Some interesting meteor showers in EDMOND database

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This paper demonstrates the growing potential of EDMOND, a database of meteor orbital data, by presenting a summary analysis of eight meteor showers based on data collected over the period 2009 to 2012. The amount of input data (EDMOND 2.0 adds 79 402 new orbits) allows for improvement of mean orbits of Ursids, Andromedids, alpha Capriconids, Leonis Minorids, December Monocerotids, sigma Leonids, October Ursae Majorids and October Camelopardalids.

1 Introduction

EDMOND (European viDeo MeteOr Network Database) is a database of meteor orbital data computed from meteors captured using video observation. It is the result of a broad international cooperation and sharing of data between EDMONd (European viDeo Meteor Observation Network) and the IMO VMN (International Meteor Organization Video Meteor Network). Contributors to EDMOND can be found in Kornoš et al., 2014.

The version EDMOND 2.0 (http://www.daa.fmph.uniba.sk/edmond) consisted of 79,402 orbits in the period of 2009 – 2012 meeting specific minimum quality criteria the details of which can be found in Kornoš et al., 2013. With a substantial number of orbits based on relatively high quality meteor observations, detailed analysis of weak meteor streams and more precise characterization of well-known meteor showers is possible. This paper presents the analysis of eight meteor showers using data from the EDMOND 2.0 database as follows:

- Ursids and Andromedids (Irregular showers)
- α Capriconids (A regular shower which exhibits a higher population of bright meteors)
- Leonis Minorids and December Monocerotids (Regular showers with lower average brightness meteors)
- σ Leonids, October Ursae Majorids, and October Camelopardalids (Showers with lacking sufficient orbits in current database)

The calculated orbits for these showers are compared with mean orbits from the IAU MDC (IAU MDC, 2013). The mean shower orbits from the IAU MDC are listed in the Table 1. For completeness, possible parent bodies for these showers are listed in Table 2.

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Table 2 – Possible parent bodies of analyzed meteor showers according to IAU MDC.

Shower name	Parent body
Ursids	8P/Tuttle
Andromedids	3D/Biela
α Capricornids	169P/Neat (= 2002 EX12)
Leonis Minorids	C/1739 K1 (Zanotti)
December Monocerotids	C/1917 F1 (Mellish)
σ Leonids	2002 GM5 (?)
October Ursae Majorids	unknown
October Camelopardalids	unknown

2 Ursids (IAU 0015 URS)

The Ursid meteor shower is active between December 17 and December 25 with the maximum activity occurring around Dec. 22 and ZHR ~ 10. It is known that returns of its parent body, comet 8P/Tuttle are correlated to irregular shower maxima with ZHR ~ 100 several years after the comet's perihelion passage.

The EDMOND database 2.0 contains 113 orbits of Ursids found by the) *radiant-*V_g method used in UFOOrbit software (SonotaCo, 2009). A subset of 86 orbits were selected using the iterative method (Porubčan & Gavajdová, 1994,Arter & Williams, 1997) with $D_{SH} < 0.15$ (Southworth & Hawkins, 1963) for mean stream orbit characterization (Table 3, Figure 1). The average $D_{SH} = 0.067 \pm 0.037$. The dataset contains only three hyperbolic orbits. The mean orbit from EDMOND data is consistent within the standard deviation with previously published orbit by Jenniskens, 2006 obtained from the similar number of meteors.

3 Andromedids (IAU 0018 AND)

Andromedids meteor shower is well known as a very active shower from the second half of the 19th century, when meteor storm displays produced frequencies ZHR 7000 in Nov. 27, 1872 and Nov. 27, 1885 (Jenniskens & J., 2007). Smaller meteor outburst with ZHR ~ 1000 was observed on Nov. 24, 1892. The meteor stream is associated with the parent comet 3D/Biela, which was observed with at least two nuclei in 1846 and 1852 after the break up in 1842/43. The last confirmed activity of the shower was observed on Nov. 15, 1940 with ZHR ~ 30, while nowadays the shower has low (less than

