journal of the international meteor organization

WGN

39:5
october 2011

Meteor conferences
Estimating meteor rates
April ρ-Cygnids confirmed
June–July video meteors
Meteor beliefs: Year of Meteors

ISSN 1016-3115

WGN Vol. 39, No. 5, October 2011, pp. 121 – 154

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Front cover photo

Bright sporadic fireball, captured on 2011 July 1 at $22^{\mathrm{h}}24^{\mathrm{m}}$ UT by EN95 all-sky station in Benningbroek, The Netherlands. Canon 400D camera equipped with 4.5-mm $f/2.8$ lens set to $f/5.0$ was used for this 88 s exposure at ISO 400. Photo courtesy: Jos Nijland.

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

Cover design Rainer Arlt

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Editorial

Javor Kac

Several great events related to meteors have taken place since the last *WGN* issue. In September, the 30th International Meteor Conference took place in Sibiu, Romania, preceded by two workshops. It was great to meet more than a hundred meteor enthusiasts from 24 different countries. With the schedule packed over three days, full of interesting presentations, and organizers' hospitality, the conference was a very enjoyable event. A detailed report from the Conference is planned for the next *WGN*.

Next was the most anticipated meteor shower of 2011 – the Draconids, occurring on October 8. While different groups making predictions agreed about the time of maximum, the predicted strength of the outburst differed by an order of magnitude. The Draconid outburst realized much as predicted with regards to timing and put on a nice show with ZHR of the order of a couple hundreds. I was lucky to witness the outburst with other observers despite unstable weather at the time of the outburst.

I hope that observers and researchers will report about their outburst observations and analyses in articles submitted to our Journal.

In the end, I would like to apologize to our readers for the late publication of the October WGN.

IMO bibcode WGN-395-editorial NASA-ADS bibcode 2011JIMO...39..121K

From the Treasurer — IMO Membership/WGN Subscription Renewal for 2012

Marc Gyssens

We invite all our members/subscribers to renew for 2012. The fees are as tabulated below. We are happy that we can offer WGN at the same cost as last year. We also continue to offer an electronic-only subscription at 5 euros or 10 dollars less than the standard rate.

IMO Membership/WGN Subscription 2012				
Electronic + paper with surface mail delivery:		€26		US$ 39
Electronic + paper with airmail delivery (outside Europe only):		€49		US$ 69
Electronic only:		€21		US$ 29
Supporting membership:	add	€26	add	US$ 39

It is possible to renew for two years by paying double the amount.

General payment instructions can be found on the IMO's website, at `http://www.imo.net/payment`. Members and subscribers who have not yet renewed will find enclosed a leaflet where these payment instructions are further detailed. Please follow these instructions! Choosing the most appropriate payment method results in low or even no additional costs for you as well as the IMO. The IMO strives to keeping these costs low in order to control the price of the journal!

When you renew, give a few minutes of thought to becoming a **supporting member**. Every year, the IMO helps active meteor workers to attend the annual International Meteor Conference, who would otherwise not have been able to come. Our ability to provide this help depends primarily on the gifts we receive from supporting members!

Another way to help meteor workers with limited funds is to offer them a gift subscription.

We already thank all our members that will renew for their continued trust in our Organization!

One final request: every year, a lot of members renew late. As a consequence, back issues that already appeared have to be sent out to these members. Please support our volunteers in their bimonthly effort to have WGN shipped to you by renewing promptly! Thank you for your understanding and cooperation!

IMO bibcode WGN-395-gyssens-renewals NASA-ADS bibcode 2011JIMO...39..121G

Conferences

First announcement of the International Meteor Conference 2012

Paul Roggemans, Gabriela Vaduvescu and Ovidiu Vaduvescu

The 31st IMC will be organized on the island La Palma of the Canary archipelago, Spain, from 20 to 23 September 2012. The standard IMC fee is set unchanged at 155 EUR. The local organisation is coordinated by Gabriela and Ovidiu Vaduvescu and further supported by an international team (Geert Barentsen, Felix Bettonvil, Valentin Grigore, José Madiedo, Francisco Ocaña González, Paul Roggemans and Casper ter Kuile) and the local officials Ana Castaneda and Carlos Fernandez representing the local "Cabildo Insular" authorities sponsoring the event.

The exceptional location of the 2012 IMC offers plenty of extras to the IMC as brainstorming forum for meteor observers, researchers and theoreticians:

- This IMC precedes the 2012 EPSC which will be organized from 24 till 28 September in Madrid, Spain, on the way home from La Palma for most participants offering both amateurs and professional astronomers the possibility to optimize traveling efforts and costs to attend both the IMC and EPSC.
  See also `http://www.europlanet-eu.org`.
- A holiday package of 4 days will be offered by the Local Organizing Committee preferably prior to the IMC2012 conference. Any other requests for extra days will be treated with pleasure, just let the LOC know about this in advance.
- New moon on 16 September offers plenty of observing opportunity under the fabulous sky of the Canary Islands.
- The possibility is offered to have workshops prior to the IMC at the same favourable conditions of the IMC.
- The IMC excursion will include a visit to the three largest telescopes of the "Roque de Los Muchachos Observatory" (ORM), offering participants the chance to visit the "Gran Telescopio de Canarias" (GTC), actually the largest optical telescope worldwide. Furthermore, a visit is planned at the famous Caldera de Taburiente getting on the edge of the caldera overlooked by the above mentioned observatories.

Traveling costs to La Palma are slightly more expensive for many IMC participants than for past IMCs. So, the faster you register the better for getting the best fee for a non-stop flight Madrid – La Palma, round trip! If we would be able to know as fast as possible the number of the participants and the countries/capital/town where the people come from to La Palma, we would have a very good chance to get a very convenient price for the flight Madrid – La Palma. Even, if we would know approximated the number of potential participants and their respective countries of departure, it would be a huge help in getting the best flight offers.

More information will be made available via the IMC website: `http://www.imo.net/imc2012`, or can be obtained by mail from `imc2012@imo.net`.

IMO bibcode WGN-395-roggemans-imcann NASA-ADS bibcode 2011JIMO...39..122R

Details of the Proceedings of the International Meteor Conference, Barèges, France, 2007

Communicated by Jürgen Rendtel

The IMC 2007 was once again precedeed by a Radio School attended by a dozen participants and followed by the 'Meteoroids 2007 Conference' in Barcelona. This is the main reason why the IMC 2007 was organized in June rather than the usual month of September. This allowed many professionals to join before going to Spain, but also unfortunately prevented many amateurs to attend. The excursion to the Pic-du-Midi observatory was a dream coming true for many people, including professionals!

Usually, the Proceedings of an IMC are produced in a way that they can be sent to the participants before the following conference. For different reasons, this did not work out in the case of the 2007 IMC. For example, some participants prepared presentation to quite similar topics at both conferences, others were too busy to provide us with papers. At some moment, we even assumed that there would be no respective publication at all. However, the Proceedings are not only a summary of presentations shown at the conference, but they also reflect the atmosphere of the meeting to some extent. Hence we publish this volume with long delay, hoping that you enjoy reading it, though.

Those who attended the Conference will already have the Proceedings. Others can order them from the International Meteor Organization: details are in the lower half of the inside back cover of this Journal and on the IMO website `http://www.imo.net/imo/publications`. We are publishing brief details of all IMC 2007 Proceedings papers here.

An Overview of the Meteor Research Program at the University of Western Ontario

Peter Brown

Western Meteor group focusses on answering basic questions about the origin and evolution of small bodies in the solar system. The research program heavily observational, with some theory (orbital dynamics, entry modelling, atmospheric propagation of meteor shocks) These include: origin of meteoroids (comets / asteroids / interstellar and what proportion of each?); origin of meteorites (asteroid belt mostly, but where specifical specifically?); physical structure of meteoroids (bulk density / dustballs what does this say about their origin?). The program also includes flux and interaction of larger meteoroids at Earth (meteorites, breakup in the atmosphere). Like low low-cost sample sample-return missions. A summary of intital results of the camera network is given.

A Permanent Double-station Meteor Camera Setup in the Netherlands

Detlef Koschny, Jonathan McAuliffe, Frans Lowiessen

The network setup is described and some initial results are listed.

Digital All-sky Cameras IV: Sinodial Shutter Design

Felix Bettonvil

In this fourth paper about digital all-sky cameras I describe the design and construction of a new type of shutter for accurate determination of the velocity of meteors. It combines sinodial modulation of the meteor trail with frequency a nalysis for finding the velocity. Two alternatives are discussed.

A New Method for Meteor Entry Dynamics Determination Based on Observations and Results of Calculations

M. I. Gritsevich

A great amount of photographic data of meteoroid trajectories in the Earth's atmosphere has been collected. Most images have been obtained by four fireball networks, which operated in USA, Canada, Europe, and Spain in different time periods. The approximation of the data by theoretical relations makes it possible to obtain additional estimates which do not directly follow from observations. In the present paper, I suggest the algorithm to find such parameters of theoretical relation between the height and the velocity of the bolide motion to fit

IMO bibcode WGN-395-imc2007proc NASA-ADS bibcode 2011JIMO...39..123R

observations along the luminous trajectories. The main difference to the previous works is that the given observations are approximated using the analytical solution of the equations of meteor physics. The model presented in this paper was applied here to a number of bright meteors observed by the Canadadian MORP camera network and to the Benešov bolide, which is one of the the brightest well observed fireballs registered by the European network. The correct mathematical modelling of meteor events in the atmosphere is necessary for further estimates of key parameters, including the extra-atmospheric mass, the ablation coefficient, and the effective enthalpy of evaporation of entering bodies. This information is needed by some applications, namely those aimed to study the problems of asteroid and comet security, to develop measures of planetary defense, and to determine the bodies that can reach the Earth's surface.

Some Remarks on the 2006 Leonid Outburst

Pavel Koten

Leonid meteor shower came back once again in the morning hours of November 19, 2006. Video observations reveal that the maximum activity occurred at 4:40 ± 0:05 UT what was in remarkable agreement with predictions of several theoretical models.

Online Analysis of Visual Meteor Data

Geert Barentsen and Rainer Arlt

Data input made by the obervers using an online report form which immediately stores the data in an online database and sends feedback to the reporting observer. It also allows an on-line generation of activity graphs applying standard procedures.

Details of the Enhanced Orionid Activity in 2006

Jürgen Rendtel

The 2006 Orionids showed significantly enhanced ZHRs up to 60 over three days combined with an unusually low population index r around 1.6. Based on data of 12 012 Orionids observed visually by 58 observers in 389 hours effective observing time we look at details of the data sample and analysis procedures particularly considering the transition between observers of different geographical regions (Rendtel, 2007). Two of the extracted ZHR sub-peaks coincide with minima of r indicating that the particle population between $207\overset{\circ}{.}8$ and $210\overset{\circ}{.}5$ significantly deviated from the average Orionid meteoroids.

Spectroscopic Analysis of Geminid Meteors

Jiří Borovička

I have analyzed 89 spectra of Geminid meteors obtained with image intensified video cameras in 1997–2004. Details of observation techniques and spectra analysis are given. Intensities of lines of Mg, Na, and Fe have been studied. Both Fe and Na lines were found to be fainter relatively to Mg than expected for chondritic composition. Moreover, the Na line intensity varied strongly from meteor to meteor. Based on the low Fe/Mg ratio, similar to other cometary meteoroids, I argue that 3200 Phaethon, the parent body of Geminids, is of cometary origin. Severe loss of Na occurred due to solar heating at the low perihelion distance of 0.14 AU. Varying meteoroid age seems to be the most plausible explanation of varying Na content from meteoroid to meteoroid, although other explanations, such as meteoroid origin in different depths in Phaethon or internal Phaethon inhomogeneities, are possible as well.

An Attempt to Detect Polarization of Meteor Light

Peter Zimnikoval

An attempt for an indirect measurement of polarization of meteor light based on a photographic phenomenon, the so called Weigert effect, was carried out. No secondary polarization of crystals in the photographic emulsion caused by polarized light of meteors was detected.

Observations of the June Boötid Meteor Shower in 2006 from Bulgaria

Valentin Velkov, Galina Gospodinova

We present visual observations of the June Boötids in 2006. Three observers of the Astronomical Club Canopus – Boris Stoilov (STOBO), Vyara Georgieva (GEOVY) and Valentin Velkov (VELVA) – carried out our traditional June Boötid watch in Bolyarci village (27°47′52″ E, 43°04′10″ N) in the period 26–29 June 2006. In 17.67h of effective observing time 133 meteors were recorded, from which 32 were June Boötids, 64 sporadic meteors and 37 belonging to other active showers (Sagittariids, α-Cygnids, λ-Sagittariids and a few daytime Arietids. A low but stable level of the June Boötid activity we registered, was due to the background component of the stream. A radiant position was obtained for the main branch of the Boötid shower.

Observations of the Leonids in 2006 from Bulgaria

Eva Bozhurova, Katya Koleva

We report on results from an expediton to Bolyarci 2006 November 17/18 and 18/19. Boris Stoilov (STOBO), Ivaylo Ivanov (IVAIV) and Valentin Velkov (VELVA) recorded 51 Leonids out of 107 meteors in 7.83 hours of total effective observing time. High activity of the Leonids on 2006 November 18/19 around 4:45-4:48 UT as recorded by other contributors to the IMO data base, was confirmed. Processing the plotted meters using the RADIANT software provided radiant positions of the Leonids, α-Monocerotids, Taurids, and new ι-Aurigid meteor shower.

Observations of Orionids and η-Aquariids in 2006 from Bulgaria

Eva Bozhurova, Desislava Zhivkova

We present observations of the η-Aquariid and Orionid meteor showers collected during observing expeditions. The 2006 May 4–6 expedition with two observers yielded 63 meteors in 4.14 h of total effective observing time. A radiant was derived from 34 η-Aquariids. The October campaign surprised all observers with the unusually high Orionid activity about twice as high as the average. In our analysis we include observing data of Boris Stoilov (STOBO), Natasha Ivanova (IVANA) and Ivan Gradinarov (GRAIV). Based on 107 recorded meteors from which 47 were Orionids seen in 9.8 total effective time for the night of 21/22 October, we obtained a mean ZHR equal to 41.5 assuming a population index $r = 2.0$.

One More Method to Determine Radar Sensitivity

Galina O. Ryabova

A method for obtaining the minimum detectable electron line density and the corresponding characteristic height fo a radar is suggested.

Ten Editions of the Astropoetry Show (Astroshow) at the International Meteor Conference

Andrei Dorian Gheorghe

A collection of contributions to the Astropoetry Shows is given.

Meteor science

Estimating meteor rates using Bayesian inference

Geert Barentsen[1,3], *Rainer Arlt*[2,3], *Hans-Erich Fröhlich*[2]

A method for estimating the true meteor rate λ from a small number of observed meteors n is derived. We employ Bayesian inference with a Poissonian likelihood function. We discuss the choice of a suitable prior and propose the adoption of Jeffreys prior, $P(\lambda) = \lambda^{-0.5}$, which yields an expectation value $E(\lambda) = n + 0.5$ for any $n \geq 0$. We update the ZHR meteor activity formula accordingly, and explain how 68%- and 95%-confidence intervals can be computed.

Received 2011 August 9

1 Introduction

The formula commonly used to estimate the Zenithal Hourly Rate (ZHR) of meteors as given in the Handbook of the International Meteor Organization (Rendtel & Arlt, 2008) and used in many meteor activity graphs (e.g., Arlt & Barentsen, 2006), is given by:

$$\mathrm{E(ZHR)} = \frac{n_{\mathrm{tot}} + 1}{T} \quad \text{with} \quad \sigma = \frac{\sqrt{n_{\mathrm{tot}} + 1}}{T}, \qquad (1)$$

where n_{tot} is the total number of meteors counted in a number of observing intervals ($n_{\mathrm{tot}} = \sum_i n_i$) and T is the observing time weighted by a given correction factor for each interval ($T = \sum_i T_{\mathrm{eff},i}/C_i$).

The use of $n_{\mathrm{tot}} + 1$ rather than n_{tot} often surprises observers, because it yields a ZHR which is larger than zero even when no meteors are observed. Whilst Arlt (1999) already indicated that $n_{\mathrm{tot}}+1$ is used to account for the effects of small-number statistics, this paper will explain the formula in more detail. However, contrary to the earlier publications, we will suggest that $n_{\mathrm{tot}}+0.5$ rather than $n_{\mathrm{tot}} + 1$ is the most appropriate formula.

We will first describe the problem of small-number statistics in §2. We then describe the solution using Bayesian inference in §3, followed by a discussion on the choice of the prior assumptions in §4. In §5 we explain how confidence intervals may be computed, and in §6 we provide examples. Finally in §7 we discuss the effect of correction factors and in §8 we present the conclusions.

2 Problem description

As explained by Bias (2011) in a recent issue of this journal, the *observed* meteor rate often tends to underestimate the *true* meteor rate due to small-number statistics. This may be understood using the following example: if we would attempt to estimate the frequency of winning the lottery based on a small group of 10 players, we are most likely to find that none of these players have ever won and that the winning frequency equals zero. Of course the true probability of winning the lottery is slightly larger than zero, but the quantity cannot reliably be obtained by extrapolating from a small number of players.

An identical effect occurs when the ZHR is extrapolated from a low number of meteors. Indeed, even when zero meteors are observed in an interval of finite length, the true average rate may well have been larger than zero because we know that the interplanetary space is not empty. The observer might have been unlucky, or the interval might have been short with respect to the true rate. Such situation may occur even during major showers, e.g. when computing rates for 1-minute intervals. The ZHR formula must take this into account in order to produce reliable estimates in all situations.

3 Solution: Bayesian inference

A common technique used in statistics to estimate parameters in the presence of sparse data is called *Bayesian inference*. In brief, one constructs a parameterized model which one thinks describes the source of the data. The probability of this model to have produced the data is then computed for each possible set of parameters, taking into account any known prior constraints on the parameters. The resulting set of probabilities is called the posterior distribution, from which expectation values and confidence intervals for the free parameters may be derived.

