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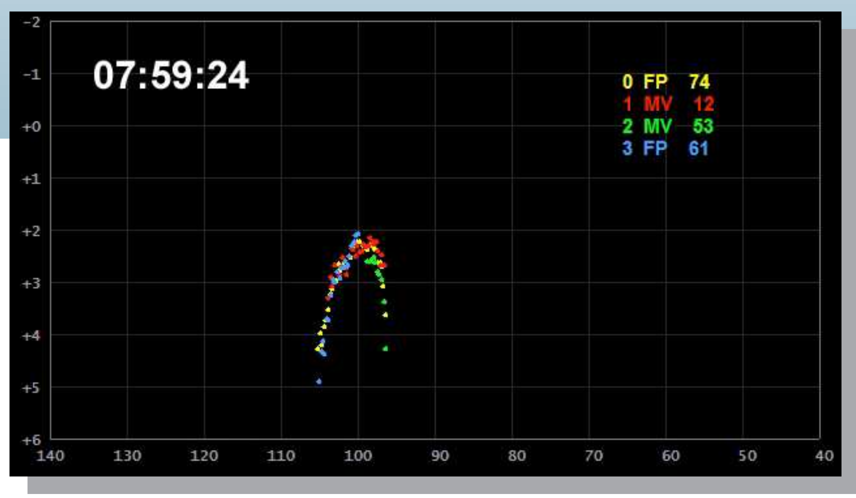

Minor bodies around 15P/Finlay
Discovery of Feb η-Draconids
Križevci meteorite fall
April–May video meteors
Ensisheim thunderstone

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Front cover photo

The 2011 February 4, $07^{\mathrm{h}}59^{\mathrm{m}}$ UT February η-Draconid light curves. Each color represents data from a different camera. This meteor was captured by two cameras in Mountain View (MV) and two at Fremont Peak (FP). Image courtesy: Peter Jenniskens.
See page 93 for details.

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` .

Cover design Rainer Arlt

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Editorial — Perseids a training for the Draconids

Javor Kac

Summer usually brings the opportunity to observe meteors more intensely. As in previous years, I took part in the Youth astronomical research camp, this year back on Pohorje mountain, Slovenia. The weather during the Camp has been one of the worst in the last couple of decades. From July 29 until August 6, I observed meteors in six nights that were at least in part clear. It was fun to watch the gradually increasing activity of the Perseids on the way to their expected August 13 maximum. After the Camp ended I was curious how the activity will continue so I made plans to observe as much as possible despite the somewhat deteriorated health and having to work the usual schedule in daytime.

Luckily, the weather improved in the nights following the Camp. In five consecutive nights from August 9 to 13 I observed with my colleagues, mostly covering the morning hours with the higher radiant altitude. The Moon was more of a nuisance night after night. Still we struggled to gather as much data as possible on this year's Perseids maximum. We were not left unrewarded. Similar to what we noticed last year, some unusually bright Perseids were seen, up to magnitude -10. Whether this trend is real or only statistical fluctuation remains to be unveiled.

Many observers were diligent, filling in their observing reports soon after the observations. This enabled an almost live view of the shower activity evolution. Looking at the Live visual activity graph of the 2011 Perseids one will immediately notice the seemingly lower shower activity when compared to "normal" years. I suspect this is the effect of two factors. First, the observer may not notice all meteors one would expect to see under bright sky conditions, especially when eyes become tired. Second, one may take too much effort seeing the stars in starfields, thereby artificially increasing his/her limiting magnitude (when compared to lower-concentration state during the observation). On the other hand, video observations show the peak of 2011 Perseids activity at ZHR ~ 150 (according to observations sent in until end of August). As this is the first time we are following the Perseid rate in this manner, we have no ways of checking whether this is a normal Perseid ZHR as derived from video observations. I expect it will turn out that this was a normal return of the Perseids.

The June WGN presented predictions of the coming Draconid outbursts. The outburst timing coincides with the bright 90-percent lit Moon fairly high in the sky. This is going to present difficult conditions for visual observer.

While observing this year's Perseids during maximum was quite frustrating when compared to years with maxima without moonlight interference, it was a good exercise for the coming Draconids. It showed the importance of shading the Moon (behind building, tree, mountain, or even an umbrella), facing away from the Moon, choosing appropriate location to minimize light scattering.

We have learned that while the visual observer had a hard time coping with the bright sky, video cameras have hardly noticed the moonlight at all, except if the Moon was inside the field of view. Photographic cameras needed exposure adjustment to prevent overexposing. All this was a valuable experience gained for the future observations under similar conditions.

Meanwhile, the International Meteor Organization has set up a web page about 2011 Draconids, located at `http://www.imo.net/draconids2011`. You may want to share the address with all interested.

I hope everyone enjoys the Draconids this year, whatever happens!

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Letter — Missing Meteor Beliefs Project papers from the 2008 IMC Proceedings

Editorial Board

Six Meteor Beliefs Project (MBP) articles presented the 2008 IMC in Šachtička, Slovakia were inadvertedly not published in the 2008 IMC proceedings because of a communication error.

Five of the six papers will be published in WGN this year and next, beginning in this issue with Alastair McBeath's exploration of beliefs surrounding the Ensisheim meteorite, which fell in 1492. The sixth, on beliefs about meteoritic weapons with lead co-author Kristine Larsen, is hoped to be presented at this year's IMC in Romania, to be followed by publication in its Proceedings volume.

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Meteor science

Family of minor bodies related to the periodic comet Finlay

Alexandra Terentjeva[1] *and Sergey Barabanov*[2]

Possible family of minor bodies associated with the periodic comet Finlay is presented. This family consists of two comets, five asteroids, a meteorite and a fireball stream.

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"On the morning of Sunday September 28, 1969, a brilliant daylight fireball appeared over northern Victoria, Australia, and dropped over one hundred meteoritic fragments in a track 3.5×11.5 km near the small rural township of Murchison", David Seargent wrote, describing circumstances of the meteorite fall (Seargent, 1988). The meteorite was identified as a type CM2 carbonaceous meteorite of unusually large mass (`http://www.lpi.usra.edu/meteor/metbull.php?code=16875`). In consequence of the daylight occurrence, the path of the Murchison fall was not well determined. Analysis of eyewitness accounts, the scatter ellipse, and fall diagrams allowed to locate an orbit of the meteorite for four possible values of the radiant. Geocentric velocity has been assumed to be 8.4 km/s according to Halliday and McIntosh (1990).

Seargent (1988) assumed the possible relationship between the Murchison meteorite and periodic comet 15P/Finlay. Also he noted that two asteroids 1979 VA and 1960 UA may be related to this meteorite and comet Finlay as well. At present, these asteroids have received a proper name and number: for 1960 UA use (2061) Anza; for 1979 VA use (4015) Wilson-Harrington and/or comet 107P/Wilson-Harrington. Discussing the cometary nature of the meteorite, Seargent suggested that the Murchison meteorite is a fragment of comet Finlay, or alternatively all the mentioned objects are remnants of a larger comet which disrupted in the relatively recent past. For the Apollo type object 107P/(4015) Wilson-Harrington photoelectric photometry has revealed a carbonaceous nature. He emphasizes that this supports "the object's candidature for being a defunct cometary nucleus".

To identify a family of minor bodies with similar orbit elements, we used available catalogues to create subsets in given ranges of orbit elements and other parameters. Since similarity of orbit elements alone is not sufficient, for selected orbits we calculated theoretical geocentric radiants and velocities for the point of the minimum distance between the orbits of minor body and of the Earth and calculated moments of their closest approach. Then, we made these parameters consistent with each other. Ranges of orbit elements and other parameters, allowed for the family, are given in Table 1.

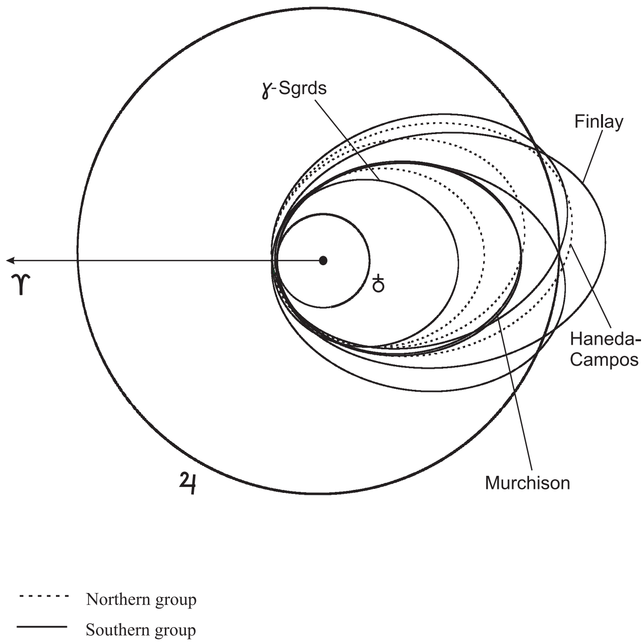

Figure 1 – Family of minor bodies connected with the periodic comet Finlay (orbital planes are superposed with the ecliptic plane).

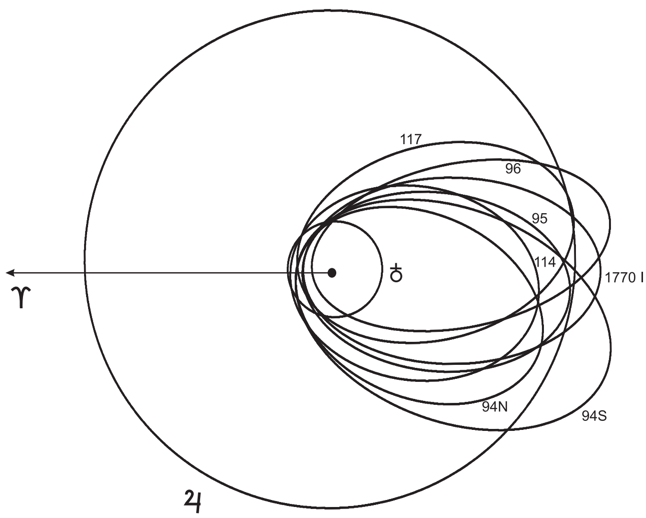

Figure 2 – Possible family of minor meteor streams associated with comet Lexell 1770 I (orbital planes are superposed with the ecliptic plane).

We carried out detailed research for a family of minor bodies of comet Finlay and obtained the following results. This large family contains two comets, five asteroids, the meteorite and a fireball stream (Table 1,

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Table 1 – Family of minor bodies connected with the periodic comet Finlay.

Name	Date (UT)	Corr. geocentric radiant		V_g (V_∞) km/s	a AU	e	q AU	i	ω	Ω	π	ρ AU	Source
		α	δ										
Northern (N) branch													
D/1978 R1 (Haneda-Campos)	Sep. 26.344	282°.5	−1°.1	11.3	3.290	0.665	1.101	5°.9	240°.5	132°.3	12°.7	0.1349	[1]
(2061) Anza	Sep. 29.581	269°.1	−6°.2	8.4	2.264	0.537	1.047	3°.8	156°.5	207°.7	4°.1	0.05196	[2]
2001 PE1	Oct. 3.823	281°.9	−9°.1	10.0	2.763	0.600	1.105	3°.5	190°.7	183°.2	13°.9	0.1057	[2]
Southern (S) branch													
15P/Finlay	Oct. 3.466	269°.7	−37°.8	10.2	3.573	0.711	1.034	3°.7	323°.6	42°.0	5°.6	0.04900	[1]
Murchison	1969 Sep. 28.456	268°.4	−37°	8.4	2.63	0.62	1.00	3°.00	358°.73	4°.47	3°.2	—	—
γ-Sagittarids	Sep. 13	270°	−31°	(12.8)	2.008	0.452	1.003	1°.0	8°.0	350°.1	358°.1	—	[3], No 48
(4015) Wilson-Harrington	Sep. 5.636	283°.4	−34°.4	9.1	2.638	0.624	0.993	2°.8	91°.3	270°.6	1°.8	0.04716	[2]
2000 PF5	Sep. 4.125	259°.4	−45°.2	11.3	3.199	0.652	1.113	6°.1	52°.2	298°.9	351°.1	0.1343	[2]
1997 YM3	Oct. 5.945	290°.4	−37°.4	10.6	3.263	0.668	1.084	3°.9	75°.5	302°.0	17°.5	0.1091	[2]

Note: Orbital elements of the γ-Sagittarid fireball stream are given for the 1950.0 equinox; for all the other objects they are given for the 2000.0 equinox. Orbital elements of the comet Finlay are given for its apparition in 1995.

Sources: [1] – `http://ssd.jpl.nasa.gov/dat/ELEMENTS.COMET`
[2] – `http://neo.jpl.nasa.gov/cgi-bin/neo_elem`
[3] – Terentjeva (1990).

Table 2 – Possible family of minor meteor streams associated with comet Lexell 1770 I (the table is taken from Terenteva (1968)). Equinox 1950.0.

Comet and meteor streams	a (AU) e q (AU)	π Ω i	P (years) C N
Lexell (1770 I)	— 0.786 0.674	$358\overset{\circ}{.}8$ $133\overset{\circ}{.}9$ $1\overset{\circ}{.}6$	5.60 0.5020 —
North-Ophiuchids (94) 16 VI–3 VII	2.74 0.712 0.763	$336\overset{\circ}{.}8$ $89\overset{\circ}{.}9$ $6\overset{\circ}{.}9$	— 0.57 ± 0.05 4
South Ophiuchids (94) 16 VI–3 VII	3.48 0.770 0.793	$338\overset{\circ}{.}7$ $278\overset{\circ}{.}0$ $4\overset{\circ}{.}0$	— 0.49 ± 0.04 3
ξ-Serpentids (95) 22 VI–6 VII	2.86 0.758 0.678	$352\overset{\circ}{.}7$ $95\overset{\circ}{.}2$ $5\overset{\circ}{.}5$	— 0.54 ± 0.04 4
Scutids (96) 12–29 VI	3.24 0.848 0.482	$10\overset{\circ}{.}0$ $91\overset{\circ}{.}8$ $9\overset{\circ}{.}2$	— 0.47 ± 0.04 4
γ-Scutids (114) 5–14 VIII	2.65 0.645 0.935	$350\overset{\circ}{.}0$ $133\overset{\circ}{.}0$ $3\overset{\circ}{.}0$	— 0.59 ± 0.03 2
η-Aquilids (117) 1–16 VIII	3.04 0.740 0.785	$15\overset{\circ}{.}0$ $133\overset{\circ}{.}0$ $13\overset{\circ}{.}5$	— 0.52 ± 0.01 2

Notes: Orbital elements of the comet are given according to the catalogue of Porter (1960); orbital elements of the meteor streams are given according to Terentjeva (1966); the last column contains the period of revolution of the minor meteor stream and the value C of Tisserand's constant (the perturbing planet is Jupiter). C is taken for the streams as the mean from n values (n being the number of individual orbits in the stream) with arithmetical mean deviations.

Figure 1). In the family we revealed two groups of radiants and corresponding orbits, being somewhat analogous to N, S–branches for meteor streams. The northern and the southern radiant groups are located symmetrically to the ecliptic plane and are active (over the month interval) on an area of $30^\circ \times 40^\circ$. This area have a shape of an ellipse with its center located on the ecliptic, while its semimajor axis is perpendicular to the ecliptic. This property for ecliptic and near-ecliptic streams with N, S–branches was found by Terentjeva (1966). The average value of coordinates of the radiant and orbit elements for the Murchison meteorite are given in Table 1 (out of four possible variants in Seargent (1988)).

It is interesting to note that three asteroids in the family of the comet Finlay have been classified and that they are all carbonaceous:

- (2061) Anza — T/C/G (Tholen, 1989; Bowell et al., 1978);
- (4015) Wilson-Harrington — C/F (Tholen, 1989);
- 1997 YM3 — C (DeMeo & Binzel, 2008).

The object (4015) Wilson-Harrington was discovered in 1949 as comet 107P/ Wilson-Harrington and re-discovered in 1979 as an asteroid, that has been assigned number 4015. There is still discussion about whether it is an extinct comet or a main belt asteroid perturbed on an Earth-approaching orbit. Anyway, this object belongs to the so-called group of "cometoids". This group was discovered more than 70 years ago by Vodopianova (1939), who studied the distributions of asteroids and short-period comets by the value of the constant of Jacobi's integral in the restricted circular three body problem. This new class of Solar System minor bodies was confirmed by Terentjeva (1964), who studied the relationship between minor bodies (asteroids, meteorites, comets and meteor bodies), also using the constant of Jacobi's integral. Later Terentjeva (1989) studied the interrelationship of several minor body populations (long-period, parabolic and short-period comets, asteroids, minor meteor streams, large meteor bodies, including meteorite-producing bodies) more comprehensively and for a wider sample, on the basis of an analysis of the distributions of minor bodies by Tisserand's constant

$$C = \frac{1}{a} + \frac{2}{a_j^{3/2}} \sqrt{p} \cos i$$

(where the perturbing planet is Jupiter). This constant is equivalent to the constant of Jacobi's integral in the restricted three body problem. This study led to a conclusion about possible genetic relations and families within minor bodies complex – comets, asteroids, large meteor bodies, including meteorites, and meteor streams. In particular, it was found that about 8% of meteorites and 15% of asteroids of the Amor group can be genetically related to Jupiter-family comets. "Mirror symmetry" has been found in C-distribution of minor bodies relative to the narrow "gap" in the center of which collinear points of libration L_2 and L_3 are located ($C_{L_2} = +0.5844$, $C_{L_3} = +0.5773$). It is known that motions are unstable in these points. Bodies seem to avoid orbits corresponding to critical values of Jacobi's (Tisserand's) constant for these points of libration. Bodies are ejected through the gap opening in the libration points L_2 and L_3, transferring from one population to the other.

