Beyond the Standard Model

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Lecture 3

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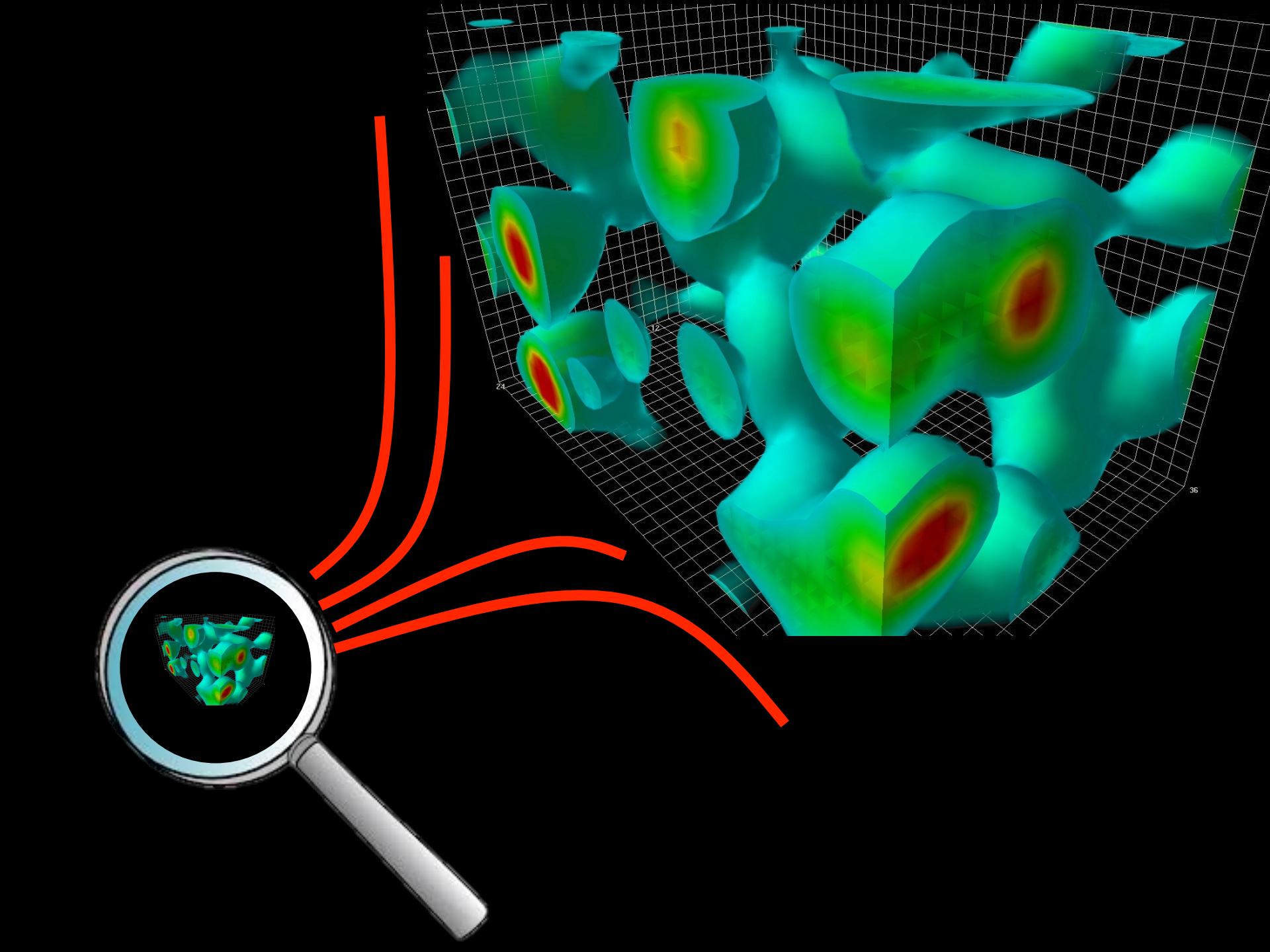
Inflation explains the initial conditions of the universe

No bang, but

- Uniform and flat because of superluminal expansion
- Expanding because of initial kick from vacuum energy
- Low entropy
- Hot because, at the end of inflation, vacuum energy is released in the form of thermal energy

