INTERSTELLAR FRONTIERS 2024

BREAKTHROUGH INITIATIVES

SKAO

Invited Talks

"The Next Decade of Radio Technosignature Searches"

Tony Beasley - NRAO

Major new instruments under construction or in planning will soon offer powerful new tools to the SETI community, including the next-generation Very Large Array planned for the northern hemisphere. Sensitive and flexible commensal and/or pointed observations with ngVLA, processed with leading-edge digital backends and new algorithms, will place important new limits on technosignature detections in our sector of the Galaxy. Some of these approaches are being pioneered today via the SI COSMIC system. Additional opportunities (e.g. the shielded zone of the Moon) and challenges (e.g. satellite constellation RFI) will also be seen in the coming decade. In this talk I will review current plans for NRAO's support of the research community's radio technosignature efforts.

The SKA and prospects for SETI and/or astrobiology

Jimi Green - SKAO

I will provide an update on the Square Kilometre Array Observatory (SKAO), the fundamental science drivers, including searches for technosignatures and astrobiology, as well as the expected design, scope and timeline of the project. I'll outline the plan for the Science Operations team within the broader observatory, the breakdown between commissioning, verification and operations, and highlight pathways for involvement (from students through science engagement to employment opportunities). I will then provide an update on the progress of the growing SKAO entity across the three sites (Australia, South Africa and the UK), including the Science and Engineering Operations Centres, and details of the roll out plan of the SKA-Low and SKA-MID telescopes. I will also provide an update on the third Aperture Array Verification System, or AAVS3, which has been deployed on the site of the SKA in Australia, Inyarrimanha Ilgari Bundara, the CSIRO Murchison Radio-astronomy Observatory, and is a means to end-to-end test the proposed antennas and station layout of the SKA-Low telescope. Across the presentation, I will aim to provide the background, and identify potential operational opportunities, to enable further discussion of SETI and astrobiology with the SKA.

"False positives in SETI from radio stars and exoplanets"

Joe Callingham – ASTRON / Leiden

Many searches for extraterrestrial intelligence presume that a clear signature is a drifting, narrowband radio burst. Such a presumption is predicated on the fact that natural astrophysical sources can not produce such characteristic emission. In this talk, I will discuss how our domain knowledge of radio stars and exoplanets is far less complete than often conjectured. I will highlight how radio emission from a radio star, passed through a simple signal-to-noise filter, can present as a narrowband drifting signal. I will conclude by detailing how important it is to fill our domain knowledge about natural radio emission processes on a range of stellar spectral types if we want to be confident in the detection of an extraterrestrial intelligence radio signal.

"Fast transients pipelines and SETI (and an all-sky monitor)"

Keith Bannister - CSIRO

The phenomenon of fast radio bursts has driven a boom new instrumentation, algorithms, software and hardware. I will describe the CRAFT coherent upgrade project (CRACO) and a few of the innovations made during that project. In particular, much of the CRACO processing is performed in FPGAs programmed in a traditional software language (C/C++). I will also describe a new algorithm, the Efficient Summation of Arbitrary Masks (ESAM) which is optimally efficient and accurate for use for both FRB searches and SETI searches. I will also describe a new all-sky monitor at 700 MHz which is currently under development, and which we hope to build over the next few years.

Western Australia's connection to the beginnings of life on Earth and the search for life on Mars

Martin Van Kranendonk – Curtin University

For decades, deep sea hydrothermal vents have been a preferred setting for the Origin of Life, but "The Water Problem" relating to organic molecule polymerization, the diluting propensity and salty nature of oceans, along with other crucial factors, suggest that a terrestrial hot spring field with the capacity for wet–dry cycling and element concentration may represent a more likely setting.

Results from a decades-long research program of the microbially-inhabited 3.5 billion-year-old Dresser Formation, Pilbara Craton (Western Australia), show that hydrothermal veins and terrestrial hot spring pools in this ancient system concentrated all of the essential elements required for prebiotic chemistry (including B, Zn, Mn, and K, in addition to C, H, N, O, P, and S).
Translated to early Earth, wet–dry cycling across a range of temporal scales, differential elemental concentration, and information exchange between multiple, geochemically-distinct, springs would lead to "innovation pools" in which complex organic molecules, lipid vesicles, and the systems chemistry required to get life started would develop. Adaptation of life to the salty oceans came later.

