Advancing the Search for Extraterrestrial Intelligence

Statement of

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Chairman Babin, Ranking Member Edwards, Chairwoman Comstock, Ranking Member Lipinski, and esteemed Members of the Subcommittees, I am honored and pleased to have the opportunity to discuss current and upcoming research endeavors in the search for extraterrestrial intelligence (SETI).

I became involved with SETI research in 2000. As an undergraduate at UC Santa Cruz, I attended the first annual Astrobiology conference held at NASA Ames Research Center. I spent my first conference lunch sitting with a group of premiere SETI researchers. During lunch, these scientists hatched the design for an improved optical SETI experiment. I eagerly joined the collaboration and spent two years assembling and commissioning the instrument, as well as learning essential skills about astronomical instrumentation, engineering, and the science behind SETI. Only years later did I appreciate the uniqueness of this fortunate experience. Given the lack of sustained academic funds for SETI, few opportunities exist worldwide for researchers and students to engage actively in SETI. Yet, many people around the globe believe there is no single discovery which will more fundamentally change humankind's view of our place in the Universe than to discover extraterrestrial intelligence (ET).

Overview

A decade ago, humanity was only able to speculate on whether Earth-like planets were common in our Galaxy. Primarily due to NASA's successful Kepler Mission, we now know that *one in every five* Sun-like stars in our Galaxy harbors an Earth-like planet. There are roughly one trillion stars per Galaxy, and the Hubble Space Telescope has revealed that there are over 100 trillion galaxies in our observable universe. Given the plentitude of stars (roughly 10^{22}) available to host a terrestrial planet coupled with our own technological advances, the search for other intelligent life seems ever more promising.

We are in the midst of a dramatic paradigm shift. For thousands of years, humans have speculated on the uniqueness of our existence in the Universe. Now in the 21st century, we know that organic molecules are abundant in interstellar space; life on Earth exists in extreme conditions in every nook and cranny; and planets are common among stars. These recent discoveries greatly encourage our search for other life, and for intelligent life elsewhere in the Universe.

The Search for Extraterrestrial Intelligence (SETI) is the scientific pursuit of technological transmissions from other intelligent life in the Universe. In particular, SETI searches for electromagnetic radiation (Figure 1) purposely sent or accidentally leaked from advanced civilizations. Historically, we have based the type of SETI searches we conduct (specifically, which frequencies we examine) on our current communications technology and capabilities. Until recently, radio and microwave wavelengths have dominated how humans have communicated over long distances on Earth and even with our spacecraft.

