Atoms & Matter

Lecture 2, Oct. 6

Astronomy 102, Autumn 2009

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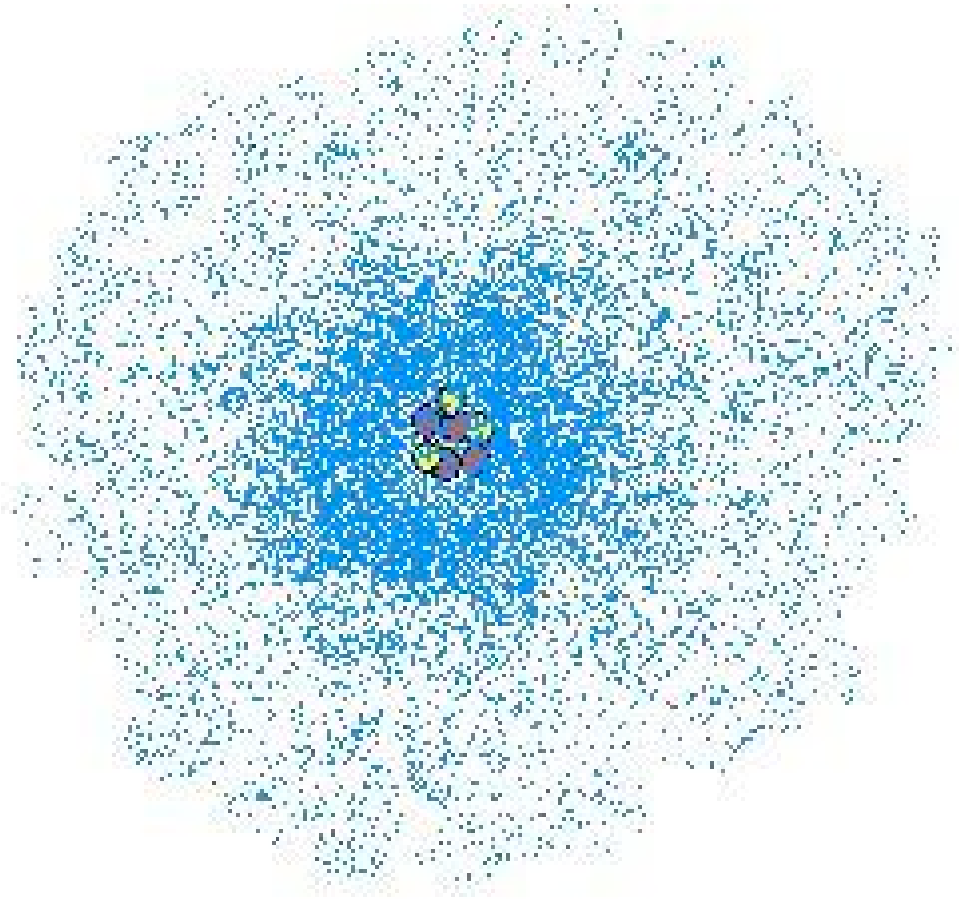
Questions of the Day

- What is the structure of an atom?
- How do elements differ from each other?
- What are the four basic states of matter?
- How do they depend upon temperature?
- What is the condition of atoms in the various states of matter?

I. The basic building block of normal matter is the atom

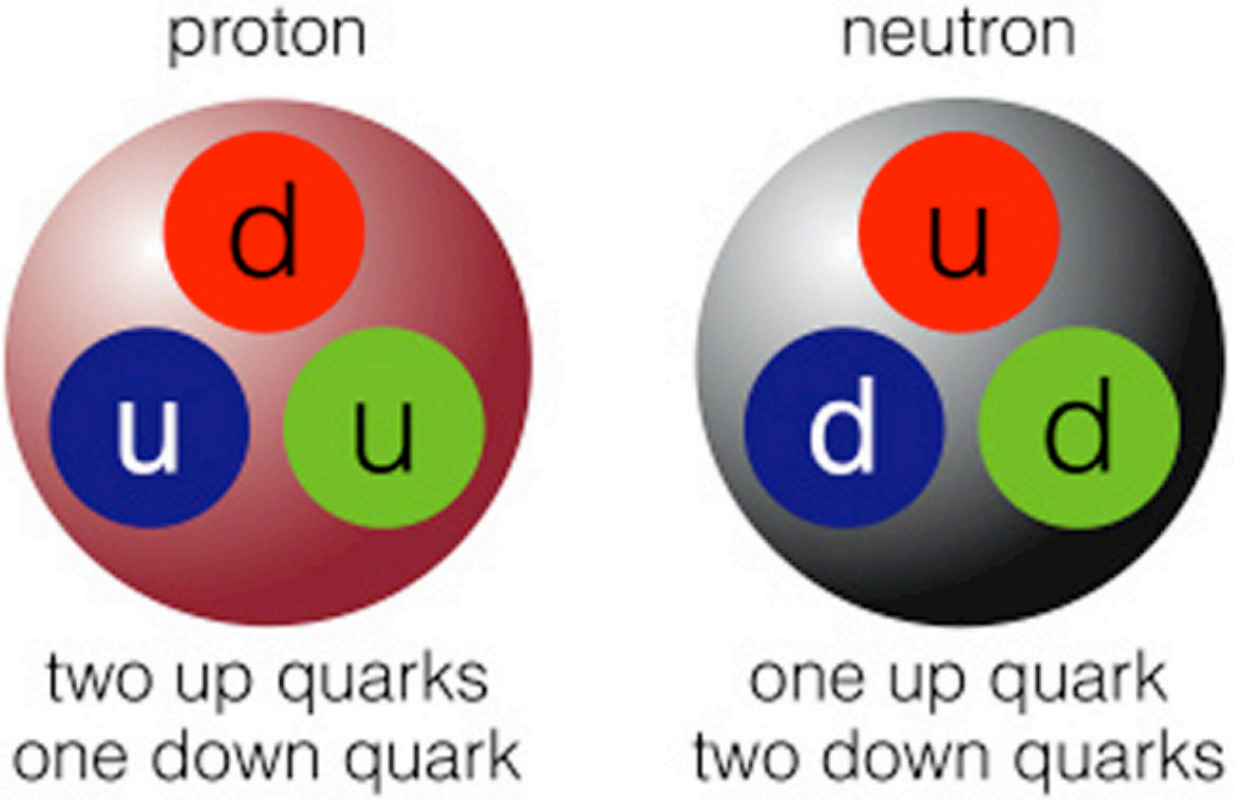


1. Electrons
   - Small Mass
   - Negative (-1) charge
2. "Up" quarks
   - Massive
   - Positive (+2/3) charge
3. "Down" quarks
   - Massive
   - Negative (-1/3) charge

Not drawn to scale!

Quarks ("subatomic particles")

Give protons & neutrons their mass and charge.



