 and May 1996.

More specifically, comet 122P/de Vico is a Halley-type comet with the orbital period of 74.35 years. Its osculating elements according to the JPL Small-

Body Database Browser[1] are (epoch JDT = 2450280.5): $q = 0,659337\,\mathrm{AU}$, $e = 0,962709$, $\omega = 12,996092°$, $\Omega = 79,624501°$, and $i = 85,382753°$.

2. Modeling of the theoretical stream

We model a theoretical stream associated with this comets, which we assume to be the parent body of the meteoroid stream, and study the dynamics of the modeled meteoroid particles. A dynamical evolution of test particles was monitored with numerical integration. The perturbations from 8 planets are considered. In more detail, the procedure was recently described in the paper by Tomko & Neslušan (2012). Here, we briefly recall the individual steps.

1. The integration of the parent body into the past. The initial position and velocity vectors are taken from JPL ephemeris (ftp://ssd.jpl.nasa.gov/pub/eph/planets/bsp/;DE406). The initial position and velocity vectors of the 8 planets, Mercury to Neptune, are taken from the Astronomical Almanac for 2004 (2002). The gravitational perturbations of the planets are included in the integration. The integration is performed by using integrator RA15 developed by Everhart (1985), which is part of the Mercury package (Chambers, 1999).

2. Modeling the theoretical particles at the moment of the parent body perihelion passage reached at the previous step. Every modeled particle is assumed to have the same magnitude of the ejection velocity equal to 1/1000 perihelion velocity of the parent body. Specifically, the ejection velocity is 37.15, 40.13, 45.71, 50.25, and 50.79 $\mathrm{m\,s^{-1}}$ for the model 750, 500, 250, 100, and $50P_o$, respectively. P_o is orbital revolution of the parent body. In this way, we generate 10 000 particles with the randomly distributed directions of their velocity vectors.

3. Numerical integration of the stream particles from the moment of their ejection until the present. Integrator RA15 within the MERCURY package is again used. The final characteristic of 8 perturbing planets and the parent body obtained by integration into the past in step 1 are taken as initial in this step.

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

5. The selection of the particles in orbits crossing or passing around of the Earth's orbit at the distance shorter than 0.05 AU.

6. The analysis of the dynamical evolution of the Earth-orbit approaching part of the theoretical stream. If there are enough such particles, a prediction of the characteristics of an eventual meteor shower associated with the studied parent body follows.

7. The identification of the Earth-orbit approaching particles with the actually observed meteors. The photographical IAU MDC (Lindblad et al., 2003), radio-meteor (Hawkins, 1963; Sekanina & Southworth, 1975; Lindblad, 2003),

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[1] http://ssd.jpl.nasa.gov/sbdb.cgi

and the SonotaCo video-meteor (SonotaCo, 2009) databases are used at this identification.

The identification is done using the "break-point method" suggested by Neslušan et al., (1995; 2012). We calculate the D-discriminant between the mean orbit of the predicted shower and the orbit of every real meteor.

