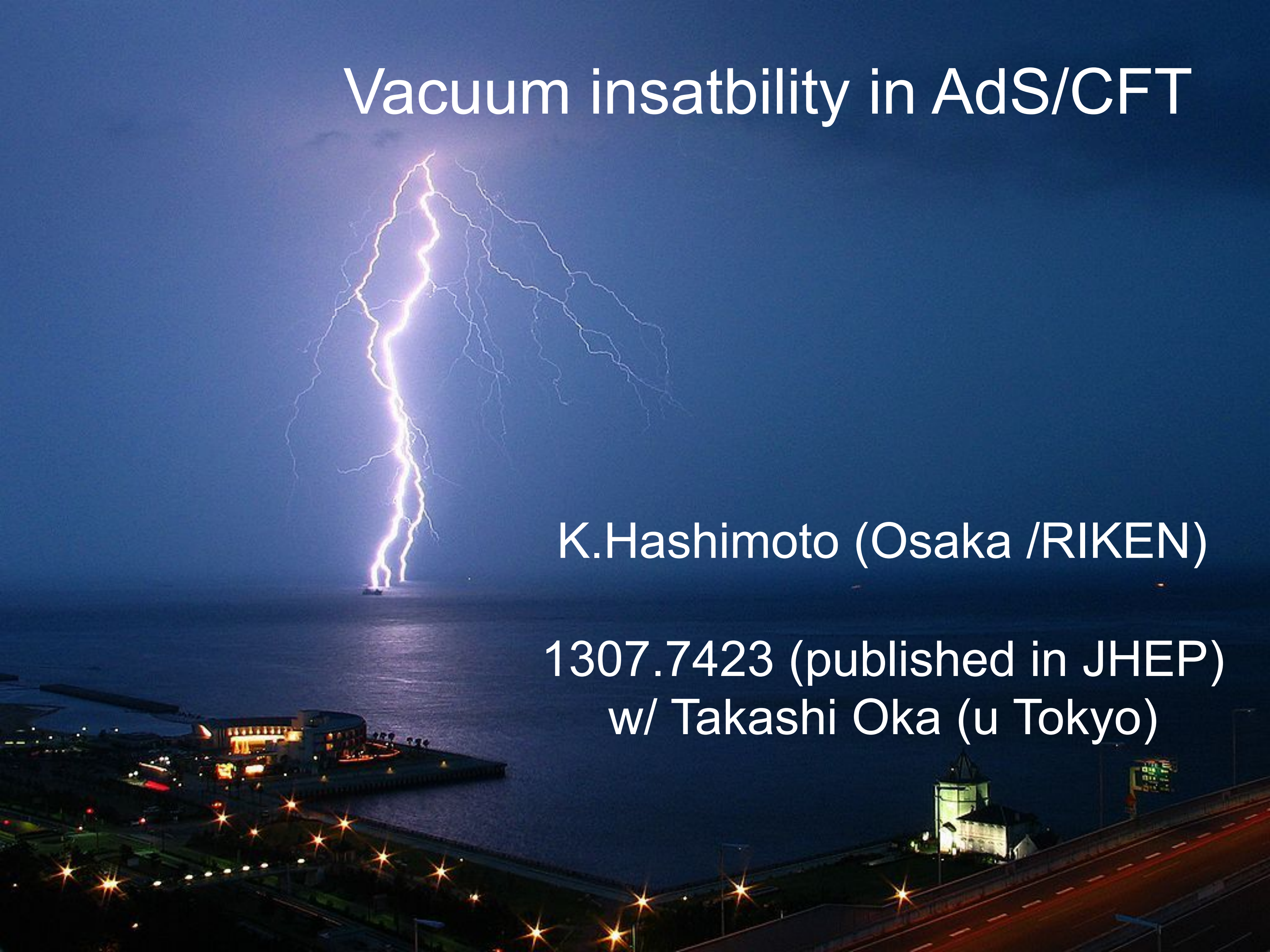

Vacuum insatbility in AdS/CFT

K.Hashimoto (Osaka /RIKEN)

1307.7423 (published in JHEP)
w/ Takashi Oka (u Tokyo)

Problem

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How can electric field break confinement?

