ON MY FAVORITE RINGS

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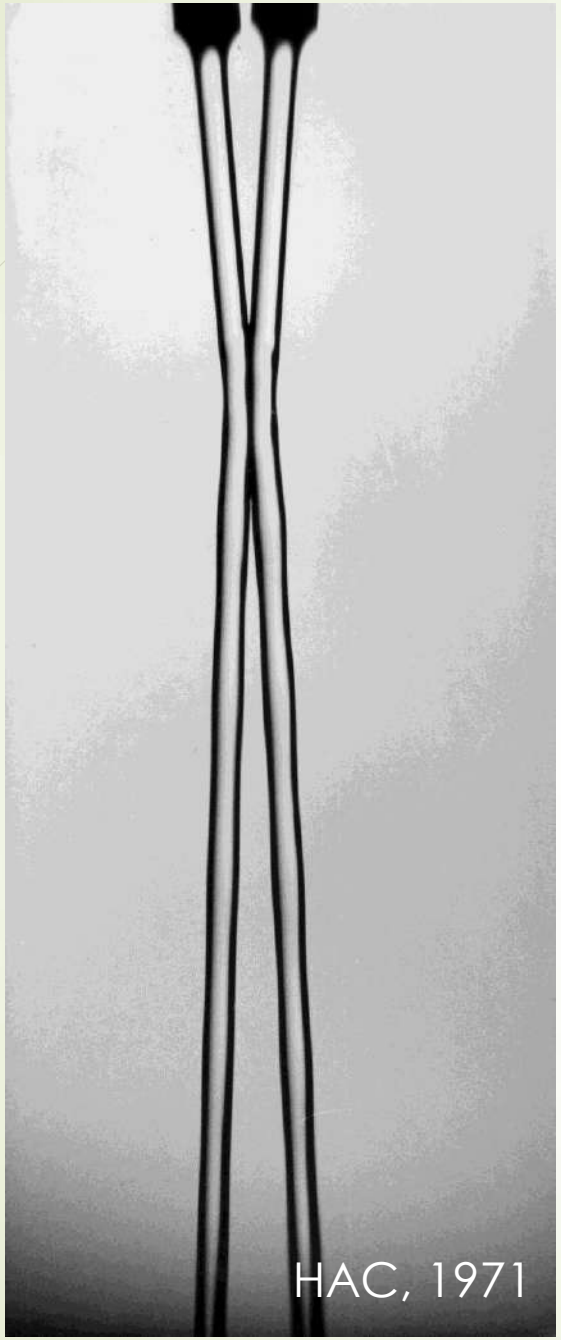
FOREWORD

The material included in this presentation is not intended to be a research piece. Hopefully, it may be considered an interesting lecture on a quite attractive aspect in Fluid Dynamics, namely VORTEX RINGS. It is related to published research, including mine. The material may be freely used for teaching or personal use by appropriate excerpting (and referencing) of third Authors. All the references may be obtained from the web, with the exception of some of my own pictures. In some cases, notes have been added.
In case of experiencing difficulties, please refer to me at:

jcferreri@gmail.com or jcferreri@ciencias.org.ar



In Memoriam,

Ing. Horacio Alberto Caruso

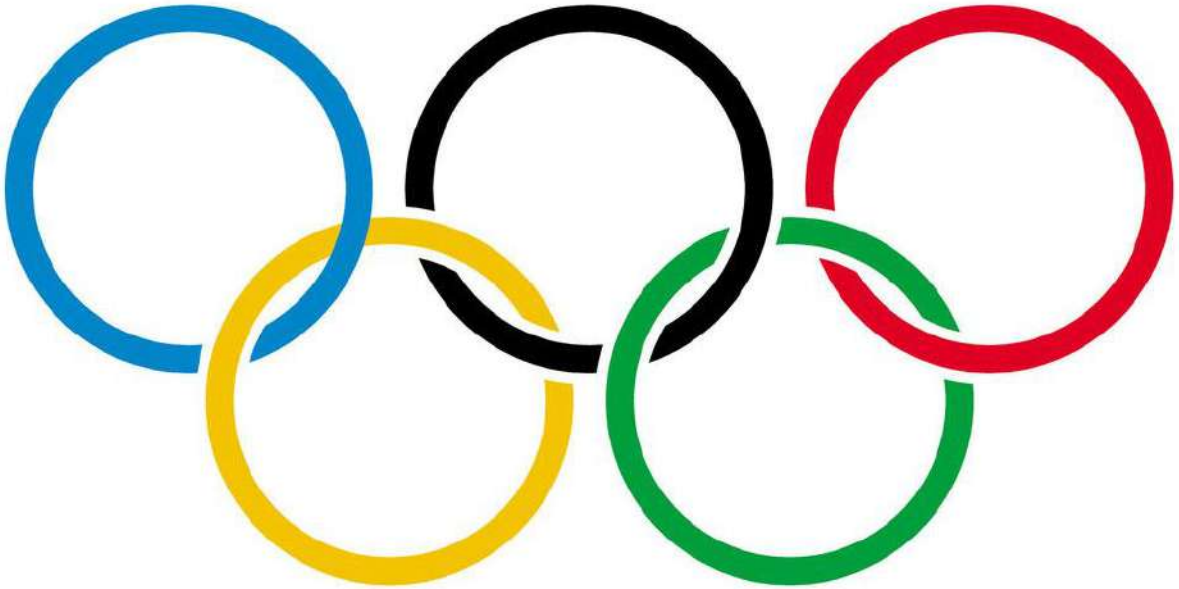
1934-2003

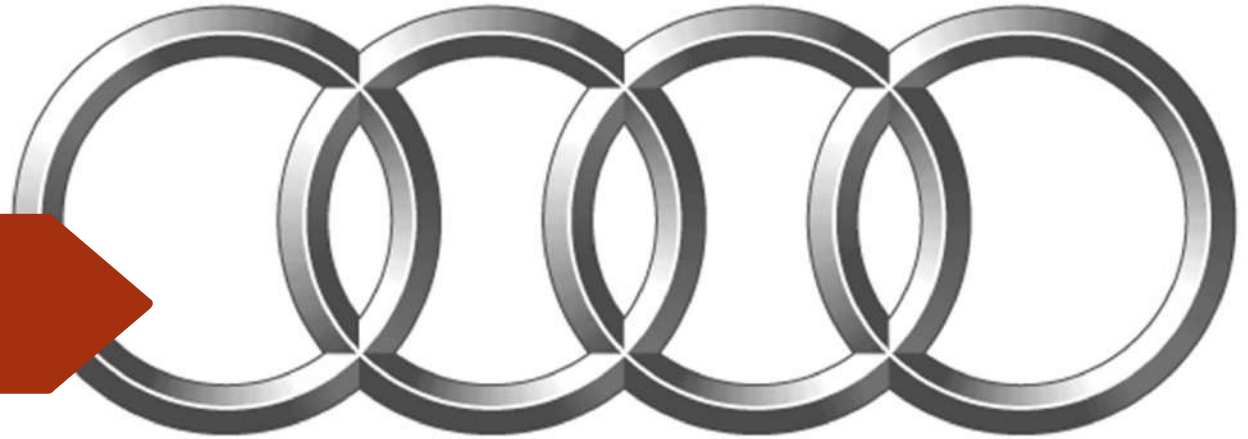
When performing experiments he had a balance between ingenuity and naivety that frequently led him to perplexity.

His curiosity kept intact along all his existence.

He was ethical.

Rings mean different things to different people…





DIFFERENT RINGS FOR DIFFERENT PEOPLE…

DIFFERENT RINGS FOR DIFFERENT PEOPLE…

Now, my favorite rings are

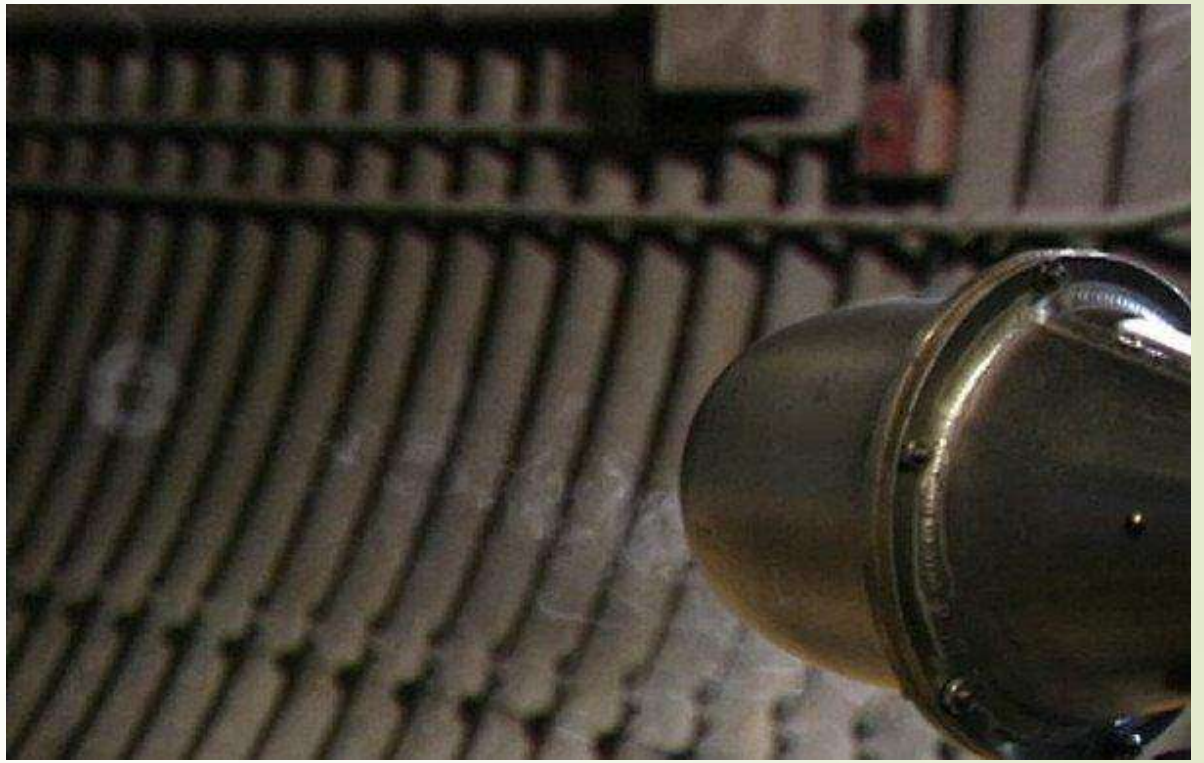
Vortex rings

(VRs from here on)

Excerpts from a family album… (not mine)

You may buy your own smoke VRs generator…

Or ask at some Lab…



Or exaggerate a bit…

Constructing your new design? Check for patents before doing… e.g.

