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Oświęcim fireball
δ-Arietids
Mythology of meteors as dragons
Leonid orbits from TV records

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Front cover photo

A 1986 Perseid flying through α-Ursa Minoris. This spectacular photo is by Koen Miskotte of Ermelo in The Netherlands. It is one of many on his website `http://home.planet.nl/~misko002/`. Reproduced with permission. [Author's reference 1986 Per-4.]

Instructions for authors

WGN welcomes submissions of papers of meteor science interest. Instructions can be found in WGN **31:4**, pp. 124–128 (2003 August). Photographs for the covers are also welcome. The Editor's contact details are inside the back cover; when e-mailing, include the word Meteor in the subject to get past the anti-spam filters.

Cover design

Rainer Arlt

Editorial

Chris Trayner

The world is getting increasingly internationalized. Ten years ago, people were talking grandly about the 'global village' happening some time in the future. For the IMO, the global village arrived years ago. WGN is now edited in Britain, proof-read in Belgium Germany and Slovenia, and printed in Germany. Equally important, the authors and readers are spread across the world.

Small voluntary groups like the IMO have often made this change to the global village faster than commercial organizations. We have to. A commercial organization can decide it will work in Novosibirsk (for example) and employ twenty people living there. A group like the IMO can only ask for volunteers, and will probably not find many in one place. The internet makes this distributed work almost as simple as if everyone lived in the same town.

It also makes it easier for more people to join in. For instance, the IMO has several jobs it would like help with:

- WGN articles are proof-read by several people before appearing in print. These people look for places where the science, clarity or layout could be improved. They make an essential contribution: by the time I have edited a paper I have been looking at it for too long, but these proof-readers see it with fresh eyes. We would like more proof-readers (who also see the articles early!)
- Radio meteor observations are important, and the IMO has a Radio Commission. We would like someone to organize this.
- We would like to get Volume 29 (2001) of WGN in a form where it can be put on a CD-ROM. A volunteer to help with this would be welcome. A knowledge of (La)TEX would be essential.

If you think you could help with any of these, please contact me at `wgn@imo.net`; remember to include the word Meteor in the subject line to get past the anti-spam filters. If you have internet you can live in Timbuktu or Texas or Tunguska, or even on the International Space Station: you can still work from home.

IMC 2004 in Varna

It has been decided that the International Meteor Conference in 2004 will be held in Varna, Bulgaria. We hope to have more details in the next WGN.

Special edition on Imaging

It has been decided that one issue of WGN in 2004 will be a special edition on photographic imaging. This will probably be the April or June issue, though this has not been finalised yet. If you would like to contribute to this, please contact me. A brief discussion document, which explains the general idea, may be found at `http://www.aoyw03.dsl.pipex.com/imo/wgn/admin/IntroPapers_SpIm.html`. It would be helpful to make contact early, so your ideas can be designed into the edition.

If this proves successful, we may have more special editions. These will have the majority of articles on the particular subject, but not all: regular contents and fresh news will not be pushed out. There are no prizes for guessing what is planned as a centenary edition for WGN 36:3 ...

Journals lost in the post

We have become aware that sometimes copies of WGN are posted but fail to reach the reader. If one of your copies has got lost in the post, and you have waited a reasonable time, please tell us and we will send a replacement. Messages about non-delivery should be sent to Ina Rendtel, whose contact details are inside the back cover. If you email her, remember to add the word Meteor in the subject line to get past the anti-spam filters we have to use. This applies to all emails to all IMO officials.

Click

Finally, don't forget that there is a competition for the best photograph submitted to WGN. The results will be published in the next WGN; the prize is a book of astronomical photographs. If you have any photographs that you think might be worth printing, please contact us. The back cover is available for photos, and for that page they need not be part of an article.

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communicated by Ina Rendtel, Treasurer

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Recent fireballs

Atmospheric trajectory and heliocentric orbit of the EN290903 Oświęcim fireball from photographic records

Pavel Spurný[1]

A description, ground track map and two photographs of this fireball are presented. The orbital data are provided.

Received 2003 November 26

A very bright fireball of almost −15 maximum absolute magnitude was recorded at two eastern stations of the Czech part of the European fireball network. Additionally, one radiometric system placed at the Ondřejov Observatory provides us with exact time of the event — $01^{\rm h}20^{\rm m}12^{\rm s}\!.6s$ UT, which is valid for the terminal flare when the fireball reached the maximum brightness and underwent the most severe fragmentation. The fireball traveled its 91.6 km luminous trajectory in 4.2 seconds and terminated at an altitude of 30.5 km. The beginning of the fireball was photographed at a height of 89.4 km close to the North Moravian town Frýdek Místek and terminated eastward from Oświęcim in Southern Poland. (Unfortunately this map does not show the Polish spelling of the latter town; it is given the German spelling of Auschwitz.) The meteoroid of initial mass of about 27 kg entered the atmosphere with the velocity of 23.1 km/s and during its flight decelerated to a terminal velocity of 11.8 km/s. Unfortunately, the initial velocity was too high for the survival of any important part of the initial mass. This is also the main reason why this very bright fireball terminated relatively high and why only small meteorites of the total mass of several hundreds of grams could land on the ground. The computed impact area lies northeast of the Polish town of Oświęcim.

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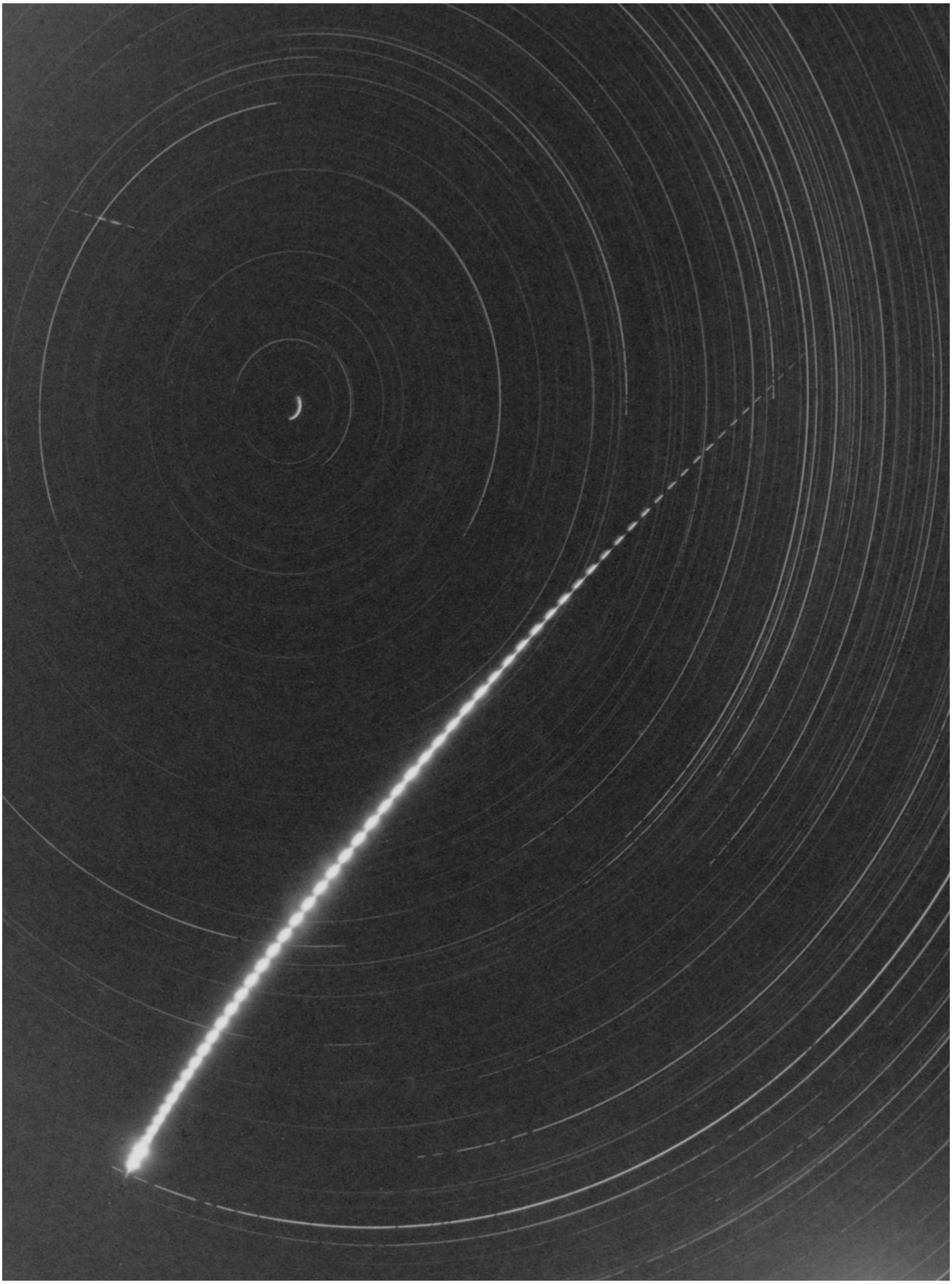

Figure 1 – Detailed view of the EN290903 fireball from the fixed all-sky camera placed at Lysá hora, the most eastern Czech station of the European Fireball Network. This camera is equipped with a Zeiss Distagon 30 mm $f/3.5$ fish-eye objective. Interruptions of the luminous path of the fireball are caused by a three-arm rotating shutter placed near the focal plane (15 breaks/s). The fireball started its luminous trajectory practically above the station, only 12 degrees far from zenith. The distance of the station from the terminal point was 77 km.

The fireball stations, especially the closest one, Lysá hora, were very favorably situated to the fireball trajectory so that all parameters describing this fireball were determined with very high precision. Before its collision with the Earth, the meteoroid orbited the Sun on a quite eccentric low inclination orbit, typical for the Apollo type asteroids. According to its behavior in the atmosphere, this fireball belongs to the type I, usually associated with quite strong material, which also supports its asteroidal origin.

All the important values describing the atmospheric trajectory and heliocentric orbit are collected in Table 1.

Figure 2 — see back cover – Detailed view of the EN290903 fireball from the fixed all-sky camera placed at the Červená hora station and equipped with a Zeiss Distagon 30 mm $f/3.5$ fish-eye objective. Interruptions of the luminous path of the fireball are caused by a three-arm rotating shutter placed near the focal plane (15 breaks/s). The distance from the station from the fireball beginning point was 104 km, while the end of the luminous trajectory was 120 km from the camera, only 14° above the horizon.

Table 1 – Characteristics of the EN290903 'Oświęcim' Fireball.

2003 September 29, T = $01^{h}20^{m}12\overset{s}{.}6 \pm 0\overset{s}{.}3$ *			
Atmospheric trajectory data			
	Beginning	Max. light	Terminal
Velocity (km/s)	23.112 ± 0.007	14.8	11.8 ± 0.3
Height (km)	89.39 ± 0.04	32.0	30.53 ± 0.03
Longitude (° E)	18.2982 ± 0.0005	19.107	19.1283 ± 0.0004
Latitude (° N)	49.6852 ± 0.0004	49.998	50.0056 ± 0.0003
Dynamic mass (kg)	27.	1.	$\simeq 0.4$
Absolute magnitude	−3.5	−14.7	−3.2
Slope (°)	40.30 ± 0.03	—	39.67 ± 0.03
Total length (km) / Duration (s)	91.59 / 4.22		
Ablation coefficient (s^2km^{-2})	0.0215 ± 0.006 (without fragmentation)		
EN stations No.	14 Červená hora, 16 Lysá hora		
Radiant data (J2000.0)			
	Observed	Geocentric	Heliocentric
Right ascension (°)	3.46 ± 0.03	0.85 ± 0.03	—
Declination (°)	13.74 ± 0.03	10.77 ± 0.03	—
Ecliptical longitude (°)	—	—	310.186 ± 0.015
Ecliptical latitude (°)	—	—	5.335 ± 0.019
Initial velocity (km/s)	23.112 ± 0.006	20.481 ± 0.007	36.488 ± 0.011
Orbital data (J2000.0)			
a (AU)	2.019 ± 0.004	ω (°)	268.39 ± 0.07
e	0.7027 ± 0.0004	Ω (°)	185.45401 ± 0.00001
q (AU)	0.6001 ± 0.0004	i (°)	6.48 ± 0.02
Q (AU)	3.437 ± 0.007	Shower	—

* Time of the fireball is given for the brightest point from radiometric record taken at the Ondřejov Observatory.

Coordinates of the impact point for the 400 g meteorites:
Longitude: $19\overset{\circ}{.}3598$ E Latitude: $50\overset{\circ}{.}0926$ N

Ongoing meteor work

Polish Visual Meteor Database 1999–2001

Kamil Złoczewski, [1] *Michał Jurek* [2] *and Konrad Szaruga* [3]

A summary of 1999–2001 visual observations collected by the Polish Comet and Meteors Workshop is presented. In total, during $4294^{\mathrm{h}}.41$ effective observing hours, 29 571 meteors were seen and plotted onto gnomonic star maps by 80 observers. The date, time, magnitude, angular velocity, and equatorial coordinates for each observed event are given. The full data for 1999–2001 as well as 1996–1998 of the Polish Visual Database (PVMDB) are accessible via Internet.

Received 2003 November 22

1 Introduction.

The Polish Comets and Meteors Workshop (CMW) has been cooperating with the International Meteor Organization (IMO) since 1994. During the first two years, we were making mostly visual observations of major showers without plotting the meteors onto gnomonic star maps. Over time the experience of our observers grew and, in 1996, we decided to start visual observations with plotting.

Every year, a complete set of our observations is sent to the IMO. In previous years it was made by mail but nowadays is made by e-mail in electronic form. They are included in the IMO Visual Meteor Database (VMDB) (see, for example (Arlt, 2000)). The VMDB contains information about hourly rates and magnitude distributions of meteor showers included in the IMO Working List of the Meteor Showers. Thus the errors made by the observers are included in the VMDB and its format gives no possibility of analysing poorly known and weak meteor showers.

The solution to the problem is a full database containing all quantities describing a meteor event including its equatorial coordinates and angular velocity. That has been already done for PVMDB 1996–1998 (Olech et al., 2000). This publication is a natural continuation of our previous work and adds three additional years to our database.

In Table 1 we summarize CMW visual work in the years 1996–2001. In total, 43 656 meteors were seen by 98 observers during $6622^{\mathrm{h}}.53$ effective observing hours. Observations of the 1999–2001 database comprise 64.69 % of the whole PVMDB, which gives a better coverage of meteor activity in these years. Our database is now very attractive material for every meteor investigator and it is a potential source of many discoveries in small shower research.

Table 2 shows a full list of the CMW observers with their effective observing time and number of meteors plotted in each of the years 1999–2001.

