The Leonids
Bulletin 12 of the International Leonid Watch: Final Results of the 1997 Leonids and Prospects for 1998

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Visual reports of the 1997 Leonid shower are used to calculate an activity profile for the Leonid stream's 1997 return. Despite the Full-Moon conditions, it was possible to derive a fairly consistent ZHR profile; the flux profile is much more noisy, as it strongly depends on the population index profile which is less reliable due to the limited number of meteor magnitude estimates available. Increased activity began near $\lambda_\odot = 235^\circ\!.0$ (all solar longitudes refer to equinox 2000.0) and persisted until at least $\lambda_\odot = 236^\circ\!.0$. The peak ZHR value is near 100 ± 15 at circa $\lambda_\odot = 235^\circ\!.22 \pm 0^\circ\!.04$, corresponding to November 17, 1997, 12^h15^m UT. High activity of ZHR > 80 persisted until $\lambda_\odot = 235^\circ\!.5$, but it is argued that this continued activity is an artifact due to underestimated limiting magnitudes as judged from sporadic rates. The population index shows an increase from 2.0 to 2.5 at $\lambda_\odot = 235^\circ\!.15 \pm 0.02$ (November 17, 10^h30^m UT), as occurred in 1996, but the statistical significance of the increase is marginal in 1997. Strong lunar interference precludes any definitive statement concerning the visual activity of the shower in 1997. The outlook for the 1998 return based on available information is summarized.

1. Introduction

As discussed in the previous *International Leonid Watch* (*ILW*) Bulletin [1], the 1997 return was well covered by observers, but the nearly Full Moon severely hampered most observations for the nights around the peak. Nevertheless, as so many observers did attempt observations, enough data are available to attempt some cautious analysis. In 1997, a total of 73 observers observing 2623 Leonids in 237.30 hours reported their observations. They were from 14 countries: Belgium, Canada, Croatia, Finland, Germany, India, Italy, Japan, Jordan, the Netherlands, Spain, the United States, Venezuela, and Yugoslavia. We thank the many observers listed below who contributed to the 1997 analysis:

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2. Population index profile

The average reported limiting magnitudes near the time of the Leonid peak in 1997 were between 4.5 and 5.5, typically resulting in large correction factors due to the limiting magnitude alone (between 2 and 5). This underscores the necessarily large uncertainties which follow in every quantity discussed (and further emphasized by the large error margins present in the figures).

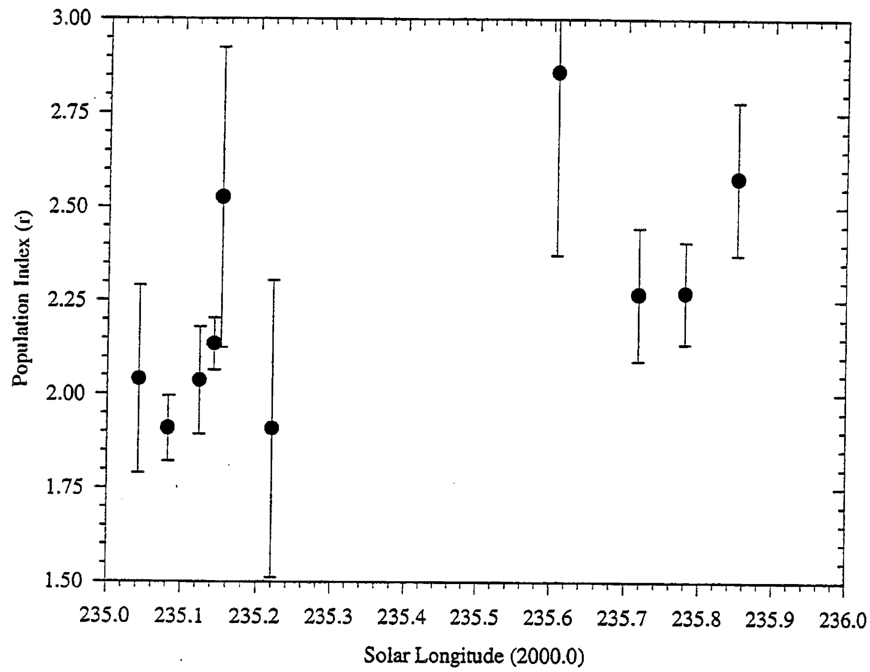

Figure 1 – Population index r versus solar longitude for the 1997 Leonid return. From 235°0 – 235°3 the magnitude data were binned in intervals of 0°06 and shifted in steps of 0°03. From 235°3 onwards, the binning windows were 0°2 wide and shifted by 0°1.

