

Nucleosynthesis in the Universe

An Introduction

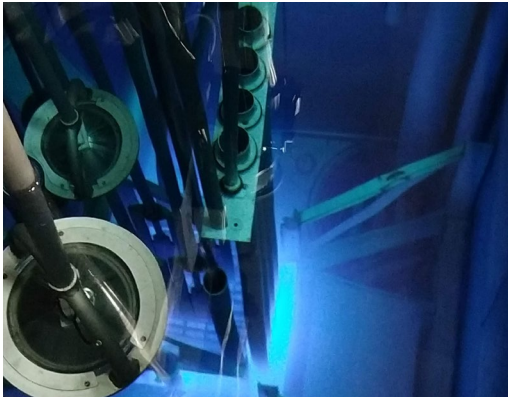
Kelsey Lund



Nuclear Astrophysics

Where do things come from?

How do processes on small (**nuclear**) scales affect large-scale systems in the Universe (**astro**)

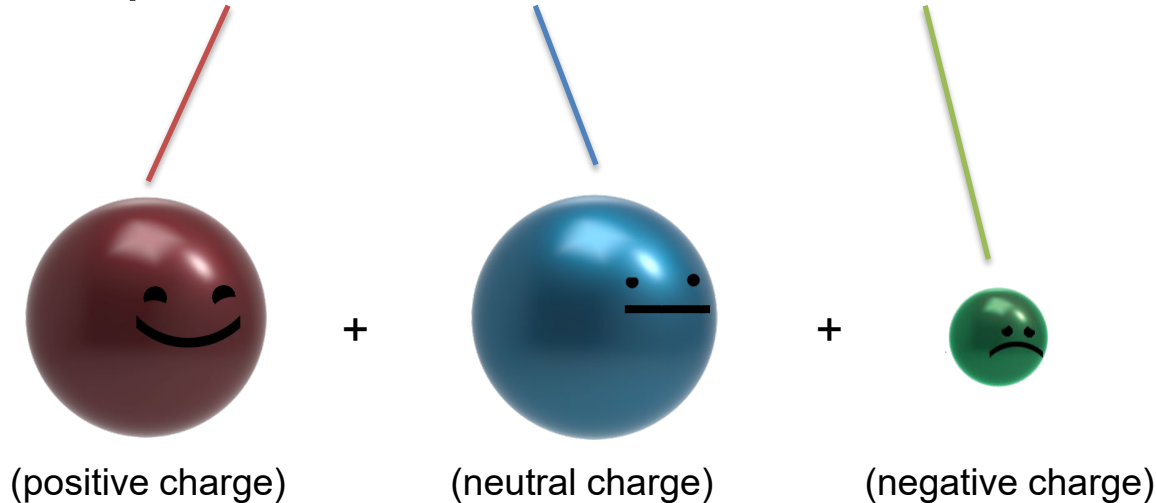


Nuclear Astrophysics

- Atoms as a basic building block of matter: kind of

Nuclear Astrophysics

- Atoms as a basic building block of matter: kind of
- Consist of protons, neutrons, and electrons



- Organize atoms by proton number (Z)
- Useful for chemical properties
- “Protons give an atom its identity, electrons its personality”

