# Draconids

## The coming 2011 Draconids meteor shower

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A detailed analysis of the coming 2011 Draconids outburst is performed with different methods. The first step was to post predict the 1933 and 1946 storms. Difficulties arise when dealing with the 1985 outburst, since no unique orbital solution is able to explain the different outbursts observed during this year. This fact emphasizes our need to better know the parent body comet 21P/Giacobini-Zinner. Fortunately, the coming outburst will be caused by the trails ejected in 1980 and 1907, already encountered in the past. No storm is expected, but the level of the shower is poorly constrained. A first highly entertaining outburst is expected on 2011 October 8 around $17^{\mathrm{h}}$ UT. The second and the main outburst is expected around $20^{\mathrm{h}}$ UT the same day. The level of the shower will be of a few hundreds (around 600 per hour).

Received 2011 May 30

## 1 Introduction

The Draconids is a meteor shower happening in early October, for which the parent body is the Jupiter family Comet 21P/Giacobini-Zinner, discovered in 1900. Both the comet and the meteor shower are peculiar. The comet is the most carbon depleted, and the meteors are known to be the slowest and the most fragile of all. In the past, the Draconids have shown several outbursts. The most famous of all happened in 1933 and 1946, there were reports then to show that there has been as many as 10 000 meteors per hour. More recently, the 2005 outburst took everybody by surprise for two reasons: first it was not expected, and second it mostly dealt with tiny particles (roughly in the range 10 to 100 $\mu$m), making the meteors mostly visible with radio techniques (Campbell-Brown et al., 2006).

In the past few years, there have been many announcements of another outburst expected in October 2011. In particular, Watanabe and Sato (2008) have shown that a change of activity of the comet is needed in order to explain the past outburst and have forecasted a level of a few hundreds of meteors per hour.

The goal of this paper is first to further investigate the coming 2011 outburst by providing a complete analysis, and second to alert the scientific community and encourage observations. Indeed, the level of a future meteor shower is one of the hardest aspects to forecast. This is usually the only trigger to motivate hundreds or even thousands of people to observe, or justify large expeditions such as the past Leonids MAC for example.

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IMO bibcode WGN-393-vaubaillon-draconids
NASA-ADS bibcode 2011JIMO...39...59V

## 2 Method

An approach by Sato and Horii is based on Sato (2003) and Horii et al. (2008) the simplest simulation of dust trail theory (e.g., Asher, 2000) is used. The particles of meteoroids were ejected parallel to the body motion, both ahead of and behind the comet at each perihelion. The ejection velocity was set to be within the range $[-30; +30]$ m/s, where "+" is in the direction of the body's motion and "−" in the opposite direction. We did not take into account the effect of radiation pressure. We used orbital elements calculated by Kinoshita (2008) 20 perihelion passages of the comet from 1880 until 2005 are included in it.

Vaubaillon's approach is based on (Vaubaillon et al., 2005): heavy computer simulations that mimic the ejection and the evolution of the meteoroid stream in the solar system. The downfall of this approach is that level of the shower is based on the photometric observations of the parent body. In this case, we know that the activity has drastically changed in the past, making this approach not as efficient as for the Leonids for example. Nevertheless, it is possible to calibrate the model based on past observations. The simulations were performed at the CINES supercomputer facility (France) and involved 24 perihelion passages of the comet, from 1852 until 2005. For each passage, three size bins in the range $\left[10^{-4}; 10^{-1}\right]$ m of each 50 000 particles were ejected.

## 3 Preliminary results: post-predictions

In order to validate the models we post-predicted the 1933 and 1946 storms. Both the models successfully predicted the storms at the right date. Figures 1 and 2 show the encounter between the stream and the Earth.

The 1933 storm was caused by the 1900 and the 1907 trails. They were respectively five and four revolutions old, that is very young. The trails were not perturbed by Jupiter, and therefore were very dense. In addition, they fall at exactly the same location on the path of the earth. In a sense, this storm was similar to the 2001 Leonids, except that the stream was coming from a Jupiter family comet.

