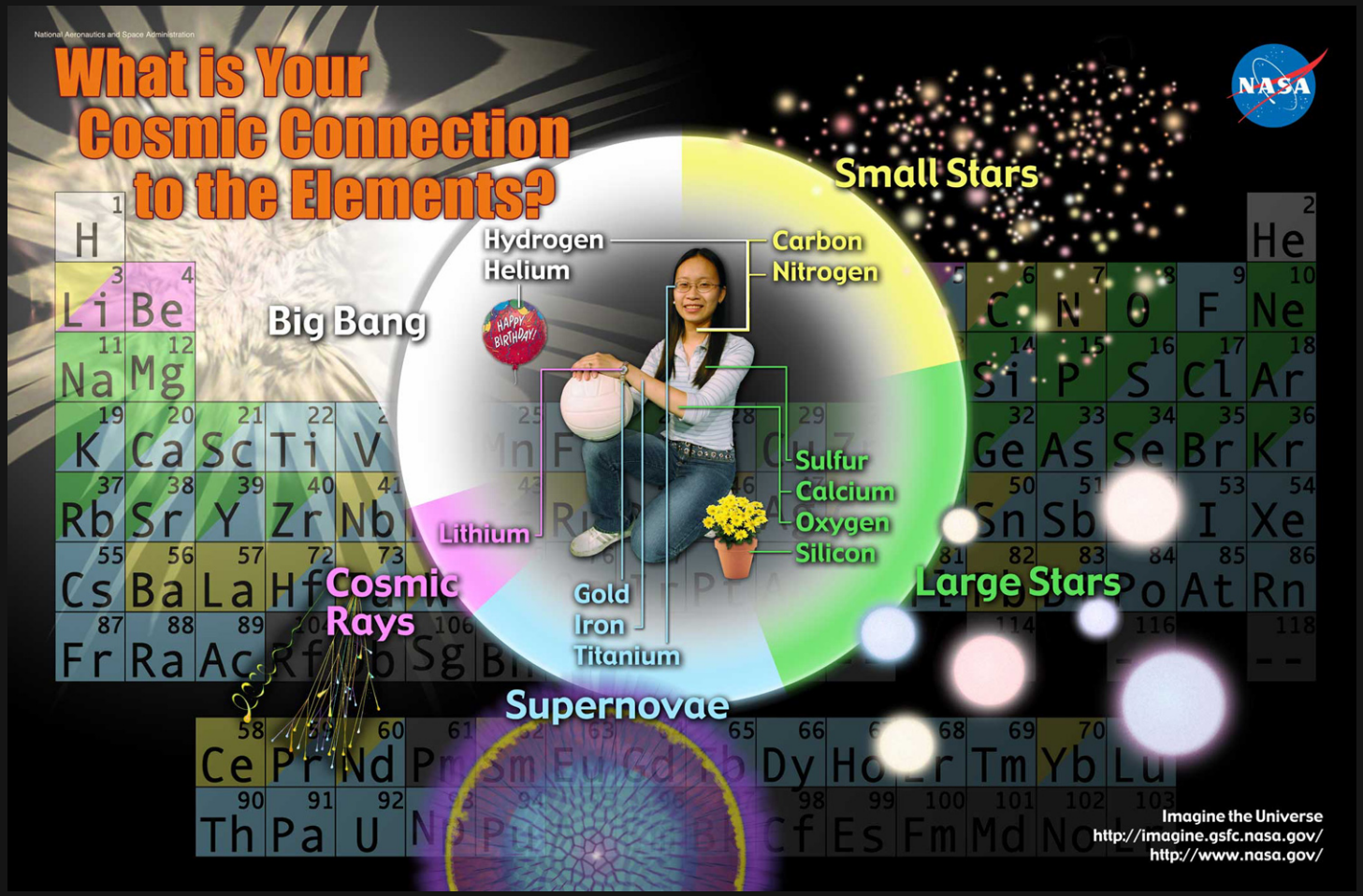
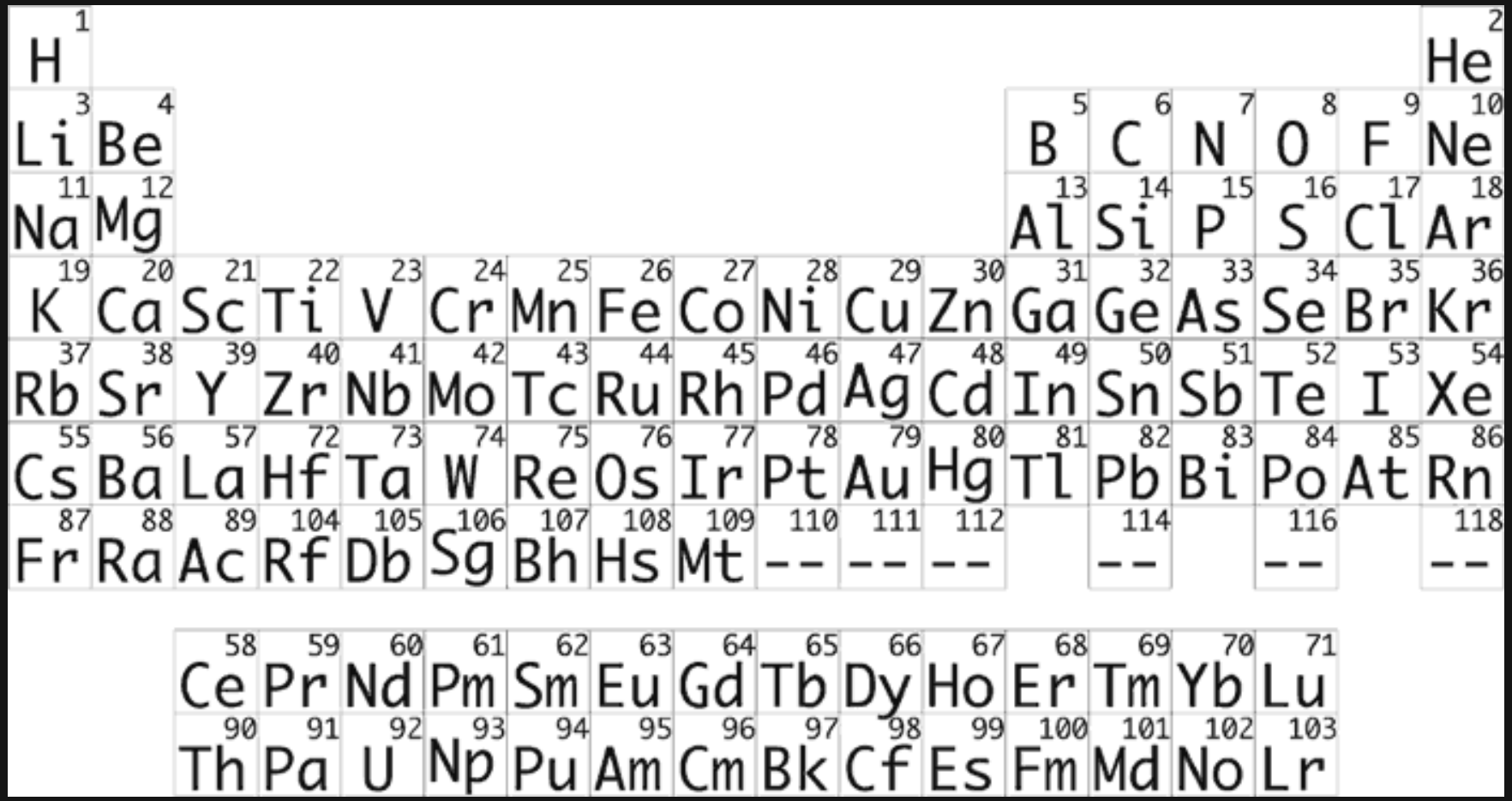
Your Cosmic Connection to the Elements

