INTRODUCTORY RESOURCES

This introductory text presents the CONTEXT of the question of our impact at large scales, the challenges of our cosmic FOOTPRINT, and introductions to the IMPORTANCE and TOPICALITY of the subject matter. About thirty links to external RESOURCES, mainly peer-reviewed papers, are then proposed, to allow for an initial assessment.

CONTEXT

The scientific and technological landscape is taking shape, for Mankind to expand dramatically the environment the terrestrial biosphere interacts with, inside and beyond the solar system boundaries. Indeed, when NASA Starlight draws a path to propel miniature spacecrafts to interstellar space using directed energy beams[4.i], the Breakthrough Starshot project, significantly funded with a first 100MUSD grant, backed by billionaires and promised to be operational within a generation[1,2], develops a laser offering a galactic scale communication and signaling capability[3]. The envisioned 1 gram probes, accelerated to 20% of the speed of light, would carry a kinetic energy (1Tj) nearing the order of magnitude of an atomic bomb (Hiroshima bombing:54Tj). Then, such a system may be used for the mitigation of the risks related to threatening asteroids[1,2], or be used or envisioned as a weapon. Moreover, as the probes speed greatly exceed the Milky Way ejection speed, their range is potentially intergalactic[6]. Considering this

alongside the billion year time capsules already launched to space by the Arch Mission Foundation[7], the probes could be durable enough to reach faraway destinations. Space resistant organisms[D], potentially specifically selected[4,19,21,22] or engineered[19,], could be intentionally, incidentally or malevolently[14], carried aboard, and create new biospheres, or contaminate existing ones[5]. The paradigm is indeed shifting along the hypothesis that life forms may be preserved through interstellar distances, survive flight time[4,D], and seed (or contaminate) worlds[4]. A 10e9 downscale (100W) of Breakthrough Starshot concept, way cheaper, could be sufficient for this purpose[5]. Interstellar directed panspermia projects such as the Genesis project[22] are coming within scope[4] . At our doorstep now, has just been proposed the idea of testing the habitability of Proxima Centauri b, the most nearby planet within an habitable zone, this through the intentional sending of spores[5]. In the meantime, well beyond the theoretical disputes around the intentional signaling to potential extraterrestrial civilisation[I], significant, thoroughly engineered messages are being sent by small groups to possibly habitable planets, located only lightyears away, so close that feedback could be welcomed (or not) within decades[F]. This, in the name of Mankind.

FOOTPRINT

We may soon - if not yet done- create, disturb, or interact with entire biospheres. Inside and even beyond the solar system. Given the range of existing technologies, and of the ones in development, our moral scope is expanding to scales of space and time, unheard of in History. Along with the

size of the playground, comes the magnitude of the possible outcomes, good and bad, and the one of our responsibilities as a species.

“ We do not want to seed, destroy or interact with a biosphere “by mistake”. Nor do we want to “inadvertently” spread Life as we know it, or connect with intelligence “by chance”. Having the capability to understand the odds at stake, and being morally tooled, we have the responsibility to decide the footprint we want to have, onto the local cosmos”

This is a question of global responsibility, towards our biosphere and the potential preexisting or future biospheres out there. Now is the moment to develop a formal global and ethical discussion regarding the footprint we decide to accept or not, as a species, beyond us, beyond Earth and possibly the Solar System, onto the local cosmos. The subject matter we propose to consider is the one our cosmic footprint: the legacy we’ll leave behind, when looking back to our pale blue biosphere, from the largest scales of space and time.

IMPORTANCE

The subject matter is of importance: indeed, considering the ultimate range of a 20%c probe when solely limited by the expansion of the universe, the reachable environment extends over a volume of elements larger than that of our solar system, in a ratio of scale similar to that which exists between the smallest droplet one can perceive with the naked eye, and the volume of

the entire terrestrial ocean. In this environment, ~1e+29[6] wider than the one we interact with presently, through the potential impact on pre-existing or potential future biospheres, the amount of impacted future human experiences, may be extremely large[6,18,19]. Even more when non-human sensibilities or when post or transhumanists views are considered[18]. To the extreme, the diffusion of Earth originated life could through various processes, impact the matter content and the local rate of expansion of the universe itself[23].

The fact that the representations shared above are not the product of science fiction, but the conclusions of an increasing array of serious and recent studies, happening within serious academical frameworks, along with the fact that some of the discussed systems are already operational and spacebound,[7]is fascinating, and concerning. Indeed, the use that is to be made of this expansion of our scope of action, lies within our hands. In this context, even when solely considering our stelar system and its most proximate neighbors, we are developing a capacity for impact at scales of time and space, much greater than those which have been played with so far. Along with the increase in the size of the playground, all possibilities may unfold at unprecedented scales. The better and the worse.

