Acta Astronautica 69 (2011) 899–904

Contents lists available at ScienceDirect

Acta Astronautica

journal homepage: www.elsevier.com/locate/actaastro

SETI and astrobiology: The Rio Scale and the London Scale ☆

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ARTICLE INFO

Article history:
Received 20 January 2011
Received in revised form
25 May 2011
Accepted 31 May 2011
Available online 24 June 2011

Keywords:
SETI
Astrobiology
Rio Scale
London Scale

ABSTRACT

The public reaction to a discovery, the character of the corresponding risk communication, as well as the possible impact on science and society all depend on the character of the phenomenon discovered, on the method of discovery, on the distance to the phenomenon and, last but not least, on the reliability of the announcement itself. The Rio Scale – proposed together with Jill Tarter just a decade ago at an IAA symposium in Rio de Janeiro – attempts to quantify the relative importance of such a "low probability, high consequence event", namely the announcement of an ETI discovery. After the publication of the book "The Eerie Silence" by Paul Davies it is necessary to control how the recently suggested possible "technosignatures" or "technomarkers" mentioned in this book could be evaluated by the Rio Scale. The new London Scale, proposed at the Royal Society meeting in January 2010, in London, is a similar attempt to quantify the impact of an announcement regarding the discovery of ET life on an analogous ordinal scale between zero and ten. Here again the new concept of a "shadow biosphere" raised in this book deserves a special attention since a "weird form of life" found on Earth would not necessarily have an extraterrestrial origin, nevertheless it might be an important discovery in itself. Several arguments are presented that methods, aims and targets of "search for ET life" and "search for ET intelligence" are recently converging. The new problem is raised whether a unification of these two scales is necessary as a consequence of the convergence of the two subjects. Finally, it is suggested that experts in social sciences should take the structure of the respective scales into consideration when investigating case by case the possible effects on the society of such discoveries.
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1. Introduction

This paper is partly based on my presentation at the Discussion Meeting of the Royal Society "The Detection of Extra-terrestrial Life and the Consequences for Science and Society" (January 2010, London) and partly reacts upon some important new ideas raised by Paul Davies on the same meeting. It is a challenge to make the two scales, the Rio Scale – which is an attempt to quantify the social impact of a putative discovery of extraterrestrial intelligence – and the London Scale – which is similar, but for extraterrestrial life – consistent with such original concepts like a "shadow biosphere" and fantastic technomarkers (or 'absent exotica') respectively, as described in his book "The Eerie Silence" [1].

2. The purpose of the scales

There are different simple scales in permanent use trying to quantify the *a priori* risk and also the *a posteriori* effect of serious and dangerous terrestrial phenomena like storms, earthquakes, hurricanes, solar outbursts and recently the threatening approach of a Near Earth Object as well (Beaufort, Richter, Saffir-Simpson, Torino Scales, etc.). The *Rio Scale* [1] attempts to quantify the relative importance of the announcement of a discovery of extraterrestrial *intelligence*; the *London Scale* [2] is a similar

☆ This paper was presented during the 61st IAC in Prague.

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doi:10.1016/j.actaastro.2011.05.036

attempt to quantify the impact of an announcement regarding the discovery of ET *life* on an analogous ordinal scale between zero and ten. Although the discovery of an independent life or extraterrestrial civilization cannot be unambiguously considered a threat or catastrophe for humanity, nevertheless the announcement of such a claim can be ranged rightfully among the low probability, but high consequence type events of human history. The media would like to know the exact interpretation immediately, although it is improbable that this claim can be met by the scientists. Although it seems to be certain that such a discovery would have a long lasting effect on science and society, the couple of announcements on a discovery of ET life up-till-now had not been accepted as fact by the scientific community and had only passing effect. The main purpose of the two scales discussed in this paper is just to give a tool to those who are asked to evaluate an announcement of a putative discovery. This flexible tool can make the communication with the press and through the media to the public easier.

There is also a secondary purpose. The real effect of such an announcement on society is the topic of several investigations worldwide. It was already the main topic of a high level Discussion Meeting of the Royal Society in January 2010, and a follow on meeting with panel discussions at the Kavli Royal Society International Center in early October. In all these discussions it is crucial to clearly indicate the kind of phenomenon in question, because the effect to be expected depends on different parameters: the class of phenomenon, the discovery type and the distance. This is obviously true also if the associated risk is estimated.

