Future Draconid outbursts (2011 – 2100)

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Descriptions of future Draconid meteor shower outburst forecasts are presented for the period 2011 – 2100. Primary attention is paid to the closest cases of expected (possible) activity in 2011, 2012, 2014, 2018 and 2019.

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1 Introduction

The Draconids are one of the most famous meteor showers, produced by the debris of comet 21P/Giacobini-Zinner. In the past this shower gave a number of outbursts, including two storms in 1933 and 1946, when hourly rates of activity reached several thousands. In this paper we introduce the results of 21P meteoroid stream modeling aimed at the prediction of future Draconid activity. The closest interesting case is the Draconids 2011, this year, which as many researchers expect should be marked by the shower's activity. It is described below with a graph, as well as other interesting cases within the period 2011 – 2020. For the years in 2021 – 2030 only textual descriptions of what could happen are given. And finally, the characteristics of expected Draconid activity in the far future are presented in Table 1. Computations of meteor particles' orbital evolution were made with the COMET'S DUST 2.0 program by S. Shanov and S. Dubrovsky (Shanov & Dubrovski, 2005). To estimate the possible intensity of Draconid outbursts the model described on pages 158–160 of (Lyytinen & van Flandern, 2000) and adapted to the Draconid stream by the author was used. Initial orbital elements of the comet 21P were taken from (Kinoshita, 2008).

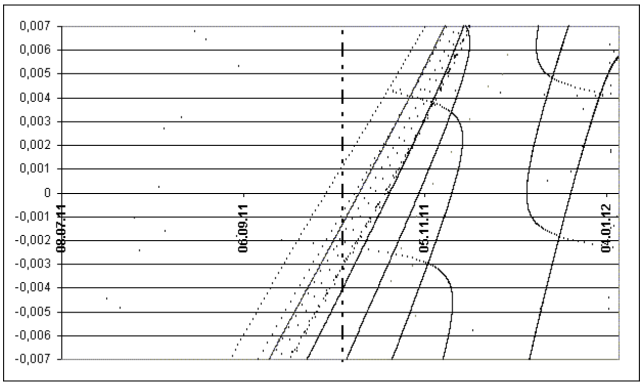

Figure 1 – 21P trails in the vicinity of the Earth's orbit around Draconid maximum time in 2011 (X-axis is time, Y-axis is distance from Earth's orbit measured in AU).

2011

In 2011 the Earth encounters a bunch of 1887 – 1926 trails. These encounters are not very close, with the closest three trails (1887, 1894 and 1900 ones) expected to pass at −0.00092 AU, +0.00107 AU and −0.00136 AU from the Earth, respectively. For this reason, we do not expect very high Draconid activity in 2011, with the ZHR reaching 40 – 50 meteors at maximum. The major part of the activity should be produced by the 1900 trail, which is several times denser than the 1887 and 1894 trails. The maximum time for the 1900 trail is 2011 October 8 at 20^h13^m UT; so far this time is expected to become the time of maximum activity of the overall outburst. Minimum distances to the 1887 and 1894 trails will be reached by the Earth some hours before this, on 2011 October 8 at 17^h04^m and 18^h06^m UT, respectively. At present, the first meteors of the outburst are expected to appear already at $17^h – 18^h$ UT on October 8, and their brightness will generally be quite high at the beginning, but with a subsequent gradual decrease to average levels closer to the main maximum time of 20^h13^m UT. Also, the decrease in activity after reaching the maximum is expected to be sharper than the rise towards maximum. The theoretical radiant of the outburst is: RA = 263°.3, Dec = +55°.8, v_g = 20.9 km/s. Unfortunately the sky quality at the expected maximum time will be spoiled by the light of the almost full Moon in the evening time, when the Draconid radiant is at its highest altitudes. However, in the northern hemisphere the Moon will not be very high in the sky.

The Draconids' 2011 outburst was predicted by many authors, Jeremie Vaubaillon (2011), Esko Lyytinen, Mikiya Sato, Hartwig Luethen among them; some of their results are listed in (Jenniskens, 2006). The given prediction is in principal agreement with these works, but its activity estimates are on the conservative side.