2 Coordinates files.

The files `coor99.txt`, `coor00.txt` and `coor01.txt`, where the digits show the year, contain data for each observed meteor. These are data such as the date of appearance, meteor number, magnitude, angular velocity (in letter scale from A to F in `coor99.txt`, `coor00.txt` and numerical angular scale in `coor01.txt`), time of appearance, equatorial coordinates of the the beginning and end, IMO code of the observer and three-letter ID code. In the file `coor01.txt`, angular velocity is described in degrees per second which is due to different scales (integer and half) used by our observers since 2001.

Figure 1 shows a small sample of such a file.

The ID code shown in last column of the `coor??.txt` file is used for connecting each meteor with the information about observation stored in the `head??.txt` file. The time of appearance of a meteor, when is not given exactly in the report form, is assumed as the middle time of each observing period. All equatorial coordinates were entered using CooReader software (Samujłło & Olech, 2000); the main work was done during CMW summer observing camps.

Table 1 – The grand total of the PVMD in the years 1996–2001

Year	Observers	T_{eff}	Meteors
1996	18	$247^{\mathrm{h}}.86$	1508
1997	25	$849^{\mathrm{h}}.41$	5269
1998	31	$1230^{\mathrm{h}}.85$	7308
1999	33	$1595^{\mathrm{h}}.00$	11262
2000	43	$1647^{\mathrm{h}}.41$	10932
2001	49	$1052^{\mathrm{h}}.00$	7377
Total	98	$6622^{\mathrm{h}}.53$	43656

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[3] *Warsaw University Observatory, Al. Ujazdowskie 4, 00-478 Warszawa, Poland. Email:* kszar@tempac.fuw.edu.pl

Table 2 – Total effective observing time in hours (T_{eff}) and number of meteors plotted (N) per observer during the years 1999–2001

Observer	Code	1999		2000		2001		Total	
		T_{eff} [h]	N	T_{eff} [h]	N	T_{eff} [h]	N	T_{eff} [h]	N
Dariusz Dorosz	DORDA	106.06	846	268.30	2371	140.83	1074	515.19	4291
Tomasz Fajfer	FAJTO	305.07	3139	175.50	1441	24.50	163	505.07	4743
Krzysztof Mularczyk	MULKR	184.32	998	242.73	1267	19.12	59	446.17	2324
Jarosław Dygos	DYGJA	209.43	1101	45.07	253			254.50	1354
Karolina Pyrek	PYRKA	112.41	564	133.67	600			246.08	1164
Ewa Dygos	DYGEW	99.32	595	100.77	579			200.09	1174
Konrad Szaruga	SZAKO	119.68	685	51.48	312	26.31	222	197.47	1219
Maciej Kwinta	KWIMA	70.48	538	60.24	382	38.58	429	169.30	1349
Anna Lemiecha	LEMAN			3.00	15	123.71	730	126.71	745
Piotr Nawalkowski	NAWPI	12.34	122	42.91	269	38.20	246	93.45	637
Arkadiusz Olech	OLEAR	45.18	499	13.45	108	34.75	350	93.38	957
Krzysztof Socha	SOCKR	40.50	242	4.20	0	39.08	457	83.78	699
Mariusz Lemiecha	LEMMA				752	80.00	460	80.00	1212
Andrzej Skoczewski	SKOAN	57.50	406	22.69	145			80.19	551
Wojciech Szewczyk	SZEWO			51.30	357	26.42	219	77.72	576
Aleksander Witczak	WITAL			74.51	265	2.00	4	76.51	269
Wojciech Jonderko	JONWO	2.00	5	13.95	64	45.85	248	61.80	317
Jarosław Nocoń	NOCJA	18.56	110	41.45	359			60.01	469
Krzysztof Wtorek	WTOKR			33.00		23.00	150	56.00	150
Michał Goraus	GORMI					53.06	420	53.06	420
Marta Puch	PUCMA			52.42	218			52.42	218
Piotr Szakacz	SZAPI	17.83	113	32.73	239			50.56	352
Izabela Fitoł	FITIZ	21.00	183	27.75	86			48.75	269
Mariusz Wiśniewski	WISMA	14.95	146	18.85	182	5.80	77	39.60	405
Łukasz Mikuć	MIKLU			4.10	12	31.29	252	35.39	264
Łukasz Kowalski	KOWLU					35.53	219	35.53	219
Marcin Konopka	KONMA	29.41	188					29.41	188
Konrad Lotczyk	LOTKO			25.30	116	1.83	3	27.13	119
Marcin Gajos	GAJMR	20.00	109	6.83	49			26.83	158
Łukasz Harhura	HARLU					26.13	216	26.13	216
Julita Thamm	THAJU					25.38	161	25.38	161
Rafał Michalski	MICRF					24.58	223	24.58	223
Kamil Złoczewski	ZLOKA	12.00	30	7.60	32	4.00	13	23.60	75
Tomasz Frontczak	FROTO					20.66	137	20.66	137
Aleksander Trofimowicz	TROAL	20.08	92					20.08	92
Tomasz Kowalski	KOWTO					18.41	97	18.41	97
Andrzej Kotarba	KOTAN					18.68	112	18.68	112
Dominik Stelmach	STEDM	8.65	48	8.60	42			17.25	90
Arkadiusz Witas	WITAR			15.12	57	1.42	6	16.54	63
Mateusz Kucharski	KUCMA					15.16	83	15.16	83
Artur Pilarczyk	PILAR					15.52	76	15.52	76
Mateusz Wysocki	WYSMA					14.50	82	14.50	82
Tomasz Mich	MICTF					13.05	49	13.05	49
Michał Kozak	KOZMI			13.00	36			13.00	36
Michał Jurek	JURMC	7.13	40	6.84	55			13.97	95
Łukasz Biegun	BIELU			5.79	31	7.14	26	12.93	57
Mariola Czubaszek	CZUMA	11.96	127					11.96	127
Magdalena Gawlas	GAWMA			4.34	12	6.77	28	11.11	40
Luiza Wojciechowska	WOJLU	11.50	68					11.50	68
Cezary Gałan	GALCE	10.17	69					10.17	69
Beata Czmut	CZMBE	10.50	61					10.50	61
Łukasz Kamiński	KAMLU					9.17	219	9.17	219
Robert Sołtys	SOLRO	7.50	87					7.50	87
Piotr Łasiński	LASPI			7.00	48			7.00	48
Łukasz Sanocki	SANLU	2.97	13	4.43	34			7.40	47
Anna Pachołek	PACAN			7.21	18			7.21	18
Dominik Gawlas	GAWDO			4.08	35	2.10	19	6.18	59
Mirosław Bogusz	BOGMI					5.50	43	5.50	43
Anna Puzio	PUZAN					5.82	39	5.82	39
Sławomir Witas	WITSL			4.45	15			4.45	15
Mirosław Należyty	NALMI			4.05	41			4.05	41
Michał Marek	MARMI					4.92	25	4.92	25
Marcin Klimczak	KLIMA					3.50	15	3.50	15
Łukasz Remiszewski	REMLU					3.84	13	3.84	13
Krzysztof Dwork	DWOKR					3.00	17	3.00	17
Karol Kania	KANKR					3.00	6	3.00	6
Gabriel Wlazłowski	WLAGA	3.00	6					3.00	6
Dorota Pietruszko	PIEDO			3.41	21			3.41	21
Piotr Masoń	MASPI					2.00	8	2.00	8
Maciej Reszelski	RESMA	1.50	13			1.20	11	2.70	24
Łukasz Woźniak	WOZLU					2.02	14	2.02	14
Jan Bielicki	BIEJA					2.00	12	2.00	12
Anna Witas	WITAN			2.41	6			2.41	6
Wojciech Kosiarek	KOSWO					1.25	18	1.25	18
Urszula Gawlas	GAWUR			1.58	3			1.58	3
Katarzyna Skoczewska	SKOKA			1.30	6			1.30	6
Katarzyna Bożek	BOZKA	1.00	15					1.00	15
Grzegorz Calek	CALGR					1.02	3	1.02	3
Gracjan Maciejewski	MACGR	1.00	4					1.00	4
Krzysztof Łoś	LOSKR					0.40	1	0.40	1
Total		1595.00	11262	1647.41	10932	1052.00	7377	4294.00	29571

3 Header files.

The files `head99.txt`, `head00.txt` and `head01.txt` contain information about each observing run, such as the ID code allowing one to connect each observing period with data on meteors presented in the coordinates files, IMO code of observer, longitude and latitude of place of observation, date, UT time of beginning and end of observation, solar longitude (interpolation based on tables published by IMO) of the middle time of each run, equatorial coordinates of observed field, effective time of observation, cloud correction factor F, stellar limiting magnitude estimated by the naked eye and the IMO code of the place of observation.

Figure 2 shows a small sample of such file.

4 Summary.

We have presented a summary of the 1999–2001 visual observations made by CMW. In total, 29 571 meteors were observed during $4294^{\mathrm{h}}.410$ effective observing hours collected by 80 observers. The date, time, magnitude, angular velocity, and equatorial coordinates for each observed event are given. The full data for 1999–2001 in the Polish Visual Database (PVMDB) with data format description is accessible via Internet at `http://www.astrouw.edu.pl/~olech/VIS/` or `http://www.pkim.org/pliki.shtml`.

The 2002–2003 visual data are still under review and will be published soon.

Acknowledgments

We would like to thank all the observers who sent their observations and all the participants of CMW summer camps who spent hundreds of hours working with CooReader. This work was supported by KBN grant 2 P03D 003 25 to K. Mularczyk.

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```
2001 01 01/02 001   0.0 17 20:52 059.24  -12.58 054.09  -15.31 LEMMA IDA
2001 01 01/02 002   3.0 17 20:52 047.63   28.42 050.02   21.54 LEMMA IDA
2001 01 12/13 001   3.0 15 19:30 087.62   11.60 087.38   07.64 LOTKO IDB
2001 01 12/13 002   3.5 10 19:30 080.36   11.70 084.28   12.18 LOTKO IDB
2001 01 12/13 003   1.0 10 19:30 076.81   09.82 067.43   05.29 LOTKO IDB
2001 01 17/18 001   0.5 15 21:03 080.76   26.84 075.08   11.22 SZEWO IDC
2001 01 17/18 002   1.5 05 21:03 111.30   20.76 108.52   21.10 SZEWO IDC
2001 01 19/20 001   4.0 30 03:35 140.53   46.13 133.51   45.45 DORDA IDD
2001 01 19/20 002   4.0 30 03:35 171.76   56.76 160.68   63.95 DORDA IDD
2001 01 19/20 003   4.5 20 03:35 114.53   49.96 110.94   48.61 DORDA IDD
```

Figure 1 – A small sample of a coordinate file.

```
IDA LEMMA  22.6 E 51.8 N 01 01 01 2020 2125 281.515 075  30 1.00 1.00 6.70 34078
IDB LOTKO  20.9 E 52.0 N 12 01 01 1855 2008 292.622 090  15 1.83 1.00 5.80 34079
IDC SZEWO  18.7 E 50.0 N 17 01 01 2047 2120 297.779 098  00 0.50 1.00 5.30 34080
IDD DORDA  18.8 E 54.6 N 20 01 01 0305 0410 300.094 135  45 1.00 1.00 6.80 34074
IDE LEMMA  22.6 E 51.8 N 23 01 01 1840 1942 303.807 068  30 1.00 1.00 6.60 34078
IDF LEMMA  22.6 E 51.8 N 23 01 01 2000 2032 303.895 068  30 1.00 1.00 6.70 34078
IDG LEMAN  22.6 E 51.8 N 24 01 01 1900 2005 304.840 124  62 1.00 1.00 6.70 34078
IDH LEMAN  22.6 E 51.8 N 24 01 01 2050 2155 304.917 124  62 1.00 1.00 6.70 34078
IDI LEMAN  22.6 E 51.8 N 24 01 01 2230 2315 305.023 124  62 0.67 1.00 6.80 34078
IDJ LEMMA  22.6 E 51.8 N 24 01 01 1900 2005 304.840 113  30 1.00 1.00 6.60 34078
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Figure 2 – A small sample of a header file.

The November–December δ-Arietids and asteroid 1990 HA: on the trail of a meteoroid stream with meteorite-sized members

Marco Langbroek [1]

Four slow meteors among multistation video records obtained by the Dutch Meteor Society in November 1995 have been tentatively associated with McCrosky & Posen's December δ-Arietids by de Lignie and Betlem. Greaves suggested a connection between these meteors and Near Earth Asteroid 1990 HA. This connection is strengthened in this contribution, and a meteor orbit search among the DMS photographic & video orbit databases and the IAU photographic orbit database employing Drummond's D' criterion yields many more members and is used here to redefine the δ-Arietid stream. The stream, which shows a northern and southern branch, appears active between at least November 15 and January 4 — an activity period of 1.5 months! The radiant area is very diffuse, some 20°–30° wide, and close to that for the Taurid stream, from which meteors are only distinguished by being evidently slower. Dynamic data on a number of these δ-Arietid meteors obtained by the MORP project strengthen the case for an asteroidal source, as the inferred densities are similar to those typical of stony meteorites. With at least one suspected meteorite dropper, MORP 219, among the stream members, the stream indeed might be a possible source of meteorites. The stream has a daylight twin counterpart in March–April, of which one morning twilight member might have been photographed by the Prairie Networks in March 1968.

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1 Introduction

In 1997 Marc de Lignie and Hans Betlem published a set of orbits and radiants obtained by multistation video observations during the 1995 DMS Leonid expedition to Spain (De Lignie & Betlem, 1997). Within the orbit dataset they found a small cluster of four slow meteors, which they cautiously linked to a stream known from the Harvard project: the δ-Arietids of McCrosky and Posen (1959); see also (Kronk, 1988). This stream was found to be active near December 8, with a radiant slightly south of that of the four DMS meteors. The four DMS video meteors agree with McCrosky and Posen's δ-Arietids in their direction of perihelion, but differ somewhat in their perihelion distance. A test with Drummond's D' criterion (Drummond, 1981) delivers a value of 0.119 with McCrosky and Posen's δ-Arietid orbit, and 0.124 with Lindblad's δ-Arietid orbit (Lindblad, 1971). Both D' values are just beyond the limit normally accepted for a stream association, which is 0.105. But should we discard the option of a link to this stream? This actually depends on how well defined the average (and slightly different) stream orbits are from the photographic data given by (McCrosky & Posen, 1959) and (Lindblad, 1971). Below, arguments will be given which do link these meteors to the δ-Arietid stream, and which strengthen a link of this stream with asteroid 1990 HA. Dynamic data on a number of meteors from this stream point to asteroidal material and might even suggest that the stream is a potential source of meteorites.

