

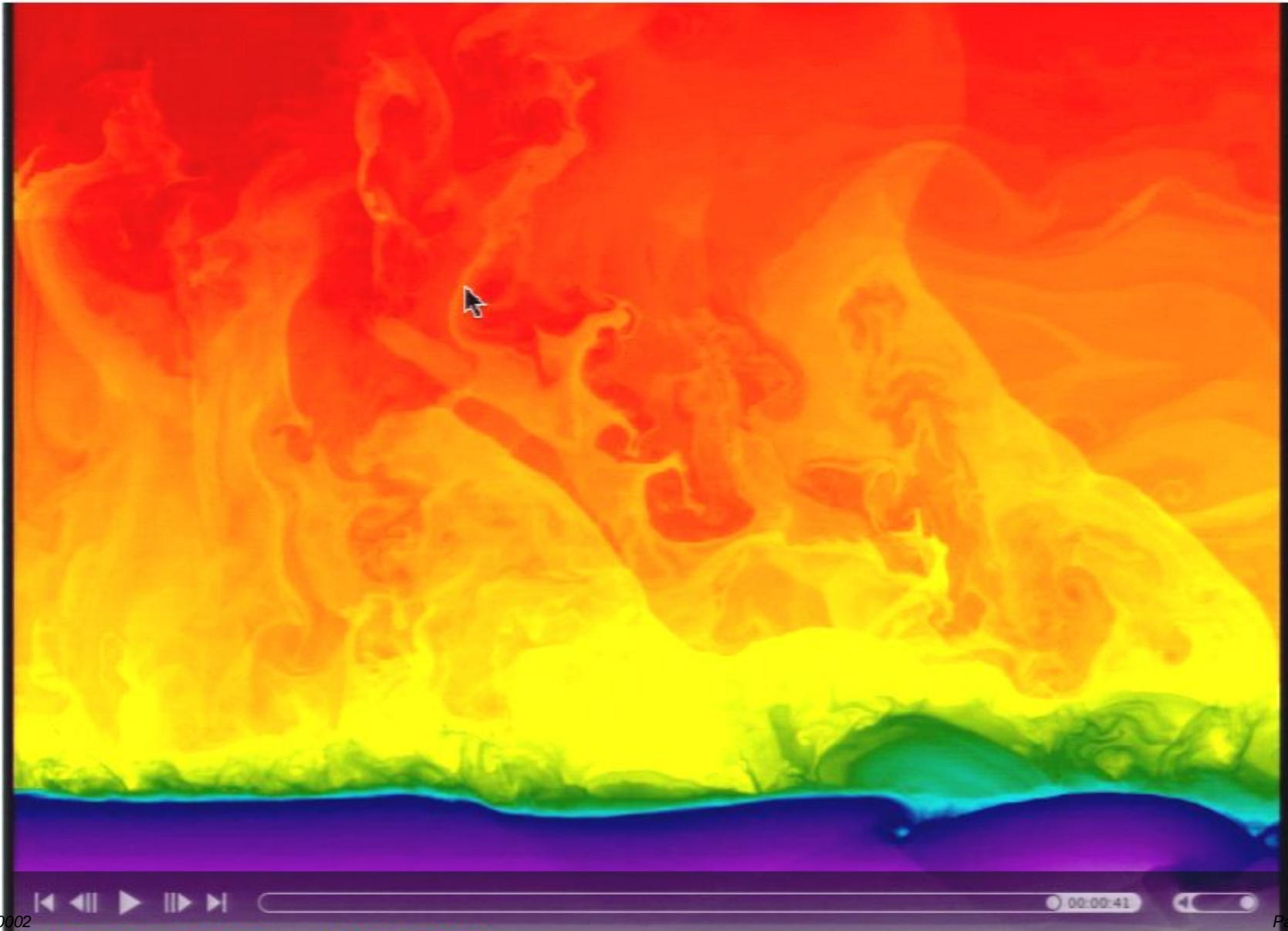
Title: Making a Splash--Breaking a Neck, The Making of Complexity in Physical Systems

Date: Mar 25, 2009 02:00 PM

URL: <http://pirsa.org/09030002>

Abstract: The fundamental laws of physics are very simple. The world about us is very complex. Living things are very complex indeed. This complexity has led some thinkers to suggest that living things are not the outcome of physical law but instead the creation of a designer. Here I examine how complexity is produced naturally in fluids.

# Explosion on Surface of Star



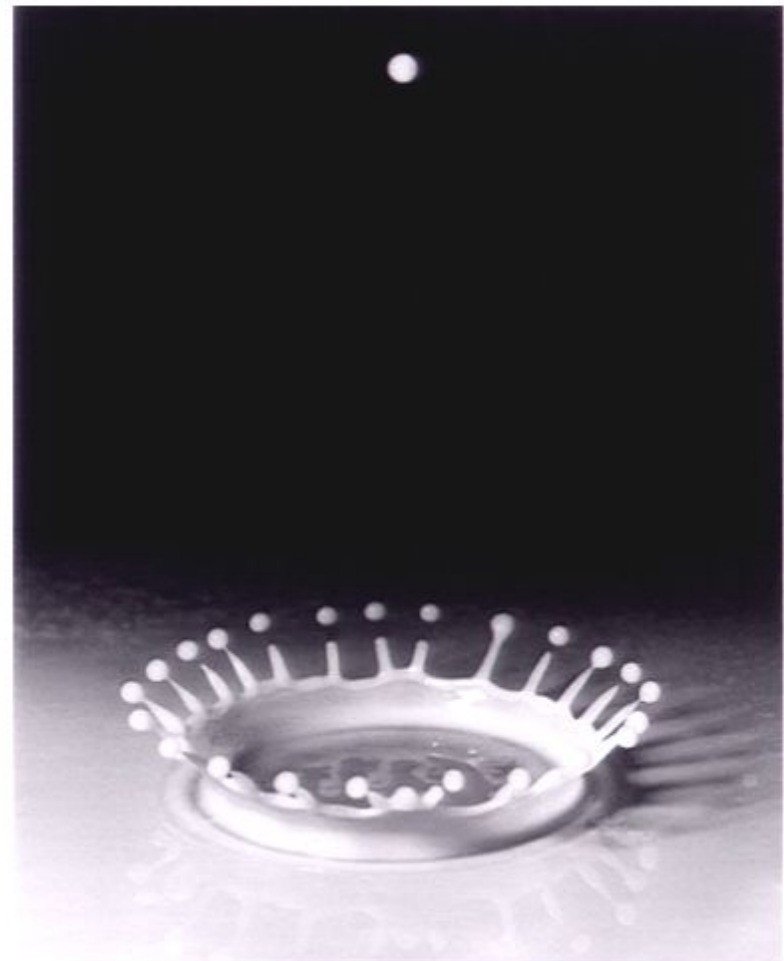
# Making a Splash--Breaking a Neck

## The Making of Complexity in Physical Systems

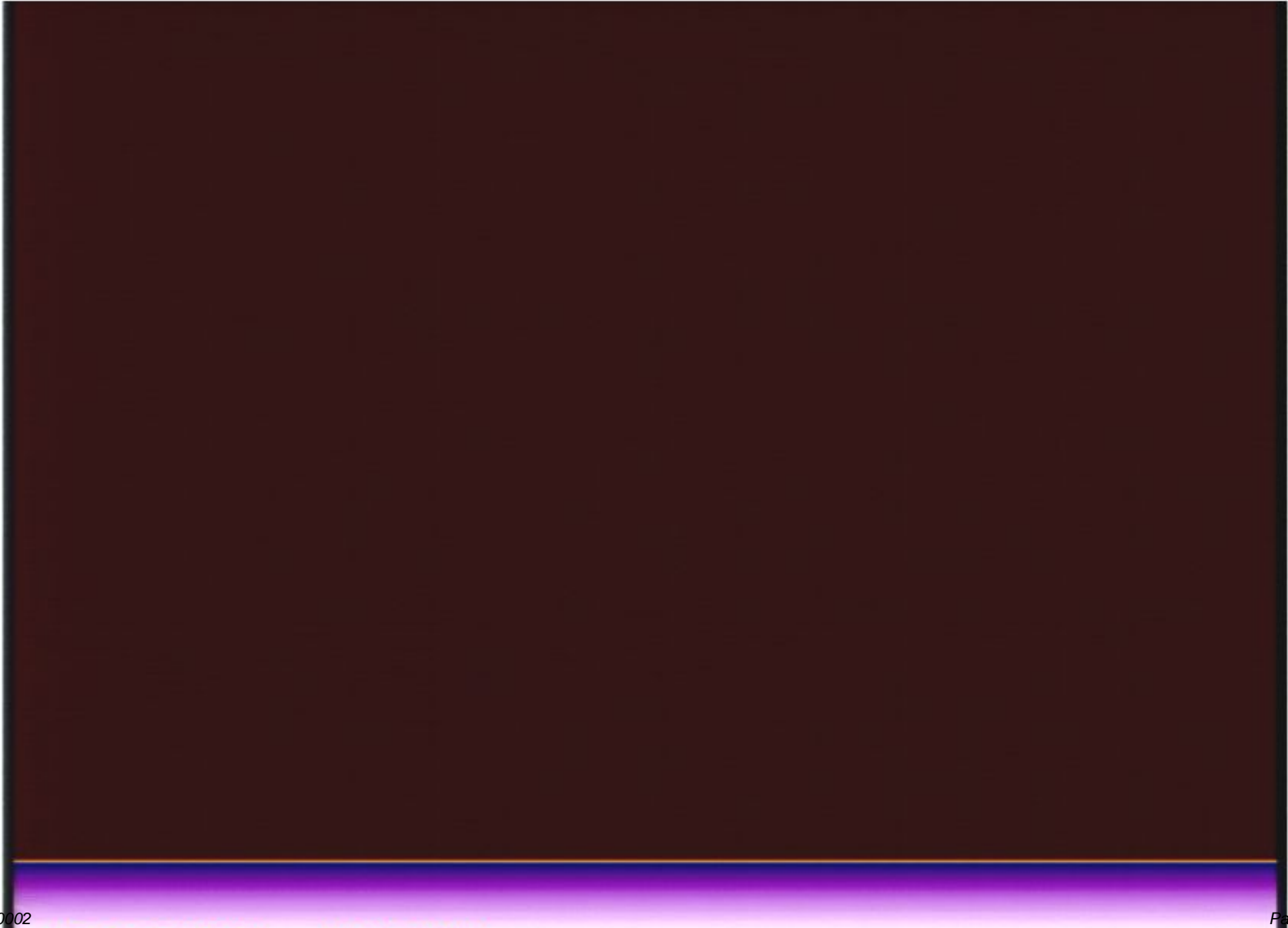
**Leo P. Kadanoff**

University of Chicago  
email: [LeoP@UChicago.edu](mailto:LeoP@UChicago.edu)