If the outburst occurs at the times given above, the best conditions for observation will be in Europe and the north-western edge of Africa. There will also be a reasonable radiant height in the major part of the Middle East and in the northern edge of Eurasia, excluding the extreme north-east. Also, observers in that part of Eurasia will have good conditions to check the expected low Draconid activity from the 1887 and 1894 trails some hours prior to the main maximum. Very good conditions for radio observations will be in Northern America; in the very north of South America the radiant will also be high enough for radio observations.

2012

As shown in Figure 2, in 2012 two trails will be present in the vicinity of the Earth's orbit. These are the 1959 and 1966 trails. This case is quite similar to the Draconids 1999 case, when a small activity outburst with

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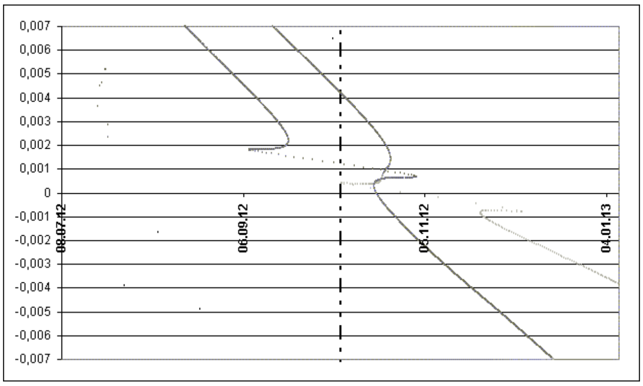

Figure 2 – 21P trails in the vicinity of the Earth's orbit around Draconid maximum time in 2012 (X-axis is time, Y is measured in AU).

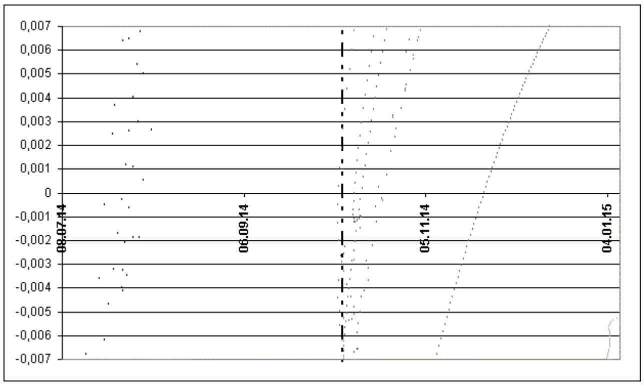

Figure 3 – 21P trails in the vicinity of the Earth's orbit around Draconid maximum time in 2014 (X-axis is time, Y is measured in AU).

ZHR of 10 – 15 occurred. However in 2012 the situation is much less auspicious. The 1959 trail, which is the closest of the two trails to the Earth, passes at 0.00121 AU (which is actually quite a large distance); moreover this part of the trail is perturbed by a previous encounter with the Earth (in 1992) and at present is several tens of times less dense than an analogous non-perturbed trail. The maximum time for this trail is 2012 October 8 at $16^{\mathrm{h}}22^{\mathrm{m}}$ UT, but any visually detectable activity is unlikely.

The 1959 trail also gives a vertical encounter with maximum time on 2012 October 8 at $16^{\mathrm{h}}54^{\mathrm{m}}$ UT. A "vertical trail", which occurs as a result of perturbations by big planets, contrasts with the usual cases of trail encounters. In a vertical trail, neighboring computed particles significantly differ in distance between their orbit and the Earth's orbit, despite extremely small differences in the times of their minimum distance passage from the Earth's orbit. Thus in plots of minimum distance value against minimum distance passage time, such trails look vertical. The computed $\mathrm{ZHR_{ex}}$ for this encounter is 0.5, so we expect to reach at best the levels of isolated meteors with very low average brightness.

