# The Abdus Salam International Center for Theoretical Physics

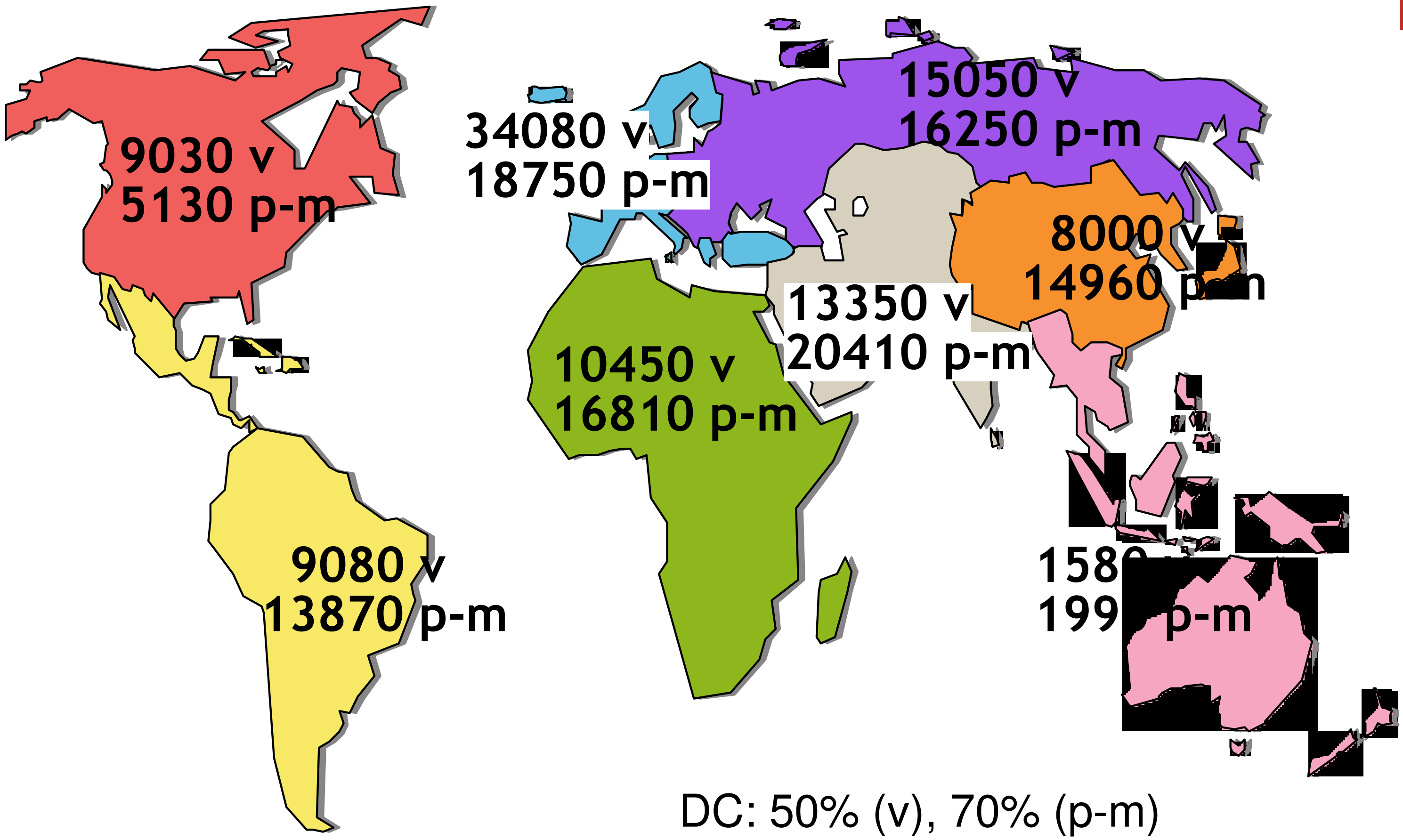
ICTP operates under a tripartite agreement between two United Nations Agencies—UNESCO and IAEA—and the Government of Italy.

Presidenza del Consiglio dei Ministri

IAEA.org International Atomic Energy Agency

UNESCO United Nations Educational, Scientific and Cultural Organization

# ICTP VISITORS STATISTICS, 1970-2006




DC: 50% (v), 70% (p-m)

| area | visitors | p-m |
|---|---|---|
| North America | 9030 | 5130 |
| Latin America | 9080 | 13870 |
| Western Europe | 34080 | 18750 |
| Eastern Europe | 15050 | 16250 |

| area | visitors | p-m |
|---|---|---|
| Africa | 10450 | 16810 |
| Middle East and South Asia | 13350 | 20410 |
| South East Asia and the Pacific | 1580 | 1990 |
| Far East | 8000 | 14960 |

v=visitors    p-m=person-months

ICTP Public Information Office, February 2007

# ICTP Scientists, Visitors and their Functions

ICTP Scientists, Visitors and their Functions

| | | |
|---|---|---|
| research and training coordination | 30 | permanent scientists |
| mostly research | 100 | temporary scientific staff: post-docs, staff associates, long-term visitors |
| do own or collaborative research, or receive training through participation | 420 | short-term visitors: associates, guest scientists |
| receive training through schools, conferences, and exchange of information | 4000-6000 per year<br>6441 in 2004 | participation in conferences, schools and workshops; diploma students |

