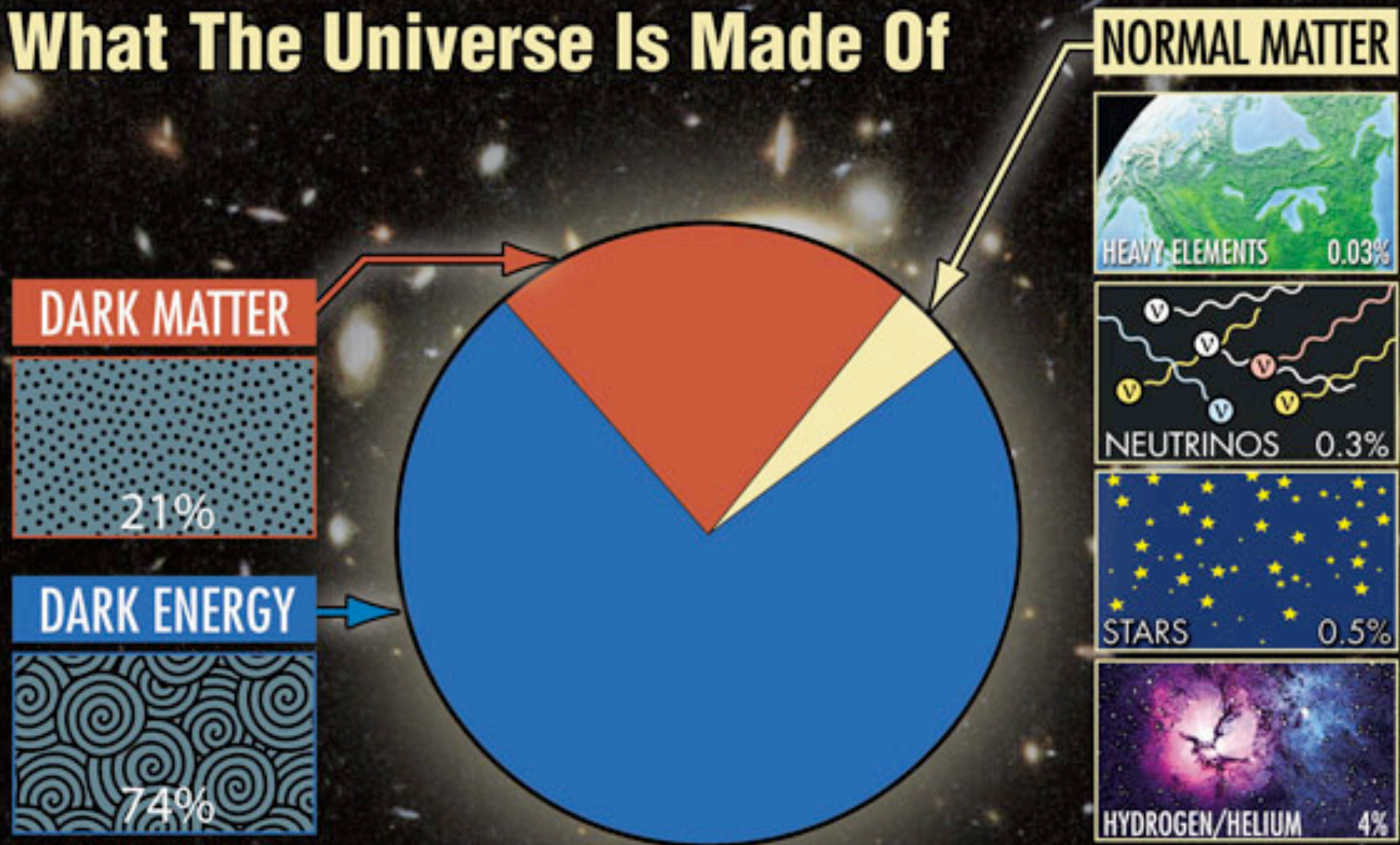




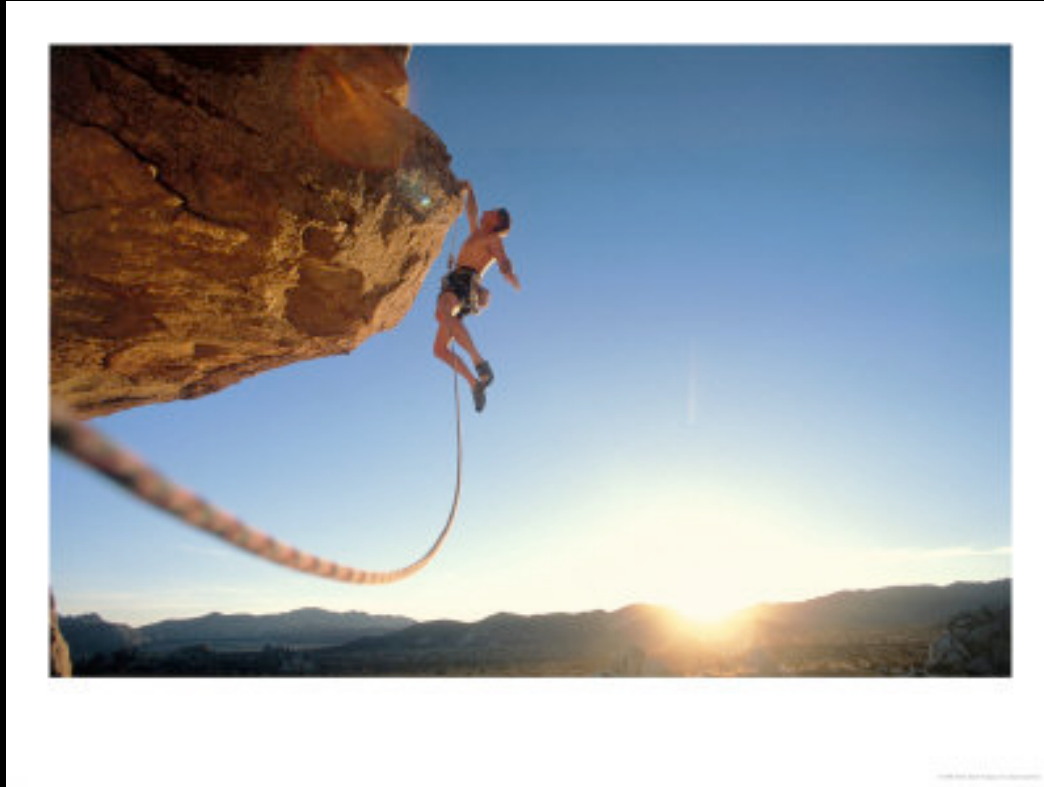
Where do atoms  
come from ?



# What The Universe Is Made Of



# What are humans made of?



The average human body contains enough: **sulphur** to kill all fleas on an average dog, **carbon** to make 900 pencils, **potassium** to fire a toy cannon, **fat** to make 7 bars of soap, **phosphorus** to make 2,200 match heads, **water** to fill a ten-gallon tank, and enough **iron** to make a 3 inch nail.

oxygen 43 kg  
carbon 16 kg  
hydrogen 7 kg  
nitrogen 1.8 kg  
calcium 1.0 kg  
phosphorus 780 g  
potassium 140 g  
sulfur 140 g  
sodium 100 g  
chlorine 95 g  
magnesium 19 g  
iron 4.2 g  
fluorine 2.6 g  
zinc 2.3 g  
silicon 1.0 g  
rubidium 0.68 g  
strontium 0.32 g  
bromine 0.26 g  
lead 0.12 g  
copper 72 mg  
aluminum 60 mg  
cadmium 50 mg  
cerium 40 mg  
barium 22 mg  
iodine 20 mg  
tin 20 mg  
titanium 20 mg  
boron 18 mg  
nickel 15 mg  
selenium 15 mg  
chromium 14 mg  
manganese 12 mg  
arsenic 7 mg  
lithium 7 mg  
cesium 6 mg  
mercury 6 mg  
germanium 5 mg  
molybdenum 5 mg  
cobalt 3 mg  
antimony 2 mg  
silver 2 mg  
niobium 1.5 mg  
zirconium 1 mg  
lanthanum 0.8 mg  
gallium 0.7 mg  
tellurium 0.7 mg  
yttrium 0.6 mg  
bismuth 0.5 mg  
thallium 0.5 mg  
indium 0.4 mg  
gold 0.2 mg  
scandium 0.2 mg



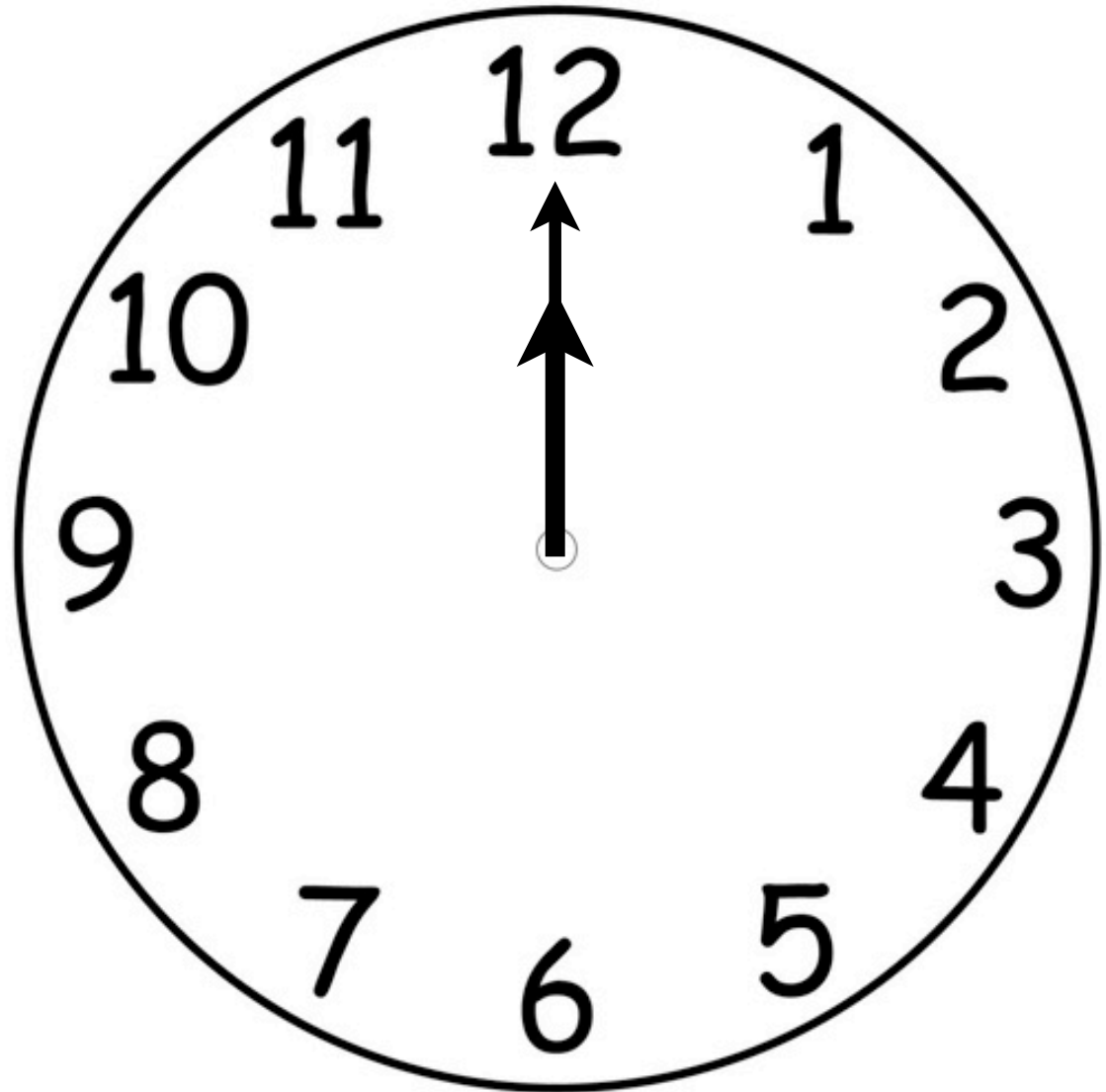
# Two fabulous facts about the elements

- The lightest elements were forged just a few minutes after the Big Bang
- Heavier elements are formed inside stars, and scattered throughout the Universe by supernovae



- 
- The Universe is 7.2 million, billion minutes old !

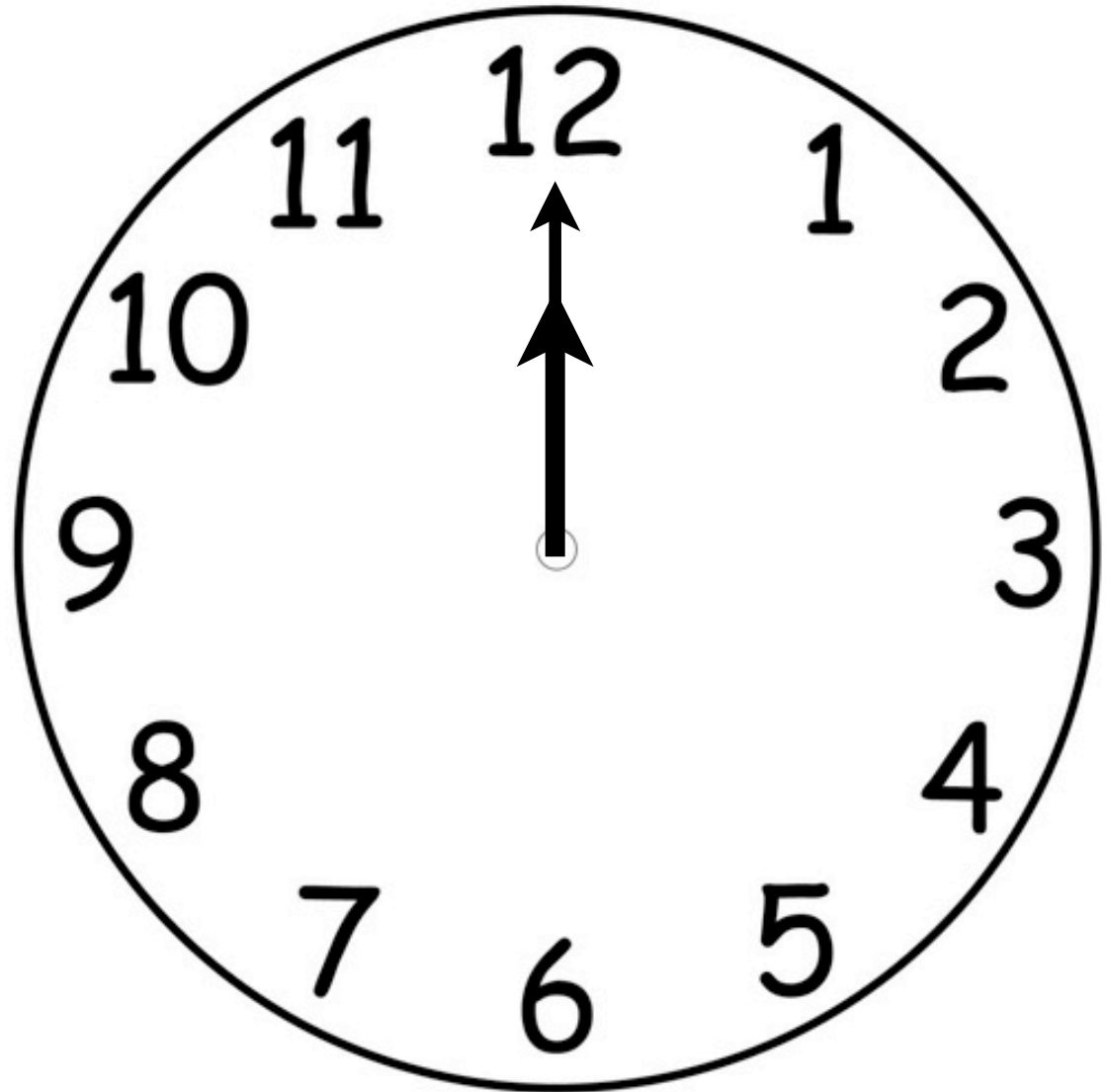
# The Universe in an afternoon





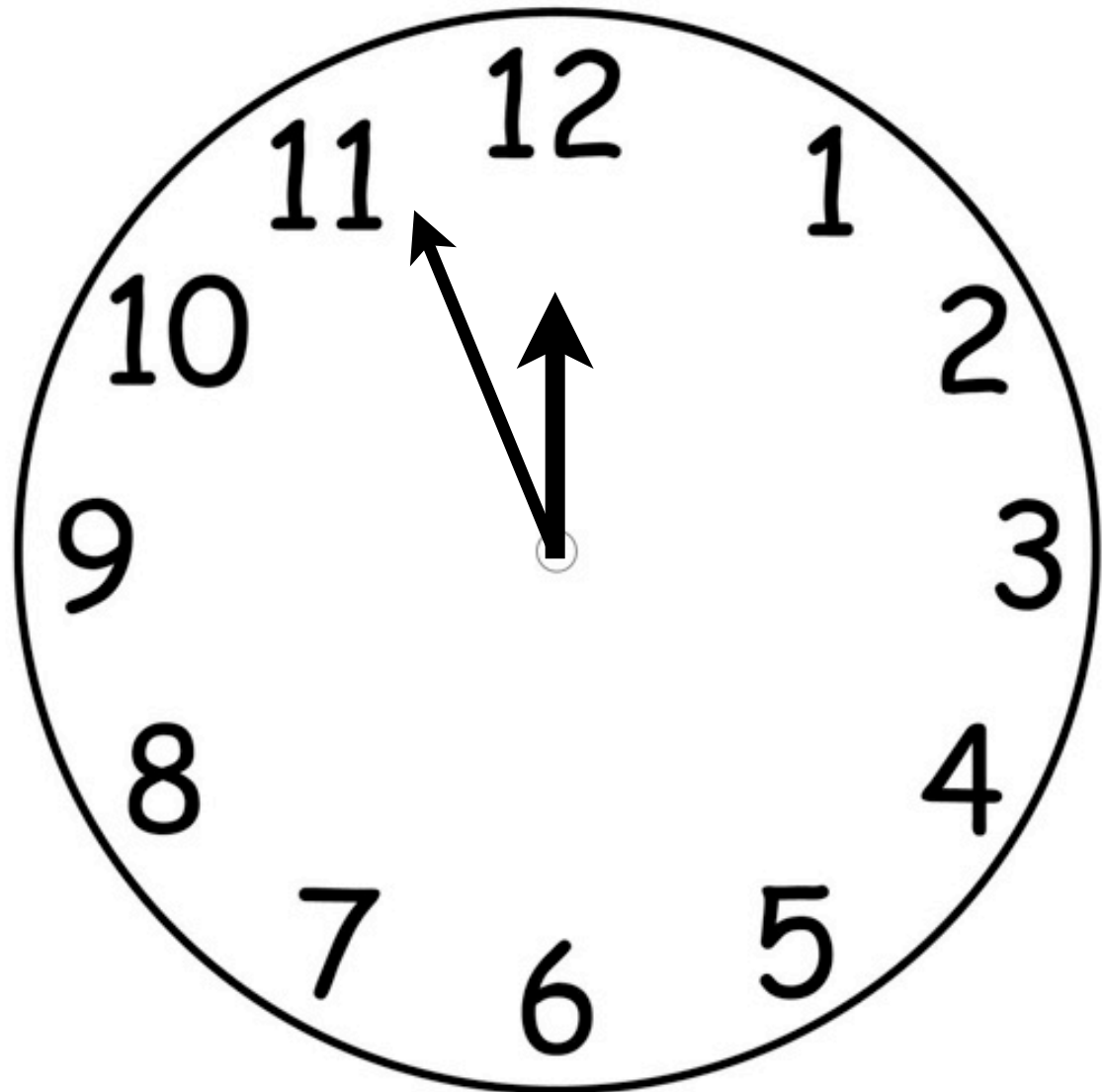
# The Universe in an afternoon

My lifetime ...



