

Insights into the Quadrantid-2024-Notch

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Abstract: The analysis of the Quadrantid-2024 data from January 4 shows a very surprising result:

Spectrograms of meteor echoes that are close in time to the notch differ significantly from spectrograms of ordinary meteor echoes. They are rather small, have a jagged surface and are similar to the spectrograms of satellites, which have a comb-like structure due to their metal surface. The reason for this could be that, for geometric reasons, only the hot plasma head with similar reflection properties to metal reflects the radar beams. If the meteor trail reflects the radar beams, the usual soft spectrograms are created.

1 Introduction

I was able to record the Quadrantid 2024 echoes on January 4th without interference, allowing a new study of the notch. Notches in meteor histograms are known from the literature. According to Felix Verbelen (Verbelen 2019) and personal communication with him, there are notches in all major streams. Kaufmann (Kaufmann, 2020) postulated that due to the Doppler shift, the meteor echo can lie outside the normal receiver bandwidths and is therefore not registered. In my meteor work (Sicking, 2022a, 2022b) I proposed a mechanism according to which the notch is created by the geometric relationships between transmitter, receiver and radiant.

An extensive work by Mike T. German (German, 2023) precisely explains the geometric relationships in meteor observation. The new Quadrantid-2024 data now allows further interesting insights into the notch.

2 Setup

A circularly polarized 4-element cross-Yagi antenna is used to receive the meteor echoes. My antennas are mounted in the attic so the configuration can be easily changed. A low-noise preamplifier with a frequency range of

140-150 MHz and a noise figure of 0.25 dB is connected directly to the antenna. The receiver is an Icom IC-R8600. Spectrum-Lab (SL) from Wolfgang Buescher (DL4YHF) is used as recording software. SL generates plots at 20 second intervals with corresponding date and time in the file name, which are later analysed using machine learning-based software developed by me (Sicking, 2024). The three-class model `mask_rcnn_model.061-0.417564.h5` was used for detection.

Result and Discussion

The first two images, Figures 1 and 2, document the respective day and provide a first impression. The satellite echoes, the interference and the noise floor are also documented. Figure 1 shows the raw data from January 4, 2024. The green dots represent the meteor echoes. The sizes of the echoes are plotted logarithmically. A dip around 8h AM, the notch, is clearly visible. Figure 2 is an hourly histogram. The yellow histogram shows the rate and the red histogram shows the rate weighted by the sizes of the meteors. However, the red histogram at the maximum of the Quadrantids is heavily overloaded. The blue histogram usually shows satellite echoes. Near the notch, the number of satellites increases sharply toward the center of the notch. This is obviously an artefact, which will be examined below.