Since sufficient magnitude estimates were made in 1997, a complete r-profile can be constructed during the principle activity period of the shower; the graph is shown in Figure 1.

The initial values for r are consistent with the longer-term average for the shower near 2.0. The values between $\lambda_\odot = 235°0$ and $\lambda_\odot = 235°15$ (equinox 2000.0 throughout this paper) are in the range 1.8–2.1, and are very similar to the profile from 1996. The large increase at $\lambda_\odot = 235°17$ is at precisely the same location as a similar (though smaller) increase recorded in 1996 [2]. However, the large error margin associated with this particular datum implies that this is only a probable concordance with the 1996 profile. Within error, however, the value of r does clearly increase between $\lambda_\odot = 235°08$ and $\lambda_\odot = 235°17$ as in 1996; it is the magnitude of the increase which is most uncertain.

Unfortunately, the remainder of the Leonid interval is only modestly covered by magnitude estimates, particularly as no magnitudes are reported from eastern Asian longitudes, and the most consistent value for r from $\lambda_\odot = 235°3$ onward is near 2.3. Curiously, these are higher (within error) as compared to the same intervals in 1996 and the longer-term average. It might be argued that, on the one hand, observers were able to estimate a reasonable limiting magnitude under the Full-Moon conditions (as can be seen from the reasonable ZHRs), but systematically underestimated meteor magnitudes on the other hand (i.e., making them fainter). This may occur since observers do not always compare a meteors appearance with a star of similar brightness. Instead, judgments like "relatively faint" might have been converted into a magnitude estimate as if under better sky conditions, making a magnitude +3 or +4 meteor a full magnitude fainter.

3. ZHR profile

The ZHR activity profile is shown in Figure 2. The build-up in activity beginning near 235°0 is apparent, and, between $\lambda_\odot = 235°1$ and $\lambda_\odot = 235°3$ (November 17, 9^h30^m–10^h UT), a clear peak with a maximum ZHR of 96 ± 13 is reached. The peak at $\lambda_\odot = 235°22 \pm 0.04$ (November 17, 12^h15^m UT) is based on reports from a dozen observers and is quite reliable (excepting the ever-present large error margins due to the Moon). Additionally, it comes after the large peak in the population index at a point where this is a large drop in r and is thus not a simple artifact of the sudden jump in r. The activity seems to decline after the peak with about the same steepness as the increase, yet is soon followed by another maximum at $\lambda_{\odot} = 235\overset{\circ}{.}45 \pm 0.05$ (November 17, $17^{\rm h}30^{\rm m}$ UT) with ZHR $= 85 \pm 13$. It should be noted that the error margins do overlap during large parts of the Leonid maximum. We cannot exclude that the maximum furnished a plateau activity between solar longitudes $\lambda_{\odot} = 235\overset{\circ}{.}15$ and $\lambda_{\odot} = 235\overset{\circ}{.}5$.

However, the sporadic HR during the second, less prominent enhancement of activity is very high, the values being definitely too high (compared to normal sporadic rates for this time of the year) by factor of about 3. We assume that the few observers contributing to these ZHR values underestimated their limiting magnitudes significantly—a typical effect under moonlit sky conditions. Upon changing the limiting magnitude by +1 to reduce the sporadic HRs by a factor of 3, Leonid ZHRs decrease by a factor of roughly 2, i.e., the ZHR graph turns into a gradually declining curve matching the reliable value of about 35 after a solar longitude of $\lambda_{\odot} = 235\overset{\circ}{.}8$.

When comparing the ZHR-graph with that of the preliminary analysis in [1], one finds the most striking difference in the high value of about 150. This value was based on very few individual counts and is now smoothed out by additional data.