# The Universe in an afternoon

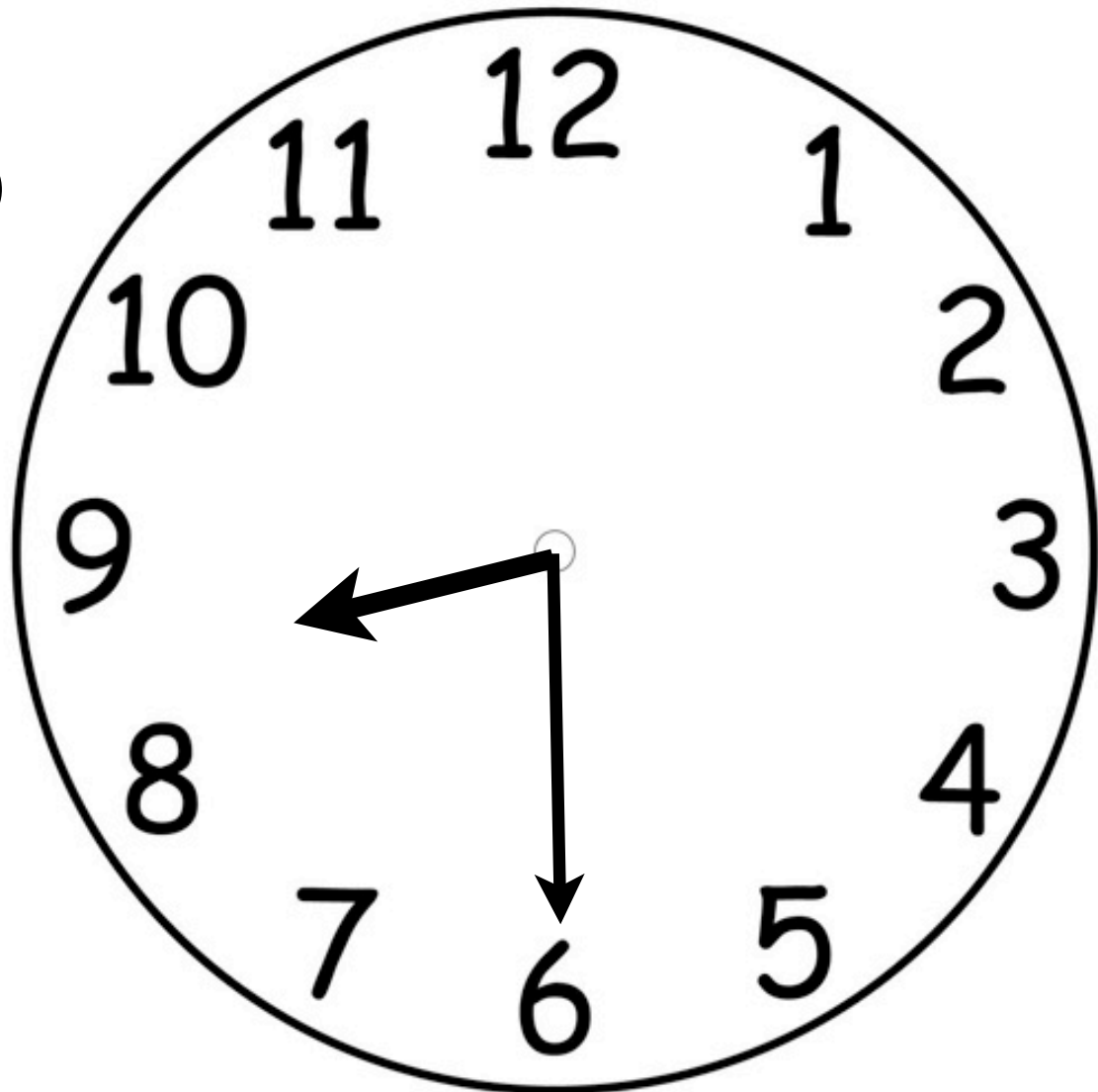
Extinction of the  
dinosaurs ...  
(65 million yrs)





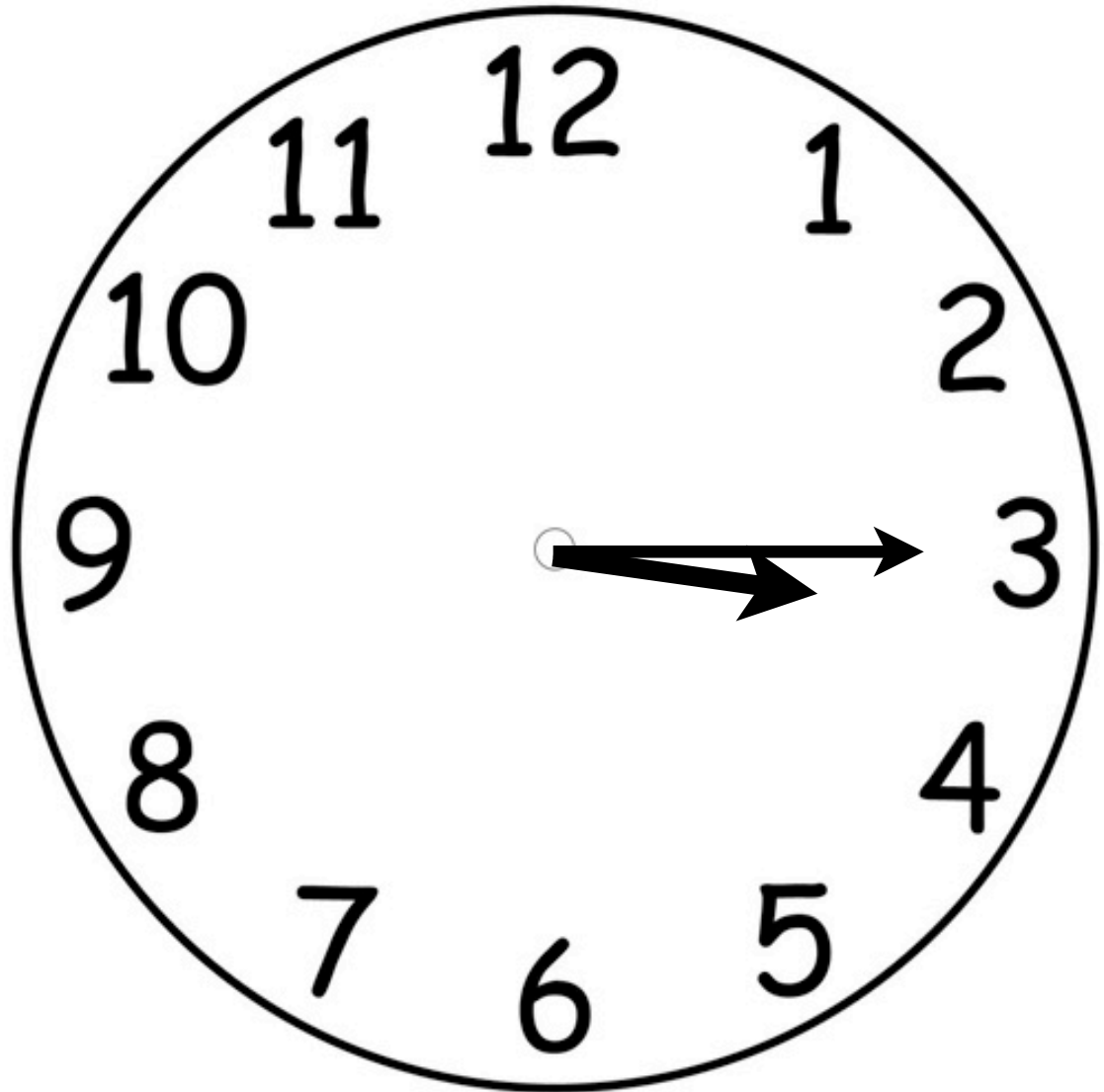
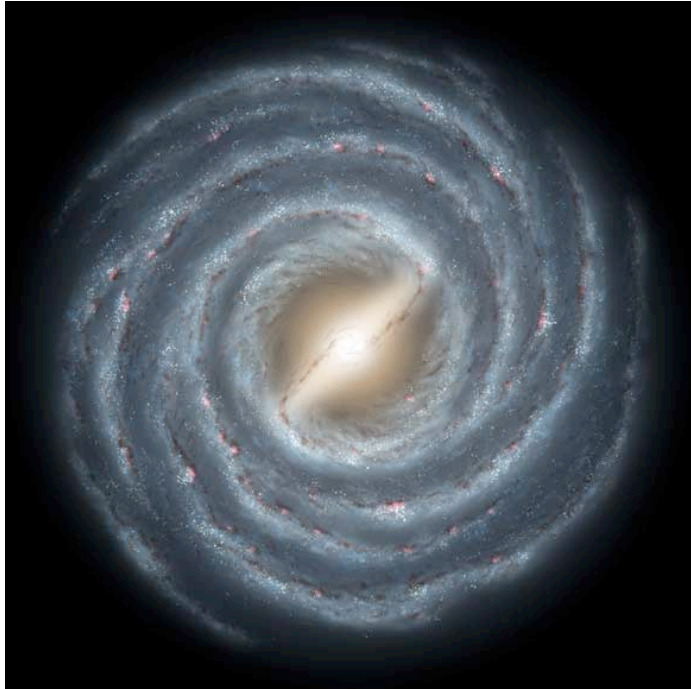
# The Universe in an afternoon

Formation of the  
solar system ...  
(approx. 4 billion yrs)



# The Universe in an afternoon

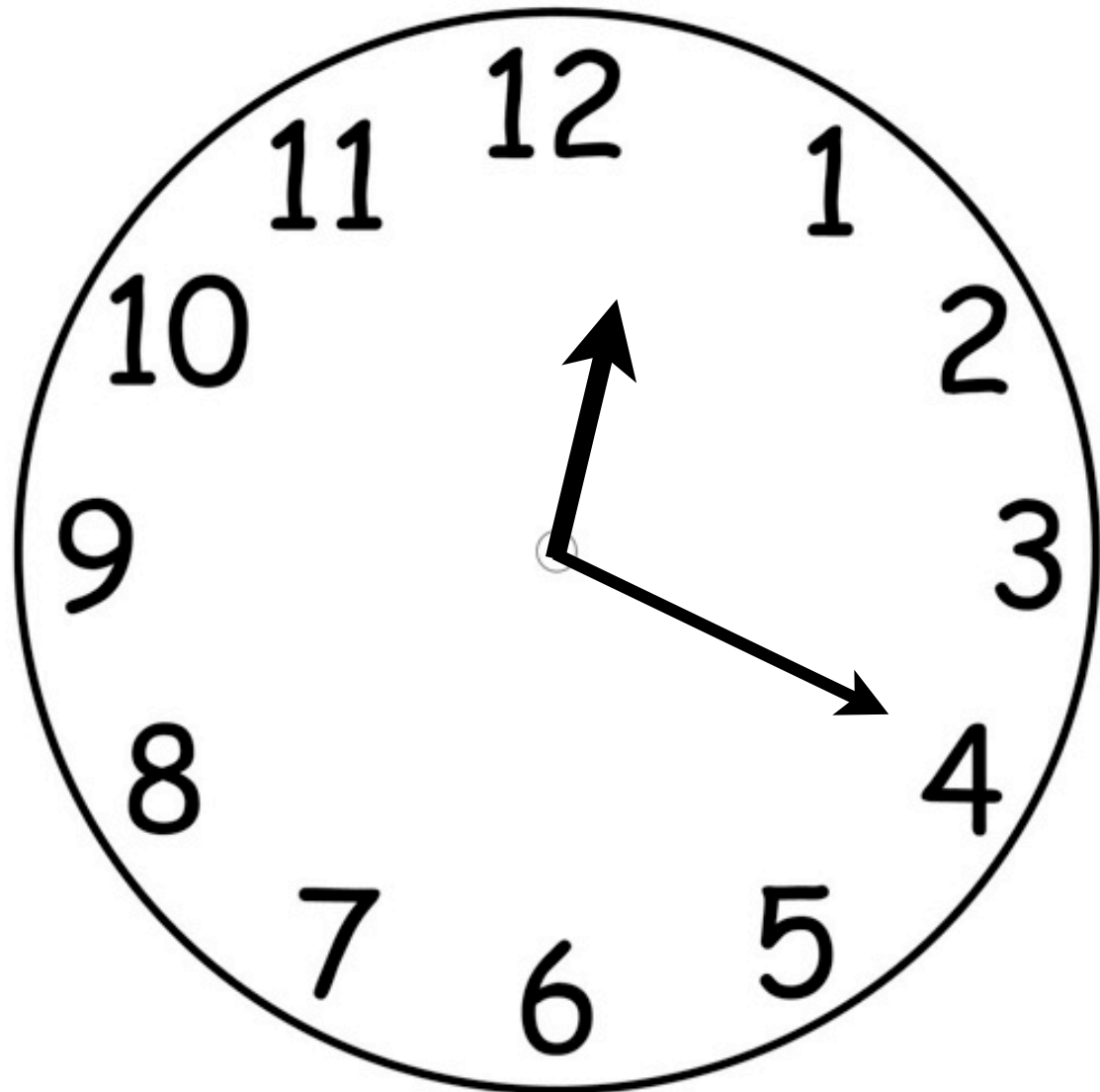
Formation of our galaxy ... (approx. 10 billion yrs)





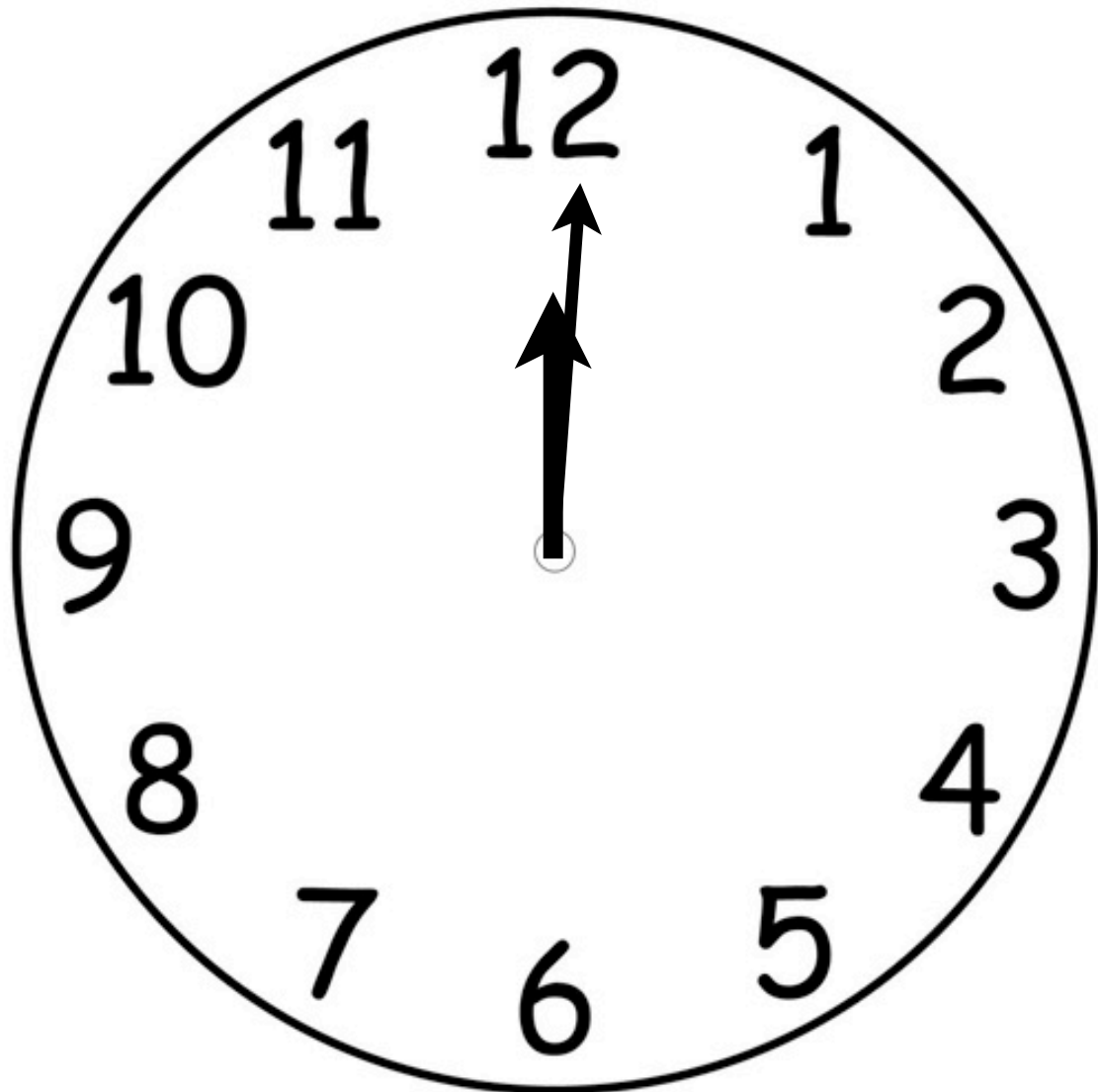
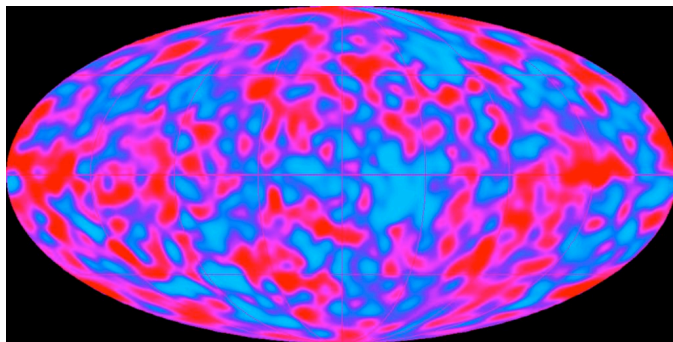
# The Universe in an afternoon

Formation of first stars ... (approx. 13.3 billion yrs)



# The Universe in an afternoon

The first light we  
can detect (13.7  
billion yrs)

