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Front cover photo

Composite image showing the Milky Way, shot from Hakos Guestfarm, Namibia. Three Capricornids, three Southern δ-Aquariids and a possible Pisces Austrinid are also visible in the original image. Canon EOS 40D equipped with Canon EF 15 mm $f/2.8$ lens was used, set to ISO 1000 and 90 s exposure, and mounted on AstroTrac Travel Mount. See page 65 for observing report. Photo courtesy: Koen Miskotte.

Writing for WGN This Journal welcomes papers submitted for publication. All papers are reviewed for scientific content, and edited for English and style. Instructions for authors can be found in WGN **31:4**, 124–128, and at `http://www.imo.net/articles/writingforwgn.pdf` .

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Ongoing meteor work

Four IAU MDC Working List Meteor Showers confirmed via SonotaCo Network Japan data

John Greaves[1]

The SonotaCo Network Japan meteor orbit database is examined using D criterion methods revealing the existence of meteor candidates confirming the four International Astronomical Union Meteor Data Center Working List showers the γ-Ursa Minorids, the x-Herculids, the ζ-Serpentids and the β-Hydrids.

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1 Introduction

The existence of the SonotaCo Network Simultaneously Observed Meteor Data Sets[a] (e.g. SonotaCo, 2009) being noted due to the recent paper of Vereš and Tóth (2011), copies of the datasets were obtained and orbital elements contained therein analysed following the Jopek (1993) modification of Southworth & Hawkins' (1963) D criterion formulation.

Some possible new showers found in the SonotaCo data were given in Greaves (2012). Using the methodology outlined in that paper this paper gives results for a further four showers catalogued as Working List Showers at the International Astronomical Union Meteor Data Center (IAU MDC)[b]. All four showers are not referenced as SonotaCo showers at the IAU MDC, so to some extent this analysis represents independent confirmation of these Working List showers.

2 Results

Four showers that were well defined enough in SonotaCo data to be likely real whilst also appearing in the full list of the IAU MDC are summarised below. Two of the showers were discovered and published within the past few years, one from a radar and one from a video meteor survey. The two remaining showers do not appear in the literature, with no reference quoted on their IAU MDC summary pages or any reference found via online literature searches.

The details for each particular shower are given in turn below, complete with shower names, acronyms and number as provided by the International Astronomical Union Meteor Data Centre's Nomenclature Committee (Jenniskens, 2008). Orbit diagrams are given for each shower.

For each shower a table giving their "localtime" identifier listing the Japanese Local Time of the meteor in YYYYMMDD_hhmmss format, observed radiant Right Ascension (α) and Declination (δ) in degrees, Solar Longitude ($\lambda_\odot$) in degrees, Geocentric Velocity (V_g) in kilometres per second and magnitude (mag.) from SonotaCo is given. Where available the values for these parameters as quoted by the IAU MDC are also given, for comparison with the data. Also given is a table giving the meteors' "localtime" identifiers and their orbital elements in the order of q (perihelion), e (eccentricity), i (inclination), ω (argument of perihelion) and Ω (ascending node) are included for each shower. The mean Right Ascension, Declination and Solar Longitude are given for each shower, and the mean of each orbital element for the orbits.

2.1 404 GUM – the γ-Ursae Minorids

Brown et al. (2009) listed amongst meteoroid streams they discovered with the Canadian Meteor Orbit Radar (CMOR) survey a shower they named the γ-Ursae Minorids, or GUM in IAU MDC coding. Later a group of Finnish observers made an optical detection of an outburst from this shower in late January 2010 (Jenniskens, 2010).

The main discrepancy between the SonotaCo and the CMOR orbital elements for this shower was the eccentricity. In the SonotaCo data were two candidate meteors each for 2007 and 2008 and four for 2009. As the SonotaCo limiting magnitude is about two there does seem to be some proclivity for a handful of bright objects from this stream, as noted in Jenniskens (2010). However there is also the possibility that the optical/video and radio meteors represented different areas of the stream due to their differing mass distribution, which may have contributed to some of the slight differences in radiant particulars apparent between the SonotaCo candidates' mean data and the IAU MDC values for the GUM shower, as illustrated in Table 1 below. Figure 1 presents the orbits of the SonotaCo GUM candidates.

Further, meteors from the Harvard Radio Meteor Patrol (Hawkins, 1963), when tested against SonotaCo GUM candidate orbits, also provided candidates for this shower from as far back as the 1960s. The orbital and radiant particulars of these Harvard radio meteors are given in Table 3 below (note the results from an earlier version of this analysis were first noted in a post to the `meteorobs.org` mailing list).

2.2 346 XHE – the x-Herculids

This shower was noted during analyses of the IMO Video Meteor Network (Molau & Kac, 2009). The Sono-

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[a]`http://sonotaco.jp/doc/SNM/`

[b]`http://www.astro.amu.edu.pl/~jopek/MDC2007/Roje/roje_lista.php?corobic_roje=0&sort_roje=0`

Table 1 – SonotaCo Radiant Particulars for the γ-Ursae Minorid candidates.

LOCALTIME	α	δ	$\lambda_\odot$	V_g (km/s)	mag.
20070120_043221	225°.1635	66°.7944	299°.249	28	+0.80
20070121_040108	226°.3433	67°.4714	300°.246	27	−2.28
20080120_004302	220°.6722	68°.8066	298°.830	29	+1.05
20080122_030728	227°.7384	65°.5818	300°.967	30	+0.67
20090118_023436	222°.9266	69°.5014	297°.623	27	−0.15
20090118_032958	221°.2099	69°.3544	297°.662	28	+1.15
20090120_054949	229°.7661	66°.7867	299°.797	29	+0.10
20090120_214839	220°.5257	70°.3676	300°.475	28	+0.65
Mean	224°.2932	68°.0830	299°.356	28	
IAU MDC	231°.80	66°.80	299°.00	32	

Table 2 – SonotaCo Orbital Elements for the γ-Ursae Minorid candidates.

LOCALTIME	q (AU)	e	i	ω	Ω
20070120_043221	0.946105	0.598378	46°.5340	206°.2066	299°.2496
20070121_040108	0.949760	0.589537	45°.1152	205°.0353	300°.2457
20080120_004302	0.946578	0.661844	47°.1738	205°.1962	298°.8301
20080122_030728	0.955962	0.681967	49°.5183	201°.6191	300°.9672
20090118_023436	0.948227	0.609727	44°.5006	205°.2369	297°.6234
20090118_032958	0.941233	0.633599	45°.1455	207°.3212	297°.6626
20090120_054949	0.952824	0.650311	47°.3588	203°.1236	299°.7976
20090120_214839	0.947293	0.594076	45°.4315	205°.8670	300°.4754
Mean Orbit	0.948498	0.627430	46°.3472	204°.9507	299°.3565

Table 3 – Orbital and radiant data of GUM candidates from the Harvard Radio Meteor Project.

ID	Date	α	δ	q	e	i	ω	Ω
HARVARD 921	1962/01/16.6	201°	+73°	0.896	0.601	41°.7	220°.5	295°.9
HARVARD 969	1962/01/18.8	222°	+71°	0.936	0.625	44°.0	208°.9	298°.1
HARVARD 970	1962/01/18.8	232°	+74°	0.951	0.548	38°.3	204°.7	298°.1
HARVARD6830	1963/01/16.7	226°	+70°	0.945	0.633	46°.4	205°.8	295°.7
HARVARD6840	1963/01/16.8	224°	+69°	0.943	0.598	46°.8	207°.5	295°.7
HARVARD6871	1963/01/17.8	240°	+69°	0.968	0.603	44°.5	196°.7	296°.7
HARVARD6908	1963/01/18.0	232°	+70°	0.958	0.644	46°.0	201°.4	297°.0
HARVARD6917	1963/01/18.9	209°	+71°	0.909	0.575	42°.6	217°.9	298°.0
HARVARD Mean		223°	+71°	0.938	0.603	43°.8	207°.9	296°.9

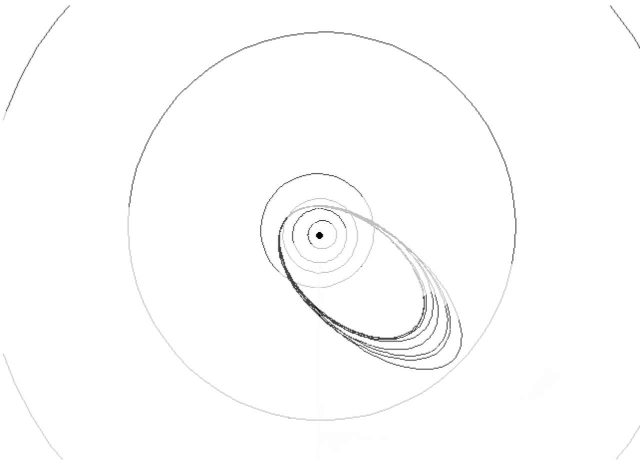

Figure 1 – Orbit Plots for the SonotaCo meteor orbits having D criterion threshold of less than 0.10 relative to each other for the γ-Ursae Minorid candidates. The orbits of the planets out to that of Saturn are also shown.

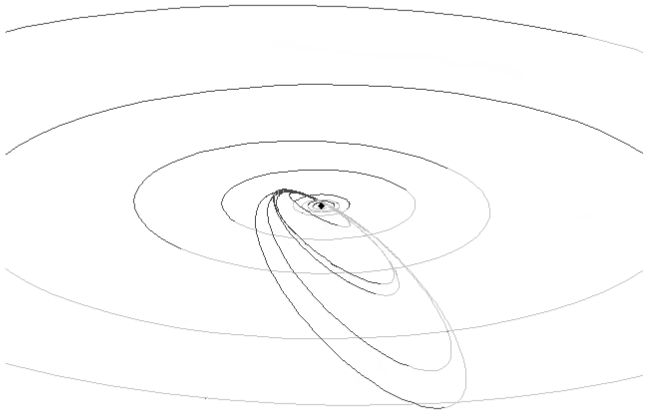

Figure 3 – Orbit Plots from SonotaCo for the ζ-Serpentid shower candidates. Planetary orbits out to that of Neptune are also shown.

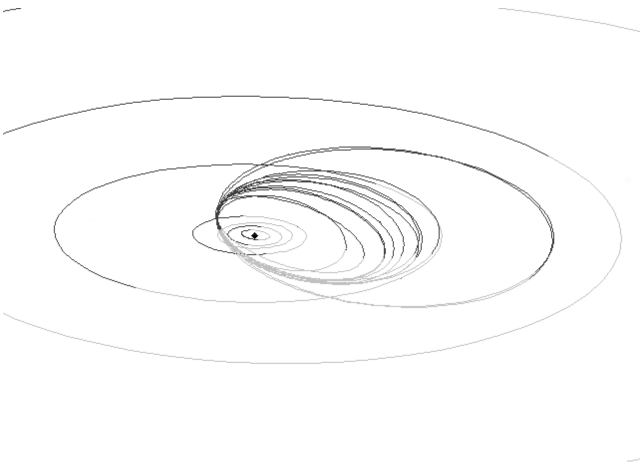

Figure 2 – Orbit Plots from SonotaCo for the x-Herculid shower candidates. Planetary orbits out to that of Neptune are also shown.

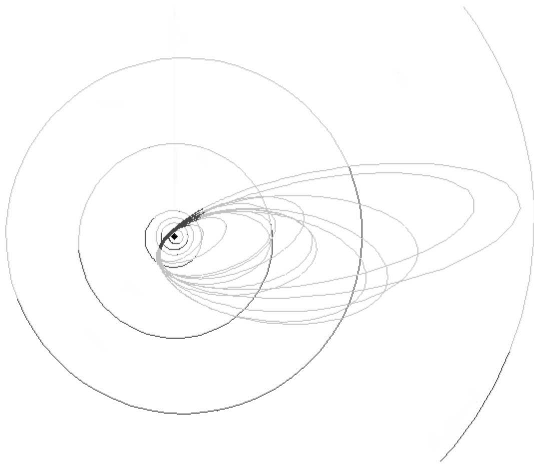

Figure 4 – Orbit Plots from SonotaCo for the β-Hydrid shower candidates. Planetary orbits out to that of Uranus are also shown.

taCo data contains a number of candidates for this shower in both 2007 and 2009. The mean radiant position from the SonotaCo candidates was off from that quoted by the IAU MDC by a couple of degrees but the mean Solar Longitude and mean Geocentric Velocity matched quite closely.

This shower appeared to be well confirmed by the candidate meteor orbit data, and the high limiting magnitude of the SonotaCo system suggested that it was and is capable of giving a relatively good showing, albeit spread over some nights, and also with the caveat that it has only been noted as existing in recent times. Somewhat counter to this caveat is the point that it is only within recent times that surveys have tended to be more all sky and all year, as opposed to being concentrated around the times of major established showers.

2.3 43 ZSE – the ζ-Serpentids

No reference was given for this working list shower at the IAU MDC, nor could one be found using any academic literature search engine or any general internet search. Further the IAU MDC gives a rather confusing Solar Longitude of 365 degrees.

With only five meteor orbits from SonotaCo when a D criterion threshold of less than 0.10 was used, as well with a very wide range of orbit aphelia (as illustrated in Figure 3), this shower was the least supported by the SonotaCo data.

2.4 316 BHD – the β-Hydrids

The β-Hydrids also had no reference given for them in neither the Meteor Shower Working List of the IAU MDC, the academic literature, or in general internet searches.

At first it seemed to be a candidate new shower, as it was centred more around ξ Hydrae than β, with the mean SonotaCo radiant being almost a dozen degrees Eastward in Right Ascension and around a dozen degrees earlier in Solar Longitude. The IAU MDC also did not quote a Geocentric Velocity for the shower with which a further comparison could be made. Thus at first the possible connection with the β-Hydrids was

Table 4 – SonotaCo Radiant Particulars for the x-Herculid candidates.

LOCALTIME	α	δ	$\lambda_\odot$	V_g (km/s)	mag.
20070308_014054	248°.80417	49°.85033	346°.6299	35	+0.25
20070312_024115	251°.69031	49°.05692	350°.6696	35	+0.90
20070312_033545	255°.89099	52°.80688	350°.7075	36	+1.17
20070315_024749	252°.94122	50°.71002	353°.6678	33	+1.90
20070315_041148	256°.54004	50°.06058	353°.7260	33	−1.55
20090309_033724	250°.90772	50°.24875	348°.2016	34	+1.55
20090311_031905	254°.12209	47°.95913	350°.1868	32	+0.60
20090311_035153	254°.42683	47°.90416	350°.2096	38	+0.55
20090312_002349	250°.49559	51°.46520	351°.0635	33	+1.67
20090312_021911	253°.45425	48°.34382	351°.1435	35	+0.07
20090315_043157	254°.89267	48°.15172	354°.2268	38	+0.05
20090315_223323	251°.57048	51°.37303	354°.9749	33	+2.15
20090320_050653	252°.01617	52°.96843	359°.2262	29	+1.40
Mean	252°.90404	50°.06915	351°.8949	34	
IAU MDC	254°.0	48°.0	352°.0	34	

Table 5 – SonotaCo Orbital Elements for the x-Herculid candidates.

LOCALTIME	q (AU)	e	i	ω	Ω
20070308_014054	0.971986	0.700938	59°.1025	198°.1534	346°.6300
20070312_024115	0.973835	0.681966	59°.0700	197°.9405	350°.6698
20070312_033545	0.986047	0.898570	58°.3041	190°.1670	350°.7076
20070315_024749	0.976592	0.633089	55°.3704	197°.4083	353°.6679
20070315_041148	0.982983	0.603294	56°.0450	194°.1048	353°.7261
20090309_033724	0.973928	0.671665	57°.6216	197°.6694	348°.2017
20090311_031905	0.977967	0.471979	56°.3829	197°.8306	350°.1870
20090311_035153	0.979767	0.804404	63°.2744	194°.1865	350°.2097
20090312_002349	0.977120	0.673224	56°.1825	196°.4585	351°.0637
20090312_021911	0.978081	0.644638	59°.6379	196°.1873	351°.1436
20090315_043157	0.976617	0.812902	62°.3349	196°.2197	354°.2270
20090315_223323	0.978323	0.615610	55°.4176	196°.8392	354°.9752
20090320_050653	0.970475	0.581407	49°.1689	201°.4279	359°.2264
Mean Orbit	0.977209	0.676437	57°.5318	196°.5072	351°.8951

Table 6 – SonotaCo Radiant Particulars for the ζ-Serpentid candidates.

LOCALTIME	α	δ	$\lambda_\odot$	V_g (km/s)	mag.
20070313_021259	259°.8229	−7°.0047	351°.6484	70	+1.10
20070315_034603	261°.1765	−5°.0638	353°.7081	68	+0.80
20080311_005242	259°.5092	−6°.5014	350°.3457	69	+0.87
20080316_025220	260°.6394	−7°.1741	355°.4159	65	+0.37
20090312_043051	260°.0199	−5°.0586	351°.2347	68	−0.67
Mean	260°.2336	−6°.1605	352°.4706	68	
IAU MDC	266°.30	−6°.30		67	

Table 7 – SonotaCo Orbital Elements for the ζ-Serpentid candidates.

LOCALTIME	q (AU)	e	i	ω	Ω
20070313_021259	0.991665	0.943903	153°.0311	185°.2487	351°.6479
20070315_034603	0.988581	0.863614	149°.1957	189°.0029	353°.7077
20080311_005242	0.993266	0.925188	152°.2430	181°.1645	350°.3456
20080316_025220	0.969635	0.556426	151°.7147	201°.6442	355°.4158
20090312_043051	0.991792	0.869598	149°.3851	184°.9914	351°.2341
Mean Orbit	0.986988	0.831746	151°.1139	188°.4103	352°.4702

not recognized and the meteors appeared to constitute a new shower. However, the parsimonious interpretation was for the seventeen meteor candidates to have been providing confirmation of the IAU MDC working list shower known as the β-Hydrids.