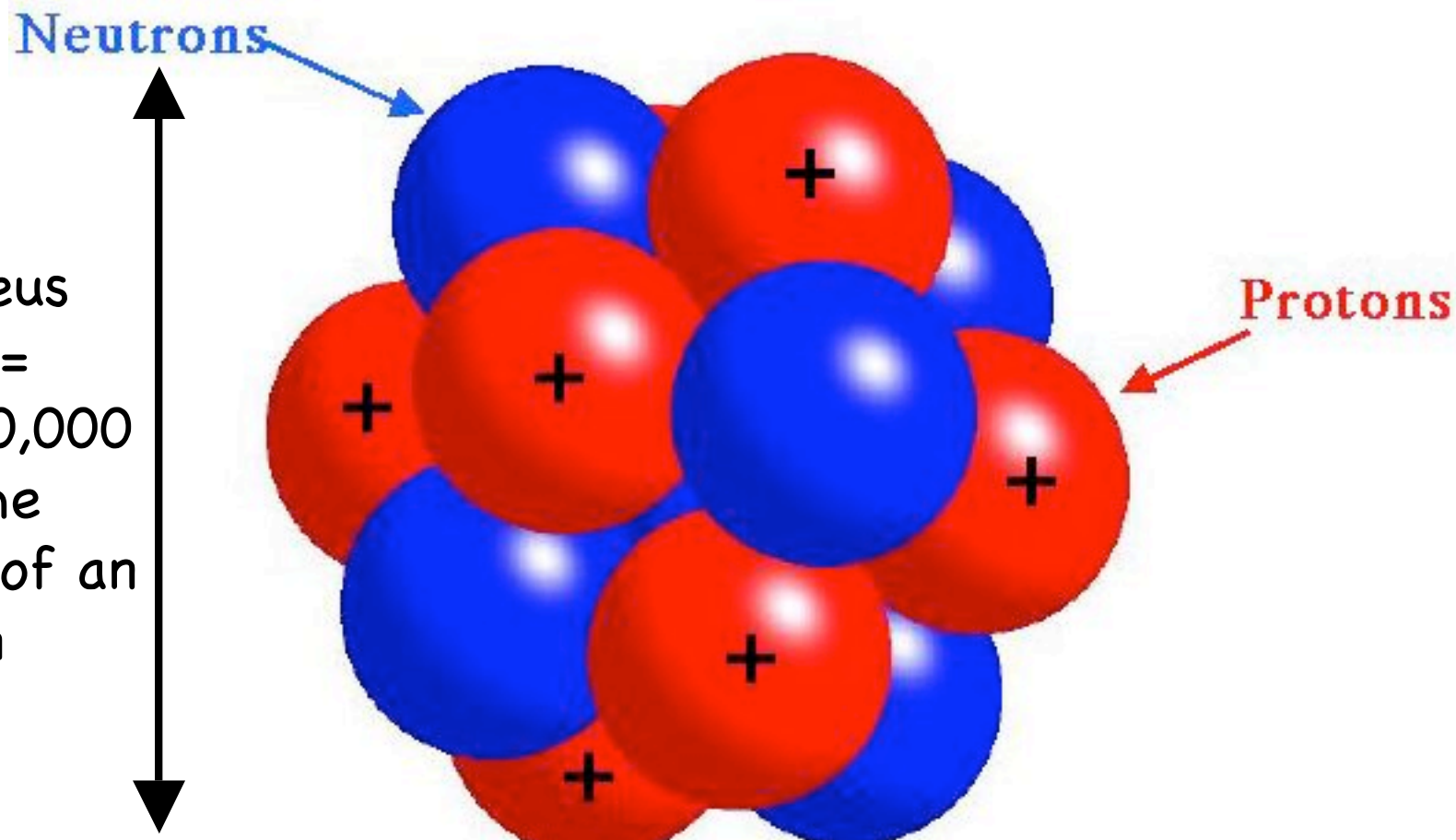
As far as we know, quarks & electrons are the fundamental building blocks of matter!

Murray Gell Mann (1929-)

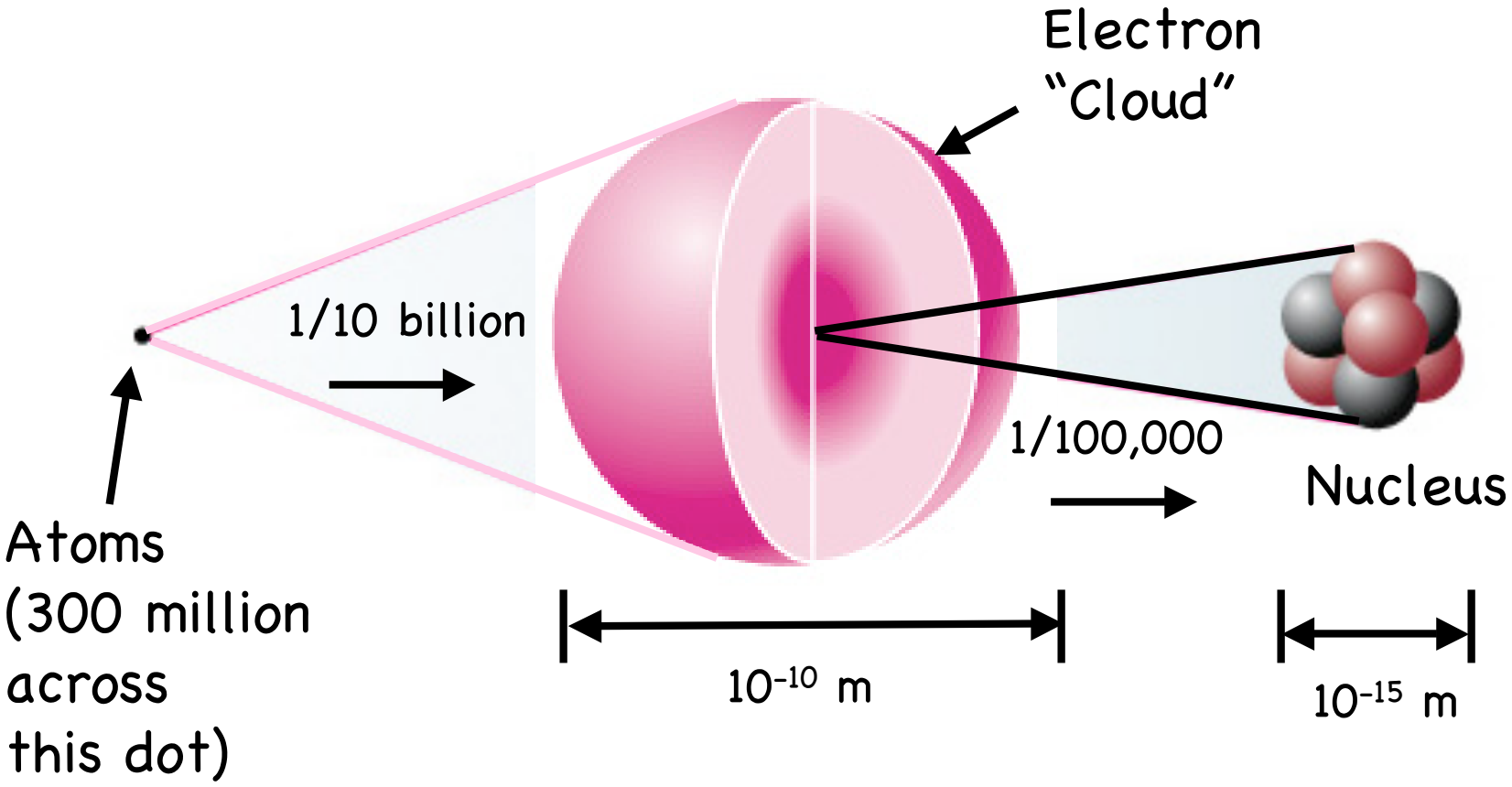
- Avid linguist & physicist
- Went to Yale at 15!
- "Quark" came from James Joyce' Finnegan's Wake
- He likes whimsical names: "Eightfold Way," "up, down, strange quarks," "Color charge," "gluons," "plectics,"...

