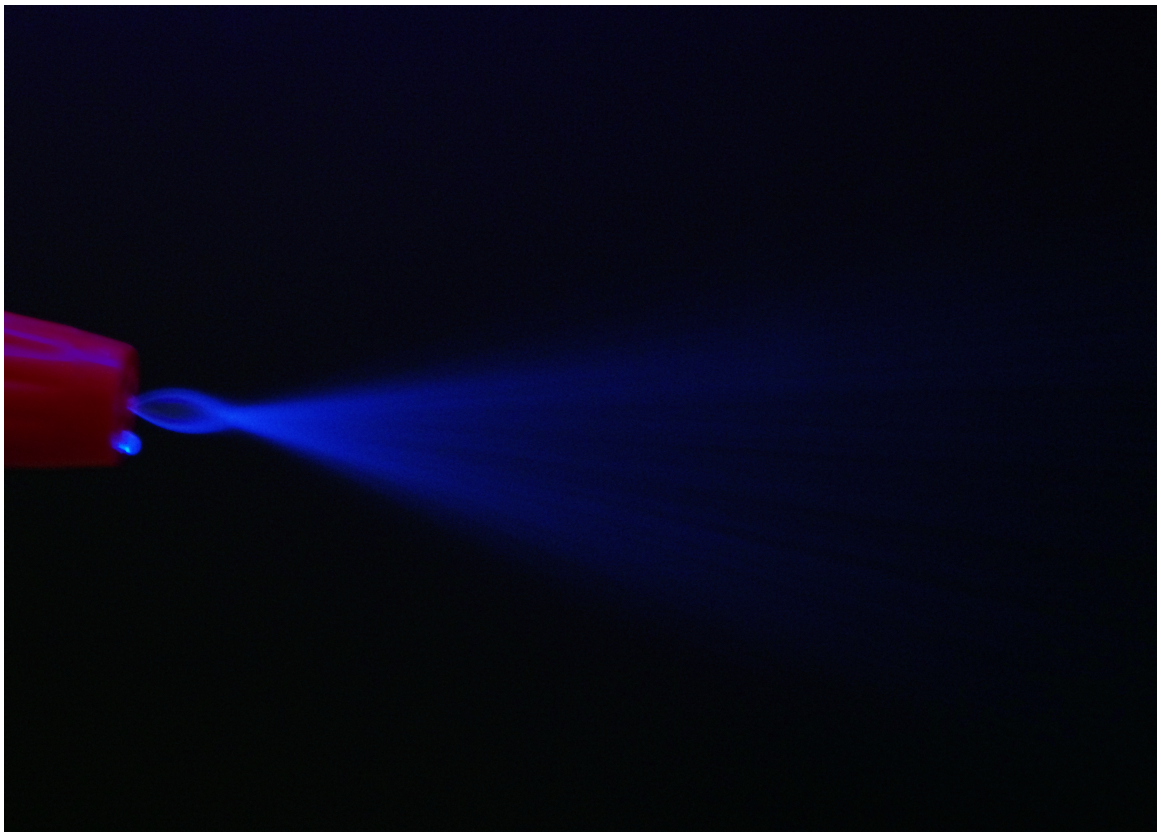
# Third Group Project

## Flow Visualization: The Art and Physics of Fluid Flow



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The associated image was taken for the third group project during the Spring 2013 semester of the Flow Visualization course. This image captures the flow coming out of a generic spray bottle on the mist setting. The image was captured in the ITLL media shack in the basement of the ITLL building on the CU campus. The team used a generic spray bottle, flat tonic water, a plastic Tupperware container and a black-light. The helpful teammates in the creation of this image were: Thomas Pohlman and James Shefchik.

This project used a generic household spray bottle to create the associated swirling annular two-phase jet[1]. A diagram of the spray bottle nozzle and the jet flow can be seen in Figure 1 below. As the user pushes on the spray bottle handle (not shown), the handle activates a spring-loaded piston that pumps the fluid from the container up and out of the container. The fluid then exits the pump head and passes through a small opening in the adjustable nozzle (about 0.5 mm). The nozzle distance from the exit of the pump can be adjusted. If the nozzle is screwed down all of the way, there is no gap between the nozzle and the pump exit, creating a swirling jet that does not break up into small water droplets. The project captures flow from when the nozzle was unscrewed and spaced a small distance away from the pump head, which activates the misting feature of the spray bottle. The fluid exiting the pump head impacts the nozzle at the small nozzle opening while swirling about its trajectory. After the nozzle opening, the swirling fluid moves around an air cavity assumed to be less than atmospheric pressure. The atmospheric pressure outside of the jet has a greater pressure than the pressure inside the air cavity. Therefore, the swirling jet is deformed by the greater exterior pressure and impacts the fluid from the opposite side of the cavity. When the fluid concentrates at the unstable point, the fluid begins to break up and create the intended mist. A separate example of the jet breaking up can be seen in Figure 2.

