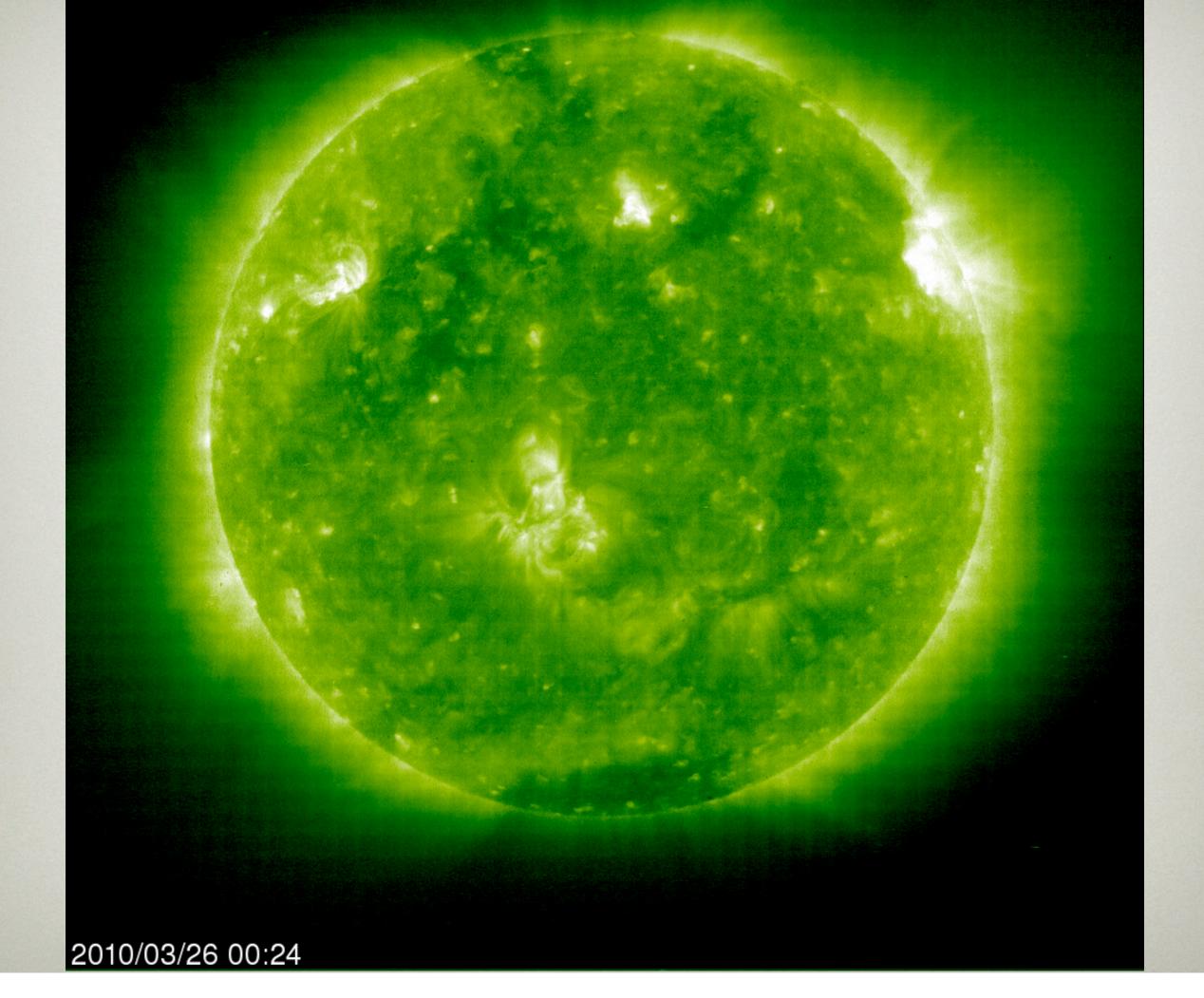
How THE STARS PRODUCE ALL OF OUR ENERGY

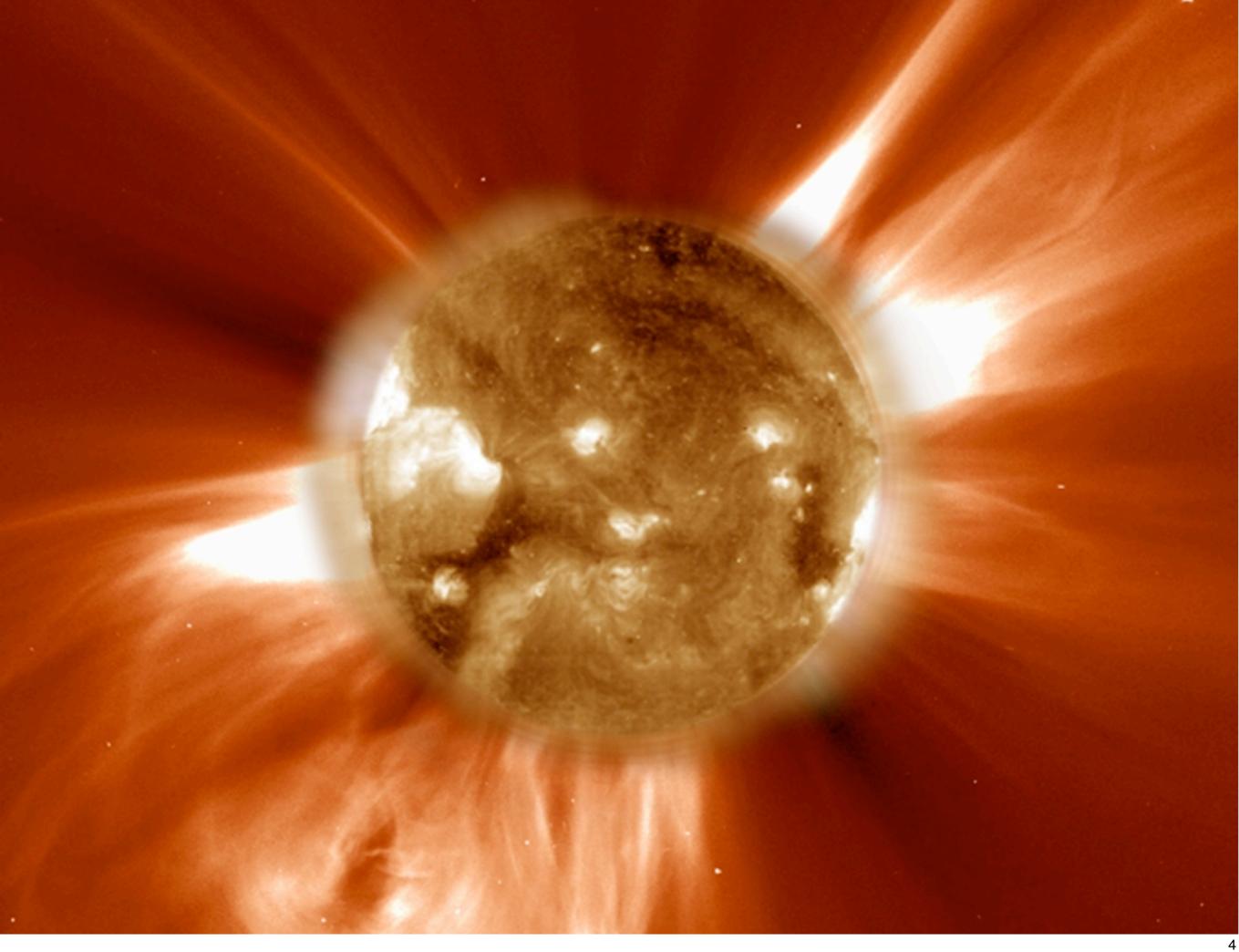


ANDREW R. ZENTNER UNIVERSITY OF PITTSBURGH









THE SUN: FACT SHEET

- One Million times the Volume of the Earth
- 300,000 Times the Mass of the Earth
- 93 Million Miles Away
- About 72% Hydrogen Gas, 27% Helium Gas, and 1% other material (Oxygen, Iron, ...)

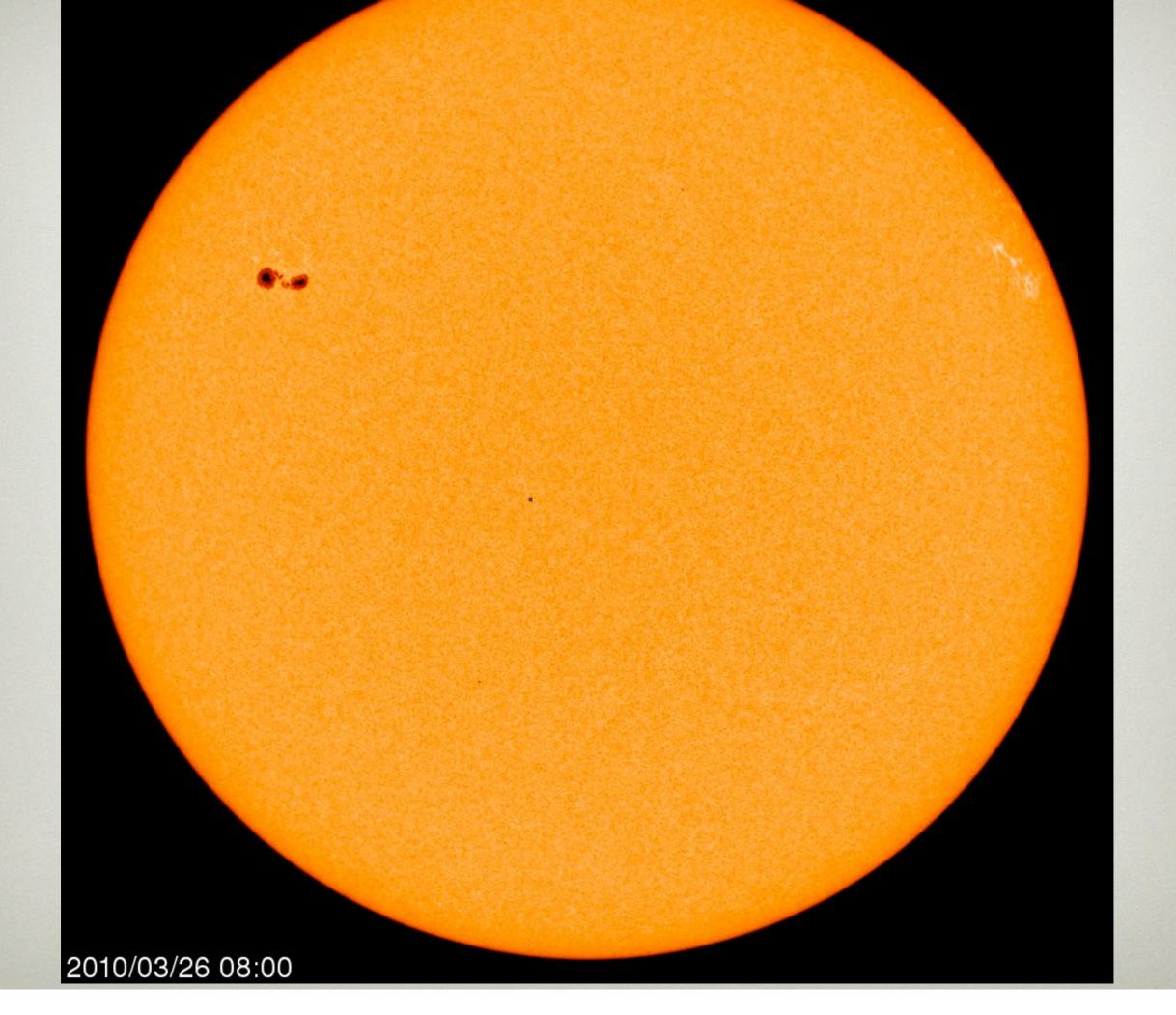
THE SUN: FACT SHEET

- Surface Temperature of 10,000 Degrees
- Interior Temperature of 30 Million Degrees
- The Sun radiates 4 Million times the yearly energy consumption of the US Population every second!
- This is more than enough to boil the all of the oceans each second!
- Each person in the US could be sustained if she/he could capture the incoming solar energy on an 8' x 8' square (0.02% of the US for everyone!)

THE SUN: FACT SHEET

- Your body radiates about 150 W of power, roughly 1/10 of your power usage
- Your body radiates, say, ~W per pound of person
- The Sun radiates about 0.0001 W, per pound of Sun, but its bright because it is really, really, really, really, big

HOW DOES THE SUN MAKE THIS ENERGY?





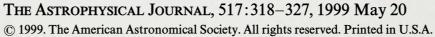
MARCH 1, 1939

PHYSICAL REVIEW

VOLUME 55

Energy Production in Stars*

H. A. BETHE Cornell University, Ithaca, New York (Received September 7, 1938)

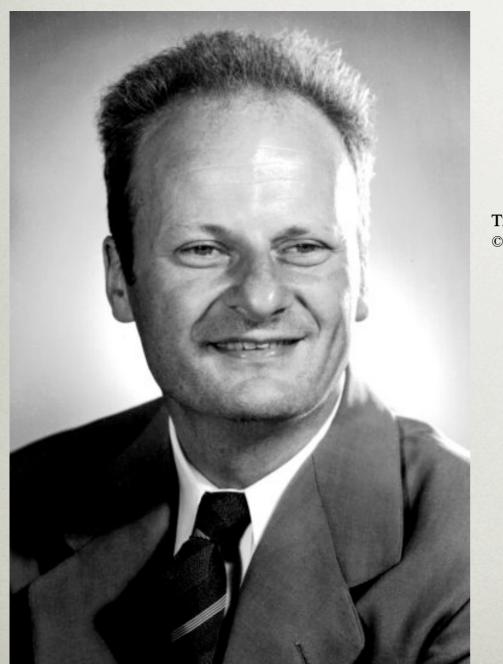


CONTRIBUTION OF HIGH-MASS BLACK HOLES TO MERGERS OF C

HANS A. BETHE Floyd R. Newman Laboratory of Nuclear Studies, Cornell University, Ithaca, New Yo

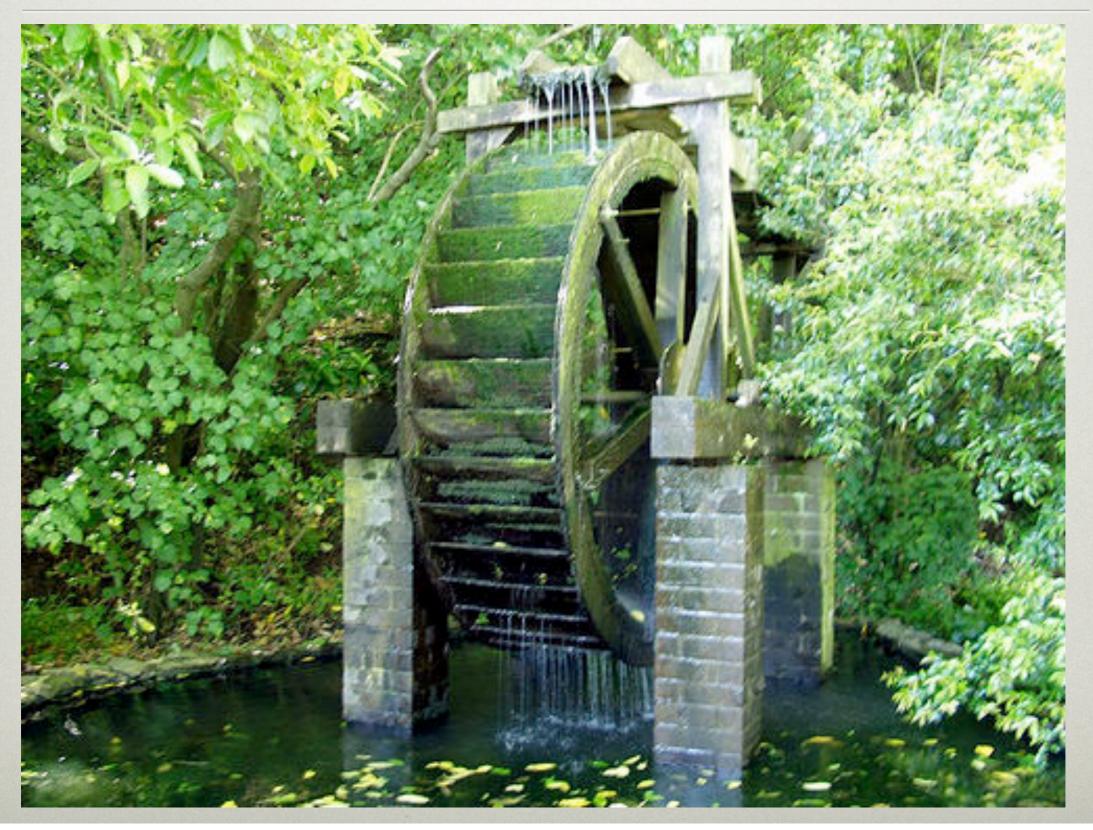
AND

G. E. BROWN Department of Physics and Astronomy, State University of New York, Stony Brook, New Y



11

ANALOGY: STUFF THAT FALLS



ANALOGY: CHEMICAL BURNING

+ \rightarrow + + ENERGY

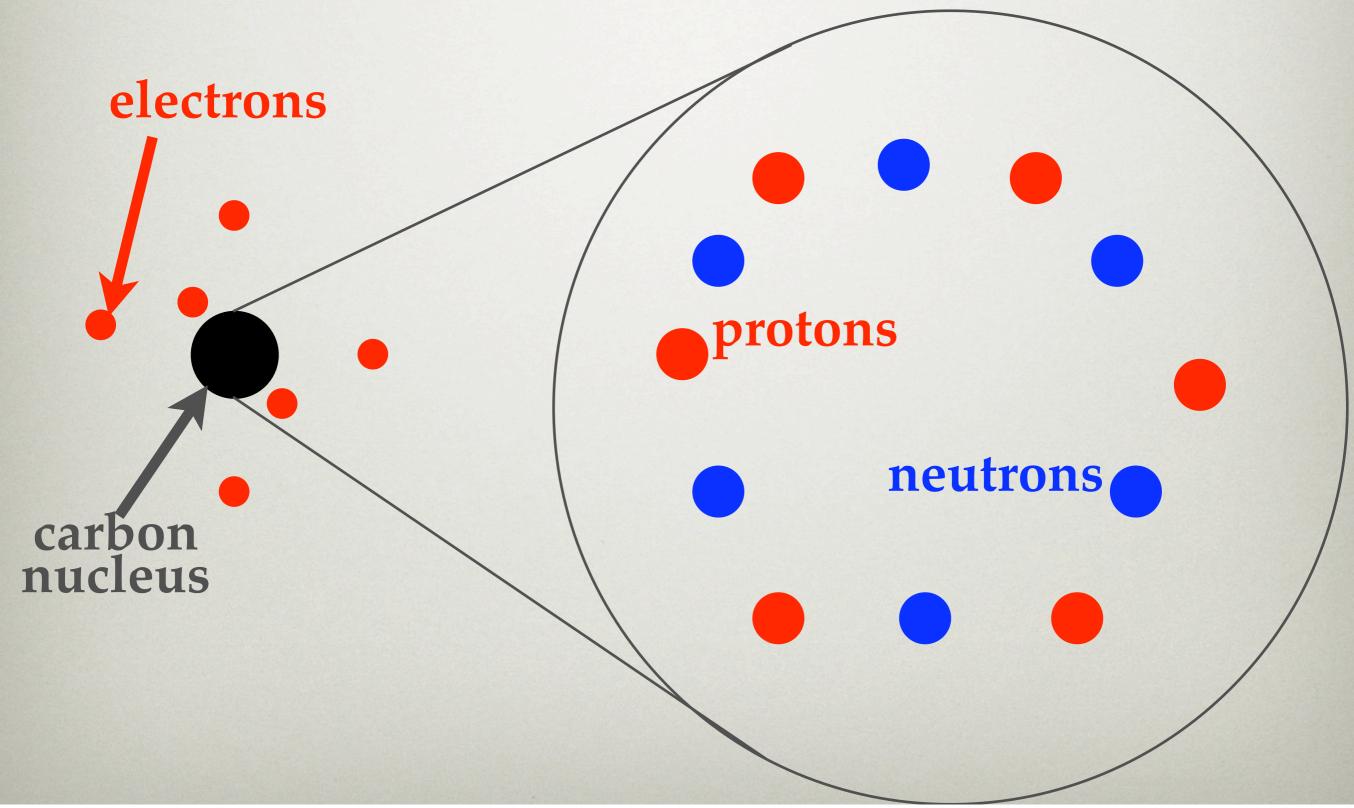
$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + ENERGY$

Natural Oxygen Gas or Methane Carbon Dioxide

Water

Few hours of electricity use per pound

CHEMICAL AND NUCLEAR REACTIONS



HYDROGEN AND HELIUM

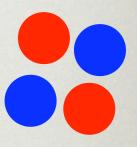
 The Universe is 75% Hydrogen, 24% Helium, and 1% other stuff.

