The Life of Civilizations

They will listen diligently, but they will not hear;
They will look carefully, but they will not see
Gospel of Matthew 13:14

Extraterrestrial intelligence, its existence, the problem of its detection and meeting with it is a fascinating topic. Probably, that is why there are so many publications on this topic, from science fiction novels to scientific articles. We should also discuss the current situation in this problem.

From a scientific point of view, we are entering a most speculative field with poor experimental and observational material. By and large, there are only two facts, and they are trivial: a) there is at least one civilization (ours) in the Universe, and b) although the properties of the Universe are the same in all its corners, no traces of other civilizations have been found so far. Nevertheless, the inquisitive part of mankind is extremely interested in the problem of neighbors in space and has developed intensive activity to search for them.

The rapid spread of civilization across the galaxy

Realizing the incompleteness of our knowledge about the origin of civilizations, let us try to estimate the probability of meeting with extraterrestrial intelligence. For analysis, let's take only our Galaxy with its hundred billion stars and see how quickly the sphere of influence of one civilization can expand. First, let's estimate its age. The Sun was lit 5 billion years ago, and that was enough time for intelligent life to evolve to our level. Let's assume that this number (5 billion years) is typical for other civilizations. But in our Milky Way galaxy, stars were born ten billion years ago. Then it turns out that some civilization may be older than us by 5 billion years. At no risk of offending it, let's assume that it was originally like ours. So it took them, like us, 100,000 years to go from a savage state to spaceflight. Even if we add another thousand years to master interstellar travel, this is a small period of time compared to the lifetime of an ancient civilization and the galaxy as a whole.

So, a few billion years ago, a civilization appeared, seeking to explore new planets (let that's their goal). The number of such independent civilizations is usually estimated. These estimates contain many uncertainties, so let's forget about them for a while and assume that only one civilization appeared. Then we make reasonable assumptions, which each of the readers can then modify at their own discretion and assume that the expansion is carried out in the following way.

From a planet inhabited by a pra-civilization, 3 ships are equipped, flying in different directions, with 1 thousand settlers and the necessary equipment. The ships fly to the nearest suitable stars, and the people settle there. The distance between the stars is L~1 parsec, the speed of the ship is v=0.2 c (i.e. a fifth of the speed of light, let it be so), so they will fly for 20 years. The chosen speed of the ship seems unattainable now, but let's not forget about the age of civilization,

and therefore about its capabilities. But here the settlers in 20 years have reached a suitable planet. Let them live and reproduce in peace for another 300 years, so that they will be able to repeat the cycle - to send 3 more ships of the same kind to the next stars. Under these assumptions, settlers would spread across the Galaxy at a rate of 1 parsec per 320 years. The size of our galaxy is 60 kiloparsecs, and to populate it all would require 60 thousand cycles of 320 years each. It's not hard to calculate that in 20 million years a single civilization will fill the entire galaxy. Of course, this is only a rough estimate. Unaccounted for factors can shift it to one side or the other. For example, a solid number of stars are concentrated close to the center of the Galaxy, and the distance between them is much less than 1 parsec. Also, not all stars have suitable planets, and it would not take time to populate them. Nevertheless, this number - 20 million years - is too small compared to the lifetime of an ancient civilization of several billion years for corrections to it to change further conclusions.

To check, let's estimate how many planets could be populated in this way. Each settlement cycle would require 3 ships, each ship would develop 1 planet, 60 thousand cycles in total. Even for 10000 cycles, $3^{10000}=10^{4771}$ planets would be inhabited, which is too much even for the whole Universe, not just our Galaxy. As you can see, it is not necessary to send 3 ships, one or two would be enough.

So, in 20 million years the Galaxy can be fully populated by colonies of only one civilization, and it could have happened already several billion years ago. That's a very short time compared to the galaxy's existence, so we would have to show up when all the seats are taken and the banquet is in full swing. And where are they, the colonists, whose civilization is billions of years old?

Why don't they make contact with us?

Why don't they make contact with us, what are they waiting for? Why the search for traces of their vital activity so far unsuccessful? Let's try to list the main options.

1. The emergence of life, much less intelligent life, is a rare event, even if there are suitable planets. We are the first in the Galaxy, and most likely in our Universe.

2. The lifetime of civilization is not very long.

3. Moving through space is dangerous and intelligent beings avoid it. Indeed, if there are many small black holes in the Galaxy, colliding with one of them is fraught with consequences.

4. They aren't interested in us.

5. They are not interested in the expansion of their own civilization.

6. We are not yet able to perceive their signals.

Let's deal with each possibility.

