No black holes from light

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III Congreso de IPARCOS – 11th December 2024

UNIVERSIDAD COMPLUTENSE MADRID

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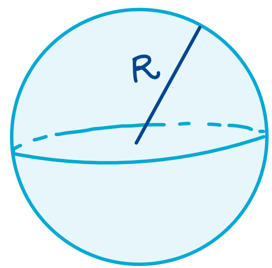
Phys. Rev. Lett. 133, 041401 (2024)

To form a Schwarzschild black hole in a sphere of radius R, we need to concentrate inside more mass than:



$$M_{BH} = \frac{Rc^2}{2G}$$

As energy, and not mass, is the ultimate responsible for the curvature of spacetime ($\epsilon = Mc^2$),

WHAT IF WE CONCENTRATED LIGHT ALONE?

Black holes from the gravitational collapse of light ...

- ✓ are allowed by General Relativity.
- ✓ have been widely studied.

Geons*

John Archibald Wheeler
Palmer Physical Laboratory, Princeton University, Princeton, New Jersey
(Received September 8, 1954)

Black hole formation by incoming electromagnetic radiation

José M M Senovilla
Published 5 December 2014

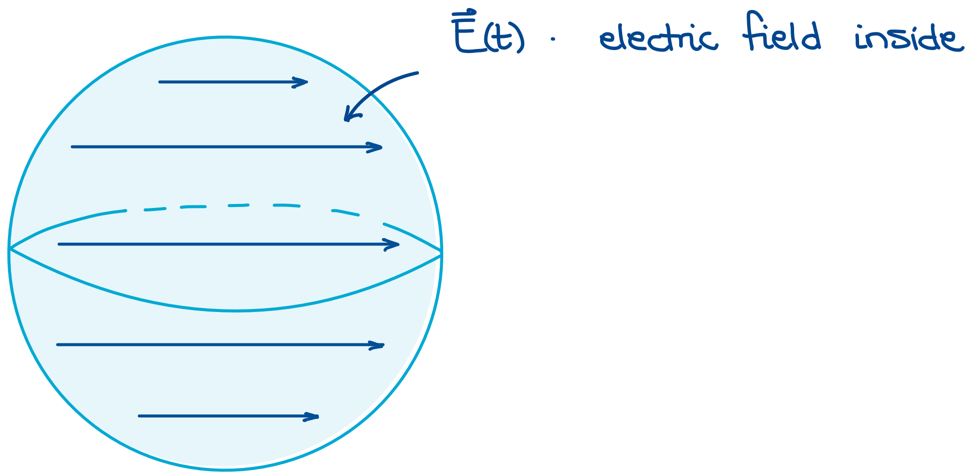
Graviballs and dark matter

B. Guiot,[a] A. Borquez,[a] A. Deur[b] and K. Werner[c]
Published: *November 27, 2020*

THE QUESTION

Can we concentrate enough light to create a black hole?

We would need an extremely intense electric field inside.



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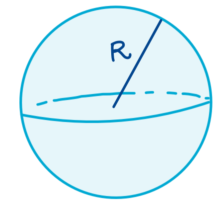

Indeed, we need electric strengths larger than

$$E_{BH} \sim \frac{10^{27}\ V}{R}$$

↑ electric strength required

THE QUESTION

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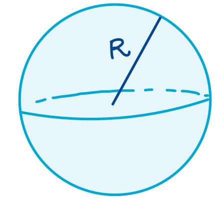
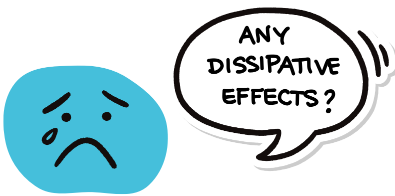
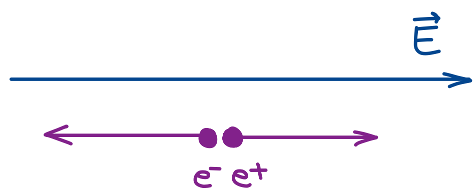




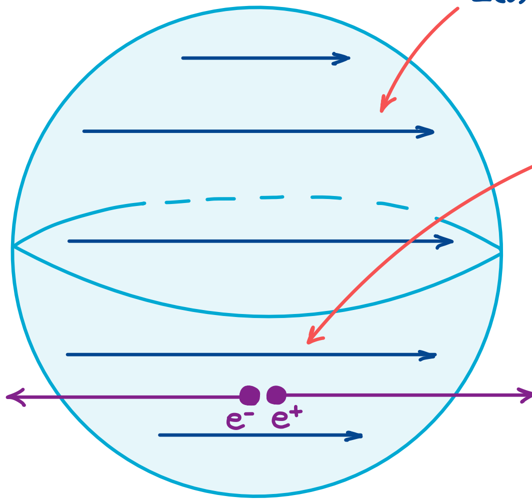
For strengths larger than 10^{18} V/m ..

