GR for Replacement of Bounded, Decaying Populations

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Abstract

GR for Replacement of Bounded, Decaying Populations. A.C. Tuary, John Wikswo (Vanderbilt University)

Einstein's lessons on the mortality of genius suggest how GR will allow replacement of a bounded, decaying population $N(t) = \int n(a,t)dt$, where a and t are in years. N decays with time as $N(t) = = \int n(a,t_o)[1-k(a)]^{t-t_o}da$, where $k(a)$ is the decay rate from www.cdc.gov\chs; for 35 < a < 85, $k(a)=7.0193\ e^{0.0870a} \bullet 10^{-5}$, with $R^2 = 0.999$. To determine $N(t)$, assume integer values for a and t and use the single-element forward-projection kernal $n(a+1,t+1) = n(a,t)[1-k(a)]$. A Monte Carlo $n(a,2002)$ with $34 < a < 71$, avg=54.1, median=55, and N(2002)=25 yielded N(2012)=21.006. The effects of a retarded decay are estimated by the temporal transformation of $k(a)$ to $k(a-\Delta)$, where Δ is an additional longevity; for $\Delta=5$ and 10, N(2012)=22.27 and 23.19, respectively. Ignoring all other decay mechanisms, we conclude that over a 10-year period the Grim Reaper (GR) will provide between one to three faculty positions in a medium-sized physics department, with the added longevity, statistical fluctuations, and the requirement for quantization of $n(a,t)$ being the most important determinants of position availability.

Einstein's lessons on the mortality of genius suggest how GR will allow replacement of a bounded, decaying population $N(t) = \int n(a,t)dt$, where a and t are in years.

- *I've had prostate cancer, I'm well aware of my mortality, so why do some physicists approach a departmental planning exercise as if they were immortal?*

N decays with time as

$$N(t) = = \int n(a,t_o)[1\text{-}k(a)]^{t-t_o}da$$

where $k(a)$ is the age-dependent decay rate from the CDC.

R.N. Anderson, "Deaths: Leading Causes for 1999, " *CDC National Vital Statistics Reports,* Vol. 49, No. 11 (2001)
http://www.cdc.gov/nchs/data/nvsr/nvsr49/nvsr49_11.pdf

Lots of universities plan their future, but the faculty doing this are seldom provided with the tools to readily assess their own mortality. A first-order approximation should be straightforward…

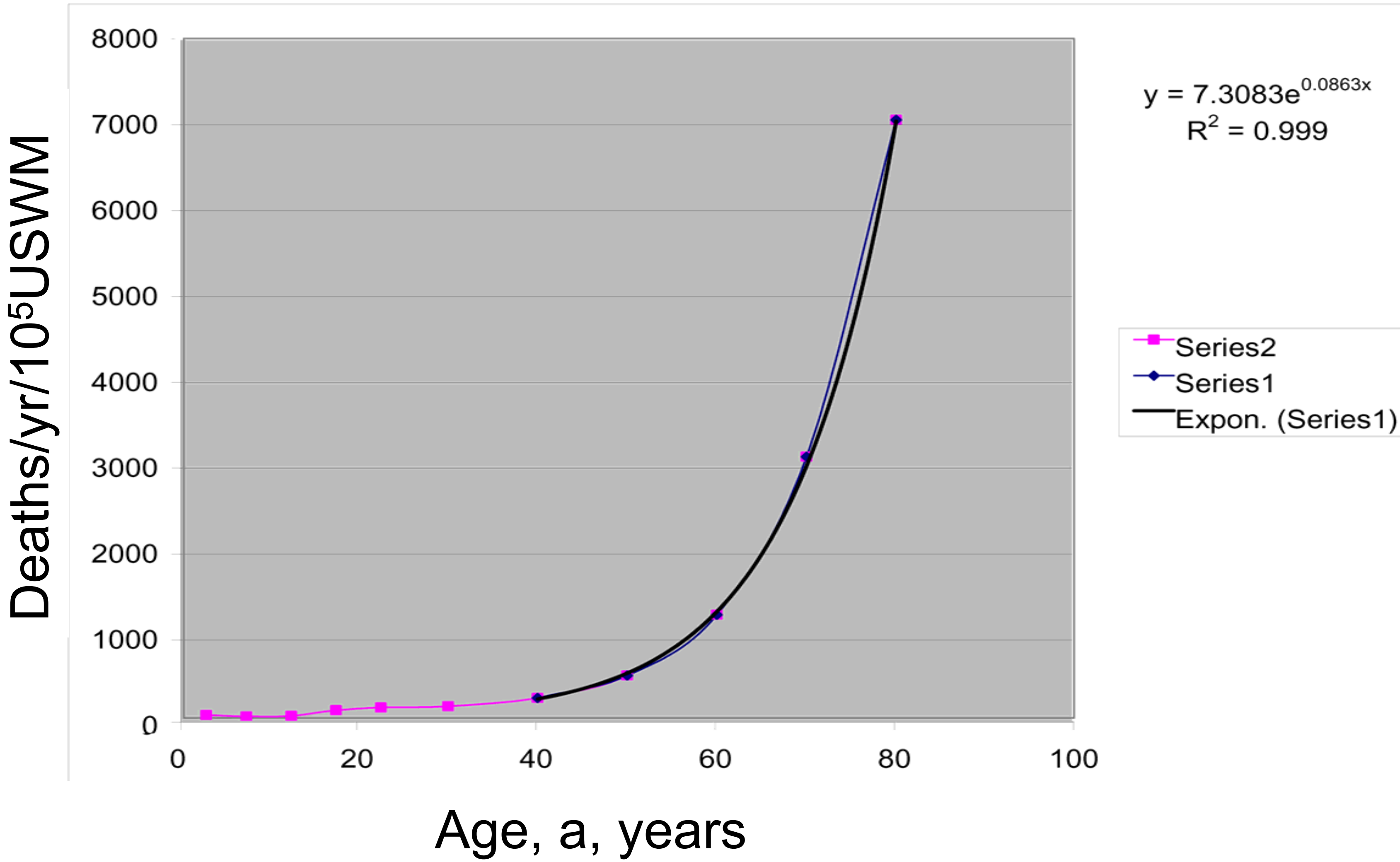
Table 1. Deaths, percent of total deaths, and death rates for the 10 leading causes of death in selected age groups, by race and sex: United States, 1999—Con.

[Rates per 100,000 population in specified group. Data for races other than white and black should be interpreted with caution because of inconsistencies between reporting race on death certificates and on censuses and surveys; see Technical notes]