The Nucleus

- Protons and Neutrons have almost the same mass.
- They are tiny in size
- Held together by the "strong" nuclear force

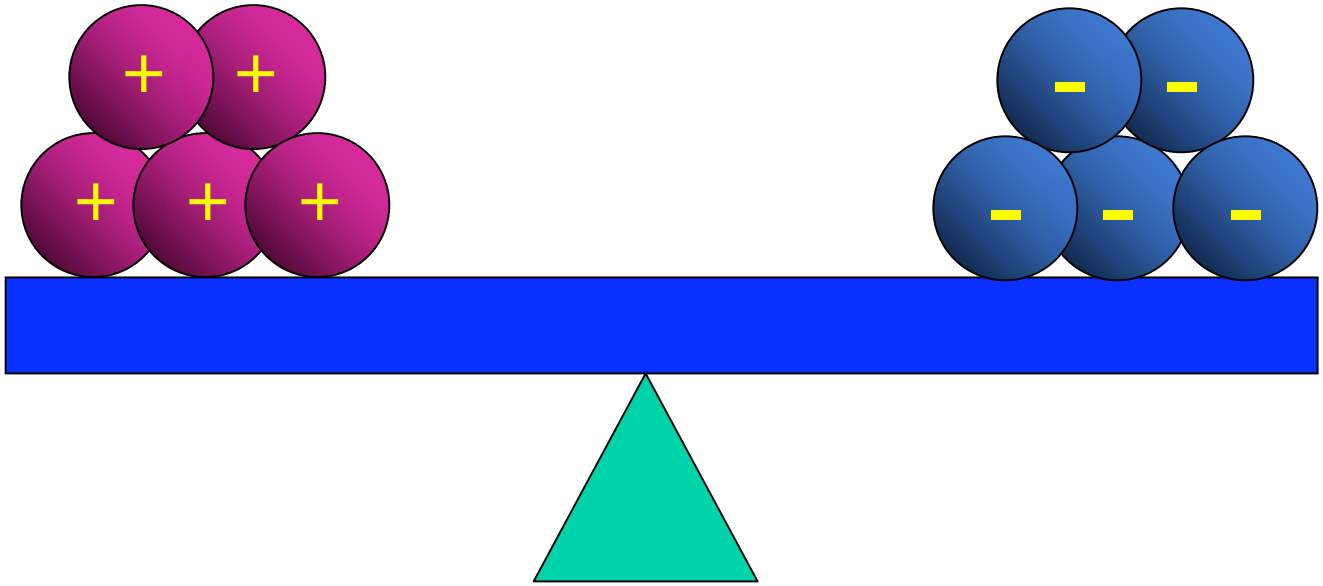


The structure an atom:



II. The basic rules of atoms

a) An atom wants to have as many electrons as protons (i.e. it wants to be electrically NEUTRAL, with *no net charge*)



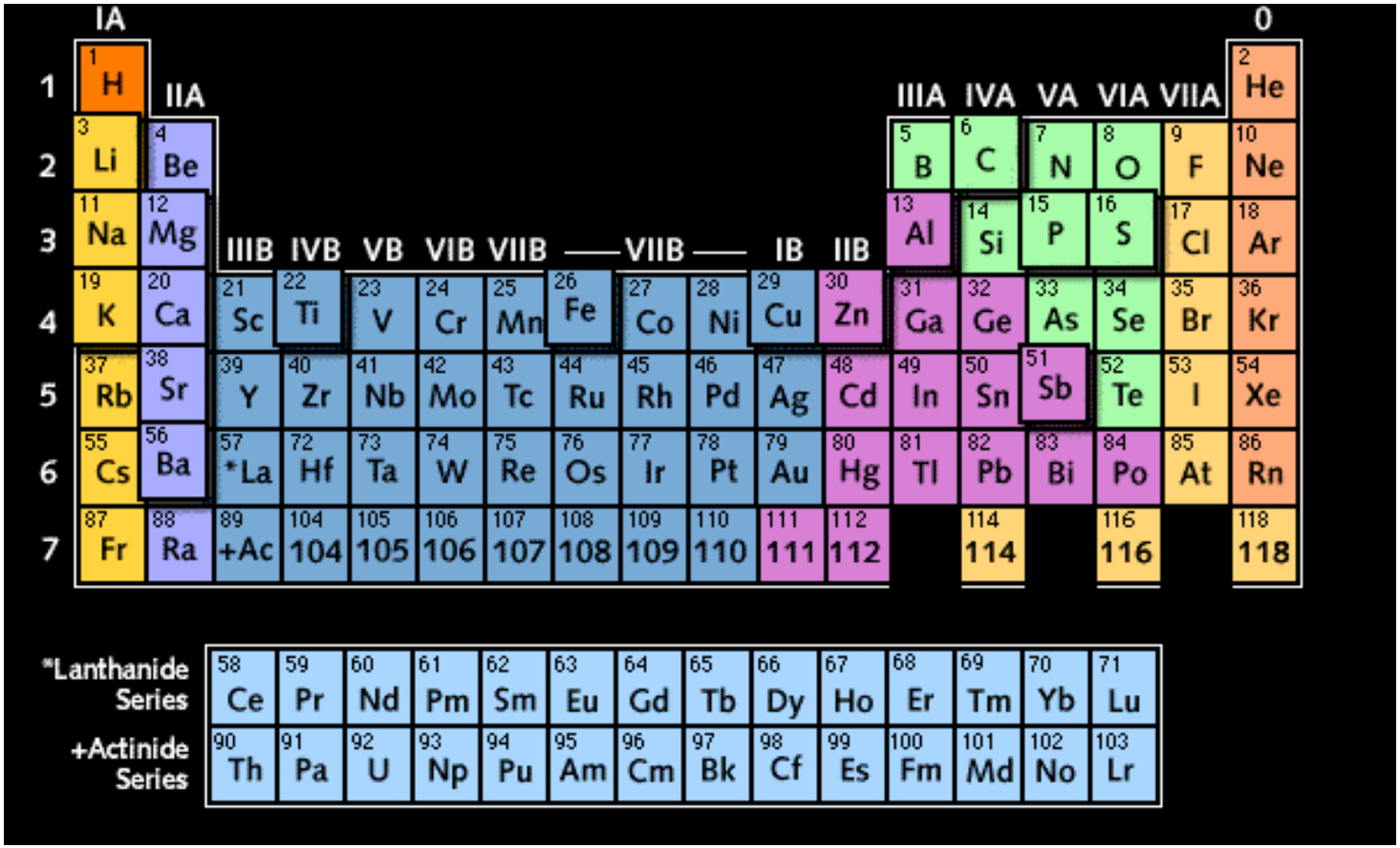
b) The number of protons strongly defines how the atom behaves chemically.

# of protons ⟺ **ELEMENT**

"Atomic Number"

