Towards an ‘operating system’ of geochronological software

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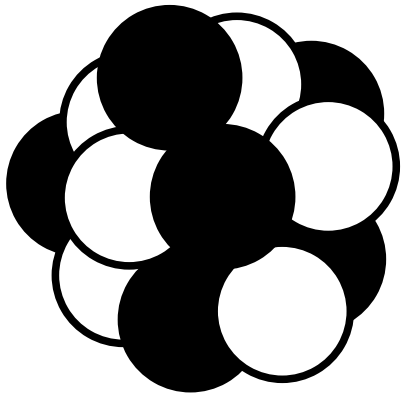
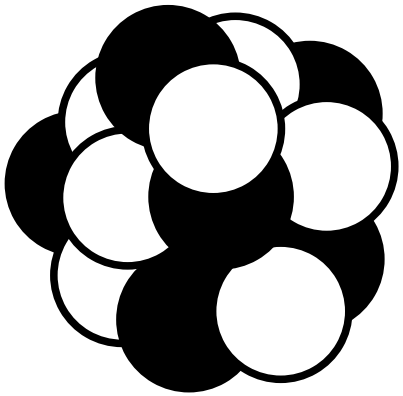
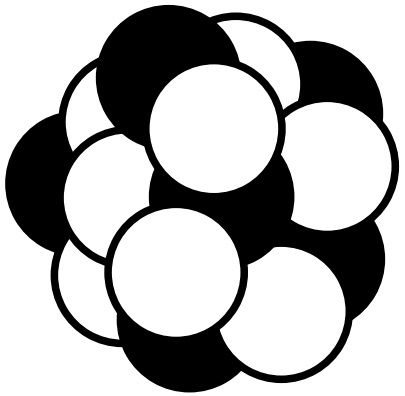
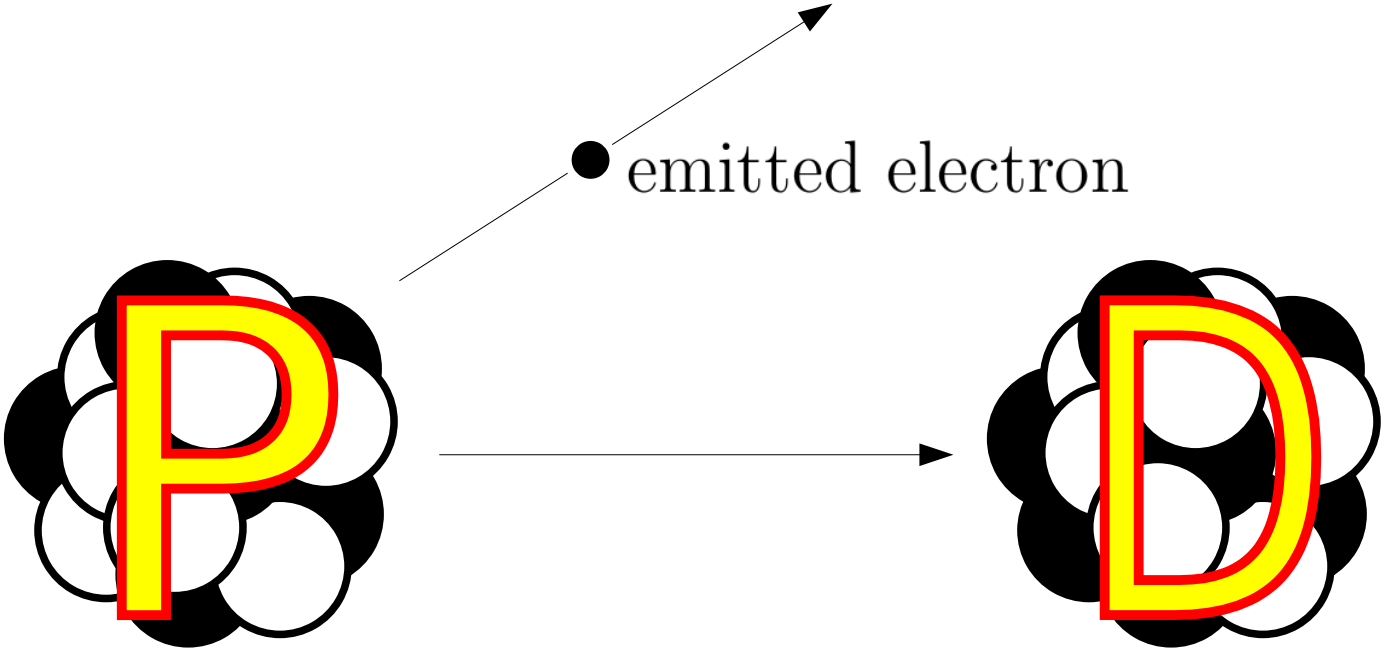
6 protons	6 protons	6 protons
6 neutrons	7 neutrons	8 neutrons
		
^{12}C	^{13}C	^{14}C

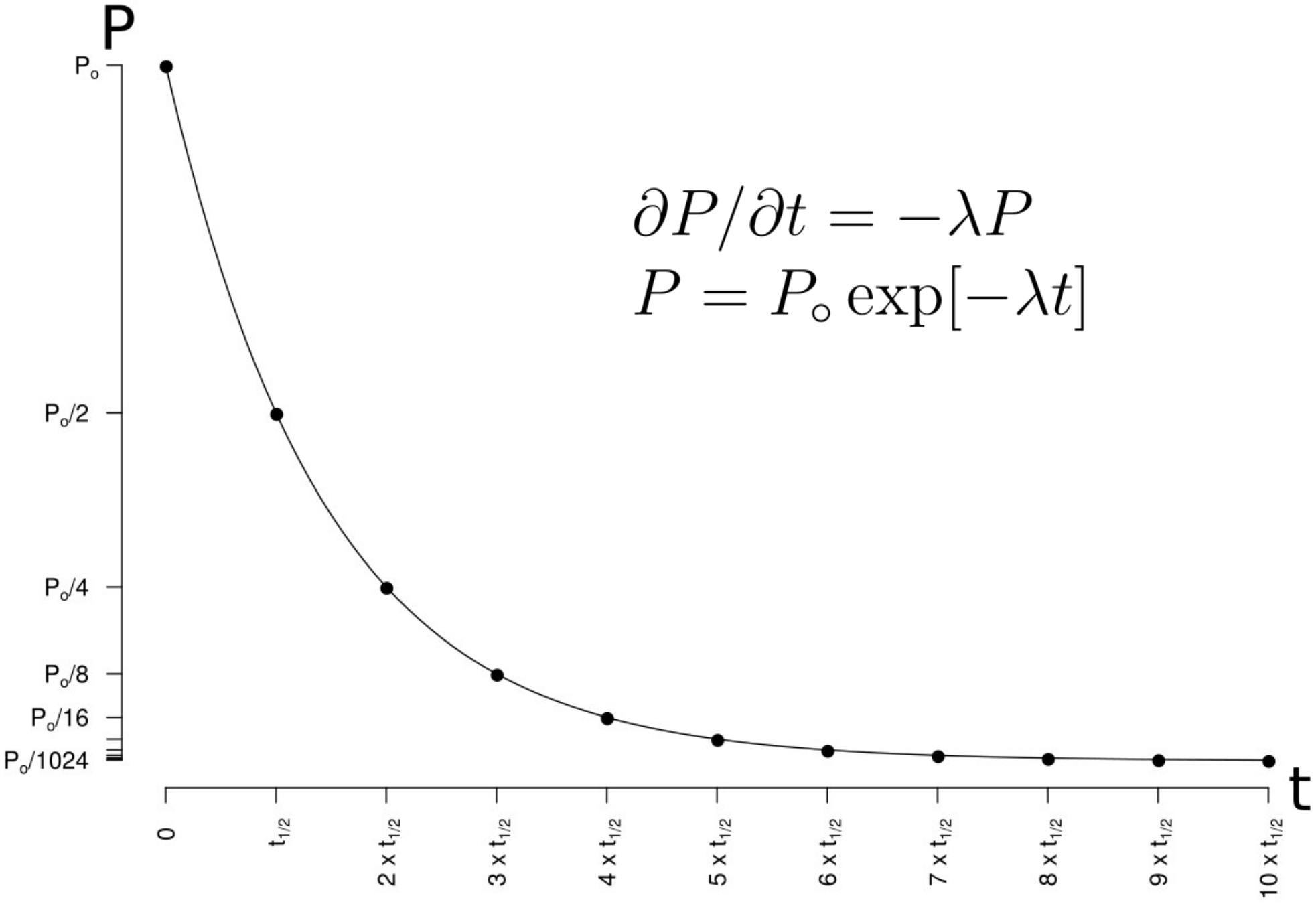


6 protons
8 neutrons
^{14}C

7 protons
7 neutrons
^{14}N

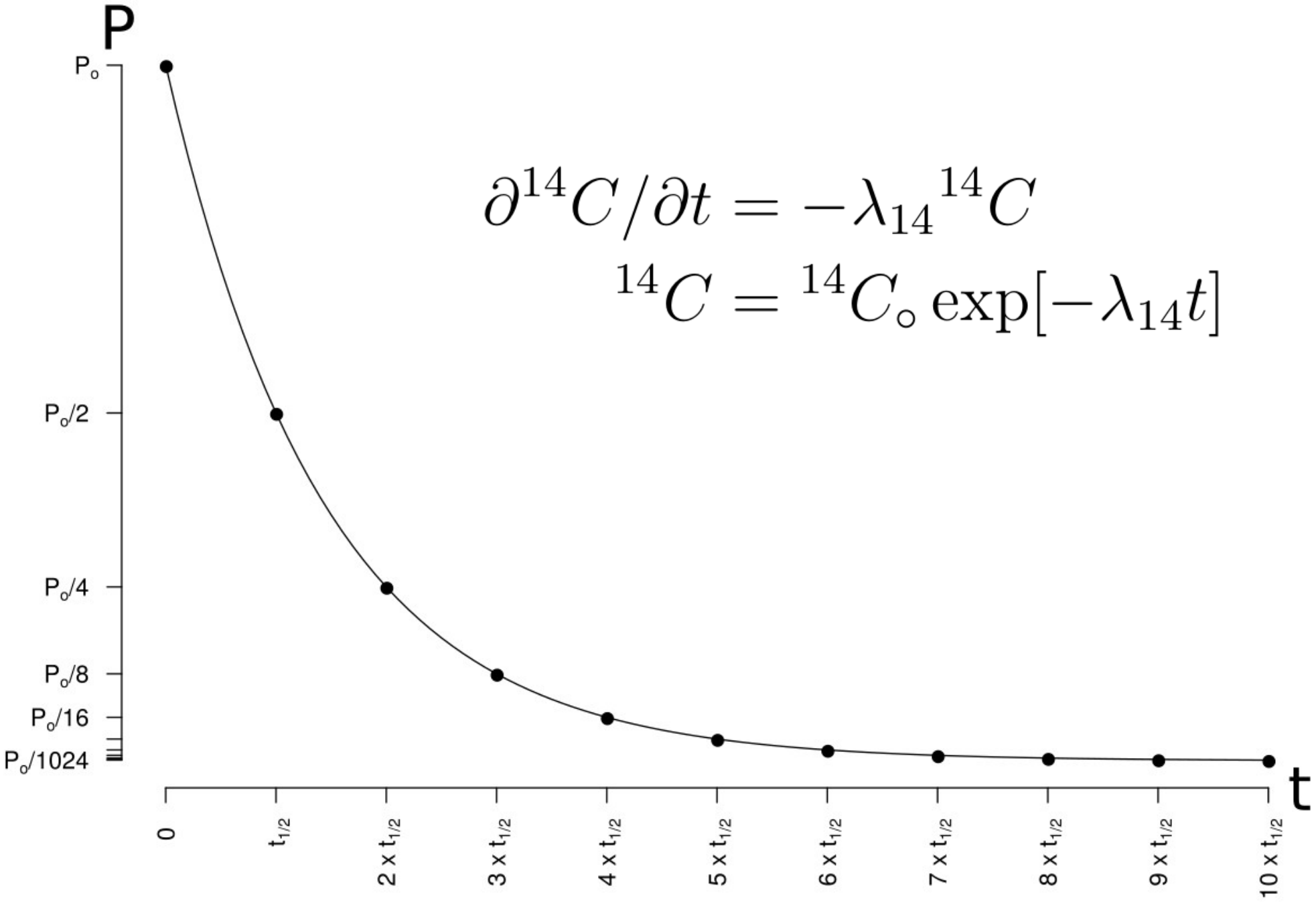
$$\partial P/\partial t$$

$$\partial P/\partial t = -\lambda P$$



$$\partial P/\partial t = -\lambda P$$

$$P = P_\circ \exp[-\lambda t]$$



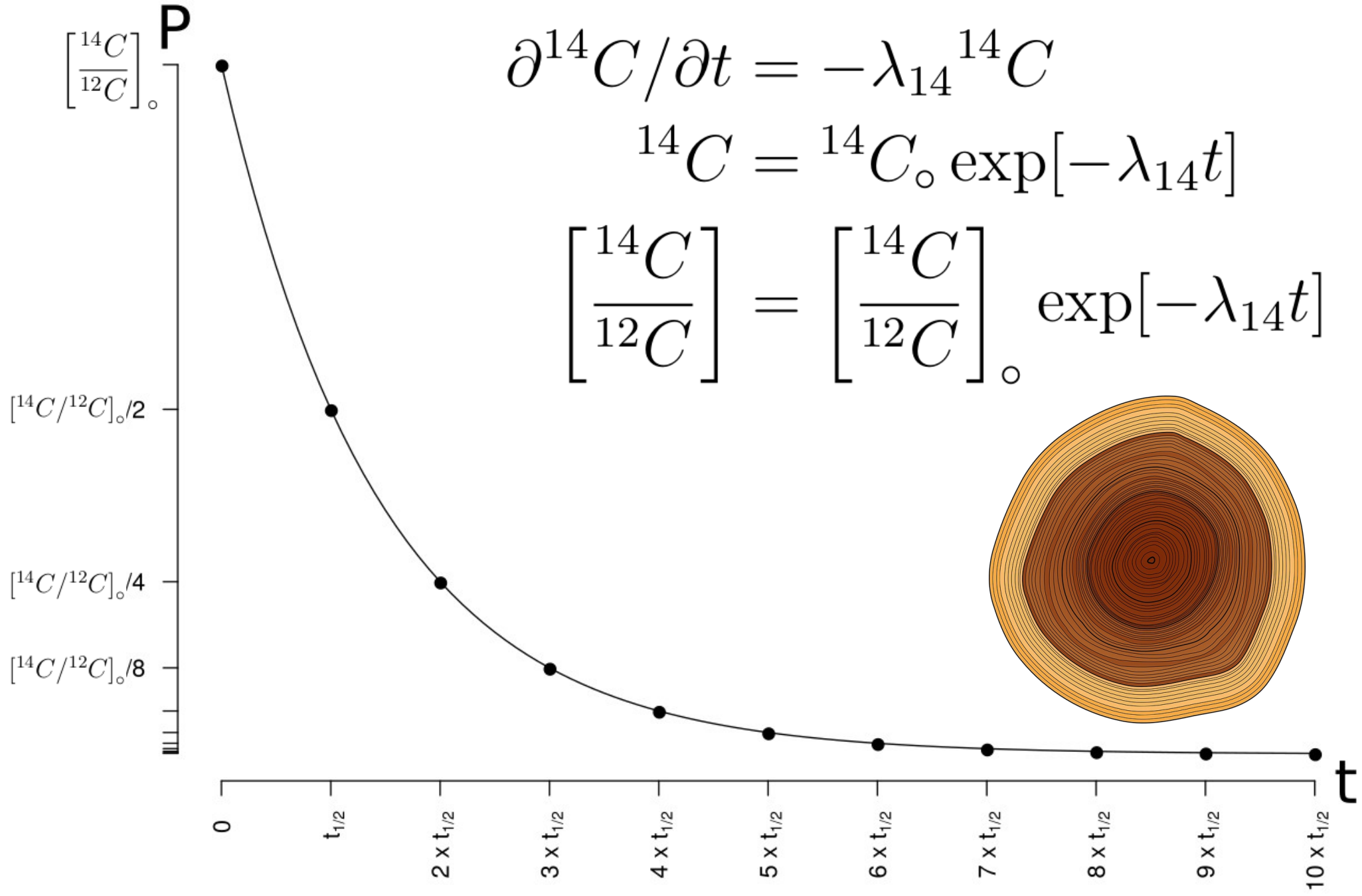
$$\partial^{14}C/\partial t = -\lambda_{14}{}^{14}C$$

$$^{14}C = {}^{14}C_\circ \exp[-\lambda_{14} t]$$

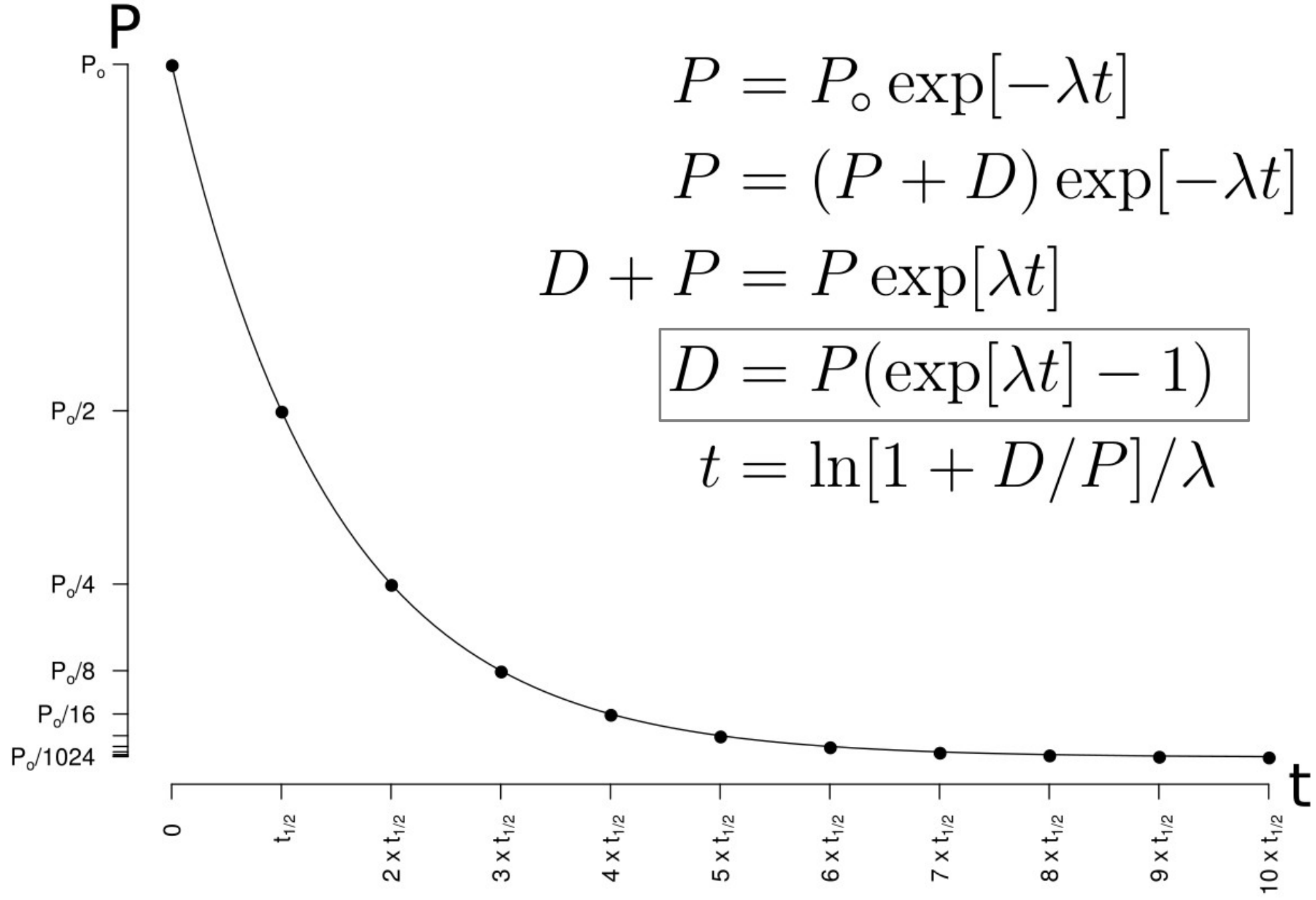
$$\partial^{14}C/\partial t = -\lambda_{14}{}^{14}C$$

$$^{14}C = {}^{14}C_\circ \exp[-\lambda_{14} t]$$

$$\left[\frac{^{14}C}{^{12}C}\right] = \left[\frac{^{14}C}{^{12}C}\right]_\circ \exp[-\lambda_{14} t]$$



parent	daughter	half life (years)
$^{14}_{6}\mathrm{C}$	$^{14}_{7}\mathrm{N}$	5.73×10^{3}
$^{235}_{92}\mathrm{U}$	$^{207}_{82}\mathrm{Pb}$	7.04×10^{8}
$^{238}_{92}\mathrm{U}$	$^{206}_{82}\mathrm{Pb}$	4.47×10^{9}
$^{87}_{37}\mathrm{Rb}$	$^{87}_{38}\mathrm{Sr}$	4.91×10^{10}



$$P = P_\circ \exp[-\lambda t]$$

$$P = (P + D) \exp[-\lambda t]$$

$$D + P = P \exp[\lambda t]$$

$$\boxed{D = P(\exp[\lambda t] - 1)}$$

$$t = \ln[1 + D/P]/\lambda$$

$$\begin{matrix} {}^{87}\mathrm{Rb} \\ {}^{85}\mathrm{Rb} \end{matrix} \xrightarrow[+\mathrm{p},\beta^-,\nu]{\text{-n}} \begin{matrix} {}^{88}\mathrm{Sr} \\ {}^{87}\mathrm{Sr} \\ {}^{86}\mathrm{Sr} \\ {}^{84}\mathrm{Sr} \end{matrix}$$

$$\begin{matrix} {}^{87}\mathrm{Rb} \\ {}^{85}\mathrm{Rb} \end{matrix} \xrightarrow[+\mathrm{p},\beta^-,\nu]{\text{-n}} \begin{matrix} {}^{88}\mathrm{Sr} \\ {}^{87}\mathrm{Sr} \\ {}^{86}\mathrm{Sr} \\ {}^{84}\mathrm{Sr} \end{matrix}$$

