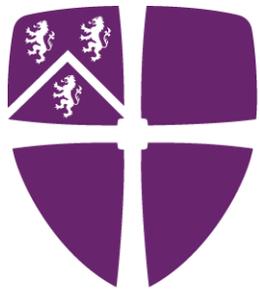


Quantifying Uncertainty in Assessment of Possible Exoplanet Biosignatures

Cambridge, 9th February, 2022

Peter Vickers, Durham University

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Durham
University

Who am I?



**UK Centre for
Astrobiology**

- I'm a philosopher of science working with the UK Centre for Astrobiology
- Leverhulme-funded project:
 - EURiCA
- 'Exploring Uncertainty and Risk in Contemporary Astrobiology'



Co-I: Sean McMahon

**BREAKING
NEWS**

The image features the words "BREAKING NEWS" in a large, bold, white, three-dimensional sans-serif font. The text is set against a vibrant red background that has a subtle grid of white lines receding into the distance, creating a sense of depth. The letters are highly reflective, with bright highlights on their top surfaces and dark shadows on their sides and bases. The words are arranged in two lines: "BREAKING" on top and "NEWS" below it. The entire graphic is centered and occupies most of the frame.



Oxygen-methane
disequilibrium
discovered in exoplanet
atmosphere!

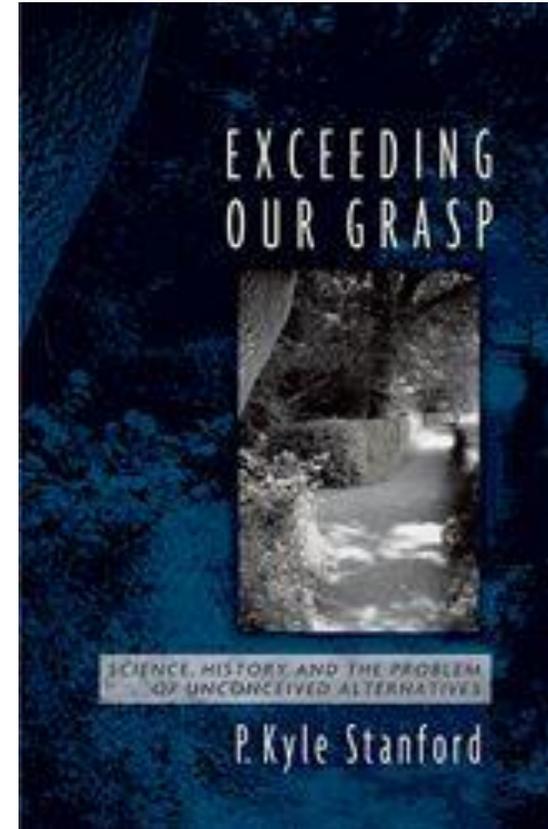
No known abiotic explanation!

Biosignature!

The problem of unconceived alternatives



Kyle Stanford



[nature](#) > [letters](#) > [article](#)Published: [31 August 2016](#)

Rapid emergence of life shown by discovery of 3,700-million-year-old microbial structures

[Allen P. Nutman](#) , [Vickie C. Bennett](#), [Clark R. L. Friend](#), [Martin J. Van Kranendonk](#) & [Allan R. Chivas](#)[Nature](#) **537**, 535–538 (2016) | [Cite this article](#)**35k** Accesses | **318** Citations | **2703** Altmetric | [Metrics](#)

Abstract

Biological activity is a major factor in Earth's chemical cycles, including facilitating CO₂ sequestration and providing climate feedbacks. Thus a key question in Earth's evolution is when did life arise and impact hydrosphere–atmosphere–lithosphere chemical cycles? Until

Waiting... [evidence for the oldest life on Earth focused on debated stable isotopic signatures of](#)

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Editorial Summary

Signs of life on an ancient Earth

Stromatolites are sedimentary formations created by the layered growth of microorganisms in shallow marine settings. Fossil stromatolites constitute some of the earliest evidence for life on Earth. Allen Nutman *et al.* describe metamorphosed stromatolites deposited around 3,700 million years ago in what is now Greenland. This is more than 200 million years

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“Here we report new research that shows a non-biological, post-depositional origin for the structures.”

nature

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[nature](#) > [letters](#) > [article](#)

Letter | [Published: 17 October 2018](#)

