

Forecast for Phoenicids in 2008, 2014, and 2019

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Abstract

We report here on a complete forecast of the activity of future Phoenicid meteor showers in the period 2008–2020. We detail predictions of Phoenicids activities during three years: 2008, 2014, and 2019. In 2008, the trail of 1866 will intersect with the Earth orbit. In 2014, the origin of the activity will be due to several trails formed from the 19th to the early 20th centuries. The display in 2014 will be the most spectacular meteor showers among the three cases because of a favorable geometric condition. In 2019, the Earth will approach four trails formed between 1872 and 1882, and one trail of 1946. Since the parent body had not been observed during the above-mentioned period, the activity of these meteor showers is important for estimating the degree of cometary activity for this parent body during this period.

Key words: interplanetary medium — meteors, meteoroids — meteor showers: individual (Phoenicids) — comets: individual (D/1819 W1 Blanpain) — solarsystem

1. Introduction

The Phoenicids was thought to be a strange meteor shower until recently. A spectacular Phoenicids display was recorded only once, on 1956 December 5. A candidate parent body was thought to be comet D/1819 W1 (Blanpain). However, since this comet was also observed only in 1819, the relation between the Phoenicids and the comet was uncertain. This changed in 2005. A newly discovered asteroid, 2003 WY25, was identified to be comet D/1819 W1 (Foglia et al. 2005). The success in linking both orbits allowed us to determine the orbit of this comet over a long time period. This provided us with enough data to calculate the dust trails of this meteor shower. We reported that the strong Phoenicid display in 1956 was caused by a bundle of dust trails formed from the 18th through the early 19th centuries by using dust trail theory (Watanabe et al. 2005). A similar result was also obtained by Jenniskens and Lyytinen (2005), emphasizing that the major contribution may have been an outburst or fragmentation of the parent object in 1819. In both studies it was also confirmed that the comet D/1819 W1 (Blanpain) was the parent body of the Phoenicids meteor shower. On the other hand, its parent body was observed as an asteroid in recent years. The exact time of cessation of the object's activity was unclear. We showed that the forecasted meteor shower could be used to trace the cometary activity of its parent body (Watanabe & Sato 2008). Namely, the degree of the cometary activity should be estimated by observing the meteor shower activity due to dust trails that formed by ejected meteoroids during an unobserved period between 1819 and 2003.

In this paper, we present details of the three predictions of Phoenicids displays: 2008, 2014, and 2019. These three cases have been chosen because of the high probability of producing outbursts on the basis of our preliminary study (Watanabe et al. 2005).

2. Calculation of the Dust Trails

We applied the simplest approach to dust trail theory (e.g., Asher 2000), which was described by Sato (2003) in detail. Each trail was assumed to be formed by meteoroids ejected during the perihelion passage of the parent body. The trail was calculated by test meteoroids ejected parallel to the body motion, both ahead of and behind the comet. At first the ejection velocity was set to be within the range between $\pm 20 \text{ m s}^{-1}$, where “+” is in the direction of the body's motion and “–” in the opposite direction. Orbital integrations were carried out by using the Runge–Kutta–Fehlberg method together with Encke's method. To calculate the perturbations, we included the three largest main-belt asteroids in addition to the eight planets, Pluto and the moon, using the JPL ephemeris DE406. We did not take into account the effect of radiation pressure on the meteoroids in our calculation. The applied orbital elements were those calculated by S. Nakano (2005).¹ The non-gravitational force was not considered because we did not have enough information about it. The calculated trails in this study were those released from the parent object during the perihelia approaches occurring between 1743 and 2014.

3. Results

Table 1 gives the situation of the dust trails in 2008, 2014 and 2019. The date is the time when Earth passed the ascending node of the given trail particles. Δr is the difference in the heliocentric distance between Earth and each trail in the ecliptic plane. The dust trails are included in this table when Δr of the trail is smaller than 0.005 AU. The parameter fM value is the degree of extension of the trail, and was derived by

¹ OAA computing section circular, Nakano Note, No. NK1168 (<http://www.oaa.gr.jp/oaacs/nk/nk1168.htm>).

Table 1. Data of trails in 2008, 2014, and 2019.