2 The δ-Arietids and asteroid 1990 HA

During a test run with an Excel application for D' criterion matches of streams to possible parent objects, the four 'δ-Arietid' DMS video orbits from (De Lignie & Betlem, 1997) were found to associate to within $D' = 0.105$ with the five Near-Earth Asteroids in Table 1. Among the five, and providing the best fit ($D' = 0.073$), is Near Earth Asteroid 1990 HA. This asteroid was discovered by A. Mrkos at the Klet observatory (Mrkos, 1990) and moves in an orbit which brings it close enough to the earth's orbit to make meteor activity theoretically possible. Indeed, a meteor stream associated with asteroid 1990 HA was found earlier by Štohl and Porubčan (1993), but without them apparently recognizing this stream as the δ-Arietids. The possible relationship between the asteroid and the four 'δ-Arietid' meteor orbits in the DMS video-database was however proposed earlier by John Greaves (2000).

Table 1 – Asteroids associating with Drummonds' D' criterion < 0.105 with the average orbit of four DMS video meteors classified as 'δ-Arietids N' in (De Lignie & Betlem, 1997). See also (Greaves, 2000).

Asteroid	D'
1990 HA	0.073
2002 VR85	0.081
2000 UL11	0.087
2001 WM15	0.093
5731 Zeus	0.096

Using the software developed by Neslusan et al. (1998), the asteroid yields a theoretical maximum around December 5, with the radiant at $\alpha = 53°$, $\delta = +22°$ and good values for the encounter geometry (D-Disc = 0.063: see Neslusan et al., 1998). The values correspond closely to the velocity, radiant and maximum date of McCrosky and Posen's δ-Arietids (McCrosky & Posen, 1959). Thus a possible link appears to emerge between the δ-Arietids and the four DMS video orbits from (De Lignie & Betlem, 1997). The link is valid if 1990 HA is the parent object of the stream (or one of the largest objects in the stream), and the core of the stream moves in orbits similar to 1990 HA.

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3 Other meteors associated with the four DMS 'δ-Arietids'

The four video meteors had been associated with each other in (De Lignie & Betlem, 1997) because of their similar radiant positions and velocities, as judged by a simple visual criterion. A stream with such a low geocentric velocity of 16 km/s, however, is expected to have a large and diffuse radiant area up to some 20°–30° in diameter (Štohl & Porubčan, 1993). The simple visual radiant matching criterion used to isolate these four meteors from the dataset, therefore, might have left out other legitimate stream members. A new search was conducted using the full DMS video orbit database, but now associating meteors more formally by using Drummond's D' criterion (Drummond, 1981) with the threshold set at < 0.105. The reference orbit was the average of the original four orbits from (De Lignie & Betlem, 1997). This search extended the sample of matching video meteors to as many as eleven, this including an additional number of other meteors obtained during the same Leonid campaign of 1995 as well as meteors obtained during the Leonid and Geminid campaigns of 1995, 1996 and 1998.

4 Meteors associated with 1990 HA, and the δ-Arietids

As an additional test, a new search was conducted, again using the D' criterion but this time with reference to the orbit of asteroid 1990 HA. This again yielded eleven meteors from the DMS video orbit database, including the original quartet of meteors from (De Lignie & Betlem, 1997). A search through the DMS photographic database added another two meteors to the set. There is a very strong overlap with the data sample found in the earlier search: only three of the previously found meteors (just) fail to meet the 0.105 criterion threshold. The photographic and video meteors which passed the test were obtained in the period between November 17 and January 4 during the Leonid, Geminid and Quadrantid observing campaigns of 1990, 1995, 1996 and 1998. These concern an activity period stretching over some 1.5 months!

The search for meteors associated with 1990 HA was extended to the IAU database of high precision photographic orbits (Lindblad, 1991). This delivered 23 associating orbits, most from the Harvard and MORP projects. These probably concern the same orbits as reported in (Štohl & Porubčan, 1993). Adding all the datasets together yields an impressive number of meteors (Table 2). The sample clearly contains a southern and a northern branch as can be seen from the ω and Ω values. The average values of both the radiant positions and the orbital elements are close to those for the δ-Arietid stream of McCrosky and Posen (1959): the average orbits for both branches compare with D' values of 0.057 and 0.078 to McCrosky and Posen's average orbit. This stream associated with 1990 HA therefore does indeed appear to be the δ-Arietid stream.

The proposal is therefore that both the δ-Arietids of McCrosky and Posen (1959) and the November DMS video meteors cautiously designated 'δ-Arietids' as found in (De Lignie & Betlem, 1997), and extended in this search to include several more meteors from November, December and early January, are linked to Near Earth Asteroid 1990 HA, as suggested by Greaves (2000). Accepting this link and using the IAU database meteors from (Štohl & Porubčan, 1993) and the additional DMS meteor sample reported here, new values for the average δ-Arietid stream orbit are given in Table 2. The southern and northern branches of the stream are now well defined.

5 The δ-Arietid asteroidal debris stream as a possible source of meteorites

The asteroidal origin of the δ-Arietids, as suggested by the possible link with 1990 HA, is corroborated by dynamic data on a number of the δ-Arietid fireballs in Table 2. Dynamic data on a number of the MORP meteors in the sample suggests objects with densities of order 2000–5000 kg/m^3 (2–5 g/cm^3) (Halliday et al., 1996) and considerable initial mass. These are densities typical of asteroidal material, and they are comparable with the densities of stony meteorites. Indeed, the stream might be a source of meteorites. Fireball MORP 219 from Table 2 is believed to have dropped a meteorite with a calculated surviving mass of 290 g on 1975 December 13 (Halliday et al., 1996). The δ-Arietid stream appears to be a stream of asteroidal debris, including significant fragments of high density material.

6 Visual stream characteristics

The stream clearly has a very diffuse radiant area, owing to the low velocity of the meteoroids. Figure 1 shows the wide scatter of radiants of the meteors in Table 2, as plotted on a gnomonic star map, with the dotted line being the ecliptic and the cross being the early December theoretical radiant position of asteroid 1990 HA. In early December the average southern δ-Arietid radiant as defined here is at $\alpha = 48°$, $\delta = +11°$, while the northern radiant is at $\alpha = 43°$, $\delta = +26°$.

The high number of video and photographic orbits from a limited number of years suggests that visual activity of this stream should be detectable. However, the very diffuse character of the radiant area makes this stream a difficult one for visual observers. The radiant area moreover is close to that of the Taurid stream, with which δ-Arietids could potentially be confused. Care should be taken when classifying 'Taurids' during the second half of November and early December, taking explicit notice of the velocities: δ-Arietids are evidently slower than Taurids. The stream should be detectable during both the Leonid and Geminid activity periods. Indeed, a few very slow meteors reported by DMS observers observing from southern Europe during the 2000 Leonid campaign might have been members of this stream.

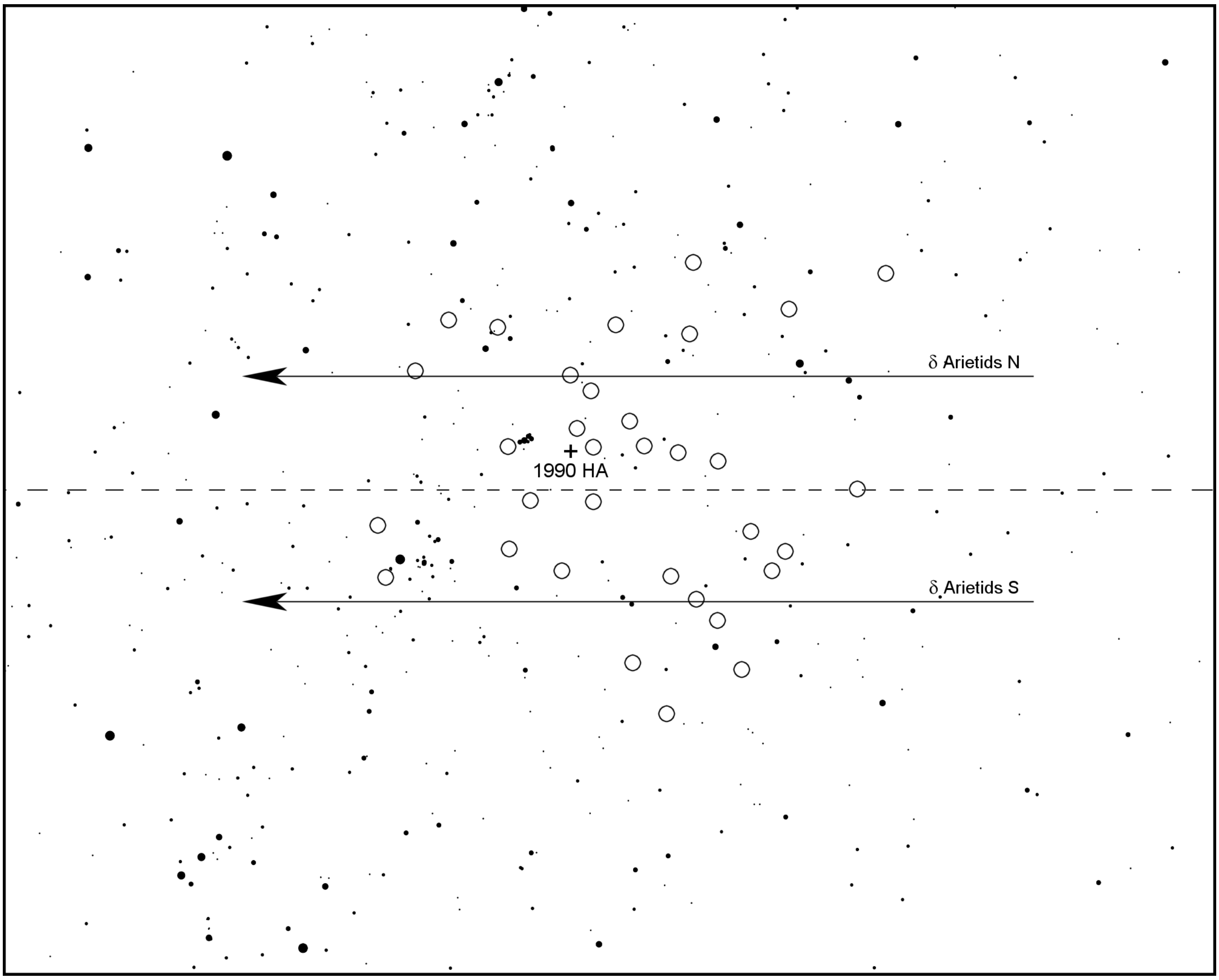

Figure 1 – A gnomonic map of the Taurus region, with the radiant positions of photographic and video meteors (open circles) associated with the orbit of Near Earth Asteroid 1990 HA plotted. The scatter defines the diffuse radiant area of the δ-Arietid stream. The cross marks the December 5th theoretical radiant position of asteroid 1990 HA. The dashed line is the ecliptic. The arrows labeled δ-Arietid N and δ-Arietid S provide some indication of the approximate centerlines and directions of radiant drifts of the northern and southern branch radiants.

7 A twin daylight stream in April

The 1990 HA orbit and the δ-Arietid orbit in Table 2 yield a twin stream occurrence in late March and early April. This is a daylight stream. The encounter conditions with respect to the 1990 HA orbit are even better during this daylight occurrence than during the peak of the night-time δ-Arietids in December. An occasional early member of this March–April twin stream might be detectable during the pre-dawn hours in mid-March, as a part of the diffuse radiant area then just peeps over the horizon. Indeed, one such meteor appears to have actually been photographed by the Prairie Networks on March 19, 1968 (meteor PN 39934, see Table 2), with a radiant altitude of only 16°!

8 Conclusions and summary

Four November DMS video meteor orbits designated as possible δ-Arietids in (De Lignie & Betlem, 1997) and cautiously linked to Near Earth Asteroid 1990 HA by Greaves (2000) can be tied to a much larger sample of meteor orbits from both the DMS and IAU databases by means of the D' criterion. The dataset defines a stream with an orbit very similar to that of asteroid 1990 HA. This stream shows an activity stretching over at least 1.5 months, centered on early December, and a separation into a northern and a southern branch. The center of the activity period, and the average stream branch orbits and radiants, are highly similar to the δ-Arietids of McCrosky and Posen (1959). They compare with D' values of order 0.06–0.08 and it is concluded here that it does concern the same stream.

It is therefore proposed that the suggestion by Greaves (2000) that δ-Arietids have their origin in asteroid 1990 HA is correct, and an improved average orbit for the stream is given (Table 2) based on a large set of high accuracy photographic and video meteors. An asteroidal origin for the stream is further corroborated by dynamic data on a number of the MORP fireballs which are present in the set of orbits (Halliday et al., 1996): their density estimates are similar to stony meteorites, with sometimes sizeable initial masses being present. The dataset even contains one fireball which is thought to have dropped a meteorite. The δ-Arietid stream thus

Table 2a – Meteors from the DMS photographic database, the DMS video database, and the IAU high precision meteor database (Lindblad, 1991), which associate with $D' < 0.105$ with the orbit of asteroid 1990 HA. This set includes the quartet of orbits from (De Lignie & Betlem, 1997), and closely corresponds to the values for McCrosky and Posen's δ-Arietid stream (McCrosky & Posen, 1959).

