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# Quadrantids filaments modeling

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## Abstract

Numeric integration of orbits of particles along mean orbit of Quadrantid meteor stream is done at time span 20000 years. Orbits are subdivided on several classes by their evolution type. A very complex dynamical behavior is detected. About 20% of modeled particles escape stream: this fact point on that stream cannot be long-live and have a source within 5000 years.

## 1. Quadrantids orbits classification

First, we integrate 180 clones, placed equidistantly in true anomaly along orbit, during 20000 years. The perturbations from 7 planets (except Mercury) on fixed circular (elliptic) orbit. The Runge-Kutta algorithm is used. Step of integration is selected equal 0.1 day for all integrations. There are six main classes of orbits for Quadrantids mean orbits from table 1. As it may be expected, there are few areas of concentration and disappearance of particles along an orbit. The presence of escaped orbit can lead to varying a stream activity from year to year.

I. Most numerous class (66 clones or 37%) – chaotic bounded orbits, when semimajor axis display chaotic variations, but in certain range. The eccentricity evolutions in nearly always cases hold a periodic character.

II. Escape/Collisions class. A very unstable orbits with hyperbolic (or collisions with Sun) final orbit. About 15% of modeled particles escape stream on time interval 20000 year. The lifetime of particles in according parts of orbit is not large 10-15 thousands year.

III. Class of orbits with tendency of decrease of semimajor axis (30 clones or more 16%). In two cases it leads to escape particles from stream. The most probable Quadrantid parent body (2003 EH1) is included in this class.

IV. Similar class III but with increasing semimajor axis (7%), most of them escape stream (IV e class).

V. A very interesting class with (temporary) trapping in regime with periodic variations of semimajor axis. There are about 19% modeled orbits.

VI. Class of orbit with destroyed periodicity in *a* (5%, escape resonance).

## 2. Quadrantids filaments evolution

After that, Quadrantid filaments dynamics are studied. It is known a few strands or filaments of stream, for different authors by Wu and Williams **[1]** and by Porubcan and Kornos **[2],** their show non-coincidence.

Table 1: Quadrantids filaments orbital elements

| Name | *a* | *e* | *i* | ω | Ω | Ref |
|---|---|---|---|---|---|---|
| IP | 2.87 | 0.657 | 72.0 | 176.8 | 282.7 | [2] |
| IIP | 2.93 | 0.666 | 72.2 | 170.3 | 283.2 | [2] |
| IIIP | 2.73 | 0.641 | 70.8 | 173.3 | 283.3 | [2] |
| IVP | 3.17 | 0.693 | 70.9 | 168.0 | 283.3 | [2] |
| VP | 3.13 | 0.686 | 72.9 | 174.5 | 283.0 | [2] |
| IW | 2.98 | 0.673 | 71.7 | 170.7 | 282.1 | [1] |
| IIW | 2.83 | 0.654 | 70.8 | 167.7 | 282.1 | [1] |
| IIIW | 2.35 | 0.585 | 71.4 | 164.3 | 281.7 | [1] |
| IVW | 4.10 | 0.761 | 72.0 | 173.7 | 282.5 | [1] |
| VW | 3.33 | 0.708 | 71.5 | 168.6 | 282.3 | [1] |

It is interesting to compare dynamical evolution of filaments from [1] and [2] to their real distinguishes. There are some addition questions: which filaments are more stable, how an activity of filaments can change in time and can some filaments have a common origin. To study these problems, we made series of numeric integrations of filaments orbits. First, we integrate 18 clones, placed equidistantly in true anomaly along orbit of each filament, during 2700 years. Than we integrate 36 clones for each filament with small variation of initial positions and velocities to study dispersion of orbits under planetary perturbations.

Results of our research are in following: F1P. Range semiaxis variation 2.75-2.915. Eccentricity (max e=0.96) and inclinations evolution curves have small width and extremum (min i=15 degree) about 1700 years ago. Possible stable filament at all longitudes and has common origin. Dispersion semimajor axis with time is relative slow: possible age of this filament up to 1700 year.

F2P. Range semiaxis variation 2.85-3.015. Eccentricity (max e=0.96) and inclinations evolution curves have broad width and extremum about 1700 years ago. Range minimum in inclination (15 degree) is wide: 1400-2100 years ago. Fast spreading close orbits (fig.4) show, that this filament cannot be longlive, not more than 500 year old. Maybe, this filament consists of a few clumps. Related to III class in our classifications.

F3P. Range semiaxis variation 2.727-2.777. Eccentricity (max e=0.965) and inclinations (17 degree) evolution curves are very narrow and extremum about 2200 years ago. Possible stable filament at all longitudes, and all particles have common origin. Dispersion semimajor axis with time is very slow: possible age of this filament up to 2200 year.

F4P. Range semiaxis variation 2.95-3.4. Eccentricity (max e=0.97) and inclinations evolution curves have broad width and extremum about 1700 years ago. Range minimum in inclination (10 degree) is wide: 1200-2000 years ago. Significant dispersion semimajor axis begins since 1500 years ago. It has a V class in our classifications. In general, results of our modeling for filaments F1P, F3P and F4P are in agreement with [2].

F5P. Range semiaxis variation up to hyperbolic orbits. Eccentricity (max e>1) and inclinations evolution curves have broad width no extremum. Range minimum in inclination (10 degree) is wide and have few minima: 1500-2000 years ago. For this filament we obtain more chaotic evolution than in [2]. Maybe, this filament consists of a few clumps. In our classification, filament has II class.

F1W. Range semiaxis variation 2.92-3.2. Eccentricity (max e=0.96) and inclinations evolution curves have broad width and extremum about 1700 years ago. Two minimums in inclination (15 degree) are wide: 1200-1500 and about 2000 years ago. In according with [1], this filament is strongly perturbed by Jupiter. Approximately coincide with filament F4P.

F2W. Range semiaxis variation 2.80-2.875. Eccentricity (max e=0.96) and inclinations evolution curves have broad width and extremum about 2200 years ago. Ranges of minimums in inclination (20 degree) are wide: 1700-1900 and about 2200-2600 years ago**.** Ranges for real meteors minimal inclinations in [1] is 2200-2600 year. It is strongly advice that this filament is a clump, and not extended over all longitudes. Approximately coincide with filament F2P.

F3W. Range semiaxis variation 2.354-2.376. Eccentricity and inclinations evolution curves have small width and extremum more than 2700 years ago. Possible stable filament at all longitudes and has common origin. In general, results of our modeling are in agreement with [1].

F4W. Range semiaxis variation 4.09-4.175. Eccentricity and inclinations evolution curves have no extremum. Significant pericenter rotation is detected. Possible, it is not Quadrantids [1].

F5W. Range semiaxis variation 3.1-3.52. Our modeling confirms a very chaotic (but bounded) evolution for this filament as is noted in [1]. In our classification, filament has I class.

Only filaments F1P, F3P and F3W are different, spread along all longitudes and long-live. Other filaments consist of separate clumps, which occurs number of meteor phenomenon in separate years and non active at different epoch. These clumps have different dynamical history, are unstable or have a small age (smaller than 500 years). A complex view of filament dynamical evolution argues in favor multistage ejection particles into a stream at different epoch.

## References

[1] Wu Z., Williams I. On the Quadrantid meteor stream complex. MNRAS, 259, 617-628, 1992.

[2] Porubcan V., Kornos L. The Quadrantid meteor stream and 2003 EH1. Contrib. Astron. Obs. Skalnate Pleso 35, 5 – 16, 2005.