James Lochner (USRA) & Suzanne Pleau Kinnison (AESP), NASA/GSFC



Elementary Connections

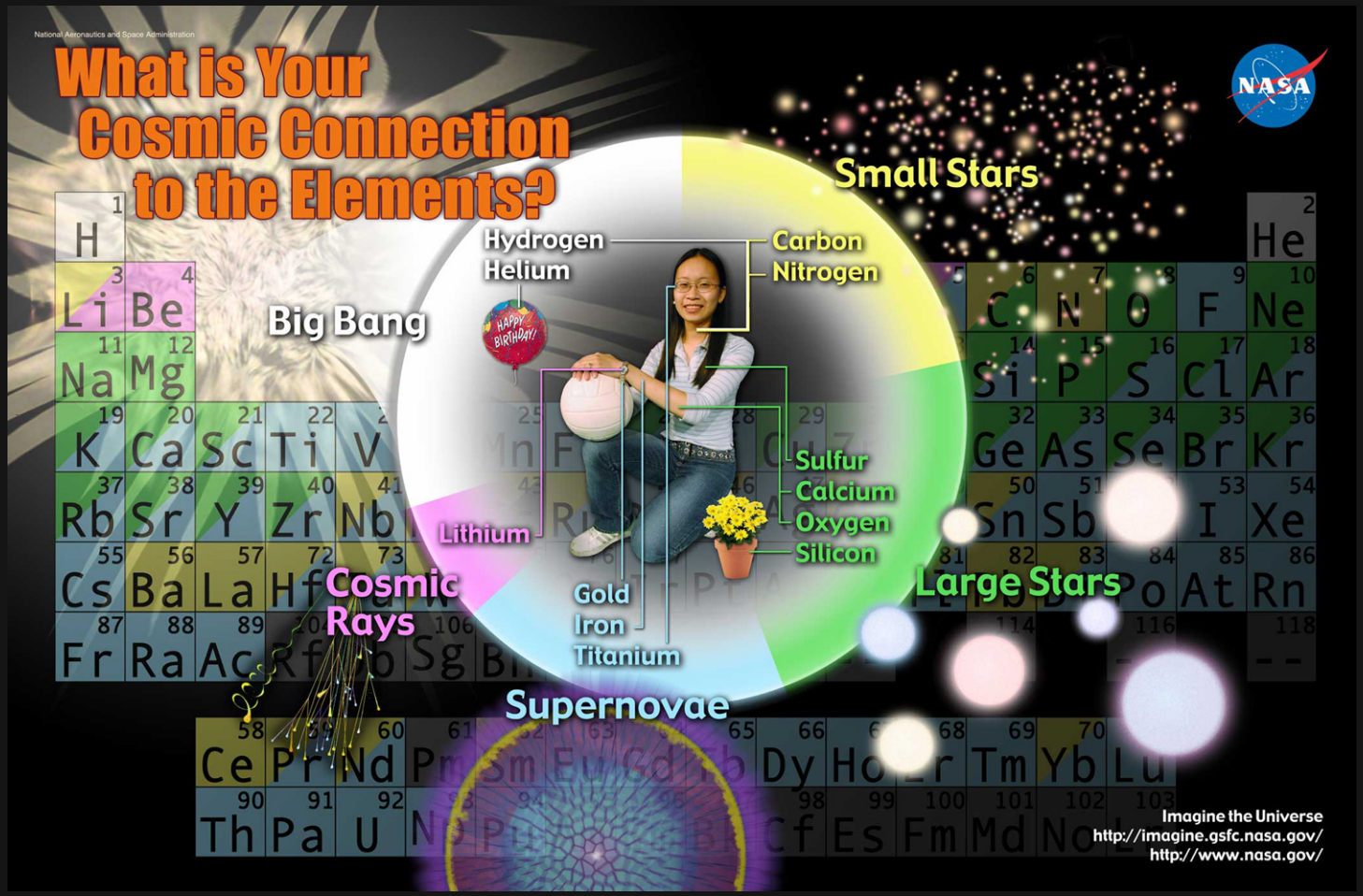


Cosmic Connections

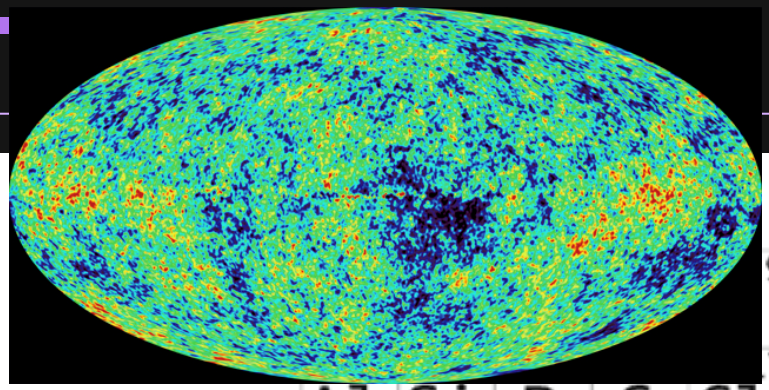
To make an apple pie from scratch,
you must first invent the universe.

Carl Sagan

Your Cosmic Connection to the Elements?



The Big Bang



1 H																	2 He
3 Li	4 Be																10 Ne
11 Na	12 Mg																18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb					46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	72 Hf	73 Ta					78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac	104 Rf	105 Db					110 --	111 --	112 --		114 --		116 --		118 --

58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

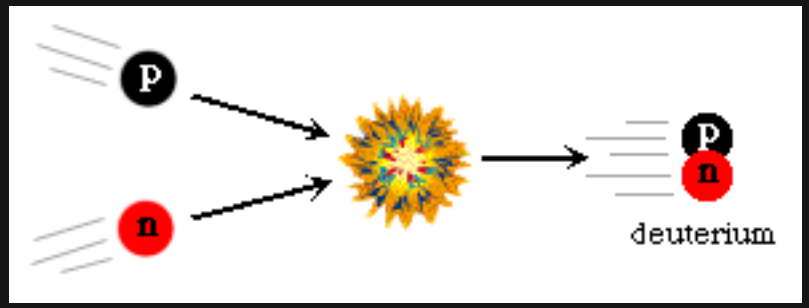
The Big Bang Cosmology

- The expansion of the universe began at a finite time in the past, in a state of enormous density, pressure and temperature.
- "Big Bang" is a highly successful family of theories with no obvious competitor.
  - Explains what we see, and has made several successful predictions.

Big Bang Nucleosynthesis

Within first three minutes, Hydrogen & Helium formed.

- At t =1 s, T=10,000,000,000 K: soup of particles: photons, electrons, positrons, protons, neutrons. Particles created & destroyed.
- At t =3 min, T=1,000,000,000 K: p+n => D



- D + D => He

Big Bang Nucleosynthesis

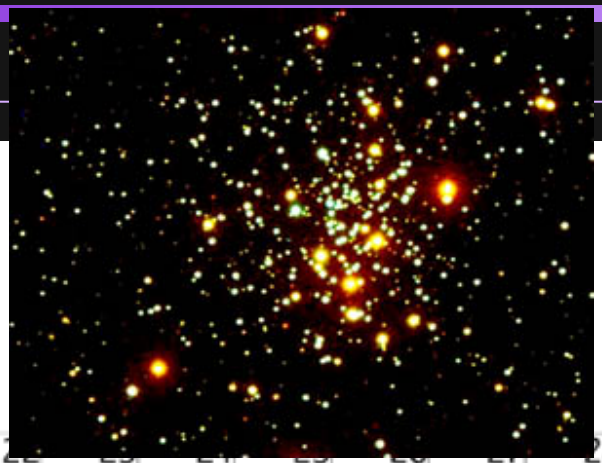
Note that the only elements that come from the Big Bang are:

Hydrogen

Helium

Lithium (a little bit)

