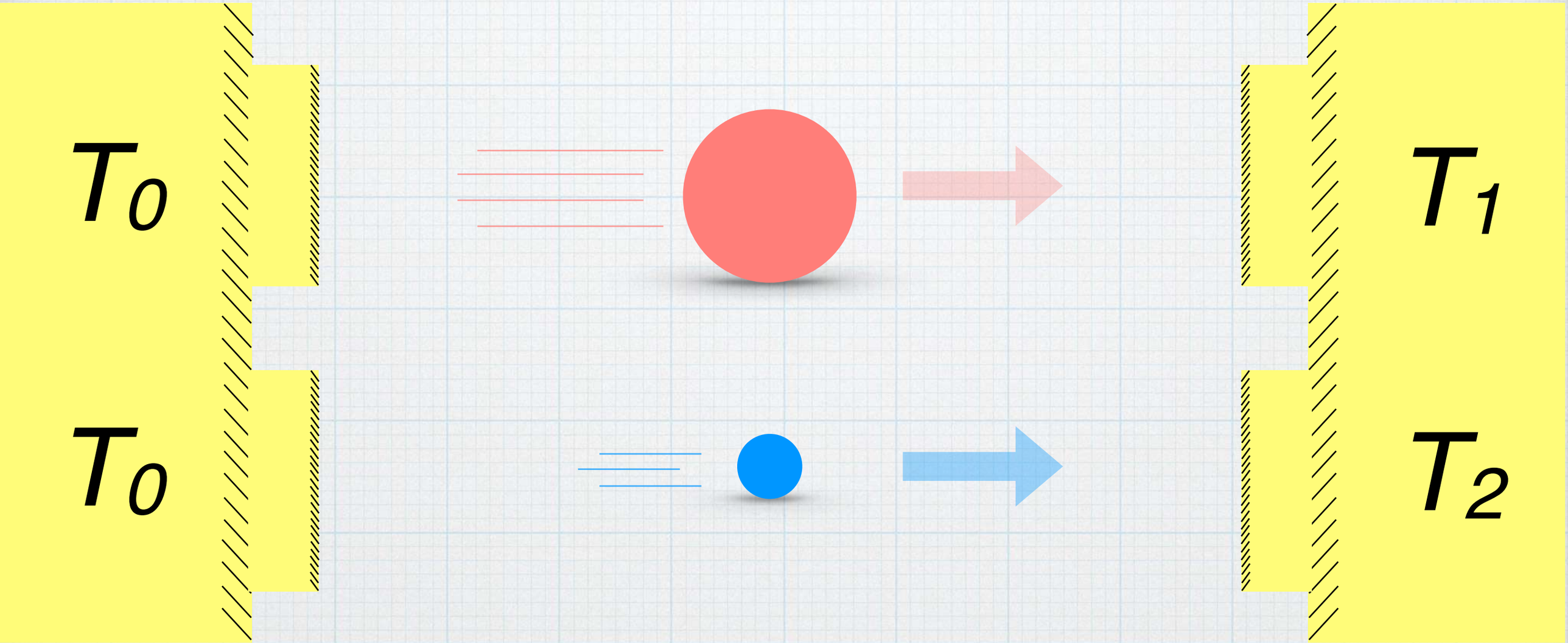
Probing the quantum structure of spacetime using a cosmic cataclysm

Javier Rico
Institut de Física d'Altes Energies, Barcelona

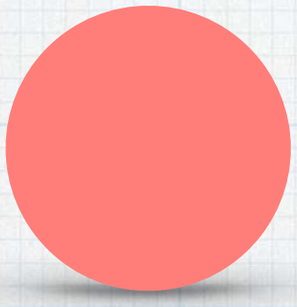
After: "Bounds on Lorentz invariance violation from MAGIC observation of GRB 190114C", The MAGIC Collaboration, Phys. Rev. Lett. 125 (2020) 021301

