Leonids

The 2003 Leonid shower from different approaches

Jérémie Vaubaillon[1], *Esko Lyytinen*[2], *Markku Nissinen*[3] *and David J. Asher*[4]

Though the Leonid meteor storm period is over now, we provide in this paper predictions for 2003, from three models. It turns out that even if no storm is expected, activity from old trails (14 or more revolutions old) will be observable. In particular the 1499 trail will provide enhanced activity on 2003 November 13 UT with ZHR estimated at about 100. Further minor enhancements are predicted on November 19 at around 07^{h}–08^{h} UT and at other times from November 19 to 22, making the longest expected Leonid meteor shower.

Received 2003 October 22

1 Introduction

These past five years (from 1998 to 2002) have seen some exceptional Leonid activity (for a full review of the observations, see Arlt & Brown 1999, Arlt & Gyssens 2000, Arlt et al. 1999, 2001, 2002, and Jenniskens 2002). For the first time, some accurate predictions have also been possible, thanks to a better knowledge of the dynamics of meteoroids in the Solar System. Following the work of Kondrat'eva & Reznikov (1985) and Kondrat'eva et al. (1997), it was shown (Asher, 1999; McNaught & Asher, 1999) that the orbit of the meteoroids, instead of the orbit of the parent body alone, is relevant to achieve such predictions. At the same time Lyytinen & Van Flandern (2000), from a 'satellite model' of the comet 55P/Tempel-Tuttle, and the consideration of non-gravitational forces, derived a model of the streams. This model has been enhanced (Lyytinen et al., 2001) thanks to the quality of the observations and the Lorentzian profile of a shower deduced by Jenniskens (2002). Recently, Vaubaillon (2002) used the photometry of the comet to make a link between the parent body and the level of the shower encountered.

A meteor storm occurs when the Earth passes close to the center of a trail of material released at a particular perihelion return of the parent comet (Kondrat'eva et al., 1997). Otherwise, a usual meteor shower is expected. Overall, meteor storms are therefore very rare. The last one occurred in 2002 but, from the results of computations, it appears that no other storm is expected for the coming decade. At present, no Leonid storm until at least 2033 has yet been identified. The question arises as to what will be seen in 2003. We shall try to answer that in this paper, by presenting the results of the above different modeling approaches.

2 2003 Leonids predictions

In his first work, Lyytinen (1999) found that the Earth will encounter very old Leonid trails in 2003 Novem-

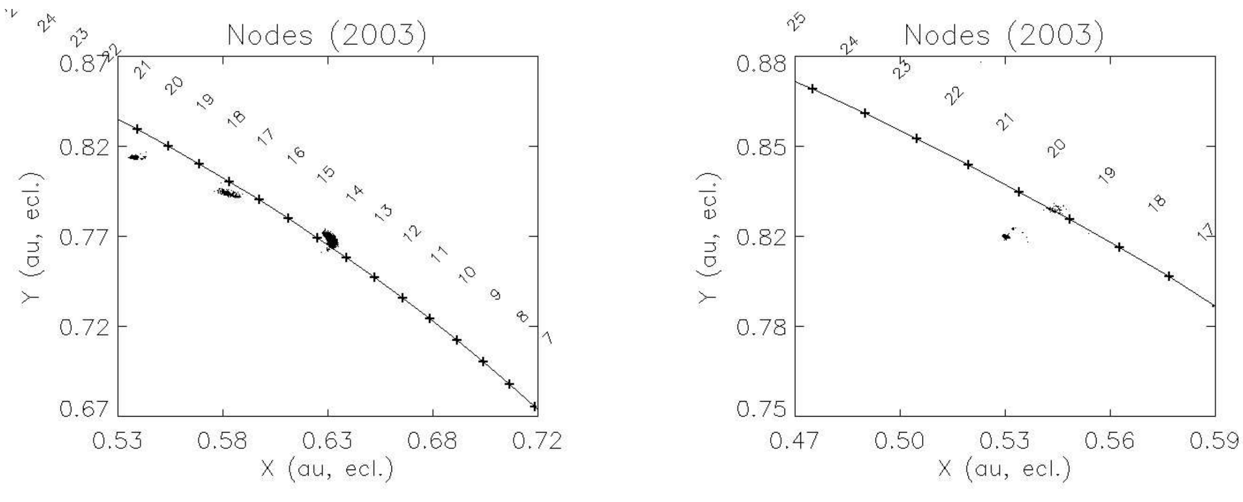

Figure 1 – General circumstances of the encounters in 2003 November with meteoroid streams ejected from 55P/Tempel-Tuttle in 1499 (left) and 1533 (right). Earth's position shown at 1-day intervals.

