Creating an Event Horizon Analogue using the Belousov-Zhabotinsky Reaction

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Black Holes

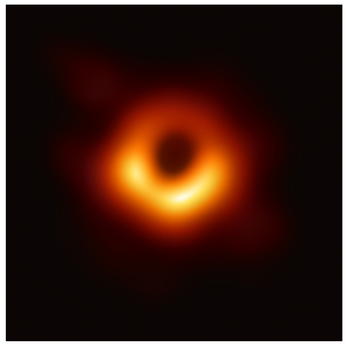


Figure 1: First picture taken of the M87 black hole. The glowing ring is the event horizon, the last place that light can escape. We want to model this by creating a standing wave. From [1].

Peristaltic Pump

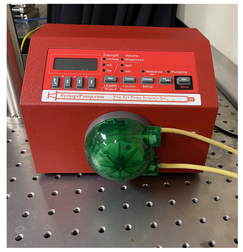


Figure 2: NE-9000G peristaltic pump with 4 roller green head attachment and a pumping range of (0.004 - 75.19) mL/min. This pump could give the flow rate needed (~0.1 ml/min).

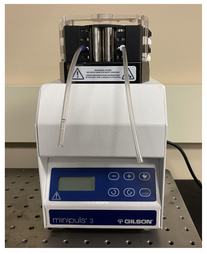


Figure 3: The Gilson Minipuls 3 with 10 rollers that can accommodate tubing of different diameters. This pump displays the rotations per minutes (RPM) that the roller mechanism rotates; therefore, it needs to be calibrated for tube diameter.

Belousov-Zhabotinsky (BZ) Reaction

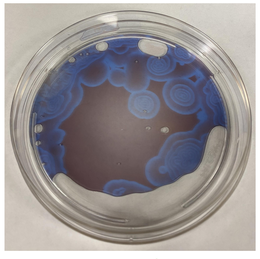


Figure 4: BZ waves and the perpendicular diffusion that changes concentration during wave propagation. The direction of the arrows represents where the diffusion is taking place and the length of the arrows represents the velocity in that region on the front. The area with the purple arrows is moving faster and diluting more than the area with the green arrows, which is moving slower compared to the red arrows at a region of κ=0.

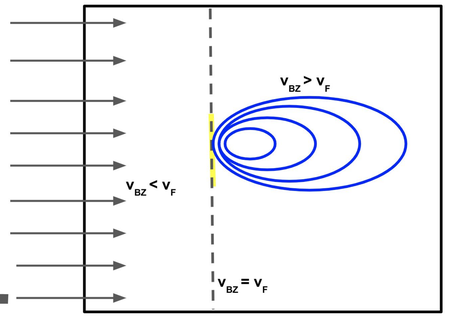


Figure 5: Theoretical BZ analogue horizon. At the dashed gray line, the velocity of the BZ solution (v_{BZ}) is equal to the velocity of the pumped fluid (v_F). A target pattern is created as a standing wave is formed along the yellow line to create the analogue. The fluid is pumped from the left while the BZ solution is moving to the right.

New Reaction Container

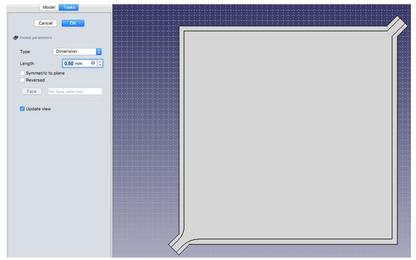


Figure 6: Old reaction container design by Sam Nash '19. Within the triangular shape, the depth is constant while the width is changing, which changes the velocity the pumped fluid. From [2].

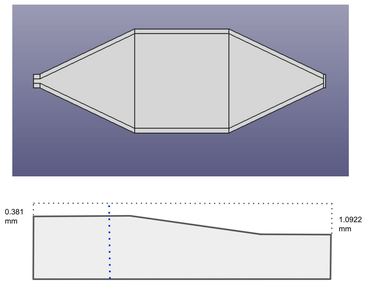


Figure 7: New reaction container with constant width and changing height. The velocity change should be slower in the constant height portion of the reaction container, making the event horizon easier to observe.