Vortex ring generator
US 7673834 B2

ABSTRACT

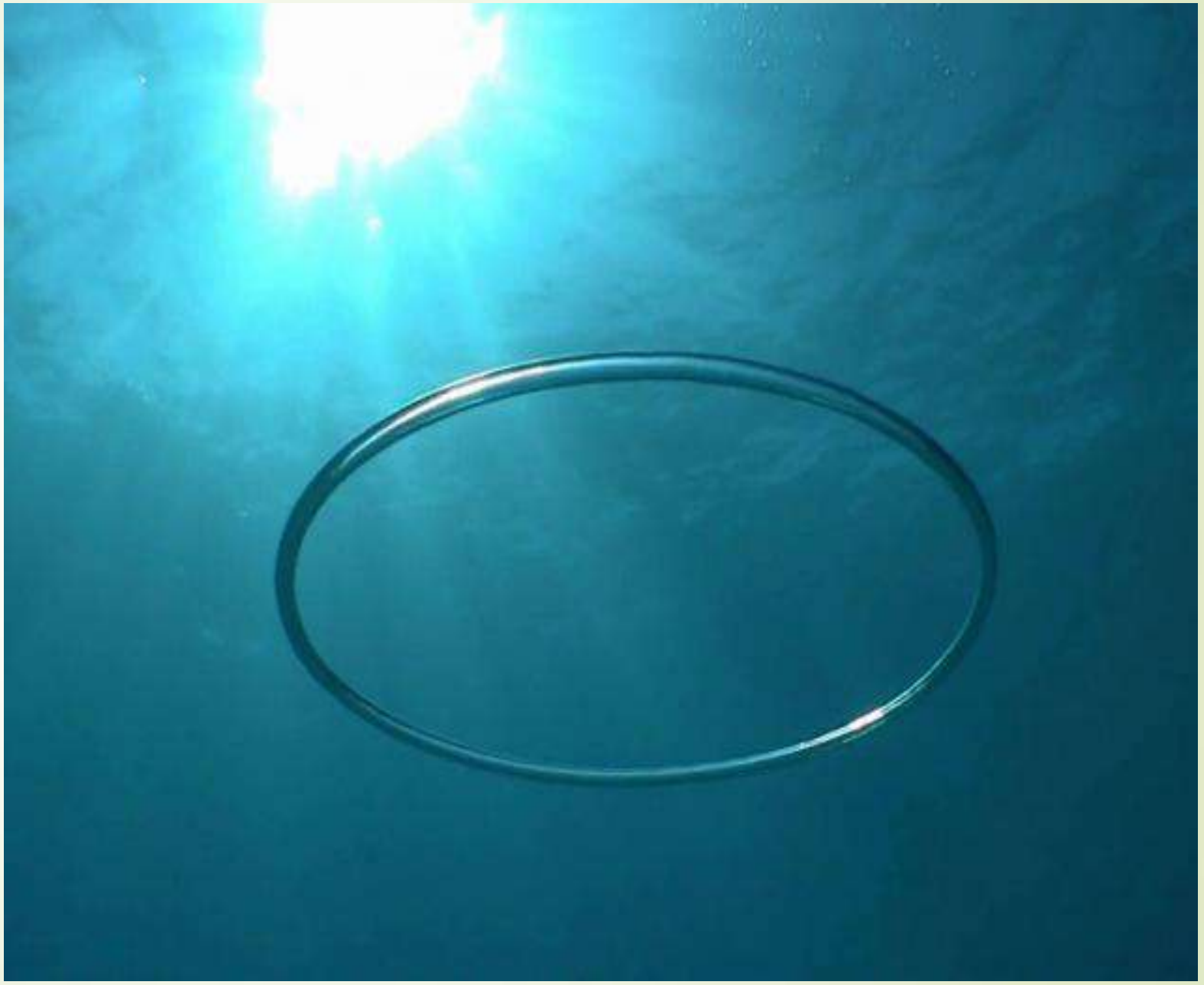
A vortex ring generator adapted to be associated with a body subjected to fluid flow, the vortex ring generator being adapted to produce a fluid flow in the form of a vortex ring with the fluid flow moving over the body from the vortex ring generator.

Publication number	US7673834 B2
Publication type	Grant
Application number	US 10/884,032
Publication date	Mar 9, 2010
Filing date	Jul 2, 2004
Priority date	Jan 3, 2002
Fee status	Paid
Also published as	CA2471816A1, 12 More »
Inventors	Jayden David Harman
Original Assignee	Pax Streamline, Inc.
Export Citation	BiBTeX, EndNote, RefMan
Patent Citations (140), Non-Patent Citations (22), Referenced by (9),Classifications (19), Legal Events (7)	

Or ask mother nature…

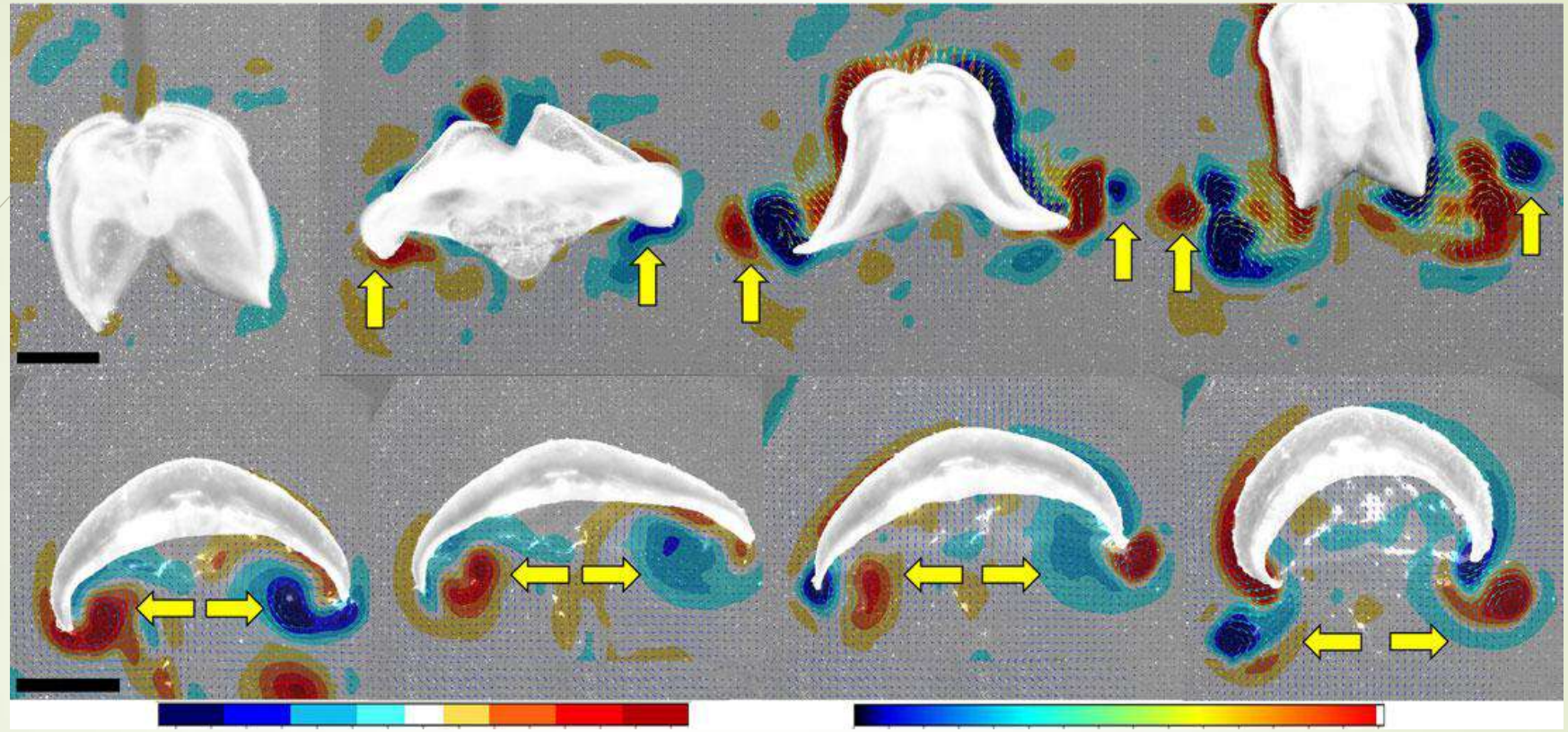
It is interesting that dolphins insert air in a pre-existing fluid vortex and due to inside low pressure in the center of the vortex core, the air expands creating the ring bubble. Rings may be up to 60 cm in diameter. They seem to do it for fun, not for reward. Captive belugas seem to do the same.