In our case, the data is the observed meteor rate n (in arbitrary time T). Our only free model parameter is the true meteor rate λ (i.e. ZHR). There are many values of λ which may explain a given n, each having the conditional probability $P(\lambda|n)$. This notation means the probability of finding λ given that one has seen n meteors. This is the posterior probability described earlier which may be estimated using the theorem by Bayes:

$$P(\lambda|n) = \frac{P(n|\lambda)\,P(\lambda)}{P(n)}, \qquad (2)$$

where $P(n|\lambda)$ is the generative model, i.e. the known probability to see n meteors for a given true rate λ. We may assume that meteors appear in a random way following a Poissonian law for independent events:

$$P(n|\lambda) = \frac{\lambda^n e^{-\lambda}}{n!}. \qquad (3)$$

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IMO bibcode WGN-395-barentsen-rates
NASA-ADS bibcode 2011JIMO...39..126B

The function $P(n)$ serves to normalize the distribution to unity, while $P(\lambda)$ expresses what we know about how probable each of the possible true rates λ are. This function is called the prior and, ideally, should be a probability distribution on its own. The challenge is to decide what we can assume about $P(\lambda)$ beforehand?

4 Choice of the prior

The criteria for choosing a suitable prior $P(\lambda)$ is a subject of debate in the statistical community. On one hand, one may decide to construct a prior based on previous evidence, for example the meteor activity in the past decade. This is called an *informative prior.* On the other hand, one may prefer a prior which contains only vague or general information and is not biased towards past observations. This is called an *objective prior.*

Whether or not it is appropriate to include previous observations in the computation of meteor rates is a philosophical question. However, given the intrinsically variable nature of meteor showers, we suggest that an objective prior is the only practical approach. We discuss the choice of such prior in what follows.

4.1 Uniform prior

A natural choice is a uniform prior $P(\lambda)$ = constant, i.e. all values of λ are assumed to be equally likely. A uniform prior leads to a distribution which cannot be normalized, and is called an improper prior. Any limit on ZHR, and be it very high, makes the distribution normalizable though, that is, asymptotically a uniform prior is not a problem.

Let us see what the uniform prior implies for the inferred rate. The expectation value of the true meteor rate is defined as the sum of every possible value of λ times its posterior probability. (In this paper, we also use the terms "average" or "mean" as synonyms for expectation value.) For a continuous quantity such as λ, the expectation value is a normalized integral over all λ which, for a uniform prior, reads:

$$\begin{aligned} \mathrm{E}(\lambda) &= \int_0^\infty \lambda\, P(\lambda|n)\, \mathrm{d}\lambda \\ &= \int_0^\infty \lambda\, \frac{\lambda^n}{n!}\, e^{-\lambda}\, \mathrm{d}\lambda \\ &= (n+1)\int_0^\infty \frac{\lambda^{n+1}}{(n+1)!}\, e^{-\lambda}\, \mathrm{d}\lambda \\ &= n+1. \end{aligned} \tag{4}$$

Similarly, the error estimate for $\mathrm{E}(\lambda)$ follows from the mathematical definition of the variance, often referred to as σ^2:

$$\begin{aligned} \sigma^2(\lambda) &= \mathrm{E}[(\lambda - \mathrm{E}(\lambda))^2] \\ &= \int_0^\infty P(\lambda|n)\, (\lambda - (n+1))^2\, \mathrm{d}\lambda \\ &= \int_0^\infty \frac{(n+1)(n+2)\lambda^{n+2}e^{-\lambda}}{(n+2)!} - \\ &\quad - \frac{2(n+1)^2\lambda^{n+1}e^{-\lambda}}{(n+1)!} + \\ &\quad + \frac{(n+1)^2\lambda^n e^{-\lambda}}{n!} d\lambda \\ &= (n+1)(n+2) - (n+1)^2 \\ &= n+1. \end{aligned} \tag{5}$$

The expectation value of the true activity rate is thus given by $(n+1)$ with spread of the distribution of $\sigma = \sqrt{n+1}$. These quantities are then simply divided by the weighted time T to obtain the ZHR. This explains the formula given in the IMO Handbook.

4.2 Exponential prior

A uniform prior may not be ideal if we want to express the fact that very large rates are very unlikely. Almost all rates ever obtained are below say 1000 meteors per hour. A suitable prior will decrease with rate, and it is mathematically convenient to use power functions like

$$P(\lambda) = 1/\lambda^{1-\alpha}, \tag{6}$$

where $0 \le \alpha \le 1$. Such a power-law has the advantage that we can use Γ-functions for the derivation of $E(\lambda)$. The resulting expectation value now involves the prior and is

$$E(\lambda) = \frac{\int_0^\infty \lambda\, P(\lambda)P(n|\lambda)d\lambda}{\int_0^\infty P(\lambda)P(n|\lambda)d\lambda}, \tag{7}$$

where the lower integral is to normalize the posterior distribution. Now, let's make use of the Γ-functions for which

$$n! = n\Gamma(n) = \Gamma(n+1) = \int_0^\infty \lambda^n e^{-\lambda} d\lambda \tag{8}$$

holds. We do not need to know how Γ is computed, we only need its properties to derive the expectation value:

$$\begin{aligned} E(\lambda) &= \frac{\int_0^\infty \frac{1}{\lambda^{1-\alpha}} \frac{\lambda^n\,\lambda}{\Gamma(n+1)} e^{-\lambda} d\lambda}{\int_0^\infty \frac{1}{\lambda^{1-\alpha}} \frac{\lambda^n}{\Gamma(n+1)} e^{-\lambda} d\lambda} \\ &= \frac{\frac{\Gamma(n+1+\alpha)}{\Gamma(n+1)}}{\frac{\Gamma(n+\alpha)}{\Gamma(n+1)}} \\ &= \frac{(n+\alpha)\Gamma(n+\alpha)}{\Gamma(n+\alpha)} \\ &= n+\alpha. \end{aligned} \tag{9}$$

Similarly, the variance is:

$$\begin{aligned}
\sigma^2(\lambda) &= E\left[\left(\lambda - E(\lambda)\right)^2\right] = \\
&= \frac{\int\limits_0^\infty P(\lambda)P(n|\lambda)\left(\lambda-(n+\alpha)\right)^2 d\lambda}{\int\limits_0^\infty P(\lambda)P(n|\lambda)d\lambda} \\
&= \frac{(n+1+\alpha)(n+\alpha)\Gamma(n+\alpha)}{\Gamma(n+\alpha)} - \\
&\quad - \frac{2(n+\alpha)^2\Gamma(n+\alpha)+(n+\alpha)^2\Gamma(n+\alpha)}{\Gamma(n+\alpha)} \\
&= (n+1+\alpha)(n+\alpha) - 2(n+\alpha)^2 + (n+\alpha)^2 \\
&= n+\alpha. \qquad (10)
\end{aligned}$$

The expectation value of the true activity rate is thus given by $(n+\alpha)$ with a spread $\sigma = \sqrt{n+\alpha}$, for a given prior $1/\lambda^{1-\alpha}$. Again, these priors are normalizable for $0 \le \alpha \le 1$ by enforcing a limitation of the valid range.

One question remains: which is the most appropriate value to adopt for α? On one hand, the uniform prior ($\alpha = 1$) yields the expectation value $n+1$, which is likely to overestimate the meteor rate due to assumption that any arbitrarily large rate is equally likely as the zero rate. On the other hand, the prior $1/\lambda$ ($\alpha = 0$) yields a "traditional" extrapolation $E(\lambda) = n$, which is likely to underestimate the rate as explained previously. It appears appropriate to adopt a prior somewhere in-between $0 < \alpha < 1$.

4.3 Jeffreys prior; $\alpha = 0.5$

The problem of choosing a suitable prior for a Poissonian process exists in other fields (e.g. radioactive decay counts, neutrino detections). An axiomatic solution has previously been proposed by Harold Jeffreys. He required that a prior should be "invariant under reparameterization", i.e. a prior should not depend on the variable investigated (Jeffreys, 1946; Jeffreys, 1961; Kass & Wasserman, 1996). One could, for example, be interested in the rate λ as well as in the mean time between events $\mu = 1/\lambda$. The priors for both expectation values should be compatible. For general relations between different quantities, the requirement of compatibility is written mathematically as

$$P(\lambda)d\lambda = P(\mu)d\mu. \qquad (11)$$

For a Poissonian distribution, such a general compatibility is achieved for a prior $\alpha = 0.5$. In this case, the estimate is not specific to either computing the rate or the mean time lapse or something else.

Because there are no further statistical principles to decide which prior is to be preferred, we suggest the use of Jeffreys prior

$$P(\lambda) = 1/\lambda^{0.5}, \qquad (12)$$

for future estimates of the rate. The expectation value for the meteor rate is then

$$E(\lambda) = (n+0.5) \pm \sqrt{n+0.5}. \qquad (13)$$

An illustration of the posterior distribution $P(\lambda|n)$ under the assumption of Jeffreys' prior is shown in Figure 1 for different values of n.

Note that in most cases, when n is large ($n \gg 0.5$), the differences between the various priors are negligible.

5 Confidence intervals

The standard deviation $\sigma = \sqrt{n+0.5}$ characterizes the spread in the posterior distribution around the expectation value. In the case of a Gaussian distribution, the standard deviation corresponds to a confidence interval (i.e. the 68%-confidence interval of a Gaussian distribution is located between -1σ and $+1\sigma$ from the mean).

However, the posterior $P(\lambda|n)$ does not follow a Gaussian shape and is more similar to a Poissonian distribution (though a Gaussian shape is approached for large n). The posterior is asymmetric with a tail towards high meteor rates, which makes it somewhat misleading to characterize the uncertainty with a single number. A better way to characterize the uncertainty is to compute the (asymmetric) error margins of the 68%-confidence interval. This may be done as follows.

Given the posterior distribution

$$P(\lambda|n) = \frac{\lambda^{n-1+\alpha}e^{-\lambda}}{\Gamma(n+\alpha)} \qquad (14)$$

The corresponding cumulative distribution function is

$$\begin{aligned}
P'(\lambda \le \lambda_{\mathrm{marg}}|n) &= \int_0^{\lambda_{\mathrm{marg}}} \frac{t^{n-1+\alpha}e^{-t}}{\Gamma(n+\alpha)}dt \\
&= 1 - \frac{\Gamma(\alpha+n, \lambda_{\mathrm{marg}})}{\Gamma(\alpha+n)}, \qquad (15)
\end{aligned}$$

with the incomplete Γ function which for integers $n > 0$ can be computed as

$$\Gamma(n, \lambda_{\mathrm{marg}}) = (n-1)!\, e^{-\lambda_{\mathrm{marg}}} \sum_{k=0}^{n-1} \frac{\lambda_{\mathrm{marg}}^k}{k!} \qquad (16)$$

By integrating the cumulative distribution function numerically for different probabilities ($P' = 2.5\%$, 16%, 84%, and 97.5%), we obtain useful quantiles which correspond to the central 68%- and 95%-confidence intervals.

These quantiles are shown in Table 1, given as a multiplier of the true rate. For example, after computing the ZHR, one may look up the corresponding relative margins for a given n_{tot} in Table 1 and obtain the 68%-interval by computing $\mathrm{ZHR} \cdot \delta_{68,\mathrm{low}}$ (negative margin) and $\mathrm{ZHR} \cdot \delta_{68,\mathrm{high}}$ (positive margin).

It is interesting to note that the 68% interval approaches symmetry from $n_{\mathrm{tot}} \gtrsim 3$, while the 95% interval is more sensitive to the wings and remains asymmetric even beyond $n_{\mathrm{tot}} \gg 1000$.

For n_{tot} larger than about 30, the 68%-interval approaches a Gaussian shape and the margins can be approximated using $\sigma = \sqrt{n_{\mathrm{tot}}+0.5}/T$ (which equals $\mathrm{ZHR}/\sqrt{\mathrm{n_{tot}}+0.5}$).

Finally, we remind the reader that the margins in Table 1 only represent the uncertainty which is due to

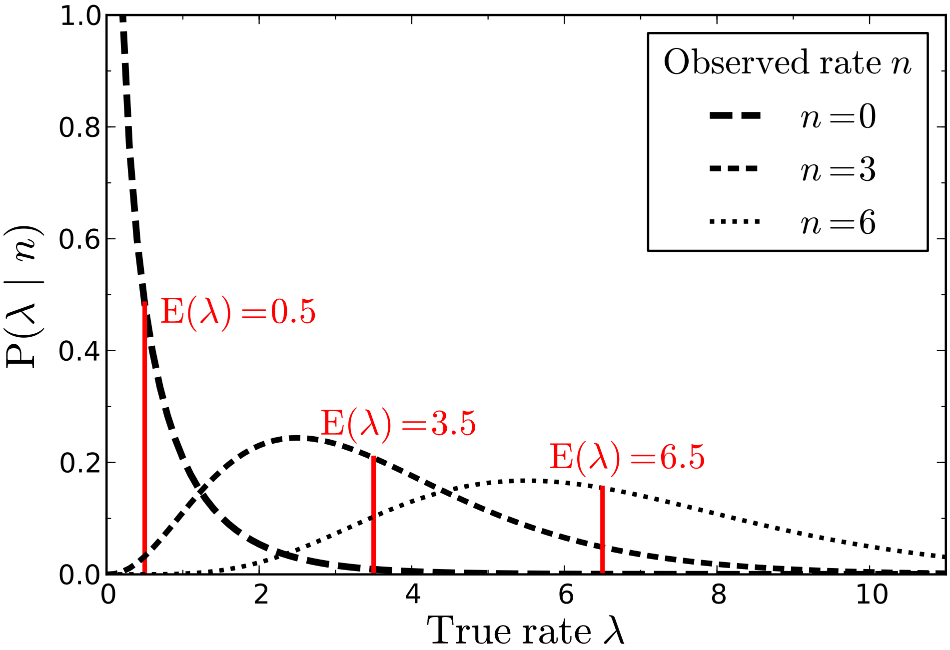

Figure 1 – Posterior distribution $P(\lambda|n)$ of the true meteor rate under Jeffreys' prior ($\alpha = 0.5$), plotted for different observed rates ($n = 0, 3, 6$). Vertical lines indicate the position of the expectation values $\mathrm{E}(\lambda) = n + 0.5$.

Table 1 – Margins of the 68%- and 95%-confidence intervals, given as multipliers to the ZHR. After computing ZHR $= (n_{\mathrm{tot}} + 0.5)/T$, the $\pm$-values can be obtained by computing ZHR $\cdot\ \delta_{68,\mathrm{low}}$ (negative margin) and ZHR $\cdot\ \delta_{68,\mathrm{high}}$ (positive margin) for the appropriate n_{tot}.

n_{tot}	$\delta_{95,\mathrm{low}}$	$\delta_{68,\mathrm{low}}$	$\delta_{68,\mathrm{high}}$	$\delta_{95,\mathrm{high}}$
0	−1.00	**−0.96**	**+0.99**	+4.02
1	−0.93	**−0.72**	**+0.73**	+2.12
2	−0.83	**−0.59**	**+0.59**	+1.57
3	−0.76	**±0.51**		+1.29
4	−0.70	**±0.45**		+1.11
5	−0.65	**±0.41**		+0.99
6	−0.61	**±0.38**		+0.90
7	−0.58	**±0.36**		+0.83
8	−0.56	**±0.34**		+0.78
9	−0.53	**±0.32**		+0.73
10	−0.51	**±0.30**		+0.69
11	−0.49	**±0.29**		+0.66
12	−0.48	**±0.28**		+0.63
13	−0.46	**±0.27**		+0.60
14	−0.45	**±0.26**		+0.58
15	−0.43	**±0.25**		+0.56
16	−0.42	**±0.24**		+0.54
17	−0.41	**±0.24**		+0.52
18	−0.40	**±0.23**		+0.50
19	−0.39	**±0.22**		+0.49
20	−0.39	**±0.22**		+0.48
22	−0.37	**±0.21**		+0.45
24	−0.36	**±0.20**		+0.43
26	−0.34	**±0.19**		+0.42
28	−0.33	**±0.19**		+0.40
30	−0.32	**±0.18**		+0.38

Poissonian statistics. The true uncertainty of a ZHR estimate is likely to be somewhat larger due to observing errors (e.g., uncertainty in the limiting magnitude determination). Fortunately, the impact of such observing errors is likely to be small when data from a sufficient number of independent observers is averaged.

6 Examples

Now let us consider the formula using a few examples. If one meteor was seen in five minutes, the rate equals $E(\mathrm{ZHR}) = \frac{n+0.5}{T} = 18.0^{+13.1}_{-13.0}$. When zero meteors are seen during five minutes, the rate equals ZHR $= 6.0^{+5.9}_{-5.8}$. The error margins are actually so close to symmetric that we can always give a single value for the error bars, i.e. ZHR $= 18 \pm 13$ and ZHR $= 6 \pm 6$ respectively. Although the rounded margins suggest so, the lower margin is not zero!

If zero meteors were seen in four hours, the rate equals to ZHR $= 0.125^{+0.124}_{-0.120}$ Indeed, rates can only be constrained to values close to zero when no meteors are observed for a very long period. A more "normal" case for a minor shower would be say a total of 12 meteors in a total of 4 hours, delivering ZHR $= 3.1 \pm 0.9$. A larger number of meteors of say 34 meteors in 11 hours gives simply ZHR $= 3.1 \pm 0.5$ with the above error for large meteor numbers.

7 The influence of correction factors

In the previous sections we have ignored the specific correction factors which are used to obtain a standardized ZHR (e.g. to account for limiting magnitude and radiant elevation). Given two rates; one without correction, $\hat{\lambda}$ and one with correction, λ, we have assumed there is a factor f which does *not* depend on the rate:

$$f\,\lambda = \hat{\lambda} \tag{17}$$

Indeed, for a set of N observing periods being combined in one expectation value for λ, all having different correction factors f_i, we obtain

$$\begin{aligned} E(\lambda) &= \frac{\int_0^\infty \frac{1}{\lambda^{1-\alpha}} \lambda \frac{(f_1\lambda)^{n_1}(f_2\lambda)^{n_2}\cdots(f_N\lambda)^{n_N}}{n_1!n_2!\cdots n_N!} e^{-\sum f_i\lambda} d\lambda}{\int_0^\infty \frac{1}{\lambda^{1-\alpha}} \frac{(f_1\lambda)^{n_1}(f_2\lambda)^{n_2}\cdots(f_N\lambda)^{n_N}}{n_1!n_2!\cdots n_N!} e^{-\sum f_i\lambda} d\lambda} \\ &= \frac{\Gamma(n_{\text{tot}}+1+\alpha)}{(\sum f_i)^{n_{\text{tot}}+1+\alpha}} \frac{(\sum f_i)^{n_{\text{tot}}+\alpha}}{\Gamma(n_{\text{tot}}+\alpha)} \\ &= \frac{n_{\text{tot}}+\alpha}{\sum f_i}. \end{aligned} \tag{18}$$

In other words, our method may be applied regardless of the values of the correction factors.