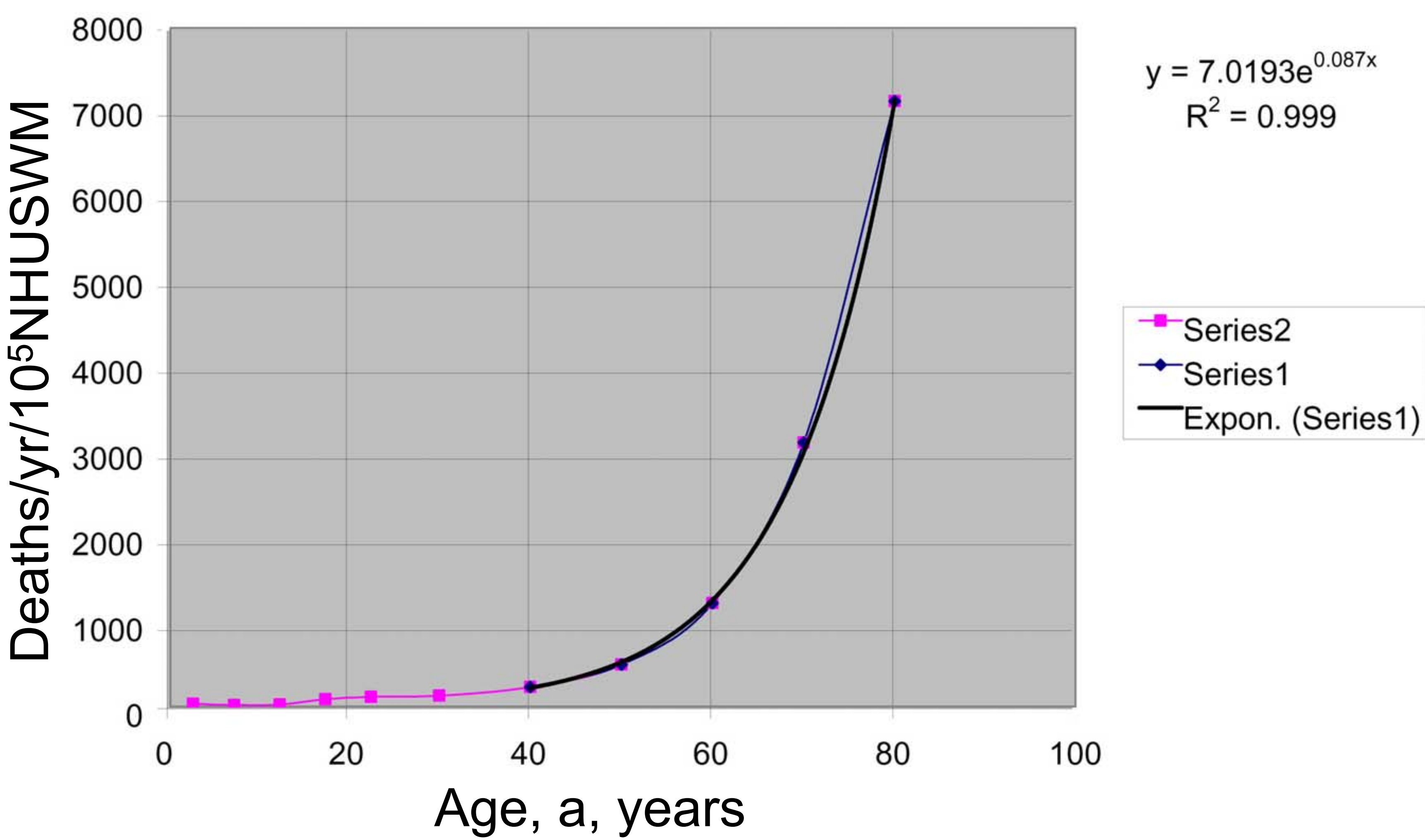
Rank[1]	Cause of death (Based on the *Tenth Revision, International Classification of Diseases,* 1992), race, sex, and age	Number[2]	Percent of total deaths[2]	Rate[2]
	White, male, 65 years and over			
...	All causes	719,502	100.0	5,633.5
1	Diseases of heart (I00–I09,I11,I13,I20–I51)	242,366	33.7	1,897.7
2	Malignant neoplasms (C00–C97)	178,847	24.9	1,400.3
3	Chronic lower respiratory diseases (J40–J47)	50,028	7.0	391.7
4	Cerebrovascular diseases (I60–I69)	47,848	6.7	374.6
5	Influenza and pneumonia (J10–J18)	21,629	3.0	169.3
6	Diabetes mellitus (E10–E14)	18,678	2.6	146.2
7	Accidents (unintentional injuries) (V01–X59,Y85–Y86)	14,165	2.0	110.9
8	Alzheimer's disease (G30)	12,351	1.7	96.7
9	Nephritis, nephrotic syndrome and nephrosis (N00–N07,N17–N19,N25–N27)	11,724	1.6	91.8
10	Septicemia (A40–A41)	8,288	1.2	64.9
...	All other causes (Residual)	113,578	15.8	889.3
	White, male, 65–74 years			
...	All causes	220,442	100.0	3,043.2
1	Malignant neoplasms (C00–C97)	73,679	33.4	1,017.1
2	Diseases of heart (I00–I09,I11,I13,I20–I51)	68,247	31.0	942.1
3	Chronic lower respiratory diseases (J40–J47)	15,973	7.2	220.5
4	Cerebrovascular diseases (I60–I69)	10,000	4.5	138.0
5	Diabetes mellitus (E10–E14)	6,787	3.1	93.7
6	Accidents (unintentional injuries) (V01–X59,Y85–Y86)	4,267	1.9	58.9
7	Influenza and pneumonia (J10–J18)	3,288	1.5	45.4
8	Chronic liver disease and cirrhosis (K70,K73–K74)	3,114	1.4	43.0
9	Nephritis, nephrotic syndrome and nephrosis (N00–N07,N17–N19,N25–N27)	2,711	1.2	37.4
10	Aortic aneurysm and dissection (I71)	2,525	1.1	34.9
...	All other causes (Residual)	29,851	13.5	412.1
	White, male, 85 years and over			
...	All causes	191,610	100.0	17,202.1
1	Diseases of heart (I00–I09,I11,I13,I20–I51)	71,980	37.6	6,462.1
2	Malignant neoplasms (C00–C97)	29,102	15.2	2,612.7
3	Cerebrovascular diseases (I60–I69)	16,435	8.6	1,475.5
4	Chronic lower respiratory diseases (J40–J47)	11,111	5.8	997.5
5	Influenza and pneumonia (J10–J18)	9,775	5.1	877.6
6	Alzheimer's disease (G30)	5,471	2.9	491.2
7	Accidents (unintentional injuries) (V01–X59,Y85–Y86)	4,140	2.2	371.7
8	Nephritis, nephrotic syndrome and nephrosis (N00–N07,N17–N19,N25–N27)	3,884	2.0	348.6
9	Diabetes mellitus (E10–E14)	3,598	1.9	323.0
10	Pneumonitis due to solids and liquids (J69)	2,845	1.5	255.4
...	All other causes (Residual)	33,259	17.4	2,985.9
	White, female, all ages[3]			
...	All causes	1,056,013	100.0	924.1
1	Diseases of heart (I00–I09,I11,I13,I20–I51)	327,533	31.0	286.6
2	Malignant neoplasms (C00–C97)	229,842	21.8	201.1
3	Cerebrovascular diseases (I60–I69)	89,960	8.5	78.7
4	Chronic lower respiratory diseases (J40–J47)	57,735	5.5	50.5
5	Influenza and pneumonia (J10–J18)	32,413	3.1	28.4
6	Accidents (unintentional injuries) (V01–X59,Y85–Y86)	29,347	2.8	25.7
7	Alzheimer's disease (G30)	29,292	2.8	25.6
8	Diabetes mellitus (E10–E14)	29,054	2.8	25.4
9	Nephritis, nephrotic syndrome and nephrosis (N00–N07,N17–N19,N25–N27)	14,409	1.4	12.6
10	Septicemia (A40–A41)	13,798	1.3	12.1
...	All other causes (Residual)	202,630	19.2	177.3

■ ■ ■

Decay Rate for U.S. White Males



Decay Rate for Non-Hispanic U.S. White Males



Fitting the Data to an Exponential, 35< *a* <85

- $k(a)=7.3083\ e^{0.0863a} \cdot 10^{-5}$, with $R^2 = 0.999$
  - All white males
  - $k(>85) = 17202.1$
  - $k(a) = 1$ for $a = 110.4$

- $k(a)=7.0193\ e^{0.0870a} \cdot 10^{-5}$, with $R^2 = 0.999$
  - Non-hispanic white males
  - $k(>85) = 17539.1$
  - $k(a) = 1$ for $a = 109.9$
- This is exponential decay with an exponentially increasing decay rate!