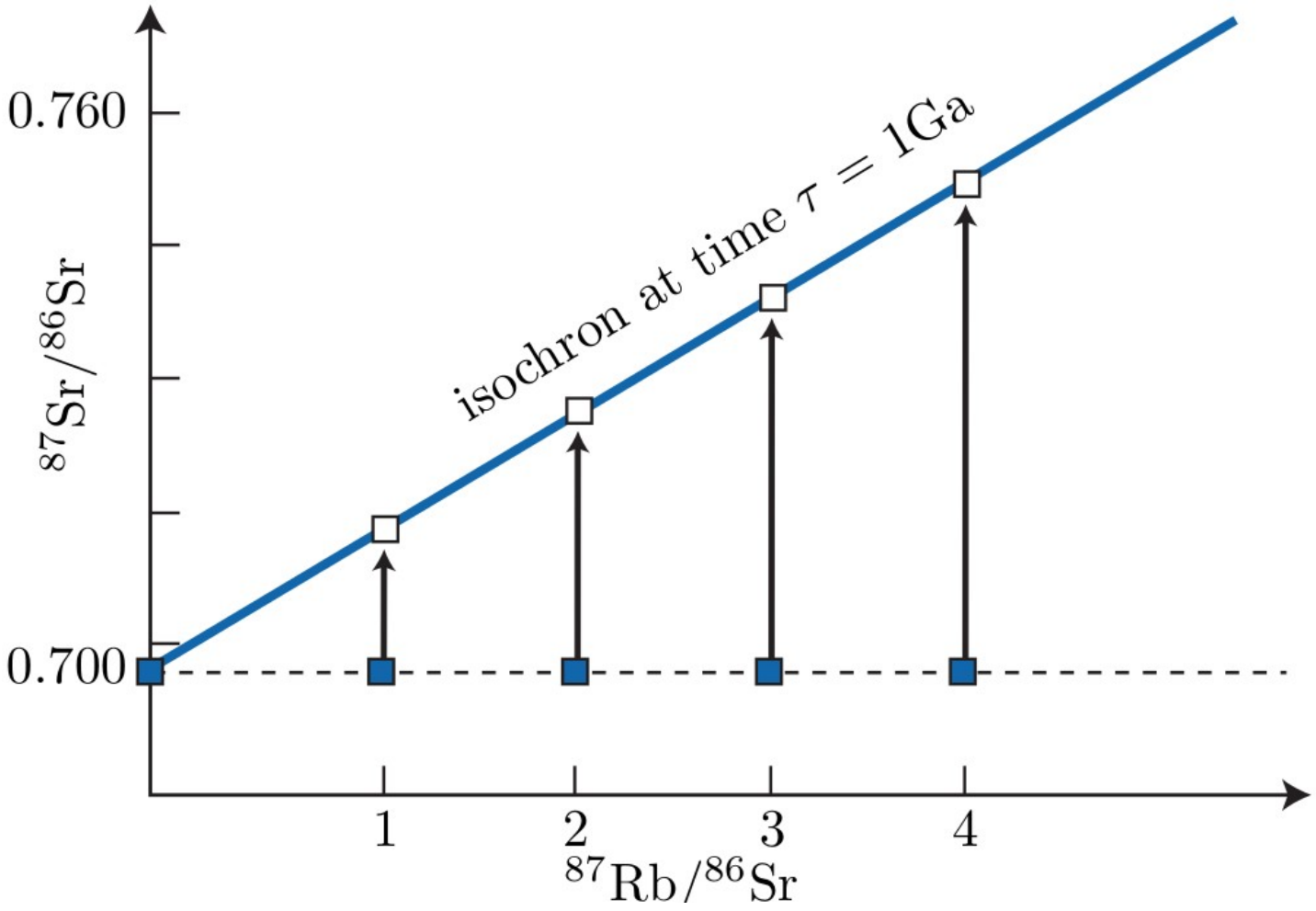
$$^{87}\mathrm{Sr} = {}^{87}\mathrm{Rb}\left(\exp[\lambda_{87}t] - 1\right)$$

$$\begin{matrix} ^{87}\mathrm{Rb} \\ ^{85}\mathrm{Rb} \end{matrix} \xrightarrow[+\mathrm{p},\beta^-,\nu]{\text{-n}} \begin{matrix} ^{88}\mathrm{Sr} \\ ^{87}\mathrm{Sr} \\ ^{86}\mathrm{Sr} \\ ^{84}\mathrm{Sr} \end{matrix}$$

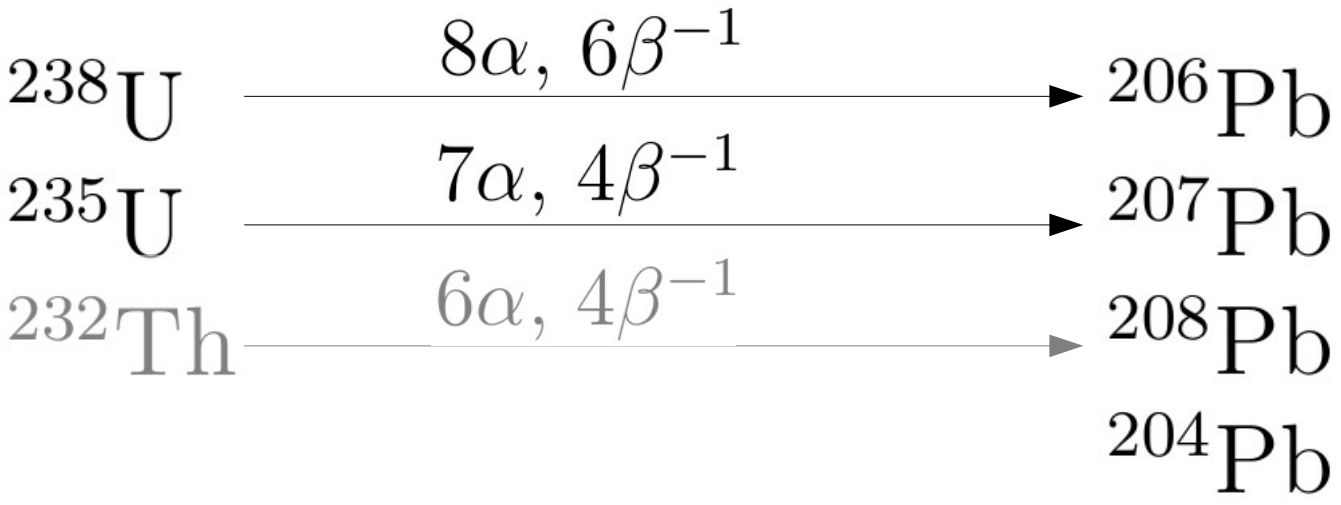
$$^{87}\mathrm{Sr} = {}^{87}\mathrm{Sr}_\circ + {}^{87}\mathrm{Rb}\left(\exp[\lambda_{87}t] - 1\right)$$

$$\begin{matrix} ^{87}\mathrm{Rb} \\ ^{85}\mathrm{Rb} \end{matrix} \xrightarrow[+\mathrm{p},\beta^-,\nu]{\text{-n}} \begin{matrix} ^{88}\mathrm{Sr} \\ ^{87}\mathrm{Sr} \\ ^{86}\mathrm{Sr} \\ ^{84}\mathrm{Sr} \end{matrix}$$

$$\left[\frac{^{87}\mathrm{Sr}}{^{86}\mathrm{Sr}}\right] = \left[\frac{^{87}\mathrm{Sr}}{^{86}\mathrm{Sr}}\right]_\circ + \left[\frac{^{87}\mathrm{Rb}}{^{86}\mathrm{Sr}}\right] (\exp[\lambda_{87} t] - 1)$$



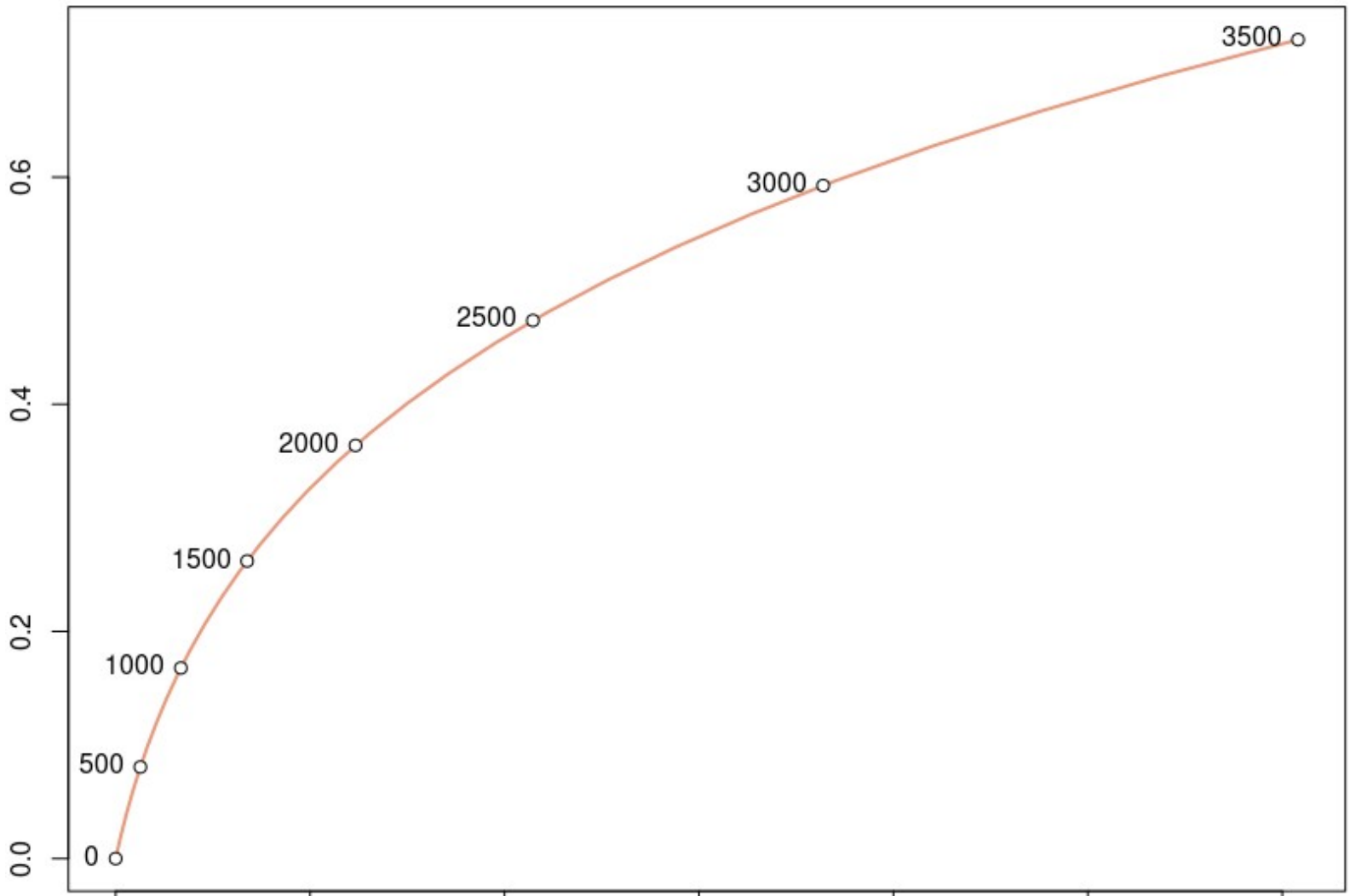
$$\left[\frac{^{87}Sr}{^{86}Sr}\right] = \underbrace{\left[\frac{^{87}Sr}{^{86}Sr}\right]_\circ}_{\text{intercept}} + \left[\frac{^{87}Rb}{^{86}Sr}\right] \underbrace{(\exp[\lambda_{87} t] - 1)}_{\text{slope}}$$



$$\left[\frac{^{206}\mathrm{Pb}}{^{204}\mathrm{Pb}}\right] = \left[\frac{^{206}\mathrm{Pb}}{^{204}\mathrm{Pb}}\right]_\circ + \left[\frac{^{238}\mathrm{U}}{^{204}\mathrm{Pb}}\right] \left(\exp[\lambda_{238} t] - 1\right)$$

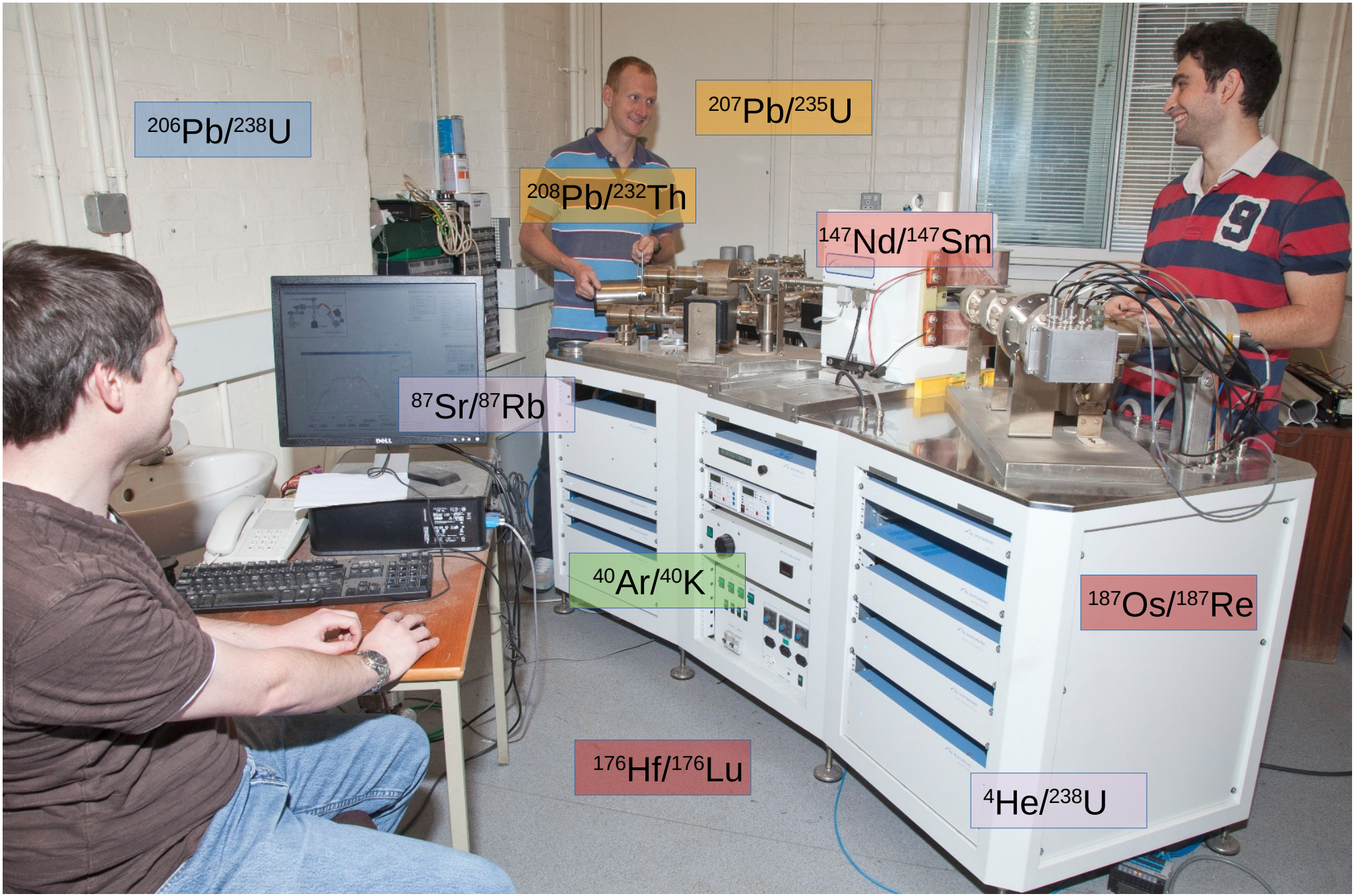
$$\left[\frac{^{207}\mathrm{Pb}}{^{204}\mathrm{Pb}}\right] = \left[\frac{^{207}\mathrm{Pb}}{^{204}\mathrm{Pb}}\right]_\circ + \left[\frac{^{235}\mathrm{U}}{^{204}\mathrm{Pb}}\right] \left(\exp[\lambda_{235} t] - 1\right)$$