8 Discussion and conclusion

In conclusion, we recommend to compute ZHR values using the term $n + 0.5$:

$$\text{E(ZHR)} = \frac{(n_{\text{tot}}+0.5)\ r^{6.5-\text{lm}}}{T_{\text{eff}} \sin h_{\text{R}}}, \tag{19}$$

with error margins:

$$\Delta\text{ZHR} = \frac{\text{ZHR}}{\sqrt{n_{\text{tot}}+0.5}}. \tag{20}$$

Note that for $n_{\text{tot}} \leq 30$, the error margins listed in Table 1 should be used instead of Equation 20 to obtain a 68%-confidence interval.

This method of computing the ZHR adds a small bias taking into account the asymmetry of possible rates. In particular, it is essential to adopt the method whenever rates are based on less than $\sim$ 10 meteors. Such situations commonly occur when a major shower is analysed using very short (e.g. 1-minute) intervals. When computing a rate based on a number of observing periods (indexed with i), *never ever* compute the rate from $n_i + 0.5$ for individual periods and average them afterwards. A more accurate estimate is based on the sum of meteors from these observing periods, and hence on $n_{\text{tot}}+0.5$. Finally, it is, of course, much better to have enough observations and large enough n_{tot} that the subtleties of choosing a good prior are no longer important, i.e. $n_{\text{tot}} \gg 0.5$.

Comprehensive information about Bayesian inference in general and the choice of priors can be found in e.g. Kass & Wasserman (1996) and Bolstad (2007; Chapter 10 for priors).

References

Arlt R. (1999). "Global analysis of the 1998 Perseid meteor shower". *WGN, Journal of the IMO*, **27**, 237–249.

Arlt R. and Barentsen G. (2006). "Bulletin 21 of the International Leonid Watch: Global analysis of visual observations of the 2006 Leonid meteor shower". *WGN, Journal of the IMO*, **34**, 163–168.

Bias P. (2011). "A note on Poisson inference and extrapolations under low rate data and short interval observation conditions". *WGN, Journal of the IMO*, **39**, 14–19.

Bolstad W. M. (2007). *Introduction to Bayesian statistics.* Wiley, Hoboken, New Jersey, 2nd edition.

Jeffreys H. (1946). "An invariant form for the prior probability in estimation problems". *Proc. Roy. Soc. London A*, **186**, 453–461.

Jeffreys H. (1961). *Theory of probability.* Oxford Univ. Press, 3rd edition.

Kass R. E. and Wasserman L. (1996). "The selection of prior distributions by formal rules". *J. Am. Stat. Assoc.*, **91**, 1343–1370.

Rendtel J. and Arlt R., editors (2008). *IMO Handbook For Meteor Observers.* IMO, Potsdam.

Handling Editor: John Correira

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Confirmation of the April Rho Cygnids (ARC, IAU#348)

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During routine low-light level video observations with CAMS (Cameras for Allsky Meteor Surveillance) in the period April 26 – May 7, we detected the April Rho Cygnids (ARC), a meteor stream discovered by the Canadian Meteor Orbit Radar (CMOR) project in the years 2002 – 2009. The stream is included in the IAU Working list of Meteor Showers as shower #348, awaiting verification. CMOR data show ARC activity from April 25 – May 4, peaking on April 28. We detected this shower on all dates, peaking on April 28 and May 1 in 2011. The orbital parameters we found match the CMOR data. Our mean orbital elements are (N = 29): $q = 0.844 \pm 0.034$ AU, $1/a = 0.18 \pm 0.10$ 1/AU, $i = 69.^{\circ}7 \pm 2.^{\circ}8$, $\omega = 130.^{\circ}4 \pm 6.^{\circ}2$, and $\Omega = 39.^{\circ}9 \pm 2.^{\circ}9$. The parent body of the ARC remains unknown, but from the recent evolution of the stream, we provide a range of possible current orbits.

Received 2011 August 17

1 Introduction

The IAU Working list of Meteor Showers contains 300+ unconfirmed showers that have yet to be verified. A new network of low-light level video cameras was established in California with the goal to do so (Jenniskens et al., 2011). Each verified minor shower can be used to identify a parent body among the recent Near Earth Object discoveries (Jenniskens et al., 2011).

Here, we report on observations during the period of April 26 to May 7, 2011, which provide confirmation of the April ρ-Cygnids (ARC) shower. This shower was discovered from wavelet analysis in the Canadian Meteor Orbit Radar (CMOR) data in 2010 by Peter Brown and coworkers (Brown et al., 2010).

2 CAMS: Cameras for Allsky Meteor Surveillance

In recent years, low-light level video cameras have become popular for monitoring meteor activity. The Cameras for Allsky Meteor Surveillance (CAMS) project (Jenniskens et al., 2011) was designed to scale up this effort. The CAMS network combines video feed from three different stations in California to triangulate +4 and brighter meteors and measure their trajectory in the atmosphere and orbit in space.

The CAMS network currently has stations at Fremont Peak Observatory, Lick Observatory, and in Mountain View in California. Each CAMS station houses five computer units running four cameras each, with a total of twenty Watec Wat-902H2 Ultimate / Pentax 12 mm $f/1.2$ cameras. These cameras are automatically timed to collect nightly videos, 8-second fragments of which are then compressed into a Four-Frame format (Jenniskens et al., 2011). During daytime, those video snippets are sorted to only leave the ones that have moving objects in them. After writing these files to a DVD, the data is transported to the SETI Institute where each night is separately calibrated and re-processed, using software written by Peter S. Gural for the CAMS project (Jenniskens et al., 2011). The re-process procedure calculates the apparent trajectory of each potential meteor, which is then used for triangulation. An interactive program asks for confirmation of each possible match. A summary table is then produced, giving information about time of arrival, velocity and orbital parameters for every detected meteor.

More information about the CAMS network can be found on the website, `http://cams.seti.org`, or in the transcript of a recently submitted paper detailing the project (Jenniskens et al., 2011).

3 Confirmation of the April ρ-Cygnids

We chose the dates of April 26 to May 7 because these were the first dates that data from Lick Observatory were collected and used in conjunction with data from the other stations. In our data from May 1, we noticed a cluster of seven meteoroid orbits with radiants in the constellation Cygnus (Figure 1).

After checking the IAU Working list of Meteor Showers, we discovered the April ρ-Cygnids were already listed but as yet unconfirmed. We established the average geocentric coordinates and velocity of the shower in our data, then looked for similar orbits in the days before and after May 1. For that, we needed to isolate the shower from the sporadic background. In establishing criteria for discriminating ARC meteors, we used the dissimilarity criteria originally outlined by Southworth and Hawkins (1963). Five different types of D-criteria were examined (Jenniskens, 2008).

The D-criterion is a measure of how much the orbit differs from an original orbit. We compared our data against the parameters of the ARC derived from the CMOR data (Brown et al., 2010). To find a suitable cutoff D-value, above which orbits are clearly different, we calculated the different types of dissimilarity criteria for all of the detected orbits between April 26 and May 7 (Figure 2). All criteria produced similar results (Table 1). The right diagram in Figure 2 shows the low D-values from orbits similar to the ARC, since the shower should give a peak of low values. We see the values are trending upwards past an initial peak below $D = 0.15$, so we used this as a cutoff value. The isolated meteors below that value, highlighted in both plots, show our potential ARC orbits.

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IMO bibcode WGN-395-phillips-arc
NASA-ADS bibcode 2011JIMO...39..131P

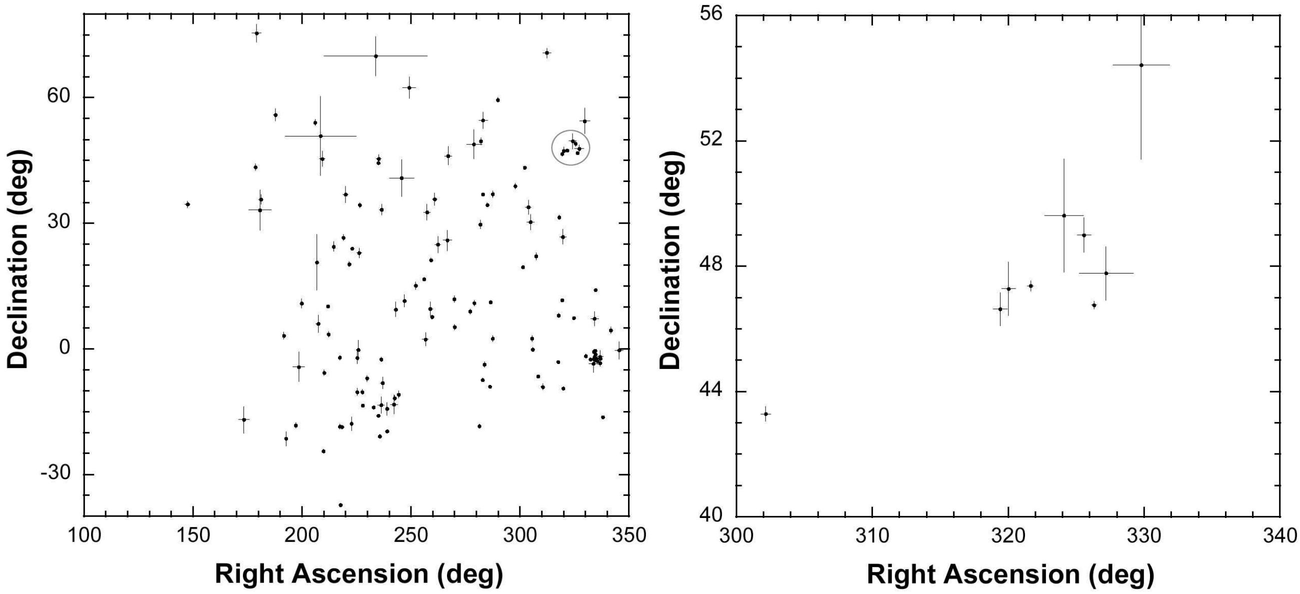

Figure 1 – Radiants found on May 1, 2011, expressed as geocentric equatorial coordinates of right ascension and declination (both in degrees). The April ρ-Cygnids are found in the upper right inside the circled area, with an average right ascension of 323° and an average declination of +48°, in the constellation Cygnus. The other meteor shower in the chart (in the lower right) is the established η-Aquariids. An enlarged diagram of the ARC radiants is shown on the right.

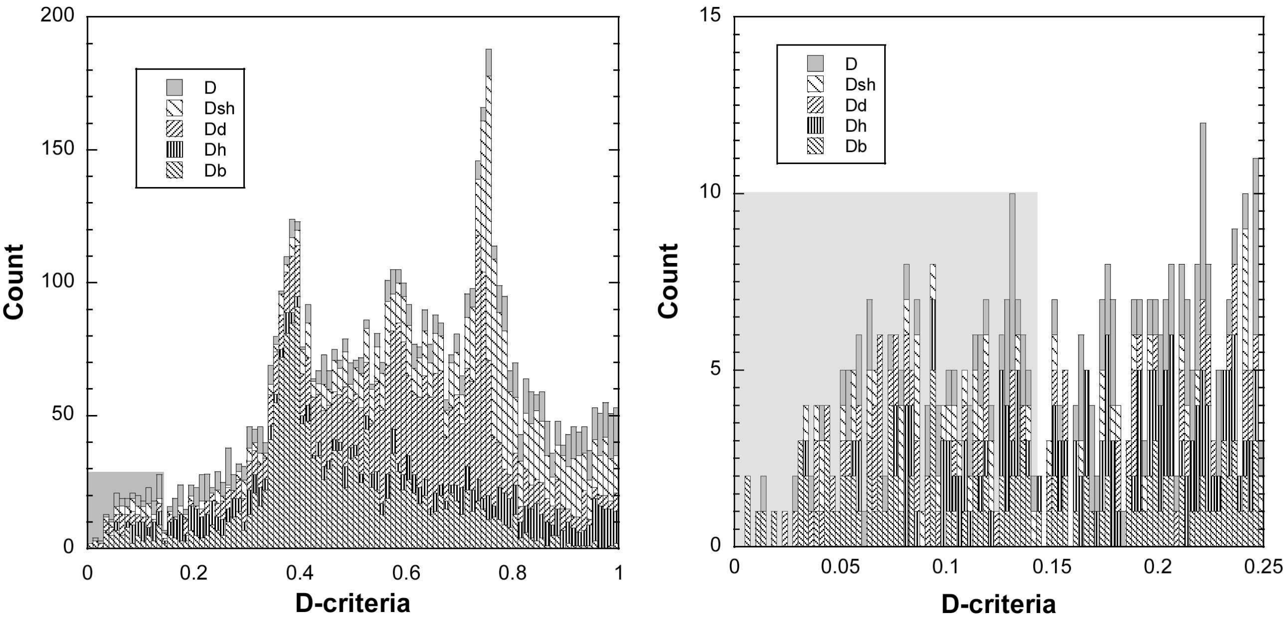

Figure 2 – Dissimilarity criteria histogram for all detected orbits between April 26 and May 7. In order to scale the D-criteria to comparable values, we reduced the D_b value by a factor of 20 and the D_{sh} value by a factor of 2. Lower D-criteria indicate similarity between our data and the average CMOR orbit. The plot on the right shows an enlarged version of the relevant low values of different dissimilarity criteria.

Some criteria isolated two groups of potential orbits. We eliminated the unrelated group by distributing the various dissimilarity criteria against right ascension. We chose to select potential meteors with right ascension coordinates that fell within ten degrees of our average May 1 orbit right ascension coordinate of 323°. In order to take into account the progression of right ascension with time, we also plotted right ascension versus solar longitude to see the precession of the radiant over time. This allowed us to then eliminate those orbits which fell outside the natural line of progression (Figure 4). Any orbits falling below the line were eliminated from our total ARC data. The orbital elements for each of the meteors satisfying both the dissimilarity criteria and right ascension requirements are shown in Table 1. The error bars in our data are based on Monte Carlo modeling. We used the standard astrometry method of determining uncertainties, and assumed the error to be a fraction of 0.4 of each pixel (Jenniskens & Gural, 2011).

The similarity between our data and the original ARC orbit is seen in the combination of low D values for each orbit in the table. These meteors represent the orbits that fit the required coordinate values and fell in a similar range of velocities, and also exhibited extremely high similarity with the original orbit discov-

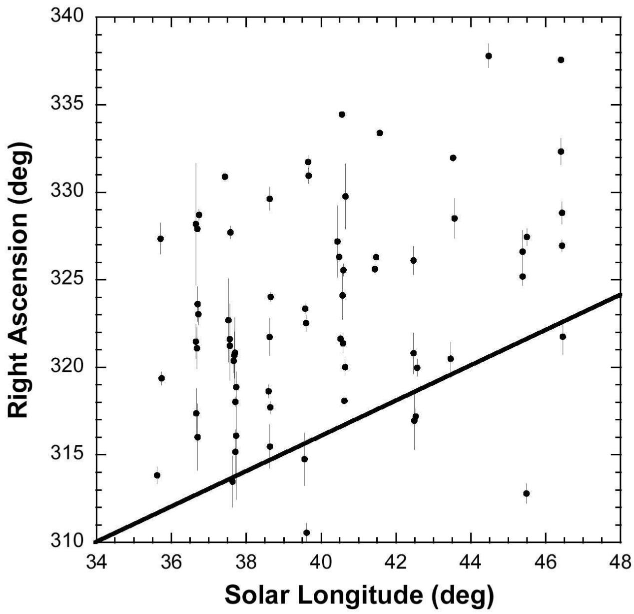

Figure 4 – Progression of the radiant of the ARC over time, shown by plotting right ascension against solar longitude. The line represents a natural progression (one degree per day).

ered in CMOR, and so can be objectively qualified as ARC orbits.

Expressed in terms of orbital elements, the ARC stand out best in a graph of inclination versus longitude of perihelion, which combines both radiant and speed information. In Figure 3 we show all our data from April 26 – May 7. The shower is clearly recognized as a cluster at high 69° inclination and a shorter longitude of perihelion than most low-inclination meteoroids.

The importance of the graph is not just its confirmation of our detected meteor stream, but also the evidence it provides about the dispersion of the shower. The distribution of the enlarged graph of the ARC is non-Gaussian in nature.

The physical attributes of the meteors are not unusual. Most lightcurve F-values scatter around relatively high values of $F \sim 0.63$ (20 have $F > 0.5$), but low values of $0.25 - 0.40$ are present too. The ARC meteors have a beginning height at the top range of other observed meteors, when plotted in a graph of beginning height versus entry speed (not shown), consistent with their cometary origin.

4 Discussion

As of yet no parent body for the ARC has been identified. However, we can try to show from our results the type of parent body that is responsible for this shower, and make predictions as to possible parent body orbits. The average meteoroid orbit from our ARC data is listed in Table 1 (Jopek et al., 2006). The mean measurement error for each radiant is also included and, in a separate row, the standard deviation of the orbits.

The semi-major axis of this orbit has $1/a = 0.18 \pm 0.10$ inverse AU, which corresponds to a semi-major axis of 5.6 AU and a $P = 13$ year mean orbital period (aphelion around 12 AU, between Saturn and Uranus), which puts this object in the realm of Jupiter family comets ($P < 20$ yr). The inclination of 69° is high, however, for typical Jupiter family comets.

To model the evolution of the stream, we calculated the heliocentric distance at the ascending node for each ARC orbit in our data (Figure 6). The ascending node scatters around $r = 3.1$ AU and has a tail with orbits passing closer to Jupiter. We suspect that the comet will have a node around $r = 3.1$ AU.

