No sign of the 2014 Daytime Sextantids and mass indexes determination from radio observations

Giancarlo Tomezzoli[1] **and Cis Verbeeck**[2]

[1] **European Patent Office, Bayerstrasse 34, D-80335, Munich, Germany**
gtomezzoli@epo.org

[2] **Royal Observatory of Belgium, Avenue Circulaire 3, 1180 Uccle, Belgium**
cis.verbeeck@oma.be

In reply to the invitation made by Rendtel at the IMC 2014 in Giron (France) to observe the Daytime Sextantids (DSX 221) by any possible means, the EurAstro Radio Station (EARS) in Munich performed radio observations in the recording period 30/09/2014, 07^h00^m UT – 05/10/2014, 16^h00^m UT. This paper presents the results of the EARS radio observations. A comparison of the number of meteor reflections when the Daytime Sextantid radiant was above and below the horizon showed no sign of the 2014 Daytime Sextantids. Since no significant other showers were active during the observation period, the meteor reflections can be considered as sporadic meteors. A new data reduction method was employed and illustrated to derive sporadic mass indexes in said recording period. This method is also valid for the determination of the mass index of meteor showers from radio observations.

1 Introduction

DSX 221[1] also indicated as Daytime Sextantids is a daytime meteor shower having poorly known features. It was discovered by Weiss in September 1957, who recorded 30 meteors per hour. No more Daytime Sextantids were reported until 1961. The next shower was in 1969, so the hypothesis has been advanced that DSX 221 is a four year periodic meteor shower.

The invitation to observe DSX 221 in the period 30 September – 05 October 2014 by any possible means was made by Rendtel at the IMC 2014 in Giron, France (Rendtel, 2014a). Because the position of the DSX 221 radiant was close to the Sun, radio observations by the EurAstro Radio Station (EARS) located in Munich (48°07'58.0" N, 11°34'47.3" E) immediately appeared particularly suitable.

2 EARS radio observation of DSX 221

EARS, based on the forward scattering principle and operated by G.T., adopted the following configuration: radio beacon from the GRAVES radar[2] (emitter at Broyes-les-Pesmaes, 47°20'51.72" N, 5°30'58.68" E, about 500 km from Munich), vertical antenna J-Pole 144, receiver ICOM 1500 (USB mode, 143.049 MHz), computer Pavillion dv6 (processor Intel Core Duo T2500) and SpecLab V26 b10 as recording software. EARS radio observations in the recording period from 30/09/2014, 07^h00^m UT – 05/10/2014, 16^h00^m UT proceeded without problems.

Meteor echoes were counted visually by G.T. by looking at the JPG images recorded by SpecLab every 5 minutes. It should be noted that the dynamical range of the signal observed by EARS is limited due to frequent saturation. This effect arose recently, probably due to ageing of EARS hardware components. However, in looking at previous EARS radio observations, it was possible to ascertain that this effect does not perturb significantly the meteor radio recording and the visual meteor counts on the spectrograms.

3 Analysis of observed meteor rates

EARS is a non-interferometric radio station, which means that it cannot distinguish whether a meteor echo is due to a sporadic or a shower meteor.

According to the Meteor Shower Workbook 2014 (Rendtel, 2014b), there are two other showers active (apart from DSX 221 and the sporadics) at the time of the observations: 2 STA (Southern Taurids, ZHR_{max} = 5 on October 10), and ORI (Orionids, ZHR = 2 around October 1). This indicates that we may neglect these minor showers with respect to the sporadics and possible DSX 221 meteors.

The observed hourly meteor rates are summarized in the diagrams of *Figure 1*. Evidently the meteors of DSX 221 were superposed on the ever present sporadic meteors. To better characterize the meteor echoes in the recording period an underdense radio echo from the images recorded by EARS was assumed as underdense reference radio echo to distinguish between recorded underdense strong and faint radio echoes, the results of the comparison are shown in *Figure 1*. Looking at the diagrams in *Figure 1*, it is possible to recognize that during the recording period there was not a single, clear, accentuated maximum.

The fact that during the recording period the radiant of DSX 221 was below the horizon for periods of about 12 hours, allowed us to directly acquire in said periods

[1] http://www.bbc.co.uk/dna/ptop/plain/A40721212
[2] http://fr.wikipedia.org/wiki/Radar_GRAVES

Figure 1 – Observed hourly meteor echo rates during the recording period.

Table 1 – Underdense and overdense meteors for DSX 221 plus sporadic meteors (in the periods in which the radiant was above the horizon, first column for each date) and underdense and overdense meteors for sporadic meteors alone (in the periods in which the radiant was below the horizon, second column for each date) , expressed in meteors per hour, for Munich (Germany).

