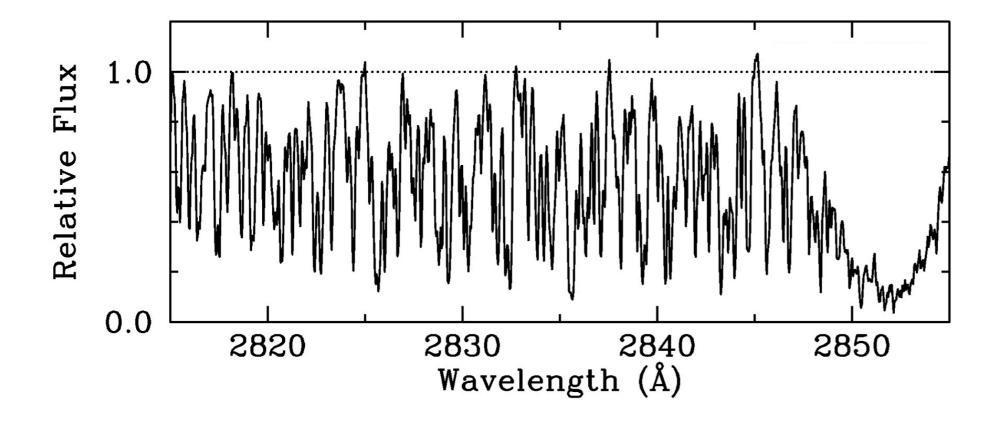
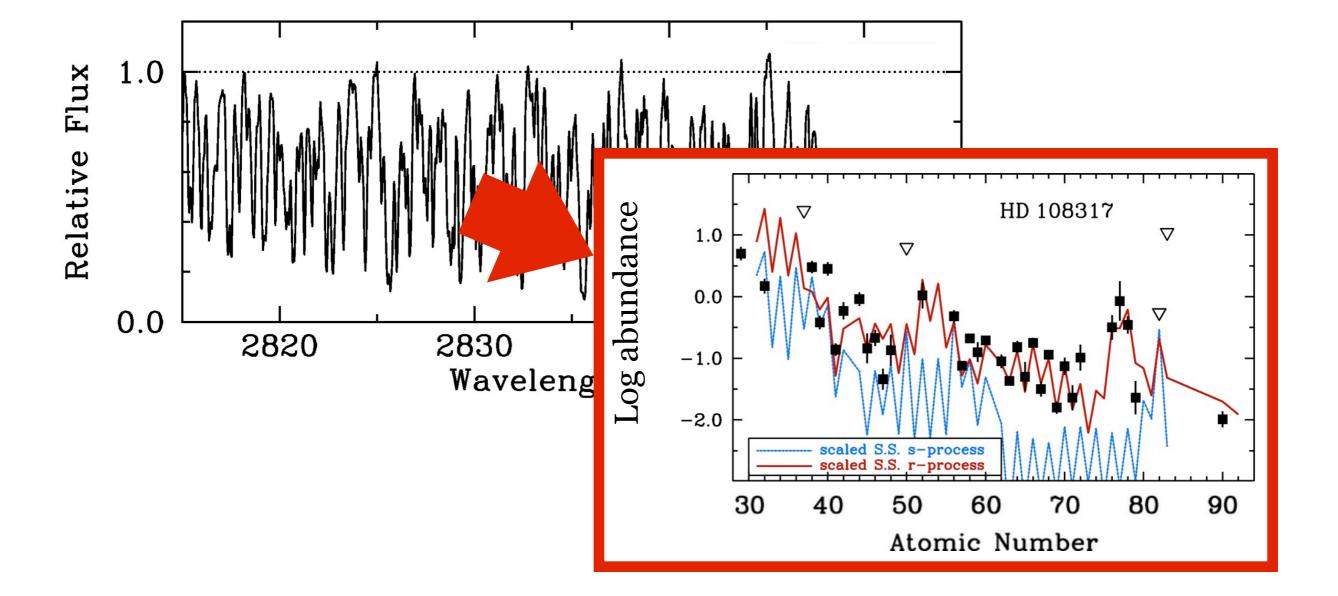
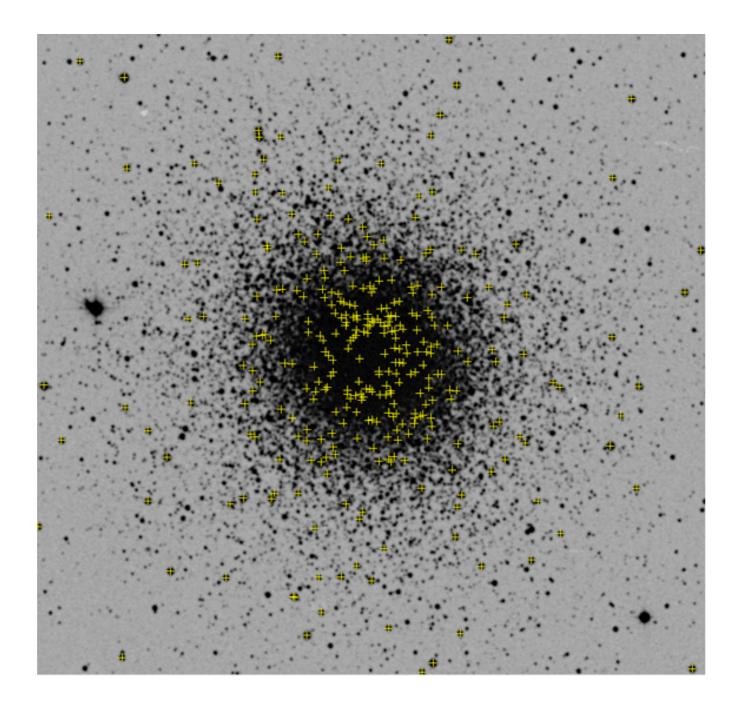
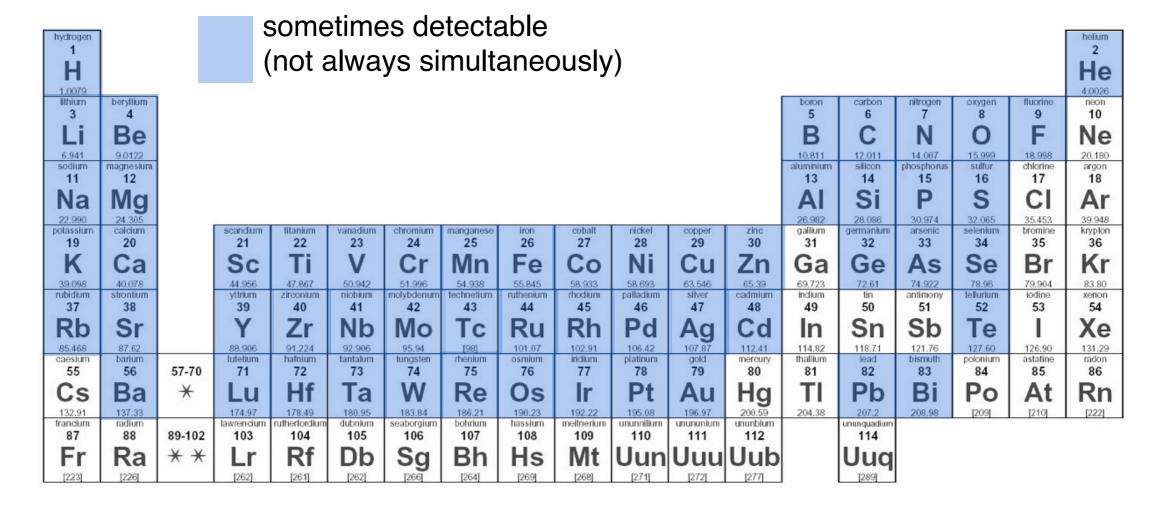


Ian U. Roederer, University of Michigan









*Lanthanide series	Ianthanum 57 La	58 Ce	praseodymium 59 Pr	60	61 Pm	62 Sm	europium 63 Eu	64 Gd	terbium 65 Tb	dysprosium 66 Dy	67 HO	erbium 68 Er	69 Tm	ytterbium 70 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
The second second second second second second	actinium	thorium	protactinium	uranium	neptunium	plutonium	americium	curium	berkelium	californium	einsteinium		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 H						es de ys si			ously	')								^{helium} 2 He
1.0079 lithium 3 Li 6.941 sodium	beryllium 4 Be 9.0122 magnesium	ſ		HST (or m		iired s big	imp	rove	men	t)			boron 5 B 10.811 aluminium	carbon 6 C 12.011 silicon	nitrogen 7 N 14.007 pnospnorus	oxygen 8 0 15.999 sulfur	fluorine 9 F 18.998 chlorine	4.0026 neon 10 Ne 20.180 argon
Na	¹² Mg		13 14 15 16 17 Al Si P S Cl 26.982 28.086 30.974 32.065 35.453															¹⁸ Ar
22,990	24,305		scandium titanium vanadium chromium manganese iron cobalt nickel copper zinc gallium germanium arsenic selenium bromine															39,948
potassium 19	calcium 20		scandiumtitaniumvanadiumchromiummanganeseironcobaltnickelcopperzincgalliumgermaniumarsonicseleniumbromine212223242526272829303132333435															krypton 36
			scandiumtitaniumvanadiumchromiummanganeseironcobaltnickelcopperzincgalliumgermaniumarsenieseleniumbromine212223242526272829303132333435															
K	Ca		21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br															Kr
39.098 rubidium	40.078 strontium		44.956 vttrium	47.867 zirconium	50.942 niobium	51.996 molybdenum	54.938 technetium	55.845 ruthenium	58.933 rhodium	58.693 palladium	63.546 silver	65.39 cadmium	69.723 indium	72.61 tin	74.922 antimony	78.96 tellurium	79,904 iodine	83.80 xenon
37	38		39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Rb	Sr		Υ	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Те	- T -	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
Cs	Ba	*	Lu	Hf	Та	W	Re	Os	Îr	Pt	Au	Hg	TI	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 97	radium	00 400	lawrencium	rutherfordium	dubnium	seaborgium	bohrium	hassium	meitnerium	ununnilium	unununium	ununbium		ununquadium				
87	88	89-102	103	104	105	106	107	108	109	110	111	112		114				
Fr	Ra	* *	Lr	Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuu	Uub		Uuq				
[223]	[226]		[262]	[261]	[262]	[266]	[264]	[269]	[268]	[271]	[272]	[277]		[289]				

*Lanthanida carica	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
the start of the start of the start of the start of the	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 H						es de ys si			ously	')								^{helium} 2 He
1.0079 lithium 3 Li 6.941 sodium	beryllium 4 Be 9.0122 magnesium			HST (or m		iired s big	imp	rove	men	t)			boron 5 B 10.811 aluminium	carbon 6 C 12.011 silicon	nitrogen 7 N 14.007 pnosphotus	oxygen 8 0 15.999 sulfur	fluorine 9 F 18.998 chlorine	4.0026 neon 10 Ne 20.180 argon
Na	¹² Mg		13 14 15 16 17 Al Si P S Cl 26.982 28.086 30.974 32.065 35.453															¹⁸ Ar
22.990	24,305		scandium titanium vanadium chromium manganese iron cobalt nickel copper zinc gallium germanium arsene selenium bromine															39.948
potassium 19	calcium 20		scandiumtitaniumvanadiumchromiummanganeseironcobaltnickelcopperzincgaliumgermannomarseneseleniumbromine212223242526272829303132333435															krypton 36
			scandiumtitaniumvanadiumchromiummanganeseironcobaltnickelcopperzincgalliumgalliumgernamourassenceseleniumbromine212223242526272829303132333435															
K	Ca		21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br															Kr
39.098 rubidium	40.078 strontium		44.956 vttrium	47.867 zirconium	50.942 niobium	51.996 molybdenum	54.938 technetium	55.845 ruthenium	58.933 rhodium	58.693 palladium	63.546 silver	65.39 cadmium	69.723 indium	72.61	74.922 antimony	78.96 tellurium	79,904 iodine	83.80 xenon
37	38		39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Rb	Sr		Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Те	- T -	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
Cs	Ba	*	Lu	Hf	Та	W	Re	Os	İr	Pt	Au	Hg	TI	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	radium	00 400	lawrencium	rutherfordium	dubnium	seaborgium	bohrium	hassium	meitnerium	ununnilium	unununium	ununbium		ununquadium				
87	88	89-102	103	104	105	106	107	108	109	110	111	112		114				
Fr	Ra	* *	Lr	Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuu	Uub		Uuq				
[223]	[226]		[262]	[261]	[262]	[266]	[264]	[269]	[268]	[271]	[272]	[277]		[289]				

*Lanthanida carica	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
the start of the start of the start of the start of the	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 H						es de ys si			ously	')								^{helium} 2 He
1.0079 lithium 3 Li 6.941 sodium	beryllium 4 Be 9.0122 magnesium			HST (or m		iired s big	imp	rove	men	t)			boron 5 B 10.811 aluminium	carbon 6 C 12.011 silicon	nitrogen 7 N 14.007 phosphorus	oxygen 8 0 15.999 sulfur	fluorine 9 F 18.998 chlorine	4.0026 neon 10 Ne 20,180 argon
¹¹ Na	¹² Mg		13 14 15 16 17 Al Si P S Cl 26.982 28.086 30.974 32.065 35.453 scandium titanium vanadium chromium manganese incl nickel conper zinc gallium urburnum selenium bromine															Ar
22.990	24.305		scandium titanium vanadium chromium manganese iron cobalt nickel copper zinc gallium germanoum arsene selenium bromine															39.948
potassium 19	calcium 20		scandiumtitaniumvanadiumchromiummanganeseironcobaltnickelcopperzincgalliumgernamonarseneseleniumbromine212223242526272829303132333435															krypton 36
			scandiumtitaniumvanadiumchromiummanganeseironcobaltnickelcopperzincgalliumgalliumgernamoncarsenceseleniumbromine212223242526272829303132333435															
K	Ca		21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br															Kr
39.098 rubidium	40.078 strontium		44.956 vttrium	47.867 zirconium	50.942 niobium	51.996 molybdenum	54.938 technetium	55.845 ruthenium	58.933 rhodium	58.693 palladium	63.546 silver	65.39 cadmium	69.723 indium	72.61	74.922	78.96 tellurium	79,904 iodine	83.80 xenon
37	38		39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Rb	Sr		Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Те	- T - 1	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
					_								-					
Cs	Ba	*	Lu	Hf	Та	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		Uuu	Uub		Uuq				
[223]	[226]		[262]	[261]	[262]	[266]	[264]	[269]	[268]	[271]	[272]	[277]		[289]				

*Lanthanida carica	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
the start of the start of the start of the start of the	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 H						es de ys si			ously	')								^{helium} 2 He
1.0079 lithium 3 Li 6.941 sodium	beryllium 4 Be 9.0122 magnesium			HST (or m		iired s big	imp	rove	men	t)			boron 5 B 10.811 aluminium	carbon 6 C 12.011 silicon	nitrogen 7 N 14.007 phosphorus	oxygen 8 0 15.999 sulfur	fluorine 9 F 18.998 chlorine	4.0026 neon 10 Ne 20.180 argon
¹¹ Na	¹² Mg		13 14 15 16 17 Al Si P S 26 28.086 30.974 32.065 35.453 scandium titanium vanadium cobalt nickel conper zinc gallium verture 32.065 35.453															¹⁸ Ar
22.990	24.305		scandium titanium vanadium chromium manganese iron cobalt nickel copper zinc gallium germanium arsene sevenum bromine															39.948
potassium 19	calcium 20		scandiumtitaniumvanadiumchromiummanganeseironcobaltnickelcopperzincgalliumgermanionalsenicseleniumbromine212223242526272829303132333435															krypton 36
ĸ	Ca		scandium titanium vanadium chromium manganese iron cobalt nickel copper zinc gallium germanium arsene seremon bromine															Kr
					V	· · ·											the second s	
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	65.39 cadmium	69.723 indium	72.61	74.922	78.96	79.904 iodine	83.80 xenon
37	38		39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Rb	Sr		Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	- T - I	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					
Cs	Ba	*	Lu	Hf	Та	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	* *	-	Rf	Db		Bh	Hs	Mt									
			Lr			Sg					ouu	oup		Uuq				
[223]	[226]		[262]	[261]	[262]	[266]	[264]	[269]	[268]	[271]	272	[277]		[289]				

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the start of the start of the start of the start of the	actinium	thorium	protactinium	uranium	neptunium	plutonium	americium	curium	berkelium	californium	einsteinium	fermium	mendelevium	nobelium
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	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No
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hydrogen 1 H			-			es de ys si			ously	')								^{helium} 2 He
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22.990	24.305		scandium titanium vanadium chromium manganese iron cobalt nickel copper zinc gallium germanium assence selemon bromine															39.948
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			scandiumtitaniumvanadiumchromiummanganeseironcobaltnickelcopperzincgalliumgermaniumarseniceseleniumbromine212223242526272829303132333435															
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Rb	Sr		Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	- T - I	Xe
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													-					
Cs	Ba	*	Lu	Hf	Та	W	Re	Os	Ir	Pt	Au	Hg		Pb	Bi	Po	At	Rn
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Fr	Ra	* *	Lr	Rf	Db	Sa	Bh	Hs	Mt	Hun	Uuu	Uub		Ilua				
		~ ~				Sg					ouu	oup		Uuq				
[223]	[226]		[262]	[261]	[262]	[266]	[264]	[269]	[268]	[271]	272	277		[289]				

*Lanthanide series	Ianthanum 57 La	^{cerium} 58 Ce	praseodymium 59 Pr	^{neodymium} 60 Nd	promethium 61 Pm	62 Sm	europium 63 Eu	^{gadolinium} 64 Gd	terbium 65 Tb	dysprosium 66 Dy	67 HO	erbium 68 Er	^{thulium} 69 Tm	ytterbium 70 Yb
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	actinium	thorium	protactinium	uranium	neptunium	plutonium	americium	curium	berkelium	californium	einsteinium	fermium	mendelevium	nobelium
	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
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potassium 19	calcium 20		scandium titanium vanadium chromium manganese iron cobalt nickel copper zinc gallium germanium alsonic segenium bromine 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35															krypton 36
K	Ca		scandium 21titanium 22vanadium 23chromium 24manganese 25iron 26cobalt 27nickel 28copper 29zinc 30gallium 31gernanium 32asone 330sevenum 33bromine 32Sc<															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
rubidium 37	strontium 38		yttrium 39	zirconium 40	niobium 41	molybdenum 42	technetium 43	ruthenium 44	rhodium 45	palladium 46	silver 47	48	indium 49	50	51	52	iodine 53	xenon 54
Rb	Sr		Y	Zr	Nb	Mo	Тс	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Те	1.1	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	80	thallium 81	lead 82	bismuth 83	84	astatine 85	radon 86
Cs	Ba	*	Lu	Hf	Та	W	Re	Os	Îr	Pt	Au	Hg	ŤI	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		Uuu	Uub		Uuq				
[223]	[226]		[262]	[261]	[262]	[266]	[264]	[269]	[268]	[271]	[272]	[277]		[289]				

*Lanthanide series	Ianthanum 57 La	^{cerium} 58 Ce	praseodymium 59 Pr	^{neodymium} 60 Nd	promethium 61 Pm	62 Sm	europium 63 Eu	^{gadolinium} 64 Gd	terbium 65 Tb	dysprosium 66 Dy	67 HO	erbium 68 Er	^{thulium} 69 Tm	ytterbium 70 Yb
* * Actinide series	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
	actinium	thorium	protactinium	uranium	neptunium	plutonium	americium	curium	berkelium	californium	einsteinium	fermium	mendelevium	nobelium
	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 H						es de ys si			ously	')								^{helium} 2 He
1.0079 lithium 3 Li 6.941 sodium	beryllium 4 Be 9.0122 magnesium	[HST (or m		iired s big	imp	rove	men	t)			boron 5 B 10.811 aluminium	carbon 6 C 12.011 silicon	nitrogen 7 N 14.007 phosphorus	oxygen 8 0 15,999 sulfur	fluorine 9 F 18,998 chlorine	4.0026 neon 10 Ne 20,180 argon
Na	12 Mg 24,305		scandium titanium vanadium chromium manganese iron cobalt nickel copper zinc gallium gernamun ansone seemium bromine															18 Ar 39.948
22.990 potassium 19	24.305 calcium 20		scandium titanium vanadium chromium manganese iron cobalt nickel copper zinc gallium germanium alsenie seremuni bromine 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35															39,948 krypton 36
K	Ca		scandium 21titanium 22vanadium 23chromium 24manganese 25iron 26cobalt 27nickel 28copper 29zinc 30gallum 31gallum 32gallum 33gallum 33gallum 33gallum 33gallum 33gallum 33gallum 33gallum 33gallum 32gallum 33gallum 33gallum 32gallum 33gallum 33gallum 34gallum 35ScTiVCrMnFeCoNiCuZnGaGeAsSeBr															Kr
39.098 rubidium	40.078		44.956 vttrium	47.867	50.942 niobium	51.996 molvbdenum	54.938 technetium	55.845	58.933 rhodium	58.693 palladium	63.546	65.39	69.723	72.61	74.922	78.96	79.904	83.80
37	strontium 38		39	zirconium 40	41	42	43	ruthenium 44	45	46	silver 47	48	indium 49	50	51	52	iodine 53	xenon 54
Rb	Sr		Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Те	- T - 1	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	71	hafnium 72	tantalum 73	tungsten 74	rhenium 75	osmium 76	iridium 77	platinum 78	gold 79	80	thallium 81	lead 82	bismuth 83	84	astatine 85	radon 86
Cs	Ba	*	Lu	Hf	Та	W	Re	Os	Ir	Pt	Au	Hg	TL	Pb	Bi	Po	At	Rn
132.91	137.33		174.97	178.49 rutherfordium	180.95 dubnium	183.84	186.21	190.23	192.22	195.08 ununnilium	196.97	200.59	204.38	207.2	208.98	[209]	[210]	[222]
francium 87	radium 88	89-102	103	104	105	seaborgium 106	bohrium 107	hassium 108	meitnerium 109	110	unununium 111	ununbium 112		ununquadium 114				
Fr	Ra	* *	Lr	Rf	Db	Sg	Bh	Hs	Mt		Uuu			Uuq				
[223]	[226]		[262]	[261]	[262]	[266]	[264]	[269]	[268]	[271]	[272]	[277]		[289]				

