

Vortex Ring

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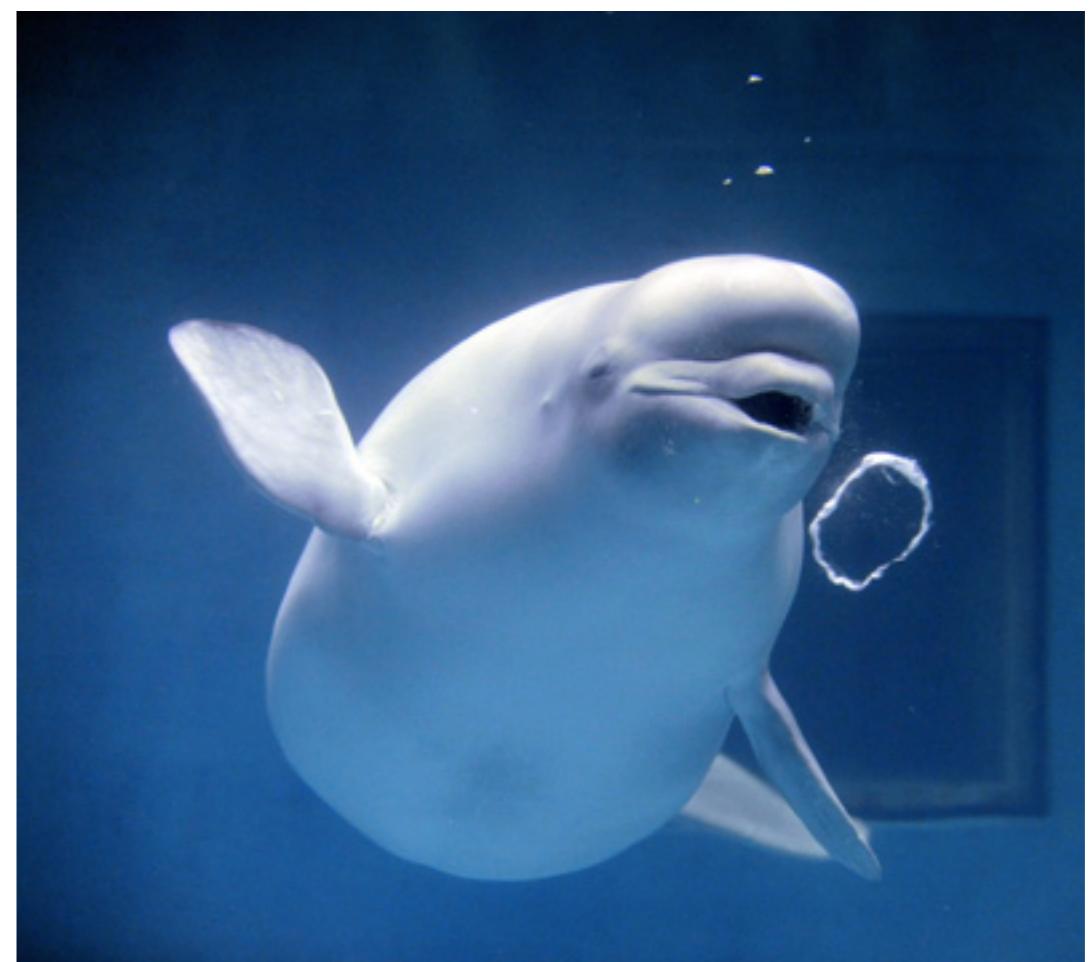
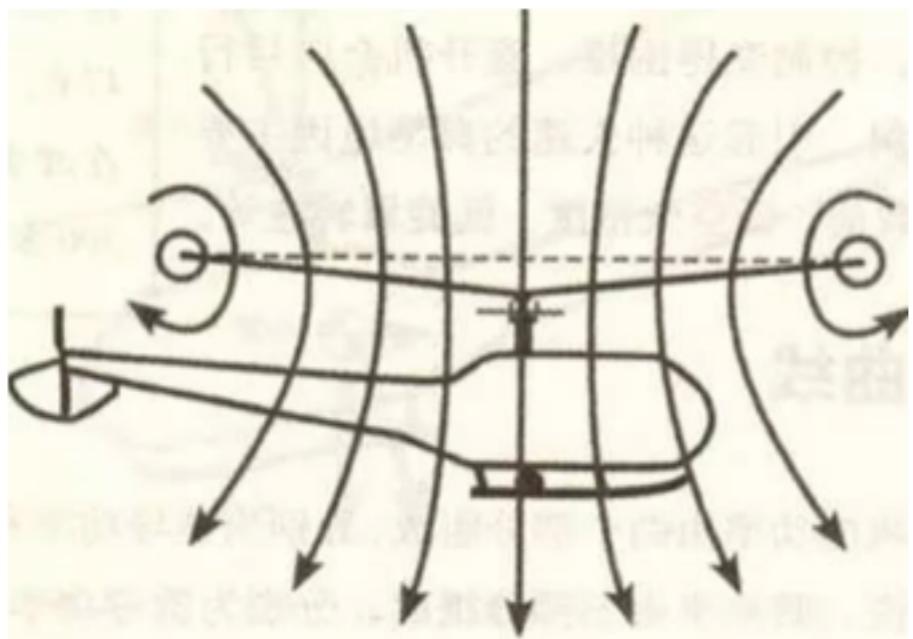
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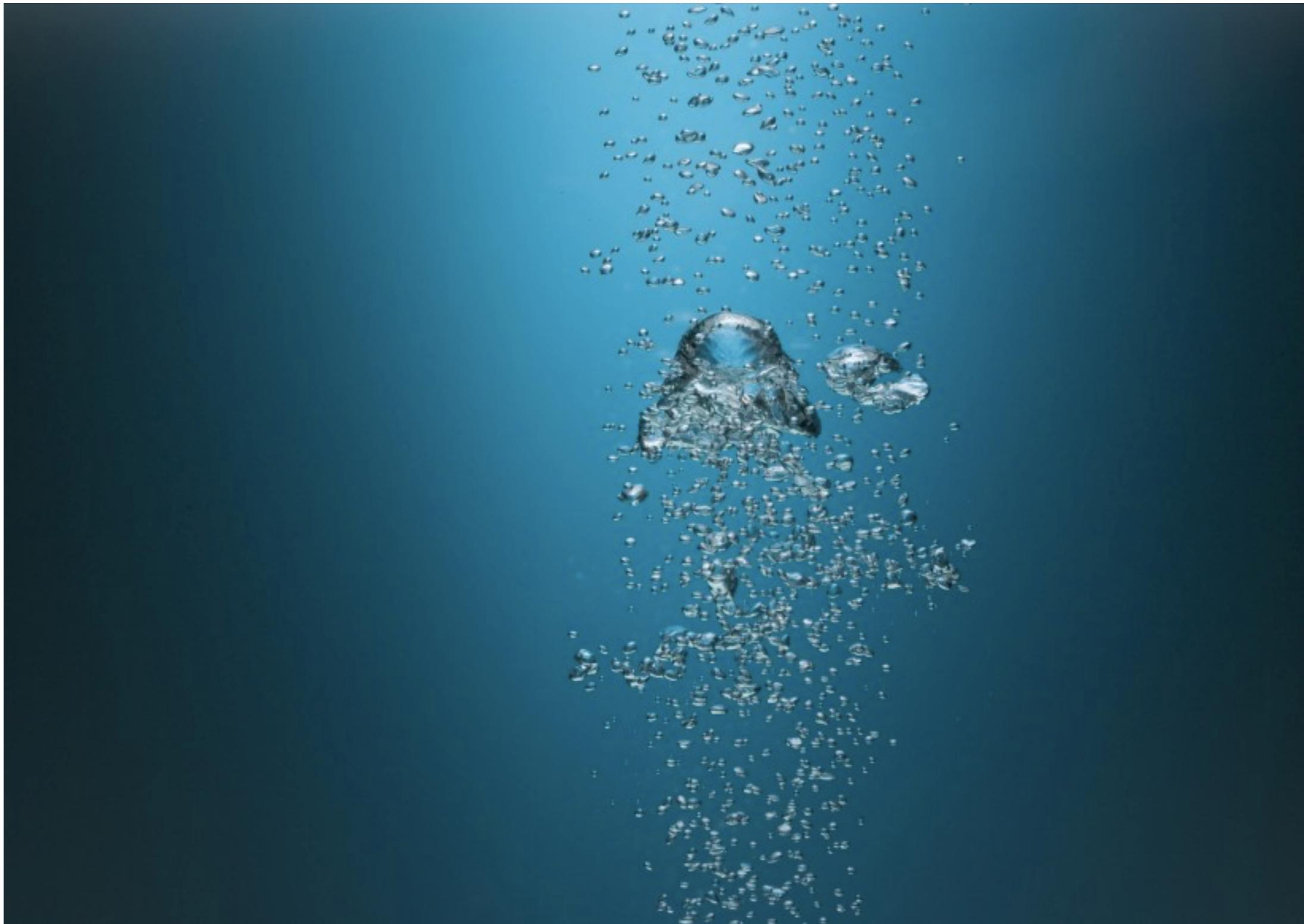
Motivation

Motivation

Some dolphin and other cetaceans (e.g. whales and porpoises) would produce their bubble rings to playing. Bubble ring would drift to the surface and gradual expansion or disintegration. We are interested in the motion of bubble ring.



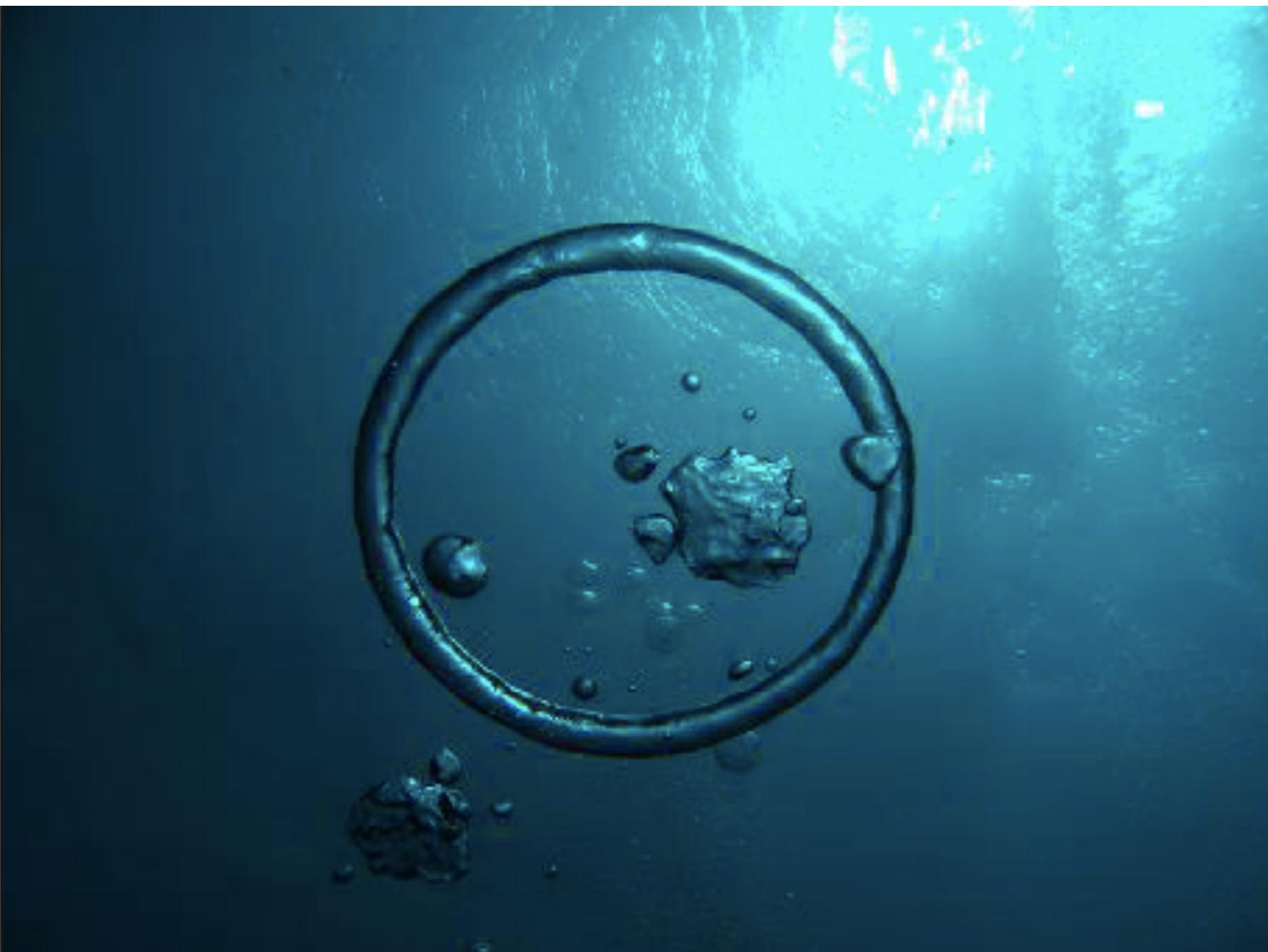
Introduction of Bubble Ring



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Introduction of Bubble Ring



Introduction of Bubble Ring



How can we produce a bubble ring?