An inference of this developing paradigm is that hot spring deposits could be the best target to search for a second genesis on Mars. This is because hot spring deposits represent the "first and last outposts" of primitive life and preserve textural and molecular evidence for life back for 3.5 billion years on Earth.

Nodular hot spring silica sinter deposits with digitate protrusions discovered by the Spirit Rover at Columbia Hills, Mars, are morphologically analogues to hot spring deposits from El Tatio, Chile, where the digitate protrusions relate to microbial activity, raising the possibility that we may have observed a potential biosignature on Mars. The Columbia Hills deposits therefore represent a tantalizing astrobiological target and form the basis of a new, light-and-nimble sample return Mars mission concept called LifeSpringsMars, which can be completed with a single launch from Earth.

"Advancing a Systems Framework to link astronomy, astrobiology and geology"

Penny King - ANU

Systems frameworks aim to simplify complex problems by delineating the interactions between mass, time, energy and rarely, momentum. For example, Earth's water cycle describes how changes in energy distribute masses of water between different reservoirs (e.g., atmosphere, ocean, rivers) within the envelope of Earth (a closed system). The advantage of such a framework is that numerical models can be used to describe the mass of each reservoir, each flux = mass/time (e.g.,

kg/yr evaporation) and this provides insight into feedbacks and the response of the system to perturbations (e.g., climate change). Systems frameworks are commonly used in geology and astrobiology to model the cycling of the chemical elements that make up life (C, H, N, O, P, S), and/or nutrients, and/or energy.

Here, we seek to link some of these approaches to expanding astronomical observations of exoplanets and their parent stars; including, their mass and radius; together with either measured or calculated stellar composition; temperature and atmospheric composition. We start with an assumption that our solar system – not solely Earth – can be used as a model for the processes within other stellar systems. This approach, combined with assumptions, will be explored in the presentation for three examples. 1) We previously predicted the temperature, surface pressure and composition of some exoplanetary atmospheres assuming only abiotic processes (McIntyre et al., 2023, MNRAS). 2) We use potential star compositions to calculate the crustal composition of surrounding rocky exoplanets and, assuming that water is added to the surface, we calculate initial surface solution compositions to evaluate if these are amenable to life. 3) We investigate examples of perturbations in our solar system that have influenced fluxes and reservoirs over time to illustrate feedbacks and the limitations of systems frameworks.

In summary, advancing a systems framework provides a useful link between astronomy, astrobiology, and geology; however, more research is needed to better constrain most stellar systems. Measurements are needed of host stellar compositions and of features affecting radiation output (e.g., rotation, storms). Data are scarce on exoplanets' obliquity, inclination, planetary rotation rates, thermal phase curves, atmospheric gas and aerosol compositions, atmospheric escape/gas removal as solids, greenhouse processes, and albedo. Finally, advances are needed to 'scale up' signatures of abiotic and biotic processes used in geology and astrobiology, to the length and time scales of astronomical observations.

Contributed Talks

"COSMIC: All-sky techno-signature search with a commensal instrument"

Chenoa Tremblay - SETI Institute

The search for intelligence outside our solar system is 60 years old and we have recently moved the search from 1000 objects in a 5-year observational program to over 1 million objects per year. This is made possible thanks to the new Commensal Open-Source Multimode Interferometer Cluster or COSMIC backend system on the VLA. The COSMIC compute cluster receives a copy of the VLA data streams after digitization and we are utilizing an ethernet-based system to record, channelize, correlate, and beamform the data. The initial goal of the system is to process data simultaneously along with the VLA all-sky survey (VLASS) to complete the largest, most sensitive, search for the existence of extraterrestrial intelligence (SETI). COSMIC is designed to ingest the data at any observing frequency and search with time resolutions between 0.1 to 5 seconds and frequency resolutions between 0.2 and 10 Hz for signals of unknown origin. Any potentially interesting signals will trigger small chunks of voltage data to be dumped onto the disk for further investigation. In this talk, we will discuss the history of SETI and why this system is important, system design, flexibility, initial goals, and the potential for other guest science projects proposed by the astronomy community.