Ejection year	Expected peak time			Δr (AU)	Ejection velocity (m s ⁻¹)	fM	Expected position of radiant		V_g^* (km s ⁻¹)
	Date (UT)	Time	LS(2000.0)				α (°)	δ (°)	
In 2008									
1866	2008/11/07.99	23:49	225.826	+0.00072	−12.11	0.0034	7.04	−5.51	11.46
1861	2008/11/09.98	23:34	227.824	−0.0036	−14.61	0.0025	6.77	−6.32	11.26
In 2014									
1882	2014/12/01.91	21:51	249.420	−0.0039	+0.97	0.012	7.61	−26.78	9.83
1877	2014/12/01.94	22:32	249.450	−0.0034	+0.70	0.0089	7.66	−26.91	9.83
1872	2014/12/01.95	22:53	249.465	−0.0031	+0.52	0.0066	7.68	−26.97	9.82
1845	2014/12/01.95	22:55	249.465	−0.0034	+0.69	0.0093	7.67	−26.96	9.83
1771	2014/12/01.96	22:59	249.469	−0.00022	−10.98	0.0018	6.44	−25.14	9.61
1850	2014/12/01.96	23:00	249.469	−0.0030	+0.36	0.0043	7.70	−27.01	9.82
1856	2014/12/01.96	23:03	249.471	−0.0030	+0.40	0.0051	7.70	−27.01	9.82
1861	2014/12/01.96	23:05	249.473	−0.0030	+0.41	0.0053	7.70	−27.01	9.82
1866	2014/12/01.96	23:05	249.473	−0.0029	+0.41	0.0053	7.70	−27.01	9.82
1819	2014/12/01.97	23:12	249.478	−0.0023	−0.21	0.0027	7.76	−27.11	9.81
1825	2014/12/01.97	23:13	249.478	−0.0022	−0.28	0.0035	7.76	−27.12	9.81
1830	2014/12/01.97	23:15	249.480	−0.0021	−0.42	0.0051	7.78	−27.14	9.81
1914	2014/12/01.97	23:16	249.481	−0.00074	−1.28	0.016	7.90	−27.31	9.79
1814	2014/12/01.97	23:18	249.482	−0.0024	−0.14	0.0018	7.74	−27.10	9.81
1835	2014/12/01.97	23:23	249.486	−0.0015	−0.88	0.010	7.82	−27.22	9.80
1919	2014/12/01.98	23:28	249.489	−0.00051	−2.03	0.026	7.92	−27.33	9.78
1925	2014/12/02.01	00:12	249.520	+0.0000027	−2.40	0.030	7.95	−27.42	9.77
1840	2014/12/02.02	00:27	249.530	+0.0013	−3.69	0.015	8.04	−27.62	9.75
1909	2014/12/02.03	00:39	249.539	+0.00015	−1.76	0.022	7.99	−27.56	9.78
1930	2014/12/02.06	01:20	249.568	+0.00086	−3.03	0.036	8.01	−27.58	9.76
1903	2014/12/02.12	02:49	249.631	+0.0017	−2.42	0.030	8.14	−27.97	9.76
1935	2014/12/02.14	03:24	249.655	+0.0026	−4.27	0.048	8.12	−27.89	9.73
1898	2014/12/02.26	06:11	249.773	+0.0046	−3.40	0.050	8.41	−28.63	9.73
In 2019									
1872	2019/11/20.65	15:40	237.742	+0.0032	−13.68	0.011	7.07	−11.15	10.00
1877	2019/11/23.03	00:39	240.140	−0.0015	−14.23	0.0082	6.30	−12.83	9.86
1882	2019/11/24.77	18:33	241.906	−0.0038	−15.90	0.014	5.77	−14.31	9.76
1898	2019/12/02.90	21:29	250.132	−0.00017	−17.29	0.0091	6.55	−28.40	9.70
1946	2019/12/02.95	22:54	250.192	+0.0015	−18.88	0.013	6.31	−27.89	9.62

* V_g is the expected geocentric velocity before the gravitational focusing of Earth.

$fM = \Delta t_0 / \Delta t$, where Δt is the time needed for a given part of the trail to pass through the ecliptic plane, and Δt_0 is the same, but at the first return. If there are no perturbations, then the fM value should be basically proportional to n^{-1} , where n is the number of returns. In reality, this is not the case due to the perturbation of the planets. In any case, fM is a measure of the density of meteoroids within the trails. In this table, trails were picked up if the fM value of the trail is larger than 0.001.

