Classicalization and UV-completions.

Works with:

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Classicalization is the dynamics underlying UV – IR correspondence.

A classicalizing Theory is characterized by:

i) A classicality scale M_*

ii) A map $r^*(s)$

$$\sqrt{s} > M^* \xrightarrow[r^*(s)]{} r^*(s) > \frac{1}{\sqrt{s}}$$

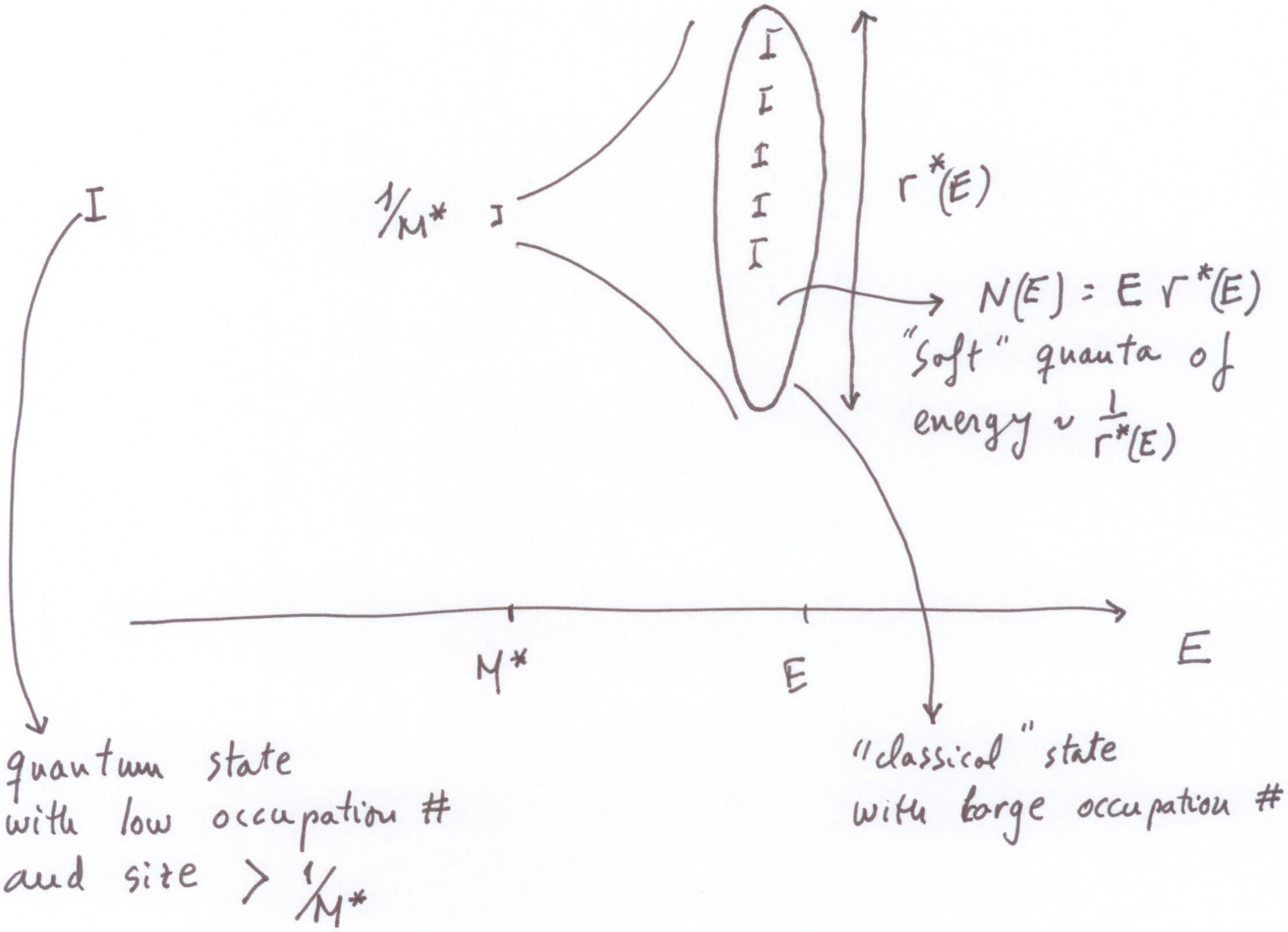
(UV) (IR)

$$\boxed{r^*(s) = L_*\left(L_*\sqrt{s}\right)^{\gamma}}$$

$\gamma > 0$

The essence of classicalization is simple:

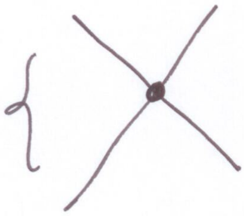
Energy acts as a SOURCE of self-interactions.



