A bright fireball over the state of Rio Grande do Sul

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On June, 7th, 2019, around 01h33m (UT), inhabitants from Brazil (mainly in the Southern Region states), Argentina, Paraguay and Uruguay observed a very bright fireball which was also recorded by two meteor monitoring stations of BRAMON. The fireball entered in the atmosphere with a velocity of 14.3 km/s at an altitude of 104 km over the south of Paraguay, travelling 393 km until reaching its dark flight at an altitude of 27.4 km over the state of Rio Grande do Sul. The calculated energy corresponds to an entry mass between 3.25×10^3 kg and 5.75×10^3 kg (this corresponds to a meteoroid with a diameter of 1.2 m to 1.4 m). It is believed that about 10% of the original mass reached the ground. The shallow trajectory created a large meteorite strewn field that could extend from the cities of Jari to Santa Maria (Rio Grande do Sul, Brazil). Teams conducted a meteorite search in the area, with no success so far.

1 Introduction

Some countries, like Morocco, have developed recently a culture of meteorite trade, making people more aware of bright meteors (Ibhi, 2014), allowing the recovery of 11 meteorite falls in the last 20 years. In the United States, a country with a much larger surface, the use of technology is a key factor that has helped the recovery of meteorite falls. In the last 20 years, at least 14 of the 19 falls were recorded by cameras, detected by radars or satellites. In Brazil, only two meteorites (Porangaba and Varre-Sai) of the six falls from the last 20 years were recorded (Meteoritical Bulletin Database, 2020)[1]. The Porangaba meteorite is the first, and so far, the only Brazilian meteorite with an estimated orbit and published orbital elements (Ferus et al., 2020).

BRAMON (Brazilian Meteor Observation Network) is a meteor monitoring network created to, among other goals,

Figure 1 – Meteor as seen from Monte Castelo (Santa Catarina state) JJS2 BRAMON station and Caxias do Sul (Rio Grande do Sul state) camera of the project Clima Ao Vivo.

[1] Meteoritical Bulletin Database, 2020, https://www.lpi.usra.edu/meteor/, May 9th, 2020.

monitor meteors and help to improve the detection of possible meteorite dropping events in Brazil (Amaral et al., 2018). In this case the atmospheric trajectory, heliocentric orbit and pre-atmospheric mass of the progenitor of the meteor seen from southern Brazil, northern Argentina, Paraguay and Uruguay (*Figure 1*) are evaluated and the mass of the meteorite fragments that could have reached the ground has been estimated.

2 Methods

Location and equipment

The trajectory was estimated using the UFOOrbit© software (SonotaCo, 2009), triangulating and comparing the duration of the event captured by a security camera in Porto Alegre and a camera of the project Clima Ao Vivo in Caxias do Sul, both in Rio Grande do Sul state, and two BRAMON monitoring stations (JJS2 and JJS3) in Monte Castelo and Santa Catarina state. The cameras had a CCD of similar sensibility curve, a quantum efficiency peak near 90% (around 650 nm) (Gural, 2014). The security and weather monitoring cameras had a cutoff for wavelengths exceeding 750 nm (removed in the BRAMON stations), the frame rate 30 / s, the luminous fluxes about 0.1 lx and a FOV of about 120 deg^2 (plate scale of hundreds of arcsec/pixel).

Analysis

In the absence of bright stars as references, the street lamps were used for photometric calibration. The light curve of the Caxias do Sul video was used as reference to synchronize each recording. The atmospheric trajectory and the heliocentric orbit were calculated using the right ascension and declination of the beginning and end of the meteor and its duration. The approximate azimuth and altitude of the cameras FOV centers were inferred by information provided by the owners (Zurita et al., 2019).

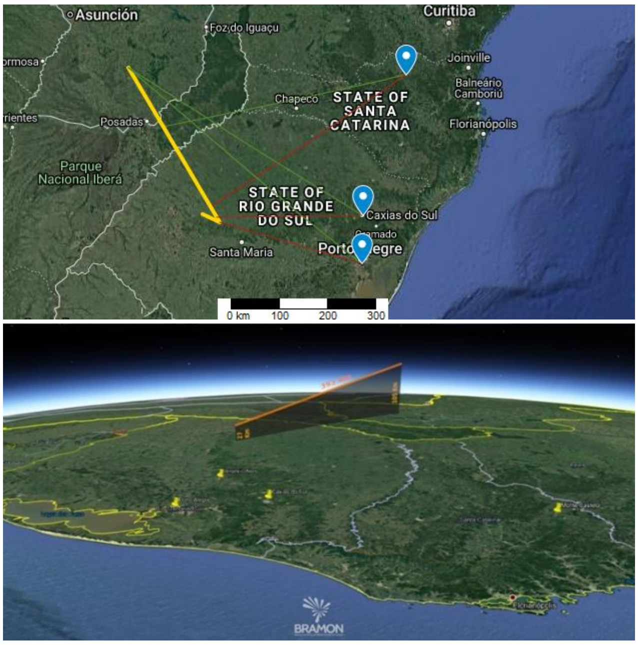

Figure 2 – Top: Position of each camera and the meteor trajectory. Bottom: Side view of the downward trajectory.

