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Surveys of the scientific community on the existence of extraterrestrial life

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Surveys of the scientific community on the existence of extraterrestrial life — Supplementary Information

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Methodological Information

Preregistration

Our specific study was not pre-registered. However, the underlying survey methodology was pre-registered for a sister project, on 2nd September 2022, using the Open Science Framework, with the title 'New method of measurement for strength of scientific consensus regarding a specific statement'; see https://osf.io/dgq4k.

Our specific study departed from the pre-registered plan in three key ways:

(i) Research software engineers at Durham University, UK, created a bespoke surveying platform. This was a vast improvement on the original vision (as described in the pre-registration).

(ii) We chose survey statements to reveal the spectrum of expert opinions regarding the likely existence of basic, complex, and extraterrestrial life.

(iii) Given the focus on astrobiology, we focused on the global astrobiology community, broadly construed, selecting potential participants from: (i) lead authors and corresponding authors of articles published in the top three astrobiology-focused journals; (ii) presenters at the major astrobiology conference AbSciCon.

Data availability and code availability

Raw data for the study is attached separately as an Excel file entitled 'Data'. Details of the bespoke survey platform, including code, are already available on Zenodo: https://zenodo.org/records/8155054.

Method

Several individuals prepared spreadsheets of scientists' names and email addresses.

For the survey of non-astrobiologist scientists, spreadsheets from a sister project (not yet published, but briefly described at https://www.nature.com/articles/d41586-023-01614-9) were utilized. In that project, scientists were selected from academic departments at a large number of academic institutions. The spreadsheets used in the current project were from the University of Durham (UK), the University of Birmingham (UK), and Stockholm University (Sweden). This amounted to 1,397 scientists in total.

For the surveys of astrobiologists, broadly construed, potential participants were selected from (i) lead authors and corresponding authors of articles published in the top three astrobiology-focused journals in the last ten years, and (ii) presenters at the astrobiology conference AbSciCon. In all cases, names and email addresses were found in the public domain. The top three astrobiology-focused journals were deemed to be *Astrobiology*, *International Journal of Astrobiology*, and *Discover Life* (previously *Origins of Life and Evolution of Biospheres*).

At the same time, we kept tabs on which participants could reasonably be described as 'Physicist', 'Biologist', or 'Other'. For the non-astrobiologist scientists this had already been done as part of the sister project (with 'Other' separated into 'Chemistry', 'Earth Sciences', and 'Health Sciences'). For the astrobiologists, only clear examples of physicists and biologists were used. For example, a scientist affiliated to a physics department, with a CV dominated by articles published in unambiguously 'physics journals', would be counted as a physicist, and similarly for biologists. Borderline cases were classified as 'Other'.

For the sister project, Research Software Engineers (RSEs) at Durham had already prepared bespoke surveying software and the survey platform (**Fig. S1**). The completed spreadsheets could be entered into the platform to generate unique voting tokens for every potential participant, ensuring that only those targeted could vote, and each person could only vote once. The voting tokens also tagged votes with the discipline of voter ('Physicist', 'Biologist', 'Other'), but no other information. Whilst the survey was open, it was possible for those with access to the server (the PI and the software engineers) to see which targeted scientists had voted, since they could see which tokens had been used. When the survey closed (after two weeks), all tokens were deleted from the server, and it was then impossible for anyone to ascertain even *if* a given targeted scientist had voted.