PARTICLE CREATION!



Pairs of electrons and positrons are created out of the vacuum.

Particle creation prevents the formation of a Kugelblitz.



$\vec{E}(t)$: extremely intense electric field inside

A pair e^-e^+ ...

1st) is created.

2nd) becomes ultrarelativistic.

3rd) exits the sphere.

$\Longrightarrow$ **ENERGY DISSIPATION**

OUR DESIRE TO CREATE BLACK HOLES FROM LIGHT

VS.

DISIPATION

WHICH WILL WIN?

OUR DESIRE TO CREATE BLACK HOLES FROM LIGHT

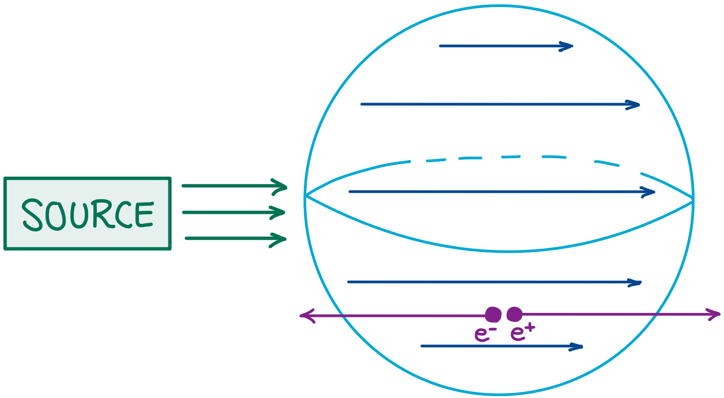
VS.

DISIPATION

WHICH WILL WIN?

in any laboratory or present-day astrophysical scenarios.

Equation for energy dissipation:



Variation of EM energy inside — Influx of EM energy — Dissipation

$$\frac{d\mathcal{E}}{dt} = 4\pi R^2 f - D(t)$$

We consider only one dissipation channel. Schwinger particle creation.

↳ Lower bound to dissipation.

To form a black hole from light

- in the lab we need intensities $\gtrsim 10^{83}\ W/m^2$, but the most intense lasers in the world have $\sim 10^{27}\ W/m^2$.
- astrophysically we need power $\gtrsim (10^{84}\ W/m) \cdot R$, but quasars have $\sim 10^{41}\ W$.

No black holes from light.

The formation of a black hole from light requires energy levels that are not achievable either naturally or artificially.

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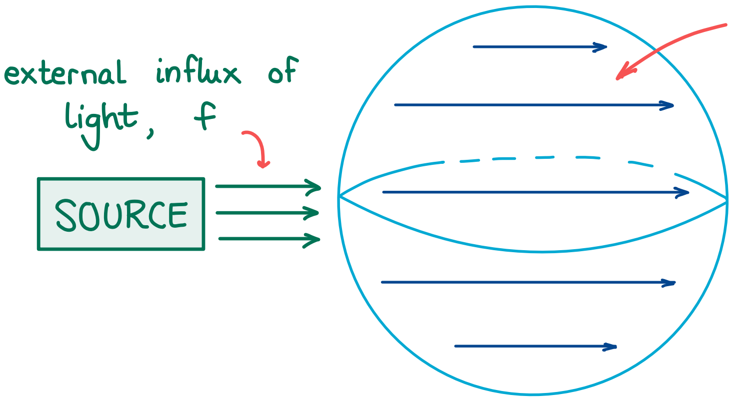
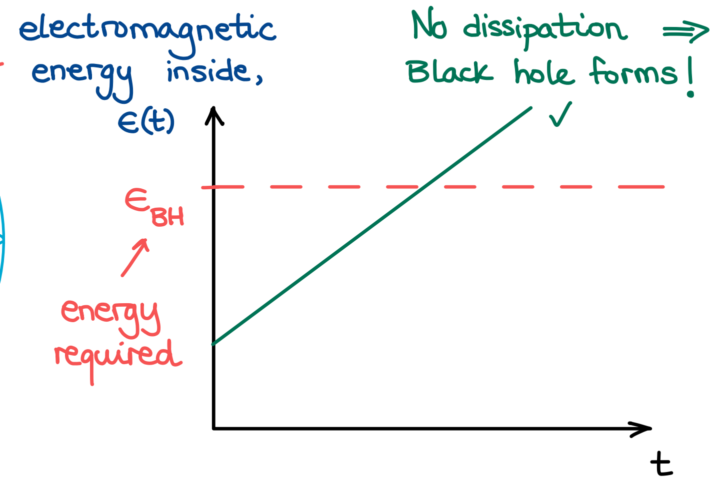
BACKUP SLIDES