Southern branch

Code	Year	Month	Day	q	a	e	i	ω	Ω	ϖ	V_g	V_h	V_∞	α Geo	δ Geo
MORP 615 168I	80	11	17.2	0.760	2.744	0.723	3.2	63.2	54.6	117.8	17.10	38.40	20.50	39.5	8.6
DMS V98320	1998	11	17.7	0.792	2.23	0.644	2.14	60.58	55.1766	115.76	14.9	37.4	18.4	37.97	9.75
DMS V98322	1998	11	17.7	0.711	2.39	0.703	4.83	71.35	55.1831	126.53	18.1	37.7	21.1	45.98	8.08
DMS V98335	1998	11	17.8	0.757	2.46	0.692	1.64	64.72	55.2411	119.96	16.6	37.9	19.7	40.11	12.07
DMS 1995211	1995	11	18.1	0.7518	2.7	0.7243	7.3	64.5	55.2667	119.81	17.74	38.33	20.79	44.06	1.90
Harvard 09375 383J	53	11	26.2	0.679	2.240	0.697	3.8	76.1	63.6	139.7	18.72	37.42	21.96	56.2	13.0
PN 39462 108F	66	12	3.4	0.786	2.346	0.665	0.4	59.5	70.6	130.1	15.42	37.69	18.70	52.2	17.9
MORP 756 201I	81	12	6.1	0.783	2.469	0.683	6.6	60.4	73.5	133.9					
Harvard 05554 326H	52	12	9.3	0.894	2.677	0.666	3.5	39.7	77.0	116.8	12.34	38.32	16.47	44.8	6.0
Harvard 02262 109W	50	12	10.3	0.854	3.260	0.738	5.6	46.5	77.6	124.1	14.82	39.08	18.40	52.3	4.5
MORP 218 042I	75	12	11.2	0.798	2.185	0.635	2.0	59.1	78.3	137.4	14.70	37.40	18.50	60.1	15.7
MORP 521 153I	79	12	11.3	0.824	2.731	0.698	0.5	52.4	78.7	131.1	15.30	38.10	18.80	57.5	19.2
MORP 219 043I	75	12	12.2	0.822	2.382	0.655	1.0	54.2	79.4	133.6					
DMS 1990103	1990	12	13.0	0.8870	3.3	0.7340	2.5	40.1	80.7840	120.88	13.39	39.19	17.25	47.47	10.38
PN 40204 249F	68	12	13.5	0.742	1.876	0.604	1.3	69.4	81.3	150.7	15.56	36.44	18.80	70.3	19.4
Harvard 12691 348P	58	12	14.2	0.898	2.748	0.673	6.0	38.5	81.5	120.0	12.61	38.44	16.90	50.7	−0.1
MORP 648 170I	80	12	16.2	0.815	3.174	0.743	1.2	53.2	84.2	137.4					
MORP 528 154I	79	12	22.3	0.798	2.804	0.716	3.1	56.8	89.5	146.3	16.10	38.60	19.50	70.3	15.3
AVERAGE				0.797	2.598	0.689	3.1	57.2	71.7	129.0	14.4	35.5	17.7	47.8	+10.8
1990 HA				0.779	2.569	0.697	3.9	(308.3)	(184.7)	133.1	16.1			53.0	+22.4

Table 2b – Meteors from the DMS photographic database, Nothern branch. For details see caption to Table 2a.

Northern branch

Code	Year	Month	Day	q	a	e	i	ω	Ω	ϖ	V_g	V_h	V_∞	α Geo	δ Geo
Harvard 05337 305H	52	11	7.1	0.758	2.594	0.708	8.4	244.3	224.5	108.9	17.44	38.04	20.90	22.9	27.6
Harvard 09252 372J	53	11	7.5	0.735	2.292	0.679	0.0	248.8	224.7	113.5	16.87	37.44	19.84	31.1	12.7
Dushanbe 84394 132D58	11	15.8	0.670	2.660	0.748	7.7	255.7	232.9	128.6	20.20	38.20	22.90	39.9	28.7	
DMS V95514	1995	11	18.0	0.640	2.21	0.711	3.54	261.27	235.2618	136.53	19.8	37.3	22.6	47.32	23.54
DMS V95518	1995	11	18.0	0.688	2.39	0.713	1.74	254.32	235.2766	129.60	18.7	37.7	21.6	43.98	19.94
DMS V95650	1995	11	21.2	0.814	2.82	0.712	6.22	234.88	238.4719	113.35	15.7	38.5	19.0	31.04	27.70
MORP 516 150I	79	11	22.3	0.673	1.825	0.631	2.0	259.9	238.9	138.8	17.40	36.20	20.50	51.0	22.3
DMS V95674	1995	11	22.1	0.671	2.99	0.776	8.38	254.57	239.3277	133.90	20.8	38.7	23.4	46.14	31.27
DMS V95701	1995	11	22.1	0.710	2.30	0.692	1.95	251.85	239.4018	131.25	17.8	37.6	20.7	46.66	21.26
DMS V95716	1995	11	22.1	0.680	1.83	0.629	4.43	258.96	239.4065	138.36	17.4	36.2	20.3	49.95	26.76
PN 39457 106F	66	11	28.1	0.712	2.325	0.694	5.1	251.4	245.2	136.6	18.00	37.62	21.31	51.4	28.4
PN 39093 032F	65	11	29.3	0.829	2.472	0.665	7.4	233.1	246.6	119.7	14.79	37.93	18.38	37.5	33.8
EN 144 144E	83	12	4.7	0.871	2.300	0.621	0.8	226.2	251.2	117.4	12.30	37.60	16.80	40.9	18.3
Odessa 094 079O	58	12	4.9	0.722	2.490	0.709	1.9	249.1	252.1	141.2	17.90	38.00	21.10	58.4	23.9
Odessa 100 085O	58	12	8.7	0.694	2.190	0.683	5.3	254.2	256.0	150.2	18.30	37.50	21.70	65.2	31.0
Harvard 05552 325H	52	12	9.3	0.824	2.596	0.682	2.1	233.2	257.0	130.3	14.69	38.19	18.33	52.0	24.1
DMS V96187	1996	12	14.0	0.787	2.56	0.693	6.21	239.40	262.3429	141.74	16.3	38.2	19.6	61.37	34.49
DMS V95021	1995	1	4.0	0.928	2.59	0.642	3.78	211.19	283.2726	134.46	10.9	38.2	15.4	56.98	33.34
AVERAGE				0.745	2.414	0.688	4.3	245.7	244.5	130.2	17.0	37.7	20.2	43.2	+26.1
1990 HA				0.779	2.569	0.697	3.9	308.3	184.8	133.1	16.1			53.0	+22.4

Daylight counterpart, early member

Code	Year	Month	Day	q	a	e	i	ω	Ω	ϖ	V_g	V_h	V_∞	α Geo	δ Geo
PN 39934 220F	68	3	19.2	0.826	2.336	0.647	9.5	124.4	358.4	122.8	15.02	37.42	18.50	6.6	27.6

appears to be a stream of asteroidal debris of which asteroid 1990 HA might be one of the largest fragments, and might be a potential source of meteorites.

The difficult character of this stream for visual observations, owing to the very diffuse radiant area and nearness of the Taurid radiant area, is stressed. Stream members could be confused with Taurids. The stream has a daylight twin counterpart appearing in March–April.

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Multi-station TV observations of the 2001 Leonids

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Multi-station TV observations by the Damine Meteor Observatory group have been performed with equatorially mounted MCP image intensifiers and CCD video cameras since 1988. On 2001 November 18 we obtained more than one hundred simultaneously photographed meteors. Precise orbits and trajectories were calculated for 21 Leonids. It was found that the radiant positions constitute a small cluster around $\alpha = 154\overset{\circ}{.}4 \pm 0\overset{\circ}{.}27$, $\delta = 21\overset{\circ}{.}5 \pm 0\overset{\circ}{.}29$ (J2000.0). The orbital elements are similar to those of our data from 1995-1997.

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1 Introduction

Predictions for the current return of 55P/Tempel-Tuttle (McNaught & Asher, 1999) have proved right. The peak ZHR of visual observations in Japan was announced as about 3000 obtained from a real one-hour rate at $17^{\rm h}40^{\rm m}$–$18^{\rm h}40^{\rm m}$ on 2001 November 18 by the Nippon Meteor Society (Iiyama, 2002). Multi-station TV observations by the Damine Meteor Observatory (DMO) group have been performed with equatorially mounted MCP image intensifiers and CCD video cameras since 1988. We recorded faint meteors simultaneously at multiple stations and calculated their orbits and trajectory parameters (Suzuki et al., 1994a; Suzuki et al., 1994b; Suzuki et al., 1999a; Suzuki et al., 1999b; Yoshida et al., 1999). This paper describes the results of Leonid meteor observations in 2001 obtained by the DMO group.

2 Observations

On 2001 November 18, multi-station TV observations by the DMO group were made at four observational sites. The locations and TV observational systems are given in Table 1.

Our TV observational systems were equipped with MCP image intensifiers (Hamamatsu VP1366P, type S25), middle focal length low f-ratio telephoto lenses, CCD video cameras set up on equatorial mounts, and video-cassette recorders. The cameras were aimed about 10° to 15° from the radiant point of the Leonids, and the cameras were guided by motor driven systems. Thus we could record very faint meteors because of the slow angular velocity.

3 Data reduction

S. Suzuki used a black and white CCD camera and recorded with a Digital Video Camera to obtain faint meteors. Video data were digitized at a resolution of 640 × 480 pixels with a personal computer (CPU: Pentium III). We measured about 20 reference stars around each meteor path to determine the position of the meteor. The mean positional error was 55″ in this study. The atmospheric trajectory parameters and the heliocentric orbital elements were calculated with the MEXY4 and ORBIT3 programs written by M. Ueda. The D-criterion (Southworth & Hawkins, 1963) and the D'-criterion (Drummond, 1979) were calculated with the DHANT program programmed by Y. Shigeno.

4 Data obtained

The results are listed in Table 2. The trajectories and orbits of 21 meteors are shown.

The apparent magnitude was estimated by comparison with nearby stars as the meteor moved across the screen, and was converted to absolute magnitude.

5 Discussion

5.1 Radiant points

The mean radiant point of the 21 Leonid meteors is given by $\alpha = 154\overset{\circ}{.}5 \pm 0\overset{\circ}{.}62$, $\delta = +21\overset{\circ}{.}3 \pm 0\overset{\circ}{.}84$ (J2000.0). Figure 1 shows the distribution of the radiant points of the central meteors. It is found that the radiant positions constitute a small cluster. The cluster is around $\alpha = 154\overset{\circ}{.}4 \pm 0\overset{\circ}{.}27$, $\delta = 21\overset{\circ}{.}5 \pm 0\overset{\circ}{.}29$ (J2000.0).

Table 1 – Location and the observational equipment.

Observer		Suzuki S.	Akebo T.	Suzuki K.	Yoshida T.
Location	Longitude	137°30′15″E	137°13′28″E	137°19′26″N	137°31′48″E
	Latitude	34°54′29″N	34°54′38″N	34°48′47″N	35°03′54″N
Lens		85 mm $f/1.2$	85 mm $f/1.4$	135 mm $f/2$	135 mm $f/2$
Field of view		13° × 10°	13° × 10°	10° × 10°	8° × 6°
Image intensifier		V1366P	V1366P	V1366P	V1366P
Video camera		WV-BD400	B05-3M	GR-S95	WV-BD400
Recording format		DVC	DVC	VHS	S-VHS

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[2] The Nippon Meteor Society, Damine Meteor Observatory group

Table 2 – The trajectories (top) and orbital elements (bottom) of 21 Leonid meteors. The top half of the table shows appearance time (UT): all were on 2001 November 18; α, δ: geocentric radiant point; Q: convergence angle (the angle between the meteor trails from the two stations); l: trail length (km), H_b: beginning height, H_m: height of maximum brightness, H_e: ending height (meteors marked '*' ended out of frame), m: apparent magnitude, M: absolute magnitude. The bottom half of the table shows V_g: geocentric velocity; V_h: heliocentric velocity; orbital elements; D- and D'-criteria.

		Radiant points and error							Meteor heights (km)			Magnitude	
No.	Time(UT)	α	δ	$\Delta\alpha$	$\Delta\delta$	Q	l	$\lambda_\odot$	H_b	H_m	H_e	m	M
1	$17^{h}50^{m}03^{s}$	154.7	21.2	0.10	0.12	21.3	35	236.443	118	101	93	6	6.0
2	$17^{h}54^{m}29^{s}$	153.2	22.8	0.08	0.06	16.9	47	236.446	117	97	86	5	5.4
3	$18^{h}11^{m}23^{s}$	155.5	19.6	0.15	0.28	15.5	34	236.458	144	127	*114	3	3.0
4	$18^{h}11^{m}33^{s}$	154.1	21.8	0.03	0.06	23.7	53	236.458	135	101	95	3	3.1
5	$18^{h}12^{m}22^{s}$	154.3	21.9	0.01	0.03	28.7	85	236.459	153	108	90	2	2.4
6	$18^{h}14^{m}40^{s}$	154.5	20.4	0.11	0.29	25.4	16	236.460	106	97	92	8	8.2
7	$18^{h}19^{m}17^{s}$	154.7	21.6	0.15	0.66	13.3	10	236.464	114	100	96	5	5.5
8	$18^{h}20^{m}54^{s}$	154.9	20.1	0.38	0.83	18.5	9	236.465	126	106	91	6	6.2
9	$18^{h}21^{m}16^{s}$	154.3	21.1	0.10	0.14	28.5	32	236.465	120	101	96	5	5.3
10	$18^{h}21^{m}57^{s}$	154.5	21.2	0.37	0.46	27.8	9	236.465	105	101	98	7	7.4
11	$18^{h}31^{m}06^{s}$	154.6	21.6	0.03	0.08	40.7	44	236.472	127	105	93	1	1.6
12	$18^{h}31^{m}13^{s}$	154.0	21.7	0.13	0.09	20.4	46	236.472	127	106	91	3	3.6
13	$18^{h}32^{m}27^{s}$	154.5	21.2	0.17	0.24	17.6	36	236.473	158	119	*113	1	1.3
14	$18^{h}33^{m}07^{s}$	154.4	21.7	0.05	0.09	37.5	51	236.473	132	102	92	3	3.7
15	$18^{h}35^{m}09^{s}$	154.1	21.9	0.08	0.10	25.4	36	236.475	134	106	97	2	2.4
16	$18^{h}57^{m}59^{s}$	154.5	21.4	0.03	0.03	60.4	53	236.491	135	102	91	2	2.8
17	$18^{h}58^{m}12^{s}$	153.3	21.8	0.45	0.22	11.3	39	236.491	143	104	93	4	4.7
18	$19^{h}04^{m}46^{s}$	154.9	21.3	0.26	0.21	27.4	18	236.495	102	88	83	6	6.7
19	$19^{h}10^{m}35^{s}$	155.0	20.7	0.08	0.21	33.6	18	236.499	117	103	*99	4	4.5
20	$19^{h}34^{m}22^{s}$	154.0	22.2	0.09	0.07	34.2	37	236.516	128	95	87	1	1.9
21	$19^{h}38^{m}13^{s}$	155.9	19.4	0.10	0.21	30.6	33	236.519	138	110	*108	1	1.5
Average		154.5	21.3	0.14	0.21	26.6	35.3	236.474	127.6	103.8	92.0	3.7	4.1
Standard deviation		0.62	0.84										