*Table 1* – Circumstances of the 1933 and 1946 Draconids storms. Negative distance to the Earth ($\delta r$) means Earth is closer to the Sun than the trail.

| Year | Trail | Nrev | by JV | | | by MS |
|---|---|---|---|---|---|---|
| | | | $\delta r$ (AU) | $\lambda_{\odot}$ | date (UT) | date (UT) |
| 1933 | 1900 | 5 | +0.0003356 | $197\overset{\circ}{.}00430$ | Oct. 9, $20^{\mathrm{h}}12^{\mathrm{m}}$ | Oct. 9, $20^{\mathrm{h}}23^{\mathrm{m}}$ |
| 1933 | 1907 | 4 | −0.0001749 | $196\overset{\circ}{.}99369$ | Oct. 9, $19^{\mathrm{h}}56^{\mathrm{m}}$ | Oct. 9, $20^{\mathrm{h}}08^{\mathrm{m}}$ |
| 1946 | 1900 | 7 | −0.0007444 | $197\overset{\circ}{.}00041$ | Oct. 10, $03^{\mathrm{h}}58^{\mathrm{m}}$ | Oct. 10, $04^{\mathrm{h}}11^{\mathrm{m}}$ |
| 1946 | 1907 | 6 | −0.0005646 | $196\overset{\circ}{.}99971$ | Oct. 10, $03^{\mathrm{h}}57^{\mathrm{m}}$ | Oct. 10, $04^{\mathrm{h}}05^{\mathrm{m}}$ |
| 1946 | 1913 | 5 | −0.0002978 | $196\overset{\circ}{.}99269$ | Oct. 10, $03^{\mathrm{h}}47^{\mathrm{m}}$ | Oct. 10, $03^{\mathrm{h}}58^{\mathrm{m}}$ |
| 1946 | 1920 | 4 | −0.0001011 | $196\overset{\circ}{.}99020$ | Oct. 10, $03^{\mathrm{h}}43^{\mathrm{m}}$ | Oct. 10, $04^{\mathrm{h}}05^{\mathrm{m}}$ |
| 1946 | 1926 | 3 | +0.0000770 | $196\overset{\circ}{.}98921$ | Oct. 10, $03^{\mathrm{h}}41^{\mathrm{m}}$ | Oct. 10, $03^{\mathrm{h}}46^{\mathrm{m}}$ |
| 1946 | 1933 | 2 | +0.0006207 | $196\overset{\circ}{.}99086$ | Oct. 10, $03^{\mathrm{h}}44^{\mathrm{m}}$ | Oct. 10, $03^{\mathrm{h}}44^{\mathrm{m}}$ |

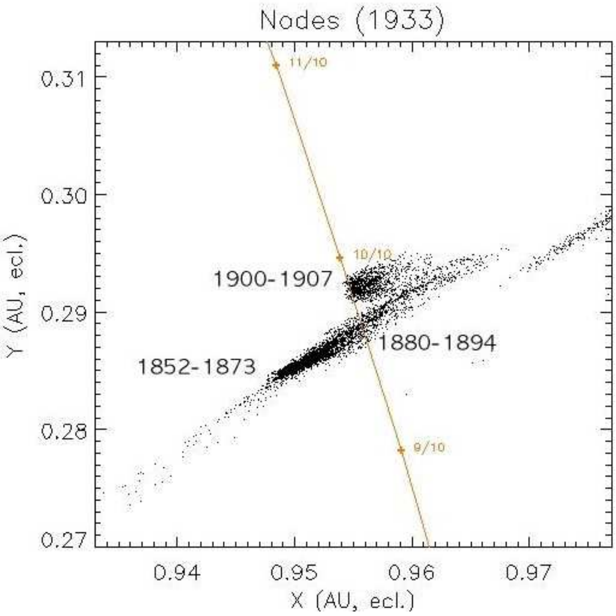


*Figure 1* – General circumstances of the 1933 Draconids meteor storm.