A new spin-0 field responsible for inflation?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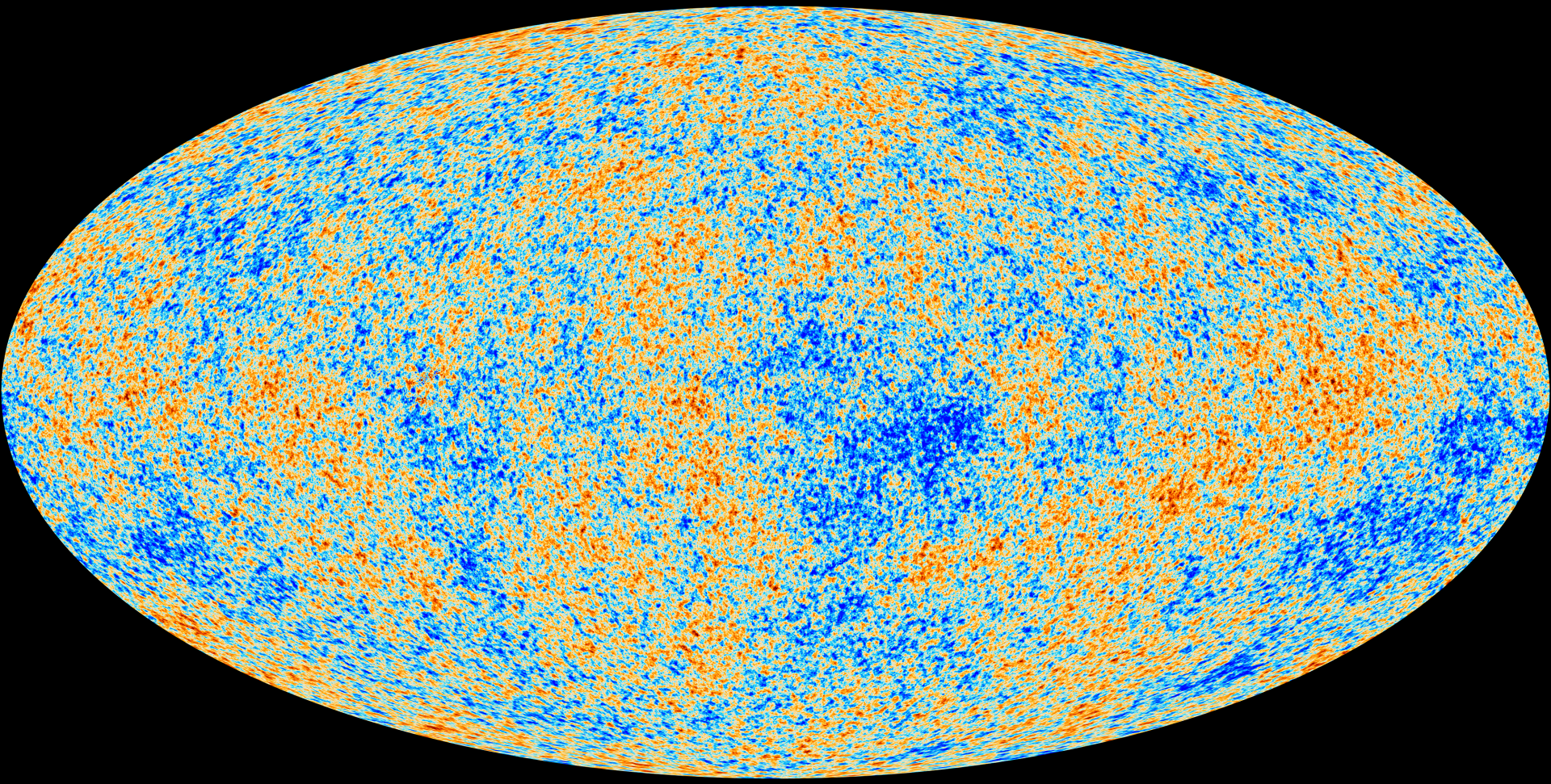
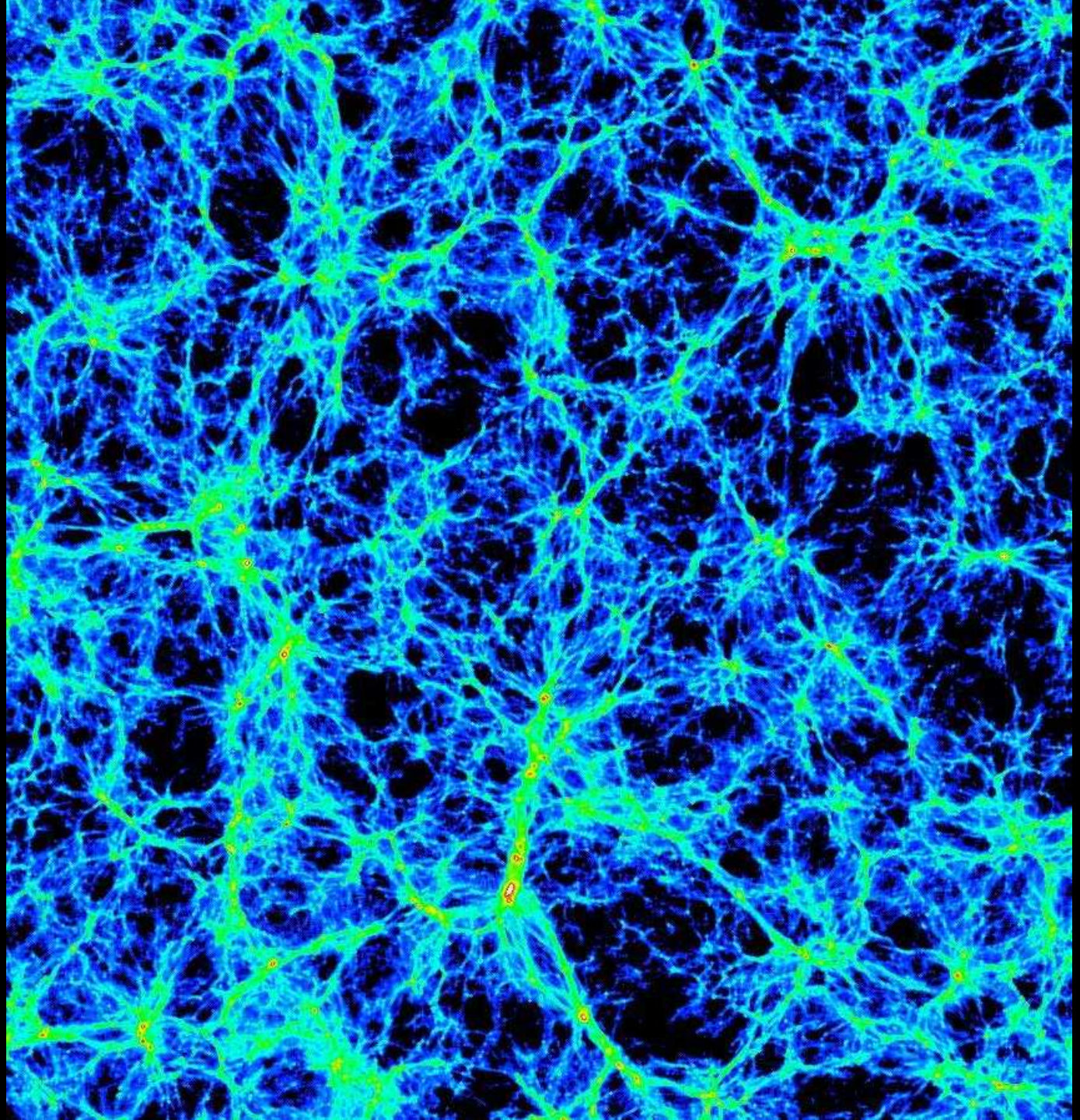
