Extraterrestrial
Institute

Markers of Extraterrestrial Activity

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Study of Extraterrestrial Activity Framework

The framework is created to depict the most important sectors within the study of extraterrestrial activity. Scientists start building assumptions and find technosignatures, based on what they already know in terms of planetary science, moving on to the habitability and biosignatures of our Solar System. When it comes to objects located far from the Milky Way, the researchers tend to use extraterrestrial chemistry and astrobiology methods in order to prove the basis of the first given assumptions.

Object

- Intelligent Life Forms
  - Active
    - Messages
    - Tech Signatures
    - Megastructures
    - Laws of Physics Obstruction
- Primitive Life Forms
  - Tracks
    - Organic or Life Signatures
    - Suitable Worlds Discovery
    - Alternative Life Forms

Research Method

- Measurement
  - Radiolocation
  - Optical
  - Spectroscopy
  - Gravitational Waves Measuring
- Modeling
  - Alternative life Forms
  - Megastructures Signatures
  - Biomarkers Signatures
  - Planetary Conditions

Location

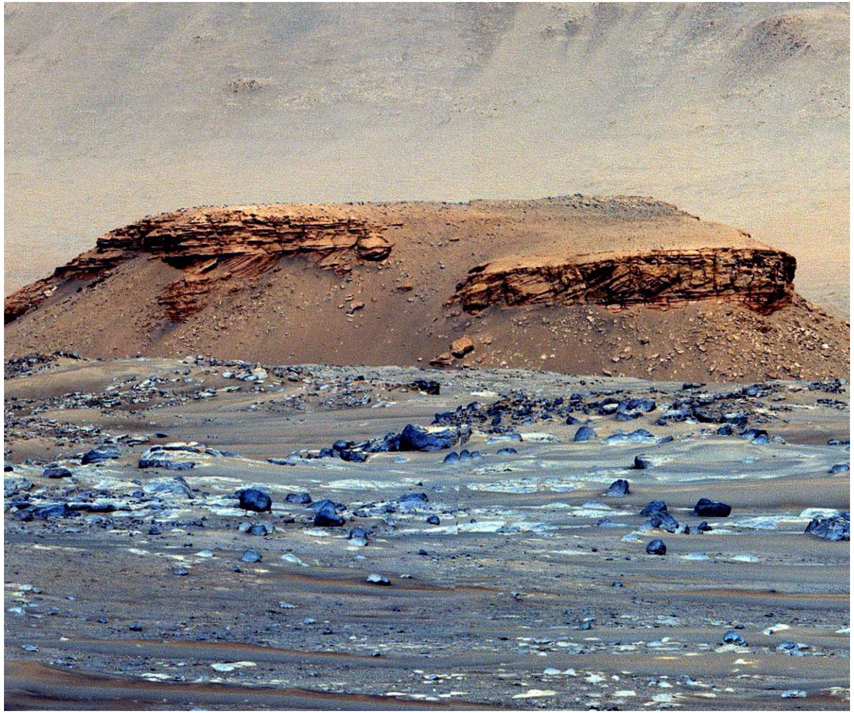
- Atmosphere
- Near-Earth Orbit
- Our Solar System
- The Milky Way
- Observable Universe

Astropaleobiology

Astropaleobiology rocketed into prominence in August 1996 with the announcement that **a meteorite from Mars contains evidence indicative of early life** on the red planet. In spite of the fact that every aspect of the evidence is disputed, the resultant burst of activity presented a challenge to paleobiologists worldwide to provide additional evidence for biological origin of microfossils.

The primary goal of astropaleobiology, to locate and interpret evidence of former life on other planets, requires a multidisciplinary approach that includes scientific efforts from a wide range of disciplines. The most common methods include the following: **Raman spectroscopy, Analysis of molecular biomarkers, Atomic force microscopy (AFM) techniques, Stable isotope methods, and Stellar population modelling.**

The success of this field will depend on the integration of evidence from multiple sources such as micropaleontology, organic geochemistry, and isotope geochemistry. Its practitioners will require a good understanding of field geology and petrology. The biggest problem is demonstrating biogenicity, and much more effort will have to be directed to improving the necessary skills.



