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1900 Draconid Trail Activity in 2011 and the Prospects for 2014

Mikhail Maslov

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Abstract The article provides an explanation of stronger than expected by the Author Draconids 2011 activity basing on the assumption of unusually high density of 1900 trail of the comet 21P Giacobini-Zinner. Also, a revised prediction for Draconids 2014 is presented, which should also be caused by 1900 trail. For this prediction a "vertical trails" approach is used. This approach is described in the article.

Keywords Meteors · Draconids · Non-perihelion particles · Vertical trails approach

1 Draconids 2011 Results

The Draconid outburst in 2011 was one of most expected cases of unusual meteor activity. It was predicted long before it had occured. Such forecasters as J. Vaubaillon, E. Lyytinen, P. Jenniskens, M. Sato and some others have published their predictions. These predictions were in relative agreement for the maximum time of the outburst, as well as for the main cause of the outburst—the dust trail, ejected by the comet 21P Giacobini-Zinner, the parent comet of the Draconids stream, in the year 1900. Some additional activity was also expected from earlier trails, ejected in 1894 in 1887, as well as from 1907 trail. But one parameter was very various in these predictions—the intensity of the expected outburst. It differed by an order, from ZHR of 50 to 600. Some of those results are presented in Jenniskens (2006) and (Vaubaillon et al. 2011).

The Author also issued a prediction, which was based on computed orbital dust trails of the comet 21P. The computed particles forming dust trails were considered to be ejected with different velocities [(50;100) m/s] from the comet nucleus at the moments of comet perihelia. The following results were obtained for Draconids 2011 (Fig. 1).

M. Maslov (✉)
Novosibirsk, Russian Federation
e-mail: feraj@mail.ru

The Fig. 1 depicts the distribution of 21P dust particles in the vicinity of the Earth's orbit during several weeks around the time of Earth passage the point of minimum distance to the 21P orbit of that time. In 2011 it was at solar longitude of 195.0145°, with the MOID of 0.03475 AU, by our computations.

The axis x in the Fig. 1 is temporal, and the axis y is spatial, so the Fig. 1 shows when (at what time) different dust particles of the comet 21P pass the points of the minimum distance between their computed orbits and the Earth's orbit, and what is the values of their MOIDs (in AU). The third important coordinate, solar longitude of the MOID, remains absent on this 2-dimentional graph.

We can see that particles are organized in regular lines, i.e. dust trails. The most important for Draconids activity in 2011 are designated by the year they were ejected.

The parameters of encounter with the two most close 1894 and 1900 trails were the following:

In the Table 1 parameter *MOID* shows minimum distance between the Earth and the respective trail particles, V_{ej} is ejection velocity of particles in the trail part most close to the Earth, *fMD* characterizes density of encountred trail part, it is a relative measure for different meteor streams, $fMD = 1$ for non-perturbed Leonid trail of 1 revolution, sol. long, is solar longitude at which the Earth passes closest to the trail, and Max time is maximum time of activity from respective trail, this time corresponds to the given solar longitude. If $fMD > 0$, it means that order of particles in the trail is progresive—the particles with lower V_{ej} move ahead of particles with higher V_{ej}. If $fMD < 0$, the order of particles is regressive—particles with higher V_{ej} pass their MOID points earlier than particles with lower V_{ej}.

Basing on the results depicted on the Fig. 1 and computed parameters of encounters with 21P trails, the following predictive description was issued by the Author.

"In 2011 the Earth will get close with a bunch of 1887–1926 trails. There won't be very close encounters, three the most close trails (1887, 1894 and 1900 ones) will pass at −0.00092 AU, +0.00107 AU, −0.00136 AU, respectively. By this reason, I don't expect very high Draconid activity in 2011, with ZHR reaching 40–50 meteors at maximum. The major part of activity is expected to be produced by 1900 trail, which is several times denser than 1887 and 1894 trails. The maximum time for 1900 trail is 20:13 UT 8 October, so far this time is expected to become the time of maximum activity of the overall outburst. Minimum distances to 1887 and 1894 trails will be passed by the Earth several hours before this, at 17:04 and 18:06 UT 8 October, respectively. So far, the first meteors of the outburst are expected to appear already at 17–18 UT 8 October, and their average brightness will be quite high at the beginning, but with the following gradual decrease to the average levels closer to the main maximum time of 20:13 UT. Also, decrease in activity after reaching the maximum levels is expected to be more sharp than its growth" (Maslov 2011). The similar result was presented by the Author earlier in Maslov (2011).