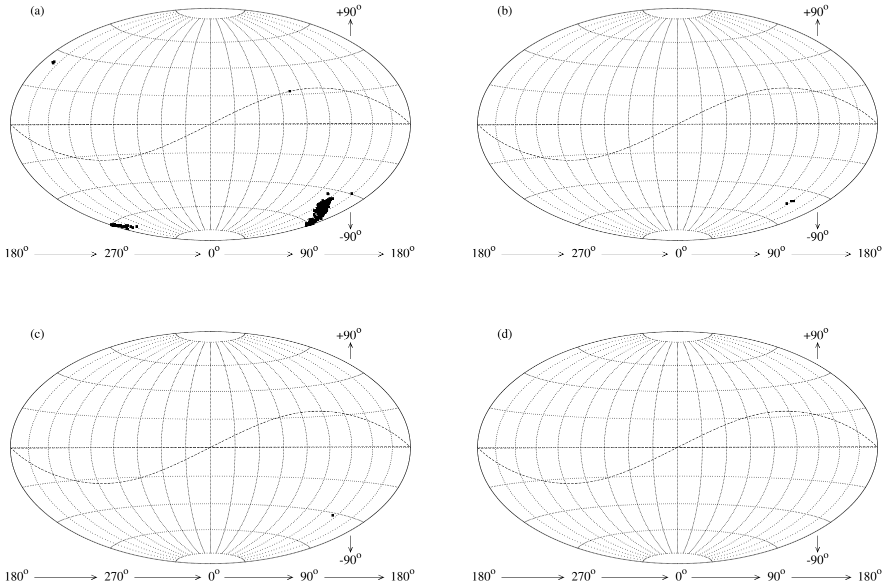

Figure 1. Positions of radiants of the 122P-stream particles moving currently in orbits, in which they can approach the Earth's orbit within 0.05 AU. The positions for the streams modeled for $500P_o$, $250P_o$, $100P_o$ and $50P_o$ in the past. The radiants in the model for $750P_o$ are shown in Fig. 5 with more details. The radiants are shown in the Hammer projection of the sky. The equatorial coordinate frame, with right ascension indicated by meridional circles and declination indicated with the declination circles, is used. The sinusoid-like curve illustrates the ecliptic.

3. The predicted stream

The theoretical stream of comet 122P/de Vico was modeled for several times of perihelion passages in the past, equal to 750, 500, 250, 100, and 50 orbital revolutions of the parent body (P_o). In years, the modeling times are 55 763, 37 175, 18 588, 7 435, and 3 718 years before the present. The first two times are approaching the maximum physical age of common meteoroid particles, there-

fil.	br.	n	t_{max}	α_g	δ_g	V_g	V_h
1	N	6	Sep. 27.57	26.8	48.1	47.9	41.3
2	N	5	Dec. 20.11	127.1	33.8	48.5	41.3
3	S	997	June 23.77	317.0	−52.4	48.8	41.2
4	S	23	Feb. 19.43	293.2	−65.2	49.3	41.7

Table 1. Mean geophysical characteristics of the individual filaments (fil.) of 122P stream which are predicted to appear as meteor showers in the Earth's atmosphere. Denotation: br. - branch of the shower (N-northern, S-southern), n - number of filament members, t_{max} - time of maximum acivity, α_g and δ_g - equatorial coordinates of geocentric radiant, V_g and V_h - geocentric and heliocentric velocity. Angular quantities are given in degrees and velocities in $\mathrm{km\,s^{-1}}$.

fore we have to be careful when drawing the conclusions from the corresponding models. We note that the lifetime of millimeter-sized particles is estimated to be about 62 000 years (Jenniskens, 2006, p. 539). The considered evolutionary period 55 000 years is at a border of the lifetime of millimeter-sized particles. We nevertheless examine these periods of stream evolution to see it in a wider context.

No particle approaches the Earth's orbit in model $50P_o$ and for models $100P_o$, $250P_o$ and $500P_o$ there are 1, 3, and 541 particles, respectively, which approach the Earth's orbit. A significant number of particles, 1035, well sufficient to predict the properties of a potential shower, occur in model $750P_o$. Although so long dynamical evolution of a common stream consisting of small particles is problematic, there is a possibility of the survival of large boulders. It is assumed that there is a stream consisting of boulders. For example, there are the meteorites Příbram and Neuschwanstein, which are likely members of a stream of similar kind.

On the basis of modeling of a more realistic period of evolution, i.e. the models for $100P_o$ and $250P_o$, the comet can associate only the low concentrated, diffuse showers. We do not present their characteristics, since these can be predicted only with a relatively large uncertainty. The radiants of the particles approaching the Earth's orbit to less than 0.05 AU are shown in Fig. 1

A relatively well-defined stream is predicted by the model for the time $750P_o$ in the past. In the following, we analyze in more detail just the model for this time. Again, we would like to emphasize that our predicted characteristics of showers are not related to classical meteor showers, but rather to a shower of "boulders", that potentially could collide with the Earth, and the collisions could occur in the same period of year and fireballs coming from the same direction (Tab. 1).

