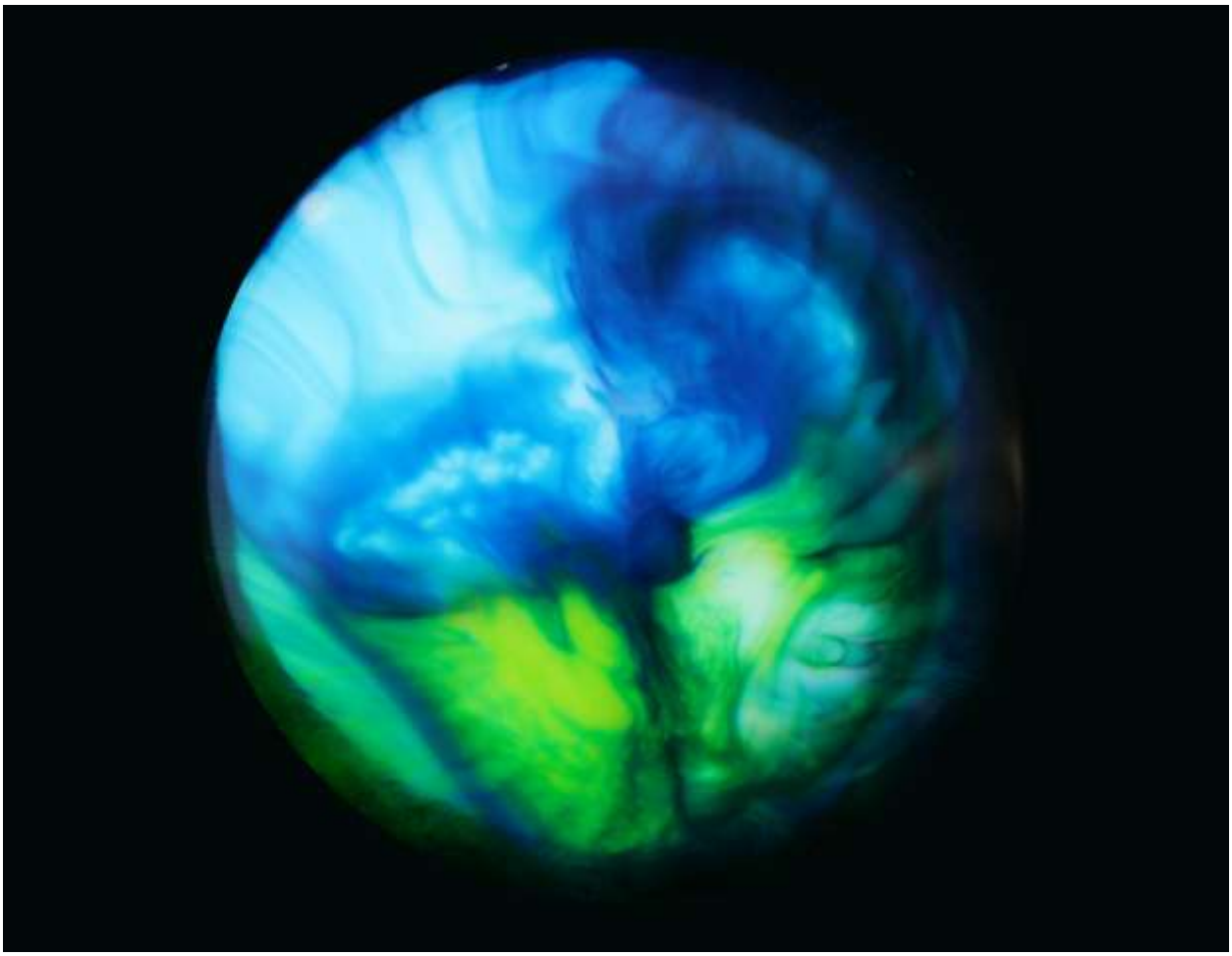
Surfactant Induced Flow of Food Coloring and Milk



Cory Fuhrmeister

Flow Visualization, Get Wet

February, 2011

The goal of this flow visualization was to capture the colorful fluid motion of food dye on top of milk created by the addition of a soap surfactant. This idea originated from a demonstration seen on the F-Yeah Fluid Dynamics website (HouseholdHacker, 2011).

The schematic in Figure 1 shows the setup of the fluid visualization. This was performed in a circular Pyrex dish approximately 5 inches in diameter and one and half inches deep. Milk was poured into the dish to a depth of a quarter on an inch. Six drops of both green and blue food coloring were added on top of the milk and allowed to settle for several seconds. Next, two drops of soap were added to initiate fluid motion.