3.1. The 2008 Phoenicid Encounter

Figure 1 gives the distributions of dust trails in 2008. In this year, some trails that were formed in the middle of the 19th century will approach Earth. Especially, the trail of 1866 will intersect Earth's orbit when the condition of Δr is within the +0.00072 AU. Since the orbit of this trail is remarkably changed by perturbations, the epoch of Earth's approach to the

dust trail is at the beginning of November, almost one month earlier than usual. Earth passes the ascending node on 2008 November 7 at 23^h49^m UTC, and the closest point between both orbits occurs on November 8 at 04^h10^m UTC. This relatively large difference is caused by the small inclination of the orbit, about 2°.4. Because the minimum distance between the trail and Earth is 0.00012 AU, the peak time is expected at this time, around 4 h. The theoretical radiant is $\alpha = 7^\circ 0$ and $\delta = -5^\circ 5$, near ι Cet, which is far north of the original position of Phenicids in 1956. The fM value of trail is 0.0034. The strong peak in 1956 was caused by ten trails whose fM values were between 0.02 and 0.03 (Watanabe et al. 2005), and the total fM value was estimated to be about 0.22. The fM value of the 1866 trail in 2008 is about 1/60 of that in 1956. Because the zenithal hourly rate (ZHR) in 1956 was estimated to be about 300 (Huruhata & Nakamura 1957), we expect that this trail

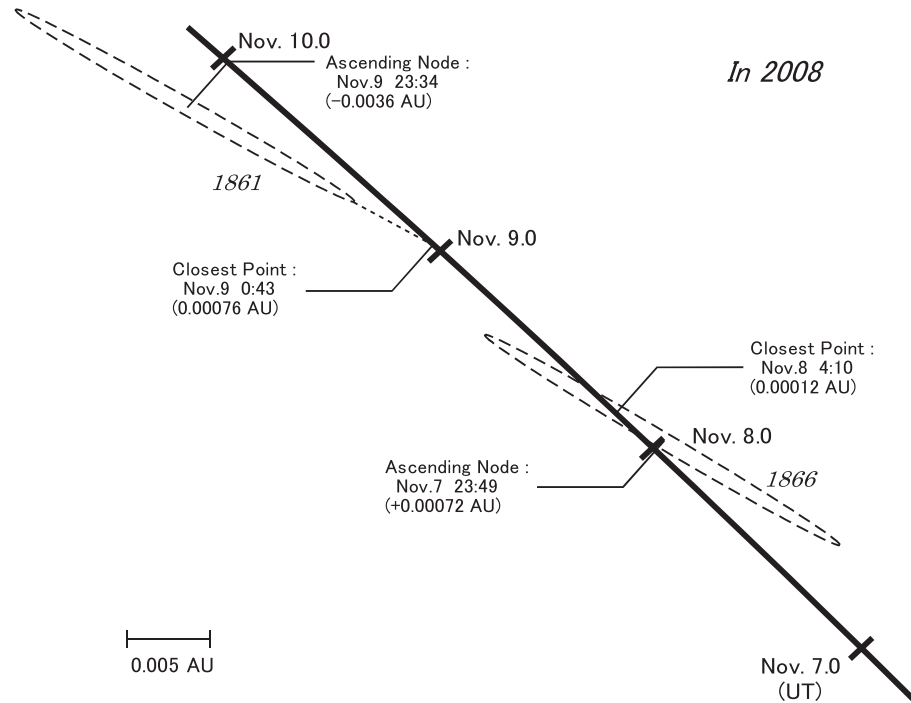


Fig. 1. Geometrical relation between the dust trails and Earth's orbit in 2008.

produced a ZHR of about 5 in 2008 by using the fM estimation if the parent body was assumed to have been active in the same way as in 1819. We also suspect that the final ZHR would be even smaller because the absolute value of the ejection velocity, about 12 m s^{-1} , is larger than that in 1956, about between 0.49 and 0.73 m s^{-1} . Actually, the effect of the cometary activity of the parent body around 1866 will strongly affect the activity of this shower.