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 About Chemistry

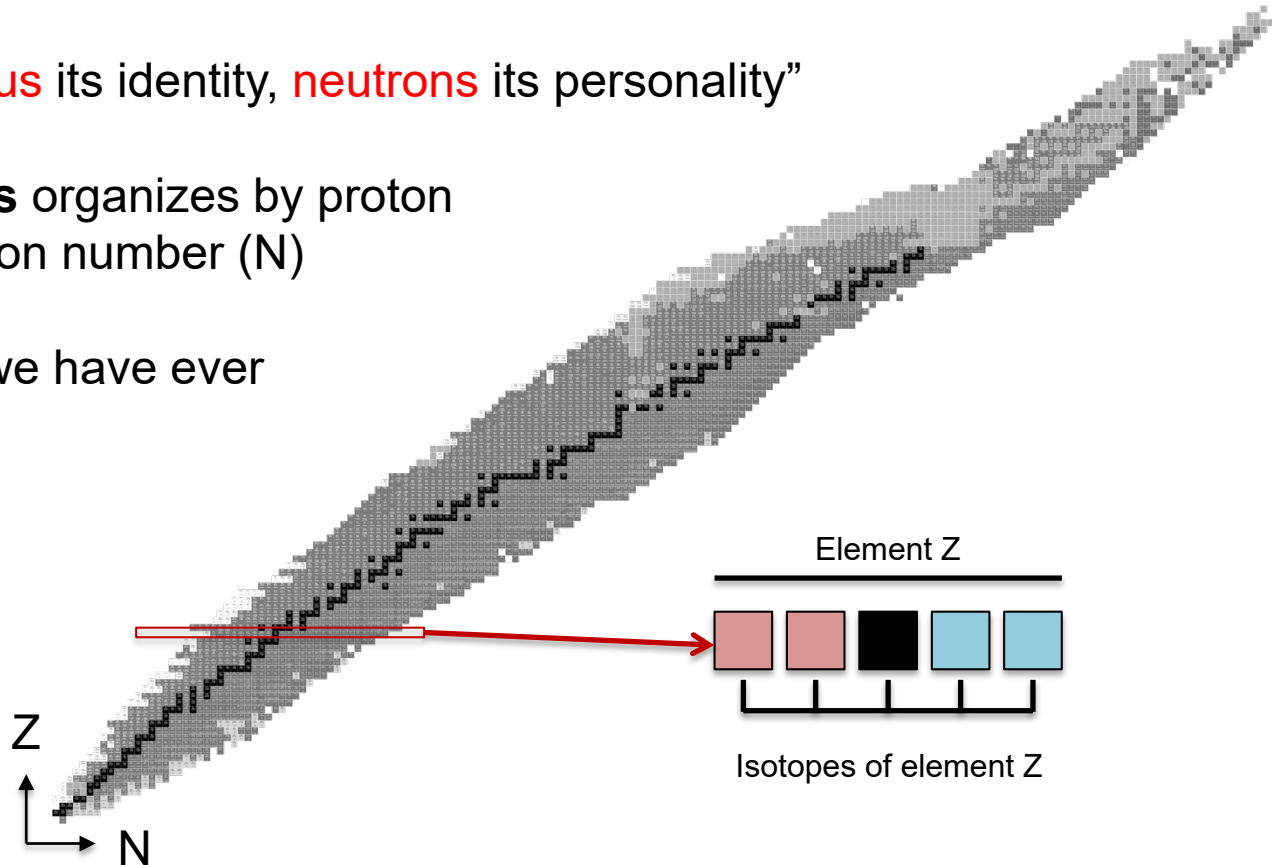
1A												8A					
1 H 1.00794											2						
2A																	
3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.0067	8 O 15.9994	9 F 18.9984032	10 Ne 20.1797
11 Na 22.989769	12 Mg 24.3050											13 Al 26.9815386	14 Si 28.0855	15 P 30.973762	16 S 32.065	17 Cl 35.453	18 Ar 39.948
		3B	4B	5B	6B	7B	8B		1B	2B							
19 K 39.0983	20 Ca 40.078	21 Sc 44.955912	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.938045	26 Fe 55.845	27 Co 58.933195	28 Ni 58.6934	29 Cu 63.546	30 Zn 65.38	31 Ga 69.723	32 Ge 72.64	33 As 74.92160	34 Se 78.96	35 Br 79.904	36 Kr 83.798
37 Rb 85.4678	38 Sr 87.62	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.96	43 Tc [98]	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.90447	54 Xe 131.293
55 Cs 132.9054519	56 Ba 137.327	57-71 Lanthanides	72 Hf 178.49	73 Ta 180.94788	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.084	79 Au 196.966569	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.98040	84 Po [209]	85 At [210]	86 Rn [222]
87 Fr [223]	88 Ra [226]	89-103 Actinides	104 Rf [267]	105 Db [268]	106 Sg [271]	107 Bh [272]	108 Hs [270]	109 Mt [276]	110 Ds [281]	111 Rg [280]	112 Cn [285]	113 Uut [284]	114 Fl [289]	115 Uup [288]	116 Lv [293]	117 Uus [294]	118 Uuo [294]
Lanthanides		57 La 138.90547	58 Ce 140.116	59 Pr 140.90765	60 Nd 144.242	61 Pm [145]	62 Sm 150.36	63 Eu 151.964	64 Gd 157.25	65 Tb 158.92535	66 Dy 162.500	67 Ho 164.93032	68 Er 167.259	69 Tm 168.93421	70 Yb 173.054	71 Lu 174.9668	
Actinides		89 Ac [227]	90 Th 232.03806	91 Pa 231.03588	92 U 238.02891	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]	

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- “Protons give a **nucleus** its identity, **neutrons** its personality”
- **Chart of the nuclides** organizes by proton number (Z) and neutron number (N)
- Contains everything we have ever measured

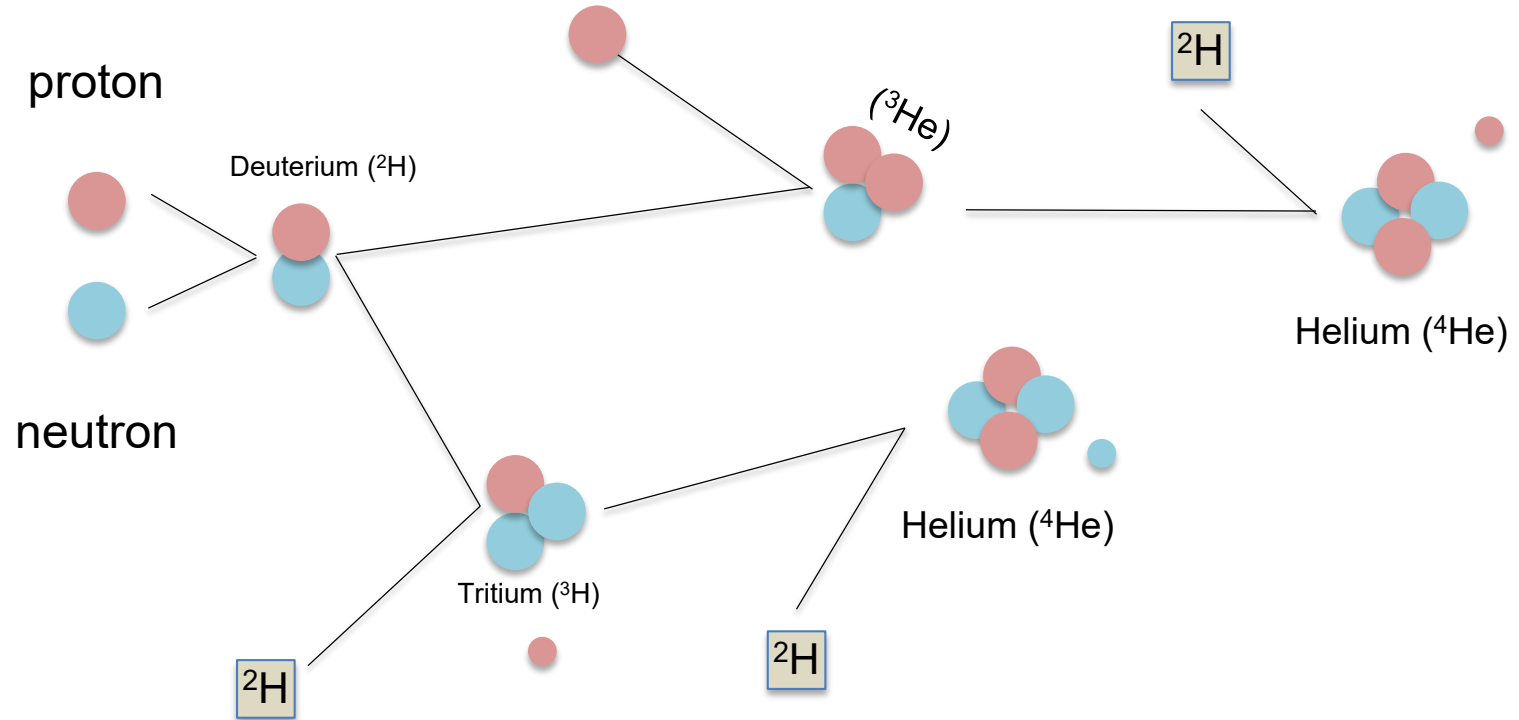


NUCLEOSYNTHESIS

The process of making new nuclei from existing nuclei and nucleons
(protons, neutrons)



