





# FYFD in brief...

**Established:** July 2010

**Platform:** Tumblr

**Format:** new posts M-F

**Posts:** 1450+

**Readers:** 228,900+

**Featured by:**

**WIRED**

**boingboing**

**Mashable**

**physicsworld**

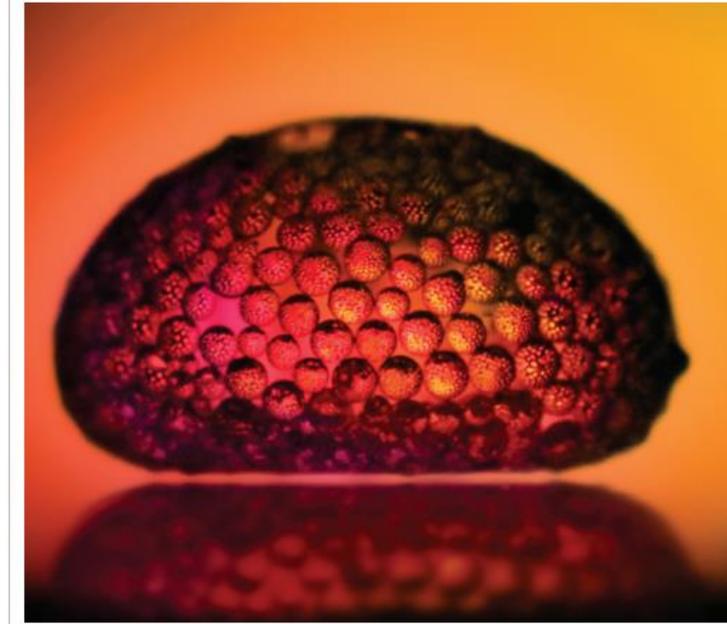
**BuzzFeed**

**GIZMODO**

**io9**

*The Atlantic*

**tumblr.**



A [Leidenfrost](#) droplet impregnated with [hydrophilic](#) beads hovers on a thin film of its own vapor. The Leidenfrost effect occurs when a liquid touches a solid surface much, much hotter than its boiling point. Instead of boiling entirely away, part of the liquid vaporizes and the remaining liquid survives for extended periods while the vapor layer insulates it from the hot surface. Hydrophilic beads inserted into Leidenfrost water droplets initially sink and are completely enveloped by the liquid. But, as the drop [evaporates](#), the beads self-organize, forming a monolayer that coats the surface of the drop. The outer surface of the beads dries out, trapping the beads and causing the evaporation rate to slow because less liquid is exposed. (Photo credit: [L. Maquet et al.; research paper](#) - pdf)

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**Fuck Yeah Fluid Dynamics**

Celebrating the physics of all that flows. [Ask a question](#), [submit a post idea](#) or [send an email](#). You can also follow FYFD on [Twitter](#) and [Google+](#). FYFD is written by [Nicole Sharp, PhD](#).

**tumblr.**

228,900+ followers



2,600+ followers



10,000+ unique  
visitors/month

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# Small versus large

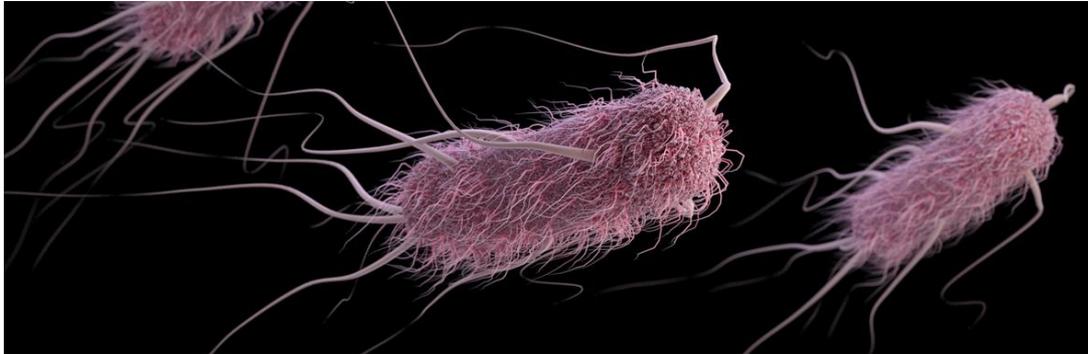


Physical size



# Small versus large

[CDC](#)



*E. Coli* – swimming micro-organisms



Physical size



# Small versus large

Tufts microfluidic device courtesy of J. Guasto



Microfluidic devices

Micro-organisms

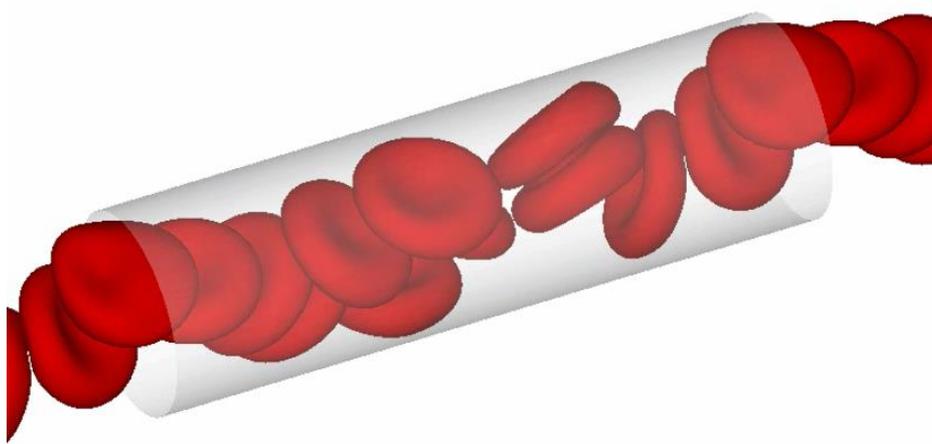


Physical size



# Small versus large

[J. Freund et al.](#)



Blood flow

Microfluidic devices



Micro-organisms



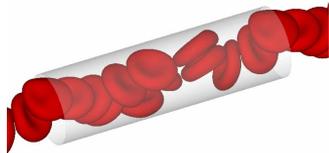
Physical size



# Small versus large

[S. Berg and S. Troian](#)

Blood flow



Microfluidic devices



Micro-organisms



Soap films



Physical size

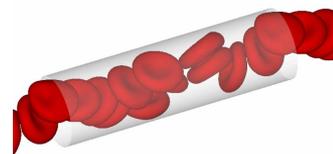


# Small versus large

[K. Winters et al.](#)



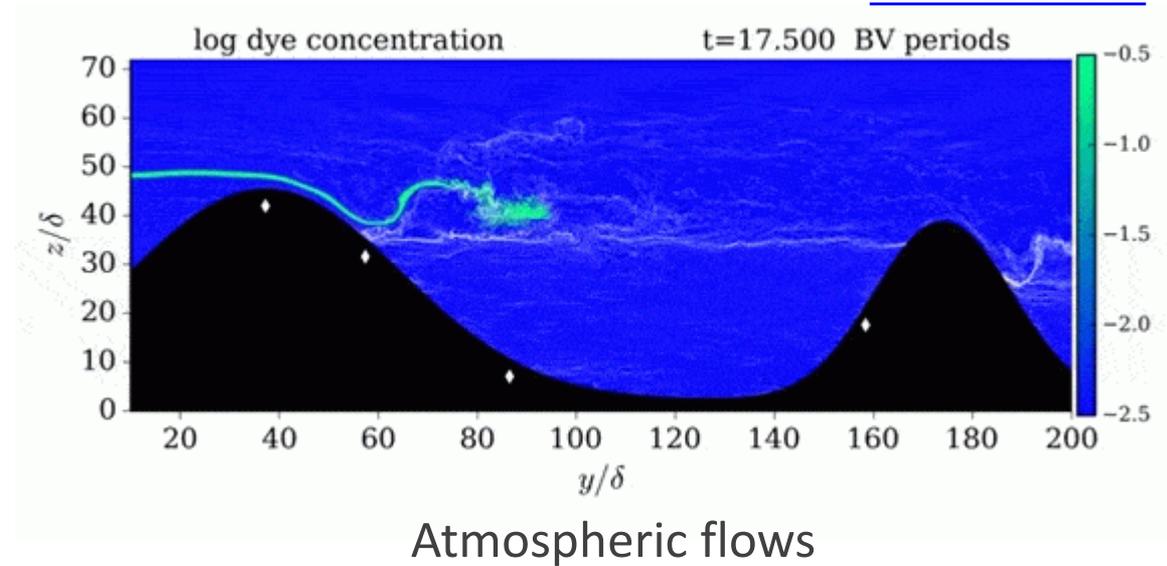
Blood flow



Microfluidic devices



Micro-organisms



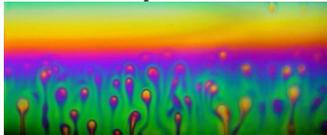
Physical size



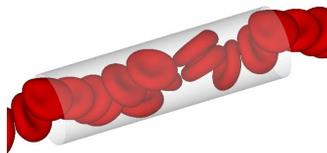
# Small versus large

[NASA](#)

Soap films



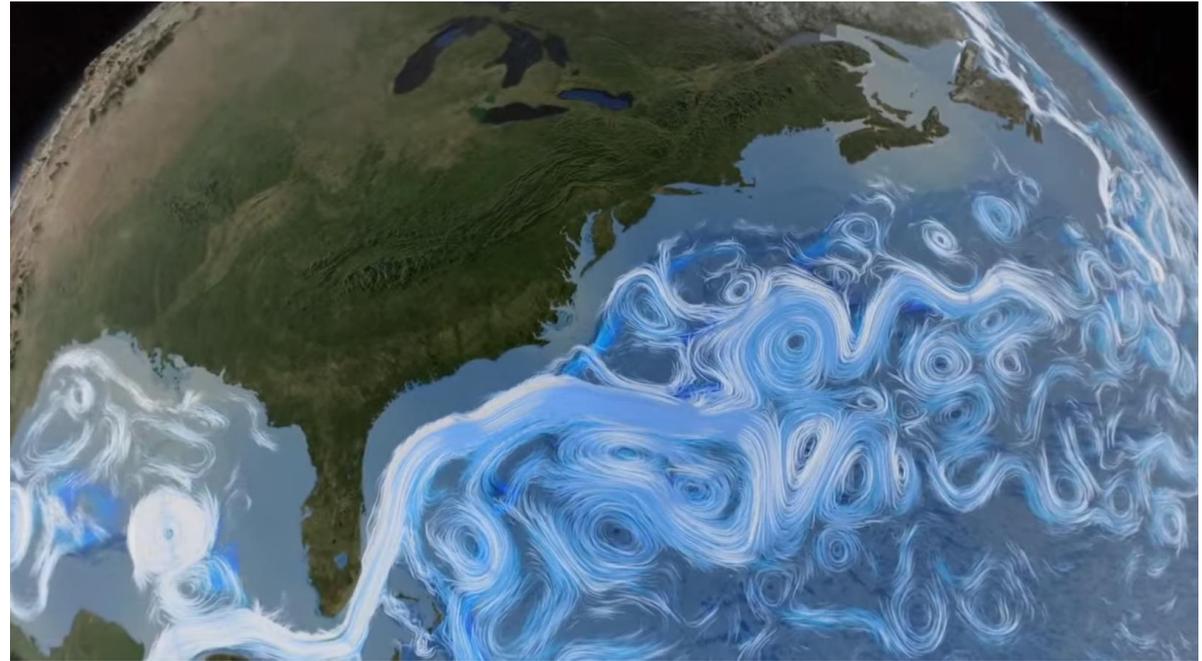
Blood flow



Microfluidic devices

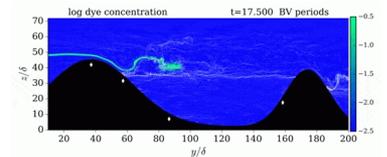


Micro-organisms



Oceanic flows

Atmospheric flows



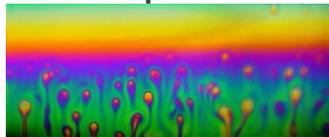
Physical size



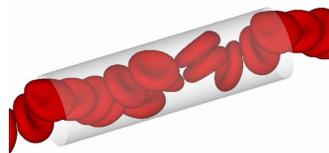
# Small versus large

[NASA](#)

