So Many Stars

So Little Time

CLAS Masters

Retired faculty share their expertise
on topics of community interest

So Many Stars,
So Little Time

Presented by

Clyde Zaidins

Professor Emeritus
of Physics

Friday, April 13th, 1:00 - 2:30 PM
Tamayo Restaurant
1400 Larimer Street
Denver, CO 80262

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10,775 FT
Mt Rainier
14,410 FT
Mt Adams
12,276 FT
Seattle
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Olympia
Morton
Mt St. Helens
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House
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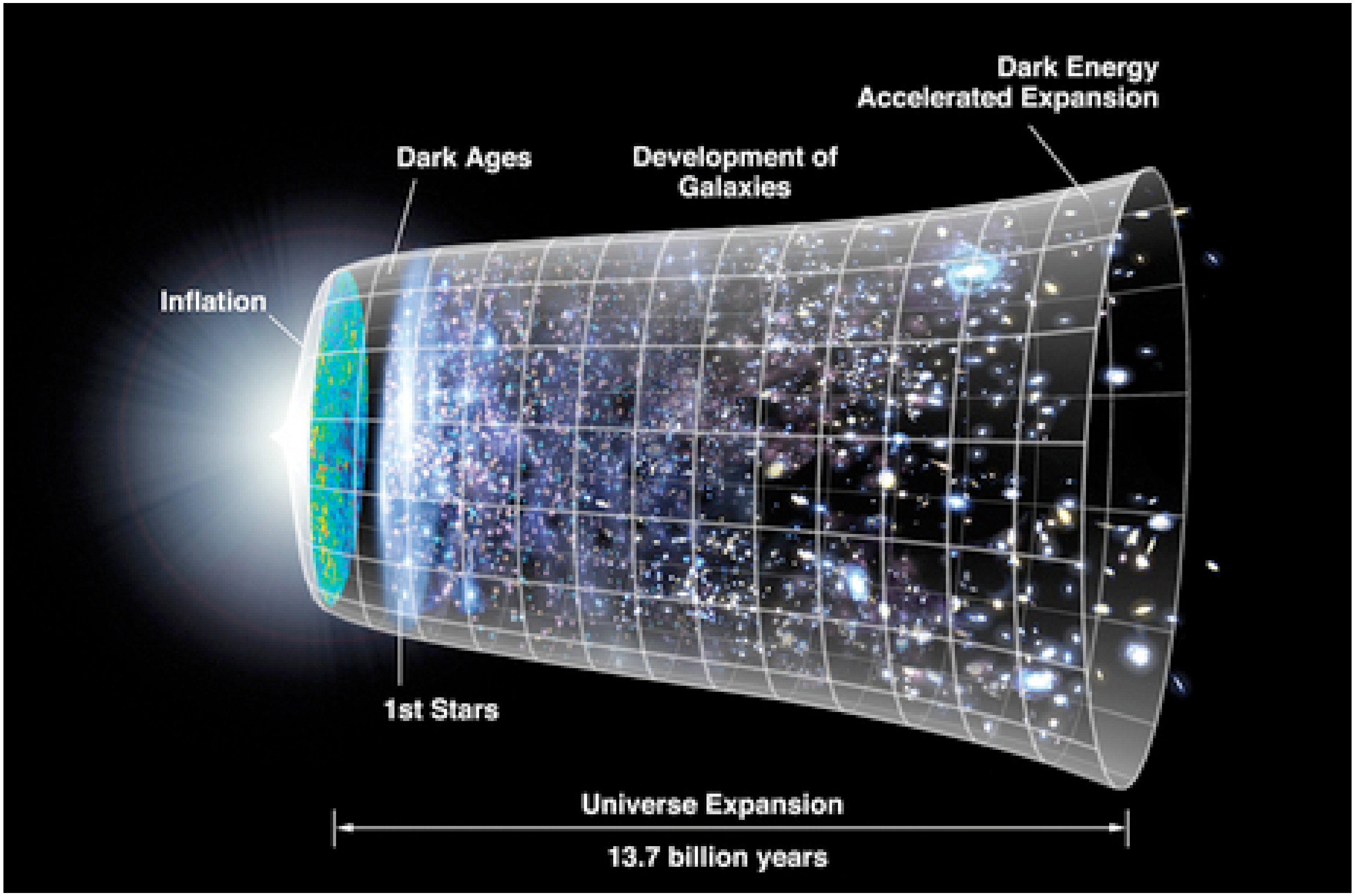
ESO/VISTA/J. EMERSON/CAMBRIDGE ASTRONOMICAL SURVEY UNIT

Stars are more than just hot balls of gas.