"Searching for Intelligent Life in Gravitational Wave Signals"

Luke Sellers - Applied Physics, UCLA

LIGO's ability to detect gravitational waves (GWs) from astrophysical sources, such as binary black hole mergers, also provides the potential to detect extraterrestrial mega-technology, such as Rapid and/or Massive Accelerating spacecraft (RAMAcraft). We discuss how LIGO is sensitive to RAMAcraft of 1 Jupiter mass accelerating to a fraction of the speed of light (e.g. 30%) around our Galaxy or a Moon mass within our solar neighborhood. Moreover, we will be able to probe the entire Local Group and beyond with upcoming detectors such as DECIGO or BBO. We calculate the waveforms for linearly accelerating RAMAcraft in a form suitable for LIGO, Virgo, and KAGRA searches and provide the range for a variety of masses and accelerations. While existing SETI searches can probe on the order of ten thousand stars for human-scale technology (e.g. radio waves), LIGO can probe all stars in the Milky Way for RAMAcraft. We therefore expect that the current and upcoming GW detectors will soon become an excellent complement to the existing SETI efforts.

"SETI in the Radio Image Plane"

Joe Bright - University of Oxford

Interferometric SETI observations offer several advantages over the single-dish searches that have traditionally dominated technosignature research, including the ability to form multiple beams with high spatial resolution, and to more confidently reject radio frequency interference (RFI). This transition has been driven primarily by an increase in our ability to process the vast data rates produced by large antenna arrays and has enabled innovative commensal observing systems such as COSMIC on the VLA and BLUSE on MeerKAT, as well as dedicated SETI instruments such as the Allen Telescope Array. These systems are capable of recording raw antenna voltages to disk around signals of interest (found by Doppler drifting signal search algorithms), allowing for arbitrary signal

analysis (including correlation) to be performed offline. While it is currently infeasible to perform high-time and frequency resolution image searches across the entire observing bandwidth, offline correlation and imaging of the raw data corresponding to signals of interest opens a new avenue for signal validation and RFI rejection. I will demonstrate early results from efforts to image offline correlated data from the ATA, COSMIC, and MeerKAT, and discuss the benefits for SETI science as well as in the broader field of radio transients.

"High Precision Astrometry: Not Just for Exoplanets - Recovering Properties of Host Stars and the Impacts on their Harboured Planet(s)"

Conaire Deagan - University of New South Wales

Significant interest in the SETI community revolves around the Alpha Centauri star system due to its proximity and similarities to our solar system. One upcoming mission - the TOLIMAN space telescope - is designed with innovative optics to achieve high-precision astrometry to detect the presence of an Earth-twin around either Alpha Cen A or B. This level of precision - better than 1 micro arc-second - has opened new opportunities in stellar physics. This presentation demonstrates the feasibility of using TOLIMAN or other long-term, high-precision astrometric missions to monitor stellar activity. By detecting magnetic surface features, such as star spots, we can infer the properties of the host stars. These properties include relative inclination, magnitude and frequency of star-spots, differential rotation curves, and potentially the presence (or absence) of a Sun-like dynamo. These insights will provide information regarding the stellar environment and habitability of any exoplanets present. Understanding the host star in detail is crucial, as things such as the stellar wind, the frequency and intensity of stellar flares, and the topology of the stellar magnetosphere directly impact the sustainability of biospheres in the surrounding environment.

"Project Phoenix at Parkes"

Phil Edwards - CSIRO

The SETI institute used the Parkes 64m radio-telescope (now known as Murriyang) between January and June 1995 to conduct a SETI search of around 200 stars in the frequency range 1200 to 3000 MHz. This talk will review Project Phoenix, including the reasons why Parkes was chosen, how the observations were conducted, and the results obtained.