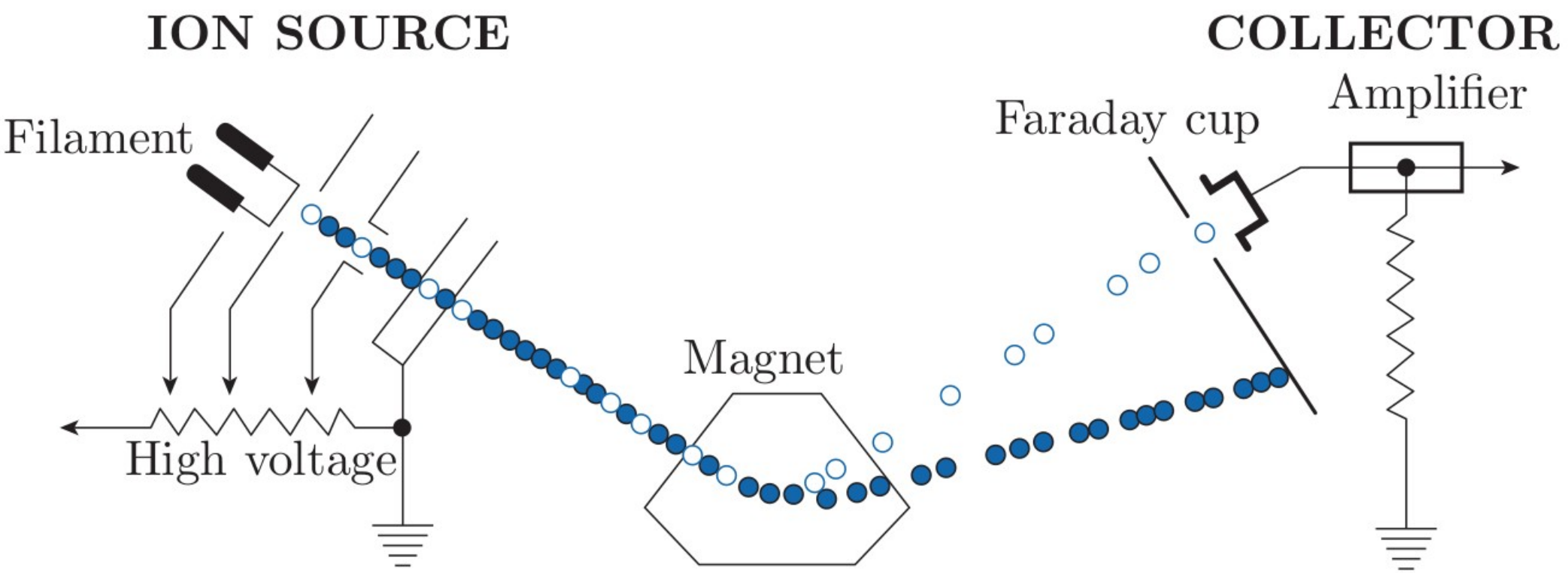
$$\frac{\left[\frac{^{206}\mathrm{Pb}}{^{204}\mathrm{Pb}}\right] - \left[\frac{^{206}\mathrm{Pb}}{^{204}\mathrm{Pb}}\right]_\circ}{\left[\frac{^{238}\mathrm{U}}{^{204}\mathrm{Pb}}\right]}$$



$$\frac{\left[\frac{^{207}\mathrm{Pb}}{^{204}\mathrm{Pb}}\right] - \left[\frac{^{207}\mathrm{Pb}}{^{204}\mathrm{Pb}}\right]_\circ}{\left[\frac{^{235}\mathrm{U}}{^{204}\mathrm{Pb}}\right]}$$

Isotopic ratios can be measured by mass spectrometry




ION SOURCE
COLLECTOR
Filament
Faraday cup
Amplifier
Magnet
High voltage

An output file of a mass spectrometer that is used for U—Pb geochronology

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Intensity Vs Time CPS
Acquired : 2/13/2015 3:52:43 PM using Batch 20150213standards.b

Time [Sec]	Si29	Zr91	La139	Hf178	Pb206	Pb207	Pb208	bkg221	Th232	U238
0.387	50467.08	0	0	0	20	16.67	66.67	0	0	0
0.764	48662.37	0	0	0	20	8.33	8.33	0	0	0
1.141	46256.36	0	0	0	20	16.67	33.33	0	0	0
1.518	47860.33	0	0	0	20	16.67	50	0	0	0
1.895	45454.42	0	0	0	0	25	25	0	0	0
2.272	47860.33	0	0	0	60	33.33	58.33	0	0	0
2.649	49263.92	400	0	0	0	16.67	50	0	0	0
3.026	44051.12	0	0	0	0	25	50	0	0	0
3.403	49063.4	0	0	0	0	25	41.67	0	0	0
3.78	49263.92	400	0	0	20	25	41.67	0	0	0
4.157	45253.95	0	0	0	0	50	83.33	0	0	0
4.534	41044.38	0	0	0	20	0	33.33	0	0	0
4.911	42247.02	400	0	0	0	58.33	16.67	0	0	0
5.288	43650.19	0	0	0	20	33.33	16.67	0	0	0
5.665	53675.87	0	0	0	40	16.67	25	0	0	0
6.042	42046.57	0	0	200	100	8.33	75	0	0	100
6.419	55280.47	16807.85	0	6801.38	580.01	1075.04	2233.49	0	3100.3	12404.8
6.797	204496.89	7615471.26	0	429017.34	5420.89	2891.92	7576.75	0	25720.53	88946.11
7.174	958426.68	36942291.45	600.01	1933877	15547.36	2950.27	5559.28	0	31681.14	113802.59
7.551	1062350.9	48668504.21	0	2366139.31	15607.42	1783.43	2708.56	0	40099.88	120450.88
7.928	1225569.66	58244638.8	0	3001998.31	17929.79	1550.07	2200.15	0	41904.47	160752.07
8.305	1423832.94	62053795.14	400	3544078.99	21053.49	1483.4	2600.21	0	50178.07	155450.16
8.682	1554580.11	60651032.61	0	3345920.39	20132.33	1608.41	2450.18	0	46266.38	158025.15
9.059	1740370.55	66859676.49	0	3516239.53	22775.79	1600.08	2891.92	0	47319.43	179398.37
9.436	1783400.43	80704070.55	0	3822985.63	22695.67	2283.49	3650.41	0	54391.72	176870.5
9.813	1830103.17	87598876.96	0	3988790.32	27242.59	1975.12	3008.61	0	50830.11	175252.88
10.19	1746135.2	84858945.65	0	4204186.03	26641.6	1758.43	2883.59	0	56549.14	173180.56
10.567	2022984.42	74790395.42	0	3898227.04	24338.03	1883.44	3050.28	0	50880.27	181774.92
10.944	1974139.11	78871820.51	0	3970253.6	25920.44	1841.77	2666.88	0	50579.33	185719.73
11.321	1659004.33	78115314.25	0	4284694.63	25019.05	1866.77	2875.25	0	45965.52	177426.62
11.698	1857140.08	72425795.37	0	3894738.37	25219.36	2275.16	2700.22	0	44411.17	161711.66
12.074	1873566.45	71660339.1	0	3708789.54	22575.51	2133.47	2608.54	0	45815.09	182482.88
12.452	2029157.08	69295389.05	0	3968987.98	24418.14	1916.78	2375.17	0	44812.28	149796.71
12.829	1568226.21	63666607.67	0	3795180.16	24658.51	1908.44	2391.84	0	45062.98	142379.57
13.206	1486630.31	64826032.7	0	3238598.51	21754.4	1908.44	2383.51	0	45113.12	153178.46

blank

signal

Data reduction [1/2]: calculating isotopic ratios

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Intensity Vs Time CPS
Acquired : 2/13/2015 3:52:43 PM using Batch 20150213standards.b

	Time [Sec]	Si29	Zr91	La139	Hf178	Pb206	Pb207	Pb208	bkg221	Th232	U238
blank	0.387	50467.08	0	0	0	20	16.67	66.67	0	0	0
	0.764	48662.37	0	0	0	20	8.33	8.33	0	0	0
	1.141	46256.36	0	0	0	20	16.67	33.33	0	0	0
	1.518	47860.33	0	0	0	20	16.67	50	0	0	0
	1.895	45454.42	0	0	0	0	25	25	0	0	0
	2.272	47860.33	0	0	0	60	33.33	58.33	0	0	0
	2.649	49263.92	400	0	0	0	16.67	50	0	0	0
	3.026	44051.12	0	0	0	0	25	50	0	0	0
	3.403	49063.4	0	0	0	0	25	41.67	0	0	0
	3.78	49263.92	400	0	0	20	25	41.67	0	0	0
	4.157	45253.95	0	0	0	0	50	83.33	0	0	0
	4.534	41044.38	0	0	0	20	0	33.33	0	0	0
	4.911	42247.02	400	0	0	0	58.33	16.67	0	0	0
	5.288	43650.19	0	0	0	20	33.33	16.67	0	0	0
	5.665	53675.87	0	0	0	40	16.67	25	0	0	0
	6.042	42046.57	0	0	200	100	8.33	75	0	0	100
signal	6.419	55280.47	16807.85	0	6801.38	580.01	1075.04	2233.49	0	3100.3	12404.8
	6.797	204496.89	7615471.26	0	429017.34	5420.89	2891.92	7576.75	0	25720.53	88946.11
	7.174	958426.68	36942291.45	600.01	1933877	15547.36	2950.27	5559.28	0	31681.14	113802.59
	7.551	1062350.9	48668504.21	0	2366139.31	15607.42	1783.43	2708.56	0	40099.88	120450.88
	7.928	1225569.66	58244638.8	0	3001998.31	17929.79	1550.07	2200.15	0	41904.47	160752.07
	8.305	1423832.94	62053795.14	400	3544078.99	21053.49	1483.4	2600.21	0	50178.07	155450.16
	8.682	1554580.11	60651032.61	0	3345920.39	20132.33	1608.41	2450.18	0	46266.38	158025.15
	9.059	1740370.55	66859676.49	0	3516239.53	22775.79	1600.08	2891.92	0	47319.43	179398.37
	9.436	1783400.43	80704070.55	0	3822985.63	22695.67	2283.49	3650.41	0	54391.72	176870.5
	9.813	1830103.17	87598876.96	0	3988790.32	27242.59	1975.12	3008.61	0	50830.11	175252.88
	10.19	1746135.2	84858945.65	0	4204186.03	26641.6	1758.43	2883.59	0	56549.14	173180.56
	10.567	2022984.42	74790395.42	0	3898227.04	24338.03	1883.44	3050.28	0	50880.27	181774.92
	10.944	1974139.11	78871820.51	0	3970253.6	25920.44	1841.77	2666.88	0	50579.33	185719.73
	11.321	1659004.33	78115314.25	0	4284694.63	25019.05	1866.77	2875.25	0	45965.52	177426.62
	11.698	1857140.08	72425795.37	0	3894738.37	25219.36	2275.16	2700.22	0	44411.17	161711.66
	12.074	1873566.45	71660339.1	0	3708789.54	22575.51	2133.47	2608.54	0	45815.09	182482.88
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	12.829	1568226.21	63666607.67	0	3795180.16	24658.51	1908.44	2391.84	0	45062.98	142379.57
	13.206	1486630.31	64826032.7	0	3238598.51	21754.4	1908.44	2383.51	0	45113.12	153178.46

ID	207Pb/235U	err	206Pb/238U	err	207Pb/206Pb	err
ALC#1	0.7949	0.00841	0.0953	0.00092	0.06063	0.00068
ALC#2	0.8585	0.00945	0.10117	0.00098	0.06168	0.00072
ALC#3	0.81067	0.01161	0.09922	0.00104	0.05939	0.00091
ALC#4	0.82027	0.00961	0.0987	0.00098	0.06041	0.00075
ALC#5	0.89669	0.01102	0.10433	0.00105	0.06247	0.00082
ALC#6	0.80764	0.00944	0.09709	0.00096	0.06047	0.00075
ALC#7	0.85788	0.00951	0.10226	0.001	0.06098	0.00072
ALC#8	0.76541	0.00911	0.09355	0.00093	0.05947	0.00075
ALC#9	6.60443	0.06755	0.36981	0.00356	0.12982	0.00141
ALC#11	0.83394	0.01012	0.09963	0.001	0.06084	0.00079
ALC#10	0.81681	0.01257	0.09917	0.00107	0.05987	0.00098
ALC#12	0.66711	0.00708	0.06713	0.00065	0.07224	0.00082
ALC#13	0.72902	0.02297	0.08971	0.00136	0.05907	0.00197
ALC#15	0.79924	0.00926	0.09759	0.00096	0.05953	0.00073
ALC#14	0.90935	0.01148	0.10735	0.00109	0.06158	0.00083
ALC#16	0.81462	0.00943	0.09583	0.00095	0.06179	0.00076
ALC#17	0.77374	0.01055	0.09494	0.00098	0.05924	0.00086
ALC#18	0.82825	0.0098	0.09631	0.00096	0.06251	0.00079
ALC#19	0.832	0.00951	0.09845	0.00097	0.06143	0.00075
ALC#20	0.73764	0.00983	0.08972	0.00092	0.05976	0.00085
ALC#21	0.66464	0.00797	0.08467	0.00084	0.05706	0.00073
ALC#22	0.8777	0.01169	0.10432	0.00107	0.06116	0.00087
ALC#24	0.39993	0.00662	0.05442	0.00059	0.05342	0.00094
ALC#26	0.81333	0.01121	0.09789	0.00102	0.0604	0.00089
ALC#25	0.91423	0.01178	0.10274	0.00105	0.06469	0.00089
ALC#27	0.82152	0.01048	0.04948	0.00075	0.12068	0.00213
ALC#28	0.80368	0.00958	0.09675	0.00096	0.06038	0.00077
ALC#30	0.84635	0.00926	0.09393	0.00091	0.0655	0.00076
ALC#29	0.78218	0.00866	0.09007	0.00088	0.06312	0.00074
ALC#31	0.81088	0.01153	0.09645	0.00101	0.06111	0.00093
ALC#33	0.82704	0.01091	0.0985	0.00101	0.06103	0.00086
ALC#32	0.87233	0.01048	0.10451	0.00104	0.06067	0.00078
ALC#34	0.72033	0.00816	0.08784	0.00086	0.05961	0.00072

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Intensity Vs Time CPS
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0.387	50467.08	0	0	0	0	20	16.67	66.67	0	0	0
0.764	48662.37	0	0	0	0	20	8.33	8.33	0	0	0
1.141	46256.36	0	0	0	0	20	16.67	33.33	0	0	0
1.518	47860.33	0	0	0	0	20	16.67	50	0	0	0
1.895	45454.42	0	0	0	0	0	25	25	0	0	0
2.272	47860.33	0	0	0	0	60	33.33	58.33	0	0	0
2.649	49263.92	400	0	0	0	0	16.67	50	0	0	0
3.026	44051.12	0	0	0	0	0	25	50	0	0	0
3.403	49063.4	0	0	0	0	0	25	41.67	0	0	0
3.78	49263.92	400	0	0	0	20	25	41.67	0	0	0
4.157	45253.95	0	0	0	0	0	50	83.33	0	0	0
4.534	41044.38	0	0	0	0	20	0	33.33	0	0	0
4.911	42247.02	400	0	0	0	0	58.33	16.67	0	0	0
5.288	43650.19	0	0	0	0	20	33.33	16.67	0	0	0
5.665	53675.87	0	0	0	0	40	16.67	25	0	0	0
6.042	42046.57	0	0	0	200	100	8.33	75	0	0	100
6.419	55280.47	16807.85	0	0	6801.38	580.01	1075.04	2233.49	0	3100.3	12404.8
6.797	204496.89	7615471.26	0	0	429017.34	5420.89	2891.92	7576.75	0	25720.53	88946.11
7.174	958426.68	36942291.45	600.01	0	1933877	15547.36	2950.27	5559.28	0	31681.14	113802.59
7.551	1062350.9	48668504.21	0	0	2366139.31	15607.42	1783.43	2708.56	0	40099.88	120450.88
7.928	1225569.66	58244638.8	0	0	3001998.31	17929.79	1550.07	2200.15	0	41904.47	160752.07
8.305	1423832.94	62053795.14	400	0	3544078.99	21053.49	1483.4	2600.21	0	50178.07	155450.16
8.682	1554580.11	60651032.61	0	0	3345920.39	20132.33	1608.41	2450.18	0	46266.38	158025.15
9.059	1740370.55	66859676.49	0	0	3516239.53	22775.79	1600.08	2891.92	0	47319.43	179398.37
9.436	1783400.43	80704070.55	0	0	3822985.63	22695.67	2283.49	3650.41	0	54391.72	176870.5
9.813	1830103.17	87598876.96	0	0	3988790.32	27242.59	1975.12	3008.61	0	50830.11	175252.88
10.19	1746135.2	84858945.65	0	0	4204186.03	26641.6	1758.43	2883.59	0	56549.14	173180.56
10.567	2022984.42	74790395.42	0	0	3898227.04	24338.03	1883.44	3050.28	0	50880.27	181774.92
10.944	1974139.11	78671820.51	0	0	3970253.6	25920.44	1841.77	2666.88	0	50579.33	185719.73
11.321	1659004.33	78115314.25	0	0	4284694.63	25019.05	1866.77	2875.25	0	45965.52	177426.62
11.698	1857140.08	72425795.37	0	0	3894738.37	25219.36	2275.16	2700.22	0	44411.17	161711.66
12.074	1873566.45	71660339.1	0	0	3706789.54	22575.51	2133.47	2608.54	0	45815.09	182482.88
12.452	2029157.08	69295389.05	0	0	3968987.98	24418.14	1916.78	2375.17	0	44812.28	149796.71
12.829	1568226.21	63666607.67	0	0	3795180.16	24658.51	1908.44	2391.84	0	45062.98	142379.57
13.206	1486630.31	64826032.7	0	0	3238596.51	21754.4	1908.44	2383.51	0	45113.12	153178.46