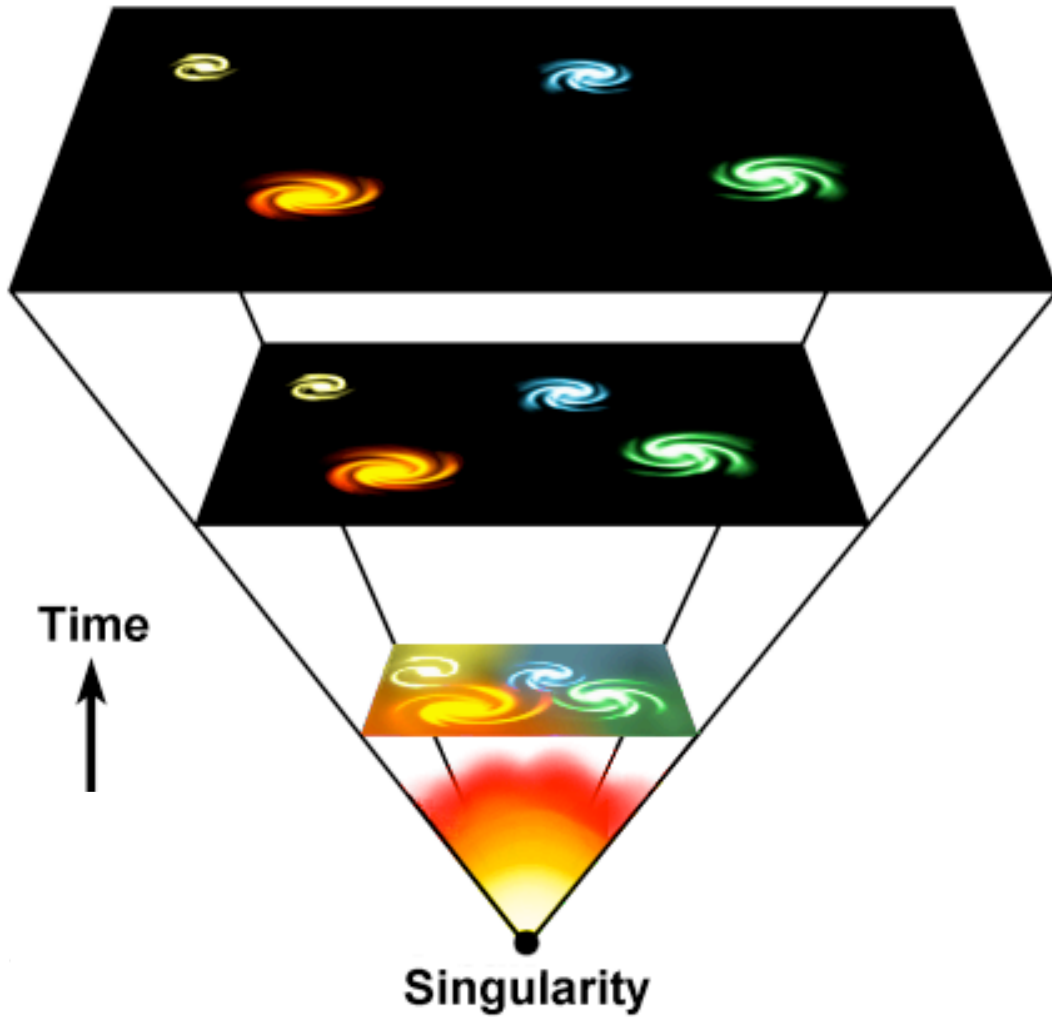




# The expanding Universe



# The expanding Universe



# The Universe is a time machine



Fun fact:  
Light travels at  
300,000 km/s

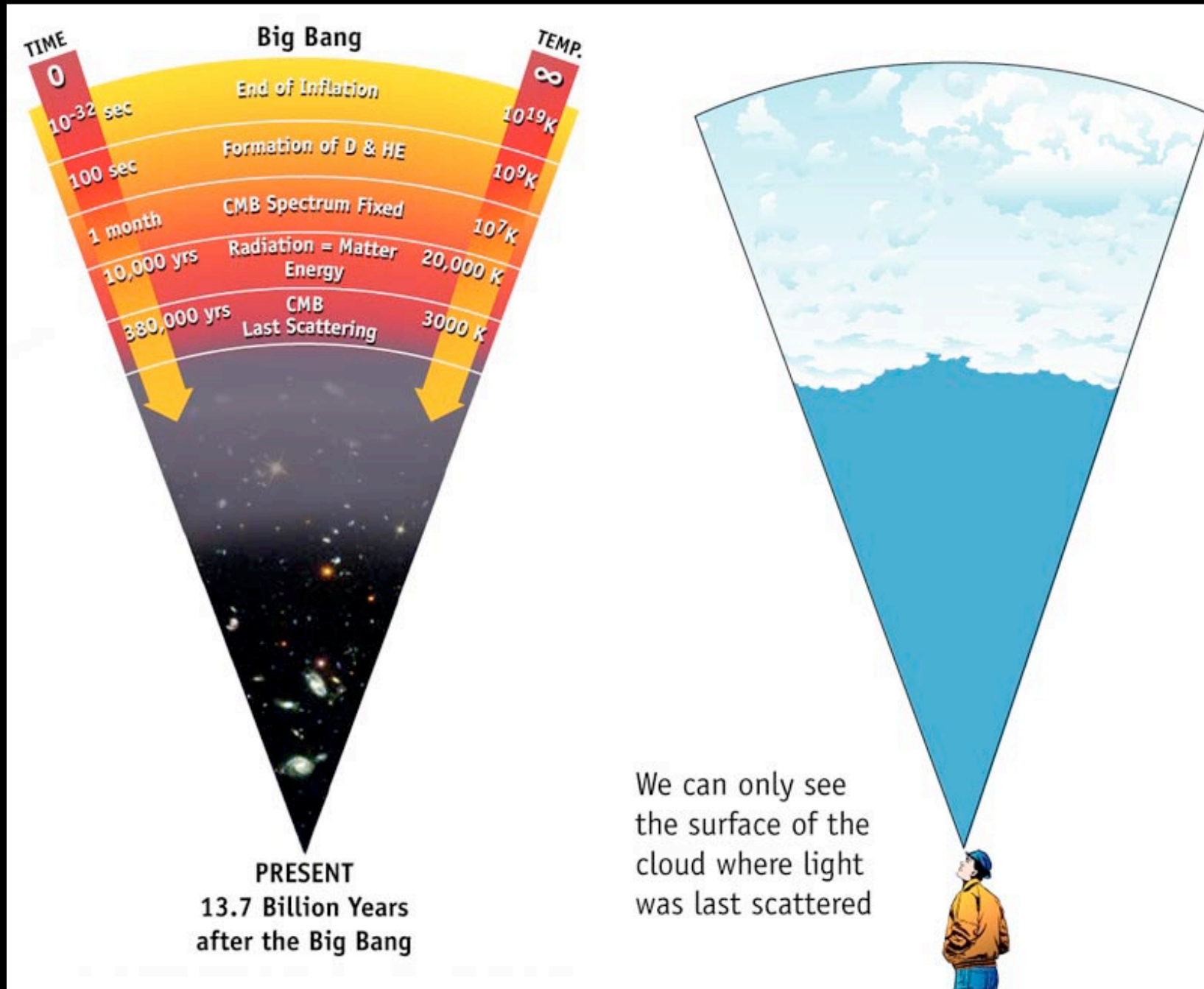


# The Universe is a time machine

<http://hubblesite.org/newscenter/archive/>

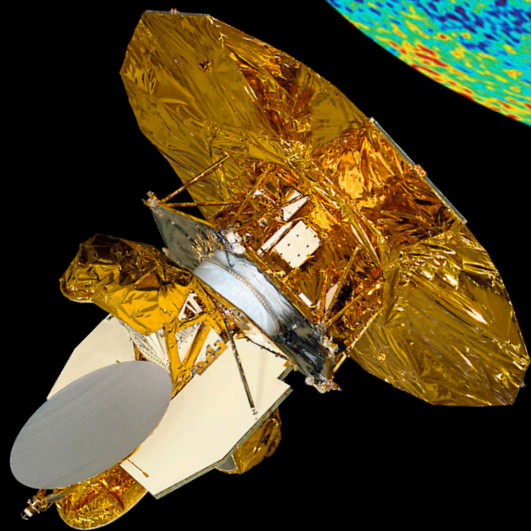
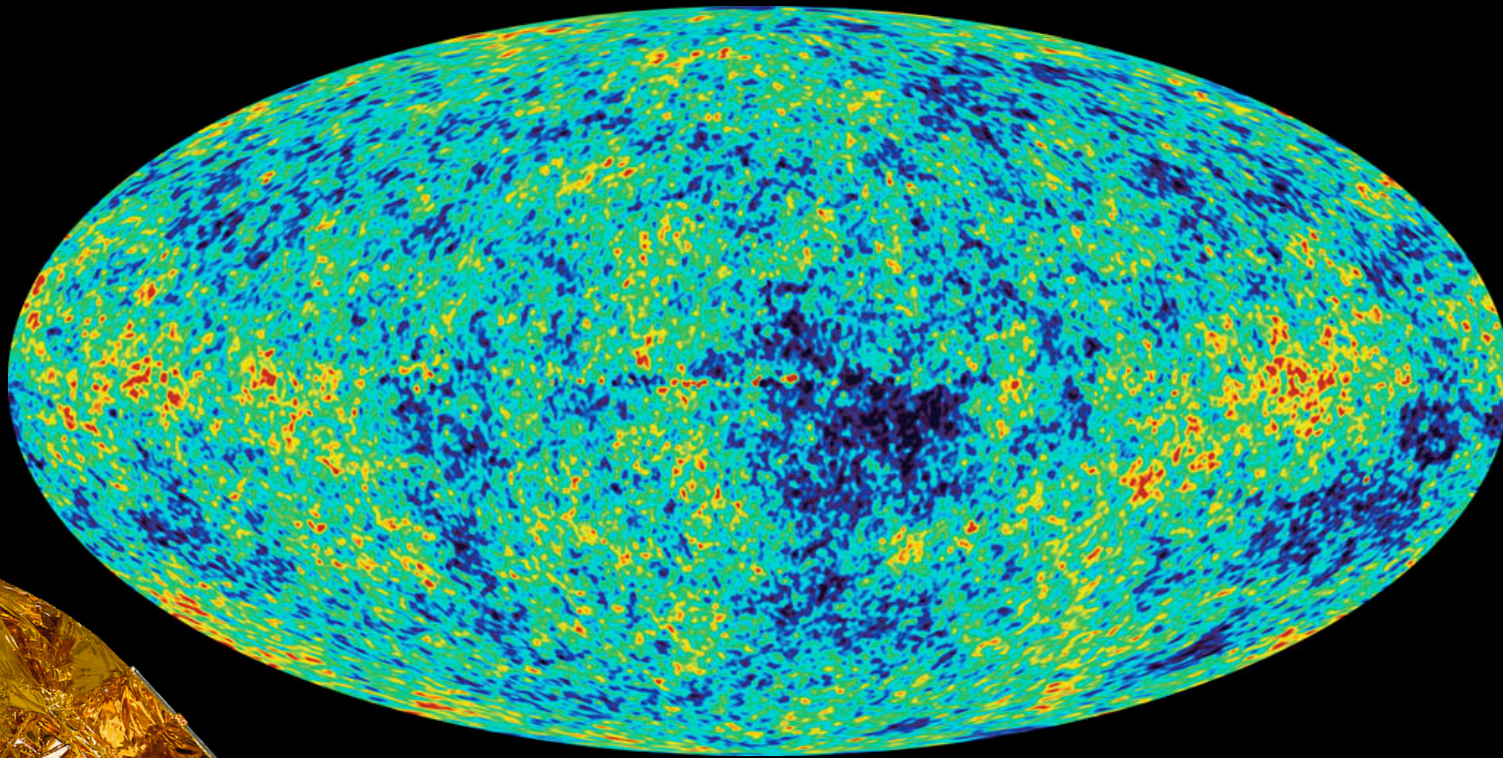


# The Cosmic Microwave Background





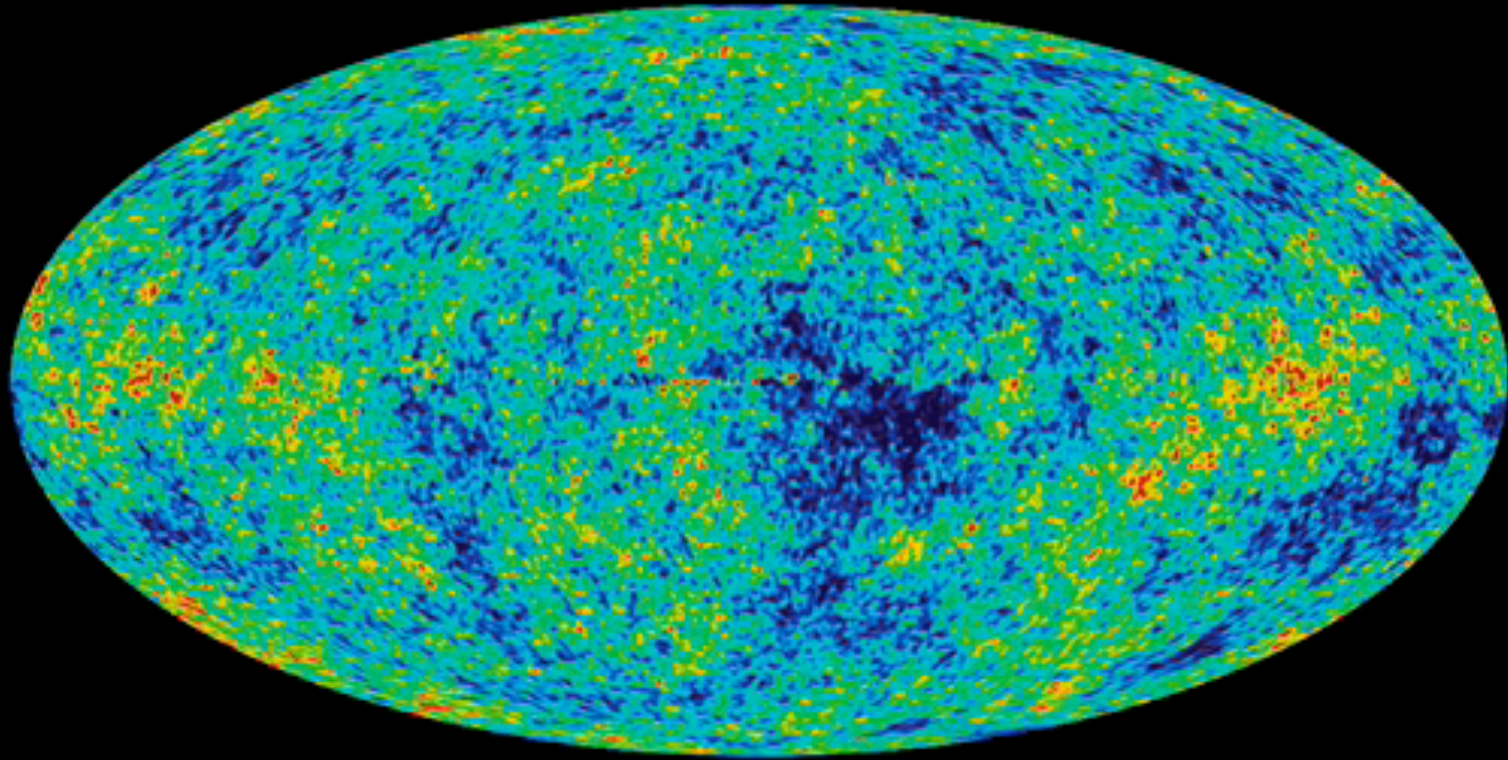
# The Cosmic Microwave Background



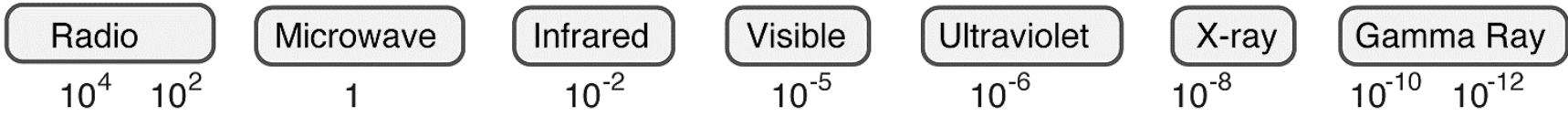
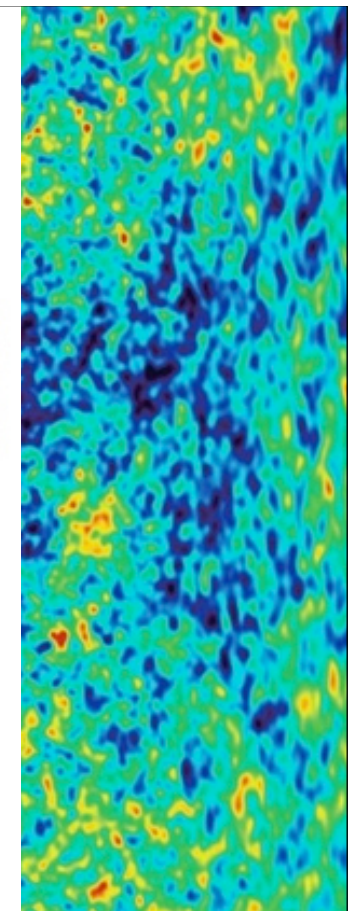
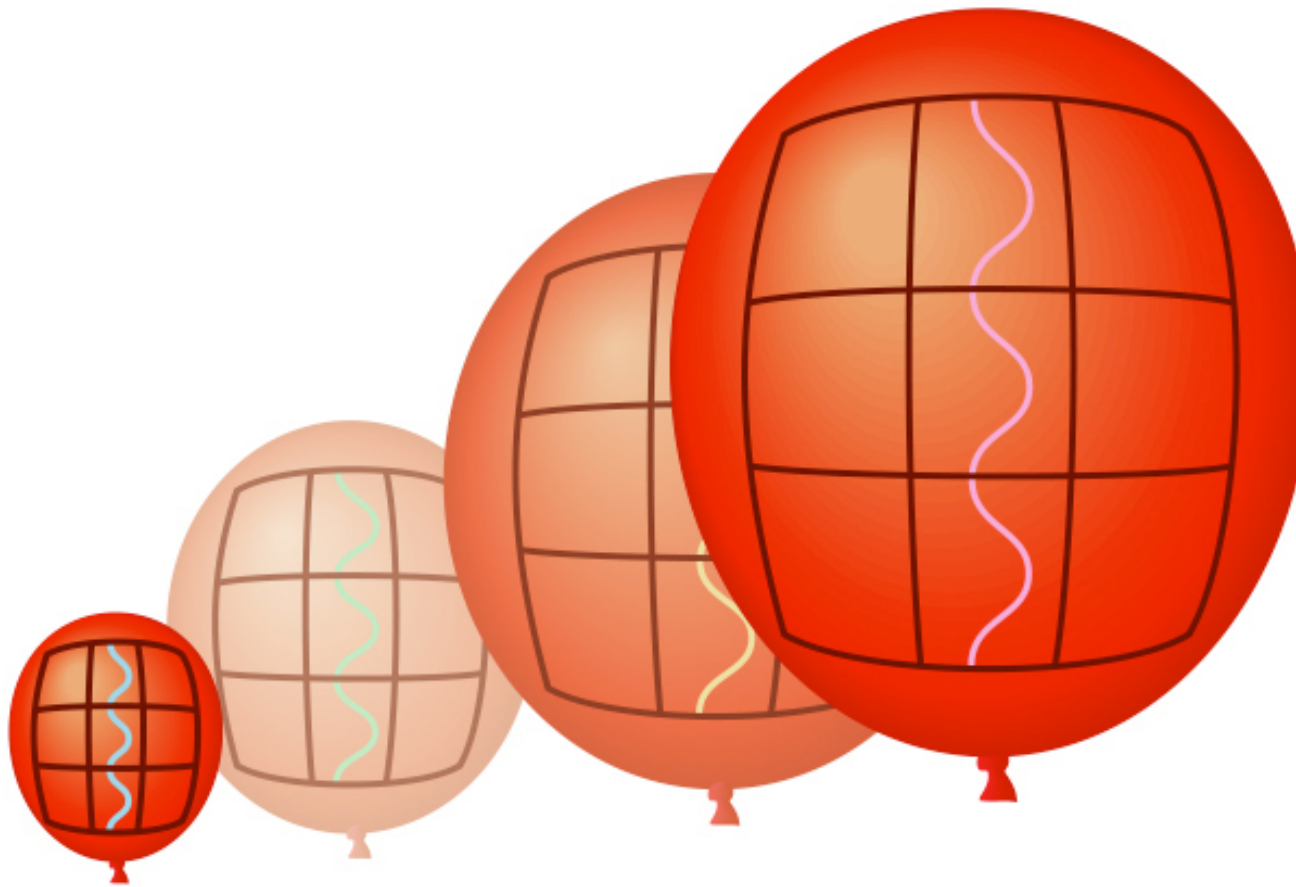
Wilkinson Microwave  
Anisotropy Probe



Now running the clock forwards ...



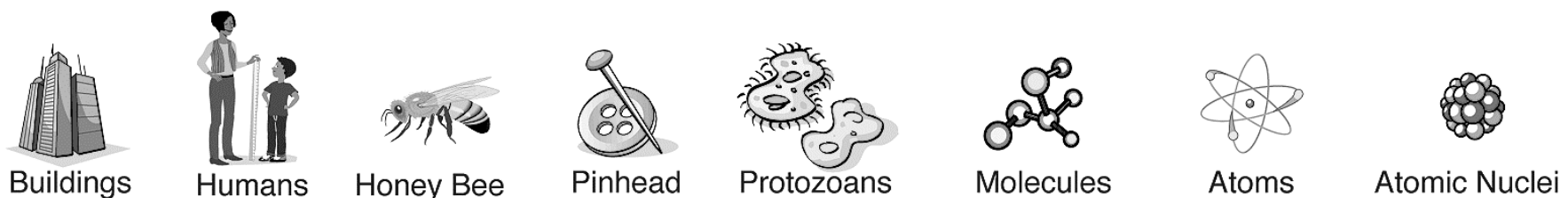
<http://map.gsfc.nasa.gov/resources/animconcepts.html>



Wavelength in centimeters

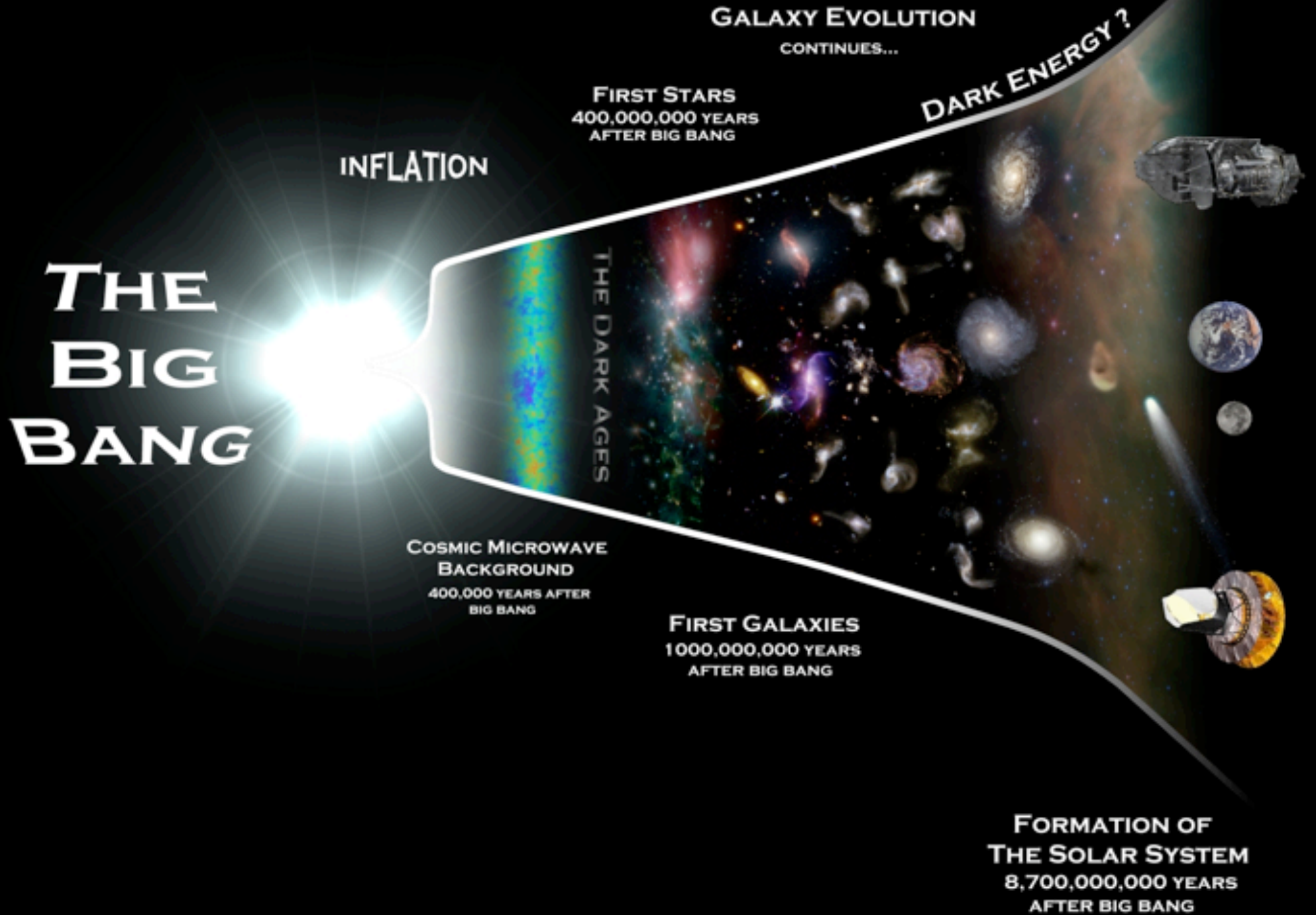


About the size of...