- Connections: Stars are the most visible part of our knowable universe.
- Stars within their galaxies map the behavior of the universe at large.
- It is important to study both the individual stars and their collective behavior.


Dark Energy
Accelerated Expansion
Dark Ages
Development of
Galaxies
Inflation
1st Stars
Universe Expansion
13.7 billion years

The age of our knowable, visible universe seems to be about 13.7 billion years (13.7 Gyr). The “Big Bang” occurred that long ago.

The mass energy composition of the universe is thought to be:

Luminous “normal” matter 5%
Dark matter (felt, but not seen) 23%
Dark Energy (drives increasing expansion) 72%

Three important and related questions:

Why are there many different kinds of stars?

What energy sources make stars shine?

Where do our chemical elements come from?

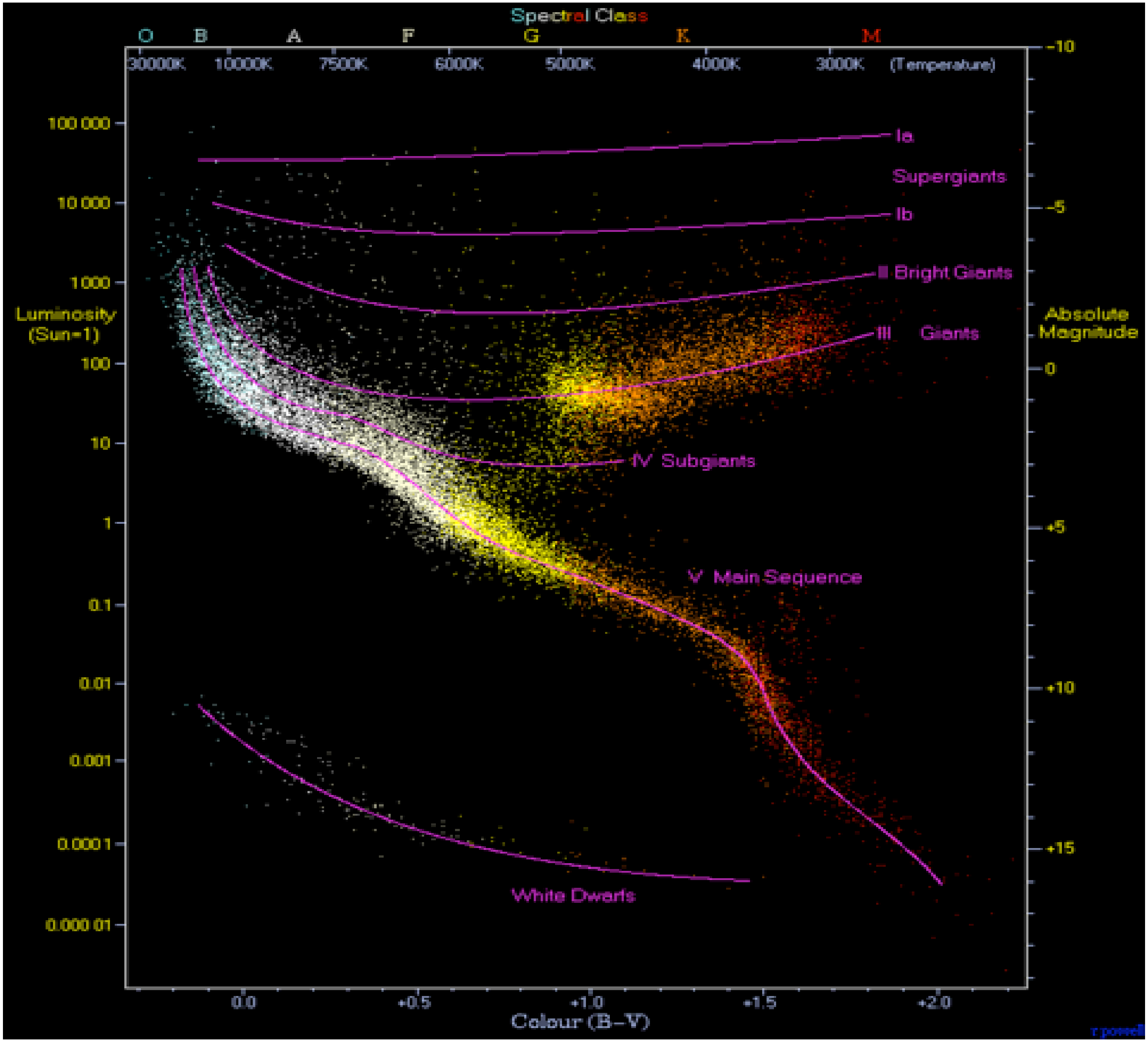
Observing stars and their properties

We can fairly easily measure the star's surface temperature, surface chemical composition, and apparent brightness (magnitude).

If we know the star's distance from us we can calculate its real (absolute) brightness.

If the star has a companion(s) we can often calculate its mass.

Plotting what we know on the H-R diagram provided the "Eureka" moment in stellar physics.



Spectral Class
O
B
A
F
G
K
M
30000K
10000K
7500K
6000K
5000K
4000K
3000K
(Temperature)
Luminosity (Sun=1)
100 000
10 000
1 000
100
10
1
0.1
0.01
0.001
0.0001
0.000 01
Absolute Magnitude
-10
-5
0
+5
+10
+15
Ia
Supergiants
Ib
II Bright Giants
III Giants
IV Subgiants
V Main Sequence
White Dwarfs
0.0
+0.5
+1.0
+1.5
+2.0
Colour (B−V)
r.powell

Stars evolve. They are born, live, and die. Their lives range from millions to billions of years.

Their future life phases depend only upon their mass, chemicals, and neighborhood at birth.

All stars spend most of their life as **Main Sequence** stars and then expand to some **Red Giant** phase.