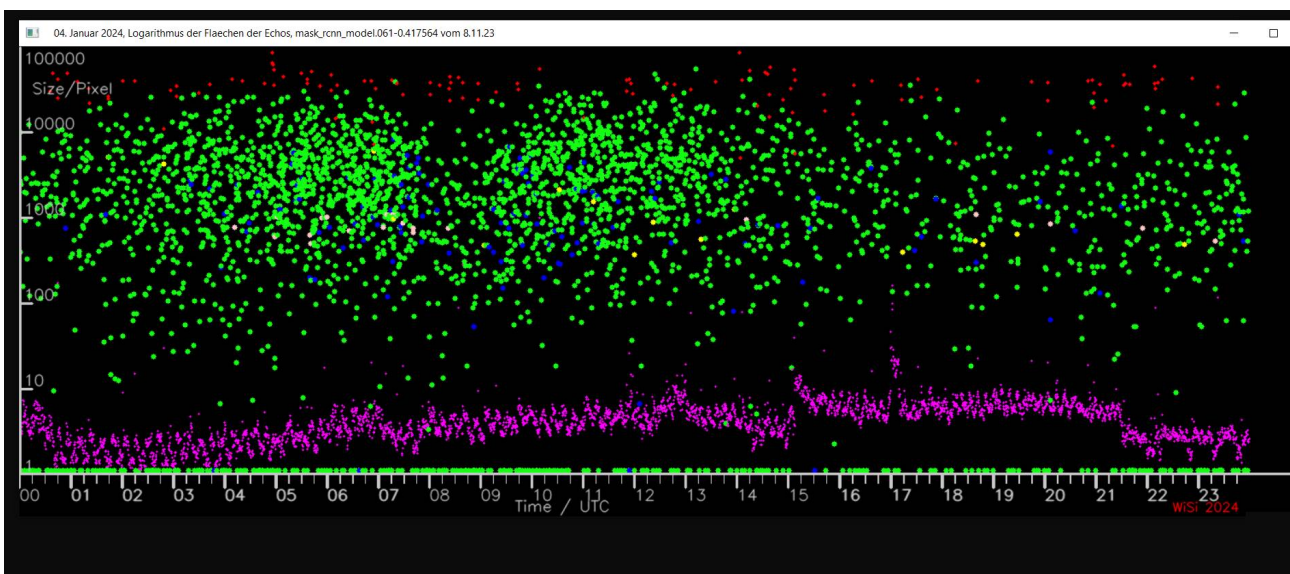


Figure 1 – Measured meteor sizes as a function of time, recorded on January 4, 2024. Each green dot represents an echo. 2960 echoes were recorded. A drastic decrease in

the rate can be seen at 8h AM. The blue dots represent satellite echoes. An unusually large number of satellite echoes are registered near the notch. An explanation of this is given in the text. The purple curve shows the background noise and interference. There were no significant disturbances that could have distorted the result.

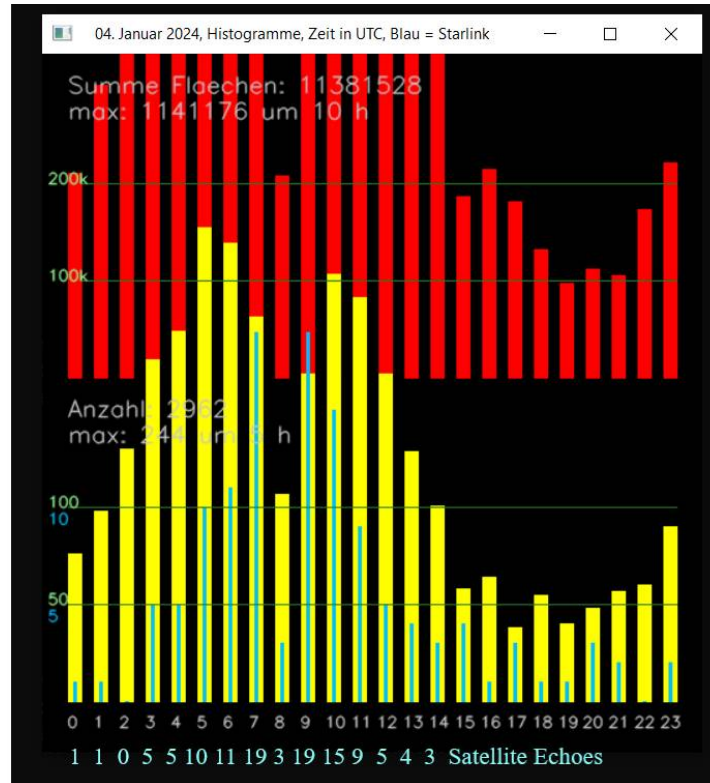


Figure 2 – The yellow histogram shows the rate and the red histogram shows the rate weighted by the sizes of the meteors. However, the red histogram at the maximum of the Quadrantids is heavily overloaded. The notch at 8h AM is clearly pronounced. The blue histogram usually shows satellite echoes. Near the notch, the number of satellites increases toward the center of the notch, indicating an artefact, see text.

Examination of the echoes at the notch

First, I examined the azimuth of the radiant of the Quadrantids using Stellarium Web. The star 44 Boötis was chosen as the radiant because, according to the CMOR radar, it occupied approximately the position of the radiant of the Quadrantids. At 7h51m AM the azimuth Dijon / 44 Boötis is 0° and the elevation of the star is 89° . At this time the radiant is in front of the GRAVES radar, so that the meteor tracks run towards the transmitter. Meteor tracks and radar beams then meet (more or less) head-on in a line.

The notch of the high-resolution histogram in Figure 3 shows two minima and the In-Line-Peak (Sicking 2022a). The first minimum appears at 8h12m AM, the second minimum is at 8h42m AM. The cause of the difference in time between 0° azimuth of 44 Boötis (7h51m AM) and the first minimum of the notch (8h12m AM) is still unclear. Theoretically the times should be identical. Further investigations will follow.

