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Comets 14P/Wolf and D/1892 T1 as parent bodies of a common, α-Capricornids related, meteor stream

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Abstract. Studying the dynamics of meteor streams associated with comets 14P/Wolf (in the orbit known before a large disturbance by Jupiter in 1922) and D/1892 T1 on the basis of gravitational action exclusively, it is possible to demonstrate that the detectable part of the stream of 14P/Wolf has been split into two rather different strands by planetary disturbances. The first of these strands is overlapped by the detectable part of stream of D/1892 T1, whilst the second strand coincides with the $\alpha-$Capricornids meteor stream. The result is drawn comparing theoretical (modelled) orbits of the streams of both comets with the orbits of actual meteors, observed photographically, which are contained in the catalogue of the IAU Meteor Data Center in Lund.

Key words: meteors, meteoroids – comets: general

1. Introduction

In a preliminary analysis of the dynamics of 77 theoretical streams associated with short-period comets moving in the orbits distant from that of the Earth and having an orbital period shorter than 10 years, we found that the particles of theoretical streams of 21 comets came within 0.2 AU of the Earth's orbit and the particles of 14 of these comets could be identified with observed meteors. Three of these comets, D/1895 Q1 (Swift), 14P/Wolf, and 43P/Wolf-Harrington, are the best candidates to be the parent bodies of observable meteor showers. In the case of comet 14P/Wolf, we found (Neslušan 1999) that the modelled meteor stream corresponds to a part of the observed, complicated meteor shower, $\alpha-$Capricornids.

The modelling of the stream of 14P/Wolf and its identification with observed meteors show that the observable structure of the stream is wider and one part coincides with the modelled and identified stream associated with comet D/1892 T1 (Barnard 3). This could be expected because the orbit of D/1892 T1 was very similar to that of 14P/Wolf before 1922. In this study, we give a more detail analysis of the observable structure of the comet 14P/Wolf stream as well as an analysis of the stream associated with comet D/1892 T1 overlapping that of 14P/Wolf.

2. Modelling of a theoretical stream

Meteoroid particles are most frequently released from the nucleus of their parent body when closest to the Sun, i.e. at the perihelion of the parent body. Taking this into account, we model a theoretical meteoroid stream at the moment of perihelion passage of the parent body considered.

The orbits of the particles are subsequently dispersed due to non-zero ejection velocity and gravitational as well as non-gravitational perturbances. The dispersion coming from the initial orbital velocity difference and non-gravitational forces cannot move the particles of an appropriate meteoroid stream associated with a distant parent body (such as 14P/Wolf and D/1892 T1) close to the Earth's orbit. Even if such particles cross the Earth's orbit, it is not possible to distinguish them from the sporadic meteor background. Therefore, stream particles can approach the orbit of our planet only due to quasi-systematic gravitational perturbances, which deflect a significant part of the stream from the original direction of its motion to a quasi-uniform new direction. To map the action of the gravitational perturbing forces, we study an evolution of a set of theoretical particle orbits being very adjacent to the orbit of their parent body, whereby we attempt to construct these orbits uniformly around the parent body orbit.

If the disturbances are quasi-systematic, one expects that these appear relatively soon after the release of the particles from the parent body. Otherwise, the non-gravitational forces would chaotically disperse the particle orbits and the disturbances could scarcely have a systematic character. Consequently, the dispersion of the modelled orbits has to be much smaller than the actual observed dispersion of (long lasting) meteoroid streams. Thus, the modelled set of orbits represents the most central part of the stream, not the entire stream.

The non-gravitational forces are not considered in the modelling.

To model the most central part of an investigated potential meteor stream and to identify the theoretical particles with the actual observed meteors in the catalogue, we execute the procedure consisting of the following steps:

• 1. Integration of parent body orbit backward up to its perihelion being most close to time $10P_{\rm o}$ before the beginning of this integration. The beginning is, practically, identical to the epoch which orbital elements of the parent body in the Catalogue of Cometary Orbits are referred to. P_o is the orbital period of the parent body at the beginning. We take into account the perturbances from 8 planets (Mercury to Neptune). Their initial radius and velocity vectors are taken from the Astronomical Almanac (1983). The integration is done by using„GAUSS–RADAU" (RA15) integration method developed by Everhart (1985).

