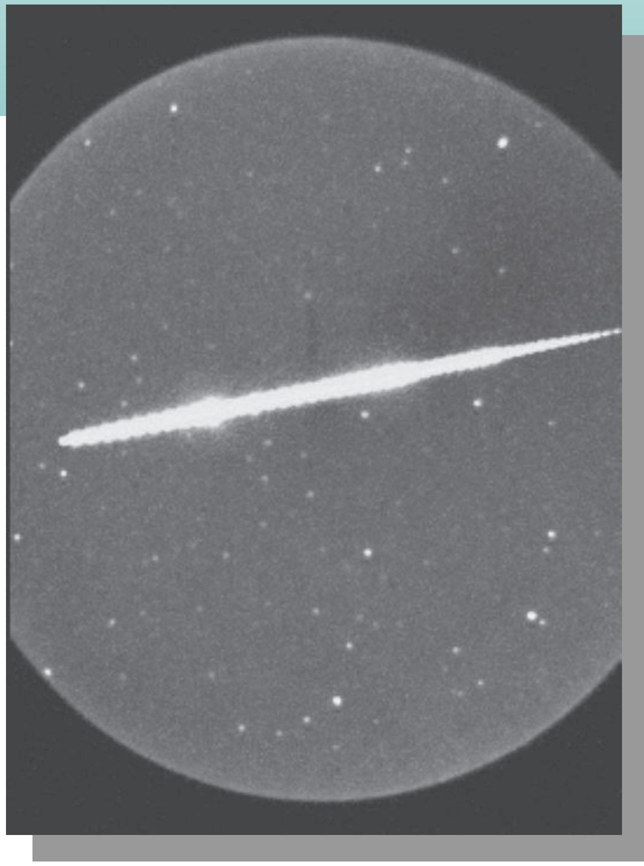
journal of the international meteor organization

# WGN

31:1
february 2003



Leonids 2002
Perseids
Radio meteors
Video observations
IMC 2001 Proceedings

ISSN 1016-3115

# WGN Vol. 31, No. 1, February 2003, pp. 1–34

## Administrative



## The Leonids



## Conferences



## The Perseids



## Erratum



## Ongoing meteor work



## Cover photo

This beautiful meteor with three light maxima was captured about 50 km north of Munich by Sirko Molau with his image-intensified video system AVIS on 2003 February 25, at $02^{h}41^{m}24^{s}$ UT. The meteor reached about magnitude −3, the trail in the image intensifier lasting nearly two seconds.

## Cover design

Rainer Arlt

## Janus

*Jürgen Rendtel*

With this issue we start the 31st volume of the IMO Journal WGN. WGN started as a Belgian Journal on meteors (originally in Dutch language) and was mainly initiated and typed by Paul Roggemans. In 1989 WGN was chosen to become the IMO Journal and Marc Gyssens was the Editor. This Journal was always meant as a communication platform between the IMO members as well as between the professional and the amateur branches of meteor work.

With six issues per year, WGN can just be one component of the communication among the members and readers. Delays in the production of the journal in the past reduced its role. However, when reading the issues one should bear in mind that it is not produced and mailed by professionals. Meteor astronomy is our hobby despite the impression that several projects are dealt with in a rather professional manner. WGN is produced by a rather small number of very enthusiastic people and sometimes other commitments require much of their time. This was also the case with Marc Gyssens.

We are very grateful to Marc, and to Rainer Arlt who effectively made the last seven issues of WGN. Of course, there were continuous contacts among the Council members in order to find an Editor for a longer period of time as Rainer has already a huge workload caused by the enormous number of visual meteor data. We are glad that now Chris Trayner volunteered for the work as the Editor of WGN.

Janus *was a Roman god with two faces, one looking to the past and one to the future, called upon at the beginning of any enterprise. Today he is often a symbol of re-appraisal at the start of the year.*

## Editorial

*Chris Trayner, Editor*

With the New Year come some changes to WGN: a new Editor and a new appearance. Rainer Arlt has produced us a new, elegant cover design. We hope that you will find the new layout pleasant, but of course it is the scientific quality which is important. We would therefore encourage you to write up your ideas as well as your results for WGN.

There are also changes to the way the Journal is produced: TEX has been replaced by LATEX. For those who don't know, these are two similar formalisms for writing articles. We will issue revised instructions for authors, but for practical reasons these will be in the next issue or possibly the one after that.

If these technical details are alien to you, don't let that put you off writing for WGN. If you don't know LATEX, just send us your contributions in whatever form you prefer and we will convert them to the format we need. It is your results and ideas that matter, not the physical format. If you have Internet access, the easiest way is to send them to `wgn@imo.net`. If you're not sure about writing, please contact me and ask.

## Solar Longitudes for 2003

*Compiled by Rainer Arlt*

A conversion table of dates to solar longitudes using (Steyaert, 1991) is given as every year. The longitudes are given on the next page; they are only valid for 2003. The conversion formulae for any time of the day are repeated here for your convenience.

If you want to calculate the solar longitude $\lambda_\odot$ of a specific time of the day, you may use a linear interpolation between two dates. Suppose you have a certain *Date* and the *Time* in hours (UT), you get the solar longitude by

$$\lambda_\odot = \lambda_{\odot,\mathrm{Date}} + (\lambda_{\odot,\mathrm{NextDay}} - \lambda_{\odot,\mathrm{Date}}) \times \frac{\mathrm{Time}}{24\ ^{\mathrm{h}}}.$$

Alternatively, if you want to convert a certain solar longitude $\lambda_\odot$ into a time of the day, look up the *Date* with the next-smaller solar longitude in the table and calculate

$$\mathrm{Time} = \frac{(\lambda_\odot - \lambda_{\odot,\mathrm{Date}})}{(\lambda_{\odot,\mathrm{NextDay}} - \lambda_{\odot,\mathrm{Date}})} \times 24\ ^{\mathrm{h}}.$$

The solar longitudes of 1988–2005 are given in 2-hour increments and with three decimals at `http://www.imo.net/solarlong`.

### Reference

Steyaert, C. (1991), "Calculating the Solar Longitude 2000.0", *WGN* **19:2**, 31–34.

Solar longitudes 2003. Dates refer to $00^{h}$ UT.

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan | 1 | 280.10 | Mar | 1 | 339.94 | May | 1 | 40.19 | Jul | 1 | 98.74 | Sep | 1 | 158.12 | Nov | 1 | 218.10 |
| Jan | 2 | 281.12 | Mar | 2 | 340.95 | May | 2 | 41.16 | Jul | 2 | 99.69 | Sep | 2 | 159.09 | Nov | 2 | 219.10 |
| Jan | 3 | 282.14 | Mar | 3 | 341.95 | May | 3 | 42.13 | Jul | 3 | 100.64 | Sep | 3 | 160.05 | Nov | 3 | 220.10 |
| Jan | 4 | 283.16 | Mar | 4 | 342.96 | May | 4 | 43.10 | Jul | 4 | 101.60 | Sep | 4 | 161.02 | Nov | 4 | 221.10 |
| Jan | 5 | 284.18 | Mar | 5 | 343.96 | May | 5 | 44.07 | Jul | 5 | 102.55 | Sep | 5 | 161.99 | Nov | 5 | 222.10 |
| Jan | 6 | 285.20 | Mar | 6 | 344.96 | May | 6 | 45.04 | Jul | 6 | 103.51 | Sep | 6 | 162.96 | Nov | 6 | 223.11 |
| Jan | 7 | 286.22 | Mar | 7 | 345.96 | May | 7 | 46.01 | Jul | 7 | 104.46 | Sep | 7 | 163.93 | Nov | 7 | 224.11 |
| Jan | 8 | 287.24 | Mar | 8 | 346.96 | May | 8 | 46.97 | Jul | 8 | 105.41 | Sep | 8 | 164.90 | Nov | 8 | 225.11 |
| Jan | 9 | 288.26 | Mar | 9 | 347.96 | May | 9 | 47.94 | Jul | 9 | 106.36 | Sep | 9 | 165.87 | Nov | 9 | 226.11 |
| Jan | 10 | 289.28 | Mar | 10 | 348.96 | May | 10 | 48.91 | Jul | 10 | 107.32 | Sep | 10 | 166.84 | Nov | 10 | 227.12 |
| Jan | 11 | 290.30 | Mar | 11 | 349.96 | May | 11 | 49.87 | Jul | 11 | 108.27 | Sep | 11 | 167.81 | Nov | 11 | 228.12 |
| Jan | 12 | 291.32 | Mar | 12 | 350.96 | May | 12 | 50.84 | Jul | 12 | 109.22 | Sep | 12 | 168.79 | Nov | 12 | 229.13 |
| Jan | 13 | 292.34 | Mar | 13 | 351.96 | May | 13 | 51.81 | Jul | 13 | 110.18 | Sep | 13 | 169.76 | Nov | 13 | 230.13 |
| Jan | 14 | 293.35 | Mar | 14 | 352.96 | May | 14 | 52.77 | Jul | 14 | 111.13 | Sep | 14 | 170.73 | Nov | 14 | 231.14 |
| Jan | 15 | 294.37 | Mar | 15 | 353.95 | May | 15 | 53.73 | Jul | 15 | 112.08 | Sep | 15 | 171.70 | Nov | 15 | 232.15 |
| Jan | 16 | 295.39 | Mar | 16 | 354.95 | May | 16 | 54.70 | Jul | 16 | 113.04 | Sep | 16 | 172.68 | Nov | 16 | 233.15 |
| Jan | 17 | 296.41 | Mar | 17 | 355.95 | May | 17 | 55.66 | Jul | 17 | 113.99 | Sep | 17 | 173.65 | Nov | 17 | 234.16 |
| Jan | 18 | 297.43 | Mar | 18 | 356.94 | May | 18 | 56.63 | Jul | 18 | 114.94 | Sep | 18 | 174.63 | Nov | 18 | 235.17 |
| Jan | 19 | 298.44 | Mar | 19 | 357.94 | May | 19 | 57.59 | Jul | 19 | 115.90 | Sep | 19 | 175.60 | Nov | 19 | 236.18 |
| Jan | 20 | 299.46 | Mar | 20 | 358.93 | May | 20 | 58.55 | Jul | 20 | 116.85 | Sep | 20 | 176.58 | Nov | 20 | 237.19 |
| Jan | 21 | 300.48 | Mar | 21 | 359.92 | May | 21 | 59.51 | Jul | 21 | 117.81 | Sep | 21 | 177.56 | Nov | 21 | 238.20 |
| Jan | 22 | 301.50 | Mar | 22 | 0.92 | May | 22 | 60.47 | Jul | 22 | 118.76 | Sep | 22 | 178.54 | Nov | 22 | 239.21 |
| Jan | 23 | 302.51 | Mar | 23 | 1.91 | May | 23 | 61.44 | Jul | 23 | 119.72 | Sep | 23 | 179.51 | Nov | 23 | 240.22 |
| Jan | 24 | 303.53 | Mar | 24 | 2.90 | May | 24 | 62.40 | Jul | 24 | 120.67 | Sep | 24 | 180.49 | Nov | 24 | 241.23 |
| Jan | 25 | 304.55 | Mar | 25 | 3.89 | May | 25 | 63.36 | Jul | 25 | 121.63 | Sep | 25 | 181.47 | Nov | 25 | 242.24 |
| Jan | 26 | 305.57 | Mar | 26 | 4.88 | May | 26 | 64.32 | Jul | 26 | 122.58 | Sep | 26 | 182.45 | Nov | 26 | 243.25 |
| Jan | 27 | 306.58 | Mar | 27 | 5.87 | May | 27 | 65.28 | Jul | 27 | 123.54 | Sep | 27 | 183.43 | Nov | 27 | 244.26 |
| Jan | 28 | 307.60 | Mar | 28 | 6.86 | May | 28 | 66.24 | Jul | 28 | 124.49 | Sep | 28 | 184.42 | Nov | 28 | 245.28 |
| Jan | 29 | 308.61 | Mar | 29 | 7.85 | May | 29 | 67.20 | Jul | 29 | 125.45 | Sep | 29 | 185.40 | Nov | 29 | 246.29 |
| Jan | 30 | 309.63 | Mar | 30 | 8.84 | May | 30 | 68.16 | Jul | 30 | 126.41 | Sep | 30 | 186.38 | Nov | 30 | 247.30 |
| Jan | 31 | 310.65 | Mar | 31 | 9.83 | May | 31 | 69.12 | Jul | 31 | 127.36 | | | | | | |
| Feb | 1 | 311.66 | Apr | 1 | 10.82 | Jun | 1 | 70.08 | Aug | 1 | 128.32 | Oct | 1 | 187.36 | Dec | 1 | 248.31 |
| Feb | 2 | 312.68 | Apr | 2 | 11.81 | Jun | 2 | 71.04 | Aug | 2 | 129.28 | Oct | 2 | 188.35 | Dec | 2 | 249.33 |
| Feb | 3 | 313.69 | Apr | 3 | 12.79 | Jun | 3 | 71.99 | Aug | 3 | 130.23 | Oct | 3 | 189.33 | Dec | 3 | 250.34 |
| Feb | 4 | 314.71 | Apr | 4 | 13.78 | Jun | 4 | 72.95 | Aug | 4 | 131.19 | Oct | 4 | 190.31 | Dec | 4 | 251.36 |
| Feb | 5 | 315.72 | Apr | 5 | 14.76 | Jun | 5 | 73.91 | Aug | 5 | 132.15 | Oct | 5 | 191.30 | Dec | 5 | 252.37 |
| Feb | 6 | 316.74 | Apr | 6 | 15.75 | Jun | 6 | 74.87 | Aug | 6 | 133.10 | Oct | 6 | 192.28 | Dec | 6 | 253.38 |
| Feb | 7 | 317.75 | Apr | 7 | 16.73 | Jun | 7 | 75.83 | Aug | 7 | 134.06 | Oct | 7 | 193.27 | Dec | 7 | 254.40 |
| Feb | 8 | 318.76 | Apr | 8 | 17.72 | Jun | 8 | 76.78 | Aug | 8 | 135.02 | Oct | 8 | 194.25 | Dec | 8 | 255.41 |
| Feb | 9 | 319.78 | Apr | 9 | 18.70 | Jun | 9 | 77.74 | Aug | 9 | 135.98 | Oct | 9 | 195.24 | Dec | 9 | 256.43 |
| Feb | 10 | 320.79 | Apr | 10 | 19.68 | Jun | 10 | 78.69 | Aug | 10 | 136.94 | Oct | 10 | 196.23 | Dec | 10 | 257.44 |
| Feb | 11 | 321.80 | Apr | 11 | 20.66 | Jun | 11 | 79.65 | Aug | 11 | 137.90 | Oct | 11 | 197.22 | Dec | 11 | 258.46 |
| Feb | 12 | 322.81 | Apr | 12 | 21.65 | Jun | 12 | 80.61 | Aug | 12 | 138.85 | Oct | 12 | 198.20 | Dec | 12 | 259.48 |
| Feb | 13 | 323.82 | Apr | 13 | 22.63 | Jun | 13 | 81.56 | Aug | 13 | 139.81 | Oct | 13 | 199.19 | Dec | 13 | 260.49 |
| Feb | 14 | 324.83 | Apr | 14 | 23.61 | Jun | 14 | 82.52 | Aug | 14 | 140.77 | Oct | 14 | 200.18 | Dec | 14 | 261.51 |
| Feb | 15 | 325.84 | Apr | 15 | 24.59 | Jun | 15 | 83.47 | Aug | 15 | 141.73 | Oct | 15 | 201.17 | Dec | 15 | 262.53 |
| Feb | 16 | 326.85 | Apr | 16 | 25.56 | Jun | 16 | 84.43 | Aug | 16 | 142.69 | Oct | 16 | 202.16 | Dec | 16 | 263.54 |
| Feb | 17 | 327.86 | Apr | 17 | 26.54 | Jun | 17 | 85.38 | Aug | 17 | 143.65 | Oct | 17 | 203.16 | Dec | 17 | 264.56 |
| Feb | 18 | 328.87 | Apr | 18 | 27.52 | Jun | 18 | 86.33 | Aug | 18 | 144.62 | Oct | 18 | 204.15 | Dec | 18 | 265.58 |
| Feb | 19 | 329.88 | Apr | 19 | 28.50 | Jun | 19 | 87.29 | Aug | 19 | 145.58 | Oct | 19 | 205.14 | Dec | 19 | 266.60 |
| Feb | 20 | 330.89 | Apr | 20 | 29.47 | Jun | 20 | 88.24 | Aug | 20 | 146.54 | Oct | 20 | 206.13 | Dec | 20 | 267.62 |
| Feb | 21 | 331.90 | Apr | 21 | 30.45 | Jun | 21 | 89.20 | Aug | 21 | 147.50 | Oct | 21 | 207.13 | Dec | 21 | 268.63 |
| Feb | 22 | 332.90 | Apr | 22 | 31.43 | Jun | 22 | 90.15 | Aug | 22 | 148.46 | Oct | 22 | 208.12 | Dec | 22 | 269.65 |
| Feb | 23 | 333.91 | Apr | 23 | 32.40 | Jun | 23 | 91.11 | Aug | 23 | 149.43 | Oct | 23 | 209.12 | Dec | 23 | 270.67 |
| Feb | 24 | 334.92 | Apr | 24 | 33.38 | Jun | 24 | 92.06 | Aug | 24 | 150.39 | Oct | 24 | 210.11 | Dec | 24 | 271.69 |
| Feb | 25 | 335.92 | Apr | 25 | 34.35 | Jun | 25 | 93.01 | Aug | 25 | 151.36 | Oct | 25 | 211.11 | Dec | 25 | 272.71 |
| Feb | 26 | 336.93 | Apr | 26 | 35.32 | Jun | 26 | 93.97 | Aug | 26 | 152.32 | Oct | 26 | 212.11 | Dec | 26 | 273.73 |
| Feb | 27 | 337.94 | Apr | 27 | 36.30 | Jun | 27 | 94.92 | Aug | 27 | 153.29 | Oct | 27 | 213.10 | Dec | 27 | 274.75 |
| Feb | 28 | 338.94 | Apr | 28 | 37.27 | Jun | 28 | 95.88 | Aug | 28 | 154.25 | Oct | 28 | 214.10 | Dec | 28 | 275.77 |
| | | | Apr | 29 | 38.24 | Jun | 29 | 96.83 | Aug | 29 | 155.22 | Oct | 29 | 215.10 | Dec | 29 | 276.79 |
| | | | Apr | 30 | 39.21 | Jun | 30 | 97.78 | Aug | 30 | 156.18 | Oct | 30 | 216.10 | Dec | 30 | 277.81 |
| | | | | | | | | | Aug | 31 | 157.15 | Oct | 31 | 217.10 | Dec | 31 | 278.82 |

# Leonids

## SSFA 2002 Leonid fireball observations

*Martin Beech, Alison Illingworth and Curtis Bouchard* [1]

Leonid fireball observations gathered by the Southern Saskatchewan Fireball Array are presented. In the time interval November 19, $01^h00^m$ UT to $11^h00^m$ UT, a total of 30 Leonid meteors brighter than magnitude −2 were detected by the all-sky video camera system operated at Regina, Saskatchewan, Canada. We find that several distinct 'bursts' of fireball activity occurred at times centered on November 19, $07^h30^m$, $08^h15^m$ and $09^h15^m$ UT. Each outburst lasted about 30 minutes. In general, however, we found the 2002 Leonid display to have been, the near-full Moon and local cloud conditions aside, decidedly fireball-weak.