The evolution of orbital elements of the whole theoretical stream is demonstrated in Fig. 2. An interesting evolution occurs in the case of the perihelion distance (Fig. 2a), eccentricity (2c), argument of perihelion (2d), and inclination

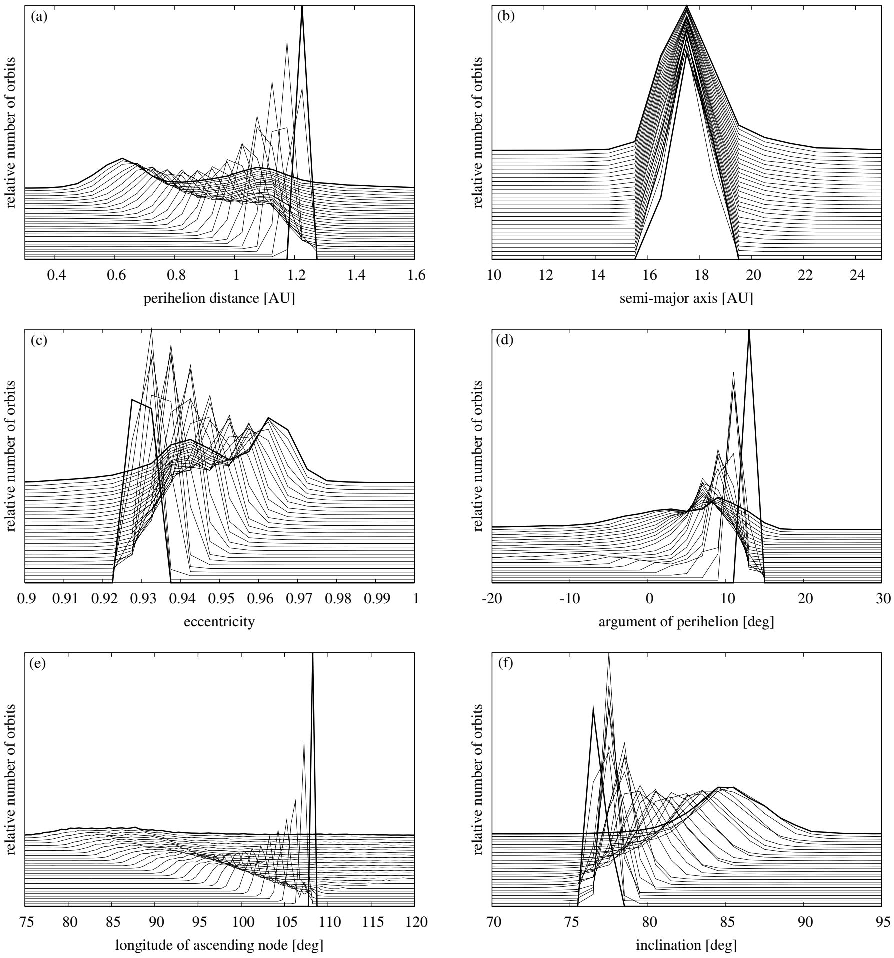

Figure 2. The evolution of orbital elements of the theoretical stream associated with comet 122P/de Vico. The stream is modelled for the time of 122P perihelion passage being closest to the time 750 P_o ago, where P_o is the orbital period of the comet. The bottom curve illustrates the distribution in the time of modeling. The higher curves show the behaviour for another successive 2000-year intervals. The top curve shows the distribution at present.

