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Shock waves generated by meteoroids impacting the Earth's atmosphere: An up-to-date state of knowledge in the field

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Abstract

Shock waves and the associated phenomena generated by strongly ablating meteoroids in the lower transitional flow regime of the Earth's atmosphere are of great interest to the scientific community, yet remain the least explored aspect of meteor science. Here, we discuss a comprehensive review covering meteor generated shock waves in the atmosphere.

1. Background and Motivation

The problem of shock waves generated by meteoroids as they interact with the Earth's atmosphere at hypersonic speeds is of great interest to the scientific community, especially from the perspective of planetary defense. The spectacular impact and subsequent airburst of the Chelyabinsk bolide in 2013 served as a sober reminder of the destructive potential of extraterrestrial bodies. While certain subdisciplines of meteor science have been receiving a great deal of attention and are well represented in literature (e.g. optical and radar observations, orbit analyses, meteorite falls), the problem of shock waves has been largely neglected. In fact, a comprehensive and up-to-date re-source encapsulating the advancements in meteor physics, in particular the shock wave phenomena associated with the meteoroid impacts into the Earth's atmosphere has been lacking until now. Much of the knowledge gained over the decades has been scattered through time, space, and disciplines. For example, some early works on hyper-sonic flows applicable to meteors remain in the domain of "grey" literature (thus are easy to fall into obscurity), while more recent developments in re-entry remain in the realm of the rarefied gas dynamics and hypersonic flow communities with little to no cross-over to meteor science. We present the up-to-date and comprehensive review of meteor generated shock waves in the Earth's atmosphere with the aim to build a go-to resource for anyone interested in the meteor phenomena.
The review paper, currently in press in Advances in Space Research [1], presents the following topics in great depth:

- Meteoroid entry, the Knudsen number, and flow regimes;
- Hydrodynamic shielding and implications for the formation of shock waves;
- A detailed description and review of meteor generated shock waves.
- To fully encapsulate the field of meteor generated shock waves, we also discuss the related topics of interest to the scientific community interested in meteor generated shock waves:
- Analytical and modeling approaches;
- Airbursts and the NEO threat;
- Radar and infrasound observations.

2. Summary

We present a detailed review of meteor generated shock waves in the Earth's atmosphere with the aim to provide an up-to-date state of the field and a comprehensive resource for anyone interested in studying the phenomena associated with meteor generated shock waves. While meteor science might be considered a mature science, we suggest that there is much more work to be done and many important scientific questions to be answered.
Some of these questions are:

- Resolving the altitudes where cm-sized meteoroids generate shock waves as a function of velocity, size and composition;
- Understanding the physico-chemical aspects of meteor shock wave phenomena in the near and far field ambient atmosphere around the meteor and its physico-chemical impact on the mesosphere and lower thermosphere (MLT);
- Development of the methods for meteor shock wave detection at the altitudes where they form;
- Understanding the risks and further constraining the lower boundary of sizes, compositions and velocities of large objects that create shock waves in the lower atmosphere and pose a potential hazard;
- Understanding the hazards of meteor generated shock waves and their effects in the mesosphere and lower thermosphere (MLT) region of the atmosphere to future frequent space travel.

We encourage the members of scientific community to embark on deciphering these and many other interesting questions that remain to be answered.

References

[1] Silber E. A. et al. (2018) Advances in Space Research. doi: 10.1016/j.asr.2018.05.010. Review paper.