IAC-05-A4.2.11

PAST AND FUTURE OF ASTRONOMY AND SETI CAST IN MATHS

Claudio Maccone

Member of the International Academy of Astronautics
Address: Via Martorelli, 43 - Torino (TO) 10155 - Italy
Phone: +39-011-2055-387.
URL: http://www.maccone.com/ - E-mail: clmaccon@libero.it

ABSTRACT. Assume that the history of Astronomy and SETI is the leading proof of the evolution of human knowledge on Earth over the last 3000 years. Then, human knowledge has increased a lot, although not at a uniform pace. A mathematical description of how much has human knowledge increased, however, is difficult to achieve. In this paper, we cast a mathematical model the evolution of human knowledge over the last three thousand years that seems to reflect reasonably well both what is known from past and might be extrapolated into the future.

Our model is based on two seminal books:

1) "Cosmos" by Carl Sagan (1980), widely known to millions of people all over the western world because of the corresponding TV series, and
2) "Interstellar Migration and the Human Experience" (by Ben Finney and Eric Jones, Editors, University of California Press, 1983).

Our model is based on the use of two cubic curves, representing the evolution of Astronomy and of SETI, respectively. We conclude by extrapolating these curves into the future and reach the conclusion that the "Star Trek" age of humankind might possibly begin by the end of this century.

1. INTRODUCTION

Human knowledge on earth has evolved a lot during the last three thousand years. It actually increased a lot, although not at a uniform pace.

A mathematical description of how much has human knowledge increased, however, is difficult to achieve. In this chapter, we cast a mathematical model the evolution of human knowledge over the last three thousand years that seems to reflect reasonably well both what is known from past and might be extrapolated into the future.

Let us start by considering two seminal books:

1) "Cosmos" by Carl Sagan (1980) (see the references), widely known to millions of people all over the western world because of the corresponding TV series, and

2) "Interstellar Migration and the Human Experience" (by Ben Finney and Eric Jones, Editors, 1983) (see the references). Back in May 1983, a Conference was held at Los Alamos about "Interstellar Migration and the Human Experience". The relevant proceedings were published in 1985 by the University of California Press under the same title and some copies of this book still are available nowadays. The book is outstanding: it offers an unprecedented perspective of human past history from the point of view of the evolution of knowledge and of SETI. In other words, it provides answers to the question: "knowing what happened to various human civilizations in the past on the earth only, how can we extrapolate this amount of information into the future and predict what we might expect in the future from humans expanding into space and contacting ETs ?

These two books thus re-read human history in the new perspectives open up by SETI. But, although wonderfully innovative from the point of view of the ideas, these two books also seemed to this author to have one drawback: they were NOT

mathematical, inasmuch as they only offer wordy descriptions of facts, but no equation was given. Real scientific progress, however, only stems out of a profound mathematical understanding of facts. So, this author sought to "cast into equations" at least a few of the lessons learned from "Cosmos" and "Interstellar Migrations and the Human Experience". And this chapter is a popular description of his mathematical results. To keep the mathematics as easy as possible, we start from a simple algebraic equation of the third degree, traditionally called "a cubic". We think that, in some sense, this cubic mirrors a trend that often happened in human history: a civilization rises from obscurity, reaches a peak, then may suffer setbacks, but finally rises again, and at such a high speed, that its own previous achievements are really dwarfed by the latest, new achievements. In other words, we assume that our mathematical model for the evolution of knowledge on Earth behaves like the cubic depicted in Figure 1.

