How to break spacetime symmetries and get away with it.

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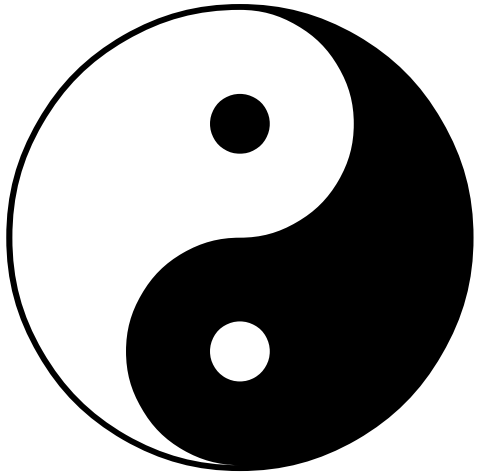
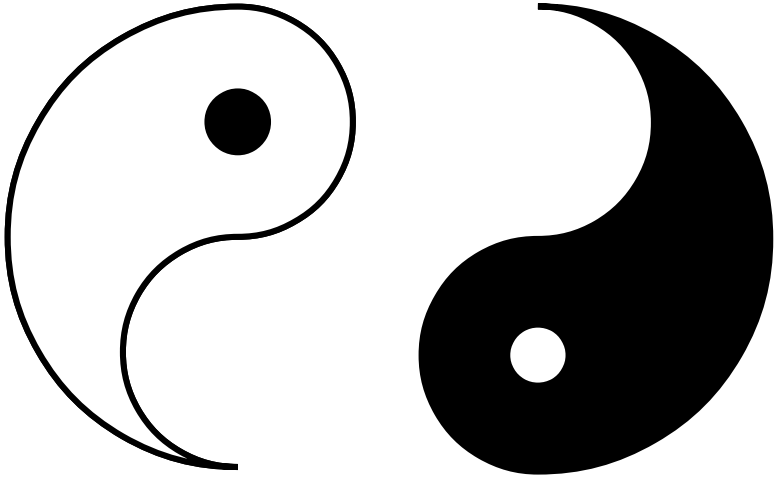


interesting



MORE interesting

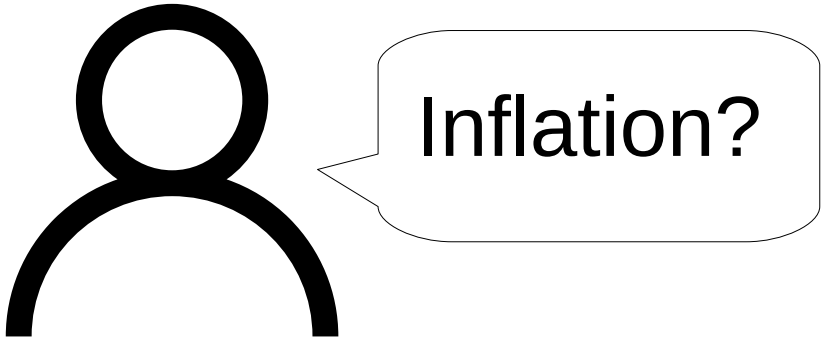
Goldstone's theorem

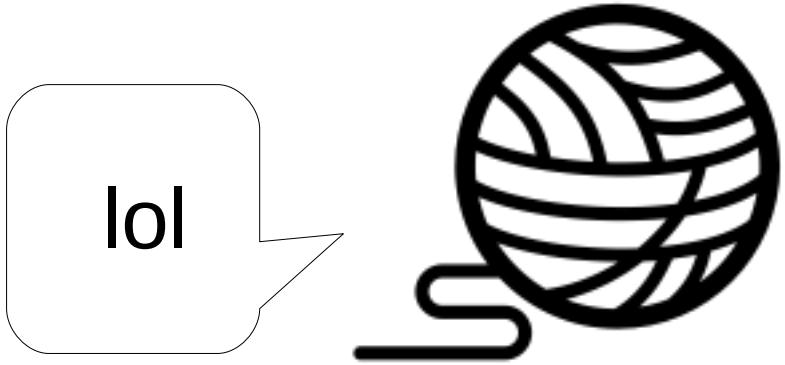
For each $Q_a|0\rangle \neq 0 \ldots$

$\ldots$ there's a massless particle π_a.

(terms and conditions apply)

Deriving the Goldstone action from a fundamental theory is great, but . . .