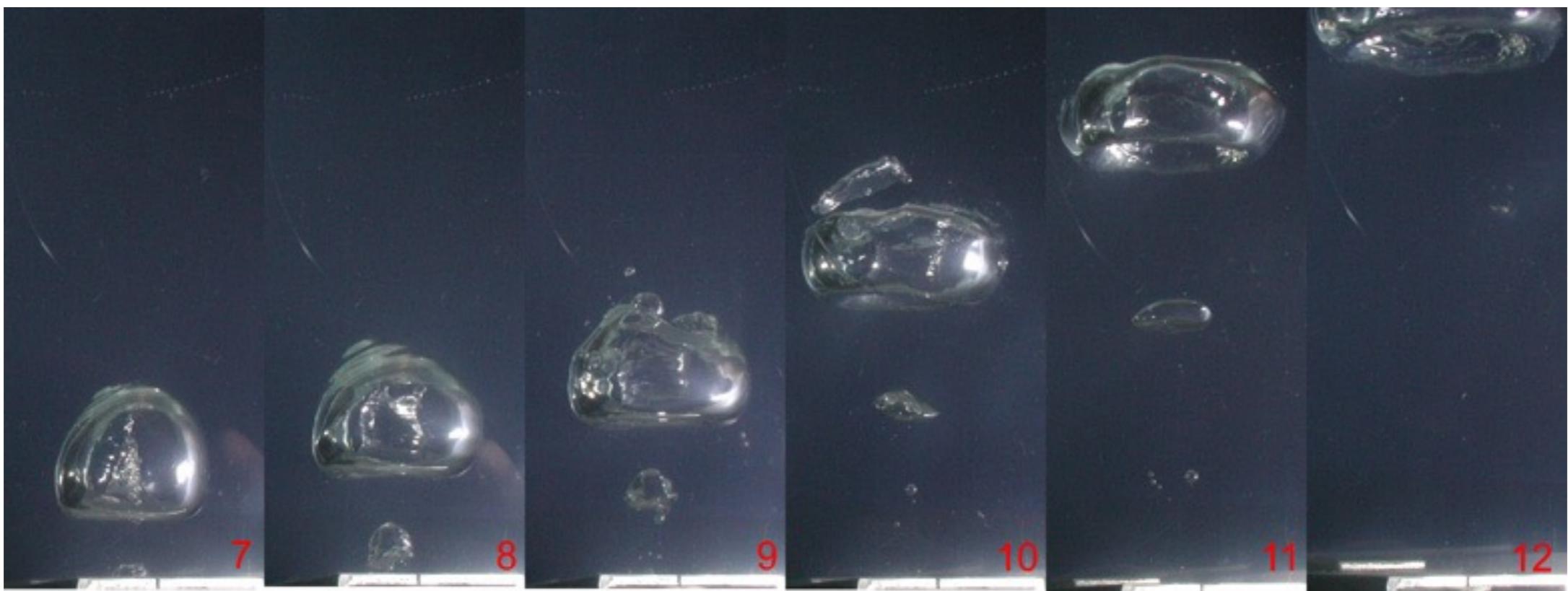


Producing the vortex ring

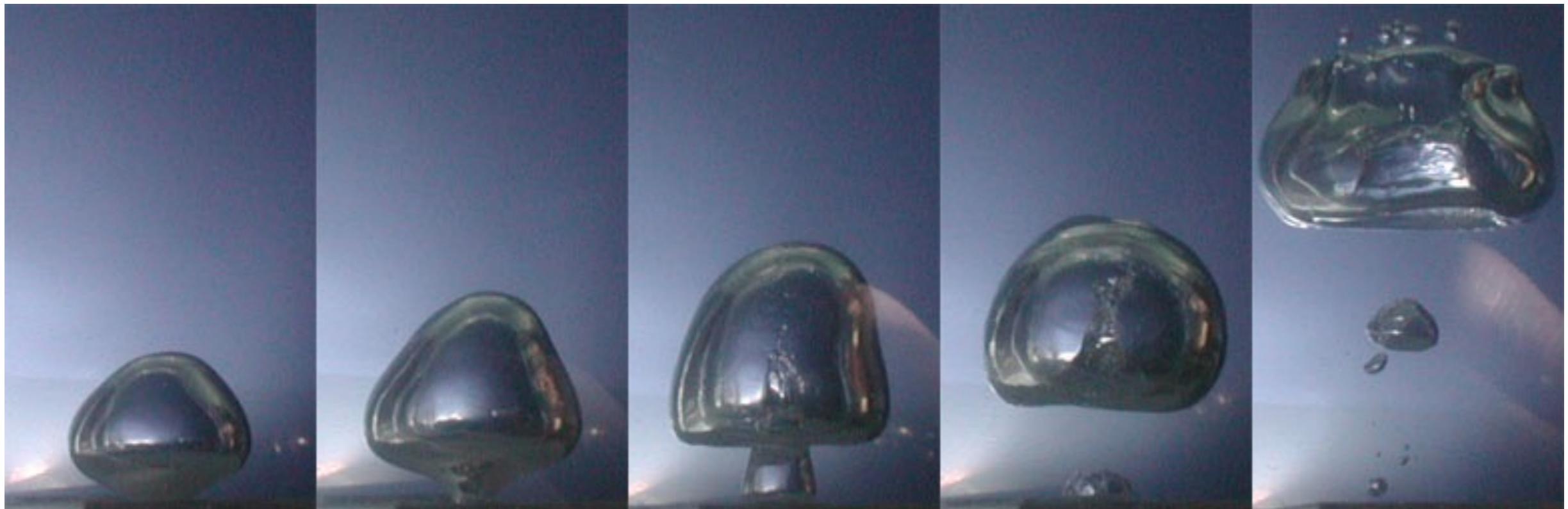
- Bubbles don't naturally turn into rings, it could be produced by
 1. letting air escape through an orifice that is opened and closed abruptly.
 2. letting a fixed amount of air escape through an orifice that is permanently opened.
 3. Dolphins can also create bubble rings by blowing air in a water vortex ring.



How Bubble Rings Form



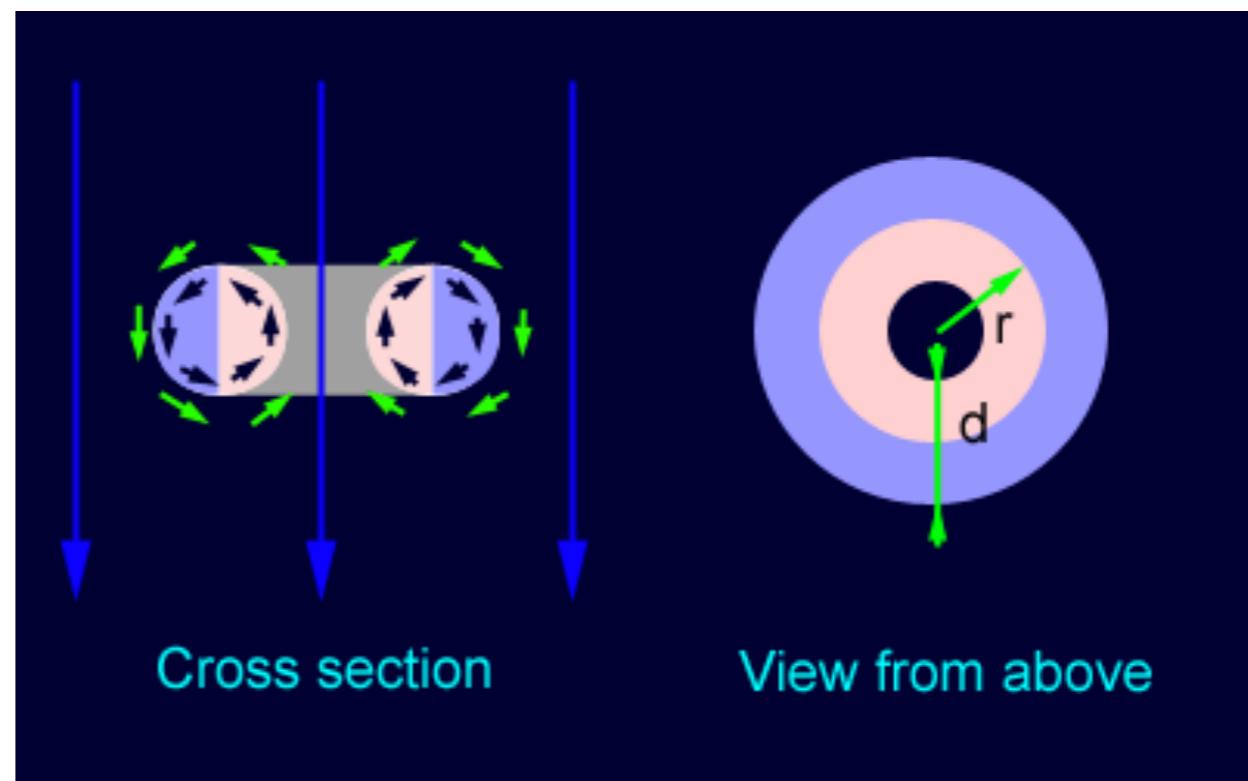
How Bubble Rings Form



Why Bubble Rings are Stable

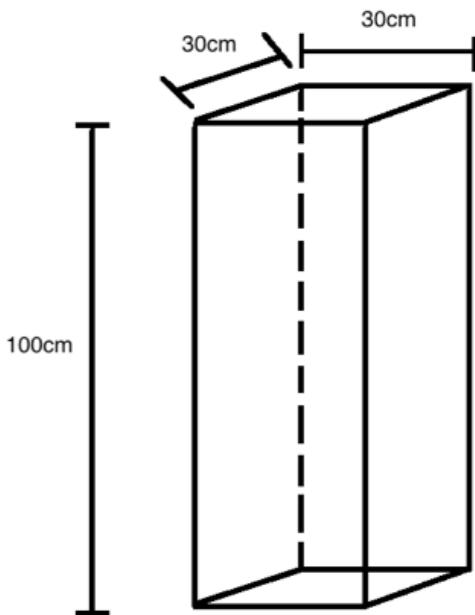
- The ring starts to float, thus creating a flow field
- The effect of the flow field drag force depends on the surface area
- The net effect makes the bubble start to rotate