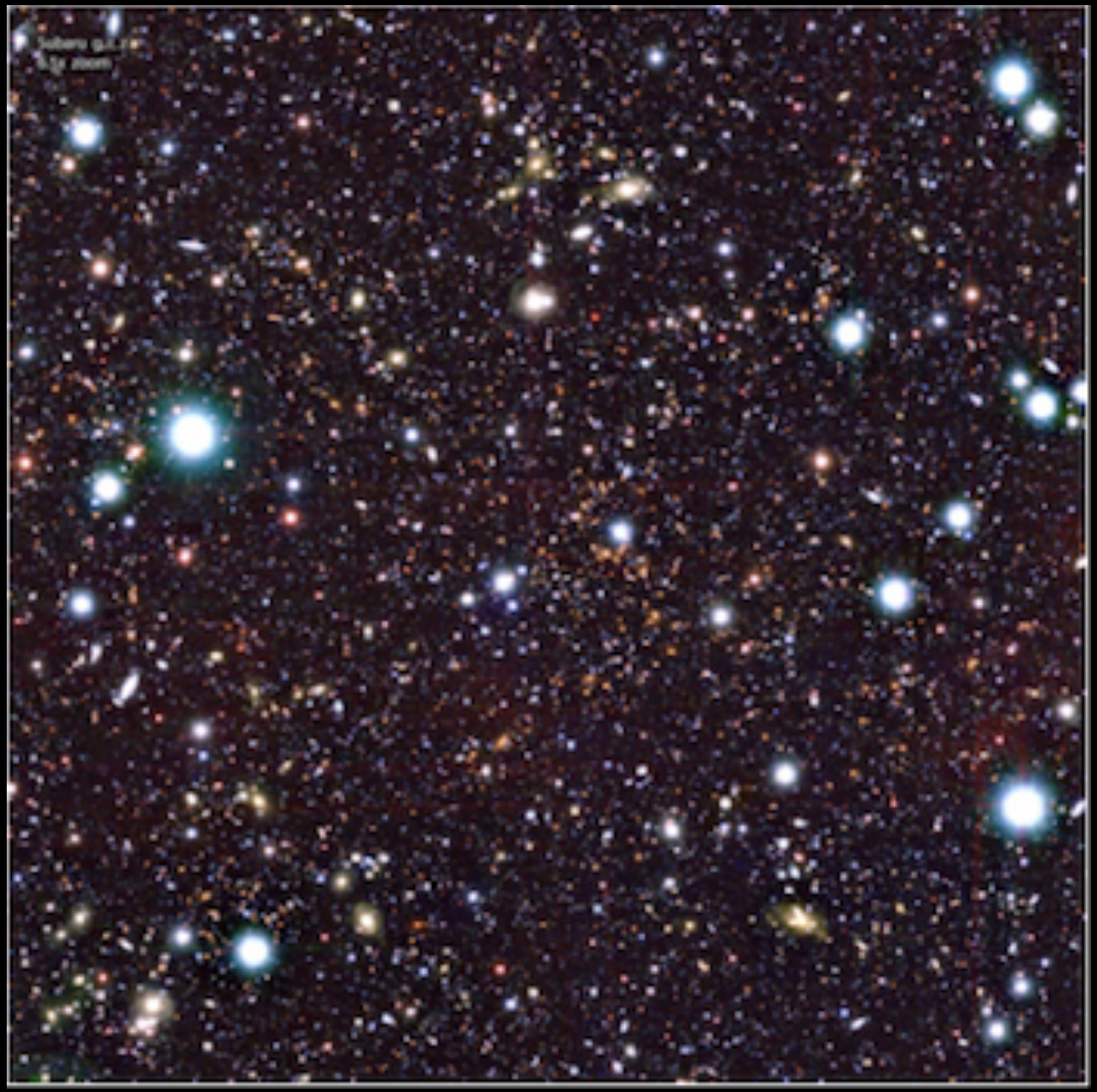
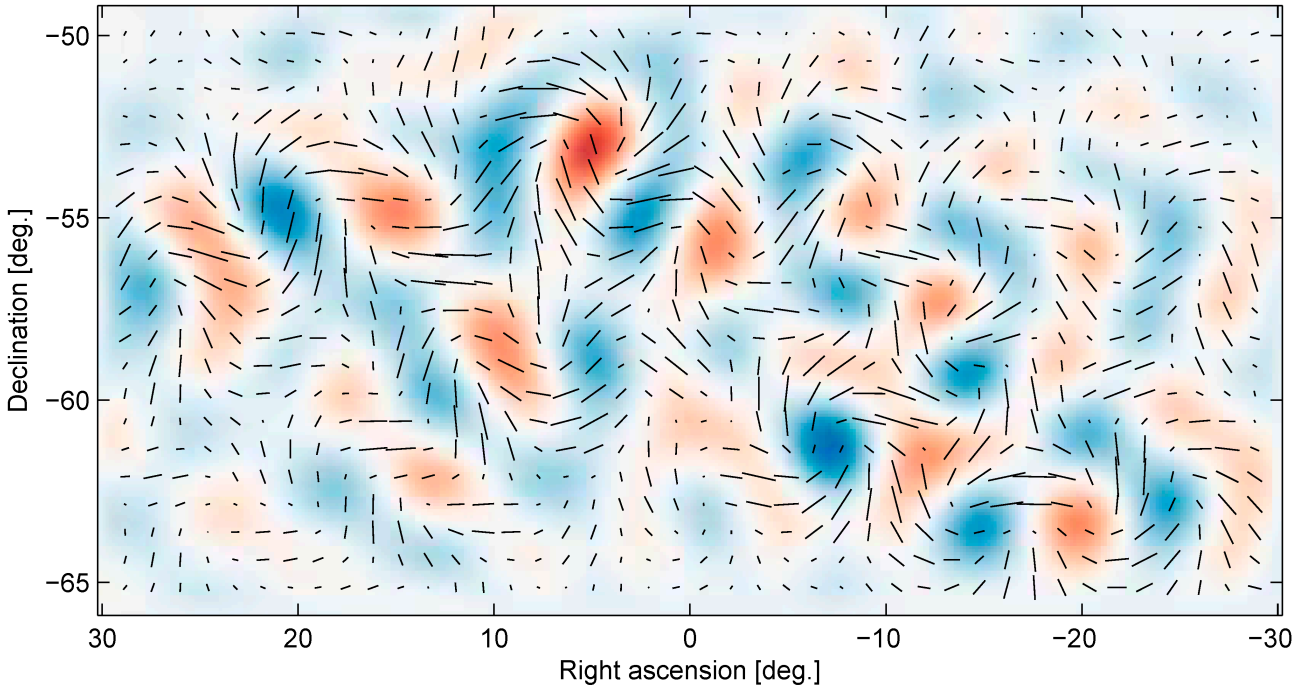