Splash:  
A drop has hit the surface of  
a glass of milk  
Edgerton Photo



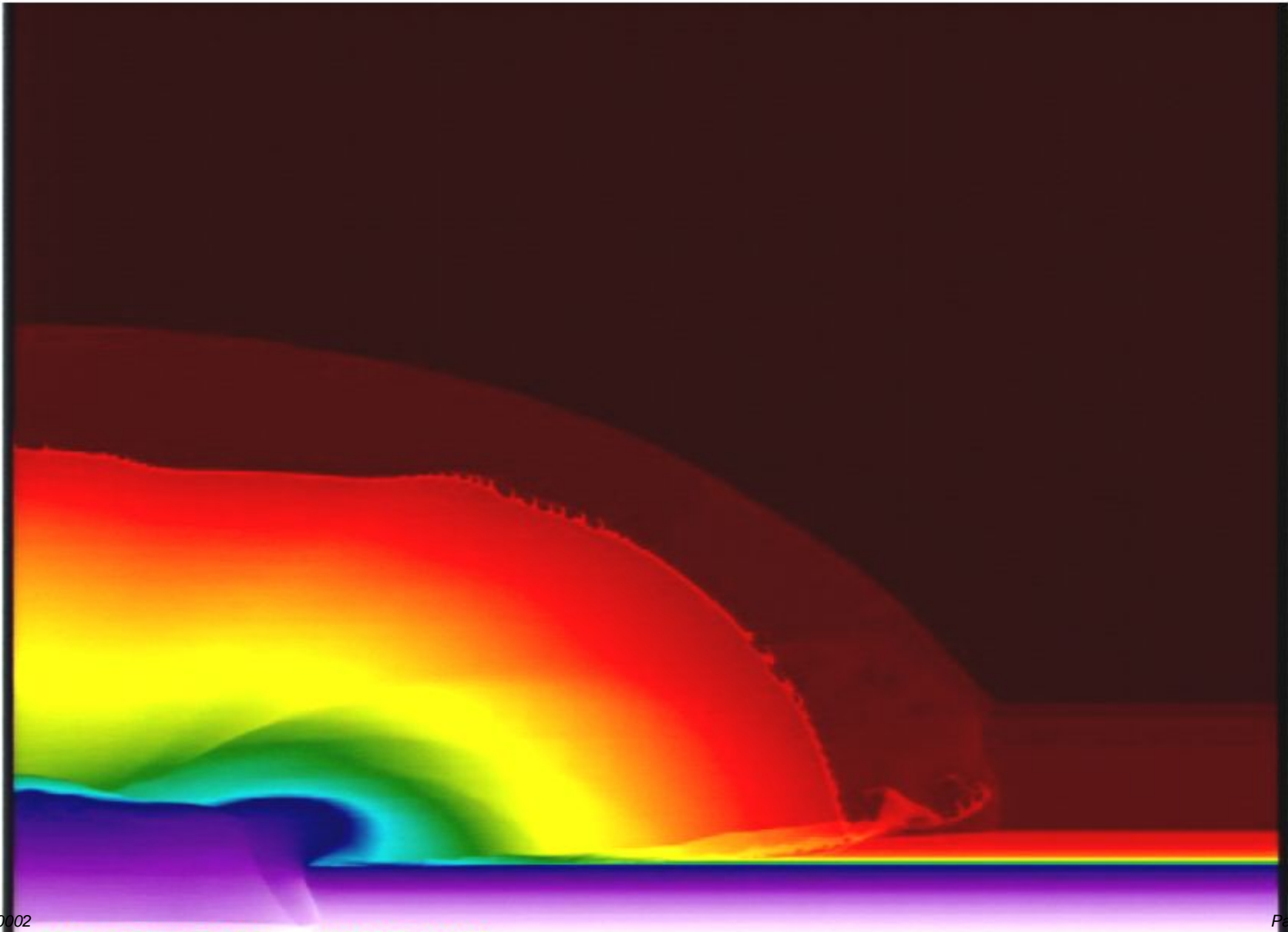
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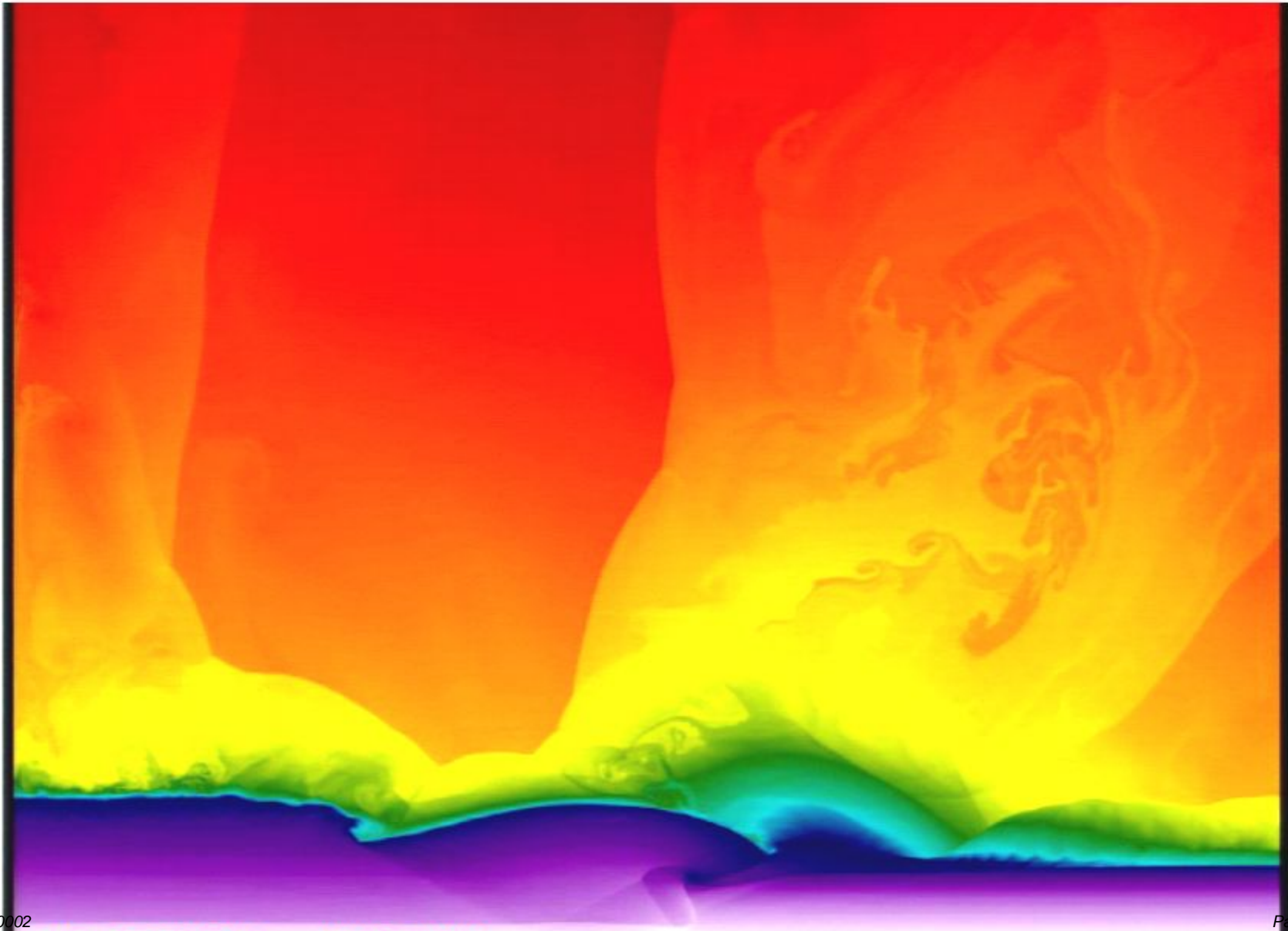
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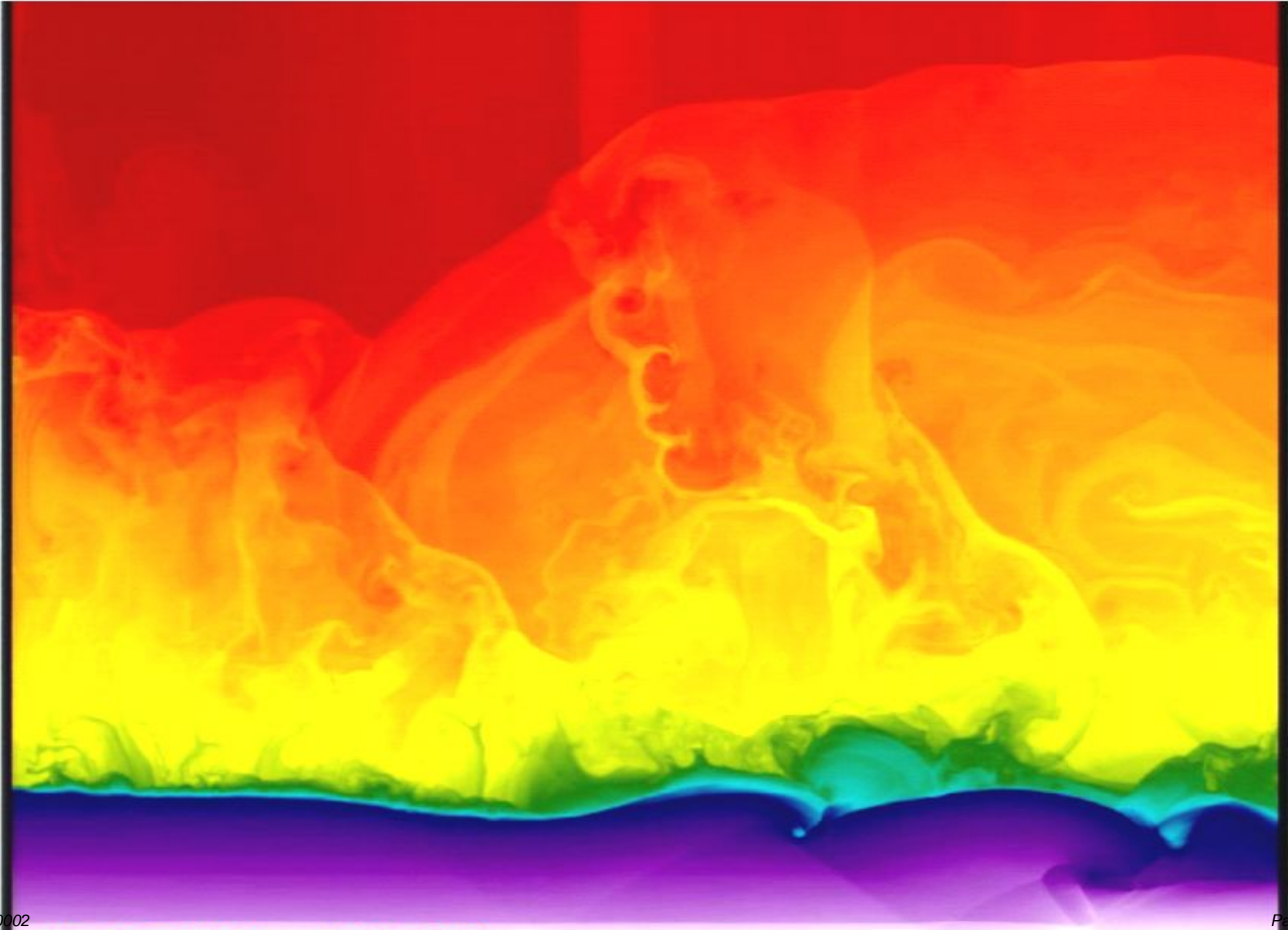
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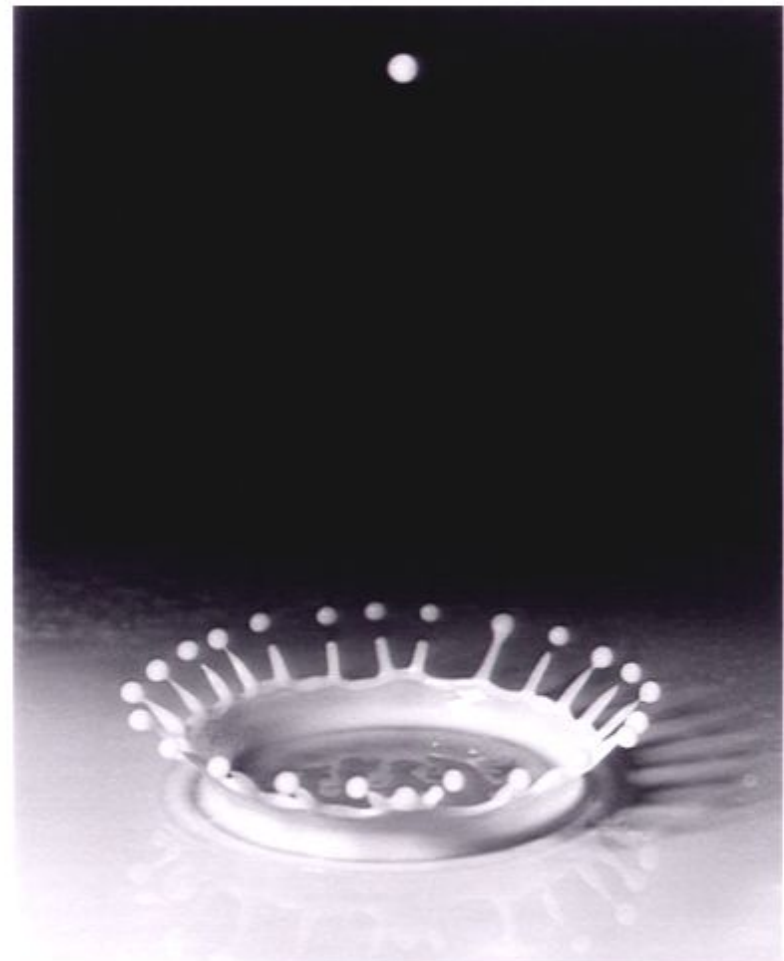
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## The Making of Complexity in Physical Systems