Soap films



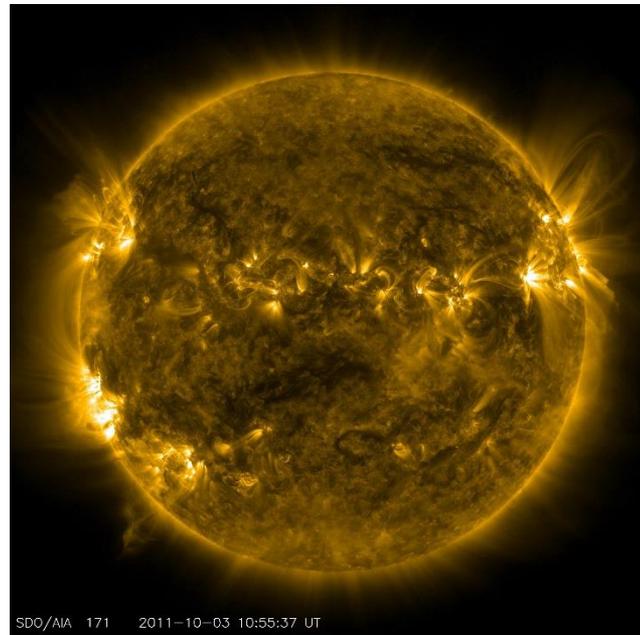
Blood flow



Microfluidic devices



Micro-organisms

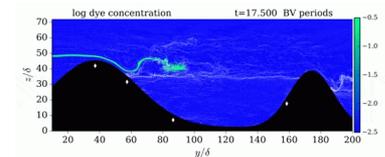


Solar dynamics

Oceanic flows



Atmospheric flows



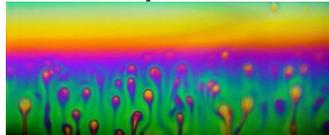
Physical size



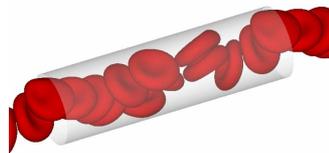
# Small versus large

[NASA/ESA](#)

Soap films



Blood flow



Microfluidic devices



Micro-organisms



Supernova remnants

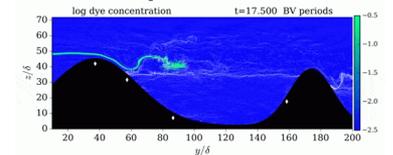
Solar dynamics



Oceanic flows



Atmospheric flows

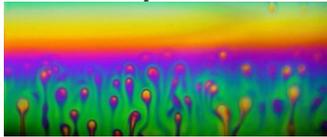


Physical size

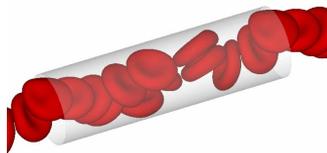


# Small versus large

Soap films



Blood flow



Microfluidic devices



Micro-organisms



Supernovas



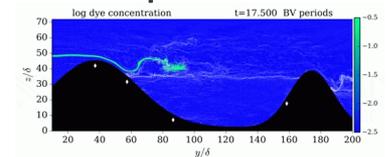
Solar dynamics



Oceanic flows



Atmospheric flows

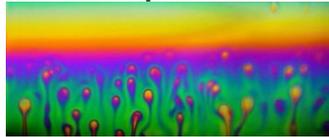


Physical size

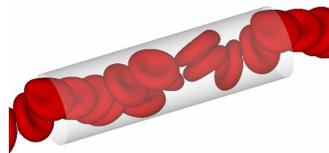


# Small versus large

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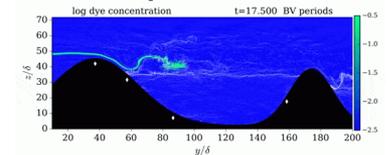
Solar dynamics



Oceanic flows



Atmospheric flows



Physical size



# Other extremes



Pitch drop experiment

Velocity





# Other extremes



Pitch drop experiment



Hypersonics



Velocity



# Other extremes



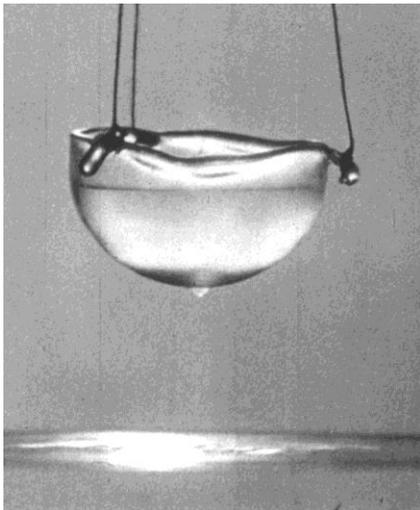
Pitch drop experiment



Hypersonics



Velocity



Superfluids



Temperature



# Other extremes



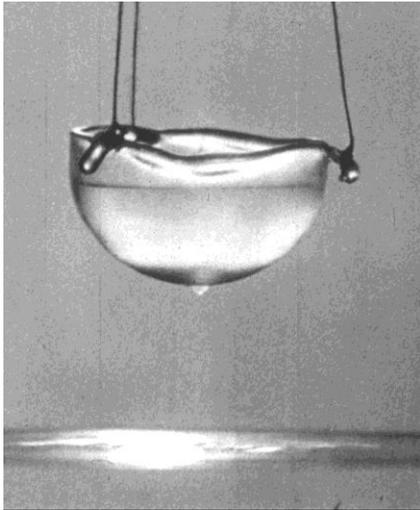
Pitch drop experiment



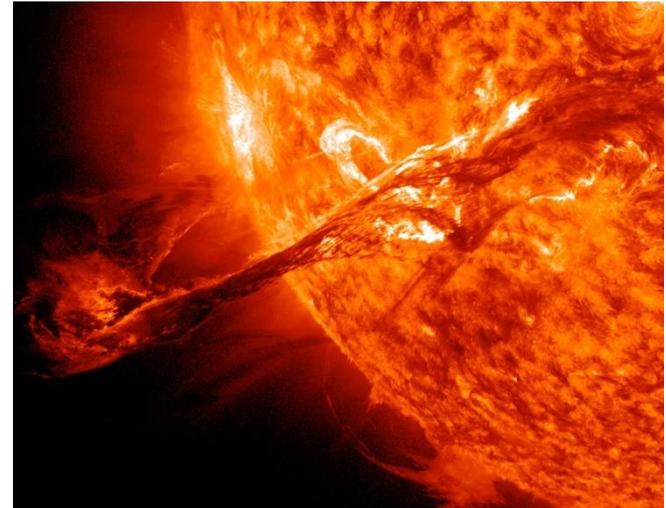
Hypersonics



Velocity



Superfluids



Plasmas



Temperature



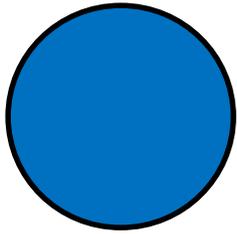
We define fluid dynamics by extremes.



# What is a fluid?



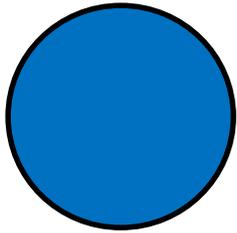
# What is a fluid?