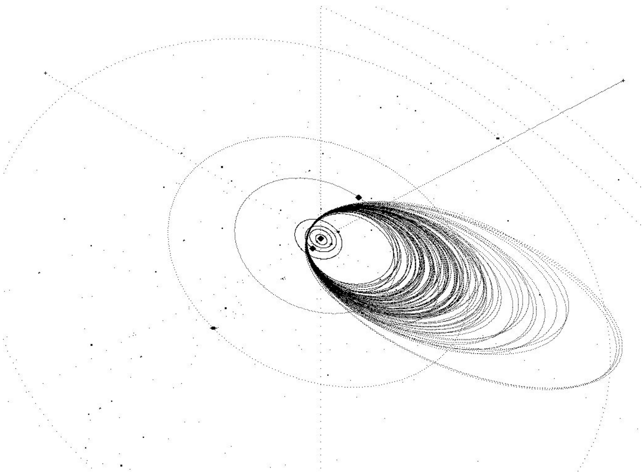

Figure 1 – Orbits of Ursids from EDMOND 2.0 database within $D_{SH} < 0.15$.

ZHR = 1) and long lasted activity from the end of October till end of November. The radiant of the stream members is not considerably concentrated and has large diameter of about 20 degrees and the geocentric velocity in the interval 17-19 km/s. There were identified 91 meteor orbits belonging to Andromedids by the *radiant-*V_g method in the EDMOND 2.0 dataset (Fig. 2). The most precise subset of 30 orbits (Fig. 3) were selected for mean stream orbit characterization (Table 4) with average $D_{SH} = 0.097 \pm 0.029$. The dispersion of mean orbits of previous authors is quite large. The mean orbit from EDMOND data defined from 30 meteors is close to the published orbits by Southworth & Hawkins, 1963, Jacchia, 1963 and Jenniskens, 2006.

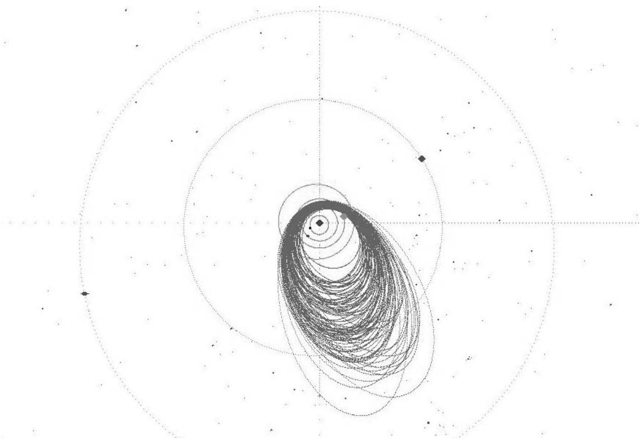

Figure 2 – Orbits of Andromedids from EDMOND 2.0 database within $D_{SH} < 0.15$.

4 α Capricornids (IAU 0001 CAP)

The α Capricornids shower is active approximately from July 15 to August 10 with no pronounced maximum activity. This aspect together with relatively high activity in the close region on the sky (Aquarius-Capricornus) at the same time, it is difficult to clearly distinguish interval of α Capricornids activity. The shower known with high rate of bright meteors, even fireballs (low population index) and broad maximum ZHR $\sim$ 5-10 was discovered by the Hungarian duke M. Konkoly-Thege in

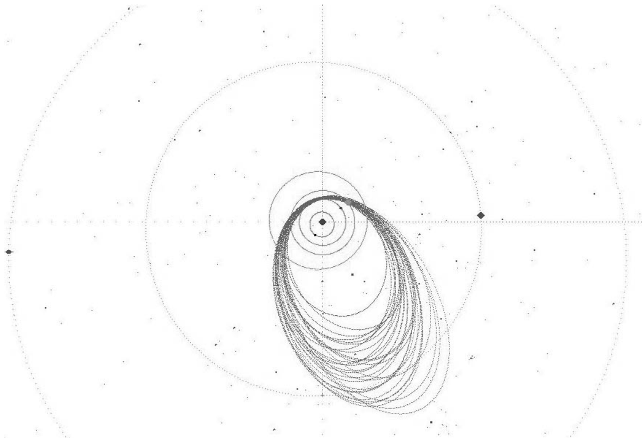

Figure 3 – Orbits of 30 Andromedids from EDMOND 2.0 database with the average $D_{SH} = 0.097$.

1871. The age of the stream is estimated in the interval 3500 - 5000 years (Jenniskens & Vaubaillon, 2010).

The EDMOND 2.0 dataset consists of 345 orbits revealed by the *radiant-*V_g method (Fig. 4). A subset of the 214 most precisely calculated were selected for mean stream orbit characterization (Table 5) with average $D_{SH} = 0.076 \pm 0.035$.). The mean orbit from EDMOND data defined from a large number of meteors is consistent to previously published orbits comparing by D_{SH} (Table 5).