1. The emergence of life is a rare phenomenon.

It is possible that this is indeed the case, but we are not yet advanced enough to even estimate the likelihood of this. Such estimates are made, of course, but the conclusions depend heavily on what a particular author wants to prove, as well as the underlying assumptions. For example, it

has long been thought that life originated in a warm broth of chemical components dissolved in water. But apparently life on Earth originated about 4 billion years ago. At that time, conditions on Earth were far from idyllic warm broth - there was a process of formation of the planetary system around the Sun, accompanied by numerous collisions of solid bodies of different masses. Meteorites, large and small, fell on the Earth, which led to spontaneous and sharp heating of the surface, and water vaporized.

According to one theory, life could have originated only deep underground, several kilometers from the surface. Interestingly, the samples of the substance brought up from a great depth gave a positive result - traces of life were indeed found! Apparently, the life form found can not be based on oxygen - at such a depth there is none. It turns out that such life forms - extremophiles - exist even now. They have been found in warm sulphur springs. Thus, to estimate the probability of the emergence of life, we must take into account all possibilities, which does not seem realistic. However, it must be recognized that life can exist under much harsher conditions than has hitherto seemed possible. For example, moss exposed for two weeks in outer space endured this ordeal without significant damage.

Finally, we will follow the general scientific postulate - similar conditions produce similar consequences. For us, this means that intelligent life is produced on every Earth-like planet, a number of each is huge.

2. The lifetime of civilization is not very long.

Not a pleasant prospect, and to assess the options for the development of events, let's look back at ourselves.

First, humanity has been engaged in self-destruction for its entire history. It may eventually succeed. Globalization of terrorism, accidental leaks of harmful bacteria, the development of new epidemics could all contribute. Each possibility seems unlikely, but it exists, and over a long period of time the probability may approach one.

Secondly, humanity has become a global factor destroying natural connections that have been established over millions of years. We can list long examples of species extinction, atmospheric pollution, etc. Nevertheless, I think that civilization is able to cope with these problems. Not our civilization, so another. This means that the above-mentioned reasons are unlikely to be the cause of the death of *all* civilizations in the Galaxy.

But, from the author's point of view, there is a not very visible factor that can lead to serious consequences, and now it is not clear how to exclude it. That factor is the absence of natural selection. Mankind has either eliminated natural selection or reversed it, and it is not clear which is worse. The sad thing is that natural selection, which is essential for the human community (the weak perish without producing offspring), contradicts the very principles of humane society, without which the existence of civilization is also problematic.

In recent years, another problem has emerged: artificial intelligence. Even if we avoid all the dangers that are being talked about everywhere, human laziness will play a cruel trick on us.

We'll hand over all the boring activities to artificial intelligence. Gradually the only interesting activities for us will be praying and playing, that is, participating in religious activities and playing all sorts of offline and online games. The final state of humanity will be similar to what was obtained in the famous experiment ‘Universe 25’.

3. Moving through space is dangerous.

Generally speaking, this argument does not seem very serious. After all, our planet also “moves in space” around the Sun at a speed of 29 km/s, and the Sun itself, being a typical star, orbits around the center of the Galaxy at a speed of about 230 km/s. And nothing terrible has happened to the Earth so far. Nevertheless, we have to keep in mind that cosmic rays penetrate spaceships with living beings inside, which is deadly for them. Unlike Earth, where the atmosphere protects us.

The last three possibilities (N 4, 5, and 6) are somewhat more optimistic. Suppose that civilizations in the Galaxy arise, and some of them overcome the difficulties and dangers mentioned above. Then, as we have seen, they are able to populate the entire galaxy in 20 million years. This is not such a long time. After the birth of our Sun from interstellar gas, 5 billion years have passed and we can already read, write and fly. The galaxy, on the other hand, has been around for about 10 billion years. So, the existence of old civilizations that are several billion years older than us seems quite possible. It is conceivable that such a civilization, being curious as usual, once devoted several million years to circling all the stars in the Galaxy. So, the aliens know about Earth and all other inhabited planets, and know them as well as we know our own planet. Or better. So why don't they make contact with us?

So, uh:

4. It's possible that they just aren't interested in us.

If they are billions of years older than us, that means the same difference in evolutionary time. Now let's think back to 2 or 3 billion years ago on Earth. Life was just beginning. Even trilobites, the precursors of today's crayfish, crabs and other arthropods, appeared only half a billion years ago. Progress is evident. Their relatives are still living today, but does the reader have a desire to get in contact with them (intellectually)? What such problems can be discussed with a shrimp? The answer is obvious. So, ancient civilizations are simply bored to communicate with primitive creatures like us.