XI anthonida agains	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
the state of the state of the state of the state of the	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 H				some (not a					ously	')								2 He
1.0079 lithium 3 Li 6.941 sodium	beryllium 4 Be 9.0122 magnesium			HST (or m			imp	rove	men	t)			boron 5 B 10.811	6 C 12.011	nitrogen 7 N 14.007	oxygen 8 0 15.999 suffur	fluorine 9 F 18.998 chlorine	4.0026 neon 10 Ne 20.180 argon
11 Na 22.990	12 Mg 24,305		Scandiumtitaniumvanadiumchromiummanganeseironcobaltrickelcopperzincgalliumgalliumprosprorussulfurchlorine1314151617161716171617161716171616171616171616171616171616161716 <td< td=""><td>18 Ar 39.948</td></td<>															18 Ar 39.948
19 K 39.098	calcium 20 Ca 40.078		scandium titanium vanadium chromium manganese iron cobalt nickel copper zinc gallium germanium alsone seemun bromine															83.80
rubidium 37 Rb	strontium 38 Sr			101001									001110	50 Sn	51 Sb	52 Te	101001	xenon 54 Xe
s5.468 caesium 55 CS	87.62 barium 56 Ba	57-70 ×	88.906 71 Lu	91.224 hafnium 72 Hf	92.906 tantalum 73 Ta	95.94 tungsten 74 W	[98] rhenium 75 Re	101.07 05111011 76 OS	102.91 iridium 77	106.42 platinum 78 Pt	107.87 gold 79 Au	112.41 80 Hg	114.82 thallium 81	118.71 lead 82 Pb	121.76 bismuth 83 Bi	127.60 84 PO	126.90 astatine 85 At	131.29 radon 86 Rn
132.91 francium 87 Fr	137.33 radium 88 Ra	89-102 ★ ★	174.97 103 Lr	178.49 rutherfordium 104 Rf	180.95 dubnium 105 Db	183,84 seaborgium 106 Sg	186.21 bohrium 107 Bh	190.23 108 HS	192.22 meitnerium 109 Mt	195.08 ununnilium 110	196.97 unununium 111	200.59 ununbium 112 Uub	204.38	207.2 ununquadium 114 Uuq	208.98	[209]	[210]	[222]
[223]	[226]		[262]	[261]	[262]	[266]	[264]	[269]	[268]	[271]	[272]	[277]		[289]				

*Lanthanide series	Ianthanum 57 La	58 Ce	^{praseodymium} 59 Pr	^{neodymlum} 60 Nd	^{promethium} 61 Pm	62 Sm	europium 63 Eu	^{gadolinium} 64 Gd	terbium 65 Tb	dysprosium 66 Dy	67 HO	erbium 68 Er	^{thulium} 69 Tm	ytterblum 70 Yb
	138.91 actinium	140.12 thorium	140.91 protactinium	144.24 uranium	[145]	150.36	151.96	157.25	158.93	162.50	164.93	167.26 fermium	168.93	173.04 nobelium
**Actinide series	89	90	91	92	neptunium 93	plutonium 94	americium 95	eurium 96	berkelium 97	californium 98	einsteinium 99	100	mendelevium 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 H						es de ys si			ously	')								^{belium} 2 He
1.0079 lithium 3 Li 6.941 sodium	beryllium 4 Be 9.0122 magnesium	Γ		HST or m		iired s big	imp	rove	men	t)			boron 5 B 10.811 aluminium	6 C 12.011 silicon	nitrogen 7 N 14.007 pnospnorus	oxygen 8 0 15.999 sulfur	fluorine 9 F 18.998 chlorine	4.0026 neon 10 Ne 20.180 argon
¹¹ Na	¹² Mg												13 A	¹⁴ Si	15 P	16 S	17 CI	¹⁸ Ar
22.990 potassium 19	24.305 calcium 20		scandium 21	titanium 22	vanadium 23	chromium 24	manganese 25	iron 26	cobalt 27	nickel 28	copper 29	zinc 30	26.982 gallium 31	28.086 germanion 32	30,974 33	32.065 Selenium 34	35.453 bromine 35	39.948 krypton 36
K	Ca		Sc	Ti	V	Cr	Mn	Fe	Со	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
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 caunium 48	69.723 indium 49	72.61 50	74.922 51	78.96 52	79.904 iodine 53	83.80 xenon 54
Rb	Sr		Ŷ	Žr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	35	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	71	hafnium 72	tantalum 73	tungsten 74	rhenium 75	76	77	platinum 78	gold 79	80	thallium 81	lead 82	bismuth 83	84	astatine 85	radon 86
Cs	Ba	*	Lu	Hf	Та	W	Re	Os	Ir	Pt	Au	Hg	TI	Pb	Bi	Po	At	Rn
132.91 francium	137.33 radium		174.97	178.49 rutherfordium	180.95 dubnium	183.84 seaborgium	186.21 bohrium	190.23	192.22	195.08 ununnilium	196.97 unununium	200.59 ununbium	204.38	207.2 ununguadium	208.98	[209]	[210]	[222]
87	88	89-102	103	104	105	106	107	108	109	110	111	112		114				
Fr	Ra	* *	Lr	Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuu	Uub		Uuq				
[223]	[226]		[262]	[261]	[262]	[266]	[264]	[269]	[268]	[271]	[272]	[277]		[289]				

*Lonthonido porios	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	
	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
the start of the start of the start of the start of the	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 H						es de ys si			ously	')								^{belium} 2 He
1.0079 lithium 3 Li 6.941 sodium	beryllium 4 Be 9.0122 magnesium	Γ		HST or m		iired s big	imp	rove	men	t)			boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 0 15.999	fluorine 9 F 18.998	4.0026 neon 10 Ne 20,180
11	12		aluminium 13silicon 14prosphorus 15sulfur 16chlorine 17AlSiPSCl															argon 18
Na 22,990	Mg 24,305												AI 26.982	SI 28.086	P 30.974	S 32.065	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	germanion 32	33	34	bromine 35	krypton 36
K	Ca		Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
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	65.39 caumum	69.723 indium	72.61	74.922	78.96	79.904 iodine	83.80 xenon
37	38		39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Rb	Sr		Y	Zr	Nb	Mo	TC	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Те		Xe
85.468 caesium	87.62 barium		88.906 Iutetioni	91.224 hafnium	92.906 tantalum	95.94 tungsten	[98] rhenium	101.07 05111011	102.91 Incium	106.42 plaunum	107.87 gold	112.41	114.82 thallium	118.71 lead	121.76 bismuth	127.60	126.90 astatine	131.29 radon
55	56	57-70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
Cs	Ba	*	Lu	Hf	Та	W	Re	Os	Ir	Pt	Au	Hg	TI	Pb	Bi	Po	At	Rn
132.91	137.33 radium		174.97	178.49 rutherfordium	180.95 dubnium	183.84 seaborgium	186.21 bohrium	190.23	192.22	195.08	196.97 unununium	200.59 ununbium	204.38	207.2	208.98	[209]	[210]	[222]
francium 87	88	89-102	103	104	105	106	107	108	109	110	111	112		ununquadium 114				
Fr	Ra	* *	Lr	Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuu	Uub		Uuq				
[223]	[226]	545565 1227	[262]	[261]	[262]	[266]	[264]	[269]	[268]	[271]	[272]	[277]		[289]				

*Lanthanide series	lanthanum 57 La	58 Ce	praseodymium 59 Pr	60 Nd	61	62 Sm	europium 63 Eu	64 Gd	65	dysprosium 66	holmium 67	erbium 68 Fr	thulium 69 Tm	ytterblum 70 Yb
	138.91 actinium	140.12 thorium	140.91 protactinium	144.24 uranium	[145] neptunium	150.36 plutonium	151.96 americium	157.25	158.93 berkelium	162.50 californium	164.93 einsteinium	167.26 fermium	168.93 mendelevium	173.04 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 H						es de ys si			ously	')								^{belium} 2 He
1.0079 lithium 3 Li 6.941 sodium	beryllium 4 Be 9.0122 magnesium			HST (or m			imp	rove	men	t)			boron 5 B 10.811 aluminium	carbon 6 C 12.011 silicon	nitrogen 7 N 14.007 phosphorus	oxygen 8 0 15.999 sulfur	fluorine 9 F 18.998 chlorine	4.0026 neon 10 Ne 20,180 argon
Na	¹² Mg		scandium titanium vanadium chromium manganese iron cobalt nickel copper zinc gallium germanioni arsenic secundiri 13 14 15 16 17 Cl 32,085 32,065 32,065 53,453 54,53 54,53															¹⁸ Ar
22.990 potassium 19	24.305 calcium 20		scandiumtitaniumvanadiumchromiummanganeseironcobaltnickelcopperzincgalliumgermaniumasonicseieniumbromine212223242526272829303132333435															39.948 krypton 36
K	Ca		scandium 21titanium 22vanadium 23chromium 24manganese 25iron 26cobalt 27nickel 28copper 29zinc 30gallium 31germanium 32seemium 3332.06535.453ScTiVCrMnFeCoNiCuZnZngallium 30germanium 31seemium 32seemium 33seemium 34bromine 35ScTiVCrMnFeCoNiCuZnGaGeAsSeeBr															Kr
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	65.39 caumum	69.723 indium	72.61	74.922	78.96	79,904 iodine	83.80 xenon
37	38		39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Rb	Sr		T	Zr	Nb	Мо	Тс	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Те		Xe
85.468 caesium	87.62 barium	F7 70	88,906 Tutetium	91.224 hafnium	92.906 tantalum	95.94 tungsten	rhenium	101.07 05111011	102.91	106.42 praunum	107.87 gold	112.41	114.82 thallium	118.71 lead	121.76 bismuth	127.60	126.90 astatine	131.29 radon
55	56 Do	57-70 ★	71	⁷² Hf	73 T O	74 W	75 Do	76	77 Ir	78 Pt	79	80	81 TI	82 Pb	Bi	⁸⁴ Po	85	86 Dp
CS 132.91	Ba	^	LU 174.97	178,49	Ta 180.95	183.84	Re 186.21	OS 190.23	192.22	195.08	AU 196.97	Hg	204.38	207.2	DI 208,98	12091		Rn
francium 87	radium 88	89-102	103	rutherfordium 104	dubnium 105	seaborgium 106	bohrium 107	108	109	110	111	ununbium 112		ununquadium 114		12201	10.01	(and)
Fr	Ra	* *	Lr	Rf	Db	Sg	Bh	Hs	Mt		Uuu			Uuq				
[223]	[226]		[262]	[261]	[262]	[266]	[264]	[269]	[268]	[271]	[272]	[277]		[289]				

*Lanthanide series	lanthanum 57 La	cerium 58 Ce	praseodymium 59 Pr	60 Nd	^{promethium} 61 Pm	62 Sm	europium 63 Eu	^{gadolinium} 64 Gd	terbium 65 Tb	dysprosium 66 Dy	^{holmium} 67 HO	erbium 68 Er	^{thulium} 69 Tm	ytterbium 70 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
* * Actinide series	actinium 89	thorium 90	protactinium 91	uranium 92	neptunium 93	plutonium 94	americium 95	eurium 96	berkelium 97	californium 98	einsteinium 99	fermium 100	mendelevium 101	nobelium 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 H						es de ys si			busly	')								^{belium} 2 He
1.0079 lithium 3 Li 6.941 sodium	beryllium 4 Be 9.0122 magnesium	Γ		HST or m	requ lakes	iired s big	imp	rove	men	t)			boron 5 B 10.811	carbon 6 C 12.011 silicon	nitrogen 7 N 14.007	oxygen 8 0 15,999 sulfur	fluorine 9 F 18.998 chlorine	4.0026 neon 10 Ne 20.180 argon
11 Na	12 Mg		13 14 15 16 17 Al Si P S Cl 26.982 28.086 30.974 32.065 35.453														18 Ar	
22.990	24.305				a	- Muschata a - 1				0.000000.00					30,974		35,453	39,948
potassium 19	calcium 20		scandium 21	titanium 22	vanadium 23	chromium 24	manganese 25	iron 26	cobalt 27	nickel 28	29	zinc 30	gallium 31	32	33	34	bromine 35	krypton 36
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
rubidium 37	strontium 38		yttrium 39	zirconium 40	niobium 41	molybdenum 42	technetium 43	ruthenium 44	rhodium 45	palladium 46	47	48	indium 49	50	51	52	iodine 53	xenon 54
Rb	Sr		Y	Zr	Nb	Мо	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Те	Ĩ	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	71	hafnium 72	tantalum 73	tungsten 74	rhenium 75	76	77	78	79	80	thallium 81	lead 82	bismuth 83	84	astatine 85	radon 86
Cs	Ba	*		Hf		W	Re		le.	Pt			TI	Pb	Bi	Po		Rn
132.91	Dd 137,33	^	LU 174.97	178,49	Ta 180.95	183,84	186.21	OS	102.22	105.08	AU	Hg	204.38	207.2	DI 208,98	12091		[222]
francium	radium		ion removal	rutherfordium	dubnium	seaborgium	bohrium	nassiani	192.22	195.08	anananan	ununbium	204.38	ununquadium	200.98	[209]	1210	222
87	88	89-102	103	104	105	106	107	108	109	110	111	112		114				
Fr	Ra	* *	Lr	Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuu	Uub		Uuq				
[223]	[226]		[262]	[261]	[262]	[266]	[264]	[269]	[268]	[271]	[272]	[277]		[289]				

*Lanthanide series	lanthanum 57	cerium 58 Ce	praseodymium 59 Pr	60	^{promethium} 61 Pm	62 Sm	europium 63 Eu	^{gadolinium} 64 Gd	terbium 65 Tb	dysprosium 66 Dy	^{holmium} 67 HO	erbium 68 Er	thulium 69 Tm	ytterblum 70 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
The second s	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 H						es de ys si			ously	<i>(</i>)								^{belium} 2 He
1.0079 lithium 3 Li	^{beryflium} 4 Be	Γ		HST		iired s big	imn	rovo	mon	+)			5 B	6 C	nitrogen 7 N	oxygen 8 O	fluorine 9 F	4.0026 neon 10 Ne
6.941 sodium	9.0122 magnesium				lanc	s big	mp	1000	men	L)			10.811 aluminium	12.011 silicon	14.007 phosphorus	15.999 sulfur	18.998 chlorine	20.180 argon
Na	12 Ma													¹⁴ Si	15 D	16 S		18 Ar
11a 22.990	Mg 24,305												26,982	28.086	30,974	32.065	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	29	zinc 30	gallium 31	germanion 32	33	34	bromine 35	krypton 36
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
rubidium 37	strontium 38		yttrium 39	zirconium 40	niobium 41	42	technetium 43	ruthenium 44	rhodium 45	palladium 46	47	48	indium 49	50	51	52	iodine 53	xenon 54
Rb	Sr		Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Те	T	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	71	hafnium 72	tantalum 73	74	rhenium 75	76	77	78	79	80	thallium 81	lead 82	bismuth 83	84	astatine 85	radon 86
Cs	Ba	×	Lu	Hf	Та	W	Re	Os	Ir	Pt	Au	Hg	TL	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	103	rutherfordium 104	dubnium 105	seaborgium 106	bohrium 107	108	109	110	111	ununbium 112		ununquadium 114				
Fr	Ra	* *	Lr	Rf	Db	Sg	Bh	Hs	Mt		Uuu	Uub		Uuq				
[223]	[226]	steps (22)	[262]	[261]	[262]	[266]	[264]	[269]	[268]	[271]	[272]	[277]		[289]				

*Lanthanide series	Ianthanum 57 La	58 Ce	praseodymium 59 Pr	^{neodymium} 60 Nd	^{promethium} 61 Pm	62 Sm	europium 63 Eu	64 Gd	65 Tb	dysprosium 66 Dy	67 HO	erbium 68 Er	^{thulium} 69 Tm	ytterblum 70 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
**Actinide series	actinium 89	thorium 90	protactinium 91	uranium 92	neptunium 93	plutonium 94	americium 95	eurium 96	berkelium 97	californium 98	einsteinium 99	fermium 100	mendelevium 101	nobelium 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 H						es de ys si			ously	')								^{belium} 2 He
1.0079 lithium 3 Li	^{beryllium} 4 Be	Γ		HST			imn	rovo	mon	+)			5 B	earbon 6 C	nitrogen 7 N	oxygen 8 O	fluorine 9 F	4.0026 neon 10 Ne
6.941 sodium	9.0122 magnesium		(lanes	s big	mp	love	men	U)			10.811 aluminium	12.011 silicon	14.007 pnospnorus	15.999 sulfur	18.998 chlorine	20.180 argon
Na	12 Ma												13 A	¹⁴ Si	15 D	16 S		18 Ar
22.990	Mg 24.305				0	S. Statistics		(8				AI 26.982	28.086	30.974	32.065	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	29	zinc 30	gallium 31	32	33	34	bromine 35	krypton 36
K	Ca		Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
39.098 rubidium	40.078 strontium		44.956 vttrium	47.867 zirconium	50.942 niobium	51.996	54.938 technetium	55.845 ruthenium	58.933 rhodium	58.693 palladium	63.546	65.39	69.723 indium	72.61	74.922	78.96	79,904 iodine	83.80 xenon
37	38		39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Rb	Sr		Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Те	I.I.	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	71	hafnium 72	tantalum 73	74	rhenium 75	76	77	78	79	80	thallium 81	82	bismuth 83	84	astatine 85	radon 86
Cs	Ba	*	Lu	Hf	Та	W	Re	Os	Ir	Pt	Au	Hg	TL	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	103	rutherfordium 104	dubnium 105	seaborgium 106	bohrium 107	108	109	110	111	ununbium 112		114				
Fr	Ra	* *	Lr	Rf	Db	Sg	Bh	Hs	Mt		Uuu	Uub		Uuq				
[223]	[226]		[262]	[261]	[262]	[266]	[264]	[269]	[268]	[271]	[272]	[277]		[289]				

*Lanthanide series	Ianthanum 57 La	cerium 58 Ce	praseodymium 59 Pr	^{neodymium} 60 Nd	^{promethium} 61 Pm	62 Sm	europium 63 Eu	^{gadolinium} 64 Gd	65 Tb	^{dysprosium} 66 Dy	^{holmium} 67 HO	erbium 68 Er	^{thulium} 69 Tm	ytterbium 70 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
* * Actinide series	actinium 89	thorium 90	protactinium 91	uranium 92	neptunium 93	plutonium 94	americium 95	curium 96	berkelium 97	californium 98	einsteinium 99	fermium 100	mendelevium 101	nobelium 102
	Ac	Th	Pa	U	Np	Pu	Am	U	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 H						es de ys si			ously	<i>(</i>)								^{belium} 2 He
1.0079 lithium 3	beryllium 4	Г		IST	-								5 D	carbon 6	nitrogen 7	oxygen 8	fluorine 9	4.0026 neon 10
6.941	Be 9.0122		(or m	akes	s big	imp	rove	men	t)			B 10.811	12.011	N 14.007	O 15,999	F 18,998	Ne 20,180
sodium 11	magnesium 12		`			5.5				-/			13	silicon 14	phosphorus 15	sulfur 16	chlorine 17	argon 18
Na	Mg												AI	Si	Ρ	S	CI	Ar
22.990 potassium	24.305 calcium		scandium	titanium	vanadium	chromium	mondonese	iron	cobalt	nickel		zinc	26.982 gallium	28.086	30.974	32.065	35.453 bromine	39.948 krypton
19	20		21	22	23	24	manganese 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 rubidium	40.078 strontium		44.956 vttrium	47.867 zirconium	50.942 niobium	51,996	54.938 technetium	55.845 ruthenium	58.933 rhodium	58.693 palladium	63.546	65.39	69.723 indium	72.61	74.922	78.96	79.904 iodine	83.80
37	38		39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	xenon 54
Rb	Sr		Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Те	T	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	71	hafnium 72	tantalum 73	74	rhenium 75	76	77	78	79	80	thallium 81	82	bismuth 83	84	astatine 85	radon 86
Cs	Ba	×	Lu	Hf	Та	W	Re	Os	Ir	Pt	Au	Hg	TL	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	103	rutherfordium 104	dubnium 105	seaborgium 106	bohrium 107	108	109	110	111	ununbium 112		114				
Fr	Ra	* *	Lr	Rf	Db	Sg	Bh	Hs	Mt		Uuu			Uuq				
[223]	[226]	~ ~	[262]	[261]	[262]	[266]	[264]	[269]	[268]	[271]	[272]	[277]		[289]				

