QCD Time Crystals, Phase transitions, Gravitational waves from the early Universe

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What We know about QCD

A lot from first colliders to high luminosity frontiers to heavy ion collisions to proton proton colliders to neutron stars … to …

Not so numerous tools:

i) RGE
ii) Lattice Quantization
iii) Istantonic methods
iv) Supersymmetry
v) recently many progresses in holographic models
vi) Large N approximation
vii) some exotic attempts for an effective string theory

But: the QCD vacua is the most complicated in the world: “spaghetti”. Confinement ???

Confinement is still a mystery of Nature,
Not very much is understood when
space-time is dynamical.

“How wonderful that we have met with a paradox. Now we have some hope of making progresses” (N.B.)

What is a time crystal?

nature

THE INTERNATIONAL WEEKLY JOURNAL OF SCIENCE

Time crystals

First observations of exotic new state of matter PAGES 164, 185, 217 & 221

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Iconic trade route arose from nomadic herding network

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To observe both time crystals and quasitime crystals, researchers used **helium-3** (helium with a missing neutron) cooled to within a whisker of **absolute zero**. Because of the uneven number of particles in the nucleus, **helium three has a strong magnetic moment**. The helium is put into a state where all the magnets

God plays with space-time crystals

Gluon Time Crystals
from
Gluon condensate approach,
space-time back reaction and relaxation phenomena.
This generates a time-crystal

YM gluon condensate coupled to gravity. Savvidy coupled to Einstein EoFs

$$\frac{1}{\varkappa}\left(R_\mu^\nu-\frac{1}{2}\delta_\mu^\nu R\right)=\frac{b}{32\pi^2}\frac{1}{\sqrt{-g}}\Bigg[\Bigg(-\mathcal{F}^a_{\mu\lambda}\mathcal{F}_a^{\nu\lambda}$$
$$+\frac{1}{4}\delta_\mu^\nu\mathcal{F}^a_{\sigma\lambda}\mathcal{F}_a^{\sigma\lambda}\Bigg)\ln\frac{e|\mathcal{F}^a_{\alpha\beta}\mathcal{F}_a^{\alpha\beta}|}{\sqrt{-g}\,\lambda^4}-\frac{1}{4}\delta_\mu^\nu\,\mathcal{F}^a_{\sigma\lambda}\mathcal{F}_a^{\sigma\lambda}\Bigg], \qquad (4)$$
$$\left(\frac{\delta^{ab}}{\sqrt{-g}}\partial_\nu\sqrt{-g}-f^{abc}\mathcal{A}^c_\nu\right)\left(\frac{\mathcal{F}_b^{\mu\nu}}{\sqrt{-g}}\ln\frac{e|\mathcal{F}^a_{\alpha\beta}\mathcal{F}_a^{\alpha\beta}|}{\sqrt{-g}\,\lambda^4}\right)=0,$$

in FLRW : initial uniform condensate.

$$\frac{6}{\varkappa}\frac{a''}{a^3}=T_\mu^{\mu,\mathrm{U}},$$
$$T_\mu^{\mu,\mathrm{U}}=\frac{3b}{16\pi^2a^4}\left[(U')^2-\frac{1}{4}U^4\right],$$
$$\frac{\partial}{\partial\eta}\left(U'\ln\frac{6e\left|(U')^2-\frac{1}{4}U^4\right|}{a^4\lambda^4}\right)$$
$$+\frac{1}{2}U^3\ln\frac{6e\left|(U')^2-\frac{1}{4}U^4\right|}{a^4\lambda^4}=0.$$

A chronon for frozen “a”:

$$U'^2 - \frac{1}{4}U^4 = \text{const}\,,$$

$$U^2 \to U^2 - U_0^2$$

$$U(\eta) \simeq \frac{v}{\sqrt{2}} \tanh[\frac{v}{\sqrt{2}}(\eta - \eta_0)]\,.$$