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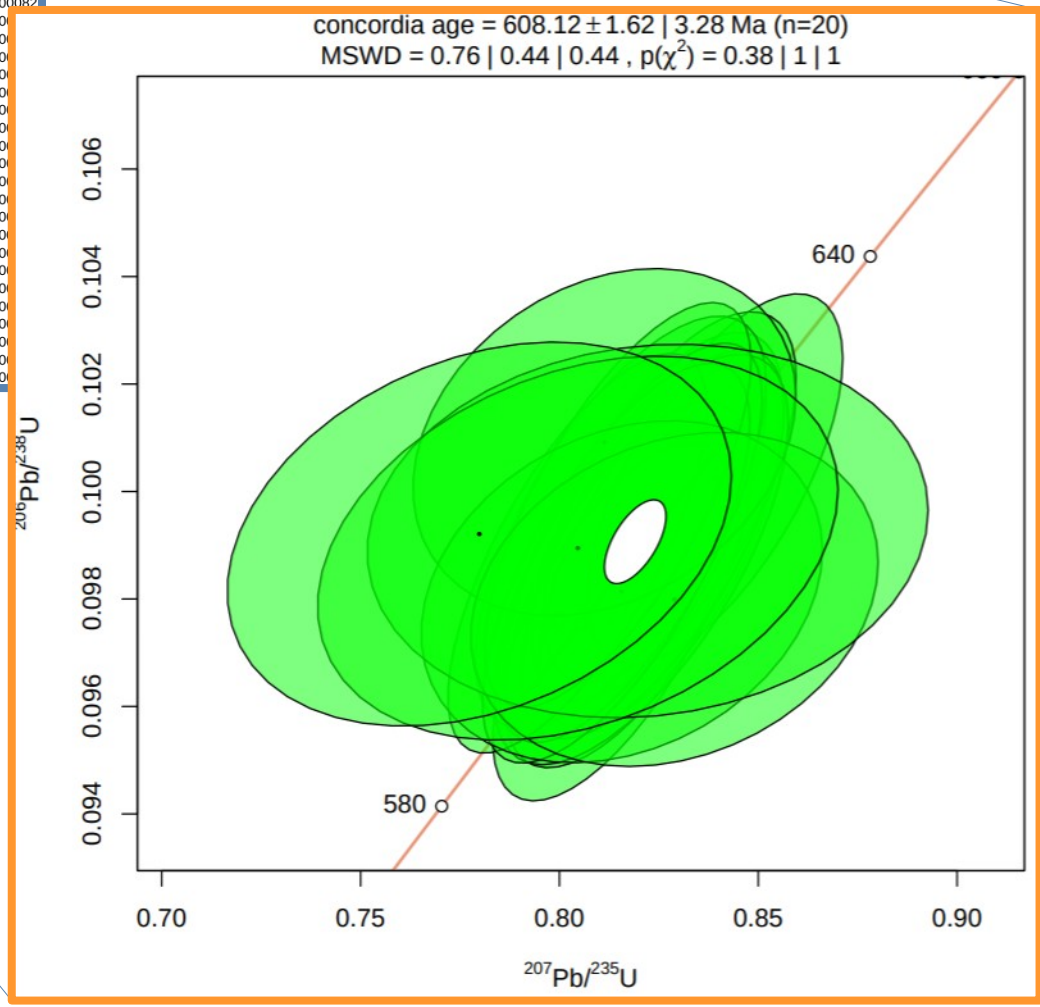
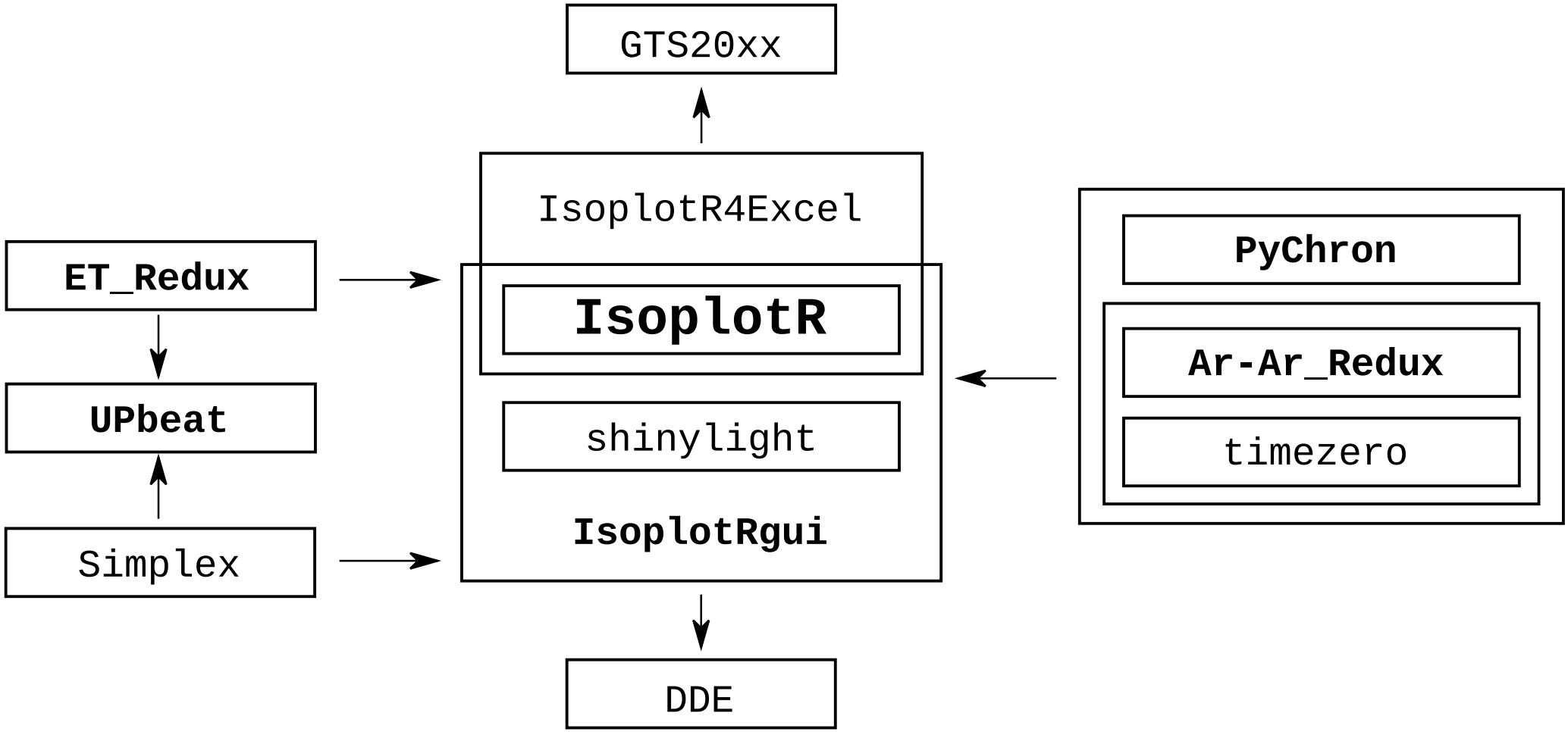
signal

ID	207Pb/235U	err	206Pb/238U	err	207Pb/206Pb	err
ALC#1	0.7949	0.00841	0.0953	0.00092	0.06063	0.00068
ALC#2	0.8585	0.00945	0.10117	0.00098	0.06168	0.00072
ALC#3	0.81067	0.01161	0.09922	0.00104	0.05939	0.00091
ALC#4	0.82027	0.00961	0.0987	0.00098	0.06041	0.00075
ALC#5	0.89669	0.01102	0.10433	0.00105	0.06247	0.00082
ALC#6	0.80764	0.00944	0.09709	0.00096	0.06047	0.00075
ALC#7	0.85788	0.00951	0.10226	0.001	0.06098	0.00072
ALC#8	0.76541	0.00911	0.09355	0.00093	0.05947	0.00075
ALC#9	6.60443	0.06755	0.36981	0.00356	0.12982	0.00141
ALC#11	0.83394	0.01012	0.09963	0.001	0.06084	0.00079
ALC#10	0.81681	0.01257	0.09917	0.00107	0.05987	0.00098
ALC#12	0.66711	0.00708	0.06713	0.00065	0.07224	0.00082
ALC#13	0.72902	0.02297	0.08971	0.00136	0.05907	0.0
ALC#15	0.79924	0.00926	0.09759	0.00096	0.05953	0.0
ALC#14	0.90935	0.01148	0.10735	0.00109	0.06158	0.0
ALC#16	0.81462	0.00943	0.09583	0.00095	0.06179	0.0
ALC#17	0.77374	0.01055	0.09494	0.00098	0.05924	0.0
ALC#18	0.82825	0.0098	0.09631	0.00096	0.06251	0.0
ALC#19	0.832	0.00951	0.09845	0.00097	0.06143	0.0
ALC#20	0.73764	0.00983	0.08972	0.00092	0.05976	0.0
ALC#21	0.66464	0.00797	0.08467	0.00084	0.05706	0.0
ALC#22	0.8777	0.01169	0.10432	0.00107	0.06116	0.0
ALC#24	0.39993	0.00662	0.05442	0.00059	0.05342	0.0
ALC#26	0.81333	0.01121	0.09789	0.00102	0.0604	0.0
ALC#25	0.91423	0.01178	0.10274	0.00105	0.06469	0.0
ALC#27	0.82152	0.01048	0.04948	0.00075	0.12068	0.0
ALC#28	0.80368	0.00958	0.09675	0.00096	0.06038	0.0
ALC#30	0.84635	0.00926	0.09393	0.00091	0.0655	0.0
ALC#29	0.78218	0.00866	0.09007	0.00088	0.06312	0.0
ALC#31	0.81088	0.01153	0.09645	0.00101	0.06111	0.0
ALC#33	0.82704	0.01091	0.0985	0.00101	0.06103	0.0
ALC#32	0.87233	0.01048	0.10451	0.00104	0.06067	0.0
ALC#34	0.72033	0.00816	0.08784	0.00086	0.05961	0.0

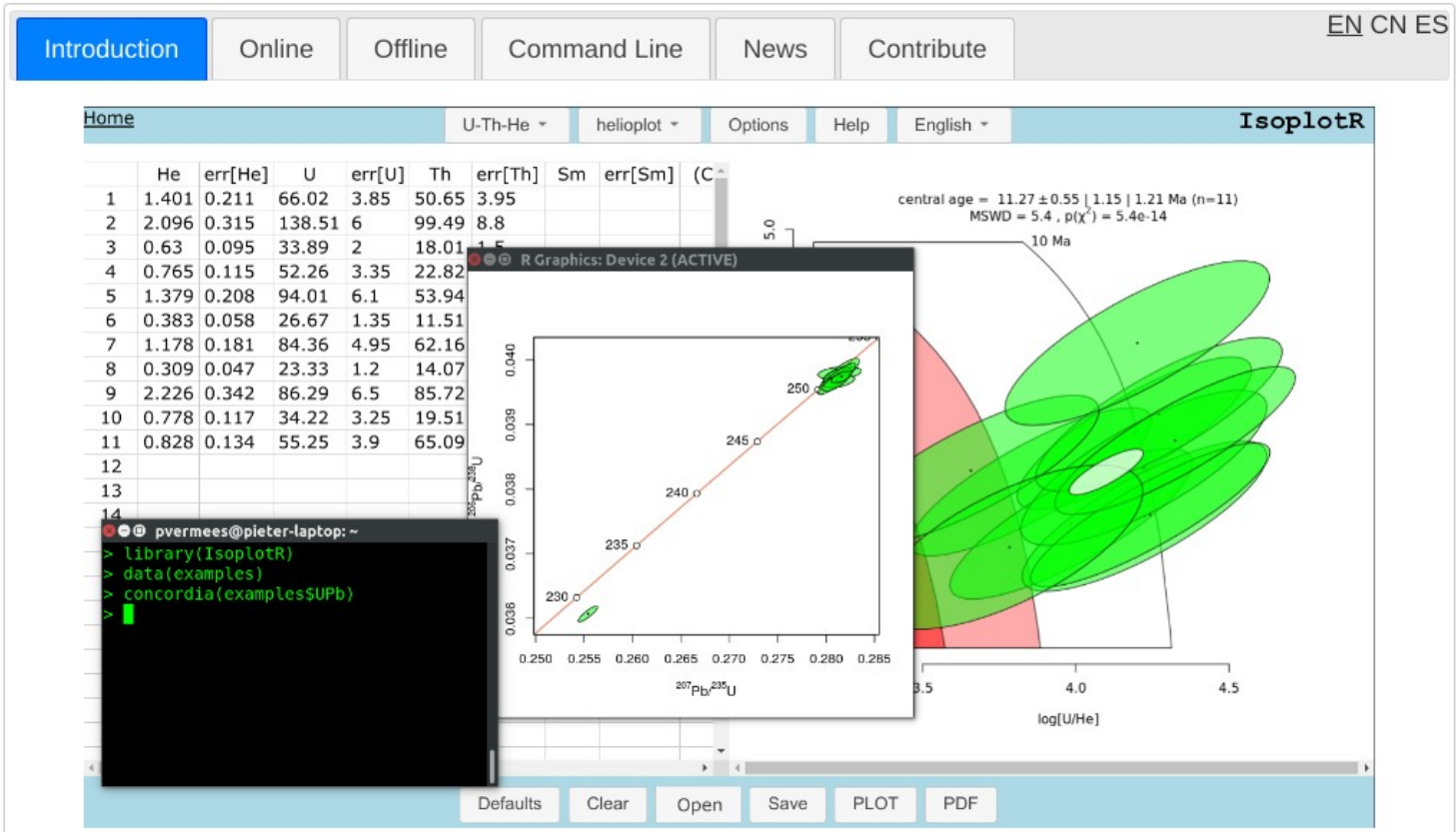


An operating system [...] means a collection of programs that are sufficient to use the computer to do a wide variety of jobs. A general purpose operating system, to be complete, ought to handle all the jobs that many users may want to do.

Richard Stallman (Free Software Foundation)


GTS20xx
IsoplotR4Excel
ET_Redux
IsoplotR
UPbeat
shinylight
Simplex
IsoplotRgui
DDE
PyChron
Ar-Ar_Redux
timezero

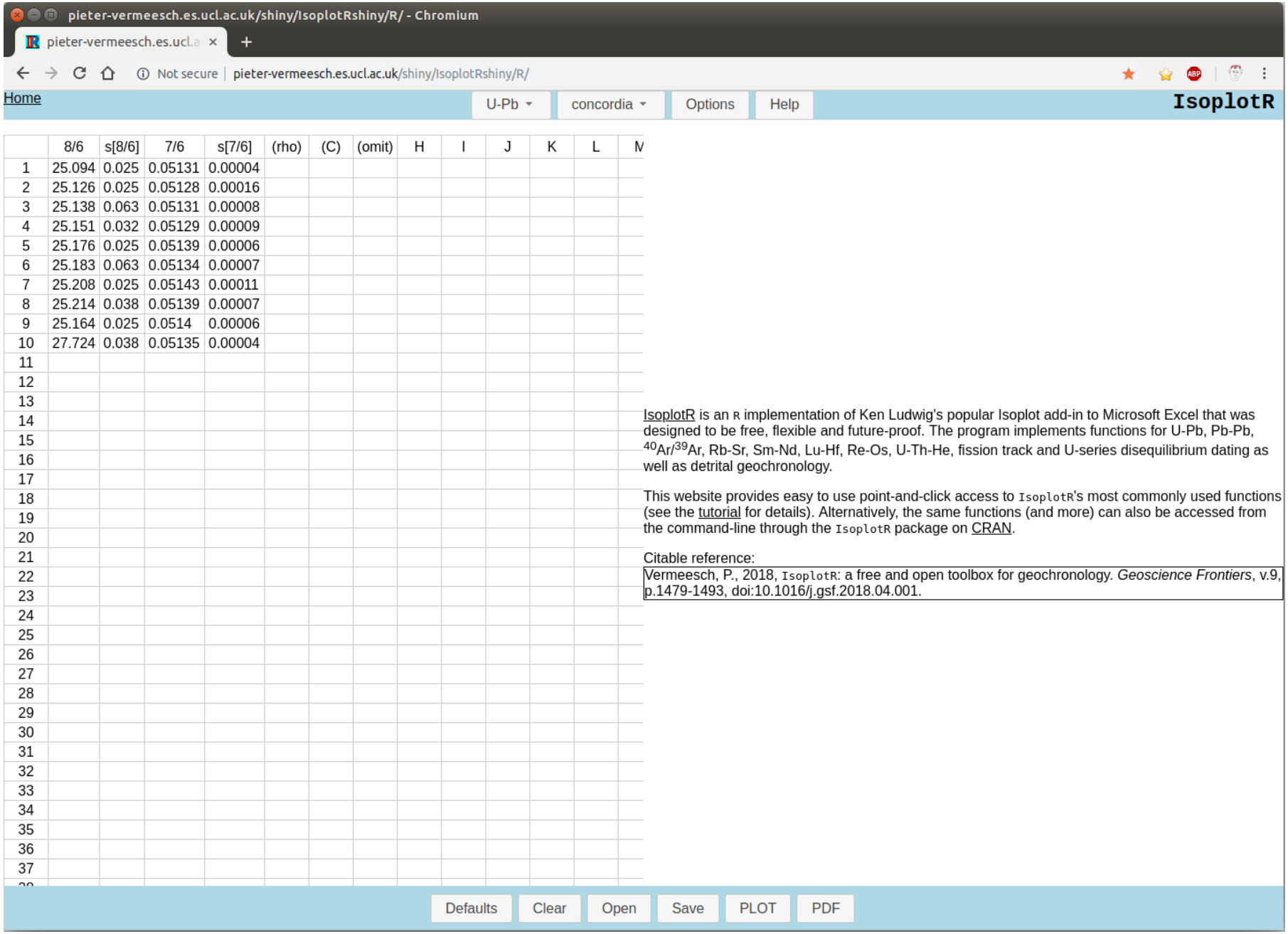
IsoplotR: a free and extendable toolbox for geochronology



IsoplotR is a free and open-source substitute for Kenneth Ludwig's popular *Isoplot* add-in to Microsoft *Excel*. *IsoplotR* is programmed in *R* and can be run in three different modes:

1. Online: A user-friendly Graphical User Interface (GUI) that runs in a web browser on any internet-connected device.
2. Offline: The GUI can be run natively on any computer that has *R* installed on it. *R* is free software that is available on Windows, Mac and Linux/Unix.
3. Command Line: Advanced users can access the full functionality of *IsoplotR* from *R*'s command line. This enables *IsoplotR* to be extended and incorporated into automation scripts.

Citable reference:
Vermeesch, P., 2018, `IsoplotR`: a free and open toolbox for geochronology. *Geoscience Frontiers*, v.9, p.1479-1493, doi: 10.1016/j.gsf.2018.04.001.



