【Grant-in-Aid for Scientific Research (S)】
Broad Section B

Title of Project： Mapping Habitable Planetary Environments with Exoplanet Imaging

Guyon Olivier
(National Institutes of Natural Sciences, National Astronomical Observatory of Japan, Subaru Telescope, RCUH Staff)

Research Project Number： 21H04998 Researcher Number： 90399288
Term of Project： FY2021-2025 Budget Allocation ： 141,400 Thousand Yen
Keyword：Astronomy, Exoplanets, Photonics

【Purpose and Background of the Research】

Most stars host their own planets, and astronomers have identified several 1000s of such exoplanets orbiting nearby stars. Some of these planets are of size and temperature similar to Earth and could potentially host life. Almost all known planets have been discovered by the perturbation they imprint on starlight, but have never been imaged, so we have limited information about their composition and physical nature. Detailed study of exoplanets, and, for Earth-size planets, detection of possible biological activity, will require that the planets are directly imaged with large telescopes. Yet, it is very challenging, as planets are much fainter than the stars they orbit, so normal cameras are blinded by bright starlight.

The purpose of this research is to image and study giant planets in the habitable zones of nearby stars to understand how planets form and evolve in the habitable zones of stars.

【Research Methods】

The existing 8.2m diameter Subaru Telescope will be used to image exoplanets around nearby stars. Instead of using conventional imaging approach, a photonics solution will be developed to solve the high contrast challenge and ensure that the bright starlight is clearly separated from the much fainter planet light..The planet light will be then analyzed by a spectrograph so that its chemical composition and temperature will be measured.

The new photonics approach is fundamentally different from conventional imaging systems: light will be injected in optical fibers and carefully combined to filter our starlight. This allows for a more efficient and precise calibration, and will enable imaging planets closer to the star that previously possible.

We will also improve the adaptive optics system that corrects for atmospheric blurring so that the photonic instrument operates at high performance with a stable optical beam. Upgrades to the system include a more sensitive camera to measure atmospheric blurring and a more capable deformable mirror that can actively cancel atmospheric blurring. The faint planet light will be imaged with a sensitive superconducting photon-counting camera.

【Expected Research Achievements and Scientific Significance】

We will identify and image new planets within the habitable zone of nearby young stars. For the first time, we will directly measure the atmosphere composition of such planets, so that we can understand how planets form and evolve in this region. While the imaged planets will be larger than Earth, the measurements will inform how dust and gas forms smaller planets, including Earth-size habitable planets.

Specifically, we will measure how planet-forming dust and gas materials collapses onto planets, and what is the composition of such material during the critical phases of planet formation in the habitable zone.

The new technical approach developed in this effort will enable future imaging and spectroscopy of potentially habitable Earth-like planets with future larger telescopes, including the Thirty Meter Telescope (TMT). Using experience acquired on the Subaru Telescope, our team will work with design a photonic system that will have the sensitivity to identify signs of biological activity on nearby Earth-like exoplanets with the TMT.

【Publications Relevant to the Project】

"Scalable photonic-based nulling interferometry with the dispersed multi-baseline GLINT instrument" Martinod, Norris, Tuthill...Guyon et al. Nature Communications (2021)
"SCExAO/MEC and CHARIS Discovery of a Low Mass, 6 AU-Separation Companion to HIP 109427 using Stochastic Speckle Discrimination and High-Contrast Spectroscopy" Steiger, Currie, Brandt, Guyon et al. AJ (2021)
"Can Ground-based Telescopes Detect the Oxygen 1.27 um Absorption Feature as a Biomarker in Exoplanets?" Kawahara, Matsuo, Takami, Fujii, Kotani, Murakami, Tamura, and Guyon, ApJ 758, 13, (2012)

【Homepage Address & Other Contact Information】

https://subarutelescope.org
https://www.naoj.org/Projects/SCEXAO