		Velocities (km/s)		Orbital elements							D, D' criteria	
No.	Time(UT)	V_g	V_h	a	e	q	Ω	i	ω	P	D	D'
1	$17^{h}50^{m}03^{s}$	69.8	40.4	5.55	0.823	0.984	236.44	162.5	172.0	13.08	0.09	0.05
2	$17^{h}54^{m}29^{s}$	70.5	41.3	9.74	0.898	0.988	236.45	161.0	179.1	30.38	0.09	0.03
3	$18^{h}11^{m}23^{s}$	70.6	41.2	8.75	0.888	0.978	236.46	164.8	167.8	25.9	0.10	0.03
4	$18^{h}11^{m}33^{s}$	70.5	41.2	9.06	0.891	0.987	236.46	162.2	175.1	27.28	0.03	0.01
5	$18^{h}12^{m}22^{s}$	70.1	40.8	6.79	0.855	0.986	236.46	161.8	174.6	17.69	0.05	0.03
6	$18^{h}14^{m}40^{s}$	70.7	41.2	9.14	0.892	0.984	236.5	164.1	172.1	27.6	0.04	0.01
7	$18^{h}19^{m}17^{s}$	70.5	41.3	9.71	0.899	0.985	236.5	162.1	173.0	30.3	0.02	0.01
8	$18^{h}20^{m}54^{s}$	68.7	39.3	6.52	0.849	0.982	236.5	164.2	170.0	16.6	0.09	0.04
9	$18^{h}21^{m}16^{s}$	70.1	40.8	6.70	0.853	0.985	236.5	163.0	173.3	17.4	0.05	0.03
10	$18^{h}21^{m}57^{s}$	70.7	46.8	6.99	0.859	0.985	236.5	162.7	173.1	18.5	0.05	0.03
11	$18^{h}31^{m}06^{s}$	69.6	40.4	5.32	0.815	0.985	236.5	162.1	173.1	12.3	0.09	0.05
12	$18^{h}31^{m}13^{s}$	69.9	41.8	5.97	0.835	0.987	236.5	162.3	175.2	14.6	0.07	0.04
13	$18^{h}32^{m}27^{s}$	70.2	41.0	6.92	0.858	0.985	236.5	162.8	173.1	18.2	0.05	0.03
14	$18^{h}33^{m}07^{s}$	69.9	40.6	6.08	0.838	0.986	236.5	162.0	173.9	15.0	0.07	0.04
15	$18^{h}35^{m}09^{s}$	70.1	40.9	7.07	0.860	0.987	236.5	161.8	175.2	18.8	0.05	0.03
16	$18^{h}57^{m}59^{s}$	69.7	40.3	5.02	0.804	0.985	236.5	162.4	172.9	11.3	0.10	0.06
17	$18^{h}58^{m}12^{s}$	69.8	40.4	5.55	0.822	0.988	236.5	162.4	177.5	13.1	0.10	0.05
18	$19^{h}04^{m}46^{s}$	70.5	41.2	9.27	0.894	0.984	236.5	162.5	172.1	28.2	0.03	0.01
19	$19^{h}10^{m}35^{s}$	70.5	41.1	8.57	0.885	0.983	236.5	163.3	170.9	25.1	0.05	0.02
20	$19^{h}34^{m}22^{s}$	70.5	41.2	9.29	0.894	0.987	236.5	161.6	176.2	28.3	0.04	0.01
21	$19^{h}38^{m}13^{s}$	70.4	41.0	7.64	0.872	0.975	236.5	164.8	171.2	21.1	0.07	0.03
Average		70.2	41.2	7.41	0.861	0.985	236.5	162.7	173.4	20.5	0.06	0.03
Standard deviation		0.479	1.394		0.030	0.003	0.021	1.035	2.542	6.460	0.026	0.015

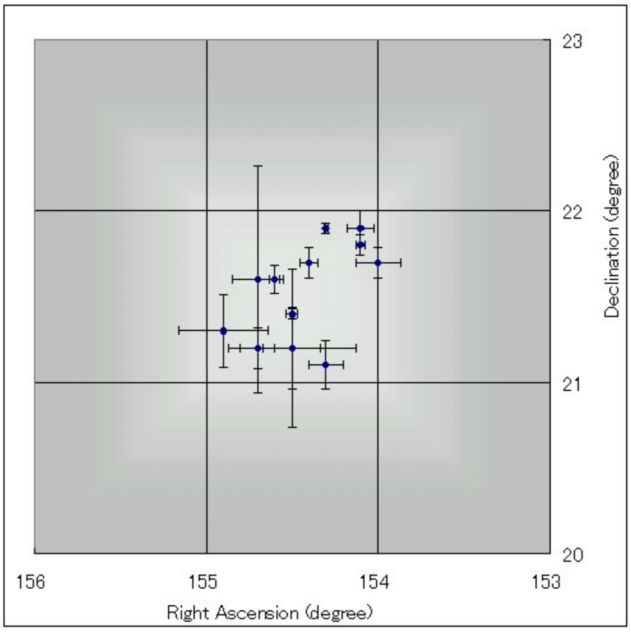

Figure 1 – Geocentric radiant points of the Leonid meteors.

M. Ueda et.al. (2002) analyzed 177 Leonid meteors, the mean radiant point of which is $\alpha = 153\overset{\circ}{.}74 \pm 1\overset{\circ}{.}14$, $\delta = 21\overset{\circ}{.}69 \pm 0\overset{\circ}{.}64$ (J2000.0).

5.2 Meteor heights

We have plotted the beginning height (H_b), height of maximum brightness (H_m) and ending height (H_e) of the Leonid meteors against absolute magnitude in Figure 2. The two lines are the least-squares fits through the data for H_b (upper) and H_e (lower). The ending height shows no relation with absolute magnitude. On the other hand, the beginning height is correlated with absolute magnitude. To compare the relation of H_b and absolute magnitude, we use the data of the 2001 Leonids with those of 1995–1997 Leonids and the 1993 Perseids. These data, shown in Table 3 below, were observed and calculated by the DMO group.

Table 3 – Observed data of the 1995–1997 and 2001 Leonids and 1993 Perseids. H_b: beginning height; M: absolute magnitude; V_g: geocentric velocity (km/s); r: correlation factor.

Shower	H_b	r	Mean V_g
LEO 2001	$-5.59M + 154.7$	0.779	70.2
LEO 1995–97	$-4.52M + 142.8$	0.859	70
PER 1993	$-2.94M + 124.4$	0.792	60

5.3 Orbital elements

The orbital elements of the 2001 Leonids, the 1995–1997 Leonids, the Leonids of the IAU database (1993), and the parent comet (1997) are shown in Table 4 (J2000.0). Those orbits are in good agreement on each other.

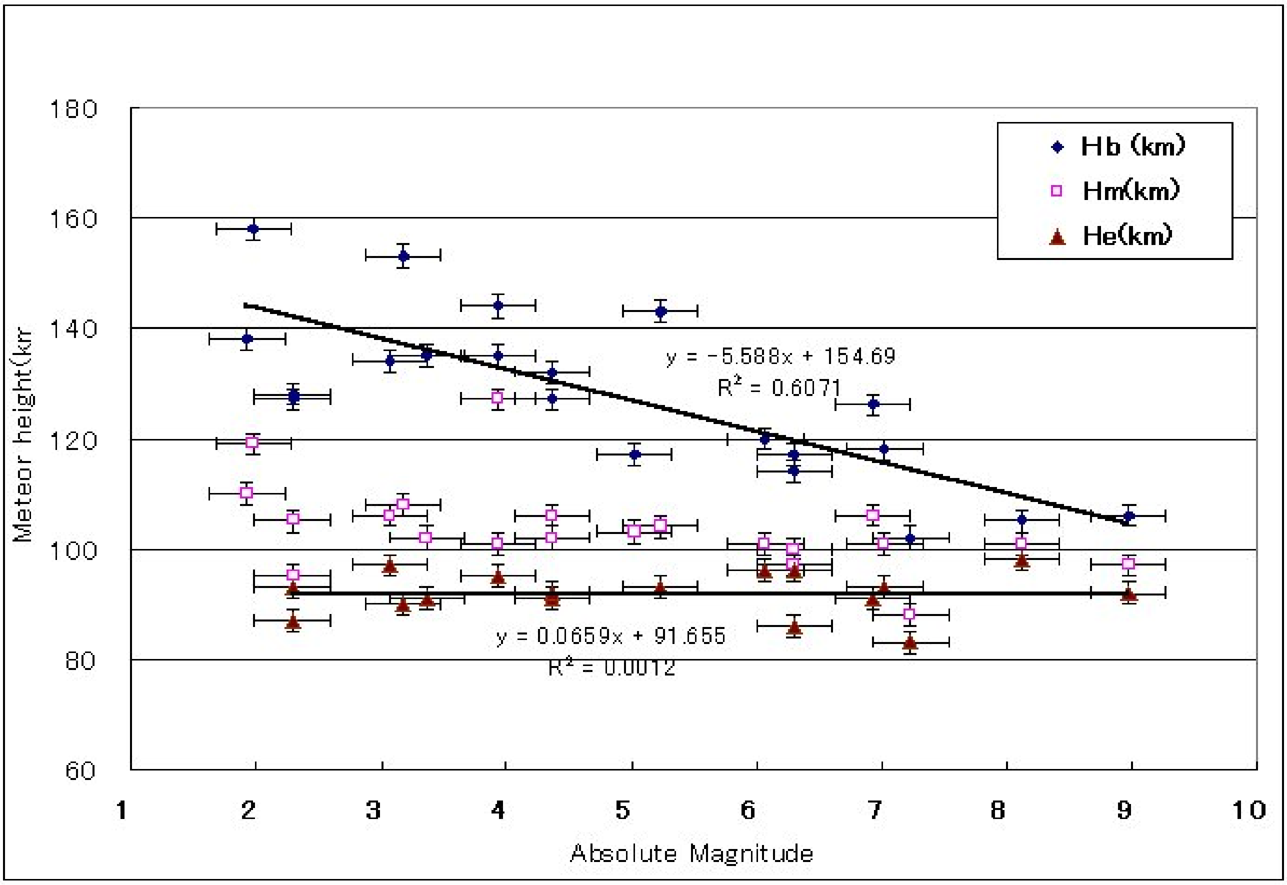

Figure 2 – Beginning and ending heights of Leonid meteors as a function of absolute magnitude. H_b: beginning height, H_m: height of maximum brightness, H_e: ending height.

Table 4 – Orbital elements of the Leonid meteoroids and the parent comet.

	a	e	q	Ω	i	ω
DMO Leonids (2001) (this work)	6.7	0.846	0.986	236.5	162.5	173.9
DMO Leonids (1995-97)	8.5	0.863	0.980	234.8	161.8	171.7
Leonids (Lindblad et al., 1993)	15.2	0.935	0.984	234.9	162.5	172.4
P/Tempel-Tuttle 1997E1 (Nakano, 1997)	10.3	0.905	0.977	235.3	162.5	172.5

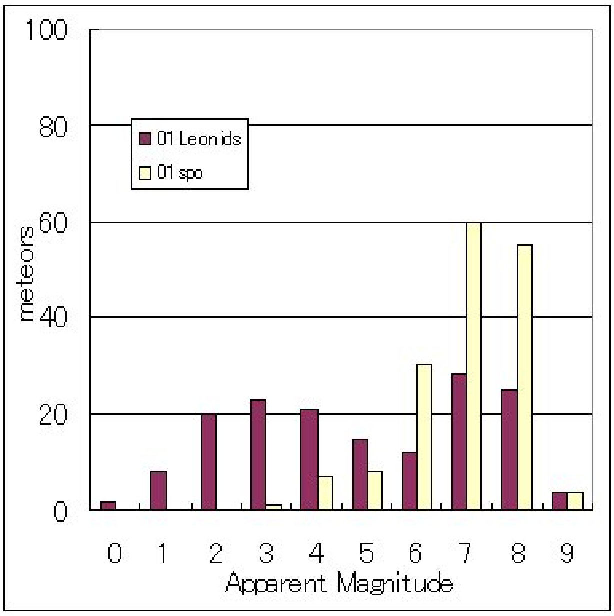

Figure 3a – Histogram of 2001 Leonid meteor apparent magnitudes; 158 Leonids (average $m = 4.9$) and 165 sporadics (average $m = 7.0$) are shown.

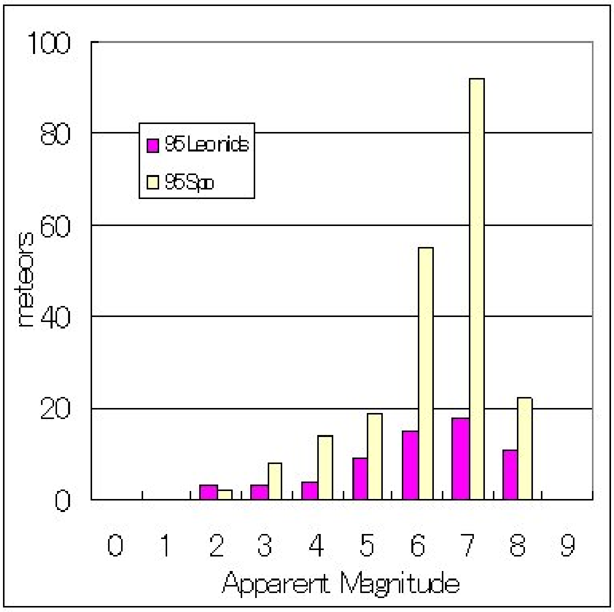

Figure 3b – Histogram of 1995 Leonid meteor apparent magnitudes.

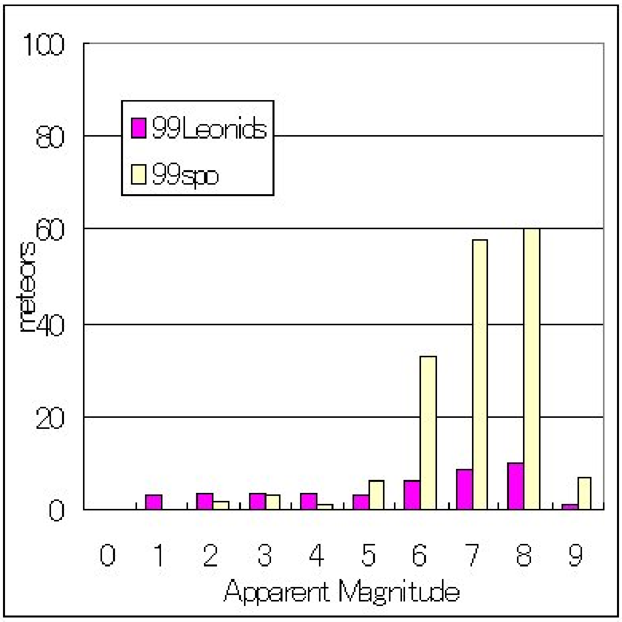

Figure 3c – Histogram of 1999 Leonid meteor apparent magnitudes.

