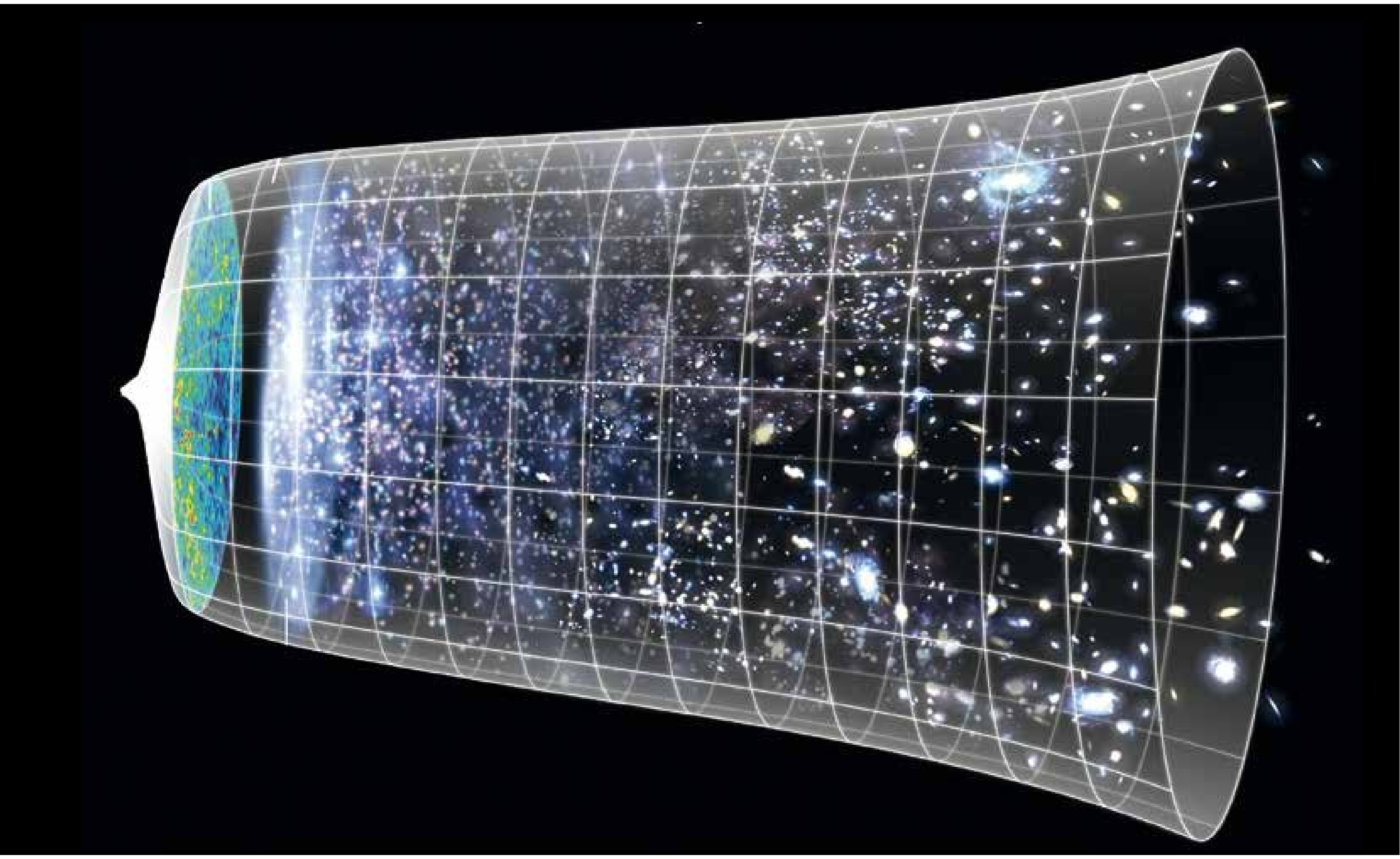
Life in space?
Part I – Drake, again and again

by Thomas Eversberg

Is there extraterrestrial life on a "second Earth" in another star system? Is there perhaps even intelligent life there? And if so, can we make contact? With the discovery of extrasolar planets (exoplanets), research is not only delivering spectacular results that are revolutionising our cosmic world view. Beyond that, there is speculation that the universe is teeming with life – after all, the laws of physics apply everywhere. But is this approach correct? Is it even possible to reliably estimate the probability of extrasolar life? And how likely is contact with another civilisation?