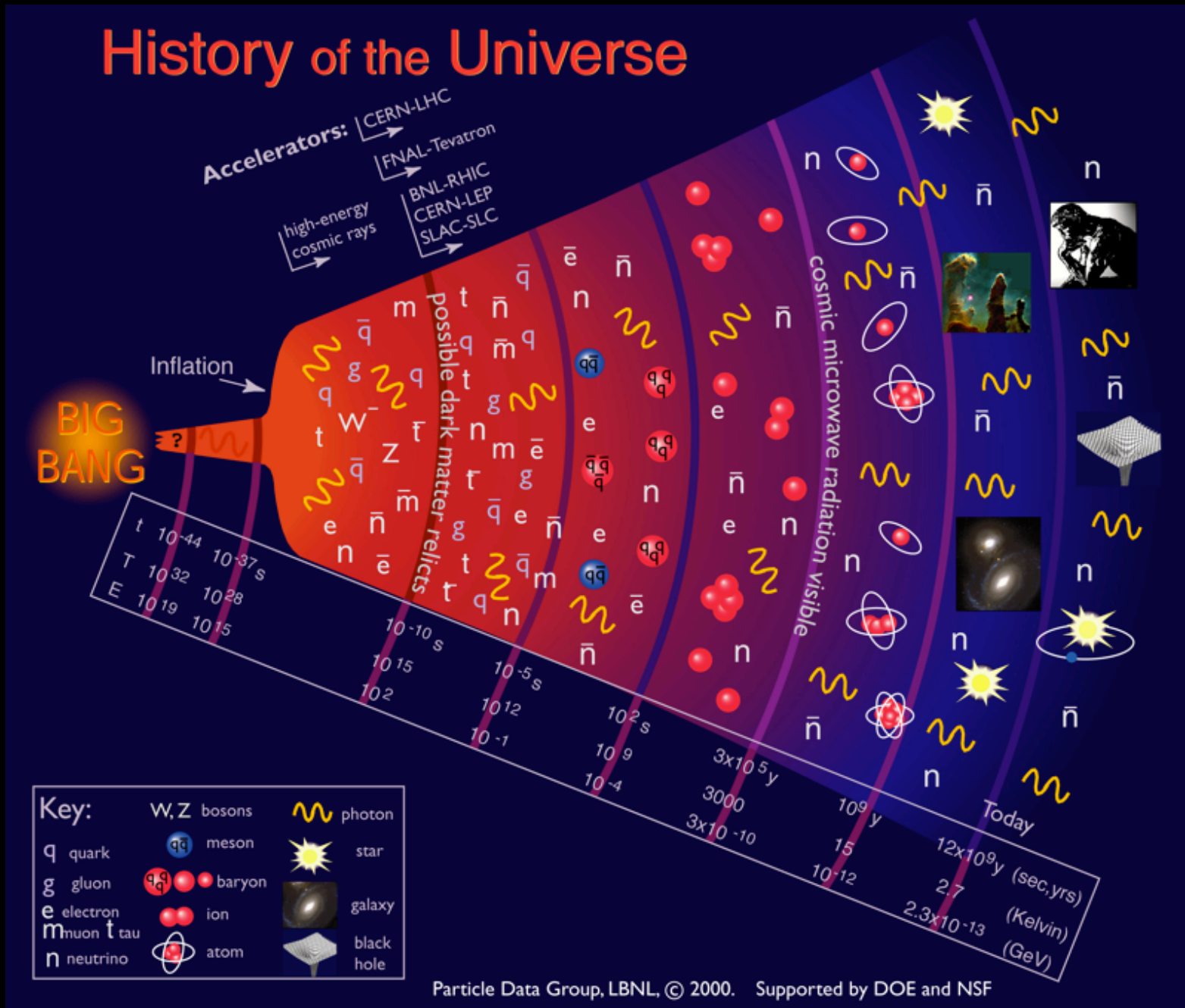


# The astronomer's view ...

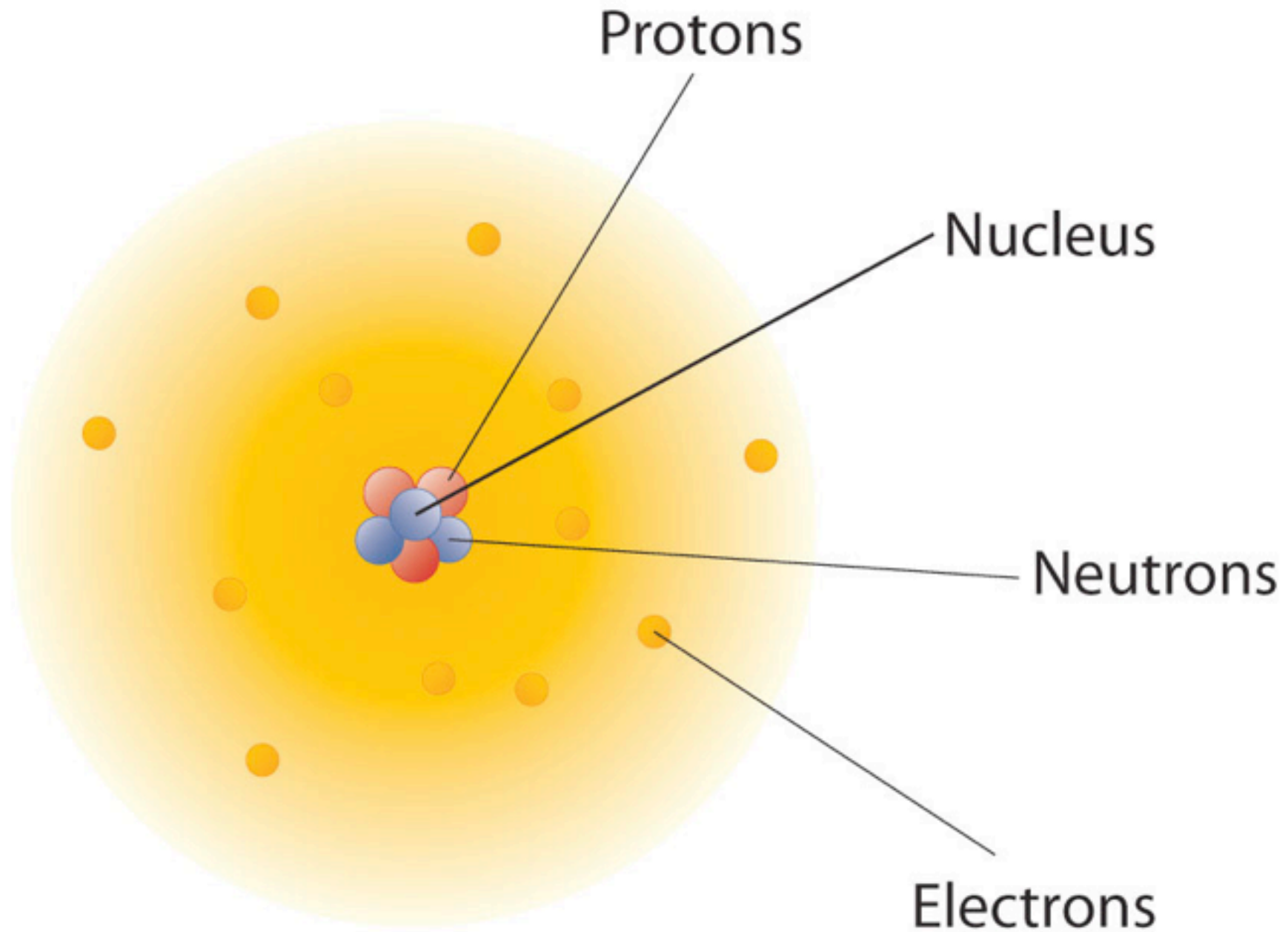




# The particle physicist's view ...



# What makes up an atom?

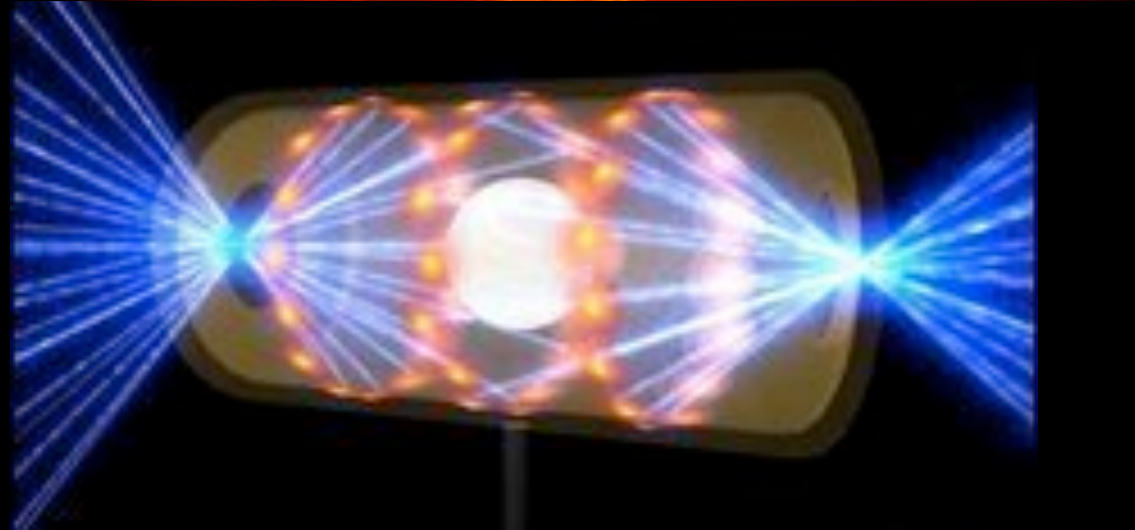
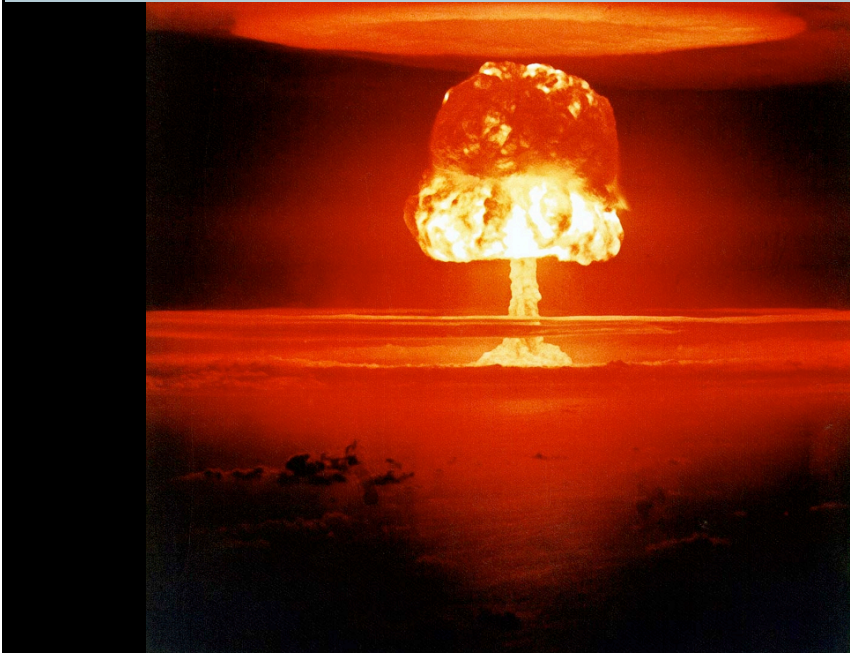
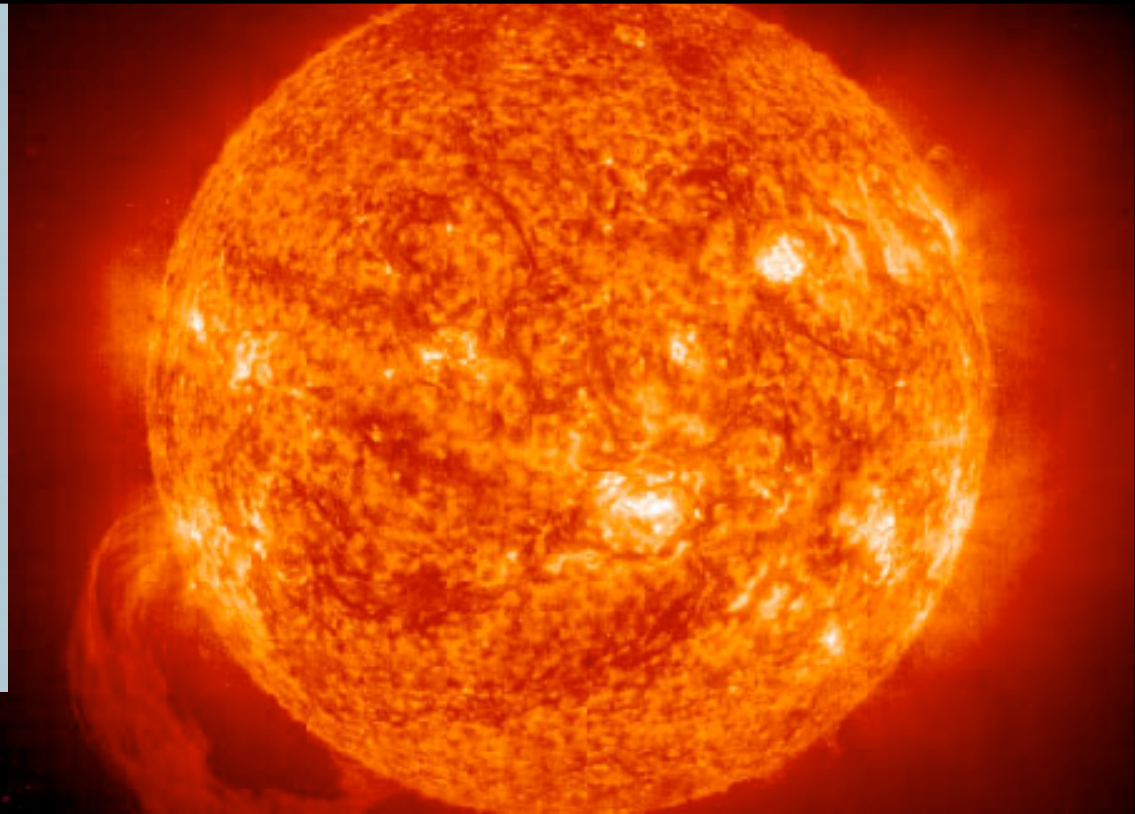
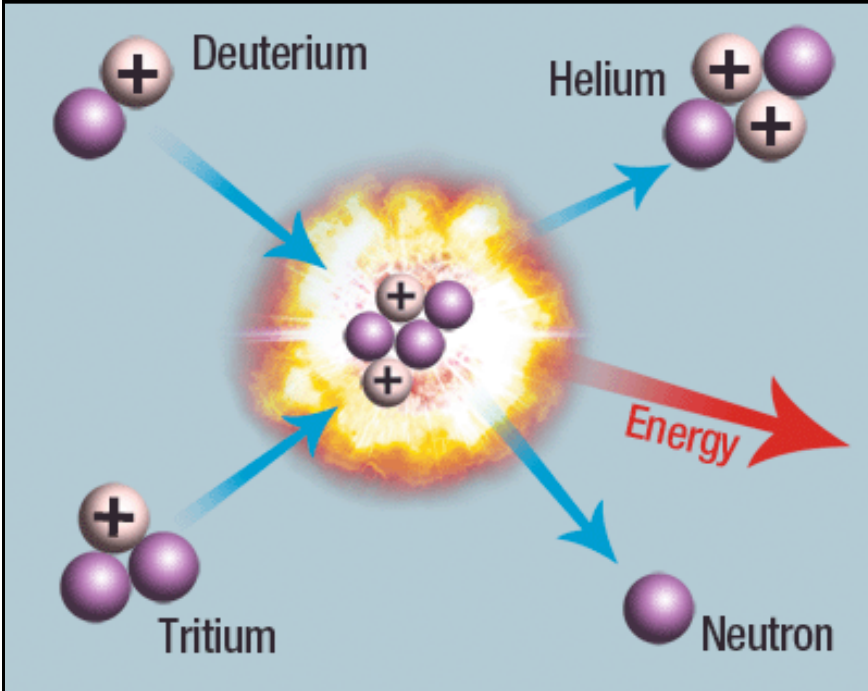


# What happens if I heat up these atoms?

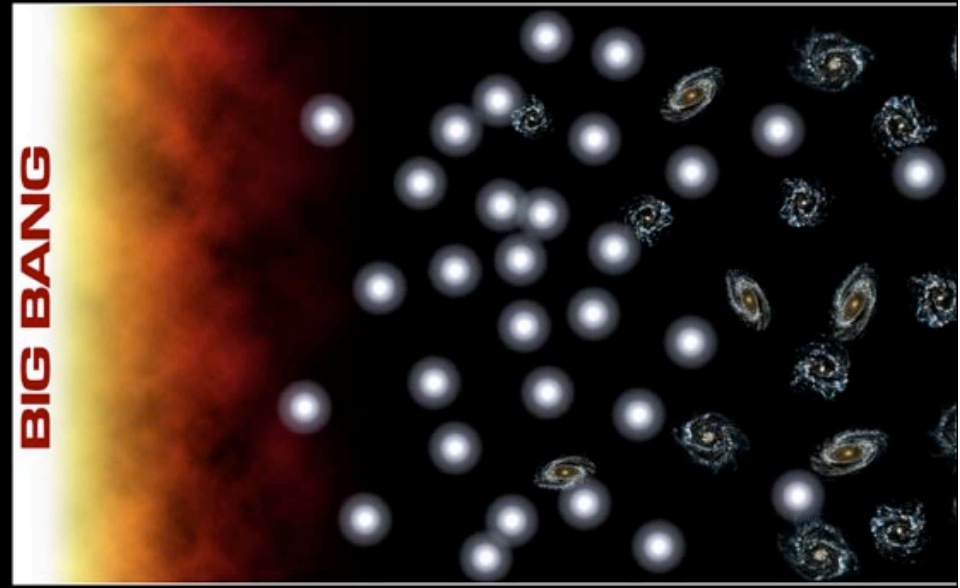
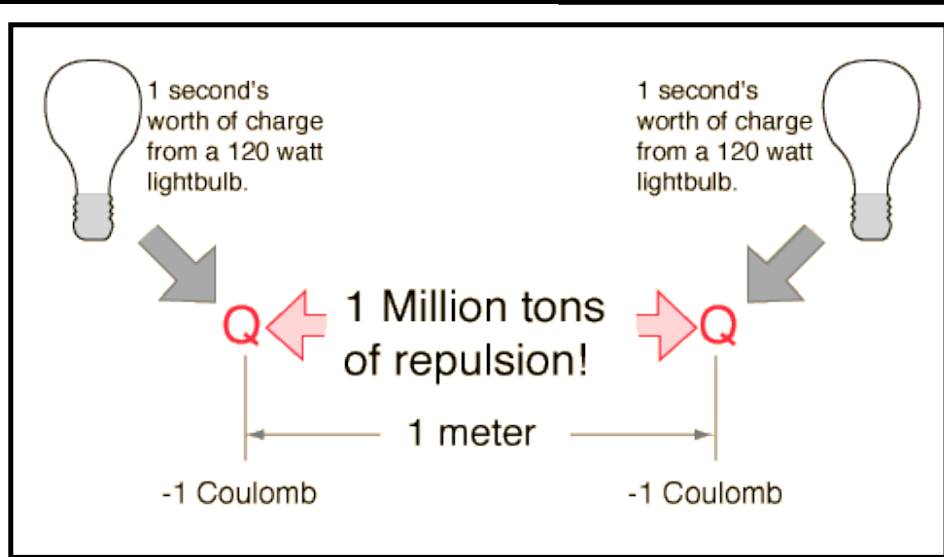
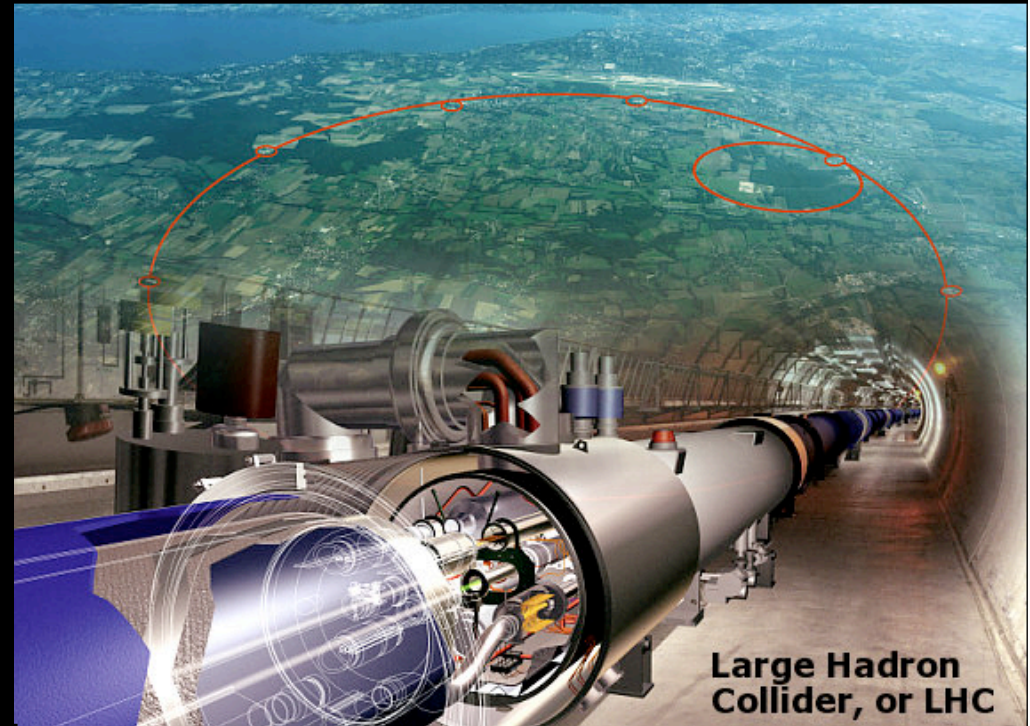
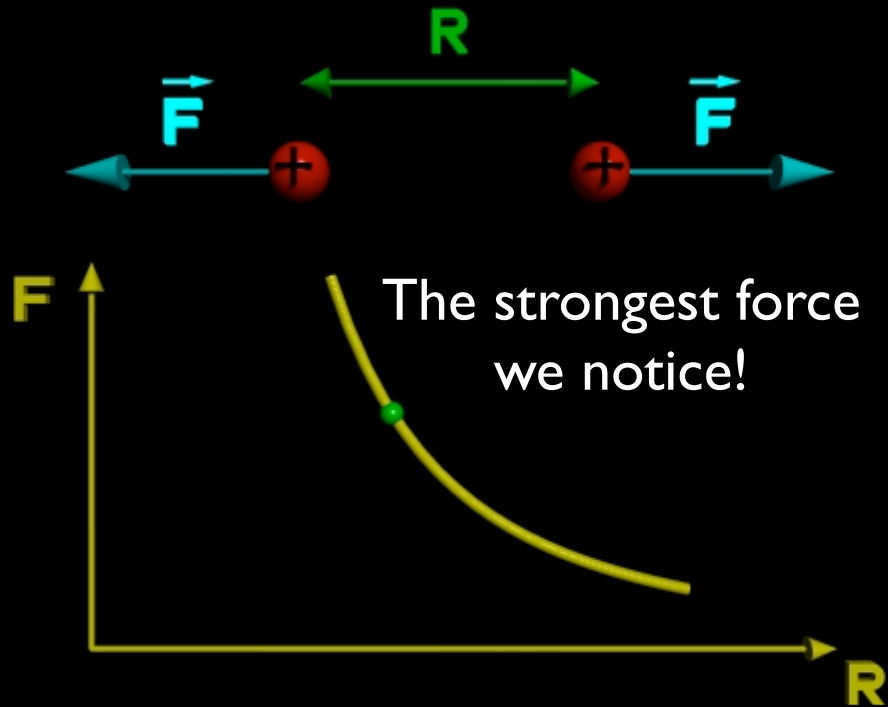
- They lose all their electrons
- They start fusing together!



