

Science in The News Presents:

# The Evolution of the Universe

*from Cosmic Soup to Earth*

Ian Czekala

Nathan Sanders

Elisabeth Newton

*Harvard University Astronomy*

October 26th, 2011

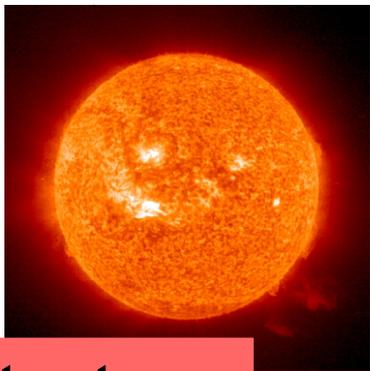


# Overview

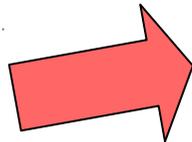
- Ian
  - The ingredients of the early universe
  - How do we create the metals we see today?
- Nathan
  - How do elements get out of stars?
  - Is our galactic neighborhood special?
- Elisabeth
  - How do we form our Sun and planets?
  - What's the forecast for planet Earth?

# From the cosmic soup to Earth

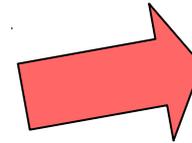
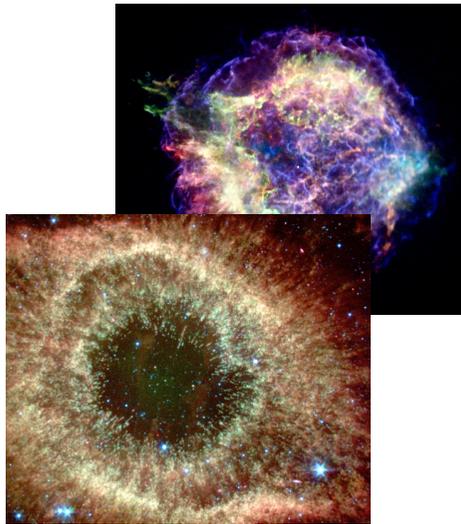
Big Bang  
and neutral  
hydrogen



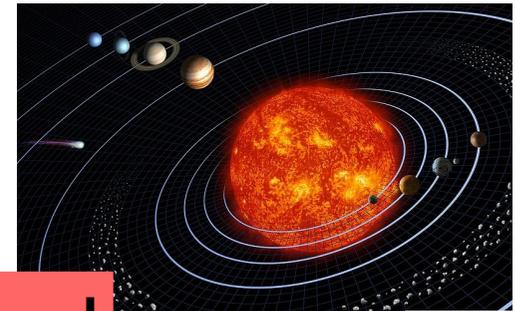
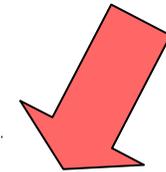
First stars



Stellar explosions  
and stellar winds



Interstellar  
gas



Stars and  
planets



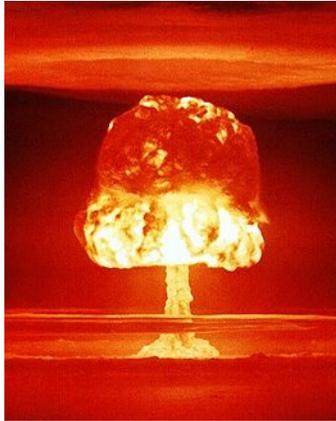
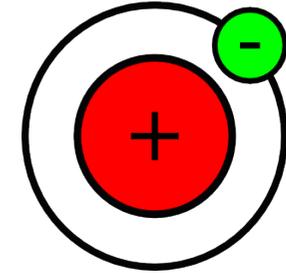
What did we start with and how  
do we get what we have now?  
*The Big Bang and Stellar  
Nucleosynthesis*