Martin et al., SciAm,1996

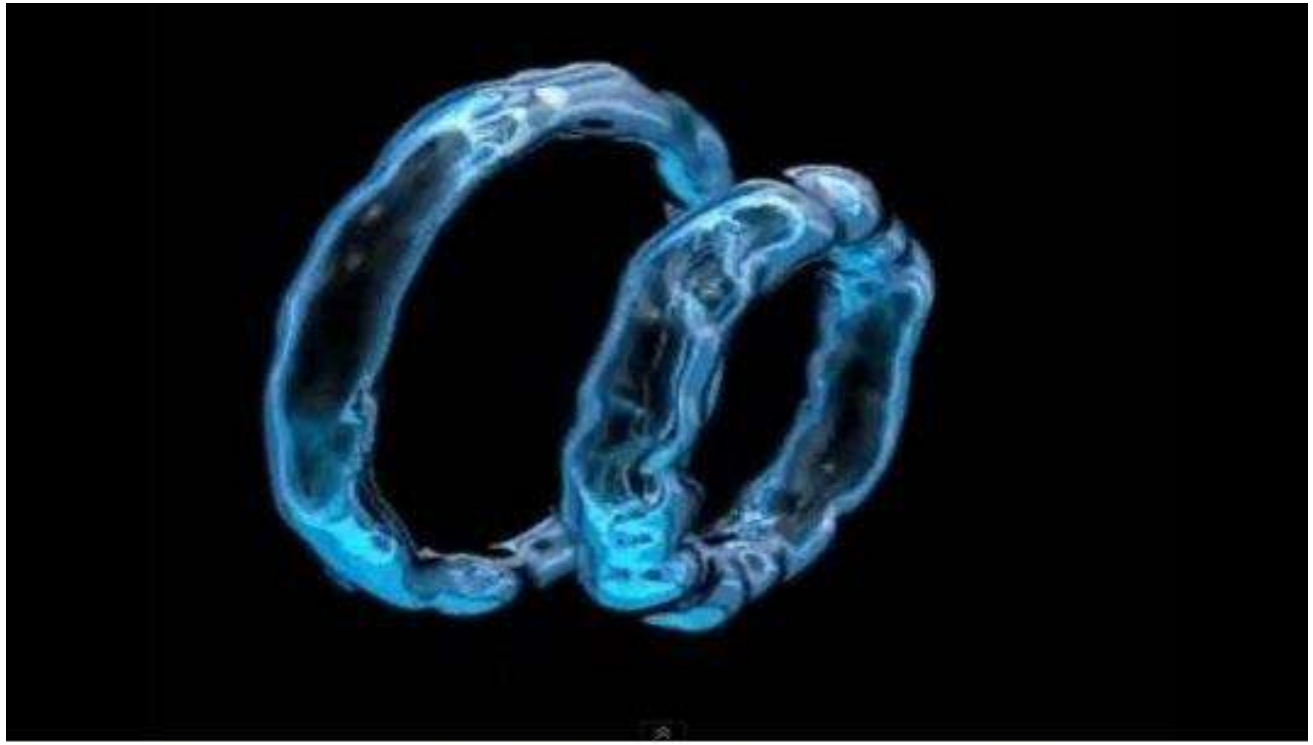


Or (again-1) ask mother nature… for a volcano generated VR

Or (again-2) ask mother nature… for bird singing generating VRs



Or (again-3) ask mother nature…
For ctenaphore advantageous propelling using VRs

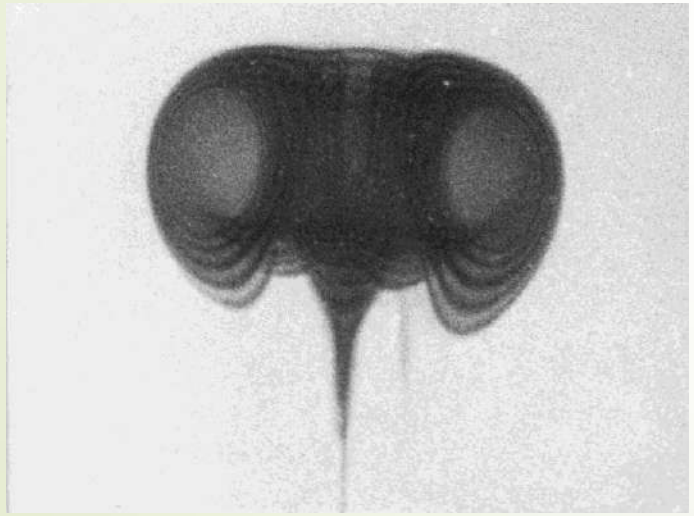


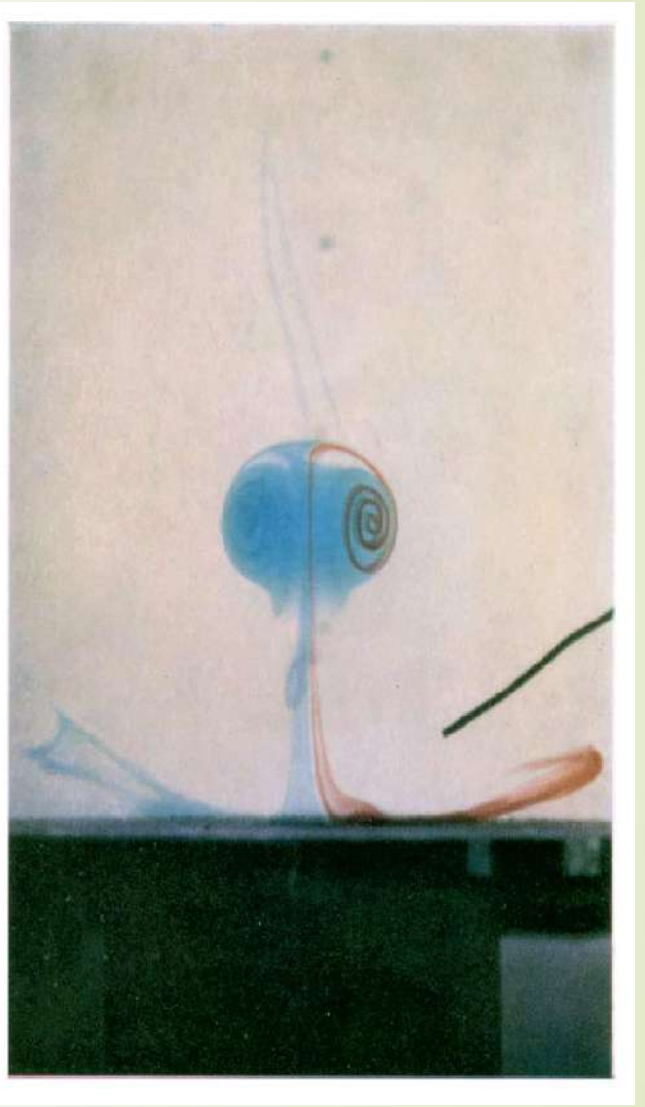
An example of a vortex ring, also called a toroidal bubble, which dolphins create under water. The concept of vortex rings lies at the heart of new University of Washington physics research.
Credit: Image courtesy of University of Washington

Aurel Bulgac, Michael McNeil Forbes, Michelle M. Kelley, Kenneth J. Roche, Gabriel Wlazłowski. Quantized Superfluid Vortex Rings in the Unitary Fermi Gas. Physical Review Letters, 2014; 112 (2) DOI: 10.1103/PhysRevLett.112.025301

Formation of a Vortex Ring emerging from a blowing camera hole in a wall

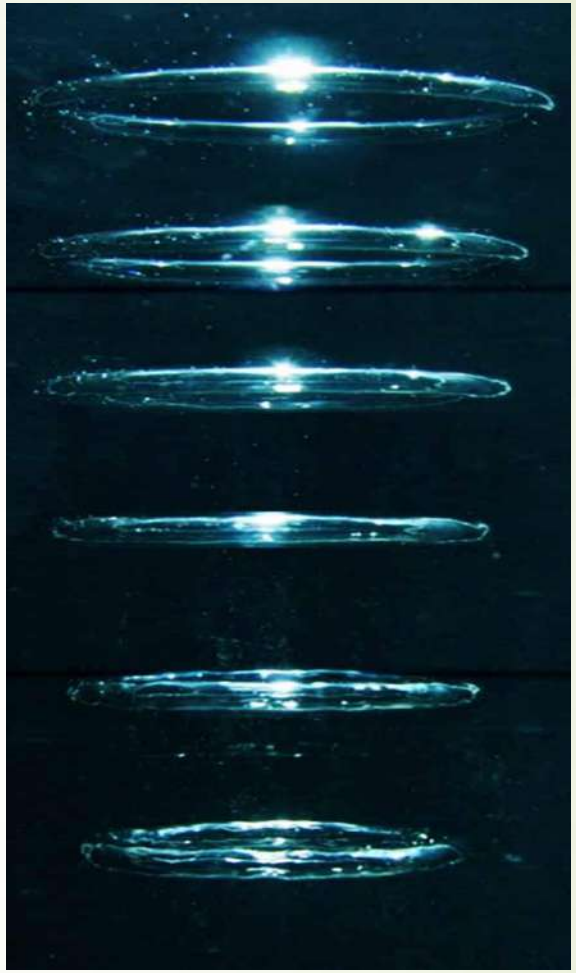
- T. Maxworthy, The structure and stability of vortex rings, *J . Fluid Mech.* (1972), *vol.* 51, *part* 1, *pp.* 15-32