Finally, the 1966 trail encounters the Earth with its non-perturbed part, but it passes at the very large distance of 0.00416 AU, which also cancels any prospects for significant activity. Maximum time for this trail is 2012 October 8 at $15^{\mathrm{h}}37^{\mathrm{m}}$ UT, computed $\mathrm{ZHR_{ex}}$ is 0.2.

As a whole we could say that in 2012 we have some chances for weak Draconid activity during the period of October 8 from 15 – 17 UT, but it is very likely that nothing will happen. Average meteor brightness (if anything occurs) is expected to be very low, and the aging Moon will not create any significant trouble for observers, at least in the evening time, when the Draconid radiant is at its highest altitudes. Considering the timings given, the best conditions for checking possible Draconid activity will be at Asian longitudes in the northern hemisphere.

2014

The Earth encounters the bunch of 1900 – 1913 trails. No direct intersections with trails are expected, but use of the "vertical trails" approach points towards chances that some particles from non-axis trail parts could collide with the Earth. The trails intersect the Earth's orbit in the period 2014 October 7 – 14. On 2014 October 6 at $20^{\mathrm{h}}10^{\mathrm{m}}$ UT a small enhancement with ZHR of 10 – 15 meteors with very low average brightness is possible. With radio observations higher activity is likely. Theoretical radiant is RA = $261\overset{\circ}{.}5$, Dec = $+47\overset{\circ}{.}4$, $v_{\mathrm{g}} = 18.3$ km/s.

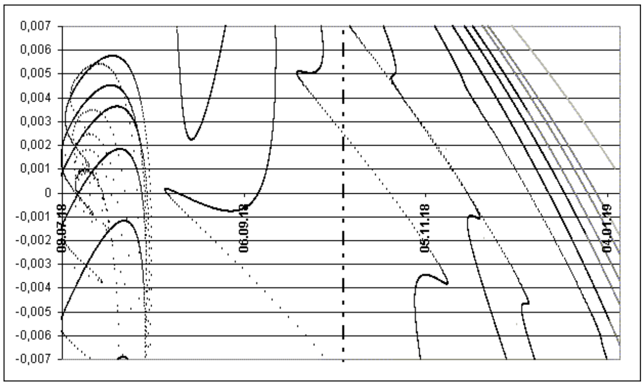

Figure 4 – 21P trails in the vicinity of the Earth's orbit around Draconid maximum time in 2018 (X-axis is time, Y is measured in AU).

2018

At first sight it is a very favorable return of the 21P comet, but it is not expected to give a strong outburst of activity, as the Earth passes through the area of strongly rarified and perturbed material within the channel (closely bunched group) of 1946 – 1959 trails. There are no close direct encounters, but the "vertical trails" approach shows the possibility of weak activity from the 1953 trail, with ZHR of 10 – 20 within the period of 2018 October 8 – 9 from $23^{\mathrm{h}} - 00^{\mathrm{h}}$ UT. Theoretical radiant is RA = $262\overset{\circ}{.}8$, Dec = $+56\overset{\circ}{.}0$, $v_{\mathrm{g}} = 21.0$ km/s.

2019

Very close direct encounter with 1959 trail. Its characteristics: $V_{\mathrm{ej}} = 62.9$ m/s, fM(fMD)= 2.377, $\lambda_{\odot}$ =

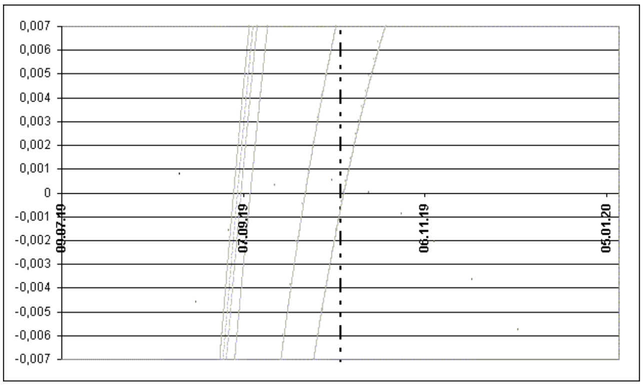

Figure 5 – 21P trails in the vicinity of the Earth's orbit around Draconid maximum time in 2019 (X-axis is time, Y is measured in AU).

