The Advanced Photon Source
How to Make a Splash

High-energy x-rays from the Advanced Photon Source (APS) were utilized to penetrate the everyday mystery of a splash, revealing previously hidden structures and dynamics.

Working at the Argonne X-ray Science Division 32-ID beamline at the APS, researchers from the University of Michigan and Argonne used both optical and phase-contrast x-ray imaging to capture images of the impact of a drop of silicone oil falling into a deep pool of the same liquid. Different viscosities and drop velocities were used to examine their effects on splash behavior.

The manner in which splashes create and disperse miniscule droplets in their surroundings holds critical implications in many industrial applications and natural processes dependent upon the control of liquids, but the precise nature of the splash remains largely unknown, even after more than a century of careful experiment and observation. The major obstacle in understanding the physics of droplet splashing had been the difficulty of directly observing and recording the phenomenon in detail, due toshort time scales and extremely small size scales. In recent years, high-speed video imaging has largely resolved the problems of time and scale, but the internal structure of the droplet and splash eluded observation.

The rough outlines of the splash inner structure have been known for some time. When a drop impacts the surface of a liquid pool, a sheet-like jet called the lamella spreads outward immediately, followed by the break-up of its leading edge into a secondary halo of droplets. But recent work, including mathematical modeling by Weiss and Yarin in 1999 showed that the splash is even more complex. The lamella is actually preceded by an ejecta sheet of even finer droplets that emerges from the "neck" area between the drop and the pool surface, as verified experimentally by Thoroddsen in 2002.

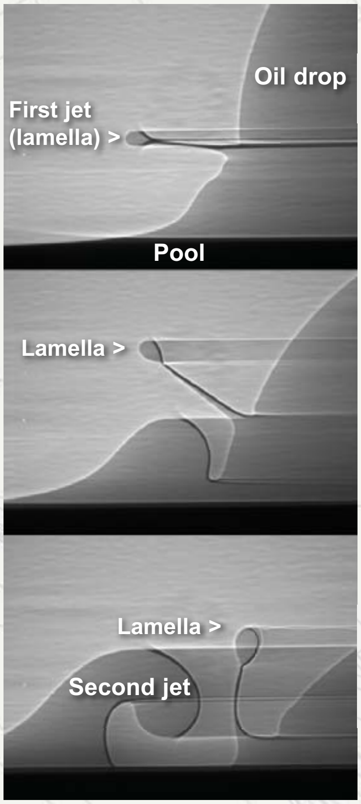
One of the main objectives of the current experiment was to identify the role of this ejecta sheet and determine how to distinguish it from the lamella. Conventional wisdom had it that there is a single jet (the lamella). But what the work at the APS revealed is that there are really two distinct jets, and that when one of them is observed, it is actually because the two of them have merged.

The experimenters found that the dynamic behavior of the splash is largely dependent upon the Reynolds number (involving fluid viscosity) and the Weber number (surface tension), dimensionless numbers that express ratios rather than exact units. After observing splashes over a wide range of Reynolds and Weber numbers, the team developed a phase diagram showing four basic regimes: (1) the drop simply merges with the fluid and forms capillary waves; (2) a single jet appears; (3) the ejecta sheet forms followed by a thicker lamella; and (4) the ejecta sheet and lamella form, but the ejecta sheet disintegrates into microdroplets.

This work confirms definitively that the splash consists of two distinct jets, but that the structural dynamics are strongly dependent upon the various parameters involved, with a continuous jet at low Reynolds numbers and two distinct jets at higher Reynolds values.

The next experimental vista for the team involves considering how additional parameters affect the splash behavior, such as the surrounding air pressure, which Sidney Nagel's group at the University of Chicago showed affected splashing from drop impact on a dry surface. The team also wants to understand how the size and number of the liquid jets are determined.

— *Mark Wolverton*



X-ray images of a splash formed by the impact of a drop on a deep pool of the same liquid, illustrating the formation of two jets. The round structure visible in the upper panel is a segment of the drop. The black band at the bottom of each image is the pool in which the x-rays are completely absorbed. The images are at 270, 440, and 620 μm after impact.

See: L. V. Zhang[1], J. Toole[1‡], K. Fezzaa[2], and R. D. Deegan[1*], "Evolution of the ejecta sheet from the impact of a drop with a deep pool," J. Fluid Mech. **690**, 5 (2012). ***Author affiliations:*** [1]University of Michigan, [2]Argonne National Laboratory. [‡]Present address: MIT

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Call for APS General-User Proposals

The Advanced Photon Source is open to experimenters who can benefit from the facility's high-brightness hard x-ray beams.

General-user proposals for beam time during Run 2013-1 are due by Friday, October 26, 2012.

Information on access to beam time at the APS is at http://www.aps.anl.gov/Users/apply_for_beamtime.html or contact Dr. Dennis Mills, DMM@aps.anl.gov, 630/252-5680.

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