Low mass stars eventually end up as a **White Dwarf**. This happens along a relatively “non-violent” path.

Massive stars explode violently as a **Supernova** and Their ultimate fate depends upon just how massive they are. Some end up as **Neutron Stars**, some become **Black Holes**, and some may be blown apart completely.

Understanding stellar evolution requires knowledge of the structure and the energy flow in the star. This is done using models based upon the laws of physics.

The life of a star is basically a struggle against gravity which the star ultimately loses. The star's tools include nuclear physics, radiation, pressure, heat, statics, energy, and hydrodynamics, but eventually gravity wins.

Along the way the star changes its structure and looks. It is generating most of its energy by nuclear reactions. In addition to energy the reactions are nature's alchemy, producing new chemicals. The study of these results is known as nucleosynthesis (nuclear astrophysics).

The center (**core**) of the star is where the temperature, pressure, and density are high enough for nuclei to react. The temperature is in the range of millions of degrees (Kelvins). These nuclear reactions release energy and change the chemical composition.

This released energy is transported from the core, through the **envelope**, to the surface where it is radiated into space.

This energy transport can be by radiation, convection, or conduction. The flow of energy helps stabilize the star. In general the pressure, temperature, and density decrease with distance from the center. The temperature is in the range of thousands of degrees.

There are about 90 chemical elements found on earth and elsewhere in the universe.

Many of them have more than one isotope with the same chemical properties but a different weight.

Some of these are radioactive and as a result change into other **nuclides**.

Nucleosynthesis has the goal of explaining the abundance of these chemicals and isotopes.