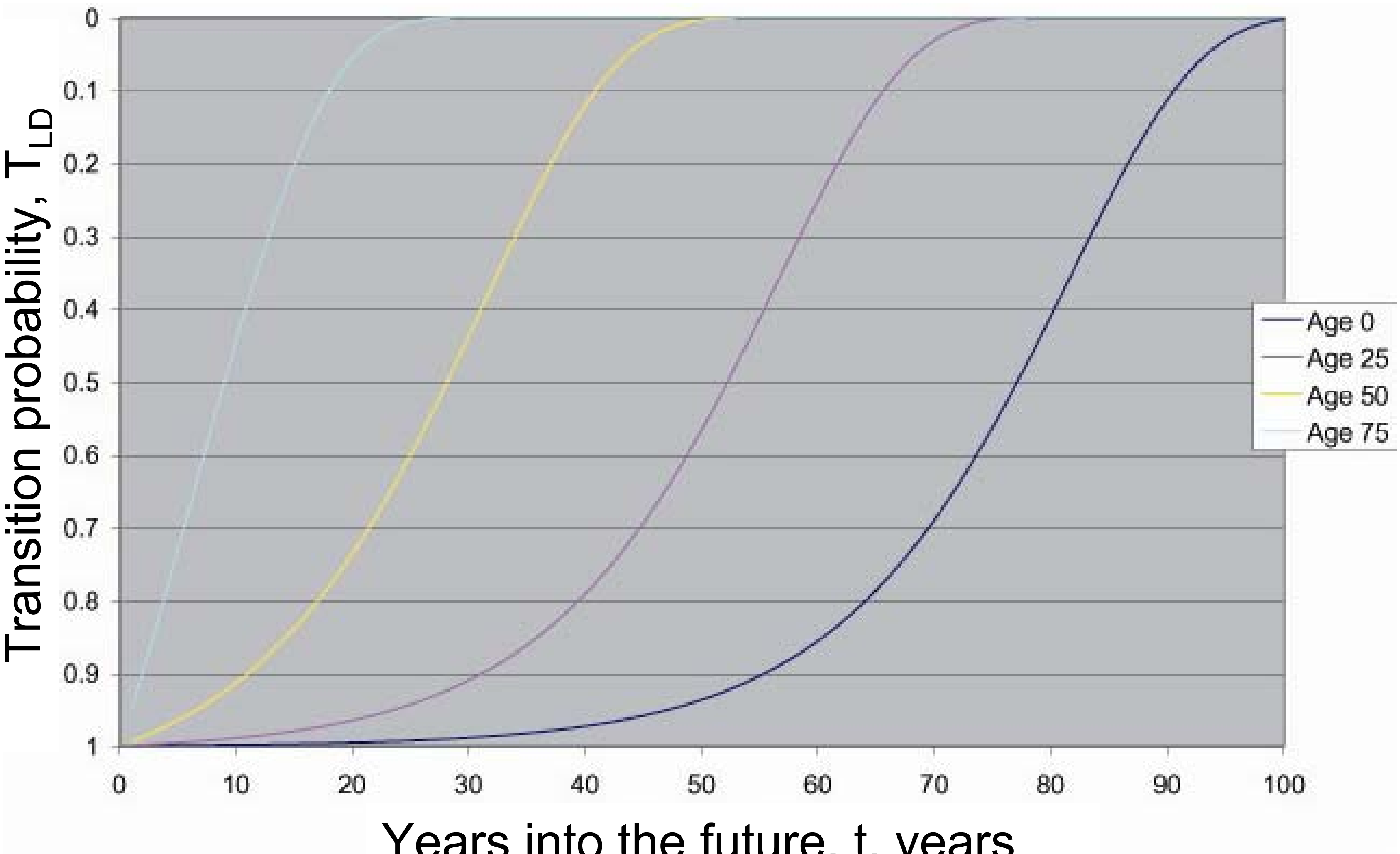
To determine $N(t)$, assume integer values for a and t and use the single-element forward-projection kernal

$$n(a+1,t+1) = n(a,t)[1-k(a)].$$

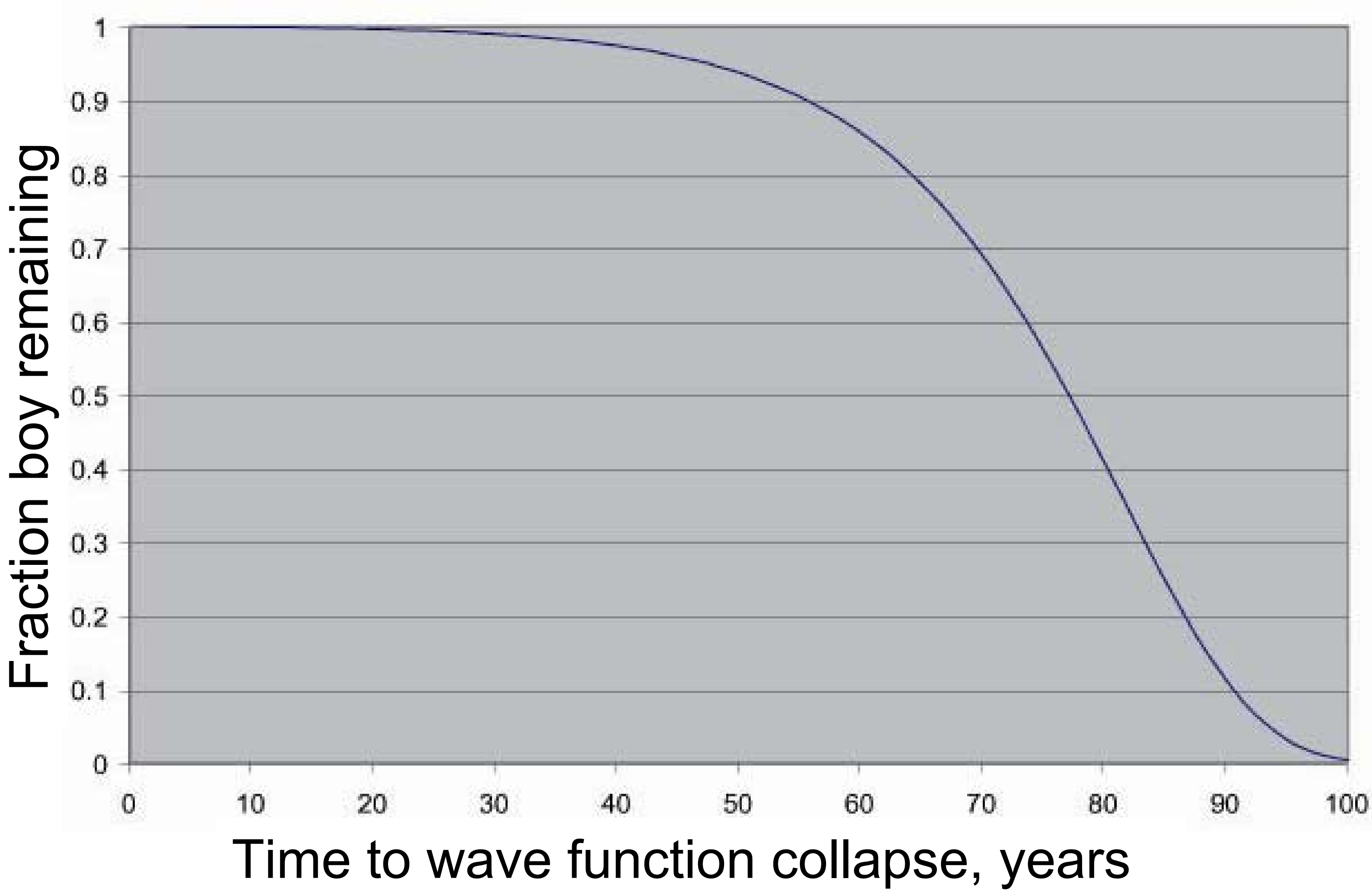
Use a spreadsheet to evaluate, year by year, the integrated death rate for the non-constant rate