The group of cometoids is only located in the range of Tisserand's constant $C = 0.50 - 0.60$. Object 107P/(4015) Wilson-Harrington is also located in this range. This object has an ambiguous classification, and there is still a long way to go to the final solution.

It is interesting that the same cometoid group comprising the minor body family of comet Finlay includes in addition another six objects. Thus seven objects out of nine are cometoids. Below we present values of Tisserand's constant C for these objects.

Object	C
D/1978 R1 (Haneda-Campos)	0.5312
(2061) Anza	0.6555
2001 PE1	0.5857
15/P Finlay	0.5032
Murchison	0.5942
γ-Sagittarids	0.7497
(4015) Wilson-Harrington	0.5924
2000 PF5	0.5399
1997 YM3	0.5324

Asteroid (2061) Anza ($C = 0.6555$) deviates from this group but not by too much because of the smaller size of its orbit. The γ-Sagittarid fireball stream is located apart from the main group ($C = 0.7497$). This can be a consequence of its shorter orbital period. In general, various physical factors can influence meteor orbits significantly.

It should be noted that two subgroups of objects with very similar values of Tisserand's constant are revealed, as seen from the previous table. The first cometoid subgroup includes three objects: D/1978 R1 (Haneda-Campos), 2000 PF5 and 1997 YM3. It means that in the past they could have shared the same orbit. The same can be said about the second subgroup including the Murchison meteorite and object 107P/(4015) Wilson-Harrington.

Thus, while the condition of Tisserand's criterion is necessary, in general, it does not contradict the assumption that all these bodies (Table 1) could form in some single process or at least in sufficiently similar conditions.

In the author's opinion, the formation of all the components of the family of comet Finlay is not necessarily related to that particular comet. This family could have originated from disruption of a larger celestial body after an extreme close approach to Jupiter or due to some other cause. Also, the family formation might have been extended in time. The comets (Finlay and others) might have been formed within the existing branches by a process of continuing disintegration.

Pokrovsky (1901) in his unfinished monograph noted a probable connection of comet 1770 I Lexell with periodic comet Finlay. Tisserand's constant for them are equal to 0.5020 and 0.5032, respectively. If this is true, a vast complex of minor bodies exists, as according to the research carried out by Terentjeva (1968) a family of five meteor streams is related to comet Lexell.

It is well known that comet Lexell drastically changed its orbit under the influence of perturbations near close approaches to Jupiter in 1767 and 1779. Great perturbations caused by a close approach to Jupiter in 1779 moved the comet's orbit away from the Earth's, and since that time the comet had not been observed. Meteor streams (Table 2, Figure 2) might have remained as relics of this comet, and the corresponding showers continue to be observed, but with a large spread in the date of activity (June–August) and in the position of radiants (up to 45°). As noted in Terentjeva (1968) "observers (W.F. Denning and I.S. Astapovich) have always been amazed by the similarity of physical properties of the meteors in these showers".

Radiants of considered vast complexes of minor bodies act on a large ellipsoidal area with sizes $40° \times 50°$. Besides, the theoretical radiant of comet Lexell and adjacent radiants of the Scutid and the γ-Scutid meteor showers from the comet family (Table 2) are located between the northern and southern groups of meteor bodies (Table 1), comprising an ecliptical-like group in this complex of minor bodies. The Earth traverses the system of all these bodies for almost four months.

Acknowledgments

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Discovery of the February Eta Draconids (FED, IAU#427): the dust trail of a potentially hazardous long-period comet

Peter Jenniskens[1] *and Peter S. Gural*[2]

A previously unknown shower was detected on 2011 February 4, during routine low-light-level video triangulations with NASA's Cameras for Allsky Meteor Surveillance (CAMS) project in California between $02^{h}20^{m}$ and $14^{h}20^{m}$ UT. During that time interval, six meteors radiated from a compact geocentric radiant at R.A. $= 239.92° \pm 0.50°$, Decl. $= 62.49° \pm 0.22°$, with speed $V_g = 35.58 \pm 0.34$ km/s. The times of arrival for the meteors were $06^{h}25^{m}$, $07^{h}59^{m}$, $10^{h}49^{m}$, $11^{h}18^{m}$, $12^{h}14^{m}$ and $13^{h}33^{m}$ UT, suggesting that the outburst peaked around 11^{h} UT ($\lambda_{\odot} = 315\overset{\circ}{.}1$) and had a duration of at least 7 hours. The shower was not detected on the days prior to or after February 4. The meteors were in a narrow magnitude range, with peak visual magnitude of +2.1, +1.9, +2.6, +2.1, +2.3 and +2.4, respectively, moving from 103.6 ± 1.4 to 95.7 ± 1.5 km altitude. The mean meteoroid orbital elements derived from the radiant and speed are: $q = (0.971 \pm 0.001)$ AU, $1/a = (-0.004 \pm 0.025)$ AU^{-1}, $i = 55\overset{\circ}{.}20 \pm 0\overset{\circ}{.}34$, $\omega = 194\overset{\circ}{.}09 \pm 0\overset{\circ}{.}35$, $\Omega = 315\overset{\circ}{.}07 \pm 0\overset{\circ}{.}10$ (one standard deviation). The orbital period of this shower is $P > 53$ y (three standard deviations), so that the meteoroids are likely the dust trail of a potentially hazardous long-period comet, which remains to be discovered.

Received 2011 June 30

1 Introduction

When a long-period comet is in an orbit that passes close to Earth's orbit, its one-revolution dust trail from a prior orbit can occasionally shower the Earth (Jenniskens, 2006). Comets that have orbits taking between 200 and about 10 000 years to complete can have dense enough dust trails to be detected in this manner. Such comets originated in the Oort cloud and were initially on orbits taking a longer 100 000 years to complete. Hence, (nearly) all such comets were in the inner solar system in an earlier orbit. During the most recent passage by the Sun, a dust cloud was released, grains of which are now returning at different times depending on the orbital period of each meteoroid. If the comet passes close enough to Earth's orbit, the continuous stream of returning dust wanders in and out of Earth's orbit when the meteoroids are directed to do so by the gravity of the planets (Jenniskens, 1997; Jenniskens et al., 1997). When they do, the Earth is literally showered by meteoroids and a brief 1-h meteor shower can be observed. Recent examples are the 1995 α-Monocerotids (Jenniskens et al., 1997) and the 2007 Aurigid outburst (Jenniskens & Vaubaillon, 2007b; Jenniskens & Vaubaillon, 2007a).

Such meteor showers are extremely rare. They happen only about once or twice every sixty years, when the thin meteoroid stream is exactly in Earth's path at the time when Earth arrives at that spot. Because they are so rare, many of these showers remain to be discovered. Here, we report that one such shower, previously unknown, just showed up on 2011 February 4.

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2 The Cameras for Allsky Meteor Surveillance (CAMS) network

The shower was detected during routine observations with a new NASA-sponsored network of low-light video cameras called the Cameras for Allsky Meteor Surveillance (CAMS) project. The project website is at: `http://cams.seti.org`. Goal of the project is to verify the 300+ meteor showers in the IAU Working List of Meteor Showers that remain unestablished. The project consists of three stations, each equipped with twenty Watec Wat-902H2 Ultimate / Pentax 12 mm $f/1.2$ cameras, which have a small $20° \times 30°$ field of view. The stations are located at Fremont Peak Observatory south of San Juan Bautista in California, at Lick Observatory, and in Mountain View. The first two-station observations with the Fremont Peak and Mountain View stations were made on 2010 October 21. At the time of the observations reported here, the Lick Observatory station was not yet in operation.

The video data is compressed in a distortion-free (Four-Frame) format, modified from (Gural & Šegon, 2009) and written to hard disk during the night. In the morning, all files are examined with MeteorScan (Gural, 1997) to find the meteors. Those files are later collected and re-processed to obtain the astrometry of the meteor tracks and the photometry of the meteor light curves at 60 Hz. Once all data are in one place, an interactive coincidence program searches for meteors and calculates the trajectory in the Earth's atmosphere and the orbit in space. The system and reduction procedures are described in detail in a recent paper submitted to Icarus (Jenniskens et al., 2011).

3 The February η-Draconids

During routine data processing, we discovered among the 80 meteoroid orbits measured in the night of 2011 February 4 (UT), a cluster of five orbits very tightly together near the star η Draconis (Figure 1). On further inspection, all meteors had a similar speed of about 35.6 km/s. This resulted in a nearly parabolic orbit, in prograde motion. The orbital elements of these meteors

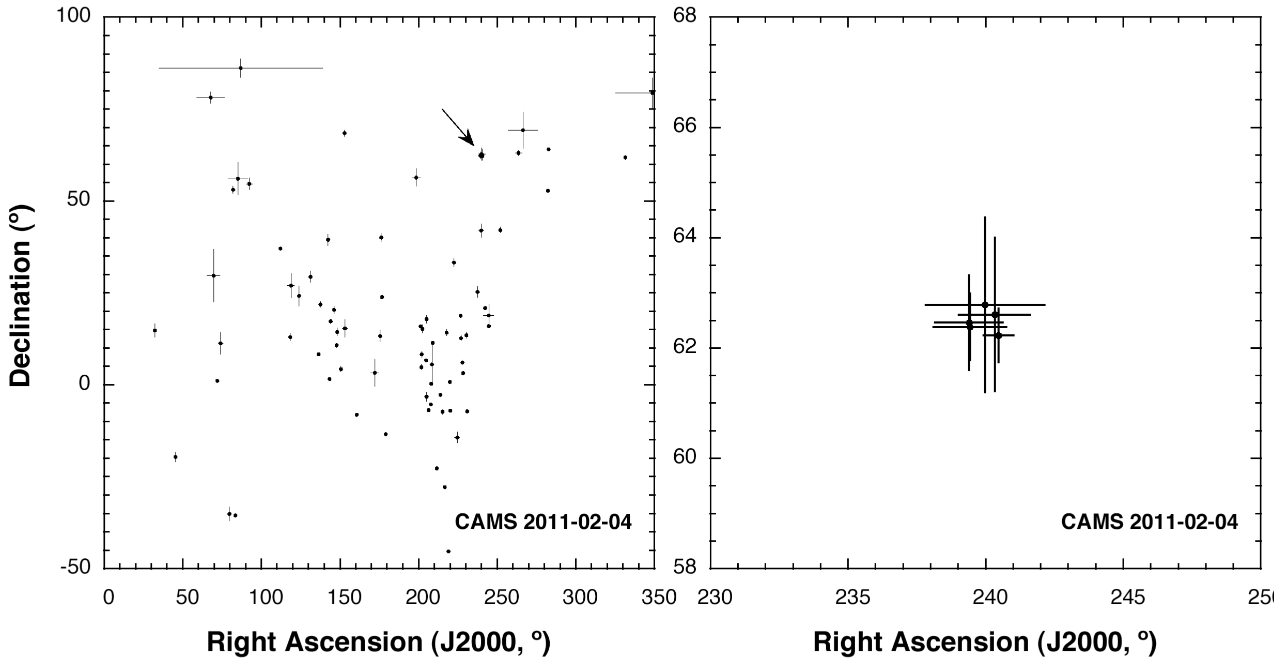

Figure 1 – Geocentric radiant positions of meteors observed in the CAMS network on 2011 February 4. Results for five meteors (marked by arrow) are shown enlarged in the right diagram.

are summarized in Table 1. Running the coincidence software again with looser constraints (radiant error in declination 2–3°) produced a sixth meteor (Table 1).

The calculated error bars (from Monte Carlo modeling of the uncertainties) are scaled with the presumed uncertainty in astrometry (fraction of a pixel). We assumed that error was of order 0.4 pixels. In reality, the error bars appear to be over estimated. The standard deviation of the meteor radiants is 0.22° (1 sigma). The mean error bar was 0.98°, a factor of 4.5 larger. The deviation in right ascension is a factor of two higher at 0.50° because of the higher declination. The calculated error is 1.3°, a factor of 2.6 higher. Possibly, the uncertainty in the astrometry was about 0.1–0.2 pixels and the quoted error bars are 3-sigma. This is the random error only; systematic errors may exist as well.

It is surprising to see that all confirmed shower members are in a narrow magnitude range of +1.9 to +2.6. This phenomenon was earlier observed for the α-Monocerotid and Aurigid showers (Jenniskens et al., 1997) and is thought to be due to the meteoroids of brighter size not being able to make it all the way to where the Earth encountered the dust (Jenniskens, 2006).

It is interesting to note that most light curves look similar: fairly broad with a rounded flattened top. None show flares. This is quite different from other meteors observed that night. The shape of the light curves suggests that these are relatively sturdy meteoroids that don't crumble easily. Figure 2 shows the light curves in one of the interactive screens to determine whether a coincidence is an actual meteor. The other two screens used in the coincidence software show altitude versus distance along the track and latitude versus longitude of the calculated track. The result from each station is shown with different colors (shown here as light and dark gray).

A brief announcement of the discovery was submitted to the IAU Central Bureau of Telegrams, after checking in with the Meteor Data Center (Tadeusz Jopek) to verify the proposed name: the February η-Draconids. The name was unique and the shower received #427 and code "FED".

4 Long-period comet dust trail?

The similarity of the orbits implies that the February η-Draconids are a dynamically young stream. The orbital period implies a long-period comet, perhaps a Halley-type comet. If this indeed is a long-period comet dust trail, then the dust was ejected in the previous return to the Sun. Such dust trails get perturbed enough on the way in that the orbital periods change dramatically and dust trail sections catch up on each other, spreading out into a more diffuse stream already after one orbit (Jenniskens, 2006).

The shower was not detected in the days before and after February 4 (February 1 to 10 were all clear nights). The shower also doesn't appear to have been active in 2007–2009, because no shower members were detected in the SonotaCo database (2007–2009) compiled by Touru Kanamori, for a 3° solar longitude interval around the current event (SonotaCo, 2009).

Surprising, however, is the long 7-h duration of the event. Other crossings of long-period comet dust trails were much shorter, of order 0.7–2 hours (Jenniskens et al., 1997). We examined the log file of astrometric tracks for all moving objects in all cameras that recorded that night (16 cameras at Fremont Peak Observatory and 16 cameras in Mountain View). We found an additional 11 meteors that were likely part of this shower. All these new trails cluster in the time period $10^{\mathrm{h}} - 13^{\mathrm{h}}$ UT. Hence, the two earlier meteors appear to have been on the wing of the activity profile (Figure 3).

Table 1 – Meteoroid physical parameters, trajectory, and orbital elements. m_V is the visual magnitude, F the light curve parameter (position of peak relative to distance from begin to end point), H_b and H_e are beginning and end altitude, RA_g and Dec_g are the geocentric Right Ascension and declination, V_g is the geocentric speed. Orbital elements are in J2000.