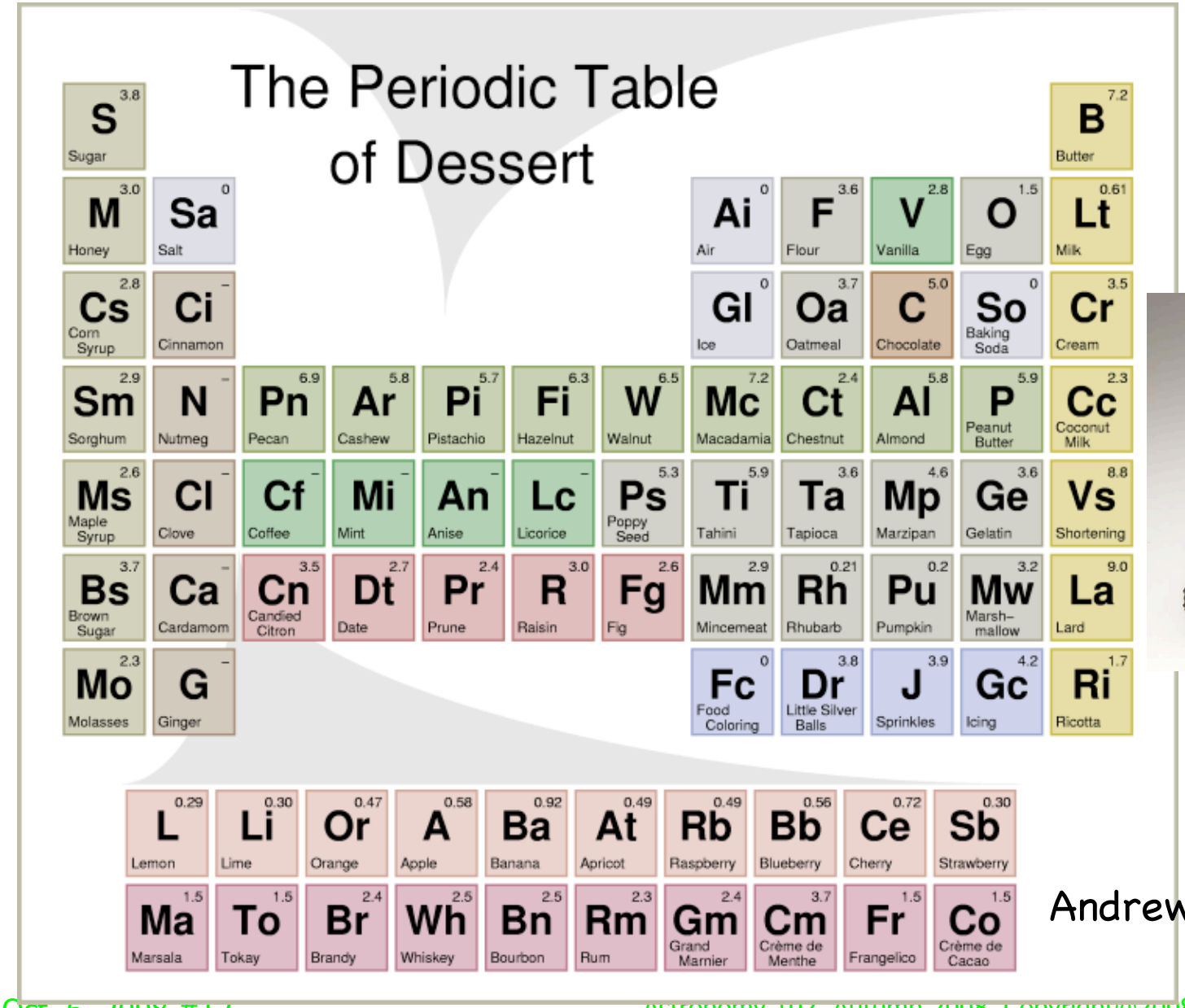
1	Hydrogen
2	Helium
6	Carbon
8	Oxygen
26	Iron

The Periodic Table



Each box is a different element, with a different number of protons.

The Periodic Table

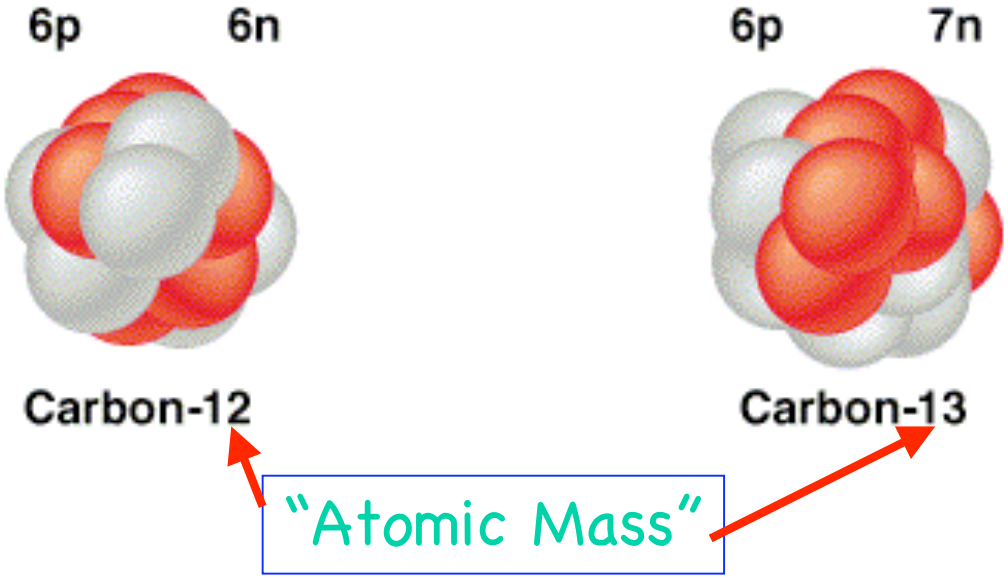


Andrew Plotkin ©2003

c) Neutrons add mass, but don't change much about how the atom behaves

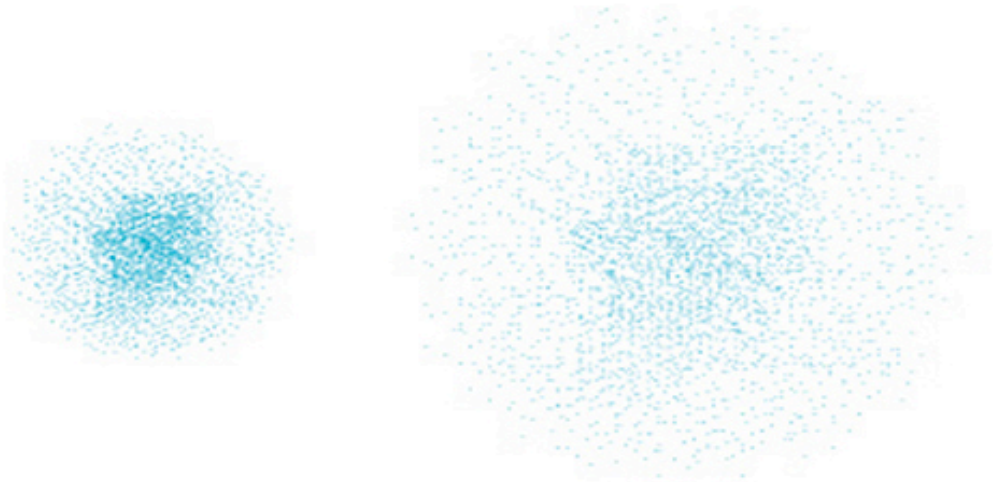
# of neutrons

Same element, but different ***isotopes***.