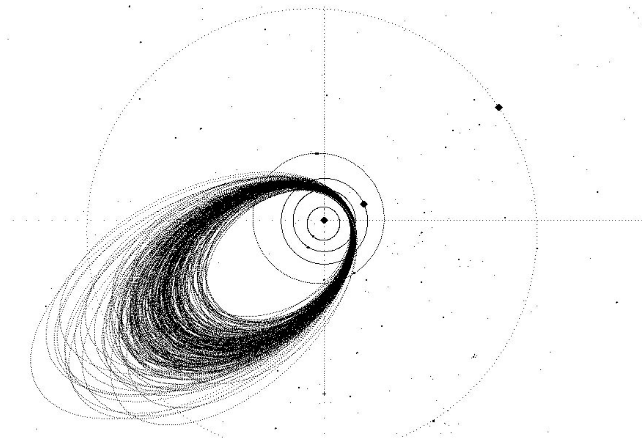

Figure 4 – Orbits of α Capricornids from EDMOND 2.0 database within $D_{SH} < 0.15$.

5 Leonis Minorids (IAU 0022 LMI)

The Leonis Minorids is a weak shower that is active from Oct. 19 to Oct. 27 with maximum ZHR $\sim$ 2-5. At more than 61km/s the geocentric velocity of its meteoroids is high and close to a parabolic limit.

The EDMOND 2.0 dataset contains 108 orbits. 32 of these orbits have an eccentricity larger than 1 (29.6%). A subset of the 55 orbits (no hyperbolic solution) were selected for mean stream orbit characterization (Table 6, Figure 5) with average $D_{SH} = 0.080 \pm 0,034$. The mean orbit from EDMOND data well defined by 55 meteors is almost identical to previously published orbits.

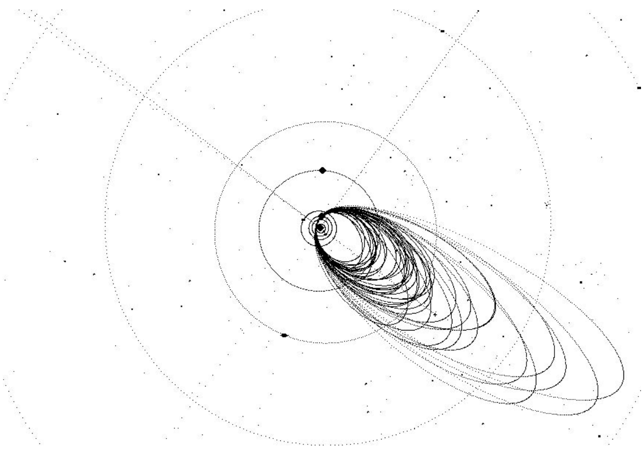

Figure 5 – Orbits of 55 Leonis Minorids from EDMOND 2.0 database with the average $D_{SH} = 0.08$.

6 December Monocerotids (IAU 0019 MON)

The December Monocerotids meteor shower is active from Nov 9 to Dec. 18 with a broad and low (ZHR $\sim$ 2-3) maximum around Dec. 11. It was discovered by F. L. Whipple in 1954 after the analysis of 144 photographic orbits recorded in 1936 - 1951 by the Harvard College Observatory.

The EDMOND 2.0 datasets contains 155 orbits of which 121 of them were used for mean stream orbit characterization (Fig. 6, Table 7). The average D_{SH} of 121 members to mean solution is 0.081 ± 0.034. However, there are 36 hyperbolic orbits among 155 orbits, which is 23.2%. The number of December Monocerotids in EDMOND is about by one order larger than previous published observations. The final orbit is derived only with small standard deviations.

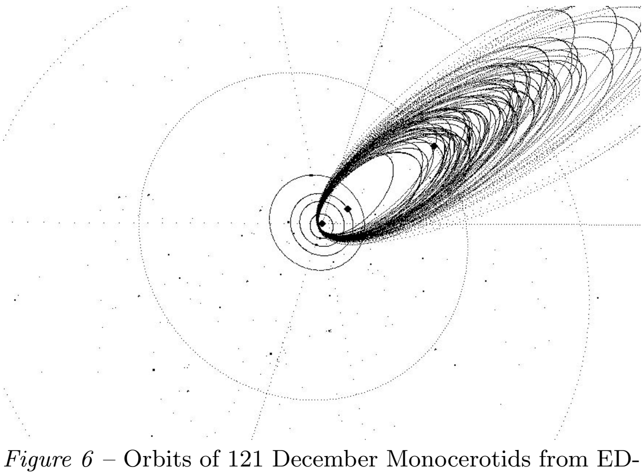

Figure 6 – Orbits of 121 December Monocerotids from EDMOND 2.0 database with the average $D_{SH} = 0.081$.