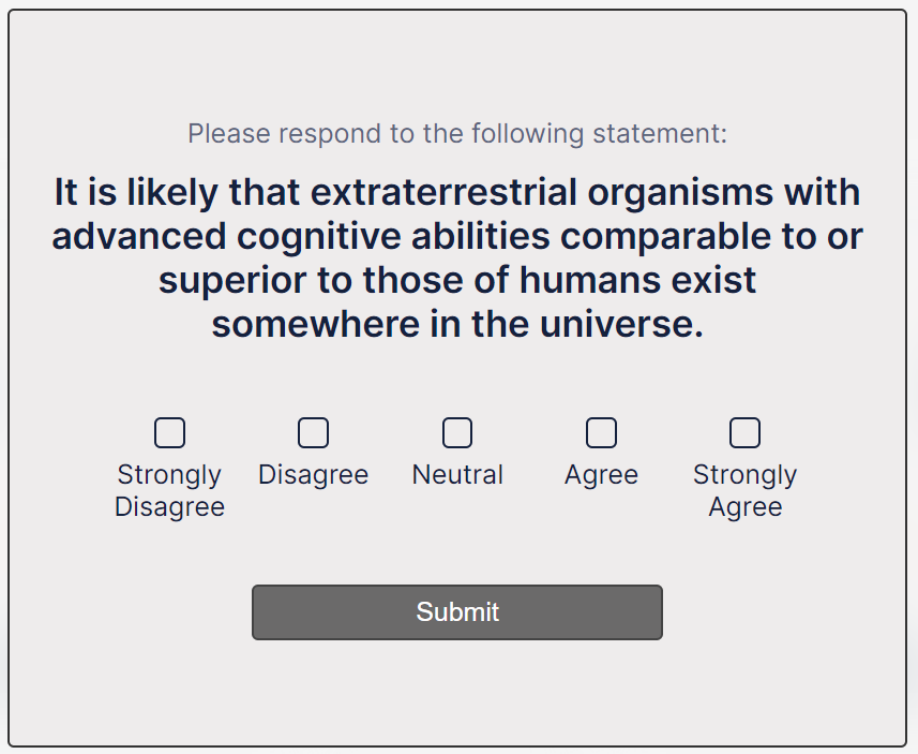

Fig. S1. The '10 second survey' platform used (with Statement S3 featured).

The four surveys were conducted across February – June 2024. In all cases a reminder email was sent after nine days, and the survey was closed after two weeks.

Alternative Representations of the Data

We here present bar charts for key results:

- **Fig. S2** shows how results for astrobiologists compare with results for non-astrobiologist scientists (for Statement S1).
- **Fig. S3** shows how results for physicists compare with results for biologists, pooling Statement S1 results for both astrobiologists and non-astrobiologist scientists.
- **Fig. S4** shows astrobiology community agreement across Statements S1-S3.