(2f). All these elements were subject to significant changes for the last 55 000 years. In the distribution of perihelion distance (2a) we can see two peaks at 0.62 and 1.13 AU. The second peak indicates that the part of the stream in the vicinity of the Earth can potentially collide with the atmosphere. In the distribution of eccentricity (2c) and argument of perihelion (2d), there is found

fil.	br.	n	q	a	e	ω	Ω	i
1	N	6	0.437	16.8	0.975	279.2	184.4	80.4
2	N	5	1.010	18.7	0.946	72.3	87.0	84.0
3	S	997	0.981	18.3	0.946	212.2	92.2	85.6
4	S	23	0.642	17.2	0.963	285.8	150.8	84.3

Table 2. Mean orbital characteristics of the individual filaments (fil.) of 122P stream which are predicted to appear as meteor showers in the Earth's atmosphere. Denotation: *br.* - branch of the shower (N-northern, S-southern), n - number of filament members, q - perihelion distance, a - semi-major axis, e - eccentricity, ω - argument of perihelion, Ω - longitude of ascending node, i - inclination. q and a are given in AU, angular quantities in degrees.

a formation of 2 areas with greater occurence of particles. The distribution of semi-major axis (2b) is substantially unchanged during the entire 55 000 years. The inclination (2f) increased from the initial value 77 ° to 85 °.

In determining how many particles approach the Earth's orbit within 0.05 AU, we found two branches. A less numerous northern branch is represented by 11 particles and more numerous southern branch by 1020 particles from the total number of 10 000 particles. In Fig. 3 and Fig. 4, the distribution of orbital elements of the southern and northern branch is demonstrated.

Analyzing the radiants, four separate radiant areas, corresponding to four distinct stream filaments, are found (Fig. 5, filaments F1-F4). We determine the mean radiant and other characteristics for each of these filaments. The mean orbital characteristics of the filaments are listed in Tab. 2

Our identification of theoretical particles with the real meteors is negative. No apparent break point in the dependence of the selected number on the D-discriminant can be found.

To see a relation of the radiant area of the predicted shower to the cardinal meteor directions, we plot the radiants of the Earth-orbit approaching particles in the ecliptical coordinate frame with the longitude shifted in such a way that the apex of Earth motion is at the origin of this frame (Fig. 6). Specifically, the common ecliptic longitude, λ_g, is replaced by angle λ_A related to λ_g by relation $\lambda_A = \lambda_g - (\lambda_\odot + 270^o)$, where $\lambda_\odot$ is the longitude of the Sun at the moment of the minimum approach of the particle to the Earth's orbit. Actually, it appears that filament 4 (Tab. 1 and Tab. 2) can be classified as the toroidal shower. Angle λ_A of the radiants of the particles in this filament is approximately equal to zero and the ecliptical latitude corresponds to the situation of the radiant in a vicinity of the south pole of the ecliptic.