• 2. Proper modelling of the theoretical stream. We consider a parent-body-centric coordinate system with the $x-y$ plane identical to the orbital plane of the parent body at the time of the end of the integration executed in step 1 (the parent body is situated at its perihelion). The $x-$axis of this coordinate system is orientated by the heliocentric perihelion velocity vector, $\boldsymbol{v}_{\rm o} = (v_{\rm ox}, v_{\rm oy}, v_{\rm oz})$, of the parent body. Every modelled particle is assumed to have the magnitude of its orbital velocity different to that of the parent body, $v_{\rm o}$, about value $\Delta v_{\rm o}$. We assume that $\Delta v_{\rm o} = \chi v_{\rm o}$, where χ is a constant factor. The spatial grid of modelled particles is produced calculating the components of the velocity vector in the parent-body-centric coordinate system. These components represent the differences, $\Delta v_{\rm x,ij}$, $\Delta v_{\rm y,ij}$, $\Delta v_{\rm z,ij}$, between the components of heliocentric velocity vectors of $ij-$th particle and the parent body. In a spherical coordinate system, v, ϑ, φ, these differences can be given as

$$\Delta v_{\rm x,ij} = \Delta v_{\rm o}.\cos(i\Delta\vartheta_{\rm j}).\cos(j\Delta\varphi) \quad (1)$$

$$\Delta v_{\rm y,ij} = \Delta v_{\rm o}.\sin(i\Delta\vartheta_{\rm j}).\cos(j\Delta\varphi) \quad (2)$$

$$\Delta v_{\rm z,ij} = \Delta v_{\rm o}.\sin(j\Delta\varphi) \quad (3)$$

where $i = 0, 1, 2,...,$ up to the nearest integer of $N_{\vartheta\rm j} - 1$, and $j = -N_\varphi, -N_\varphi + 1,..., -1, 0, 1, 2,..., N_\varphi - 1, N_\varphi$. Assuming a uniform distribution, $\Delta\varphi$ is constant and $N_\varphi = 90°/\Delta\varphi$. The uniformity of the spatial grid further requires $N_{\vartheta\rm j} = (360°/\Delta\varphi).\{\sin[(j + 0.5)\Delta\varphi] - \sin[(j - 0.5)\Delta\varphi]\}/[2.\sin(\Delta\varphi/2)]$. If $j = -N_\varphi$ ($j = +N_\varphi$), then $N_{\vartheta\rm j} = (360°/\Delta\varphi).\{\sin[(j + 0.5)\Delta\varphi] - 1\}/[2.\sin(\Delta\varphi/2)]$ ($N_{\vartheta\rm j} = (360°/\Delta\varphi).\{1 - \sin[(j - 0.5)\Delta\varphi]\}/[2.\sin(\Delta\varphi/2)]$). Finally, $\Delta\vartheta_{\rm j} = 360°/N_{\vartheta\rm j}$.

In our particular case, we chose $\Delta\varphi = 4°$. Consequently, we obtain a total number of 2578 particles. At the moment of parent body perihelion passage, the heliocentric velocity vector of $ij-$th particle is $\boldsymbol{v}_{\bf ij} = (v_{\rm ox} + \Delta v_{\rm x,ij}, v_{\rm oy} + \Delta v_{\rm y,ij}, v_{\rm oz} + \Delta v_{\rm z,ij})$ and its heliocentric radius vector is identical to that of the parent body. Based on both the vectors, the appropriate orbit can be determined.

The ejection velocity of particles from the cometary nucleus is a free parameter in the above construction. Kresák & Kresáková (1987) spoke about this parameter in term of multiples (χ in our paper) of the orbital heliocentric velocity of the nucleus. For comet Halley, they considered value $\chi = 10^{-4}$ corresponding to $\Delta v_{\rm o} \approx 5$ m s^{-1}. Utilizing the observations of dust trails performed by the Infrared Astronomical Satellite, Sykes et al. (1989) considered the values lower than 10 (Type I trails) and about 100 m s^{-1} (Type II trails). The values 10 and 100 m s^{-1} correspond to $\chi \doteq 0.0003$ and $\chi \doteq 0.003$, respectively. In our particular case, we consider 3 values of χ equal to 0.0005, 0.001, and 0.002. These correspond to ejection velocities from 14P/Wolf equal to 14.7, 29.4, and 58.8 m s^{-1}, and that from D/1892 T1 equal to 15.7, 31.4, and 62.8 m s^{-1}, respectively.

We again note, only the most central strand of the stream is modelled in this way. E.g. for comet 14P/Wolf, the dispersion of orbits in this strand, characterized with the Southworth-Hawkins (1963) $D-$discriminant, is 0.0016, 0.003, and 0.006 for $\chi = 0.0005$, 0.001, and 0.002, respectively. The dispersion of orbits in an actual observed stream is that of order of $D \approx 10^{-1}$ (Neslušan et al. 1995). So, the modelled orbits are actually much less dispersed than those of an actual observed stream.