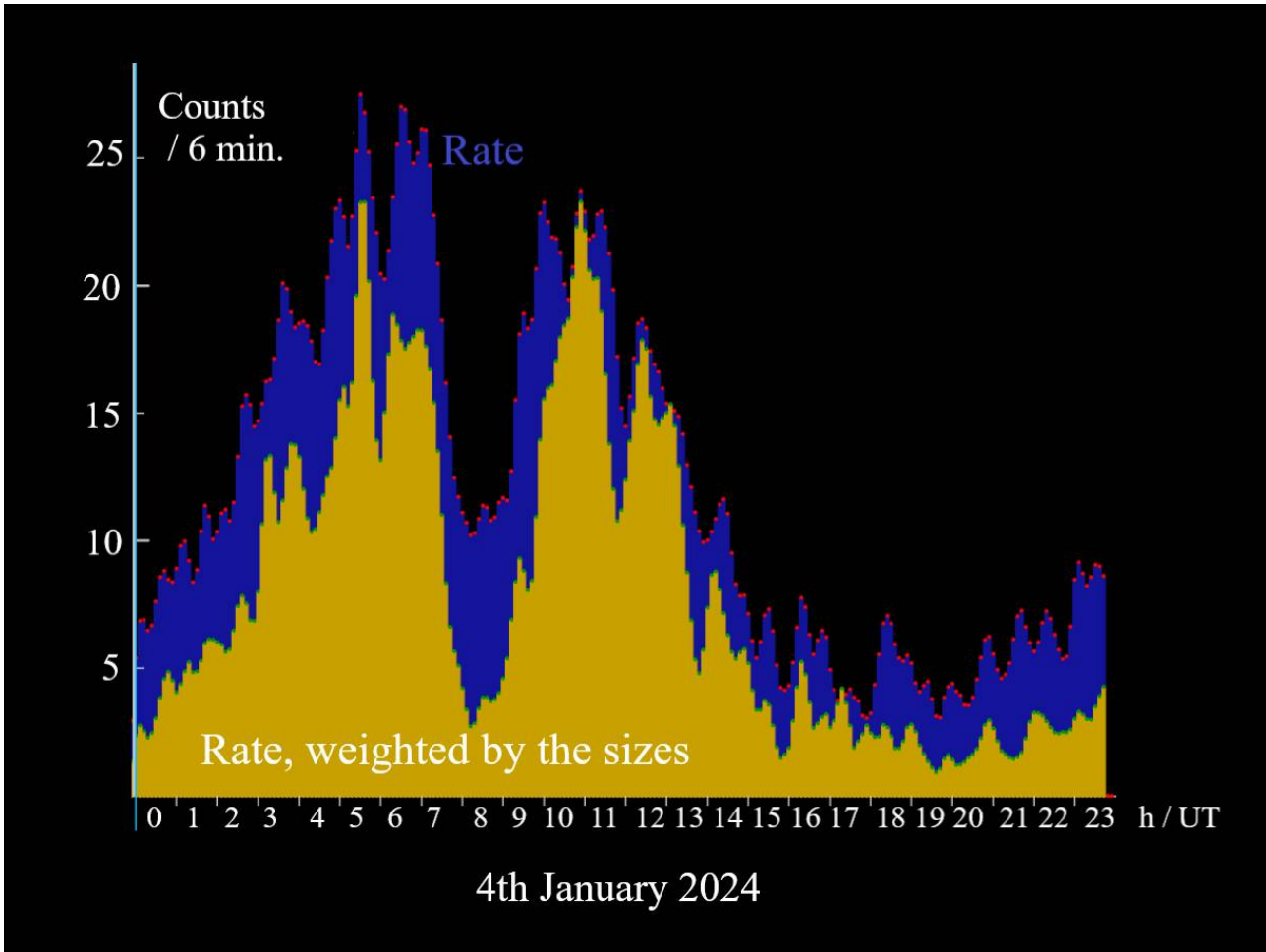


Figure 3 – The figure shows a histogram with a time resolution of 6 minutes. This allows details such as the In-Line-Peak to be displayed. The histograms are smoothed with a fixed Gaussian like filter with the coefficients 0.31, 0.74, 1.0, 0.74 and 0.31.

Spectrograms from four times before the notch are shown in Figures 4 to 7. The aim is to examine the change in meteor echoes and the increase in satellite echoes towards the notch. I chose the plots so that as many echoes as possible are combined in one image in order to keep the number of images as low as possible. Because of the importance of the statement, there were four figures.

