The Leonids in the off-season
Part 2 – 2018: two small outbursts?

Koen Miskotte

Dutch Meteor Society
k.miskotte@upcmail.nl

A comprehensive analysis of the Leonids 2018 is presented based on visual observational data sent to the International Meteor Organization and to the author. After the 2017 analysis of the Leonids a second one could be done based on visual meteor data. This article presents the results of this analysis. It seems there was a normal nodal Leonid maximum, but on 19 and 20 November there were two (possible) small outbursts of the meteor shower. On November 19 a bit higher as usual activity was recorded (ZHR ± 12), but with unusual numbers of bright Leonids, also on November 20 with a ZHR of 20 also with bright Leonids.

Introduction

It is already 16 years ago that the last major outbursts of the Leonids took place. After that year outbursts were more often observed, but these were only a fraction of the strength of the big outbursts. This lasted until 2009, when a last outburst took place with a ZHR of 100. After this, it seemed to be quiet. In 2018, the author made a first analysis of the Leonids, based on visual observations from 2017. Even though there was not so much data available, the result was nice with two possible outbursts on 17 and 20 November 2017 (Miskotte, 2018). The result of this analysis was a reason, if there was enough data, to do an analysis on the Leonids 2018 with the available Leonid observations.

The Leonids are only sparingly visible from the BeNeLux. This has nothing to do with the astronomical conditions, but with the weather conditions. Very often it is cloudy in November. This was very different in 2018. High pressure over Northern Europe led to NO / SE winds during the period of 15–20 November. That resulted in the Benelux in four clear nights in a row between 15 and 19 November. The author for example, was able to observe the Leonids in the mornings of the 16th, 17th and 18th November for the first time since 2007!

Predictions

The 2018 Meteor Shower Calendar of the IMO (Rendtel, 2017) contains a summary of all the predictions made by various astronomers. It is interesting to see if there has been something observable visually. *Table 1* gives an overview. Peter Jenniskens gives no extra activity for the Leonids in 2018 in his book (Jenniskens, 2006).

IMO's on the fly graph

The author also looked on the IMO website at the well-known ZHR-on-the-fly curve (*Figure 1*). There, 27 observers had observed during 55 sessions, in which observations were collected for 135 count periods. The result was a graph based on 432 Leonids. The graph on the IMO website also contains an error, which is removed in *Figure 1*. It concerns a ZHR point at $\lambda_{\odot}$ 229.336° (12 November 2018 at 01^h08^m UT: ZHR 7 ± 7 based on 0 Leonids. The graph of the IMO is based on data with a limiting magnitude of 5.0, and an assumed r value of 2.50.

A single ZHR point of 24 ± 5 found at $\lambda_{\odot}$ 237.699° (November 20, 2018 at 08^h21^m UT) is remarkable. This looks like an error or an observation where the radiant height is very low. However, further research shows that this is indeed an accurate observation!

Table 1 – Overview of predictions for the Leonids in 2018 (from Rendtel, 2017).

Modeller	Date	Time (UT)	$\lambda_{\odot}$	Trail	Remarks
Nodal passage	17 Nov. 2018	22^h30^m	235.267	~	
Vaubaillon	18 Nov. 2018	23^h27^m	236.316	~	?
Sato	19 Nov. 2018	22^h20^m	237.277	1069	Rate increase 10<
Vaubaillon	19 Nov. 2018	23^h59^m	237.347	1069	?
Sato	20 Nov. 2018	07^h04^m	237.642	1433	Rate increase 10<
Maslov	20 Nov. 2018	09^h30^m	237.747	1466	Bright meteors
Vaubaillon	21 Nov. 2018	00^h54^m	238.394	~	?
Vaubaillon	25 Nov. 2018	23^h26^m	243.384	1567	?

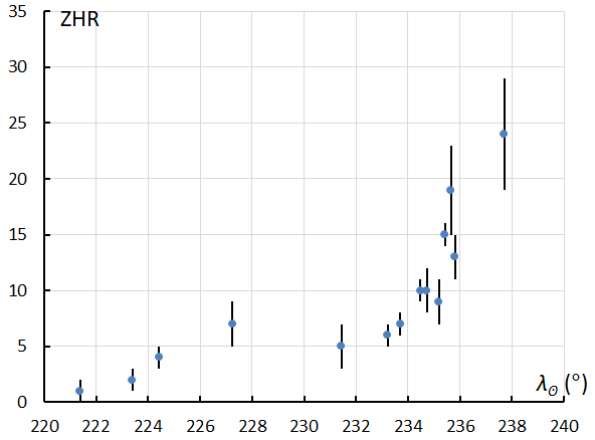

Figure 1 – The on-the-fly ZHR profile of the IMO for the Leonids 2018.