*Lanthanide series	Ianthanum 57 La	58 Ce	praseodymium 59 Pr	^{neodymium} 60 Nd	^{promethium} 61 Pm	^{samarium} 62 Sm	europium 63 Eu	^{gadolinium} 64 Gd	65 Tb	^{dysprosium} 66 Dy	^{holmium} 67 HO	erbium 68 Er	^{thulium} 69 Tm	ytterbium 70 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
**Actinide series	actinium 89	thorium 90	protactinium 91	uranium 92	neptunium 93	plutonium 94	americium 95	curium 96	berkelium 97	californium 98	einsteinium 99	fermium 100	mendelevium 101	nobelium 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 H					etime alwa				ously	<i>'</i>)								^{helium} 2 He
1.0079 lithium 3 Li 6.941 sodium	beryllium 4 Be 9.0122 magnesium	Γ			requ nakes		imp	rove	men	t)			5 B 10.811	carbon 6 C 12.011 silicon	nitrogen 7 N 14.007 phosphorus	oxygen 8 0 15,999 sulfur	fluorine 9 F 18.998 chlorine	4.0026 neon 10 Ne 20.180 argon
11 Na 22,990	12 Mg 24,305												13 AI 26.982	14 Si 28.086	15 P 30.974	16 S 32.065	17 CI 35.453	18 Ar 39.948
potassium 19	calcium 20		scandium 21	titanium 22	vanadium 23	chromium 24	manganese 25	iron 26	cobalt 27	nickel 28	29	zinc 30	gallium 31	32	33	34	bromine 35	krypton 36
K 39.098	Ca		SC	Ti 47.867	50.942	Cr	Mn 54,938	Fe	CO 58.933	Ni 58.693	Cu 63.546	Zn	Ga 69.723	Ge 72.61	As 74.922	Se 78.96	Br	Kr
rubidium 37	strontium 38		yttrium 39	zirconium 40	niobium 41	Horybuenum 42	technetium 43	ruthenium 44	rhodium 45	palladium 46	47	48	indium 49	50	51	52	iodine 53	xenon 54
Rb	Sr		Υ	Zr	Nb	Мо	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Те	1	Xe
85.468 caesium	87.62 barium		88,906 Tutetium	91.224 hafnium	92.906 tantaloni	95.94	[98] rhenium	101.07 05111011	102.91 Indium	106.42 praunum	107.87 gold	112.41	114.82 thallium	118.71 lead	121.76 bismuth	127.60	126.90 astatine	131.29 radon
55	56 Do	57-70 ★	71	72	73 T O	74 W	75 Do	76	77 Ir	78 Pt	79	80	81	82 Dh	Bi	84 Do	85	86 Dm
CS	Ba	*	LU 174.97	Hf	180.95	183.84	Re 186.21	OS 190.23	192.22	PL 195.08	AU 196.97	Hg	204.38	Pb	DI 208.98	PO		Rn
francium 87	radium 88	89-102	103	rutherfordium 104	105	seaborgium 106	bohrium 107	108	109	110	111	ununbium 112		114				
Fr	Ra	* *	Lr	Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuu	Uub		Uuq				

*Lanthanide series	^{lanthanum} 57 La	cerium 58 Ce	praseodymium 59 Pr	^{neodymium} 60 Nd	^{promethium} 61 Pm	62 Sm	europium 63 Eu	^{gadolinium} 64 Gd	65 Tb	^{dysprosium} 66 Dy	67 HO	erbium 68 Er	^{thulium} 69 Tm	ytterbium 70 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
* * Actinide series	actinium 89	thorium 90	protactinium 91	uranium 92	neptunium 93	plutonium 94	americium 95	curium 96	berkelium 97	californium 98	einsteinium 99	fermium 100	mendelevium 101	nobelium 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 H]						etecta multa		ously	<i>'</i>)								^{helium} 2 He
1.0079 lithium 3	beryflium 4 Be	Г		HST	requ	iired	_						5 B	carbon 6 C	nitrogen 7 N	oxygen 8 O	fluorine 9 F	4.0026 neon 10 Ne
6.941	9.0122		(or m	lakes	s big	imp	rove	men	t)			10.811	12.011	14.007	15.999	18.998	20.180
sodium 11	magnesium 12					Ū	•						13	silicon 14	15	sulfur 16	chlorine 17	argon 18
Na 22,990	Mg												AI 26,982	Si	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	29	zinc 30	gallium 31	germanion 32	33	34	bromine 35	krypton 36
K	Ca		Sc	Ťi	Ň	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
rubidium 37	strontium 38		yttrium 39	zirconium 40	niobium 41	42	technetium 43	ruthenium 44	rhodium 45	palladium 46	47	48	indium 49	50	51	52	iodine 53	xenon 54
Rb	Sr		Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Те	I.	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	71	hafnium 72	73	74	rhenium 75	76	77	78	79	80	thallium 81	82	bismuth 83	84	astatine 85	radon 86
Cs	Ba	*	Lu	Hf	Та	W	Re	Os	Ir	Pt	Au	Hg	TL	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	103	rutherfordium 104	105	106	bohrium 107	108	109	110	111	ununbium 112		114				
Fr	Ra	* *	Lr	Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuu	Uub		Uuq				
[223]	[226]		[262]	[261]	[262]	[266]	[264]	[269]	[268]	[271]	[272]	[277]		[289]				

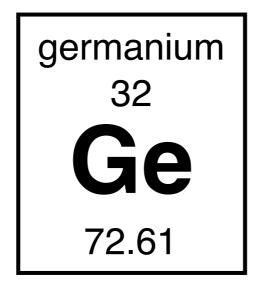
*Lanthanide series	^{Ianthanum} 57 La	cerium 58 Ce	praseodymium 59 Pr	^{neodymium} 60 Nd	^{promethium} 61 Pm	62 Sm	europium 63 Eu	^{gadolinium} 64 Gd	65 Tb	^{dysprosium} 66 Dy	^{holmium} 67 HO	^{erbium} 68 Er	^{thulium} 69 Tm	ytterbium 70 Yb
	138.91	140.12	140.91	144.24	[145]	150.36	151.96	157.25	158.93	162.50	164.93	167.26	168.93	173.04
* * Actinide series	actinium 89	thorium 90	protactinium 91	uranium 92	neptunium 93	plutonium 94	americium 95	curium 96	berkelium 97	californium 98	einsteinium 99	fermium 100	mendelevium 101	nobelium 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]

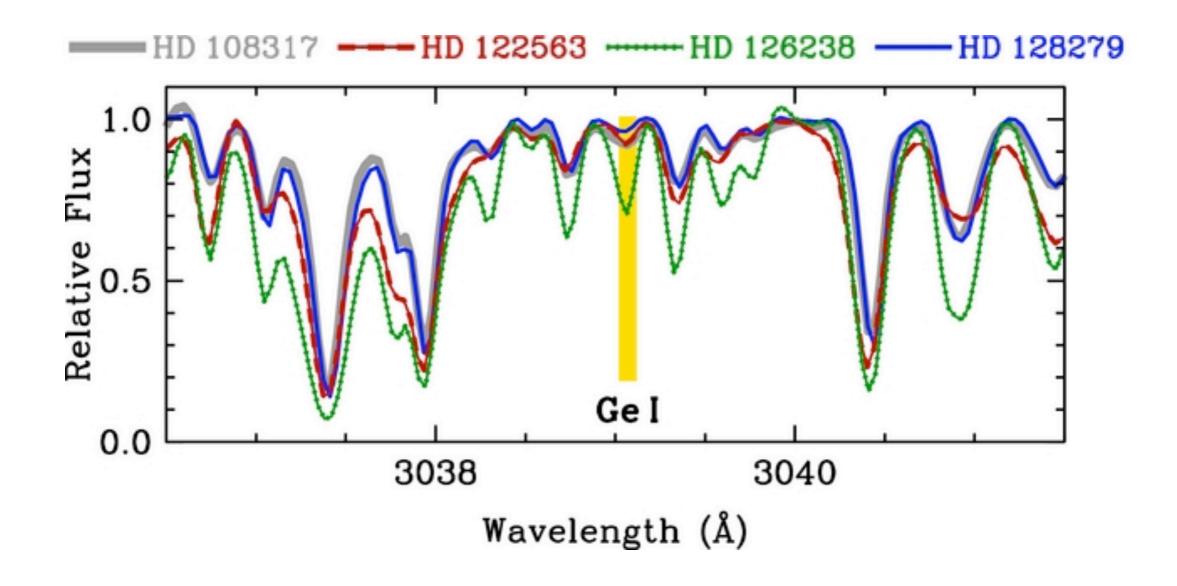
hydrogen 1 H							etecta mult		ously	<i>r</i>)								2 He
1.0079 lithium 3 Li 6.941	beryllium 4 Be 9.0122				requ lakes		imp	rove	men	t)			5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 0 15.999	fluorine 9 F 18.998	4.0026 neon 10 Ne 20.180
sodium 11	magnesium 12		`			U	•			,			13	silicon 14	15	sulfur 16	chlorine 17	argon 18
Na 22,990	Mg												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	29	zinc 30	gallium 31	germanion 32	33	32,005 Seleman 34	bromine 35	krypton 36
K	Ca		Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
39.098 rubidium	40.078 strontium		44.956 yttrium	47.867 zirconium	50.942 niobium	51.996 norybaenan	54.938 technetium	55.845 ruthenium	58.933 rhodium	58.693 palladium	63,546	65.39 caunnum	69.723 indium	72.61	74.922	78.96	79,904 iodine	83.80 xenon
37	38		39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Rb	Sr		Y	Zr	Nb	Мо	Тс	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Те		Xe
85.468 caesium	87.62 barium		88.906 Iutetuni	91.224 hafnium	92.906 tantatom	95.94	[98]	101.07 osmium	102.91 Incium	106.42 praunum	107.87 gold	112.41	114.82 thallium	118.71 lead	121.76 bismuth	127.60	126.90 astatine	131.29 radon
55	56	57-70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
Cs	Ba	*	Lu	Hf	Та	W	Re	Os	lr	Pt	Au	Hg	TL	Pb	Bi	Po	At	Rn
132.91 francium	137.33 radium		174.97	178.49 rutherfordium	180.95	183.84	186.21	190.23	192.22	195.08	196.97	200.59 ununbium	204.38	207.2	208.98	[209]	[210]	[222]
87	88	89-102	103	104	105	106	107	108	109	110	111	112		114				
Fr	Ra	* *	Lr	Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuu	Uub		Uuq				
[223]	[226]		[262]	[261]	[262]	[266]	[264]	[269]	[268]	[271]	[272]	[277]		[289]				

*Lanthanide series	Ianthanum 57 La	58 Ce	praseodymium 59 Pr	^{neodymium} 60 Nd	^{promethium} 61 Pm	^{samarium} 62 Sm	europium 63 Eu	^{gadolinium} 64 Gd	terbium 65 Tb	dysprosium 66 Dy	^{holmium} 67 HO	erbium 68 Er	^{thulium} 69 Tm	ytterblum 70 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
Sector and the sector she will be an an and	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
. "SIGNED AND SAFETY SAF	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]

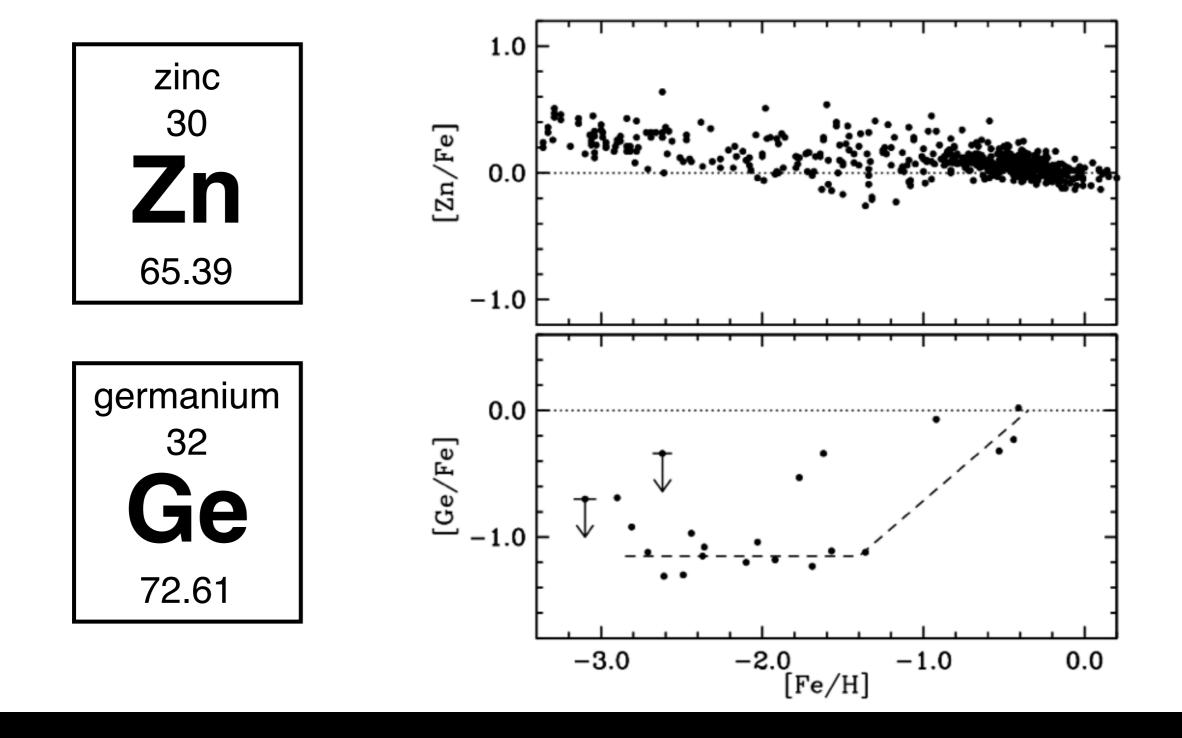
hydrogen 1 H		sometimes detectable (not always simultaneously)														2 He		
1.0079 lithium 3 Li 6.941 sodium	beryllium 4 Be 9.0122 macmosium	HST required (or makes big improvement)												carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 0 15.999	fluorine 9 F 18.998 chlorine	4.0026 neon 10 Ne 20.180
11 Na	12 Mg	13 14 15 16 17 Al Si P S Cl												17	18 Ar			
22.990 potassium 19	24.305 calcium 20		scandium 21	titanium 22	vanadium 23	chromium 24	manganese 25	iron 26	cobalt 27	nickel 28	29	zinc 30	26.982 gallium 31	28.086 gernamori 32	30.974 33	32.065 Selenium 34	35.453 bromine 35	39.948 krypton 36
K	Ca 40.078		Sc 44.956	Ti 47.867	50.942	Cr	Mn 54,938	Fe 55,845	Co 58.933	Ni 58.693	Cu 63.546	Zn	Ga 69.723	Ge 72.61	As 74.922	Se 78.96	Br	Kr 83.80
39.098 rubidium 37	strontium 38		44.956 yttrium 39	zirconium 40	niobium 41	noiybdenun 42	technetium 43	ruthenium 44	rhodium 45	palladium 46	47	65.39 caumium 48	indium 49	50	51	52	iodine 53	xenon 54
Rb	Sr		Y	Zr	Nb	Мо	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Те	Ĩ	Xe
85.468 caesium	87.62 barium		88.906 Tutetiuni	91.224 hafnium	92.906	95.94	[98]	101.07	102.91	106.42	107.87	112.41	114.82 thallium	118.71 Jean	121.76	127.60	126.90 astatine	131.29 radon
55	56	57-70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
Cs	Ba	*	Lu	Hf	Та	W	Re	Os	lr	Pt	Au	Hg	TI	Pb	Bi	Po	At	Rn
132.91 francium	137.33 radium		174.97	178.49 rutherfordium	180.95	183.84	186.21	190.23	192.22	195.08	196.97	200.59 ununbium	204.38	207.2	208.98	[209]	[210]	[222]
87	88	89-102	103	104	105	106	107	108	109	110	111	112		114				
Fr	Ra	* *	Lr	Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuu	Uub		Uuq				
[223]	[226]		[262]	[261]	[262]	[266]	[264]	[269]	[268]	[271]	[272]	[277]		[289]				

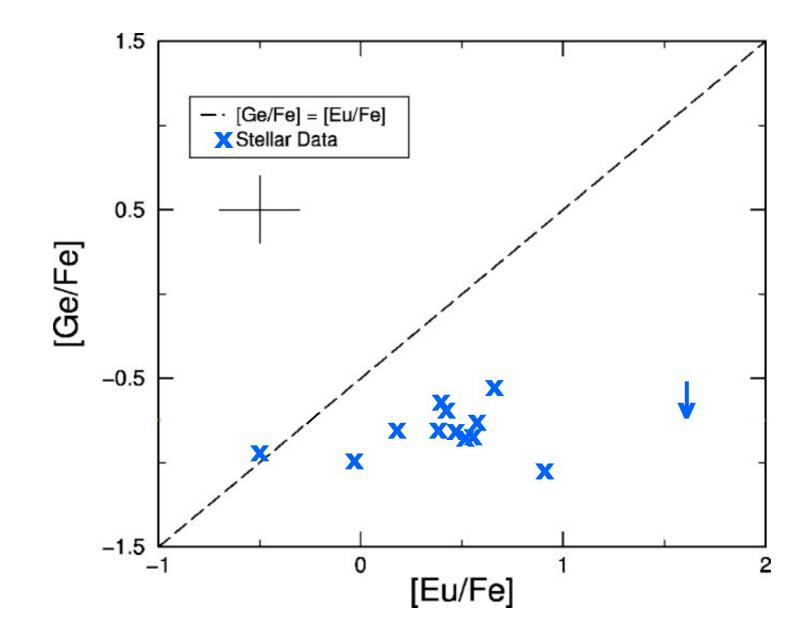
*Lanthanide series	Ianthanum 57 La	58 Ce	praseodymium 59 Pr	^{neodymium} 60 Nd	^{promethium} 61 Pm	62 Sm	europium 63 Eu	^{gadolinium} 64 Gd	terbium 65 Tb	dysprosium 66 Dy	67 Ho	erbium 68 Er	^{thulium} 69 Tm	ytterblum 70 Yb
	138.91	140.12	140.91	144.24	[145]	150.36	151.96	157.25	158.93	162.50	164.93	167.26	168.93	173.04
* * Actinide series	actinium 89	thorium 90	protactinium 91	uranium 92	neptunium 93	plutonium 94	americium 95	curium 96	berkelium 97	californium 98	einsteinium 99	fermium 100	mendelevium 101	nobelium 102
Actinide series	_	90		92	95		95		A. 8 (1997)	90	99	100		102
 Include enclosed same PC PT LL PC PORCED/DVPC 	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]



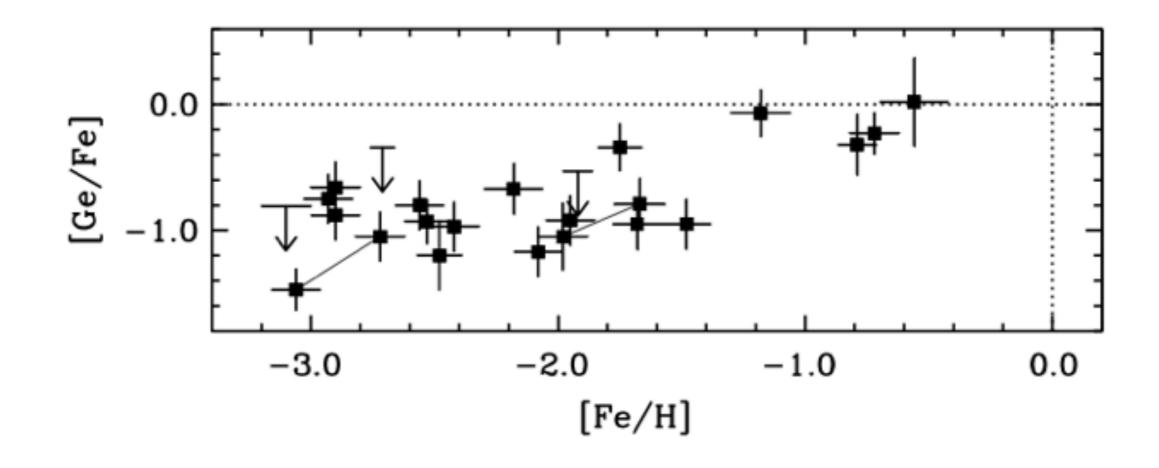


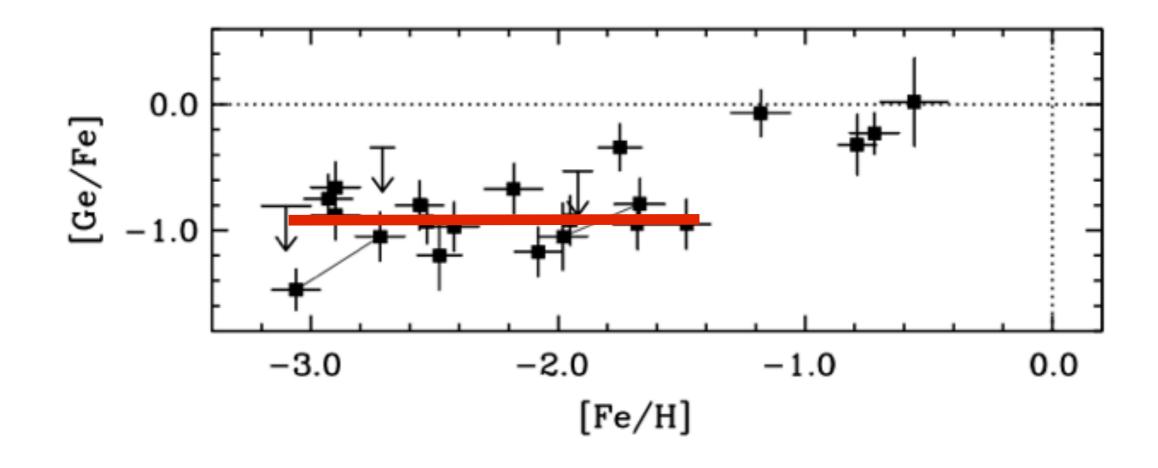
Roederer et al., Astrophys. J. Sup. Ser., 203, 27 (2012)

