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Possible sources of meteoroids falling on Earth

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Abstract

In this paper we present the results obtained from the spectral analysis using the new gapped wavelet technique of a time series of brightest fireballs to find its possible source. The spectra shows four periodicities at 4.6, 3.2, 1.6 and 0.7 years. These periodicities are related to three regions in the solar system according with the third Kepler law: the asteroid belt, the Amor asteroids (NEO´s) and the place located at Venus orbit.

1. Introduction

One of the main problems of Planetary Sciences is to identify the source from which meteoroids come to Earth. In the last decades several studies have been done on this matter and indicate that some meteorites could come from the asteroid belt and be associated with resonance zones from where they could be ejected into the inner solar system and be trapped by the Earth's gravitational field. At the same time the gravitational infuence of Jupiter on asteroids contribute to several bodies can be catapulted from the belt to the interplanetary medium. In 2002, Bottke and his co-workers created a statistical model to locate the possible source of meteorites on Earth and concluded that the inner main belt produces a substantial percentage of near-Earth asteroids (NEO´s) that corresponds to the Amor, Apollo and Aten families as well as Objects residing inside Earth's orbit (IEO´s), [1]. In this decade, the Chelyabinsk fall observation (February 15, 2013), [2] and its subsequent study from the astronomical point of view indicate that its origin could be associated with the Apollo asteroids or with the Flora family in the asteroid belt [3].his is the introduction section of your paper.

2. The spectral method

A time series of brightest fireballs from January 1, 1994 to April 30, 2019 was spectrally studied using the wavelet technique. The data were taken from the Near Earth Object Program (http://ssd-api.jpl.nasa.gov/doc/fireball.html). Because of this time series has gaps, the new gapped wavelet transform (equation 1) was used to do the spectral analysis. This function is defined as [4]:

$$W_g(t,a) = \sqrt{\frac{1}{aC(a,t)}} \int_{-\infty}^{\infty} \psi'(t',t,a) f_g(t') dt \qquad (1)$$

with:

$$\psi'(t',t,a) = \left[h\left(\frac{t'-t}{a}\right) - C(a,t) \right] \Phi\left(\frac{t'-t}{a}\right) G(t') \qquad (2)$$

and,

$$C(a,t) = \frac{\int_{-\infty}^{\infty} h\left(\frac{t'-t}{a}\right) \Phi\left(\frac{t'-t}{a}\right) G(t') dt}{\int_{-\infty}^{\infty} \Phi\left(\frac{t'-t}{a}\right) G(t') dt} \qquad (3)$$

The function G(t) is equal to 1 if the signal is registered and 0 if the data is lost or no reported.

3. Results and discussion

Four periodicities were identified from the spectral analysis (figure 1). They are located at 4.6 ± 0.9, 3.2 ± 0.5, 1.6 ± 0.3 and 0.7 ± 0.1 years. The figure 1 shows the power spectral density spectra (PSD) where four periodicities can be seen on the left side of the plot. They were obtained with a confidence level greater than 95% and are inside the cone of influence (COI). The uncertainties of every peak position were obtained from the peak full width at half maximum.

Applying the Kepler third law (T^2 α a^3) to these periodicities (4.6, 3.1, 1.6 and 0.7 years) it is found that the aphelion is located at: 2.8 AU, 2.2 AU, 1.36 AU and 0.79 AU respect to the center of the Solar System. Looking for celestial bodies at these

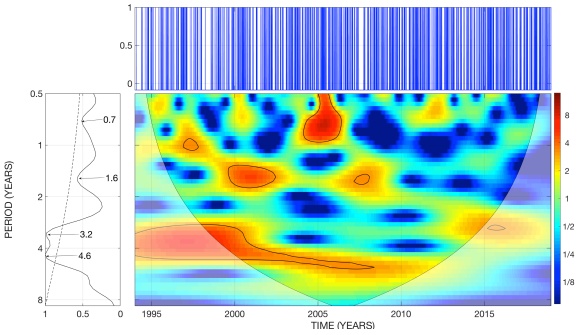

Figure 1: Power spectral density of a time series of brightest fireballs from January 1, 1994 to April 30, 2019. On the left side four peaks at 4.6, 3.2, 1.6 and 0.7 years are shown.

distances, it is found that part of the main asteroid belt is located between 2.2 to 2.8 AU leaving the Flora family asteroids and Ceres within it. In particular, the Flora asteroids are located at 2.2 AU while Ceres is located at 2.77 AU. On the other hand, the Amor asteroids are located between 1.07 to 1.3. AU as part of NEO's and Venus turns around the Sun at 0.723 AU [5]. These bodies either have a gravitational influence on the meteoroids, or/and cause them to enter resonance zones where they can be expelled into space. In the case of asteroids Flora and Amor, they can be a source of meteoroids, while Ceres could contribute to the entrance of asteroids in the areas of resonance in the belt from where they can be ejected to the inner solar system and be captured as meteoroids by the Earth´s gravitational field. Finally Venus could gravitationally modify the trajectory of meteoroids in the interplanetary medium and catapult them towards Earth.

Additionally the geographic location was used to do the spatial analysis and the fireballs energy data were used to find the height at which the fireballs reach their maximum brightness. In Figure 2, the probability density function of the altitude at peak brightness is presented. The altitude shows a multimodal distribution, and it was found that 70% of fireballs release most of their energy at an altitude of between 10 and 40 km.

4. Summary and Conclusions

The source of the brightest meteoroids could be associated with resonant regions in the asteroid belt located in the main section where the Flora and Ceres asteroids are located. The Amor asteroids (part of NEO´s) could also be a source of meteoroids while Venus could be a gravitational trigger of meteoroids from their neighborhood to Earth.

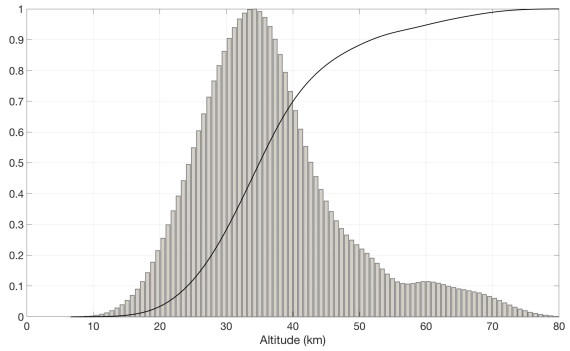

Figure 2: Probability density (gray bars) and cumulative distribution (black line) functions of the date of each fireball event and their altitude at peak brightness.

Acknowledgements

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