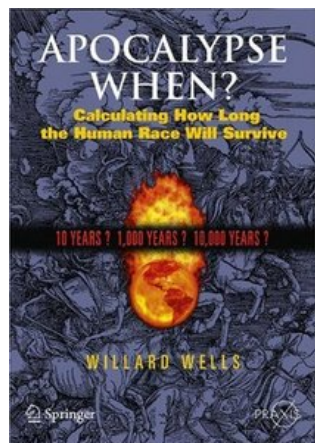**Apocalypse when? Calculating how long the human race will survive** *Willard Wells*, Springer Verlag (New York), and Praxis Publishing (Chichester, UK) 2009 (xxiv+212 p.), soft cover, ISBN 978-0-387-09836-4, 29,95€.


Apocalypse, well Wells, Welles, what's the link in the names? H.G. (Herbert George) Wells (1866–1946) is the well known science fiction writer whose novels *The Time Machine: a future apocalypse (1895)* and *The Invisible Man (1897)* are classics, but most of all his *The War of the Worlds (1898)* is best known by a wide public because of the radio drama directed by Orson Welles (sic) on 30 October 1931 that caused panic in the US because people believed the Martians really had landed in New Jersey. As far as I know, there was no "Well(e)s" connected with Francis Ford Coppola's film *Apocalypse now (1979)* about the Vietnam war. And now there is Willard Wells' book *Apocalypse when? (2009)*. Dr. Willard Wells, who received his Ph.D. in theoretical physics and mathematics from Caltech in 1959, under the supervision of Richard Feynman. Until his retirement in 1994, Wells worked at L-3 Photonics. Before, he also led the Quantum Electronics group at Caltech/Jet Propulsion Laboratory, where he worked in space communications and co-invented a satellite de-spin mechanism.

So one may not expect a novel here, but rather a "scientific" approach of some probably controversial viewpoints. Such subjects will always raise strong polarization between believers and sceptics.

Let me start with the conclusions: the risk of civilization collapse now is about 1% every year. Thus the chance that it will happen in a near future is real. About the risk covered by an average insurance policy. But do not worry. This will ultimately be a blessing for the human race. It will whipe out most of the humans but it will also destroy all the hazards, the man-made but perhaps also some natural ones, and this will result in the very long run in a 70% chance that the human race (in whatever form it may exist) will eventually

Willard Wells

survive. With a half-life of 8.6 billion people-centuries[1], we shall be around for a while in this universe if the world population number does not explode.
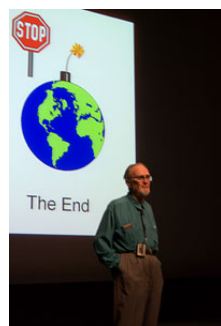
Willard Wells at USCD, October 2009

Those are quite precise numbers, but note that the subject is really about "when" and not about the nature of the cataclysm that will happen. It is not a prediction of the future, and there is no guideline about what parameters we have to monitor to avoid the apocalypse. In fact all the known hazards are not the real threats. It is a completely unexpected one or an interplay of several of these that we have to fear. But you cannot fear what you do not know. Hence you may still rest in peace.

So how does Wells arrive at these numbers? Well, he uses four quite different approaches that converge to approximately the same value. They rely on rather simple reasoning backed up by some "fuzzy" mathematics, that may be the cause of dispute and scepticism. There are (1) available statistics of businesses and stage shows, (2) random hazard rates, (3) history of survival, and (4) a Bayesian theory.

To explain this in some detail, Wells needs to explain some notions, which I will summarize below. I apologize in advance but if it is a bit confusing, it only reflects the style of the book.

The principle of indifference is a term coined by J.M. Keynes[2]. It says that if there are N possibilities and there is no further information, then each one will happen with the same probability $1/N$.

The major player in this book is the Doomsday Argument (1983) or rather Gott's survival predictor (GSP) of 1993 which is named after J. Richard Gott III. The argument in this historical paper goes as follows. Let n be the number of years humans exist, and N the number of years humans will survive. The probability of a total N prior to knowing n is $P(N) = k/N$ (k is a normalizing constant). Now by the indifference principle $P(n|N) = 1/N$. Since also $P(n) = k/n$ and using a Bayesian formula, we arrive at

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[1]To be understood in the sense of man-hours: more people means less centuries.

[2]Its earlier name was "principle of insufficient reason" used by Boole, Venn and others referring to Leibniz's "principle of sufficient reason". Wells attributes that to Laplace himself, but according to wikipedia, Laplace thought this to be so obvious that he never cared about giving it a name.