# Nuclear fusion

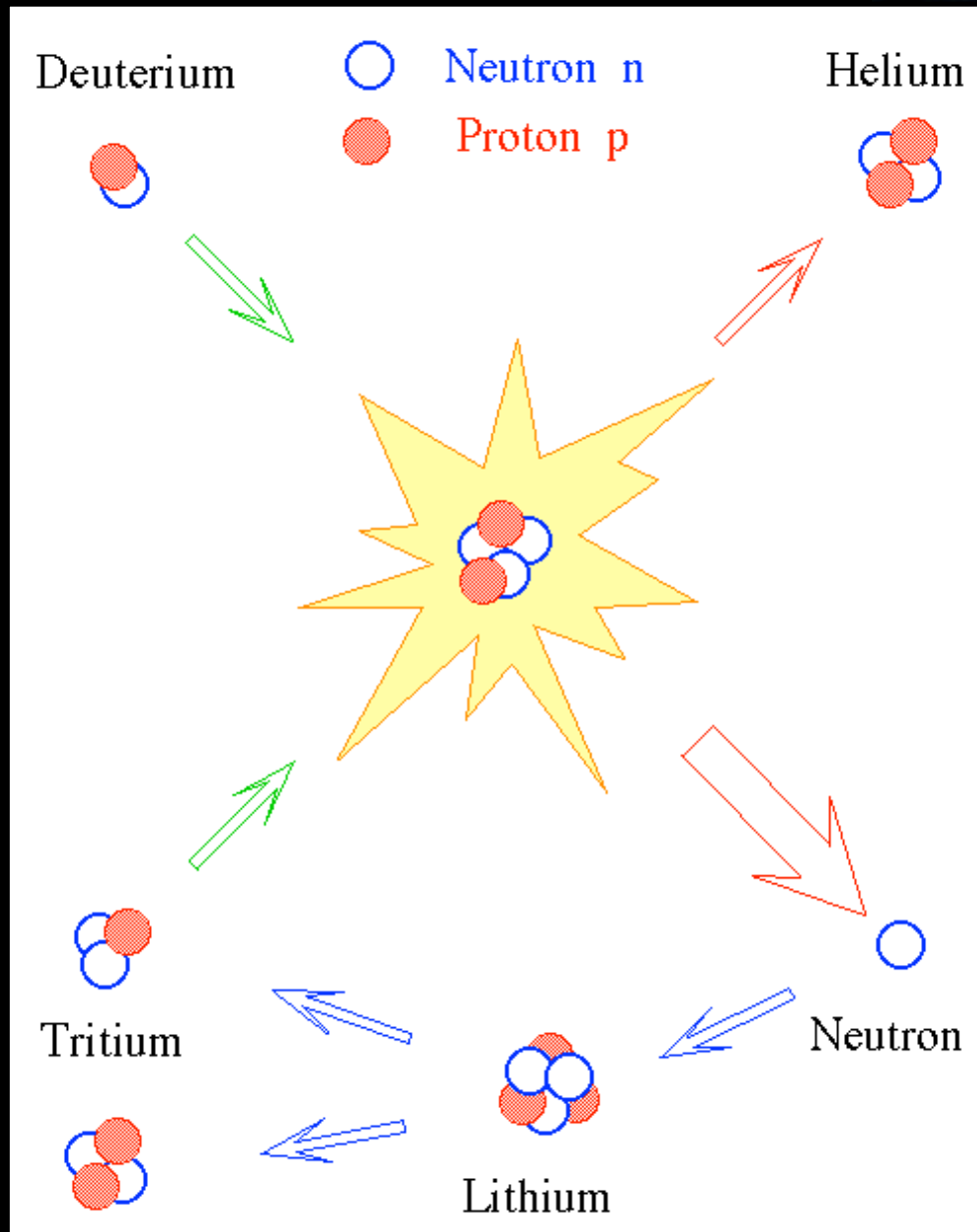


# Why does fusion need such heat?



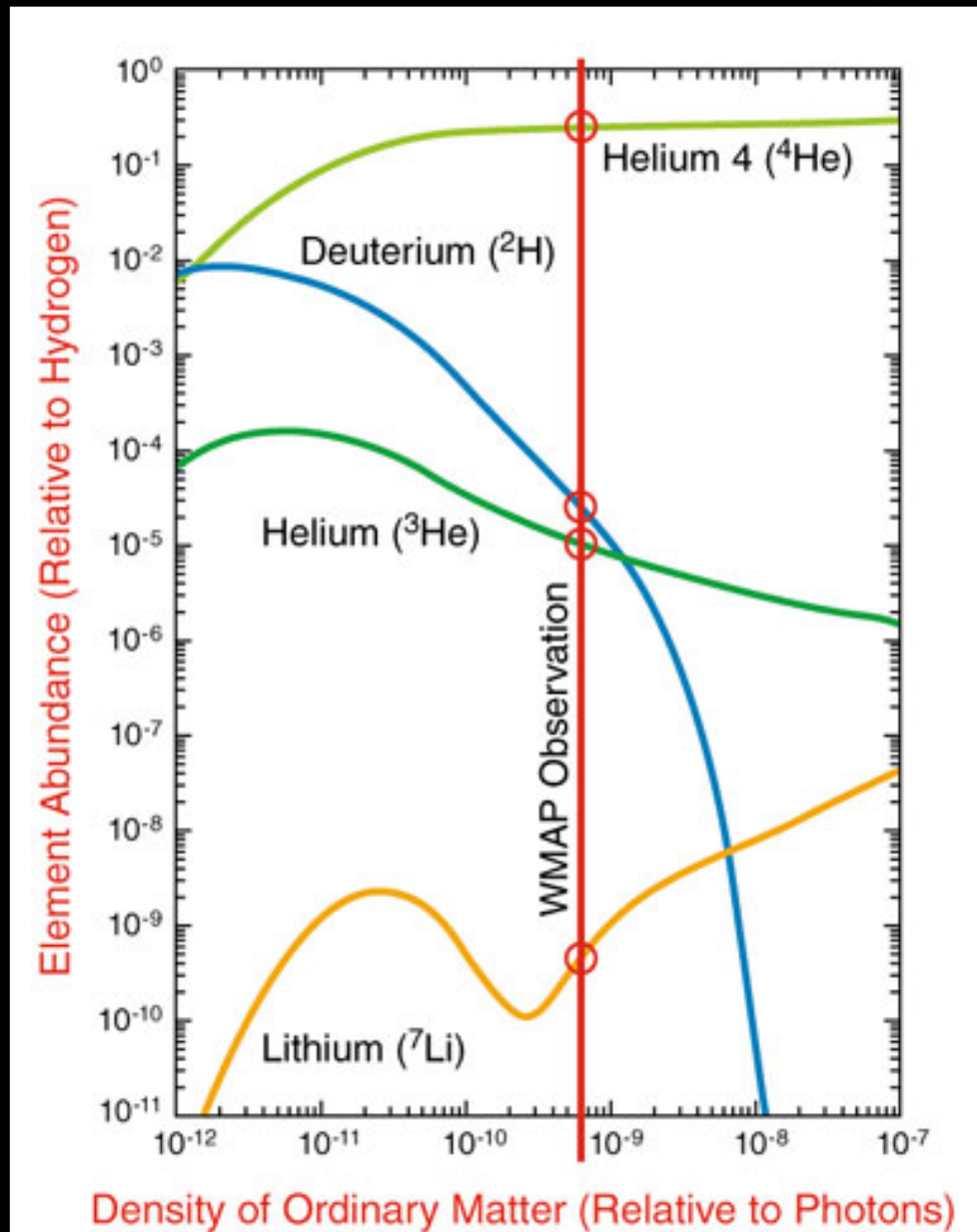


# Big Bang Nucleosynthesis





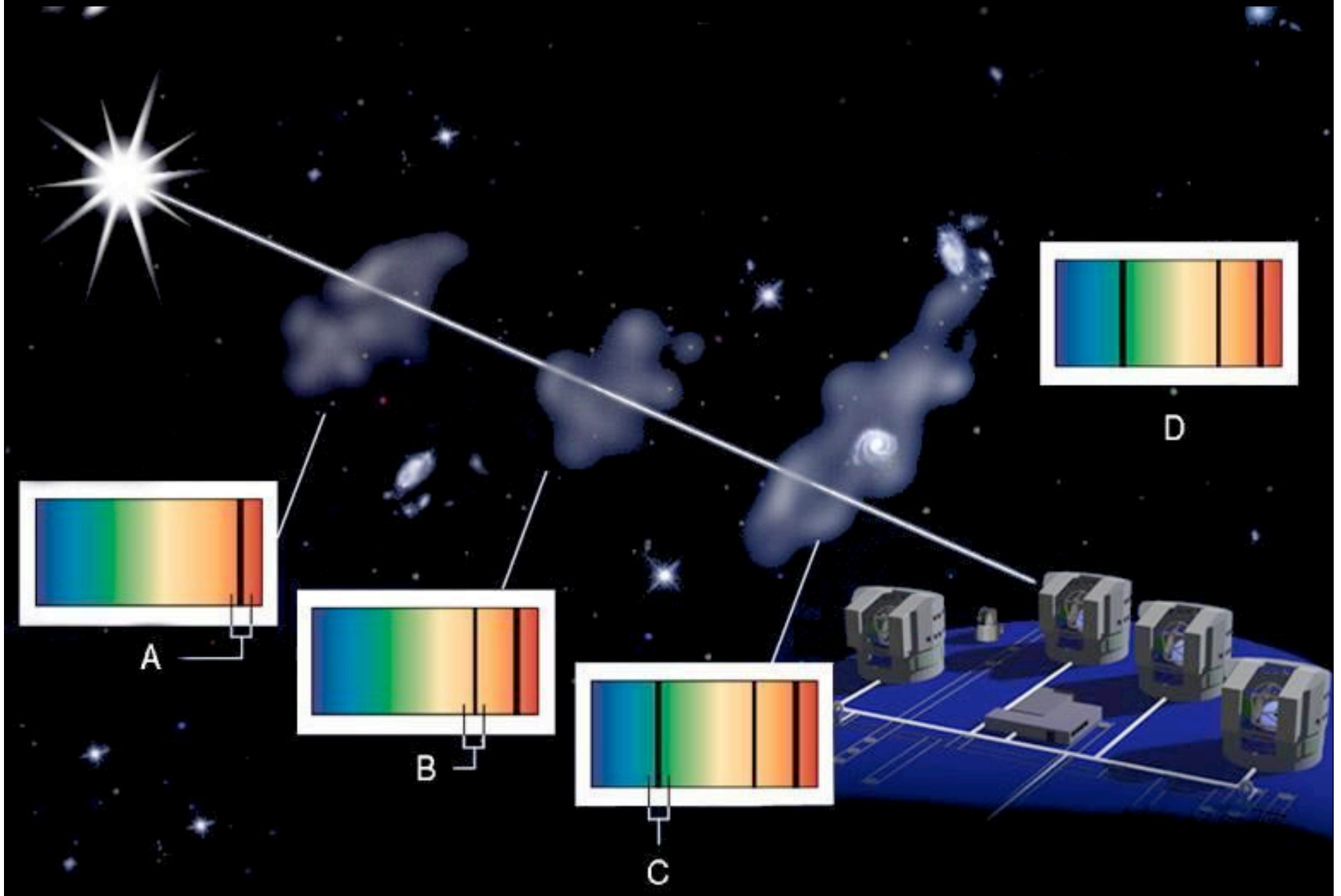
# Big Bang Nucleosynthesis



# Searching for the primordial gas clouds

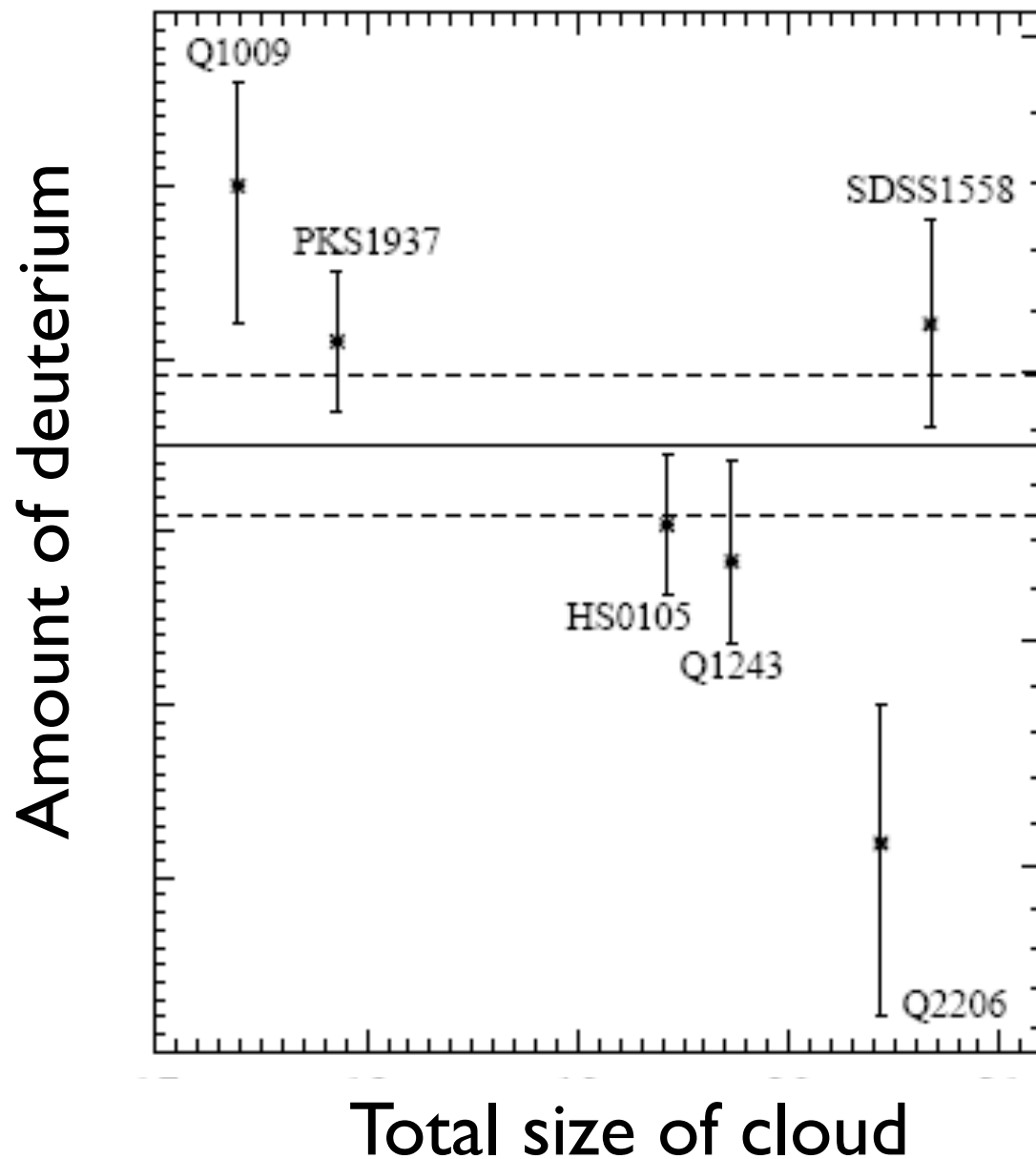


# Searching for the primordial gas clouds



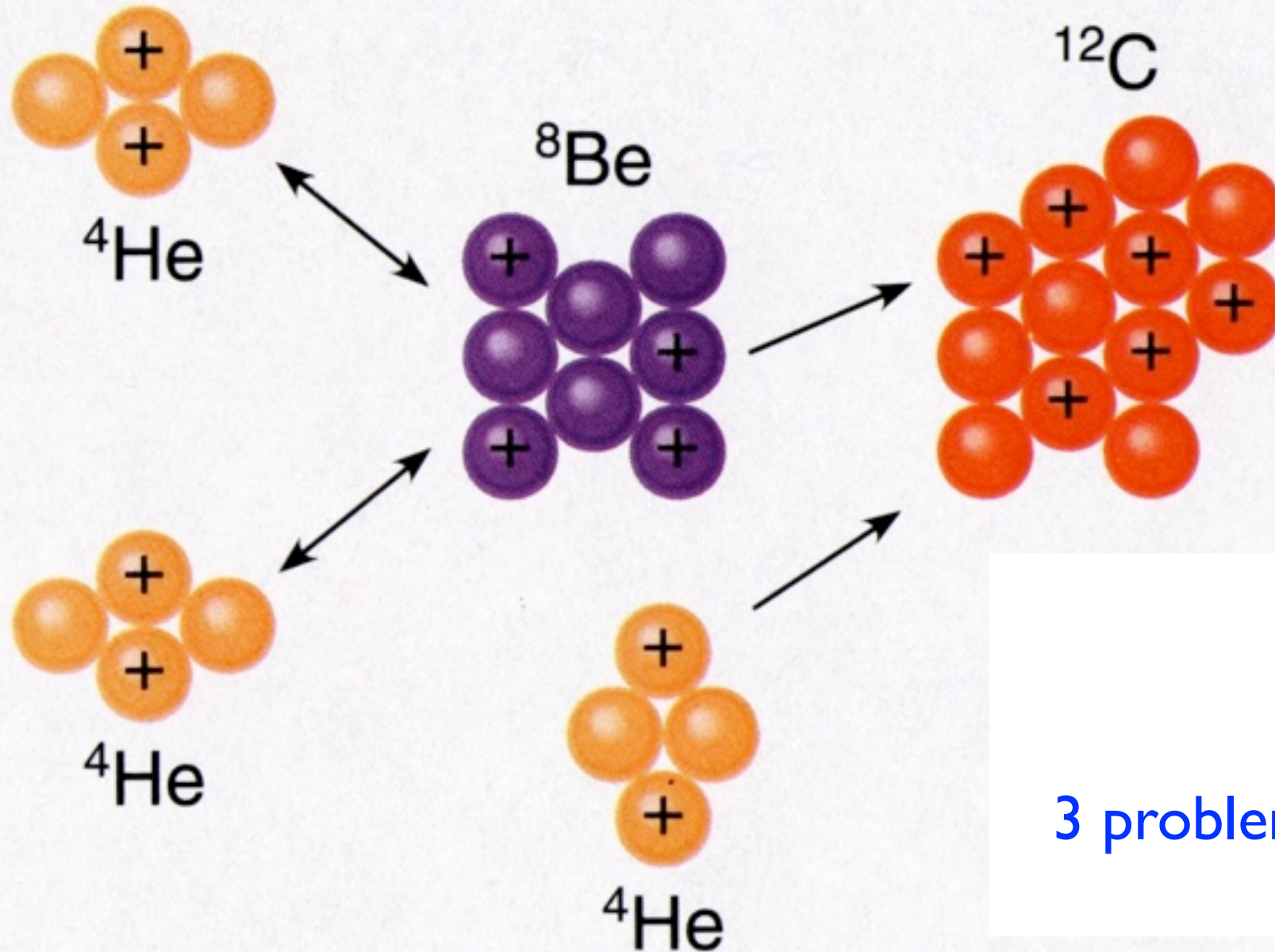


# Searching for the primordial gas clouds



This line shows the prediction of the Big Bang