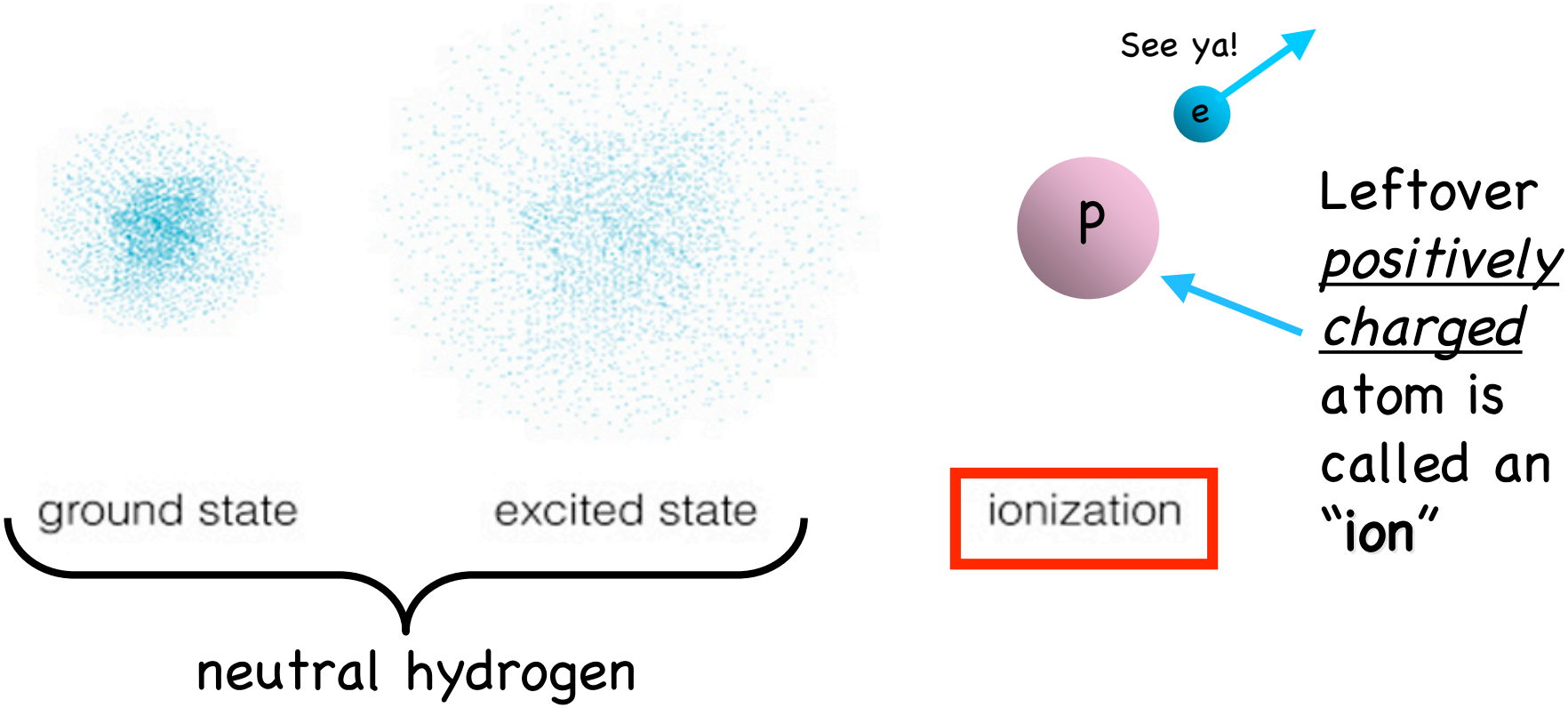
d) The structure of the electrons is affected by the energy of the atom.

Low energy→ electrons close in.

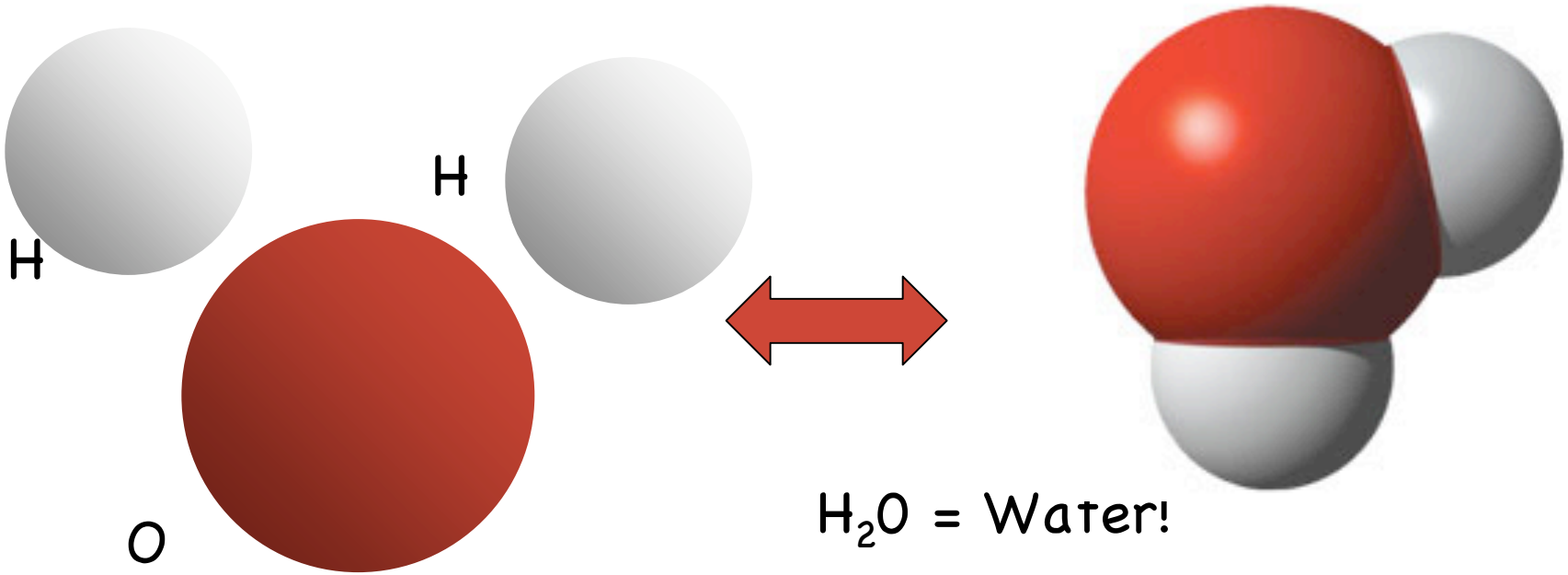


High energy→ electrons further out.

e) Highly energetic electrons can be *stripped* from the atom: "Ionization"



f) Atoms combine to form molecules by sharing electrons, but the nuclei don't interact (usually).



H_2O = Water!

Question 1:

An ordinary atom of Helium has 2 protons + 2 neutrons in its nucleus.

An atom with: 2 protons is:
1 neutrons
2 electrons

A. Neutral Helium
B. Ionized Helium
C. A neutral isotope of Helium
D. An ionized isotope of Helium
E. An element other than Helium

Question 2:

An ordinary atom of Helium has 2 protons + 2 neutrons in its nucleus.

An atom with: 3 protons is:
2 neutrons
2 electrons

A. Neutral Helium
B. Ionized Helium
C. A neutral isotope of Helium
D. An ionized isotope of Helium
E. An element other than Helium

Question 3:

An ordinary atom of Helium has 2 protons + 2 neutrons in its nucleus.

