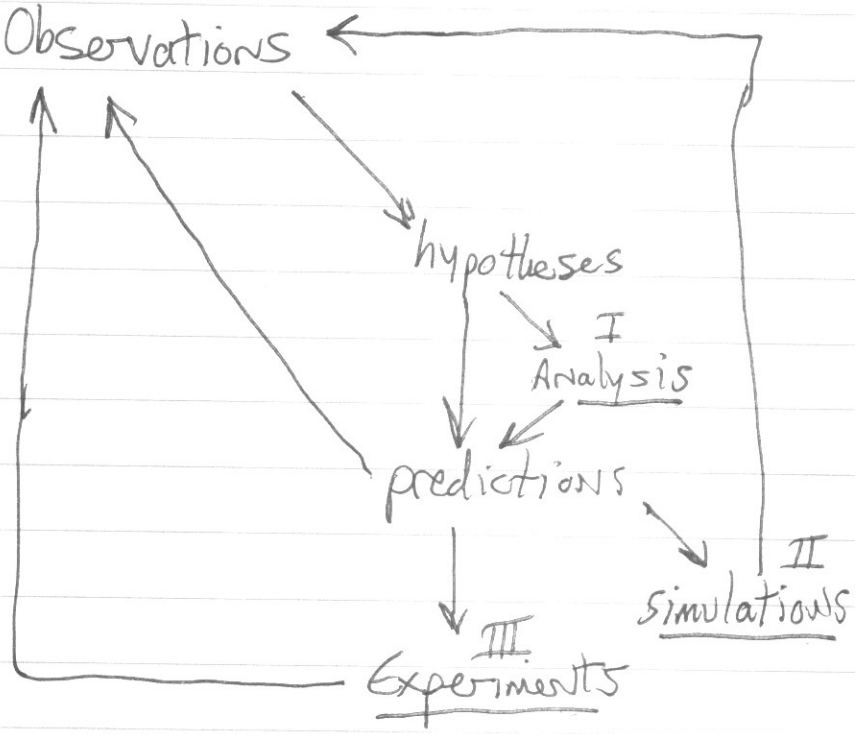
Experiment is the sole source of truth. It alone can give us certainty. These are two points that cannot be questioned.

Henri Poincare, from “Science and Hypothesis” Part IV, Ch. IX 1905.

How is knowledge obtained?

Scientific method

Old school:
- Observations
- Hypotheses
- Experiments
- Theory



If I, II, & III agree ⇒ theory

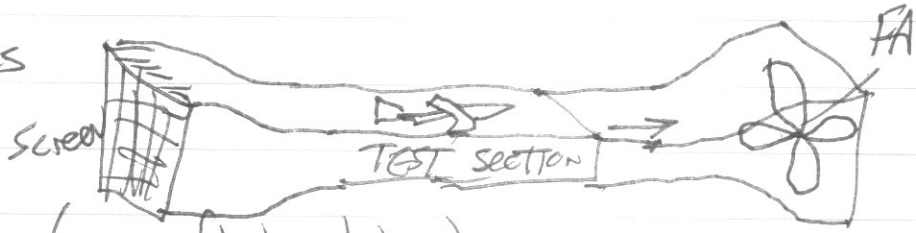
Experiments are the referee of the process

Types of turb. experiments

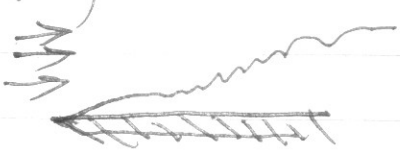
lets

Pipe flow

Wind tunnels

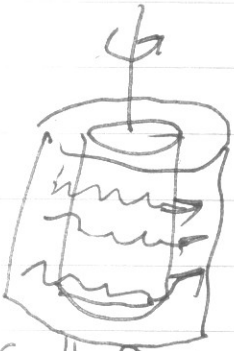


Blasius flow (on a flat plate)

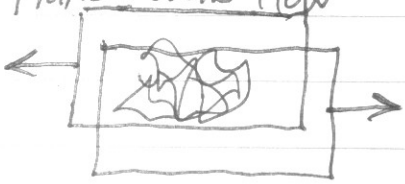


Field studies
Salt flats

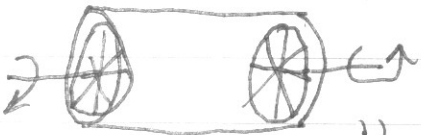
Cyl. Covette flow - Taylor - Covette flow
Sph. Covette flow



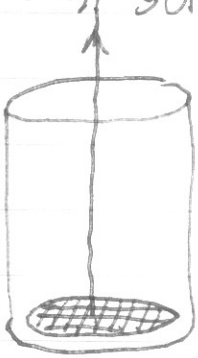
Plane Covette flow



French blenders - von Karman



Lagrangian exploration!
Icosohedron - impeller on each surface!