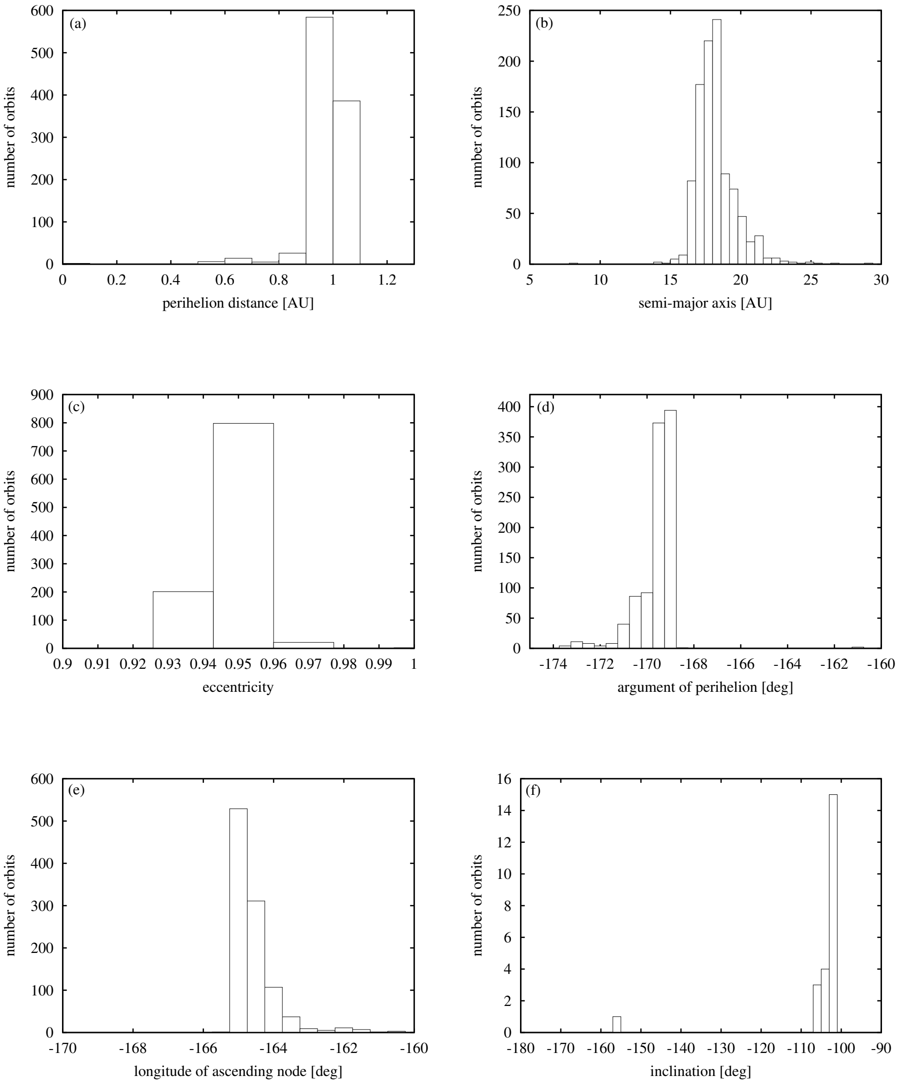

Figure 3. The distribution of orbital elements of the southern Earth-orbit approaching part of theoretical stream associated with comet 122P/de Vico, according to the model made for 750 P_o.

