From Depicting to Deploying
Fluids in Art

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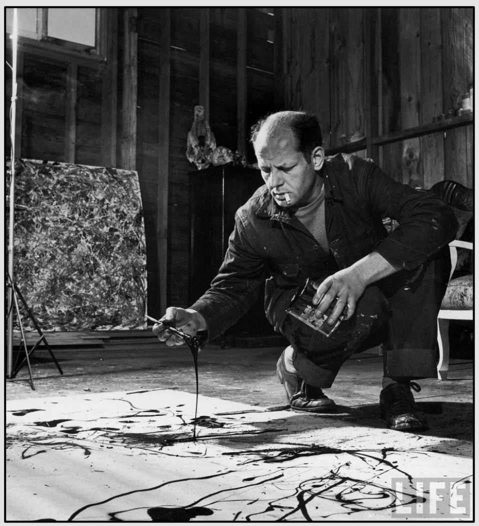
Boston College

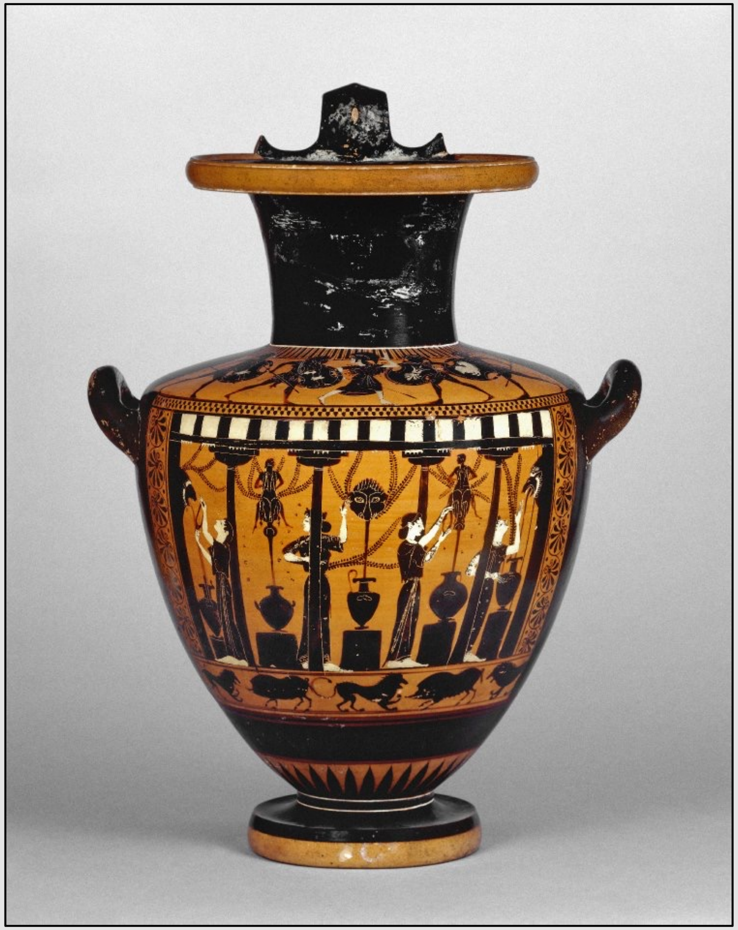


XXV Fluid Mechanics Conference
Politechnika Rzeszowska
Krasiczyn 8-IX-2022

Part I: Fluids *Depicted*

Ancient depictions
Hydrostatics, bubbles – pressure
Streams – inviscid & viscous jets
Shallow waves – plane & Huygens wavelets
Deep waves – breaking & turbulent
Instabilities –PR & TS
Complex flows – vortices & turbulence

Water flows – Greek Vases

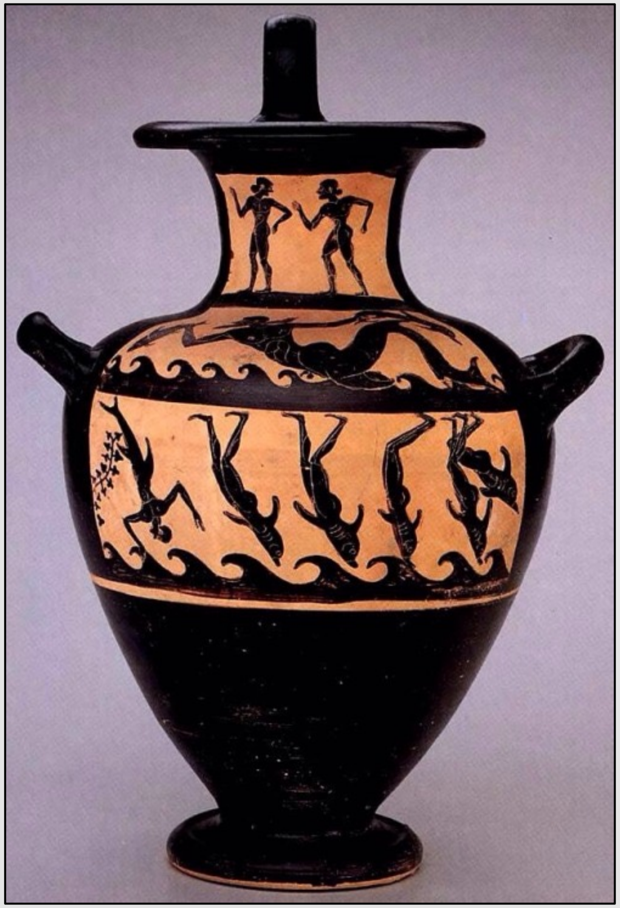


Women at a Fountain,
British Museum (Athenian, 6th c. BC)

Polyxena at the Fountain,
Louvre (Athenian, ca 480 BC)

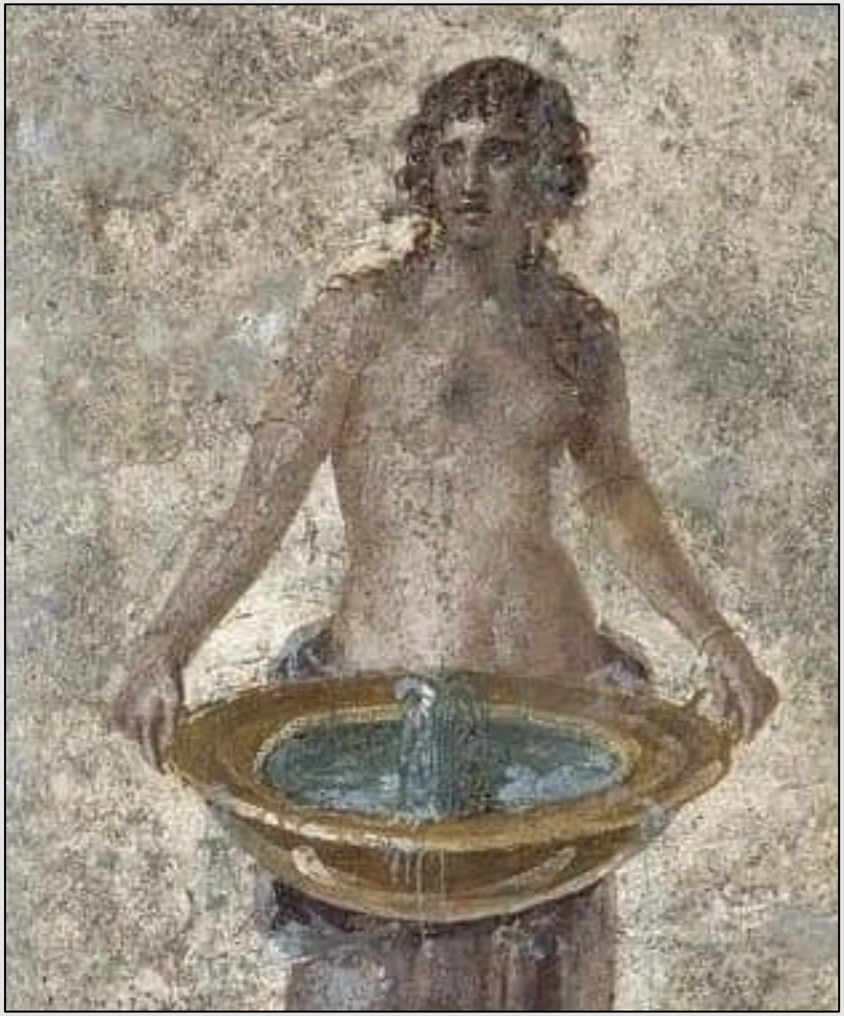
Waves – Greek Vases

The Siren Vase (Odysseus)
British Museum (Attica, ca 470 BC)