Collecting the meteor data

The necessary Leonid data was downloaded from the website of the International Meteor Organization. The author also received some Leonid observations from observers who did not report to IMO.

Just like in 2017 rather few observations were done. The cause may be the bad weather conditions in November and the low activity of the Leonids. The workflow: first, of course, the available observational data were critically examined. Radiant height (observations below 25 degrees radiant height were not used), limiting magnitude (limiting magnitude 5.9 or less was not used), extreme outliers were removed and only data from observers with a reliable C_p were used.

After selecting all the data that met the requirements described above, 507 Leonids remained for the analysis. These are 201 Leonids more than for the analysis of 2017.

Leonids 2018: population index r

In contrast to 2017, a population index value could be determined for 2018 for the period from 16 to 18 November 2018 and this only based on the European data. The results are shown in *Table 2*. A total of 367 Leonids were used for the determination of the population index *r*. Because the interval r [0; 5] yields the best numbers during the three nights, meteors were chosen for that selection.

Table 2 – Population index r for the Leonids 2018. In the ZHR calculations r [0; 5] was used.

16 November			17 November			18 November		
	r	n LEO		r	n LEO		r	n LEO
r[–2;5]	~	~	r[–2;5]	2.75	92	r[–2;5]	2.33	246.5
r[–1;5]	~	~	r[–1;5]	3.08	90.5	r[–1;5]	2.39	242.5
r[–1;4]	~	~	r[–1;4]	2.84	77.5	r[–1;4]	2.14	225.5
r[0;4]	2.81	25	r[0;4]	2.59	76.5	r[0;4]	2.20	206.5
r[0;5]	3.02	28.5	r[0;5]	2.98	89.5	r[0;5]	2.53	233.5
r[1;5]	3.14	27.5	r[1;5]	3.11	85	r[1;5]	2.68	218

Table 3 – Calculated ZHR values based on 507 Leonids.

Year	Month	Day	t/m UT	$\lambda_\odot$	Periods	n LEO	ZHR	±	r[–2;5]
2018	11	4	4.10	221.427	1	1	0.4	0.4	2.50
2018	11	6	3.26	223.397	4	4	1.9	1.0	2.50
2018	11	7	3.59	224.414	4	8	3.7	1.3	2.50
2018	11	10	3.21	227.411	5	18	7.4	1.8	2.50
2018	11	14	5.95	231.550	6	18	7.2	1.7	2.50
2018	11	15	4.25	232.486	2	5	2.8	1.3	2.50
2018	11	16	3.77	233.457	8	29	6.2	1.1	3.02
2018	11	17	4.75	234.456	15	74	10.2	1.2	2.98
2018	11	17	11.04	234.786	3	19	8.5	1.9	2.98
2018	11	18	2.25	235.425	28	228	13.8	0.9	2.53
2018	11	18	10.70	235.780	8	56	13.6	1.8	2.53
2018	11	19	2.75	236.454	2	20	12.5	2.8	2.50
2018	11	20	8.36	237.809	2	27	26.9	5.2	2.50

Leonids 2018: ZHR

The ZHR was determined by the method of Peter Jenniskens as described in Jenniskens (1994) and in Miskotte and Johannink (2005) with the radiant height correction set at 1.0 instead of 1.4 to make a comparison with the IMO curve. For the nights 15–16 (maybe too low numbers), 16–17 and 17–18 November 2018, enough data

was available for a population index *r* determination r [0; 5]. Values for the population index *r* as equal to 3.02, 2.98 and 2.53 were used respectively for the nights 15–16, 16–17 and 17–18 November. With a strong number of bright meteors during the morning of November 19, the author assumed a *r* value of 2.40 and for all other nights the IMO value of 2.50 was used. For the ZHR determination a total of 507 Leonids could be used, this resulted in *Table 3* and *Figure 2*.