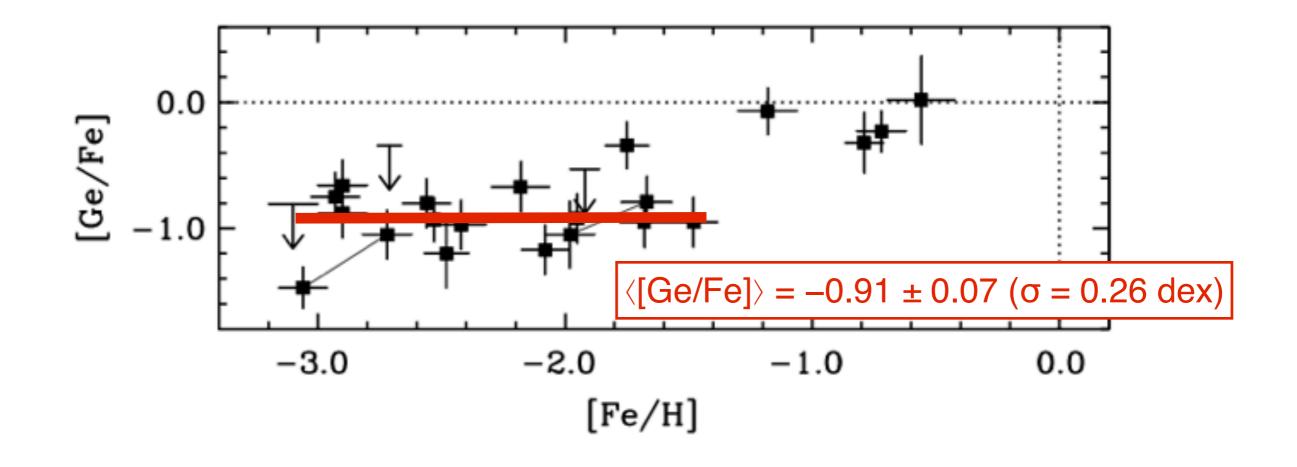


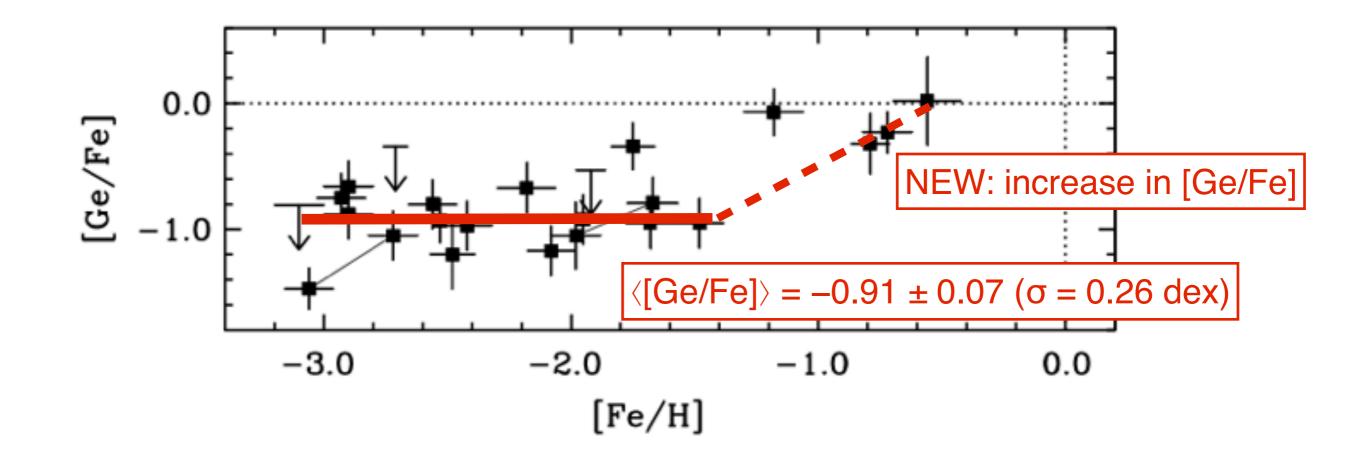


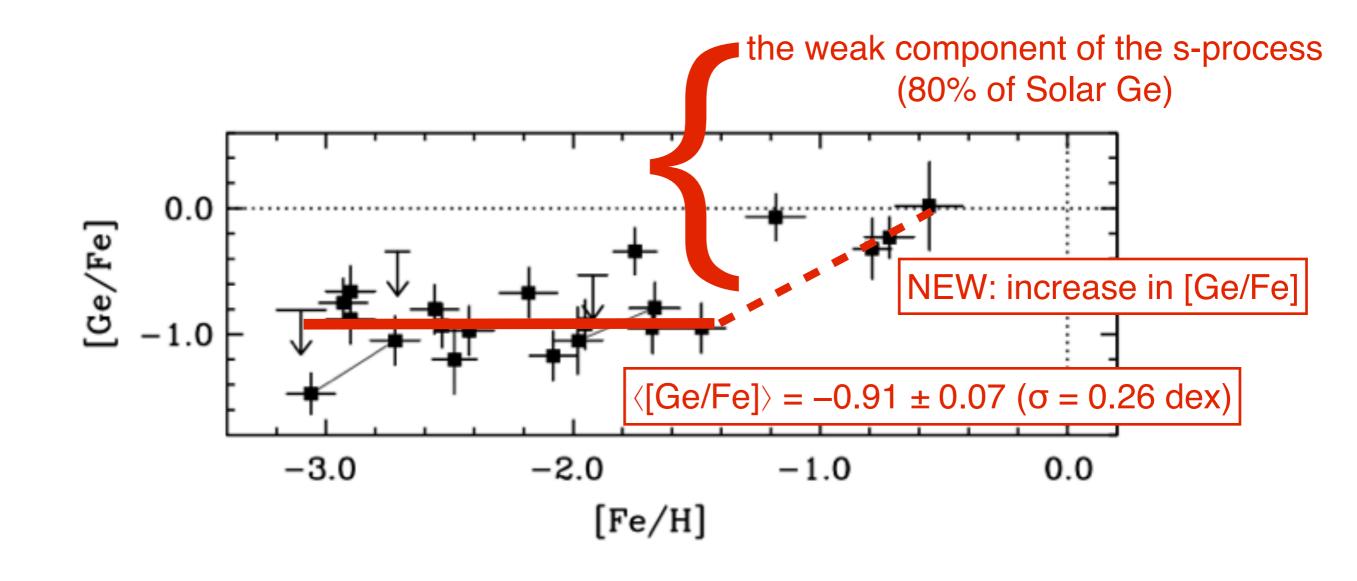
updated from Cowan et al., Astrophys. J., 627, 238 (2005)

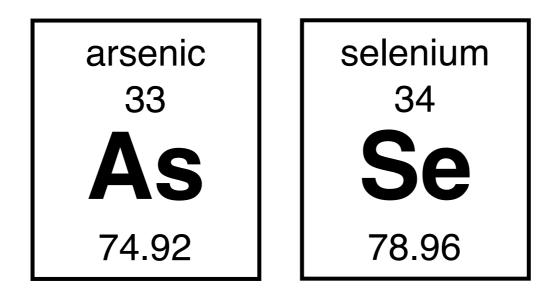


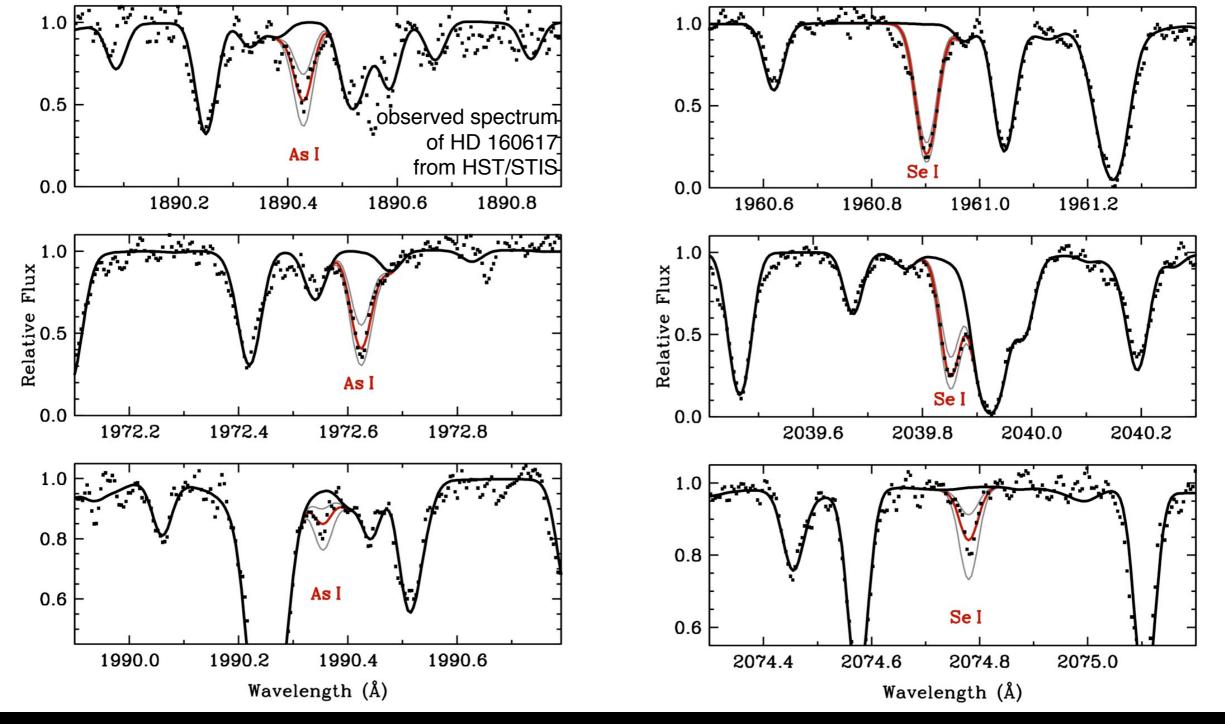




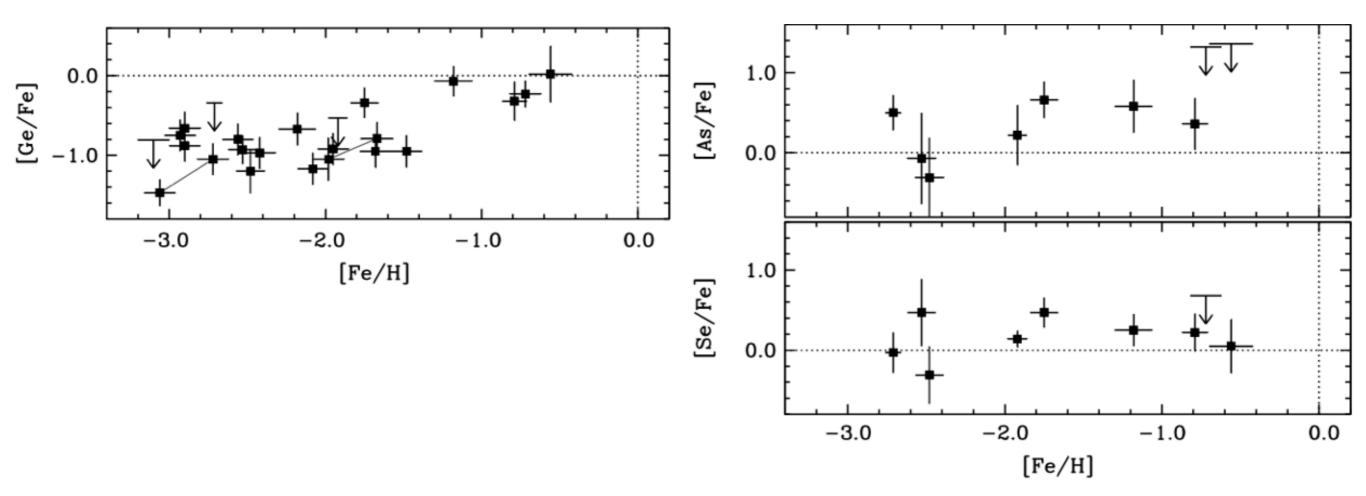




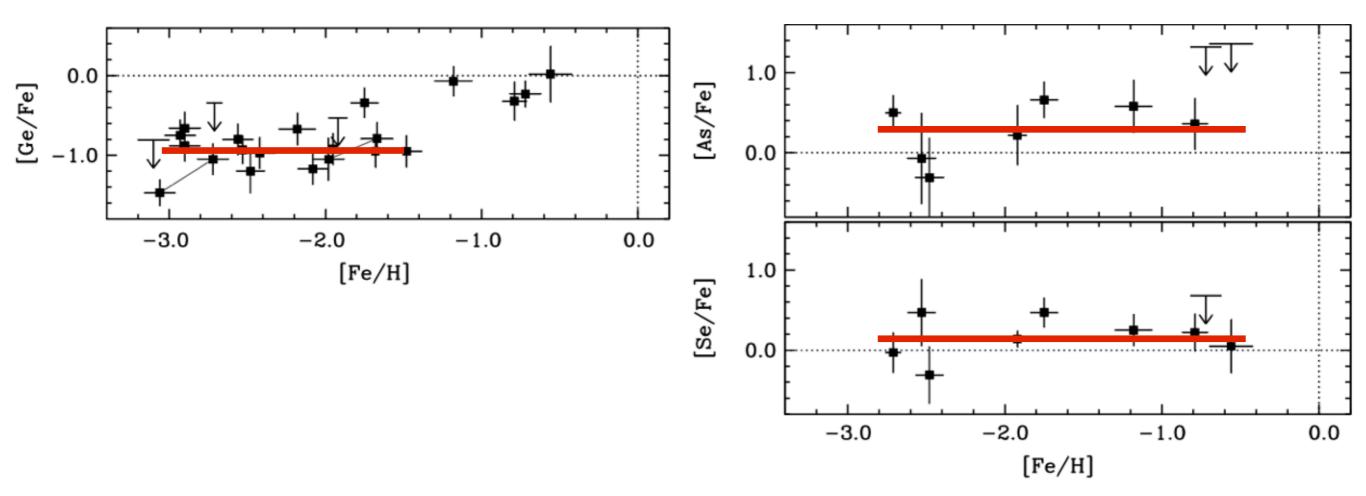




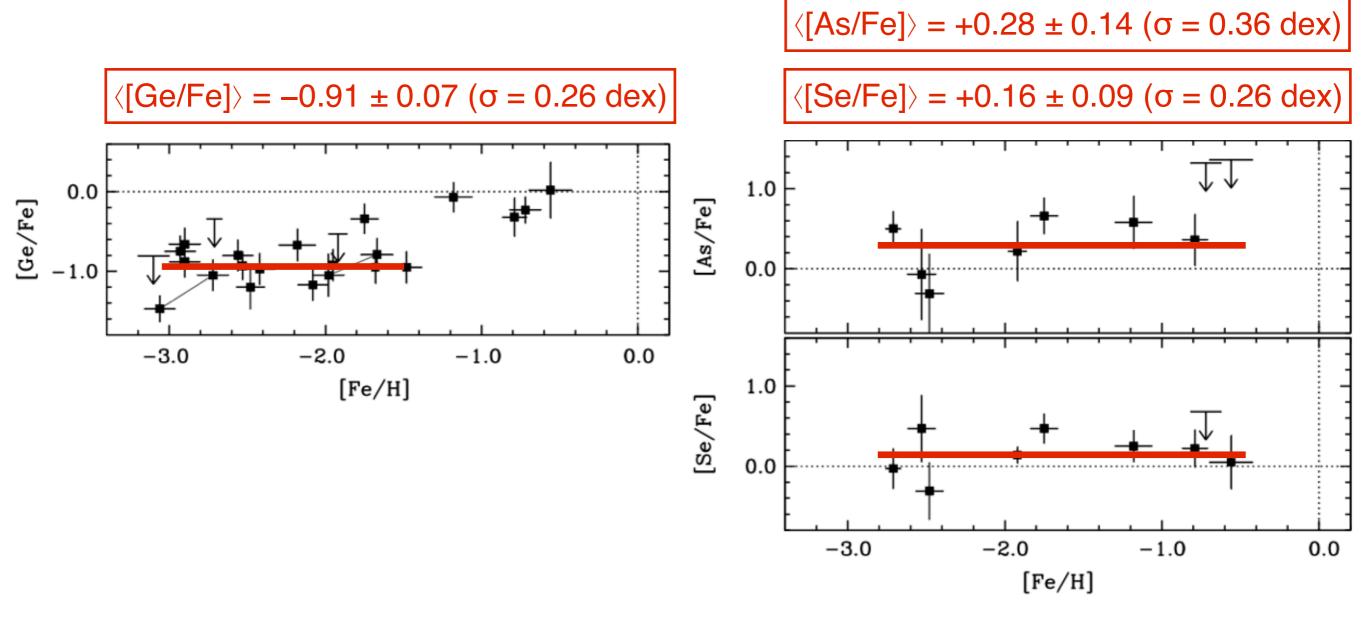
Roederer & Lawler, Astrophys. J., 750, 76 (2012)



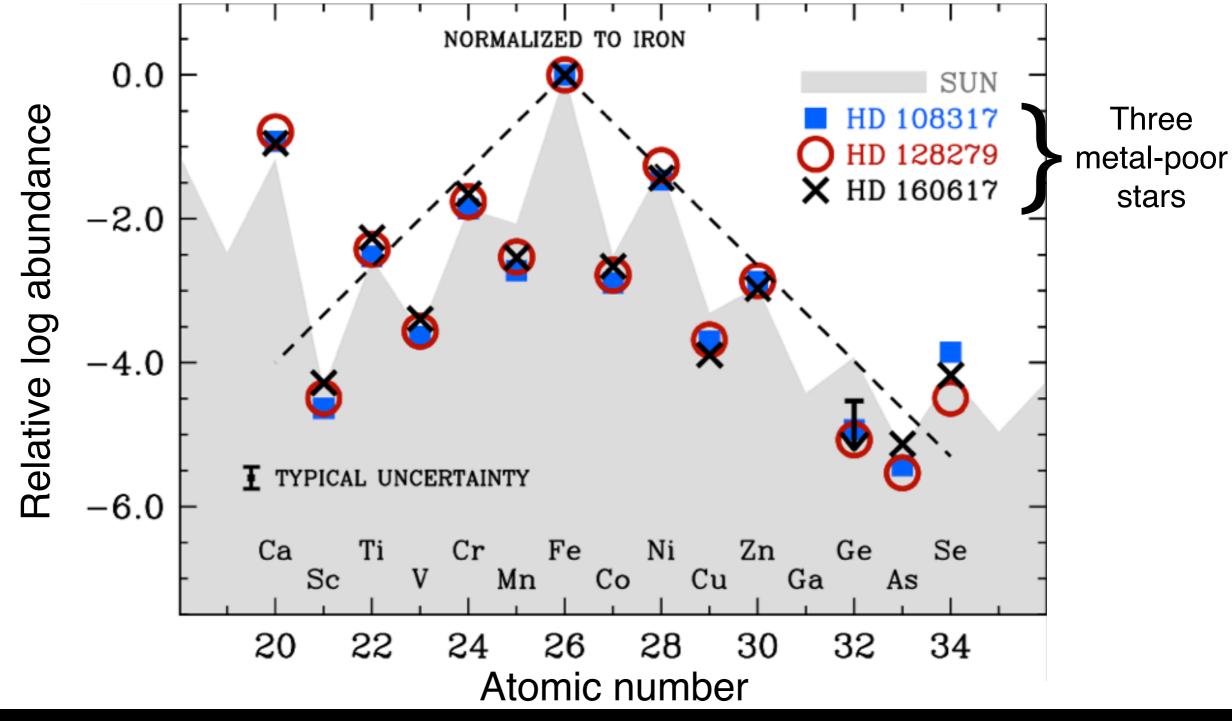
Roederer et al., Astrophys. J., 791, 32 (2014)



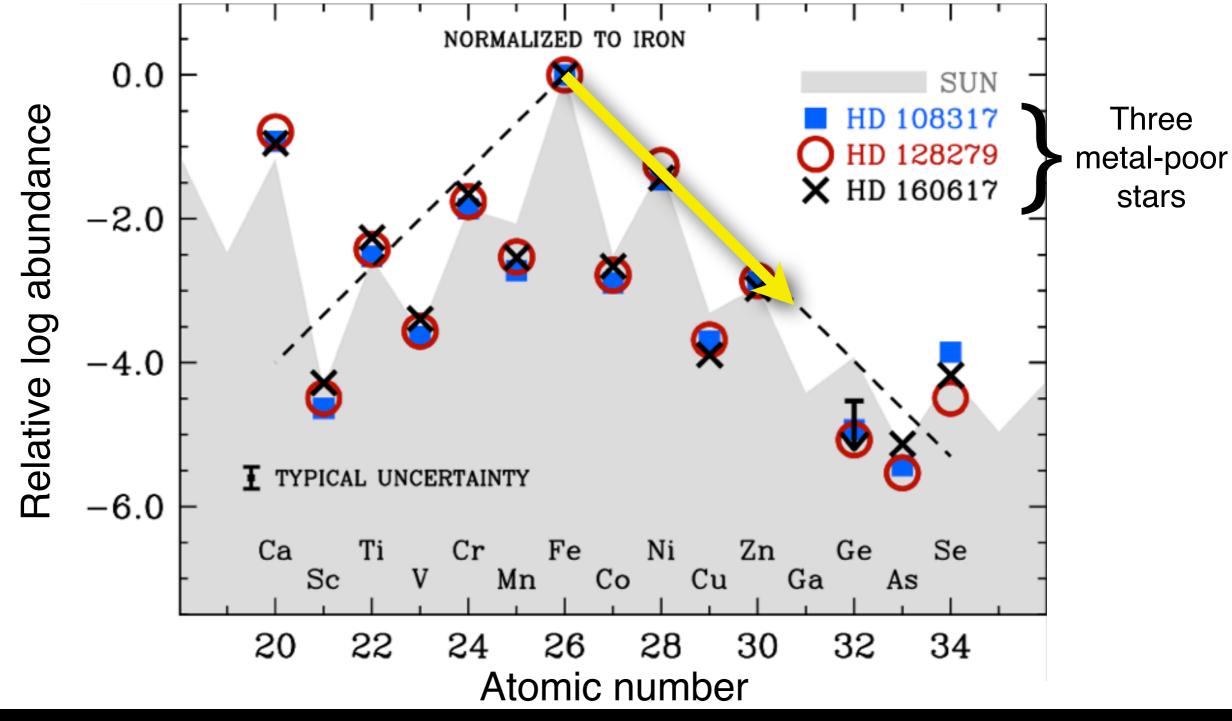
Roederer et al., Astrophys. J., 791, 32 (2014)