3.2. The 2014 Phoenicid Encounter

A situation of dust trails in 2014 is summarized in figure 2. In 2014, many trails formed from the 19th to the early 20th century will approach Earth. Because their distributions are complicated, we show two figures of the trails divided by the formation epoch before and after 1900. The geometrical condition of trails that were formed in the early 20th century is ideal to show strong activity of the meteor shower. The values of Δr of five trails formed between 1909 and 1930 are smaller than 0.001 AU , and the absolute value of the ejection velocity is low enough to supply many large meteoroids to the trails. Each fM value is between 0.016 and 0.036 , about between $1/14$ and $1/6$ of that in 1956. The ZHR at the peak time of each trail is expected to be between 20 and 50 if the comet is as active as in 1819. If the cometary activity of a parent body in the early 20th century was weak, this ZHR will become smaller. The expected peak time is from 2014 December 1 at $23^{\text{h}}30^{\text{m}}$ UTC to December 2 at $01^{\text{h}}30^{\text{m}}$ UTC; especially, the peak of the 1925 trail is expected on December 2 at $00^{\text{h}}12^{\text{m}}$ UTC, because of the very small distance, $2.7 \times 10^{-6} \text{ AU}$, of about 400 km . While old trails of the 18th century also approach Earth, the values of Δr are larger than 0.001 AU . Therefore, the displays by these old trails are expected to be weak. We also found that the older trail of 1771 also crosses Earth orbit.

However, the ZHR should be very low because of the low fM value, 0.0018 .

3.3. The 2019 Phoenicid Encounter

In 2019 the dust trails encountered by Earth can be separated into two groups. One includes those formed between 1872 and 1882, with the peak time at the end of November. The other includes those formed in 1898 and 1946, having their close approaches to Earth at the beginning of December. Figure 3 gives the distributions of these dust trails in 2019. The dust trail that approaches closest to Earth is that formed in 1898; Δr is -0.00017 AU . We predict a ZHR of about 12 by using an fM value of 0.0091 with the assumption that the cometary activity in 1898 was of the same level as in 1819.

4. Concluding Remarks

In the above section, we listed three predictions concerning the Phoenicids. It is worth briefly summarizing the situation again. During the 2008 return by the 1866 trail, the conditions are likely to be so unfavorable that we may not be able to observe any activity. Even if there is no appearance of meteors, it is not necessarily proof of no cometary activity of the parent body in 1866. On the other hand, if we can observe some activity of the meteor shower, this suggests the parent body was still active in 1866. In terms of our prediction for 2014, a meteor shower is highly expected due to ideal conditions for the dust trails formed at several perihelion passages in the early 20th century. Under such ideal conditions, no activity of meteor showers will reveal that the cometary activity of the parent body was insufficient to eject meteoroids in this period. Careful observations in 2014 are highly recommended for these three cases. In 2019, the activity will be caused by a few