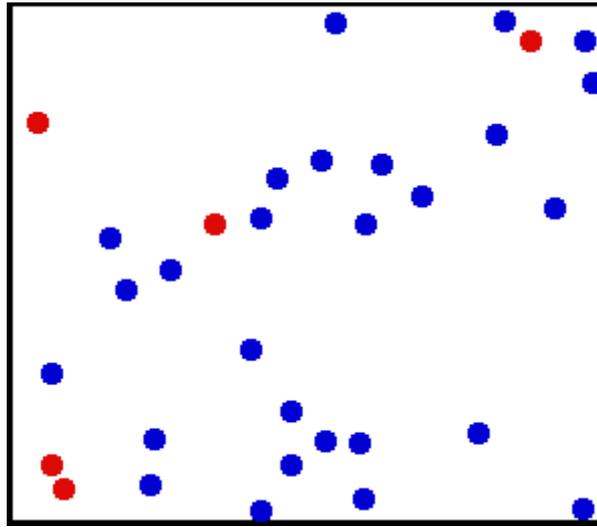
Atom



# What is a fluid?



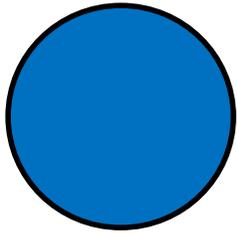
Atom



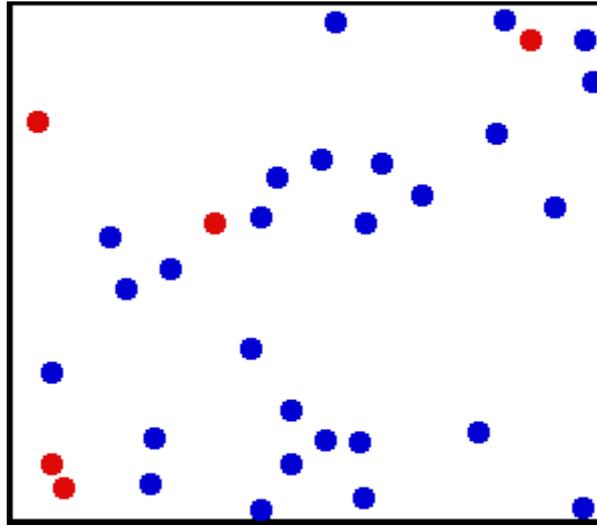
Fluid Atoms



# What is a fluid?



Atom



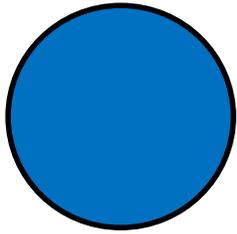
Fluid Atoms

$$Kn = \frac{\textit{mean free path}}{\textit{flow lengthscale}}$$

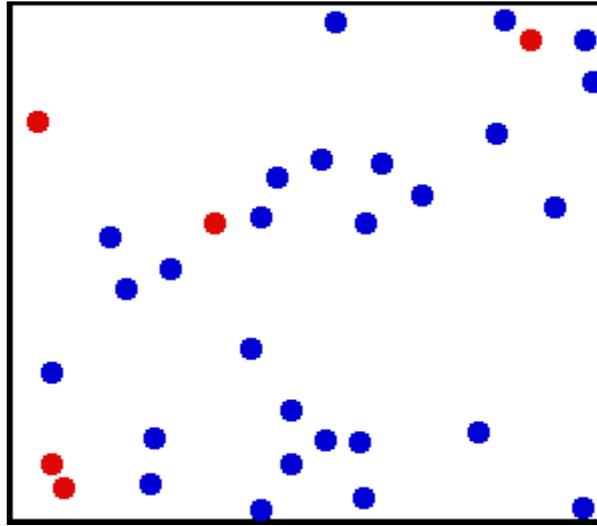
Knudsen Number



# What is a fluid?



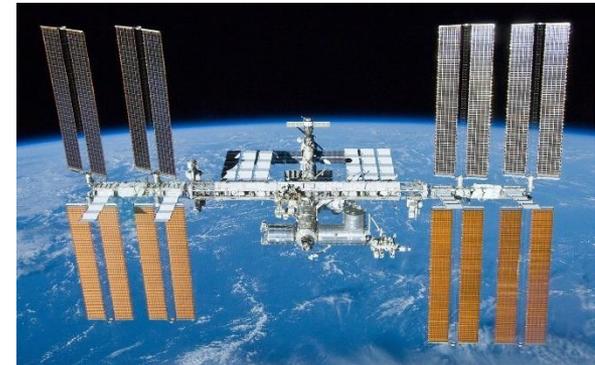
Atom



Fluid Atoms

$$Kn = \frac{\text{mean free path}}{\text{flow lengthscale}}$$

Knudsen Number



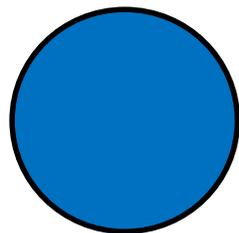
Free Molecular Flow

Knudsen Number

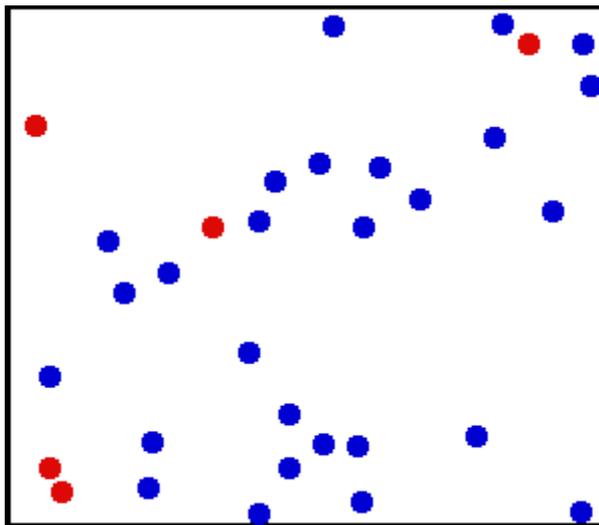




# What is a fluid?



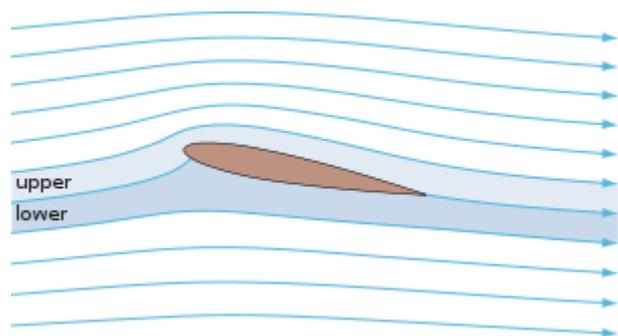
Atom



Fluid Atoms

$$Kn = \frac{\textit{mean free path}}{\textit{flow lengthscale}}$$

Knudsen Number



Continuum Mechanics



Free Molecular Flow

Knudsen Number





# Navier-Stokes

$$\frac{\partial \bar{u}}{\partial t} + (\bar{u} \cdot \nabla) \bar{u} = -\frac{1}{\rho} \nabla p + \bar{g} + \nu \nabla^2 \bar{u}$$



# Navier-Stokes

$$\underbrace{\frac{\partial \bar{u}}{\partial t}}_{\text{Unsteady}} + \underbrace{(\bar{u} \cdot \nabla) \bar{u}}_{\text{Convective}} = - \underbrace{\frac{1}{\rho} \nabla p}_{\text{Pressure}} + \underbrace{\bar{g}}_{\text{Body Force}} + \underbrace{\nu \nabla^2 \bar{u}}_{\text{Viscous}}$$



# Navier-Stokes

$$\underbrace{\frac{\partial \bar{u}}{\partial t}}_{\text{Unsteady}} + \underbrace{(\bar{u} \cdot \nabla) \bar{u}}_{\text{Convective}} = - \underbrace{\frac{1}{\rho} \nabla p}_{\text{Pressure}} + \underbrace{\bar{g}}_{\text{Body Force}} + \underbrace{\nu \nabla^2 \bar{u}}_{\text{Viscous}}$$

Scaling arguments



$$\text{Re} = \frac{\textit{inertial effects}}{\textit{viscous effects}}$$



# Navier-Stokes

$$\underbrace{\frac{\partial \bar{u}}{\partial t}}_{\text{Unsteady}} + \underbrace{(\bar{u} \cdot \nabla) \bar{u}}_{\text{Convective}} = - \underbrace{\frac{1}{\rho} \nabla p}_{\text{Pressure}} + \underbrace{\bar{g}}_{\text{Body Force}} + \underbrace{\nu \nabla^2 \bar{u}}_{\text{Viscous}}$$

Scaling arguments



$$\text{Re} = \frac{\textit{inertial effects}}{\textit{viscous effects}}$$

Something more tractable



# Extremely viscous

$$\text{Re} = \frac{Ux}{\nu} \ll 1$$



# Extremely viscous

Slow

$$\text{Re} = \frac{Ux}{\nu} \ll 1$$

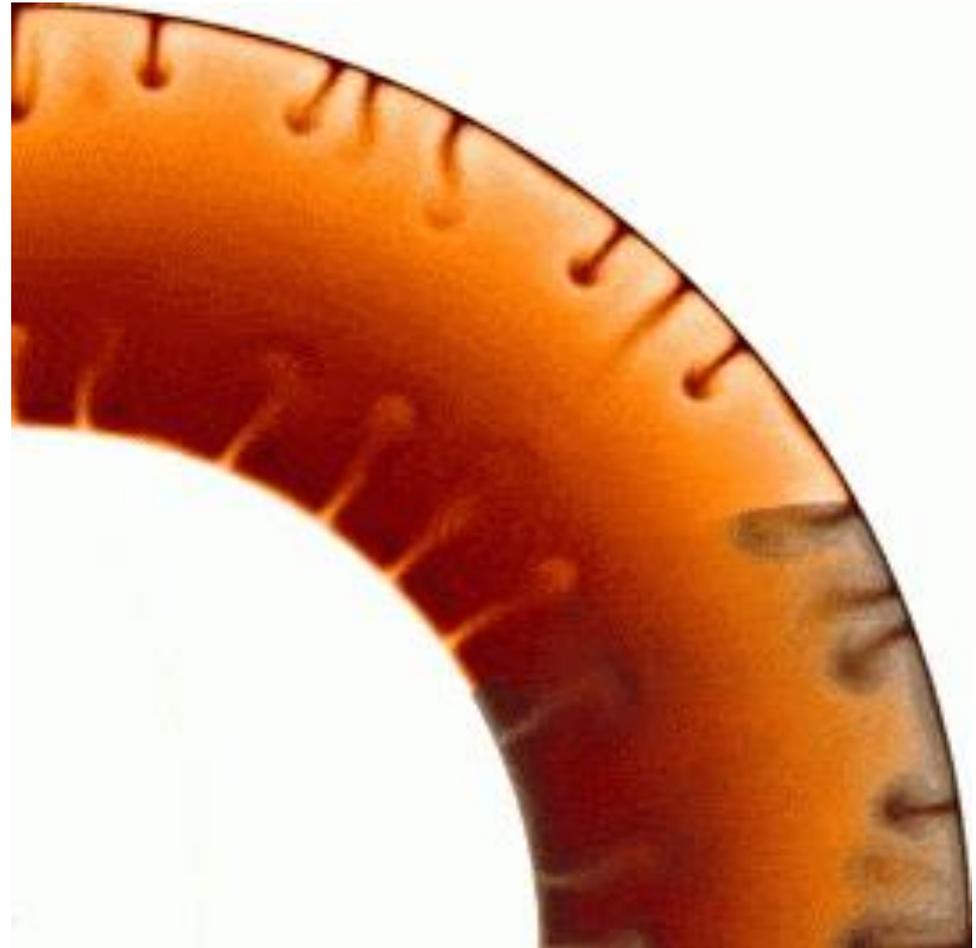


# Extremely viscous

Slow

$$\text{Re} = \frac{Ux}{\nu} \ll 1$$

Mantle Convection





# Extremely viscous

$$\text{Re} = \frac{Ux}{\nu} \ll 1$$

Tiny

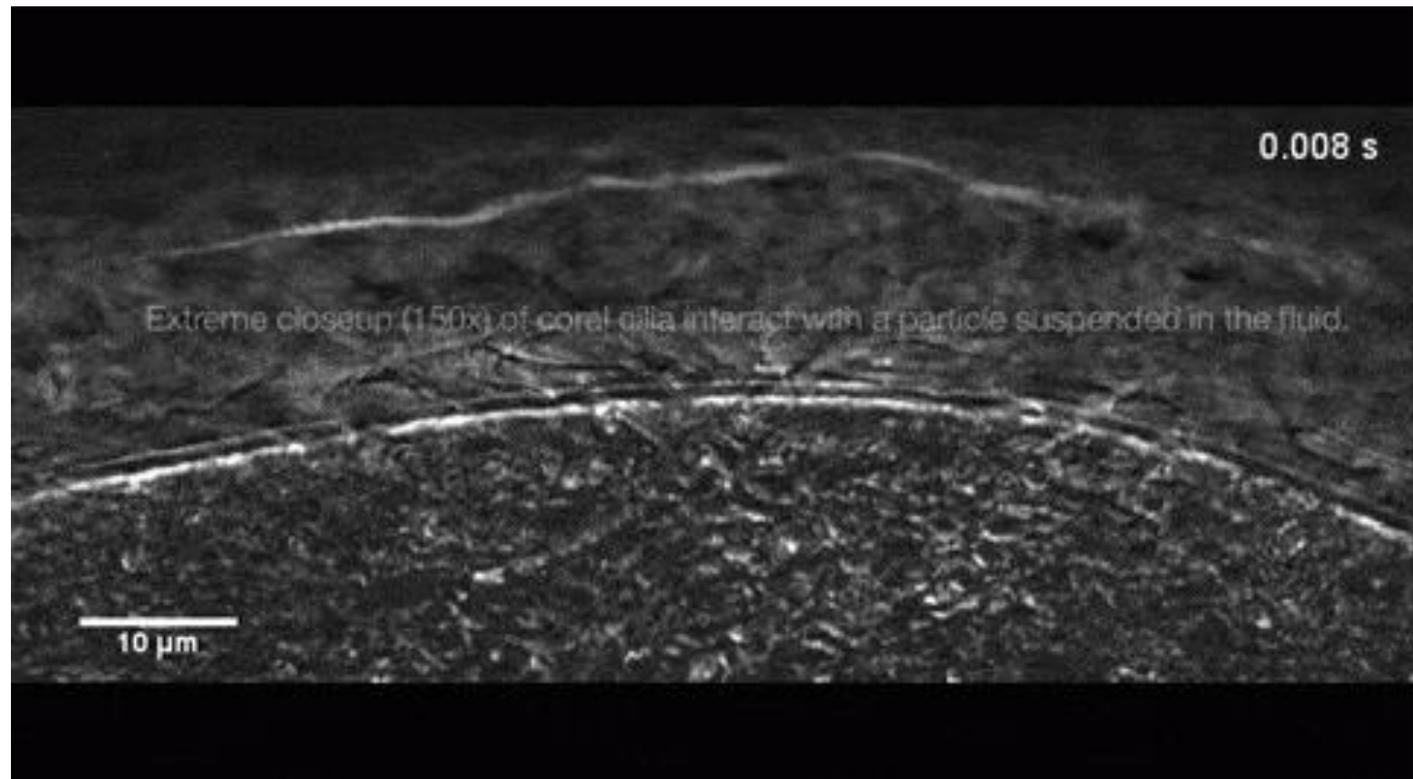


# Extremely viscous

$$\text{Re} = \frac{Ux}{\nu} \ll 1$$

Tiny

## Beating Cilia





# Extremely viscous

$$\text{Re} = \frac{Ux}{\nu} \ll 1$$

Hard to deform



# Extremely viscous

$$\text{Re} = \frac{Ux}{\nu} \ll 1$$

Hard to deform

## Glacial Flow



[K. Wakata](#)



