journal of the international meteor organization

WGN

34:1
february 2006

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ISSN 1016-3115

WGN Vol. 34, No. 1, February 2006, pp. 1 – 32

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Front cover photo

A bright Taurid of magnitude −9, captured with the digital all sky camera of Klaas Jobse, Oostkapelle, the Netherlands, on 2005 November 3 at $22^{h}50^{m}$ UT. Camera: Canon 300D digital set to ISO 1600, with $f = 45$ mm $f/4.0$ lens looking down onto a convex mirror. Exposure: 180 s. See also the papers on pages 7 and 11.

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

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Janus

Alastair McBeath[1]

Janus was a fascinating, if now little-understood, deity. He was the ancient Roman god of door and gate, *ianua* (= 'a door'), though as Frazer's Appendix to his translation of Ovid's 'Fasti' suggested (J. G. Frazer, 1931, "Ovid in Six Volumes – Volume V, Fasti", Harvard University Press & William Heinemann (Loeb Classical Library imprint), pp. 387–389), this alternative term for a door may well have derived from Janus' name, not *vice versa*. With two faces on his head set back to back, Janus was the controller of beginnings and endings, sender of peace and war, the Opener and Closer, the gatekeeper of heaven, facing simultaneously east and west, to regulate the rising and setting of all the heavenly bodies. Indeed Ovid's description demonstrated his perceived celestial power. In Janus' own words:

The guardianship of this vast universe is in my hands alone, and none but me may rule the wheeling pole. ('Fasti' I.119–120; op. cit., pp. 10–11)

Frazer also discussed the possibility that Janus was earlier a sky god, perhaps associated with the Moon as a masculine version of the Roman lunar goddess Diana, 'Dianus', which would certainly have given him both strong celestial and calendrical links. Ovid's extensive commentary on Janus ('Fasti' I.89–294) included his ancient origins as a being called Chaos, a shapeless lump which became humanoid in form only when the four elements — air, fire, earth and water — were first separated. The plasticity of his early shape was symbolically retained in his double-faced form.

Much of this has meteoric relevance, with Janus representative of duality, change and boundaries. Meteors occur at the boundary between the atmosphere and space, passing into one from the other, changing state from solid to vapour in doing so, with incredible violence. Janus' early shapeless form could be almost meteoritic, reminiscent of the resolidified fusion crust of a freshly-landed object, perhaps.

The dualism of the deity invites consideration of other dualities, such as the segregation between "the arts" and "the sciences". None of us would argue against the meteor observations we carry out being as scientific as we can make them, I think, but that does not prevent us from having an aesthetic appreciation of an impressive meteor when one chances-by. One of the better aspects of the IMO to me is the way meteoric "art" and "science" are able to coexist in our publications, meetings and correspondence, which is as it should be with any group of well-balanced individuals. The hard science of the latest global meteor analyses and fireball orbital determinations, sits comfortably next to the literature, poetry and imaginative thoughts of past and present in this Journal and at the IMCs, for instance. Both aspects are perfectly valid human responses to meteoric phenomena; both enrich our understanding and appreciation of part of the Universe. Who among us would continue watching for meteors if we did not enjoy what we saw?

Janus as doorward of time always begins the year with his own-named month, and this element is particularly appropriate for us to contemplate in 2006, a year which sees a newly-elected IMO Council beginning its fresh term. Not only those on the Council are so affected by such thoughts, as everyone within the IMO needs to remember it is only by the efforts of such people that the Organization continues to exist. If you have an idea for improving what the IMO does, and are willing to help put it into practice, or if you feel moved to write a letter or an article on an interesting topic of matters meteoric for publication, make your own pact with Janus, and cross the threshold to join those already helping to make the IMO work!

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

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IMO bibcode WGN-341-mcbeath-janus NASA-ADS bibcode 2006JIMO...34....1M

Guest editorial — From the President

Jürgen Rendtel

First, still my best wishes for a prosperous and peaceful New Year. For the IMO, the year 2006 began with the newly elected Council. After many years of continuous work as the IMO's Treasurer, Ina Rendtel handed this position to Marc Gyssens. The Treasurer's post is essential for the work of an organization and requires quite some work to coordinate the various transactions. Hence our sincere thanks to Ina for her work and our best wishes to Marc. We also welcome new Council members and hope that we all together can continue and improve the practical work. I see that we should increase the amount of information about the Council's activities to our members. This way we may attract further IMO members to consider a candidacy for the Council or to take responsibility for posts in the organization. In the same manner as the size of an organization increases its weight, recognition and possible influence, the active participation in the Council work improves the efficiency of the work and guarantees a variety of views in the Council which is necessary for decisions and plans. While a local group often relies or depends on the activity of rather few people, the IMO should make use of the worldwide distribution of its members and therefore the wide variety of views on our common topic: meteors.

A few years ago, the Leonid returns were a major attraction and motivation for various aspects of meteor astronomy. A huge amount of data, obtained with different techniques is stored in the IMO databases. Of course, this also includes valuable information about other meteor showers. I'd like to encourage interested people to make use of this real treasure collected by motivated and ambitious observers over the years. Standardized observing and analysing techniques are a backbone of the IMO's activities. And, yes, I'd like to emphasize the importance of further continuous efforts. It is no secret that many meteor showers may produce unusual activities of which only a fraction will be predicted by respective model calculations. At the same time it is always worth and necessary to think about new projects and technical solutions to obtain additional information about meteors and meteoroid streams. This all offers a wide spectrum of possibilities to actively take part in the IMO's work, and thus to make the IMO our organization.

IMO bibcode WGN-341-editorial NASA-ADS bibcode 2006JIMO...34....2R

International Meteor Conference 2006

Roy Keeris [1]

The 2006 International Meteor Conference (IMC) will be held in Roden, a village in the North of the Netherlands. This year the conference will be organised by the Royal Netherlands Association for Meteorology and Astronomy (KNVWS).

At the conference, which will take place from 2006 September 14–17, astronomers and meteor enthusiasts will meet and exchange scientific results. During the weekend participants will visit the Low Frequency Array (Lofar), which will be the largest radio telescope in the world. There is also the possibility to join a specialized course ahead of the conference, and of course there will be some entertainment.

For more information please visit the web site of the IMC: `http://www.imo.net/imc2006/`. If you have any questions left please don't hesitate to contact the organisation: `imc2006@imo.net`.

Full details will be announced in future WGNs, but you can already register on the above website.

[1] *The IMC 2006 Organising Committee, The Netherlands*

IMO bibcode WGN-341-imc-announcement NASA-ADS bibcode 2006JIMO...34....2K

Taurids

Spectacular Taurid meteor shower in 2005

Audrius Dubietis[1] *and Rainer Arlt*[2]

We present a short summary of observations of the Taurid meteor shower in 2005. Visual data revealed an enhanced Taurid activity from October 29 to November 12, which peaked on the night of November 1/2 with ZHR = 15.3 ± 2.6. An increased number of Taurid fireballs was reported by observers worldwide. The heightened activity is attributed to the appearance of a resonant meteoroid swarm in the Taurid Complex.

Received 2006 February 2

1 Introduction

The Taurid meteoroid complex and the associated meteor showers (namely Piscids, Taurids, and χ-Orionids) attract much interest from professional and amateur meteor astronomers. The reasons for this continuous attention are manyfold, and many different tasks are pursued. Unlike most ecliptical meteoroid streams producing meteor showers throughout the whole year, the Taurid Complex has a well established parent comet, 2P/Encke (Whipple 1940), and its evolution over many ages is well understood (Steel *et al.*, 1991). Deeper insight into the structure and origin of the Taurid Complex revealed that a number of Near-Earth (Apollo-type) asteroids might contribute to the meteoroid stream (Olsson-Steel, 1987; Klačka, 1995; Klačka & Pittich, 1998; Babadzhanov, 2001). Such a complex membership of parent objects has produced some real foundations for the hypothesis of a disintegrated giant comet (Clube & Napier, 1984). The famous Tunguska impact is also linked to the alleged activity of the Taurid Complex (Asher & Steel, 1998).

From the long-term photographic and visual observations in the past, the Taurid meteor shower has been designated a complex radiant structure with clear Northern and Southern branches that develops under planetary perturbations on a large time scale (Jones, 1986). Numerous smaller theoretical radiants, related to the asteroidal counterpart of the stream, and spread throughout the constellations of Taurus, Aries, Cetus and Pisces, have also been predicted (Babadzhanov, 2001). However, recent analysis of about 58 000 video meteors (Triglav-Čekada & Arlt, 2005) revealed just a distinct double radiant of the Taurids, with clearly separated Northern and Southern branches (referred as Northern Taurids, NTA and Southern Taurids, STA, respectively). The same double structure has been found persistent also for Piscids and χ-Orionids.

The Taurid meteoroid stream produces quite a remarkable ecliptical meteor shower visible in October and November with the maximum extending through the first decade of November. There are some indications that the Taurids produced a prominent meteor shower some thousand years ago (Ahn, 2003), although the distinction between Taurids and Leonids is not reliable. Nowadays activity of the Taurid meteor shower is rather modest, with rates not exceeding 10 meteors per hour at their best (Bone, 1991; Jenniskens, 1994; Rendtel *et al.*, 1995).

It has been widely recognized that the Taurid meteor shower, despite its moderate activity, produces a great number of bright fireballs in some years. A Taurid swarm being in 7:2 resonance with Jupiter was proposed by Asher (1991) to produce occasional enhanced activity. A comparison of the swarm model with visual regular and fireball observations of the Nippon Meteor Society by Asher and Izumi (1998) was indeed successful in finding a correlation. The proposed model describes a meteoroid swarm of trapped particles, which evolves as a consequence of the 7:2 resonance of Comet 2P/Encke with Jupiter. In the course of the 'swarm model', an enhanced Taurid activity, in particular that for the bright fireballs, was predicted for the years 1998 and 2005. Indeed, an exceptional Taurid fireball activity has been detected in 1998. There was also an indication of increased numbers of visual Taurid meteors in that year (McBeath, 1999), however no detailed analysis has been performed so far. More recently, an extended analysis of the Taurid fireball activity from six independent sources just confirmed the model predictions (Beech *et al.*, 2004). Therefore, in agreement with predictions of Asher and Izumi (1998), 2005 appears to be a special year for Taurids.

In this Paper we provide an evidence of an exceptional Taurid activity in 2005 based on the available records collected in the Visual Meteor Data Base (VMDB).

2 Observations

2005 was a promising year for Taurid observations from the point of view of visual observations, as the most intense part of the shower was not interfered with by the full moon. The Taurid activity period was proposed to be October 1 to November 25 by Rendtel *et al.* 1995, but mainly in order to avoid confusing overlaps of designations, and to a lesser extent from actual activity graphs. This period corresponds to the solar longitude

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IMO bibcode WGN-341-dubietis-taurids
NASA-ADS bibcode 2006JIMO...34....3D

interval of between $\lambda_\odot = 180°$ and $\lambda_\odot = 245°$.

Over that period, 59 observers worldwide reported a total of more than 5000 meteors in 363.51 h of net observing time to the IMO. Out of these, 1199 meteors were associated with the Taurids (287 NTA, 368 STA and the remaining 544 simply as TAU). For simplicity we made no distinction between the NTA and STA branches, further referring to the shower as the Taurids.

By January 5, 2006, the following observers had submitted their reports to the IMO, to whom we are very grateful :

Jure Atanackov (ATAJU, $4^{\mathrm{h}}\!.32$, 36), Pierre Bader (BADPI, $11^{\mathrm{h}}\!.90$, 38), Ričardas Balčiūnas (BALRC, $8^{\mathrm{h}}\!.50$, 18), Jean-Marie Biets (BIEJE, $3^{\mathrm{h}}\!.50$, 16), Jiang Chang-gui (CHAJI, $2^{\mathrm{h}}\!.10$, 3), Rong Chen (CHERO, $2^{\mathrm{h}}\!.10$, 5), Tim Cooper (COOTI, $1^{\mathrm{h}}\!.30$, 1), Tibor Csörgei (CSOTI, $0^{\mathrm{h}}\!.50$, 1), Nadka Dankova (DANNA, $1^{\mathrm{h}}\!.82$, 0), David Dickinson (DICDA, $1^{\mathrm{h}}\!.10$, 4), Jaka Dobaj (DOBJA, $3^{\mathrm{h}}\!.03$, 15), Audrius Dubietis (DUBAU, $15^{\mathrm{h}}\!.64$, 64), Bo Gao (GAOBO, $1^{\mathrm{h}}\!.10$, 0), George W. Gliba (GLIGE, $3^{\mathrm{h}}\!.00$, 17), William Godley (GODWI, $11^{\mathrm{h}}\!.25$, 42), Mitja Govedič (GOVMI, $1^{\mathrm{h}}\!.33$, 8), Robin Gray (GRARO, $15^{\mathrm{h}}\!.15$, 17), Daniel Grün (GRUDA, $1^{\mathrm{h}}\!.01$, 3), Davood Hemati (HEMDA, $1^{\mathrm{h}}\!.00$, 0), Yandong Hu (HU YA, $1^{\mathrm{h}}\!.00$, 0), Andrey Igoshev (IGOAN, $5^{\mathrm{h}}\!.00$, 2), Carl Johannink (JOHCA, $10^{\mathrm{h}}\!.20$, 25), Bhargav Joshi (JOSBH, $2^{\mathrm{h}}\!.45$, 0), Javor Kac (KACJA, $12^{\mathrm{h}}\!.36$, 73), Soheil Khoshbin Far (KHOSO, $1^{\mathrm{h}}\!.00$, 0), Velislava Kiryakova (KIRVE, $3^{\mathrm{h}}\!.75$, 0), Dovilė Kraulaidienė (KRADO, $2^{\mathrm{h}}\!.15$, 4), Jens Lacorne (LACJE, $3^{\mathrm{h}}\!.60$, 3), Peter van Leuteren (LEUPE, $0^{\mathrm{h}}\!.50$, 6), Anna S. Levina (LEVAN, $4^{\mathrm{h}}\!.84$, 73), Michael Linnolt (LINMI, $1^{\mathrm{h}}\!.92$, 5), Ming-hui Liang (LINMN, $2^{\mathrm{h}}\!.48$, 0), Xuan Liu (LIUXU, $2^{\mathrm{h}}\!.72$, 0), Jin Ma (MA JI, $2^{\mathrm{h}}\!.45$, 0), Veikko Mäkelä (MAKVE, $1^{\mathrm{h}}\!.12$, 0), Paul Martsching (MARPA, $12^{\mathrm{h}}\!.75$, 9), Pierre Martin (MARPI, $14^{\mathrm{h}}\!.81$, 78), Mikhail Maslov (MASMI, $12^{\mathrm{h}}\!.29$, 16), Alastair McBeath (MCBAL, $14^{\mathrm{h}}\!.35$, 14), Koen Miskotte (MISKO, $19^{\mathrm{h}}\!.66$, 115), Markku Nissinen (NISMA, $1^{\mathrm{h}}\!.25$, 0), Sven Näther (NATSV, $21^{\mathrm{h}}\!.63$, 45), Robert Pomohaci (POMRO, $1^{\mathrm{h}}\!.22$, 0), Jürgen Rendtel (RENJU, $22^{\mathrm{h}}\!.87$, 66), Mikiya Sato (SATMK, $1^{\mathrm{h}}\!.50$, 0), Tomoko Sato (SATTM, $1^{\mathrm{h}}\!.50$, 0), Alex Scholten (SCHAE, $4^{\mathrm{h}}\!.11$, 20), Svetlana Slavova (SLASV, $5^{\mathrm{h}}\!.57$, 5), Wesley Stone (STOWE, $1^{\mathrm{h}}\!.50$, 0), Richard Taibi (TAIRI, $1^{\mathrm{h}}\!.20$, 2), Kazumi Terakubo (TERKA, $1^{\mathrm{h}}\!.50$, 0), Josep M. Trigo Rodríguez (TRIJO, $1^{\mathrm{h}}\!.94$, 0), Alexandru Tudorica (TUDAL, $5^{\mathrm{h}}\!.16$, 4), Shigeo Uchiyama (UCHSH, $10^{\mathrm{h}}\!.26$, 30), Nejc Ucman (UCMNE, $2^{\mathrm{h}}\!.46$, 11), Michel Vandeputte (VANMC, $35^{\mathrm{h}}\!.71$, 173), Valentin Velkov (VELVA, $5^{\mathrm{h}}\!.76$, 19), Kim S. Youmans (YOUKI, $12^{\mathrm{h}}\!.05$, 81), Jurga Zieniūtė (ZIEJU, $4^{\mathrm{h}}\!.34$, 24).