Despite all the problems of limited listed parameters to test against, a number of bright meteors could be found that emanated from this region at a particular time of year and with high inclination retrograde orbits (precluding it being a symptom of some general Ecliptic mass of meteoroids like, for example, the antihelion showers), thus they were reasonably close enough fits to the IAU MDC working list shower known as the β-Hydrids for them to be candidate members thereof.

3 Conclusion

With the application of a D criterion test it was possible to assess some IAU MDC Working List showers for their potential validity, and furthermore test them using meteor orbit data independent of the data with which they were discovered (none of these showers are published as, or listed as, SonotaCo discoveries).

For the γ-Ursae Minorids the original discovery of the shower was via 3D wavelet analysis (Brown et al., 2009) of radio meteor orbits, and the shower had already been optically confirmed (Jenniskens, 2010). For the x-Herculids radiant clustering was the method of discovery (Molau & Kac, 2009). For the ζ-Serpentids and the β-Hydrids no discovery details nor literature were found.

Via the independent D criterion assessment of the independent SonotaCo data it was possible to find coorbital objects with radiant and at times Solar Longitude and Geocentric Velocity particulars that could be matched to these IAU MDC Working List showers.

It is perhaps time that showers defined from orbital elements generated from multistation meteor surveys automatically included D criterion tests as a standard practice.

In the first instance any group of candidate objects that is new or unconfirmed can be tested against their own mean elements, which can then be refined by the removal of failing members, and if this refinement is such that the mean becomes sufficiently different from the initial input value then this new mean can be used as new seed to look within a dataset again for candidates. Unconfirmed and confirmed showers can have their elements tested via D criterion against candidates from new datasets to identify any new members contained in said.

Away from the Ecliptic and Antihelion regions at least it appears to give a meaningful means of testing between happenstance and actual relationship for apparently related objects.

Acknowledgement

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Table 8 – SonotaCo Radiant Particulars for the β-Hydrid candidates.

LOCALTIME	α	δ	$\lambda_\odot$	V_g (km/s)	mag.
20070126_011018	173°.0816	−33°.8766	305°.2123	56	+1.27
20070126_041613	176°.7137	−31°.4502	305°.3435	55	+2.43
20070130_024228	178°.8636	−32°.2572	309°.3418	59	+1.16
20070202_022952	177°.9953	−35°.7054	312°.3780	58	+0.50
20070203_025118	180°.2154	−35°.8429	313°.4075	59	+0.75
20070203_045758	180°.2851	−35°.4047	313°.4967	58	+0.20
20080126_034044	170°.2950	−32°.9025	305°.0582	57	+1.30
20090125_013037	172°.7851	−31°.9268	304°.7024	59	+1.00
20090125_050653	173°.8014	−30°.9362	304°.8551	60	+1.58
20090126_040839	176°.1941	−30°.0206	305°.8311	60	+1.26
20090127_032305	174°.2880	−31°.7785	306°.8159	59	−0.40
20090128_010234	171°.6946	−34°.8158	307°.7334	58	+0.67
20090128_040603	177°.7087	−30°.8565	307°.8628	60	+0.95
20090201_055932	180°.5885	−33°.5904	312°.0066	60	+1.13
20090202_022624	175°.5833	−32°.6506	312°.8715	60	+1.20
20090202_034814	176°.2161	−32°.9488	312°.9290	59	+0.90
20090206_040722	180°.8947	−34°.1408	316°.9991	59	+2.95
Mean	176°.3061	−33°.0061	309°.2262	58	
IAU MDC	187°.0	−34°.0	320°.7		

Table 9 – SonotaCo Orbital Elements for the β-Hydrid candidates.

LOCALTIME	q (AU)	e	i	ω	Ω
20070126_011018	0.683853	0.764994	109°.7160	72°.8168	125°.2123
20070126_041613	0.614994	0.661764	113°.8683	86°.7036	125°.3435
20070130_024228	0.662865	0.866416	117°.1127	72°.8087	129°.3418
20070202_022952	0.679880	0.905121	110°.4337	69°.6666	132°.3780
20070203_025118	0.697362	0.959115	113°.2203	66°.2472	133°.4075
20070203_045758	0.664747	0.881642	111°.9823	72°.2206	133°.4967
20080126_034044	0.660061	0.886762	108°.0128	72°.6073	125°.0583
20090125_013037	0.682363	0.903454	113°.7273	69°.2993	124°.7025
20090125_050653	0.676045	0.973056	116°.3260	68°.6082	124°.8553
20090126_040839	0.662675	0.929817	119°.4540	71°.2504	125°.8313
20090127_032305	0.656204	0.914886	113°.8614	72°.4352	126°.8160
20090128_010234	0.693017	0.957903	107°.8031	66°.7705	127°.7334
20090128_040603	0.662009	0.936868	119°.1527	71°.1946	127°.8629
20090201_055932	0.670470	0.944912	116°.3906	69°.9839	132°.0067
20090202_022624	0.617884	1.048764	111°.3423	74°.2541	132°.8715
20090202_034814	0.618872	1.021806	111°.3237	74°.6947	132°.9291
20090206_040722	0.608529	0.972009	112°.3421	77°.0988	136°.9991
Mean Orbit	0.659519	0.913488	113°.2982	72°.2741	129°.2262

Orbits of the July Pegasid meteors observed during 2008 to 2011

Masayoshi Ueda[1]

During 2008 to 2011, we observed 63 TV meteors of the July Pegasids simultaneously with the SonotaCo Network in Japan. The activity period of the stream was determined as July 6–19. We derived the corrected radiant $\alpha_G = 349\overset{\circ}{.}6$, $\delta_G = +11\overset{\circ}{.}3$ at the solar longitude $\lambda_\odot = 110\overset{\circ}{.}9$ (equinox 2000.0), and geocentric velocity V_G = 63.9 km/s. In addition, the theoretical radiant and geocentric velocity from Comet Bradfield (1979 X = C/1979 Y1) are in accordance with these values, as Rendtel et al. (1995) and Jenniskens (2006) already suggested. From this fact, we are able to confirm that Comet Bradfield (1979 X) is the parent comet of the July Pegasids.

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1 Introduction

The July Pegasids (JPE) have an activity period during July 7 to July 13. The zenithal hourly rate (ZHR) of JPE is about 3 (Rendtel et al., 1995). In addition, from the data of July during 1996 to 1999 in the Visual Meteor Databases of the International Meteor Organization (IMO), it is determined that the activity period is July 5–15, maximum $\lambda_\odot = 108\overset{\circ}{.}52 \pm 0\overset{\circ}{.}24$, and ZHR = 3.11±0.13 (Olech & Wiśniewski, 2002). Two positions of the JPE radiant have been reported: one from visual observations and another from photographic observations (Jenniskens, 2006). Triglav-Čekada & Arlt (2005) stated that the radiant point of the JPE could not be found from the data of July–August of 1993–2004 in the IMO video network database. But Molau & Rendtel (2009) derived the shower's radiant position and drift, and its velocity and drift, from analysis of 591 JPE meteors with the IMO Video Meteor Network. Furthermore, the JPE were active above the sporadic background from 2010 July 8 to 16 (Molau & Kac, 2010).

2 TV observations

TV meteor data of the JPE from 2008 to 2011 have been reported to the SonotaCo Network from the following observers: K. Adachi, H. Horigane, H. Inoue, T. Kamimura, T. Komai, T. Masuzawa, K. Maeda, K. Miyazaki, H. Muroishi, J. Nakai, S. Okamoto, N. Saito, the Sanbonmatsu High School, T. Sekiguchi, Y. Shiba, SonotaCo, the Toyama Astronomical Observatory, M. Ueda, S. Uehara, H. Yamakawa and J. Yokomichi.

The observation software used was UFOCaptureV2, and the TV meteors were analysed by the software UFOAnalyzerV2 and UFOOrbitV2 (`http://sonotaco.com/e_index.html`).

3 Data of the July Pegasid meteor stream

We found 34 simultaneous meteors belonging to the JPE in the meteor data of July 2011 (Figure 1 and Table 1). Furthermore, as a result of the investigated meteor data of 2008–2010, 29 meteors of the JPE were found (Table 1). Tables 2 and 3 show the radiants and orbital elements of 63 meteors belonging to the JPE. The explanation to Table 2 is as follows:

Table 1 – Number of simultaneous meteors observed by the SonotaCo Network in July, 2008–2011.

Month	No. of JPE	No. of other shower meteors	No. of sporadic meteors	Total
July 2008	1	220	288	509
July 2009	11	150	441	602
July 2010	17	266	828	1111
July 2011	34	224	794	1052
Total	63	860	2351	3274

YYYYMMDD: year, month, day.
hhmmss: hour, minute, second (UT).
α_G, δ_G: the right ascension and declination of the geocentric radiant, corrected for zenith attraction and diurnal aberration (degrees, eq. 2000.0).
V_∞: the initial velocity (km/s).
V_G: the geocentric velocity of the meteoroid, corrected for the Earth's gravitational effects (pre-atmospheric geocentric velocity corrected as above) (km/s).
V_H: the heliocentric velocity (km/s).
Q: the angle between the great circles of the trails at the two stations.
Abs.: maximum absolute magnitude of the meteor.
H_b: the height at which the meteor was first observed (km).
H_e: the height at which the meteor vanished (km).
*: the beginning or the ending of meteor is out of camera field.

And the explanation to Table 3 is:
Dur: duration of meteor.
a: semi-major axis (AU).
e: eccentricity.
q: perihelion distance (AU).
Ω: longitude of the ascending node (degrees, eq. 2000.0).
i: inclination of the orbit (degrees).
ω: argument of perihelion (degrees).
P: period (years).
$\lambda_\odot$: solar longitude (eq. 2000.0).
Ent. ang.: entry angle of the meteoroid into the atmosphere (degrees; 90 degrees = zenith).
Length: trajectory length (km).

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Table 2 – The radiants, velocities and heights of July Pegasid meteors observed by TV (equinox 2000.0).

No.	Date	UT	Radiant		V_∞	V_G	V_H	Q	Abs.	H_b	H_e
	(YYYYMMDD)	(hhmmss)	α_G (°)	δ_G (°)	(km/s)	(km/s)	(km/s)	(°)	(mag.)	(km) *	(km) *
1	20080716	180028	352.7	+12.1	65.2	64.1	41.3	66.3	−2.8	114.4 *	86.0
2	20090706	164125	345.0	+9.8	64.5	63.3	40.1	62.8	−1.4	108.0	95.4
3	20090709	182410	347.4	+11.1	64.9	63.8	40.7	19.4	−0.1	111.1	95.2
4	20090712	154855	349.3	+11.0	65.1	63.9	40.9	37.4	−0.1	112.6	95.6
5	20090713	153332	350.8	+9.1	65.9	64.7	41.4	16.6	−0.7	106.6	96.3
6	20090713	174012	349.1	+10.9	63.5	62.4	40.0	36.6	−0.8	109.1	92.6
7	20090714	165052	351.0	+12.2	66.2	65.1	42.1	85.5	−2.0	115.9	90.1
8	20090714	173025	350.8	+10.5	62.4	61.2	38.5	77.0	1.0	106.0 *	101.4
9	20090715	180816	352.7	+10.8	63.8	62.8	39.6	42.5	0.2	106.4	96.1
10	20090715	181235	351.4	+12.1	64.7	63.7	41.0	55.8	0.5	105.2	95.4
11	20090715	183660	352.8	+12.3	65.1	64.1	40.8	27.1	−1.4	108.5	83.0
12	20090719	155758	351.4	+12.2	64.3	63.1	41.7	16.3	−3.4	112.2	90.9
13	20100707	160012	348.1	+8.8	66.7	65.5	41.2	77.1	0.7	110.7	102.0
14	20100707	163147	345.0	+11.1	66.5	65.4	42.3	18.2	−1.9	111.2	94.7
15	20100707	180630	345.7	+10.5	65.8	64.7	41.4	47.0	−2.0	107.4	93.7
16	20100709	142356	347.6	+12.4	64.4	63.1	39.8	78.2	−3.0	103.0	87.7
17	20100709	174248	345.0	+10.6	68.1	67.0	44.5	69.7	−0.1	108.2	96.1
18	20100712	140324	349.0	+11.1	63.8	62.5	39.6	49.9	−1.0	109.9	96.9
19	20100715	152142	350.8	+12.0	64.9	63.7	41.1	22.2	−4.4	114.9	83.2
20	20100715	181235	351.9	+11.6	67.0	66.0	42.9	18.0	0.1	104.0	96.1
21	20100716	165601	352.1	+11.5	64.1	63.0	40.3	16.6	−2.4	110.7	92.4
22	20100716	170250	351.1	+12.0	64.7	63.6	41.3	68.3	−2.2	111.3	89.8
23	20100716	181357	350.8	+11.9	63.5	62.4	40.3	23.8	−2.3	108.1	95.1
24	20100717	163612	353.5	+12.3	64.2	63.0	40.1	48.2	−2.4	106.1	93.8
25	20100718	150558	351.0	+10.0	63.4	62.1	40.6	14.9	−1.8	100.1 *	88.4
26	20100718	180257	352.4	+13.2	61.6	60.5	38.6	40.7	−2.1	109.3	97.2
27	20100718	182653	353.7	+13.2	65.2	64.2	41.5	31.0	−0.6	105.7	92.0
28	20100718	185526	353.0	+11.6	64.9	63.9	41.5	35.7	−3.1	108.8	83.0
29	20100719	180609	354.3	+12.8	66.7	65.7	43.0	50.0	0.2	105.1	97.4
30	20110709	130046	346.7	+10.4	66.0	64.6	41.5	15.8	−1.8	116.5	98.0
31	20110709	151912	346.5	+10.5	65.4	64.1	41.1	89.4	−2.5	111.7	92.3
32	20110709	163042	346.1	+10.3	65.5	64.3	41.4	88.0	−1.0	109.3	98.0
33	20110710	154304	347.0	+10.4	67.1	65.9	42.9	73.4	0.9	109.1	99.8
34	20110710	170112	347.5	+10.6	64.1	63.0	40.0	36.2	0.3	104.4	96.1
35	20110710	171022	347.1	+10.9	65.6	64.5	41.5	89.5	−1.8	107.0 *	96.2
36	20110710	173006	348.2	+10.9	66.2	65.1	41.8	37.9	−0.7	109.8	97.2
37	20110710	175351	347.2	+10.8	64.9	63.9	40.9	68.7	−0.5	112.2	95.6
38	20110710	175830	347.7	+11.2	65.2	64.2	41.0	86.7	−3.0	114.1	92.1
39	20110710	180507	347.1	+10.6	64.8	63.8	40.9	83.7	0.4	109.3	96.6
40	20110710	184521	346.6	+10.5	66.2	65.2	42.5	86.1	−0.4	101.1	92.0
41	20110711	154958	348.3	+11.2	65.2	64.0	40.9	63.2	−2.8	112.4	88.2
42	20110711	161646	349.3	+11.9	68.0	66.8	43.3	81.4	0.0	107.8	97.6
43	20110711	163601	347.9	+10.2	65.4	64.2	41.3	80.2	−2.3	108.7	94.6
44	20110711	190017	347.5	+11.0	66.4	65.4	42.7	87.8	−3.8	115.7	92.1
45	20110712	154238	348.5	+10.6	65.6	64.4	41.5	10.9	−1.5	113.1	100.3
46	20110712	163627	348.7	+11.1	64.8	63.6	40.8	81.9	−1.7	114.3 *	91.8
47	20110712	170315	347.8	+10.7	67.2	66.1	43.5	32.6	−3.5	116.6	86.2
48	20110712	185428	348.9	+10.7	64.9	64.0	41.1	31.1	−2.5	107.9	94.2
49	20110713	134444	348.6	+10.9	64.9	63.6	41.1	21.3	0.0	114.6	105.5
50	20110713	170909	350.0	+12.0	64.4	63.3	40.3	18.7	−3.6	118.6	81.7
51	20110713	184037	348.6	+11.9	64.1	63.1	40.7	75.5	−0.6	105.5	94.9
52	20110714	143521	351.6	+12.2	65.5	64.2	40.9	56.4	−1.2	106.3	97.5
53	20110714	160729	349.6	+11.4	64.4	63.2	40.7	72.2	−0.5	108.2	96.3
54	20110714	164740	349.8	+11.3	64.8	63.7	41.1	78.0	−1.3	109.1	91.2
55	20110714	171748	352.5	+13.1	64.8	63.7	40.1	52.8	−2.7	107.5	89.3
56	20110714	180000	349.9	+11.9	64.0	63.0	40.4	64.8	−1.5	109.2 *	89.5
57	20110714	180809	350.2	+11.7	66.1	65.2	42.3	42.5	−0.1	105.2	97.3
58	20110714	183111	351.0	+10.1	65.2	64.3	41.1	88.0	−1.4	102.8 *	90.1
59	20110714	183107	350.7	+12.0	62.9	61.8	39.0	35.5	−0.6	112.8 *	92.0
60	20110715	151103	349.4	+10.6	65.7	64.4	42.2	27.5	−4.0	105.0	89.7
61	20110717	171116	351.1	+13.4	63.6	62.5	40.5	85.7	−1.3	108.1 *	92.0
62	20110717	173613	352.3	+12.1	65.9	64.9	42.2	75.6	−0.1	110.2	93.0
63	20110717	183207	350.8	+13.3	62.1	61.1	39.4	24.1	−2.2	105.4	89.1
		Mean:			65.0			52.3	−1.4	109.2	93.4

Table 3 – The orbital elements of the July Pegasid meteors observed by TV (equinox 2000.0).