We do not present values for flux, as the large errors in r and ZHR make flux values virtually indeterminate. We can only say that near the time of the early peak ($\lambda_{\odot} \approx 235\overset{\circ}{.}2$), the shower flux was somewhere in the interval 0.01–0.05 meteoroids/km^{-2} hour^{-1} to a limiting absolute magnitude of +6.5.

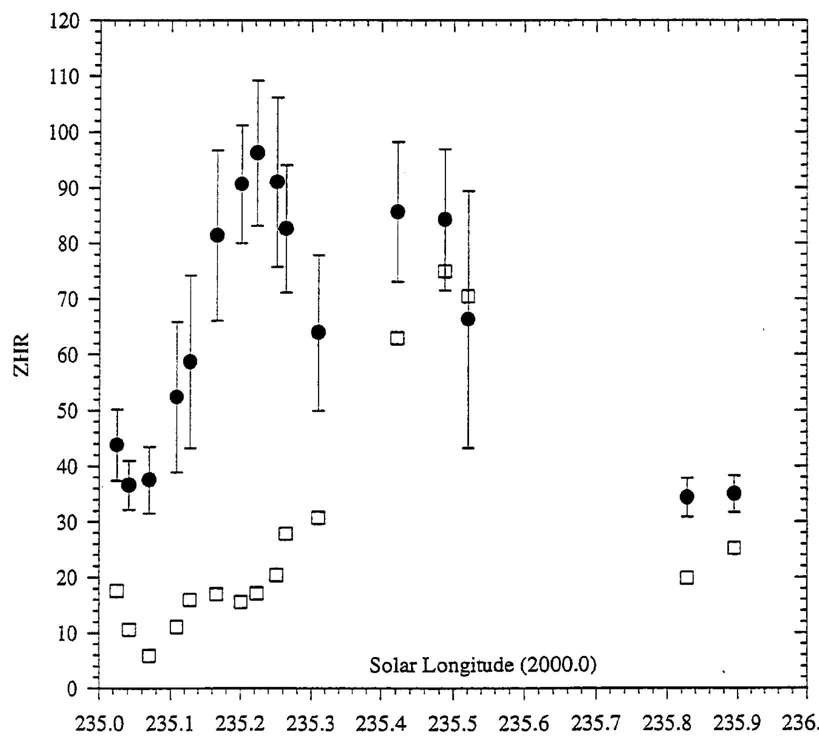

Figure 2 – The ZHR versus solar longitude for the 1997 Leonid return. Observations were binned in windows of $0\overset{\circ}{.}06$ size from $\lambda_{\odot} = 235\overset{\circ}{.}0$ to $\lambda_{\odot} = 235\overset{\circ}{.}3$ and smoothed in steps of $0\overset{\circ}{.}03$, while from $\lambda_{\odot} = 235\overset{\circ}{.}3$ to $\lambda_{\odot} = 235\overset{\circ}{.}6$, the binning intervals were $0\overset{\circ}{.}2$ wide and the steps used were $0\overset{\circ}{.}1$. For all intervals after $\lambda_{\odot} = 235\overset{\circ}{.}6$, the bins were $1\overset{\circ}{.}0$ wide and stepped at $0\overset{\circ}{.}5$ intervals.

4. Prospects for 1998

As all visual data have now been analyzed in the lead-up to 1998, we may attempt to use the features from the last few years, plus model and other general considerations to estimate the time of the peak of the shower in 1998. The magnitude of the peak ZHR in 1998 is much more difficult to divine, but we present some of the most recent predictions in Table 1.

Table 1 – Recent predictions for the Leonid meteor storm expected for 1998. The ZHRs are estimates for the anticipated activity.