# Why can't we form carbon?



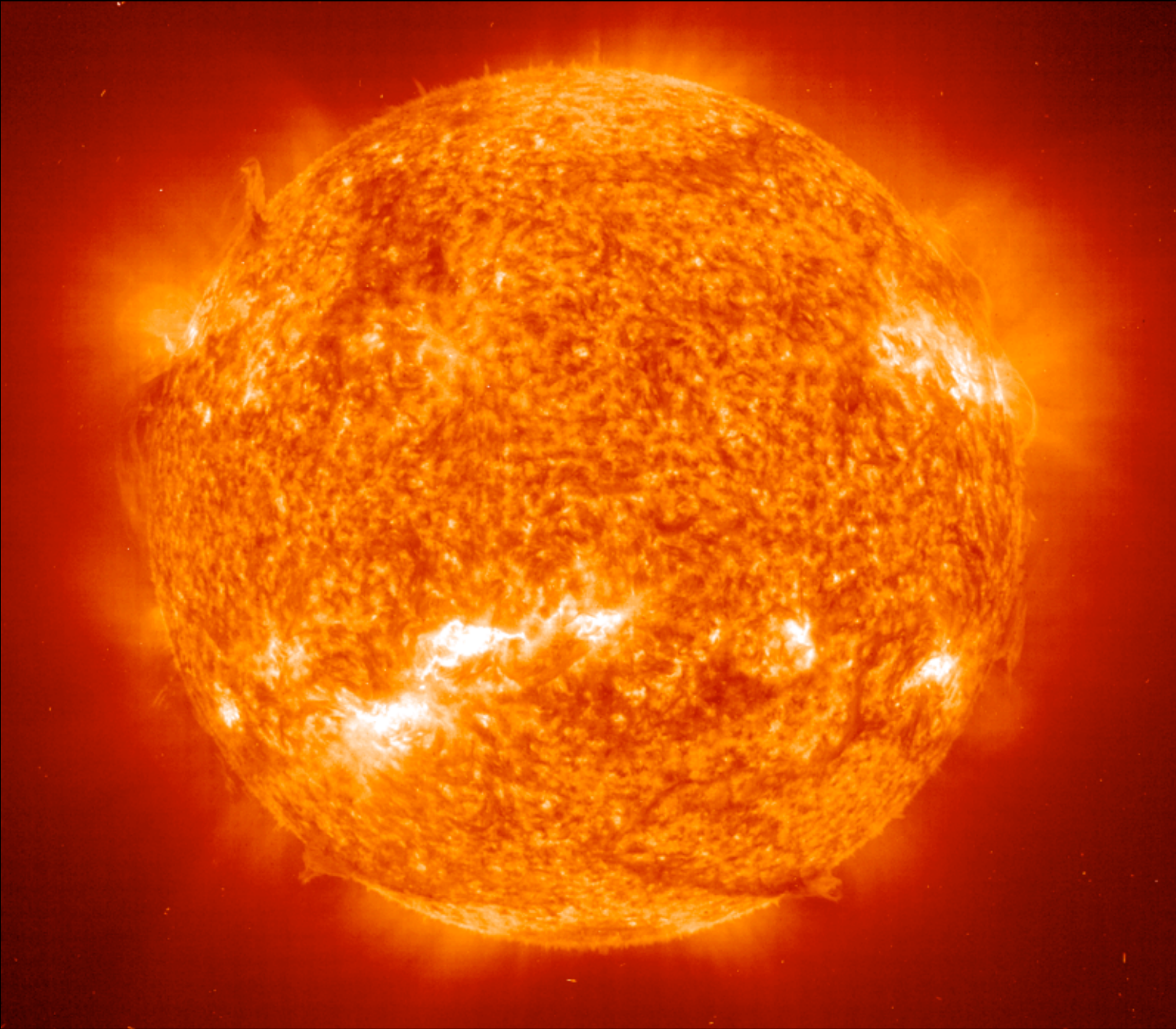
3 problems ...

# Big Bang Nucleosynthesis

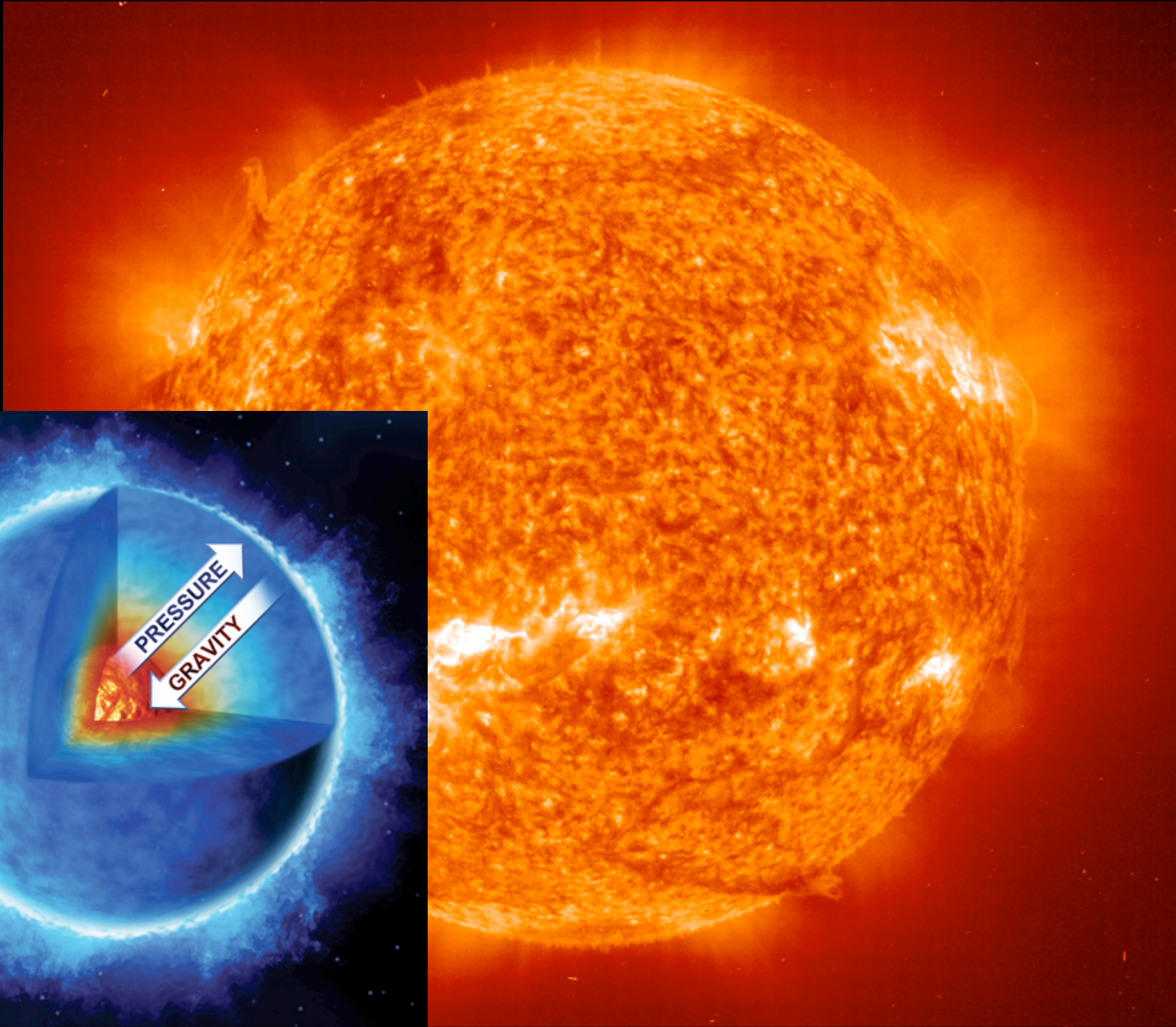
- Forms the light elements (helium, deuterium, lithium)
- We can measure their abundances and confirm the theory



Where do the other elements come from?

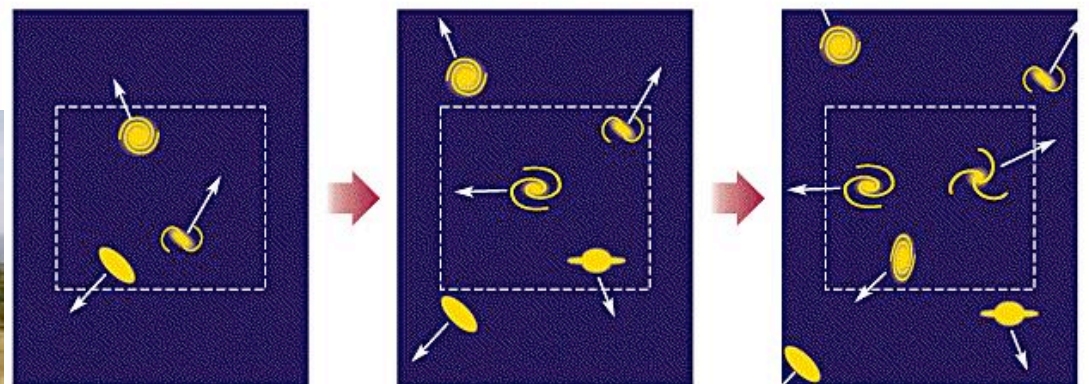
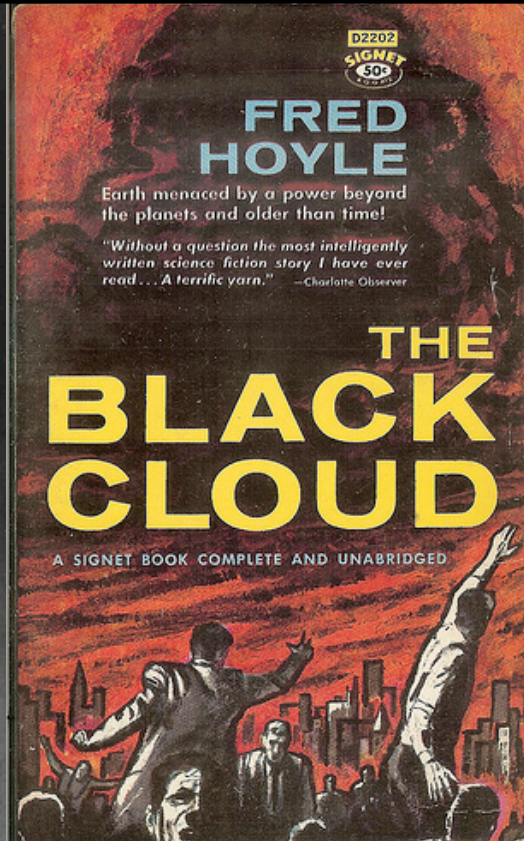
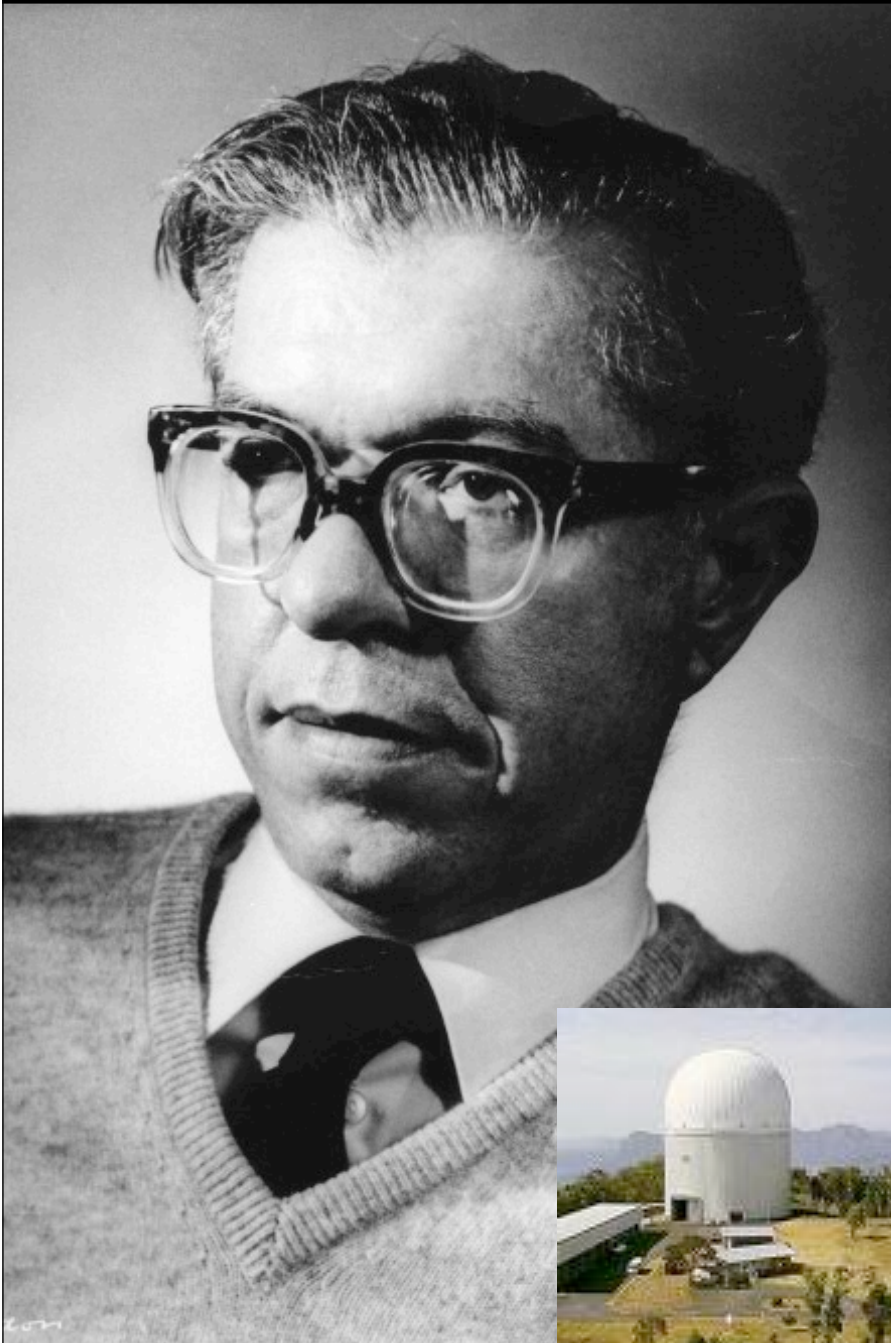