Considering the options permitted by this expansion, and the ethical postures in the ideological landscape, we see there the potential for quenching our curiosity, the strive for quests, conquests, occupation, exploitation, and representative adventures. We may look for a first contact. We may eventually find an answer to the question of the origin of life on earth. Some see the potential for seeding the universe with earth originated life. Others see the one for the diffusion and preservation of human culture. Existential risks, related to a wide range of values, such as for example consciousness, mankind, or DNA based life, could be reduced through expansion in space. This expansion also includes the potential for wars and destruction.

Yes, the exponential expansion of the playground also involves laying the grounds for possible positive outcomes, and ethical cataclysms, at unprecedented scales.

TOPICALITY

The topicality of the question may not be understated. We humans may be a blink by the universe scales. Still today a single mistake in planetary protection measures may lead to the creation, or contamination of entire biospheres[J]. Still, a single successful signal, picked up by some intelligence out there, could be a game changer, not only for our species, but for all involved biospheres [I]. When the mismanagement of our new power, today, may outlast us by billions of years, and have an impact at galactic scales, we need to cope with our responsibilities. Our moral scope is, right now, in the process of expanding drastically. This might be one of the greatest opportunities of our times.

Having the moral and scientific capability to engage into the analysis of the ins and outs, we propose that we do have the responsibility to do so, before consequences unfold in an unchecked manner, in the wake of the accelerating evolution of the above discussed technological landscape.

RESOURCES

A. Directed energy small spacecraft are a near term possibility:

[1] Breakthrough Initiatives.

[2] Parkin, K. L. G. The Breakthrough Starshot system model. Acta Astronautica vol. 152 370–384 (2018). doi.org/10.1016/j.actaastro.2018.08.035

B. Directed energy systems and small relativistic spacecrafts offer a variety of secondary capabilities:

[3] Lubin, P. Implications of directed energy for SETI. Planetary Defense and Space Environment Applications (2016) doi:10.1117/12.2238212

[4] Lantin, Stephen & all. Interstellar space biology via Project Starlight. Acta Astronautica, Volume 190, 2022, Pages 261-272, doi.org/10.1016/j.actaastro.2021.10.009

(i) "NASA Starlight program details a path to send small relativistic spacecraft to interstellar space."

(ii) Paper highlight: "Relativistic spacecraft can transport seeds and live organisms to characterize and expand life."

(iii) "We are rapidly approaching the technological capability for interstellar flight on meaningful timescales. As such, we must consider the benefits of sending life outside of the solar system."

(iv) "Current planetary protection regulations cannot address ethics of extrasolar biology missions."

[5] Intervention from Georges Church on Day 2: Breakthrough Discuss 2021: Alpha Centauri System: A Beckoning Neighbor. (2021). https://youtu.be/mTFx5-AMmTk?t=319

(i) Starshot laser, 100GW, with 10 minutes pulses, amounts to +-1e12j per probe, compared to little boy atomic bomb (5e13)

(ii) A 10e9 scaledown (100W) of starshot concept for biological payloads

(iii) Getting a feedback on habitability through forward contamination

(iv) Identification of one of the ethical issue and stepping aside as a scientist: 01:59. "assuming we have a very short window of opportunity to terraform another planet, maybe we don't have enough time for finetuning, and maybe we should simply disperse DNA at greater haste ?" on day one, a similar question was proposed at 2:53

[6] Normier, A. Kingmakers: Life's Gateway to the Stars. (2020):

(i) 20%C greatly exceeds the Milkyway escape speed. Theoretical range reaches XXXLy, Xfold of the event horizon

C. Space Bound time capsules with a billion year capability are already roaming in the solar system:

[7] Arch Mission Foundation - Preserving humanity forever, in space and on Earth. Website: https://www.archmission.org.

(i) Lunar Library

(ii) Time Capsules with a Billion year theoretical capability, already in space within "libraries", including beyond Terrestrial Orbit

D. Recent discovery shed light on the unexpected space resilience of some lifeforms:

Resistance over time:

[8] Morono, Y. et al. Aerobic microbial life persists in oxic marine sediment as old as 101.5 million years. Nat. Commun. 11, 3626 (2020). doi.org/10.1038/s41467-020-17330-1

[9] Resistance over time: Kirkpatrick, J. B., Walsh, E. A. & D'Hondt, S. Fossil DNA persistence and decay in marine sediment over hundred-thousand-year to million-year time scales. Geology 44, 615–618 (2016). doi.org/10.1130/G37933.1

Surviving takeoff and reentry:

[10] Thiel, C. S. et al. Functional Activity of Plasmid DNA after Entry into the Atmosphere of Earth Investigated by a New Biomarker Stability Assay for Ballistic Spaceflight Experiments. (2014) doi:10.1371/journal.pone.0112979.