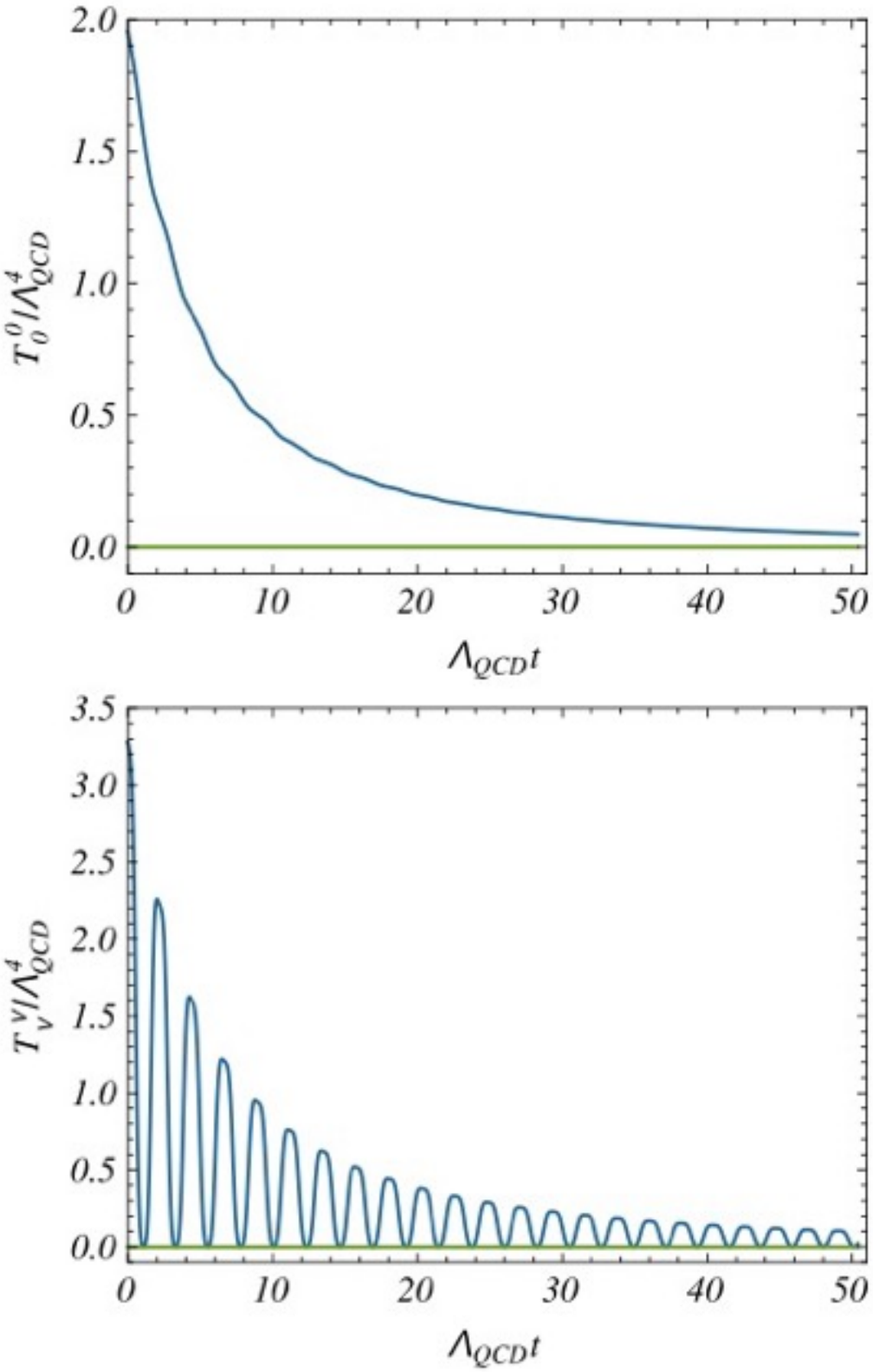
T-symmetry is spontaneously broken

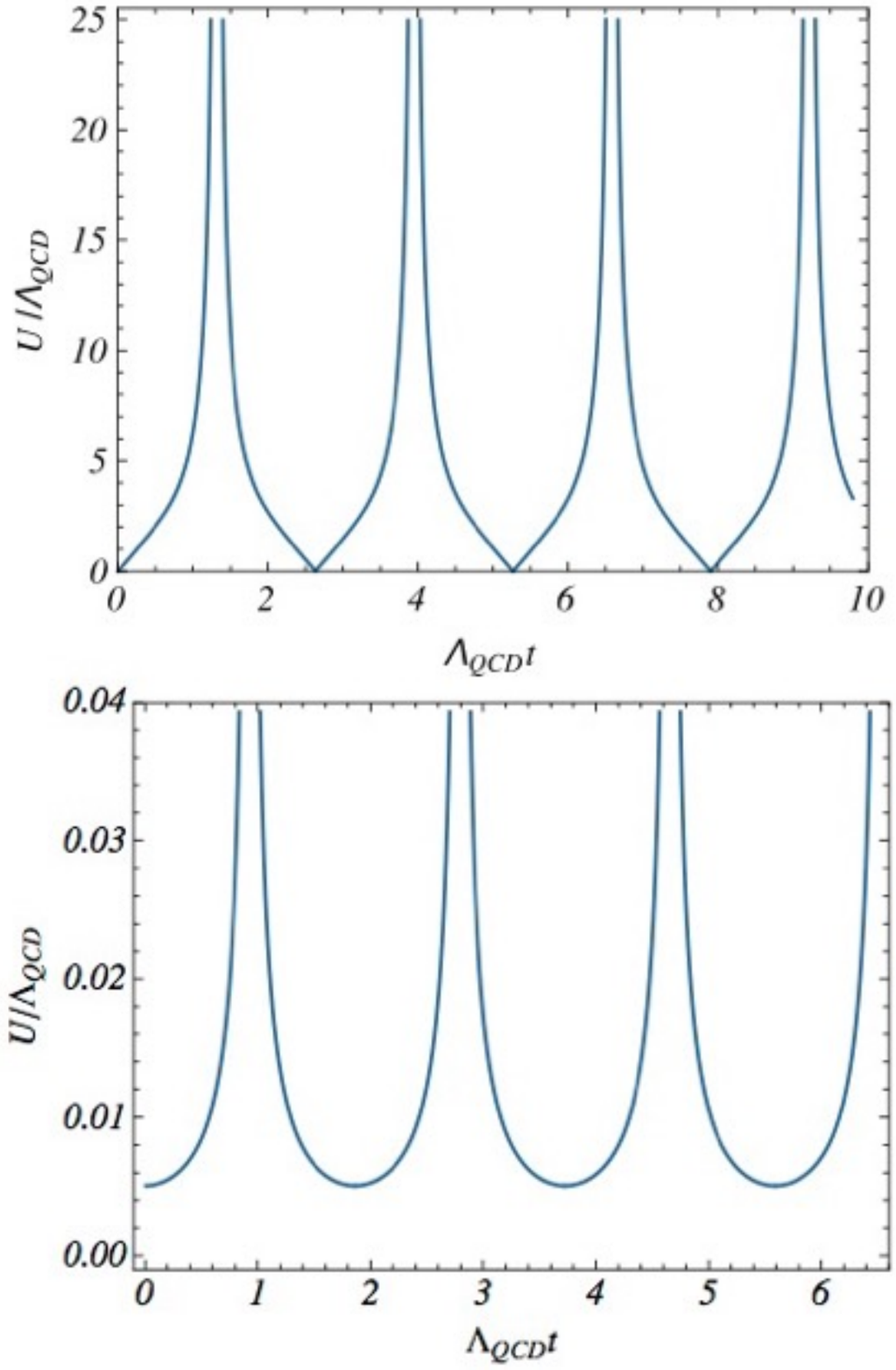
A chronon is highly unstable

A chronon is like a S-brane

A chronon is like a tachyon like Dp-AntiDp branes

Chronons $T_n : t \to t + n\Lambda_{\mathrm{QCD}}^{-1}$





What we can learn from Gravitational Waves

Radio-astronomy