The IMO observer code, the effective observing time, and the number of Taurids reported are given in brackets. The observers are from the following 20 countries:

Belgium, Bulgaria, Canada, China, Finland, France, Germany, India, Iran, Israel, Japan, Lithuania, the Netherlands, Russia, Slovakia, Slovenia, South Africa, Spain, the UK, and the USA.

3 Activity profile

First we calculated the population index. The procedure involved a calculation of average differences lm-m, where lm is the limiting stellar magnitude and m is the magnitude of a meteor, and subsequent conversion into the population index. The full description of the method and conversion tables are given in (Arlt, 2003). Following this procedure we obtained a population index of $r = 1.90 \pm 0.04$ for $\mathrm{lm} \geq 5.5$, based on available 978 magnitude estimates.

For the ZHR calculations we used a mean Taurid radiant position of $\alpha = 52^{\circ}\!.0$ and $\delta = +17^{\circ}\!.9$ (for November 5, $\lambda_\odot = 222°$) with an averaged daily drift of $\Delta\alpha = +0^{\circ}\!.82$ and $\Delta\delta = +0^{\circ}\!.18$. This simplified ephemeris is based on the radiant positions recently derived by Triglav-Čekada and Arlt (2005). One may ask whether this linear drift for the combined branches is too much of a simplification. If more accurate radiant positions are used, the question of which radiant position was adopted by each individual observer also arises. We believe that a more sophisticated radiant ephemeris will not improve the reliability of the results significantly, unless one goes back to the original meteor positions and analyzes these. The ZHR profile was calculated using a standard IMO procedure:

$$\overline{\mathrm{ZHR}} = \frac{1 + \sum_i n_i}{\sum_i \frac{T_{\mathrm{eff},i}}{C_i}}, \tag{1}$$

where n_i is the individual number of shower meteors observed during a time period $T_{\mathrm{eff},i}$, and C_i is the total correction for a limiting magnitude lm, field obstruction factor F, and the radiant elevation h_{R}:

$$C_i = \frac{r^{(6.5-\mathrm{lm})} F}{\sin h_{\mathrm{R}}}. \tag{2}$$

For the sake of simplicity, we have not applied other radiant-height corrections such as $\sin^\gamma h_{\mathrm{R}}$ with $\gamma \neq 1$. Individual perception coefficients were all taken to be unity. Data discrimination according to $C_i \leq 5$ as usually, was applied. The error margins were estimated as

$$\Delta\mathrm{ZHR} = \frac{\overline{\mathrm{ZHR}}}{\sqrt{1 + \sum_i n_i}}. \tag{3}$$

Figure 1 shows the activity profile of the Taurids. Most of the data points in the ZHR-profile plot were calculated using a 1° bin size; only in marginal cases, where the data was not sufficient, we used an average over 2° in solar longitude. Although there is a good observational coverage of the entire Taurid activity window, there is an open gap in the data points between $\lambda_\odot = 202°$ and $\lambda_\odot = 212°$. The very few observations available at that time were much constrained by the full moon, and hence did not produce any meaningful data. Another paucity of data affects the time around the maximum at $\lambda_\odot = 220 - 221°$.

The plotted ZHR-profile clearly shows an enhanced Taurid activity with $\mathrm{ZHR} \geq 10$ for the solar longitude interval within $\lambda_\odot = 215-228°$ (see also tabulated ZHR values in Table 1). The highest Taurid activity with

Table 1 – Activity profile of the 2005 Taurids around their maximum. n_{obs} is the number of observers, n_{int} is the number of observing intervals, N_{TAU} is the number of Taurid meteors.

Date		$\lambda_\odot$	n_{obs}	n_{int}	N_{TAU}	ZHR
Oct	29	215.80	5	7	59	9.0 ± 1.2
Oct	29–30	216.75	10	24	153	8.4 ± 0.7
Oct	30	217.51	6	8	67	9.1 ± 1.1
Oct	31	218.50	5	7	54	12.1 ± 1.6
Nov	1–2	219.62	2	4	35	15.3 ± 2.6
Nov	4–5	222.57	10	26	171	13.3 ± 1.0
Nov	5–6	223.66	7	20	126	10.8 ± 1.0
Nov	6–7	224.47	7	10	47	7.1 ± 1.1
Nov	7–8	225.55	3	4	19	12.1 ± 2.7
Nov	8–9	226.63	8	17	106	7.3 ± 0.7
Nov	9–10	227.67	3	10	60	8.0 ± 1.0
Nov	10–11	228.59	2	3	16	10.5 ± 2.6
Nov	11–12	229.56	4	6	24	7.5 ± 1.5

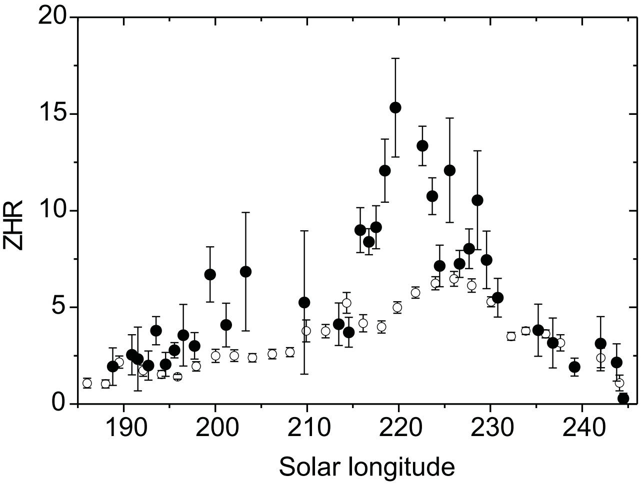

Figure 1 – ZHR profile of the 2005 Taurids (full circles) and the annual activity curve, compiled from the observations in 1997 and 1999 (open circles).

Figure 2 – A bright Taurid meteor photographed by R. Balčiūnas nearby Ignalina, Lithuania at $19^{\mathrm{h}}43^{\mathrm{m}}$ UT, October 31. The bright lights near the horizon are from an aurora seen at the time.

ZHR $= 15.3 \pm 2.6$ was recorded on the night of November 1/2 ($\lambda_\odot = 219\overset{\circ}{.}6$), almost a week earlier than the 'traditional' Taurid maximum. It is worth remembering that local maxima of the Southern and the Northern counterparts of the shower are near November 5 and November 10, respectively, so altogether producing an extended maximum, centered on November 7/8 (Rendtel *et al.*, 1995). An annual Taurid activity curve in Fig. 1 is added for a comparison, as derived from the VMDB records of 'ordinary' years 1997 and 1999, showing a flat 'traditional' maximum with ZHR $= 6.5 \pm 0.4$ at $\lambda_\odot = 226°$.

4 Fireballs

The Taurid meteor shower is famous for its bright and numerous fireballs. Beech *et al.* (2004) have proved that enhanced fireball activity is indeed linked to so-called 'swarm years'. Therefore something special was expected in 2005. Indeed, numerous fireballs were recorded during the 2005 Taurid return. Observers from the Polish Fireball Network captured two fireballs on the night of October 30 and a sequence of six brilliant Taurid fireballs (magnitudes -7 to -10) that occurred in a short period of time between $22^{\mathrm{h}}55^{\mathrm{m}}$ UT and $01^{\mathrm{h}}00^{\mathrm{m}}$ UT on the night of October 31/November 1 (Olech, 2005). Another brilliant fireball of magnitude -15 was photographed by the same Network at $20^{\mathrm{h}}19^{\mathrm{m}}$ UT on November 4. Unusually high fireball activity has also been detected by the American observers and casual witnesses on Halloween night, October 31 (Drobnock, 2005). These observations, of course, provide just a fragmented picture and more detailed analysis on the fireball activity should be done, however it seems to be well linked to the enhanced visual rates.

Magnitude records gathered by visual observations also show a high proportion of fireballs and bright meteors in the 2005 Taurid meteor shower. The calculated population index of $r = 1.90$ is significantly lower than the average for the Taurids, as the main sources based on long-term observations provide a typical value of $r = 2.30$ (Jenniskens, 1994; Rendtel *et al.*, 1995). In

2005, 190 Taurids of the total 978 reported with magnitude estimates, had magnitudes of 0 and brighter, and 43 of them might be classed as fireballs (brighter than or equal to -3). The vast majority of bright meteors and fireballs (147 and 36, respectively) appeared within the two-week interval of enhanced shower activity with ZHR ≥ 10 within $\lambda_{\odot} = 215-228°$. In Fig. 2 is presented a photograph of a bright Taurid casually captured by Ričardas Balčiūnas in Lithuania, while taking pictures of the northern lights, visible on that evening.

5 Conclusions

In conclusion, the year of 2005 has brought a nice display of the Taurid meteor shower in good agreement with Taurid swarm predictions by Asher and Izumi (1998). Exceptional fireball activity has been witnessed worldwide, being a typical signature of a Taurid 'swarm year'. Moreover, IMO observers reported an enhanced activity of visual Taurid rates as well, extending for more than two weeks with ZHR ≥ 10 in the solar longitude interval of $\lambda_{\odot} = 215 - 228°$ (October 28 – November 11). A high proportion of bright Taurid meteors has to be noted, and is reflected by an unusually low population index of $r = 1.90$. Preliminary analysis based on the available data suggests the maximum on $\lambda_{\odot} = 219^{\circ}\!.6$ (November 1/2) with ZHR $= 15.3 \pm 2.6$, which in fact is a week earlier and two times stronger than the 'traditional' maximum of the annual Taurid meteor shower.

References

Ahn S.-H. (2003). "Meteors and showers a millennium ago". *Mon. Not. R. Astron. Soc.*, **343**, 1095–1100.

Arlt R. (2003). "Bulletin 19 of the International Leonid Watch: population index study of the 2002 Leonids". *WGN*, **31:3**, 77–87.

Asher D. (1991). *The Taurid meteoroid complex.* PhD thesis, New College, Oxford.

Asher D. J. and Izumi K. (1998). "Meteor observations in Japan: new implications for a Taurid meteoroid swarm". *Mon. Not. R. Astron. Soc.*, **297**, 23–27.

Asher D. J. and Steel D. I. (1998). "On the possible relation between the Tunguska bolide and comet Encke". *Planet. Space Sci.*, **46**, 205–211.

Babadzhanov P. B. (2001). "Search for meteor showers associated with near-earth asteroids. I. Taurid complex". *Astron. Astrophys.*, **373**, 329–335.

Beech M., Hargrove M., and Brown P. (2004). "The running of the bulls: a review of Taurid fireball activity since 1962". *The Observatory*, **124**, 277–284.

Bone N. M. (1991). "Visual observations of the Taurid meteor shower 1981–1988". *J. Br. Astron. Assoc.*, **101**, 145–152.

Clube S. V. M. and Napier W. M. (1984). "The microstructure of terrestrial catastrophism". *Mon. Not. R. Astron. Soc.*, **211**, 953–968.

Drobnock G. J. (2005). "Electric and acoustic effects of bolides". *WGN*, **33:6**, 147.

Jenniskens P. (1994). "Meteor stream activity. I. The annual streams". *Astron. Astrophys.*, **287**, 990–1013.

Jones J. (1986). "The effect of gravitational perturbations on the evolution of the Taurid meteor stream complex". *Mon. Not. R. Astron. Soc.*, **221**, 257–267.

Klačka J. (1995). "The Taurid complex of asteroids". *Astron. Astrophys.*, **295**, 420–422.

Klačka J. and Pittich E. M. (1998). "Origin of the Taurid meteor stream". *Planet. Space Sci.*, **46**, 881–886.

McBeath A. (1999a). "On the occurrence of bright Taurids". *WGN*, **27:1**, 53–56.

McBeath A. (1999b). "SPA Meteor Section results: September–October 1998". *WGN*, **27:3/4**, 209–214.

Olech A. (2005). "IMO-News mailing list at `imo-news@yahoogroups.com`".

Olsson-Steel D. (1987). "Asteroid 5025 P-L, comet 1967 II Rudnicki, and the Taurid meteoroid complex". *The Observatory*, **107**, 157–160.

Rendtel J., Arlt R., and McBeath A., editors (1995). *Handbook for visual meteor observers.* Potsdam, IMO.

Steel D. I., Asher D. J., and Clube S. V. M. (1991). "The structure and evolution of the Taurid complex". *Mon. Not. R. Astron. Soc.*, **251**, 632–648.

Triglav-Čekada M. and Arlt R. (2005). "Radiant ephemeris of the Taurid meteor complex". *WGN*, **33:2**, 41–58.

Whipple F. (1940). "Photographic meteor studies. III The Taurid shower". *Proc. Amer. Phil. Soc.*, **83**, 711–745.

Taurid activity 1988 – 2005

Carl Johannink [1] *and Koen Miskotte* [2]

We present an activity profile of the Taurid meteor stream between 1988 and 2005, based upon visual observations by members of the DMS and IMO. These observations show up to 50% higher activity in resonance years in the first week of November ($\lambda_\odot \sim 220°$–$225°$ (2000.0)), as predicted by Asher & Izumi (1998). Our analysis suggests that the increase originates primarily from the Southern Taurid branch.

Received 2006 Jan 14

1 Introduction

Asher and Izumi (1998) showed that, as a result of a 7:2 resonance between comet 2P/Encke and Jupiter, the Earth crosses a denser part of the Taurid meteor stream (Table 1).

In this article we will focus on the encounters in November and the consequences for Taurid activity in the years between 1988 and 2005.

2 Reduction of visual data

The Dutch Meteor Society (DMS) has been active since the late seventies with photographic and visual observations. The Taurids have had our attention ever since, because it is well known that this stream sometimes produces bright fireballs (Figure 1 and back cover).

To create a visual activity profile of this stream over a long period, we selected visual observations from the DMS-database in the period 1988 – 2005, limited to years with only slight disturbance from the Moon. This reduced our search to the years 1988, 1989, 1991, 1994, 1996, 1997, 1999, 2000, 2002 and 2005. This does not include the resonance years 1995 and 1998. A Full Moon in the first week of November caused bad observing conditions in these years. Nevertheless some bright Taurids were photographed by members of the Dutch Meteor Society during their Leonid campaign in 1995 November (Figure 2).

Table 1 – Swarm encounters predicted by Asher & Clube (1993). ΔM is the difference in mean anomaly form the modelled centre of the resonant swarm (*op cit*).

Year (June)	ΔM	Year (Nov)	ΔM
1975	1	1978	23
1982	25	1981	−18
1985	−17	1988	5
1992	7	1991	−36
1995	−34	1995	29
1999	30	1998	−13
2002	−11	2005	11
2009	13	2008	−30

Figure 1 – A really brilliant picture of a Taurid, taken on 1981 November 8 at $03^h21^m38^s$ UT by Klaas Jobse, Oostkapelle. This Taurid reached a brightness of magnitude −12. Picture taken with an $f = 35$ mm, $f/2.8$ lens. Film : Kodak Tri-X. A rotating shutter was used (25 breaks per second).

As a result, the different 'swarm encounters' predicted by Asher & Clube in 1993, and the 'Asher-Izumi-model' in 1998, could not be tested with new visual observations until now. We excluded from these data observations made under LM < 5.75. For all DMS observers we know from their observations of sporadic activity in August their specific observer dependent perception correction factor C_p. This factor enables us to normalise the counts from different observers as described by Jenniskens (1994). This makes a good comparison possible between various years and different observers. Additionally, we searched for data in the IMO database (see `www.imo.net`) in the years mentioned above. We used a sample from all available Taurid observations. Only observers with Taurid data in at least one resonance year and at least two non resonance years (and also with LM > 5.75) were taken into account.

Furthermore, for reasons given earlier, we derived for these observers from their sporadic rates in August their value of C_p from

$$C_\mathrm{p} = n_\mathrm{spo} 3.4^{6.5-\mathrm{LM}} / T_\mathrm{eff} \qquad (1)$$

If we could not determine sporadic rates in August of an observer, or if the C_p for an observer varied significantly from year to year, we neglected these observations or observers. This resulted in data from the DMS and IMO observers shown in Table 2.

