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Deep Space Communications With Extraterrestrials

Motivation

With only humans as an example of intelligent life, it cannot be helped that the search for intelligent extraterrestrials is anthropocentric. Humans associate intelligence with the ability to communicate. As a result, people have been turning the dial on their radios listening for an extraterrestrial signal. Radio astronomy now has the ability to listen to multiple channels at once going over the entire area of the sky but no radio signal has yet to be found. Assuming that extraterrestrial intelligence surpasses that of humans, the search needs to go beyond Radio Frequency (RF) communication by considering where future technology will take data transmission. One of the ways communication is being innovated is by using optics. As fiber-optic cables are welcomed into neighborhoods, Free-Space Optical (FSO) communication is to be embraced in space. If extraterrestrials already possess this technology, maybe traces of their optical communications can be found. There are ground optical telescopes such as the Automated Planet FInder being utilized by the Search for Extraterrestrial Intelligence (SETI) Institute but observing optical signals is difficult because their short wavelengths, unlike radio waves, can easily attenuate on their journey to Earth and in the Earth's atmosphere. However, as FSO systems advance, will it be possible to observe exterrestrial optical signals originating as far as Deep Space and then attempt to make contact if a signal is found?

Background[1,2,3]

FSO communication is more efficient than RF communication because FSO can transfer more data per time than RF. NASA's Deep Space Optical Communications (DSOC) project is currently working on two-way FSO communication to increase data transmission by 10 to 100 times faster than RF systems for future robotic and human Deep Space missions. These missions also require communication over distances larger than NASA's current capability without data loss. To communicate at further distances NASA's Laser Communications Relay Demonstration (LCRD) project will use the Tracking and Data Relay Satellite (TDRS) system to connect Optical Ground Stations (OGS) to space satellites that relay data using near-infrared and infrared lasers. From 2013 to 2014, NASA used the Lunar Laser Communications Demonstration (LLCD) to show that lasers can be used to send data to and from space that is faster and has a higher bandwidth than RF communication. However, NASA is also looking into combining RF and FSO systems with the integrated Radio and Optical Communication (iROC) project.

Research Proposal

I believe the DSOC and LCRD projects have the potential to benefit optical (and possibly radio) astronomy. Specifically, I would like to use these projects to expand SETI's search for extraterrestrial optical signals. Laser SETI, Optical SETI, and Breakthrough and Listen all have experience searching for engineered signals so they can collaborate with one another and work alongside NASA to develop space telescopes, determine where to look for signals, and process data. Also, if a signal is found, an attempt at contact can be made.

Methods

How to integrate optical space telescopes into the LCRD to search for Deep Space optical signals and potentially send a message to extraterrestrials:

1. Space Test Program (STP) satellites will carry LCRD technology[1]
2. Optical Space Telescopes
    a. LCRD payload's key components are an Optical Module or optical transceiver, Flight Modem that modifies signals, and a Controller Electronics Module.[1,2] This same technology can be put onto other STP satellites that connect to the relay system but instead of transmitting human communications it will be used to find optical signals. These STP satellites will also need to carry Photomultipliers or Charge-Coupled Devices (CCDs) and spectrographs.
    b. The telescopes can potentially be chosen to point at stars within 5 pc of the Sun, Main sequence and Giant Stars within 50 pc, galaxies, and exotica (where life is not expected to be found, such as brown dwarfs, asteroids, etc).[6]
3. TDRS will allow movement in the relay system so the objects of study can change throughout time.
4. OGS
    a. DSOC has plans to build two OGS, one in California and another in Hawaii. NASA also wants backup optical receivers to mitigate atmospherical challenges. To avoid costs, optical apertures can be added to the already existing DSN.[4,5] This placement is convenient if the LCRD project is extended to RF communication.
5. SETI@home algorithm for data processing can be used.
6. If a potentially engineered optical signal is found, multiple telescopes in the LCRD system can be directed to this location. Also, the DSOC's two-way communication system will allow for a signal to be sent back in hopes of making contact.

Impact

Why using developing technology to find extraterrestrial signals in Deep Space is important:

1. Searching for Extraterrestrial Life Development
    a. The current methods of searching for extraterrestrials have been exhausted. Continuing these methods of search means constantly having to take in enormous amounts of data that require a lot of processing power. Using a FSO relay system in Deep Space will invigorate the search for extraterrestrials by allowing the exploration of uncharted territory.
2. Optical Astronomy Development
    a. There will be an increase in data for optical astronomers.
3. Communications Development
    a. The LLCD project proved that FSO systems have great potential but a relay system into Deep Space requires innovation and precision. FSO technology presents challenges that are unique to optical waves that have not been encountered in RF systems, such as high-precision signal pointing and tracking.
4. Creates More Resources For SETI

a. A Deep Space FSO relay system will require a partnership between optical systems teams and NASA.

1 https://directory.eoportal.org/web/eoportal/satellite-missions/l/lcrd
2
https://dspace.mit.edu/bitstream/handle/1721.1/61673/Boroson-2009-The%20Lunar%20Laser%20Communications%20Demonstration%20%28LLCD%29.pdf?sequence=1&isAllowed=y
3 https://www.nasa.gov/mission_pages/tdm/dsoc/index.html
4 https://arc.aiaa.org/doi/10.2514/6.2018-2554
5 https://www.sciencedirect.com/science/article/abs/pii/S0030401817305813
6 https://arxiv.org/pdf/1701.06227.pdf