	30/09 – 01/10		01/10 – 02/10		02/10 – 03/10		03/10 – 04/10		04/10 – 05/10		05/10
	02^h52^m 14^h57^m	14^h57^m 02^h47^m	02^h48^m 14^h52^m	14^h53^m 02^h43^m	02^h44^m 14^h49^m	14^h50^m 02^h39^m	02^h40^m 14^h45^m	14^h46^m 02^h36^m	02^h37^m 14^h41^m	14^h42^m 02^h32^m	02^h37^m 14^h52^m
$Under_{min}$	30	30	27	30	21	33	35	26	34	26	36
$Under_{max}$	43	78	76	71	56	71	60	82	74	74	59
$Under_{mean}$	38.3	49.5	49.9	48.1	36.4	50.4	48.4	51.1	51.6	48.9	47.5
$Over_{min}$	0	0	1	1	1	0	0	2	2	0	3
$Over_{max}$	4	6	7	6	7	8	7	11	6	7	11
$Over_{mean}$	2.1	1.9	4.4	2.9	4.0	4.1	4.2	5.5	4.3	2.6	5.5

information about the sporadic meteors alone, as opposed to information about DSX 221 meteors plus sporadic meteors in the periods of about 12 hours in which the radiant was above the horizon. *Table 1* indicates the periods in which the radiant of DSX 221 was above and below the horizon, and in said periods the minimum and maximum numbers per hour of underdense and overdense meteors and the average number per hour of underdense and overdense meteors both for DSX 221 meteors plus sporadic meteors and sporadic meteors alone. A possible attempt to estimate the number of DSX 221 meteors would consist of counting the numbers of sporadic underdense or overdense meteors in the periods in which the DSX 221 radiant was below the horizon and by subtracting these numbers from the numbers of underdense or overdense meteors in the corresponding preceding periods in which the DSX 221 radiant was above the horizon. However, in the case of DSX 221 this attempt does not work since the number of sporadic meteors is clearly a lot higher than the number of DSX 221 meteors, in some cases such subtractions would even provide negative results.

The average number of underdense meteors per hour observed when the radiant was above (45.3) and below the horizon (49.6), suggests that the observed meteor activity corresponds to fluctuations of the sporadic background. Also, there is no single 10h period with the radiant above the horizon where the number of meteors was significantly higher than the number of meteors with the radiant below the horizon in the previous or next period. This leads to the same conclusion.

On the other hand, the average number of overdense meteors (roughly corresponding to the larger particles which produce visual meteors) when the radiant was above the horizon (4.1) was higher than when the radiant was below the horizon (3.4). This may suggest the presence of bright stream meteors. However, statistical analysis revealed that he number of overdense meteors per hour when the radiant is above the horizon is not significantly larger than the number of overdense meteors per hour when the radiant is below the horizon (assuming Gaussian distributions and testing at a confidence level of 95%). Hence, we can assume that we did not observe any DSX 221 activity that exceeds the standard deviation of the sporadic rates.

We conclude that the activity of the DSX 221 meteors, if present at all, was at a much lower level than the sporadic activity.

4 The mass index of a meteoroid stream

The mass index *s* describes the meteoroid mass distribution within a meteoroid stream (or the sporadics), which is governed by a power law. The larger the mass index of a meteoroid stream, the larger the relative number of small particles. Along with meteoroid flux density, the mass index is an important parameter for constraining meteoroid stream models. Exploiting the relationship between meteoroid mass and magnitude of the corresponding visual meteor, the mass index *s* can be expressed in terms of the population index *r* as follows: $s = 1 + 2.5\ b\ \log r = 1 + 2.3 \log r$, where $b = 0.92$ (Koschack and Rendtel, 1990a,b).

Employing the power law and the fact that the duration of an overdense reflection is roughly proportional to the mass of the meteoroid, we find that the relation between the logarithm of the duration *T* of the overdense meteors and the logarithm of the cumulative number *N(T)* of overdense meteors with duration at least *T* is a straight line with slope $1 - s$.

In the next section, we will employ this relationship to obtain the mass index *s* for the sporadics during the observation period.

More detailed explanations regarding the meaning of the mass index and how to calculate it can be found in Belkovich (2006) and Verbeeck (2014). In particular, it is explained in Verbeeck (2014) how to obtain the mass index from the amplitude distribution of all meteor reflections. This method has an advantage over the present method (which uses the duration distribution of the overdense reflections), since larger statistics are obtained when all reflections can be taken into account instead of just the overdense reflections. This shows it is worthwhile to obtain the maximum power or amplitude of every individual meteor reflection.