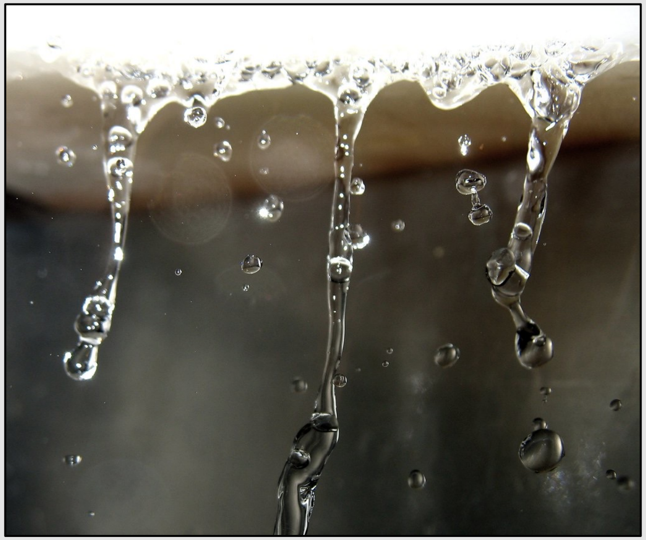


Dionysus changes pirates into dolphins,
Toledo Museum (5th century BC)

Roman frescoes (I c. AD)



Woman with a labrum, fresco (fragment)
Pompei (I century AD)



Liquid sheet breakup
& Plateau-Rayleigh instability

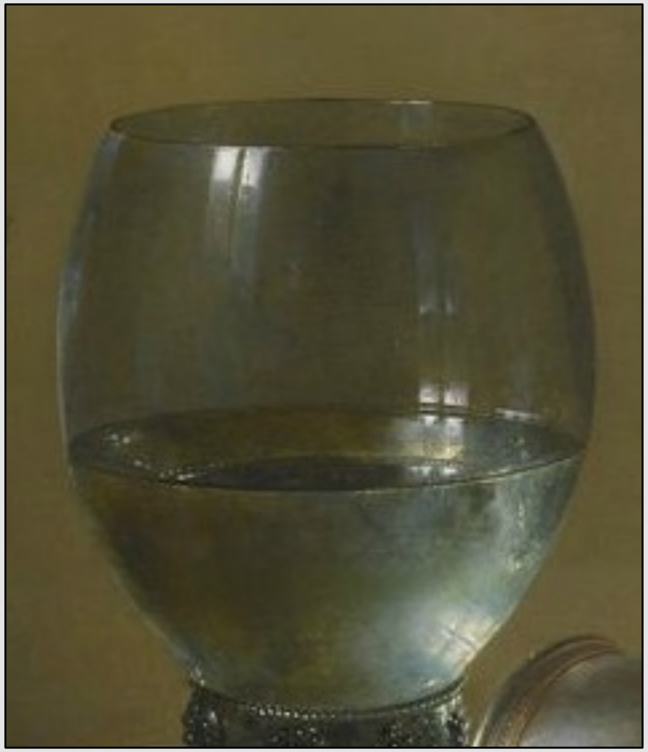
Waves (II c. AD)

Odysseus and the Sirnes, mosaic
Bardo Museum in Tunis (II century AD)

Shallow waves – Roman Mosaic (III c. AD)

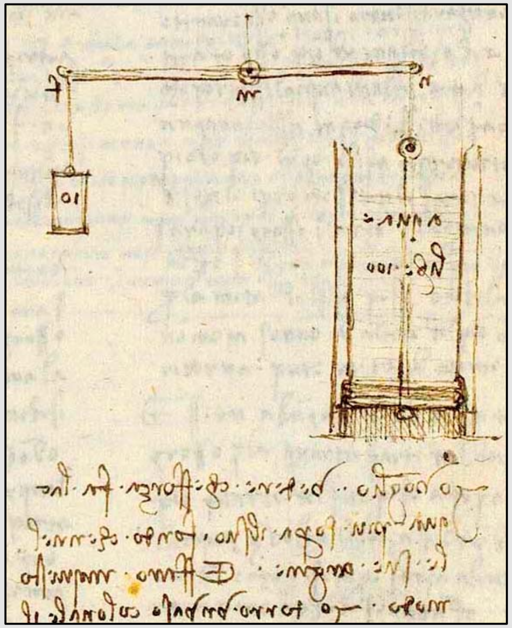
Theseus Escaping from Crete, Floor Mosaic (III century AD, University of Pennsylvania)

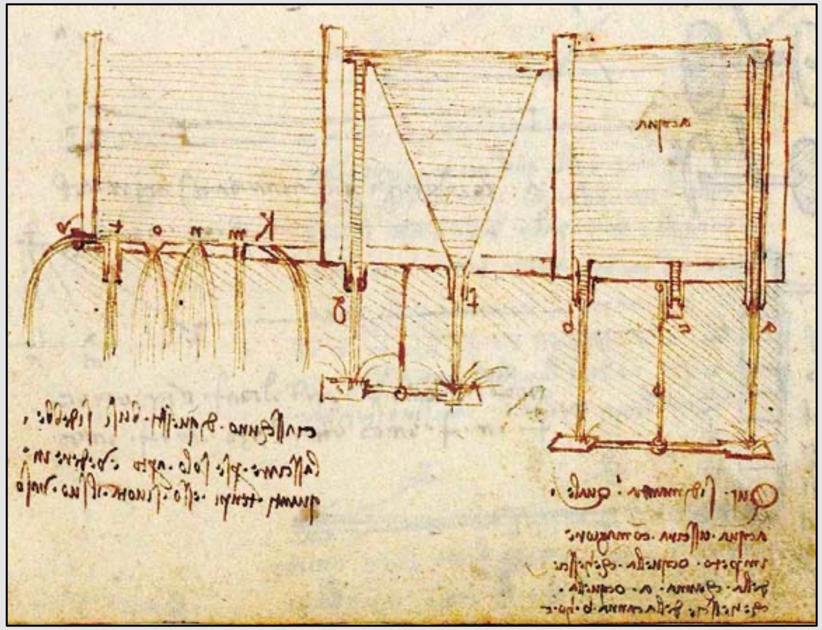
Hydrostatics & optics (1633)



Willem Claesz Heda
Still Life (1633, private colection)

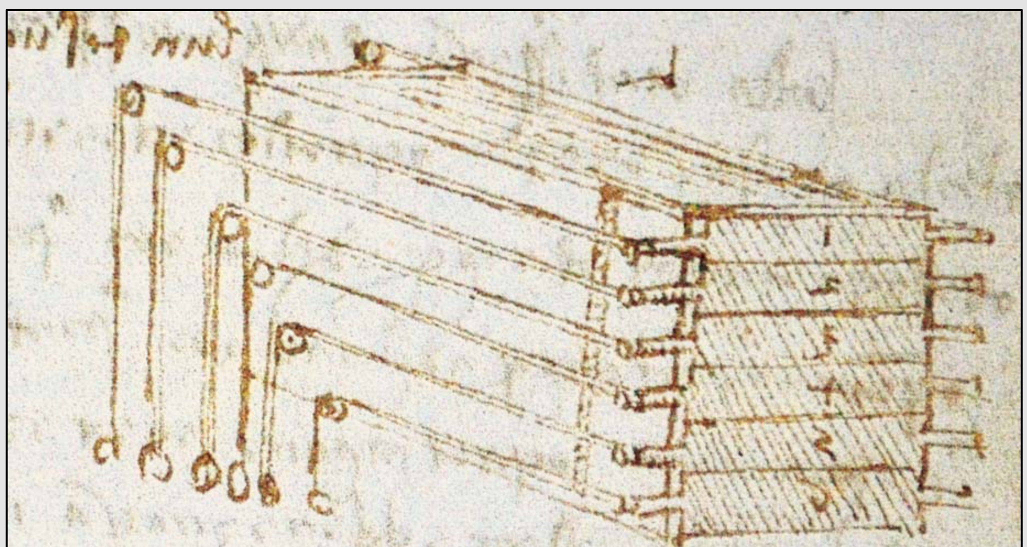
Hydrostatic pressure





Leonardo da Vinci
Notebooks (1495, 1508)
(Phys. Today, Aug. 2014)

$$\Delta p = \rho g h \text{ ??}$$

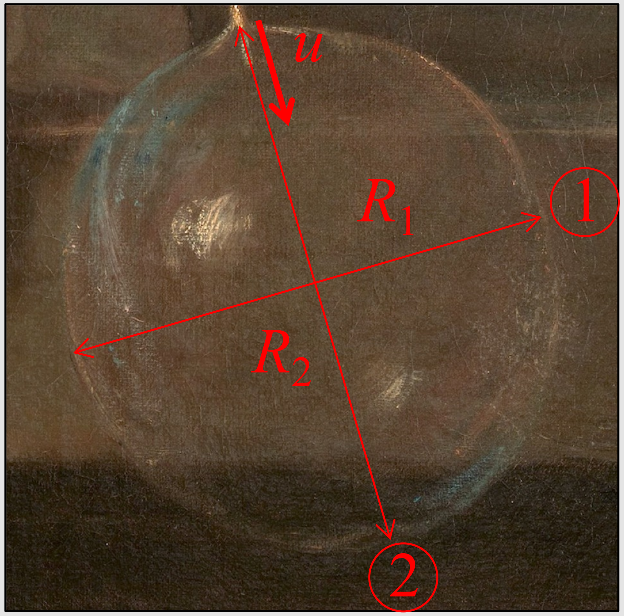


Soap Bubbles (1735)

