Title: Emergence/analogy and Hawking Radiation

Date: Oct 27, 2011 10:00 AM

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Abstract: The concepts of emergence and analogy are very closely related -- A is like B vs A is B. I will discuss this in the context of the emergence of/analogy with Hwking radiation in the arena of fluid systems, and the possibility of doing experiments in the lab. Does this mean gravity is emergent from some aether like theory? I think attempts to do that are fraught with difficulties, and will briefly discuss why I think so.

Emergence/Analogy and Hawking radiation

W.G.Unruh

gr-qc:1008.1911
PRL 106, 021302 (2011)

What is emergence?

I do not know

What is analogy?

A is like **B** in some aspect

Difference between emergence and analogy?

A is the same as **B** if only we look at **A** in the *right* way

Black Hole evaporation

1974-- Hawking "predicted" that black holes were not black

but had a temperature

$$T = \frac{1}{8\pi M}\frac{(c^3 \hbar)}{(k_B G)}$$

$T(\text{solar}) \sim 10^{-5} K$

Bekenstein suggested (1972)black holes have an entropy based on Area increase theorems by Hawking and Christodulou

Since Area increases and Entropy increases

Area ≈ Entropy

Bad Analogy

But right?

Led him to all sorts of contortions to show 2nd Law obeyed for Black Holes.

New Entropy/energy bound to save second Law

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New Entropy/energy bound to save second Law

$$TdS = dE$$

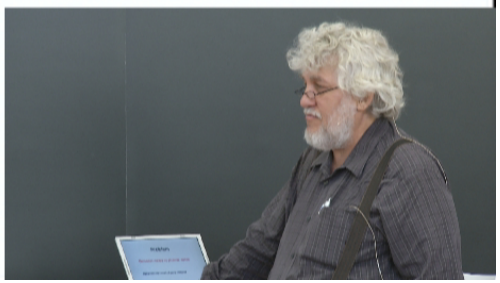
$$S = \int 8\pi M\, dM = \pi(2M)^2 = \frac{A}{4}$$