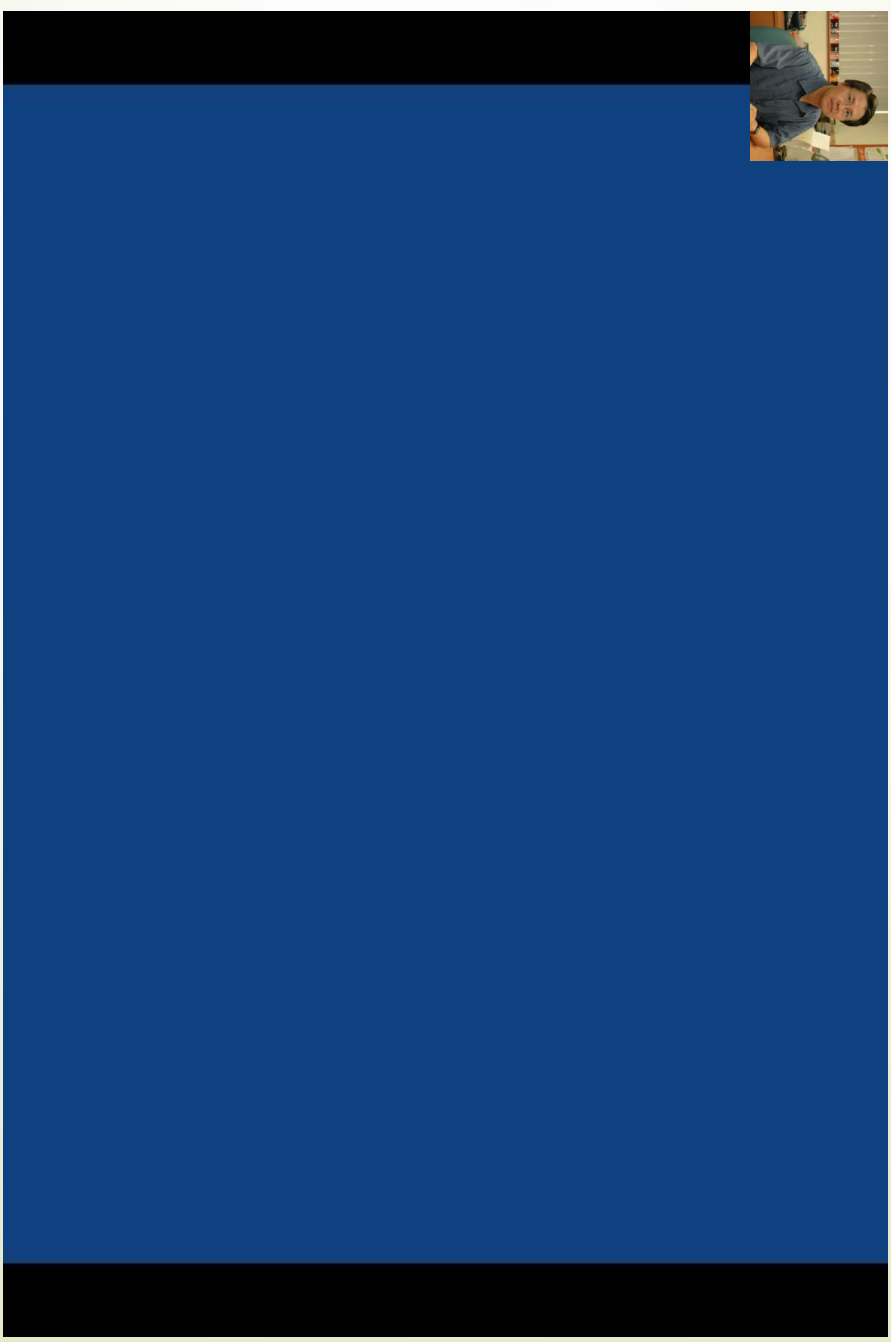
VR in free "flight" – mine, 1971

T.T. Lim, Nat. Univ. of Singapore
http://serve.me.nus.edu.sg/limtt/index.html



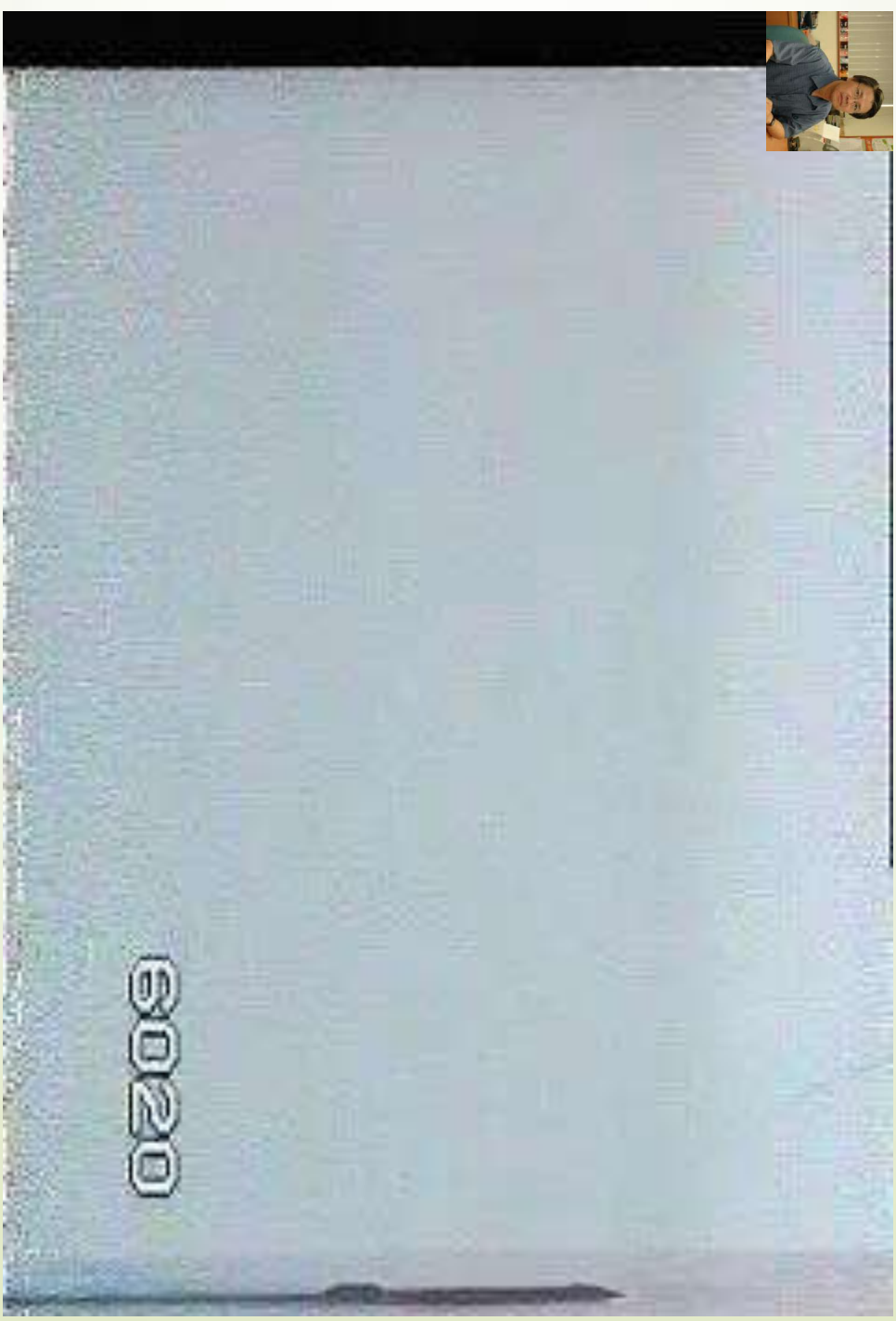
Multiple-exposed pictures of the motion of a SINGLE bubble ring rising in a vertical water tank
(Cheng, Lou & Lim: Phys. Fluids, Vol 25, 2013)

T.T. Lim, Nat. Univ. of Singapore
http://serve.me.nus.edu.sg/limtt/index.html

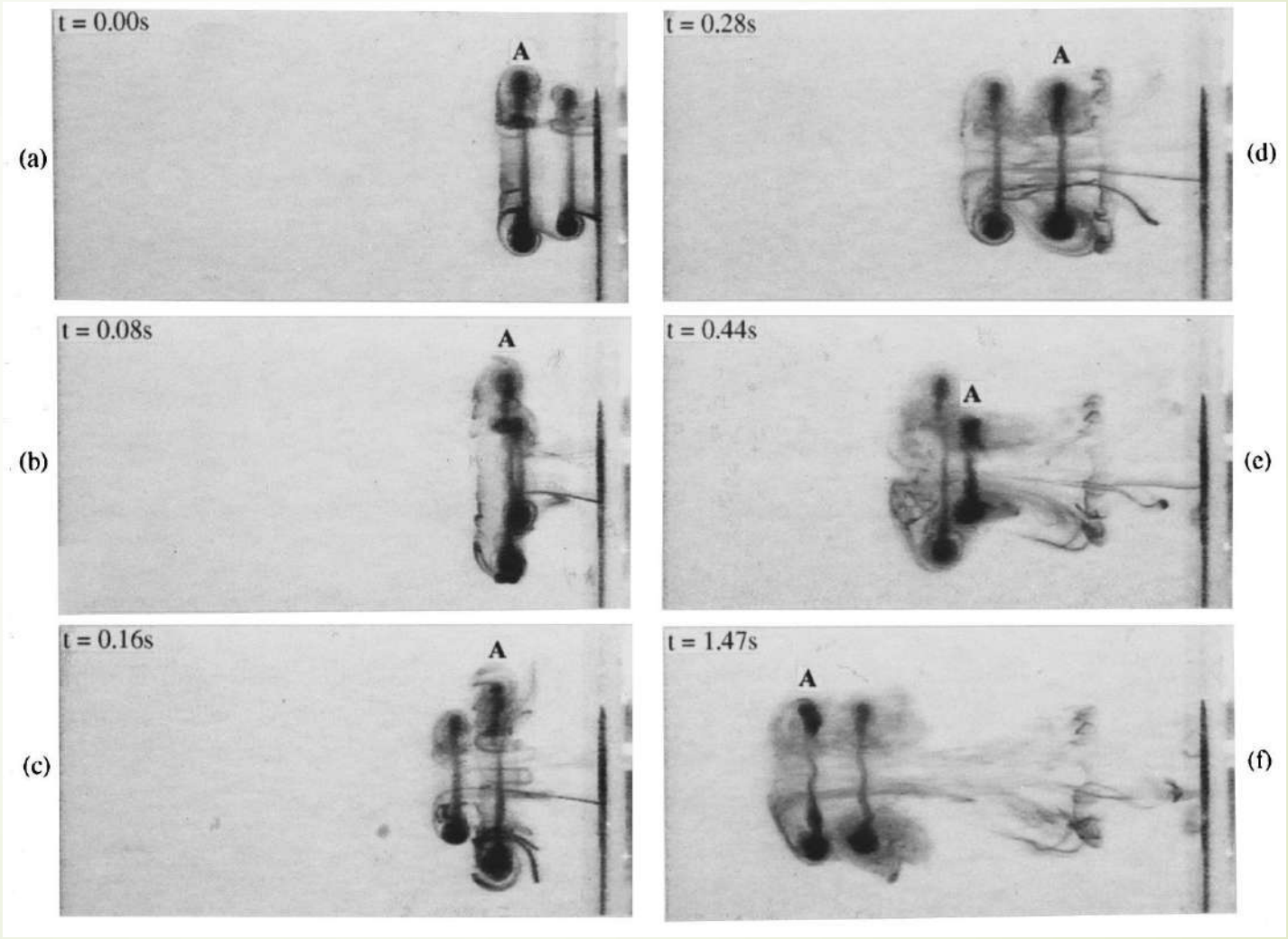


R_e based on ejection velocity and mouth diameter

T.T. Lim, Nat. Univ. of Singapore
http://serve.me.nus.edu.sg/limtt/index.html



R_e = 2780 [based on initial –isolated- ring velocity and mouth diameter] and piston slug/mouth diameter = 1.54



- ✓ Too many references come from Vortex© riffle artifacts
- ✓ Others come from Theory of Flight (helicopters & birds)
- ✓ They have also been investigated for military applications "The U. S. Army Limited War Laboratory has an interest in the potentialities of vortex rings in applications to problems of counterinsurgency.", 1966
- ✓ Animal propulsion in water
- ✓ How to: giant vortex rings generators http://makezine.com/projects/blow-smoke-vortex-cannons/

My vortex rings

From all the above to (my) firstly reported kitchen experiments

The experiments were essentially like this:

http://www.abc.net.au/science/surfingscientist/toroidalvortex.htm

VRs from falling drops have been described a bit before… 😐

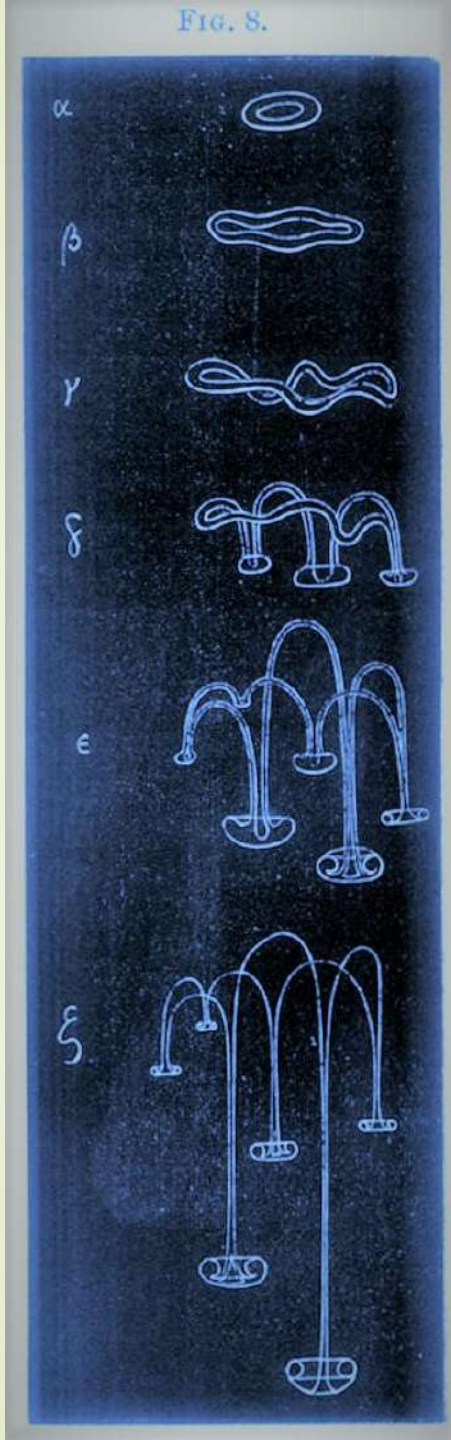
Theoretically by ***Helmholtz, H., 1867****,*
LXIII. "On Integrals of the hydrodynamical equations,
which express vortex-motion"

Philosophical Magazine Series 4, 33:226, 485-512

Experimentally by ***Thomson, J.J. and Newall H.F., 1885****,*
"On the formation of vortex rings by drops falling into liquids, and some allied phenomena"

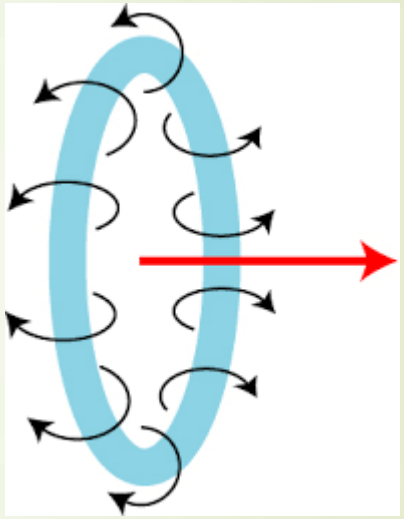
Proc. R. Soc. Lond. 39:417–36

Color edited



Excerpted from Thomson, J.J. and Newall H.F., **1885**

“When a drop of ink falls into water from not a great height, it descends through the water as a ring, in which there is evidently considerable rotation about the circular axis passing through the centres of its cross sections; … “



The criteria for the formation of VRs from falling drops have been elucidated quite recently by Lee et al., ["Origin and dynamics of vortex rings in drop splashing", Nature Communications, 6:8187, 2015]

(EXCERPTS quoted)
"Over the past two decades, the formation criterion for a vortex ring has been characterized by its **Weber number**:

$$W_e = ⑨DU^2/ ≪ < 64$$

where ⑨ is the liquid density, **D** is the drop diameter, **U** is the drop impact speed and ≪ is the surface tension of the liquid". Lee et al.'s "results show that this criterion is not correct and that a vortex ring can actually form, even for a large **We >64**"

The "criterion to determine whether a vortex ring forms is the **Ohnesorge number**, which relates the viscous forces to the inertial and capillary forces as:

$$O_h = μ/(⑨D≪)^{½}$$

with μ as the dynamic viscosity of liquid, rather than the Weber number… …An investigation of a wide range of liquids using water, glycerol and ethanol mixtures shows that **the vortex rings formed only for Oh < 0.011**."