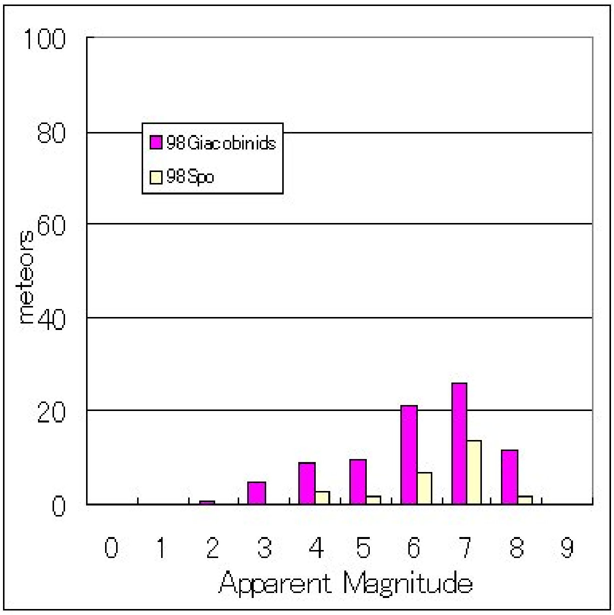

Figure 3d – Histogram of 1998 Giacobinid meteor apparent magnitudes.

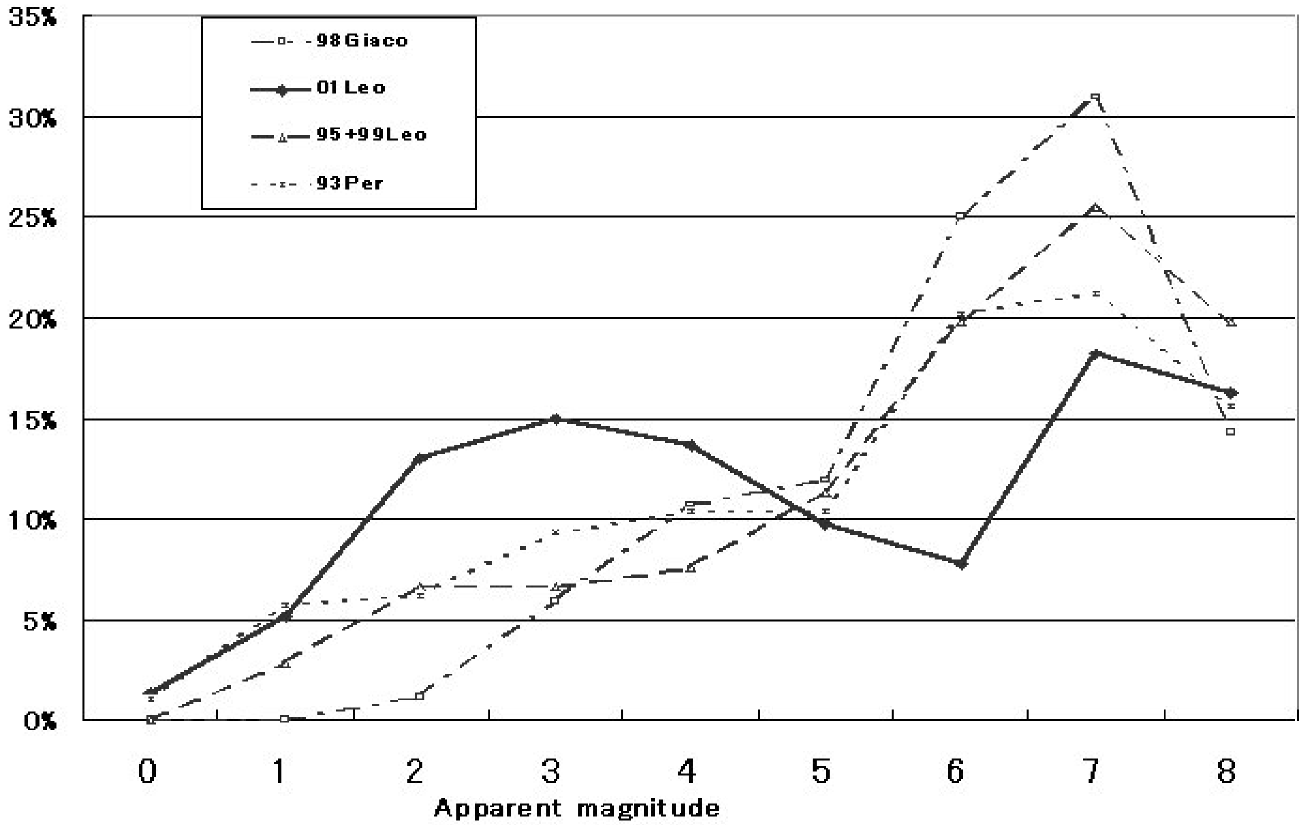

Figure 4 – Magnitude distribution of main showers.

5.4 Magnitude distribution

Figure 3 (previous page and below) shows a histogram of the meteor apparent magnitude observed by S. Suzuki only.

It is certain that the magnitude distribution has the same tendency in many meteor showers (b), (c), (d), (e) and in sporadic meteors. The tendency is that the number of bright meteors is small, and the fainter the meteor brightness, the more the number of meteors. But the 2001(a) Leonids have a different pattern. The distribution of the 2001 Leonids has twin peaks (around magnitude 3 and magnitude 7). Figure 4 shows a comparison of the meteor magnitude distributions.

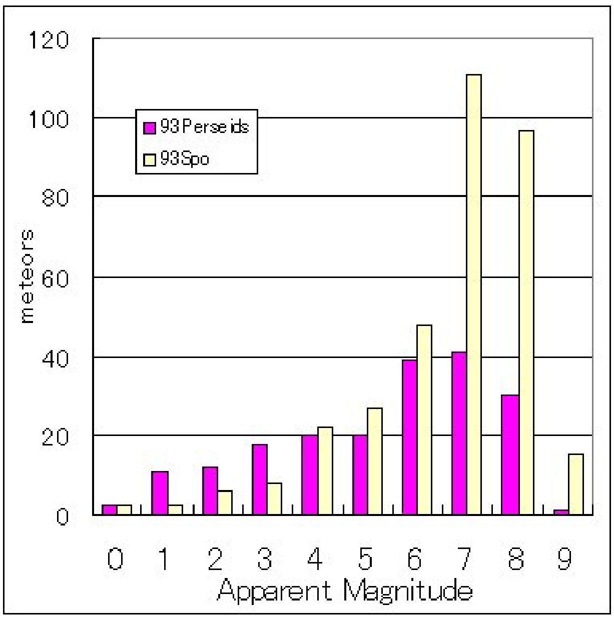

Figure 3e – Histogram of 1993 Perseid meteor apparent magnitudes.

6 Acknowledgments

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History

Meteor Beliefs Project: an introduction to the meteor-dragons special

Alastair McBeath[1]

By way of introduction to three Meteor Beliefs Project articles on the connection between dragons and meteors in East European folk-belief in this issue of WGN, some notes are given on the possible origins of this largely western Eurasian belief, together with some short comments leading in to the three articles.

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1 Introduction

This issue of WGN contains three Meteor Beliefs Project articles concerning meteoric dragons in Serbian, Bulgarian and Russian folk beliefs. One cannot go far in studying beliefs about meteors without coming across this topic, as it is a recurrent one across Europe from early medieval times at least. My colleague and co-organizer of the Meteor Beliefs Project, Andrei Gheorghe, and I have addressed the subject before in IMO publications, including my brief general notes as (Gheorghe & McBeath, 1998; McBeath, 1997; McBeath & Gheorghe, 1999). The draconic aspects of the latter two dealt with Romanian meteor-dragon beliefs, which included the creatures called *zmei* and *balauri*, often described as fiery flying dragons, or man-dragons. This article provides a brief introduction to the material presented this time, but begins with some notes on where the European meteor-dragon idea may have originated.

2 Possible origins of the European draconic meteor concept

The earliest mention of a dragon that was quite probably a very bright, deeply-penetrating, meteor which I have come across in European sources so far, dates to 735 AD in the *Annals of Ulster*: 'A huge dragon was seen, with great thunder after it, at the end of autumn' (Mac Airt & Mac Niocaill, 1983, pp. 188–189). References to similar fiery dragons in the air occur in several early medieval chronicles however, so it is likely the belief in meteoric dragons was relatively commonplace even by the early 8th century, which implies a still earlier oral origin. This origin may lie with Christian biblical texts such as *The Revelation to John*, Chapter 12, verses 1–6, where the seven-headed red dragon cast down one-third of the stars from the sky with its tail. Such apocalyptic Christian material was very popular, and recurs in numerous late ancient to medieval variants (cf. McBeath, 1999). There is though another, perhaps more directly plausible, link, through the draconic 'windsock' style of military standard, which the ancient Romans called the *draco*.

As a single source discussing the *draco* in some detail, (Lofmark, 1995, pp. 40–43 and Figure 11, p. 35) is difficult to beat, and it includes the appropriate references. To recap, the Roman army adopted the *draco* some time after first encountering it in use by their Dacian enemies in the area of modern Romania in the late 1st and early 2nd centuries AD. Similar standards were also in use around this time by the Dacians' Sarmatian allies, and by another contemporaneous foe of the Romans, the Parthians in the Near East, who came from the modern region of northern Iran. By the 3rd century AD, the *draco* was the standard of the Roman cohort (a unit of either 480 or 800 men; only every tenth cohort was of this latter strength), while the *aquila* (eagle) remained the emblem of the legion. Each legion was composed of ten cohorts, and as Roman power declined in the centuries before their final withdrawal from their more northerly conquered lands, such as modern Britain, military units here operated increasingly as cohorts, probably making the *draco* a common sight, perhaps in some respects like a police force badge.

The *draco* was a very visible emblem, surprisingly rather more so than the *aquila*. Estimates from period artwork coupled with archaeological finds suggest the *draco* was around 1.5–2 m long (mostly consisting of a brightly coloured cloth body, in a tapering tube), with a cast metal, hollow, often canine, head roughly 20–25 cm across. It would have been borne on a tall (maybe $\simeq$ 2–3+ m long) pole, probably gilded. Some of the best-preserved illustrations of the Dacian *draco* are on Trajan's column in Rome, set up to commemorate that emperor's final victory over the Dacians in 106 AD. However, the plaster full-size replicas of the scenes on the column kept in the Victoria and Albert Museum in London are more accessible and less worn than the original. A good photographic record and description of the whole column is available in (Rossi, 1971).

As various contemporary texts attest, the *draco* loudly hissed, howled or whistled as the wind passed through it, and several ancient authors commented on the aura of fear this generated in enemy troops. Indeed, *draco* standards were often described as if they were alive, and it may be they were thought sometimes to be living dragons. By at least the 4th century (e.g. Constantius II, 357 AD), the *draco* had become associated with the Emperor. Later still, it appeared in use as a common battle standard among the Britons/Welsh, Saxons and others in northern Europe, such that by about the 9th century AD, an appropriately-coloured

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dragon could be used, in a figurative sense, as meaning an army, or even a people, on its own (e.g. Morris, 1980, pp. 30–31). As an honorific title indicating a great leader or heroic warrior, 'draig' (Welsh for 'dragon') first appears in texts that have been suggested as dating to around the late 6th century, which certainly hints towards continuity of use of the *draco* after the Romans left the British Isles finally, in the 5th century.

The surviving references to a belief in meteors being called dragons (or dragons in the sky which are described in meteoric terms) all significantly postdate the widespread use of the *draco*-style standard. When coupled with the familiar, bright, mobile nature of the *draco* in use, representing authority and order, it seems likely that meteors, especially the brighter fireballs, which typically have a readily defined head and a tapering, apparently flowing, tail, should have acquired their draconic title from the use of this military symbol.

Some medieval references occasionally describe comets as being dragon-like. For instance, Geoffrey of Monmouth, writing in his imaginative and historically-unreliable text, before 1136 AD (Geoffrey, 1966, viii.15–16, pp. 200–201), has 'a star of great magnitude and brilliance, with a single beam shining from it' appear three times in quick succession to commemorate the death of one great king, foretell the accession of a second, and celebrate the birth of the second king's son, the legendary Arthur. This cometary star with a beam had at its end 'a ball of fire, spread out in the shape of a dragon. From the dragon's mouth stretched forth two rays of light', one of which split into seven smaller shafts of light. As a vivid, romanticized, description of a bright and impressive comet, it would be difficult to better this today. Since Geoffrey lived at a time when bright comets were relatively common, his description may have derived from personal experience.

Such material has been taken by some modern meteoric impact commentators as meaning most early references to dragons in the sky are meant to refer to comets, not meteors, and to assume this comet-dragon concept predates the use of the dragon as a military emblem. From the evidence, this seems highly implausible. It is more probable that the rough similarity in physical appearance between bright meteors and comets would easily lead to a comet being described as dragon-like, meaning like a bright meteor, which was itself like and called after the dragon standard. Geoffrey of Monmouth's use of the phrase 'a ball of fire, spread out in the shape of a dragon' indicates his invented comet took on the shape of either a bright, draconic, meteor, or indeed was comparable to the *draco* standard, still in use with the armies of his own time. This makes more sense than having a comet, a remote, rare, unpredictable, nocturnal, and generally feared object, being reconfigured as a dragon before being adopted as a proud, beneficial, common, military symbol, in late ancient to early medieval times. The subsequent popular confusion as to just what a comet or a meteor was, which continues to the present day with inexperienced observers, or those unfamiliar with astronomy, has certainly helped further cloud the issue since the medieval period.

3 Notes regarding this issue's meteoric dragon articles

The first two articles discuss some aspects of meteoric dragons in Serbian and Bulgarian folk-belief. The Serbian meteor-dragon details were extracted from a previously-published article I co-authored with Vesna Slavković. When this was written, Vesna was a student of science and astronomy at Belgrade University, and continues to be active as a visual meteor observer, when her other pursuits allow.

The Bulgarian material, here translated by Eva Bojurova, was taken from a longer unpublished article on Bulgarian dragons. Eva will be well-known to anyone who has attended the IMCs in recent years, or anyone who has been in contact with the Bulgarian observers based in Varna, where she lives and works as a physics teacher and lecturer, based at the Nicholas Copernicus Planetarium and Observatory. More brief Bulgarian meteor-dragon notes were given by (Momcheva, 2001).

The main article is the third one, concerning Russian meteor-dragon beliefs, and is by Elizabeth Warner. Her extensive contribution came by a chance contact, following a comment in an earlier article (Warner, 2002), indicating a possible Russian belief connecting lightning, comets and a huge serpent/dragon. Elizabeth is Emerita Professor of Russian at the University of Durham in England. She has authored numerous publications on Russian folklore, most recently the book 'Russian Myths' (British Museum Press, 2002), which has received a very positive welcome among reviewers. Her fieldwork currently involves filming and documenting rural life in northern Russia.

4 Conclusion

A combination of materials coming together on similar topics like this is unusual so far in the information submitted for the Meteor Beliefs Project. Part of the interest in the Project for the coordinators is seeing what new details come through from other people. Please do keep sending us your ideas, quotes and suggestions to help move the Project along. We look forward to seeing your inspiration!