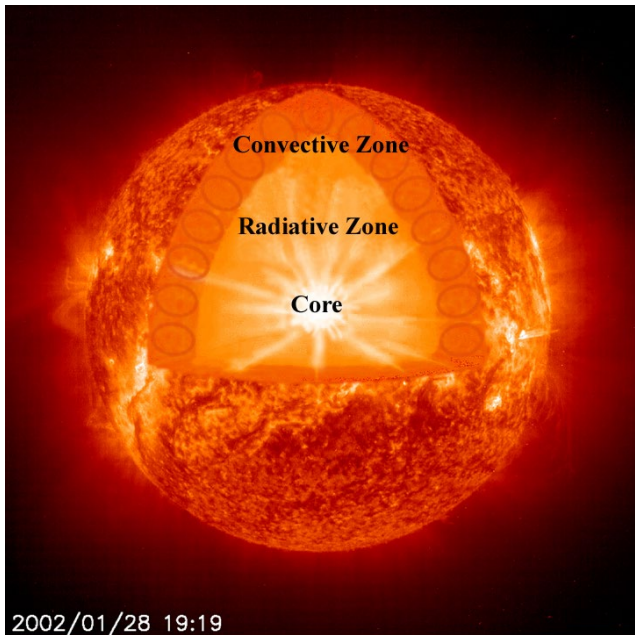
The first few minutes



Hundreds of millions of years later...

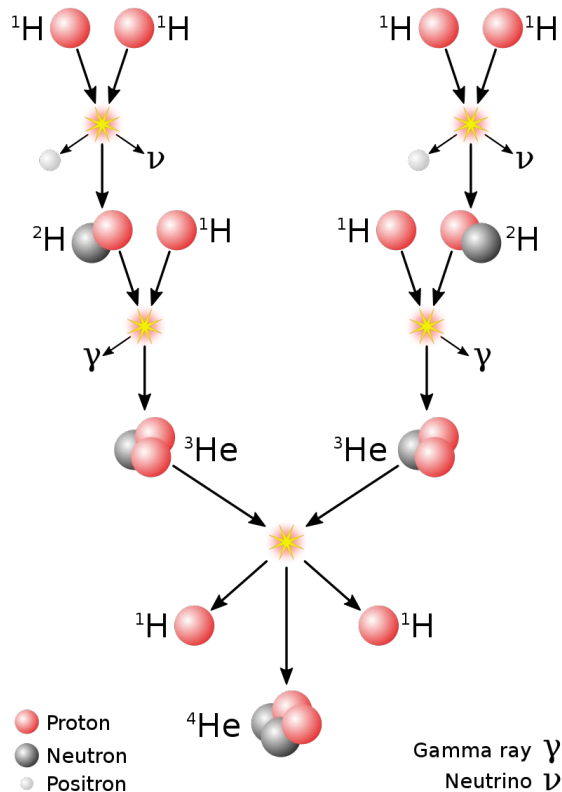


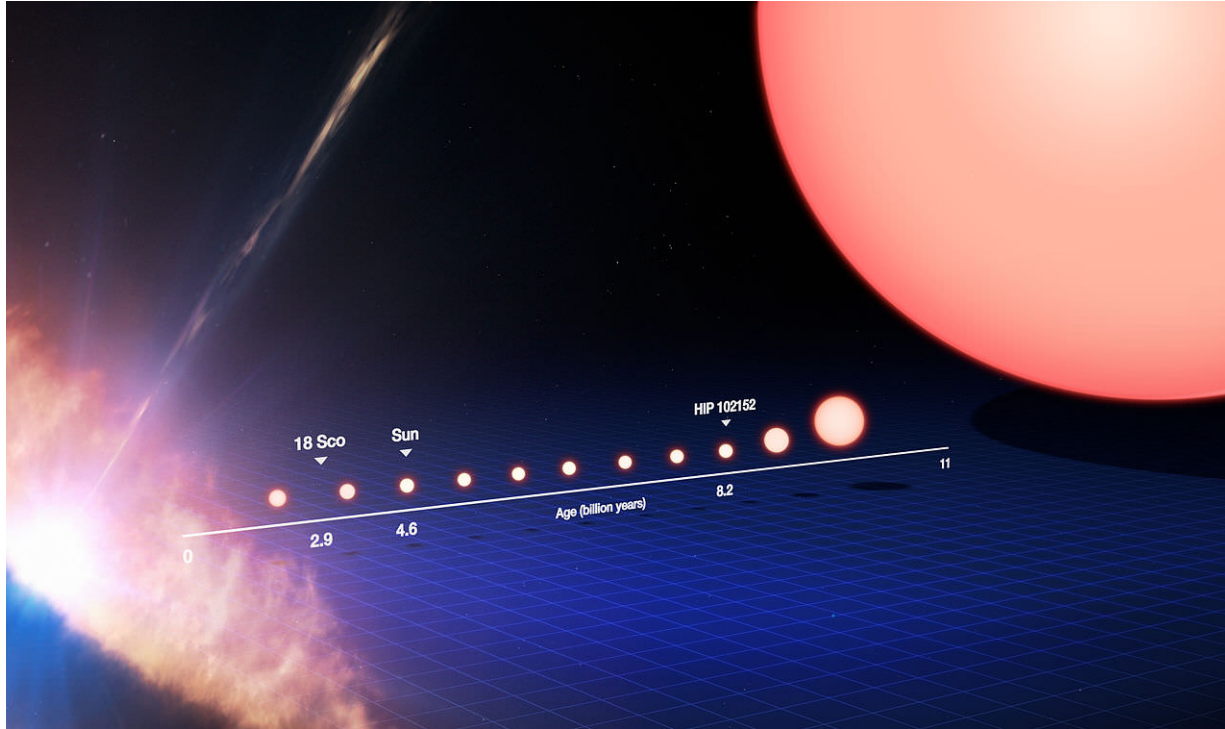
Stellar Nucleosynthesis: Proton-Proton Chain



