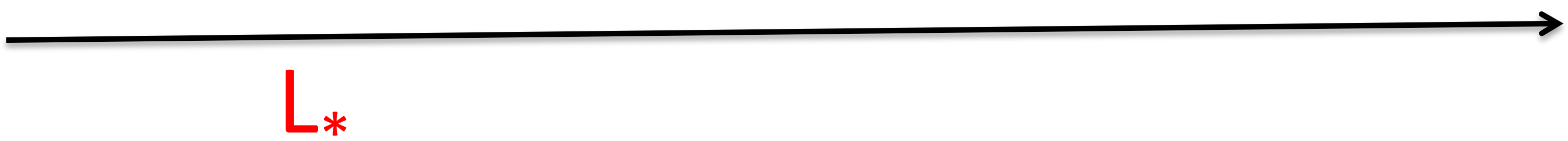
UV-Completion by Classicalization.

Gia Dvali
LMU-MPI, CERN, NYU
with:
GianGiudice, Cesar Gomez, Alex Kehagias;
David Pirtskhalava.
Earlier studies, with: Cesar Gomez; Dieter Lust; Sarah Folkerts, Cristiano Germani…

Usual (Wilsonian) approach to UV-completion of non-renormaizable theories, with a cutoff length L_*, is to integrate-in some weakly-coupled new physics.



Our idea is to suggest an alternative, in which a theory "refuses" to get localized down to short distances, and instead of becoming short and quantum, becomes large and classical.

This can happen in theories that are (self)-sourced by energy (e.g., containing gravity or Nambu-Goldstone bosons).

In this case, the high-energy scattering is dominated by production of classical configurations (classicalons) of a certain bosonic field (classicalizer):

Theory classicalizes

In remaining 15 min, let me give you a general sense of this idea.

In a generic theory cross section can be written as a geometric cross section

$$\sigma \sim r_*(E)^2$$

where $r_*(E)$ is a classical radius, not containing any dependence on $\hbar$.

$r_*(E)$ can be defined as a distance down to which, at given center of mass energy E, particles propagate freely, without experiencing any significant interaction.

But, if a classical r_*-radius can be defined in any theory, what determines classicality of a given theory?

In a generic weakly-coupled theory, r_* is a classical radius, but it is much shorter then the other relevant quantum length-scales in the problem.

Fore example, in Thomson scattering the role of r_* is played by the classical radius of electron,

$$r_* = r_e = e^2/m_e ,$$

but system is quantum because it is much shorter than relevant quantum length in the problem, the Compton wave-length of electron.

Another example is the gravitational Schwarzschild radius of electron,

$$r_S = m_e L_P{}^2 \ ,$$

where $L_P = 10^{-33}$cm is the Planck length.

Although r_S is a classical radius, electron is not a classical gravitating system, because r_S is much shorter than the Compton wave-length of electron,

$$r_S \ll 1/m_e \ ,$$

The crucial point is, that in classicalizing theories $r_*(E)$-radius grows with E,

and becomes much larger than any relevant quantum scale in the problem.

At this point the system Classicalizes!

To be short, consider (a tree-level) scattering in two theories,

$$L = (\partial\phi)^2 - \lambda\phi^4$$

and

$$L = (\partial\phi)^2 + L_*^4 (\partial\phi)^4$$

In both theories cross section can be written as

$$\sigma \sim r_*^2,$$

where, r_* is distance at which the correction to a free-wave becomes significant:

$$\phi = \phi_0 + \phi_1$$

where ϕ_0 is a free wave and ϕ_1 is a correction due to scattering.

In ϕ^4-theory we have $r_* = \lambda/E$, and

$$\sigma = (\lambda/E)^2$$

On the other hand in

$$L = (\partial\phi)^2 + L_*^4(\partial\phi)^4,$$

story is very different, because ϕ_1 is sourced by the energy of ϕ_0 .

Let at $t=-\infty$ and $r = \infty$, ϕ_0 be a free collapsing in-wave of a huge center of mass energy E and very small occupation number. Because of energy self-sourcing,

$$\partial^2 \phi_1 = - L_*^4 \, \partial(\partial\phi_0(\partial\phi_0)^2)$$

scattering takes place at a macroscopic classical distance

$$r_* = L_* (EL_*)^{1/3}$$

Let us summarize what happened.

By scattering very energetic particles, we thought that we could probe very short distances, such as $1/E$ (or at least, L_*).

Instead, the scattering took place at a macroscopic classical distance,

$$r_* = L_* (EL_*)^{1/3} >> L_* >> 1/E$$

At this distance ϕ_1 becomes same order as ϕ_0, and we simply cannot deny, that scattering took place.

The free-waves refuse to get localized:

Theory classicalizes!

An immediate consequence is, that $2 \rightarrow 2$ scattering takes place via very low momentum-transfer:

$$A_{2\rightarrow 2} \sim (L_*/r_*)^{4/3}$$

The dominant process is

$2 \rightarrow$ classicalon $\rightarrow$ many

The total cross section becomes geometric

$$\sigma = r_* (E)^2 = L_*^2 (EL_*)^{2/3}$$

What does classicalization teach us about gravity?

Systems considered here share the bare essentials with gravity: existence of a classical length that grows with energy.

In this sense, gravity is an universal classicalizer :

$2 \to$ Black Hole $\to$ many

From the point of view of unitarization, this is no different than

$2 \to$ Classicalon $\to$ many

Other peculiarities of the Black hole physics, such as entropy and thermality are inessential.

From this point of view (otherwise fundamentally important) things, such as entropy and (approximate) thermality, are just particularities of the way gravity accomodates existence of the horizon.

(By now, we understand, that black holes have no choice, they must have Bekenstein entropy, because they have horizon

[exact derivation is another matter, secondary for our discussion])

But, what is essential for unitarization is classicalization: Any consistent theory that in high energy scattering is dominated by

$$2 \rightarrow \text{Anything Classical} \rightarrow \text{many}$$

can (should) unitarize by classicalization.

Micro Black Holes (e.g., the ones that may be produced at LHC), will not have time to forget their origin, and therefore cannot carry a well-defined entropy.

Micro black holes will be qualitatively indistinguishable from classicalon resonances predicted by other classicalizing theories.

An example of a prediction:

Applying idea of classicalization to longitudinal WW-scattering:

$$A_{2\to 2} \sim (\sqrt{s}/V)^{4/9}$$

and

$$\sigma = V^{-2} (\sqrt{s}\, 250 / V)^{2/3}$$

where $V = 250$ GeV

Above V, scattering is dominated by production of classicalon resonances.

Of course, there are many questions:

1) Does it work?
2) Is GR self-UV-completed by classicalization?
3) What does it mean from conventional point of view (in terms of degrees of freedom) to be classicalized?
4) What are the pheno-applications: Higgless SM? Yet another solution to the Hierarchy Problem?.....

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