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Analysis of the dynamic parameters of the Cancrids meteor shower and its drift motion

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We consider the Cancrids meteor shower and analyze its dynamical parameters. For each branch of the shower we determined radiants, their displacements, and radiation areas. The dependences of the semi-major axis and eccentricity on magnitude were studied. Resonances from Jupiter were determined for the meteor shower. It is concluded that the branches of the shower have different evolutionary mechanisms of origin.

Keywords: meteor shower, radiants, meteor complex, resonances.

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The study of the astrophysical characteristics of small celestial bodies is currently of particular importance, since they contain the primordial matter of the Solar System, which is important in the construction of an evolutionary theory. The purpose of this work is to determine the dynamic parameters of the Cankrid shower of meteors (CSM) and to study its drift motion [1] using regression simulation methods. The Cankrid Meteor Complex (CMC) is a small shower with two branches [2]. These are NCC — the Northern Branch of the CMC and SCC — the Southern Branch of the CMC. Both branches are observed during January and are numbered 96 and 95 by the Meteor Data Center, respectively. Information about the CMC branches based on the data [3–7] is given in Table 1: geocentric velocity V, [km/s], radiant coordinates $\mathbf{RA}^\circ$ and $\mathbf{DE}^\circ$, Sun longitude $\mathbf{L}^\circ$, semi-major axis of the orbit $\mathbf{a}$ in au, orbital eccentricity $\mathbf{e}$.

There are very few photoorbits for the CSM, so radar and television observations [4] were used in the studies, namely the SonatoCo and CMN television catalogs, where a sufficient number of orbits are given. The minimum recorded magnitude for the CSM was $+3.4^{\mathrm{m}}$, the error in determining the geocentric velocity was about 1.0 km/s.

Figure 1 shows the distribution of CSM radiant coordinates $\mathbf{RA}^\circ$ and $\mathbf{DE}^\circ$ as a function of the longitude of the Sun $\mathbf{L}^\circ$. SonatoCo catalog: shaded circles — NCC radiants, shaded triangles — SCC. CMN Catalog: Shaded Stars — NCC Radiants, Cross Marker — SCC. Other authors (Table 1): unshaded triangles — SCC. B Table 1 shows the coordinates of the radiant $\mathbf{RA}^\circ$ and $\mathbf{DE}^\circ$ and its daily position, which is called radiant drift **dRA**, **dDE**. The radiant drift is determined in order to more accurately indicate the position of the radiant within the constellation. The diurnal radiant drift is due to the motion of the Earth within the meteor shower.

The diurnal radiant drift **dRA**, **dDE** for each branch was determined from the individual coordinates $\mathbf{RA}_i$ and $\mathbf{DE}_i$ of the meteors. Formulas for calculating the coordinates of the geocentric radiants RA_i' and DE_i' of the CSM branches, considering their diurnal displacements:

$$RA_i' = RA_i - (L_i - L_0)dRA,$$

$$DE_i' = DE_i - (L_i - L_0dDE,$$

where RA_i, DE_i — are the individual coordinates of the radiants of the meteors, L_I — is the ecliptic longitude of the Sun at the time of meteor registrations, $L_0 = 298^\circ$, the values of **dRA**, **dDE** are found by correlation analysis in Fig. 1, they are plotted as a solid line in Fig. 1 indicating the name of the meteor shower branches — SCC and NCC. The parameters of the geocentric radiants of the CSM branchesRA_i' and DE_i', the values of their daily displacements **dRA**, **dDE**, as well as the averaged values of geocentric velocities V_g for each of the catalogs are given in Table 2.

Analyzing Fig. 1, it can be noted that the CMC branches NCC and SCC branches are observed on the same dates, there is agreement in terms of velocities (Table 1), and the radiants are clearly localized by declination and right ascension. According to all the sources used, the values of $\mathbf{DE}^\circ$ are higher for NCC than for SCC, and the values of $\mathbf{RA}^\circ$ are lower for SCC. The coordinates of the radiants and their diurnal variations for each branch were determined both from the coordinates of the individual radiants and from coordinates averaged to 1° solar longitude. The correlation coefficients for the values of right ascensions $\mathbf{RA}^\circ$ and declinations $\mathbf{DE}^\circ$ do not exceed the values of 0.2. To study the distribution of radiants and orbital elements, robust analysis methods were used. The application of robust analysis is used for observational selection in order to sample and account for unequal observations. In this paper,

Table 1. CSM Branch Details

Shower		V, km/s	**RA**°	**DE**°	**L**°	**a**, au	**e**	Sources
Cankrids	NCC	28.2	127.6	21.5	296.9	2.408	0.835	[5]
(CSM)	SCC	27.9	117.5	16.1	287.1	2.298	0.399	[5]
	NCC	27.0	127.6	21.5	296.0	2.260	0.810	[6]
	NCC	29.9	131.4	17.6	299.0	–	–	[6]
	SCC	26.8	134.1	10.1	296.3	2.114	0.761	[7]
	SCC	28.7	131.5	10.6	298.0	–	–	[8]