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## The Making of Complexity in Physical Systems

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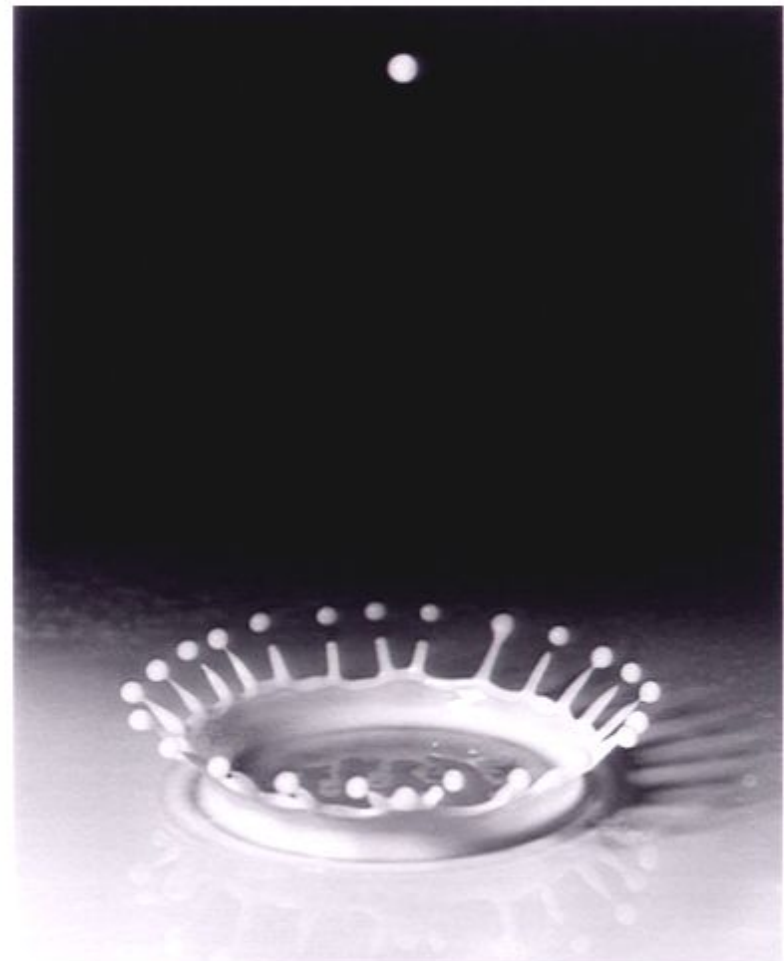
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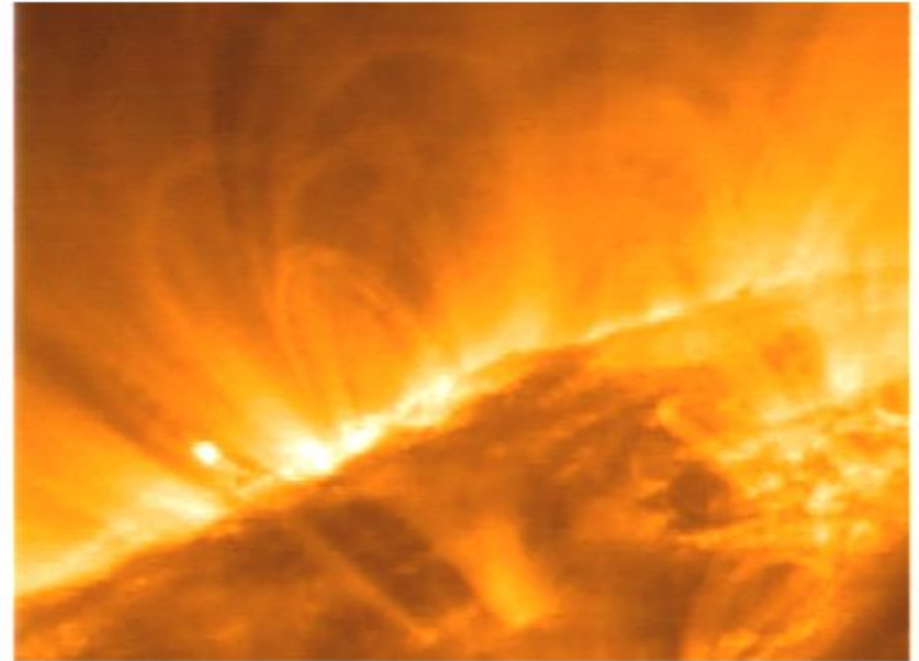
# Summary of Talk

The fundamental laws of physics are very simple.

The world about us is very complex.

Living things are very complex indeed.

This complexity has led some thinkers to suggest that living things are not the outcome of physical law but instead the creation of a designer.



Credit: NASA/Trace  
magnetic storm on surface of sun

Here I examine how complexity is produced naturally in fluids.

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# First Interlude: Intelligent Design

is the subject of a political and intellectual discussion  
Its proponents argue that biological systems are too complex to have been the product of a natural evolution, Darwinian or otherwise, but instead are the result of a fashioning by some (super-) intelligent creator (or Creator).

Proponents:

**William Paley** (1743-1805).

**M. Behe**, a biochemist who looks at cells

**Bill Dembski**, a philosopher and mathematician\* who has theorems which describe a search process.

\* I was his thesis adviser for his math Ph.D

# “Political Context”:The Discovery Institute

The Discovery Institute supports Intelligent Design research and the spread of ID ideas as part of a “Wedge Strategy” which “seeks nothing less than the overthrow of materialism and its cultural legacies.” It has “re-opened the case for a broadly theistic understanding of nature.”

“We will move toward direct confrontation with the advocates of materialist science through challenge conferences in significant academic settings. We will also pursue ..... the integration of design theory into public school science curricula.”

Quotes are from their Wedge Document:  
<http://www.antievolution.org/features/wedge.html>

## What to do?

As academics we should consider the validity of the ID arguments with an open but critical mind.

As intelligent citizens, we should think about curricular issues for our schools. This talk is mostly about science, but it does return to school-issues at the end.

# The Structure of Physics

The laws are simple, a few lines of partial differential equations to express rates of change of physical quantities in space and time.

The ideas are simple:

The world is lawful.

The same basic laws hold everywhere and always. New domains of nature may require new laws, but all the different laws are consistent with one another.

Everything is simple, neat, and expressible in terms of everyday mathematics, usually partial differential equations.





Esher's framework

Everything is simple and neat--except, of course, the world.

Before understanding comes observation.....

We ask: Why is the world so complicated?

# Type I Complexity

Structures repeated with variations in size shape placement.

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Structures repeated with variations in size shape placement.



flow past cylinder

# Type I Complexity

Structures repeated with variations in size shape placement.