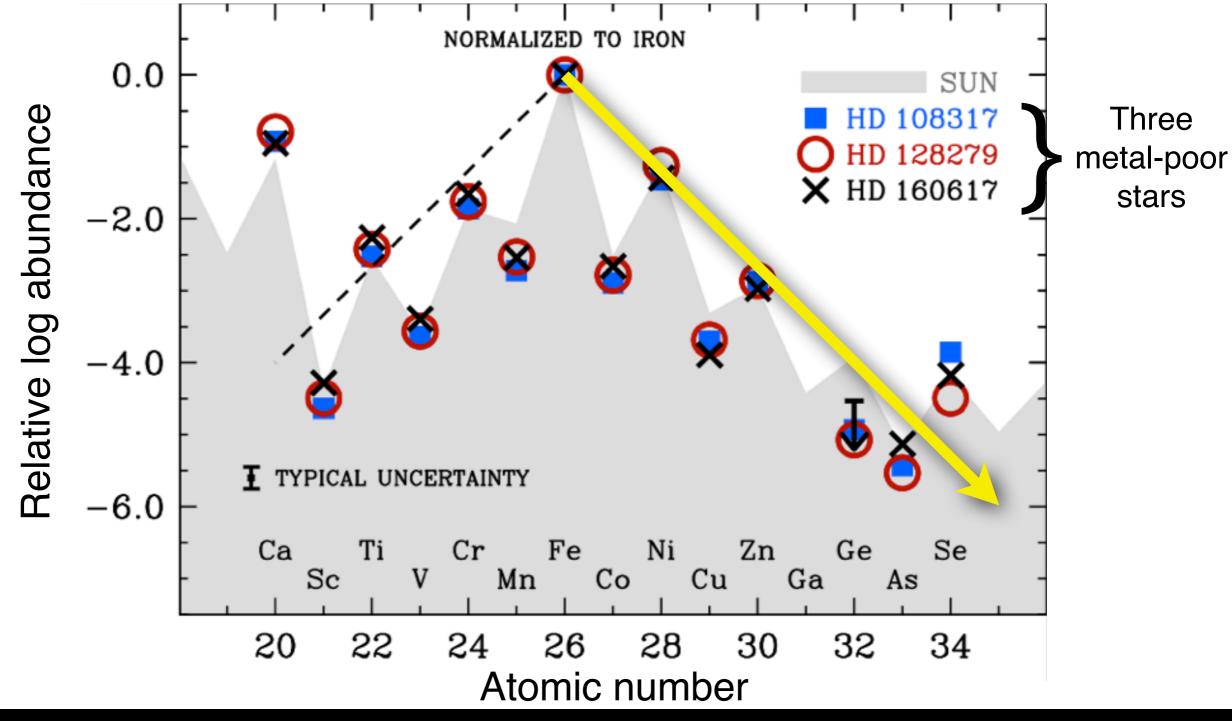
Roederer et al., Astrophys. J., 791, 32 (2014)



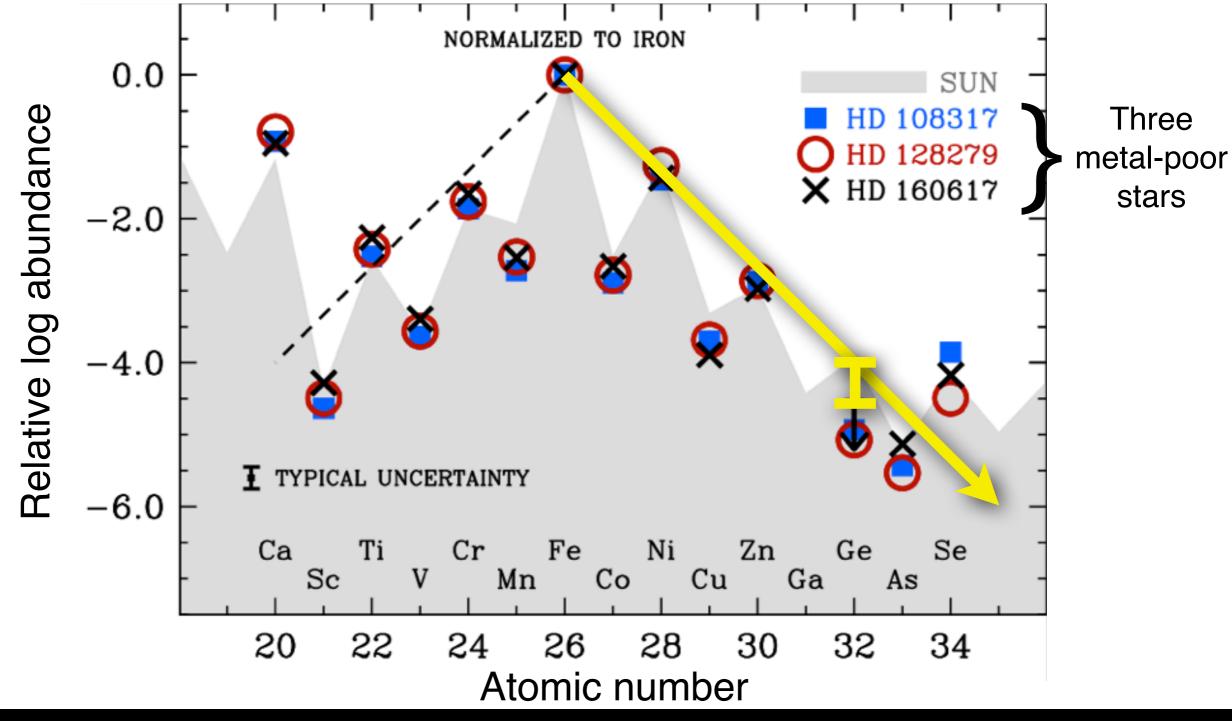
Roederer et al., Astrophys. J., 791, 32 (2014)



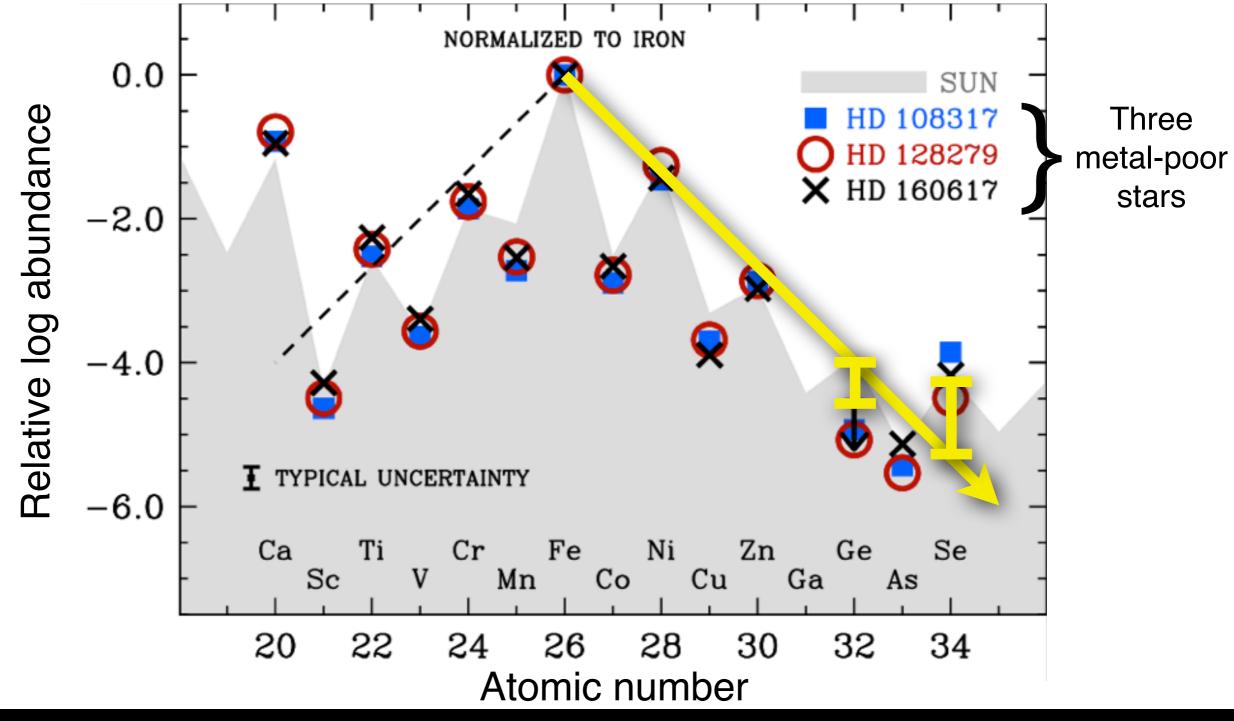
Roederer et al., Astrophys. J., 791, 32 (2014)



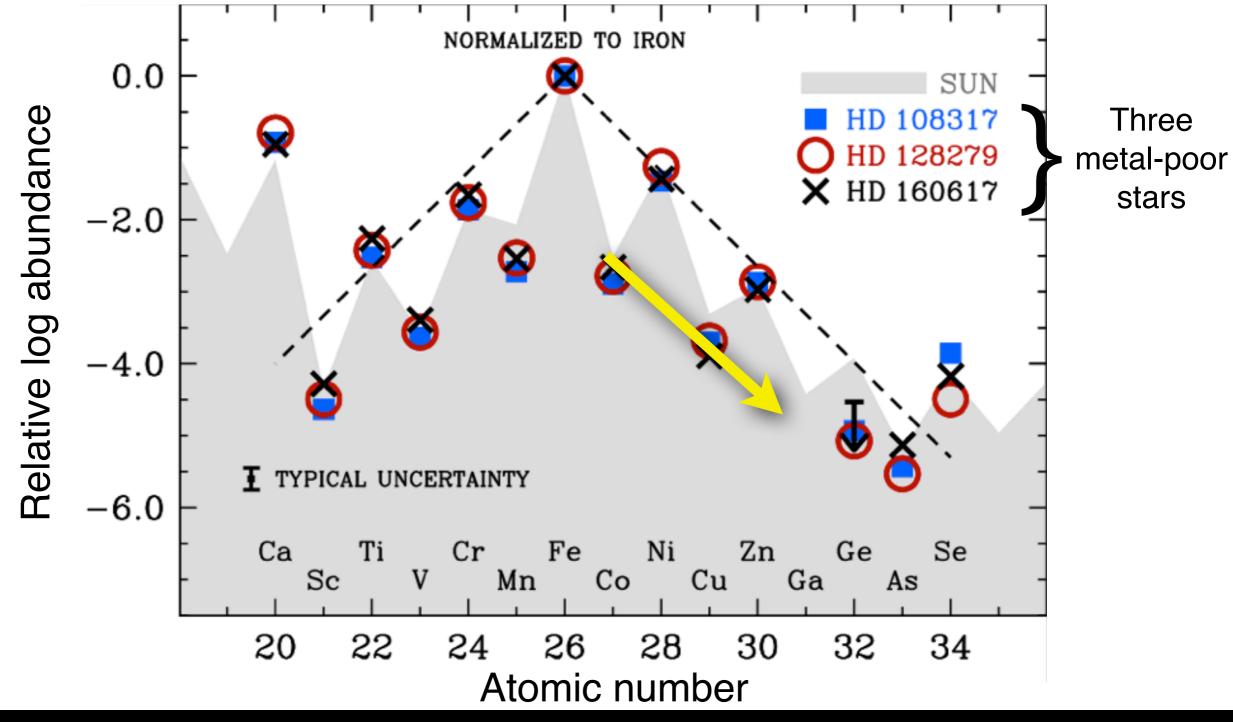
Roederer et al., Astrophys. J., 791, 32 (2014)



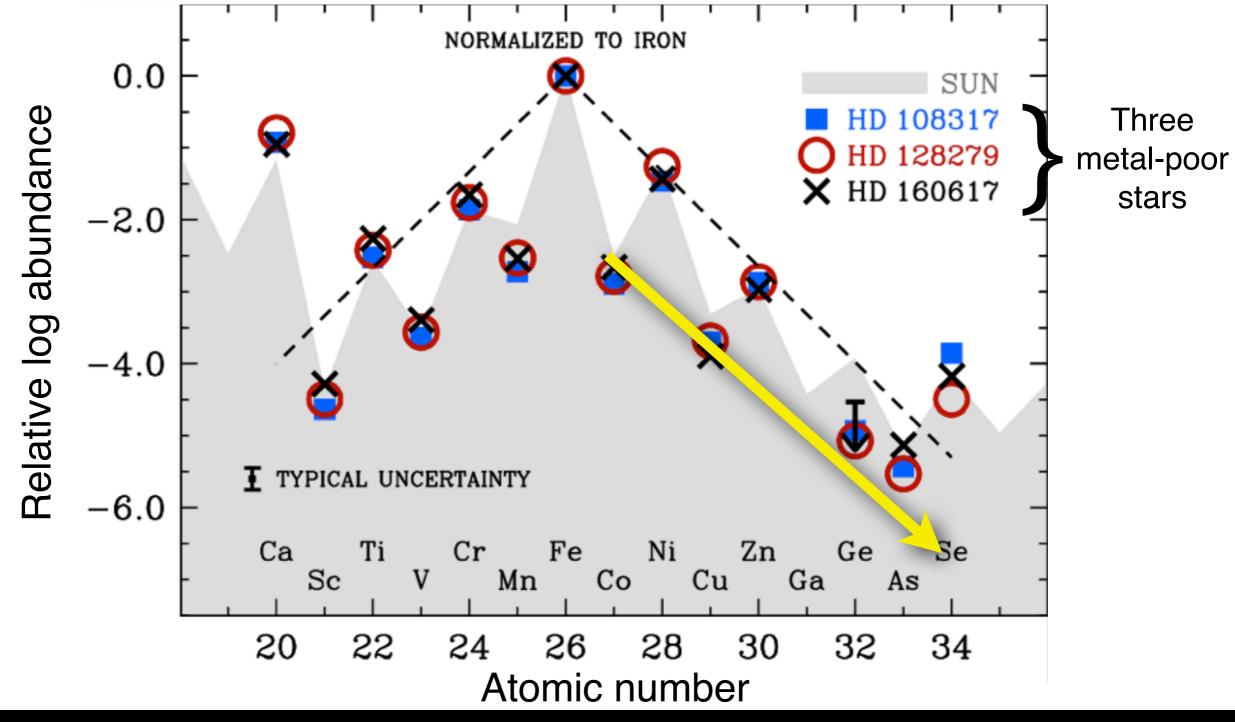
Roederer et al., Astrophys. J., 791, 32 (2014)



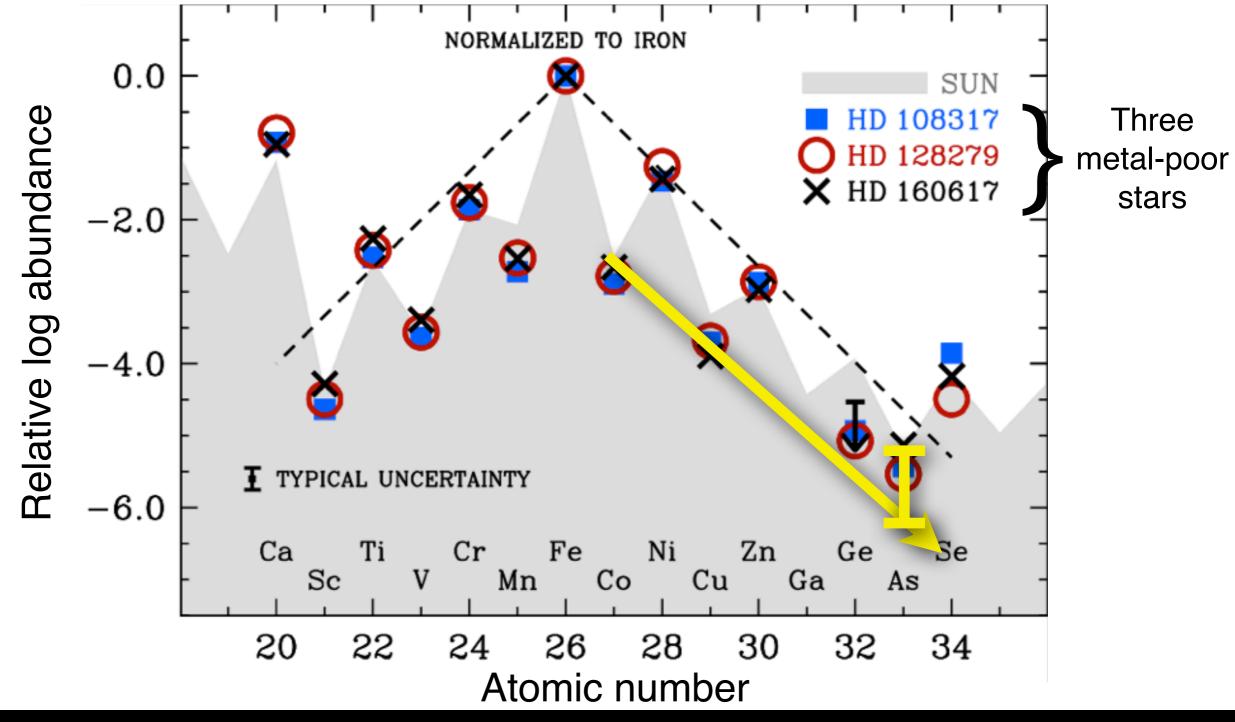
Roederer et al., Astrophys. J., 791, 32 (2014)



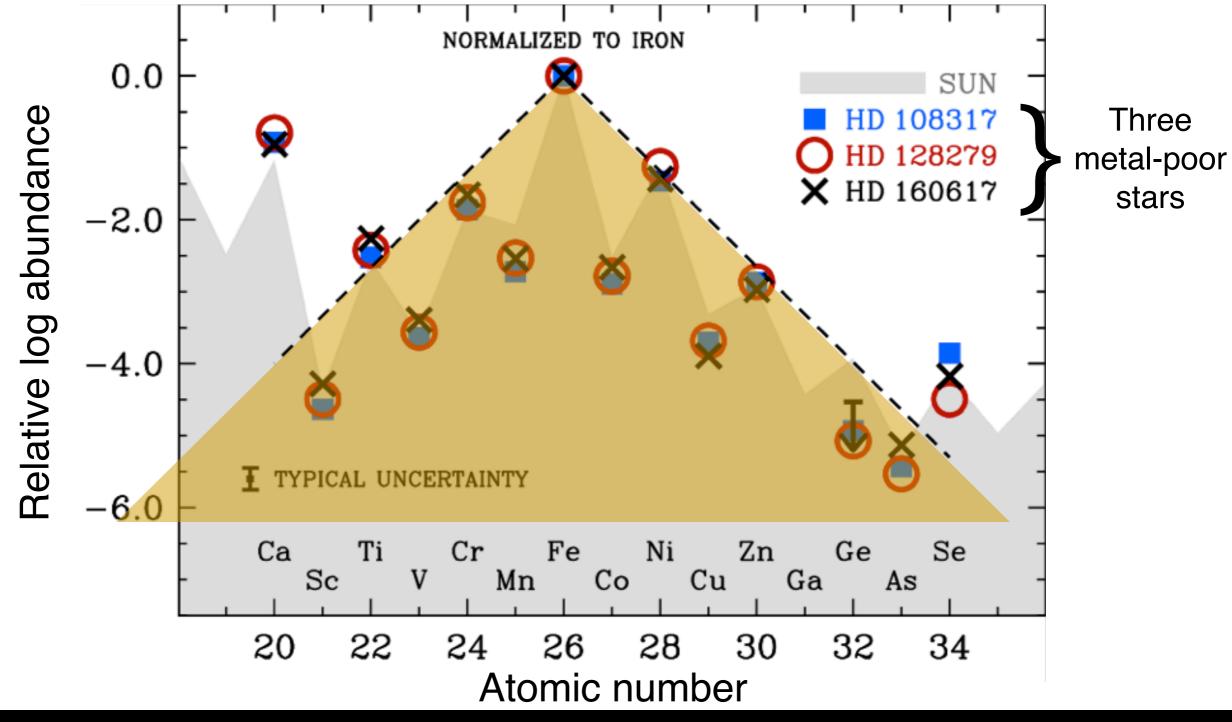
Roederer et al., Astrophys. J., 791, 32 (2014)



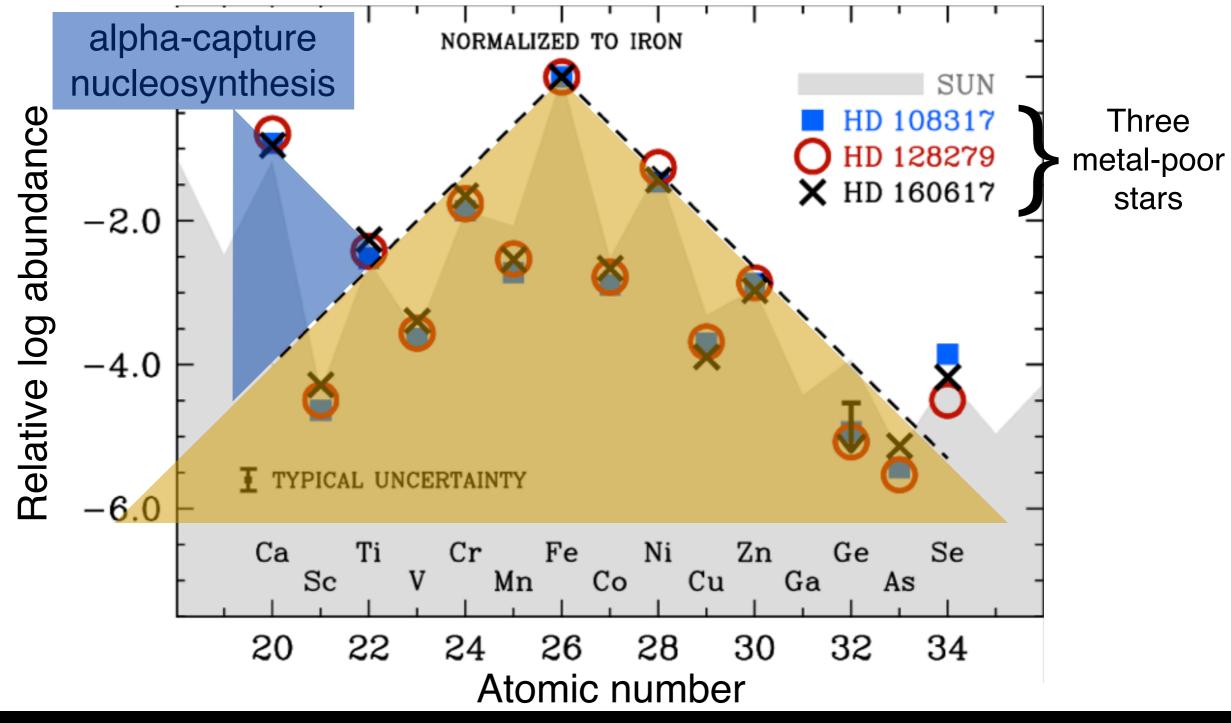
Roederer et al., Astrophys. J., 791, 32 (2014)