Sources Astropaleobiology in the 21st Century

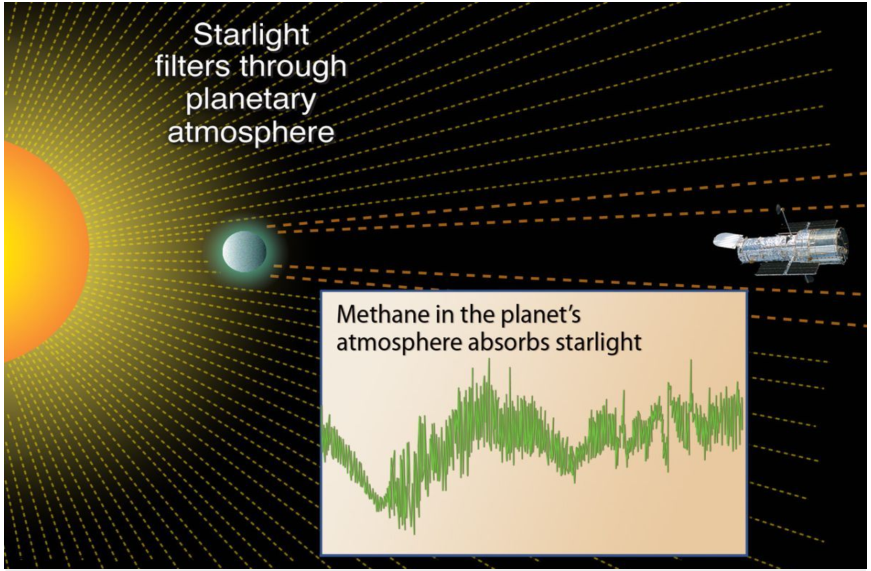
Produced Biosignatures

The term **Biosignatures** include chemical, morphological, sedimentary, or isotopic processes or structures that are known to be biogenic on Earth and could indicate the past or present presence of life on a celestial body. They are often referred to as *Biomarkers* and *Traces of Life,* and while these terms differ a bit, *Indices of life* or *Bioindices* are the recommended terms to be used as a generalisation of the concept.

In general, biosignatures can be grouped into 10 broad categories:

- **Isotope patterns**
- **Chemical features**
- **Organic matter**
- **Minerals or biomineral-phases**
- **Microscopic structures and textures**
- **Macroscopic physical structures and textures**
- **Temporal variability**
- **Surface reflectance features**
- **Atmospheric gases**
- **Technosignatures**

A higher gear is being put into the hunt for extrasolar life indicators. In order to prepare for examining the atmospheres of rocky, Earth-like extraterrestrial worlds, scientists are compiling a list of chemicals that may potentially contain signs of life.



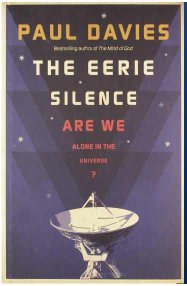
Astronomers can study the starlight that filters through exoplanet atmospheres, searching for signatures of molecules that may be signs of life. (Image credit: NASA, ESA and A. Feild (STScI))