Time	m_V	F	H_b	H_e	RA_g	Dec_g	V_g
06:24:31	+2.3	0.68	105.1	94.6	239.43 ± 1.32	62.38 ± 0.60	35.67 ± 0.28
07:59:25	+2.1	0.59	105.1	96.3	240.47 ± 0.53	62.23 ± 0.48	35.16 ± 0.07
10:48:53	+2.6	0.62	102.7	97.0	239.40 ± 1.22	62.46 ± 0.85	35.90 ± 0.34
11:17:46	+1.9	0.67	103.9	97.1	239.98 ± 2.14	62.79 ± 1.58	35.30 ± 1.06
12:13:49	+2.1	0.40	103.1	95.7	240.33 ± 1.28	62.61 ± 1.39	35.87 ± 0.61
13:32:19	+2.4	0.67	101.4	93.4	239.80 ± 2.88	61.38 ± 3.01	35.62 ± 0.94

Time	Sol. long	q (AU)	1/a (1/AU)	i (°)	ω (°)	Ω (°)
06:24:31	$314.^\circ 929$	0.970 ± 0.002	-0.002 ± 0.030	55.39 ± 0.44	194.42 ± 1.05	314.923
07:59:25	$314.^\circ 995$	0.972 ± 0.001	$+0.032 \pm 0.020$	54.94 ± 0.29	193.73 ± 0.43	314.990
10:48:53	$315.^\circ 115$	0.970 ± 0.002	-0.022 ± 0.043	55.54 ± 0.64	194.41 ± 0.88	315.111
11:17:46	$315.^\circ 135$	0.971 ± 0.003	$+0.002 \pm 0.095$	54.74 ± 1.51	194.17 ± 1.39	315.132
12:13:49	$315.^\circ 175$	0.972 ± 0.002	-0.032 ± 0.072	55.37 ± 1.07	193.73 ± 0.84	315.175
13:32:19	$315.^\circ 229$	0.971 ± 0.004	$+0.037 \pm 0.136$	55.90 ± 2.11	194.09 ± 2.24	315.228

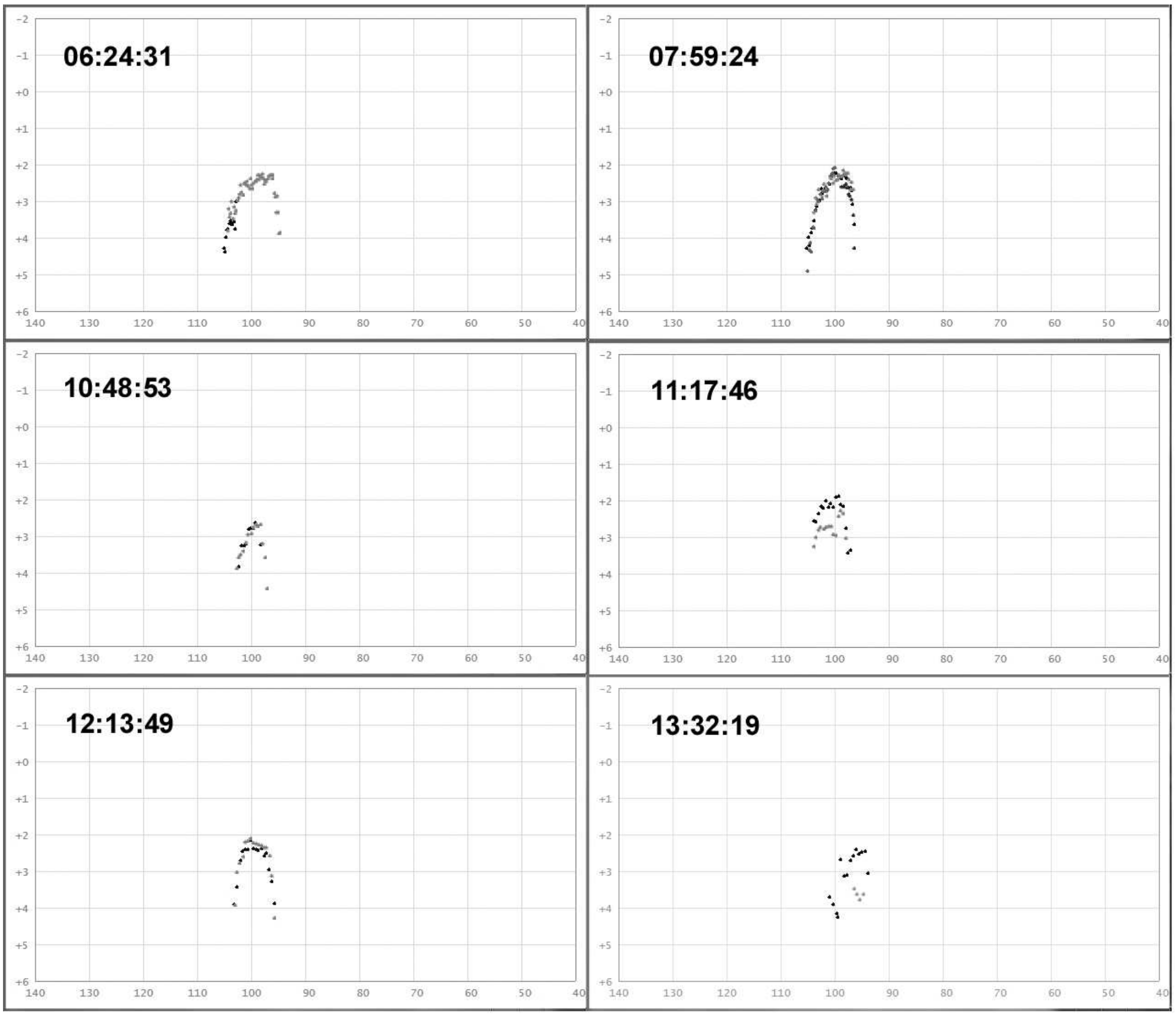

Figure 2 – Meteor light curves of shower members. Each graph shows brightness from bottom to top ranging from +6 to −2 visual magnitude, and altitude left to right ranging from 140 to 40 km.

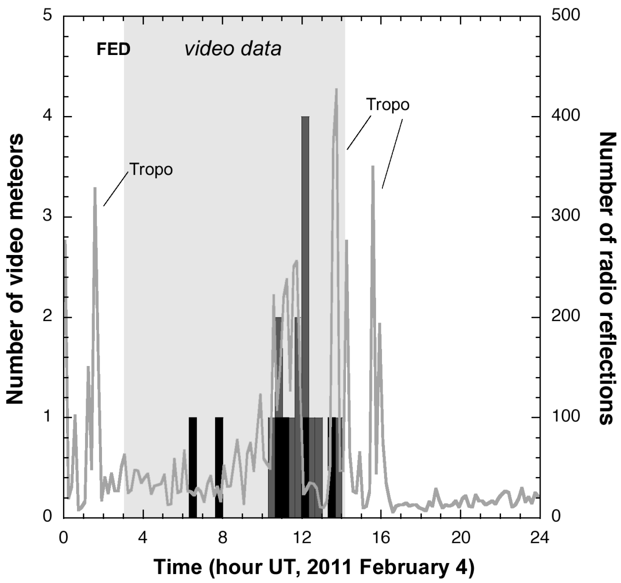

Figure 3 – Number of detected shower meteors as a function of time on 2011 February 4. The gray area is the timeframe for which video observations are available. Also shown is the count of radio reflections in observations by Ilkka Yrjölä of Kuusankoski, Finland (GlobalMSNet).

The time of detections was compared to the 10-minute count of radio reflections during that day, obtained by Ilkka Yrjölä of Kuusankoski Finland in routine observations for GlobalMSNet. A peak in reflection count is observed between 10^{h} and 12^{h} UT on February 4. Unfortunately, during February, there was a lot of tropospheric propagation interference, as well as aurora. It is not certain that the measured peak was due to the meteor shower.

5 Implications

This is an important discovery, because it points to the presence of a Potentially Hazardous Comet. A comet is considered a potentially hazardous comet if its minimum orbit intersection distance with respect to Earth (MOID) is less than MOID = 0.05 astronomical units (AU) and its diameter is at least 150 m. Presently, we know of no long-period comets with a diameter less than 150 m. The abundance of short and long period comets drops off significantly for diameters less than 1.25 km (Snodgrass et al., 2011; Meech et al., 2004). As long as no activity is detected from objects smaller than 150 m, a potentially hazardous comet is any comet that can pass to within 0.05 AU from Earth's orbit.

This particular comet can come closer than that. The dust trail hit the Earth on February 4, and is expected to do so once or twice every 60 years. Upon request, Esko Lyytinen calculated the FED orbit back in time, generated dust 2 000 years ago, then calculated where the trail would cut the ecliptic plane at the present time. For this calculation, it does not matter how far back in time the initial orbit is taken, because the perturbations only occur back on the way in when the cloud of dust has turned into a trail from different particles coming back at different times (Jenniskens, 2006). Lyytinen found that the trail is in Earth's path again in 2016 (but only 1.98 months after Earth reaches the node). If the shower does not return in that year, the next return may be in 2023, when the trail reaches the node 2.10 months before Earth. After that, the trail is expected to return not until 2076 (Jenniskens & Lyytinen, 2011). Most of the time, therefore, the trail passes just inside or outside of Earth's orbit.

One-revolution long period comet dust trails move in and out of Earth's orbit with an amplitude and periodicity much like the Sun's reflex motion (Jenniskens, 1997). The amplitude of that motion is 0.0101 AU. That means that the orbit of the FEDs at any given moment in time pass to < 0.0202 AU from Earth's orbit. The trail model shows that the FEDs pass at any given moment in time to within 0.008 AU from Earth's orbit, much closer in that the maximum allowed MOID of 0.05 AU.

Past long-period comet dust trails were detected from orbits in the range 450 (Lyrids) – 2 000 (Aurigids) years. The sensitivity of CAMS makes it possible to detect less prominent trails, from smaller comets or comets in longer orbital periods. The longer the orbital period, however, the lower the dust density. Most likely, the FED dust trail was from a comet in an intermediate orbital period of between 200 and 10 000 years. New comets (with longer orbital periods of about 100 000 years) don't tend to leave much ejected dust in bound orbits. Shorter period Halley-type comets tend to create detectable annual showers.

Because the trail is dynamically young, the comet still moves in much the same orbit as the dust particles. The comet has a highly inclined orbit that keeps it far away from Jupiter. The planetary perturbations do not depend on the mass of the object. The outgassing of the comet (so called non-gravitational forces) are expected to change the orbital period of the comet slightly, but not to change the orientation of the orbit significantly. Also, radiation pressure on the dust particles and the ejection speed of the dust grains are expected to change orbital period, but not much else.

Hence, both comet and dust initially will move out together as a cloud of objects, then they return at different times due to differences in orbital period. On the way in is when the planets perturb the particles depending on where they are located along the stream that has now formed. As a result, the comet is expected to be pretty much somewhere among the dust trail and the comet orbit wags in and out of Earth's orbit in much the same way as the dust. Hence, if the dust trail can hit the Earth, so can the comet.

The MOID of the comet is very nearly the same as that of the dust trail over the course of a period of time, hence less than 0.0202 AU. Because of that, this undiscovered comet can be classified as a Potentially Hazardous Comet. It is not known whether the yet-to-be discovered comet has passed us by hundreds of years ago, or is still on approach. Because the radiation pressure tends to make the orbital period of the meteoroids longer, the comet most likely returned already some time ago. Dust trail crossings of the Lyrids, however, were observed both before and after passage of parent comet Thatcher.

Of course, an impact will occur only if the comet orbit is perturbed into Earth's path right at the time when Earth passes by the comet orbit on February 4. That happens perhaps twice every 20×60 years, because the dust trail is about 20 times wider than the Earth, while the comet diameter is much smaller (making the Earth cross section what matters). From the trail model, we have a mean distance between trail and Earth of ± 0.0026 AU from year to year perpendicular to Earth's orbit and a similar mean value of about ± 0.15 days in Earth's path. Hence, on February 4 each year, Earth has a 15% chance of being in the region where the trail wags around. Also, the comet would have to be at exactly the right spot in its 200–10 000 year orbit, a period of about 5 minutes given the diameter of the Earth. That makes a collision highly unlikely at the tune of about 1 collision every $1/(2/20/60 \times 0.15 \times 5/60/24/365/200) \sim 84$ billion years for a 200-yr orbit to $\sim 4\,200$ billion years for a 10 000 year orbit.

More precise calculations show that the mean impact probability of long-period comets is about 1 impact every 500 million perihelion passages (Weissman, 2006), which would correspond to about 1 collision every 100 and 5 000 billion years for a 200 and 10 000-year orbit, respectively. Indeed, collisions with long-period comets are rare in Earth's history, but they do occur, as there are sufficient numbers. Because they also impact at relatively high impact speeds, long-period comets are though to account for 3–9 % of craters > 10 km in diameter on Earth and a higher fraction of > 100 km craters (Weissman, 2006).

It is in principle possible to guard against such impacts by looking along the FED parent comet orbit to those spots where the comet would be in a dangerous position. In that way, perhaps a few years of warning could be provided. All comets with orbital periods in the range 200 − 10 000 years that passed close to Earth's orbit in their previous return should have such dust trails. A video meteor orbit survey monitoring for at least 60 years makes it possible to map out the presence of all potentially hazardous comets in that orbital period range.

6 Conclusion

A new meteor shower was discovered caused by the dust trail of a long period comet. The shower is now listed as #427 in the IAU Working List of Meteor Showers and is called the February η-Draconids (FED). The shower traces the orbit of a Potentially Hazardous Comet. The narrow dispersion of the 6 measured orbits conclusively detected this trail of dust. CAMS is capable of detecting dust trails of low dust density from comets in relatively long orbits.

Acknowledgements

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Preliminary results

Meteorite-dropping bolide over north Croatia on 4th February, 2011

Damir Šegon [1], *Korado Korlević* [2], *Željko Andreić* [3], *Javor Kac* [4,7], *Jure Atanackov* [5,7] *and Gregor Kladnik* [6,7]

On the night of 2011 February 4, a very bright bolide was observed over Slovenia and Croatia. The bolide was recorded by four cameras of the Croatian Meteor Network (CMN), by four cameras of the Slovenian meteor network (SMN) and by one European Network camera. Based on the preliminary reduction of CMN and SMN data, the meteoroid's orbit was determined, and a ground search was initiated. So far a single 292-gram meteorite fragment has been recovered.

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1 Introduction

Just past local midnight, on 2011 February 4, starting at $23^{\mathrm{h}}20^{\mathrm{m}}41\overset{\mathrm{s}}{.}3$ UT a very bright bolide was observed over Slovenia and Croatia. One of the authors (JA) witnessed the bolide and based on its appearance and speed suspected a meteorite fall might have occurred. Data collection was started immediately with several eyewitness reports as well as detections by four meteor video and imaging systems of the Slovenian meteor network, which were gathered within minutes of the event. Within 24 hours a (very) preliminary atmospheric trajectory and probable fall area of potential meteorites was determined.

Further data analysis showed the bolide was recorded by four cameras of the Croatian Meteor Network (CMN Petrovsko, CMN Zagreb_Titus, CMN Zagreb_RGN, and CMN Valpovo_B, see Figure 1) and four cameras of the Slovenian fireball network (Črni Vrh Observatory allsky camera, Rezman Observatory allsky camera, and Rezika and Smetka video meteor cameras from Rezman Observatory (Kamnik), see Figure 2). This event was also recorded by one of the European Network cameras.

2 Preliminary trajectory and orbit

Preliminary trajectory results based on the four CMN observations showed that the body was first recorded at 95 km altitude, entering Earth's atmosphere at velocity of slightly over 18 km/s. The brightest part of the meteor (magnitude around −14, followed by fragmentation reported by eyewitnesses) occurred at some

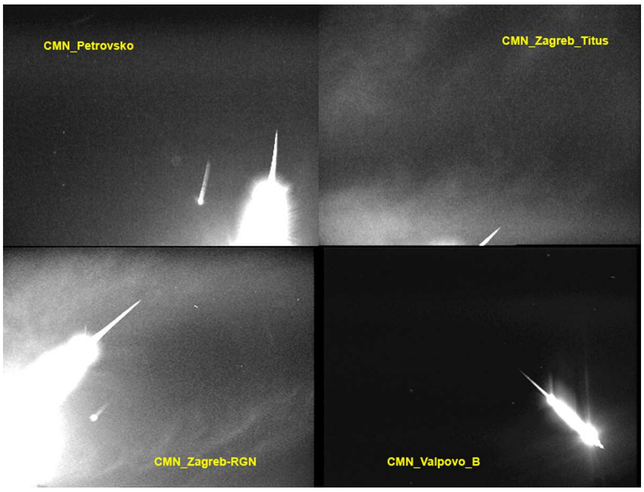

Figure 1 – A mosaic of time integrated CMN images of the Križevci bolide.

32 km, with the meteor ending at 21.8 km (a few km from the town of Križevci). The preliminary orbit of the meteoroid is an Apollo-type orbit (Figure 3), with a perigee of 0.74 a.u. and eccentricity of 0.5, and a very low inclination (only about 0.5 degrees).

3 Meteorite find

Based on this preliminary analysis and dark flight calculations, a strewn field model was made and the search for meteorites was initiated: on 2011 February 20, one meteorite of 292 g was recovered from the field (up to date, this is the only fragment found – see Figure 4). Very interesting indeed, as the last meteorite find in Croatia dated exactly 60 years ago (Dubrovnik meteorite, fell on 1951 February 20 near Molunat (Hoinkes et al., 1978)). The search by local astronomical society and amateur astronomers from Croatia is ongoing (mostly on weekends), and future searches are planed in order to collect as many meteorite fragments as possible.