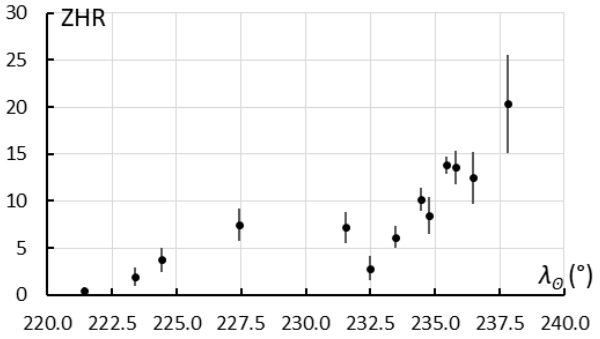

Figure 2 – ZHR graph Leonids 2018 based on Table 2 (507 Leonids). The period shown is from 4 to 21 November 2018. The ZHR is calculated with a variable population index r.

There is little difference between the ZHR curves from this analysis and the IMO ZHR-on-the-fly curve (*Figures 1 and 2*). The differences are caused, among other things, because not all IMO data has been used, data from observers have been used who do not report to IMO and an assumed population index *r* = 2.50 has been used for the IMO curve. See also *Figure 3* that combines the IMO chart and that of the author. Very small differences in the first nights but in the period 16–19 November we notice somewhat larger differences.

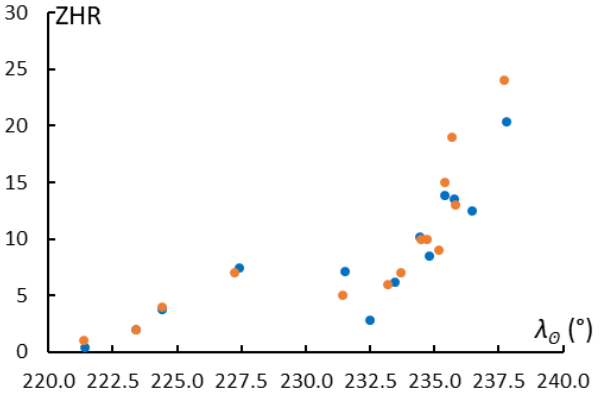

Figure 3 – Comparison Leonids ZHR 2018 between this analysis (blue dots) and the IMO ZHR-on-the-fly curve (orange dots). The ZHR is calculated with a variable population index r.

16–17 November 2018

We zoom in on the ZHR values found per hour in the night 16–17 November. This resulted in *Figure 4*. According to the IMO Meteor Shower Calendar 2018 (Rendtel, 2017) the nodal passage in 2018 was at $\lambda_\odot$ = 235.27° (17 November 2018 at 22^h30^m UT). As expected, we see a slightly increasing ZHR from 8 to 12 over Europe that night, these are the first four ZHR points. This European part of the graph is based on 93 Leonids (12 periods, 7 different observers). This mainly concerns weak Leonids, but it is striking that several observers also see a relatively large number of 0 to –3 Leonids, few of +2 but again a lot of +3 and +4.

We see declining ZHRs over the American continent. However, caution is required here, it concerns three ZHR points based on only 2 individual observers, namely *Terence Ross* (5th ZHR point) and *Wesley Stone* (6th and 7th ZHR points).

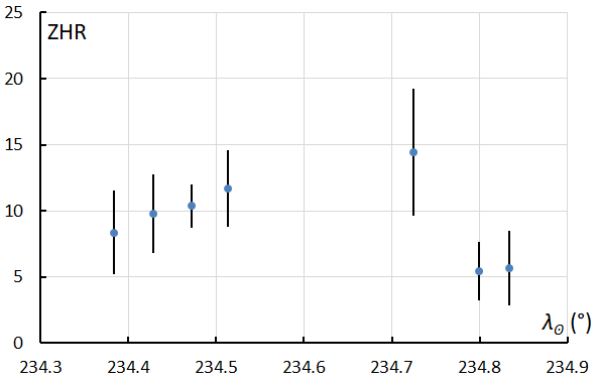

Figure 4 – ZHR Leonids in the period November 17, 2018 between 01^h and 13^h UT. The ZHR is calculated with a population index r = 2.98.

