

Fenómenos cuánticos macroscópicos en sistemas materia-luz

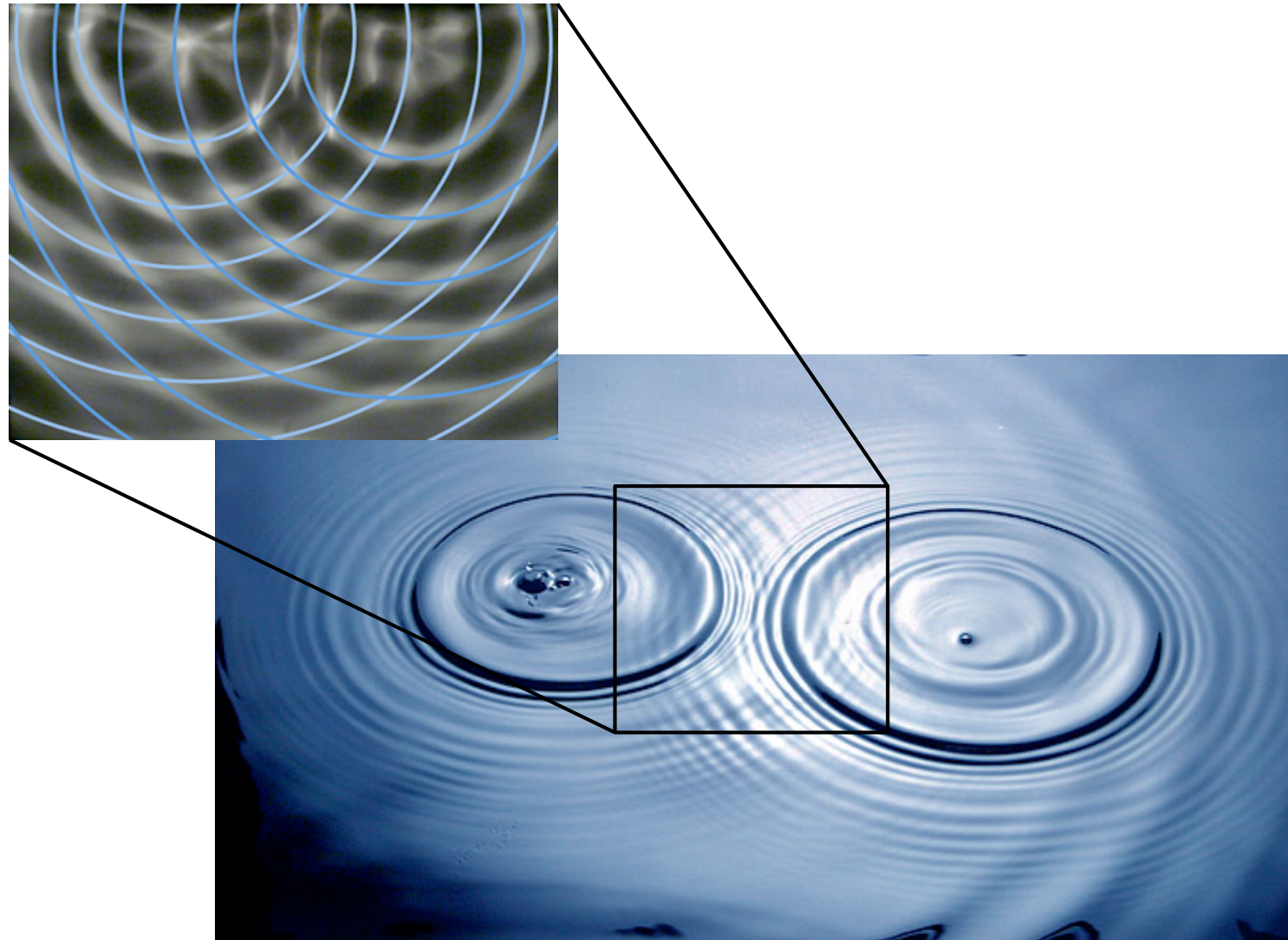
Francesca Maria Marchetti



UAM, 3 de Octubre de 2014

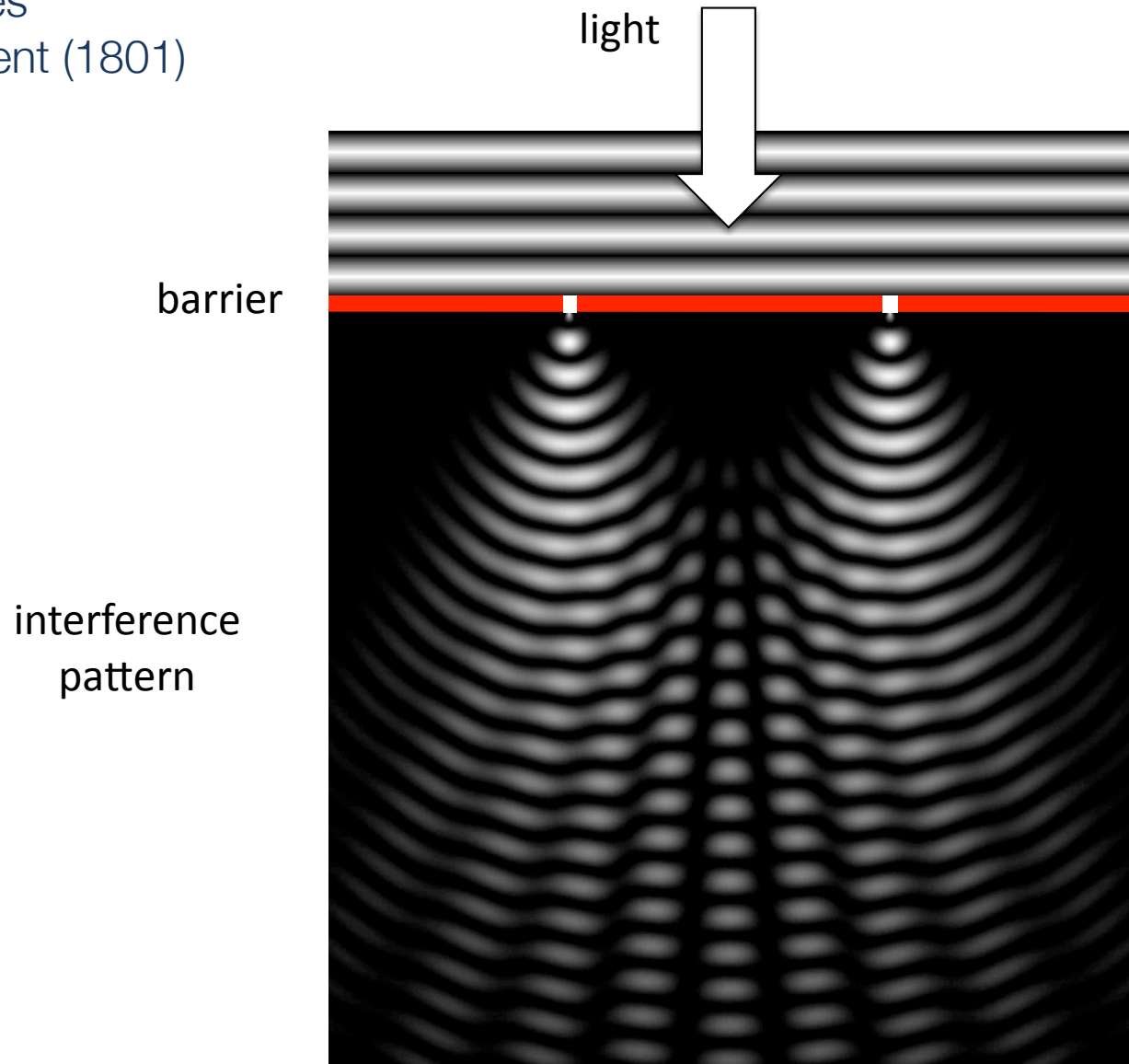
Particles as waves

✧ Interference of waves



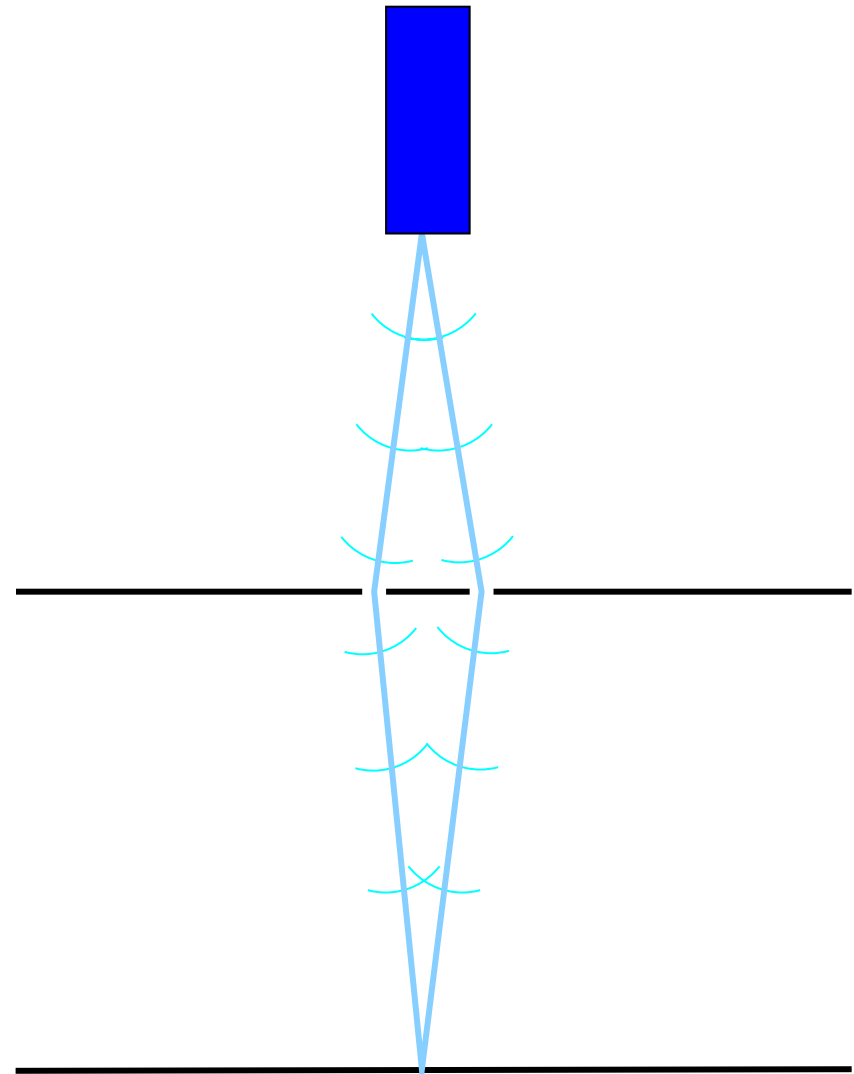
Particles as waves

- ✧ Interference of waves
- ✧ Double-slit experiment (1801)



