How Old Is ET?

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ABSTRACT

This paper considers the factors that determine the probable age of a civilisation that might be detected in a SETI search. Simple stellar evolution considerations suggest an age of a few Gyr [gigayears or billion years]. Supernovae and gamma-ray bursters could in principle shorten the lifetime of a civilisation, but the fact that life on Earth has survived for at least four Gyr places a severe constraint on such factors. If a civilisation is detected as a result of a SETI search, it is likely to be of order one Gyr more advanced than we are.

1. Introduction

When we conduct searches for extraterrestrial intelligence, we often make implicit assumptions about the age of the civilisation that we are trying to find. For example, our strategy for searching for a life-form of a similar age to us is likely to be different from that for a civilisation billions of years more advanced than we are. Similarly, in the event of a confirmed detection, the way in which we plan our response will also depend on how advanced that civilisation may be. In this paper, I estimate the likely age of the civilisation that we are most likely to detect, should we be successful in our searches.

The two key factors that determine how old a detected civilisation is likely to be are (a) the length of time since intelligent life first appeared in our galaxy and (b) the median lifetime of a civilisation. The second of these is more problematic, since the development of a civilisation can be cut short by a wide range of events, including disease, war, global mismanagement, asteroids, supernovae, and gamma-ray bursters. We should also acknowledge the possible existence of other hazards, of which we are not yet aware. For example, the devastating effect of gamma-ray bursters has been appreciated only in the last two to three years, and there are probably other phenomena yet to be discovered. Events such as disease, war, and global mismanagement are almost impossible to quantify, and so in this paper I concentrate on those events that we *can* quantify: asteroids, supernovae, and gamma-ray bursters. In the first section of this paper, I consider what the maximum lifetime of a planetary-bound civilisation might be.

Throughout this paper, I make a very conservative assumption that an extraterrestrial civilisation (ET) resembles us in most significant respects (other than age and evolution). In other words, ET lives on a planet orbiting a solar-type star and has taken as long after the formation of its star to evolve to "civilisation" as we have, which is ~5 Gyr (gigayears or billion years). I therefore estimate the longevity of ET by looking at the hazards that confront the Earth.

2. The Natural Lifetime of a Civilisation

I assume that stars like our Sun have been forming since the formation of the galaxy some ten Gyr ago. Observed changes in metallicity since then are not sufficient to alter this simple assumption significantly. Our Sun is now about five Gyr old and has an expected total lifetime of ten Gyr.

For the first five Gyr of the life of the galaxy, there would not have been enough time for a civilisation to develop, and so ET did not exist. Between five and ten Gyr, assuming a constant rate of star formation, the number of civilisations would increase linearly until the present day. At around the present time, some of those first solar-type stars will be dying at the same rate as others are forming; so, assuming their civilisations die at the same rate as they do, the number of civilisations is then level from now on.

The median age of a civilisation is therefore the median age of those civilisations that started between five and 0 Gyr ago, which is 1.7 Gyr. Therefore, in the absence of other factors, any civilisation that we detect via SETI is likely to be 1.7 Gyr more advanced than we are.

3. The Effect of Supernovae

A supernova results from the explosion of a high-mass star after its hydrogen and helium fuels are used up, at the end of its lifetime. A supernova exploding within 50 light-years of the Earth would have a catastrophic effect. The 1040 J of energy produced in the first few days would bathe the Earth in a total amount of ionisation some 300 times greater than the annual amount of ionisation from cosmic rays. Surprisingly, little of this radiation would reach Earth. Instead, most of it would ionise atmospheric nitrogen, which reacts with oxygen to form nitrous oxide, which in turn reacts with ozone.[3] The effect would be to reduce the amount of ozone in the Earth's atmosphere by about 95%, resulting in a level of UV on the Earth's surface some four orders of magnitude greater than normal, which would continue for a period of two years. This would certainly result in almost 100% mortality of small organisms and most plants. The effect on mammals is not clear; some might survive. However, this two-year period would be followed by a longer (80 years) period of bombardment by the cosmic rays from the supernova, which have similar, although slightly reduced, effects. It is difficult to see how anything other than an advanced civilisation could survive such an extended holocaust.