Jean-Baptiste-Siméon Chardin
Soap Bubbles (1733-5)
(National Gallery of Art, Washington, DC)

The bubble is elongated…

Soap Bubbles-2



J. B. P. Chardin
Soap Bubbles - fragment

$R_1 = 10^{-1}$ m

$R_2 = R_1 + \delta$ & $\delta = 10^{-2}$ m

$\gamma = 0.025$ N/m

$\rho = 10^3$ kg/m^3

Laplace Pressure Formula:

$$p_1 - p_o \approx \frac{4\gamma}{R_1}\left(1 - \frac{\delta}{R_1}\right) \qquad p_2 - p_o \approx \frac{4\gamma}{R_1}\left(1 + \frac{\delta}{R_1}\right)$$

$$\Delta p \approx \frac{8\gamma}{R_1^2}\delta$$

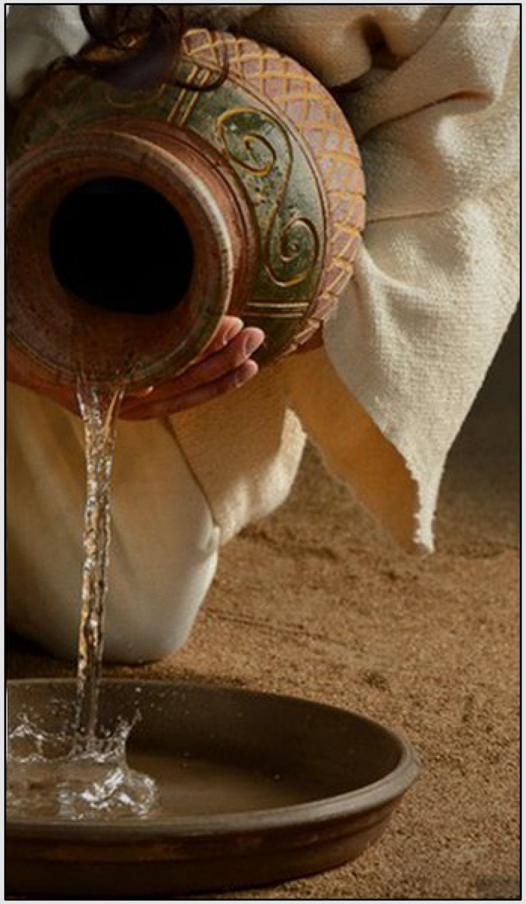
Bernoulli Equation: $\Delta p \approx \frac{1}{2}\rho u^2$

$$\rightarrow \quad u \approx \frac{4}{R_1}\sqrt{\frac{\gamma\delta}{\rho}}$$

For Chardin's bubble: $u \approx 2$ cm/s

Thanks to R. Krechetnikov

Poured water – jets (12th c.)



Mosaic from the Daphni Monastery (near Athens)
Byzantine (ca 1100)

Viscous stream (1500)

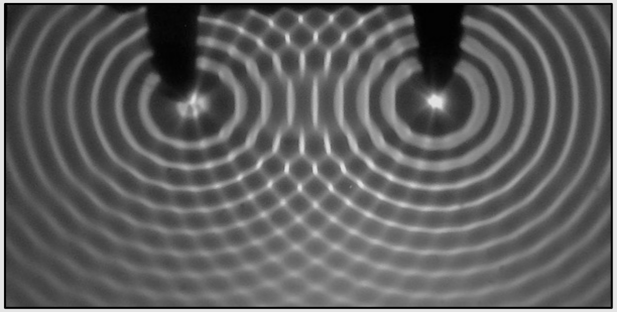
Ink diffusing in water (photo Ariel Balter)

Miniature from illuminated Dutch manuscript book (anonym. ca. 1500)

Laminar jet (1658)

Johannes Vermeer
The Milkmaid (1657-8)

Huygens Wavelets (1508)



Gerrad David
Baptism of Christ (Jan des Trompes Triptych)
Groeningemusuem, Bruges (1502-1508)

Vortex flow (1513)

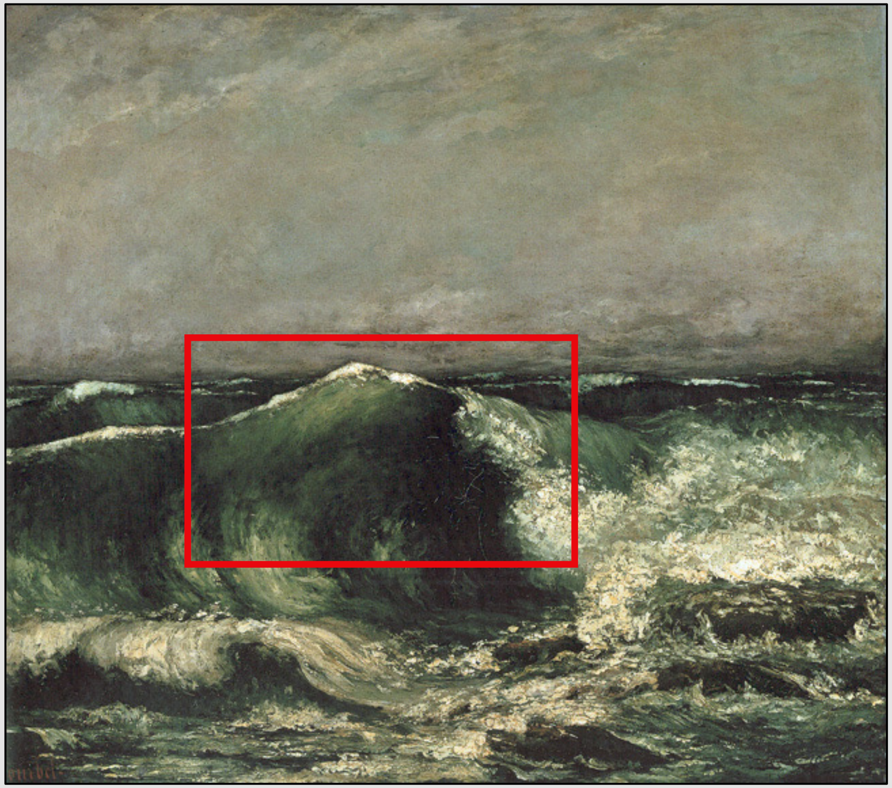
Leonardo da Vinci
Study of Water Passing Obstacles
(ca 1513)

vortex shedding behind cylinder
Photo Don Boroughs (U. Michigan)

Deep Water Waves (1701)

Ludolf Bakhuysen
Seascape (etching 1701)

Breaking waves (1870)



Gustave Courbet, *The Wave* (1870)

Turbulent Waves (1819)

William Turner, *The bell rock lighthouse*
(Tate Gallery, 1819)

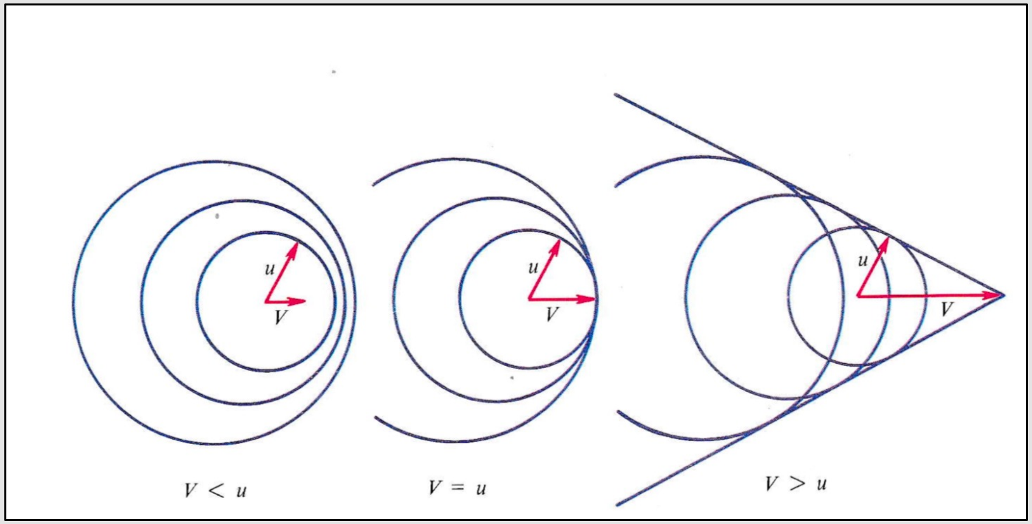
Quessant Lighthouse
(photo Mathieu Rivrin)

Bow Waves (1901)

Bow wave or Kelvin Cone?