Small Stars



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37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd				50	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt				82	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 --				114		116 --		118 --
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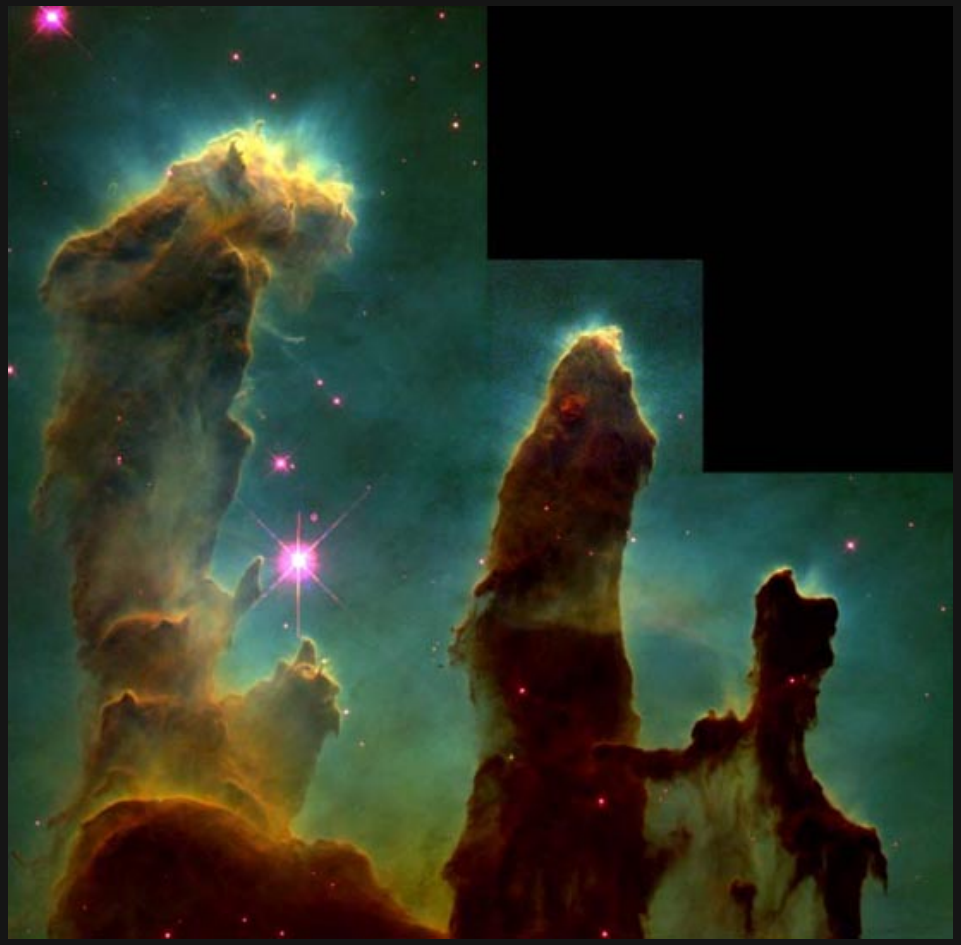
Stellar Nursery



Space is filled with the stuff to make stars.

Stars start from clouds

Clouds provide the gas and dust from which stars form.

But not this kind of dust

Rather: Irregular Grains Of Carbon or Silicon

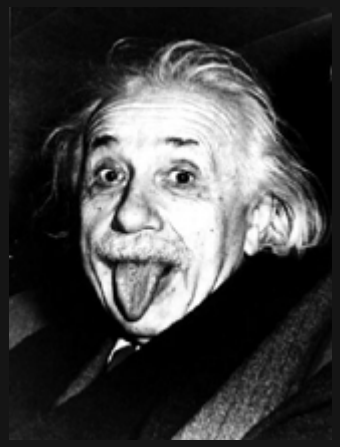
Small Stars: Fusion of light elements

Fusion: (at 15 million degrees !)

4 (^{1}H) => ^{4}He + 2 e^+ + 2 neutrinos + energy

Where does the energy come from ?

Mass of four ^{1}H > Mass of one ^{4}He

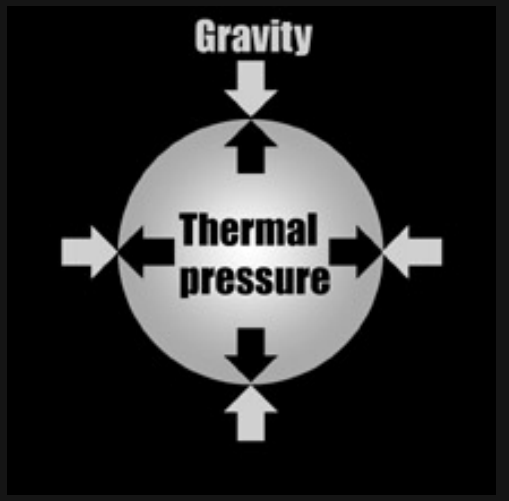


$E = mc^2$

Small Stars to Red Giants

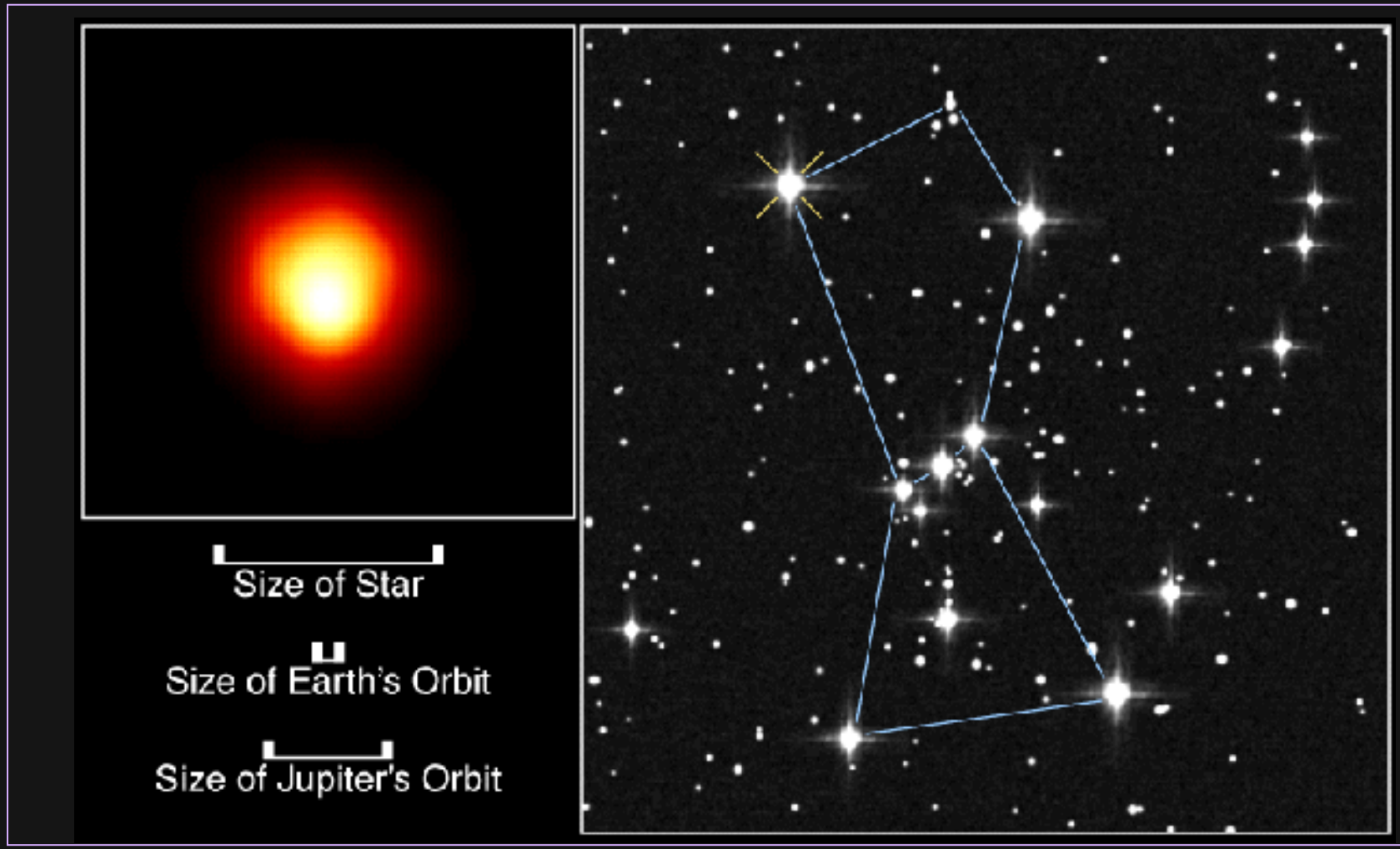
After Hydrogen is exhausted in core,

Energy released from nuclear fusion no longer counter-acts inward force of gravity.



- Core collapses,
  - Kinetic energy of collapse converted into heat.
  - This heat expands the outer layers.
- Meanwhile, as core collapses,
  - Increasing Temperature and Pressure ...