"Prospects for VLBI Technosignature Searches"

Chris Phillips -CSIRO

Traditional technosignature searches rely on characterising the Doppler Shift because of the expected relative motion between the earth (orbiting the sun) and an extra-terrestrial source orbiting its star. Local RFI would be expected to have little to no Doppler shift, while a satellite or aircraft will have a significantly different Doppler signature to a transmitter in orbit around a distant star. Technosignature search algorithms sift through the millions of detected narrowband signals rejecting any with Doppler behaviour that does not match an expected technosignature signal. This approach is not perfect, as is evident in "Breakthrough Listen Candidate 1" (BLC1). The Parkes technosignature survey, funded by the Breakthrough Foundation, found a candidate that mimicked a technosignature signal and passed the standard filters[1]. However further investigation concluded the signal was a frequency drifting local RFI signal.

A much better approach is to use multiple telescopes as an interferometric array. The amplitude of the visibility gives the power of the signal, while the phase gives information on the direction (and distance if it is close) of the received signal. The Allan Telescope Array is such an array, but the baselines are relatively short. Very Long Baseline Interferometry (VLBI) is a much better approach. In this talk I will outline the advantages of using VLBI for technosignature searches and argue that any SETI candidate detected using VLBI techniques will have much stronger confidence for being real than is possible with any single dish or connected element instruments.

"All-sky transient monitors - earth and moon"

Ron Ekers - CSIRO/Curtin

OSS (Omni-directional SETI System) is a potentially rewarding but unexplored search domain. New and innovative phased array technology developments now make it practical to construct relatively sensitive all-sky transient monitors. I will describe how the new technology developments could be used for both terrestrial and lunar far-side implementations. The lunar far side may be the only way to essentially eliminate the challenge of interference from terrestrial intelligence (TI).
In contrast to many SETI experiments, an all-sky monitor will have a broad impact on radio surveys for naturally generated astronomical transients, including FRBs, pulsars, magnetars and gravitational wave events. These possibilities will be summarised but are not the focus of the talk. However, they may herald the beginning of a new era in which our challenge is to separate naturally occurring events from those controlled by ETI.

"Dipping SETI toes into unchartered cosmic waters"

Michael Garrett - University of Manchester & Leiden

Most SETI radio surveys have observed in a fairly narrow frequency range - typically between 1-5 GHz (30-6cm). This reflects the good characteristics of radio propagation through the Earth's atmosphere in this part of the radio spectrum and the low sky-background noise. As a result, many large and sensitive radio telescopes (e.g. GBT, Parkes, MeerKAT) function optimally at these frequencies. Over the last decade, observations made by the MWA and more recently LOFAR have extended SETI surveys down to 100 MHz. Plans to locate a SETI-capable instrument on the far side of the Moon can further extend SETI surveys to below the ionospheric cut-off (~15 MHz).
Until recently, the mm and sub-mm parts of the radio spectrum have been largely ignored by SETI. Of course, there are good reasons for this, the background sky noise increases due to the CMBR and thermal emission from dust, and the propagation of radio waves through the troposphere is subject to significant absorption and coherency limitations. However, the great scientific success of interferometers like ALMA and NOEMI demonstrates that observations can be made at these frequencies, and SETI needs to consider how it can open up this new window for techno-signature research. We are trying to characterise the mm/sub-mm sky for SETI, with consideration of the complex molecular emission present in this part of the radio spectrum, using theoretical line predictors and GBT observations. We will present some of the special challenges of doing SETI at mm-wavelengths, and our plans to exploit the ALMA archive and the telescope's natural field of view in combination with Gaia identifications.

In addition, we are conducting a techno-signature search for Kardashev Type III civilisations in the Mid-IR using the LOw-Frequency ARray (LOFAR) Two-metre Sky Survey (LoTSS) and the value-added catalogue that includes source identifications from the WISE all-sky surveys at 3.4, 4.6, 12 and 22 μm, in addition to redshift information. We are looking for Type III candidates that are optically faint but anomalously bright in the near/mid IR. We previously demonstrated that it was possible to eliminate many false positives using the IR-radio correlation to break the degeneracy between

waste heat from Type III civilizations and natural star formation processes, and we're extending this approach to include the extended DR2 archive. We will discuss the nature of our candidates and place limits on the detection of Type IIIs using this particular method.