194°.759. Taking as a basis Draconid activity in 1999, we can expect a small visual peak not higher than ZHR $5-10$, on 2019 October 8 at $14^{h}45^{m}$ UT. On the other hand, radio observations could show much higher activity. Theoretical radiant: RA = 261°.4, Dec = +53°.9, $v_{g} = 20.5$ km/s.

2023

Encounter with 1887 trail. We used the "vertical trails" approach, as this trail crosses the Earth's orbit on 2023 October 12. A notable activity enhancement is likely, up to ZHR $10-20$, on 2023 October 8 at $12^{h}10^{m}$ UT with a high proportion of fireballs. Theoretical radiant: RA = 263°.4, Dec = +56°.3, $v_{g} = 21.0$ km/s.

2025

Encounter with channel of $1907-1953$ trails, intersecting the Earth's orbit at the end of September. According to the "vertical trails" approach, significant activity enhancements with lots of submaxima are likely within 2025 October 8 from $05^{h} - 11^{h}$ UT. Suggested time and intensity of these submaxima are the following: $05^{h}01^{m}$ UT, ZHR $10-15$; $07^{h}25^{m}$ UT, ZHR $20-25$; $09^{h}06^{m}$ UT, ZHR $20-25$; $10^{h}17^{m} - 10^{h}49^{m}$ UT, ZHR $50-60$. So far, we expect an oscillating increase of activity, and the first meteors can already appear at $01^{h}20^{m}$ UT. Meteor brightnesses will be quite high; lots of fireballs are likely. We would also like to note that due to the high density of this channel of trails and experimental character of the "vertical trails" approach used, ZHR estimates given above are quite optimistic and the real activity can be much lower. Theoretical radiant is RA = 261°.9, Dec = +54°.8.

Direct encounter with 2-revolution 2012 trail on 2025 October 8 at $15^{h}14^{m}$ UT. Ejection velocity of encountered trail particles is very high, 88.3 m/s. So far we expect visual activity at the level of only $10-40$ in ZHR, average brightness very low. However with radio observations, much higher activity is likely, up to very strong storm with tens of thousands meteors per hour. Theoretical radiant: RA = 262°.8, Dec = +55°.9, $v_{g} = 21.1$ km/s.

2030

Direct encounter with a quite rarified channel of $1817-1859$ trails on 2030 October 8 at $21^{h}-22^{h}$ UT. Activity should rise to ZHR $10-20$, perhaps with lots of submaxima. Meteor brightnesses will be high, with lots of fireballs. Theoretical radiant: RA = 263°.5, Dec = +58°.1, $v_{g} = 21.7$ km/s.

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Table 1 – Years of expected Draconid activity in 2031 – 2100.

year	day, time (UT)	ZHR_{ex}	comments
2038	Oct. 7, 00^h – 04^h	5	bright meteors
2038	Oct. 7, 16^h – Oct. 8, 02^h	20 – 30	faint meteors
2050	Oct. 6, 17^h03^m	4 – 5	very faint meteors
2062	Oct. 6, 08^h05^m	500 – 600	bright meteors
2064	Oct. 6, 05^h41^m	200 – 300	very bright meteors
2069	Oct. 6, 02^h – 06^h	5 – 10	very faint meteors
2078	Oct. 4 – 5	10 – 20	bright meteors
	Oct. 6, 05^h32^m	2 – 3	very bright meteors
	Oct. 7, 11^h – 12^h	4 – 5	very bright meteors
	Oct. 7, 23^h41^m	20 – 40	very bright meteors
2084	Oct. 6, 20^h27^m	10 – 20	bright meteors
2097	Oct. 5, 17^h – 18^h	50 – 60	bright meteors
2098	Oct. 5, 04^h20^m	1500 – 2000, up to 10000 – 20000	very bright meteors
	Oct. 5, 07^h17^m	500, up to 5000	very bright meteors
	Oct. 5, 15^h20^m	100 – 200	bright meteors