A Red Giant You Know



Beginning of Heavier Elements

At 100 million degrees Celsius, Helium fuses:

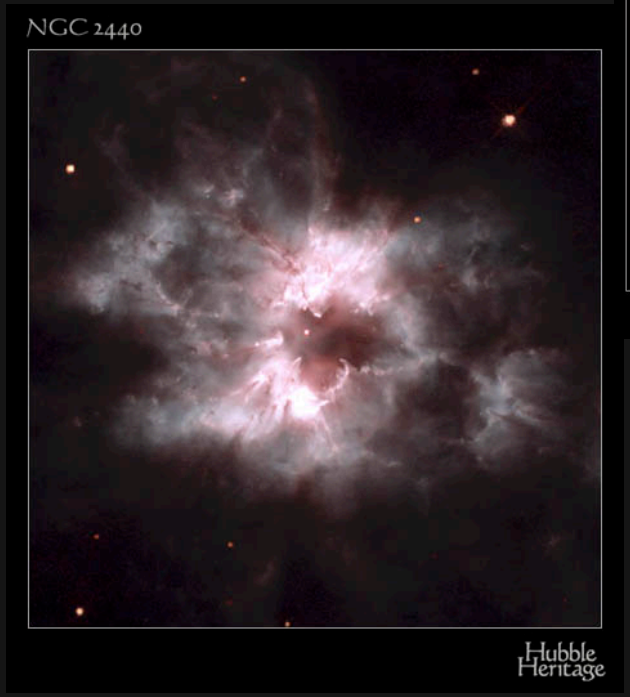
$3\ (^{4}He) \Rightarrow {}^{12}C + \text{energy}$

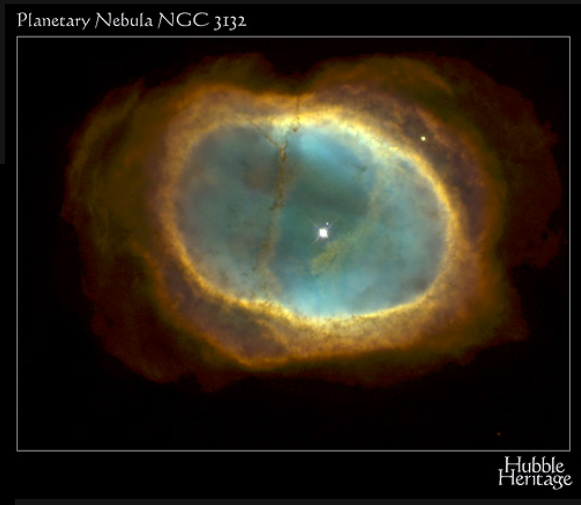
After Helium exhausted, small star not large enough to attain temperatures necessary to fuse Carbon.

The end for small stars

After Helium exhausted, outer layers of star expelled

Planetary Nebulae





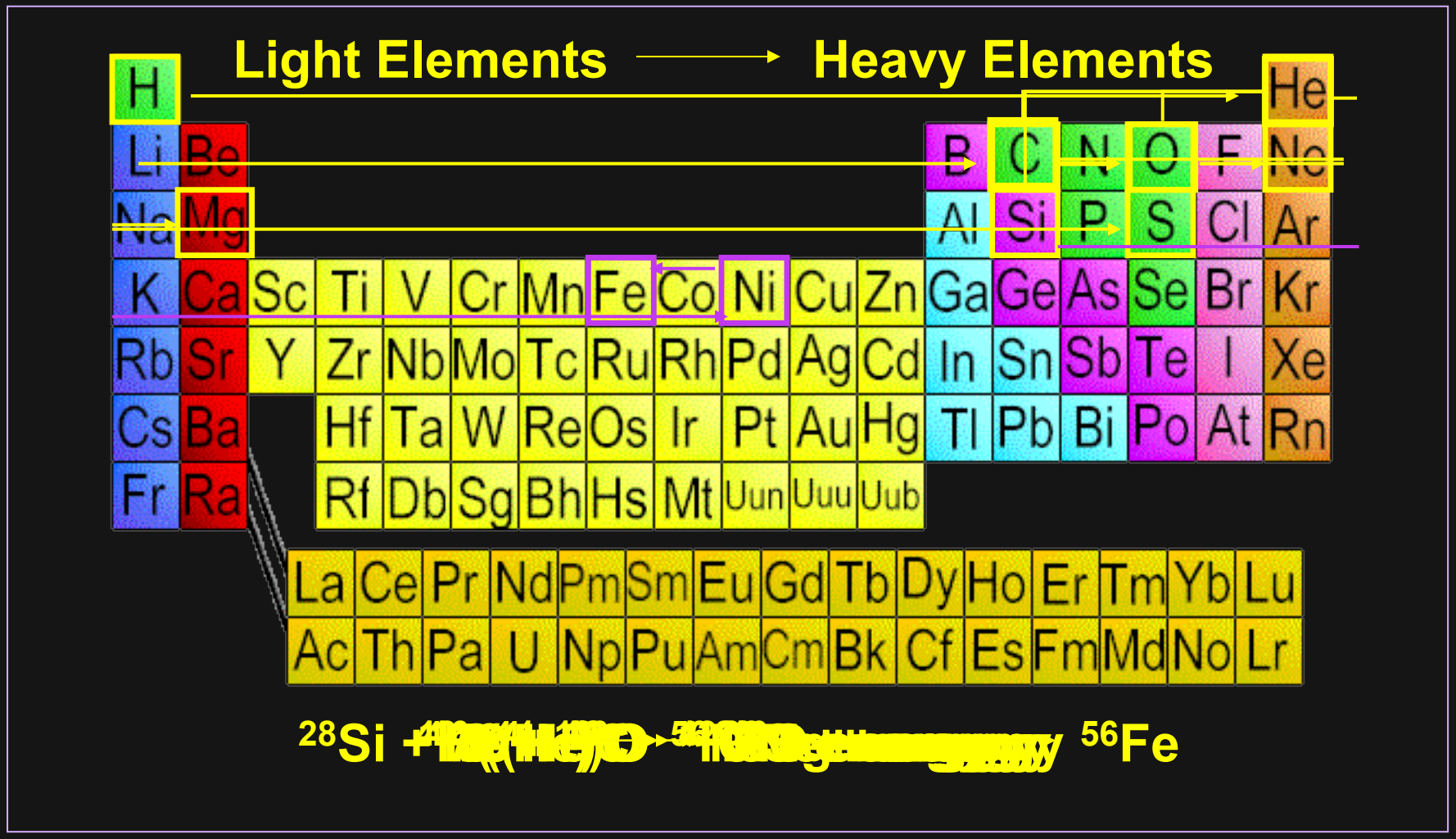
Large Stars

Heavy Elements from Large Stars

Large stars also fuse Hydrogen into Helium, and Helium into Carbon.

But their larger masses lead to higher temperatures, which allow fusion of Carbon into Magnesium, etc.

Element Formation through Fusion



Supernova

Supernova !

Supernova

Fusion of Iron takes energy, rather than releases energy.

So fusion stops at Iron.

Energy released from nuclear fusion no longer counter-acts inward force of gravity.