### 1 The SSFA

The all-sky camera system used in this study forms part of the Southern Saskatchewan Fireball Array (SSFA) located in the southernmost prairie region of Saskatchewan, Canada (50.°45N, 104.°617W). The camera system was designed and supplied by Sandia National Laboratories, New Mexico, and consists of a 45-cm diameter spherical mirror combined with a centrally mounted, downward looking video camera. The camera system affords all-sky monitoring to a limiting magnitude of about magnitude −2 (Beech & Illingworth, 2001a; Beech & Illingworth, 2001b). In addition to the camera system the Regina observatory houses a radiometer, also supplied by Sandia National Laboratories (Zinn, 1999), which is used to monitor and log the times of optical transients. The radiometer returns, and stores directly to a PC hard drive, 1200 sky brightness samples per second, and these data are later analyzed for the times of optical transients and are used to reconstruct high time-resolution light curves. The limiting magnitude for achieving good light curve reconstruction with the radiometer data is estimated to be about magnitude −7.

### 2 Video observations

Continuous video observations were made with an all-sky camera system housed at Campion College, Regina from November 18, $18^h00^m$ UT to November 19, $12^h00^m$ UT. Figure 1 shows the fireball activity as recorded by the all-sky video system in 15-minute time intervals starting from November 19, $07^h00^m$ UT. The videotapes were reviewed manually and eye-estimates of fireball brightness were made according to achieved observations of the Moon at various phases and the planets Venus, Mars and Jupiter. The planet Jupiter was visible in the video images at most times during the night, and we take its brightness of magnitude −2 to be the system limiting magnitude. Table 1 indicates the magnitude distribution of recorded fireballs. In general the fireball activity was weak, with typically five fireballs being recorded per hour prior to November 19, $10^h$ UT. The fireball rate did pick up at $10^h15^m$ UT, but simultaneously the local weather conditions deteriorated. At the time of the reported peak activity (circa $10^h45^m$UT) the local cloud coverage was estimated to be of order 80%.

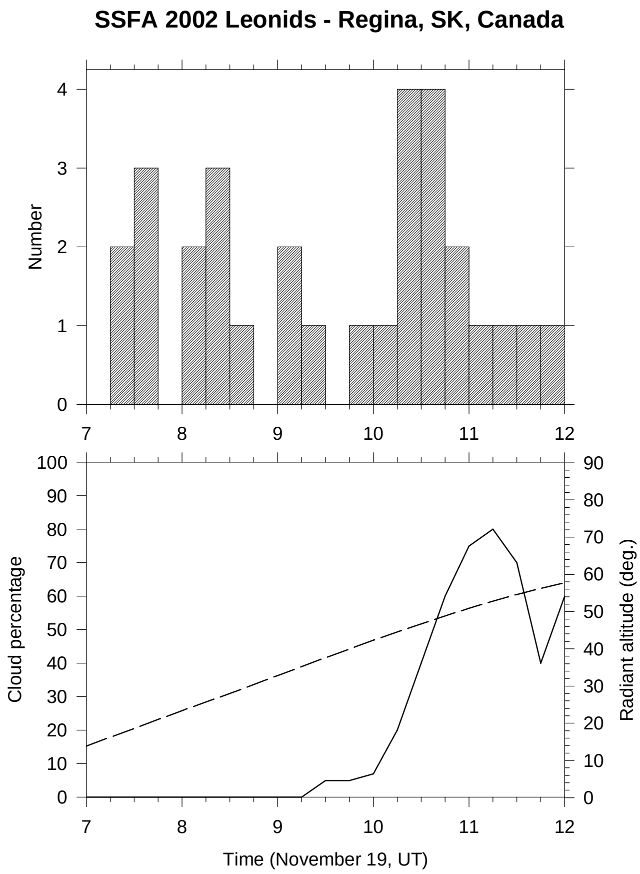



*Figure 1* – (Top panel) Leonid fireball activity as recorded by the Regina all-sky camera system. The data is presented in counts per 15-minute time interval. (Bottom panel) percentage cloud cover (solid line) and radiant altitude (dashed line) during the observing time interval.

*Table 1* – Magnitude distribution of fireballs recorded between $07^h$ and $12^h$ UT, 2002 November 19, from Regina, Saskatchewan.

| Magnitude | −2 | −3 | −4 | −5 | −6 | −7 | −8 |
|---|---|---|---|---|---|---|---|
| Leonids | 2 | 15 | 5 | 5 | 3 | 0 | 1 |

[1] All authors: Campion College, The University of Regina, Regina, Saskatchewan, Canada S4S 0A2.

The fireball activity prior to November 19, $10^{\mathrm{h}}$ UT, is particularly interesting. Distinct 'bursts' of activity beginning at $07^{\mathrm{h}}15^{\mathrm{m}}$, $08^{\mathrm{h}}00^{\mathrm{m}}$ and $09^{\mathrm{h}}00^{\mathrm{m}}$, and lasting about 30 minutes, are observed. Given the low radiant altitude at the times of these bursts, the actual ZHR must have been substantially elevated (i.e., the correction factor being of order $1/sin$(radiant altitude) – see Figure 1, lower panel), and, we note, the 'burst' activity is apparently not a feature of variable cloud coverage. We also note that each of the times of elevated fireball activity has a counterpart in the ZHR reductions derived from the LEO-MAC observations (`http://leonid.arc.nasa.gov`). It would appear that the Earth sampled sub-streamlets containing higher concentrations of larger mass (i.e. fireball-producing) Leonid meteoroids at approximately 45-minute intervals (corresponding to spatial separations of order 80 000 km) during the time interval from November 19, $07^{\mathrm{h}}$ to $10^{\mathrm{h}}$ UT.

## 3 Radiometer observations

The limiting magnitude for fireball detection by the radiometer installed at Regina is estimated to be of order −7 (Beech & Illingworth, 2001a; Beech & Illingworth, 2001b). The somewhat effete display of bright fireballs this year, however, resulted in just one event, recorded at $05^{\mathrm{h}}11^{\mathrm{m}}54^{\mathrm{s}}$ UT with an estimated magnitude of −8 to −9, being detected at a level sufficient for a light curve to be reconstructed. The light curve shows an early symmetrical profile and a distinct terminal flare. The zenith distance of the fireball was 55°, and the light curve according to the scheme suggested by Spurný (Spurný et al, 2000; Beech & Illingworth, 2001b) had a Type II profile. A detailed analysis of Leonid fireball light curve morphology will appear in a subsequent communication.

## 4 Acknowledgments

MB wishes to extend his many thanks to Dr. R. Spalding of Sandia National Laboratories for supplying the radiometer and all-sky camera system used in this study. This research has also been partially supported by a grant to MB from the Natural Sciences and Engineering Research Council of Canada.

## References

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Beech, M. and Illingworth, A (2001b), "SSFA 2001 Leonid Fireball Observations", *WGN* **29:6**, 200–205.

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# Visual observations of the 2002 Leonids by the MBK Team

*Javor Kac* [1], *Jure Zakrajšek* [2], *and Jure Atanackov* [3]

The *MBK Team* organized another Leonid expedition in 2002. We observed the meteor storm from the French Alps, employing visual, photographic and video techniques. Visual observation results from five observers covering 18.2 observing hours with 5518 Leonids are presented here. The peak ZHR of 3600 was reached on 2002 November 19, $04^{\rm h}10^{\rm m}$ UT ($\lambda_\odot = 236.^\circ616$).

## 5 Introduction

Several research groups predicted two maxima of the Leonids in 2002 (Lyytinen & van Flandern, 2000; McNaught & Asher, 2002; Vaubaillon, 2002). It was predicted that on November 19 between $03^{\rm h}56^{\rm m}$ and $04^{\rm h}04^{\rm m}$ UT the Earth would cross the dust trail ejected in 1767. The second peak was predicted to occur between $10^{\rm h}34^{\rm m}$ and $10^{\rm h}47^{\rm m}$ UT as a result of Earth crossing the 1866 dust trail.

The weather is traditionally poor over Slovenia in November. As only the peak night of Leonids 1998 and the pre-peak night of Leonids 2001 were clear in the last six years, there was an obvious need for an expedition. After expeditions to north-west Italy in 2000 (Atanackov & Kac, 2003) and Arizona, USA in 2001 (Atanackov & Kac, 2002) the *MBK Team* organized their third successful expedition in 2002, this time to France.

The *MBK Team* is a group of active meteor observers with special interests in comets, eclipses, aurorae and the Sun. The Team consists of more than ten members who are also members of the *Orion Astronomical Society* from Maribor, Slovenia. The observing team consisted of six members: Jure Atanackov, Dani Crnčec, Dunja Fabjan, Javor Kac, Nina Lampič, and Jure Zakrajšek (Figure 2). The weather forecast for the maximum night was bad for Slovenia, the closest clear sky being forecast at the French-Italian border. To accommodate all observers and the observing equipment we rented a van and drove toward Nice. We received invaluable information from Werfried Kuneth, who kindly passed the latest weather information via mobile phone. We reached Nice at around $21^{\rm h}$ UT, where the monotonous overcast began breaking up. The clouds were relatively low and it was evident that there was no higher cloud above. We turned inland towards the Alps; the mountain village of St. Martin-Vesubie at about 1500 m seemed a good destination. After an hour's drive we reached St. Martin. The view was absolutely breathtaking: the snow-covered peaks bathed in moonlight with crystal clear winter skies above! But the horizon was a bit less satisfying – reaching as high as 40° in the north. After about an hour's search we found a suitable observing spot on a ski slope on Pic de Colmiane at 1790 m elevation.

We set up our observing equipment which included an all-sky camera system with a low-light video camera, a photographic camera array and visual observing equipment. As the temperature was quite low (about −10° C) and the humidity fairly high, ice formed at the mirror surface of the all-sky camera. Thus we abandoned the all-sky system and pointed the video camera toward the sky. Visual observations were carried out from about $01^{\rm h}20^{\rm m}$ UT until dawn.

## 6 Shower analysis and results

The population index was calculated according to Arlt & Gyssens (2000) using the magnitudes of all meteors recorded by each observer during the night. Individual population indices were weighted by the number of meteors seen by the observer and the average was calculated. We obtained the value of $r = 2.3$ which was then used in the ZHR calculations. The zenithal hourly rate (ZHR) was calculated using the standard formula ZHR $= (1 + \sum {\rm LEO}_i)/\sum (T{\rm eff}_i/C_i)$, where ${\rm LEO}_i$ is the number of Leonids seen in a given period, $T{\rm eff}_i$ the total effective observing time in the period and $C_i$ the total correction factor in the period, calculated as $C_i = r^{(6.5-{\rm LM})}F/\sin(h_R)$, where LM is the limiting magnitude, $F$ the field obstruction correction, and $h_R$ is the average radiant height during the period.

We got a peak ZHR of $3600 \pm 130$ at $04^{\rm h}10^{\rm m} \pm 3^{\rm m}$ (Figure 1). The full width at half maximum was 35 minutes and the ZHR was above 1000 for about 56 minutes. No secondary peaks were apparent. The results are quite similar to the analysis by Arlt et al. (2002).

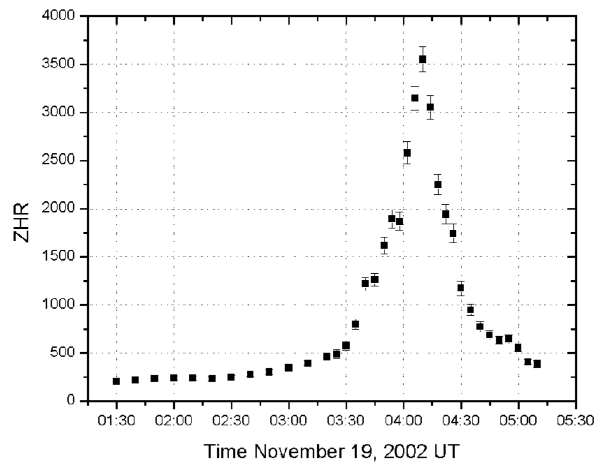


*Figure 1* – ZHR profile of the 2002 Leonids as seen by the *MBK Team*.

[1] Na Ajdov hrib 24, SI-2310 Slovenska Bistrica, Slovenia, email javor.kac@orion-drustvo.si
[2] Elektrarniška 14, SI-2351 Kamnica, Slovenia, email jure.zakrajsek2@guest.arnes.si
[3] Aškerčeva 22, SI-3420 Velenje, Slovenia, email excel@amis.net

*Figure 2* – *MBK Team* observers (from left: Javor Kac, Dani Crnčec, Jure Zakrajšek, Nina Lampič, Jure Atanackov, and Dunja Fabjan) drinking a toast after the successful observing night.

*Table 1* – Observers, their *IMO* codes, total effective observing time in hours ($T$eff), average limiting magnitude (LM) and numbers of meteors recorded during the night 2002 November 18/19.

| Observer | Code | Teff | LM | nLEO | nTAU | nAMO | nSpor |
|---|---|---|---|---|---|---|---|
| Jure Atanackov | ATAJU | 3.95 | 5.91 | 1773 | 2 | 1 | 12 |
| Dunja Fabjan | FABDU | 3.26 | 5.28 | 924 | 1 | - | 11 |
| Javor Kac | KACJA | 3.75 | 5.65 | 1052 | 1 | 1 | 16 |
| Nina Lampič | LAMNI | 3.53 | 5.67 | 665 | - | - | 5 |
| Jure Zakrajšek | ZAKJU | 3.71 | 5.87 | 1104 | 2 | - | 16 |

*Figure 3* – A magnitude −4 Leonid at $03^h41^m17^s$ UT. The bright star near the meteor is Alphard ($\alpha$ Hydrae). Exposed from $03^h38^m04^s$ to $03^h41^m35^s$ UT with a $f$ = 37mm, f/2.8 lens.

## 7 Conclusion

The *MBK Team* members witnessed their second meteor storm, both resulting from the Earth crossing the dust trail from 1767. The number of meteors seen by each observer was lower than during the 2001 Leonid storm, due to the full Moon, but also due to the shorter duration of the meteor storm. The actual ZHRs were similar to but different from those of the 2001 storm. No secondary peaks were apparent.

## 8 Acknowledgments

We would like to thank Werfried Kuneth for his help with the navigation to the final observing location. We are also grateful to the *Orion Astronomical Society* of Maribor.

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

# Diversity radio observations of the 2002 Leonids on November 19

*R.B. Minton*[1]

Figure 1 shows the second peak of the 2002 Leonids on November 19 UT as recorded over the United States. Two digital AM/FM car radios were used to count meteor trail reflections at two different FM frequencies. Each radio has a 1/4-wave vertical ground-plane antenna, audio discriminator, analog-to-digital converter, and computer. The omnidirectional antenna has best reception towards the horizon at all azimuths, and vertical polarization. This type of antenna is well suited for meteor forward scatter signals which predominate near the horizon. There are about 20 radio stations within a 250 mile (400 km) radius, and 41 within a 500 mile (800 km) radius in a total of 38 cities. This large number of reception path azimuths reduces trail orientation and polarization effects, and increases counts compared to one transmitter–receiver path. The first radio is tuned to 92.9 MHz and uses an audio discrimination circuit set to high sensitivity, thus counting faint as well as bright meteors. There are 3 stations on this frequency in New Mexico, and 18 in other states. The second radio is tuned to 96.1 MHz and is set to a lower sensitivity, thus favoring only the brightest meteors. There are no stations on this frequency in New Mexico. The audio settings were monitored throughout the radio observations to verify proper counting, and not changed. No false counts due to noise, aircraft or sporadic-E were noted.

The upper curve in Figure 1 is a plot of six-minute integration counts at 96.1 MHz, and the lower is the same at 92.9 MHz. Both show the Leonid display lasting six hours from about $07^h$ to $13^h$ UT. The upper plot has a rather flat and unpronounced maximum lasting from about $08^h$–$11^h$ with large count variations during this interval. The lower plot has a pronounced peak not shown in the upper plot. This peak lasted from $10^h$–$11^h$ with a sharp maximum at $10^h42^m$–$10^h48^m$ UT. These differences strongly suggest the maximum from $10^h$–$11^h$ was due to fainter, more numerous Leonids.

*Table 1* – Radio counts per hour at the specified frequencies, and the altitude of the radiant.

| UT | 96.1 MHz | | 92.9 MHz | | Altitude |
|---|---|---|---|---|---|
| 04–05 | 18 | | 34 | | −15° |
| 05–06 | 44 | | 37 | | −6° |
| 06–07 | 70 | | 45 | | +5° |
| 07–08 | 181 | | 101 | | +16° |
| 08–09 | 241 | | 155 | | +28° |
| 09–10 | 281 | (max) | 224 | | +40° |
| 10–11 | 239 | | 399 | (max) | +52° |
| 11–12 | 162 | | 287 | | +63° |
| 12–13 | 71 | | 181 | | +72° |
| 13–14 | 37 | | 94 | | +75° |

There is no correlation between the two data sets, other than in the start and end times of the entire shower. This would be expected if sampling totally different volumes of space. Recall that only 3 out of 41 cities have a radio station operating at each frequency. The lack of correlation is very probably due to the narrow forward scattering angle of the meteor trail, with the azimuth of adjacent transmitters greater than this.

The six-minute counts can be measured off the $Y$-axis, but this is strictly valid only if the counts last one hour. Table 1 lists the counts for each hour at both frequencies, the respective maxima, and the altitude of the radiant 30 minutes past each hour. Cloudiness prevented visual observations, photography and video recordings.

All radio meteor systems have different counting characteristics, but these counts nevertheless reveal the times of shower commencement, end, and the relative variations in the meteor shower intensity. These times (not counts) locate the meteoroid stream boundary in space. Now, using diversity reception, it may be possible to measure the radio population index of a meteor shower. As long as counts from multiple receivers are uncorrelated they can be co-added to increase the signal-to-noise ratio, allowing measurement of more sparse meteor showers.

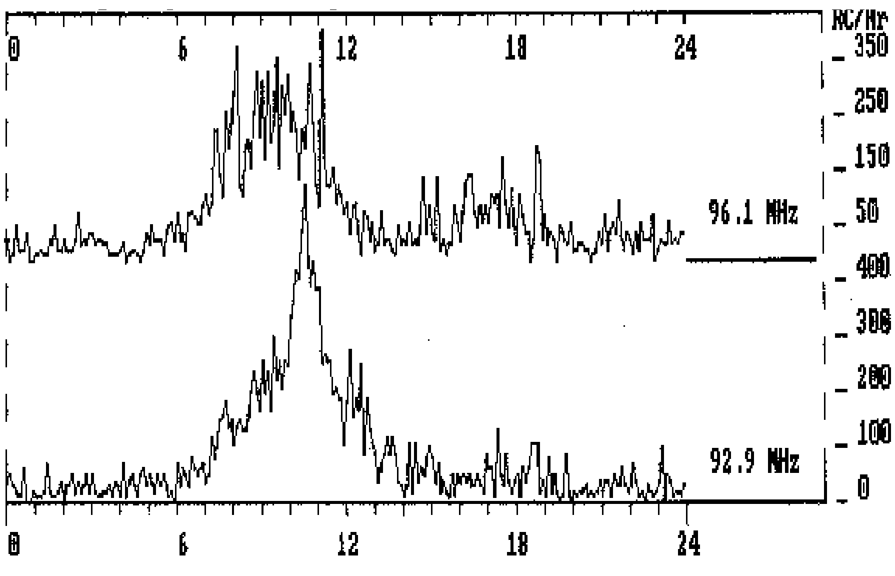


*Figure 1* – Radio meteor counts for the New Mexico–Colorado region, USA. Diversity reception at two frequencies for 24 hours using six-minute integrations. $X$-axis: time in hours UT on 2002 November 19. $Y$-axis: radio counts per hour.