• 3. Forward integration of the orbits of all modelled particles together with the orbit of the parent body itself. An evolution of all the orbits is observed making the output from the integration after elapsing every $nP_{\rm o}$ for $n = 0, 1, 2, 3,...,10$.

• 4. Identification of orbits of the modelled particles with the orbits of actual meteors observed photographically, which are contained in the catalogue of the IAU Meteor Data Center in Lund (Lindblad 1987, 1991; Lindblad & Steel 1994). This identification is performed at each output.

We regard as similar orbits where the Southworth-Hawkins (1963) $D-$discriminant is not higher than 0.24. Investigating a mutual relationship among identified orbits of actual observed meteors, we found that the limiting value $D = 0.12$ characterizing the dispersion of the best orbits of $\alpha-$Capricornids in the catalogue is too strict for the similarity determination. This value is in accord with the purpose of the method of selection of the meteors from the database to select only such meteors, which can definitely be assigned to the shower. The method of optimal separation of meteors (Porubčan et al. 1995) could not unfortunately be applied and limiting value of D obtained for $\alpha-$Capricornids because of their complicated structure. Since the limiting value of the $D-$discriminant determined by the second (optimal) method is about 2 times higher than that determined by the first method for four studied major showers (Porubčan et al. 1995) on average, we decided to consider the value 0.12 twice as high in this paper.

3. Orbital evolution of 14P/Wolf stream

The distributions of orbital elements of modelled particles associated with comet 14P/Wolf are demonstrated in Fig. 1, plots a–f. The value $\chi = 0.001$ is considered in this modelling. In each plot, the distributions for every 11 outputs of numerical integration are drawn. A characteristic feature of all the behaviours is a splitting of the initial sharp peak to two or more milder peaks after an elapsed time $3P_{\rm o}$. The resultant peaks are shifted to both sides around the initial peak. For example, the initial peak at the value of perihelion distance about 1.6 AU (plot a) splits into the main resultant peaks at the values of about 0.85 and 1.95 AU, and another peak at the value of about 2.5 AU. In such a way, a quasi-stable dynamical structure of two-strand corridor of the stream can be recognized. A more detailed study shows that the individual particles of a stream can move from

Table 1. The numbers of actually observed meteors associated with the 'old' orbit (before 1922) of comet 14P/Wolf, which are identified with the modelled particles released by this comet. The numbers are given by 11 consecutive equidistant intervals beginning on May 3.56978, 1905 and ending on June 28.70888, 1987. $n_{\rm MDC}$ is the number of orbits from the IAU Meteor Data Center Catalogue, which are similar to at least one of the orbits of modelled particles, $n_{0.2}$ is number of modelled-particle orbits which come within 0.2 AU of the orbit of the Earth at the end of the given period. Three values of $n_{\rm MDC}$ as well as $n_{0.2}$ correspond to the three values, 0.0005, 0.001, and 0.002, of the χ parameter (see text Sect. 2, point 2) used to model three individual theoretical streams. $P_{\rm o}$ is the initial (catalogue) orbital period of 14P/Wolf.

time	$n_{\rm MDC}$			$n_{0.2}$		
0 $P_{\rm o}$	0	0	0	0	0	0
1 $P_{\rm o}$	0	0	0	0	0	0
2 $P_{\rm o}$	0	0	0	0	0	0
3 $P_{\rm o}$	0	78	79	0	614	423
4 $P_{\rm o}$	0	91	97	0	600	399
5 $P_{\rm o}$	42	90	98	9	605	398
6 $P_{\rm o}$	49	98	108	11	609	388
7 $P_{\rm o}$	45	81	110	8	602	380
8 $P_{\rm o}$	55	97	103	9	604	396
9 $P_{\rm o}$	59	94	102	9	604	396
10 $P_{\rm o}$	90	107	120	18	547	373

one strand to another, and also move to an orbit crossing the orbit of the Earth. It indicates our idea on the detectable meteor shower associated with a comet in a distant orbit, suggested in the introduction, is not only a theoretical possibility.