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IMO bibcode WGN-341-johannink-taurids
NASA-ADS bibcode 2006JIMO...34....7J

Table 2 – List of observers 1988 – 2005. BETHA (Hans Betlem, NL), BIEJE (Jean Marie Biets, BE), DIJSI (Sietse Dijkstra, NL), JENPE (Peter Jenniskens, NL), JOBKL (Klaas Jobse, NL), JOHCA (Carl Johannink, NL), KLUAN (Andre Kluitenberg, NL), KOSRA (Ralf Koschack, DE), LANMA (Marco Langbroek, NL), LEUPE (Peter van Leuteren, NL), LIGMA (Marc de Lignie, NL), LUNRO (Robert Lunsford, US), MCBAL (Alistair McBeath, UK), MISKO (Koen Miskotte, NL), RENJU (Jürgen Rendtel, DE), ROGPA (Paul Roggemans, BE), SCHAL (Alex Scholten, NL), VANMC (Michel Vandeputte, BE).

Code	C_p	1988	1989	1991	1994	1996	1997	1999	2000	2002	2005
BETHA	0.8	√									
BIEJE	0.7										√
DIJSI	1.0										√
JENPE	1.0		√								
JOBKL	1.0										√
JOHCA	1.2	√	√					√	√	√	√
KLUAN	1.0	√									
KOSRA	1.2	√	√	√		√		√			
LANMA	1.4						√	√	√	√	
LEUPE	1.0										√
LIGMA	1.0	√									
LUNRO	0.9	√		√	√	√	√	√	√		
MCBAL	1.4	√		√		√		√		√	
MISKO	1.2	√		√		√	√	√	√	√	√
RENJU	1.1	√	√	√	√	√	√	√	√	√	√
ROGPA	1.1	√	√	√							
SCHAL	1.0	√									√
VANMC	1.0							√		√	√

Table 3 – Distribution of visually observed numbers of NTAs and STAs, as numbers and percentages.

Resonance years:												
	1988				1991				2005			
	NTA	STA	%NTA	%STA	NTA	STA	%NTA	%STA	NTA	STA	%NTA	%STA
< Nov 1	9	11	45	55	59	53	53	47	39	52	43	57
Nov 1–7	109	78	58	42	85	109	44	56	44	96	31	69
> Nov 7	15	11	58	42	75	54	58	42	44	31	59	41

Non resonance years:				
	Total			
	NTA	STA	%NTA	%STA
< Nov 1	32	59	35	65
Nov 1–7	145	136	52	48
> Nov 7	164	117	58	42

Table 4 – Photographic results from the DMS database (Betlem *et al.*; see `www.dmsweb.org`).

Code	Year	Month	Day	Stream	M_V	RA		DEC		Geocentric		Quality
						Value	Tol	Value	Tol	RA	DEC	
1988032	1988	Nov	2.9713	STA	−1	53°.51	0°.34	15°.76	0°.21	53°.44	14°.38	4
1988033	1988	Nov	3.0035	STA	−4	51°.97		18°.34		51°.54	17°.11	3
1988035	1988	Nov	3.7977	SPO	−5	299°.16	0°.12	41°.05	0°.06	293°.67	0°.15	9
1988036	1988	Nov	4.0566	SPO	−1	130°.91		62°.23		131°.31	62°.38	0
1988037	1988	Nov	4.9162	STA	−3	52°.54		17°.12		52°.92	15°.55	1
1988038	1988	Nov	4.9387	STA	−1	53°.49		16°.18		53°.58	14°.91	7
1988039	1988	Nov	4.9977	STA	−3	54°.35		15°.80		53°.81	14°.54	7
1988041	1988	Nov	5.0026	STA	−4	54°.87	0°.02	15°.97	0°.02	54°.36	14°.79	9
1988042	1988	Nov	5.0269	STA	−2	53°.56	0°.20	14°.77	0°.20	52°.83	13°.37	8
1988043	1988	Nov	5.1042	STA	−1	56°.28		16°.52		55°.01	15°.11	4
1988044	1988	Nov	21.0355	NTA	−3	70°.39		28°.35		69°.59	27°.50	7

Figure 2 – Another Taurid captured with a Canon T70 camera on Kodak Tri-X film. This picture was taken on 1995 November 17, in a 'swarm' year according to Asher & Izumi.

All observations were combined per night per year, after which we calculated ZHRs with the formula

$$\mathrm{ZHR} = n(\sin h)^{-\gamma} r^{6.5-LM} C_{\mathrm{p}}^{-1} / T_{\mathrm{eff}} \qquad (2)$$

with γ defined as 1.4 (Jenniskens,1994). We used $r = 2.3$ as used by IMO (Rendtel *et al.*, 1995). The results are shown in Figure 3.

Before $\lambda_\odot = 220°$ (2000.0) the activity in all these years does not show much difference, although there are few observations in the resonance years 1988 and 2005 available for this period. One point of 2005 with ZHR ~12 near $\lambda_\odot \sim 216°$ is from one observer. But between $\lambda_\odot = 220°$ and 225° (roughly the period of November 1–7 every year) the activity in the resonance years 1988 and 2005 showed an increase of ~50% compared with non-resonance years, e.g. 1997. One year is of special interest: the activity in 1991 is clearly lower than in 1988 or 2005, but higher than in other years. 1991 is a resonance year, but with a value of $\Delta M = 36°$. According to D. J. Asher (pers. com.; Asher & Clube, 1993), the highest concentration of particles in the swarm can be expected roughly up to a value of $\Delta M = 30°$. That means that 1991 could be a 'near miss' resonance year. In non-resonance years, the Taurid ZHR is $\sim 6 \pm 2$ with only two exceptions in the year 1999. At $\lambda_\odot = 232\overset{\circ}{.}3$ (November 15) ZHR = 12, and at $\lambda_\odot = 233.3$ (November 16) ZHR = 9, but both are based on observations made by one observer with T_{eff} just over 1 hour. Before and after this time in 1999 we find ZHR ~ 4. Therefore we think these points should be taken with some care.

We also looked at the distribution of Southern and Northern Taurids in the data we used. Therefore all observed periods were broken up into three intervals: the first period before November 1, the second period between November 1 and 7 (the period where we found higher activity in resonance years), and the last one

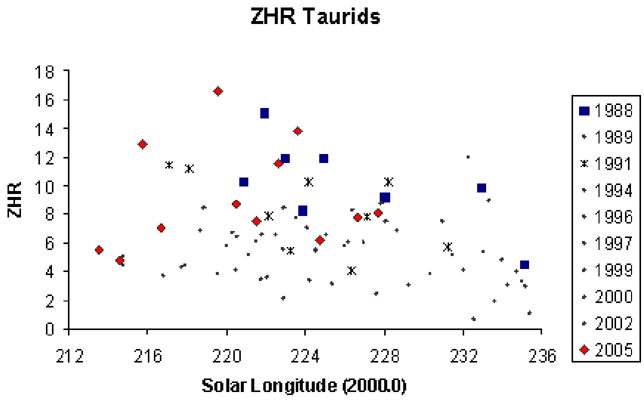

Figure 3 – Taurid activity in various years.

after November 7. We counted all NTAs and STAs in these periods (see Table 3).

In 2005 about 2/3 of all visual observed Taurids in the second period were STAs and, from the photographic data in 2005, all five photographed Taurids were STAs (for example the fireball Koen Miskotte captured on November 5/6; see the back cover of WGN 33:5). In 1991 we also saw more STAs than NTAs in the second period, but this could also be a result of the fact that the STAs have their regular peak on November 5. In non-resonance years, though, there were slightly more NTAs than STAs in this period. In 1988 there were more NTAs in the second period (based on observations by one observer), but on the other hand the DMS photographic database in this period showed eight simultaneous photographed Taurids, all of them STAs (Table 4).

In non-resonance years we do not see an abundance of STAs in the second period at all, so we wonder whether the STAs are responsible for the higher activity in resonance years. Further observations in the years to come should confirm this idea. At this point it may be interesting to note that in 1920 (also a resonance year according to Asher & Izumi) William F. Denning pointed out that the majority of the 'considerable number of fireballs' which appeared in early November came from a Taurid shower at RA = 59°, DEC = +12°; and in a 1924 article he pointed out that the Southern Taurids exhibited 'marked variation in strength in different years' (Kronk, no date).

3 Conclusion

From the data used from DMS and IMO observers it is clear that Taurid activity is significantly higher in resonance years in the first week of November. We think the STAs are the main contributors to this increase. Further observations are needed to prove this.

Acknowledgements

Thanks to all observers for their data and to Marc de Lignie, Peter Bus and Jaap van 't Leven for their comments on this article.

References

Asher D. and Clube S. (1993). "An extraterrestrial influence during the current Glacial-Interglacial". *Q.J.R. Ast. Soc.*, **34**, 481 – 511.

Asher D. and Izumi K. (1998). "Meteor observations in Japan: new implications for a Taurid meteoroid swarm". *Mon. Not. R. Ast. Soc.*, **297**, 23 – 27.

Jenniskens P. (1994). "Meteor stream activity I, The annual streams". *Astron. & Astrophys.*, **287**, 990 – 1013.

Kronk G. (no date). `www.comets.amsmeteors.org`.

Rendtel J., Arlt R., and A. M. (1995). *Handbook for visual meteor observers*. IMO monograph no. 2. IMO, Potsdam.

Taurids 2005: results of the Dutch Meteor Society

Koen Miskotte [1] *and Carl Johannink* [2]

The Dutch Meteor Society (DMS) was successful in monitoring the activity of the Taurid meteor shower during October / November 2005. Both visual and photographic observations indicate that the Taurid activity was above normal with many bright meteors, as predicted by Asher & Izumi (1998).

Received 2006 January 3

1 Introduction

Taurid activity is ruled by a 7:2 resonance between comet Encke and Jupiter. Asher & Izumi (1998) showed that as a result every 3.5 year a denser part of the Taurid stream crosses the Earth's orbit. The year 2005 would be the next chance to see possibly more and brighter Taurids than in non-resonance years. Bright and relatively mild weather permitted observers of the DMS to observe the Taurids during many nights between October 26 and November 9. Photographic results were obtained by the authors, Jaap van 't Leven and mainly by Klaas Jobse, who runs a digital all-sky camera in the southwestern part of the Netherlands (see `http://cyclops.klaas-jobse.net/`).

2 Visual observations

In 63.2 hours of net observing time we obtained results for 378 Taurids (Table 2). Activity was above normal with some bright fireballs on most nights. For example, during the night of November 5/6 observers in Lattrop, Bussloo, Gildehaus (Germany) and Ronse (Belgium) saw at least 5 fireballs of magnitudes −4, −6, −8, −5 and −4.

We calculated ZHRs with the formula

$$\mathrm{ZHR} = \frac{n r^{6.5-\mathrm{LM}}}{(\sin h)^{\gamma} C_{\mathrm{p}} T_{\mathrm{eff}}} \qquad (1)$$

With γ taken as 1.4 (Jenniskens, 1994).

From the magnitude distributions (Table 3) we derived $r = 2.27$ in the interval $[-2, 5]$. This is very close to the IMO value from previous years (Rendtel *et al.*, 1995). The C_{p} of the observers is derived from the number of sporadic meteors seen around local midnight in August. A standard observer is defined as seeing 10 sporadic meteors in average during these hours. C_{p} is then

$$C_{\mathrm{p}} = n_{\mathrm{spo}} 3.4^{6.5-\mathrm{LM}} / T_{\mathrm{eff}} \qquad (2)$$

According to our results between $\lambda_{\odot} \sim 220°$–$224°$ (equinox 2000.0) the Taurid ZHRs were about 50% above average (Table 1 and Figure 1).

3 Photographic observations

During our observations, several CANON 10D cameras were successful in recording Taurid trails. Klaas Jobse photographed 17 Taurids with magnitudes −2 to −9 in the period October 21 to November 19 (Table 4).

4 Conclusion

The Taurid-campaign from the Netherlands was very successful. Activity during the first week of November was up to 50% above the normal level reported by IMO and DMS, and the Taurids showed many bright meteors. The forecast of Asher & Izumi was confirmed.

Acknowledgements

Thanks to all observers for their data and to Marc de Lignie for his comments on this article.

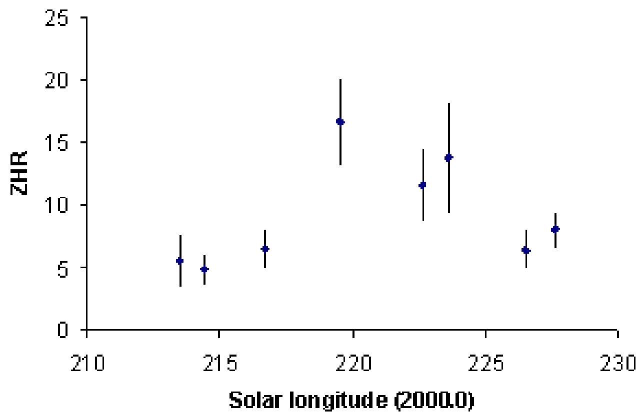

Figure 1 – Taurid ZHRs plotted against solar longitude.

Table 1 – Taurid ZHRs, with solar longitude $\lambda_{\odot}$ and standard deviation σ, calculated as $\sigma = \mathrm{ZHR}/\sqrt{(n)}$, where n is the number of meteors observed.

$\lambda_{\odot}$ (2000.0)	ZHR	σ
213.5	5.5	2.1
214.4	4.8	1.3
216.7	6.5	1.5
219.5	16.6	3.4
222.6	11.6	2.8
223.6	13.8	4.4
226.5	6.4	1.6
227.6	8	1.4

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IMO bibcode WGN-341-miskotte-taurids
NASA-ADS bibcode 2006JIMO...34...11M

Date	IMO code	Observer	T_{eff}	LM	STA	NTA	TAU	ORI	LMI	LEO	SPO	Total
October 12/13	JOBKL	Klaas Jobse	1.00	6.2			2				9	11
October 26/27	VANMC	Michel Vandeputte	2.00	6.5	0	0	7	3		0	20	30
October 27/28	MISKO	Koen Miskotte	3.15	6.5	7	8	1	8	1	0	44	69
	VANMC	Michel Vandeputte	3.25	6.6	4	4	2	7		0	36	53
October 29/30	MISKO	Koen Miskotte	3.72	6.4	11	7	2	12	1	0	52	85
	VANMC	Michel Vandeputte	3.17	6.7	7	4	4	10		0	50	75
November 01/02	MISKO	Koen Miskotte	2.53	6.4	16	6	2	2		0	26	52
November 04/05	BIEJE	Jean Marie Biets	3.50	6.2	0	0	16	2		2	7	27
	DIJSI	Sietse Dijkstra	3.75	6.1			23	3		2	15	43
	JOBKL	Klaas Jobse	1.00	6.4			3				10	13
	JOHCA	Carl Johannink	2.00	6.0	0	0	9	0		1	16	26
	MISKO	Koen Miskotte	2.40	6.6	12	3	6	4		4	35	64
	VANMC	Michel Vandeputte	2.30	6.5	13	5	1	1		0	23	43
November 05/06	JOBKL	Klaas Jobse	1.00	6.4			2				8	10
	JOHCA	Carl Johannink	1.40	6.0	0	0	10	0		0	9	19
	LEUPE	Peter van Leuteren	0.50	6.1	0	0	6	0		0	1	7
	MISKO	Koen Miskotte	2.23	6.4	11	4	8	3		0	26	52
	SCHAL	Alex Scholten	4.11	6.1	5	15	0	0		0	23	43
	VANMC	Michel Vandeputte	5.00	6.7	27	8	6	3		1	77	122
November 08/09	JOHCA	Carl Johannink	2.03	6.2	0	0	6	0		0	15	21
	MISKO	Koen Miskotte	3.13	6.6	7	7	5	3		3	41	66
	VANMC	Michel Vandeputte	5.00	6.7	12	15	5	0		2	67	101
November 09/10	VANMC	Michel Vandeputte	5.00	6.7	10	19	3	0		10	61	103
Total			63.2		142	105	129	61	2	25	671	1135

Table 2 – All observations during this Taurid campaign by DMS observers. (LMI: Leo Minorids (Jenniskens, 1994, p.1007)).