[1] Institut de Mécanique Céleste et de Calcul des Ephémerides, 77 Avenue Denfert Rochereau, 75014 Paris, France. Email: vaubaill@imcce.fr

[2] Kehäkukantie 3 B, 00780 Helsinki, FINLAND. Email: esko.lyytinen@luukku.com

[3] Naavakuja 9 B 8, 78870 Varkaus, FINLAND. Email: markku.nissinen@pp.inet.fi

[4] Armagh Observatory, College Hill, Armagh BT61 9DG, Northern Ireland. Email: dja@arm.ac.uk

ber. Following this result, Asher and Vaubaillon have run their model for various trails, confirming Lyytinen's findings. Figure 1 shows the general circumstances of the two main encounters. Figure 2 is a closer view around each encounter.

Old streams have suffered many planetary perturbations and are split into several parts. This is clearly visible in Figure 1. As old trails are, generally speaking, more dispersed than young ones, one can expect a very low ZHR value for the two expected showers. McNaught & Asher (2002) and Vaubaillon (2002) have independently shown the presence of gaps in meteoroid streams, and their relevance for making meteor shower forecasts. But because of the complexity of gravitational perturbations, there can, in addition to the gaps, be dense parts in a stream, increasing the ZHR. Table 1 provides the timing and the ZHR value from the different approaches of the authors.

There is a lot of fine structure in old trails, and when the original dust trail calculation method is applied to the 1499 trail, multiple encounters are found (Figure 3). The two most significant ones are the first two entries in Table 1; the former is closer to the Earth's orbit although both nominally miss the Earth by well over ten Earth diameters. In reality, material is dispersed over this whole region (Figure 2, left plot), and activity may last half a day (next entry in Table 1). Figure 3 shows a lot of particles compressed into a small range of nodal crossing times, effectively increasing f_M compared to the nominal values. The parameter f_M (McNaught &

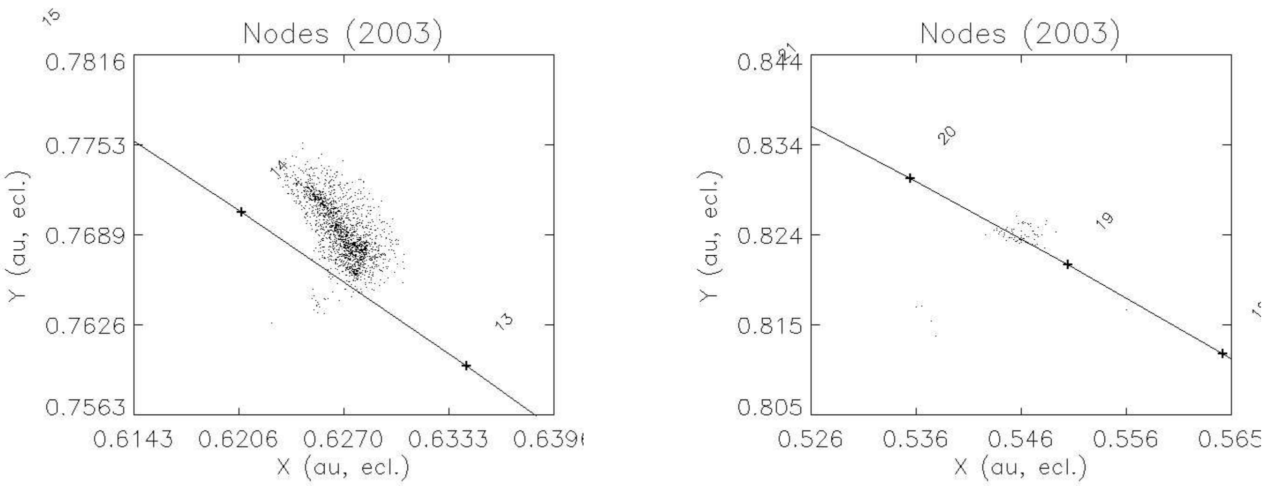

Figure 2 – Closer view of Figure 1.