Grid turbulence
Decay experiments

What can be measured & how?

$\nabla \cdot U = 0$

$\partial_t U + (U\cdot\nabla)U = -\frac{1}{\rho}\nabla P + \nu\nabla^2 U$

$\nabla\cdot$: $\nabla\cdot[(U\cdot\nabla)U] = -\frac{1}{\rho}\nabla^2 P \rightarrow \nabla^2 P = -\rho\nabla\cdot[(U\cdot\nabla)U]$

$= [\text{strain}^2 - \text{vorticity}^2]$ Ref

Questions?

Pressure measurement

$\tau_w = \rho\nu\left|\frac{\partial U}{\partial y}\right|$ wall shear stress

$\Sigma = \frac{\nu}{2}(\partial_i v_j + \partial_j v_i)^2$ show squared strains

Scalar fields $c(\vec{r},t)$ $\partial_t c + (U\cdot\nabla)c = D\nabla^2 c$

Vector fields (Mag.?) $B(\vec{r},t)$ $\partial_t \vec{B} + (U\cdot\nabla)\vec{B} = (\vec{B}\cdot\nabla)\vec{U} + \eta\nabla^2\vec{B}$

Other cases! Density, complex fluids

Measure:

Power $P = \vec{F}\cdot\vec{V} =$ also $\int \rho\Sigma\, d^3r$

Power input => electrical

Torques $\vec{T} = \vec{r}\times\vec{F}$ $T = \int \vec{r}\times\vec{\tau}_w\, d^2a$

Force sensors

Strain gauges

Velocity: well... so many ways

Pitot tube ⌐¬ ← $P \simeq \frac{1}{2}\rho v^2$

Aircraft! Wasps!

Hot wire/Hot film $V^2 \sim \tau_w^{1/3}$ calibration!

diagram of that!