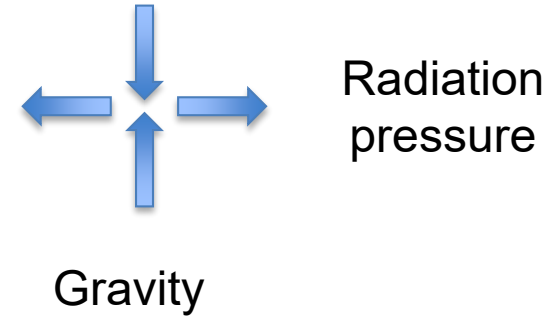
2002/01/28 19:19

Mass_{Sun} = 1 M_☉ ~ 2 x 10³⁰kg

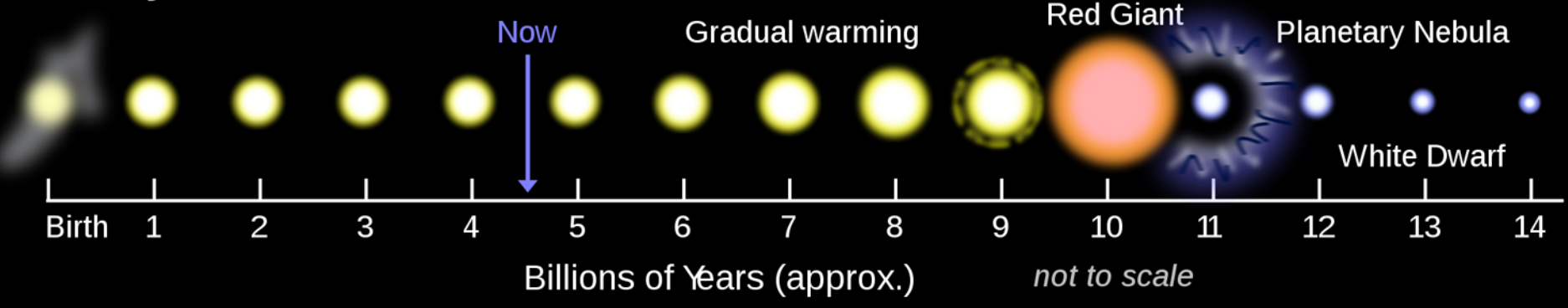


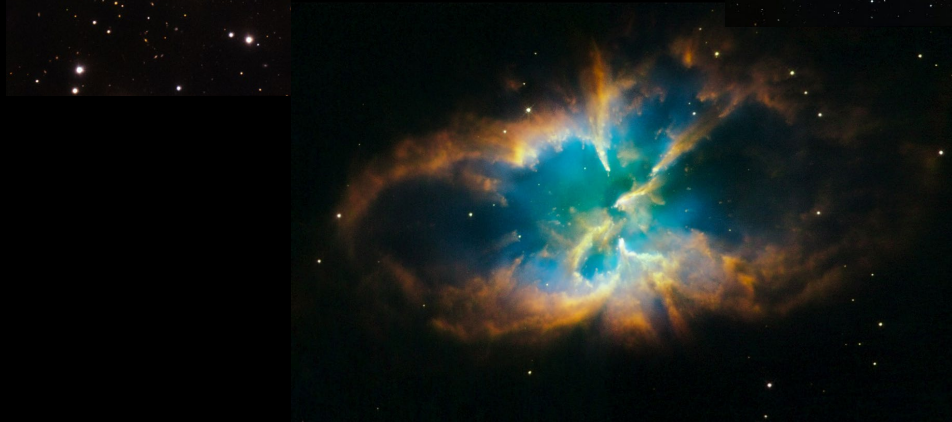


Eventually, the Sun will run out of fuel