In reality, as we know, Draconids gave a strong outburst on 8 October. As follows from Draconids 2011 activity profile, created by the IMO basing on 6948 Draconids reported in 1807 intervals and assuming population index $r = 2.8$, maximum intensity of the outburst occurred at 20:12 UT, when ZHR reached 306 (Draconids 2011).

We can see, that real maximum time essentially coincided with the predicted one, but real ZHR is $\sim$7 times higher than predicted (306 vs. 40–50). Actually, it was assumed, that 1900 trail is a usual Draconid trail, and to estimate its impact on meteor activity during Draconids 2011 a model developed by E. Lyytinen and T. Van Flandern and adopted for Draconids by the Author was used (Lyytinen and van Flandern 2000). But there are some reasons to suspect that 1900 trail is denser than "usual" Draconid trails, as the comet 21P

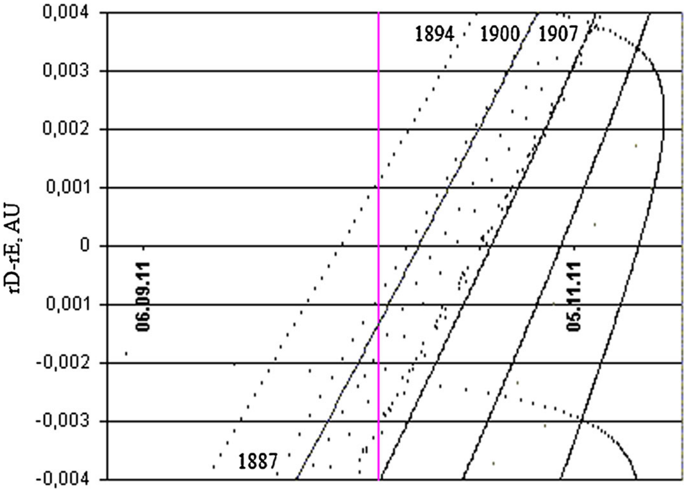

Fig. 1 21P dust trails at the Earth's orbit in 2011. The solid rows of points are regular young trails (such as 1887, 1894, 1900 and 1907 trail). Also some other older trails and nineteenth century are shown as scattered points mainly between 1900 and 1907 trails

Table 1 The parameters of encounter with 1894 and 1900 Draconid trails in 2011

Trail	*MOID* (AU)	V_{ej} (m/s)	*fMD*	Sol. long (°)	Max time (UT)
1894	0.00107	2.2	−0.187	194.948	08.10.2011 18:06
1900	−0.00136	8.3	−0.767	195.035	08.10.2011 20:13

passed 0.188 AU from Jupiter at 28 October 1898 (Kinosita 2012). As a result, the comet's perihelion distance shifted from 1.23 AU at 1894 perihelion to 0.93 AU in 1900. The comet passed sufficiently closer to the Sun in 1900 and that happened after quite close encounter with Jupiter in 1898. These two factor could lead to significant increase of 21P nucleus activity and to form the denser 1900 trail.

This assumption cant'be directly veryfied or calibrated from past Draconid outburst. The most suitable should be the outburst of 1933, which was caused by 1900 and 1907 trails. The reports say the number of meteors reached 450/min (Kronk 1988), which gives an equivalent of 27,000 meteors/h, and ZHR at least 35,000–40,000. Assuming, that both 1900 and 1907 trails gave equal number of meteors, the ZHR of 1900 could be around 20,000. Meanwhile, computed ZHR for 1900 trail is only 7,000—$\sim$3 times lower.

The Draconids are far not the only shower, which parent object can demonstrate different activity at different perihelia. Similar approach is used in Watanabe and Sato (2008) to predict possible returns of the Phoenicids in 2008 and 2014, as their probable parent object 2003 WY25 is thought to be a dormant fragment from comet P/1819 W1 (Blanpain). However, it could still be active in the first half and the middle of twentieth century, and if so its trails ejected then are predicted to encounter the Earth.