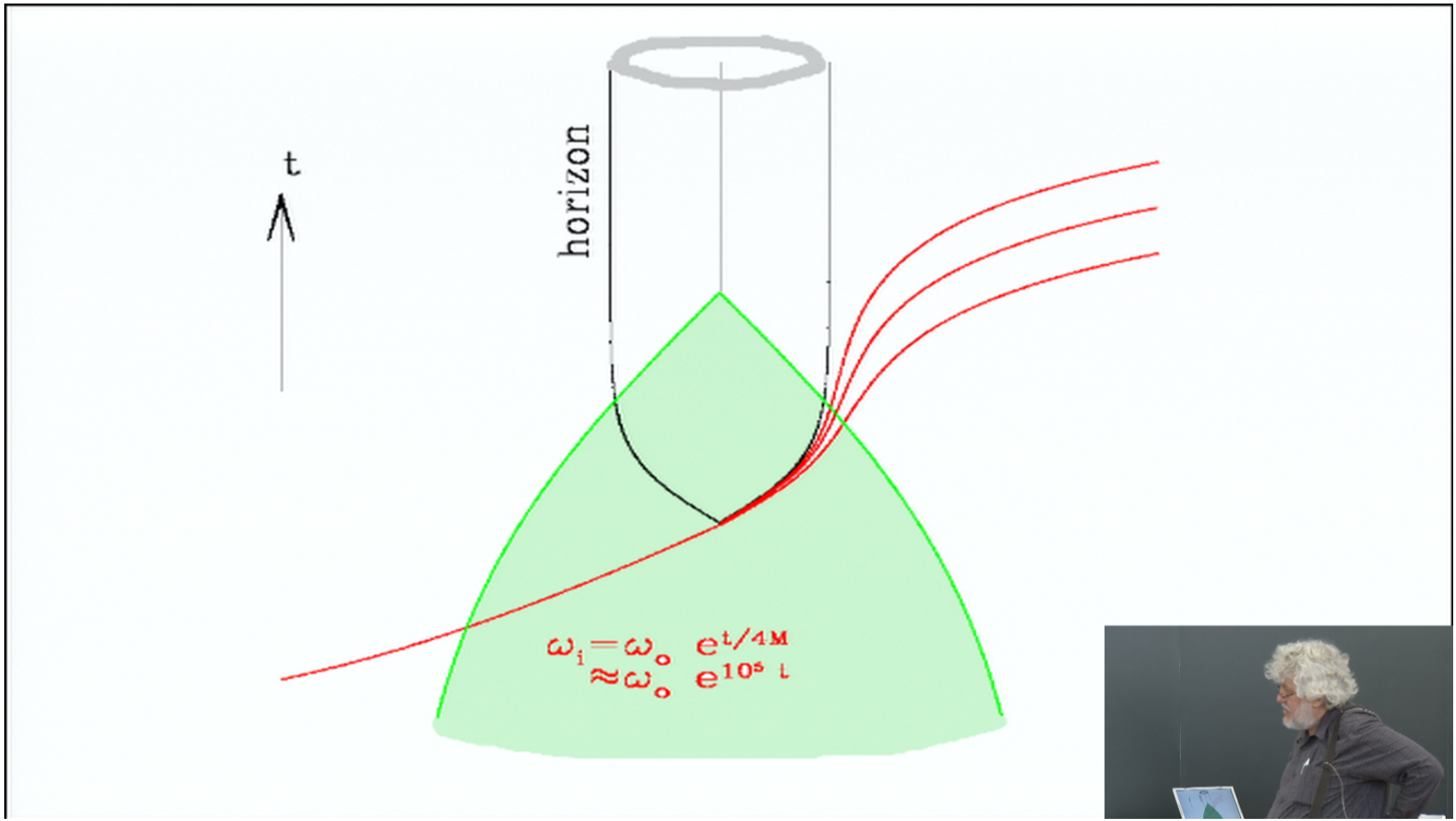
Black holes have an entropy

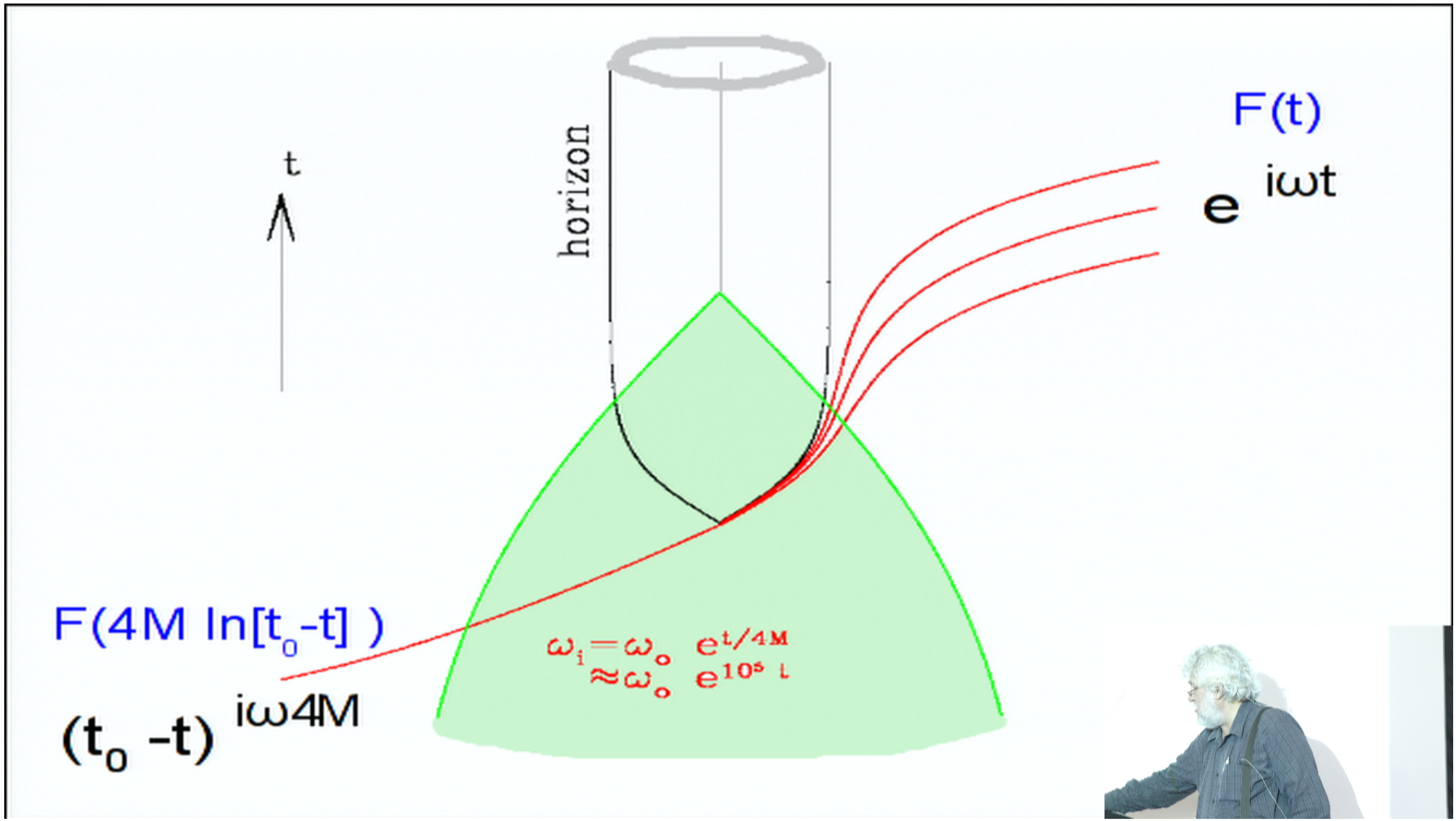
Problem

Derivation makes no physical sense

Mathematically correct, physical nonsense




t
horizon
$\omega_i = \omega_o \; e^{t/4M}$