What we do



$$T_1 \overset{?}{=} T_2$$

Particle/wave duality

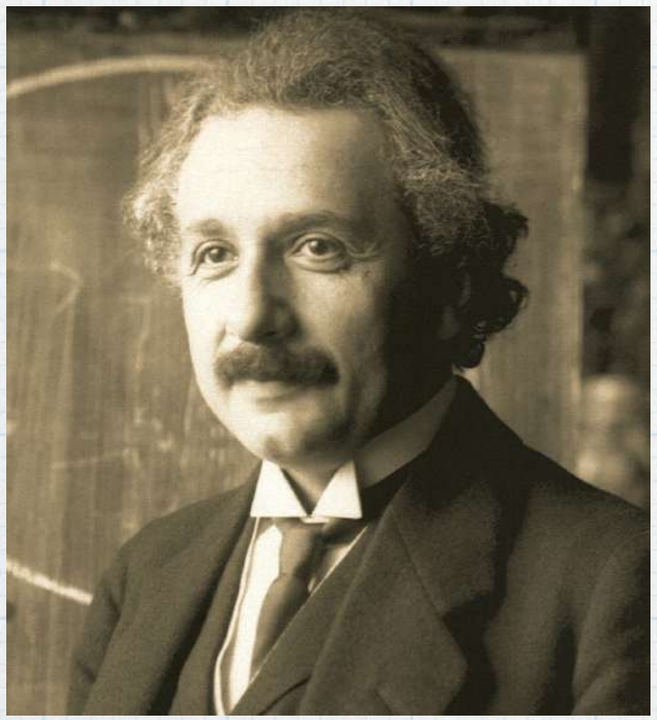


$E \downarrow \Rightarrow L \uparrow$

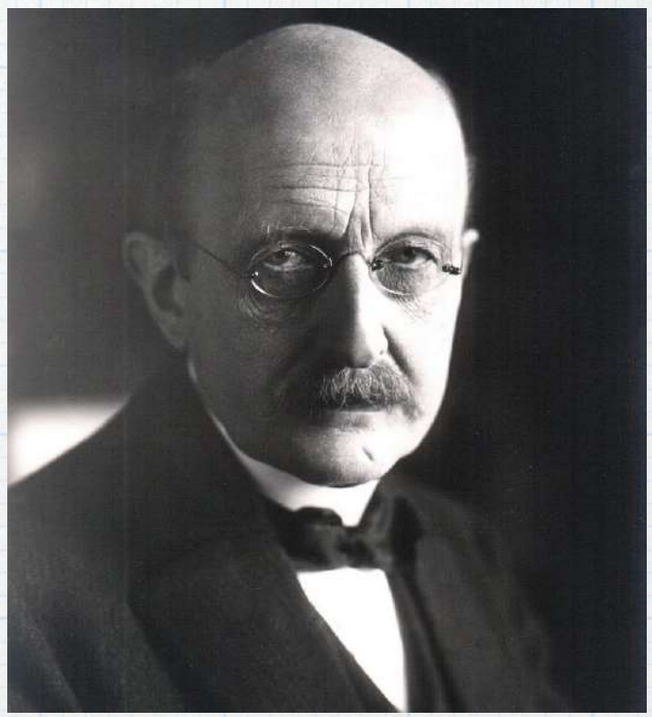
$E \uparrow \Rightarrow L \downarrow$

Why we want to do that

A. Einstein



M. Planck



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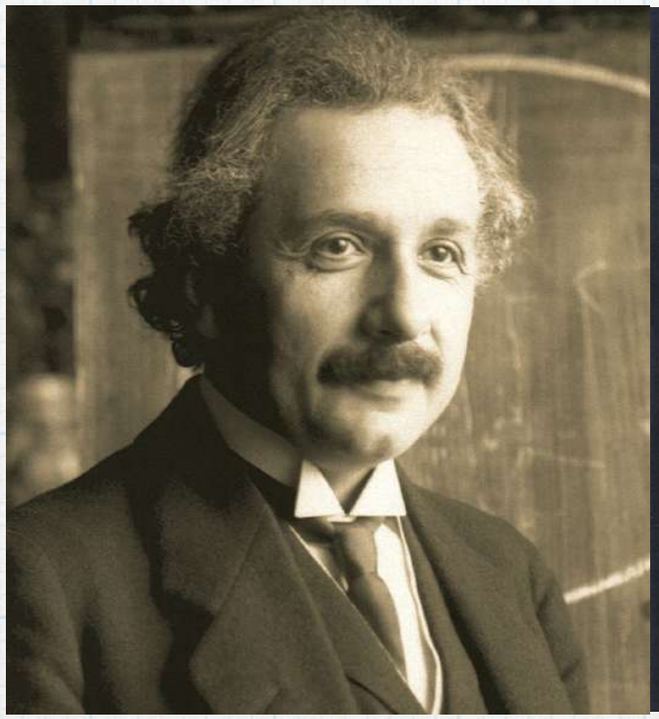

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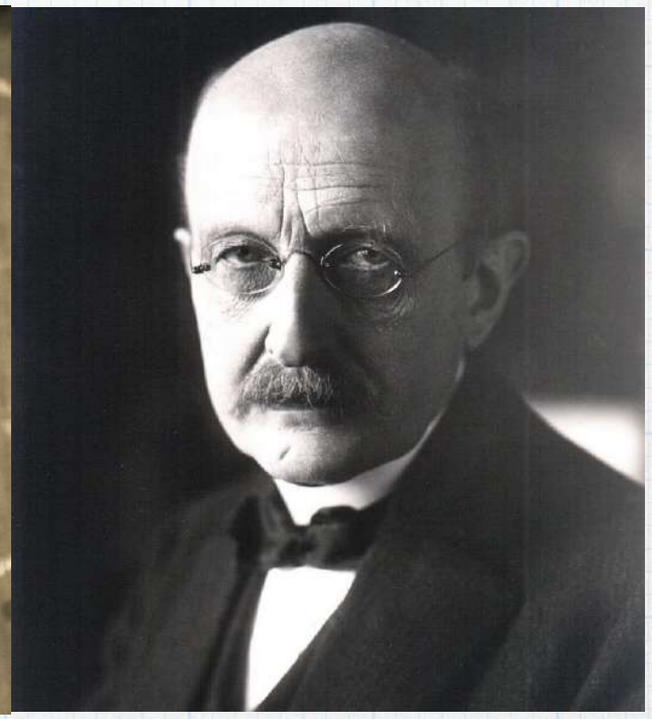
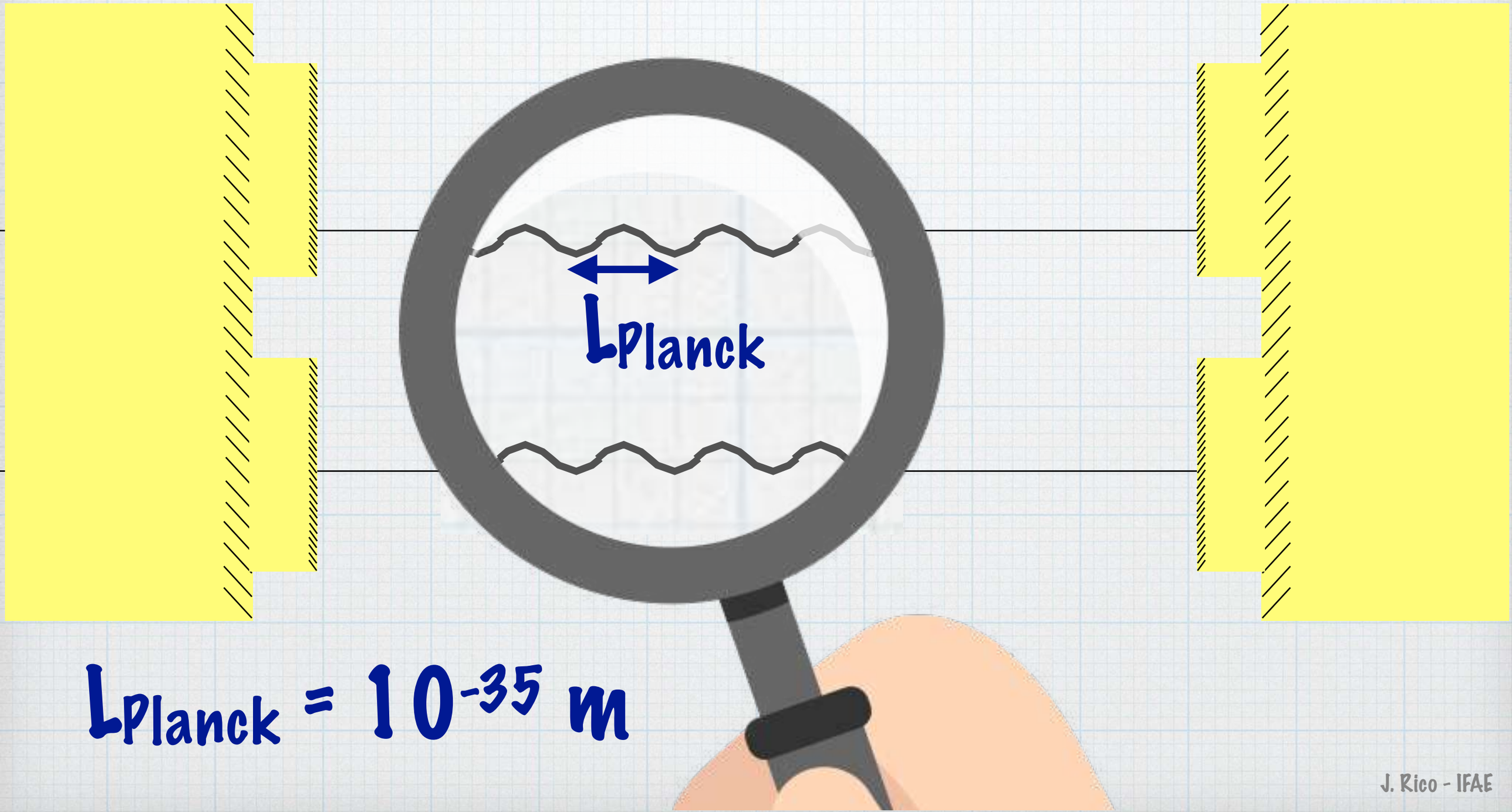