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Cause

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Non-linear elemag and strong coupling

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Our solution

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$\mathcal{N}$=2 superQCD

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Gauge/Gravity duality

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Schwinger effect, Rapid thermalization

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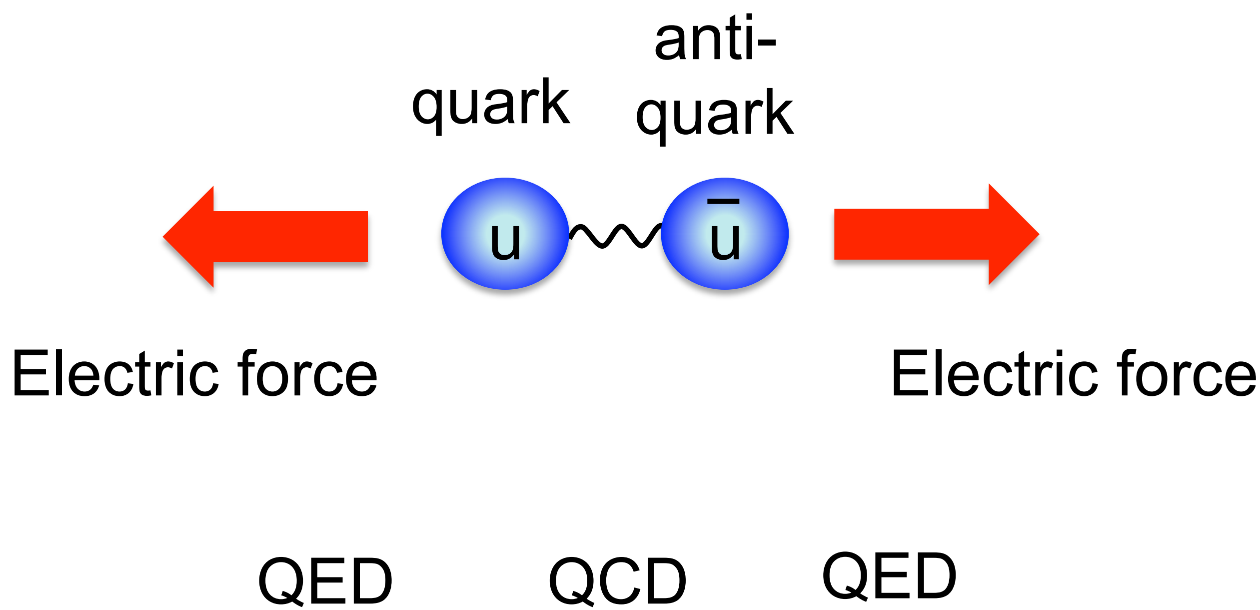
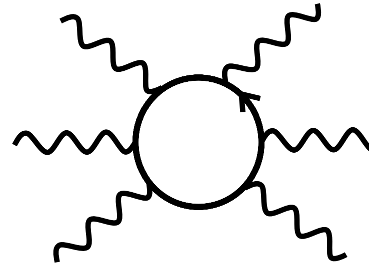
1 How can electric field break confinement?

Strong electric field can make confined quarks separate?



2 Non-linear elemag and strong coupling?

Perturbation: "Nonlinear elemag"



$$\mathcal{L} = \frac{1}{2}E^2 - \frac{1}{8\pi^2}\int_0^\infty \frac{ds}{s^3}\left[eEs\cot(eEs) - 1 + \frac{1}{3}(eEs)^2\right]$$

[Heisenberg, Euler 1936]

$$\mathrm{Im}\,\mathcal{L} = \sum_{n=1}^{\infty}\frac{e^2E^2}{4\pi^3}\frac{1}{n^2}\exp\left[-\frac{n\pi m_e^2}{eE}\right]$$

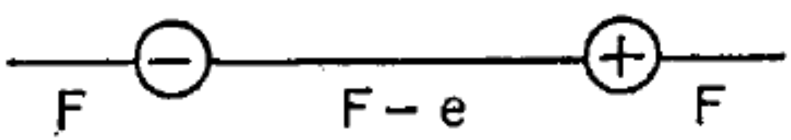
From poles…

[Schwinger 1951]

pair-creation of electron positron

At strong coupling? Expect :

Decay possible only with *E* stronger than confining force.