Figure 2 – Klaas Jobse's all-sky camera equipment. Photo: Klaas Jobse

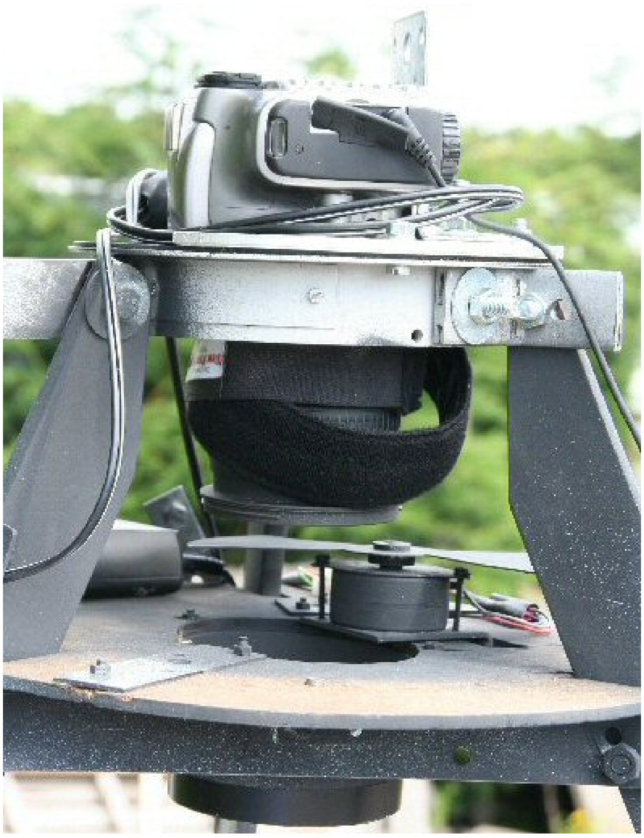

Figure 3 – Detail of the camera of the all-sky camera equipment. Photo: Klaas Jobse.

References

Asher D. and Izumi K. (1998). "Meteor observations in Japan: new implications for a Taurid meteoroid swarm". *Mon. Not. R. Ast. Soc.*, **297**, 23 – 27.

Jenniskens P. (1994). "Meteor stream activity I, The annual streams". *Astron. & Astrophys.*, **287**, 990 – 1013.

Rendtel J., Arlt R., and A. M. (1995). *Handbook for visual meteor observers.* IMO monograph no. 2. IMO, Potsdam.

Table 3 – Magnitude distributions of the Taurids observed by DMS observers. N: number of Taurids observed. $\overline{m}$: mean magnitude.

Night	Observer	≤ -6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	N	$\overline{m}$
Oct. 12/13	JOBKL								1	1					2	1.5
Oct. 26/27	PUTMI				1				1		5				7	1.86
Oct. 27/28	MISKO					1		2	2	1	2	6	2		16	2.63
Oct. 27/28	PUTMI				1		1		1	1	2	3	1		10	2.2
Oct. 29/30	MISKO						2	1	1	3	4	6	3		20	2.8
Oct. 29/30	PUTMI							1	4	7	1	2			15	1.93
Nov. 01/02	MISKO	1				1	1	1	1	7	4	6	2		24	2.17
Nov. 04/05	BIEJE					3	1		1	2	2	5	2		16	2.13
Nov. 04/05	DIJSI						1	2	5	9	4	1	1		23	1.87
Nov. 04/05	JOBKL							1		1	1				3	1.67
Nov. 04/05	JOHCA						1	1	1	2	2	2			9	2
Nov. 04/05	MISKO							1		5	7	5	3		21	3.14
Nov. 04/05	PUTMI				1			2	2	5	3	6			19	2.21
Nov. 05/06	JOBKL										1	1			2	3.5
Nov. 05/06	JOHCA			1		1			1	1	2	4			10	1.9
Nov. 05/06	LEUPE	1					1	1	1	1	1				6	−0.17
Nov. 05/06	MISKO	2		1						2	7	9	2		23	2.39
Nov. 05/06	PUTMI	1	2	3	1	2	1	1	1	11	8	8	2		41	1.29
Nov. 05/06	SCHAL	1		1	1	1	1	1	2	6	4	1	1		20	0.95
Nov. 08/09	JOHCA							1		1		3	1		6	3.17
Nov. 08/09	MISKO							2	2	5	4	5	1		19	2.58
Nov. 08/09	PUTMI	1			1	1	1	2	3	7	8	8			32	1.91
Nov. 09/10	PUTMI							1	2	11	6	12			32	2.81

Table 4 – Photographic results from Klaas Jobse. Taken with a 36 cm diameter mirror from Dieter Heinlein. A CANON 300D camera is placed at a height of 90 cm above the mirror. With this digital camera, the speed setting shows the equivalent film speed. Using an $f = 45$ mm lens, this apparatus is able to photograph the whole sky. See Figures 2 and 3.

Nr	Date	Time (UT)	Classification	Camera		
				Speed	Exposure	Aperture
1	2005 October 21	22^h46^m	TAU -8	ISO 800	124 s	$f/3.5$
2	2005 October 26	04^h06^m	SPO -3	ISO 800	124 s	$f/3.5$
3	2005 October 26	04^h39^m	SPO -8	ISO 800	124 s	$f/3.5$
4	2005 October 27	01^h50^m	SPO -5	ISO 1600	180 s	$f/3.5$
5	2005 October 28	04^h41^m	TAU -3	ISO 1600	180 s	$f/3.5$
6	2005 November 1	01^h26^m	TAU -5	ISO 1600	180 s	$f/4.0$
7	2005 November 2	23^h20^m	TAU -2.5	ISO 1600	180 s	$f/4.0$
8	2005 November 3	01^h51^m	TAU -6 (flare)	ISO 1600	180 s	$f/4.0$
9	2005 November 3	21^h14^m	TAU -4 (flare)	ISO 1600	180 s	$f/4.0$
10	2005 November 3	21^h45^m	TAU -1.5	ISO 1600	180 s	$f/4.0$
11	2005 November 3	21^h45^m	SPO -5	ISO 1600	180 s	$f/4.0$
12	2005 November 3	22^h50^m	TAU -9	ISO 1600	180 s	$f/4.0$
13	2005 November 4	18^h17^m	TAU -2	ISO 1600	180 s	$f/4.0$
14	2005 November 4	23^h19^m	TAU -3	ISO 1600	180 s	$f/4.0$
15	2005 November 5	22^h53^m	TAU -4	ISO 1600	180 s	$f/4.0$
16	2005 November 6	00^h21^m	TAU -5	ISO 1600	180 s	$f/4.0$
17	2005 November 6	$00^h31^m50^s$	TAU -7	ISO 1600	180 s	$f/4.0$
18	2005 November 8	22^h12^m	TAU -4 (flare)	ISO 1600	180 s	$f/4.0$
19	2005 November 8	22^h58^m	SPO -4	ISO 1600	180 s	$f/4.0$
20	2005 November 9	23^h18^m	TAU -4 (flare)	ISO 1600	180 s	$f/4.0$
21	2005 November 10	04^h10^m	TAU -4	ISO 1600	180 s	$f/4.0$
22	2005 November 10	04^h24^m	TAU -4 (flare)	ISO 1600	180 s	$f/4.0$
23	2005 November 19	00^h17^m	SPO -3	ISO 800	124 s	$f/4.0$

Ongoing meteor work

The meteors from 73P/Schwassmann-Wachmann 3 in 1930 and 2006

Rainer Arlt [1] *and Jérémie Vaubaillon* [2]

Observations of meteors from the disintegrated Comet 73P/Schwassmann-Wachmann 3 reported in 1930 are reviewed and considered highly doubtful, the maximum found by simulations being certainly missed. The shower is also called the τ-Herculids. Numerical particle simulations show no evidence for enhanced activity of the shower in 2006.

Received 2006 February 23

1 Visual data and the 1930 event

The orbit of Comet 73P/Schwassmann-Wachmann is sufficiently close to that of the Earth that it may cause a meteor shower. Discovered in May 1930, the Comet became particularly interesting when it showed a dramatic increase in brightness during September and October 1995. What happened was that the object broke up into pieces of which at least three were optically separated first in December 1995. The actual breakup occurred much earlier, most likely even before the brightening of the comet (Sekanina et al. 1996).

A comprehensive account of the historical observational records was given by Lüthen et al. (2001). We would like to review the questionable report of 1930 here with some details. We use comprehensive citations of the Japanese sources, since they are not easily accessible in today's astronomical libraries. A prediction of the radiant of the meteors of Schwassmann-Wachmann 3 was given in the Bulletin of the Kwasan Observatory of the Kyoto Imperial University, Japan (henceforth called 'Kyoto Bulletin' (Kyoto, 1930)) No. 171 of May 14.

Along with an approximate orbit and an ephemeris for the Comet, a radiant position at $\alpha = 15^{\rm h}38^{\rm m}$, $\delta = +44^\circ$ was predicted (note that the position was wrong and was corrected in Kyoto Bulletin No. 173). The closest encounter was computed for June 9.7, at 0.0086 au. After this was published, an immediate 'discovery' of a new shower was reported in Kyoto Bulletin No. 172 of May 23. Details appeared in Kyoto Bulletin No. 173: 'In Bulletin 172 it was announced that a splendid display of new special meteors was observed on May 21 by Mr. T. Miyazawa and several other members of the Kwasan Observatory. The number of those meteors was estimated as many as 14 in 68 minutes through variable clouds (or, 11 in 25 min. or, 100 or over by Mr. Nakamura) so that it was impossible to record all of them.'

Because of the rapid decline of activity in the subsequent nights, it was concluded that these meteors were not caused by 73P/Schwassmann-Wachmann 3, whose closest orbital encounter was expected more than two weeks later, for June 9/10. Kyoto Bulletin 174 reports on the observations on that night for which the prediction held: 'These expected showers of meteors were successfully observed by Mr. K. Nakamura and others at the Kwasan Observatory mostly on June 9 and 10.' We cannot rely on the fact that other witnesses saw the event, since the Bulletin says about Nakamura that he 'was practically the sole observer of this rich display owing to the faintness of the meteors.' The event was actually reported by *a single* observer. Nakamura must have had an unusual eyesight as it is said that 'almost all of those meteors were very faint, and only a few of them were as bright as 4th magnitude.' One may conclude that meteors of magnitude +5 and +6 were most abundant.

The Bulletin further reports 'that bright moon light was always interfering the field observers. Moreover, clouds and mists were frequently visiting the Observatory during the season, and that especially so on the critical nights of June 9 and 10 when bright lunar haloes were high above the southern horizon.' Even an observer with extremely good vision will not be able to see an abundance of +5 and +6 meteors under such unfavourable conditions. This and the fact there is no backup observer leads us to the assumption that there was no outburst of τ-Herculid activity observed in 1930.

However, the story is even more complicated, since numerical simulations of particles of Comet 73P/Schwassmann-Wachmann 3 do show a concentration of meteoroids on June 8.3–8.4. The same date and time were found from dust trail computations by Lüthen et al. (2001) and more extensive particle simulations by Wiegert et al. (2005) caused by the 1880, 1886 and 1892 trails. The timing is about one day before the observation of Nakamura. The (Japanese) night of June 8/9 was apparently cloudy at Kwasan Observatory as there is no report about that night, but of other nights.

We may also assume that the Kwasan observatory received a lot of criticism on the observing report as Bulletin 174 contains an appendix in which I. Yamamoto defends the meteor observations of the 'specialists'. How special K. Nakamura's observations were was shown already in his observations of the 1921 June Boötids which later led to the assumption there was an outburst of meteors. The meteors he plotted were listed by Yamamoto & Nakamura (1922); we plotted them in Figure 2. Many of the meteors start within

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IMO bibcode WGN-341-arlt-schwasswach
NASA-ADS bibcode 2006JIMO...34...15A

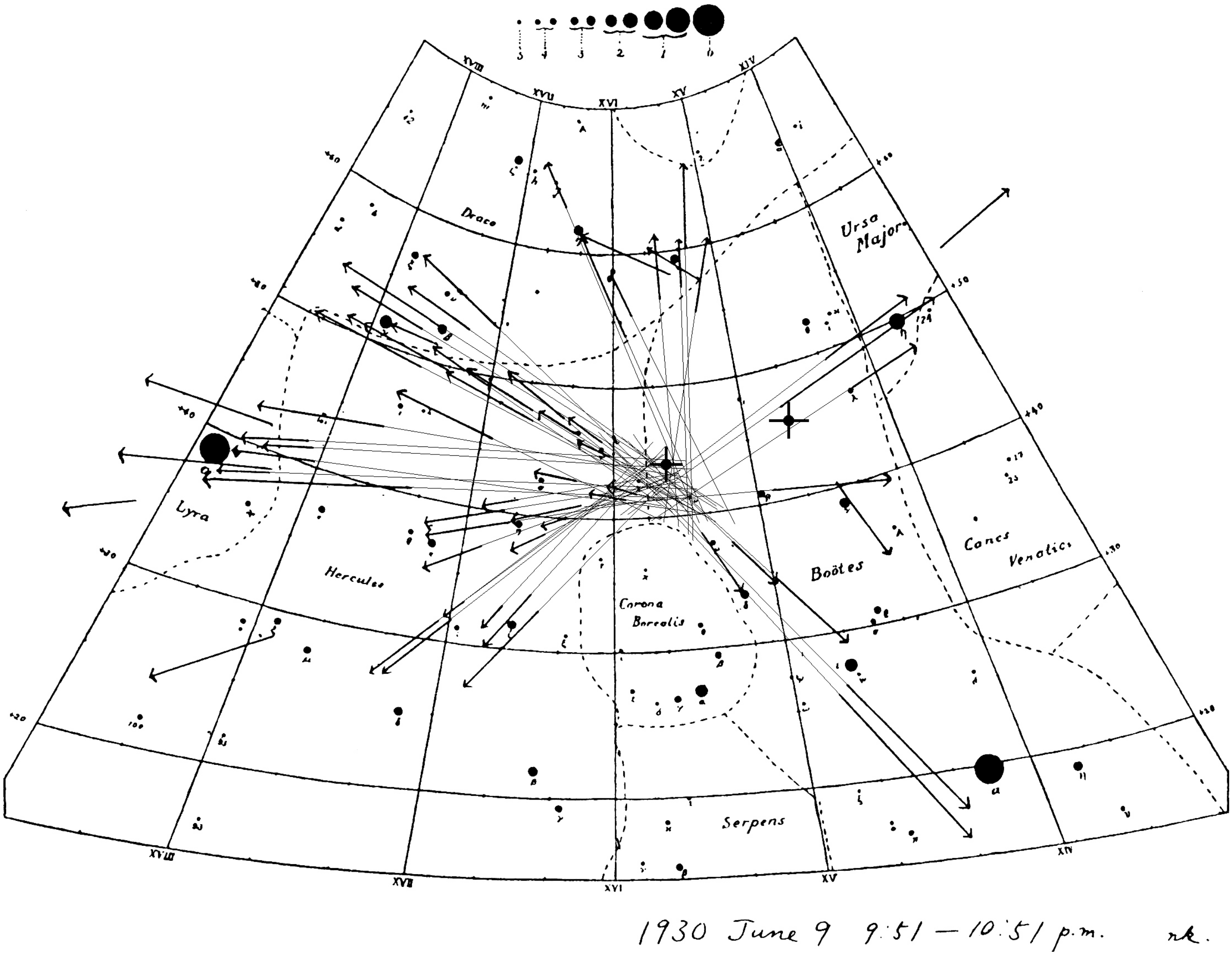

Figure 1 – Meteor positions reported by Kaname Nakamura for the 1930 τ-Herculids. We have added backward prolongations to the original figure by Nakamura (1930). We also plotted the prediction of the radiant according to the knowledge in 1930 (left cross) and according to present knowledge of the Comet's orbit and its evolution (right cross).