To find a quantum theory of Gravity

Quantum nature of spacetime



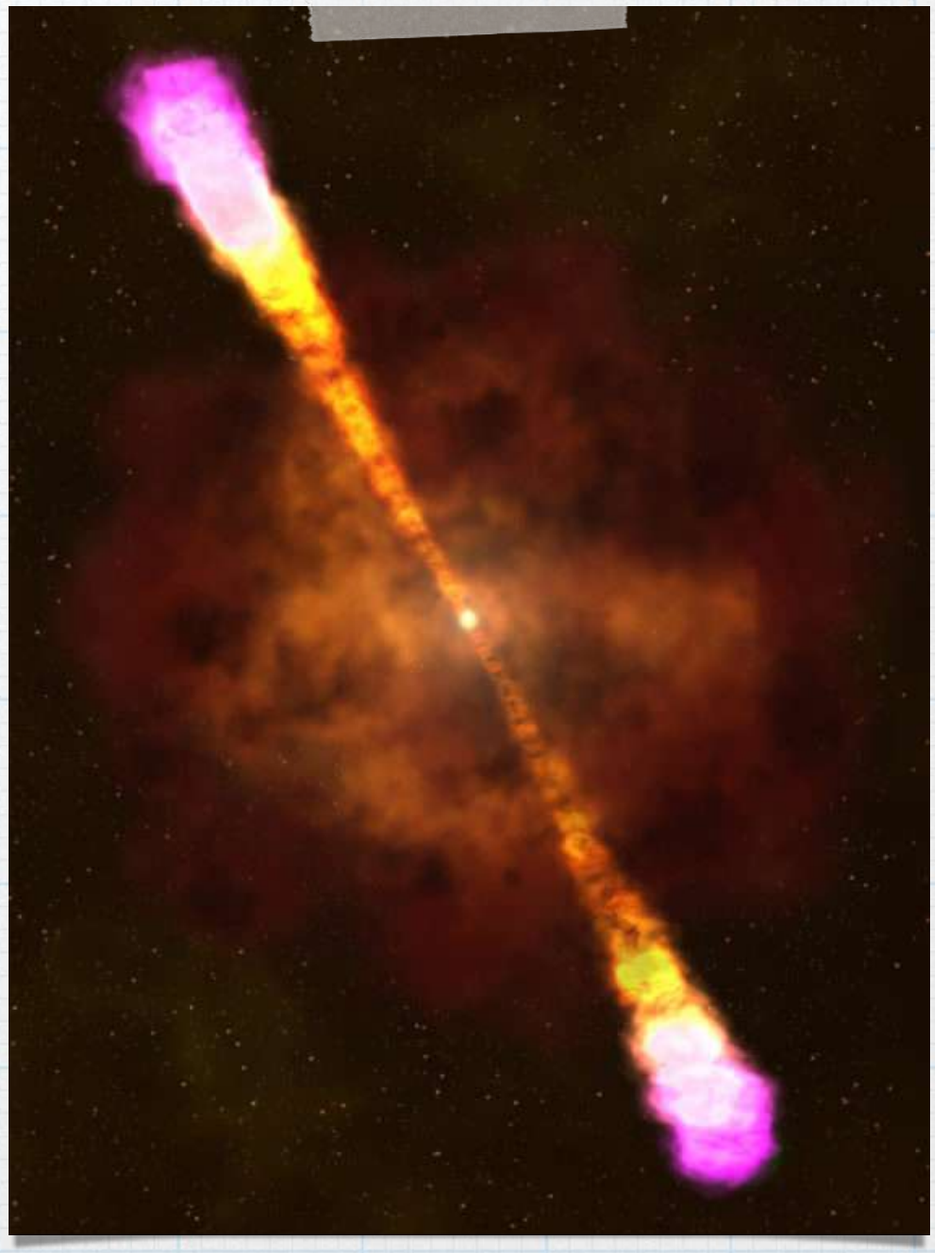
$L_{Planck} = 10^{-35}$ m

J. Rico - IFAE

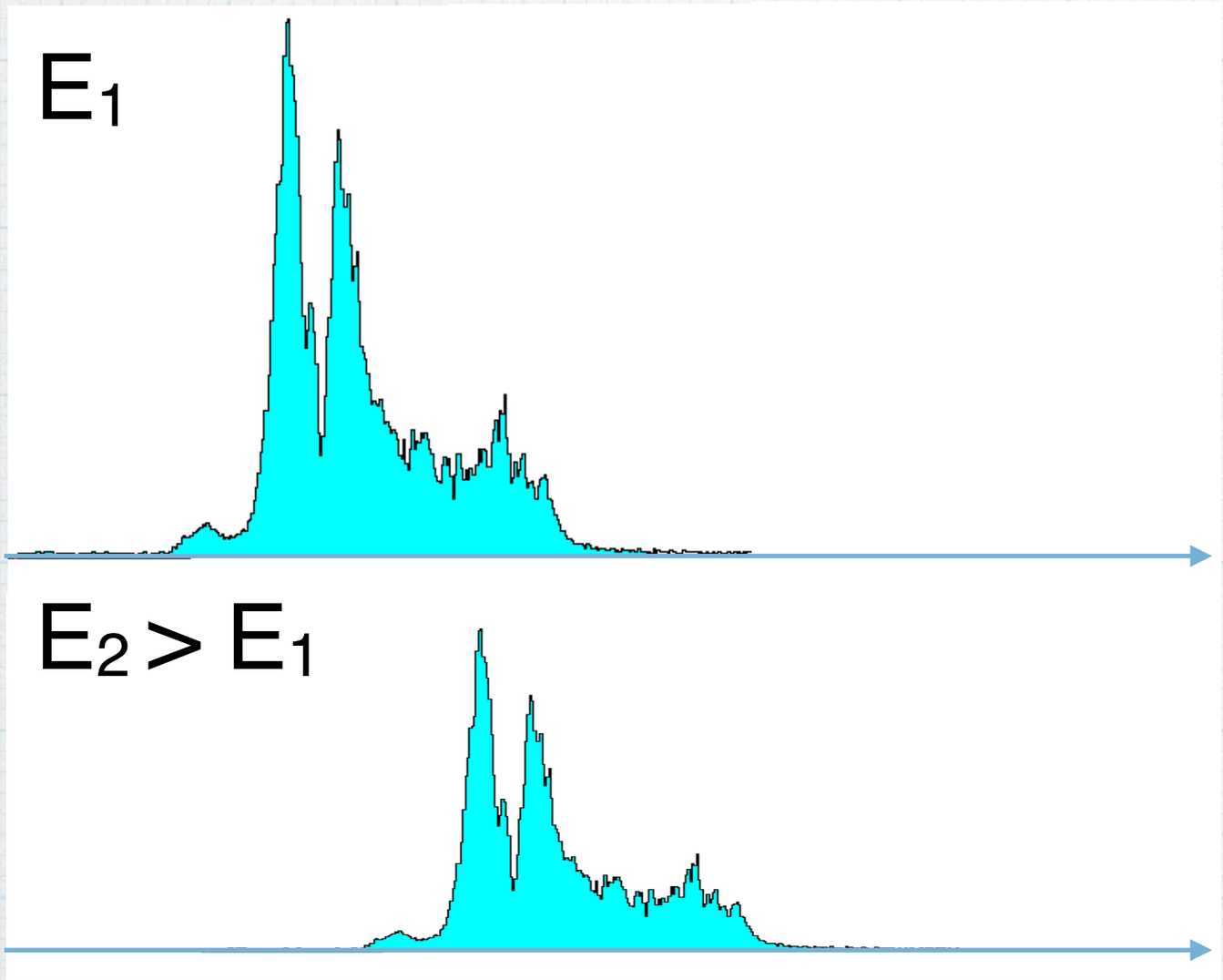
What we measure in practice

* Gamma-ray Bursts (GRBs) = cosmic explosions from massive star collapse or neutron star merger