5 Calculation of sporadic mass indexes from radio observations

The mass index in the recording period has been calculated according to the following method:

(1) the recording period has been subdivided in 10 periods coincident with the periods of about 12 hours in which the radiant of DSX 221 was below or above the horizon. Hours in which the radiant crossed the horizon were excluded from the calculation of the mass index (since we first hoped to calculate mass indexes for DSX 221 plus sporadics as well) – for this reason each one of said 10 periods was composed of 10 hours;

(2) in each period, each overdense meteor has been visually identified thanks to the JPG spectrograms recorded every 5 minutes by SpecLab V26 b10;

(3) in each period, for each overdense meteor identified, its radio echo duration *T* in seconds has been measured and the corresponding $log_{10}(T)$ has been calculated;

(4) in each period, because all the values of $log_{10}(T)$ appeared to be between 0 and 1.5, three bins $log_{10}(T)>=0$; $log_{10}(T)>=0.5$; $log_{10}(T)>=1.0$ have been defined and the cumulative numbers $N(T_0)$, $N(T_1)$, and $N(T_2)$ of overdense meteors in the respective bins have been counted. E.g., $N(T_0)$ is the cumulative number of overdense meteors having $log_{10}(T)>=0$;

(5) in each period, the points $x=0$, $y=log_{10}(N(T_0))$; $x=0.5$; $y=log_{10}(N(T_1))$, and $x=1.0$; $y=log_{10}(N(T_2))$ have been plotted, and the slope $1 - s$ of the straight line interpolating said points has been calculated. Hence, the mass index *s* for that period is obtained.

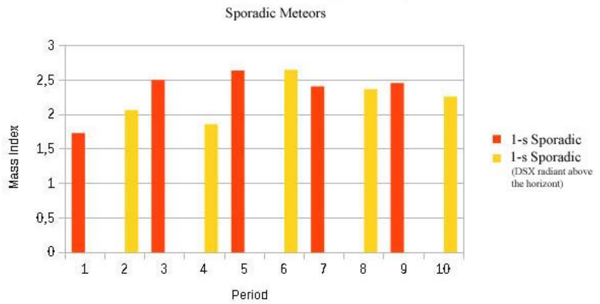

Figure 2 – Mass index variation for sporadic meteors in the periods 1–10.

Table 2 and *Figure 2* show the values of the mass index for the sporadic meteors in said 10 periods of 10 hours, obtained according to the method sketched above.

Table 2 – Mass index variation for sporadic meteors in the periods 1–10.

Period	From	UT	to	UT	mass index
1	30/09	15:00:00	1/10	1:00:00	1.74
2	1/10	3:00:00		13:00:00	2.07
3	1/10	15:00:00	2/10	1:00:00	2.51
4	2/10	3:00:00		13:00:00	1.87
5	2/10	15:00:00	3/10	1:00:00	2.64
6	3/10	3:00:00		13:00:00	2.65
7	3/10	15:00:00	4/10	1:00:00	2.41
8	4/10	3:00:00		13:00:00	2.37
9	4/10	15:00:00	5/10	1:00:00	2.46
10	5/10	3:00:00		13:00:00	2.26

All mass indexes except those for periods 1 and 7 were calculated based on 3 points: the cumulative number of overdense meteors with $log_{10}(T)$ larger than or equal to 0, 0.5, and 1.0, respectively. The mass indexes for periods 1 and 7 are probably less accurate, since they were only based on 2 points because no meteors with $log_{10}(T)$ larger than or equal to 1 were observed in those periods.

6 Discussion

The EARS observations did not permit to separate the sporadic meteors from the DSX 221 meteors, which means that the activity of the DSX 221 meteors, if present at all, was at a much lower level than the sporadic activity.

In their preliminary DSX 221 activity profile from 2011–2014 Molau et al. (2015) describe a maximum with ZHR value 60 (zenith exponent 1.5) and a population index of 2.65 (hence, a mass index of 1.97) around solar longitude 186.5° (September 29, 23^h UT in 2014). It is not clear whether this peak was also present in 2014 since the dataset is too small to permit such calculations for 2014 alone (Molau, personal communication). The EARS observations started at 8^h UT on September 30, and did not detect any DSX 221 activity standing apart from the sporadic background. In the RMOB radio data[3] Haik Saroyan is the only radio observer out of 35 who recorded a possible enhanced activity between 2^h and 8^h UT on September 30, which suggests the enhancement could be contributed to by geometrical effects due to the changing position of the radiant with respect to the receiving antenna rather than to real meteor activity. There are some hints of increased meteor activity in RMOB data on October 1–2 but they are not very consistent (for 5 observers from 2^h to 6^h UT, for 2 observers from 8^h to 14^h UT, no enhancement at all for 23 observers). Again, this is probably a geometrical effect rather than a genuine peak of meteor activity.