Mike Garrett, Louisa Mason, Tongtian Ren, Andrew Siemion & Hongying Chen.

"A Search for Periodic Technosignatures in the Parkes Southern Sky Survey Data"

Yuta Shiohira (he/him) - Kumamoto University

In terms of transmission power efficiency, periodic pulse signals are considered one of the promising targets in the radio search for extraterrestrial intelligence. In this presentation, we report the first search results for such signals from the Parkes Southern Pulsar Survey. This survey was carried out by the Parkes Telescope at a centre frequency of 436 MHz with a bandwidth of 32 MHz, and it covered the entire southern sky that was visible by the telescope. We searched for pulsed signals with periods between 3 and 56 seconds by comparing the data from multiple sky locations using the BLIPSS software package, which is based on the Fast Folding Algorithm (FFA). However, we detected no such signals. In this presentation, we discuss the evaluation of the search performance and the constraints on the number of extraterrestrial transmitters.

"The ongoing search for radio emissions from exoplanets"

Jake D. Turner (he/him) - Cornell University

One of the most important properties of exoplanets has not yet been directly detected despite decades of searching: the presence of a magnetic field. Observations of an exoplanet's magnetic field would yield constraints on its planetary properties that are difficult to study, such as its interior structure, atmospheric dynamics and escape, habitability, and any star-planet interactions. Observing planetary auroral radio emission is the most promising method to detect exoplanetary magnetic fields.

In this talk, I will present our large ongoing survey utilizing many different low-frequency telescopes to search for radio emissions from dozens of ideal candidates. First, I will discuss our recent study of the Tau Bootis exoplanetary system where we have the first possible detection of an exoplanet in the radio using LOFAR (Turner et al. 2021). If this detection is confirmed it will place important constraints on dynamo theory, comparative planetology, and exoplanetary science in general. Second, I will discuss the synergies between auroral radio searches and canonical SETI radio searches. Many lessons can be shared between the two fields. Finally, I will briefly highlight the promising landscape of studying exoplanets on the radio in the coming decades with future radio telescopes on the ground and the Moon.

"All-sky searches for FRBs and Technosignatures with SKA-Low stations"

Marcin Sokolowski - Curtin University

Hundreds of Fast Radio Bursts (FRBs) detected by CHIME down to 400 MHz and several detections at even lower frequencies by LOFAR and other telescopes confirm that at least some FRBs can be detected at frequencies below 350 MHz. Extrapolations of FRB rates measured at higher frequencies

show that a single station of the low-frequency Square Kilometre Array (SKA-Low) is sufficiently sensitive to detect even hundreds of FRBs per year using all-sky imaging capability. Additionally, such a system used in high-frequency resolution mode enables an unprecedented all-sky survey for technosignatures. A high time/frequency resolution all-sky monitoring system implemented on SKA-Low stations will open a new parameter space for FRB and SETI searches in terms of frequency, southern sky coverage, and enormous instantaneous field of view. I will discuss the idea and present our efforts toward implementing such a system on existing and future SKA-Low stations.

"Simultaneous multiple beam-forming approaches for lunar and terrestrial all-sky monitors"

Paul Roberts - CSIRO

Forming multiple simultaneous beams suitable for a scientifically useful phased array-based all-sky survey instrument presents many challenges, whether terrestrial or lunar-based. As the bandwidth, number of receptor elements, and number of beams increase, and the power budget decreases, this becomes ever more difficult. I will examine some of the approaches available for multiple beam simultaneous beamforming in this context. Given the unique properties and constraints of our particular use case, I will suggest that a hybrid solution based on a combination of analog and digital approaches could provide a practical and realizable solution for an instrument of this type.

"SETI@home Candidate Selection and Observations of the Best 100 Candidates"

Dan Werthimer - UC Berkeley

I'll review several optical and radio SETI projects that we are working on, but this talk will concentrate on candidates from the SETI@home project.
The SETI@home commensal sky survey ran for 20 years at Arecibo Observatory. SETI@home is Earth's most sensitive SETI sky survey, thanks to the millions of SETI@home volunteers who formed one of our planet's most powerful supercomputers to search for a plethora of signal types using sensitive coherent integration techniques (which require immense computing). Most of the Arecibo sky was observed at least three times, and several patches of the sky were observed 100 or more times. We discuss techniques to identify, score, and rank the most promising candidates from the SETI@home sky survey, as well as recent observations of these candidates at the FAST 500 meter telescope.