Based on this argument, we chose one of our ARC orbits with close-to-average values of both heliocentric distance and longitude of perihelion, and with small error bars, and generated its ephemeris in the JPL Horizons system. We chose not to use the average ARC orbit because of the wide dispersion of nodes and semi-major

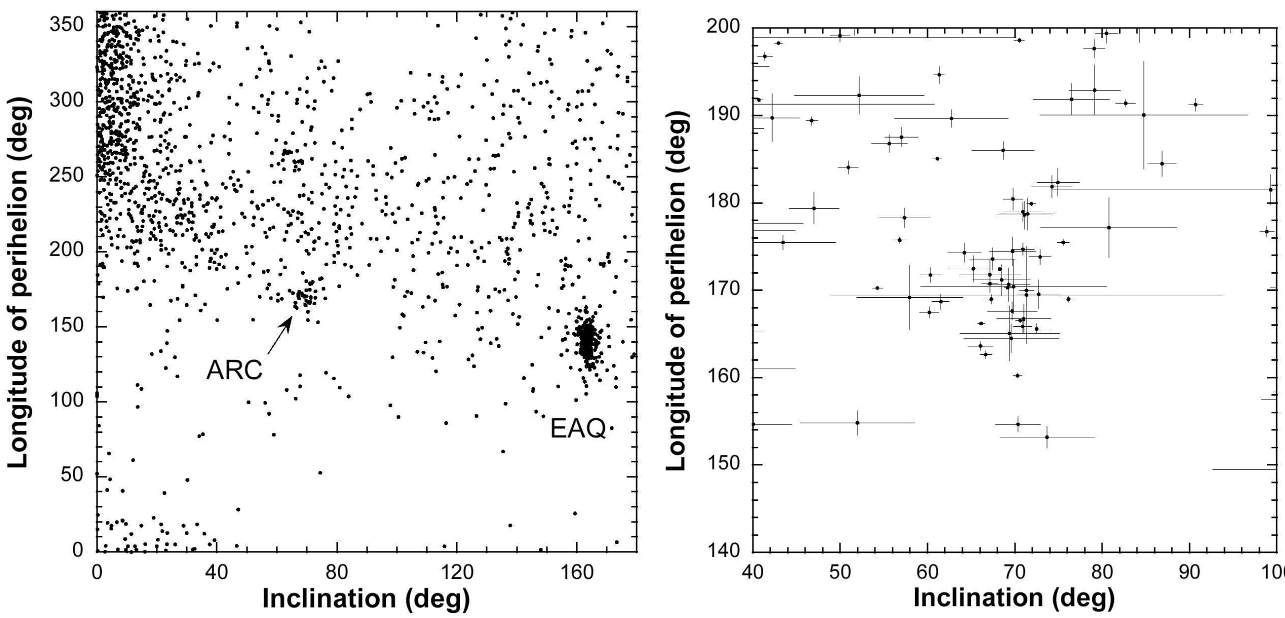

Figure 3 – Longitude of perihelion against inclination for each orbit. On the left are all of our detected orbits during the April 26 – May 7 period, with the clustered shower indicated. On the right is an enlarged graph of the April Rho Cygnids.

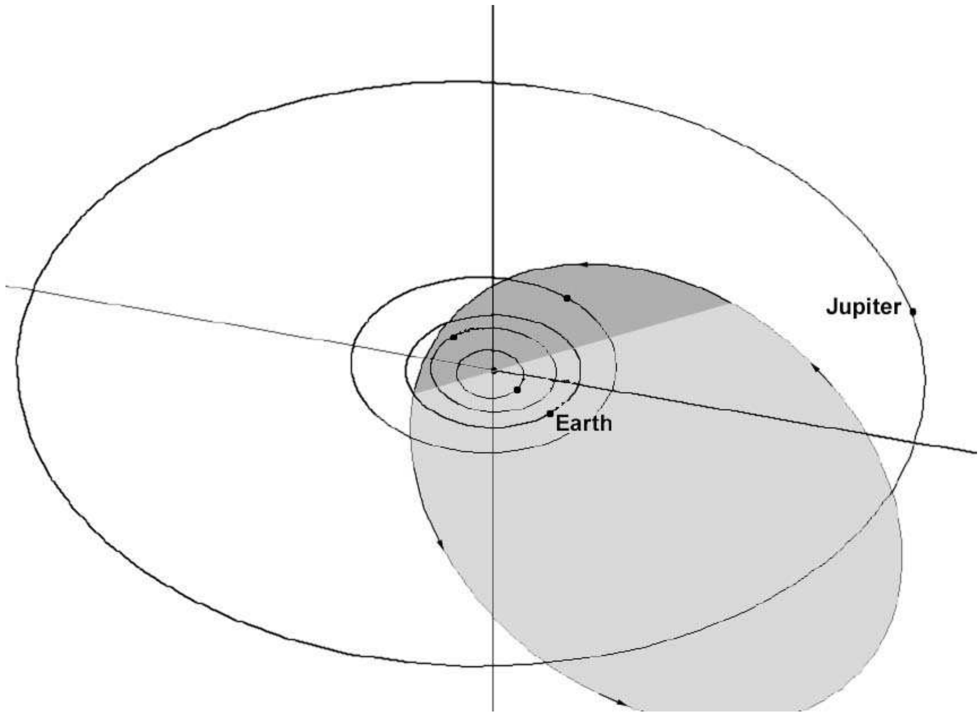

Figure 5 – ARC-092102 orbit. Planet positions on August 18, 2011. Graphic created with the OrbitViewer applet by Osamu Ajiki (AstroArts) and Ron Baalke (JPL).

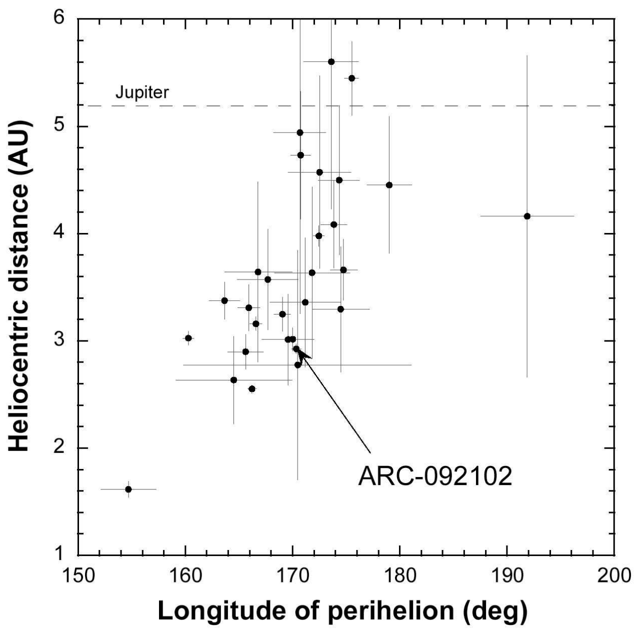

Figure 6 – Heliocentric distance (in AU) of each of the 29 ARC orbits against their longitude of perihelion (in degrees). The orbit indicated by the arrow represents the orbit we used to model the stream's evolution over time in Horizons, because of its small error bars and central location within the scatter of orbits. The orbit chosen is called ARC-092102 from its time of arrival ($09^h21^m02^s$ UT).

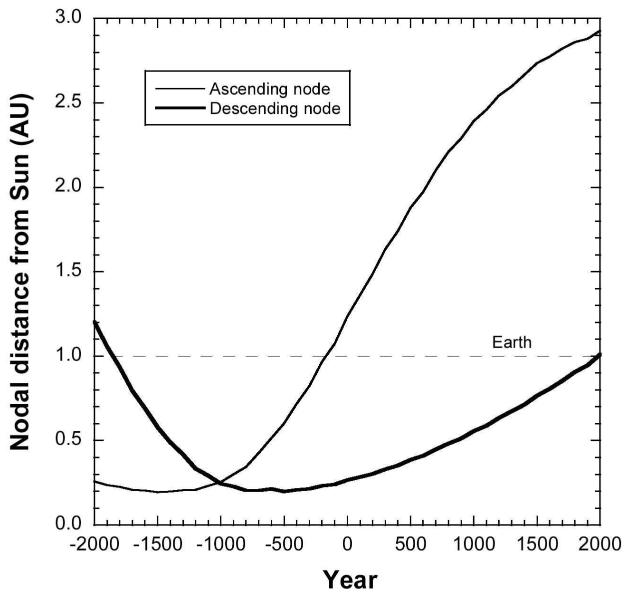

Figure 7 – Nodal distance from the Sun (in AU) over time. The darker line indicates the evolution of the descending node, while the lighter line is the evolution of the ascending node. The dotted line on the graph represents the heliocentric distance of the Earth's orbit.

axes in our collective data. A visual representation of this orbit is shown in Figure 5.

The ephemeris generated the orbital elements of the stream in the past 4000 years, beginning at 2000 BC. We chose to use a 4000 year period because this is about the average nutation period of this orbit. We suspect that the comet still is located somewhere along this nutation cycle, possibly lagging behind the meteoroids. In Table 2 we show the parameters of the ARC orbit, in intervals of 400 years in the past. The comet could have orbital elements similar to any set of these.

The comet orbit had a much lower inclination in the past, and much lower perihelion distance. The resulting change in heliocentric distance of the node over time, given by the $r+$ and $r-$ columns and shown in Figure 7, shows when the ascending and descending nodes of the orbit crossed Earth's orbit, indicated by the line at 1 AU.

Table 1 – Table of orbital elements and dissimilarity criteria (compared to the 2010 CMOR orbit) of 29 ARC meteors. Also included are the orbital elements of our average orbit, with calculated errors, and the standard deviations of those elements, along with the average CMOR orbit which was used as the original in the calculation of each D-criterion. The D-value is based only on the parameters a, e and i, while the D_{sh} values also include the node and the longitude of perhelion (not included in the table). D_d uses the ecliptic latitude and longitude and is given in natural units, whereas D_h combines the previous equations for $_{sh}$ and D_d. The D_b value uses orbital invariants calculated from the given parameters to describe secular orbital perturbations. In order to compare the different values, our D_{sh} values are scaled down by a factor of 2 and our D_b values by a fact or of 20. The similarity between our data and the original ARC orbit is seen in the combination of low D values for each orbit in the table. These meteors represent the orbits that fit the required coordinate values and fell in a similar range of velocities, and also exhibited extremely high similarity with the original orbit discovered in CMOR, and so can be objectively qualified as ARC orbits.

Date	RA	Dec	V_g	q	e	i	ω	Ω	D	D_{sh}	D_d	D_h	D_b
04/26/11	313.84	44.08	44.24	0.894	0.900	75.53	139.89	35.613	0.13170	0.12038	0.09621	0.11511	0.44268
04/26/11	319.38	45.39	41.61	0.844	0.828	70.89	130.16	35.738	0.060583	0.040545	0.041488	0.058009	0.16447
04/27/11	321.49	49.36	40.97	0.859	0.933	67.13	134.09	36.655	0.090065	0.078792	0.065276	0.081332	0.31432
04/27/11	321.11	48.13	42.12	0.856	0.953	69.28	133.99	36.677	0.091249	0.079203	0.067602	0.083817	0.27541
04/28/11	322.70	46.20	42.39	0.832	0.896	71.02	129.27	37.511	0.036215	0.037603	0.028628	0.032795	0.10116
04/28/11	321.25	49.99	41.36	0.868	0.966	67.43	136.05	37.552	0.11625	0.10610	0.084603	0.10722	0.38622
04/28/11	321.62	50.77	39.81	0.866	0.905	65.25	134.95	37.555	0.10310	0.092955	0.069995	0.093222	0.37956
04/28/11	327.72	45.60	42.57	0.784	0.927	70.30	122.70	37.568	0.058511	0.034634	0.036302	0.055720	0.15566
04/28/11	320.38	44.43	41.88	0.836	0.788	72.47	127.95	37.656	0.10130	0.055556	0.059420	0.099774	0.11183
04/28/11	320.84	45.71	40.23	0.834	0.747	69.59	126.83	37.693	0.13036	0.066900	0.080727	0.12947	0.14442
04/28/11	316.10	45.77	39.73	0.875	0.689	69.86	132.73	37.721	0.19706	0.11245	0.13033	0.19077	0.30876
04/29/11	318.65	45.57	41.04	0.860	0.755	71.34	131.42	38.591	0.13244	0.085842	0.087120	0.12915	0.24233
04/29/11	321.75	51.74	39.14	0.873	0.886	64.22	135.70	38.621	0.11799	0.10864	0.077234	0.10966	0.42410
04/29/11	329.65	48.90	40.88	0.799	0.942	66.06	125.01	38.625	0.095383	0.050210	0.045547	0.098568	0.017872
05/01/11	327.21	47.77	42.18	0.816	0.926	69.71	127.24	40.425	0.051470	0.055357	0.038088	0.076012	0.063467
05/01/11	326.32	46.76	42.07	0.814	0.877	70.62	126.09	40.479	0.013369	0.042487	0.024558	0.058596	0.047422
05/01/11	321.65	47.37	40.17	0.851	0.762	69.18	129.82	40.517	0.12090	0.087010	0.080899	0.13002	0.22655
05/01/11	324.12	49.61	40.26	0.849	0.859	67.13	131.24	40.569	0.064200	0.082267	0.050266	0.080662	0.25197
05/01/11	321.38	46.45	42.97	0.859	0.882	72.90	133.26	40.583	0.072116	0.098238	0.064666	0.084646	0.24710
05/01/11	325.57	48.99	40.26	0.833	0.847	67.28	128.43	40.594	0.058380	0.063786	0.038549	0.080511	0.16694
05/01/11	320.03	47.28	41.44	0.870	0.817	70.91	134.11	40.632	0.085362	0.10386	0.074653	0.092507	0.31362
05/02/11	325.62	49.53	41.26	0.843	0.908	68.24	131.01	41.427	0.054991	0.089232	0.052559	0.086843	0.21597
05/02/11	326.31	48.74	38.91	0.821	0.761	66.15	124.75	41.465	0.13191	0.079618	0.076783	0.15017	0.14308
05/03/11	326.12	43.80	39.01	0.769	0.615	70.35	112.21	42.467	0.26331	0.14818	0.18750	0.27694	0.10808
05/03/11	320.82	48.53	41.93	0.880	0.869	70.94	136.54	42.468	0.072660	0.13758	0.086444	0.10082	0.39390
05/04/11	328.52	49.37	41.15	0.824	0.882	68.47	127.63	43.557	0.029507	0.086373	0.044825	0.11034	0.13067
05/06/11	313.68	44.81	43.01	0.938	0.731	76.48	146.57	45.307	0.22432	0.24237	0.18135	0.24448	0.65623
05/06/11	327.46	49.20	41.25	0.838	0.844	69.73	129.00	45.489	0.041945	0.11525	0.065083	0.14344	0.19183
05/07/11	332.34	47.31	43.35	0.791	0.911	72.73	123.17	46.403	0.063972	0.10032	0.068866	0.16727	0.18063

Some features of the shower point to recent formation with a strong perturbing effect of Jupiter. The shower is active over two weeks, having significantly dispersed in node. The highest rates were detected on April 28 and May 1. Taking into account the range of uncertainty in the rates for individual nights suggests a peak on April 30, but no ARC were detected on April 30 itself (Table 1). To determine with certainty whether or not the shower has two peaks would require more data.

Also, the radiant dispersion is larger than the measurement error. The non-Gaussian distribution in the inclination and longitude of perihelion of the shower (Figure 3) suggests the dispersion might come from perturbations from Jupiter. Our detected stream is dense enough to suggest that the dust may have originated from the fragmentation of a Jupiter-family parent rather than through regular outgassing activity (Jenniskens, 2006).

5 Conclusions

We confirm the existence of the April ρ-Cygnids, previously detected by Brown et al. (2010). We find that the shower peaked on April 28 and May 1 in 2011, and was active for at least 12 days in the period April 26 – May 7. There is no known parent body at the present time, perhaps because of its relatively long orbital period. Our observations suggest the shower was created during the fragmentation of a Jupiter family comet.

Acknowledgements

We thank Peter Gural for developing the software algorithms used in this investigation. We also thank the Fremont Peak Observatory Association and the Lick Observatory staff for their assistance in maintaining the CAMS stations, specifically FPOA director Rick Morales and board member Mark Levine. CAMS is supported by the NASA Planetary Astronomy program.

References

Brown P., Wong D., Weryk R., and Wiegert P. (2010). “A meteoroid stream survey using the Canadian Meteor Orbit Radar – II: Identification of minor showers using a 3D wavelet transform”. *Icarus*, **207**, 66–81.

Jenniskens P. (2006). *Meteor Showers and Their Parent Bodies*. Cambridge University Press, Cambridge, UK.

Jenniskens P. (2008). “Meteoroid streams that trace to candidate dormant comets”. *Icarus*, **194**, 19–22.

Jenniskens P. and Gural P. (2011). “Discovery of the February Eta Draconids (FED, IAU#427): the dust trail of an Earth-theatening long-period comet”. *WGN, Journal of the IMO*, **39**, 93–97.

Jenniskens P., Gural P., Dynneson L., Grigsby B., Newman K., Borden M., Koop M., and Holman D. (2011). “CAMS: Cameras for Allsky Meteor Surveillance to validate minor meteor showers”. *Icarus*, **216**, 40–61.

Jopek T., Rudawska R., and Pretka-Ziomek H. (2006). “Calculation of the mean orbit of a meteoroid stream”. *Mon. Not. Royal Astron. Soc.*, **371**, 1367–1372.

Handling Editor: Carl Hergenrother

Table 2 – ARC-092102, traced back in time to 2000 BC. Included are the year and each orbit's eccentricity, perihelion distance, inclination, argument of perihelion, node, longitude of perihelion, and heliocentric distances at both the ascending ($r+$) and descending ($r-$) nodes.

