

# What don't we know?

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# A small selection...

- Neutrino masses
- Dark matter
- Inflation
- Matter / antimatter asymmetry
- 3 generations / mass hierarchy
- 4 dimensions

# Neutrino Masses

- 3 types, which can turn into one another
- Until this discovery, they were assumed to be massless.
- Two ways to explain where the mass comes from

# Dark Matter

- All our measurements (going back to 1930s) tell us something is out there
- But it doesn't look like anything we've seen before
- Lots of experiments looking for something new

# Inflation

- The universe is very flat and looks the same everywhere
- But it seems too big to be this way
- Inflation is an idea to try and explain this

# Matter / Antimatter Asymmetry

- Antimatter is just the same as normal matter

# Matter / Antimatter Asymmetry

- Antimatter is just the same as normal matter
- So where is it all?
- We think we know – but the numbers don't work

# 3 of everything

## FERMIONS

matter constituents  
spin = 1/2, 3/2, 5/2, ...

Leptons spin = 1/2			Quarks spin = 1/2		
Flavor	Mass GeV/c <sup>2</sup>	Electric charge	Flavor	Approx. Mass GeV/c <sup>2</sup>	Electric charge
$\nu_L$ lightest neutrino*	$(0-2) \times 10^{-9}$	0	<b>u</b> up	0.002	2/3
<b>e</b> electron	0.000511	-1	<b>d</b> down	0.005	-1/3
$\nu_M$ middle neutrino*	$(0.009-2) \times 10^{-9}$	0	<b>c</b> charm	1.3	2/3
$\mu$ muon	0.106	-1	<b>s</b> strange	0.1	-1/3
$\nu_H$ heaviest neutrino*	$(0.05-2) \times 10^{-9}$	0	<b>t</b> top	173	2/3
$\tau$ tau	1.777	-1	<b>b</b> bottom	4.2	-1/3



# 3 of everything

- The Standard Model has 3 copies of all the particles that make up matter
- But the world around us is only made up of one set

# 3 of everything

- The Standard Model has 3 copies of all the particles that make up matter
- But the world around us is only made up of one set
- So who ordered the other two?

# 4 of some things

- Our world is 4 dimensional:
  - 3 space
  - 1 time
- Is this even a sensible question to ask?



**Thanks!**