$\approx \omega_o \; e^{10^5 \, t}$


t
horizon
F(t)
e iωt
F(4M ln[t0-t])
(t0 -t) iω4M
ωi = ωo et/4M
≈ωo e10^5 t

Frequencies which cause the outgoing radiation
Are absurdly high in the ingoing state.
After 1 second for solar mass black hole

e^{10^5} Any units make no difference

Experiment would be deteminant.

But small black holes are hard to find

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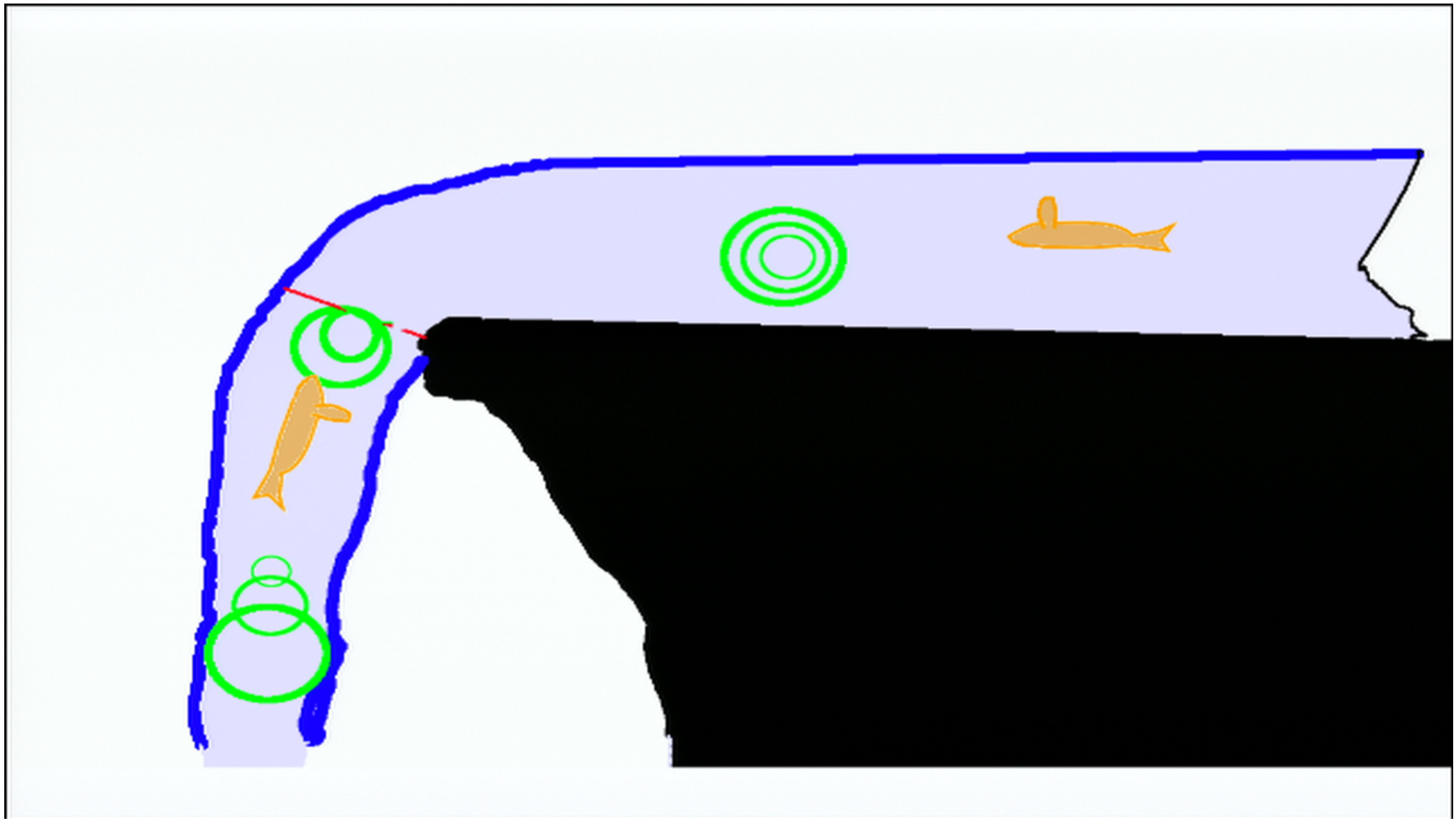