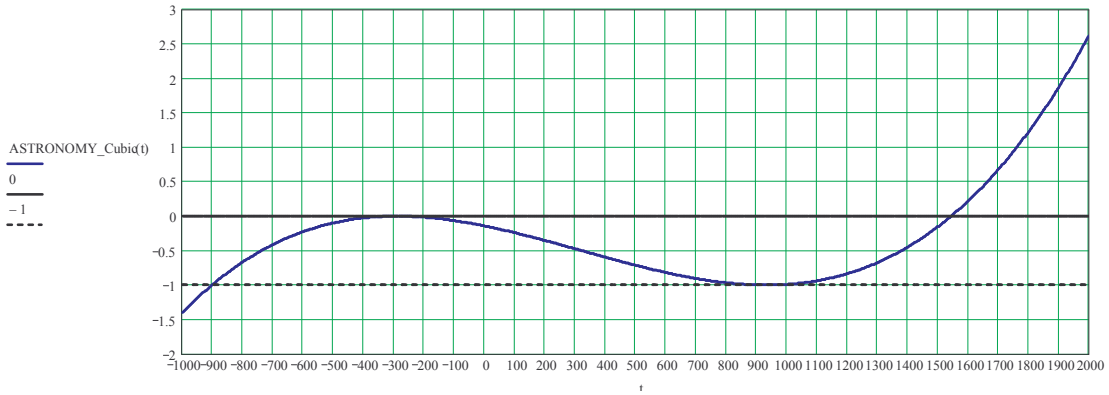

Figure 1. Evolution of Human Knowledge exemplified by the History of Astronomy as a Cubic.

2. HISTORY OF ASTRONOMY AS PROOF OF EVOLVING HUMAN INTELLIGENCE

To The first example of the cubic law we wish to investigate is provided by the 3000 years-old History of Astronomy. After Astronomy had arisen from obscurity in pre-historic times, the Ancient Greeks were the first to realize that the Earth revolves around the sun in the person of Aristarchus (floruit circa 290 B. C.) (peak of Greek Astronomy). Greek Astronomy, however, fell into decadence during the Roman Empire. Later still, the Dark Ages set on, and only in the Renaissance were the new and scientifically correct tracks of Astronomy rediscovered and first published by Copernicus (1543 A. D.). This section describes that string of events by virtue of a simple algebraic cubic curve, in the hope that it might be the starting point for deeper mathematical investigations by others future authors. Also, this section intends to be a tribute to Carl Sagan (1934-1996), whom this author had the honor and privilege to be acquainted to on the eve of the opening of the NASA SETI program, on October 11th, 1992, in Barstow, California. Carl Sagan's seminal book "Cosmos" (1980 - based on his 13-part television series, see the references) inspired to this author the mathematical model developed in this chapter. In particular, the figure on page 335 in Cosmos' Part XIII (entitled "Who Speaks for Earth?"), let this author think of "casting into some simple mathematical formula"

1) the achievements of ancient Greek Astronomy in the time of Aristarchus (290 B. C.), followed by
2) the Dark Ages of the Middle Ages (roughly 476 A. D. through 1492), and
3) finally followed again by the Copernican revolution (1543) and its aftermath, up to the Moon Landing and beyond, into our own future.

The simplest formula this author could conceive is just a cubic fit, as shown in Figure 1. The fit appears to be remarkable inasmuch as:

1) The inflection point of the cubic indeed corresponds to a turning point in history: the years (around 321 A. D.) when the Roman Emperor Constantine openly accepted the

change in religion from Paganism to Christianity. Not a small change at all!

2) The bottom of the Dark Ages, as predicted by our cubic model, occurs around the year 932 A.D. This was indeed the time when the dissolution of the former Empire of Charlemagne reached its peak.
3) A few more notable coincidences are pointed out at the end of Section 3.

To a mathematician, the history of Astronomy is charming (apart from the charm of the topic itself!) as it clearly shows a peak (Aristarchus, 290 B. C.), then a fall (Dark Ages), and then a rise again (Copernicus, 1543, and beyond).

It is natural to think of some simple mathematical curve that would adapt to these three key features at best. The easiest fitting curve appears to be a cubic (i.e. an algebraic equation of the third degree) in which the time *t* obviously is the independent variable:

$$Cubic\,(t) = a_3 \cdot t^3 + a_2 \cdot t^2 + a_1 \cdot t + a_0. \qquad (1)$$

This is just the most general algebraic equation of degree 3 with in t its four undetermined coefficients a_3, a_2, a_1 and a_0 .

Our task is then to find "intelligent formulae" for the coefficients a_3, a_2, a_1 and a_0.

This may be done in different ways. In the first three sections of this chapter, we'll only describe a procedure that appears to us to fit the history of Astronomy at best:

1) We require that the cubic's maximum occurs at the time when Aristarchus firstly claimed (~ 290 B. C.) the solar system to have all planets revolving around the sun, and

2) We require that Copernicus rediscovered Aristarchus's result in the year 1543, the year of both his death and publication of his book "De Revolutionibus Orbium Coelestium".