> Hydrogen: 1 proton

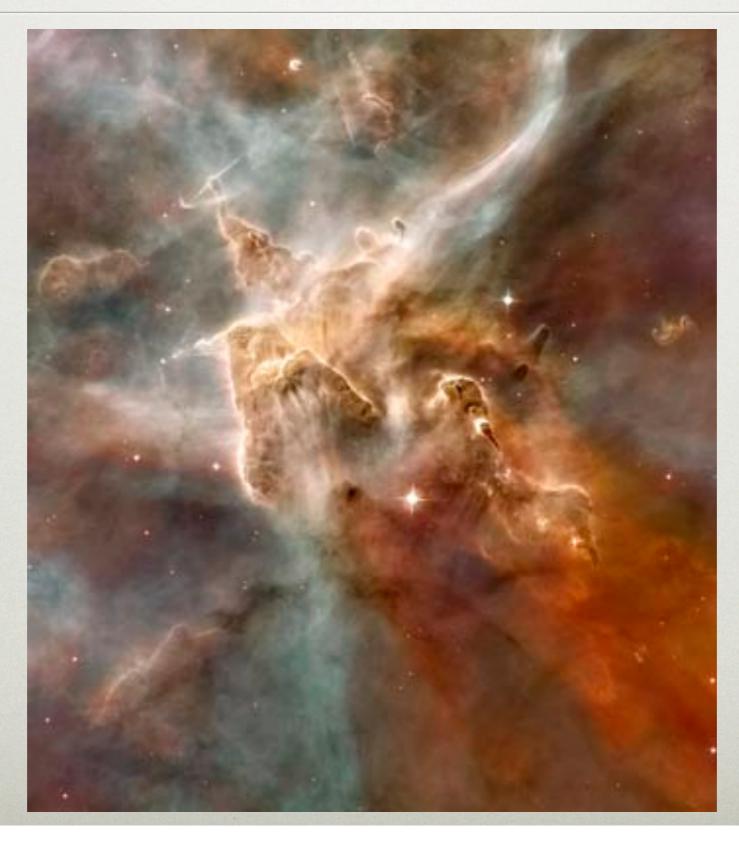
Helium: 2 protons, 2 neutrons, very strongly held together

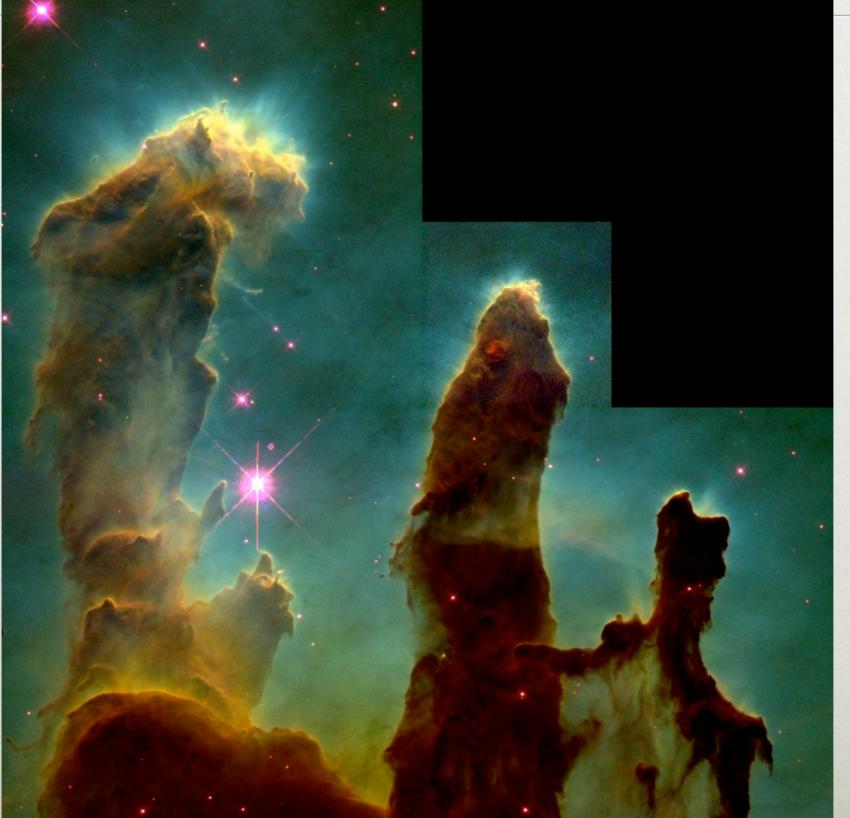
THE "STRONG" NUCLEAR FORCE

 Our Helium nucleus is held together by a new force, the Strong Nuclear Force

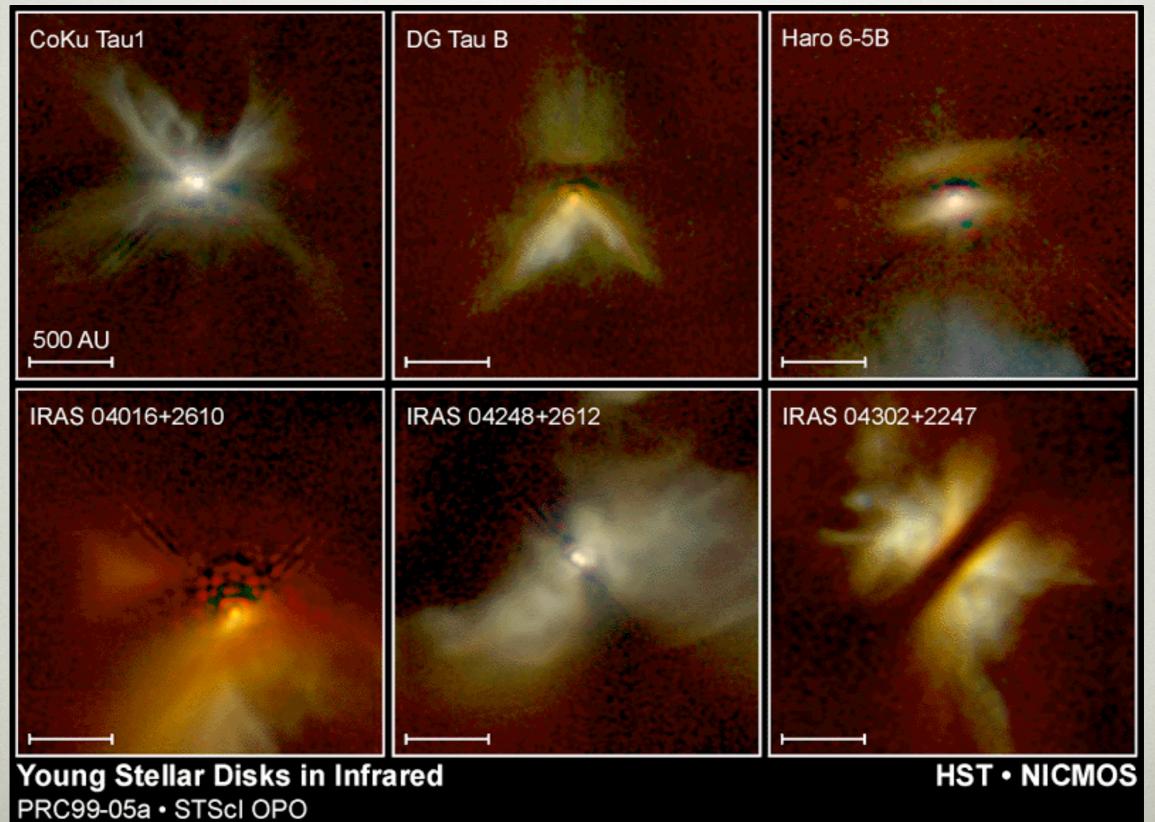


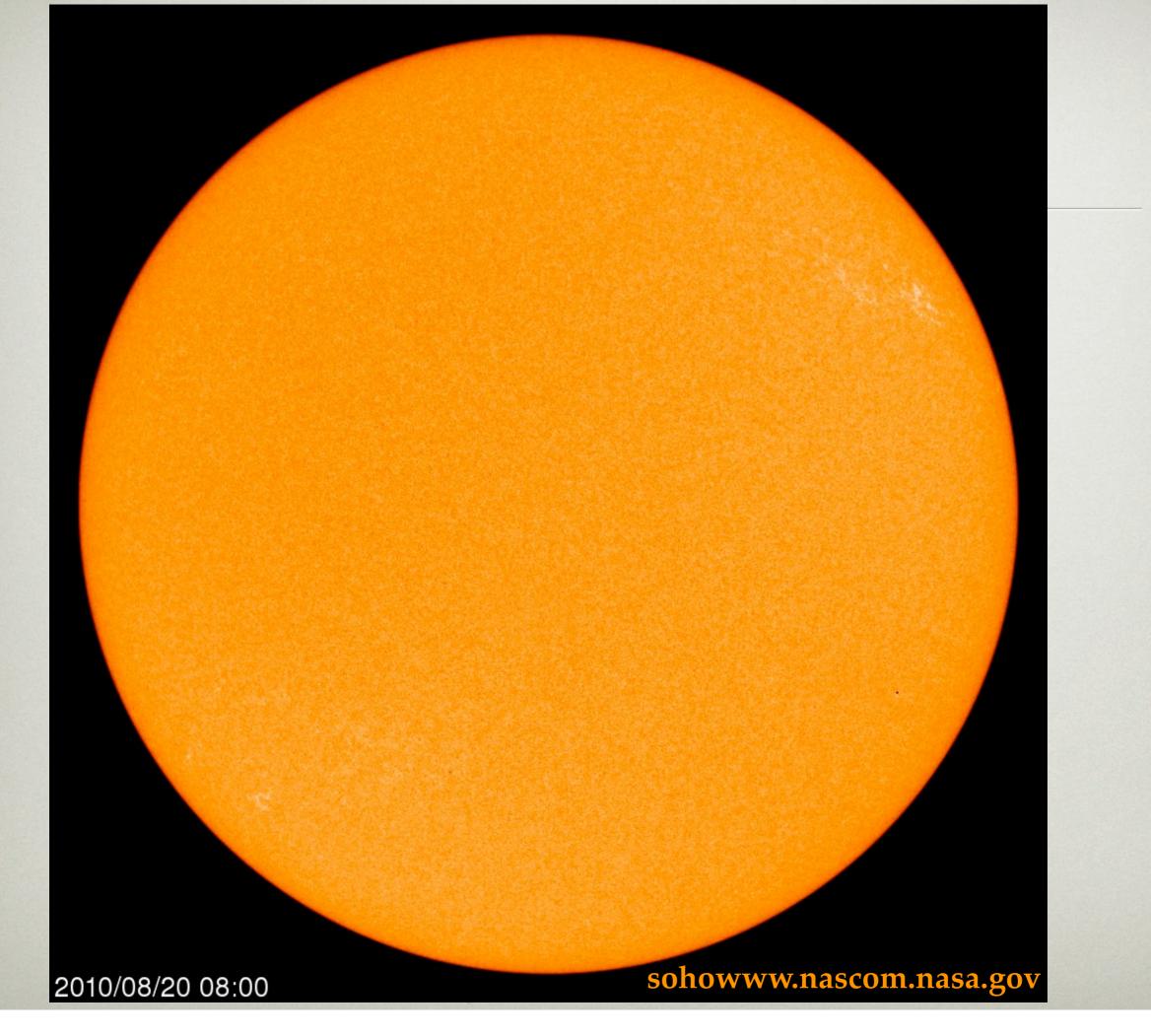
- The Strong force can overcome electricity & magnetism, but only over a short range (one millionth of one billionth of an inch!)
- Nuclear fusion is the act of getting nuclei close enough such that the strong force takes over, and nuclei "fall" together according to the nuclear force

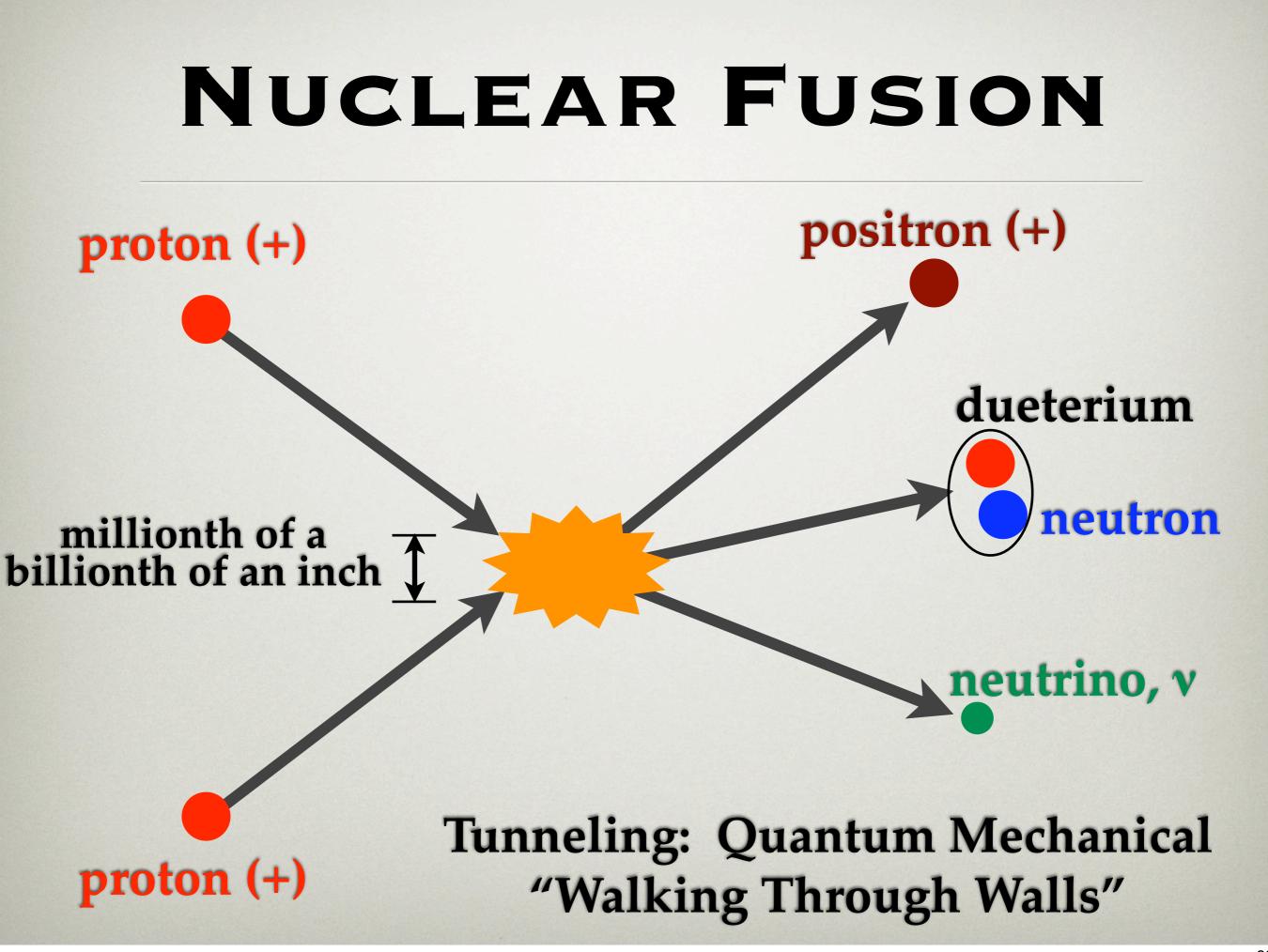












THE OBSERVATORY,

A MONTHLY REVIEW OF ASTRONOMY.

Vot. XLIII.

入物

13

OCTOBER, 1920.

No. 557.

The Internal Constitution of the Stars *.

LAST year at Bournemouth we listened to a proposal from the President of the Association to bore a hole in the crust of the Earth and discover the conditions deep down below the surface. This proposal may remind us that the most secret places of Nature are, perhaps, not 10 to the *n*-th miles above our heads, but 10 miles below our feet. In the last five years the outward march of astronomical discovery has been rapid, and the most remote worlds are now scarcely safe from its inquisition. By the work of H. Shapley the globular clusters, which are found to be at distances scarcely dreamt of hitherto, have been explored, and our knowledge of them is in some respects more complete than that of the local aggregation of stars which includes the Sun. Distance lends not enchantment but precision to the view. Moreover, theoretical researches of Einstein and Weyl make it probable that the space which remains beyond is not illimitable; not merely the material universe, but space itself, is perhaps finite; and the explorer must one day stay his conquering march for lack of fresh realms to invade. But to-day let us turn our thoughts inwards to that other region of mystery-a region cut off by more substantial barriers, for, contrary to many anticipations, even the discovery of the fourth dimension has not enabled us to get at the inside of a body. Science has material and non-material appliances to bore into the interior, and I have chosen to devote this address to what may be described as analytical boring devices—absit omen !

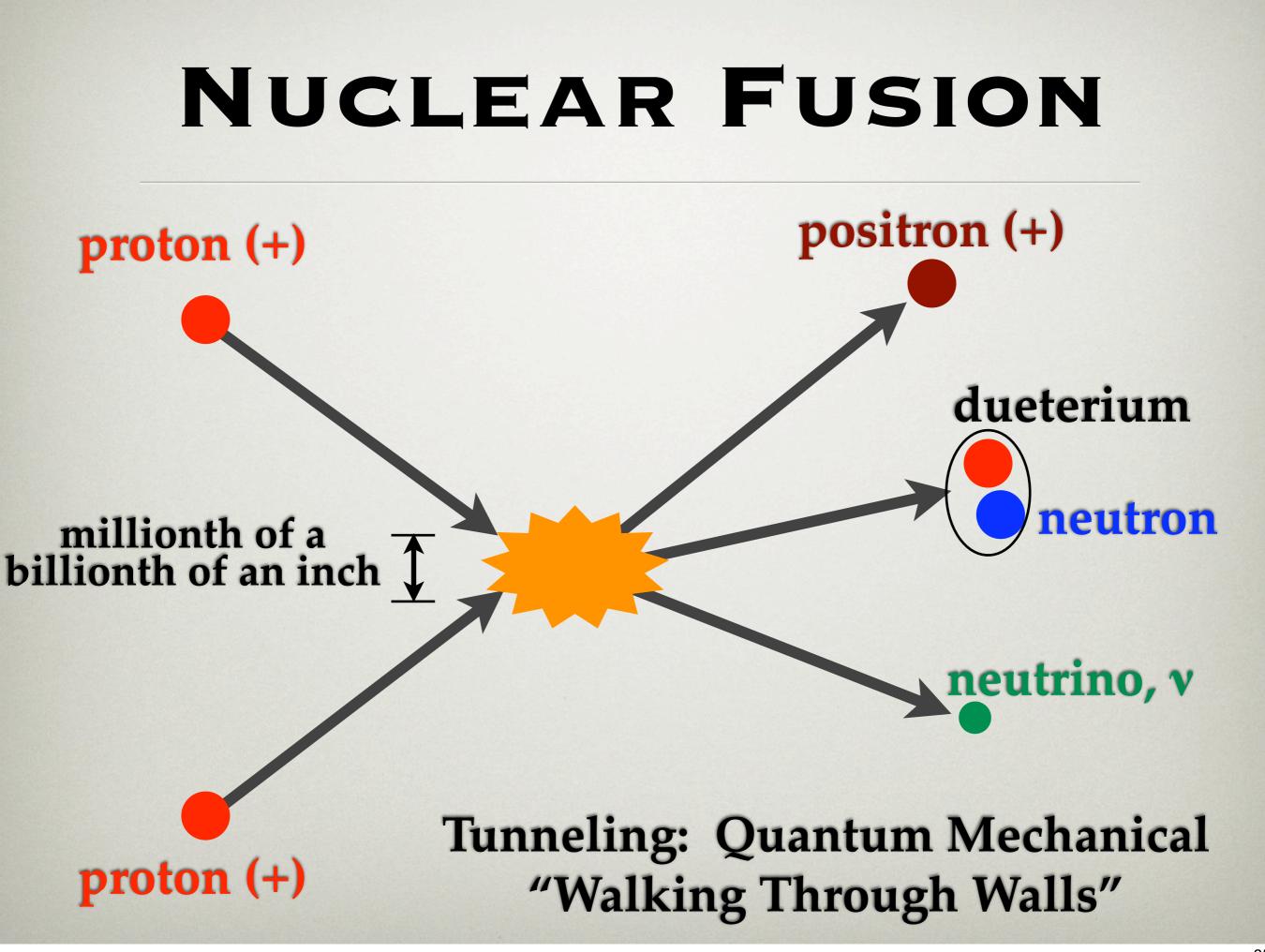
The analytical appliance is delicate at present, and, I fear, would make little headway against the solid crust of the Earth. Instead of letting it blunt itself against the rocks, let us look round for something easier to penetrate. The Sun? Well, perhaps. Many have struggled to penetrate the mystery of the interior of the

* Presidential Address of Professor Eddington to Section A of the British Association at Cardiff, 1920 August 24.