4 Conclusions

To the best of authors' knowledge, this is the first meteorite find based on calculations strictly from dedicated amateur video meteor network observations – which gives us hope it will not be the last one. Future work on this event will be done in collaboration with experts in the respective field of interests, which we expect to

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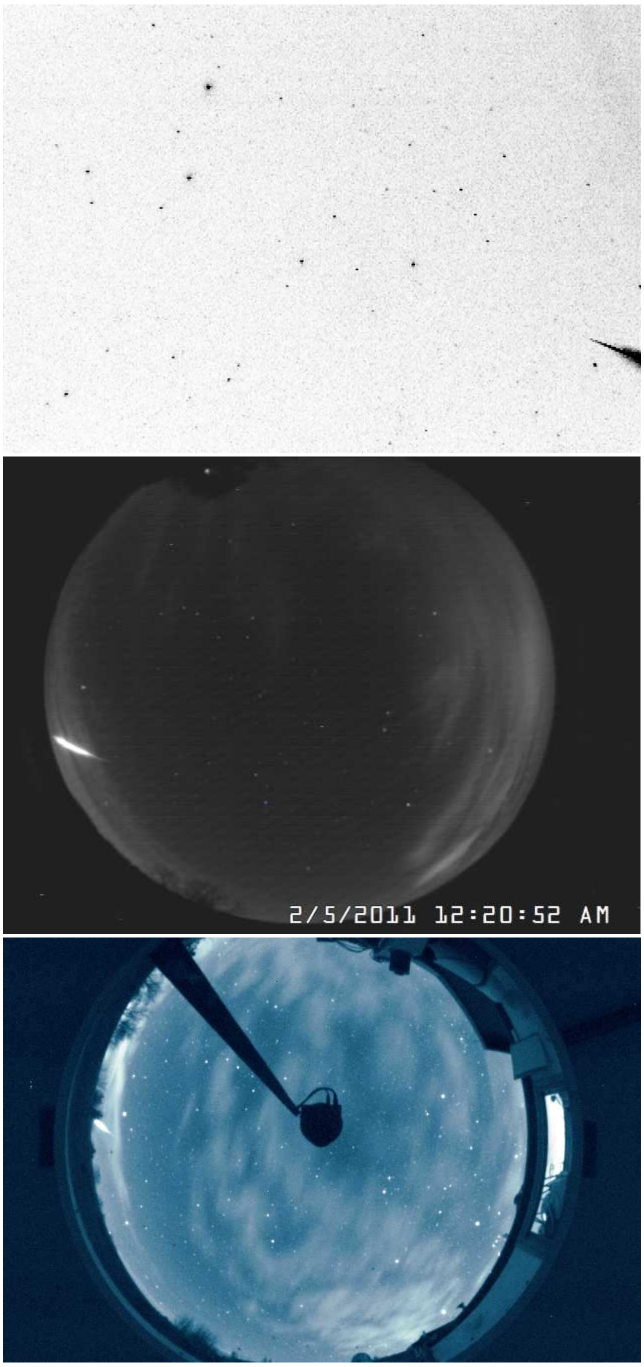

Figure 2 – Images acquired by the Slovenian network. Top: Rezika; middle: Rezman Observatory allsky camera; bottom: Črni Vrh Observatory allsky camera.

provide very important results on the meteorite itself as well as on amateur video astronomy work. This fall also marks the second meteorite fall recorded by the Slovenian meteor network after the fall of Jesenice meteorite in 2009 (Spurný et al., 2010).

Acknowledgements

Our acknowledgements go to all members of Croatian Meteor Network and all participants of search teams for their dedication and persistence that made all this possible. We are grateful to Črni Vrh Observatory for providing the fireball image from the all-sky camera. Rezman Observatory is acknowledged for hosting the cameras used to record the fireball.

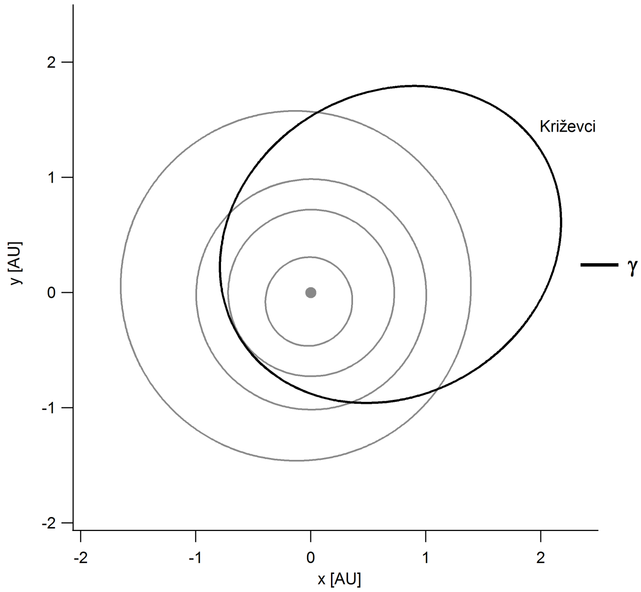

Figure 3 – The preliminary orbit of Križevci meteoroid, projected on the plane of ecliptic, with orbits of the inner planets.

Figure 4 – The 292-gram meteorite fragment found near the town of Križevci.

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Results of the IMO Video Meteor Network — April 2011

Sirko Molau[1], *Javor Kac*[2], *Erno Berko*[3], *Stefano Crivello*[4], *Enrico Stomeo*[5], *Antal Igaz*[6] *and Geert Barentsen*[7]

April 2011 was again a very successful month for the IMO Video Meteor Network. More than 13 500 meteors were recorded in over 4 700 hours of effective observing time. The recent improvement of MetRec allows us to follow the Lyrids activity in almost real time with an online tool. The activity profile of Lyrids is presented and compared to visual results. Both the time of maximum (2011 April 22/23) and the activity level obtained using video data were comparable to visual results. The impact of using video data in addition to visual observations for shower activity profiles is discussed.

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1 Introduction

Incredible: March 2011 was already a month with unusually good weather conditions (Molau et al., 2011), but it was still beaten by April! The month which is generally renowned for rapidly changing conditions presented perfect skies to the observers. As in March the more northern observers were slightly favored. Thirty-two out of fifty cameras managed to record meteors in twenty or more nights, and seven of them even in twenty-five or more nights (Table 1 and Figure 1). April 2010 broke already the record with respect to meteor number and effective observing time, but this year both values increased by additional 50% (Molau & Kac, 2010). With respect to the effective observing time, April 2011 is the second best month ever in the long-term statistics of the IMO network!

Ernö Berko started to operate a third camera named Hulud3, and once more we won a new observer in Slovenia. Gregor Kladnik is now operating the camera Tacka in Tacen, with Javor Kac giving him initial support. Tacka consists of a Mintron camera with a long-focal 12 mm Computar lens.

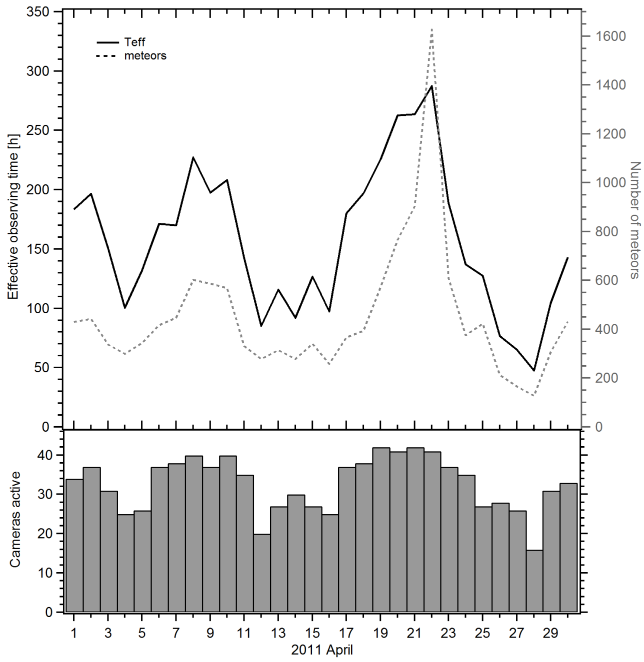

Figure 1 – Monthly summary for the effective observing time (solid black line), number of meteors (dashed gray line) and number of cameras active (bars) in 2011 April.

2 MetRec improvements and online flux analysis tool

As reported in the previous month, a new version of MetRec was released in late March, which allows for the calculation of flux densities for meteor showers. All observers of the IMO Video meteor network were asked to upgrade to the new software version before the Lyrids to do a first large-scale test with this shower. Of course, the switch was not immediately successful for all cameras, but most observers upgraded to the new release soon. In the end we obtained suitable flux density data from 36 cameras in April.

In time for the Lyrid maximum, Geert Barentsen provided a first version of his online flux analysis tool. Similar to the well-known visual quick-look analysis at the IMO homepage, the flux density is determined over all available data sets and presented in graphical form. As some observers uploaded their post-processed video observations already the next day we could present a first Lyrid activity profile within less than 24 hours.

Two weeks later, Geert improved the software to the version which is currently available at the following site: `http://vmo.imo.net/flx/`. Contrary to the visual quick-look analysis, the interval length of each data point is not fixed. The raw data have a resolution of one minute in time. So the user has the option to adjust the temporal resolution by two parameters (minimum interval length and minimum meteor number per interval) interactively. In addition there is the option to choose the start and end date and the meteor shower, whereby all showers recognized by MetRec (i.e. essentially the

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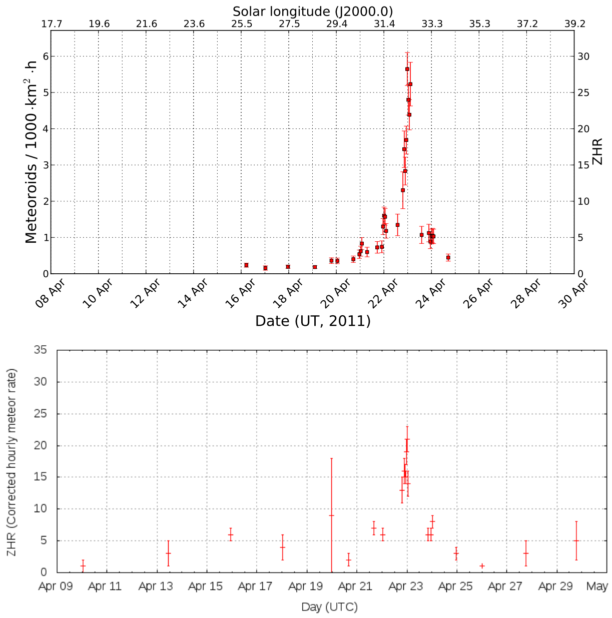

Figure 2 – Comparison of the online Lyrid flux density profile of the IMO network (upper graph) with the IMO quick-look analysis of visual observations (lower graph).

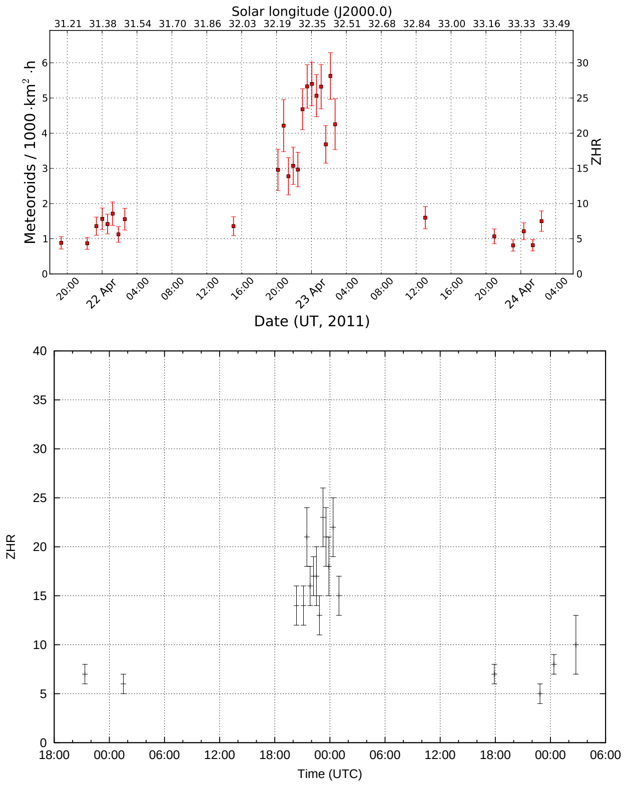

Figure 3 – Detailed flux density profile from the maximum of the Lyrids obtained from video data of the IMO network (upper graph) and the IMO quick look analysis of visual observations (lower graph, covering data from April 21, 18^{h} UT to April 24, 06^{h} UT).

IMO working list) can be chosen. The data set can also be restricted to one camera, which helps to find errors. Even though version 0.2 of the flux analysis tool is only preliminary and there are still many proposals for improvements, the tool is already well suited for meteor shower analyses, in particular since the data set was sufficiently large thanks to the weather conditions.

3 Lyrids

Now we come to the question: How does the flux density profile from video data compare to results of visual observers of IMO? Figure 2 compares both profiles, using the time interval from April 9 to 30 (which was defined by the visual observations and goes well beyond the activity interval of the Lyrids) and a minimum interval length of approximately one hour. The video profile is based on 1213 Lyrids obtained by 35 cameras, the visual profile on 897 Lyrids from roughly twice as many observers (International Meteor Organization, 2011).

First of all it is amazing how well the video profile looks. It is immediately clear that the standard deviation of video data away from the peak is much smaller than in the visual profile. That is not a big surprise, as most visual observers are only active near the maximum, whereas the distribution of video data depends only on the weather conditions.

Let us now have a detailed look at the activity peak. For Figure 3, and interval of 30 hours before and after midnight of April 22/23 was chosen, and the minimum interval length was reduced to 30 minutes. It becomes clear that the flux density increased significantly between $20^{\mathrm{h}}00^{\mathrm{m}}$ UT and $24^{\mathrm{h}}00^{\mathrm{m}}$ UT on April 22. The peak is reached shortly before midnight. Thereafter, the activity stays almost constant until the end of the European observing window at $04^{\mathrm{h}}00^{\mathrm{m}}$ UT. Note that the shape of the profile changes with slightly adapted parameters, so the existing data set is pushed to the limits.

In the visual data, the peak occurs slightly before midnight of April 22/23 as well. The scatter is smaller than in the video data, but so is the time interval covered by visual observations.

Beside the qualitative analysis, let us now have a look at quantitative aspects. The primary result of the video observations are flux densities measured in meteoroids per thousand square kilometers effective collection area and hour, that are capable of producing meteors brighter than magnitude +6.5. In addition, Geert used an equation from an old *WGN* paper by R. Koschak and J. Rendtel to determine flux densities from visual ZHRs (Koschack & Rendtel, 1990). He used the formula the other way round to transform the flux densities into ZHR (right y-axis in Figures 2 and 3) for better comparison of the results with visual observations. By applying the formula directly without any adaptation or correction, we yield a peak ZHR of 27 in the lower resolution video profile (Figure 2), which compares to 21 in the visual profile. It is amazing how well these values fit given that the formula has to cope with the unknown human field of view, reduced detection probability away from the center of FOV, and the impact of meteor motion. In addition, the perception coefficient is hardly known for individual observers, but it has a significant impact on the flux density. On the other hand, these factors are either constant or they can be accurately calculated for video observations. It seems almost too good to be true that the relative error is only 25% under these conditions.

Let us investigate which effects impact the determined flux density of video data in which way:

- The limiting magnitude for stars is determined from an averaged background image. That shows much more stars than an individual video frame, which are the basis for meteor detection. So the limiting magnitude may be too optimistic, which will reduce the effective collection area and increase the flux density. On the other hand, the human eyes has an "integrating function". In the video stream we see many more objects than in a single video frame. The set of stars which is used by MetRec to determine the limiting magnitude matches quite well to those stars that the human observer recognizes in the video stream. In addition, the meteor detection in MetRec is not based on single frames either. A meteor is only reported if it can be detected in several consecutive video frames. Thus, the software detects also meteors which stand out hardly from the background noise in single frames.
- Currently the algorithm supposes (contrary to the visual analysis) that the detection probability for meteor is 100% down to the determined limiting magnitude, which will hardly be the case. In reality, more meteors are visible than detected by the software, which also means that the flux density is currently over- rather than underestimated.

In total, the deviation between visual and video data will be larger than 25%. But even if they differ in the end by a factor of two or three, we still regard this as a wonderful proof that both the algorithm to compute flux densities from video data as well as the formula to calculate flux densities from visual ZHR work reasonably well.

4 Antihelion source

Let us have a look at the Antihelion source in April. It shows a nearly constant flux density of 1.5 to 2 meteoroids per hour and thousand square kilometers effective collection area.

5 Conclusions

In the end we shall discuss the question: Will visual observations become useless now that also flux densities can be obtained from video data? So let us have a look at the strengths of each observing technique.

Video data are objective in their meteor shower assignment and yield suitable data not only for the peaks of major showers. The size of the data set depends only from the weather conditions. Once its childhood diseases are cured, they will also yield more accurate absolute flux densities than visual observations. The boundary conditions (field of view, observing direction, detection probability in the field of view, dependency of

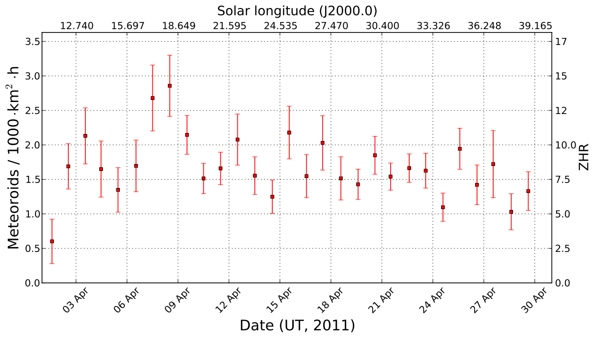

Figure 4 – Flux density profile of the Antihelion source in April 2011.

the limiting meteor magnitude form the angular velocity) and their impact on the flux density measures can be calculated much more accurately.