Although the EARS observations did not permit us to separate the sporadic meteors from the DSX 221 meteors in order to proceed to a determination of the mass index variation of the DSX 221 meteors plus sporadics in the recording period, we have employed the method described above to calculate the mass index of the sporadic meteors in said recording period.

Note that the mass index in periods 1 and 7 was obtained using only two log duration bins instead of three, and hence is less accurate than the other values.

The calculated sporadic mass indexes in *Table 2* and *Figure 2* vary between 1.74 and 2.65, with an average value of 2.30.

Though this calculated value is close to the often-cited standard value of 2.35 for the sporadic mass index (e.g., Simek, 1968), the origin of this value is a study by Hawkins and Upton (Hawkins, 1958) which employed only 300 sporadic meteors detected with Super-Schmidt cameras, the average mass of which was between 15 and 30 g. This is a different size population than the sporadic meteors observed in our current analysis.

More recent investigations of the year-round sporadic mass index involving several hundreds of thousands or even millions of meteors, have found values closer to 2, e.g., the sporadic mass index range found by Blaauw (2011) in the period 2007–2010 is 2.17 ± 0.07.

The calculated mass indexes should of course be compared to mass indexes in previous studies that are valid around solar longitude 186° to 192°. Population indexes between 2.9 and 3.2 were obtained by Rendtel (2006), which corresponds to mass indexes between 2.06 and 2.16.

Hence, most of our mass index values are quite high. Let us have a look at the periods with highest mass index:

Period 3 (2.51) contains only 41 overdense reflections while the average number per period is 61

Period 5 (2.64) and period 6 (2.65) each contain just one overdense reflection in the bin $log_{10}(T)>=1,0$

All three cases suggest poor statistics.

To get better statistics, we can take longer time intervals, with the disadvantage that we get a lower time resolution of the mass index. Employing just one time interval for the whole observing period from September 30 till October 5, a mass index value of 2.35 is obtained, from a total of 614 overdense meteor reflections. The corresponding log cumulative duration distribution plot is provided in *Figure 3*. The mass index is 1 minus the slope of the linear fit. As can be seen in *Figure 3*, the number of overdense reflections with $log\ T >= 1$ (19) is still smaller than the line between the two other points

[3] http://www.rmob.org

would suggest. The line between the other two points corresponds to a lower mass index. Perhaps this effect is still due to too small statistics. Of course our results are only indicative since they are based on statistics that are several orders of magnitude smaller than that of Blaauw (2011).

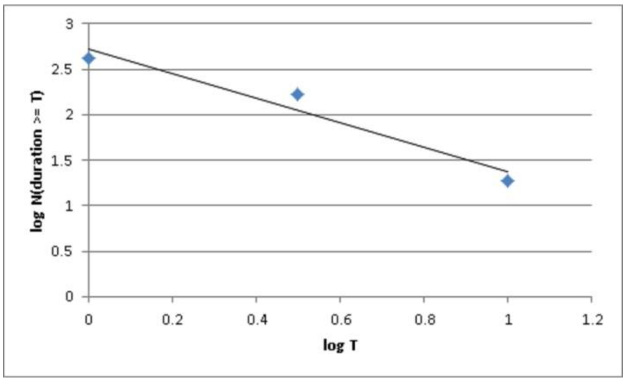

Figure 3 – The log cumulative duration distribution plot for all overdense meteor reflections observed from September 30 ti1l October 5, 2014. The (base 10) logarithm of the number of overdense meteor reflections with duration longer than T is plotted for *log T* equal to 0; 0.5; and 1. The resulting mass index is 1 minus the slope of the linear fit.

Part of the systematic overestimation in the mass index values obtained by EARS may be linked to the characteristics of the GRAVES radar. Its radar beam performs a full rotation of its transmission beam every 800 ms, which means that airplane and meteor reflections are interrupted in slices every 800 ms. Therefore, EARS would get an average underestimation of meteor durations of 0.4 s. For the mass index calculation, we have used duration bins of log T = 0; 0.5 and 1, so T = 1, $\sqrt{10}$, and 10 seconds. For the long duration meteors, this underestimation error is not important, but we will probably underestimate the number of meteors with duration longer than $\sqrt{10}$ seconds and overestimate the number of meteors of duration lower than $\sqrt{10}$ seconds. This means that we will overestimate the mass index. We should point out that in the EARS observations, we see this kind of slice only in airplanes reflections and not in meteor reflections.