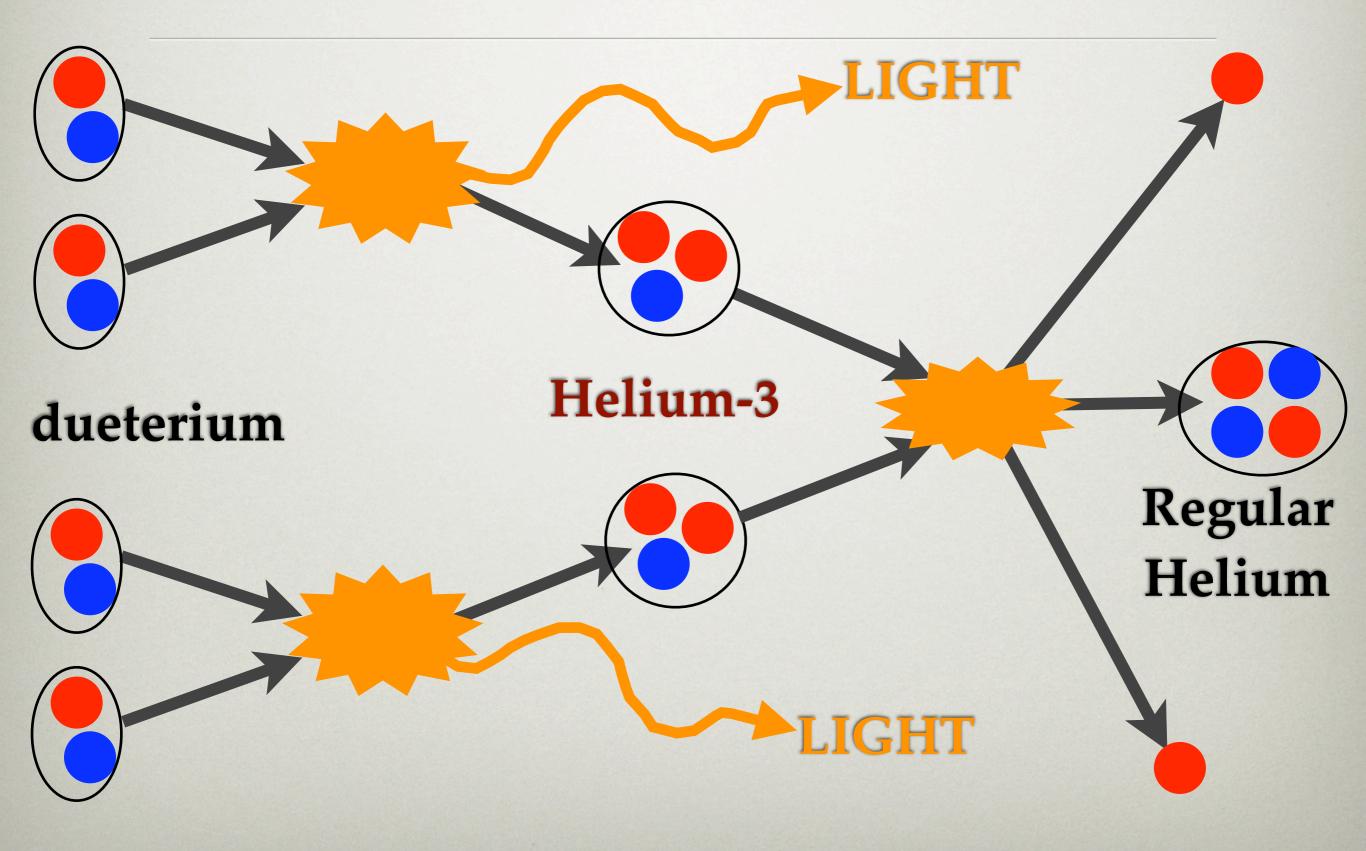
VOL. XLIII.

The helium which we handle must have been put together at some time and some place. We do not argue with the critic who urges that the stars are not hot enough for this process; we tell him to go and find a hotter place.

Sir Arthur Eddington, 1920 The Internal Constitution of the Stars



NUCLEAR FUSION



ENERGY TRANSPORT

- Almost all of the energy produced by the Sun, is produced within 10% of the Solar radius
- The sun is very thick with gas, so this energy leaks out, it takes 100,000 years for the energy produced, to find its way to the surface 400,000 miles away
- It takes only 8 minutes to go from the surface of the sun, to us, another 93,000,000 miles away!

SEEING NEUTRINOS



- In Visible Light, we only see the Sun's surface...
- We have detected neutrinos from the inner 0.1% of the Sun, where fusion is furious!





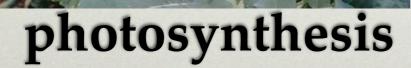
Nuclear Fusion of 5 ounces of Hydrogen



oil: decay, heat, compress for millions of years



coal: decay, heat, compress for millions of years



CAN WE CAPTURE THE SUN'S ENERGY?

• With Plants?



- Unfortunately, only 1/7 of the Sun's energy makes it to the ground
- Plants only capture about 0.05% of that (USDoE)
- So ... supporting US Energy on corn requires 3 times the area of the US! Transportation needs alone require 1 entire US filled with corn!

CAN WE CAPTURE THE SUN'S ENERGY?

• With Solar Power Plants?



CAN WE CAPTURE THE SUN'S ENERGY?

• With Solar Power Plants?



- The best such systems are more than 10% efficient...
- So, crunching the numbers indicates that we could cover only 3% of the US that way, and get all of our energy!

NUCLEAR? GEOTHERMAL?

- Nuclear power comes from Uranium fission
- Geothermal heat comes from radioactivity deep below the Earth's surface
- The raw materials for these processes (Uranium, Thorium, Potassium, ...) are produced by earlier generations of stars

THE END OF THE SUN

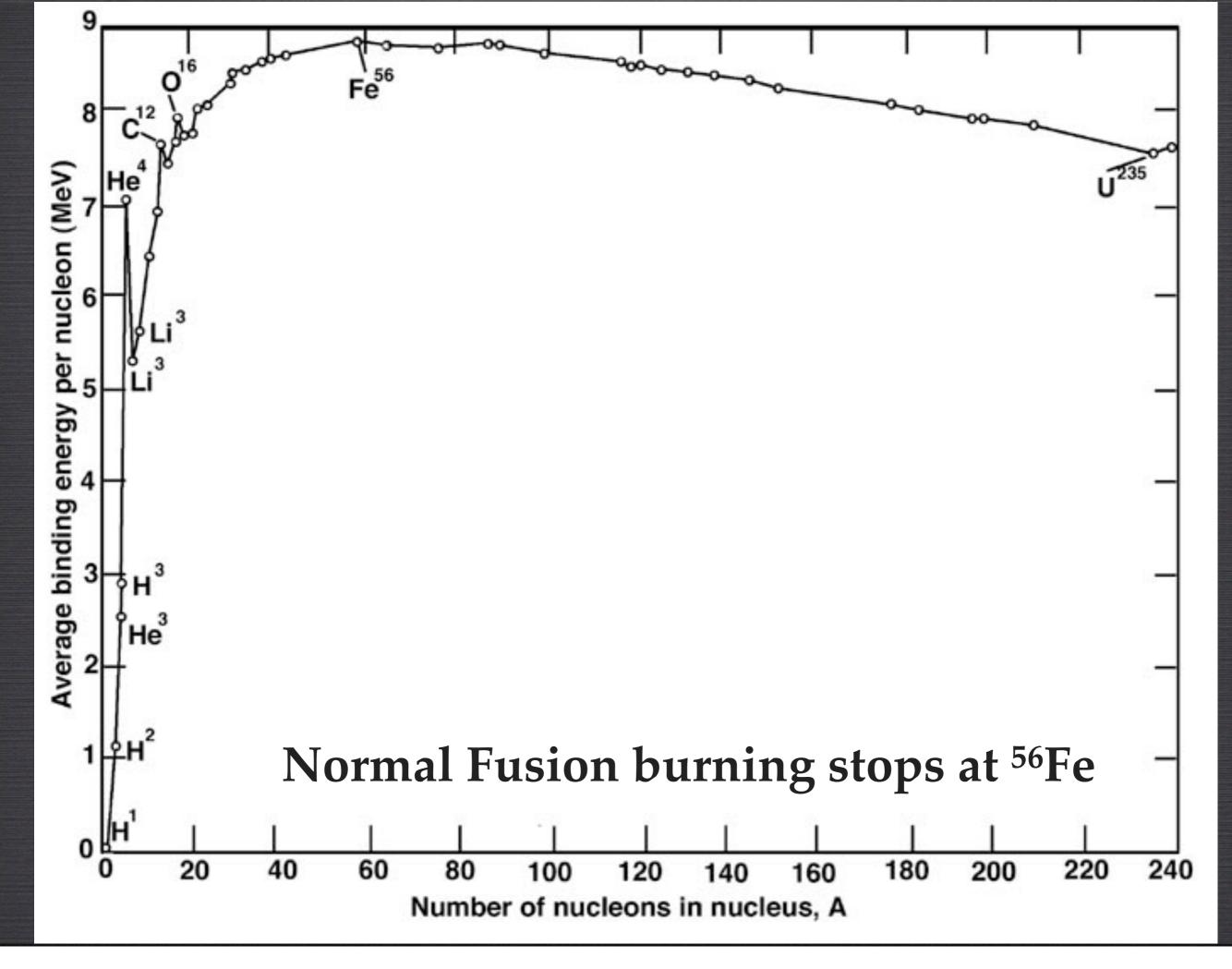
 When the Sun runs out of Hydrogen to burn in its core, it will stop producing its own energy and eventually, become a "white dwarf"

• The Sun has been around for about 5 billion years, this "death" will occur in about 5 billion years.



WAKING HEAVY ELEMENTS

- More massive stars can exert more gravitational squeezing on their interiors, and cause continued fusion
- Helium can combine to form Carbon, then Neon, then Magnesium, then Silicon, then Sulfur, ...
- A star more massive than ~5 solar masses will "burn" its interior all the way to Iron
- Burning produces by adding one Helium to the previous nucleus in the chain



hydrogen 1 H 1.0079																		helium 2 He 4.0026
lithium 3	beryllium 4												boron 5	carbon 6	nitrogen 7	oxygen 8	fluorine 9	neon 10
Li	Be												В	С	N	0	F	Ne
6.941 sodium	9.0122 magnesium												10.811 aluminium	12.011 silicon	14.007 phosphorus	15.999 sulfur	18.998 chlorine	20.180 argon
11 No	12												13	14	15 D	16 C	17	18
Na 22.990	Mg 24,305												AI 26,982	Si 28.086	P 30.974	S 32.065	CI 35.453	Ar 39,948
potassium 19	calcium 20		scandium 21	titanium 22	vanadium 23	chromium 24	manganese 25	iron 26	cobalt 27	nickel 28	copper 29	zinc 30	gallium 31	germanium 32	arsenic 33	selenium 34	bromine 35	krypton 36
Κ			Sc		V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
n	Ca		36		v		IVIII		~~		U U	6	u		10			
39.098	40.078		44.956	47.867	50.942	51,996	54.938	55.845	58.933	58.693	63,546	65.39	69.723	72.61	74.922	78.96	79,904	83.80
39.098 rubidium	40.078 strontium		44.956 yttrium	47.867 zirconium	50.942 niobium	51.996 molybdenum	54.938 technetium	55.845 ruthenium	58.933 rhodium	58.693 palladium	63.546 silver 47	65.39 cadmium	69.723 indium	72.61 tin	74.922 antimony	78.96 tellurium	79,904 iodine	83.80 xenon
39.098 rubidium 37 Rb 85.468	40.078 strontium 38 Sr 87.62		44.956 yttrium 39 Y 88.906	47.867 zirconium 40 Zr 91.224	50.942 niobium 41 Nb 92.906	51,996 molybdenum 42 Mo 95,94	54.938 technetium 43 TC [98]	55.845 ruthenium 44 Ru 101.07	58.933 rhodium 45 Rh 102.91	58.693 palladium 46 Pd 106.42	63.546 silver 47 Ag 107.87	65.39 cadmium 48 Cd 112.41	69.723 indium 49 In 114.82	72.61 tin 50 Sn 118.71	74.922 antimony 51 Sb 121.76	78.96 tellurium 52 Te 127.60	79.904 iodine 53 126.90	83.80 xenon 54 Xe 131.29
39.098 rubidium 37 Rb	40.078 strontium 38 Sr	57-70	44.956 yttrium 39 Y	47,867 zirconium 40 Zr	50.942 niobium 41 Nb	51,996 molybdenum 42 MO	54.938 technetium 43 TC	55.845 ruthenium 44 Ru	58.933 rhodium 45 Rh	58.693 palladium 46 Pd	63.546 silver 47 Ag	65.39 cadmium 48 Cd	69.723 indium 49 In	72.61 tin 50 Sn	74.922 antimony 51 Sb	78.96 telurium 52 Te	79.904 iodine 53	83.80 xenon 54 Xe
39.098 rubidium 37 Rb 85.468 caesium 55 Cs	40.078 strontium 38 Sr 87.62 barium 56 Ba	57-70 ×	44.956 yttrium 39 Y 88.906 Iutetium 71 LU	47,867 zirconium 40 Zr 91.224 hafnium 72 Hf	50.942 niobium 41 Nb 92.906 tantalum	51,996 molybdenum 42 Mo 95,94 tungsten	54.938 technetium 43 TC [98] rhenium	55.845 ruthenium 44 Ru 101.07 osmium 76 OS	58.933 rhodium 45 Rh 102.91 iridium	58.693 palladium 46 Pd 106.42 platinum	63.546 silver 47 Ag 107.87 gold	65.39 cadmium 48 Cd 112.41 mercury 80 Hg	69.723 indium 49 In 114.82 thallium	72.61 tin 50 Sn 118.71 lead 82 Pb	74.922 antimony 51 Sb 121.76 bismuth 83 Bi	78.96 tellurium 52 Te 127.60 polonium 84 Po	79.904 iodine 53 126.90 astatine	83.80 xenon 54 Xe 131.29 radon 86 Rn
39.098 rubidium 37 Rb 85.468 caesium 55 Cs 132.91	40.078 strontium 38 Sr 87.62 barium 56 Ba 137.33		44.956 yttrium 39 Y 88.906 Iutetium 71 Lu 174.97	47.867 zirconium 40 Zr 91.224 hafnium 72 Hf 178.49	50.942 niobium 41 Nb 92.906 tantalum 73 Ta 180.95	51.996 molybdenum 42 MO 95.94 tungsten 74 74 W 183.84	54.938 technetium 43 TC [98] rhenium 75 Re 186.21	55.845 ruthenium 44 Ru 101.07 osmium 76 OS 190.23	58.933 rhodium 45 Rh 102.91 iridium 77 Ir 192.22	58.693 palladium 46 Pd 106.42 platinum 78 Pt 195.08	63.546 silver 47 Ag 107.87 gold 79 Au 196.97	65.39 cadmium 48 Cd 112.41 mercury 80 Hg 200.59	69.723 indium 49 In 114.82 thallium 81	72.61 tin 50 Sn 118.71 lead 82 Pb 207.2	74.922 antimony 51 Sb 121.76 bismuth 83	78.96 tellurium 52 Te 127.60 polonium 84	79.904 iodine 53 126.90 astatine 85	83.80 xenon 54 Xe 131.29 radon 86
39.098 rubidium 37 Rb 85.468 caesium 55 Cs	40.078 strontium 38 Sr 87.62 barium 56 Ba		44.956 yttrium 39 Y 88.906 Iutetium 71 LU	47,867 zirconium 40 Zr 91.224 hafnium 72 Hf	50.942 niobium 41 Nb 92.906 tantalum 73 Ta	51.996 molybdenum 42 MO 95.94 tungsten 74 W	54.938 technetium 43 TC [98] rhenium 75 Re	55.845 ruthenium 44 Ru 101.07 osmium 76 OS	58.933 rhodium 45 Rh 102.91 iridium 77 Ir	58.693 palladium 46 Pd 106.42 platinum 78 Pt	63.546 silver 47 Ag 107.87 gold 79 Au	65.39 cadmium 48 Cd 112.41 mercury 80 Hg	69.723 indium 49 In 114.82 thallium 81	72.61 tin 50 Sn 118.71 lead 82 Pb	74.922 antimony 51 Sb 121.76 bismuth 83 Bi	78.96 tellurium 52 Te 127.60 polonium 84 Po	79.904 iodine 53 1 126.90 astatine 85 At	83.80 xenon 54 Xe 131.29 radon 86 Rn
39.098 rubidium 37 Rb 85.468 caesium 55 CS 132.91 francium	40.078 strontium 38 Sr 87.62 barium 56 Ba 137.33 radium	*	44.956 yttrium 39 Y 88,906 Iutetium 71 LU 174.97 Iawrencium	47.867 zirconium 40 Zr 91.224 hafnium 72 Hf 178.49 rutherfordium	50.942 niobium 41 Nb 92.906 tantalum 73 Ta 180.95 dubnium	51.996 molybdenum 42 MO 95.94 tungsten 74 74 W 183.84 seaborgium 106	54.938 technetium 43 TC [98] rhenium 75 Re 186.21 bohrium	55.845 ruthenium 44 Ru 101.07 osmium 76 OS 190.23 hassium	58.933 rhodium 45 Rh 102.91 iridium 77 Ir 192.22 meitnerium	58.693 palladium 46 Pd 106.42 platinum 78 Pt 195.08 ununnilium 110	63.546 silver 47 Ag 107.87 gold 79 Au 196.97 unununium	65.39 cadmium 48 Cd 112.41 mercury 80 Hg 200.59 ununbium 112	69.723 indium 49 In 114.82 thallium 81	72.61 tin 50 Sn 118.71 lead 82 Pb 207.2 ununquadium	74.922 antimony 51 Sb 121.76 bismuth 83 Bi	78.96 tellurium 52 Te 127.60 polonium 84 Po	79.904 iodine 53 1 126.90 astatine 85 At	83.80 xenon 54 Xe 131.29 radon 86 Rn
39.098 rubidium 37 Rb 85.468 caesium 55 CS 132.91 francium 87	40.078 strontium 38 Sr 87.62 barium 56 Ba 137.33 radium 88	★ 89-102	44.956 yttrium 39 Y 88.906 Iutetium 71 LU 174.97 Iawrencium 103	47.867 zirconium 40 Zr 91.224 hafnium 72 Hf 178.49 rutherfordium 104	50.942 niobium 41 Nb 92.906 tantalum 73 Ta 180.95 dubnium 105	51.996 molybdenum 42 MO 95.94 tungsten 74 74 W 183.84 seaborgium	54.938 technetium 43 TC [98] rhenium 75 Re 186.21 bohrium 107	55.845 ruthenium 44 Ru 101.07 osmium 76 OS 190.23 hassium 108	58.933 rhodium 45 Rh 102.91 iridium 77 Ir 192.22 meitnerium 109	58.693 palladium 46 Pd 106.42 platinum 78 Pt 195.08 ununnilium 110	63.546 silver 47 Ag 107.87 gold 79 Au 196.97 unununium 111	65.39 cadmium 48 Cd 112.41 mercury 80 Hg 200.59 ununbium 112	69.723 indium 49 In 114.82 thallium 81	72.61 tin 50 Sn 118.71 lead 82 Pb 207.2 ununquadium 114	74.922 antimony 51 Sb 121.76 bismuth 83 Bi	78.96 tellurium 52 Te 127.60 polonium 84 Po	79.904 iodine 53 1 126.90 astatine 85 At	83.80 xenon 54 Xe 131.29 radon 86 Rn