* A typical GRB releases as much energy in a few seconds as the Sun will in its entire 10-billion-year lifetime



Measuring time of flight differences



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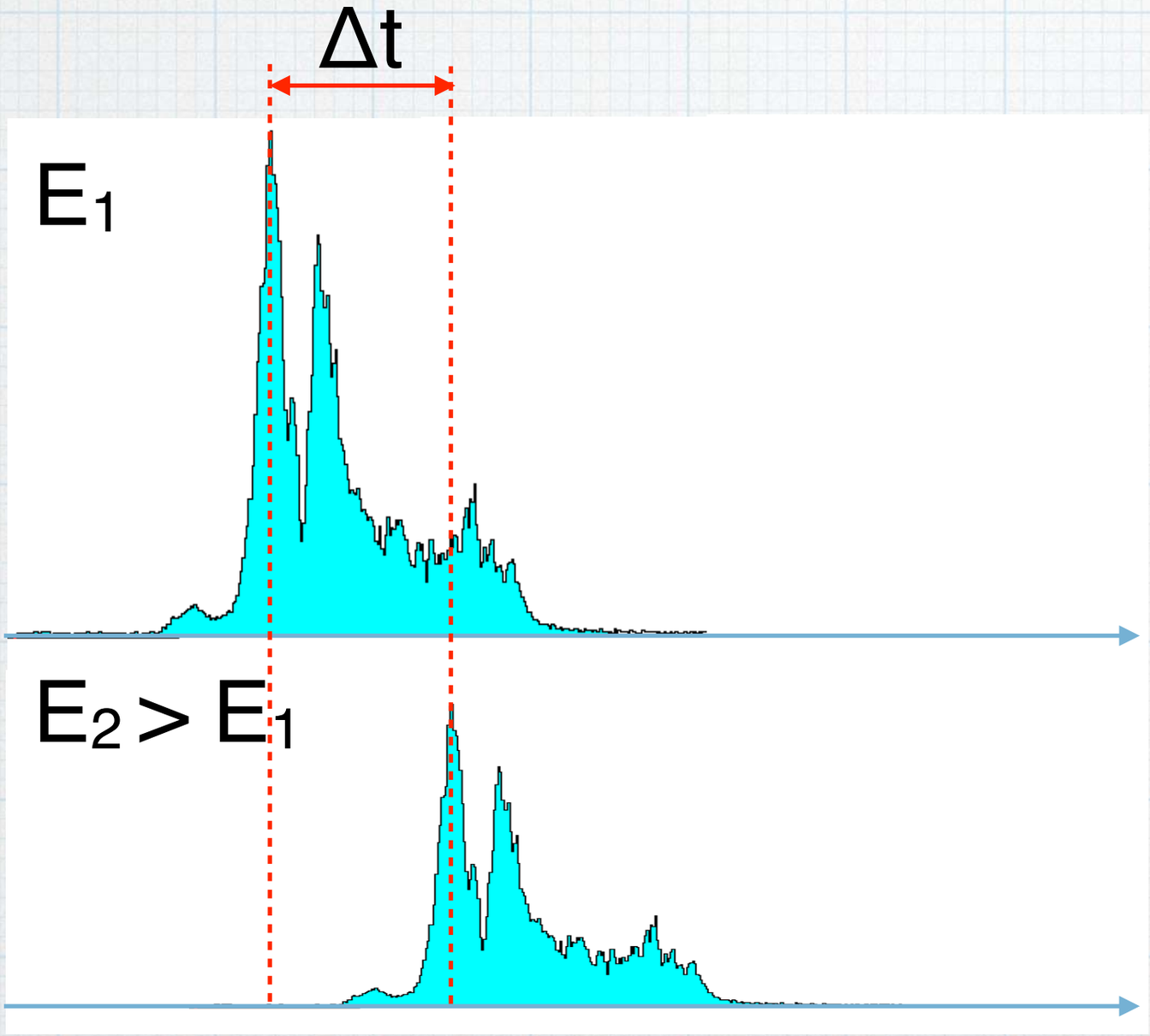