WITH A FEW MORE DETAILS

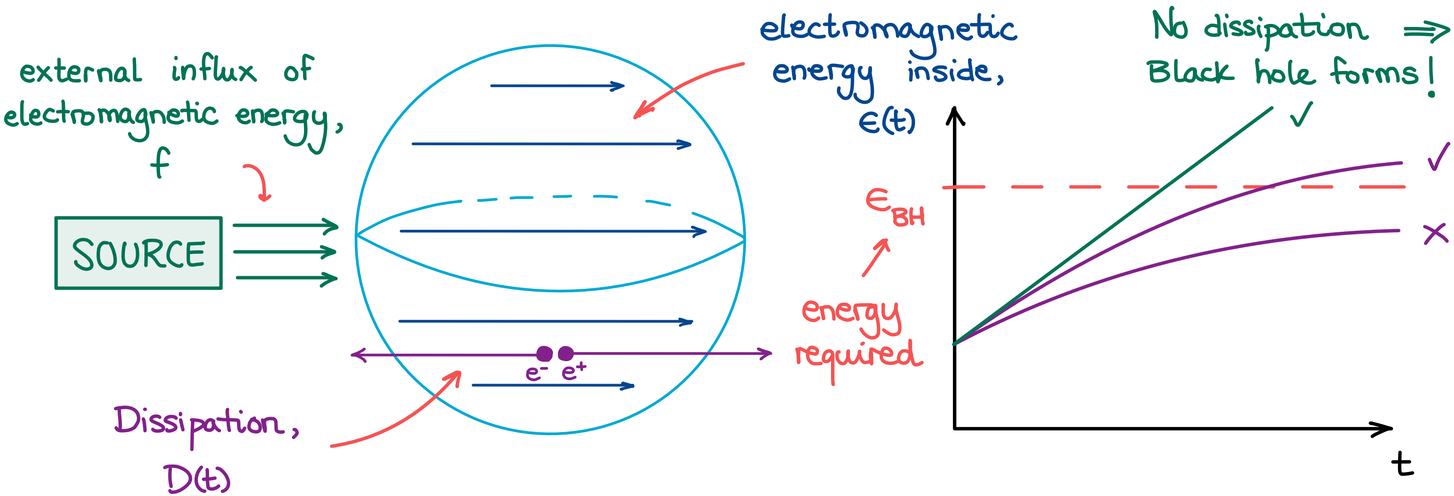




$$\frac{d\epsilon}{dt} = 4\pi R^2 f$$

We would just need to wait enough time.