*Lanthanide series	lanthanum 57	cerium 58	praseodymium 59	neodymium 60	promethium 61	samarium 62	europium 63	gadolinium 64	terbium 65	dysprosium 66	holmium 67	erbium 68	thulium 69	ytterbium 70
Lanthanide Series	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb
	138.91	140.12	140.91	144.24	[145]	150.36	151.96	157.25	158.93	162.50	164.93	167.26	168.93	173.04
and the second	actinium	thorium	protactinium	uranium	neptunium	plutonium	americium	curium	berkelium	californium	einsteinium	fermium	mendelevium	nobelium
* * Actinide series	89	90	91	92	93	94	95	96	97	98	99	100	101	102
	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No
	[227]	232.04	231.04	238.03	[237]	[244]	[243]	[247]	[247]	[251]	[252]	[257]	[258]	[259]

hydrogen	1		10.000			0.50			1.01				cale and	and the second				helium
1																		2
н																		He
1.0079																		4.0026
lithium	beryllium											[boron	carbon	nitrogen	oxygen	fluorine	neon
3	4												5	6	7	8	9	10
Li	Be												B	C	N	0	F	Ne
6.941	9.0122												10.811	12.011	14.007	15.999	18.998	20.180
sodium 11	magnesium 12												aluminium 13	silicon 14	phosphorus 15	sulfur 16	chlorine 17	argon 18
Na	Mg												AI	Si	P	S	CI	Ar
22.990	24.305		a a an di um	literature	seens discon	abramium		Inco	as half	niekol		ain e	26.982	28.086	30.974	32.065	35.453	39,948
potassium 19	calcium 20		scandium 21	titanium 22	vanadium 23	chromium 24	manganese 25	100 26	cobalt 27	nickel 28	copper 29	zinc 30	gallium 31	germanium 32	arsenic 33	selenium 34	bromine 35	krypton 36
1000								2002		1000						26225	10000	345365
	Co		Sa	Ti		Cr	NID	Fo	Co		CII	Zn	Ca	Co	Ac	Sa	Dr	1 m
Κ	Ca		Sc	Ti	V	Cr	Mn	Fe	Со	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
39.098	40.078		44.956	47.867	50.942	51.996	54.938	55.845	58.933	58.693	63.546	65.39	69.723	72.61	74.922	78.96	79,904	83.80
					-													
39.098 rubidium 37	40.078 strontium 38		44.956 yttrium	47.867 zirconium 40	50.942 niobium 41	51.996 molybdenum 42	54.938 technetium 43	55.845 ruthenium 44	58.933 rhodium 45	58.693 palladium 46	63.546 silver 47	65.39 cadmium 48	69.723 indium 49	72.61 tin 50	74.922 antimony 51	78.96 tellurium 52	79,904 iodine	83.80 xenon 54
39.098 rubidium 37 Rb	40.078 strontium 38 Sr		44.956 yttrium 39 Y	47.867 zirconium 40 Zr	50.942 niobium 41 Nb	51,996 molybdenum 42 MO	54.938 technetium 43 TC	55.845 ruthenium 44 Ru	58.933 rhodium 45 Rh	58.693 palladium 46 Pd	63.546 silver 47 Ag	65.39 cadmium 48 Cd	69.723 indium 49 In	72.61 tin 50 Sn	74.922 antimony 51 Sb	78.96 tellurium 52 Te	79,904 iodine 53	83.80 xenon 54 Xe
39.098 rubidium 37 Rb 85.468	40.078 strontium 38 Sr 87.62		44.956 yttrium 39 Y 88.906	47.867 zirconium 40 Zr 91.224	50.942 niobium 41 Nb 92.906	51,996 molybdenum 42 Mo 95,94	54.938 technetium 43 TC [98]	55.845 ruthenium 44 Ru 101.07	58.933 rhodium 45 Rh 102.91	58.693 palladium 46 Pd 106.42	63.546 silver 47 Ag 107.87	65.39 cadmium 48 Cd 112.41	69.723 indium 49 In 114.82	72.61 tin 50	74.922 antimony 51 Sb 121.76	78.96 tellurium 52 Te 127.60	79.904 iodine 53 126.90	83.80 xenon 54 Xe 131.29
39.098 rubidium 37 Rb	40.078 strontium 38 Sr	57-70	44.956 yttrium 39 Y	47.867 zirconium 40 Zr	50.942 niobium 41 Nb	51,996 molybdenum 42 MO	54.938 technetium 43 TC	55.845 ruthenium 44 Ru	58.933 rhodium 45 Rh	58.693 palladium 46 Pd	63.546 silver 47 Ag	65.39 cadmium 48 Cd	69.723 indium 49 In	72.61 tin 50 Sn 118.71	74.922 antimony 51 Sb	78.96 tellurium 52 Te	79,904 iodine 53	83.80 xenon 54 Xe
39.098 rubidium 37 Rb 85.468 caesium 55	40.078 strontium 38 Sr 87.62 barium 56	57-70 ★	44.956 yttrium 39 Y 88.906 Iutetium 71	47.867 zirconium 40 Zr 91.224 hafnium 72	50.942 niobium 41 Nb 92.906 tantalum 73	51.996 molybdenum 42 MO 95.94 tungsten 74	54.938 technetium 43 TC [98] rhenium 75	55.845 ruthenium 44 Ru 101.07 osmium 76	58.933 rhodium 45 Rh 102.91 iridium 77	58.693 palladium 46 Pd 106.42 platinum 78	63.546 silver 47 Ag 107.87 gold 79	65.39 cadmium 48 Cd 112.41 mercury 80	69.723 indium 49 In 114.82 thallium	72.61 tin 50 Sn 118.71 lead 82	74.922 antimony 51 Sb 121.76 bismuth 83	78.96 tellurium 52 Te 127.60 polonium 84	79.904 iodine 53 126.90 astatine 85	83.80 xenon 54 Xe 131.29 radon 86
39.098 rubidium 37 Rb 85.468 caesium 55 Cs	40.078 strontium 38 Sr 87.62 barium 56 Ba		44.956 yttrium 39 Y 88.906 Iutetium 71	47,867 zirconium 40 Zr 91.224 hafnium 72 Hf	50.942 niobium 41 Nb 92.906 tantalum 73 Ta	51,996 molybdenum 42 Mo 95,94 tungsten 74 W	54.938 technetium 43 TC [98] rhenium 75 Re	55.845 ruthenium 44 Ru 101.07 osmium 76 OS	58.933 rhodium 45 Rh 102.91 iridium 77 Ir	58.693 palladium 46 Pd 106.42 platinum 78 Pt	63.546 silver 47 Ag 107.87 gold 79 Au	65.39 cadmium 48 Cd 112.41 mercury 80 Hg	69.723 indium 49 In 114.82 thallium 81 TI	72.61 tin 50 Sn 118.71 lead 82 Pb	74.922 antimony 51 Sb 121.76 bismuth 83 Bi	78.96 tellurium 52 Te 127.60 polonium 84 Po	79,904 iodine 53 I 126,90 astatine 85 At	83.80 xenon 54 Xe 131.29 radon 86 Rn
39.098 rubidium 37 Rb 85.468 caesium 55 CS 132.91 francium	40.078 strontium 38 Sr 87.62 barium 56 Ba 137.33 radium	*	44.956 yttrium 39 Y 88.906 Iutetium 71 LU 174.97 Iawrencium	47,867 zirconium 40 Zr 91,224 hafnium 72 Hf 178,49 rutherfordium	50.942 niobium 41 Nb 92.906 tantalum 73 Ta 180.95 dubnium	51.996 molybdenum 42 MO 95.94 tungsten 74 W 183.84 seaborgium	54.938 technetium 43 TC [98] rhenium 75 Re 186.21 bohrium	55.845 ruthenium 44 Ru 101.07 osmium 76 OS 190.23 hassium	58.933 rhodium 45 Rh 102.91 iridium 77 Ir 192.22 meitnerium	58.693 palladium 46 Pd 106.42 platinum 78 Pt 195.08 ununnilium	63.546 silver 47 Ag 107.87 gold 79 Au 196.97 unununium	65.39 cadmium 48 Cd 112.41 mercury 80 Hg 200.59 ununbium	69.723 indium 49 In 114.82 thallium	72.61 tin 50 Sn 118.71 lead 82 Pb 207.2 ununquadium	74.922 antimony 51 Sb 121.76 bismuth 83	78.96 tellurium 52 Te 127.60 polonium 84	79.904 iodine 53 126.90 astatine 85	83.80 xenon 54 Xe 131.29 radon 86
39.098 rubidium 37 Rb 85.468 caesium 55 CS 132.91 francium 87	40.078 strontium 38 Sr 87.62 barium 56 Ba 137.33 radium 88	★ 89-102	44.956 yttrium 39 Y 88.906 lutetium 71 LU 174.97 lawrencium 103	47.867 zirconium 40 Zr 91.224 hafnium 72 Hf 178.49 rutherfordium 104	50.942 niobium 41 Nb 92.906 tantalum 73 Ta 180.95 dubnium 105	51.996 molybdenum 42 Mo 95.94 tungsten 74 74 W 183.84 seaborgium 106	54.938 technetium 43 TC [98] rhenium 75 Re 186.21 bohrium 107	55.845 ruthenium 44 Ru 101.07 osmium 76 OS 190.23 hassium 108	58.933 rhodium 45 Rh 102.91 iridium 77 Ir 192.22 meitnerium 109	58.693 palladium 46 Pd 106.42 platinum 78 Pt 195.08 ununnilium 110	63.546 silver 47 Ag 107.87 gold 79 Au 196.97 unununium 111	65.39 cadmium 48 Cd 112.41 mercury 80 Hg 200.59 ununbium 112	69.723 indium 49 In 114.82 thallium 81 TI	72.61 tin 50 Sn 118.71 lead 82 Pb 207.2 ununquadium 114	74.922 antimony 51 Sb 121.76 bismuth 83 Bi 208.98	78.96 tellurium 52 Te 127.60 polonium 84 Po	79,904 iodine 53 I 126,90 astatine 85 At	83.80 xenon 54 Xe 131.29 radon 86 Rn
39.098 rubidium 37 Rb 85.468 caesium 55 CS 132.91 francium	40.078 strontium 38 Sr 87.62 barium 56 Ba 137.33 radium	*	44.956 yttrium 39 Y 88.906 Iutetium 71 LU 174.97 Iawrencium	47,867 zirconium 40 Zr 91,224 hafnium 72 Hf 178,49 rutherfordium	50.942 niobium 41 Nb 92.906 tantalum 73 Ta 180.95 dubnium	51.996 molybdenum 42 Mo 95.94 tungsten 74 74 W 183.84 seaborgium 106	54.938 technetium 43 TC [98] rhenium 75 Re 186.21 bohrium	55.845 ruthenium 44 Ru 101.07 osmium 76 OS 190.23 hassium	58.933 rhodium 45 Rh 102.91 iridium 77 Ir 192.22 meitnerium	58.693 palladium 46 Pd 106.42 platinum 78 Pt 195.08 ununnilium 110	63.546 silver 47 Ag 107.87 gold 79 Au 196.97 unununium	65.39 cadmium 48 Cd 112.41 mercury 80 Hg 200.59 ununbium 112	69.723 indium 49 In 114.82 thallium 81 TI	72.61 tin 50 Sn 118.71 lead 82 Pb 207.2 ununquadium 114	74.922 antimony 51 Sb 121.76 bismuth 83 Bi 208.98	78.96 tellurium 52 Te 127.60 polonium 84 Po	79,904 iodine 53 I 126,90 astatine 85 At	83.80 xenon 54 Xe 131.29 radon 86 Rn
39.098 rubidium 37 Rb 85.468 caesium 55 CS 132.91 francium 87	40.078 strontium 38 Sr 87.62 barium 56 Ba 137.33 radium 88	★ 89-102	44.956 yttrium 39 Y 88.906 lutetium 71 LU 174.97 lawrencium 103	47.867 zirconium 40 Zr 91.224 hafnium 72 Hf 178.49 rutherfordium 104	50.942 niobium 41 Nb 92.906 tantalum 73 Ta 180.95 dubnium 105	51.996 molybdenum 42 MO 95.94 tungsten 74 W 183.84 seaborgium	54.938 technetium 43 TC [98] rhenium 75 Re 186.21 bohrium 107	55.845 ruthenium 44 Ru 101.07 osmium 76 OS 190.23 hassium 108	58.933 rhodium 45 Rh 102.91 iridium 77 Ir 192.22 meitnerium 109	58.693 palladium 46 Pd 106.42 platinum 78 Pt 195.08 ununnilium 110	63.546 silver 47 Ag 107.87 gold 79 Au 196.97 unununium 111	65.39 cadmium 48 Cd 112.41 mercury 80 Hg 200.59 ununbium 112	69.723 indium 49 In 114.82 thallium 81 TI	72.61 tin 50 Sn 118.71 lead 82 Pb 207.2 ununquadium	74.922 antimony 51 Sb 121.76 bismuth 83 Bi 208.98	78.96 tellurium 52 Te 127.60 polonium 84 Po	79,904 iodine 53 I 126,90 astatine 85 At	83.80 xenon 54 Xe 131.29 radon 86 Rn

*Lanthanide series	lanthanum 57	cerium 58	praseodymium 59	neodymium 60	promethium 61	samarium 62	europium 63	gadolinium 64	terbium 65	dysprosium 66	holmium 67	erbium 68	thulium 69	ytterbium 70
Lanthanide Series	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb
	138.91	140.12	140.91	144.24	[145]	150.36	151.96	157.25	158.93	162.50	164.93	167.26	168.93	173.04
and the second	actinium	thorium	protactinium	uranium	neptunium	plutonium	americium	curium	berkelium	californium	einsteinium	fermium	mendelevium	nobelium
* * Actinide series	89	90	91	92	93	94	95	96	97	98	99	100	101	102
	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No
	[227]	232.04	231.04	238.03	[237]	[244]	[243]	[247]	[247]	[251]	[252]	[257]	[258]	[259]

hydrogen			1000		1000	200			1.04					of the sec		51.04		helium
1	1																	2
н	1																	He
1.0079		1																.0026
lithium 3	beryllium 4	1											boron 5	carbon 6	nitrogen 7	oxygen 8	fluorine 9	neon 10
.		1											1.	C			1000	1220202000
	Be	1											В	C	N	0	F	Ne
6.941 sodium	9.0122 magnesium	1											10.811 aluminium	12.011 silicon	14.007 phosphorus	15.999 sulfur	18.998 chlorine	20.180 argon
11	12	1											13	14	15	16	17	18
Na	Mg												AI	Si	P	S	CI	Ar
22.990	24.305	ł –			(A								26.982	28.086	30.974	32.065	35.453	39,948
potassium 19	calcium 20	i – 1	scandium 21	titanium 22	vanadium 23	chromium 24	manganese 25	iron 26	cobalt 27	nickel 28	copper 29	zinc 30	gallium 31	germanium 32	arsenic 33	selenium 34	bromine 35	krypton 36
1000		/ /				-					-			-			10000	12020
		·)	C a l			- 14	0.0 10	-					C O					
K	Ca		Sc	TI	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
39.098	40.078		44.956	47.867	50.942	51,996	54.938	55.845	58.933	58.693	63.546	65.39	69.723	72.61	74.922	78.96	79,904	83.80
39.098 rubidium	40.078 strontium		44.956 yttrium	47.867 zirconium	50.942 niobium	51.996 molybdenum	54.938 technetium	55.845 ruthenium	58.933 rhodium	58.693 palladium	63.546 silver 47	65.39 cadmium	69.723 indium	72.61 tin	74.922 antimony	78.96 tellurium	79,904 iodine	83.80 xenon
39.098 rubidium 37 Rb 85.468	40.078 strontium 38 Sr 87.62		44.956 yttrium 39 Y 88.906	47.867 zirconium 40 Zr 91.224	50.942 niobium 41 Nb 92.906	51.996 molybdenum 42 Mo 95.94	54.938 technetium 43 TC [98]	55.845 ruthenium 44 Ru 101.07	58.933 rhodium 45 Rh 102.91	58.693 palladium 46 Pd 106.42	63.546 silver 47 Ag 107.87	65.39 cadmium 48 Cd 112.41	69.723 indium 49 In 114.82	72.61 tin 50 Sn 118.71	74.922 antimony 51 Sb 121.76	78.96 telurium 52 Te 127.60	79.904 iodine 53 126.90	83.80 xenon 54 Xe 131.29
39.098 rubidium 37 Rb 85.468 caesium	40.078 strontium 38 Sr 87.62 barium	57-70	44.956 yttrium 39 Y 88.906 Jutetium	47.867 zirconium 40 Zr 91.224 hafnium	50.942 niobium 41 Nb 92.906 tantalum	51.996 molybdenum 42 Mo 95.94 tungsten	54.938 technetium 43 TC [98] rhenium	55.845 ruthenium 44 Ru 101.07 osmium	58.933 rhodium 45 Rh 102.91 iridium	58.693 palladium 46 Pd 106.42 platinum	63.546 silver 47 Ag 107.87 gold	65.39 cadmium 48 Cd 112.41 mercury	69.723 indium 49 In 114.82 thallium	72.61 tin 50 Sn 118.71 lead	74.922 antimony 51 Sb 121.76 bismuth	78.96 tellurium 52 Te 127.60 polonium	79.904 iodine 53 126.90 astatine	83.80 xenon 54 Xe 131.29 radon
39.098 rubidium 37 Rb 85.468 caesium 55	40.078 strontium 38 Sr 87.62 barium 56	57-70	44.956 yttrium 39 Y 88.906 lutetium 71	47.867 zirconium 40 Zr 91.224 hafnium 72	50.942 niobium 41 Nb 92.906 tantalum 73	51.996 molybdenum 42 MO 95.94 tungsten 74	54.938 technetium 43 TC [98] rhenium 75	55.845 ruthenium 44 Ru 101.07 osmium 76	58.933 rhodium 45 Rh 102.91 iridium 77	58.693 palladium 46 Pd 106.42 platinum 78	63.546 silver 47 Ag 107.87 gold 79	65.39 cadmium 48 Cd 112.41 mercury 80	69.723 indium 49 In 114.82 thallium 81	72.61 tin 50 Sn 118.71 lead 82	74.922 antimony 51 Sb 121.76 bismuth 83	78.96 tellurium 52 Te 127.60 polonium 84	79.904 iodine 53 126.90 astatine 85	83.80 xenon 54 Xe 131.29 radon 86
39.098 rubidium 37 Rb 85.468 caesium 55 Cs	40.078 strontium 38 Sr 87.62 barium 56 Ba	57-70 ★	44.956 yttrium 39 Y 88.906 lutetium 71 Lu	47.867 zirconium 40 Zr 91.224 hafnium 72 Hf	50.942 niobium 41 Nb 92.906 tantalum 73 Ta	51.996 molybdenum 42 MO 95.94 tungsten 74 W	54.938 technetium 43 TC [98] rhenium 75 Re	55.845 ruthenium 44 Ru 101.07 osmium 76 OS	58.933 rhodium 45 Rh 102.91 iridium 77 Ir	58.693 palladium 46 Pd 106.42 platinum 78 Pt	63.546 silver 47 Ag 107.87 gold 79 Au	65.39 cadmium 48 Cd 112.41 mercury 80 Hg	69.723 indium 49 114.82 thallium 81 TI	72.61 tin 50 Sn 118.71 lead 82 Pb	74.922 antimony 51 Sb 121.76 bismuth 83 Bi	78.96 tellurium 52 Te 127.60 polonium 84 Po	79.904 iodine 53 1 126.90 astatine 85 At	83.80 xenon 54 Xe 131.29 radon 86 Rn
39.098 rubidium 37 Rb 85.468 caesium 55 Cs 132.91	40.078 strontium 38 Sr 87.62 barium 56 Ba 137.33		44.956 yttrium 39 Y 88.906 lutetium 71 Lu 174.97	47.867 zirconium 40 Zr 91.224 hafnium 72 Hf 178.49	50.942 niobium 41 Nb 92.906 tantalum 73 Ta 180.95	51.996 molybdenum 42 MO 95.94 tungsten 74 74 W 183.84	54.938 technetium 43 TC [98] rhenium 75 Re 186.21	55.845 ruthenium 44 Ru 101.07 osmium 76 OS 190.23	58.933 rhodium 45 Rh 102.91 iridium 77 Ir 192.22	58.693 palladium 46 Pd 106.42 platinum 78 Pt 195.08	63.546 silver 47 Ag 107.87 gold 79 Au 196.97	65.39 cadmium 48 Cd 112.41 mercury 80 Hg 200.59	69.723 indium 49 In 114.82 thallium 81	72.61 tin 50 Sn 118.71 lead 82 Pb 207.2	74.922 antimony 51 Sb 121.76 bismuth 83	78.96 tellurium 52 Te 127.60 polonium 84	79.904 iodine 53 126.90 astatine 85	83.80 xenon 54 Xe 131.29 radon 86
39.098 rubidium 37 Rb 85.468 caesium 55 Cs	40.078 strontium 38 Sr 87.62 barium 56 Ba		44.956 yttrium 39 Y 88.906 lutetium 71 Lu	47.867 zirconium 40 Zr 91.224 hafnium 72 Hf	50.942 niobium 41 Nb 92.906 tantalum 73 Ta	51.996 molybdenum 42 MO 95.94 tungsten 74 W	54.938 technetium 43 TC [98] rhenium 75 Re	55.845 ruthenium 44 Ru 101.07 osmium 76 OS	58.933 rhodium 45 Rh 102.91 iridium 77 Ir	58.693 palladium 46 Pd 106.42 platinum 78 Pt	63.546 silver 47 Ag 107.87 gold 79 Au	65.39 cadmium 48 Cd 112.41 mercury 80 Hg	69.723 indium 49 114.82 thallium 81 TI	72.61 tin 50 Sn 118.71 lead 82 Pb	74.922 antimony 51 Sb 121.76 bismuth 83 Bi	78.96 tellurium 52 Te 127.60 polonium 84 Po	79.904 iodine 53 1 126.90 astatine 85 At	83.80 xenon 54 Xe 131.29 radon 86 Rn
39.098 rubidium 37 Rb 85.468 caesium 55 CS 132.91 francium 87	40.078 strontium 38 Sr 87.62 barium 56 Ba 137.33 radium 88	*	44.956 yttrium 39 Y 88.906 lutetium 71 LU 174.97 lawrencium 103	47.867 zirconium 40 Zr 91.224 hafnium 72 Hf 178.49 rutherfordium 104	50.942 niobium 41 Nb 92.906 tantalum 73 Ta 180.95 dubnium 105	51.996 molybdenum 42 MO 95.94 tungsten 74 W 183.84 seaborgium 106	54.938 technetium 43 TC [98] rhenium 75 Re 186.21 bohrium 107	55.845 ruthenium 44 Ru 101.07 osmium 76 OS 190.23 hassium 108	58.933 rhodium 45 Rh 102.91 iridium 77 Ir 192.22 meitnerium 109	58.693 palladium 46 Pd 106.42 platinum 78 Pt 195.08 ununnilium 110	63.546 silver 47 Ag 107.87 gold 79 Au 196.97 unununium 111	65.39 cadmium 48 Cd 112.41 mercury 80 Hg 200.59 ununbium 112	69.723 indium 49 114.82 thallium 81 TI	72.61 tin 50 Sn 118.71 lead 82 Pb 207.2 ununquadium 114	74.922 antimony 51 Sb 121.76 bismuth 83 Bi 208.98	78.96 tellurium 52 Te 127.60 polonium 84 Po	79.904 iodine 53 1 126.90 astatine 85 At	83.80 xenon 54 Xe 131.29 radon 86 Rn
39.098 rubidium 37 Rb 85.468 caesium 55 CS 132.91 francium	40.078 strontium 38 Sr 87.62 barium 56 Ba 137.33 radium	★ 89-102	44.956 yttrium 39 Y 88.906 lutetium 71 LU 174.97 lawrencium	47.867 zirconium 40 Zr 91.224 hafnium 72 Hff 178.49 rutherfordium	50.942 niobium 41 Nb 92.906 tantalum 73 Ta 180.95 dubnium	51.996 molybdenum 42 MO 95.94 tungsten 74 W 183.84 seaborgium	54.938 technetium 43 TC [98] rhenium 75 Re 186.21 bohrium	55.845 ruthenium 44 Ru 101.07 osmium 76 OS 190.23 hassium	58.933 rhodium 45 Rh 102.91 iridium 77 Ir 192.22 meitnerium	58.693 palladium 46 Pd 106.42 platinum 78 Pt 195.08 ununnilium 110	63.546 silver 47 Ag 107.87 gold 79 Au 196.97 unununium	65.39 cadmium 48 Cd 112.41 mercury 80 Hg 200.59 ununbium 112	69.723 indium 49 114.82 thallium 81 TI	72.61 tin 50 Sn 118.71 lead 82 Pb 207.2 ununquadium	74.922 antimony 51 Sb 121.76 bismuth 83 Bi 208.98	78.96 tellurium 52 Te 127.60 polonium 84 Po	79.904 iodine 53 1 126.90 astatine 85 At	83.80 xenon 54 Xe 131.29 radon 86 Rn