Reassessing evidence of life in 3,700-million-year-old rocks of Greenland

[Abigail C. Allwood](#) , [Minik T. Rosing](#), [David T. Flannery](#), [Joel A. Hurowitz](#)  & [Christopher M. Heirweh](#)

[Nature](#) **563**, 241–244 (2018) | [Cite this article](#)

14k Accesses | **74** Citations | **908** Altmetric | [Metrics](#)

 An [Author Correction](#) to this article was published on 29 November 2018

 This article has been [updated](#)

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[Proposed early signs of life not set in stone](#)

Mark A. van Zuilen

[News & Views](#) | 17 Oct 2018

[Sections](#)

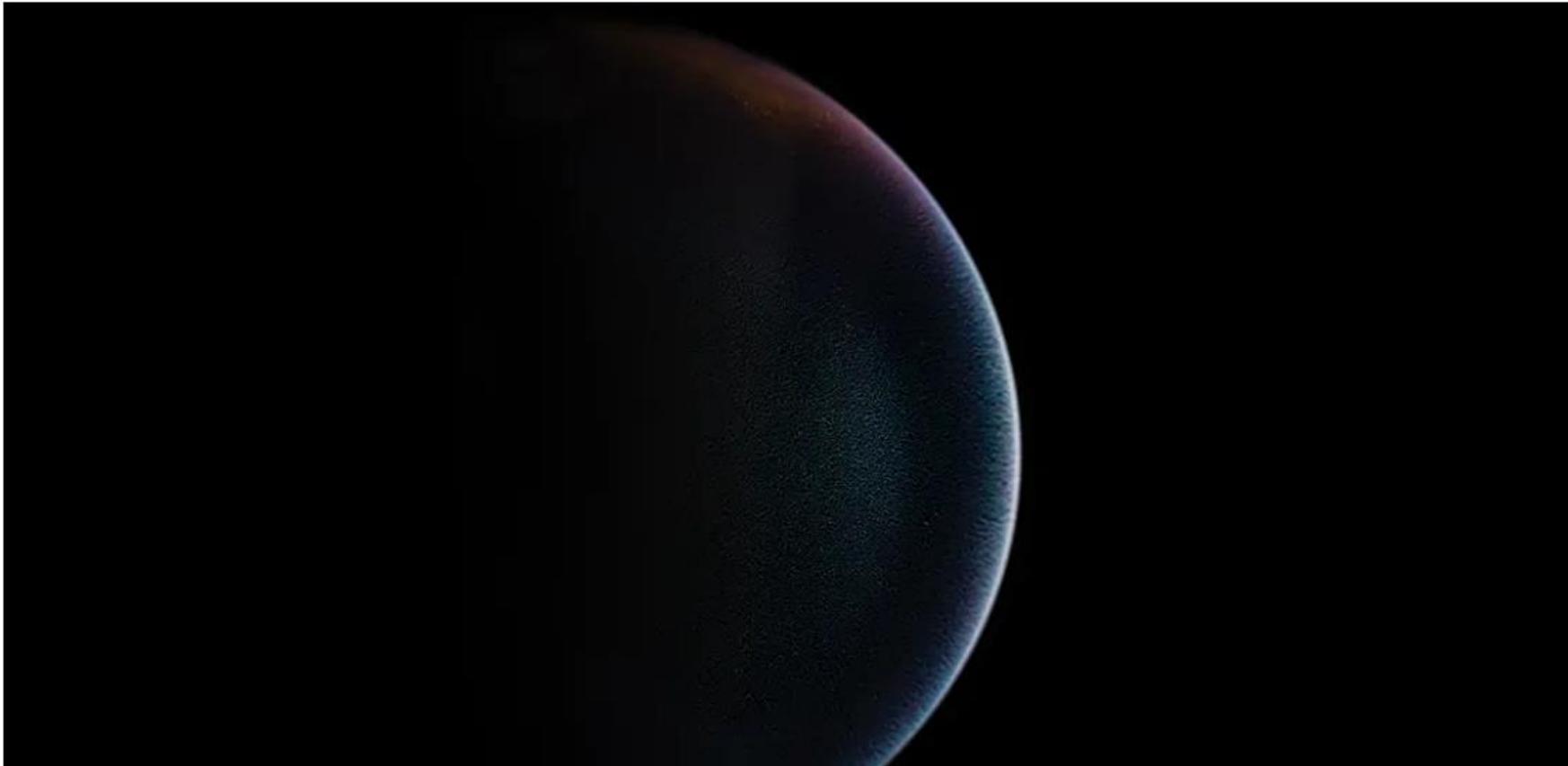
[Figures](#)