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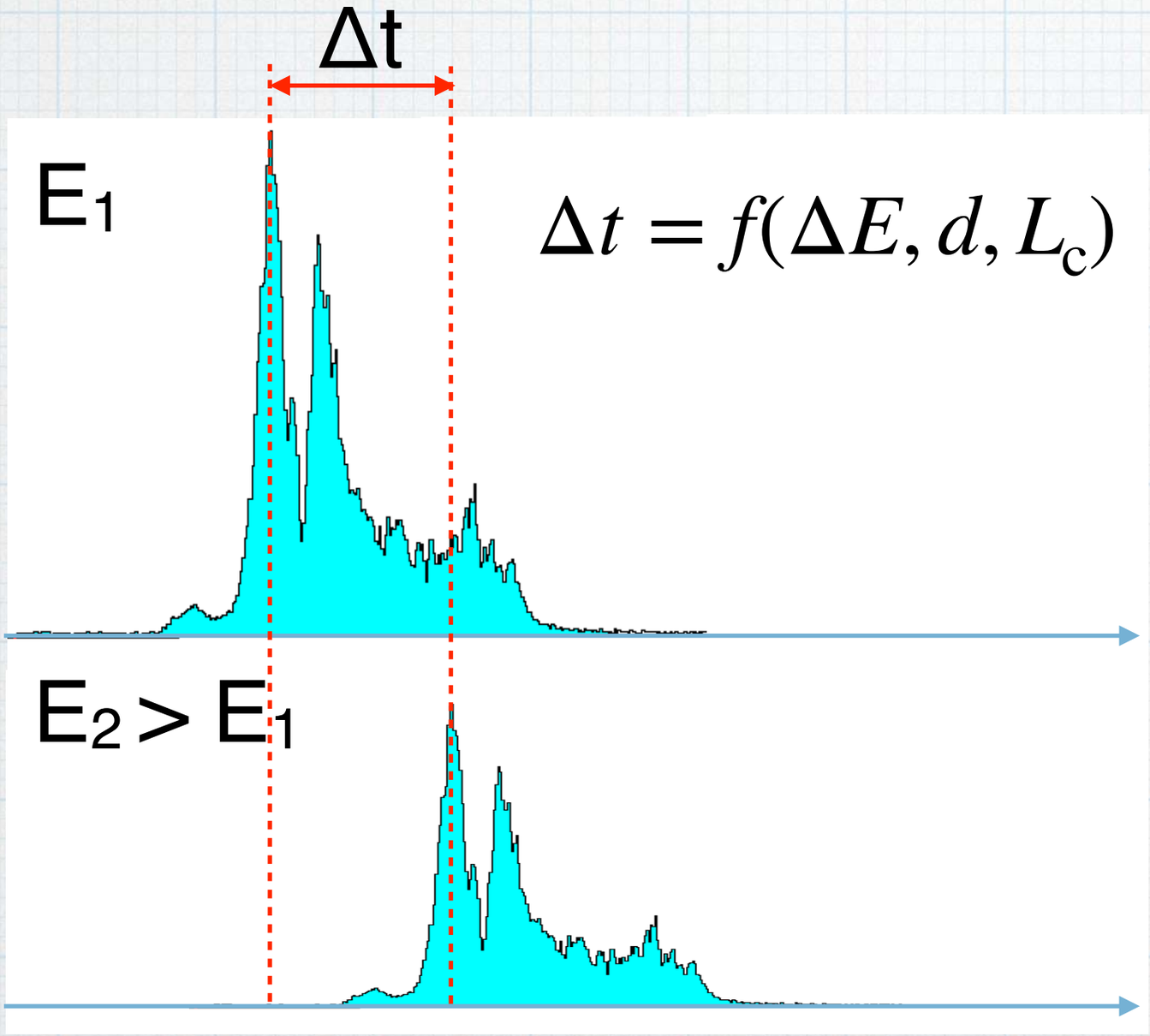