Metric equivalence

The equation of motion of the sound waves in irrotational flowing fluid identical (in Hydrodynamic limit) to equations of massless scalar field In background metric.

$$\mathbf{v}=\nabla\varphi \Rightarrow \quad \Box\varphi=0$$

$$g_{tt} = c^2 - v^2 \qquad g_{ti} = v_i \qquad g_{ij} = \delta_{ij}$$

C is velocity of sound in fluid.

If v purely radial and of form $c\sqrt{(2M/r)}$

Schwartzschild metric in Painleve Gullstrand coords.

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Using the same arguments as Hawking

$$T = \frac{1}{4\pi c}\frac{d(c^2 - v^2)}{dx}$$

Temperature determined by the geometry of background Fluid flow.

Problem-- Hydrodynamic approx.
Suffers from the same ultra high freq problem.

Atomic nature of matter-- prevents ultra high freq problem
Cannot have sound waves with wavelength
Shorter than interatomic spacing.

Does this destroy the effect?
(What is the influence of the ultra high freq. on Penomenon?)

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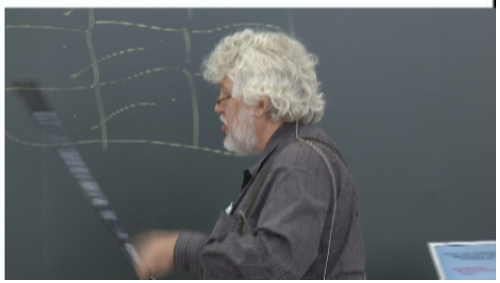
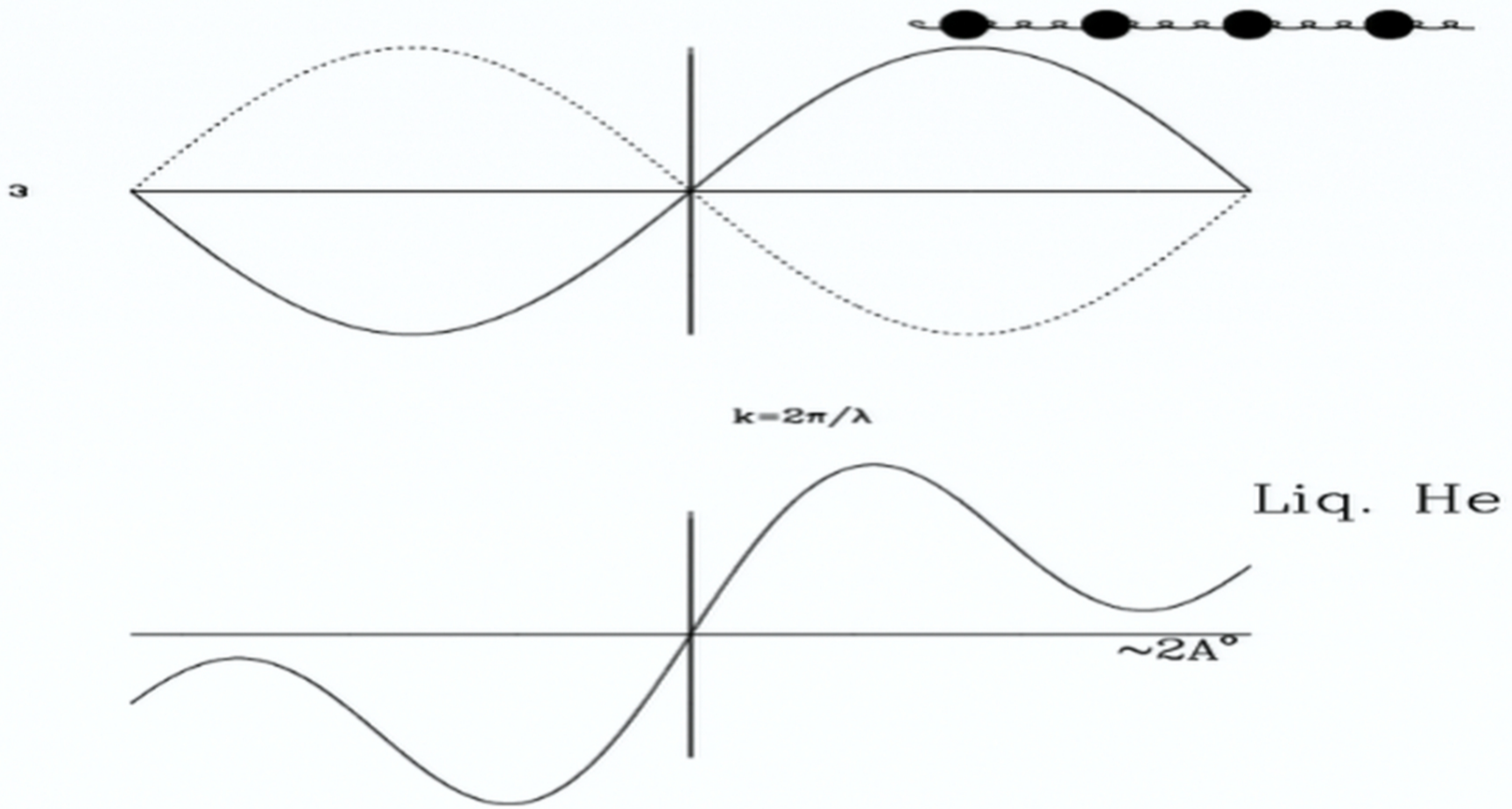
(Jocobsen) Dispersion relation of sound waves

$$\omega + vk = F(k)$$
$$\omega = F(k) - vk$$




ω
k=2π/λ
Liq. He
~2A°

PHYSICAL REVIEW
LETTERS

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Experimental Black-Hole Evaporation?

W. G. Unruh
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(Received 8 December 1980)

It is shown that the same arguments which lead to black-hole evaporation also predict that a thermal spectrum of sound waves should be given out from the sonic horizon in transsonic fluid flow.

PACS numbers: 04.60.+n, 04.80.+z, 47.90.+a, 97.60.Lf

Black-hole evaporation[1,2] is one of the most surprising discoveries of the past ten years. Black holes emit thermal radiation with a temperature given by $\hbar c^3/8\pi kGM$, and thus seem to combine quantum mechanics and gravitation to equation at small scales on the evaporation process, and one might even contemplate the experimental investigation of the thermal emission process.

The model of the behavior of quantum field in a

Analogy: Waves in fluids (sound, surface,...)
Electromagnetic waves in waveguides, fibres

Obey same equations as Hawking's fields at low freq.