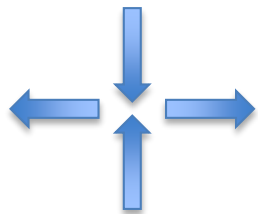


Life Cycle of the Sun



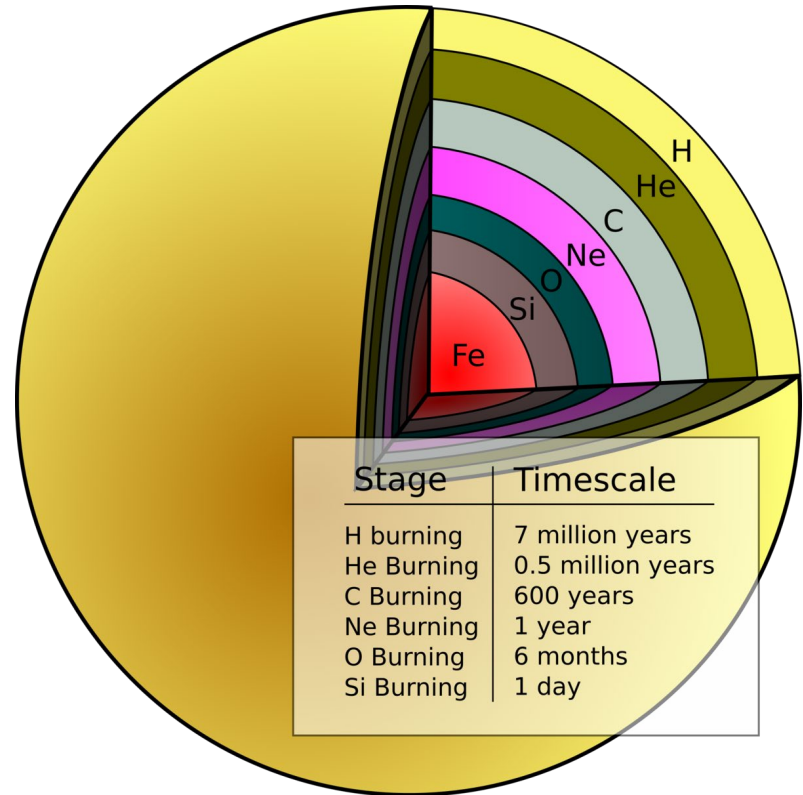


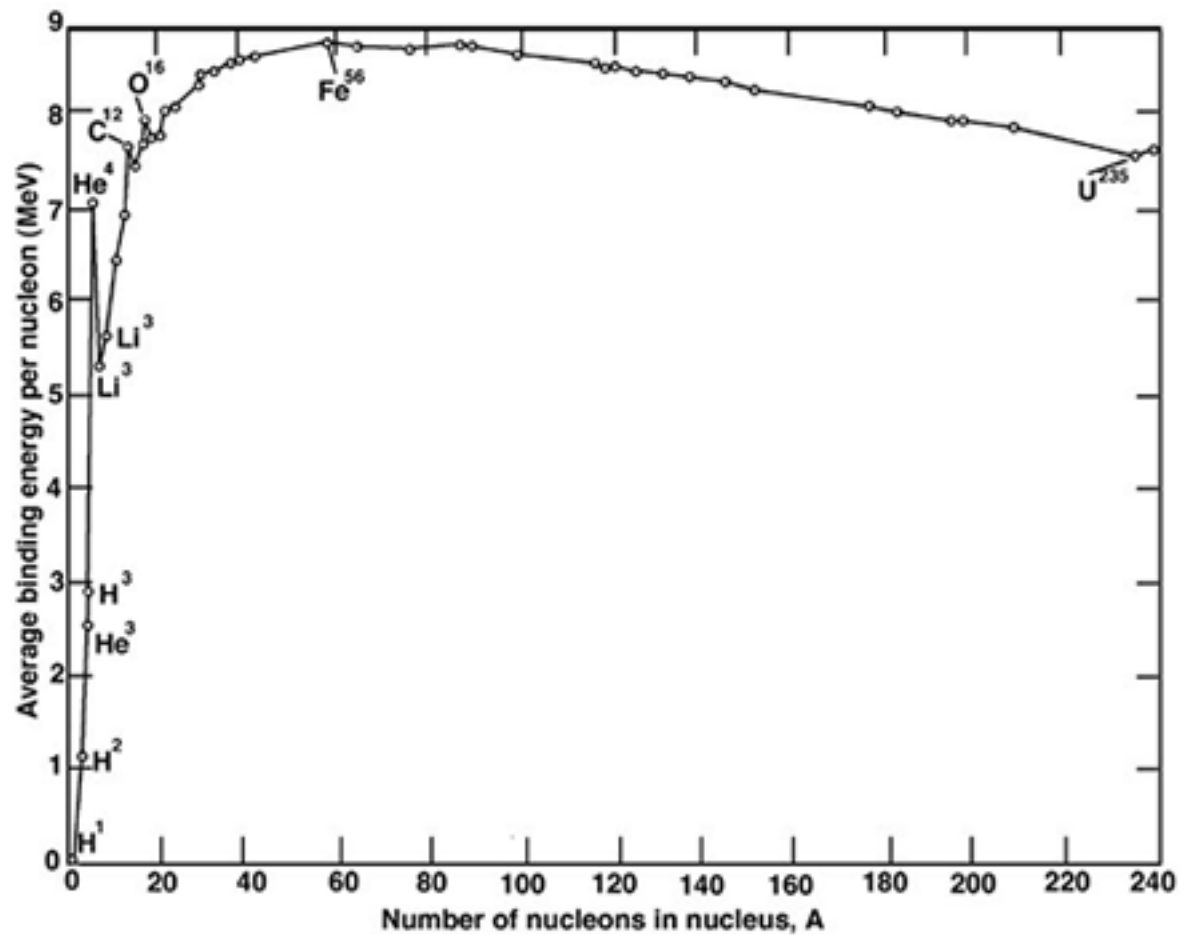
Massive Stars: Core-Collapse



Radiation pressure