flow past cylinder



cake of soap-200x

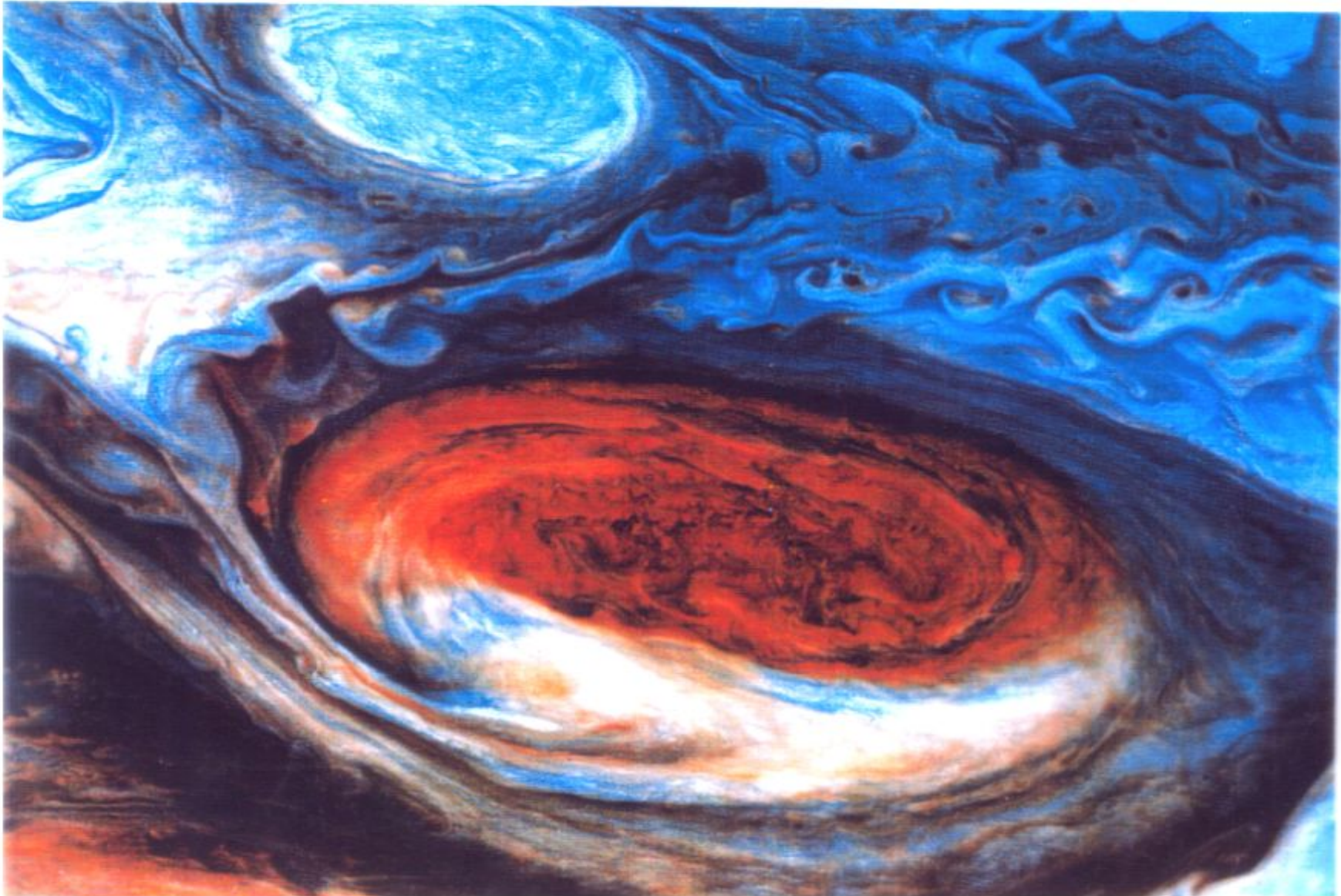
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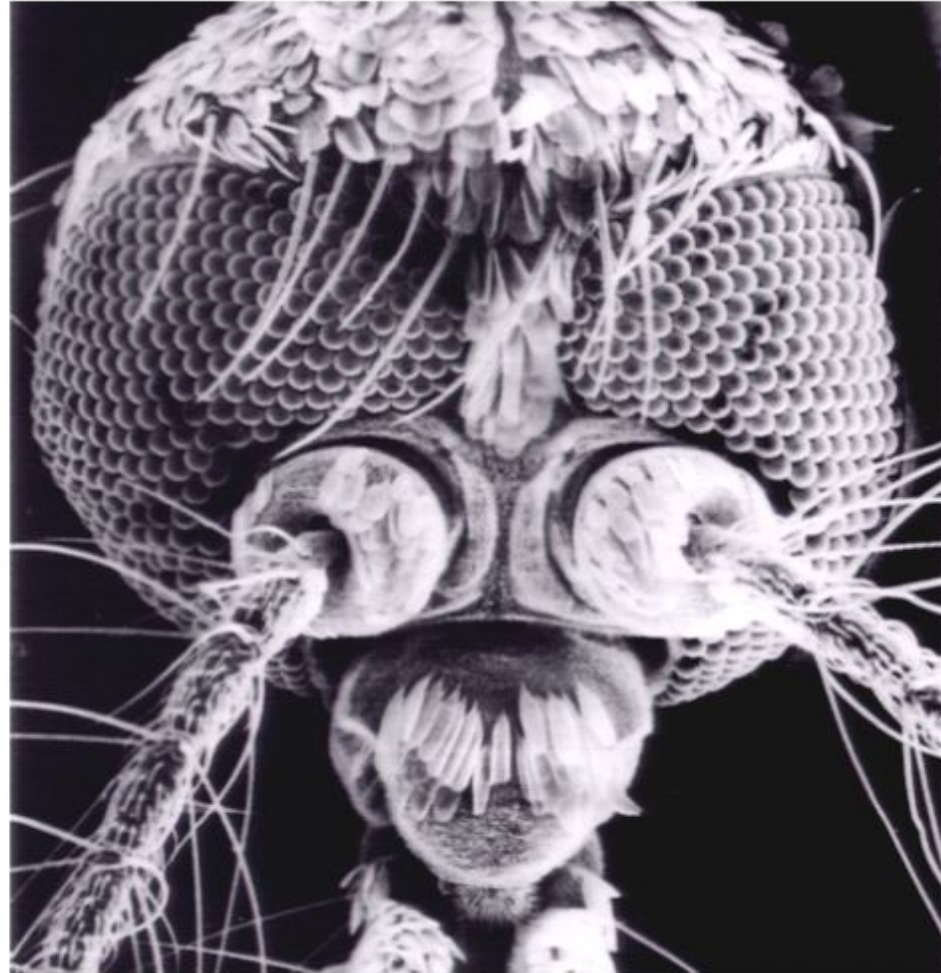
# Red Spot Jupiter:

different things happen in different places



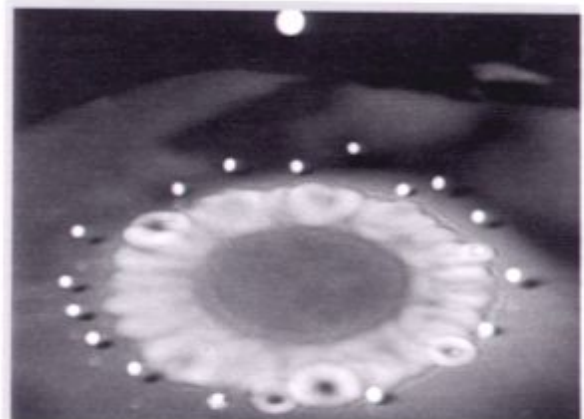
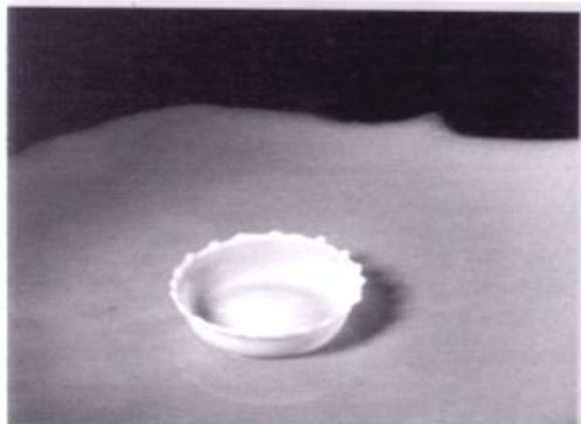
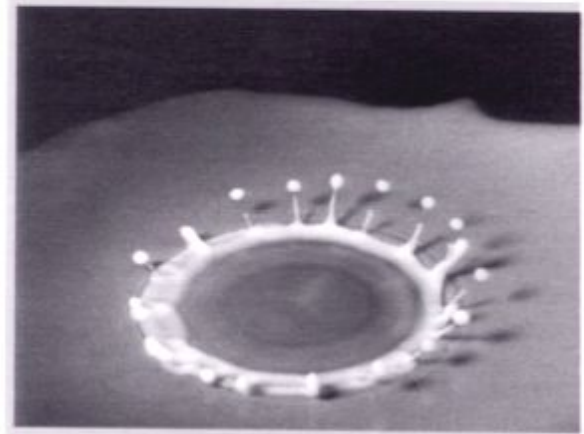
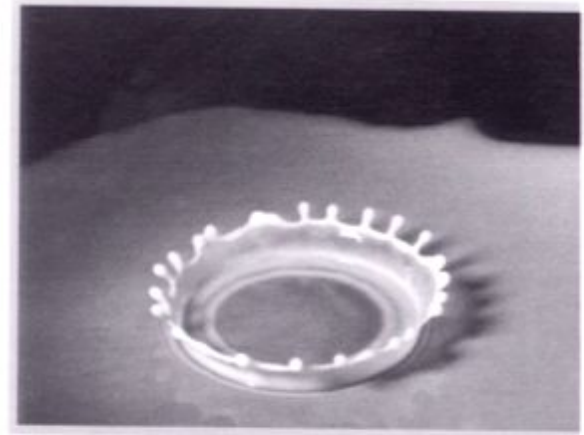
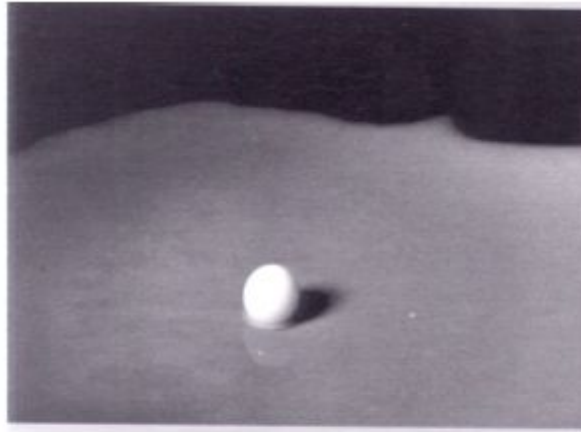
## Type II Complexity

Many different structures working together, all for an apparent purpose (bite us).



mosquito- 200x

A complex  
result  
produced  
simply:  
Splash  
Dynamics



Harold Edgerton photo



# Words

**Type I Complexity** means that we have structure with variations. (The soap.)

**Type II Complexity** means structures are piled upon structures to achieve an apparent purpose. (The Mosquito.)

**Chaos** means that there are many different variations and that it is hard to predict which one will come out in a given place and time. (The splash.)

A Complex world is interesting

In a Chaotic world we do not know what is coming next

Our world is both Complex and Chaotic

## Behe's Unlikely World

Behe argues that biological objects, cells in particular, are too complex to have arisen from any natural process. They are composed of many working parts and each part is necessary for the organism to function. How could so many parts evolve independently?

Since he cannot imagine any natural process which might have produced them, Behe argues that **such a complex outcome requires a creator or Creator.**

Behe's argument is mostly theoretical  
It depends upon the strength of his  
imagination.

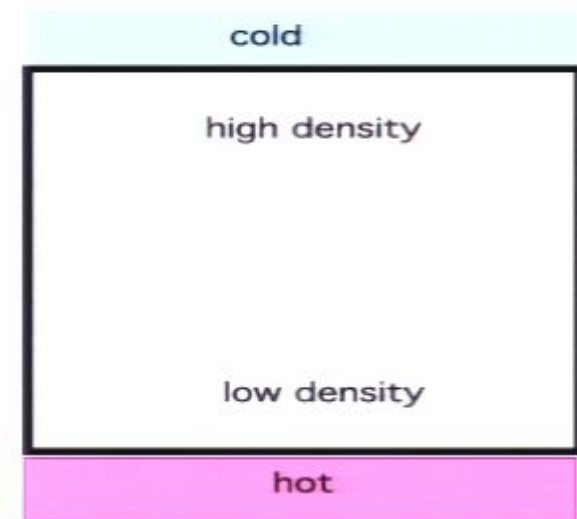
Let's be more real.

Let's look and see how complexity actually arises in  
our world.

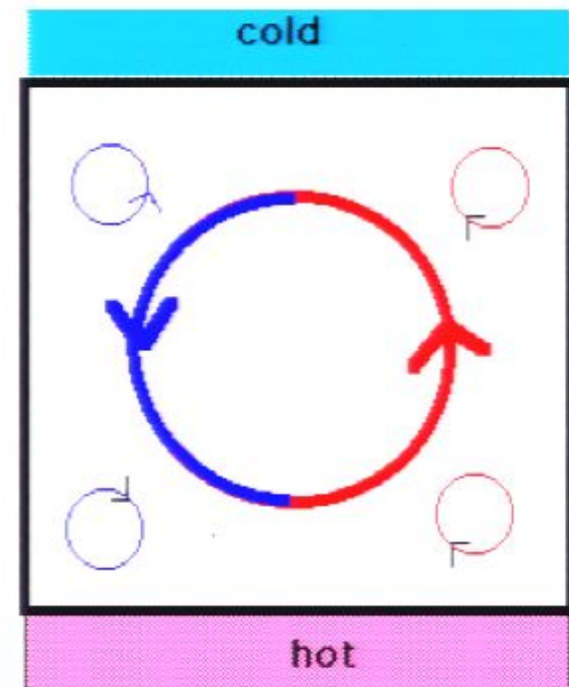
Look at a particular fluid flow.

# Fluids Heated From Below

Start from a box filled with fluid. A little heating of system from below causes no motion of fluid.



A larger temperature difference between top and bottom causes a motion of the fluid, carrying additional heat from bottom to top.



## Beginning of Chaos

Then as the temperature difference is increased still further the motion of the swirls becomes non-repeating and chaotic with different portions of the cell wiggling independently of one another.