	8/6	s[8/6]	7/6	s[7/6]	(rho)	(C)	(omit)	H	I	J	K	L	M
1	25.094	0.025	0.05131	0.00004									
2	25.126	0.025	0.05128	0.00016									
3	25.138	0.063	0.05131	0.00008									
4	25.151	0.032	0.05129	0.00009									
5	25.176	0.025	0.05139	0.00006									
6	25.183	0.063	0.05134	0.00007									
7	25.208	0.025	0.05143	0.00011									
8	25.214	0.038	0.05139	0.00007									
9	25.164	0.025	0.0514	0.00006									
10	27.724	0.038	0.05135	0.00004									
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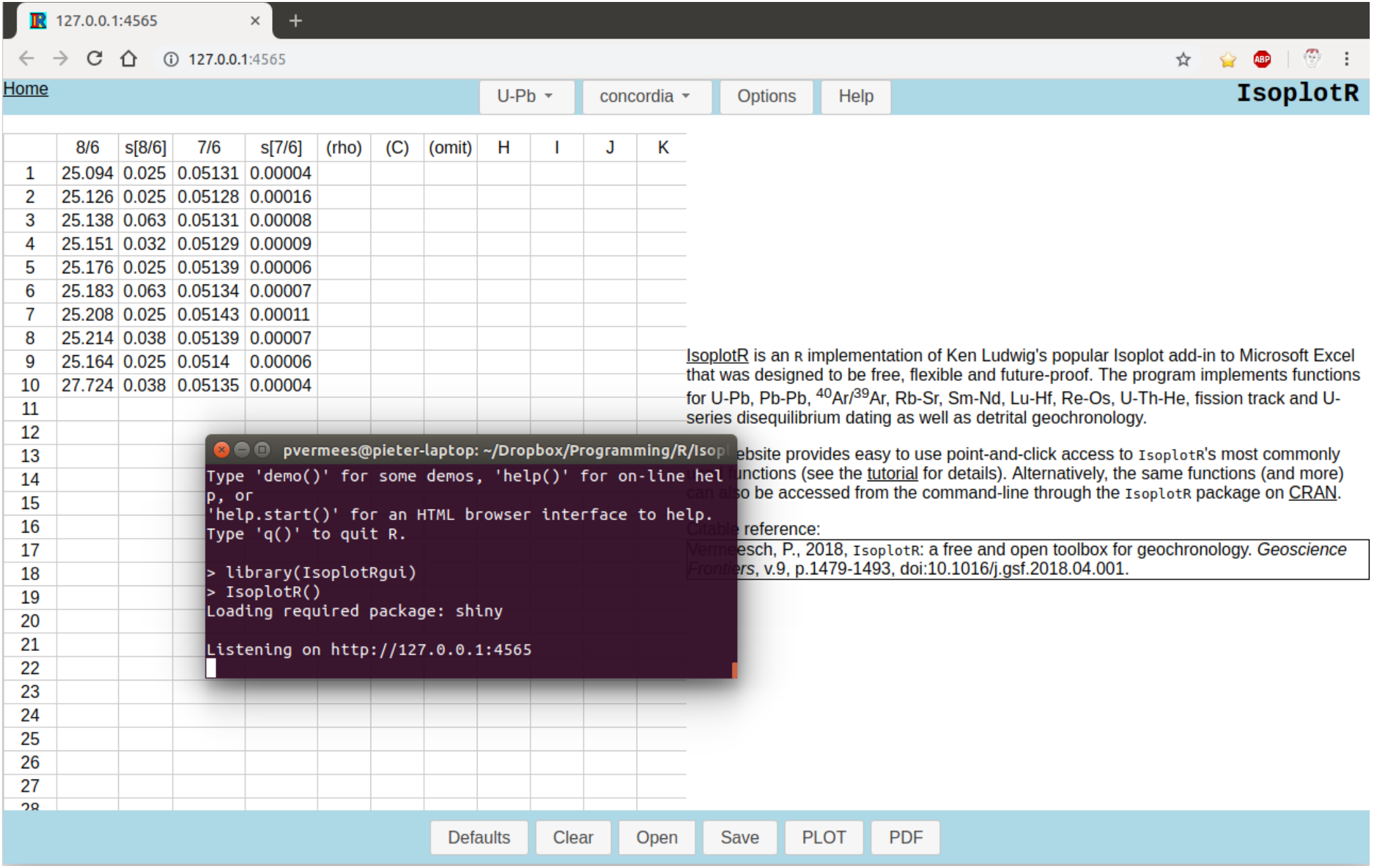

	8/6	s[8/6]	7/6	s[7/6]	(rho)	(C)	(omit)	H	I	J	K
1	25.094	0.025	0.05131	0.00004							
2	25.126	0.025	0.05128	0.00016							
3	25.138	0.063	0.05131	0.00008							
4	25.151	0.032	0.05129	0.00009							
5	25.176	0.025	0.05139	0.00006							
6	25.183	0.063	0.05134	0.00007							
7	25.208	0.025	0.05143	0.00011							
8	25.214	0.038	0.05139	0.00007							
9	25.164	0.025	0.0514	0.00006							
10	27.724	0.038	0.05135	0.00004							
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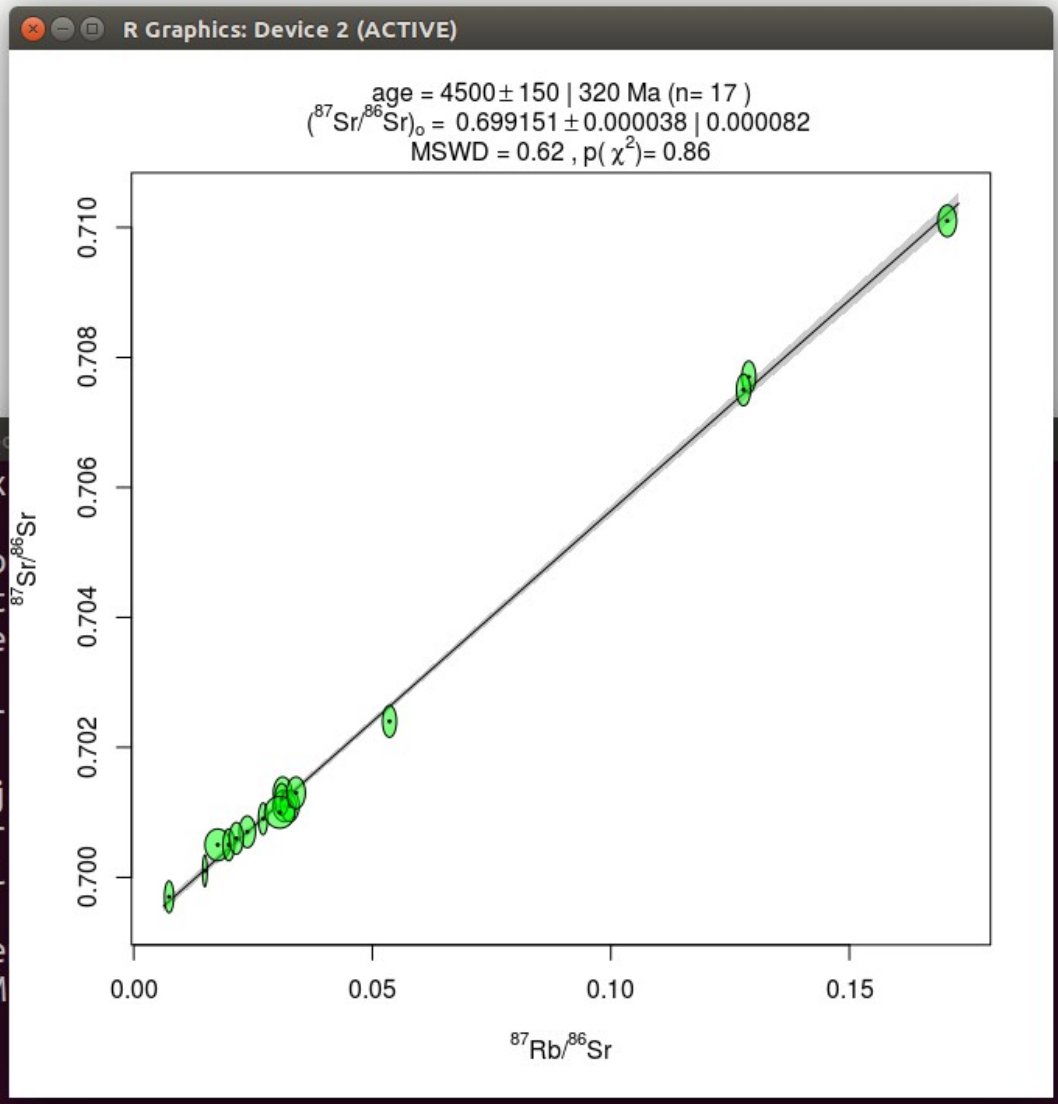
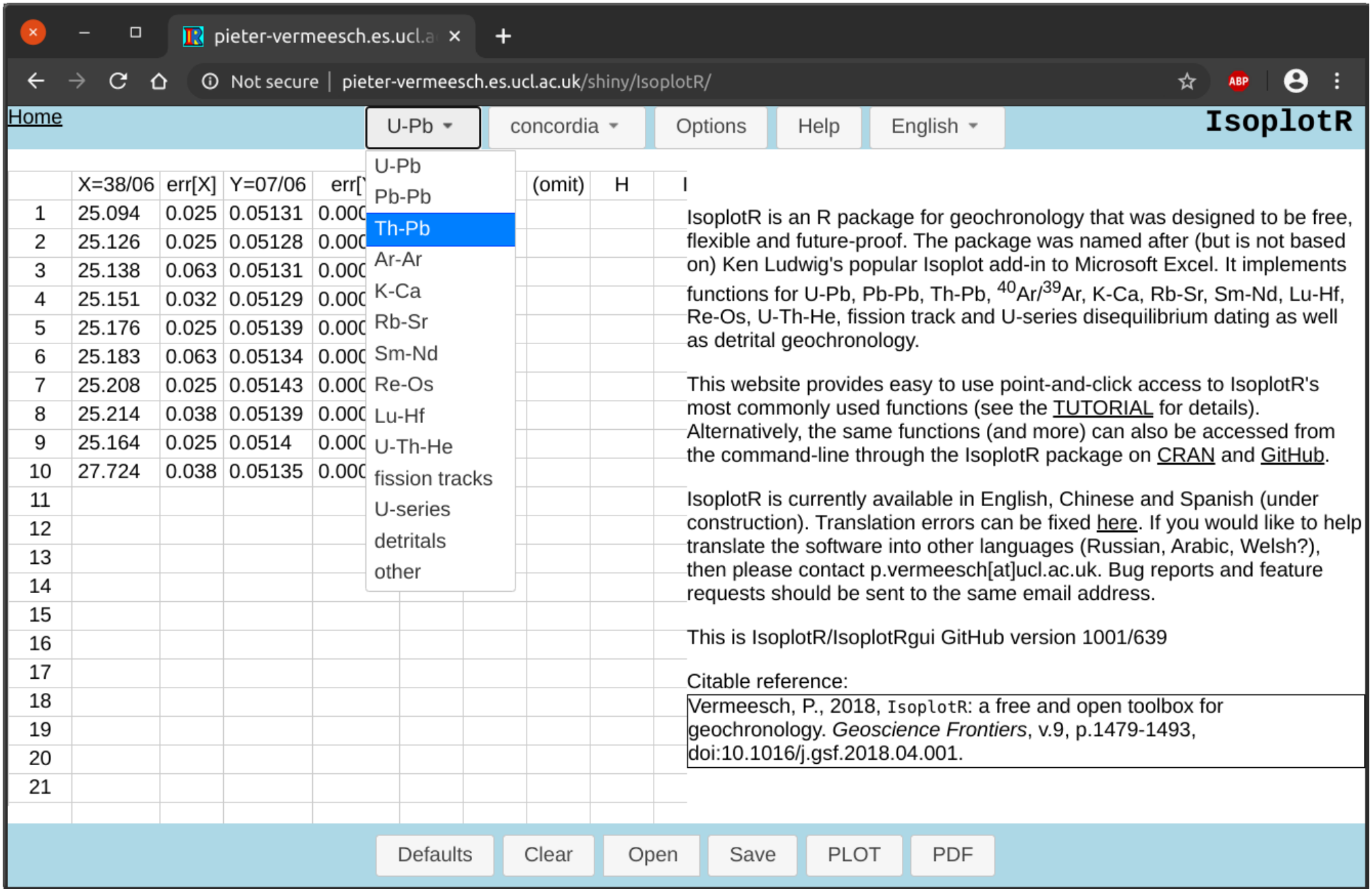



```
pvermees@pieter-laptop: ~/Dropb
Platform: x86_64-pc-linux

R is free software and co
You are welcome to redist
Type 'license()' or 'lice

  Natural language suppor

R is a collaborative proj
Type 'contributors()' for
'citation()' on how to ci

Type 'demo()' for some de
'help.start()' for an HTM
Type 'q()' to quit R.

> library(IsoplotR)
> RbSr <- read.data('RbSr1.csv',method='Rb-Sr',format=1)
> isochron(RbSr)
>
```

IsoplotR currently implements 14 geochronological methods



Introduction | Online | Offline | Command Line | News | Contribute

EN CN ES

An online GUI is hosted by the following international collaborators:

1. London (UK): Pieter Vermeesch (University College London)
2. Austin (USA): Daniel Stockli (University of Texas)
3. Beijing (China): Yang Li (Chinese Academy of Sciences)
4. Changchun (China): Qiuye Yu (Changchun Institute of Technology)
5. Keyworth (UK): Ian Millar (British Geological Survey)
6. Salta (Argentina): Sofía Bordese (LA.TE.ANDES)
7. Santa Barbara (USA): John Cottle (University of California)

Click on one of the yellow boxes below to select a nearby mirror:

If you would like to make your own `IsoplotR` mirror available to the world via this website, then please get in touch with me at *p.vermeesch [at] ucl.ac.uk*.

Synchronizing Rock Clocks of Earth History

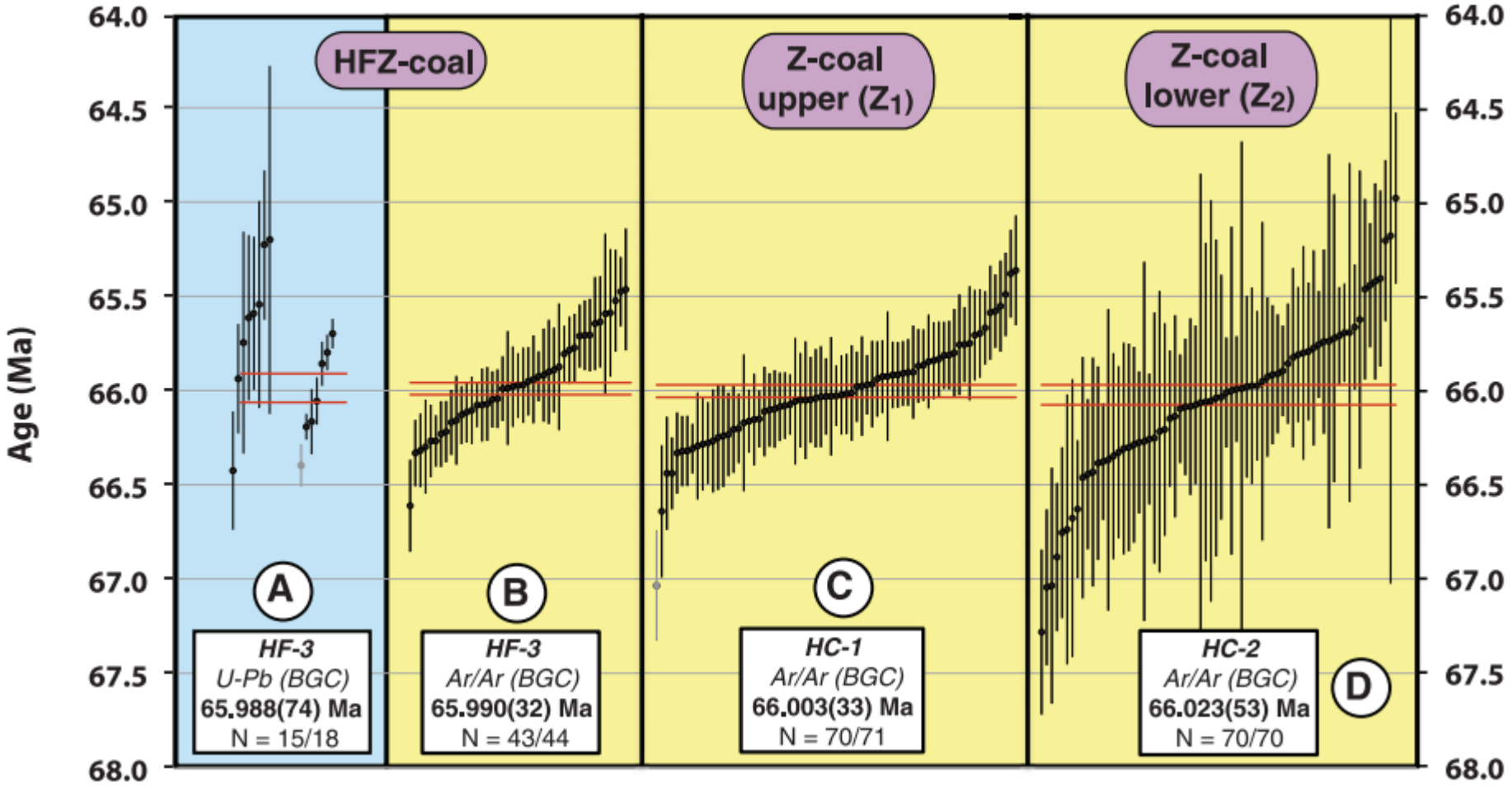
K. F. Kuiper,[1,2] A. Deino,[3] F. J. Hilgen,[1] W. Krijgsman,[1] P. R. Renne,[3,4] J. R. Wijbrans[2]

25 APRIL 2008 VOL 320 SCIENCE

Time Scales of Critical Events Around the Cretaceous-Paleogene Boundary

Paul R. Renne,[1,2]* Alan L. Deino,[1]† Frederik J. Hilgen,[3]† Klaudia F. Kuiper,[4]† Darren F. Mark,[5]† William S. Mitchell III,[2,6]† Leah E. Morgan,[5]† Roland Mundil,[1]† Jan Smit[4]†