[1] 568 North First Street, Raton, New Mexico, 87740, USA

# The 2002 Leonids in Poland — preliminary results

*Arkadiusz Olech*[1]

The preliminary results of the Polish observations of the 2002 Leonids are presented. The first peak occurred on November 19, $04^h12^m$ UT with ZHR = $2351 \pm 80$. The FWHM of the maximum was only $18^m$ which is about five times smaller than the predictions of the models.

## 9 Introduction

According to the models of McNaught & Asher (2002) and Lyytinen et al. (2001) (hereafter LNV), in 2002 we had the last chance to see the Leonid storm. Both these models, as well as new approaches performed by Jenniskens (2001) and Vaubaillon (2002), predicted two main maxima. The first one was expected around 04 UT on November 19, i.e. a very good time for observers in Poland.

The models predicted relatively large values of FWHMs for both maxima. These values were around two hours indicating that, during the first maximum, ZHRs of around 1000 should be observed as early as about 02 UT.

## 10 Observations

November weather conditions in Poland are usually very poor. Nevertheless we decided to organize an astronomical camp devoted to observations of the Leonids. The camp took place in the Warsaw University Observatory Station in Ostrowik in the period November 15–21.

The weather during the first part of the camp surprised all participants. The daytime temperatures were around 17°C and the nights were mostly clear. The best conditions occurred on November 17/18 when some of our observers made around 10 hours of visual observations. Unfortunately on November 18 it started to rain and the weather forecasts gave us no chance of clear skies during the night. In fact they were wrong and around midnight the sky started to clear and around 01 UT we started our visual, photographic and video observations.

In Ostrowik, good conditions lasted until 04 UT when thin clouds arrived from the west covering the whole sky. Fortunately our observers from the southern and eastern parts of Poland could observe even until 05 UT.

Here we present the preliminary results based on the observations of ten observers belonging to the Polish *Comets and Meteors Workshop (CMW)* who sent us their reports in electronic form soon after the night of the maximum. We focus only on the data from the night of November 18/19. The total effective time we collected was 22.29 hours during which we observed 2356 Leonids. This sample was divided into 270 estimates of the hourly rates. Below we show the list of our observers with their effective times of observation and numbers of detected meteors:

Dariusz Dorosz ($3^h\!.80$, 542), Tomasz Fajfer ($1^h\!.50$, 70), Karol Fietkiewicz ($0^h\!.90$, 63), Maciej Kwinta ($3^h\!.60$, 459), Krzysztof Mularczyk ($2^h\!.95$, 181), Arkadiusz Olech ($2^h\!.88$, 259), Łukasz Sanocki ($3^h\!.13$, 488), Konrad Szaruga ($0^h\!.21$, 66), Kamil Złoczewski ($2^h\!.84$, 177), Przemysław Żołądek ($0^h\!.48$, 51).

## 11 Results

In our calculations of the activity profile we assumed the population index $r$ to be 2.0. A similar value of $r$ was observed in 2001 during the maximum which occurred over Northern and Central America (Arlt et al., 2001). According to the models, this maximum and the first peak of the 2002 Leonids are caused by the same material ejected from the comet in 1767. Thus it is safe to assume that both profiles are characterized by the same value of population index.

The results of our calculations are presented in Figure 1, where we show the activity profile of the European peak of the 2002 Leonids. The data collected between 03:45 and 05:00 UT were fitted with a Gaussian function.

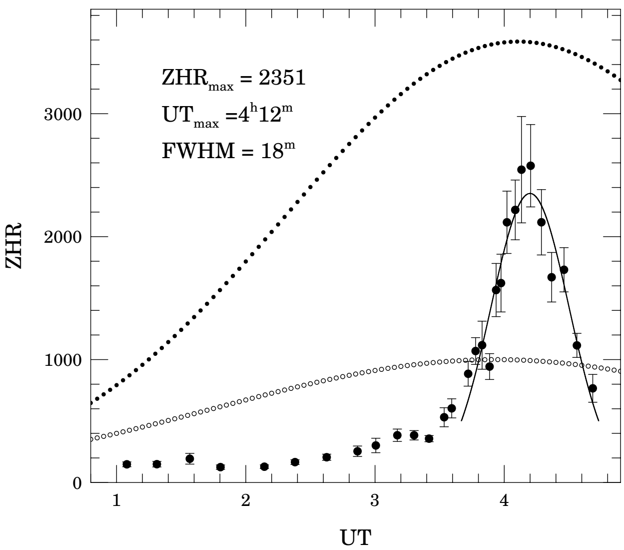


*Figure 1* – The activity profile of the European peak of the 2002 Leonids based on the observations collected by the Polish *Comets and Meteors Workshop*. The solid line corresponds to the Gaussian fit to the data around the maximum. The open and filled circles denote predictions of models McNaught & Asher and LNV, respectively.

From this fit we found that the peak occurred at $04^h12^m$ with ZHR = $2351 \pm 80$. The FWHM of the max-

[1] Nicolaus Copernicus Astronomical Center, Polish Academy of Science, ul. Bartycka 18, 00-716 Warszawa, Poland. email: olech@camk.edu.pl

imum was only $18^{\mathrm{m}}$ which is about five times smaller than the predictions of the models presented in (McNaught & Asher, 2002; Lyytinen et al, 2001). To show this discrepancy in a better form we plotted the activity profiles predicted by the models of Asher and McNaught and LNV with open and filled circles, respectively.

Our results are with excellent agreement with data presented in *IMO Shower Circular* (Krumov et al, 2002). According to this publication the European peak was observed at $04^{\mathrm{h}}10^{\mathrm{m}}$ UT with ZHR = $2353 \pm 64$.

## 12 Acknowledgments

I would like to thank to all observers who sent us their data. This work was supported by the KBN grant number 2P03 022 22 to M. Wiśniewski.

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# Leonids 2002 — TV observations and the population index

*Peter Zimnikoval*[1] *and Miroslav Znášik*[2]

Television observations were carried out on the morning of 2002 November 19, during the first outburst of the Leonids. Despite the high number of visual meteors observed, the TV records show a very low number of meteors registered. From this it was concluded that there were almost no small particles in the outburst generated by particles released from comet 55P/Tempel-Tuttle in 1767. By comparing the TV and visual observations, the population index $r$ is discussed.

## 13 The observations

Television observations were carried out in Banská Bystrica, Slovakia (48°43′N, 19°09′E, 586 m) on 2002 November 19 from $1^h52^m$ to $4^h40^m$ UT. An OSCAR TV camera was used with a Meopta 1:1, $f = 50$ mm lens. The field of view was about 6° × 8°. This configuration gave a limiting magnitude of +7.5 during all observation intervals. The camera was driven by an equatorial mount. One object of the observations was to determine the flux of small particles and to find any difference between the time of the maximum for visual and faint TV meteors. Tens or hundreds of recorded meteors were expected, but these expectations were not realized. A visual control observation (observer M. Znášik) was performed from $03^h10^m$ to $04^h40^m$ UT. Magnitude was recorded orally by the observer using a tape recorder. The visual limiting magnitude was 4.5.

## 14 The results

Despite the high Leonid activity, only eight meteors were found in the record. A relative magnitude for all recorded meteors was estimated. Two meteors were sporadics. The Leonids recorded were very bright (magnitudes +5, 0, 0, +1, +6 and +3). The meteor of 6th magnitude started at the edge of the field and increased in brightness, and therefore was not used for the next process. The absence of faint meteors implies that fewer small particles were present in the outburst.

The distribution of meteors across the brightness classes is described by the population index $r$. Values of $r$ from 1.8 to 2.4 were determined from previously observed Leonid outbursts, e.g. (Arlt & Gyssens, 2000). The most probable value was 2.1. Assuming that the value of $r$ was similar in 2002 we should have observed high numbers of faint meteors, but this was not the case.

Figure 1 shows a magnitude distribution of the observed visual and TV meteors. On the horizontal axis is the apparent magnitude and on the vertical is the number of meteors (on a logarithmic scale). A theoretical distribution for $r = 2.4$ is plotted (the line marked V). This value was derived from the visual observations using a method of cumulative meteor numbers, taking into account the probability of perception (Znášik, no date).

The relatively low number of meteors recorded is due to the small field of view of the camera. Despite this, the meteors photographed must be distributed with the same value of $r$ as the visual ones. It is therefore valid to draw a line with the same slope as V in the TV part of the histogram. Thus the line marked TV represents a distribution of meteors for the TV camera. If the value of $r$ is valid for all visual magnitudes, hundreds of meteors to magnitude 6 should have been registered. Such meteors would have been within the sensitivity range of the camera, and moreover there is no influence of the probability of perception as there is in visual observation. Nor is the extremely low value of the population index ($r = 1.35$) able to explain observed numbers of meteors. A similar effect was observed during Leonids 2001. The population index from visual observations was determined as 2.1 while from TV observation a value of 1.35 was obtained (Molau et al, 2002). The difference between the indices was explained by a shift of the magnitude scale due to different observing methods. This shift exists, of course, but the absence of faint meteors found in the 2002 data cannot be explained by such an effect.

From the facts mentioned above, it seems that there were almost no faint visual and telescopic particles in the observed Leonid storm.

## 15 Conclusions

1. The Leonid outburst produced by particles ejected from comet 55P/Tempel-Tuttle in 1767 contains almost no small particles generating faint visual and telescopic meteors. The question is if small particles were separated during the intervening period of around 340 years, or if the material was produced from the comet with the observed size distribution.

2. By a simple linear dependence of meteor counts in single magnitude classes (population index $r$), it is not possible to describe adequately the distribution of meteors in separated streams, like the first Leonid maximum this year.

3. A calculation of the ZHR for standard conditions (LM = 6.5) produces values which do not correspond to reality.

4. The value of $r$ is valid only in the magnitude interval where is possible to verify it. In special cases it will be necessary use another, non-linear distribution of the particles in meteor streams.

[1] Observatory Banská Bystrica, Slovakia
[2] Observatory Žilina, Slovakia

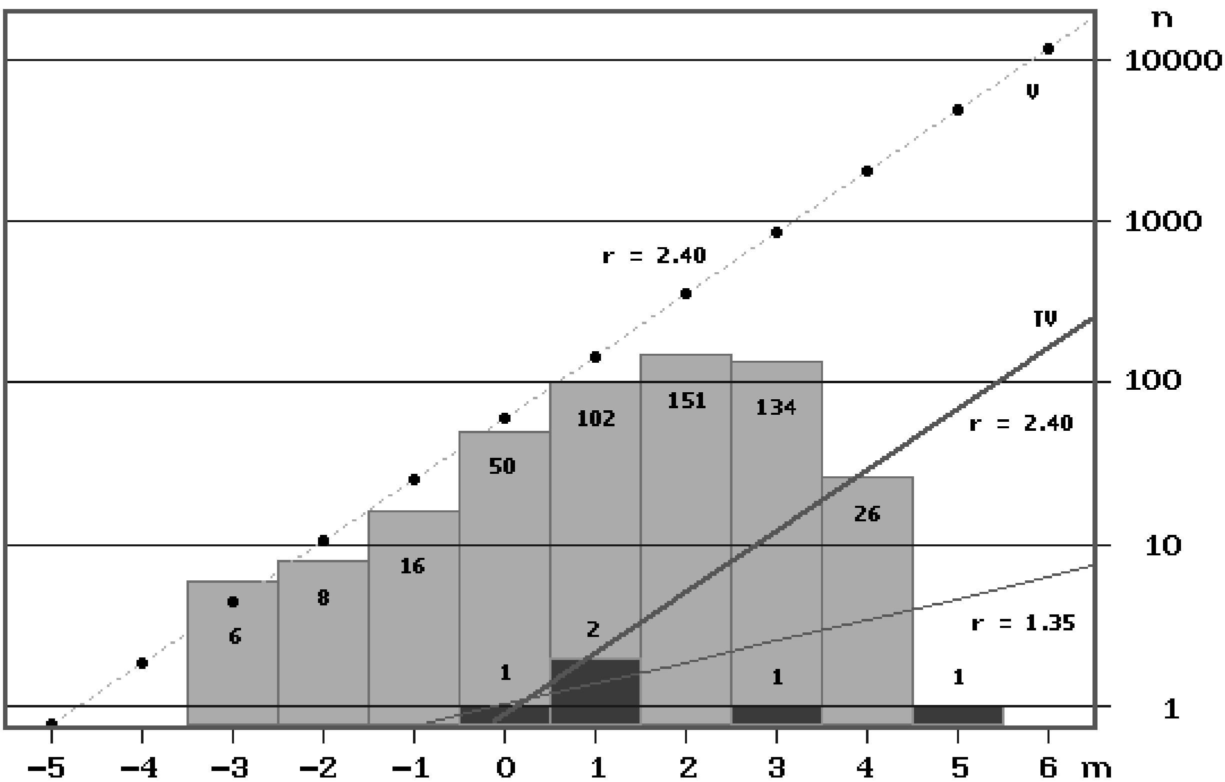


*Figure 1* – Magnitude distribution of the observed visual and TV meteors. Horizontal axis: apparent magnitude. Vertical axis: number of meteors (logarithmic scale).

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# Radio observations of the 2002 Leonids from Slovenia

*Jure Zakrajšek* [1], *Javor Kac* [2] *and Jure Atanackov* [3]

The Leonid meteor storm was predicted to occur over Europe on 2002 November 19. The Leonid activity was measured by forward scattering of radio waves. The first radio activity peak was found at $04^h10^m$ UT and the secondary peak at $10^h40^m$ – $11^h00^m$ UT. Our radio data was also used in the The International Project for Radio Meteor Observation – 2002 Leonids.

## 16 Introduction

In 2002 two maxima were predicted by several research groups (Lyytinen & van Flandern, 2000; McNaught & Asher, 2002; Vaubaillon, 2002). They predicted that on November 19 between $03^h56^m$ and $04^h04^m$ UT the Earth would cross the dust trail ejected in 1767. The second peak was predicted to occur between $10^h34^m$ and $10^h47^m$ UT as a result of the Earth crossing the 1866 dust trail.

We monitored the activity carefully since November 1, so that we could define the background activity level. The strong activity started on November 19 at $00^h$ UT. The number of long echoes increased so much that it was impossible to count separate meteor echoes. That is why we used reflection time percentages instead of numbers of meteor echoes. In the analysis a complex peak structure with two major peaks was found.

## 17 Radio meteor station

We started with radio meteor observations on 2002 August 4, when we successfully set the dipole antenna in Kamnica (46°57N 15°61E) near Maribor, Slovenia. The Perseids were the first meteor shower observed with the new equipment (Kac, 2003).

We used a simple ICOM IC-R10 radio receiver, tuned to 53.7600 MHz, where two transmitters in Southern Italy (Figure 1) transmit continuous 30 kW beacons. The low-power transmitter at Unid produced few echoes and was not monitored. We used the HROFFT software developed by Kazuhiko Ohkawa to record meteor activity. We ran the software using Wine on a Linux workstation. The software takes the input sound and analyzes it by taking a Fast Fourier Transform (FFT) every half second. Every ten minutes one image is produced and saved. Figure 2 shows examples of HROFFT screens during the normal sporadic activity and during the peak.

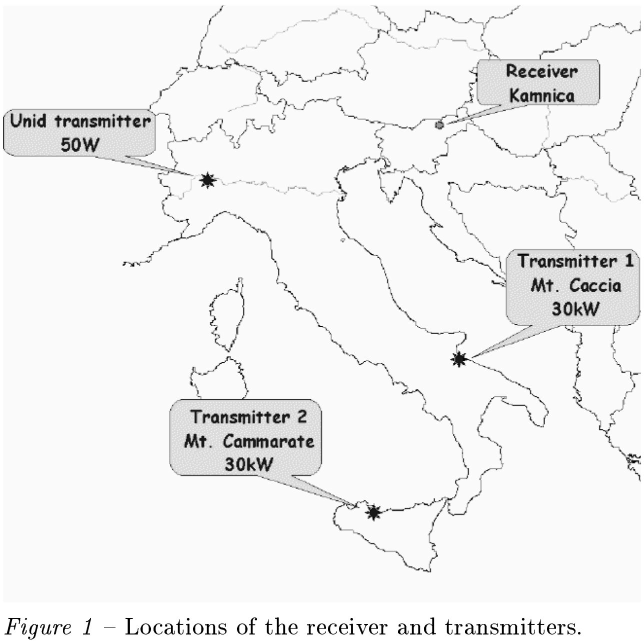


*Figure 1* – Locations of the receiver and transmitters.

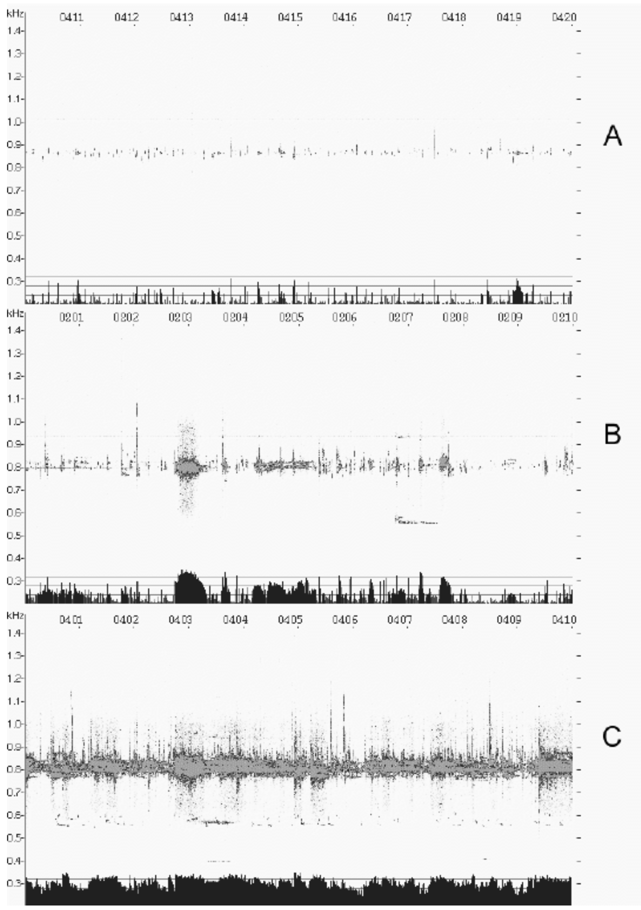


*Figure 2* – Examples of HROFFT screens: (A) at highest sporadic activity in the morning of November 29, $04^h10^m$ to $04^h20^m$ UT; (B) Leonid activity on November 19, $02^h00^m$ to $02^h10^m$ UT; and (C) fully saturated sample during the first peak on November 19, $04^h00^m$ to $04^h10^m$ UT.

[1] Elektrarniška 14, SI-2351 Kamnica, Slovenia, email jure.zakrajsek2@guest.arnes.si
[2] Na Ajdov hrib 24, SI-2310 Slovenska Bistrica, Slovenia, email javor.kac@orion-drustvo.si
[3] Aškerčeva 22, SI-3420 Velenje, Slovenia, email excel@amis.net

## 18 Analysis method

For analyzing the collected data, we used software written by Werfried Kuneth. This is a simple Quick Basic program, which analyzes the HROFFT pictures and makes a text file output with the following data: echo count, sorted into 8 groups depending on the echo duration; sums of the total echo duration in the ten-minute period ('Total Reflection Time'); and longest echo duration. This method is fully automatic, but it is always advisable to check manually for interference. When we have analyzed the whole set of data, we can take a first look at the activity with the next program also written by Werfried Kuneth. This program takes the data file and makes simple colorgrams.