Visual observations from the peak times of major showers are available from round the globe and yield a better geographic and temporal coverage. The limiting magnitude of visual observers is closer to +6.5 mag which minimizes the influence of the population index. Also meteor magnitudes are (currently) more precisely estimated by visual observers. Last but not least, we are using standardized visual observing techniques and analysis methods for some decades now, which makes visual observations mandatory for long-term analyses.

In view of this, both techniques can verify and calibrate each other. Video observations will cover minor shower and the ascending and descending branches of major showers more accurately than visual observations, as was shown in case of the Lyrids. Visual observations, on the other hand, may cover the peak times of major showers with only little gaps.

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Table 1 – Observers contributing to 2011 April 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
BENOR	Benitez-S.	Las Palmas/ES	Times4 (1.4/50)	2359	3.2	492	13	31.6	18.7	95
BERER	Berko	Ludányhalászi/HU	Hulud2 (0.75/6)	6500	3.8	2209	17	84.3	—	239
			Hulud3 (0.75/6)	4661	3.9	1052	8	28.3	42.9	76
BRIBE	Brinkmann	Herne/DE	Hermine (0.8/6)	2374	4.2	1084	28	101.5	80.3	261
		Bergisch Gladbach/DE	Klemoi (0.8/6)	2386	5.4	2781	24	88.2	94.0	249
CASFL	Castellani	Monte Baldo/IT	Bmh1 (0.8/6)	2350	—	—	22	77.6	—	220
			Bmh2 (1.5/4.5)*	4243	—	—	26	81.1	—	199
CRIST	Crivello	Valbrevenna/IT	C3P8 (0.8/3.8)	5575	4.2	2525	21	134.5	134.9	259
			Stg38 (0.8/3.8)	5593	4.3	2810	21	130.9	276.9	358
CSISZ	Csizmadia	Zalaegerszeg/HU	Huvcse01 (0.95/5)	2439	3.0	249	23	50.1	16.7	124
CURMA	Currie	Grove/UK	Mic4 (0.8/6)	1471	5.2	3008	18	105.7	—	209
ELTMA	Eltri	Venezia/IT	Met38 (0.8/3.8)	5620	4.3	1778	19	134.2	—	234
GONRU	Goncalves	Tomar/PT	Templar1 (0.8/6)*	2188	5.3	2331	18	123.5	138.1	367
			Templar2 (0.8/6)*	2303	5.0	2397	18	100.1	143.9	242
GOVMI	Govedič	Središče ob Dravi/SI	Orion2 (0.8/8)	1471	6.0	3916	23	85.0	—	240
HERCA	Hergenrother	Tucson/US	Salsa3 (1.2/4)*	4332	4.0	1471	28	222.0	243.6	276
HINWO	Hinz	Brannenburg/DE	Akm2 (0.85/25)*	754	5.7	1306	25	131.4	152.5	300
IGAAN	Igaz	Baja/HU	Hubaj (0.8/3.8)	5600	4.3	3338	20	47.6	60.1	139
		Hódmezővásárhely/HU	Huhod (0.8/3.8)	5609	4.2	3031	22	65.4	—	163
		Budapest/HU	Hupol (1.2/4)	3929	3.5	1144	22	54.8	82.2	152
JONKA	Jonas	Budapest/HU	Husor (0.95/4.0)	5262	3.9	1159	19	57.3	—	146
KACJA	Kac	Kostanjevec/SI	Metka (0.8/8)*	1381	4.0	2246	13	74.1	—	130
		Ljubljana/SI	Orion1 (0.8/8)	1420	5.3	2336	20	118.9	32.2	188
		Kamnik/SI	Rezika (0.8/6)	2307	5.0	2293	19	124.3	65.1	458
			Stefka (0.8/3.8)	5540	4.2	2882	23	138.2	—	318
KERST	Kerr	Glenlee/AU	Gocam1 (0.8/3.8)	5238	4.2	2637	24	199.3	412.3	1344
KLAGR	Kladnik	Tacen/SI	Tacka (0.8/12)	715	5.4	796	15	73.6	41.7	304
KOSDE	Koschny	Noordwijkerhout/NL	Lic4 (1.4/50)*	2027	—	—	20	89.0	269.7	148

Table 1 – Observers contributing to 2011 April data of the IMO Video Meteor Network – continued from previous page.

Code	Name	Place	Camera	FOV [°2]	Stellar LM [mag]	Eff.CA [km^2]	Nights	Time [h]	Tot.CA [10^{3}km^{2}h]	Meteors
LUNRO	Lunsford	Chula Vista/US	Bocam (1.4/50)*	1860	5.1	1719	15	72.0	—	231
MOLSI	Molau	Seysdorf/DE	Avis2 (1.4/50)*	1771	6.1	4182	23	158.8	383.0	1052
			Mincam1 (0.8/8)	1477	4.9	1716	29	188.1	231.2	470
		Ketzür/DE	Remo1 (0.8/3.8)	5592	3.0	974	23	137.3	36.5	166
			Remo2 (0.8/3.8)	5635	4.3	2846	23	143.9	94.1	242
MORJO	Morvai	Fülöpszállás/HU	Huful (1.4/5)	2522	3.5	532	21	55.0	33.4	118
OTTMI	Otte	Pearl City/US	Orie1 (1.4/5.7)	3837	—	—	3	9.1	—	33
PERZS	Perko	Becsehely/HU	Hubec (0.8/3.8)*	5448	3.4	1500	22	88.6	162.1	269
ROTEC	Rothenberg	Berlin/DE	Armefa (0.8/6)	2369	4.8	1801	8	38.7	45.3	71
SCHHA	Schremmer	Niederkrüchten/DE	Doraemon (0.8/3.8)	5537	3.0	846	26	64.6	—	159
SLAST	Slavec	Ljubljana/SI	Kayak1 (1.8/28)	604	6.5	1849	21	81.1	—	222
STOEN	Stomeo	Scorze/IT	Min38 (0.8/3.8)	5631	4.1	2407	23	135.7	—	444
			Noa38 (0.8/3.8)	5609	4.9	5800	23	137.7	159.8	344
			Sco38 (0.8/3.8)	5598	5.0	4416	24	150.3	—	455
STORO	Stork	Kunžak/CZ	Kun1 (1.4/50)*	1913	5.4	2778	3	21.5	67.1	243
		Ondřejov/CZ	Ond1 (1.4/50)*	2195	5.8	4595	4	25.1	99.4	290
STRJO	Strunk	Herford/DE	Mincam2 (0.8/6)	2357	4.7	1380	24	67.7	—	203
			Mincam3 (0.8/12)	728	6.1	2271	22	83.8	133.7	217
			Mincam5 (0.8/6)	2344	5.2	2535	25	114.3	—	395
TEPIS	Tepliczky	Budapest/HU	Humob (0.8/6)	2375	4.9	2258	21	80.3	—	264
TRIMI	Triglav	Velenje/SI	Sraka (0.8/6)*	2222	—	—	13	34.4	61.3	85
YRJIL	Yrjölä	Kuusankoski/FI	Finexcam (0.8/6)	2337	5.5	3574	18	62.7	—	145
						Overall	30	4 703.2	—	13 556

* active field of view smaller than video frame

Results of the IMO Video Meteor Network — May 2011

Sirko Molau[1], Javor Kac[2], Erno Berko[3], Stefano Crivello[4], Enrico Stomeo[5], Antal Igaz[6] and Geert Barentsen[7]

Excellent weather conditions enabled record observing statistics in May 2011. Almost 15 000 meteors were registered in more than 4 800 hours of effective observing time. Results of the η-Aquariid activity are presented. A broad maximum lasted between 2011 May 2/3 and 9/10, with the peak activity occurring on 7/8. The activity profile of the η-Lyrids is presented, showing a peak on 2011 May 11.

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1 Introduction

Thanks to the perfect weather conditions, March 2011 was an unusually successful month with more than 4 700 hours of effective observing time (Molau et al., 2011a). Even though the nights were getting shorter, April was even better with over 4 800 observing hours (Molau et al., 2011b). However, even that result was surpassed: the observing conditions were so perfect in May, that notwithstanding the short early summer nights (if we forget our single Australian observer for a moment) 4 850 observing hours could be collected (Table 1 and Figure 1). Also the number of meteors was impressive: almost 15 000 registered events is more than what we recorded in the same month of the years 2008 till 2010 together! Two of these meteors are presented in Figures 6 and 7.

Contrary to the previous two months, the conditions in northern and southern Europe were comparable now. In total, 39 of the 52 cameras were active in 20 or more observing nights.

Once more we could welcome new observers and camera systems in the IMO network. Martin Breukers is now contributing observations with his camera Mbb3 (a Watec camera with 6 mm $f/0.75$ Panasonic lens) not far from the German–Dutch border. His field of view has a nice overlap with the cameras of Bernd Brinkmann and Jörg Strunk.

In the Hungarian city of Sopron, close to the border between Hungary, Austria and Slovakia, Antal Igaz installed Husop (a Mintron camera with 6 mm $f/0.8$ Computar lens). Zoltan Zelko extended the network with the camera Huvcse02 in Budapest. For the first time in the history of the IMO network it is not Germany that hosts the most video systems (currently 12), but Hungary (currently 13). What a surprise if we remember that the first Hungarian camera was installed just two years ago! Congratulations to our diligent Hungarian observers – in particular Antal Igaz, who promoted and extended our network so successfully in his home country.

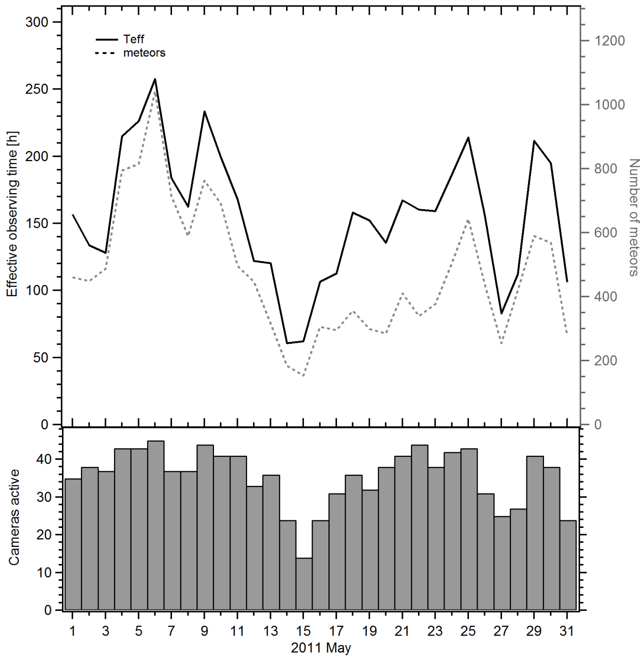

Figure 1 – Monthly summary for the effective observing time (solid black line), number of meteors (dashed gray line) and number of cameras active (bars) in 2011 May.

Below we present the observing results. With the η-Aquariids and the η-Lyrids, the IMO working list contains two showers in May. The activity profile of both could be followed with only little delay online at `http://vmo.imo.net/flx/`.

2 η-Aquariids

The analysis of the η-Aquariids proved to be particularly interesting. At mid-northern latitudes, where most cameras are located, this shower can only be observed for a short time before sunrise. Thus, each camera can contribute only a small effective collection area and each recorded η-Aquariid meteor increases the meteor shower flux notably. On the other hand, the radiant is well placed for our Australian observer presenting to him large meteor counts. More than one third of the 1554 η-Aquariids available in total for the flux analysis were provided by Gocam1. In the ideal case, when the limiting magnitude, the field of view and all other pa-

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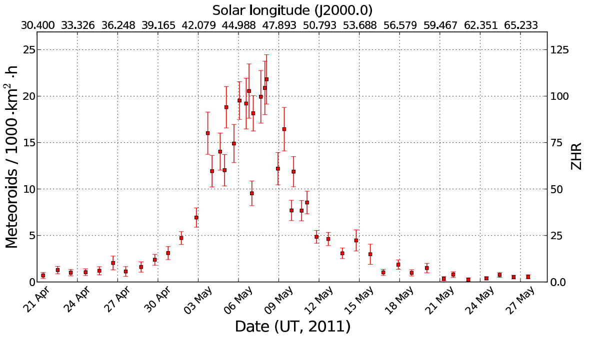

Figure 2 – Online flux density profile of the η-Aquariids in April/May 2011 obtained from video observations of the IMO network.

rameters are exactly determined and the procedures to determine the flux density are precise, that should not make any difference. But what about the practice?

Figure 2 shows the flux density profile of the η-Aquariids in the full activity interval between April 21 and May 28. Similar to the Lyrids (Molau et al., 2011b), the ascending and descending activity branch are covered nicely with only little scatter. Between midnight of May 2/3 and 9/10 UT, the flux density was higher than 10 meteoroids per 1000 square kilometers per hour. In that time interval, the scatter is increasing and some outliers can be found. The maximum was reached between midnight of May 5/6 and mid-day of May 8 UT when the flux density hovered around 20 within the 60 hours time interval. Peak activity occurred at midnight of May 7/8 UT.

For comparison, the same activity profile is given, separated in Figure 3 for GOCAM1 (upper graph) and all other cameras (lower graph). As expected, the Australian profile shows less scatter. In total there is a good agreement between the graphs, both with respect to the shape of the profile and the strength of the maximum. That is encouraging as it proves that sensible results can also be obtained under adverse conditions if only there are sufficient cameras that contribute data.

Note that the strong activity dip in the evening of May 6 can be explained by the fact that this interval contains only observations with a very low radiant. If the interval is extended, the outlier disappears.

3 η-Lyrids

The activity profile of the η-Lyrids (Figure 4) is based on exactly 333 meteors and is as expected less exciting. The flux density remains below a level of one meteoroid per 1000 square kilometers per hour. Peak activity was found near the end of the activity interval on May 11 (solar longitude 50 degrees). The 2009 long-term analysis revealed a nice symmetric activity profile for this shower with starting point at 48, peak at 50, and return to the start activity at 52 degrees solar longitude. Hence, the meteor shower list of METREC has to be adapted so that in the future also the descending branch can be covered completely.

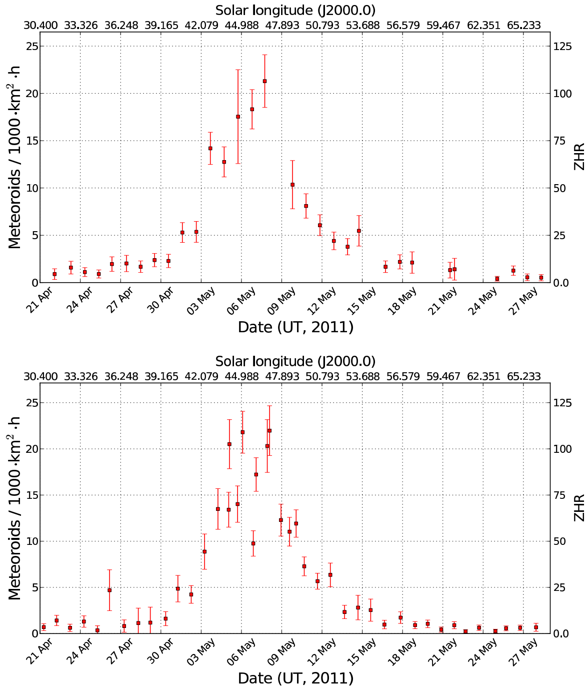

Figure 3 – Comparison of the flux density profiles of the η-Aquariids obtained by a single Australian camera (upper graph) and all other cameras located mainly in Central Europe (lower graph).

4 Sporadic meteors

At the end let us have a look at an interesting phenomenon: when the flux density is plotted for those over 8000 sporadic meteors recorded in May, there is significant scatter visible (Figure 5). It is caused by the diurnal variation with maximum sporadic activity in the local morning hours. This variation was not modeled so far, as METREC calculated with a fixed sporadic angular velocity and radiant altitude. In the latest software version, however, sporadic meteors are now modeled as a weighted mixture of the most important sporadic sources (N/S Apex, Helion, N/S Toroidal). The Antihelion source is not used, as it is covered by its own shower entry ANT in the meteor shower list. The weights of the sporadic sources are chosen such that the two Apex sources together yield 100%, and the other sources give an extra contribution.

First experiments have shown that the effective collection area for Sporadics is now increasing towards

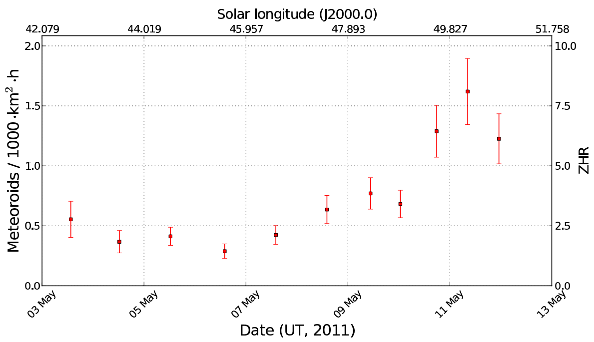

Figure 4 – Online flux density profile of the η-Lyrids in May 2011 obtained from video observations of the IMO network.