$$p = \rho g h$$



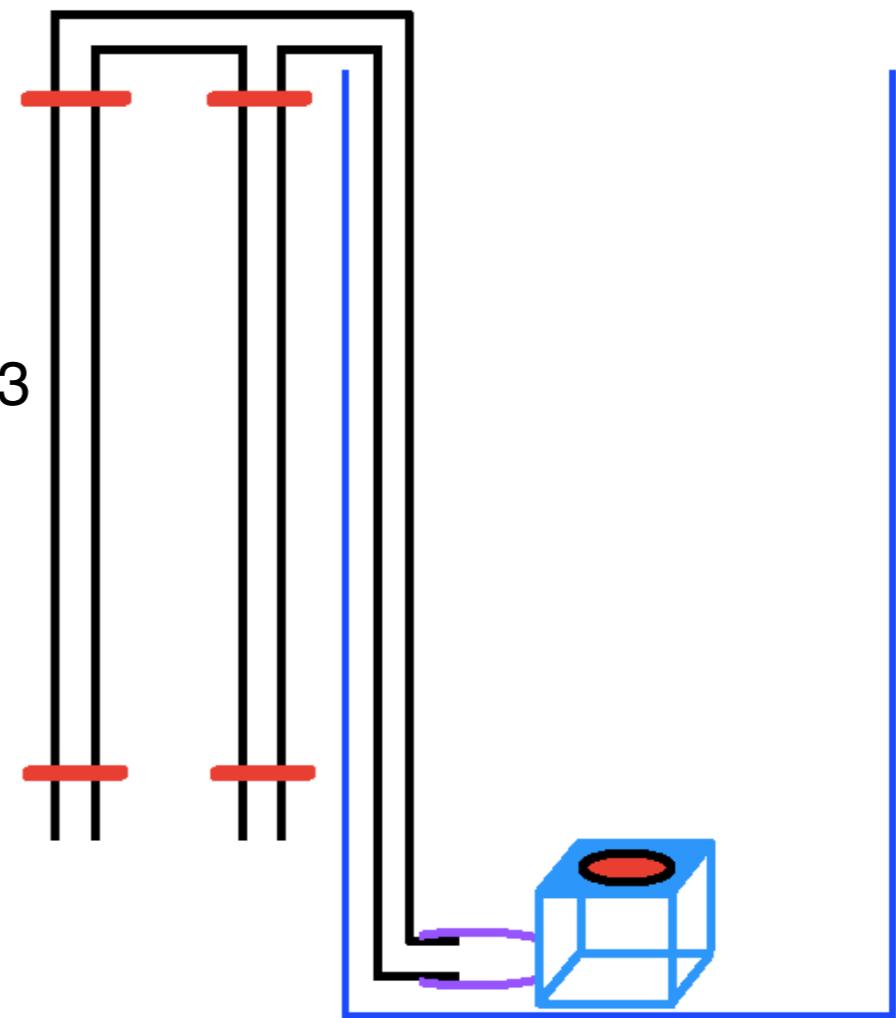
Experimental Setup

- Acrylic tank ($30 \times 30 \times 100$)cm 3
- A inflator
- High speed camera with 300 pics per second
- The brass and four valves
- The hose
- Porous Aluminum block ($5.5 \times 3.2 \times 12.1$)cm 3



$$R = \sqrt[3]{\frac{3R_0^2 L}{4\gamma}}$$

$$R = \sqrt[3]{\frac{3R_0^2 L}{4\gamma}} = \sqrt[3]{\frac{3 \times 0.01^2 \times 0.45}{4}} = 0.0334$$



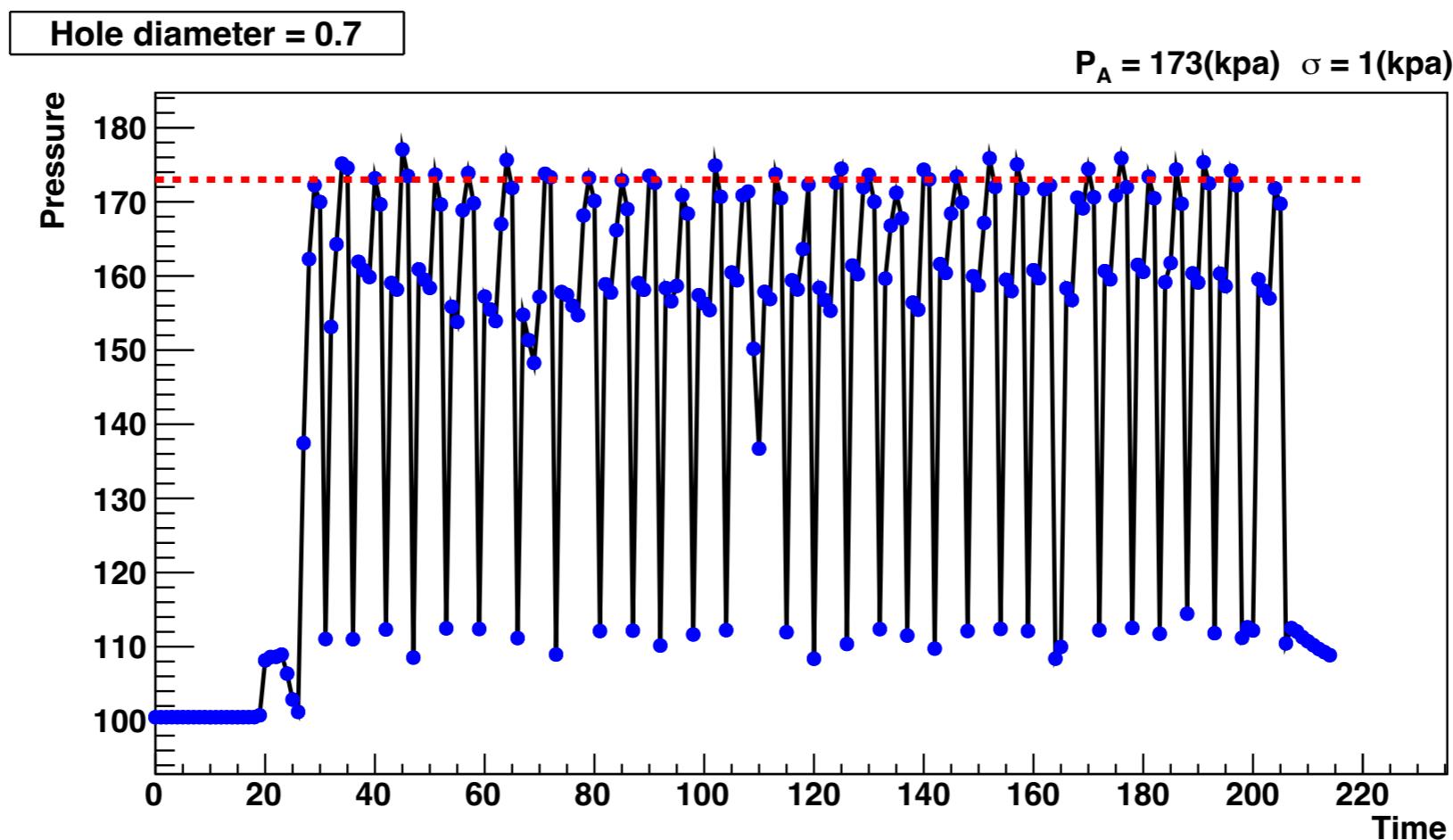
Experimental Procedures (Creating the Ring)

- We first pump out the water in the pipe
- Then we pump the air to the pressure we need
- We abruptly open the valve to create the bubble ring



Experimental Procedures (Controlling Air Pressure)

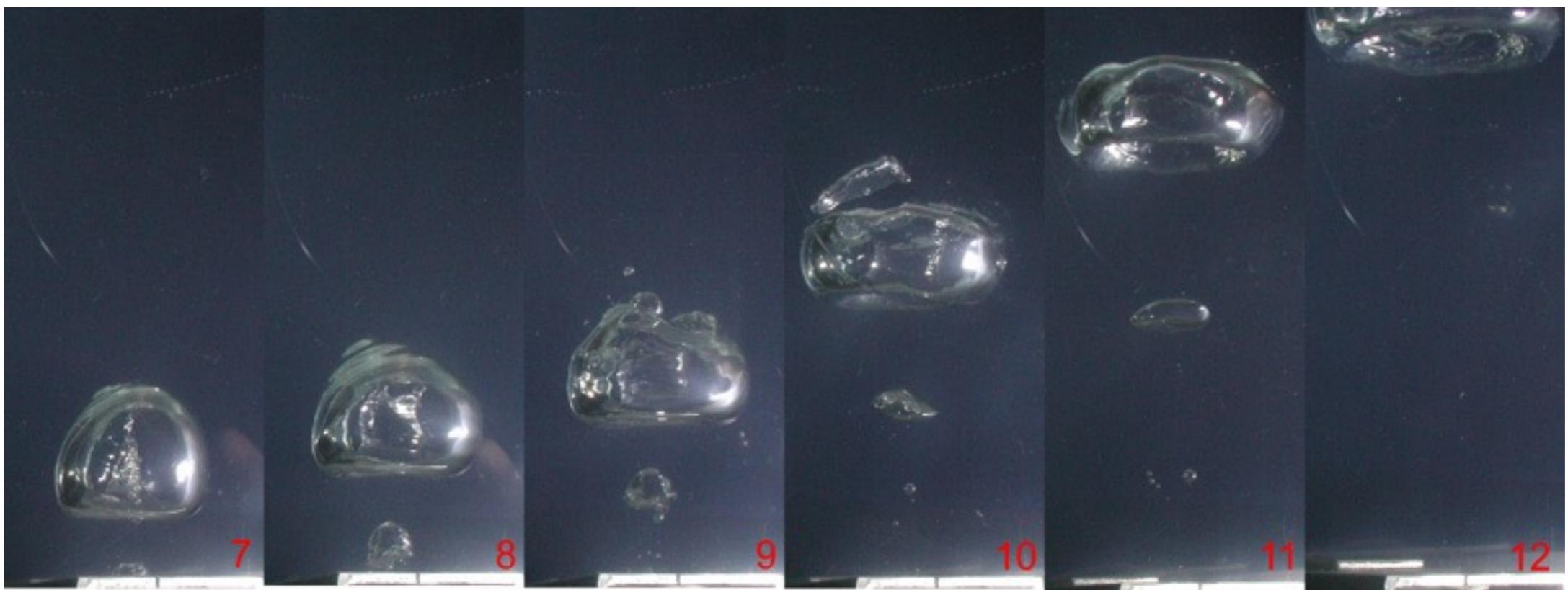
- We use a manual pump to pump the air
- We also use a pressure meter to measure the exact value