*Lanthanide series	lanthanum 57	cerium 58	praseodymium 59	neodymium 60	promethium 61	samarium 62	europium 63	gadolinium 64	terbium 65	dysprosium 66	holmium 67	erbium 68	thulium 69	ytterbium 70
Lanthanide Series	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb
	138.91	140.12	140.91	144.24	[145]	150.36	151.96	157.25	158.93	162.50	164.93	167.26	168.93	173.04
and the second	actinium	thorium	protactinium	uranium	neptunium	plutonium	americium	curium	berkelium	californium	einsteinium	fermium	mendelevium	nobelium
* * Actinide series	89	90	91	92	93	94	95	96	97	98	99	100	101	102
	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No
	[227]	232.04	231.04	238.03	[237]	[244]	[243]	[247]	[247]	[251]	[252]	[257]	[258]	[259]

hydrogen									1.091				600.000	000000				helium
1	1																	2
н	1																	He
1.0079	1															• /		.0026
lithium	beryllium											1	boron	carbon	nitrogen	oxygen	fluorine	neon
3	4												5	6	7	8	9	10
LI	Be												B	C	N	0	F	Ne
6.941	9.0122												10.811 cluminium	12.011 cilicon	14.007	15.999	18.998	20.180
sodium 11	agnesium 12												aluminium 13	silicon 14	phosphorus 15	sulfur 16	chlorine 17	argon 18
Na	Mg												AI	Si	P	S	CI	Ar
22.990	24.305		condism	Manakum,		-hereit ma		inne	ashalt	niskal		-	26,982	28.086	30.974	32.065	35.453	39.948 konstan
potassium 19	calcium 20		scandium 21	titanium 22	vanadium 23	chromium 24	manganese 25	iron 26	cobalt 27	nickel 28	copper 29	zinc 30	gallium 31	germanium 32	arsenic 33	selenium 34	bromine 35	krypton 36
1000		1 1						2022	-		1.12282		18380		_	2022		10000
	C 2		Se	Ti	V	Cr	Mn	Fo	CO	NI	Cul	7n	Ga	Go	Ac	Sa	Dr	Kr.
K	Ca		Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
39.098	40.078		44.956	47.867	50.942	51,996	54.938	55.845	58.933	58,693	63,546	65.39	69.723	72.61	74.922	78.96	79.904	83.80
					-			11.23.222										
39.098 rubidium 37	40.078 strontium 38		44.956 yttrium	47.867 zirconium 40	50.942 niobium 41	51.996 molybdenum 42	54.938 technetium 43	55.845 ruthenium 44	58.933 rhodium 45	58.693 palladium 46	63.546 silver 47	65.39 cadmium 48	69.723 indium 49	72.61 tin 50	74.922 antimony 51	78.96 tellurium 52	79,904 iodine	83.80 xenon 54
39.098 rubidium 37 Rb	40.078 strontium 38 Sr		44.956 yttrium 39 Y	47.867 zirconium 40 Zr	50.942 niobium 41 Nb	51,996 molybdenum 42 MO	54.938 technetium 43 TC	55.845 ruthenium 44 Ru	58.933 rhodium 45 Rh	58.693 palladium 46 Pd	63.546 silver 47 Ag	65.39 cadmium 48 Cd	69.723 indium 49 In	72.61 tin 50 Sn	74.922 antimony 51 Sb	78.96 tellurium 52 Te	79.904 iodine 53	83.80 xenon 54 Xe
39.098 rubidium 37 Rb 85.468	40.078 strontium 38 Sr 87.62		44.956 yttrium 39 Y 88.906	47.867 zirconium 40 Zr 91.224	50.942 niobium 41 Nb 92.906	51,996 molybdenum 42 Mo 95,94	54.938 technetium 43 TC [98]	55.845 ruthenium 44 Ru 101.07	58.933 rhodium 45 Rh 102.91	58.693 palladium 46 Pd 106.42	63.546 silver 47 Ag 107.87	65.39 cadmium 48 Cd 112.41	69.723 indium 49 In 114.82	72.61 tin 50 Sn 118.71	74.922 antimony 51 Sb 121.76	78.96 telurium 52 Te 127.60	79.904 iodine 53 126.90	83.80 xenon 54 Xe 131.29
39.098 rubidium 37 Rb	40.078 strontium 38 Sr	57-70	44.956 yttrium 39 Y	47.867 zirconium 40 Zr	50.942 niobium 41 Nb	51,996 molybdenum 42 MO	54.938 technetium 43 TC	55.845 ruthenium 44 Ru	58.933 rhodium 45 Rh	58.693 palladium 46 Pd	63.546 silver 47 Ag	65.39 cadmium 48 Cd	69.723 indium 49 In	72.61 tin 50 Sn	74.922 antimony 51 Sb	78.96 tellurium 52 Te	79,904 iodine 53	83.80 xenon 54 Xe
39.098 rubidium 37 Rb 85.468 caesium 55	40.078 strontium 38 Sr 87.62 barium 56		44.956 yttrium 39 Y 88.906 Iutetium 71	47.867 zirconium 40 Zr 91.224 hafnium 72	50.942 niobium 41 Nb 92.906 tantalum 73	51.996 molybdenum 42 MO 95.94 tungsten 74	54.938 technetium 43 TC [98] rhenium 75	55.845 ruthenium 44 Ru 101.07 osmium 76	58.933 rhodium 45 Rh 102.91 iridium 77	58.693 palladium 46 Pd 106.42 platinum 78	63.546 silver 47 Ag 107.87 gold 79	65.39 cadmium 48 Cd 112.41 mercury 80	69.723 indium 49 In 114.82 thallium	72.61 tin 50 Sn 118.71 lead 82	74.922 antimony 51 Sb 121.76 bismuth 83	78.96 tellurium 52 Te 127.60 polonium 84	79.904 iodine 53 126.90 astatine 85	83.80 xenon 54 Xe 131.29 radon 86
39.098 rubidium 37 Rb 85.468 caesium 55 Cs	40.078 strontium 38 Sr 87.62 barium 56 Ba	57-70 ×	44.956 yttrium 39 Y 88.906 lutetium 71 LU	47,867 zirconium 40 Zr 91.224 hafnium 72 Hf	50.942 niobium 41 Nb 92.906 tantalum 73 Ta	51,996 molybdenum 42 Mo 95,94 tungsten 74 W	54.938 technetium 43 TC [98] rhenium 75 Re	55.845 ruthenium 44 Ru 101.07 osmium 76 OS	58.933 rhodium 45 Rh 102.91 iridium 77 Ir	58.693 palladium 46 Pd 106.42 platinum 78 Pt	63.546 silver 47 Ag 107.87 gold 79 Au	65.39 cadmium 48 Cd 112.41 mercury 80 Hg	69.723 indium 49 In 114.82 thallium 81 TI	72.61 tin 50 Sn 118.71 lead 82 Pb	74.922 antimony 51 Sb 121.76 bismuth 83 Bi	78.96 tellurium 52 Te 127.60 polonium 84 Po	79.904 iodine 53 I 126.90 astatine 85 At	83.80 xenon 54 Xe 131.29 radon 86 Rn
39.098 rubidium 37 Rb 85.468 caesium 55 CS 132.91 francium	40.078 strontium 38 Sr 87.62 barium 56 Ba 137.33 radium	*	44.956 yttrium 39 Y 88.906 lutetium 71 LU 174.97 lawrencium	47,867 zirconium 40 Zr 91,224 hafnium 72 Hf 178,49 rutherfordium	50.942 niobium 41 Nb 92.906 tantalum 73 Ta 180.95 dubnium	51.996 molybdenum 42 Mo 95.94 tungsten 74 74 W 183.84 seaborgium	54.938 technetium 43 TC [98] rhenium 75 Re 186.21 bohrium	55.845 ruthenium 44 Ru 101.07 osmium 76 OS 190.23 hassium	58.933 rhodium 45 Rh 102.91 iridium 77 Ir 192.22 meitnerium	58.693 palladium 46 Pd 106.42 platinum 78 Pt 195.08 ununnilium	63.546 silver 47 Ag 107.87 gold 79 Au 196.97 unununium	65.39 cadmium 48 Cd 112.41 mercury 80 Hg 200.59 ununbium	69.723 indium 49 In 114.82 thallium	72.61 tin 50 Sn 118.71 lead 82 Pb 207.2 ununquadium	74.922 antimony 51 Sb 121.76 bismuth 83	78.96 tellurium 52 Te 127.60 polonium 84	79.904 iodine 53 126.90 astatine 85	83.80 xenon 54 Xe 131.29 radon 86
39.098 rubidium 37 Rb 85.468 caesium 55 CS 132.91 francium 87	40.078 strontium 38 Sr 87.62 barium 56 Ba 137.33 radium 88		44.956 yttrium 39 Y 88.906 lutetium 71 Lu 174.97	47.867 zirconium 40 Zr 91.224 hafnium 72 Hf 178.49 rutherfordium 104	50.942 niobium 41 Nb 92.906 tantalum 73 Ta 180.95	51.996 molybdenum 42 MO 95.94 tungsten 74 74 W 183.84 seaborgium 106	54.938 technetium 43 TC [98] rhenium 75 Re 186.21 bohrium 107	55.845 ruthenium 44 Ru 101.07 osmium 76 OS 190.23 hassium 108	58.933 rhodium 45 Rh 102.91 iridium 77 Ir 192.22 meitnerium 109	58.693 palladium 46 Pd 106.42 platinum 78 Pt 195.08 ununnilium 110	63.546 silver 47 Ag 107.87 gold 79 Au 196.97 unununium 111	65.39 cadmium 48 Cd 112.41 mercury 80 Hg 200.59 ununbium 112	69.723 indium 49 In 114.82 thallium 81 TI 204.38	72.61 tin 50 Sn 118.71 lead 82 Pb 207.2 ununquadium 114	74.922 antimony 51 Sb 121.76 bismuth 83 Bi 208.98	78.96 tellurium 52 Te 127.60 polonium 84 Po	79.904 iodine 53 I 126.90 astatine 85 At	83.80 xenon 54 Xe 131.29 radon 86 Rn
39.098 rubidium 37 Rb 85.468 caesium 55 CS 132.91 francium	40.078 strontium 38 Sr 87.62 barium 56 Ba 137.33 radium	*	44.956 yttrium 39 Y 88.906 lutetium 71 LU 174.97 lawrencium	47,867 zirconium 40 Zr 91,224 hafnium 72 Hf 178,49 rutherfordium	50.942 niobium 41 Nb 92.906 tantalum 73 Ta 180.95 dubnium	51.996 molybdenum 42 MO 95.94 tungsten 74 74 W 183.84 seaborgium 106	54.938 technetium 43 TC [98] rhenium 75 Re 186.21 bohrium	55.845 ruthenium 44 Ru 101.07 osmium 76 OS 190.23 hassium	58.933 rhodium 45 Rh 102.91 iridium 77 Ir 192.22 meitnerium	58.693 palladium 46 Pd 106.42 platinum 78 Pt 195.08 ununnilium 110	63.546 silver 47 Ag 107.87 gold 79 Au 196.97 unununium	65.39 cadmium 48 Cd 112.41 mercury 80 Hg 200.59 ununbium 112	69.723 indium 49 In 114.82 thallium 81 TI 204.38	72.61 tin 50 Sn 118.71 lead 82 Pb 207.2 ununquadium 114	74.922 antimony 51 Sb 121.76 bismuth 83 Bi 208.98	78.96 tellurium 52 Te 127.60 polonium 84 Po	79.904 iodine 53 I 126.90 astatine 85 At	83.80 xenon 54 Xe 131.29 radon 86 Rn
39.098 rubidium 37 Rb 85.468 caesium 55 CS 132.91 francium 87	40.078 strontium 38 Sr 87.62 barium 56 Ba 137.33 radium 88	★ 89-102	44.956 yttrium 39 Y 88.906 lutetium 71 LU 174.97 lawrencium 103	47.867 zirconium 40 Zr 91.224 hafnium 72 Hf 178.49 rutherfordium 104	50.942 niobium 41 Nb 92.906 tantalum 73 Ta 180.95 dubnium 105	51.996 molybdenum 42 Mo 95.94 tungsten 74 74 W 183.84 seaborgium	54.938 technetium 43 TC [98] rhenium 75 Re 186.21 bohrium 107	55.845 ruthenium 44 Ru 101.07 osmium 76 OS 190.23 hassium 108	58.933 rhodium 45 Rh 102.91 iridium 77 Ir 192.22 meitnerium 109	58.693 palladium 46 Pd 106.42 platinum 78 Pt 195.08 ununnilium 110	63.546 silver 47 Ag 107.87 gold 79 Au 196.97 unununium 111	65.39 cadmium 48 Cd 112.41 mercury 80 Hg 200.59 ununbium 112	69.723 indium 49 In 114.82 thallium 81 TI 204.38	72.61 tin 50 Sn 118.71 lead 82 Pb 207.2 ununquadium	74.922 antimony 51 Sb 121.76 bismuth 83 Bi 208.98	78.96 tellurium 52 Te 127.60 polonium 84 Po	79.904 iodine 53 I 126.90 astatine 85 At	83.80 xenon 54 Xe 131.29 radon 86 Rn

*Lanthanide series	lanthanum 57	cerium 58	praseodymium 59	neodymium 60	promethium 61	samarium 62	europium 63	gadolinium 64	terbium 65	dysprosium 66	holmium 67	erbium 68	thulium 69	ytterbium 70
Lanthanide Series	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb
	138.91	140.12	140.91	144.24	[145]	150.36	151.96	157.25	158.93	162.50	164.93	167.26	168.93	173.04
and the second	actinium	thorium	protactinium	uranium	neptunium	plutonium	americium	curium	berkelium	californium	einsteinium	fermium	mendelevium	nobelium
* * Actinide series	89	90	91	92	93	94	95	96	97	98	99	100	101	102
	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No
	[227]	232.04	231.04	238.03	[237]	[244]	[243]	[247]	[247]	[251]	[252]	[257]	[258]	[259]