+ about 140 general staff

# Programs at ICTP

**Diploma (ICTP),**

**Masters (with Italian partners)**

**Ph.D. (both Italian University system and SANDWICH).**

**Post-doctoral appointments**

**Associateships**

**TRIL fellowships**

**Schools; Colleges; Workshops; Conferences**

**Electronic access to scientific literature**

**Support for regional conferences, often with other donors***

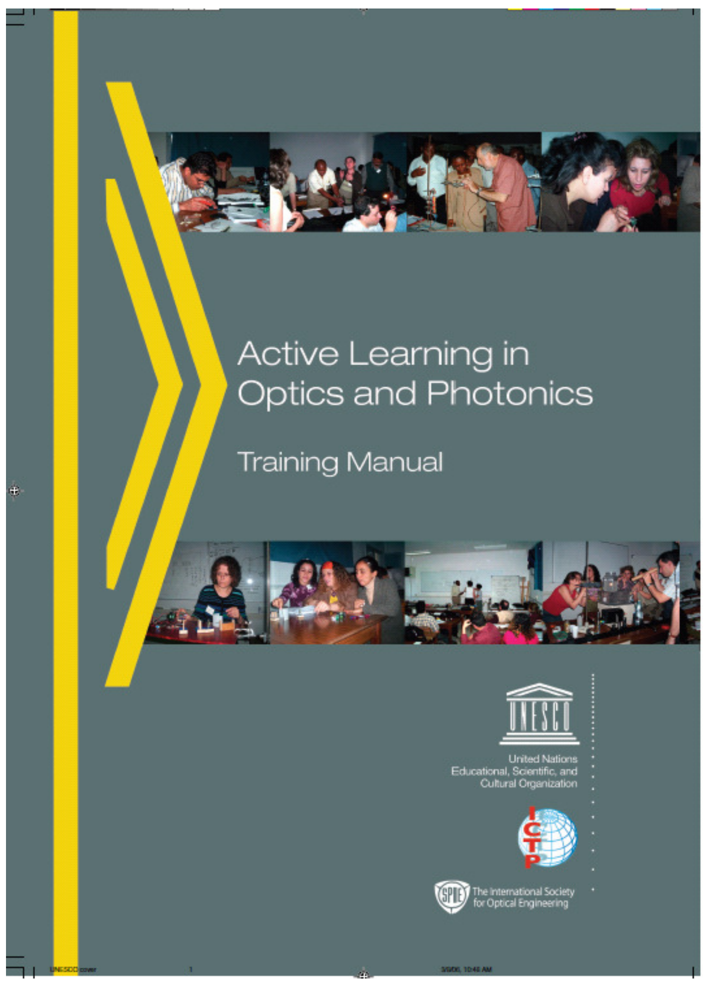
***Many thanks here to Central European Initiative (CEI) for their support**

# New UNESCO Chair in Bucharest

## For Sustainable Development
## through Research and Education in Modern Physics

Horia Hulubei Foundation / Fundatia Horia Hulubei (FHH)

# On the road with UNESCO's ALOP program




With stops at:

Philippines
Ghana
Tunisia
Morocco
Mexico
Brazil
Chile
Tanzania
Cameroon
Zambia
India
Nepal
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.
.

In its efforts to promote creativity and innovations in the way introductory physics is taught at the university level, UNESCO has supported activities in different developing countries to address the need for teacher upgrading and to introduce innovative learning approaches.

In recent years, the focus in workshops for teacher trainers has been on the *active learning approach.* This has included the development of teaching and learning materials that incorporate this approach.

The introduction of active learning in physics in developing countries is especially encouraged by UNESCO because it fosters hands-on laboratory work, promotes conceptual
learning and encourages instructors to do research in physics education that may lead to a significant improvement in their students' learning.

Most of the activities described here are derived from the Real-Time Physics ® program developed in the US by David Sokoloff, Ron Thornton and Priscilla Laws. Sokoloff is a member of the ALOP team.

## Why Active Learning?

Active learning in physics, developed over the last decade, has been demonstrated in the United States and other developed countries to enhance student understanding of basic physics concepts. In this learning strategy, students are guided to construct their knowledge of physics concepts by direct observations of the physical world.

Use is made of a learning cycle including 1) predictions, 2) small group discussions, 3) observations and 4) comparison of observed results with predictions. This learning cycle can also be represented as *PODS—Prediction, Observation, Discussion and Synthesis.*

In this way, students become aware of the differences between the beliefs that they bring into the introductory physics classroom, and the actual physical laws that govern the physical world.

Table I-1: Passive vs. Active Learning Environments

| Passive Learning Environment | Active Learning Environment |
|---|---|
| Instructor (and textbook) are the authorities--sources of all knowledge. | Students construct their knowledge from hands-on observations. Real observations of the physical world are the authority. |
| Students' beliefs are rarely overtly challenged. | Uses a learning cycle in which students are challenged to compare predictions (based on their beliefs) to observations of real experiments. |
| Students may never even recognize differences between their beliefs and what they are told in class. | Changes students' beliefs when students are confronted by differences between their observations and their beliefs. |
| Instructor's role is as authority. | Instructor's role is as guide in the learning process. |
| Collaboration with peers often discouraged. | Collaboration and with peers is encouraged. |
| Lectures often present the "facts" of physics with little reference to experiment. | Results from real experiments are observed in understandable ways. |
| Lab work, if any, is used to confirm theories "learned" in lecture. | Laboratory work is used to learn basic concepts. |

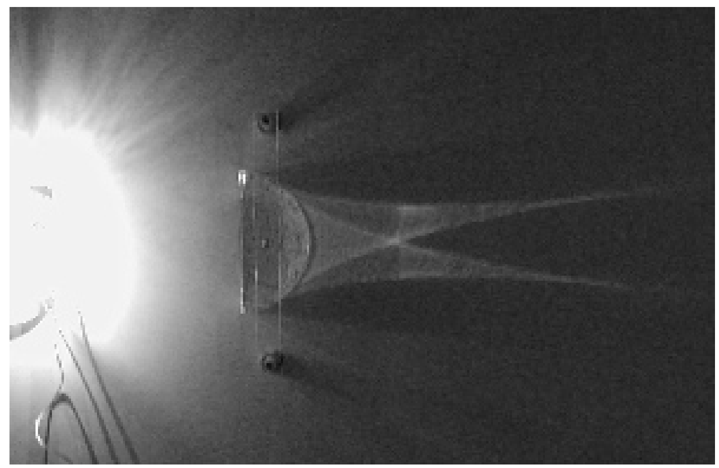
Of critical importance is the change in the role of the instructor when active learning materials are introduced into the classroom. In both the developed and developing worlds, it can be challenging for a physics instructor to pull back from thier traditional role of explaining everything as the authority, to a role as guide through active learning materials.

For this transition to be successful requires acceptance of the evidence that introductory students often do not learn effectively even from the most logical explanations by their instructors

The ease of this transition is dependent not only on a willingness to give up the role of authority, but also on a number of cultural factors that differ from country to country. This is the ultimate challenge in presenting active learning training workshops in different parts of the developing world, and is one important reason why recruitment and training of local trainers has been incorporated into this project.

# The problem of large classes

Most physics students in the world continue to be taught in lectures, often in large lectures with more than 100 students (200 is typical in many universities). It is necessary to design a strategy to make learning in large classes more “active.” This has led to the development of a teaching and learning strategy called *Interactive Lecture Demonstrations (ILDs)*



ILDs on image formation (above) are a good demonstration of the fact that significant learning gains can be brought about with low-cost materials. The cylindrical lens can be fabricated with a transparent plastic jar filled with water. In addition to this, only two flashlight bulbs in sockets and a 9 V battery are needed.

# Active Learning in Optics and Photonics

The original set of active learning activities in these UNESCO sponsored programs covered a range of physics topic areas, including mechanics, heat and thermodynamics and electricity.

Active learning in optics has the advantage of a favorable cost/benefit ratio. Furthermore, as the basis of many modern advances in high technology, optics is an “enabling science,” and it is hoped that improving optics and photonics education will result in a viable and well-educated workforce for emerging industries in African countries and other developing nations where specific skills in this area will be needed.