Let us also agree about two conventions that we would like to adopt:

a) On the horizontal axis of the time, dates in the Christian Era are denoted by positive numbers, while the dates before Christ are denoted by negative numbers.

b) On the vertical axis, negative numbers are in correspondence to times when "the people regarded as true what nowadays is regarded by science as false". Then, in Astronomy, the cubic curve that we are seeking must have negative values for times smaller that –290 (times before Aristarchus) and after Aristarchus but before Copernicus (Dark Ages of Astronomy), while, after Copernicus, the cubic must be positive.

In so assuming, we have really requested our cubic to pass through two points:

1) The Aristarchus point

$$Maximum\_time \equiv Mt = -290 \qquad (2)$$

2) The Copernicus point

$$Recovery\_time \equiv Rt = 1543. \qquad (3)$$

Let us still look carefully at the graph shown in Figure 1. This is our way to "show" or "summarize" the history of Astronomy by virtue of the cubic (1). A glance to this graph reveals that:

1) Before Aristarchus all values of the cubic are negative, meaning that the truth, i.e. the Earth's 24-hours rotation and its revolution around the Sun in just one year, had not been understood yet. Aristarchus was the first to understand this around the year 290 B. C. The site http://www-gap.dcs.st-and.ac.uk/~history/Mathematicians/Aristarchus.html , tells Aristarchus lived in between 310 and 230 B. C., and, according to the site http://www-gap.dcs.st-and.ac.uk/~history/Chronology/500BC_1AD.html#290 he put forward his revolutionary theory around 290 B. C. Unfortunately, Aristarchus was not understood by his fellow countrymen. The Encyclopedia Britannica reports at the site http://www.britannica.com/eb/article?eu=9551 that Cleanthes the Stoic declared that Aristarchus ought to be indicted for impiety. So, Aristarchus' greatest discovery hardly had any immediate influence of the development of Astronomy, and the whole world had to wait for 1833 more years for the truth to come out. Along our cubic curve, Aristarchus thus represents the "single point" with coordinates (*Mt*, 0). This is precisely the case where the cubic has two coinciding real roots and this root is a zero also, as we pointed out at the end of Section 2. In Jesus' time (0 – 33 A. D.), the decadence of the Greek civilization (negative values and negative derivative of the cubic) had begun already. This is historically correct, inasmuch as the Romans (since about 0 A. D. through 476 A. D.) were in essence culturally inferior to the Greeks.
2) After Aristarchus and before Copernicus (1543 A. D.) all the cubic's values are negative again. These were the "Dark Ages" of Astronomy, and, indeed, the Dark Ages of civilization as well. The bottom of the Dark Ages, our graph shows, was reached around the year 932, when Western Europe was lying in a state of virtually complete feudal anarchy. In addition, Vikings, Magyars

and Muslims were freely raiding Western Europe. Some slow recovery from this havoc only began after 955 A. D., when Otto I (Holy Roman Emperor, i.e. German Emperor) defeated the Magyars at Lechfeld. The year 1000 A. D. is usually regarded as "when the rebirth of the Western civilization began".

Notice that, after the year 1000 A. D., the recovery of the West developed at a much faster pace than its own decadence had gone on. Actually, this pace was *twice* as much faster! This fact is faithfully mirrored by our cubic, though we cannot prove it mathematically here due to lack of space. After Copernicus, of course, all values of the cubic are positive. Giordano Bruno in 1582 was the first not only to fully accept the Copernican structure of the solar system, but also to understand that the sun is a just star as many, and that other live beings might well inhabit the planets revolving other stars (historic beginning of SETI). Bruno was burned at the stake in Rome on 17 February 1600 by the orders of the Roman Catholic Inquisition. But the truth could not be hidden any more. After Galileo, Kepler and Newton, science defeated all "religious beliefs".