Ex. 1+1 dim. QED

[Coleman, Jackiw, Susskind 1975]

[Coleman 1976]

3-1 Holography and D-brane action

Euler-Heisenberg action = D7-brane in $AdS_5 \times S^5$

$$\mathcal{L} = \mathcal{T}_{\mathrm{D7}} 2\pi^2 R^2 \int_0^\infty dr\ r^3 \sqrt{1 - (2\pi\alpha' E)^2 \frac{R^4}{((2\pi\alpha' m)^2 + r^2)^2}}$$

Result 1. Critical *E* field
= confinement force

$$E_{\mathrm{cr}} = \frac{2\pi\alpha' m^2}{R^2} = \frac{\sqrt{2}\pi m^2}{\sqrt{\lambda}}$$

Result 2. "Automatic Schwinger"

$$\mathrm{Im}\ \mathcal{L} = \frac{N_c}{2^5\pi} e^2 E^2 \left(1 + 2^{5/2} \frac{m^2}{\sqrt{\lambda} eE} \log \frac{m^2}{\sqrt{\lambda} eE} + \text{higher}\right)$$

Result 3. Rapid thermalization

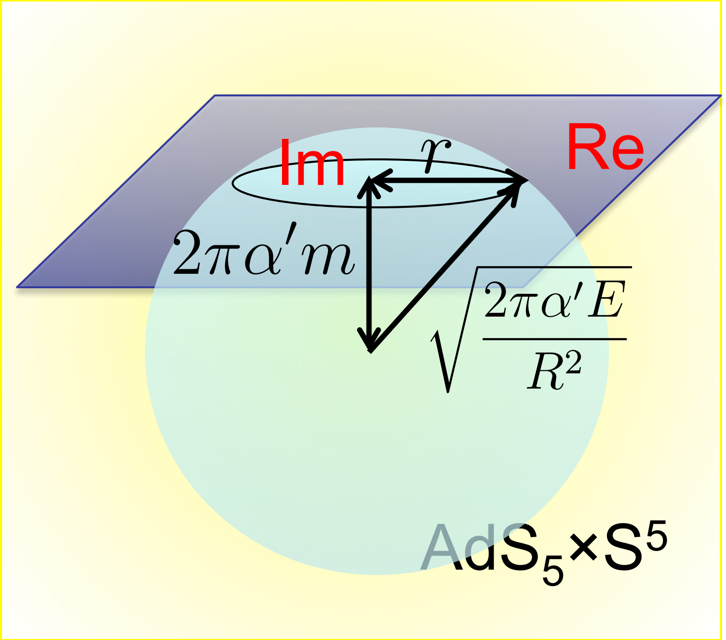
3-2

Holography and D-brane action

Result 1. Critical *E* field = confinement force

Full nonlinear elemag is obtained, easy

$$\mathcal{L} = \mathcal{T}_{\rm D7} 2\pi^2 R^2 \int_0^\infty dr\; r^3 \sqrt{1-(2\pi\alpha' E)^2 \frac{R^4}{((2\pi\alpha' m)^2+r^2)^2}}$$



Positivity inside the sq root

$$\Leftrightarrow \quad (2\pi\alpha' m)^2 + r^2 > 2\pi\alpha' E R^2$$

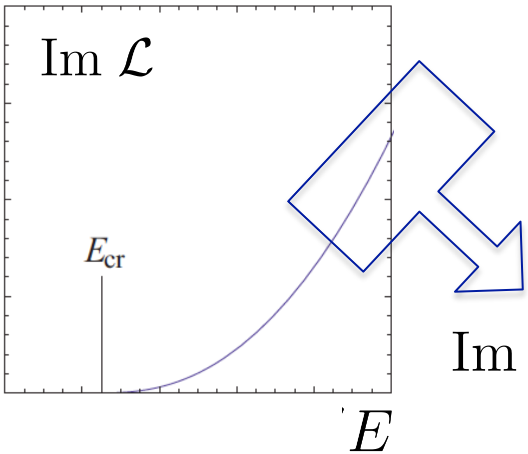
Imaginary action
above critical electric field

$$E_{\rm cr} = \frac{2\pi\alpha' m^2}{R^2} = \frac{\sqrt{2}\pi m^2}{\sqrt{\lambda}}$$

[Erdmenger, Meyer, Shock (07)]

3-3 Holography and D-brane action

Result 2. "Automatic Schwinger"



Expand the imaginary part of DBI for large *E*

$$\text{Im } \mathcal{L} = \frac{N_c}{2^5 \pi} e^2 E^2 \left(1 + 2^{5/2} \frac{m^2}{\sqrt{\lambda} e E} \log \frac{m^2}{\sqrt{\lambda} e E} + \text{higher} \right)$$