The *Active Learning in Optics and Photonics* (ALOP) project was conceptualized and begun by UNESCO in 2003. UNESCO coordinates and funds the project, with additional support from the Abdus Salam International Center for Theoretical Physics (ICTP), and the International Society for Optical Engineering (SPIE). The focus of the project is on one of the experimental physics areas that is relevant and adaptable to research and educational conditions in many developing countries.

Other organizations that have contributed are: the American Association of Physics Teachers (AAPT), the National Academy of Sciences (US), the Association Francaises de l’Optique et Photonique, and Essilor.

# ALOP modules for a 5-day course

Module 1: Introduction to Geometrical Optics
Module 2: Lenses and Optics of the Eye
Module 3: Interference and Diffraction
Module 4: Atmospheric Optics
Module 5: Optical Data Transmission
Module 6: Wavelength Division Multiplexing

In general, we have found the following structure to be successful:

- 1/2 day for introductions—both participants and resource people.
- 1/2 day for introduction to workshop goals and active learning, pre-test, and a brief session to prepare workshop materials.
- 3 days for hands-on work with the modules.
- 1/2 day for touring both teaching and research facilities.
- 1/2 day for wrap-up discussions and post-test.

## Lessons we are learning…

"Anyone who attends international conferences quickly discovers that physics educators from other countries share many of the same challenges and frustrations. But, in addition, educators throughout the developing world have to cope with severe resource limitations that limit their access to basic equipment, computer technology, and professional development opportunities." – *Priscilla* Laws, Dickinson College, writing about the ALOP program

### Some commonly voiced problems:

- Large classes of 200 or more—how to do hands-on activities?
- Chaos in the classroom—what if my director walks in?
- Isolation—need for networking
- Equipment— expensive to supply to small groups limited to 3 and if it breaks will it be fixed or repaired?

Need to continually develop the LOCE—*light and optics conceptual evaluation*-- to gauge effectiveness of the methods. Such tests are an integral part of the physics education research (PER). Language can be a problem in accessing conceptual understanding on multiple choice tests.

Follow-up is crucial for success—which is measured by its sustainability. There is a need to identify and train new facilitators. These people need to be enthusiastic and self-motivated. In return, the ALOP team offers support year-round (including manuals, equipment, materials, etc.) as well as leaving behind complete kits and manuals after a UNESCO workshop.

**ALOP has had enormous success in recruiting resource people and having them conduct follow-on workshops. The Manual has been translated into French and Spanish.**

Final observation:
Any newcomer is always impressed by the hard work of teachers in these workshops under adverse conditions. The first workshop in Cape Coast Ghana was conducted without electricity for ½ of the activities—meaning battery powered circuits and no cooling fans in a darkened room for 8 hours each day.

