Recent developments in the BRAMS project

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In 2009, the Belgian Institute for Space Aeronomy (BIRA-IASB) initiated the development of BRAMS, a Belgian network of radio receiving stations using forward scattering techniques to detect meteors. The primary goals of the project are (1) to collect data and to provide them to the community; (2) to retrieve information about the meteoroid trajectory; and (3) to study the activity profiles of the main meteor showers. In this paper, the work performed since the 2012 International Meteor Conference in La Palma, Canary Islands, Spain, is presented: (1) a software to decode the GPS signal has been developed and added to all BRAMS stations; (2) a workshop about automatic detection of features in radio data was organized in order to discuss about suitable image processing techniques that can be used for radio meteor echoes detection in the BRAMS spectrograms; (3) to assess the quality of such an image processing technique, a big set of manually counted meteors is necessary. A web application has been developed to support this task and facilitate the comparison of counts by different users; (4) to compute the meteoroid flux and for other applications, the radiation pattern of the different antennas must be known. Someone has been hired recently to make simulations of these radiations patterns as well as to carry out measurement campaigns; and (5) detection of solar flares in BRAMS data has been investigated.

1 Introduction

The Earth's atmosphere is constantly hit by thousands of meteoroids with sizes ranging from submillimeters to several meters. Their estimated cumulative mass is in the range of 40 to 100 tons per day. They play a crucial role in a number of astronomical and aeronomical studies and, given their intercept velocities in excess of 11 km/s, they pose a significant threat to spacecraft.

Traditionally, they have been detected by visual means or with radars during their interaction with the atmosphere. In 2009, the Belgian Institute for Space Aeronomy (BIRA-IASB) initiated the development of BRAMS, a Belgian network of radio receiving stations using forward scattering techniques to detect meteors. This project is carried out in collaboration with 25 Belgian radio amateurs or groups of amateur astronomers which host several receiving stations throughout the country (Calders and Lamy, 2012) and a dedicated beacon located in Dourbes (in the South of Belgium). This radio transmitter emits circularly polarized pure sine wave at a constant power of 150 W and a frequency of 49.97 MHz toward the zenith.

In Section 2, the primary goals of the BRAMS project are listed. In Section 3, the work that is performed since the last International Meteor Conference in La Palma, Canary Islands, Spain, is discussed. In the final section, the importance of the recent developments for the various objectives is emphasized.

2 Primary goals

The objectives of the BRAMS project are discussed in more details by Calders and Lamy (2012). They are briefly summarized below.

One of the primary goals is to collect the meteor radio observations of all stations and provide the data to the community. In the summer of 2013, 25 stations are equipped to observe the beacon in Dourbes. Data from these stations are collected every month and archived. The BRAMS viewer allows to visualize them (Lamy et al., 2013).

Each observation of a meteor by an individual BRAMS station provides information about only one point along the trajectory of the object. However, when a meteor is detected simultaneously by several stations, this allows in principle to retrieve information about the meteoroid trajectory. This is the second important objective of the BRAMS project.

A third aim is to study the activity profiles of the main meteor showers. Due to different geometries and radiation patterns of the emitting and receiving antennas, the counts obtained at different stations during a meteor shower are different. This can be compensated by using the Observability Function (Verbeeck, 1997). A test of this theory was done with BRAMS data of the 2011 Draconids, but only using geometrical corrections since the radiation patterns of the antennas were not available yet (Calders et al., 2013).

3 Recent developments of the BRAMS project

- Each station uses a GPS receiver as an accurate time source (1 ms) to synchronize stations. A pulse is sent each second followed by coded information, the NMEA (National Marine Electronics Association) sentences. To record both the observations and the time reference, two channels of an external sound card are used. The sampling frequency is set to 22 050 Hz to be able to decode the NMEA sentences. Data are recorded on a local PC in a WAV format every 5 minutes. The size of each file is approximately 24 MB. Each day, at 2^{h} UT, the NMEA sentences are decoded automatically and stored in a particular chunk of the WAV file. Then, the GPS channel is removed from the WAV file and the signal in the other channel is down-sampled to 5512 Hz, which leads to an effective bandwidth of about 2.5 kHz, suitable for our applications. The final size of each 5 minutes file is about 3 MB.

- On May 31, an STCE (Solar-Terrestrial Center of Excellence) workshop about automatic detection of events in radio data was organized. Several signal and image processing techniques used in solar, ionospheric, meteor, and weather research were presented. Among them, different image processing techniques were considered as potentially useful to automatically detect meteors echoes in the BRAMS spectrograms: median filtering, Radon transform, 2D FFT of the spectrograms were proposed as well as the study of the phase of the signal. Evaluation of the usefulness of these techniques for our goals is currently underway.

- To assess the quality of such an image processing technique, a database with a statistically relevant number of manually counted meteors is needed. To support this task, a web application has been developed. This web application allows the user to draw rectangles around the radio meteor echoes (for an example, see Figure 1). The coordinates of the rectangles are stored in a database and can later be used to obtain approximate information about the time and frequency of each meteor, which is useful to compare counts of different users. The user can differentiate between "short" and "long" meteor echoes. The distinction is rather arbitrary, and is actually related to the aspect of the echo in the spectrogram: if it is mostly vertical, it is considered "short". If it is elongated, it is considered "long". Note that this distinction does not strictly correspond to the classical underdense versus overdense dichotomy. Indeed, in the BRAMS spectrograms, the time resolution is approximately 3 seconds, so the only way to confirm the underdense character of a meteor is by going back to the original signal and looking at the shape and duration of the echo. The reason to distinguish between "short" and "long" meteor echoes is related to the future automatic detection method that will most probably be different for the two types of echoes. The results can be downloaded in CSV format.