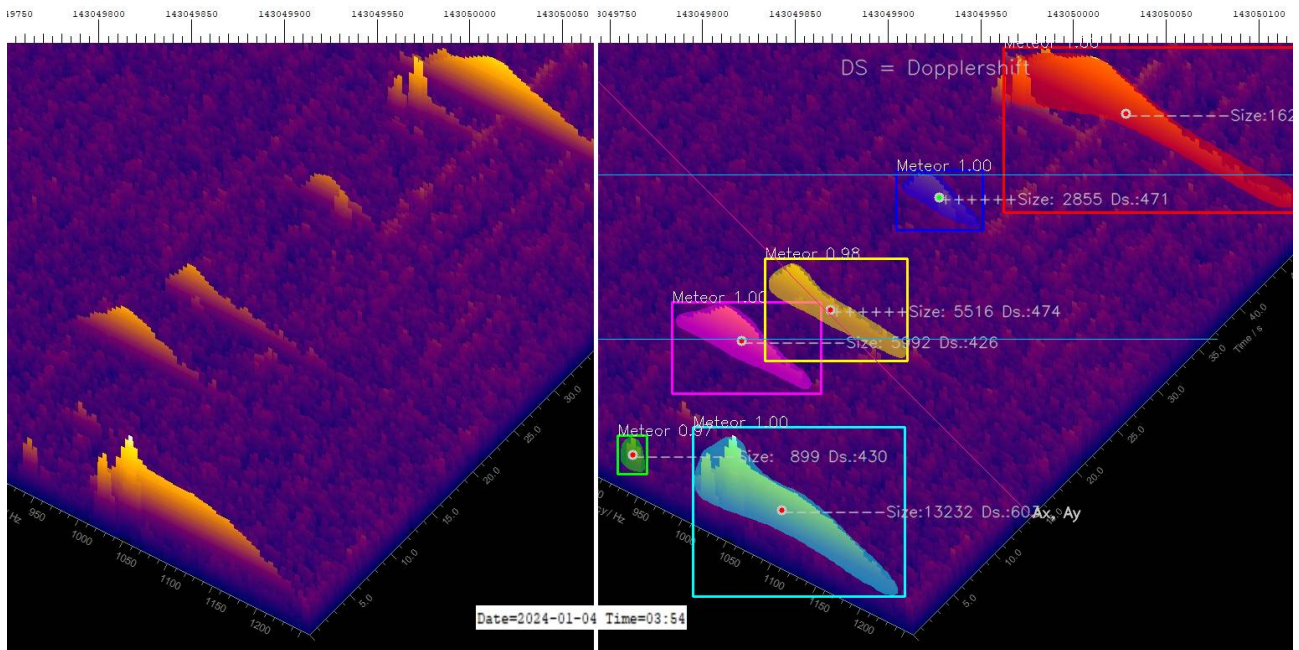


Figure 4 – 3h54m AM. Examples of “normal” echoes.

Figure 4 from 3h54m AM shows meteor echoes commonly seen. They have the typical curved, often Gaussian shape and a smooth surface. There are of course other forms of echoes, but they don't play a role here.