What we want to know

1. How does the ring form?
2. How does the ring evolve?
3. What is the flow field around it?

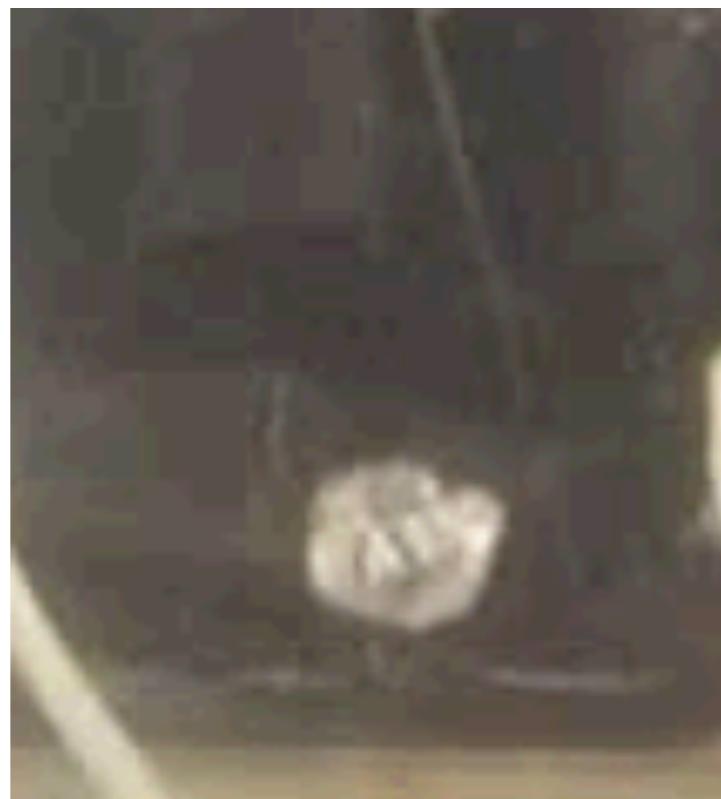
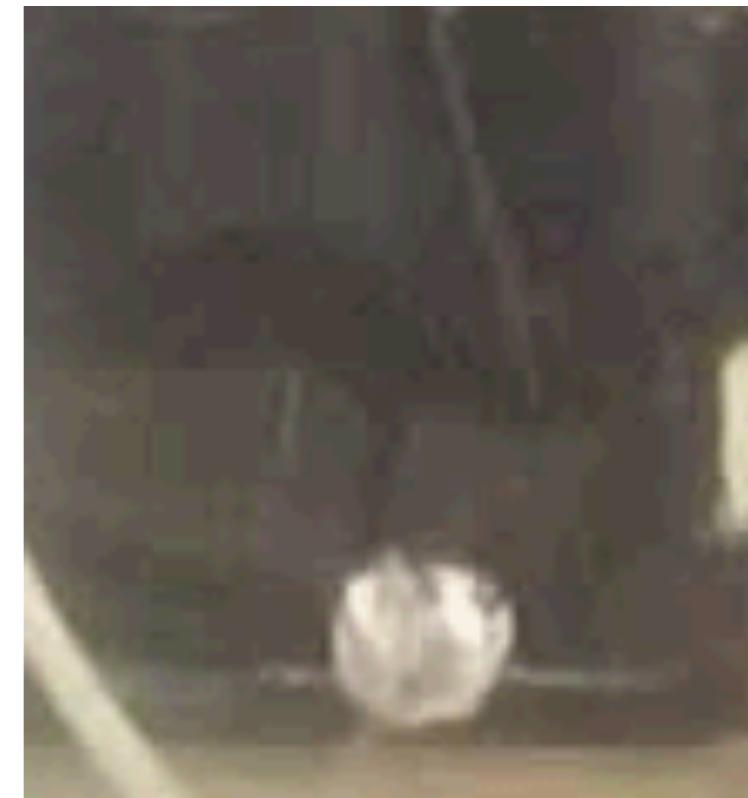
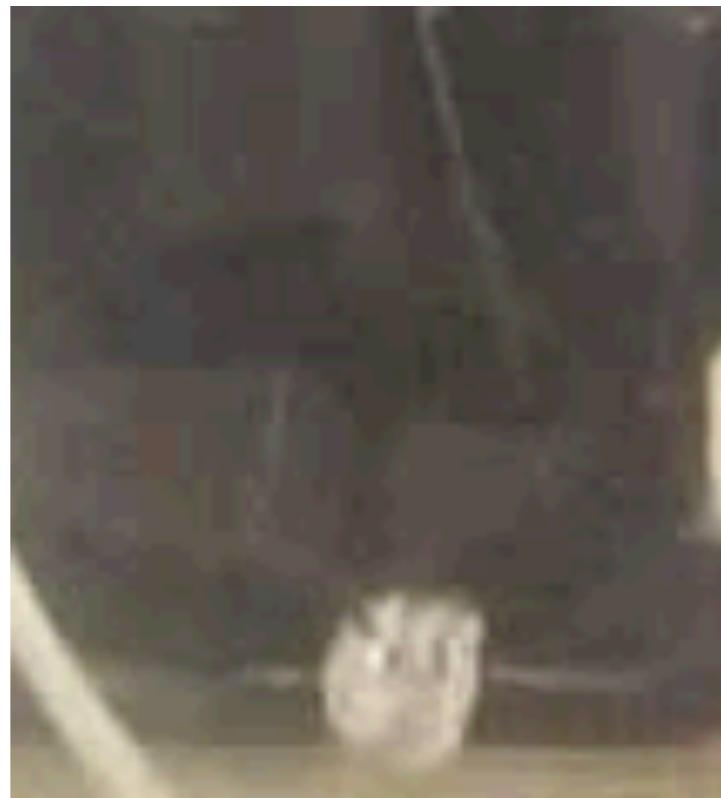
Expectation of Ring Formation



The Formation of the Rings



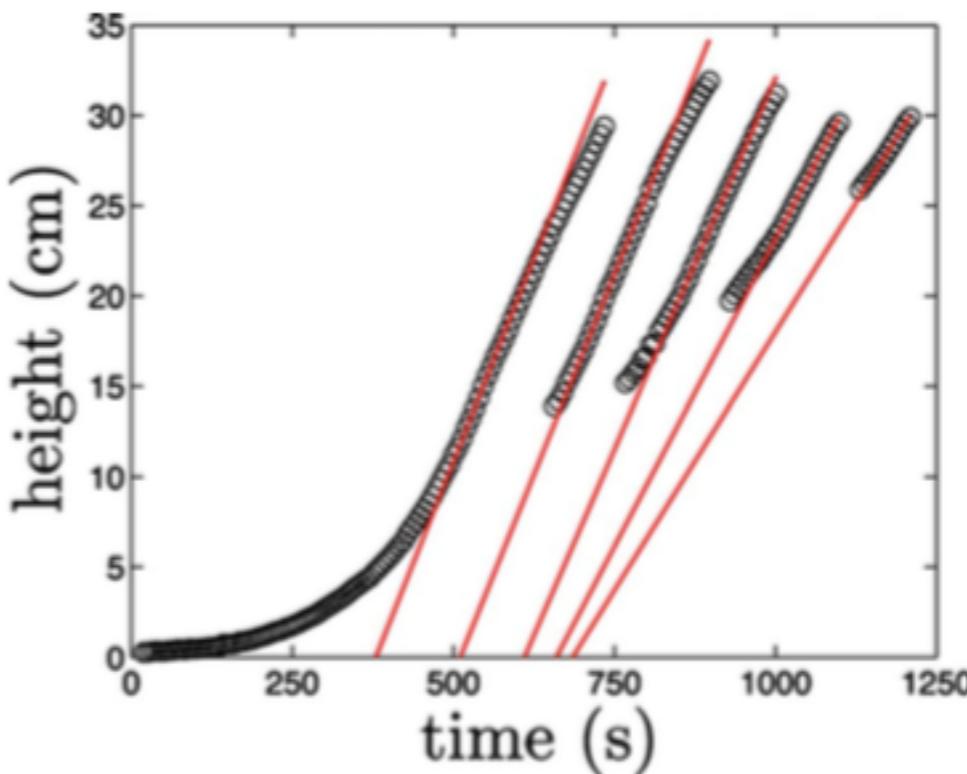
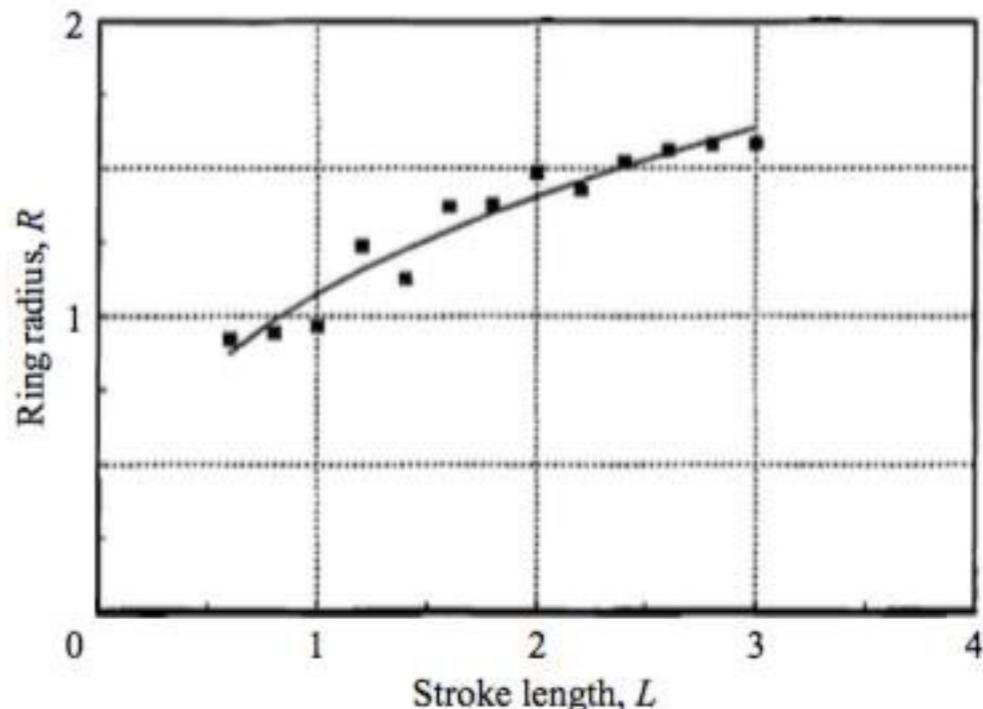
The Formation of the Rings



Expectation of the Evolution

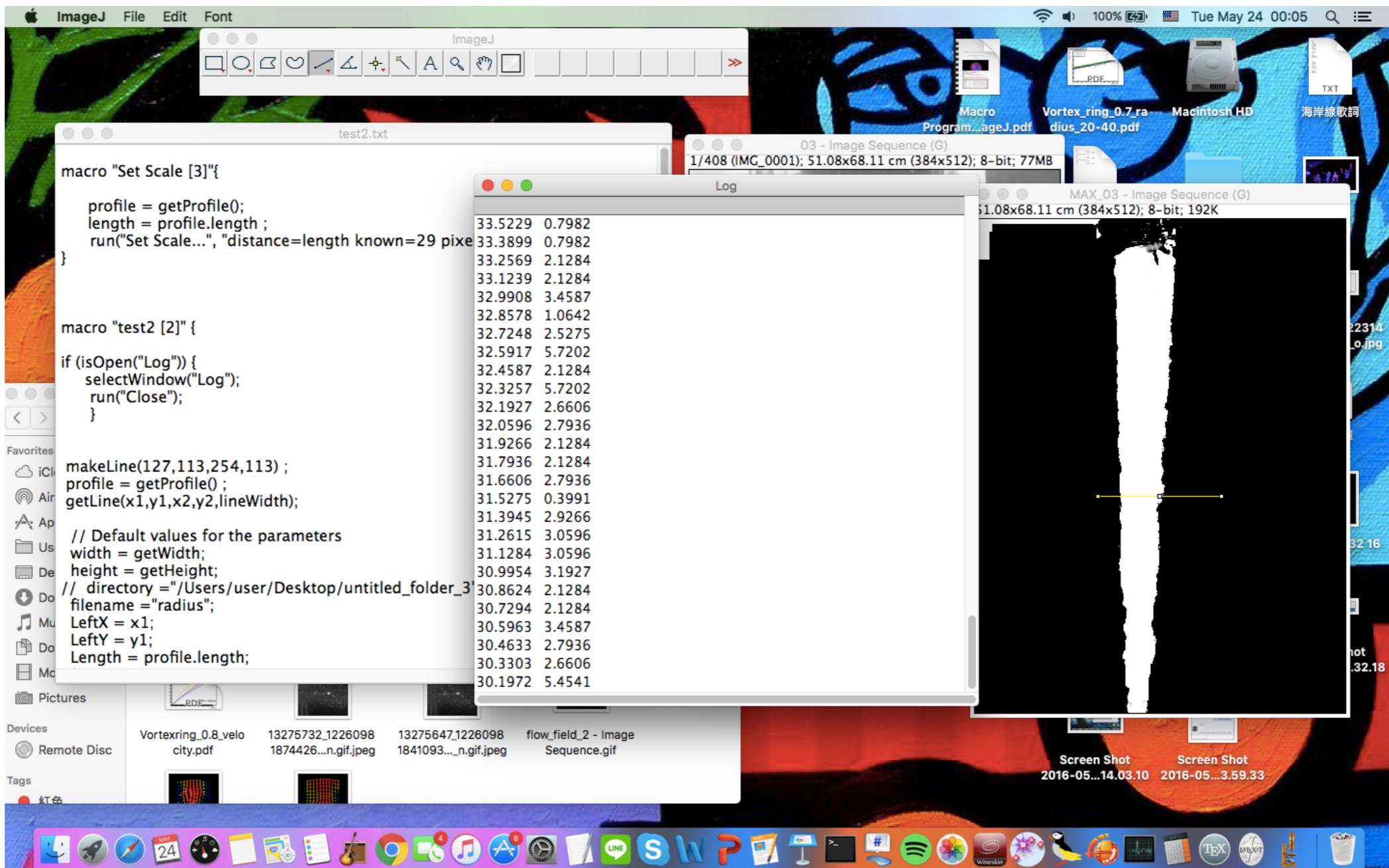
We expect the radius grows like $L^{\frac{1}{3}}$

