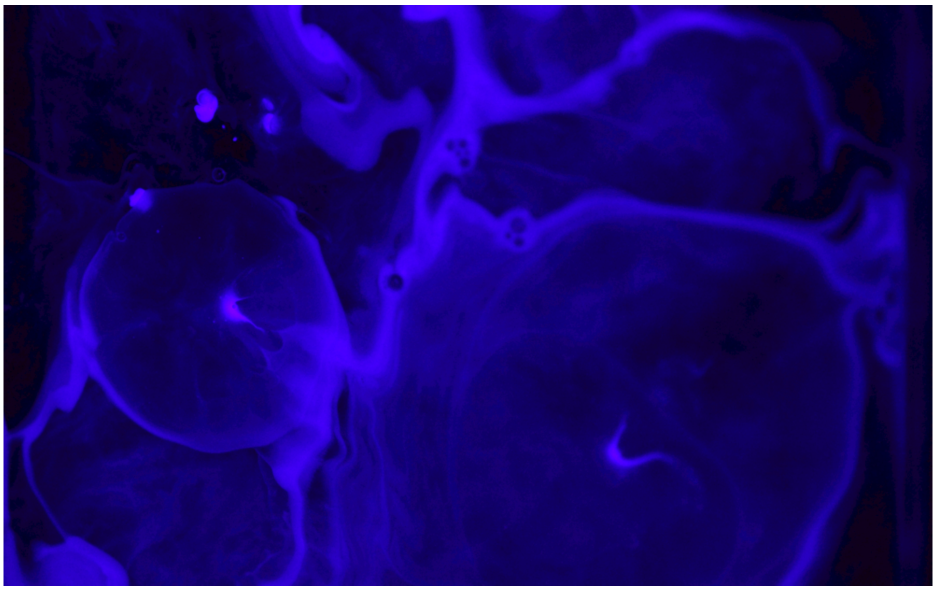
Blue Cosmos

Get Wet Image Report



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This report lists and describes the techniques performed to capture the photo *Blue Cosmos* as part of the "Get Wet" assignment. It also details the fluid phenomena captured in the photo and the relevant physics that explain such phenomena. The photo was one of several photographs captured during the project period, and it was found to be the most aesthetically-pleasing. It is successful in illustrating several flow phenomena. The image intends to display the dynamics of emulsions and surfactants on liquid interfaces of high surface tension. The photo was taken with help from my friend and fellow classmate, Shea Zmerzlikar, who provided the camera and blacklight for the experiment.

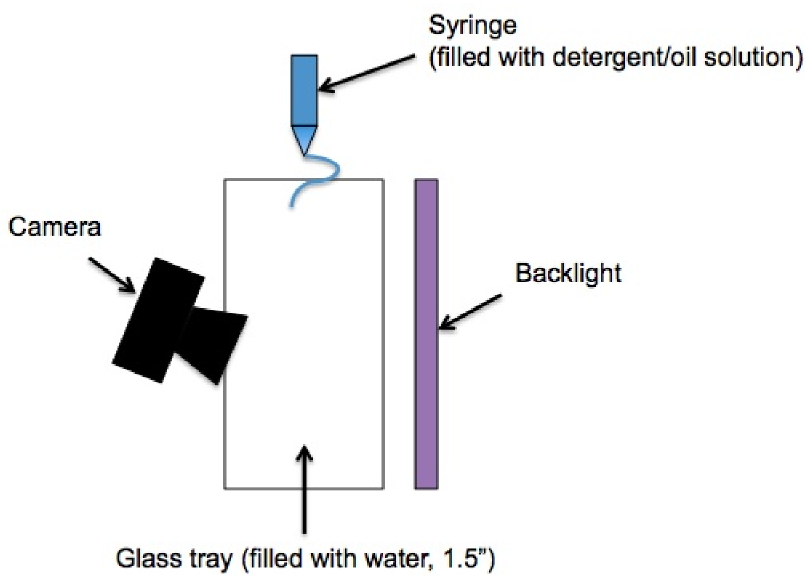

Figure 1: Schematic of Experimental Setup

The experimental setup is shown above in Figure 1. The photo was captured in a dark room under UV light. A 18" x 12" glass tray was filled with water to a depth of 1.5". A blacklight was positioned next to the tray and 1" above its rim. An emulsion of equal parts olive oil and laundry detergent was placed in a 10mL syringe. Droplets of the mixture were distributed at one end of the water tray. The emulsion was carried across the water's surface and several images were captured near the middle of the tray.