# Turbulence

Then for slightly higher heating rates a different pattern emerges:

There is an overall motion, here counterclockwise, which becomes composed of independently moving structures, called **plumes**. They look a little like mushrooms.

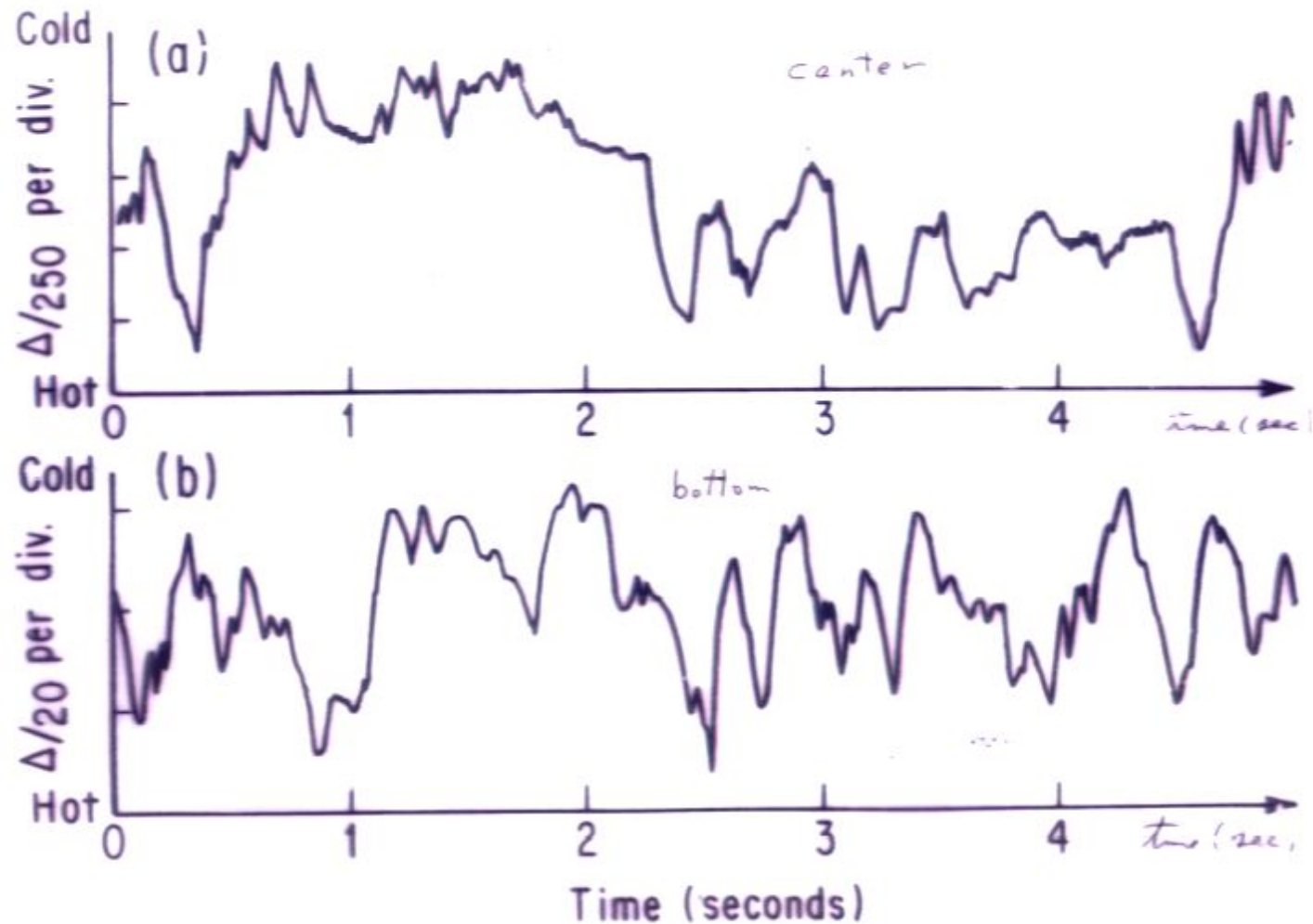


picture from **Penger Tong's** laboratory  
fluid: glycol.

note thermometer in cell

# Plume motion past thermometers produces chaotic readings

from laboratory  
of Albert  
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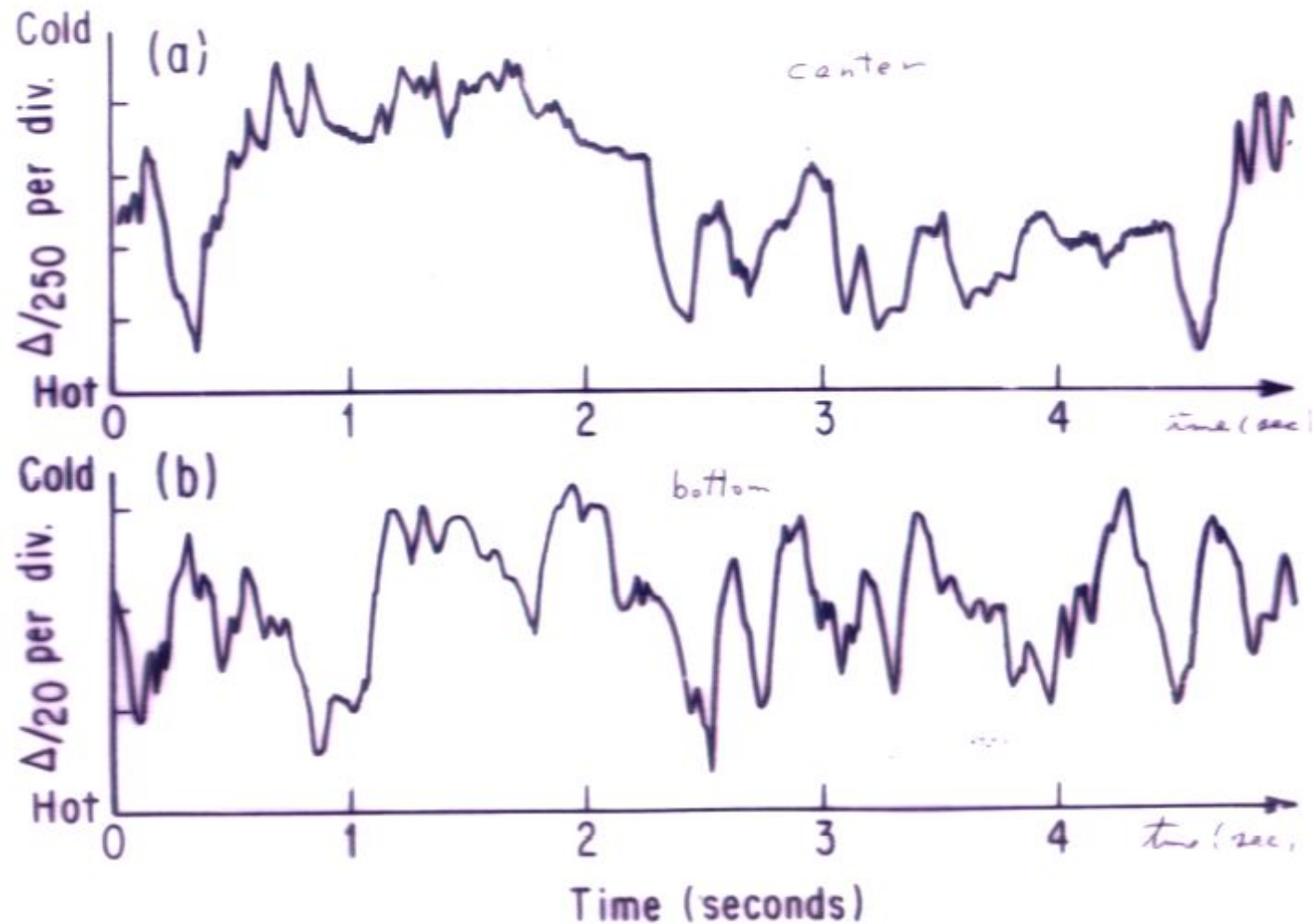
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## Description via Equations

$F=ma$       $[\partial_t + u(r, t) \cdot \nabla]u(r, t) = -\nabla p(r, t) + \nu \nabla^2 u(r, t) + g\alpha T(r, t)$

fluid is incompressible

$$\nabla \cdot u(r, t) = 0$$

temperature

flows with fluid and  
diffuses

$$[\partial_t + u(r, t) \cdot \nabla]T(r, t) = \kappa \nabla^2 T(r, t)$$

From studying many simple situations we learn  
these equation describe and predict all fluid flows

But in interesting, complex situations  
mostly you cannot learn much from directly  
examining the equations

## So look at structures = Plumes

Hot fluid rises through the stalk and reaches the head.

The head pushes upward but the fluid above pushes back.

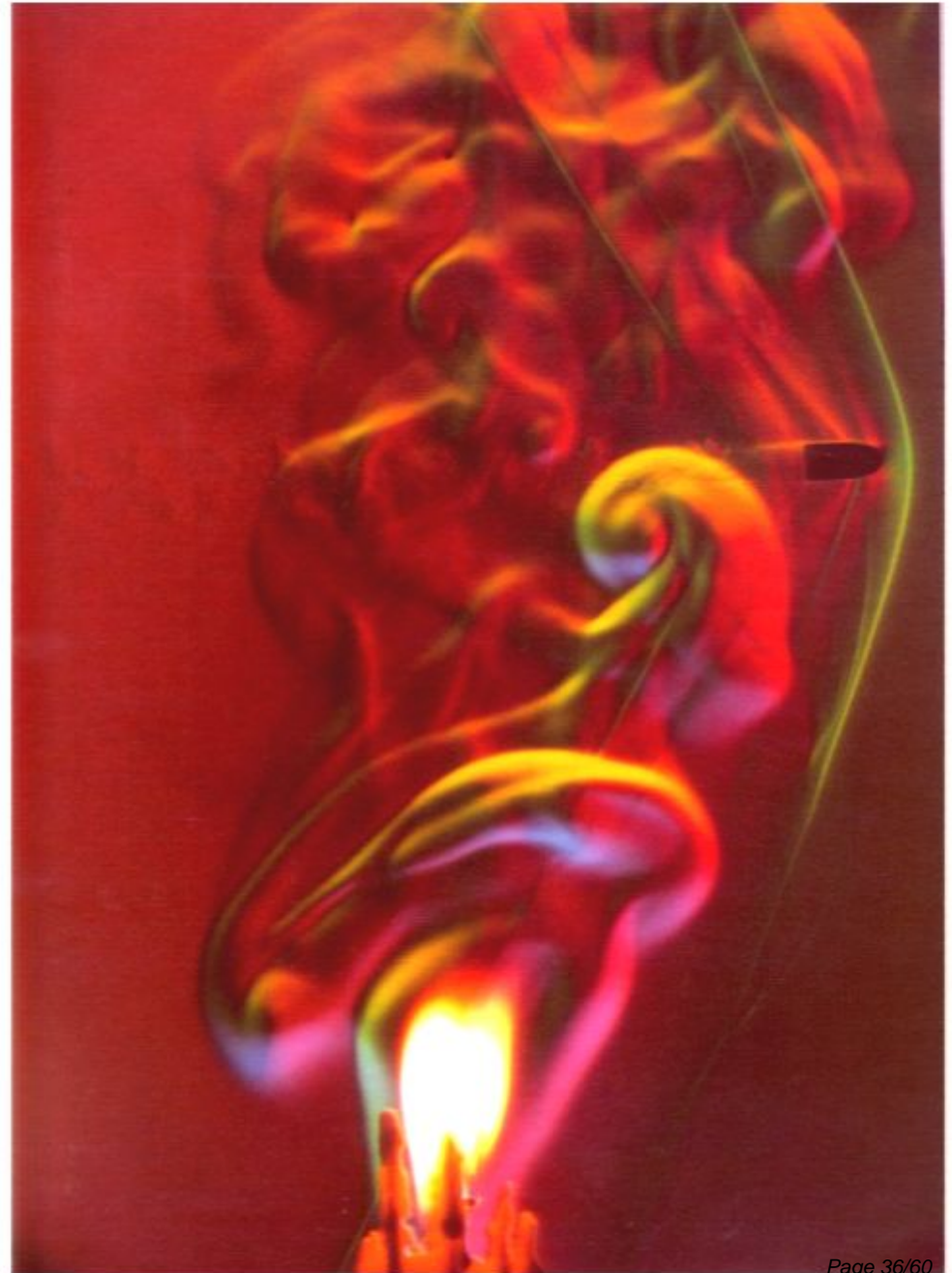
So the head grows outward, until the outward pushing hot fluid is pushed back and under by the colder fluid.