An atom with: 2 protons is:
2 neutrons
1 electrons

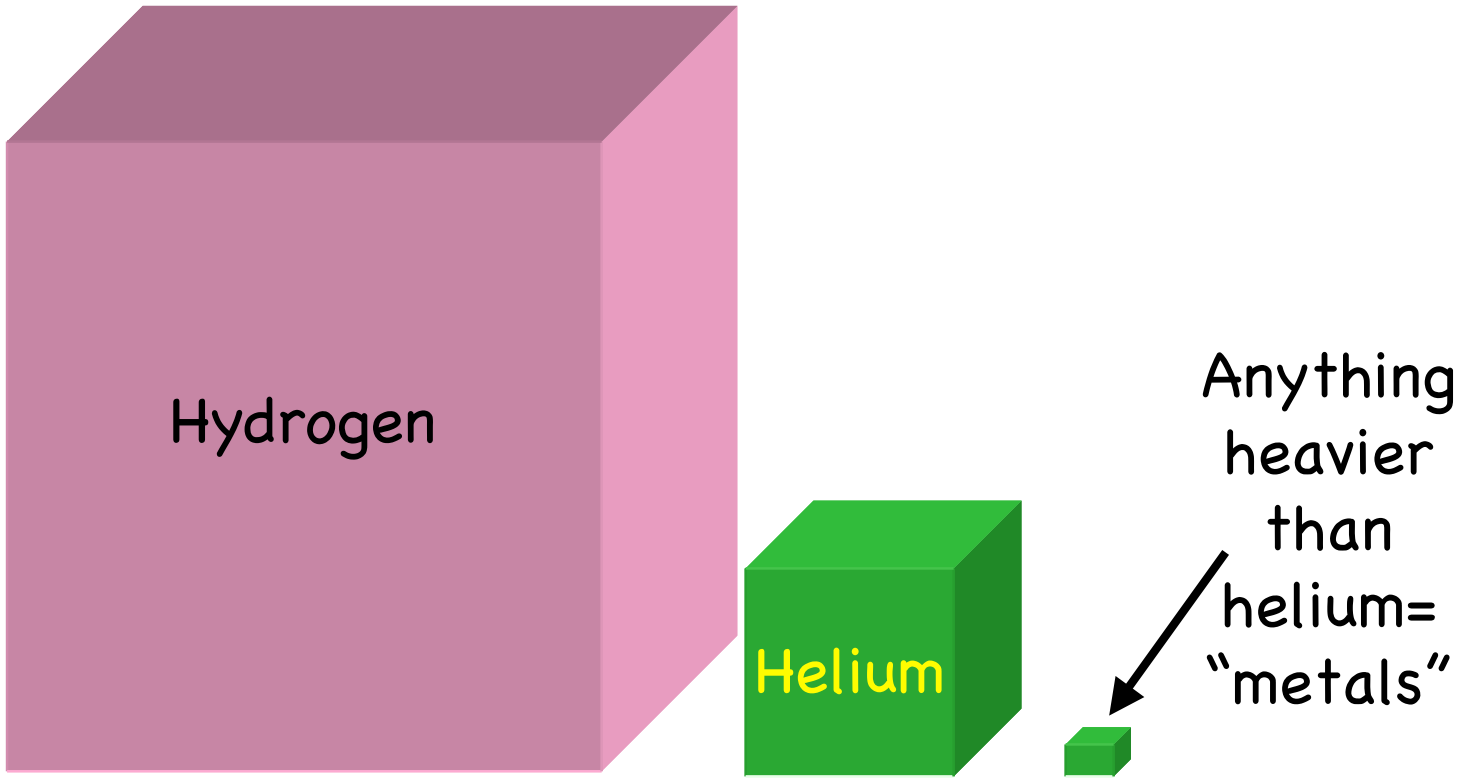
A. Neutral Helium
B. Ionized Helium
C. A neutral isotope of Helium
D. An ionized isotope of Helium
E. An element other than Helium

Elements, Atoms, & Molecules: Why are they important?

- universe is made of elements, atoms, and/or molecules → raw material for planets, stars, & galaxies

- Almost all *light* in the universe is generated through processes related to elements, atoms, & molecules.

Of all the possible elements, the Universe is made up almost entirely of Hydrogen and Helium.



Of all the possible elements, the Universe is made up almost entirely of Hydrogen and Helium.

ELEMENT	PERCENTAGE BY NUMBER OF ATOMS	PERCENTAGE BY MASS
Hydrogen	92.0	73.4
Helium	7.8	25.0
Carbon	0.03	0.3
Nitrogen	0.008	0.1
Oxygen	0.06	0.8
Neon	0.008	0.1
Magnesium	0.002	0.05
Silicon	0.003	0.07
Sulfur	0.002	0.04
Iron	0.004	0.2

III. Elements occur in many different forms

a) Solids

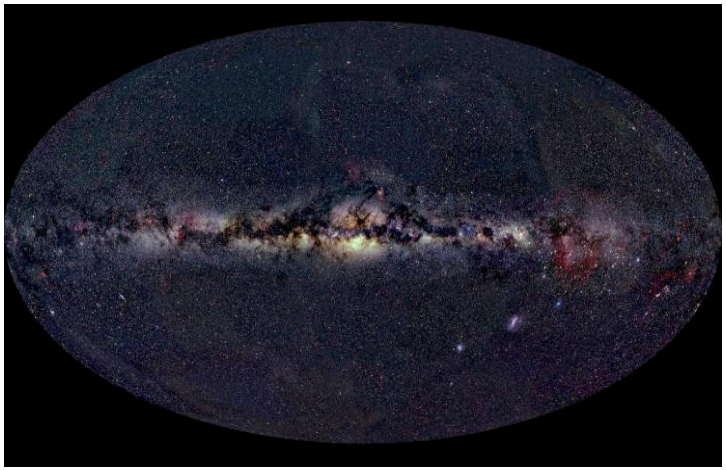
←The surface of the moon, taken during the Apollo 17 mission.

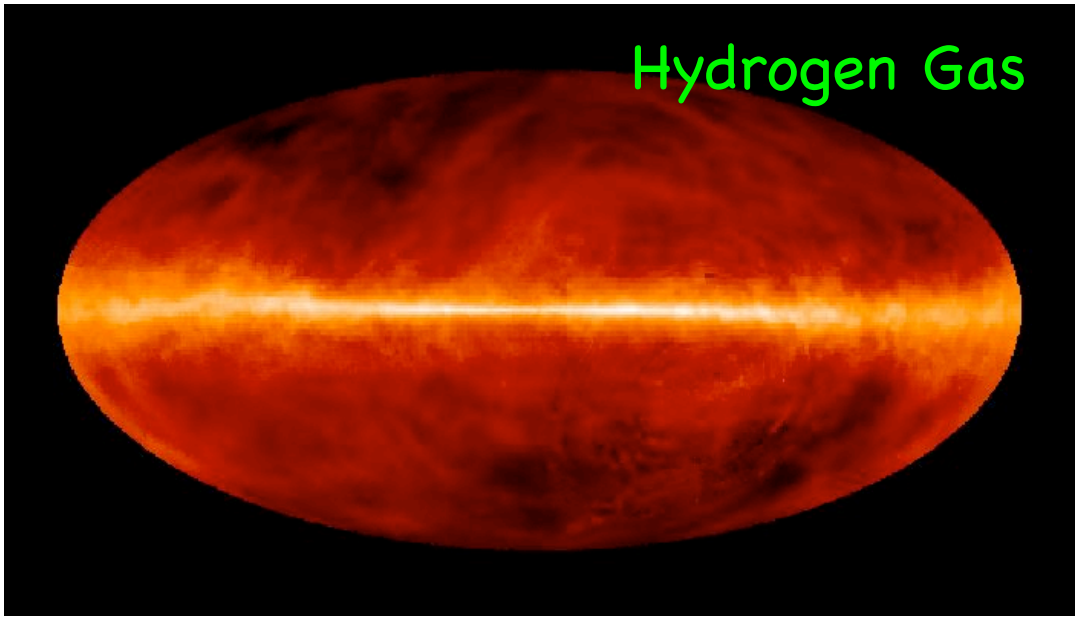
Interstellar dust cloud →

b) Liquids (not much)

c) Gas (lots!)