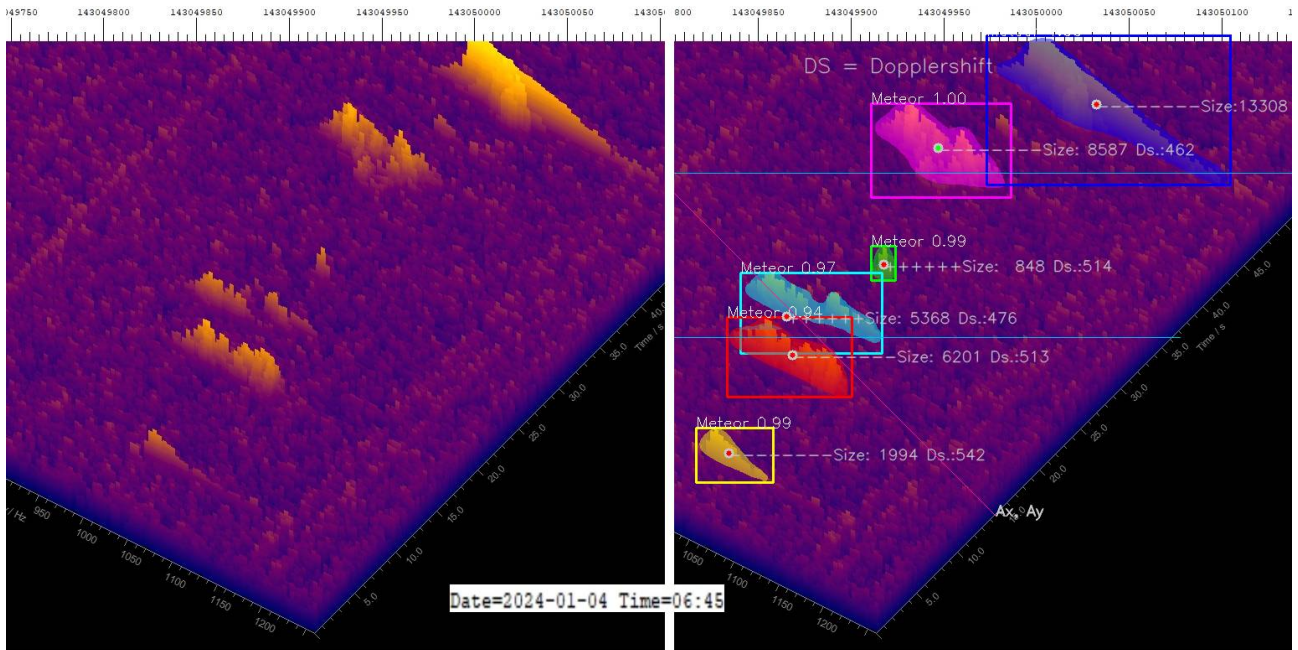


Figure 5 – 6h45m AM. The echoes show a clearly jagged surface, but are still correctly recognized by the ML software.

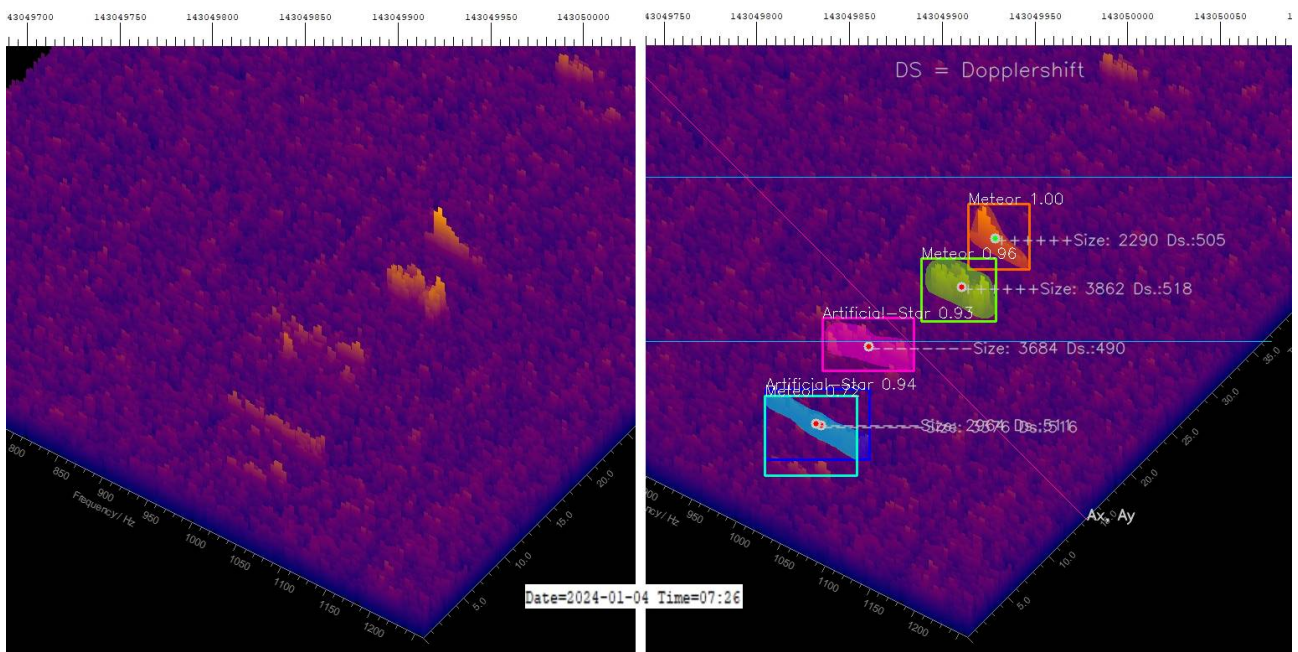


Figure 6 – 7h26m AM. The echoes are very small and are almost no longer observable. Two faint echoes are recognized as satellites.