$$V = \frac{\Gamma}{4\pi R} \left(\ln \frac{8R}{a} - \frac{1}{2} \right)$$

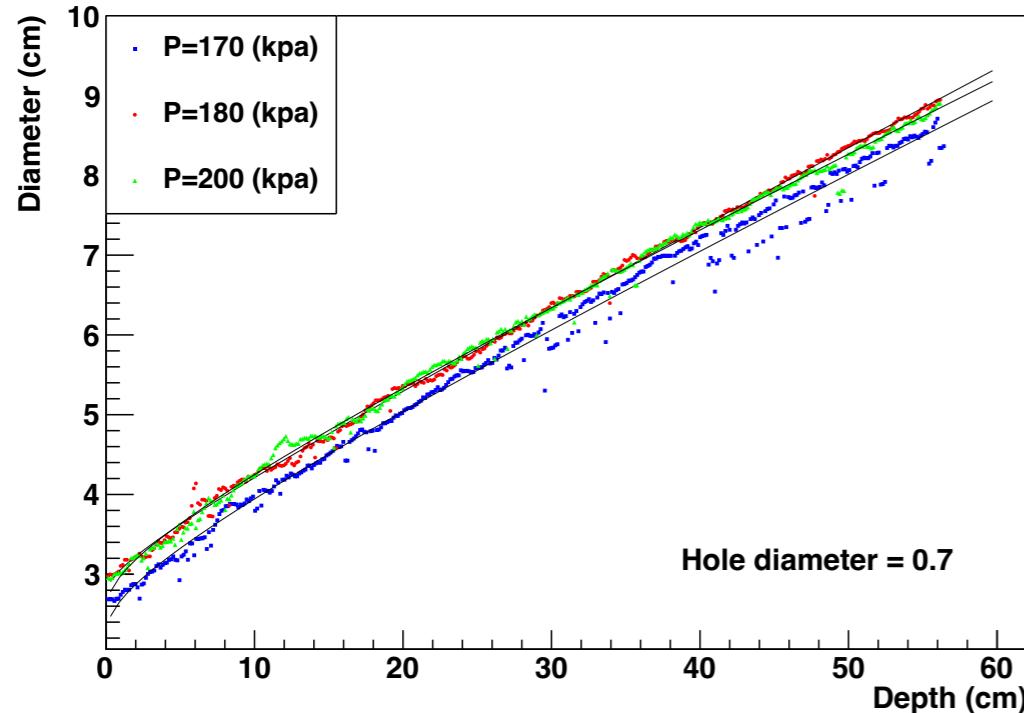
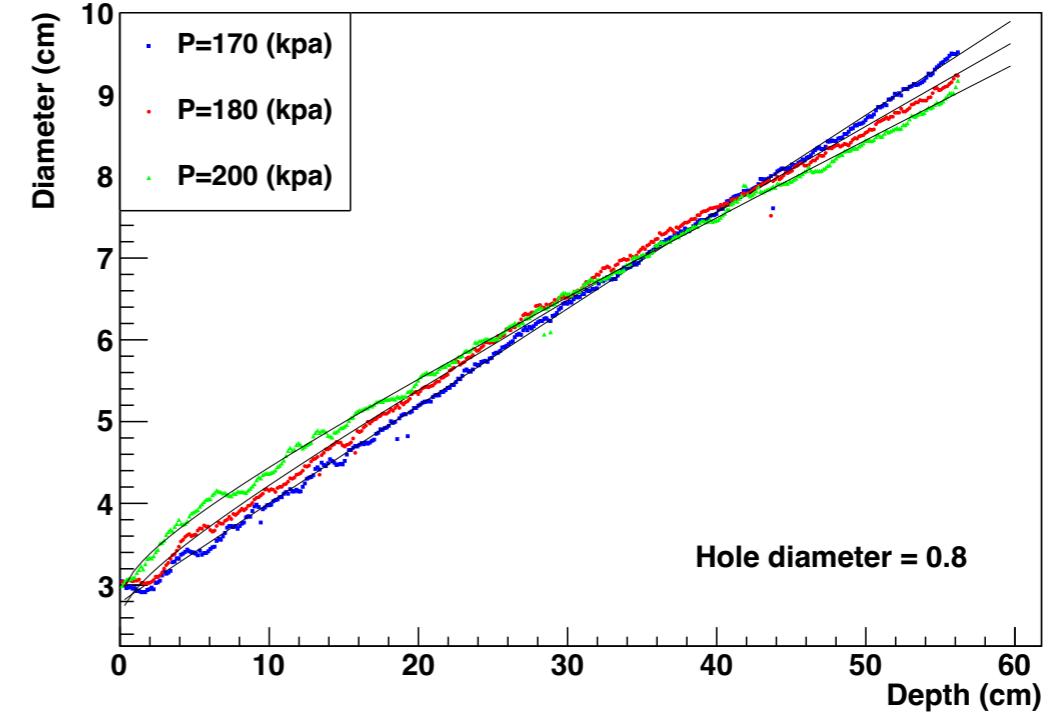
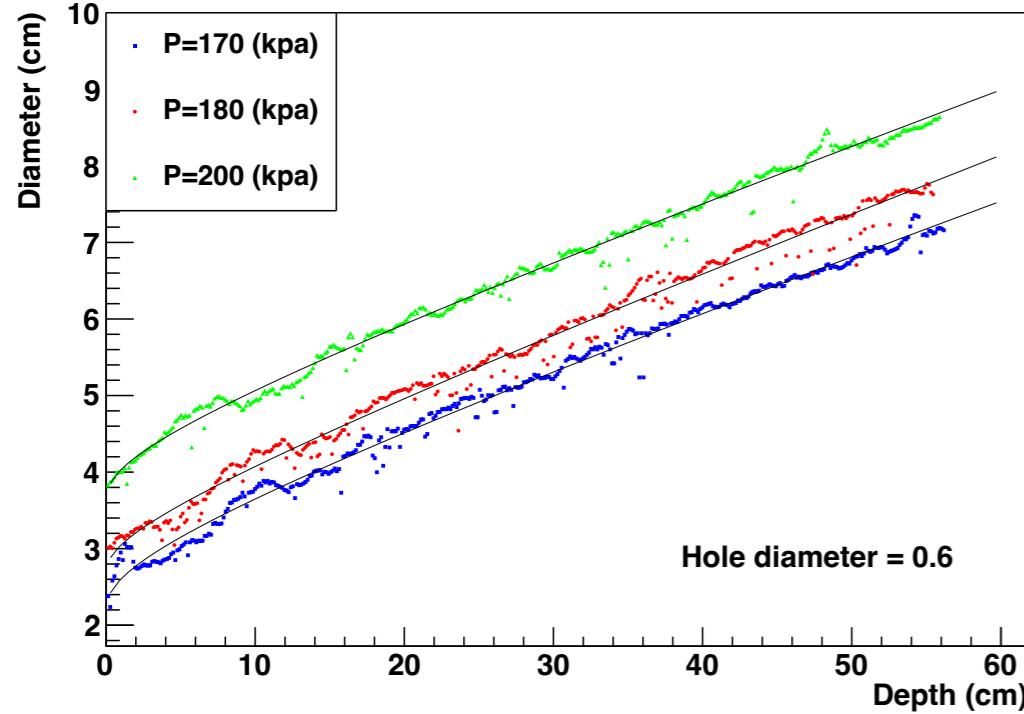


Analysis

- We use the software Imagej to analyse our videos
- We can write programs suitable for our measurement and compile it with the software

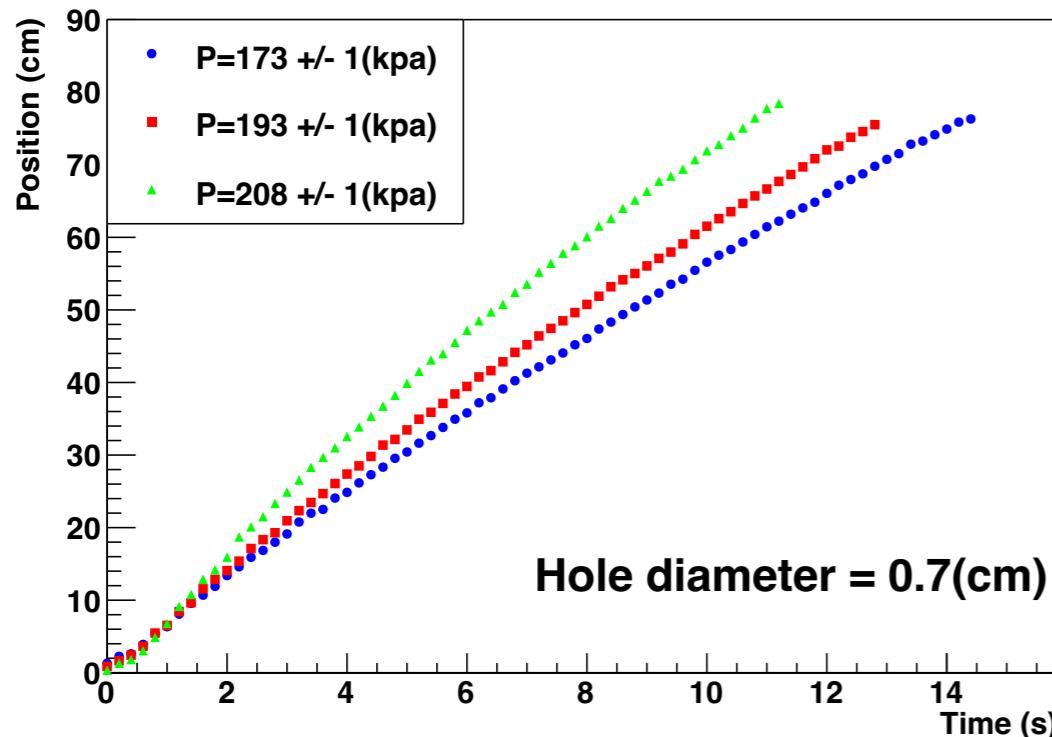
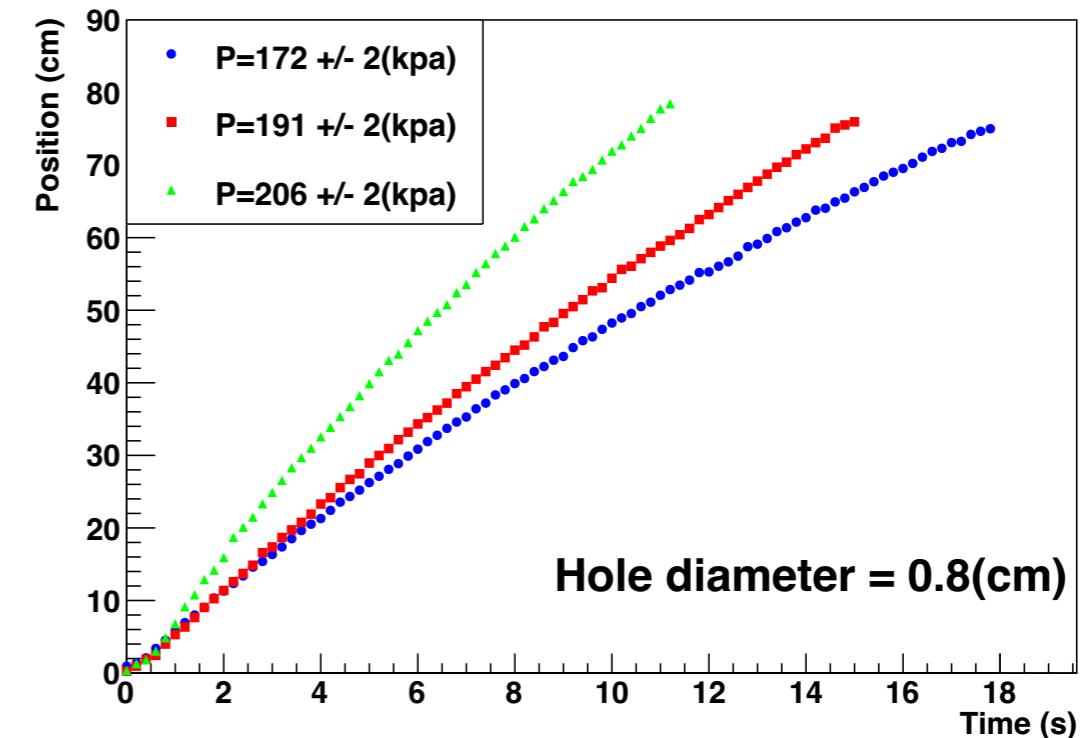
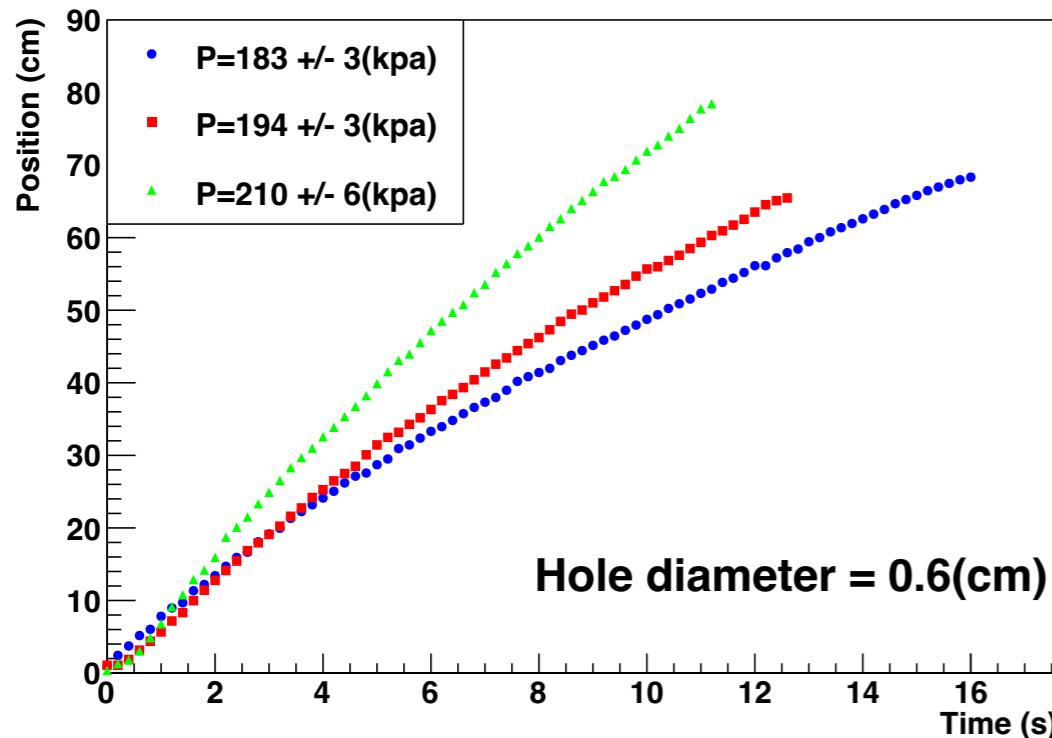


