The Origin and Maintenance of a Retrograde Exoplanet

NARITA, Norio[1], TAKAHASHI, Yasuhiro, H.[2/1], KUZUHARA, Masayuki[2/1], HIRANO, Teruyuki[2]
SUENAGA, Takuya[3], KANDORI, Ryo[1], KUDO, Tomoyuki[1], SATO, Bun'ei[4], SUZUKI Ryuji[1], IDA, Shigeru[4]
NAGASAWA, Makiko[4], ABE Lyu[5], BRANDNER, Wolfgang[6], BRANDT, Timothy, D.[7], CARSON, Joseph[8]
EGNER, Sebastian, E.[1], FELDT, Markus[6], GOTO, Miwa[9], GRADY, Carol, A.[10], GUYON, Olivier[1]
HASHIMOTO, Jun[1], HAYANO, Yutaka[1], HAYASHI, Masahiko[1], HAYASHI, Saeko, S.[1], HENNING, Thomas[6]
HODAPP, Klaus, W.[11], ISHII, Miki[1], IYE, Masanori[1], JANSON, Markus[7], KNAPP, Gillian, R.[7]
KUSAKABE, Nobuhiko[1], KWON, Jungmi[3], MATSUO, Taro[12], MAYAMA Satoshi[3], McELWAIN, Michael, W.[10]
MIYAMA, Shoken[13], MORINO Jun-Ichi[1], MORO-MARTIN, Amaya[14], NISHIMURA, Tetsuo,[1] PYO, Tae-Soo[1]
SERABYN Eugene[15], SUTO, Hiroshi[1], TAKAMI Michihiro[16], TAKATO, Naruhisa[1], TERADA, Hiroshi[1]
THALMANN, Christian[17], TOMONO, Daigo[1], TURNER, Edwin, L.[7/18], WATANABE, Makoto[19]
WISNIEWSKI, John, P.[20], YAMADA, Toru[21], TAKAMI, Hideki[1], USUDA, Tomonori[1], TAMURA, Motohide[1]

1:NAOJ, 2: University of Tokyo, 3: Graduate University for Advanced Studies, 4: Tokyo Institute of Technology, 5: Université de Nice-Sophia Antipolis, 6: Max Planck Institute for Astronomy, 7: Princeton University, 8: College of Charleston, 9: Ludwig-Maximilians-Universitét, 10: Goddard Space Flight Center, 11: University of Hawaii, 12: Kyoto University, 13: Hiroshima University, 14: Consejo Superior de Investigaciones Científicas, 15: Jet Propulsion Laboratory, 16: Academia Sinica, 17: University of Amsterdam, 18: Kavli Institute for Physics and Mathematics of the Universe, 19: Hokkaido University, 20: University of Oklahoma, 21: Tohoku University

We previously discovered the first evidence of a retrograde orbit of an extrasolar planet, HAT-P-7b (Narita et al. 2009) [1]. Although retrograde planets, which have orbits that run counter to the spin of their central stars, are absent in our Solar System, they occur in other planetary systems in the Universe. However, astronomers and planetary scientists did not know how such retrograde planets formed.

Generally speaking, planetary orbits are considered to be well aligned with the host star's rotation, at least at the initial stage. Thus in a retrograde planetary system, it is expected that other bodies in the planetary system had altered the orbit of the retrograde planet.

We used the HiCIAO and HDS instruments of the Subaru telescope to search for such other massive bodies in the HAT-P-7 system. Consequently, we found a binary low-mass stellar companion at over 1000 AU, and another giant planet at over 5 AU in this system.

Then, how did the retrograde orbit of the planet develop? We consider that the existence of the companion star (HAT-P-7B) and the newly confirmed outer planet (HAT-P-7c) are likely to play an important role in forming and maintaining the retrograde orbit of the inner planet (HAT-P-7b) via the Kozai mechanism, a longterm process during which a more massive object has an effect on the orbit of another.

In the case of HAT-P-7b, we posited so-called "sequential Kozai migration" as an explanation of this retrograde planet. It suggests that the companion star (HAT-P- 7B) first affected the orbit of the newly confirmed outer planet (HAT-P-7c) through the Kozai mechanism, causing it to tilt. When the orbit of that planet inclined enough, HAT-P7c altered the orbit of the inner planet (HAT-P-7b) through the Kozai mechanism, so that it became retrograde. This sequential orbital evolution of the planet is one of the scenarios that could explain the origin of retrograde/tilted/eccentric planets.

We have demonstrated the importance of this kind of follow-up observations for retrograde planetary systems to check for the presence of outer massive bodies, which may play an important role in understanding the entire picture of planetary migration. The findings provide important clues for understanding the origin of a variety of planetary systems, including those with highly tilted and also eccentric orbits [2].

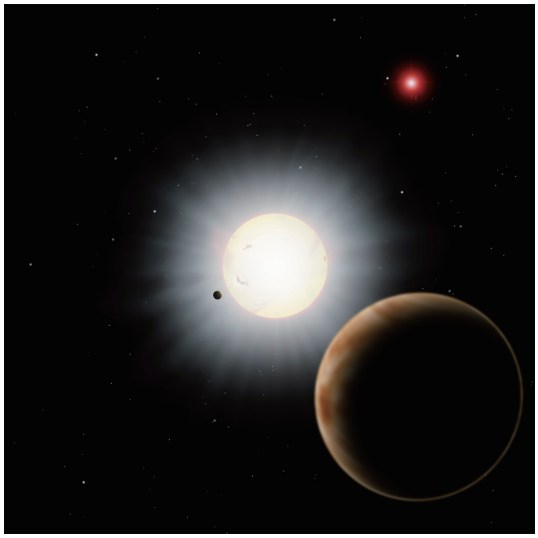

Figure 1: Artist's rendition of the HAT-P-7 system. We used the Subaru Telescope to discover the retrograde planet (nearest the central star), another giant planet (in the foreground), and a companion star (upper right) in this system.

References

[1] Narita, N., et al.: 2009, *PASJ*, **61**, L35.
[2] Narita, N., et al.: 2012, *PASJ*, **64**, L7.