The impact of non-gravitational forces could be among other possible explanations. This approach is actively developed by E. Lyytinen, results are presented, say in (Jenniskens 2006). He calls it "A2-effect", which sometimes can shift dust trails closer to the

Earth and cause higher activity than expected from computations taking into account only gravitational forces.

The possibility to check, if this assumption (of closer perihelion distance influence) is correct, will occur quite soon—in October 2014, for which the computations show that parts of 1900 will again pass close to the Earth. The Fig. 2 depicts the results of 21P dust trails simulation for Draconids 2014. It is analogous to the Fig. 1 and depicts the distribution of 21P dust particles in the vicinity of the Earth's orbit during several weeks around the time of Earth passage the point of minimum distance to the 21P orbit of that time.

We can see that 1900 trail again passes close to the Earth, parameters of the encounter are given in the Table 2.

These parameters of direct encounter tell us that 1900 Draconid trail in 2014 will be quite shallow and too far from the Earth (at 0.00617 AU) to expect any notable activity. But this trail "verticalized" at the point of its intersection with the Earth's orbit (10:48 UT on 7 October 2014). There are evidences that such trails can give a notable activity at certain conditions even when parameters of direct encounter are not promising.

2 "Vertical Trails" Approach

In this section we describe an approach to indirect prediction of meteor activity which is base on the analysis of dust trails configuration when their direct encounter with the Earth are absent. When we compute orbits of meteor particles, we factually trace the orbital evolution of trail central axis, or, in other words, of particles, ejected in tangential direction on the parent comet's trajectory at the moment of its perihelion. When the Earth encounters such trails we call it "direct encounter". In this section we'll try to understand what to expect from "trail body", i.e. from particles, not belonging the central axis of the trail, but lying slightly aside of it.

It's clear that in the reality trails are not very thin lines in space, but have quite substantial wideness—tens or hundreds of thousands kilometers (depending on their age and perturbations). This is the reason of quite lengthy meteor action when the Earth encounters dust trails and even when it doesn't pass very close to the axis of trail.

Many models (say, described in Lyytinen and van Flandern (2000), developed for meteor activity prediction, are successfully used for already long time, and these models consider among other things the distance between the Earth and trail central axis. Lets look at the Fig. 3.

2.1 Situation 1

A regular trail with area of effective encounters aroud it (earlier we called it "trail body", it is depicted with grey color). If the Earth passes through this area, we have an encounter close enough for meteor outburst.

2.2 Situation 2

The same trail after encounter with the Earth. We can see typical lapels, consisting of perturbed particles, and a cavity between them. To be simple, we showed area of effctive encounter in its non-perturbed condition in order not to spend time for depiction of unnecessary curves.

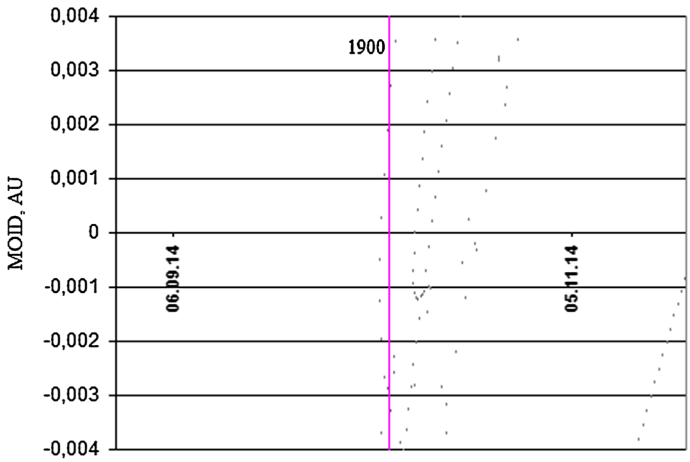

Fig. 2 21P dust trails at the Earth's orbit in 2014

Table 2 The parameters of encounter with 1900 Draconid trail in 2014

Trail	MOID (AU)	V_{ej} (m/s)	fMD	Sol. long (°)	Max time (UT)
1900	−0.00617	24.9	−0.013	193.335	06.10.2014 21:19