7 Conclusion

We have divided the EARS observations from September 30 to October 5, 2014, into periods when the DSX 221 radiant was above the horizon (hence, in principle DSX 221 and sporadic meteors could be observed) and periods when the radiant was below the horizon (hence, only sporadic meteors could be observed).

The average number of underdense meteor reflections per hour observed when the radiant was above (45.3) and below the horizon (49.6), suggests that the observed meteor activity corresponds to fluctuations of the sporadic background. Statistical analysis revealed that also the number of overdense meteor reflections per hour when the radiant was above the horizon was not significantly larger than the number of overdense meteor reflections per hour when the radiant was below the horizon (assuming Gaussian distributions and testing at 95% confidence). Hence, we conclude that we did not observe any DSX 221 activity that exceeds the typical standard deviation of the sporadic rates.

The sporadic mass index was calculated for ten 10-hour intervals during the observation period, based on the distribution of the duration of overdense meteor reflections. Calculated sporadic mass index values varied between 1.74 and 2.65, with an average value of 2.30. These values lie above the year-round sporadic mass index range 2.17 ± 0.07 found by Blaauw (2011) in the period 2007–2010, and also above the mass index range 2.06–2.16 obtained around solar longitude 186° to 192° by Rendtel (2006).

The apparent overestimation of the mass index is probably due partially to poor statistics and partially to the effects of the rotation of the GRAVES radar beam. The latter effect can be easily mitigated in future studies by using a non-rotating transmitter.

We advise fellow radio observers to adopt both our method of separating radiant above horizon and radiant below horizon periods, and our method for calculating the mass index. For meteor showers with a higher ZHR, the overdense shower meteors should stand out better from the sporadics and more conclusive results are possible. For a radio set-up that records the maximum power or amplitude for each individual meteor reflection, an alternative and preferred method for determining the mass index is described in Verbeeck (2014). It delivers more accurate mass index values thanks to the larger statistics of the total number of meteor reflections in comparison to the number of overdense meteor reflections that is employed in our current analysis. This may well remove the apparent overestimation in calculated mass indexes.

References

Belkovich O. I., Pajović D., Wislez J.-M. (2006). “Basic elements of meteor stream theory”. In Verbeeck C. and Wislez J-M, editors, *Proceedings of the radio Meteor School*, 10–14 September 2005, Oostmalle, Belgium. IMO, pages 17–20.

Blaauw R. C., Campbell-Brown M. D., Weryk R. J. (2011). “Mass distribution indices of sporadic meteors using radar data”. *Monthly Notices of the Royal Astronomical Society*, **412**, 2033–2039.

Hawkins G. S., Upton E. K. L. (1958). “The Influx Rate of Meteors in the Earth's Atmosphere”. *The Astrophysical Journal*, **128**, 727–735.

Koschack R. and Rendtel J. (1990a). “Determination of spatial number density and mass index from visual meteor observations (I)”. *WGN, Journal of the IMO*, **18**, 44–58.

Koschack R. and Rendtel J. (1990b). “Determination of spatial number density and mass index from visual meteor observations (II)”. *WGN, Journal of the IMO*, **18,** 118–140.

Molau S., Kac J., Crivello S., Stomeo E., Barentsen G., Goncalves R., Saraiva C., Maciewski M. and Maslov M. (2015). “Results of the IMO Video Meteor Network — September 2014”. *WGN, Journal of the IMO*, **43**, 28–32.

Rendtel J. (2006). “Visual sporadic meteor rates”. *WGN, Journal of the IMO*, **34**, 71–76.

Rendtel J. (2014a). “Daytime meteor showers”. In Rault J.-L. and Roggemans P., editors, *Proceedings of the International Meteor Conference*, Giron, France, 18–21 September 2014. IMO, pages 93–97.

Rendtel J. (editor) (2014b). *Meteor Shower Workbook 2014*. IMO, pages 10–11.

Simek M., McIntosh B. A. (1968). “Meteor Mass Distribution from Underdense-Trail Echoes”. In Kresak L., Millman P. M., editors, *Physics and Dynamics of Meteors*, Reidel, Dordrecht, pages 362–372.

Verbeeck C. (2014). “An introduction to radio astronomy”. In. Gyssens M., Roggemans P. and Zoladek P., editors, *Proceedings of the International Meteor Conference*, Poznan, Poland, 22–25 August 2013. IMO, pages 57–69.

The author, *Giancarlo Tomezzoli* (Photo by *Axel Haas*).