$P(N|n) = P(n|N)P(N)/P(n) = n/N^2$. Thus $P(N \leq Z) = \int_{N=n}^{N=Z} P(N|n)dN = (Z-n)/Z$. This is how Gott derives with 97.5% certainty that, given $n = 2 \times 10^5$ years, our race still has $N - n = 7.8 \times 10^6$ years to go.

Another player in this book is of course the appearance of possible hazards that can lead to the end of an entity. If $Q(T)$ is the fraction that survives after T years, then it decays like $Q(T) = 1/(1 + T/J)$. Here J is a parameter used to fit the data[3]. The age A of an individual is also important. Let F be the future time until extinction then the probability of survival given age A reads $G(F|A) = 1/(1 + F/P)$ with $P = A + J$ the "past" and J a parameter[4].

H.G. Wells, author of War of the worlds. Orson Welles turned it into a radio play in 1937, causing panic in the US.

However if hazard rates are not constant and vary in time, then T is not the appropriate parameter. In that case it is better to replace the time axis T with a risk axis Z where Z is the cumulative risk (or cum-risk) of all possible hazards. For example one could write $G(Z_f|Z_a) = 1/(1 + Z_f/Z_p)$. Thus time is a particular instance of cum-risk, billion people centuries (BPC) could be another one. For natural hazards, time is the appropriate scale, but since man-made hazards have drastically increased since the 1950's, time is obviously not the best choice here.

In several appendices, Wells writes out mathematical arguments to justify the formula $Q(T)$ above and writes other more detailed expressions for e.g. Q or Z. The previous formula is then checked in Chapter 2 against statistical data about the survival of stage plays in London theaters, or Portugese business firms. Wells argues that these (and similar data) are subject to hazards just as the human race (although at a different time scale) and these data can be brought in correspondence with the above mentioned formula by choosing an appropriate value for the parameter J.


Apocalypse now, a film by Francis Ford Coppola

Chapters 3 and 4 make a distinction between man-made and natural risks. For multiple risks, one has to use a formula for Q which is the product of $(Q_i)^{\alpha_i}$ where each Q_i represents the the survival rate of the individuals according to hazard i and the sum of the α_i's equals 1. For natural phenomena, the GSP is $G_n = 1/(1 - T_f/T_p)$ and for man-made hazards $G_m = 1/(1 + M_f/M_p)^{\omega+1}$, where M is the number of people-years lived after the start of technology measured by US patents (here 1350 AD). The parameter ω is used to fit the data (here $\omega = 2.1$). This gives an overall GSP probability of survival of the human race equal to $G_n^{1-q} \cdot G_m^{q(1+\omega)}$, $0 < q < 1$. By filling in all the data and the parameters, it turns out that the chance is higher that you will die in a global disaster than in a house fire (if you are living in a normal house).

The last chapter is devoted to "apocalypse how"[5] where possible scenarios are discussed ranging from a global epidemic over selfsustaining robots, a mutant phytoplankton to a mega-rich person going bananas.

All in all it is a book that has some juicy stuff that will attract many readers but it ends up being a bit chaotic. It somehow hesitates between being mathematics, statistics or just entertaining. It is obviously intended for a wide public, but I doubt that most of them will finish it or get the essence of it. Most "entertaining" if you may say so, is Chapter 5 with all the doomsday scenarios. But the mathematics, hidden in the appendices (they use 80 pages or 40% of the book) are a bit messy and the relation with the rather simple formulas in the chapters is not always made very clear. It could be a commercial success, attracting readers by its title, or by the controversies it may give rise to. But I believe a well structured paper about the mathematics would be very welcome for mathematicians.   Adhemar Bultheel
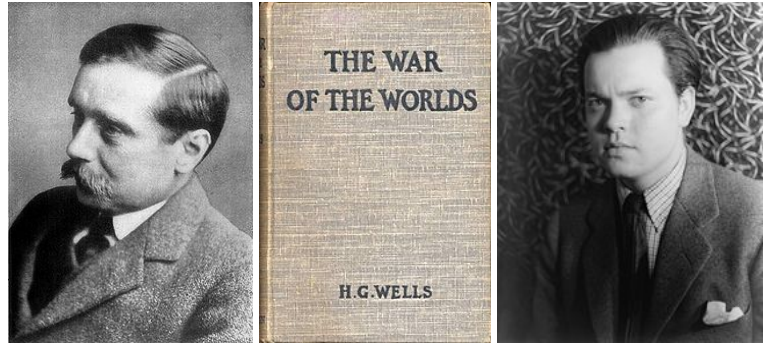
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[3] Almost every formula in this book has this magic GSP form $1/(1 + R/S)$.

[4] G refers to Gott's predictor. I use below a for "age", p for "past" and f for "future".

[5] This is only 1 letter away from the Vietnam movie.