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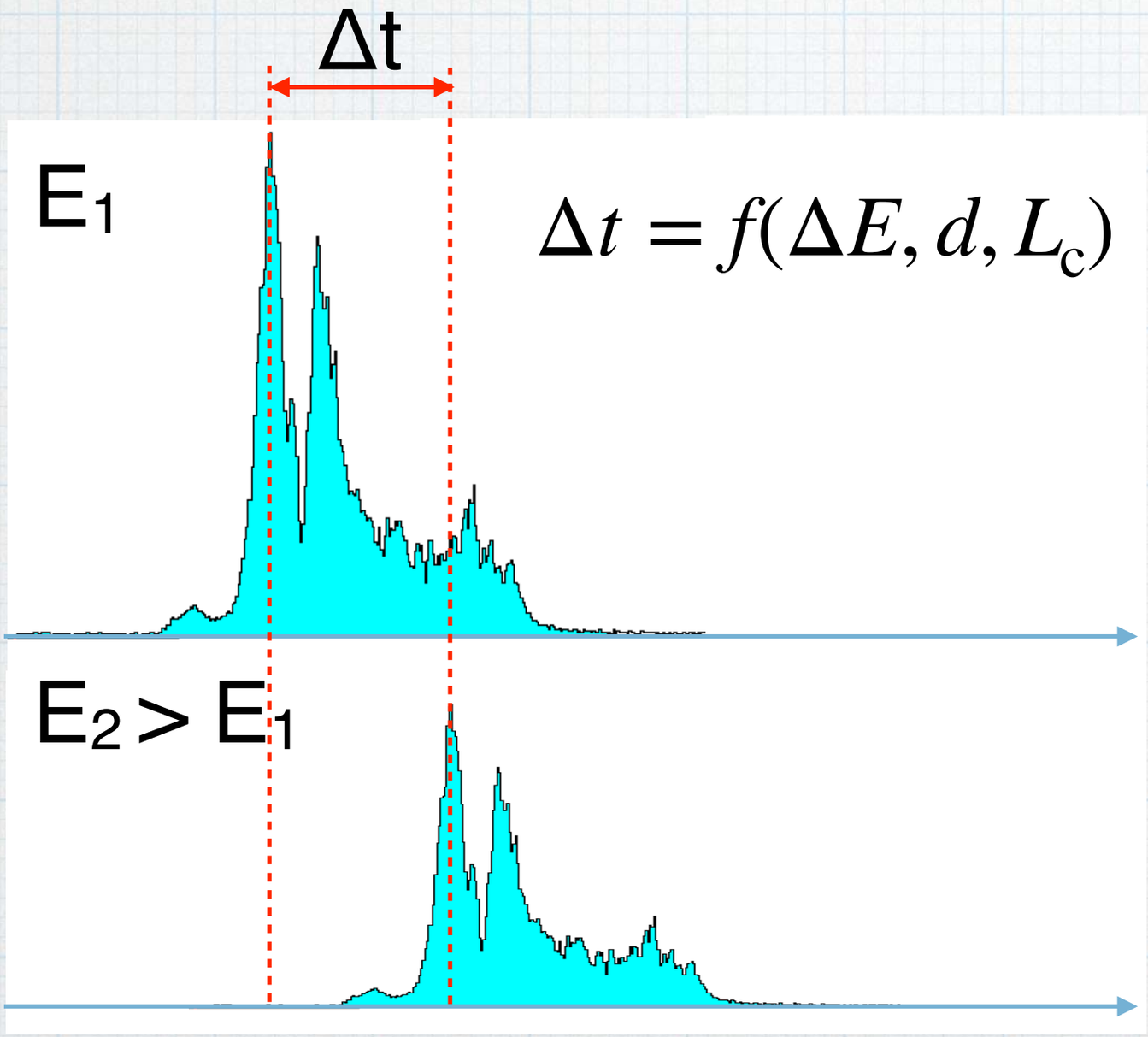

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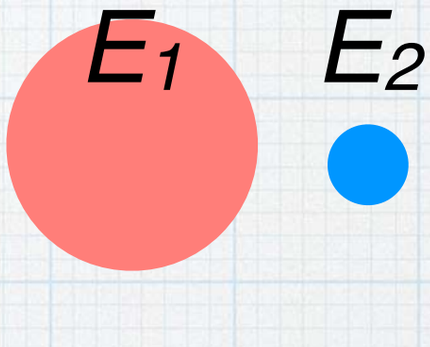

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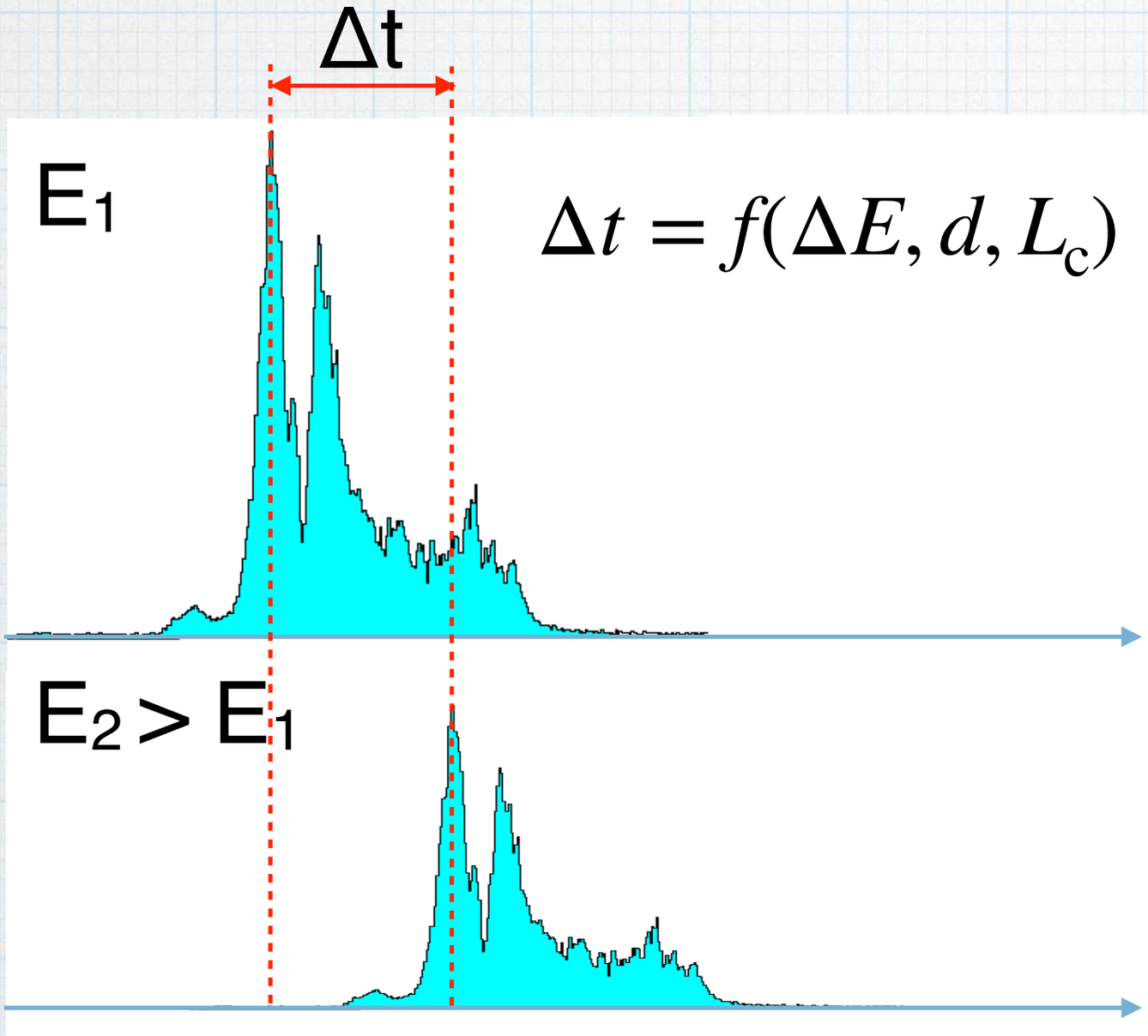