"Narrowband Signal Searches Towards the Galactic Plane and Center"

Karen Perez (she/her) - Columbia University/Breakthrough Listen

Two of the primary targets of the Breakthrough Listen program are the Galactic Center (GC) and a comprehensive blind survey of the entire Galactic Plane (GP) to search for artificial narrowband signals from ETIs. The line of sight toward the GC offers the largest integrated galactic star count of any direction in the sky, is a widely cited possible location for a beacon built by an advanced intelligence, and is the most energetic region in the Milky Way. Likewise, the GP is an ideal direction to search for such signals due to the increased likelihood that transmitters would emit toward this region as opposed to random directions. Here, I will discuss our observing and narrowband search

strategy, as well as results from the Parkes Telescope, Green Bank Telescope, and Sardinia Radio Telescope for our GC Survey (0.7 – 93 GHz) so far. I will also discuss an extension of these strategies for our GP Parkes 21cm Multibeam Receiver Survey, covering two full scans of the GP. We employ a multibeam coincidence rejection technique used for Fast Radio Burst detection, which allows us to distinguish terrestrial interferences from truly sky-localized signals. In addition to our traditional narrowband search filters, we incorporate a machine learning filter in the form of a convolutional neural network to differentiate signals from false positives across the 13 beams, resulting in a significant reduction of detected candidates.

"Exploring Alien Megastructures: Analyzing Transit Light Curves for Anomalies with Machine Learning"

Abraham Mathews (He/Him) - Indian Institute of Space Science and Technology

Within our assumptions concerning advanced extraterrestrial civilizations, we explore the possibility of colossal artificial structures designed for transportation or harnessing energy from host stars. If prevalent in the galaxy, these hypothetical megastructures might leave discernible signatures within transit light curves. We employ Convolutional Neural Network-based machine learning (ML) techniques to predict the shape of transiting objects based solely on their respective transit light curves. A substantial deviation from a circular shape in the predicted outline could indicate the presence of potential alien megastructures. We created a library of 10^5 transiting light curves generated using different artificial closed shapes orbiting stars to train our ML algorithm. Our algorithm provides excellent results with perfect light curves, and we get reasonably good predictions even for transit light curves forward modeled from the Kepler satellite with SNR > 50. Our next steps involve applying these trained algorithms to Kepler light curves to generate a catalog of potential transiting megastructure candidates. These candidates will be further followed up for anomalous and targeted radio signals through collaborative efforts with Berkeley SETI labs in search of extraterrestrial intelligence (SETI). The speaker will share insights into our ongoing work during the presentation, highlighting encountered challenges and presenting preliminary findings. By addressing these challenges and leveraging machine learning techniques, we aim to advance the detection and understanding of artificial megastructures by analyzing transit light curves.

"Are we alone in the universe?" - A Participatory Science Project

Megan Grace Li she/her - UCLA SETI

"Are we alone in the universe?" is a Zooniverse-based citizen science project designed to accelerate the Search for Extraterrestrial Intelligence (SETI). The project launched on February 14, 2023 and is accessible at http://arewealone.earth. It features UCLA SETI data obtained with the 100 m Green Bank Telescope (Margot et al., 2023, AJ, in press, http://arxiv.org/abs/2308.02712).

Volunteers are presented with spectrograms containing narrowband radio signals, and tasked to answer a few questions about each signal's structure. These answers enable progress through a decision tree and result in the classification of each signal into one of twenty categories. Along the way, volunteers highlight the most promising technosignatures. The final product is a labeled set of spectrograms. This labeled set, while a work in progress, is currently being used to train a machine learning application to excise radio frequency interference (RFI) from future SETI datasets.

Preliminary results are promising, with the application identifying the top 4 most common forms of RFI with an F-1 score of over 0.85 (0.96 on the most common form). We will present improvements to the design of the application and updated performance metrics at the meeting.