The colorgrams have a minor weakness in that only one-hour data are plotted, so resolution is lost. However, they are very good to see if there was any activity at all.

We made some further analyses to get a better look at this year's Leonid activity. We calculated the activity level $A(t)$ as described by Ogawa et al. (2002) with the simple formula $A(t) = (H - H^0)/(\sin(h) * D)$, where $H^0$ is the background level (data from November 11 to 15 were used), $H$ is the activity level in a given period, $h$ is the radiant elevation, and $D$ is the average daily activity in days from November 11 to November 15.

The activity level tells us how many times the observed activity is stronger than the average background.

## 19 Results

With the analysis as described above we obtained the following results:

From the colorgram (reproduced in monochrome as Figure 3) we can see the very strong activity on November 19, but no structure of the activity is evident.

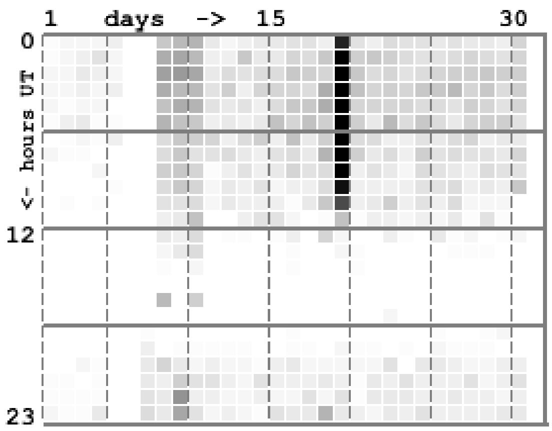


*Figure 3* – Radio meteor activity in 2002 November.

Figure 4 shows the reflection time percentage during a four day period from 2002 November 17 to 21. The radio activity of the Leonids was very complex. We can see the activity with the reflection time in the 10% – 20% range on November 18, indicating some radio activity from the Leonids. On November 19 the reflection time percentages peaked at $04^h00^m$ – $04^h10^m$ UT with a complete saturation of the system. We can detect at least two more peaks, the first at $08^h50^m$ UT and the next at about $10^h50^m$ UT.

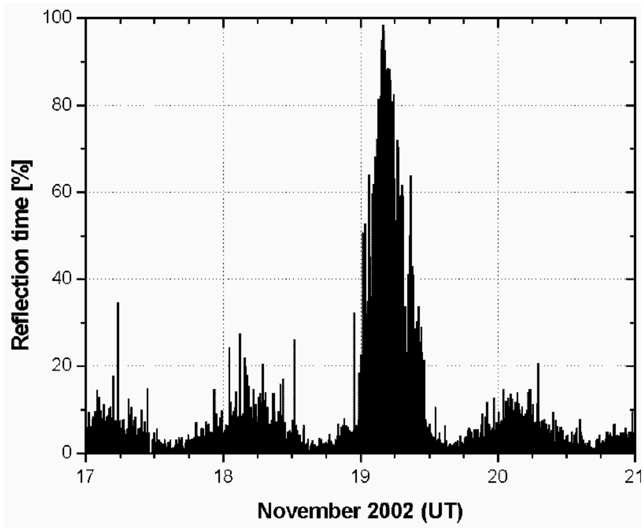


*Figure 4* – Reflection time percentages during a four-day period centered on 2002 November 19, $00^h$ UT.

A smoothed activity level profile fitted with a double Lorentzian is shown in Figure 5. At least two peaks are evident from the graph. The primary peak appeared at $04^h10^m$ UT, with an activity level of 19. The full width at half maximum (FWHM) was about $450 \pm 30$ min. The secondary peak appeared at $10^h00^m$ UT with a much lower activity level at about 4. The FWHM of this peak was about $200 \pm 30$ min. The times of both peaks correspond well with those that Arlt et al. (2002) obtained in a preliminary analysis from visual observations around the globe.

## 20 Conclusion

The radio Leonids peaked twice on 2002 November 19 as seen from Slovenia. The first peak occurred at $04^h10^m$ UT and the secondary peak at $10^h00^m$ UT. During the maximum activity the number of long echoes increased so much that it was impossible to count every meteor echo. Instead we used the reflection time percentages for the analysis of the activity.

We will continue to monitor the radio meteor activity and analyze the activity of the major meteor showers.

## 21 Acknowledgments

We would like to thank Werfried Kuneth for his help with our radio setup, for providing the software for the analysis and for reviewing the manuscript. We are also grateful to *Orion Astronomical Society* from Maribor.

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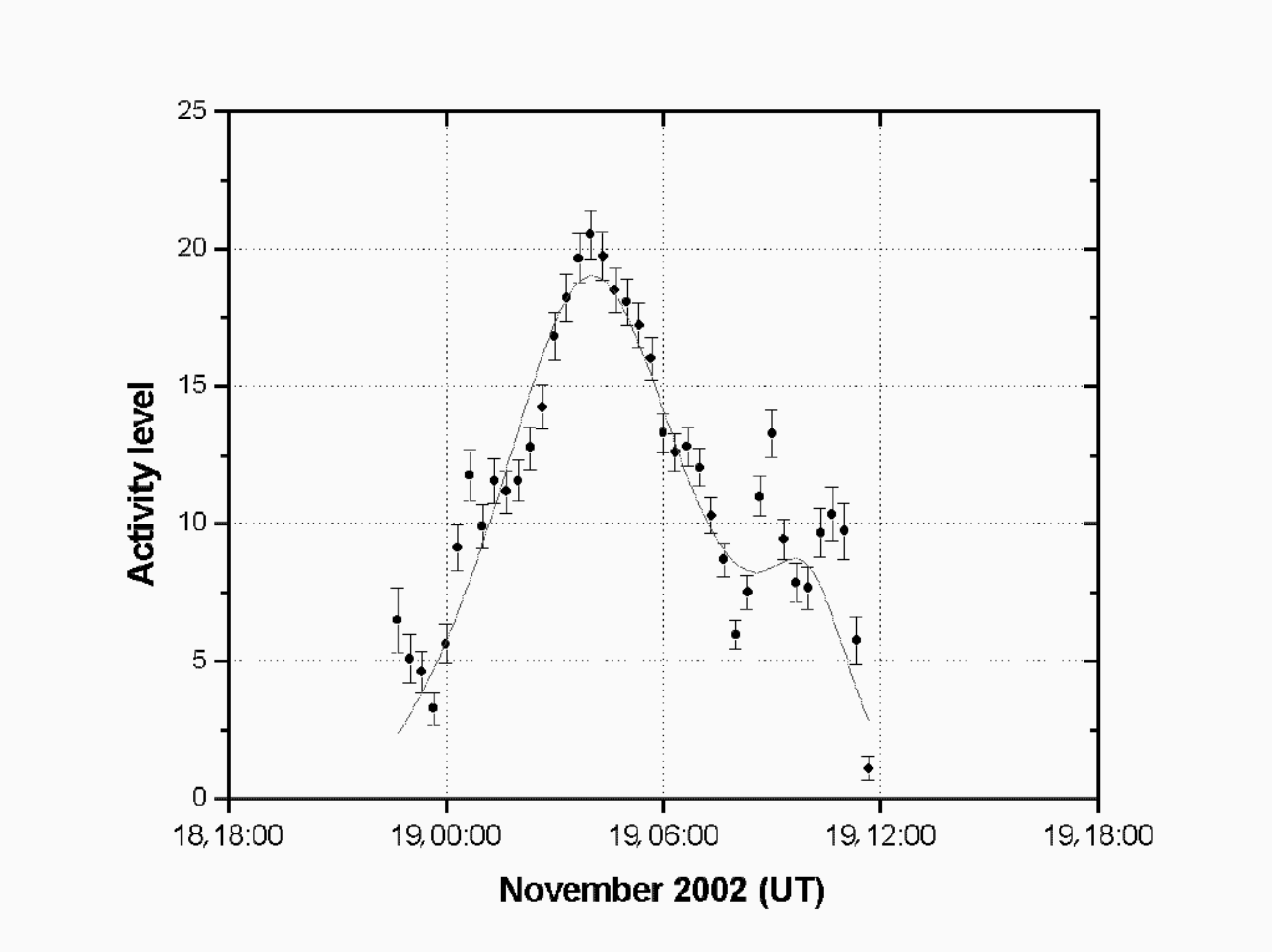


*Figure 5* – A smoothed radio meteor activity profile.

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# Conferences

## Details of the Proceedings of IMC 2001, Cerkno, Slovenia

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Those who have attended an International Meteor Conference (IMC) will know that they present many high-quality papers on a wide range of meteor subjects. This material is less well known outside the circle of conference-goers, however. To make it more widely available, we are publishing brief details of all IMC 2001 papers here.

Those who attended the Conference will already have the Proceedings. Others can order them from the IMO: details are in the lower half of the inside back cover of this Journal.

### Leonids 2000 — Slovenian Expedition

*Atanackov, J. and Kac, J.*

Having missed the 1999 Leonid outburst due to bad weather, the MBK Team organized an expedition in 2000 to find clear skies. On November 18, the team observed from a small mountain village Triora in northwest Italy. They were met with clear skies with periods of increased cloud cover and Leonid rates reaching 5 per minute. Visual as well as photographic results are presented.

### Observation of Quadrantids 2001 Meteor Shower using Forward Scatter Technique

*Bujdoš, M.*

Forward scatter meteor observations are described. A receiver in Slovakia detected signals from a TV transmitter in Germany. The transmitter was about 750 km away on a frequency of about 48 MHz. Observations and analysis are presented.

### Polish observations of the $\xi$-Bootid shower

*Gajos, M.*

We present a visual study of the $\xi$-Bootid shower. Based on the Polish visual observations from last four years (from 1997 to 2001) the existence of two new radiants is suspected. The first one is placed in Bootes near $\alpha = 206°$ and $\delta = +28°$ (for $\lambda_\odot = 305.9°$ and a geocentric velocity equal to 50 km/s) and a second one is in Corona Borealis near $\alpha = 233°$ and $\delta = +34°$ (for $\lambda_\odot = 316°$ and a geocentric velocity equal to 70km/s).

### Meteor Art at the IMCs before the IIIrd Millennium

*Gheorghe, A.D.*

A chronology of meteor art presented at IMCs since 1995 is presented. The work described includes poetry, painting, sculpture, photography, theatre and computer art.

### Romanian Observational Campaign on Summer Meteor Showers in 2001

*Grigore, V. and Berinde, S.*

Two Perseid observational campaigns are described. These were part of the annual PERSEIDE astronomical youth camps organised by the Romanian Society for Meteors and Astronomy.

## Meteor Observation Simulation Tool

*Gural, P.S.*

A meteor observation simulation tool has been developed to study the phenomenology of meteor observations. This will form the basis for a series of articles to be published in WGN looking at the various aspects of visual and video meteor observation and analysis. This paper represents the first in the series describing the basic modelling and simulation capabilities.

## Meteor Roots of a Canadian Amateur

*Hall, C.*

The personal history of an amateur astronomer is related. The history of groups at Ottawa, Quiet Site, Springhill, the North Mountain Observatory and Victoria University is touched upon.

## Observations of the $\eta$-Aquarid Meteor Shower by Astroclub "Canopus" in 2001

*Koleva, K.*

Results of the last $\eta$-Aquarid observing campaign of the Astroclub "Canopus" are presented. Data of around 200 meteors were recorded by 7 observers and are used in this analysis.

## Meteor Observations of Astroclub "Canopus" in Summer 2001

*Krumov, V.*

The summer observations carried out by the Astroclub "Canopus" — Varna, Bulgaria — in July and August 2001 are presented. The results obtained, namely the ZHR and radiant positions of the observed showers, are described.

## Impact-related Research in Croatia

*Marjanac, T. and Biliškov, N.*

Meteor/comet impact research conducted in Croatia is described. The sites described are the islands of Krk and Rab in the Adriatic, and the Split–Katela Basin in central Dalmatia.

## Observing Video Meteors in Infrared Method

*Radu, G.-C. and Omat, C.*

The first video meteor observations in Romania are presented. The equipment is described and its quality assessed.

## Design Information for Writing a Computer Program for the Spectrophotometric Investigation of Meteor Images

*Smirnov, V.A.*

Information on how to write a computer program for the photometric investigation of meteors is presented.

## The Wave Principle of Material Distribution within the Solar System

*Smirnov, V.A.*

The wave principle of the formation of planets and of the satellite systems of Jupiter, Saturn and Uranus in the Solar system is considered.

## On the Spring Meteor Showers

*Trofimowicz, A.*

The preliminary results of visual observations from May 25 to June 11 are reported. Based on a five-year database, two new possible showers were noted. The co-ordinates of the radiants are $\alpha = 233°$ $\delta = +84°$ and $\alpha = 318°$ $\delta = +45°$. The geocentric velocities were estimated as 23 km/s and 35 km/s respectively.

## Leonids 2000 Observations and Dust Cloud Evolution

*Vaubaillon, J.*

The IMCCE meteor observations and simulations are presented. The first maximum of the 2000 Leonids has been observed, but our observational technique can be still improved. The first results of the simulation show a good agreement with previous work. The way the dust is spread around the cometary orbit, and how the IRAS observations are reproduced, are also shown.

## The False Radiants — a Simulation of the Meteor Sky

*Wiśniewski, M. and Puzio, A.*

We have made a simple simulation of July meteor observations. This artificial database includes the sporadic meteors and also events from known meteor showers: the Perseids, the Aquarid complex, the $\alpha$-Capricornids, the July Pegasids and the Sagittarids. We found that meteors from known radiants could not produce a false radiant in Delphinus.

## September Showers in Visual Observations of the Polish Comet and Meteor Workshop

*Wiśniewski, M.*

We present the results of the visual observations made by Polish meteor observers during the end of August, September and the beginning of October in the years 1996–2000. The results are based on the co-ordinates and velocities of 6723 plotted meteors. Analyzing our data using the Radiant software, we detected clear radiants of the $\alpha$-Aurigids and the Southern Piscids. We found a trace of the double structure of the $\kappa$-Aquarid radiant and only weak traces of the $\delta$-Aurigids and $\pi$-Eridanids. There is no sign of the October Capricornids or the $\sigma$-Orionid radiants in our data.

Our calculations strongly suggest that meteors from the telescopic shower of $\alpha$-Triangulids are also seen in visual data.

We propose that there are few new showers active in September. The first, the $\alpha$-Cepheids, is probably active from August 20 to September 20 with $V_\infty = 65$ km/s and equatorial coordinates of the radiant: $\alpha = 320°$, $\delta = +65°$. The second, the $\iota$-Cygnids, is probably active from September 1 to 20 with $V_\infty = 45$ km/s and equatorial coordinates $\alpha = 296°$, $\delta = +50°$. The third, the September Draconids, is active from September 1 to 25 with $V_\infty = 20$ km/s and equatorial coordinates $\alpha = 236°$, $\delta = +47°$.

## From Lunar Meteors to Dark Meteors

*Zimnikoval, P.*

TV observations of possible Lunar impacts were carried out on the night before the Perseid maximum in 2001. No such effects were recorded. However three cases of another disputed phenomenon, dark meteors, were recorded. Dark meteors are discussed.

## V Spectrum of a Sporadic Meteor

*Zimnikoval, P. and Rapavy, P.*

The spectrum of a sporadic meteor was obtained by a CCD camera during Perseid observations 2000 August 2–3. The observations and analysis are presented.

# Perseids

## Radiant ephemeris for the Perseid meteor shower

*Rainer Arlt*[1]

The radiant position of the Perseid meteor shower as a function of time is determined from single-station video observations. The radiant shifts by $1\overset{\circ}{.}02$ per day in ecliptical longitude and by $-0\overset{\circ}{.}007$ per day in ecliptical latitude. The shower was the major source in an area of 50° around the Perseids between July 22 and August 19.

### 22 Synopsis of the Perseids

The Working List of Visual Meteor Showers of the *IMO* lists the Perseids with an activity period from July 17 to August 25 (Table 1). At a solar longitude of $\lambda_\odot = 140°$ (roughly August 12), a radiant position of $\alpha = 46°$, $\delta = +58°$ is given. A detailed radiant drift is given, too, based on the tables compiled by Rendtel et al. (1995).

### 23 Data set and methods

The following radiant investigation of the Perseid meteor shower is based on individual meteors recorded by image-intensified video systems, most of them consisting of an objective lens of short focal length, an image intensifier with a luminescent output screen, and a CCD camera imaging this screen. A typical system is described in Molau (2000). The meteor data of the following video observers and cameras were used in this paper:

> Luis Bellot Rubio (camera TIMES1), Orlando Benitez (TIMES4), Stephen Evans (EMILY), Otto Farago, André Knöfel, Detlef Koschny (ICC1, ICC2, ICC4), Sirko Molau (AKM2, AVIS, ESCIMO, and MOVIE), Mirko Nitschke (VK1, VK2), Jürgen Rendtel (CARMEN, TIMES1), Ulrich Sperberg (AKM1), Rosta Štork (cameras at Ondřejov and Kunžak), Jörg Strunk (FAMOS), and Ilkka Yrjölä.

The full set of data between July 1 and August 25 contained 11 933 video meteors. Table 2 lists the meteor numbers per year. The astrometric accuracy of the video data varies between the different cameras used. All the meteors were measured using the MetRec software by Molau (1999). The positional accuracy is of the order of a few arc minutes. Time differences are known very precisely due to the constant rate of video frames, so the determination of the angular velocity is as accurate as that of the positions. The velocity accuracy in °/s is thus simply the positional error multiplied by $1/D$ with $D$ being the duration of the meteor in seconds.