# Original ALOP Facilitators

Zohra Ben Lakhdar
University El Manar, Tunisia

Ivan B. Culaba
Ateneo de Manila University, Philippines

Vasudevan Lakshminarayanan (Vengu)
University of Waterloo, Canada

Joel T. Maquiling
Ateneo de Manila University, Philippines

Alex Mazzolini
Swinburne University of Technology, Australia

David R. Sokoloff
University of Oregon, USA

Minella Alarcon, UNESCO Paris; J. Niemela, ICTP, Trieste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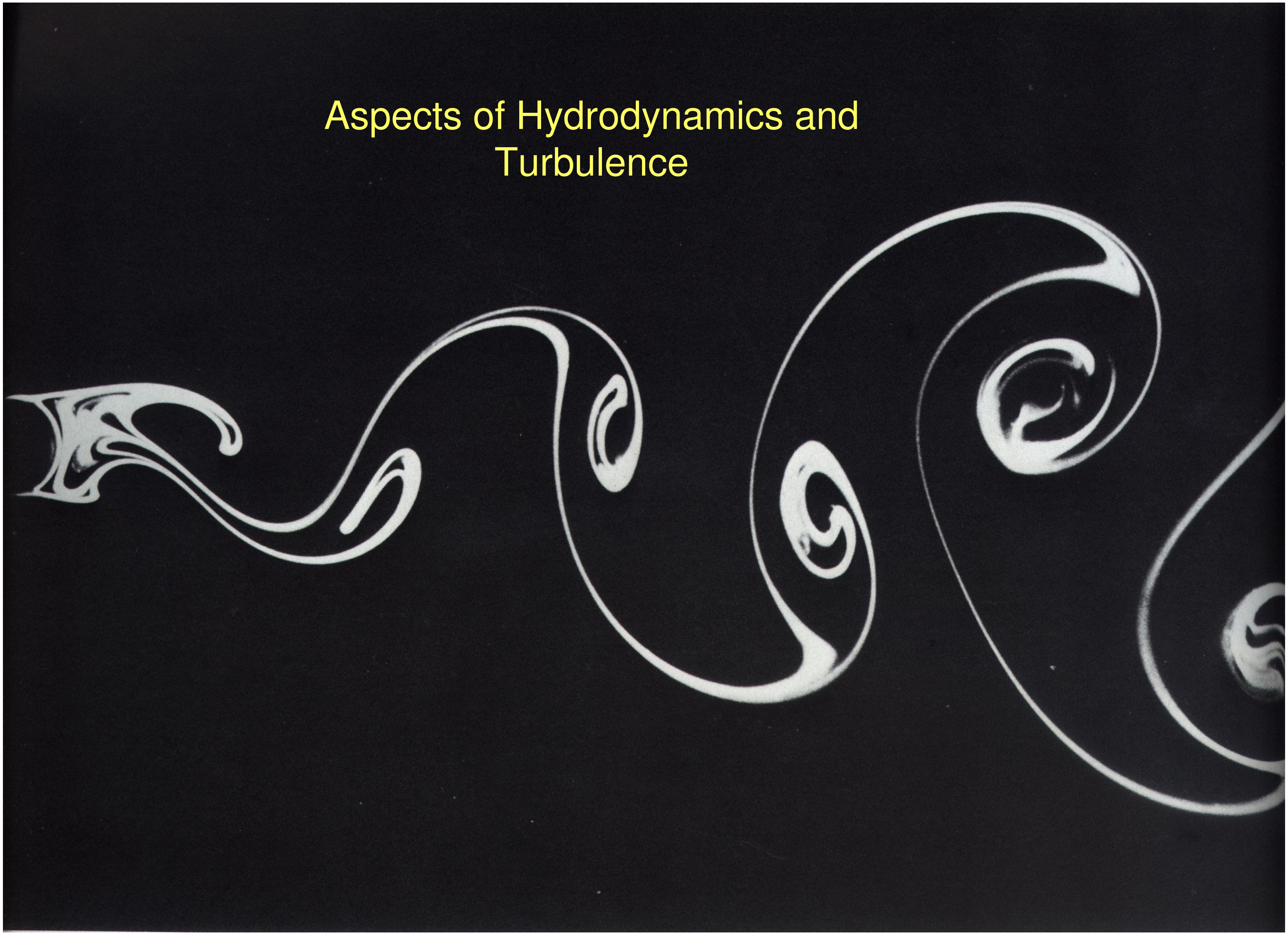
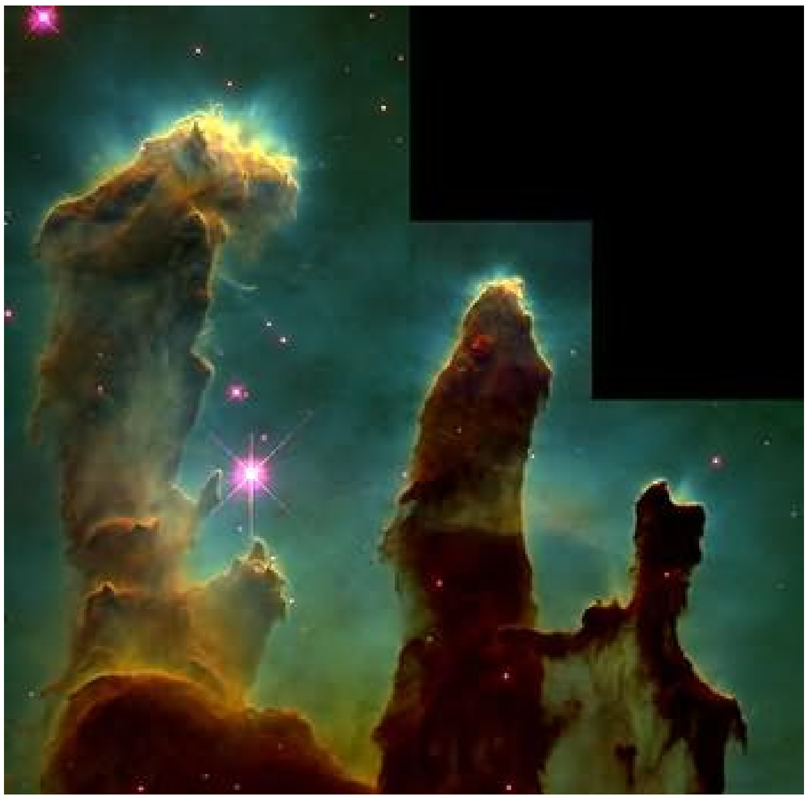
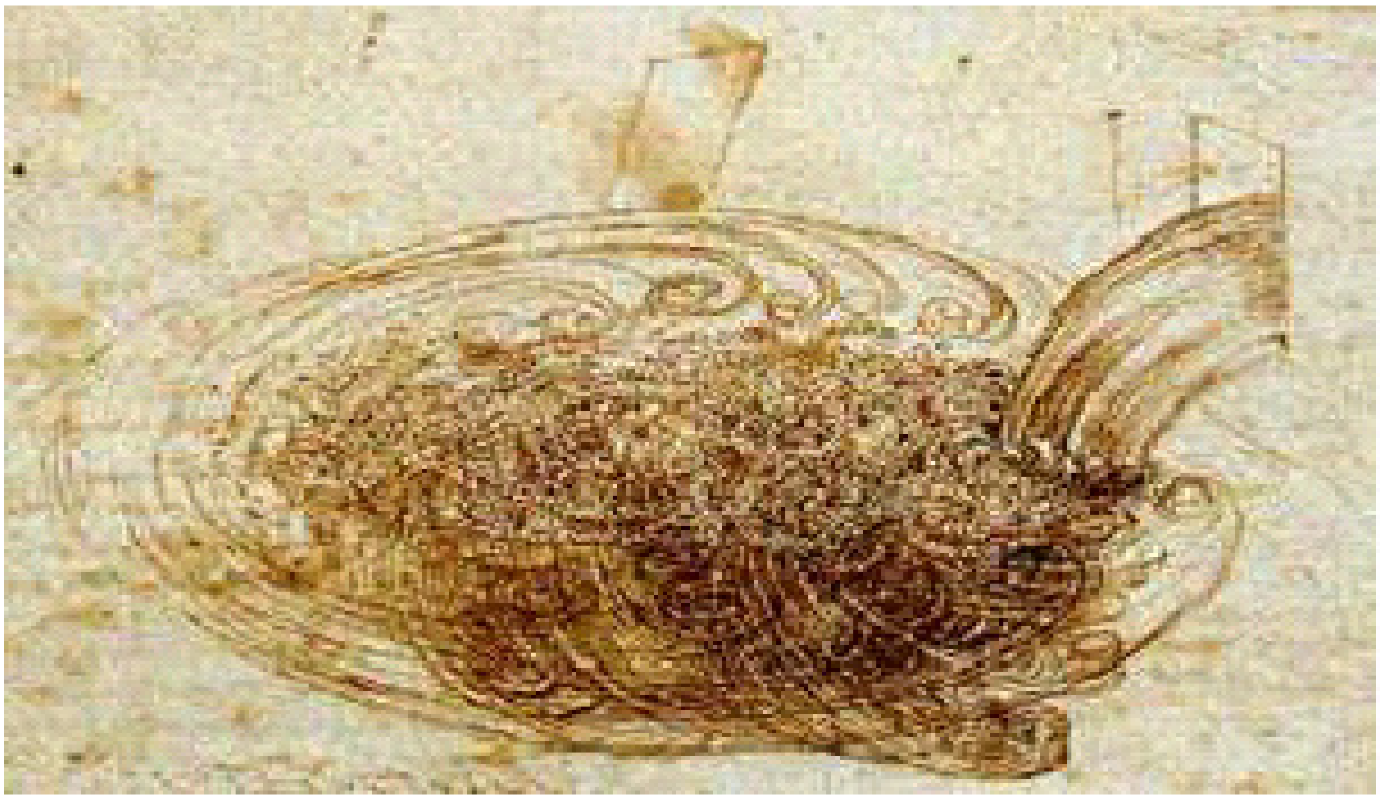
# Aspects of Hydrodynamics and Turbulence



*"Perhaps the fundamental equation that describes the swirling nebulae and the condensing, revolving, and exploding stars is just a simple equation for the hydrodynamic behavior of nearly pure hydrogen gas".* -- Richard Feynman



Turbulence is widespread, indeed almost the rule, in the flow of fluids. It is a complex phenomenon, for which the development of a satisfactory theoretical framework has been one of the greatest unsolved challenges of classical physics.