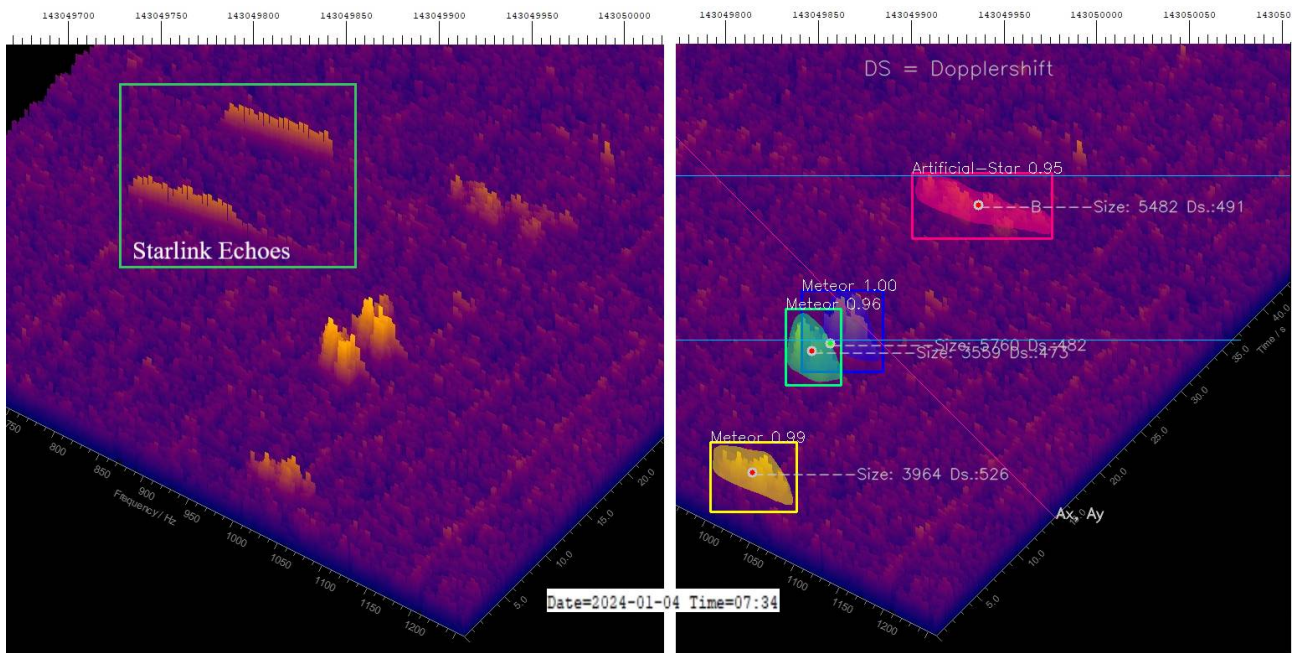


Figure 7 – 7h34m AM. An echo (magenta) is incorrectly recognized as a satellite. The inset at the top left shows real Starlink echoes for comparison.

The notch occurs because the echoes become smaller and at some point are no longer perceptible. This will be examined in more detail in the next chapter. However, the shape of the echoes also changes drastically towards the notch: they have a jagged surface, see Figures 5, 6 and 7. It is now clear why the number of satellite echoes increases near the notch: some echoes are more similar to satellite echoes, than they look like normal echoes used in training the ML model.

From this it can be concluded that Figures 5, 6 and 7 show spectrograms of meteor echoes in which essentially only the head was exposed to the radar beams. The hot plasma head apparently has similar reflection properties to the surface of the satellites, which produce echoes with a comb-like structure due to their metal surface (Sicking, 2024). If the trace also reflects, a softer echo is created, according to the hypothesis.

In previous streams I already noticed that echoes near the notch are jagged. The increase in satellite echoes near the notch occurred for the first time in the 2024 Quadrantids. After all, the increase in satellite echoes towards the notch shows that there is a systematic connection

Such spectrograms are not contained in the training data of the ML-model used, or are only contained sporadically. However, the reason for the notch are not the misdetected or undetected echoes. The error is $<10\%$ at 7h AM and the notch is also recorded by other observers.