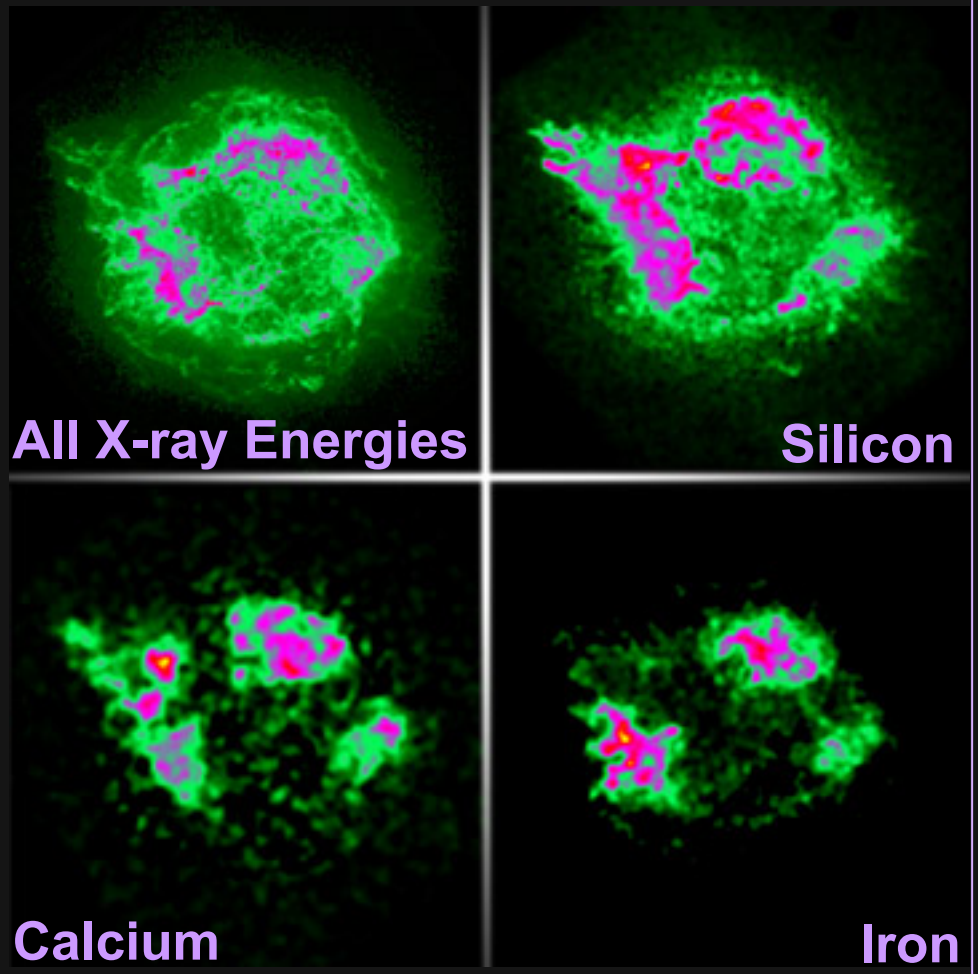
But now there is nothing to stop gravity.

Massive star ends its life in supernova explosion.

Supernova

Explosive power of a supernova:

- Disperses elements created in large stars.
- Creates new elements, especially those heavier than Iron.

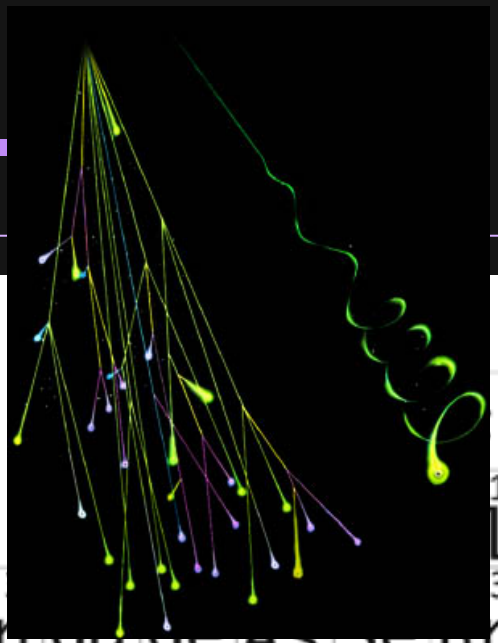


From Death comes Life

Supernovae compress gas and dust which lie between the stars. This gas is also enriched by the expelled material.

This compression starts the collapse of gas and dust to form new stars.

Cosmic Rays



AA
4 PACK
LITHIUM
Energizer
PHOTO
LASTS
5X
LONGER
DIGITAL
CAMERAS
2009

Cosmic Rays

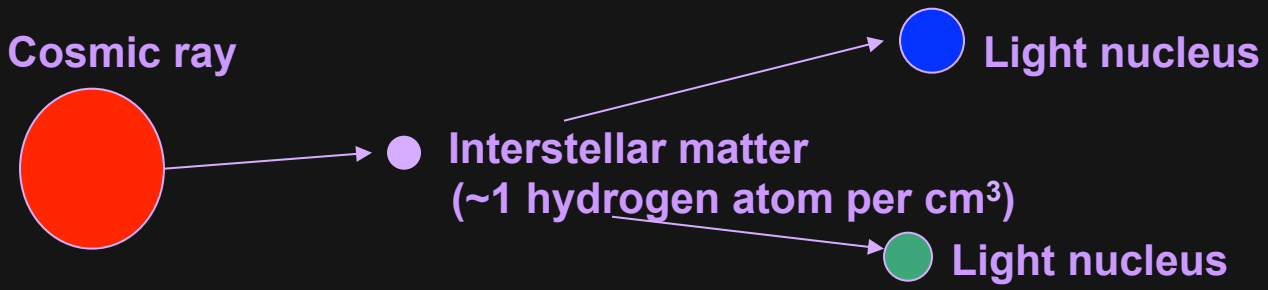
Lithium, Beryllium, and Boron are difficult to produce in stars.

(L, Be, and B are formed in the fusion chains, but they are unstable at high temperatures, and tend to break up into residues of He, which are very stable).

So what is the origin of these rare elements?

=> Collisions of Cosmic Rays with Hydrogen & Helium in interstellar space.

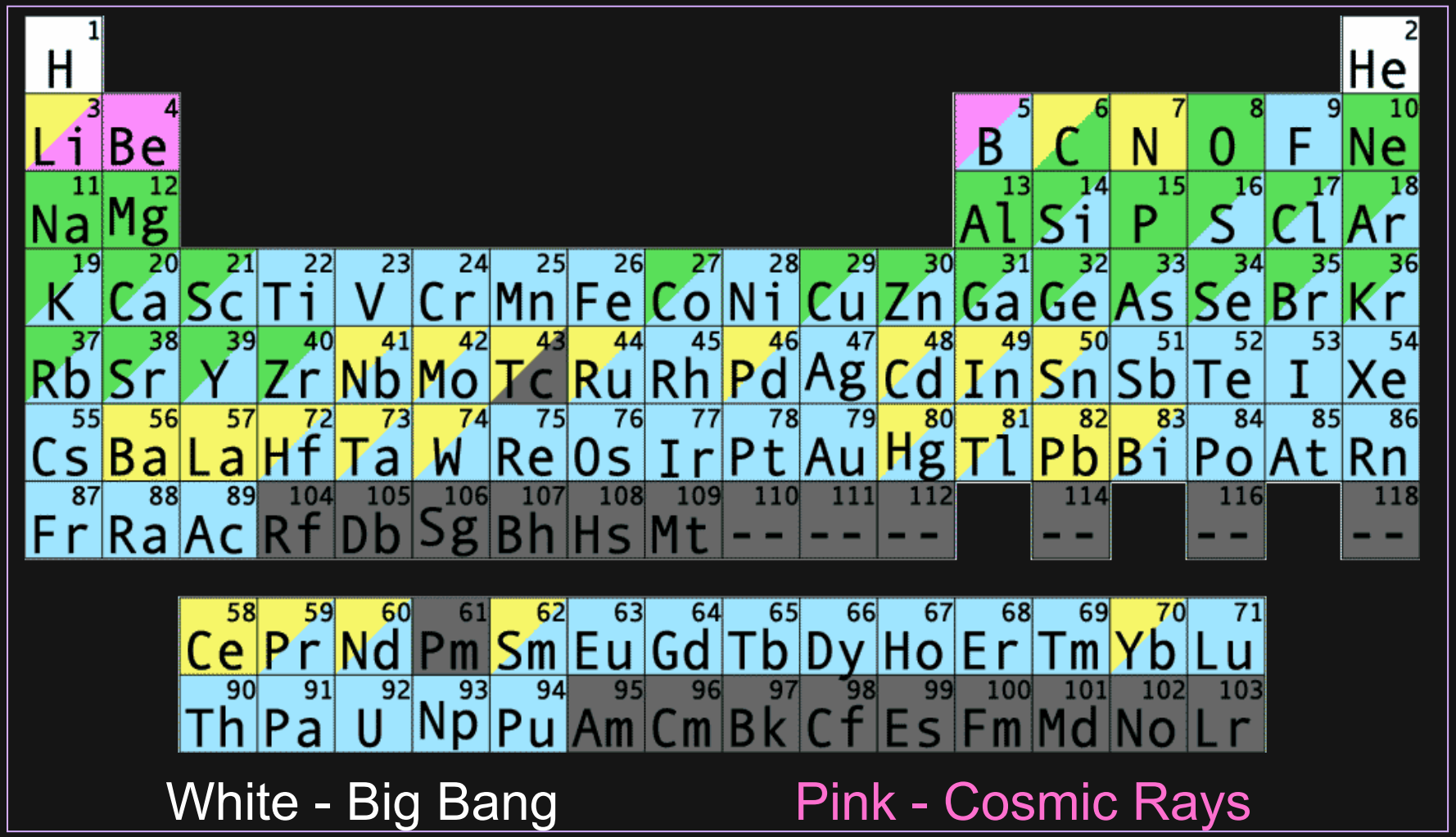
Cosmic Rays Collisions with ISM



Lithium, beryllium, and boron and sub-iron enhancements attributed to nuclear fragmentation of carbon, nitrogen, oxygen, and iron with interstellar matter (primarily hydrogen and helium).