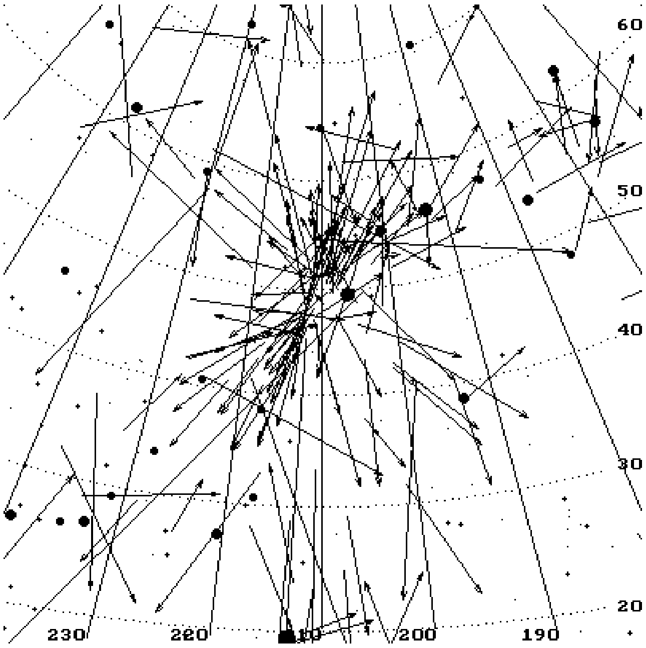

Figure 2 – Meteor positions reported by Nakamura for the alleged 1921 outburst of the June Boötids. The meteor positions are taken from Yamamoto & Nakamura (1922).

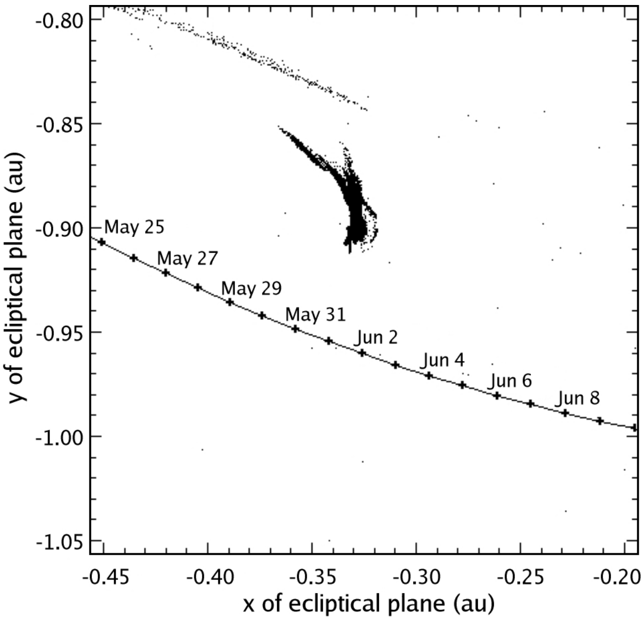

Figure 3 – Distribution of orbital nodes of simulated particles for 2006. The curve with dates on it is the Earth's orbit. The particles were ejected at the perihelion passages of 1801 and later (after Wiegert et al., 2005)

the radiant area and move out up to 10°. This is geometrically impossible and indicates limited trustworthiness in the recordings of that observer. However, Nakamura learnt his lesson and plotted Figure 1 for the 1930 Schwassmann-Wachmann-3 event.

The radiant position found by Nakamura was within 2–3° of the predicted one. Despite the low entry velocity of the τ-Herculids, the radiant position was probably little altered by zenithal attraction since the radiant was nearly in the zenith as seen from Japan at that time. Today's better knowledge of the orbital elements of the Comet and their evolution leads to a radiant position which was 10° away from the old estimate. The plots by Nakamura (1930) are shown in Figure 1; we have added backward prolongations to most of the meteors. We also added the radiant prediction of the erratum in Kyoto Bulletin 173 with which Nakamura was actually faced when starting his observations (left cross). The theoretical radiant position in 1930 according to today's knowledge of the Comet and its orbital evolution is the right cross. The Figure indicates that Nakamura was very much led by strong expectations; the difference in positions should have been detectable visually.

The activity in other years must have been very low as far as the time of the year was covered by observations. Weak radiants which may be associated with the τ-Herculids have been reported since the end of the 19th century. A ZHR of 3 may have been reached in 2000 as reported by Japanese observers, but their listed radiant position lies 20° south of the position we assume for the τ-Herculids today ($\alpha = 220°$, $\delta = +46°$, see also Section 2). The activity in 2001 was widely monitored but turned out to be virtually absent (Arlt, 2001).

2 Prospects for 2006

The orbital evolution of particles ejected at all the perihelion passages of the Comet since 1801 was calculated in a computer simulation. All these particles move individually with varying ejection conditions at the comet and various perturbations by other planets. Their orbital nodes where they cross the orbital plane of the Earth are plotted as dots in Figure 3. The curve with dates on it is the Earth's orbit. There is no clump of nodes of particle orbits which lies anywhere near the orbit of the Earth. Very few particles cross the ecliptic at places which are passed by the Earth on June 1–2. They are too few to restrict possible weak activity to these two nights. A monitoring of the period May 28 to June 6 seems more recommendable than promoting a single night. The radiant computed from the position of the particles shown in Figure 3 with the program developed by Neslušan et al. (1998) gives a radiant located at $\alpha = 207°$, $\delta = +31$. This differs significantly from the values in the year 2000.

According to the simulations, the activity level in 2006 must be much lower than in 1930. After the above considerations, the latter return may actually have passed undetected, on June 8, 1930, and we cannot scale the activity level by that return. If the period of interest is monitored in 2006, one should not be misled by the designation of the shower, the τ-Herculids. The radiant is also not at the position shown in Figure 1. It will be located several degrees west of ϱ Boötis, actually a little bit north of the globular cluster M3.

The entry velocity of the particles is extremely slow. At $v_\infty = 16$ km/s, all the meteors appear very slow, much slower than nearly all sporadic meteors, and clearly slower than ecliptical meteors radiating from Ophiuchus/Scorpius at that time of the year. The waxing Moon will be at high declinations and disturb the observations moderately as it sets rather late given its young age.

3 Conclusion

Despite the negative prediction, observations are recommended and should be carried out by plotting all the meteors seen, along with noting estimates of the angular velocity.

References

Arlt R. (2001). "Results of the Schwassmann-Wachmann-3 meteors". *WGN*, **29**, 93–95.

Kyoto (1930). *Bull. Kwasan Obs. Kyoto Imperial Univ.*, **Nos. 171–174**.

Lüthen H., Arlt R., and Jäger M. (2001). "The disintegrating Comet 73P/Schwassmann-Wachmann 3 and its meteors". *WGN*, **29**, 15–28.

Nakamura K. (1930). "On the observation of faint meteors, as experienced in the case of those from the orbit of Comet Schwassmann-Wachmann, 1930d". *Mon. Not. R. Astron. Soc.*, **91**, 204–209.

Neslušan L., Svoreň J., and Porubčan V. (1998). "A computer program for calculation of a theoretical meteor-stream radiant". *A&A*, **331**, 411–413.

Sekanina Z., Boehnhardt H., Kaufl H. U., and Kirkle K. (1996). "Relationship between outbursts and nuclear splitting of Comet 73P/Schwassmann-Wachmann 3". Technical report, JPL Cometary Sciences Group Preprint Series No. 183.

Wiegert P. A., Brown P. G., Vaubaillon J., and Schijns H. (2005). "The τ-Herculid meteor shower and Comet 73P/Schwassmann-Wachmann 3". *Mon. Not. R. Astron. Soc.*, **361**, 638–644.

Yamamoto I., Nakamura K. (1922). *Mem. College Sci., Kyoto Imperial Univ.*, **5**, 277.

SPA Meteor Section: The Leonids 1998–2002 — A Retrospective

Alastair McBeath[1]

Brief reminders of the strong to storm Leonid activities seen between 1998 and 2002 are given, along with a set of commentaries by observers, as a look back on those interesting times. The material was presented as part of a display by the SPA Meteor Section at the inaugural SPA Convention, held in Cambridge, England, in October 2005.

Received 2005 October 15

1 Introduction

This article celebrates one of the most interesting periods in the SPA Meteor Section's history, the five years of strong to storm Leonid activity between 1998 and 2002, associated with the shower's parent comet, 55P/Tempel-Tuttle, returning to perihelion in 1998. Reports published previously in this journal and elsewhere detailed how the Section's observers saw the Leonid events in each of these years. This Retrospective takes a broader look back at these great Leonid years, comprising part of the Section's contribution to the displays at the inaugural SPA Convention in Cambridge, England, on 2005 October 15.

2 The Years in Brief

As a reminder of what occurred in each year, some short notes are given here. From 1998 to 2000 inclusive, the ZHR data was extracted from the IMO global results. All other data was from SPA Meteor Section results, except where noted. Particular emphasis was placed on how the events were viewed from Britain, naturally enough for a UK meeting.

1998: The Great Fireball Night

- Moon new on November 19.
- First peak: ZHR $\sim$ 340 $\pm$ 20, November 17, $01^{\rm h}30^{\rm m}$ UT; many fireballs (about 15–20% of all Leonids) up to magnitude -17!
- Second peak: ZHR $\sim$ 180 $\pm$ 20, November 17, $20^{\rm h}30^{\rm m}$ UT; more faint to ordinary meteors.
- The fireball night of November 16–17 happened the night before the maximum was expected, catching many observers by surprise.
- UK observers in much of Britain away from the north-west saw at least part of the fireballs display under better skies.
- Final SPA Meteor Section visual totals: 10 136 Leonids in 261 observing-hours.

1999: The First Storm

- Moon between first quarter (November 16) and full (November 23).
- Storm peak: ZHR $\sim$ 3400 $\pm$ 100, November 18, $02^{\rm h}02^{\rm m}$ UT; few very bright or very faint meteors.
- Second peak: ZHR $\sim$ 180 $\pm$ 20, November 18, $16^{\rm h}00^{\rm m}$ UT; fairly normal meteor population.
- The storm peak occurred almost exactly as predicted.
- Lucky UK watchers saw amazing storm activity in partly clear skies from northern England to central Scotland.
- Leonid photos and video recordings from two observers in north-east England allowed an excellent Leonid radiant determination from the storm peak.
- Final SPA Meteor Section visual totals: 24 409 Leonids in 155 observing-hours.

2000: Three Peaks

- Moon at last quarter on November 18, in Leo!
- First peak: ZHR $\sim$ 130 $\pm$ 20, November 17, $08^{\rm h}05^{\rm m}$ UT.
- Second peak: ZHR $\sim$ 290 $\pm$ 20, November 18, $03^{\rm h}24^{\rm m}$ UT.
- Third peak: ZHR $\sim$ 480 $\pm$ 20, November 18, $07^{\rm h}12^{\rm m}$ UT.
- The peaks occurred fairly near their predicted times, but all were ill-defined, with normal Leonid populations.
- Better UK skies allowed coverage of good Leonid rates for much of England and parts of south Wales on either November 16/17 or 17/18.
- Final SPA Meteor Section visual totals: 1885 Leonids in 94 observing-hours.

2001: The First Double Storm

- Moon between new (November 15) and first quarter (November 22).
- First storm peak: ZHR $\sim$ 1970$\pm$90, November 18, $10^{\rm h}45^{\rm m}$ UT (North America).

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IMO bibcode WGN-341-mcbeath-leonids
NASA-ADS bibcode 2006JIMO...34...19M

- Second storm peak: ZHR $\sim 2200 \pm 330$, November 18, $18^{h}00^{m}$ to $18^{h}20^{m}$ UT (Asia and Australasia).
- IMO November 18 peak data: Storm 1 = ZHR $\sim 1620 \pm 40$ at $10^{h}39^{m}$ UT; Storm 2 = ZHR $\sim 2830 \pm 70$ at $18^{h}02^{m}$ UT and ZHR $\sim 3430 \pm 90$ at $18^{h}16^{m}$ UT.
- Normal Leonid populations, and peak timings occurred much as predicted.
- Neither storm peak was visible from Britain, but clouds dominated over the UK from November 16 to 19 anyway!
- Final SPA Meteor Section visual totals: 67 251 Leonids in 487 observing-hours.

2002: The Final Double Storm

- Moon full on November 20.
- First storm peak: ZHR $\sim 3180 \pm 80$, November 19, $04^{h}05^{m}$ UT (Europe and North Africa); brighter Leonids preceded this peak.
- Second storm peak: ZHR $\sim 2640 \pm 110$, November 19, $10^{h}45^{m}$ UT (North America); many faint meteors — ZHR recomputed using IMO magnitude data gave 3460 ± 140.
- IMO November 19 peak data: Storm 1 = ZHR $\sim 2510 \pm 60$ at $04^{h}10^{m}$ UT; Storm 2 = ZHR $\sim 2940 \pm 210$ at $10^{h}47^{m}$ UT.
- Storm peaks occurred much as predicted.
- The first storm was seen in better skies across north Wales, northern England and central Scotland, with parts of south-east England. Imaging data allowed an excellent radiant plot from British results alone.
- Final SPA Meteor Section visual totals: 27 585 Leonids in 348 observing-hours.

3 The Leonids recalled

Several of the most active observers who reported data to the Section were kind enough to provide some thoughts on how they remembered these wonderful Leonid years, additional to what was previously published by some of them. These commentaries are given below.

The Leonid Years, by Steve Evans, England

[Steve has been observing meteors for a good number of years, often by photography, but in more recent years by intensified video, and he now operates a video meteor system every clearer night.]

The Leonid fireball night of 1998 was for me the precursor of five years of adventure. At Newmarket, in Suffolk, England, a clear start to a cold night gradually gave way to mist and then fog, eventually lifting to low cloud by the early hours, effectively blotting out the unexpected display of pyrotechnics.

The following day, frustration was replaced by determination and I vowed not miss the strong returns of the following years because of the weather. Whatever the difficulties I would put myself under clearer skies. So, an expedition to the Algarve region of Portugal was mounted in 1999 and an Arizona campaign in 2001 was sandwiched between two trips to Spain.

My travels have always involved participation in multiple-station observation programmes and I have worked with a number of amateur and professional observers. Although realisation of scientific objectives was always the greatest precedent, I had a great deal of fun in wonderful company, which has resulted in enduring friendships.

In 2000, 2001 and 2002 the expeditions were mobile, using motor homes as observing bases. With four adults sharing cramped accommodation for a week at a time, comfort was minimal. Recompense was provided by the opportunity to observe at remote locations free from light-pollution, and life in a 'Campervan' is my strongest memory of the Leonid years.

Another enduring memory is hundreds of hours spent at the PC measuring the meteor trails we were lucky enough to capture. The elation of photographing over 5000 meteor trails in 2001 was soon replaced by the sobering thought of the effort required to measure them. Work was eventually completed in 2003 and I can now happily say that I no longer dream of meteor images on a computer screen!

For me, meteor observing has always been a solitary pursuit. Memories of long hours spent in a sleeping bag on a cold night in spring with few if any meteors are vivid, but the tranquillity of the early morning hours has always appealed. My wish was always to enjoy the same tranquillity but to see lots of meteors. From a residential astronomy centre on the Algarve, the 1999 Leonid return was memorable. Enjoyment was lessened to some extent by the understandably excited chatter of the other guests, but mainly by the attention of a Portuguese TV crew who insisted on interviews at the height of the shower. My dream of seeing a meteor storm in perfect conditions, in solitude, was realised in Arizona in 2001, a truly once in a lifetime experience.

Memories of the Leonids 2002, by Robin Leadbeater, England

[Robin is a relative newcomer to meteor work, as he explains, but has quickly developed an excellent reputation for his video recordings. His most recent success was capturing his first meteor spectrum, from a Perseid fireball on 2005 August 12–13.]

Two-thousand-and-two was a memorable year for me, as it saw an unexpected increase in my leisure time through poor health. Every cloud has a silver lining however, and the result was that I was converted from being a casual observer of the night sky to becoming an avid (my wife might say obsessive!) amateur astronomer.

The Leonids that year were my first chance to view what the experts were promising should be a decent meteor shower and I was hopeful of capturing some of it for posterity using a newly built sensitive CCD camera. The conditions were not going to be ideal however, with a bright Moon, and the weather forecast for the expected peak in the early hours of November 20 was not promising either.

Moonlight streaming in through the window when the alarm went off at 3 a.m. signalled that there was at least some clear sky however, so I duly dragged myself out of bed and set the camera up, aimed at the radiant close to bright Jupiter. The camera looked rather silly perched on the sturdy equatorial mount, a little plastic box with its tiny wide field lens - would it really pick up anything?

I set it running and stood back to enjoy the show. Despite the bright Moon, perhaps two or three meteors a minute were counted, but then just after four a.m. the pace quickened markedly, until for a brief period they were almost overlapping. Wow! This was definitely worth staying up for!