The same laws = extraterrestrial life? – The anthropic principle In 1973, theoretical physicist Brandon Carter discussed the properties of the observable universe. In particular, he related fundamental natural constants to the development of life in the universe, specifically to the existence of humans who observe this universe. The so-called anthropic principle basically states that the structure of the universe as we observe it is the prerequisite for this observation in the first place [1].

Or, in other words: the universe must be as we see it, because otherwise there would be no observers[1]. A good example of this is the expansion rate of the universe. It cannot be too small, of course, because otherwise the universe would collapse again before secondary stars with higher elements could develop. Life would not have time to emerge. On the other hand, the expansion must not be too rapid, so that the matter does not become too thin and the contraction of matter clouds into stars is not possible in the first place. The situation is similar with the minimum lifetime of protons. If it were shorter than about 10^{16}years, there could be no life due to the radioactive radiation that would then occur everywhere. Further examples



1 The expansion of the universe (Image: Wikipedia)

are the cosmological constant, the balance between the masses of protons and electrons, and the strengths of electromagnetic and strong nuclear forces. In short, if the constants of nature had values even slightly different from those we observe, there would be no life in the universe.

However, it should be noted that the anthropic principle does not imply that laws that are equally valid throughout the universe automatically mean that life also exists elsewhere. In its simplest form, it merely states the cosmological conditions under which life can arise in the first place. However, it does not say that this must necessarily happen. Therefore, one cannot conclude that physical laws that are valid everywhere will necessarily give rise to life everywhere. There is no such causal connection.

Do we know all the prerequisites for life?

When indigenous peoples first came into contact with the so-called civilised world in recent centuries, they all felt that the world they lived in was the most beautiful imaginable. And it was perfectly clear to them that the rest of the world, if it existed, must look just like theirs and be just as paradisiacal [2]. This was said by the Arctic Inuit as well as the Yanomami of the Amazon jungle. For these people, it was a shocking experience to discover that this was not true and that the foreign worlds looked completely different. From this, we can conclude that we should be very cautious when estimating the probability of extraterrestrial life. This is especially true when the information available about alien worlds is extremely uncertain. Furthermore, we should not fall into the illusion of thinking that we know all the prerequisites for life or even assign probabilities to them. The famous Drake equation, which is often cited in discussions on this topic, illustrates this point.

In 1961, astrophysicist Frank Drake devised an approach to determine the probability of developed civilisations in space that are able to contact us via radio waves [3]. This probability N should result from the following product:

$$N = R_* \bullet f_p \bullet n_e \bullet f_l \bullet f_i \bullet f_c \bullet L$$

Where R_* is the average star formation rate in our galaxy, f_p is the of stars with planets, n_e the average number of planets in a star system that can also produce life, f_l the number of planets that actually produce life, f_i the number of planets that then produce intelligent civilisations, f_c the number of civilisations that develop appropriate transmission technologies, and L is the length of time during which developed civilisations can send signals to us.

Drake was, of course, fully aware that his simple multiplication of partially unknown factors could not provide a reliable statement. He had merely introduced it as a basis for discussion for the SETI (Search for Extraterrestrial Intelligence) project. A closer look at the parameters of the equation makes this clear: the average star formation rate in our galaxy is known relatively precisely, at three to five sun-like stars per year. For several years now, it has also been possible to provide initial estimates of the proportion of stars with planets. Based on discoveries to date, this is estimated to be around 20 per cent (i.e. 0.2), and sometimes as high as 40 per cent. The accuracy of these two parameters is surprisingly high at around 20 per cent. However, this changes abruptly for all subsequent parameters.

The number of planets in a star system that can also produce life is generally determined by the "habitable zone" around the home star, i.e. the area in which moderate temperatures prevail that are conducive to life as we know it on Earth. But in reality, behind the average number of planets in a star system, the number of planets that actually produce life, and the number of planets that produce intelligent civilisations, there is an abyss of possible influences, most of which cannot even be estimated

Some examples of the many questions we are still unable to answer today:

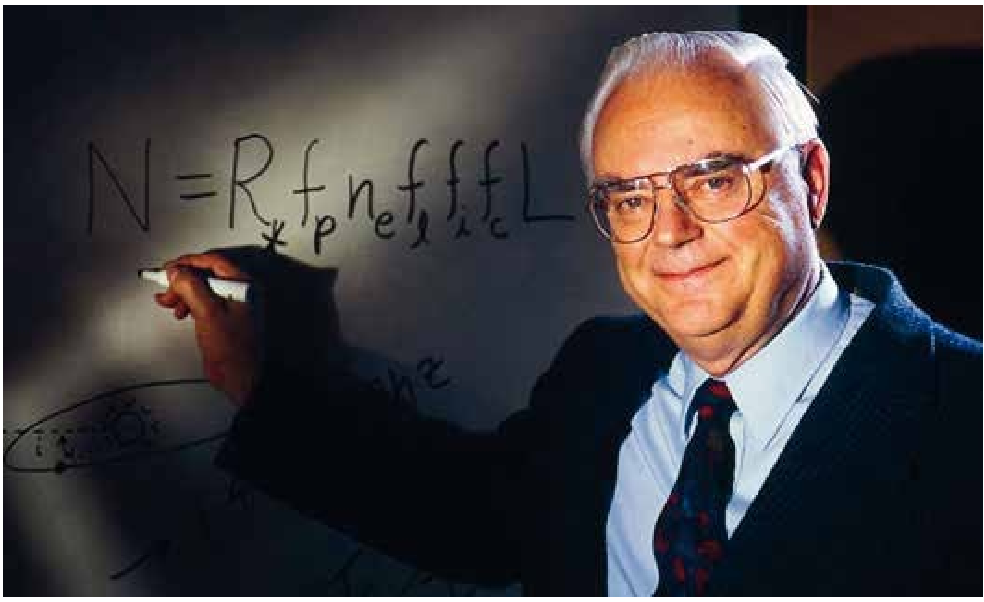
- Under what conditions and with what probability did early single-celled organisms develop?
- Can microbes also develop into intelligent life at higher temperatures?
- Are tidal forces, triggered by a relatively large moon, necessary for the development of early life, and if so, to what extent?
- Do global glaciation cycles of planets, such as those that occurred during the Earth's history, reduce or increase the probability of life?
- How strong is the impact of global catastrophes such as the volcanic eruptions of the Permian period and the meteorite impact at the end of the Cretaceous period?

It can be assumed that the number of factors influencing the development of intelligent life will increase massively when different scientific disciplines are taken into account (astronomy, biology, geology, etc.). Here are just two examples from astronomy:

- To determine the number of planets, Erik Zackrisson from Uppsala University simulated the universe using the latest models of galaxy, star and planet formation and applied them to a realistic early universe. In doing so, he found that
  Among other things, it not only suggests that there should be 720 trillion rocky planets, but also that rocky planets typically orbit M stars and that the average age of planets, at around eight billion years, is roughly twice that of our Earth. This would have given life there billions of years to build an interstellar civilisation. Since no such civilisation is known to exist, intelligent life seems to be rarer than the Drake equation claims.
- Scott Fleming from the Space Telescope Science Institute discovered an increased number of weak flares in M stars using the Galaxy Evolution Explorer (GALEX). Since weak flares occur relatively often, they have a potentially negative impact on potential life in the habitable zone.

The two examples show that a Drake equation that is truly useful for estimating intelligent life certainly has many more parameters of unknown number with extremely high uncertainties than seven factors. These, in turn, can have a multiplicative or perhaps even exponential or differential effect on the result. This makes it understandable that the last two parameters of the equation (the number of civilisations that develop the corresponding transmission technologies and the length of time during which developed civilisations can send signals to us) are also subject to extraordinary uncertainty. The original equation devised by Drake with only seven factors must therefore be very incomplete. However, this means that it is quantitatively meaningless and can only stimulate critical discourse, just as Drake intended.

If we simply multiply the parameters known from the Drake equation, we arrive at extremely low probabilities for further life in space and contact with extraterrestrial civilisations. What's more, these probabilities are also hopelessly inaccurate. As a consequence, the first two factors (star formation rate and the proportion of stars with planets) have virtually no effect on the result – they can be safely ignored. The remaining factors – and, as I said, there must be far more than Drake had indicated – dominate the result due to their number and small size. An example: if we assume an average probability of 5% for only 20 factors (e.g. around 5% of marine life survives an event similar to the Permian catastrophe), we arrive at a total probability for all factors of 10^{-26}. So, purely statistically, we would expect to find a planet with life among approximately 10^{26} stars. Since, depending on the estimate, there are around 10^{22} stars in the universe, this would give a total probability of 1 in 10,000 for a planet with life in the entire universe. But once again, such figures are necessarily extremely uncertain, and Drake's equation does not really help us. And so the proportion of