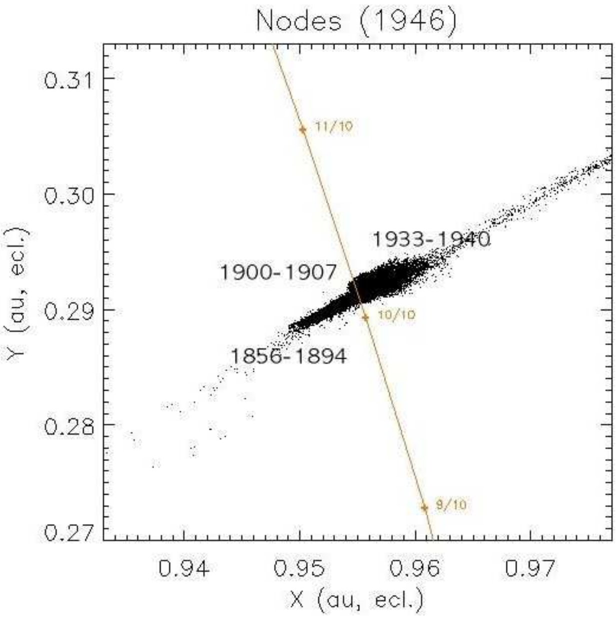


*Figure 2* – General circumstances of the 1946 Draconids meteor storm.

In 1946, the exact same trails were encountered again, but this time, there were also extremely fresh trails, ejected one and two revolutions before the storm. In a sense, the 1946 Draconids meteor storm was the perfect storm.

Records in the order of 10 000 meteors per hour for those two events are found in the literature, raising hopes for a storm in 2011. However, the level of the shower is hard to determine since back then there was no standard technique to reduce the data.

It is worth mentioning that in the two cases, the models predict another outburst before each storm, caused by the trails ejected before the comet discovery (during the 19th century). However, these outbursts are very uncertain for a number of reasons. The most important is that the orbit of the comet is poorly known before its discovery in 1900, since it had had a close encounter with Jupiter in 1898. In other words, we need to solve the problem of the orbit of comet 21P.

## 4 The orbit of comet 21P/Giacobini-Zinner

The comet was discovered in 1900. After this, almost all passages were observed. Because the comet is a Jupiter family comet, there are today 15 recorded passages. However, we discovered that several slightly different orbital solution lead to different forecasts for the Draconids meteor showers. In Table 2 we show the details for the 1985 outburst, for the solution provided by JPL and by IMCCE. Note that the latter was used to derive the predictions published in Jenniskens (2006). Since then, several minor effects have been taken into account (e.g. first terms on special relativity) to compute the orbit of the comet. Still, the way the observations are treated is different, and it is often custom-made on a case-by-case bases by the scientists providing the cometary ephemeris. Automated methods consider all the reported observations, within a chosen matching criterion. However, the definition of outlier can also be manual. In this case, we do not know exactly how the data were reduced, but they provide significant differences in terms of Draconids showers as shown in Table 2.

We can see that the solution provided by JPL is able to explain the first outburst whereas the “IS” one is off by two hours. One could natively conclude that the JPL solution is the closest to reality. However, it does not explain the second outburst, and for which Shanov’s

*Table 2* – Circumstances of the 1985 Draconids from different comet solutions and models: "V-IMCCE" stands for (Vaubaillon et al., 2005) model with comet orbit provided by P. Rocher (after corrections), "V-JPL" for the same model with the comet orbit provided by JPL, "MS" stands for a model by Sato and Horii with comet orbit provided by Kinoshita; "IS" refers to I. Shanov's work published in Jenniskens (2006). Observation data are taken from the same book.

| Model | Trail | $\delta r$ (AU) | $\lambda_\odot$ | date (UT) |
|---|---|---|---|---|
| V-JPL | 1933 | −0.01125 | 195.°173 | Oct. 8, $07^h35^m$ |
| V-IMCCE | 1933 | −0.00981 | 195.°154 | Oct. 8, $07^h06^m$ |
| MS | 1933 | −0.01664 | 195.°127 | Oct. 8, $06^h27^m$ |
| MS | 1940 | −0.01797 | 195.°115 | Oct. 8, $06^h10^m$ |
| IS | 1933 | +0.01114 | 195.°253 | Oct. 8, $09^h45^m$ |
| observation | | | 195.°174 | Oct. 8, $07^h36^m$ |
| V-IMCCE | 1894 | −0.00927 | 195.°203 | Oct. 8, $08^h18^m$ |
| V-IMCCE | 1946 | +0.01724 | 195.°391 | Oct. 8, $12^h52^m$ |
| V-JPL | 1946 | +0.01306 | 195.°365 | Oct. 8, $12^h15^m$ |
| MS | 1946 | +0.01125 | 195.°356 | Oct. 8, $12^h01^m$ |
| IS | 1946 | +0.01114 | 195.°253 | Oct. 8, $09^h45^m$ |
| observation | | | 195.°256 | Oct. 8, $09^h36^m$ |

solution is better. The very least we can say is that this situation is puzzling, and makes forecasting difficult.

