TRAJECTORY ANALYSIS OF 04/2019 METEOR IN COSTA RICA

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Abstract

On 4/24/2019 3:07 AM UTC a meteor was detected in Costa Rica. The object fragments found showed to be a relatively unusual CM2 carbonaceous type. Through surveillance cameras at Marina Pez Vela in Quepos and TV Turrialba we were able to analyze the meteor's trajectory. Through numerical integration, considering the atmospheric drag, and fragments with masses from 1g to 100kg, we obtained a probable fall area, where meteorites were later located. Performing the reverse integration, up to 1000 km of altitude, we find the position and speed of entry of the meteoroid into the atmosphere. Based on these data, we proceed with the reverse integration, considering from this moment on, the gravitational forces of the Sun-Earth-Moon system, up to the point where the meteoroid would have crossed the Earth's sphere of influence. At this point, we determine, in the heliocentric coordinate system, the values of the meteorite's orbital elements, such as 1.290718 au for the semi-major axis, 0.225 for eccentricity and 0.8534 degrees for inclination. This being an NEA type Apollo. We found, through a profound integration, that the object would collide with Earth even without the influence of the Moon. Finally, we performed a reverse numerical integration, considering the Sun, the Moon and the eight planets for 100 thousands years ago. We observed that there were no significant variation in the orbital elements, with the exception of the precession of the pericenter, a low inclination NEA Apollo remaining.

Image analysis

Meteor images were obtained from three sources: Marina Pez Vela, TV Turrialba and Irazu Volcano

However, the images of the volcano, despite providing accurate astrometry, had to be discarded, as they presented the brightness of the meteor, but not its trace. From the comparison of the daytime images from the cameras and the bright fixed points recorded during the passage of the meteor, such as lights, poles, mountains, etc., we were able to make an astrometric mask for each of the cameras.

Figure:1 Meteor on the Marina's camera, with reference points for astrometry.

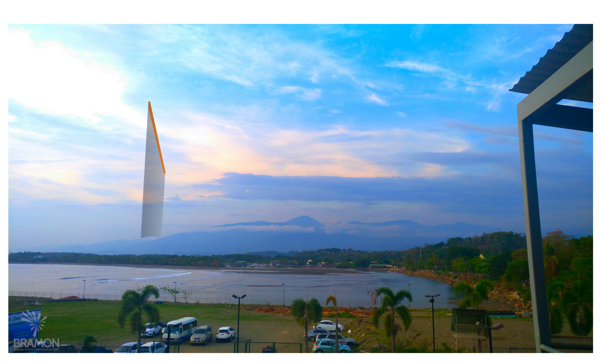


Figura 2: Marina view of the meteor's trajectory.

After generating the astrometric masks referring to the meteor's trajectory, we used the software UFOAnalyzer and UFOOrbit, to pair the two cameras, thus obtaining two points, P1 and P2, of the trajectory, described in Table 1.

Table 1: Points of the meteor trajectory.

-	P1	P2
Latitude	10,41037	10,40603
Longitude	-84,38637	-84,37854
Altitude	42039 m	35546 m

The time interval between points in the images is 0.56 s.

Impact Points

Through points P1 and P2 we estimate the velocity and direction of the meteor. Using numerical integration, considering the gravitational force of the Earth and the atmospheric drag, we calculate the possible meteorite drop locations.

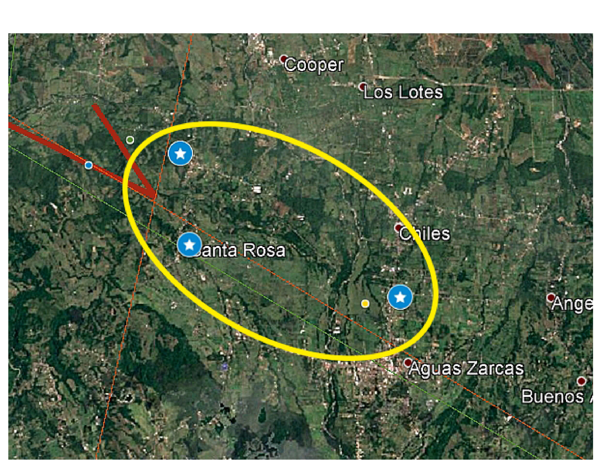


Figure 3: Dispersion Region.

With this we determine the impact points for fragments from 1g to 100 kg, generating a dispersion region between -84 21 42 and -84 20 8 degrees in longitude and 10 23 48 and 10 22 56 degrees in latitude. Thus forming a region with a perimeter of 3.5 km. In the regions close to what we estimate, meteorite hunter Michael Farmer found more than 6 kg of meteorites.

Figure 4: One of the material found in the dispersion region.

The meteorites found are relatively uncommon, of the type carbonaceous CM2.

Orbits

To estimate the object's orbit, we perform the reverse integration, considering the Earth's gravitational force and atmospheric drag.