# Inertially-dominated

$$\text{Re} = \frac{Ux}{\nu} \gg 1$$



# Inertially-dominated

Fast

$$\text{Re} = \frac{Ux}{\nu} \gg 1$$

## Peregrine Falcon





# Inertially-dominated

$$\text{Re} = \frac{Ux}{\nu} \gg 1$$

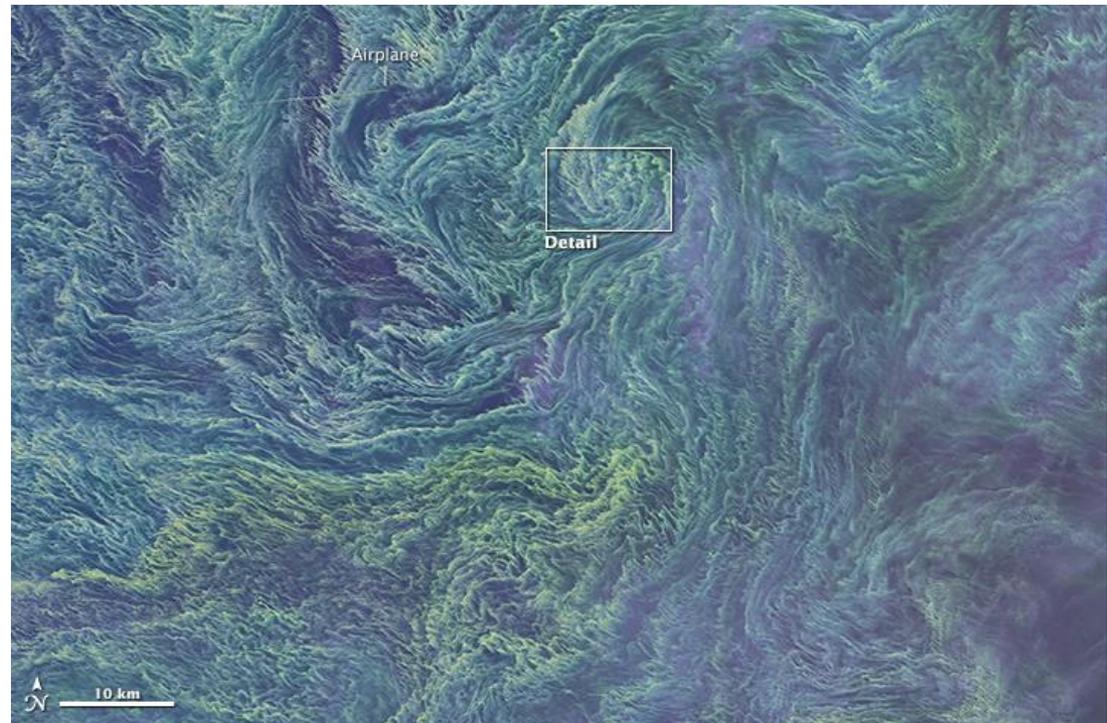
Big

Peregrine Falcon



[M. Baird](#)

# Phytoplankton Blooms



[NASA](#)



# Inertially-dominated

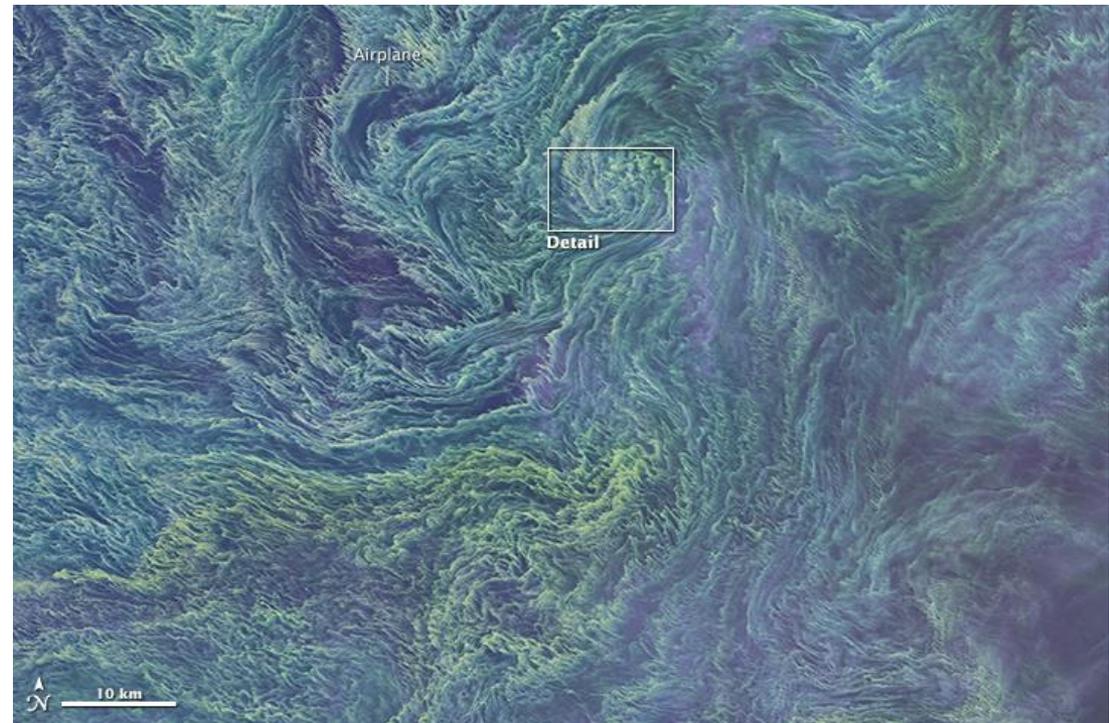
$$\text{Re} = \frac{Ux}{\nu} \gg 1$$

## Peregrine Falcon

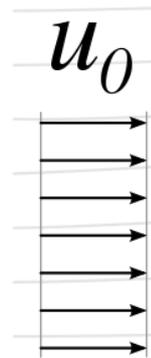


[M. Baird](#)

## Phytoplankton Blooms



[NASA](#)



[Wikimedia](#)



# Inertially-dominated

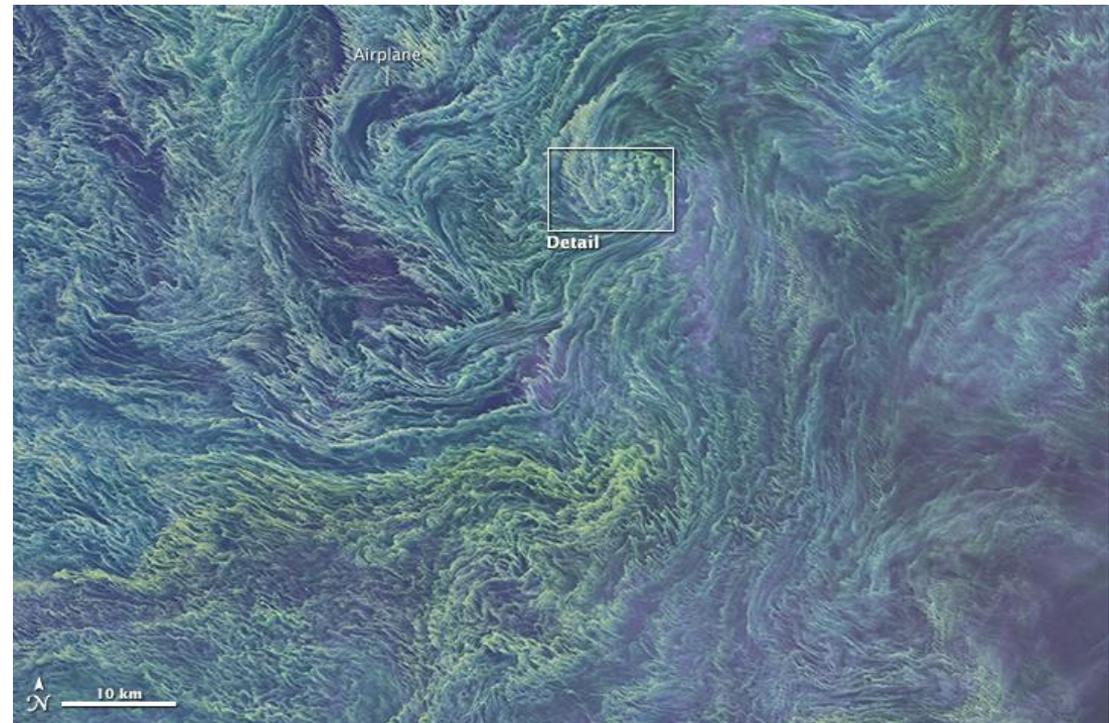
$$\text{Re} = \frac{Ux}{\nu} \gg 1$$

Peregrine Falcon



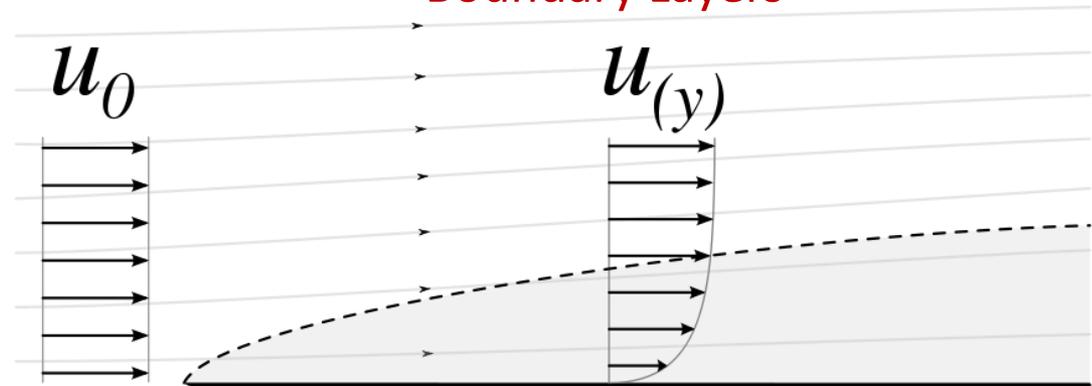
[M. Baird](#)

# Phytoplankton Blooms



[NASA](#)

Boundary Layers



[Wikimedia](#)



# Boundary layers

30 m



[Wikimedia](#)



# Boundary layers

30 m

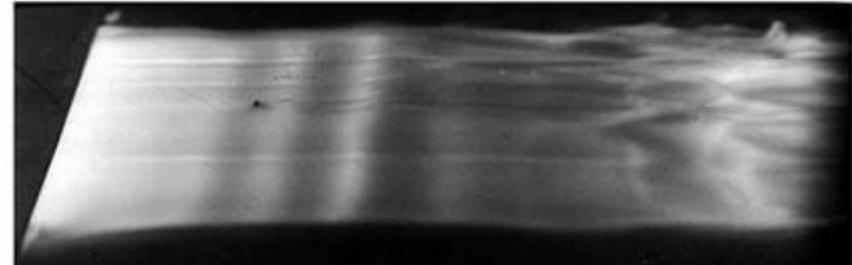


[Wikimedia](#)

0.01 m

Incoming  
flow

Linear and nonlinear instabilities of the laminar boundary layer



From H.Werlé (ONERA)



# Boundary layers

30 m

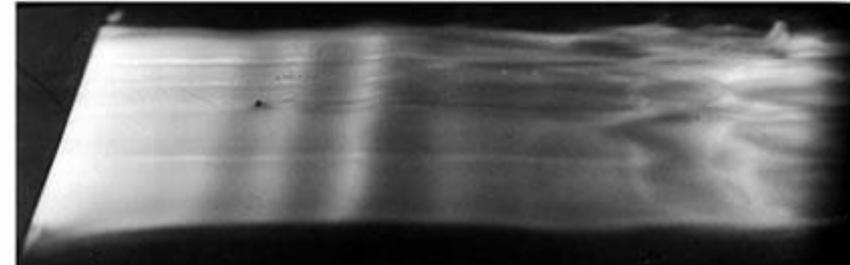


[Wikimedia](#)