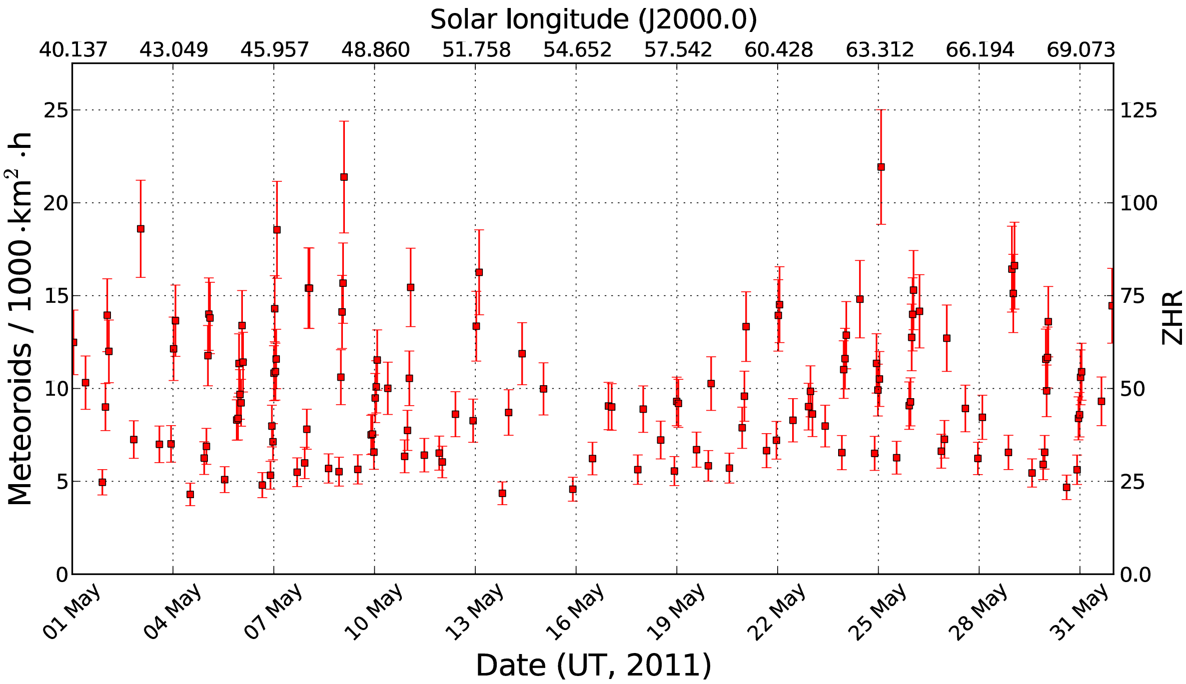

Figure 5 – Diurnal variation of the sporadic flux density in May 2011.

Figure 6 – Bright meteor recorded by the IMO Video Meteor Network camera GOCAM1 on 2011 May 5, $12^{h}29^{m}18^{s}$ UT from Glenlee, Australia.
Photo courtesy: Steve Kerr.

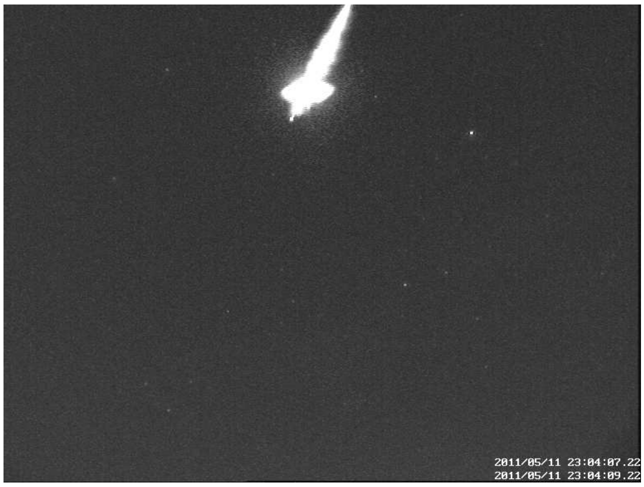

Figure 7 – Magnitude −4 sporadic fireball, captured on 2011 May 11, $23^{h}04^{m}07^{s}$ UT by the IMO Video Meteor Network camera HUBAJ, stationed in Baja, Hungary.
Photo courtesy: Antal Igaz.

dawn as the Apex source rises. Hence, the scatter of the sporadic flux is reduced. How good the chosen sporadic model and the empirical weights are in reality can only be answered in fall, though, when there are sufficient observations from many observers.

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CASFL	Castellani	Monte Baldo/IT	Bmh1 (0.8/6)	2350	—	—	23	88.0	—	255
			Bmh2 (1.5/4.5)*	4243	—	—	23	81.4	—	187
CRIST	Crivello	Valbrevenna/IT	C3P8 (0.8/3.8)	5455	4.2	1586	28	151.7	197.7	344
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ELTMA	Eltri	Venezia/IT	Met38 (0.8/3.8)	5631	4.3	2151	24	136.3	195.7	275
GONRU	Goncalves	Tomar/PT	Templar1 (0.8/6)*	2179	5.3	1842	18	103.2	164.1	327
			Templar2 (0.8/6)*	2080	5.0	1508	18	95.6	119.2	251
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IGAAN	Igaz	Baja/HU	Hubaj (0.8/3.8)	5552	2.8	403	23	85.7	34.5	188
		Hódmezővásárhely/HU	Huhod (0.8/3.8)	5502	3.4	764	25	96.3	62.7	214
		Budapest/HU	Hupol (1.2/4)	3790	3.3	475	22	19.4	13.5	49
		Sopron/HU	Husop (0.8/6)	2031	3.8	460	27	86.2	26.5	246
JONKA	Jonas	Budapest/HU	Husor (0.95/4)	2286	3.9	445	19	55.5	79.8	147
KACJA	Kac	Kostanjevec/SI	Metka (0.8/8)*	1372	4.0	361	16	91.9	—	180
		Ljubljana/SI	Orion1 (0.8/8)	1402	3.8	331	25	134.1	—	188
		Kamnik/SI	Rezika (0.8/6)	2270	4.4	840	26	147.8	86.0	626
			Stefka (0.8/3.8)	5471	2.8	379	24	140.3	40.1	308
KERST	Kerr	Glenlee/AU	Gocam1 (0.8/3.8)	5189	4.6	2550	27	221.3	432.9	2019
KOSDE	Koschny	Noordwijkerhout/NL	Lic4 (1.4/50)*	1986	5.3	2147	16	62.5	109.2	79

Table 1 – Observers contributing to 2011 May 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 [10^3km²h]	Meteors
MOLSI	Molau	Seysdorf/DE	Avis2 (1.4/50)*	1776	6.1	3817	22	114.7	321.4	938
			Mincam1 (0.8/8)	1477	4.9	1084	23	131.4	143.3	328
		Ketzür/DE	Remo1 (0.8/3.8)	5600	3.0	486	27	108.5	33.9	119
			Remo2 (0.8/3.8)	5613	4.0	1186	24	108.7	88.2	209
MORJO	Morvai	Fülöpszállás/HU	Huful (1.4/5)	2509	3.1	194	20	56.6	16.4	126
OTTMI	Otte	Pearl City/US	Orie1 (1.4/5.7)	3837	—	—	20	65.4	—	187
PERZS	Perko	Becsehely/HU	Hubec (0.8/3.8)*	5498	2.9	460	26	108.6	54.9	310
ROTEC	Rothenberg	Berlin/DE	Armefa (0.8/6)	2366	4.5	911	19	75.2	106.7	155
SCHHA	Schremmer	Niederkrüchten/DE	Doraemon (0.8/3.8)	4900	3.0	409	21	37.4	—	90
SLAST	Slavec	Ljubljana/SI	Kayak1 (1.8/28)	588	—	—	20	66.8	—	193
STOEN	Stomeo	Scorze/IT	Min38 (0.8/3.8)	5566	—	—	27	136.7	—	557
			Noa38 (0.8/3.8)	5609	4.2	1911	28	132.4	198.3	415
			Sco38 (0.8/3.8)	5598	—	—	29	131.2	—	547
STORO	Stork	Kunžak/CZ	Kun1 (1.4/50)*	2338	5.7	3778	3	15.1	55.1	207
		Ondřejov/CZ	Ond1 (1.4/50)*	2265	6.2	6102	3	14.4	75.7	186
STRJO	Strunk	Herford/DE	Mincam2 (0.8/6)	2362	4.6	1152	21	62.5	—	154
			Mincam3 (0.8/12)	728	5.7	975	23	66.7	82.0	185
			Mincam5 (0.8/6)	2349	5.0	1896	23	83.8	—	285
TEPIS	Tepliczky	Budapest/HU	Humob (0.8/6)	2388	4.8	1607	27	111.2	221.4	326
TRIMI	Triglav	Velenje/SI	Sraka (0.8/6)*	2222	—	—	26	85.0	—	206
YRJIL	Yrjölä	Kuusankoski/FI	Finexcam (0.8/6)	2313	4.6	1046	10	16.1	39.5	34
ZELZO	Zelko	Budapest/HU	Huvcse02 (0.95/5)	1606	3.8	390	3	19.6	12.6	31
						Overall	31	4 845.7	—	14 771

* active field of view smaller than video frame

History

Meteor Beliefs Project: The Ensisheim thunderstone

Alastair McBeath[1]

An examination of claimed events and beliefs, some of them portentous, concerning the Ensisheim meteorite's fall on November 7, 1492 AD (Julian) is given, from the time of the fall through to modernity.

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1 Introduction

Millennialism and apocalypticism, so prevalent around the turn of the latest calendrical millennium, is nothing new. It seems to recur to a greater or lesser extent either side of most new centuries. Aspects of it in respect to meteors and comets have been discussed before in IMO publications – e.g. (McBeath, 1999). There seems to have been an especial upsurge in such beliefs near the last half-millennium across Europe, around 1500 AD, with an expectation that the world was likely to end, based on interpretations of Christian religious texts such as the biblical 'Revelation to John'. The Greek Orthodox Church calculated the final millennium would end in 1492. Hartmann Schedel's 'Nuremberg Chronicle', published in Latin and German versions in 1493, while disproving the 1492 end-date by its existence, concurred that the end-times were indeed imminent. Columbus's (re-)discovery of the American 'New World' in 1492 (and the subsequent introduction of the disease syphilis to Europe, apparently from the Americas) added to the mix. Into all this dropped what was, until 1979/1983, the world's oldest known preserved meteorite seen to fall, an LL6 olivine-hypersthene chondrite, near Ensisheim in Alsace, then part of the Holy Roman Empire, now in eastern France, on November 7, 1492 (November 16, Gregorian), as shown in Figure 1. Information regarding the millennialism and major historical events affecting Europe *circa* 1500 AD can be found, for example, in Peter Parshall's essay 'The Vision of the Apocalypse in the Sixteenth and Seventeenth Centuries', in (Carey, 1999, pp. 99–124). The oldest preserved known meteorite seen to fall is now considered to be the chondrite maintained in a Shinto shrine at Nogata-shi in Japan, which was recorded as falling on May 19, 861 AD. Its existence beyond the shrine's monks became known only in 1979, but it was not scientifically described in print until 1983 (Shima et al., 1983). Notes on the nature of the Ensisheim meteorite here were from (Graham et al., 1985, p. 136).

That as much of the Ensisheim stone was preserved for so long, while it remained continuously available for public scrutiny, helped the survival of tales about it and its perceived importance, although the factual details of its arrival and the aftermath became embellished over time, some amendments made even within

Figure 1 – A contemporary woodcut print showing the Ensisheim meteorite's fall, from Sebastian Brant's second broadsheet on it of 1492, originally issued by Johann von Olpe of Basel. The title line can be translated as: "Of the thunderstone that fell in the 92nd year before Ensishein".

the past thirty years. Consequently, this seemed an appropriately significant object to examine as part of the Meteor Beliefs Project.

During the research for this article, the detailed, illustrated review of the history surrounding the Ensisheim stone by Ursula Marvin (1992), prepared for the 500th anniversary of the fall, was located. Its coverage is well-informed for many such matters, including translations of most of the key texts on its fall and nature, so it has been preferentially used here where no notable discrepancy could be found to the original sources (as far as translation of the sometimes obscure late medieval languages, printing fonts and conventions allows). Marvin's text should be read in full by those interested in gaining a better understanding of beliefs about the stone and the historical events near the time it fell. She has more recently (2006) published a précis of parts of that article, plus one additional illustration not featured in her earlier text, from Sigismondo Tizio's 'History of the Sienese' of *circa* 1505/1528.

2 Beliefs about the stone's fall

Table 1 provides a timeline of what the main written sources had to say about events connected to the Ensisheim meteorite's fall, mostly as translated in (Marvin, 1992). While some contained material directly copied from earlier sources, it is clear errors or revisions crept in over time. Some of these were made apparently surprisingly quickly, such as that by Johann Linturius, said by Marvin to have been written around 1496 (*op. cit.*, p. 57), assuming it had not been altered subsequently in the nearly thirty years before it was published. The dates cited for the fall are chiefly in the Julian calendar, as stated in the original texts, and again

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NASA-ADS bibcode 2011JIMO...39..110M

following Marvin's lead, even in those sources published since the adoption of the Gregorian calendar in the countries involved. Descriptions of the stone's physical appearance are frequently vague. In the Table, the few linear dimensions have been converted to metric that Marvin gave in inches, but the weights have in general been left in the quantities stated in the original texts, as it is commonly unclear which of the earlier 'pound' or 'hundred weight' measures were meant. This may explain some of the weight variations, which in places have the precision of conversion factors. Other texts that mentioned the stone exist, some of which Marvin noted too, but Table 1 contains the leading versions.

Even in the earliest texts, there are some minor inconsistencies in matters such as the fall's nature, timing and associated sounds, plus there is no mention of just who witnessed it prior to the 1802–1804-preserved copies of the Ensisheim city protocol of 1589, the protocol itself dated nearly a century later than the fall. The fact it was witnessed by more than one person is strongly implied by the fact the stone was found so soon afterwards (before soil could slump into the hole and conceal it, for instance), and that the earliest (Figure 1) and some later illustrations showed one or two people watching it drop from the clouds. Merklen's shepherd and the sheep in the field (Table 1, 1840 entry) came from no identifiable earlier source, and rather like his anachronistic rifle sounds and the object being preserved for science, may be merely his own reinterpretation of events. Marvin (1992, pp. 60–62) discussed the sheep and shepherd elements particularly, at length.

Most of the early illustrations showed the stone as falling from a notable cloud-mass, but whether this was from eye-witness accounts, perhaps trying to describe the roiling smoke or dust train often associated with a substantial meteoritic fireball's atmospheric flight, is not clear. Schedel's comment from 1493 that the sky darkened after the explosion, but before the stone was seen to fall might tally with that, while Linturius too, circa 1496, implied a meteoric/meteoritic cloud of some kind in a clearer sky, despite his dating inaccuracy, and his implausible 'sign on the Moon'. It is difficult to be too critical when the source which might be thought most likely correct, as supposedly coming from the city itself, the Ensisheim protocol, had the fall apparently at night on the wrong date! It is equally possible the stone may have fallen through some ordinary tropospheric clouds instead, with the brilliance of the fireball illuminating them in advance of the stone's arrival.

Whether there was an understanding that the preceding fireball and fallen stone were linked is also uncertain. Brant's use of the term 'burning stone' in his 1492 Latin poem may indicate only that the outer fusion crust on the stone had an obviously fiery origin ('singed' in the Latin text, 'blackened' in the accompanying German poem). However, his comment about 'evil things' seen in the sky at the time is suggestive some such connection was made. His German text (alone) elaborates further on these 'evil things'. In translation:

> "Little pieces scattered hither and yon,
> Were widely dispersed and seen as far as
> Tonaw [modern Donau; the upper Danube], Neckar,
>   Aare, Ill and Rhine
> Swiss, Uri, heard the sound of it.
> Also the Burgundians heard it, and
> It struck fear into the French"

(Marvin, *op. cit.*, p. 34, with minor amendments). I have given a longer citation here because there seems to have been some confusion among later authors (including *op. cit.*, p. 29) that all the listed rivers were really places the sound was heard, but this is not what Brant's text seems to state, where only the Swiss, Uri, Burgundians and possibly the French are said to have heard the event from this list, while it was seen over a much wider area. Figure 2 gives a sketch map to assist with orientation regarding the places and likely riverine regions involved nearer Ensisheim, while Figure 3 sets this area in a wider context. As even the closer parts of some of these river valleys are around 100–120 km from Ensisheim, this makes it highly unlikely witnesses there could have seen the stone's fall, though they may easily have heard its sounds, and/or seen the fireball.

It is very difficult to say anything especially useful about the possible trajectory of the fireball, unfortunately. None of the texts give even a vague description of the likely approach direction, which leaves only some of the illustrations (most are available in Marvin, 1992) and the places the sounds were heard as potential guides. These have been used to give the possible incoming tracks in Figure 2.

