APPLICATION OF HIGH POWER LASERS FOR A LABORATORY SIMULATION OF METEOR PLASMA

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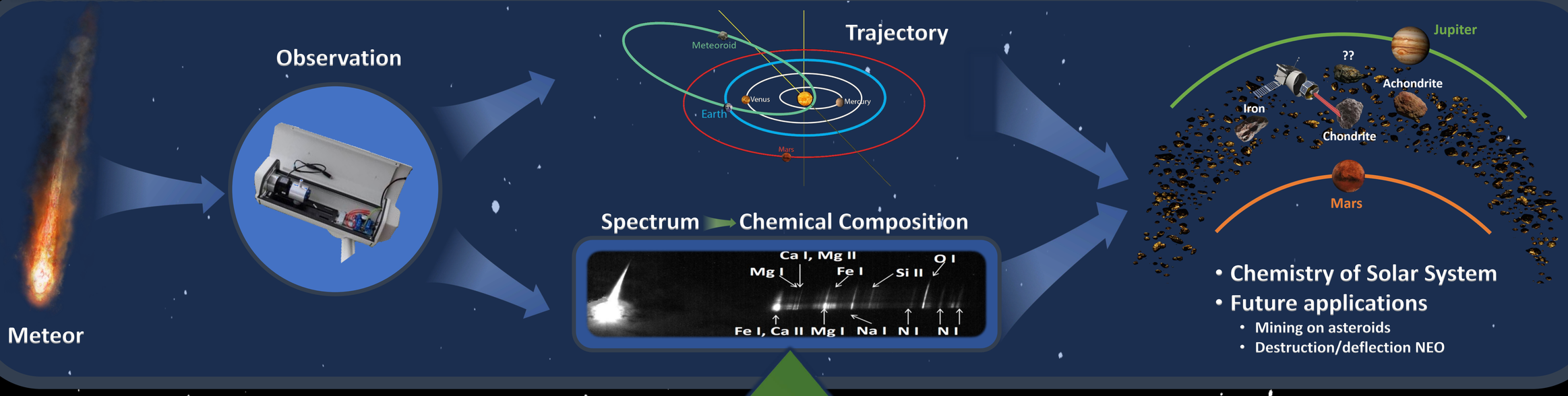
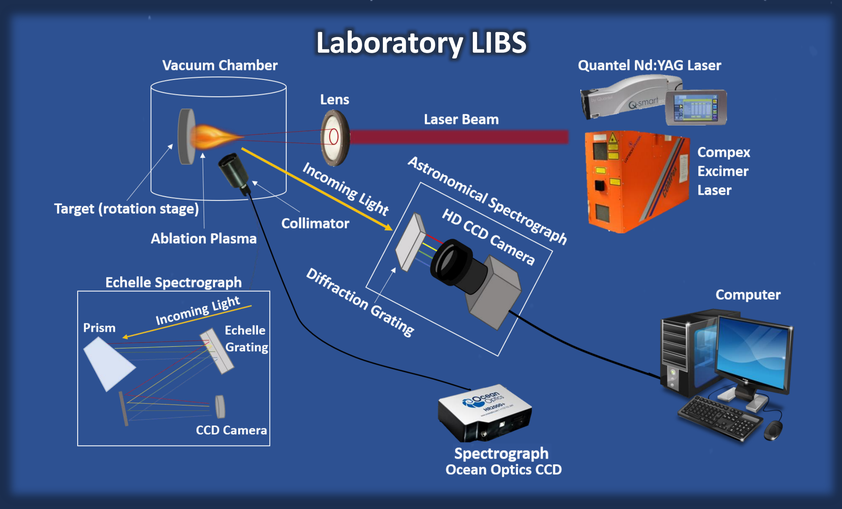
Abstract

Interpretation of meteor plasma dynamics, its spectra and the dominant spectral features is currently mostly provided by mathematical modelling. Our results show that synthetic spectra calculation is not the only method for such in-depth study of meteor spectra. Laboratory experiments can help with qualitative and quantitative evaluation of the observational data and assignment of important spectral features in meteor emission spectra. Plasma induced by high power lasers provides very suitable experimental approach for such purely laboratory simulation of meteor plasma. Importantly, target experiments with ablation of various real specimens of meteorites help to understand behavior of meteor plasma under strictly controlled laboratory conditions. We show that at least extrapolation of parameters is better than only theoretical simulation. In our study, we provide description, evaluation of advantages and also limitations of this new experimental approach based on laser ablation of real meteorite samples using a wide range of laser sources: Terawatt-class large laser infrastructure PALS, high power Ti:Sa femtosecond laser, laboratory Nd:YAG, ArF excimer laser and large diode pumped solid state laser infrastructure HiLASE.