No.	Date (YYYYMMDD)	UT (hhmmss)	Dur (s)	a (AU)	e	q (AU)	Ω (°)	i (°)	ω (°)	P (yr)	$\lambda_\odot$ (°)	Ent. ang. (°)	Length (km)
1	20080716	180028	0.484	21.80	0.974	0.556	114.44	149.78	265.25	101.82	114.441	64	31.5
2	20090706	164125	0.250	6.46	0.909	0.586	104.61	148.28	263.64	16.44	104.609	50	16.4
3	20090709	182410	0.267	9.66	0.938	0.596	107.54	148.07	261.68	30.01	107.536	67	17.2
4	20090712	154855	0.400	12.22	0.954	0.567	110.29	149.15	264.66	42.72	110.293	40	26.2
5	20090713	153332	0.250	29.70	0.981	0.555	111.24	153.97	265.27	161.92	111.237	38	16.7
6	20090713	174012	0.284	5.96	0.914	0.513	111.32	147.79	272.11	14.54	111.321	62	18.6
7	20090714	165052	0.467	−37.07	1.016	0.595	112.24	148.89	259.77	—	112.242	56	31.3
8	20090714	173025	0.083	3.40	0.857	0.487	112.27	149.66	277.37	6.27	112.268	60	5.3
9	20090715	180816	0.184	5.00	0.893	0.533	113.25	151.83	270.46	11.20	113.247	62	11.6
10	20090715	181235	0.167	12.94	0.957	0.552	113.25	148.46	266.24	46.57	113.250	65	10.9
11	20090715	183660	0.417	11.43	0.949	0.584	113.27	150.08	262.70	38.68	113.266	68	27.6
12	20090719	155758	0.434	268.06	0.998	0.471	116.98	146.14	274.27	4390.63	116.978	49	28.3
13	20100707	160012	0.200	17.93	0.964	0.646	105.29	153.87	255.12	75.92	105.290	41	13.4
14	20100707	163147	0.317	−20.71	1.030	0.632	105.31	146.92	255.31	—	105.311	50	21.5
15	20100707	180630	0.234	27.52	0.977	0.621	105.37	148.26	257.78	144.46	105.373	63	15.4
16	20100709	142356	0.551	5.57	0.889	0.617	107.13	146.07	260.51	13.17	107.133	26	35.1
17	20100709	174248	0.200	−3.76	1.162	0.608	107.27	147.36	255.42	—	107.265	63	13.6
18	20100712	140324	0.484	5.02	0.892	0.544	109.98	148.10	269.26	11.25	109.981	26	29.9
19	20100715	152142	0.717	14.94	0.963	0.549	112.90	147.97	266.43	57.77	112.896	43	47.0
20	20100715	181235	0.133	−9.51	1.063	0.598	113.01	150.90	258.41	—	113.009	65	8.7
21	20100716	165601	0.334	7.19	0.927	0.524	113.91	149.68	270.40	19.28	113.912	58	21.7
22	20100716	170250	0.384	20.62	0.974	0.532	113.92	147.83	268.03	93.69	113.917	59	25.1
23	20100716	181357	0.234	7.28	0.931	0.504	113.96	147.04	272.67	19.66	113.964	65	14.4
24	20100717	163612	0.250	6.35	0.915	0.542	114.85	149.63	268.72	16.02	114.853	51	15.9
25	20100718	150558	0.317	9.00	0.952	0.431	115.75	149.32	280.44	26.99	115.748	35	20.3
26	20100718	180257	0.217	3.48	0.864	0.472	115.86	144.98	278.90	6.48	115.865	65	13.4
27	20100718	182653	0.234	36.40	0.985	0.561	115.88	148.56	264.44	219.71	115.881	64	15.4
28	20100718	185526	0.450	41.16	0.987	0.519	115.90	150.20	269.15	264.15	115.900	62	29.3
29	20100719	180609	0.133	−8.64	1.066	0.571	116.82	149.98	261.34	—	116.821	66	8.4
30	20110709	130046	1.585	35.05	0.983	0.601	106.84	148.82	259.90	207.56	106.838	11	103.7
31	20110709	151912	0.484	15.03	0.961	0.590	106.93	148.19	261.79	58.28	106.930	38	31.5
32	20110709	163042	0.234	28.30	0.979	0.582	106.98	148.21	262.20	150.57	106.977	50	14.9
33	20110710	154304	0.200	−9.73	1.062	0.604	107.90	149.26	257.75	—	107.899	43	13.6
34	20110710	170112	0.167	6.03	0.907	0.562	107.95	148.30	266.53	14.82	107.951	54	10.3
35	20110710	171022	0.200	46.02	0.987	0.591	107.96	148.04	260.93	312.35	107.957	55	13.1
36	20110710	173006	0.217	569.89	0.999	0.619	107.97	149.56	257.51	13604	107.970	59	14.7
37	20110710	175351	0.284	12.66	0.954	0.579	107.99	148.12	263.25	45.04	107.986	64	18.5
38	20110710	175830	0.384	14.56	0.959	0.599	107.99	148.21	260.80	55.56	107.989	62	25.0
39	20110710	180507	0.217	12.55	0.954	0.572	107.99	148.23	263.99	44.48	107.993	64	14.1
40	20110710	184521	0.150	−15.47	1.038	0.587	108.02	148.25	260.17	—	108.020	64	10.1
41	20110711	154958	0.517	12.51	0.953	0.586	108.86	148.26	262.44	44.28	108.857	46	33.8
42	20110711	161646	0.200	−6.96	1.095	0.659	108.87	149.62	250.87	—	108.875	49	13.4
43	20110711	163601	0.284	21.61	0.974	0.566	108.89	149.46	264.15	100.50	108.887	50	18.5
44	20110711	190017	0.350	−11.85	1.050	0.593	108.98	148.23	259.25	—	108.983	65	26.0
45	20110712	154238	0.284	44.49	0.987	0.567	109.81	149.34	263.65	296.84	109.805	44	18.5
46	20110712	163627	0.434	10.74	0.947	0.564	109.84	148.27	265.13	35.19	109.841	54	28.0
47	20110712	170315	0.551	−6.21	1.094	0.586	109.86	149.02	259.10	—	109.859	57	36.5
48	20110712	185428	0.234	14.89	0.962	0.564	109.93	149.29	264.67	57.45	109.932	66	15.1
49	20110713	134444	0.384	15.76	0.966	0.542	110.68	148.11	267.17	62.59	110.680	21	24.8
50	20110713	170909	0.651	7.38	0.922	0.574	110.82	147.90	264.66	20.06	110.816	60	42.5
51	20110713	184037	0.184	9.91	0.945	0.547	110.88	146.25	267.19	31.21	110.876	65	11.7
52	20110714	143521	0.284	12.03	0.950	0.599	111.67	149.46	260.94	41.72	111.667	28	18.6
53	20110714	160729	0.250	10.28	0.948	0.537	111.73	147.90	268.27	32.95	111.728	48	16.0
54	20110714	164740	0.334	15.82	0.965	0.547	111.75	148.44	266.58	62.93	111.755	55	21.8
55	20110714	171748	0.317	6.44	0.904	0.617	111.77	148.76	260.11	16.36	111.775	59	21.2
56	20110714	180000	0.334	7.88	0.931	0.545	111.80	147.26	267.81	22.13	111.803	65	21.7
57	20110714	180809	0.133	−19.52	1.030	0.583	111.81	149.03	260.78	—	111.808	65	8.8
58	20110714	183111	0.217	16.62	0.967	0.553	111.82	152.16	265.84	67.79	111.823	65	13.9
59	20110714	183107	0.350	3.98	0.866	0.534	111.82	147.57	271.34	7.93	111.823	67	22.6
60	20110715	151103	0.384	−22.91	1.023	0.524	112.64	148.96	267.56	—	112.644	38	24.9
61	20110717	171116	0.284	8.22	0.936	0.523	114.63	144.81	270.18	23.59	114.631	62	18.2
62	20110717	173613	0.284	−24.12	1.023	0.560	114.65	149.44	263.50	—	114.647	64	19.2
63	20110717	183207	0.284	4.52	0.891	0.491	114.68	143.70	275.56	9.62	114.684	69	17.5
	Mean:		0.329								110.897	54	21.5

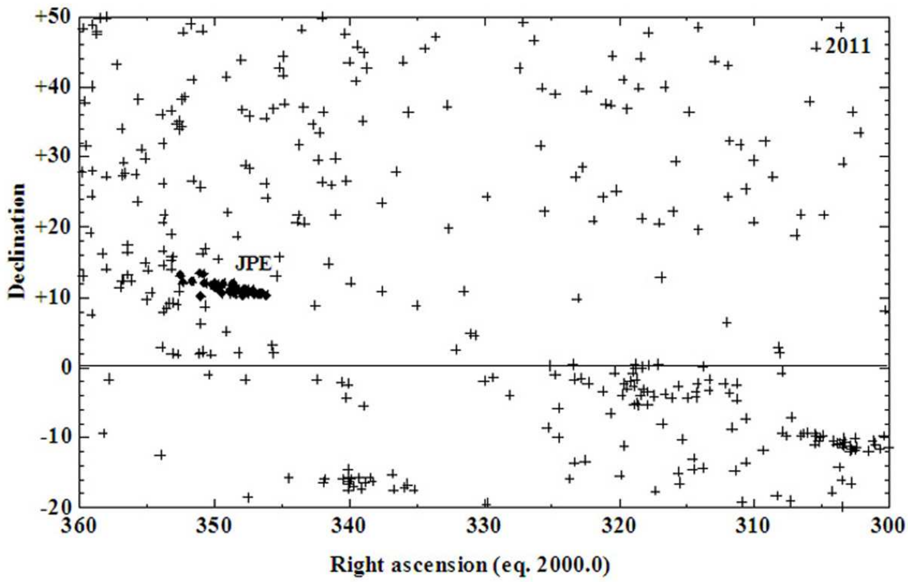

Figure 1 – Simultaneous meteor radiant mapping on celestial sphere in July, 2011
● Radiants of the July Pegasids in July, 2011
+ Radiants of the non-JPE meteors in July, 2011

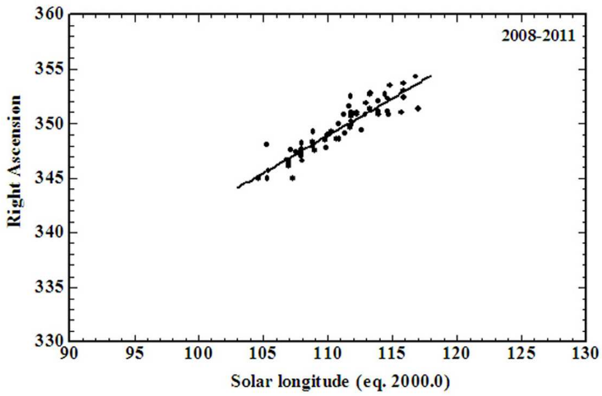

Figure 2 – The right ascensions of the July Pegasids (63 radiants) observed in 2008–2011.

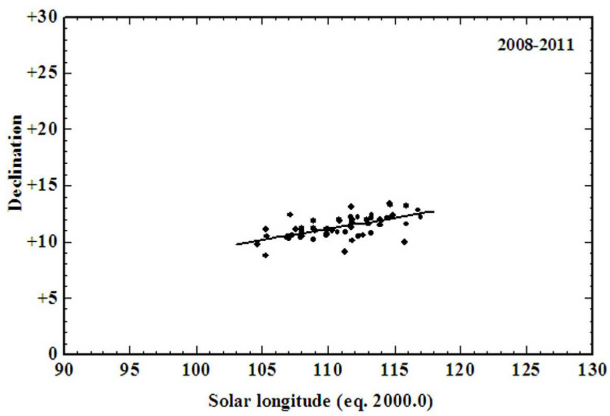

Figure 3 – The declinations of the July Pegasids (63 radiants) observed in 2008–2011.

From Tables 2 and 3, the activity period of JPE is $\lambda_\odot = 104{.}^\circ61$–$116{.}^\circ98$ (July 6–19). Figures 2, 3 and 4 show the daily motion of the JPE radiants and velocity. The corrected radiant is at $\alpha_G = 349{.}^\circ6 \pm 1{.}^\circ0$, $\delta_G = +11{.}^\circ3 \pm 0{.}^\circ9$ and the geocentric velocity is $V_G = 63.9$ km/s at $\lambda_\odot = 110{.}^\circ9$. The daily motions (per 1° in solar longitude) in right ascension, declination and the geocentric velocity of JPE are

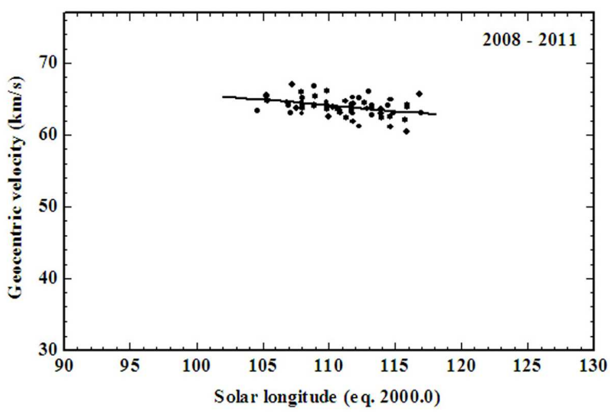

Figure 4 – The geocentric velocities of the July Pegasids (63 meteors) observed in 2008–2011.

$$\alpha_G = 349{.}^\circ55 + 0{.}^\circ707(\lambda_\odot - 110{.}^\circ9) \pm 1{.}^\circ0,$$

$$\delta_G = +11{.}^\circ27 + 0{.}^\circ170(\lambda_\odot - 110{.}^\circ9) \pm 0{.}^\circ9,$$

$$V_G = 63.87 - 0.149(\lambda_\odot - 110{.}^\circ9) \pm 1.2 \text{ km/s}.$$

The values of JPE radiant and velocity obtained from the above equations are shown in Table 4. In Table 5, we compare the radiant point, velocity and these drifts. Table 5 gives a value of the velocity drift that is quite similar. The magnitude distribution (absolute magnitude) of simultaneous JPE meteors in 2011 is shown in Table 6. There was a bright meteor of magnitude −4 among the meteors which belonged to the JPE.

4 Parent comet of July Pegasids

The parent comet of JPE is Comet C/1979 Y1 (Bradfield) (= 1979 X) (e.g., Rendtel et al., 1995). The theoretical radiant and geocentric velocity of JPE are shown

Table 4 – Mean radiant position and geocentric velocity of JPE observed during 2008–2011 (equinox 2000.0).

λ (°)	Date	α_G (°)	δ_G (°)	V_G (km/s)	a (AU)	e	q (AU)	Ω	i	ω	P (yr)
104.6	July 7	345.1	+10.2	64.8	34.63	0.982	0.622	104°.60	148°.40	257°.47	203.8
106	July 8	346.1	+10.4	64.6	25.48	0.976	0.609	105°.96	148°.57	259°.10	128.6
108	July 10	347.5	+10.8	64.3	19.73	0.970	0.590	108°.00	148°.55	261°.45	87.6
108.61	July 11	347.9	+10.9	64.2	18.41	0.968	0.584	108°.61	148°.55	262°.25	79.0
110	July 12	348.9	+11.1	64.0	15.86	0.964	0.570	110°.00	148°.71	263°.94	63.1
110.9	July 13	349.6	+11.3	63.9	14.78	0.962	0.564	110°.90	148°.77	264°.73	56.8
112	July 14	350.3	+11.5	63.7	13.40	0.959	0.552	112°.00	148°.70	266°.22	49.0
114	July 17	351.7	+11.8	63.4	11.65	0.954	0.531	114°.00	148°.84	268°.70	39.8
116	July 19	353.2	+12.1	63.1	10.01	0.949	0.512	116°.00	149°.11	271°.08	31.7
116.98	July 20	353.8	+12.3	63.0	10.24	0.951	0.503	116°.98	149°.00	272°.11	32.7

Table 5 – Comparison of JPE radiant (J2000.0), velocity and their drifts. The values α_G, δ_G, V_∞ and V_G are at the reference solar longitude $\lambda_\odot = 108°$, while $\Delta\alpha$, $\Delta\delta$, ΔV_∞ and ΔV_G are the values per 1° in $\lambda_\odot$.

Ref.	Period	Radiant position and drift (°)				V_∞	ΔV_∞	V_G	ΔV_G	
$\lambda_\odot$(°)	$\lambda_\odot$(°)	α_G	$\Delta\alpha$	δ_G	$\Delta\delta$	(km/s)	(km/s)	(km/s)	(km/s)	
108	105–126	347.2	+0.9	+11.1	+0.2	68.1	−0.16	—	—	Molau & Rendtel (2009)
108	105–117	347.5	+0.71	+10.8	+0.17	65.5	−0.17	64.3	−0.15	This work

Table 6 – Distribution in absolute magnitude of JPE and sporadics in July, 2011.

Mag.	−6	−5	−4	−3	−2	−1	0	1	2	3	Total
JPE			4	5	7	10	7	1			34
SPO	1	3	23	68	147	242	197	89	20	4	794

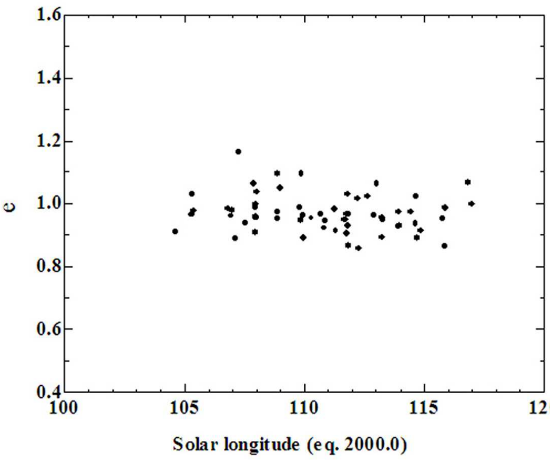

Figure 5 – Relation between heliocentric orbital element e and the solar longitude of 63 JPE meteors.

in Table 7. The theoretical position of the JPE radiant given by our analysis accords with our observations well. From this fact, we can say that the parent comet of JPE is Comet Bradfield (1979 X). The orbital elements of the JPE change with the solar longitude at the meteor apparition (see Figures 5, 6 and 7). This can be seen in Table 4.