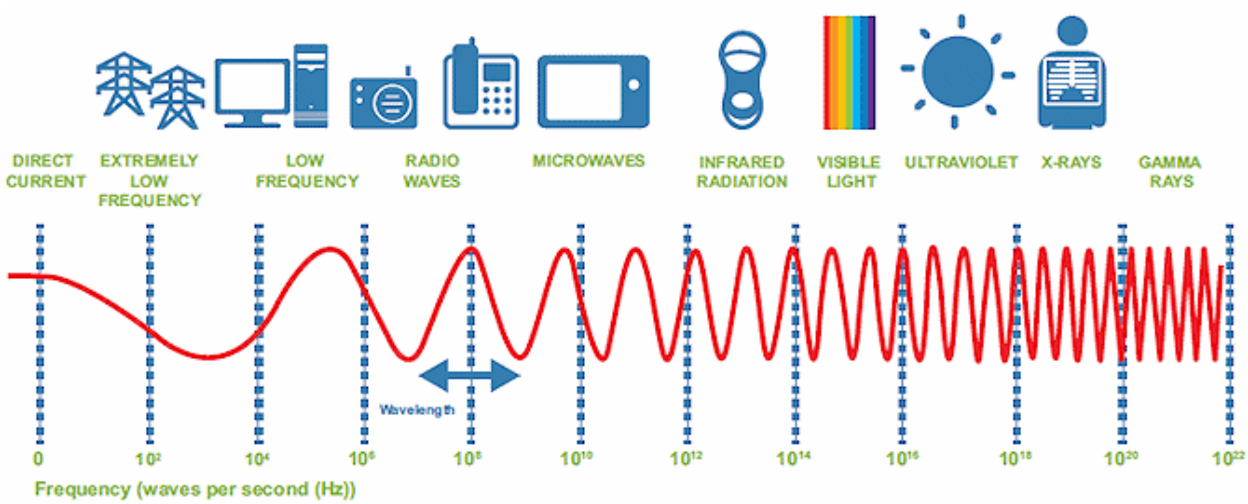

Figure 1*: The electromagnetic spectrum and its constituent wavelengths of light. SETI has predominantly been applied at regions of the EM spectrum that humans use for telecommunications. (Photo Credit: ISP review).*

Radio SETI

The first SETI experiment commenced over 55 years ago with a radio search by Frank Drake using the National Radio Astronomy Observatory Green Bank Telescope. Radio wavelengths offer distinct advantages for interstellar communication. Generating radio waves is relatively inexpensive because they are low energy, and radio waves can easily traverse through the interstellar medium without being absorbed by intervening dust and gas. However, sizes of the transmitting and receiving antennae must be relatively large (e.g., >> 10 meters) to send and receive distant signals, and the signal frequency needs to be somehow known for the receiver to detect it. In fact, how we communicate with current satellite missions in the Solar System, such as Juno, is greatly limited by the size and weight of the transmitter and receiver aboard the spacecraft.

Since this initial experiment, SETI has been predominantly conducted at radio wavelengths. Radio searches must make trade-offs between searching for the signal among many frequencies, the sensitivity with which they can detect a signal, and the expanse of sky covered in the search. Usually, if you scan many radio frequencies at great sensitivity, you are limited to a targeted search where you can "listen" to only one star at a time. SETI searches that cover large areas of the sky rather than pointing at a particular star have been conducted, albeit at the price of decreased sensitivity and number of frequencies covered.

Numerous SETI programs have made use of the largest US radio telescopes, the Green Bank Telescope and the Arecibo Observatory. These searches have been complemented by other efforts using international facilities such as the Low Frequency Array in Europe and the Murchison Widefield Array in Australia. Still, SETI radio searches have barely scratched the surface for detecting faint interstellar signals. Our current searches to date have been likened to catching fish in all the worlds' oceans by gathering a single scoop of water in a pint glass.

Thanks to continual improvements in instrumentation and technology, the coming years promise new SETI radio searches with increased sensitivity at a greater number of frequencies to detect fainter signals with better sky coverage.

Breakthrough Listen, a ten-year $100 million SETI initiative launched by philanthropist Yuri Milner, began operations in January 2016. This program supports both radio and optical SETI. *Breakthrough Listen* is using the Green Bank Telescope in West Virginia and Parkes Radio Telescope in Australia to simultaneously cover both hemispheres, and conduct a radio SETI search 50 times more sensitive with state-of-the-art electronics and detectors. It will also cover 10 times more sky than previous radio searches. *Breakthrough Listen* supports an optical SETI program that seeks laser signals in the optical wavelength regime using spectra from the Automatic Planet Finder at Lick Observatory (see next section).

Just this month, July 2016, the Chinese have finished final assembly of the world's largest radio dish that will be competitive with Arecibo Observatory (Figure 2). Construction of the 500-meter dish was completed in 5 ½ years for $180 million. Chinese scientists have slated this dish to be used for a very sensitive SETI program that promises to be more sensitive than previous SETI searches, thus challenging US leadership in this field.