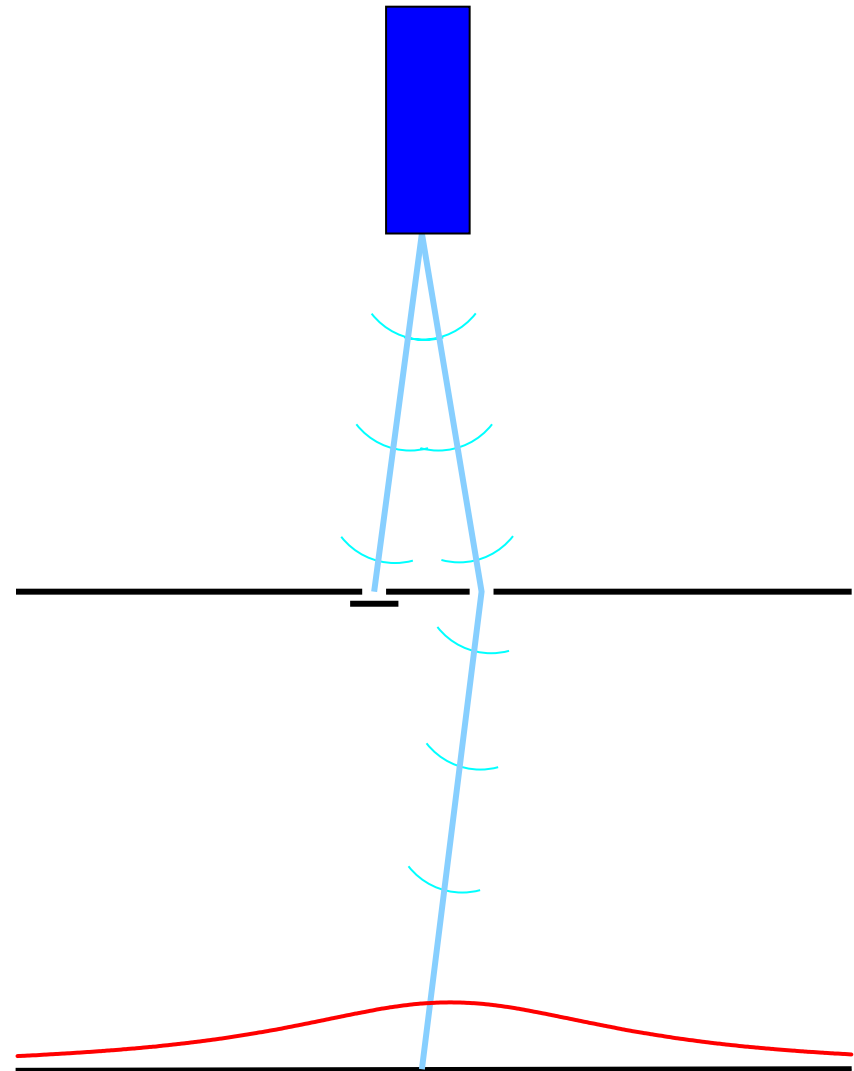
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- ✧ Interference of waves
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- ✧ With particles (e.g., electrons) (1961)



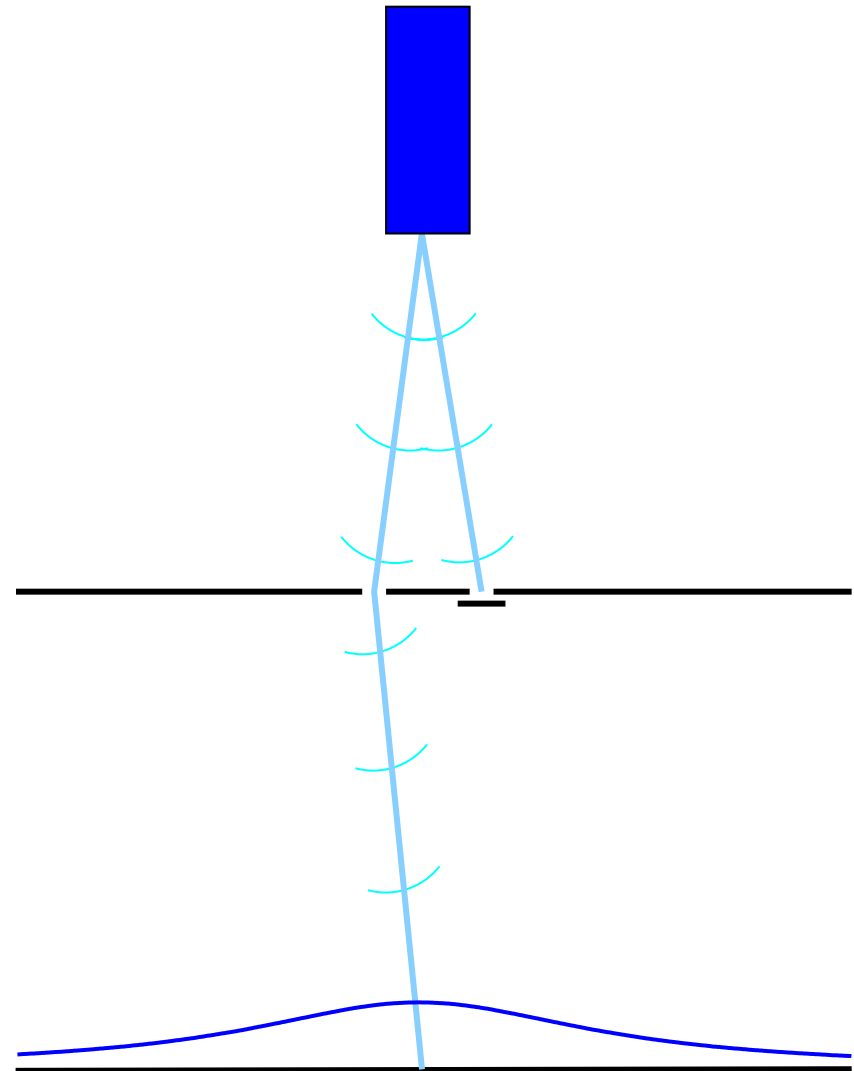
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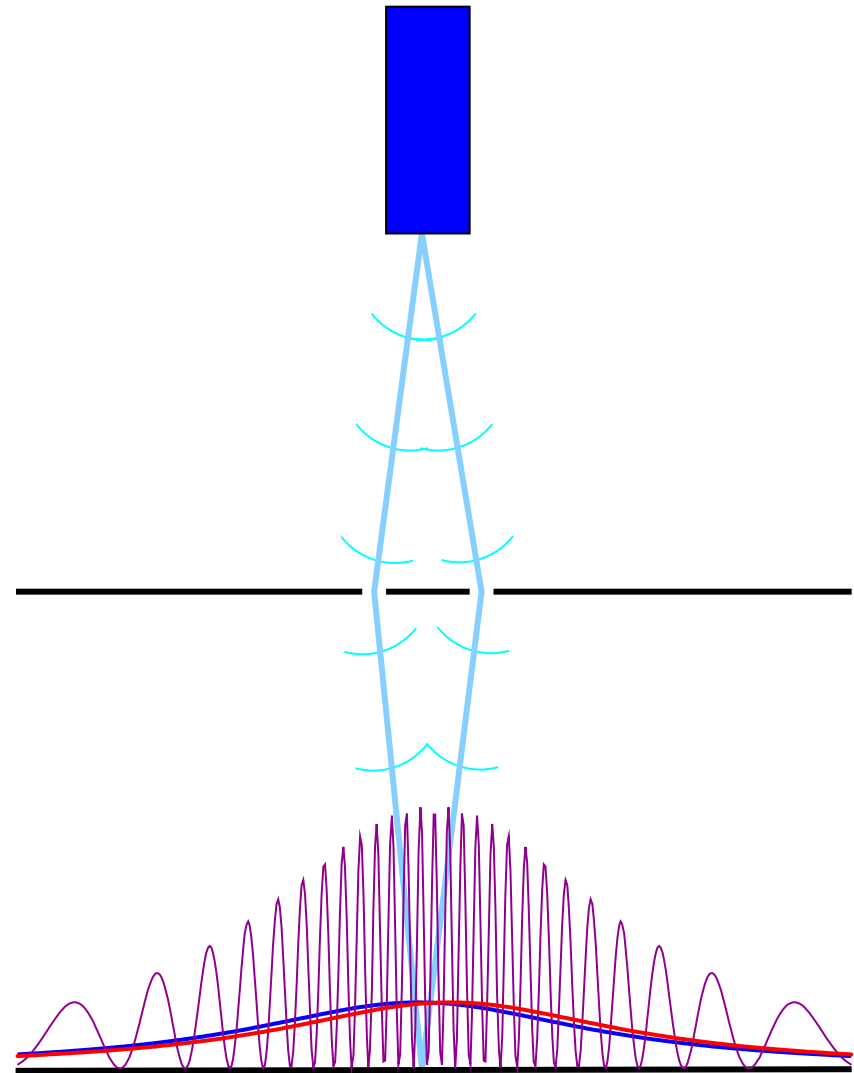
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the electron is interfering with itself

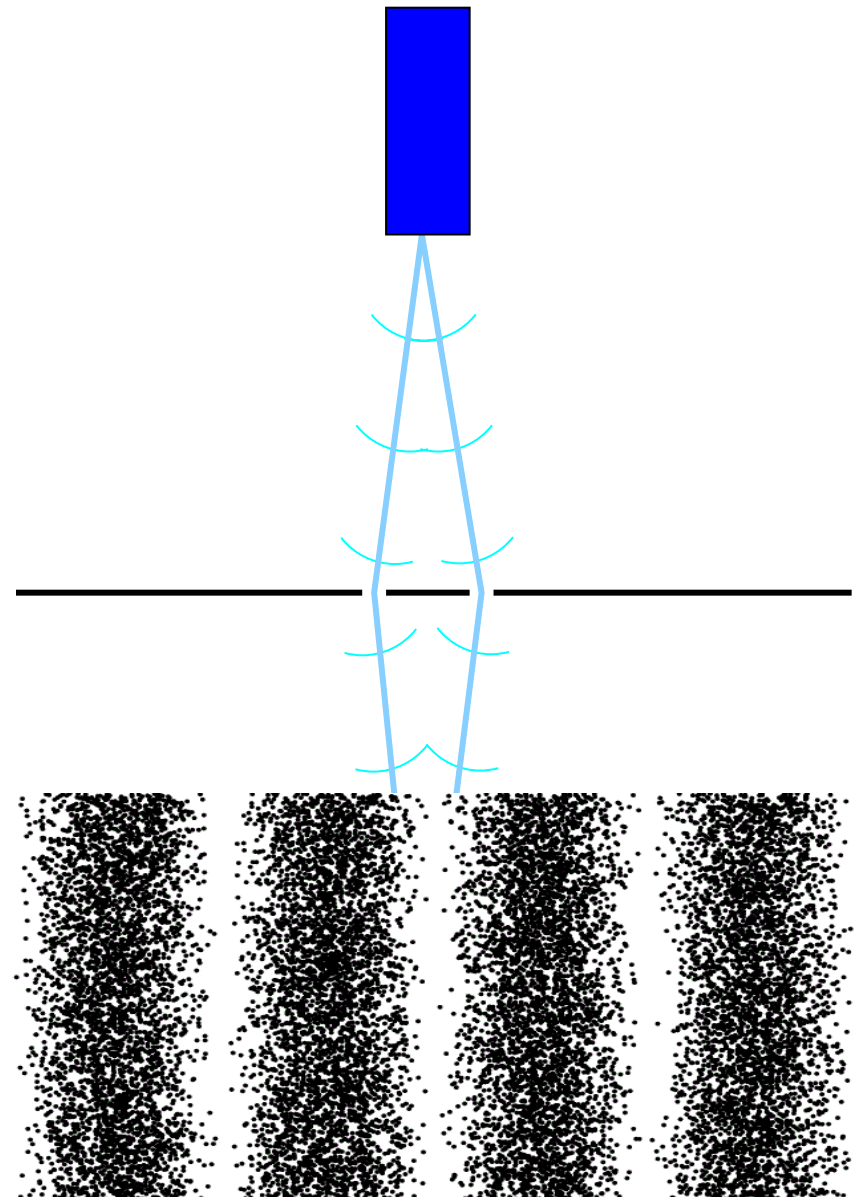
Particles as waves

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“a phenomenon which is impossible to explain in any classical way... In reality, it contains the only mystery of quantum mechanics”

[Richard Feynman]

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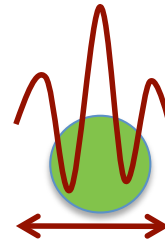


Quantum at macro scales?