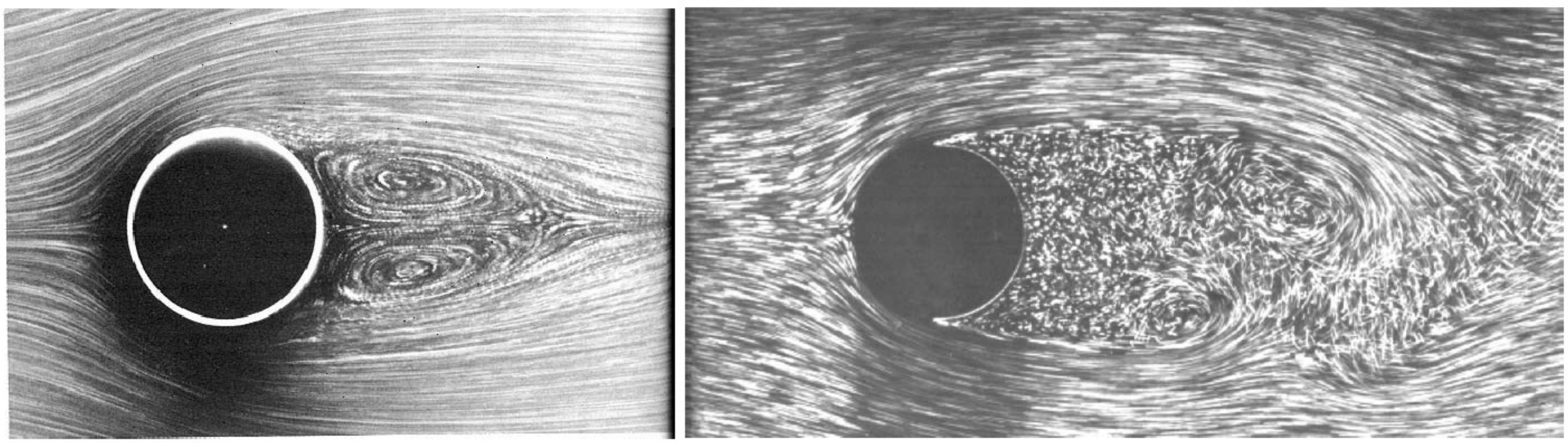


The first scientific investigations of fluid turbulence are generally attributed to Leonardo Da Vinci.

In dimensionless form the Navier-Stokes equation* describing simple pressure driven flows (including turbulence) contains only one parameter– the Reynolds number

$$Re = UL/\nu$$

Here, U, L, and $\nu$ are the characteristic velocity, length scale and kinematic viscosity associated with a flow. The Reynolds number expresses the ratio of **inertial** (resistant to change or motion) forces to **viscous** forces. It is the measure of turbulence in a flow.



