EPSC Abstracts
Vol. 12, EPSC2018-1226, 2018
European Planetary Science Congress 2018

Investigating Fireball Flight in Three Dimensions

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Abstract

Fireball trails recorded on long exposure, Desert Fireball Network images are encoded with a unique time sequence that is synchronised between systems to 0.4 ms. This allows triangulation of individual positions along a meteoroid path as it passes through the atmosphere. Using this technique on the >21 second long fireball caught by the DFN in 2015 shows a distinctly non-linear path. A 3D particle filter, using raw astrometric observations is best suited to characterise the meteoroid and its trajectory.

1. Introduction

Dedicated camera networks, such as the Desert Fireball Network in Australia (DFN), have been established to observe the fireball phenomenon associated with meteoroid entry through the atmosphere. Multi-station triangulation can recreate a meteoroid's path, facilitating orbit determination and meteorite recoveries. The DFN captures approximately one $>$ 2 seconds fireball per night over its 3 million km^2 observing area. This exceptionally large collecting area, combined with the very high astrometric precision of the DFN instruments, allow us to look at a significant number of long and shallow meteoroid entries in great detail.

1.1 Calculating trajectories

Typical methods for triangulating meteoroid trajectories assume a straight line path, with deviations added for known phenomena such as gravity. The DFN captures long exposure images and the modulation of a liquid crystal shutter results in segmented fireball trails. The de Bruijn encoding used by the DFN embeds a unique, absolute time signature which is synchronised across the network via GNSS. This provides the unique capability of individually triangulating meteoroid positions for every time-step with multi-station observations. Performing this *pointwise* triangulation allows us to investigate the true movement of a meteoroid without imposing any assumptions on trajectory geometry and fireball dynamics.

1.2 Characterising meteoroids

Meteoroid characteristics such as mass and density are estimated by assessing deceleration profiles and light curves. This modelling is inherently linked to the triangulation solution. A particle filter, as applied by Sansom et al. (in review), is an iterative Monte Carlo technique that does not aim to fit the entire trajectory at once, rather it estimates the state (position, velocity, mass, density, etc.) at each observation time using a cloud of particles. Using this method with a three dimensional model allows the raw astrometric observations to weight particle fits. This removes the need for pre-triangulating the entire trajectory, eliminating the need for preconceived assumptions such as a straight line trajectory.

2 Investigating meteoroid data

The >21 second long fireball observed by the DFN in December 2015 is shown to not follow a straight line path. A 3D particle filter is well suited to analysing the characteristics of this meteoroid case. The entry radiant is also affected, changing the predicted heliocentric orbit noticeably.

References

[1] Sansom, E. K., Jansen-Sturgeon, T., Rutten, M. G., Devillepoix, H. A. R., Bland, P. A., Howie, R. M., Cox, M. A., Towner, M. C., Cupák, M., Hartig, B. A.: 3D Meteoroid Trajectories, ICARUS, in review.