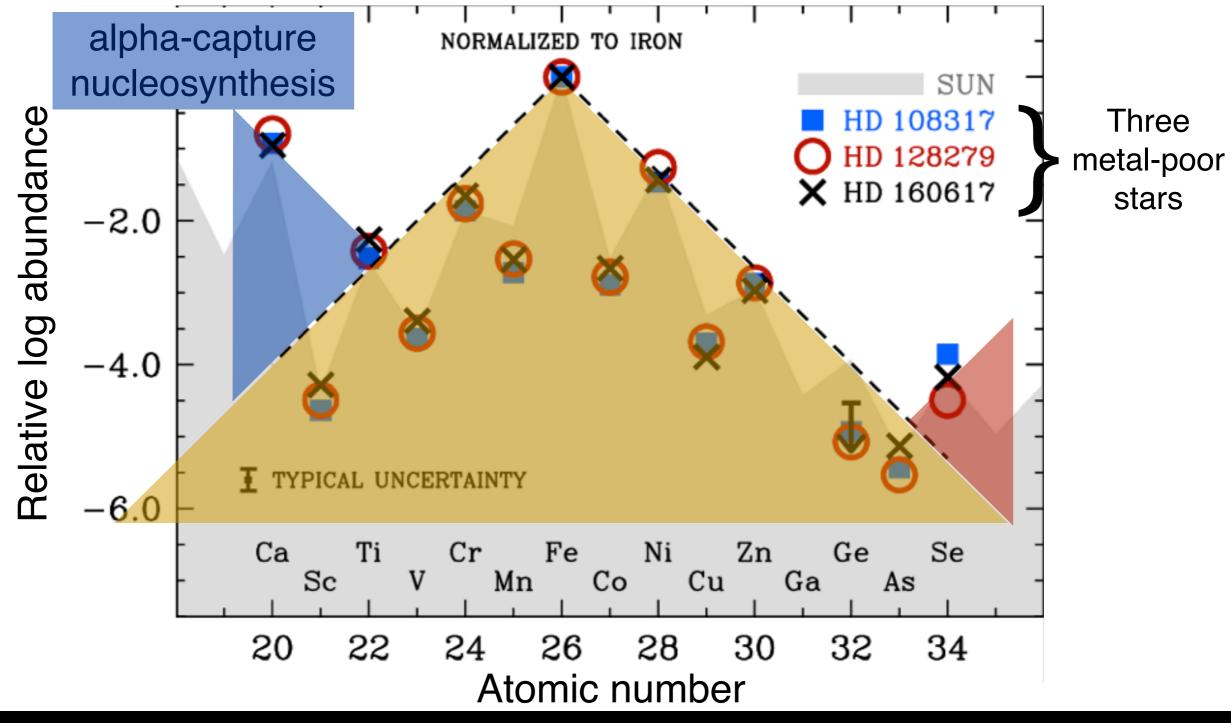
Roederer et al., Astrophys. J., 791, 32 (2014)



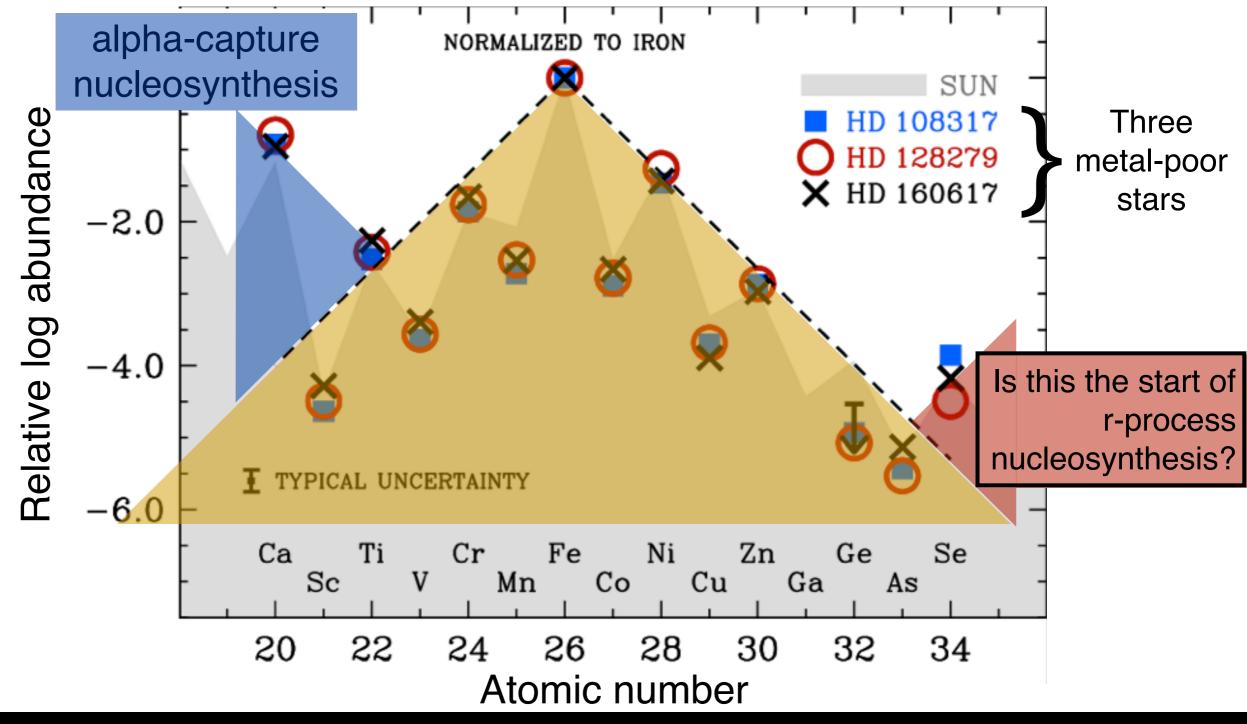
Roederer et al., Astrophys. J., 791, 32 (2014)



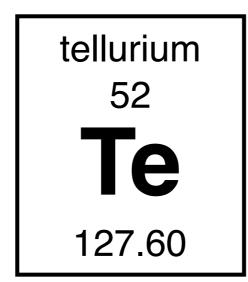
Roederer et al., Astrophys. J., 791, 32 (2014)

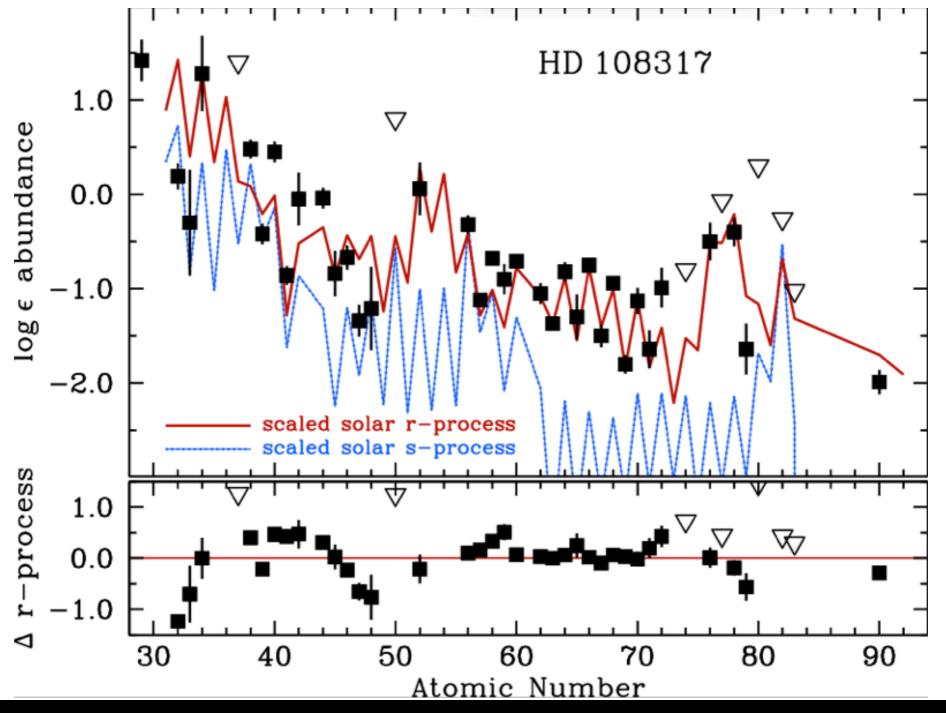


Roederer et al., Astrophys. J., 791, 32 (2014)

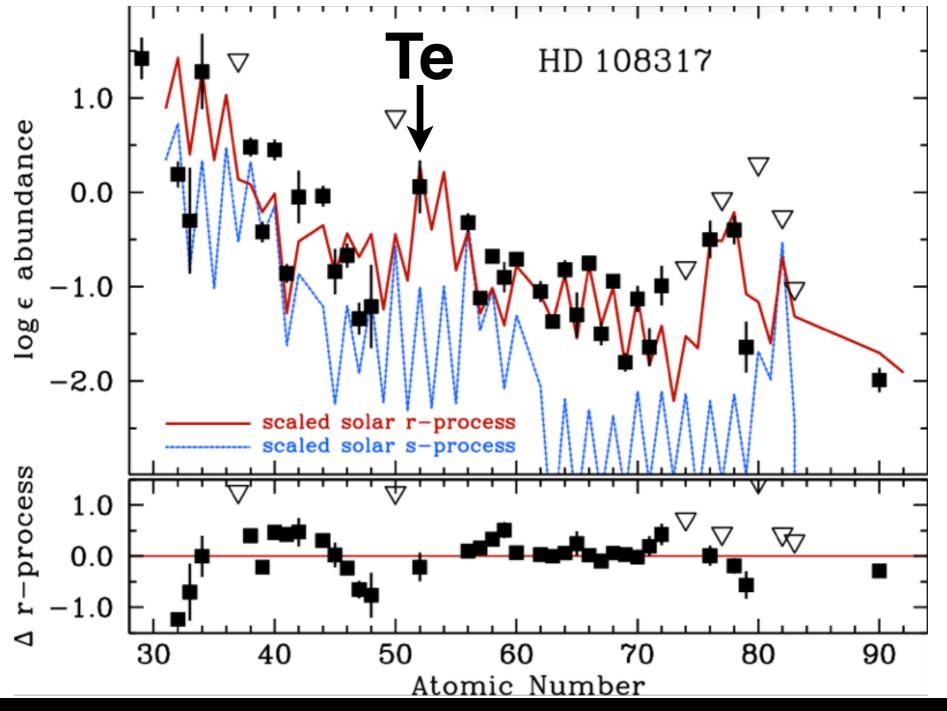


Roederer et al., Astrophys. J., 791, 32 (2014)

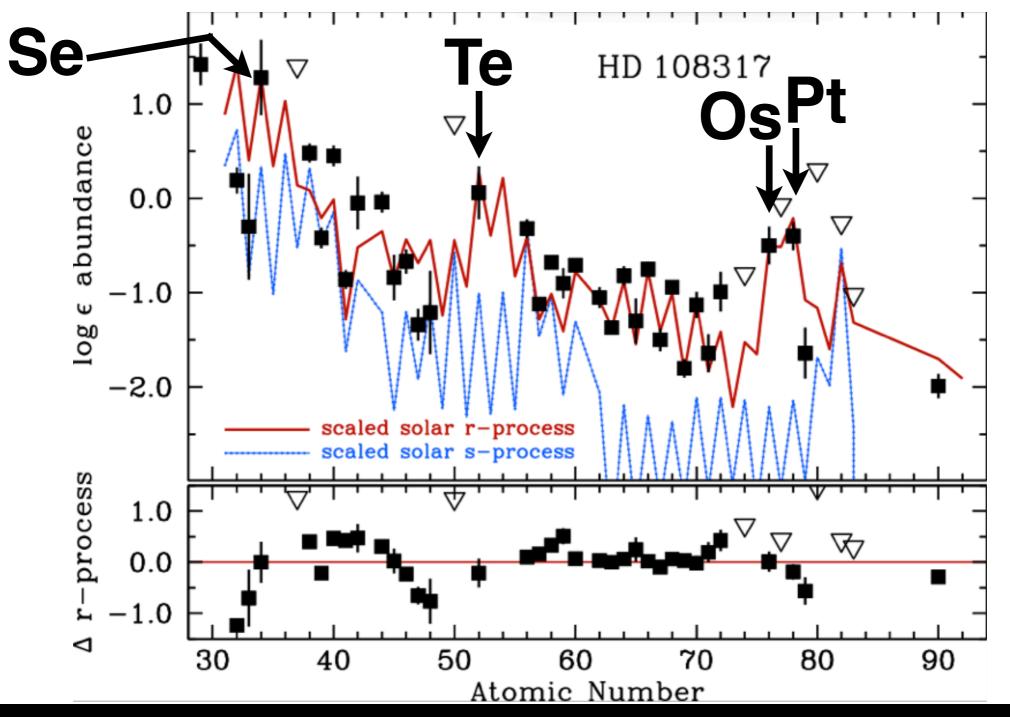




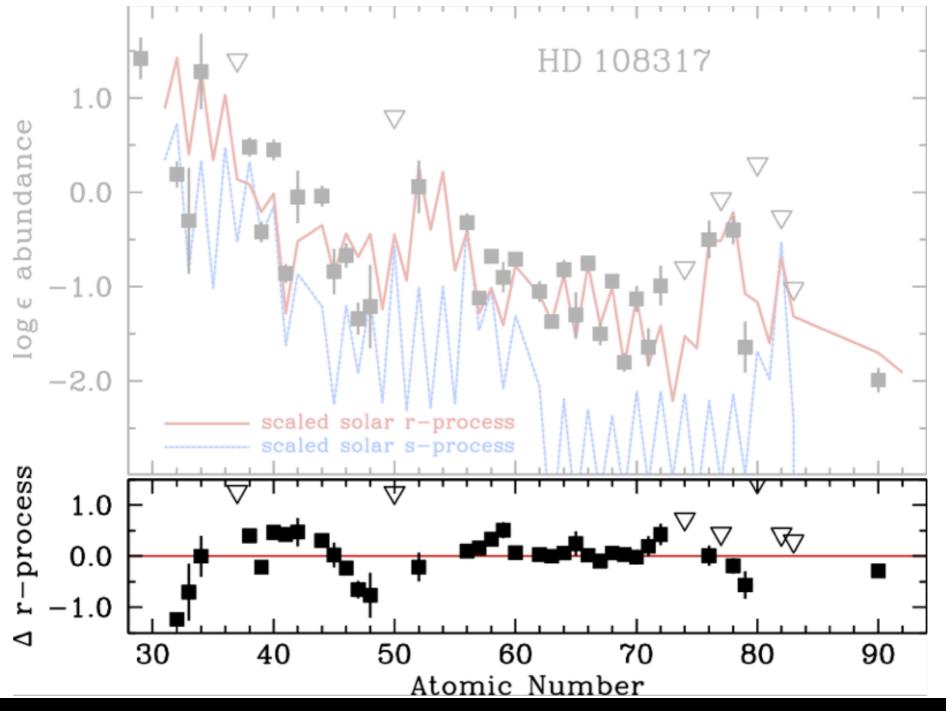
Roederer et al., Astrophys. J., 791, 32 (2014)



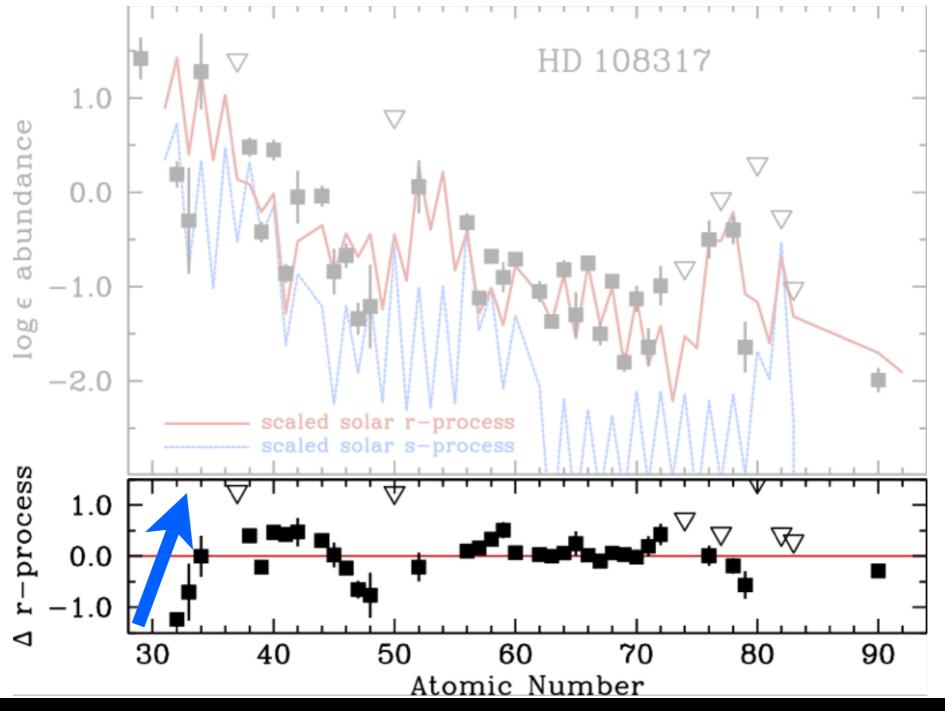
Roederer et al., Astrophys. J., 791, 32 (2014)



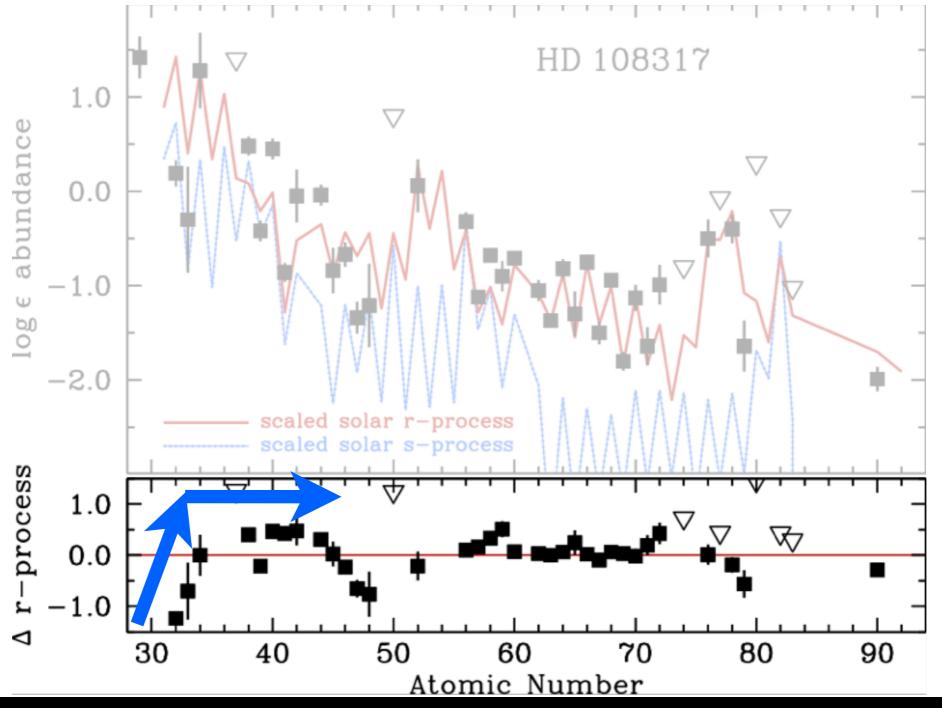
Roederer et al., Astrophys. J., 791, 32 (2014)



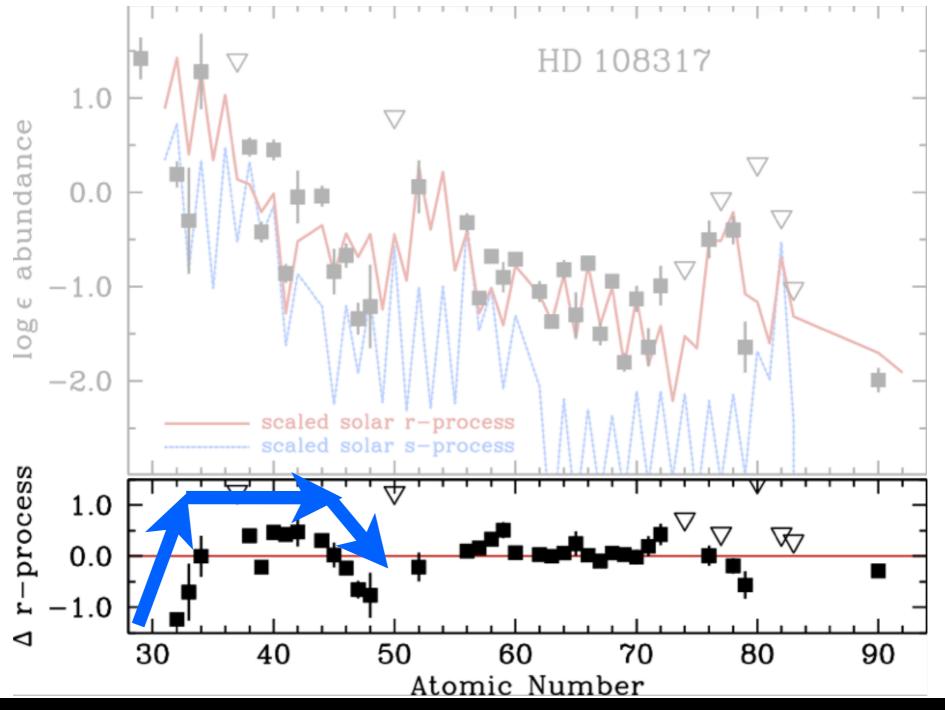
Roederer et al., Astrophys. J., 791, 32 (2014)



Roederer et al., Astrophys. J., 791, 32 (2014)



Roederer et al., Astrophys. J., 791, 32 (2014)



Roederer et al., Astrophys. J., 791, 32 (2014)

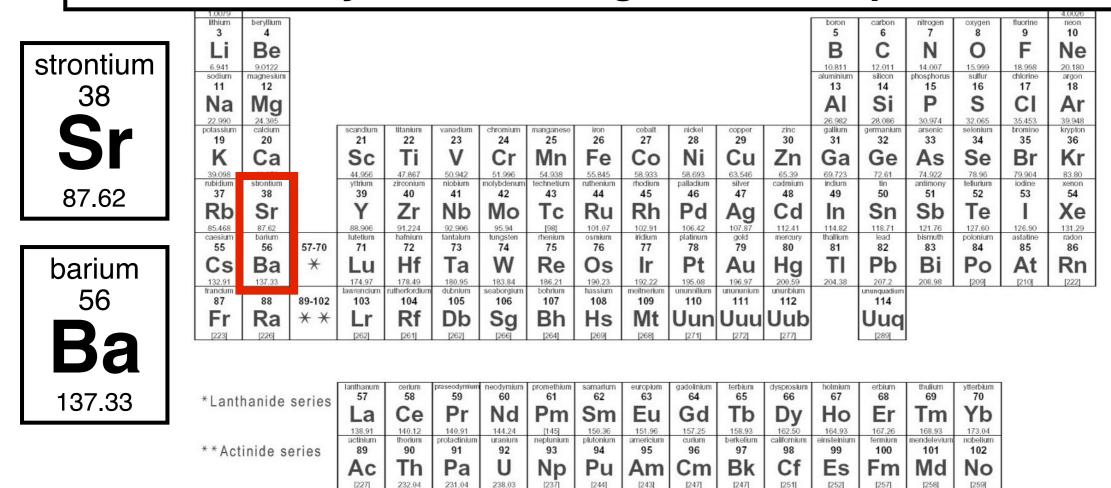
Some stars are highly enriched in neutron-capture elements.