17–18 November 2018

Of course, we also zoom in on the ZHR during this night. As mentioned earlier in this article, nodal passage took place on 17 November at $\lambda_\odot$ = 235.27° (17 November 2018 at 22^h30^m UT. The ZHR above Europe (the first 6 ZHR points) decreases from 15 to 10–13, exactly what was to be expected. The first point above America seems to be high, the other three are more in line with what to expect.

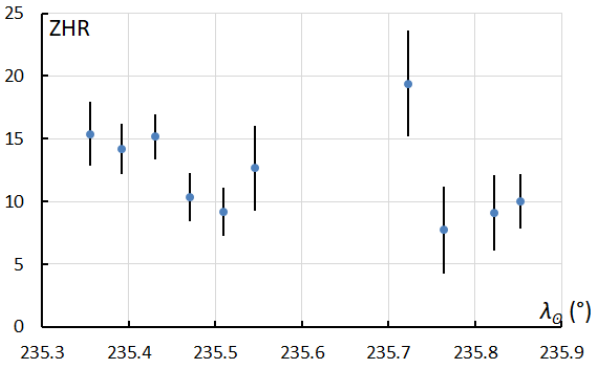

Figure 5 – ZHR Leonids in the period November 18, 2018 between 00^h and 13^h UT. The ZHR is calculated with a population index r = 2.53.

Outburst Leonid activity in 2018?

After the maximum night of November 17–18, we enter the "interesting area" of the Leonids (Rendtel, 2017). Unfortunately, the weather barely cooperated. There are few Leonid data in the IMO database after November 18th. There are three observations of "suspicious" Leonid activity.

18–19 November 2018

Only one observer could observe in this night. *Michel Vandeputte* reported relatively high activity of bright Leonids. He wrote: "*At 01^{h}45^m UT I was installed in the backyard and tsjakka: immediately an impressive –2 Leonid with persistent train moving to the southern parts of the sky! Immediately countered by a not much less beautiful –1 sporadic meteor from Canis Minor. More of it please! Here and there, there was a small cumulus-cloud, but they did not really bother. I could observe for two hours before the clouds re-appeared. The night sky was better at times than last night: more transparent and less hectic. But the wind blew a lot more and it felt pretty cold. The Leonids were much more attractive to my surprise! A whole battery of nice bright meteors between –2 and +2, certainly hourly counts of 10. Only in the end of my session the activity decreased a bit.*"

For those two hours a ZHR is calculated of 12 ± 4 with an assumed population index *r* of 2.40. The ZHR found is somewhat higher than the American ZHR values from *Figure 5* of November 18, 2018. The magnitude distribution is also strange, see *Table 4* below. Unfortunately, Michel was the only observer who observed this event. The lack of weak Leonids is striking with as a result the high average magnitude of 1.15.

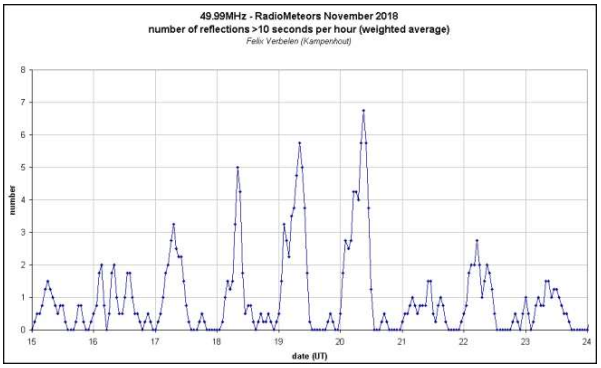

Figure 6 – Graph based on radio observations of the Leonids by Felix Verbelen of all overdense reflections longer than 10 seconds. These can be best compared with visual data because of the bright meteors.

Vandeputte's observations are supported by radio observations published by *Felix Verbelen*, he wrote the following on the VVS mailing list: "*Yesterday (20181118) it seemed that the Leonid activity this year would be moderate … Not so. Today, since 01^h UT, many strong and long-lasting reflections! Attached are some eye-catchers on the frequency of our VVS beacon (49.99 MHz), here in Kampenhout.*"

If we look at the graph of overdense reflections longer than 10 seconds of Felix (*Figure 6*) then we see indeed an increasing activity in the nights 16–17, 17–18, 18–19 and 19–20. Although the ZHR was lower in the night 18–19 than in the previous night, the number of bright Leonids turned out to be higher on the night of November 18–19 than on the previous night. See also Felix's article in Meteornews (Verbelen, 2019).