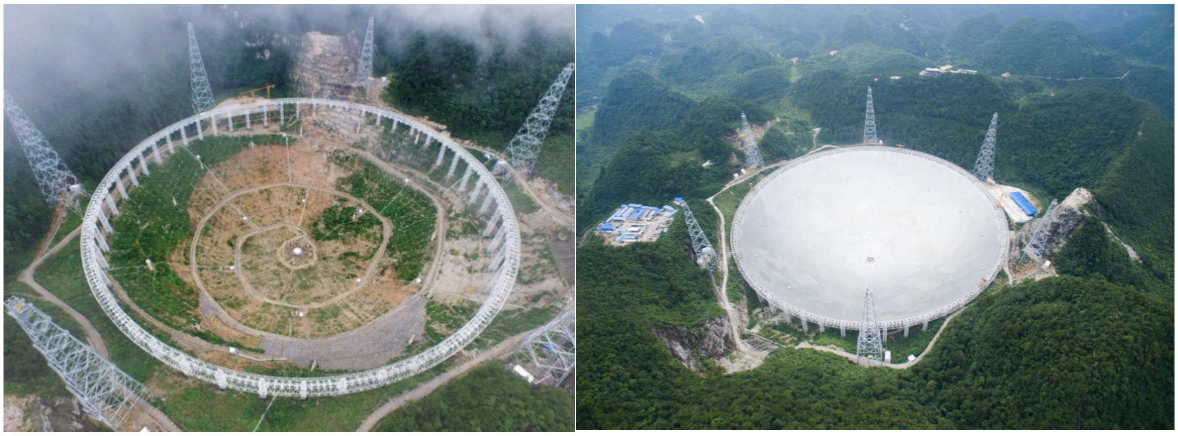

Figure 2*: (LEFT) Five-hundred-meter Aperture Spherical Telescope (FAST) under construction in Guizhou Province in 2011. (RIGHT) Completed FAST telescope photographed in July 2016 with all panels installed. FAST operation is scheduled for September 2016, with one of the scientific goals to conduct a sensitive SETI program. (Photo Credit: News.cn).*

Optical and Infrared SETI

The radio regime is just one small portion of the electromagnetic spectrum. It has been suggested for decades that there may be more favorable wavelengths at which to conduct our SETI search. Soon after the invention of the laser (or "maser") in 1959, physicist-inventor Charles Townes suggested that lasers would be one of the best means to communicate on our planet, as well as with spacecraft within the Solar System, and especially across interstellar distances.

The discovery of laser technology opened a new realm of communication, and offered several advantages over radio. Lasers can be narrowly beamed, thus transmitting power efficiently. Additionally, a laser beam can be packed with more information (i.e., energy per bit). Laser communication is an excellent choice for transmission across large distances to a specific target. Laser communication on Earth is advantageous for these same reasons (see Figure 3).

A significant advantage of transmitting lasers across large interstellar distances, particularly at optical and infrared wavelengths, is the ability to generate a signal which outshines a planet's host star by many orders of magnitude. Lawrence Livermore National Laboratory is capable of generating peak power of a petawatt (10^{15} W) during very short duration laser pulses. Such pulses, when concentrated into a narrow beam by a large telescope, are so powerful that for a brief time they would far outshine *all* of the light from our sun as seen by an extraterrestrial looking our way. Using today's laser technology, humans have the capability to transmit a signal that would easily be detectable with only meter-class telescopes more than 1,000 light years from Earth, a distance which includes more than a million stars. Realizing this, the SETI community has operated several modest laser SETI programs at optical wavelengths for the last two decades.

These optical searches have focused either on detecting pulsed or continuous laser signals.