Ian Czekała

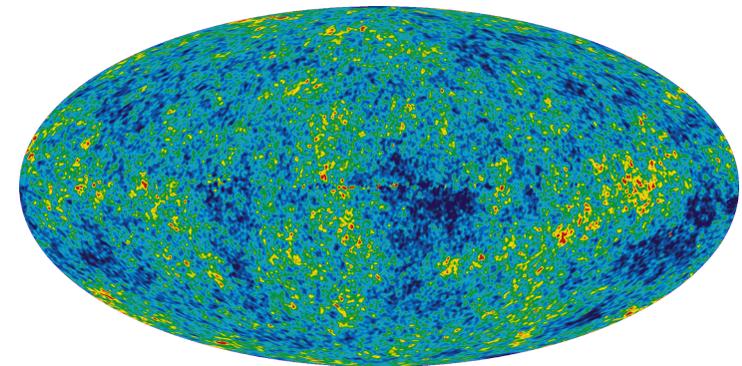
*Harvard University Astronomy*

# Outline

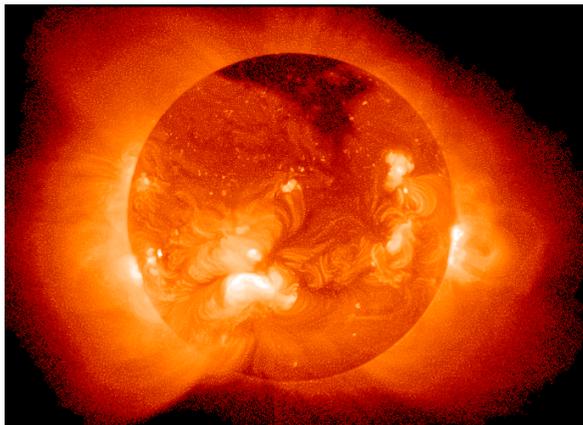
1) building blocks of atoms and ions



2) chemical vs. nuclear reactions



3) the Cosmic Microwave Background

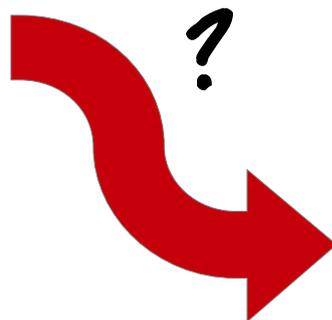


4) stars as element factories

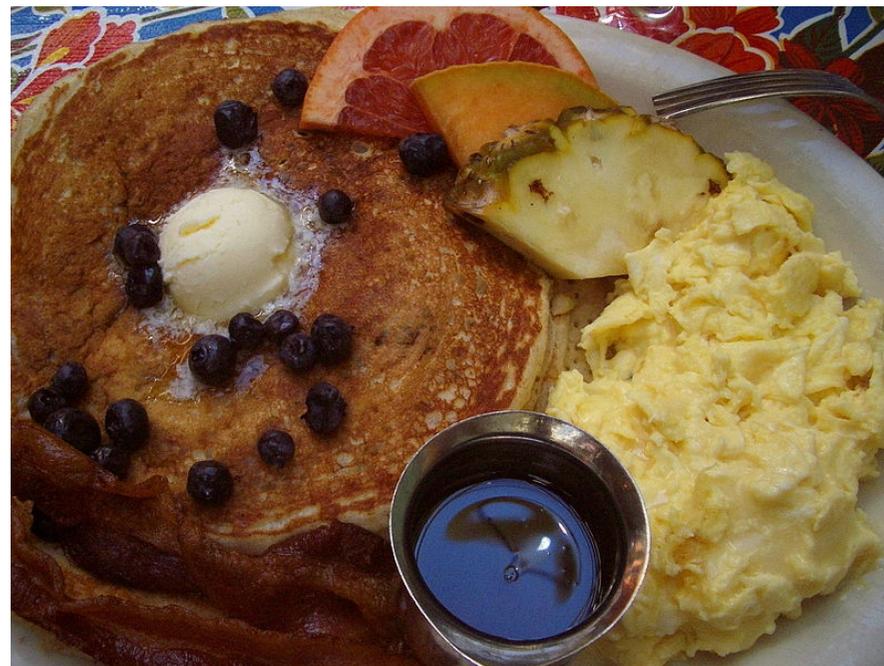
# Our chemical history



diffuse hydrogen gas

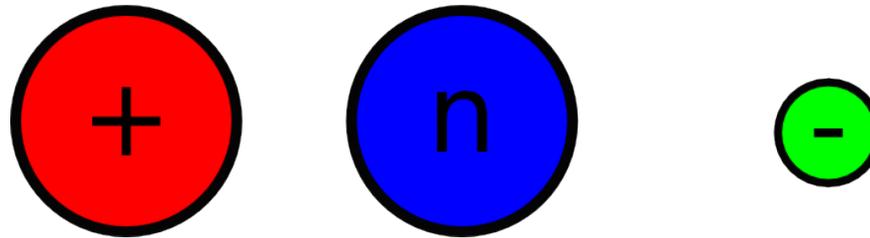


Tasty breakfast with  
metal utensils and all



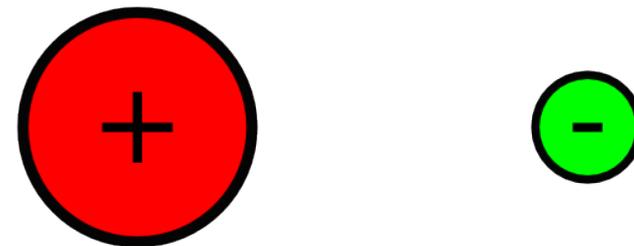
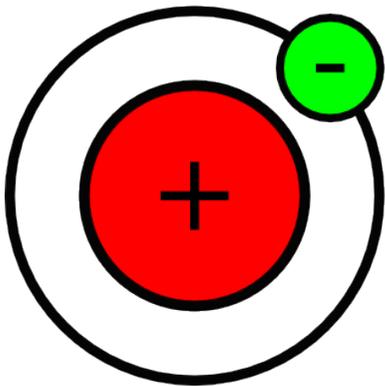
# Atoms: the Building Blocks of elements

Proton    Neutron    Electron



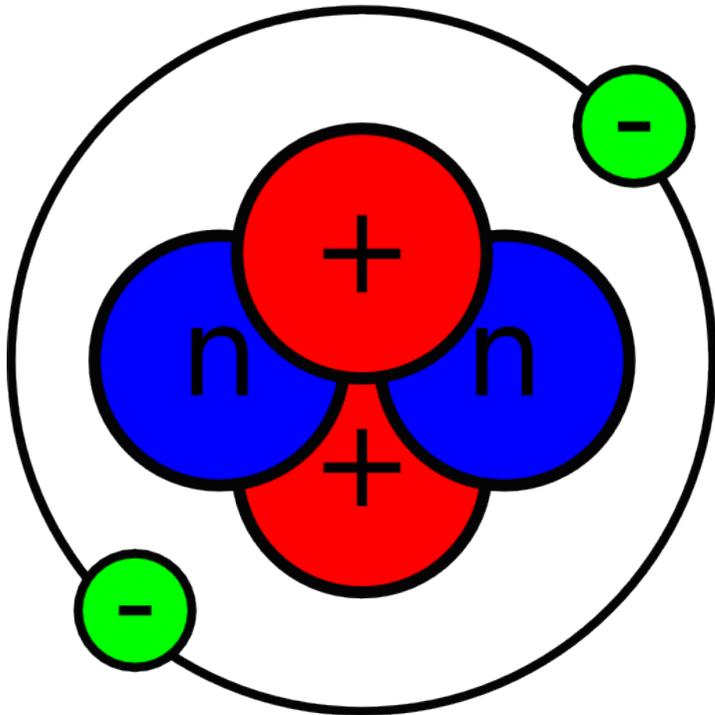
Neutral Hydrogen (H)

Ionized Hydrogen ( $H^+$ )



# Atoms and Ions

## Neutral Helium (He)



Anything with more protons than helium, astronomers consider a “metal”

- Oxygen (O)
- Carbon (C)
- Nitrogen (N)

*What's the difference between a nuclear bomb and a campfire?*

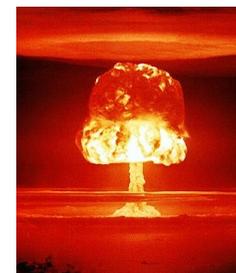
# Nuclear Reactions vs. Chemical Reactions

Nuclear reactions create and destroy new elements

- Fusion: joining of atoms, release energy
- Fission: splitting of atoms, release energy



new elements created



Chemical reactions rearrange combinations of atoms. No elements are created or destroyed. Release a smaller amount of energy.



same elements, but rearranged



# The Big Bang

The Big Bang is a theory that the Universe originated in an intensely energetic expansion and has since been expanding outward, cooling off.

Eventually, protons and electrons combined to form hydrogen and some helium and minute traces of heavier “metals.”

- Observational evidence that the early universe was much hotter and denser
- Most of what we see is hydrogen and helium

# Cosmic Microwave Background

When the universe was hot, everything was ionized (electrons separated from atoms).

After a while, the universe was cool enough for the electrons to recombine with the atoms for the first time, releasing light.