Optical

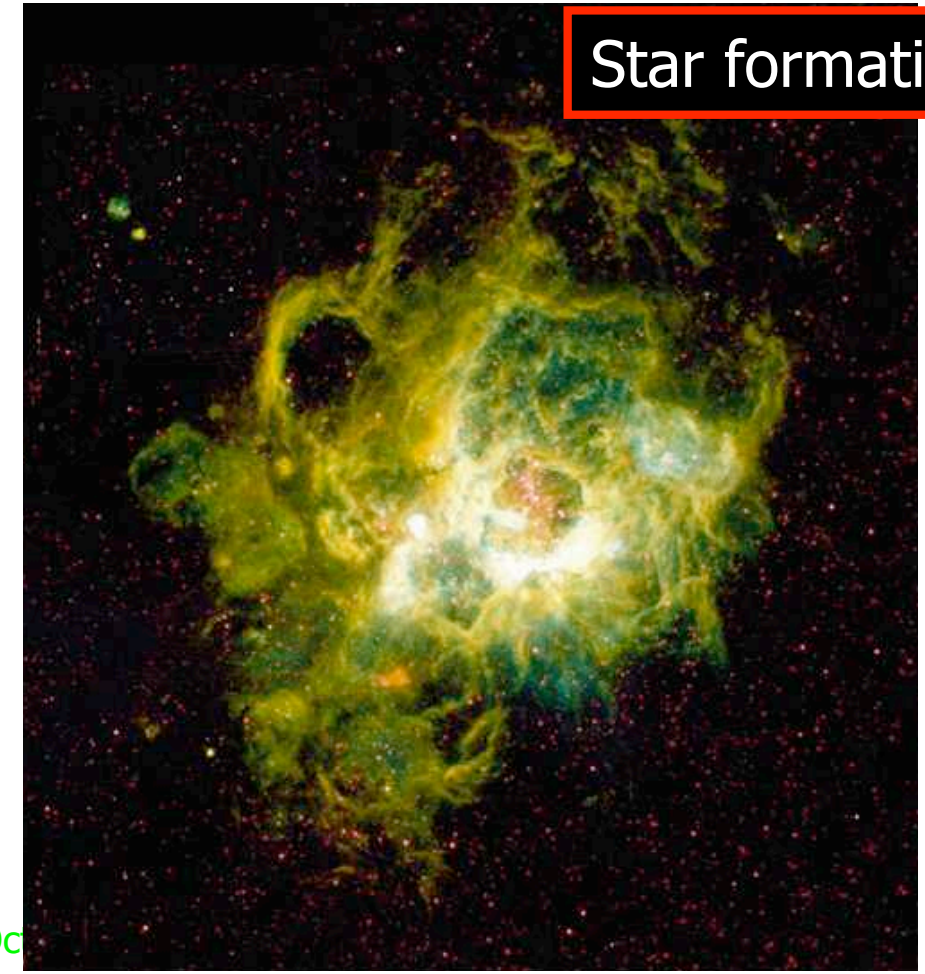




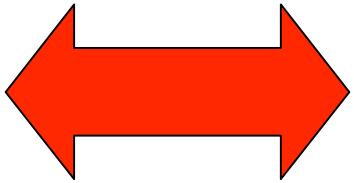
Milky Way Galaxy

d) Plasma or ionized gas (electrons are ripped from atoms)

Star formation regions



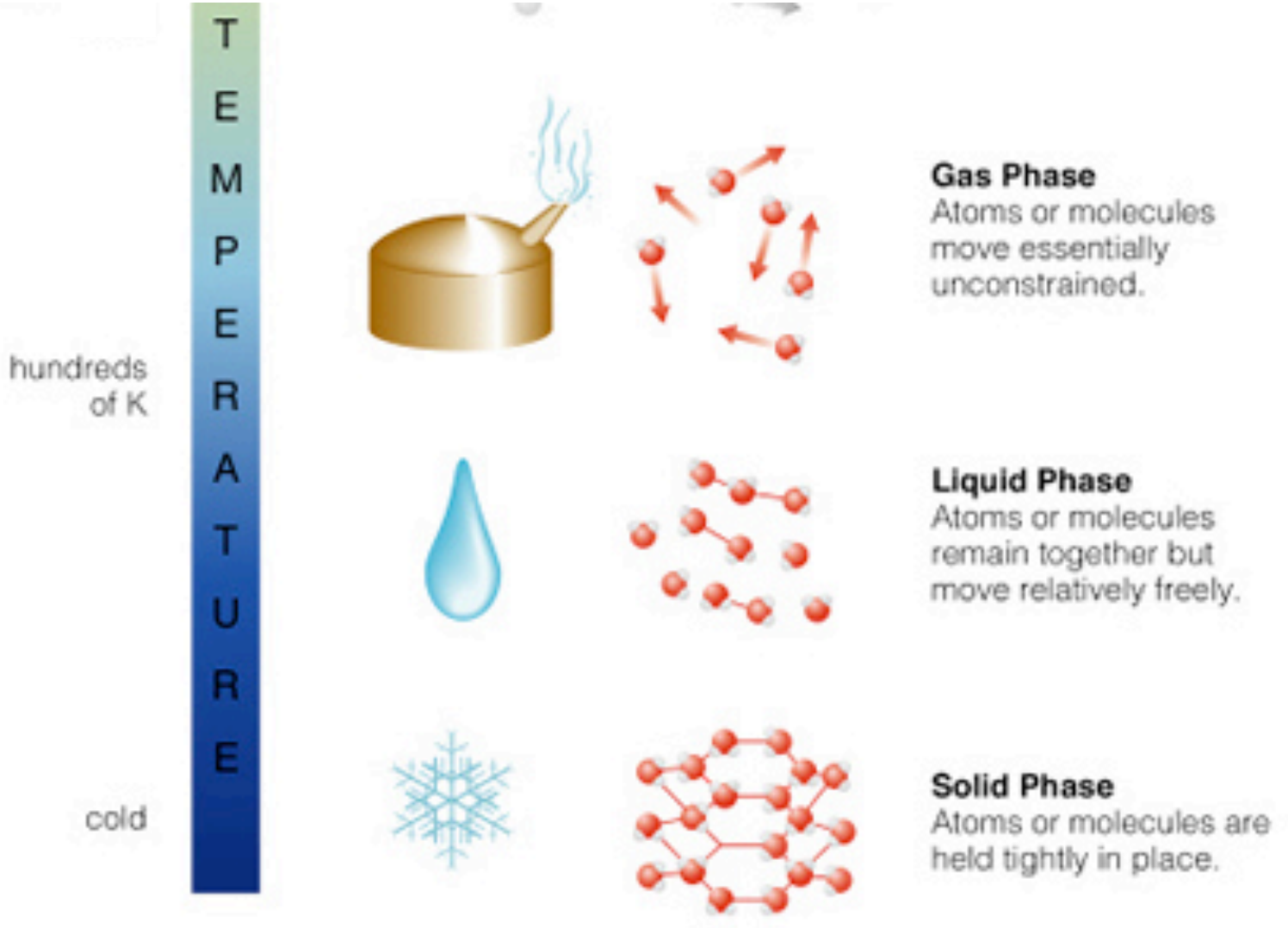
IV. How does temperature affect the state of matter?



Temperature alters the structure of the atoms and/or molecules.

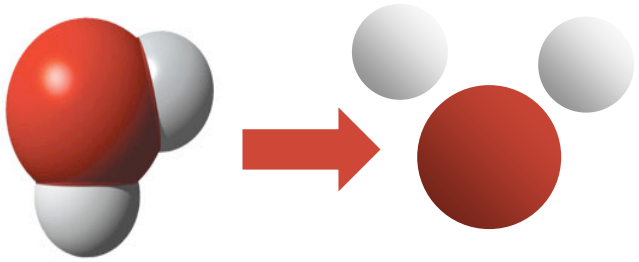
States of Matter

Temperature changes how closely atoms and molecules are bound to each other

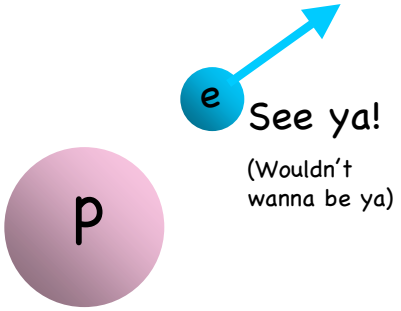


At extreme temperatures:

1. Molecules "dissociate"
   = Atoms cannot remain bound together



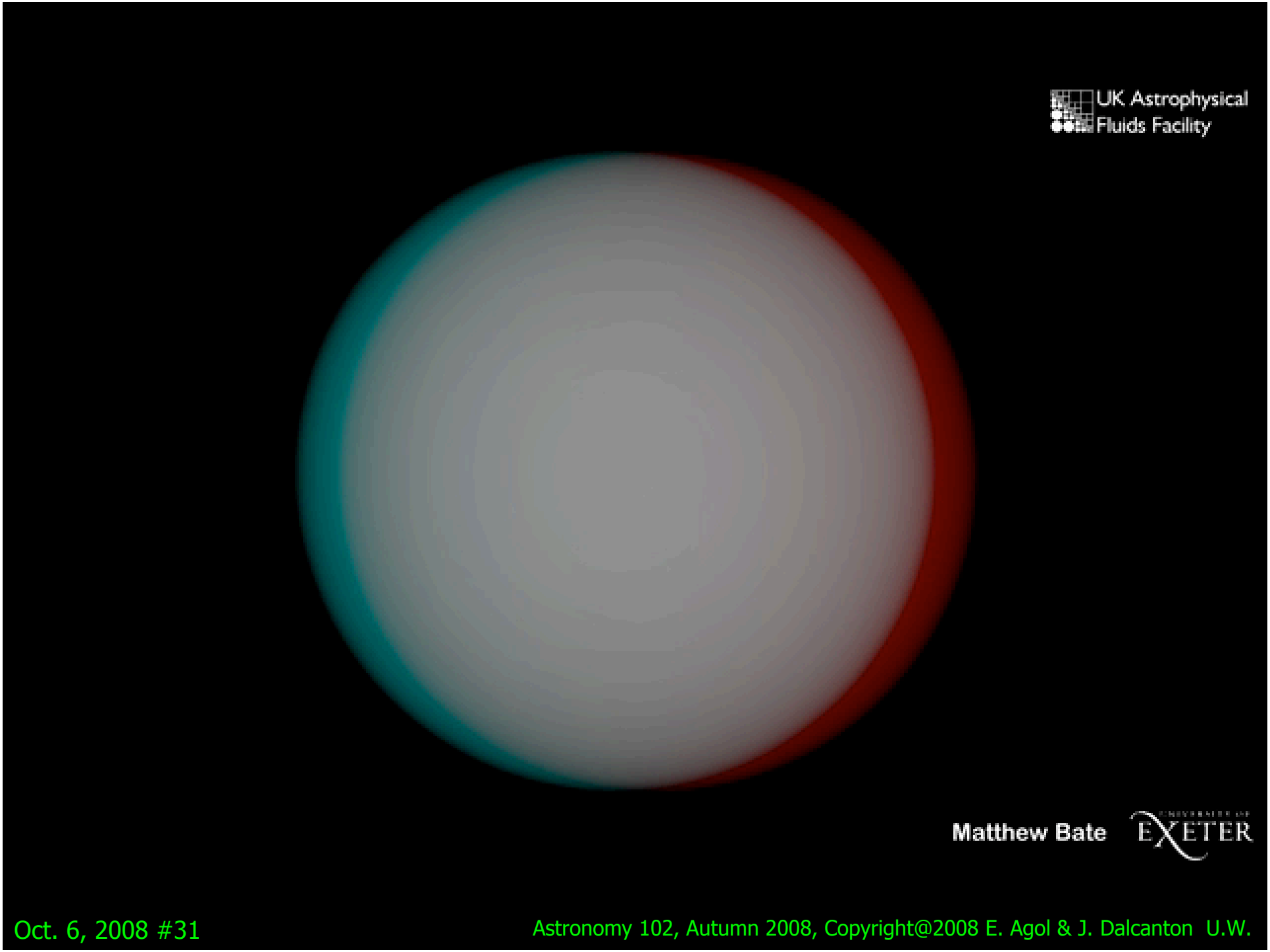
2. Atoms lose their electrons = ionization = plasma

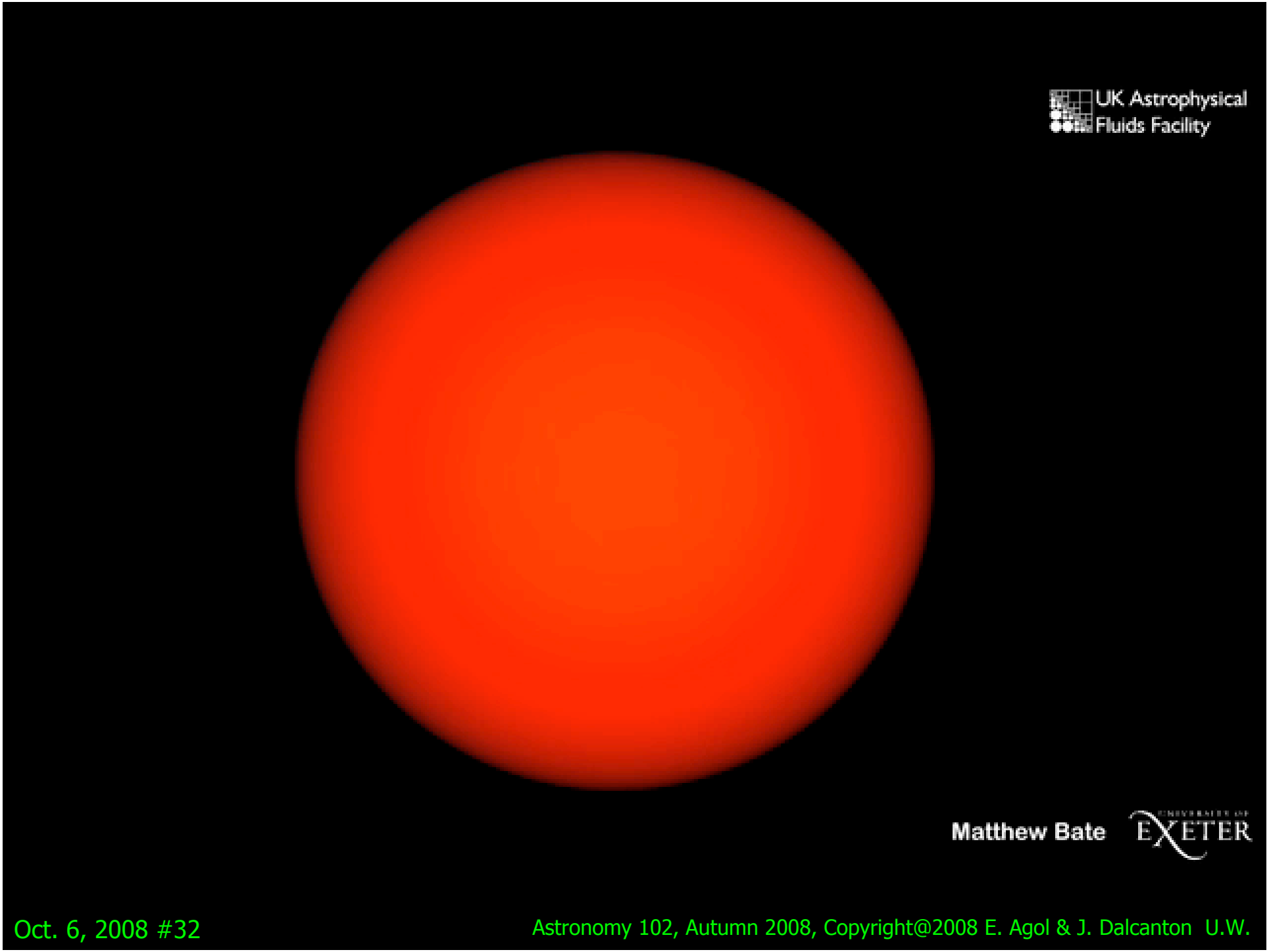


Note: These changes in "phase" do not take place at the exact same temperature for all materials

← Nitrogen is a liquid even when it's very cold (77 degrees above absolute zero = -321°F)

A saucepan is still solid even when water changes from liquid to gas →





Recap

- An atom is made of a nucleus (made of protons & neutrons) plus electron cloud
- Number of protons determines chemical element
- Number of neutrons -> isotope
- Number of electrons -> neutral or ion
- Atoms make up molecules - chemistry
- Solid, liquid, gas & plasma phases are determined by increasing temperature