$$N(t) = = \int n(a,t_o)[1-k(a)]^{t-t_o} da$$

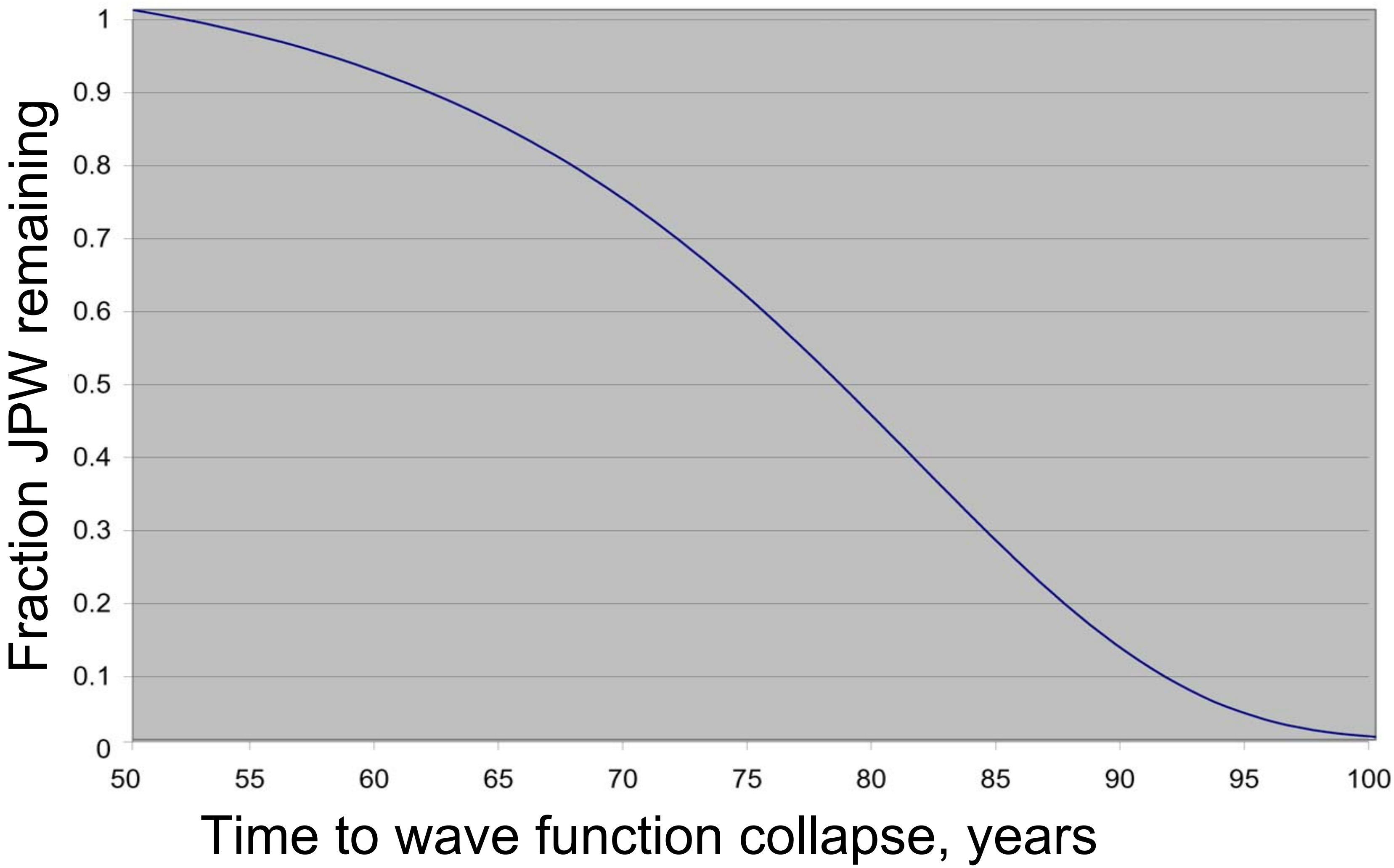
Transition Probability From the Living State to the Dead State, Starting in 2002



Decay of a One-Year-Old Schrodinger Boy Starting in 2002



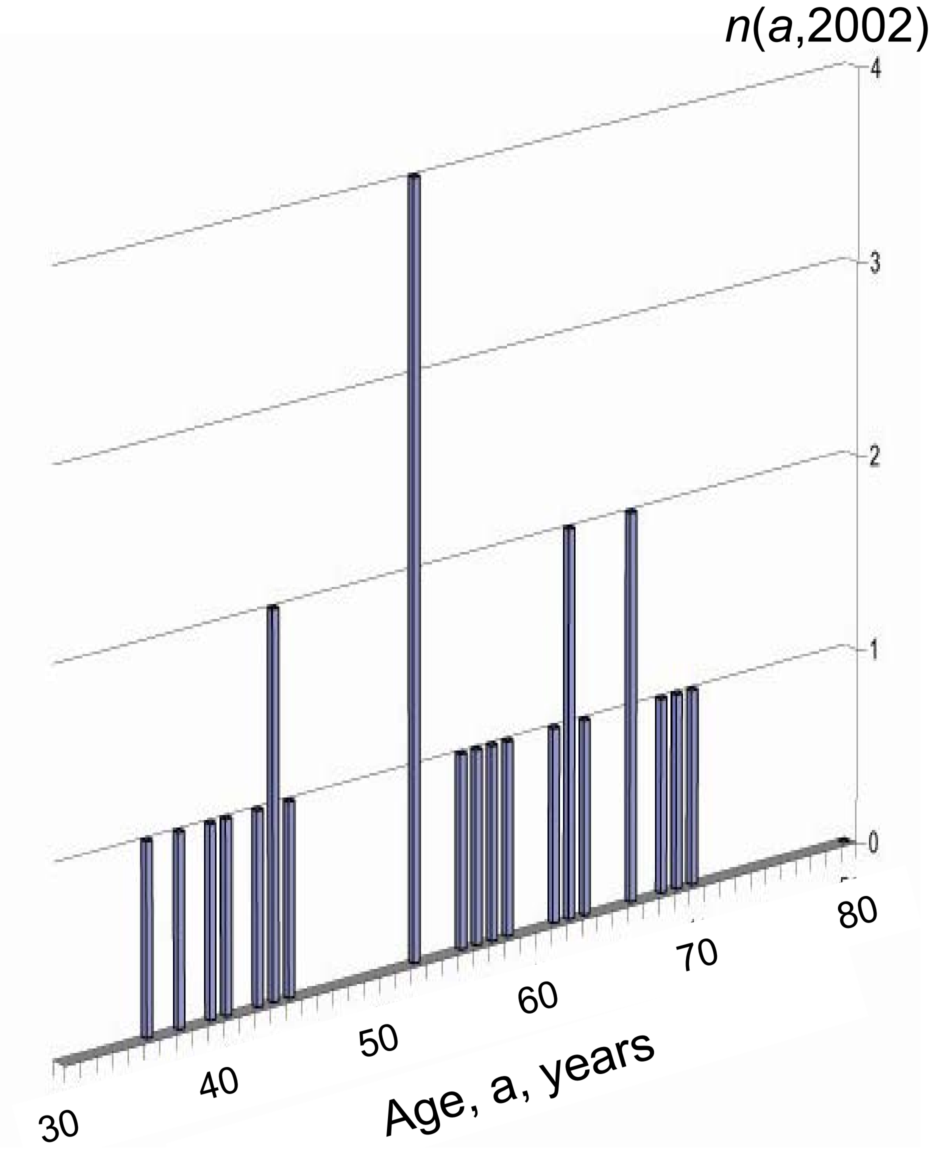
Decay of a 50-Year-Old Schrodinger Man Starting in 2002