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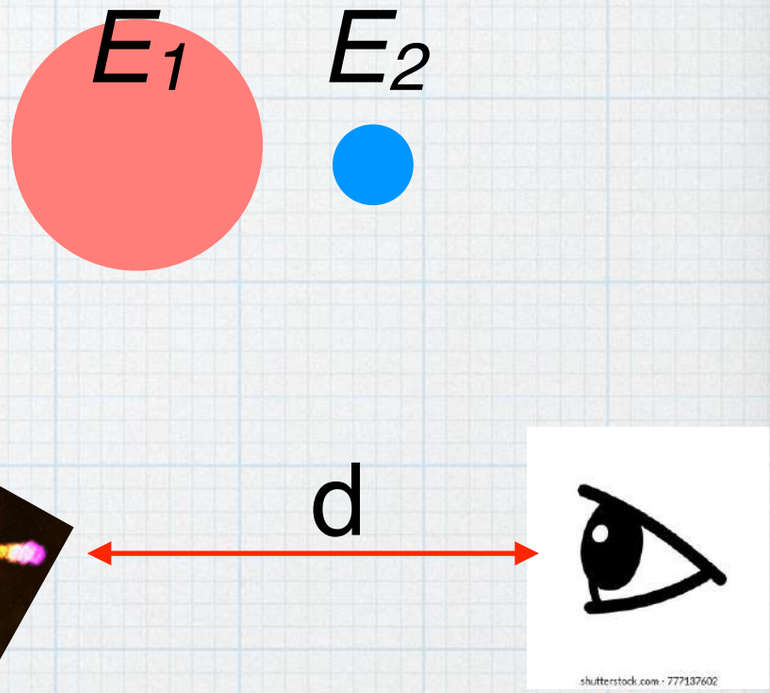

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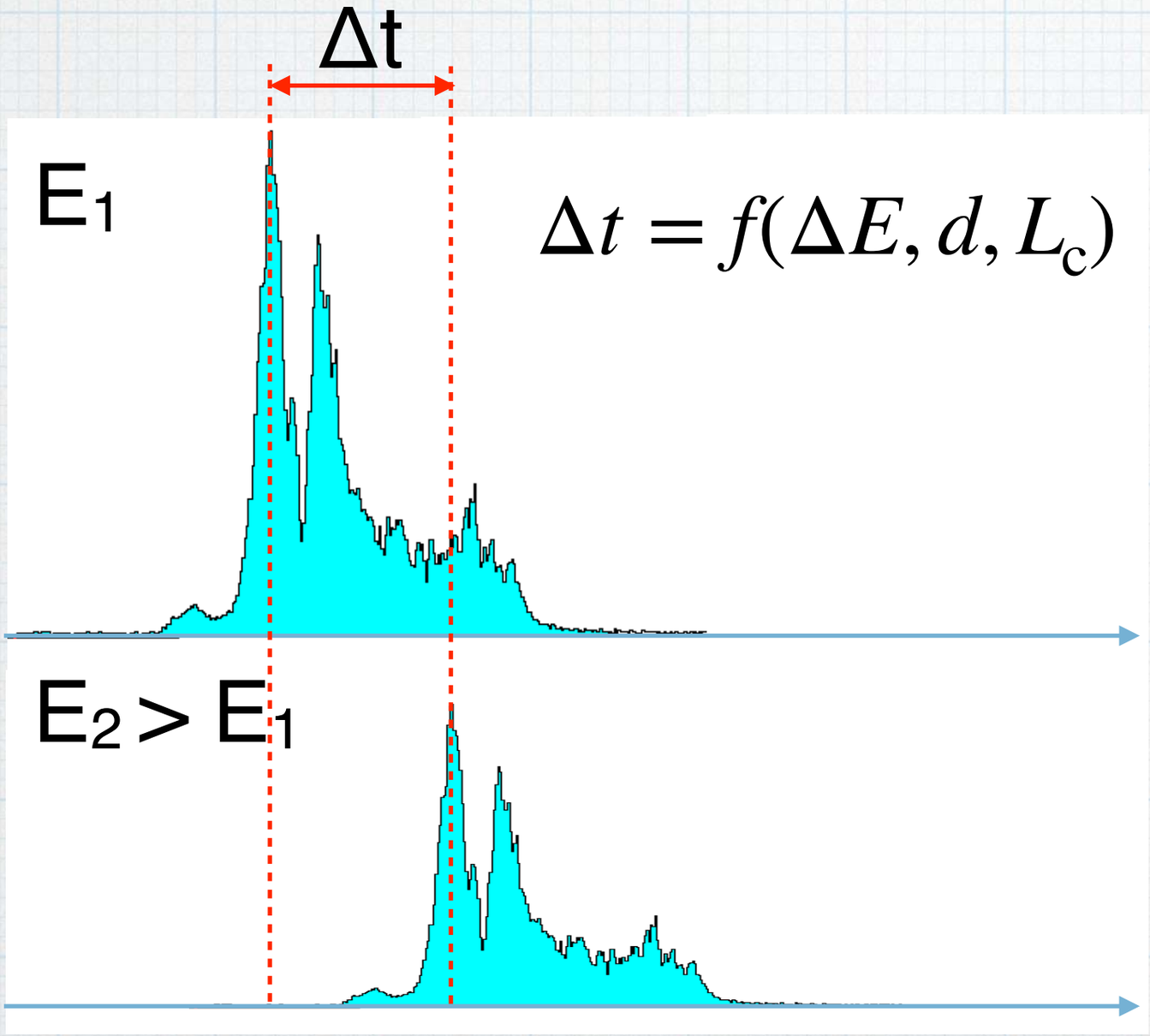