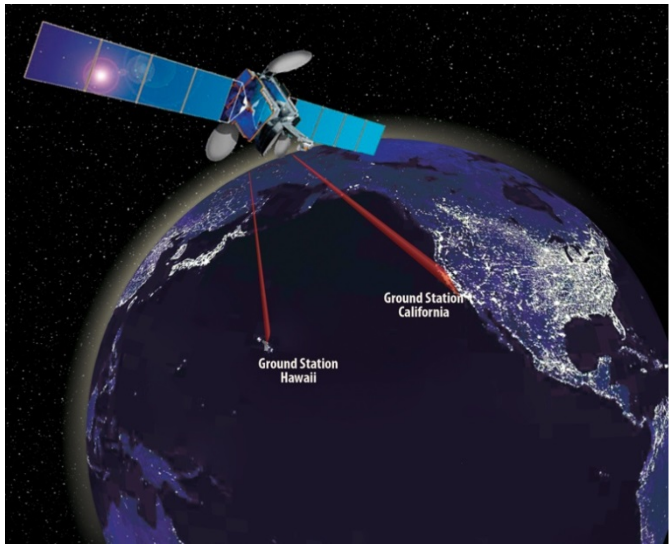

***Figure 3**: Conceptual drawing of NASA Laser Communications Relay Demonstration (LCRD) mission that uses optical lasers to improve data speeds and bandwidths by a factor 10 compared to traditional radio transmitters. Using lasers across interstellar distances would benefit similarly, with a boost of information per energy sent. (Photo Credit: NASA).*

Fast pulsed laser signals (nanosecond or shorter) have the advantage of being distinguishable from other background signals, including terrestrial, atmospheric, and as far as we know, astrophysical phenomena. Although we have no convincing evidence that any natural phenomena will produce a nanosecond or shorter signal at visible or infrared wavelengths, we now have the unique ability to study exotic astrophysical sources like black holes and pulsars in this unexplored frequency and time regime. Such brief pulses would be a particularly distinctive beacon for any civilization wishing to make contact, but *any* such brief signal we detect will be extremely interesting.

On the receiving end, a pulsed optical laser signal has the convenience of being bright even if the frequency of the narrow laser line is not known *a priori*. Constructing an optical SETI experiment is relatively inexpensive compared to radio searches, and can operate on smaller, more economical telescope facilities. Even ground-based gamma-ray telescopes which use fast optical detectors have been cleverly modified to carry out occasional optical SETI searches. A group at Harvard has constructed a dedicated optical SETI experiment to scan large areas of the sky for pulsed laser signals. Our group, in collaboration with Berkeley SETI Research Science Center, has constructed optical SETI instruments at Lick and Leuschner Observatories. Since 2000 we have carried out a targeted search of over 10,000 nearby stars with these instruments. The Lick Observatory instrument was even used for monitoring NASA's Deep Impact satellite slamming into Comet Tempel 1.

In parallel, a team from Berkeley has carried out continuous laser signal searches with the W. M. Keck Observatory using data obtained since 1997. Previous measurements of nearby stars taken with high-resolution optical spectrographs were scanned for any unusual signatures of lasers. Spectrograph searches for a continuous laser signal achieve very high sensitivity and would be able to detect a relatively weak signal, but the required observing time per star is high. An all-sky search with this technique is beyond our reach with current spectrographs, and this type of search, while entirely worthwhile, is less efficient in covering large areas of the sky than pulsed laser SETI experiments.

Until recently, most laser SETI searches have focused on receivers that could detect optical wavelengths of light, because available detectors were sufficiently advanced and sensitive. However, sending a laser signal in the infrared is advantageous because the light is less diminished by intervening dust and gas. A laser signal propagating in the near-infrared rather than optical ("visible") light through the Galactic plane would be far less diminished, by several orders of magnitude. In addition, infrared suffers less from interference by background light from our galaxy. The telecommunications and defense industries have rapidly improved the performance and sensitivity of infrared detectors, which has only recently made an infrared pulsed laser SETI search possible.

Beginning in 2012, our team has procured uniquely capable state-of-the-art infrared detectors, and designed and constructed the first near-infrared pulsed laser SETI experiment. This instrument was commissioned at Lick Observatory in the spring of 2015 (Figure 4). We are now operating in full campaign mode, targeting a range of nearby stars and unusual astrophysical sources, as well as distant galaxies. Our program excels in training next generation scientists while engaging them in active SETI research. This small and privately funded near-infrared SETI program has already involved three undergraduates, one graduate student, and one postdoctoral fellow. Superb training is offered in general astronomical instrumentation and observations, as well as unique SETI research. This system is the first of its kind and will evolve as newer, more sensitive detectors become available. Although our current campaign is a targeted search there is significant interest to extend this experiment to larger areas of the sky.