(CNO or Fe) + $(H \& He)_{ISM}$ $\Rightarrow$ (LiBeB or sub-Fe)

Cosmic Elements



White - Big Bang

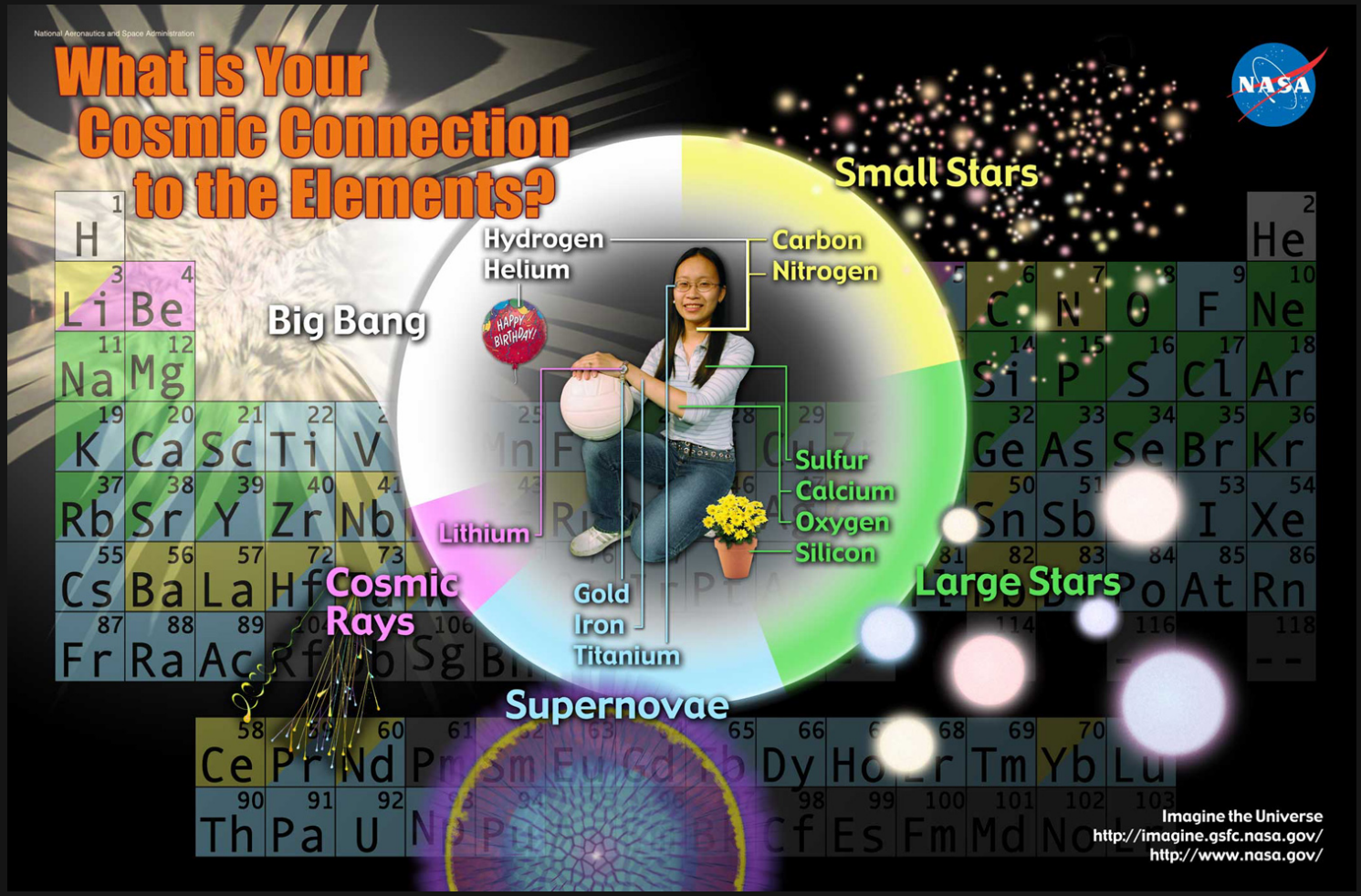
Pink - Cosmic Rays

Yellow - Small Stars

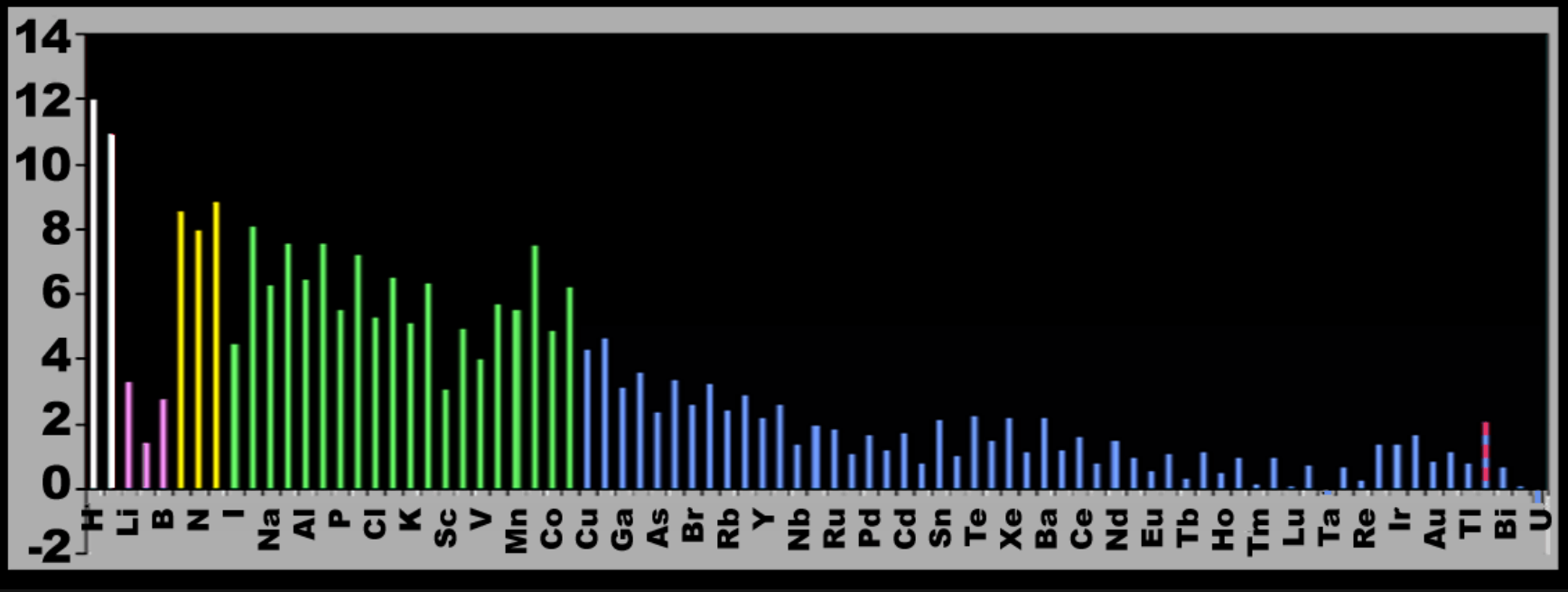
Green - Large Stars

Blue - Supernovae

Your Cosmic Connection to the Elements?



Composition of the Universe



Actually, this is just the solar system.