Illustration of the formation of VRs from falling drops

Lee et al., "Origin and dynamics of vortex rings in drop splashing"
Nature Communications, 6:8187, 2015

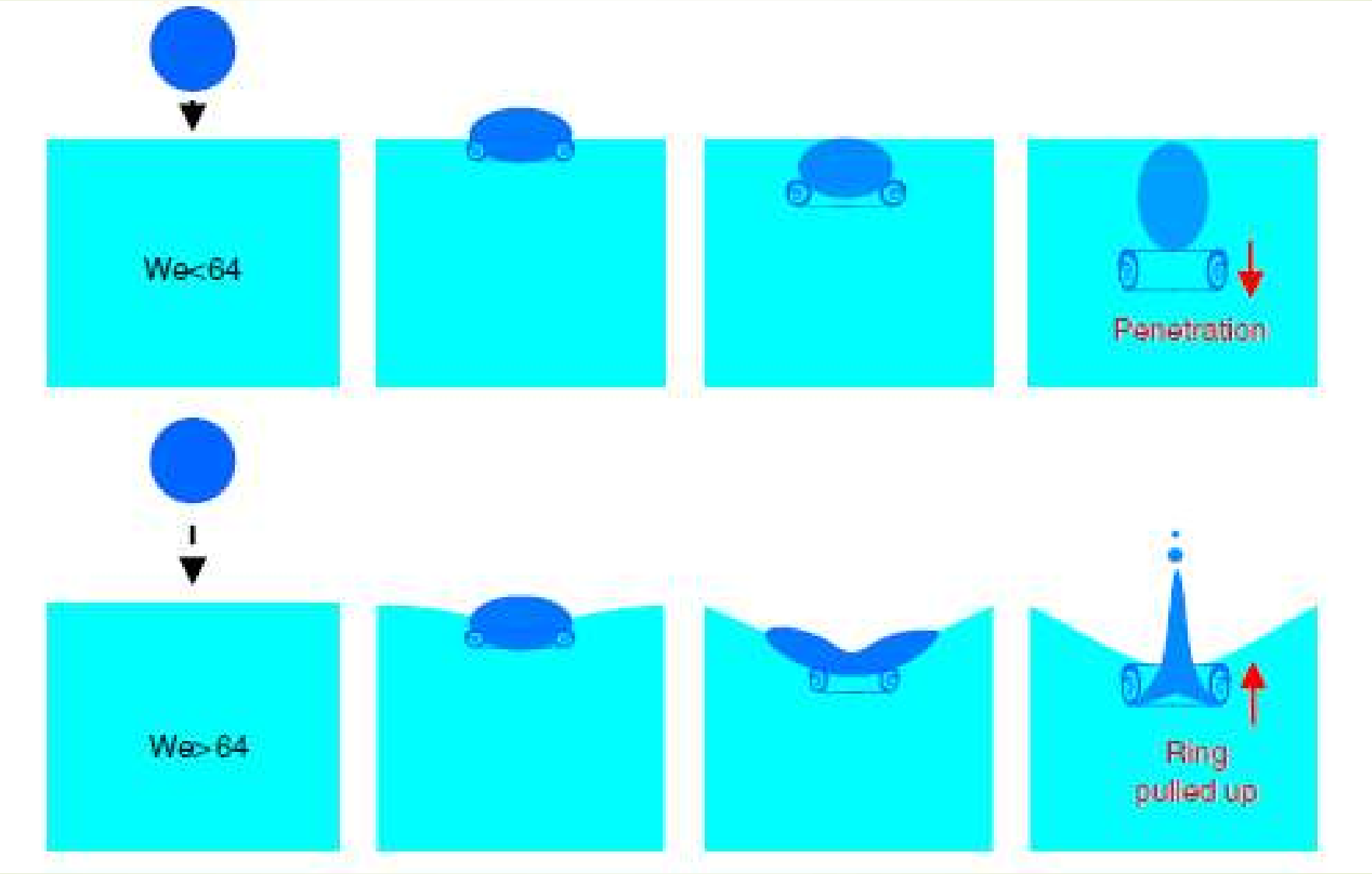
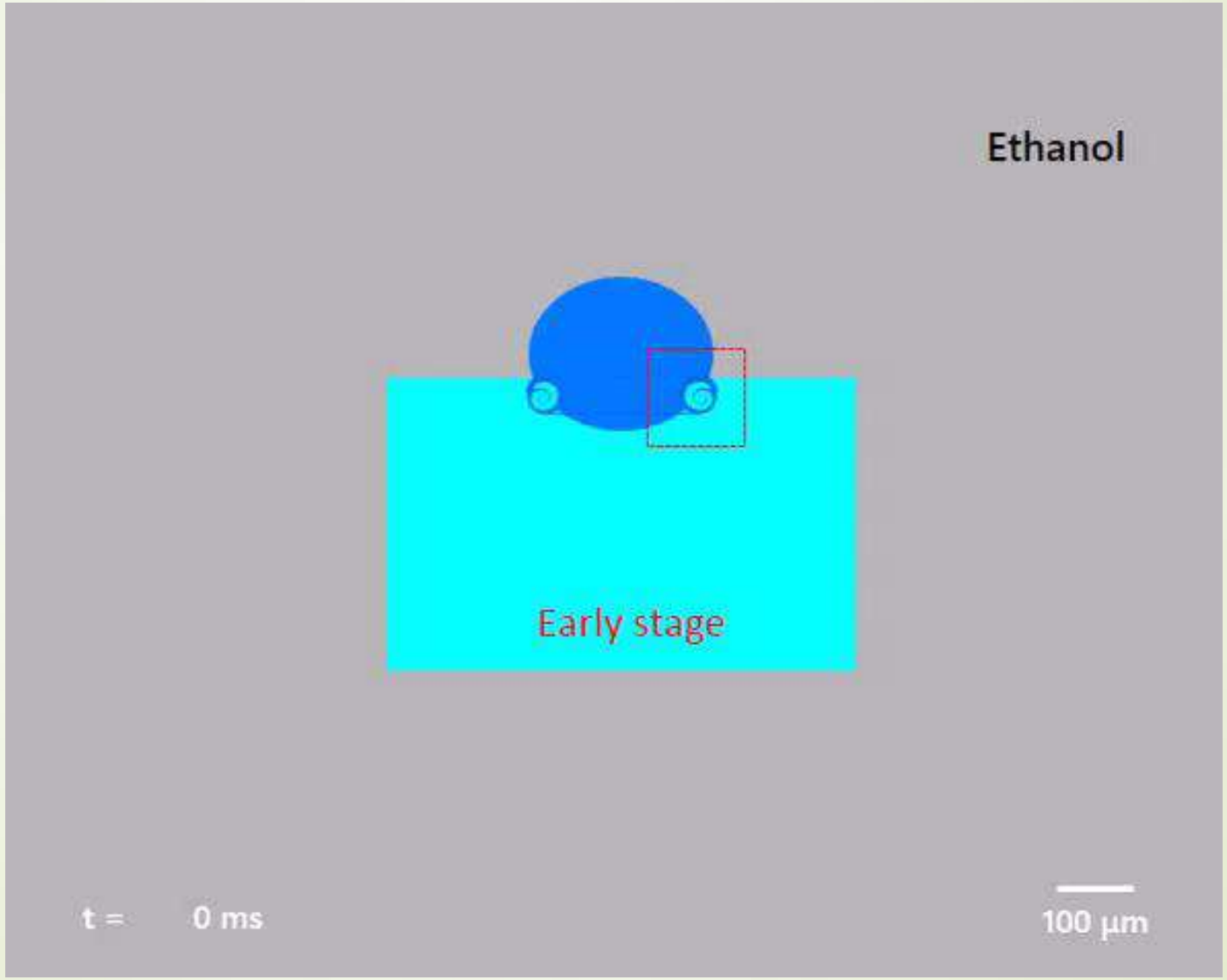


Illustration of the formation of VRs from falling drops

Lee et al., "Origin and dynamics of vortex rings in drop splashing"

Nature Communications, 6:8187, 2015



Are “VORTEX RINGS + Walls” popular in the WWW ?

According to Google Scholar©, accessed October 2019:

Searched ”vortex rings”

- ✓ Google web all times: aproximadamente 17900 refs
- ✓ G Scolar from 2018: 1750
- ✓ G Scolar from 1700 to 1973: 1460
- ✓ G Scholar from 1973: 17100
- ✓ G Scholar in 1973: 112
- ✓ Google Scholar: 23500

Searched "vortex rings" + vicinity + wall

- ✓ from 2018: 304
- ✓ All times: 3490
- ✓ en 1973: 18
- ✓ desde 1700 a 1973: 176

WHY 1973 ?

(BECAUSE OF MY SECOND PAPER)

"Behavior of Vortex Rings in the Vicinity of a Wall"

U. Boldes and J.C. Ferreri,

The Physics of Fluids, 16, pp. 2005-2006, 1973

http://dx.doi.org/10.1063/1.1694246

WHY THIS COMMUNICATION ?