LDV H.Z. Cummins – diagram

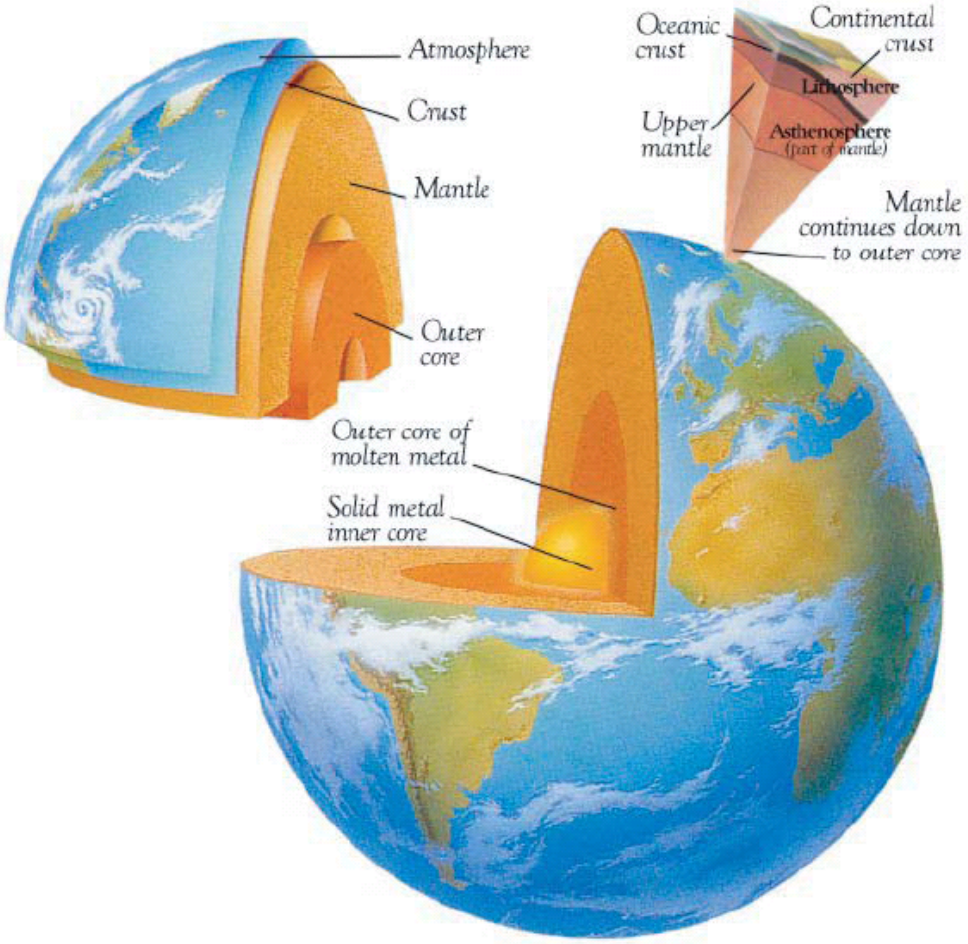
PIV Ron Adrian – diagram

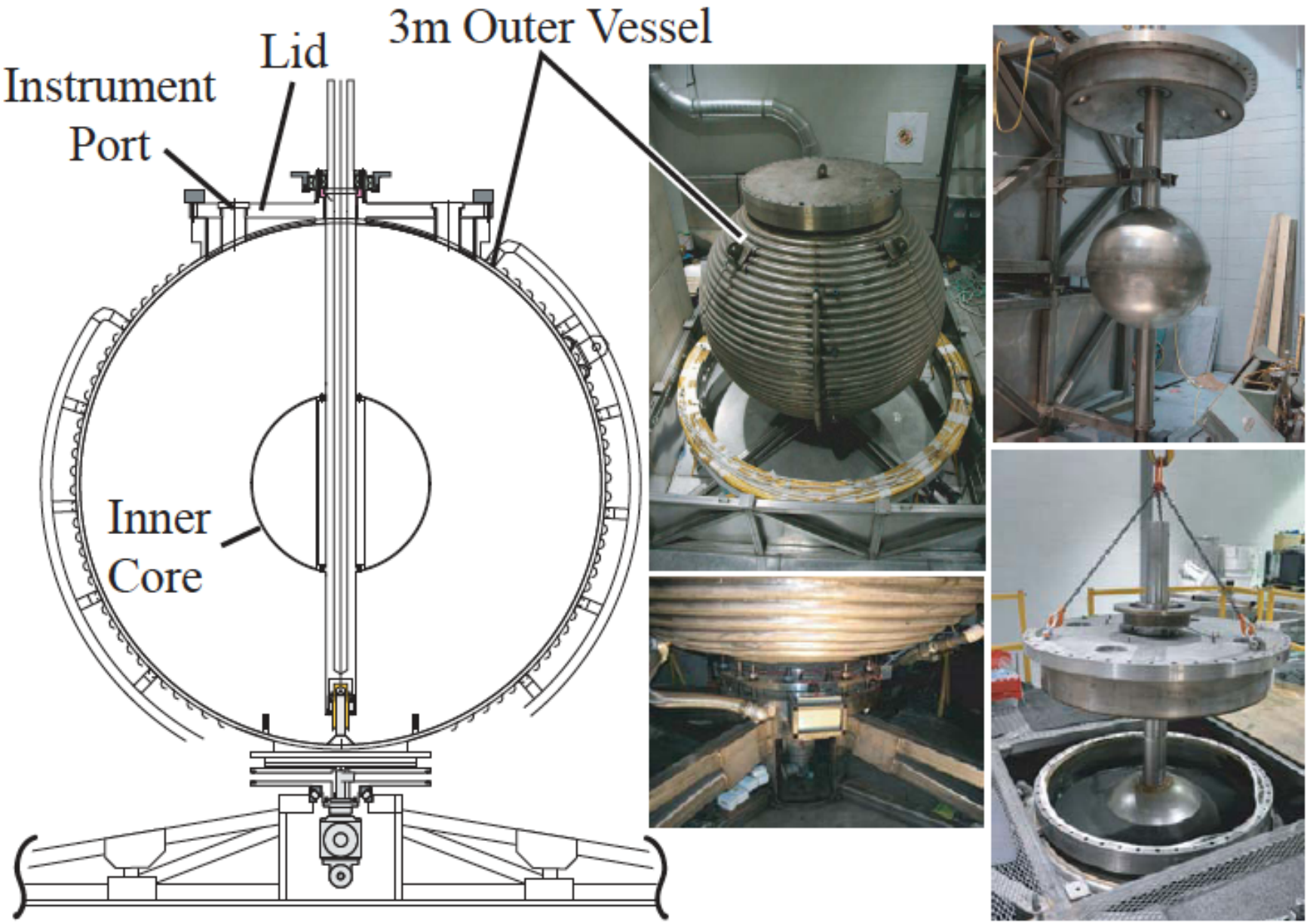
Particle tracking

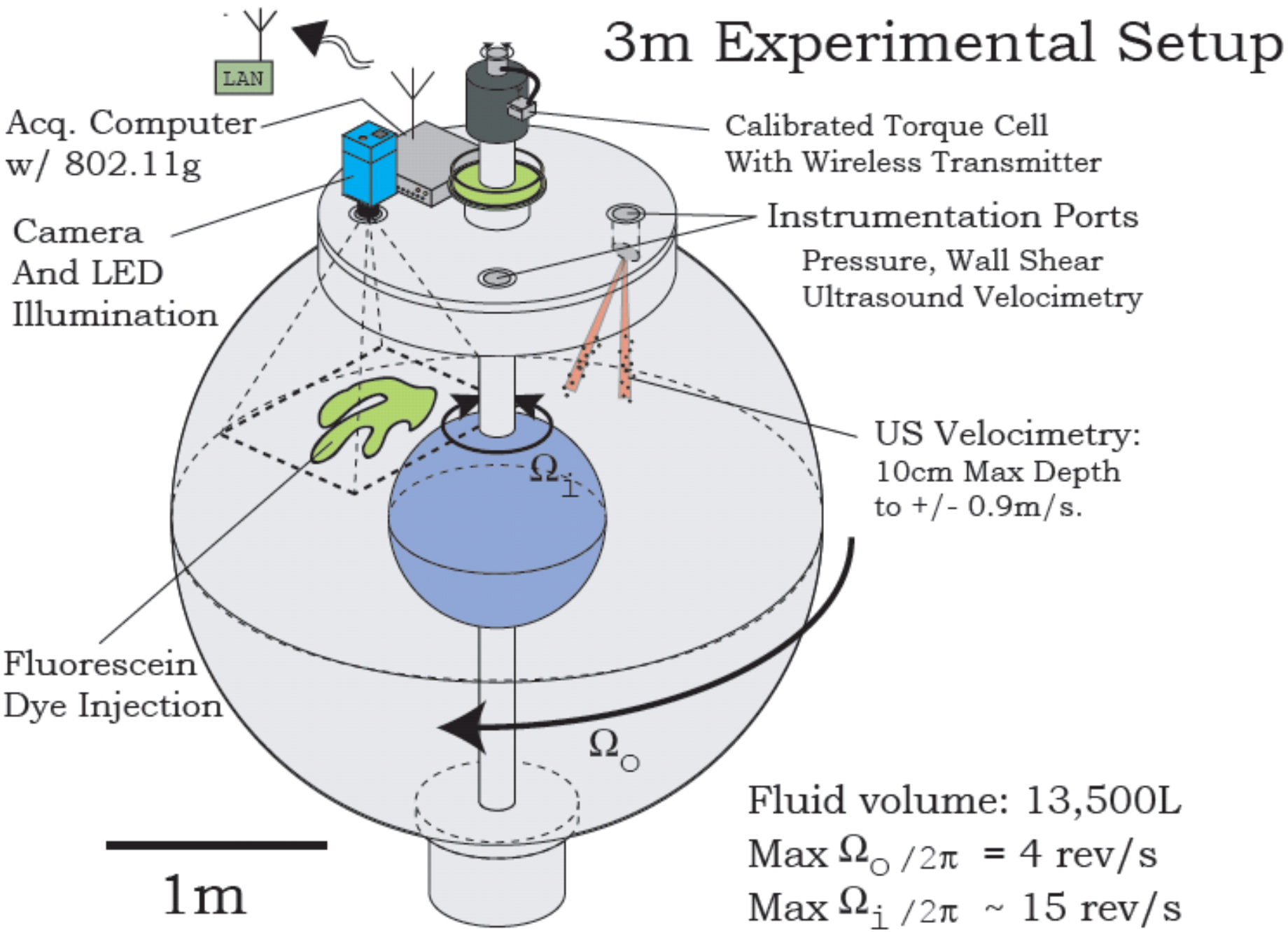
Pressure – microphone, diaphragm sensor

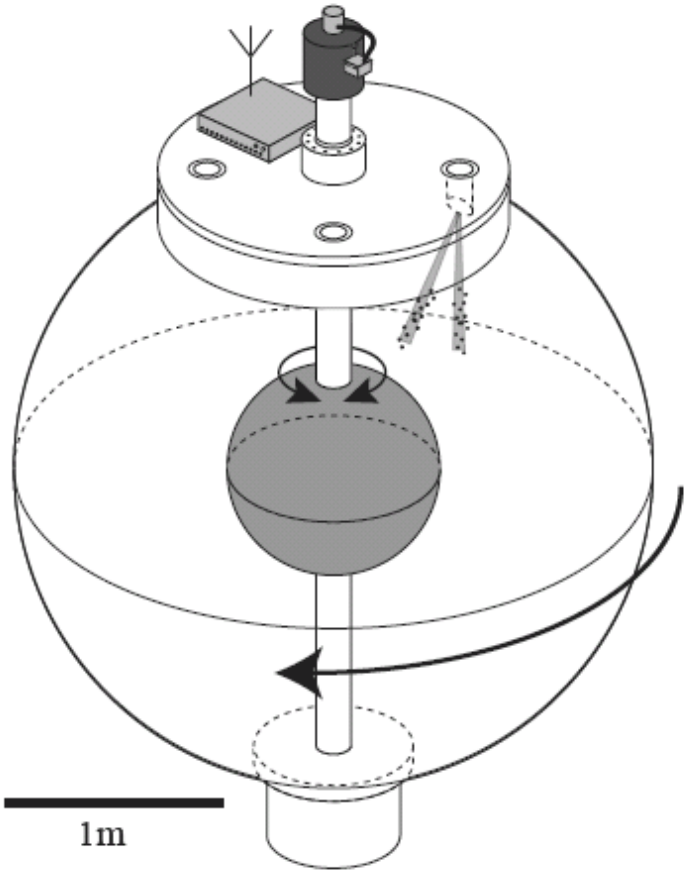
Wall shear stress – hot film, PIV

Scalars – Imagery


Atmosphere
Crust
Mantle
Outer core
Outer core of molten metal
Solid metal inner core
Oceanic crust
Continental crust
Lithosphere
Upper mantle
Asthenosphere
(part of mantle)
Mantle continues down to outer core


