

Astro2020 Science White Paper

The Cusp of Discovery in Astronomy

Thematic Areas:

- Planetary Systems
- Star and Planet Formation
- Formation and Evolution of Compact Objects
- Cosmology and Fundamental Physics
- Stars and Stellar Evolution
- Resolved Stellar Populations and their Environments
- Galaxy Evolution
- Multi-Messenger Astronomy and Astrophysics

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Abstract: We are on the cusp of the discovery of life elsewhere in the Universe. As a mission to humanity, we should unite and uniquely focus the ASTR2020 report on this theme, and work to achieve this revolutionary discovery in the next decade.

Twenty-five years ago, astronomers discovered the presence of life on Earth. In a prescient paper, Carl Sagan with co-authors Reid Thompson, Robert Carlson, Donald Gurnett, and Charles Hord [1] used the Galileo spacecraft to find oxygen-laden gases and methane which were suggestive of abundant life on Earth. In addition, from pulsed AM signals that cannot appear in normal astrophysical conditions, they concluded that intelligent life must also be present. Since that time, we have made a number of other pioneering discoveries in the search for life. We have found a planet entirely inhabited by robots. We also know that life probably exists on at least two solar system bodies besides Earth.

Of course, the planet of the robots is Mars. We put them there. And while controversial, Apollo 12 astronauts retrieved a camera from the lunar lander Surveyor 3 which when studied back in a lab on Earth, the bacteria *Streptococcus mitis* were found to have survived three years on the lunar surface [2]. With this discovery, we have evidence for the theory of panspermia.

The ASTR2020 report will propose a mind-bending range of great science – science projects that will be remembered decades, perhaps centuries from now. It is our hope that we will find and measure the first galaxies and stars, and understand the transition from the dark ages of neutral hydrogen to the sudden appearance of galaxies and black holes. We will look deeply into regions of star formation to understand the complicated and messy ways stars and their planets form. Perhaps an unambiguous signal of B-mode polarization in the CMB will point us to a theory of quantized gravity. We all desperately hope that the dark matter particle will be found in the next ten years, or at least rule out that it cannot exist. We will have rich data lists of exoplanets to understand planetary evolution.

And so much more. Our science only grows in excitement and the pace of discovery.

I would argue however, that this decade is uniquely different from previous decades. *We are on the verge of the greatest discovery in science – the discovery of life elsewhere in the Universe.* This will be the discovery for all times. The discovery will touch all societies. It will have a revolutionary impact on theology and philosophy. Like the landing on the Moon, it will create a moment in time when we, as a species, unite across all borders and creeds. All humanity can look up into the sky, point to a star, and know that the star harbors a cousin planet filled with life. It will launch new directions of scientific research into biology, biophysics, non-equilibrium physical chemistry, astrophysics, atmospheric sciences, and so much more.

The single discovery of life outside the solar system will almost certainly mean that the Universe is teeming with life.

We must recognize that we are on the verge of this revolutionary epoch and that this science goal is like no other we have faced. And it is in the next decade that we will set down the direction we take to get to this discovery and even to achieve the detection of extraterrestrial life.

In this white paper, I am asking our astronomical community to recognize our time in history,

and to make the simple search for life our uniting science directive. We should simply state that in this decade, we will lead humanity on the greatest science quest ever. All the number one projects that we will select will still be in the report. But sitting above all these outstanding science goals, we need to unite behind this one overarching theme, to find life outside of Earth.

In saying this, I do not suggest that we not do all the other exciting things we will recommend. But we should unite as much of the science – observational, theoretical, and instrumental – into this single theme for our report.

I am an observational cosmologist, and the search for life is about as far away from my science as it could be. I used to joke to my exoplanet colleagues that I liked exploding stars because they incinerate all the silly little planets around them (which in detail is actually not true). But it is clear to me that we have in our hands the chance to make the final push to discover life elsewhere in the Universe in this decade. I believe that almost all astronomers believe this too. I also know that of all the scientific achievements we could make in astronomy, this is the one that more than any, will capture the imagination of the society that supports our science.

It should be our goal.

References

[1] Sagan, C., Thompson, W. Reid, Carlson, R., Gurnett, D., & Hord, C. 1993, *Nature*, **365**, 714.

[2] Mitchell, F. J., & Ellis, W. L. 1971, in *Proceedings of the Second Lunar Science Conference*,” (MIT Press), vol. 2, 2721. But see also Mennigmann, H.D. 1989, *Advances in Space Research*, **9**, 3.