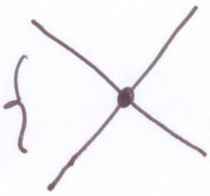
When the system reaches $E > M^*$ the self interactions induce "fragmentation" into $N(E)$ soft quanta of characteristic wave length $r^*(E)$

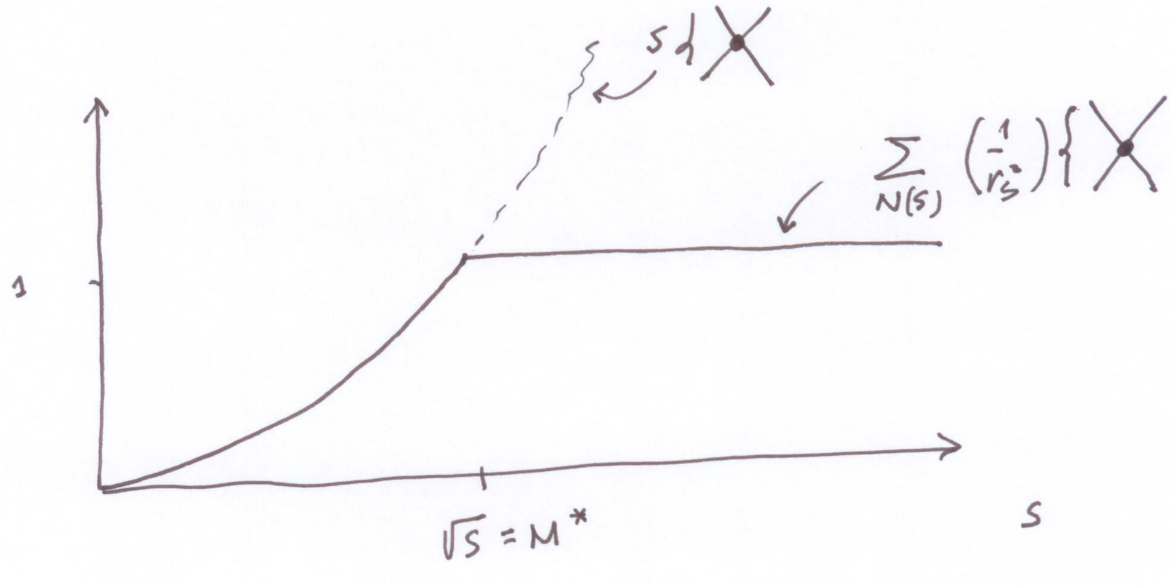
How classicalization helps unitarization?

Tree level unitarity problem:

s  $\sim L_*^4 s^2 + \ldots$ (1)

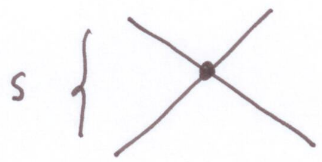
If the theory classicalizes with classicality scale L_*^{-1} (1) becomes (for $\sqrt{s} > M^*$)

$\sum_{N(s)} \left(\frac{1}{r^*_{(s)}}\right)^2$  ~ 1



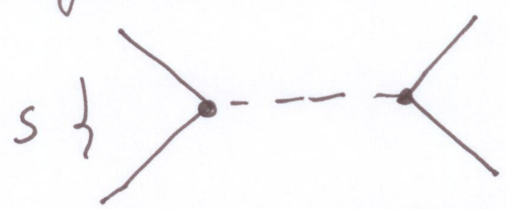
Note the difference with standard unitarization procedures:

Wilsonian Unitarization:

problem at tree level  $\sim L_*^4 s^2$

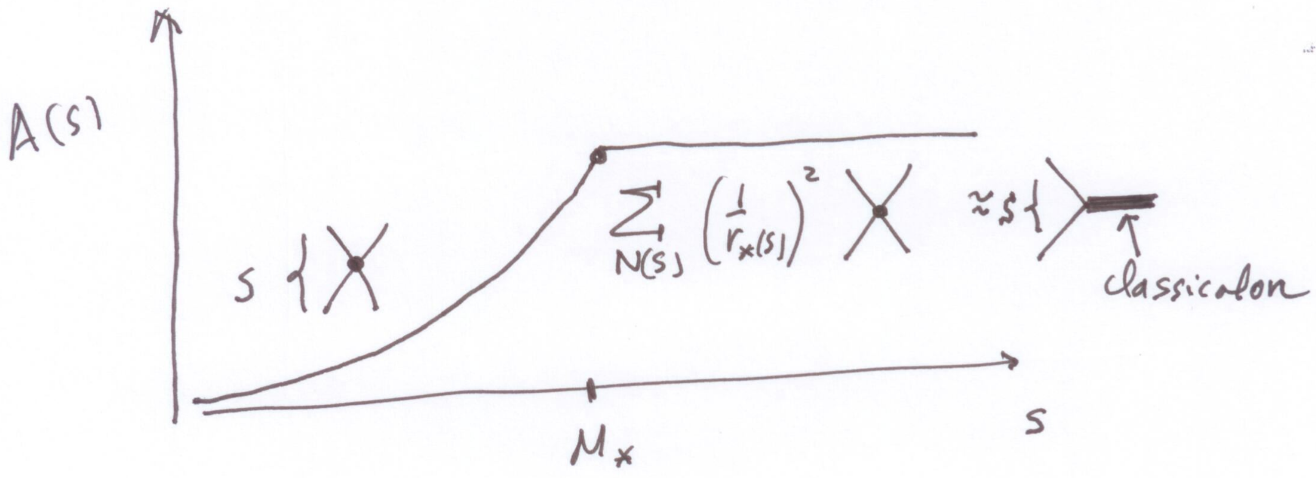
$+$

Add extra degree of freedom



unitary theory.

In classicalization:



How to estimate $r^*(s)$ for a given theory?

- Start with a localized packet of energy $\sqrt{s}$

$$\phi_0(r,s) \qquad ; \quad \Box \phi_0 = 0$$

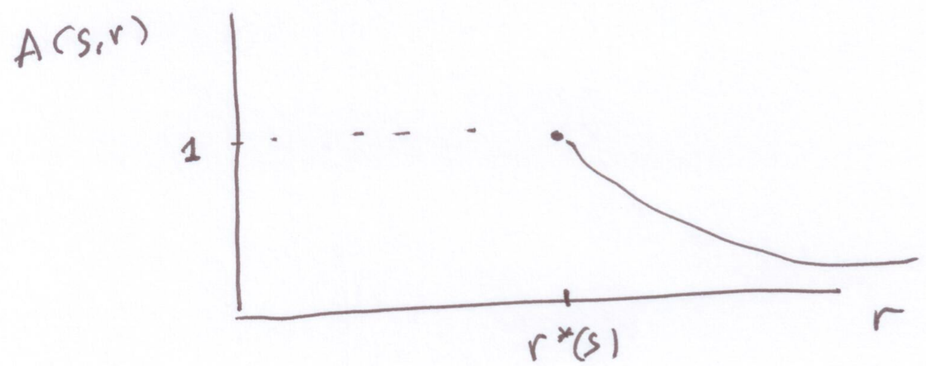
- Compute the effect of self interaction at first order:

$$\Box \phi_{(1)} = F(\phi_0(r;s))$$

↳ differential operator depending on the particular theory.

$r^*(s)$ is defined by:

$$\phi_0(r^*,s) = \phi_1(r^*,s) \equiv A(s,r)\,\phi_0$$



Classicality function:

$$\gamma \equiv \frac{d\, r^*(s)}{ds}$$

> 0 classicalizing Theories

< 0 No classicalizing Theories.

Examples: (massless theories)

$\lambda \phi^4$ $\gamma < 0$

"Goldstone" theory: $\gamma > 0$

$$(\partial\phi)^2 + L_*^4 \left((\partial_\mu \phi)^2\right)^2$$

$L_*^{n-4}\, \phi^n$ $n > 4$ $\gamma < 0$

Einstein gravity $\gamma > 0$

$\hookrightarrow$ $r^*(s) = L_P \, (L_P \sqrt{s})$

is the gravitational radius.

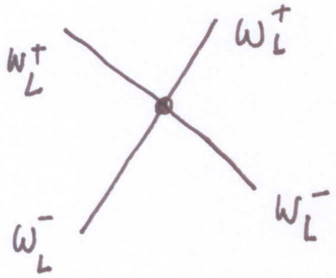
Classicalization of Standard Model (?)