[References](#)

Oxygen biosignature alone does not indicate life on other planets

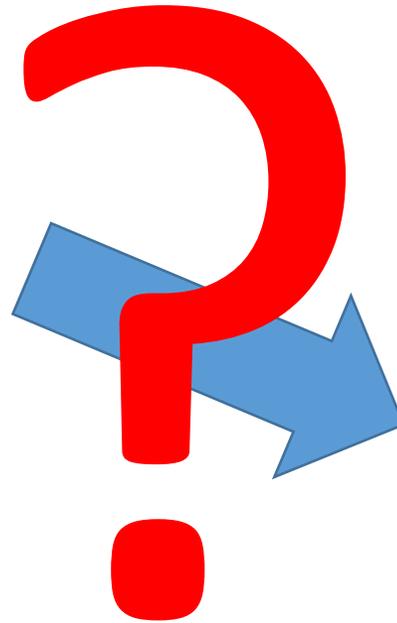
by Victoria Corless | Apr 16, 2021

Oxygen is a promising exoplanet biosignature, but several scenarios exist in which a lifeless, rocky planet could evolve to have non-biological oxygen in its atmosphere.



Oxygen-methane disequilibrium?

“We can’t currently conceive of any plausible abiotic mechanism for such a disequilibrium”



“Highly likely the disequilibrium has a biotic cause”

[nature](#) > [perspectives](#) > [article](#)

Perspective | [Published: 27 October 2021](#)

Call for a framework for reporting evidence for life beyond Earth

[James Green](#) , [Tori Hoehler](#), [Marc Neveu](#), [Shawn Domagal-Goldman](#), [Daniella Scalice](#) & [Mary Voytek](#)

[Nature](#) **598**, 575–579 (2021) | [Cite this article](#)

5568 Accesses | **1097** Altmetric | [Metrics](#)

Abstract

Our generation could realistically be the one to discover evidence of life beyond Earth. With this privileged potential comes responsibility. The magnitude of the question of whether we are alone in the Universe, and the public interest therein, opens the possibility that results

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Sections

Figures

References

[Abstract](#)

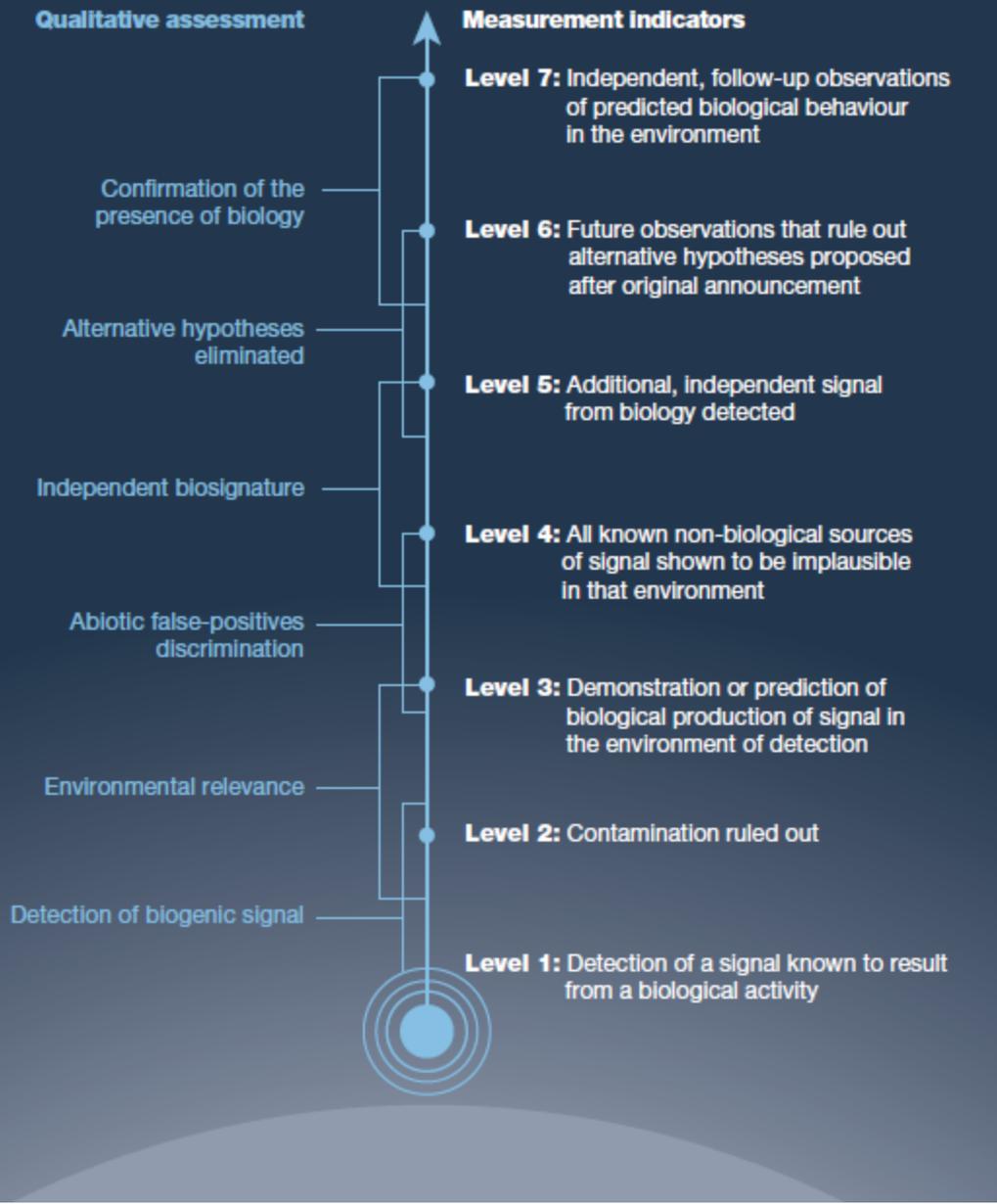
[Main](#)