3 Results and discussion

Atmospheric trajectory, photometry and orbit

The meteor was very long and lasting and began at an altitude of 104 km over southern Paraguay (relative to sea level) with a geocentric velocity (v_g) of 14.3 km/s. For 27.5 seconds, it crossed 393 km through the atmosphere travelling to SSE and passing over parts of Argentina and the Northwest of the Rio Grande do Sul state, disappearing at 27.4 km altitude above the town of Jari (*Figure 2*). It reached a peak of absolute magnitude equal to –13, with a relative deviation of 20%. The light curve is shown in *Figure 3*. The orbital elements are shown in the *Table 1* (with a relative deviation of about 10%) and the orbit is shown in *Figure 4*. It was classified as a sporadic meteor and could be associated with the Atens near-Earth asteroids group.

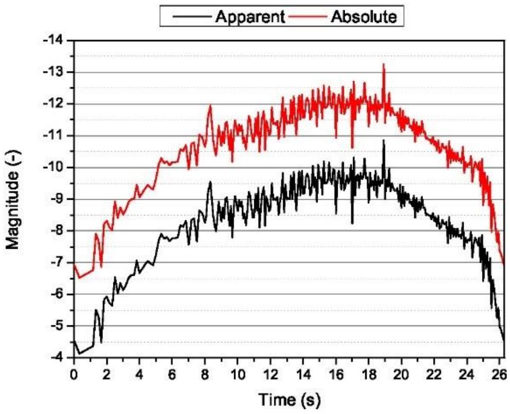

Figure 3 – The meteor light curve from Caxias do Sul (Rio Grande do Sul state) video.

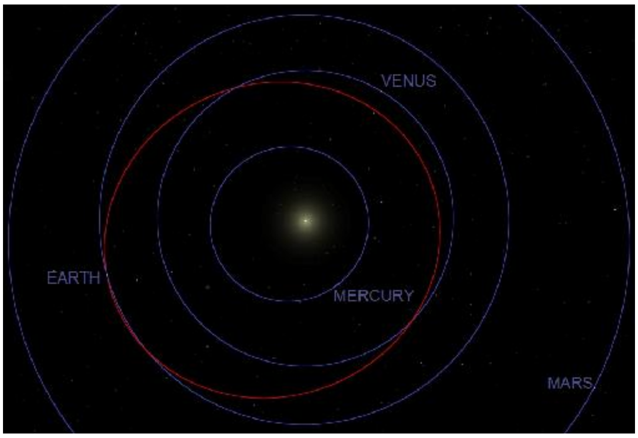

Figure 4 – Top view of the meteor orbit (red) relative to the Inner Solar System.

Pre- and post-atmospheric mass

The analysis of the luminous intensity indicates an initial mass between 3.25 × 10^3 and 5.75 × 10^3 kg (Ceplecha et al., 1996), with an uncertainty which is caused by the inaccuracy of the luminous flux in different recordings (Romig, 1965). Using the average density of an ordinary chondrite meteorite, 3.84 g/cm^3 (Britt and Consolmagno, 2003), the diameter of the meteoroid size was estimated

Figure 5 – Meteorite strewn field estimate.

between 1.2 m to 1.4 m. When applying the ablation model by Hawkins (1964), it seems that about 10% of the original mass reached the ground. The shallow trajectory and the low intensity of the winds over the area allowed the fragments to travel more than 50 km during the dark flight, creating a large strewn field (*Figure 5*) which could extend from the cities of Jari to Santa Maria (Rio Grande do Sul state). Teams went to the area and conducted searches, but no fragments were found so far. The area has plantations and cattle, making the search difficult.

Table 1 – Orbital elements of the fireball.

Elements	Value
a	0.817 AU
e	0.256 -
q	0.607848 AU
i	17.9°
Ω	255.8°
ω	194.2°
M	153°
P	0.738 years

4 Conclusions

The meteor travelled 393 km from south Paraguay towards mid-west Rio Grande do Sul with an entry velocity of 14.3 km/s. Its luminous trajectory began at 104 km with a peak in absolute magnitude of –13 until the fireball reached the dark flight at an elevation of 27.4 km. It had an entry mass over 3 metric tons (diameter over 1.2 m) and it is estimated that about 10% of the original mass fell between Jari and Santa Maria although no fragment was found until now.

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