0.01 m

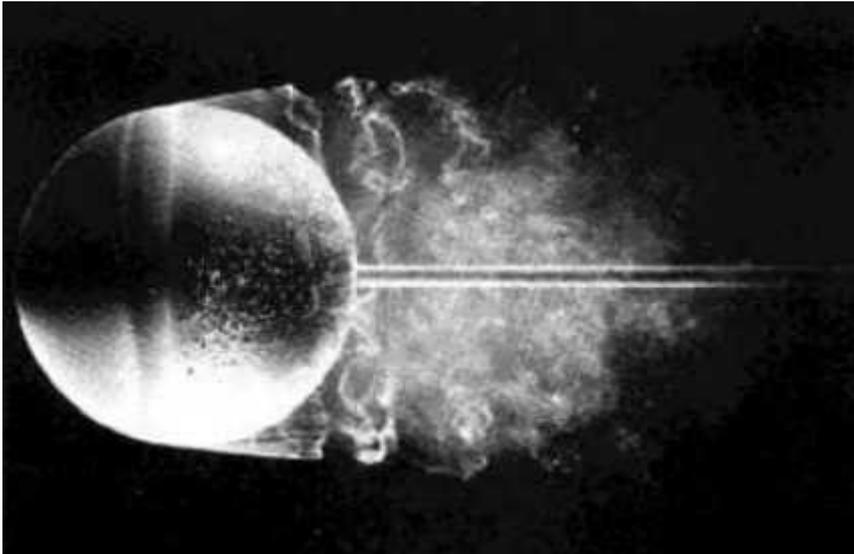
Linear and nonlinear instabilities of the laminar boundary layer

Incoming  
flow



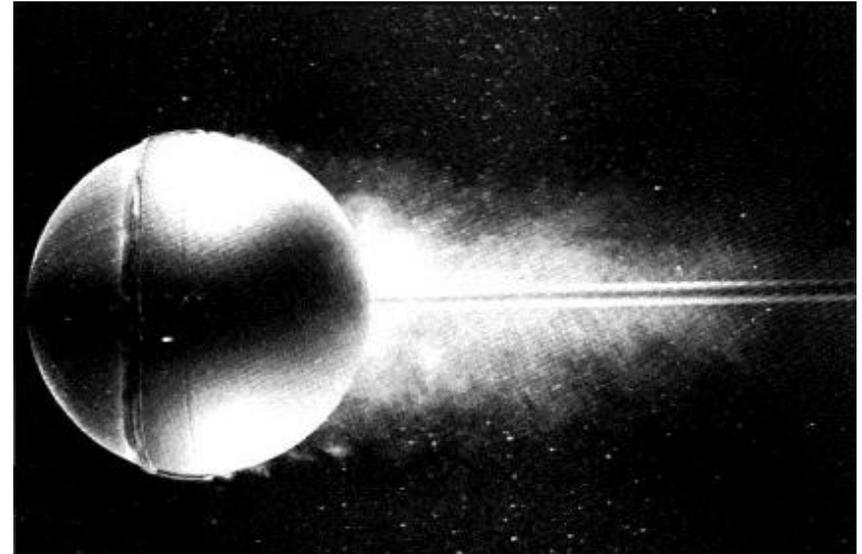
From H.Werlé (ONERA)

## Laminar Boundary Layer



[M. Van Dyke](#)

## Turbulent Boundary Layer



[M. Van Dyke](#)



# Boundary layers

## Protruding Gap Filler



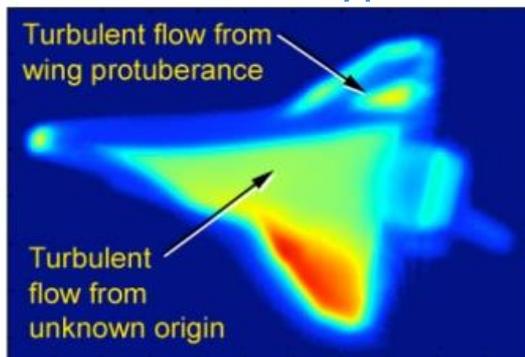


# Boundary layers

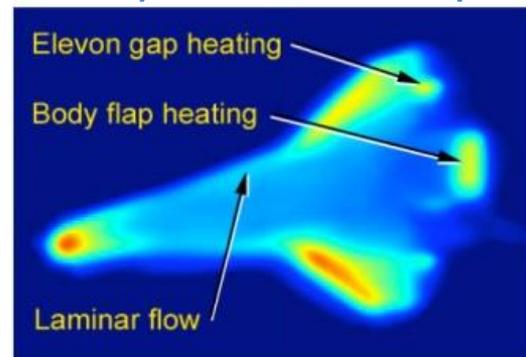
## Protruding Gap Filler



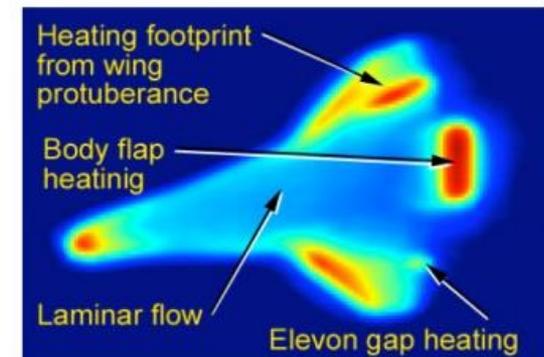
## Hypersonic Re-Entry and Boundary Layer Transition



**Fig. 8. STS-119 Mach 8.4**



**Fig. 9. STS-125 Mach 14.3**



**Fig. 10. STS-128 Mach 14.7**

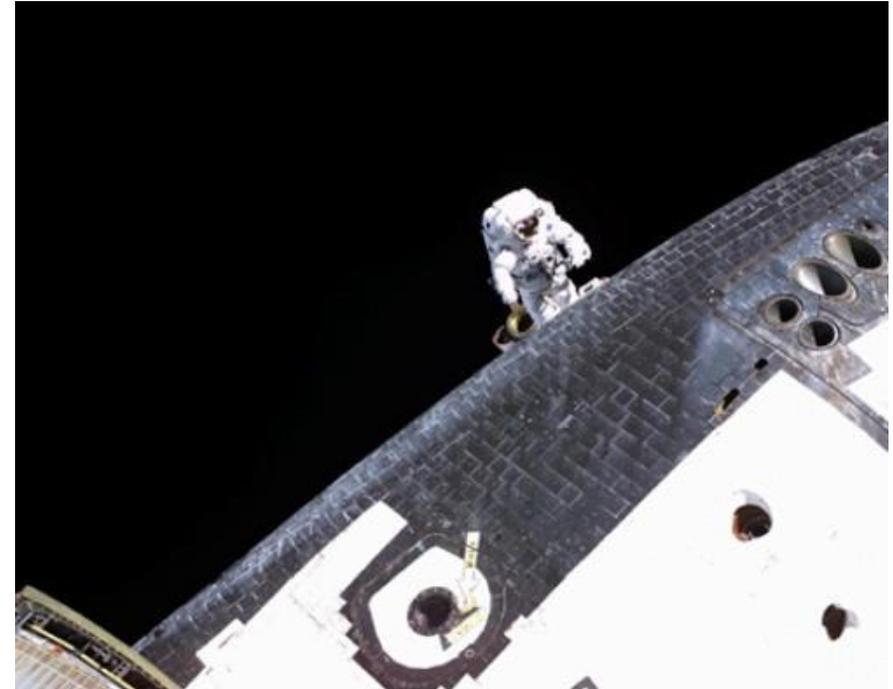


# Boundary layers

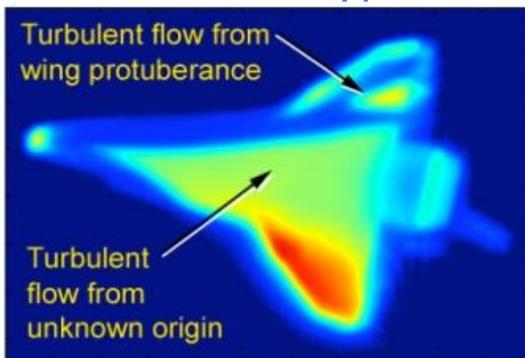
## Protruding Gap Filler



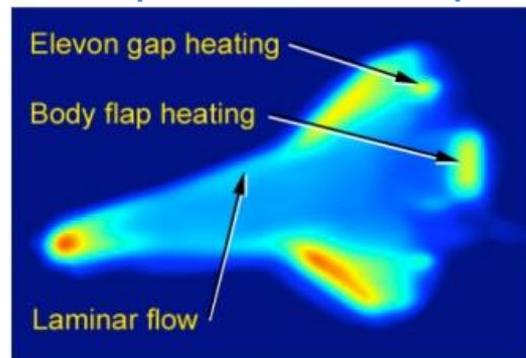
## Removing the Gap Filler



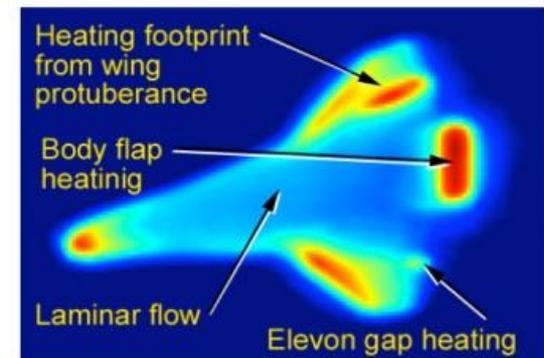
## Hypersonic Re-Entry and Boundary Layer Transition



**Fig. 8. STS-119 Mach 8.4**



**Fig. 9. STS-125 Mach 14.3**



**Fig. 10. STS-128 Mach 14.7**

Collections

About the Collections

Objects

Archival Collections

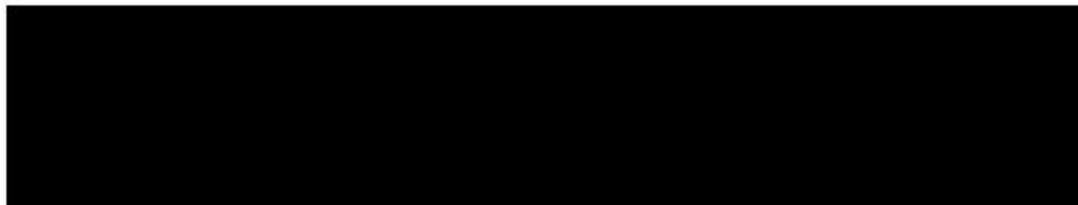
Multimedia Gallery

Earth & Planetary

Preservation and Restoration

Home > Collections > Objects > Tile Gap Filler, Shuttle, STS-114

### Tile Gap Filler, Shuttle, STS-114



See full size image

Share, Tweet, +1, Pin it

Summary

### Display Status

This object is on display in the [Moving Beyond Earth](#) exhibition at the National Air and Space Museum, Washington, DC.



### Related Collections:



Human Spaceflight



# Boundary layers



Mako shark

[jidanchaomian](#)



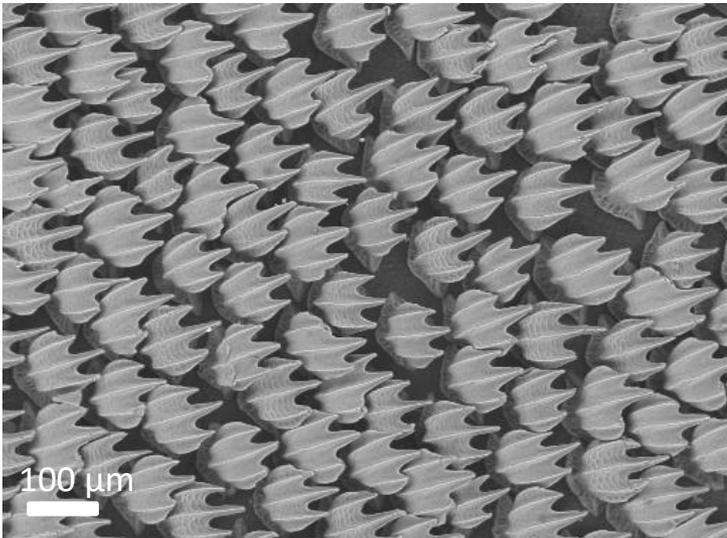
# Boundary layers



Mako shark

[jidanchaomian](#)

## Denticles



[J. Oeffner and G. Lauder](#)