7 σ Leonids (IAU 0136 SLE)

The σ Leonids is very weak shower with maximum ZHR $\sim$ 1-2 which is assumed to be around April 18. (IAU MDC). The interval activity is not known and similar situation is in stream orbital description, where only limited number of orbits was available, some of them from visual observations.

Database EDMOND 2.0 contains 23 orbits out of which we selected 16 for mean stream orbit determination (Fig. 7, Table 8). The average D_{SH} to mean orbits of these 16 stream members is 0.083 ± 0.035. Our result defines a new mean orbit of sigma Leonids.

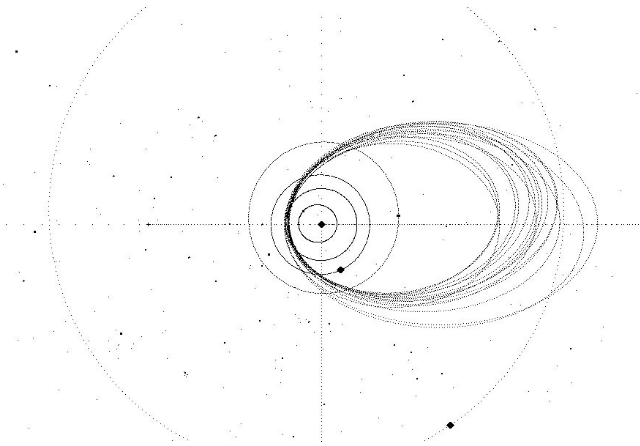

Figure 7 – Orbits of 16 sigma Leonids from EDMOND 2.0 database with the average $D_{SH} = 0.083$.

8 October Ursae Majorids (IAU 0333 OCU))

The October Ursae Majorids was discovered by Uehara et al., 2006 based on 14 video orbits and confirmed by another authors and observational techniques (e.g. Gajdoš, 2007). Database EDMOND 2.0 consists of 107 orbits from the stream. 45 orbits were used for mean orbit of the stream characterization (Fig. 8, Table 9). Their average D_{SH} to the mean solution is 0.088 ± 0.033, which represents high internal orbital similarity among stream members similar like above mentioned meteor streams. However, there are 20 orbits from 107 stream members with $e > 1$, which is 18.7%. It is a natural to have hyperbolic orbital solution in the datasets, especially for streams with relatively high geocentric velocity, where small error in velocity measurements is transformed in larger spread of orbital parameters, especially semimajor axis and eccentricity (Hajduková, 2008; Hajduková, 2011).

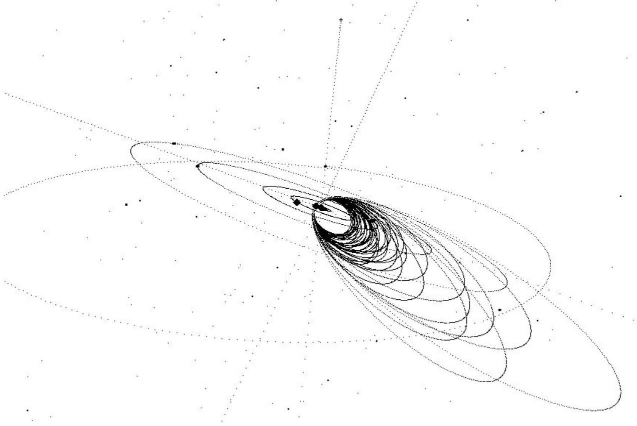

Figure 8 – Orbits of 45 October Ursae Majorids from EDMOND 2.0 database with the average $D_{SH} = 0.088$.

9 October Camelopardalids (IAU 0281 OCT)

The October Camelopardalids is another recently identified meteor shower. Its identification is based on 13 orbits after the outburst in Oct. 5, 2005 by Jenniskens et al., 2005. The database EDMOND 2.0 contains 100 orbits. We used only 19 of them for mean orbit of the stream characterization (Fig. 9, Table 10), where mean value of D_{SH} is 0.080 ± 0.024.). Our result differs from Jenniskens et al., 2005 mainly in eccentricity. More detail analysis would be needed in the future.