# Where do the other elements come from?



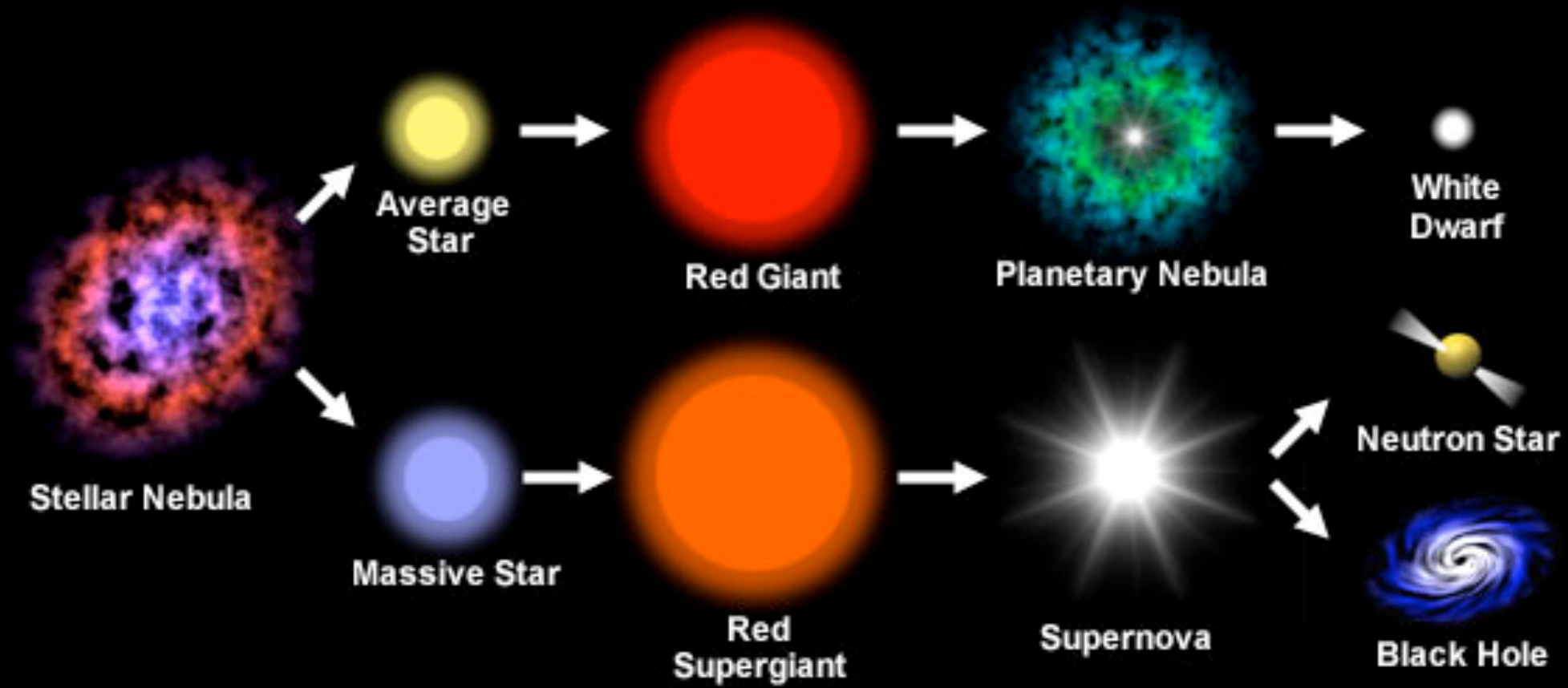


# Sir Fred Hoyle

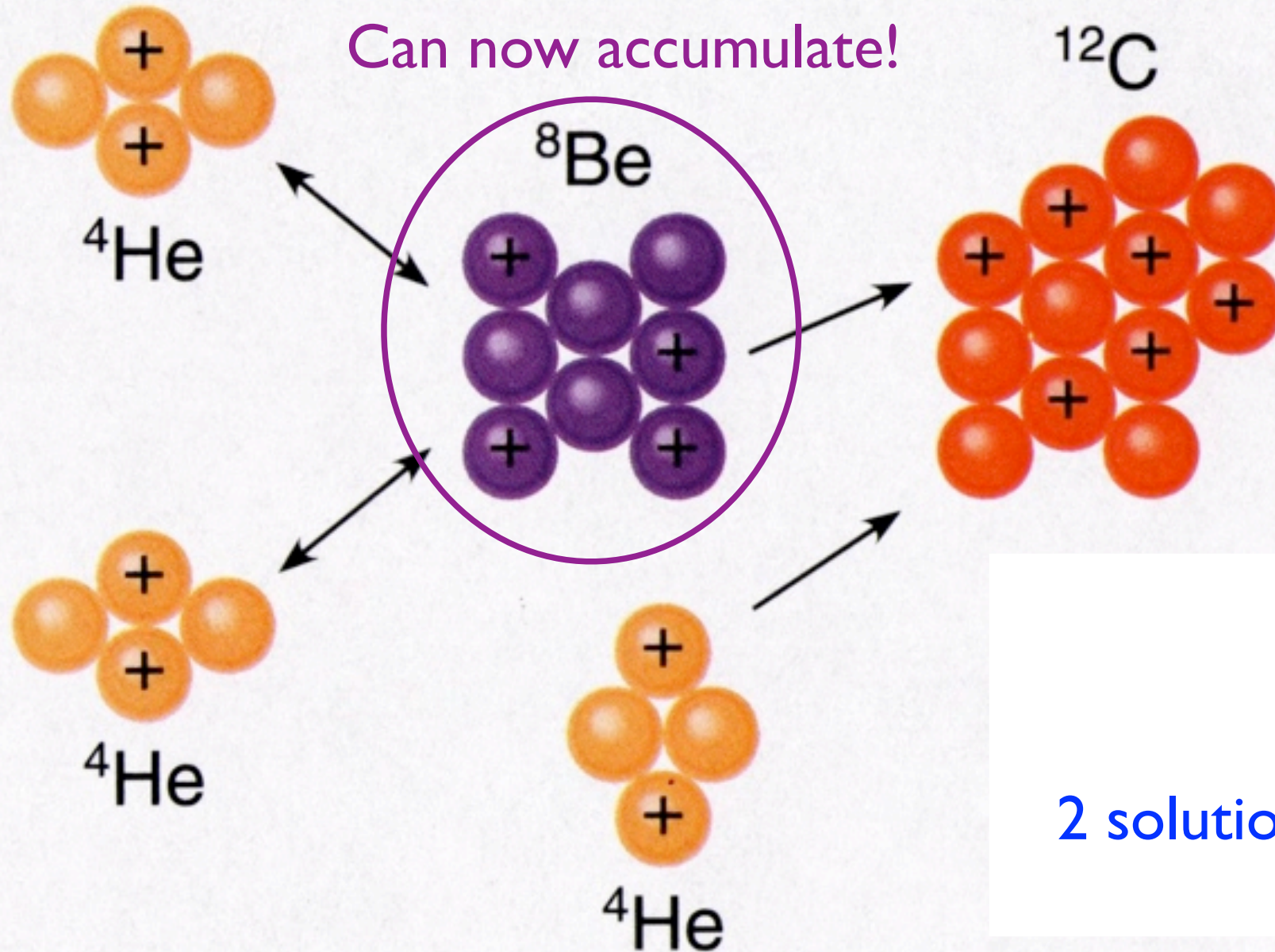




# Life Cycle of a Star



# Formation of carbon

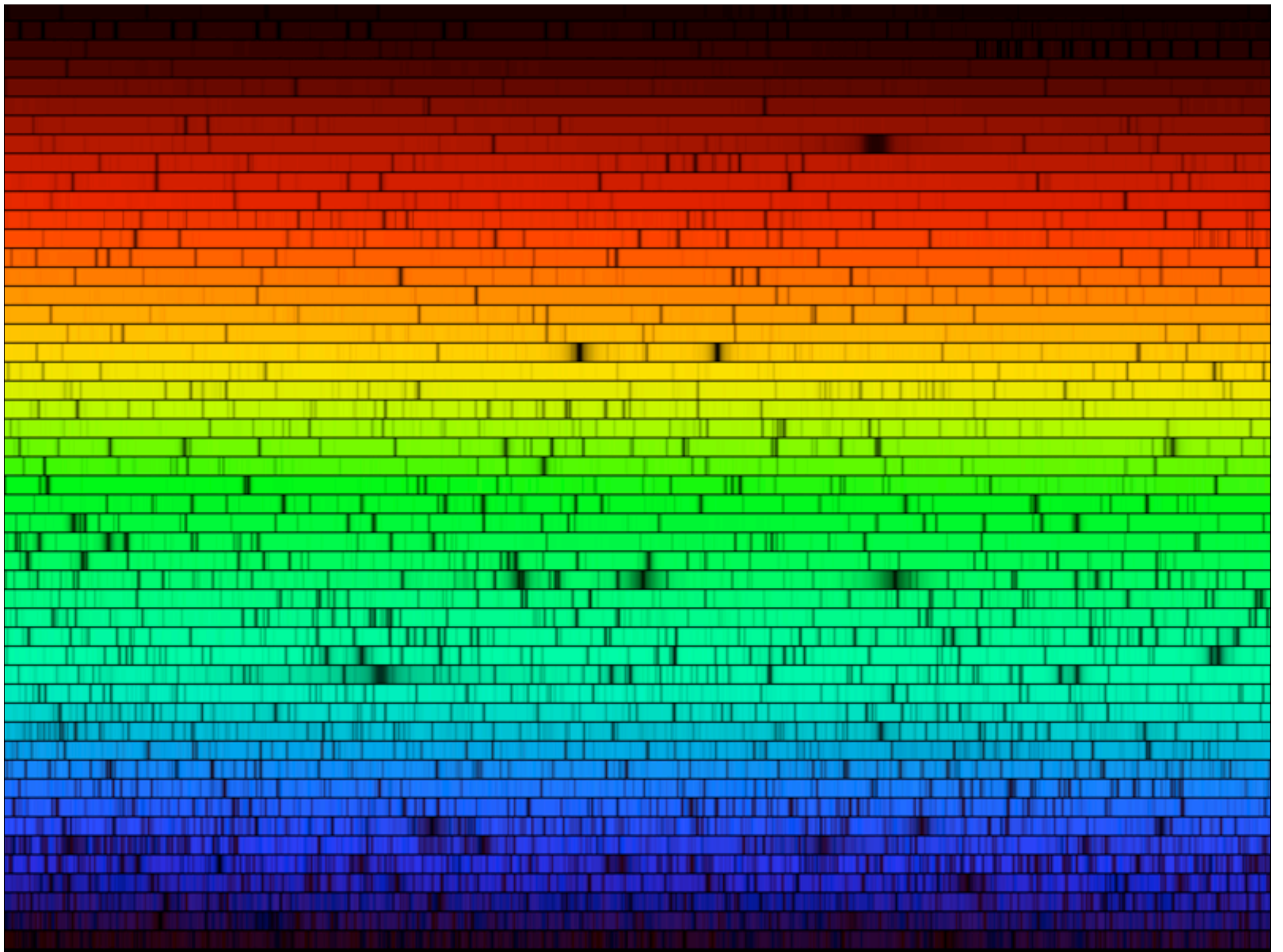


2 solutions ...

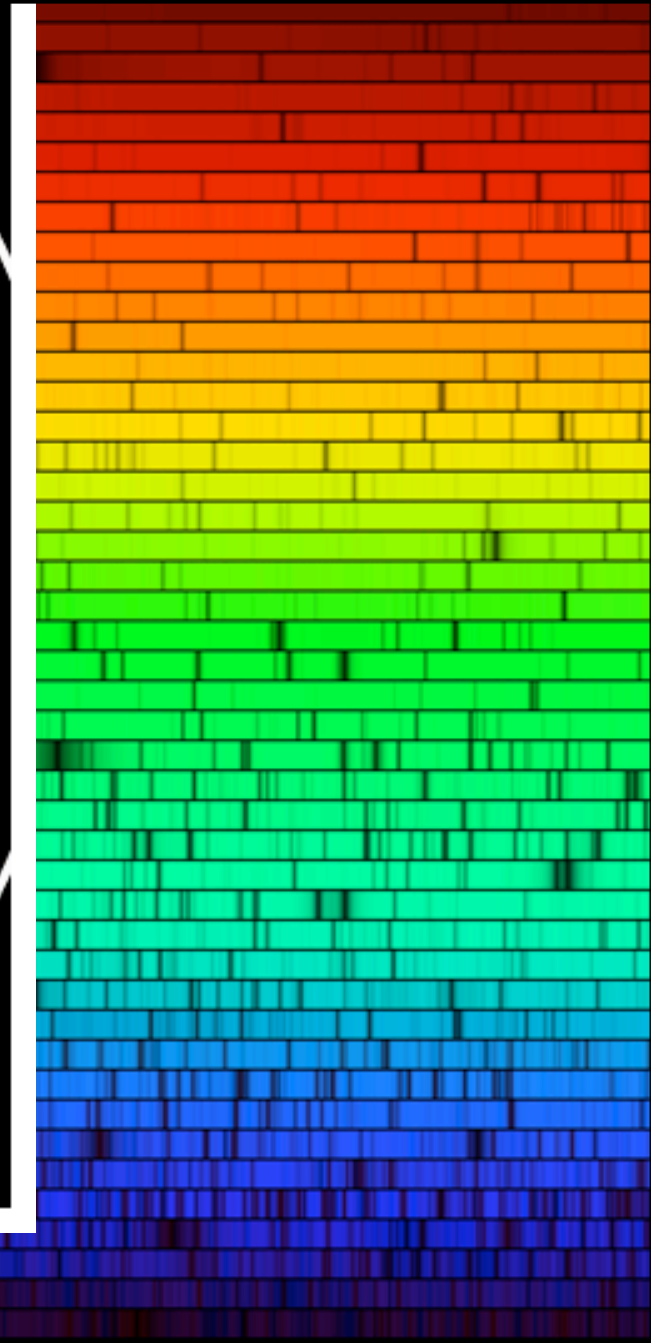
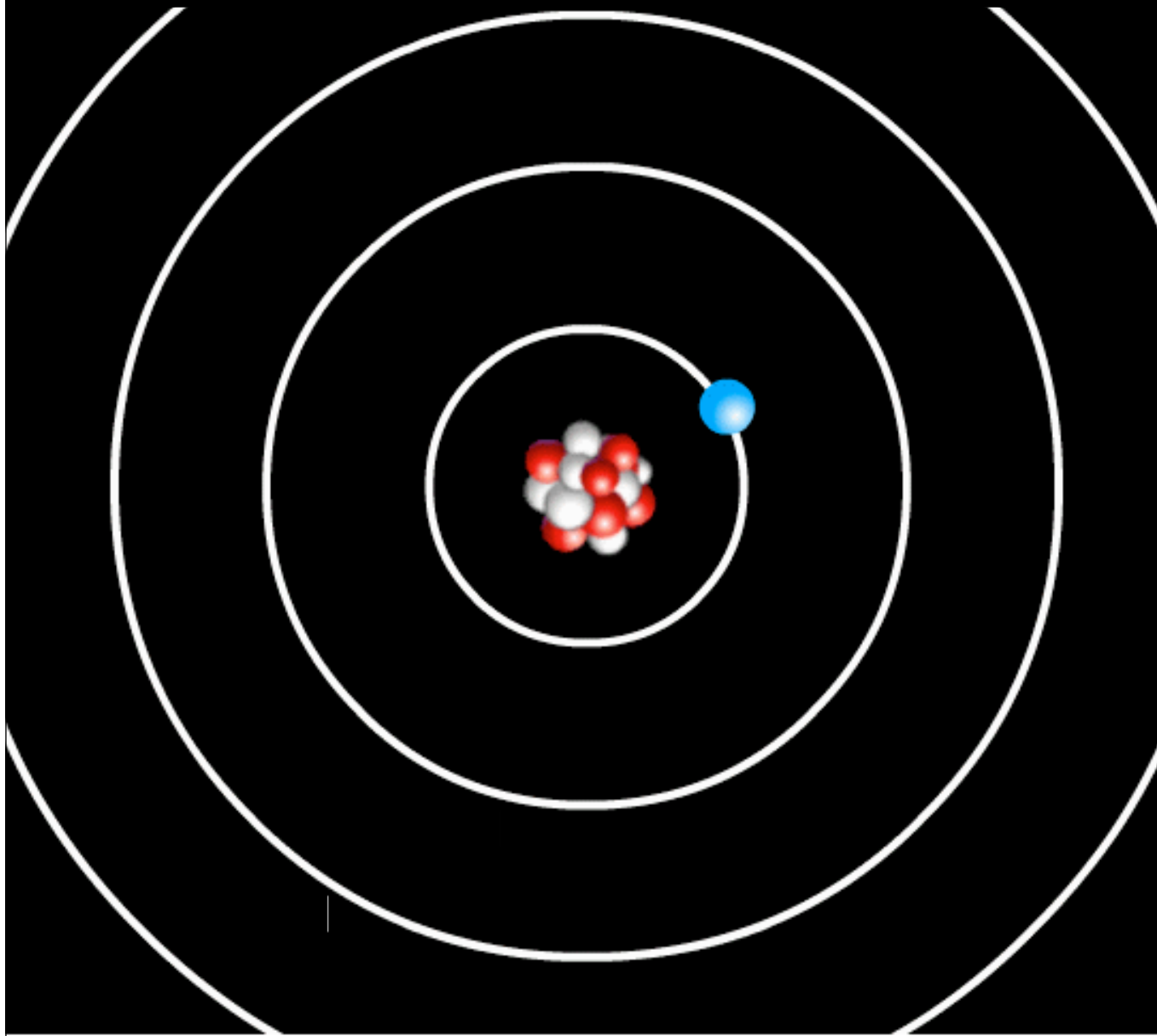
# Resonance



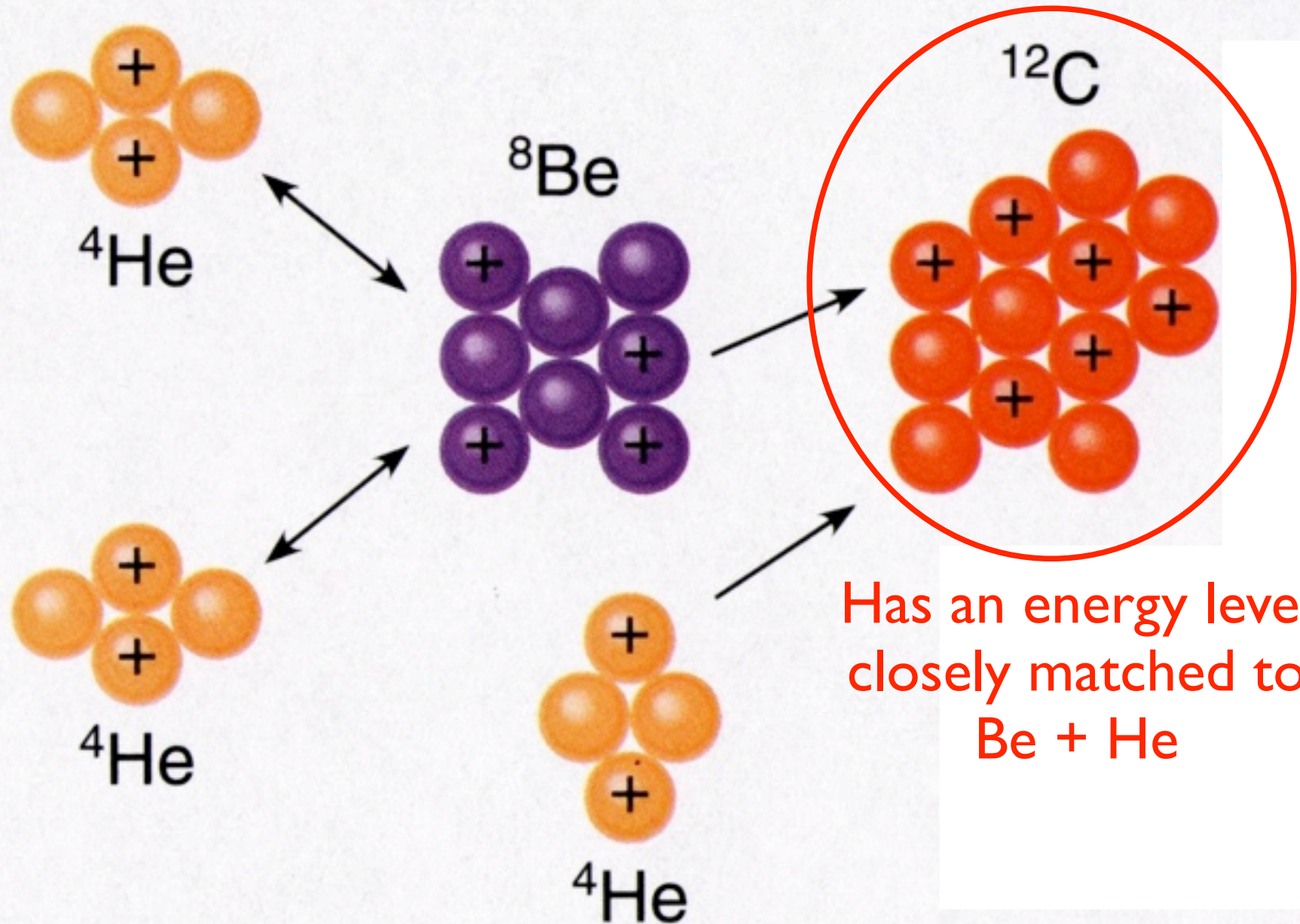




# Atomic energy levels



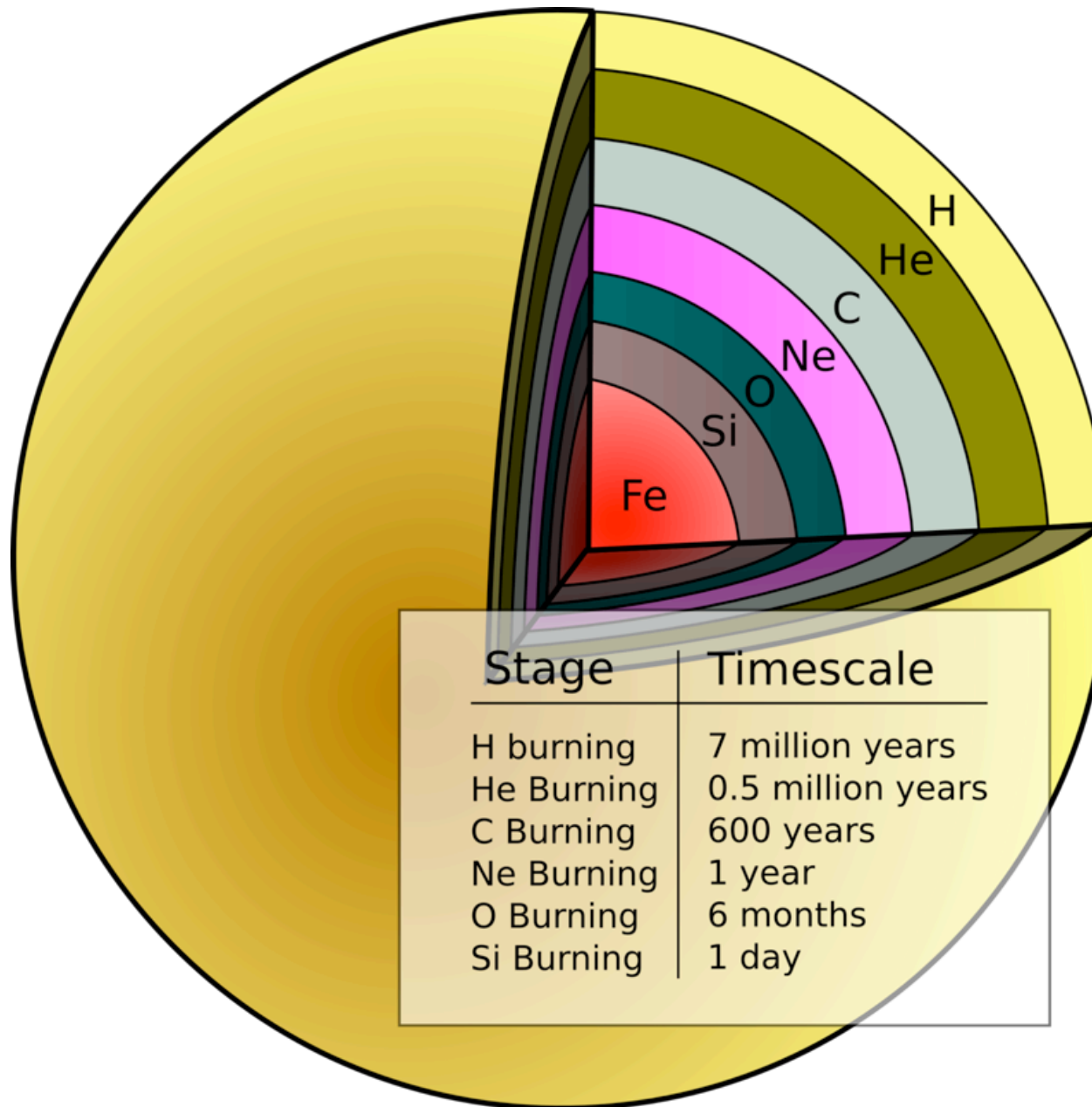
# Formation of carbon





- 
- A successful prediction of the anthropic principle!

# The build up of elements inside stars

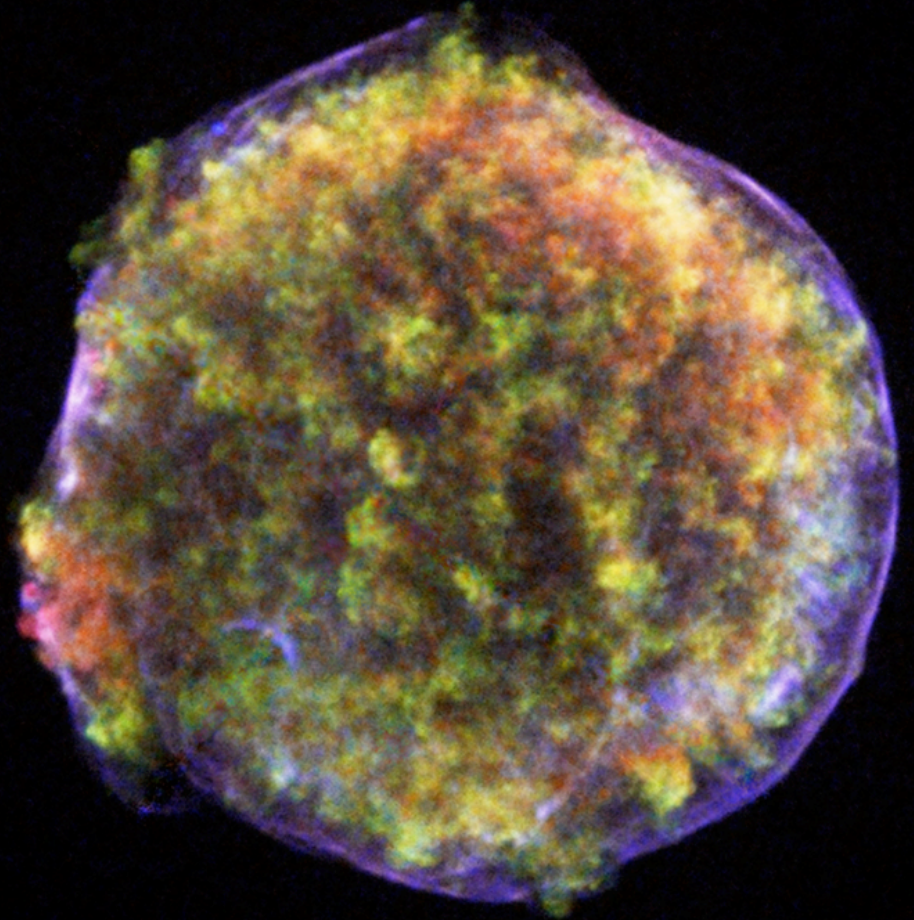
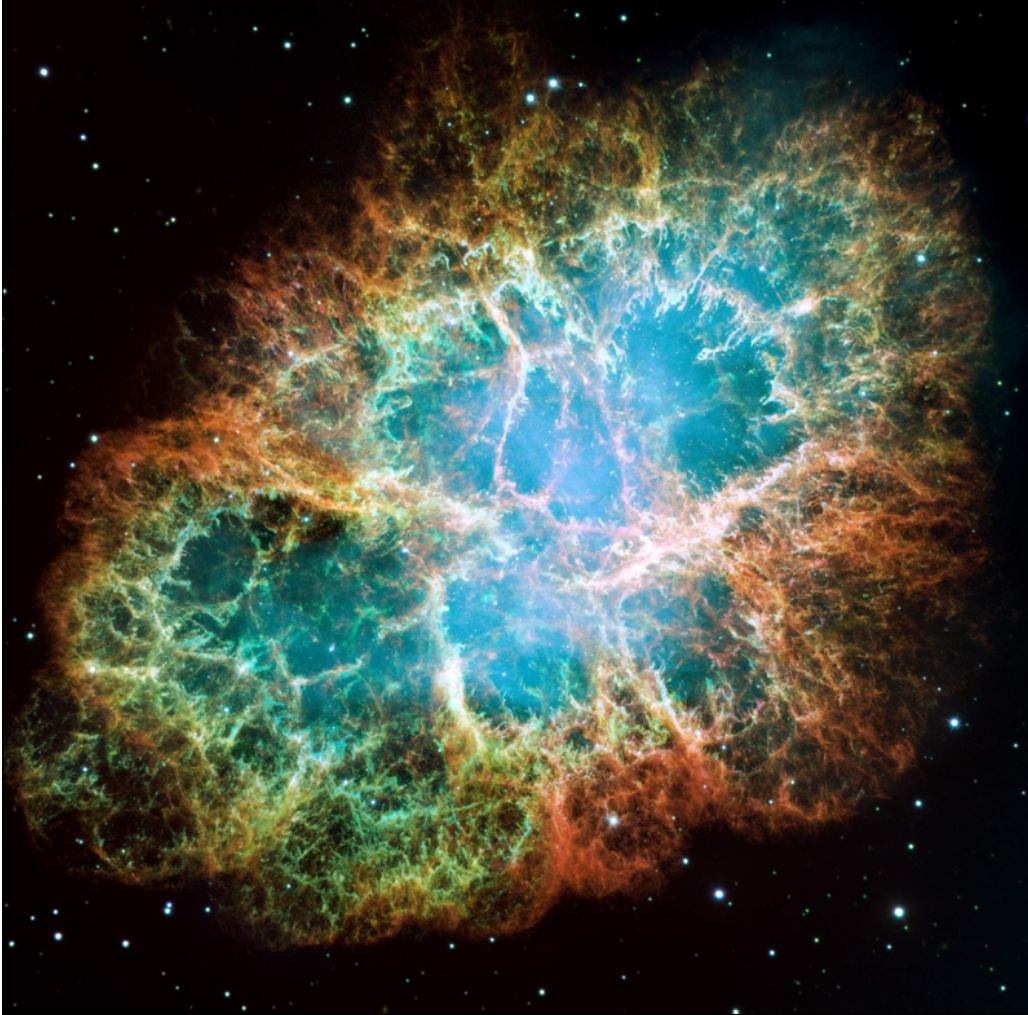