✧ Interference on macro scales?

⇒ De-Broglie wavelength (1924): small

⇒ Different initial conditions wash out path

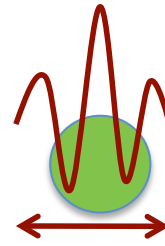


$$\lambda = \frac{2\pi\hbar}{p}$$

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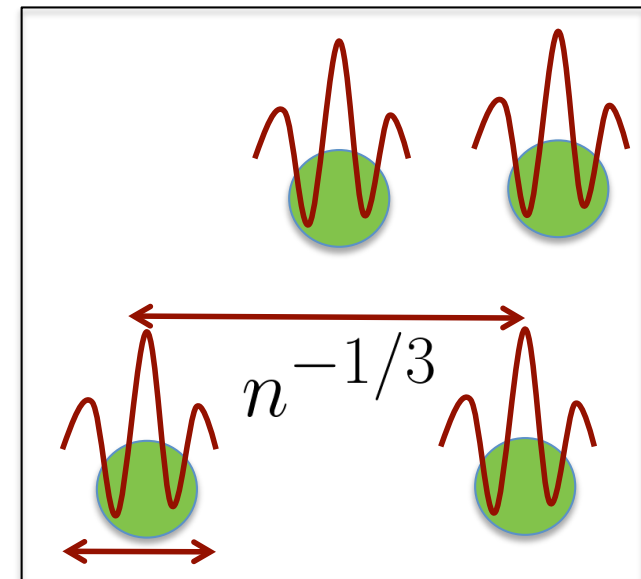


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✧ Temperatures for quantum behaviour

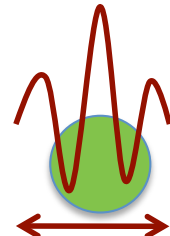
$$k_B T \simeq \frac{p^2}{2m} \quad \lambda_T = \left(\frac{2\pi\hbar^2}{mk_B T} \right)^{1/2}$$



Quantum at macro scales?

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A green circle representing a particle is shown with a red wavy line representing its wavefunction. A red double-headed arrow below the circle indicates the wavelength of the wavefunction.

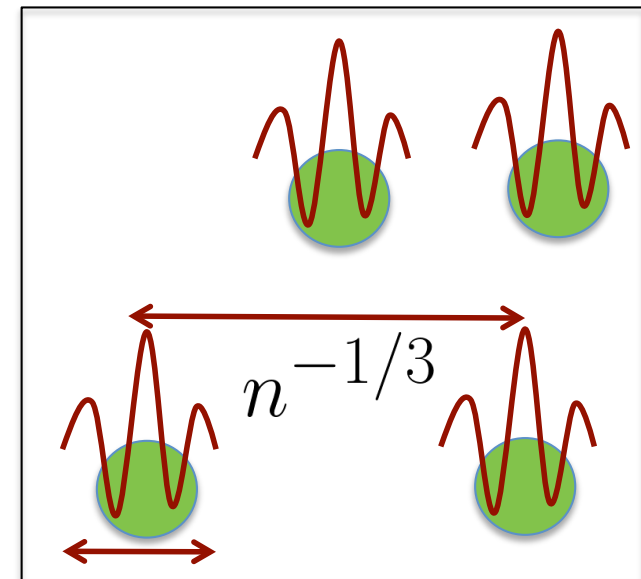
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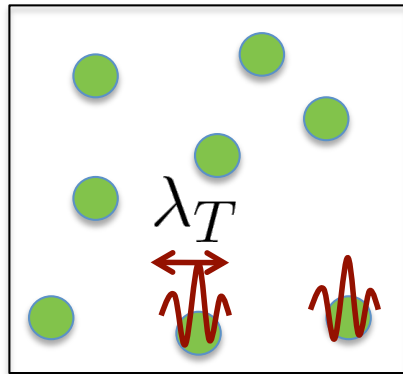
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⇒ requires $n\lambda_T^3 > 1$

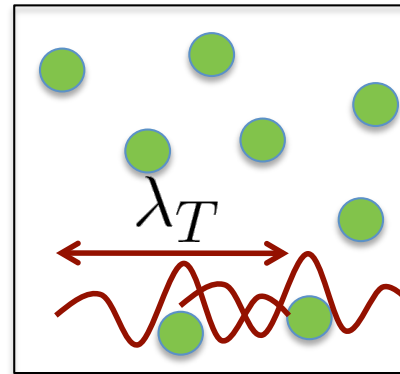


Quantum at macro scales? Quantum condensates

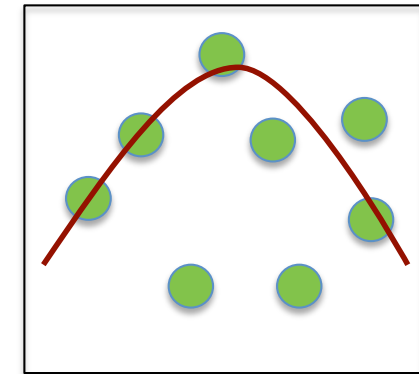
lowering the temperature →



MICRO

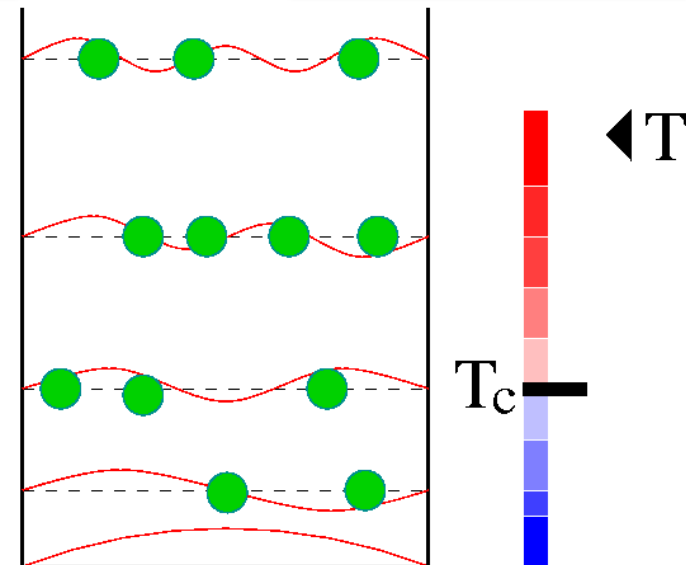


synchronization



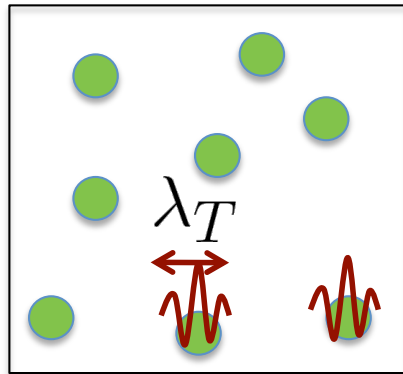
MACRO
coherence

condensación
de
Bose-Einstein

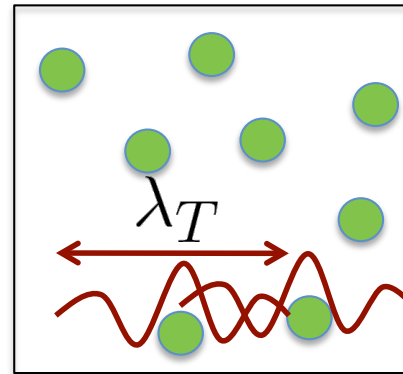


Quantum at macro scales? Quantum condensates

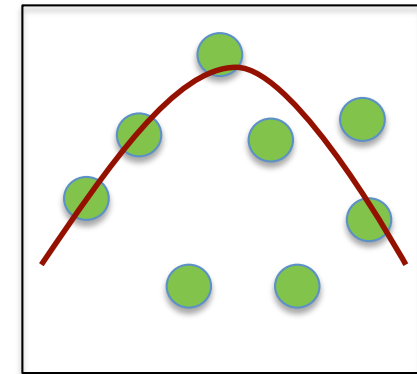
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MICRO



synchronization



MACRO
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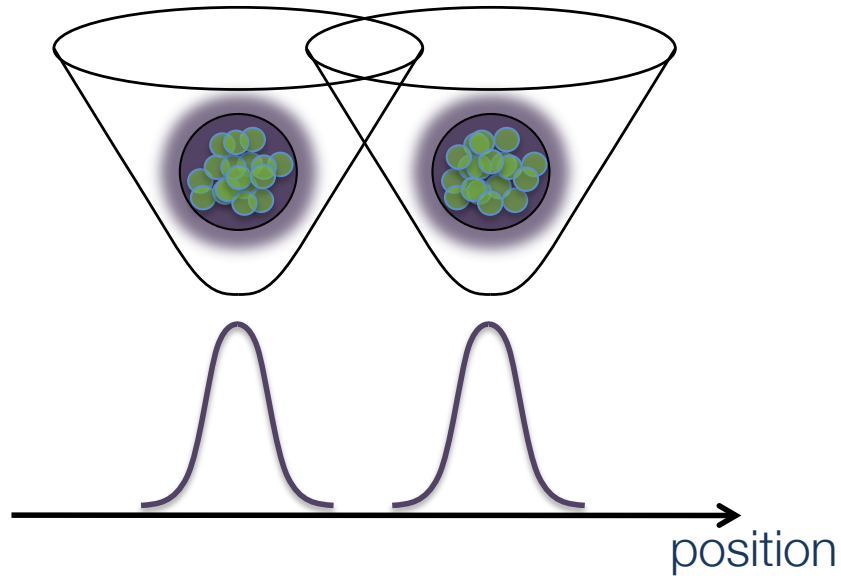
condensación
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Macroscopic quantum coherence