A second confirmation of the nice activity of bright Leonids on the morning of November 19 was on the well-known website of *Hirofumi Sigumoto* (*Figures 7 and 8*). The way in which Sigumoto performs his calculations is described in Meteornews (Sugimoto, 2017). The prediction of Jeremie Vaubaillon is the closest to this particular observation. So perhaps Michel has seen some activity from the associated dust trail.

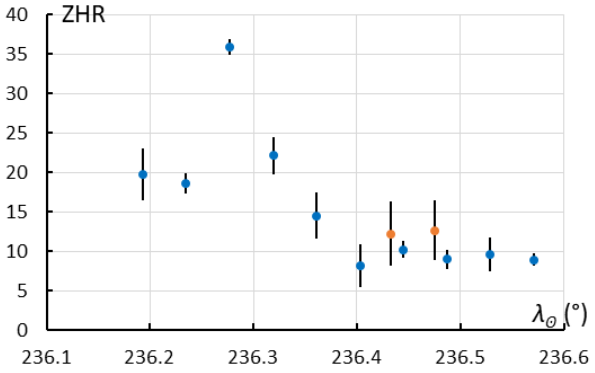

Figure 7 – A part of the Leonids radio ZHR curve of Hirofumi Sugimoto (blue dots), combined with the visual data (ZHR) by Michel Vandeputte (orange dots). The graph suggests that there may have been some more Leonid activity in the period before Michel did his observations.

Table 4 – Observation of the night 18–19 November 2018 by Michel Vandeputte.

Date	Period UT	Lm	–2	–1	0	1	2	3	4	5	LEO	Mm
19-11-2018	01^{h}45^m-03^{h}45^m	6.3	1	2	2	6	6	3	0	0	20	1.15

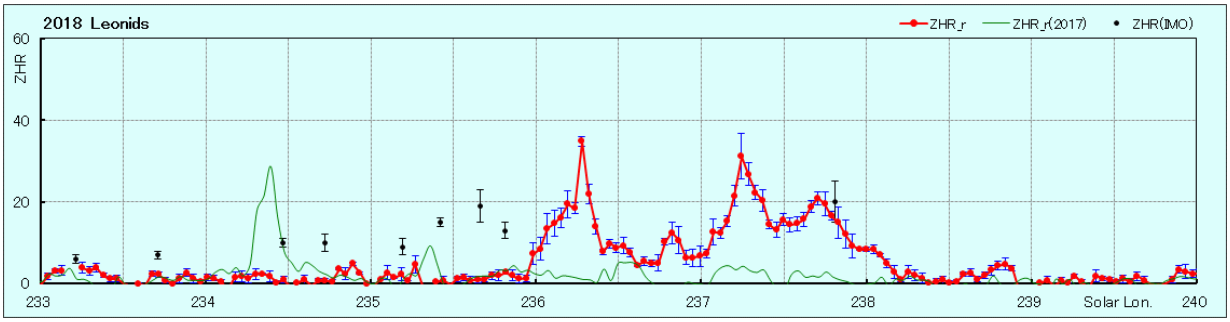

Figure 8 – Leonid ZHRs determined based on radio observations from RMOB (Sugimoto, 2017).

November 20, 2018

In both the IMO ZHR-on-the-fly graph (*Figure 1*) and the graph of this analysis (*Figure 2*) we see the fairly high ZHR point around November 20 ($\lambda_\odot$ = 237.80). This appears to be a ZHR point based on an observation reported by the active American observer *Terrence Ross*. His observation was done from Alpine, Texas on November 20 between 10^h26^m and 11^h30^m UT with a radiant height of 62 degrees. It yields a ZHR of 20. His observation can be found online[2].

The number of bright Leonids is also striking, somewhat comparable to the observation by *Michel Vandeputte* of November 19, 2018. Unfortunately, Ross is the only observer who has observed this.

However, there is another observation that was done earlier on the 20th by *Pedro Pérez Corujo* from the island of Cran Canaria. His observation can be found online[3].

His observation could unfortunately not be used in this analysis because of the too low limiting magnitude. But because of Ross's observation, it is used to compare the observations. Corujo sees 12 Leonids with a limiting magnitude of 5.5 between 05^h15^m and 06^h15^m UT and a radiant height of 70 degrees. This yields a ZHR of 33 ± 9.7. Unfortunately, this observer did not provide any magnitude distributions. His observation is roughly 5 hours before the observation of Ross and seems to be an indication that a possible small outburst happened on November 20th.