5 Conclusion

In July of 2011, 34 TV simultaneous meteors of JPE have been observed by the SonotaCo Network. The numbers of simultaneous meteors in each year from 2008 to 2010 have been less than those in 2011 (Table 8). This is believed to have been affected by the bad weather

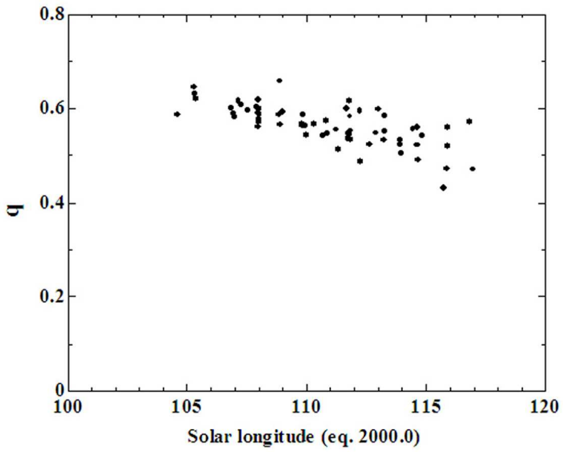

Figure 6 – Relation between the heliocentric orbital element q and the solar longitude of 63 JPE meteors. The q changes with progress of the solar longitude.

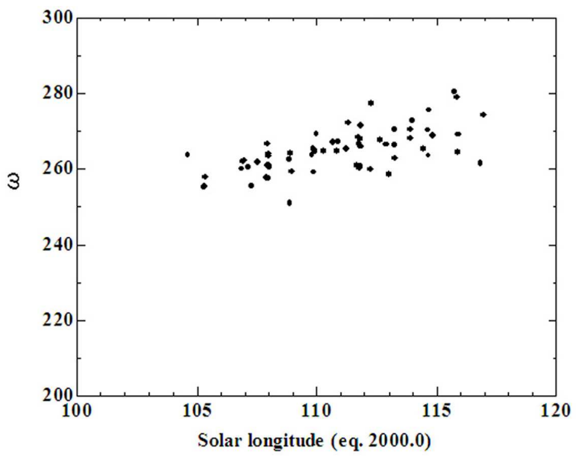

Figure 7 – Relation between the heliocentric orbital element ω and the solar longitude of 63 JPE meteors. The ω changes with progress of the solar longitude.

Table 7 – Comparison of theoretical radiant from parent comet C/1979 Y1 (Bradfield) and the JPE radiant determined by this study (equinox 2000.0).

	$\lambda_\odot$ (°)	α_G (°)	δ_G (°)	V_G (km/s)	a (AU)	e	q (AU)	Ω (°)	i (°)	ω (°)	P (yr)	Remarks
C/1979 Y1	108.61	346.5	+11.2	63.99	45.02	—	0.57	108.61	146.37	263.93	291	Jenniskens (2006)
July Pegasids	108.61	347.9	+10.9	64.2	18.41	0.97	0.58	108.61	148.55	262.25	79.0	This work
C/1979 Y1	110.6	348.5	+10.5	64.1	—	0.988	0.545	103.219	148.602	257.585	291	†
July Pegasids	110.6	349.3	+11.3	64.0	17.23	0.97	0.57	110.60	148.60	264.16	71.5	This work

†: Calculated by the method of Hasegawa (1990). The orbital elements are given in Marsden and Williams' Catalogue (1996).

Table 8 – Numbers of simultaneous TV meteors – JPE and sporadic meteors.

July Date	2008 JPE	2008 SPO	2009 JPE	2009 SPO	2010 JPE	2010 SPO	2011 JPE	2011 SPO
1		35		0		2		1
2		8		0		1		7
3		0		0		0		2
4		11		1		1		0
5		14		6		1		59
6		0	1	12		1		0
7		0		14	3	16		0
8		0		0		2		0
9		1	1	3	2	19	3	65
10		3		1		11	8	107
11		2		12		0	4	74
12		4	1	19	1	0	4	43
13		1	2	17		0	3	35
14		3	2	32		1	8	68
15		2	3	106	2	30	1	47
16	1	4		6	3	50		54
17		0		12	1	81	3	91
18		5		5	4	146		0
19		8	1	63	1	62		0
20		4		1		94		26
21		3		1		71		18
22		14		16		54		2
23		5		1		58		33
24		21		2		15		14
25		13		28		7		30
26		14		42		21		1
27		37		0		42		1
28		40		4		24		1
29		5		18		0		11
30		25		13		5		0
31		6		6		13		4
Total	1	288	11	441	17	828	34	794

in Japan. In this study, we have been able to determine the accurate radiant positions and geocentric velocities of the JPE meteors. This is why we think that the JPE should be added to the established 64 meteor showers of the International Astronomical Union (IAU). In addition, we are able to confirm that Comet Bradfield (1979 X = C/1979 Y1) is the parent comet of the JPE. Although the JPE is a weak shower, continued observations are encouraged in the future.

Acknowledgement

We thank Ichiro Hasegawa for his comments and suggestions.

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Results for the Aquariid-expedition to Namibia, July 2011

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A team of 8 observers of the Dutch Meteor Society (DMS) went to Namibia to observe the δ-Aquariids under perfect sky conditions. The article lists the observational results which confirm the values found in 2008 and during earlier observations. The ZHR profile is rather skew with a steep increment to its maximum in the range of $25-30$ meteors per hour followed by a slow decline in activity after solar longitude 126°.

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1 Introduction

Three years after the observing project at La Palma (Canary Islands, Spain) the phase of the Moon allowed another undisturbed Aquariid expedition (New Moon 2011 July 30). The meteor rates recorded at La Palma in 2008 gave encouragement for another expedition. A quick look at favorable places and their climate pointed to one destination: Namibia, the place-to-be.

With the radiant almost the entire night above 30 degrees of elevation, rising up to the zenith shortly after midnight and with almost no risk for cloudy nights, conditions could not be better. Moreover, the astronomical circumstances were identical to 2003, the year when Koen Miskotte observed a significantly increased activity of this stream at Crete, Greece, in the night of 2003 July 28–29 (Miskotte, 2004). This motivated us to plan new observations of this meteor shower. On Sunday, July 24, six observers went to Windhoek in Namibia for a 14 day stay at 'Hakos Gästefarm': Inneke Vanderkerken, Michel Vandeputte, Casper ter Kuile, Peter van Leuteren and both authors. Klaas Jobse and Jaap van 't Leven arrived one day earlier to prepare two video stations for one week run. For this purpose Jaap stayed at the Tivoli Farm, about 100 km East from Hakos.

The exceptional observing conditions and weather at this site explain the record amount of data gathered. In over 180 hours of effective observing time, 8713 meteors were recorded. Table 1 lists all the details: 11 out of 13 nights were observed. The night of July 27–28 was lost due to clouds and around August 1 we were on excursion.

2 Magnitude distributions

A magnitude distribution was made for each observer for all observed SDAs and sporadic meteors like in 2008 (Johannink et al., 2008). The average limiting magnitude for each observer and each night was reduced to a limiting magnitude of 6.50. From the average luminosities of meteors observed in 2011 it is again noted that the average magnitude of the SDAs was significantly brighter than the average magnitude of sporadics. This is similar to the conclusions we drew from the analysis based on the observations from 2008 and earlier years (Miskotte & Johannink, 2007; Johannink, 2006).

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NASA-ADS bibcode 2012JIMO...40...65J

3 Population index r

Using the probability function of Peter Jenniskens (to filter out the variations in the limiting magnitude) a distribution was derived where the number of meteors per magnitude class is corrected for the limiting magnitude. This probability function is described in (Jenniskens, 1994). From this distribution the population index r could be derived (Miskotte & Johannink, 2005). The computed r-values are listed in Table 3. The number of SDA meteors is too small to derive a reliable population index for the night of July 25–26. For the nights from August 3–4 to August 6–7 a single population index was determined, given as the value for August 3–4 in the Table 3. For the entire set of 3476 SDA meteors a population index of 2.67 was found to be identical to the population index for 2008. (Johannink et al., 2008).

Comparing these results with the results from 2008 we get the following graph (Figure 1) (Johannink et al., 2008).

We see roughly the same pattern:

- mainly faint meteors before the maximum, comparable in brightness to the sporadic background.
- during and immediately after the maximum a significant increase in the number of bright meteors.
- after the maximum a gradual decrease in the number of bright meteors.

We consider this as an explanation for the discrepancy in average magnitude between observations from the Northern and the Southern hemisphere like we de-

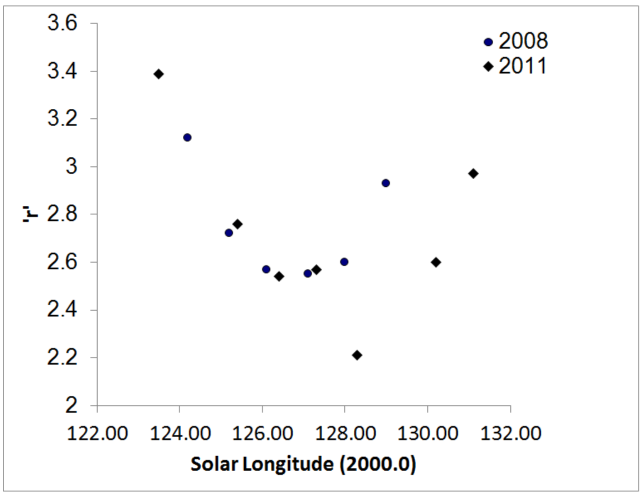

Figure 1 – Population index derived from the SDA observations in 2008 and 2011.

Figure 2 – Composition by Peter van Leuteren. The image shows the Southern hemisphere pole with the Large and Small Magellanic clouds, three SDA meteors and the bright star Achernar (α Eridani). Exposure was made with a Canon EOS 40D equipped with a Canon EF 15 mm F 2.8 fish-eye lens.

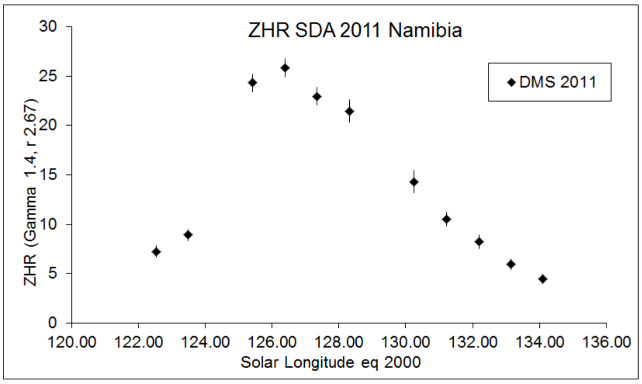

Figure 3 – ZHR-distribution for the SDAs in 2011.

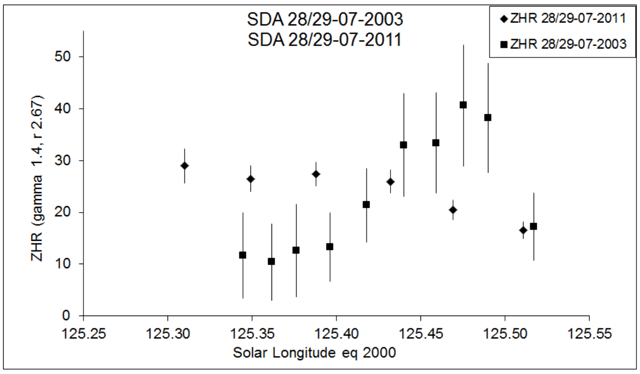

Figure 4 – ZHR distribution of the SDAs for the night of July 28–29 in 2003 and in 2011.

scribed in the analyses of the 2008 observations (Arlt & Dubietis, 2004; Johannink et al., 2008).

4 ZHR calculations

With the population indices r for each night and the personal perception coefficients C_p we calculated the ZHR according to the method described in (Miskotte & Johannink, 2005). Some observers have been changing the observing direction from South East to North West during the night to ensure that the SDA radiant remains in the field of view.

The SDA activity increases quickly around July 25 to its maximum and decreases gradually after the maximum. The maximum ZHR is in the range of 25 to 30. The discrepancies between the individual observers is somehow larger.

In the night of 2003 July 28–29 at Crete, Greece, Koen Miskotte had observed a temporary enhanced activity around solar longitude 125.49. The ZHR then rose up to 40 (Miskotte, 2004). Since our 2011. observations were performed around the same solar longitudes it was interesting to check if this phenomenon would be seen again. No evidence was found for this as can be seen from the comparison of the ZHRs in the nights of 2003 July 28–29 and 2011 July 28–29 (Figure 4).

However, the overall results agree very well with what we already observed in 2008 (see Figure 5). Again, we see a steep increase in activity towards the maximum.

Table 1 – Recorded data per observer.

Date	IMO code	T_{eff}	lm	SDA	CAP	PAU	ANT	KCG	PER	SPO	Tot	Remarks
Jul 25/26	JOHCA	2.82	6.6	10	7	5	6		0	53	81	
	LEUPE	4.70	6.7	36	17	7	23	0	0	76	159	
	MISKO	5.02	6.8	41	21	6	9		0	89	166	−3 SPO
	VANMC	4.67	6.9	69	29	8	7			87	200	−4 CAP
Jul 26/27	JOHCA	4.17	6.5	34	14	9	9		0	89	155	−5 CAP
	LEUPE	5.03	6.7	48	27	9	20	0	0	106	210	2× −4 CAP
	MISKO	3.03	6.8	37	13	2	4		0	66	122	−5 CAP
	VANMC	5.67	6.9	84	26	11	8			138	267	2× −5 CAP
Jul 28/29	JOHCA	5.13	6.5	92	22	9	12		0	156	291	−4, −3 CAP
	LEUPE	6.73	6.7	157	50	17	28	2	3	103	360	−5 CAP, −4 CAP
	MISKO	5.87	6.8	186	34	5	9	3	3	134	374	2× −5 CAP
	VANMC	7.50	6.9	265	39	14	5	3	3	112	441	−5, −4, −3 CAP
Jul 29/30	JOHCA	4.75	6.5	98	15	4	9		3	116	245	
	LEUPE	5.96	6.7	204	35	13	21	2	2	99	376	3× −3 CAP
	MISKO	4.79	6.8	190	26	5	12	1	1	130	365	2× −3 CAP
	VANMC	6.67	6.9	257	39	8	7	2	3	123	439	−5 CAP, 2× −3 CAP
Jul 30/31	JOHCA	4.35	6.5	72	22	6	5		0	106	211	−6, −4 CAP
	LEUPE	5.53	6.7	189	45	12	10	0	4	69	329	−6, −4 CAP
	MISKO	4.60	6.8	124	14	3	10	0	0	112	263	
	VANMC	6.50	6.9	217	56	1	4	0	6	110	394	−6, −4 CAP
Jul 31/	LEUPE	5.00	6.6	157	36	3	16	1	4	89	306	−5 CAP, −3 SDA
Aug 01	MISKO	2.95	6.6	51	12	1	6	0	2	61	133	−3, −5 CAP
	VANMC	5.00	6.8	155	44	1	1	1	1	76	279	−4 SDA, −5, −3 CAP
Aug 02/03	MISKO	2.18	6.6	35	4	1	2	0	1	43	86	
	VANMC	4.50	6.8	122	27	3	2	1	7	110	272	
Aug 03/04	JOHCA	2.35	6.3	15	3	1	1		5	48	73	
	LEUPE	4.50	6.7	74	18	3	9	0	8	93	205	
	MISKO	3.17	6.6	39	14	1	6	0	3	66	129	−3 SDA
	VANMC	5.17	6.8	80	14	5	4	0	7	114	224	−3 SPO
Aug 04/05	JOHCA	2.78	6.5	13	2	1	6		7	62	91	
	LEUPE	3.05	6.7	43	7	1	3	0	1	56	111	
	MISKO	3.18	6.7	24	5	2	7	0	8	65	111	
	VANMC	3.67	6.9	58	10	2	2	0	13	93	178	
Aug 05/06	JOHCA	2.45	6.6	7	3	1	5		2	70	88	
	LEUPE	5.53	6.7	37	7	1	4	0	5	87	141	
	MISKO	3.25	6.8	20	6	0	7	0	3	79	115	−3 SDA, −3 SPO
	VANMC	3.67	6.8	47	8	1	0	0	9	121	186	
Aug 06/07	JOHCA	2.80	6.5	9	2	1	3		11	79	105	
	LEUPE	4.05	6.7	25	6	0	6	0	5	92	134	
	MISKO	3.60	6.8	28	6	0	6	0	6	100	146	
	VANMC	4.00	6.8	27	8	0	3	0	9	105	152	
11 nights	4	180.34		3476	793	183	317	16	145	3783	8713	

Table 2 – Summary of all observational data from Hakos Gästefarm.

Sessions	T_{eff}	SDA	CAP	PAU	ANT	KCG	PER	SPO	TOT
9	31.60	350	90	37	56	0	28	779	1340
10	50.08	970	248	66	140	5	32	870	2331
11	41.64	775	155	26	78	4	27	945	2010
11	57.02	1381	300	54	43	7	58	1189	3032
31	180.34	3476	793	183	317	16	145	3783	8713

5 Conclusions

Our results indicate that the SDA activity gets higher than that past reports indicated. It is likely that the population index r has a dip just at the time of the maximum activity, around solar longitude 126.2 degrees.

6 Acknowledgements

Great thanks to the visual observers and participants of the SDA expeditions of 2008 and 2011. Without their observations, enthusiasm and perseverance we wouldn't have been able to make this analysis. Further a word of

Table 3 – r-values for the SDAs in the magnitude interval of [−2;5] for the nights of July 26/27 to August 2/3. The value given for the night of August 3/4 is derived from all observed SDAs in the nights of August 3/4 to 6/7.