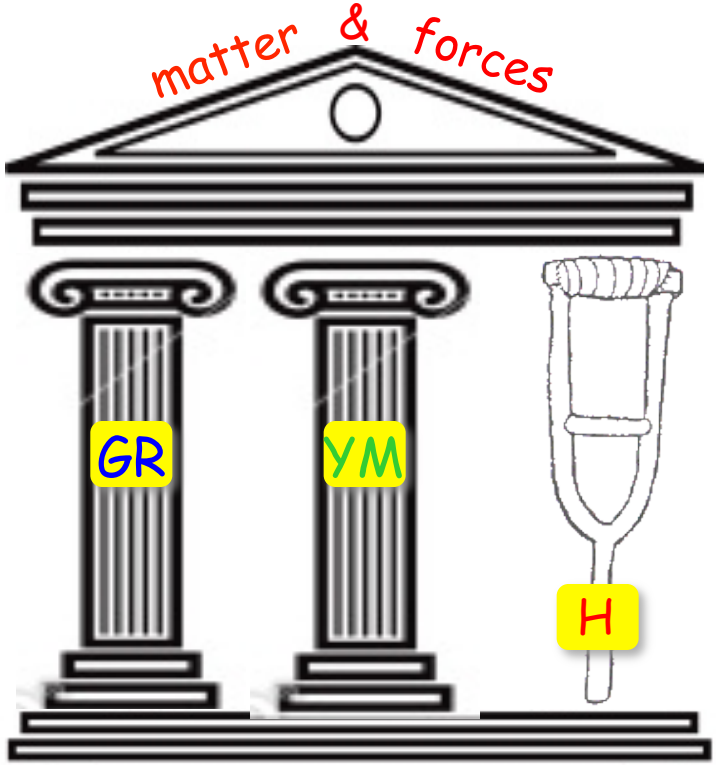




BICEP2 B−mode signal



The Standard Model is an extraordinary conceptual success

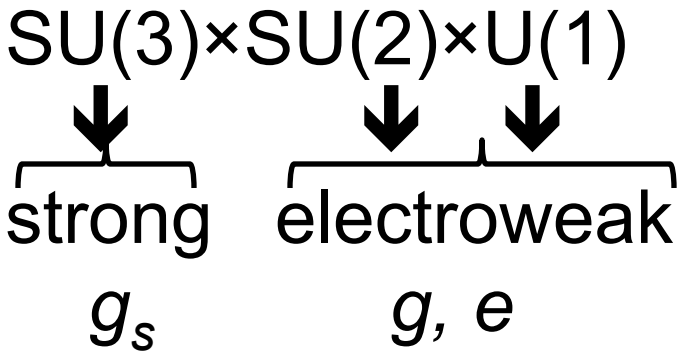


- GR & YM are elegant structures dictated by symmetry, have few free parameters, and fare marvelously with exp. data
- The Higgs sector looks like a provisional structure

➔ we have to look deeper (BSM)

