The Radio Meteor Zoo: Involving citizen scientists in radio meteor research

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The BRAMS (Belgian RAdio Meteor Stations) Network, consisting of one beacon and about 25 receiving stations, generates a huge amount of data with thousands of meteor echoes detected every day. With such large amount of data, it is difficult to process it all ourselves. Several attempts were made to develop an automatic detection algorithm, but up-to-now none of these algorithms can perfectly mimic the human eye which stays the best detector. Therefore, the BRAMS researchers, in collaboration with the Zooniverse team (`http://www.zooniverse.org/`), have launched a citizen science project called the Radio Meteor Zoo (RMZ, `http://www.radiometeorzoo.org/`) in August 2016. With the RMZ, thousands of citizen scientist eyes are manually identifying meteor echoes during meteor showers. Hitherto more than 5000 registered volunteers have identified meteors in almost 30 000 spectrograms. In 2016 the Perseids and the Geminids meteor showers were processed. In 2017 the volunteers helped us with processing the Quadrantids, Lyrids, and Perseids meteor showers. In this paper the results obtained during the first year of the Radio Meteor Zoo are discussed. We will also look into the future: how can we improve the RMZ and what will be done with these results?

1 Introduction

BRAMS (Belgian RAdio Meteor Stations) is a radio network located in Belgium using forward scatter measurements to detect and characterize meteoroids. It consists of one dedicated transmitter located in Dourbes, in the south of Belgium, and approximately 25 receiving stations spread all over the Belgian territory. The transmitter emits a circularly polarized continuous wave (CW) at a frequency of 49.97 MHz and with a power of 150W. All receiving stations use the same equipment (including a 3-elements Yagi antenna) and are synchronized using GPS clocks. More details can be found in, e.g., Lamy et al. (2015).

Each BRAMS receiving station is recording continuously, producing each day 288 WAV files and detecting circa 1500-2000 meteors. This huge amount of data requires the use of automatic detection algorithms. Several attempts were made to identify meteor reflections either in raw data or in spectrograms by using automatic detection algorithms, with varying degrees of success (Calders and Lamy, 2014). The automatic detection of overdense radio meteor echoes in particular remains a difficult task due to the various and complex shapes they produce in spectrograms (see Figure 1). This problem is particularly striking during meteor showers where these types of meteor echoes are observed abundantly.

On 12 August 2016, the BRAMS researchers launched the Radio Meteor Zoo (`http://www.radiometeorzoo.org`), a citizen science project hosted on the Zooniverse platform (`http://wwww.zooniverse.org`; see also Lintott, 2008). So, instead of detecting meteor reflections automatically by means of software, we rely on the best detector which is the (trained) human eye for classifying radio meteors during certain campaigns. Volunteers are asked to draw rectangles around what they consider to be a meteor. The first campaign was focused on generating a plot of the Perseids 2016 activity.

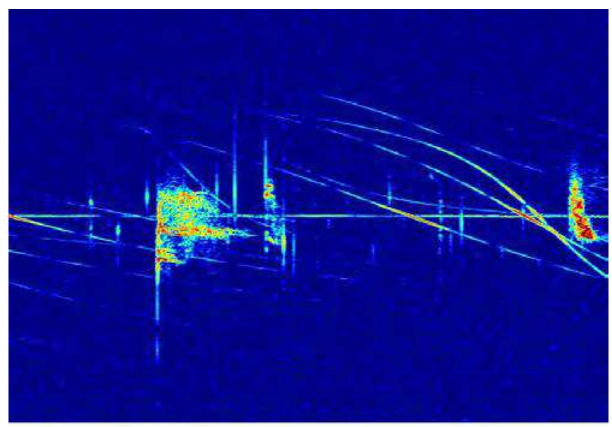

Figure 1 – An example of a spectrogram with complex meteor reflection shapes, closely interwoven with airplane reflections (oblique lines). Here, the human eye remains the best detector to identify the meteor reflections.

2 Method description

The objectives of the Radio Meteor Zoo are twofold:

1. to calibrate and to validate existing and future automatic detection algorithms; and
2. to detect the complex shapes of overdense radio meteor reflections. These reflections are more abundant during meteor showers.

New volunteers are asked to first read a tutorial. This tutorial explains what a spectrogram looks like and provides examples of typical signatures of meteor reflections and common distortions (like reflections on airplanes or broad-band interferences). Finally, the tutorial explains what is expected from the volunteer: drawing rectangles around potential meteor echoes and how to do it correctly.

Each spectrogram is shown to ten different volunteers to improve the quality of the classifications. A region in the spectrogram is considered to be a real meteor if at least four volunteers selected it. So, when one volunteer makes a mistake (either forgetting a meteor echo or classifying incorrectly another signal as a meteor), the risk of a false detection is minimal. An extensive discussion of the classification algorithm applied in the Radio Meteor Zoo can be found in Calders et al. (2016).

Finally a forum has been installed to allow interaction among the volunteers and between the volunteers and the researchers. Four topics are available: notes (for questions and comments about individual spectrograms); science (a place to talk about the science behind the Radio Meteor Zoo and related research): chat ("everything you want to know about meteors but were afraid to ask"); and help (questions about the classification interface, bug reporting, and general help).