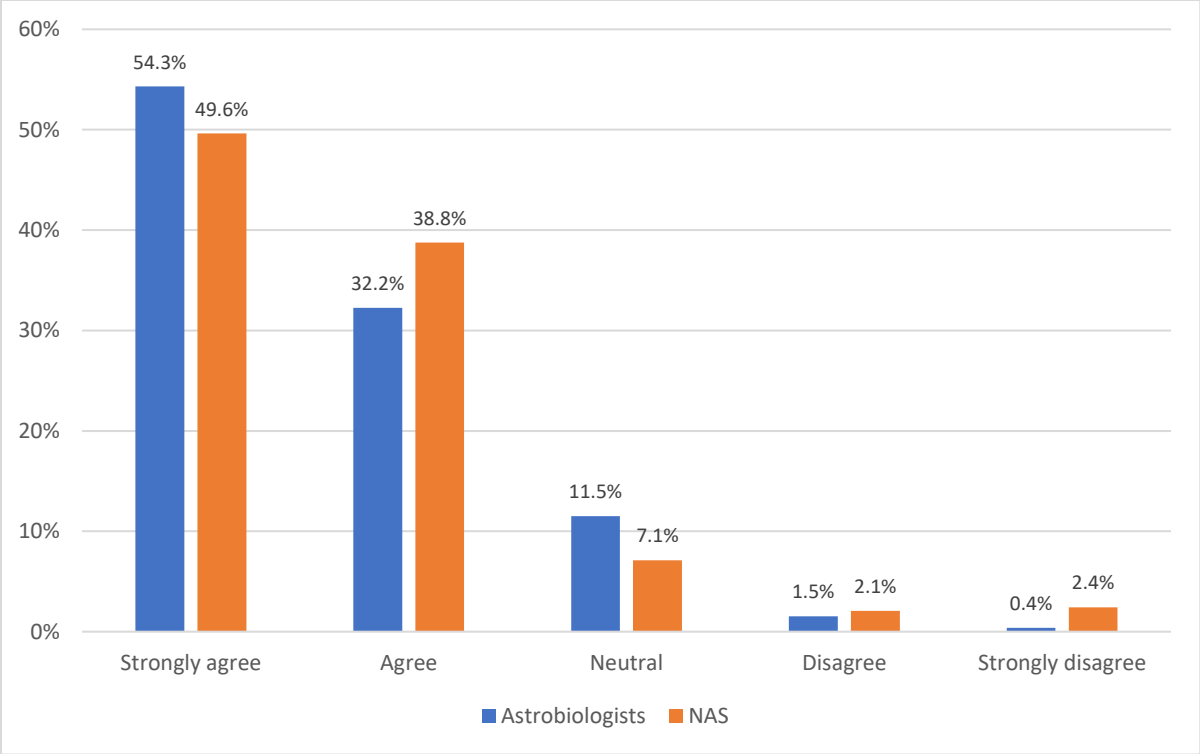

Fig. S2. Results for Statement S1. Comparison of 'Astrobiologists' (N=521) with 'Non-Astrobiologist Scientists', or 'NAS' (N=534). Overall agreement stands at 86.6% for the former, and 88.4% for the latter. For explicit calculations from raw data, see 'Data' file, tabs entitled 'Statement S1' and 'NAS (S1)'. See also tab entitled 'Fig. S2'.

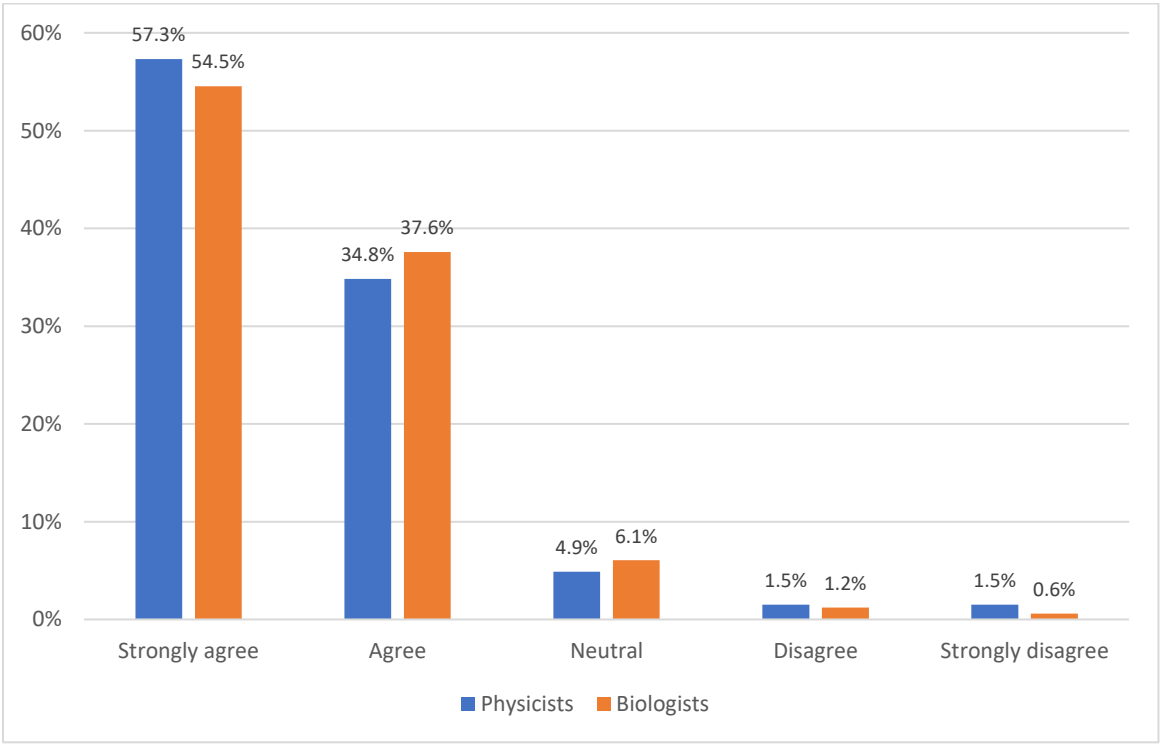

Fig. S3. Comparison of physicists and biologists across entire set of S1 votes (astrobiologists and non-astrobiologist scientists). For explicit calculations from raw data, see 'Data' file, tab entitled 'S1 & NAS'. See also tab entitled 'Fig. S3'.