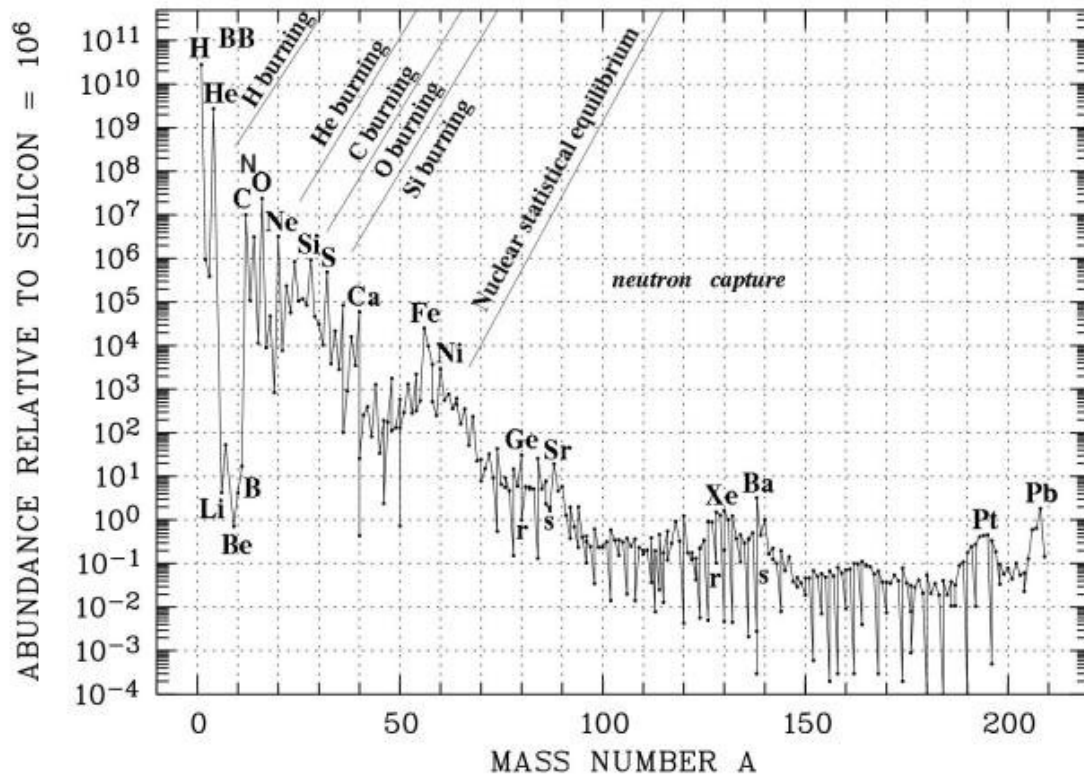
Gravity



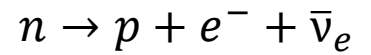
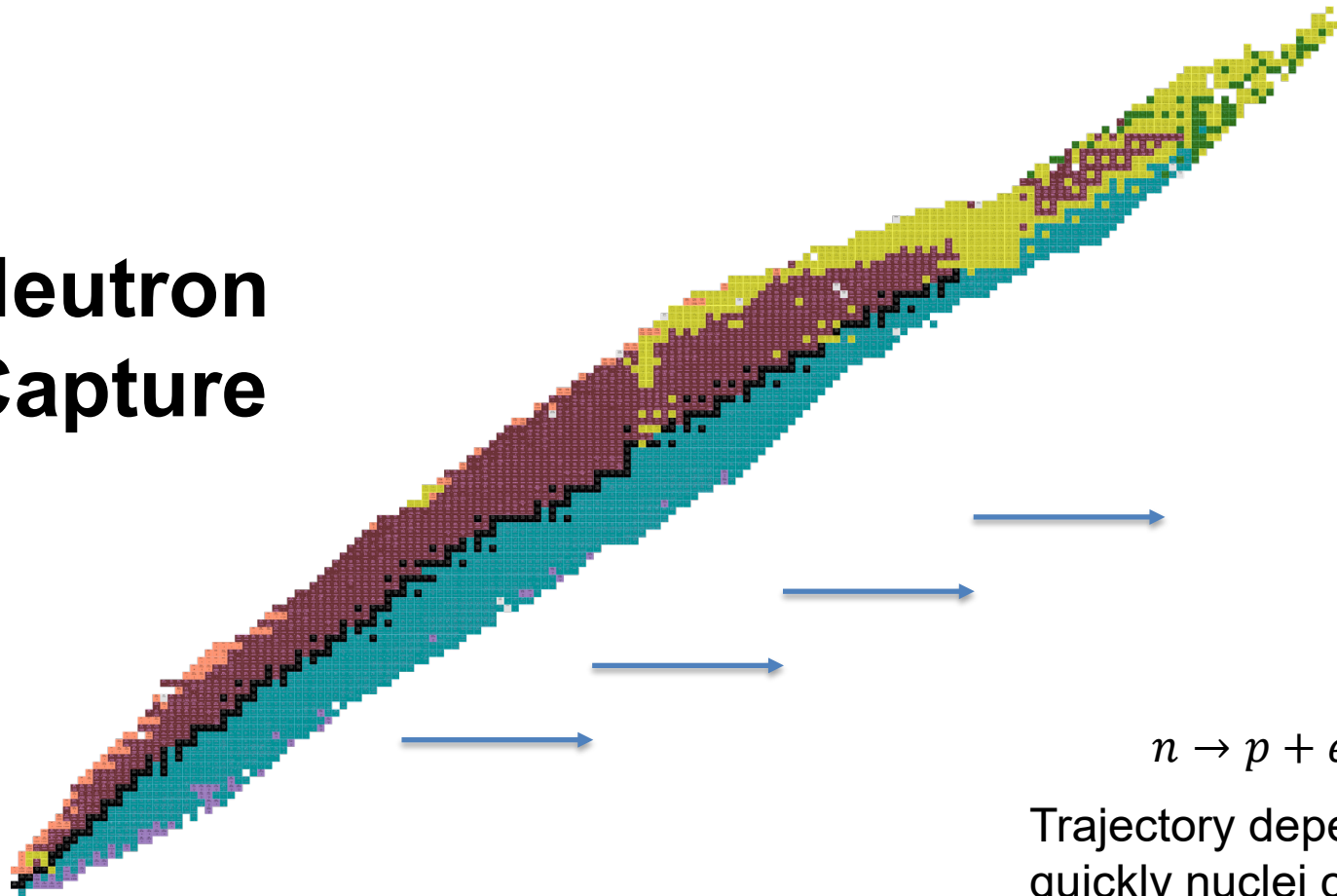
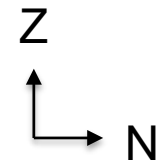




Explosive Nucleosynthesis!