Agrees with the Schwinger effect, identified as $E_{\rm cr} \leftrightarrow m_e^2$

$$\text{Im } \mathcal{L} = \frac{N_c}{2^5 \pi} e^2 E^2 \left(1 + \frac{4}{\pi} \frac{m_e^2}{eE} \log \frac{m_e^2}{2eE} + \text{higher} \right)$$

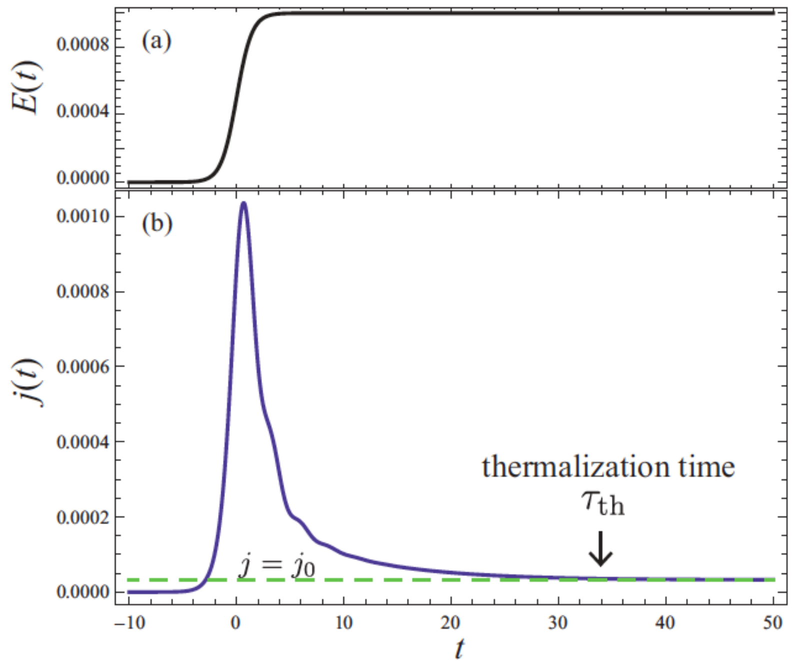
$$\left(\text{Im } \mathcal{L}_{\rm spinor} = \frac{e^2 E^2}{8\pi^3} \sum_{n=1}^{\infty} \frac{1}{n^2} \exp\left[-\frac{m_e^2 \pi}{eE} n \right] , \quad \text{Im } \mathcal{L}_{\rm scalar} = \frac{e^2 E^2}{16\pi^3} \sum_{n=1}^{\infty} \frac{(-1)^{n-1}}{n^2} \exp\left[-\frac{m_e^2 \pi}{eE} n \right] \right)$$

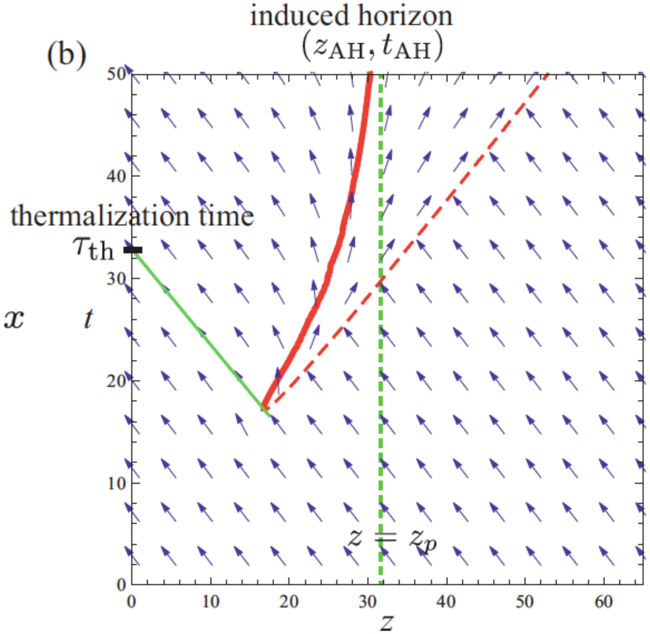
3-4 Holography and D-brane action

Result 3. Time-dependence solved, thermalization.

$$E(t) = \frac{E}{2}(1 + \tanh(\omega t))$$

It relaxes and approaches the stationary current.





Thermalization?

Apparent horizon for the induced metric on the D7-brane, formed at a Planckian time.

$$\tau_{\rm th} \sim a\pi \left(\frac{\lambda}{2\pi^2}\right)^{1/4} \frac{\hbar}{k_B} E^{-1/2} \sim 1 \ [{\rm fm/c}]$$

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