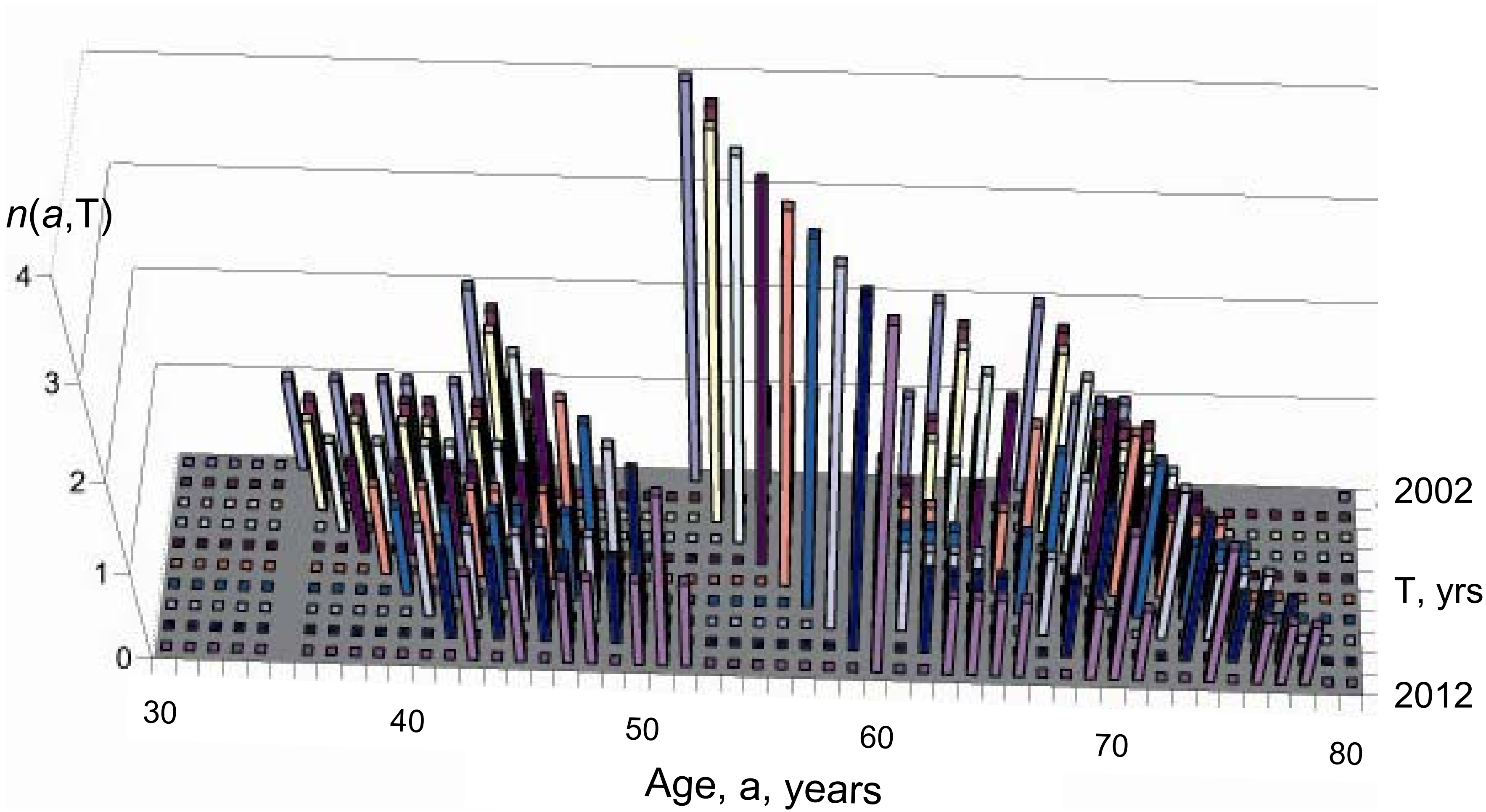
Initial Conditions

A Monte Carlo $n(a,2002)$ with $34 < a < 71$, avg =54.1, median=55, and N(2002)=25…

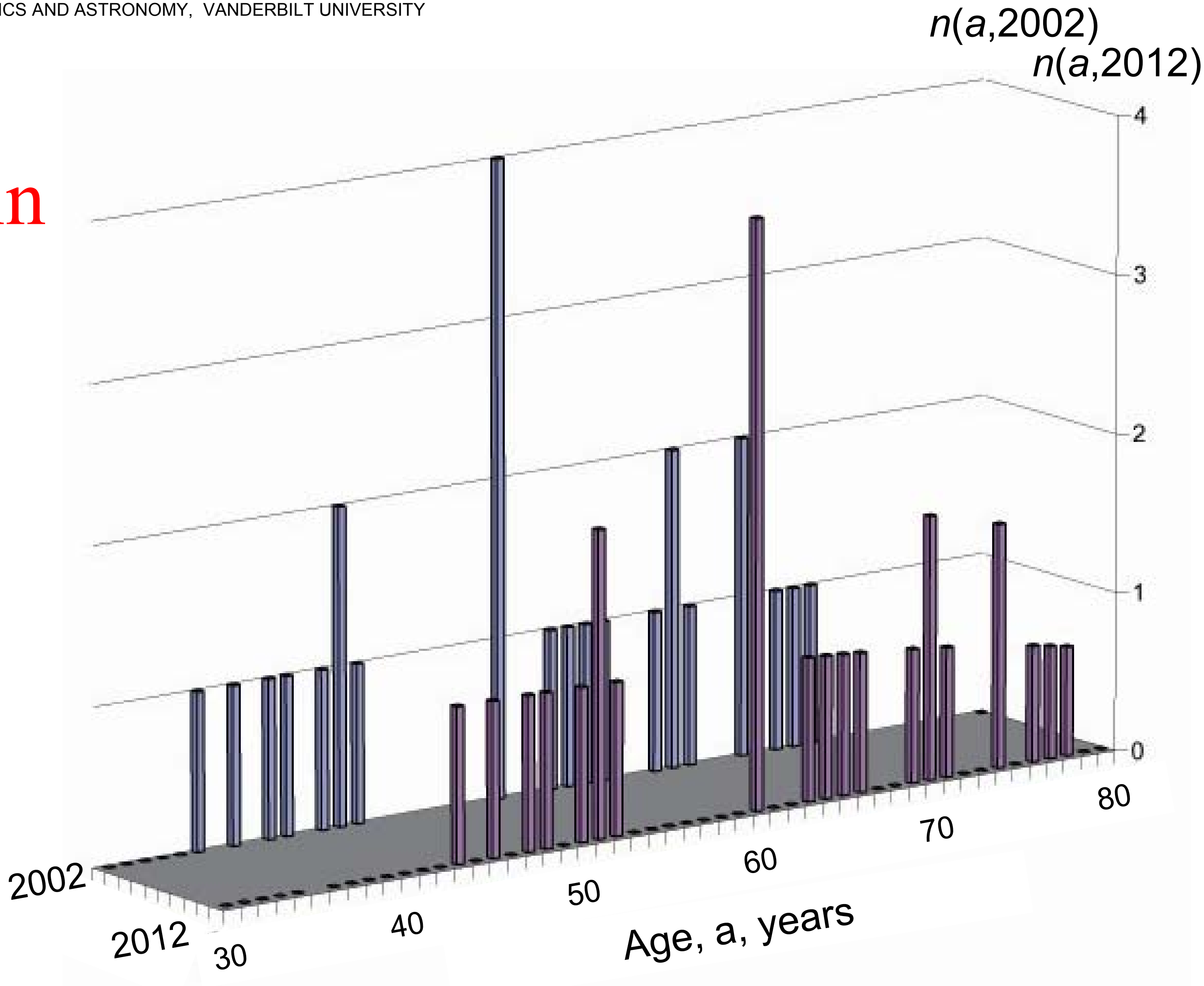
…a hypothetical, medium sized physics department…