Can such scale values help also in an *a priori* risk assessment? Sometimes yes, sometimes it is doubtful. In a third scale proposed to be used for active SETI or METI experiments (the *San Marino Scale* in 2005) it is rather clear that a larger SMI value belongs to a higher risk [3]. The San Marino Scale is intended to quantify the potential hazard not from reception, but from message-transmission from Earth into space. SMI values are obtained by considering both the intensity of a candidate transmission (I) and its inherent nature, information content, and duration (C): $SMI=I+C$. In the Rio Scale the *RSI* value has already not such a direct connection to risk (if there is any) and in the London Scale we have completely separated the treatment of the risk problem.

3. New convergence in astrobiology and SETI

Fifty years ago SETI started as a simple project in radio astronomy searching for artificial ET signals and messages in the microwave spectrum coming from interstellar distances (Project OZMA). Somewhat later one might say that astrobiology (at that time called exobiology or bioastronomy) began its early searches for possible ET life within the solar system when NASA sent space probes to Mars with sophisticated equipment looking for simple life forms based on life as we know it (Viking missions in 1970s). In the following decades the basic principles did not change: the SETI community carried out searches using more and more sophisticated radio telescopes and multichannel spectrum analyzers, with targets being strictly outside the Solar System; and astrobiologists continued to focus on planetary missions and research within the Solar System.

In the last 15 years, however, as conventional searches continued, some unconventional suggestions have emerged in both communities. For example, searches for extraterrestrial artifacts (SETA) have been proposed and carried out in the Solar System and astrobiologists have studied meteorites in order to find traces of extinct ET life. Recently both SETI and astrobiology communities became interested in carrying out "targeted searches" of potentially habitable extrasolar planets (e.g., the Kepler mission). Further, the SETI community has accepted that investigations in the optical and infrared regions might also be useful. The astrobiology community has accepted that optical (spectroscopic) observations of exoplanets might be of interest when looking for biomarkers (e.g. biogenic atmospheric signatures associated with known living systems). Thus, what were initially very different targets and search methods used in SETI and astrobiology, respectively, seem to be converging.

What does this trend mean for the future announcement of a putative discovery of either ET life or ET intelligence? The simple old assumptions are not valid anymore. A SETI discovery need not be confined to far away phenomena registered only by radio telescopes; and astrobiologists may not need to rely only on tangible samples brought back by spacecraft from a nearby planet. Today there are other possible discovery scenarios both in SETI and astrobiology that could result in announcements of important discoveries. To address the scientific complexity and possible confusion associated with announcements about purported discoveries of evidence for ET life, the London Scale – similar in conception and structure to the Rio Scale – has been proposed last year for evaluating the importance, reliability and associated risk of a discovery of ET *life* that is presumably non-intelligent and relatively nearby (in the Solar System or in our Galaxy). Such a scale may be useful when communicating about the complex factors involved in evaluating new astrobiological 'discoveries' of ET life.

4. The Rio Scale: do we need to modify it?

4.1. The Rio Scale for a putative discovery of extraterrestrial intelligence

In anticipation of the likely public interest in detection of a putative extraterrestrial signal or artifact, the Rio Scale was developed as an ordinal scale valued between zero and ten, to quantify the impact of any public announcement regarding evidence of extraterrestrial *intelligence* or *technological civilization*. The concept was first proposed by Almár and Tarter in 2000 at a SETI symposium in Rio de Janeiro (hence its name) in order to bring some objectivity to the otherwise subjective interpretation of any claimed ETI detection. After several discussions it has been modified until the following form has been accepted:

Structure

The present Rio Scale Index (RSI) is mathematically defined as

$$RSI = Q \times \delta$$

where Q, an estimated level of consequences, is the sum of three parameters, and δ represents the assessed credibility of a claimed discovery. The value for Q is quantified as a function of the class of the reported phenomenon, the type of discovery, and the estimated distance to the phenomenon detected. SETA means Search for Extraterrestrial *Artifacts*. (A credible artifact would constitute evidence for intelligent ET life even without ET beings.) The value assigned for δ is somewhat more subjective, and is likely to vary over time. Table 1 shows the values assigned to the three Q-associated parameters and the reliability factor in the RSI.

Selecting the relevant line in each of the three parameter sub-categories and adding the three numbers at the end of each line gives a Q value from 3 to 15. If a sub-category is uncertain, two limiting values for Q can only be determined. Then, multiplying the Q value by the reliability factor (δ) yields an *RSI* value that can range from 0 to 10 (11 separate qualitative categories). The zero to ten ranking is essentially an interpretation that a discovery is meaningless or insignificant (0, 1) to moderate (4) to extraordinary (10) (Table 2).

Over time, the *RSI* values assigned to any SETI detection can be expected to change – either upward or downward – to reflect new information about the signal. The RSI was accepted by the SETI Committee of the International Academy of Astronautics (IAA) in 2002.