Radiant charts are created from these single-station data with the program RADIANT (Arlt 2001). All the radiant plots are the result of the "Probability functions" in the RADIANT software. The meteor does not simply provide a backward prolongation, but points to an area of positions in which each position has a certain probability of being the radiant of that meteor. The values in this probability area form a sort of two-dimensional Gaussian function. A sketch of such an area is shown in Figure 3. The point $R$ is the place which is the most probable radiant of the meteor according to its path and angular velocity (for a given entry velocity of the meteoroid into the atmosphere). The width perpendicular to the backward prolongation is mainly defined by the positional accuracy, the width along the prolongation is defined mostly by the velocity error. Each meteor creates an elliptic "radiant area" for which the backward prolongation coincides with one of the axes of the ellipse. The standard deviations used for such Gaussians vary with distance of the meteor from the currently processed point and with the angular velocity of the meteor. The values used in this analysis

*Table 1* – Radiant drift of the Perseids as given in the Working List of Visual Meteor Showers.

| Date | July 15 | July 20 | July 25 | July 30 | Aug 5 | Aug 10 | Aug 15 | Aug 20 | Aug 25 |
|---|---|---|---|---|---|---|---|---|---|
| $\alpha$ | 12° | 18° | 23° | 29° | 37° | 43° | 50° | 57° | 65° |
| $\delta$ | +51° | +52° | +54° | +55° | +57° | +58° | +59° | +59° | +60° |

*Table 2* – Number of video meteors available for analysis between July 1 and August 25 for 1993–2001. The third line gives the number of cameras operated in that period.

| Year | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|---|---|---|---|
| Meteors | 211 | 113 | – | 468 | 1187 | 202 | 1783 | 2690 | 5279 |
| Cameras | 1 | 1 | – | 2 | 2 | 2 | 3 | 10 | 15 |

[1] Friedenstr. 5, D-14109 Berlin, Germany, e-mail rarlt@aip.de

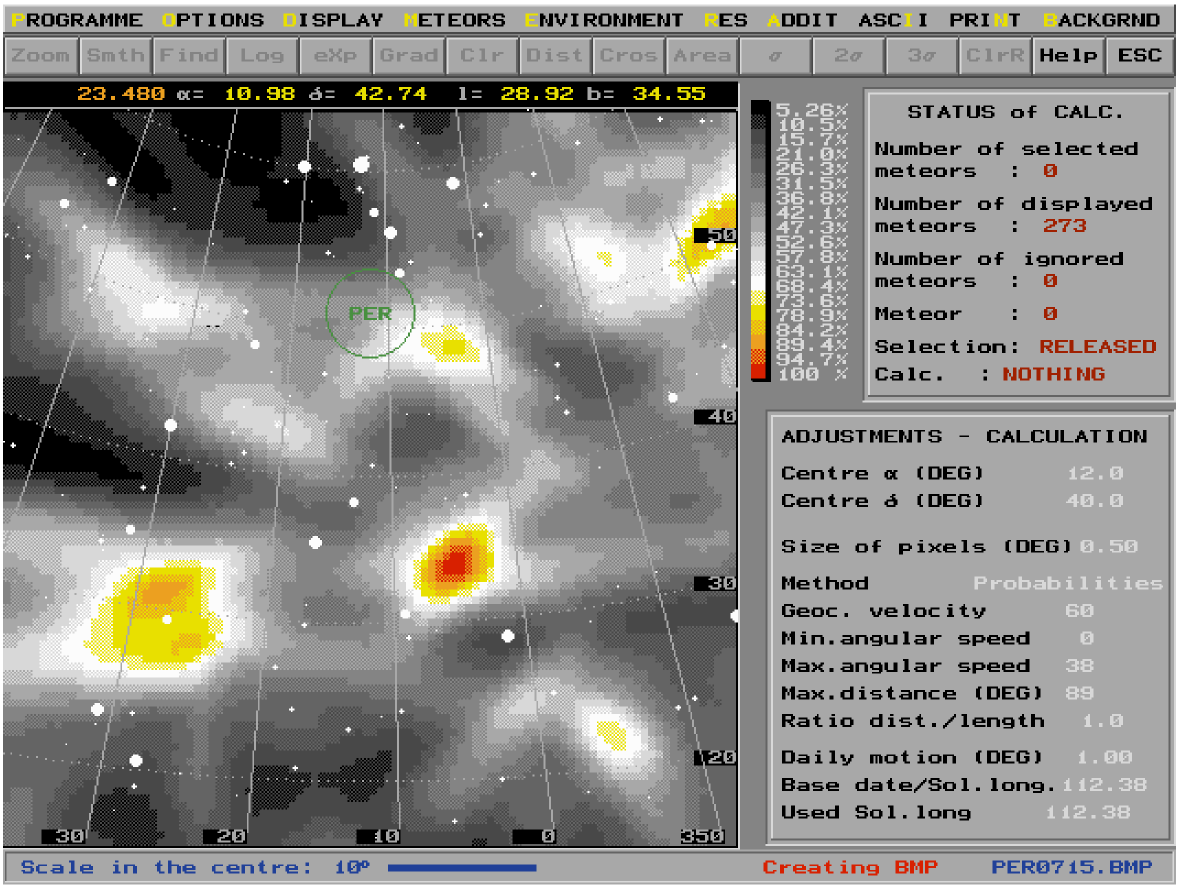


*Figure 1* – Perseid radiant of July 1–20 centered on July 15.

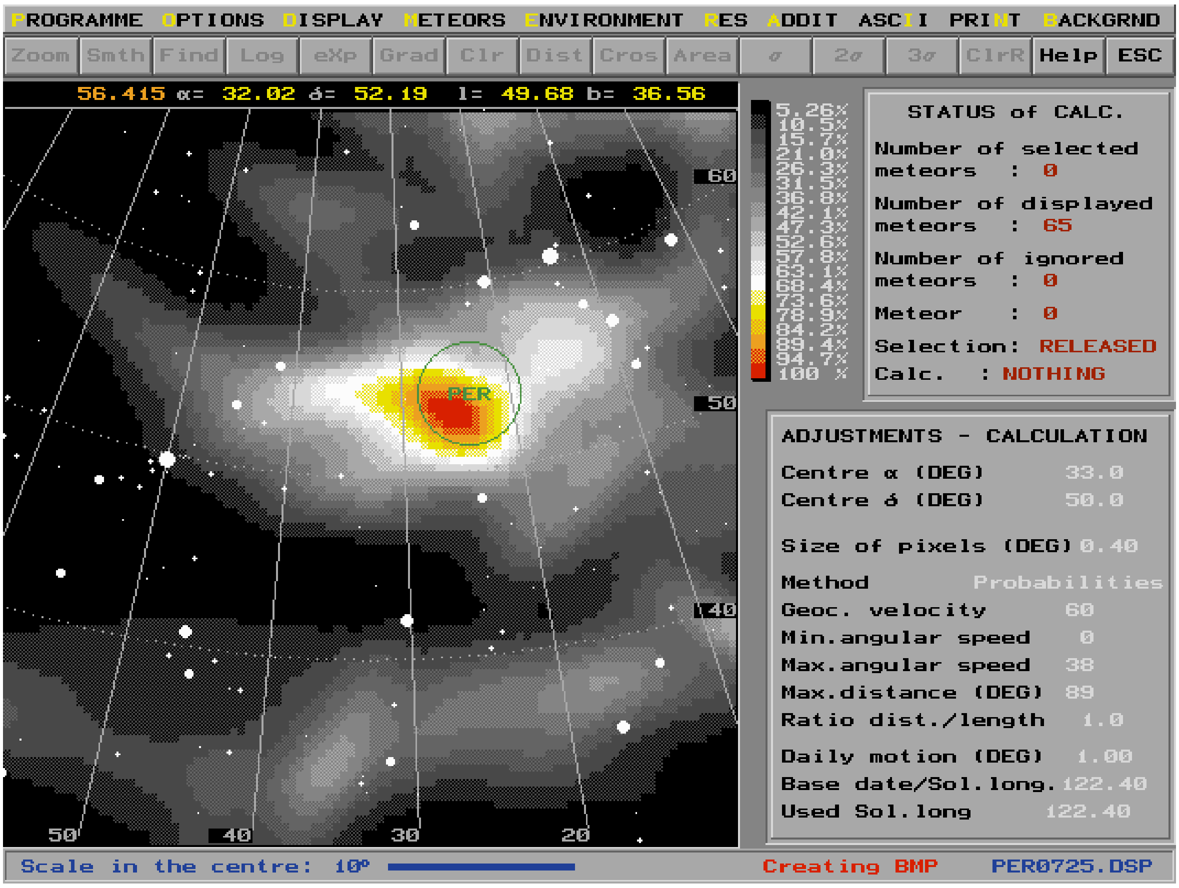


*Figure 2* – Perseid radiant of July 25.

are compiled in Table 3. The probability areas produced using these values of $\sigma$ are smaller than the example in Figure 3 suggests. Yet the standard deviations are larger than one would expect from the astrometric accuracy. If smaller values of $\sigma$ were used, the physical radiant structure would become visible. Before the entire radiant distribution was filled with very narrow probability areas, a lot more meteors would be necessary. Since we are primarily interested in the average radiant position, we may smear out the probability areas from each meteor in order to reach a good filling with fewer meteors.

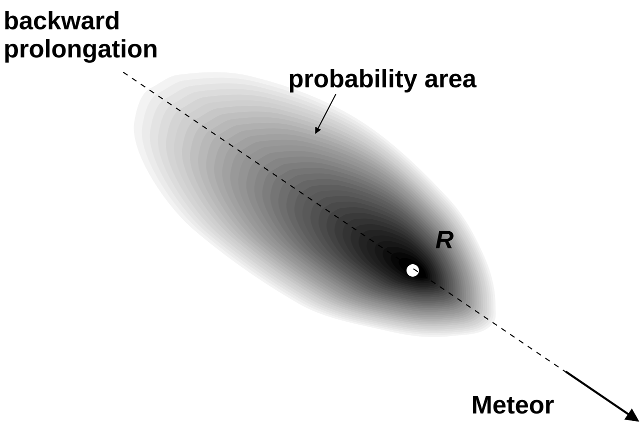


*Figure 3* – Principle of probability areas for meteor radiants. The grey shading represents the probability of any place in this graph being a radiant of the meteor.

Most of the charts derived here comprise data of one day. It was easiest to select meteors by a day of the month. This implies, however, that they cover more than a degree in solar longitude, since a given day does not coincide with the same solar longitude in different years. The effective duration of each period is about 1.8 days. During that time, the radiant will have shifted roughly by 1°.8 parallel to the ecliptic. The Radiant software accounts for meteors belonging to different solar longitudes by shifting individual meteors parallel to the ecliptic before using them for the probability function. This, of course, requires the daily motion parallel to the ecliptic as an input parameter. A wrong value is dangerous only if the meteors have a very skew distribution in the (short) period selected. If they are fairly evenly distributed, an error in the presumed daily drift results in a broader radiant area without shifting the center much. We set this daily drift value to 1°, and we will later see that this was a suitable choice.

## 24 Radiant drift

The daily ephemeris of the Perseid shower is given in Table 4. The date to which the solar longitudes refer varies from year to year. The solar longitude of 139°.6, for example, corresponds to dates between August 12, $00^h$ and $19^h$ UT in the years near 2000. The value of $n$ gives the number of meteors contributing to the entire radiant distribution with an edge length of 38° × 38°. The number is smaller than the number of meteors in the database for the selected period (typically one day), but larger than the number of actual Perseids building up the radiant, since the size of the "radiant field" allows for sporadics, too. Figures 1–2 (left) and 4–5 (overleaf) show examples of radiant plots of the first half of July, late July, near the shower's maximum, and August 18. The original colour shading covers black-white-red. Dark parts within white areas thus mean the strongest radiants. Note that the coordinates above the radiant distribution are just the position of the (invisible) cursor and have no relation to the radiant position.

*Table 3* – Standard deviations used for the construction of two-dimensional Gaussian functions behind meteors. $\Delta$ is the shortest distance of the calculated point from the backward prolongation of the meteor. Values at any point $(\Delta, \omega)$ are obtained by linear interpolation.

| Distance $d$ | $\sigma(d)$ for $\Delta$ | Ang. velocity $\omega$ | $\sigma(\omega)$ |
|---|---|---|---|
| 0° | 0°.5 | 2°.5/s | 1°.0/s |
| 5° | 0°.9 | 7°.5/s | 1°.5/s |
| 15° | 1°.3 | 12°.5/s | 1°.9/s |
| 30° | 1°.5 | 17°.5/s | 2°.3/s |
| 50° | 1°.7 | 22°.5/s | 2°.6/s |
| 70° | 1°.8 | 27°.5/s | 2°.9/s |
| | | 32°.5/s | 3°.0/s |

Because the probability distributions are computed on a discrete grid of cells, we do not only search for the cell with the highest value. The position of the cell with the largest probability is only one estimate of the radiant position. Another is obtained by the fit of a two-dimensional function of $\alpha$ and $\delta$ (or of $x$ and $y$ on the gnomonically projected radiant area). We applied circular, two-dimensional Gaussian functions, since the observed radiant areas appear to be fairly circular. The position of the maximum of this Gaussian is a good estimate of the radiant position with sub-cell accuracy. Since possible non-circularity or deviations from Gaussian cross-sections may have a bad effect on the position of the maximum of the Gaussian, we rather prefer to present the average position of two positions from Gaussian fits, applied to two arbitrary selections around the radiant, and the position of the cell with the highest probability. These averages are given in Table 4 in equatorial and ecliptical coordinates. The "Error" given is roughly the scatter of the three estimates. The positions are plotted on a star map in Figure 6.

The results agree well with the ephemeris given in the Working List of Visual Meteor Showers of the *IMO*. The radiant is unambiguously detectable between July 15 and August 18. Plots after August 18 do show radiant areas, but all these are situated north-west of the last positions of the Perseid radiant. Until July 20, several radiants appear in the distributions with the radiant closest to what is found in Table 1 not always being the strongest source. The radiant position of July 22 has the largest deviation from the listed positions. The error of 1°.1 in Table 4 suggests that it was indeed more difficult to fix a position.

Table 4 also suggests that the radiant drift is fairly parallel to the ecliptic. The choice of a single parameter as a drift value in ecliptical longitude seems appropri-

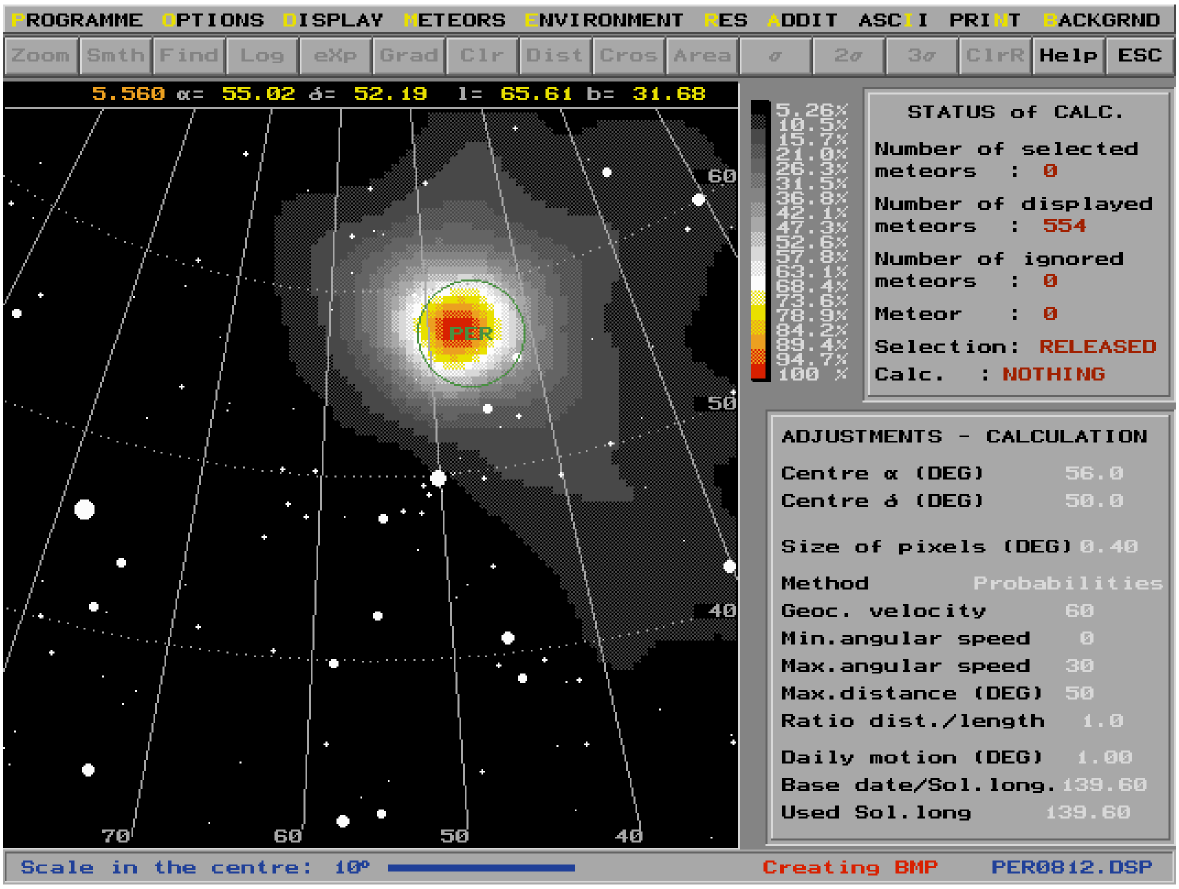


*Figure 4* – Perseid radiant of August 12.

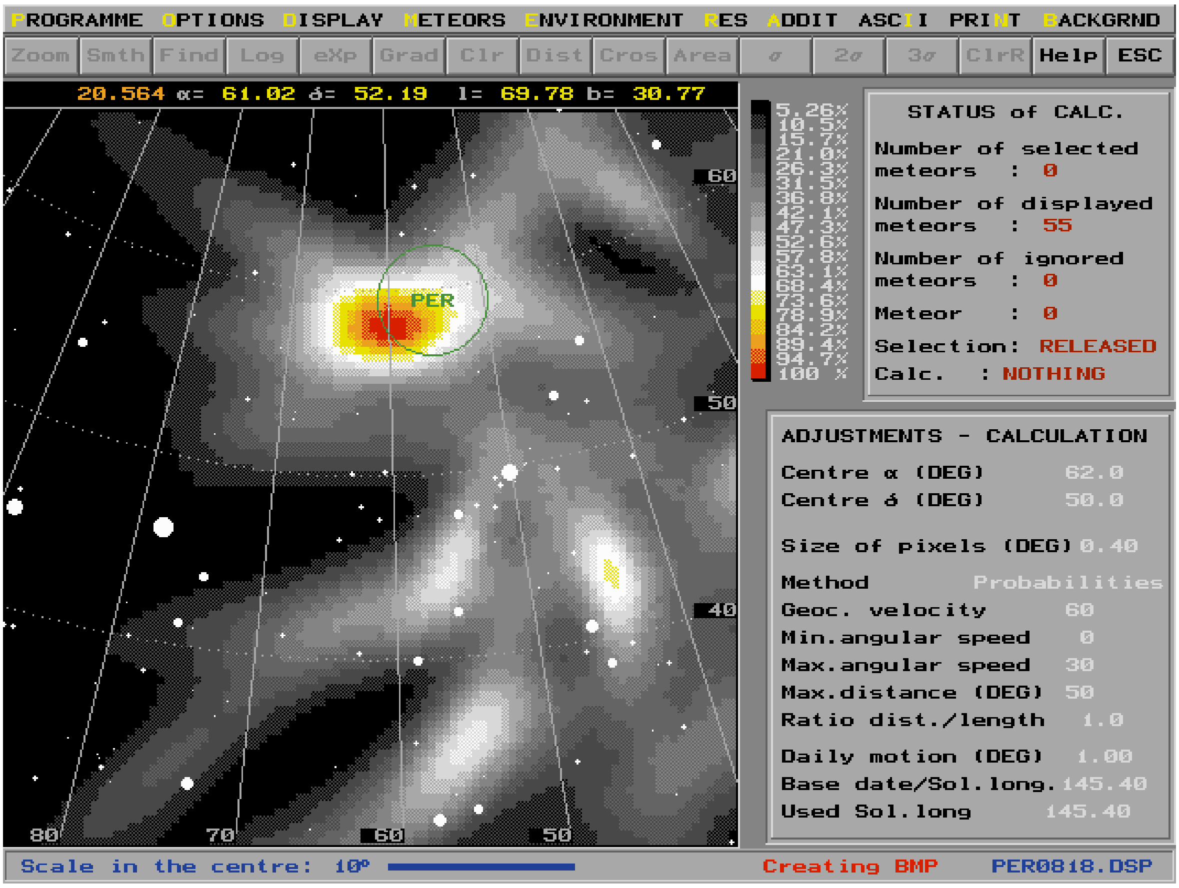


*Figure 5* – Perseid radiant of August 18.