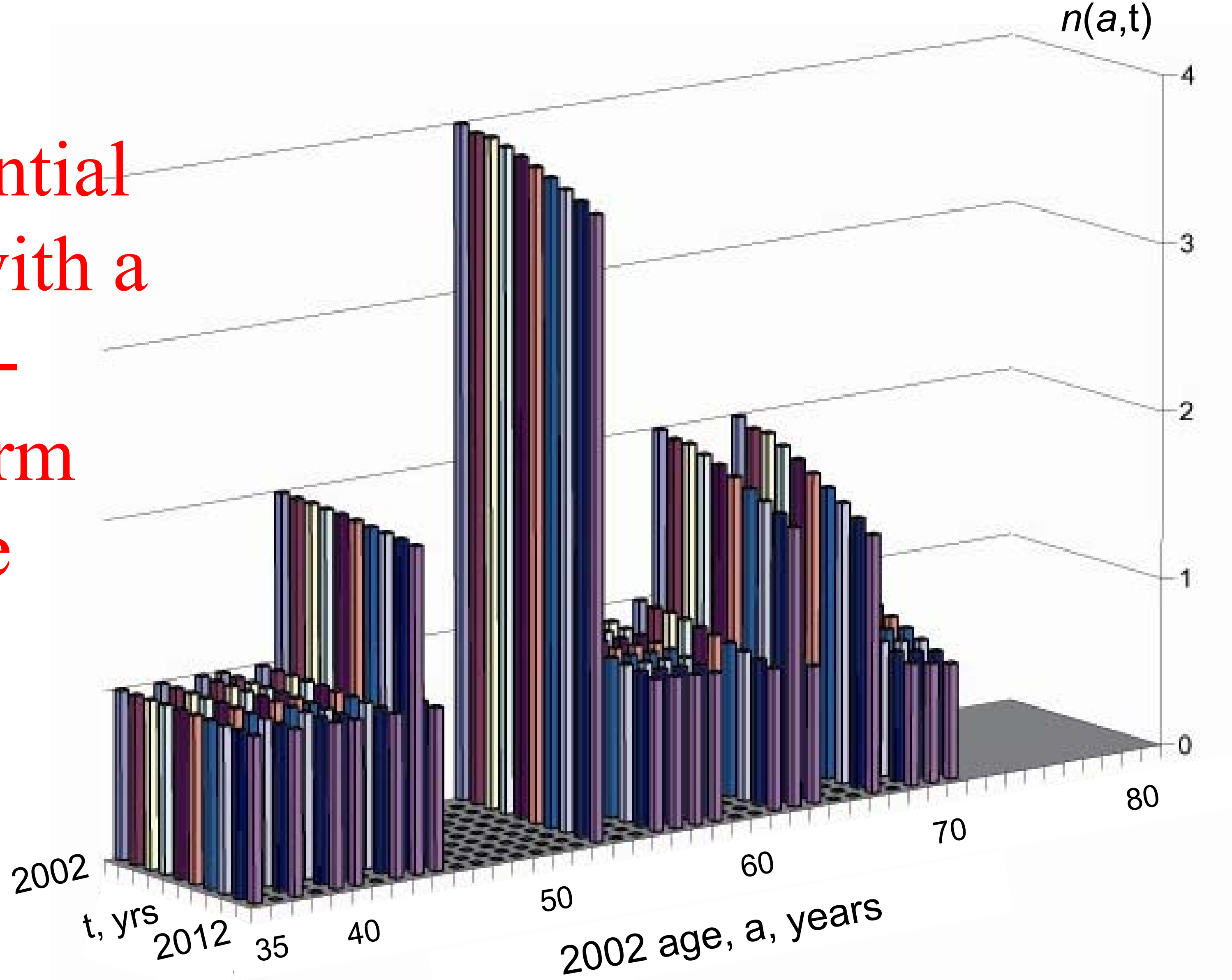
Time Marches On



Now and in 10 Years



Exponential Decay with a Non-Uniform Rate

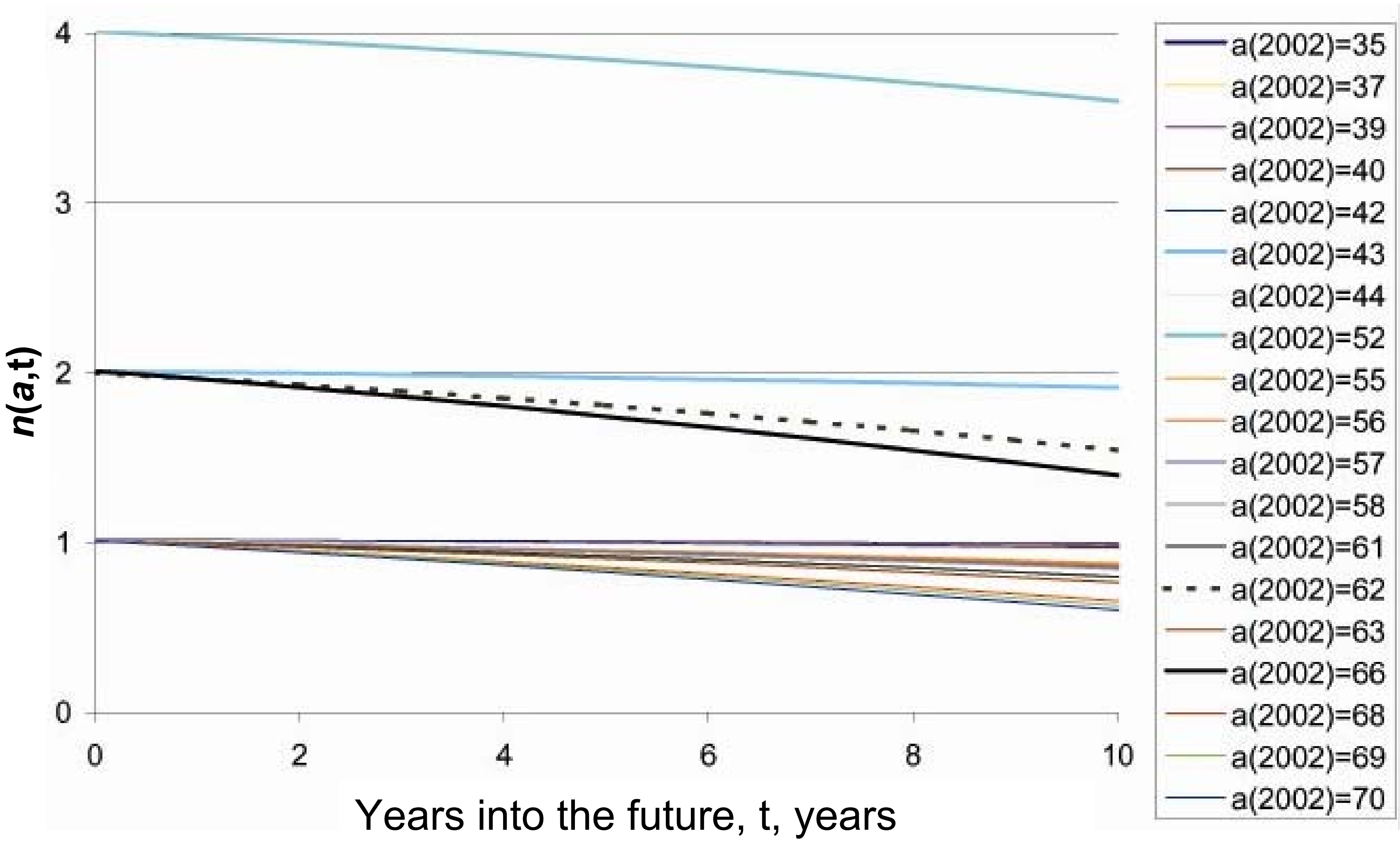


The Numbers

…yielded N(2012)=21.006 ….

