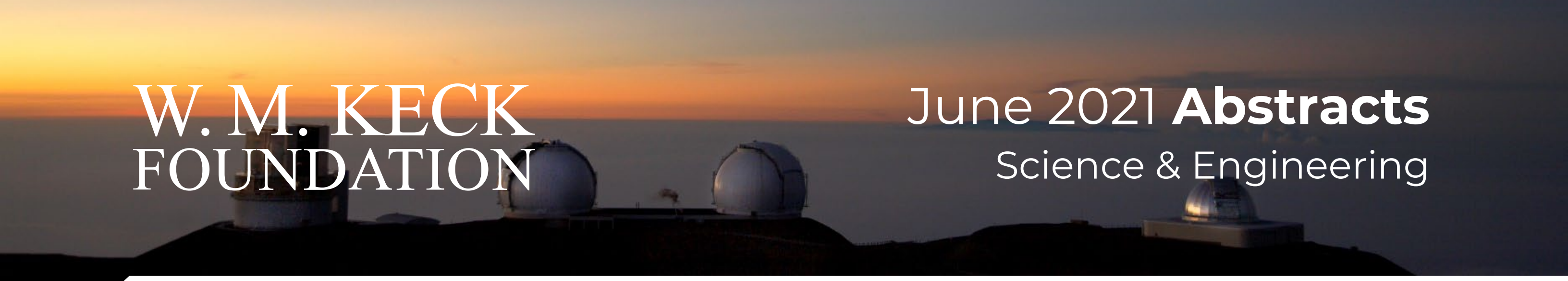

W. M. KECK FOUNDATION

June 2021 **Abstracts**
Science & Engineering

California Institute of Technology
Pasadena, CA
Dmitri Mawet, Quinn Konopacky, Michael Fitzsimmons, Marc Kassis, Nemanja Jovanovic, Richard Dekany
$1,100,000
June 2021

Twenty-five years after the discovery of the first planet orbiting a star other than the Sun, it is now clear that extrasolar planets are ubiquitous in the galaxy. Though our understanding of exoplanet demographics has dramatically expanded in recent years, many fundamental questions about their origin and composition remain. High-precision high-resolution spectroscopy (HRS) in the near-infrared (NIR) on large telescopes enables the most detailed measurements of exoplanet properties, including their atmospheric composition and dynamics, orbits, and masses. A team of researchers from the California Institute of Technology, the University of California, San Diego, the University of California, Los Angeles, and the W. M. Keck Observatory (WMKO) will build a new infrastructure infused with state-of-the-art technologies for the WMKO to dramatically increase the efficiency (3X gain) and precision (100X gain) of NIR high-resolution spectroscopy, which is required to precisely capture exoplanet properties. The new infrastructure will immediately benefit NIRSPEC, the workhorse NIR high-resolution spectrograph at WMKO, and in the future HISPEC, the new High-resolution NIR Spectrograph for Exoplanet Characterization. Completion of this project will also allow the team and the Keck community to conduct studies beyond the exoplanet frontier; they will measure the velocity of stars orbiting the Galactic Center (2020 Nobel Prize in Physics) with unprecedented precision, probe the chemodynamical history of nearby dwarf galaxies and the galactic halo, and open a new window on Solar System studies (e.g., active volcanism on Venus).

Colorado School of Mines
Golden, CO
Zhexuan Gong and Shuo Sun
$1,000,000
June 2021

A pair of researchers from the Colorado School of Mines and the University of Colorado Boulder plan to develop a new quantum simulator that can generate highly tunable long-range interactions among a large number of qubits—the first of its kind. This quantum simulator can be used to explore uncharted areas of quantum many-body physics where interactions are non-local, speed up the generation of many-body entangled states, and provide new insights to the design of novel materials. The quantum simulator is based on an array of solid-state atomic defects known as color centers. These color centers behave similarly to atoms, but they naturally live inside a solid-state semiconductor without trapping. The interactions among color centers will be tailored through a one-dimensional or two-dimensional photonic crystal fabricated on the same host material, which provides a structured photonic bath to mediate long-range interactions among the spins of the color centers. The effective spin interactions have a widely and dynamically tunable interaction pattern via the control of the driving lasers. They expect to build this quantum simulator by first creating a lattice of defect centers on top of a photonic crystal, and then demonstrating single-qubit control and tunable-range two-qubit interactions via benchmarking experiments. Guided by theoretical study, the researchers will then explore a broad range of topics at the frontier of quantum many-body physics using the developed experimental quantum simulator.