Year	e	q	i	ω	Ω	Π	$r+$	$r-$
−2000.0	0.93850	0.21914	48.728	46.405	181.82	228.22	0.25791	1.2039
−1600.0	0.95472	0.16145	39.998	55.229	167.08	222.31	0.20433	0.69279
−1200.0	0.96331	0.13055	32.416	76.046	139.62	215.67	0.20799	0.33386
−800.0	0.96315	0.13099	32.659	105.27	103.60	208.88	0.34458	0.20511
−400.0	0.95361	0.16563	40.261	125.18	77.235	202.41	0.71803	0.20885
0.0	0.93677	0.22584	48.809	133.59	62.927	196.52	1.2352	0.26575
400.0	0.91415	0.30561	55.809	136.57	54.537	191.10	1.7400	0.35159
800.0	0.88234	0.42044	60.806	136.68	49.291	185.97	2.2104	0.48200
1200.0	0.84616	0.54973	64.390	135.25	45.649	180.90	2.5434	0.63392
1600.0	0.80578	0.69170	67.341	133.04	42.591	175.63	2.7725	0.80587
2000.0	0.76108	0.85245	68.863	129.81	40.643	170.46	2.9281	1.01000

Preliminary results

Results of the IMO Video Meteor Network — June 2011

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

In June 2011 observers of the IMO Video Meteor Network recorded more than 10 000 meteors in about 3 100 hours of effective observing time. The June Boötids did not show significant activity this year.

Received 2011 August 18

1 Introduction

At some time the weather too needs a rest. After March, April and May presented optimal conditions to observers, the weather shifted to a lower gear in June and presented only mediocre observing conditions to central European observers. Farther to the south in Hungary, Italy and Portugal, the weather conditions remained good and presented twenty and more observing nights to many observers. Also our observers in Arizona and Australia enjoyed perfect conditions. With an overall total of 3 100 hours of effective observing time (Table 1 and Figure 1), we exceeded the result of 2010 by 50% (?). For the first time we managed to record more than 10 000 meteors in June. As meteor activity will rise in the following months, this year should become the first where we record more than 10 000 meteors each month.

In June 2011, we could win the addition of a second Portuguese observer for the IMO network. In the suburbs of Lisbon, Carlos Saraiva is operating two Watec cameras RO1 and RO2 with 6-mm $f/0.75$ Panasonic lens. His observing site suffers from strong light pollution, which is why his meteor counts are not the best yet, but with some optimizations this may still improve.

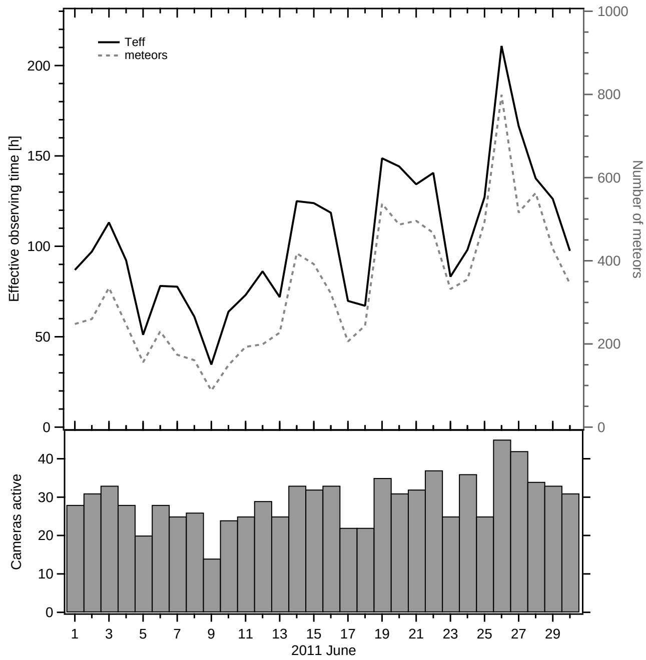

Figure 1 – Monthly summary for the effective observing time (solid black line), number of meteors (dashed gray line) and number of cameras active (bars) in 2011 June.

2 New online tool functions and the June Boötids

Whereas June marks the start of winter with long nights in Australia, the nights are correspondingly short in the northern hemisphere. That cannot be compensated by the slightly improving hourly meteor counts in June. In northern Germany there are still a few observing hours left each night, but our observer in Finland has to pause completely from mid-May to early August. Also with respect to meteor showers, June is rather boring. Only the June Boötids present exceptional activity every now and then – but not in 2011. After uploading all June data, the online flux density profile (Figure 2) shows a uniform activity profile at a very low level. The stream did not obviously stand out from the sporadic background.

At this point we mention that Geert Barentsen implemented a few new functions in the online tool. Now you can select the shower from the IMO working list, for example, and the flux tool automatically selects the right activity interval. Geert has also implemented a new binning algorithm for the observations. Beside the minimum and maximum interval length, you can now not only specify the envisioned number of meteors per bin, but alternatively also the effective collection area (in km^{2}h).

The philosophy is slightly different here: When specifying the meteor count it is assumed that at least x shower meteors are required to estimate the flux density with sufficient accuracy. The relative error is inversely proportional to the root of the meteor count. Thus, a fixed number of meteors per bin yields the same relative error for each data point. In case of low activity as

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IMO bibcode WGN-395-molau-vidjun
NASA-ADS bibcode 2011JIMO...39..137M

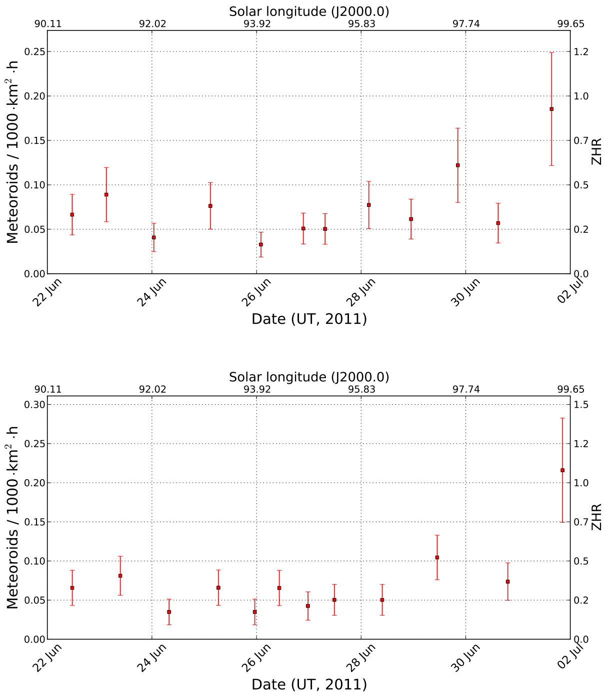

Figure 2 – Online flux density profile of the June Boötids with binning by meteor count (upper graph) respectively effective collection area (lower graph).

for the June Boötids, individual intervals may get quite long, and during high activity the bin size is very small.

Now the question is whether a fixed relative error is the right criterion? Whether the flux density is 90 or 100 seems to be more relevant than whether it is 0.9 or 1.0. If the bin size is defined by the effective collection area, it is specified how long has to be observed under normalized conditions to yield a statistically significant measurement. That approach is independent of the number of shower meteors in each interval. At low rates, the intervals are not getting too long and the relative error is increasing, whereas at high rates the temporal resolution is lower.

At this time it is still open which of the two methods gives better results. In case of the June Boötids and given the same number of intervals (12 bins with 9 meteors respectively 150 000 km^{2}h per bin), it seems that the second method yields slightly less scatter. Maybe even a combination of both methods is best, i.e. for each bin at least a given meteor count x or effective collection area y has to be obtained.

References

Molau S., Kac J., Berko E., Crivello S., Stomeo E., Igaz A., and Barentsen G. (2011). "Results of the IMO Video Meteor Network – April 2011". *WGN, Journal of the International Meteor Organization*, **39:4**, 100–104.

Handling Editor: Javor Kac

Erratum: Results of the IMO Video Meteor Network – April 2011

The WGN Editorial Team

In the August issue of WGN, the April 2011 report of the IMO Video Meteor Network was published (Molau et al., 2011). We regret that there was an error in the second item listing the effects impacting the flux density determination (Page 102). The correct rendition of the second bullet is reproduced below:

- Currently the algorithm supposes (contrary to the visual analysis) that the detection probability for meteor is 100% down to the determined limiting magnitude, which will hardly be the case. In reality, more meteors are visible than detected by the software, which also means that the flux density is currently under- rather than overestimated.

References

Molau S., Kac J., Berko E., Crivello S., Stomeo E., Igaz A., and Barentsen G. (2011). "Results of the IMO Video Meteor Network – April 2011". *WGN, Journal of the International Meteor Organization*, **39:4**, 100–104.

IMO bibcode WGN-395-erratum
NASA-ADS bibcode 2011JIMO...39..138E

Table 1 – Observers contributing to 2011 June data of the IMO Video Meteor Network. Eff.CA designates the effective collection area and Tot.CA the total collection area.

Code	Name	Place	Camera	FOV [$^{\circ 2}$]	Stellar LM [mag]	Eff.CA [km^2]	Nights	Time [h]	Tot.CA [$10^3 km^2 h$]	Meteors
BERER	Berko	Ludányhalászi/HU	HULUD1 (0.95/3)	2256	4.8	1540	23	80.3	92.0	286
			HULUD2 (0.75/6)	4860	3.9	1103	22	73.5	69.7	155
			HULUD3 (0.75/6)	4661	3.9	1052	19	65.9	47.8	127
BREMA	Breukers	Hengelo/NL	MBB3(0.75/6)	2399	4.2	699	12	31.7	34.3	102
BRIBE	Brinkmann	Herne/DE	HERMINE (0.8/6)	2374	4.2	678	11	32.8	17.3	95
		Bergisch Gladbach/DE	KLEMOI (0.8/6)	2286	4.6	1080	16	47.2	32.6	133
CASFL	Castellani	Monte Baldo/IT	BMH1 (0.8/6)	2350	—	—	17	54.7	—	157
			BMH2 (1.5/4.5)*	4243	—	—	20	49.1	—	141
CRIST	Crivello	Valbrevenna/IT	C3P8 (0.8/3.8)	5455	4.2	1586	22	100.1	105.2	273
			STG38 (0.8/3.8)	5614	4.4	2007	22	97.4	163.2	422
CSISZ	Csizmadia	Zalaegerszeg/HU	HUVCSE01 (0.95/5)	2423	3.4	361	14	33.7	7.2	77
CURMA	Currie	Grove/UK	MIC4 (0.8/6)	2411	5.2	2373	17	40.9	—	116
ELTMA	Eltri	Venezia/IT	MET38 (0.8/3.8)	5631	4.3	2151	14	57.2	—	162
GONRU	Goncalves	Tomar/PT	TEMPLAR1 (0.8/6)*	2179	5.3	1842	25	142.1	189.8	540
			TEMPLAR2 (0.8/6)*	2080	5.0	1508	27	122.0	153.6	339
GOVMI	Govedič	Središče ob Dravi/SI	ORION2 (0.8/8)	1447	5.5	1841	17	50.3	—	144
HERCA	Hergenrother	Tucson/US	SALSA3 (1.2/4)*	2198	4.6	894	29	185.8	—	398
HINWO	Hinz	Brannenburg/DE	AKM2 (0.85/25)*	767	5.7	1101	12	29.1	—	76
IGAAN	Igaz	Baja/HU	HUBAJ (0.8/3.8)	5552	2.8	403	28	73.3	29.7	213
		Hódmezővásárhely/HU	HUHOD (0.8/3.8)	5502	3.4	764	25	65.4	49.3	191
		Budapest/HU	HUPOL (1.2/4)	3790	3.3	475	18	26.8	8.4	55
		Sopron/HU	HUSOP (0.8/6)	2031	3.8	460	21	42.9	14.4	120
JONKA	Jonas	Budapest/HU	HUSOR (0.95/4)	2286	3.9	445	14	53.5	—	133
KACJA	Kac	Kostanjevec/SI	METKA (0.8/8)*	1372	4.0	361	4	11.5	4.8	27
		Ljubljana/SI	ORION1 (0.8/8)	1402	3.8	331	19	83.8	—	133
		Kamnik/SI	REZIKA (0.8/6)	2270	4.4	840	17	80.4	—	357
			STEFKA (0.8/3.8)	5471	2.8	379	17	77.6	20.5	216
KERST	Kerr	Glenlee/AU	GOCAM1 (0.8/3.8)	5189	4.6	2550	21	213.6	356.4	1416

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

Code	Name	Place	Camera	FOV [°^{2}]	Stellar LM [mag]	Eff.CA [km^2]	Nights	Time [h]	Tot.CA [10^3km^{2}h]	Meteors
MOLSI	Molau	Seysdorf/DE	Avis2 (1.4/50)*	1776	6.1	3817	4	18.4	54.1	167
			Mincam1 (0.8/8)	1477	4.9	1084	21	68.2	—	227
		Ketzür/DE	Remo1 (0.8/3.8)	5600	3.0	486	21	62.9	—	76
			Remo2 (0.8/3.8)	5613	4.0	1186	23	72.8	48.8	157
OTTMI	Otte	Pearl City/US	Orie1 (1.4/5.7)	3837	3.8	460	17	51.4	—	160
PERZS	Perko	Becsehely/HU	Hubec (0.8/3.8)*	5498	2.9	460	27	85.9	37.1	302
ROTEC	Rothenberg	Berlin/DE	Armefa (0.8/6)	2366	4.5	911	14	49.6	52.5	109
SARAN	Saraiva	Carnaxide/PT	Ro1 (0.75/6)	2362	3.7	381	16	47.8	—	119
			Ro2 (0.75/6)	2381	3.8	459	20	60.9	43.7	185
SCHHA	Schremmer	Niederkrüchten/DE	Doraemon (0.8/3.8)	4900	3.0	409	21	44.0	—	116
SLAST	Slavec	Ljubljana/SI	Kayak1 (1.8/28)	588	—	—	11	29.9	117.5	122
STOEN	Stomeo	Scorze/IT	Min38 (0.8/3.8)	5566	4.8	3270	21	71.0	149.9	315
			Noa38 (0.8/3.8)	5609	4.2	1911	20	66.2	135.0	240
			Sco38 (0.8/3.8)	5598	4.8	3306	19	71.4	—	335
STRJO	Strunk	Herford/DE	Mincam2 (0.8/6)	2362	4.6	1152	10	18.7	24.4	48
			Mincam3 (0.8/12)	728	5.7	975	17	25.6	—	68
			Mincam5 (0.8/6)	2349	5.0	1896	15	32.4	50.5	116
TEPIS	Tepliczky	Budapest/HU	Humob (0.8/6)	2388	4.8	1607	23	79.0	—	281
TRIMI	Triglav	Velenje/SI	Sraka (0.8/6)*	2222	—	—	23	63.3	—	175
ZELZO	Zelko	Budapest/HU	Huvcse02 (0.95/5)	1606	3.8	390	18	64.3	30.2	147
						Overall	30	3 106.3	—	10 069

* active field of view smaller than video frame

Results of the IMO Video Meteor Network — July 2011

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

In 2011 July, more than 18 000 meteors were recorded by 52 cameras of the IMO Video Meteor Network in over 3 700 hours of effective observing time. The Network was expanded by three additional cameras. The Pisces Austrinids could not be reliably detected in 2011. The α-Capricornids reached a plateau of activity between $\lambda_\odot$ 120° and 125° whereas the Southern δ-Aquariids reached a similar but stronger plateau of activity between $\lambda_\odot$ 125° and 129° with a peak at $\lambda_\odot = 128°$. The activity profiles of all three showers are presented. Accidental sprite detections using MetRec are also presented.

Received 2011 September 10

1 Introduction

July 2011 was a fine month for video observers. In the first half of July all observers enjoyed excellent conditions – more than 40 cameras were active in selected nights – while the weather deteriorated significantly only for the more northern observers in the second half. In southern and eastern Europe the conditions remained favorable, so that in total 23 out of 52 cameras collected data during twenty or more observing nights (Table 1 and Figure 1). Also Steve Kerr enjoyed the best winter observing conditions in Australia and collected almost 300 observing hours and more than 3 000 meteors in 30 nights. With a single camera, he currently ranks second with respect to meteor detections in the interim result behind Enrico Stomeo, who operates three cameras. However, the yield of Steve will reduce rapidly in the months to come, whereas the meteor season has just begun for the northern hemisphere observers.

Since July 2010 presented fine observing conditions, the increase is not as high in this month as before. With a total of 3 700 hours we collected less effective observing time than in March till May 2011, but still 700 hours more than in July of last year. The meteor count increased by 3 000 to more than 18 000 compared to 2010 (Molau & Kac, 2010).

In July we welcomed three new camera systems to the IMO network at once, two of them operated from new countries. From France, Arnaud Leroy has begun submitting data. He operates the 902H2 Watec camera Saphira with a 6 mm $f/1.2$ lens from a small suburb east of Paris. With Luc Bastiaens, we now also have a Belgian observer in our midst. His camera Urania1 employs a Watec 902H2 camera as well, but with a varifocal $f/0.95$ Fujinon lens. The current camera location is strongly illuminated and the field of view is restricted by nearby trees and houses, but Luc is already looking for a better place.

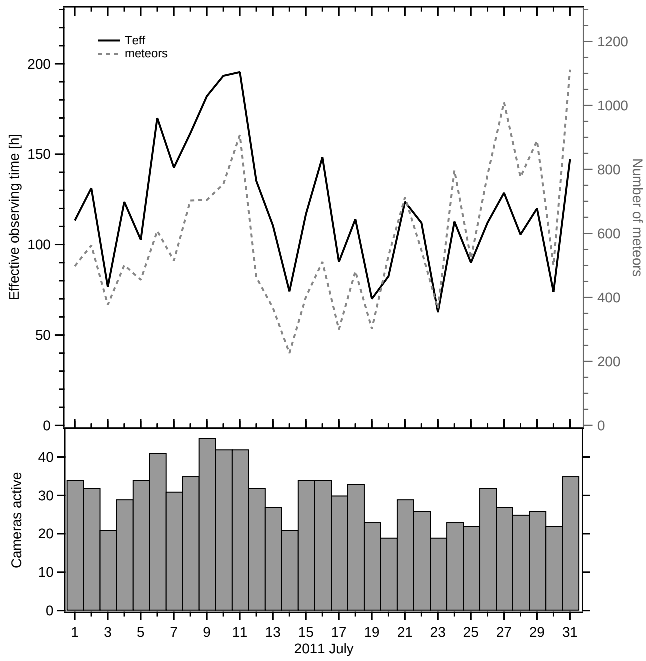

Figure 1 – Monthly summary for the effective observing time (solid black line), number of meteors (dashed gray line) and number of cameras active (bars) in 2011 July.

Finally, Erno Berko deployed his third camera Hulud3, which gives Hungary a further edge.