Nikolay Rerikh - Никола́й Ре́рих
Merchants from Overseas (1901)
Tretyakov Gallery in Moscow

Bow Waves - 2



Scale Estimates:

$\lambda \sim 0.4$ m

$h \sim 0.3$ m

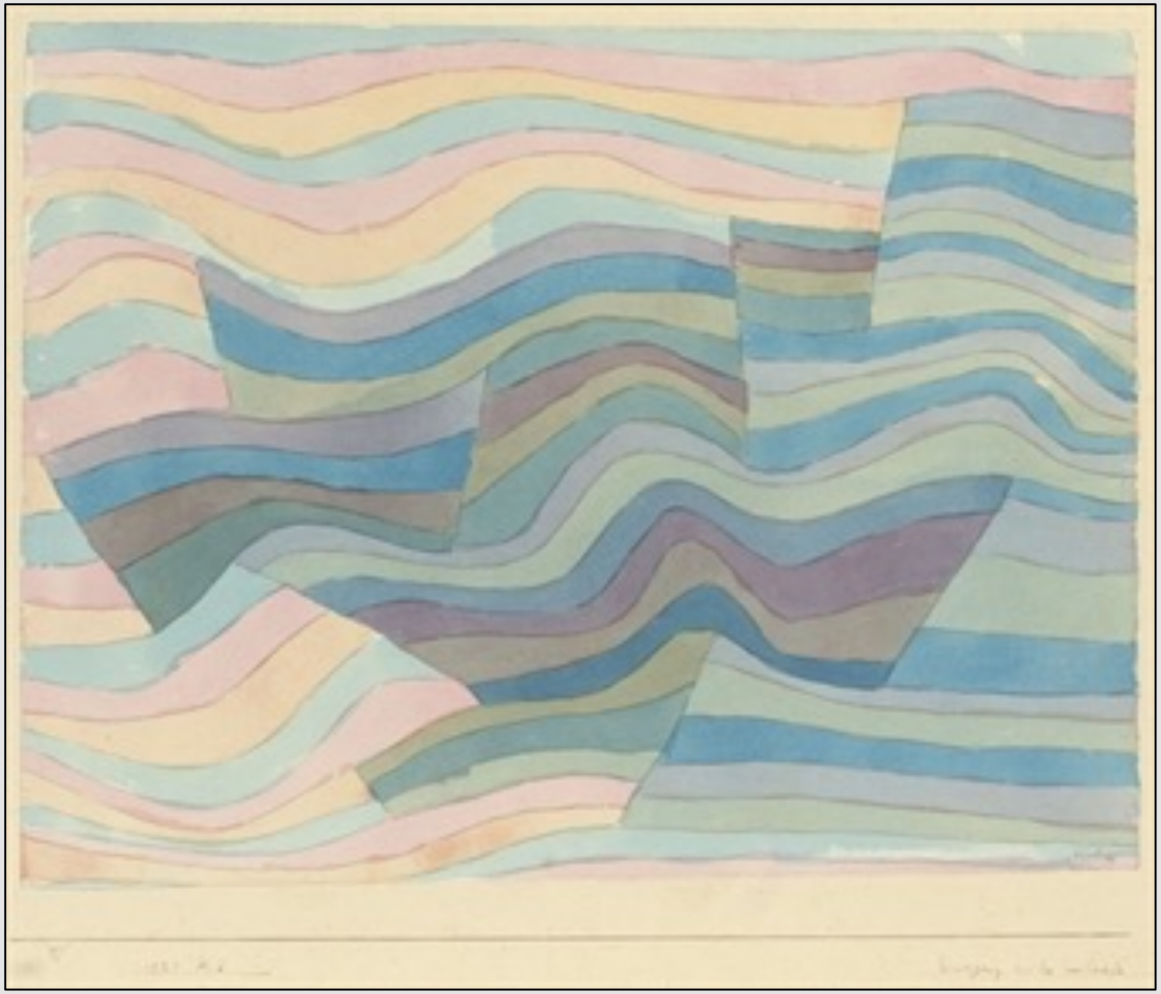
$$u = \sqrt{\frac{g\lambda}{2\pi}} \approx \sqrt{\frac{10\times 0.4}{6}} \approx 0.8 \text{ m/s}$$

$$V \geq \frac{\sqrt{2gh}}{\sin\alpha} = 2\sqrt{gh} \approx 2\sqrt{10\times 0.3} \approx 3.5 \text{ m/s}$$

$\rightarrow$ $V >> u$ inconsistent!

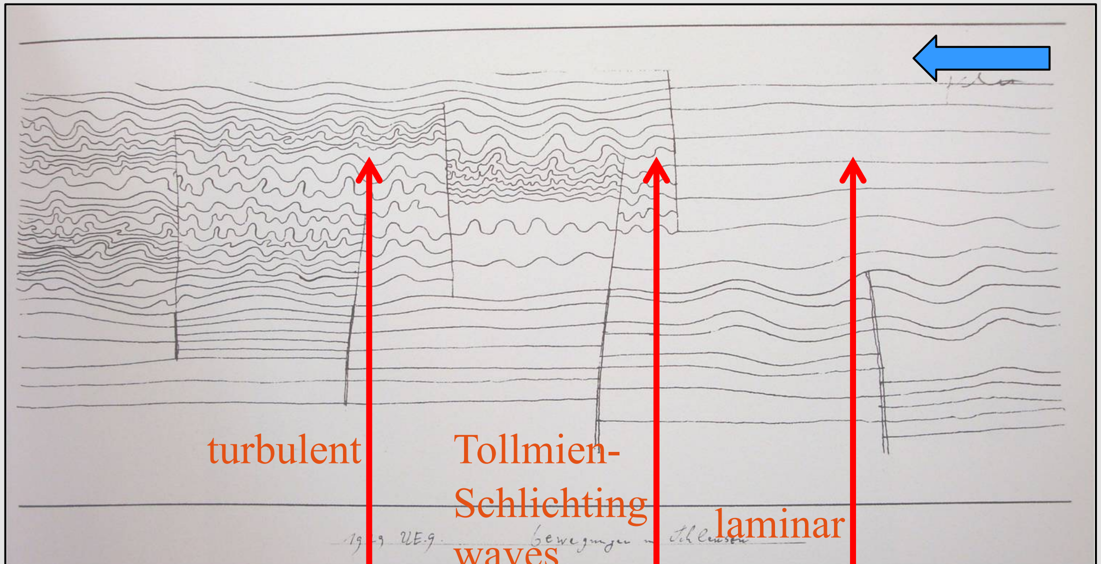
Thanks to R. Krechetnikov
& M. Lisicki

Shallow water waves (1920)

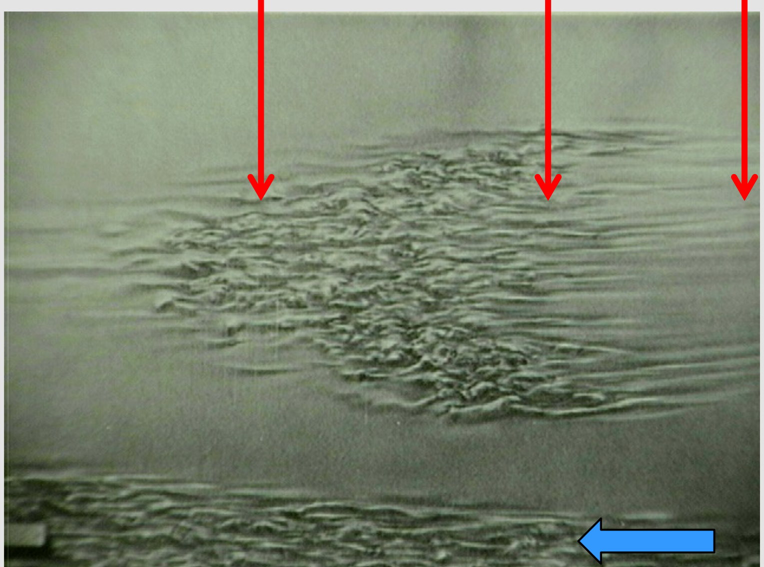


Paul Klee
Motion near the coast (1920)

Transition to turbulence (1929)



Movement in Locks
Paul Klee (Notebooks, II-49, 1929)



Transition between laminar and turbulent flow in fluid over a flat plate (Re ~10^5).