Figure 4*: (LEFT) The near-infrared SETI instrument installed at Lick Observatory, California has been in full operation since March 2015. (RIGHT) UC San Diego undergraduate students Melisa Tallis and Andres Duenas discuss results with Dr. Jérôme Maire, Dunlap Postdoctoral Fellow and near-infrared SETI team member. This instrument was constructed and will be used by multiple undergraduate and graduate students. (Photo Credits: Laurie Hatch).*

Making use of the latest technological advancements in electronics, computing, and instrumentation is essential for advancing SETI efforts. Our group is now collaborating with Harvard and Berkeley to design both an *all-sky all-the-time* optical pulse SETI system, in addition to a wide field of view infrared pulsed SETI system. These new programs will be seeking funds to build dedicated telescopes and new instrumentation that will make use of the most advanced detectors. Pulsed laser SETI instruments are relatively cost effective, typically \$0.2-1 million, and will advance SETI in completely new directions.

Concluding Remarks

Humans have been using radio communication for barely over 100 years and laser communication for the last 30 years. This is only a sliver of time compared to the lifetime of human civilization (> 10,000 years) and life on our planet (> 3 billion years). Technology available today dictates the types of SETI searches we currently conduct, but many creative SETI programs await to explore other portions of the electromagnetic spectrum. Theoretical astrophysicists contemplate possibilities of communication with neutrinos or even gravity waves. If we hope to answer the question that has intrigued us for centuries (*Are we alone*?), we need the best and brightest scientists creating new methods for SETI.

Enthusiasm is ever-increasing for SETI, but resources are scarce. A huge disparity exists between the enormous public and scientific interest in whether we are unique in the Universe, and resources that are actually allocated to SETI research. Since 1977, the rate of refereed papers about SETI (Figure 5) is roughly flat, with the number of worldwide dedicated SETI researchers level at about a mere two dozen. With few exceptions, SETI researchers must derive salaries and academic advancement from other sources, while maintaining their SETI research on the side simply because they believe it is important and worth doing. A large fraction of SETI research is funded by private donors and foundations. Lack of a steady stream of support discourages the best and brightest young scientists from moving into this area of study. Our team and other SETI collaborations are making considerable efforts to involve undergraduate and graduate students in SETI research. However, with unreliable funding and only a handful of SETI researchers at academic institutions, the number of students trained remains small.

Our new understanding that *planets are plentiful* is rippling through the astrobiology and astronomical communities. We are bound to wonder who and what might occupy these planets. New initiatives and innovative advances in instrumentation should allow SETI to flourish through the next decade. In addition, there will likely be substantial international competition. Without sustained and supportive programs for SETI research and training, the US community risks being left on the sidelines. Even with the much needed catalyst of funds recently contributed by private foundations, leveraging both private and public sector funding is vital for creating a sustainable and growing community of SETI researchers.

Two decades ago, unknowns about astrobiology and the likelihood of extrasolar planets discouraged government funding for SETI. Today, thanks to successful NASA, NSF, and nationally supported missions and investigations, former concerns about the value of SETI research no longer apply. While there is much to learn about astrobiology and exoplanets, the relevance for advancing SETI is stronger today than ever before in the history of humankind.