[Considerations for a progressive scale](#)

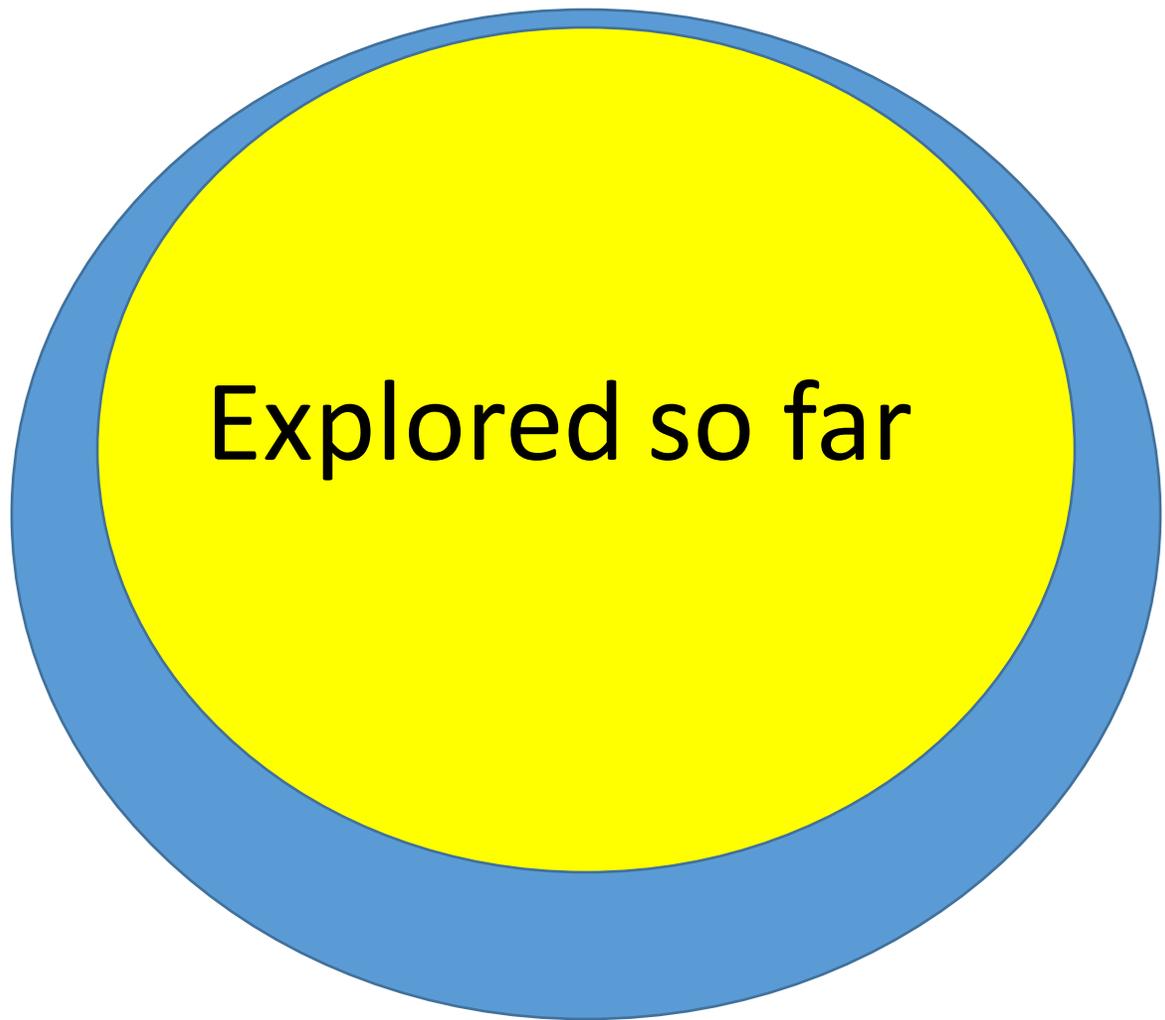
[An example progressive scale](#)