2 Frank Drake with the equation named after him (photo: SETI Institute)

Stars with planets play a much smaller role in the overall context than expected. Of course, the situation is even worse if only one parameter has an extremely low probability and thus drastically influences the final result. If only one parameter had a value of zero, any discussion would be superfluous. This fact stands in stark contrast to the sensational promises made by many media outlets about a "second Earth", but also by individual scientists who suggestively link their research on exoplanets to the search for life in space. It can be assumed that this is merely a matter of acquiring research funding through spectacular PR. At least, this is what I have noticed on several occasions when evaluating research proposals at the European Commission.

In the SETI context, people like to argue based on the sheer number of stars. Their motto is: there are so many stars with planets, so space must be teeming with life. That may well be true, but we cannot know for sure. In any case, from a statistical point of view (and that is all that matters), this frequently cited argument collapses under the weight of the above considerations. The number argument is pure belief. So we can see how unsuitable the Drake equation is for estimating the probability of life in space . We do not know all the elements of the equation, nor do we know enough about their accuracy.

Footnotes:

1 *There are a number of variants of the anthropic principle that I cannot go into here.*

2 *It is precisely this intention of Drake's that is usually ignored, and his equation is often sold as a reliable estimate.*

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[2] *Diamond, J., 2006, Poor and Rich: The Fates of Human Societies, Edition: 9 – 2006, ISBN 3596172144*

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Life in space?
– II. Longing for contact

by Thomas Eversberg

Is there extraterrestrial life on a "second Earth" in another star system? Is there perhaps even intelligent life there? And if so, can we make contact? With the discovery of extrasolar planets (exoplanets), research is not only delivering spectacular results that are revolutionising our cosmic world view. There is now also speculation that the universe is teeming with life – after all, the laws of physics apply everywhere. But is this approach correct? Is it even possible to reliably estimate the probability of extrasolar life? And how likely is contact with another civilisation? *(Part I of this article appeared in the VdS Journal of Astronomy 64 (I-2018), p. 119)*

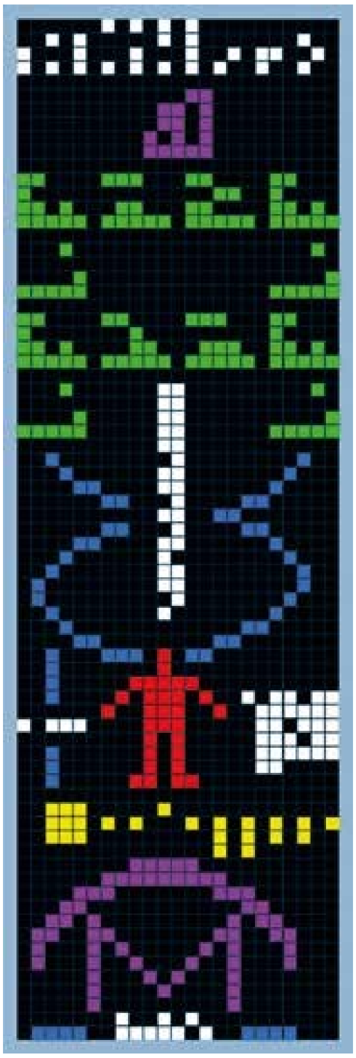
1 **The Andromeda Nebula, with a structure and size similar to our galaxy (Wikipedia)**

