Indirect observation of the extrasolar planetes

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1. Introduction

Astronomical observations provide evidence of extrasolar planets. Planets orbiting a star other than the Sun were first discovered in 1992. Wolszczan & Frail (1992) found a periodic delay in the pulses of the radio emission from a pulsar, indicating that two planetary-mass objects orbit a pulsar PSR 1257+12. Since then, more than 240 extrasolar planets have been found. As discussed below, extrasolar planets are very faint and are located in very close proximity to the bright central star. Although direct detection of an extrasolar planet has not yet been achieved, many indirect evidences of extrasolar planets have been reported. I will present recent important results on extrasolar planetary systems, based on the observations with the Subaru Telescope.

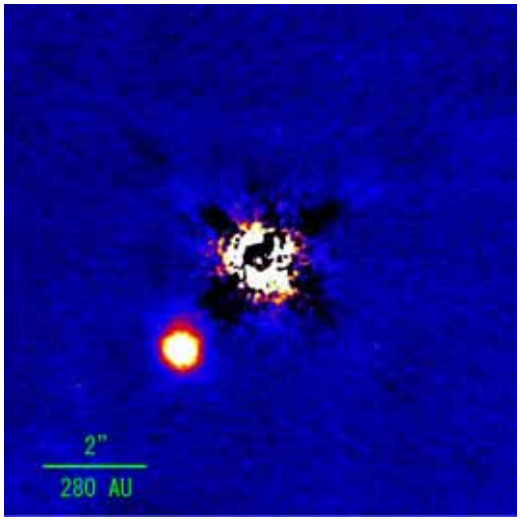
2. Indirect Detection - Doppler Shift Measurements

By definition, a planet orbits a star. A star and a planet make a common gravitational potential within the system. Both the star and the planet orbit the potential minimum, which is not located exactly at the center of the star. Imagine a system consisting of the Sun and Jupiter. The Sun and Jupiter orbit the potential minimum with a period of 12 years, which means that an observer outside the Solar System could notice the orbital motion of the Sun. The periodic change in radial velocity could be detected by high-resolution spectroscopy as a Doppler shift of the stellar spectrum. The first discovery of an extrasolar planet around a solar-type star was announced by Mayor & Queloz (1995). They found periodic variations in the radial velocity of the solar-like star, 51 Peg. It was interpreted as a Jupiter-mass planet orbiting the star with period of 4.23 days.

An evolved star also harbors a planet. Sato et al. (2003) revealed a Jupiter-mass planet around a G-type giant. Since G-type giants are the successors of 2-3 solar mass main-sequence stars, this discovery proves that planets are associated not only with solar-mass stars but also with 2-3 solar mass stars. Sato et al. (2007) found a planet around a G-type giant in the Hyades cluster, while 94 solar-mass dwarfs in the same cluster were found to have no Jupiter-mass planets (Paulson et al. 2003). This implies that a massive planet tends to be born around a massive star. This idea is also supported by the rareness of massive planets around less massive field stars.

3. Direct Detection - Coronagraphic Imaging

Direct detection is undoubtedly desirable, but nobody has so far succeeded in obtaining an image of an extrasolar planet. The brightness of a planet results mostly from the reflected light of the central star in optical and near-infrared wavelengths, which means that the contrast between a star and a planet is huge. For the Sun -- Jupiter system, this flux ratio is as small as 3×10^{-9}. Since such a faint object is located in very close vicinity to the bright central star, direct detection of an extrasolar planet is exceedingly difficult. A coronagraph is a powerful instrument to detect very faint objects close to bright objects.



Itoh et al. (2005) discovered a young brown dwarf companion (DH Tau B) associated with a classical T Tauri star DH Tau, using a coronagraph on the Subaru Telescope (see figure). The companion has H=15.0 mag located at 2.34" (330 AU) away from the primary DH Tau A. Comparing its position to a Hubble Space Telescope archive image, it is confirmed that DH Tau A and B share a common proper motion, suggesting that they are physically associated with each other. From the near-infrared spectra of DH Tau B, its effective temperature and surface gravity are derived to be Teff =2700 -- 2800 K and log g = 4.0--4.5, respectively. The location of DH Tau B on the Hertzsprung-Russell diagram

indicates that its mass is between 30 and 50 Jupiter mass. Thus, this object is classified as a young brown dwarf companion.

Conclusion

From ground-based observations, a number of indirect evidences of extrasolar planets have been announced. On the other hand, direct detection of an extrasolar planet is not yet achieved. Spatially resolved images of extrasolar planets will be obtained in next decades.

References

Y. Itoh, et al: Astrophys. J., 620, 984 (2005)

M. Mayor, D. Queloz: Nature, 378, 355 (1995)

B. Sato et al: Astrophys. J., 597, L157 (2003)

B. Sato et al: Astrophys. J., accepted (2007)

A. Wolszczan, D. A. Frail: Nature, 355, 145 (1992)