[Example applications of the CoLD scale](#)

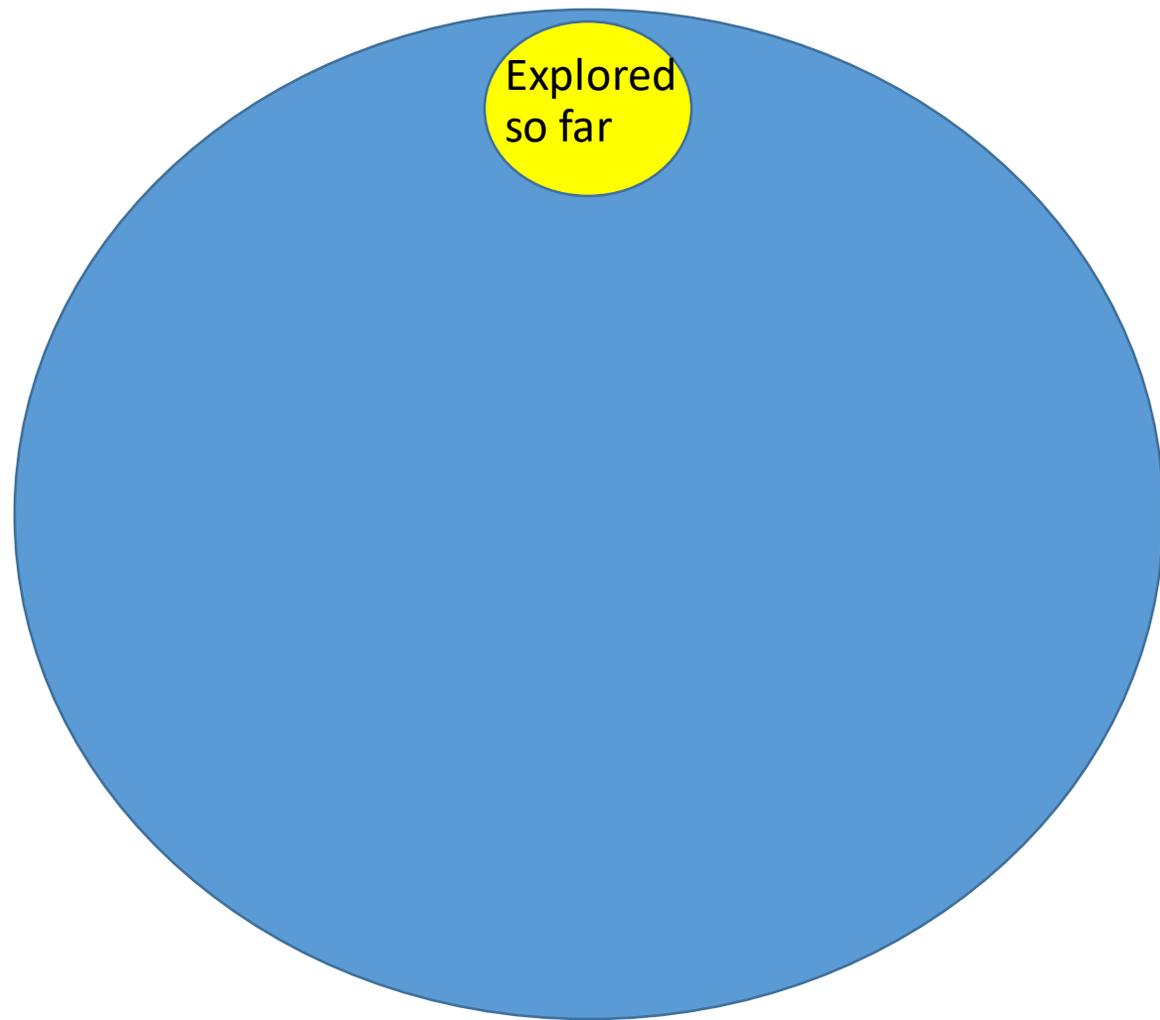
[A call to action](#)