Some stars are missing neutron-capture elements.

Some stars are missing neutron-capture elements...?

	1.0079	the second second second																	4.0026
	ithium	beryllium											ĺ	boron	carbon	nitrogen	oxygen	fluorine	neon
	3	4											I	5	6	7	8	9	10
	Li	Be												В	С	Ν	0	F	Ne
	6.941	9.0122												10.811	12.011	14.007	15.999	18.998	20.180
S	sodium	magnesium											I	aluminium	silicon	phosphorus	sulfur	chlorine	argon
	11	12											I	13	14	15	16	17	18
	Na	Mg												AI	Si	Ρ	S	CI	Ar
	22.990	24.305												26.982	28.086	30.974	32.065	35.453	39.948
po	tassium	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
	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
n	ubidium	strontium		yttrium	zirconium	niobium	molybdenum	technetium	ruthenium	rhodium	palladium	silver	cadmium	indium	tin	antimony	tellurium	iodine	xenon
	37	38		39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
	Rb	Sr		Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te		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
C	aesium	barium	F7 70	lutetium	hafnium	tantalum	tungsten	rhenium	osmium	iridium	platinum	gold	mercury	thallium	lead	bismuth	polonium	astatine	radon
	55	56	57-70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
	Cs	Ba	*	Lu	Hf	Та	W	Re	Os	lr	Pt	Au	Hg	TI	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]
fr	ancium	radium	00 400	lawrencium	rutherfordium	dubnium	seaborgium	bohrium	hassium	meitnerium	ununnilium	unununium	ununbium		ununquadium				
	87	88	89-102	103	104	105	106	107	108	109	110	111	112		114				
	Fr	Ra	* *	Lr	Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuu	Uub		Uuq				
	[223]	[226]		[262]	[261]	[262]	[266]	[264]	[269]	[268]	[271]	[272]	[277]		[289]				

*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
Lanthainue 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
	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]



Literature sample:

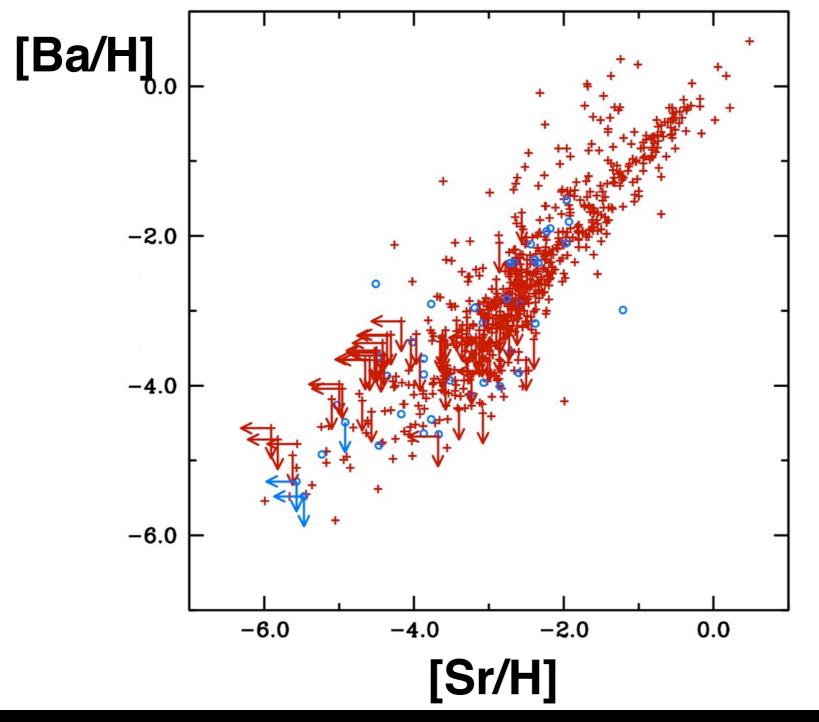
707 halo field stars

with
$$Z < \frac{1}{100} Z_{sun}$$
 ([Fe/H] < -2.0)

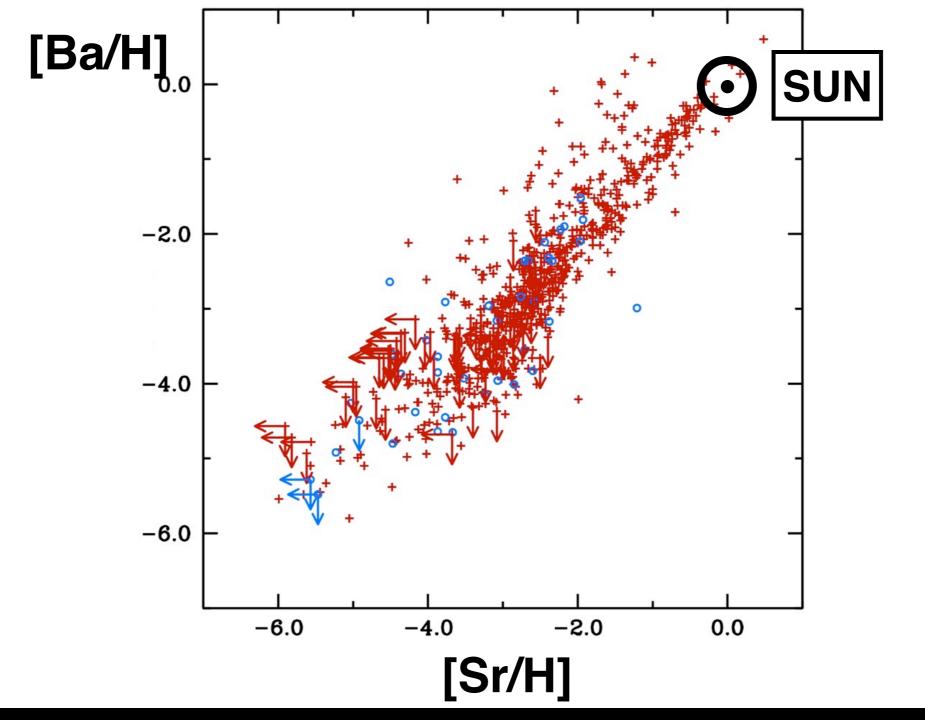
Literature sample:

707 halo field stars 69 stars in Local Group dwarf galaxies

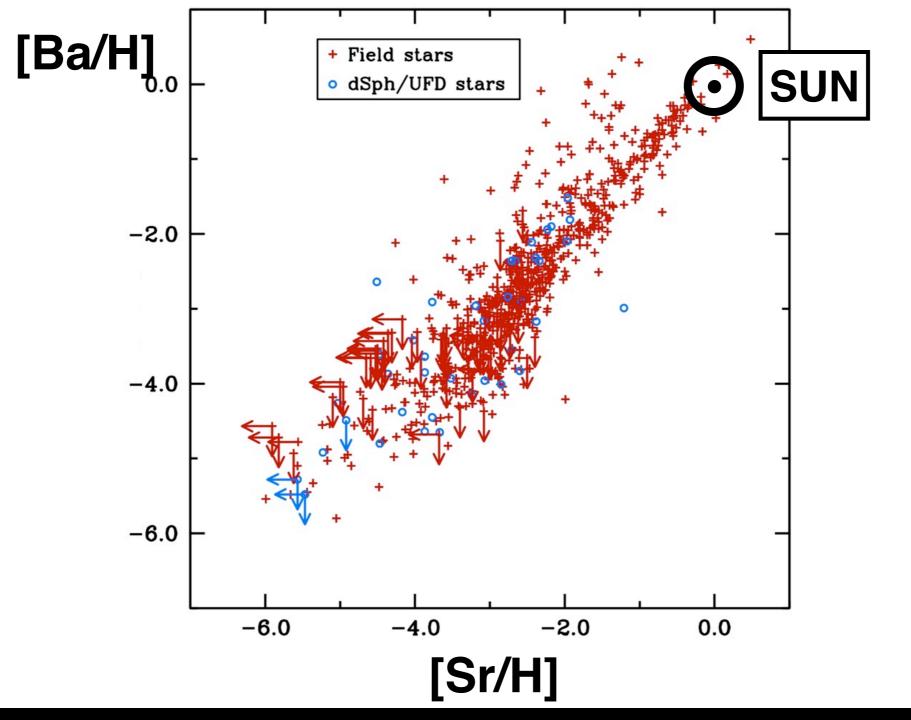
with $Z < \frac{1}{100} Z_{sun}$ ([Fe/H] < -2.0)



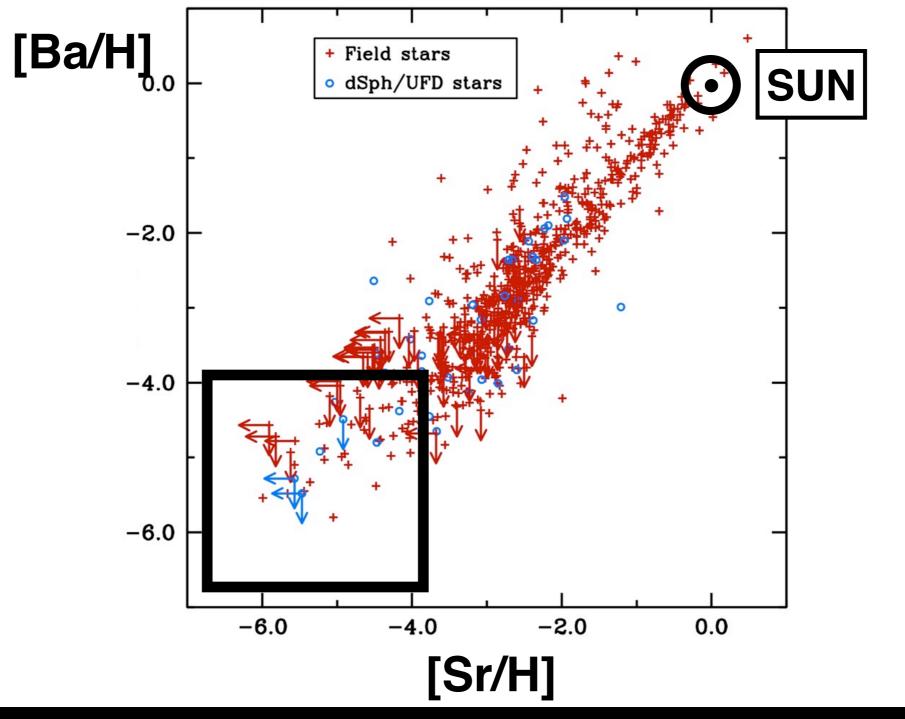
Roederer, Astronom. J., 145, 26 (2013)



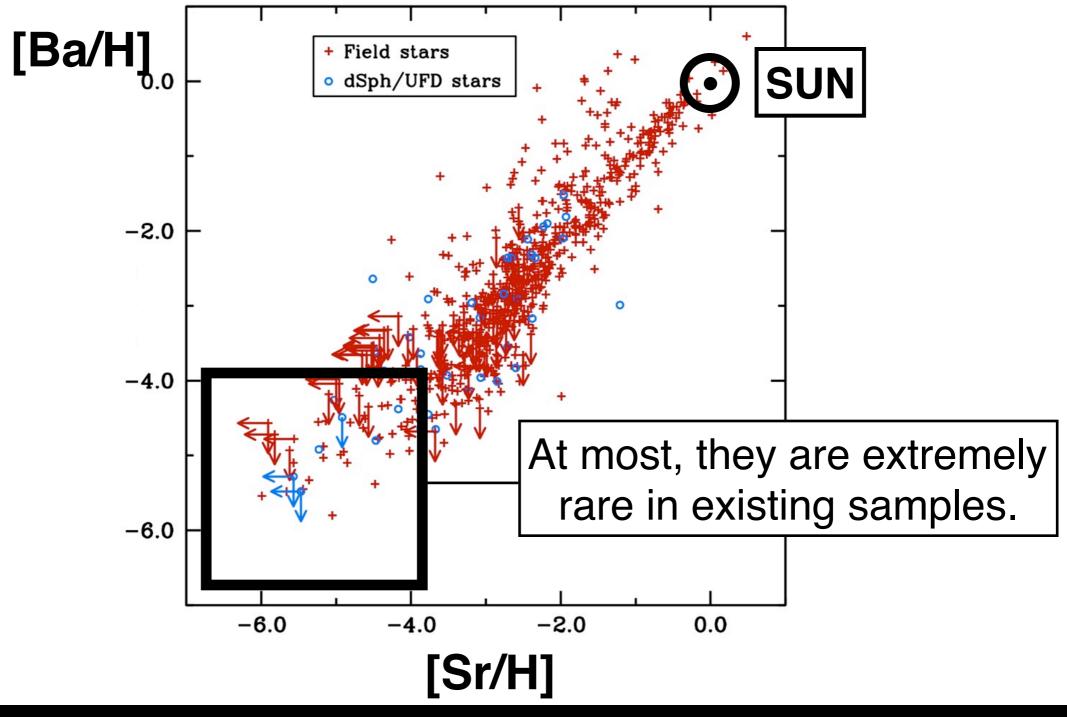
Roederer, Astronom. J., 145, 26 (2013)



Roederer, Astronom. J., 145, 26 (2013)



Roederer, Astronom. J., 145, 26 (2013)



Roederer, Astronom. J., 145, 26 (2013)

metal-poor red giant stars high spectral resolution high S/N in the blue **RESULTS FROM** (part of) <u>a ten-year observing campaign with the MIKE spectrograph at Magellan:</u>

metal-poor red giant stars high spectral resolution high S/N in the blue

84 stars with [Fe/H] < -2.5

R ~ 40,000

S/N > 60 @ 4100 Å

see Roederer et al., Astronom. J., 147, 136 (2014)

RESULTS FROM (part of) <u>a ten-year observing campaign with the MIKE spectrograph at Magellan:</u>

metal-poor red giant stars high spectral resolution high S/N in the blue

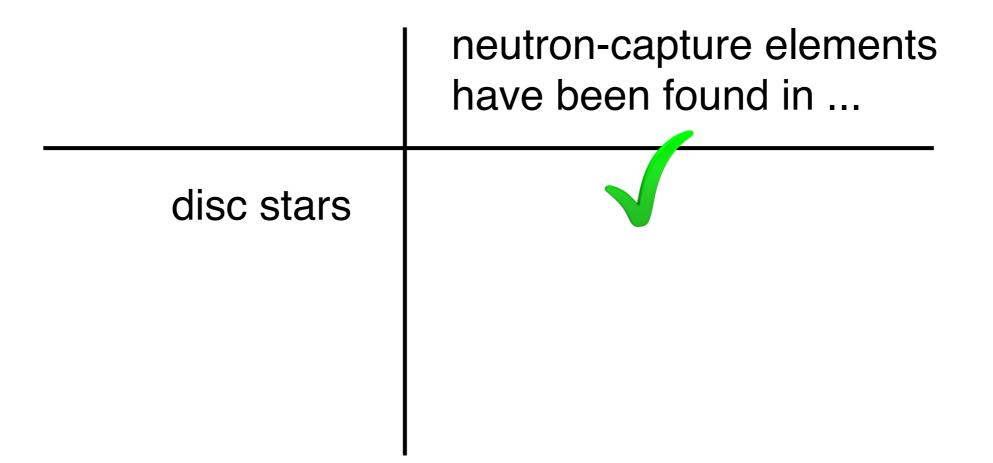
84 stars with [Fe/H] < -2.5

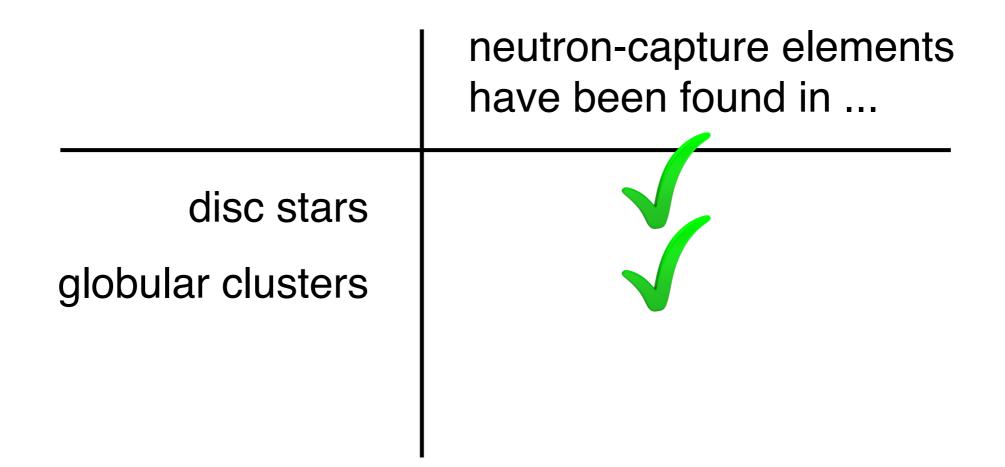
R ~ 40,000

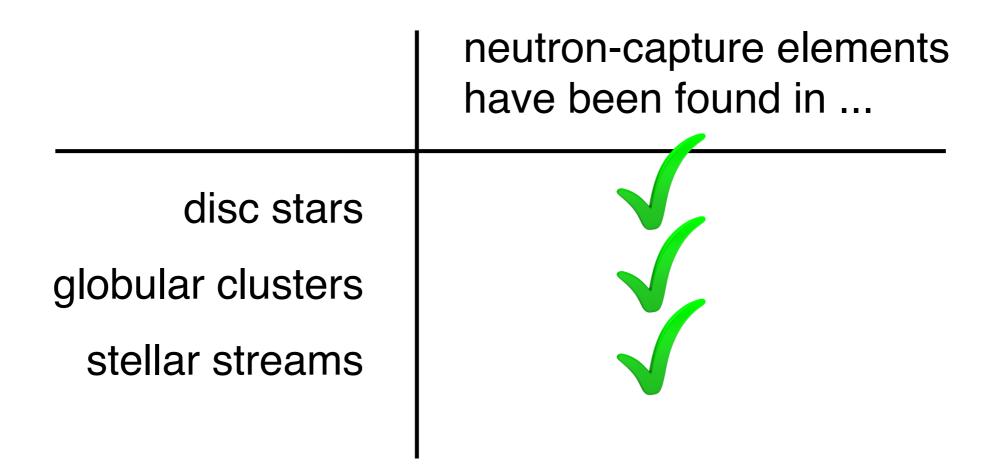
S/N > 60 @ 4100 Å

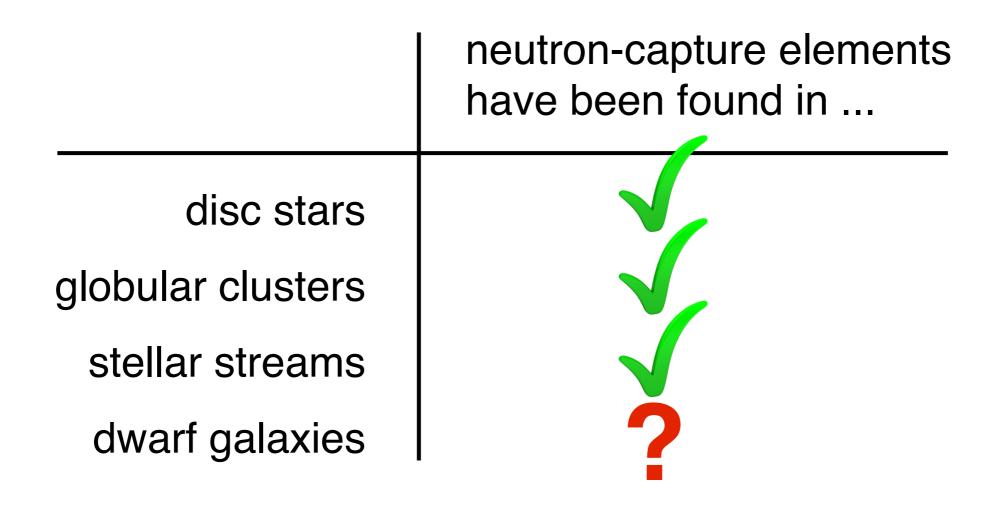
Strontium and barium are detected in every one of these stars.