4. Relationship between the meteoroids of the 14P/Wolf and D/1892 T1 streams

The number of similar (mutually identified) theoretical and actual orbits at consecutive periods (outputs from numerical integration of orbits of modelled particles), from 0 to $10P_{\rm o}$, can be seen in Table 1 for comet 14P/Wolf. From the 2-nd to 4-th columns, there are numbers of meteors in the orbits from the IAU MDC database, which are similar to at least one orbit of the modelled particles. Three values correspond to the identification at three models with $\chi = 0.0005, 0.001$, and 0.002. Hereinafter, we refer to these meteors as associated with comet 14P/Wolf. Their numbers are variable but significant. First modelled particles are moved to orbits similar to that of observed meteors after period equal to $3P_{\rm o}$ ($5P_{\rm o}$ for $\chi = 0.0005$). The value 0.001 of the free parameter χ seems to be the most appropriate from the three values considered. For $\chi = 0.0005$, the number of identified meteors is relatively low. On the other hand, increasing this parameter to 0.002 does not result in a significant increase in the number of identified meteors either.

The identification of each meteor from the IAU MDC database with every modelled particles can seem to be unusual. However, we modelled only the central part of the theoretical stream and the IAU MDC database contains the data on a very small number of all meteors which have appeared in the Earth's atmosphere. Therefore, one meteor in our study, observed as modelled, is a representative of an entire "beam" of meteors, which should have been modelled (if we knew the way how to create an exact model and had sufficient computational facilities) or have existed, respectively. An indication that the procedure used is far from leading to random identification, comes from the fact that no meteor could been identified for 7 comets (in the preliminary analysis of 77 comets mentioned in Sect. 1) in spite of the particles of their streams approached the Earth's orbit closer than 0.2 AU. An extreme example are the particles of the comet 37P/Forbes stream, where as much as 52% of these approached the Earth's orbit below 0.2 AU, but none could be identified with any observed meteor. There occurs to be a sufficiently distinct boundary between the positive and negative cases.

Table 2. The numbers of observed meteors associated with the orbit of comet D/1892 T1 (Barnard 3) which are identified with the modelled particles released by this comet. The structure of table and used notation is the same as in Table 1. Here, $P_{\rm o}$ is the initial (catalogue) orbital period of D/1892 T1 and the entire analysed period begins on December 11.17421, 1892 and ends on February 23.43521, 1958.

time	$n_{\rm MDC}$			$n_{0.2}$		
0 $P_{\rm o}$	0	0	0	0	0	0
1 $P_{\rm o}$	0	0	0	0	0	0
2 $P_{\rm o}$	0	0	0	0	0	0
3 $P_{\rm o}$	0	0	0	0	0	0
4 $P_{\rm o}$	0	0	0	0	0	0
5 $P_{\rm o}$	11	11	12	1176	586	297
6 $P_{\rm o}$	11	11	12	1182	591	296
7 $P_{\rm o}$	20	20	21	1252	742	468
8 $P_{\rm o}$	20	20	20	1252	744	482
9 $P_{\rm o}$	21	20	21	1249	761	585
10 $P_{\rm o}$	20	20	20	1249	761	590

In the last three columns in Table 1, there are numbers of modelled particles in the orbits within 0.2 AU of the orbit of the Earth. The maximum of such orbits is obtained for $\chi = 0.001$.

The appropriate associated stream is modelled on May 3.61, 1905. After 1922, the comet finished contributing to that part of stream which approached the Earth's orbit: an analogous modelling in the case of new orbit, after 1922, shows that no modelled particle approaches the Earth's orbit and can be identified with any orbit of actually observed meteor. It is obvious seeing the large difference between the old and new orbits of the comet (Table 4).

In Table 2, there are analogous numbers of meteor orbits as in Table 1, but for comet D/1892 T1 (the meteors associated with D/1892 T1). Here, the first modelled particles are moved to the orbits similar to that of observed meteors after a period equal to $5P_{\rm o}$. The numbers of identified actual observed meteors are less than analogous numbers for 14P/Wolf, but not zero in contrast to those for the first known $\alpha-$Capricornids parent body, comet 45P/Honda-Mrkos-Pajdušáková, for $\chi = 0.001$ (Neslušan 1999, Table 3), for example. The choice of value of free parameter χ was not a significant influence on the number of identified meteors in this case: the number is almost the same for $\chi = 0.0005$, 0.001 and 0.002.