Lost in space and time

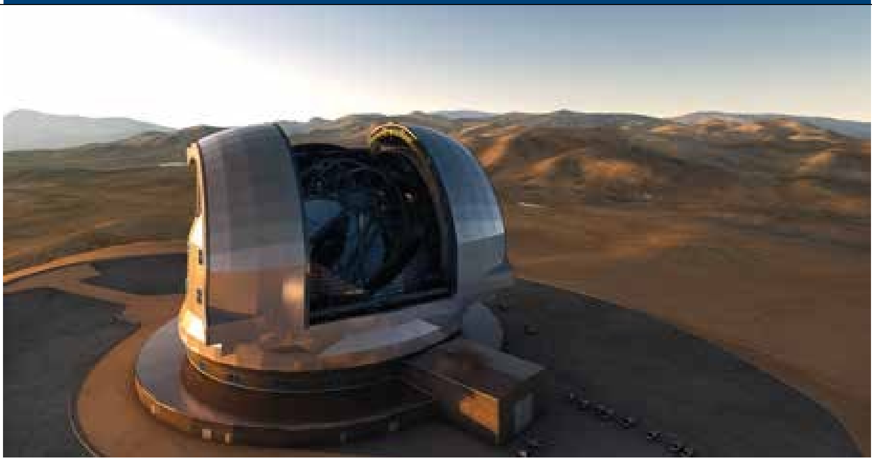
A special parameter of the Drake equation is the length of time during which developed civilisations can send signals to us. It is unique in that it depends both on the distance to other civilisations and on the time it takes for a transmitted signal to reach us. Given that it takes around 100,000 years for a signal to travel, a civilisation at the "other end of our galaxy" will, to say the least, only be able to transmit rather outdated messages, and meaningful communication will be impossible. Furthermore, the respective civilisational epochs must coincide. The sender must be able to send and the receiver must be able to receive with a corresponding delay, both in eras in which the appropriate technology is available. For Earth, this is the last 150 years, or just under one 25,000th of the time since the appearance of humans around 4 million years ago. And since this must be possible for mutual communication, one inevitably encounters problems of different epochs in the development and existence of intelligent species. In any case, the dialogue partners should not live too far apart, otherwise a conversation would again be pointless (Fig. 1). Furthermore, it depends on the length of time during which developed civilisations can send signals to us (the factor L in the Drake equation – see Part I) again depends on the uncertainties mentioned in the first part. Who knows if and when radio technology will be developed in general? And how long a species can exist depends on many unknown parameters, as we can clearly see from our uncertain prospects for the future. With these considerations in mind, the overall uncertainty of the Drake equation can only increase, not decrease.

What do we want to talk about?

One might argue that advanced civilisations could well have emerged at the right time in our cosmic neighbourhood within a few hundred light years. That is, of course, entirely correct, even if we cannot know for sure. Apart from the extremely low probability of this situation, however, one must then question the "entertainment value" of a dialogue in which the



2 **The Arecibo message sent in the direction of M 13 and correctly decoded (Wikipedia)**



3 The European Extremely Large Telescope (Wikipedia), currently under construction

answers would be delayed by several hundred years. Or to put it another way: would we be interested in the answer to a question we asked 1,000 years ago to a civilisation 500 light years away?

One might argue that an alien civilisation could send us interesting information in a one-way street, so to speak. However, the probability of such an action and of receiving such a message is likely to be very low. Humanity has already done this once before, when it
On 16 November 1974, the Arecibo radio telescope transmitted a coded message in the direction of the globular cluster M 13. Apart from the fact that this "Arecibo message" [4] (Fig. 2), initiated by Frank Drake and Carl Sagan, cannot reach the star cluster due to the declining signal strength, a dialogue with a delay of around 50,000 years would be meaningless, even if such a message could provide relatively complex information if it were decoded. Regardless, the Arecibo message was purely a publicity stunt. I am not saying that the attempt to receive alien messages with radio dishes is doomed to failure in principle. Whether the financing of such radio telescopes can be communicated to the public in view of the Drake probabilities underlying the SETI project (SETI expects 300 civilisations in the Milky Way) and completely uncertain real factors is another question altogether. This is particularly true when the costs run into the billions of dollars, as was the case in 1971 for the proposed Cyclops project (an antenna park with
1,500 telescopes with a diameter of around 100 metres). Furthermore, one should ask whether contact with a highly advanced civilisation is good for us. When different cultures encountered each other on Earth, murder and manslaughter almost always ensued, so that Douglas Adams in
"The Hitchhiker's Guide to the Galaxy" probably hit the nail on the head. In any case, the Vogon spaceships blew up the Earth in favour of an intergalactic motorway ...

Faith and knowledge

We must therefore assume that the same physical laws and the Drake equation cannot provide satisfactory answers to the question of extraterrestrial life or even extraterrestrial intelligence. It is simply impossible to estimate the probability of life in space, even approximately. On the one hand, we lack the relevant statistical facts (there is only one known example of life on a planet, our Earth) and, on the other hand, we lack knowledge about the prerequisites for low or even intelligent life. All we know are a few factors that may have been generally important in the course of around four billion years of evolution. However, the potential variations in different geological and evolutionary developments are so numerous that they cannot provide reliable scenarios. It is perfectly possible to entertain the idea that there must be life "out there" – I freely admit that I am not immune to this romantic notion myself. But then one should realise that this is essentially following the ideas of primitive peoples and thus our origins. This is hardly surprising, since in terms of evolutionary history, our behaviour has not developed significantly further, even though we have, of course, accumulated a great deal of knowledge. We still have "one foot in the Martian canal and the other in Neanderthal Valley" (Udo Lindenberg), which is not surprising given how little time has passed since our ancestors lived. However, if we look at the facts in a scientific sense, we should always make a clear distinction between belief and knowledge. This means, however, that we simply do not know whether extraterrestrial life exists. And presumably
that will not change in the foreseeable future.