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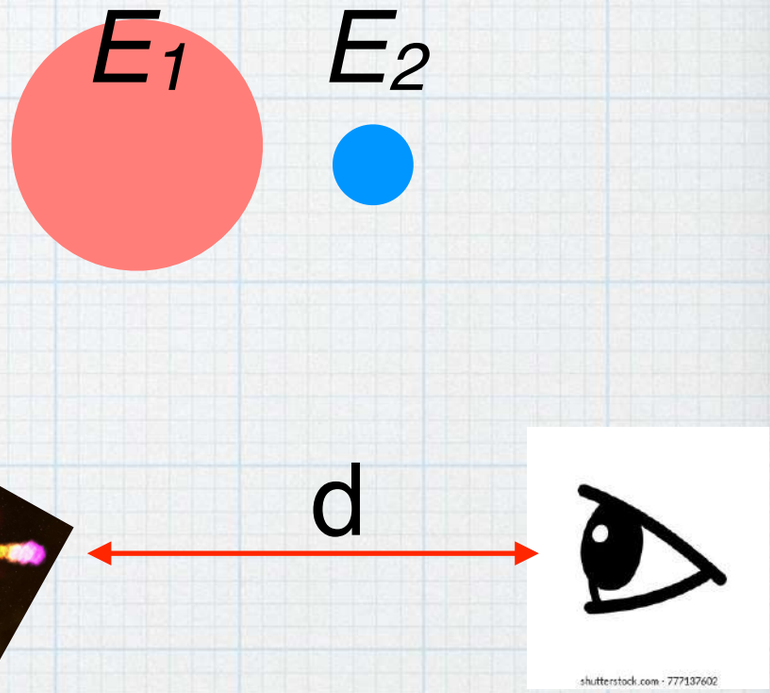

How we measure GRBs: the MAGIC telescopes

2 x 17m diameter gamma-ray telescopes

Roque de los Muchachos observatory, La Palma

GRB190114C

* T_0 = 20:57:03 UTC on the 14th January 2019
* MAGIC started observations 57 seconds later
* MAGIC measured 877 gamma rays in 20 min
* First time high-energy gamma-rays observed from a GRB
* Distance: d = 4500 million lightyears

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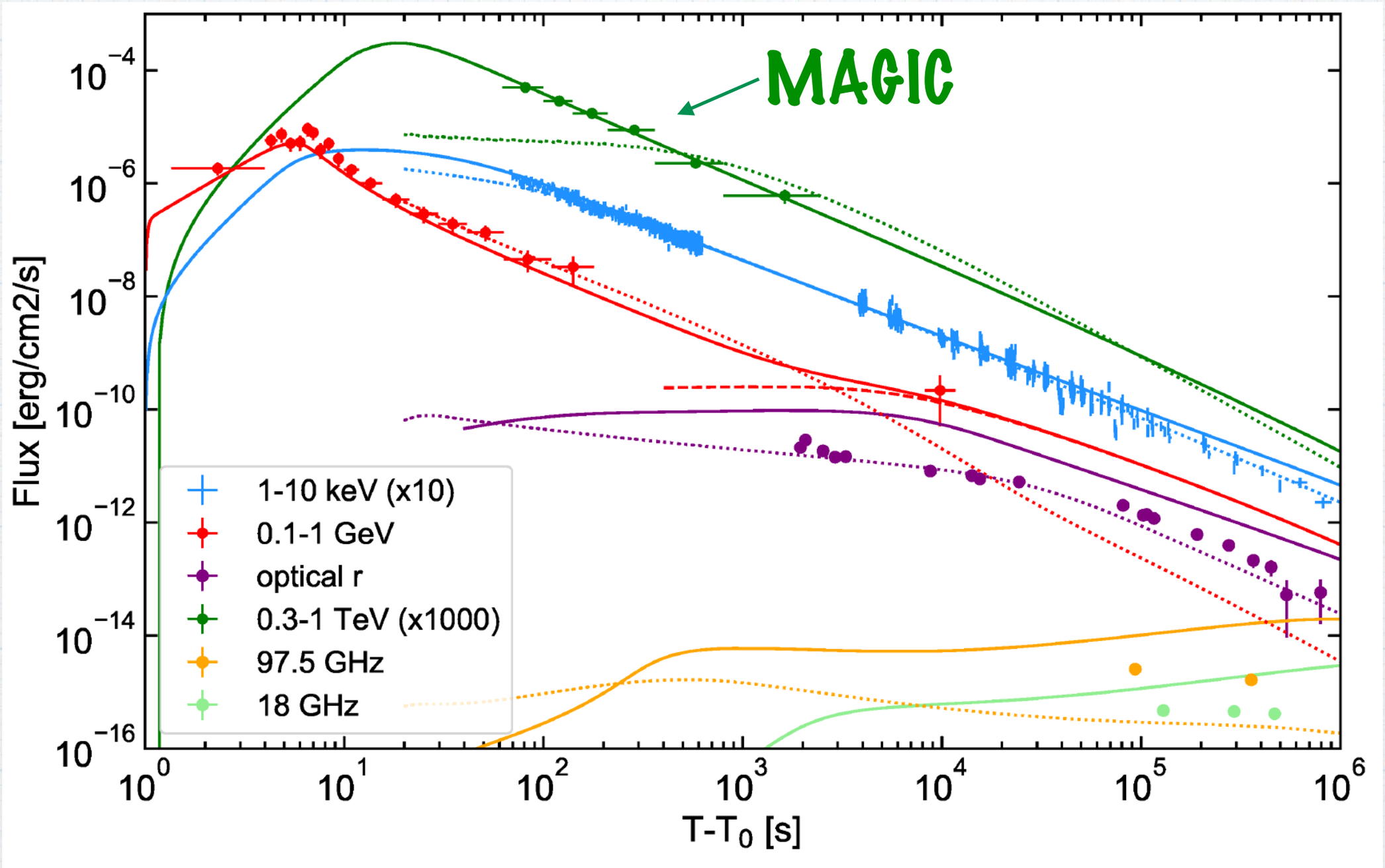
MAGIC
Flux [erg/cm2/s]
T-T0 [s]
1-10 keV (x10)
0.1-1 GeV
optical r
0.3-1 TeV (x1000)
97.5 GHz
18 GHz

Results

* No time delay for high-energy gammas was observed
* First high-energy photon was observed at T_0+74 s
* $\Delta t \leq 74$s
* Remember $\Delta t = f(\Delta E, d, L_c)$
* Then we obtain: $L_c \leq 1.6\ L_{Planck}$

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  * Catching more distant GRBs
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Thank you very much for you attention