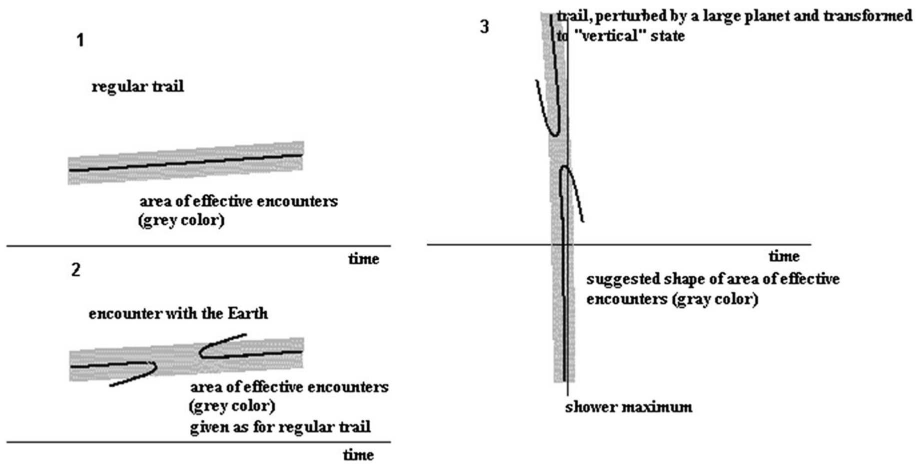

Fig. 3 Trail verticalization

2.3 Situation 3

The main one. We can see a trail after one or several encounters with strong sources of perturbation (Jupiter, for example) which transformed it into "vertical" condition. In the reality it is not vertical, of course, but it but it looks so in Fig. 3 where time is plotted on the x-axis—the particles with very different ejection velocities pass their minimal distances to the Earth's orbit at nearly one time (within a short period of time, at least). Compare to a regular trail—in this case times are different, but minimal distances are nearly the same for all the trail. Such a "verticalization" is very frequient event in the streams of Jupiter family comets. The particles in the area of effective encounters (trail body) should also be "verticalized". And it seems to happen. To demonstrate it we just showed the trail, suffered a local perturbation from encounter with the Earth. Resulting lapels are just in the area of effective encounters and can serve as "markers" of what happens to this area when central axis of a trail gets verticalized. Orbital computations show that these lapels behave themselves as organic parts of the trail, i.e. they are also became verticalized (such verticalized lapels are shown on Situation 3). It is logical to assume, that area of effective encounters will also transform to a form, similar to one shown on the Situaltion 3 (it is also given as not perturbed by encounter with the Earth there). This leads us to an interesting conclusion: meteor activity can occur, if central axis of vertical trail intersects the Earth's orbit close to the moment of shower maximum. In this case direct encounter can easily (even most likely) would be absent—MOID value for direct encounter would have too high value, excluding the activity. This is also shown on the Situation 3.

The trail passes downwards; in the case shown it does not intersect at all the line of shower maximum, which reflects the moment of time, when the Earth passes closest to the orbit of trail central axis. Meanwhile, though the central axis of the trail, as we can see, intersected the Earth's orbit shortly before the maximum, the Earth passes through the area of effective encounters. There is no close encounter with central trail axis, because the latter during even 1–2 days (difference between the intersection of the Earth orbit and the Earth arrival to the point of intersection) will go very far to a vast distance for meteor outburst. But we still have such outburst. As an example we can take Draconids 1985, when the shower gave a strong outburst on October 8 around 11:50 UT (Draconids meteor shower 1985). The Author's computations show that there was no direct encounter, but vertical 1946 trail intersected the Earth's orbit on 18 October, 10 days after Draconids maximum. Computed time of maximum is 8 October 10:50 UT, which is in quite good agreement with observations.

3 Prospects for Draconids 2014

In 2014 central axis of 1900 trail intersects the point of intersection 0.6 days after the Earth passage of the intersection point. So there good reasons to suspect that particles ejected not exactly at the perihelion point and forming trail body instead of its central axis, will encounter with the Earth. And as computations show, the particles ejected by the comet 21P 90 days prior to its perihelion in 1900 pass at only 0.00050 AU from the Earth at 22:42 UT on 6 October 2014.