Composition varies from place to place in universe, and between different objects.

"What's Out There?"

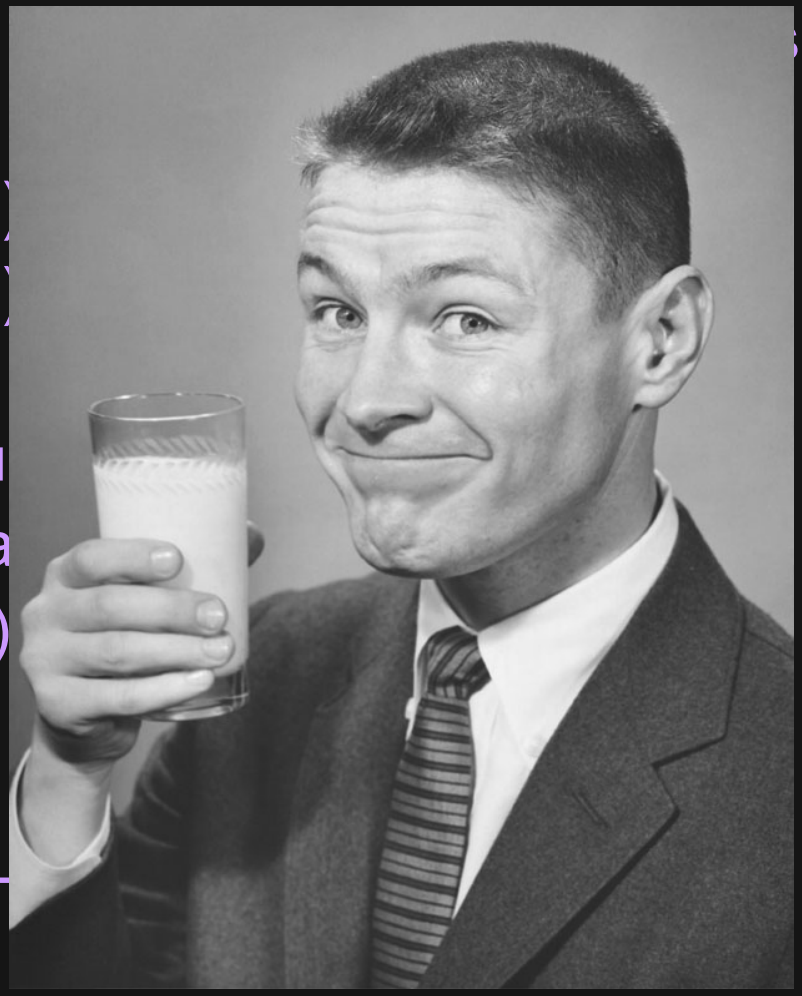
(Developed by Stacie Kreitman, Falls Church, VA)

A classroom activity that demonstrates the different elemental compositions of different objects in the universe.

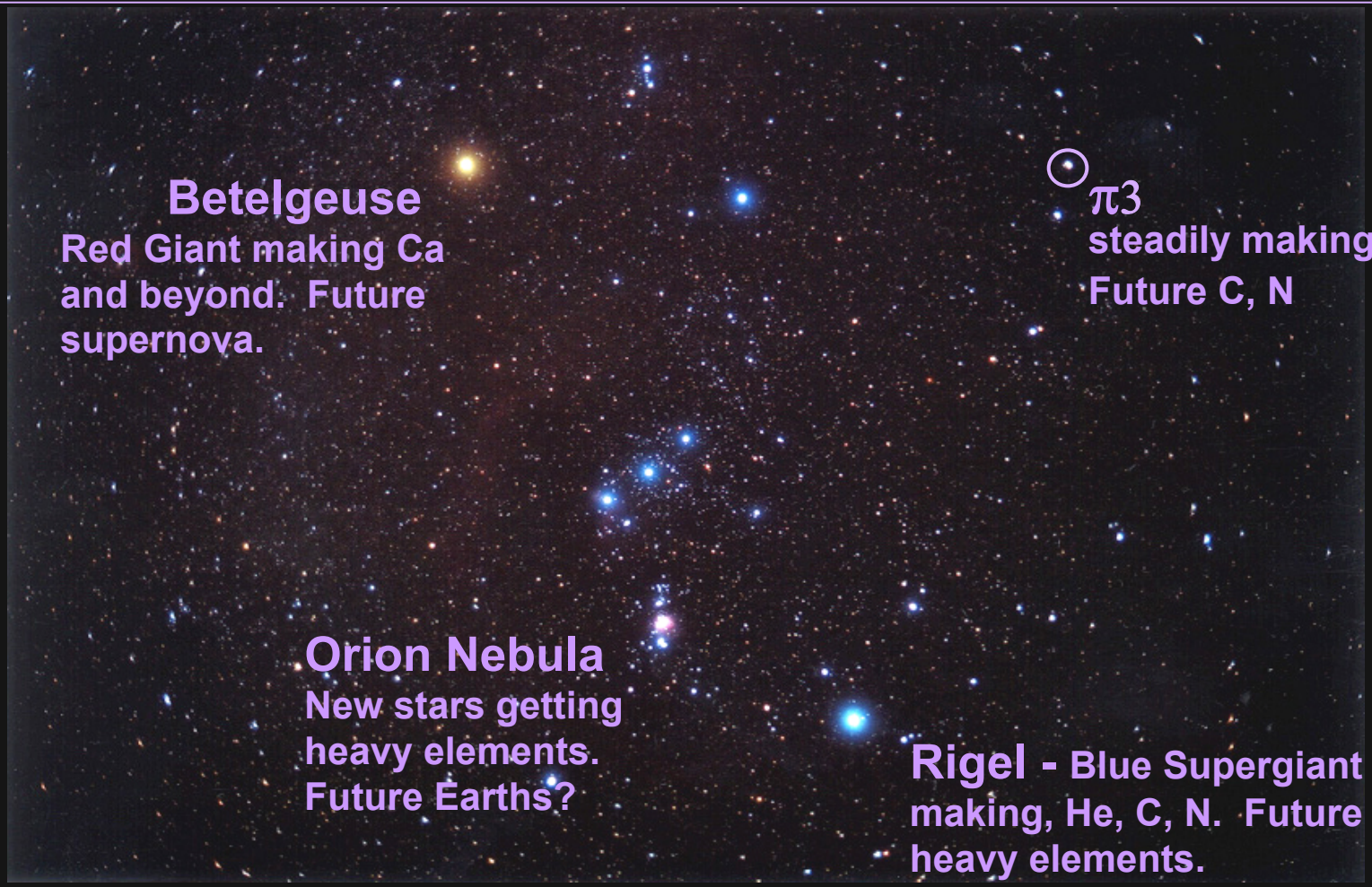
- Demonstrates how we estimate the abundances.