✧ The two-slit experiment with two condensates

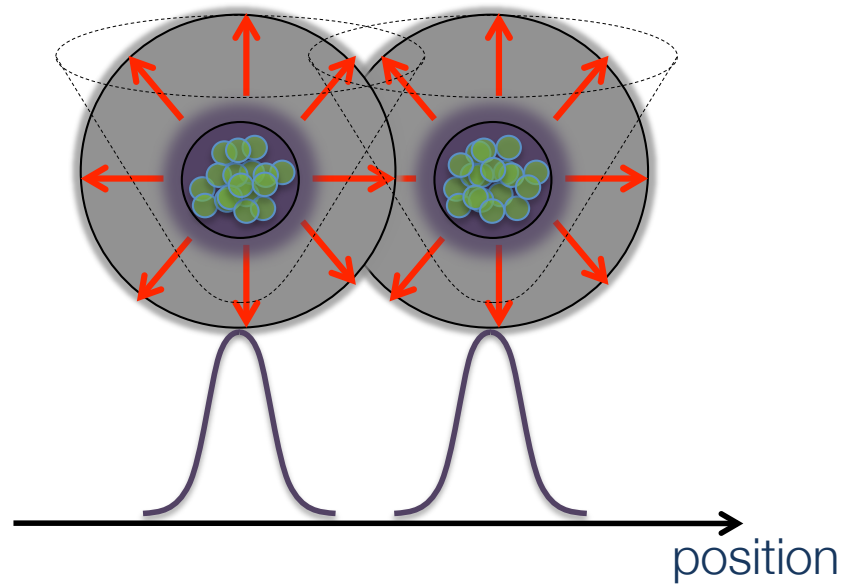
⇒ all atoms in a single quantum state --- GIANT MATTER WAVE



Macroscopic quantum coherence

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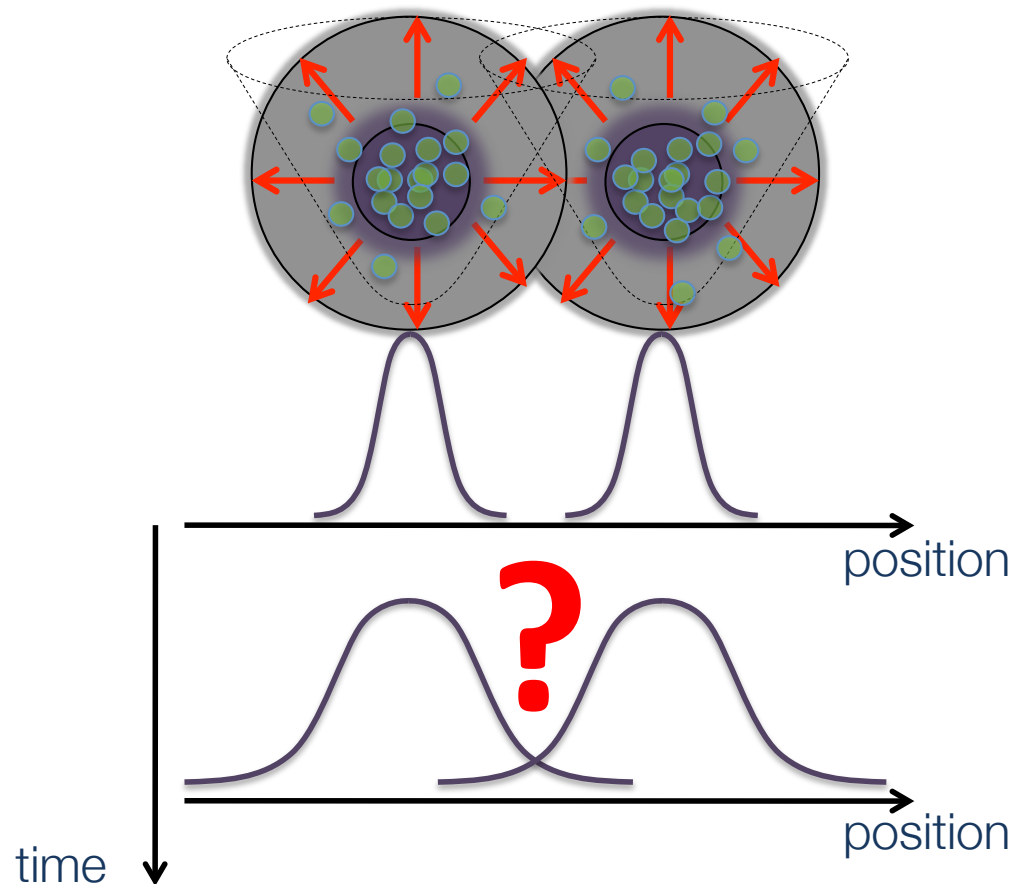
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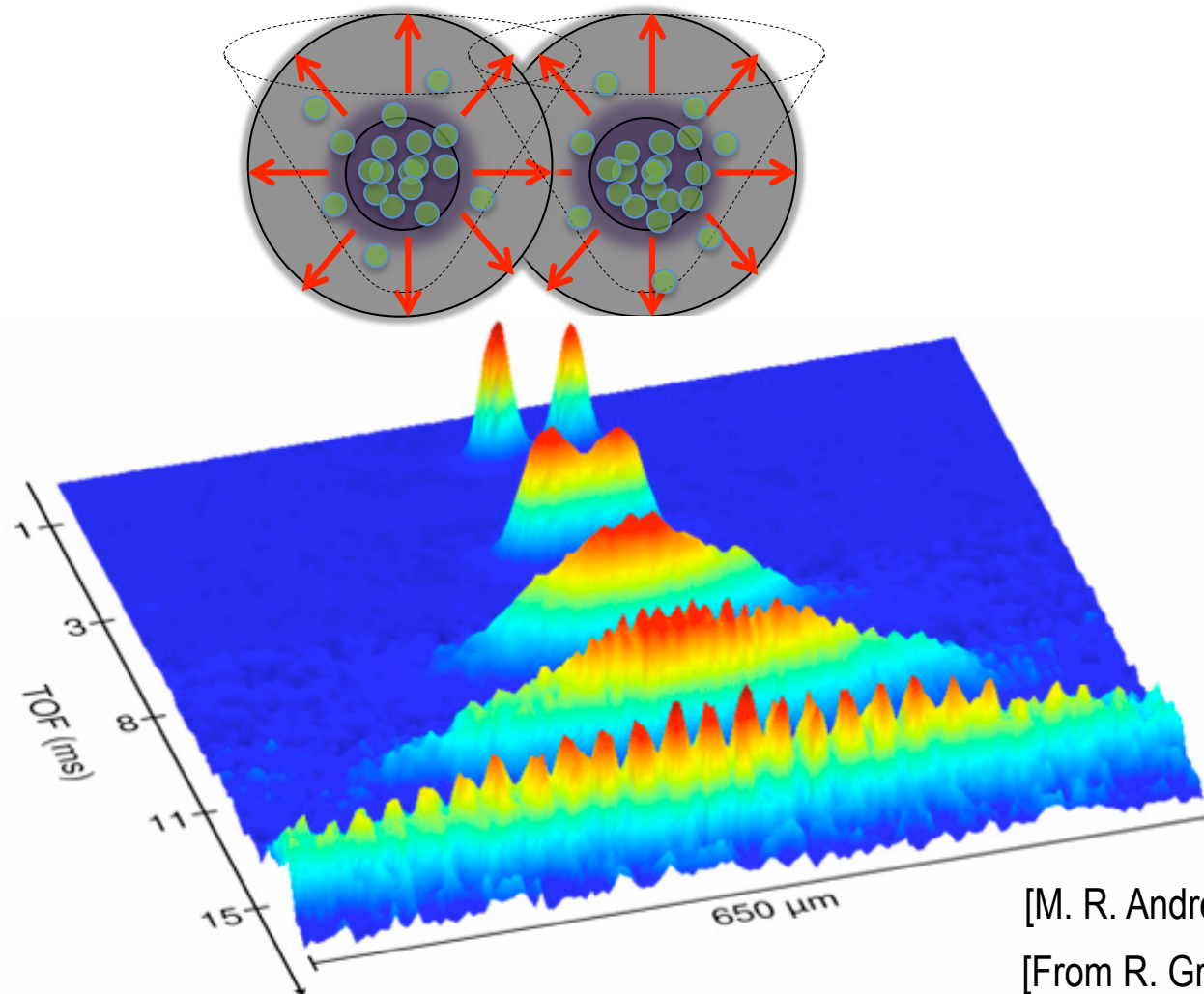
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Macroscopic quantum coherence

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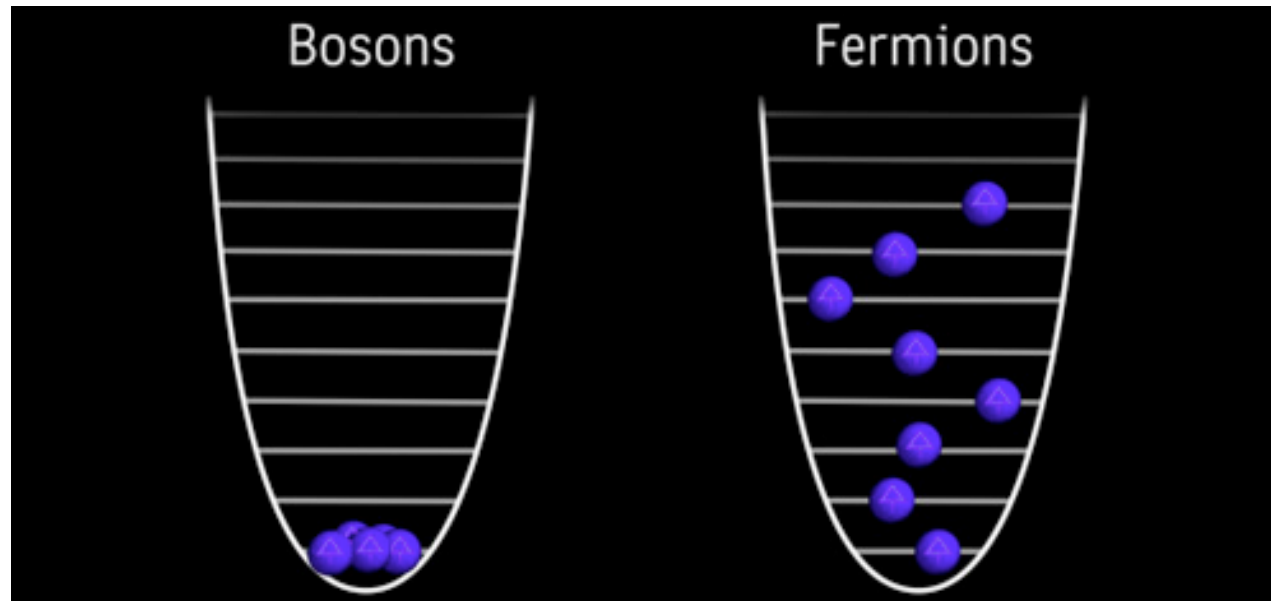
⇒ all atoms in a single quantum state --- GIANT MATTER WAVE



[M. R. Andrews *et al.* Science **275**, 637 (1997)]

[From R. Grimm's group (recent)]

Bosons vs. Fermions



gregarious

quantum individualists

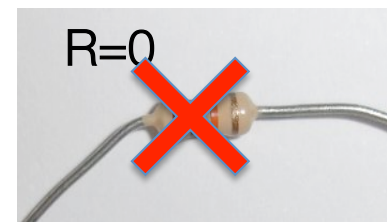
can condense
in pairs!