3. WHAT IS THE REAL MEANING OF THE CUBIC'S VERTICAL AXIS ?

The So far, we have carefully avoided talking about the "meaning" of the cubic's vertical axis. Our convention b), where the vertical axis is mentioned, is not affected by the previous discussion, since the latter simply involves the sign of the positive vs. negative values of the vertical axis. So the natural question arises: "What is plot along the cubic's vertical axis?". Unfortunately (or fortunately!) this question may be given different answers according to the scientific research field that each author wants to investigate. This is a very important topic for the various possible applications of our "cubic recovery law". Some more answers are provided in Maccone 2004 (see the refencences), but, again, we cannot analyze these basic questions here due to lack of space. More future papers by this author will hopefully help by providing more applications to other fields of science like, for instance paleontology (recovery after the mass extinctions occurred on Earth 251 and 65 millions years ago, respectively).

4. DETERMINING THE CUBIC IN TERMS OF *Mt* AND *Rt* ONLY

In this section we give, without any mathematical proof (that would take several pages), the anaytical expressions of the four coefficients a_3, a_2, a_1 and a_0 of the cubic (1) under the three hypotheses:

1) The time (or historical epoch) *Mt* of the maximum is assigned (i.e. is known).
2) The time (or historical epoch) *Rt* of the recovery is assigned (i.e. is known).
3) The cubic is normalized in units of falsity, that is, the ordinate of both *Mt* and *Rt* is zero and the ordinate of the minimum is, by assumption, -1. This normalization of all cubics to –1 is necessary in order to compare different cubics with one another, as we shall later see by comparing the cubic of Astronomy with the (different) cubic of SETI.

This author has proven mathematically that, under the three conditions above, the four coefficients of the cubic (1) are given by

$$\begin{bmatrix} a_0 = -\dfrac{27\,Mt^2\,Rt}{4(Rt-Mt)^3} \\ a_1 = \dfrac{27\,Mt(2Rt+Mt)}{4(Rt-Mt)^3} \\ a_2 = -\dfrac{27(Rt+2Mt)}{4(Rt-Mt)^3} \\ a_3 = \dfrac{27}{4(Rt-Mt)^3} \end{bmatrix}. \qquad (4)$$

The mathematical proof of the above equations is rather lengthy and will not be given here. It can be found in the 2004 paper by Maccone listed in the references list.

As consequences of equations (4), one also finds the following results:

a) Time (or historical epoch) of the inflection point of the cubic:

$$t_{inflection} = \frac{2}{3}Mt + \frac{1}{3}Rt \qquad (5)$$

with the corresponding ordinate given by –1/2 (because any cubic is and "odd" function around its own inflection point).

b) Time (or historical epoch) of the minimum of the cubic:

$$t_{minimum} = \frac{1}{3}Mt + \frac{2}{3}Rt. \qquad (6)$$

with corresponding ordinate given by –1 by assumption (normalization in falsity units).

c) The decadence time span, defined as $t_{minimum} - t_{Maximum}$ is given in terms of *Mt* and *Rt* by

$$Decadence\_Time\_Span = \frac{2}{3}Rt - \frac{2}{3}Mt, \quad (7)$$

d) The recovery time span, defined as $Rt - t_{minimum}$ is expressed in terms of *Mt* and *Rt* by

$$Recovery\_Time\_Span = \frac{1}{3}Rt - \frac{1}{3}Mt. \quad (8)$$

It can be proven that

$$Recovery\_Time\_Span = \frac{Decadence\_Time\_Span}{2}. \quad (9)$$

e) We found useful to define the PreMaximum time, denoted by $t_{preMaximum}$, as the time before the Maximum at which the *y* value is as low as the *y* value of the minimum will later be. In the language of the history of Astronomy, the preMaximum time is a time before Aristarchus at which the knowledge of Astronomy was as bad as it will later be only at the very bottom of the Dark Ages. Then, it can be proven that

$$t_{preMaximum} = \frac{4}{3}Mt - \frac{1}{3}Rt. \quad (10)$$

5. HISTORY OF ASTRONOMY NORMALIZED IN UNITS OF THE WORST DARK AGES

An immediate application of (4) is of course the cubic of Astronomy, now normalized to –1. This cubic is defined by only two conditions: the Aristarchus point and the Copernicus point, respectively located on the time axis at the two values