Billions of years later they've reached us as a uniform distribution on the sky. This is a map of that radiation.

# Status Report

- neutral hydrogen
- neutral helium

Everywhere. EVERYWHERE!

- not much else

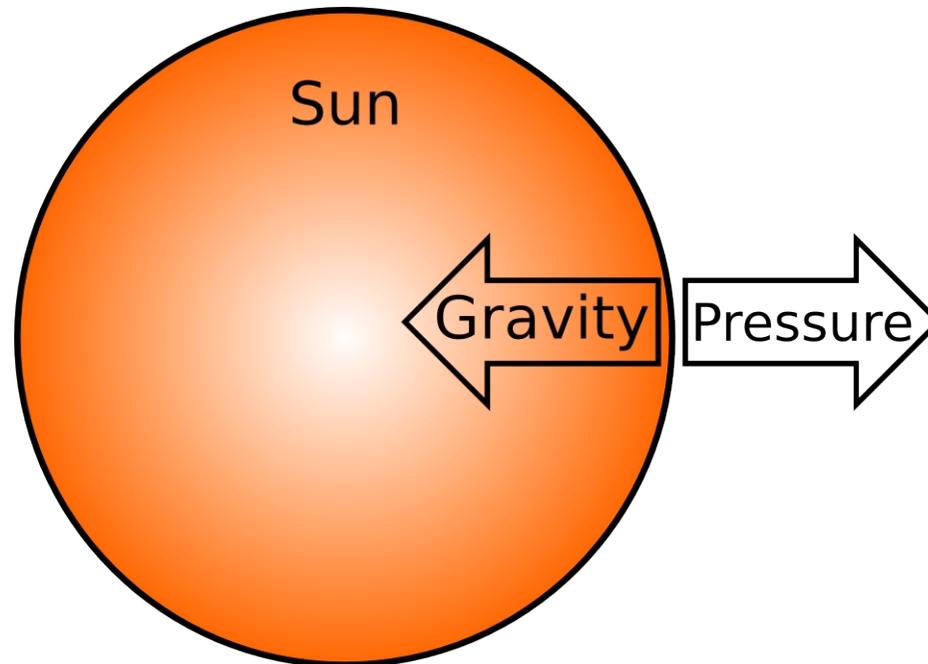


Next: how do we get the ingredients for our breakfast?

Questions?