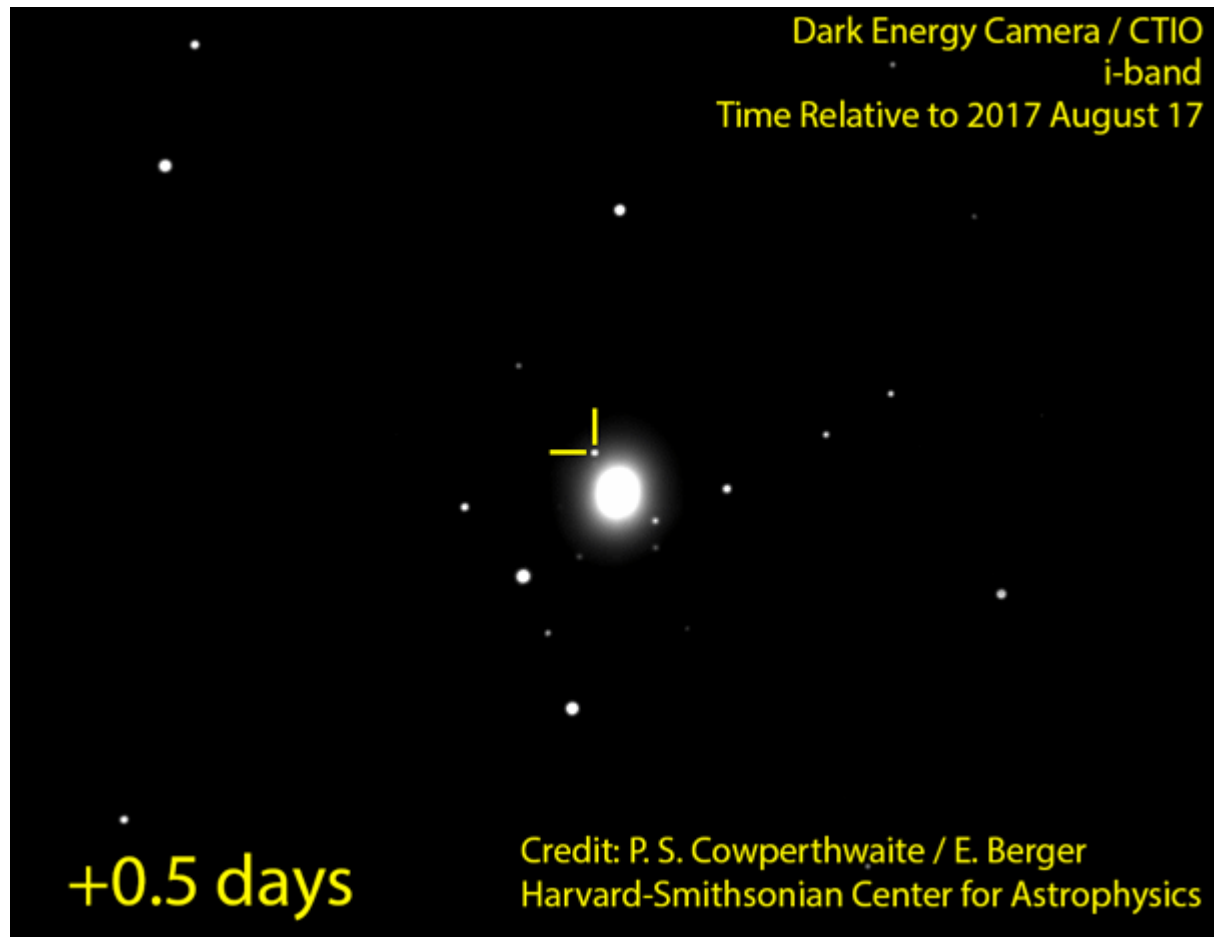
Neutron Capture



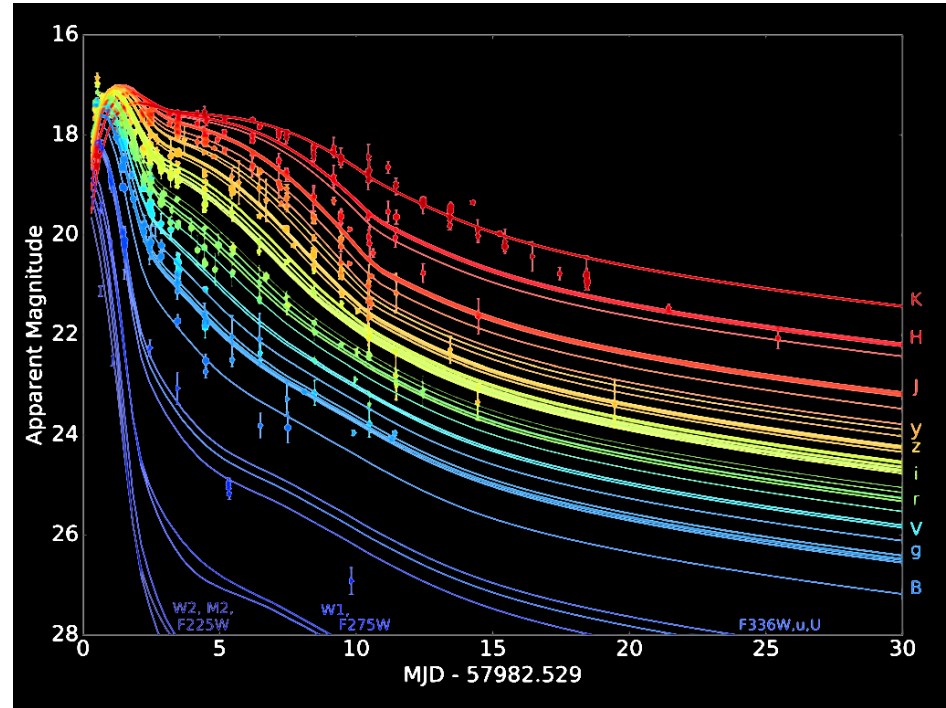
Trajectory depends on how quickly nuclei can capture!

An even longer time later....