WITH A FEW MORE DETAILS

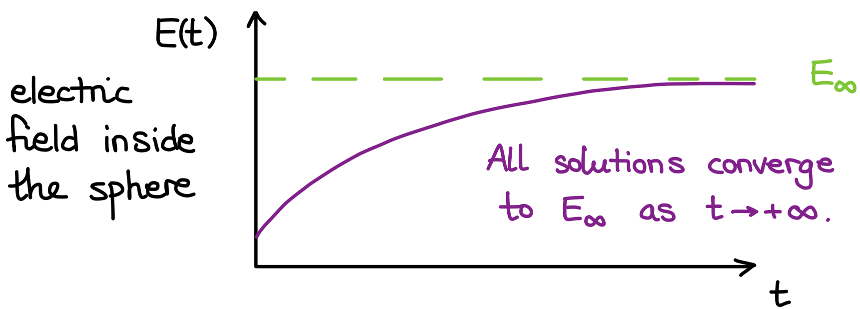


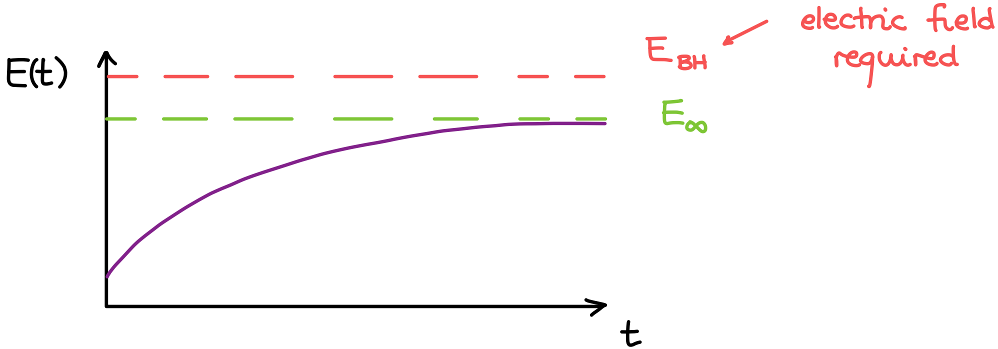
$$\frac{dE}{dt} = 4\pi R^2 f - D(t)$$

With dissipation.. who knows?
We do!

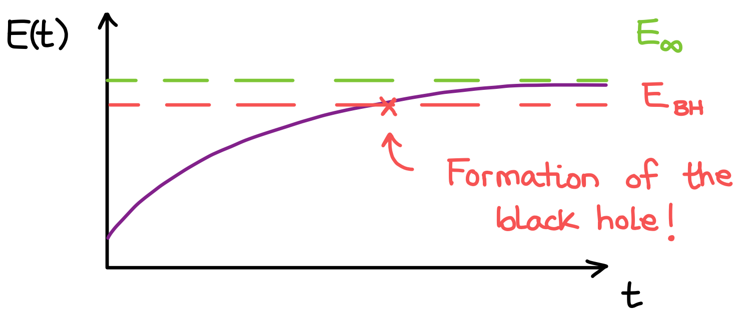
Solutions to the equation :

$$\varepsilon_0 E(t) \frac{dE}{dt} = \frac{3}{R} f - \frac{2e^3 \tau_x}{3\pi^3 \hbar^2} E(t)^3$$





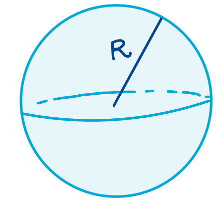
If $E_{BH} > E_\infty$, the black hole would never form.



For the black hole to form, it must be $E_{BH} < E_\infty$.

Is the condition $E_\infty > E_{BH}$ feasible?

$$E_\infty > E_{BH} \sim \frac{10^{27}\,V}{R} \longrightarrow \boxed{fR \gtrsim 10^{83}\ W/m}$$



- If we used the most intense laser pulses in the world to create little black holes, we would be more than

50 orders of magnitude away.

- If we used the highest-intensity sources in the universe (quasars and supernovae)

$$4\pi R^2 f_{quasar} \sim 10^{41}\ W.$$

Many orders of magnitude away

Validity of the Results

① Assumption of a Minkowski background.

Energies are well within the weak (gravitational) field approximation.

Indeed,

$$\frac{v_{esc}}{v} \approx \frac{E(t)}{E_{BH}}$$

escape velocity (v_{esc})

velocity of scattered particles (v): $v \approx c$

← The gravitational influence of the radiation on the exiting pairs is negligible except when $E(t) \approx E_{BH}$, which is far from taking place.

VALIDITY OF THE RESULTS

② Uniform electric field approximation.

MAGNETIC FIELDS	→	↑ PAIR PRODUCTION	✓
SPATIAL INHOMOGENEITIES	→	↓ PAIR PRODUCTION	
		↑ But one would need incredibly high frequencies, beyond any realistic scenario order of magnitude.	
LIGHT FROM MULTIPLE SOURCES	→	↑ PAIR PRODUCTION	✓

Overall, the approximation leads to an underestimation of dissipation.

VALIDITY OF THE RESULTS

③ What if we tried to confine the fermions?

Remember that pairs are ultrarelativistic!

Most of the energy carried by pairs would still be dissipated away in the form of bremsstrahlung during their extreme deceleration.

We considered 2 cases:

A) Slowing particles down before they leave.

B) Making them orbit inside.

Even in the best-case-scenario, this would only increase E_∞ in one order of magnitude.