Case Western Reserve University
Cleveland, OH
Beverly Saylor, Yohannes Haile-Selassie Ambaye, Naomi Levin, Mulugeta Alene Araya, Doris Barboni, Christopher Campisano, Alan Deino, Sarah Feakins, David Feary, Luis Gibert, Daniel Hembree, Kaye Reed, Denise Su, Jeffrey Yarus
$1,200,000
June 2021

The Afar region of Ethiopia is known for its 6-million-year record of human evolution, including hundreds of fossils of *Australopithecus afarensis*. This species has been considered the most likely ancestor to the human genus, and was long thought to be the only potential human ancestor in the region during its time. However, recent work demonstrates the contemporaneous presence of other hominins (e.g., *Australopithecus deyiremeda)*, indicating that *A. afarensis* was not the only potential human ancestor living in the Afar, but instead was part of a more diverse human family tree. The distribution of these fossils reflects that multiple hominin species lived in close proximity at some locations, but not everywhere, raising the question of why some of the Afar's rifted landscapes supported diverse hominin populations while others did not. The research team from Case Western Reserve University, Arizona State University, University of Michigan, Addis Ababa University, Aix Marseille University, University of Barcelona, Berkeley Geochronology Center, Ohio University, and University of Southern California will address this question by comparing — over the same time period — the geology, paleoecology, and paleontology at Woranso-Mille, where new discoveries indicate that multiple early hominin species shared the Afar landscape, to nearby Hadar, where *A. afarensis* is best documented and co-existed with no other recognized hominin species. This multidisciplinary study will integrate physical, chemical, and biological proxies for vegetation, hydrology, climate, and mammalian ecology with multi-scale reconstructions of the physical landscape to assess differences in the ecology of *A. afarensis* and its close relatives. These multi-proxy reconstructions will enable — for the first time — an understanding of the influence of rift setting on biological diversity and human evolution.

University of Central Florida
Orlando, FL
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$1,000,000
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Macroscopic objects can be accelerated by conventional forces exerted via mechanical contact. On the other end of the scale of object size, electromagnetic forces are utilized for accelerating elementary particles in large-scale facilities such as the Large Hadron Collider. This approach is also useful with charged micro-particulates, as currently realized in Van de Graaff systems where metallic or metal-clad particles are routinely accelerated to large velocities. This leaves a large gap in our ability to impart motion to matter; specifically, controlling the motion of dielectric micro- and nanoparticles that do not respond to electric or magnetic fields and cannot be accelerated through contact forces. A pair of researchers for the University of Central Florida will make use of spatio-temporally structured laser light to accelerate such particles in vacuum, ultimately to hypersonic speeds. By precisely sculpting the spatio-temporal spectrum of a pulsed optical field, several key requirements for efficient light-matter coupling can be satisfied; namely, maintaining tight spatio-temporal focus of the propagating wave packet, in addition to versatile tunability of its group velocity in free space. This work builds on recent achievements by the proposing team in synthesizing so-called 'space-time' wave-packets endowed with these unique features. Furthermore, novel strategies will be devised for stabilizing accelerating dielectric particles, as necessitated by the absence of viscosity in vacuum. Success in this effort will dramatically enhance our understanding of light-matter interactions and will provide new experimental strategies for furthering planetary and space sciences, materials science, and potentially in devising new medical therapies.

University of California, San Diego
San Diego, CA
Joel Yuen Zhou, Noel C. Giebink, Keith A. Nelson, Mohammad Movassaghi
$1,000,000
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A team of researchers from the University of California, San Diego, the Pennsylvania State University, and the Massachusetts Institute of Technology, will develop the novel concept of Polariton Amplification of Stimulated-Enhancement of Reactions (PASERs), which is analogous to LASERs, except that scattering occurs into the same polaritonic mode of molecular products, raising the remarkable possibility of coherently stimulating a desired chemical reaction and thus amplifying its efficiency. To demonstrate this concept, they plan to achieve the stimulated scattering regime by optically pumping polaritons that hybridize infrared cavity photons with particular C=O vibrations of carboxylic acid derivatives. The reactants undergo mild regioselective reactions that are important for modern organic synthesis and are well-suited for PASER control of branching between different products. Just as LASERs revolutionized science and technology by amplifying light with the same characteristics, a successful PASER demonstration could revolutionize chemical synthesis by amplifying desired reaction pathways with unprecedented efficiency and specificity.

University of Southern California
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The last century's quantitative understanding of electron transport physics in solid-state materials has completely transformed our society by underpinning today's information age. With recent surprising discoveries of electronic transport in bacteria, we now stand at the cusp of another revolution with vast implications for biotechnologies that interface directly to living cells. In a particularly stunning development, there is now mounting evidence of centimeter-scale electron transport in conductive networks formed by cable bacteria. Cable bacteria are multicellular filaments composed of up-to-thousands of cells and are found worldwide in both marine and freshwater sediments, where they gain energy by coupling sulfide oxidation in deeper sediment to oxygen reduction near the sediment-water interface. Efficient charge transport over these distances was previously thought impossible in biology, but the molecular pathway and mechanism of this long-distance electron transport remain enigmatic. To address this knowledge gap, a senior researcher at the University of Southern California will deploy solid-state physics, electrochemistry, bioenergetics, and microbiology tools to discover the underlying physics of biological electron transport and energy distribution over these unprecedented length scales. Specifically, he will identify the mechanisms of electron conduction in cable bacteria and their networks of conductive nanofibers, reveal the link between electron transport and cellular energy distribution in vivo, and discover the identity of the charge carriers. The project is expected to reveal new insights into how biology exploits physical principles to achieve an 'electric metabolism', and usher in new bioelectronic concepts for studying and harnessing the activity of living cells even beyond bacteria.