3m Outer Vessel
Lid
Instrument
Port
Inner
Core

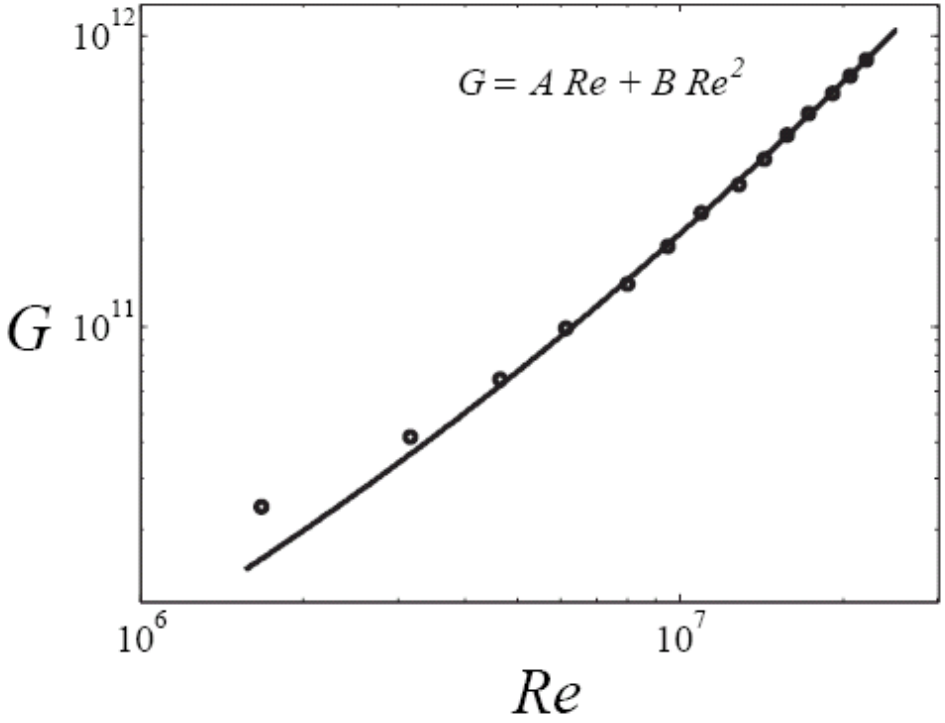

3m Experimental Setup
LAN
Acq. Computer
w/ 802.11g
Camera
And LED
Illumination
Calibrated Torque Cell
With Wireless Transmitter
Instrumentation Ports
Pressure, Wall Shear
Ultrasound Velocimetry
US Velocimetry:
10cm Max Depth
to +/- 0.9m/s.
Fluorescein
Dye Injection
Ω_i
Ω_o
1m
Fluid volume: 13,500L
Max $\Omega_o/2\pi$ = 4 rev/s
Max $\Omega_i/2\pi$ ~ 15 rev/s
Max Power Input: 320kW