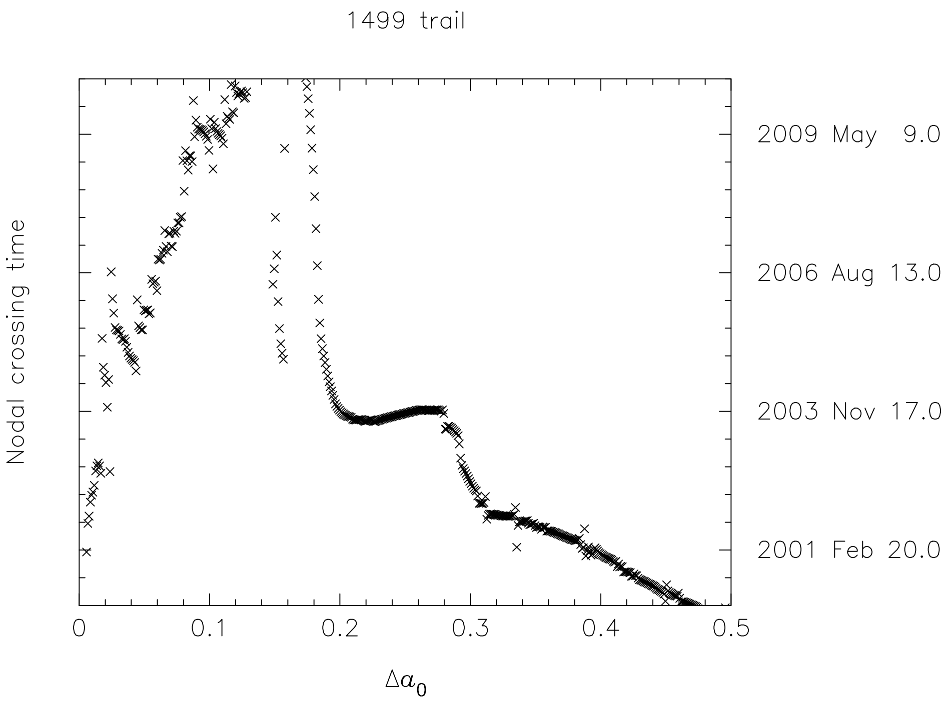

Figure 3 – Nodal crossing time in early 21st century of particles ejected tangentially at perihelion in 1499, as a function of orbital period at ejection time (equivalently $\Delta a_0 \equiv$ difference in semi-major axis from cometary value). Multiple values of Δa_0 allow particles to reach the ecliptic in mid-November of 2003.

Asher, 1999) measures the extent to which a trail has stretched in the along-orbit direction, being 1.0 for a 1-revolution trail and closer to zero for more stretched (lower density) trail sections. We can see from Table 1 that the conditions of the encounter with the 1499 stream are very good, with $f_M > 1$. The high value in Table 1 is somewhat surprising for such an old stream, but again gravitational perturbations have a complicated influence on the streams. Lyytinen (1999) pointed out that the 1499 stream is one revolution late, compared to the parent body, comet 55P/Tempel-Tuttle.

The difference between Lyytinen and Vaubaillon's results for the 1533 stream comes from the very poor number of simulated particles selected by the method (see Vaubaillon, 2002). It is then hard to compute a density that makes sense. The value of 100 for ZHR is thus very uncertain. The Asher & McNaught timing is for the nominal center of the trail, which the Earth misses by only a small distance; $r_E - r_D = -0.0002$ AU (cf. McNaught & Asher, 1999). The miss distance for the 1333 trail is much larger; $r_E - r_D = -0.0017$ AU.

Another consequence visible in Table 1 is that the two main showers are separated by 6 days. During the recent Leonid observations (1998–2002), this has never been observed. This is more surprising since the two streams have only one revolution difference.

3 Discussion and conclusions

The different models agree fairly well overall because they are all based on orbital dynamics. It is worth mentioning that the differences for very old streams seen in these predictions result from different cometary elements at time of ejection. Lyytinen uses the orbit of Nakano (1999), whereas Vaubaillon uses P. Rocher's one (personal communication). Differences in non-gravitational parameters induce, after a long time integration (here more than 1000 years), a very different time of perihelion. The same problem has been encountered with 2003 Perseids between Lyytinen and Vaubaillon's approaches. The orbit of 55P/Tempel-Tuttle is increasingly poorly constrained going back in time from the 1366 return, when the comet was first observed. Although an accurate orbit for the comet is the essential input parameter to the trail encounter calculations, observing the meteors may conversely provide information on the time of perihelion of comet 55P/Tempel-Tuttle a long time ago, by showing which of two possible orbits better matches the observations. If one observation discredits one orbit solution, it does not however definitely prove that the other one is the correct one. Indeed, a negative observation is a necessary condition to refute one solution, but is not sufficient to accept another one. At any rate, as such old streams are very perturbed, the ZHR is expected to be low.

Even if the Leonid meteor storm period (Lyytinen, 1999; McNaught & Asher, 2002) is over now, the year 2003 will provide good conditions to observe some showers. The times in Table 1 correspond to Pacific and east Asian regions being favored for the 1499 trail encounter, and Atlantic and east American regions six days later for the 1533 encounter. We have to emphasize that the last encounter with such old streams was the famous 1998 one. On the other hand, this year is expected to be poor in bright meteors. Although details of the predictions are harder than for younger trails, we encourage everybody to conduct some observations if possible. They will again help to constrain the models of the streams, and also give information on the orbit of the parent body more than 1000 years ago. The encounter with the trail from 1733 is quite a distant (~0.003 AU) encounter in the nominal solution, but strong non-gravitational effects could bring meteoroids near the Earth's orbit. Even though this

Table 1 – Times (UT) and ZHR forecasts for 2003 Leonids. Larger values of Δa_0 correspond to fainter meteors (see McNaught & Asher, 2002).

