Infrared Thermal Remote Sensing to Detect Life-Sustaining Niches in Space

Peter A. Johnson[1,3]; John C. Johnson[1,2,3]; Svetozar Zirnov[1,2,3]; and Austin A. Mardon[1,3*]

[1]Faculty of Medicine and Dentistry, University of Alberta
[2]Faculty of Engineering, University of Alberta
[3]Antarctic Institute of Canada, 103, 11919-82 Str. NW, Edmonton, Alberta, Canada. T5B 2W4.

E-mail: mardon@ualberta.ca*
paj1@ualberta.ca
jcj2@ualberta.ca

ABSTRACT

The search for life on the surface of Mars may focus on the detection of waste byproducts and thermal biomarkers associated with the conversion/consumption of energy required by all known lifeforms. In this paper, the authors examine the potential and limitations of using thermal biomarkers in the search for extraterrestrial life forms.

(Keywords: life detection, extraterrestrial life, thermal detection, infrared detection, thermal biomarkers, remote sensing probes).

INTRODUCTION

All life consumes energy, which can become converted and result in the production of some form of waste byproduct. Every life form possesses a waste product removal or excretion mechanism to either emit or consume thermal energy. This makes it possible to detect signatures of life and locations, which are thermo-stable.

Currently, there is a lack of evidence for life on the surface of Mars suggesting life may have a specialized subsurface niche characterized by a microbial ecology. Finding a habitable environment depends on identifying these niches. In fact, excavation missions have yet to explore a large majority of planetary craters or dig underground and as such, suggesting the possibility an ecosystem for habitable living underneath Martian and lunar regolith [1].

Thermal Biomarker for Habitable Life

The metabolic reduction-oxidation reactions themselves involve formation of byproducts including heat, which could potentially be used in the detection of extant life and habitable niches to sustain human life.

Currently however, infrared thermal remote-sensing methods can miss subsurface and sub-regolith regions. Wynne and Titus suggest cave detection using thermal remote sensing on Earth and other planetary objects are limited by (1) capturing imagery in the appropriate thermal wavelength, (2) the size of cave opening vs. the sensor's spatial resolution, (3) the viewing angle of the platform in relation to the slope trajectory of the surface, (4) the strength of the thermal signal associated with the surface opening, and (5) the time of day and season of thermal image capture. This may well be extended to search for crater niches that support life.

Potential Methods for Searching

Based on these identified limitations, a method of searching must be able to overcome these technical and physical barriers. First, there is a need to use remote-sensing probes or excavating robot to identify such habitable regions beneath Martian regolith. Our group has previously identified elemental composition analysis and nano-scale vibration techniques for detecting micro-organisms, there are limitations when considering their use of remote sensing [2-3]. Additionally, aerial imaging using remote drones may miss craters and subsurface regions beneath regolith.

Using current technology, it is crucial to note there are conditions under which the emission and reflection wavelengths encounter interference from weathering as well as the vast and diverse geography and topology of Mars. Identifying stable thermal signal alone may be a motivating factor to search certain locations for the presence of craters.

An area of interest are the polar ice caps along with regions characterized by surface frost and water ice glaciers, particularly because the presence of water in itself, is known to be key to habitable life. Regions with a constant supply of energy and stable environmental conditions (i.e. absence of thermal fluctuations) would be ideal. Additionally, areas proximal to volcanic surfaces should be avoided especially in locations of active thermal fluctuation.

The heat of geothermal activity may also play a significant role in melting permafrost or other sub-surface sources of water for a subsurface microbial community, which can be beneficial for identifying a habitable site with access to water.

Limitations

The successful implementation of these searches and/or excavation systems incorporating these approaches requires an advanced technological development including probes, remote sensing systems and drones, which may be resource-exhaustive. Excavation has also yet to have been performed beneath Martian regolith. Moreover, the current body of evidence regarding thermal sensing limits the validation of these ideas and as such, the majority of evidence and knowledge remains hypothesis-based.

CONCLUSION

Thermal signatures can be used for the detection of subsurface and regolith regions of interest for habitable life. However, there are several limitations and limited evidence for its feasibility currently.

RESEARCH SUPPORT

This research was supported by the #RisingYouth initiative via the Government of Canada under the Canada Service Corps program and Antarctic Institute of Canada.

REFERENCES

1. Wynne, J. and T. Titus. 2008. "On Developing Thermal Cave Detection Techniques for Earth, the Moon, and Mars". *Earth Planet Sc Lett*. 272(1-2): 240–250.

2. Johnson, J.C., P.A. Johnson, and A.A. Mardon. 2019. "Soil Sampling with Nanoscale Vibration Sensors for On-Site Detection of Microorganisms". *Mars Extant Life: What's Next?* LPI Contrib. No. 2108: 5079.

3. Johnson, P.A., J.C. Johnson, and A.A. Mardon. 2020. "Remote Sensing Elemental Composition Analysis Technology for Analysis of Microorganisms In Outer Space". *Pacific Journal of Science and Technology*. 21(1):18-19.

SUGGESTED CITATION

Johnson, P.A., J.C. Johnson, S. Zirnov, and A.A. Mardon. 2020. "Infrared Thermal Remote Sensing to Detect Life-Sustaining Niches in Space". *Pacific Journal of Science and Technology*. 21(2):107-108.

Pacific Journal of Science and Technology