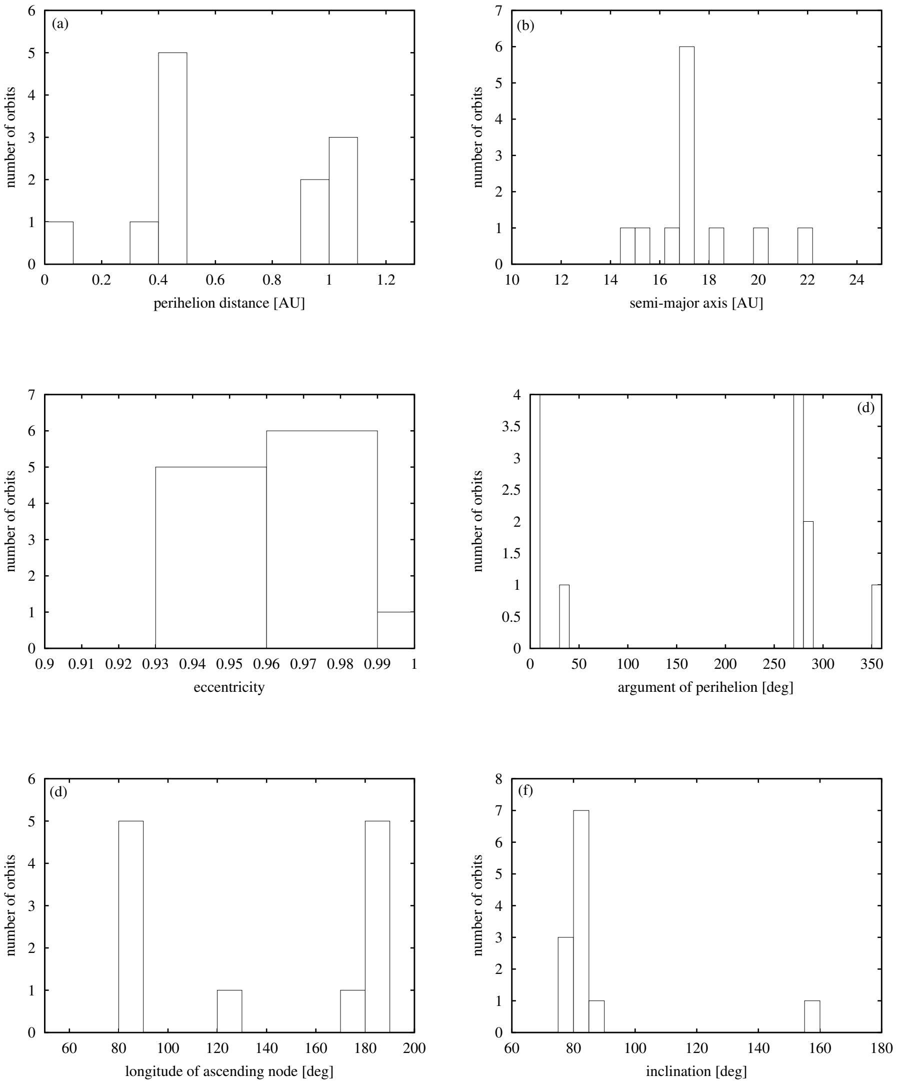

Figure 4. The distribution of orbital elements of the northern Earth-orbit approaching part of theoretical stream associated with comet 122P/de Vico, according to the model made for $750\,P_o$.

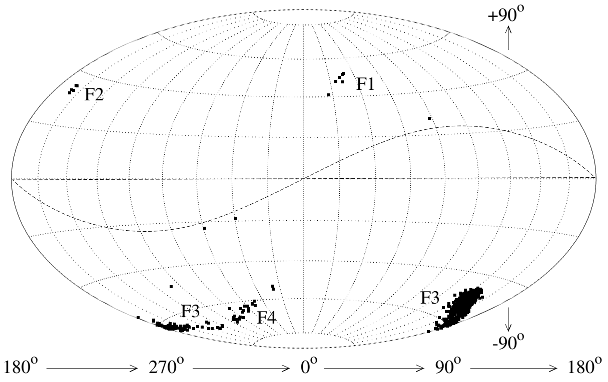

Figure 5. Positions of radiants of the 122P-stream particles moving currently in orbits, in which they can approach the Earth's orbit within 0.05 AU, according to the model made for $750\,P_o$ before the present. The stream is split into 4 filaments having 4 distinct radiant areas. The radiants are shown in the Hammer projection of the sky. The equatorial coordinate frame is used. The sinusoid-like curve illustrates the ecliptic.

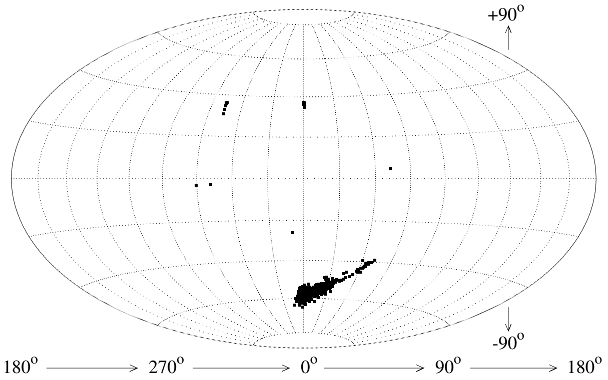

Figure 6. The demonstration of the toroidal direction of one filament of the predicted 122P meteor-shower complex. The plot illustrates the positions of radiants, the same as in Fig. 5, in the modified ecliptical coordinate frame (λ_A, β_g) in the Hammer projection of the celestial sphere. The common ecliptic longitude, λ_g, is replaced by the angle λ_A measured from the ecliptic longitude of the Earth's apex. This apex is situated at the origin of the frame.

4. Conclusions

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

If the dynamics of eventual boulders associated with 122P is followed during a period longer than about 37 millenia, then the planetary perturbations change the orbits of a quite large number of the particles to the orbits approaching the orbit of the Earth. In more detail, these particles would hit our planet concentrated in four filaments. The radiant area of the most numerous filament **is** predicted on the southern sky.

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