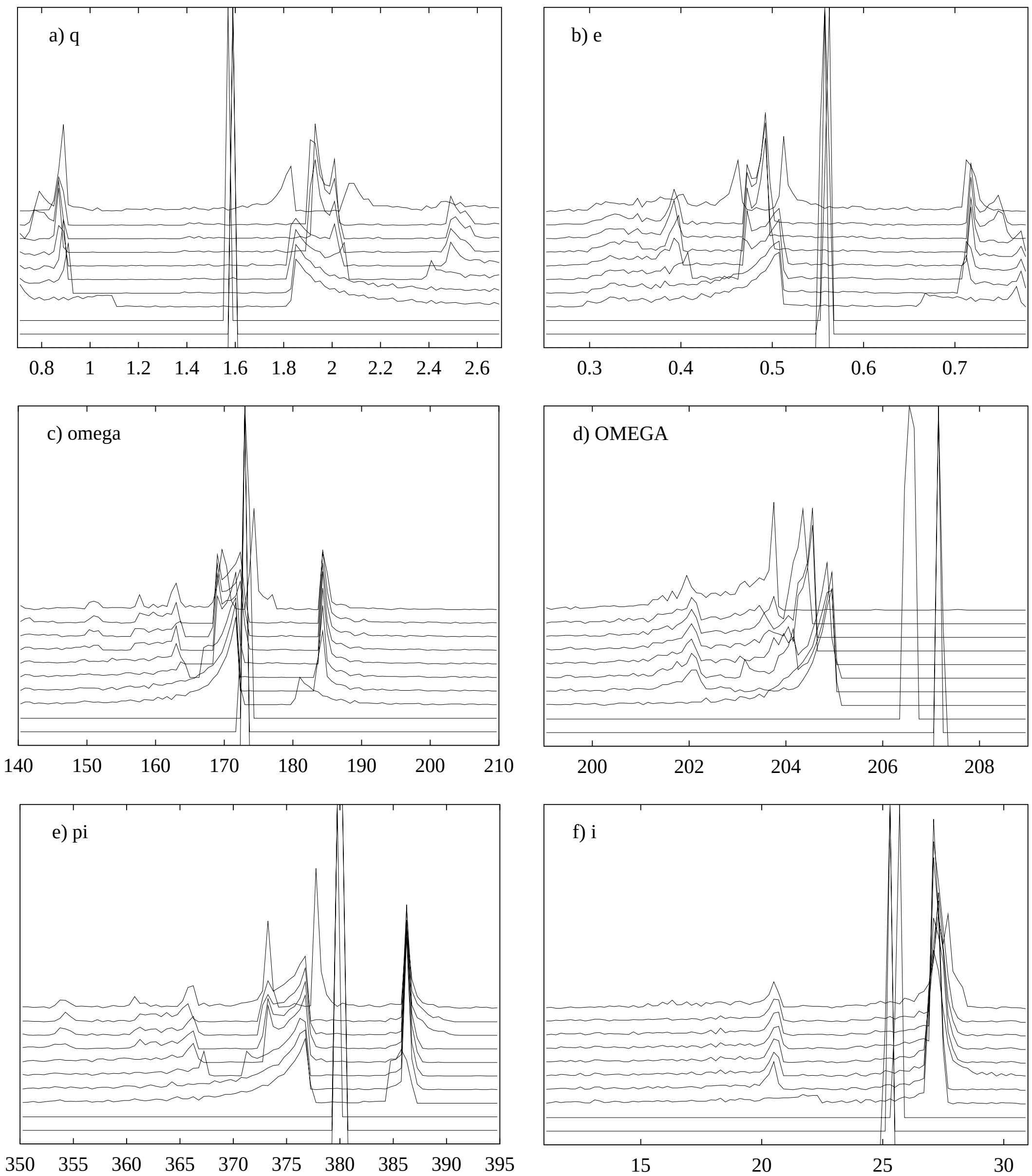

Fig. 1a–f. The distributions of orbital elements of the modelled meteor stream associated with comet 14P/Wolf. The theoretical stream is modelled considering $\chi = 0.001$. The evolution of orbital elements of the stream is analysed during the period from May 3.56978, 1905 to June 28.70888, 1987, which covers 10 orbital periods of the parent comet. In each plot, the distributions at the beginning of evolution as well as at the end of each period are given. Perihelion distance is given in AU, angular elements in degrees.

The mean orbital elements of observed meteors identified with the modelled particles associated with comets 14P/Wolf, D/1892 T1, as well as 45P/Honda-Mrkos-Pajdušáková are given in Table 3. (The angular elements as well as coordinates of radiants are, hereinafter, referred to the same equinox as the angular elements and radiant coordinates in the utilized photographic database, i.e. equinox 1950.0.) For a comparison, the mean orbital elements of the $\alpha-$Capricornids meteor shower are attached. The mean parameters of the shower are determined in the same way as in our previous paper (Neslušan et al. 1995) except for considering the limiting value $D = 0.24$ instead of $D = 0.12$. The elements of an individual meteor belonging to the given stream are considered as many times in the calculation of the mean elements as were identified with modelled particles at the outputs of particle-orbit integration (the sum of all 3 terms of $n_{\rm B3}$ in Table 5 in the case of comet D/1892 T1). In other words, the number of identifications of a given meteor represents its weight in the calculation.