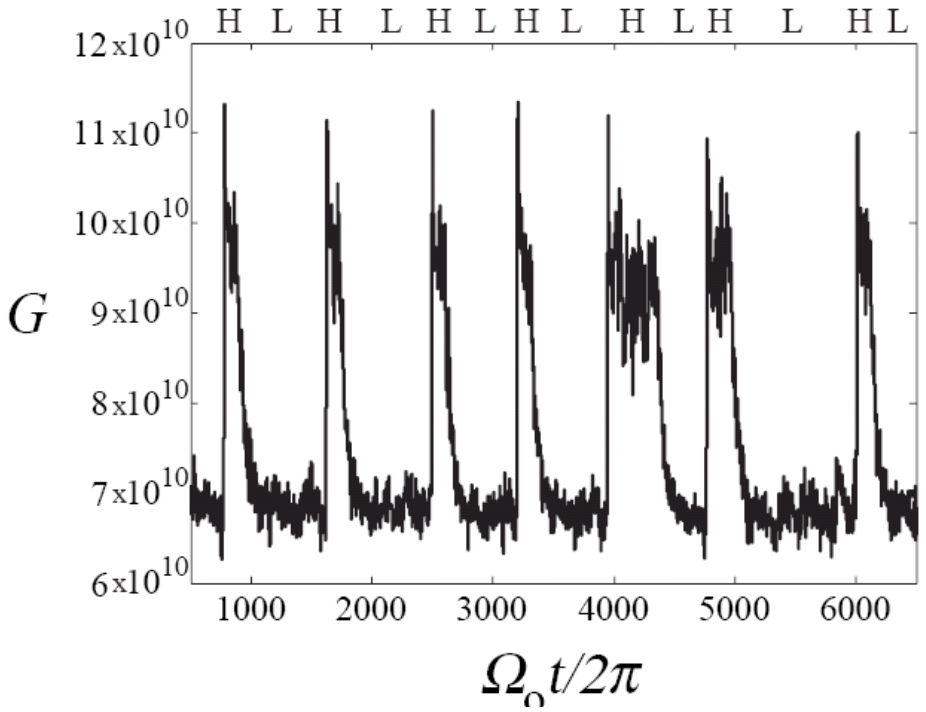
Water experiments in the 3 m system

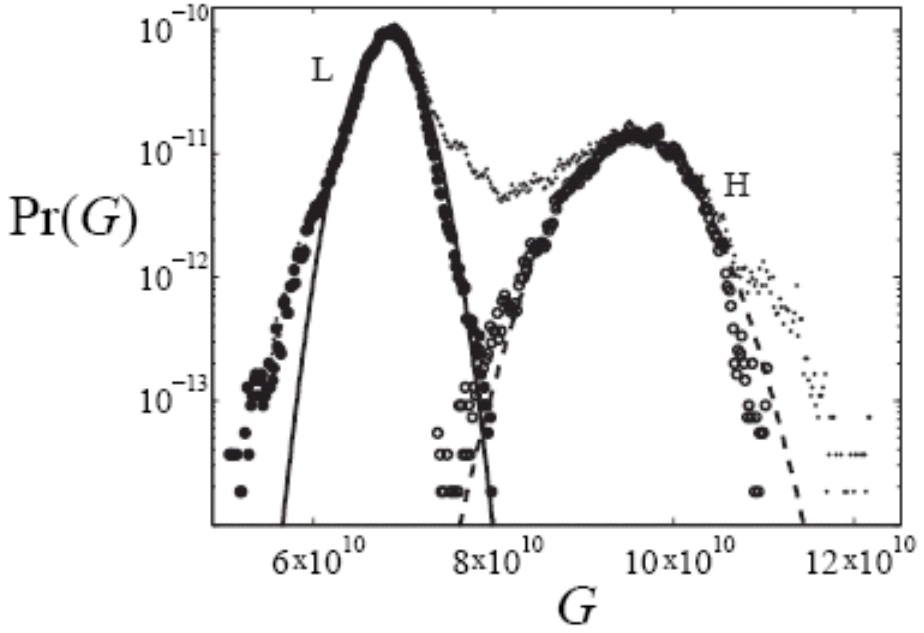
Dimensionless torque

$$G = \frac{T}{\rho \nu^2 a}$$

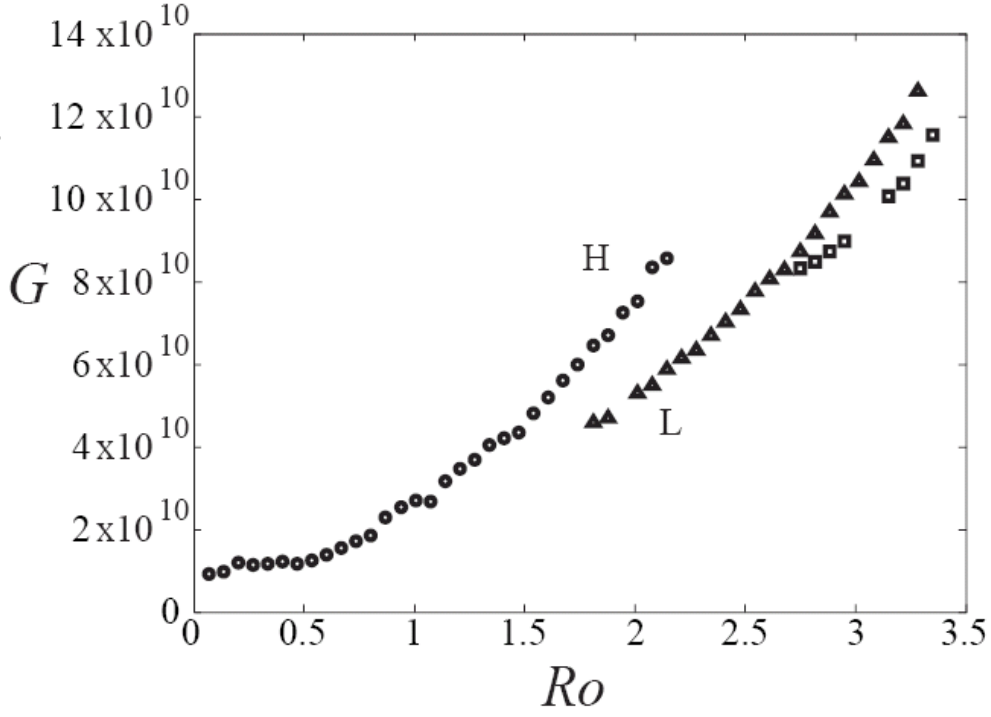