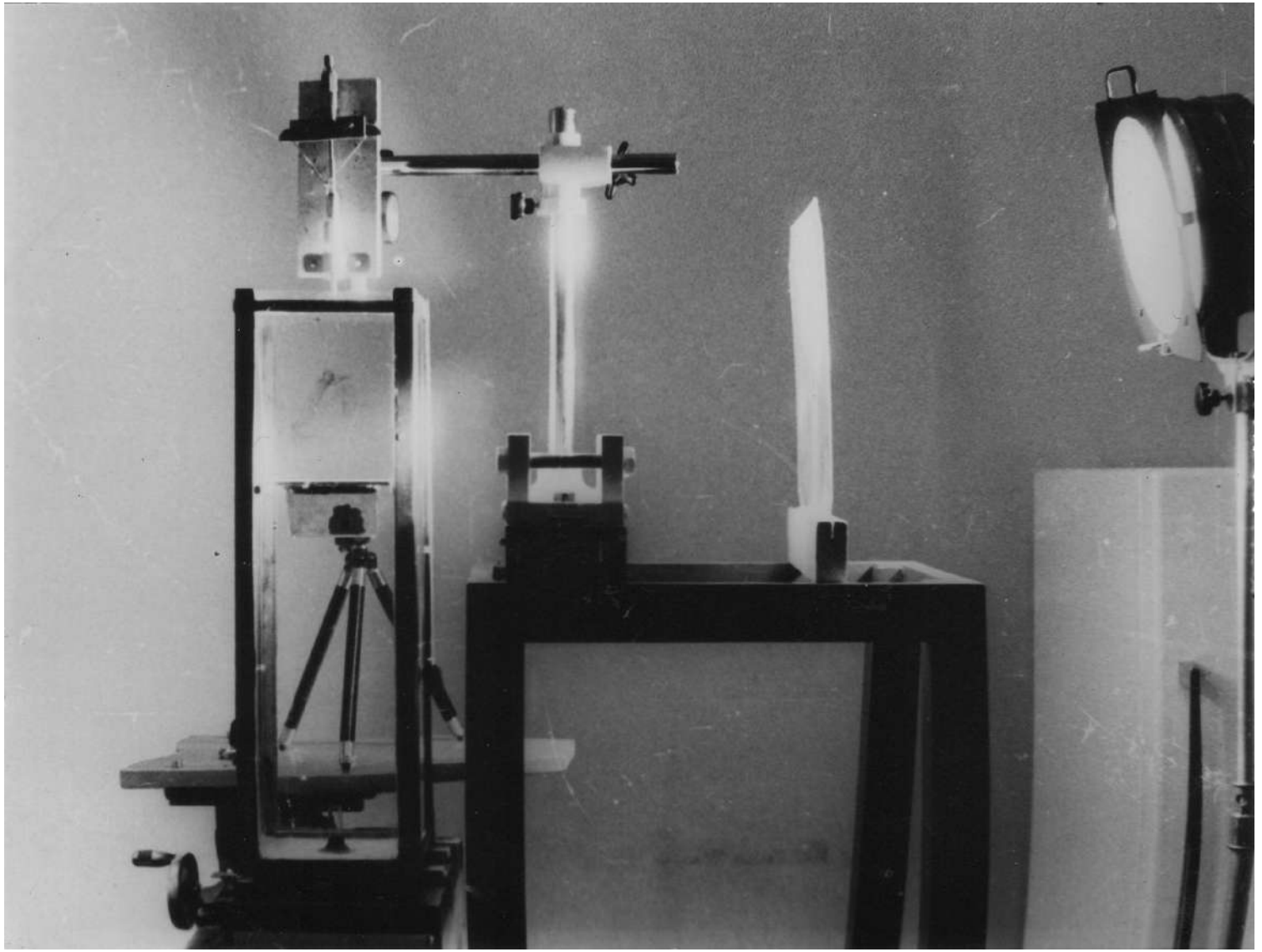
Because this curious aspect got 53 CITES STARTING IN 1976 AND UP TO 2019

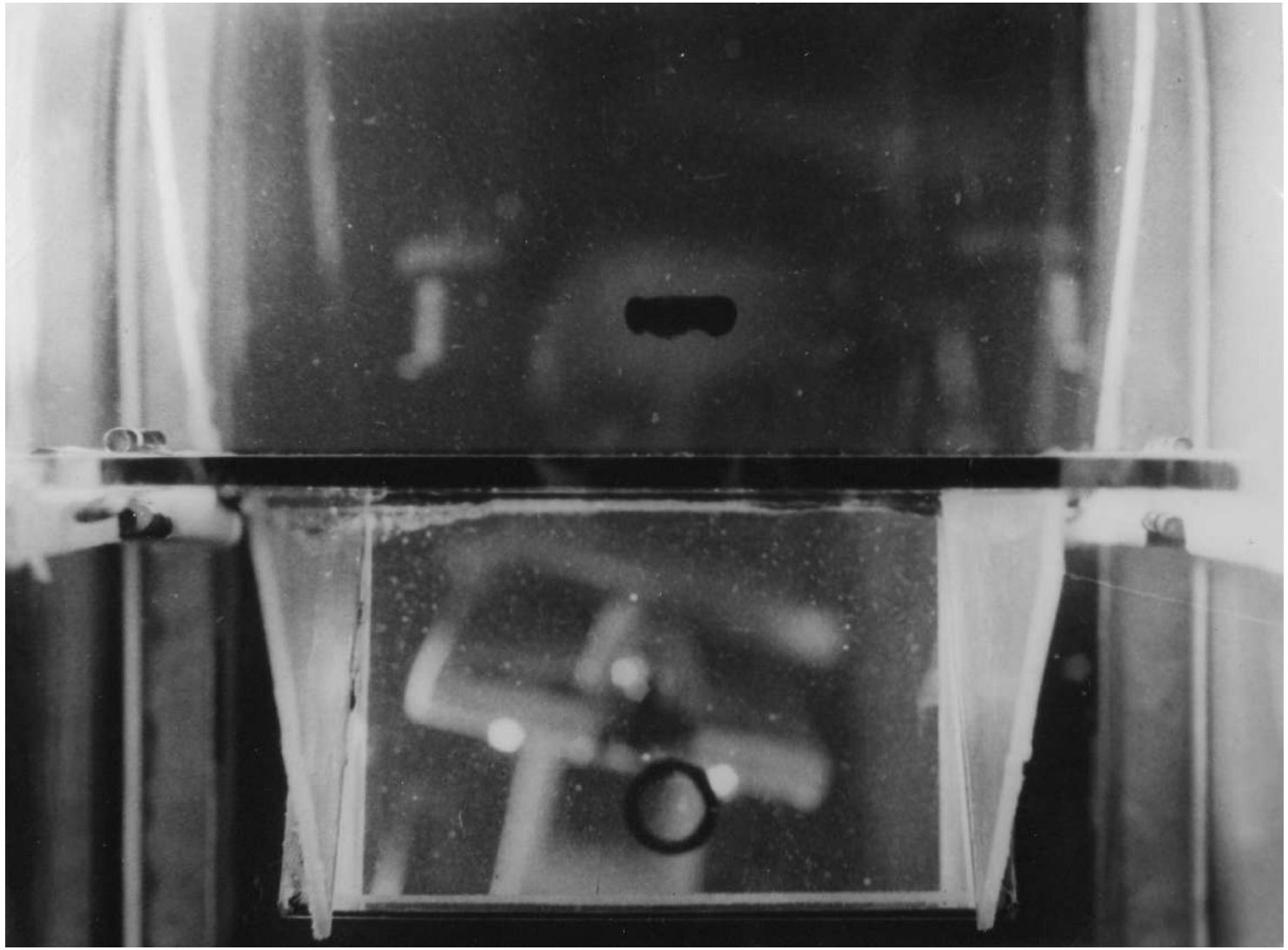
Obviously, this number is not huge.
However, considering the attractive subject and its exotic applications in present day physics, I considered its “celebration” worth doing.

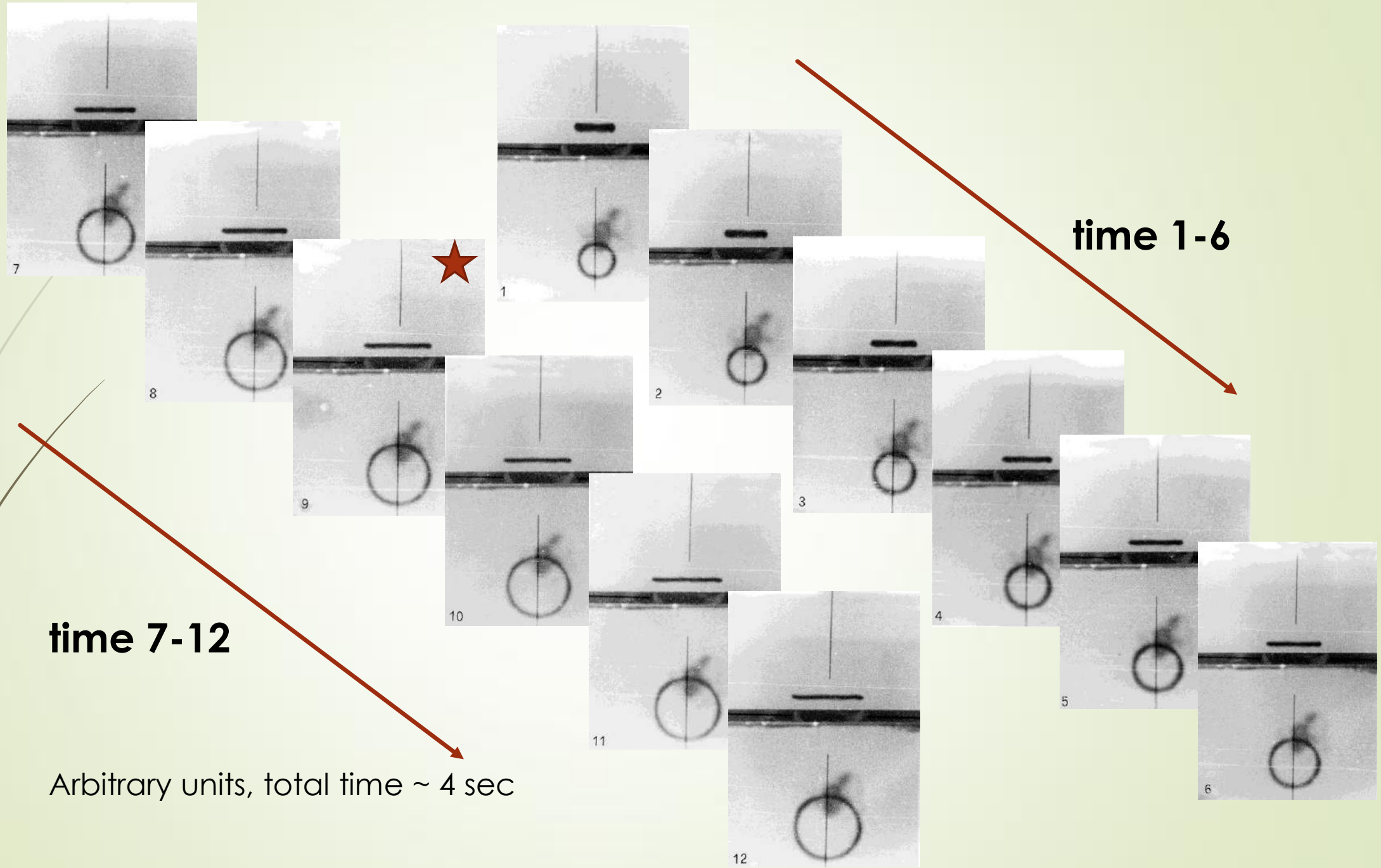
Preparing this presentation I have found a reference from 1964, the oldest one I think exists on this subject (VRs + wall), but focusing on other aspects, like stability and “disintegration” of the ring

By the way, the paper by Prandtl in 1904, founding of boundary layer theory only gets the absurdly low number of nearly 4000 references!!