$\lambda_{\odot}$(2000.0)	Night	r
123.°5	Jul 26/27	3.39
125.°4	Jul 28/29	2.76
126.°4	Jul 29/30	2.54
127.°3	Jul 30/31	2.57
128.°3	Jul 31/32	2.21
130.°2	Aug 2/3	2.6
131.°1	Aug 3/4	2.97

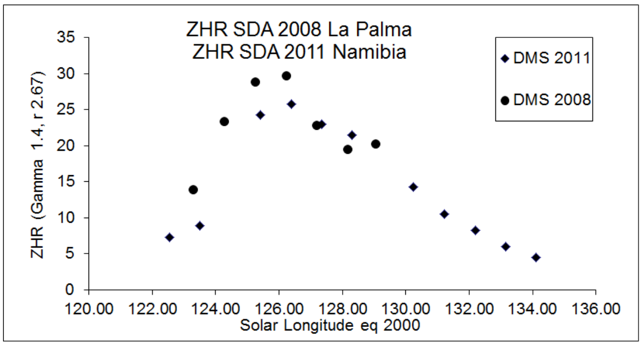

Figure 5 – Comparison of the ZHR profiles for 2008 and 2011 according to the data sets from La Palma and from Namibia.

thanks to Paul Roggemans who translated this article for WGN.

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Preliminary results

Results of the IMO Video Meteor Network — December 2011

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December 2011 results are presented of the IMO Video Meteor Network, based on more than 33 000 meteors collected in over 6 000 hours of effective observing time by 68 cameras. The Geminid flux density profile is presented, reaching the maximum on December 13/14 at $03^{\mathrm{h}}15^{\mathrm{m}}$ UT. Activity profile of the Ursids is also presented, showing a maximum on December 22 at 19^{h} UT. The overall statistics of the Network in 2011 are presented. Substantial growth of the Network is again noted, expanding to 80 cameras that collected almost 69 000 hours of observing time and recorded more than 311 000 meteors.

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1 Introduction

The year 2011 ended with unsteady weather. Between December 6 and 8 and during the Geminid maximum there were once more about 50 cameras active, but later in the month there were larger gaps. Only our southern European observers in Italy, Portugal and Greece collected twenty and more observing nights. In total, there were 68 cameras in operation – twenty more than a year before (Molau et al., 2011). Whereas the effective observing time almost doubled to over 6 000 hours with respect to 2010 December, the number of meteors increased only by about 10% to 33 000 (Table 4 and Figure 1). More than 5 300 meteors were recorded in the night of December 13/14 alone, which became the second best night of this year after October 21/22.

Our camera network added two new observers at the end of year. Szabolcs Kiss from Sulysap in Hungary is operating Husul, a KTC350BH camera with vari-focal $f/0.95$ Fujinon lens at 5 mm focal length. In Italy, Mario Bombardini joined our forces. His Mintron camera Mario is currently equipped with a 4 mm $f/1.2$ Tamron lens.

Mitja Govedič installed two new cameras Orion3 and Orion4 at his Slovenian observing site. The camera Icc7 of Detlef Koschny was shipped from Holland to the Canary Islands and is now serving at the Izana Observatory at Tenerife.

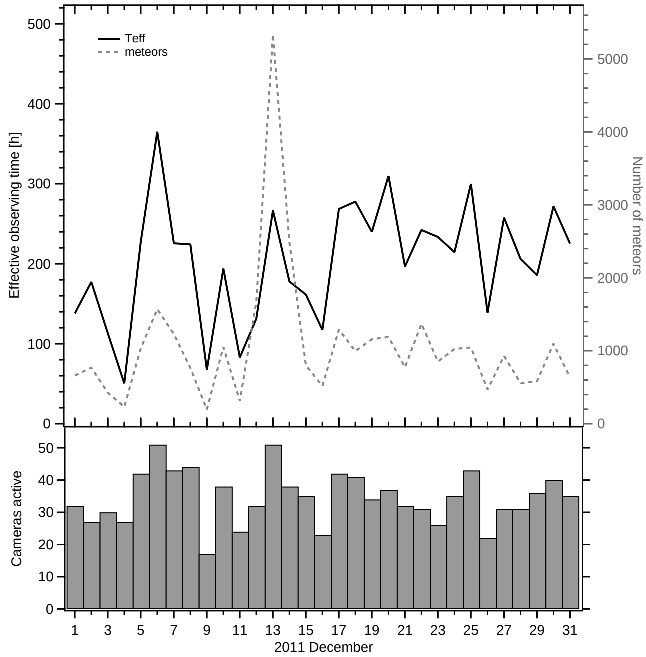

Figure 1 – Monthly summary for the effective observing time (solid black line), number of meteors (dashed gray line) and number of cameras active (bars) in 2011 December.

2 Geminids

The highlight of December was the Geminids, as expected. Figure 2 shows their flux density profile at the peak interval of December 12 to 15, based on 3 900 Geminids and roughly 800 sporadics in parallel. At northern latitudes the radiant is located high above the horizon for most of the night, which is why the influence of the zenith exponent is rather small. Still the data set was processed with zenith exponents between 1.0 and 2.0 in steps of 0.1. At $r = 1.0$, there is a temporary activity increase both in the nights before and after the maximum, whereas at $r = 2.0$ there is a fish tail at the beginning of the peak night. At a value of $r = 1.5$, the profile looks the best overall. For demonstration, Figure 2 shows only the flux density profile for the discussed three values.

Overall the Geminid activity increased by more than a factor of two during the night of December 13/14, and thereafter it dropped more than a factor of two

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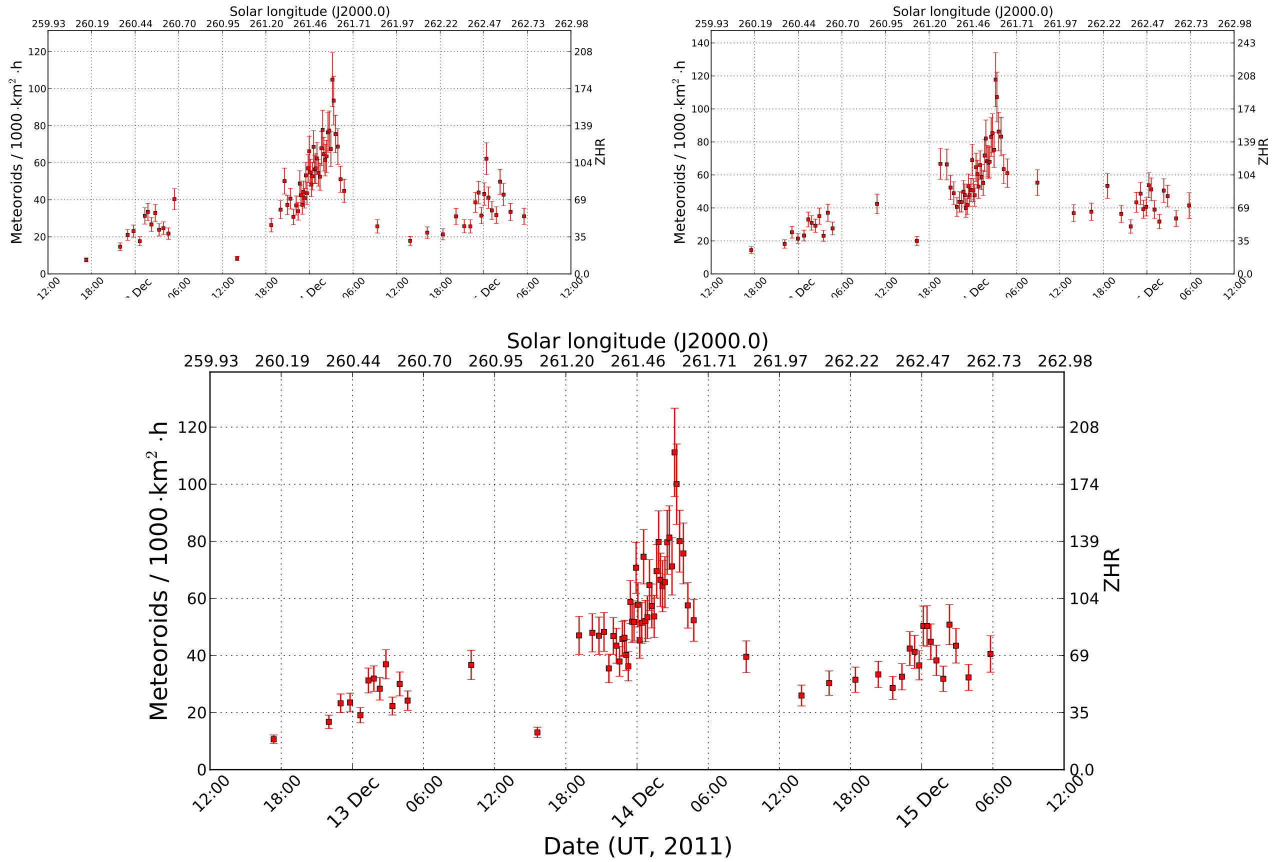

Figure 2 – Flux density profile of the Geminid peak 2011, calculated with zenith exponents of 1.0 and 2.0 (top) as well as 1.5 (bottom).

at dawn. The highest flux density value of above 100 meteoroids per 1 000 km^2 per hour was measured in a 15 minute time interval at 03^{h}15^m UT on December 14. That corresponds to a ZHR of roughly 180 at a solar longitude of 261.°596. So the peak was quite early, given that it was observed in previous years between 261.°5 and 262.°4 solar longitude (Rendtel, 2004).

In the flanking intervals between 02^{h}30^m and 03^{h}50^m UT the flux density was still above 80 meteoroids per 1 000 km^2 per hour, which corresponds to a ZHR of 150. For comparison, the Perseids yielded hardly a flux density of 40, whereas even at the Draconid outburst the flux density was just marginally higher with about 110 meteoroids per 1 000 km^2 per hour.

Let us compare the result with the IMO quick look analysis for the Geminds (International Meteor Organization, 2011). Unfortunately, visual observers were less active during the Geminds 2011 – probably because the Moon hampered the observations significantly. Based on roughly 1 500 visual Geminids, the highest ZHR of 200 was observed in the afternoon hours of December 14 (15^h UT). At the video maximum time, the visual ZHR was only about 100.

There is a simple explanation why the ZHR values derived from the Geminid flux densities are more realistic than before. Upon checking the code of the online flux tool, Geert Barentsen noticed that the population index was fixed at 2.0. In the latest version of the tool, the same r-values as used by MetRec are introduced, i.e. $r = 2.6$ for the Geminids. That reduced the calculated zenithal hourly rates by almost a factor of three!

3 Ursids

The Ursids showed a sharp peak in the evening hours of December 22 at 19^h UT (Figure 3). That corresponds to a solar longitude of 270.°40. Here the flux density was little above 10 meteoroids per 1 000 km^2 per hour, which is about the same figure as the ZHR calculated with a population index of 3.0.

Also in case of the Ursids, the peak was earlier than usual. There were, however, predictions for one or two extra peaks in the evening hours of December 22 with exactly the observed ZHR (Jenniskens et al., 2007; Maslov, 2011). They resulted from the proximity of the parent comet 8P/Tuttle.

4 Summary of 2011

In conclusion we present the annual statistics for 2011. As reported recently (Molau et al., 2012), the exponential growth of the IMO network with respect to the effective observing time and number of meteors continued in 2011. 46 observers (2010: 34) from 16 countries (2010: 12) took part in the video network with an overall of 80 video systems (2010: 58). For the first time, Germany lost the pole position with respect to the number of cameras. In December, there were 15 active cameras in Hungary, 12 in Germany, and 11 in Italy and Slovenia. Further cameras were located in Belgium, Spain,

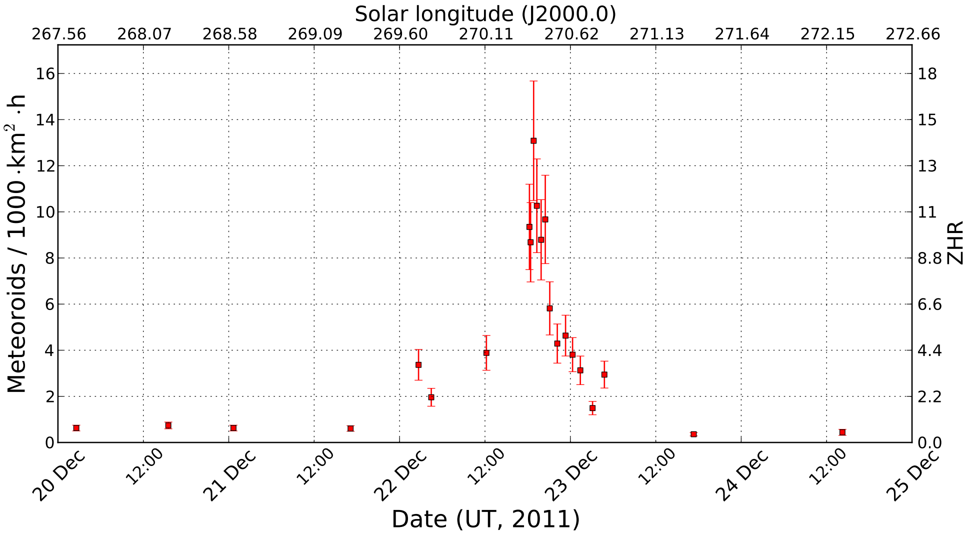

Figure 3 – Flux density profile of the Ursids in 2011, derived from observations of the IMO Video Meteor Network.

Table 1 – Monthly distribution of video observations in the IMO camera network in 2011.

Month	Observing Nights	Eff. Observing Time	Meteors	Meteors / Hour
January	31	2 895.1	12 774	4.4
February	28	3 366.6	11 289	3.4
March	31	4 692.6	11 534	2.5
April	30	4 819.0	13 857	2.9
May	31	4 952.9	15 115	3.0
June	30	3 106.4	10 069	3.2
July	31	3 865.6	18 838	4.9
August	31	7 353.5	53 541	7.3
September	30	8 691.7	36 374	4.2
October	31	10 104.7	59 645	5.9
November	30	8 829.7	35 692	4.0
December	31	6 308.5	33 176	5.3
Overall	365	68 986.3	311 901	4.5

Table 2 – Details for the individual observers of the IMO Video Meteor Network in 2011.

Observer	Country	Observing Nights	Eff. Observing Time [h]	Meteors	Meteors / h	Cameras (Sites)
Sirko Molau	Germany	324	5 430.8	27 831	5.1	4 (2)
Antal Igaz	Hungary	320	4 474.7	19 470	4.3	4 (4)
Stefano Crivello	Italy	315	4 411.8	23 887	5.4	2 (1)
Flavio Castellani	Italy	295	2 862.5	11 176	3.9	2 (1)
Bernd Brinkmann	Germany	280	2 341.3	9 033	3.9	2 (2)
Rui Goncalves	Portugal	278	4 343.9	17 858	4.1	3 (1)
Enrico Stomeo	Italy	277	5 386.4	35 905	6.7	3 (1)
Javor Kac	Slovenia	270	5 159.2	25 200	4.9	4 (3)
Zsolt Perkó	Hungary	269	1 401.1	9 074	6.5	1 (1)
Erno Berkó	Hungary	258	3 641.0	14 196	3.9	3 (1)
Hans Schremmer	Germany	251	900.2	3 009	3.4	1 (1)
Steve Kerr	Australia	247	1 868.9	14 165	7.6	1 (1)
Mitja Govedič	Slovenia	246	1 323.5	5 365	4.1	1 (1)
Jörg Strunk	Germany	245	2 523.8	10 584	4.2	3 (1)
Mihaela Triglav	Slovenia	235	982.6	3 395	3.5	1 (1)
Carl Hergenrother	USA	233	1 670.3	3 774	2.3	1 (1)
Maurizio Eltri	Italy	229	1 658.5	7 281	4.4	1 (1)
Istvan Tepliczky	Hungary	223	1 252.2	6 411	5.1	1 (1)
Karoly Jonas	Hungary	223	1 095.0	4 101	3.7	1 (1)
Szilárd Csizmadia	Hungary	220	770.9	2 641	3.4	1 (1)
Mike Otte	USA	219	1 023.2	4 568	4.5	1 (1)
Jozsef Morvai	Hungary	197	1 066.7	3 083	2.9	1 (1)
Detlef Koschny	Netherlands	173	1 197.8	5 958	5.0	2 (1)
Eckehard Rothenberg	Germany	173	816.0	2 498	3.1	1 (1)
Stane Slavec	Slovenia	169	682.9	2 320	3.4	1 (1)
Carlos Saraiva	Portugal	168	2 031.8	6 584	3.2	2 (1)
Ilkka Yrjölä	Finland	155	682.6	2 918	4.2	1 (1)
Maciej Maciejewski	Poland	132	2 022.7	4 890	2.4	3 (1)
Wolfgang Hinz	Germany	132	816.4	4 565	5.5	1 (1)
Leo Scarpa	Italy	118	916.9	3 896	4.2	1 (1)
Arnaud Leroy	France	100	379.7	818	2.2	1 (1)
Malcolm Currie	UK	97	416.6	1 139	2.7	1 (1)
Martin Breukers	Belgium	86	720.4	2 696	3.7	2 (1)
Orlando Benitez-Sanchez	Spain	79	311.1	676	2.2	1 (1)
Zoltán Zelko	Hungary	74	585.2	1 578	2.7	2 (1)
Gregor Kladnik	Slovenia	59	316.4	1 469	4.4	1 (1)
Luc Bastiaens	Belgium	58	138.7	285	2.0	1 (1)
Robert Lunsford	USA	51	318.0	1 311	4.1	1 (1)
Grigoris Maravelias	Greece	36	225.0	1 783	7.9	1 (1)
Szabolcs Kiss	Hungary	35	152.6	294	1.9	1 (1)
Tom Roelandts	Belgium	31	199.5	345	1.7	1 (1)
Rosta Stork	Czech Rep.	20	143.4	2 897	20.2	2 (2)
Daniel Judge	Australia	17	100.4	252	2.5	1 (1)
Grahame Kelaher	Australia	16	121.7	131	1.1	1 (1)
Mario Bombardini	Italy	12	78.7	268	3.4	1 (1)
Klaas Jobse	Netherlands	5	57.3	423	7.4	1 (1)

Portugal, France, Finland, Poland, Greece, the Netherlands and the Czech Republic. The English camera is currently moved to Hawaii and will hopefully resume operation soon. Outside Europe, we were supported by observers from the United States and Australia.