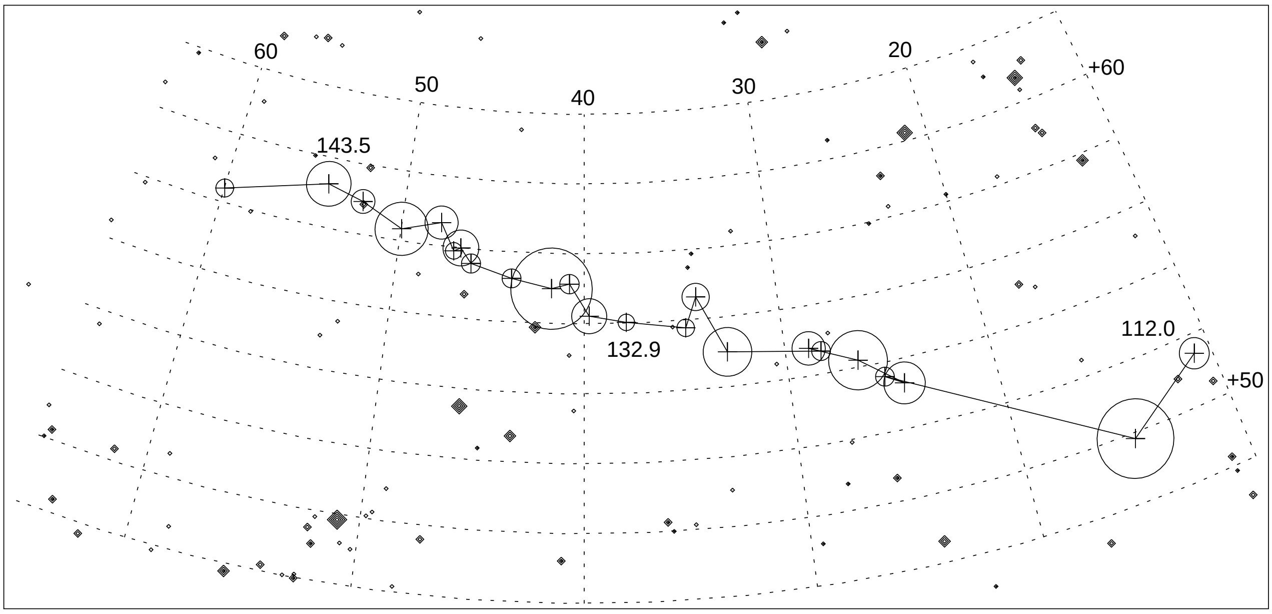


*Figure 6* – Radiant motion of the Perseid meteor shower from single-station video data of 1993–2001. The bright star near the lower left corner is $\alpha$ Persei, the star in the upper right corner is $\gamma$ Cassiopeiae. The circles represent the error estimate as given in Table 4.

ate. Using the period of more reliable radiant positions between $\lambda_\odot = 132.^\circ9$ and $\lambda_\odot = 143.^\circ5$ we obtain $\Delta l = 1.^\circ02$ per day or, given that on August 1 d $= 0.^\circ94$ in solar longitude, $\Delta l = 1.^\circ09$ per degree in $\lambda$.

*Table 4* – Radiant drift of the Perseids as derived from single-station video observations in 1993–2001. The number of meteors contributing to the radiant distribution is $n$. Besides equatorial coordinates $\alpha$ and $\delta$, we also give the ecliptical coordinates $l$, $b$. All data refer to eq. J2000.0.

| $\lambda_\odot$ | $n$ | $\alpha$ | $\delta$ | Error | $l$ | $b$ |
|---|---|---|---|---|---|---|
| 112.°0 | 247 | 10.°8 | +51.°5 | 0.°4 | 34.°36 | +42.°14 |
| 119.°5 | 76 | 14.°8 | +49.°8 | 1.°1 | 36.°14 | +39.°46 |
| 122.°4 | 65 | 25.°4 | +53.°6 | 0.°3 | 45.°91 | +39.°59 |
| 124.°3 | 96 | 24.°5 | +53.°3 | 0.°6 | 45.°14 | +39.°57 |
| 125.°3 | 69 | 26.°5 | +54.°2 | 0.°8 | 47.°06 | +39.°82 |
| 126.°2 | 59 | 28.°8 | +54.°8 | 0.°5 | 48.°95 | +39.°72 |
| 127.°2 | 112 | 28.°2 | +54.°7 | 0.°3 | 48.°47 | +39.°76 |
| 128.°1 | 82 | 32.°9 | +55.°0 | 0.°7 | 51.°75 | +38.°89 |
| 129.°1 | 102 | 34.°2 | +56.°6 | 0.°4 | 53.°56 | +40.°04 |
| 130.°0 | 67 | 34.°8 | +55.°8 | 0.°3 | 53.°50 | +39.°11 |
| 132.°9 | 89 | 37.°8 | +56.°0 | 0.°2 | 55.°60 | +38.°65 |
| 133.°9 | 99 | 39.°7 | +56.°2 | 0.°5 | 56.°94 | +38.°40 |
| 134.°9 | 148 | 40.°8 | +57.°1 | 0.°3 | 58.°06 | +39.°03 |
| 135.°8 | 177 | 41.°7 | +57.°0 | 1.°2 | 58.°60 | +38.°71 |
| 136.°8 | 271 | 43.°8 | +57.°2 | 0.°3 | 60.°09 | +38.°51 |
| 137.°7 | 391 | 46.°0 | +57.°6 | 0.°3 | 61.°65 | +38.°40 |
| 138.°7 | 535 | 46.°7 | +58.°0 | 0.°5 | 62.°24 | +38.°68 |
| 139.°6 | 545 | 47.°0 | +57.°9 | 0.°2 | 62.°42 | +38.°50 |
| 140.°6 | 408 | 47.°8 | +58.°7 | 0.°5 | 63.°29 | +39.°08 |
| 141.°6 | 448 | 50.°0 | +58.°3 | 0.°8 | 64.°49 | +38.°40 |
| 142.°5 | 346 | 52.°3 | +58.°9 | 0.°3 | 66.°21 | +38.°58 |
| 143.°5 | 168 | 54.°4 | +59.°3 | 0.°6 | 67.°63 | +38.°54 |
| 145.°4 | 55 | 60.°0 | +58.°4 | 0.°3 | 70.°85 | +36.°95 |

Figure 8 shows the progression of the radiant's ecliptical longitude with time. The drift in ecliptical latitude is smaller than a hundredth of a degree per day. We now see that our initial choice of 1° per day in ecliptical longitude was appropriate. It should be emphasized that we have not simply obtained what we have put in, though; the input parameter for the daily motion was only meant to combine meteors of a period of 1.8 days more precisely, and now we face an ephemeris covering more than a month!

Linear regression through the points from $\lambda_\odot = 132.^\circ9$ to $\lambda_\odot = 143.^\circ5$ leads to

$$l = 63.^\circ53 + (\lambda_\odot - 140^\circ) \times 1.^\circ09/^\circ,$$

$$b = 38.^\circ61 - (\lambda_\odot - 140^\circ) \times 0.^\circ007/^\circ.$$

The period was chosen because it does not exhibit severe excursions of the measured radiant position due to poor statistics or physically diffuse radiants. Corresponding regression lines through the equatorial coordinates of 132.°9–143.°5 deliver

$$\alpha = 48.^\circ29 + (\lambda_\odot - 140^\circ) \times 1.^\circ46/^\circ,$$

$$\delta = 58.^\circ21 + (\lambda_\odot - 140^\circ) \times 0.^\circ29/^\circ.$$

After we have derived the detailed ephemeris, and after we have proven the radiant drift to be very close to 1° per day in ecliptical longitude, we can compute an ephemeris in 5-day steps which will be smooth enough to serve as a reference for shower association in visual observations (Table 5). The resolution of the radiant distribution grid was increased to a pixel size of 0.°1 while

*Table 5* – Final, smooth radiant drift of the Perseids as derived from 6-day periods in 5-day steps. The pixel resolution of the radiant displays was increased to 0°.1. The radiant drift assumed to combine meteors from within the period is 1°.02 per day as derived from the daily ephemeris. $N$ is the number of meteors selected in the 6-day period centered on $00^h$ UT of the date given (except for the first: July 10–20) and $n$ is the number of meteors contributing to the radiant display of 10° edge length.

| $\lambda_\odot$ | 112°.4 | 117°.1 | 121°.92 | 126°.7 | 132°.4 | 137°.2 | 142°.0 | 146°.8 | 151°.6 |
|---|---|---|---|---|---|---|---|---|---|
| Date | July 15 | July 20 | July 25 | July 30 | Aug 5 | Aug 10 | Aug 15 | Aug 20 | Aug 25 |
| $N$ | 266 | 178 | 753 | 1542 | 867 | 3458 | 3348 | 722 | 1308 |
| $n$ | 55 | 32 | 173 | 348 | 249 | 1367 | 898 | 85 | 116 |
| $\alpha$ | – | – | 24°.8 | 29°.9 | 38°.9 | 44°.7 | 51°.4 | 57°.4 | 63°.3 |
| $\delta$ | – | – | +52°.7 | +54°.7 | +55°.6 | +57°.2 | +58°.6 | +58°.0 | +58°.5 |
| $l$ | – | – | 45°.0 | 49°.6 | 55°.4 | 60°.7 | 65°.5 | 69°.1 | 73°.0 |
| $b$ | – | – | +38°.9 | +39°.4 | +38°.2 | +38°.3 | +38°.4 | +37°.0 | +36°.6 |

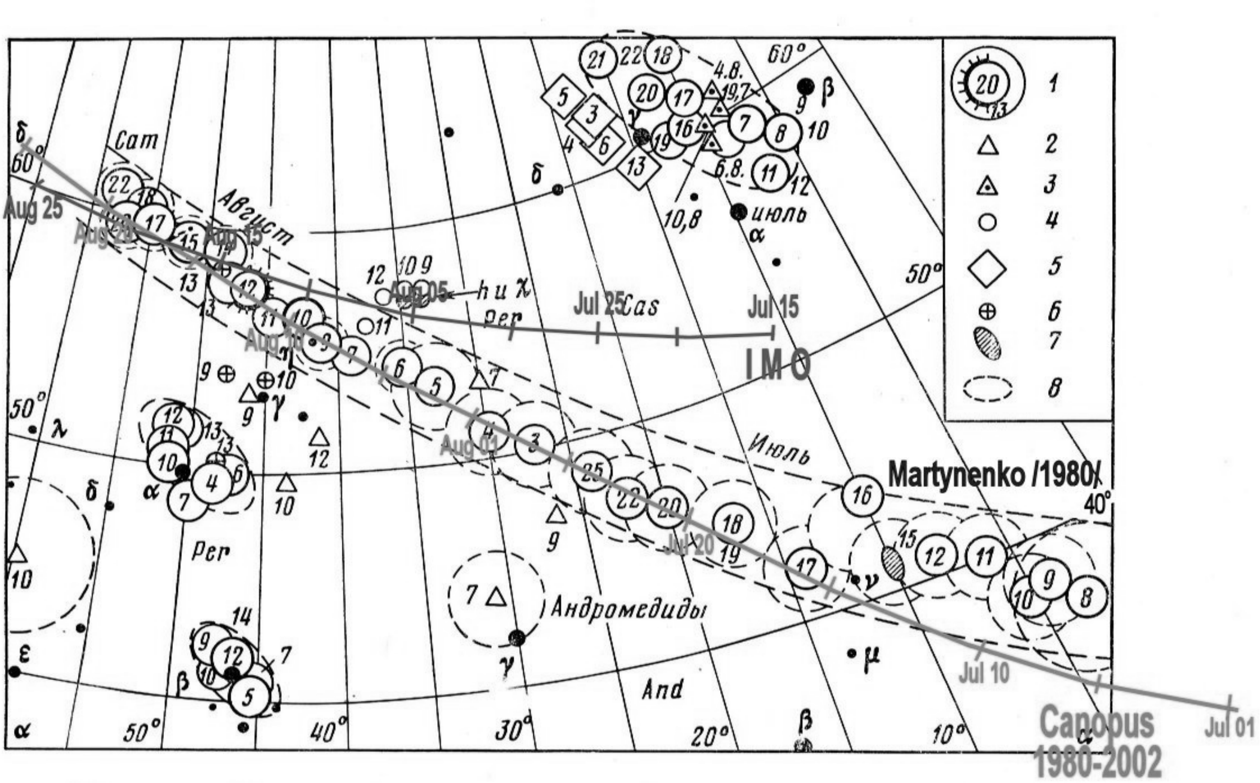


*Figure 7* – Radiant ephemeris obtained by observers on Crimea (sequence of circles) and observers from the Astroclub Canopus in Varna, Bulgaria (grey line). The black line labelled IMO is the radiant drift of Table 1; it does *not* show the new positions of Table 5.

*Table 6* – Dependence of radiant position of the Perseids on magnitude (mass) range.

| Magnitude range | $-\infty < m < +1.0$ | $+1.0 \leq m < +2.7$ | $+2.7 \leq m < +7.9$ |
|---|---|---|---|
| Mass range | $\infty > M > 0.011$ g | $0.011$ g $> M > 0.0021$ g | $0.0021$ g $> M > 10^{-4}$ g |
| $\alpha$ | 45°.46 | 47°.16 | 48°.72 |
| $\delta$ | +57°.95 | +58°.01 | +57°.87 |

the distributions of Figures 1–5 had 0 .°4. It is very satisfying to note at this point that the results obtained agree with Table 1, i.e. that the shower association of the Perseids did not suffer significantly from wrong assumptions about the radiant drift. This drift has been widely used at least since 1987 when a radiant drift table with positions very similar to those in Table 1 was published by Roggemans (1987).

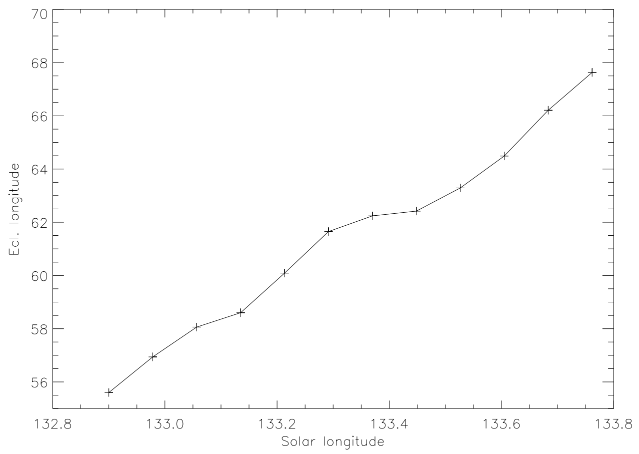


*Figure 8* – Progression of the ecliptical longitude of the Perseid radiant.

Reliable Perseid radiants were found for the averages referring to July 25 to August 25, which include meteors from July 22.0 to August 28.0 UT. Remarkably, the period of detectability extends beyond the one in the daily ephemeris, which ceases on August 19.

## 25 Comparison with other sources

We can compare these single-station results with the analysis of multiple-station orbital data as presented by Lindblad & Porubčan (1995). The search was performed on the files of the *IAU* Meteor Data Centre in Lund. The ephemeris in that paper is given in terms of equatorial coordinates and needs to be converted to eq. J2000.0. We assume that the actual slopes in $\alpha$ and $\delta$ will not alter significantly in 50 years precession and obtain

$$\alpha = 47^{\circ}\!.52 + 1^{\circ}\!.387/^{\circ}(\lambda_{\odot} - 139^{\circ}\!.64)$$

$$\delta = 57^{\circ}\!.96 + 0^{\circ}\!.195/^{\circ}(\lambda_{\odot} - 139^{\circ}\!.64).$$

The agreement with the results presented here is very good given the errors of a few tenths of a degree. The correlation coefficients for right ascension and declination in Lindblad & Porubčan (1995) are relatively low, indicating a natural scatter in the radiant area of 1°–2°.

Hoffmeister (1948) gives an ephemeris for $\lambda_{\odot} = 122^{\circ}$ to $\lambda_{\odot} = 146^{\circ}$ (July 25–August 19). He comments: 'Denning gives the period of activity of the radiant as July 11 to August 19. One would be closer to the truth if he limits this period to July 20 to August 19.' This is exactly the outcome of the present analysis. The result is that the signal-to-noise ratio of the Perseid radiant is too small outside the period mentioned. This is particularly true for early and mid-July, a period for which significant Perseid activity has often been claimed. Radiant areas do exist but they are scattered over a large area in Cassiopeia and Andromeda with no obvious systematic radiant drift, according to the present analysis.

Another early radiant ephemeris from a comprehensive data set is given by Bakharev (1955) who compiles mostly telescopic data from the Dushanbe observatory. The scatter of radiants is large, yet he determines drifts of $\Delta\alpha = 1^{\circ}\!.32/^{\circ}$ and $\Delta\delta = 0^{\circ}\!.27/^{\circ}$. The drift does not, according to Bakharev, differ from the radiant drift he obtained for visual meteors.

Large compilations of visual Perseid meteors by the meteor group of V.V. Martynenko (Crimea, Ukraine) and of the Canopus group of V.D. Velkov (Varna, Bulgaria) led to ephemerides very similar to each other as shown in Figure 8. The circles represent a daily ephemeris from the Crimean group, while the Bulgarian results are given as a smoothed curve in gray. The radiant of the period before August 10 was found at more southerly positions than are found here. Towards earlier dates, the difference grows to as much as 10° in mid-July.

Note that the positions near $\alpha$ and $\beta$ Persei are most probably artifacts. A true radiant is supposed to show a systematic radiant drift over 10 days. Bright stars typically exhibit false radiant areas, because they are preferentially used by observers for the orientation of meteor plots. Such a bias does not exist in video data, and it is not surprising that no significant $\alpha$- or $\beta$-Perseid radiants are detected.

There is a southern radiant area in Figure 1, but this again is another 8° farther south from the Crimea/Varna positions for mid-July. The general outcome of the present study is that the Perseid radiant area becomes very diffuse and scattered before July 22.

The compilation of precise photographic orbits by Betlem et al. (1998) from 1981 to 1993 multiple-station data contains information about 111 Perseids. The geocentric radiant positions agree well with the present results from single-station video data. The large scatter of radiant positions for a given date or short period is again remarkable. The photographic record which is earliest in July is of $\lambda_{\odot} = 126^{\circ}\!.6$ (1990 July 29.9), the latest in August is of $\lambda_{\odot} = 143^{\circ}\!.1$ (1986 August 16.1). In this period no clear trend towards more southerly positions — as suggested by visual data above — can be found.