Effective theory for the SSB sector.

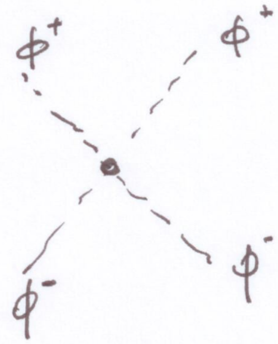
Theory of Goldstone bosons of type:

$$\left(\partial\phi\right)^2 + L_*^4 \left(\left(\partial_\mu\phi\right)^2\right)^2 \qquad L_* = \frac{1}{\langle v \rangle}$$

Equivalence Theorem:



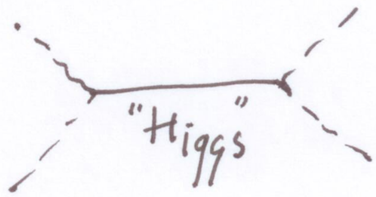
$\approx$



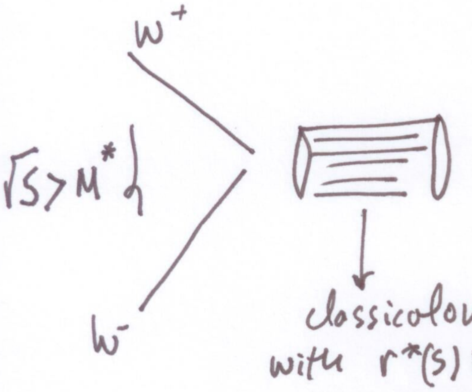
$\sim \; L_*^4 \, s^2$

unitarity problem.

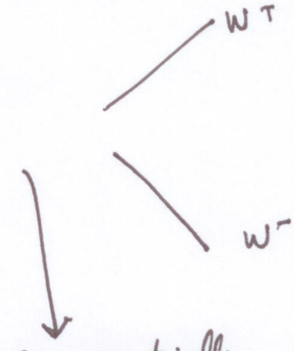
Instead of adding:



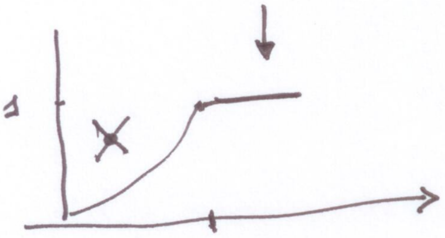
Let us classicalize the Goldstone theory:



classicalon with $r^*(s)\sqrt{s} \sim N(s)$ soft constituents and "size" $r^*(s)$



exponentially suppressed $e^{-N(s)}$



<u>Comment</u>: The Goldstone theory that classicalizes is NOT determined by symmetry i.e by the geometry of the coset space G/H.

Classicalization requires to tune higher order terms like $\left((\partial_\mu \phi)^2\right)^2$.

<u>Thus</u>: Classicalization for EW is a <u>possibility</u> NOT a theorem!

The case of gravity:

classicalon	$\approx$	Black hole
$r^*(s)$	$=$	gravitational radius
$N(s)$	$=$	B.H - entropy
exponential suppression e^{-N}	$=$	Boltzmann suppression factor
		Hawking Temperature.

However all these classicalon properties can be derived using pure scattering theory i.e don't rely on special features of space-time as horizon .. etc.

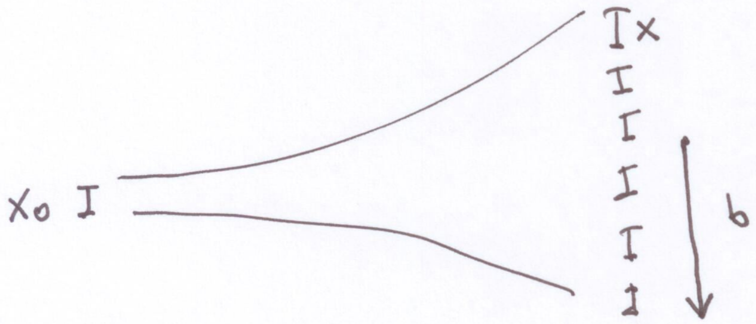
A comment on small-x physics.