Table 1
Parameter values and reliability factor associated with the Rio Scale Index.

	Value
Class of phenomenon	
Traces of astroengineering or indication of technological activity by an extant or extinct civilization at any distance, or an ET artifact, artifact, the purpose of which is unknown	1
Leakage radiation, without possible interpretation, or ET artifact whose purpose is understandable	2
Omnidirectional beacon designed to draw attention, or ET artifact with message of a general character	3
Earth-specific beacon to draw our attention, or an ET artifact with a message to mankind	4
Omnidirectional message with decipherable information, or a functioning ET artifact or space probe	5
Earth-specific message, or an ET artifact, capable of contact, or a physical encounter	6
Discovery type	
From archival data; a posteriori discovery without possibility of verification	1
Non-SETI/SETA observation; transient phenomenon that is reliable but never repeated	2
SETI/SETA observation; transient phenomenon that has been verified but never repeated	3
Non-SETI/SETA observation; steady phenomenon verifiable by repeated observation or investigation	4
SETI/SETA observation; steady phenomenon verifiable by repeated observation or investigation	5
Distance	
Extragalactic	1
Within the Galaxy	2
Within a distance which allows communication (at light speed) within a human lifetime	3
Within the solar system	4
Reliability factor (δ)	
Obviously fake or fraudulent	0
Very uncertain, but worthy of verification efforts	1/6
Possible, but should be verified before taken seriously	2/6
Very probable, with verification already carried out	3/6
Absolutely reliable, without any doubt	4/6

4.2. Technomarkers, instead of artifacts?

According to the ideas raised or summarized by Paul Davies [4], the possibility of the discovery of *any sign* of a technical civilization should be taken into account, not only active or passive artifacts on celestial bodies within the Solar System. There might be also different

Table 2
Definition of different parameters: the scales for the four parameter values, as well as the categories used to rate the reliability factor.

	Value
Class of phenomenon: Life form	
Possible signature of life, but indirect information only (e.g. volatile, trace)	1
Terrestrial type life form, but some uncertainty remains	2
Life definitely, but a previously unknown variant of terrestrial life (in structure or composition) (e.g. if DNA is present, different amino acids are used)	3
Likely to be non-terrestrial, but some uncertainty remains	4
Completely alien life form	5
Nature of evidence	
Biomarkers (indirect evidence, like volatiles, metabolites, biochemical signatures, etc.)	1
Fossilized life or remnants of life forms	2
Uncertain whether living or not (like a virus)	3
Extant life with suspended functioning (like a spore)	4
Simple life (low level of organization)	5
Complex life (high level of organization)	6
Type or method of discovery	
By remote sensing from the surface of the Earth or from satellites, flybys etc.	1
By a surface robot, *in situ*, on another celestial body	2
By a manned mission, *in situ*, on another celestial body	3
By analyzing something found on Earth's surface or in the atmosphere (e.g., meteorite, atmospheric sample)	4
By analyzing the result of a sample return mission (origin of the sample is well known)	5
Distance to the discovered life form at time of announcement	
Beyond the Solar System (*in situ* research impossible)	1
On or outside the orbit of Jupiter, but in the Solar System (*in situ* research possible, but difficult)	2
Inside the orbit of Jupiter (*in situ* research more easily possible)	3
Zero distance (on Earth)	4
Reliability factor (δ)	
Obviously fake or fraudulent	0
Probably not real	0.1
Controversial, but not rejectable	0.2
Testable, needs further evidence	0.3
Probably real	0.4
Certain or highly reliable	0.5

kinds of unusual "technomarkers" or "technosignatures" mentioned by Davies as "alien magic" or "technology as 'nature plus'". It is a completely new idea, mentioned as "absent exotica", that the lack of something in the macrocosmos or in the microcosmos might also be a kind of technosignature. Davies enumerates some of them in his book as follows: hijacking the missing extrasolar comets, or blowing up a protoplanet between Mars and Jupiter in the Solar System, or at the other end of the mass range mini-black holes, quark stars, cosmic strings, magnetic monopoles–their existence is predicted by theory, but nobody could find them up-till-now.

If the term "artifact" is changed to "technomarker" than a part of the problem of these possibilities might be solved. Technomarker may mean any sign of an existing or extinct technical civilization—except a message or a beacon which belongs to traditional SETI. In some cases it would be difficult or impossible to decide the distance or the type of discovery; in cases when the lack of something is suspicious to the experts we are helpless in particular. In these cases it is difficult to interpret the distinction between "SETI/SETA observation" and "non-SETI/SETA observation", although a high level of expertise is definitely needed in such dubious cases before a decision is made how probable or improbable a natural interpretation of the phenomenon in question might be. (One can argue that any distinction between a natural or an artificial explanation inevitably rests on the best current understanding of the phenomenon in question. Probably most scientist would reject an artificial explanation except in cases when this explanation rests on very solid foundations.)