BZ Recipe

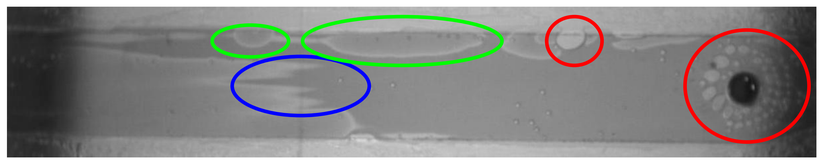


Figure 8: Different elements that we were trying to avoid when perfecting the BZ recipe. First it contains phase waves (blue oval), which can be identified because they usually move fast and disrupt excitation waves (green ovals). There are also air bubbles (red circles) around the hole used to fill the container with BZ reaction. This is an indication that this recipe cannot glide smoothly over the container. Image size: (137 x 30) mm^2

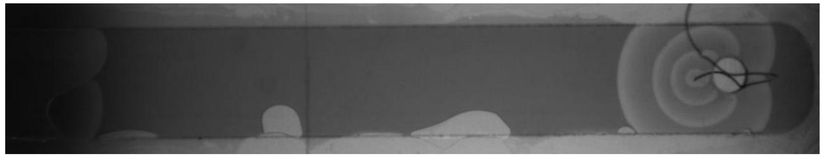


Figure 9: This recipe is much less excitable, so only creates waves when the silver wire is inserted, or air inhibits the system. The production of waves is much easier to control with this recipe, and we used this recipe for the rest of our experimentation. This recipe easily creates the target pattern we look to use for the analogue. Image size: (137 x 30) mm^2

Results

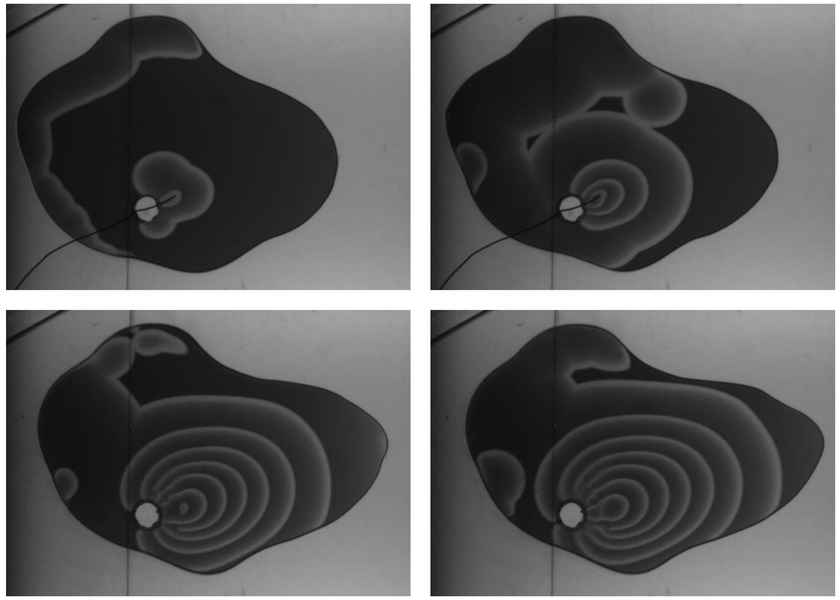
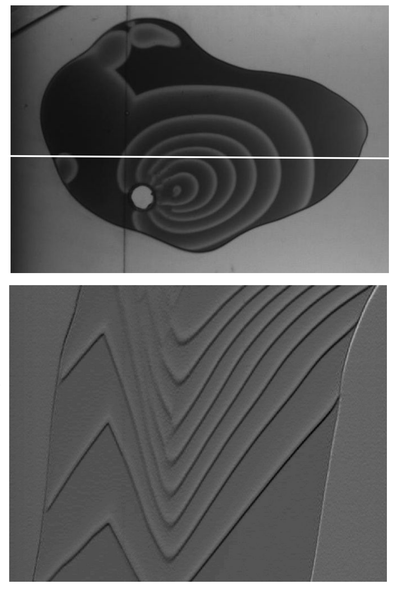


Figure 10: BZ-Air Test. We pump air at 0.65 rpm, which should produce a flow rate to exactly oppose the BZ waves at a depth of (0.8 - 0.9) mm. These images were taken 100 s, 300 s, and 400 s after the first frame in the top right. Image size: (65 x 46) mm^2.

Figure 11: Time space plot of the BZ-Air Test. We are looking for the distance between the lines on one side to lengthen to indicate the wavelength between wave fronts is increasing.. The white strip indicates the region from the data that the time space plots was made from. In the time space plot, x=65.8 mm and t=505 s. Strip photo image size: (65 x 46) mm^2.



References

[1] The Event Horizon Telescope Collaboration. First M87 Event Horizon Telescope Results. I. The Shadow of the Supermassive Black Hole.*The Astrophysical Journal Letters*, 875(1), April 2019.

[2] Sam Nash. *Using Belousov-Zhabotinsky Waves as an Analogue to the Event Horizon of a Black Hole.* Bachelor Thesis, The College of Wooster, Wooster, OH, USA, 2019

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