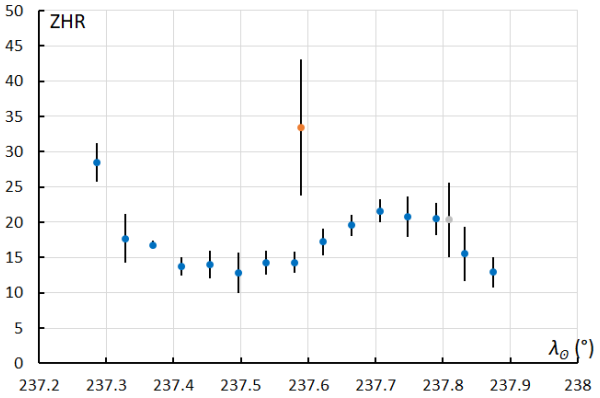

Figure 9 – The radio ZHR graph of Hirofumi Sugamoto (blue dots) compared with visual observations (ZHR) from Pedro Pérez Corujo (CORPE – orange dot) and Terrence Ross (ROSTE – grey dot).

The observations of Ross and Corujo are also supported by the graphs of *Hirofumi Sugimoto* (*Figure 9*) and *Felix Verbelen* (*Figure 6*). The ZHR on November 20 was higher than on November 19 and indeed the graph of *Felix Verbelen* also shows higher activity on November 20 than on November 19. All three modellers Sato, Vaubaillon and Maslov give candidates for this possible outburst: the observation of Corujo fits best with Sato (1433 dust trail), that of Ross with Maslov (1466 dust trail). The radiograph of Sigumoto (*Figure 8*) shows two broad peaks on November 20th. It is therefore very unfortunate that not more observers were active during this period.

Conclusions

Like the analysis of the Leonids for 2017, this analysis also shows that the Leonids between 15 and 25 November can be very interesting with sometimes small "outbursts". Therefore, I make a call to actively observe this meteor shower visually! And also, in 2019 when the conditions are moderate because of the Moon, the shower should be monitored. Who knows what surprises we will get to see?

I would also like to urge all observers to observe more in the period at the end of July and during entire August. This way I can calculate more reliable C_p's and add more data in the analyzes.

Acknowledgment

First of all, a huge word of thanks to the observers who observed the Leonids in 2018. These are: *Alexandre Amorim, Shrinivas Aundhkar, Pierre Bader, Steve Brown, Tim Cooper, Tibor Csorgei, Kai Gaarder, Glenn Hughes, Paul Jones, Javor Kac, Adam Marsh, Ken Marsh, Pierre Martin, Koen Miskotte, Rafael Neumann, Pedro Pérez Corujo, Ina Rendtel, Jürgen Rendtel, Terrence Ross, Kai Schutze, Ben Sharp, Ulruch Sperberg, Wesley Stone, Hanjie Tan, Michel Vandeputte, Roland Winkler, Frank Wächter* and *Sabine Wächter*.

A word of thanks also goes to *Paul Roggemans*, *Carl Johannink* and *Michel Vandeputte* for a critical review of this article and for the suggestions given. *Felix Verbelen* and *Hirofumi Sigumoto* are thanked for providing radio data and useful discussions.

References

Jenniskens P. (1994). "Meteor Stream activity 1. The annual streams". *Astron. & Astrophys.*, **287**, 990–1013.

Jenniskens P. (2006). Meteor showers and their Parent Comets. Cambridge Univ. Press., 790 pages.

Miskotte Koen (2018). "The Leonids during the off-season period: Part 1 – 2017: a small outburst!". *eMetN*, **3**, 148–152.

Rendtel J. (2017). "2018 Meteor Shower Calendar". IMO.

Sugimoto H. (2017). "The new method of estimating the ZHR using radio meteor observations". *eMetN*, **2**, 109–110.

Verbelen F. (2019). "Radio meteors – November 2018". *eMetN*, **4**, 44–48.

[2] https://www.imo.net/members/imo_vmdb/view?session_id=77963

[3] https://www.imo.net/members/imo_vmdb/view?session_id=78032