Results (Radius)



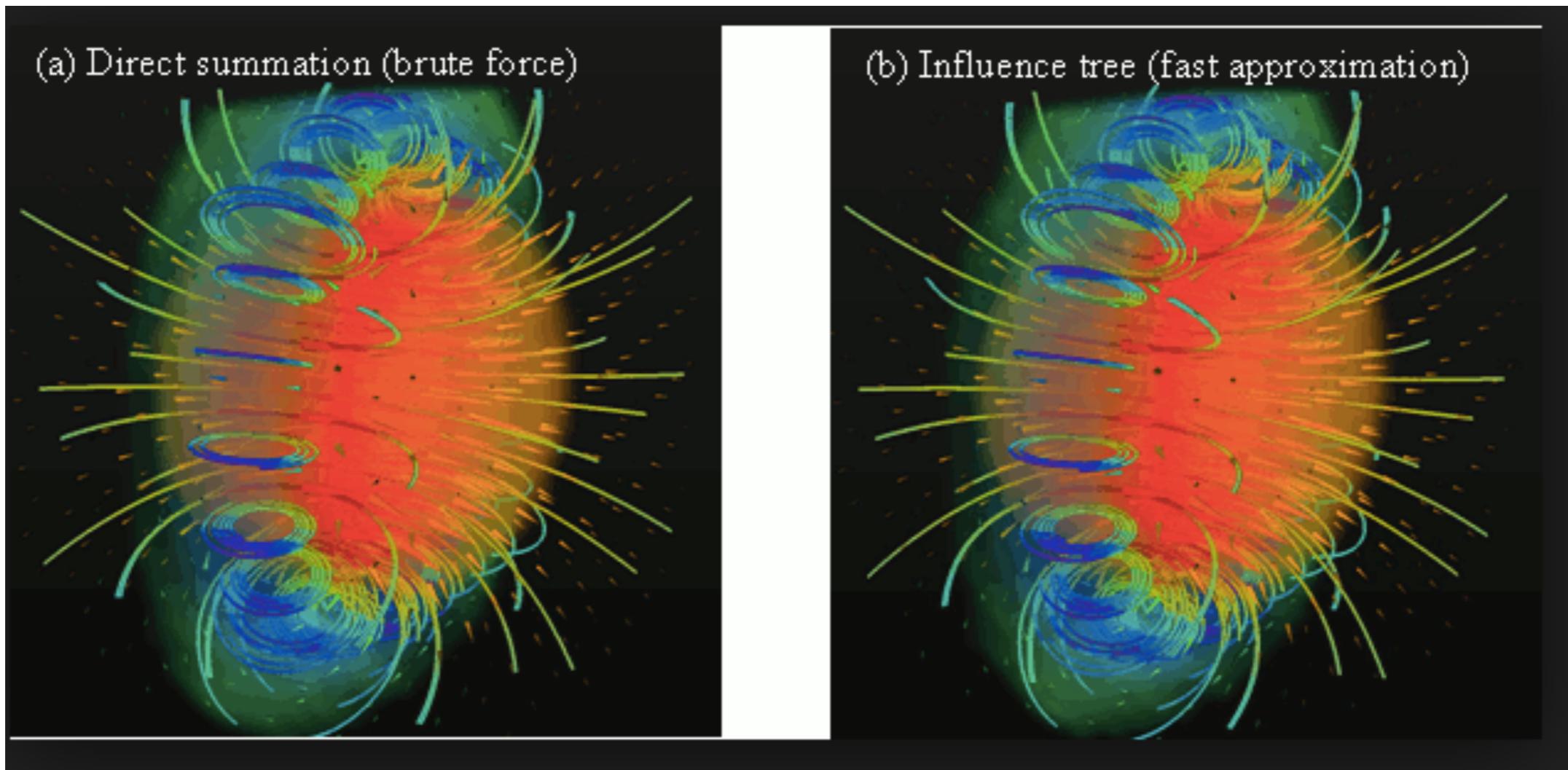
We also add a linear term to fit our data

Results (Velocity)



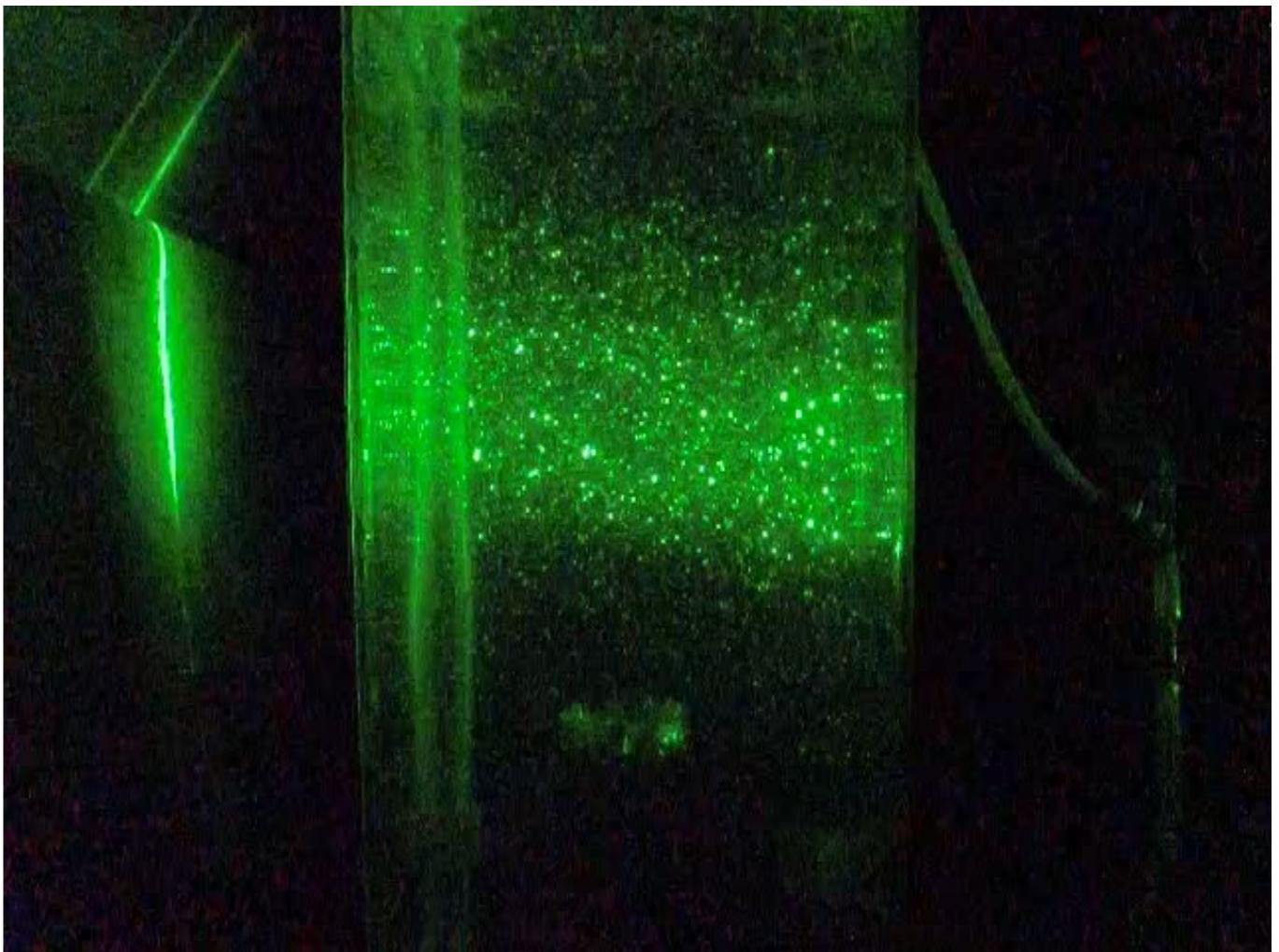
The velocity is faster when generated by a larger pressure