hydrogen				1000		250.2			1054			1.	Constantine.	and the				helium
																		2
Н																		He
1.0079 lithium	beryllium											Ì	boron	carbon	nitrogen	oxygen	fluorine	.0026 neon
3	4												5	6	7	8	9	10
LN	Be												B	C	N	0	F	Ne
6.941	9.0122												10.81	12.011	14.007	15.999	18.998	20,180
sodium 11	agnesium 12												aluminiun 13	silicon 14	phosphorus 15	sulfur 16	chlorine 17	argon 18
Na	Mg												AI	Si	P	S	CI	Ar
22.990	24,305												26.982	28,086	30.974	32.065	35.453	39,948
potassium	calcium		scandium	titanium	vanadium	chromium	manganese	iron	cobalt	nickel	copper	zinc	gallium	germanium	arsenic	selenium	bromine	krypton
19	20		21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
							The second se											
ĸ	Ca		Sc		V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
39.098	40.078		44.956	47.867	50.942	51.996	54.938	55.845	58,933	58,693	63.546	65.39	69.723	72.61	74.922	78.96	79.904	83.80
					-			31. 21 CONT										
39.098 rubidium 37	40.078 strontium 38		44.956 yttrium 39	47.867 zirconium 40	50.942 niobium 41	51.996 molybdenum 42	54.938 technetium 43	55.845 ruthenium 44	58.933 rhodium 45	58,693 palladium 46	63.546 silver 47	65.39 cadmium 48	69.723 indium 49	72.61 tin 50	74.922 antimony 51	78.96 tellurium 52	79.904 iodine	83.80 xenon 54
39.098 rubidium 37 Rb 85.468	40.078 strontium		44.956 yttrium 39 Y 88.906	47.867 zirconium 40 Zr 91.224	50.942 niobium 41 Nb 92.906	51,996 molybdenum 42 Mo 95,94	54.938 technetium	55.845 ruthenium	58.933 rhodium	58.693 palladium 46 Pd 106.42	63.546 silver 47 Ag 107.87	65.39 cadmium	69.723 indium 49 In 114.82	72.61 tin	74.922 antimony 51 Sb 121.76	78.96 tellurium 52 Te 127.60	79.904 iodine 53 126.90	83.80 xenon 54 Xe 131.29
39.098 rubidium 37 Rb 85.468 caesium	40.078 strontium 38 Sr 87.62 barium	57-70	44.956 yttrium 39 Y 88.906 Iutetium	47,867 zirconium 40 Zr 91.224 hafnium	50.942 niobium 41 Nb 92.906 tantalum	51.996 molybdenum 42 Mo 95.94 tungsten	54.938 technetium 43 TC [98] rhenium	55.845 ruthenium 44 Ru 101.07 osmium	58.933 rhodium 45 Rh 102.91 iridium	58.693 palladium 46 Pd 106.42 platinum	63.546 silver 47 Ag 107.87 gold	65.39 cadmium 48 Cd 112.41 mercury	69.723 indium 49 In 114.82 thallium	72.61 tin 50 Sn 118.71 lead	74.922 antimony 51 Sb 121.76 bismuth	78.96 tellurium 52 Te 127.60 polonium	79,904 iodine 53 126.90 astatine	83.80 xenon 54 Xe 131.29 radon
39.098 rubidium 37 Rb 85.468 caesium 55	40.078 strontium 38 Sr 87.62 barium 56	57-70	44.956 yttrium 39 Y 88.906 lutetium 71	47.867 zirconium 40 Zr 91.224 hafnium 72	50.942 niobium 41 Nb 92.906 tantalum 73	51.996 molybdenum 42 MO 95.94 tungsten 74	54.938 technetium 43 TC [98] rhenium 75	55.845 ruthenium 44 Ru 101.07 osmium 76	58.933 rhodium 45 Rh 102.91 iridium 77	58.693 palladium 46 Pd 106.42 platinum 78	63.546 silver 47 Ag 107.87 gold 79	65.39 cadmium 48 Cd 112.41 mercury 80	69.723 indium 49 In 114.82 thallium 81	72.61 tin 50 Sn 118.71 lead 82	74.922 antimony 51 Sb 121.76 bismuth 83	78.96 tellurium 52 Te 127.60 polonium 84	79.904 iodine 53 126.90 astatine 85	83.80 xenon 54 Xe 131.29 radon 86
39.098 rubidium 37 Rb 85.468 caesium 55 Cs	40.078 strontium 38 Sr 87.62 barium 56 Ba	57-70 ★	44.956 yttrium 39 Y 88.906 Iutetium 71 LU	47,867 zirconium 40 Zr 91.224 hafnium 72 Hf	50.942 niobium 41 Nb 92.906 tantalum 73 Ta	51.996 molybdenum 42 MO 95.94 tungsten 74 W	54.938 technetium 43 TC [98] rhenium 75 Re	55.845 ruthenium 44 Ru 101.07 osmium 76 OS	58.933 rhodium 45 Rh 102.91 iridium 77 Ir	58.693 palladium 46 Pd 106.42 platinum 78 Pt	63.546 silver 47 Ag 107.87 gold 79 Au	65.39 cadmium 48 Cd 112.41 mercury 80 Hg	69.723 indium 49 In 114.82 thallium 81 TI	72.61 tin 50 Sn 118.71 lead 82 Pb	74.922 antimony 51 Sb 121.76 bismuth 83 Bi	78.96 tellurium 52 Te 127.60 polonium 84 Po	79,904 iodine 53 I 126,90 astatine 85 At	83.80 xenon 54 Xe 131.29 radon 86 Rn
39.098 rubidium 37 Rb 85.468 caesium 55 Cs 132.91	40.078 strontium 38 Sr 87.62 barium 56 Ba 137.33		44.956 yttrium 39 Y 88,906 Iutetium 71 Lu 174.97	47.867 zirconium 40 Zr 91.224 hafnium 72 Hf 178.49	50.942 niobium 41 Nb 92.906 tantalum 73 Ta 180.95	51.996 molybdenum 42 MO 95.94 tungsten 74 W 183.84	54.938 technetium 43 TC [98] rhenium 75 Re 186.21	55.845 ruthenium 44 Ru 101.07 osmium 76 OS 190.23	58.933 rhodium 45 Rh 102.91 iridium 77 Ir 192.22	58.693 palladium 46 Pd 106.42 platinum 78 Pt 195.08	63.546 silver 47 Ag 107.87 gold 79 Au 196.97	65.39 cadmium 48 Cd 112.41 mercury 80 Hg 200.59	69.723 indium 49 In 114.82 thallium 81	72.61 tin 50 Sn 118.71 lead 82 Pb 207.2	74.922 antimony 51 Sb 121.76 bismuth 83	78.96 tellurium 52 Te 127.60 polonium 84	79.904 iodine 53 126.90 astatine 85	83.80 xenon 54 Xe 131.29 radon 86
39.098 rubidium 37 Rb 85.468 caesium 55 CS 132.91 francium 87	40.078 strontium 38 Sr 87.62 barium 56 Ba		44.956 yttrium 39 Y 88.906 Iutetium 71 LU	47,867 zirconium 40 Zr 91.224 hafnium 72 Hf	50.942 niobium 41 Nb 92.906 tantalum 73 Ta	51.996 molybdenum 42 MO 95.94 tungsten 74 W	54.938 technetium 43 TC [98] rhenium 75 Re 186.21 bohrium 107	55.845 ruthenium 44 Ru 101.07 osmium 76 OS 190.23 hassium 108	58.933 rhodium 45 Rh 102.91 iridium 77 Ir	58.693 palladium 46 Pd 106.42 platinum 78 Pt	63.546 silver 47 Ag 107.87 gold 79 Au	65.39 cadmium 48 Cd 112.41 mercury 80 Hg	69.723 indium 49 In 114.82 thallium 81 TI 204.38	72.61 tin 50 Sn 118.71 lead 82 Pb 207.2 ununquadium 114	74.922 antimony 51 Sb 121.76 bismuth 83 Bi 208.98	78.96 tellurium 52 Te 127.60 polonium 84 Po	79,904 iodine 53 I 126,90 astatine 85 At	83.80 xenon 54 Xe 131.29 radon 86 Rn
39.098 rubidium 37 Rb 85.468 caesium 55 CS 132.91 francium 87	40.078 strontium 38 Sr 87.62 barium 56 Ba 137.33 radium 88	*	44.956 yttrium 39 Y 88.906 lutetium 71 LU 174.97 lawrencium 103	47.867 zirconium 40 Zr 91.224 hafnium 72 Hf 178.49 rutherfordium 104	50.942 niobium 41 Nb 92.906 tantalum 73 Ta 180.95 dubnium 105	51.996 molybdenum 42 MO 95.94 tungsten 74 W 183.84 seaborgium 106	54.938 technetium 43 TC [98] rhenium 75 Re 186.21 bohrium 107	55.845 ruthenium 44 Ru 101.07 osmium 76 OS 190.23 hassium 108	58.933 rhodium 45 Rh 102.91 iridium 77 Ir 192.22 meitnerium 109	58.693 palladium 46 Pd 106.42 platinum 78 Pt 195.08 ununnilium 110	63.546 silver 47 Ag 107.87 gold 79 Au 196.97 unununium 111	65.39 cadmium 48 Cd 112.41 mercury 80 Hg 200.59 ununbium 112	69.723 indium 49 In 114.82 thallium 81 TI 204.38	72.61 tin 50 Sn 118.71 lead 82 Pb 207.2 ununquadium 114	74.922 antimony 51 Sb 121.76 bismuth 83 Bi 208.98	78.96 tellurium 52 Te 127.60 polonium 84 Po	79,904 iodine 53 I 126,90 astatine 85 At	83.80 xenon 54 Xe 131.29 radon 86 Rn
39.098 rubidium 37 Rb 85.468 caesium 55 CS 132.91 francium	40.078 strontium 38 Sr 87.62 barium 56 Ba 137.33 radium	★ 89-102	44.956 yttrium 39 Y 88.906 Iutetium 71 LU 174.97 Iawrencium	47.867 zirconium 40 Zr 91.224 hafnium 72 Hf 178.49 rutherfordium	50.942 niobium 41 Nb 92.906 tantalum 73 Ta 180.95 dubnium	51.996 molybdenum 42 MO 95.94 tungsten 74 W 183.84 seaborgium	54.938 technetium 43 TC [98] rhenium 75 Re 186.21 bohrium	55.845 ruthenium 44 Ru 101.07 osmium 76 OS 190.23 hassium	58.933 rhodium 45 Rh 102.91 iridium 77 Ir 192.22 meitnerium	58.693 palladium 46 Pd 106.42 platinum 78 Pt 195.08 ununnilium 110	63.546 silver 47 Ag 107.87 gold 79 Au 196.97 unununium	65.39 cadmium 48 Cd 112.41 mercury 80 Hg 200.59 ununbium 112	69.723 indium 49 In 114.82 thallium 81 TI 204.38	72.61 tin 50 Sn 118.71 lead 82 Pb 207.2 ununquadium	74.922 antimony 51 Sb 121.76 bismuth 83 Bi 208.98	78.96 tellurium 52 Te 127.60 polonium 84 Po	79,904 iodine 53 I 126,90 astatine 85 At	83.80 xenon 54 Xe 131.29 radon 86 Rn

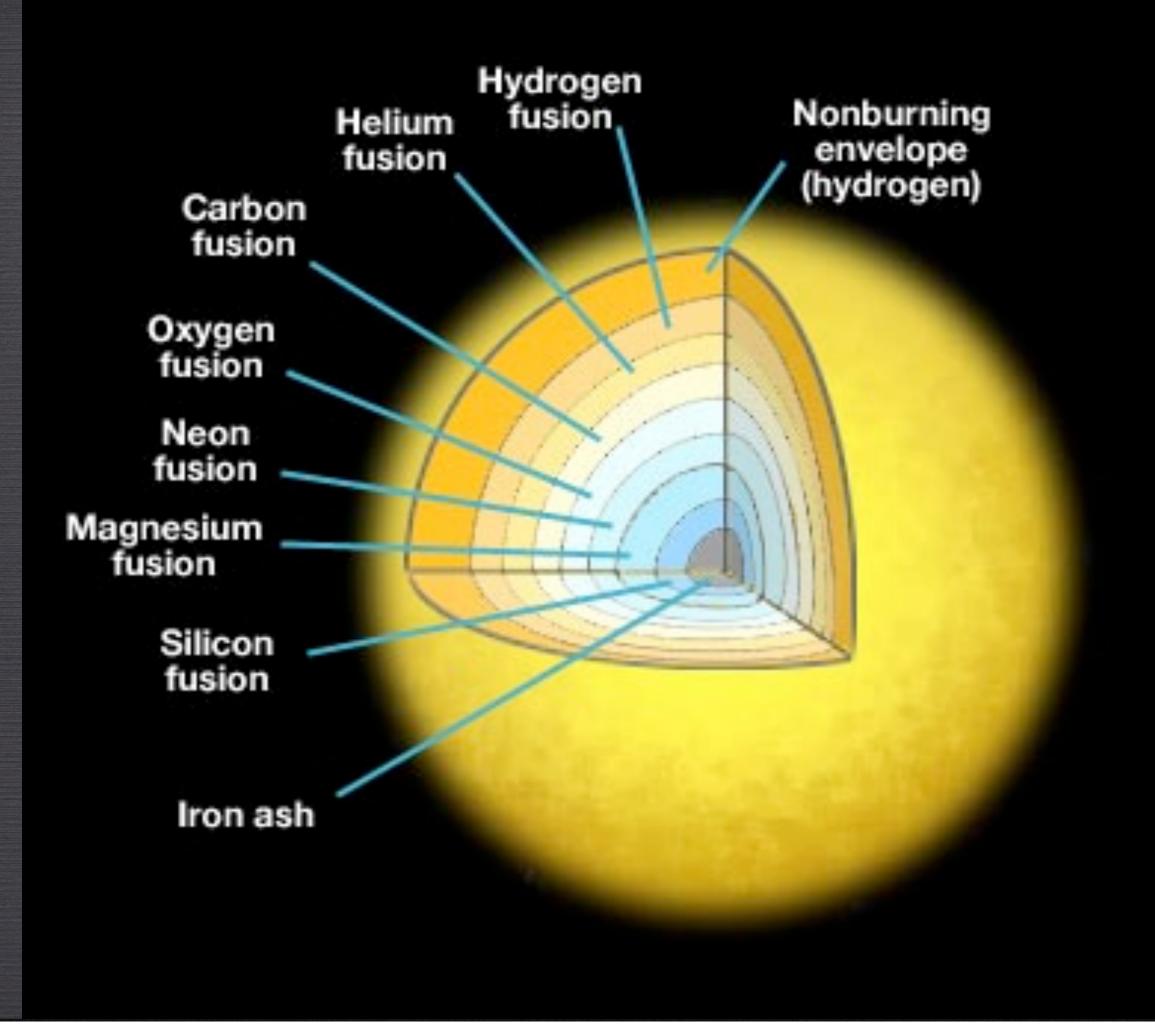
*Lanthanide series	lanthanum 57	cerium 58	praseodymium 59	neodymium 60	promethium 61	samarium 62	europium 63	gadolinium 64	terbium 65	dysprosium 66	holmium 67	erbium 68	thulium 69	ytterbium 70
Lanthanide Series	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb
	138.91	140.12	140.91	144.24	[145]	150.36	151.96	157.25	158.93	162.50	164.93	167.26	168.93	173.04
and the second	actinium	thorium	protactinium	uranium	neptunium	plutonium	americium	curium	berkelium	californium	einsteinium	fermium	mendelevium	nobelium
* * Actinide series	89	90	91	92	93	94	95	96	97	98	99	100	101	102
	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No
	[227]	232.04	231.04	238.03	[237]	[244]	[243]	[247]	[247]	[251]	[252]	[257]	[258]	[259]

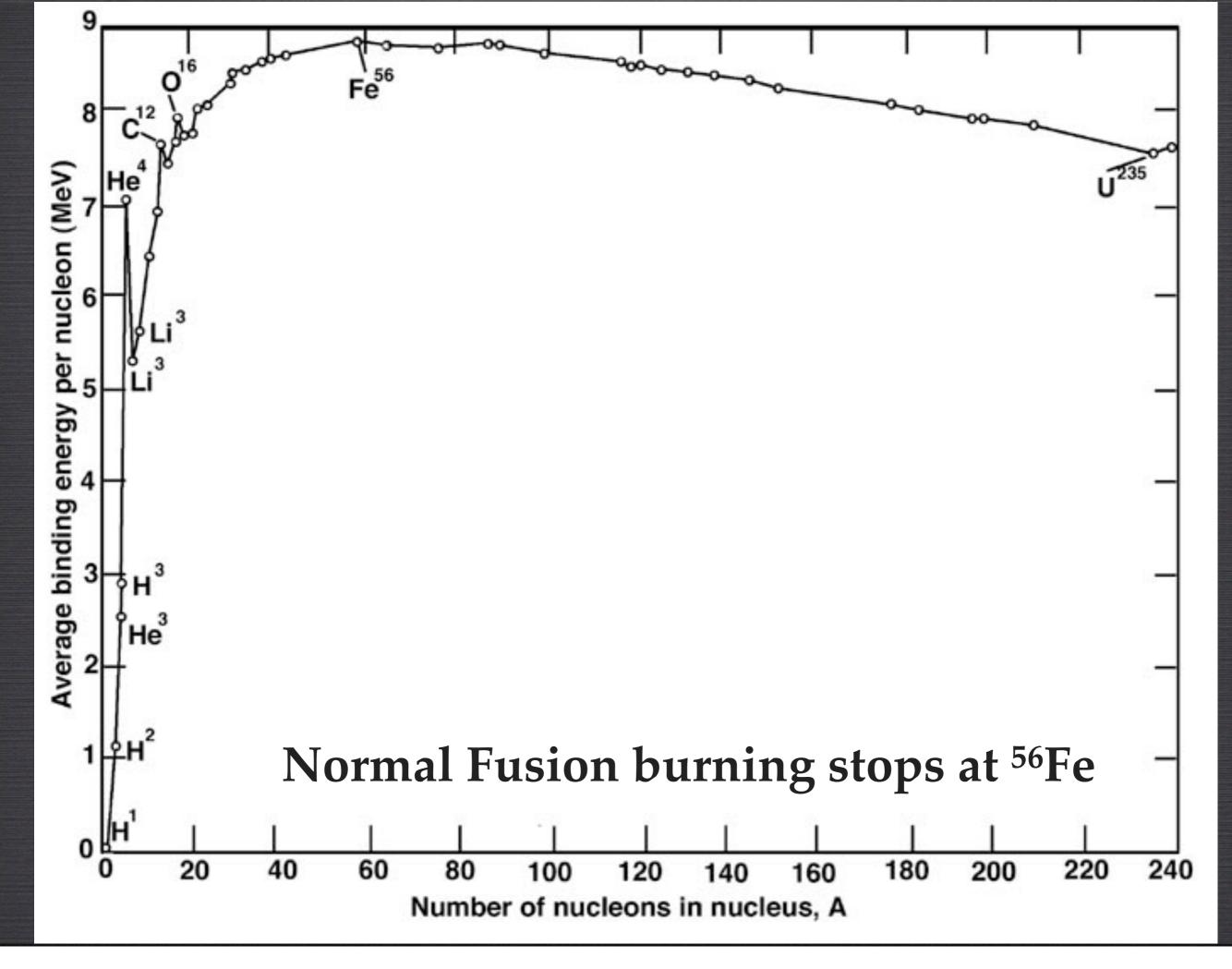
hydrogen	Constant of				200	2522			100			10000		and the	10000	0.000		helium
	1																	2
п	1																	He
1.0079 lithium	beryllium	1										ſ	boron	carbon	nitrogen	oxygen	fluorine	.0026 neon
3	4	I											5	6	7	8	9	10
Lì	Be	I											B	C	N	0	F	Ne
6.941	9.0122	1											10.81	12.1	14.007	15.999	18.998	20,180
sodium 11	agnesium 12	1											aluminiun 13	silion 14	phosphorus 15	sulfur 16	chlorine 17	argon 18
		I												Si	P		CI	
Na	Mg	I											AI		-	S		Ar
22.990 potassium	24.305 calcium	i i	scandium	titanium	vanadium	chromium	manganese	iron	cobalt	nickel	copper	zinc	26.982 gallium	28.086 germanium	30.974 arsenic	32.065 selenium	35.453 bromine	39.948 krypton
19	20	, J	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
K	Ca		Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
39.098	4																and the second se	
rubidium	40.078 strontium	·)	44.956 vttrium	47.867 zirconium	50.942 niobium	51.996 molybdenum	54.938 technetium	55.845 ruthenium	58.933 rbodium	58.693 palladium	63,546	65.39	69.723	72.61	74.922	78.96	79.904	83.80
rubidium 37	40.078 strontium 38		44.956 yttrium 39	47.867 zirconium 40		51,996 molybdenum 42	54.938 technetium 43	55.845 ruthenium 44	58.933 rhodium 45	58.693 palladium 46							and the second se	
	strontium		yttrium	zirconium	niobium	molybdenum	technetium	ruthenium	rhodium	palladium	63.546 silver 47	65.39 cadmium	69.723 indium	72.61 tin	74.922 antimony	78.96 tellurium	79,904 iodine	83.80 xenon
37 Rb 85,468	strontium 38 Sr 87.62		yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	42 Mo 95.94	43 43 TC [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	63.546 silver 47 Ag 107.87	65.39 cadmium 48 Cd 112.41	69.723 indium 49 In 114.82	72.61 tin 50 Sn 118.71	74.922 antimony 51 Sb 121.76	78.96 tellurium 52 Te 127.60	79.904 iodine 53 126.90	83.80 xenon 54 Xe 131.29
37 Rb	strontium 38 Sr	57-70	yttrium 39 Y	^{zirconium} 40 Zr	^{niobium} 41 Nb	42 Mo	43 TC	44 Ru	45 Rh	46 Pd	63.546 silver 47 Ag	65.39 cadmium 48 Cd	69.723 Indium 49 In	72.61 tin 50 Sn	74.922 antimony 51 Sb	78.96 tellurium 52 Te	79.904 iodine 53	83.80 xenon 54 Xe
37 Rb 85.468 caesium 55	strontium 38 Sr 87.62 barium 56	57-70 ×	yttrium 39 Y 88.906 Iutetium	zirconium 40 Zr 91.224 hafnium	niobium 41 Nb 92,906 tantalum 73	42 Mo 95.94 tungsten	43 TC [98] rhenium	ruthenium 44 Ru 101.07 osmium	rhodium 45 Rh 102.91 iridium	palladium 46 Pd 106.42 platinum	63.546 silver 47 Ag 107.87 gold 79	65.39 cadmium 48 Cd 112.41 mercury 80	69.723 indium 49 In 114.82 thallium	72.61 tin 50 Sn 118.71 lead	74.922 antimony 51 Sb 121.76 bismuth	78.96 tellurium 52 Te 127.60 polonium	79.904 iodine 53 126.90 astatine	83.80 xenon 54 Xe 131.29 radon 86
37 Rb 85.468 caesium 55 Cs 132.91	strontium 38 Sr 87.62 barium 56 Ba 137.33		yttrium 39 Y 88.906 Iutetium 71 Lu 174.97	zirconium 40 Zr 91.224 hafnium 72 Hf 178.49	niobium 41 Nb 92.906 tantalum 73 Ta 180.95	molybdenum 42 Mo 95.94 tungsten 74 W 183.84	technetium 43 TC [98] rhenium 75 Re 186.21	ruthenium 44 Ru 101.07 osmium 76 OS 190.23	rhodium 45 Rh 102.91 iridium 77 Ir 192.22	palladium 46 Pd 106.42 platinum 78 Pt 195.08	63.546 silver 47 Ag 107.87 gold 79 Au 196.97	65.39 cadmium 48 Cd 112.41 mercury 80 Hg 200.59	69.723 indium 49 In 114.82 thallium 81	72.61 tin 50 Sn 118.71 lead 82 Pb 207.2	74.922 antimony 51 Sb 121.76 bismuth 83	78.96 tellurium 52 Te 127.60 polonium 84	79.904 iodine 53 126.90 astatine 85	83.80 xenon 54 Xe 131.29 radon
37 Rb 85.468 caesium 55 Cs 132.91 francium	strontium 38 Sr 87.62 barium 56 Ba 137.33 radium	*	yttrium 39 Y 88.906 Iutetium 71 Lu 174.97 Iawrencium	zirconium 40 Zr 91.224 hafnium 72 Hf 178,49 rutherfordium	niobium 41 Nb 92.906 tantalum 73 Ta 180.95 dubnium	molybdenum 42 Mo 95.94 tungsten 74 W 183.84 seaborgium	technetium 43 TC [98] rhenium 75 Re 186.21 bohrium	ruthenium 44 Ru 101.07 osmium 76 OS 190.23 hassium	rhodium 45 Rh 102.91 iridium 77 Ir 192.22 meitnerium	palladium 46 Pd 106.42 platinum 78 Pt 195.08 ununnilium	63.546 silver 47 Ag 107.87 gold 79 Au 196.97 unununium	65.39 cadmium 48 Cd 112.41 mercury 80 Hg 200.59 ununbium	69.723 indium 49 In 114.82 thallium 81 TI	72.61 tin 50 Sn 118.71 lead 82 Pb 207.2 ununquadium	74.922 antimony 51 Sb 121.76 bismuth 83 Bi	78.96 tellurium 52 Te 127.60 polonium 84 Po	79,904 iodine 53 I 126,90 astatine 85 At	83.80 xenon 54 Xe 131.29 radon 86 Rn
37 Rb 85.468 caesium 55 CS 132.91 francium 87	strontium 38 Sr 87.62 barium 56 Ba 137.33 radium 88	★ 89-102	yttrium 39 Y 88.906 Iutetium 71 Lu 174.97 Iawrencium 103	zirconium 40 Zr 91.224 hafnium 72 Hff 178.49 rutherfordium 104	niobium 41 Nb 92,906 tantalum 73 Ta 180,95 dubnium 105	molybdenum 42 Mo 95.94 tungsten 74 W 183.84 seaborgium 106	technetium 43 TC [98] rhenium 75 Re 186.21 bohrium 107	ruthenium 44 Ru 101.07 osmium 76 OS 190.23 hassium 108	rhodium 45 Rh 102.91 iridium 77 Ir 192.22 meitnerium 109	palladium 46 Pd 106.42 platinum 78 Pt 195.08 ununnilium 110	63.546 silver 47 Ag 107.87 gold 79 Au 196.97 unununium 111	65.39 cadmium 48 Cd 112.41 mercury 80 Hg 200.59 ununbium 112	69.723 indium 49 In 114.82 thallium 81 TI	72.61 tin 50 Sn 118.71 lead 82 Pb 207.2 ununquadium 114	74.922 antimony 51 Sb 121.76 bismuth 83 Bi	78.96 tellurium 52 Te 127.60 polonium 84 Po	79,904 iodine 53 I 126,90 astatine 85 At	83.80 xenon 54 Xe 131.29 radon 86 Rn
37 Rb 85.468 caesium 55 Cs 132.91 francium 87 Fr	strontium 38 Sr 87.62 barium 56 Ba 137.33 radium 88 Ra	*	yttrium 39 Y 88.906 Iutetium 71 Lu 174.97 Iawrencium 103 Lr	zirconium 40 Zr 91.224 hafnium 72 Hf 178,49 rutherfordium 104 Rf	niobium 41 Nb 92,906 tantalum 73 Ta 180,95 dubnium 105 Db	molybdenum 42 Mo 95.94 tungsten 74 W 183.84 seaborgium 106 Sg	technetium 43 TC [98] rhenium 75 Re 186.21 bohrium 107 Bh	ruthenium 44 Ru 101.07 osmium 76 OS 190.23 hassium 108 HS	rhodium 45 Rh 102.91 iridium 77 Ir 192.22 meitnerium 109 Mt	palladium 46 Pd 106.42 platinum 78 Pt 195.08 ununnilium 110 Uun	63.546 silver 47 Ag 107.87 gold 79 Au 196.97 unununium 111 Uuu	65.39 cadmium 48 Cd 112.41 mercury 80 Hg 200.59 ununbium 112	69.723 indium 49 In 114.82 thallium 81 TI	72.61 tin 50 Sn 118.71 lead 82 Pb 207.2 ununquadium 114 Uuq	74.922 antimony 51 Sb 121.76 bismuth 83 Bi	78.96 tellurium 52 Te 127.60 polonium 84 Po	79,904 iodine 53 I 126,90 astatine 85 At	83.80 xenon 54 Xe 131.29 radon 86 Rn
37 Rb 85.468 caesium 55 CS 132.91 francium 87	strontium 38 Sr 87.62 barium 56 Ba 137.33 radium 88	★ 89-102	yttrium 39 Y 88.906 Iutetium 71 Lu 174.97 Iawrencium 103	zirconium 40 Zr 91.224 hafnium 72 Hff 178.49 rutherfordium 104	niobium 41 Nb 92,906 tantalum 73 Ta 180,95 dubnium 105	molybdenum 42 Mo 95.94 tungsten 74 W 183.84 seaborgium 106	technetium 43 TC [98] rhenium 75 Re 186.21 bohrium 107	ruthenium 44 Ru 101.07 osmium 76 OS 190.23 hassium 108	rhodium 45 Rh 102.91 iridium 77 Ir 192.22 meitnerium 109	palladium 46 Pd 106.42 platinum 78 Pt 195.08 ununnilium 110	63.546 silver 47 Ag 107.87 gold 79 Au 196.97 unununium 111	65.39 cadmium 48 Cd 112.41 mercury 80 Hg 200.59 ununbium 112	69.723 indium 49 In 114.82 thallium 81 TI	72.61 tin 50 Sn 118.71 lead 82 Pb 207.2 ununquadium 114	74.922 antimony 51 Sb 121.76 bismuth 83 Bi	78.96 tellurium 52 Te 127.60 polonium 84 Po	79,904 iodine 53 I 126,90 astatine 85 At	83.80 xenon 54 Xe 131.29 radon 86 Rn