The better of the two woodcuts on Brant's broadsheets of 1492 (Figure 1) suggested the object may have been moving towards Ensisheim from roughly the direction of Battenheim, a village to the south-south-east of Ensisheim. The woodcut with Schedel's description of 1493 showed a less-defined approach from over some hills to the left of Battenheim as viewed, that is from the east of the village, so perhaps coming in from somewhere between south-east to east-south-east. The ink & watercolour painting with Tizio's 1505/1528 description seems a confused and ill-omened version of the main Brant woodcut, where the hill-line background has been replaced by what seems a winding river-line, ideoplastically turned to represent the horizon (illustrated on p. 20 of Marvin, 2006, but a better reproduction is on p. 20 of Rowland, 1990). The meteorite there seems to be descending from slightly east of Battenheim, so perhaps from the south-east, if it is not simply slightly miscopying the woodcut from Brant's broadsheets. The painting in Schilling's text of 1513 seems to be looking towards Ensisheim from the south-east, while the stone falls in from its bright cloud to the viewer's top right, so maybe entering from the north-east. An easterly approach direction, perhaps more south-east to south-south-east, might be inferred from all this, but not with any strong conviction, owing to the vagaries of the artworks, and the likelihood at least some artistic licence has been used in creating the compositions, plausibly influenced by the claimed find-spot for the meteorite lying roughly 1.2 km east-south-east of the old city

Table 1 – A timeline of parameters attributed to the Ensisheim meteorite and its fall of November 1492 by various authors, based on the translated texts in (Marvin, 1992) unless noted. A dash, ‘ — ’, indicates such information was not given in that source.

Source	Time & date of fall	Size	Weight	Shape	Colour	Sonic effects	Witnessed by	Notes
Sebastian Brant, broadsheet (4 versions), 1492 [Latin text]	Before midday on the 7th day before the Ides of November [= 7 November 1492]	—	Great	Triangular, like a Greek ‘Delta’, with three sharp corners	Singed, earthy and metalliferous	Horrendous explosion; “thunderbolt clanging”; “multisounding”; widely heard	Woodcuts on 3 of the 4 broadsheets show a mounted man and a foot figure seeing the stone fall (Figure 1), but no text reference	“Lightning stone”; seen to fall to the ground obliquely; “a burning stone”; plunged into a field and devastated the ground; it was “pulled apart in all directions”
Sebastian Brant, broadsheet (4 versions), 1492 [German text]	About midday on St. Florentius’ Day [= 7 November 1492]	—	Three hundred weight	Three cornered	Blackened and earthy, like a metal ore	Horrendous thunderclap, widely heard	Woodcuts on 3 of the 4 broadsheets show a mounted man and a foot figure seeing the stone fall (Figure 1), but no text reference	“Thunderstone”; it fell into a hole in the earth; little pieces were scattered and widely dispersed [but this may refer to the fireball fragmenting, as seen over a large area]; “evil things” were seen in the sky as it fell
Hartmann Schedel, ‘Nuremberg Chronicle’, July 1493 [Latin text]	At noon on the 7th day before the Ides of November 1492	Enormous	Great	Form of a ‘Delta’; triangular with three sharp corners	—	Dreadful explosion	None stated or shown in accompanying woodcut	The sky grew dark after the explosion and a thunderbolt fell obliquely through the air into a field, devastating the ground; it was broken into pieces
‘Nuremberg Chronicle’, December 1493 [German text compiled by Georges Acten]	At noon on 7 November 1492	Large, but slightly smaller than a saltlick [for cattle; size uncertain, but variable & probably < 1 m across]	300 pounds	Triangular like the Greek letter ‘Delta’	—	—	None stated or shown in accompanying woodcut	-
Johann Linturius, chronicle, written circa 1496 but only published posthumously in 1525	After St. Martin’s festival [so, after 11 November] 1492	—	300+ pounds	—	Varied	—	—	Fell from a brilliant and flaming cloud, while the rest of the horizon was clear; a red cross appeared on the Moon simultaneously [the Moon was waning gibbous on 7 November 1492]

Table 1 – (continued).

Source	Time & date of fall	Size	Weight	Shape	Colour	Sonic effects	Witnessed by	Notes
Sigismondo Tizio, 'History of the Sienese', Volume 6, written after 1505, but not published till 1528 (Rowland, 1990)	7 November 1492	Great	—	Triangular	Charred; colour of a metal ore	Fall accompanied by crashing thunder and lightning	A young man on horseback is shown seeing and pointing to the falling stone on the accompanying ink and watercolour illustration	The stone split into several pieces on impact as it travelled obliquely and flattened the earth where it struck; it landed near the city of Ensisheim and the village of Bauenhem [a misinterpretation of the black letter printing of 'Battenheim' from the Brant woodcut]
Petermann Etterlin, 'Chronicle of the Swiss Confederation', 1507	At almost midday on 7 November 1492	Great, but a little smaller than a saltlick	Almost three hundred weight	Shaped like a Greek 'D', with three corners	Grey, like an ore	Gruesome thunderclap	—	—
Diebold Schilling, 'Chronicle of Lucerne', 1513	Midday, 7 November 1492	Large; a little smaller than a saltlick	About three hundred weight	Like a Greek letter 'Delta', with three sharp corners	The accompanying painting shows it as grey-blue with red outlining [perhaps to show its fiery origins?]	Great clangour, like thunder	A man on horseback harrowing a field and another man following on foot sowing seed are shown in the painting observing the fall	The meteorite in the painting is shown falling obliquely towards a ploughed field amid red rays, from a brilliant red and yellow cloud in what seems a partly clear sky otherwise; the stone was hung in Ensisheim's church as a memorial
Johannes Trithemius, chronicle, 1514	Under entries for 1492	Prodigious	255 pounds	—	—	—	—	Thunderstone; broken in two on landing; the largest piece was suspended from an iron chain at the door of Ensisheim's church
Paulus Langius, chronicle, circa 1518	7 November 1492	Prodigious	—	Form of a 'Delta', with its points in a triangle	—	The stone fell with a horrible crash	—	The heavens appeared to be on fire during a great storm; the stone fell while the thunder roared

Table 1 – (continued).

Source	Time & date of fall	Size	Weight	Shape	Colour	Sonic effects	Witnessed by	Notes
Paracelsus (Theophrastus von Hohenheim), ‘Liber Meteorum’, 1569 [published posthumously, but based on his examination of the stone in 1528]	—	—	About 100 pounds [the largest surviving piece only]	—	—	—	—	Stony body; “thunderstone”; resembled earthly materials, not some miraculous substance [as the people of Ensisheim seem implied as believing]
Conrad Lycosthenes, ‘Chronicle of Prodigies’, 1557	7 November 1492 [the accompanying woodcut shows a stone falling from the sky with the Sun on the horizon, but this was also used to illustrate 7 earlier meteorite falls elsewhere in Lycosthenes’ text]	Huge	250 pounds	—	—	Great explosion	—	The stone was suspended in Ensisheim’s church as a reminder of this miracle
Conrad Gesner, text on fossils, stones and gems, 1565	1492	—	300 pounds	No particular shape, suggested as because so much material had been removed from it	—	—	—	The stone was suspended in the church at Ensisheim [Gesner examined a specimen, and found it of similar hardness to sandstone, but made few other new comments on it]
Christian Wurstisen, ‘Chronicle of Basel’, 1580	At noon, on Wednesday, 7 November 1492	About one ell high [$\sim$ 115 cm]	About 280 pounds	—	Like an ore of iron	Huge thunderclap; deafening noise; the sound was widely heard according to Brant	—	The stone fell into a field, from which it was dug out, and it was suspended in the church at Ensisheim

Table 1 – (continued).

Source	Time & date of fall	Size	Weight	Shape	Colour	Sonic effects	Witnessed by	Notes
Ensisheim city protocol, 1589 [preserved only in a series of French, English and German translations said to be from the original German, made in 1802–1804 by various people]	Between 11 and 12 on Wednesday, 7 November 1492, the night before St Martin's Day [which would put the fall before midnight on 10 November instead]	Large	260 pounds	—	—	Loud thunderclap and a long-continued noise heard at a great distance; well away from Ensisheim (at Lucerne, Villing and elsewhere) the noise was thought almost loud enough to overturn houses	A child [English translation] or a boy [French and German translations]	The stone landed in a wheatfield, making a hole as deep as a man's height, but caused no other damage; at King Maximilian's order, it was taken to Ensisheim's church, to be suspended there to preserve it; it was suspended in the choir
Johann Wolf, 'Lectionem Memorabilium', 1600	1493	Huge	—	Form of a Greek 'Delta'	—	—	—	[Wolf used Brant's poem as source, but presumably from its 1493 reprint, as Wolf also dated the fall to the reign of **Emperor** Maximilian, who became Emperor only after Friedrich III died on 19 August 1493;] the stone was kept in Ensisheim's church
Matthacus Merian, 'Topographia Alsatiae', 1644	7 November 1492	—	250 pounds (1544); 280 pounds (1580)	—	Of iron	Clap of thunder	—	A stone or a clod; it gave off sparks when struck with steel; [Merian cited as sources 'Munsterus'(1544; probably a lost text by Sebastian Münster) and Wurstisen (1580)]
Ignatio Cimarolo, 'Chronology of the Christian World', 1727	1492	—	A) 246 pounds; B) 255 pounds	—	—	—	—	The stone fell violently and broke in two; the larger piece was preserved suspended in Ensisheim's church; [Cimarolo gave brief details of the fall twice on the same page, with two specific, yet different, weights]

Table 1 – (continued).

Source	Time & date of fall	Size	Weight	Shape	Colour	Sonic effects	Witnessed by	Notes
E.F.F. Chladni's text on meteors, fireballs, fallen stones and masses of iron, 1794	A) 1493 B) 1630 C) 1492	A) Large B) — C) —	A) — B) $\sim$ 300 pounds C) 200 pounds	A) 3 cornered B) — C) —	A) — B) Dark, bearing tracks of fires C) —	—	—	A) Wolf, 1600 B) Pieter van Muschenbroek, writing in 1755 C) Details Chladni accepted as correct
J.J. 'Casimir' Karpff, ink & watercolour sketches of the stone and its accompanying inscriptions in Ensisheim's church, 1795	A) 7 November 1492 B) 7 November 1492 C) 7th of 'The Wintermonth' 1492	A) Huge B) — C) Huge [$\sim 32 \times 41 \times 31$ cm]	A) 171 pounds B) — C) 250 pounds	—	A) — B) — C) Iron	A) — B) — C) Great noise; stone fell with a thunderclap	—	A) — [Latin text] B) A frightful stone [French text] C) Stone fell on a bright day [German text] [The stone is shown suspended on three bent iron crampons, but no chain, perhaps just for clarity; the surviving stone's dimensions and weight are given in Karpff's own notes, probably from actual measurements]
F.-J. Merklen, paraphrased revision of the original tale, 1840	Between 11 and noon on 7 November 1492	—	260 pounds	—	—	Violent thunderclap, followed by a loud, prolonged noise like thousands of distant rifles; felt most strongly away from Ensisheim	A shepherd; many people gathered soon after; there was a sheep in the field	Aerolite; the stone buried itself $\sim$ 1 m deep in the earth at the feet of the shepherd; it was later dug up and subsequently suspended in the parish church, preserved "as a precious object of science"
(Graham *et al*, 1985, p. 136)	$11^{\rm h}30^{\rm m}$ on 16 November 1492 (Gregorian)	—	127 kg [equivalent to 280 pounds UK Imperial 20th century measure]	—	—	Stone fell after detonations	—	Long-preserved in Ensisheim's parish church; an olivine-hypersthene chondrite (LL6), by modern analyses

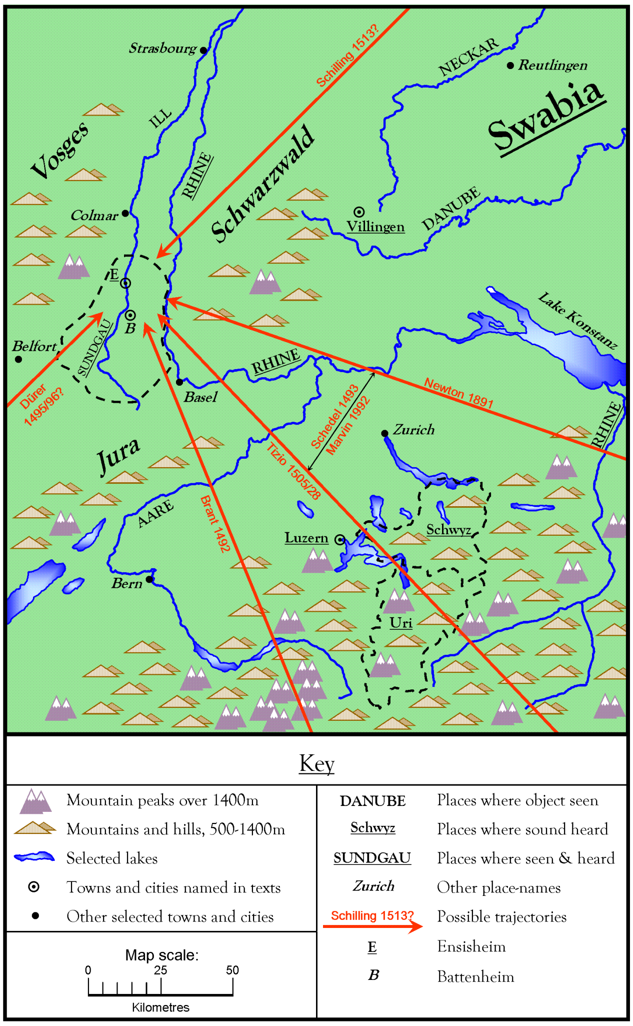

Figure 2 – A sketch map of the area around Ensisheim to help identify the places named in the various contemporary and later sources regarding the 1492 meteorite fall there. Modern spellings have been preferred for most place-names. The dashed lines show the approximate limits of the Sundgau region of Alsace (the limits in the 15th–16th centuries were somewhat variable), and the modern Schwyz and Uri cantons of Switzerland, which latter roughly correlate with those same regions for circa 1492. Lines showing possible approach directions for the Ensisheim chondrite from the named sources have been added. These are at best only crude suggestions. Note that the woodcut with Schedel's 1493 text and Marvin's (1992) assessment both infer a range of potential directions between the two lines indicated. Question marks show the two least certain approach paths.

of Ensisheim, near the road to Battenheim (the ring surrounding the dot marking Ensisheim on Figure 2 is about this distance from the old city).

In 1891, H A Newton attempted to determine a possible trajectory using just the sonics, but seems to have partly misread the sources, according to Marvin. He favoured an east-south-east approach for the object, something Marvin approximately concurred with (1992, pp. 63–64), although she gave rather eccentric azimuth bearings of between "25° to the ESE" to "45° SE". From her accompanying sketch map, these must be azimuths 115° to 135°. Her reasons for choosing these directions were far from obvious and, like Newton's, seemed based on a flawed understanding of the uncertainties of sonic boom effects associated with fireballs, where the path of the meteor was assumed as having to pass over or near the places the sound was heard. This need not have been the case at all, and given the ill-defined and likely incomplete list of the places sonics were reported from, coupled with the reflective and focusing effects the Alps may have had, set such reasoning on still shakier ground. Rather oddly, Marvin (and from her comments, probably Newton too, though this is not certain) seemed to have ignored Brant's Latin text, concentrating on just the German description of from where the object was both seen **and** heard, cited above. This German list may have included the River Inn, around 80–90 km south-east of the easternmost Schwyz-Uri border at its closest to the impact point. This may be due to a misinterpretation in the original broadsheets however. The two versions published in Basel read: "Switz, Uri, hort den klapff der In", which could be poetically taken as suggesting the river area as another place the 'clap'/sound was heard, with the Schwyz and Uri regions. The other two versions, from Reutlingen and Strasbourg gave: "Schweiz, Uri hort den klapff darein" instead, so meaning something closer to 'the Schwyz and Uri heard the clap out there', or as Marvin interpreted it, 'heard the sound of it'. Facsimiles of all four broadsheets are given complete on pp. 30–33 inclusive of (Marvin, 1992). I have slightly rationalized the variant spellings for clarity here, while Marvin discussed the whole matter further on (*op. cit.*, p. 63).

The Latin text, translated in (*op. cit.*, p. 34), mentioned that Ensisheim and all Suntgaudia, the region around the city, **felt** the force of the impact, but of the sonics noted:

> "The explosion was heard on both sides of the Rhine,
> Heard also by the Uri among the Alps,
> It astounded the Noricians, the Swabians and Rhet-
> icans:
> It sounded in the Burgundians ears, and caused
> the French to tremble."

The various river valleys from all this are readily identifiable still (albeit the Rhine's length and tributaries are problematic for precision), along with the Swiss cantons of Schwyz and Uri, and Burgundy in eastern France. The reference to 'the French' might simply refer loosely to what is still modernly France, but it may be a more specific note meaning the Franche-Comté region, which from 1482–1493 was part of France, not the Holy Roman Empire. It lay, and still lies, between the Sundgau/Suntgaudia and the Duchy of Burgundy, as Figure 3 indicates. Franche-Comté was reclaimed by the Empire in the aftermath of the stone's fall.