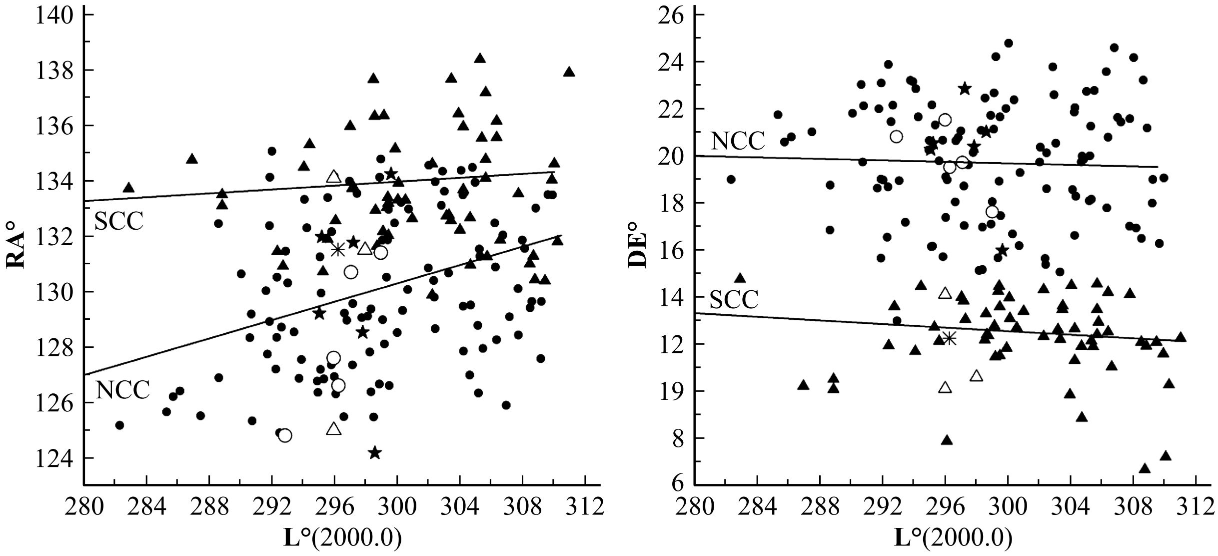

Figure 1. Coordinates of the radiants of the CSM as a function of the longitude of the Sun.

Table 2. Information on the velocities and CSM radiants obtained by the authors

CSM	V_g, km/s	V_h, km/s	**RA**°	**DE**°	**d RA**°	**d DE**°	S_r
NCC	27.10 ± 3.40	37.41 ± 1.31	129.80 ± 2.71	19.83 ± 2.70	0.170 ± 0.032	0.033 ± 0.031	$7 \times 6°$
SCC	28.00 ± 3.10	36.80 ± 2.21	133.52 ± 2.10	12.31 ± 1.70	0.021 ± 0.040	-0.020 ± 0.041	$4 \times 3°$

the method of robust analysis by grouping observational data is used. This interval-based method makes it possible to reduce the impact of non-equilibrium observations by means of special sorting or exclusion.

As a result, the following results were obtained (Table 2). The table shows the following data: velocities V_g and V_h, [km/s], right ascension **RA**° and declination **DE**° and their daily displacements **dRA**° and **dDE**° with the indication of standard errors, radiation area S_r.

The data obtained by the authors and given in Table 2 are in good agreement with the data in Table 1. The velocities have similar values, whereas right ascension and declination are different, and the area of radiation also differs. It is likely that the CMS branches were formed under different conditions and at different times. In the case of SCC, there are smaller values S_r and **RA**°, **DE**°, so SCC cannot be ruled out as a result of the breakdown of the progenitor of the stream. For the southern branch of the CMC, the diurnal radiant drift is determined more reliably than for the northern branch, due to the presence of a larger observational base of its orbit.

In order to understand how the CMC evolves, it is important to study the distribution of orbital elements as a function of magnitude (their mass), since the radiation forces cause the meteoroid to move towards the Sun along the spiral trajectory and the speed of movement is very much influenced by the size of the particle, the so-called Poiting-Robertson effect (PR). To understand the effect of PR on particles, let us study the dependencies of the semi-major axes and eccentricities for CMC.

