Wilson Galaxy

Kristopher Tierney

MCEN 5151 – Flow Visualization

Group Assignment 3

4/29/2014

University of Colorado, Boulder

Introduction

Wilson Galaxy was created as the third and final team project for the Flow Visualization course. This project was not only used to again promote students to create and photograph more complex and intriguing fluid phenomena than they would on their own, but also as a final reinforcement in the importance of proper group dynamics in a team project setting. Unfortunately, due to the complications involved with scheduling experiments during the final weeks of senior design, the only group member that was able to participate in this experiment was William Derryberry, which is a little ironic given the team-building aspect of this project. The intent of *Wilson Galaxy* was to capture an image that shows a fluid phenomenon never investigated within the Flow Visualization course, which later evolved into a clear example of the Fibonacci ratio. This choice came from the Golden ratio being one of my personal favorite scientific-mathematical phenomena, naturally behind pi. This report will not only elaborate on the physics involved in *Wilson Galaxy*, but will also detail the setup of the experiment and the post processing of the image.

Description of Flow Physics

Wilson Galaxy is a clear example of a fluid dynamic phenomenon known as adhesion. Adhesion is the tendency of dissimilar particles to "stick", or adhere to one another. This is caused by a multitude of forces, including molecular Van der Waals forces, as well as chemical and mechanical adhesion[1]. In this experiment specifically, where water molecules are present, causing strong cohesion forces (the tendency of similar particles to "stick" together) to also play a large role, the polar water molecules are not only attracted to themselves, causing a layer of water to form a liquid film around the ball, but also are held to the tennis ball due to its layer of "hair". This hair provides a multitude of small pores for the water molecules to fill, and subsequently cling to other water particles around them, as well as the ball itself. These water molecules are separated when the tennis ball is spun, and the centripetal force caused by the angular velocity of the ball exceeds these adhesive and cohesive forces.

The most interesting physical phenomenon present in this image does not come from how the water is held to the surface of the tennis ball, however, but rather how the water behaves after it leaves the ball's surface. Although it is hard to recognize immediately without a specific interest in the phenomenon, the water leaving the tennis ball follows one of the most interesting ratios in the physical or mathematical worlds, the Fibonacci ratio. Also known as the Golden ratio, the Fibonacci ratio is one of the most surprisingly common ratios found in nature. Not only can it be used to predict the shapes of spirals, such as snail shells and curling waves, but it can be also found as the packing structure for many fruit and seed bearing plants, such as the seeds on a sunflower, or the ridges on a pineapple[2]. The Fibonacci ratio can be obtained by taking a number, and subsequently summing it with the number that preceded it. If the process is started with the number "1", the sequence becomes, "1, 1, 2, 3, 5, 8, 13, 21, 34, 55..."

When this is used to create a spiral using squares of side lengths defined by the sequence, the result is shown below in figure 1. Remarkably, it can be seen that the experimental spiral almost exactly conforms to its theoretical equivalent.

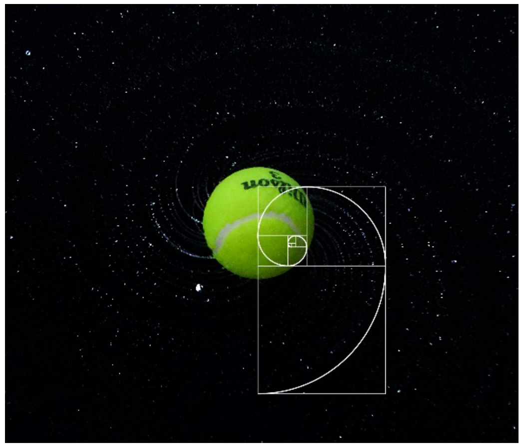

Figure 1: Fibonacci spiral comparison

Experimental Setup

To create *Wilson Galaxy* an exceedingly simple setup was used. First, a large, black sheet was laid on the ground to create a plain, dark background to contrast the light reflecting off the water droplets spiraling off the tennis ball. Next, the tennis ball was dipped in water and spun by hand to generate the angular velocity necessary to achieve large, clearly defined spirals. No external lighting was used other than the natural light of the sun, which provided the necessary brightness to achieve clear reflections within the water droplets. Due to the unpredictable nature of the experiment, the camera was held by hand without the aid of a tripod. This was to grant the camera greater ease of movement, to allow for close rage shots while simultaneously ensuring the camera was not repeatedly sprayed with water.