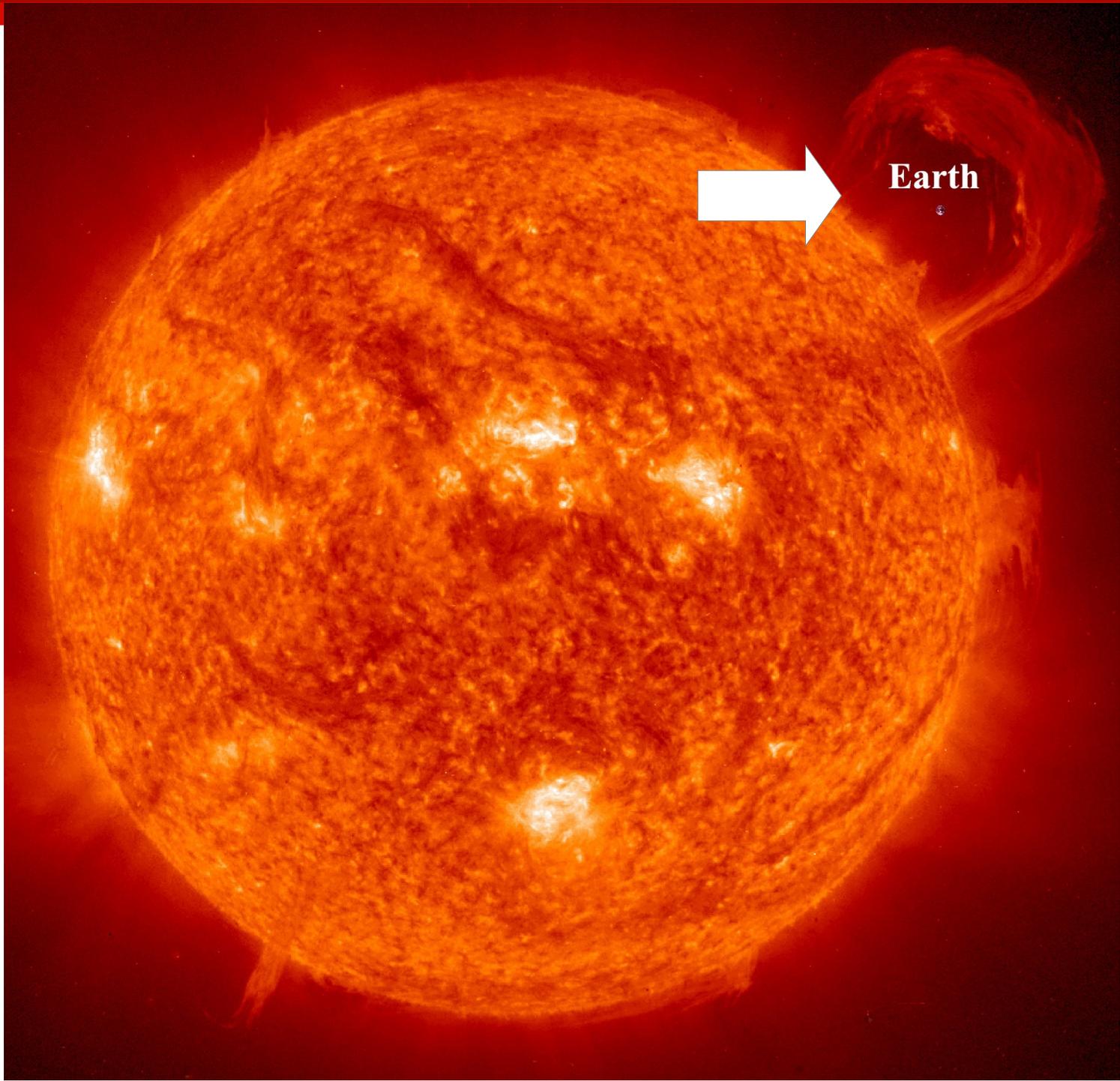
# Everyone's a star

A giant ball of gas that is gravitationally attracted to itself but supported by thermal pressure given off from nucleosynthetic processes in its core.



Earth's atmosphere

- one pressure and density at the surface
- pressure and temperature decrease as we move into space



Earth

# Stars are big and hot

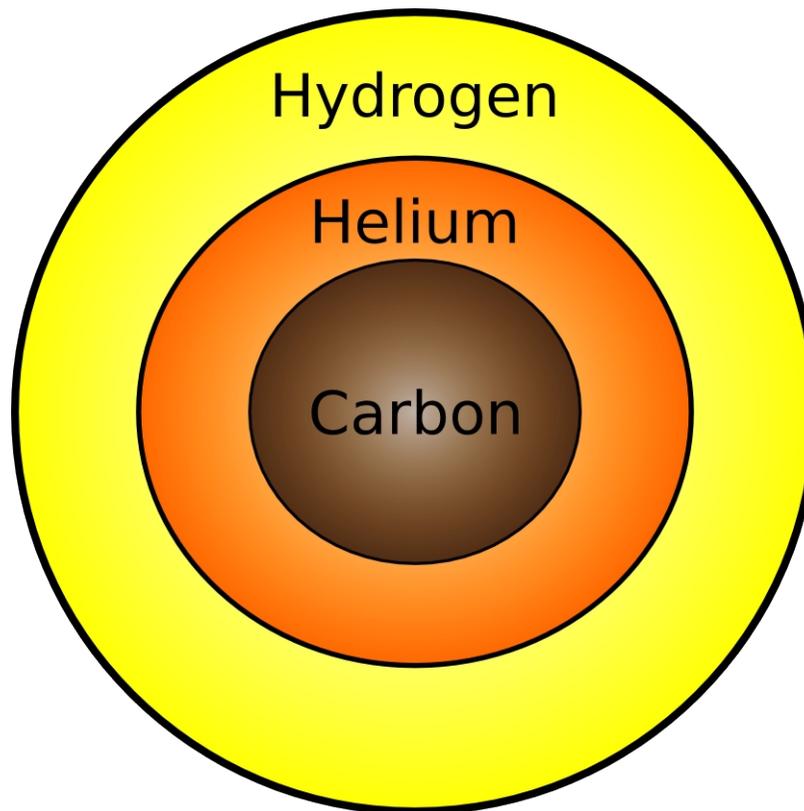
- generate extremely high temperatures and pressures
- conditions are right for fusing elements into "heavier" elements via nucleosynthesis
- proton-proton chain
  - fuses hydrogen into helium
- triple Alpha process
  - fuses helium into carbon