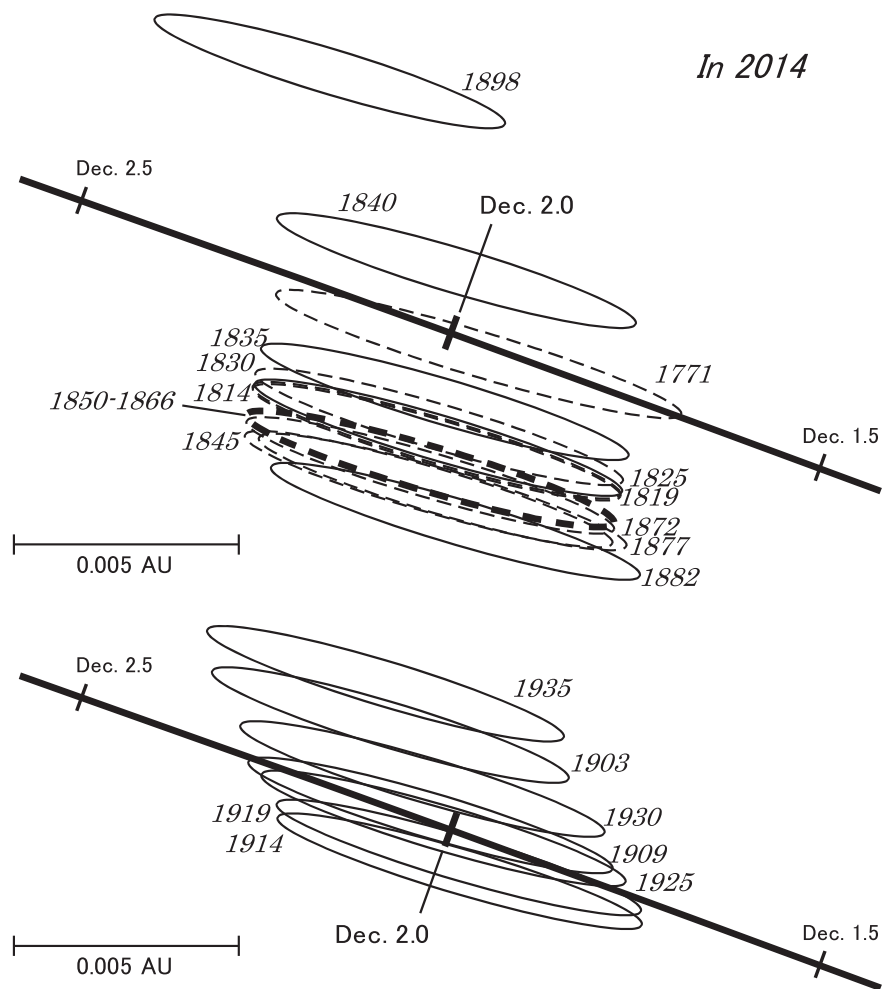


Fig. 2. Geometrical relation between the dust trails and Earth's orbit in 2014. The upper panel shows those trails formed before 1900, while the lower panel shows those after 1900. The dotted line shows a trail whose fM value is smaller than 0.01.

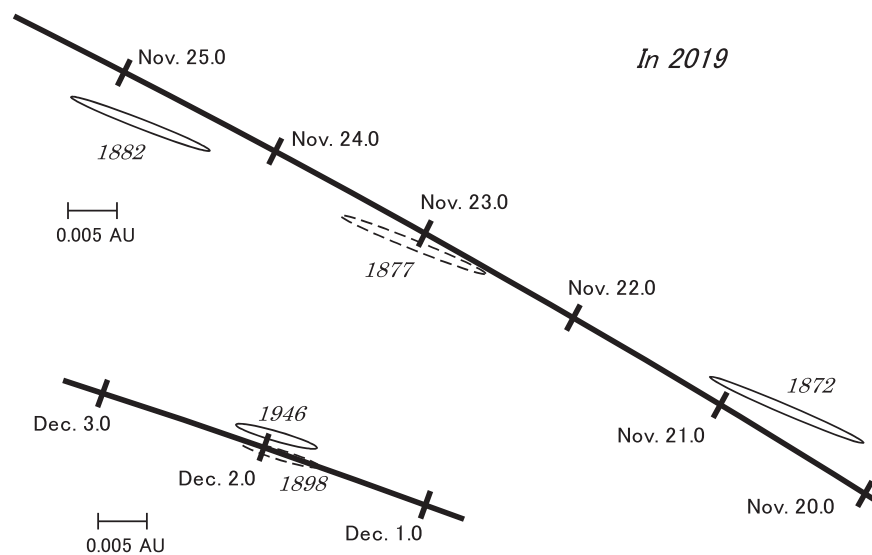


Fig. 3. Geometrical relation between the dust trails and Earth's orbit in 2019. The upper-right panel shows those trails which approach in November, while the lower-left panel shows those in December. The dotted line shows a trail whose fM value is smaller than 0.01.

trails formed between 1872 and 1946. Because of the lengthy period of the predicted display over a period of two weeks, each activity, if any, might yield information concerning the correspondence of specific showers and trails.

It should be noted that the activities of Phoenicids we predicted here are due to the dust trails mostly formed after 1819, when the parent body was discovered as a comet. Because it had never been observed until the recovery in 2003 as an asteroid, we do not know how this object ceased its activity as a comet. Jenniskens and Lyytinen (2005) concluded that the 2003 WY25 represent the remnant of a large nucleus

fragmented before 1819. On the other hand, Jewitt (2006) found an extremely faint coma around this object. Such observation suggests that 2003 WY25 might have been still active between 1819 and 2003. Therefore, observations of these meteor showers would help us to trace the history of the cometary activity of this parent object.

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References

- Asher, D. J. 2000, in *Proc. Int. Meteor Conf.*, Frasso Sabino, ed. R. Arlt (Mechelen, Belgium: International Meteor Organization), 5
- Foglia, S., Micheli, M., Ridley, H. B., Jenniskens, P., & Marsden, B. G. 2005, *IAU Circ.*, 8485
- Huruhata, M., & Nakamura, J. 1957, *Tokyo Astron. Bull.*, 2nd Ser., No.99
- Jenniskens, P., & Lyytinen, E. 2005, *AJ*, 130, 1286
- Jewitt, D. 2006, *AJ*, 131, 2327
- Sato, M. 2003, *WGN*, 31, 59
- Watanabe, J., & Sato, M. 2008, *Earth, Moon, Planets*, 102, 111
- Watanabe, J., Sato, M., & Kasuga, T. 2005, *PASJ*, 57, L45