3 Results

A press release was sent to Belgian newspapers and radio stations to announce the launch of the Radio Meteor Zoo on 12 August 2016.[1] The Zooniverse team has also sent an e-mail to all volunteers that contributed in the past to one of the other projects hosted on their citizen science platform. In total more than 2000 volunteers registered during the first days after the launch. The very first day, more than 12 500 spectrograms were processed. Motivated by this huge success, the authors made available spectrograms observed during the Perseids shower from eight different receiving stations.

Later on in 2016, also the Geminids (5 stations) meteor showers were processed. In 2017, a successful campaign has been launched to obtain an activity plot of the Quadrantids (2 stations), Lyrids (1 station), and Perseids (3 stations) meteor showers. For the Perseids 2017, all registered volunteers were contacted by e-mail to ask their support for this campaign. More than 10 000 spectrograms were processed in only two days, which gave the authors the opportunity to produce a preliminary activity plot quickly after the Perseids peak (see Figure 2).

In October 2017, more than 5000 registered volunteers had produced aggregated classifications of meteors in almost 29 500 spectrograms (i.e., each of these spectrograms is processed by ten different volunteers). This result is above and beyond all expectations.

[1] E.g., https://www.imo.net/the-brams-team-needs-your-help-to-detect-perseid-echoes-in-the-radio-meteor-zoo-project/.

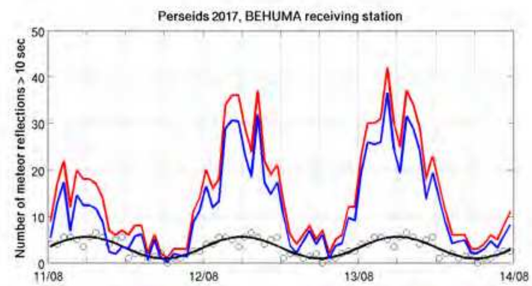

Figure 2 – The Perseids 2017 activity curve (reflections lasting at least 10 seconds) for the Humain receiving station, based on the results obtained from the Radio Meteor Zoo. The red curve is the total activity, the blue curve only the Perseids. (All times are in UT.)

4 Future plans

As a first step, the aggregated classification of meteors in a spectrogram is calculated as described in Calders et al. (2016). However, when comparing each individual classification with the aggregated result, the authors notice sometimes major deviations. Therefore, we are testing if the data quality can be improved by automatically removing classifications that are obviously wrong (see, e.g., Figure 3). The following formula will be used:

$$\alpha = \frac{|S_{\text{agg}} \cap S_i|}{|S_{\text{agg}} \cup S_i|}$$

with S_{agg} the surface of the aggregated rectangles and S_i the surface of the rectangles drawn by one volunteer. If α is small, the rectangles drawn by this volunteer are excluded from the dataset.

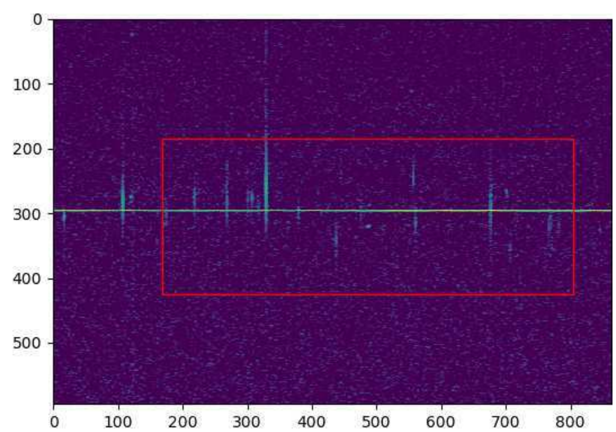

Figure 3 – Here, a volunteer has drawn a rectangle around all meteors together instead of each meteor individually. This result should be excluded from the aggregated classification set.

A new aggregated classification is then calculated on a smaller but more accurate set of classifications. It should however be noticed that we still adhere to the egalitarian principle: all volunteers are considered as equal; only classifications that are too far off the aggregated classification are removed from the dataset. It does not make any difference if the classification has been made by a registered or an unregistered volunteer.

The next step is to correct the activity curve for parameters such as the radiant height and the sensitivity of the receiver. The Observability Function (OF, Verbeeck, 1997) represents the sensitivity of a particular forward scatter setup to detect underdense meteors of a given shower at a given time t. If the OF at time t_1 is twice as big as the OF at time t_2, and the meteor activity is constant, then the set-up will observe twice as many shower meteors at t_1 than at t_2. The OF is a number that varies with each configuration of the transmitter and receiver (each receiving station in the case of BRAMS) and with the position of the radiant of the meteor shower (hence with time).

The aggregated results of the Radio Meteor Zoo will be also used as the ground truth for the calibration and validation of the automatic detection algorithms (cf. the first objective mentioned before).

5 Conclusions

Thanks to the Radio Meteor Zoo, the BRAMS project can analyze for the first time several meteor showers per year.

However, this citizen science project depends on the motivation of volunteers to classify the spectrogram. Therefore, a continuous effort is needed to make publicity for this project to the general public, to give feedback to the volunteers, and to explain what has been done with their work. People who would like to contribute to this effort are invited to contact the article's first author (`stijn.calders@aeronomy.be`) .

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[2]`http://www.aeronomie.be/`.
[3]`http://www.stce.be/`.