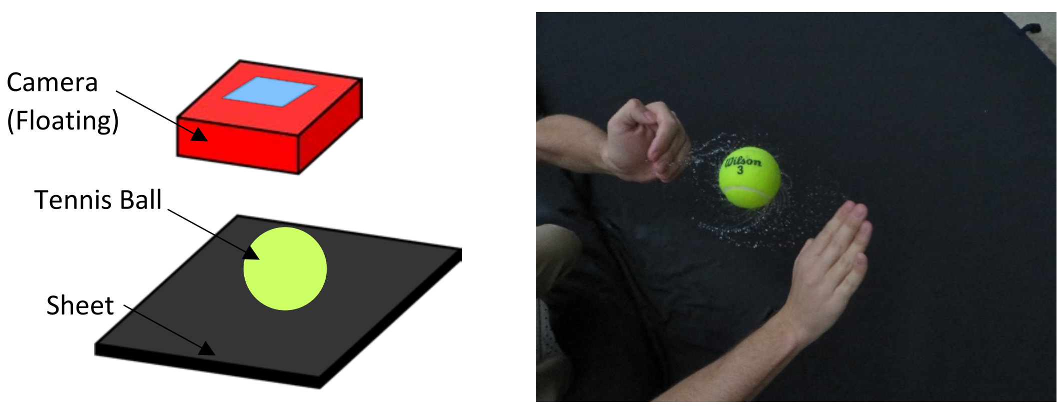

Figure 2: Animated experimental setup (Left), Realistic experimental setup (right)

Photographic Technique

To take the original JPEG image of *Wilson Galaxy* a 12.1 megapixel Canon PowerShot SX280 HS Digital Camera was used. As the camera is a simple "point and shoot", the default 4.5 - 90.0 mm focal length with 20x optical zoom and image stabilization lens was used. The camera, with lens extended, was held about 20 cm above the tennis ball to minimize the distance from the lens to the ball while also allowing the camera to remain a safe distance from the ring of water projected from the ball while it was spinning. The camera was then manually focused on the ball before each test, and adjusted using customized exposure specifications. Specifically, a fast shutter speed of 1/2500 seconds and an aperture of f/6.3 were used to ensure the capture of the quick flowing fluid with minimal motion blur. A large ISO of 1600 was also used to compliment this shutter speed and aperture size as ample light was present.

For the post processing of the image, Adobe Photoshop CS5 was used. First, the image was cropped from 4000 x 3000 pixels to 2358 x 2014 pixels. This was to reduce the field of view of the image from about 122 cm x 91 cm to around 72 cm x 61 cm, thus removing all the blank space from around the primary spiral of water around the ball. Then the sharpness, highlights and shadows, contrast, and color levels of the image were all adjusted to allow for more visible fluid flow, and a generally more appealing image. Although this process did remove some of the "stars" within the spirals of the ball, I believe the blackness of the background, and contrast of the image give the space-like feel of the image.

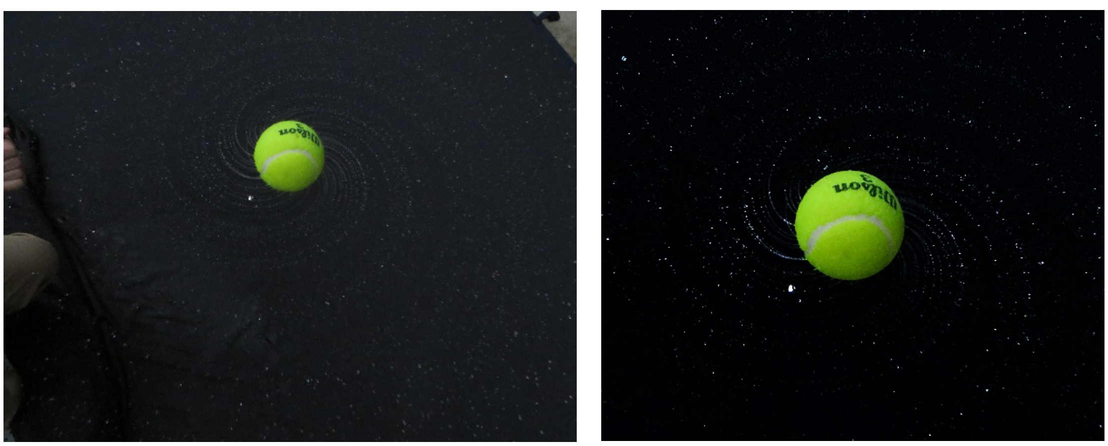

Figure 2: Pre-processed image (Left), Post-processed image (right)

Conclusion

Wilson Galaxy not only clearly displays the strong adhesive and cohesive forces present in water, but also clearly displays one of the most peculiar ratios known to science. Overall, there is little could be done to this image to make me happier with how it turned out. Not only do I love seeing examples of the Fibonacci ratio in nature, but I love the space-like feeling of the image. The one improvement I would make if I were to redo this experiment, would be to ensure it was done on a cloudless day. When this image was taken the sky was slightly overcast, which I feel provided less vibrant, shining “stars” within the galaxy structure.

References

[1] Wake, W. C. (1977). *Theories of Adhesion and Uses of Adhesives: a Review.* London, UK: The City University

[2] Mitchison, G. J. (1977). *Phyllotaxis and the Fibonacci Series*. *Science*, New Series, Vol. 196, No. 4287