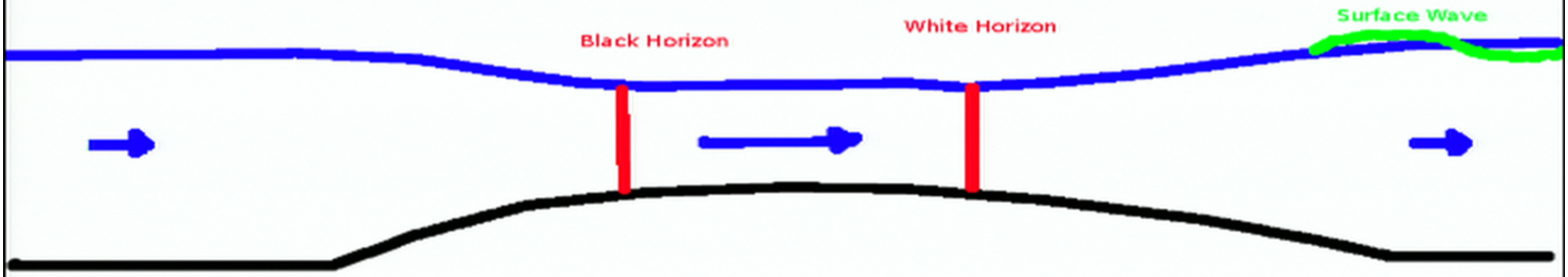
Obey different equations than Hawking's at short wavelengths

Metric appears only at low wavenumbers
Emergent gravity?

Can use differences to test dependence of effect
(Thermal emission) on short wavelength physics.
Does Hawking effect really depend on ultra short physics?

Black hole-- Incoming waves ultra high wavenumber
Outgoing waves low wavenumber

White hole-- Time reverse of black hole (Nothing can go Into a white hole)
Incoming waves low wave number. Outgoing waves high wavenumber



Schuetzhold, Unruh (2002)

$\omega^2 = g\, k \tanh(k\, h)$

$c^2 = gh$ (low k)

$= g/k$ (high k-- phase)

$= g/2k$ (high k-- group)

Linear Quantum Systems

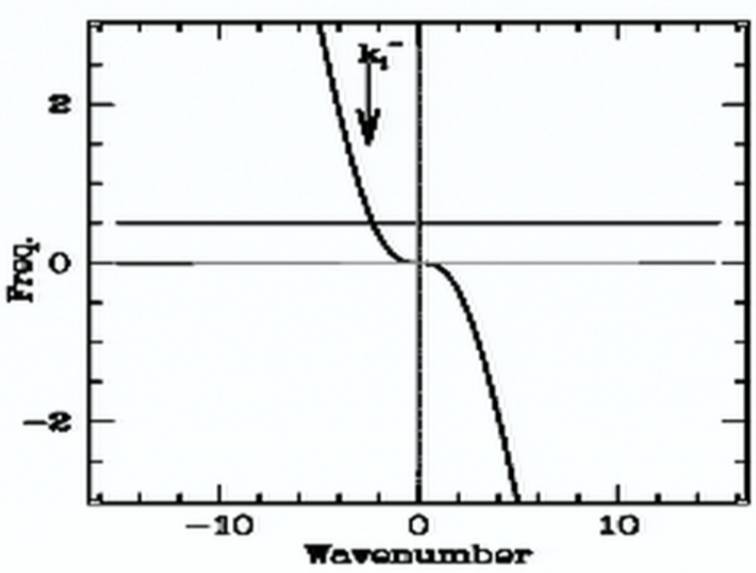
The quantum behaviour is completely determined by classical behaviour.

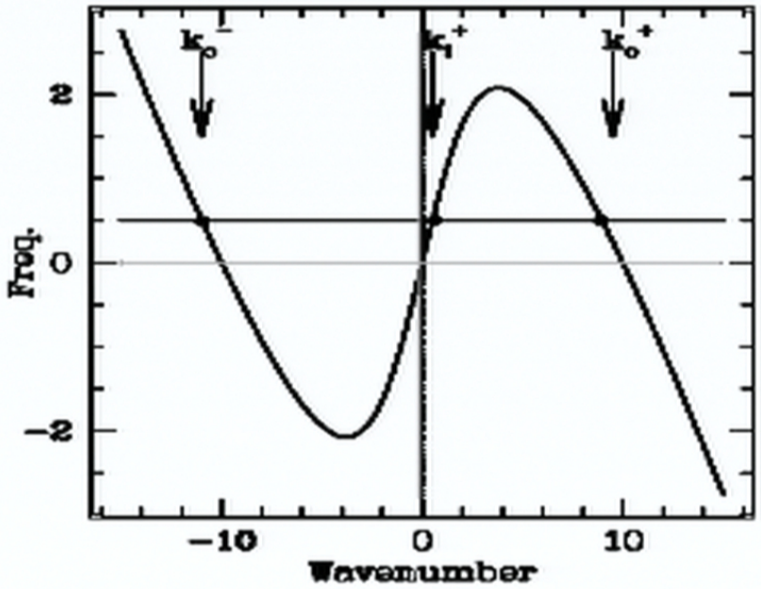
$$\langle \Phi_1, \Phi_2 \rangle = i/2 \, \Sigma_i \, (q_{1\,i}^{*} \, p_{2i} - p_{1\,i}^{*} \, q_{2i})$$