Substance	**Density** ($\frac{kg}{m^3}$)
Water	1,000
All Laundry Detergent	$\sim$ 885
Olive Oil	918-926

Table 1: Liquid Densities

The densities of the liquids used in this experiment are displayed Table 1. Assuming the volume of the mixture is proportional to its mass and that the proportionality constant is the same for the mixture, the density of the mixture is dependent on the densities of its individual components and their mass fractions.

$$\rho_n = \sum (x_i * \rho_i)_n \tag{1}$$

Since equal parts olive oil and detergent were mixed, equation 1 is simplified to:

$$\rho_n = 0.5(\bar{\rho}_{oil} + \rho_{det}) = 0.5(922 + 855)\frac{kg}{m^3}$$

$$\rho_n = 903.5\frac{kg}{m^3}$$

Thus, the addition of oil to the detergent yields a surfactant-containing emulsion with a density closer to that of water. Detergent was chosen for the emulsion because it is a surfactant, meaning it can lower the interfacial tension between two liquids. It should also be noted that detergent was also used because it contains fluorescein, which can be used as a fluorescent tracer under UV light. Thus, it allows for enhanced visualization of flow phenomena. Surfactants are amphiphilic compounds; they contain both a polar and non-polar parts. Therefore, they are partly water-soluble and partly water-insoluble. At the interface between oil and water, detergents interact with lipids by solubilizing their non-polar hydrocarbon tails. In doing so, the polar groups are forced outward into the surrounding water. This alignment of surfactants molecules at the interface modifies the surface tension between the oil-detergent emulsion and water[1].

Once dispersed on the water surface, the emulsion droplets are sheared and deformed. The interfacial tension between two low density difference liquids containing a surfactant results in "topological changes on the initially spherical drop, which deforms into an ellipsoid and orients respect to the flow direction"[3]. The once spherical drops spread across the water and the detergent from the mixture begins to experience coalescence as the drops are pulled and spread apart. This flow phenomenon is clearly depicted in the image. The calculation for interfacial tension, γ, of the system "relies on a density of states algorithm and the difference in free-energy between bulk and interfacial systems."[2] The calculation is shown in equation 2.

$$\gamma = \frac{F + pV - (\mu)N}{A} \tag{2}$$

where F is the Helmholtz free-energy, p is the pressure, V is the volume, μ is the chemical potential, N is the number of molecules, and A is the interfacial area of the system. The free energy if the system $F(T)$ requires iterative density of states calculations dependent on associated probability distributions.[2] The mathematics behind this phenomenon is quite involved and beyond the scope of this project. For further explanation of the physics behind this fluid flow, see [2].

The image was captured with a Canon 5D Mark II DSLR camera and Tamron 90mm macro lens. The area of field of view was 22.6mm x 15.2mm. The distance from the lens to the water surface was approximately 150mm. The exposure time was 1/500, with an F-stop of 2.8 and ISO of 1600. The focal length was 90mm. The original image was not altered with any post-processing software, such as Photoshop. My main photographic intent was to achieve a clear, focused image of the fluid flow with strong contrast. That was my main reason for utilizing a blacklight. I felt the image more than adequately displayed the flow phenomenon I intended to capture, and no computer contrasting was necessary.

I named the image *Blue Cosmos* because the colors and flow remind me of cosmic nebulae. In general, I am pleased with my final photograph. If I could change anything, it would be the overall focus of the image. The right half is slightly out of focus when compared to the left half. During photography, the emulsion was spreading across the surface so fast, several images had to be taken quickly in repetition to effectively capture the flow. This made it difficult to adjust the focus while the emulsion was moving. Despite this, I am extremely satisfied with my image. I feel it is effective in conveying both the beauty and physics of fluid flow.

References

[1] Bhardwaj, Anil and Hartland, Stanley. (1994). Dynamics of Emulsification and Demulsification of Water in Crude Oil Emulsions. *Industrial & Engineering Chemistry Research.*

[2] Jain, Tushar S. and de Pablo, Juan. (2003). Calculation of Interfacial Tension from Density States. *American Institute of Physics*,

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[4] Weast, R.C. CRC Handbook of Chemistry and Physics. (1989). Boca Raton: CRC Press, 3rd Edition.