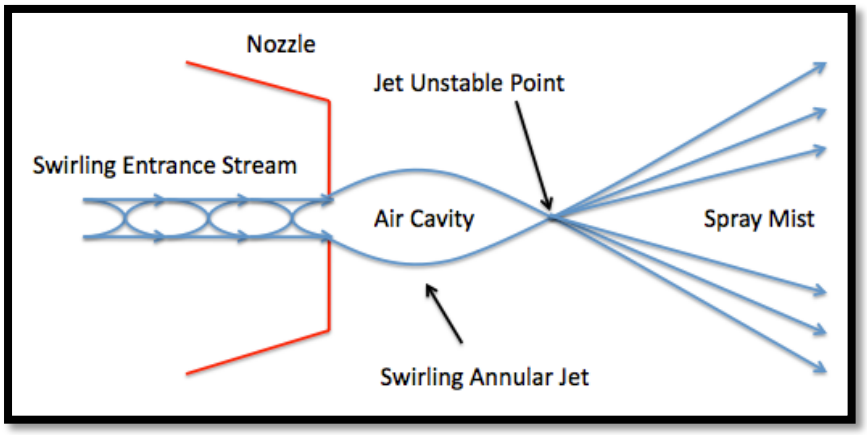


Figure 1: Diagram of flow in the swirling annular jet


Figure 2: Up close image of jet near misting spray bottle nozzle[2]

The fluid velocity was not directly measured. During the 1/6th of a second exposure time, the fluid is assumed to have moved across the 3-inch (72.2 mm) field of view. The viscosity of the fluid is assumed to be that of water (1.004 E-6 $m^2/s$). The Reynolds number calculation for the jet leaving the nozzle is calculated below. A Reynolds number of 9 implies that the flow is laminar as it exits the nozzle.

$$Re = \frac{UD}{\upsilon} = \frac{(\frac{3mm}{\frac{1}{6}s})(0.5mm)(1E-6\frac{m}{mm})}{1.004 * 10^{-6}\frac{m^2}{s}} \approx 9$$

The project used some basic visualization techniques. Tonic water is known to glow a fluorescent blue under black-light due to the quinine in the fluid, which is the bittering agent in tonic water. Tonic water is a common carbonated drink that can be purchased at any supermarket, gas station or liquor store. The spray bottle was purchased from McGuckin's hardware and can vary between a stream and a misting spray. The spray setting creates the interesting flow for the associated image. The team used a black-light borrowed from Professor Hertzberg and a basic 50W filament bulb found in the media shack. The filament bulb was pointed at a wall and used as background lighting. Without the background light, the camera would not have been able to pick up enough light to see the flow very well. The single-bulb, hand-held halogen black-light was placed as lose to the fluid stream as possible without coming into the field of view. The black-light was placed above and behind the flow from the perspective of the camera.

The field of view in the image is approximately 3 inches across. In the original image (see Figure 3), some fingertips can be seen for perspective. I would have liked to make the field of view closer to 3/4 of an inch, but the macro lens we were using was not taking in enough light to create an acceptable image. The camera was approximately 6 inches from the fluid flow. This distance permitted the best focus on the fluid while capturing enough detail on the exit of the stream. The lens used had a focal length of 55 mm with a capable range of 18 mm to 55 mm. The camera used was a Pentax K-5 DSLR camera. The original image width was 4928 pixels and the height was 3264 pixels at 300 pixels per inch. The image exposure specs were: a shutter speed of 1/6 of a second, an aperture of f/7.1 and an ISO rating of ISO 3200. The shutter speed required some initial experimentation. Ultimately, the 1/6 of a second helped to capture enough light to define the outline of the flow. However, the long shutter speed created a streaking capture of the flow and did not allow for enough detail to be captured. The original intention was to have a short shutter speed that captured individual droplets of tonic water. The compromise on the shutter speed allowed for an artistic image to still be captured. In Photoshop, the fingertips and bottle handle were cropped out, the RGB contrast was increased, the

blue contrast was increased, the level of blue light was increased and the level of red light was decreased. The use of levels allowed for the blue fluid to be emphasized and the red nozzle to be de-emphasized.