As in the year before, we did not have to skip a single night. In total we achieved 68 900 hours (2010: 35 500) of effective observing time in those 365 nights, which almost doubled the result of the year before. For the first time, we recorded more than 10 000 meteors in every month, with a range of about 11 000 meteors in February to almost 60 000 in October. The annual total was over 310 000 meteors (2010: 192 000) – which is an increase of more than 60%. On average we recorded 4.5 meteors per hour, which matches almost exactly the average value over the last ten years.

With respect to the weather, 2011 presented strong contrasts. Almost perfect spring (March to May) and fall (September to November) months alternated with only mediocre summer and winter months (Table 1). Overall, the weather was clearly better than in the year before, though, which is why the individual outcome of almost all observers improved.

In the observer statistics, the top flight has further compacted: In 2011, three observers managed to collect more than 300 observing nights. Sirko Molau recaptured the prime position with 324 nights and barely won out over Antal Igaz (320 nights) and Stefano Crivello (315 nights). 18 further observers managed to collect more than 200 nights, and another 10 observers more than 100 nights.

With respect to the effective observing time, Sirko Molau ranked first with little over 5 400 hours, followed by Enrico Stomeo with almost 5 400 and Javor Kac with almost 5 200 hours. When it comes to the number of recorded meteors, however, Enrico was defeated by no one, as in the year before. With more than 35 900 meteors he performed clearly better than Sirko Molau (27 800 meteors) and Javor Kac (25 200 meteors).

Table 2 gives the details for all active observers in the IMO Video Meteor Network, whereby the number of cameras and sites in the last column refers to the number that were operative during the largest number of nights of the year.

In 2011, the TOP 10 of the most successful video cameras is clearly dominated by Italian observers (Table 3) – there are only occasionally cameras from Hungary, Portugal and Germany in between. The differences are only small, though. The places 11 to 13, for example, are held by three cameras with 257 observing nights. Once more two cameras with most meteors are not in the TOP 10: Gocam1 (14 165 meteors), which obtained also the second best effective observing time (1 868.9 hours) and Avis2 (13 865 meteors).

Acknowledgements

As always, we would like to thank the diligent observers, and in particular the team of IMO network administrators, who check all the observations for consistency every month and assure the quality of the database. Knock on wood that the new year will be as sympathetic to us as 2011!

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Table 3 – The ten most successful video systems in 2011.

Camera	Observing Site	Observer	Observing Nights	Eff. Observing Time [h]	Meteors	Meteors / h
C3P8	Valbrevenna (IT)	Stefano Crivello	277	1 919.3	8 217	4.3
Sco38	Scorce (IT)	Enrico Stomeo	273	1 812.4	13 809	7.6
Hubec	Becsehely (HU)	Zsolt Perkó	269	1 401.1	9 074	6.5
Min38	Scorce (IT)	Enrico Stomeo	266	1 842.0	12 512	6.8
Noa38	Scorce (IT)	Enrico Stomeo	266	1 732.0	9 584	5.5
Mincam1	Seysdorf (DE)	Sirko Molau	260	1 516.0	5 690	3.8
Bmh1	Monte Baldo (IT)	Flavio Castellani	260	1 513.9	5 731	3.8
Bmh2	Monte Baldo (IT)	Flavio Castellani	260	1 348.6	5 445	4.0
Templar2	Tomar (PT)	Rui Goncalves	259	1 678.2	6 655	4.0
Remo1	Ketzür (DE)	Sirko Molau	258	1 447.6	4 672	3.2

Table 4 – Observers contributing to 2011 December data of the IMO Video Meteor Network. Eff.CA designates the effective collection area and Tot.CA the total collection area.

Code	Name	Place	Camera	FOV [$^{\circ 2}$]	Stellar LM [mag]	Eff.CA [km^2]	Nights	Time [h]	Tot.CA [10^3km^{2}h]	Meteors
BASLU	Bastiaens	Hove/BE	Urania1 (0.8/3.8)*	4545	2.5	237	8	12.7	—	16
BENOR	Benítez-Sánchez	Las Palmas/ES	Times4 (1.4/50)	2359	3.2	492	10	80.2	—	207
BERER	Berko	Ludányhalászi/HU	Hulud1 (0.95/3)	2256	4.8	1540	12	68.8	58.6	437
			Hulud2 (0.75/6)	4860	3.9	1103	12	52.2	37.0	240
			Hulud3 (0.75/6)	4661	3.9	1052	11	45.4	29.1	152
BOMMA	Bombardini	Faenza/IT	Mario (1.2/4.0)	5794	3.3	739	12	78.7	56.0	268
BRIBE	Brinkmann	Herne/DE	Hermine (0.8/6)	2374	4.2	678	18	67.0	—	253
		Bergisch Gladbach/DE	Klemoi (0.8/6)	2286	4.6	1080	12	33.5	—	273
CASFL	Castellani	Monte Baldo/IT	Bmh1 (0.8/6)	2350	5.0	1611	25	188.5	208.8	714
			Bmh2 (1.5/4.5)*	4243	3.0	371	23	185.4	374.9	817
CRIST	Crivello	Valbrevenna/IT	Bilbo (0.8/3.8)	5458	4.2	1772	28	243.4	—	1534
			C3P8 (0.8/3.8)	5455	4.2	1586	27	235.1	338.4	1058
			Stg38 (0.8/3.8)	5614	4.4	2007	8	69.3	282.2	415
CSISZ	Csizmadia	Zalaegerszeg/HU	Huvcse01 (0.95/5)	2423	3.4	361	10	54.3	17.4	250
ELTMA	Eltri	Venezia/IT	Met38 (0.8/3.8)	5631	4.3	2151	20	156.6	—	837
GONRU	Goncalves	Tomar/PT	Templar1 (0.8/6)	2179	5.3	1842	25	203.8	265.1	856
			Templar2 (0.8/6)	2080	5.0	1508	26	232.5	290.2	819
			Templar3 (0.8/8)	1438	4.3	571	26	221.9	132.7	605
GOVMI	Govedič	Središče ob Dravi/SI	Orion2 (0.8/8)	1447	5.5	1841	21	108.7	—	715
			Orion3 (0.95/5)	2665	4.9	2069	7	15.0	—	50
			Orion4 (0.95/5)	2662	4.3	1043	14	62.8	36.9	236
HINWO	Hinz	Brannenburg/DE	Acr (2.0/35)*	557	7.4	4954	8	44.4	—	280
IGAAN	Igaz	Baja/HU	Hubaj (0.8/3.8)	5552	2.8	403	15	58.0	—	382
		Debrecen/HU	Hudeb (0.8/3.8)	5522	3.2	620	8	42.0	18.2	160
		Hódmezővásárhely/HU	Huhod (0.8/3.8)	5502	3.4	764	14	73.5	—	261
		Budapest/HU	Hupol (1.2/4)	3790	3.3	475	4	26.5	9.5	85
		Sopron/HU	Husop (0.8/6)	2031	3.8	460	19	82.0	95.8	783
JONKA	Jonas	Budapest/HU	Husor (0.95/4)	2286	3.9	445	14	66.9	59.2	285
KACJA	Kac	Kostanjevec/SI	Metka (0.8/8)*	1372	4.0	361	9	59.5	27.0	146
		Ljubljana/SI	Orion1 (0.8/8)	1402	3.8	331	14	60.9	—	436
		Kamnik/SI	Cvetka (0.8/3.8)	4914	4.3	1842	12	83.1	—	568
			Rezika (0.8/6)	2270	4.4	840	13	95.1	—	883
			Stefka (0.8/3.8)	5471	2.8	379	12	90.4	—	449
KERST	Kerr	Glenlee/AU	Gocam1 (0.8/3.8)	5189	4.6	2550	15	80.4	151.2	731
KISSZ	Kiss	Sülysáp/HU	Husul (0.95/5)*	4295	—	—	15	46.8	—	98
KLAGR	Kladnik	Tacen/SI	Tacka (0.8/12)	715	5.4	796	5	21.1	—	75

Table 4 – Observers contributing to 2011 December data of the IMO Video Meteor Network – continued from previous page.

Code	Name	Place	Camera	FOV [°²]	Stellar LM [mag]	Eff.CA [km²]	Nights	Time [h]	Tot.CA [10³km²h]	Meteors
KOSDE	Koschny	Izana Obs./ES	Icc7 (0.85/25)*	714	5.9	1464	15	136.0	—	1162
		Noordwijkerhout/NL	Lic4 (1.4/50)*	2027	6.0	4509	13	59.4	39.4	245
LERAR	Leroy	Gretz/FR	Saphira (1.2/6)	3260	3.4	301	16	39.4	18.4	119
MACMA	Maciejewski	Chelm/PL	Pav35 (1.2/4)	4383	2.5	253	17	74.3	—	265
			Pav36 (1.2/4)*	5732	2.2	227	20	88.3	—	332
			Pav43 (0.95/3.75)*	2544	2.7	176	17	87.6	—	219
MARGR	Maravelias	Lofoupoli-Crete/GR	Loomecon (0.8/12)	738	6.3	2698	22	133.5	283.8	1299
MOLSI	Molau	Seysdorf/DE	Avis2 (1.4/50)*	1776	6.1	3817	7	42.2	82.1	694
			Mincam1 (0.8/8)	1477	4.9	1084	17	85.0	63.8	549
		Ketzür/DE	Remo1 (0.8/8)	1467	6.0	3139	23	128.0	239.5	1219
			Remo2 (0.8/3.8)	5613	4.0	1186	22	118.1	82.6	710
MORJO	Morvai	Fülöpszállás/HU	Huful (1.4/5)	2522	3.5	532	16	97.0	47.5	317
OTTMI	Otte	Pearl City/US	Orie1 (1.4/5.7)	3837	3.8	460	17	97.9	—	417
PERZS	Perko	Becsehely/HU	Hubec (0.8/3.8)*	5498	2.9	460	23	98.5	—	1350
ROTEC	Rothenberg	Berlin/DE	Armefa (0.8/6)	2366	4.5	911	10	29.6	12.6	108
SARAN	Saraiva	Carnaxide/PT	Ro1 (0.75/6)	2362	3.7	381	29	217.3	—	561
			Ro2 (0.75/6)	2381	3.8	459	30	221.9	—	598
			Sofia (0.8/12)	738	5.3	907	30	217.9	—	410
SCALE	Scarpa	Alberoni/IT	Leo (1.2/4.5)*	4152	4.5	2052	25	159.3	232.7	691
SCHHA	Schremmer	Niederkrüchten/DE	Doraemon (0.8/3.8)	4900	3.0	409	20	79.1	—	415
SLAST	Slavec	Ljubljana/SI	Kayak1 (1.8/28)	588	—	—	8	28.2	—	107
STOEN	Stomeo	Scorze/IT	Min38 (0.8/3.8)	5566	4.8	3270	21	177.6	316.8	1257
			Noa38 (0.8/3.8)	5609	4.2	1911	21	135.2	229.6	650
			Sco38 (0.8/3.8)	5598	4.8	3306	21	147.0	—	1293
STORO	Stork	Ondrejov/CZ	Ond1 (1.4/50)*	2195	5.8	4595	3	11.6	17.0	288
STRJO	Strunk	Herford/DE	Mincam2 (0.8/6)	2362	4.6	1152	11	24.2	—	145
			Mincam3 (0.8/12)	728	5.7	975	13	30.2	—	171
			Mincam5 (0.8/6)	2349	5.0	1896	15	32.1	—	245
TEPIS	Tepliczky	Budapest/HU	Humob (0.8/6)	2388	4.8	1607	15	87.4	—	691
TRIMI	Triglav	Velenje/SI	Sraka (0.8/6)*	2222	4.0	546	8	22.7	—	77
YRJIL	Yrjölä	Kuusankoski/FI	Finexcam (0.8/6)	2337	5.5	3574	11	32.0	—	151
ZELZO	Zelko	Budapest/HU	Huvcse03 (1.0/4.5)	2224	4.4	933	2	10.4	7.7	14
						Overall	31	6 308.5	—	33 176

* active field of view smaller than video frame

Results of the IMO Video Meteor Network — January 2012

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January 2012 presented almost perfect observing conditions at many sites of the IMO Video Meteor Network. Almost 29 000 meteors were recorded in over 9 000 hours of effective observing time by 66 cameras. The Quadrantids reached their maximum on January 4 UT; their flux density profile is presented.

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1 Introduction

The year 2012 started with a big beat of the drum. Typically, the number of recorded meteors is going down significantly after the Quadrantids, and mediocre weather is doing the rest. Thus, we never got more than 3 000 hours of effective observing time in January, and last year was the first where we had recorded more than 10 000 meteors. Not so in 2012! The observers in Southern and Eastern Europe experienced nearly perfect observing conditions, and even in Germany a few cameras collected more than 20 observing nights. With 66 active cameras and the longest nights of the year, the effective observing time suddenly jumped to over 9 000 hours, which is the second best monthly outcome ever. With 29 000 meteors, the meteor count also was more than considerable (Table 1 and Figure 1). It is more than we recorded in January of the previous three years altogether. A year can hardly begin any better than this!

Some of the brightest fireballs are shown in Figures 3 to 5.

With the beginning of 2012, the Slovenian team grew by one more observer. Rok Pucer has been operating a Mintron camera dubbed Mobcam1 with 6 mm $f/0.75$ Panasonic lens.

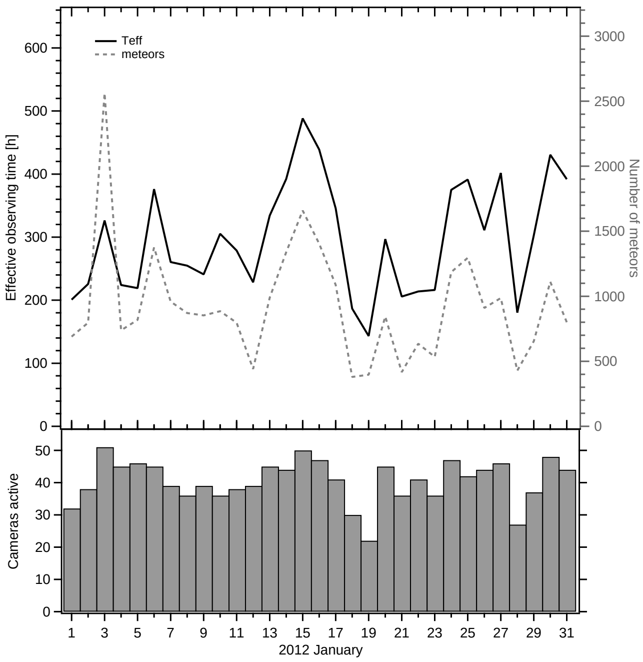

Figure 1 – Monthly summary for the effective observing time (solid black line), number of meteors (dashed gray line) and number of cameras active (bars) in 2012 January.

2 Quadrantids

With respect to meteor showers, there was only one highlight in January. The maximum of the Quadrantids was predicted for $07^{\rm h}$ UT on January 4 (McBeath, 2011). That was outside the observing window for most European observers but did let us expect steeply growing rates in the night of January 3/4. On the one hand, the (at mid-northern latitudes) circumpolar radiant is becoming significantly higher after local midnight. On the other hand, the peak is of only short duration which lets the activity rise sharply in the hours before the maximum. And it was just that which the observers witnessed. Figure 2 shows the overall flux density profile from the Quadrantids 2012 based on 925 shower meteors (with more than 1 100 sporadics in parallel). Within twelve hours, the Quadrantid activity rose from the sporadic background level with less than one meteoroid per 1 000 km^2 per hour to a peak value beyond 15, which translates to a ZHR of about 70. Compared to the flux density of other major showers like the Perseids (over 40) or Geminids (over 100), the Quadrantid peak flux density was rather weak. That may suggest that the real peak occurred as expected after the European observing window. A look at IMO's visual profile confirms this at least partly – highest rates were observed between $05^{\rm h}$ and $09^{\rm h}$ UT (International Meteor Organization, 2012). However, even there the ZHR hardly passed 80. That is not much for a shower that can produce zenithal hourly rates in the triple-digit range. Whether another growth in visual rates at $18^{\rm h}$ UT on January 4 is real or just caused by other visual observers cannot be decided because of a gap in the video data.

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IMO bibcode WGN-402-molau-vidjan
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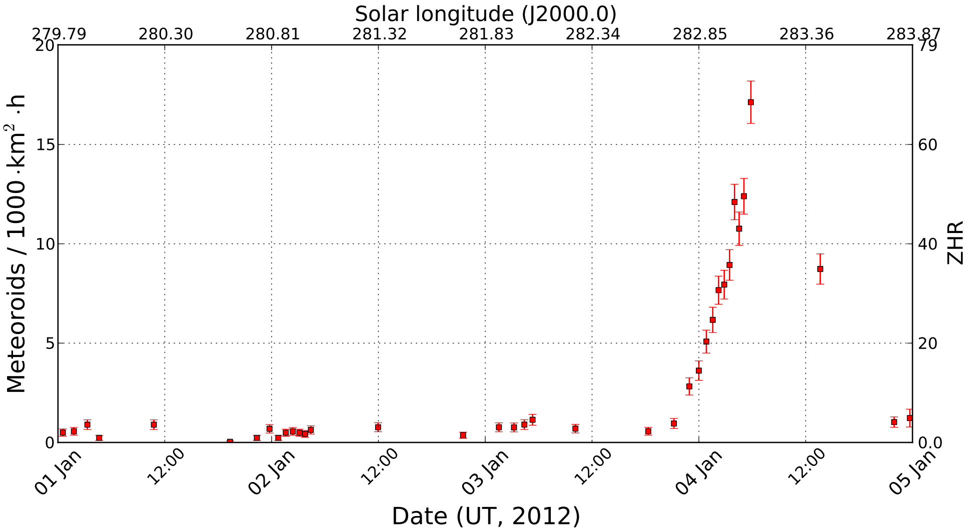

Figure 2 – Flux density profile of the Quadrantids 2012, obtained from 925 shower meteors.

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McBeath A. (2011). *2012 Meteor Shower Calendar*. International Meteor Organization. IMO INFO(2-11).