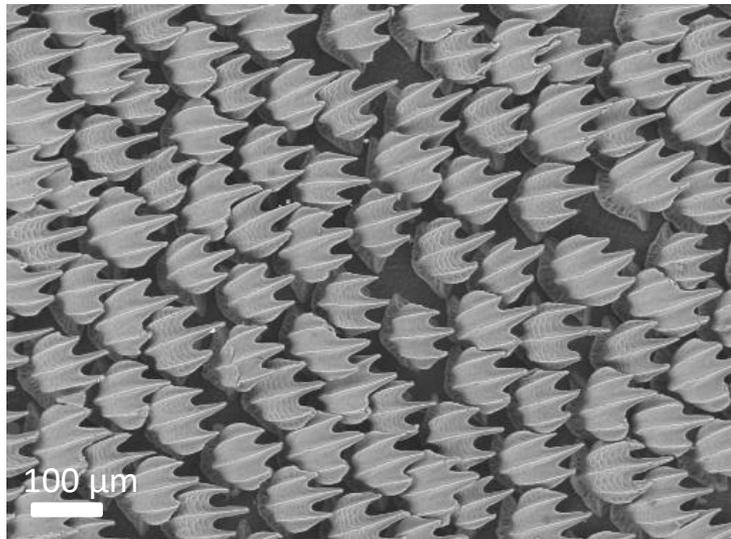
# Boundary layers



Mako shark

[jidanchaomian](#)

Denticles



[J. Oeffner and G. Lauder](#)

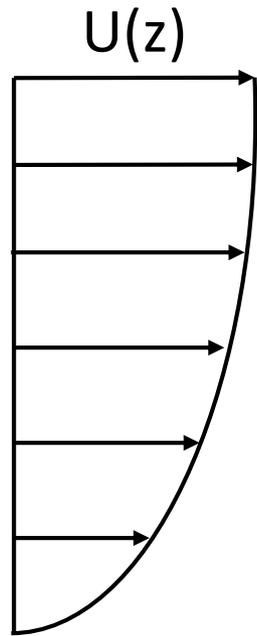
Bristling



[A. Lang et al.](#)



# Living in boundary layers



## Barnacles



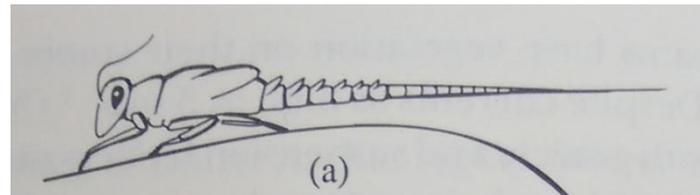
[S. Rohrlach](#)

## Feather Mites



[S. Mironov & R. Palma](#)

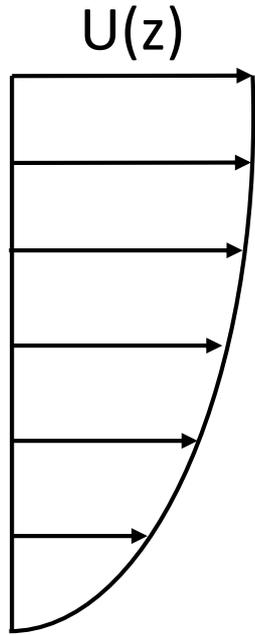
## Mayfly Nymphs



S. Vogel



# Living in boundary layers



Humans



[Wikimedia](#)

Barnacles



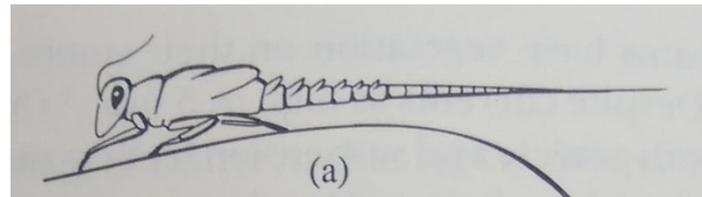
[S. Rohrlach](#)

Feather Mites



[S. Mironov & R. Palma](#)

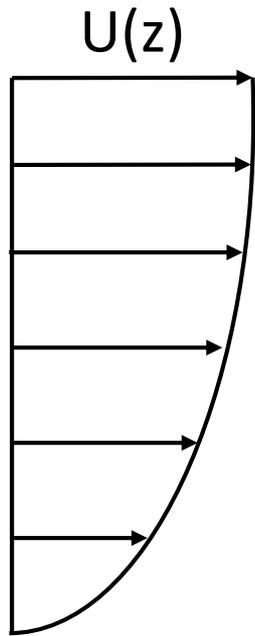
Mayfly Nymphs



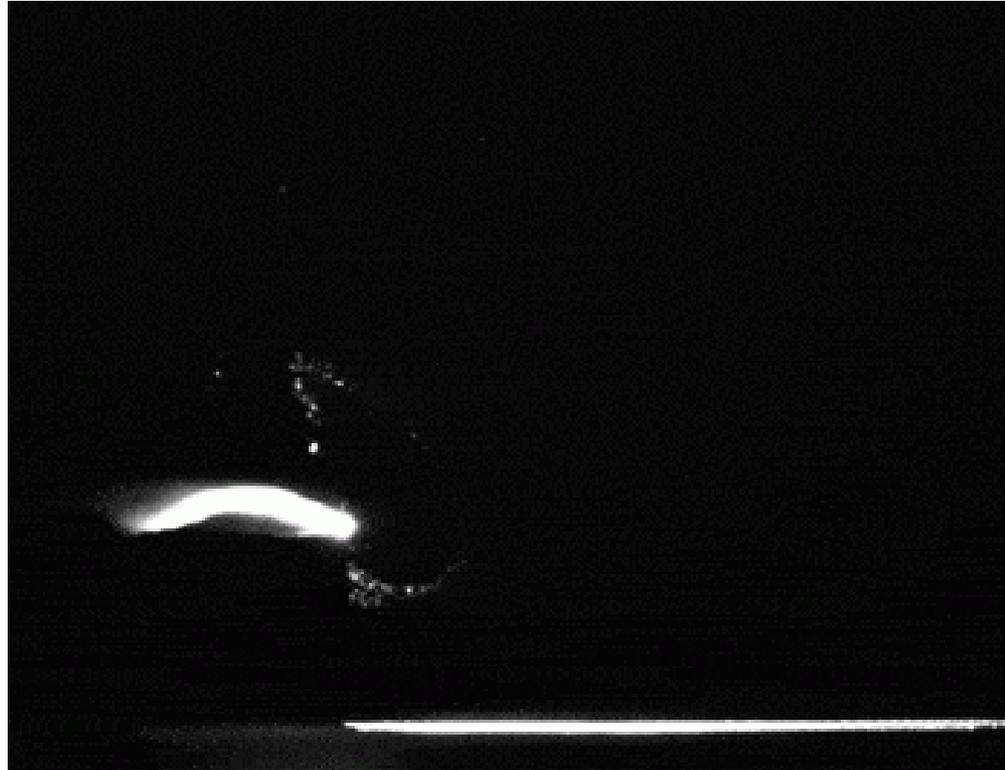
S. Vogel



# Living in boundary layers



Mushrooms

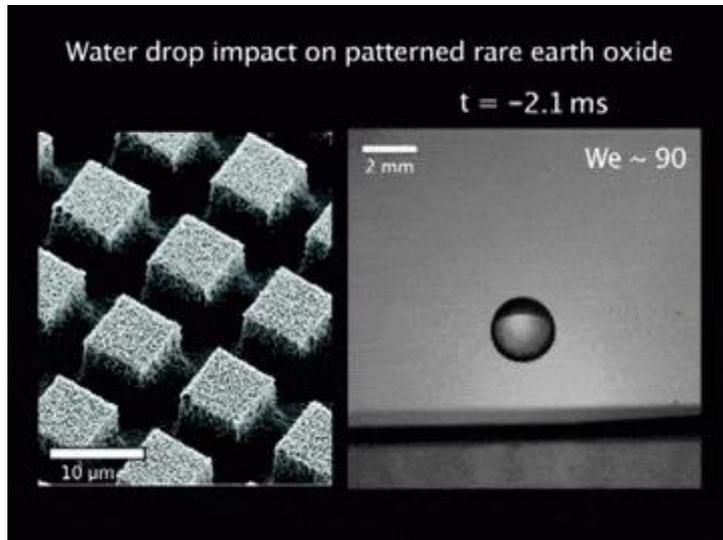


[E. Dressaire et al.](#)



# Where small becomes important

## Superhydrophobic Surfaces



[G. Azimi et al.](#)

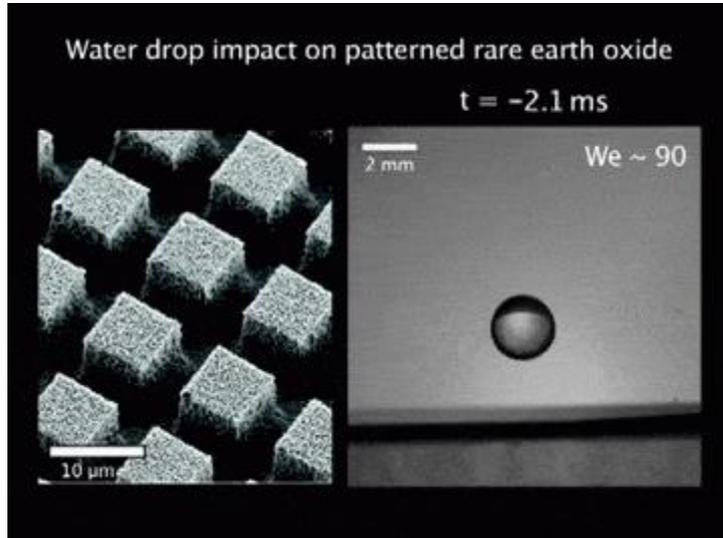


[K. Hounsell et al.](#)



# Where small becomes important

## Superhydrophobic Surfaces



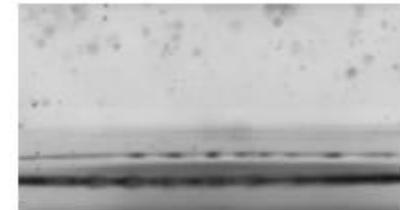
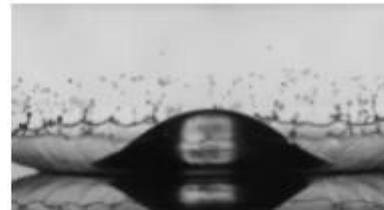
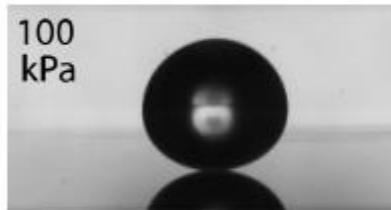
[G. Azimi et al.](#)



[K. Hounsell et al.](#)

## Droplet Splashing

High  
Pressure

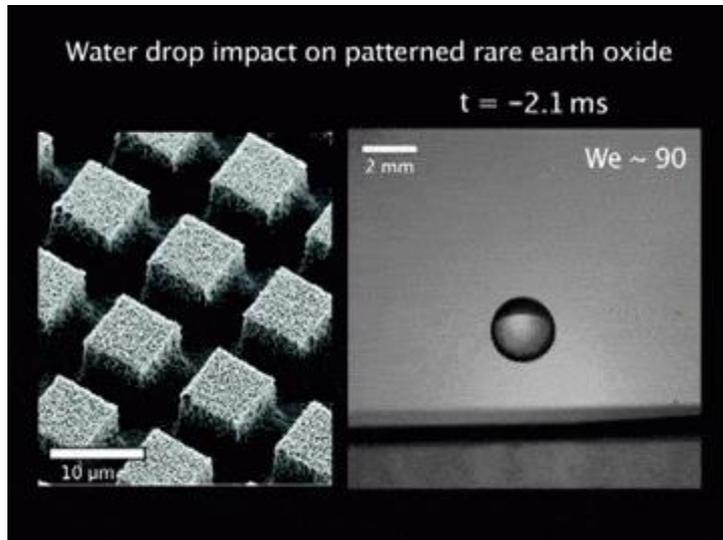


[L. Xu et al.](#)