Let us take a closer look at the changes in the NCC orbit elements using the data from the CAMS catalog, which contains individual parameter errors. The study of the dependence of semi-major axes and eccentricities in the magnitude range from -4^m to $+4^m$ showed (Fig. 2) that for the northern branch the values of the semimajor axes and

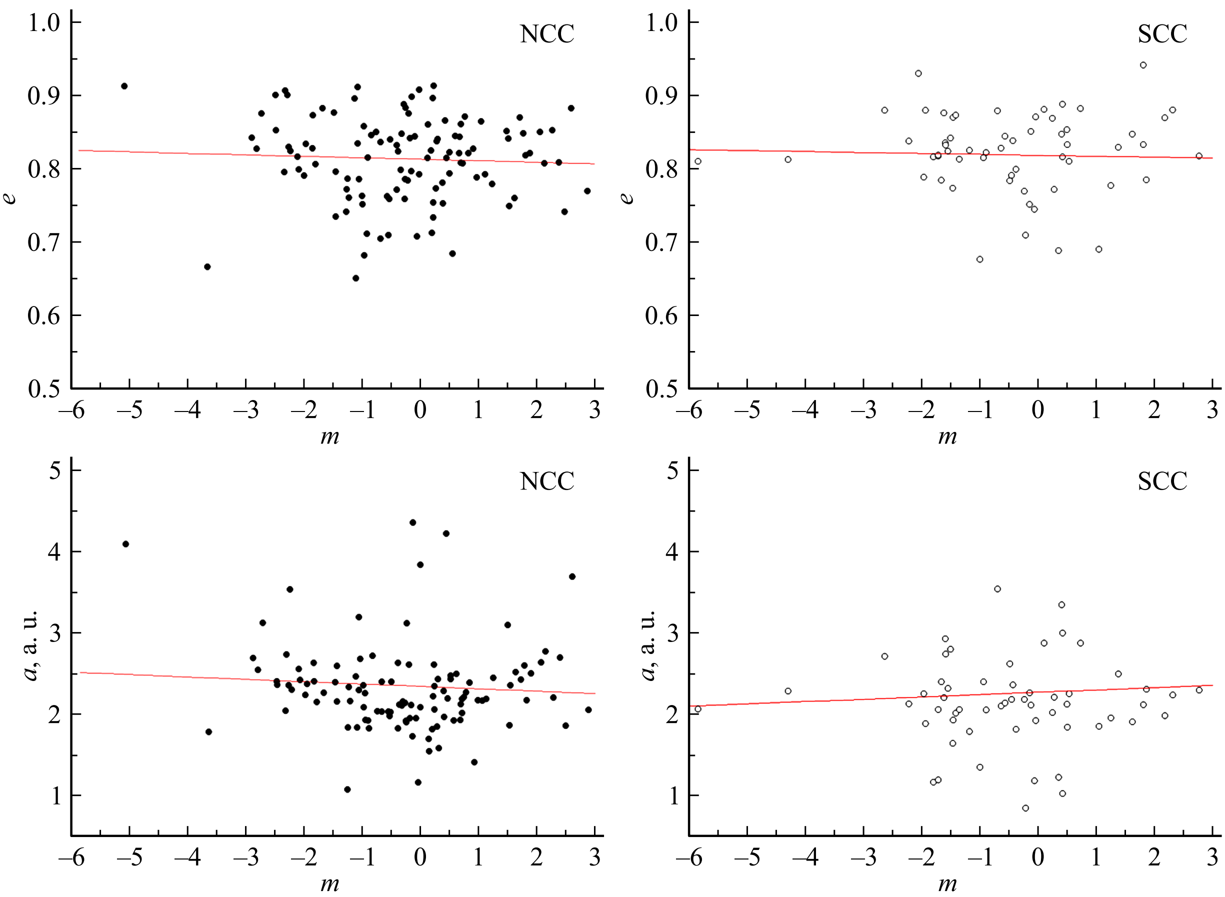

Figure 2. Dependence of the semi-major axes and eccentricities of the CMC on the magnitude of the meteors.

eccentricities decrease depending on the magnitude and the change is about 0.22 au. This decrease may be due to the influence of non-gravitational effects due to the significant age of the flow. For the southern branch, no such changes have been recorded. The geocentric velocities for both branches are almost identical. The radiants of each branch are evenly distributed, and no subradiants are detected. Based on a linear approximation in the magnitude range from -2^{m} to $+3^{\mathrm{m}}$ for NCC, the changes are: semi-major axes $\Delta a = 0.192$ au, eccentricities $\Delta e = 0.023$ (Fig. 2).

The Cankrid meteor complex has an orbital period of about 4 years and is subject to strong gravitational perturbations from Jupiter. The Southern branch is located in the zone of strong resonances of 2:1 and 1:1. Radiants for the CMC are obtained that are consistent with the data obtained by other authors [9]. The values of the diurnal course of radiants have been clarified, and the radiation areas have been determined. It can be assumed that the southern and northern CSM branches were formed as a result of various evolutionary processes, for example, during the secondary disintegration of the parent body [10].

Thus, the paper investigates the dynamic parameters of the CSM and studies its drift motion [1] using regression simulation methods, and the following results are obtained. For each branch of the CMC, radiants are determined that are in good agreement with the results of other authors, their displacements and radiation areas. The dependencies of the semi-major axis and eccentricity on magnitude have been studied. Resonances from Jupiter for the CMC have been determined. It has been concluded that the CMC branches have a different evolutionary mechanism of origin.

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Conflict of interest

The authors declare that they have no conflict of interest.

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