BRAMS : status of the network and preliminary results

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Recently, the Belgian Institute for Space Aeronomy has been developing a Belgian network for observing radio meteors using a forward scattering technique. This network is called BRAMS (Belgian RAdio Meteor Stations). A radio transmitter emits a circularly polarized pure sine wave toward the zenith at the frequency of 49.97 MHz. This beacon is located in Dourbes (southern Belgium) and emits a constant power of 150 W. The receiving network consists of about 20 stations hosted mainly by radio amateurs. Two stations have crossed-Yagi antennas measuring horizontal and vertical polarizations of the waves reflected off meteor trails. This will enable a detailed analysis of the meteor power profiles from which physical parameters of the meteoroids can be obtained. An interferometer consisting of 5 Yagi antennas is installed at the site of Humain in order to determine the angular detection of one reflection point, allowing to determine meteoroid trajectories. We describe this new meteor observing facility and present the goals we expect to achieve with the network.

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. Here, we propose to study the meteoroid population with the BRAMS (Belgian RAdio Meteor Stations) network, a set of radio receiving stations using forward scattering techniques and a dedicated beacon as transmitter. Its current state is described in Section 2, while Section 3 is devoted to the objectives of the project. In the conclusion, the advantages of a forward scattering system over traditional radar systems will be briefly discussed.

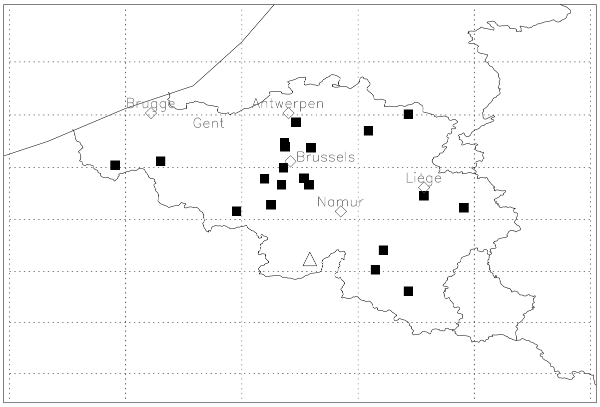

Figure 1 – Geographical distribution of the stations of the BRAMS network. The black squares represent the receiving stations, and the triangle represents the beacon in Dourbes. The biggest cities of Belgium, represented by rhombs, have been added to facilitate identification of the stations.

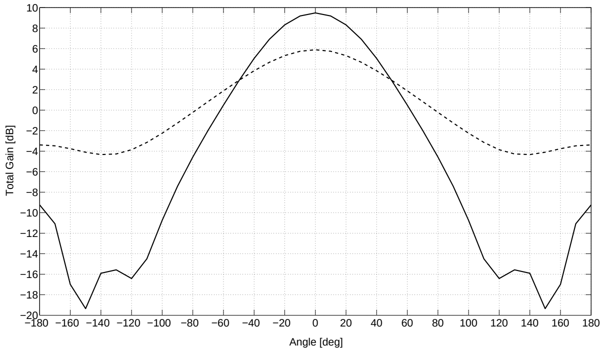

Figure 2 – Theoretical radiation pattern (in dB) of the beacon antenna in Dourbes, with an 8 m × 8 m grid (solid curve) and without a grid (dashed curve).

2 The BRAMS network

In 2009, BISA, the Belgian Institute for Space Aeronomy 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 about 20 Belgian radio amateurs or groups of amateur astronomers which host several stations throughout the country (see black squares on Figure 1).

The transmitter is a dedicated beacon located in Dourbes (the triangle on Figure 1). It is a crossed 2-element Yagi antenna which emits a pure sinusoidal wave with a constant power of 150 W at 49.97 MHz. This frequency is protected to avoid ambiguity about the origin of detected meteor echoes. The beacon in Dourbes has been active since September 2010. Since October 2011, an 8 m × 8 m grid acts as the reflector to increase the power emitted upward (HPBW ≈ 64°; see Figure 2). With this grid, the total gain is increased by 3.6 dB. The stability of the frequency of the Dourbes beacon is secured with a GPS disciplinated OCXO (Oven-Controled Crystal Oscillator) 10 MHz reference.