Sources: Space.com, liebertpub.com

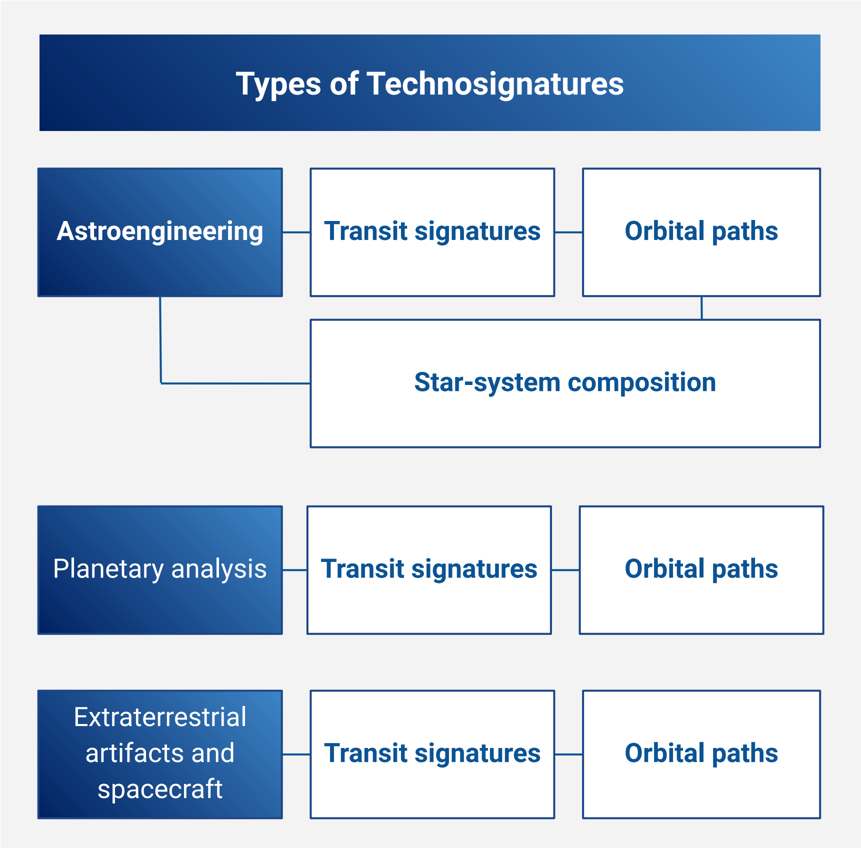
What Are Technosignatures?

Any quantifiable characteristic or result that offers objective proof of previous or contemporary technology is referred to as a **technomarker** or **technosignature**. Similar to biosignatures, which indicate the presence of life, whether sentient or not, technosignatures indicate the presence of intelligent life capable of advanced technology. Radio broadcasts are sometimes left out of definitions by authors; however this limited usage is not common.

Jill Tarter (American astronomer) has proposed that the search for extraterrestrial intelligence (SETI) be renamed into **'the search for technosignatures'.**



Some examples of technosignatures are described in **Paul Davies**'s 2010 book ***The Eerie Silence*** although the terms 'technosignature' and 'technomarker' do not appear in the book.



Types of Technosignatures

Astroengineering — **Transit signatures** — **Orbital paths**

Star-system composition

Planetary analysis — **Transit signatures** — **Orbital paths**

Extraterrestrial artifacts and spacecraft — **Transit signatures** — **Orbital paths**