2 Pisces Austrinids

Now to the observing results: The IMO working list contains three showers in July which all have their maxima at the end of July. At first we shall mention the far southern shower of the Pisces Austrinids, which could not be confirmed by our 2009 meteor shower analysis (Molau & Rendtel, 2009). In the Australian data set of 2010 there are 62 meteors matching the PAU radiant (with 1 285 sporadics in parallel), equally distributed over the full activity interval. The flux density remained below 0.3 meteors per 1 000 km^2 per hour, which hints on chance alignments of sporadic meteors. If all other data are added, the data set expands to 207 meteors matching the PAU radiant (7 021 sporadic meteors in parallel). Because of some systematic variation, the flux density now reaches values up to 0.8, but remains es-

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IMO bibcode WGN-395-molau-vidjul
NASA-ADS bibcode 2011JIMO...39..141M

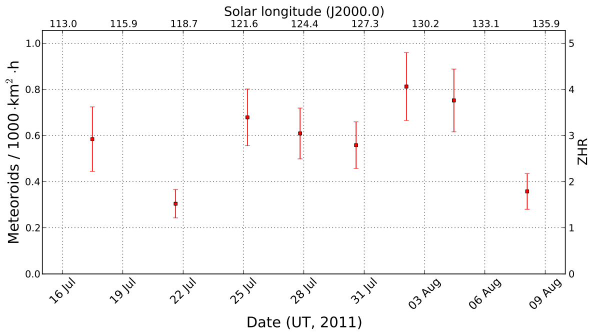

Figure 2 – Flux density profile of the Pisces Austrinids from observations of the IMO Video Meteor Network in July/August 2011.

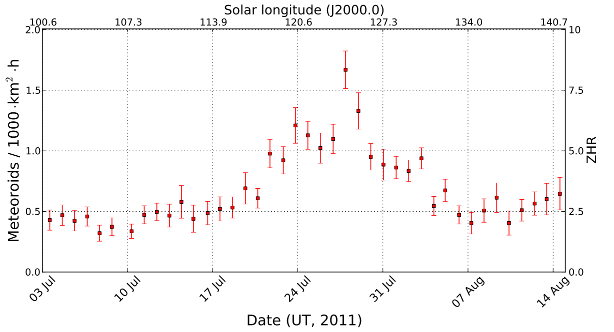

Figure 3 – Flux density profile of the α-Capricornids from observations of the IMO Video Meteor Network in July/August 2011.

sentially constant in the full interval (Figure 2). Hence, also in this year the shower cannot be detected with any certainty.

3 α-Capricornids

The α-Capricornids (CAP), on the contrary, were clearly detected in the 2009 meteor shower analyses (Molau & Rendtel, 2009). They were detected between 109 and 138 degrees solar longitude. The maximum occurred at $\lambda_\odot = 125°$, with a plateau of activity between $\lambda_\odot$ 120° and 125°.

The 2011 data set contains 1 788 shower meteors in the full activity interval until mid-August, with 13 562 sporadic meteors recorded at the same time. The flux density starts to increase at $\lambda_\odot = 115°$ and goes back to background level at $\lambda_\odot = 134°$. The plateau of activity between 120 and 125 degrees is confirmed at a level of slightly above 1 meteoroid per 1 000 km^2 per hour. There is a short peak at $\lambda_\odot = 124°$ (Figure 3).

Looking only at the Australian data, the plateau become more rounded and the peak disappears. The reason might be that as also in case of CAP shower the European data give on average slightly higher flux densities, and this particular interval falls right into the Australian daytime hours.

4 Southern δ-Aquariids

Finally we have the strongest shower of July, the Southern δ-Aquariids. In the 2009 analysis they show a steep rise between 118 and 124 degrees solar longitude, fol-

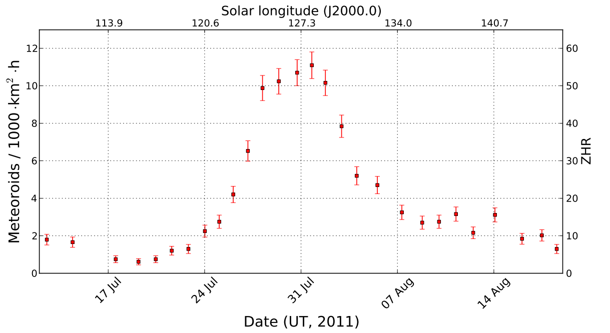

Figure 4 – Flux density profile of the Southern δ-Aquariids from observations of the IMO Video Meteor Network in July/August 2011.

lowed by a short activity plateau with a peak at $\lambda_\odot = 127°$, and a slower drop which ends around $\lambda_\odot = 140°$ (Molau & Rendtel, 2009).

Based on 2 559 Southern δ-Aquariids until mid-August (with 11 257 sporadic meteors recorded at the same time), the 2011 flux density profile has a similar shape (Figure 4). With 11 meteoroids per 1 000 km^2 per hour, they are about half as strong at the η-Aquariids in May.

5 Sprites

Sprites are brief electrical discharges occurring in the upper atmosphere. Sharing the same space with meteors, these luminous events can be recorded by video cameras. On July 8/9, the Polish observer Maciej Maciejewski managed to record two sprites with MetRec from his observing site in Chelm, even though MetRec is not designed for such events (contrary to UFOCapture). Sprites are typically extremely short-lived events and occur in single video frames only. So they are filtered out in the standard configuration of MetRec to increase the sensitivity for faint meteors. In this case, some flash lights illuminated a lower cloud causing the "false detections" (Figure 5). More details can be found at `http://www.pkim.org/?q=pl/node/1563`.

On this occasion we learned that Hungarian observers had also recorded sprites with MetRec on some occasions previously, in one case even triggered by a meteor that appeared at the same time. Figure 6 shows two nice recordings by Zsolt Perko, taken with Hubec from Becsehely on 2011 May 27. More details are given at `http://www.videometeor.hu/2011-majusi-lidercek`. Two further sprite records taken by Javor Kac in 2009 and 2011 using MetRec are shown in Figure 7.

References

Molau S. and Kac J. (2010). "Results of the IMO Video Meteor Network – July 2010". *WGN, Journal of the IMO*, **38:5**, 167–170.

Molau S. and Rendtel J. (2009). "A comprehensive list of meteor showers obtained from 10 years of observations with the IMO Video Meteor Network". *WGN, Journal of the IMO*, **37:4**, 98–121.

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Figure 5 – Two sprites, recorded by chance by Maciej Maciejewski with MetRec in Poland on 2011 July 8/9.

Figure 6 – Two further chance recordings, taken by Hubec by Zsolt Perko of Hungary on 2011 May 27.

Figure 7 – A couple of sprite records, taken with Orion1 on 2009 July 15 (left) and Stefka on 2011 May 26 (right) by Javor Kac of Slovenia.

Table 1 – Observers contributing to 2011 July data of the IMO Video Meteor Network. Eff.CA designates the effective collection area and Tot.CA the total collection area.

Code	Name	Place	Camera	FOV [$^{\circ 2}$]	Stellar LM [mag]	Eff.CA [km^2]	Nights	Time [h]	Tot.CA [10^3km^{2}h]	Meteors
BASLU	Bastiens	Hove/BE	Urania1 (0.95/4)*	4545	2.5	237	5	7.8	2.8	18
BERER	Berko	Ludányhalászi/HU	Hulud1 (0.95/3)	2256	4.8	1540	22	93.7	79.8	447
			Hulud2 (0.75/6)	4860	3.9	1103	25	94.9	51.1	241
			Hulud3 (0.75/6)	4661	3.9	1052	23	77.1	44.3	167
BREMA	Breukers	Hengelo/NL	Mbb3(0.75/6)	2399	4.2	699	8	28.3	21.5	104
BRIBE	Brinkmann	Herne/DE	Hermine (0.8/6)	2374	4.2	678	16	43.7	—	161
		Bergisch Gladbach/DE	Klemoi (0.8/6)	2286	4.6	1080	21	53.5	34.6	202
CASFL	Castellani	Monte Baldo/IT	Bmh1 (0.8/6)	2350	—	—	17	83.3	—	337
			Bmh2 (1.5/4.5)*	4243	—	—	24	73.5	—	276
CRIST	Crivello	Valbrevenna/IT	C3P8 (0.8/3.8)	5455	4.2	1586	25	119.2	122.7	553
			Stg38 (0.8/3.8)	5614	4.4	2007	19	95.8	151.3	719
CSISZ	Csizmadia	Zalaegerszeg/HU	Huvcse01 (0.95/5)	2423	3.4	361	19	47.8	9.5	111
CURMA	Currie	Grove/UK	Mic4 (0.8/6)	2411	5.2	2373	13	38.1	—	162
ELTMA	Eltri	Venezia/IT	Met38 (0.8/3.8)	5631	4.3	2151	21	113.9	—	455
GONRU	Goncalves	Tomar/PT	Templar1 (0.8/6)	2179	5.3	1842	26	154.9	188.8	825
			Templar2 (0.8/6)	2080	5.0	1508	28	147.6	119.1	692
			Templar3 (0.8/8)	1438	4.3	571	5	19.7	11.0	117
GOVMI	Govedič	Središče ob Dravi/SI	Orion2 (0.8/8)	1447	5.5	1841	18	78.9	39.6	337
IGAAN	Igaz	Baja/HU	Hubaj (0.8/3.8)	5552	2.8	403	18	68.8	21.2	253
		Hódmezővásárhely/HU	Huhod (0.8/3.8)	5502	3.4	764	27	118.6	60.4	412
		Budapest/HU	Hupol (1.2/4)	3790	3.3	475	19	41.7	19.8	125
		Sopron/HU	Husop (0.8/6)	2031	3.8	460	23	65.3	13.5	198
JONKA	Jonas	Budapest/HU	Husor (0.95/4)	2286	3.9	445	23	101.2	—	347
KACJA	Kac	Kostanjevec/SI	Metka (0.8/8)*	1372	4.0	361	10	58.2	—	166
		Ljubljana/SI	Orion1 (0.8/8)	1402	3.8	331	22	100.6	24.7	220
		Kamnik/SI	Rezika (0.8/6)	2270	4.4	840	15	65.2	45.8	461
			Stefka (0.8/3.8)	5471	2.8	379	12	54.6	10.6	207
KERST	Kerr	Glenlee/AU	Gocam1 (0.8/3.8)	5189	4.6	2550	30	291.7	669.3	3250
KOSDE	Koschny	Noordwijkerhout/NL	Lic4 (1.4/50)*	2027	—	—	9	34.7	74.6	174

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

Code	Name	Place	Camera	FOV [°²]	Stellar LM [mag]	Eff.CA [km²]	Nights	Time [h]	Tot.CA [10³km²h]	Meteors
LERAR	Leroy	Paris/FR	SAPHIRA (1.2/6)	3260	3.4	301	16	59.5	23.3	65
MOLSI	Molau	Seysdorf/DE	AVIS2 (1.4/50)*	1776	6.1	3817	10	36.9	100.5	666
			MINCAM1 (0.8/8)	1477	4.9	1084	23	61.3	45.3	281
		Ketzür/DE	REMO1 (0.8/3.8)	5600	3.0	486	14	46.5	—	85
			REMO2 (0.8/3.8)	5613	4.0	1186	16	54.5	31.2	153
MORJO	Morvai	Fülöpszállás/HU	HUFUL (1.4/5)	2522	3.5	532	12	51.5	35.7	184
OTTMI	Otte	Pearl City/US	ORIE1 (1.4/5.7)	3837	3.8	460	20	88.4	—	332
PERZS	Perko	Becsehely/HU	HUBEC (0.8/3.8)*	5498	2.9	460	24	72.5	—	343
ROTEC	Rothenberg	Berlin/DE	ARMEFA (0.8/6)	2366	4.5	911	13	43.0	29.5	122
SARAN	Saraiva	Carnaxide/PT	RO1 (0.75/6)	2362	3.7	381	25	89.0	—	402
			RO2 (0.75/6)	2381	3.8	459	23	86.5	46.5	353
SCHHA	Schremmer	Niederkrüchten/DE	DORAEMON (0.8/3.8)	4900	3.0	409	17	45.3	—	122
SLAST	Slavec	Ljubljana/SI	KAYAK1 (1.8/28)	588	—	—	17	48.2	—	198
STOEN	Stomeo	Scorze/IT	MIN38 (0.8/3.8)	5566	4.8	3270	20	95.7	179.0	687
			NOA38 (0.8/3.8)	5609	4.2	1911	24	108.3	189.4	587
			SCO38 (0.8/3.8)	5598	4.8	3306	24	107.8	185.7	767
STORO	Stork	Ondřejov/CZ	OND1 (1.4/50)*	2195	5.8	4595	2	7.5	15.8	132
STRJO	Strunk	Herford/DE	MINCAM2 (0.8/6)	2362	4.6	1152	10	24.1	21.4	70
			MINCAM3 (0.8/12)	728	5.7	975	14	30.5	—	85
			MINCAM5 (0.8/6)	2349	5.0	1896	12	33.2	34.7	143
TEPIS	Tepliczky	Budapest/HU	HUMOB (0.8/6)	2388	4.8	1607	23	84.4	72.5	373
TRIMI	Triglav	Velenje/SI	SRAKA (0.8/6)*	2222	—	—	21	75.9	—	280
						Overall	31	3 722.7	—	18 167

* active field of view smaller than video frame

History

Meteor Beliefs Project: "Year of Meteors"

Alastair McBeath[1], *George J. Drobnock*[2] *and Andrei Dorian Gheorghe*[3]

We present a discussion linking ideas from a modern music album by Laura Veirs back to a turbulent time in American history 150 years ago, which inspired poet Walt Whitman to compose his poem "Year of Meteors", and the meteor beliefs of the period around 1859–60, when collection of facts was giving way to analyses and theoretical explanations in meteor science.

Received 2011 August 25

1 Introduction

The inspiration for this article was a letter received in 2007 March from American singer-songwriter Laura Veirs, in which she provided some insights into her 2005 album "Year of Meteors", especially her choice of title for it. This led us into fresh discoveries from the period around 150 years ago, a time when meteor astronomy was developing rapidly from being largely a descriptive process of collecting reports with limited analyses, to a more scientific understanding of why some meteors occurred in showers that were seen annually, and why a few of those showers occasionally produced exceptional meteor numbers.

Note that this paper was originally presented as a poster to the 2008 IMC, and should have been published in full in the IMC Proceedings volume for that year. For unknown reasons this did not happen. We have made changes to update the material in places here, but the bulk of the article is as prepared for that Conference, the preprint for which has been available on the Project's CD-ROM (available from IMO's online shop) since the IMC in 2008.

2 "Year of Meteors" (2005)

As described previously (McBeath & Gheorghe, 2010), and as those who have checked the Project's webpage, `www.imo.net/projects/beliefs`, in recent times will be aware, since December 2005, we have been collecting meteoric mentions from contemporary song lyrics and other meteor-related music. One of the first such items we encountered in this "Musical Meteors" strand was the 2005 album "Year of Meteors" by Laura Veirs.

Laura is a singer-songwriter – or perhaps more precisely, a musical performance poet – from the northwest USA. Though starting out in the American folk tradition of "Country & Western", her musical style has developed rapidly into something unique, through a series of six albums since 2001. Her most recent work, "July Flame", was released in 2009. Here, it is her fourth album we shall particularly concentrate on. Her recent albums especially have received considerable praise, and as usual in the Project, we would recommend hearing in full what we provide only brief text extracts from. The bare lines cannot recreate the effect of hearing them performed as they were meant to be. As music critic Mark Edwards (2007) put it, "Special she does as a matter of course, just occasionally moving up a gear to transcendent". Laura tours various parts of the world regularly, and catching one of her live shows is highly worthwhile too. For more information, see `www.lauraveirs.com`.

"Year of Meteors" contained a number of meteorically- or astronomically-intriguing track titles, such as "Fire Snakes", "Galaxies", "Through the Glow" and "Where Gravity is Dead", but the significance of the titles and the lyrics was sufficiently open to allow the listener's imagination to participate too. "Fire Snakes" might have been very meteoric from all the fiery meteor-dragons we have met in the Project, but the lyrics invited a connection to lava streams instead. Stars as falling tears in "Galaxies" could have been equally meteoric, recalling the Romanian meteor-tear imagery we have examined previously (Gheorghe & McBeath, 2005). "Through the Glow" seemed more the golden light of the low Sun on the sea, but late mentions of straining up to the stars and swimming in the sparkling dark hinted at more imaginary journeys, while "Where Gravity is Dead" was a more direct flying escape route – but on a raft!

In two tracks, we seemed to find more distinctly meteoric images. At the very end of "Magnetized" (track four), the ghostly narrator and another were caught in a web, where:

> we can struggle
> with white spider stars coming down
> and night blowing black from the ground
> (Veirs, 2005).

The last two lines were repeated again in the full song. The idea of swift-scuttling spider-star meteors was a new concept in what we have found with the Project so far, but seemed a fascinating suggestion.

In verse two of "Black Gold Blues" (track ten) was what appeared to us the most marvellous poetic description of a fireball:

> arrow on fire
> flash the night

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IMO bibcode WGN-395-mcbeath-yearofmeteors
NASA-ADS bibcode 2011JIMO...39..146M

gonna fade away
to the trees and caves
salt salt lamp
romance the spark
and you'll shine shine shine
up the wild deep dark
(*ibid.*)

We have adopted this as the Project's anthem, since it is difficult to imagine a better fireball word-picture which touches on so many resonances of the experience of witnessing such an event, from the Project's perspective. Even the chorus of "Black Gold Blues" could have been written with an astronomical observer in mind – "A sliver, a crack of light/ is all you need to see"!

There is much besides these few selections to enjoy on the full album, including other astronomical items, such as this splendid sunrise depiction, from verse two of "Lake Swimming", the last formal track:

enter the sun
marching like a matador
flashing her velvet yellow suit
throwing a red cape on the sky
(*ibid.*)

Laura mentioned (personal communication, March 2007) that the album's title came about because its focus overall was on air and space, plus its preparation coincided with some dramatic changes in her personal life, so the idea of similarly dramatic and portentous meteors seemed appropriate. As for the actual name: "I chose the title – or rather, borrowed it, from a great poem by Walt Whitman (actually called "Year of Meteors.")" Which led the Project to this hitherto undiscovered poem.