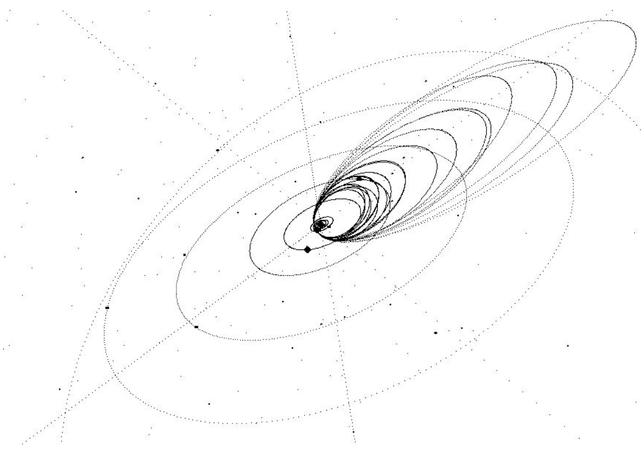

Figure 9 – Orbits of 19 October Camelopardalids from EDMOND 2.0 database with the average $D_{SH} = 0.080$.

10 Conclusions

This paper demonstrates the benefits of data sharing. EDMOND has brought together many meteor observers and represents the combined data from 8 national networks. With the availability of more data comes improved accuracy and increased potential to identify statistically significant results.

To demonstrate the potential of the EDMOND database, we have analyzed eight meteor shower datasets within the EDMOND 2.0 database (2009 - 2012) including established showers and showers on the IMO working list. Mostly we refined the mean orbits of these streams by using larger number of available orbits from the EDMOND database, compared to previous works, with quite low dispersions in orbital parameters.We were in this way able to improve the precision of all parameters when compared with previous calculations.

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Table 1 – Orbital elements of analyzed meteor showers according to IAU MDC. For each shower the following parameters are provided: Sol - Solar longitude of shower maximum, RA, DEC - radiant position, dRa, dDe - daily radiant motion, v_g - geocentric velocity (in km/s), a - semimajor axis (in AU), q - perihelion distance, e - eccentricity, ω - argument of perihelion, ω - ascending node, i - inclination, N - number of orbits in the IAU MDC. All angular values are given in degrees.

name	ID	$\lambda_\odot$	RA	dRA	DEC	dDE	v_g	a	q	e	ω	Ω	i	N
Ursids	15 URS	271	219.35		75..34		33.0	4.62	0.944		204.9	270.74	51.5	64
Andromedids	18 AND	232	24.2	+0.63	32.5	+0.33	17.2	2.76	0.789		238.9	231.0	10.0	18
α Capricornids	I1 CAP	127	306.6	+0.54	-8.2	+0.26	22.2	2.618	0.602		266.67	128.9	7.68	36
Leonis Minorids	22 LMI	209	159.5	+1.42	36.7	-0.36	61.9	286	0.616		102.73	208.36	125.32	10
December Monocerotids	19 MON	260.9	101.8	+0.83	8.1	-0.05	42	50.7	0.193		128.1	80.2	35.2	11
σ Leonids	136 SLE	27.7	192.6		3.1		23	2.141	0.561		271.9	8.7	6.2	0
October Ursae Majorids	333 OCU	202	144.8		64.5		54.1	5.9	0.979	0.875	163.7	202.1	99.7	10
October Camelopardalids	281 OCT	193	166		79.1		46.6	368	0.993		170.6	192.57	78.6	0

Table 3 – Comparison of orbital elements of the Ursids mean orbit calculated from EDMOND 2.0 database compared with the Meteoroid Stream Working List (Jenniskens, 2006) and other authors results. The following parameters are provided: q - perihelion distance, e - eccentricity, ω - argument of perihelion, ω - ascending node, i - inclination, N - number of orbits, D_{SH} - orbital similarity criterion between EDMOND and other authors results, RA, DEC - radiant position, v_g - geocentric velocity (km/s), H1, H2 - average beginning and terminal heights (km), respectively. σ is the standard deviation of the corresponding values.