Trail	Model	Δa_0	f_M	Time	ZHR
1499	Asher & McNaught	0.28	~0.03	Nov 13, 13^{h}15^m	
	Asher & McNaught	0.26	~0.8	Nov 13, 18^{h}20^m	
	Lyytinen	0.28	~1.6	Nov 13, 16^{h}40^m, half a day	100
	Vaubaillon			Nov 13, 17^{h}17^m	120
1533	Asher & McNaught	0.30	−0.04 *	Nov 19, 06^{h}30^m	
	Lyytinen	0.30	~0.1	Nov 19, 08^h	dozen(s)
	Vaubaillon			Nov 19, 07^{h}28^m	100
1333	Asher & McNaught	0.12	~0.02	Nov 20, 00^{h}50^m	
	Lyytinen		~0.02	Nov 20, 01^{h}30^m	20
	Vaubaillon			Nov 20, 01^{h}26^m	15
736	Lyytinen	−0.008		Nov 22, 21^h	10
	Vaubaillon			Nov 22, 22^{h}02^m	2
636	Vaubaillon			Nov 23, 02^{h}56^m	10
1733	Lyytinen	0.11		Nov 19, 00^{h}25^m	a few dozen?

* Negative values of f_M occur when the order of meteoroids is reversed due to planetary perturbations. The degree of dispersal when $f_M = -0.04$ is the same as when $f_M = +0.04$.

encounter is expected to give only weak rates, observations of this could determine the existence or absence of such a strong non-gravitational effect.

References

Arlt R., Bellot Rubio L., Brown P. and Gyssens M. (1999) "Bulletin 15 of the International Leonid Watch: First Global Analysis of the 1999 Leonid Storm", *WGN*, **27:6**, 286–295.

Arlt R. and Brown P. (1999) "Bulletin 14 of the International Leonid Watch: Visual Results and Modeling of the 1998 Leonids", *WGN*, **27:6**, 267–285.

Arlt R. and Gyssens M. (2000) "Bulletin 16 of the International Leonid Watch: Results of the 2000 Leonid Meteor Shower", *WGN*, **28:6**, 195–208.

Arlt R., Kac J., Krumov V., Buchmann A. and Verbert J. (2001) "Bulletin 17 of the International Leonid Watch: First Global Analysis of the 2001 Leonid Storms", *WGN*, **29:6**, 187–194.

Arlt R., Krumov V., Buchmann A., Kac J. and Verbert J. (2002) "Bulletin 18 of the International Leonid Watch: Preliminary Analysis of the 2002 Leonid Meteor Shower", *WGN*, **30:6**, 205–212.

Asher D.J. (1999) "The Leonid meteor storms of 1833 and 1966", *MNRAS*, **307**, 919–924.

Jenniskens P. (2002) "More on the dust trail of comet 55P/Tempel-Tuttle from the 2001 Leonid shower flux measurements", Proceedings of Asteroids, Comets, Meteors — ACM 2002, International Conference, 29 July – 2 August 2002, Berlin, Germany, 117–120.

Kondrat'eva E.D., Murav'eva I.N. and Reznikov E.A. (1997) "On the forthcoming return of the Leonid meteoric swarm", *Solar System Res.*, **31**, 489–492.

Kondrat'eva E.D. and Reznikov E.A. (1985) "Comet Tempel-Tuttle and the Leonid meteor swarm", *Solar System Res.*, **19**, 96–101.

Lyytinen E. (1999) "Leonid predictions for the years 1999–2007 with the satellite model of comet", *Meta Research Bulletin*, **8**, 33–40.

Lyytinen E., Nissinen M. and Van Flandern T. (2001) "Improved 2001 Leonid Storm Predictions from a Refined Model", *WGN*, **29:4**, 110–118.

Lyytinen E. and Van Flandern T. (2000) "Predicting the Strength of Leonid Outbursts", *Earth Moon and Planets*, **82**, 149-166.

McNaught R.H. and Asher D.J. (1999) "Leonid Dust Trails and Meteor Storms", *WGN*, **27:2**, 85–102.

McNaught R.H. and Asher D.J. (2002) "Leonid dust trail structure and predictions for 2002", *WGN*, **30:5**, 132–143.

Nakano S. (1999) "OAA computing section circular, Nakano Note 722", Web page: `http://www.oaa.gr.jp/~oaacs/nk/nk722.htm`.

Vaubaillon, J. (2002) "Activity level prediction for the 2002 Leonids", *WGN*, **30:5**, 144–148.