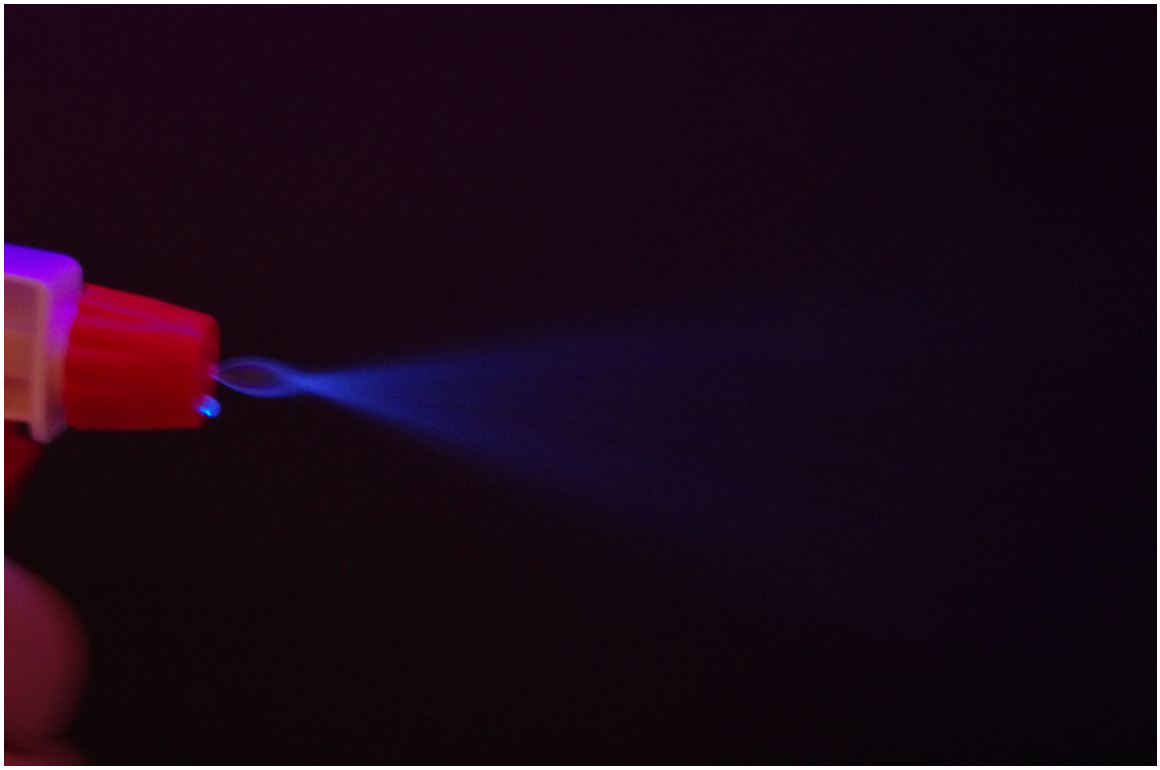

Figure 3: Original image that includes the fingertips and spray bottle handle

The image reveals a beautiful detail about the flow at the exit of a spray bottle on the misting setting. The tonic water under black-light creates a great contrast to the dark background and allows the viewer to clearly see what is happening in a pleasing manner. The physics are pretty well shown. However, some better detail as to the individual water droplets could be beneficial to understanding what is happening inside of the water cavity. I would like to improve the perspective from the camera to not be purely a side-view, but instead include aspects of head on and side view of the exit flow. I would like to play with more powerful lighting and use a macro lens to capture this effect.

[1] Siamas, George A., Xi Jiang, and Luiz C. Wrobel. "Numerical investigation of a perturbed swirling annular two-phase jet." *International Journal of Heat and Fluid Flow*. 30.3 (2009): 481-493. Web. 30 Apr. 2013. <http://journals2.scholarsportal.info/details.xqy?uri=/0142727x/v30i0003/481_nioapsatj.xml>.

[2] http://www.shutterstock.com/pic-1355903/stock-photo-stop-action-shot-of-water-coming-out-of-a-spray-bottle.html