PLANETARY COSMOGONY OF THE SOLAR SYSTEM: THE ORIGIN OF DANGEROUS METEOROIDS

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Abstract:

Among huge number of natural particles that belong to the Solar System and cross Near-Earth space, some are members of meteor or fireball streams, and the rest seems to be sporadic ones. Their distribution by coming up directions looks like chaotic, but most of these meteors belong to scarcely detectable meteor streams. As the periods of revolutions around the Sun of the Earth and of the streams are not divisible, and the distribution of rare particles inside such streams is not homogeneous, there are annual variations of their activity, that make observations of current meteor activity very important for cosmogony as well as for meteor astronomy itself. Due to obvious weakness of the mentioned streams, it is very important to detect these disappearing streams and to reconstruct by observational data former order of the Solar system.

The goal of our investigations is continuous monitoring of meteor events by two ways: from nearby sites (about 20 km distance) for triangle observations and simultaneously from some observation sites separated by approximately thousand kilometres. The last one will reveal spatial heterogeneity's of meteor streams.

Since July 2002 at the Arkhyz Space Tracking Station (North Caucasus) a hybrid TV-cameras with CCD ("PatrolCa") are used for meteor observations. Limiting magnitude of the first camera is about +5 magn in the 52-degrees field under frame rate 25 f/sec, the second camera has limiting magnitude $11{,}5^m$ in field 18x22 degrees with rate 7,5 f/sec. Since June 2006 4 extra PatrolCa begin stereo (basis) TV-observation near Moscow with the aim of determinations of individual orbits of observed meteors and their physical density. Observed by meteor monitoring data shows that at least 40% of sporadic meteors may be referred to catalogued weak meteor streams.

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The origin of meteors is not still known well. Ordinary meteors are observed as members of meteor streams [1], but nearly half of them is not connected with any stream and seems to be sporadic [2]. There is an opinion that all of the sporadic meteors are remnants of population of exhausted meteor streams [3], and about 400 of so called "weak meteor streams" were recently detected and catalogued [4]. This number is very rough, mainly due to the procedure of meteor stream's detection (that is based on requirement at least on some (>4) meteors observed during 72 hrs). When observable activity of a weak stream is low, and number of its meteors will be 2 or 3, or the weather conditions did not allow continuing observations three nights in succession, the stream will be missed. This is why different authors report on meteor streams, which number being up to several thousand [4-6]. As the periods of revolutions around the Sun of the Earth and particles of the streams are not divisible, and the distribution of rare particles inside such streams is not homogeneous, there are annual variations of their activity. So observations of current meteor activity are very important for verification of existence of weak meteor streams and for determination of their properties.

Most of meteor streams seem to be formed by comets since their total or partial destruction. There are several observations that prove this process [7], and for many meteor streams possible parent comets were fixed. We do not share delusion of some astronomers that some meteor streams were produced by direct collisions of asteroids in form of swarms of their fragments [8], because proposed conditions of such collisions are too rear or too unattainable to be seriously considered [9, 10], and because there is not any observation that proves the idea but only theoretical hypotheses.

Physically distinct conception of meteor streams as born by comets means is that meteors may be real indicator of comets' pre-history. There are three main hypotheses on comet's origin: 1) they are captured from interstellar media, or 2) they were ejected from other members of the Solar system, and 3) they were formed with the rest bodies of the Solar system at the very beginning of its history [9, 10]. The last idea seems to be most preferable, as it does not contradict (as the eruptive hypothesis does) to the observed data that confirm the stability of meteoritic bombardment for the last 4 billion years. And it does not postpone the problem of comet nuclei genesis to the interstellar media, as the capture hypothesis does.

The simplest scenario for comet nuclei formation is primitive condensation of proto-planetary matter into snowballs of various volatility's with addition of refractory dust particles that are named "planetesimals" [13] as building breaks for larger planet formation.