superfluidez

condensación

superconductividad



zero electrical
resistance

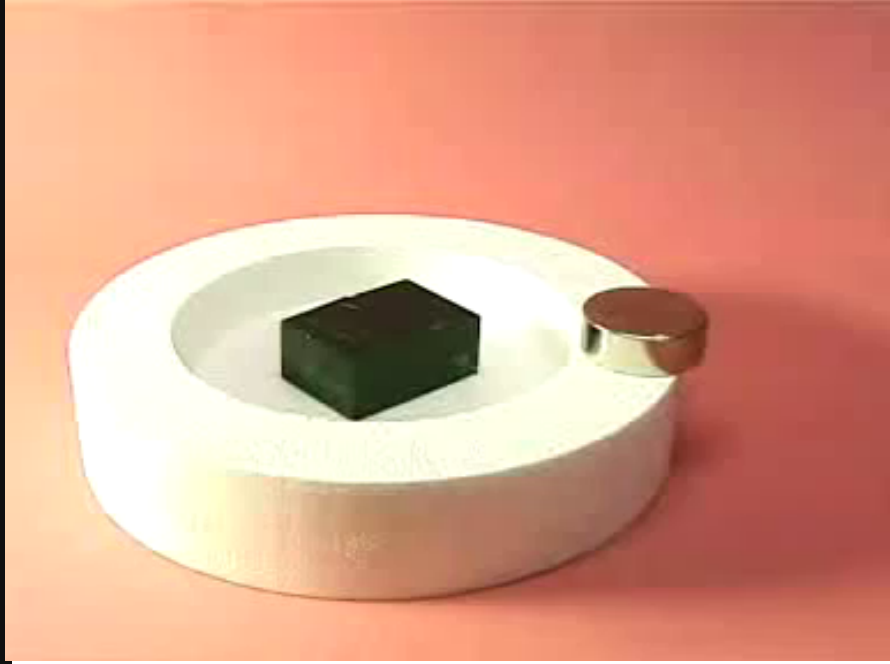
Superfluids vs. superconductors

bosons --- superfluids

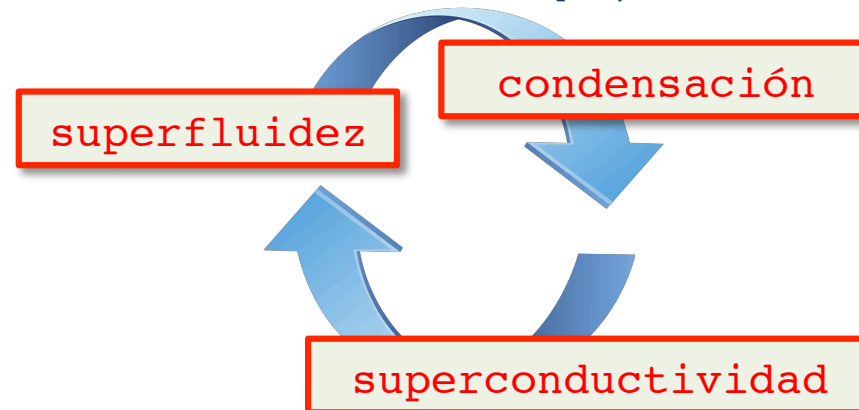


[fountain effect]

fermions --- superconductors



[superconducting magnetic levitation]



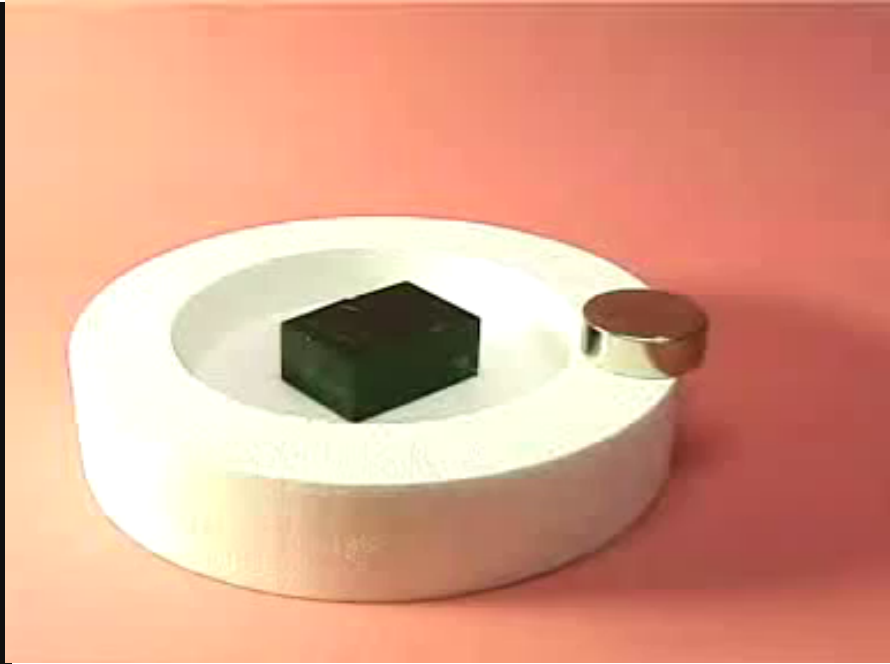
Superfluids, superconductors, & lasers!

bosons --- superfluids



[fountain effect]

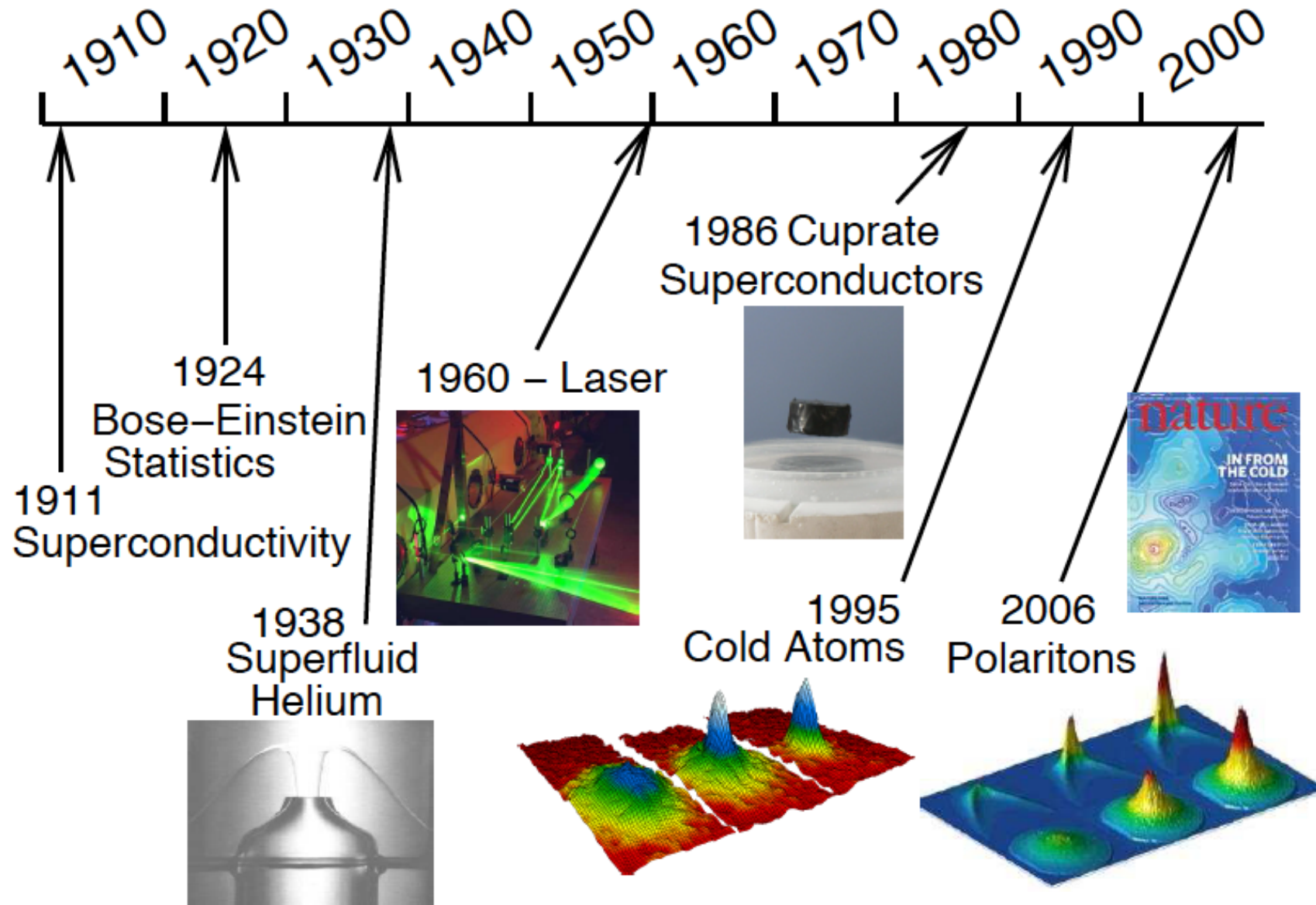
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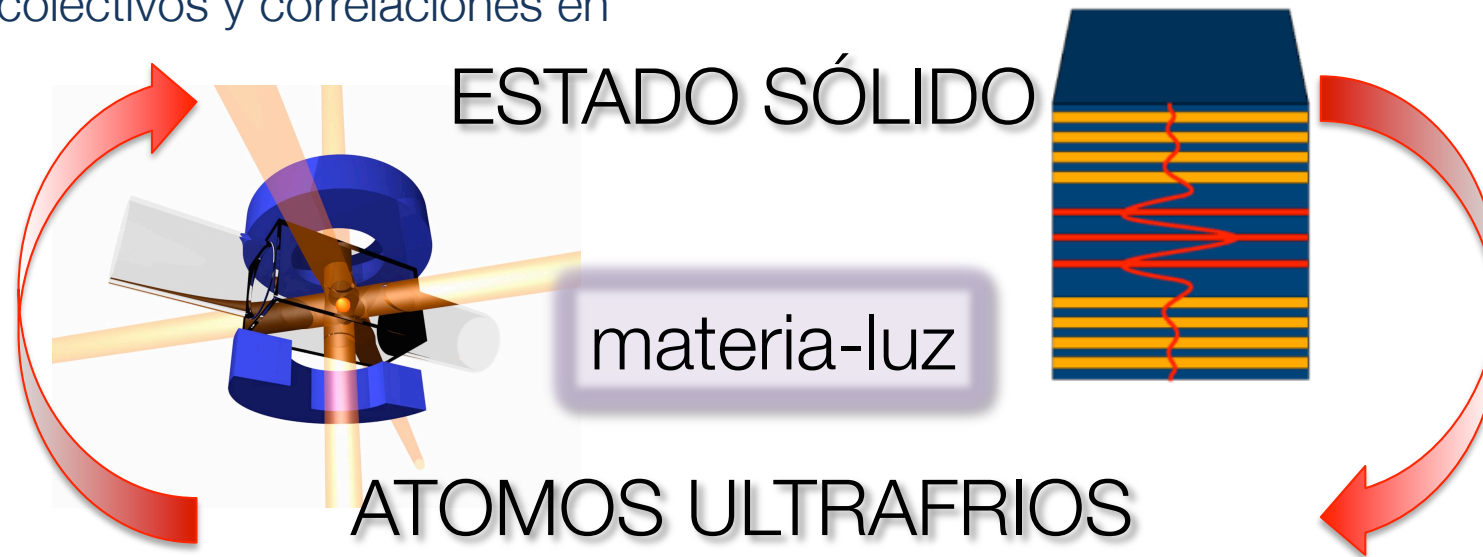