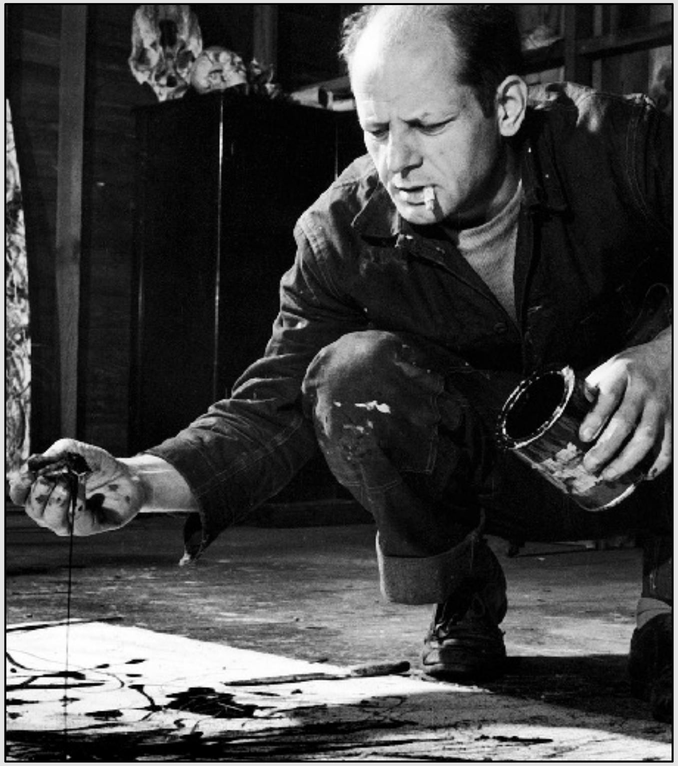
(photo Brian Cantwell)

Turbulent splash (1967)

David Hockney, *A Bigger Splash*
Tate Gallery (1967)

(photo by Olga Pink)

Part II: Fluids *Deployed*



Jackson Pollock – viscous jets & coiling
Morris Louis – laminar rivulets
Robert Motherwell – sprays, RP instability
Sam Francis – viscous drop formation
Adolph Gottlieb, Larry Poons – drops, sprays
Pat Steer – thin film instability
James Nares & Manoel Veiga
– viscous flows & viscous fingering

Jackson Pollock – viscous jets

Jackson Pollock, *Number 14* (1948)

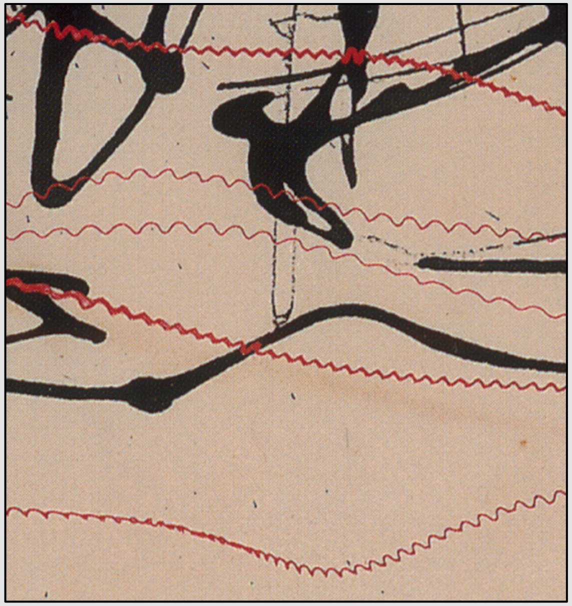
1912 - 1956

Photos: Hans Namuth, 1950

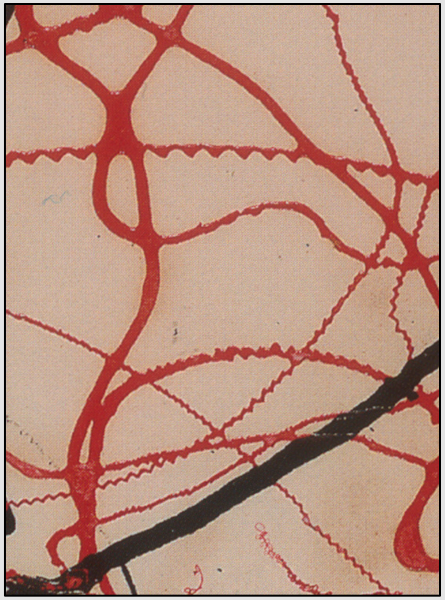
…mostly jets (and some drops)

Coiling Traces: *Untitled 1948-49*

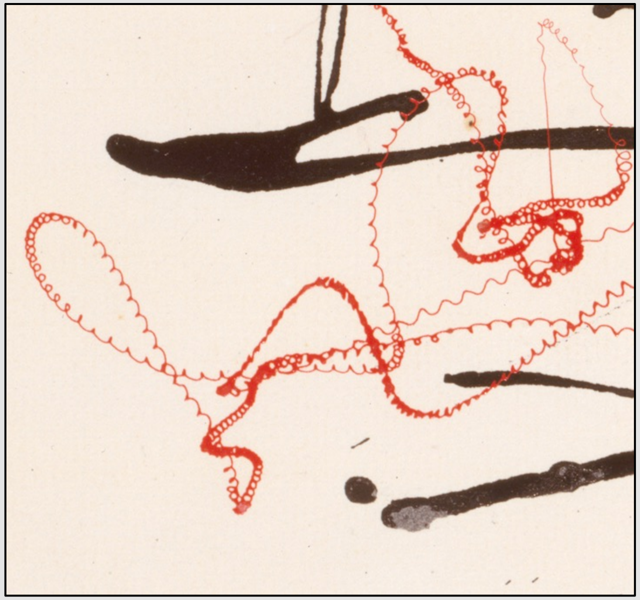
Untilled 1948-49 - details



(detail 1)



(detail 2)

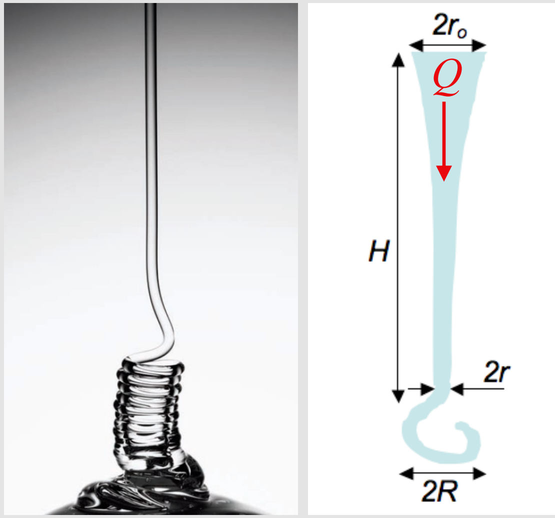


(detail 3)

oscillatory skeins → *coiling instability* + *lateral displacement*

…form of coiling traces indicates lateral speed!