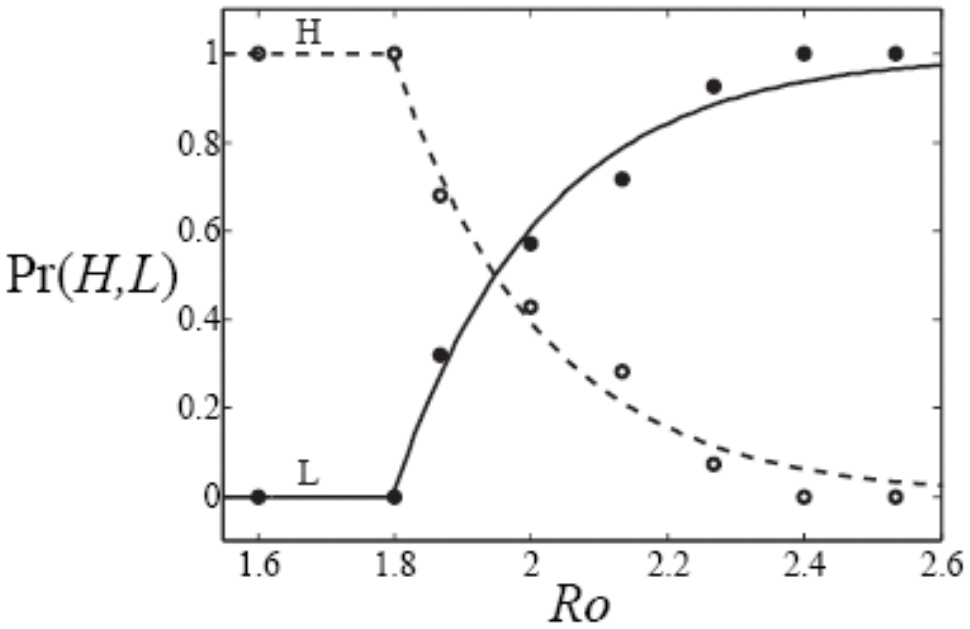
Torque
bi-stability
around Ro=2

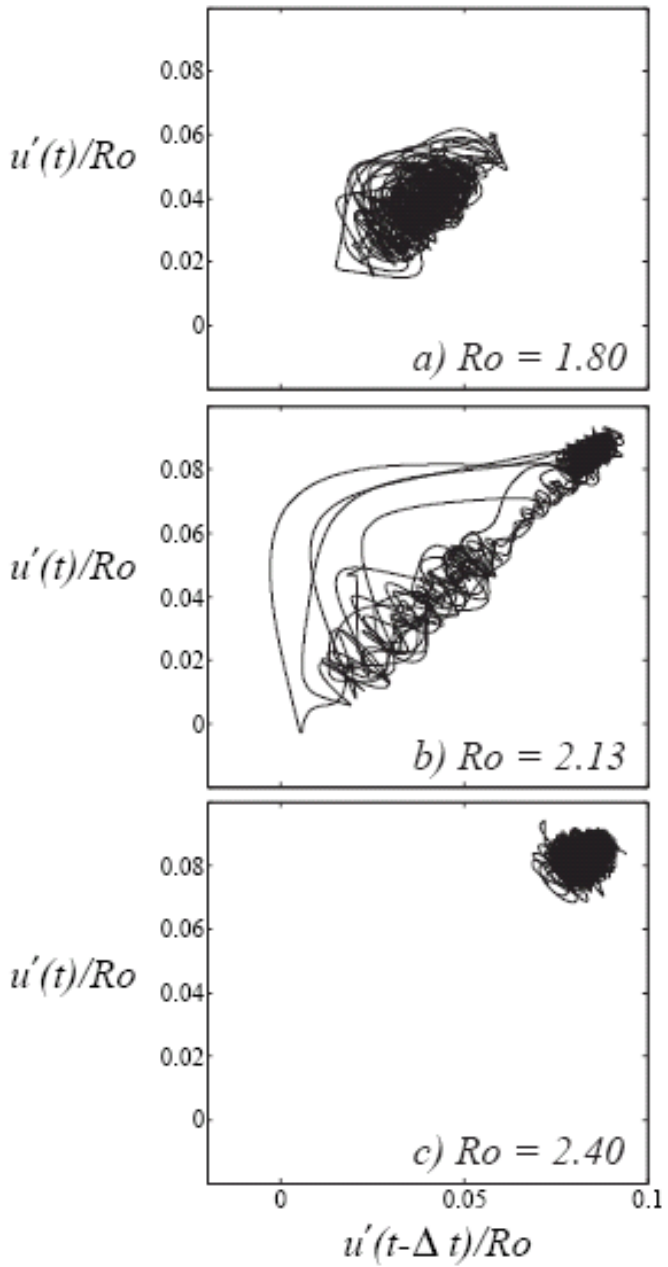


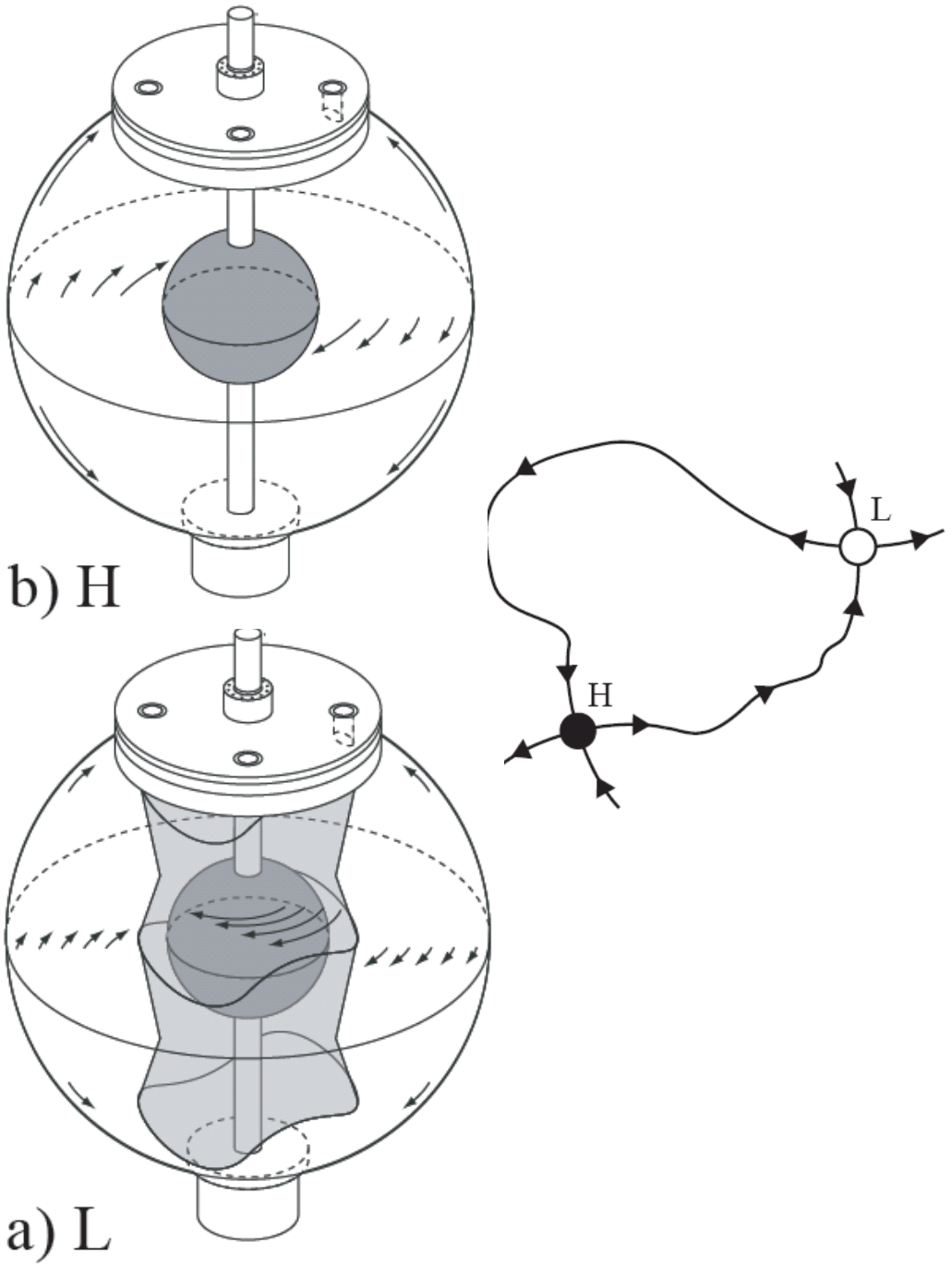


Dimensionless torque






u′(t)/Ro
0.08
0.06
0.04
0.02
0
a) Ro = 1.80
u′(t)/Ro
0.08
0.06
0.04
0.02
0
b) Ro = 2.13
u′(t)/Ro
0.08
0.06
0.04
0.02
0
c) Ro = 2.40
0
0.05
0.1
u′(t-Δ t)/Ro


b) H
a) L
L
H

"Mr. Osborne, may I be excused? My brain is full."