The three other highland peoples are rather suggestive of a poetic phrasing hinting that the boom was heard the length of the Alps (see Figure 3), given that the Noric Alps are the extreme south-easternmost range in Austria, around 500–700 km east-south-east of Ensisheim. Franche-Comté to Burgundy would add a further $\sim$ 200–300+ km western extension to this zone, making an overall linear region of maybe 1000 km.

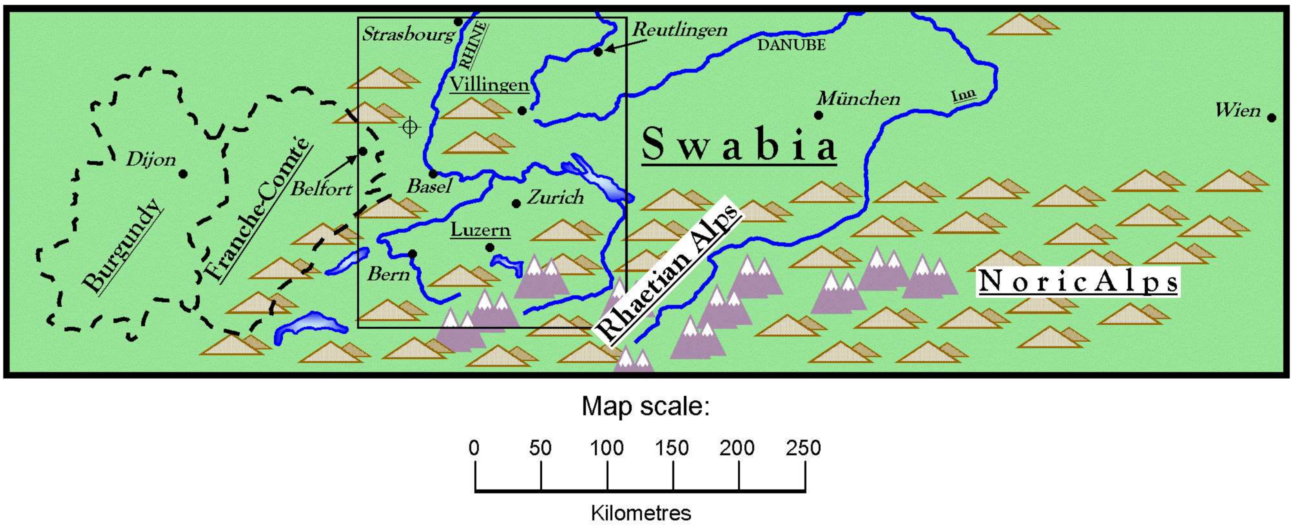

Figure 3 – A sketch map setting the Ensisheim fall (target symbol) in its wider mid-European context, to indicate the more distant places Sebastian Brant's texts of 1492 implied sounds associated with the event were heard. The boxed area gives the approximate limits of Figure 2 here, while the same key for place-names as that Figure has been used again, though only selected towns and cities are shown on this map. The areas of Burgundy and Franche-Comté are merely approximate, as the borders were not fixed when the fall occurred, and in the early to mid 15th century, both were parts of Burgundy, as the Duchy and County respectively. Snow-topped mountain symbols show areas of over 3000 m elevation, the lesser mountain symbols, land between 500–3000 m.

While this may seem an excessive distance for the sound to have propagated, it is always possible it may have been channelled along Alpine valleys so far east, or this may be indicative that the east-south-east approach direction preferred by Newton was correct, perhaps even that the fireball was seen from places along this line. The specific extension into French lands may have had a more political than physical dimension too, as will be discussed further in Section 3 below.

The Ensisheim city protocol of 1589/1802–1804 added to the list of locations for sonic reports with Lucerne/Luzern, Villing(en), "and many other places, so loud it was thought the houses were all overturned" (Marvin, 1992, p. 58). It is interesting so many of the named places were in the north-east to south-east directions from Ensisheim. This might indeed tally with a similar arrival bearing for the fireball, but if the sound were projected forwards from the incoming body at a shallow angle to the horizontal, an opposite approach heading, from the west or north-west, could have helped channel the noise far eastwards along the Alpine ranges, and reflect it back towards Burgundy/Franche-Comté/France.

Albrecht Dürer (1471–1528), the great German artist from Nuremberg, remains famous today through his huge canon of surviving works, perhaps the most influential of which from his early woodcuts was his series of superb plates of 'The Apocalypse', published in 1498, when he was 26. Dürer has been suggested as the artist who created the better woodcuts used on three of Brant's four 1492 broadsheets, including Figure 1 here, but on stylistic grounds, this has been dismissed as unlikely. He completed his apprenticeship in 1489 and from 1490 to 1494 is known to have travelled widely in parts of Europe, on the traditional post-training *Wanderjahr*. He was in Basel in early November 1492, so could have seen the Ensisheim fireball from there. There are two sketchy paintings attributed to him which may support this idea, both on the backs of wood panels he is believed to have created religious paintings upon, presumably later. The possibly earlier 'fireball' scene is on the back of 'Christ as the man of sorrows' of circa 1493, and shows a fiery pillar or explosion in the sky above a landscape, perhaps with the cloud reaching the surface, reproduced in Lüdke (2001, p. 400, item 235). The other is a clear representation of an orange-red exploding fireball in a break in some clouds, which are also tinged with red. This is on the reverse of 'St. Jerome in a landscape' of *circa* 1497. Marvin (1992, Plate II, p. 39; 2006, Figure 6, p. 23) showed the 'fireball' one, and most recently suggested it was painted between 1495–1496, but did not mention the earlier apocalyptic painting. Bartrum (2002, item 47, pp. 115–116) showed only both sides of the St. Jerome panel in full colour, but described both apocalyptic paintings on pp. 114 and 116. In neither case was it clear if the scene was by day or (perhaps moonlit) night, so a definite identification with the Ensisheim event is impossible to make. Either or both may simply have been experimentation with apocalyptic meteoric imagery before he draughted his 'Apocalypse' woodcuts – and assuming that the attribution of them to Dürer is correct. If the 'fireball' painting was meant as an eye-witness' view of the Ensisheim meteor as seen from Basel, it would seem to contradict all the other illustrations, as the object is descending from left to right at a shallow angle, about 10° from the horizontal. This would only apply had the object approached Ensisheim from the south to west of that city, perhaps most likely from the south-west, as I have suggested in Figure 2. The 'fiery cloud' painting has the pillar-like shape to the viewer's left as well, though it is difficult to attribute a clear direction to it beyond this.

3 Beliefs in the stone's meaning

From the first, Brant's Latin broadsheet texts mentioned earlier portents from the Classical authors down to signs in the sky during the times of Friedrich I (Barbarossa; 1123–1190) and Friedrich II (1194–1250), to tie in with the Ensisheim fall in the time of Friedrich III, and lend an air of ancient authority to the 1492 event. These included the fall of another great stone during the reign of Friedrich II, said by Brant to have been cast out from a storm cloud, and which stone was "marked with a cross and secret signs" (Marvin, 1992, p. 34). A similar description was given in the German texts for this earlier object, which while potentially meteoritic, has regrettably not survived into modernity. The German poems were less specific about the more ancient portents however, presumably because the people able to read the German text alone would have known less about such earlier writings, available just to Latin scholars. The reuse of earlier portents implying continuity to his own times, was invoked to give credence to Brant's own predictions of what the Ensisheim stone's fall meant. Part of this included using St. Florentius, apostle of Alsace, whose day was November 7, referred to to heighten the significance of the fall in Alsace, and thus its perceived importance for the ruler of that province, King Maximilian, heir to Friedrich III as Holy Roman Emperor. Subsequent authors clearly felt St. Florentius was too parochial, and either omitted any saintly connection, or replaced him with St. Martin (whose day was November 11, helping generate a degree of confusion about when the stone fell in some quarters, including in the Ensisheim city protocol). St. Martin was a much better-known saint, who was also patron of the church in Ensisheim where the meteorite was taken to spend most of its post-arrival existence.

Brant initially stated a little vaguely his belief that the Ensisheim fall portended a great future event, to allow the overcoming of enemies of the Holy Roman Empire, specifically the French. At the end of all four of his 1492 broadsheets, Brant placed a poetic exhortation in German to Maximilian, whom he obviously saw the stone's portentous, positive, appearance as intended to inspire (*loc. cit.*):

> "Take as truth that the stone was sent to you
> God warns you in your own land
> That you should arm yourself.
> Oh mild King, lead out your army
> Let armour clang and roar of guns,
> Let triumph resound:
> Curb the swollen pride of France
> Preserve your honor and your good name"

Schedel's Latin text for the 'Nuremberg Chronicle' was published in July 1493, and followed Brant's lead in what the stone's fall meant:

"It is an omen of things to come.

"Wars will ensue between King Maximilian and the king of France over the Duchess of Brittany. Many battles will be fought and without doubt our cause will flourish" (*op. cit.*, p. 40).

These different predictions turned out truly, after a fashion, as by the time the German text of the 'Nuremberg Chronicle' was ready, in December 1493, the 'wars' were already over and peace restored, though in fact the main fighting was underway by late 1492, meaning even Brant's 'predictions' were not quite so miraculous, perhaps, as might be supposed from just a reading of the meteorite-related texts alone. The military action culminated in the spectacular defeat of about 5000 French cavalry by a much smaller force of German troops at the Battle of Salins on January 19, 1493. Brant published a broadsheet poem on this Battle later in 1493, which specifically referred to his correct interpretation of the Ensisheim meteorite's fall as a beneficial omen for Maximilian and the future:

> "And the luck which it brings you in this year
> Will follow you and
> Be true to you until you leave this life"

(*op. cit.*, p. 43; Marvin also gave a solid précis of the complex historical events around this time on pp. 41–43).

Friedrich III died on August 19, 1493, and Brant then used the stone's fall as having foretold the Emperor's death – a great portent for a great man, much as we have seen with meteors as portents of death in the Project before (for example, the set of four articles in the October 2006 issue of *WGN*, **34:5**, pp. 143–152). Of course, such an interpretation could only be made after the event, without unfortunate repercussions for the prognosticator! Maximilian invoked the portentous nature of the meteorite's fall himself when unsuccessfully trying to raise money to fight the Turks in 1503. All of this helped ensure the stone remained linked with Maximilian's time and person, at least within the Holy Roman Empire, where several other early 16th century writers reused Brant's interpretations, including the event as predicting the Emperor's death.

It seems the ominous nature of the stone was not seen so positively elsewhere, however. As noted earlier, Sigismondo Tizio's 'History of the Sienese' of 1505/1528 contained an illustrated description of the fall. Though his text involved only some minor variations on what had gone before it, the ink and wash sketch featured several fresh elements. An owl sat atop a rooftop wheel (intended to encourage the nesting of storks) in Ensisheim, while four other birds dropped stunned or dead from the sky, two of them by the falling stone emerging from its cloud, the stone itself surrounded by descending red rays. A blowing human face, a personified wind, was in the clouds directly behind where the meteorite must have fallen from. A wild quadruped of some sort hid its head in its burrow as the stone descended above it, while two smaller animals, one a squirrel, watched the event from the relative safety of a wood's edge. A long-tailed lizard-like animal headed away from where the fallen stone lay in a crop-field (?). In a ploughed field on the opposite side of this depiction of the landed meteorite, a man on horseback pointed skywards and looked up at the falling rock. The visibility and atypical behaviour of the animals reinforced the unusualness of the event, all with indications of fear or stunned surprise. The owl and falling birds have long-standing especially negative connotations, one or other featuring elsewhere when some particularly calamitous happening was highlighted, and here perhaps the literal representation of the 'evil things' in the sky from Brant's 1492 German broadsheet text.

After this though, indeed from about the time of Maximilian's death in 1518, the portentous beliefs surrounding the Ensisheim lightning-stone seem to have disappeared, other than the fall being perceived as an apparently miraculous occurrence, something its long-term preservation on public display in the city's church probably helped reinforce. The stress on the stone's triangular form can also be interpreted this way, as a symbol of the Christian Holy Trinity.

4 Late 19th, 20th and 21st centuries

Since Chladni's time, when it was finally (re-)recognised as a genuine meteorite, the Ensisheim stone has become a secularly venerated object. A special meeting of the Geological Society of the Upper Rhine was held in its honour in early 1881, at which the stone was thoroughly cleaned in soapy water, and a lengthy poem, comical in parts and some of it more fanciful than factual, was composed and read by Professor Knop of Karlsruhe, after the meeting's banquet. This included the unique interpretation that the meteorite was tempted to Earth after scenting the fine wine, much enjoyed at said banquet, 'The Knight' of Alsace! Marvin provided a complete text for the poem (1992, p. 66). It seems we are not quite so pioneering in our use of poetry and enjoyment of fine food, drink and good company at IMCs as we might have supposed (an IMC in Ensisheim in future, perhaps?)!

Twentieth century innovations regarding the stone included the idea that it may have been only part of a meteorite shower – possible, though unlikely from the contemporary records – and that having been taken to the church, it was chained to the wall to prevent it escaping back to the heavens. This latter item Marvin (*op. cit.*, p. 60) noted as first attributed in English to the 1980 translation of Ochiren Namnandorj's 'Meteorites of Mongolia' (published by Field Research Projects, Miami), though this has appeared unattributed in other sources subsequently (e.g. McSween, 1987, p. 1). By the 1990s, 'Meteor Beer' brewed in Hochfelden north-west of Strasbourg, was named for the meteorite, and a special uniformed group formed to celebrate it, the Guardiens de la Meteorite d'Ensisheim. The latest addition to the tale Marvin found was an item featured in Ensisheim's tourist information literature, where a farmer was claimed as still supposedly keeping part of the meteorite as a weight in his sauerkraut barrel, something which appears to be entirely fictitious (Marvin, 1992, p. 68).

The 21st century has continued to see elaborations on the Ensisheim legend. Most recently, this item was discovered in a book review: "The French sometimes chained meteorites to the ground where they fell, in case they decided to depart from Earth as swiftly as they arrived" (Hughes, 2007, p. 196). Though pluralised for effect and not specifically mentioning Ensisheim, as far as I am aware there is no other French meteorite fall such chain-use was associated with. Luckily, the Ensisheim stone was not chained to the Earth at its find-spot either, or there would be no such stone now!

5 Conclusion

The changing descriptions and associations of the Ensisheim chondrite and its fall with time show how very malleable such beliefs can be, often coloured by error or misinterpretation. Even so, it is also interesting to see how much of Brant's original description survived in the later versions. We are fortunate so much of the stone itself has survived into the present so we can be sure for once that whatever those beliefs were said to be, they belonged to a genuine sky-fallen stone, unlike many other events we have examined during the Project for which no similar confirmation was possible.

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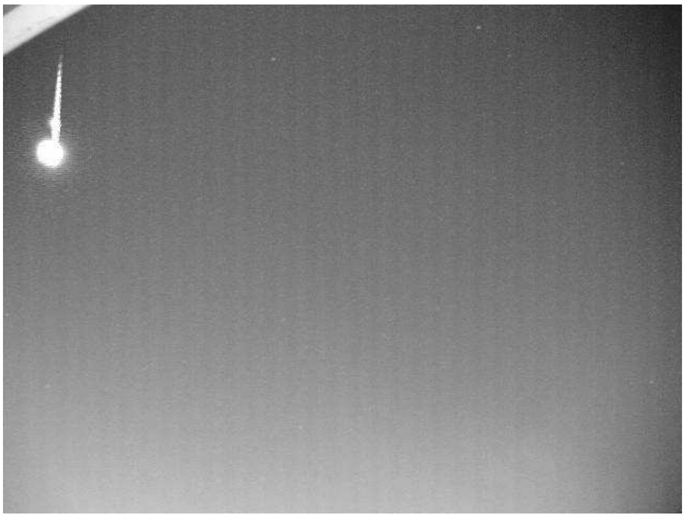

Magnitude −5 sporadic
2011 January 21 at $01^{\mathrm{h}}46^{\mathrm{m}}21^{\mathrm{s}}$ UT
Author: Jean-Paul Godard, Paris

Magnitude −3 sporadic
2011 March 6 at $23^{\mathrm{h}}09^{\mathrm{m}}12^{\mathrm{s}}$ UT
Author: Christophe Demeautis, Bollwiller

Magnitude −12 sporadic
2011 June 24 at $03^{\mathrm{h}}00^{\mathrm{m}}29^{\mathrm{s}}$ UT
Author: Jean Brunet, Fontenay-le-Marmion

Magnitude −12 sporadic
2011 June 24 at $03^{\mathrm{h}}00^{\mathrm{m}}29^{\mathrm{s}}$ UT
Author: Stéphane Jouin, May-sur-Orne

Magnitude −5 sporadic
2011 March 21 at $04^{\mathrm{h}}02^{\mathrm{m}}08^{\mathrm{s}}$ UT
Author: Arnaud Leroy, Gretz-Armainvilliers

Magnitude −5 Perseid
2011 August 12 at $02^{\mathrm{h}}26^{\mathrm{m}}15^{\mathrm{s}}$ UT
Author: Tioga Gulon, Nancy

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