$$Mt = -290, \quad Rt = 1543. \quad (11)$$

No further condition is requested inasmuch as the vertical axis is now normalized in units of falsity (1 unit of falsity = the false ideas about Astronomy they had in the worst Dark Ages, i.e. around 932 A. D.). Numerical calculations then yield:

a) Transition from Paganism to Christianity (Emperor Constantine) $t_{inflection} = 321.$ (12)

b) Worst Dark Ages, $t_{minimum} = 932.$ (13)

c) How far back in ancient Greek history one has to go in order to find as many false ideas about Astronomy as they had in the Worst Dark Ages

$$t_{preMaximum} = -901. \quad (14)$$

d) How many years it took for Astronomy to reach the worst level of misunderstanding after the truth had first been found by Aristarchus

$$Decadence\_Time\_Span = 1222. \quad (15)$$

e) How many years it took to Astronomy to rediscover the truth since the worst Dark Ages

$$Recovery\_Time\_Span = 611. \quad (16)$$

f) Numerical coefficients of the cubic of Astronomy normalized to –1:

$$\begin{bmatrix} a_0 = -0.14223 \\ a_1 = -8.88692 * 10^{-4} \\ a_2 = -1.05546 * 10^{-6} \\ a_3 = 1.09602 * 10^{-9} \end{bmatrix}. \quad (17)$$

g) We would like to complete this section by two historical remarks. The first one is summarized by the Latin sentence "Graecia capta ferum victorem coepit" i.e. "The captured Greeks indeed captured (by culture) their own ferocious conquerors (the Romans)". This said the Roman poet Horace (65 B. C. - 8 B. C.), and he was right! He meant that the Greeks always were culturally superior to the Romans, even close to Jesus' time, when Horace lived. And our cubic law just quantifies this statement: "The Greeks were 17% culturally superior to the Romans already in Jesus Christ's and Horace's time, and much more in later times still", as one can find by applying the two equations

$$\left| t_{Jesus\_death} = 33 \quad cubic\_for\_Astronomy = -0.17266 \right| \quad (18)$$

h) The second remark is that the Copernicus point might actually correspond to the year 1514, rather than to 1543. This is because, according to the University of St. Andrew's web site http://www-gap.dcs.st-and.ac.uk/~history/Mathematicians/Copernicus.html Copernicus actually put forward his revolutionary ideas for the first time in 1514, rather than in 1543, in a handwritten (not printed) work called "Little Commentary". It would be interesting to develop a "theory of errors" in this regard, but we do not have space to do so here.

6. HISTORY OF SETI AS A CUBIC

Let us now change the scenario completely. In this section we claim that also the history of SETI (the modern Search for ExtraTerrestrial Intelligence) may basically be cast in a cubic shape. SETI, in fact, had its true historic beginnings back in 1582, when, in his work "De l'Infinito, Universo e Mondi" ("About Infinity, the Universe and the Worlds"), the Italian scholar Giordano Bruno (1548-1600), showed to have fully realized that:

1) The Copernican System was the right one.
2) Our Sun is just one star as many. It looks much brighter only because it is much closer to us.
3) Just as we know planets to orbit our Sun, so we might infer that other planets could possibly orbit other stars (a fact not proven scientifically until 1995, when Michel Mayor and Didier Queloz of Geneva discovered (in France, at OHP) the first extrasolar planet around the star 51 Pegasi).
4) Just as our planet is inhabited by humans and animals, so the other planets might host living extraterrestrials.

Because of these great conceptual achievements by Bruno, we claim that the Maximum of the Cubic of SETI is given by

1) The Giordano Bruno point:

$$Maximum\_time \equiv Mt = 1582 . \qquad (19)$$

Bruno was the Aristarchus of SETI. He was burned at the stake by the orders of the Roman Catholic Inquisition on 17 February 1600 in Rome (in Campo dei Fiori, where his Memorial now stands). At least in part, he died at the stake because his doctrines were much of a blow to the ruling Roman Catholic establishment of his days. Ironically, the name of the Pope who had Bruno burned was Clemens VIII, and, in Latin, Clemens means "the mercyful" !