Expectation of Flow Field

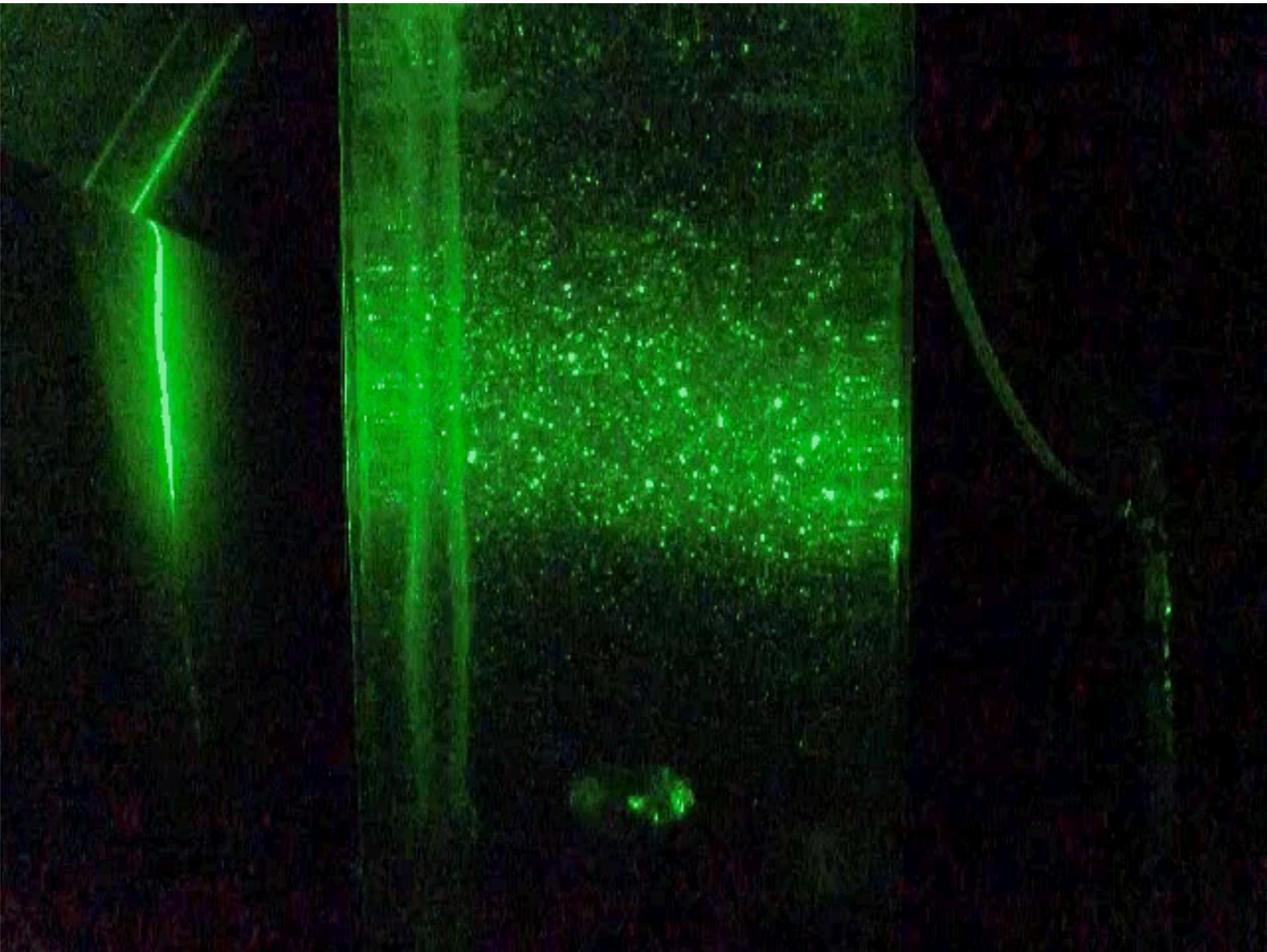


Flow Field Visualising

- We add mushroom powder into our tank and point a laser sheet to it

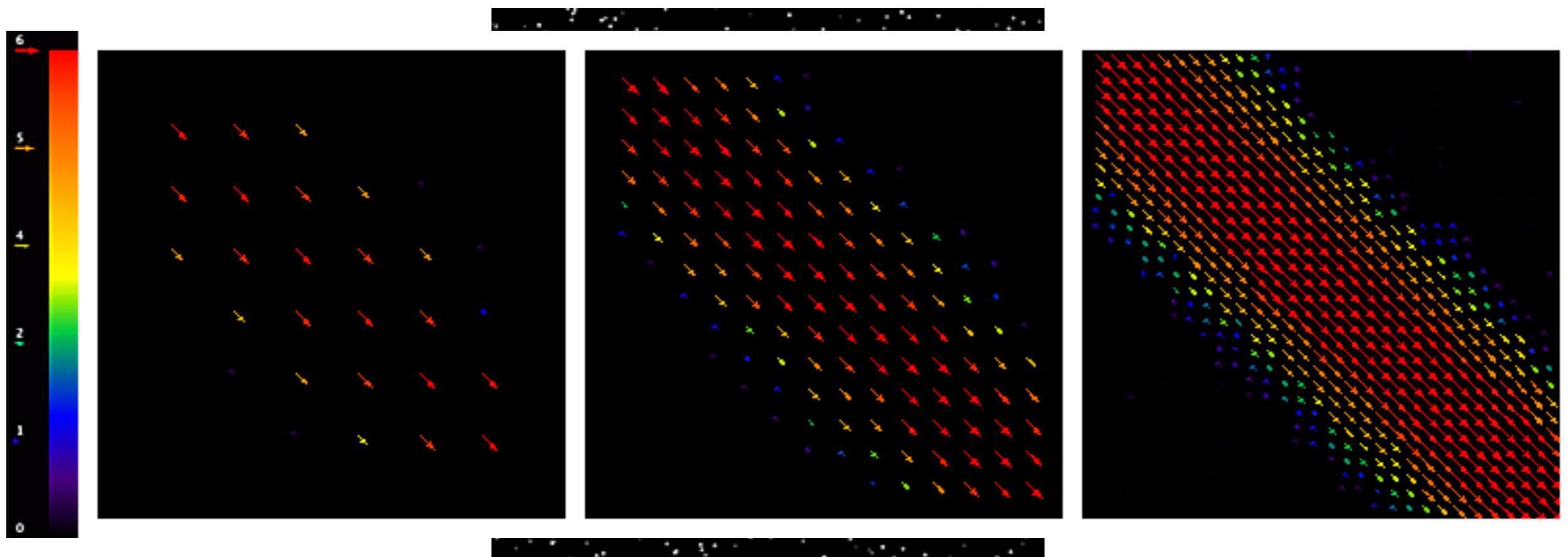


Flow Field Visualising



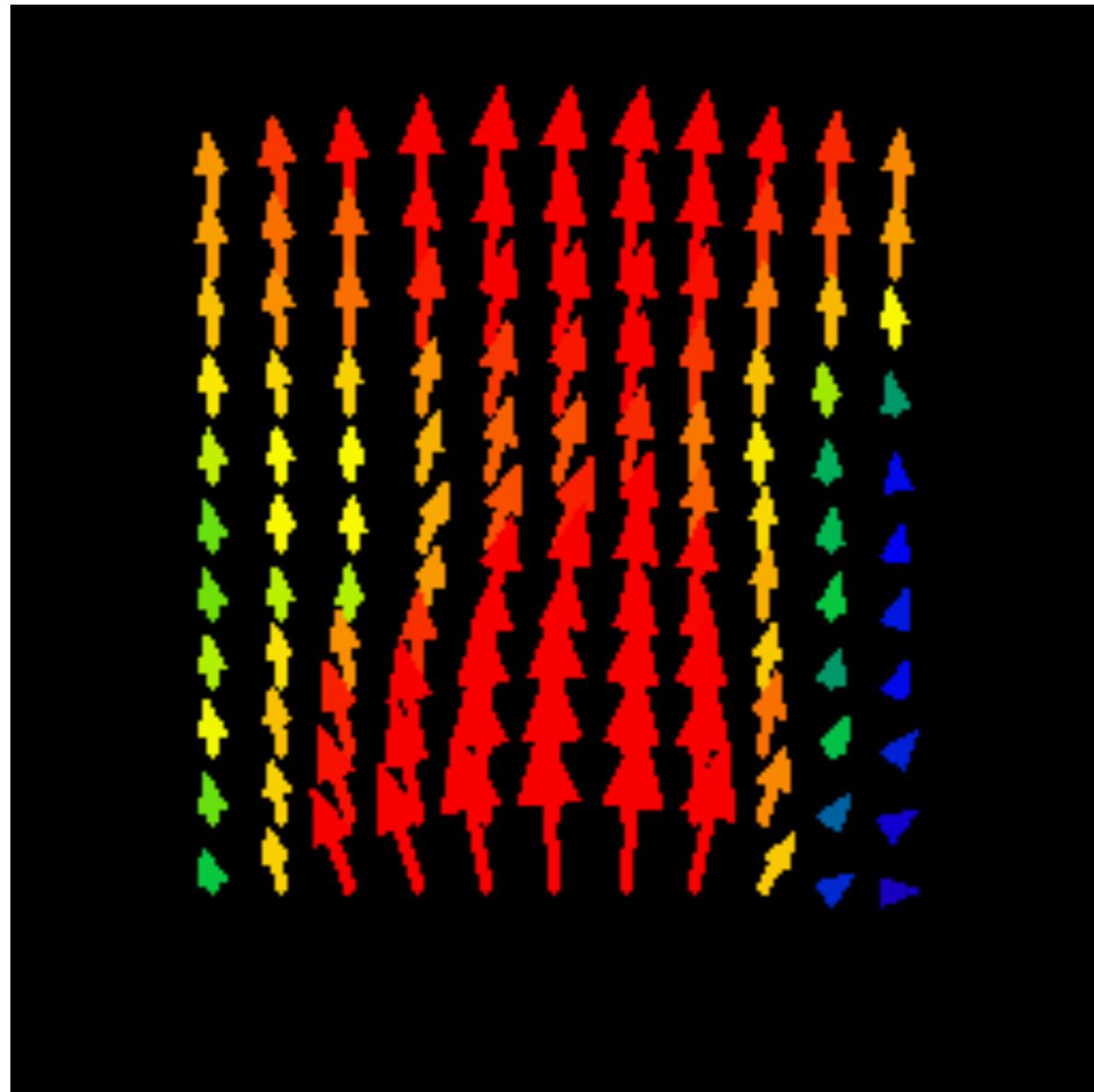
PIV Analysis

- We use the Imagej PIV plugin to analyse the flow field



Results (Flow Field)

- After analysing all the flow field of our images, we get an animation of the overall flow field



Conclusion

1. We had know how the bubble ring forms
2. The relation between water depth and radius is linear
3. The flow field is just like the one we expected
4. With a smaller orifice, a larger pressure is needed



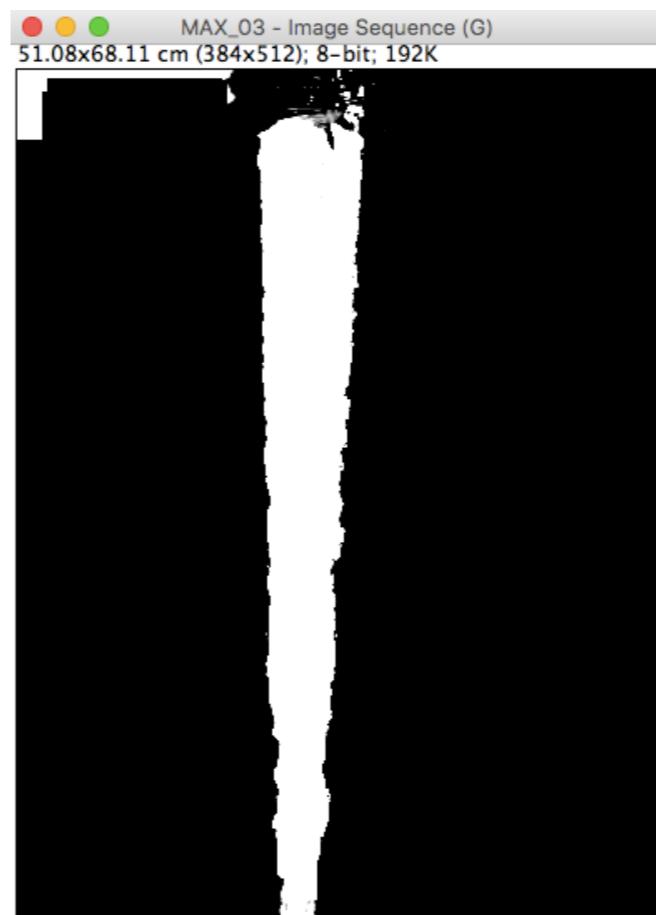
Thanks for Your Listening

References

1. http://www.ivsky.com/tupian/shuiqipao_v2002/pic_53114.html
2. http://www.oceanlight.com/bubble_ring_photo.html
3. <http://www.depocean.net/depocean/index.php?science09.php>
4. <http://goo.gl/CDVP7v>