Surviving extreme accelerations:

[11] Deguchi, S. et al. Microbial growth at hyper accelerations up to 403,627 x g. Proceedings of the National Academy of Sciences 108, 7997–8002 (2011). doi.org/10.1073/pnas.1018027108

[12] Souza, T. A. J. de, de Souza, T. A. J. & Pereira, T. C. Caenorhabditis Elegans Tolerates Hyper Accelerations up to 400,000 x g. Astrobiology vol. 18 825–833 (2018). doi.org/10.1089/ast.2017.1802

[13] Barney, B. L., Pratt, S. N. & Austin, D. E. Survivability of bare, individual Bacillus subtilis spores to high-velocity surface impact: Implications for microbial transfer through space. Planet. Space Sci. 125, 20–26 (2016). https://doi.org/10.1016/j.pss.2016.02.010

E. Unlawful action in space has began:

[14] Taylor, C. 'I'm the first space pirate!' How tardigrades were secretly smuggled to the moon. Mashable https://mashable.com/article/smuggled-moon-tardigrade/ (2019).

F. Intentional signaling to potential extraterrestrial intelligences is occuring:

[15] METI International. http://meti.org/.

[16] SONAR CALLING: signaling to an habitable exoplanet

[17] Billingham, J. & Benford, J. Costs and Difficulties of Large-Scale 'Messaging', and the Need for International Debate on Potential Risks. (2011). doi.org/10.48550/arXiv.1102.1938

G. Directed panspermia is being advocated::

[18] Bostrom, N. Astronomical Waste: The Opportunity Cost of Delayed Technological Development. Utilitas vol. 15 308–314 (2003). doi.org/10.1017/S0953820800004076

[19] Mautner, M. N. Seeding the Universe with Life: Securing Our Cosmological Future. (Michael Mautner, 2000). (Pdf)

[20] Planetary protection—A microbial ethics approach. Space Policy 21, 287–292 (2005). doi.org/10.1016/j.spacepol.2005.08.003

[21] Panspermia Society.

[22] Gros, C. Developing Ecospheres on Transiently Habitable Planets: The Genesis Project. (2016) doi:10.1007/s10509-016-2911-0.

[23] Grand Futures: Thinking Truly Long Term | Anders Sandberg. (2020).

H. The hypothesis of the relation between the distribution of life and the cosmos dynamics

[24] Olson, S. J. & Jay Olson, S. Homogeneous cosmology with aggressively expanding civilizations. Classical and Quantum Gravity vol. 32 215025 (2015). doi.org/10.1088/0264-9381/32/21/215025

I. The Conversation on METI: no regulation, and a disagreement

[25] Vakoch, D. A. In defence of METI. Nature Physics vol. 12 890–890 (2016). doi.org/10.1038/nphys3897

[26] Zaitsev, A. L. Detection Probability of Terrestrial Radio Signals by a Hostile Super-civilization. (2008). doi.org/10.48550/arXiv.0804.2754

[27] Gertz, J. REVIEWING METI: A CRITICAL ANALYSIS OF THE ARGUMENTS.

[28] Buchanan, M. Searching for trouble? Nat. Phys. 12, 720–720 (2016). doi.org/10.1038/nphys3852

[29] SETI Statement Regarding METI

J. The conversation on planetary protection: COSPAR Planetary protection requiring an update, A UN Body required on cross contamination of celestial bodies.

[30] Milanov, A. & Penchev, G. The Need for Establishing a New United Nations Body to Protect Earth from Back Contamination and Outer Space from Forward Contamination. LifeScience Global (2020) doi:10.6000/1929-4409.2020.09.96.

[31] Planetary protection—A microbial ethics approach doi.org/10.1016/j.spacepol.2005.08.003

[32] Sherwood, B., Ponce, A. & Waltemathe, M. Forward Contamination of Ocean Worlds: A Stakeholder Conversation. Space Policy vol. 48

1–13 (2019): “a modernized, proactive, ongoing, and broad stakeholder conversation about the forward-contamination hazard and how humanity is managing it”, is advocated” doi.org/10.1016/j.spacepol.2018.06.005

[33] Gros, C. Why planetary and exoplanetary protection differ: The case of long duration genesis missions to habitable but sterile M-dwarf oxygen planets. Acta Astronautica vol. 157 263–267 (2019) doi.org/10.1016/j.actaastro.2019.01.005.

[34] Planetary Biosecurity: Applying Invasion Science to Prevent Biological Contamination from Space Travel BioScience, Volume 72, Issue 3, March 2022, Pages 247–253, doi.org/10.1093/biosci/biab115

[35] Inevitable future: space colonization beyond Earth with microbes first, stating that contamination is inevitable, and should be considered as an asset to engineer. doi.org/10.1093/femsec/fiz127