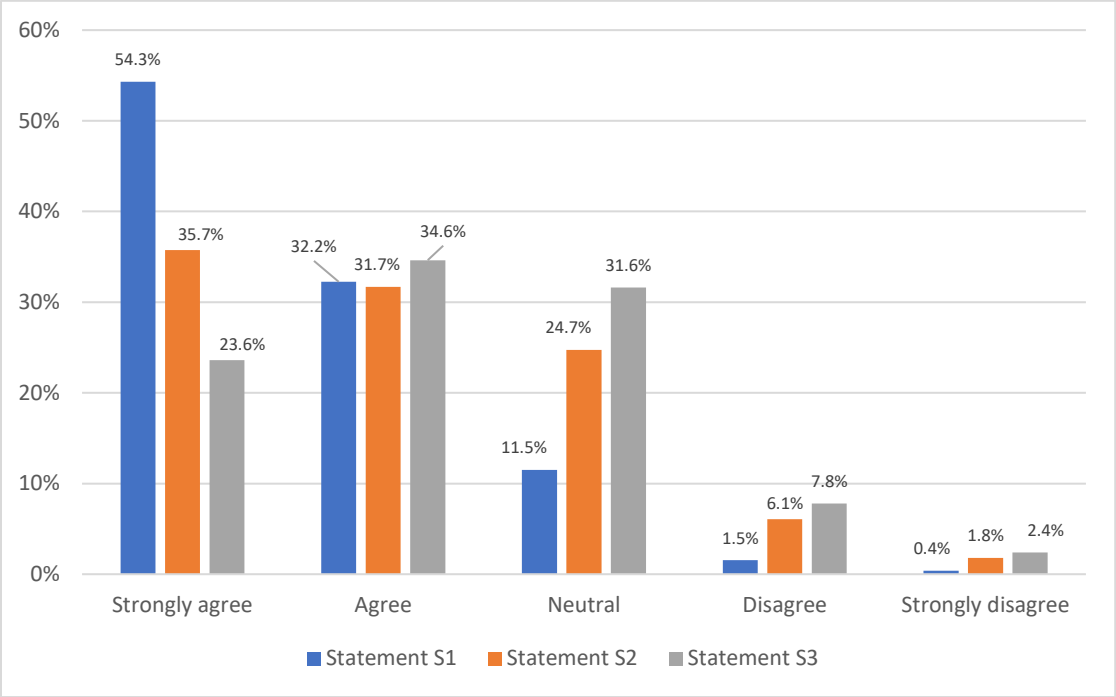

Fig. S4. Astrobiology community agreement across Statements S1-S3. Overall agreement stands at 86.6%, 67.4%, and 58.2%, respectively. For explicit calculations from raw data, see 'Data' file, tabs entitled 'Statement S1', 'Statement S2', and 'Statement S3'. See also tab entitled 'Fig. S4'.

Physicists versus Biologists

We also compared votes of physicists and biologists for all four surveys combined (S1x2, S2, and S3), with N = 392 for physicists and N = 288 for biologists. The results are presented in **Fig. S5**.