When we discuss the problem of comet nuclei, we have to take in account two obvious facts: proto-stellar nebulae consist of various chemical elements in forms of gas or dust particles of sub-micron dimensions, so comet nuclei have to contain no meteoritic materials like metallic or stone mouldings, that are common to meteor streams. It is obvious that it is impossible to imagine physical processes chain that would results in melting of iron and silicates inside comet nuclei without total evaporating of its volatility's. So we come to the conclusion that an intermediate process must be included to the scenario of the comet origin. At the same time this intermediate process has to take place under conditions at the very beginning of the Solar system history.

We know only one process that leads to the melting of refractory matter as well as to its separation by physical density. This process is heating of interiors of large planets by their radioactivity. So we may suppose that there was a large planet in the Solar system that was formed and destroyed some time before the initial conditions in proto-planetary nebula were radically changed. This is well-known conception of Olbers' planet destruction (later named "Phaeton" by S.Orlov), that is shared by many mineralogists and rejected by many celestial mechanics.

The conception of lost planet seemed to be unacceptable when there was no natural mechanism for total destruction of whole planet. Obviously, the internal energy (e.g. of radioactive elements) is very hard to keep undiluted until moment of disaster. This rock may be easily overcame if suppose that necessary energy was brought from outside. Say, direct collision of moon-mass body at velocity about 100 km/s has kinetic energy that is above gravitational energy of an Earth-like planet [14].

The last step to a real scenario of the very beginning of planetary system is an idea that the point of changing of the initial conditions in proto-planetary nebula is formation of Sun as a star. Since the beginning of its shine increased temperature and radiation pressure have to move off remnants of gas and dust components of surrounding sun nebula. Proto-planetary disc lighted by sun is doomed to be scattered in few thousand years, and even faster from its internal parts.

Now we can reconstruct the early history of our Solar system. It was condensed from comparatively small gaseous nebula just after close explosion of a supernova star. The nebula was enriched by this explosion with heavy elements, some of them being in form of refractory dust particles. Being hot at the beginning, this nebula was cooled by dust, that emitted kinetic energy of gas in infra-red. Due to this cooling, gaseous pressure was soon decreased to the level of few tens degrees, and could not counteract gravitational forces. Gravity condensed nebula into a compact slowly rotating formation, and rotation produced flat proto-planetary disk. Every particle in the disk was at its own circular orbit, because turbulence in cold gas was depressed.

A new cosmogony proposed by author [3] bases on idea that formation of planets takes place at pre-solar stage of evolution of proto-stellar/proto-planetary nebula. When rotation momentum is large enough to stop collapse of the proto-stellar nebula, the proto-star itself at this stage may have too little mass to initiate nuclear reactions, and it will need time to grow by gathering material from the disk. Dust in the disc must deeply freeze its material, so all chemical elements but molecular hydrogen and helium can exist only in form of snowflakes. Every particle moved by perfectly circular orbit around center of masses of the nebula, so only the particles that lost momentum could fall down to the proto-star. As momentum exchanges at cryogenic temperatures were extremely low, diffusion of nebula's matter to the center could not be fast.

The proto-planetary disk had differential rotation, and neighbor levels had close to zero relative velocities. The total rotation instability produced mass concentrations that attracted snowflakes of the disk. Snowflakes could not accelerate their velocities going through dense gas, so any contact between snowflakes leaded to pure coagulation. Just the same mechanism of light collisions provided fast growth of planetezimales and planets themselves. The time formation of Earth-type planets seems to be about some hundred thousands years, and it was the cause of collection short-living isotopes inside them.

In the inner part of the disk planets were formed very quickly and stopped their growth when whole material in their feeding zones were exhausted. Giant planets gathered enough material not only for themselves, but for their satellites too, including rings of number of small ones. In the outer parts planetesimals growth had to be slow, as the density of disk was less and rotation periods were long. This is why there were few large planets in the centre of the future Solar system and a huge number of low-mass planetesimals in its periphery as well as unused snowflakes far away from the centre. At that moment in the centre of system there was a massive proto-Sun, and it was accompanied by planets and planetesimals on circular orbits.