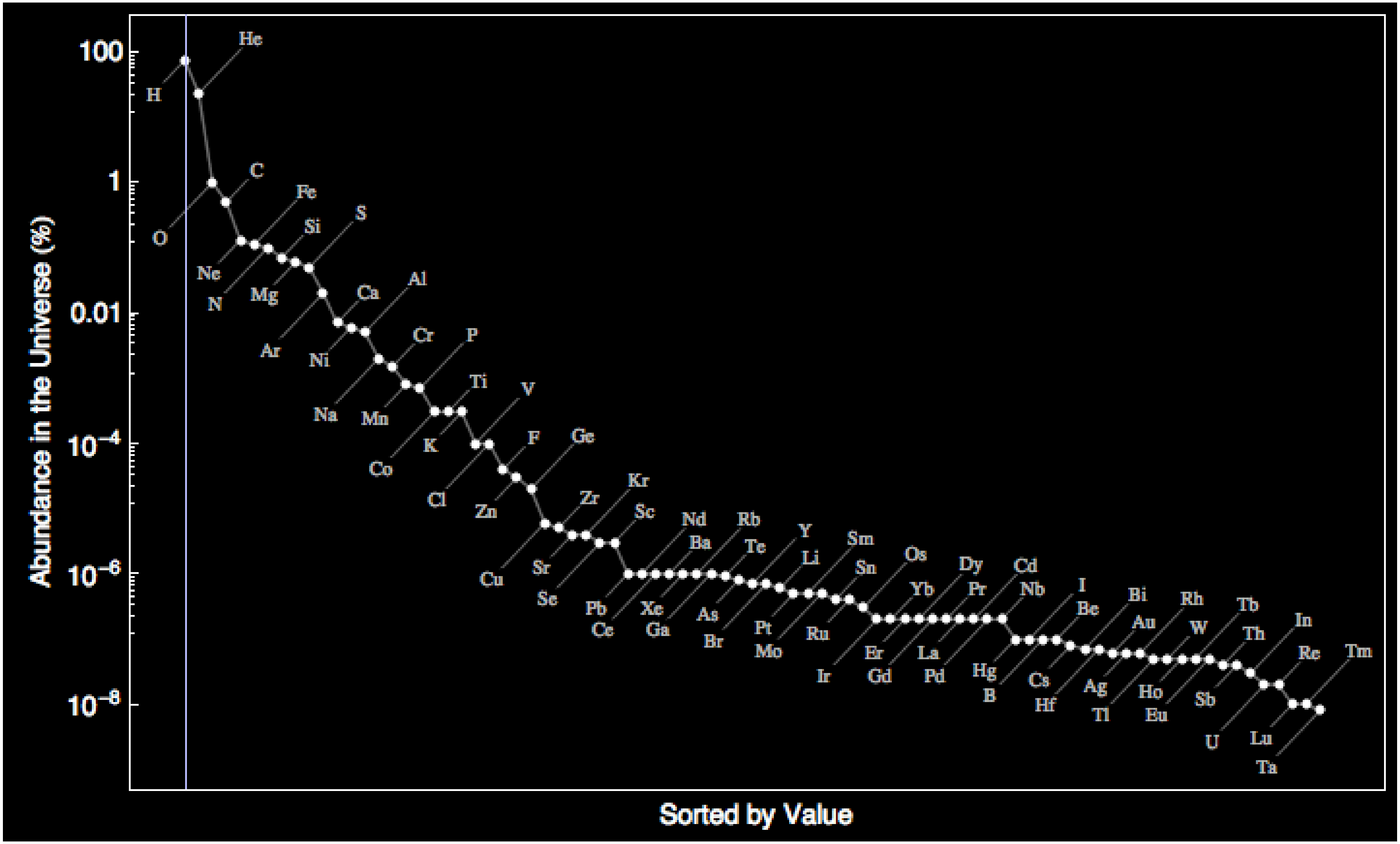
Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Period																		
1	1 H 1.008																	2 He 4.003
2	3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3	11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
4	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.64	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.79
5	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
6	55 Cs 132.9	56 Ba 137.3	*	72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.5	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra (226)	**	104 Rf (261)	105 Db (262)	106 Sg (266)	107 Bh (264)	108 Hs (277)	109 Mt (268)	110 Ds (281)	111 Rg (272)	112 Cn (285)	113 Uut (286)	114 Uuq (289)	115 Uup (289)	116 Uuh (291)	117 Uus (294)	118 Uuo (294)