All too soon though, the pace slowed to a trickle and I decided to have a look what I had captured. Success! Forty-three trails had been imaged in just over an hour, and at the height of the storm they were turning up at ten-second intervals. I quickly put a composite image together, posted it on the Internet and retired to bed. Imagine my surprise when I found dozens of congratulatory e-mails next morning! It had been picked up by NASA TV, and used on their broadcast leading up to the radiant rising in the US! The image subsequently appeared on BBC TV and in various magazines and of course a detailed analysis of the results was included in the SPA report. Exciting times and a fascinating insight into a truly global hobby!

Watching the Leonids, by Robert Lunsford, California, USA

[As he explains below, Robert has been meteor observing for a good many years. As most readers here will appreciate, he is currently IMO Secretary-General, but is also Editor of the American Meteor Society's journal *Meteor Trails*.]

I've been watching the Leonids since 1966, and my excitement grew during the 1990s as Leonid activity increased. November 16, 1998, caught the public's attention, when the sky was filled with brilliant Leonid fireballs, many brighter than the full Moon. Most North American observers viewed modest rates, but with the average magnitudes brighter than zero, this display was certainly a surprise and an unforgettable memory to all who witnessed it.

THE year for maximum Leonid activity was expected to be 1999. To enjoy the best, I flew to Germany to view the expected spectacle with some IMO comrades. A weather system forced us to relocate to the mountains north of Malaga, Spain. The bright Moon sank in the west as the Leonid radiant rose in the east, but at first, Leonid rates were dreadfully low, making me fear that my journey might have been in vain. Quite suddenly though, scores of faint Leonids began to appear, and soon Leonids were streaking the sky every few seconds. It was an unforgettable scene as grown men and women were giddy with joy and laughter as though a childhood dream had finally been realized. There were also those who tried to keep reporting the activity by recording only magnitudes, or talking into their cassette recorders. The outburst lasted approximately one hour and my highest rate per MINUTE was 46.

Last quarter Moon interfered with the 2000 Leonids. I stayed close to home and viewed the show from the local mountains. No strong outbursts were expected and none materialized. My highest hourly count was only 14.

A substantial peak was forecast for North America in 2001. I drove to Mt. Lemmon, Arizona, as part of the ground crew for Dr. Peter Jenniskens' airborne-observing Leonid MAC missions. I was to transcribe my data onto tape, and also use a computer mouse to log meteors, so that the results could be posted instantaneously to the Internet. The skies filled with cirrus in the evening and we feared we would be clouded out. We started observing at midnight under partly cloudy skies and several atmosphere-grazing Leonids were seen despite this. Conditions improved later and the Leonids were truly spectacular. Best rates were slightly less than those seen from Spain in 1999, but the 2001 Leonids were much brighter. Near the peak, seven simultaneous Leonids shot in different directions, like the spokes of a wheel! It was a grand night topped off by a champagne toast to all that remained awake.

In 2002, I was lucky to view both Leonid maximums. I was again a member of the MAC team, but this time I flew on NASA's specially modified DC8 aircraft. I viewed the display through goggles attached to intensified video cameras, helping to avoid the problems the full Moon posed for ground-based observers. We were over the eastern Atlantic Ocean for the first Leonid peak, then flew to Greenland, where we saw an impressive auroral display, a first for me! We viewed the second peak over the western Atlantic and North America, finally landing in Omaha, Nebraska. The second peak was slightly stronger than the first, but neither was as intense as in 1999 or 2001.

I feel very fortunate to have witnessed part of all the most recent Leonid outbursts from some exotic locations. Those memories and the new friends I encountered will be forever savored as one of the highlights of my astronomical career.

The Leonids 1998–2002 in Romania, compiled by Valentin Grigore and Andrei Dorian Gheorghe

[Valentin and Andrei Dorian are leading members of the Romanian Society for Meteors and Astronomy — SARM; Valentin was the Society's founder.]

1998 November 16/17:

Flights of light,
whispers of stars,
the sky in the night
embracing the Earth.

(Valentin Grigore)

Near Târgovişte, Valentin Grigore noted about 800 meteors (including almost 200 fireballs!) and took many photos. Next morning, he wrote: 'No stars in the sky, only meteors!' Sometimes, the whole sky seemed to catch fire, as if bombarded by celestial artillery. Three big fireballs lit the sky almost like daylight. The night's last fireball was 30 minutes after sunrise!

1999 November 17/18:

Fragments of fire
from the roar of the Lion —
alarm in the sky.

(Andrei Dorian Gheorghe)

There were clouds, but flashes from above frequently lit them up. Only a SARM mobile expedition (300 km by car) found a very brief clear-sky oasis, and Leonids.

2000 November 17/18:

But you, sweet Leonid gleams
Raising my emotion,
You run too rapidly,
Don't you understand?

(Ştefan Berinde)

Clouds again. Only Ştefan Berinde in Transylvania created a few celestial documents, by taking some Leonid photos.

2001 November 16 to 19:

Manes of lions passing
through jungles of air;
we are breathing light.

(Adrian Sima)

Tens of SARM observers, spread all over Romania, were lucky in observing the Leonids over three consecutive nights. Meteors fell in gusts, undulating silver traces, some atmosphere-grazers, including fireballs, as jewels coming from the sky-treasury (of magnitude -10 and -12, and trails over 160° long).

2002 November 18/19:

'My planetary being
was crying,
avidly drinking Leonids...

(Dan Mitruţ)

Clear skies for many SARM observers again. A few fireballs up to magnitude -8, and over 700 meteors, most during the storm maximum, with over 20 per minute at times. The full Moon in a halo, and Venus, looked on, followed by a rich sunrise ending the fascinating Leonid cycle.

The 2002 Leonid Meteor Storm, by Roy Watson, Scotland

[Roy has been observing with the Meteor Section since March 1992.]

The early hours of 2002 November 19, will be eternally etched in my memory, as then a spectacle of dream-world proportions transfixed me — a Leonid Meteor Storm.

For years I had eagerly anticipated the occasion, but on its eve, I feared I would not get the opportunity of seeing it, as weather forecasts united in painting a picture of gloom — with mist and low cloud to be the order of the night.

It was midnight. True to their word, there was complete cloud cover. With fading hope, I stood, I looked, and willed the clouds away. I tried to imagine just what was actually happening behind the clouds, but the more I thought the more I yearned to witness it for real.

Time was heavy. I took a break from my vigil and came back after half an hour, at 3^h21^m, by which time, to my unquestionable excitement, the clouds had thinned and a clear sky had opened up to reveal its treasures for the night. I had to pinch myself — even though I had witnessed strong meteor activity from Perseid peaks, nothing could have prepared me for what was unfolding before me — it was a meteor storm.

From the constellation of Leo, which stood guard in the eastern sky, dazzling meteors streaked here, there and everywhere. All were very fast and bright, with magnitudes ranging from $+1$ to -3; many were white in colour, some were blue — all had a beauty to themselves. By the predicted peak of 4^h00^m, Leonids were appearing every 15 seconds or so. Like celestial fireworks they lit up the night sky, leaving brief trails in their wake, as they burnt up. If that was not enough, at 4^h35^m, a magnitude -4 Leonid fireball shot overhead, moving in a northwesterly direction, and disappearing behind a range of hills. Stunned, I turned back to Leo and the meteors just kept on coming.

The near-full Moon could do nothing to drown out or dampen the enveloping pageant; in all, it added a deeper sense of mystery and magic to the night. I could do nothing but stand in silent tribute to what was before my eyes.

Sadly, by 6^h00^m, the meteors began to get lost in the morning twilight but I knew I had not lost out on being able to marvel at one of astronomy's greatest sights — a Leonid Meteor Storm!

My view of the 2002 Leonid Storm, by Shelagh Godwin, England

[Shelagh has been observing meteors since she joined the SPA (then the JAS) Meteor Section in 1986. She continues to actively observe, and has been the Section's Assistant Director since 1994.]

The Leonid storms are now behind us. And at long last I managed to see one. The prospect of seeing a storm from this country was initially bleak, with only one group of experts predicting a storm for about 4 a.m. on Tuesday morning, 2002 November 19. However, as the date approached, other experts also came through with fresh predictions. They confirmed the probability of a storm between 3^h50^m and 4^h00^m on November 19. So out I went.

My attempts in previous years to see a Leonid storm had been frustrated by cloud — Peter Ward's mad dash down the M4 motorway west of London in search of clear skies in 1999 is now history in the Guildford Astronomical Society. In 2002, again, I thought the clouds might win when I looked out of the window about $1^{h}30^{m}$. Surely fog had been predicted, not cloud! I remembered seeing a Geminid maximum in 1991 when there was thick fog all around, except near the zenith where the radiant was, and I got a good show.

I went back to bed miserable, but soon after heard a bird singing and thought I could see moonlight through the curtains, so I got up again, got dressed, and went downstairs. To my delight and astonishment the clouds had melted away. For a blissful 45 minutes I watched meteors, mostly Leonids, coming at a rate of two or three every ten minutes, and mostly bright because the Moon had washed out the faint ones. It was nice, but not a storm. Then at $3^{h}20^{m}$, just as the rates appeared to be increasing, the clouds started rolling in from an unusual direction, the south-east. Certainly not forecast and not good. However, there were holes in the cloud and as the critical time of $3^{h}50^{m}$ approached these holes got larger. Then I started seeing bright Leonids in the clouds and through the holes. It was obvious that the rates were much, much higher.

And then, oh joy! At just after 4 a.m. the clouds parted like the Red Sea, leaving a crystal clear sky full of meteors. I must have seen 18 meteors in 10 minutes at least, plus two trains from meteors I had missed seeing. There were probably many more, because I am not good at seeing the fainter objects even in a moonless sky, and I was noting everything down too. Most of the meteors were of zero or brighter magnitude, but I saw no real fireballs (−4 was the brightest I saw that night). And then, at $4^{h}15^{m}$ the clouds rolled in again, and stayed persistently for the next half hour. After they cleared at $4^{h}45^{m}$ there was still a good show of meteors, about 6 every ten minutes. I finally went inside at $5^{h}15^{m}$ when the clouds came in again. But what a night. I was so pleased to have seen a Leonid storm at last. The next chance might not be till 2034 or after!

The Leonids 1998–2002: A Retrospective, by Alastair McBeath

[Written in December 2004]

Were expectations too high?
Was there disappointment later?
Did the storms not fill the skies as you'd hoped?
Were you too occupied by clouds to enjoy the meteors?
Did you complain, even to yourself?

Not me!
For me, the Leonids were a delight in dreadful times.
And a remembrance of my father, now he is gone.
His excitement and enthusiasm
Mirrored mine,
From the great fireball night,
To the crisp storm dawns.
And he was there.
And always will be so.

This year's meteor starburst: Two sporadics at Leonid-time.
But two years ago to the very night, it was three Leonids at the storm's height.
And another; and another; and another, and another, and another; and ANOTHER,
Till the minute was done.
That on a night of fogs, and clouds, and a wonderful, sudden clearance.
A night that earlier had the gothic light of Poe's cloud-shrouded Moon,
That in Maryland was the light of Gaugin.

Three more years back, and the night before.
The clouds, the gaps, the meteors:
The First Storm.

How could there be so much cloud,
Yet still show so many meteors?
Imagining what the clouds hid.
But what was missed, with four Leonids dripping together
From a sliver of starry-cake sky, wrapped in a cloud icing?
Six, six, six, eight;
How many Leonids in four minutes to make our pulses race?
Did we notice the clouds? Or the cold?
No — just the meteors, and each other's joy.

So back to '98; another cloudy night.
But never think November's clouds won't part.
Ask if the Alpha Monocerotids saw Morpeth for the truth of that.

The door opens. Cool air. Clouds.
Step out - a Leonid! A Leonid in clouds!
What the chance? What the brightness to be seen?
And another! I'm still on the step!
Has the storm come a year early, and a night too soon?
Awake now; very awake. Rouse others. Observe.
The clouds are gone, chased by the meteors and the heat of our elation.
Gaze in amazement at a Moon-bright flash,
With a minutes-long train - a line, a curve, a ring.
Meteors making their own clouds of glowing radiance.
The sky lights up with an unseen flare.
No time to fret at that; there are plenty more.
So many fireballs, and trains, and awe, and wonder.
Even into the dawn, another fireball roars,

as the Lion fades.
And is gone.

O tempora, O mores!
A time for Leonids, and the custom of watching them.

4 Conclusion

Those of us fortunate enough to have lived and observed through these five marvellous Leonid years will already realise that we will probably never see the like of such times again. The development of new techniques like video being put to real use for the first time, and the first time such very detailed predictions for meteor shower maxima had been issued (which proved more accurate than we might have hoped), were two of the most outstanding technical achievements. Equally important was the rapid spread of news after the events by e-mail and the Internet, and the IMO's own central role in that, as the analysts pushed themselves to the limits to get almost real-time data analysed and issued electronically. It was quite something to me to send my 1999 storm report off by e-mail, and get a response almost immediately from the IMO Leonid HQ, so even before sunrise on November 18, I already had an idea of how colleagues across Europe had fared earlier that morning. What a time to be a meteor observer!

5 Acknowledgements

The contributions by hundreds of individual observers active and reporting to us from the UK and around the world during the 1998–2002 Leonids, are once again most gratefully acknowledged, as well as those groups which very kindly allowed us free use of their data, notably the American Meteor Society (`www.amsmeteors.org`), the German *Arbeitskreis Meteore* (`www.meteoros.de`), and the Radio Meteor Observation Bulletin observers (`www.rmob.org`). Additional thanks go to those contributors who provided their personal recollections for use here.

Quadrantids

Global forward scatter observations of the 2006 Quadrantid maxima

Jeffrey L. Brower [1]

The radio maximum of the 2006 Quadrantid shower was determined by conducting a global survey incorporating over 5,000 hours of radio forward scatter data. A significant rise in echo activity above the background sporadic counts began at 2006 January 3, $10^{h}00^{m}$ UT and continued into January 4, $06^{h}00^{m}$ UT. The strongest sustained activity levels for raw echo counts occurred during the hours of 19^{h}–22^{h} UT. The maximum mean echo rate occurred during the hour of 19^{h} UT or at $\lambda_{\odot} = 283\overset{\circ}{.}190$–$\lambda_{\odot} = 283\overset{\circ}{.}232$. However, the mean echo duration data showed the maximum was reached during the hour of 18^{h} UT, or between $\lambda_{\odot} = 283\overset{\circ}{.}147$ and $\lambda_{\odot} = 283\overset{\circ}{.}190$. A brief secondary duration peak was noticed at 22^{h} UT. The mean echo duration data is in strong agreement with the predicted peak of $18^{h}20^{m}$ UT. Although the visual observation data are too limited for a definitive conclusion the visual maximum does seem to be co-located near the same general solar longitude as the radio maximum. All epochs are J2000.0.

Received 2006 February 17

1 Introduction

The Quadrantid shower is a short-period stream with a radiant located at an RA of $\alpha = 15\overset{\circ}{.}33$ and a declination of $\delta = +49\overset{\circ}{.}1$. The meteors have an average geocentric velocity of 40.90 km s^{-1}.

The shower has two components. The older outer component is very diffused having been perturbed by Jupiter's gravity over thousands of years. The diffused outer component can be detected by radar up to 4 days either side of the main peak. The inner component is much younger in age with origins around 200–250 (Wiegert & Brown, 2005) to 500 (Jenniskens et al., 1997) years before present. The onset of the younger, inner core's maximum is rapid and the flux curve is fairly narrow in width. The elevated activity level from the inner component last 12 to 14 hour. The inner component was the focus of this paper.

The maximum of the 2006 Quadrantid shower was predicted to peak at $18^{h}20^{m}$ UT on January 3, at $\lambda_{\odot} = 283\overset{\circ}{.}16$. Therefore, the optimum radiant elevations for visual observers occurred during the daylight hours over North America making radio forward scatter observations critical in the recording of the peak.

The IMO shower calendar was consulted (Anon., 2006) prior to the shower. The calendar alerted radio and telescopic observers that mass sorting might cause the fainter members of the stream to reach a maximum up to 14 hours before the brighter, visual or photographic members did. The calendar stated that in the years since 2000 the primary radio maximum could trail the visual maximum by 9 to 12 hours.