Examination of the rates and the rates weighted by the sizes of the echoes

Figure 8 shows the echoes divided into four classes of sizes. The most important result is shown by the yellow trace, which represents the small echoes: The small echoes have a (secondary) maximum at the minimum of the notch, see the yellow dot. The amount of the larger meteors is decreasing. This does not mean that the number of small echoes has increased, but it means that large echoes now appear smaller due to perspective and appear in the class of small echoes. The maximum of the yellow trace in the minimum of the notch is therefore a confirmation of the theory that geometric conditions as described above cause the notch.

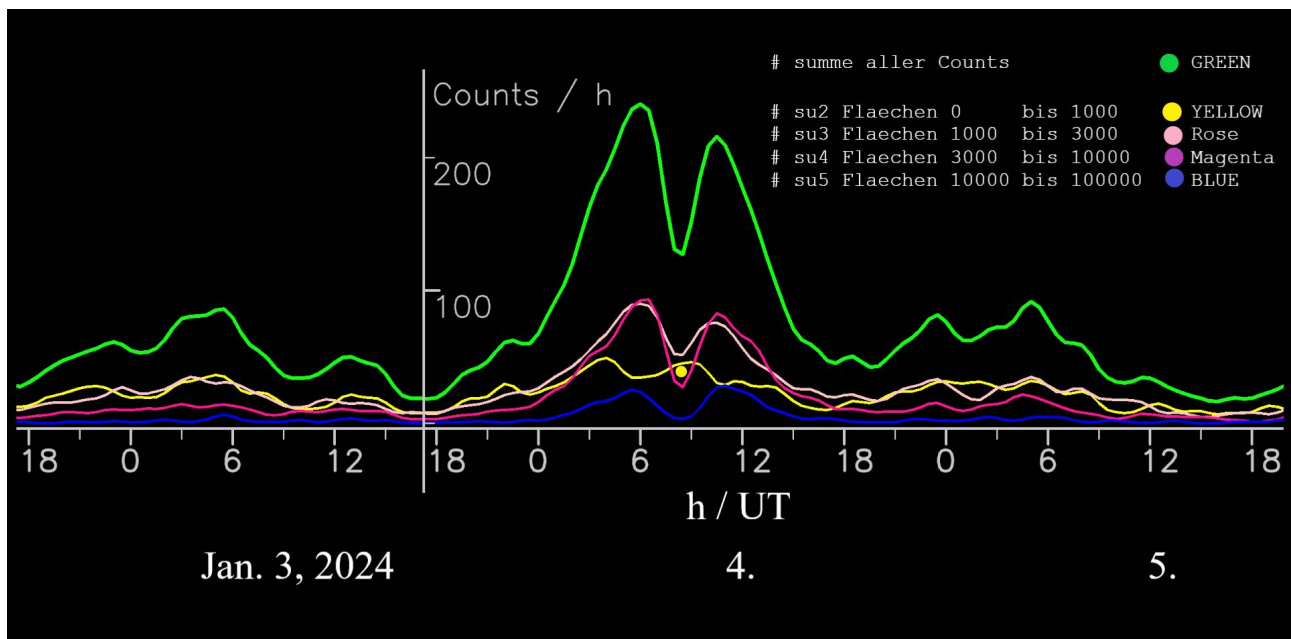


Figure 8 – Meteor rates for different echo sizes of the 2024 Quadrantids over 3 days. The blue line represents the rate of large echoes (10,000 to 100,000 pixels), the purple/magenta line shows the medium sized echoes (3000 to 10,000 pixels), the pink line shows the echoes (1000 to 3,000 pixels) and the yellow line shows the small echoes (below 1000 pixels). Finally, the green curve shows the rate of all echoes

summed up. The yellow trace (echoes under 1000 pixels) shows a maximum (see yellow dot) where the notch and all other meteor sizes have a minimum. The histograms are smoothed with a fixed Gaussian like filter with the coefficients 0.25, 0.71, 1.0, 0.71 and 0.25.

Conclusion

In this work it was shown that spectrograms can be used to identify meteors where the radar beams hit the meteor frontally and only expose the plasma head. A separate ML class should be developed for these meteors in order to be able to identify them in future streams.

In addition, the theory that geometric conditions cause the notch has been experimentally proven.

Acknowledgment

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References

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