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Meteor Beliefs Project: some notes on the Serbian meteor-dragon

Vesna Slavković and Alastair McBeath[1]

Comments on the fiery Serbian dragon, the *zmaj*, are given, indicating its clear meteoric connections.

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1 Introduction

The material discussed here concerns the main type of Serbian dragon, the *zmaj*, and its connections to meteors. It was extracted from an earlier article 'Atmospheric Dragons from Jugoslavia', which we published in *The Dragon Chronicle* 17 (2000, pp. 11–13). That article drew heavily on the book 'Astronomy in the Folk Traditions of the Serbs' by Nenad D. Janković (published in Beograd, Serbia, undated; otherwise unattributed quotes in this article are from this text), together with some personal knowledge, where necessary translated into English by VS. The dating of much of this is unknown, but some elements are associated with events from the 16th century onwards, so a late medieval origin for parts at least can probably be implied. Most was not collected until the 19th and early 20th centuries, however.

Zmaj is also the name for a kite in Serbian, something that is found with words for 'dragon' in other European languages as well (including Romanian and, at the other end of Europe, Scottish Gaelic). Sometimes there are just references to winged snakes or serpents in Jugoslavian folklore, rather than *zmaj*s, but the descriptions and activities of these beasts clearly indicate them to be draconic creatures. Another mythical flying creature which appears with draconic attributes in Jugoslavian tales is the winged lizard *ala* or *azdaja*. In some cases, *ala*, *azdaja* and *zmaj* are used synonymously as words describing the Jugoslavian dragon. For simplicity here, we only use *zmaj*.

One other aspect of possible interest in relation to the introductory article in this Meteor Beliefs Project Special concerns comets. The Serbs sometimes called a comet *zmaj*, but, in common with many other peoples since ancient times, they also saw a cross, a sword, a knife or a head with long flowing hair in such objects. The Jugoslavians knew the tail of a comet as a 'battle-flag', and the appearance of a bright comet was frequently taken as a sign to start a rebellion against the Turkish Ottoman Empire, which ruled much of the Balkans for over 400 years. A specific connection between this cometary battle-flag and the dragon is not made in the surviving Serbian folklore, however.

2 The meteoric *zmaj*

The Serbian folk-name for a meteoric fireball is *zmaj*, and fireballs seem to have attracted especial popular attention. They were anthropomorphized in popular belief, folk-songs and tales into living creatures with supernatural powers, sometimes to the extent of being equal to the gods or other celestial bodies. In this vein, a fireball*zmaj* was viewed 'as a flaming hero from whom the fire pours forth, and he shines while he is in flight'.

Although draconic, the *zmaj* could be imagined as human-shaped, with feathered wings, and was mighty, brave and noble. As a result, many local Jugoslavian heroes were described as *zmaj*s, or that they had characteristics like one, while the true *zmaj* remained a fiery hero. Even modern airforce pilots are sometimes called *zmaj*s. In a way, this makes the fiery dragon the mythological forefather of the Serb peoples, as in the following poetic quote: 'Wherever there is a Serbian hero/ Each one was raised by a she-fairy,/ Many were born of *zmaj*s'.

In some cases, the *zmaj* was also thought of as a variety of bird with a long, serpentine tail, but one which flew only at night. Elsewhere, the *zmaj* itself is described as a winged, flaming serpent. This seems to be particularly true when it had to fight troublesome *ala*s, which were perceived in such an instance as the ice-clouds preceding stormy weather. Then, the *zmaj* could take on the form of an eagle in order to soar up to the battle.

Some poems describe the *zmaj* as a flaming bird that burnt up the grass as it strutted along the ground. Whether in human or bird form however, the *zmaj* always appeared by night, sometimes accompanied by a whistling, or a louder thunder-like roaring, sound, another particularly meteoric trait, linked to notably bright fireballs.

3 Conclusion

The fiery Serbian meteor-dragon streaking across the sky seems familiar, by comparison with other similar ones in European folk-beliefs, but as in most cases, often with a few fresh twists to it, such as its almost entirely positive nature. The interest shown in fireballs may relate to a people only waiting for another celestial sign, in the shape of a comet, to begin a new uprising against a desperately unpopular conqueror. The link between what seem typical meteor acoustic noises and the *zmaj*-fireball may perhaps give an insight into the perceptiveness of the people who created the original folklore.

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Meteor Beliefs Project: the *Zmey*, a meteor-dragon from Bulgarian folklore

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Some notes are given regarding the *zmey*, a draconic creature in Bulgarian folklore, which in some forms is also a bright meteor.

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1 Introduction

It seems appropriate that we should be considering the Bulgarian *zmey* in December, as the leading Bulgarian dragon-fighting saint is Saint Nikola, whose day is December 6, and who is described in a number of tales as possessing very *zmey*-like characteristics. Indeed, it is entirely possible he was a *zmey* himself. Saint Nikola in the West is Saint Nicholas, who has become intimately associated with the December Christmas holiday as Santa Claus although, in the West, he enjoys no dragon-slaying characteristics.

The notes about the *zmey* which follow were largely extracted from the book 'Folk Mythology' by Ivanichka Georgieva (Naooka I Izkoostvo, 1993; in Bulgarian). These have been translated into English (by EB) for the first time here, as far as we are aware. Some slight amendments and additions from personal knowledge have been included as well. We should also comment that the more meteoric aspects of the *zmey* are only one strand of a whole cloth of folkloric fabric woven around this draconic creature, and that similar beliefs seem common across much of eastern Europe.

2 The *zmey* and its meteoric connections

The *zmey* is chief among Bulgaria's dragons and draconic creatures. It is considered male, and was believed to be a creature that really existed in the past, but now has disappeared, according to comments from Bulgarian villagers collected in the late 19th and early 20th centuries, whose memories of such tales would carry back two or three generations at least.

Various origin tales have survived. One belief was that if a snake, usually a grass-snake, had not been seen by human eyes for a long time (the time varies but is frequently given as either 40 or 100 years in different tales), it became a *zmey* with seven, or nine, heads, and seven tails. Another was that some *zmey*s originated from fish. It was held that if lightning like a chain was seen, then *zmey*s had risen into the air from being grass-snakes, but if the lightning was a more normal flash, that showed a *zmey* had just matured from being a fish.

There were also stories about people who turned into *zmey*s. This might be achieved using a magical potion poured over the victim. In alternative cases, such a transformation could be undergone only by children conceived on a Saturday during the Unclean Days (that is, the days around Christmas and New Year). A woman might have children by a *zmey* too, which would be born after eleven, rather than the normal nine, months.

A *zmey* was said to look like a snake, a man or a bird, but in tales it might have many variant appearances. It normally had wings, feet and a scaly tail at least, but it could be many-headed and multi-tailed, as noted above. It could be a long, scaled, grass-snake with bat wings and four feet; or half-*zmey*, half-man, with wings; or a strong young man with wings under his arms, a big head and large eyes, possessed of unusual strength. Often, in a more human form, he would be visible only to the girl he loved, appearing for her on a horse and carrying her away.

When a *zmey* flew, it glowed, causing a strong wind, and leaving a trail of flying sparks. It could be fiery, and could take the appearance of a thunderbolt, a fiery arrow, a fiery beam, a large red ball, or a white cloud. Red and white are important 'good luck' colours in Bulgaria, even today. Each year in late winter and early spring, the people give one another small pairs of woolen tassels, one red, one white, representing good health for the coming year, after the dismal, cold, winter days. These are called *martenicas*, and are said to bring good luck if one is worn until the first stork is seen during the spring.

From the preceding notes, it is no surprise that meteors were considered to be *zmey*s too. When a lot of meteors were seen, this was said to mean *zmey*s were flying, and stealing away girls to be their wives or lovers. Lightning and meteors are commonly confused with one another in the popular imagination, still more so in earlier times. Lightning was said to flash from a *zmey*'s eye. Tornadoes were also known to be *zmey*s. These occur mainly during thunderstorms. If one of these were to blow on a woman, she would bear a *zmey*-child, so it was said.

For all their links with thundery weather, the *zmey* were regarded ambiguously as supernatural guardians of the crops. In particular, they were believed to battle with the *hala*, another draconic creature, which was evil and would destroy the fields if not prevented by the *zmey*. When fighting the *hala*, the *zmey* used fiery arrows and stones, often perceived by the people as lightning flashes and thunderclaps. The *hala* was female, but only after a sex-change, as the belief ran that after

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a *zmey* had lived many years, it became a *hala*, and went to live in the sky. *Zmey*s were considered assistants to Saint Iliya too, whose rumbling chariot wheels passing across the sky were heard as thunder by the people. In a reflection of the thunder-meteor confusion apparent in many places across the world, in Bulgaria too we find that ancient stone arrow-heads found in caves were called 'thunder-stones' (often an alternative folk-name for meteorites), or God's arrows. These were reckoned to be *zmey*-weapons, and might be used as healing amulets when found by ordinary people.

In common with many eastern European places, young Bulgarian women apparently suffering from what would be diagnosed modernly as one of a variety of mental illnesses, or physical wasting diseases, were thought to be beloved of a *zmey*. The *zmey*'s powerful mental control over the woman was thought to lead to such symptoms as uncommunicativeness, the avoidance of other people, and becoming careless about their dress and appearance. Such girls were pale and sad, and cried all the time.

The *zmey* would visit the chosen girl in the night, flying to her home like a meteor, then squeezing in through the chimney as fire, lightning, or a snake. Once indoors, he would turn into a handsome young man. The fate of those the *zmey*s loved was to pine away and die. When a *zmey*-struck girl like this shared with someone else that a *zmey* was in love with her, or when her relatives tried to marry her off, the *zmey* would 'take her away' too (that is, she died). The *zmey* would descend like a cloud, a fog, a whirlwind, a shooting star or a thunderbolt. On landing, he would turn into a posy of flowers or a piece of jewellery or other adornment. Picking up the object sealed the girl's fate. Consequently, until the mid-19th century, Bulgarian girls strictly observed a prohibition to take any thrown flowers or adornments, just in case. There were also female versions of the *zmey*, the *zmeica*, whose appearance and behaviour was similar, but their victims were young men. As we might expect, Bulgarian folklore also records a large number of charms and protective methods for preventing any of these *zmey*-attacks from occurring.

3 Conclusion

This brief foray into the world of the Bulgarian *zmey* reveals links with other east European folklore, and meteoric associations between the dragon, lightning, thunderbolts (a term sometimes used as synonymous with meteorites), and death, which we also find in variant forms in other places too. The age of such beliefs in Bulgaria is not possible to trace with any accuracy, but from the date when oral tales were first collected, and the ages of the people involved, they can be traced more or less directly back to the 18th or early 19th centuries at least, and are probably significantly older than this.

Meteor Beliefs Project: dragons as meteors or comets in Russian folk beliefs

Elizabeth A. Warner[1]

An investigation is presented into the connections in Russian folk beliefs between meteors (and comets, which are not always clearly distinguished from meteors in such beliefs) and dragons. The datable surviving texts span from the early eleventh-century to modern times, although most of the material was recorded from the eighteenth-century onwards.

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1 Introduction

I began to investigate the relationship between dragons and meteors in Russian folklore in response to an enquiry from Alastair McBeath. The following is not intended as a research article and its content is limited to sources in my personal library. I have had no opportunity to check references taken from secondary sources, some of which were given without page numbers.

My first reaction to the question 'Do the Russians traditionally equate meteors with dragons?' was that, according to my recollection, they definitely did. Later, I realized that I had no clear idea what a meteor was. After reading through the available material I came to the conclusion that Russian folkloric sources are equally confused. Lack of a precise definition of the term 'meteor' before the twentieth century is clear from Russian dictionary entries. Sreznevskii's dictionary of Old-Russian, which covers usage in the mediaeval period, has no entries for 'meteor' or 'comet' as such but does have one for 'star with a tail' (*zvezda khvostata* or *zvezda s khvostom* in modern Russian), which is defined as a 'comet' (*kometa*) (Sreznevskii, 1958, Vol. 1, p. 964). Vladimir Dal′'s 'Etymological Dictionary of the Great-Russian Language' (Dal′, 1955), one of the most authoritative dictionaries of the nineteenth-century, contains the generalized definition of 'meteor' as 'any atmospheric phenomenon'. Meteors may thus be aqueous, igneous, aerial or luminous. Under 'igneous meteors' Dal′ mentions thunderstorms, fiery pillars, balls and stones, whereas aerial meteors may be winds, whirlwinds and mist. The definition of 'comet' in Dal′'s dictionary is 'a heavenly body which, in comparison to others, is of huge mass, though sparse, nebulous and transparent; sometimes it may be seen to have a nucleus, while the surrounding area forms something like a tail, beard, or tangled locks; a star with a tail'. The term 'star with a tail' is also referred to under the entry 'star'. Dal′, in addition to his linguistic interests, was also a keen collector of folklore and illustrates many of his definitions with folk beliefs and sayings. Thus, the 'shooting star' is linked with the belief that a young girl could determine where her future husband lived by watching the direction taken by such a star at Christmastide. There are many Russian folktales in which the erotic connotations of both the shooting star and the star with a tail are expressed more overtly. In the dictionary, however, the 'star with a tail' is referred to as 'an omen of war' (Dal′, 1955, Vol. 1, p. 673).

Below, I have listed, in chronological order, all the references I could find to hand about dragons in Russian folklore in the context of phenomena which might be loosely described as meteors or comets.

2 Sources

Although there are numerous Old-Russian texts, hagiographies and suchlike, in which dragon-demons are associated with thunder and lightning, there are few early references to dragons as meteors or comets. There are some Chronicle entries, dating to between the eleventh and sixteenth centuries, to which I shall return later. The earliest scholarly text to deal with this subject is, as far as I am aware, an eighteenth-century one (Chulkov, 1772, quoted in Ryan, 1999). As I do not have a copy of the original, I quote what Will Ryan has to say about it in his book on magic in Russia, in the section entitled 'Shooting stars':

'Both comets and meteors were often thought of as fiery serpents. An eighteenth-century dictionary of Russian superstitions states that comets foretell bad luck, plague, famine, war etc., and that shooting stars are demons who come out at night to have intercourse with women, in particular virgins and recent widows ...' (Chulkov, 1772, pp. 202, 205, quoted in Ryan, 1999, p. 135). Paraphrases of these comments in Chulkov's work crop up frequently in nineteenth- and twentieth-century texts.