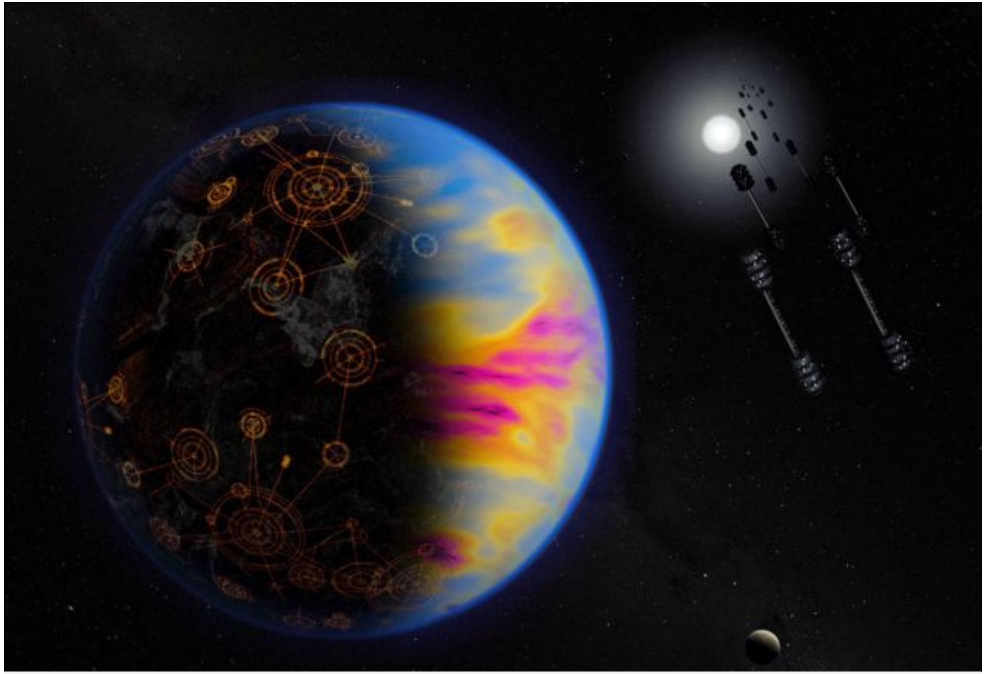
Sources: NASA

Technosignatures From Advanced Civilisations

Ever since planets beyond our Solar System were first discovered, astronomers have been hunting life beyond our world. While biological signatures are crucial, the idea of scouring the skies for signs of technosignatures from advanced civilisations is gaining momentum.

In 2015, citizen scientists from the Planet Hunter project noticed odd fluctuations in the light curve from an **F-type main-sequence star, some 450 parsecs from Earth**. It drew the attention of professional astronomers, including Tabetha Boyajian of Yale University who detected an irregular dimming of the star's brightness of up to 22%. These unexpected observations of 'Tabby's star', as it is now known, led to conjectures of everything, from a planetary debris field to an extraterrestrial megastructure, to freed exomoons, before finally concluding the most likely cause was space dust.

Ultimately, finding proof of extraterrestrial life will come from collecting vast amounts of data on technosignatures and biosignatures unless the aliens pay us a visit.



Probing pollution. One indication of advanced alien life could be industrial pollution. Therefore, the presence of gases such as nitrogen dioxide might serve as a technosignature that we could detect on exoplanets. (Credit: NASA/Jay Freidlander)

Sources: PhysicsWorld

Picking Up Pollution and Alien Megastructures

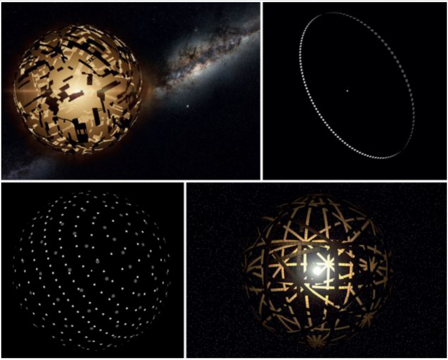
Another technosignature could be the pollution that aliens in the early stages of technological development are pumping into the atmosphere of the planets they inhabit. Indeed, atmospheric chemical pollutants could be identified in the same way as biosignatures like oxygen and methane by looking at the spectral data. Spectral templates will come from running climate models that depend on the planet's features.

SETI has traditionally focused on looking for signs of life by scanning the skies for **electromagnetic radiation**.

Image: *A false-color view constructed using infrared data from the Spitzer Space Telescope of the Orion Nebula.*

Another suggested technosignature pollutant is nitrogen dioxide, NO_2, which is found here on Earth as a byproduct of combustion from vehicles and fossil-fuelled power plants.

A notable technosignature would be the detection of a Dyson sphere – a hypothetical megastructure first proposed by Freeman Dyson in *Science* magazine in 1960. Originally conceived as a hollow shell that an advanced exocivilisation might construct surrounding its host star, the sphere would capture all of the star's energy – in our case, two billion times more energy than falls on Earth's upper atmosphere.