Coiling Analysis



N.Ribe et. al., *Sci. Am.*, Feb. 2014, p 66

Coiling frequency in the inertial regime:
(dominated by viscous torque & inertia)

$$\omega^3 \sim \nu^{-1} r^{-10} Q^4$$

Observable (á posteriori):

$$R \sim \nu \left(\frac{Q}{H^4 g^2} \right)^{1/3} \qquad r \sim \frac{1}{H} \left(\frac{\nu Q}{g} \right)^{1/2}$$

Estimates based on *Untitled 1948-49*:

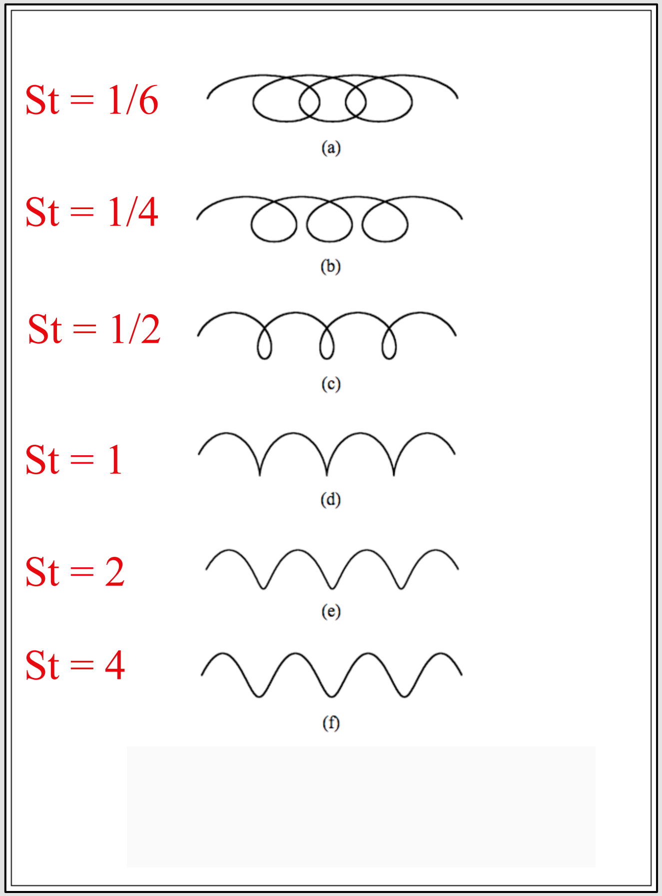
$R \sim 0.1 - 0.2\ cm \quad r \approx 0.05\ cm \quad \nu \approx 10^3 cm^2/s$ silicon oil

$Q \sim \frac{\nu r^4}{R^3} \sim 0.8 - 6.5\ cm^3/s$ & $H \sim 17 - 50\ cm$

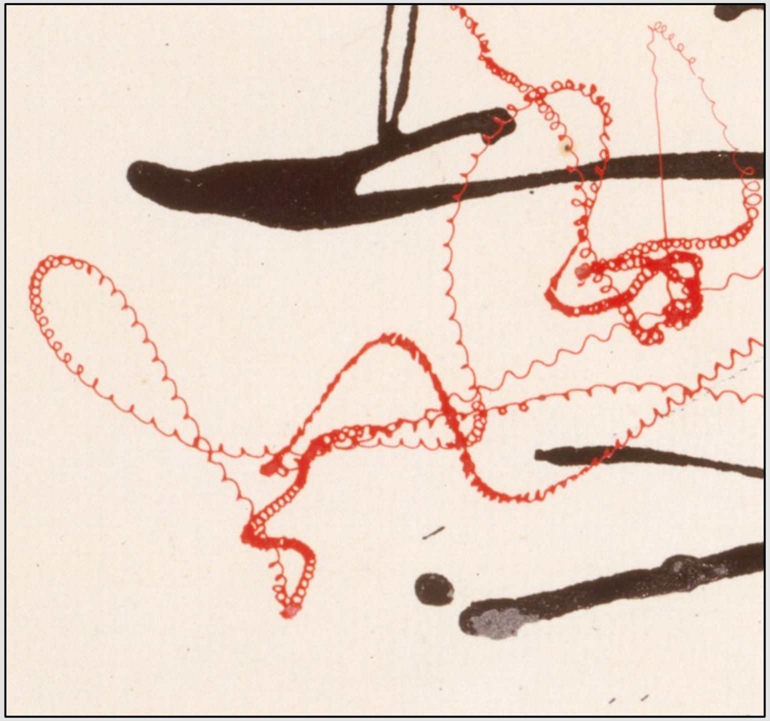
L. Mahadevan et. al., *Nature*, **392**, 140 (1998); *Nature*, **403**, 502, (2000)
A. Herczynski et. al., *Physics Today*, **64** No 6, 31 (2011)

Untilled 1947 - detail 3

coiling trace $\Rightarrow$ *indicator of speed*



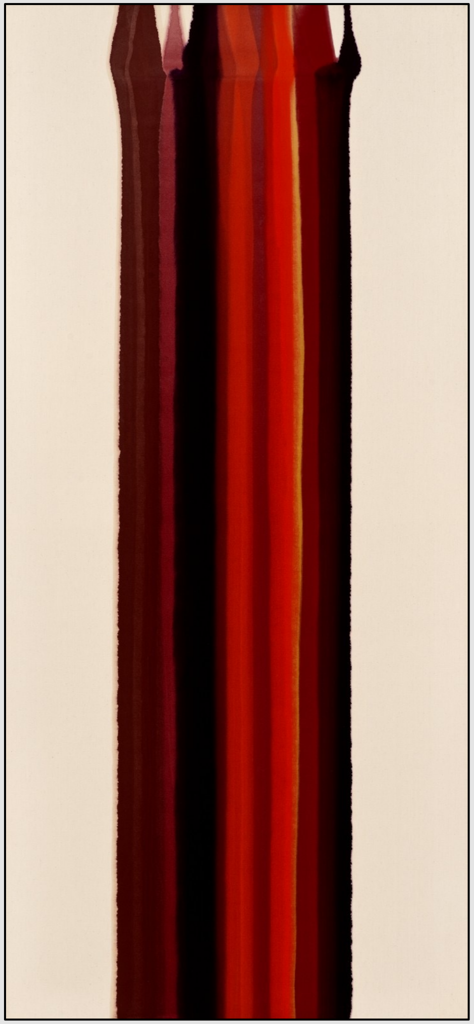
$$St = \frac{U}{\omega R}$$



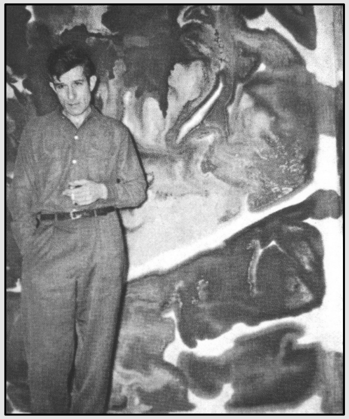
Untitled 1948-49 (detail 3)