- Level 4:
- “*All known non-biological sources of signal shown to be implausible in that environment.*”
- But how significant is it that all *known* abiotic sources have been ruled out?



?



?



REVIEW ARTICLE | NOVEMBER 17, 2021

False biosignatures on Mars: anticipating ambiguity

Sean McMahon ; Julie Cosmidis

Journal of the Geological Society (2021) jgs2021-050.

<https://doi.org/10.1144/jgs2021-050> [Article history](#) [Standard View](#) [PDF](#) [Cite](#) [Share](#) [Tools](#)

Abstract

It is often acknowledged that the search for life on Mars might produce false positive results, particularly via the detection of objects, patterns or substances that resemble the products of life in some way but are not biogenic. The success of major current and forthcoming rover missions now calls for significant efforts to mitigate this risk. Here, we review known processes that could have generated false

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Fig. 1.

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Pseudomicrobialites. (a) Laminated red siltstones draping the surface of boulders (Brasier *et al.* 2017). (b, c) Stromatolite branching columns formed by aerosolized collagen (McLoughlin *et al.* 2008). Images reproduced with permissions.

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- “this area of enquiry has received rather scant and unsystematic attention from astrobiologists, who have tended to focus their published work on expanding our knowledge of life’s signatures rather than its abiotic mimics.”
- “[G]iven the haphazard and unsystematic way in which varieties of false biosignature have so far been identified, we can only assume that many others remain undiscovered.”



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Outline

Keywords

The terrestrial biosphere and extremophiles

Maps of habitability under synchronous extremes

Microbial adaptations to multiple stressors

Polyextremophiles and space exploration

Concluding remarks and future directions

Acknowledgments

Appendix A. Supplementary data

References

Glossary

Show full outline

Figures (4)