	q	e	ω	Ω	i	N	D_{SH}	RA	DEC	v_g	H_1	H_2
EDMOND												
Mean	0.9368	0.8001	206.73	269.74	51.97	86		218.76	76.27	32.60	101.4	86.4
σ	0.0079	0.0503	2.26	1.78	1.99			5.03	2.07	1.11		
Other authors												
Jenniskens, 2006	0.944	0.796	205.90	270.74	51.50	64	0.024	219.35	75.34	33.00		
Kashcheyev & Lebedinets, 1963	0.890	0.660	224.00	270.70	52.00	-	0.268	190.50	74.70	32.00		

Table 4 – Orbital elements of mean orbit of Andromedids from EDMOND 2.0 database compared to other authors. The symbols used are the same as in the Table 3.

	q	e	ω	Ω	i	N	D_{SH}	RA	DEC	v_g	H_1	H_2
EDMOND												
Mean	0.7501	0.7194	245.17	224.40	9.38	30		22.66	28.59	18.09	92.4	84.8
σ	0.0289	0.0458	4.01	4.91	1.81			3.99	4.34	1.37		
Other authors												
Jenniskens, 2006	0.789	0.714	238.90	231.00	10.00	18	0.127	24.2	32.5	17.2		
Jopek, 1992	0.691	0.605		221.00	12.00	5		27.2	34.9	17.6		
Porubčan & Gavajdová, 1994	0.760	0.680	245.20	207.20	14.30	3	0.153	3.3	31.8	18.1		
Terentjeva, 1989	0.738	0.698	248.60	201.90	12.40		0.202	2.6	26.3	18.7		
Terentjeva, 1989	0.854	0.532	232.40	234.80	13.80		0.302	17.7	46.3	14.1		
Southworth & Hawkins, 1963	0.777	0.732	242.70	225.50	7.50	23	0.059	23.7	9.3	18.9		
Jacchia, 1963	0.740	0.726	247.00	226.00	6.80		0.057	27.7	25.2	18.0		

Table 5 – Orbital elements of mean orbit of alpha Capricornids from EDMOND 2.0 database compared to other authors. The symbols used are the same as in the Table 3.

	q	e	ω	Ω	i	N	D_{SH}	RA	DEC	v_g	H_1	H_2
EDMOND												
Mean	0.5921	0.7602	268.02	126.89	7.12	214		305.87	-9.47	22.28	93.5	83.5
σ	0.0278	0.0369	3.36	3.75	1.47			3.08	2.16	1.18		
Other authors												
Jenniskens, 2006	0.602	0.770	266.67	128.90	7.68	36	0.036	306.6	-8.2	22.2		
Galligan & Baggaley, 2002	0.550	0.745	273.30	122.30	7.70	269	0.110	306.7	-9.3	23.4		
Hasegawa, 2001	0.594	0.766	267.60	123.80	7.20		0.028	303.4	-10.6	22.2		
Porubčan & Gavajdová, 1994	0.626	0.726	266.20	138.50	4.90	15	0.118	315.9	-8.7	20.6		
Galligan, 2003	0.544	0.733	275.90	123.50	7.00		0.137	306.4	-9.9	22.5		
Jopek & Froeschle, 1997	0.580	0.780	268.00	134.70	6.00		0.062	314.7	-8.8	23.0		
Sekanina, 1976	0.620	0.677	267.90	136.60	6.10	44	0.111	315.9	-7.1	19.7		
Sekanina, 1973	0.630	0.659	267.20	147.50	0.90	28	0.206	327.1	-11.7	18.8		
Lindblad, 1971	0.592	0.765	267.90	126.10	7.10	18	0.009	305.4	-9.6	25.0		
Cook, 1973	0.590	0.770	269.00	127.70	7.00	21	0.021	308.4	-9.6	22.8		

Table 6 – Comparison of orbital elements of the Leonis Minorids mean orbit calculated from EDMOND 2.0 database compared with the Meteoroid Stream Working List (Jenniskens, 2006) and other authors results.

	q	e	ω	Ω	i	N	D_{SH}	RA	DEC	v_g	H_1	H_2
EDMOND												
Mean	0.6167	0.9531	102.68	208.19	124.63	55		159.06	37.16	61.23	113.5	99.1
σ	0.0226	0.0499	3.24	2.63	1.62			2.96	1.22	0.99		
Other authors												
Jenniskens & Vaubaillon, 2010	0.616	0.978	102.73	208.36	125.32	10	0.028	159.5	36.7	61.9		
Lignie & Betlem, 1999	0.641	0.980	106.30	209.90	124.50	4	0.069	160.7	37.2	61.8		
Cook, 1973	0.650	0.988	106.00	211.70	124.00		0.081	162.7	36.7	61.8		