**A plume is an example of an emergent object**



Plumes are  
everywhere fluids  
are heated

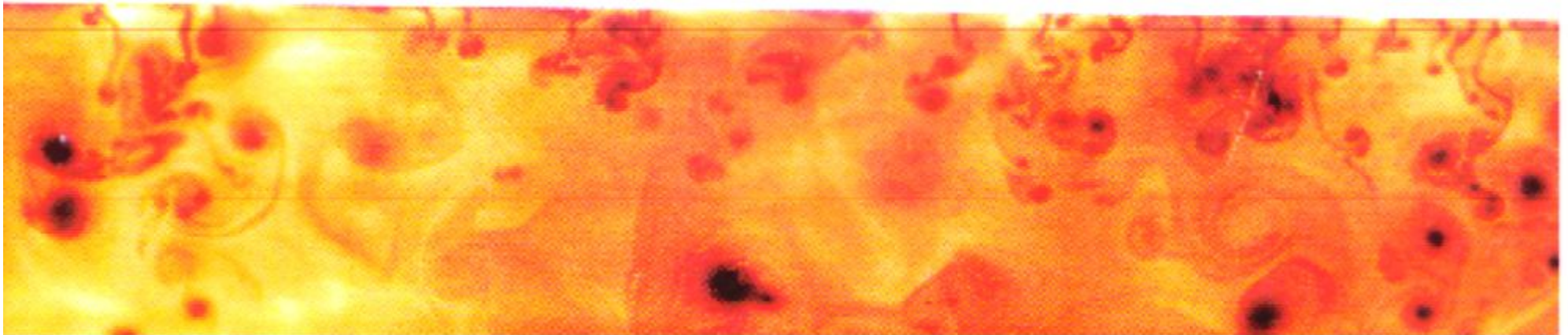
Edgerton picture  
of fluid heated by  
candle





## Plume from a Nuclear Explosion

## Plumes at Solar Surface



Cold plumes fall  
downward from surface

Colors Describe Temperature

Simulation by Malagoli, Dubey, Cattaneo

Return to fluid heated from below:  
**Plume Moves across bottom  
of Cell**

time

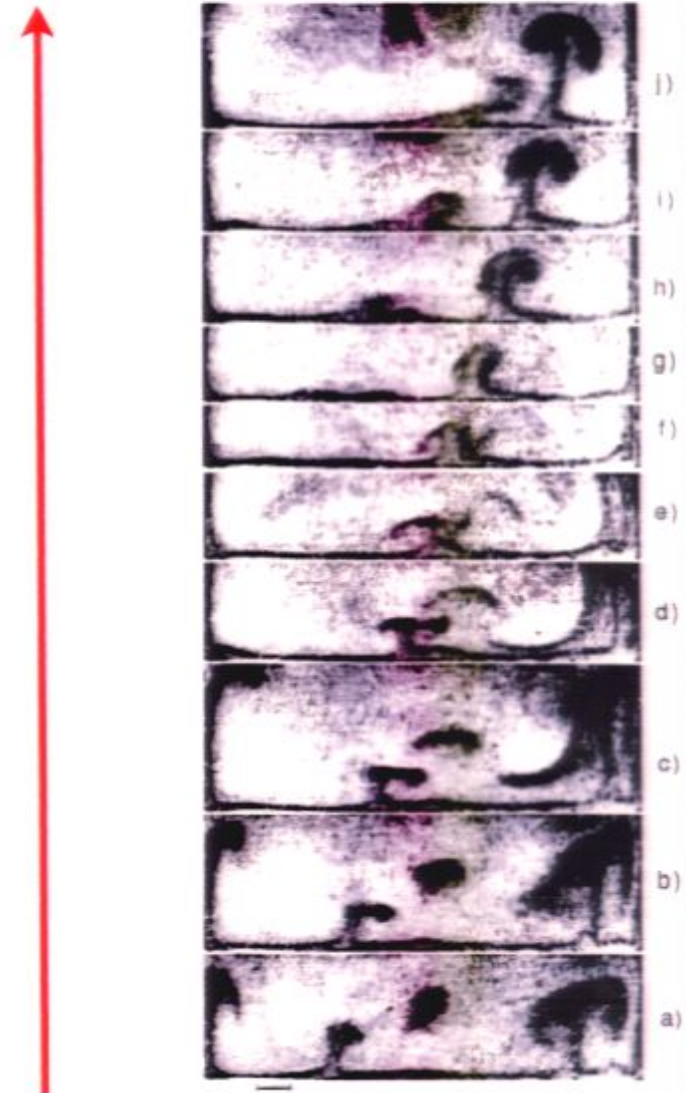


Figure 7. Waves and eruptions of the lower thermal boundary layer. Images of the region near the boundary layer are spaced 1.5 s apart. The dark region is the boundary layer, and the bar at the lower right is 5 mm long.

Credit: Gluckman, Williams, & Gollub 1993

# The Cell Becomes a Machine: Photo

a complex  
machine emerges

The plume is only a  
part of a more  
complex 'Machine':  
How does the  
machine work? first  
look at the cell



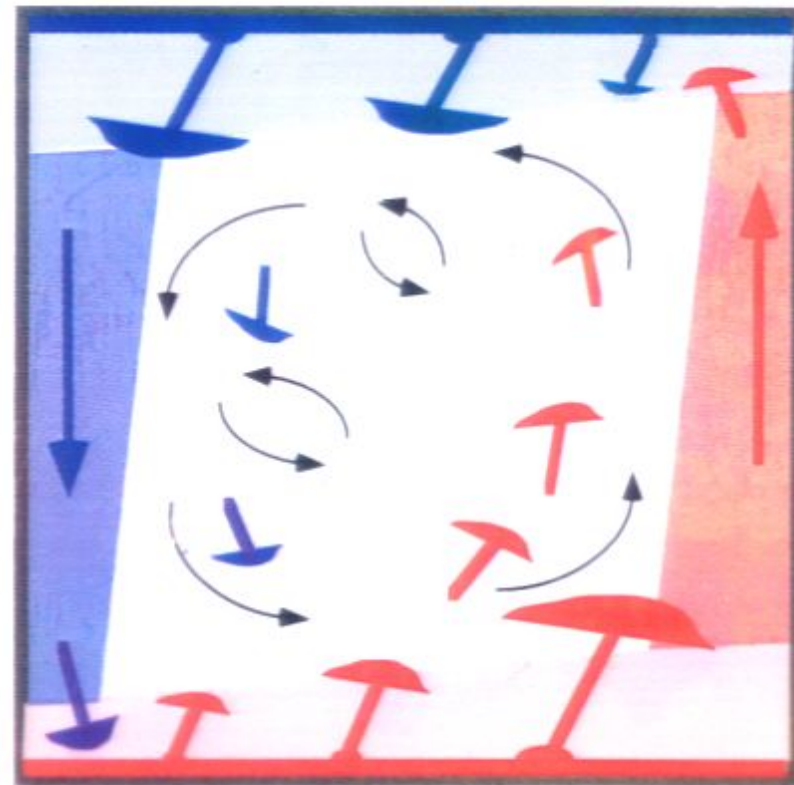
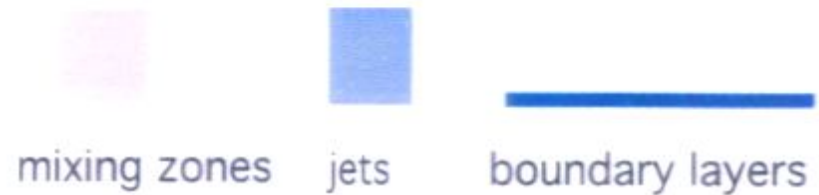


# The Cell Becomes a Machine: The Geometry

The plumes play different roles in different regions of the cell.

Note waves at the bottom

Overall flow

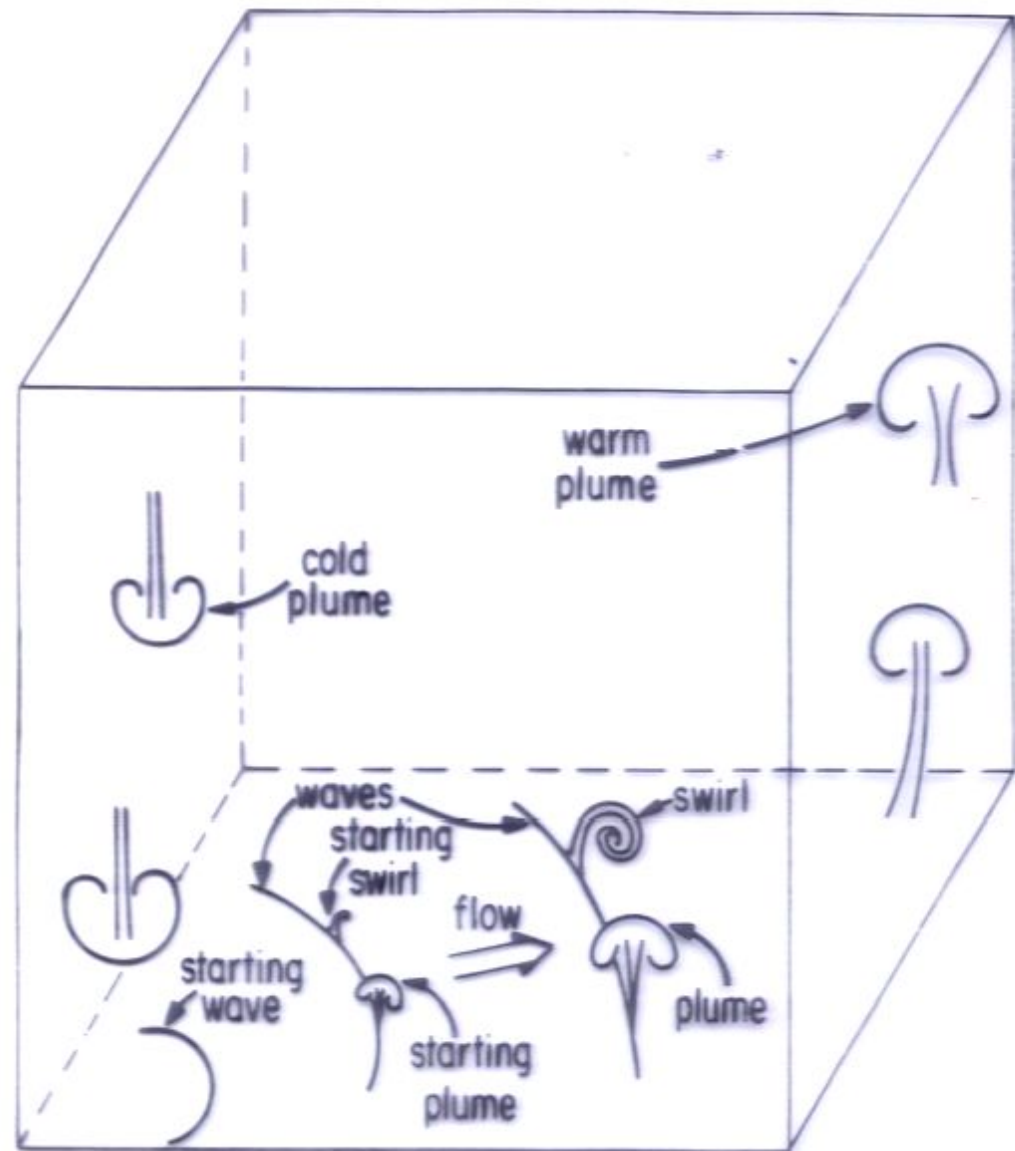


Raleigh Benard Cartoon

# The Cell Becomes a Machine: The Dynamics

The wind in the cell starts a wave moving across the bottom of the cell...