A review of the Quadrantid literature showed showed the concepts of mass sorting and temporal offset of radio maxima to the visual maxima are being contended. McIntosh and Šimek (1984) found no strong pattern of mass sorting and at times noted just the opposite trend, with the weaker meteors trailing the brighter.

Canadian radio astronomers using the CLOVAR-ST (Canada London Ontario VHF Atmospheric Radar-Stratosphere-Troposphere) radar site (Brown et al., 1998) and later the Canadian Meteor Orbital Radar (CMOR) near Tavistock Ontario (Wiegert & Brown, 2005) did not see any significant displacement of the radio maximum from the visual maximum.

With this information in mind three goals were set. First establish when the radio peak occurred. The second, determine whether the radio peak preceded the visual peak or not. If it did, then by how much. The third, determine if a radio peak trailed the visual peak this year, and if so, then by how much.

2 The data set

Wiegert and Brown (*ibid*), on page 142 cautioned:

> Even broad all-sky radar systems will show large changes in apparent sensitivity to the radiant on time scales shorter than the duration of the main part of the shower. Hence, any one location making radar observations in any one year is likely to record a peak time which is more a function of the radiant-beam geometry than the true shower flux.

With this caveat in mind a global survey of forward scatter results was conducted. The survey was composed of data from radio observers in Europe, North America, and Asia. The main source of data was collected from the Radio Meteor Observatory's On Line web site (Terrier, 2006). Okamoto's data appeared in the Radio Meteor Observation Bulletin No.150, (Steyaert, 2006). Suzuki's data came from his personal archive page (Suzuki, 2006).

The data from each observer was entered on a spreadsheet and plotted. Data from sites that showed no or weak diurnal curves or appeared to be undersampled were rejected for this study. Also, sites that

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IMO bibcode WGN-341-brower-quadrantids
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Table 1 – Observers' data sets used. R = raw echo counts. RD = Both raw echo counts and duration data. West longitudes are negative. CW = continuous wave carrier, FM = Frequency Modulated carrier.

Observer	Latitude N	Longitude	MHz	Mode	
Algeciras	41°17′	1°15′	48.247	CW	R
Brower	49°50′	-119°33′	61.260	CW	RD
De Wilde	51°14′	-5°06′	49.990	CW	R
Entwistle	53°49′	-2°40′	55.250	CW	R
Knol	53°19′	6°51′	53.739	CW	RD
Nelson	33°26′	-104°30′	88.700	FM	R
Okamoto	35°07′	137°53′	53.750	CW	R
Smith	50°32′	-4°08′	55.250	CW	RD
			62.213	CW	RD
Swan	50°47′	-1°44′	55.250	CW	R
Suzuki	34°49′	137°19′	55.250	CW	R

had good data for the shower period but lacked comparative data from the prior month were not used for this study.

Table 1 shows the observers providing data and their locations.

Nelson's data was corrected from Mountain Standard Time (-7^{h} UT) to UT. Okamoto's and Suzuki's data were corrected from Japanese Standard Time ($+9^{\mathrm{h}}$ UT) to UT as were their UT dates.

3 Methodology

Radio observation data have a unique set of variables that make data reduction difficult. Prime examples of such variables include the unknown geometry of the echo's path, echo heights, various transmitter power levels, wide variability in radio sensitivity and antenna gain, and the employment of different meteor detection algorithms and techniques (e.g. FFT versus broken squelch). It was not surprising that the first look at the raw echo count data did not show any clear trends between the various data sets.

In order to suppress the noise introduced by the variables mentioned above, a technique that was successfully used by Hiroshi Ogawa (Ogawa et al., 2003) during the International Project for Radio Meteor Observation Leonid campaigns was adopted.

Each observers' hourly raw echo counts H were recorded during the period between 2005 December 16 to December 30. By averaging each hour's echo counts during this 14 day pre-storm period an average hourly sporadic background count, H_{o}, was derived for each observer. An activity level nearly zero means there was no increase in echo counts over the background sporadic counts. In other words, no stream activity was detected.

Individual hourly raw echo counts H were also recorded during the period of 2005 December 31 to 2006 January 5. The counts during this period were not averaged.

The average hourly background echo rate activity level, $\mathrm{AL}(H)$, a relative index with no units, was then derived by using Equation 1 for each observer's data set.

$$\mathrm{AL}(H) = \frac{H - H_{\mathrm{o}}}{H_{\mathrm{o}}} \tag{1}$$

After each observer's activity level, $\mathrm{AL}(H)$, were calculated, they were summed with the other observers' data for each hour. The hourly sum was then divided by the number of observers N. The result is the mean hourly activity level of raw echoes, $\mathrm{AL}_{\mathrm{total}}$. $\mathrm{AL}_{\mathrm{total}}$ is a relative index with no units. This procedure is represented in Equation 2, where i is the individual observer.

$$\mathrm{AL}(H)_{\mathrm{total}} = \frac{\sum_{i=1}^{N} \mathrm{AL}(H)_i}{N} \tag{2}$$

After the raw count data was reduced employing Equations 1 and 2, the Activity Level, $\mathrm{AL}_{\mathrm{total}}$, was plotted against a time axis measured in solar longitude.

Raw echo counts are useful during periods of normal and moderate activity but during strong shower outbursts the counts become an inaccurate indicator of activity due to saturation. Saturation occurs when strong overdense echoes mask the weaker underdense echoes. The weaker echoes are not detected by the software so the raw counts are undercounted during periods of intense activity. During strong showers the raw echo counts tend to decline due to this saturation process. See Figure 1 for a spectrogram which shows a saturation condition that occurred on 2006 January 3, between $18^{\mathrm{h}}55^{\mathrm{m}}$ and $19^{\mathrm{h}}00^{\mathrm{m}}$ UT.

Using the total duration of echo reflections yields more accurate information during the highest activity periods. Unfortunately, many radio meteor observers do not record duration data. Therefore, the duration samples were limited to a subset of four data sets. Contributors to the duration data sets are labelled 'RD' in Table 1 above.

The duration data was reduced by employing Equation 1 and 2, as above. The duration Activity Level, $\mathrm{AL}_{\mathrm{total}}$, was plotted.

4 Results of the data reduction

The reduced raw echo count curve shows a sharp rise in echoes beginning during the 10^{h} UT hour period.

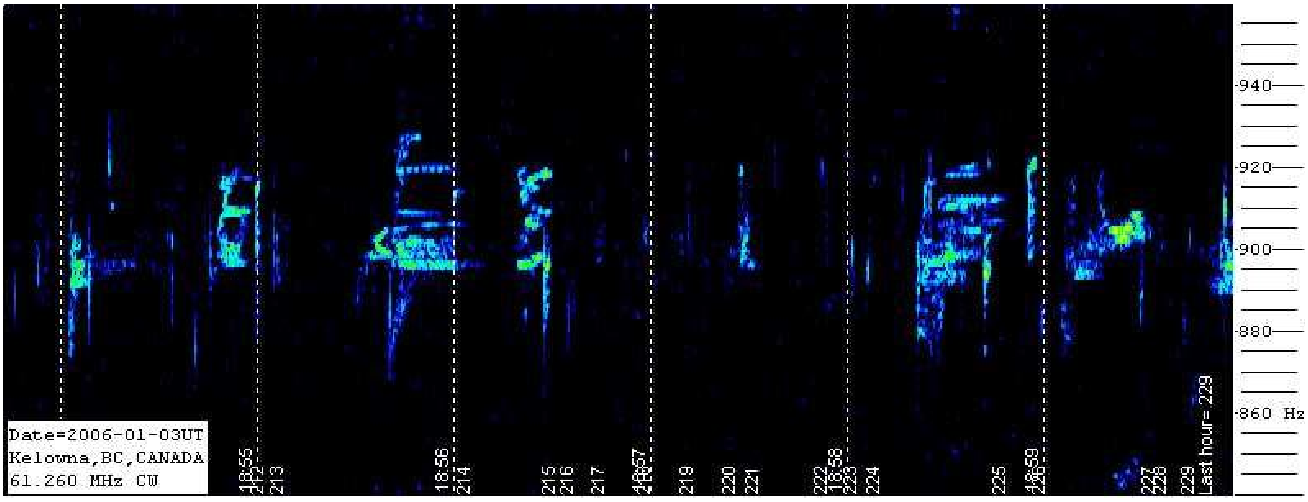

Figure 1 – Spectrogram at 2006 January 3, $18^{h}55^{m}$–$19^{h}00^{m}$ UT. The strong overdense echoes prevent the detection of numerous weaker underdense echoes, thus reducing the true count.

Activity levels of greater than 1 were seen over the next ten hours; $14^{h}00^{m}$ UT until January 4, $00^{h}00^{m}$ UT. An activity level of greater than 1.5 was maintained for 4 hours; from $19^{h}00^{m}$ to $23^{h}00^{m}$ UT.

The highest raw echo activity level, $AL_{total} = 1.69$, occurred during the hour of $19^{h}00^{m}$ UT. This corresponds to a solar longitude range from $\lambda_{\odot} = 283.^{\circ}190$–$283.^{\circ}232$. The second highest activity level, $AL_{total} = 1.65$, occurred during the hour of $21^{h}00^{m}$ UT. A solar longitude range of $\lambda_{\odot} = 283.^{\circ}274$–$283.^{\circ}317$. See Figure 2 for the Activity Level of the raw echo counts.

The mean duration data activity curve shows a small rise in the activity level between $10^{h}00^{m}$ and $14^{h}00^{m}$ UT. A very steep rise in echo duration begins at $16^{h}00^{m}$ UT. The peak duration value, $AL_{total} = 5.79$, was reached sometime during the hour of $18^{h}00^{m}$ UT. This occurred between a solar longitude of $\lambda_{\odot} = 283.^{\circ}147$ and $\lambda_{\odot} = 283.^{\circ}190$. The duration then dropped sharply until the hour of $22^{h}00^{m}$ UT at which time a weaker secondary peak was observed. At that time, the activity level reached an $AL_{total} = 4.8$ between $\lambda_{\odot} = 283.^{\circ}317$ and $\lambda_{\odot} = 283.^{\circ}360$.

Brower recorded duration data in ten minute segments during the shower. His data shows a cluster of high values of AL_{total} index during the period of $22^{h}00^{m}$–$22^{h}40^{m}$ UT. The 10 minute data shows a maximum of this secondary peak was reached some time during the the 20 minute period between $22^{h}10^{m}$ and $22^{h}30^{m}$ UT. The radiant height at this time was 31° above his horizon. Caution must be used as this peak in duration lengths may be inflated by the favourable signal geometry during this period and/or by the fact that it only takes one or two overdense echoes to quickly skew the 10 minute samples.

A small spike in duration was recorded during $18^{h}00^{m}$ UT on January 4; 24 hours after the peak of the shower. See Figure 3 for the reduced duration of echo counts.

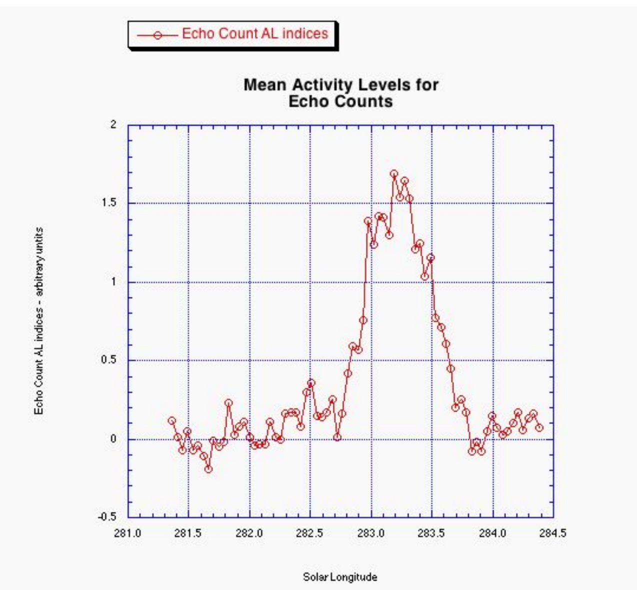

Figure 2 – Plot of mean activity levels, AL_{total}, of echo count data.

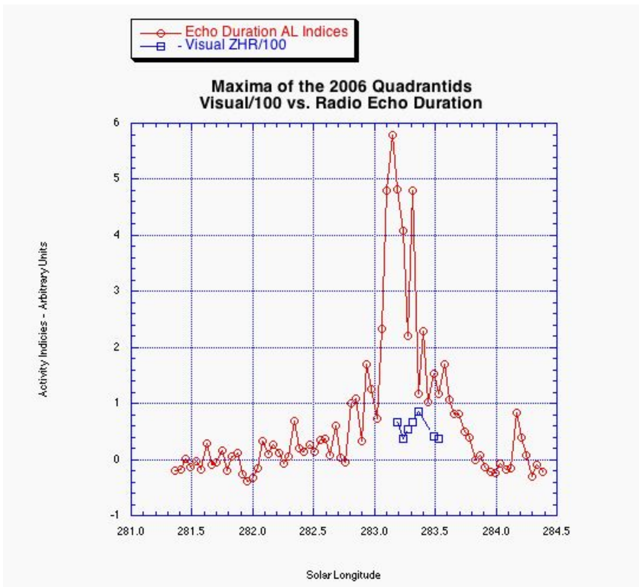

Figure 3 – Plot of mean activity levels, AL_{total}, of echo duration data (circles) and the visual ZHR/100 reported by Arlt (squares).

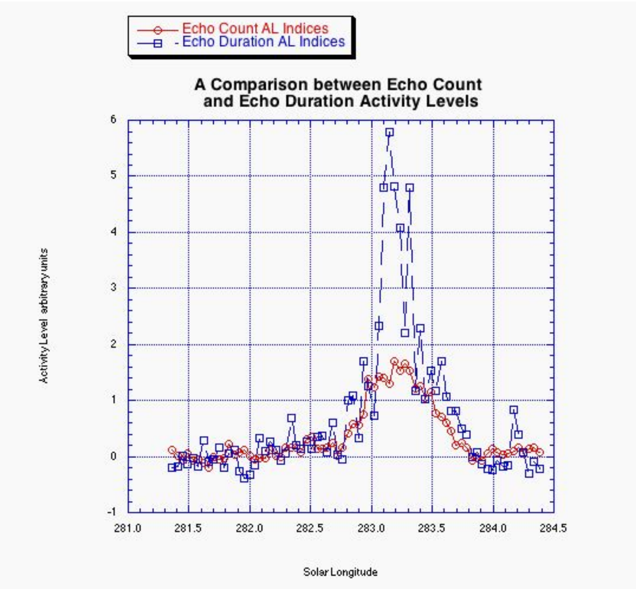

Figure 4 – Comparison curves of mean activity levels of raw count data (open circles) and echo duration (squares).

When the activity level indices are superimposed they are in agreement, showing coherent and parallel trends. Figure 4 provides a comparison of the duration versus raw count curves.

As is often the case for the Quadrantids, visual observations were extremely limited this year. This was due to poor weather conditions as well as the fact the maximum came during the daylight hours for observers with good radiant angles.

In his summary of the 2006 Quadrantids, Arlt (2006) reported a lower than normal ZHR of about 85 at 23^h40^m UT at $\lambda_\odot = 283\stackrel{\circ}{.}389$. This was derived from a total sample of 303 Quadrantids over an effective observing time of 34 hours as recorded by 21 observers. There was a strong secondary high count at 19^h00^m UT at $\lambda_\odot = 283\stackrel{\circ}{.}190$. This coincides with the radio raw echo maximum.

When the meagre visual data is superimposed over the forward scatter duration data it suggests the maxima are in general agreement with each other. However the scant data makes it hard to draw an unambiguous conclusion. See Figure 3.

5 Conclusions

The inner component of the Quadrantid shower is very narrow and short lived. This restricts visual observers with optimal radiant heights to a small longitudinal arc. Unlike visual observers, the observations from forward scatter data are not nearly as constrained. Radio echoes can be detected as the radiant approaches horizon and even when it is slightly below the horizon. With the exception of Okamoto of Japan, located at a latitude of 35°N, the Quadrantids were a circum-polar target for the forward scatter observers in this study. This allowed for a more continuous coverage of the short inner component of the shower.