	0	1	2	3	4	5	6	7	8	9	10	%Lost
35	1	0.998	0.997	0.995	0.993	0.990	0.988	0.985	0.982	0.979	0.975	2.5%
36												
37	1	0.998	0.996	0.994	0.991	0.988	0.985	0.982	0.979	0.975	0.971	2.9%
38												
39	1	0.998	0.995	0.992	0.989	0.986	0.983	0.979	0.975	0.970	0.965	3.5%
40	1	0.997	0.995	0.992	0.989	0.985	0.981	0.977	0.973	0.968	0.962	3.8%
41												
42	1	0.997	0.994	0.990	0.986	0.982	0.978	0.973	0.968	0.962	0.955	4.5%
43	2	1.993	1.986	1.979	1.970	1.961	1.951	1.941	1.929	1.917	1.903	4.8%
44	1	0.996	0.993	0.988	0.984	0.979	0.974	0.968	0.961	0.955	0.947	5.3%
45												
46												
47												
48												
49												
50												
51												
52	4	3.972	3.941	3.908	3.872	3.833	3.792	3.746	3.698	3.646	3.590	10.3%
53												
54												
55	1	0.991	0.981	0.970	0.959	0.946	0.933	0.919	0.903	0.887	0.869	13.1%
56	1	0.990	0.979	0.968	0.955	0.942	0.927	0.912	0.895	0.877	0.858	14.2%
57	1	0.989	0.977	0.965	0.951	0.936	0.921	0.904	0.886	0.867	0.846	15.4%
58	1	0.988	0.975	0.962	0.947	0.931	0.914	0.896	0.876	0.855	0.833	16.7%
59												
60												
61	1	0.985	0.968	0.950	0.931	0.911	0.890	0.867	0.842	0.816	0.789	21.1%
62	2	1.966	1.930	1.892	1.851	1.807	1.760	1.711	1.658	1.603	1.544	22.8%
63	1	0.982	0.962	0.941	0.919	0.895	0.870	0.843	0.815	0.785	0.754	24.6%
64												
65												
66	2	1.953	1.902	1.849	1.792	1.732	1.669	1.602	1.533	1.460	1.385	30.7%
67												
68	1	0.972	0.942	0.910	0.877	0.842	0.806	0.768	0.728	0.687	0.645	35.5%
69	1	0.969	0.937	0.903	0.867	0.829	0.790	0.749	0.707	0.664	0.620	38.0%
70	1	0.967	0.931	0.894	0.855	0.815	0.773	0.730	0.685	0.639	0.593	40.7%
Tot	25.000	24.701	24.382	24.041	23.679	23.293	22.884	22.451	21.993	21.512	21.006	

Decay of a Schrodinger Population Density



Education-Induced Longevity (EIL)

- 1990 Life Expectancy for
  - All white males (All)
  - Less than high school (<HS)
  - High school (HS)
  - Some college (>HS)
  - Bachelor degree (C)
  - More than bachelor (>C)

H. Richards and R. Barry, "U.S. Life Tables for 1990 by Sex, Race, and Education," *J. Forensic Economics,* 11: 9-26 (1998)

Age	All	<HS	HS	<C	C	>C	Δmax	C-H	>C-All
0	74.0	70.3	72.9	73.4	75.8	77.3	7.0	-0.9	3.3
5	69.7	66.0	68.7	69.2	71.6	73.1	7.1	-0.8	3.4
10	64.8	61.1	63.8	64.2	66.6	68.2	7.1	-0.9	3.4
15	59.9	56.2	58.9	59.3	61.7	63.3	7.1	-0.9	3.4
20	55.2	51.5	54.2	54.6	57.1	58.7	7.2	-0.9	3.5
25	50.6	46.9	49.6	50.0	52.3	54.1	7.2	-0.9	3.5
30	45.9	42.5	44.9	45.3	47.5	49.3	6.8	-1.2	3.4
35	41.3	38.2	40.4	40.7	42.8	44.4	6.2	-1.5	3.1
40	36.7	33.8	35.9	36.2	38.2	39.6	5.8	-1.6	2.9
45	32.1	29.5	31.4	31.8	33.5	35.0	5.5	-1.7	2.9
50	27.5	25.3	27.1	27.4	28.9	30.5	5.2	-1.9	3
55	23.1	21.3	22.9	23.2	24.5	26.0	4.7	-2.1	2.9
60	19.2	17.7	19.0	19.4	20.3	21.8	4.1	-2.3	2.6
65	15.5	14.5	15.6	15.8	16.6	18.0	3.5	-2.7	2.5
70	12.3	11.6	12.5	12.3	13.1	14.2	2.6	-3.3	1.9
75	9.5	9.1	9.6	9.5	10.0	11.1	2.0	-3.6	1.6

Education-Induced Longevity (EIL)

Predicted age at time of death for age in 1990

Age	All	<HS	HS	<C	C	>C	Δmax	C-H	>C-All
0	74.0	70.3	72.9	73.4	75.8	77.3	7.0	-0.9	3.3
5	74.7	71.0	73.7	74.2	76.6	78.1	7.1	-0.8	3.4
10	74.8	71.1	73.8	74.2	76.6	78.2	7.1	-0.9	3.4
15	74.9	71.2	73.9	74.3	76.7	78.3	7.1	-0.9	3.4
20	75.2	71.5	74.2	74.6	77.1	78.7	7.2	-0.9	3.5
25	75.6	71.9	74.6	75.0	77.3	79.1	7.2	-0.9	3.5
30	75.9	72.5	74.9	75.3	77.5	79.3	6.8	-1.2	3.4
35	76.3	73.2	75.4	75.7	77.8	79.4	6.2	-1.5	3.1
40	76.7	73.8	75.9	76.2	78.2	79.6	5.8	-1.6	2.9
45	77.1	74.5	76.4	76.8	78.5	80.0	5.5	-1.7	2.9
50	77.5	75.3	77.1	77.4	78.9	80.5	5.2	-1.9	3
55	78.1	76.3	77.9	78.2	79.5	81.0	4.7	-2.1	2.9
60	79.2	77.7	79.0	79.4	80.3	81.8	4.1	-2.3	2.6
65	80.5	79.5	80.6	80.8	81.6	83.0	3.5	-2.7	2.5
70	82.3	81.6	82.5	82.3	83.1	84.2	2.6	-3.3	1.9
75	84.5	84.1	84.6	84.5	85.0	86.1	2.0	-3.6	1.6

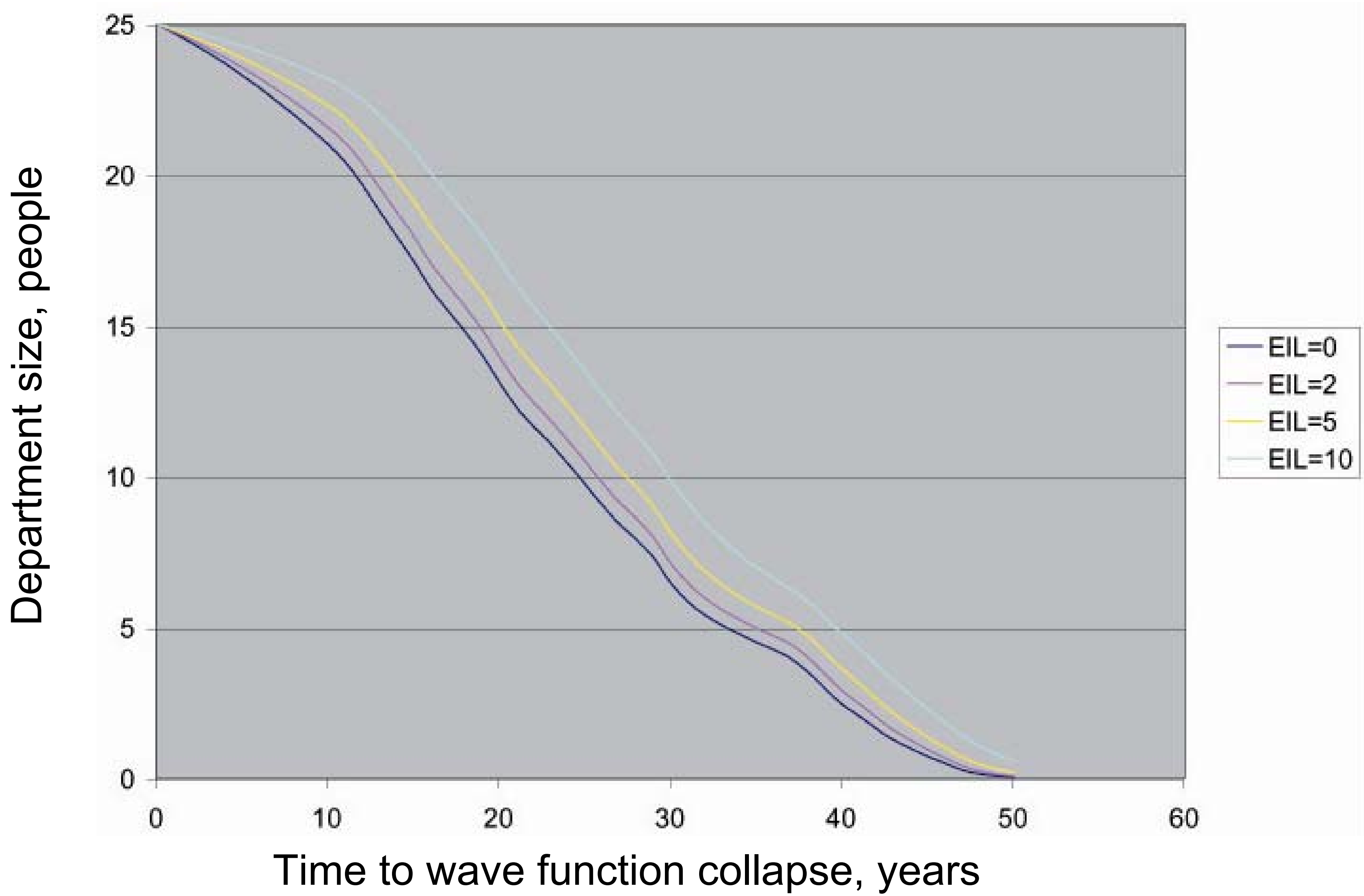
The effects of a retarded decay are estimated by the temporal transformation of $k(a)$ to $k(a\text{-}\Delta)$, where Δ is an additional longevity; for $\Delta=5$ and 10 years, N(2012)=22.27 and 23.19, for a net, ten-year decrease in population of 2.73 or 1.81, respectively.