# Where small becomes important

## Superhydrophobic Surfaces



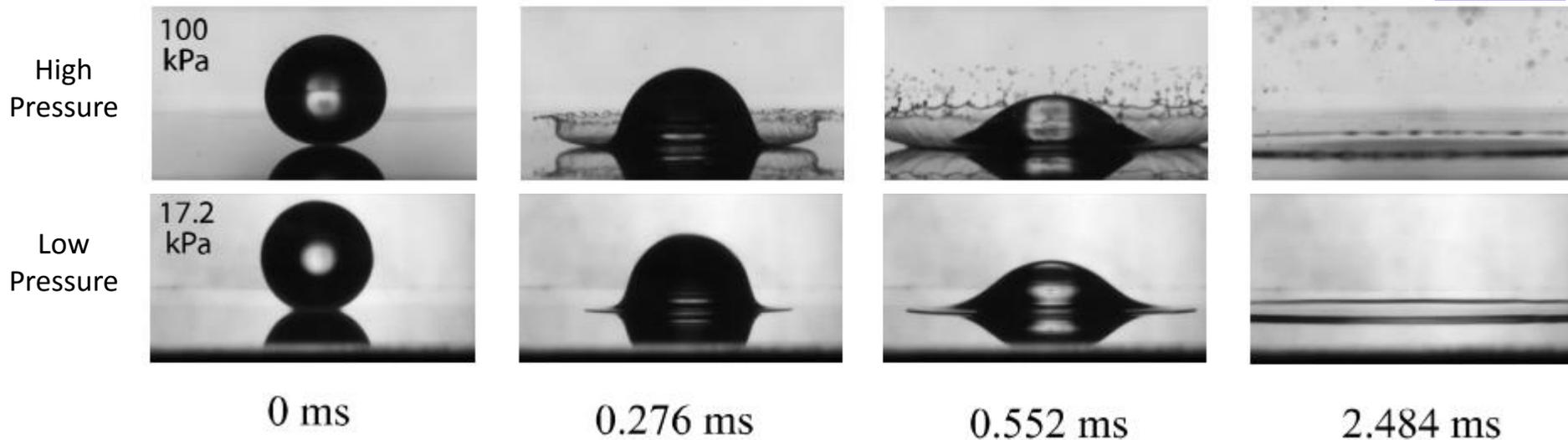
[G. Azimi et al.](#)



[K. Hounsell et al.](#)

## Droplet Splashing

[L. Xu et al.](#)





# Where small becomes important

## Shock Waves

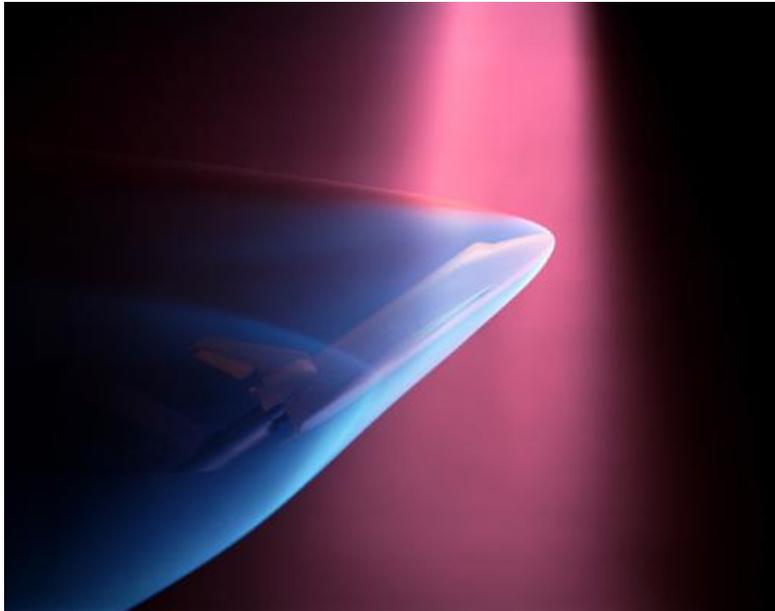


[NASA Langley](#)

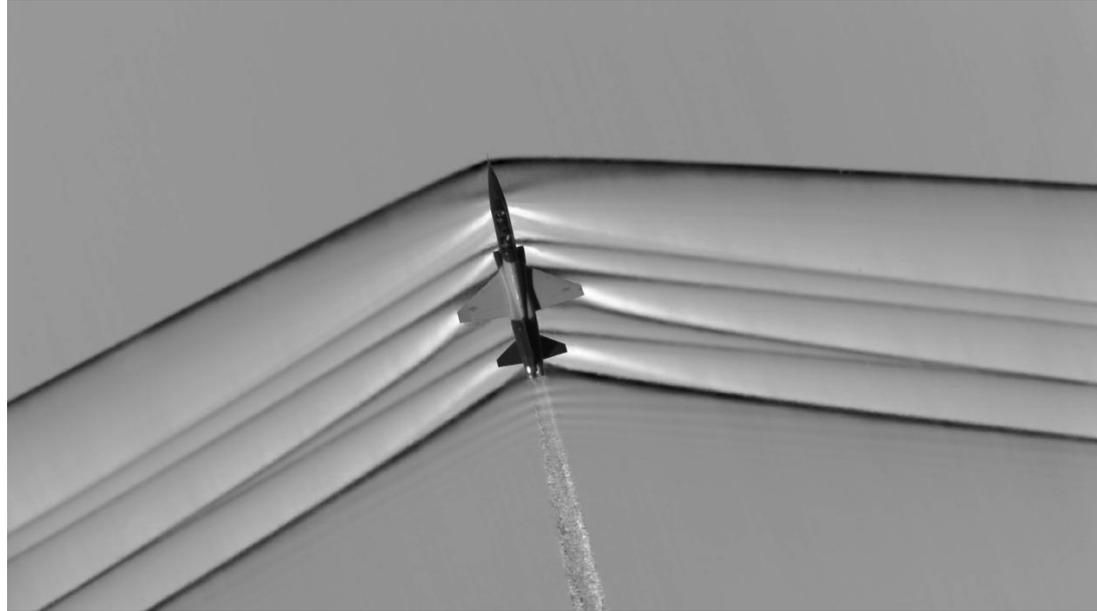


# Where small becomes important

## Shock Waves



[NASA Langley](#)



[NASA](#)



# Where small becomes important

## Shock Waves



**HH47**

**1994**

[NASA/ESA/P. Hartigan/G. Bacon](#)

...and not very small



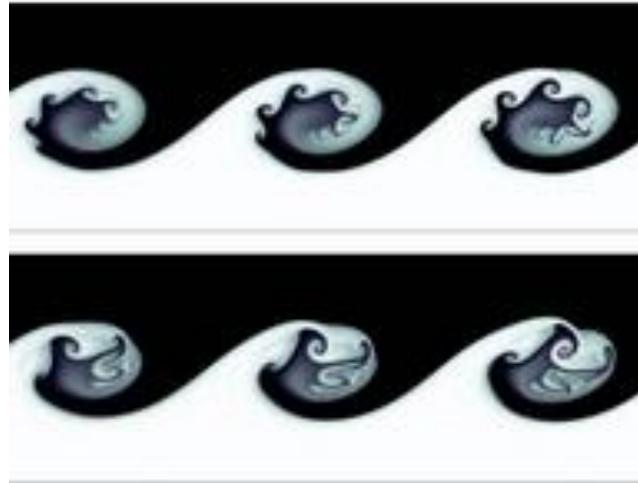
# Ubiquitous and universal

## Von Karman Vortex Street



[P. Nathan](#)

## Kelvin-Helmholtz Instability



[J. Fontaine et al.](#)

## Rayleigh-Taylor Instability



[jadvera09](#)



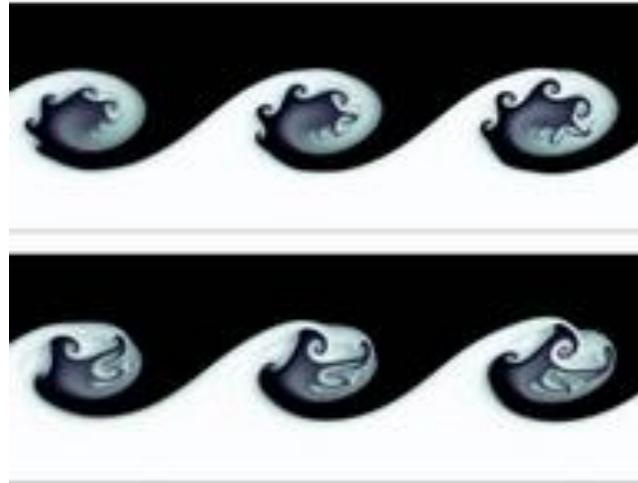
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[NASA](#)



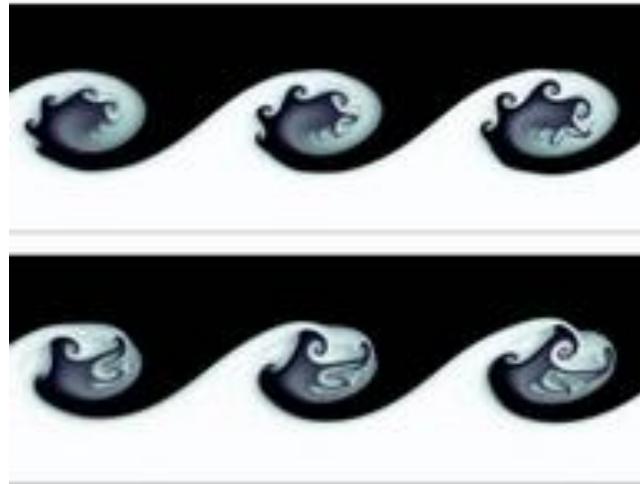
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Von Karman Vortex Street



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[NASA/Voyager 1](#)



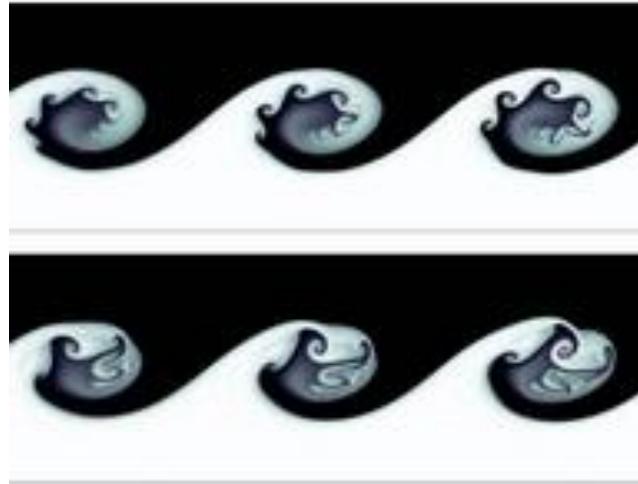
# Ubiquitous and universal

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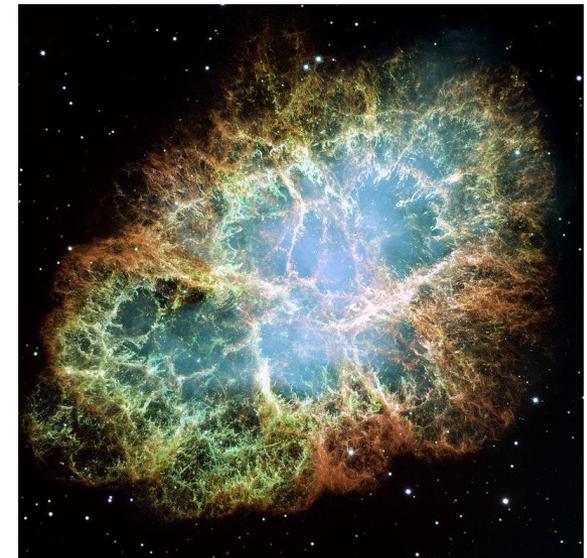
[jadvera09](#)



[NASA](#)



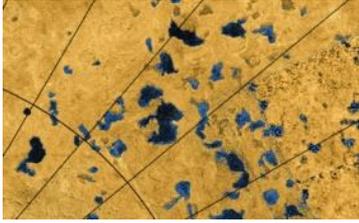
[NASA/Voyager 1](#)