Three goals were set. The first was to determine when the radio peak occurred. Both the raw echo activity index as well as the duration activity index show a parallel rise and fall in their AL_{total} curves. The mean raw count maximum of the inner component occurred during the hour of 19^h UT. This is at least 40 to 100 minutes after the forecasted peak time. But as noted above, raw counts are suppressed during periods of intense peak activity through due to a process called saturation. It may be more significant to note that the mean echo duration index, AL_{total}, reached a maximum some time during the hour of 18^h00^m UT. This coincided with the forecasted peak at 18^h20^m UT.

The second goal was determine whether the radio peak preceded the visual peak, and if so, by how much. Unfortunately the visual data are too small to draw any definitive conclusions as to whether the radio peak came before or after the visual peak. Only one visual observer, Uchiyama of Japan, was recording at 19^h UT. If however, the 19^h00^m UT 'secondary' high visual ZHR of 60.6 ± 16.8 he recorded was actually the descending side of the missed 18^h20^m UT maximum, then no, the radio peak did not precede the visual peak. They were co-located at the same solar longitude. If however, the 23^h UT peak is taken as the true maximum, then the visual peak trailed the radio peak by some 4 (raw counts) to 5 (duration) hours. Either answer remains speculative as well as unresolved. This goal was not satisfactorily met.

The third goal asked did a radio maximum occur after the visual maximum this year. There was no evidence that supports a radio maximum occurred after the visual peak.

Because of budgets restraints, there are very few full time professional radar sites operating today. However, there are a growing number of dedicated amateurs that do monitor meteor echoes 24 hours a day. The forward scatter data can be of varying quality, but if the proper selection criteria are applied there is a wonderful, under utilized resource of data available for researchers.

Acknowledgements

This study would not have been possible without Pierre Terrier who maintains the Radio Meteor Observatory's On Line web site. Nor would it be possible without the years of dedication that Chris Steyaert has put in as editor of the RMOB and his disposition of data into Terrier's RMOB archives. Chris, along with Pierre, provide the primary means for the amateur radio observer to disseminate his or her data.

Without the individual radio observers there would be no data to analyse. The following long standing contributions to the RMOB data archives deserve my sincere thanks: Enric Fraile Algeciras (Spain) , Gaspard De Wilde (Belgium), David Entwistle (UK), Peter Knol (Netherlands), Stan Nelson (USA), Sadao Okamoto (Japan), Andy Smith (UK), Dave Swan (UK), and Kazuhiro Suzuki (Japan). Also a warm thank you to the visual observers for their data. A special thank you to Andy Smith and Peter Knol who responded quickly to my request for their duration data as well as 10 minute split data for analysis.

References

Anon. (2006). "Shower calendar January to March 2006". http://www.imo.net/calendar/2006/winter.

Arlt R. (2006). "Quadrantids 2006, visual". http://www.imo.net/news/quadrantids2006.

Brown P., Hocking W., Jones J., and Rendtel J. (1998). "Observations of the Geminids and Quadrantids using a stratosphere-troposphere radar". *Mon. Not. Astron. Soc.*, **295**, 847–859.

Jenniskens P., Betlem H., de Lignie M., Langbroek M., and van Vliet M. (1997). "Meteor stream activity V. The Quadrantids, a very young stream". *Astron. Astrophys.*, **327**, 1242–1252.

McIntosh B. and Šimek M. (1984). "Quadrantid meteor shower: A quarter-century of radar observations". *Bull. Astron. Inst. Czechoslov.*, **35**, 14–28.

Ogawa H., Toyomasu S., Ohnishi K., Amikura S., Ashina T., Miyao K., and Maegawa K. (2003). "Leonids 2001 by radio meteor observation all over the world". *The Institute of Space and Astronautical Science Report*, **SP No. 5**, 82–83.

Steyaert C. (2006). "Radio meteor observation bulletin". http://www.rmob.org.

Suzuki K. (2006). "HRO today, February 2006 at Toyokawa Observatory". http://www.tcp-ip.or.jp/~kaze/data/htyk0602.htm.

Terrier P. (2006). "Radio meteor observatory's on line". http://radio.data.free.fr/main.php3.

Wiegert P. and Brown P. (2005). "The Quadrantid meteoroid complex". *Icarus*, **179**, 129–157.

History

Meteor Beliefs Project: Meteoric images from the works of John Milton

Andrei Dorian Gheorghe[1] *and Alastair McBeath*[2]

Meteoric references found in the works of Englishman John Milton (1608–1674) are presented, with some discussion.

Received 2005 December 14

1 Introduction

The great English writer John Milton (1608–1674) lived through turbulent and difficult times, including the English Civil War (1642–1648), followed by the execution of King Charles I in 1649, and various purges and reassemblies of Parliament in the 1650s. The restoration of the monarchy in 1660, with the ascension to the throne of King Charles II, effectively returned a somewhat calmer period to England, but in 1665 plague, and then the Great Fire in 1666, ravaged London, where Milton spent much of his adult life. Throughout all of this, he wrote numerous political pamphlets, which sometimes provoked great controversy, and occasionally even severe personal danger. His anti-monarchist views meant his books were publicly burnt on the restoration of Charles II, and he narrowly escaped execution himself, even so, being jailed from October to December 1660.

His private life was not free from difficulty and tragedy either. After his initial schooling, he studied at Cambridge University, his birth town, from 1625 to 1632, when he moved into six years of scholarly retirement at home, having gained his Master of Arts degree. His mother died in 1637, following which he travelled in Europe, notably Italy, for over a year in 1638–39, returning to a new home in London, where he became a private tutor. His first political pamphlets were published in 1641, and in the summer of 1642 he married 16-year old Mary Powell, who sadly deserted him and returned to her parents less than two months later. She was reconciled with him only in 1645, later bearing him three daughters, Anne (1646), Mary (1648) and Deborah (1652), and a son John (1651), during which period Milton's father died (in 1647). The year of Deborah's birth was a dreadful one. After years of deteriorating sight, Milton became totally blind (something which seems to have counted in his favour when threatened with execution in 1660), his wife died three days after Deborah was born in early May, and then in June, his son John died.

In late 1656, Milton was married again, to Katherine Woodcock, who bore him a daughter, also Katherine, the following autumn. Tragically, both Katherines died in 1658, his wife in February, his daughter in March. After his own close-shave with death by execution, he was married a third time, to Elizabeth Minshull in 1663, who did survive him, but which marriage severely strained relations with his three daughters from his first marriage. Despite all this, he lived on, publishing the first version of his magnificent epic *Paradise Lost* in 1667, then *Paradise Regained* in 1671, followed by a second edition of *Paradise Lost* in 1674, shortly before he died early that November.

From at least his late teenage years, Milton seems to have wanted, and prepared himself, to write an epic work, by consciously following a similar course of learning and preliminary writings to previous epic poets, whose lives and works provided inspiration to him, Virgil (70–19 BC), and the more nearly contemporary Edmund Spenser (circa 1552–1599). There is no question that he achieved his ambition. For more on Milton's life, times and activities, see the relevant notes in our two chief sources here, (Carey & Fowler, 1968) and (Leonard, 2000).

As diligent followers of the Meteor Beliefs Project articles may appreciate, we have referred to items from Milton, at least in passing, before, notably in our first such article (McBeath & Gheorghe, 2003), and in the discussion of meteors in Blake's works (McBeath, 2004). We have expanded on those earlier items here, with other material, and discussion of Milton's probable sources or influences in some cases, where appropriate or relevant. As normal, we would encourage anyone interested to read more fully in the works we merely scratch the surface of here. The texts chosen are presented in datal order, as far as that is known.

2 *On the Death of a Fair Infant Dying of a Cough* (Winter 1625–26)

As promised in our original article in this series, when quoting from Edgar Allen Poe, we firstly return to this poem, written in praise of an unnamed child not a year old, who, as the title clearly states, was dying. The meteoric text is from lines 43–49 of the poem, in Verse VII (Carey & Fowler, 1968, pp. 16–17):

> Wert thou some star which from the ruined
>   roof
> Of shaked Olympus by mischance didst fall;

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IMO bibcode WGN-341-mcbeath-mbp18
NASA-ADS bibcode 2006JIMO...34...30G

Which careful Jove in nature's true behoof
Took up, and in fit place did reinstall?
Or did of late Earth's sons besiege the wall
Of sheeny heaven, and thou some goddess fled
Amongst us here below to hide thy nectared head?

'Earth's sons' refers to the Giants or Titans of ancient Greek mythology, who fought and lost a war against the ruling deities, an intriguing precursor to *Paradise Lost*, which partly revolves around events of another mythological celestial war between the angelic armies of the Christian God and Satan. There is also the suggestion that while falling stars are often used to signify a death, in this case, perhaps Milton wished to have the child's star replaced in heaven to prevent it from dying on Earth.

3 *A Masque Presented at Ludlow Castle* (1634)

In the opening scene of this play, which was set in a wild wood, the character of the Attendant Spirit speaks to the audience, setting the tone for the whole play. Lines 78–82 of this speech (Carey & Fowler, 1968, p. 180) are:

Therefore when any favoured of high Jove,
Chances to pass through this advent'rous glade,
Swift as the sparkle of a glancing star,
I shoot from heaven to give him safe convey,
As now I do...

Here we have the concept of the guardian angelic spirit portrayed as meteoric, something which recurs in elements of folklore found elsewhere, though Milton is using it thus more as an indication of rapid motion.

4 *Paradise Lost* (1667, 1674)

Given the subject matter (the Fall of Satan and the Fall of Man in Christian understanding) of this novel-length epic poem, it is scarcely surprising that most of our Miltonian quotes derive from this source. There is much beside of an astronomical nature in *Paradise Lost*, and the whole should really be read complete for a true appreciation of Milton's genius. In addition, although there are no especially meteoric illustrations among them, it is worth seeking out a copy of John Martin's engravings to this work, for their striking power and clarity in pictorially representing Milton's words (for example, in (Milton, 1833)). Other artists have also depicted elements from Milton, but we have not attempted an overview of those works here.

Straightaway, the poem begins with Satan's defeat, expulsion from heaven, and fall. Book I, lines 44–49 (Leonard, 2000, p. 4):

...Him the Almighty Power
Hurled headlong flaming from th' ethereal sky
With hideous ruin and combustion down
To bottomless perdition, there to dwell
In adamantine chains and penal fire,
Who durst defy th' Omnipotent to arms.

This draws on biblical descriptions of Satan/Lucifer's fall from heaven, including that in *Isaiah* 14:12–15, which was discussed in relation to meteors earlier (McBeath, 1999). Another relevant biblical passage is that in *Luke* 10:18, where Satan falls like lightning from heaven.

Later, once in Hell, Satan has Azazel, a tall fallen angel, bring forth his banner, to lead the army of the fallen ones. Book I, lines 535–539 (Leonard, 2000, p. 16):

Who forthwith from the glittering staff unfurled
Th' imperial ensign, which full high advanced
Shone like a meteor streaming to the wind
With gems and golden lustre rich emblazed,
Seraphic arms and trophies...

This sets the quotation of part of these lines which we featured previously (McBeath & Gheorghe, 2003) in its proper context.

Our next passage refers to the fall from the heavens of Mulciber, recalling Satan's own plunging descent. 'Mulciber' was a name for the ancient Roman god of fire, Vulcanus. Although Vulcanus was the god of destructive fire, his worship was primarily to avert such calamities, from which his title 'Mulciber' derived (Latin *qui ignem mulcet*, 'he who mitigates fire'). Vulcanus/Mulciber was linked closely, at least by Classical times, with the Greek god of fire, blacksmiths and craftsmen, Hephaistos. This duality, of destructive and constructive fire, is illustrated by Ovid's use of Mulciber in his *Metamorphoses* for instance, with Mulciber as master craftsman of the Sun-god's palace in Book II, 1–18, or as the consumer of Hercules' mortal remains on his pyre in Book IX, 262–265. Milton's description of Mulciber's fall was derived from the casting down from Olympus of Hephaistos by Zeus, as found in Homer's *Iliad*, Book I, 591–595, for example. More information and references on Mulciber, Hephaistos and Vulcanus can be found in (Price & Kearns, 2003, pp. 248–249 'Hephaestus' and p. 571 'Volcanus'). The Milton quote is from Book I, lines 740–746 (Leonard, 2000, pp. 21–22):

Men called him Mulciber; and how he fell
From Heav'n, they fabled, thrown by angry Jove
Sheer o'er the crystal battlements: from morn
To noon he fell, from noon to dewy eve,
A summer's day: and with the setting sun
Dropped from the zenith like a falling star,
On Lemnos th' Aegean isle...

It is naturally not coincidental that William Blake used a very similar line in his poem *Milton* to return Milton's spirit from beyond the grave into his own being (*Then first I saw him in the Zenith as a falling star*), as covered earlier in this series (McBeath, 2004).

Bypassing a probable reference to the great comet of 1618, while its head was in Ophiuchus, in Book II, lines 707–711, as it has no substantial meteoric content, we leap forward for our next quote to Book IV, lines 555–560 (Leonard, 2000, p. 88):

> Thither came Uriel, gliding through the even
> On a sunbeam, swift as a shooting star
> In autumn thwarts the night, when vapours fired
> Impress the air, and shows the mariner
> From what point of his compass to beware
> Impetuous winds...

Uriel was one of the heavenly angels, reinforcing the point that angels, whether fallen or not, might also appear meteorically, or with meteoric speed. It is interesting that the autumn is singled out for commenting on this meteoric appearance, as this ties in with the part of the year when meteors are more plentiful in the northern hemisphere generally, suggesting this point may have been commonly known in earlier times. The supposed meteorologically prognosticative powers of meteors in respect of the wind date back to the ancient Classical authors, to which topic we hope to return in a later article.

Lastly from *Paradise Lost*, near the very end of the work (the final line of the poem is number 649 in Book XII), comes a more ambiguous meteoric reference, in its variant meteorological, lower atmospheric, sense, but still with some relevance here. Book XII, lines 626–636 (Leonard, 2000, p. 287):

> ...and from the other hill
> To their fixed station, all in bright array
> The Cherubim descended; on the ground
> Gliding metéorous, as ev'ning mist
> Ris'n from a river o'er the marish glides,
> And gathers ground fast at the labourer's heel
> Homeward returning. High in front advanced,
> The brandished sword of God before them blazed
> Fierce as a comet; whirls with torrid heat,
> And vapour as the Libyan air adust,
> Began to parch that temperate clime...

5 *Paradise Regained* (1671)

Our closing Miltonian selection comes from one of the last major works he published, although its date of composition is not well known. Some commentators have suggested it was written in the 1640s–1650s, which would predate the writing of *Paradise Lost* if so. This is not widely-accepted, however. Book IV, lines 618–621 (Carey & Fowler, 1968, p. 1166):

> But thou, infernal serpent, shalt not long
> Rule in the clouds; like an autumnal star
> Or lightning thou shalt fall from heaven trod down
> Under his feet...

The 'infernal serpent' is of course Satan, while this passage seems again to contain a reference to autumnal meteor activity.

6 Conclusion

Although the meteoric items from Milton's works are relatively few and slight, they provide attractive imagery even so, and draw on previous beliefs and ideas about meteors too. Milton's standing as a poet ensured that some of these items continued to influence other poets into the 19th century at least, and still provide fascination today.

References

Carey J. and Fowler A., editors (1968). *The Poems of John Milton.* Longmans, Green & Co.

Leonard J., editor (2000). *John Milton: Paradise Lost.* Penguin Books.

McBeath A. (1999). "Meteors, comets, and millennialism". *WGN*, **27:6**, 318–326.

McBeath A. (2004). "Meteor Beliefs Project: Meteoric images in the works of William Blake". *WGN*, **32:6**, 161–174.

McBeath A. and Gheorghe A. D. (2003). "Meteor Beliefs Project: Introduction". *WGN*, **31:2**, 55–58.

Milton J. (1833). *The Paradise Lost of John Milton, with Illustrations by John Martin.* Charles Tilt.

Price S. and Kearns E., editors (2003). *The Oxford Dictionary of Classical Myth and Religion.* Oxford University Press.

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Taurid fireball

A Taurid fireball taken on 1981 November 8 at $03^{\mathrm{h}}21^{\mathrm{m}}38^{\mathrm{s}}$ UT by Klaas Jobse, Oostkapelle, the Netherlands. This Taurid reached a brightness of magnitude -12. Picture taken with an $f = 35$ mm, $f/2.8$ lens. Film : Kodak Tri-X. A rotating shutter was used (25 breaks per second).
See the paper on page 7.