Table 7 – Orbital elements of mean orbit of December Monocerotids from EDMOND 2.0 database compared to other authors.

	q	e	ω	Ω	i	N	D_{SH}	RA	DEC	v_g	H_1	H_2
EDMOND												
Mean	0.1882	0.9825	129.29	78.61	35.28	121		100.70	8.09	41.32	101.4	87.3
σ	0.0174	0.0208	2.62	3.00	2.67			2.34	1.04	1.49		
Other authors												
Jenniskens, 2006	0.193	0.996	128.10	80.20	35.20	11	0.038	101.8	8.1	42.0		
Ohtsuka, 1989	0.188	0.991	128.90	80.20	34.90	15	0.026	102	8.3	41.6		
Lindblad & Olson-Steel, 1990	0.187	0.993	128.90	81.10	34.90	12	0.037	102.2	8.3	41.8		
Sekanina, 1976	0.153	0.975	135.80	72.50	22.30	30	0.282	95.1	14.5	40.0		
Sekanina, 1973	0.119	0.983	141.20	68.00	24.70	52	0.356	92.1	15	41.6		
Lindblad, 1971	0.175	0.997	131.00	82.50	31.50		0.097	100.7	8	42.0		
Gartrell & Elford, 1975	0.190	0.975	130.00	82.70	39.90	3	0.100	106.7	5.9	40.5		
Nilsson, 1964	0.110	0.980	138.90	76.90	39.00	6	0.204	102.3	9.5	42.2		
Nilsson, 1964	0.110	0.990	135.30	73.90	22.60	4	0.275	95.5	14.5	41.3		
Terentjeva, 1989	0.121	0.965	141.90	89.00	22.30		0.385	113.7	13.9	41.6		
Nilsson, 1964	0.200	0.990	131.50	77.30	18.70	4	0.293	96.8	15.1	40.6		
Jacchia, 1963	0.140	0.997	135.80	77.60	24.80	3	0.224	100.5	14	42.4		
Whipple, 1957	0.186		128.20	81.60	35.20	2		103.7	7.9	42.4		

Table 8 – Orbital elements of mean orbit of sigma Leonids from EDMOND 2.0 database compared to other authors.

	q	e	ω	Ω	i	N	D_{SH}	RA	DEC	v_g	H_1	H_2
EDMOND												
Mean	0.6854	0.7283	255.4494	19.3379	5.3458	16		194.49	3.07	20.16	92.47	82.80
σ	0.0318	0.0304	4.4438	3.3185	1.6843			3.42	1.53	1.01		
Other authors												
Porubčan & Gavajdová, 1994	0.561	0.738	271.90	9.40	6.20		0.300	193.3	3.1	23.0		
Terentjeva, 1989	0.605	0.734	266.30	14.50	2.20		0.195	192.6	-2.3	21.2		
Hoffmeister, 1948	0.480	0.686	286.00	13.70	1.90	vis	0.461	200.7	-6.3			

Table 9 – Orbital elements of mean orbit of October Ursae Majorids from EDMOND 2.0 database compared to other authors.

	q	e	ω	Ω	i	N	D_{SH}	RA	DEC	v_g	H_1	H_2
EDMOND												
Mean	0.9739	0.8675	162.16	202.97	100.45	45		146.67	63.54	54.70	112.2	96.4
σ	0.0085	0.0640	3.36	1.43	2.35			3.90	1.50	1.06		
Other authors												
Uehara et al., 2006	0.979	0.875	163.70	202.10	99.70	14	0.031	144.8	64.5	54.1		

Table 10 – Orbital elements of mean orbit of October Camelopardalids from EDMOND 2.0 database compared to other authors.

	q	e	ω	Ω	i	N	D_{SH}	RA	DEC	v_g	H_1	H_2
EDMOND												
Mean	0.9903	0.8842	168.61	192.15	77.80	19		164.62	78.52	45.27	106.0	93.2
σ	0.0044	0.0667	2.57	1.07	1.42			5.62	1.21	0.99		
Other authors												
Jenniskens et al., 2005	0.993		170.50	192.59	79.30	13		164.1	78.9	47.3		
Jenniskens et al., 2005	0.993	0.997	170.60	192.57	78.60		0.119	166.0	79.1	46.6		