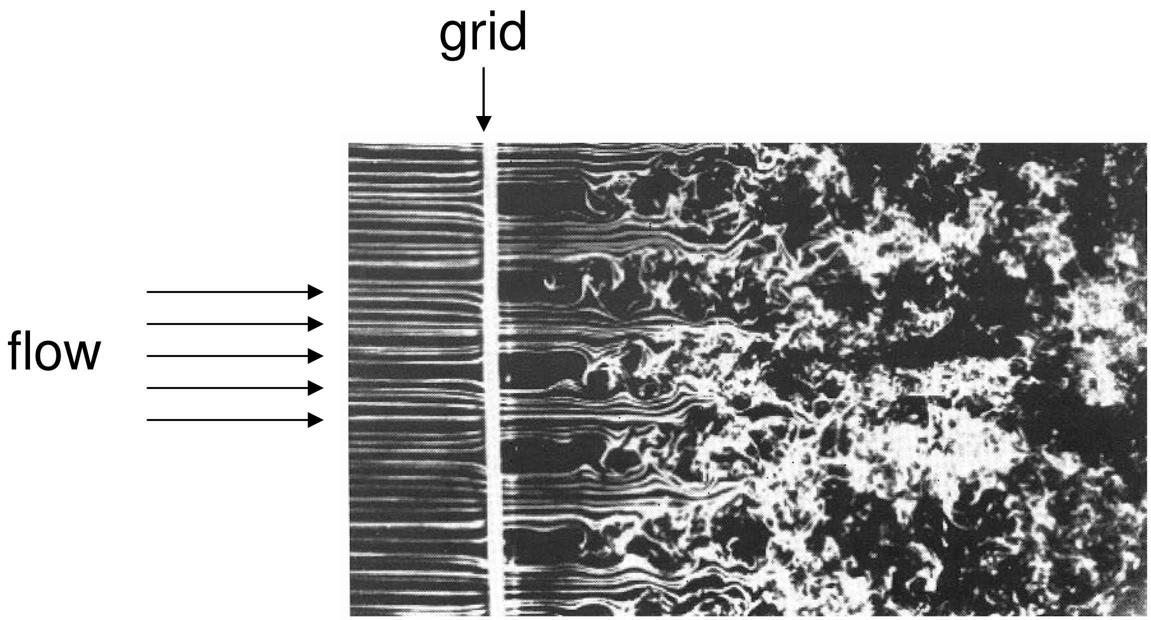
a b

**Flow past a circular cylinder. (a) Re = 26 (laminar). (b) Re = 2000 (turbulent).**

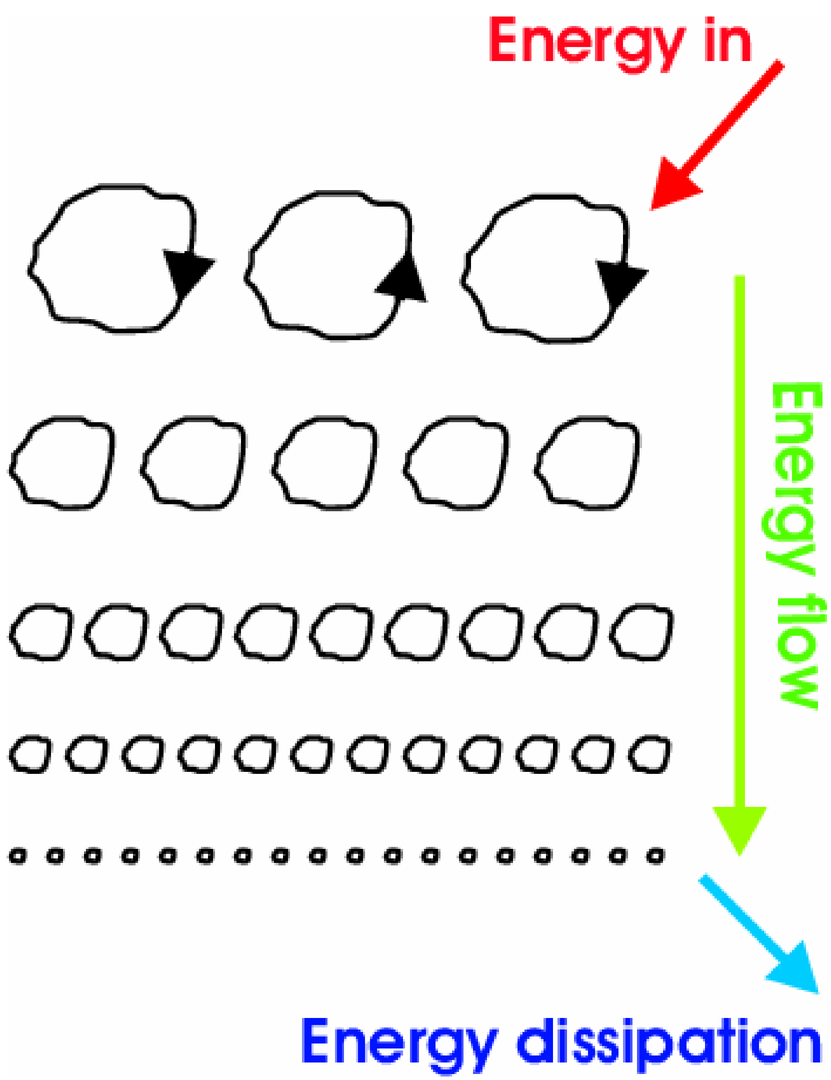
* $$\frac{\partial v'}{\partial t} + (v' \cdot \nabla')v' = -\nabla' p' + \frac{1}{Re}\nabla'^2 v'$$

# Making Turbulence in the laboratory

Large arrays of wake-producing “cylinders” can be placed in a flow in order to generate something approaching homogeneous and isotropic turbulence.



# What happens in turbulence?




Eddies or "whirls" produced by flow (e.g., through a grid at length scale M= mesh size)

↓

Cascade of energy to smaller scales

↓

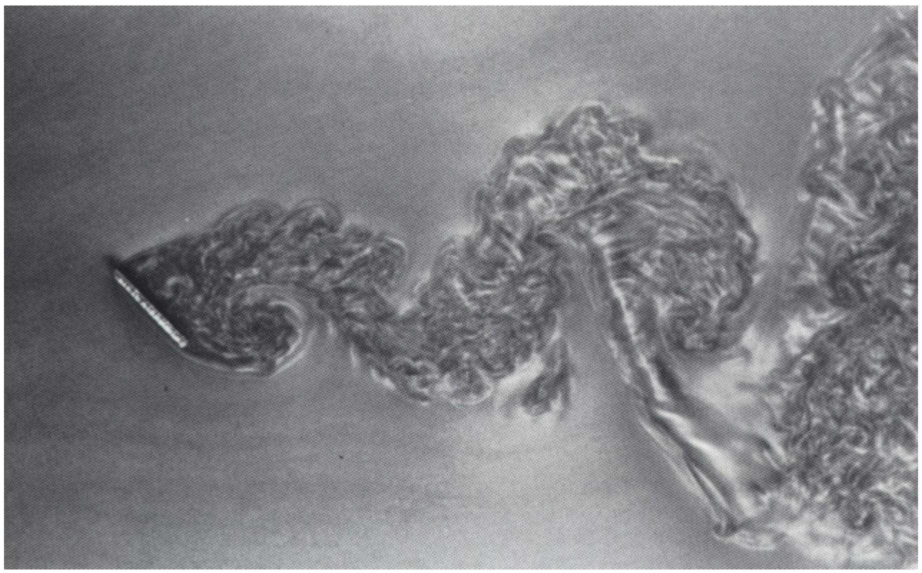
Viscous dissipation at small scales

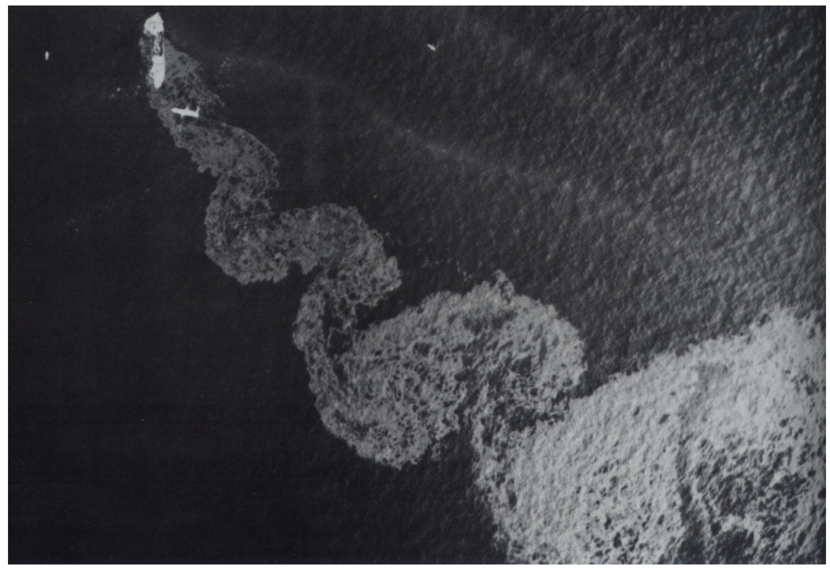
The higher the Re for a flow, the smaller the smallest scale for a given fixed large scale. What happens when the small scales become of atomic size?

# Dynamical similarity

If we consider two simple flows that are *geometrically similar*, then they are also *dynamically similar* if the corresponding *Re* is the same for both, *regardless of the specific velocities, lengths and fluid viscosities involved.*

Matching such parameters between laboratory testing of a model and the actual full-scale object is the principle upon which aerodynamic model-testing is based.



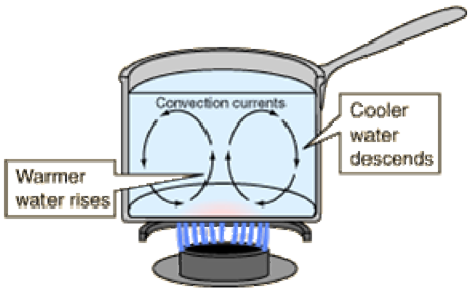


Above left: wake behind a flat plate in the laboratory inclined 45 degrees to the direction of the flow (left to right). Above right: A foundered ship in the sea inclined 45 degrees to the direction of the current.