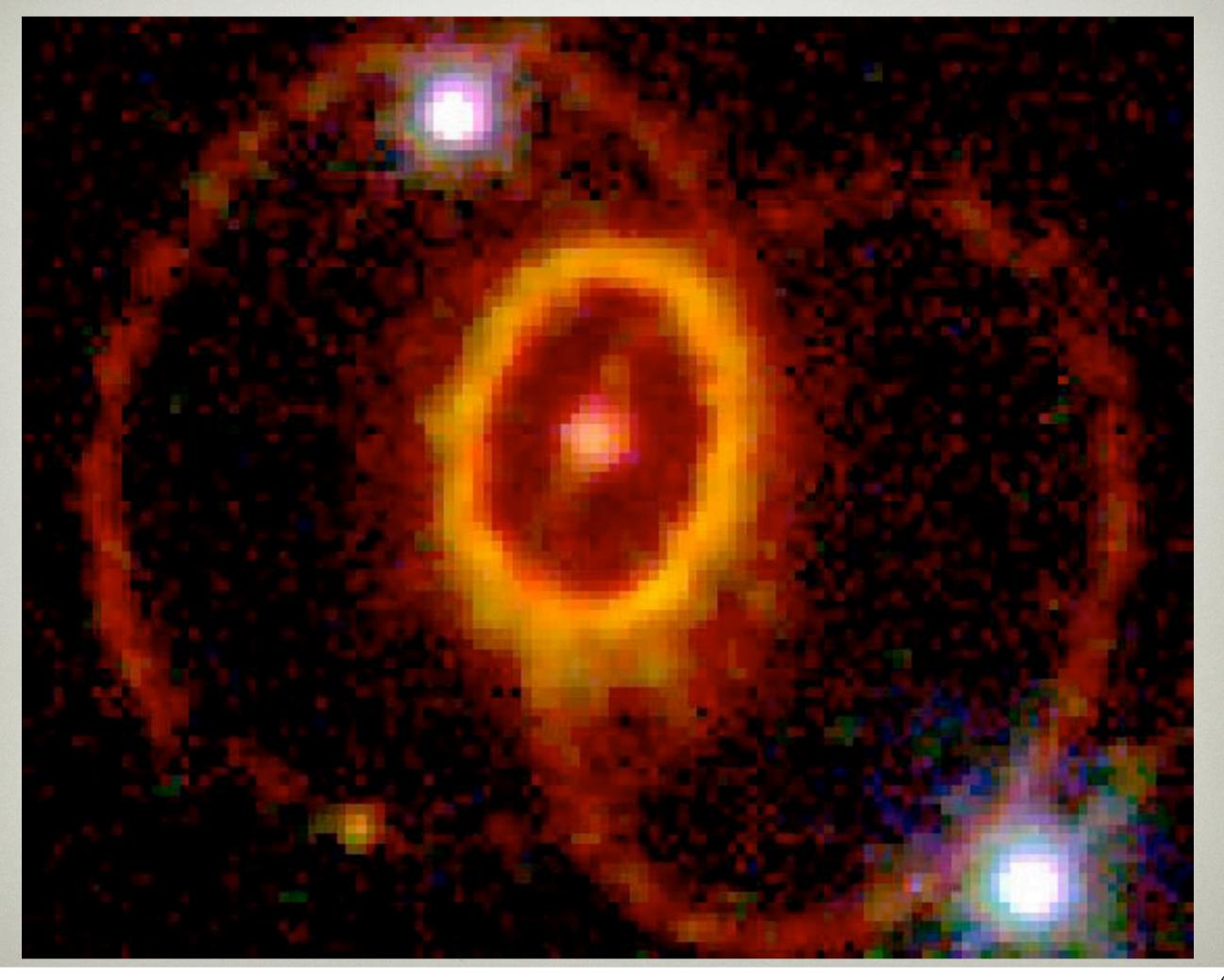
*Lanthanide series	lanthanum 57	cerium 58	praseodymium 59	neodymium 60	promethium 61	samarium 62	europium 63	gadolinium 64	terbium 65	dysprosium 66	holmium 67	erbium 68	thulium 69	ytterbium 70
Lanthanide Series	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb
	138.91	140.12	140.91	144.24	[145]	150.36	151.96	157.25	158.93	162.50	164.93	167.26	168.93	173.04
and the second	actinium	thorium	protactinium	uranium	neptunium	plutonium	americium	curium	berkelium	californium	einsteinium	fermium	mendelevium	nobelium
* * Actinide series	89	90	91	92	93	94	95	96	97	98	99	100	101	102
	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No
	[227]	232.04	231.04	238.03	[237]	[244]	[243]	[247]	[247]	[251]	[252]	[257]	[258]	[259]

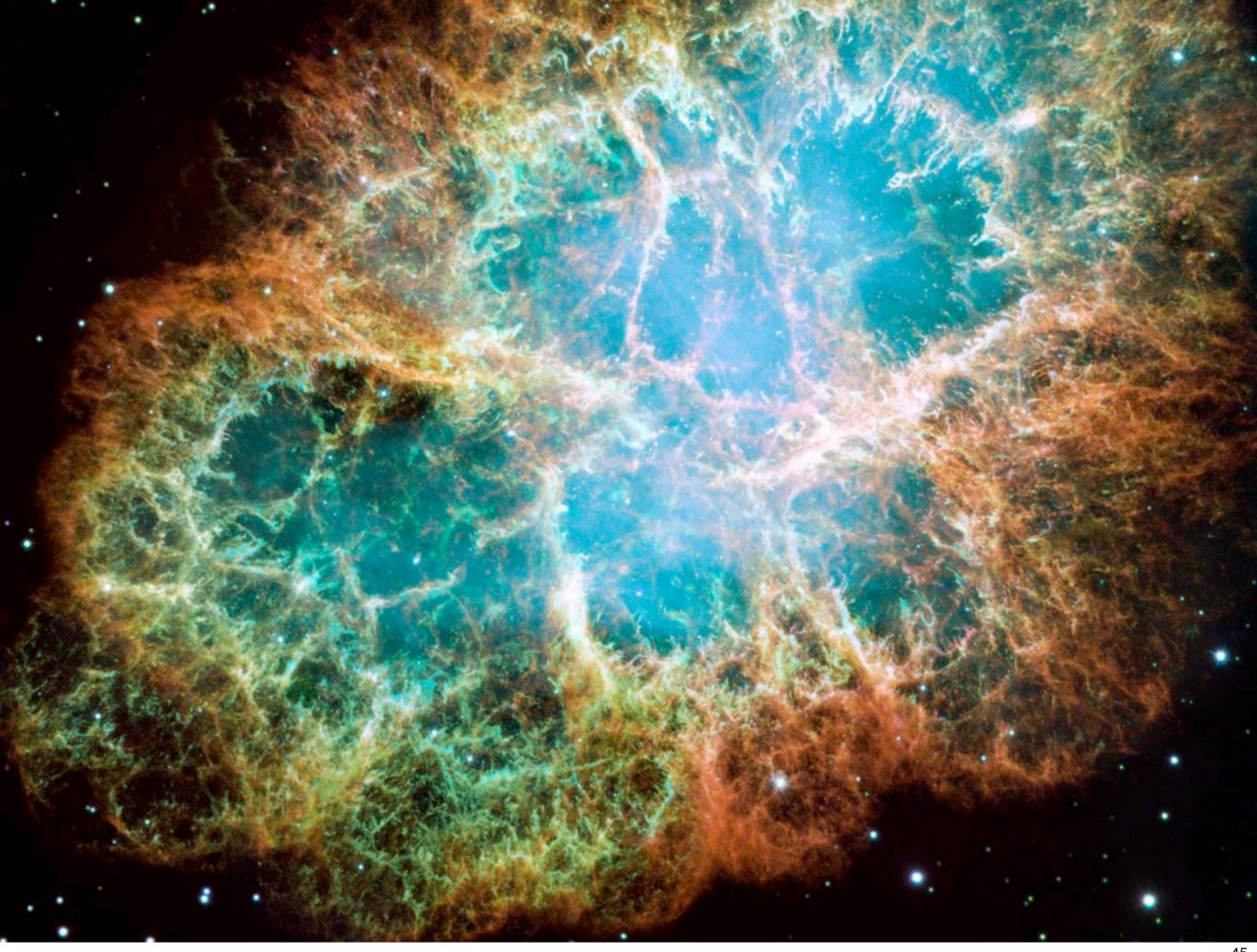
hydrogen	Canada		1000	100					101			1000		and the second	0.640.00	0.000	citatio e	helium
1																		2
HI																		He
1.0079																		.0026
lithium	beryllium]	boron	carbon	nitrogen	oxygen	fluorine	neon
3	4												5	6	7	8	9	10
Li	Be												B		N	0	F	Ne
6.941	9.0122												10.81	12.1	14.007	15.999	18.998	20,180
sodium	agnesium						C	TO					aluminiun	silion	phosphorus	sulfur	chlorine	argon
11	12							TO					13	14	15	16	17	18
Na	Mg												AI	Si	P	S	CI	Ar
22.990	24,305				66. a vez 200 m N e 3	. Section					441.442.000-00.00		26.982	28.086	30.974	32.065	35.453	39,948
otassium	calcium		scandium	titanium	vanadium	chromium	mang nese	iron	ct alt	nickel	copper	zinc	gallium 24	germanium	arsenic	selenium	bromine	krypton
19	20		21	22	23	24	5	26	2	28	29	30	31	32	33	34	35	36
K	Ca		Sc		V	Cr	Mn	Fe	CD	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
39.098	40.078		44.956	47.867	50.942	51.996	54 738	55.845	58. 3	58,693	63.546	65.39	69.723	72.61	74.922	78.96	79.904	83.80
rubidium 37	strontium 38		yttrium 39	zirconium 40	niobium 41	molybdenum 42	technotium 43	ruthenium 44	rhy num 45	palladium 46	silver 47	cadmium 48	indium 49	tin 50	antimony 51	tellurium 52	iodine 53	xenon 54
			V												A CONTRACT OF	_		
Rb	Sr		Y	Zr	Nb	Mo	Tc	NU	Rh	Pd	Ag	Cd	In	Sn	Sb	Те		Xe
85.468	87.62		88.906	91.224	92.906	95.94	[98]	101.07	102.91	106.42	107.87	112.41	114.82	118.71	121.76	127.60	126.90	131.29
caesium 55	barium 56	57-70	lutetium 71	hafnium 72	tantalum 73	tungsten 74	rhenium 75	osmium 76	iridium 77	platinum 78	gold 79	mercury 80	thallium 81	lead 82	bismuth 83	polonium 84	astatine 85	radon 86
-								-					TI					100 million 100
Cs	Ba	*	Lu	Hf	la	W	Re	Os	Ir	Pt	Au	Hg	- 11	Pb	Bi	Po	At	Rn
132.91	137.33		174.97	178.49	180.95	183.84	186.21	190.23	192.22	195.08	196.97	200.59	204.38	207.2	208.98	[209]	[210]	[222]
francium 87	radium 88	89-102	lawrencium 103	rutherfordium 104	dubnium 105	seaborgium 106	bohrium 107	hassium 108	meitnerium 109	ununnilium 110	unununium 111	ununbium 112		ununquadium 114				
			_															
Fr	Ra	* *	Lr	Rf	Db	Sg	Bh	Hs	Mt	oun	Uuu	QUD		Uuq				
[223]	[226]																	

*Lanthanide series	lanthanum 57	cerium 58	praseodymium 59	neodymium 60	promethium 61	samarium 62	europium 63	gadolinium 64	terbium 65	dysprosium 66	holmium 67	erbium 68	thulium 69	ytterbium 70
Lanthanide Series	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb
	138.91	140.12	140.91	144.24	[145]	150.36	151.96	157.25	158.93	162.50	164.93	167.26	168.93	173.04
and the second	actinium	thorium	protactinium	uranium	neptunium	plutonium	americium	curium	berkelium	californium	einsteinium	fermium	mendelevium	nobelium
* * Actinide series	89	90	91	92	93	94	95	96	97	98	99	100	101	102
	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No
	[227]	232.04	231.04	238.03	[237]	[244]	[243]	[247]	[247]	[251]	[252]	[257]	[258]	[259]