Can modern telescopes help?

As of today (February 2018), we know of around 3,700 exoplanets, most of which are gas planets. This is undoubtedly thanks to modern telescope and detector technologies. Spectroscopic measurements now even provide data on the composition of the atmospheres of some exoplanets. It therefore seems reasonable to assume that decisive breakthroughs, including the discovery of signs of life, are imminent. This is hardly surprising in view of scientific public relations work, as scientists active in the field actively promote such fantasies in order to obtain research funding for corresponding basic research, as already described [5]. However, these fantasies do not play a significant role in astrophysical literature. Why is this the case?

Once again, the answer lies in financial and physical constraints. Scientists are well aware that even extremely large telescopes (Fig. 3) cannot deliver quantum leaps in data quality. Most researchers already believe that new exoplanets can only be discovered with large telescopes with an aperture of around 4 metres or more. Furthermore, fundamental investigations of the physical parameters of exoplanets do not seem to be sufficient to legitimise the corresponding field of research and the huge telescopes it necessitates in the eyes of the public. Astronomy has embarked on the path of expensive large-scale research in a manner entirely analogous to high-energy physics, and astronomers will probably soon reach their "natural financial limits" as well.

as has already happened with particle accelerators. Access to funding is limited. Furthermore, for physical reasons, we cannot expect future large telescopes in the 40-metre class to provide us with information that overcomes the fundamental problems described above. Larger telescopes, whether in space or on Earth, will provide better data with smaller error bars. However, telescope optics are essentially dominated by two factors: geometric or spectral resolution and image contrast (the signal-to-noise ratio of the data). Both parameters depend on the diameter of the mirror and not on its area. This means that the upcoming E-ELT will improve data quality linearly by a factor of about 4 compared to current large telescopes, but not by orders of magnitude, as the term "quantum leap" so often suggests. Amateurish imagination and the longing for other Earths are certainly helpful in acquiring research funding.

Longing for contact?

My observations may be rather sobering for some enthusiasts. We are not in a position to say anything reliable about the probability of life in space. Furthermore, the overwhelming distances between the stars prevent any meaningful dialogue, should other civilisations exist. Therefore, we are left with only fundamental investigations of alien worlds through measurements. In the interests of scientific integrity, we should realistically abandon fantastical notions of contact with other civilisations.

Many people seem to find this difficult. There is lively discussion about inhabited exoplanets and the desire for interstellar contact. In most cases, this happens with complete disregard for scientific facts, whether out of enthusiasm or ignorance. However, there must be a reason for this longing. It should be noted that, in terms of evolutionary history, humans are herd animals. Whether hunting or raising offspring, it was only in groups that our species was able to survive for millions of years.

be successful (Fig. 4). And in doing so, we have always been wanderers in search of new worlds. It therefore stands to reason that we generally have a tendency to gravitate towards other people and worlds. Or, to put it another way: since we live on a technologised, completely explored and networked planet, we may even be psychologically compelled to shift our inclinations towards the unknown universe. This inclination is probably also the psychological driver behind manned spaceflight. The fact that all this fails due to the overwhelming distances in space is somewhat tragic, and we will have to compensate for the unfulfillability of this longing in an intelligent and rational manner. In this regard, I leave the last word to science fiction author Stanislaw Lem. In his novel Solaris [6], he provides insight into our nature and the challenges that await us in reality.

We do not want to conquer the cosmos; we only want to expand the Earth to its limits. Some planets are completely desert, like the Sahara, others are icy like the poles or tropical like the Brazilian jungle. We are humanitarian and noble; we do not want to subjugate other races, we only want to convey our values to them and, in return, accept their heritage. We consider ourselves the knights of holy contact. ... We are looking for humans, no one else. We don't need other worlds. We need mirrors. We don't know what to do with other worlds. Our own is enough, and we are already suffocating in it."

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