Trends in Microbiology



Volume 21, Issue 4, April 2013, Pages 204-212

Review

The limits for life under multiple extremes

Jesse P. Harrison , Nicolas Gheeraert, Dmitry Tsigelnitskiy, Charles S. Cockell

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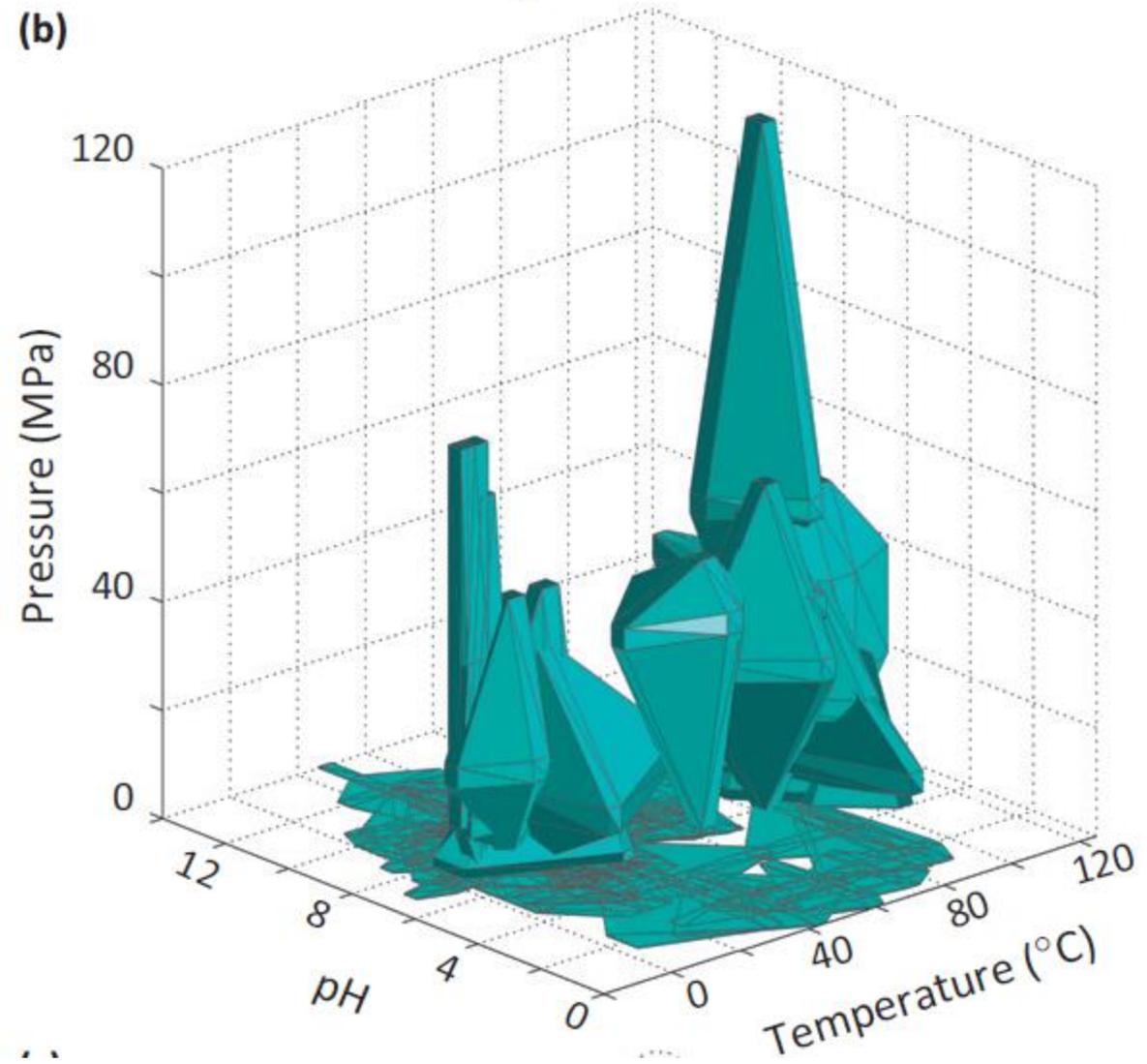
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<https://doi.org/10.1016/j.tim.2013.01.006>

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Life on Earth is limited by physical and chemical extremes that define the 'habitable space' within which it operates. Aside from its

(b)

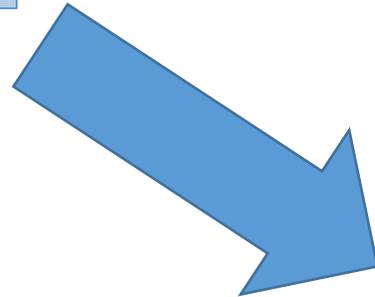


Bayes theorem?