But if they are so much more perfect than us, they should have populated our planet long ago, before the dinosaurs or even earlier, in the era of the same trilobites. Then mankind would simply not have arisen. But we do exist! And that could mean that

5. Aliens are not interested in the expansion of their own civilization.

Actually, why should a civilization strive to increase its number? Apparently, this desire has been developed over millions of years of evolution and is embedded in us at the level of unconditional reflexes. All species that did not possess this property were forced out of areas adapted for reproduction and therefore became extinct. But a civilization that a couple of billion years ago

was able to fly around the galaxy does not need such a reflex. A man who has traveled a lot during his life is hard to be seduced by distant countries in old age. He is more likely to engage in some creative activity. Perhaps the same thing happens with elderly civilizations. However, if they continue to travel, it is likely that they have already traveled to other galaxies. This means that we should not hope that they will try to contact us.

6. *We are not yet able to perceive their signals.*

As already mentioned, we should not count on their attempts to make contact. There is hardly any hope of detecting random signals either. Simply because we are not yet able to perceive their signals. They may have evolved to communicate by means other than electromagnetic waves. We will not learn how to do this for some time yet, although changes in the way information is transmitted are happening before our eyes. Frank Drake, President of the SETI Institute (Search for Extra-Terrestrial Intelligence), has pointed out that the flow of radio waves from our planet into the surrounding space is not increasing over time, as would be expected, but decreasing. The reason lies in new technologies, such as cable and satellite television, for example**.** In this regard, it is interesting that cell phone conversations of airplane passengers are interfering with the SETI project's search for extraterrestrial civilizations. Radio waves from cell phones are readily picked up by sensitive antennas pointed into space and can be interpreted as an extraterrestrial signal from intelligent beings.

So far we have been discussing humanity's relations with a civilization far beyond our intellectual level. But we should also expect contacts with partners closer in development, who appeared about the same time as we did. It is this fascinating and multifaceted problem that has been discussed at length in the literature for a long time.

In 1961, F. Drake proposed a formula for determining the probability of the appearance of a civilization in our Galaxy:

$N = R \cdot F_p \cdot N_e \cdot F_l \cdot F_i F_c \cdot L,$

where N is the number of developed civilizations; R is the number of stars formed per year; Fp is the fraction of stars with planets; Ne is the fraction of planets with conditions suitable for the origin of life; Fl is the probability of origin of life in favorable conditions; Fi is the probability of origin of mind in the presence of life; Fc is the probability of development of a civilization capable of interstellar contacts; L is the lifetime of the civilization.

The formula is good because analyzing it helps us understand how uncertain our knowledge, and thus predictions in this area, are. Some things we know reliably, other aspects are worse, and some are not even well known at all. For example, the rate of star formation in our galaxy R is known very well - a few new stars per year. The fraction of stars that have planetary systems, F_p ~1, is also well predicted by model calculations. The value N_e is no longer very certain. When it is discussed, debates immediately begin about what is considered “life” and what conditions are sufficient for its occurrence. The main controversy is the value of F_l, the probability of the emergence of life, even if the conditions for it are in place. The opinion of some scientists is that F_l ~

1, is not at all shared by those who consider such a probability to be close to zero. The problem is aggravated by the fact that it is not clear at all which object should be considered alive, and even more so, intelligent. Many science fiction novels are based on misunderstandings of this kind. Estimating values F_i and F_c is also highly dependent on the mentality of the appraiser. Finally, the estimate of the time of life of an advanced civilization, L, ranges from 1 thousand years to infinity.

Let us note an important circumstance: Drake's formula does not include the influence of the oldest civilization on its neighbours who have fallen behind in their development. This factor is difficult to assess, since we do not know the morality of a civilization that has been developing for several billion years, nor its attitude to its future and to us, its lesser brothers. It is quite possible that an ancient civilization suppresses the development of younger ones. After all, we treat butterflies and mosquitoes differently too. The methods of suppression may be different, but let's not talk about sad things. And supercivilizations have a problem worthy of their intelligence and capabilities - it is the problem of their own survival in the cooling Universe.

Longstanding dangers for supercivilization

Modern models of the evolution of the Universe provide several future scenarios to choose from, and all of them do not give grounds for complacency. I will briefly list the main ones.

The basic scenario is that the Universe will be forever expanding and cooling, which is possible if the cosmological constant really does not change with time. Eventually there will be only particles left - neutrinos, photons and perhaps electrons and protons. No stars or black holes. Just uniformly distributed particles separated by large distances. There are few particles even now - less than one proton per cubic meters, but in the future the density will only decrease, simply because of the expansion of the Universe. The rate of expansion depends on the ratio between energy density and pressure, and this is the reason for discussion. After all, now about 70% of the energy density is delivered by dark energy, the properties of which are not yet completely clear. Let us choose the simplest variant: the density of dark energy is constant. Then in the equations describing the expansion of space, a summand similar to the cosmological constant is added, first unjustifiably introduced and then vainly discarded by Einstein.