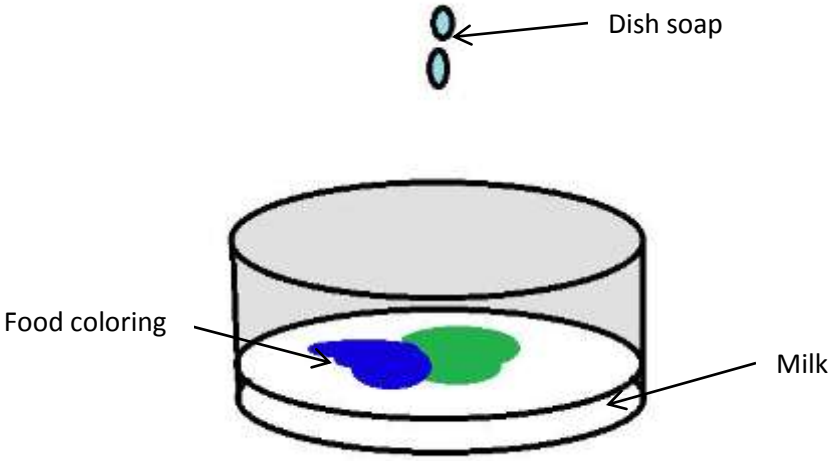


Figure 1: Setup

The series of photos below show the progression of the surfactant driven flow.

Figure 2: Food coloring on top of milk

After adding soap, the food coloring jets away from the center creating the flower-like pattern shown below. This image was taken about 2 seconds after adding the soap.

Figure 3: Flowering effect seen after the addition of the soap surfactant

The fluid continued to churn for about 40 seconds or more. During this time the food coloring revealed several different shapes and forms. The final image shown below was taken about 15 seconds after the addition of soap.

Figure 4: Final image un-cropped

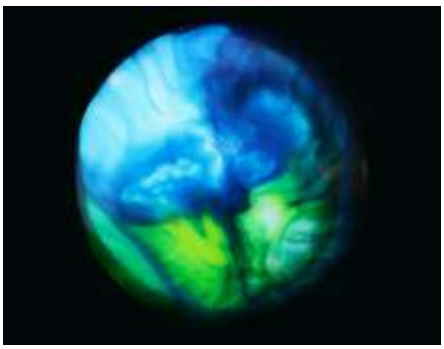


Figure 4: Final image cropped

So what's going on? The soap is acting as a surfactant which is any substance that lowers the surface tension of a liquid. Surface tension is a fluid property that holds a fluid together in the presence of an outside force. This phenomenon is what keeps water from overflowing from a glass when the fluid height is above the rim. When a surfactant is added to the mixture the surface tension of the milk and food coloring is reduced as cohesive bonds are broken

(Spangler, 2011). This causes the fluid to move erratically in a attempt to balance the surface tension. This initial motion causes further mixing of the soap, milk, and food coloring which creates more and more motion. The food coloring allows us to see what is happening as the fluids mix turbulently. The soap also breaks down fats in the milk as it mixes adding more randomness to the flow. Eventually, the fluid reaches equilibrium after about 40 sec.

The two tables below show the materials used and fluid properties (www.engineeringtoolbox.com). The maximum speed of the fluids was assumed to be 5 in. per second.

Table 1: Materials

Materials
King Scoopers 2% milk
Pyrex Dish 5in. Diameter
Kroger Neon Food Coloring
Seventh Generation Natural Dish Soap

Table 2: Fluid Properties

Material	Density ($kg/m^{3)}$	Kinematic Viscosity (m^2/s)	Surface Tension (N/m)	Re #
Milk	1030	1.12E-06	7.34E-02	5357.14
Food Coloring	1000	1.12E-06	7.34E-02	5357.14
Dish Soap	960	1.19E-03	6.33E-02	5.04

All photos shown were taken on Jan. 27th, 2011 in sunlight from an overcast sky. The following photographic settings were used on a Canon EOS Digital Rebel XS (Lens EF-S 18-55 mm 1:3.5-5.6 IS):

- No flash
- Shutter Priority
- Distance from lens to object: 45 mm
- Focal length: 47 mm
- Original image dimensions: 3888 X 2592 pixels
- Cropped image dimensions: 2985 X 2303 pixels
- Exposure: 1/125 sec.
- Aperture: f/5.6
- ISO: 400
- White balance: Auto

The image was cropped but no other adjustments were made to the original image.

The image reveals the randomness associated with turbulent flow and powerful forces that a surface tension instability can impose on a fluid. The physics of this flow are well demonstrated, however they provide only qualitative evidence of certain instances of fluid motion. I really like the atmospheric feel of the image and the cell-like structures that can be seen around the edges. I wish I could have eliminated the glossy reflection a bit and sharpened the focus at the center of the image a bit more. As I learn more about my camera I feel that I will be capable of improving this image to my satisfaction.

References

HouseholdHacker: *Scientific Tuesdays (2011),* http://fuckyeahfluiddynamics.tumblr.com/post/2531217529/in-this-video-the-householdhacker-heads-to-the

Steve Spangler Science: *Color Changing Milk* (2011), http://www,stevespanglerscience.com/experiment/00000066