The basic model gives an estimation for ZHR of 15–20. However, if the assumption of unusual density of 1900 trail is correct, than it is $306/45 = 6.8$ times denser than a usual trail. But in 2014 the Earth is expected to encounter the particles ejected by the comet 21P when it was $\sim$90 days prior to the perihelion. At this time the comet was about 1.57 AU from the Sun. Using the usual m2 parameter of this comet of 7, which is typical for it (Yoshida 1998, 2005, 2012), we get that comet was 5.8 times less active than at the moment in perihelion in 1900. So far, we have to multiply our estimation for the outburst from 1900 trail in 2014 to a coefficient $6.8/5.8 = 1.17$. Considering large inaccuracies peculiar to predicted ZHR, the estimation of ZHR = 15–20 can be kept unchanged. So far, the prediction of Draconids 2014 activity could be formulated in the following way: In 2014 the Earth is expected to encounter to 1900 trail. This trail is "verticalized", and his

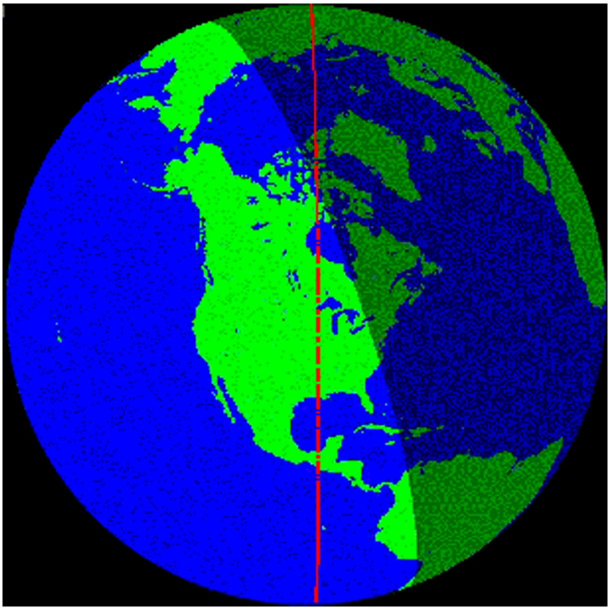

Fig. 4 The Earth as seen from coming Draconid meteors (RA = 261.5°, Dec = +47.6°) during the expected maximum time of outburst from 1900 trail in 2014 at 22:42 UT 6 October. Red line shows the border of hemisphere where the Moon is above horizon (the right hemisphere). The picture obtained with the Hewgill (2003)

center composed of particles ejected at the perihelion of the comet 21P, doesn't come very close to the Earth, but intersects its orbit 0.61 day after the Earth passes the point of intersection. However the particles ejected 90 days before the perihelion pass at 0.0050 AU from the Earth at 22:42 UT on 6 October.

Around this time we expect moderate Draconid activity with ZHR of 15–20 and low meteor brightness. It is possible also that activity peak will occur 1–2 h earlier than computed time. Theoretical radiant coordinated are the following: RA = 261.5°, Dec = +47.6°. It should be noted that it differs significantly in declination from traditional Draconid radiant (RA = 262°, Dec = +54°, (Calendar 2013)), shifting the radiant to the south of the Draco head to the north-eastern part of Herculis.

The Fig. 4 shows observing condition of Draconid outburst if it occurs at the expected time. In a whole the land territories are situated quite unfavorable for observations. The best conditions will be in Greenland and extreme north-eastern part of North America. Good conditions will be in Iceland and on Spitsbergen, satisfactory conditions—in Scandinavia, United Kingdom and Ireland. Quite high in the night sky the radiant will be in Venezuela. In Russia the radiant will be at low altitude in European part of the country as well as in Ural and Western Siberia up to the Taimyr Peninsula longitude, the more to the north—the higher the radiant. The similar situation will be in the continental Europe and extreme north of Africa.

The additional worsening circumstance will be connected with the almost full Moon (phase = 0.97) present above the horizon during all the night. Nevertheless, activity with ZHR of 15–20 should be notable even under the full Moon light, so this case of possible Draconid activity remains interesting for observations.

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