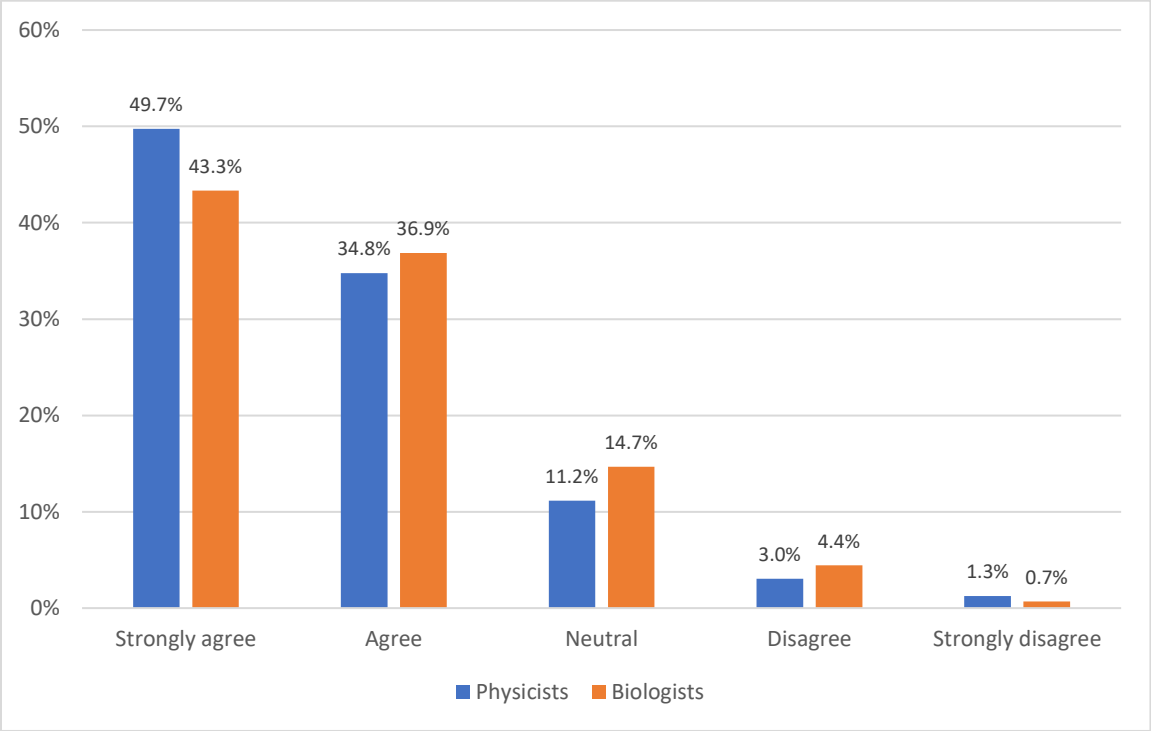

Fig. S5. Comparison of physicists and biologists across all four surveys. For explicit calculations from raw data, see 'Data' file, tab entitled 'All four surveys'. See also tab entitled 'Fig. S5'.

The overall agreement for physicists is now 84.5%, and the overall agreement for biologists is 80.2%. To test whether or not this is statistically significant, we performed a standard chi square test of independence. This resulted in a p-value of 0.169; thus, we fail to reject the null hypothesis at the common statistical level of 0.05. If a small difference between physicists and biologists exists, one would need a larger sample size to show it.

Additional Statistical Results

One statistically significant result, briefly reported in the main article, concerns disagreement results for statement S1, comparing astrobiologists and non-astrobiologist scientists (NAS). There are actually two different significant results here: variance across astrobiologists and NAS for (i) 'strongly disagree', and (ii) overall disagreement. In the case of (i), 13 non-astrobiologists voted 'strongly disagree' (2.4%), whereas 2 astrobiologists voted 'strongly disagree' (0.4%). A chi square test shows statistical significance: a chi square statistic of 8.25 and p-value of 0.004 without Yates' correction *[11]*, and a chi square statistic of 6.82 and p-value of 0.009 with Yates' correction. Either way, the p-value is substantially below the standard significance level of 0.05. In the case of (ii), overall disagreement, 24 non-astrobiologists voted either 'disagree' or 'strongly disagree' (4.5%), whereas only 10 astrobiologists voted either 'disagree' or 'strongly disagree' (1.9%). A chi square test once again shows statistical significance: a chi square statistic of 6.04 and p-value of 0.01 without Yates' correction, and a chi square statistic of 5.22 and p-value of 0.02 with Yates' correction. Thus, tentatively, non-astrobiologists are more likely to disagree vis-à-vis likely existence of (basic) ET life than are astrobiologists. We say 'tentatively', since (a) these are small sample sizes, and (b) we did not pre-register a specific investigation into disagreement levels.