Morris Louis - laminar rivulets

Untitled 1958

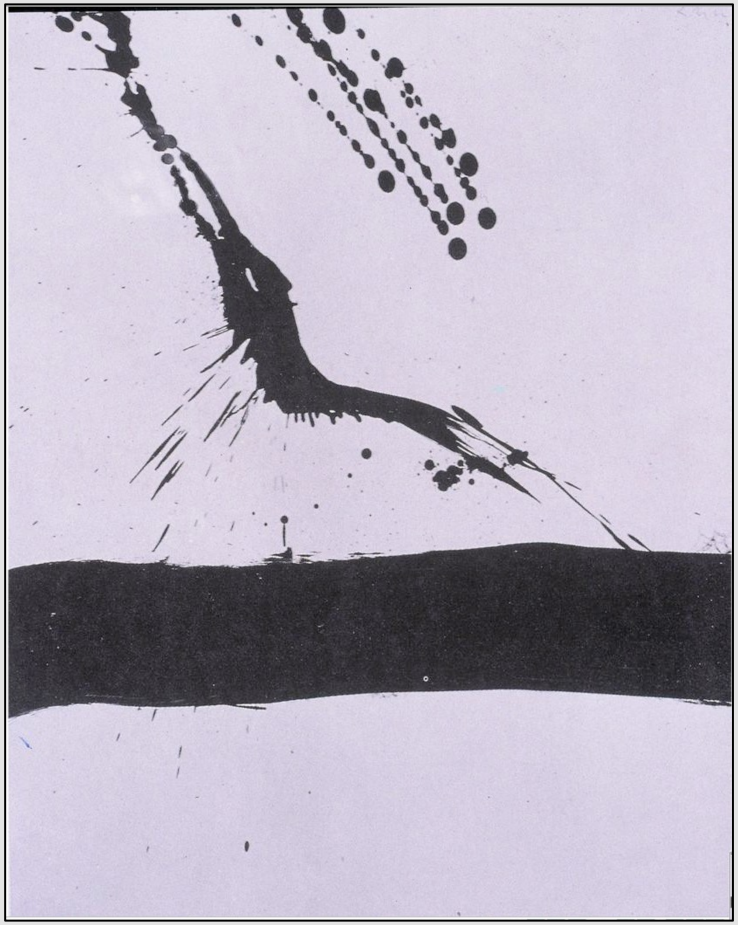


Pillar of Delay 1961

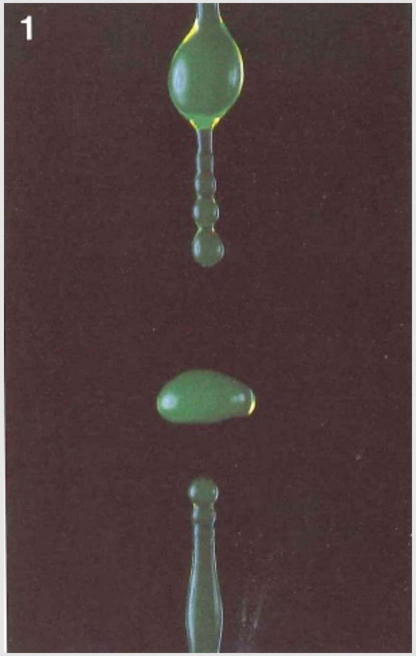


1912 - 1962

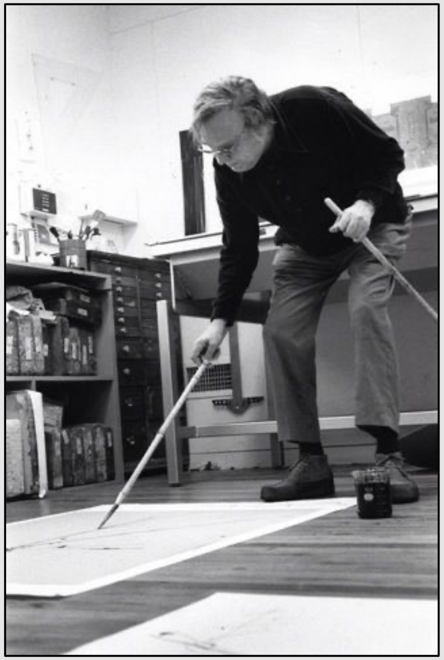
Robert Motherwell – sprays & capillary instability



Besides the Sea 1962
(oil on paper)



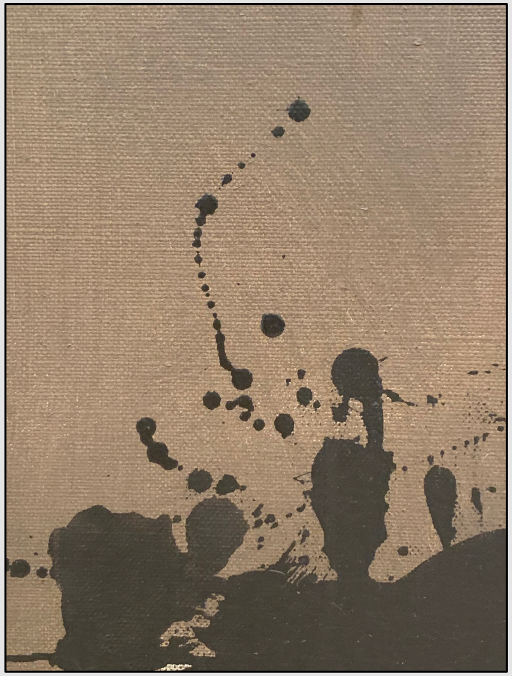
Stanley Middleman
Modeling Axisymmetric Flows
(Acad. Press 1985)



1915 - 1991

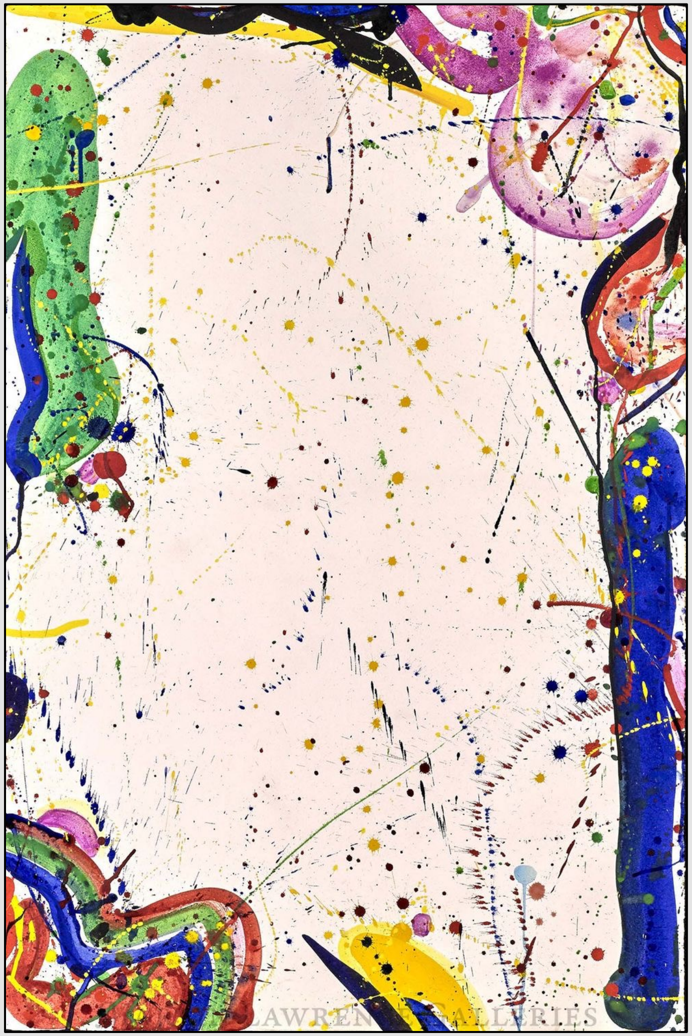
Adolph Gottlieb – sprays

A. Gottlieb, *Rising* 1962
(Rose Art Museum)



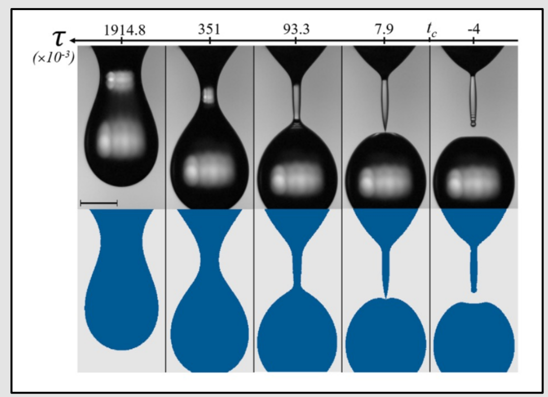
Rising 1962 (fragments)

Sam Francis – viscous drop formation



Bright Ring Drawing, 1964

1923 - 1994

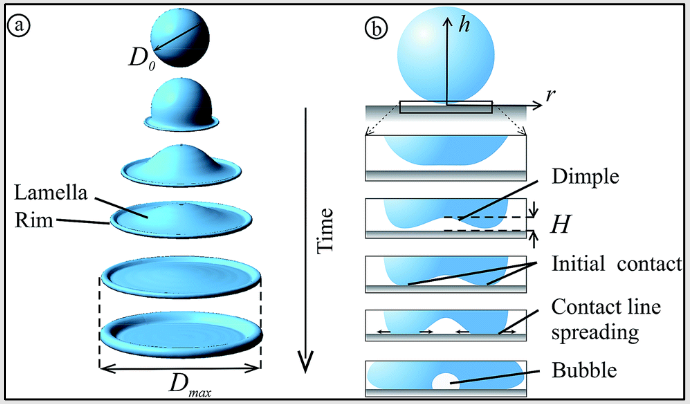


Deblais *et. al.*
(PRL v. 121, 254501, 2018)

Larry Poons – splashes, surface flows

Old Dominion (1980)

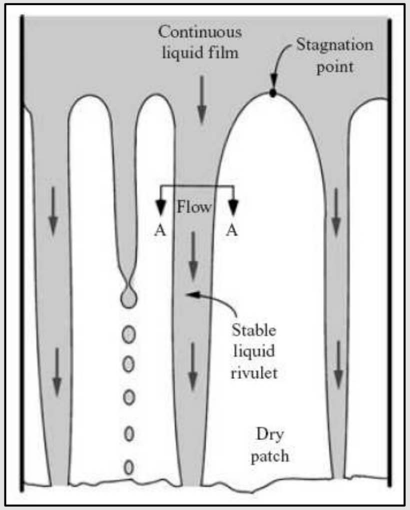
1937 -



C.W. Visser et. al
(Soft Matter, v. 11, 1708, 2015)

Pat Steer – thin film breakup

Three Little Dragon Waterfalls (1990)