The result: Flowing fluids can organize themselves to produce the most amazing complexity with many different working parts each serving a different function.



Zacchi Moses Libchaber

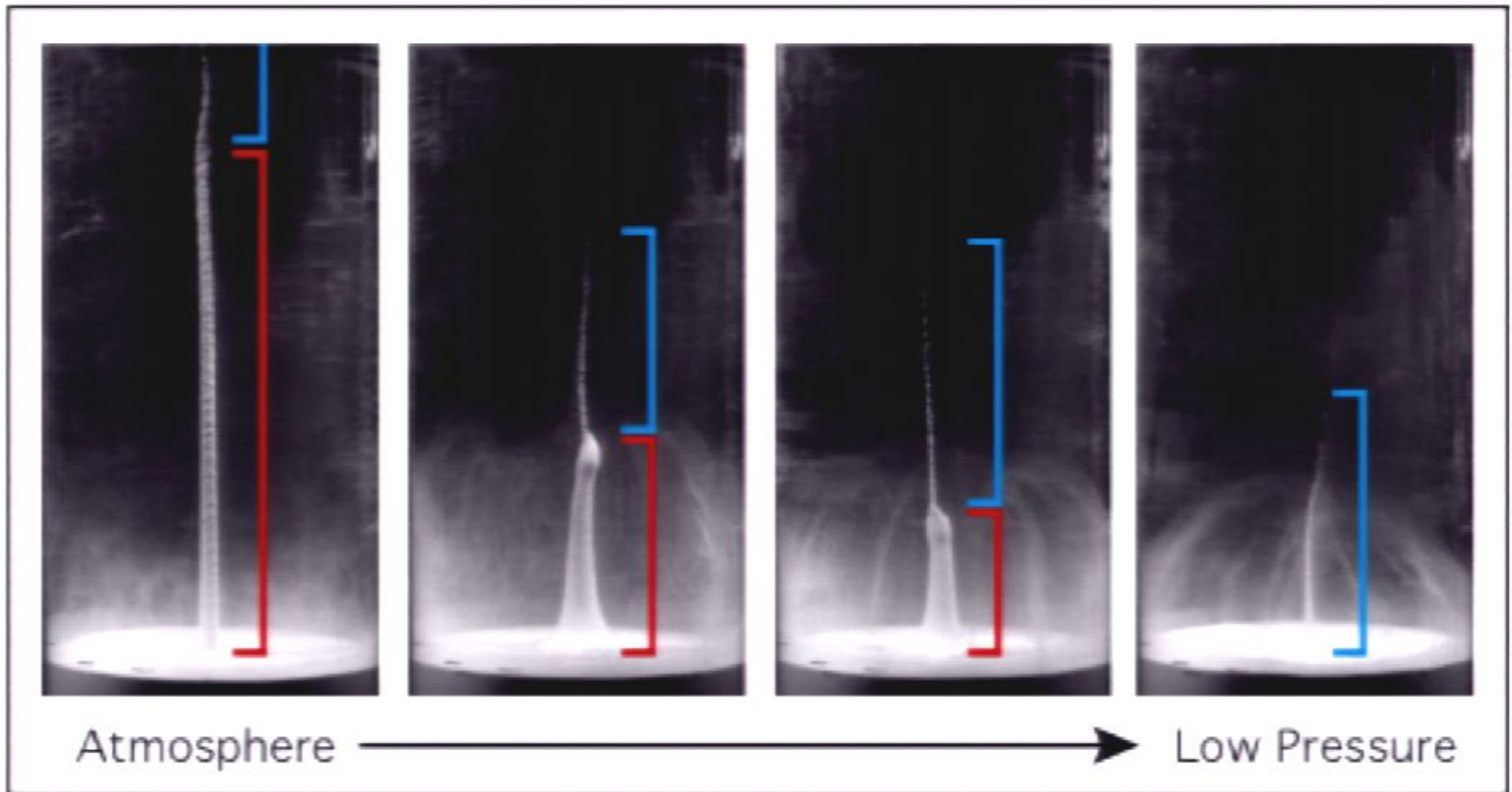
## Behe's world and ours

**Behe** cannot imagine how a thing as complex as a living cell might have been produced.

In physics we often see things that are far beyond our initial imagination and expectation.

Behe thinks he can predict when complexity will arise...but the world is full of surprises

sand jets: A metal ball is dropped into uncompact sand two jets emerge



# The world is full of surprises

Ethanol is dropped into a dry saucer.

Work of Nagel, Zhang, Lei Xu.