## 5 2011 encounter of the Earth with the stream

For the year 2011, many different models all confirm the eventuality of an outburst. Figure 3 and Table 3 show the circumstances of this encounter. The good news is that the second and the most important outburst will be cause by trails ejected in 1900 and in 1907, already encountered in 1933 and in 1946. Figure 4 shows the 1900 trail in 2011. Even though this Jupiter family trail is 17 revolutions old, we can see that it is not highly perturbed. Those two facts give us confidence for this coming outburst. However, we have seen in the previous section that the orbit of the comet still presents some puzzling problems. The first outburst is expected a few hours before the main one. Because of the uncertainties on the orbit of the comet, this first event is highly uncertain. A further analysis shows that it will be composed of relatively large particles (that is, larger than 1 mm). As a consequence, we hope that this outburst will be the occasion to refine our knowledge on the dynamics of this comet.

As mentioned previously, the photometry of the comet is not available for the years of ejection of the trails. As a consequence the level of the shower is based on a relative comparison of the 1933 and 1946 showers. However, even those showers are not perfectly known, since the method of reduction were not well defined back in those days. Moreover, Watanabe et al. (2008) have shown that the activity of the comet has changed between passages. As a consequence, the level of the shower could be as much as a factor of two higher or lower than what it is presented here.

All the models agree that the level will be unusual, and on the order of a few hundreds per hour. No storm is expected though. The first outburst (if any) will be on the order of 200 meteors per hour at most, whereas the second will be around 600 per hour.

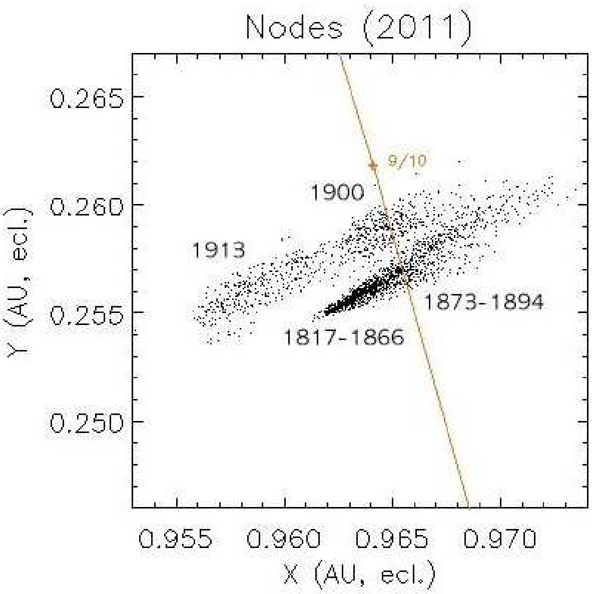


*Figure 3* – General circumstances of the 2011 Draconids meteor shower.

## 6 Discussion

As mentioned several times throughout this paper, the level of this coming shower is not as certainly determined as in the 2002 Leonids for example. What seems the most likely is that a Draconids outburst is expected, caused by the 1900 and the 1907 trails. Note that Maslov's results only forecast a minor outburst for this year with a level of at most 50/hr (Maslov, 2011).

Why is it important to observe? To our knowledge, this coming shower is the first significant Draconids outburst to be forecasted. As a seen previously, it will be the occasion to study the orbit of the comet, especially before its discovery in 1900. Moreover, we will be able to study the disintegration of the most fragile meteoroid into Earth's atmosphere with great detail, thanks to a higher than usual activity level. This event is also potentially the most abundant in terms of number of meteors since the great days of the Leonids. We hope that this article will motivate people all around the world that they should go outside and observe these events.