This integration took place until the object was at the height of 1000 km. From this point onwards, we proceed to reverse integration, but considering the gravitational forces of the Sun-Earth-Moon system. In this step, we perform the reverse integration until the object crosses the sphere of influence of the Earth-Moon system, obtaining the object's orbital parameters in the heliocentric system.

With this, we obtained as orbital parameters the values shown in Table 2. We can thus conclude that the original meteoroid would be an Apollo-type NEA.

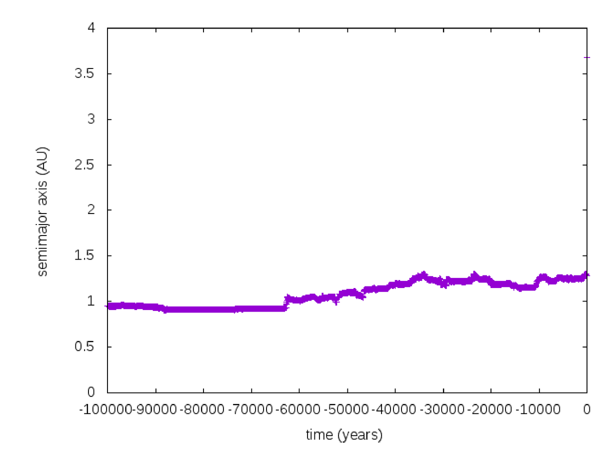
Table 2: Meteor orbital elements.

Semi-major axis	1.290718 ua
Eccentricity	0.2250342
Inclination	0.8534
Longitude of pericenter	193.7
Longitude of the ascending node	33.7
Mean anomaly	349.2

In order to test the influence of the Moon in the capture of the meteoroid, we performed a integration, starting from the obtained orbit, but in this case, without considering the gravitational influence of the Moon. The result has not changed significantly, resulting in an impact on Earth at points close to meteorite records. Thus, we can conclude that the Moon had no significant importance in this impact or is responsible for the capture of this meteor.

Orbital Evolution

With the meteorite's orbital parameters, we performed the reverse integration considering the Sun and the eight planets. We used as an integrator the Burlish-Stoer from the Mercury package (Chambers, 1999), in an integration of 100,000 years. The results showed that the meteoroid remains a low-slope Apollo-type NEA. The eccentricity and the major semi-axis did not change significantly. The meteor remained between 1.7 and 0.8 au throughout the integration. The greatest planetary approach occurred with Earth, followed by Mars, both around 0.001 AU.



Figur3 5: Meteor semi-major axis evolution.

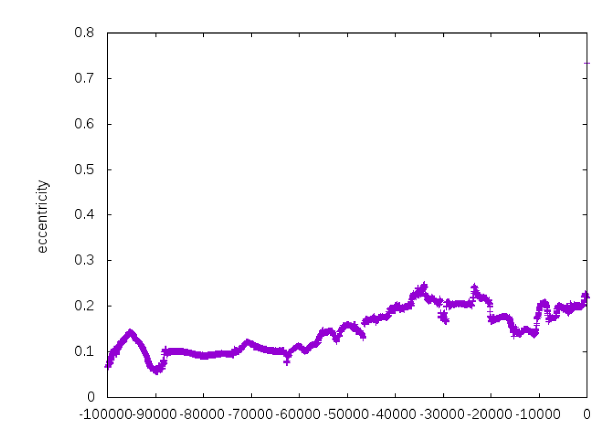


Figure 6: Meteor eccentricity evolution.

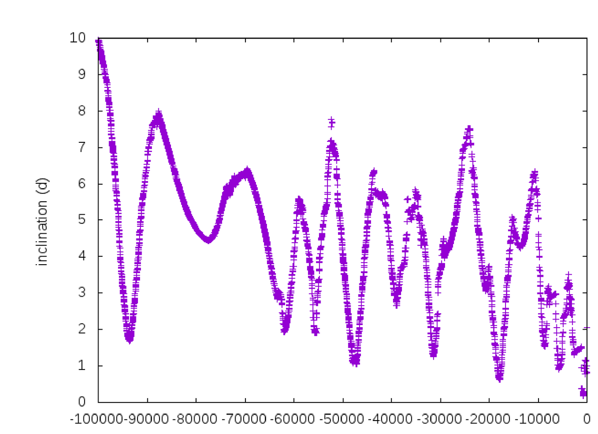


Figure 7: Meteor inclination evolution.

Conclusions

In this work, we analyzed the meteor that occurred in Costa Rica on the 4th of 2019. Through images from security cameras we obtained the trajectory of the meteor. Using two points of the trajectory, considering the atmospheric drag we determine the possible points of collision with the ground and the point of entry into the atmosphere. This meteor is special because it is carbonaceous. After determining the points of entry into the atmosphere, we obtain the orbital parameters of the meteor, through reverse integration considering the Sun-Earth-Moon system. We found it to be a low-slope Apollo meteor. We also observed that the Moon did not influence the capture of this meteor. Finally, the meteor's trajectory reversed for 10,000 years, considering the Sun and the eight planets, concluding that the meteor remains an Apollo-type NEA during the entire integration.