A supernova such as this goes off in our galaxy roughly every five years, and we expect one within 50 light-years of the Earth roughly once every five million years. We expect one even closer (within ten light-years) every 200 million years. All life would be expected to be destroyed at this interval. Clearly this has not happened, since we are still here, and I will return to possible reasons in a later section.

4. The Effect of Gamma-Ray Bursters

Gamma-ray bursters (GRB) are a recently discovered phenomenon, in which some 1045 J of energy is released in a few seconds. The ones that have been observed on Earth appear to be distributed uniformly across the observable universe. Their power is such that we are able to detect GRB right up to the edge of the observable universe. The mechanism is still not known, but is likely to involve the merging of two neutron stars, possibly resulting in the formation of a black hole.

A GRB is some five orders of magnitude more energetic than a supernova, and could occur even at the galactic centre, 25,000 light-years away from us, and have a similar effect as a supernova within 50 light-years. However, in this case there is an even more deadly effect, in that, should a GRB go off in the galactic centre, the immediate blast of ionising radiation would be followed by an intense blast of cosmic rays lasting perhaps a few weeks.[4] These cosmic rays would initiate a shower of relativistic muons in the Earth's atmosphere, causing a radiation level on the surface of the Earth some 100 times greater than the lethal dose for a human being. The muons are so energetic that they would even penetrate nuclear air-raid shelters to a depth of perhaps hundreds of metres.[2]

We expect such a GRB roughly once every 200 million years, and it would almost certainly result in the extinction of all life on Earth other than that deep in the ocean. Again, clearly this has not happened, since we are here.

5. Mass Extinctions on Earth

The geological and biological record shows a series of mass extinctions of life on Earth. The most famous is that at the Cretaceous-Tertiary (KT) boundary, which was almost certainly caused by an asteroid hitting the Earth about 65 million years ago. The KT mass extinction wiped out the dinosaurs and paved the way for the emergence of mammals as the dominant species on Earth.

Less well known are a series of similar, and in some cases even more extreme, mass extinctions every few tens of millions of years, and many smaller extinctions, the last of which was only 11,000 years ago. The cause of most of these is unknown. It is likely that a range of causes, including asteroids, distant supernovae, and climatic changes, is responsible for them.

All these mass extinctions are on a much smaller scale than the catastrophic events we expect from a nearby supernova or a gamma-ray burst in the galactic centre. In each of these cases, a number of species (sometimes as many as 50 percent) were extinguished, but a sufficient range of diversity remained for the biota to recover in a relatively short time.

6. Why Are We Here?

I have identified two causes that should wipe out essentially all life on Earth roughly every 200 million years, and yet we are here. Two possible explanations are: (1) The calculation of either the time scales or the severity of the effects is erroneous, or (2) we have been very lucky!

In the first case, simply multiplying the time scale by a factor of a few is insufficient. We have been evolving for at least four Gyr, and so the interval between catastrophes must be at least four Gyr for us to survive so far. Presumably the precise interval will vary randomly around this figure, so any surviving civilisation can look forward to a lifetime of between zero and a few Gyr. In this case, if we detect ET, then ET will have a median age of perhaps one or two Gyr, which is similar to the 1.7 Gyr derived from simple stellar evolution arguments. Thus, in this case, the supernovae and GRBs have not significantly changed the median age of ET.

In the second case, we have already survived for some 20 times the mean interval between catastrophes, which is very lucky indeed. Whilst it is not possible to quantify this without more detailed knowledge of the frequency distribution of supernovae and GRBs, it is likely that the probability is so low that we are alone in the galaxy. Apart from providing a solution to the Fermi paradox,[1] this implies that the median lifetime of ET is meaningless, as we will never detect ET!

7. Conclusion

Conventional models imply that supernovae and gamma-ray bursters will extinguish life on planets at intervals of about 200 million years. Since this has not happened on Earth, either these conventional models are wrong, or else life on Earth is probably unique in the galaxy. The first case predicts a median age of ET as being of the order of one billion years. The second case predicts that we will never detect ET. Thus, if we *do* detect ET, the median age is of order one billion years. Note that in this case the probability of ET's being less than one million years older than we are is less than one part in a thousand.

Therefore, any successful SETI detection will have detected a civilisation almost certainly at least a million years older than ours, and more probably of order a billion years older.

References

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