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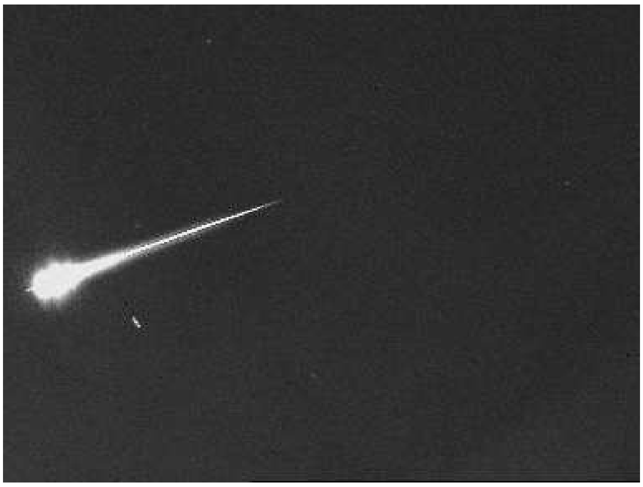

Figure 3 – A bright fireball recorded on 2012 January 11 at $18^h20^m35^s$ UT by Stefka.

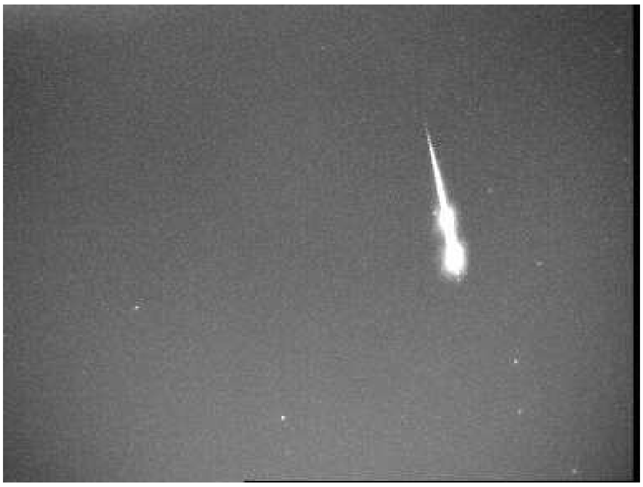

Figure 4 – Fireball recorded on 2012 January 17 at $00^h52^m34^s$ UT by Ro2.

Figure 5 – Triple detection of a fragmenting fireball on 2012 January 16 at $03^h41^m38^s$ UT by Bmh1, Noa38 and Min38 (left to right).

Table 1 – Observers contributing to 2012 January data of the IMO Video Meteor Network. Eff.CA designates the effective collection area.

Code	Name	Place	Camera	FOV [°²]	Stellar LM [mag]	Eff.CA [km²]	Nights	Time [h]	Meteors
BASLU	Bastiaens	Hove/BE	Urania1 (0.8/3.8)*	4545	2.5	237	11	63.6	40
BERER	Berko	Ludányhalászi/HU	Hulud1 (0.95/3)	2256	4.8	1540	17	134.1	612
			Hulud2 (0.75/6)	4860	3.9	1103	17	95.1	280
			Hulud3 (0.75/6)	4661	3.9	1052	17	77.9	228
BOMMA	Bombardini	Faenza/IT	Mario (1.2/4.0)	5794	3.3	739	17	62.0	210
BREMA	Breukers	Hengelo/NL	Mbb3 (0.75/6)	2399	4.2	699	15	127.5	237
			Mbb4 (0.8/8)	1470	5.1	1208	16	111.3	208
BRIBE	Brinkmann	Herne/DE	Hermine (0.8/6)	2374	4.2	678	20	119.6	253
		Bergisch Gladbach/DE	Klemoi (0.8/6)	2286	4.6	1080	14	90.9	239
CASFL	Castellani	Monte Baldo/IT	Bmh1 (0.8/6)	2350	5.0	1611	29	173.2	589
			Bmh2 (1.5/4.5)*	4243	3.0	371	28	153.7	559
CRIST	Crivello	Valbrevenna/IT	Bilbo (0.8/3.8)	5458	4.2	1772	23	197.0	820
			C3P8 (0.8/3.8)	5455	4.2	1586	23	193.9	698
			Stg38 (0.8/3.8)	5614	4.4	2007	22	209.0	1175
CSISZ	Csizmadia	Zalaegerszeg/HU	Huvcse01 (0.95/5)	2423	3.4	361	18	107.2	169
ELTMA	Eltri	Venezia/IT	Met38 (0.8/3.8)	5631	4.3	2151	24	223.1	604
GONRU	Goncalves	Tomar/PT	Templar1 (0.8/6)	2179	5.3	1842	25	235.2	846
			Templar2 (0.8/6)	2080	5.0	1508	26	270.7	786
			Templar3 (0.8/8)	1438	4.3	571	28	299.6	685
GOVMI	Govedič	Središče ob Dravi/SI	Orion2 (0.8/8)	1447	5.5	1841	27	188.7	652
			Orion3 (0.95/5)	2665	4.9	2069	20	99.7	235
			Orion4 (0.95/5)	2662	4.3	1043	25	166.7	272
HINWO	Hinz	Brannenburg/DE	Acr (2.0/35)*	557	7.4	4954	12	68.2	394
IGAAN	Igaz	Baja/HU	Hubaj (0.8/3.8)	5552	2.8	403	25	98.6	364
		Debrecen/HU	Hudeb (0.8/3.8)	5522	3.2	620	19	131.9	268
		Hódmezővásárhely/HU	Huhod (0.8/3.8)	5502	3.4	764	20	126.4	234
		Budapest/HU	Hupol (1.2/4)	3790	3.3	475	7	32.0	35
		Sopron/HU	Husop (0.8/6)	2031	3.8	460	18	64.0	346
KACJA	Kac	Kostanjevec/SI	Metka (0.8/8)*	1372	4.0	361	12	117.9	251
		Ljubljana/SI	Orion1 (0.8/8)	1402	3.8	331	26	216.8	501
		Kamnik/SI	Cvetka (0.8/3.8)	4914	4.3	1842	24	201.2	799
			Rezika (0.8/6)	2270	4.4	840	24	209.7	1158
			Stefka (0.8/3.8)	5471	2.8	379	24	209.8	716
KERST	Kerr	Glenlee/AU	Gocam1 (0.8/3.8)	5189	4.6	2550	11	64.0	421

Table 1 – Observers contributing to 2012 January data of the IMO Video Meteor Network – continued from previous page.

Code	Name	Place	Camera	FOV [$^{\circ 2}$]	Stellar LM [mag]	Eff.CA [km^2]	Nights	Time [h]	Meteors
KOSDE	Koschny	Izana Obs./ES	Icc7 (0.85/25)*	714	5.9	1464	21	168.3	1216
		Noordwijkerhout/NL	Lic4 (1.4/50)*	2027	6.0	4509	15	115.2	240
LERAR	Leroy	Gretz/FR	Saphira (1.2/6)	3260	3.4	301	3	9.2	10
MACMA	Maciejewski	Chelm/PL	Pav35 (1.2/4)	4383	2.5	253	17	71.5	91
			Pav36 (1.2/4)*	5732	2.2	227	18	76.1	108
			Pav43 (0.95/3.75)*	2544	2.7	176	15	28.1	63
MARGR	Maravelias	Lofoupoli-Crete/GR	Loomecon (0.8/12)	738	6.3	2698	7	38.5	205
MOLSI	Molau	Seysdorf/DE	Avis2 (1.4/50)*	1776	6.1	3817	7	58.0	507
			Mincam1 (0.8/8)	1477	4.9	1084	24	154.2	310
		Ketzür/DE	Remo1 (0.8/8)	1467	6.0	3139	21	151.2	734
			Remo2 (0.8/3.8)	5613	4.0	1186	15	105.4	306
MORJO	Morvai	Fülöpszállás/HU	Huful (1.4/5)	2522	3.5	532	24	190.7	424
OTTMI	Otte	Pearl City/US	Orie1 (1.4/5.7)	3837	3.8	460	21	137.0	437
PERZS	Perko	Becsehely/HU	Hubec (0.8/3.8)*	5498	2.9	460	27	159.3	955
PUCRC	Pucer	Nova vas nad Dragonjo/SI	Mobcam1 (0.75/6)	2398	5.3	2976	28	219.1	593
ROTEC	Rothenberg	Berlin/DE	Armefa (0.8/6)	2366	4.5	911	13	74.2	201
SARAN	Saraiva	Carnaxide/PT	Ro1 (0.75/6)	2362	3.7	381	29	279.0	518
			Ro2 (0.75/6)	2381	3.8	459	28	273.6	528
			Sofia (0.8/12)	738	5.3	907	29	297.8	476
SCALE	Scarpa	Alberoni/IT	Leo (1.2/4.5)*	4152	4.5	2052	24	218.2	478
SCHHA	Schremmer	Niederkrüchten/DE	Doraemon (0.8/3.8)	4900	3.0	409	19	128.7	187
STOEN	Stomeo	Scorze/IT	Min38 (0.8/3.8)	5566	4.8	3270	26	268.1	948
			Noa38 (0.8/3.8)	5609	4.2	1911	26	263.5	751
			Sco38 (0.8/3.8)	5598	4.8	3306	26	255.3	1133
STRJO	Strunk	Herford/DE	Mincam2 (0.8/6)	2362	4.6	1152	9	47.3	118
			Mincam3 (0.8/12)	728	5.7	975	5	26.6	58
			Mincam5 (0.8/6)	2349	5.0	1896	13	71.9	266
TEPIS	Tepliczky	Budapest/HU	Humob (0.8/6)	2388	4.8	1607	20	145.1	493
TRIMI	Triglav	Velenje/SI	Sraka (0.8/6)*	2222	4.0	546	26	139.1	460
YRJIL	Yrjölä	Kuusankoski/FI	Finexcam (0.8/6)	2337	5.5	3574	7	19.5	47
ZELZO	Zelko	Budapest/HU	Huvcse02 (0.95/5)	1606	3.8	390	1	9.3	4
			Huvcse03 (1.0/4.5)	2224	4.4	933	8	47.9	90
						Overall	31	9 187.1	28 839

* active field of view smaller than video frame

History

Meteor Beliefs Project: *Spears of God*

Howard V. Hendrix, Alastair McBeath[1] *and Andrei Dorian Gheorghe*

A selection of genuine or supposedly sky-fallen objects from real-world sources, a mixture of weapons, tools and "magical" objects of heavenly provenance, are drawn from their re-use in the near-future science-fiction novel *Spears of God* by author Howard V Hendrix, with additional discussion. The book includes other meteoric and meteoritic items too, some of which have been the subject of previous Meteor Beliefs Project examinations.

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1 Introduction by AM & ADG

The starting point for this somewhat eclectic compilation of beliefs surrounding meteoritic or possibly meteoritic objects, was the science-fiction novel *Spears of God* (Hendrix, 2006). It is set in 2016, and revolves around meteorites and what some of them may contain, touching on panspermia, but concentrating mainly on what some people perceive as a potential, new, powerful weapon. This is so potentially powerful that one of several groups slaughters almost an entire South American tribe to possess one key meteorite. From then on, various groups and individuals are followed around the world to meteoritic sites and meteorite collections in a race to be first to crack the secrets, or prevent others from doing so, amid shifting loyalties, doublecrosses, and the wildcard of a murderously vengeful meteorite hunter. It is entertaining and finely-paced, with a careful blending of fact and fiction in the use of its meteoric, meteoritic, geological and biological materials, far better and more accurately than most other speculative fiction (SF) sources we have examined for the Project so far. There are clear indications of its fictional context, of course (like the fact the sky is always clear whenever there is a stronger meteor shower maximum!), but it has set a new and much improved standard of scientific accuracy in the fictional representation of the fields of meteor and meteorite science. As usual, we would urge anyone interested to read the book complete, rather than rely on this brief synopsis and the notes used in this article.

From the book, we have selected a number of items for discussion beyond those which are likely to be either well enough known to *WGN* readers so as to need little further comment here – such as the basics of meteor astronomy nomenclature and the Tunguska event – or which have already been discussed in IMO forums before – including the folkloric links between meteors and fungi (Beech, 1993, and the subsequent letters in *WGN* **21:5** (1993, p. 225) and **22:2** (1994, p. 28), plus the additional notes in (McBeath & Gheorghe, 2007, p. 27)), meteorites as "thunderstones" (McBeath, 1997; McBeath, 2011), and the potentially meteoritic stones associated with the ancient deities Cybele/Magna Mater, Zeus (said to have been swallowed by Cronos) and Elagabalus (McBeath & Gheorghe, 2005).

However, some we have not covered in detail below may be less familiar. A very useful text to assist in this regard is (McCall et al., 2006), which detailed the world's leading meteorite collections, like those at the Smithsonian, Vatican and British Natural History Museum that featured in *Spears of God*, as well as covering a number of individual meteoritic events, including the Campo del Cielo, Argentina, coarse octahedrite shower (Hendrix, 2006, p. 39). This may have been witnessed by the local inhabitants *circa* 2000 BC, as in 1576 AD the Indians there still regarded the irons as having fallen from the sky in fire (Marvin, 2006, pp. 28–30). Buchwald too (1975) was extremely helpful for his discussion of many of the meteorites featured in the novel (Campo del Cielo was in Volume 2, pp. 373–379, for instance), and confirmed tales of a destroyed city associated with the Wabar craters in Saudi Arabia (Volume 3, pp. 1269–1275), which area was of central importance in part of the book too, e.g. (Hendrix, 2006, pp. 71–72).

We are delighted to be joined here by the novel's author Howard Hendrix. *Spears of God* was his sixth novel, and his tenth book overall. He is a noted science-fiction author, and university professor. His first degree was in biology in 1980, but he subsequently studied English literature to MA, then PhD, level, by 1987, and continues to teach on matters literary in central California, when not engaged in research, writing, gardening and other less sedentary outdoor pursuits. Anyone interested in finding out more about his published works should see the website at: `www.howardvhendrix.com`.

Note that this paper was originally presented as a poster to the 2008 IMC, and should have been published in full in that IMC's *Proceedings* volume. For unknown reasons, that did not happen. In giving the paper finally here, we have made several changes to amend cross-references and outdated material, but the bulk of the text is as prepared for the 2008 IMC. Some works previously published referred to this paper as a forthcoming source, in expectation of its earlier appearance. These may now be helpful in adding notes beyond the discussions here, such as (McBeath, 2010).

In each subsequent section, we have given some notes derived from *Spears of God* first, and then some "real world" references and discussion.

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2 The Brenham pallasites

The Brenham meteorite in Kiowa County, Kansas, USA (home area of the most plentiful pallasites) has been known and "mined" since 1882, but the area was largely forgotten for the last several decades. More recent successes were achieved by Steve Arnold and his comrades in the Brenham Meteorite Company, by applying new ideas and new technologies. They looked to the broader strewn field, rather than just the Haviland crater and the stones found on the Kimberly family's "Kansas Meteorite Farm". Arnold and company also used sophisticated metal detectors and even ground-penetrating radars to pinpoint their new finds. While hardly considered magical now, these pallasites are still important modernly, and the gemstone-quality olivine crystals (peridots) are objects of value and wonder too, as extraterrestrial jewels. It was in this "wondrous" capacity that pallasites helped open the novel (Hendrix, 2006, p. XIV).

Brenham was described in Buchwald's Volume 2, and the Brenham Meteorite Company is quite genuine, but the pallasites are of greatest interest in terms of possibly associated earlier beliefs because of the identical material found in archaeological contexts linking it to the Hopewell Culture of Ohio, some 1500 km away. The Hopewell People flourished from $\sim$ 500 BC to $\sim$ 500 AD, and had a complex society, perhaps best-known now for their huge earthwork burial mounds. A variety of cold-worked and unaltered meteoritic iron objects have been found: adze, chisel and knife blades, jewellery, drill bits and unworked nuggets. While the distance from the Kansas source may seem considerable, other Hopewell artefacts show the people to have been very active long-distance traders – including in obsidian from northwest Wyoming, about 2500 km away. Clearly, the material's tradability and uses reinforced its importance to them, though we cannot demonstrate if this extended beyond its properties as a metal. The iron from a pallasite would be more easily separated and worked than other types of iron from meteorites, though the heavily oxidized and damaged nature of most of the altered objects clearly showed such reused iron survives much less well than the untouched originals (Buchwald, 1975, Volume 2, pp. 656–660; Burke, 1986, pp. 223–224). Further notes on the Hopewell meteoritic objects, and the reuse of pallasitic iron in this respect were in (McBeath, 2010).

3 The "Black Stone" of the Kaʻaba

Traditions of the Black Stone of the Kaʻaba in Mecca as meteoritic in origin featured heavily in (Hendrix, 2006, including pp. 19, 275 and especially 296–297). Islamic and pre-Islamic beliefs held that the angel Gabriel brought the stone from heaven and gave it to the patriarch Abraham, while reports of some Westerners on hajj (including non-Muslims in disguise, such as Sir Richard Burton) claimed the Black Stone was a meteorite. From a novelist's perspective, the Black Stone being a sacred object meant it would be unlikely to be scientifically examined in the near term, and thus would retain its mystery. In addition, the state of the world after September 11, 2001, made a meteorite in Mecca seem tailor-made thriller material.

Burke (1986, pp. 221–223) discussed this object in some detail, with the various legends regarding its possible heavenly origins, but the actual information on it is contradictory, and very little about it is definitively recorded. It seemed to have been broken at least four times, according to historical sources, twice when it was stolen. What is visible today seems to be a collection of fragments held together. The colour is dark or black, largely through its having been touched or kissed by millions of pilgrims, but it is said to have lighter inclusions in places, and some sources indicated it may originally all have been light-coloured. Some examiners have suggested the whole as meteoritically heavy, while one source noted that when the pieces were recovered after a theft, they were identified as parts of this stone because they floated on water! Others have suggested the stones were agates, or impactite glass from Wabar. It is a curiosity that Muslim sources do not claim the stone as having a meteoritic origin, beyond the tales that it may have begun as heaven-related (usually that it was an angel transformed, or that it was some object brought by an angel). Those commentators suggesting it was specifically meteoritic, rather than simply legendarily so, seem exclusively non-Muslim in origin, from the early to mid 19th century onwards. Burke summed up the modern view as only that there was considerable doubt over this "black stone" being a meteorite at all.