A typical receiving station is made of a 3-element Yagi antenna linked to an ICOM IC-R75 receiver by a coaxial cable. The received signal is sampled by an external USB sound card (Behringer UCA222) and stored on a local PC. With 20 receiving stations spread over Belgium, we increase both the number of meteor detections and the chance of having the same meteor detected simultaneously by several stations. This last point is essential for the determination of meteoroid trajectories, since each detection yields information about only one point of the trajectory. This requires a very good synchronization of the stations, which is achieved by using the Meinberg NTP (Network Time Protocol) application and a local GPS (Garmin GPS 18x LVC Sensor) as reference clock. Accuracy of at least 1 ms is expected. The GPS and the output signal from the ICOM receiver are sampled simultaneously by the external USB sound card to mitigate signal latency. Each station generates approximately 2 GB of data per day. These data are temporarily stored on local hard disks and sent monthly by postal mail to the IT facilities of BISA, where all data are analyzed and archived. In these data there will be a large number of meteor echoes but also a large number of "spurious" echoes such as reflection of radio waves on planes, sporadic E, thunderstorms, etc. as well as local broad-band interferences. A software program is currently being developed to automatically discriminate meteor echoes.

The station in BISA (located in Uccle in the south of Brussels) is also equipped with an additional antenna, a crossed 3-element Yagi. With this setup, we will measure both polarizations (horizontal and vertical) of the meteor echoes and combine them to obtain the total power reflected by the meteor. This will allow us to perform quantitative analyses of the signal in order to retrieve physical parameters of the meteoroids.

An interferometer consisting out of 5 Yagi antennas is installed in the radio-astronomical site of Humain to determine the angular direction of the reflection point within 1–2° accuracy. Humain is located about 60 km northeast of Dourbes. We use the 5 antenna configuration of Jones et al. (1998), consisting of two orthogonal linear arrays of 3 antennas with the central one common to both arrays. The central antenna is a crossed 3-element Yagi antenna used to obtain the total power of the incoming waves like in the BISA station. To get information on the angular direction of the reflection point, the phases of the signals from the 5 antennas are compared. For this purpose, the phase of the 5 receivers are synchronized by a 10 MHz reference oscillator similar to the one used for the beacon in Dourbes.

3 Objectives of the project

With the BRAMS network, we aim for the objectives described below. They are separated according to whether they require with a single station, several stations, or several stations and the interferometer.

1. By using data from a single receiving station, activity profiles of meteor showers (number of echoes versus time) can be obtained by subtracting sporadic meteor echoes from all echo counts. These activity profiles must be corrected for the observability function of the station, which describes its sensitivity for detecting meteoroid echoes from a specific direction in the sky (Hines, 1958; Verbeeck, 1997; Steyaert et al., 2006). The activity profiles of the main meteor showers will be studied and compared to results from prior research. Mass indexes and flux densities will be calculated for meteor showers and sporadic background using the method developed by Belkovich (2006) and Ryabova (2008; 2009).

2. Simultaneous detection of a meteor by several stations allows in principle to retrieve some information about the meteoroid trajectory. We will test a method proposed by Nedeljkovic (2006) exploiting the fact that a meteor trail is tangential to a family of ellipsoids with the receivers as one focal point and the transmitter as the other one (specularity condition). If the meteor is also detected by the interferometric station in Humain, the problem is simplified as we then know the angular direction of the reflection point for this particular geometry. The height of this reflection point can be obtained for shower meteors, but is still unknown for sporadic meteors. However, for underdense meteors, it can be estimated from the exponential decay of the power profile (with the use of a good atmospheric model such as MSISE-00) and for overdense meteors, it can be estimated with the method proposed by Carbognani et al. (2000). With the 3D position of one specular point and with detections of the meteor by other stations, we can retrieve the trajectory of the meteoroid even for sporadic meteors (Wislez, 2006). Eventually, the goal is to produce a map in Sun-centered ecliptical coordinates of the distribution of meteor radiants and to compare it to similar ones obtained by optical or radar means (e.g., Campbell-Brown, 2008).

