[JJ] Evening Poster | P (Space and Planetary Sciences) | P-AE Astronomy & Extrasolar Bodies

[P-AE20]Exoplanet

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Exoplanetary science, which began with the discovery of a hot Jupiter in 1995, has reached a major turning point by the discovery of countless super-Earths by the Kepler mission. More recently, planets that are similar in size to the Earth and also receive similar amounts of stellar radiation (namely, located in the so-called habitable zone) have been discovered around nearby stars such as Proxima Centauri and TRAPPIST-1. As a result, not only theoretical, but also observational studies on the atmospheres and surface environments of Earth-like exoplanets have been started. Moreover, the number of planets discovered around early-type and late-type stars has become large enough that the occurrence rate and orbital distribution of planets around a wide variety of host stars have become clear. Thus, new observational insights, which become the basis of pan-planet formation theory, are now gathering. While exoplanets have been mainly targeted for astronomy until recently, it can be said that earth planetary science is finally becoming a research field to make a central contribution. In this session, we aim to share cutting-edge research results in exoplanetary science which is in such a transition period.

[PAE20-P06]Transit Observations and Light-curve Analyses on TRAPPIST-1 d &e for Mass Estimation

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Earth-sized exoplanets orbiting around M-dwarfs have attracted attention these days. Among them, the planets orbiting TRAPPIST-1are most important to be observed in detail because they are relatively close (about 12pc) to the Solar system, and they form a compact system of small seven planets orbiting closely (< 0.1au) around a tiny M-dwarf star. Moreover, three of those planets, TRAPPIST-1 e, f, g, are thought to orbit inside the star's habitable zone, which means that liquid water could exist on their surface. For further discussion about their habitability, it is important to know their composition. To constrain the planets bulk densities and compositions, we need to estimate their radii and masses. Usually, a planetary radius is measured by the transit method and a mass is estimated by the radial velocity method. However, it is difficult to estimate the TRAPPIST-1 planets' masses with the radial velocity method, because the star is too faint at visible wavelengths, each planet is very small, and it is a complex system of seven planets. Fortunately, for such multiple transit planetary systems, the TTV (Transit Timing Variation) method can be used. TTVs arise from mutual gravitational interaction between adjacent planet pairs. By multi-epoch transit observations, TTVs can be observed and comparing with theoretical models, which then yields the masses which responsible for the gravitational perturbation.Because the TRAPPIST-1 planets orbit in a near-resonant configuation, the TTVs are large enough to be measured precisely, which in turn enables their masses to be estimated with relatively high accuracy.

Previous researches [1][2] used the transit data of the TRAPPIST survey, Spitzer, K2 mission and other telescopes for the TTV analysis, but the size of dataset is still not big enough to measure the masses precisely. In this study, we conducted new transit observations and light curve analyses on TRAPPIST-1 d and e, in order to derive the accurate transit center times for TTV analysis.

Using the MuSCAT camera installed on 188-cm telescope at the Okayama Atrophysical Observatory, we observed consecutive transits of TRAPPIST-1 d &e in z-band, on November 5, 2017. We analyzed the derived light-curve by model fitting. We assumed that model is a combination of transit model and systematics model. For the transit model, we used the python module 'PyTransit' and adapted it for a double transit. In this study we chose the radius ratio and transit center time as free parameters, and used literature values from previous research for the other values (semimajor axis, impact parameter, orbital period, limb-darkening parameters). We approximated the systematics model as linear combination of factors, such as the position of the point of telescope and airmass. In order to select the best parameter set, we used the Bayesian Information Criterion(BIC) We chose 10 good parameter sets and then did more robust model fitting using Markov chain Monte Carlo (MCMC). We used the emcee.EnsembleSampler to minimize chi-square, and calculated the time of transit center and its standard deviation, using long enough chains (100 walkers and 2000 steps, taking into account the autocorrelation).
As a result, we were able to add one new data point to each TTV data set of TRAPPIST-1 d and e (from Wang et al.(2017)[2] FIG.3) to constrain the TTV model. From this study, we can restrict the masses of TRAPPIST-1 c, d, e and f, which are in orbital resonance with TRAPPIST-1 d and e.

[1] Gillon et al., 2017, Nature, Vol 542
[2] Wang et al., 2017, ArXiv e-prints, 1704.04290