[NASA](#)



## Looking outward

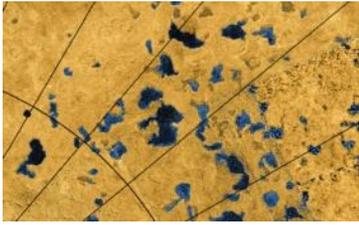


# Dissolving Surface May Form Titan's Lakes

[Scientific American](#)

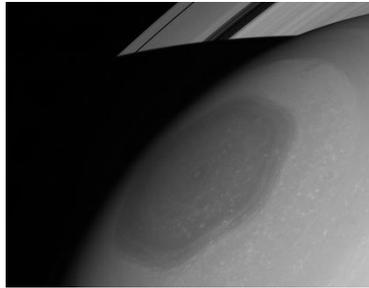


## Looking outward



# Dissolving Surface May Form Titan's Lakes

[Scientific American](#)

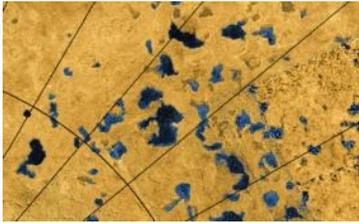


# Saturn's Weird Hexagon Vortex Stuns in NASA Photo

[Space.com](#)

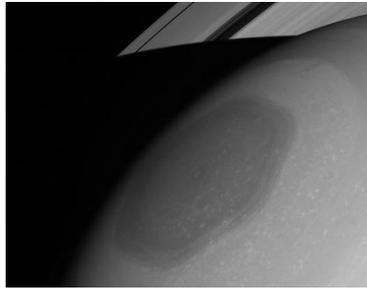


## Looking outward



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[Scientific American](#)



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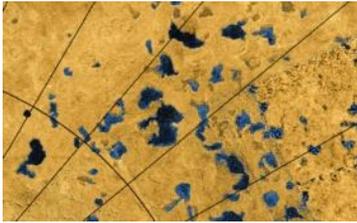


# 5400mph winds discovered hurtling around exoplanet

[Phys.org](#)

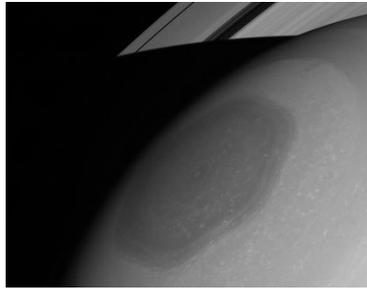


## Looking outward



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[Scientific American](#)



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[Space.com](#)



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# Molten Lava Flows On This Super-Earth's Surface Like Water

[Gizmodo](#)



## Looking outward



# Floating Mountains on Pluto—You Can't Make This Stuff Up

[National Geographic](#)



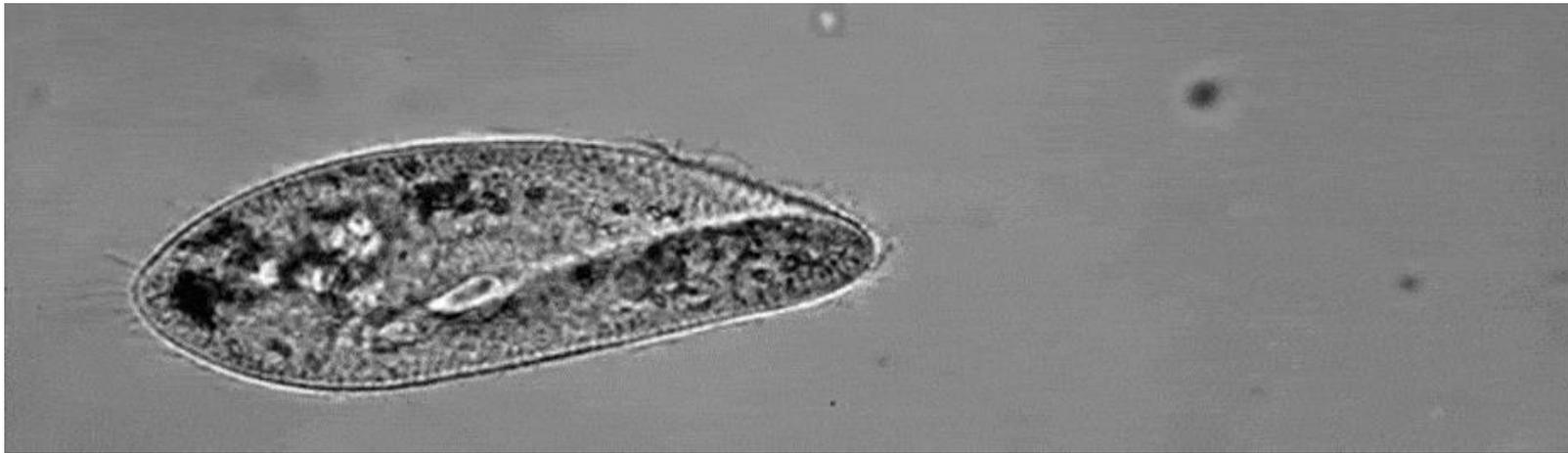
# Looking outward



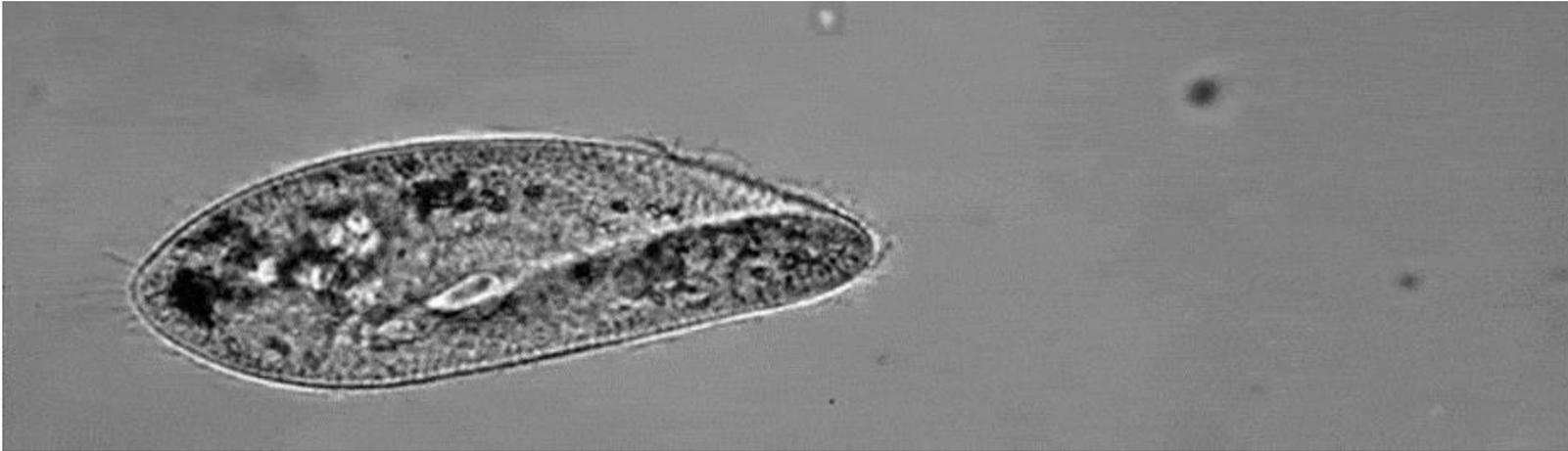
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[National Geographic](#)





[C. Baroud](#)



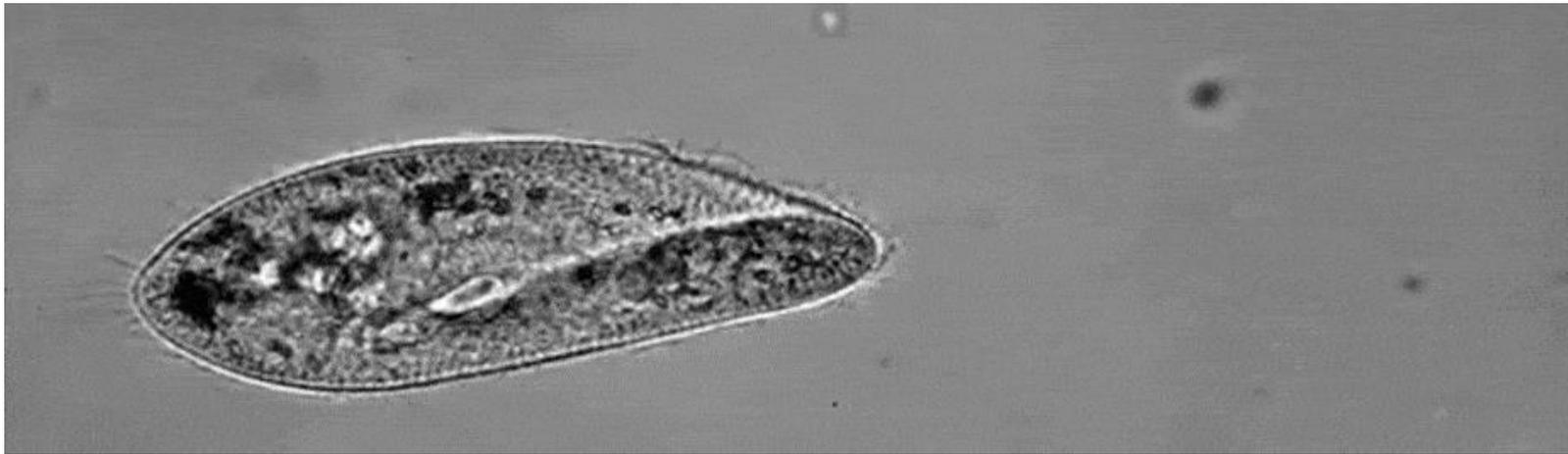
[C. Baroud](#)



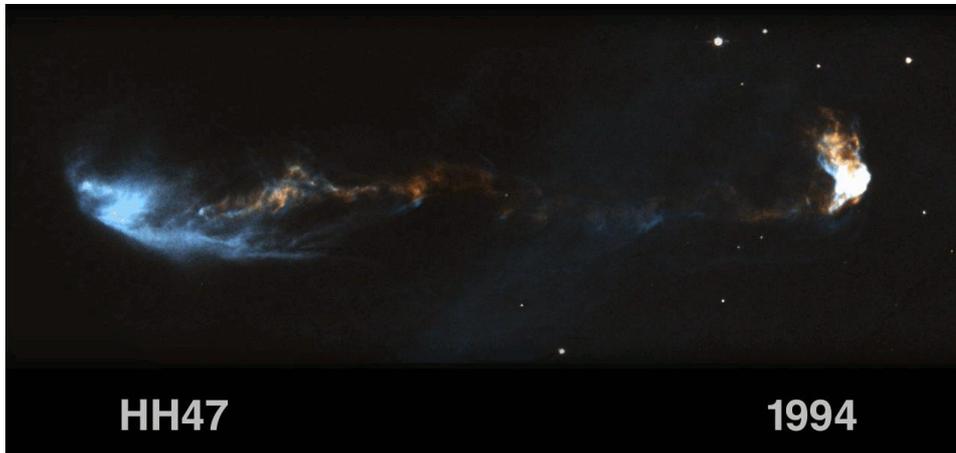
[NASA/ESA/P. Hartigan/G. Bacon](#)



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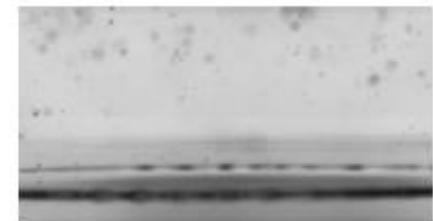
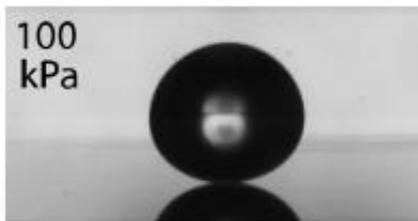
[C. Baroud](#)



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[L. Xu et al.](#)