4 Betyls and other sacred stones

Jacob's stone pillow dream in the biblical "Book of Genesis", Chapter 28, was at a place he called *Beth El*, the Gate of Heaven or House of God, and afterwards, he set up the stone and anointed it with oil, in many sources called "oil received from heaven". Beth El is linked linguistically to the root of the word *Babel*, "Gate of God". Also to *baetyl*, the Greek "House of God", as in Zeus Baetylos. A betyl was a sacred rock that both manifested and housed the deity – and the root meaning of *baetylos* is "he who falls", "he who causes lightning and thunder", and is generally interpreted as "sacred meteorite" (Hendrix, 2006, pp. 18–19).

A quick check of the standard dictionaries suggests that the ancient term *betyl* does indeed mean "meteorite".

Liddell & Scott (1940, p. 303): βαίτυλος – "A meteoric stone; held sacred because it fell from heaven."

Simpson & Weiner (1989, Volume I, p. 878): bætyl – "a sacred meteoric stone", with the first reference in English cited to 1854.

However, the dating of this first English usage, and the late 18th to early 19th century controversy regarding whether meteorites could fall from the sky at all, raised significant questions over the reliability of this connection. Later citations of the English use in Simpson & Weiner show it referred to coral and even standing stones in Britain, neither of which can be classed as "meteoritic" by any modern standard. The agreed meaning among scholars has settled chiefly on "betyl" just meaning "a sacred stone", which might, or might not, be meteoritic. Numerous so-called "betyl coins" from *circa* 300 BC to *circa* 300 AD have been found from the Greco-Roman world, the obverse of which showed a conical or rounded hemispherical object resting on a flat base, an *omphalos* or "navel" (that is, a central point or focus of worship, sometimes seen as the world's pivot, the fixed earthly extension of the sky's rotational pole). Some modern commentators have convinced themselves that markings shown on the surfaces of these coin-illustration omphaloi (the stones originally located in various ancient temples), represented regmaglypts, despite the tiny size of such depictions, and apparently ignoring the fact that virtually all natural stones on Earth have marked or pitted surfaces without needing to have fallen from the sky recently first.

Burke (1986, pp. 219–221) gave a discussion with four sample coins, one of which showed the "black stone" of Elagabalus, investigated previously (McBeath & Gheorghe, 2005, especially p. 143). As noted there, while Herodian's description of this stone (*History*, V.3.5) sounded plausibly meteoritic, he was at pains to indicate it was only "worshipped as though it were sent from heaven", not that it was really believed to have fallen from the sky. Taking this into account with other non-meteoritic "heavenly" deities, again as discussed earlier (e.g. "Heavenly Aphrodite", so named for her purity, not her perceived origin – McBeath & Gheorghe, *loc. cit.*), and the fact that clearly non-meteoritic objects were supposed to have fallen from the sky too (such as the wooden idol of the Palladium or Palladion, the goddess Pallas Athene at Troy – see (McBeath & Gheorghe, 2004)), compounded as few such worshipped objects have survived to allow modern examination, none of which have proven meteoritic, it seems unwise to assume such betyls, omphaloi or other revered stones were always of natural extraterrestrial, terrestrial, or manufactured, origin, without examination on a case-by-case basis.

5 Uvavnuk

Another linkage of sacred skystone and prophetic visions was the recorded history of the 19th-century Inuit seer Uvavnuk, a woman whom witnesses claimed was struck by a falling star or a fireball (accounts differ), and as a result was forever after possessed by a sky spirit known as a *tupilak*, who purportedly granted her visions and poetic abilities (Hendrix, 2006, p. 133). Detailed sources on the beliefs and mythologies of the Arctic peoples are few, but the tales of the Inuit seer Uvavnuk recur in most. A good general introductory synopsis and context volume is (Allan et al., 1999), with their chosen Uvavnuk variant on p. 86.

6 Mesoamerican star-spears and meteorites

Central American spears from heaven and the beings they were or who wielded them, as potentially associated with meteorites, helped name the novel "Spears of God", and featured in several important passages in the book (Hendrix, 2006, pp. 83, 130–131, 136–139). The Mesoamerican bark book known as the *Codex Boturini*, particularly its history of the Aztec migration into Tenochtitlan, the *Tira de la Peregrinación*, contained the Mixtec term *nuhu*, "spear of God" or "spear of the gods". Anthropologist Karl Taube has suggested this referred to meteors and meteorites. Several scholars have suggested the nuhus were part of a "meteorite storm" that struck the Americas, leaving "magical" magnetic stones and pebbles in the mountains and on the plains, meteoritic remnants which were also reflected in Aztec tales of Tlaloc and Huitzilopochtli.

The *Tira* told how the "god" Huitzilopochtli – who also seemed to have been a nuhu, from the red and white symbols associated with him – was discovered in a cave (or perhaps a crater) in a mountainside. It has been suggested that this was a magnetic stone, later named Huitzilopochtli, found in what the codices show as Curl Mountain Cave. In the codices, Huitzilopochtli was reportedly carried on the back of a *yahui* (= priest) with the glyph-name of Serpent. This priest led the pilgrims who went on to found Tenochtitlan. Scholars who have examined the iconography of these codices have suggested that Huitzilopochtli had to be carried by a yahui because, although he could "speak", he was a sacred mummy bundle without feet. These speaking bundles without feet appeared never to have been human beings in any form. They were instead objects treated not so much as "gods" as simply "sacred" or "belonging to" the gods. It has been speculated that a magnetic iron meteorite would have the ability to "speak North". Its opposite end would then "speak South". When the pilgrims in the *Tira* became discouraged on their long road and would go no further, the priest insisted that Huitzilopochtli spoke to him and said he wished them to continue their journey, a powerfully fascinating possibility that a magnetic meteorite could have helped found a new nation.

Buchwald (1975) discussed items under three meteorites from Mexico which seemed of particular potential relevance to these ideas, in respect of the Aztecs who settled at Tenochtitlan *circa* 1325 AD (the city was sacked finally in 1521 by the Spanish). These three were Casas Grandes and Morito, both in Chihuahua, and Toluca, not far from modern Mexico City, and still closer to the former site of Tenochtitlan itself.

The main meteorite at Casas Grandes was a large, medium octahedrite, weighing 1545 kg, which was found in a ruined temple on the west bank of the Rio de las Casas Grandes, first described in 1867 by E G Tarayre. However, another iron meteorite had come to light in the ruins during an earlier excavation. This was described as a lens-shaped object about 50 cm across, which had been carefully wrapped in cloths similar to those of the mummies found in a series of tombs outside the temple. Each tomb was a small elliptical chamber in which the body was seated with its knees drawn up. Unfortunately, this other meteorite seemed not to have survived, and from the description, Tarayre apparently did not see it himself (Buchwald, 1975, Volume 2, pp. 433–435). More examples and discussion of wrapped and buried meteorites from northern America were in (McBeath, 2010).

An even larger medium octahedrite, of at least 10.1 tonnes, was first recorded near Morito on the western slopes of the Western Sierra Madre in south-west Chihuahua in 1619. It was a noted landmark even then, and was said to have been a venerated memorial for the native peoples when they first moved from the north to settle in Mexico. It seemed to have been mined by Europeans from around 1600. A somewhat irregular cone-shaped piece about 100 cm tall was taken to Mexico City much later, and mounted on a pillar there in the Palazzio de Mineria (Buchwald, 1975, Volume 3, pp. 838–841).

Toluca, in the former Aztec heartland, is near the site of an important iron meteorite strewnfield, estimated at $\sim$ 5 km NE-SW by $\sim$ 4 km NW-SE, centred on the plaza of Xiquipilco village, as judged by H H Nininger in 1952. Thousands of coarse octahedrite fragments were recovered from the hillsides nearby, but many others had been used for making tools such as spades, axes and ploughs by the locals, going back many generations prior to the first non-native recorded witness in about 1776. Even then, there were two experienced smiths in the village who would forge the iron to the shape required with little difficulty. Sources from the 18th and early 19th centuries concurred that the fragments were most easily recovered after rainstorms had washed them from the soil, and that the natives needed no other source of iron for their agricultural implements. Buchwald suggested a total recovered mass of at least 2.8 tonnes was likely (op. cit., pp. 1209–1215).

7 More mythological weapons

A variety of other mythological weapons with potentially meteoritic origins featured in the novel, especially brought out in a discussion between two leading characters on their way across the desert to the Wabar site in Saudi Arabia (Hendrix, 2006, pp. 83–84) These included: Odin's spear Gungnir, said to have been made of *uru* metal from Asgard in the heavens; the Hindu Vajra, the "diamond thunderbolt", described as having many of the same attributes as Gungnir; the magical Spears of Lugh and Luin from Celtic legends, which influenced the Arthurian texts; and Arthur's own sword Excalibur, which may have come from material that fell from heaven, as well as the earlier sword with which he proved his right to the kingship, by pulling it from a stone, which some have suggested as a reference to forging steel taken from meteoritic iron.

Most of these magical weapons were more often perceived as lightning spears or swords, where any such connection could be ascribed to them in their various myths. The legendary Old Irish spear (= *gae*) of Lug originally belonged to another member of the Tuatha Dé Danann, Assal. The Gae Assal always killed its target if the word *ibar* (= "yew") was spoken as it was thrown, and it then returned to the hand of its thrower. Lug's common epithet was *Lámfhota*, "long-armed", indicative of his ability to hurl weapons a great distance, rather than implying some deformity in his limbs. Elements of Lug's character linked him loosely with other warrior deities, like the Norse Thor and Hindu Indra, both of whom also possessed thunder/lightning weapons, respectively Mjollnir the thundering axe-hammer, and *vajra*, "the thunderbolt". Lug's magical abilities gave him similar links to Thor's father Odin, and Varuna, the mysterious figure Indra gradually replaced in Hindu myths.

Lúin was a magical spear itself (the Old Irish translated as "lance"), normally said to have been owned by Celtchar, a great warrior-hero from the Ulster Cycle of tales. It was a fiery weapon, rather than a lightning one, whose blood-lust was so great it had to be regularly quenched in poison to stop it bursting into flame.

In general, it was the Old Irish Caladbolg, a probable forerunner in tales of the later Arthurian Excalibur (likely also related to the Welsh version of one of Arthur's swords Caledfwlch – there are numerous alternative spellings/pronunciations for all), which came across as most apparent as a lightning weapon, rather than Excalibur itself.

As discussed before in various articles in *WGN*, including in the Meteor Beliefs Project, thunder and lightning were commonly associated with meteors and meteorites in earlier thought, though not necessarily in all cases. Whether the links in the specific instances above can be taken as potentially meteoric is a matter of personal preference, though there was no clear suggestion of a meteoritic iron origin for any, as far as the tales allow. Further information can be traced in good general texts on myths, such as (Willis, 1993), but the Irish detail can be best-sourced via (MacKillop, 1998).

8 Wolfram's Grail

One further Arthurian object was also mentioned during the same discussion (Hendrix, 2006, p. 84), from Wolfram von Eschenbach's *Parzival*. This was the grail, which Wolfram called *lapsit exillis*, a phrase which has been suggested as derived from *lapis ex coelis* or *lapis de coelis*, both of which meant "the stone from the heavens", or perhaps as a contraction of *lapis lapsus ex illis stellis*, ''the stone which came down from the stars".

Wolfram von Eschenbach's story *Parzival* – e.g. (Lefevere, 1991) – was one of the most original of the early flowering of medieval allegorical tales about the Arthurian Grail, probably constructed in the very early 1200s AD. His grail was unique for its time, being an almost undescribed "pure" stone, which magically provided food and drink to those who served it (called "templars" in *Parzival*, not to be confused with the real-world military order of knights of that name), giving all who saw it regularly perpetual life and youth. When necessary, it communicated with its servants by an inscription which appeared on its outer edges, that faded once read. The stone was powered by a small white wafer, brought each Good Friday (the Friday before Easter Sunday in the Christian calendar) by a pure white dove that descended from heaven, and then returned to it (*op. cit.*, pp. 144–145).

In Wolfram's conception, the grail's history was known only to a heathen astrologer of Israelite stock, Flegetanis: "He said there was a thing called the grail, whose name he had read among the stars, without question as to what it was called. A host of angels left it on earth; they rose up high above the stars, because their innocence drew them back there. Since then baptised sons of men must guard it with the same flawless breeding. Men who are called forth to the grail are always honorable" (*op. cit.*, pp. 121–122).

The term *lapsit exilis* used for the stone in Book 9 was a nonsense phrase, which has exercised many minds over the years. Recently, Wood (2000, p. 179) called it *lapsis exilis*, and suggested this might be "a deliberate distortion of the Latin term *lapsis ex caelis* (that which fell from heaven)", which, right or wrong, would fit with the angelic delivery idea at least. Whether this also showed an understanding of the possibility of meteorite falls inserted into a fictional context, or simply reiterated the belief that different things might descend from the heavens to the Earth, not all of them meteoritic, cannot be readily shown, however. [Part of this grail commentary was published previously as (McBeath, 2004).]

9 Conclusion by AM & ADG

Given the sometimes very negative elements in the meteor beliefs and folklore we have examined in the Project so far, and in many of those SF sources where we have sought meteoric imagery in particular, *Spears of God* has provided a pleasingly different, and often much more positive, counterpoint. That it did so while still being an enjoyable read, yet has retained strong aspects of factual accuracy in its scientific subjects, is, we believe, a great credit to the abilities of its author.

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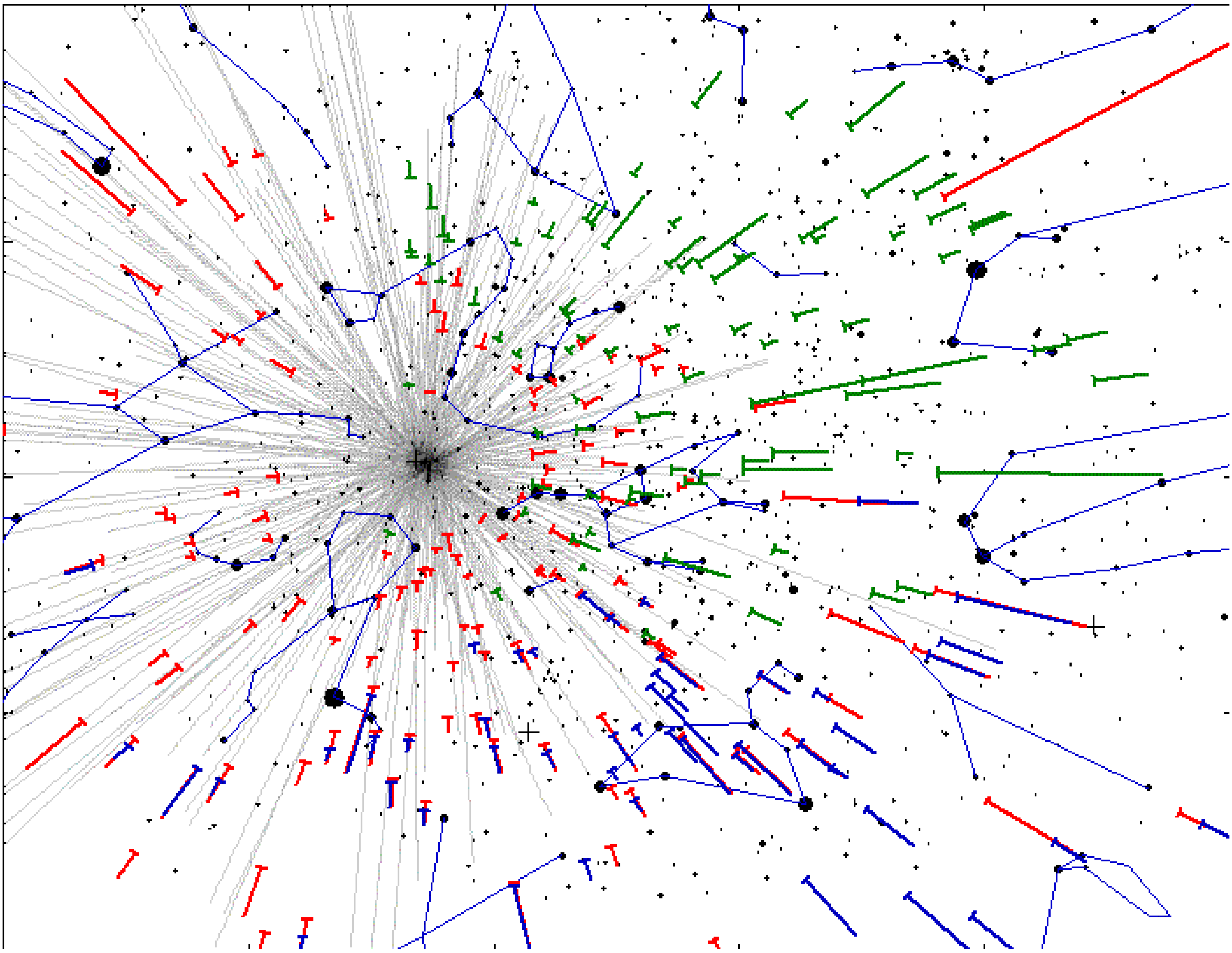
2012 Quadrantids from Italy

Members of the Meteor Section of the Italian Amateur Astronomers Union (Unione Astrofili Italiani) successfully recorded the 2012 Quadrantid maximum. Some results are presented below. (See also page 76 for the IMO Video Meteor Network report.)



Backward tracings of 2012 Quadrantids recorded on January 3/4 by video cameras operated by S.Crivello from Genoa and Caserza (Valbrevenna, GE), Italy.

Bright Quadrantids recorded on 2012 January 3/4 by S.Crivello: $03^{h}32^{m}$UT with Bilbo (left), $04^{h}18^{m}$UT with C3P8 (center), $05^{h}56^{m}$UT with Stg38 (right).