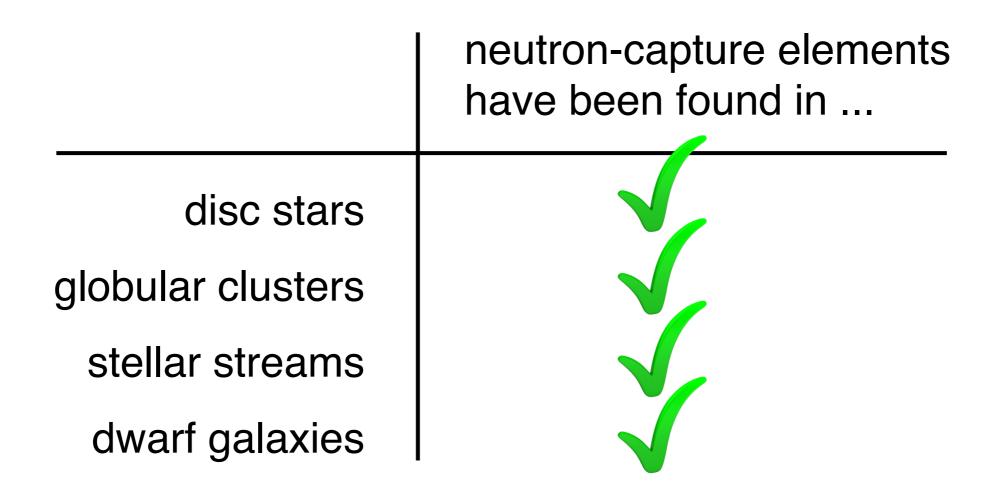
see Roederer et al., Astronom. J., 147, 136 (2014)



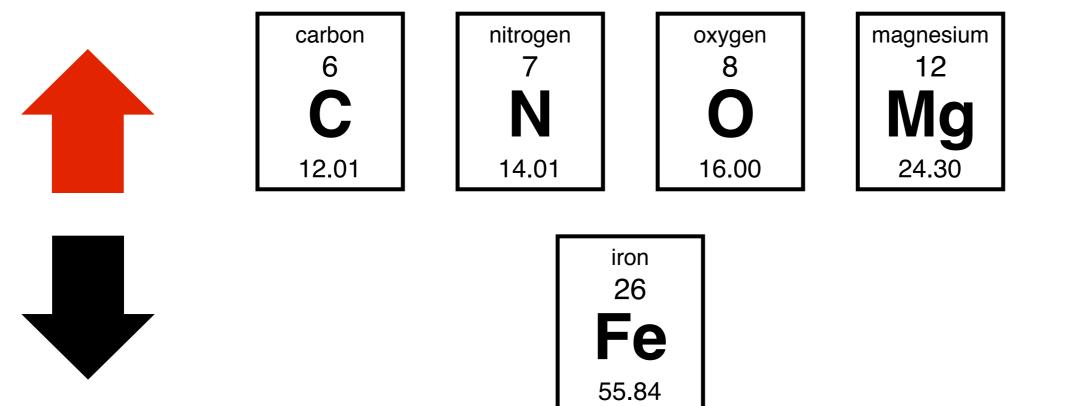


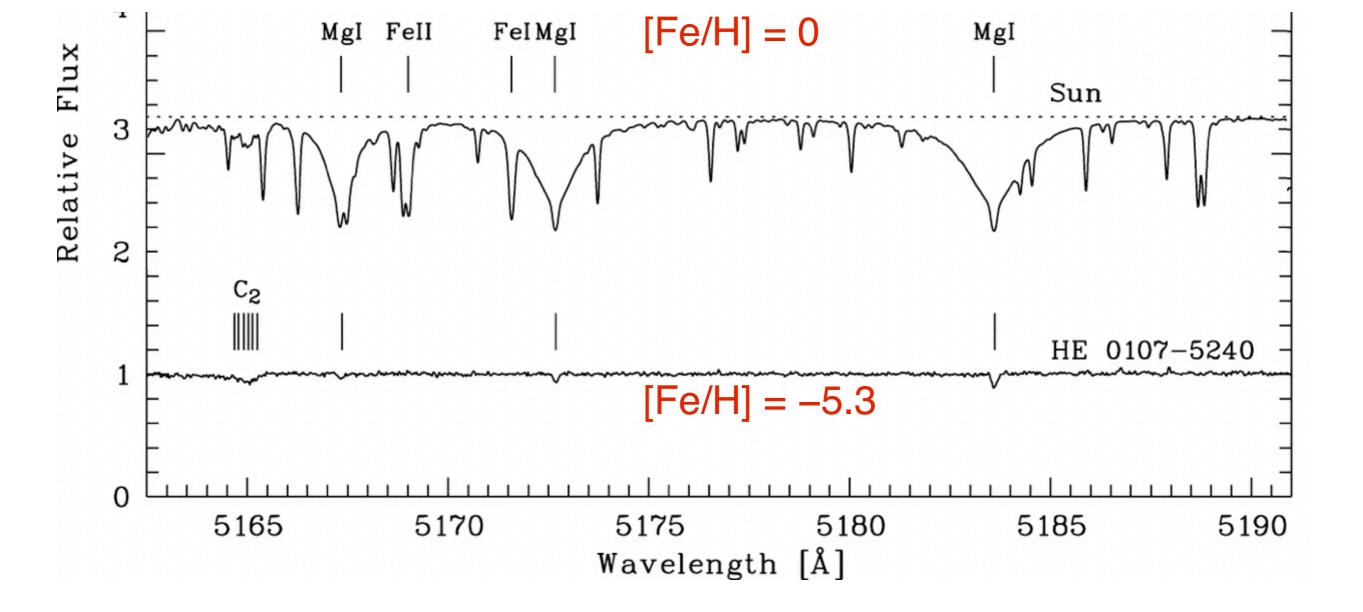




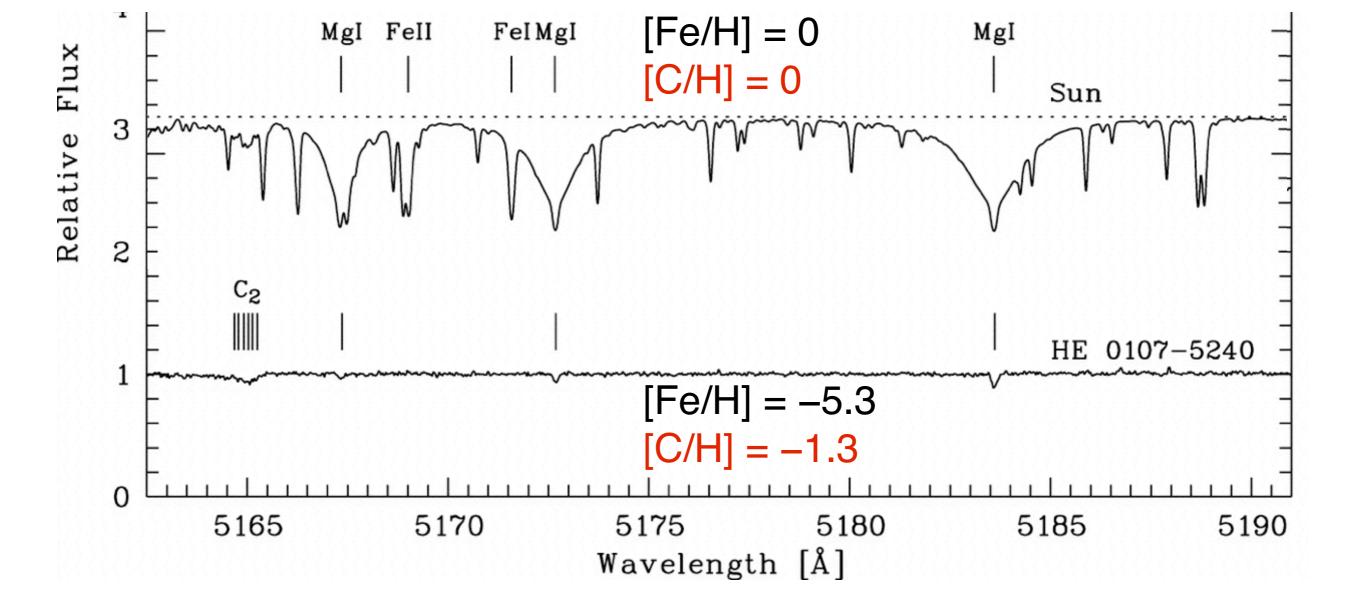


Neutron-capture elements are rarely, if ever, missing from the star-forming environments that built up the Milky Way and its neighbors.





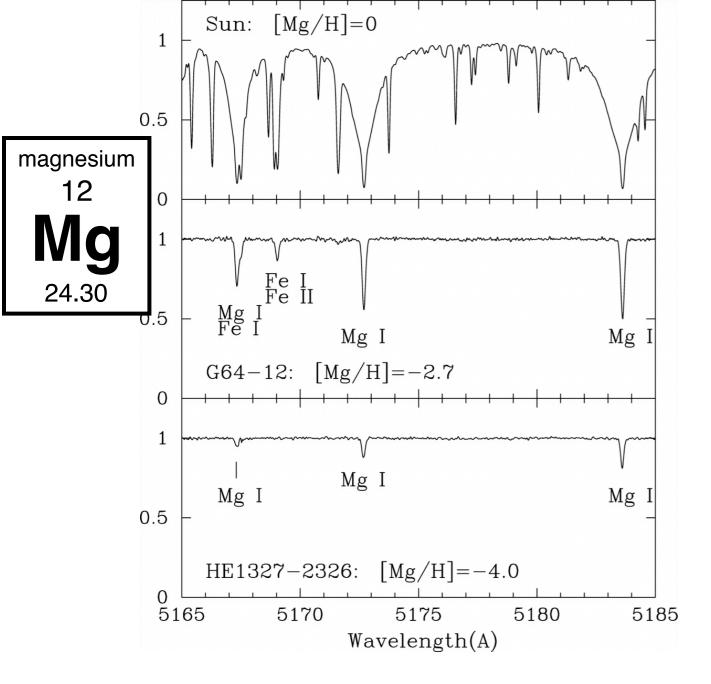
Christlieb et al., Astrophys. J., 603, 708 (2004)



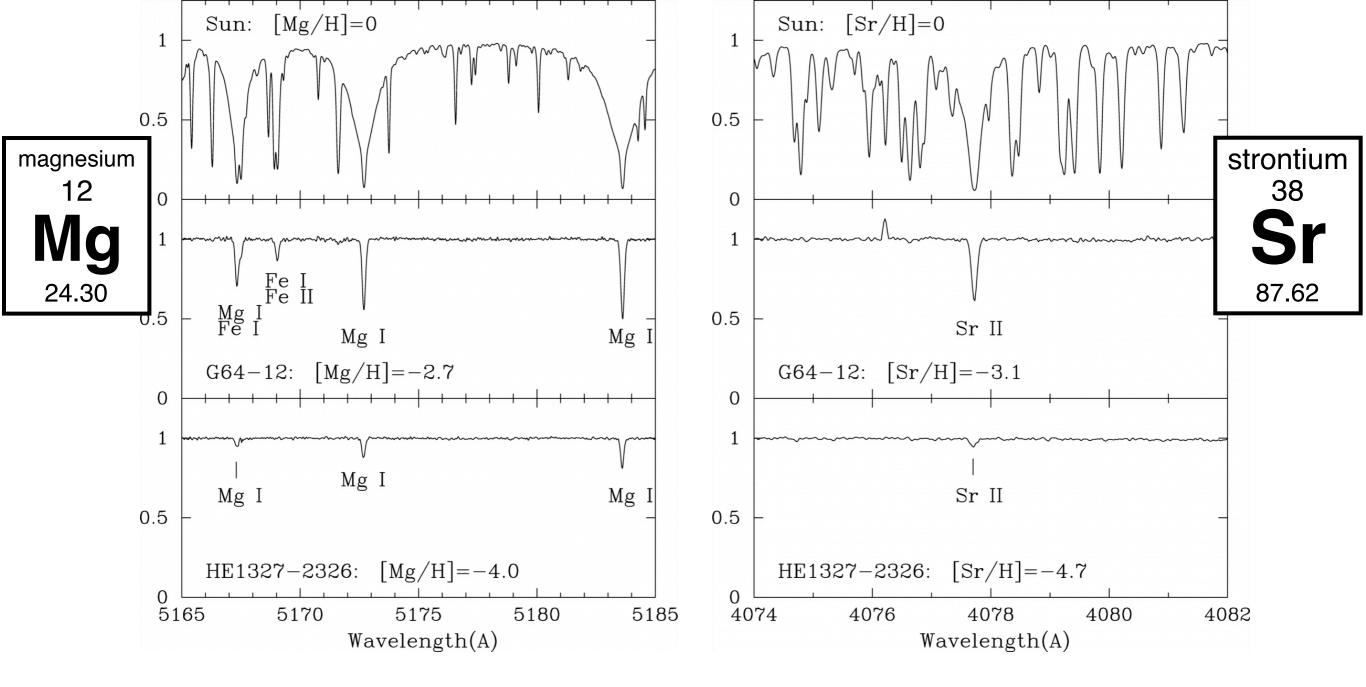
Christlieb et al., Astrophys. J., 603, 708 (2004)

These carbon-enhanced and ridiculously iron-poor stars formed from only the metals produced by one zero-metallicity star.

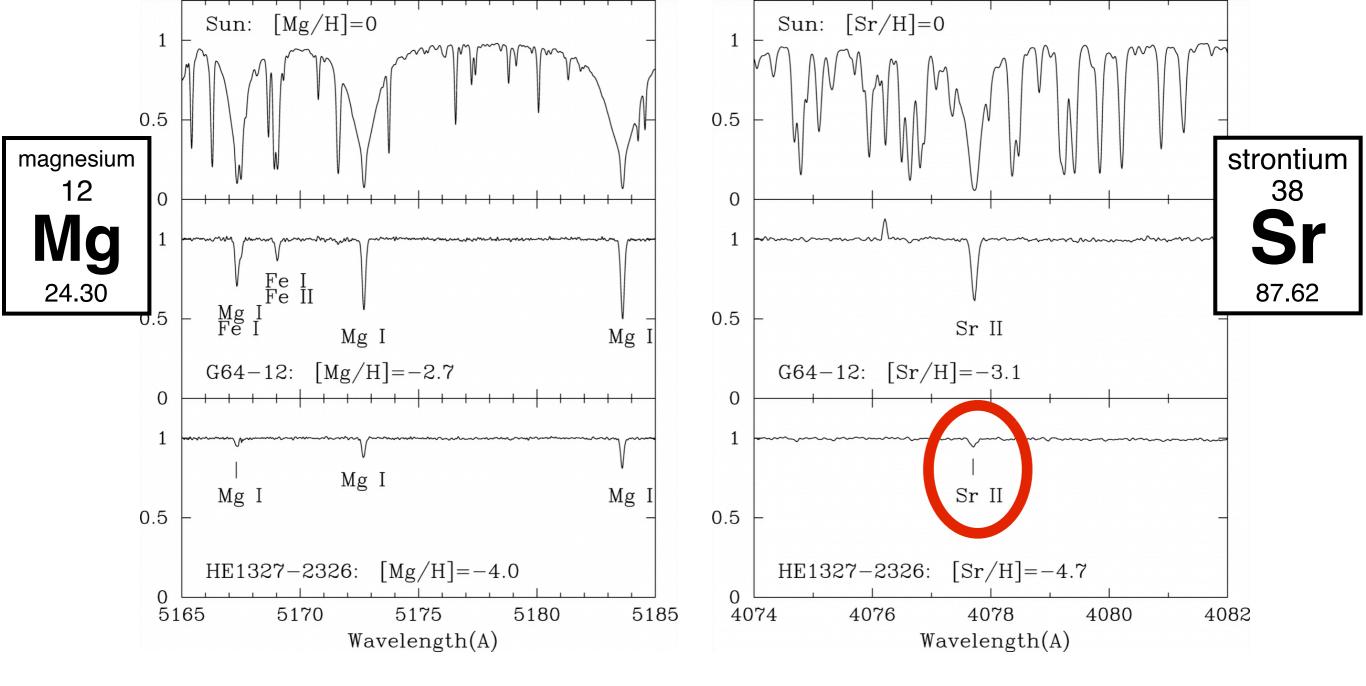




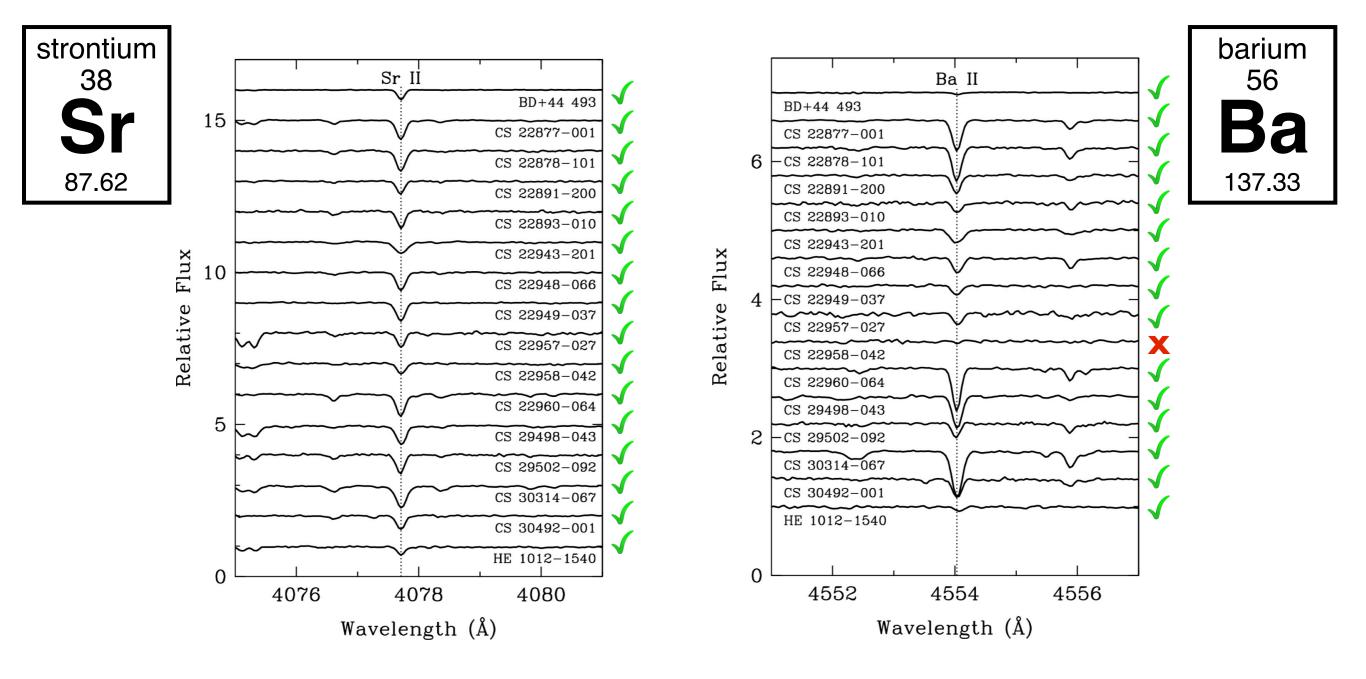
Aoki et al., Astrophys. J., 639, 897 (2006)



Aoki et al., Astrophys. J., 639, 897 (2006)

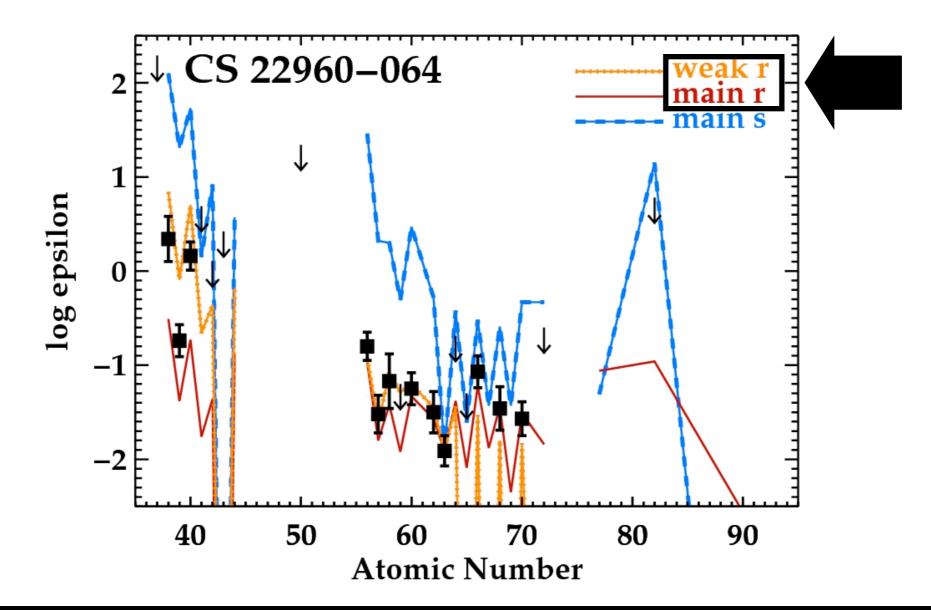


Aoki et al., Astrophys. J., 639, 897 (2006)



Roederer et al., Astrophys, J., 784, 158 (2014)

Other heavy elements in these stars indicate the presence of r-process material.



Roederer et al., Astrophys, J., 784, 158 (2014)

these carbon- or nitrogen-enhanced metal-poor stars were enriched by products of zero-metallicity supernovae only,



THEN the presence of these heavy elements indicates that at least one form of heavy-element nucleosynthesis operated in some of the first stars.

I owe many thanks to my collaborators for the work presented today.

T. Beers (Notre Dame) J. Cowan (Oklahoma) A. Frebel (MIT) I. Ivans (Utah) J. Lawler (Wisconsin) G. Preston (Carnegie) H. Schatz (Michigan State) S. Shectman (Carnegie) C. Sneden (Texas) J. Sobeck (Virginia) I. Thompson (Carnegie)