I performed the first experiments in ~1971 in order to teach to the Fluid Mechanics students about the peculiarities of vortex dynamics. The device was very simple and, because of the transparent wall I realized that the interaction near the wall was not (could not be) described in the available literature in terms of classical theory. The first findings were –almost literally- “kitchen experiments” performed at the Departamento de Aeronáutica, FI-UNLP. Later, Ing. Jorge (“el Conde”) Sforza was my effective and efficient camera operator)







Arbitrary units, total time ~ 4 sec

After this first visual observation we (Prof. Ulfilas Boldes and me) proceeded to perform additional experiments, made detailed movies, measured picture by picture and explained the phenomenon in the terms of the quoted reference.

We introduced the word “rebound” for the first time to describe the momentary inversion of movement of the ring. It has been used by many of the researchers that followed us.

The Originally Reported Experiment

(annotated figure)

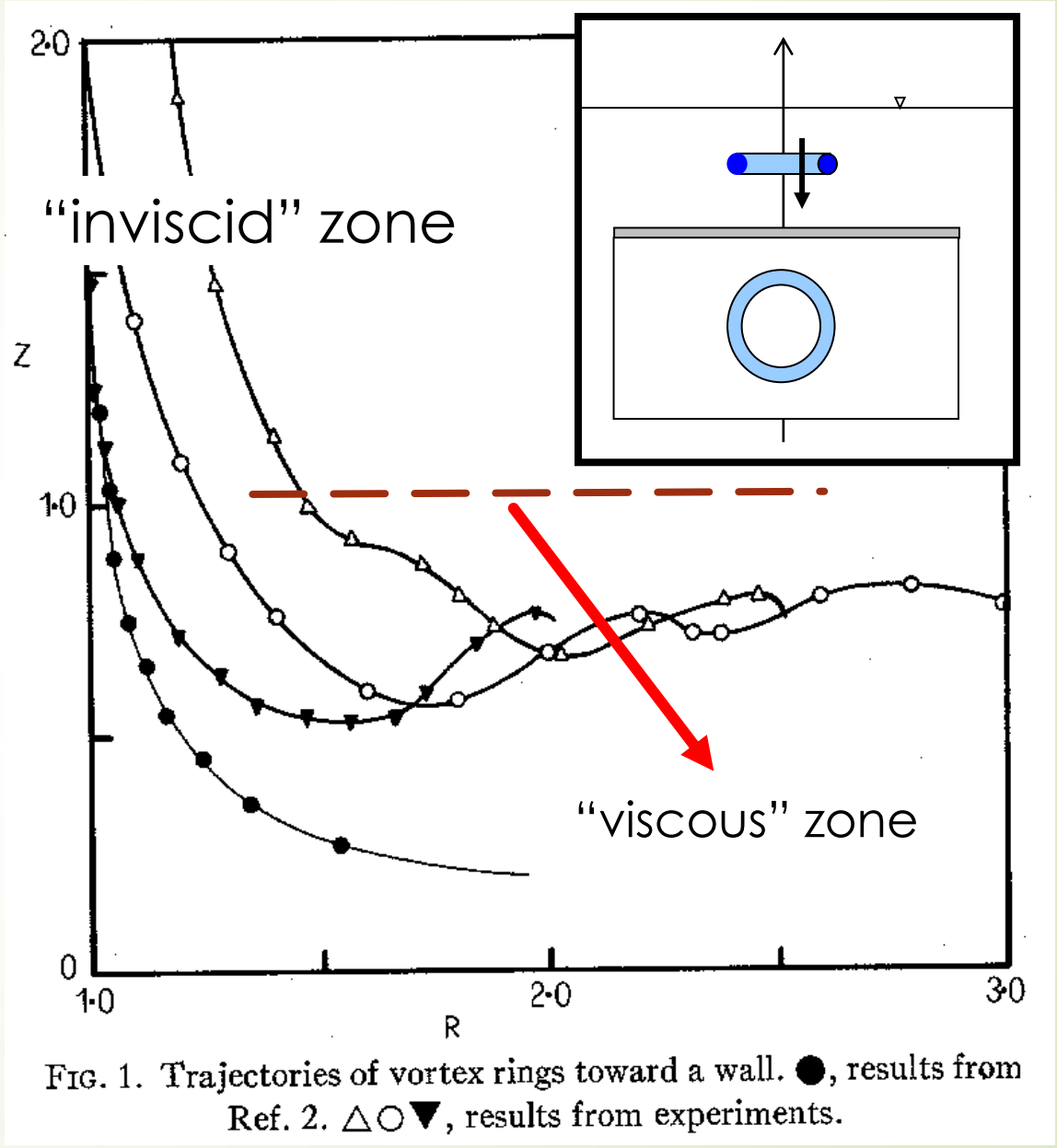


FIG. 1. Trajectories of vortex rings toward a wall. ●, results from Ref. 2. △○▼, results from experiments.

UB had the clever idea of using a non-colored ring and distributing dye on the horizontal wall to visualize the shear layer…

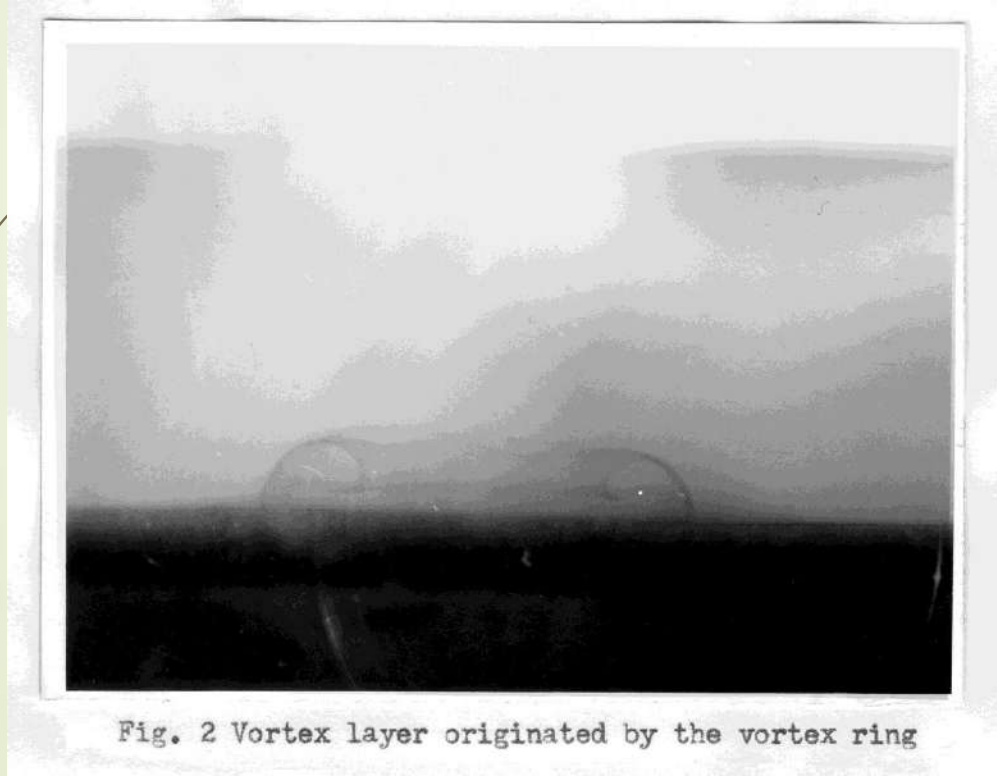


Fig. 2 Vortex layer originated by the vortex ring

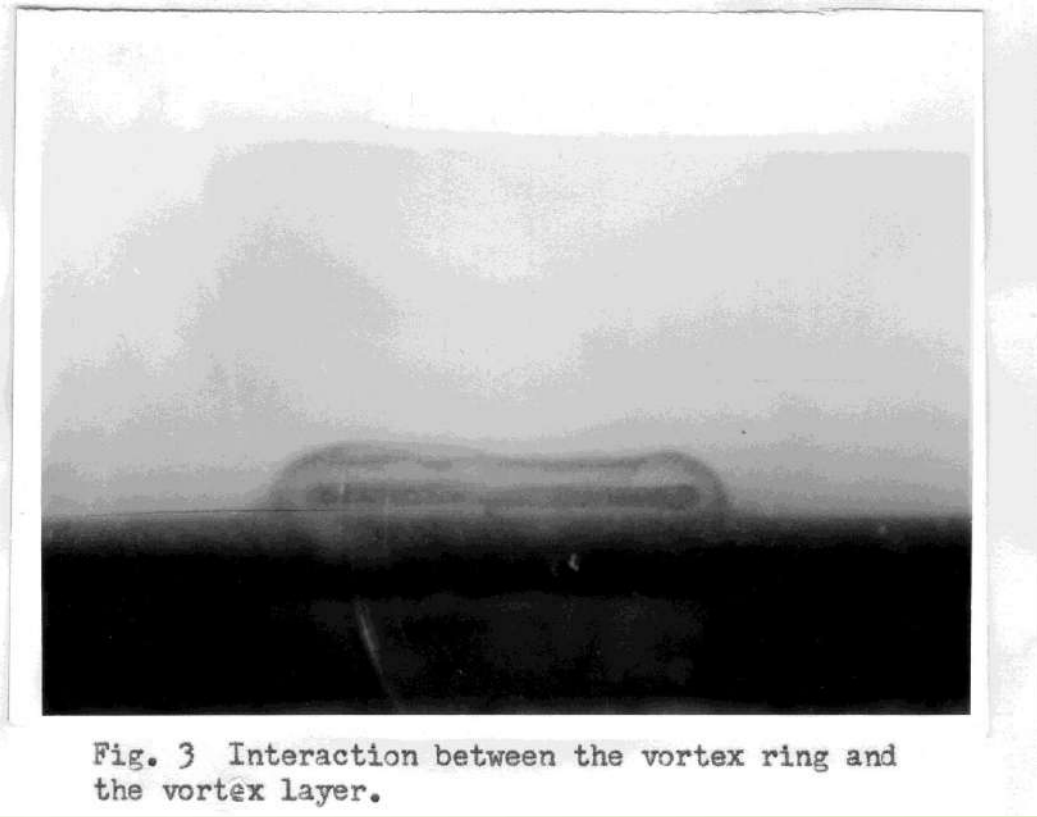
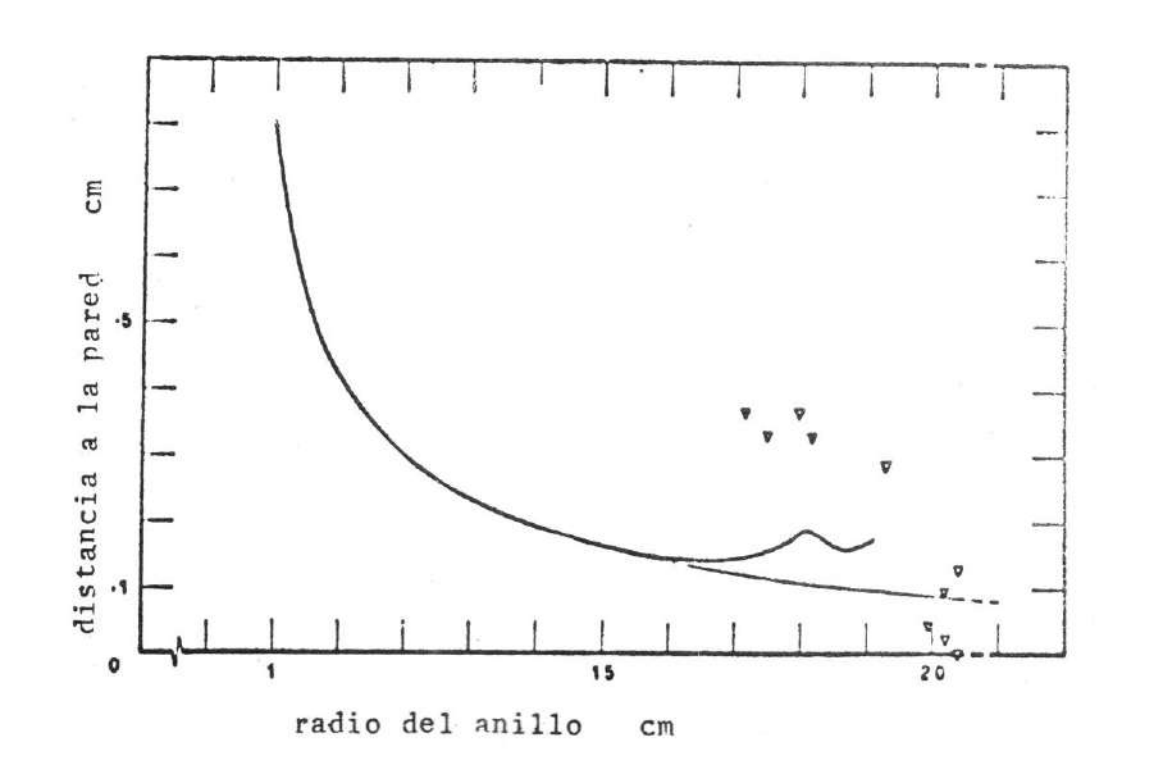