Fast building of large planets resulted in accumulation of short-live radioactive isotopes in their interiors. The nuclear decay heated planetary interior. Material of inner parts was melted and stratified. Even now our Earth has very thin hard shell and heated to the melting interiors, - after 4,5 billion years since its creation. If such "liquid" planet was collided by large planetezimal lost by another star (with kinetic energy about $4 \cdot 10^{32}$ J), it had to be destroyed into number of moldings totally.

It seems that former planet of our Solar system (Olber's planet, or Phaeton, as it was named by S.Orlov) was destroyed about 4,5 billion years ago [15]. Fragments of internal parts of the planet remain on orbits close to the former planet's one, and produce The Main Asteroids Belt. The other moldings had to be ejected toward different directions, including periphery of solar system. The last ones may be individual bodies as well as swallows of tiny fragments, - some drops were dispersed into tiny mouldings by internal pressure like volcanic bombs. They produced lot of compact swarms, they crossed proto-planetary disk and heaped up its snowflakes that preserved beyond giant planets' orbits. So they grew, gathered together and produced planetesimals with number mouldings inside. As most material of these bodies was gathered of particles on circle-like orbits, they obtained slightly elliptical orbits. They became population of the Kuiper Belt as well as of other belts between large external planets. These planetesimals strongly differ from the planetesimals of the first, initial formation. Second generation of planetesimals preserve Phaeton's mouldings inside deeply frozen snow of volatility's [16].

Process of formation of the second generation of planetesimals took no long time, because swarms had sufficient velocities relative to snowflakes on distant orbits. It is very significant moment. Was it a coincidence or there was any causal connection, but ***very soon after Phaeton's destruction the proto-Sun became a star and began shining***. Its radiation heated internal planet to the temperatures, that forced them to lose free hydrogen from their atmospheres. Besides that solar radiation pushed away gas and dust of the remnants of proto-planetary disk [17]. Taking in account that initial stellar activity is like T Tau, the period of simultaneous existence of the Sun and of the disk was not more then few thousand years.

The followed thermal equilibrium inside Solar system and absence of gas between planets stopped its evolution and practically preserves for billion years its condition.

Since destruction of Phaeton the initial order of Solar system was broken. Now there are not only bodies of the first generation that rested on circular orbits, but a number of two types bodies of the second generation on mainly elliptical orbits - asteroids and planetesimals.

Solar radiation cannot now and could not in the past act on planetesimals that are beyond Jupiter's orbit. Thus planetesimals of the second generation keep save initial material of the proto-planetary nebula as well as of former planet's mouldings that hardened before Sun became star. They keep save traces of former order as well as of its decay.

It is obvious that both types of planetesimals can become comets if they come close to the Sun. As a comet, they would behave themselves equally, producing tails and losing their material by time. The main difference between them will be seen in meteor streams that they produce. Decayed as comets, the planetesimals of the first generation can produce short-living icy particles with miserable addition of refractory pebbles. These particles must have physical density about 1 g/cm^3, and their strength must be low too. As life time of ice-form volatiles is extremely short at distance 1 a.e. from Sun, there cannot exist any meteor streams produced by comet nuclei of the first generation.

As for planetesimals of the second generation, their remnants will consist of the same icy particles, and besides that lot of hard heavy particles with density above 2.5 g/cm^3, and with high strength. These particles are long live because they are massive and resist solar radiation forces as well as because they are refractory and do not evaporate for any time. So it is clear that meteor streams studying allow understanding nature of former comet nuclei and the history of our Solar system.

Planetesimals of the first generation are real representatives of the initial order of our planetary system since they kept safe their circular orbits. As these orbits were not disturbed during four billion years, it is easily to suppose that these objects rarely can be captured to the comet orbits. On the other hand, planetesimals of the second generation were from the beginning on eccentric orbits, which can be perturbed by giant planets comparatively easily. Therefore overwhelming majority of comets has to be descended from planetesimals of the second generation. The real ratio of these two types of comets can be determined from meteor streams observations.