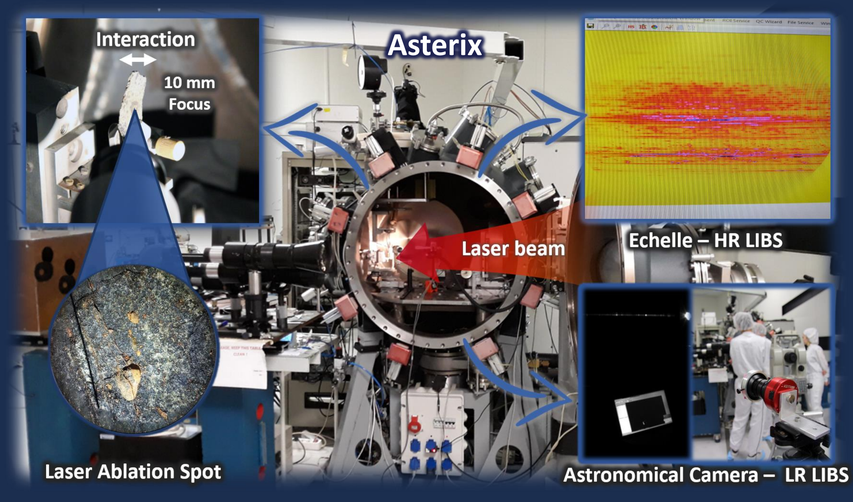
Motivation



Experiments – Multiple Laser Sources



- Meteoroid plasma was simulated in the laboratory under strictly defined conditions via the laser ablation of chondritic meteorite samples using several different lasers: ArF excimer laser, Nd:YAG laser, Ti:sapphire laser, and high-power terawatt-class iodine laser Asterix.
- The elements are evaporated together with the whole matrix, as well as during the meteoroid descent.
- High-resolution spectrum was measured using Echelle Spectrograph and the low-resolution spectrum was simultaneously obtained via an astronomical spectrograph.



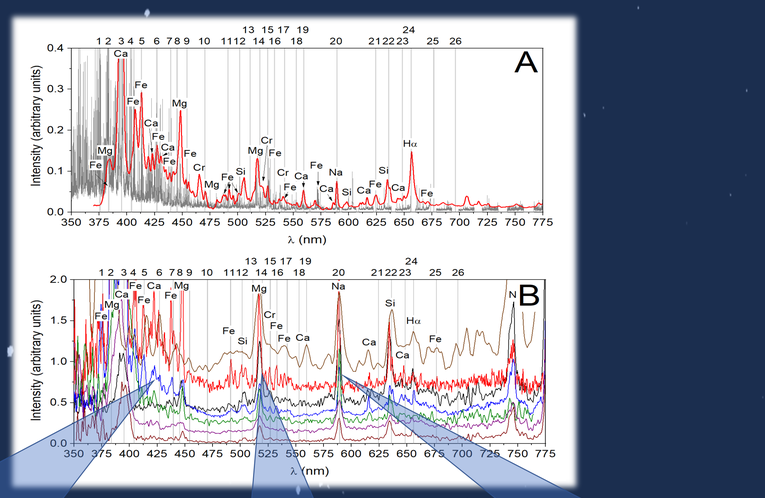
Results

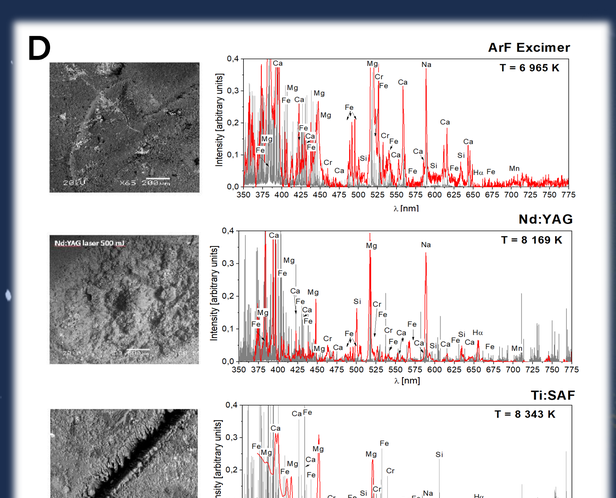
Panel A: High-resolution (gray) together with the low-resolution (red) experimental spectrum obtained using terawatt-class laser Asterix.

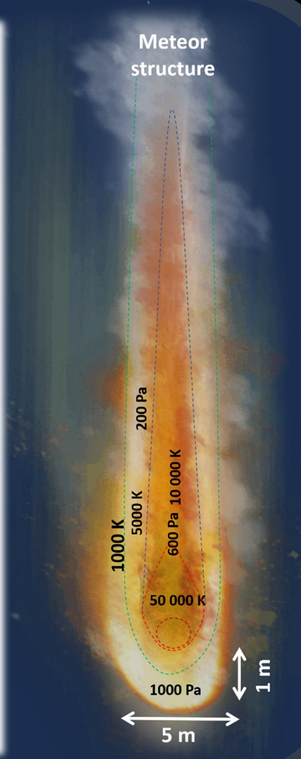
Panel B: Examples of spectra recorded by observational spectographs.

Panel C: Exapmles of spectral features. The upper part of the figures shows the synthetic spectra calculated under diferent temperatures: blue shows 4000 K, green shows 7000 K, and red shows 10000 K. The lower part shows the high-resolution emission spectrum of the meteorite laser ablation plasma.

Panel D: High-resolution (gray) and low-resolution (red) spectra measured using four different lasers together with laser ablation spots and a diagram of the meteor structure.







Conclusion

- It can be estimated, that laser shot delivers energy comparable with penetration of m-size body through the atmosphere.
- We show that ablation using large terawatt-class lasers approaches several conditions in meteor plasma and therefore, this kind of simulations is really worth of study.
- Power lasers are also very promising for possible future applications in the area of astronomy and astronautics, such as minig on asteroids or destruction/deflection of potentially dangerous near-Earth object (NEO).

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