# A PROBABILITY FUNCTION FROM DCV ESTIMATES

Peter Jenniskens *

### Introduction

In order to obtain the mass influx from Zenithal Hourly Rate counts we have to know the effective collecting area ($D_e$) monitored by an observer. If the meteors are homogeneously distributed over the sky, $D_e(m)$ is related to the fraction of all appearing meteors of magnitude m, that are detected by the observer. This is called the *Probability function* P(m) [1].

$$D_e(m) = cos^{-1}(1 - P(m)) \tag{1}$$

Determining P(m) by Öpik's method of double counts [2],[3] involves a serious change in the usual observing conditions: the observers observe in a group and they are forced to keep their center of vision fixed at one point (f.e. the zenith.). In order not to loose concentration due to staring, the observer will put his attention at the edge of his field of view and not at the center. Our experience is, that observers following this procedure, see more meteors than others. However, they are registered less accurately, which makes magnitude estimates and –for example– plottings less reliable.
The usual procedure is to scan the sky above 45 degrees altitude at a slow rate and to 'hunt' for meteors which appear close to the center of vision. We would like to obtain a probability function for such conditions. This is possibly if for all observerd meteors a DCV *(Distance from Center of Vision)* estimate is made.

### The method

It is assumed that all meteors are uniformly distributed over the area scanned by the observer. Is is also assumed that in every part of this area, the meteors have an exponentional distribution:

$$n(m) = n(0)r^m \tag{2}$$

where $r$ is the *magnitude distribution index*. Regarding $n(m)$ as the true number of meteors appearing in the whole sky and let $N(m)$ be the observed number of meteors, then we have:

$$N(m) = n(m) \times P(m) \tag{3}$$

From DCV estimates we select those meteors that appear within a small area around the center of vision. Because DCV estimates are usually expressed as D=0°, D=10°, D=20° etc. we choose the area with D $< 15°$. The probability of detecting bright meteors in this small area is very close to 1.
A plot of $^{10}\log[N(m, D < 15°)]$ versus m shows a linear dependence up to a bending point, beyond which the probability of detecting a meteor is less than 1 and drops quickly. From a linear fit to the number of bright meteors, having slope $^{10}\log r$ , r is derived. Extrapolation to faint meteors gives the true number of meteors $n(m, D < 15°)$.
The probability of detecting faint meteors in this area $P(m, D < 15°)$ is found from:

$$N(m, D < 15°) = n(m, D < 15°) \times P(m, D < 15°) \tag{4}$$

If we start from the usual magnitude distribution of all meteors observed in the sky, we have to know which fraction $f(m)$ of these meteors appeared outside D=15°. This may also be found from the DCV estimates.
We choose $f(m)$ in such a way that:

$$N(m) = N(m, D < 15°) \times f(m) \tag{5}$$

Now, the total number of meteors appearing in the sky can be obtained.
The surface area of part of a sphere DCV degrees from the center of vision is:

$$A = 2\pi \int_0^{DCV} sin(D)dD \ = 2\pi(1 - cos(DCV)) \tag{6}$$

With DCV=15° and DCV=90° we have a ratio of surfaces of 0.034.
The total number of meteors in the sky is:

$$n(m) = n(m, D < 15°)/0.034 \tag{7}$$

From equation 3–7 it follows that the probability function is given by:

$$P(m) = P(m, D < 15°) \times 0.034 \times f(m) \tag{8}$$

### Observations

DCV estimates for sporadic meteors are available from three DMS observers: Rudolf Veltman (1982–1985), Klaas Jobse (1983–1984) and Peter Jenniskens (1984–1989). These observations are listed in table 1.
The slope fitted to the data of bright meteors has $r = 2.6$, less than the value found by Kresáková [1]: $r = 3.4 \pm 0.2$.
KJO is found to see all meteors up to magnitude +2 for D<15°. He detects considerably more meteors than RVO and PJM, both in his center of vision as well as outside this area.
The difference in perception between *KJO* and *RVO/PJM* of a factor of 1.5 ,which was derived before from a comparisson of sporadic rates, is in good agreement with the difference in $\sum_m P(m)r^m$ of about 1.4.