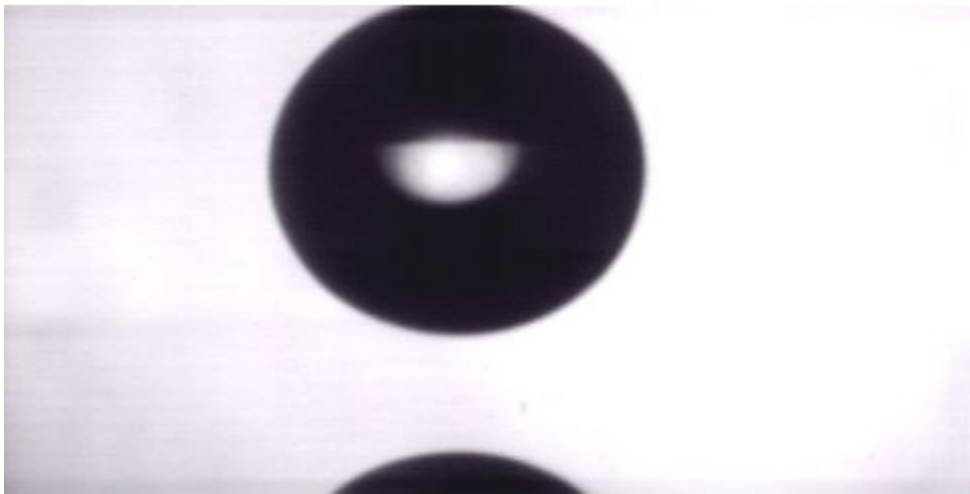
547 torr

242 torr

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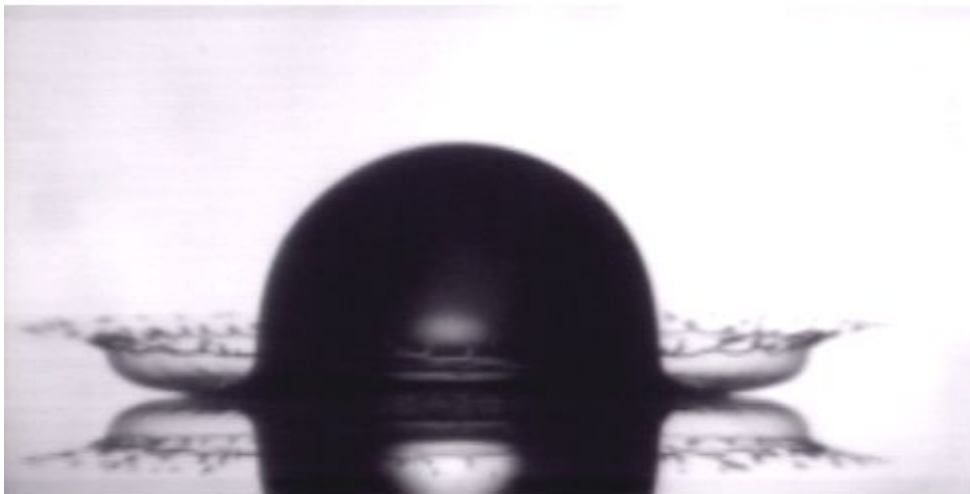
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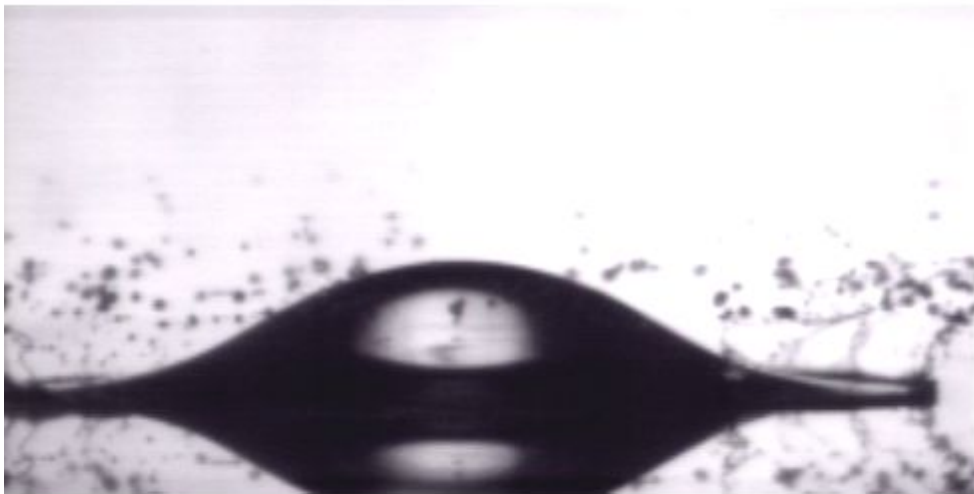
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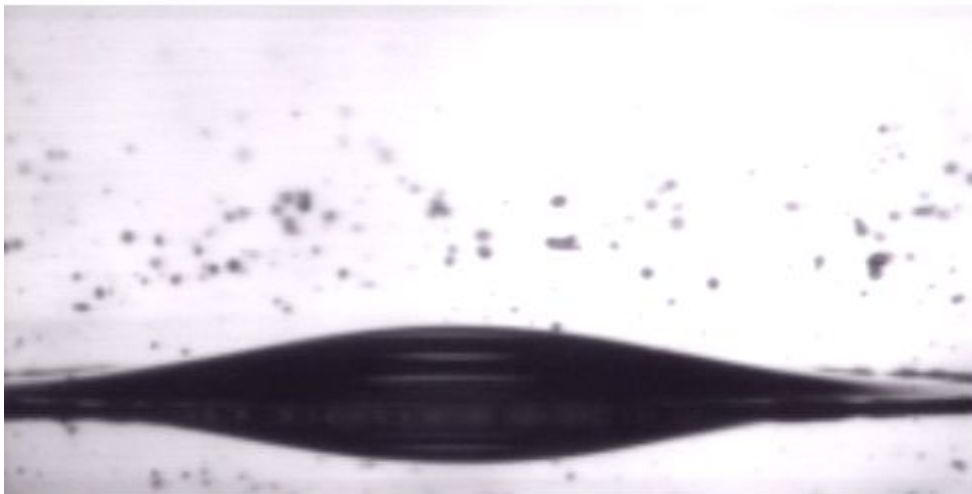
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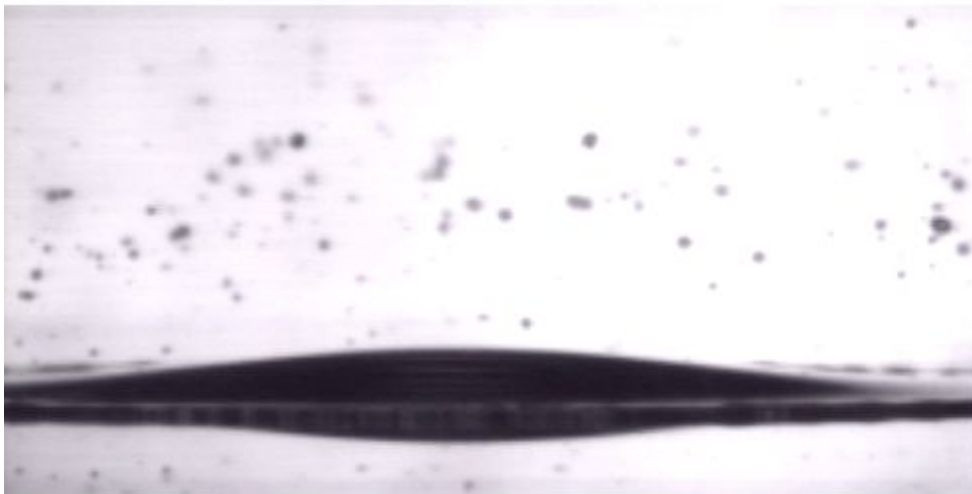
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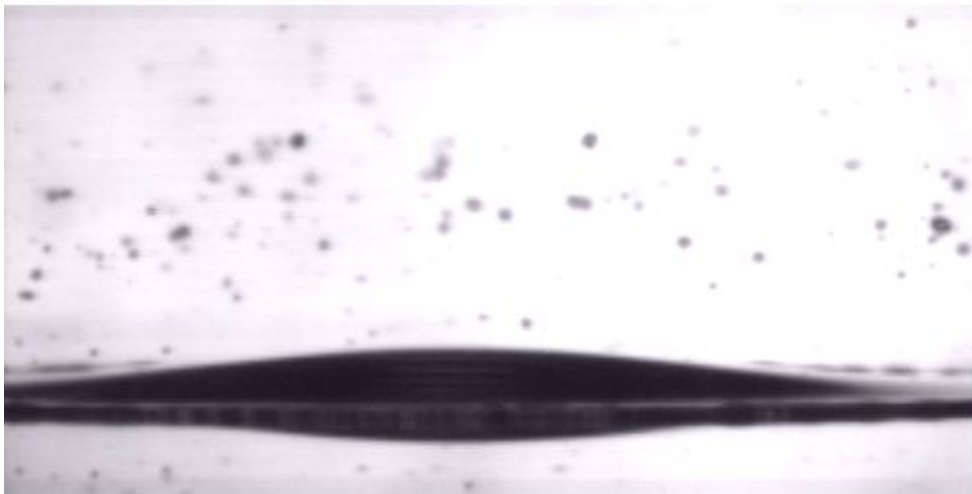
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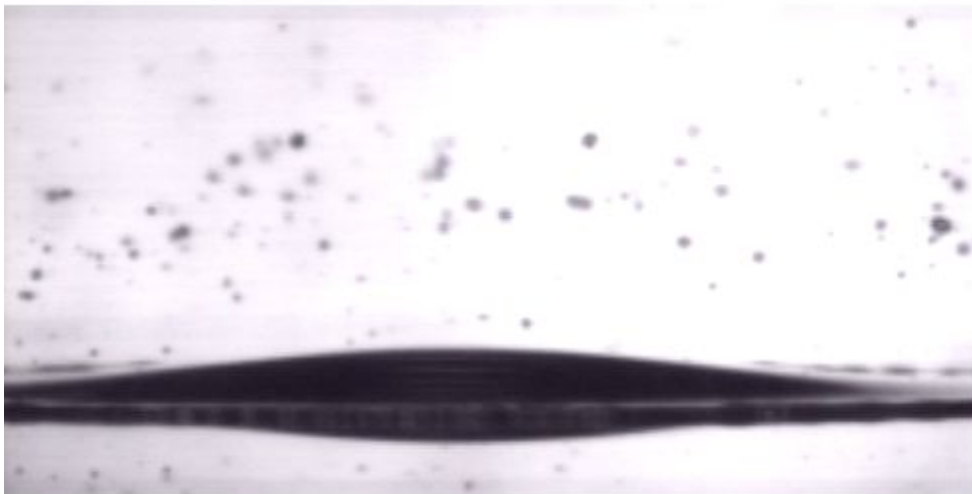


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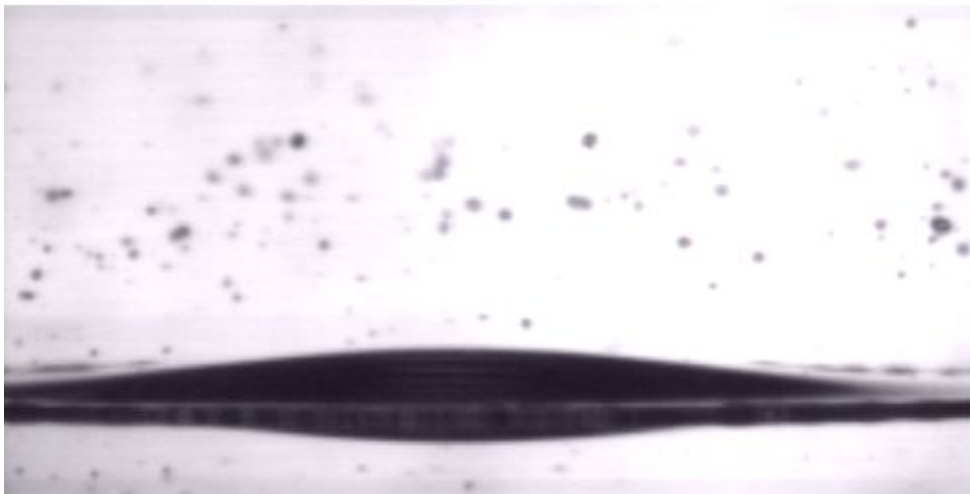


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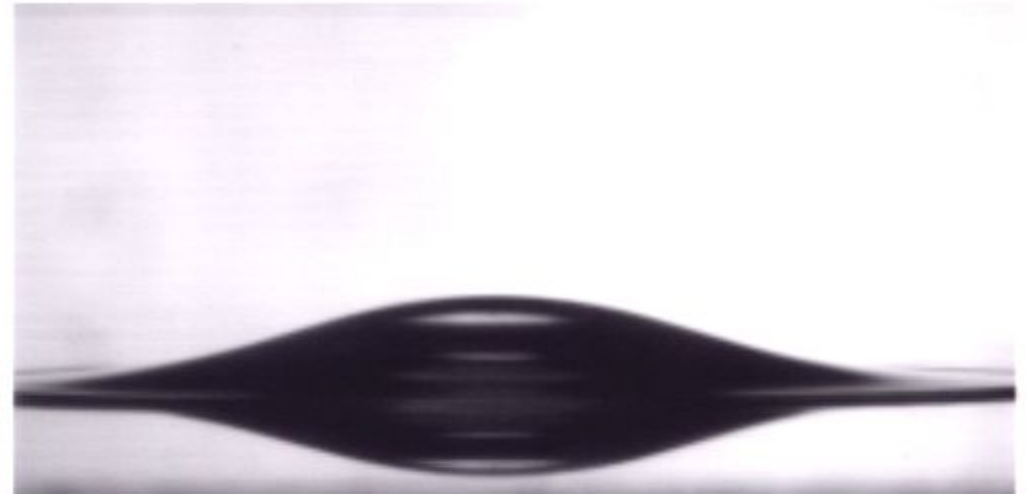
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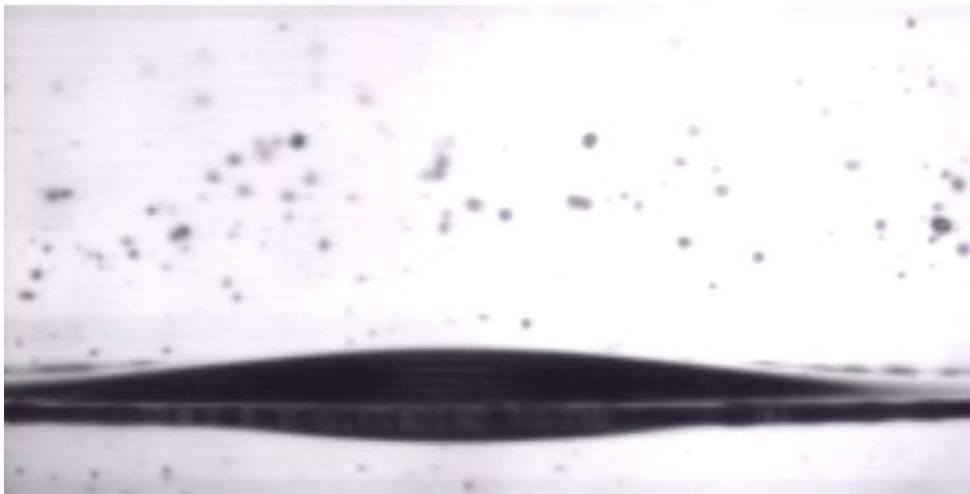


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# Fluids in Motion: A square dance

theory: four basic ideas define fluid mechanics.

First: A fluid contains many particles in motion

Second: ‘conservation laws’: some things (particles and momentum) are never lost only moved around

Third: momentum moves with the particles

Fourth: Technical requirements (translational invariance, rotational invariance, locality)

The big idea: Do the above right (plus a little more or maybe a little less.) and you will construct a model fluid with behavior just like a real one.

# Conclusion I

Our examples show that simple rules applied many times can make structures (like the plume) and machines (like the heat engine) .

Thus complexity can arise from simplicity. Complex patterns arise naturally and ubiquitously. **What if ...** these patterns themselves rearranged themselves into superstructures, like the “machine” we saw in the heated box, and these were chaotic and these superpatterns arranged themselves into chaotic structures..... Such piling of complexity upon complexity could work to produce the richness of biological systems.



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# Knowledge and Ignorance

We don't have much knowledge about how complexity arises, either in the physical world or for the earliest biological forms. Dembski and Behe do us some good by pointing out that ignorance, but neither they nor the ID people generally seem to have much positive to add to the discussion.

A better view than theirs is that of Saint Augustine of Hippo (354-430)

“The Universe was brought into being in a less than fully formed state, but was gifted with the capacity to transform itself from unformed matter into a truly marvelous array of structure and life forms”

Howard J. van Till

# About school curricula

In the last 1600 years, we have learned some specifics to help flesh out Augustine's good overview. We should not let the particular view of the universe provided by ID's followers replace science in the school curricula. Instead, we should notice that

Evolutionary biology, paleontology, and cosmology are not speculations. They are root parts of science and human knowledge. They belong in schools as part of the basics of our curriculum and of our understanding of the material world.

Other subjects, unrooted in experiment, should be avoided in school science classrooms.

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