We also note here some of the more obvious statistical results. In particular, we wish to demonstrate that astrobiologists are significantly more optimistic about 'at least basic' ET life (Statement S1) than about 'complex' ET life (statement S2), and significantly more optimistic about 'complex' ET life (Statement S2) than about 'intelligent' ET life (Statement S3). The overall agreement results for S1, S2, and S3 are 86.6%, 67.4%, and 58.2%. Based on the results of standard chi square tests, we observe significant decreases in overall agreement for both S1-S2 and S2-S3, with or without Yates' correction. With Yates' correction applied (to be slightly more cautious and conservative), the S1-S2 drop in overall agreement is highly significant, with a chi square statistic of 49.76 and a tiny p-value. With Yates' correction applied, the S2-S3 drop in overall agreement is significant, with a chi square statistic of 7.80 and a p-value of 0.005.

Looking at the chi square statistics alone, the S1-S2 drop-off is notably larger than the S2-S3 drop-off. Moving from S1 to S2 there is a drop-off in support for the 'strongly agree' and 'agree' options equivalent to 19.2% of all respondents, while the median position moves from 'strongly agree' to 'agree'. Moving from S2 to S3, the decrease is only 9.2% and the median position is still 'agree'. Similarly, moving from S1 to S2 there is an increase in support for the 'disagree' and 'strongly disagree' options equivalent to 6% of respondents, whereas the increase as we move from S2 to S3 is only 2.3%. Finally, moving from S1 to S2 the increase in support for 'neutral' is equivalent to 13.2% of respondents; moving from S2 to S3 it is only 6.9%. Thus, across various different ways of identifying a drop-off in confidence, the drop-off is much more notable for the move from 'basic' to 'complex' ET life than it is for the move from 'complex' to 'intelligent' ET life.

A statistically rigorous approach to comparison of the S1-S2 drop-off with the S2-S3 drop-off is achievable with a z-test for the difference between two proportions. We calculate a z-score for the difference in differences of 2.379, and a p-value of 0.017. Thus, the larger drop in agreement from S1 to S2 compared with the drop from S2 to S3 is not likely due to chance.

Ethics Approval

We have complied with all relevant ethical regulations. The ‘sister project’ – which used an almost identical survey methodology – went through a comprehensive ethical approval at Durham University, UK, equivalent to IRB. A full Data Protection Impact Assessment (DPIA) was completed, including a Legitimate Interests Assessment (LIA). The assessment result was 'low risk'.

The specific project undertaken here also went through ethical approval at Durham University, but as an addendum to the sister project ethical approval. This is because the survey methodology was almost identical, and any differences were not ethically significant. In particular, the survey statements used were different, and the targeted scientists were different, but not in any ethically significant respect.

The need for participants’ explicit prior consent was waived by the ethics committee. We stress that if participants did not consent, they could simply ignore or delete the survey invitation email. Clicking the survey link embedded in the email is equivalent to consenting for one's opinion to be included, anonymously, as part of the survey. It is ethically sound to take a scientist’s decision to click the survey link in the invitation email as signaling their consent to their opinion being included in the survey. Scientists were able to permanently ‘opt out’ in two clicks.

Ethics and Inclusion Statement (Authorship)

The authors listed for this paper are all (and only) those individuals meeting the authorship criteria as detailed on the Nature Portfolio ‘Authorship’ webpage (which can be found at https://www.nature.com/nature-portfolio/editorial-policies/authorship). The lead author (and PI) is Vickers, who led the research and wrote the paper. The final author listed, McMahon, contributed substantially to all aspects of the paper, and is the Co-Investigator on this project. Other authors are listed in order of surname.

Supplementary References

11. Yates F (1934). Contingency Tables Involving Small Numbers and the χ2 Test. *Supplement to the Journal of the Royal Statistical Society* **1**(2): 217–35.