Energy harvester
The classic Dyson sphere is a 'shell' (top left) that completely surrounds a star. This would be mechanically unstable, but other Dyson megastructures that are more likely to work include the ring (top right), bubble (bottom left), and swarm (bottom right).

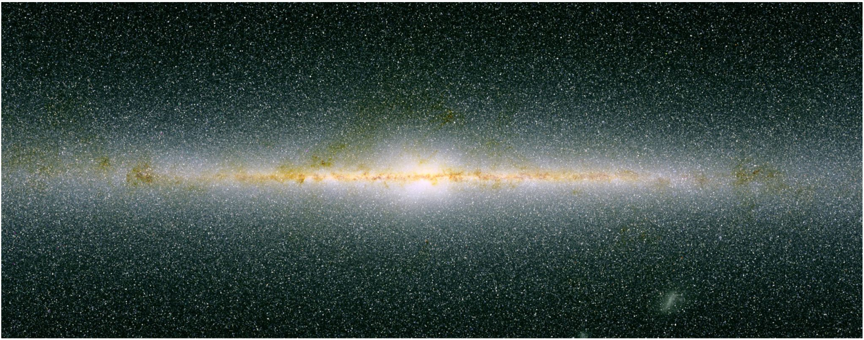
Solar collectors on these structures could beam microwaves down to the planet's surface for power, which could drastically modify the star's spectrum, creating an infrared blackbody.

Sources: MotherJones, NewScientist

Alien Bacteria on Venus and Ocean World of the Milky Way

Venus has long been second fiddle to the supposedly more hospitable Mars thanks to its sweltering surface temperature, extreme pressure, and sulfuric-acid clouds. Yet, a research team used the James Clerk Maxwell Telescope in Hawaii and the Atacama Large Millimetre/submillimetre Array in Chile to look at Venus and found phosphine in a cloud layer with temperatures and pressures almost identical to those on Earth. Terrestrial bacteria are known to flourish in a variety of harsh environments, so a biological explanation is not out of the question. Many in the community are sceptical, but it will at least mean more funding for life searches in unusual places.

Ocean worlds, defined as worlds with considerable amounts of water on or near their surfaces, are surprisingly widespread in our Solar System. Earth, of course, is one of them, but Jupiter's moon Europa is suspected to have extensive seas beneath its icy shell while Saturn's moon Enceladus is known to have aqueous geysers spouting from its surface. In fact, there is growing momentum in the astronomy community to send a probe to either satellite in the 2030s to see if there are any live beings lurking behind their shells. A quarter of the 53 planets have the right parameters to be classified as ocean worlds, suggesting they are common in the galaxy.



Sources: Lifescience

Big Data ML-Modelling for Biomarkers Signatures Detection (1/2)

Methods/Problems

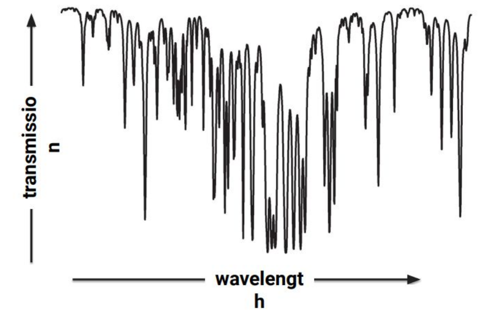
- **How do we determine if life exists on exoplanets?**

Researchers use sophisticated telescopes that record information about a planet's temperature, tilt, rotation, and atmosphere, along with other stellar and planetary parameters. From these parameters, they are able to look for biohints (biohints may be molecules, patterns, or other signals known to be indicators of whether or not life may exist on an exoplanet).