# Stellar Evolution

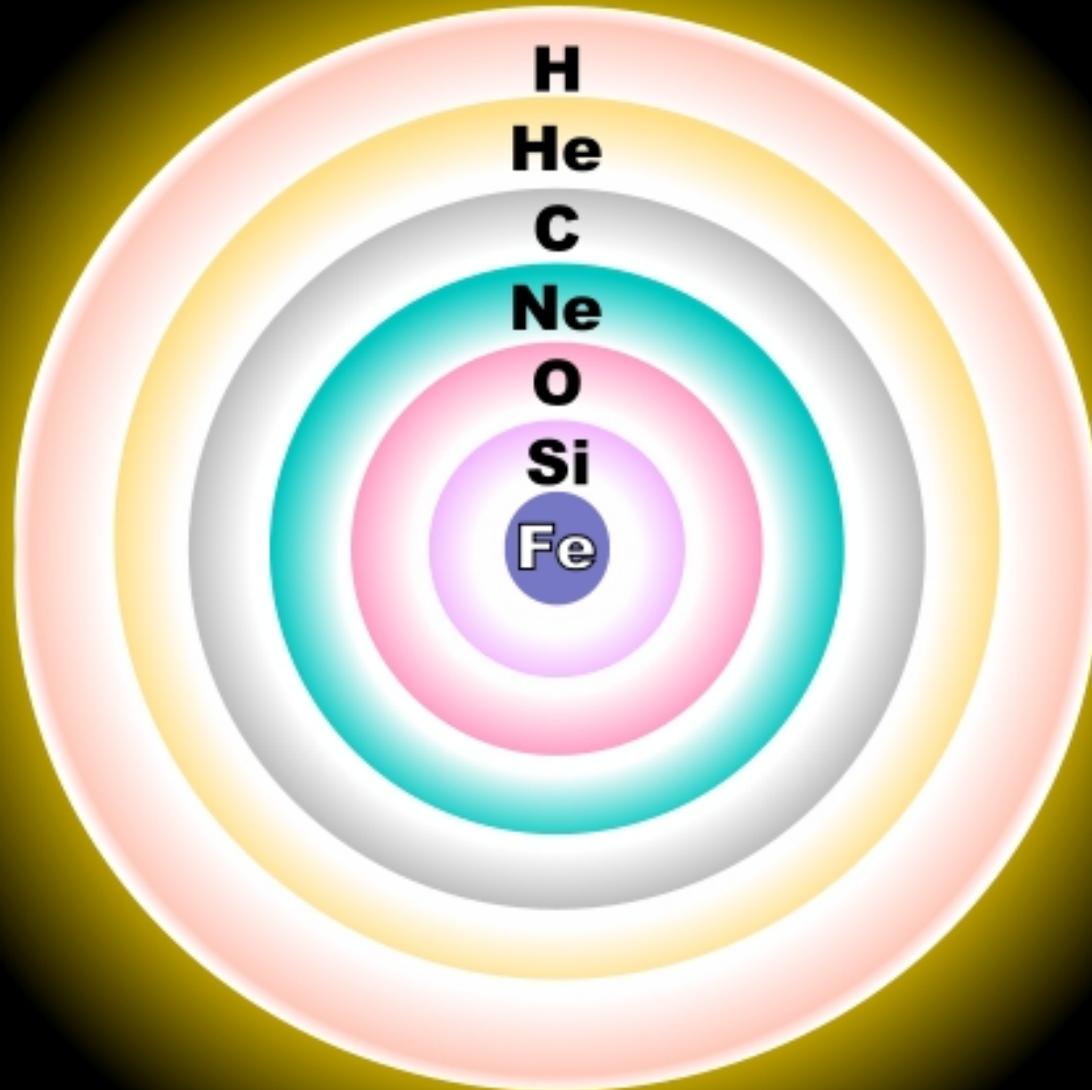
The star burns hydrogen into helium  
Eventually runs out.

The star radiates energy, contracts, heats up in center

Hotter temperatures fuse helium, but eventually runs out



# The End State of Stellar Evolution



# Summary

- Matter is made of atoms, which are made of protons, electrons, and neutrons.
- The universe started with the hot, dense, Big Bang and began expanding and cooling
- Initially, there was only hydrogen, helium, and trace elements
- Stars are elemental factories
- The final structure is an onion shell with the elements locked inside