2) The Cocconi-Morrison point :

$$Recovery\_time \equiv Rt = 1959 . \qquad (20)$$

Giuseppe (misspelled Guiseppe in many English textbooks) Cocconi (1914-) is an Italian physicist of the school of Enrico Fermi, now retired director of the CERN proton syncrotron in Geneva. Phil Morrison (1915-2005) was physics professor at MIT. In 1959, Cocconi and Morrison published a seminal paper proposing the potential of microwaves in the search for interstellar communications. That paper marked the beginning of modern, experimental SETI, especially since in 1960 Frank Drake first searched two nearby stars (ε Eridani and τ Ceti) for possible "intelligent signals" around 1.420 GHz.

By virtue of the two conditions (19) and (20), the four equations (4) thus yield a new cubic that we call the Cubic of SETI and is plot in Figure 2.

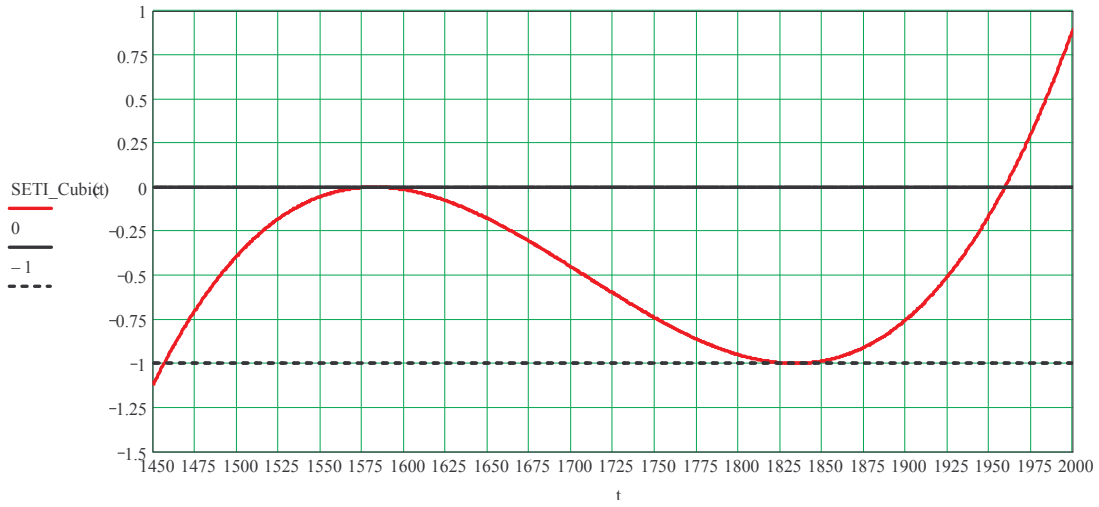

Figure 2. History of SETI as a Cubic (as usual, normalized to –1, i.e. in Falsity Units).

To see how this cubic "makes sense", consider that (6) yields

$$t_{minimum} = 1833. \qquad (21)$$

These were indeed the "Darkest Ages" of the Restoration in Europe, namely the 33 years elapsed in between the fall of Napoleon (1815) and the European Revolution of 1848. (Note: we do not regard the Parisian Revolution of July 1830 as very significant. In fact, it brought changes only to the history of France, not to the history of the whole Europe, as the subsequent Revolution of 1848 did). In other words, since Giordano Bruno's death in 1600, strong persecution by the Roman Catholic Church, as well as by most other national churches, against claims like "we are not alone in the universe" forced any "reasonable person" to keep silent about any claim the existence of any ETs at all. On the other hand, the existence of ETs could not possibly be proven scientifically until about

1950, and so the long sleep of the search for ETs lasted about 350 years.

Indeed, the decadence time span, given by (15), for SETI is, in years,

$$Decadence\_Time\_Span = 251, \qquad (22)$$

the SETI inflection point, by (5), falls at

$$t_{inflection} = 1707 \qquad (23)$$

and, finally, the recovery time span, by (16), is

$$Recovery\_Time\_Span = 125. \qquad (24)$$

The preMaximum time falls at

$$t_{preMaximum} = 1456 \qquad (25)$$

(Renaissance leading to a new conception of the universe), with actual coefficients of the SETI cubic

$$\begin{bmatrix} a_0 = -617.6282 \\ a_1 = 1.0961 \\ a_2 = -6.45363 * 10^{-4} \\ a_3 = 1.25974 * 10^{-7} \end{bmatrix}. \qquad (26)$$