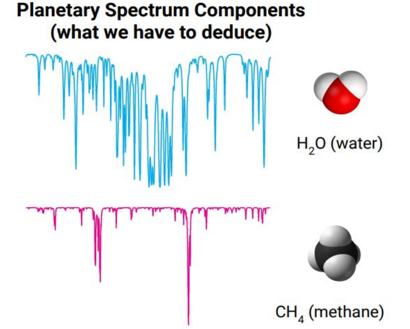
- **Received Planetary Spectrum and its Components are very complex, and their observation is complicated, takes much time and other resources.**

Telescopes record emissions from molecules in a planet's atmosphere at different wavelengths. These result in a complicated Planetary Spectrum, which we then have to deconvolve into potential atmospheric molecular components. On the one hand, traditional approaches for determining the atmospheres of exoplanets from telescopic spectral data (called an atmospheric retrievals) involve time-consuming and compute-intensive Bayesian sampling methods, requiring a compromise between physical and chemical realism and overall computational feasibility. On the other hand, Machine learning (ML) offers a feasible and reliable approach to expedite the process of atmospheric retrievals; however, ML models require a large data set to train on.

Planetary Spectrum observed at high resolution



Planetary Spectrum Components (should be deduced)



Sources: Researchgate

Big Data ML-Modelling for Biomarkers Signatures Detection (2/2)

Machine Learning solutions expedite the speed and accuracy of determining the composition of exoplanetary atmospheres

In 2018, Molly D. O’Beirne*, Michael D. Himes, Frank Soboczenski, et al. introduced Intelligent exoplaNet Atmospheric RetrievAl (INARA). The model uses a data set of 3 million simulated atmospheric spectra of rocky, terrestrial exoplanets generated across a broad parameter space of stellar and planetary properties, including 12 molecular species relevant for determining extant life. In a matter of seconds, INARA is capable of retrieving accurate concentrations of 12 molecular atmospheric constituents when given an observed spectrum. It is the first large-scale simulated spectral data set and first atmospheric retrieval ML model for rocky, terrestrial exoplanets.

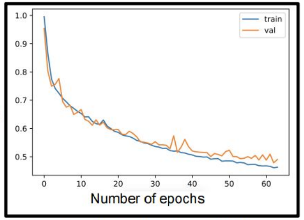
Proof of Concept:

Synthetic Spectra Input

SET	CURRENT	FUTURE
Training	100,000	2,5M
Validation	10,000	400,000
Test	7,710	200,000

Machine Learning Models

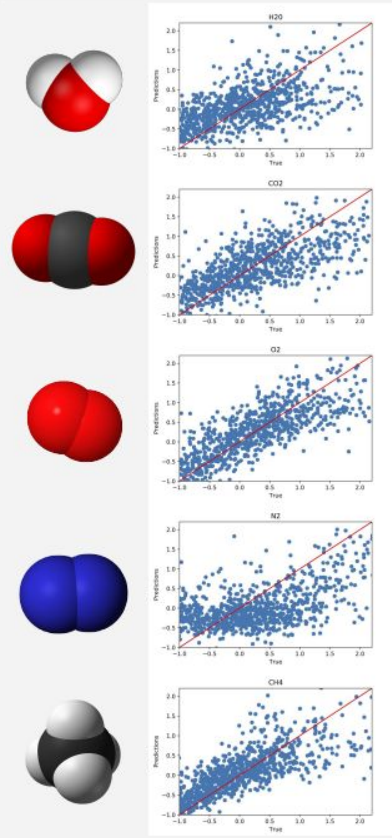
We explored many model architectures, ranging in complexity from linear regression and feed-forward neural networks to convolutional neural networks (CNNs). We present results from the best performing model, a 1D CNN with the following configuration: Conv1d(64) tanh - MaxPool - Conv1d(64) - relu - MaxPool - Conv1d(128) - relu - MaxPool - Conv1d (256) - relu - FC(256) - relu - FC(12) - T. Loss(0.42) - V. Loss (0.49) - 64 epochs.



Loss plot for the chosen CNN

Posterior distributions of the relative molecular abundances for one planet

True vs. CNN predicted values



Sources: Frank Soboczenski, Michael D. Himes, Molly D. O’Beirne, 2020