Author	Peak	Time (UT)	Peak ZHR
Jenniskens, 1996 [7]	235.°34	21^h30^m	10 000
Yeomans, 1998 [8]	235.°26	19^h40^m	200–5000
Brown et al., 1998 [6]	235.°24	18^h50^m	1000–10 000
Kresak, 1993 [9]	234.°8	08^h30^m	10 000

From the analysis of each of the returns in 1995, 1996, and 1997 [2,3], a period of transient activity has been noted in each of these years. The peak ZHR values and location in 1995 are most uncertain (ZHR $\approx$ 50 and peak near $\lambda_\odot = 235.^\circ0$), while a clear outburst feature was noted in 1996 near $\lambda_\odot = 235.^\circ16$ with a peak ZHR of 90. The present analysis suggests another "early" peak near $\lambda_\odot = 235.^\circ22$ with a peak ZHR approaching 100. In all cases, the trend appears to be for the peaks to be shifting closer to the nodal longitude of 55P/Tempel-Tuttle ($\Omega = 235.^\circ26$) in the few years immediately before the comet reaches perihelion. The most reliably determined of these peaks (that from 1996) is also at the same longitude as the 1966 meteor storm.

On general dynamical grounds, it is expected that any meteor storm in 1998 will occur near the time of the comet's nodal passage [4]. From the recorded Leonid meteor storms over the last 200 years, there is a clear trend whereby the strongest storms occur closest to the cometary node. Curiously, the 6 largest storms all peaked 0.5–2 hours after the nodal longitude of the comet [5].

The most recent numerical modeling results suggest that, if a storm occurs in 1998, it will likely do so within 0.5 hours of the nodal passage (specifically somewhat before the time of the passage) [6]. The most recent predictions for 1998 are summarized in Table 1, along with estimates of the peak ZHR where these have been given.

5. The eighth ILW period: November 5–25, 1998

Summarizing all of the above, it appears most probable that any significant enhancement in Leonid activity in 1998 will occur in the interval $\lambda_\odot = 235.^\circ15$–$235.^\circ3$. This implies the best location is likely to be in the Western Pacific or Eastern Asia. Noting the possible plateau in activity observed in 1997 and similar behavior observed in past Leonid returns near the time of the comet's passage (such as in 1965 [5]), it is quite probable that much higher than normal activity from the extended component of the shower may be visible for as much as 24 hours centered about the cometary node.

As a result, observers are encouraged to exercise special vigilance during their local 0^h–6^h times on the mornings of November 17 and 18 in particular. The days around the time of the peak will be completely free of lunar interference and ideal for observations. As 1998 has some prospect for producing a meteor storm, observers are reminded that fixed cameras may be most useful during the storm, though disciplined observers should be able to make successful counts should rates reach even as many as several Leonids per second [6]. A detailed description of various observing methods during the Leonid maximum is given earlier in this issue.

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The June Bootids

Surprising Activity of the 1998 June Bootids

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After a quiescent period of several decades, the June Bootid meteor shower (sometimes referred to as June Draconids) surprised a number of regular and casual observers by an outburst with maximum ZHRs near 100. A total number of 619 meteors was recorded during regular meteor observations. An average population index of $r = 2.22 \pm 0.07$ was derived from 511 magnitude estimates. The broad activity profile with high rates for more than 10 hours and the large radiation area in 1998 resemble the appearance of the 1916 and 1927 outbursts. The peak time is found to be between $\lambda_\odot = 95\overset{\circ}{.}7$ and $\lambda_\odot = 96\overset{\circ}{.}0$ (eq. 2000.0); the average radiant is $\alpha = 230°$ and $\delta = +47°$.

1. Introduction

Considerable activity of the June Bootids was observed at two occasions in 1916 and 1927. Some sources also list the year 1921, but the activity reported from this return is rather low (see Table 1). Additionally, there are some reports of possible activity before and after these returns, but the association to the June Bootids is not certain. Nevertheless, Hoffmeister [1] considered the shower (listed as June Draconids on p. 88) as a "real shower," which was excluded from his final catalogue only because of insufficient observation. When the current *IMO* working list of meteor showers was established by Arlt [2], the shower was rejected because its regular activity was practically below the detection limits for many years. However, June is a period of the year which is poorly covered by meteor observations generally, and in particular from the northern hemisphere.

Observers were surprised by a high meteor activity in the night June 27-28, 1998. The display attracted the attention of casual witnesses, because there were numerous bright meteors visible.