History of quantum condensates



Interdisciplinary ground

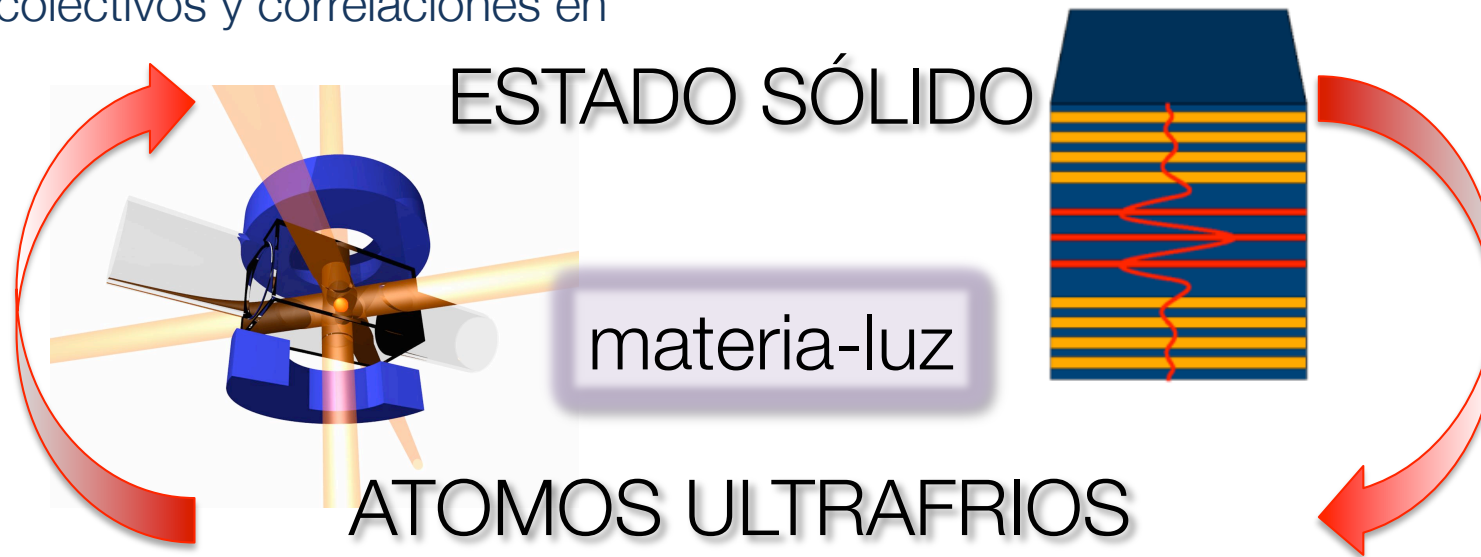
- ✧ Coherencia de fase macroscópica, condensación, superfluidez, fenómenos colectivos y correlaciones en



- manipulación de la interacción
- control
- exploración versátil
- baja dimensionalidad
-
-
-

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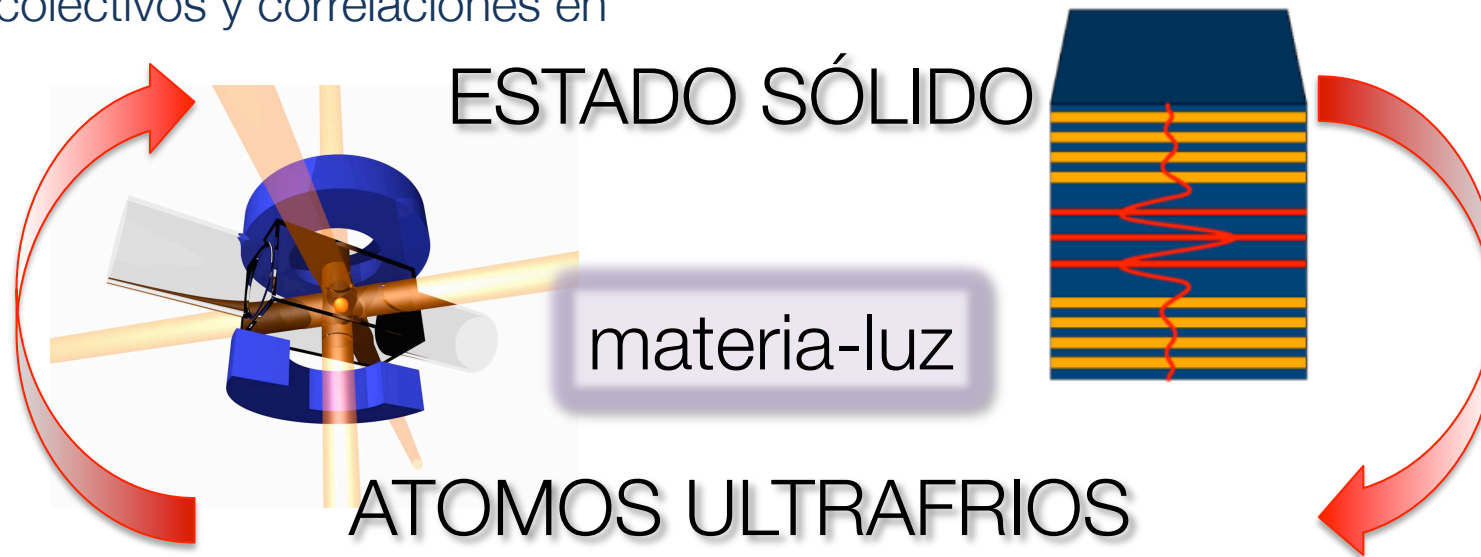
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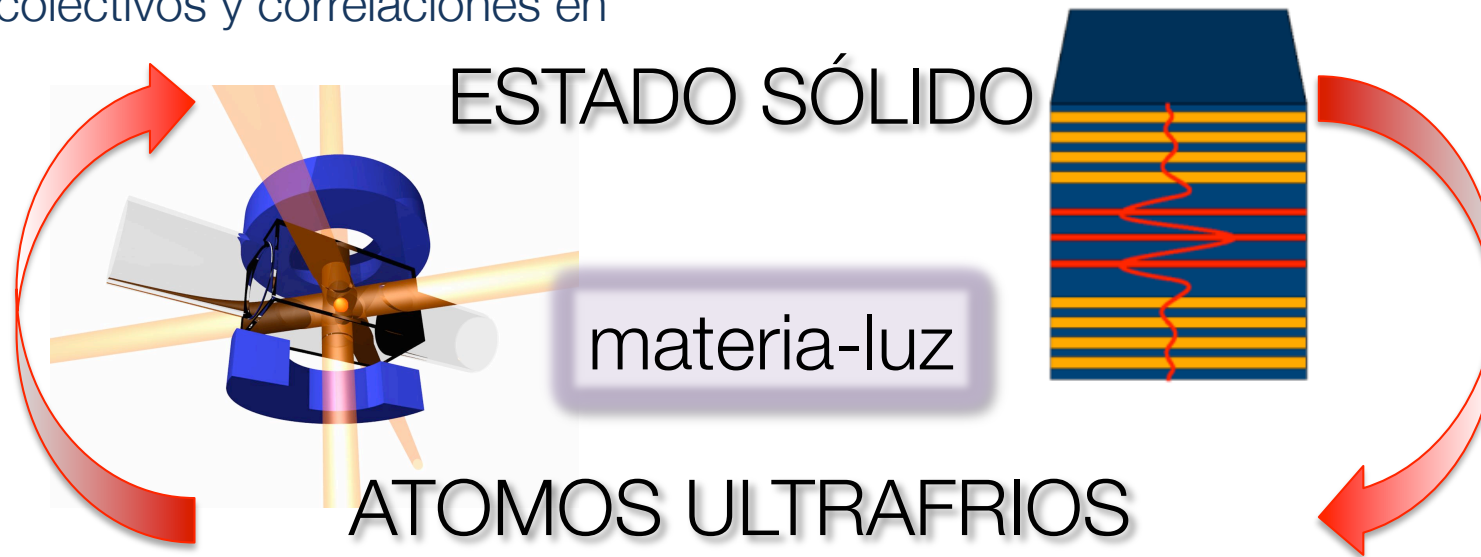
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Interdisciplinary ground

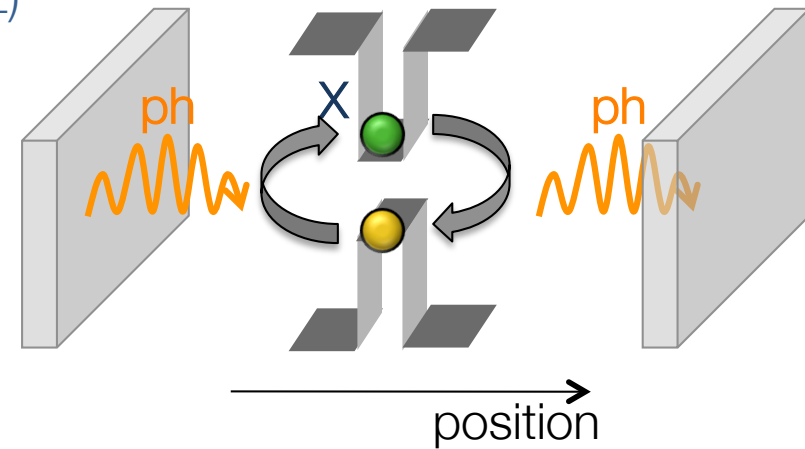
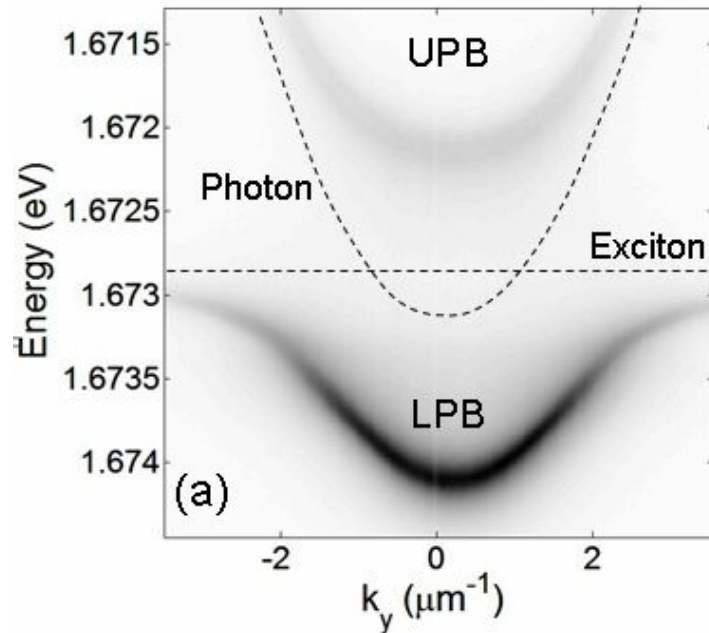
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- vinculo con experimentos (explicar, propuestas y previsiones)