Ottimismo

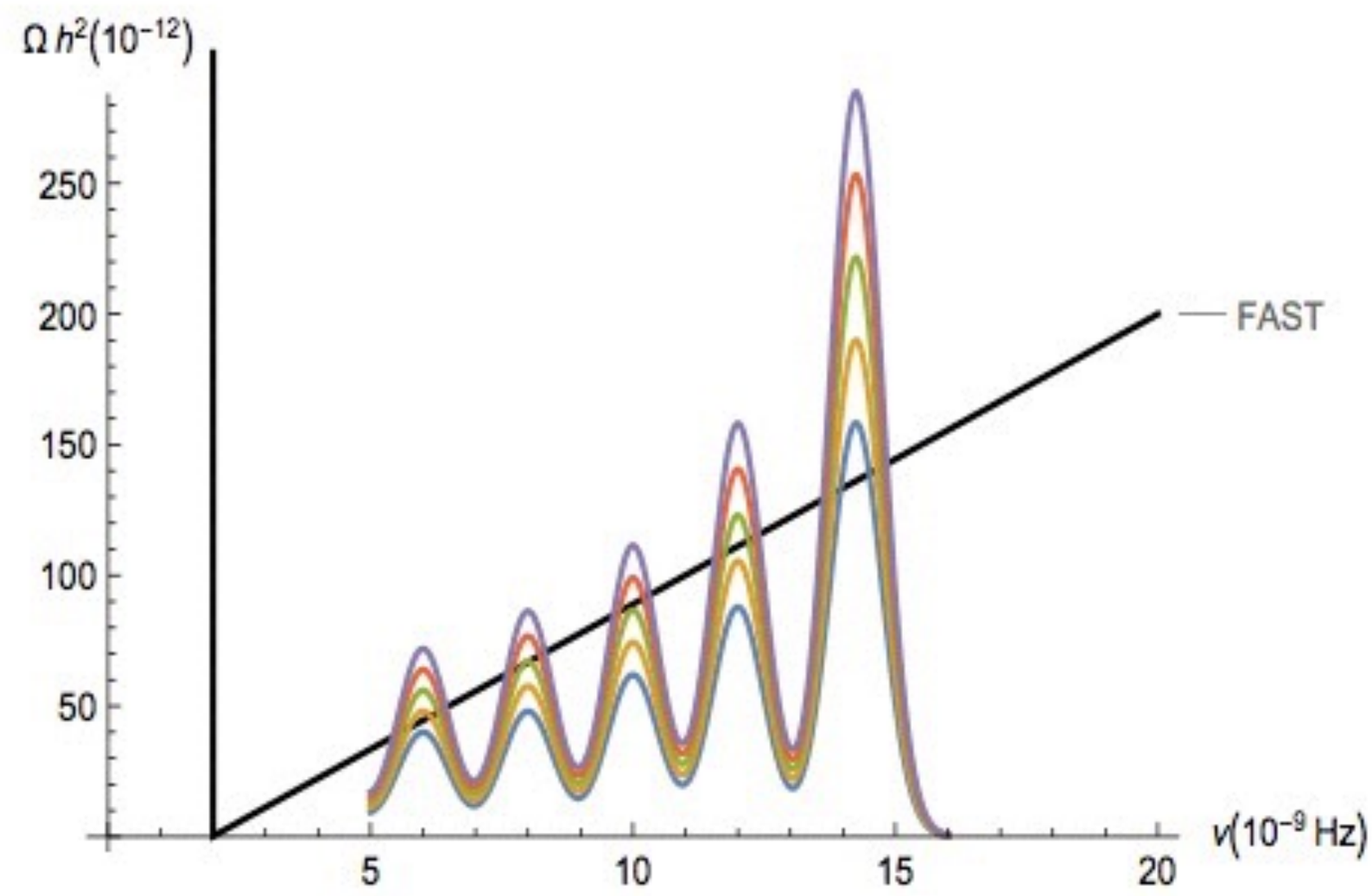
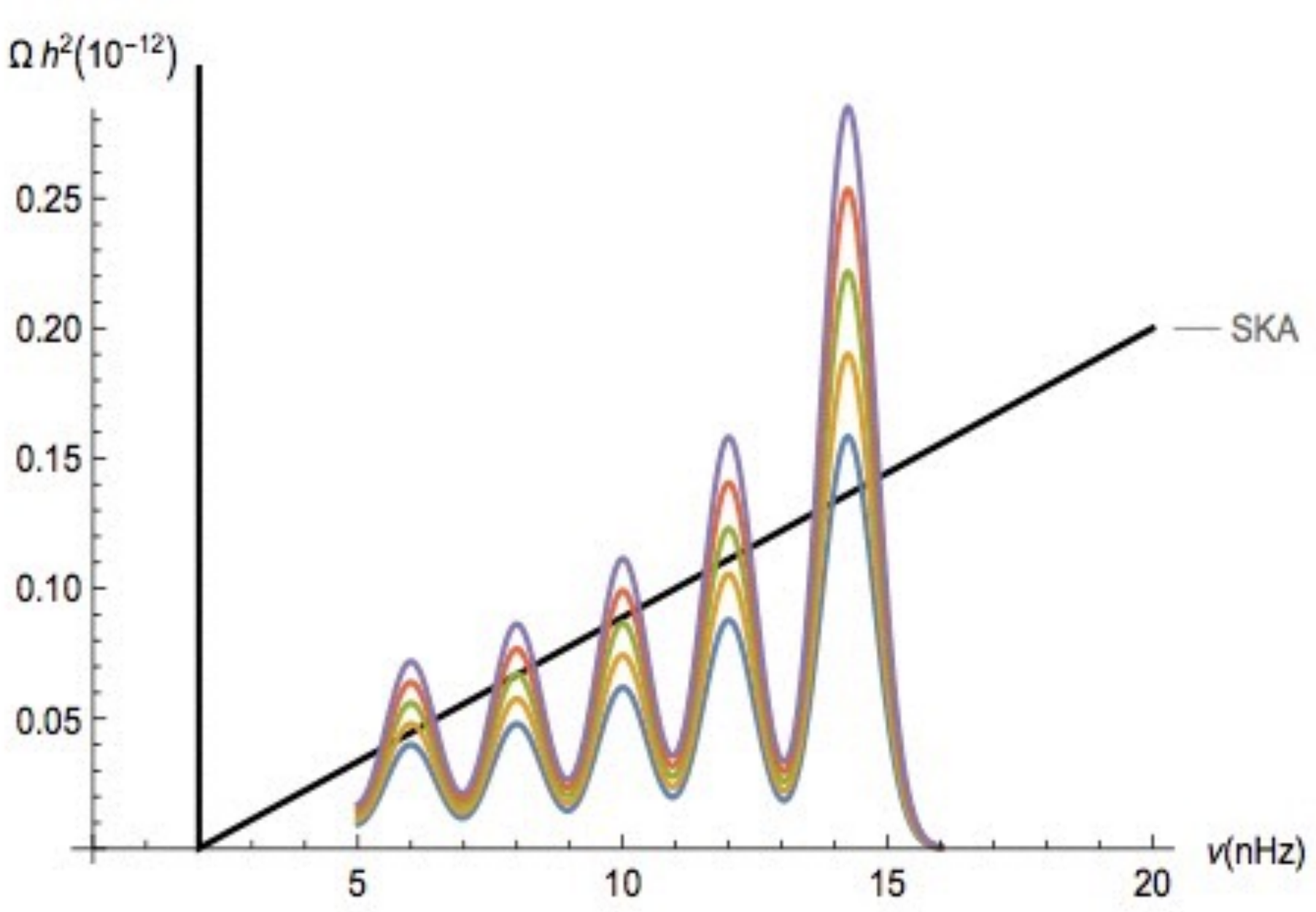


FIG. 1. The gravitational waves spectrum is displayed for different efficiency factors, in comparison with FAST sensitivity curve [24]. The efficiency factor considered are $\kappa = 0.03 \div 0.1$.

Pessimismo



WHY?

What’s the physics behind it?

Savvidy vacuum is unstable, but its instability has a back-reaction generating GW

Theorems are formulated to be dynamically broken.
Here we violate the
Nielsen-Olesen (NO) “dogma”

Confinement?
Dynamically Emergent Mirror Symmetry (DEMS).
Screening of chromoelectric and chromomagnetic contributions.

What happens for Axion Dark Matter??? open questions

Why are the community not advancing in our understanding of QCD confinement???

1) We are too afraid to make crazy mistakes. We kill our originality.

2) We are too much boring, Mainstreams and Sectorialization, Young people does not find a job if not, Old people is reactionist by definition,

3) We do not think enough slow-motion multi-tasking.