Analyzing the radiants of individual meteors (see Sect. 5), it is convenient to divide the stream associated with 14P/Wolf into two strands: the upper corresponding to the stream of D/1892 T1 and the lower corresponding to the $\alpha-$Capricornids meteor shower (or the stream associated with 45P/Honda-Mrkos-

Table 3. The mean orbital elements of meteors identified with the modelled particles of theoretical streams associated with a given parent body (its name is given in the first column) as well as mean orbital elements of the $\alpha-$Capricornids meteor shower. $\langle q\rangle$ - perihelion distance (in AU), $\langle e\rangle$ - eccentricity, $\langle\omega\rangle$ - argument of perihelion, $\langle\Omega\rangle$ - longitude of ascending node, $\langle i\rangle$ - inclination to the ecliptic ($\langle\omega\rangle$, $\langle\Omega\rangle$, and $\langle i\rangle$ are given in degrees).

stream of	$\langle q\rangle$	$\langle e\rangle$	$\langle\omega\rangle$	$\langle\Omega\rangle$	$\langle i\rangle$
14P-upper strand	0.977	0.664	189.7	194.7	20.1
D/1892 T1	0.983	0.664	183.9	199.1	26.8
14P-lower strand	0.727	0.725	208.7	166.0	5.0
45P	0.623	0.767	218.8	187.4	5.9
α-Capricornids	0.610	0.759	254.7	143.3	6.7

Pajdušáková). Consequently, there are two sets of mean elements of 14P/Wolf stream in Table 3.

Now, let us analyze the relationship between the orbits of meteors associated with D/1892 T1 (Barnard 3) and those associated with 14P/Wolf. Both the comets had similar orbits before 1922 as is clear from their elements (compare lines 1 and 3 in Table 4). The nucleus of comet D/1892 T1 was probably a fragment of 14P/Wolf, separating sometime before 1892, which belonged to the common stream. Therefore, a coincidence of their streams can be expected. Actually, such coincidence is already observable comparing the mean orbital elements of upper strand of 14P/Wolf stream and D/1892 T1 stream (the first and second lines in Table 3).

Another proof of the coincidence can be seen in the list of the meteors associated with comet D/1892 T1 given in Table 5. At each meteor, there are presented the numbers of identifications of the meteor with the modelled stream at the integration outputs. Three terms correspond to the numbers for $\chi = 0.0005$, 0.001, and 0.002, respectively. We can see that 19 of 22 meteors (86%) associated with comet D/1892 T1 are meteors which can also be associated with comet 14P/Wolf. Two (9%) meteors of these can perhaps be associated with comet 45P/Honda-Mrkos-Pajdušáková. Only 3 (14%) meteors are associated exclusively with D/1892 T1.

Seeing Table 5, the stream of D/1892 T1 was active from the end of September to the end of October.

Table 4. The orbits of comets 14P/Wolf (before and after 1922) and D/1892 T1 (Barnard 3) referred to epoch $Ep.$ (Marsden 1989). q - perihelion distance (in AU), e - eccentricity, ω, Ω, i - argument of perihelion, longitude of ascending node, and inclination, respectively (in degrees).

comet	$Ep.$	q	e	ω	Ω	i
14P/Wolf	1919 Jan. 2	1.58	0.56	173	207	25
14P/Wolf	1942 Jun. 10	2.44	0.41	161	204	27
D/1892 T1	1892 Dec. 8	1.43	0.59	170	207	31

Table 5. The observed meteors (contained in the IAU Meteor Data Center database) associated with comet D/1892 T1 (Barnard 3) and their relationship to comets 14P/Wolf and 45P/Honda-Mrkos-Pajdušáková. $date + PSNO$ – date of meteor detection, its publication serial number, and author or station code as presented in the IAU MDC database; $n_{\rm B3}$, $n_{\rm 14P}$, $n_{\rm 45P}$ – number of identifications of given meteor with the modelled particles at individual outputs of particle-orbit integration (from $0P_{\rm o}$ to $10P_{\rm o}$ – see text and Table 1) in the case of comet D/1892 T1, 14P, and 45P, respectively. Three terms represent the numbers for $\chi = 0.0005$, 0.001, and 0.002.

