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The SEEDS Exoplanet and Circumstellar Diks Survey

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About 1,000 extrasolar planets (or exoplanets) have been discovered by now. Furthermore, Kepler survey has reported the presences of more than 3,000 exoplanet candidates (Huber et al. 2013). Thus, the planetary systems are common in our Galaxy, but it has known that those exoplanets have a variety of properties. Meanwhile, studies for circumstellar disks, which are the birth-places of planets, have also progressed. In particular, the radio telescope ALMA, whose operations have recently started, have provided intriguing data for the structure properties of protoplanetary disks (e.g., van der Marel et al. 2013; Casassus 2013). ALMA should provide a deep insight to the studies of circumstellar disks.

Direct imaging observations enable the discovery and study of exoplanets orbiting their host stars at wide orbital separations comparable to a few tens of AU, but the detections of those are impractical with indirect techniques such as radial velocity or transit method. Direct imaging is also useful to characterize circumstellar disks. The high-resolution observations of scattered light from protoplanetary disks or debris-disks have provided many important clues to reveal the physical disk-planet connections. We have progressed the SEEDS project, which aims at detecting and characterizing giant exoplanets and circumstellar disks with the Subaru 8-m ground-based telescope, state-or-the-art adaptive optics AO188, and a high-sensitivity infrared camera HiCIAO that we have newly developed. The total SEEDS sample will reach 500 targets, and this target sample adequately covers stellar ages ranging from 1 to 1000 Myr for solar-type stars. Also, intermediate-mass or low-mass stars are included in our SEEDS sample. The survey is currently in its fifth year, and to date, it has identified intriguing structures, such as gaps or spirals, in more than 10 transitional or debris disks (e.g., Hashimoto et al. 2012; Grady et al. 2013). Furthermore, SEEDS has discovered a massive giant planet candidate orbiting the B-type star Kappa Andromedae (Carson et al. 2013) and a Jovian planet in orbit with a size of about 44 AU (GJ 504b) around the G0-type Sun-like star GJ 504. GJ 504b has an estimated mass of about 4 Jupiter masses and effective temperature of 500 K. Among such the wide-orbit exoplanets directly imaged so far, GJ 504b represents the lowest-mass Jovian planet, and the inferred effective temperature is the coldest. The follow-up observations for GJ 504b have revealed the presences of methane in its atmosphere (Janson et al. 2013), allowing us to report the first methane detection in an atmospheres of directly imaged exoplanet. Thus, SEEDS has successfully identified and studied the exoplanets with the previously unknown properties. After the end of SEEDS survey, the comprehensive and statistical analysis of entire survey sample will be carried out. This analysis leads to improve our understanding about exoplanets and circumstellar disks. In addition, it should become a promising clue that connects to future exoplanet/disk studies, such as a survey of extrasolar Earths.

Here, we report the latest achievements of SEEDS project, such as the detection of GJ 504b. Moreover, its whole survey status and progress are also reported, as well as the future plan of SEEDS project.

Keywords: extrasolar planet, debris disk, protoplanetary disk, giant planet, direct imaging observation