5. The London Scale: do we need to modify it?

5.1. The London Scale for ET life

In the section below, we introduce the London Scale for astrobiology (proposed at the Royal Society Discussion Meeting in January 2010 in London, hence its name) whose structure and logic are intentionally analogous to the Rio Scale for ET intelligence. It has been developed as an ordinal scale with index values between zero and ten, which can be used to evaluate and present complex information about the scientific importance, validity and potential consequences of an alleged discovery of ET life via various astrobiological methods and within the Solar System or in our Galaxy. The London Scale Index (LSI) is mathematically defined as

$$LSI = Q \times \delta$$

where Q (importance) is the sum of four parameters (the life form, nature of evidence, method of discovery, and distance), and δ represents the assessed credibility of a claimed discovery.

The Q factor is quantified based on specific values assigned to key phenomena and methods of the discovery. The first two parameters relate to the class of phenomenon discovered, the other two relate to methods and distance, as follows:

- *Type of life* discovered, which may range from something similar to terrestrial life, to a variant in structure or chemical composition, or in the extreme, to a completely alien life form.
- *Nature of the evidence*, which focuses on the variety of possible forms that may be associated with the evidence (alive, dead, dormant, pieces, fossil, biomarkers, etc.). Different values are assessed across the range of evidence from chemical biomarkers, fossils or dormant states, to obviously organized simple or complex life forms.
- *Type or method of discovery*, which focuses on how directly or indirectly the phenomenon can be studied, ranging from remote sensing approaches to manipulative methods, direct observation of materials, and experiments.
- *Distance to the discovered life form*, which is also considered, relates indirectly to how detailed and repeated the study of the discovery can be. Distance values vary based on whether the discovery is beyond the Solar System, at intermediate distances where *in situ* research may be possible, or on Earth.
- Similar to the Rio Scale, the assigned *credibility value* δ is somewhat more subjective and likely to vary over time as new research or findings add useful information.

Selecting the relevant line in each of the four parameter sub-categories and adding the four numbers at the end of each line gives a Q value from 4 to 20. If a sub-category is uncertain, two limiting values for Q can be determined. Then, multiplying the Q value by the reliability factor (δ) yields an LSI value that can range from 0 to 10, with higher values indicative of more scientifically important, credible discoveries. The London Scale value assigned to any ET discovery can be expected to change – upward or downward – over time as new findings or research provide additional information.

Undoubtedly, if a claimed discovery involves life forms that are complex or dissimilar to terrestrial forms and involves direct scientific method(s) and instruments used on Earth by researchers, it is likely to be viewed as more credible evidence for ET life than something studied only afar and by remote methods. Already, we can anticipate a variety of discovery scenarios that may involve media announcements about ET life. Applying a standard scale to various "discoveries" is a way for the science community and the public to examine the disparate factors that go into a claim or announcement. In addition to ranking the discoveries, such a scale is useful to highlight and understand the types or categories of information that may be needed for further validation or dismissal of a claim.

5.2. Weird life and shadow biosphere

In his book "*The Eerie Silence*" Paul Davies writes in a chapter on *Seeking a Second Genesis on Earth:* "If life started more than once on Earth, we could be virtually certain that the universe is teeming with it. Unless there is something *very* peculiar about our planet, it is inconceivable that life would have begun twice on one Earth-like planet but hardly ever on all the rest." "Direct confirmation could come from the discovery of living

descendants of other genesis events, sharing our planet with us, and constituting a shadow biosphere." "Life today is represented by millions of different species, but if we trace evolution backward over billions of years, then they converge on the 'trunk of the tree'." "The question I am raising – writes Paul Davies – is simply, does all life on Earth belong to this *single* tree, or might there in fact be more than one tree?" He summarizes why biologists think all *known* life shares a common origin: "The main evidence comes from biochemistry and molecular biology." All known living creatures – as far as we know – "use DNA and RNA to store information, and proteins to serve as enzymes and as structural building blocks. Energy is stored and released using molecules known as ATP. " "The fact that such complicated and specific features as ribosomes, ATP and the triplet code are found to be universal would be hard to explain unless all the species had descended from a universal ancestor." He adds that "Astrobiologists refer to known organisms as 'standard life' and to the hypothetical alternative forms as 'weird life'. (Weird life could be alien life in the sense of 'not one of us', but also in the sense of having an extraterrestrial, e.g. Martian origin.)"