8 FEBRUARY 2013 VOL 339 SCIENCE

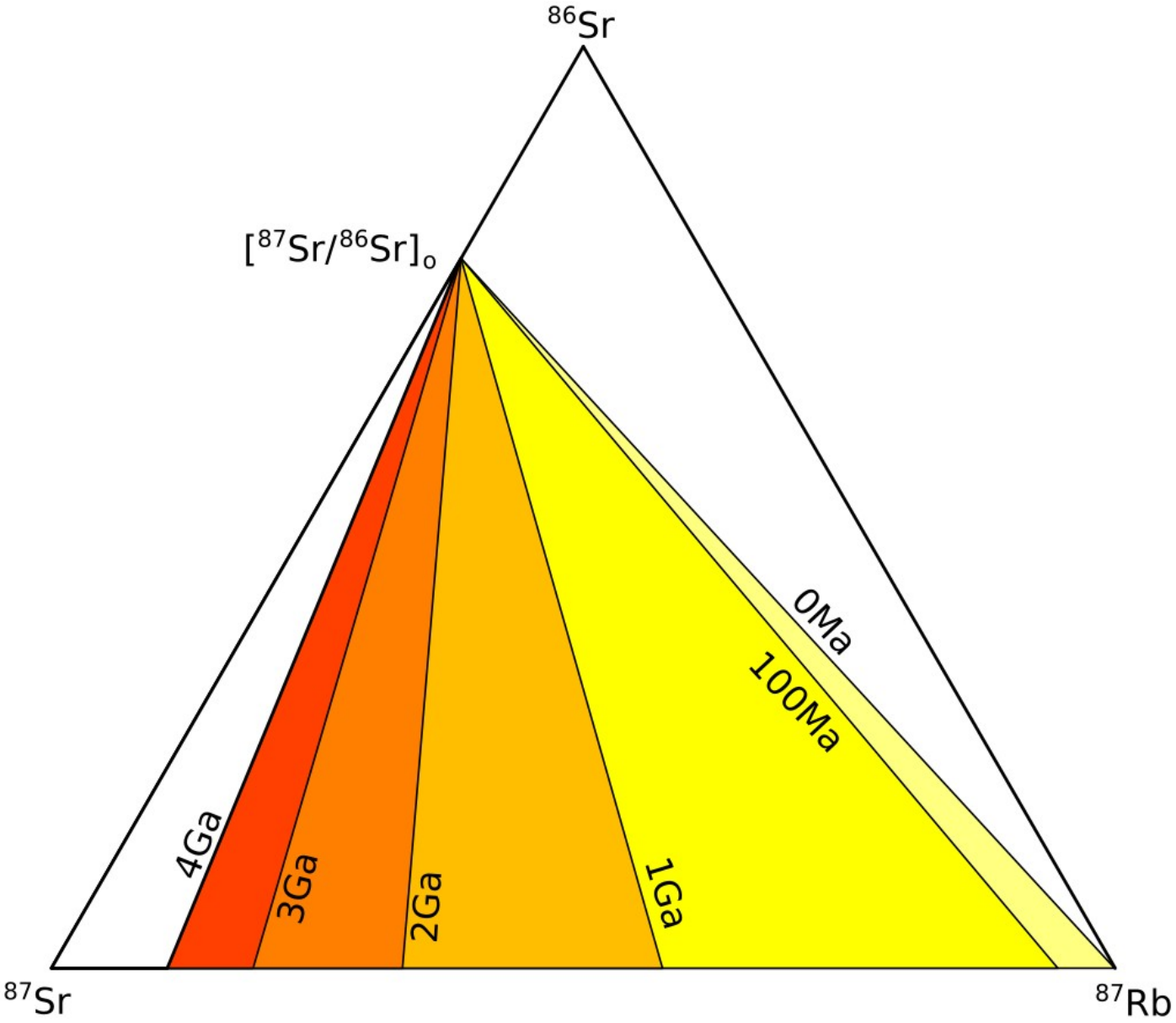


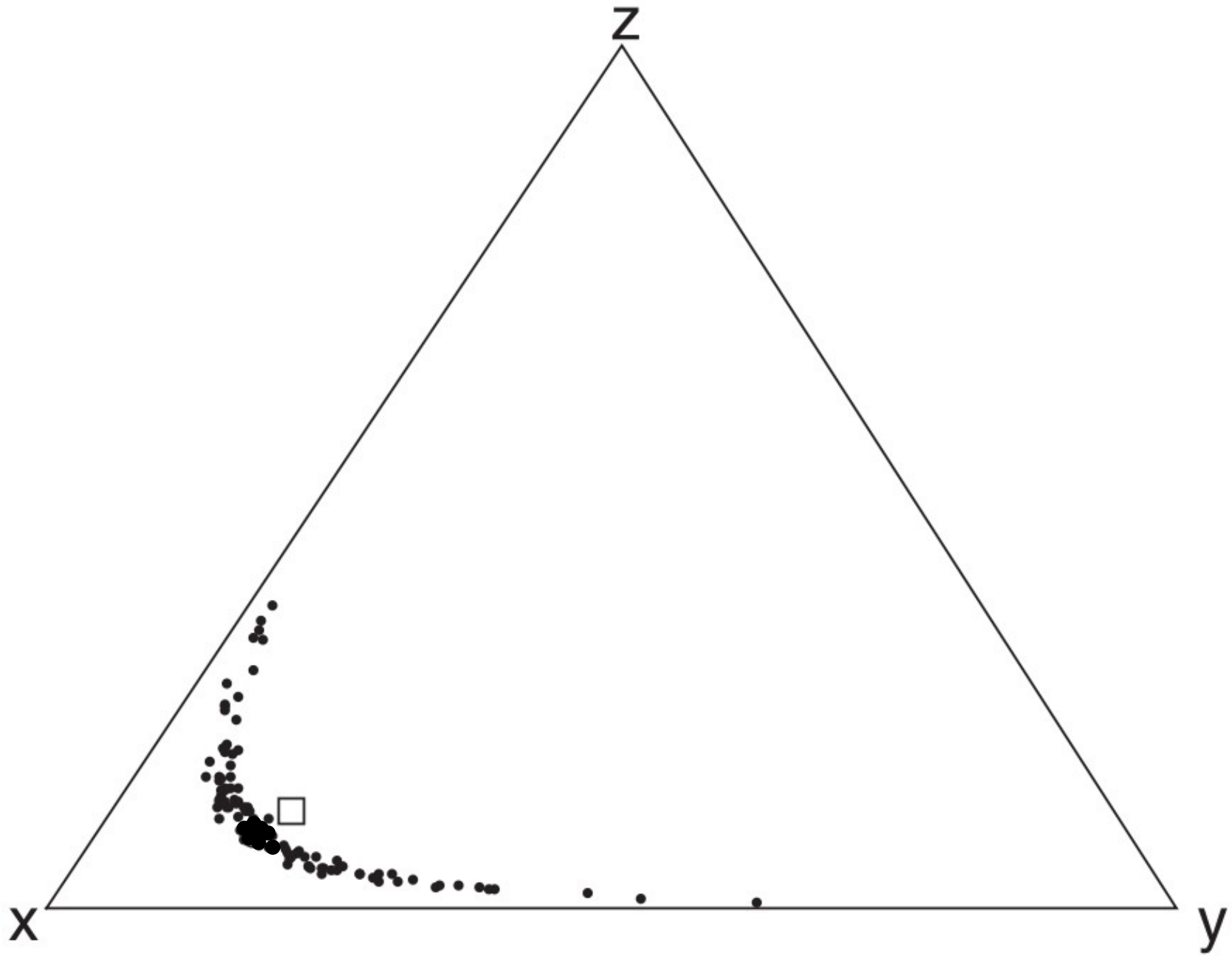
1. Isotopic measurements are compositional data

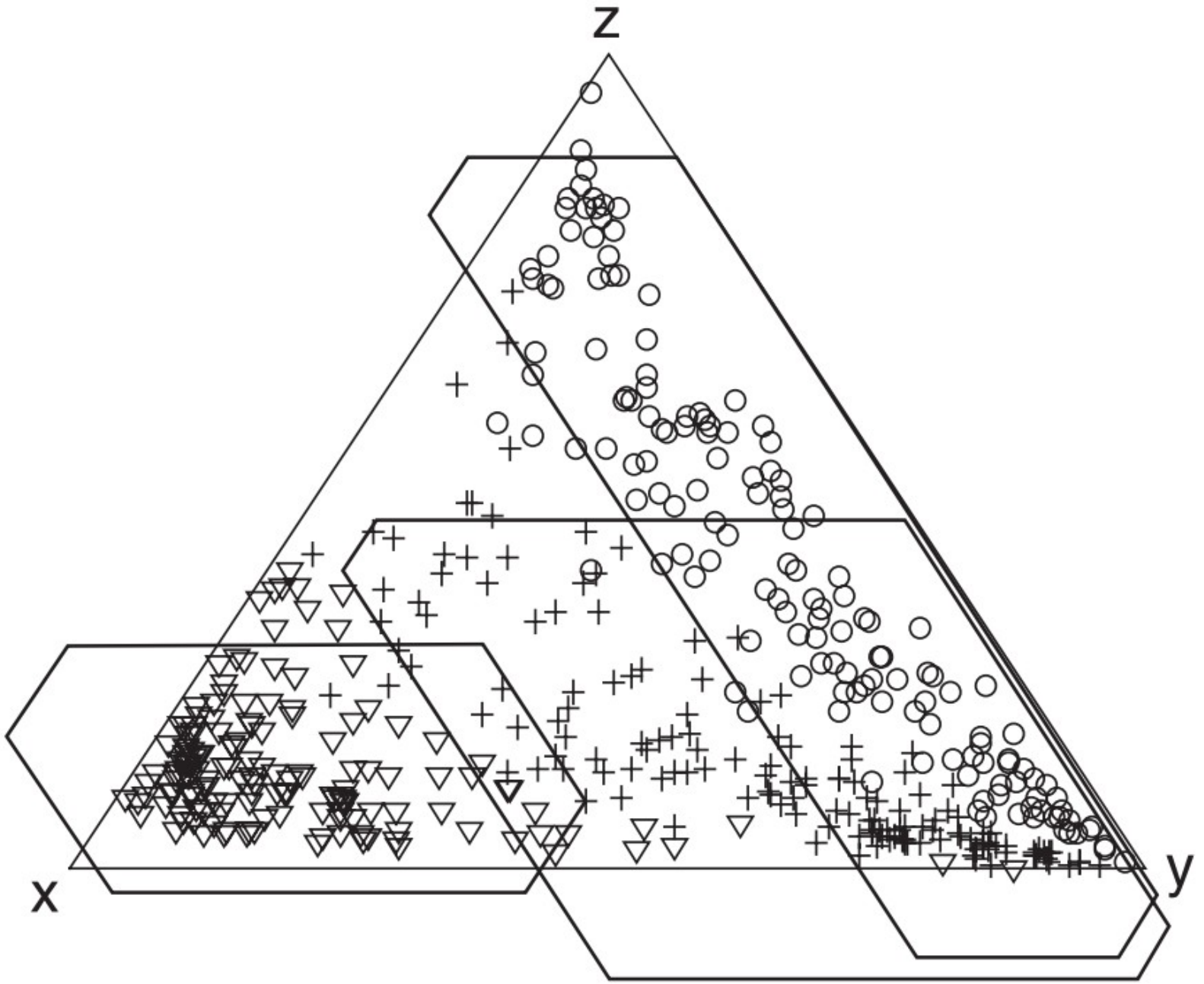
2. Error correlations are commonplace in geochronology

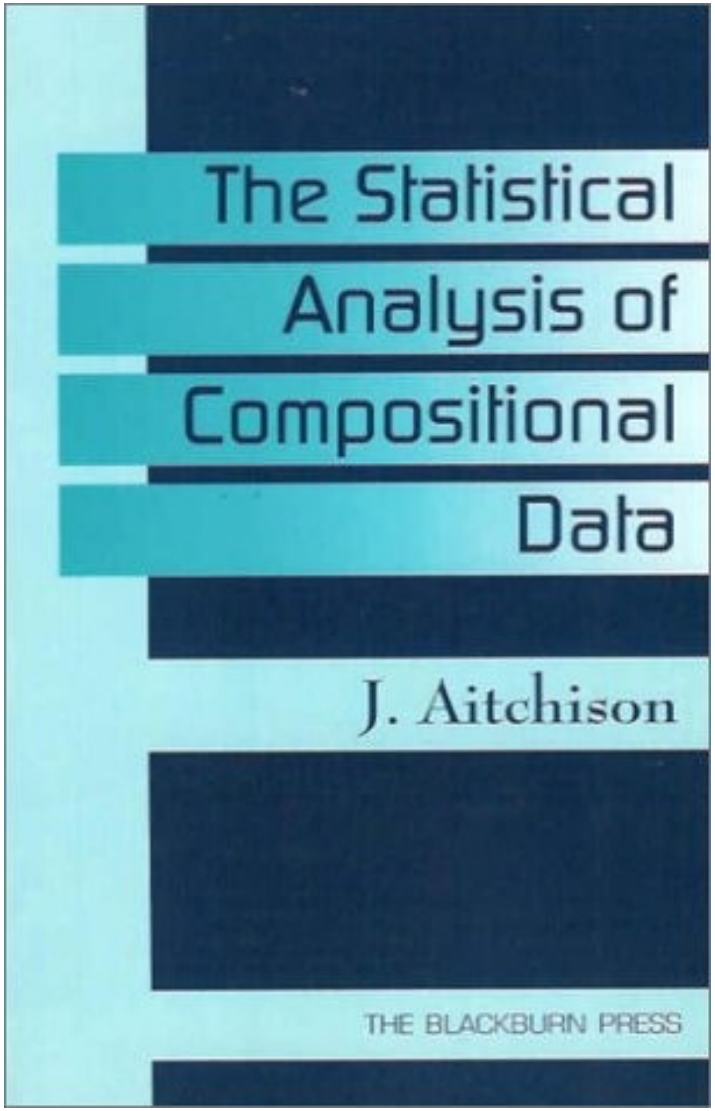
$$\begin{matrix} {}^{87}\mathrm{Rb} \\ {}^{85}\mathrm{Rb} \end{matrix} \xrightarrow[+\mathrm{p},\beta^-,\nu]{\text{-n}} \begin{matrix} {}^{88}\mathrm{Sr} \\ {}^{87}\mathrm{Sr} \\ {}^{86}\mathrm{Sr} \\ {}^{84}\mathrm{Sr} \end{matrix}$$

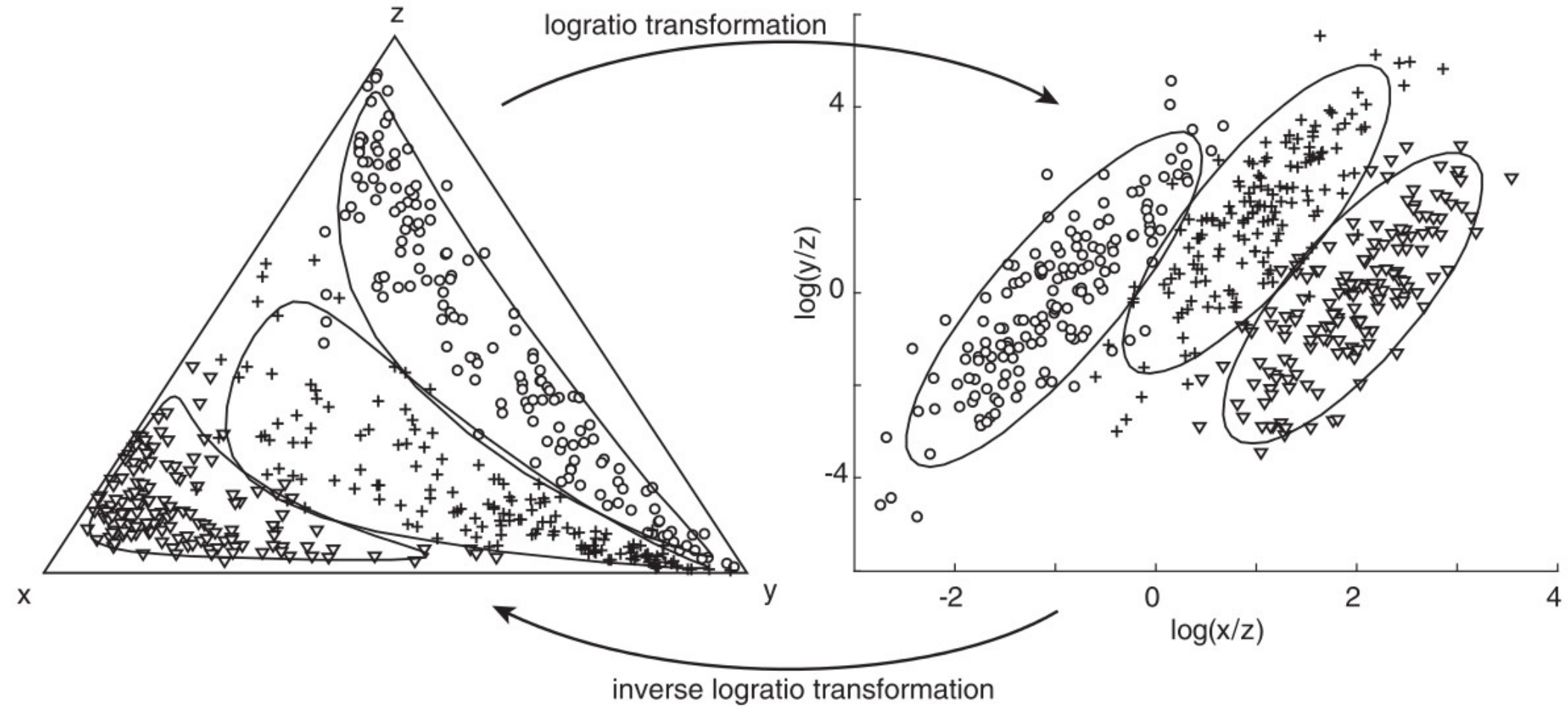
$$\left[\frac{{}^{87}\mathrm{Sr}}{{}^{86}\mathrm{Sr}}\right]_m = \left[\frac{{}^{87}\mathrm{Sr}}{{}^{86}\mathrm{Sr}}\right]_\circ + \left[\frac{{}^{87}\mathrm{Rb}}{{}^{86}\mathrm{Sr}}\right]_m \left(\exp[\lambda_{87} t] - 1\right)$$