### Discussion

*Pelikaanhof 59a, 2312 EC Leiden, Netherlands

| | RVO (n=713) | | | | KJO (n=856) | | | |
|---|---|---|---|---|---|---|---|---|
| m | N(m,D<15°) | $f(m)$ | P(m,D<15°) | $P(m)$ | N(m,D<15°) | $f(m)$ | P(m,D<15°) | $P(m)$ |
| -1 | 2 | (2.4) | 1.00 | 0.082 | 2 | (4.6) | 1.00 | 0.16 |
| 0 | 12 | (2.1) | 1.00 | 0.071 | 9 | (3.9) | 1.00 | 0.13 |
| +1 | 29 | 1.90 | 1.00 | 0.065 | 22 | 3.09 | 1.00 | 0.11 |
| +2 | 69 | 1.68 | 0.87 | 0.050 | 63 | 2.68 | 1.00 | 0.091 |
| +3 | 98 | 1.59 | 0.48 | 0.026 | 145 | 1.91 | 0.95 | 0.062 |
| +4 | 120 | 1.35 | 0.23 | 0.011 | 186 | 1.24 | 0.48 | 0.020 |
| +5 | 146 | 1.02 | 0.11 | 0.0038 | 75 | 1.05 | 0.076 | 0.0027 |
| +6 | 30 | 1.00 | 0.009 | 0.0003 | 0 | – | 0.000 | 0.000 |

| | PJM (n=473) | | | | Czech. (n=1344) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| m | N(m,D<15°) | $f(m)$ | P(m,D<15°) | $P(m)$ | N(m,D<15°) | $f(m)$ | P*(m,D<15°) | $P(m)$ | $P^{**}(m)$ |
| -1 | 3 | (2.6) | 1.00 | 0.088 | – | – | – | – | – |
| 0 | 7 | (2.4) | 1.00 | 0.083 | – | – | – | – | – |
| +1 | 18 | 2.22 | 1.00 | 0.075 | 3 | 16 | 1.0 | 0.53 | 0.42 |
| +2 | 35 | 1.63 | 0.74 | 0.041 | 20 | 13 | 1.0 | 0.45 | 0.34 |
| +3 | 62 | 1.44 | 0.51 | 0.025 | 106.5 | 4.9 | 1.0 | 0.17 | 0.23 |
| +4 | 124 | 1.31 | 0.40 | 0.018 | 108.5 | 3.8 | 0.19 | 0.024 | 0.064 |
| +5 | 81 | 1.01 | 0.10 | 0.0035 | 40.5 | 2.5 | 0.013 | 0.0011 | 0.008 |
| +6 | 16 | 1.00 | 0.008 | 0.0003 | 2.5 | 1.4 | 0.00014 | 0.000007 | 0.00007 |

Table 1: *Probability functions derived from DCV estimates as described in this article. *r=5.5. **ref.1. Öpik method.*

The slope of the probability function is good agreement with [1] (Last column in table 1.), but there is an absolute shift in probabilities that amounts to a factor of 4 (KJO) to 8 (RVO,PJM).
This discrepancy agrees with the difference in mean DCV claimed by the observers above <DCV(4)>≈11° and that of the Czechoslovakian Öpik team <DCV(4)>≈24°. [1]
The latter group finds a larger collecting area.
Table 1 gives the results of the analysis described here on the Czechoslovakian data [1], although these data are from six observers watching according to Öpiks methods.
A value of $r = 5.5$ is needed to fit the number distribution. The final values for P(m) are in good agreement with the Öpik results.
Uncertainties in the method are mainly due to systematic errors in the DCV estimates. Underestimates of the DCV for bright meteors may cause an error in r; a general underestimation of the DCV=15° may cause an error in the transformation to all sky–values. Five degrees is equivalent to a factor of 1.8.
Error in magnitude estimates are probably not very important, as only the meteors seen in the central part of the field of vision are used.
The Öpik method may be a more efficient way of observing, which amounts to a factor of two (based on Öpik observations by a team of observers from Loosdrecht, the Netherlands.)
The limiting magnitude of the sky, typically 6.0 for our observations, lowers the probability function and not merely shifts it to lower magnitudes as is often assumed. This was found from a subset of the data above for $L_m \approx 6.5$. Such a shift may account for a factor of $3.4^{(L_m-6.0)}$, where $L_m$ is a typical value at the Skalnaté Pleso Observatory during the observations in 1958. Assuming $L_m$ is about 6.6, this amounts to a factor of 2.
To explain the factor of 4–8 difference between our probability function and the values given by Kresáková and others [1] several of the above factors may be of importance.
Finally, in the Öpik method $D_e(m)$ may be over estimated by decreasing brightness estimates for large DCV, by interaction between the group members and if the meteors are not homogeneously distributed over the sky. The brighter ones tend to be more abundant at lower altitudes.

**Conclusion**

From a minimum of about 500 DCV estimates, a reliable probability function can be derived. Important is to define a good boundary for DCV=15°; always a bit ambiguous because the exact point of center of vision is seldom known, as well as the position of the meteor due to its intrinsic lenght and non–homogeneous appearence. The latter problem is also important for Öpik observations. A lower limiting magnitude tends to lower $P(m)$ and not merely shift it. This effect needs further study.

**Aknowledgements**

I thank *Rudolf Veltman* for initiating the recordings of DCV estimates, *Klaas Jobse* for the supply of a large amount of data and *David Hughes* who urged me to look into the problem of probability functions of observers. •

# References

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