$date + PSNO$	$n_{\rm B3}$	$n_{\rm 14P}$	$n_{\rm 45P}$
09/20.3459/1957 – 214P	4+4+4	–	–
09/23.7460/1965 – 012O	1+0+1	3+8+8	–
09/30.3160/1978 – 110I	0+0+1	2+8+8	–
10/01.1810/1967 – 168F	4+4+4	2+8+8	–
10/04.1500/1942 – 043W	4+4+4	1+8+8	–
10/08.4500/1985 – 196N	6+6+6	2+3+1	–
10/09.1922/1953 – 328J	6+6+6	3+8+8	–
10/09.2334/1953 – 330J	6+6+6	3+8+8	–
10/09.2982/1950 – 044W	4+4+4	–	–
10/10.1010/1965 – 019F	6+6+6	1+1+1	–
10/10.2155/1956 – 005P	4+4+4	1+8+8	–
10/10.3130/1971 – 286F	6+6+6	2+3+1	–
10/11.3121/1956 – 015P	4+4+4	0+8+8	0+0+1
10/12.2170/1967 – 172F	6+6+6	1+1+1	–
10/14.1830/1967 – 174F	6+6+6	3+8+8	–
10/15.4560/1965 – 020F	4+4+4	–	–
10/15.8260/1971 – 027E	6+6+6	3+6+4	–
10/21.0920/1967 – 180F	6+6+6	2+8+8	–
10/22.0440/1967 – 183F	6+6+6	3+8+8	–
10/24.8653/1978 – 074E	4+4+4	1+1+1	–
10/27.1610/1966 – 099F	6+6+6	3+7+7	–
10/27.7323/1983 – 143E	4+4+6	1+8+8	1+1+1

5. Analysis of radiants

In the previous paper (Neslušan 1999), we found that 69% of observed $\alpha-$Capricornids meteors selected from the IAU Meteor Data Center database at the limiting value of D discriminant equal to 0.24 were also identified with the modelled particles of 14P/Wolf stream. However, no meteor of $\alpha-$Capricornids was identified with the particles of stream of D/1892 T1 in spite of the relationship between the streams of 14P/Wolf and D/1892 T1 demonstrated in Sect. 4. This apparent paradox can be explained analysing the radiants of the observed meteors identified with the modelled streams of both the comets as well as the radiants of $\alpha-$Capricornids.

The radiants of the meteors of the $\alpha-$Capricornids meteor shower, the meteors associated with comet 14P/Wolf, and the meteors associated with D/1892 T1 (Barnard 3) are displayed in Fig. 2, plots a, b, c, respectively. In plot b, one can see two regions where the radiants of individual meteors of 14P/Wolf stream are grouped. Hence, it is natural to divide the stream into two strands: upper and lower. Another reason for such a division comes from a certain grouping of orbital elements of the meteors (see Table 3). The lowest ecliptic latitude of meteors of the upper strand is $40.0°$ and the highest ecliptic latitude of meteors of lower strand is $27.6°$, therefore ecliptic latitude