Neutron Star Mergers

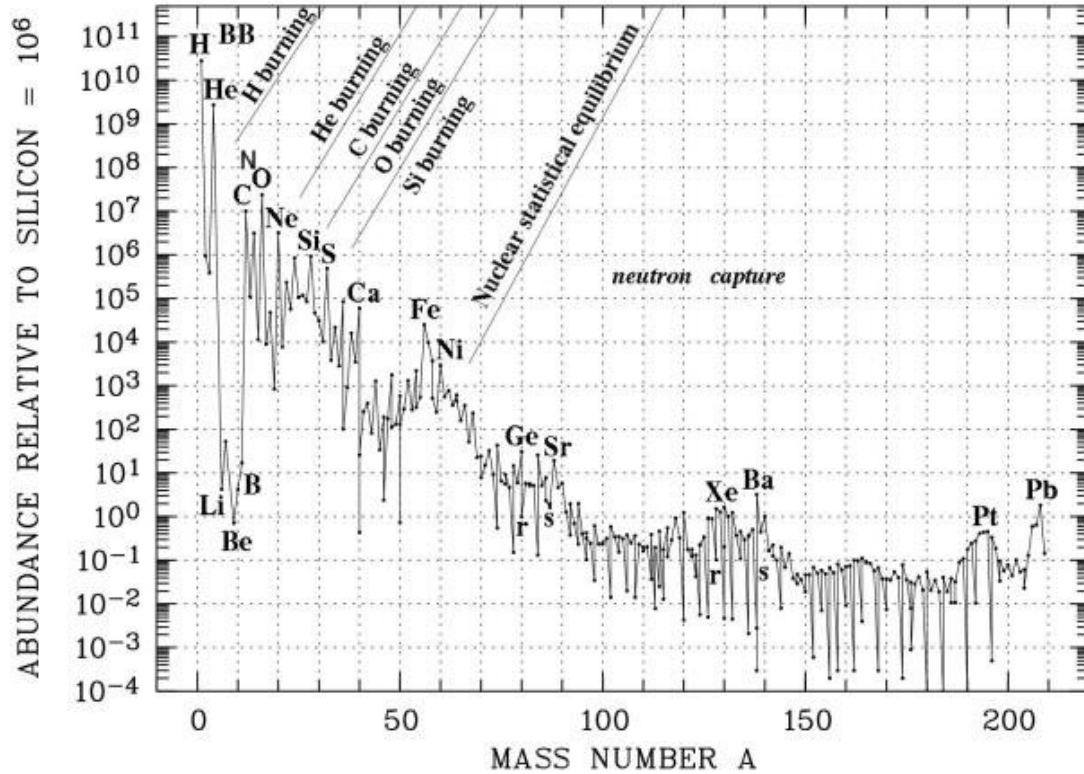


Neutron Star Mergers



Big Picture

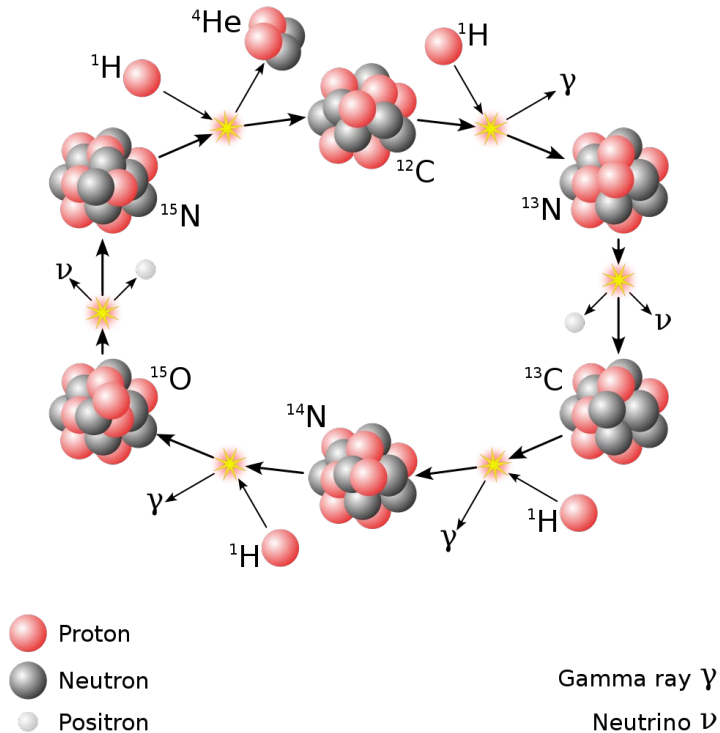
Big Picture



**Thank
you!**

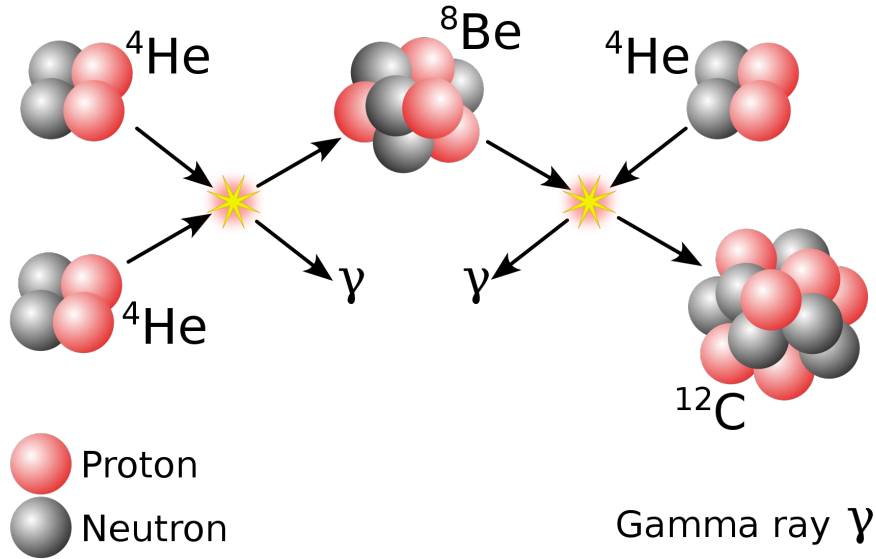
kalund@ncsu.edu

Stellar Nucleosynthesis: CNO Cycle



Occurs in larger stars ($>1.3 M_{\odot}$), where higher temperatures are possible

Stellar Nucleosynthesis: Triple- α Process



Needs very high temperatures!