## 26 Mass sorting

An interesting issue arises from the full-stream modelling of Brown & Jones (1998) who integrated the motion of millions of particles ejected from parent comet 109P/Swift-Tuttle between 59 and 1862 AD. At the present time, particles in the mass range 0.1–10 g form an average radiant at $\alpha = 46^{\circ}\!.1 \pm 0^{\circ}\!.1$, $\delta = +57^{\circ}\!.66 \pm 0^{\circ}\!.05$ referring to a solar longitude of $\lambda_{\odot} = 139^{\circ}\!.7$. When comparing this result with our Table 4, we find good agreement in declination, but a

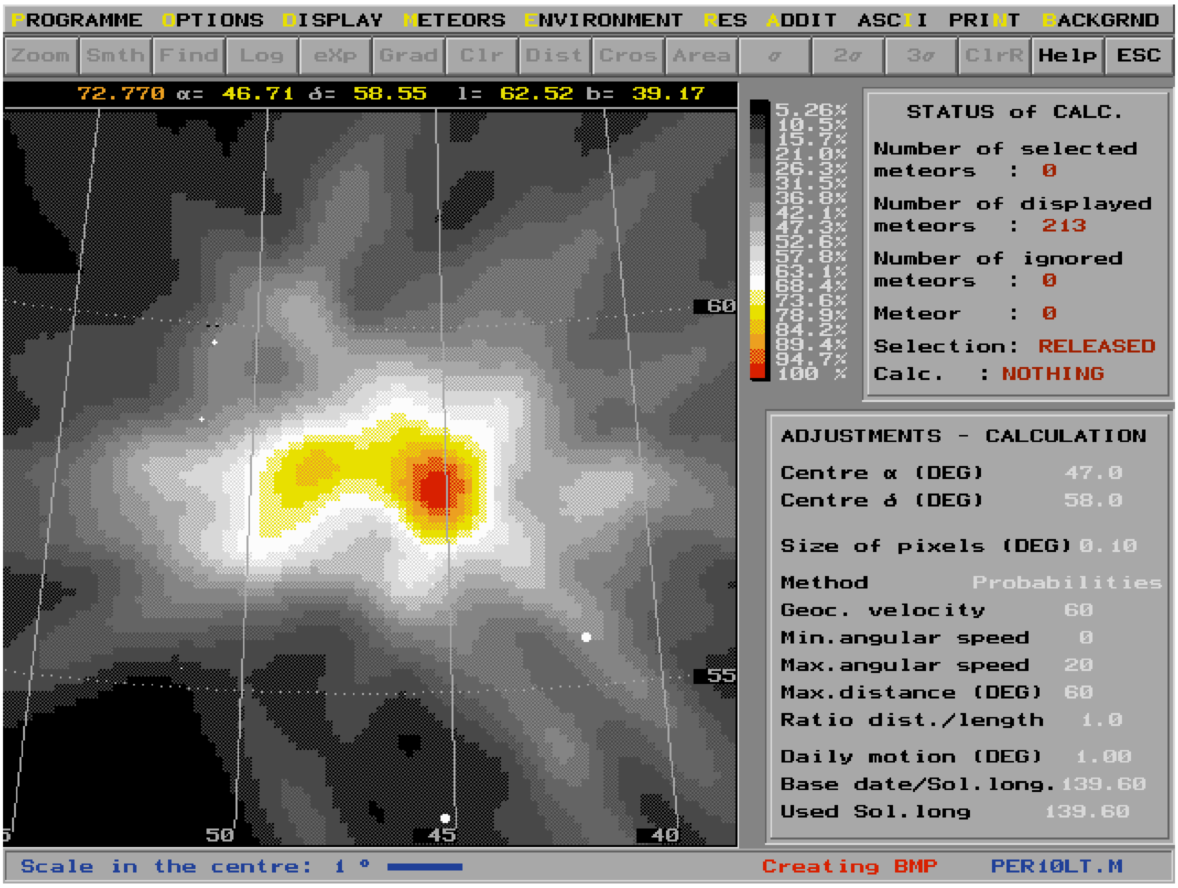


*Figure 9* – Perseid radiant of August 11–13 for meteors brighter than magnitude +1.

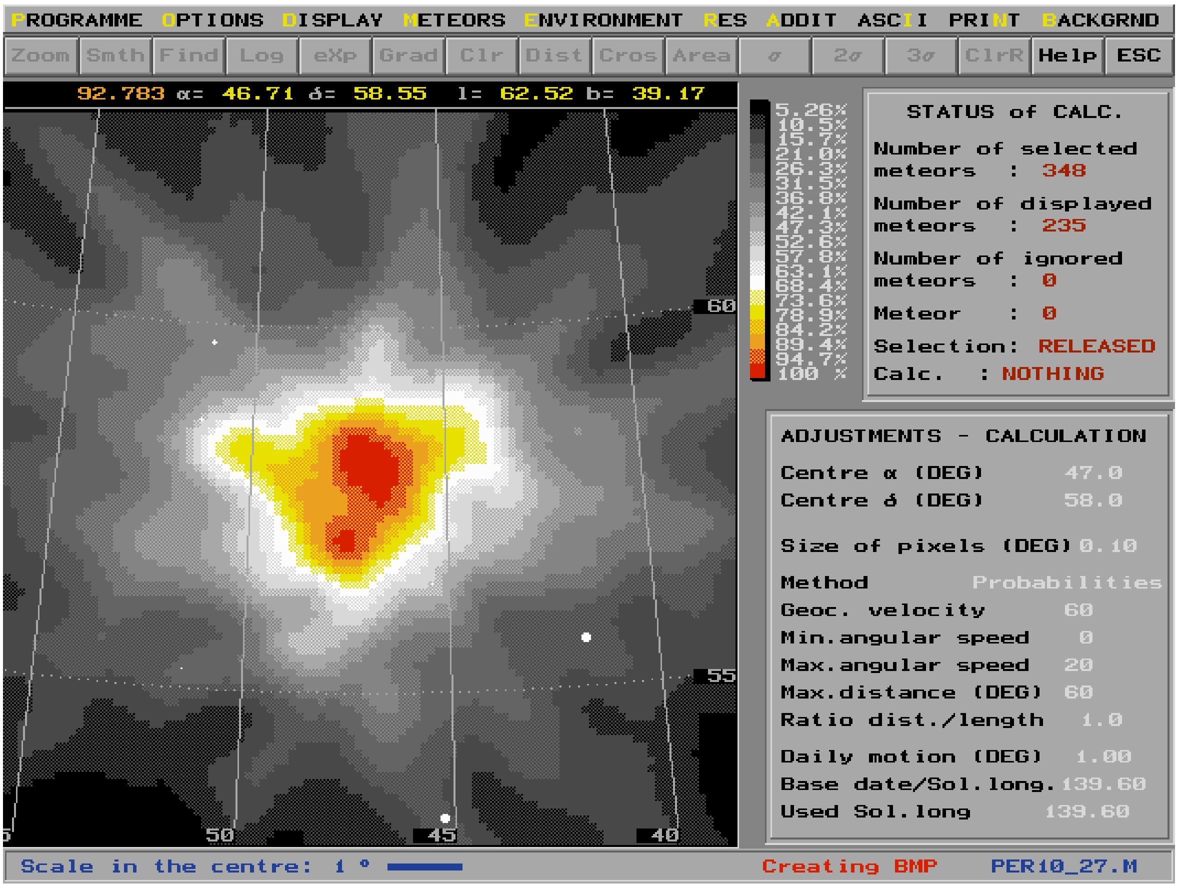


*Figure 10* – Perseid radiant of August 11–13 for meteors between magnitude +1 and +2.7.

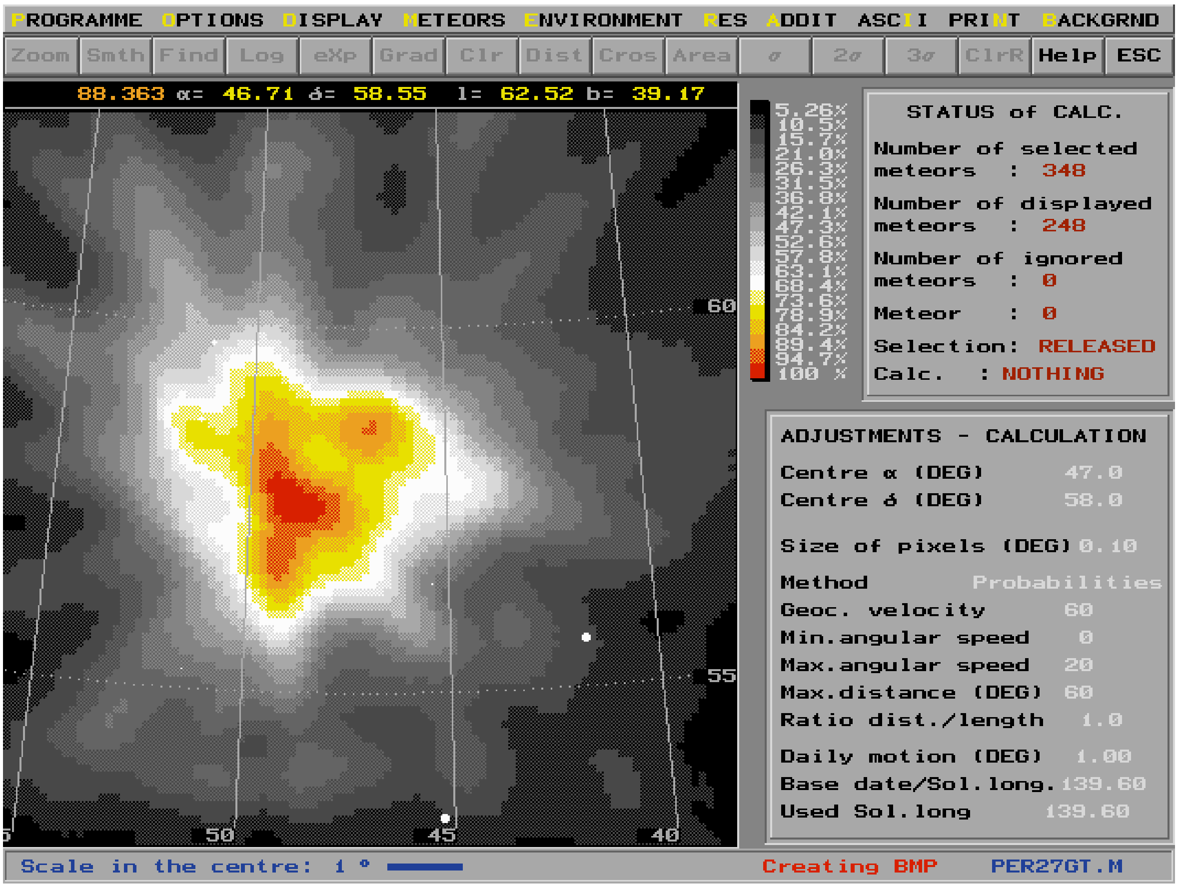


*Figure 11* – Perseid radiant of August 11–13 for meteors fainter than magnitude +2.7.

significant difference in right ascension. The model radiant actually being formed by photographic-sized meteoroids lies at a more western position. The positions for $\lambda_\odot = 139.^\circ 6$ in Table 4, however, are obtained from visual meteors.

Mass sorting in radiant positions appears to be an explanation for the difference. The number of meteors in the video sample is large enough to check for the radiant position in different mass ranges. Three subsets of data were selected from the period August 11, $00^h$ UT to August 13, $00^h$ UT. This period will again mean different ranges in solar longitude in individual years. The correction for a reference solar longitude in the Radiant program is supposed to be accurate enough for periods as short as two days. The three magnitude ranges are $-\infty < m < +1.0$, $+1.0 \leq m < +2.7$, and $+2.7 \leq m < +\infty$, the faintest magnitude ever determined in the full set of video meteors being +7.9. Figures 9–11 show the radiant distributions for these three classes. We decreased the standard deviations of Table 3, in order to unveil the substructure of the radiant which was not relevant in finding the visual average radiant position of the Perseids in Section 3. A clear mass sorting is found, with larger particles causing a radiant west of the radiant of smaller particles. The average positions of the three mass ranges are given in Table 6. The relation of magnitudes to meteoroid masses is taken from Verniani (1973):

$$m = 40 - 2.5 \log \left(2.732 \times 10^{10} M^{0.92} v_\infty^{3.91}\right),$$

where $M$ is the mass of the particle and $v_\infty$ is the entry velocity into the Earth's atmosphere. The finding is consistent with the results from video meteors (Yoshida 1999) where the radiants of visual-class meteors have their radiants at smaller (western) right ascensions than telescopic-class meteors. The difference in average radiant positions for meteors brighter and fainter than +5.5 in that paper is large, but the position for the class +5.5 to +9.1 at $\alpha \approx 49^\circ$, $\delta \approx +57^\circ$ adds nicely to the right-hand side of our Table 6.

## 27 Summary and epilogue

A radiant ephemeris of the Perseid meteor shower has been derived from single-station video observations. Table 5 gives the final positions. The radiant was detectable unambiguously between July 22 and August 19. The radiant drift tables used for visual observations may be updated with the results of the present study. Since the values of July 25 match the values of Table 1 fairly well, we may keep the radiant drift of before July 25 from the old list, and see whether a larger set of meteors will provide conclusive radiant positions.

I would like to emphasize at this point that comprehensive analyses are a readily achievable goal for many amateur astronomers. The data used here were simply downloaded from the Internet. I would like to encourage all interested meteor observers to tackle an analysis project. A lot of projects are waiting!

## Acknowledgments

The present paper is an expression of the fruitfulness of the tremendous work of Sirko Molau in setting up and maintaining the video network. I am very grateful for his efforts and for providing the databases. I would also like to thank all the video observers who have contributed to this analysis. Special thanks to Vladimir Krumov and Valentin Velkov for discussions and their permission to use the ephemeris graph in Figure 7.

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# Erratum on 'Bulletin 18 of the International Leonid Watch: preliminary analysis of the 2002 Leonid meteor shower' WGN 30:6

*Rainer Arlt*

In the process of supplying the readers with quick, reliable results on the Leonids, too hasty writing caused an error on page 208 in the third paragraph. The sentence with '...observers in Norway saw the European peak about 5 minutes before colleagues in southern Spain...' actually meant *after*, since the Leonid meteoroid stream is first encountered by observers in southerly latitudes, roughly speaking. The following sentence with 'southern France saw the peak about 1.6 to 2 minutes earlier' also meant *later*, and finally 'Algeria encountered the peak 0.7 after' converts to *0.7 minutes before*. It is important to add though that the computations were done correctly. The version on the IMO web pages was corrected accordingly.

# Ongoing meteor work

## Radio observations of the 2002 December Ursids from Northeastern Italy

*Walter Boschin, Diego Ganzini, Alessandro Candolini and Giuseppe Candolini*[1]

Radio observation results by the forward scattering technique are given for the 2002 December Ursid meteor shower. The radio data show a weak activity from this shower from $16^{\rm h}$ UT to $24^{\rm h}$ UT on 2002 December 22.

### 28 Introduction

Ursids are associated with the comet 8P/Tuttle. The radiant of this poorly known shower is circumpolar for the northern hemisphere, where it is visually observable during the entire night. Usually this shower presents a short maximum lasting only a few hours, when about ten Ursids per hour can be seen (Roggemans, 1989). However, in the last century this shower surprised observers with important outbursts on at least two occasions (1945 and 1986), with ZHRs of many tens of meteors per hour. In 2002, a theoretical model from some authors (Lyytinen & Nissinen, 2002) predicted an Ursid outburst on December 22, with two possible activity peaks at $19^{\rm h}00^{\rm m}$ UT and $20^{\rm h}40^{\rm m}$ UT.

We report here the results of radio observations obtained on December 22 and 23 at the observatory of the Associazione Friulana di Astronomia e Meteorologia (AFAM) in Remanzacco (Northeastern Italy).

### 29 The equipment

Meteors were detected by receiving forward scatter VHF radio waves at a frequency of 62.1875 MHz in SSB mode. The receiver used was an ICOM IC-R9000 with an RF sensitivity of 0.32 $\mu$V for a signal-to-noise ratio of 10 dB and an IF selectivity of 2.4 kHz/$-6$ dB (in SSB mode). The transmitter, a German TV station, is located in Flensburg and the receiver is located in Remanzacco (Northeastern Italy). The path length between Flensburg and Remanzacco is about 990 km. A four-element Yagi antenna was used at the receiving station. The antenna was directed to azimuth 350° with an elevation of 10° towards Flensburg.

### 30 The observational data

Sporadic activity was recorded in 1-hour intervals from December 17 to December 20 by using a slightly modified version of the software MOP (Anon, no date). This software analyzes via FFT the audio signal taken from the receiver. When the transmitter video carrier signal rises 5 times over the median value of the audio spectrum, a meteor is counted. On December 22 and 23, the total meteor activity was recorded by MOP in 1-hour intervals. Dead-time corrections were applied according to the Geiger-counter method. Dead-time marks the period in which a certain signal of a given amplitude may mask other signals of lesser amplitude.

### 31 The activity of the shower

To estimate the activity of the shower, I use an activity parameter $A(t)$ defined as $A(t) \equiv H(t)/H_b(t) - 1$. In this formula $H(t)$ is the hourly rate of meteors (Ursids + sporadics) registered at time $t$, while $H_b(t)$ represent the sporadic rate at time $t$ as estimated from the counts obtained from December 17 to December 20. If there is no activity from the shower, then $A(t) \sim 0$, otherwise $A(t)$ is significantly higher than zero.

### 32 The results

The Ursid activity recorded is plotted in Figure 1. Here the activity parameter $A(t)$ as a function of time is given for all recorded echoes (crosses) and for long-lasting reflections of more than one second (filled circles). In general, for a meteor shower $A(t)$ is higher if we compute it considering only long-lasting reflections. This is because showers usually contain a higher fraction of massive particles (producing long echoes) than sporadics. In fact, note that from $16^{\rm h}$ to $24^{\rm h}$ UT the total number of recorded meteors is only $977/692 = 1.5$ times higher than the estimated background, while the number of long reflections is $140/50 = 2.8$ times higher than the background.

There is indication of a weak activity by Ursids from about $16^{\rm h}$ UT to $24^{\rm h}$ UT ($\lambda_\odot = 270\overset{\circ}{.}6 - 270\overset{\circ}{.}9$), quite consistent with the times of the predicted outburst. The activity is seen better when considering the activity parameter for long reflections, even though in this case the error bars ($1\sigma$ confidence level) are larger due to poorer statistics. Of course, the activity profile is modulated by the observability function of the shower (Hines, 1955; Steyaert, 1987), which has a minimum from $10^{\rm h}$ UT to $16^{\rm h}$ UT and rises in the evening up to $02^{\rm h}$ UT. In total, in the period from $16^{\rm h}$ UT to $24^{\rm h}$ UT we recorded 977 meteors, of which 140 produced long-lasting echoes. (The estimated backgrounds in the same period were 692 and 50 meteors respectively.) Two-thirds of long-lasting reflections had a duration of the order of 1–4 seconds, while only 13 reflections were longer than 10 seconds.

