Exoplanet Biosignatures Workshop

The search for life beyond our Solar System motivates future exoplanet missions to observe for biosignatures with global, potentially detectable, impacts on a planet. Biosignatures occur in an environmental context in which geological, atmospheric, stellar processes and interactions, and evolutionary history may work to enhance, suppress or mimic these biosignatures. Thus biosignature science is inherently multi-disciplinary and may inform the design of the next flagship missions that will obtain spectra of habitable extrasolar planets.

NASA’s Nexus for Exoplanet System Science and the NASA Astrobiology Institute held a joint Exoplanet Biosignatures Workshop Without-Walls in June-July 2016, which brought together astrobiology, exoplanet, and mission concept communities to review, discuss, debate, and advance the science of biosignatures. A broad range of experts were engaged, merging the interdisciplinary processes and interactions, and evolutionary history may work to inform the design of the next flagship missions that will obtain biosignatures.

The workshop focused around three goals:
1. State of the Science Review: What are known remotely-observable biosignatures, the processes that produce them, and their known non-biological sources?
2. Advancing the Science of Biosignatures: How can we develop a more comprehensive conceptual framework for identifying additional biosignatures and their possible abiotic mimics?
3. Confidence Standards for Biosignature Observation and Classification: How can we develop assessment strategies, but reviews currently existing literature to provide a foundation for a path forward. We survey some biogenic spectral features that are well-known in the specialist literature but not yet robustly vetted in the context of exoplanet biosignatures. We also briefly review advances in assessing biosignature plausibility, including novel methods of determining chemical disequilibrium and the minimum biomass required for a given atmospheric signature.

The workshop activities have culminated in five review papers on the science and technology of remote searches for signs of life on exoplanets. Broad participation was solicited for these papers, which will serve as an interdisciplinary, educational, state of the art reference for use across a wide community. Community comments are invited in May 2017 at: nesxss.info.

Exoplanet Biosignatures: A Review of Remotely Detectable Signs of Life

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This paper provides an in-depth review of current understanding of potential exoplanet biosignatures including gaseous, surface, and temporal biosignatures. We focus particularly on advances made since the review by Des Marais et al. (2002). This paper does not propose new biosignatures strategies, but reviews currently existing literature to provide a foundation for a path forward. We survey some biogenic spectral features that are well-known in the specialist literature but not yet robustly vetted in the context of exoplanet biosignatures.

Exoplanet Biosignatures: Understanding Oxygen as a Biosignature in the Context of Its Environment

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O2 remains our most robust biosignature. However, possibilities for false negatives exist, as on the early Earth when accumulation of biogenic O2 in the atmosphere was delayed by at least a billion years. Possibilities for false positives also have been uncovered through computer modeling of mechanisms for abundant O2 in the absence of a biosphere. We review past and current biosignature research to detail the story of O2 as a specific example of how life is a function of and modifies its planetary environment, and how we would use remote-sensing observations to search for biosignatures in the near term. In addition, we describe current knowledge of specific photometric, spectroropic and time-dependent observations of environmental context that could be made by future observatories to identify O2 as a biosignature, and discriminate it from potential false positives.

Exoplanet Biosignatures: A Framework for Their Assessment

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We present a general scheme for observing potential exoplanet biosignatures and gauging and expressing confidence levels for positive detection of signs of life. An appropriate framework uses models with data (in the form of exoplanetary system properties and spatial or photometric data) to find the Bayesian likelihoods of those data occurring if the exoplanet has or does not have life. The latter includes the case of false positives, i.e., where abiotic sources mimic biosignatures from knowledgability (including all factors that influence habitability and previous exoplanet observations) would be combined with the likelihood to arrive at the probability of life existing on a given exoplanet given the observations.

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