Symmetry is the language of the fundamental laws of nature

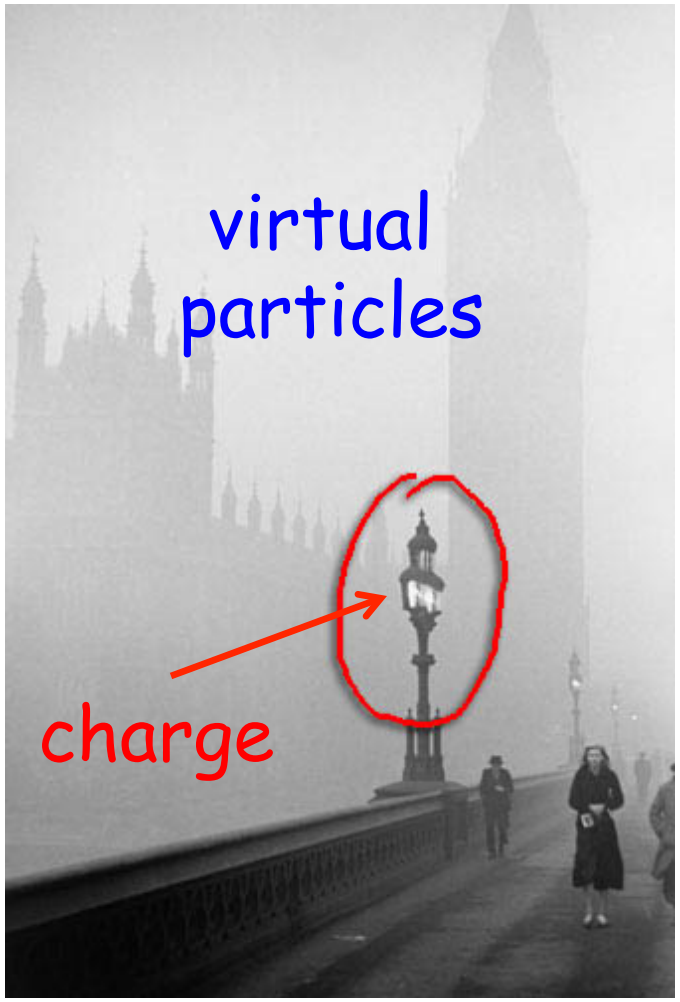
SM based on a symmetry principle:



Can we go further?

Grand unification: single force ➔ single coupling

Classical physics: force depends on distance
Quantum physics: charge depends on distance



A strange phenomenon

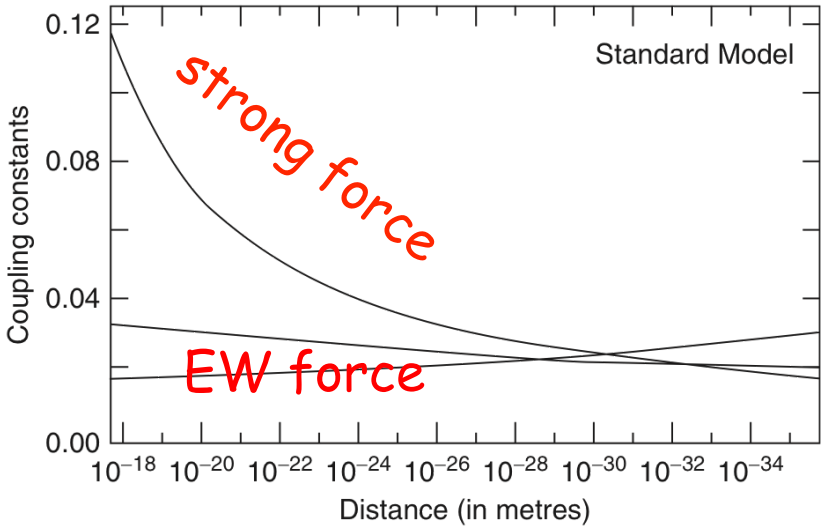
QED: virtual particles screen the charge ➔ charge gets weaker as we move away

Even stranger

QCD: virtual particles antiscreen the charge ➔ charge gets stronger as we move away

$$\frac{dg_i^{-2}}{d\ln Q} = \frac{b_i}{4\pi}$$

b_3=−7, b_2=−19/6, b_1=41/6



The screening (and antiscreening) depends on all species of existing particles

Extraordinary extrapolation to $M_X \sim 10^{14\text{-}16}$ GeV
Above M_X theory with single coupling (SU_5, SO_{10})