How to put the announcement of a putative discovery of such a weird life *on Earth* into the London scale? Shadow biosphere? Not extraterrestrial life, but weird life? Such a discovery certainly would be an important step towards the discovery of extraterrestrial life both theoretically and practically. Theoretically because it would be a proof that life having a different, non-terrestrial structure and origin can exist within the Solar System, or even on Earth. Practically because its discovery would be a great help in the search for extraterrestrial life on other planetary bodies.

Convinced by the arguments of Paul Davies it is clear that it might represent a discovery of enormous *scientific* importance. But what kind of social or political impact of such an announcement is to be expected? Would the world view or religious belief of the man in the street change if it will be proved that some deep-living microbes, remaining trapped in isolated pockets for eons, might represent a fundamentally different life form? Very probably not in the slightest degree. The media would be interested only in the problem whether this weird life is extraterrestrial or not. If it is proved that they probably were ever belonging to our biosphere, the impact on society of such a discovery will disappear at once.

It means that the announcement of a shadow biosphere on Earth represents a case when the scientific value of the event would be very high and its social impact very low. Since both the Rio Scale and the London Scale are suggested to quantify the importance (both for science and for society) of a putative discovery of traces of *extraterrestrial* technology and life, respectively, I am inclined to exclude this possibility from the cases listed in the London Scale. Accepting that such a discovery (of weird life on Earth) would be a very important one, nevertheless – because of a probable lack of impact on media and society – I don't think that in such a case there would be a need to use a simple, understandable ordinal scale in the communication with the media. My opinion is that it would belong to the long list of important discoveries in basic sciences, which are treated mainly in science journals, magazines and TV or radio science programs, where mostly well informed media people comment the event.

6. A combined scale for life and intelligence?

Taking into account the recent convergence of SETI and astrobiology the question arises whether we need *two* scales to quantify the importance of any discovery within the broad range of "search for life and intelligence in the Universe"? Is it possible that somebody announces such a discovery and it is dubious whether it is intelligent or non-intelligent life? At present I doubt that such a dilemma might occur. In the case of a result of a research within the Solar System (where we mostly use direct investigation by space probes or just normal field research on the surface of the Earth) it would probably be easy to distinguish between a weird life form and a technical artifact. (Though just in these cases it is very difficult to distinguish terrestrial life and artifact from something really weird and alien.) The result of a research outside the Solar System is made by remote sensing (optically, by radio etc.) and no confusion is expected even in the case when we find a biosignature or a technosignature. In the latter case traces of a highly advanced technical civilization will be obviously different from a planet with traces of some kind of life on its surface. Nevertheless there might be cases, when it would be difficult to decide whether we see a natural biosphere, or some product of an alien biotechnology or directed panspermia. It does not mean, however, that an exoplanet, where biosignatures are discovered, is in want of intelligent life, but we cannot find it if the results of its technology are invisible for us.

7. Conclusions

Experts of social sciences should take the structure of the respective scales, as well as the RSI or LSI values into consideration when investigating in a hypothetical case the possible effects of an announcement of a putative discovery of ET life or intelligence on science, on world view and on society. The social impact of such an announcement depends namely critically on the scale value and every kind of generalization is misleading. It is improbable that the IAA Post Detection Task Group would act in case of an announcement of an ET life discovery (either on the Earth or elsewhere), therefore an independent body of experts should be organized to prepare a "Declaration" like document for such cases and react as an authority to such an announcement. At a recent NASA astrobiology conference near Johnson Space Center the following statement was declared: "Because the stakes involved with any announcement of possible or likely extraterrestrial life are so high – both for science and for the societal and religious implications of such a discovery – the issue brings out very strong feelings. At the conference, a leading cautionary voice in astrobiology proposed that a special protocol be established to oversee release of any journal articles making dramatic extraterrestrial claims. Andrew Steele of the Carnegie Institution for Science in Washington … compared the absence of astrobiology review

with the formal procedures set up by scientists involved in the search for extraterrestrial intelligence…" [5]. I interpret this warning also as an invitation to prepare a scale, like the Rio Scale, in case an announcement of the discovery of extraterrestrial *life* is made and there is an urgent need to communicate it properly to the public through the media. This is exactly the purpose of the London Scale.

Acknowledgements

Special thanks are due to Dr. Margaret Race whose help has been very useful in constructing the London Scale. Mr. Henrik Hargitai and Mr. Pál Decsy have both helped to prepare this presentation. Also the useful remarks of the reviewers is acknowledged. Support by Collegium Budapest (ESA ECS-project no. 98076) is gratefully acknowledged.

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