# Fluid flows in nature and at home…

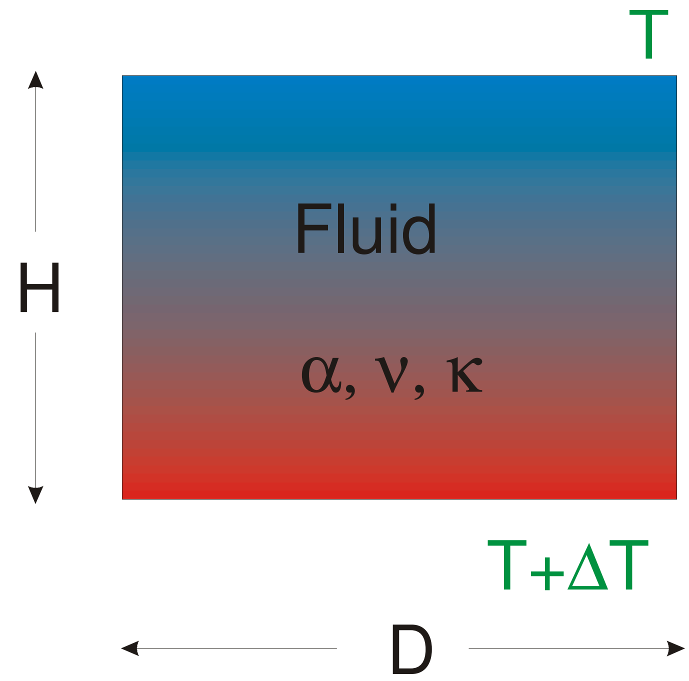
## The most common flow is that of thermal convection

*Thermal convection transports and mixes heat from the bottom of a cooking pot to the top.*




Thermal convection plays a prominent role in the energy transport within stars, including our own Sun, atmospheric and oceanic circulations, the generation of the earth's magnetic field, movements of the continental plates, and also innumerable engineering processes in which heat transport is an important factor. *It is possibly the most ubiquitous fluid flow in the universe.*

# In the laboratory: a simplified Rayleigh-Benard convection

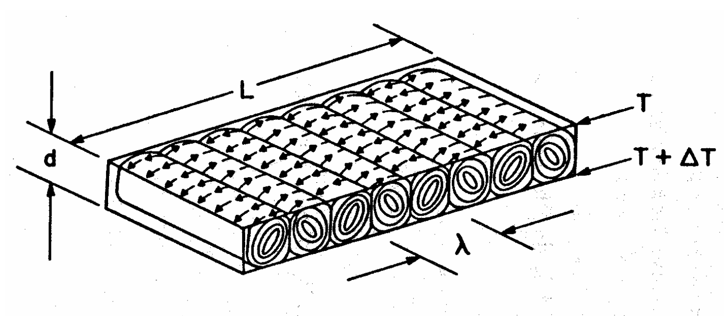


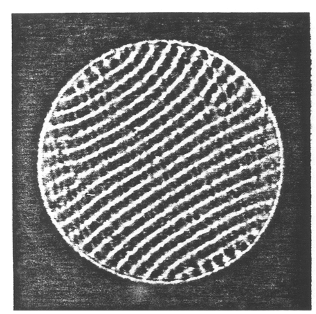

$\alpha$ fluid thermal expansion coefficient

$\nu$ fluid kinematic viscosity

$\kappa$ fluid thermal diffusivity

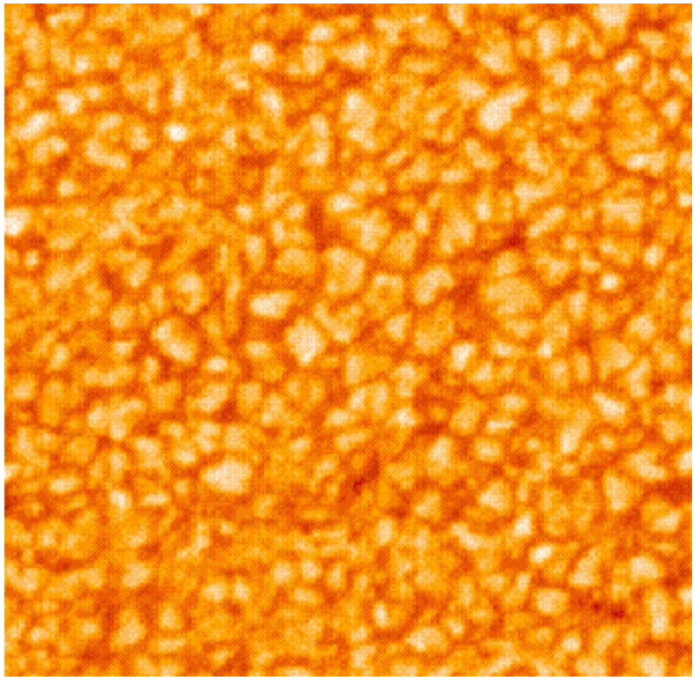
The *dimensionless* temperature difference, or Rayleigh number: $\mathrm{Ra} = \frac{g\alpha\Delta T H^3}{\nu\kappa}$