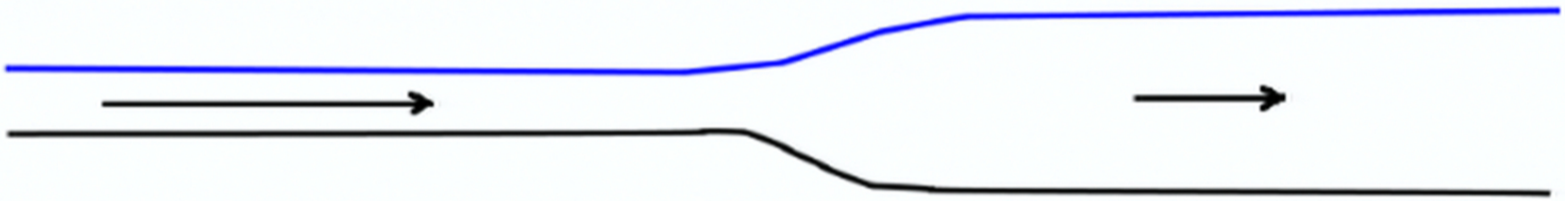
Positive norm input-> negative norm output
Particle creation creation determined by classical negative norm output.

$$\frac{|B|^2}{|A|^2} = e^{+H/kT}$$

B-> Amplit. Neg freq
A-> Amplit. Pos freq


k_1^-
2
0
−2
Freq.
−10
0
10
Wavenumber


k_0^-
k_1^+
k_0^+
2
0
−2
Freq.
−10
0
10
Wavenumber



Full Emergence?

Is gravity an aspect of Condensed Matter?

Aether?
fluctutations in the properties of the aether
--various fields in physics.

Earthquakes==> P waves (Pressure waves)
S waves (Shear waves)
Rayleigh (Surface waves)

Are these just different fields in nature?

Zhang (surface states of quantum Hall)

Horava-- Higher order disperion theory
(renormalisable)

Problems : Models have special time (Newtonian)

P waves and S waves travel with very different velocities

Generic feature of theories with special time

Universality of c ("speed of light in vacuum")

All fields have same limiting speed at high energies ("low energies" in dispersive theories?)

Superluminal neutrinos almost certainly wrong even though why experiment wrong unclear

Emergent theories have different velocities unless fine tuning of theory.

Emergence (**A** is same as **B**) can be very problematic. **A** and **B** are different, so difference must either be neglected, or subsumed

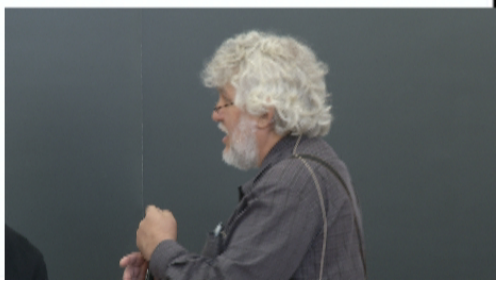
Distraction-- concentrate on differences

Analogy (similarities) can still be immensely powerful and can illuminate both **A** and **B**

See Weinfurtner's talk later today

Physics as Pun

Why is a steamship like and elephant?



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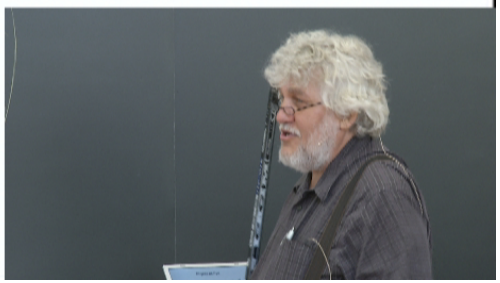

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Why is an H_2O like Argon?

They both carry Navier Stokes as collective description