3 "Year of Meteors (1859–60)"

We have met the noted American poet Walt Whitman (1819–92) in the Project before, with his recollection of Abraham Lincoln's memories of the 1833 Leonid storm in his "Specimen Days & Collect" (McBeath & Gheorghe, 2005, p. 91). Born on Long Island, New York, he worked in various capacities associated with printing, publishing and teaching, mostly in places in and around New York and New Jersey. His major poetry collection "Leaves of Grass" was first published in 1855, a work he revised and reprinted nine times, into the year he died. During the Civil War in 1861–65, he worked as a hospital visitor to wounded and dying troops, and it was from this period his poem "Year of Meteors (1859–60)" came. It is not clear exactly when it was written, but it was first published in 1865, and featured in the 1867 revision of "Leaves of Grass". The text cited from here is the 1891–92 "Leaves of Grass" edition, as given on pp. 267–268 of (Murphy, 1975), which text also provided the biographical notes here, notably pp. 21 & 25–29. Footnotes to the poem were on p. 813. (McBeath & Gheorghe, 2005)

The poem began:

Year of meteors! brooding year!
I would bind in words retrospective some of your deeds and signs.
I would sing your contest for the 19th Presidentiad.
I would sing how an old man, tall, with white hair, mounted the scaffold in Virginia,
(I was at hand, silent I stood with teeth shut close, I watch'd,
I stood very near you old man when cool and indifferent, but trembling with age and your unheal'd wounds you mounted the scaffold;)

The presidential contest was the 1860 election which Lincoln won, while the executed old man was the abolitionist John Brown (1800–59), whose incitement of the slaves to rebel in 1859 helped lead to the Civil War. His execution followed his capture after he led an armed raid on Harper's Ferry, Virginia (now West Virginia) on 1859 October 17, intended to free slaves there. His party of twenty-two men seized the US armoury and arsenal, where they were besieged by US marines under Colonel Robert E. Lee, and Lieutenants Green and J. E. B. Stuart on October 19. Ten of his followers, including two of his sons, died in the ensuing battle. Five, including another son Owen, escaped, and the remaining seven were caught and hanged after trial. John Brown was the first to be killed thus, still wounded from the battle as Whitman accurately stated, on December 2 (Imboden, 1887, pp. 116–117 Editors' footnote, with engravings, maps and sketches there and pages adjacent). After the event, Brown was regarded by some as a heroic martyr, by many others, notably in the contemporary media, as a dangerous lunatic.[1]

Whitman's poem continued through more general matters, such as the census returns and the "proud black ships of Manhattan" arriving with their immigrants and cargoes, to the specific visit of the young English Edward, Prince of Wales (1841–1910; later King Edward VII, who succeeded Queen Victoria in 1901) to New York in October 1860, where Whitman saw him from among the crowds. He then proceeded:

> Nor forget I to sing of the wonder, the ship as she swam up my bay, Well-shaped and stately the Great Eastern swam up my bay, she was 600 feet long, Her moving swiftly surrounded by myriads of small craft I forget not to sing; Nor the comet that came unannounced out of the north flaring in heaven, Nor the strange huge meteor procession dazzling and clear shooting over our heads, (A moment, a moment long it sail'd its balls of unearthly light over our heads, Then departed, dropt in the night, and was gone;)

[1] Drobnock et al. (2009) gave more details on John Brown and his meteoric associations, albeit that paper was originally prepared and intended to be read after the current one. References in that 2009 *WGN* paper to "McBeath et al., forthcoming" were thus actually to this present article.

> Of such, and fitful as they, I sing – with gleams from them would I gleam and patch these chants Your chants, O year all mottled with evil and good – year of forebodings! Year of comets and meteors transient and strange – lo! even here one equally transient and strange! As I flit through you hastily, soon to fall and be gone, what is this chant, What am I myself but one of your meteors?

Thus the poem concluded. The Great Eastern steamship ($\sim$ 185 m long) reached New York while Whitman looked on, on 1860 June 28. We were intrigued by the comet and "meteor procession", which passed unremarked in the footnotes to the versions of the poem we encountered, so we investigated further.

4 Whitman's comet and fireball

Our initial thought was that the comet must have been the spectacular Donati's (C/1858 L1), though that was seen from 1858 June to 1859 March, and was a frequently stunning naked-eye object from 1858 August 19 to December 4 (Olson & Pasachoff, 1998, Chapter V; Olson, 1985, pp. 93–100). However, Whitman's description of it coming "out of the north" did not fit well with the behaviour of Donati's Comet, best known perhaps for passing in front of the star Arcturus (α Boötis) on 1858 October 5, when it was in the western evening sky. Instead, it seemed probable Whitman was drawing on his memories of Comet C/1860 M1, visible to the naked-eye from 1860 June 18 till the end of July. It was discovered "in the evening twilight of June 18 on the north-western horizon, situated in Auriga" (Bortle, 2007). It was first magnitude then, and faded steadily as it passed through Lynx and Leo, then Crater and Corvus, being independently discovered in late July from the southern hemisphere.

In tracing Whitman's "strange huge meteor procession", we discovered four major fireballs were seen from America between 1859 November and 1860 August:

1859 November 15, at 9:30 a.m., a daylight fireball headed south-southwest over Connecticut, New York City and southern New Jersey, an event that was widely-reported on both sides of the Atlantic in the scientific literature;

1860 April 21, a brilliant fireball dropped meteorites in Ohio;

1860 July 20, a superb, very long, fireball was seen from Minnesota to eastern Long Island and far out over the Atlantic; and

1860 August 2, at 10:30 p.m., a Sun-bright fireball was seen trailing sparks, followed by a double sonic boom, from Charleston, Tennessee.

All four were described at least briefly (the Tennessee event was given greatest prominence there, as the most recent) in *Scientific American*, Vol. III, No. 10 (new series) for 1860 September 1, p. 150, under the heading "The Year of Great Meteors"! We found the idea Whitman's poem title may have come from this popular science journal, and reached down to us nearly 150 years later thanks to Laura Veirs' modern album, a marvellous arts-science circle!

Of the four, it is most likely the July 20 fireball was the one Whitman featured in his poem, assuming a distinct chronological sequence was intended by the passage cited above. We found a fuller description of this meteor in *Scientific American*, Vol.III, No.6 (new series), for 1860 August 4, p. 89, under the heading "Meteors – What Are They?" Deliciously, the same page featured a discussion of the Great Eastern too, under "The Seven Wonders of the World – and the Last"![2]

The significance of this July fireball was stressed by the text, which promised the likelihood of a more detailed account of its atmospheric flight than any other previously, due to its having happened over such a densely populated area, where there were many people sufficiently interested and able to collect and analyze the witness reports. The editors gave a preliminary figure for its height of around 60 km-equivalent, and similarly a size was estimated for the object (presumably the glowing fireball's head at the suggested height) of $\sim$ 1.2 km. They concluded that any meteorites likely dropped into the Atlantic, and ended with an exhortation to anyone seeing such a fireball to make and report carefully their sighting details, a sentiment that more than 150 years on, we would still fully endorse.

Walt Whitman of course also used these things as foretelling the Civil War, in the ancient omen tradition of meteors and other celestial signs, something the initial publication date for his "Year of Meteors" reinforced, as coinciding with the war's ending, when the horrific cost in lives and destruction was well-known. However, it seemed he may have been inspired in this usage by another contemporary writer and poet, Herman Melville.

5 "The meteor of the war"

Herman Melville (1819–91) is better known modernly for his prose than his poetry, though he was prolific in both. Perhaps his best-remembered work now is his novel "Moby Dick" of 1851 (another influence on Laura Veirs' music, incidentally). Like Whitman, Melville was born in New York in 1819, where he worked in various jobs till he was 18, when he went to sea as a ship's boy, travelling thereafter by sea and land in America. After numerous adventures, including deserting, living with cannibal natives in the Marquesa Islands, and being imprisoned in Tahiti for taking part in a mutiny, he returned to Boston in 1844. He moved to New York and married in 1847, becoming a writer, in which he drew on his travel experiences extensively. He struggled against depression and disillusionment, particularly when "Moby Dick" was received with public apa-

[2] Note that our identification of Whitman's fireball, presented at the 2008 IMC, was made entirely independently of that published subsequently by Olson et al. (2010), on which see also Drobnock (2010) in this journal. Having been in contact with Donald Olson since the publication of the *Sky & Telescope* article, we are hopeful a more detailed examination of this remarkable fireball may be possible jointly between our two teams as part of the Meteor Beliefs Project.

thy, which turned him towards poetry writing, though regrettably this was often no more favourably received. He is better-regarded now, if not by all critics.

Melville's poem of interest to us here was "The Portent" from 1859, which we give complete:

Hanging from the beam,
Slowly swaying (such the law),
Gaunt the shadow on your green,
Shenandoah!
The cut is on the crown
(Lo, John Brown),
And the stabs shall heal no more.

Hidden in the cap
Is the anguish none can draw;
So your future veils its face,
Shenandoah!
But the streaming beard is shown
(Weird John Brown),
The meteor of the war.

As with Melville's biographical notes here (pp. 71–73), this was taken from (Jones, 1980, pp. 75–76).

The Shenandoah Valley was where John Brown's last acts were played out. Harper's Ferry is at the confluence of the Shenandoah and Potomac Rivers. The description of Brown's head and face hidden by the bag placed over the condemned's head before he was hung, leaving his bushy white beard hanging free, was intended to draw attention to the physical similarity to a meteor or a comet, often confused with one another in the public mind then, as occasionally still today. The use of Brown as the meteoric portent of the Civil War, which Whitman clearly concurred with, seemed to have originated here.

However, there was equally a general movement to associate figuratively the death of John Brown with a meteor. On the day of his death, the Reverend J. Sella Martin delivered a long public address in praise of him in Boston (printed in "The Liberator" for 1859 December 9) which included depicting Brown's death as a meteor having fallen from the heavens, while on 1859 December 5, the noted American essayist Henry D. Thoreau wrote in his journal: "…[h]is cause these 6 weeks, I mean, has been meteor-like, flashing in the darkness in which we live" (Torry & Allen, 1906, Vol. 13). Others subsequently reused some variation on this concept, down to the present day, as we discussed in Drobnock et al. (2009). Whitman and Melville were obviously impressed enough by the comparison to draw on it for their own works, or perhaps came to it independently.

6 Comets and meteors in the 1850s & 1860s

Bright comets seemed unusually prevalent throughout the 19th century, which when coupled with the wholesale changes in Western civilization during that time, made a lasting impression scientifically and in the public mind. See for instance the discussions in Olson (1985, Chapter Five) and Olson & Pasachoff (1998, Chapters III to VII). We have touched on parts of this period before too, particularly the early 19th century in respect of English poet and artist William Blake (McBeath, 2004b). As mentioned above, this was still a period when the definitions of "meteor" and "comet" were blurred and often interchangeable, but with time, the more scientific segregation of them became established during this century too. The period from 1850–62 brought a particularly fine collection of comets, many of them reaching naked-eye brightnesses, including Donati's in 1858–59, and the last recorded return of 3D/Biela in 1852, responsible for the Andromedid storms in the later 19th century. This led to comets being again used satirically in cartoons, much as had happened earlier with French Emperor Napoleon, for example the last three (*loc. cit.*).

"Meteor" and "comet" passed into general usage for other things too, like sales and events advertised as "meteoric", or publications calling themselves "The Comet". Olson (1985, p. 106) referred to this aspect of 19th century comet reusage, and cited ships called "Metacomet" and "The Blazing Star", the latter an interesting continuation or revival of this phrase for a comet, which we discussed earlier in relation to the 16th century stage effect (Gheorghe & McBeath, 2007). While such object naming implied something swift or remarkable, the duality of meteors and comets as objects of ill-omen might be invoked if the ship ran into difficulties, or sank, as happened with the steamboat "Comet" (Olson, *loc. cit.*).

In respect of matters covered here, we were delighted to discover that Herman Melville had taken a trip from Boston to San Francisco round Cape Horn in his brother Thomas's ship "Meteor" – in 1860! It was Captain Melville's second journey round the Horn in charge of this vessel, which was a medium clipper ship of 1068 tons, around 60 m long. She was owned by Curtis & Peabody at the time, having been built by E. & H. O. Briggs of South Boston in 1852. Part of Herman Melville's journal of the voyage has survived (Melville, 1929), from notes in which edited reprint the above information was extracted. This was the last sea voyage he made.

In a comparable way, some American Civil War generals were designated as "meteors", and two comets became linked closely in America with the early years of the war, Comet Tebbutt of 1861 (C/1861 J1) and Comet 109P/Swift-Tuttle, parent of the Perseid meteors, in 1862. In America, these were seen as portending the battles of Shiloh (or Pittsburg Landing, Tennessee, 1862 April 6 & 7) and Williamsburg (Virginia, 1862 May 5), though Swift-Tuttle was first observed only on 1862 July 16 (Olson, 1985, p. 100). Tebbutt's Comet was by far the more notable, as a brilliant naked-eye object visible in daylight at its best, and which cast shadows at night from 1861 June 29 to July 1 (*op. cit.*, p. 97). Its closest approach to Earth, when the Earth was believed to have passed through its tail with no discernible effect, was on 1861 June 30. It has been suggested that a caricature illustration of General Winfield

Scott as "The Great War Comet of 1861", published in *Vanity Fair* for 1863 August 3, was based on Tebbutt's Comet (*op. cit.*, p. 99).

For all this, there were still throwbacks to earlier meteorological "meteors". In the same volume of *Scientific American* in which we found the "Year of Great Meteors" and "Meteors – What Are They?" items referred to above (Vol. III, No. 2, 1860 July 7, p. 19), we chanced upon a detailed description of an exceptionally long-lasting, violently destructive tornado, which carved a path of devastation ~ 225 km long across the states of Iowa and Illinois for about an hour and a half between 5 and 7 p.m. on 1860 June 3. Almost 150 people were killed by it, and between 300 and 400 injured. Three times in the article tornadoes were called "meteors". From the start of paragraph two:

"The meteor originated about 80 miles [130 km] west of the Mississippi river. A thin, somewhat elongated, cone was seen to descend toward the earth, said cone having an almost inky blackness, and (as first seen from a distance) it was about the dimensions of a man's arm. As it moved eastward, it increased rapidly in size and the well-defined proportions of an inverted cone became plainly visible (like the meteor described by M. Seltier as seen in France on June 18, 1839) "little clouds were flattering and whirling around the cone and rising and falling rapidly." "

After further description of its power, appearance and noise, was a note that "A strong sulphurous odor was also, in many places, plainly perceptible." Interestingly, this tallied with the smell detailed in quite a number of freshly-fallen meteorite reports. Obviously, no meteorite fell in this case, but perhaps the smell may have had a similar origin, in the violent disturbance of the atmosphere and surface soil.

The final "meteor" reference was near the start of the third paragraph:

"A high wind from the North, accompanied by a drenching rain, almost immediately followed. In the progress of the meteor eastward, it rose and fell occasionally, and seemed to visit with greater destruction the highest points of land. As it swept onward in its course (within the narrow belt, from one-quarter to one-half a mile [400–800 m], everything animate or inanimate was doomed to certain destruction."

While in no way astronomical, the connection of the term "meteor" with so dreadful an event was surely not accidental.

In 1850s art too, more and less realistic depictions of meteors now featured. Jean François Millet, whose entwined lovers flying through the sky in his painting "The Shooting Stars" of 1847–49 we discussed previously (Gheorghe et al., 2005; perhaps the doomed souls of the 13th century lovers Paolo Malatesta and Francesca da Rimini, immortalized in Dante's "Inferno", Canto V), painted another meteoric oil-on-canvas scene circa 1851, "Starry Night". In a dark landscape with trees, a pale twilight lingered on the horizon, while a starry clear sky above had several – at least two but possibly four or more – meteor trails, shown as if loosely radiating from a point towards the upper right of the scene. The original, $\sim 65 \times 81$ cm in size, is in the Yale University Art Gallery, New York, but an image is available online *via* `http://artgallery.yale.edu`. The Yale website suggested it may have been painted soon after Millet moved to Barbizon in 1849, but was retouched by him around 1864, and it may have subsequently influenced Van Gogh's own more famous "Starry Night" painting of 1889, which featured cometary, rolling, tailed stars. Olson (1985, pp. 88–89) did not show Millet's painting unfortunately, but indicated it was done *circa* 1850–57, and called it "a much more realistic rendering of a meteor shower, closely resembling the summer Perseids", something the unidentifiable star patterns and shallow angle of the meteors in what must have been the western or northwestern sky, made it impossible to corroborate. Indeed, as she went on to note that Millet's letters showed "his Romantic, mystical attitude toward nature" (*loc. cit.*), it is perhaps more surprising it was so realistically painted, except for a slight curvature of the longer meteor trails. It was more an impression of a meteor shower than a precise rendition, though nonetheless attractive for that.

By contrast, the English poet and painter Dante Gabriel Rossetti (1828–82), one of the three founders of the Pre-Raphaelite brotherhood of artists, showed a series of tailed, meteoric flames descending from top right to bottom left, as the background to one segment of his tripartite "Paolo and Francesca" watercolour of 1855, the doomed 13th century lovers already noted, shown in life together to the left of his painting, and flying intertwined amid the flaming "meteors" to the right, with Virgil and Dante looking on from the middle segment. Dante made no mention of any meteors or flames in this respect in his text, but such an artistic connection in the mid 19th century was obviously understood. The painting, reproduced from The Tate Gallery, London only in black-and-white, is shown as Fig. 136 in Olson & Pasachoff (1998, p. 266 and discussed on pp. 266–269 & 303), who made the curious suggestion (p. 268) that Rossetti could have seen the 1833 November 13 Leonid storm as a child, and re-used it in his (stylized and quite unrealistic) rendition 22 years later. Given that the 1833 Leonid storm was visible only from North American longitudes, and that Rossetti lived in England, this would have been impossible, but he may have seen or heard of the poorly-recorded, much weaker Leonid storm of 1832 November 13, which was observed from parts of Europe, including Britain (Littmann, 1998, pp. 59–63; see also now McBeath, 2011a, p. 29). Rossetti painted two later near-copies, in 1862 and 1867.