Condensation of matter-light particles (polaritons)

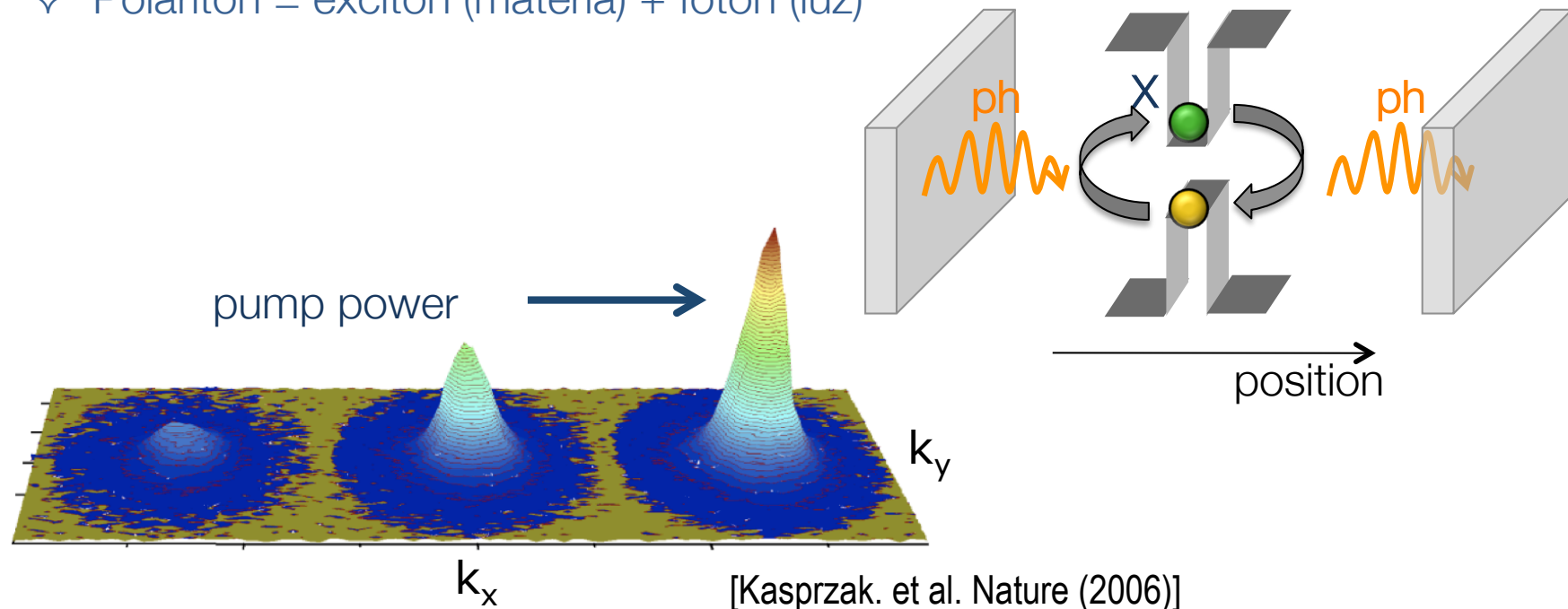
✧ Polaritón = excitón (materia) + fotón (luz)



✧ Frontera entre la materia condensada y la óptica cuántica

Condensation of matter-light particles (polaritons)

✧ Polaritón = excitón (materia) + fotón (luz)



✧ Frontera entre la materia condensada y la óptica cuántica

✧ Porqué novedoso?

✧ Plétora de fenómenos cuánticos a escala mesoscópica

⇒ transiciones de fases y fenómenos críticos

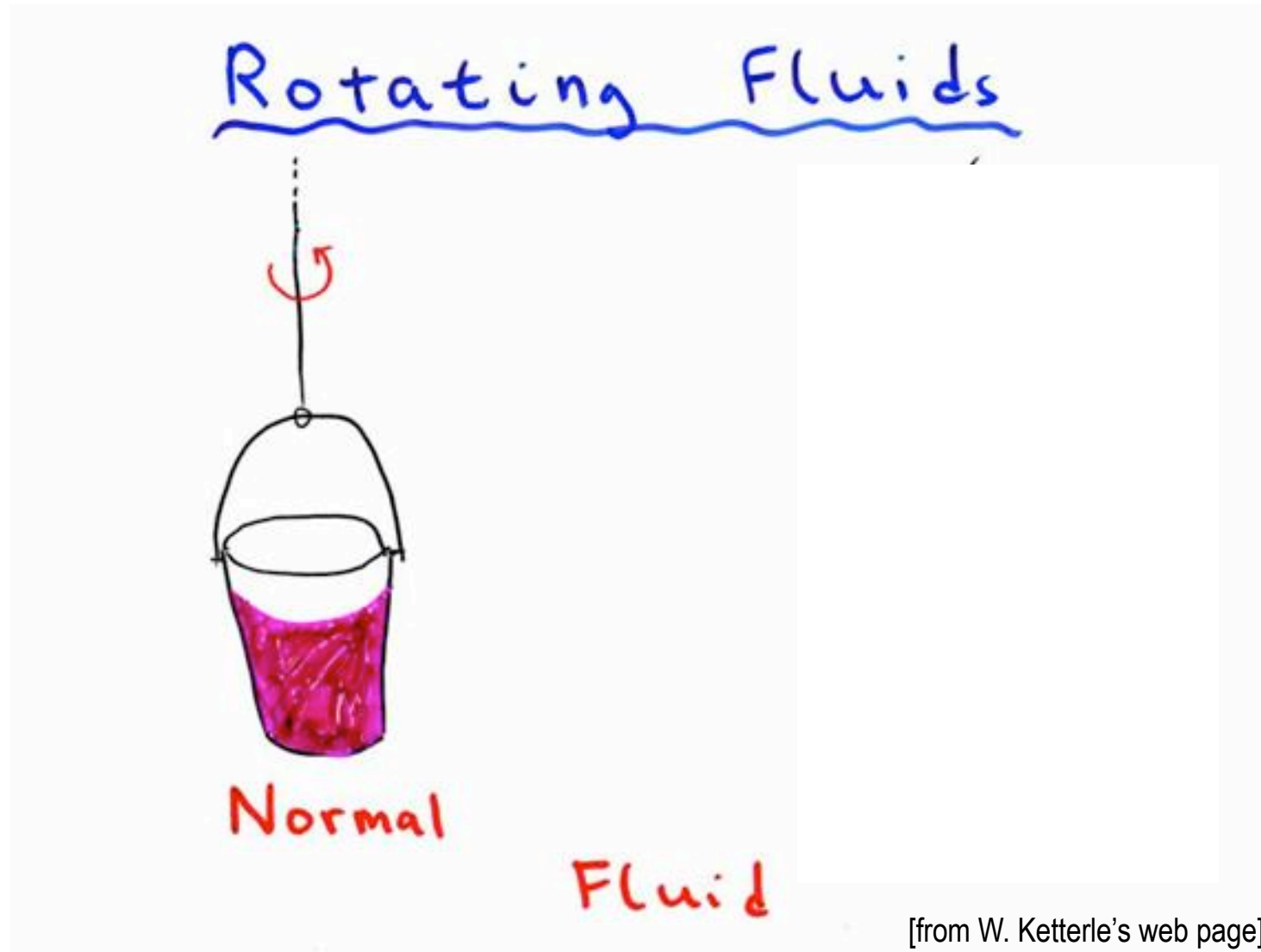
⇒ superfluidez

⇒ dispositivos ópticos

fuera del equilibrio

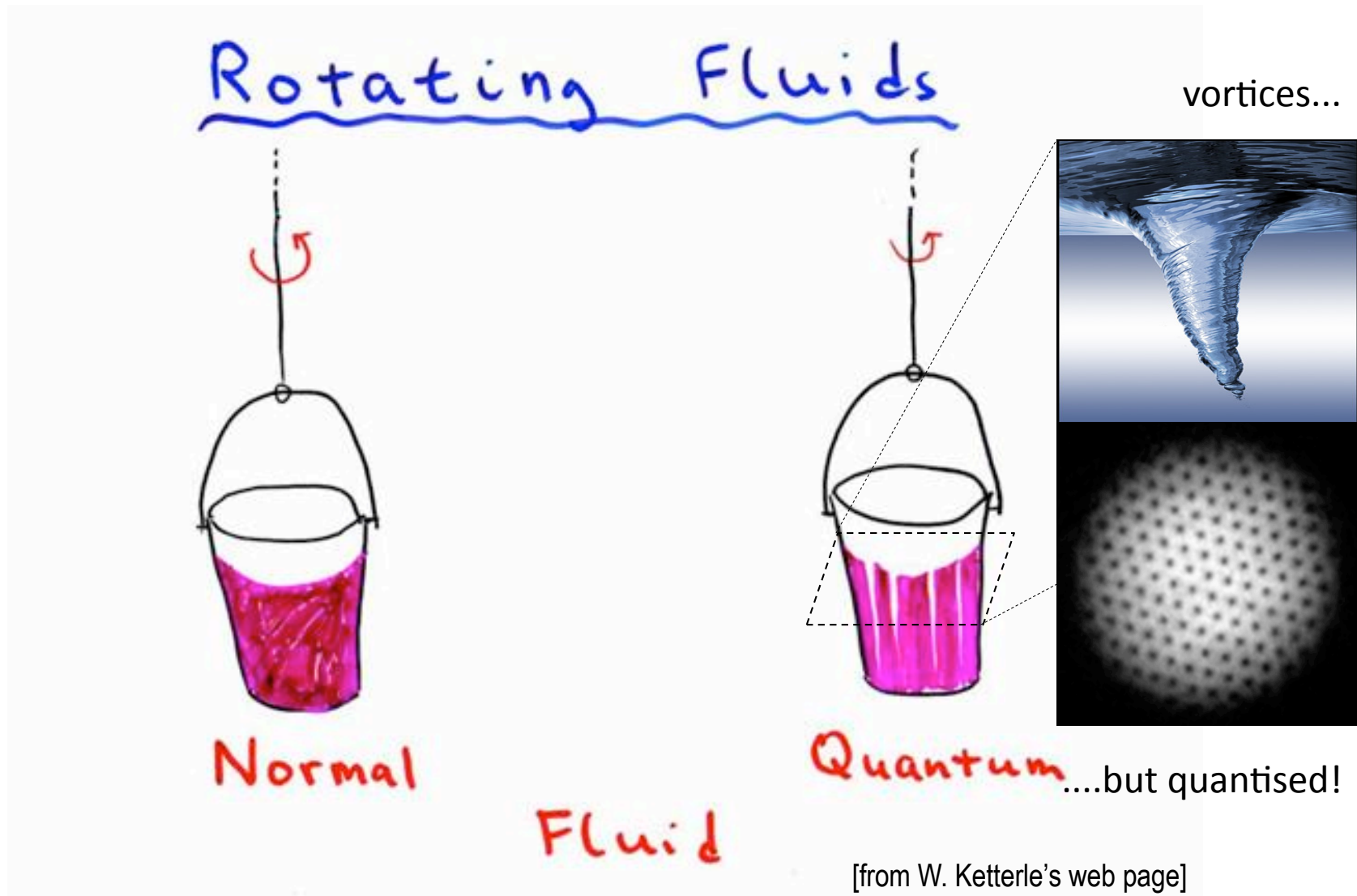
Superfluidity in quantum fluids of light