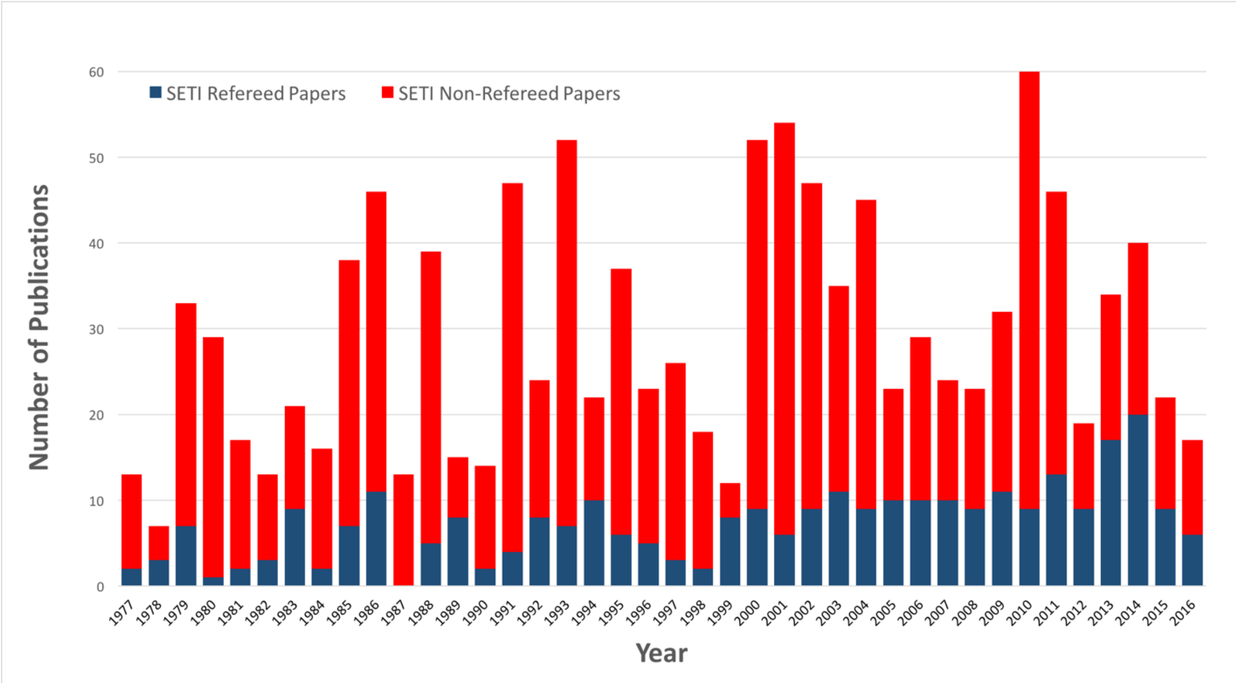

Figure 5*: The number of scientific publications on SETI research for the last 39 years. (Data collected from the NASA Astrophysics Data System).*

Dr. Shelley A. Wright

Short Narrative Biography

Shelley Wright is an Assistant Professor at the University of California, San Diego in the Department of Physics and the Center for Astrophysics and Space Sciences. Wright has extensive experience working with optical and infrared instrumentation, with a particular focus on imaging cameras and spectrographs that operate behind Adaptive Optics systems on large telescopes. Her observational research focuses on galaxy and supermassive black hole formation and evolution across cosmic time. Wright currently serves as Project Scientist for the first light instrument (IRIS) for the future Thirty Meter Telescope.

Throughout her career, Wright has been an active collaborator in optical and near-infrared SETI instrument development and research. Wright has been involved with design, construction, and implementation of pulsed laser SETI instruments. Wright was a critical team member that developed one of the most advanced optical SETI experiments, and is now Principal Investigator of the first near-infrared SETI instrument and survey.

Wright received her B.S. in Physics at University of California, Santa Cruz in 2001. She served as support astronomer at the Isaac Newton Group of Telescopes on La Palma, then continued her graduate studies at University of California, Los Angeles (UCLA) in the Physics & Astronomy Department. Wright conducted her graduate research on Keck Observatory instrumentation and observations while working in the Infrared Astrophysical Laboratory at UCLA, receiving her Ph.D. in 2008. Wright then served as a postdoctoral researcher at University of California, Irvine in 2008-2009 working on instrumentation development and scientific studies for the Thirty Meter Telescope. In 2009, she received a NASA Hubble Postdoctoral Fellowship and the University of California President's Fellowship at University of California, Berkeley for her observational research program on distant galaxies. Prior to her arrival at UC San Diego, Wright was Assistant Professor at the University of Toronto in the Department of Astronomy & Astrophysics and the Dunlap Institute for Astronomy & Astrophysics from 2012-2014. Wright was recently named a 2016 Hellman Fellow at UC San Diego.