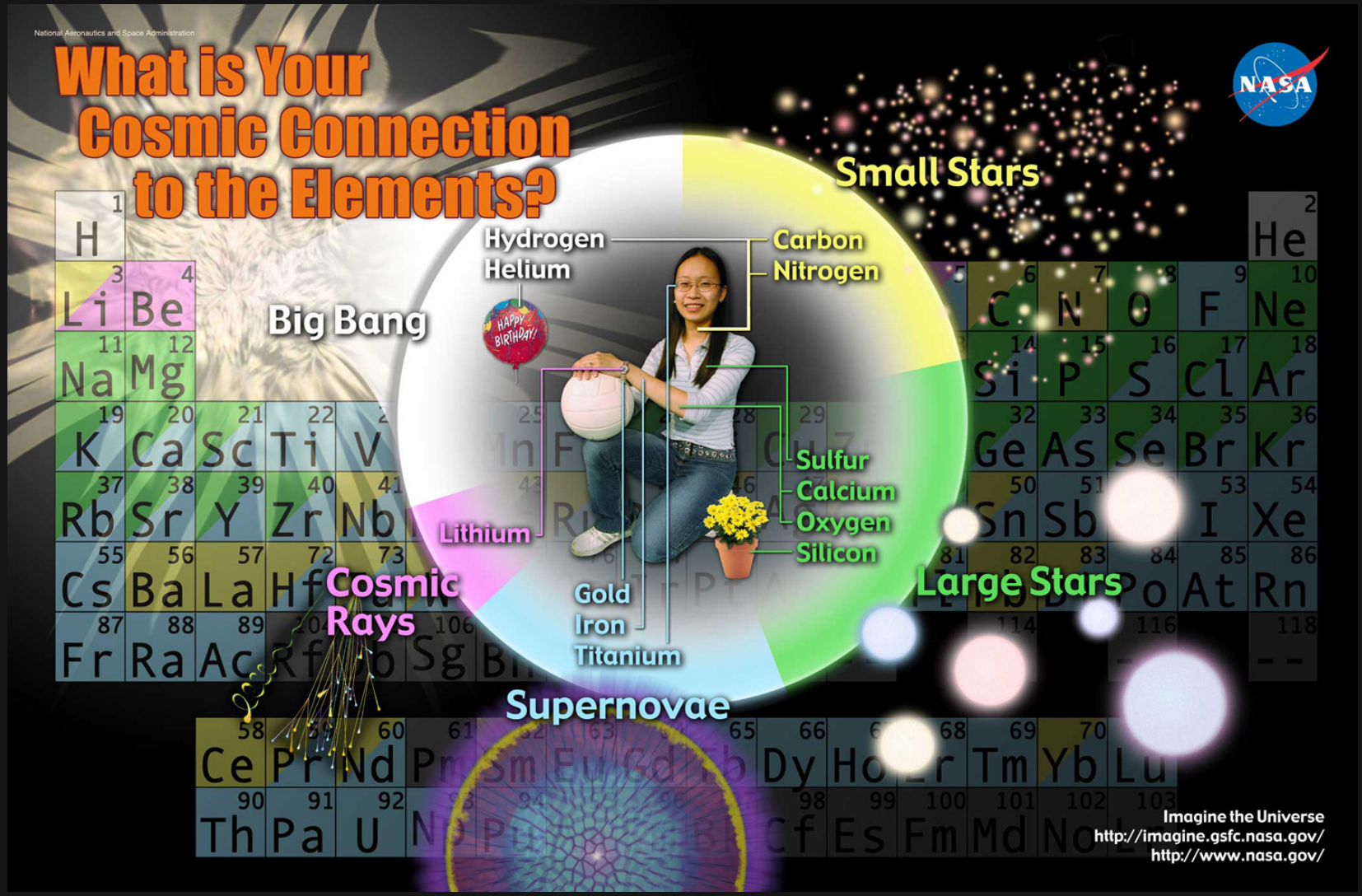
Top 10 Elements in the Human Body

	Element	mic Process
10.	Magnesium	SN
9.	Chlorine (Cl)	
8.	Sodium (Na)	
7.	Sulfur (S)	LS
6.	Phosphorou	
5.	Calcium (Ca	
4.	Nitrogen (N)	LS
3.	Carbon (C)	LS
2.	Oxygen (O)	SS
1.	Hydrogen (H	



What's Your Cosmic Connection to the Elements?





http://imagine.gsfc.nasa.gov/docs/teachers/elements/

Spectral Analysis

We can't always get a sample of a piece of the Universe.

So we depend on light !

Spectral Analysis

Each element has a unique spectral signature:

- Determined by arrangement of electrons.
- Lines of emission or absorption arise from re-arrangement of electrons into different energy levels.

Hydrogen

Nickel-odeon Classroom Activity

(Developed by Shirley Burris, Nova Scotia)

Spread a rainbow of color across a piano keyboard

Then, “play” an element

Hydrogen

More Musical Elements

Now play another element

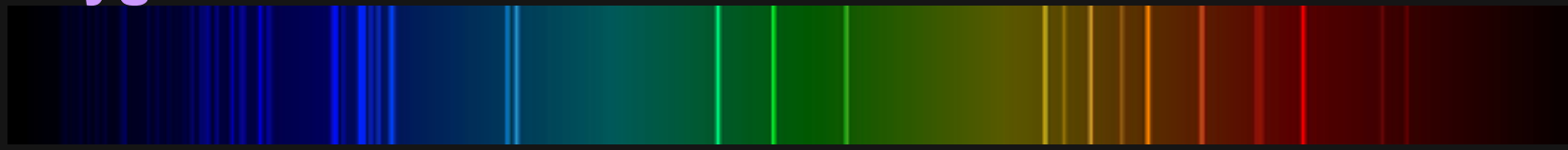
Helium

And Another

Carbon

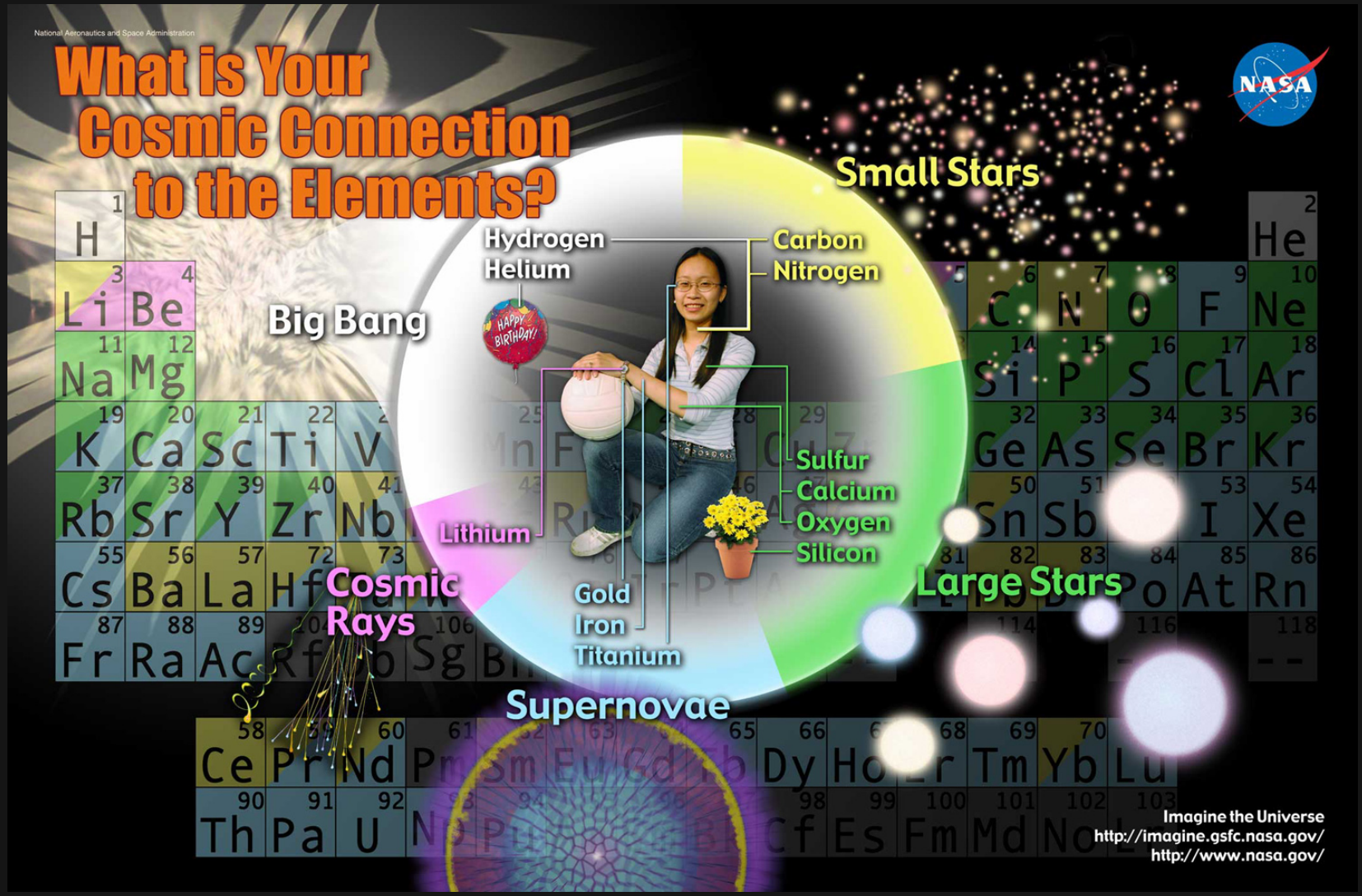
Getting a Handle on Water

Oxygen



Hydrogen

All together now ... Water



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