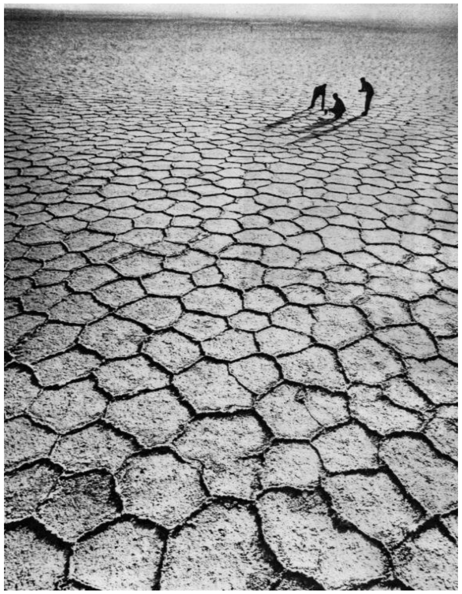



# Convective patterns in Nature

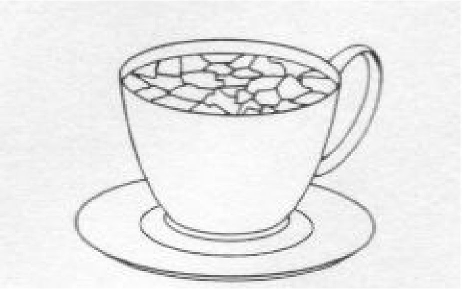
atmosphere



Solar granulation



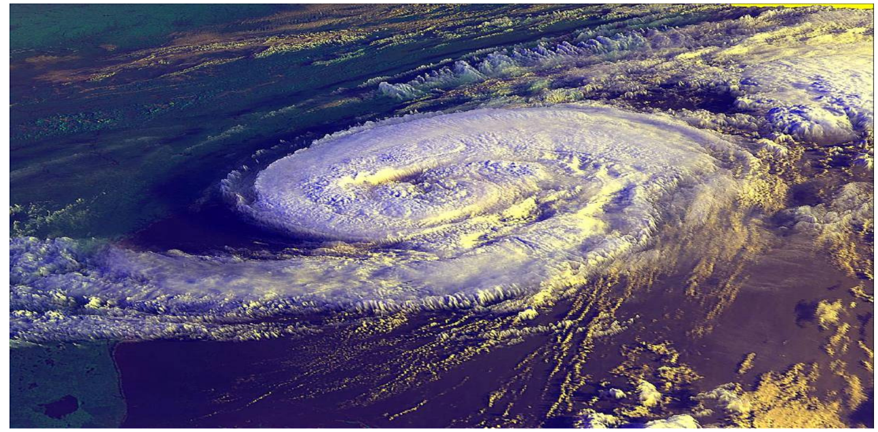
Residue of lake patterns



This morning's coffee

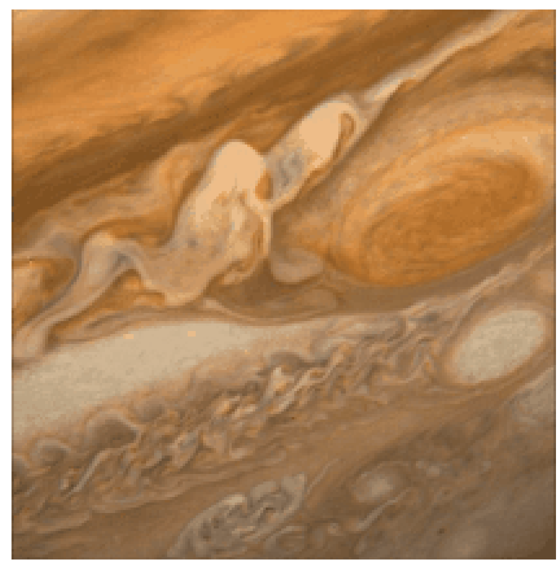
# Large and not-so-rare fluid flows in planetary atmospheres

A tornado in Kansas….



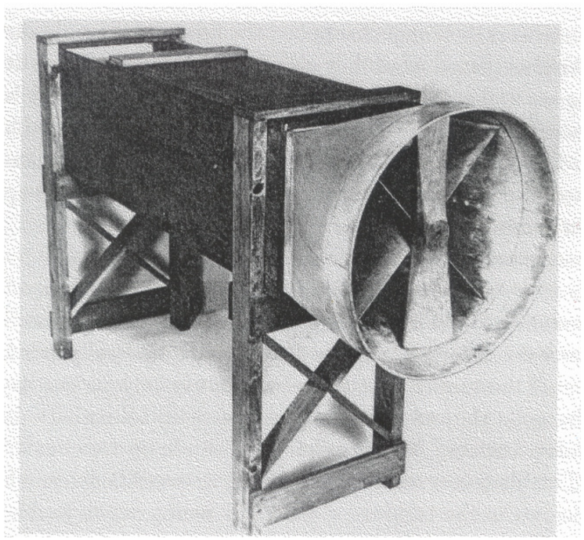
On earth, hurricane Bonnie approaches the U.S. Drawing its energy from warm tropical waters, it quickly dissipates over land.

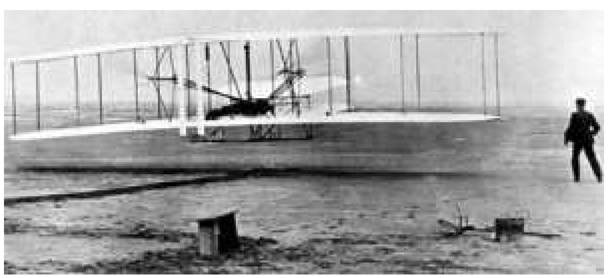
Jupiter's "Red Spot": A hurricane the size of 3 Earths that has persisted for at least 400 years!



# Applications of fluid dynamics

## The Wright Brothers: 1st successful application of wind tunnel data



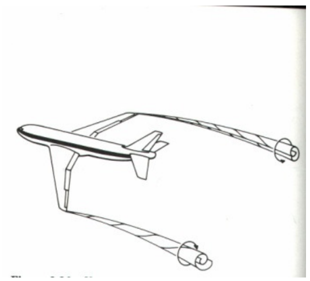


"We directed the air current from an old fan in the back shop room into the opening of the wooden box. Occasionally I had to yell at my brother to keep him from moving even just a little in the room because it would disturb the air flow and destroy the accuracy of the test."

"Over a two month period we tested more than two hundred models of different types of wings. All of the models were three to nine inches long. We finally stopped our wind tunnel experiments just before Christmas, 1901. We really concluded them rather reluctantly because we had a bicycle business to run and a lot of work to do for that as well."

---Wilber Wright

# A problem that remains:  wingtip vortices



Wingtip vortices reduce some of a plane's lift.  They create dangerous conditions during takeoff and landings, both for the aircraft and those that follow.

A Boeing 747 flying into Hong Kong.  Vortices shed from the wing can be seen in smoke from a factory below.

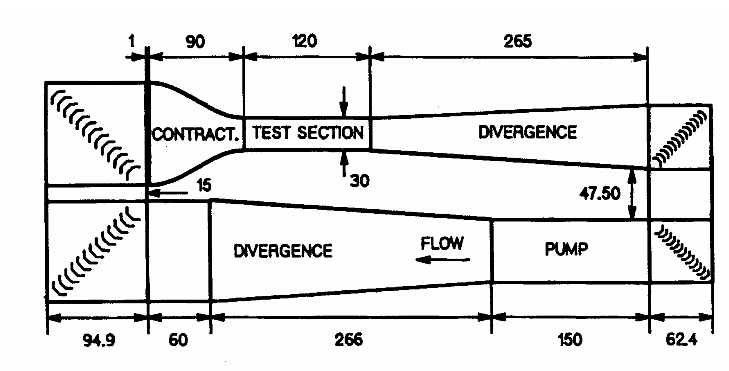
A patch that helps: winglets

In a formation of flying geese it is presumably the geese on the tips who work the hardest.

# Wind tunnels today

One of the most powerful wind tunnels today: a liquid nitrogen cooled facility at NASA Langley. The cooling lowers the kinematic viscosity which raises the value of Re for a given flow speed and tunnel size.

# And tomorrow….?




Schematic of the helium tunnel

Due to helium’s small viscosity it may be possible to build a “pocket-sized” wind tunnel operating near the absolute zero of temperature and capable of ultra high Re testing.

# In Bucharest last year…