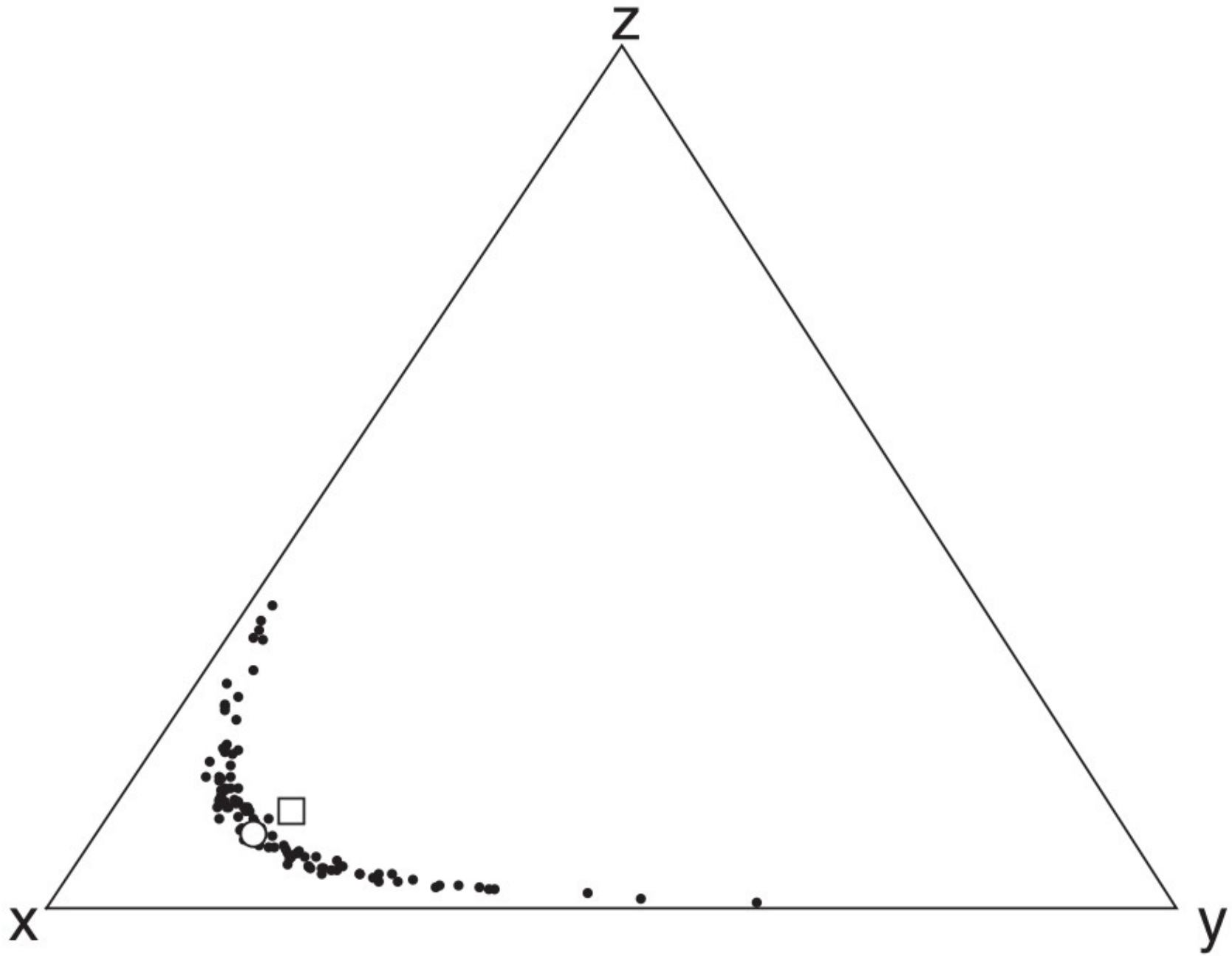

^{86}Sr
$[^{87}Sr/^{86}Sr]_o$
^{87}Sr
^{87}Rb
4Ga
3Ga
2Ga
1Ga
100Ma
0Ma

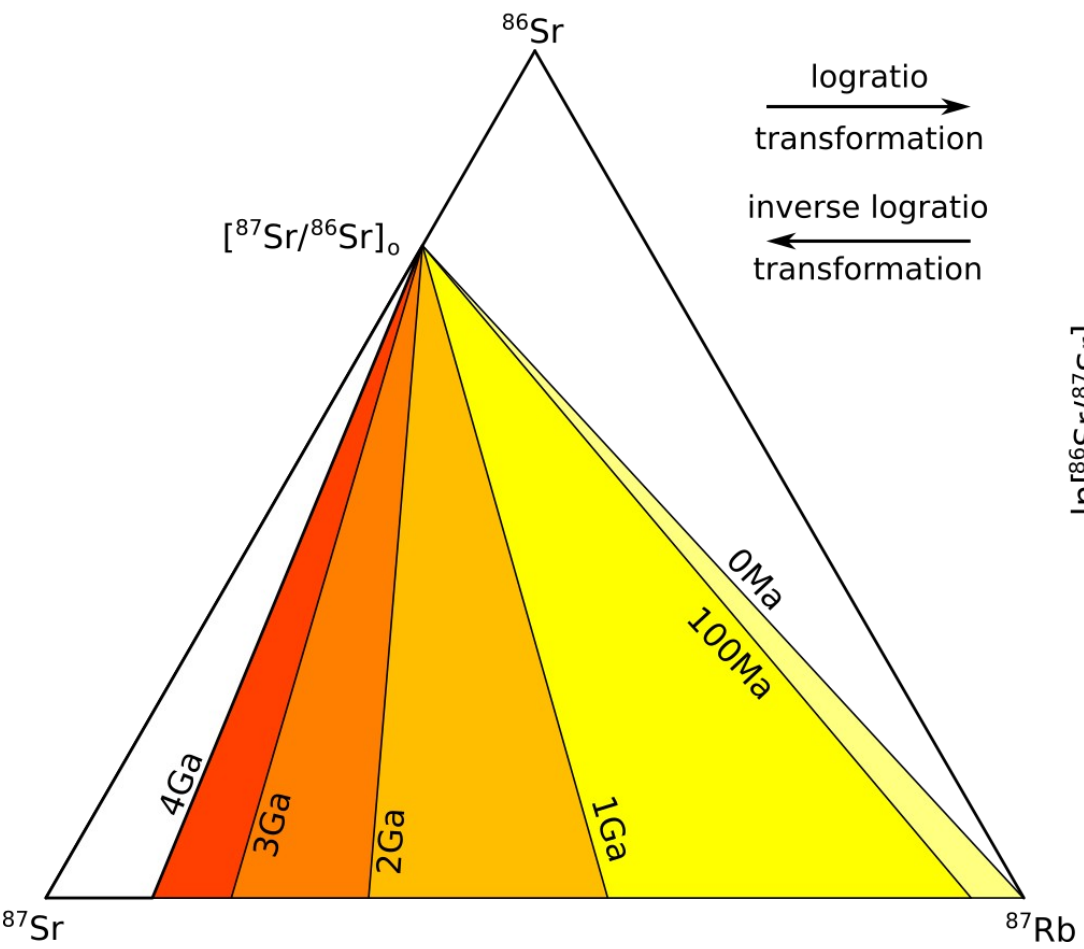

z
x
y

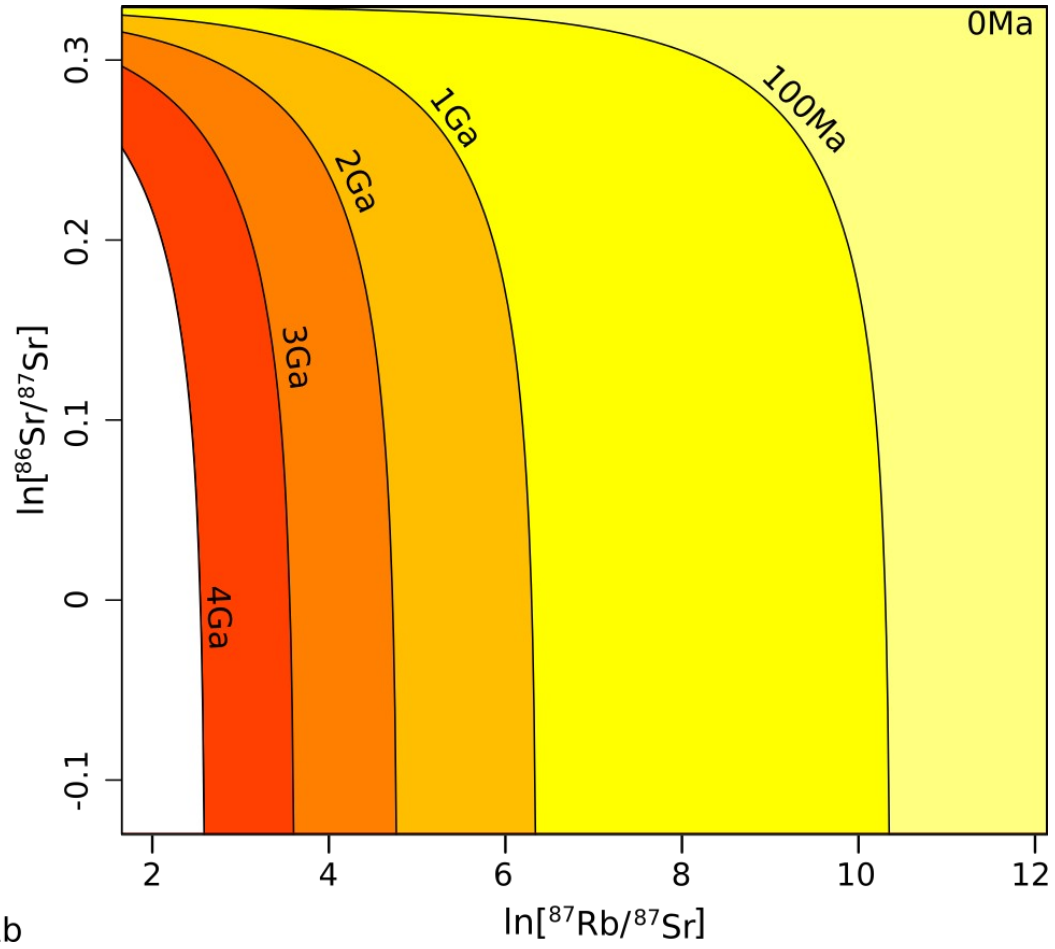

Z
x
y


The Statistical Analysis of Compositional Data
J. Aitchison
THE BLACKBURN PRESS


z
x
y
logratio transformation
inverse logratio transformation
log(y/z)
log(x/z)
4
0
-4
-2
0
2
4


z
x
y


^{86}Sr
$[^{87}Sr/^{86}Sr]_o$
logratio
transformation
inverse logratio
transformation
4Ga
3Ga
2Ga
1Ga
100Ma
0Ma
^{87}Sr
^{87}Rb

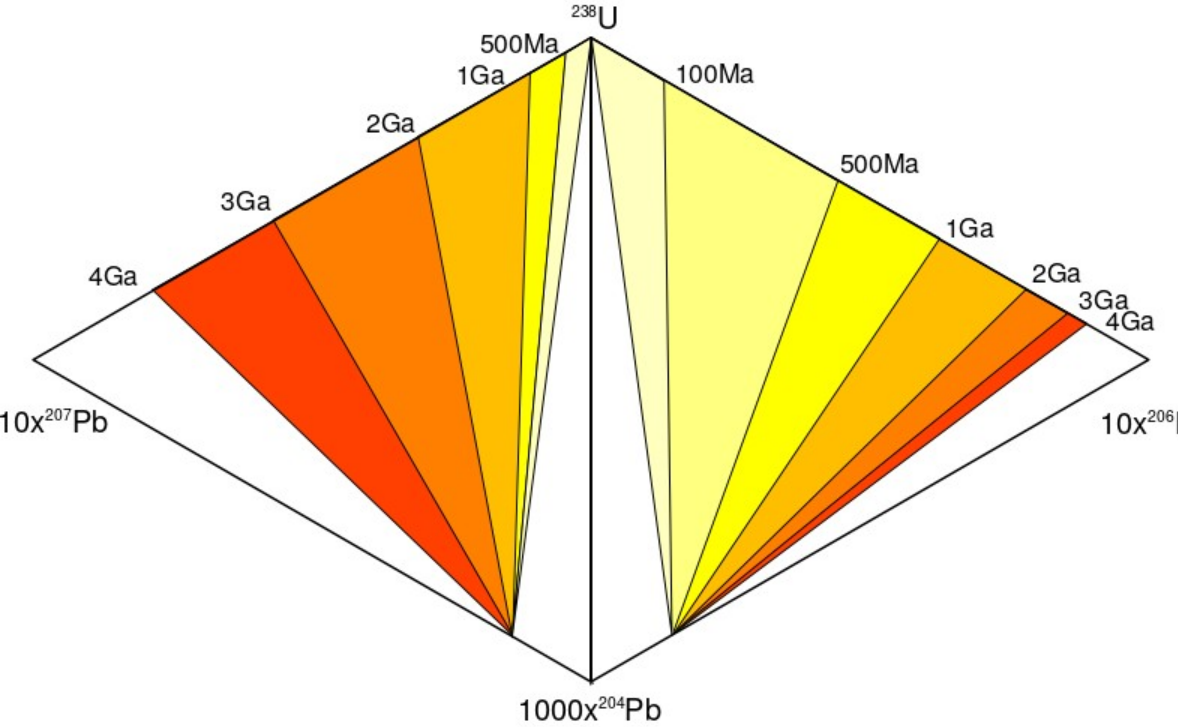

0Ma
100Ma
1Ga
2Ga
3Ga
4Ga
0.3
0.2
0.1
0
-0.1
ln[^{86}Sr/^{87}Sr]
2
4
6
8
10
12
ln[^{87}Rb/^{87}Sr]

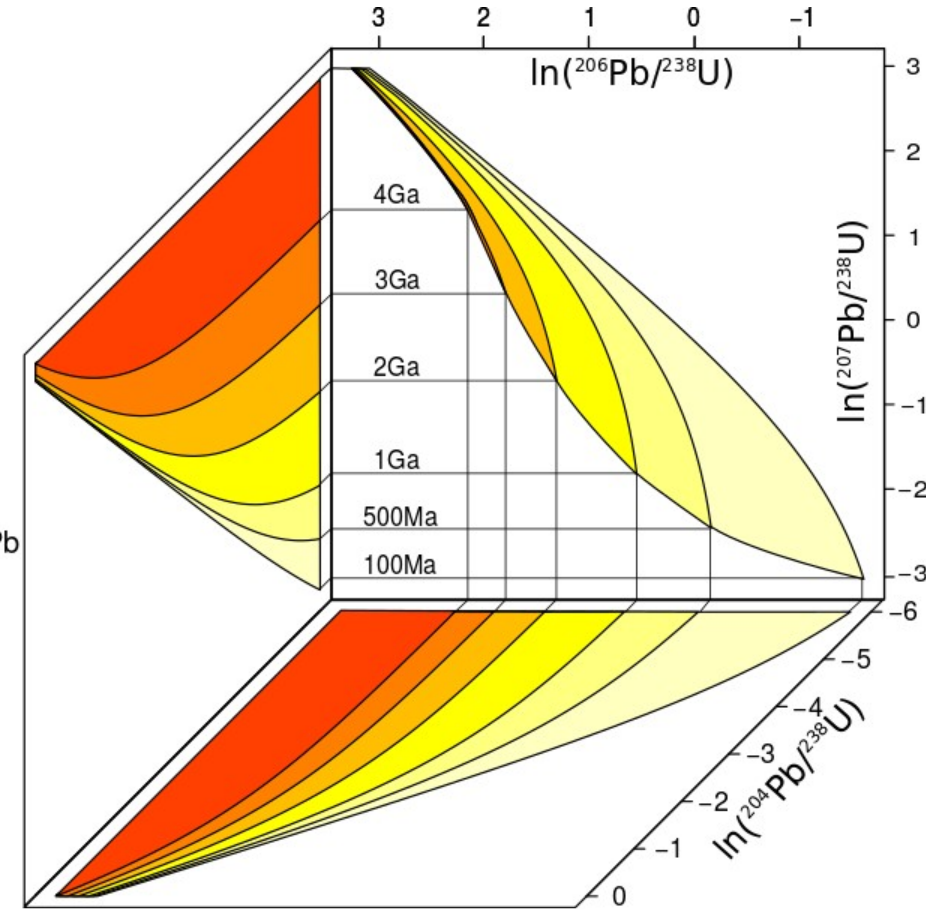
$$^{238}\mathrm{U} \xrightarrow{8\alpha,\ 6\beta^{-1}} {}^{206}\mathrm{Pb}$$
$$^{235}\mathrm{U} \xrightarrow{7\alpha,\ 4\beta^{-1}} {}^{207}\mathrm{Pb}$$
$$^{232}\mathrm{Th} \xrightarrow{6\alpha,\ 4\beta^{-1}} {}^{208}\mathrm{Pb}$$
$$^{204}\mathrm{Pb}$$

$$\left[\frac{^{206}\mathrm{Pb}}{^{204}\mathrm{Pb}}\right]_m = \left[\frac{^{206}\mathrm{Pb}}{^{204}\mathrm{Pb}}\right]_\circ + \left[\frac{^{238}\mathrm{U}}{^{204}\mathrm{Pb}}\right]_m \left(\exp[\lambda_{238} t] - 1\right)$$

$$\left[\frac{^{207}\mathrm{Pb}}{^{204}\mathrm{Pb}}\right]_m = \left[\frac{^{207}\mathrm{Pb}}{^{204}\mathrm{Pb}}\right]_\circ + \left[\frac{^{235}\mathrm{U}}{^{238}\mathrm{U}}\right] \left[\frac{^{238}\mathrm{U}}{^{204}\mathrm{Pb}}\right]_m \left(\exp[\lambda_{235} t] - 1\right)$$

$$\left[\frac{^{238}\mathrm{U}}{^{235}\mathrm{U}}\right] = 138.818$$


^{238}U
500Ma
1Ga
2Ga
3Ga
4Ga
100Ma
500Ma
1Ga
2Ga
3Ga
4Ga
10x^{207}Pb
10x^{206}Pb
1000x^{204}Pb


3
2
1
0
−1
ln(^{206}Pb/^{238}U)
4Ga
3Ga
2Ga
1Ga
500Ma
100Ma
ln(^{207}Pb/^{238}U)
ln(^{204}Pb/^{238}U)

Home | U-Th-He | helioplot | Options | Help | English | IsoplotR

	He	err[He]	U	err[U]	Th	err[Th]	Sm	err[Sm]	(C)	(omit)
1	1.401	0.211	66.02	3.85	50.65	3.95				
2	2.096	0.315	138.51	6.0	99.49	9.0				
3	0.63	0.095	33.89	2.0	18.01	1.5				
4	0.765	0.115	52.26	3.35	22.82	1.9				
5	1.379	0.208	94.01	6.0	53.94	5.05				
6	0.383	0.060	26.67	1.35	11.51	0.75				
7	1.178	0.181	84.36	4.95	62.16	5.5				
8	0.309	0.047	23.33	1.2	14.07	1.05				
9	2.226	0.342	86.29	6.5	85.72	6.5				
10	0.778	0.117	34.22	3.25	19.51	2.2				
11	0.828	0.134	55.25	3.9	65.09	6.25				
12										
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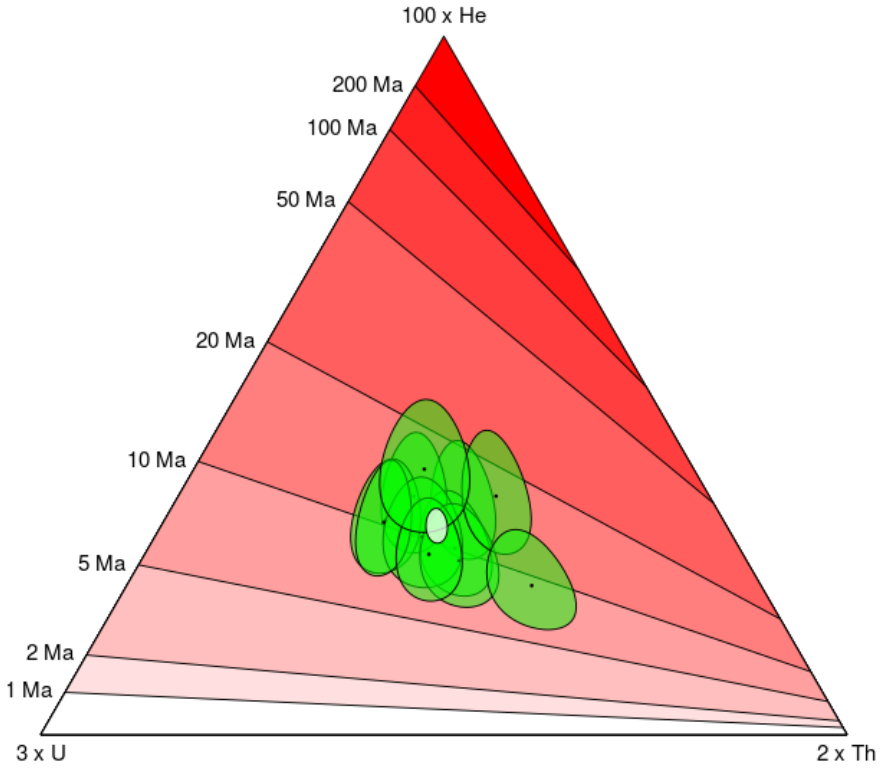
central age = 11.27 ± 0.55 | 1.15 | 1.22 Ma (n=11)
MSWD = 5.4 , $p(\chi^2)$ = 4.9e-14



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1. Isotopic measurements are compositional data

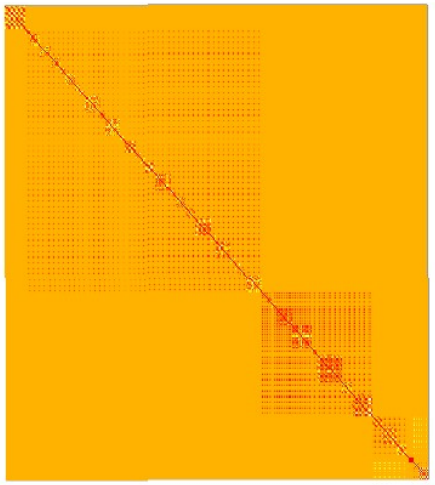
2. Error correlations are commonplace in geochronology

$$z = f(x, y)$$

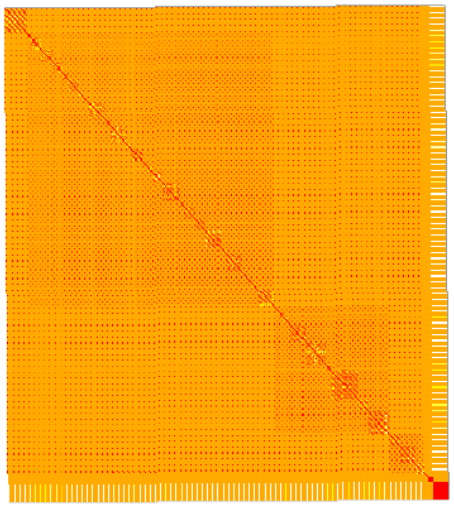
$$\sigma_z^2 = \left(\frac{\partial f}{\partial x}\right)^2 \sigma_x^2 + \left(\frac{\partial f}{\partial y}\right)^2 \sigma_y^2 + 2\frac{\partial f}{\partial x}\frac{\partial f}{\partial y} cov(x, y)$$

$$\sigma_z^2 = \begin{bmatrix} \frac{\partial f}{\partial x} & \frac{\partial f}{\partial y} \end{bmatrix} \begin{bmatrix} \sigma_x^2 & 0 \\ 0 & \sigma_y^2 \end{bmatrix} \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix}$$

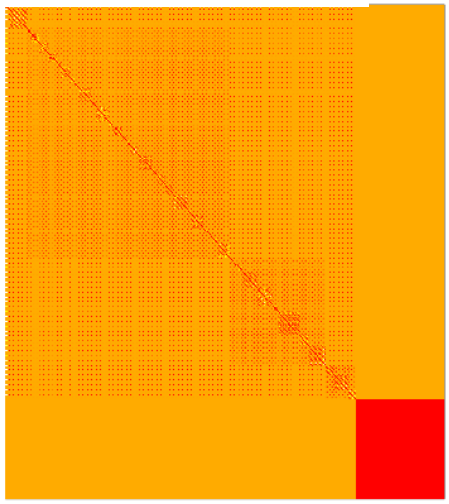
$$\sigma_z^2 = \begin{bmatrix} \frac{\partial f}{\partial x} & \frac{\partial f}{\partial y} \end{bmatrix} \begin{bmatrix} \sigma_x^2 & cov(x,y) \\ cov(x,y) & \sigma_y^2 \end{bmatrix} \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix}$$