Fig. 3 Interaction between the vortex ring and the vortex layer.

In passing, it may be mentioned that we also performed a simplified numerical simulation of the folding shear layer using vortex rings, but it was not accepted by the referees because it was too “simplistic”.



I was young by those days but I still remember this…
I wonder whether the limitations of Ockham’s razor concept application should be considered…

The dots represent the position of the ejected VRs that simulated the vortex layer at the instant of the first rebound, at maximum VR height.

Boldes, U. and Ferreri, J.C., “Sobre el comportamiento de un anillo vorticoso en las cercanías de una pared”, in Spanish, Pub. 182, Depto. De Aeronáutica, FI-UNLP. 1972

Again, a nice and modern version of our experiment

T.T. Lim, Nat. Univ. of Singapore
http://serve.me.nus.edu.sg/limtt/index.html

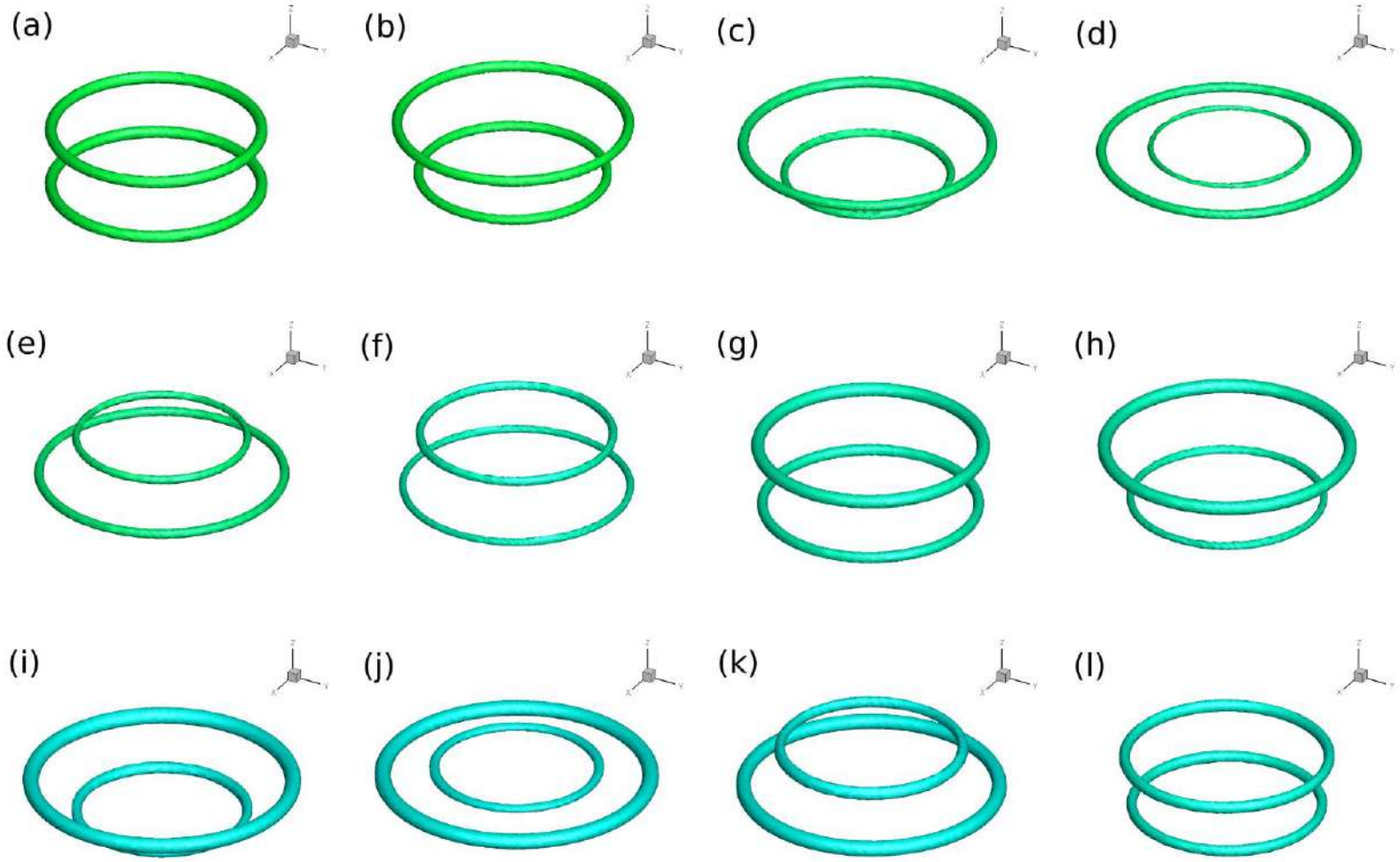
Numerical simulations of this phenomena proliferate…

An interesting and elucidating example is:

Numerical Simulation of Vortex Ring Interactions with Solid Wall
D. Ghosh and J. D. Baedery

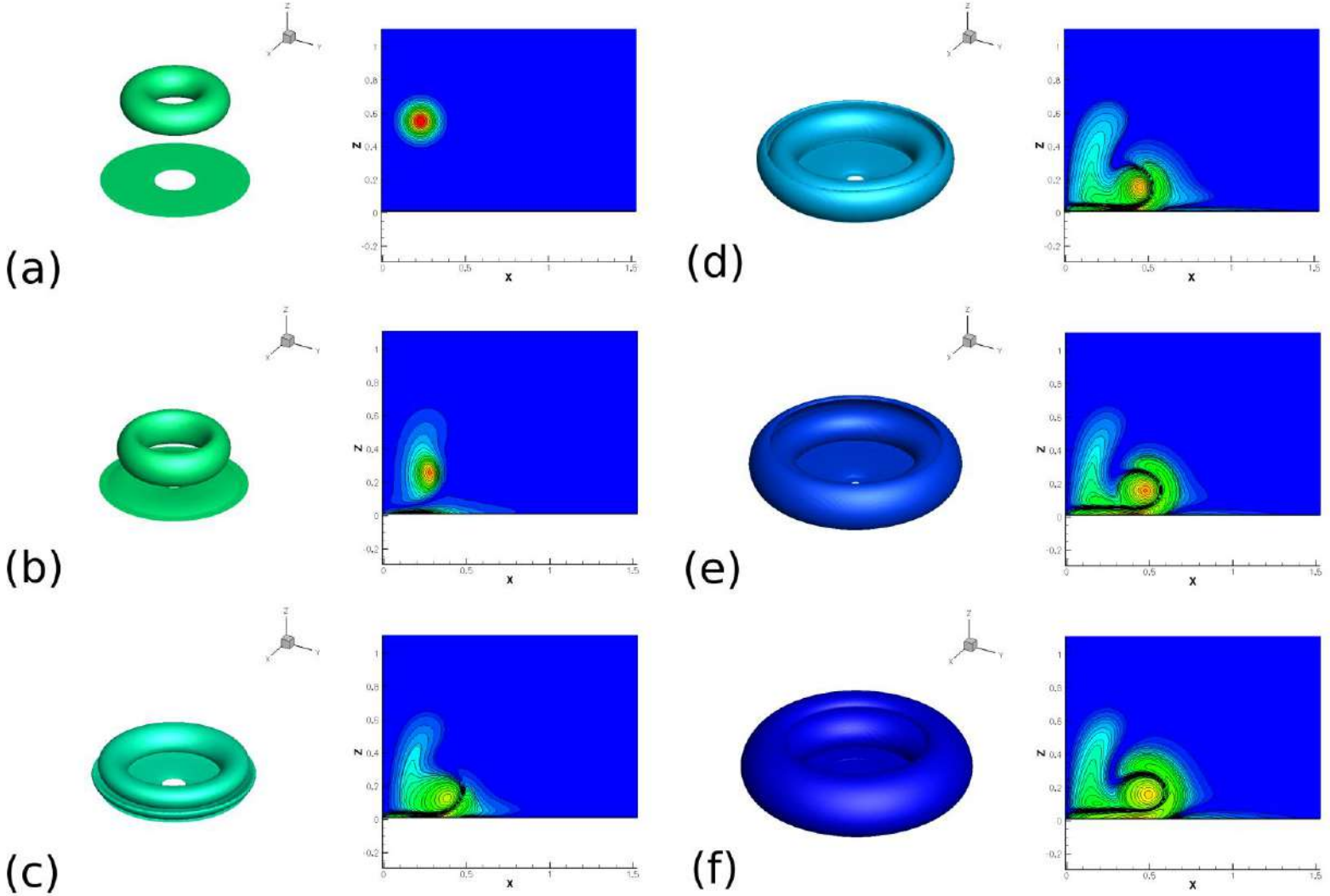
49th AIAA Aerospace Sciences Meeting including the New Horizons Forum and Aerospace Exposition, 4 - 7 January 2011, Orlando, Florida

Numerics…



Leapfrogging…

Numerics…



Interaction with a wall

CONCLUSIONS

- The interest in a singular aspect of vortex rings viscous interaction with a wall reported in 1973 seems still prevailing, including unsuspected fields in physics
- The authors, Prof. U. Boldes and me, are somewhat surprised and happy by this continuous citing along the years
- Anyway, we think that, in some cases, cites simply come from the somewhat new “journals standards” regarding citing completeness

but ☺ …

Thanks for attending

and

for your attention