Simulation of the Chicxulub fireball impact with an intense laser pulse and spectroscopic characterization

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An asteroid impacted the Yucatan carbonate platform in the Southern Gulf of Mexico about 66 million years ago. The resulting ejecta and fireball introduced massive amounts of gas and dust into the atmosphere causing major global environmental effects that led to Cretaceous-Paleogene (K-Pg) mass extinctions. We simulate the asteroid impact by laser ablation of target sediments recovered from the Yaxcopoil-1 drillhole in the Chicxulub impact crater [1]. The ablation experiment was performed under a reconstructed K-Pg atmosphere composed of 0.16 % CO_2, 30% O_2, and 69.84% N_2 at 1 bar. The initial propagation velocities of the shockwave and fireball were 4.5(± 0.1) km s^{-1} and 2.3(±0.4) km s^{-1}, respectively measured by shadowgraphy. The fireball slowed down to a constant subsonic of 290(±40) m s^{-1} after 20 µs. The temperature and electron density of the Chicxulub fireball were determined using neutral calcium emission lines. Time-resolved spectroscopic analyses from the laser-induced plumes were carried out using experimental and synthetic spectra. The vapor plumes had similar temperatures (≥7800 K) at 1 µs and their spectra showed similar emissions. The highest temperature and electron density were $1.0(\pm4.2)\times10^4$ K at 0.2 µs and $2.9(\pm0.4)\times10^{17}$ cm^{-3} at 0.4 µs, respectively. These values rapidly decreased during adiabatic expansion and then remained constant at $3.2(\pm0.5)\times10^3$ K and $0.7(\pm0.1)\times10^{17}$ cm^{-3} at 4.0 µs. Knowledge of the fireball's temperature is critical to predict the phases and mixing ratios of the chemical species present in the Chicxulub fireball.

[1] Karina F. Navarro, Jaime Urrutia-Fucugauchi, Mayo Villagran-Muniz, Citlali Sánchez-Aké, Ligia Perez-Cruz, and Rafael Navarro-González, Emission spectra of a simulated Chicxulub impact-vapor plume at the Cretaceous–Paleogene boundary, Icarus, Vol. 346 (2020). 113813, https://doi.org/10.1016/j.icarus.2020.113813