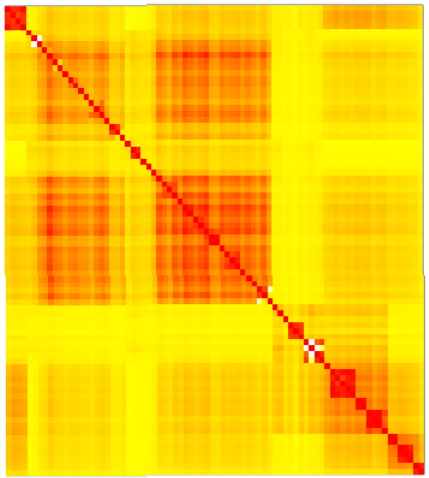
Blank correction



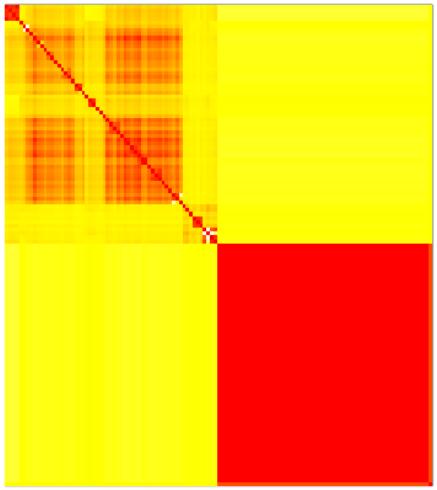
Regression to t_0



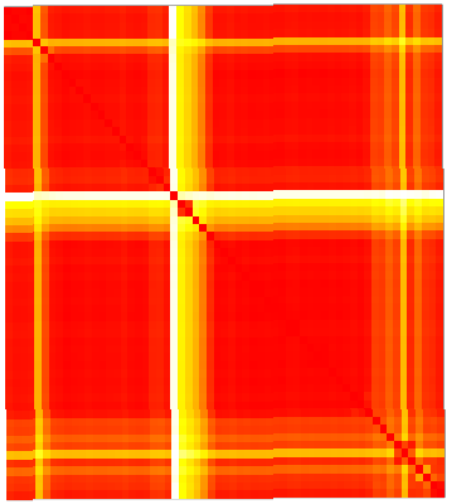
Decay correction



Interference correction



J-factor



40Ar*/39Ar

Home | Rb-Sr | isochron | Options | Help | English | IsoplotR

	Rb87/Sr87	err[Rb87/Sr87]	Sr86/Sr87	err[Sr86/Sr87]	(rho)	(C)	(omit)
1	0.04449	0.00114	1.42592	0.0002	0.0056		
2	0.07631	0.00085	1.42369	0.0002	0.0127		
3	0.04507	0.00143	1.42633	0.0002	0.0045		
4	0.04664	0.00114	1.42633	0.0002	0.0058		
5	0.03866	0.00057	1.42674	0.0002	0.0097		
6	0.02128	0.00029	1.42837	0.0002	0.0106		
7	0.03397	0.001	1.42714	0.0002	0.0049		
8	0.01058	0.00057	1.42918	0.0002	0.0026		
9	0.02512	0.00157	1.42755	0.0002	0.0023		
10	0.04421	0.00086	1.42613	0.0002	0.0074		
11	0.02841	0.00071	1.42755	0.0002	0.0057		
12	0.03069	0.00086	1.42735	0.0002	0.0051		
13	0.04365	0.00185	1.42653	0.0002	0.0034		
14	0.04848	0.00114	1.42592	0.0002	0.0061		
15	0.24011	0.00113	1.40825	0.0002	0.03		
16	0.18214	0.00085	1.41303	0.0002	0.0303		
17	0.18064	0.00085	1.41343	0.0002	0.0301		
18							
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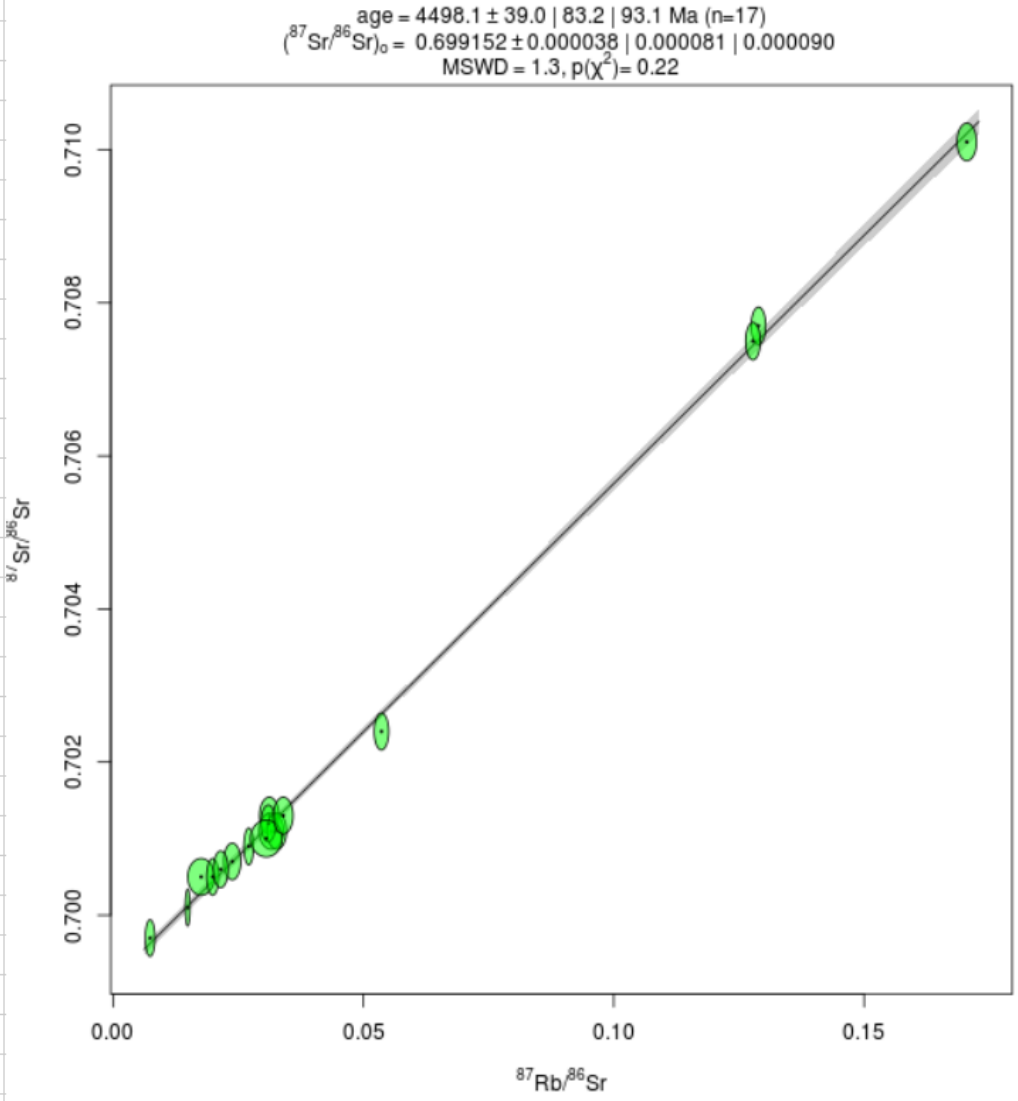

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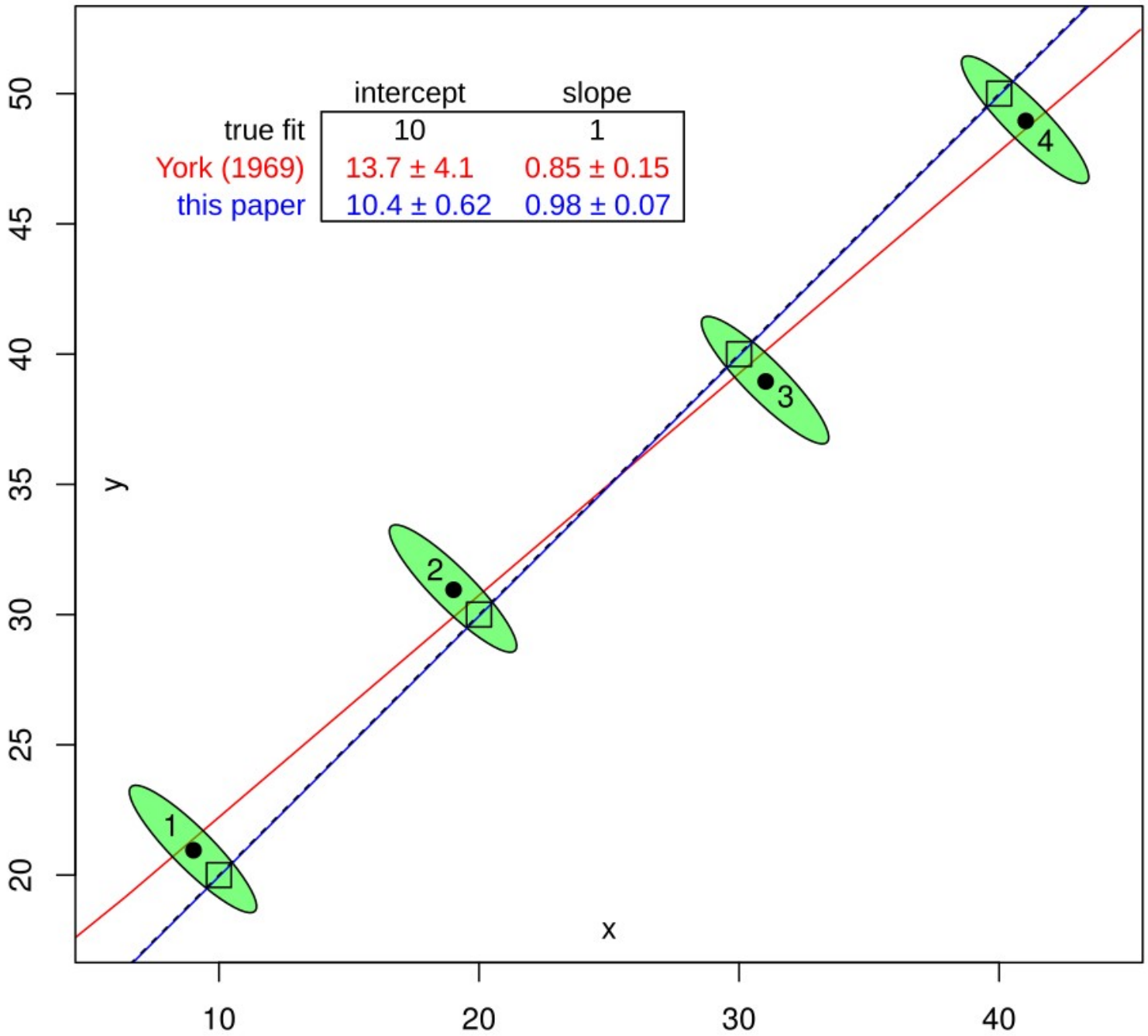
intercept
slope
true fit
10
1
York (1969)
13.7 ± 4.1
0.85 ± 0.15
this paper
10.4 ± 0.62
0.98 ± 0.07
1
2
3
4
y
x
20
25
30
35
40
45
50
10
20
30
40

true values		measure-ments		covariance matrix							
				X1	X2	X3	X4	Y1	Y2	Y3	Y4
x1	10	X1	9	1	0.99	0	0	-0.9	-0.9	0	0
x2	20	X2	19	0.99	1	0	0	-0.9	-0.9	0	0
x3	30	X3	31	0	0	1	0.99	0	0	-0.9	-0.9
x4	40	X4	41	0	0	0.99	1	0	0	-0.9	-0.9
y1	20	Y1	21	-0.9	-0.9	0	0	1	0.99	0	0
y2	30	Y2	31	-0.9	-0.9	0	0	0.99	1	0	0
y3	40	Y3	39	0	0	-0.9	-0.9	0	0	1	0.99
y4	50	Y4	49	0	0	-0.9	-0.9	0	0	0.99	1

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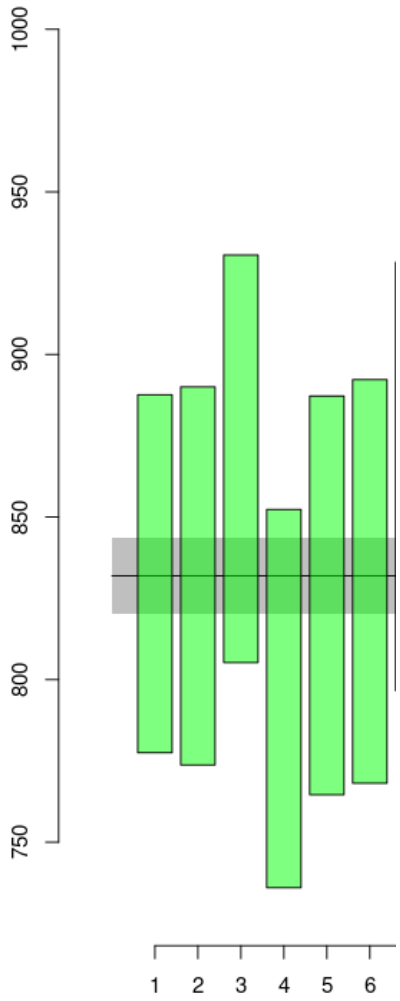
	K40/Ca44	err[K40/Ca44]	Ca40/Ca44	err[Ca40/Ca44]	rho	(C)	(omit)	H	I	J	K	L	M
1	54.749	3.092	94.316	5.251	0.849								
2	65.793	4.093	99.996	6.15	0.859								
3	79.784	5.44	113.167	7.646	0.87								
4	79.413	5.366	101.12	6.775	0.867								
5	89.754	6.423	111.515	7.921	0.875								
6	102.107	7.649	118.681	8.834	0.881								
7	130.123	10.859	139.815	11.612	0.893								
8	119.797	9.648	126.548	10.139	0.888								
9	139.483	12.01	145.562	12.479	0.896								
10	135.326	11.529	140.15	11.887	0.894								
11	152.376	13.564	151.266	13.414	0.9								
12	153.985	13.653	146.845	12.973	0.899								
13	144.645	12.317	132.8	11.266	0.895								
14	184.432	17.852	177.12	17.091	0.908								
15	160.832	14.483	149.376	13.405	0.901								
16	218.38	22.881	204.152	21.336	0.915								
17	147.093	12.435	134.613	11.338	0.896								
18	174.808	16.124	160.95	14.8	0.905								
19	185.403	17.466	162.86	15.3	0.907								
20	193.415	18.297	168.628	15.91	0.908								
21	186.42	17.41	166.888	15.542	0.907								
22	173.443	15.426	149.031	13.217	0.903								
23	197.103	18.644	171.947	16.222	0.909								
24	152.612	12.72	135.733	11.275	0.897								
25	166.93	14.407	149.985	12.904	0.902								
26	175.897	15.176	149.926	12.899	0.903								
27	180.054	15.766	157.136	13.72	0.905								
28	198.422	18.289	170.538	15.679	0.909								



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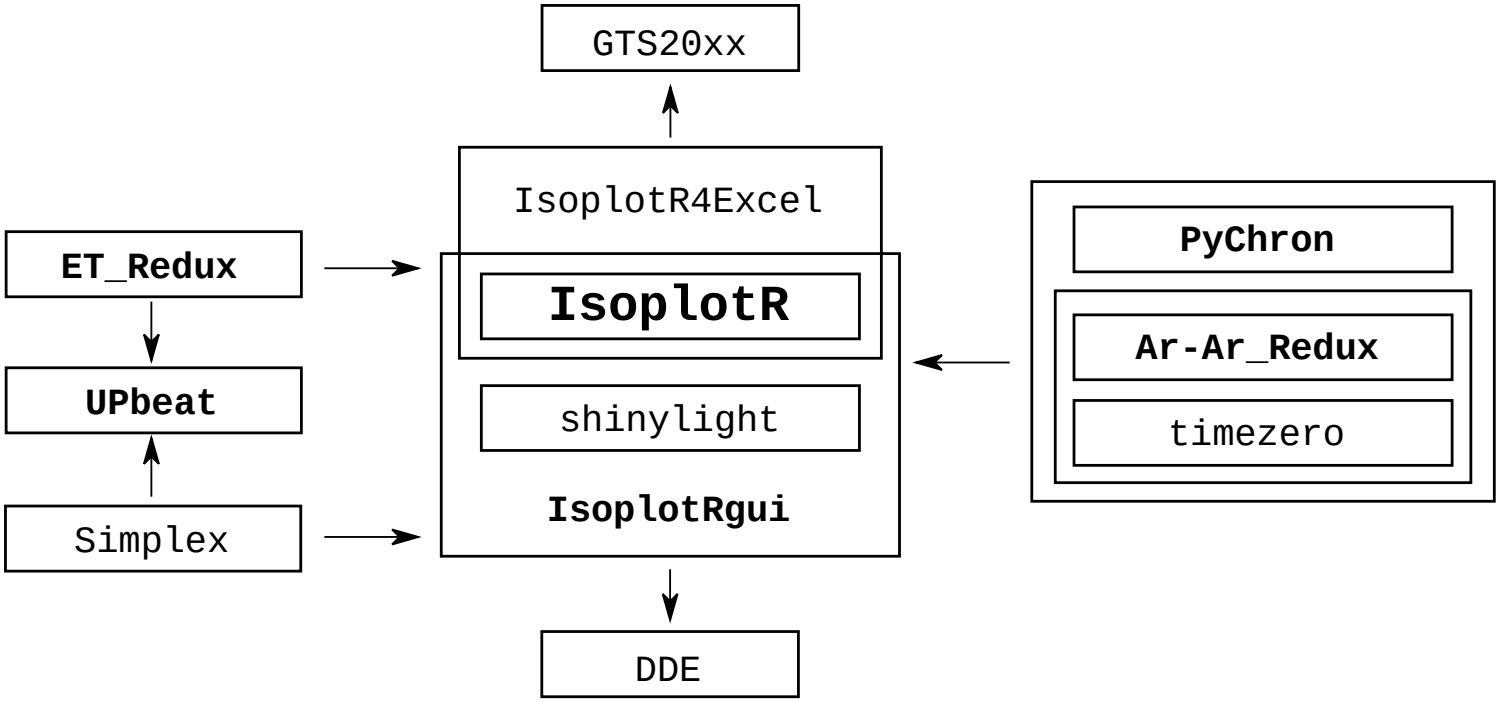
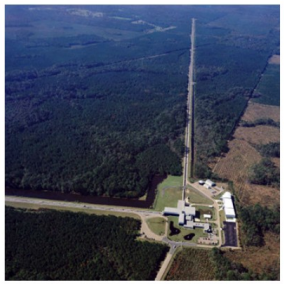


Cheap storage and open software allow us to store *raw* data and promote reproducible and fully traceable science.

The Gravitational Wave Open Science Center provides data from gravitational-wave observatories, along with access to tutorials and software tools.


LIGO Hanford Observatory, Washington
(Credits: C. Gray)


LIGO Livingston Observatory, Louisiana
(Credits: J. Giaime)


Virgo detector, Italy
(Credits: Virgo Collaboration)