Newly born meteor streams may contain different particles with different properties. If an initial comet nuclei look like grape palm [18], it can be destroyed into several parts at the beginning, and later destruction can produce meteoroid swarms from any comet nuclei fragment (Fig.1). Many of meteoroids may be pieces of ice, even large ones [19]. Nevertheless old meteor streams must lose icy components and consist exclusively of stones or metallic ingots. Taking in account that old meteor streams have to be exhausted by long time collisions with the Earth, these streams may be very weak. As it was mentioned above, members of so weak streams may be easily taken for sporadic meteors.

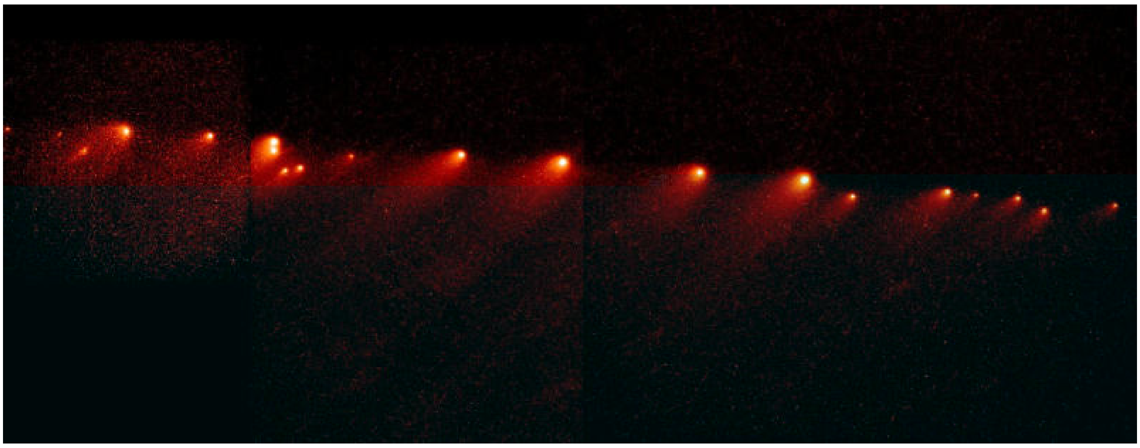

Fig.1. A number of fragments of Showmakers-Levy-9 as seen by HST.

Nevertheless, observable meteors can survive as distinct indicators meteoroid streams that may contain a huge bodies. They may be very dangerous as impactors: the well-known Tungusska 1908 Event seems to be produced by fall of only 50-meters body from beta-Taurids shower [20]. If so, meteoroid streams are real sources of asteroid hazard. Hence we have to reveal all still active meteoroid streams by meteor observation and to prepare a schedule of their activity for instant control of large bodies existence on trajectories of Earth's collision [21]. Now there are about few thousand both strong and minor known meteor showers. Every day one can see not more then 2 tens of showers (Fig.2). As any dangerous object is large enough to be detected at distance at least few million miles, from where it will approach to the Earth 3-5 days, it is not a hard problem to examine radiants of today showers with a total area about 100 square degrees for its detection.