- For various applications (e.g,. to compute the meteoroid flux), the 3-D radiation pattern of the BRAMS antennas (transmitter and various receivers) must be known.

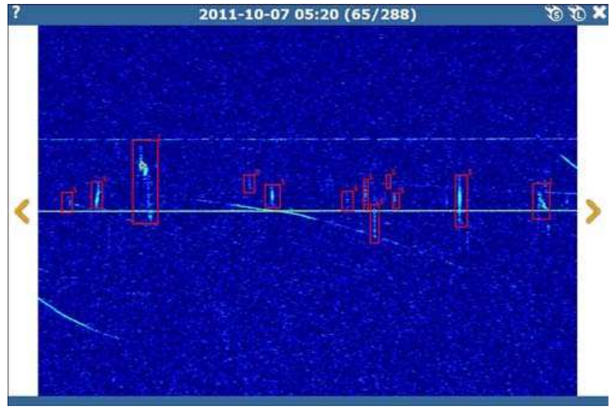

Figure 1 – A web application supports the manual counts of meteors in spectrograms. The horizontal axis represents the time (5 minutes in total), and the vertical axis the frequency (200 Hz centered on the horizontal line in the middle, which is the beacon). The user can interactively select regions of the spectrograms around possible meteor echoes and draw rectangles around them (indicated here as the red boxes). A distinction is made between short and long meteors.

Somebody has been hired to work on this since October 2013. Two complementary studies are planned: a software simulation of the antennas and a campaign of measurements on site to check the results and estimate the impact of the immediate environment on the antennas. For this, the basic idea is to use a known source, located in the so-called far-field region of the antenna under test, which starts at distance $L \approx 2D^2/\lambda$, where D is the dimension of the antenna, and λ the wavelength. For a BRAMS antenna, L is about 3 m. For that purpose, an artificial source (an antenna connected to a signal generator) will be set up at different positions around the antenna under test. Several possibilities will be considered, such as a telescopic and moveable mast supporting the source or an UAV (unmanned aerial vehicle) or drone. The position of the points of measurement will be determined accurately through GPS or geometric measurements. The calibration will initially be done for the antennas in Dourbes (transmitter), in Humain (interferometer), and in Uccle, but later on might be extended to all BRAMS stations.

- Besides the meteor detection, the BRAMS data are also sensitive to solar flares (see, e.g., Figure 2). A preliminary study was made to investigate the possibility of automatic detection of solar flares with the BRAMS network and to determine which characteristics of the flares observed in the spectrograms could be useful to the solar community. A clear conclusion is that the BRAMS network is mainly sensitive to the most intense solar flares and only weakly sensitive to the faint ones (intensities used according to the definition of NOAA, National Oceanic and Atmospheric Administration). For the solar flares with intermediate intensities, there were no definite conclusions, since some BRAMS stations could detect them while others could not. This can be explained by orientation effects such as elevation of the Sun, or obstacles in the direction of the Sun. but is also highly dependent on the radiation pattern of the receiving antennas. The most important aspect of solar flare observations with BRAMS is to have access to a very fine structure of the flares in frequencies that could potentially be used to discriminate among possible emission mechanisms. This work will continue in the future in collaboration with the Royal Observatory of Belgium.

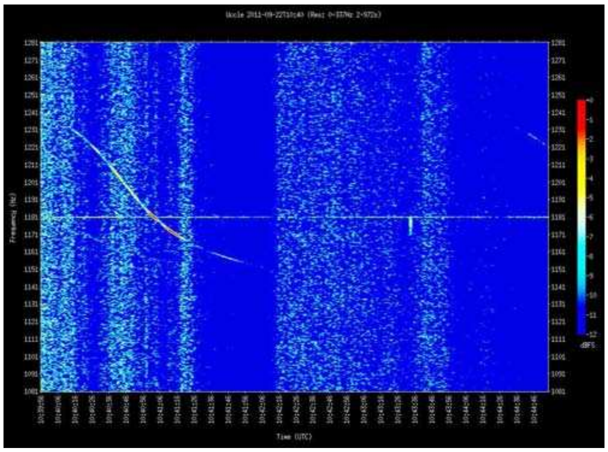

Figure 2 – Example of a BRAMS spectrogram recorded in Uccle on September 22, 2011, at $10^{h}40^{m}$ UT, showing a very intense solar flare (appearing as "broadband noise").

4 Conclusions

The work that was performed last year was important for the realization of the three primary objectives defined by Calders et al. (2012). The integration of the accurate timing from the GPS clock will allow us to combine the observations of several stations and to retrieve trajectory information. Several image processing techniques proposed by scientists working in other fields are currently investigated to perform an efficient automatic detection of meteors in the spectrograms. The quality of the image processing technique that will be chosen will be assessed by comparing its results with a database of manually counted meteors. The radiation pattern measurement of the BRAMS antennas is important to retrieve the trajectory information and to study the activity profiles of the main meteor showers. Finally, the detection of solar flares is an example of how BRAMS data can contribute to research in other areas such as solar physics and space weather.

The latest information on the project can be found on our website[1].

Acknowledgements

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