Lanthanide Series*	57 La 138.9	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.2	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
Actinide Series**	89 Ac (227)	90 Th 232	91 Pa 231	92 U 238	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

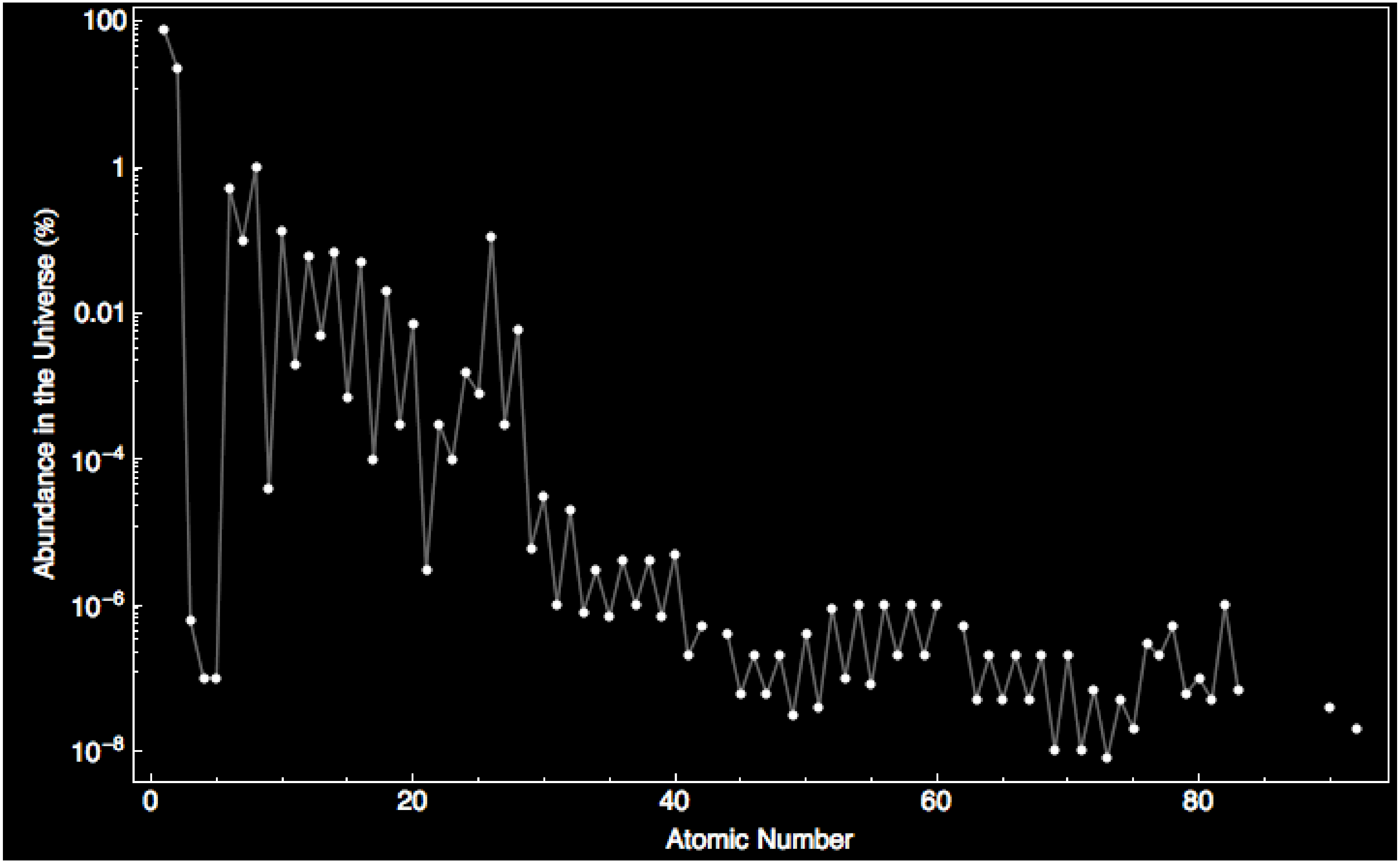
A few minutes after the Big Bang the normal matter in the universe consisted of isotopes of H, He, and Li. (Astronomers name all chemicals heavier than H and He as metals.)