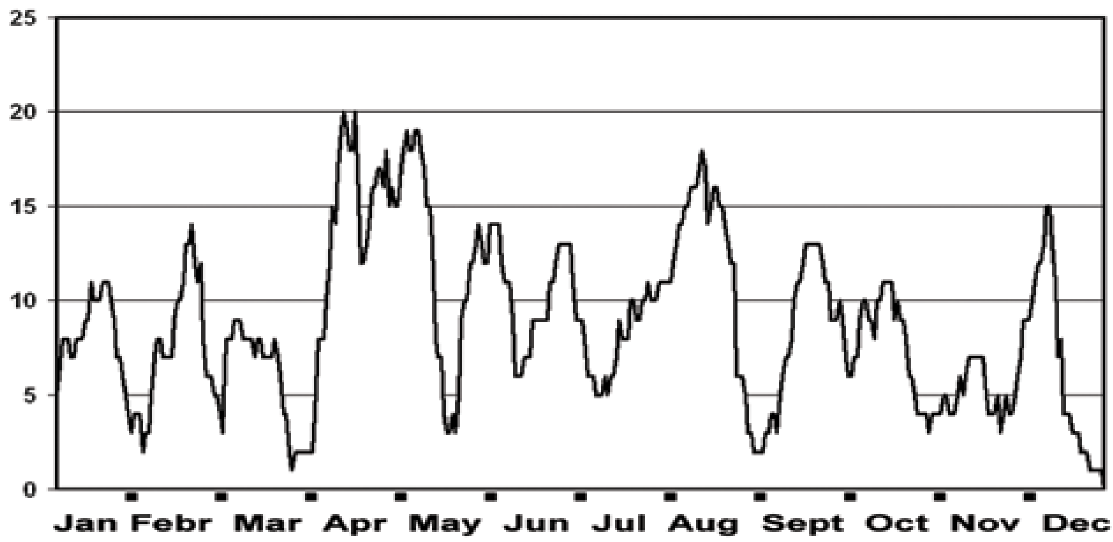

Fig.2. Number of known meteor showers simultaneously acted during a night versus date.

An unsolved problem is detection of really acting but not revealed showers, which meteors are traditionally posed as sporadic. The main goal of our observation program is monitoring of meteor events for gathering observational data on current activity of known meteor streams as well as on sporadic meteors. If there is weak but stable meteor stream, we are in position to combine meteor observations of the same date of several years to detect such stream. It seems to be unbelievable that in the Solar system there are huge number of absolutely individual particles that preserved since the beginning of planetary system formation or that are born continuously by unknown mechanism till now. We believe that all sporadic meteors belong to still unknown weak streams. All of them are witnesses of the milestone of the Solar system history - of the event that broken initial order in planetary system and brought to it chaos elements.

We intend to get observational proves for the described hypothesis of the origin of two generation of planetesimals. So the program of our TV-meteor observations includes registration of individual track of any observed meteor for getting instant picture of meteor activity and for obtaining radiants of scattered streams by correlation of meteors observed in the same dates of some years.

Institute of Astronomy RAS began meteor monitoring in late July, 2002. A wholly automatic hybrid TV-cameras with CCD ("PatrolCa") is used for meteor observations. Limiting magnitude of the first camera, installed at the Arkhyz Space Tracking Station (North Caucasus), is about +5 magn for the 52-degrees field under frame rate 25 f/sec. The more powerful camera FAVOR has limiting magnitude $11{,}5^{m}$ inside field of 18x22 degrees with rate 7,5 f/sec. Since June 2006 four extra PatrolCa begin stereo (basis) TV-observation near Moscow. As we use TV-registration of meteor events with frame ratio 25 sec^{-1} and every meteor is registered on 8…18 frames, therefore we may use methods of determination of physical densities of meteor particles that were developed for the photo-observations with obturator cameras. Our set of Observations were done every night when at least half of the field of view was clean. During 4-year period it were registered about 2450 hours of video-records with more than 4600 meteor tracks on 46000 frames with accuracy of direction measurements about few angular minutes. These data are used for Meteor Data Base.

Our investigations proved the idea that old meteor streams consist of comparatively large particles. They are represented by bright meteors only, so valuable observation data for their study can be obtained from simple and cheep TV-cameras of the Patrolca type. Observations with super-sensitive camera FAVOR revealed measurable Poynting-Robertson drag of light particles that allows direct measurement of meteor stream age. To continue this investigation we have to have individual orbits of weak meteors; an analogue of the FAVOR camera for basis observation is under construction. Presentation of meteors streams as ensembles of individual orbits of particles with known densities will allow studying properties of young and old streams and their history.

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