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Simulations of Meteor Trajectories Observations from Orbiting Spacecraft

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Abstract

We have analyzed the possibilities of a spacecraft-based meteor search in the atmosphere of planets, focusing on Earth and Mars. This work concentrates on the geometrical conditions and prospects when using the wide-angle camera SPOSH (Smart Panoramic Optical Sensor Head) [1] in varying heights above the surface and incident angles of meteor streams.

1. Introduction

The conventional means of meteor shower research on Earth with frame and video cameras are often affected by external circumstances. The maximum of a shower might occur during daytime and a full moon or a clouded sky can (partially) render observation attempts useless. Some effects can be mitigated by carefully planning observation campaigns beforehand but ambiguous long term weather forecasts will always put question marks on the schedule. Spacecraft-mounted cameras though work mostly independent from atmospheric conditions. On Earth meteors appear in heights of up to 100 km, far above the troposphere, which extends to a height of up to 18 km at the equator. Due to the thin atmosphere of Mars, meteors appear in lower altitudes of 50 to 90 km [2], while occasional CO_2 ice clouds typically occurring 66 to 83 km above ground [3]. These clouds are opaque in shorter wavelengths only, so a broadband sensor would be able to see meteors in a clouded Martian atmosphere.

2. Camera System

A wide-angle camera, which covers the entire planet disk from orbit, is the natural choice for such an observational task. A highly sensitive CCD ensures the acquisition of faint meteors in the atmosphere. Both of these properties are found in SPOSH, co-developed by the DLR and Jena-Optronik GmbH under a contract by ESA, which features a custom-made fish-eye lens offering a 120° x 120° Field-of-View (168° over the diagonals) and a highly sensitive back-illuminated 1024 x 1024 pixels CCD chip with a high-dynamic range of 14 bits. The camera's lens system uses an equidistant projection which provides a constant Instantaneous Field-of-View (IFOV) over the whole image. Breadboards employed in the observation of the Perseids in recent years [4] showed the excellent performance of this design.

3. Analysis

We have calculated the distribution and appearance of meteors in the atmosphere of Earth and Mars as seen by SPOSH. A vector field of 10,000 randomly distributed parallel lines mimicking a meteor stream has been intersected with the planetary spheres including the atmosphere layer. The resulting meteor trails were projected into the image plane. Since the goal was to derive geometrical information about the emerging patterns of meteor trails in the image, we did not consider time-varying brightness and extinction effects near the limb.

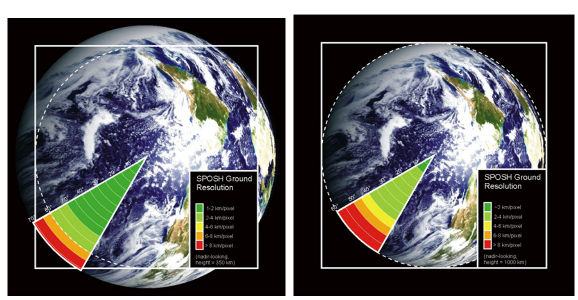

Figure 1: Ground resolution for orbit heights above Earth of 350 km (left) and 1,000 km (left).

Because of the low ground resolution (Fig. 1) caused by the wide FOV the effects of deceleration on the meteor trails are regarded as insignificant and have not been included in this study. Several combinations of orbit heights and incidence angles of the meteor stream have been applied to simulate changing orbit conditions during the mission (Fig. 2).

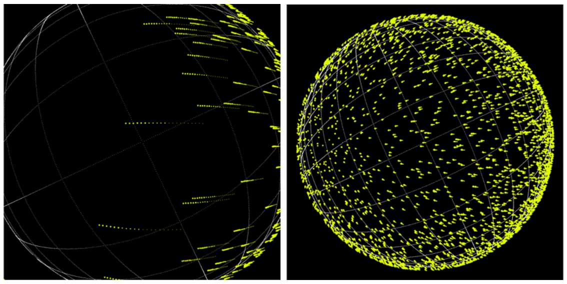

Figure 2: Meteor visualizations in the Martian atmosphere as seen by SPOSH from a height of 400 km with an incidence angle of 5° (left), resp. 1,000 km and 45° (right).

While higher orbit heights result in a much larger covered area (Table 1) and therefore the number of potentially detectable meteors increases, their length in the images decreases. This means a lower achievable accuracy with which individual trajectories can be determined. The incidence angle has a direct influence on the total amount of meteors seen in the image. Low incidence angles lead to a relatively low number of imaged meteors which on the other hand can be of exceptional length and quality.

Table 1: Coverages from different orbit heights

Planet	Orbit Height	Covered Area
Earth	350 km (ISS)	1,400,000 km²
Earth	400 km	1,900,000 km²
Earth	1,000 km	34,200,000 km²
Mars	300 km	1,200,000 km²
Mars	400 km	2,600,000 km²
Mars	1,000 km	16,300,000 km²

The distribution of meteors in the image is similar for every combination of incidence angle and orbit height with the vast majority (80-90%) of visible shooting stars appearing near the horizon.

4. Summary

We found the prospects of a spacecraft-based meteor search promising in terms of sky coverage and visibility of meteors in combination with a dedicated camera system such as SPOSH.

References

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