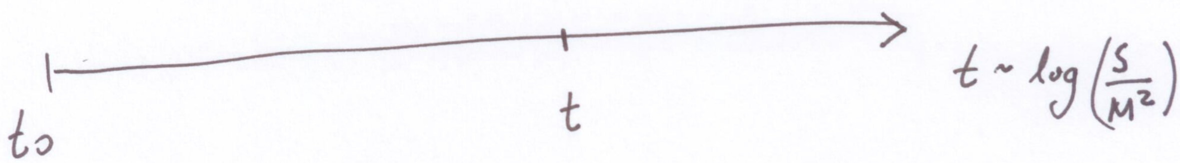
Hidden Classicality in High Energy QCD.

perturbative QCD $\qquad \alpha_s \ll 1 \qquad \alpha_s \log s \sim O(1)$

* dipole-dipole scattering at the level of one BFKL pomeron exchange.

* More precisely we are interested in evolution with rapidity of a dipole of initial size x_0.





$n(x_0, x, b, t) =$

density of dipoles of size x at distance b.

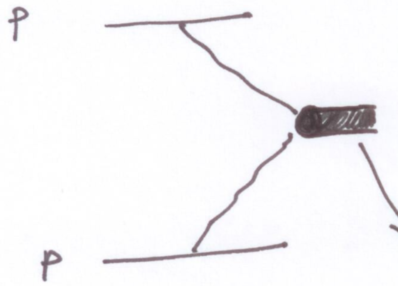
In one pomeron approximation:

$$n(x_0 x, b, t) \sim \frac{x_0}{x\, b^2}\, e^{\gamma t}$$

Thus we can define "effective size" requiring $n \simeq O(1)$.

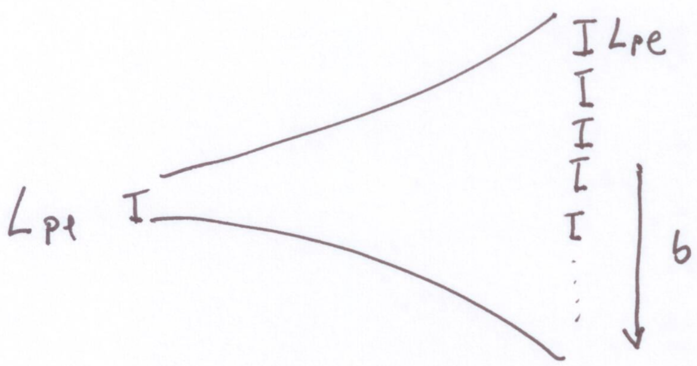
$$\boxed{b^2(t) = x_0 x\, e^{\gamma t}}$$

The QCD analog of $r^*(t)$!.

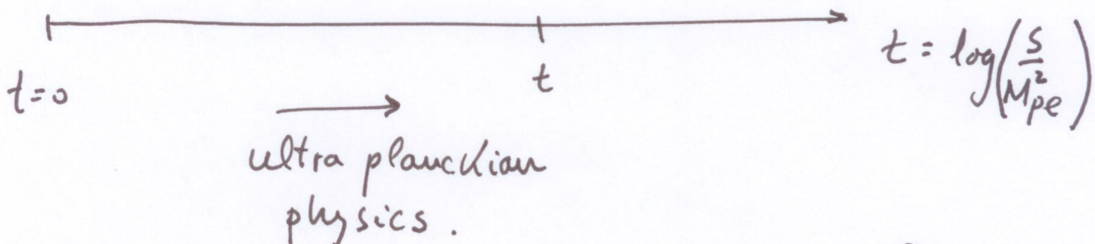


"classicalon" of effective size $b(t) < L_{QCD}$

It could be illustrative to imagine something similar in gravity:



"like in QCD"



$$n(L_{pe}\, L_{pe}\,;\, t,\, b) \sim e^{\gamma t - \log \frac{b^2}{L_{pe}^2}}$$

for some γ

leading to effective size:

$$\boxed{b^2(t) = L_{pe}^2 \left(s L_{pe}^2\right)^{\gamma}}$$

i.e the gravitational radius for $\gamma = 1$!.

B-H entropy $\approx$ # of quanta you create by increasing energy.

In summary:

Whenever energy self sources interaction you get classicality i.e

$$\gamma > 0$$

It looks that we can think of two forms of UV-completion:

Wilsonian:	$\beta < 0$	AF
Classicality:	$\gamma > 0$	