[1] Associazione Friulana di Astronomia e Meteorologia, Piazza Giordano Miani 1, I-33047 Remanzacco, Italy. email boschin@ts.astro.it

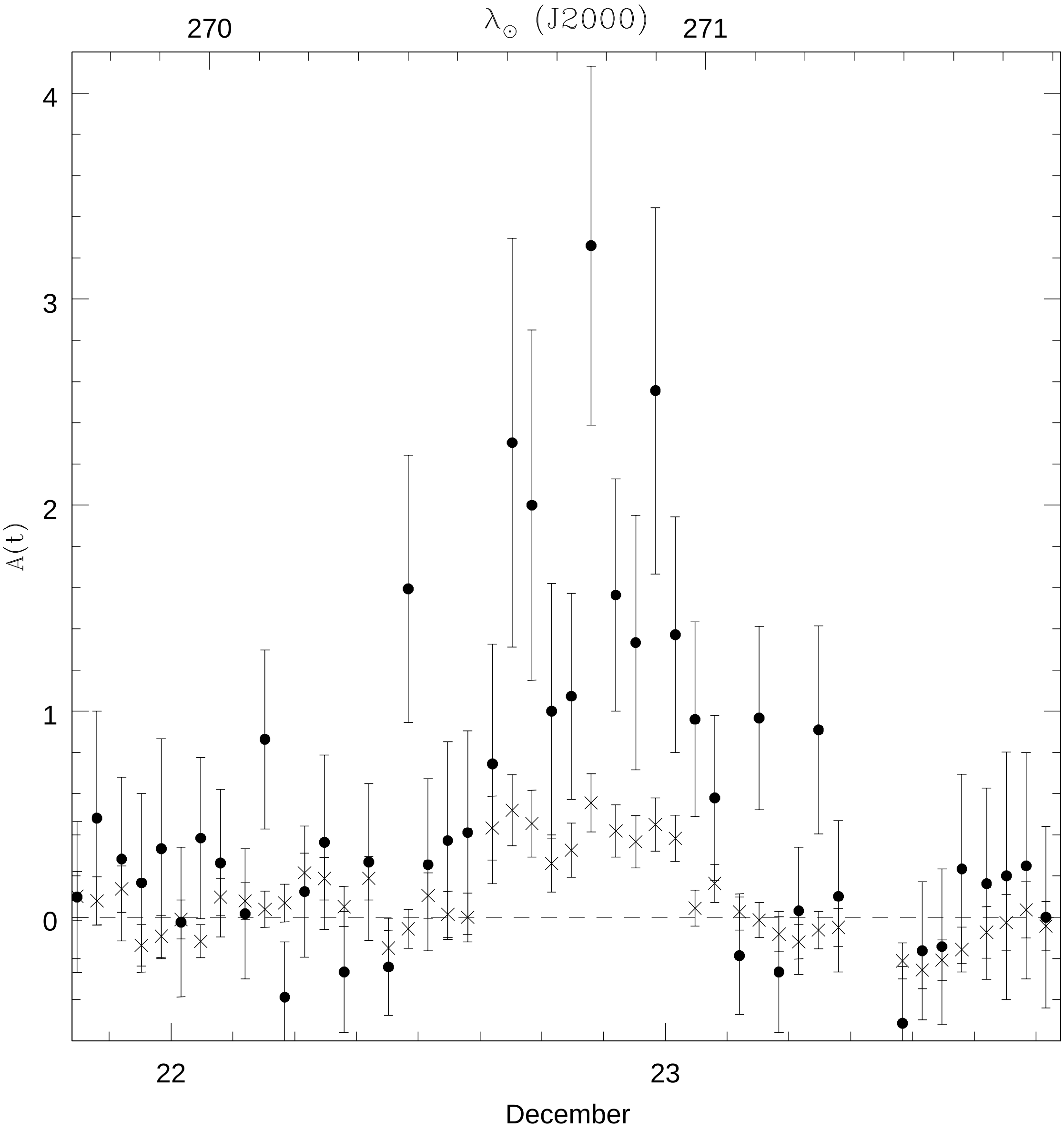


*Figure 1* – The activity profile $A(t)$ (see text) on December 22 and 23 computed from all reflections (crosses) and long-lasting reflections (filled circles, duration more than one second). A weak Ursid activity appears from about $16^{h}$ UT to $24^{h}$ UT on December 22.

## Acknowledgments

We thank A. Hagen for having made his software MOP available through the Internet.

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# Radio observations of the 2002 Ursids

*R.B. Minton*[1]

The 2002 Ursids were detected for 15 hours at mid-western United States longitudes on December 22–23 UT. The radio meteor system has been described in detail elsewhere (Minton & Lunsford, 2002), but will be briefly repeated. The components are a vertical 1/4-wavelength ground plane antenna, a digital car radio tuned to 92.9 MHz, an audio signal conditioner, a digital multimeter performing signal conversion; and lastly, software and a computer to collect and store data for 29 days. Other programs can apply post-processing to better show meteoric events. All software was written in GW Basic by myself. The location is $36\overset{\circ}{.}91$N, $104\overset{\circ}{.}44$W, altitude 2001 meters.

Count data for December 2–30 has been plotted (Figure 2, next page) and shows the 2002 Geminids display on December 12–14. In addition, the elusive Ursids appear to show a hint of activity as a noisy clump on December 22. To test this possibility, I averaged 22 days of diurnal counts which did not show meteor activity (using a time resolution of 30 minutes). These values are plotted in the lower right of Figure 2. Subtracting the 30-minute integrated diurnal background from the 30-minute integrated Ursid data produced a better plot, so I repeated this step using a one-hour integration for both. This produced an even better (smoother) plot. I did not integrate counts beyond on hour as radio counts per hour (RC/hr) is a convenient unit of measure.

A third step was employed to further reduce the noise. I applied a three-point moving average (with weights 0.5:1.0:0.5) to the 48 data points (24 per day for two days). This averages the data set over a three-hour interval, but gives a double weight to the central hour of data (and does not shift the times of maximum or minima).

Figure 1 shows how the original noisy clump of data in Figure 2 has become a much more easily measured data set. After two days of signal processing, a quick trip to the local high school and borrowing a teachers' Internet computer confirmed that others had also seen the 2002 Ursids as a weak outburst at approximately the same data and time (Misato, no date). To the first approximation, my data indicates a uniform change in counts from the start to maximum, and to the end. The minimum times are assumed to be where lines drawn through the counts above 10 intersect the $X$-axis (at zero counts/hour). Data before December 2, $14^{h}00^{m}$ and after December 23, $05^{h}00^{m}$ are assumed to be noise. The low count values and the attendant noise do not warrant a more detailed analysis of the data. Table 1 summarizes my interpretation of the data, the aspect of the radiant, and lists the solar longitudes at Ursid maximum, minima, and the half-maximum points. Solar longitudes are computed using (Duffett-Smith, 1985), and appear to be correct to $\pm0\overset{\circ}{.}04$.

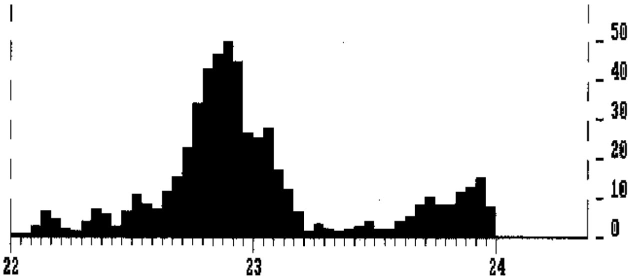


*Figure 1* – Hourly counts of 2002 Ursids for the New Mexico–Colorado region, USA. Reception of four FM radio stations at multiple azimuths at 92.9 MHz. $X$-axis: date (UT) in 2002 December; minor ticks are 1 hour. $Y$-axis: radio counts per hour.

The Ursid radiant never rose above 47° altitude and does not display the double maximum signature visible in the Geminid data. This is an instrumental effect, and is seen whenever a meteor radiant passes near the zenith.

*Table 1* – Summary and analysis of Ursid observations.

| Aspect or event | Date/Time UT | Ursid RC/hr | Solar Long. | Radiant Alt | Radiant Azim | Radiant Hr angle | Remarks |
|---|---|---|---|---|---|---|---|
| | Dec 22 | | | | | | |
| Ursid minimum | $14^{h}00^{m}$ | 0 | $270\overset{\circ}{.}57$ | 46 | 005 | $23^{h}38^{m}$ | Start of Ursid activity |
| Upper culmination | $15^{h}20^{m}$ | 10 | | 47 | 000 | $00^{h}00^{m}$ | (of radiant) |
| Diurnal maximum | $17^{h}00^{m}$ | (65) | | | | | Diurnal counts, not Ursids |
| Ursid half-maximum | $18^{h}00^{m}$ | 25 | $270\overset{\circ}{.}74$ | 44 | 351 | $02^{h}39^{m}$ | Day in USA, night in Europe |
| Ursid maximum | $21^{h}30^{m}$ | 50 | $270\overset{\circ}{.}89$ | 36 | 348 | $06^{h}09^{m}$ | Min. to max. = $7\overset{h}{.}5$ |
| | Dec 23 | | | | | | |
| Ursid half-maximum | $01^{h}00^{m}$ | 25 | $271\overset{\circ}{.}04$ | 29 | 353 | $09^{h}40^{m}$ | Astron. twilight $01^{h}16^{m}$ |
| Diurnal minimum | $01^{h}00^{m}$ | (33) | | | | | Diurnal counts, not Ursids |
| Lower culmination | $03^{h}20^{m}$ | 10 | | 27 | 000 | $12^{h}00^{m}$ | (of radiant) |
| Ursid minimum | $05^{h}00^{m}$ | 0 | $271\overset{\circ}{.}21$ | 28 | 005 | $13^{h}41^{m}$ | Max. to min. = $7\overset{h}{.}5$ |

[1] 568 North First Street, Raton, New Mexico, 87740, USA

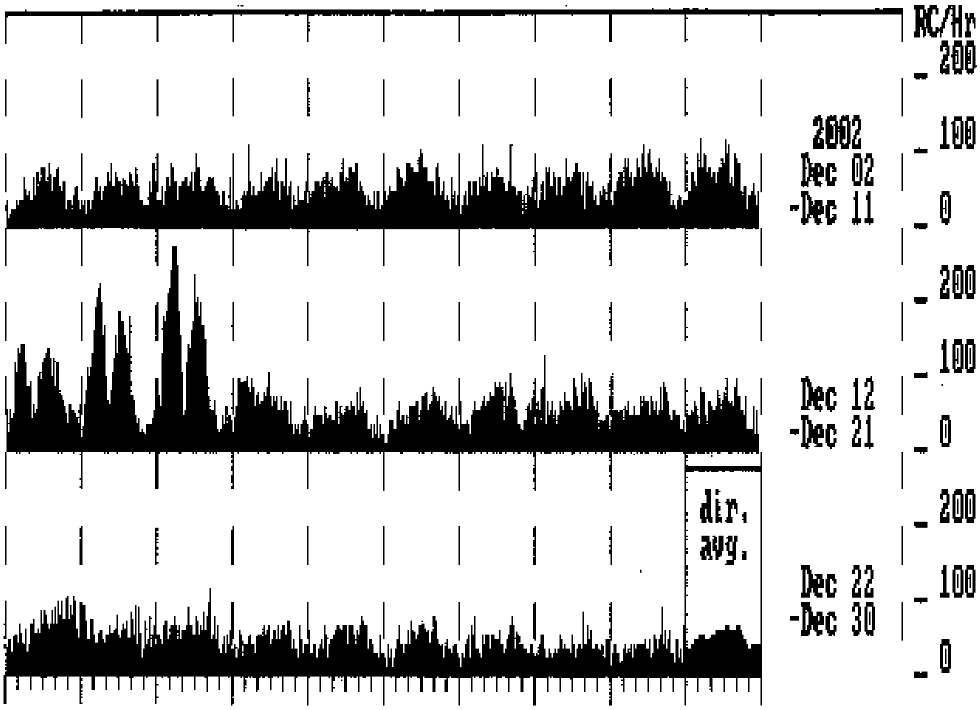


*Figure 2* – Twenty-nine days of radio meteor counts for the New Mexico–Colorado border region, USA. Radio system tuned to 92.9 MHz, sensitivity high. $X$-axis: major ticks — $00^{\mathrm{h}}$ UT; minor ticks — 4 hours.

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# Radio observations of the 2002 Geminids

*R.B. Minton* [1]

Radio meteor observations of the 2002 Geminids are plotted from December 12 to December 19. They are evident starting on the 12th at about 125 radio counts per hour, and on the 13th around 250. Maximum was reached on the 14th near 350, and last evident on the 15th again near 125 radio counts per hour. During this 9-day interval the diurnal background was about 25 per hour near each minimum, but the maximum for each day increased from about 50 to 100.

There is a strong minimum in shower counts as the radiant crosses the local meridian; this effect is visible on all 4 shower dates. It is due to the vertical polarization of the antenna combined with the vertical orientation of the meteor trails. The radiant crossed the meridian 5° south of the zenith near $09^{\mathrm{h}}$ UT each day. A computer outage occurred near the end of the 14th resulting in no data collection for five hours.

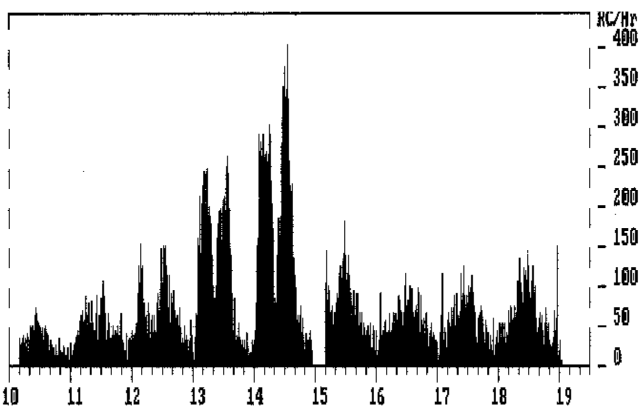


*Figure 1* – Radio meteor counts per hour over New Mexico–Colorado, USA. FM digital car radiom 96.1 MHz, 9 radio stations at different azimuths. $X$-axis: time UT on 2002 December 10–19 with 4-hour marks. $Y$-axis: radio counts per hour.

[1] 568 North First Street, Raton, New Mexico, 87740, USA

# Polish Automated Video Observations (PAVO)

*Mariusz Wiśniewski*[1*], *Piotr Kędzierski*[2*], *Krzysztof Mularczyk*[3*] *and Kamil Złoczewski*[4*]

We describe the current status of video observations of meteors in Poland. The setup contains four very low light CCTV cameras. The video system has so far made 185 hours of observations. Most of the data comes from Leonids nights. We decided to use the MetRec program for video tape analysis. The data will be fully reduced and presented soon. We made a visual inspection of tapes of the period $03^h04^m$– $04^h13^m$ UT from the night 2002 November 18/19. We detected a rapidly growing number of meteors near the start of the predicted maximum of the Leonid shower. At $04^h13^m$ UT clouds fully covered the sky at the Ostrowik Observatory.

## 33 Introduction

Polish meteor observers have been collecting nearly two thousand hours of visual observations per year in recent years, but until now they could only dream of video observations. The cost of an image intensified video system was similar to one year's income for a typical amateur astronomer in Poland. The only way to start video observations of meteors was to find an institution which would cover the equipment costs.

The largest institution which supports science research in Poland is KBN - the State Committee For Scientific Research. In January 2001 we submitted an application for a grant dedicated to observations of meteors with a video camera. We planned to buy a camera with an image intensifier and a computer with a Matrox Meteor II frame grabber for the automatic detection of meteors by the MetRec software designed by Sirko Molau (Molau, 1999).

Our application was turned down. Even for KBN, the cost of only one camera was too high. Fortunately, technical progress in the construction of video cameras lead to an increase in their sensitivity to a level useful for meteor observations. The first camera of such a kind was the WATEC 902H.

We decided to submit another grant application, but this time instead of one camera we wanted to buy three WATEC cameras. In 2002 January our application was accepted and finally we could start to gather the equipment.

In the meantime a new generation of CCDs had been created by SONY. The new SONY ExView HAD (R) is characterized by very high sensitivity, low noise and lower price than the WATEC 902H. Each pixel on this kind of CCD has its own small lens which increases the sensitivity of the chip.

We wanted to order everything as quickly as is possible but we ran into bureaucracy everywhere. At first we waited five months for the approval of the committee to start working. Then we waited a month for the money. In the middle of July we could order the equipment, but summer is the worst time to do so. Most video equipment dealers were on their vacation or had no low light cameras in stock. In September, the Polish Comets and Meteors Workshop organized the International Meteor Conference in Frombork, so we had no time for video. Finally we received the cameras in October 2002. We also ordered the Matrox Meteor II but we had to wait two months for delivery.

## 34 Polish Automated Video Observations of meteors (PAVO) setup

We bought four TC-3181-62B cameras made by TAYAMA. They had 480 TV lines and SONY $1/3''$ ExView HAD CCD chips. Their sensitivity is 0.001 lux with an $f/1.4$ lens. The cameras work on the 230V power supply. They have their own microphones. Typically they can run at $-10°$ C, but they worked even at $-20°$ C! Our lenses have a focal length of $f = 12$ mm and $f/1.2$. During good weather conditions in continuous frames we can detect stars of even magnitude 6 on the screen. The limiting magnitude of a single frame is around magnitude 4.

We bought four LV2798 6-head video tape recorders made by LG. Everything was connected with 40 meters of $75\Omega$ co-axial cable for the video signal and 40 meters of audio cable (10 meters for each camera).

Observations are recorded on TDK HS 240 (High Quality Standard) video tapes designed for frequent recording. Each camera is mounted on a common board – each one on a separate mounting bracket. This makes it easier to transport and install cameras at the observation site (see Figure 1).

The project was called Polish Automated Video Observations (PAVO) and the cameras were called Polish Automatic Video Observer with a number: PAVO1, PAVO2, PAVO3 and PAVO4. Up till now we have recorded 185 hours of observations. We will use the MetRec software (Molau, 1999) for the reduction of observations collected on the video tapes.

## 35 Leonids 2002 in PAVO data

Observations of Leonids by PAVO were conducted in Ostrowik at the Observing Station of Warsaw University Astronomical Observatory. We collected 65 hours of observations from November 16 to November 19. Vi-

[1] email mwisniew@astrouw.edu.pl
[2] email virtek@ds2.uw.edu.pl
[3] email kmularczyk@ds2.uw.edu.pl
[4] email kzloczewski@ds2.uw.edu.pl
*Warsaw University Astronomical Observatory, Al. Ujazdowskie 4, 00-478 Warsaw, Poland

sual (Olech, 2003) and photographic observations were performed in parallel.

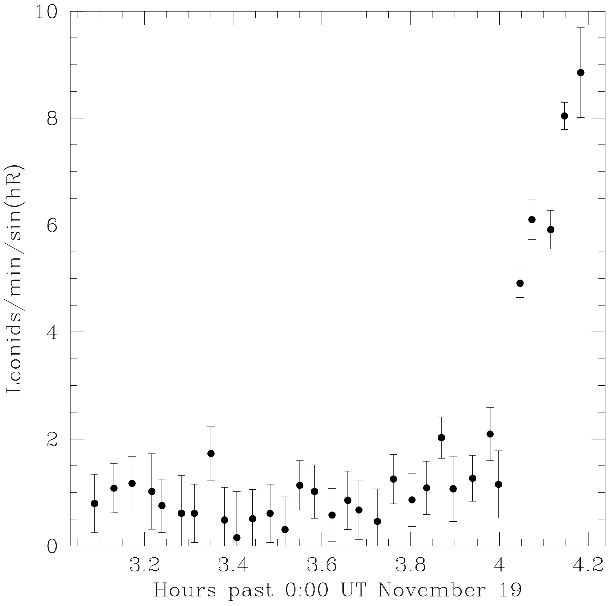


*Figure 2* – Preliminary results of an analysis of the activity near the Leonid shower maximum 2003 November 19, obtained from the PAVO system. The number of recorded meteors per minute was multiplied by the sine of the Leonid radiant altitude ($h_{\mathrm{R}}$).

Unfortunately, we were not lucky enough to see the maximum of the Leonid shower. The weather was poor until midnight. Then we started to observe, but at about $04^{\mathrm{h}}00^{\mathrm{m}}$ UT we could see a rapidly growing number of meteors and clouds in the sky. For the next 13 minutes I tried to point cameras at those fields where clouds were absent, but at $04^{\mathrm{h}}13^{\mathrm{m}}$ UT the sky was totally covered.

The recorded material from period $03^{\mathrm{h}}04^{\mathrm{m}}$–$04^{\mathrm{h}}13^{\mathrm{m}}$ UT was inspected visually. The cameras captured 239 meteors in this period. Preliminary results of Leonid shower activity from PAVO data are presented in Figure 2. The real values of activity could be even higher for the last minutes of observations because there were a lot of clouds in the cameras' fields of view.

## Acknowledgments

This work was supported by the KBN grant number 2 P03D 022 22 to M. Wiśniewski.

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*Figure 1* – Polish Automated Video Observations of meteors (PAVO) setup: four TAYAMA low light CCTV cameras called PAVO1, PAVO2, PAVO3 and PAVO4, four LG LV2798 VCRs, one old TV set for monitoring the video signal and a lot of TDK HS 240 video tapes. The rotating shutter for photographic observations is visible behind the cameras. Also in picture are (from left) on top: Konrad Szaruga, Piotr Kędzierski, Arkadiusz Olech; bottom: Mariusz Wiśniewski and Andrzej Skoczewski. The picture was taken after observation of the Leonid shower maximum.

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