Funded by NASA, The Planetary Society, and generous donors, "Are we alone in the Universe?" has already inspired over 20,000 volunteers who have collectively submitted over 700,000 classifications and generated a labeled training set with over 25,000 entries.

"Planetary Complexity Revealed by the Joint Differential Entropy of Eigencolours"

Stuart Bartlett (he/him) - California Institute of Technology

We propose a measure, the joint differential entropy of eigencolours, for determining the spatial complexity of exoplanets using only spatially unresolved light curve data. The measure can be used to search for habitable planets, based on the premise of a potential association between life and exoplanet complexity. We present an analysis using disk-integrated light curves from Earth, developed in previous studies, as a proxy for exoplanet data. We show that this quantity is distinct from previous measures of exoplanet complexity due to its sensitivity to spatial information that is masked by features with large mutual information between wavelengths, such as cloud cover. The measure has a natural upper limit and appears to avoid a strong bias toward specific planetary features. This makes it a candidate for being used as a novel and generalizable method, which when combined with other methods, can broaden the available indicators of habitability.

"Lunar SETI and Moon Farside Protection"

Claudio Maccone - International Academy of Astronautics (IAA - Paris - France) and Istituto Nazionale di Astrofisica (INAF - Rome - Italy)

Lunar SETI done from the Moon Farside will be better than any SETI done from the Earth Surface. However, a new TREATY under the United Nations auspices is urgently needed to avoid the radio pollution around the Moon just as the sky around the Earth is currently polluted by Starlink and other satellites. Claudio Maccone's IAA Team is working hard to promote such a "Moon Farside Treaty" while the Moon Farside still is radio-quiet.
Please see the website https://iaaspace.org/event/1st-iaa-moon-farside-protection-symposium/

"Are we alone? New estimates of transmitter prevalence from UCLA SETI data"

Jean-Luc Margot - UCLA

SETI is a cost-effective, hypothesis-driven scientific enterprise that may yield unambiguous evidence of extraterrestrial life in our lifetime. Since 2016, UCLA SETI has been searching narrowband radio technosignatures with the Green Bank Telescope. We have sampled over 55,000 stars and detected over 82 million candidate signals to date. I will describe our algorithms and results to date, including performance and search volume metrics, AI acceleration, and prevalence estimates (https://doi.org/10.3847/1538-3881/acfda4). Our search is tightly integrated with an annual SETI course at UCLA and an ongoing collaboration with 25,000 volunteers at http://arewealone.earth.

"A reproducible, participatory Futures Literacy workshop format to pre-empt monsterization in a future discovery of extraterrestrial life"

George Profitiliotis (He/Him) - Research Scientist, Blue Marble Space Institute of Science

As an international and intergenerational effort that greatly accelerates the search for life beyond Earth, the Square Kilometre Array is in a unique position to lead by example the effort of governing the ethical and societal aspects of the search across its pre-discovery, discovery, and post-discovery phases. Outer space has been described as a liminal landscape. As such, it appears to have an intricate connection to the concept of the "monster" which is a powerful metaphor that reflects and demarcates the culture that constructs it. In this vein, the scientific search for extraterrestrial life, including intelligence, has been previously argued in published literature to possess characteristics of monstrosity. Consequently, the object of this search, i.e., extraterrestrial life, also bears the mark of the "monster", as it can effortlessly tap into the particular leitmotifs of the monstrous that are largely constant across cultures, despite the situatedness of the monster. This foreshadows a risk of monsterization of the parties involved in a future discovery of extraterrestrial life, due to public gut-level reactions, i.e., the monsterization of humans and extraterrestrial life. In turn, this can adversely affect moral appraisals in future discovery situations by rendering theoretical ethical approaches ineffective, as monsters are not only always outside the moral order but essentially defy and transgress it.

Grounded on the intertwinement of moral imagination and anticipation and drawing on the inherent educational power of monsters, as explained in Monster Studies, this talk summarizes the theoretical argumentation and offers a practical, reproducible intervention in the form of a novel, participatory Futures Literacy workshop to help pre-emptively decrease the potential for the monsterization of humans and extraterrestrial life in the case of a future discovery. This contribution is offered for implementation across the SKAO Partner countries, targeting diverse groups, thereby mitigating potential adverse public reactions in post-detection.