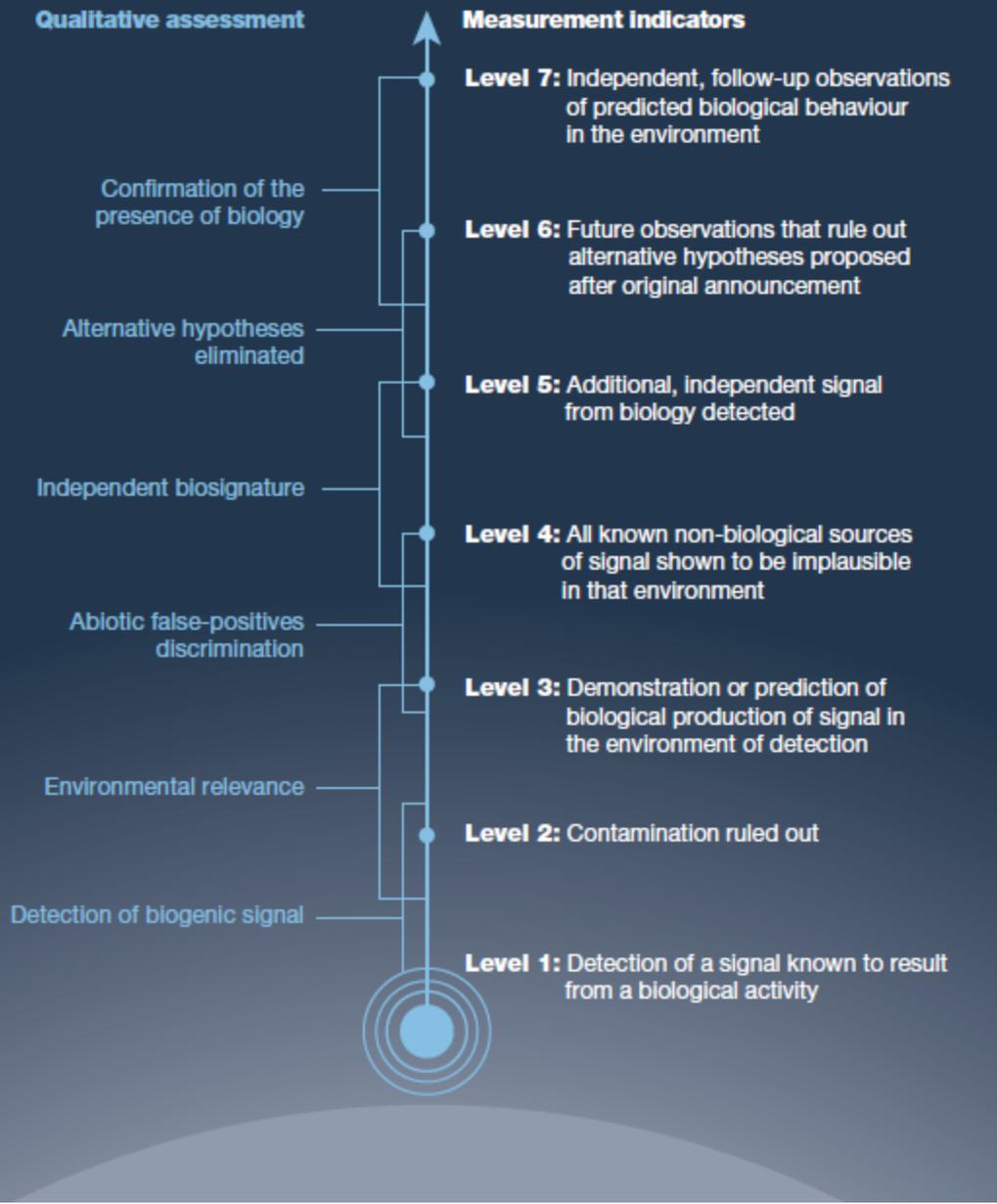
$$p(L, E) = \frac{p(E, L)p(L)}{p(E)} = \frac{p(E, L)p(L)}{p(E, L)p(L) + p(E, \neg L)p(\neg L)}$$

- How on Earth to fill in $p(E/\neg L)$?
 - If we haven't explored the possibility space very much, we can't responsibly input a value here.
 - We should say: "We just don't know; we haven't done the research"
- Seems to be a conflict between what would happen if we discovered an oxygen-methane disequilibrium, and what a sober assessment of the relevant uncertainties would suggest.

“We can’t currently
conceive of any plausible
abiotic mechanism for X”



“Highly likely X has a
biotic cause”



- Level 4, where the maximum is 7.
 - Time to start getting excited, perhaps?
- Reaching Level 4 is hugely significant *if we've* thoroughly explored the possibility space.
- Otherwise it means nothing.



7

- 'CoLD scale'
- 'Confidence of Life Detection'

1

- 
- How confident?
 - VERY, if we've explored the possibility space thoroughly.
 - NOT AT ALL, if we've just started.

Take-home message:

Quantifying uncertainty in assessment of possible exoplanet biosignatures requires...

...quantifying the extent to which we've explored the possibility space of abiotic mimics.

Questions?

Cambridge, 9th February, 2022

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