A superfluid cannot rotate as an ordinary fluid (rigid body)



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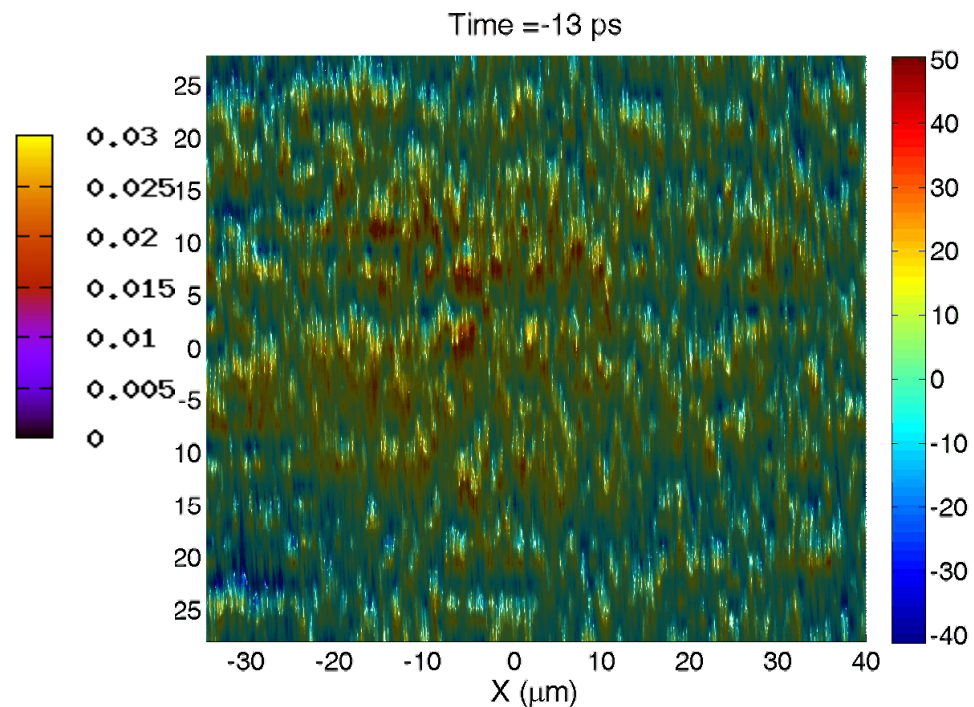
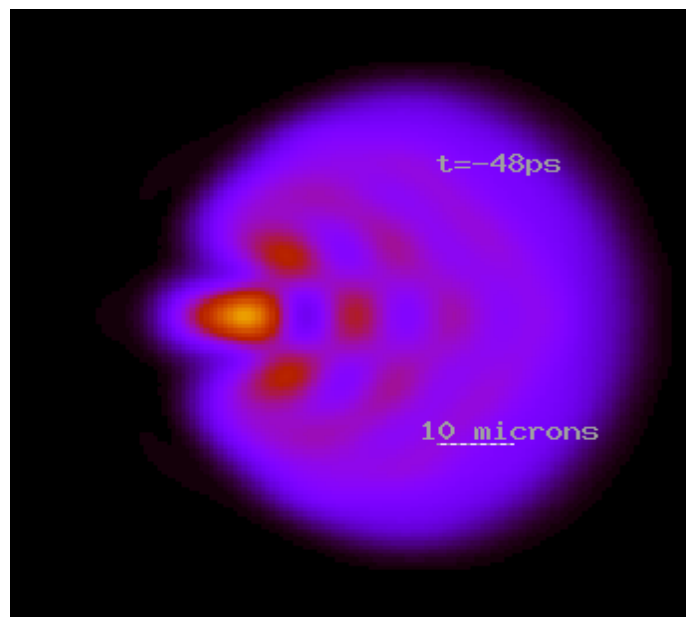
Superfluidity in quantum fluids of light

A superfluid cannot not rotate as an ordinary fluid (rigid body)

Superfluidez en fluidos afuera del equilibrio

✧ Vórtices & persistencia de las corrientes en fluidos cuánticos de polaritones

⇒ experimentos mod. 04!



Quienes somos



E Del Valle



F Laussy



FM Marchetti



C Tejedor

Fuentes cuánticas de luz



E Del Valle



F Laussy



FM Marchetti



C Tejedor

Naturaleza ondulatoria y corpuscolar de la luz: cuantos de luz=fotones

- ✧ Interacting photons (nonlinear optical media)
- ✧ Optical quantum entanglement
- ✧ Quantum coherence and correlation (at FEW-body level)

Quantum optics
&
quantum information

- ⇒ Quantum dots in cavities
- ⇒ Superconducting Q-circuits
- ⇒ Trapped atoms & ions

Fuentes cuánticas de luz



E Del Valle



F Laussy



FM Marchetti

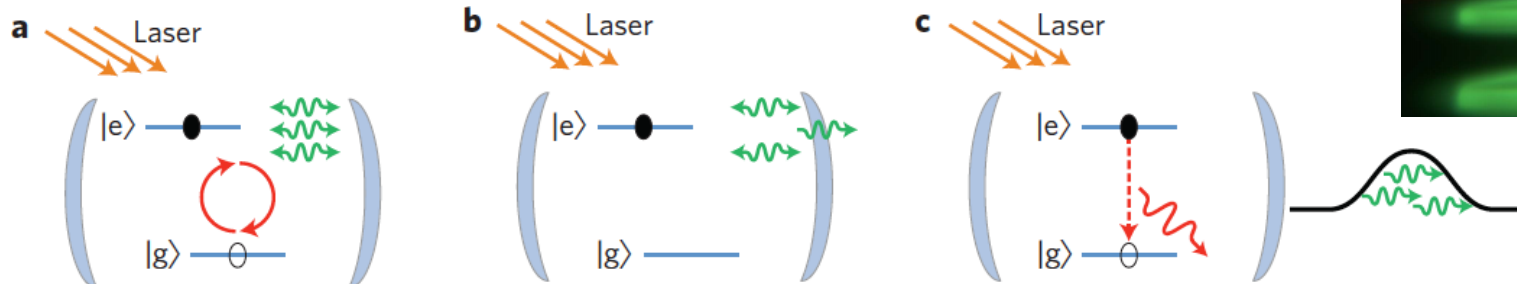
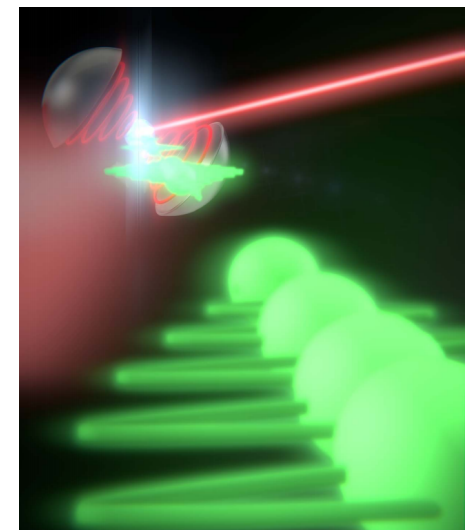


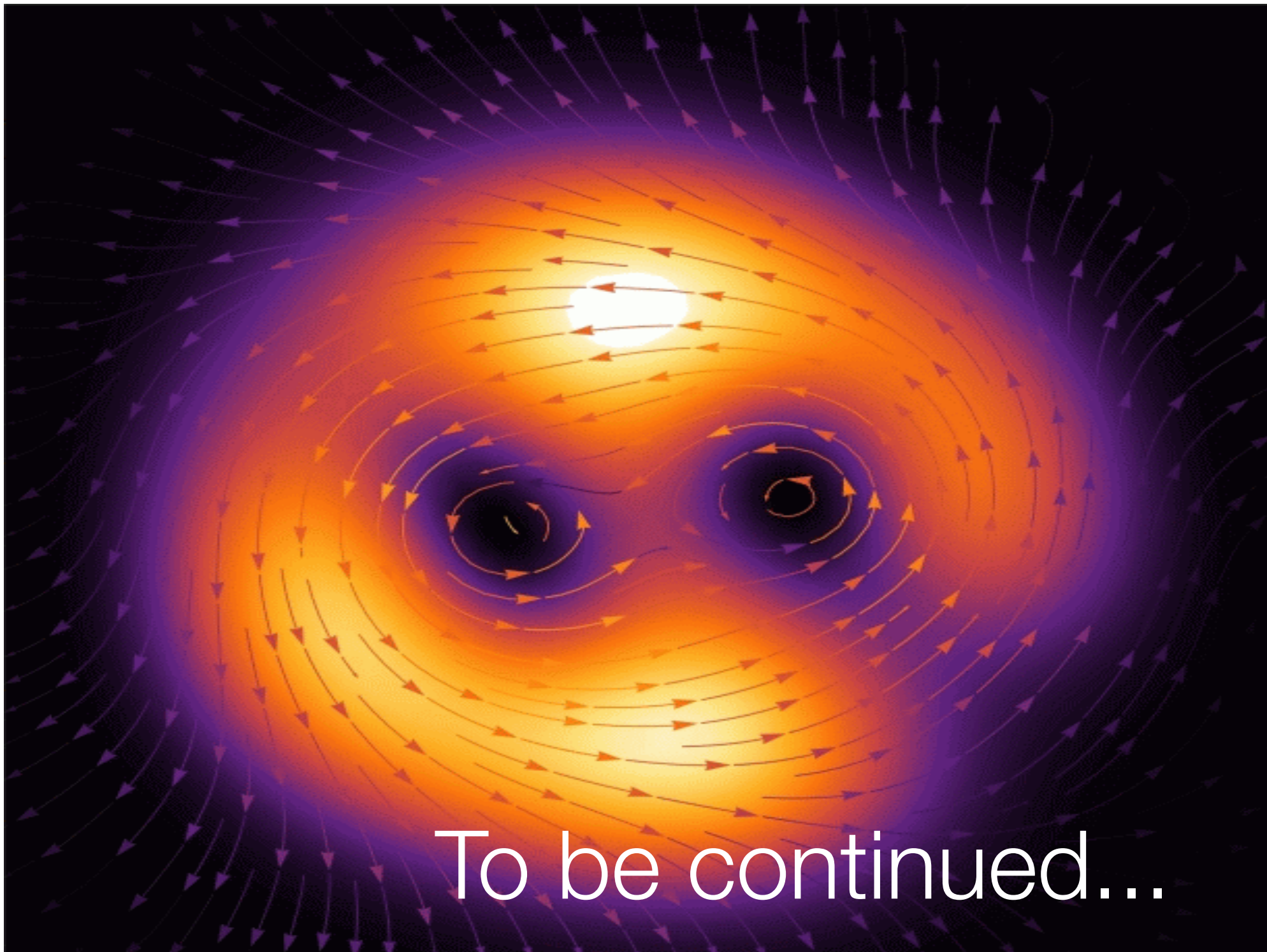
C Tejedor

Quantum emitters of photon bundles!

[C. Sánchez Muñoz et al. Nature Photon. (2014)]

✧ Emission coordinata de fotones de pocos en pocos





To be continued...