Ph.D. proposal

Title : Sound propagation near the surface of planetary atmospheres

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The study of acoustic wave propagation in extraterrestrial atmospheres is a rapidly advancing research field. Acoustic techniques offer a valuable means of probing planetary environments, providing insights into atmospheric composition, temperature, winds, density, pressure, and potentially planetary interiors.

The first acoustic signals from another planet were recorded on Venus by the Venera 13 and Venera 14 missions. These measurements were used to estimate near-surface wind speeds. Titan was the second planetary body where acoustic data were obtained. The Huygens probe, which landed in 2005, measured sound speed along with pressure and temperature, enabling estimation of methane concentration in Titan's nitrogen-rich atmosphere.
The upcoming Dragonfly mission, scheduled for the 2030s, will carry microphones designed to further characterize Titan's atmosphere through acoustic observations.

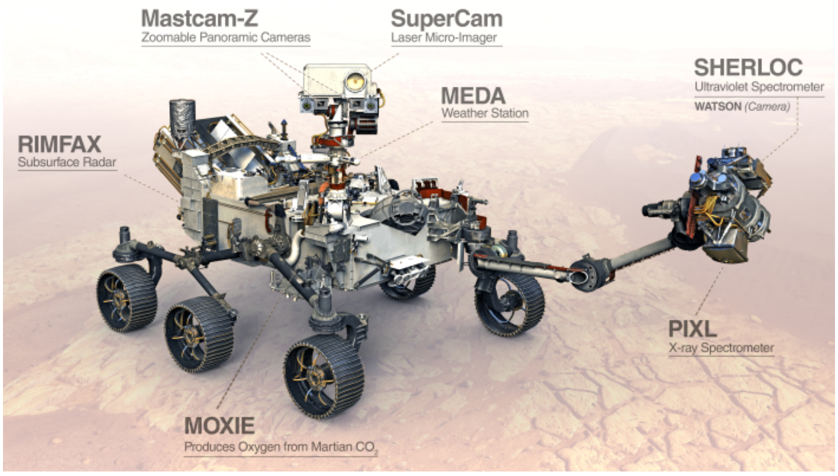

Figure 1: *Perseverance* and the *SuperCam* instrument

More recently, the Perseverance rover, which landed on Mars in 2021, recorded the planet's first audio signals using the microphone embedded in the SuperCam instrument (Figure 1). These data have been used to study atmospheric turbulence and acoustic attenuation caused by the vibrational relaxation of CO_2.
Accurately characterizing the fluid dynamic properties of a planetary atmosphere, such as wind velocity, density, temperature, pressure, and chemical composition, via acoustic methods requires a thorough understanding of sound propagation in

complex, inhomogeneous, and turbulent media. These atmospheric conditions give rise to phenomena such as reflection, refraction, diffraction, scattering, and attenuation, all of which significantly influence wave propagation.

This Ph.D. project will focus on modeling acoustic wave propagation near the surface of planetary atmospheres. The relevant frequency range is below 10 kHz, with propagation distances ranging from a few meters up to several kilometers. The candidate will develop a wave equation that incorporates spatial and temporal atmospheric inhomogeneities and turbulence effects. Three-dimensional numerical simulations will then be performed to investigate the influence of turbulence and absorption on acoustic propagation. High-order finite difference and time integration schemes will be employed for this purpose. The simulation code will be implemented in C/C++ and parallelized using MPI and CUDA to efficiently utilize high-performance computing clusters equipped with CPUs and GPUs. This computational framework will enable scalable simulations for a broad range of planetary conditions.

References

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