ハレアカラ観測所T60/DIPOL-2を用いた系外惑星の偏光観測
Polarimetry of exoplanets using T60/DIPOL-2 at the Haleakala observatory

前田 東暁[1]、*坂野井 健[1]、鍵谷 将人[1]
Haruaki Maeda[1], *Takeshi Sakanoi[1], Masato Kagitani[1]

1. 東北大学大学院理学研究科惑星プラズマ・大気研究センター
1. Planetary Plasma and Atmospheric Research Center, Graduate School of Science, Tohoku University

Many exoplanets have been found since the first discovery of exoplanet in 1995, and observation methods have been developed so far. In this study we particularly focus on polarimetry of the exoplanets. Light scattered at exoplanetary atmosphere is polarized with a periodic variation of it's revolution. Thus, we expect to obtain exoplanetary orbital element and exoplanetary atmosphere information from phase, amplitude, wavelength dependence of polarization. The measurement of exoplanetary polarization is characterized by photon noise limited, which enable us to observe with a small-sized telescope.
Since 2000, several groups attempted to detect the polarimetry of exoplanets. Some groups suggested that the polarization degree less than 10^-4 exists, however other groups reported that there is no significant variation in exoplanetary polarization. In this study, we purpose to establish the measurement method of exoplanetary polarization using DIPOL-2 installed on the Tohoku 60 cm telescope(T60) at Haleakala, Hawaii, and also aim to develop the data analysis method which is required to estimate the exoplanetary polarization very accurately.
DIPOL-2 observation data involve exoplanetary polarization as well as instrumental polarization. Thus, we need to subtract the instrumental polarization precisely from the observed data. In case that the instrumental polarization is too large compared with exoplanetary polarization, it might be impossible to detect exoplanet polarization. To verify the stability of instrumental polarization, we carried out two kinds of observations of non-polarized standard stars as follows. One is the observation of 44 non-polarized standard stars, and the other is the continuous observation of a non-polarized standard star HD142373.
Observations of 44 non-polarized standard stars were performed on 90 nights during the period from May 2015 to October 2016. From the useful dataset for 39 stars, we estimated Stokes Q and U of instrumental polarization are 1.20 x 10^-5 and 2.63 x 10^-6, respectively. From continuous observation of a non-polarized standard star HD142373 in August 2016, we also estimated the lower limits of variabilities in Stokes Q (sigma_Q) and U (sigma_U) of the instrumental polarization as 1.0 x 10^-5 and 8.8 x 10^-6, respectively. These variabilities in instrumental polarization defines the estimation limit of exoplanetary polarization.
On the exoplanetary observation, we first estimated the expected amplitude of stokes parameter and observation S/N based on previously known parameters of exoplanet, such as the distance between exoplanet and main star, and brightness of main star. From this estimation, we selected three target exoplanets, HD189733 b, τ Boo b, υ And b.
From the data analysis of HD189733 b, we could not obtain significant periodic variation in stokes parameters obtained in past observation by Berdyugina et al. [2011]. Standard deviations in observed stokes parameters were close to the those of instrumental polarization, and therefore it seems further accurate observation is required to evaluate the polarization parameters for HD18933 b. On exoplanet τ Boo b and υ And b, the standard deviation in observed data was larger than expected estimation errors including photon shot noise and uncertainty of instrumental polarization (Stokes Q=65%, and Stokes U=128% for τ Boo b, and Stokes Q=20%, and Stokes U=39% for υ And b). Therefore, we conclude that

the data should show exoplanetary polarization although any significant orbital phase dependence in exoplanetary polarization was not seen. This may be due to insufficient accuracy of estimated instrumental polarization parameters, and thus we suggest further accurate calibration of instrumental polarization and its dependence on telescope environment, such as temperature, air pressure, viewing angle and seasonal dependence, should be needed in future study.

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