To estimate the characteristic expansion time, it is sufficient to take into account only the contribution of dark energy - it is large now, and its fraction will only increase in the future. In this case the sizes grow with time *t* according to the exponential law:

$$R(t) = R_0 e^{H_0 t}$$

The first danger. If we scatter all atoms of our Universe uniformly throughout the Universe, there will be 1 proton in a cube with a side of 1 meter. Our Universe is expanding, and it's not hard to figure out that in a time span of 910 billion years, this cube will expand to the size of the

visible part of the Universe that is now 10^{28} cm. So, in a volume equal to the size of the modern Universe, there will remain 1 proton, from which it is unlikely to be possible to form an intelligent being. The task of supercivilization is to preserve the concentrated energy, the basis of existence of any form of matter. How to prevent energy from dispersing in any form - in the form of particles, electromagnetic or any other radiation, including gravitational? This is not easy to do, as will be seen in what follows.

The second danger is that the Universe will shrink into a pre-Big Bang state. The probability of such a development of events has decreased after the discovery of dark energy, but nevertheless exists.

The third danger is the so-called 'Big Rip'. This idea was put forward in 2003 in the article 'Phantom Energy and the Cosmic End of the World' by R. R. Caldwell, M. Kamionkowski and N. N. Weinberg and has been intensively discussed since then. There are certain grounds to assume that the magnitude of the interaction between particles, due to which all structures, starting from atoms, exist, decreases with time. Then in 20-30 billion years, when the interaction is significantly reduced, there will be a collapse of all vital objects, including mind. First galaxies will disintegrate into separate stars, then planets will separate from stars, electrons - from atoms, etc.

The fourth danger. It is quite possible that our space consists not of three spatial dimensions, but of a (much) larger number. We do not notice the remaining dimensions because of their small size. But if the size of additional dimensions grows with time, they will already seriously affect the dynamics of our world, and, of course, not for the better.

The fifth danger. Modern models often use the concept of 'brane'. It is a surface in multidimensional space on which we supposedly live. If this is true, then particles can fly off the brane into multidimensional space. To us, this would look like the sudden disappearance of a particle. Since our universe has been around for a long time, the probability of such events is small, even if these models are correct. But over a long period of time in the future, all the matter in our universe could vaporize.

It is unlikely that the ancient civilization is concerned only about the above mentioned disasters, but there is clearly cause for concern.

Thus, if the ancient civilization is not indifferent to its own fate (which, however, is quite possible), it should devote itself to solving the problem of survival in the future.

It turns out that some of the most prudent representatives of mankind are also concerned about these issues. Let us consider some variants of the way out of the situation. Let us first assume that the development follows the most probable first scenario. Then the main problem is where to draw energy from in the future? There are no familiar objects left - the temperature is almost absolute zero. But life, whatever it means, involves energy losses, and replenishing them is the most important task. For example, as Dyson (Dyson) suggested, it is possible to lower the temperature of bodies, which, it turns out, gives significant savings in energy costs. At our usual body temperature of 309.75 K, the human body consumes 100 watt, and at 155 K, four times less. True, he

will think twice as slowly. But the latter is not so important, because it will be true for everyone. Of course, adapting to low temperatures, will have to make small sacrifices. For example, you'll have to completely rebuild your body, which is just a protective shell for your mind. (It would be interesting to see a beauty pageant from the distant future.) However, we are still a long way from complete victory. For example, if we have to cool faster than the universe cools during expansion, civilization will have problems with heat dissipation. There is another trick in store, long mastered by animals on Earth - ‘winter hibernation’, during which energy is practically not consumed. By falling into anabiosis for longer and longer periods of time, it is possible to significantly prolong their existence.

Another unpleasant constraint is imposed by quantum mechanics. According to the Heisenberg uncertainty principle, the uncertainty in the position of the system is inversely proportional to the uncertainty in the momentum. By decreasing the energy of the system, and hence its momentum, we increasingly ‘blur’ the system, it becomes less and less deterministic and predictable.

But modern field theory together with the theory of gravitation provide a curious possibility of salvation. It turns out that there may exist such unusual objects as, for example, wormeholes and black holes with a scalar field inside them. Gravity plays a paramount role in the creation of such objects. You can take advantage of the fact that time flows inside such objects in a different way than it does away from them. Therefore, it is only necessary to be inside, and you can prolong your existence as long as you want. The attentive reader may recall that black holes are also not eternal, which would seem to destroy the previous idea. Indeed, for an observer looking at a black hole ‘from the outside’, the lifetime of a black hole is finite. But for those inside, time flows quite differently, and for them the black hole will exist forever.