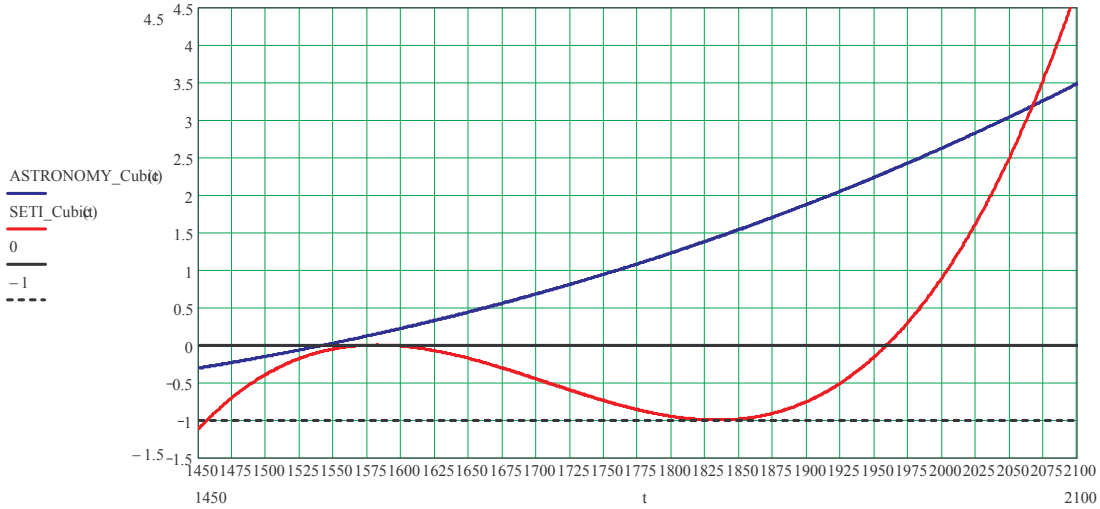

Figure 3. Combining the two Cubics of Astronomy and SETI. Finding their intercept.

7. EXTRAPOLATING THE TWO CUBICS UP TO THE WARP DRIVE INVENTION (2067 A. D. ?)

So far, we only fit two cubics to the human history of past centuries. This is interpolation. Now we try to have a look at our future, and must thus do extrapolation. To this end, let us plot both the cubics of Astronomy and SETI on the same plot (Figure 3). Notice that only "the right branch" of the cubic of Astronomy appears in this plot because the time span only starts at the year 1450 A. D., just as in Figure 2. Also, the plot extends now up to the end of the present century, i.e. to 2100 A. D.

One notices immediately that, after the 1959 year of Cocconi and Morrison, the SETI cubic is much "steeper" than the Astronomy cubic. In other words, SETI is developing much "faster" (in importance) than the rest of "traditional" Astronomy. The prediction is that SETI will become even more important than Astronomy itself after the year 2067 A. D., that is the abscissa of the intercept between the two cubics in the graph above.

Does this prediction of our theory make sense? Well, nobody can predict the future, of course. But… if we "are to believe" the Star Trek TV series… well the year 2063 will be extremely significant! It will be the year when Zephram Cochrane (born in 2030) invents the Warp Drive and pilots Earth's first faster-than-light space flight (see the references).

Science fiction only? May be not. In the years 1996-2002, NASA's Breakthrough Propulsion Physics Program (BPP – web site http://www.grc.nasa.gov/WWW/bpp/) was the first NASA forum to let experts in Relativity and Quantum Field Theory study the possibilities of faster-than-light (FTL) space flight. Not to mention other "photon-state teleportation" experiments that seem to be challenging Special Relativity itself!