One of the first Russian pieces of serious research into the origins and characteristics of the dragon is the series of articles by Aleksandr Afanas′ev on the zoomorphic deities of the Slavs (Afanas′ev, 1852). In his second article, Afanas′ev defines the dragon as a zoomorphic Slavonic deity connected with fire, among other things. He derives the origins of the dragon from various natural phenomena which seem to conjure up the image of a flying, fiery beast, scattering sparks: 'The folk imagination ... creating mythic images ... personified aerial meteors, falling stars and especially lightning' (p. 98). 'Even today' [i.e. the middle of the nineteenth-century — EAW], he continues, 'simple folk take falling stars and meteors to be dragons'. Afanas′ev comments on

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a couple of early Russian references to heavenly bodies compared to dragons. Of particular interest is a description of several meteors (Afanas′ev's word), which appeared in 1662–3 in Belorusskii *uezd*[1] [an administrative area smaller than a *guberniya* or province — EAW].

The first 'meteor' is described as follows: 'There appeared something like a huge star and it rushed across the sky with the speed of lightning and the sky was split in two and a head and tail all on fire stretched out across the sky, like a dragon, and it remained there for about half an hour'. The second description is shorter: 'The object stretched out across the sky, like a huge dragon all on fire, and smoke issued from it' (Afanas′ev, 1852, p. 98, quoting from Otechestvennye zapiski, No. 6, 1842, p. 57 and Istoricheskie akty, Vol. 4, No. 170). In the original, the fiery object is referred to as 'a star', while Afanas′ev assumes that it was a meteor.

In his later, monumental work on Russian mythology, 'The poetic views of the Slavs on nature', Afanas′ev (1994) repeats much the same ideas about 'meteors and falling stars' being visualized as dragons. He quotes several Chronicle entries about dragon-shaped, fiery, heavenly bodies. Thus, in 1028: 'A dragon-shaped sign appeared in the heavens, visible to the whole earth'. In 1144, a strange object was seen beyond the Dniepr in Kiev *volost′*: 'There flew from the sky to earth something resembling a fiery circle, which left in its wake a sign in the shape of a great dragon ...'. In 1556, 'there was a sign from the place where a star had been in the sky; an object shaped like a dragon appeared, with no head, but with a tail like a trunk, and then it became like a barrel and fell to earth in flames, and what appeared to be smoke covered the ground' (Afanas′ev, 1999, Vol. 2, p. 510).

To these we might add the following Chronicle entry. In 1091, 'When Vsevolod was out hunting beyond Vyshgorod ... a huge serpent/dragon (*zmei*) fell from the sky and everyone was struck with terror. At the same time the earth rumbled so that many heard it' ('Povest′ vremennykh let' 1950, Vol. 1, p. 342).

In Vol. I of 'The poetic views of the Slavs on nature' (p. 73) Afanas′ev mentions the commonly-held association between comets and 'stars with tails'. According to Afanas′ev, it was the very rarity of the arrival of comets that led simple people to regard them as a warning from God of the disasters ahead, with which He would punish their sins. The link between unusual and frightening displays in the sky and impending doom is stated unambiguously in a Chronicle reference of 1202, quoted (unfortunately, without a reference to its exact source) by M. I. Kastorskii in an early work on Slavonic mythology (Kastorskii, 1841): 'In 1202, at five o'clock in the morning, the sky flooded over with scarlet, like blood, so that the snow, lying on the ground and on the houses seemed suffused with blood and many people witnessed the passage of stars across the sky. The stars fell out of the sky onto the earth and the people who saw this were much afraid, thinking that the end of the world was nigh' (Kastorskii, p. 56). Although this quotation appears in the context of 'fiery dragons' it does not make a specific connection between the meteor shower and dragons. On the other hand, Kastorskii makes a definite link between dragons and thunderstorms: 'when they tumble and twist and roll over the fields, across barns and rooftops'. Quoting from N. I. Karamzin's 'History of the Russian State'[2] Kastorskii refers to a thunderstorm in Novgorod in February 1215, during which 'there was a dragon flying' (Kastorskii, p. 57–8).

Towards the end of the nineteenth-century, M. Zabylin produced a compendium of Russian folk beliefs and customs (Zabylin, 1990), drawn, for the most part, from secondary sources, including Chulkov's eighteenth-century dictionary of folk beliefs. Here, there are two relevant entries. Firstly, 'Fiery dragons':

> 'This is the aerial meteor, which we often see rushing through the air in the shape of a long and wide ribbon of reddish sparks, flying either in an arc or horizontally. Russian people consider it to be an evil spirit or a fiery dragon, paying a visit in the evening, or at night, to a widow or young woman pining away her lonely life ... ' (p. 266).

Secondly, 'The comet and its significance among the ordinary folk':

> 'The appearance of a passing comet, especially one with a tail, is taken by simple folk to indicate some societal tragedy — that is plague, famine, war and so on ... ' (p. 267).

In these two comments we find a number of attributes of the dragon, which are often found together in Russian folklore and folk beliefs, specifically its association with fire, its demonic nature and its role as the bringer of harm, either physical or spiritual, to human beings. Clearly, this conjunction of characteristics has been influenced by the Bible and other religious writings, such as hagiographies and sermons, where the Devil is frequently portrayed as a fire-breathing dragon, which appears in order to torment and seduce God-fearing Christians. In Russia's epic poems, the *byliny*, the heroic Christian knight Dobrynya fights a perfidious dragon, who has kidnapped Zabava, the favourite niece of Prince Vladimir, as well as other Russian maidens. This dragon showers Dobrynya with sparks and emerges from a flaming river to do battle with him. In the folktales (*skazki*) the dragon is portrayed as a ravisher of maidens and a seducer of wives, as well as one of the main enemies of the hero. In anecdotal tales of the supernatural (*bylichki*) the dragon assumes the guise of a handsome youth or the husband of some widow: 'A young woman's husband died. The whole village began to notice that every night a fiery dragon flew to visit

[1]This must be a misprint for Belozerskii *uezd*. It is given as Belozerskii *uezd* in other publications, including later works by Afanas′ev himself.

[2]Kastorskii does not specify which edition of Karamzin's 'Istoriya gosudarstva rossiiskogo' he is referring to.

her. It would dissolve over her chimney in a puff of smoke. The woman began to show signs of stress. She grew thin and pale. At night she seemed to be talking to someone ... Eventually, the woman confessed that her dead husband appeared to her at night, bringing her gifts and conversing with her' (Dal′, 1994, pp. 466–7). This particular story has been taken from A. M. Smirnov's collection of Russian folktales, 'Sbornik velikorusskikh skazok arkhiva RGO', vypusk 1–2, Zapiski RGO po otd. etnografii, t. XLIV [Petrograd, 1917], vypusk 1–2.). The fifteenth-century 'Tale of Petr and Fevroniya', which shows a mixture of folk and hagiographical features, also revolves around the immoral nature of the fiery dragon, who begins to court the wife of Prince Pavel of Murom. (For more on these aspects of the dragon see (Warner, 2002).)

Several references to comets may be found in A. E. Burtsev's collection of ethnographical materials (Burtsev, 1911): 'Comets are fiery dragons, i.e. devils' and 'Comets, or, as people call them, "*planidy*" emerge from the last, i.e. the seventh, heaven. They are sent by God himself in order to forewarn the people of the imminent arrival of some significant event, famine, war, the death of a member of the royal family and suchlike. A comet can set fire to the earth. It is a living being' (op cit, p. 64). Like Zabylin, Burtsev rarely gives the source of any of the beliefs he describes, which are merely presented as being widely held among the peasantry and uneducated Russians.

In 1927, the eminent Russian ethnographer D. K. Zelenin wrote the following in his book about the ethnography of the East Slavs: 'Night-time meteors and bolides/fire-balls, as well as shooting stars, have given rise to the superstitious idea of the flying, fiery dragon. Among Great-Russians it is closely linked with the hallucinations suffered by love-sick women, especially young widows; this dragon is considered to be a demon. The flying dragon ... flies in during the night, in the shape of a flaming red ball, and dissipates in a shower of sparks over the chimney from the stove of the house which he intends to enter ... ' (Zelenin, 1991, p. 417).

In Marina Vlasova's 'Encyclopaedia of Russian Folk Beliefs' (Vlasova, 1998) there is a lengthy entry entitled 'Star with a tail ... comet'. Here, she comments on the many Russian beliefs, recorded in the Middle Ages, about the 'star with a tail' as a 'living being', which may resemble the dragon. Similar beliefs in the anthropomorphic nature of 'comets, meteorites and unusual, fiery, heavenly phenomena' can be found, according to Vlasova, in nineteenth century sources. One of the most interesting additions to the usual material about comets in her book is an extract from a memorate in a collection of tales about the life of the Ural Cossacks. The event described supposedly took place in 1858, in the steppe, in broad daylight and in the presence of some Kirgiz people living near Khanskaya Stavka. According to witnesses, a huge dragon fell to earth out of the sky. It was 'as wide as the biggest camel and around 20 sazhens[3] long. For a moment, the dragon lay motionless, then it coiled itself up, raised its head about 2 sazhens from the ground and gave a piercing hiss, like a stormy wind. People, cattle, all living creatures, fell flat on the ground from terror. They thought the end of the world had come. Suddenly, a cloud descended from the sky and came to rest some 5 sazhens above the dragon. The dragon jumped onto the cloud, the cloud enveloped it, began to swirl and ascended into the heavens. On the earth, after the dragon, all that was left was smoke and a stink' (op cit, p. 180, quoting I.I. Zheleznov, 'Ural′tsy: Ocherk byta ural′skikh kazakov, Polnoe sobranie sochinenii', 3rd edn., St Petersburg, 1910, Vol. 1–3). The story itself does not suggest what phenomenon in particular may have given rise to this 'dragon'.

In the encyclopaedia 'Slavonic Antiquities' ('Slavyanskie drevnosti', 1999), under 'stars', we find the comments that: 'stars also include comets (in Russian "the star with a tail" ...) and meteorites' (pp. 290–291)[4]; 'in predictions about the future, special significance is given to falling stars and comets, which are thought to be indications of various misfortunes — deaths, wars, famine, epidemics and so on' (p. 293); 'various demonic beings may take the form of a star. Most often ideas about demons are associated with falling stars, meteorites and comets'. The entry for 'the flying dragon' contains the following information: 'In the air he looks like a big serpent. He has golden wings (Bulgaria), which may be situated on his legs (Macedonia). The flying dragon is associated with stars, meteors and the rainbow. Fire, scattering in sparks from his mouth, and the light streaming from him are characteristic features of the flying dragon; in flight he resembles a fiery mass (Serbia, Bulgaria), a shining or falling star (Bulgaria, Macedonia), a fiery bird with a tail (North-East Serbia) ... ' (p. 330).

A large number of the above descriptions of dragons and their links with various heavenly phenomena have been drawn from secondary sources and are both general and repetitive in nature. The authors of the works quoted rarely refer to precise dates, locations, or the exact source of their information. I searched through my papers for any mentions of dragons as meteors or comets which were directly attributable to an identifiable folk source, field notes, ethnographical sketches and so on, but with little success, apart from two snippets of contradictory information drawn from published nineteenth-century archive material: 'Comets are "fiery dragons", that is devils' (recorded from S. Galakhova, 1898, in Zhuikha village, Davydovskaya *volost′*, Vladimir *uezd*, Vladimir *guberniya* in (Firsov & Kiseleva, 1993, p. 118)). Another informant provided the following information which denies the demonic nature of the dragon: 'Comets are angels, which at God's command take the appearance of stars with tails and forewarn of misfortune' (recorded from P. I. Kaminin, 1899, village of Dominino, Lyakhovskaya

[3] The sazhen was a pre-Revolutionary unit of length, about 2 metres –*Ed.*

[4] Probably neither the author of this entry nor Vlasova are using the term 'meteorite' in its precise scientific meaning.

volost′, Melemkovskii *uezd*, Vladimir *guberniya*, (Firsov & Kiseleva, 1993, p. 119)).

3 Conclusions

On the basis of this limited information, it is clear that in Russian folk beliefs and folklore, comets, meteors and other aerial phenomena, such as lightning, were indeed associated, to some extent, with the dragon. As far as terminology is concerned, however, 'meteor' appears to occur much less frequently in the context of dragons than 'falling star', 'star with a tail' and 'comet'. Although I have come across mentions of 'comets', 'stars with tails' and 'planets' ('*planety*' or '*planidy*' in folk-speak) in material recorded in the field (as opposed to secondary literature on the subject), I cannot recollect seeing any direct references to meteors. This, of course, is a purely subjective judgement. However, given the lack of a precise scientific definition of the phenomenon now known as a 'meteor' even in the latter half of the nineteenth-century, and not only in Russia of course, one has to wonder what any informant using the term would have meant by it. The Oxford English Dictionary (OED), like Dal′'s dictionary, points out that in the past 'meteor' was applied to a variety of phenomena, aerial, aqueous, and luminous, as well as igneous. Again, according to the OED, it has been equated with fireballs, shooting stars and the aurora borealis. To add to the confusion, in the seventeenth-century the term 'meteor' was also applied to comets. I would suspect that this was still the case in rural communities in nineteenth-century Russia. Although the Russian peasants did use the terms 'comet' and 'star with a tail', when referring to dragons, we cannot be entirely sure what they meant by these terms either. Nineteenth-century ethnographical information reveals a widespread depth of ignorance among the peasantry about the nature and causes of most natural phenomena. We have to conclude that descriptions such as 'comet', 'planet', 'star' and various other fiery aerial phenomena were often used pretty much interchangeably.

The term 'star with a tail' for 'comet' does, of course, suggest a zoomorphic being. In Russian folk pictures of the nineteenth-century, the dragon is often depicted with a long, scaly tail or tails, ending in sharp spikes, reminiscent of jagged lightning. In folktales and *byliny*, on the other hand, few details are given, through which one might form a visual picture of the dragon. Teeth, claws, jaws spewing fire, tails, wings and heads may all be mentioned from time to time. However, most scholars seem to agree that in folk narratives the only relatively constant physical feature is the head, or rather heads, and not the tail, (Propp, 1986, p. 217) and (Novikov, 1974, pp. 180–1).

From the eighteenth-century onwards, commentators have tended both to repeat much the same information and to use the same sources, often without informing the reader what those sources were. This creates the impression that the beliefs described were more widespread and consistent than might have been the case in reality. Furthermore, little attempt appears to have been made by scholarly commentators, even in the twentieth-century and more recently, to be more accurate and discerning in their use of terminology than the original informants.

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The EN290903 Oświęcim fireball

View of the EN290903 fireball of 2003 September 29, $01^{h}20^{m}12\overset{s}{.}6$ over the Czech Republic and Poland. This photograph was taken from the Červená hora fixed all-sky camera equipped with a Zeiss Distagon 30 mm $f/3.5$ fish-eye objective. Interruptions of the luminous path of the fireball are caused by a three-arm shutter rotating at 15 breaks/second placed near the focal plane.

Full details can be found on page 171.