The first stars formed more than 12 billion years ago and had very little metal. As later stars were formed, they had greater metal component. The sun is approximately 4.6 billion years old and is about 2% metal. The newest stars are about 3 to 4% metal.

Almost all of the rest of the chemical elements were formed by the stars as they evolved, starting with the main sequence and continuing up through their various stages including supernovae explosions.



Abundance in the Universe (%)
Sorted by Value
100
1
0.01
10^{-4}
10^{-6}
10^{-8}
H
He
O
C
Ne
Fe
N
Si
Mg
S
Ar
Ca
Ni
Al
Na
Cr
Mn
P
Co
K
Ti
V
Cl
F
Zn
Ge
Cu
Zr
Sr
Kr
Se
Sc
Pb
Nd
Ce
Ba
Xe
Ga
Rb
As
Te
Br
Y
Pt
Li
Mo
Sm
Ru
Sn
Ir
Os
Er
Yb
Gd
Dy
La
Pr
Pd
Cd
Hg
Nb
B
I
Cs
Be
Hf
Bi
Ag
Au
Tl
Rh
Ho
W
Eu
Tb
Sb
Th
U
In
Lu
Re
Ta
Tm



100
1
0.01
10^{-4}
10^{-6}
10^{-8}
Abundance in the Universe (%)
0
20
40
60
80
Atomic Number

There are many nuclear processes and stages.
Here are few of the interesting highlights:

Main sequence H-burning 4H –> He.
(Hans Bethe and the CNO cycle)
Solar neutrinos (ν)

Production of Oxygen (O) and Carbon (C)

The high abundance of Iron (Fe)

The abundances of the metals heavier than Fe and their isotopic ratios

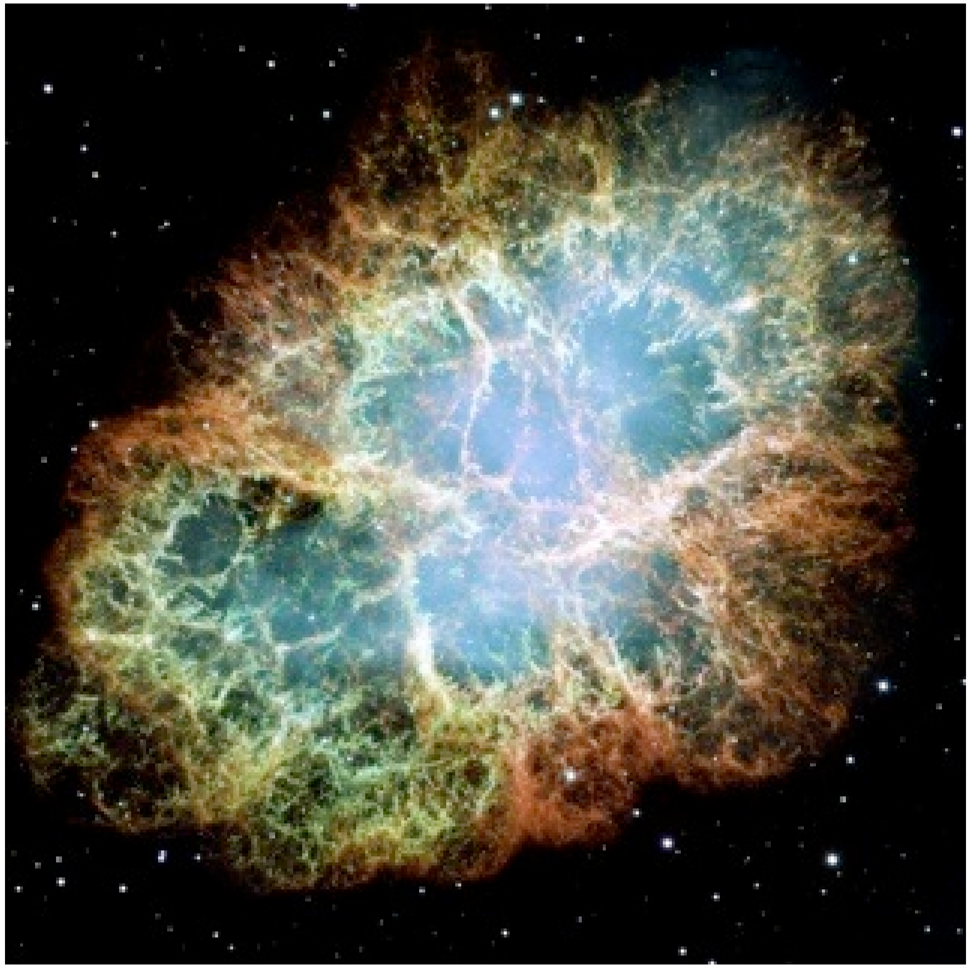
The shortage of Boron (B), Beryllium (Be), and Lithium (Li)