We should not forget that the fear of comets and meteoritic impacts was invoked at times around this period as well. The great comet of 1843 (C/1843 D1), visible, indeed first seen, in daylight, with an immensely long tail, provoked William Miller to suggest to his band of New England followers that this was a sign his prediction of the end of the world in 1843 was confirmed. The Millerite movement quietly faded away like the comet when nothing untoward happened (Yeomans, 1991, pp. 178–179; on this comet, see also Olson, 1985, pp. 90–91, and Olson & Pasachoff, 1998, pp. 199–206).

In Europe, an expectation grew from calculations based on comets seen in 1264 and 1556, that this was a single body which would return sometime between 1856–60. A German astrologer decided this comet was in fact going to hit the Earth on 1857 June 13, news which was picked up and publicised by the media, causing panic in some places, apparently especially in Paris. Nothing occurred. It was later found the calculations were in error, and the "comet" was actually two different ones, that were not liable to return again (Yeomans, 1991, pp. 186–187; Olson & Pasachoff, 1998, pp. 218–219).

7 Comet and meteor science in the 1850s & 1860s

It is stimulating to reflect on the different perceptions put on the significance of meteors and comets during this time. In America, so instrumental in the discovery of meteor showers following the 1833 Leonid storm and the formative first steps towards modern meteor science, the comets of the later 1850s were seen to have presaged the Civil War there, along with the brilliant fireballs of 1859–60 and the meteoric link made to John Brown by Melville, Whitman and others. In Europe, apart from occasional panics such as the 1857 "phantom comet" one, aside from an overall public interest, meteors and comets seemed to have been treated as less worrisome events, having apparently little influence even on science. In the official history of the British Royal Astronomical Society for example (Dreyer & Turner, 1923), meteors and comets were virtually ignored prior to Donati's Comet in 1858 (p. 113). The 1832 and 1833 Leonids passed unremarked in Dreyer's Chapter II. His assessment of the decade (*op. cit.*, p. 81): "The period 1830–40 was on the whole a quiet period in the history of astronomy"! Chapter V, covering 1860–70, by H. F. Newall, opened much more positively (*op. cit.*, p. 129): "A decade which was so full of activity and achievement in all branches of astronomical progress as that between 1860 and 1870, makes great demands on the self-restraint of an astronomer who is called upon to set forth the history of our Society at that time." He then listed things like photography and spectroscopy, which had been first tried astronomically in the 1850s, but which only began to bear considerable first fruits in the 1860s. He continued (p. 130): "We see greatly increased activity in the observation of meteors and meteor radiants, and also the establishment of the identity of orbits of certain comets and meteors", later on the same page listing five "remarkable astronomical events" during the decade, two of which were the Earth passing through Comet Tebbutt's tail in 1861, the other the predicted Leonid storm return over Europe on 1866 November 14.

Reading E. H. Grove-Hills' preceding Chapter IV on 1850–60, there is pleasure in the developments that took place then, but an overall feeling of a time of preparation, that the techniques developed would only become valuable later. Even so, despite the disappointing results to photograph a comet for the first time (Donati's), there was a real sense that by 1858–60, a turning point had been reached in astronomy overall, and comet and meteor science no less than elsewhere. Olson & Pasachoff (1998, p. 227) appreciated this change too, in titling their Chapter V "Donati's Comet, the Watershed", for example. It seemed to us in reviewing this period, that Whitman's "Year of Meteors (1859–60)" marked that point as well as anything. Before then in meteor astronomy, there were many data collected and published in raw form, but little significant analysis, after the 1833 Leonids. In Britain, this early work was largely carried out by the British Association for the Advancement of Science (BAAS), a body noted before in the Project (McBeath, 2004a, p. 35; see too now McBeath, 2011a & 2011b). In their annual reports, the first such mention was by J. D. Forbes (1841), who summarized the findings regarding the "November meteors", as he called the Leonids, from 1832–39, noting in passing the 1799 display, and the comments and theories of the day about meteors, concluding with a note on Quetelet's 1836 identification of a second periodic occurrence of meteors during the year due to the "August meteors". Most of this summary was in the form of where and when the event was seen, with typically just qualitative remarks on what happened. Meteors were still meteorological, and a hiatus followed this until the late 1840s.

A fresh impetus began in 1847, with a summary table of reported meteor showers from various dates and places between 1841–46, compiled by Baden Powell (1848), though in fact the table was only a text list of reported meteors, including single fireball sightings and meteorite falls. The following year, due to the enthusiasm shown for his 1848 publication, Powell (1849) began a series of annual summaries of meteors reported to him from the previous year, which included sightings from many earlier years sometimes. In general, these were properly tabulated, but came with only limited discussion of a few events per year. They continued till 1859. Powell died in June 1860, but his work was continued by the BAAS, who set up a committee, at times called the "Luminous Meteor Committee", to do so, feeling that no one person left was capable of the effort Powell had put in alone for the previous twelve years, and suggesting that meteors were expected to remain important for the foreseeable future.

The Committee's first report was for 1859–1860 (Glaisher et al., 1861). In light of events seen from America in that interval, and the "Year of Meteors" imagery they generated there, it was notable that from Britain, "Within the past year there does not seem to have been any unusual exhibition of meteors, either in August or November; and there is little to be added to the observations themselves" (*op. cit.*, p. 1). The observations referred to were tabulated just as Powell had done, the table consisting often of lone, ordinary meteor sightings, as well as fireballs, and two qualitative mentions of "Many shooting stars" on 1859 September 22 and 24 in the evening hours, seen by Committee member J H Gladstone (*op. cit.*, pp. 8–9). The 1859 November 15 daylight fireball over America was described in detail after the table (pp. 12–15), followed by notes from published papers, including a critique of Lubbock's solar reflection theory of meteors by R. P. Greg (on which theory, see Beech, 1995 & 1996), a discussion of meteor persistent trains and visible durations from a paper by Schmidt in *Comptes Rendus*, a basic analysis of the directions and occurrence times of 168 fireballs from 1841–53 by Coulvier-Gravier, also from *Comptes Rendus*, and some similar statistics by Greg. Further to this, Greg provided a simple analysis of the dates of fireball and meteorite falls from his own collated catalogue of such events between 2 AD to 1860, published in the same BAAS report, beginning on p. 48.

Such simple, perhaps even simplistic, analyses seemed to indicate the need for more than merely collecting and listing facts by this stage, a need to understand the reasons behind the occurrence of meteors. We should recall that 1859 saw the publication of Charles Darwin's "The Origin of Species by Means of Natural Selection" as well. The controversy it aroused seemed to have been part of an overall stirring of science at the time. In our subject, such stirrings led to the discovery of the links between comets and meteor showers in the 1860s, beginning with Giovanni Schiaparelli's connection of 109P/Swift-Tuttle and the "August meteors", the Perseids, in 1866 (see for instance Littmann, 1998, Chapter 8; Yeomans, 1991, pp. 188–201).

Perhaps the connection might have been made sooner had substantial meteor activity happened when the Earth passed through Comet Tebbutt's tail in 1861, but it did not. Oddly though, Olson & Pasachoff (1998, p. 264) claimed that it did: "Tebbutt had correctly predicted that the earth would pass through its tail on 30 June when the comet's appearance was accompanied by a spectacular meteor show in Europe, a day after it became visible in England." We could find little evidence to support their claim, nor did they cite a reference for this remarkable statement, a negative view confirmed by IMO Visual Commission Director Rainer Arlt some years ago (personal communications, 2001 February), who suggested the error may have arisen because of a misunderstanding or misinterpretation of some of the contemporary descriptions of Comet Tebbutt, which mentioned "luminous veils" in the coma, while "streams of light" were seen extending in arcs from the elliptical nucleus.

The prolific British 19th-century meteor observer E J Lowe was reported as having seen "many meteors" on June 30 in both 1860 and 1861, according to Denning (1916), which information Denning used to suggest possible June Boötid returns before the 20th century. He made no link with Comet Tebbutt. However, no other reports substantiated Lowe's sightings, nor was it clear just what Lowe's reports may have meant, especially as the data he presented in the annual BAAS *Reports* often included notes on the weather and the aurora as well. For example, from Glaisher et al. (1861), he noted "Many meteors. Lightning and snow" on 1859 October 22 (pp. 2–3), "Many large meteors, chiefly in N. E." on 1859 November 2 (pp. 4–5; though actually seen only by his brother), and "12 meteors. Clouds numerous all evening and night, and this, added to a full moon, caused most of the meteors to be invisible. Faint Aurora Borealis" from $2^{h}40^{m}$ to 03^{h} a.m. on 1859 November 13. The cited weather conditions at least raised questions about how accurate some of these claims may have been, and whether some of the "meteors" may have been meteorological or electrical instead. Oddly, given Denning's comment, there was no report from Lowe for 1860 June 30 in either the 1860 or 1861 (Glaisher et al., 1862) BAAS *Reports*, but there was one for 1861 June 30 of "Many fine meteors" seen in the evening (*op. cit.*, pp. 8–9). The apparently missing 1860 report would not disprove Denning's remark however, as in his notes from 1860 July 10 (*op. cit.*, pp. 2–3), made on a trip away from Britain to northern Spain, near Santander, Lowe wrote "Several small meteors seen, but not nearly so many as on the evening of 4th and early morning of 5th instant.", implying another "many meteors" event for 1860 July 4–5, but one which received no entry in the BAAS' tabular summary. Consequently, it would have been quite feasible for Denning to have had access to notes from Lowe in 1916 which have not survived modernly, and which passed unpublished nearer the time they were made. No mention was made in the BAAS *Reports* of any possible meteor activity due to Comet Tebbutt.

Recently, Bhathal (2010, p. 1.25) repeated this idea regarding Tebbutt's Comet of 1861, stating that "When the Earth duly passed through the tail, there were spectacular meteor showers in Europe", albeit again, like Olson & Pasachoff, without referencing the point. Bhathal also mentioned that it was this tail-passage event which was seen as so portentous of the American Civil War, rather than just the comet itself. Subsequent correspondence (McBeath, 2010; Williams, 2010) commented on the lack of such a meteor-comet connection in regard to Comet Tebbutt, and the Lowe observations of 1861.

The correct prediction of the Leonid storm return in 1866 confirmed the understanding of the cyclicity of such events, and the discovery of Comet 55P/Tempel-Tuttle in 1866 allowed confirmation of the link between it and the Leonids. Thus was modern meteor science firmly established. (See too on this Williams, 2011.)

8 Conclusion

The "Year of Meteors" idea, representing a time of changes and events both good and bad, fits with the general pattern of beliefs about meteors we have discussed in the Project, albeit there has been a tendency for many such beliefs to be more negative overall. We were fascinated and delighted by the way in which a modern music album was able to point the way for us to such a plethora of meteoric links and beliefs 150 years ago, even leading one of us (GJD) to a greater appreciation of his own country's history in that turbulent period. The resonance of the concept through time, place and between arts and sciences has been a particularly pleasing aspect for us in this.

Our grateful thanks go again to Laura Veirs for her initial inspiration, and we would use that fact to inspire

others who may have chanced upon even a seemingly minor item of meteoric lore, to contact us with it. You never know where it may lead!

References

Beech M. (1995). “The Makings of Meteor Astronomy: Part XI”. *WGN, Journal of the IMO*, **23:6**, 210–211.

Beech M. (1996). “The Makings of Meteor Astronomy: Part XIII”. *WGN, Journal of the IMO*, **24:5**, 154–157.

Bhathal R. (2010). “Australia’s great comet hunter”. *A & G*, **51:1**, 1.23–1.25.

Bortle J. E. (2007). “Comet C/1860 M1 (Great Comet; O.S. 1860 III)”. `www.cfa.harvard.edu/icq/bortle.html` .

Dreyer J. L. E. and Turner H. H., editors (1923). *History of the Royal Astronomical Society, Volume 1, 1820-1920.* RAS, London.

Drobnock G. J. (2010). “Letter - Re: Texas State astronomers solve Walt Whitman meteor mystery”. *WGN, Journal of the IMO*, **38:4**, 113–114.

Drobnock G. J., McBeath A., and Gheorghe A. D. (2009). “Meteor Beliefs Project: Meteoric imagery associated with the death of John Brown in 1859”. *WGN, Journal of the IMO*, **37:6**, 191–194.

Edwards M. (2007). “Laura Veirs, “Saltbreakers”, Nonesuch 104316”. *Sunday Times Culture*, **:March 25**, 30. Review.

Gheorghe A. D. and McBeath A. (2005). “Meteor Beliefs Project: Meteoric verse from three Romanian poets”. *WGN, Journal of the IMO*, **33:4**, 108–110.

Gheorghe A. D. and McBeath A. (2007). “Meteor Beliefs Project: Shakespeare revisited and the Elizabethan stage’s ‘blazing star”’. *WGN, Journal of the IMO*, **35:3**, 66–68.

Gheorghe A. D., McBeath A., and Taibi R. (2005). “Meteor Beliefs Project: Meteors as symbols of love”. *WGN, Journal of the IMO*, **33:1**, 30–32.

Glaisher J., Gladstone J. H., Greg R. P., and Lowe E. J. (1861). “Report on Observations of Luminous Meteors, 1859-60”. *Report of the British Association for the Advancement of Science 1860*, pages 1–27.

Glaisher J., Gladstone J. H., Greg R. P., and Lowe E. J. (1862). “Report on Observations of Luminous Meteors, 1860-61”. *Report of the British Association for the Advancement of Science 1861*, pages 1–44.

Imboden J. D. (1887). “Jackson at Harper’s Ferry in 1861”. In Johnson R. U. and Buel C. C., editors, *Battles and Leaders of the Civil War, Volume I*, pages 111–125. The Century Magazine.

Jones P. (1980). *A Reader’s Guide to Fifty American Poets.* Heinemann and Barnes & Noble.

Littmann M. (1998). *The Heavens on Fire: The Great Leonid Meteor Storms.* Cambridge University Press.

McBeath A. (2004a). “Meteor Beliefs Project: ‘Meteor’ and related terms in English usage”. *WGN, Journal of the IMO*, **32:1**, 35–38.

McBeath A. (2004b). “Meteor Beliefs Project: Meteoric imagery in the works of William Blake”. *WGN, Journal of the IMO*, **32:6**, 161–174.

McBeath A. (2010). “Comet Tebbutt’s ‘meteor showers”’. *A & G*, **51:2**, 2.4. Letter.

McBeath A. (2011a). “History of Meteor Observing Project: An overview of British meteor observing, Part I, 1563 to 1860”. *WGN, Journal of the IMO*, **39:1**, 24–32.

McBeath A. (2011b). “History of Meteor Observing Project: An overview of British meteor observing, Part II, 1861 to 2010”. *WGN, Journal of the IMO*, **39:3**, 76–86.

McBeath A. and Gheorghe A. D. (2005). “Meteor Beliefs Project: Notes from our correspondents”. *WGN, Journal of the IMO*, **33:3**, 90–92.

McBeath A. and Gheorghe A. D. (2010). “Meteor Beliefs Project: Musical Meteors, meteoric imagery as used in contemporary song lyrics”. In Andreić Z. and Kac J., editors, *IMC Proceedings 2009*, pages 95–99. IMO.

Melville H. (1929). “Journal of Melville’s Voyage in a Clipper Ship”. *The New England Quarterly*, **2:1**, 120–125.

Murphy F., editor (1975). *Walt Whitman: The Complete Poems.* Penguin Books.

Olson D. W., Olson M. S., Doescher R. L., and Pope A. G. (2010). “Walt Whitman’s “Year of Meteors””. *Sky & Telescope*, **:July**, 28–33.

Olson R. J. M. (1985). *Fire and Ice: A History of Comets in Art.* Walker & Company.

Olson R. J. M. and Pasachoff J. M. (1998). *Fire in the Sky: Comets and Meteors, the Decisive Centuries, in British Art and Science.* Cambridge University Press.

Powell B. (1848). “On Periodic Meteors”. pages 15–16.

Powell B. (1849). “A Catalogue of Observations of Luminous Meteors”. *Report of the British Association for the Advancement of Science 1848*, pages 1–11.

Torry B. and Allen F., editors (1906). *Journal of Henry D. Thoreau.* Cambridge, Massachusetts.

Veirs L. (2005). *Laura Veirs - Year of Meteors*. Nonesuch Records. Lyrics booklet included with music album.

Williams I. P. (2010). "The association between meteor showers and comets". *A & G*, **51:3**, 3.6. Letter.

Williams I. P. (2011). "The origin and evolution of meteor showers and meteoroid streams". *A & G*, **52:2**, 2.20–2.26.

Yeomans D. K. (1991). *Comets: A Chronological History of Observation, Science, Myth, and Folklore*. John Wiley & Sons Inc.

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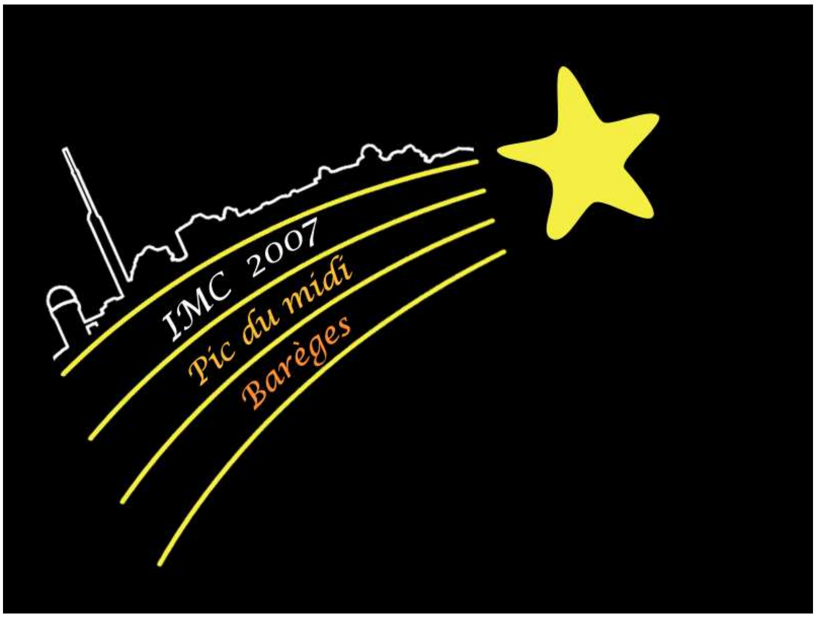

Published by the International Meteor Organization 2010

edited by

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