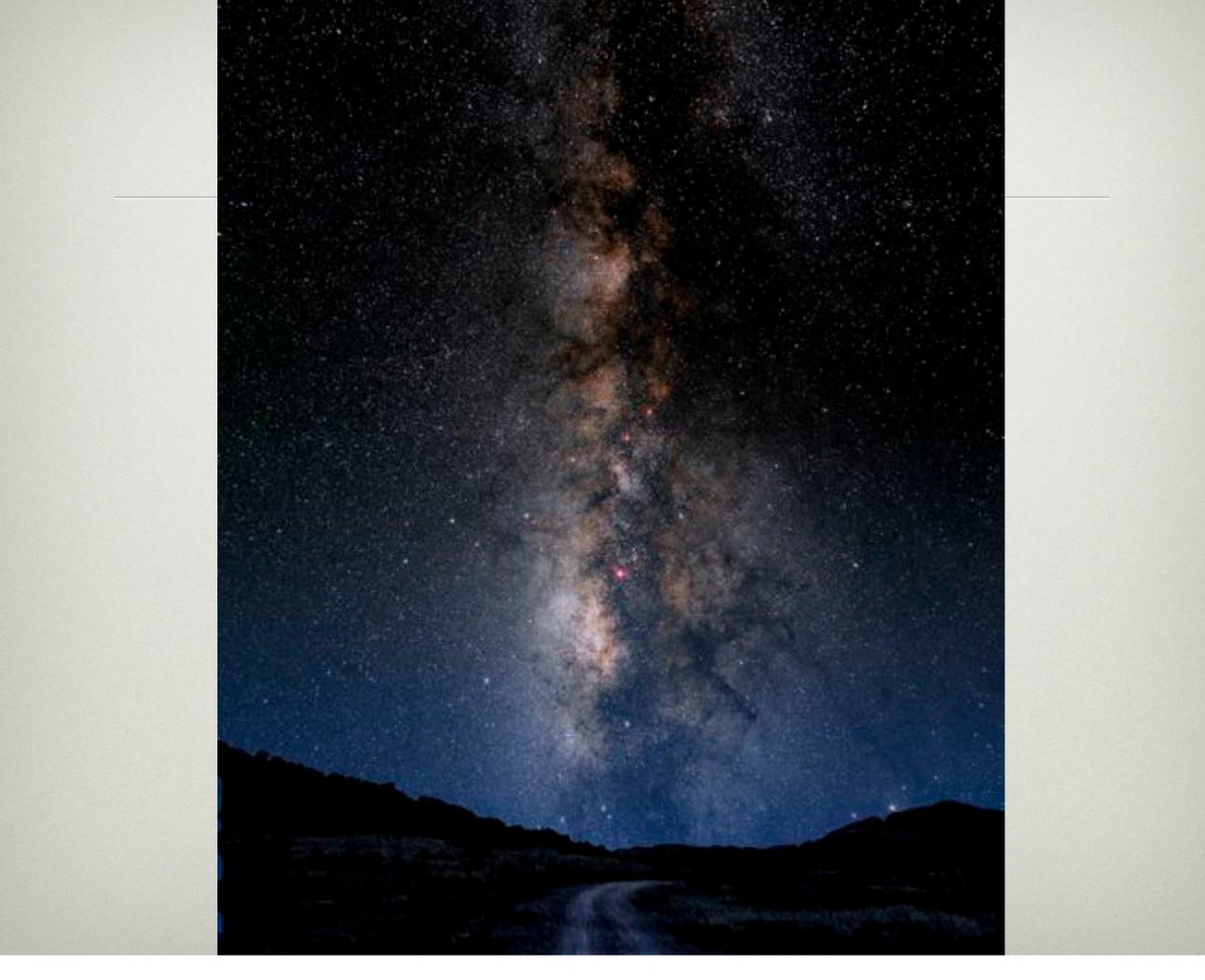


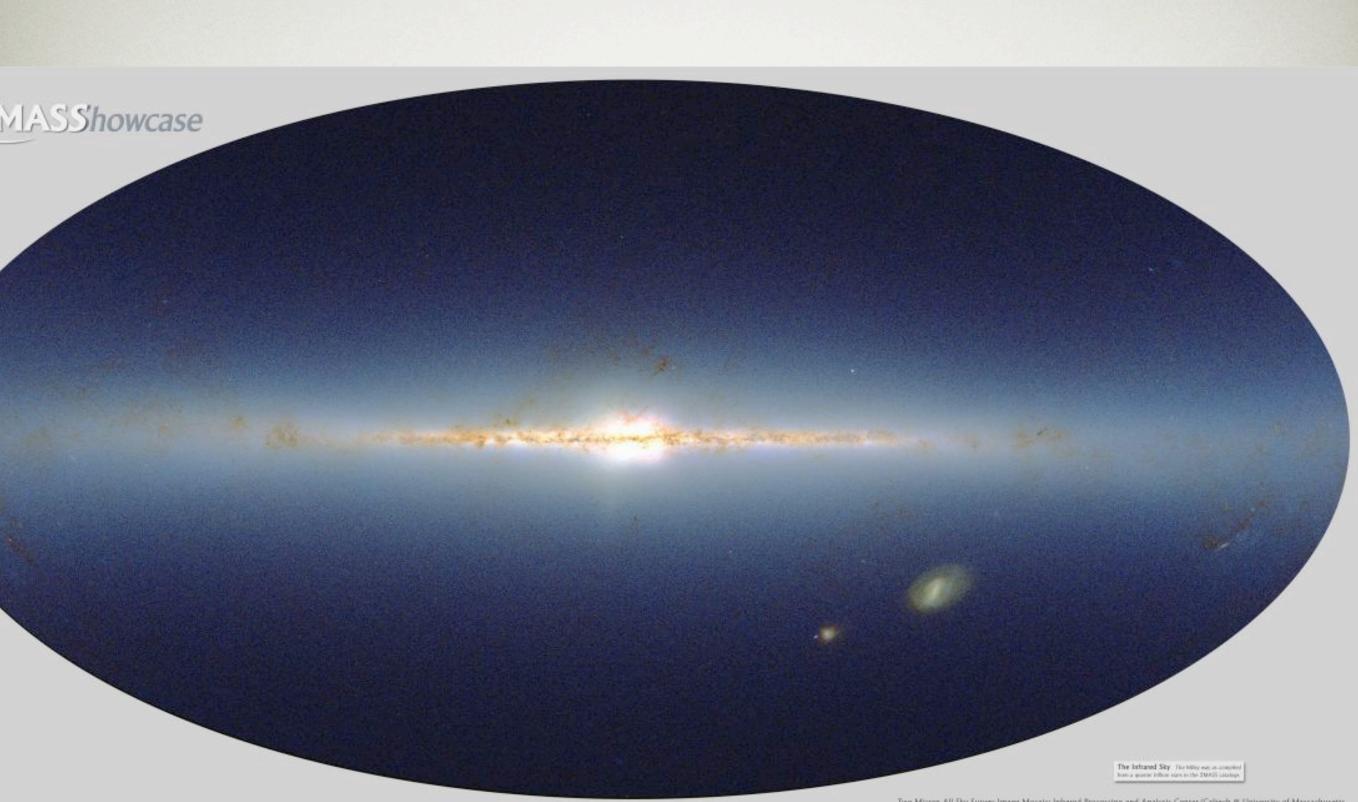








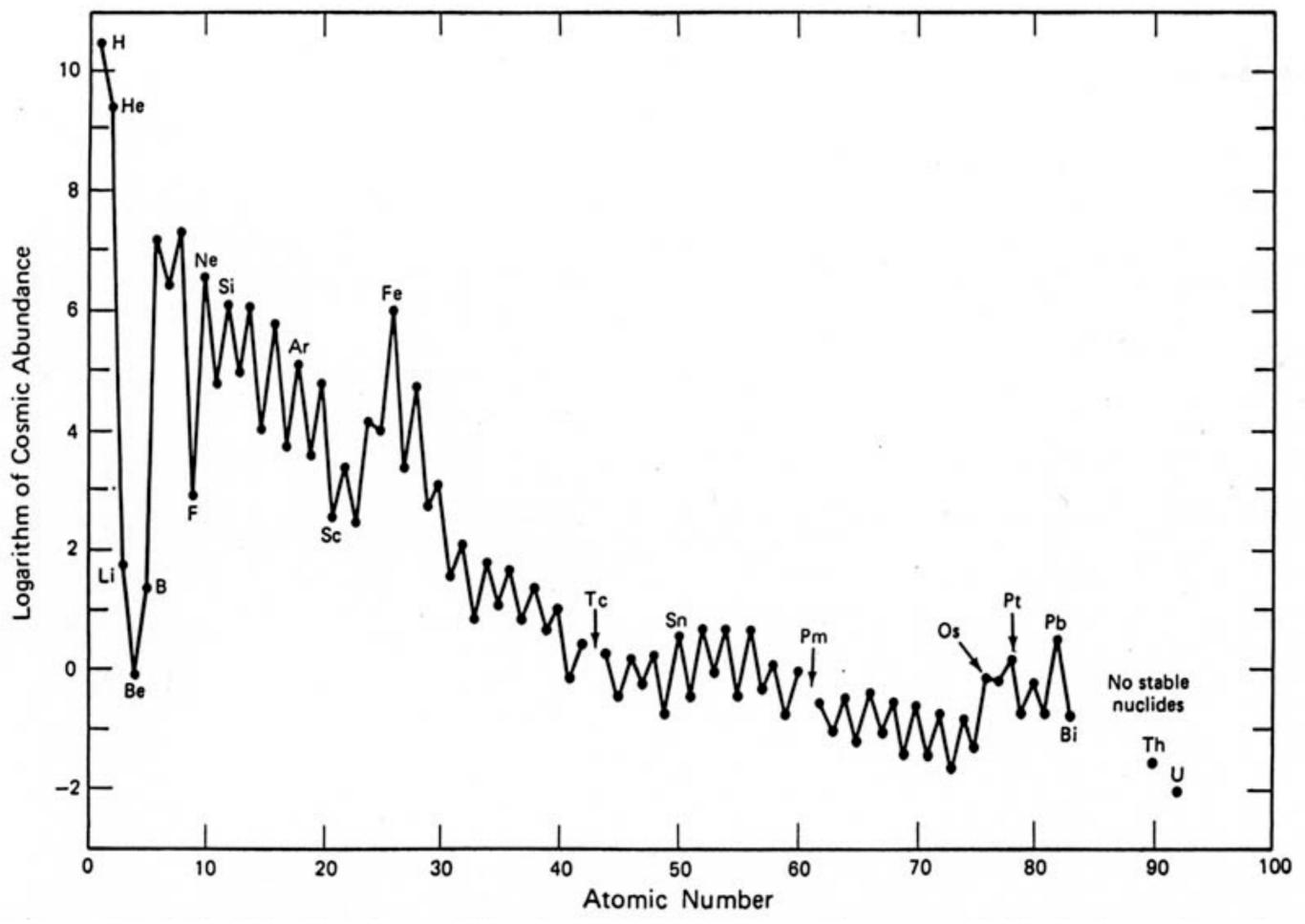


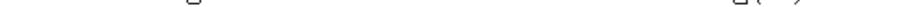


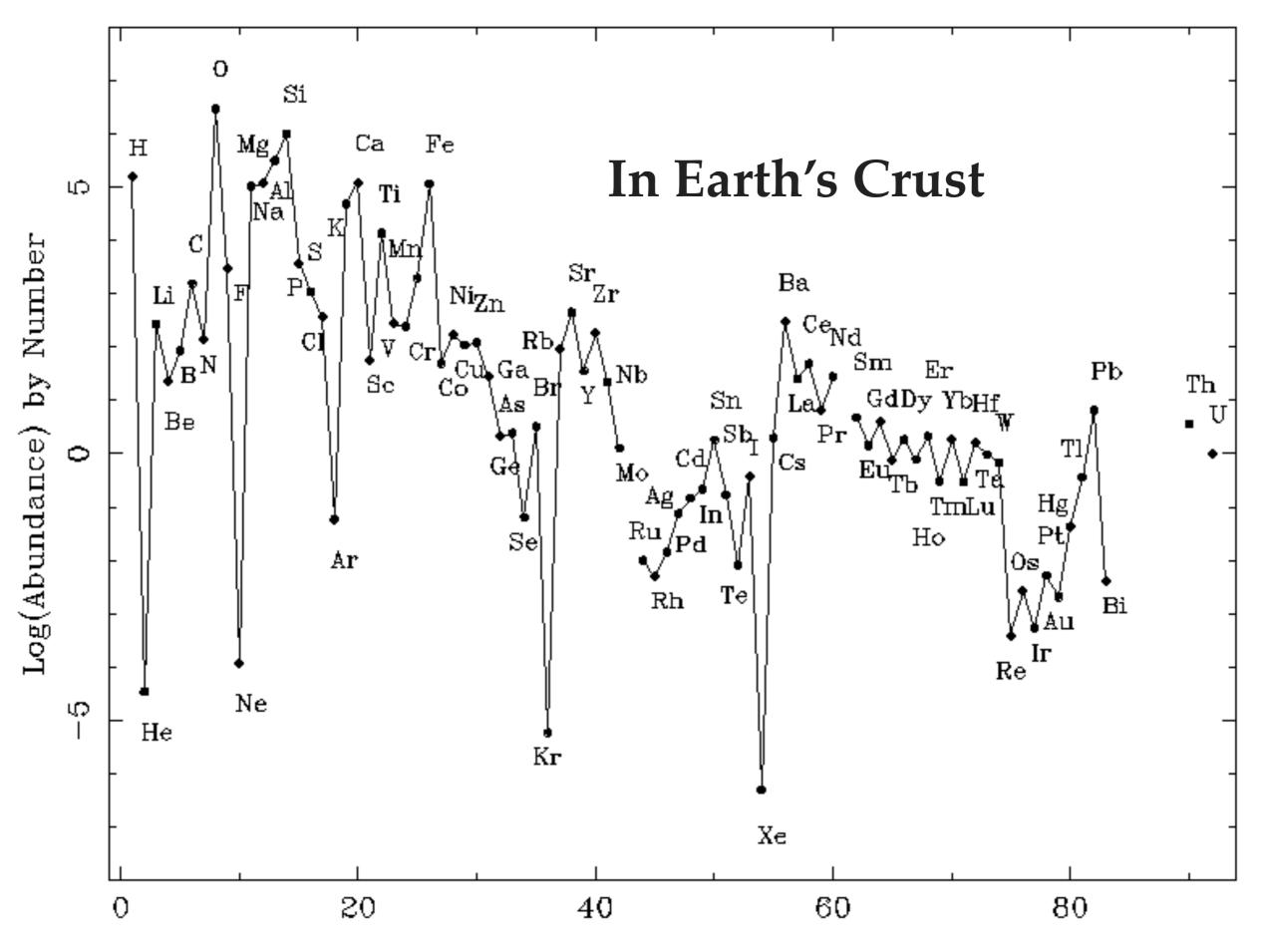
Two Micron All Sky Survey Image Mosaic: Infrared Processing and Analysis Center/Caltech & University of Massachusetts



GALAXIES IN OUR UNIVERSE



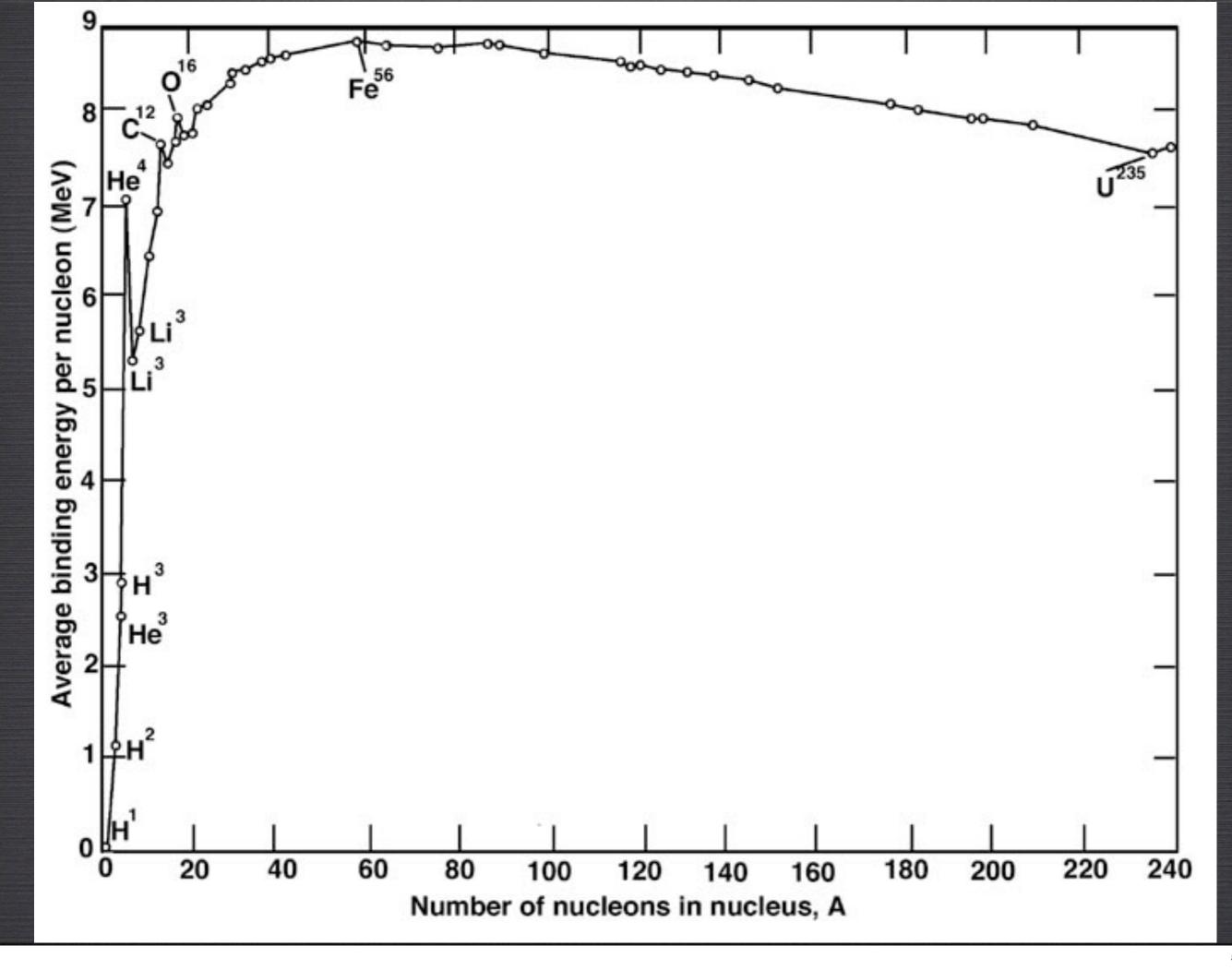


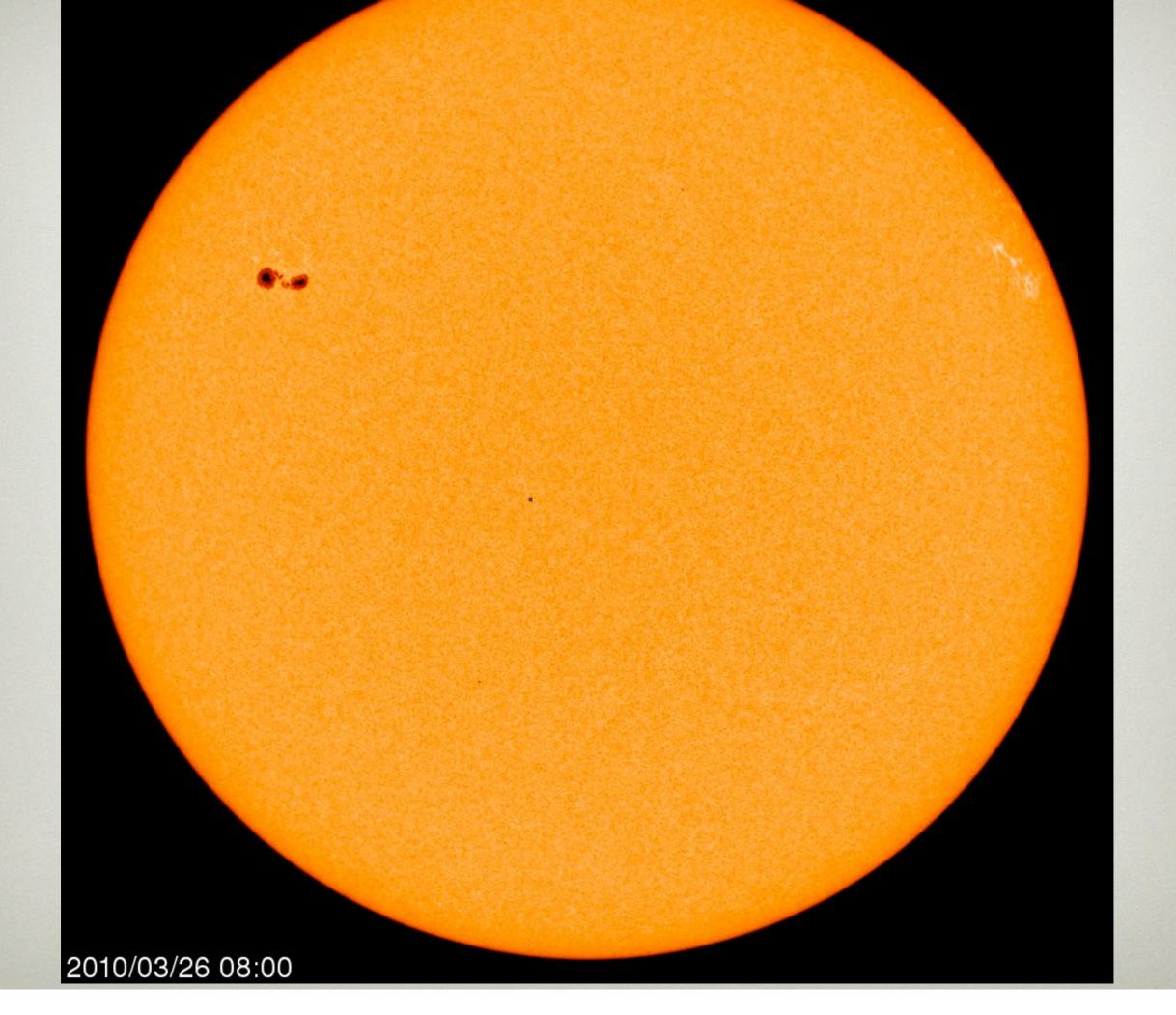


Atomic Number

NUCLEAR? GEOTHERMAL?

- These are energy sources from stars other than the Sun!
- Nuclear fission energy can sustain all of our needs for ~100 years, utilizing only 0.01% of US land area!
- Unfortunately, US energy needs are about as much as all upward flux of geothermal energy!

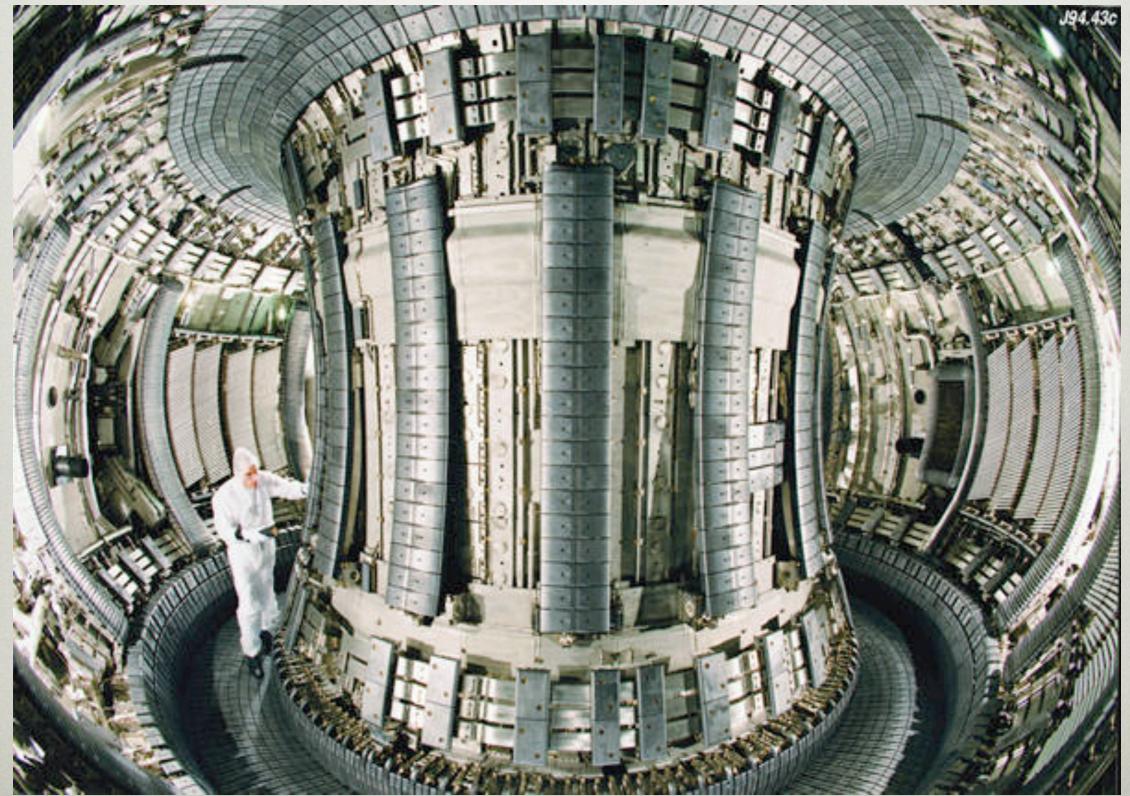




FUSION ON EARTH?

- Can we recreate the fusion reaction on Earth to produce energy?
- This would be the first time we would be able to utilize an energy source not packaged for us by a star!
- An amount of water equal to 1/3 the annual drinking water used in Mt. Lebanon, could supply all US energy needs in this way.

RECREATING THE SUN?



CONCLUSIONS

- Stars are powered by squeezing Hydrogen and letting quantum mechanics work its magic
- Stars provide all of the materials (other than Hydrogen and Helium) that we use for energy or anything else
- Nuclear fusion could end our exploitation of the stars for energy