*Table 3* – Circumstances of the 2011 Draconids.

| Year | Trail | by JV | | | by MS & SH | |
|---|---|---|---|---|---|---|
| | | $\delta r$ (AU) | $\lambda_\odot$ | date (UT) | $\delta r$ (AU) | date (UT) |
| 2011 | 1866 | −0.0036438 | 194°.87353 | Oct. 8, $16^{h}13^{m}$ | | |
| 2011 | 1873 | −0.0031428 | 194°.88429 | Oct. 8, $16^{h}29^{m}$ | | |
| 2011 | 1880 | −0.0024856 | 194°.90063 | Oct. 8, $16^{h}53^{m}$ | +0.00327 | Oct. 8, $19^{h}04^{m}$ |
| 2011 | 1887 | −0.0015047 | 194°.92248 | Oct. 8, $17^{h}25^{m}$ | −0.00071 | Oct. 8, $17^{h}05^{m}$ |
| 2011 | 1894 | +0.0010553 | 194°.97733 | Oct. 8, $18^{h}45^{m}$ | | |
| 2011 | 1900 | −0.0022798 | 195°.02944 | Oct. 8, $20^{h}01^{m}$ | +0.00097 | Oct. 8, $20^{h}36^{m}$ |
| 2011 | 1907 | −0.0052619 | 195°.00594 | Oct. 8, $19^{h}26^{m}$ | −0.00244 | Oct. 8, $19^{h}59^{m}$ |

Moreover, we hope that reports will be sent to the International Meteor Organization so that a global analysis will be performed and a complete view of the shower and the stream can be drawn. Comparison with what happened in 1933 and 1946 will provide us insight about the way data were analyzed back then.

## 7 Planned observations

Since the Draconid meteor shower is not usually very active, the predicted outbursts provide us with unique opportunity to investigate its properties. Not only can we test models of the orbital evolution of another meteoroid stream, but also we could collect more data on the meteoroids, that are the most fragile material among all the other showers (Borovička et al., 2007).

The timing of the outburst favors Middle East and eastern parts of Europe. On the other hand the meteorological conditions are not kind at this part of the year on the majority of the continent. Therefore the idea of the airborne observational campaign arose. The most promising area in terms of weather is south-eastern Europe. However the radiant might be low on the horizon (as pointed out by R. Arlt – personal communication), causing a significant decrease in the number of observed meteors. We already know of many ground-based expeditions in Mediterranean countries (Greece, Israel, Turkey and so on). As usual, the contribution of each and every country will provide the world wide view of the phenomenon. Automated analysis will be available on the website of the International Meteor Organization. Once again we would like to emphasize here the importance of the work performed by amateurs, for both the observation and the analysis.

Because the expected peaks are not expected to be observed in Japan, Japanese observers are planning to perform an expedition for the observation as National Astronomical Observatory of Japan (NAOJ). Considering the observing conditions with possible cloud coverage, the Japanese professional astronomers chose the site of Maidanak observatory, which is located at the center of the Eurasian Continent, Uzbekistan. Mount Maidanak is near the border of Afghanistan, whose time zone is GMT+5 hours, the longitude +66.89641 degree, the latitude +38.67332 degree, and the altitude 2593 m above the sea level. The Maidanak observatory has a 1.5 m telescope, a 1 m telescope and four 60 cm telescopes. Moreover the NOAJ observatory has a memorandum of understanding in the collaboration with this observatory for observation of asteroids. Several researchers in National Astronomical Observatory of Japan often visit Maidanak observatory for observing asteroids by using their telescopes under good sky condition (Ehgamberdiev et al., 2000). There are more than 200 clear nights per year, especially from July to

