Direct Imaging of a Cold Jovian Planet Orbiting the Sun-like Star GJ 504

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Among the techniques to observe extrasolar planets (exoplanets), direct imaging plays a crucial role in its ability to probe for wide-orbit giant planets. Indeed, this technique is responsible for the majority of detections and characterizations of wide-orbit ($r > \sim 10$ AU) exoplanets.

The Strategic Exploration of Exoplanets and Disks with Subaru (SEEDS) campaign has surveyed exoplanets via the direct imaging technique since 2009. As part of this survey, a nearby G0-type star, GJ 504, was observed, resulting in the discovery of a wide-orbit ($r \sim 43.5$ AU) exoplanet (GJ 504b) orbiting the star [1] (see Fig. 1). The GJ 504 system has an age of 160^{+350}_{-60} Myr, inferred through gyrochronology and chromospheric activity techniques (e.g., [2]). A comparison of GJ 504b's age and measured infrared luminosities with luminosity evolution models for giant planets [3] yields an estimated mass of $4^{+4.5}_{-1.0}$ Jupiter masses, placing GJ 504b among the lowest of exoplanets ever directly imaged. Furthermore, since GJ 504b has a relatively old age, the mass estimation is only weakly influenced by uncertainties related to choices of initial conditions in the evolutionary models for giant planets [4]. Using the aforementioned luminosity-evolution models, an effective temperature of GJ 504b was estimated to be ~510 K, making it significantly cooler than any previous thermally imaged exoplanet. Compared with other directly imaged exoplanets (e.g., HR 8799's planets [5]), the *J*–*H* color (~ -0.2) of GJ 504b is relatively blue, which may suggest a less cloudy atmosphere.

According to core accretion theory, it is extremely difficult to explain an in situ formation for a wide-orbit giant planet like GJ 504b [6]. The true origin of GJ 504b remains poorly constrained, as does its atmospheric properties. However, its further characterization will help scientists better understand the origins and properties of GJ 504b, and thereby help uncover the more general origin and evolution of wide-orbit exoplanets.

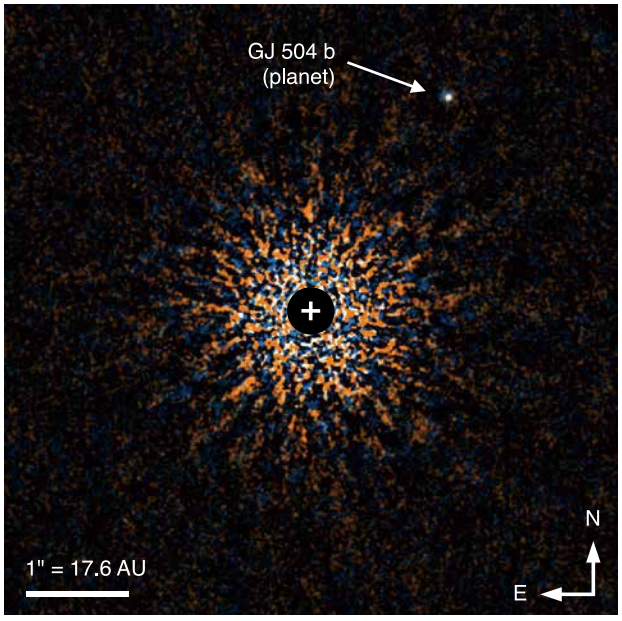

Figure 1: High-contrast images of the GJ 504 system. The *J*-(~1.2 μm) and *H*-band (~1.6 μm) images were overlaid to create this false color-composite image, where blue and orange represent *J* and *H* band, respectively. In order to compensate for the planet's observed orbital motion, the *J*-band image was rotated by 0.9°. The fluxes from the host star were suppressed in the images, through data processing. The planet GJ 504b is seen as a white spot at a projected separation of ~43.5 AU from GJ 504 [1].

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