H. Saber and M. el-Genk, (JFM v. 500, 113, 2004)

1940 -

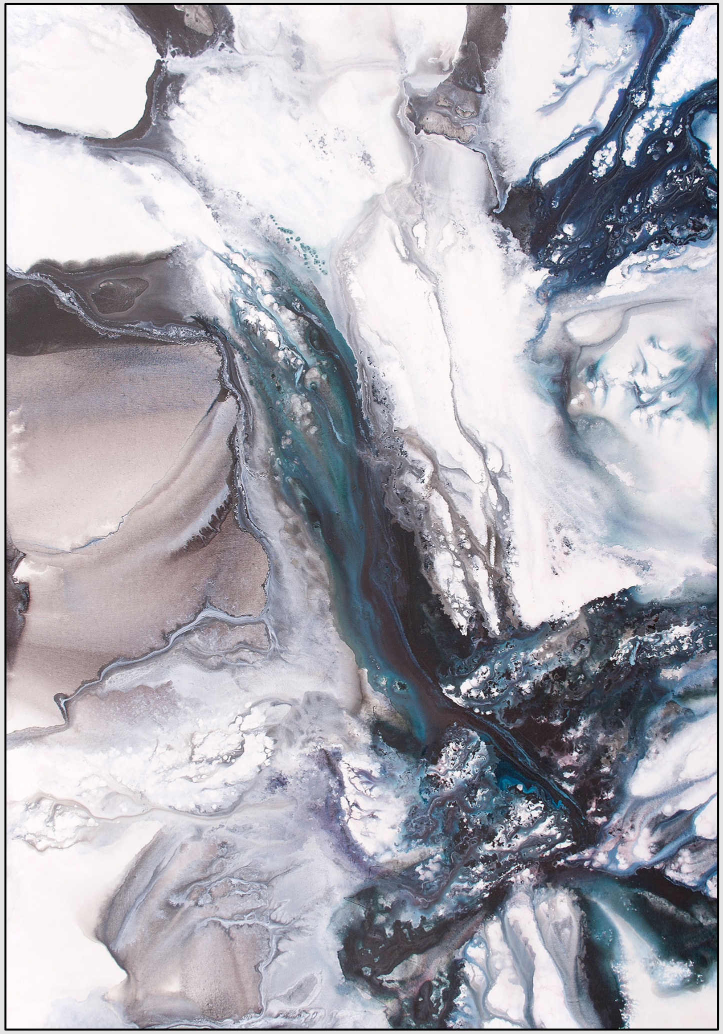
Jamie Nares – viscous "brush" flows & sprays

Untitled (oil on paper 2004, MoMA)

James "Jamie" Nares 1953 -

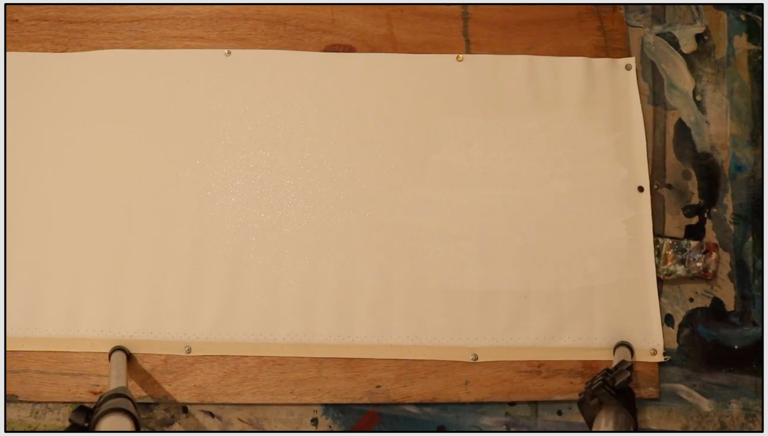
J. Nares – demonstration (April 2022)

Manoel Veiga – diffusive flows & viscous fingering



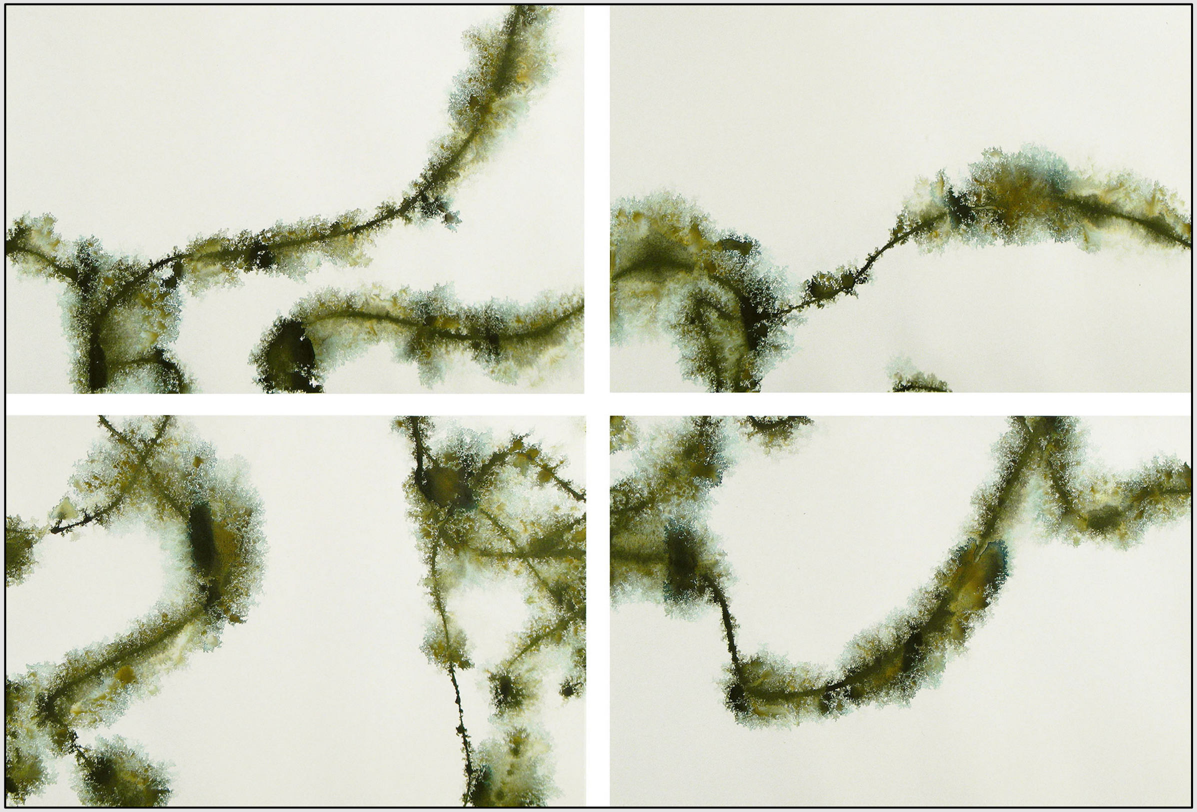
Untitled (acrylic on canvas 2013)

Manel Veiga 1966 -

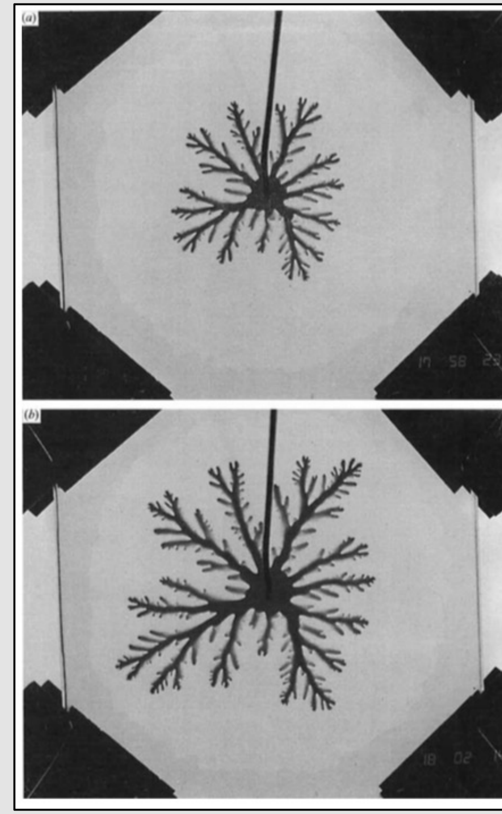


M. Veiga – demonstration (2017)

Manoel Veiga – viscous fingering



untitled (acrylic on paper, 2005)



J.D. Chen
(JFM, vol 201, p. 223, 1989)

Concluding Remarks

1. Fluid dynamics has served as a subject in art for almost the entire art history, from ancient Greece to modern times.
2. *Depicting fluids* endows paintings with a sense of reality and serves to convey motion in the static medium.
3. Through experimentation, abstract painters learned to manipulate liquids inviting Nature to "co-author" their pieces.
4. *Deploying liquids* in abstract paintings does not provide an "illustration" but directly captures natural phenomena.
5. In both approaches, there is a "give-and-take" between art and physics, and an opening for a dialogue with physicists.

Thanks to past collaborators, Claude Cernuschi and L. Mahadevan *…and Thank You!*

Dziękuję za uwagę i cierpliwość!