Goldstones and effective theories

unbroken: $\phi \to a\phi + \ldots$

Linear

so $\phi = 0 \to \phi = 0$

broken: $\pi \to c + a\pi + \ldots$

Affine

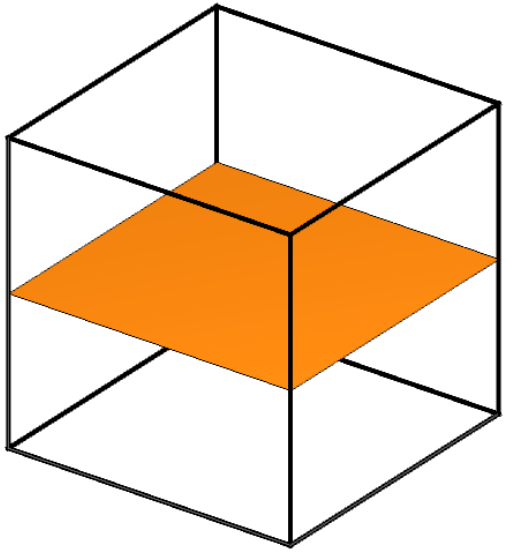
so $\pi = 0 \to \pi \neq 0$

Goldstones and effective theories

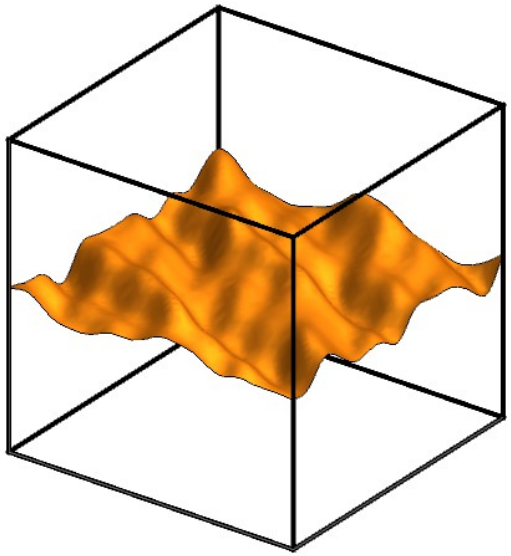
Unique affine transformations are scarce: not much choice.

Most general effective action can be constructed.

Useless Goldstones



$$\begin{array}{ccc} P_0 & P_1 & \cancel{P_2} \\ M_{01} & \cancel{M_{02}} & \cancel{M_{12}} \end{array}$$



1 scalar π
0 vector (A_0, A_1)

Useless Goldstones

internal breaking

$$\begin{aligned} \pi &\rightarrow c + a\pi + \ldots \\ \mathrm{d}\pi &\rightarrow a\mathrm{d}\pi + \ldots \end{aligned}$$

Affine
Linear

spacetime breaking

$$\begin{aligned} \pi &\rightarrow c + bx + a\pi + \ldots \\ \mathrm{d}\pi &\rightarrow b + a\mathrm{d}\pi + \ldots \end{aligned}$$

Affine
Affine

Useless Goldstones

Unique affine transformations are scarce: not much choice.

π	$\partial_0 \pi$	$\partial_1 \pi$

A_1

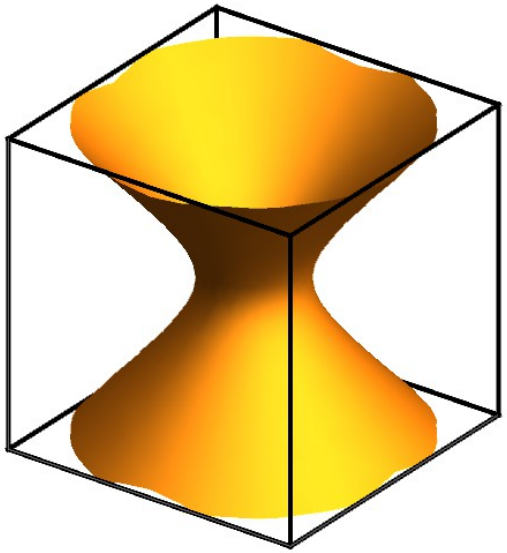
A_0

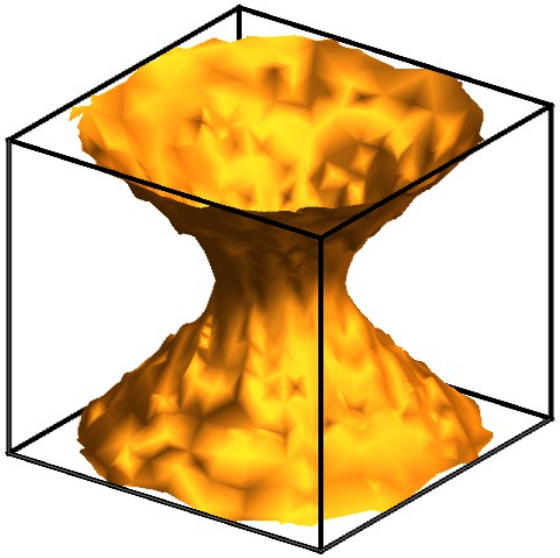
Really useless?

How can we know which Goldstones are essential and which aren't?

Let's try breaking Poincaré to de Sitter.

Really useless?





$\cancel{P_0}$ $\cancel{P_1}$ $\cancel{P_2}$

M_{01} M_{02} M_{12}

1 scalar π

0 vector (A_0, A_1)

Really useless?

I lied: spacetime also transforms affinely. So it really looks like this:

x^0	x^1	π	$\partial_0 \pi$	$\partial_1 \pi$

A_1

A_0

Really useless?

Can we shuffle things?

A_0	A_1	π	x^0	x^1

Really useless?

Yes, it works.

New theory, different from the first (how to pick?)

Scalar+vector in non-dynamical de Sitter space.

The End

We like using symmetry breaking and the Goldstones that arise to construct effective theories. But when we break spacetime symmetries, we don't know which Goldstones to use or how to classify all possible theories.

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