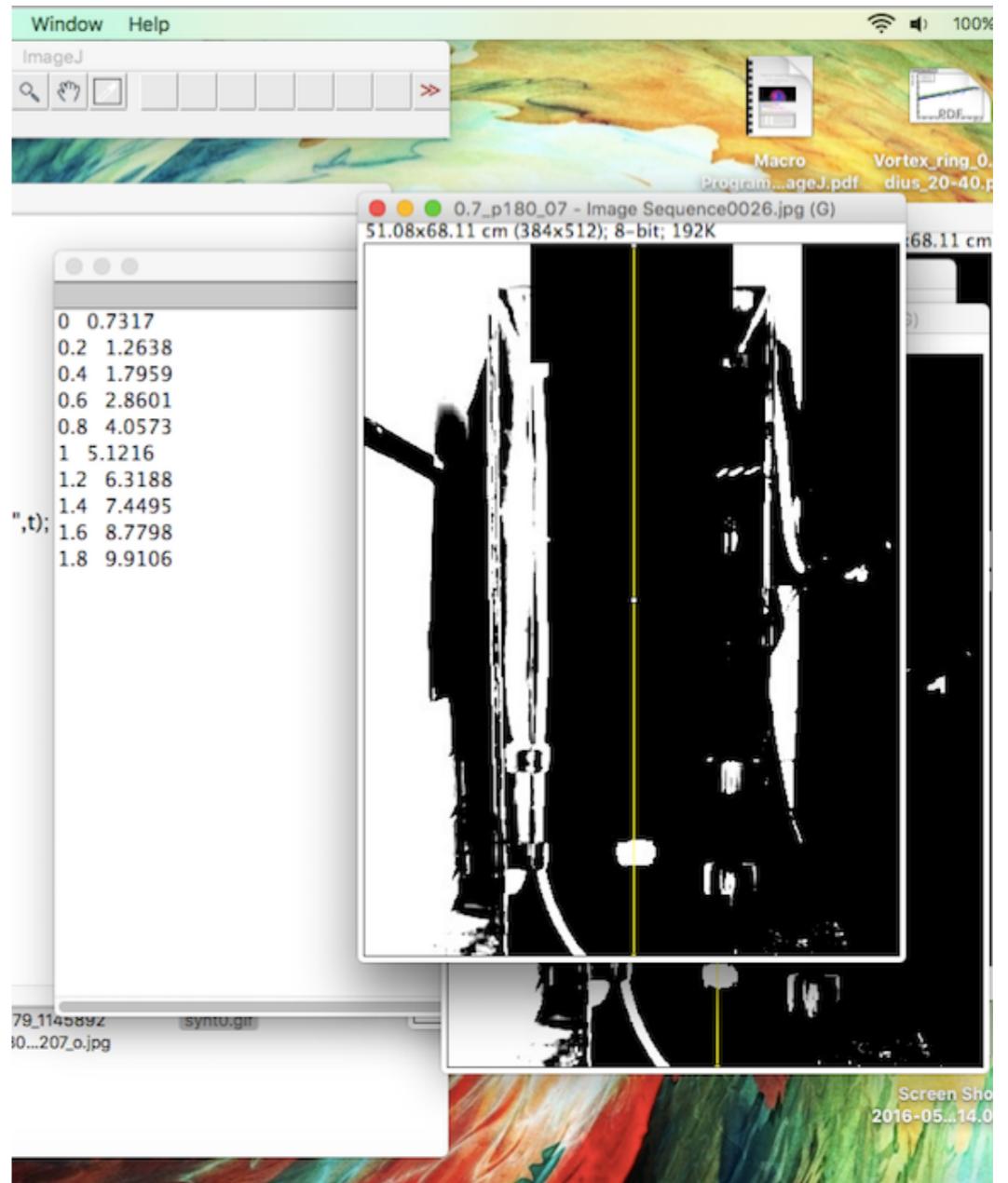
Analysis (Radius)

- We first transfer our videos into image sequence, and makes a stack of the image
- Then we adjust the contrast to make the outline of bubbles clearer
- We erase the surrounding image and leaving only the bubble
- Last, we use the program we wrote to collect the radius of bubble ring at different depth

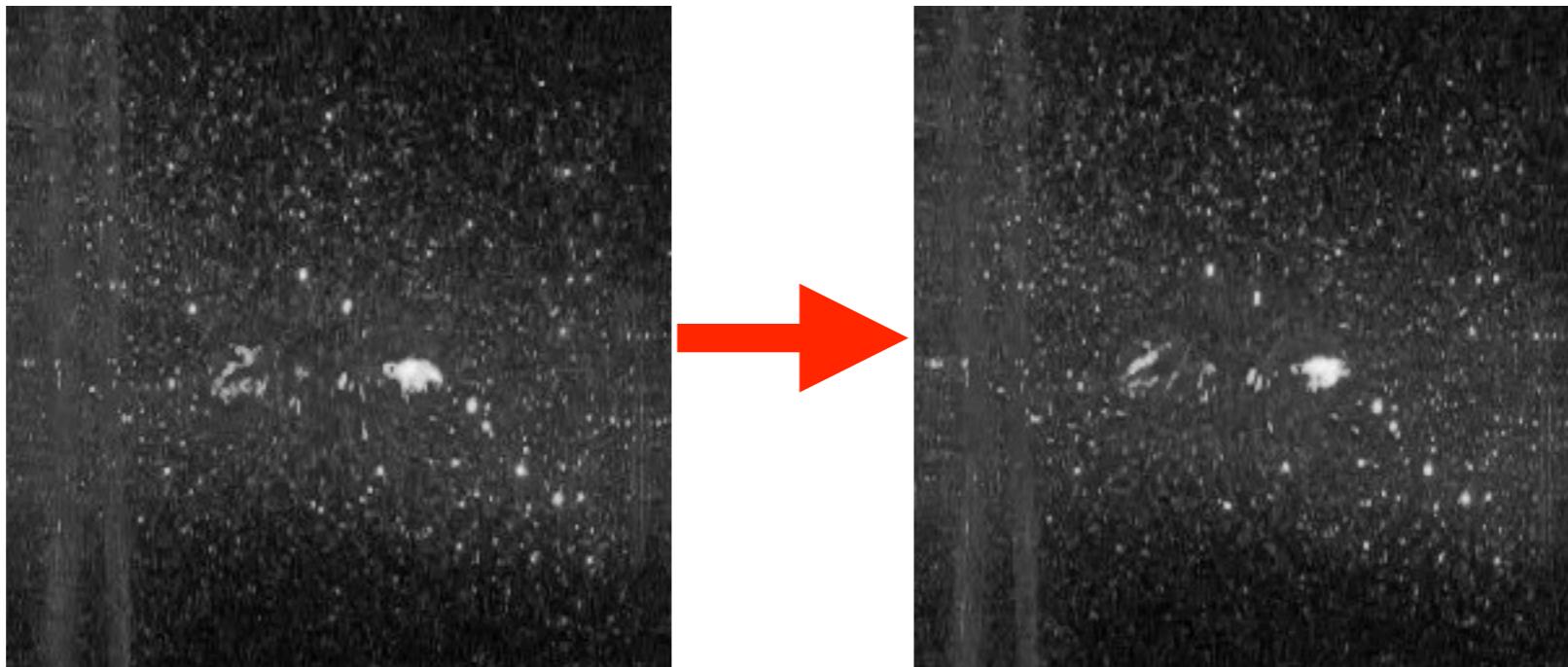


Analysis (Velocity)

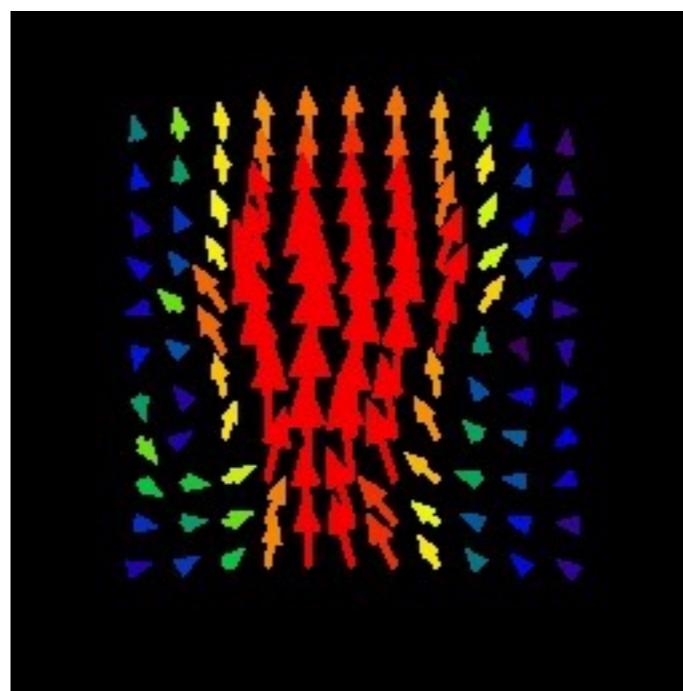
- We first process the images in a similar way to make it easier to analyse
- The program will get all the coordinates of the bubble and add them up, thus getting the middle point of the bubble
- We can then know how many distance has the bubble traveled as time passed



Results (Flow Field)



After PIV analysing, the result flow field is



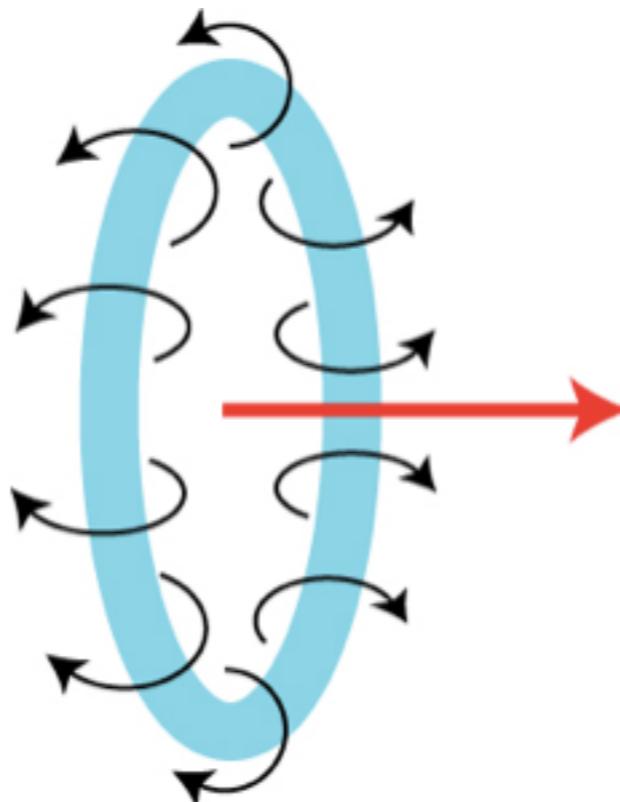
Expected results of Fifth one

1. The formation in different pressures of pump.
2. The diagram of height verse time in the different pressures of water.
3. The diagram of radius verse time in the different pressures of water.
4. The diagram of speed of ring verse height or the radius.
5. **The air condition of bubble rings ?**
6. The motion after the bubble ring disintegrate ?
7. The motion between the bubble ring and bubble ?
8. The motion between the bubble ring and bubble ring ?



Expected results of Sixth and Seventh one

1. The formation in different pressures of pump.
2. The diagram of height verse time in the different pressures of water.
3. The diagram of radius verse time in the different pressures of water.
4. The diagram of speed of ring verse height or the radius.
5. The air condition of bubble rings ?
6. The motion after the bubble ring disintegrate ?
7. The motion between the bubble ring and bubble ?
8. The motion between the bubble ring and bubble ring ?



Expected results of Eighth one

1. The formation in different pressures of pump.
2. The diagram of height verse time in the different pressures of water.
3. The diagram of radius verse time in the different pressures of water.
4. The diagram of speed of ring verse height or the radius.
5. The air condition of bubble rings ?
6. The motion after the bubble ring disintegrate ?
7. The motion between the bubble ring and bubble ?
8. **The motion between the bubble ring and bubble ring ?**