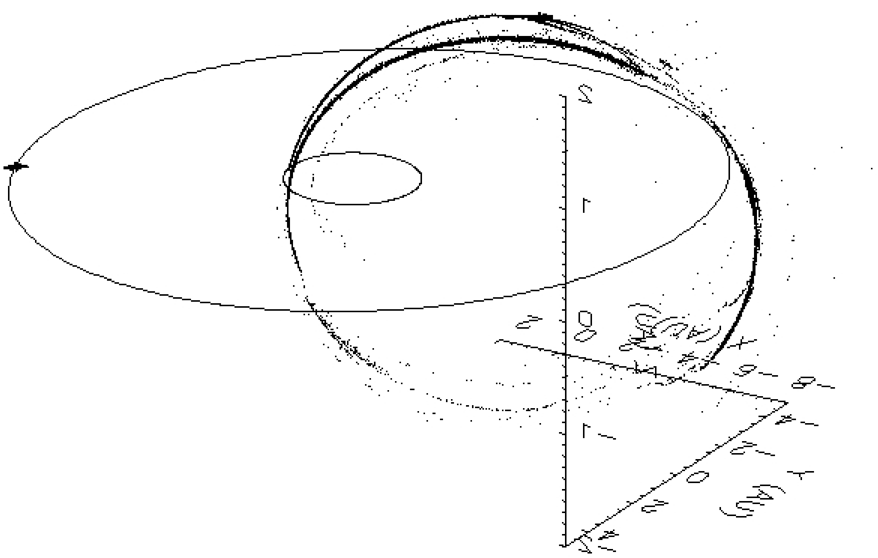

*Figure 4* – 3D view of the Draconids meteoroid stream as in October 2011.

September with a probability of 90 %, although such high probability of clear nights in October is not expected. NAOJ astronomers plan to stay a few nights before and after the expected peaks, and to carry out video observation by using Watec a CCD video camera system mainly for monitoring activity of this shower.

In Europe, the plan is to use two different small planes and establish a double station observation. The French SAFIRE Falcon 20 is partly already granted and the preparations are underway. The second one would be the DLR Falcon 20, but there is still ongoing discussion with EUFAR office, whether it will financially support such a mission. If two planes are available, we plan to fly them in the same line one behind the other. Such configuration will allow us to use the instruments on both sides of the planes for the double station observations. The distance between the planes would be up to 100 km. Due to the Falcon 20 4 hours autonomy, we plan two flights to cover both predicted maxima. The base for whole mission will be Kiruna airport in northern Sweden. Between both flights the planes will land here to be refueled. Timing will be very tight so planning is essential.

Each plane will carry set of different instruments. There will be narrow (about $\simeq 40°$) and wide ($\simeq 90°$ to $\simeq 120°$) field of view video cameras with low (1 per second) and high (50 per second) frame rate as well as the spectral cameras working in visible and infrared light. SAFIRE Falcon will accommodate 10 instruments, whereas DLR Falcon will have six or seven. The goals of the mission are measurements of the population index, activity profile, flux, light curves and atmospheric trajectories and spectra of meteors. If both planes are available then the heliocentric orbits will be studied as well. Finally, NASA may also support a Gulfstream airplane to join the two European ones. However, we will not know until July 2011.

Since the event will be visible on a Saturday evening at reasonable time, this meteor shower is the perfect occasion for the broadcasting of science, astronomy and meteors. Many amateur clubs in Europe will have a public outreach event during this night. This aspect should not be neglected, since many professional astronomers became interested in the field by witnessing a meteor shower.

## 8 Conclusion

Most of the forecasting methods used around the world predict an outburst for the Draconids in 2011. Based on past observations, this outburst will happen on October 8 at around $20^{\mathrm{h}}$ UTC. The level of the shower is hard to predict because of the peculiar orbit of the comet. Observations of the meteors as well as the comments in the coming months will provide us with insight on the structure of the meteoroid stream around 21P.

## Acknowledgement

We are thankful to the National Astronomical Observatory of Japan (Mitaka, Tokyo) for partly supporting this work. The heavy computations were performed at CINES, France. We are thankful to the International Meteor Organization for their requests and help in writing this article. In the same way, where are thankful in advance to all the people who will report their observations to the IMO website, as well as those who will fully analyze the results. Heartfelt thanks also to the SAFIRE and EUFAR teams for helping us defining how the airplane campaigns might work (regardless of the results), as well as the referees granting us 100% of the French aircraft flying time.

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*Handling Editor:* Javor Kac
This paper has been typeset from a LaTeX file prepared by the authors.