# Supernova explosions



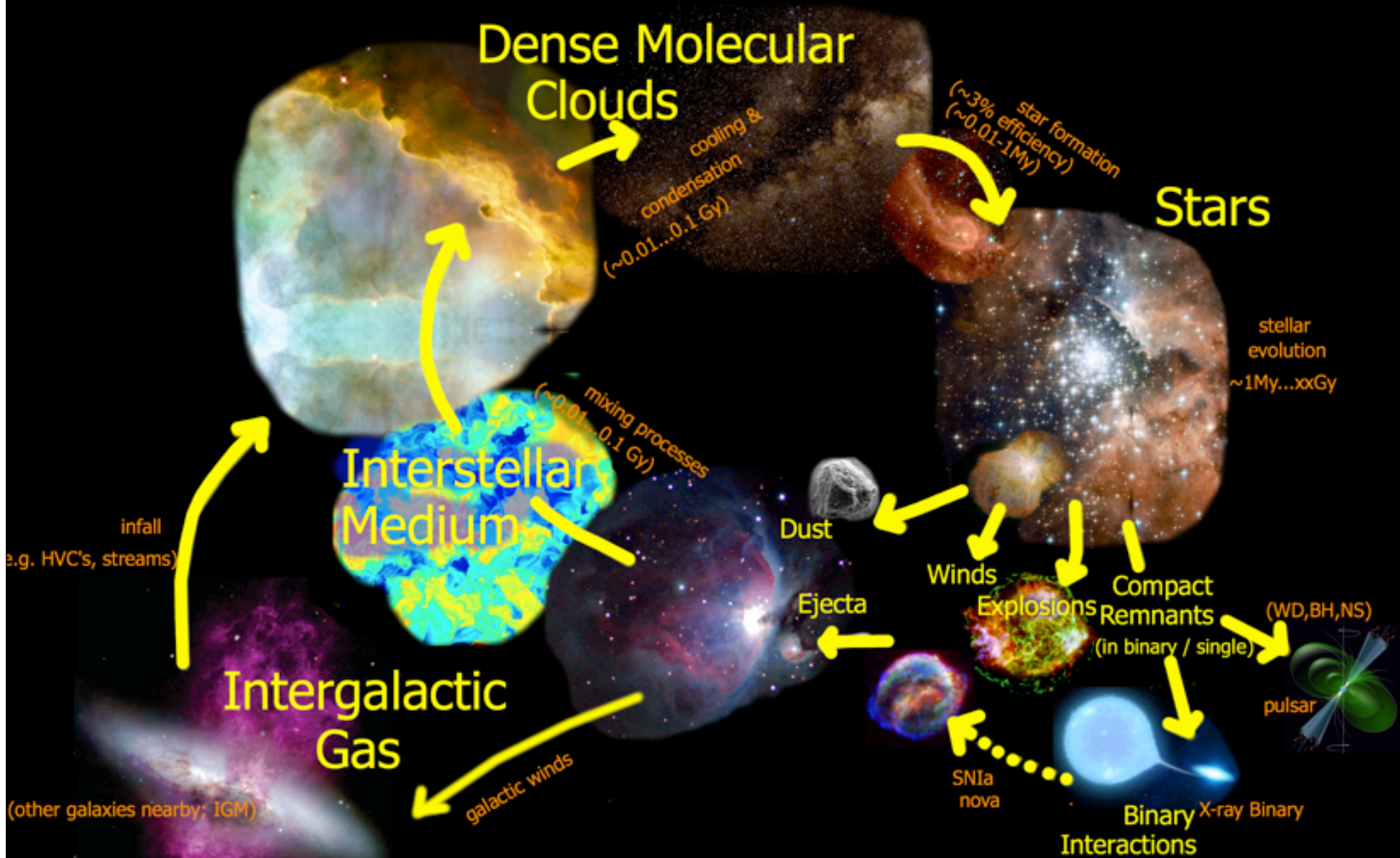


# Supernova explosions



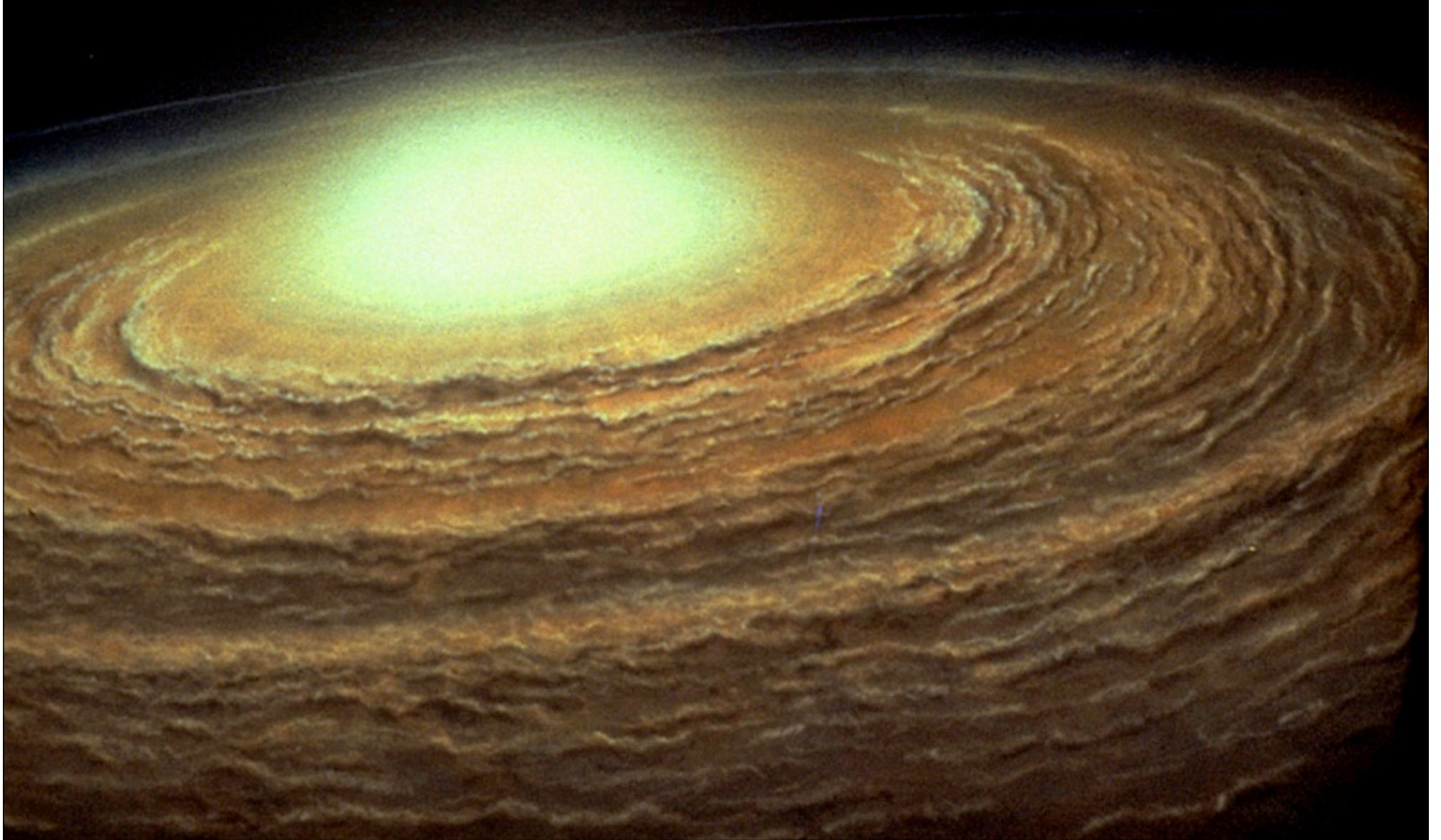


# Cycle of matter



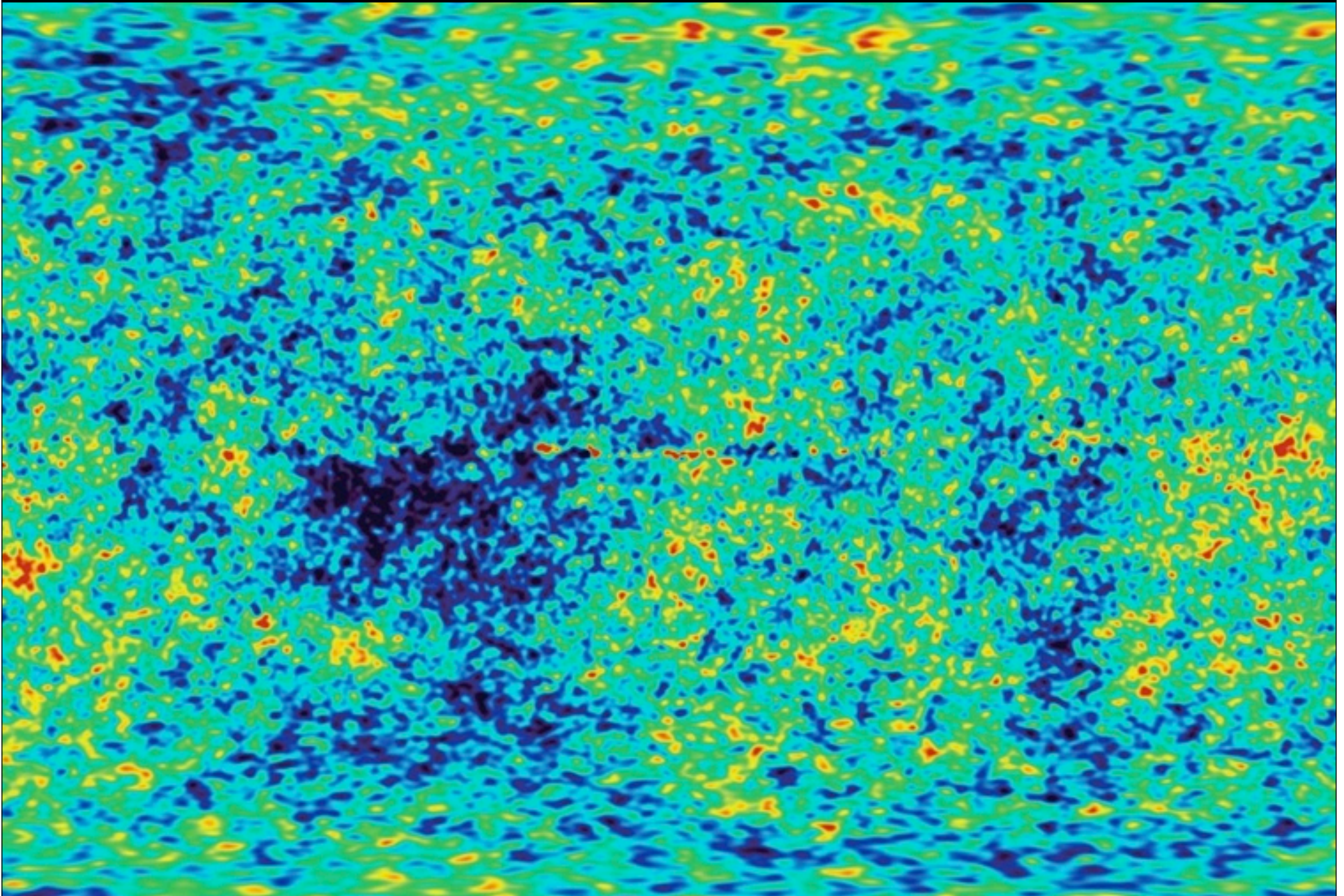


# Planet formation



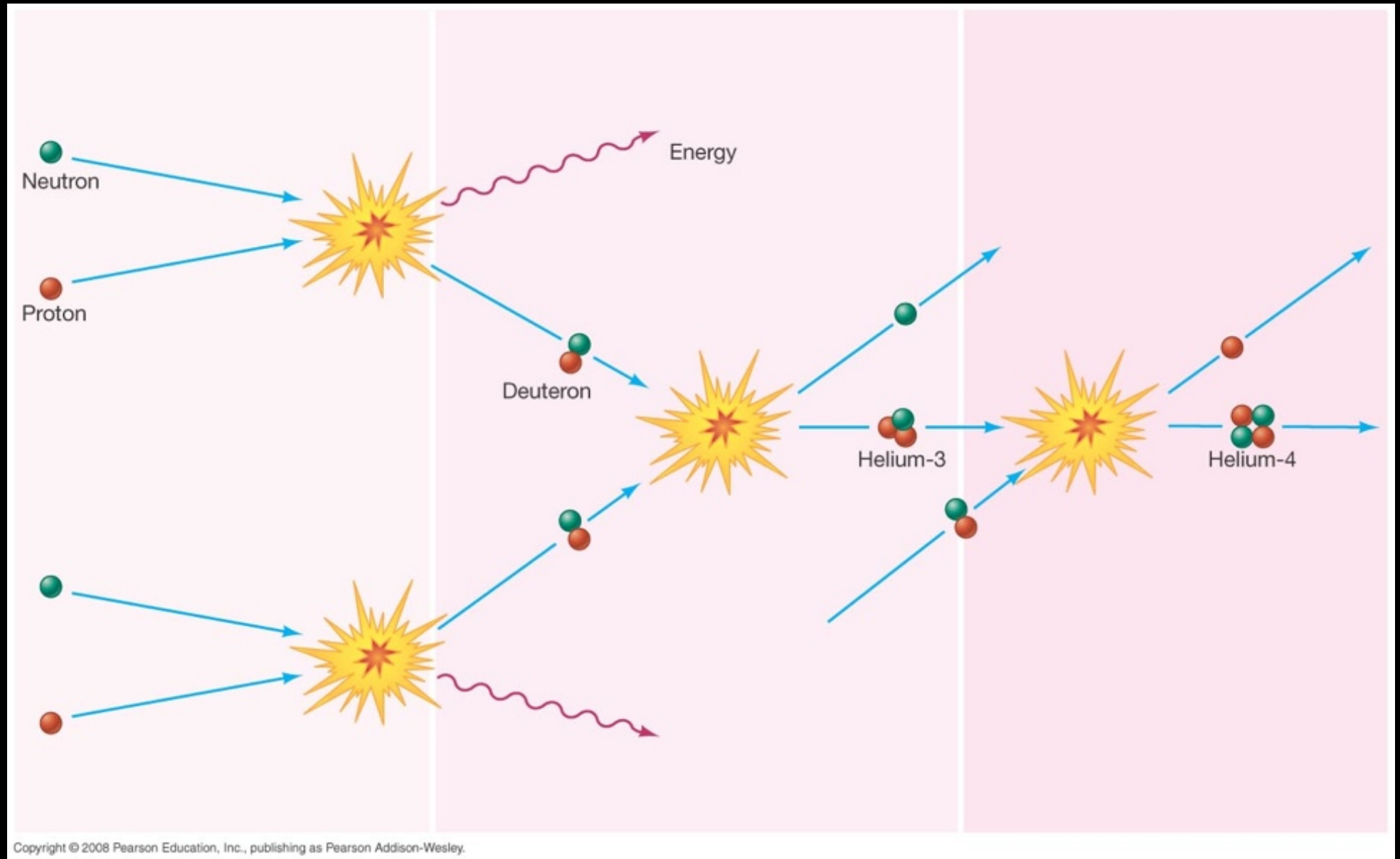


The early Universe was hot and dense ...



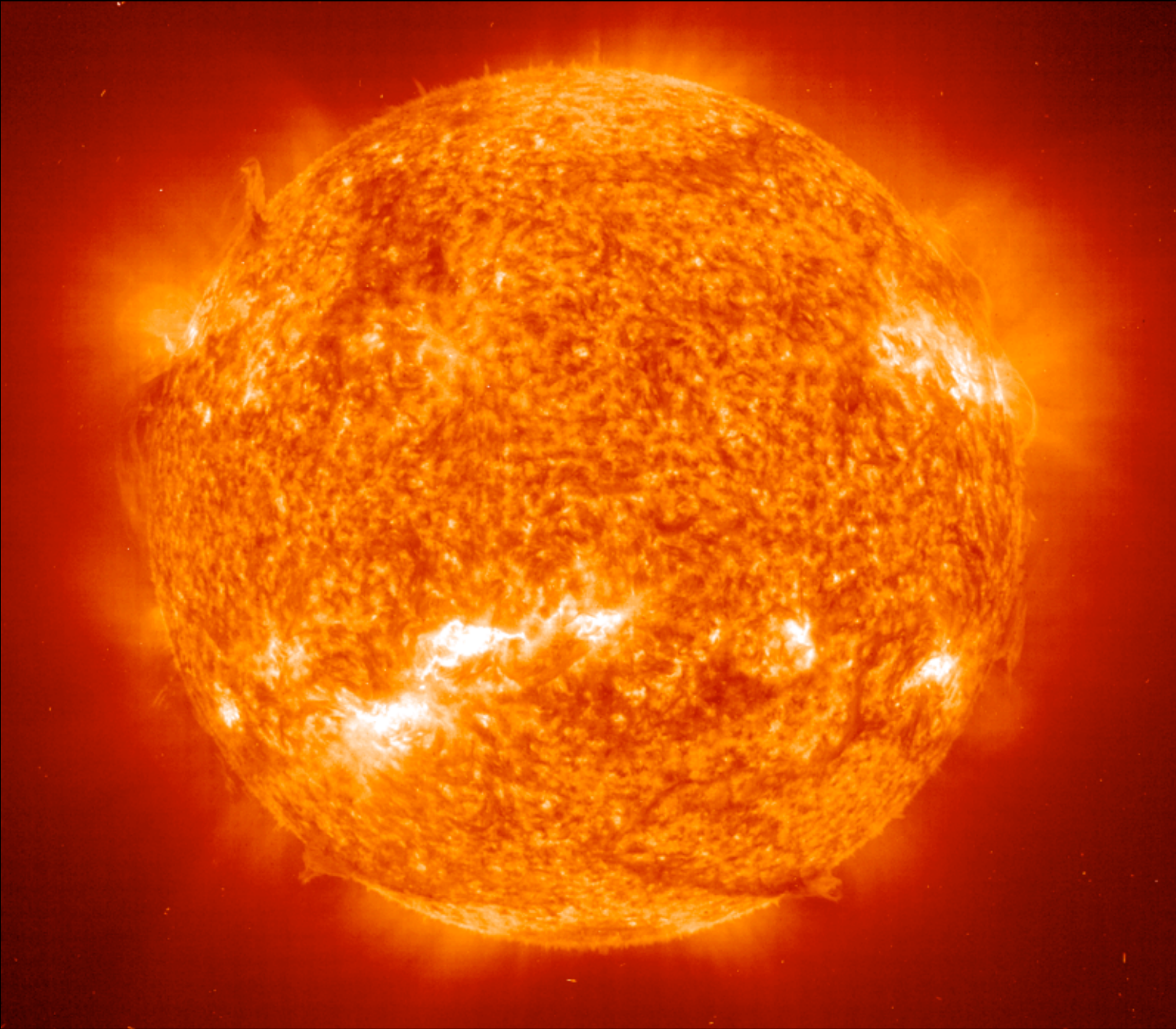


# The light elements formed through nuclear fusion reactions in the first few minutes ...





The heavier elements formed inside stars



Thank you for coming !