But let us go back to Figure 3. To take a few final, bold steps of extrapolation into the future, we now assume that variable on the vertical axis represents the "distance from Earth reached by humans at various epochs". Under this assumption, the ordinate corresponding to the year 1969 must then be the Moon distance, i.e. 384,000 km. Having calibrated the two cubics in this fashion, when will humans reach the nearest star, α Centauri, at the distance of 4.29 light years? Here are some answers:

1) According to the (slow) Cubic of Astronomy, humans will reach α Centauri in 612,810 years;
2) According to the (steeper = faster) Cubic of SETI, humans will reach α Centauri in 55,803 years.
3) But these are rather "discouraging" predictions! More realistically, then, we may replace the Moon distance of 1969 by the Voyager 1 distance of 2004 (i.e. we may consider robotic probes instead of manned flights) and re-calibrate the vertical axis accordingly. In this case the results are more encouraging:
4) According to the (slow) Cubic of Astronomy, robotic probes will reach α Centauri in 18,220 years;
5) According to the (steeper = faster) Cubic of SETI, robotic probes will reach α Centauri in 4,377 years.
6) We are now reaching the ultimate conclusion. We now claim that only the result 4) is the right one! In other words, we claim that human robotic probes will reach α Centauri in 4,377 years, or in about 4,000 years from now. The reason for our claim is that the cubic of SETI is so steep that it shows SETI will overcome general Astronomy in the public interest at least from the year 2060 onward. It is already so now (2005) to some extent: lay people "believe in UFO" (incorrectly, of course, by scientific standards), thus revealing that the "need for contact" with alien civilizations already is "in the air" and "in the lay people's mind". Also, as of the year 2005, both NASA and ESA are planning space missions intended to find ***other Earths*** outside the solar system. These two missions (robotic high-tech telescopes to be located at the Lagrangian point L2 of the Earth-Sun system) are called TPF (Terrestrial Planet Finder) and Darwin, respectively. They are scheduled for launch around 2010. When other Earths will have been found, humans will then hardly refrain from sending robotic probes towards them. Thus, we may well conclude that the evolution of human knowledge on Earth has reached an unprecedented peak, and is actually paving the way to the human expansion into Space.

8. A GLANCE TO THE FUTURE OF OUR MATHEMATICAL MODEL OF THE EVOLUTION OF INTELLIGENCE

We tried to model the Evolution of Intelligence on Earth by two cubics of the time. But which differential equation does a cubic fulfill? Just differentiate the cubic (1) twice:

$$\frac{d^2\ Cubic\,(t)}{dt^2} = 6 \cdot a_3 \cdot t + 2 \cdot a_2 . \qquad (27)$$

From this equation, one might naïvely infer that "The force behind progress increases linearly in time". This conclusion may be too simplistic, though. A more serious mathematical model would imply regarding the cubic (1) as the (deterministic) mean value, $Cubic\,(t) = \langle X(t) \rangle$, of some unknown stochastic process $X(t)$, that one would then try to determine by more advanced mathematical techniques than the simple cubics we used here. This endeavor, however, has to be deferred to a further, more profound mathematical study.

CONCLUSION

Our feeling is that we just skimmed the (mathematical) surface of some more profound theory. This theory would embrace key features in human history and sociology, as well as in the "geography" of Space, and bind them together inside a single mathematical structure. In other words, here we made just a beginning to investigate the Evolution of Human Intelligence by mathematical tools updated to the coming age of the conquest of Space.

ACKNOWLEDGEMENT

The author is grateful to Dr. Steve Dick, NASA Chief Historian and Director of the NASA History Office at NASA Headquarters, for reading the preliminary version of the mathematical theory developed in this chapter, and for letting the author know about his opinions.

REFERENCES

Finney, Ben R. and Jones, Eric M., editors. "Interstellar Migration and the Human Experience". Proceedings of the Conference on Interstellar Migration, Los Alamos, May 1983. University of California Press, 1985.

Maccone, Claudio, "A Mathematical "Cubic Law of Recovery": Part 1 – Applications to History of Astronomy, SETI and Modern Europe", Frontier Perspectives (published by Temple University, Philadelphia, PA, USA), Volume 13, Number 2, Fall/Winter 2004, pages 22-33.

Okuda, Michael and Denise, "Star Trek Chronology – The History of the Future", Pocket Books, New York, 1996. See, in particular, pages 26 and 28.

Sagan, Carl, "Cosmos", Random House, New York, 1980, ISBN 0-394-50294-9 (hard cover), ISBN 0-394-71596-9 (paperback). See in particular the unnumbered figure on page 335 that inspired much of this chapter.