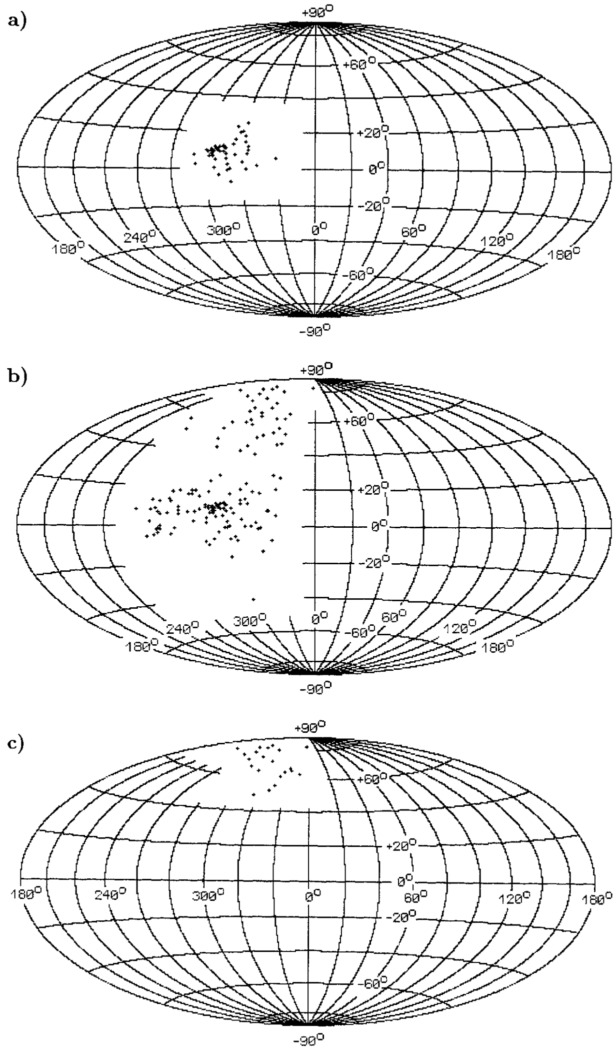

Fig. 2a–c. The radiants of meteors of the $\alpha-$Capricornids meteor shower **a**, meteors associated with comet 14P/Wolf **b**, and meteors associated with comet D/1892 T1 **c** displayed in the Hammer projection of a celestial sphere. The frame is ecliptic. The meteors are selected using limiting $D = 0.24$.

of about $34°$ can be recognized as a border between both the regions. (In the database, where the radiants are specified by the equatorial coordinates, the lowest declination of meteors of the upper strand is $20.4°$ and the highest declination of the lower strand is $9.9°$. Here, declination about $15°$ can be regarded as the border.)

Comparing the plots, it is clear that the meteors of D/1892 T1 coincide only with those of the upper strand of 14P/Wolf stream. Since both the strands of 14P/Wolf stream mutually coincide because of the common parent body and the lower strand of 14P/Wolf stream coincides with the $\alpha-$Capricornids meteor shower as well as, at the same time, with the stream of 45P/Honda-Mrkos-Pajdušáková, we can regard the D/1892 T1 stream as one part of the overlapping stream complex of all three comets considered.

Table 6. Some geophysical data of meteor streams associated with comets 14P/Wolf (upper and lower strands), D/1892 T1, as well as 45P/Honda-Mrkos-Pajdušáková having associated a stream coinciding with the lower strand of the 14P/Wolf stream. The corresponding data on the $\alpha-$Capricornids meteor shower are attached, too. $\langle\alpha\rangle$, $\langle\delta\rangle$ - right ascension and declination of mean radiant (in degrees), $\langle v_{\rm g}\rangle$, $\langle v_{\rm h}\rangle$ - mean geocentric and heliocentric velocities (in km s^{-1}).

stream of	$\langle\alpha\rangle$	$\langle\delta\rangle$	$\langle v_{\rm g}\rangle$	$\langle v_{\rm h}\rangle$
14P $-$ upper strand	288.8	39.6	15.17	38.34
D/1892 T1	281.0	50.9	18.22	38.38
14P $-$ lower strand	306.1	-11.3	18.26	37.64
45P	321.6	-4.6	21.85	37.69
$\alpha-$Capricornids	310.5	-8.7	21.91	37.38

The mean radiants as well as geocentric and heliocentric velocities of the streams considered are given in Table 6. As in the calculation of mean elements in Sect. 4, weighted values are used into the calculation of mean quantities. The time of stream activity maximum is not presented because its determination on the basis of a very low number of meteors is not reliable (no peak well defined can be noticed).

6. Summary

Our study of dynamics of meteor streams is based on the gravitational action, exclusively. Only this action can, in a quasi-systematic way, deflect the particles of a stream from their original orbital corridor to create an observable strand of the stream.

The dynamical study of the meteor stream associated with comet 14P/Wolf shows that the planetary gravitational disturbances split the corridor of the stream into several strands. The meteors of two of these strands can enter the Earth's atmosphere and become observable. They have rather different orbital characteristics. The mean radiants deviate so much as $53.4°$.

The strand with higher declination of mean radiant (the upper strand) coincides with the meteor stream associated with comet D/1892 T1 (Barnard 3). The deviation of mean radiants is $12.5°$ and corresponding orbital elements are also very similar. That means, the upper strand of the stream of 14P/Wolf was enriched with the meteoroids of D/1892 T1 stream in 20-th century.

The strand of 14P/Wolf stream with lower declination of radiant (the lower strand) coincides with the well-known meteor shower $\alpha-$Capricornids, as was already concluded in the previous paper (Neslušan 1999). The deviation of mean radiant of the strand (calculated using weighted input elements) from the mean radiant of $\alpha-$Capricornids is only $5.1°$ and corresponding orbital elements are in rough agreement, too.

In 1922, comet 14P/Wolf was moved to a new orbit due to the gravitational disturbance by Jupiter and stopped releasing meteoroid particles into the orbits crossing the orbit of the Earth.

In the case of D/1892 T1 stream, it is not clear if the nucleus of its parent comet became dormant and still releases new meteoroid particles or it disappeared absolutely and the stream has also been disappearing continually. This question could be answered studying an evolution of numerosity of this stream in the future.

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