...In fact, I was being generous to those who believe that education and clean living results in immortality...

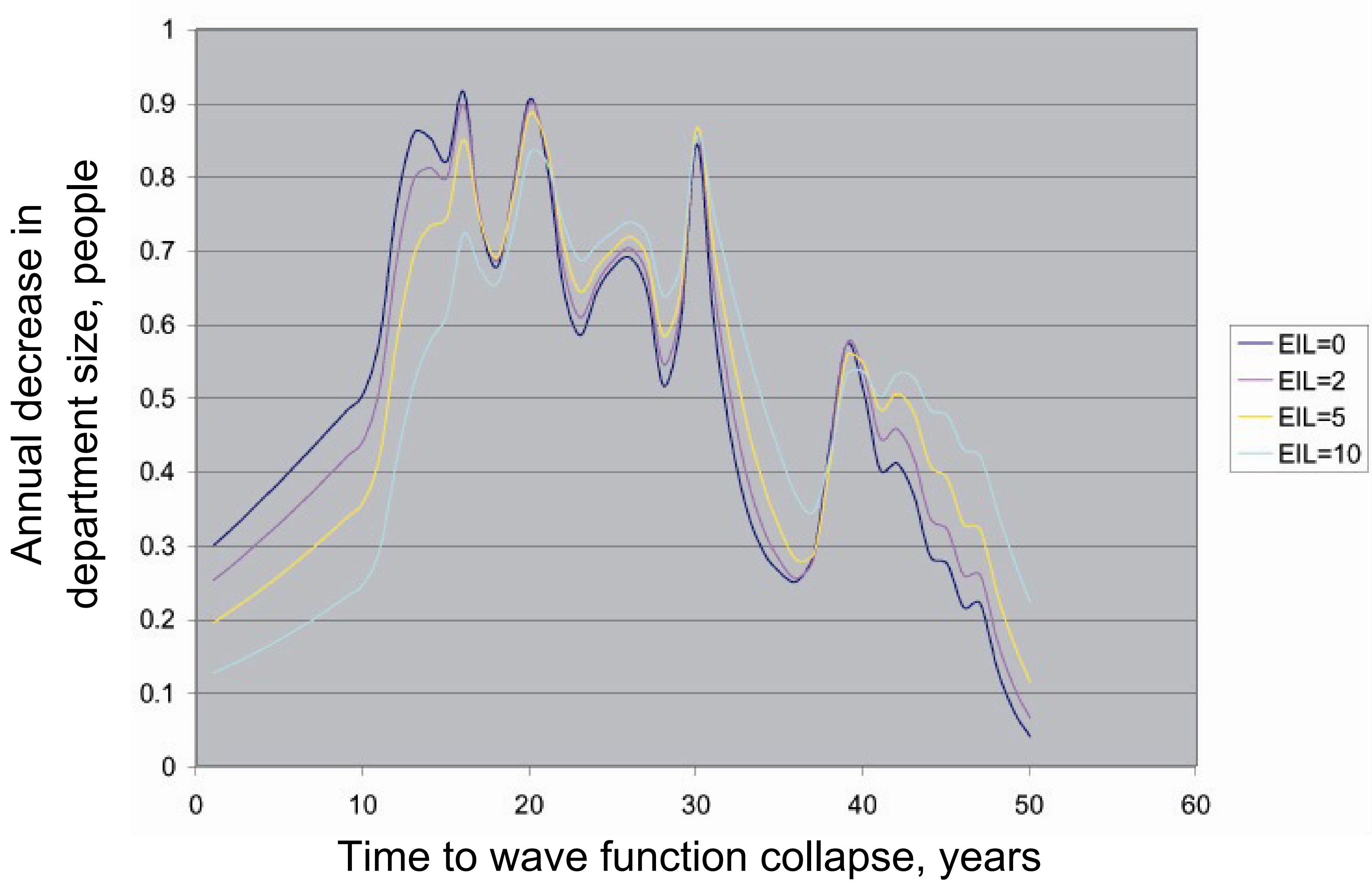
Conclusions: Education-Induced Longevity

- As compared to <H, >C extends life by up to 7 years
- As compared to the general population, EIL provides 1.6 to 3.5 years of additional life
  - Peaks at ages 20 to 25
  - Less than 2 years ages >70
- Education takes more of your life than it extends it
  - For a=70, C extends life 0.4 years over HS, but required 4 years, for a net loss of 3.6 years
  - Be sure that your educational years are fulfilling, because they could be detracting from your time to enjoy life…

Decay of a Schrodinger Department Starting in 2002



Decay Rate of a Schrodinger Department Starting in 2002



Ignoring all other decay mechanisms, we conclude that over a 10-year period the Grim Reaper (GR) will provide between one to three faculty positions in a medium-sized physics department, with the added longevity, statistical fluctuations, and the requirement for quantization of $n(a,t)$ being the most important determinants of position availability.

- *Over 10 years, you may not lose more than 30% to 40% of any one single senior faculty member.*
- *The rate of loss may accelerate significantly after 2012*
- *Gaps such as n(a,2002) being zero for 44<a<52 may exacerbate later population decreases relative to the near term.*

Caveats

- I am not an actuary.
- I am using secondary sources.
- The CDC numbers are adjusted in a manner that I do not yet fully understand: "Age adjustment, using the direct method, is the application of age-specific rates in a population of interest to a standardized age distribution in order to eliminate differences in observed rates that result from age differences in population composition. This adjustment is usually done when comparing two or more populations at one point in time or one population at two or more points of time."
- The death rates are declining with time, but I am using 1990 and 1999 data for future decay rates
- Gender and minority representation are changing within physics departments, and my analysis is based upon death rates for US non-hispanic white males.
- I did not include income-induced longevity, which does exist.
- I have considered only death, and not disability, which does not exhibit a 1-to-0 wave function collapse.
- I did not address sub-discipline-dependent occupational risks of experimentalists versus theorists.

Acknowledgements

- For adjusting $k_{JPW}(a,t)$
  - Joseph Smith, M.D.
- For assistance in locating statistical data
  - Don Berry
  - Gary Ward