"The Implications of 'Oumuamua on Panspermia"

David Cao; He/Him - Thomas Jefferson High School for Science and Technology; George Mason University

Panspermia is the hypothesis that life originated on Earth from the bombardment of foreign interstellar ejecta harboring polyextremophile microorganisms. Since the 2017 discovery of the comet-like body 'Oumuamua (1I/2017 U1) by the Pans-STARRS telescope, various studies have re-examined panspermia based on updated number density models that accommodate for 'Oumuamua's properties. By utilizing 'Oumuamua's properties as an anchor, we estimate the mass and number density of ejecta in the ISM. We build upon prior work by first accounting for the minimum ejecta size to shield microbes from supernova radiation. Second, we estimate the total number of impact events on Earth after its formation and before the emergence of life (~0.8 Gyr). We derive a conditional probability relation for the likelihood of panspermia for Earth specifically, given several factors including the fraction of ejecta harboring extremophiles and other factors that are poorly constrained. We outline scenarios for which panspermia could be plausible for the Earth specifically, with a ~10^{-6}-10^{-1} maximum chance of occurrence.

"The Desert Fireball Network: determining meteorite origins for origins of life?"

Eleanor Sansom - Curtin University

When looking into the origins of life, understanding the formation and evolution of our own solar system is key. Meteorites preserve the earliest records, and allow us to study first hand the primitive chemistries of our own disk. However, very few have constrained origins (<0.1%). Dedicated networks such as the Desert Fireball Network (DFN) in Australia have been set up to observe the bright, fireball phenomenon as extraterrestrial material comes through our atmosphere. This permits the reconstruction of orbits, as well as determining possible fall locations of surviving meteorites. Providing the spatial/orbital context for these samples enable their unique geological record to be fully exploited.

Even in cases where no meteorites survive, high precision observations allow an investigation of material strengths and other properties of the incoming meteoroids. From building knowledge on asteroid families to the first decimetre-sized rocky body originating from the Oort cloud, these observations can help inform competing planet formation models.

"The Allen Telescope Array: an upgraded radio interferometer for SETI, compact objects, slow and fast transients"

Alexander Pollak - SETI Institute

The Allen Telescope Array (ATA) is a radio interferometer hosted at the Hat Creek Radio Observatory, a facility owned and operated by the SETI Institute. The ATA is comprised of 42 elements, each 6.1m in diameter, it is the first instrument built from the ground up to perform the search for extraterrestrial intelligence (or SETI). Mounted on the focus of each telescope, a dual-polarization log-periodic design feed senses electromagnetic radiation in the 1 to 14 GHz range that gets amplified and sent over fiber to a centralized signal processing room. Custom in-house-built hardware and software backends are deployed to correlate and beamform signals from the individual antennas. Observers can then access this data to perform a plethora of scientific investigations, including the study of Fast Radio Bursts, neutron stars, GRB afterglows, accreting black holes and blazars, interacting stellar/black hole binary systems, and the search for extraterrestrial technology.

In this talk, I will give an overview of the current and projected capabilities of the Allen Telescope Array, and then delve into the upgrade that the ATA is experiencing, including the current and potential science that the telescope is promising to deliver both as a survey and a fast response follow-up radio facility.

"Coupling Panoramic SETI with multi-messenger astrophysics"

Shelly Wright - UC San Diego

Panoramic SETI is an optical SETI program designed to detect optical flashes over several decades of time: nanoseconds to milli-seconds. While the initial technology development stemmed from optical SETI research, the Panoramic SETI program is directly pertinent and pioneering in the realm of cutting-edge astrophysics and physics experiments. Our team has led collaborative efforts, applying Panoramic SETI to explore high-energy gamma-ray sources, dark matter annihilation searches, and astrophysical transient phenomena. Recent resources have been allocated for a new Panoramic SETI telescope site, enabling various scientific applications. We will present these multi-messenger astrophysics science cases and provide an update on the Panoramic SETI program.