Stellar Winds, Planetary Nebulae, and Supernovae eject matter back into space. This metal enriches The stuff that stars are made of. Voila **“stardust”.**

Supernovae (SN) are the most important source of metals. How and why they explode is still a big research area. There are several types of SN.

SN Type I originate from a binary system and make good “**Standard Candles**”.

SN Type II originate from massive stars. Some examples are SN1054 and SN1987A



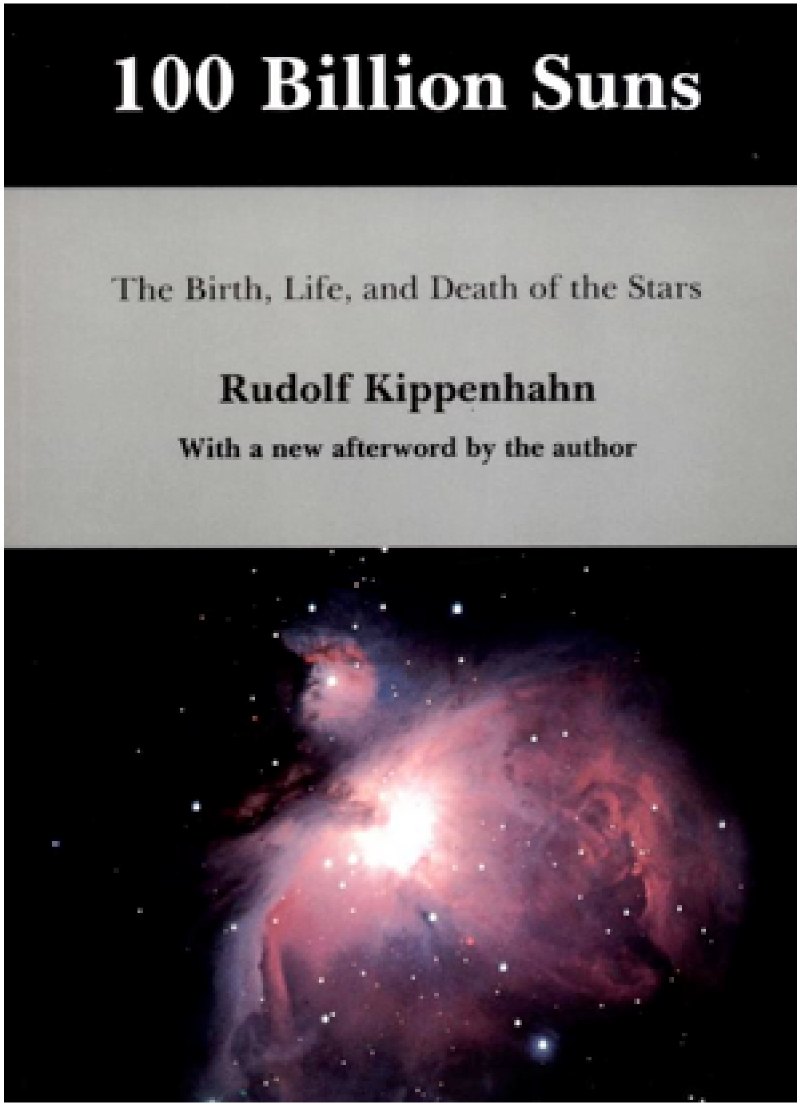
Crab Nebula   SN1054 Remnant

Planetary Nebula

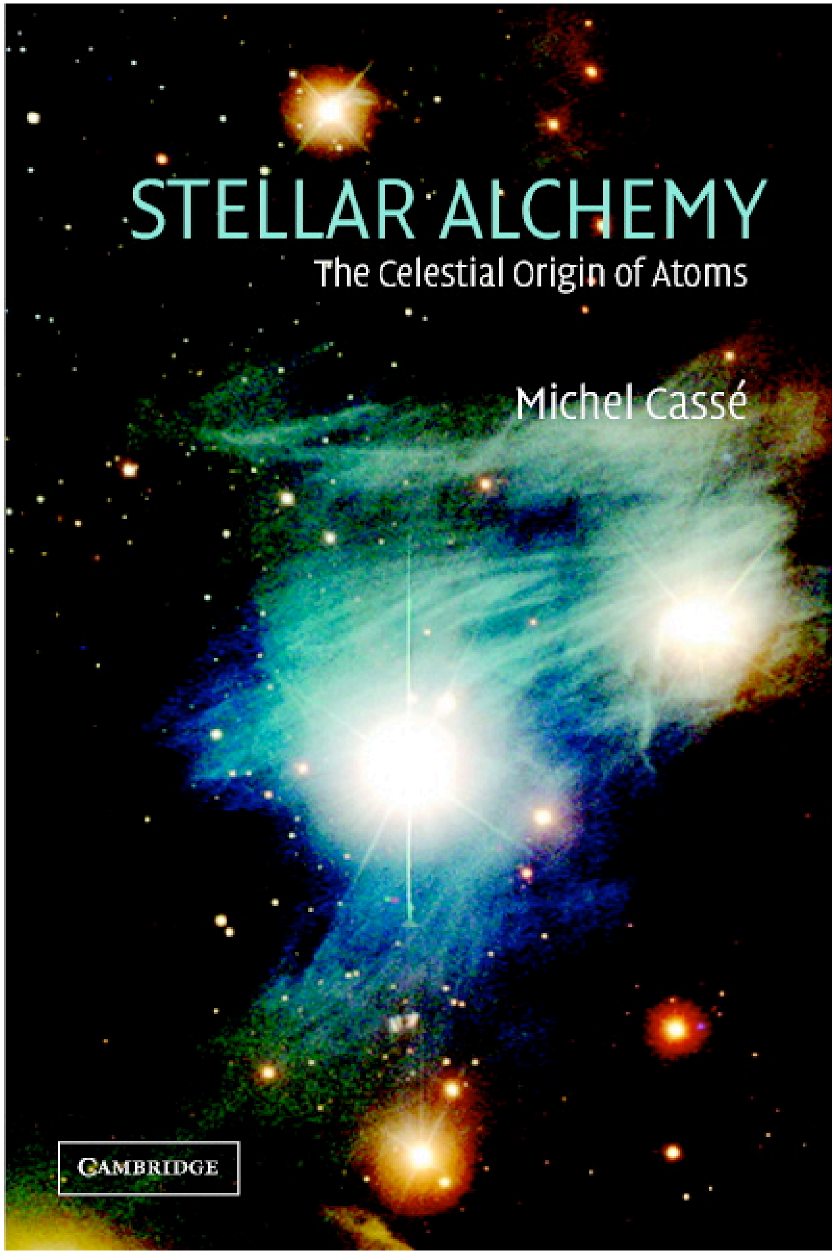
Some of the Major Contributors

(Slightly subjective list)

Lord Kelvin
Arthur Eddington
Fritz Houtermans
George Gamow
William A. (Willy) Fowler
Margaret Burbidge
Hans Bethe
Edwin Salpeter
Don Clayton
Carl Hansen
Herman Helmholtz
Georges Lemaître
Robert Atkinson
S. Chandrasekhar
Fred Hoyle
Geoffrey Burbidge
Al Cameron
Stirling Colgate
Stan Woosley
Dave Arnett


100 Billion Suns
The Birth, Life, and Death of the Stars
Rudolf Kippenhahn
With a new afterword by the author

1993


STELLAR ALCHEMY
The Celestial Origin of Atoms
Michel Cassé
CAMBRIDGE

2003