3. For a given meteor, when the geometry is fully resolved, the study of the power profiles give access to several important physical parameters if the technical characteristics of the receiving station (antenna gains, polarization of the reflected wave, calibration of the acquisition card, etc.) are perfectly known (Wislez, 2006). These characteristics will only be known for the stations in Uccle and in Humain. For the others, we will only have reasonable estimates. The electron line density at the reflection point can be computed from the maximum of the power profile. If the electron line density is obtained in several points of the meteoroid trail (from multi-station observations), the initial mass of the meteoroid can be estimated with models of meteoroid ablation in the Earth's atmosphere (e.g., Campbell-Brown and Koschny,

2004). The ambipolar diffusion coefficient can be obtained from the exponential decay of underdense meteors and yields information on the meteor's height. The speed of the meteoroid can be determined by several methods: (a) from Fresnel oscillations if these are present and if the signal-to-noise ratio of the data is large enough, (b) from initial rise times of the power profiles if the meteor is observed by several stations (requiring a good synchronization from the various stations), and (c) from the Doppler effect for head echoes (see below).

4. Head echoes are associated with the ionized region in front of the meteoroid. Therefore, these echoes in spectrograms show a large Doppler effect due to the high velocity component of the object along the line of sight. If such an echo is detected by at least 3 stations, we can in principle retrieve the total velocity of the meteoroid (Richardson and Kuneth, 1998; Steyaert et al., 2010). In combination with an ablation model, the meteoroid mass and density can be estimated. Comparison with the results on head echoes obtained with High-Power Large-Aperture (HPLA) radars will be considered.

5. Once we have the radiant of individual meteors and also an estimate of the relative intercept velocity of the incoming particle, the next step is to calculate the orbital parameters of the detected meteoroids. A correction must be applied for the acceleration produced by the gravitational focusing of Earth as well as for the Earth's heliocentric velocity. Knowing the orbital parameters contributes to a better understanding of the distribution and evolution of material in the Solar System.

6. Another advantage of having stations with dual polarized antennas is the ability to investigate the polarization of the received waves. Since most of receiving stations can detect only one polarization, it is very important to determine the depolarization coefficient of the reflections on the meteor trail. The rotation of the polarization plane of the incoming wave can be due to ionospheric Faraday rotation or as a result of the scattering from meteor trails. We will investigate whether the depolarization depends on the type, the trajectory, or the size of the meteor trail. To our knowledge, very few similar measurements have been done with a forward-scatter system (see, however, Billam and Browne, 1955).

4 Conclusion

The BRAMS network will be a very useful tool to better characterize the distribution of meteoroids in the Solar System. Most researchers employ a backscatter setup rather than a forward-scatter system, as the latter has a much more complicated geometry. However, backscatter systems suffer from the echo ceiling selection effect, which limits their views on faint and fast meteors. Forward-scatter setups are much less vulnerable to this selection effect, hence yielding a less biased meteoroid population.

To our knowledge, there are only two other forward-scatter systems run by professional astronomers: the Bologna-Lecce-Modra system (Cevolani et al., 1996) and the HRO system at the Kochi University in Japan (Yamamoto et al., 2007). The former has only 2 receiving stations and no interferometric capabilities while the latter has only 6 stations. BRAMS combines the observations of at least 20 stations that will allow improved multi-station analysis and will also have the additional advantage of an interferometric system.

You can find the latest information of the project on our website: `http://brams.aeronomie.be`.

Acknowledgements

BRAMS is a project of the Belgian Institute for Space Aeronomy funded by the Belgian Solar Terrestrial Center of Excellence (STCE; `http://www.stce.be`). This project is carried out in collaboration with many radio amateurs from Belgium. We would like to thank them for their participation in this project.

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