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Drop impact on thin film: mixing, thickness variations and ejections

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Stalagmites of all shapes and sizes (Fig. 1 (a)) grow on the floor of caves by precipitation of calcium ions. These ions are found in the residual water film covering the top of the stalagmite, which is progressively drained away at the same time. Drops dripping from stalactites ensure the renewal of these ions and of the liquid film. Over short timescales, the distribution of calcium ions, which dictates subsequent stalagmite growth rate and morphology, is affected by the way drops impact this film.

The residual film thickness δ varies in time and space in response to both drop impacts and drainage. It is of the order of $[50, 500]$ μm thus $\delta/R \lesssim 0.2$, where $R \simeq 2.6$ mm is the drop radius [1]. Cave ceiling heights sometimes reach several tens of meters, yielding impacting drop velocities to range in $[1, 10]$ m/s. High velocity drop impacts on very thin, miscible films have been described in [2,3]. They are mostly characterized by i) prompt splash accompanied by a large amount of secondary droplet ejections before and during the jetting phase, ii) a crown inclined at a small angle with the horizontal, developing and fragmenting in a similar manner as on a dry wall, iii) a retraction phase (Fig. 1 (b)). The latter is not similar to that of impacts on a dry wall and does not yield the formation of a large Worthington jet as for drop impacts on a deep bath either.

The retraction phase is at the very heart of the film thickness variability post-impact. We investigate how this film thickness is affected, as well as how would ions be redistributed in the solution following the impact. We proceed by recording high-speed impacts on films of controlled thickness in a lab environment. By using two different colors for the drop and the film and applying a colorimetry technique (Fig. 1 (c)), we assess the mixing between the drop and the film. We also measure the film thickness δ right after impact in all points from the impact position up to the unperturbed free surface, and deduce how much liquid would be added following one impact. In a second time, we collect and take pictures of post-impact ejections in an area of radius 100 times larger than R (Fig. 1 (b)). Based on the same technique, we evaluate which ejected proportion comes from either the drop or the film. We finally relate all these parameters to the various regimes observable in situ.

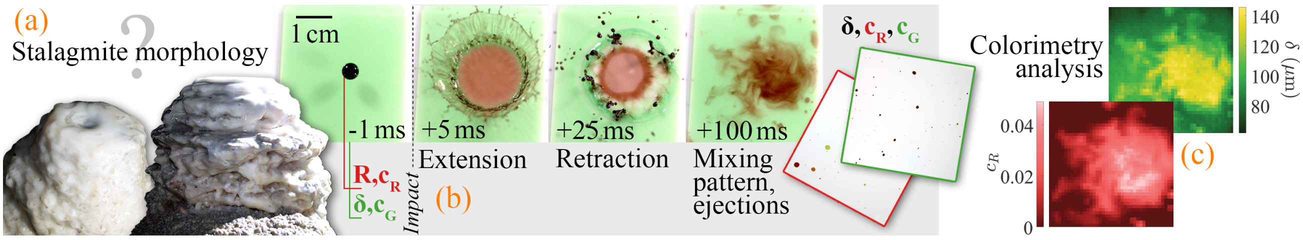

Figure 1: (a) Possible stalagmite shapes. (b) Time sequence of an impact showing the crown extension, the lamella retraction and the mixing pattern obtained ($R = 2.3$ mm, $\delta \simeq 100$ μm), along with two ejection patterns. (c) Measurements obtained for δ and the red dye concentration after impact, using colorimetry analysis.

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