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Terminus: A Time-domain Simulator for Exoplanet Observations with Space-based Telescopes

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Abstract

Space-based telescopes offer unparalleled opportunities for observing exoplanets via transit and eclipse spectroscopy. However, observatories in low Earth orbits (e.g. Hubble, CHEOPS, Twinkle and an ever increasing number of cubesats) cannot be continuously pointed at a target due to Earth obscuration. For transit spectroscopy this causes gaps in the light curve, which reduces the information content and can diminish the science return of the observation. Terminus, a time-domain transit and eclipse simulator has been developed to model the occurrence of these gaps to predict the potential impact on future observations. Terminus has been base-lined on the Twinkle Space Telescope but the model can be adapted for any space-based telescopes and is especially applicable to those in a low-Earth orbit.

1. Methodology and Results

Terminus has been constructed in Python and has several different stages. The initial module of Terminus models the atmosphere of the planet. To simulate transmission (and emission) forward models, the open-source exoplanet atmospheric retrieval framework Tau-REx [5, 6] is used. Within Tau-REx, cross-section opacities are calculated from the ExoMol database [7] where available and from HITEMP [4] and HITRAN [3] otherwise. Planetary parameters are loaded from catalogue values and once the forward model is created at high resolution, it is binned to the instrument resolutions (here R$\sim$250 for λ <2.42μm and R$\sim$60 for λ >2.42μm). For each of these spectral bins, PyLightCurve[1] is used to model a noise-free transit (or eclipse) of the planet. The stellar flux at Earth is calculated using spectral energy distributions (SEDs) from the Phoenix atmospheric models from [1]. A instrument file is loaded (which includes parameters such as telescope aperture, quantum efficiency etc.) and the star flux on the detector calculated. This, along with instrument noise and planetary parameters, is used to generate noisy light curves for each of the spectral bins. These noisy light curves are then fitted with a Markov Chain Monte Carlo (MCMC) algorithm to produce a spectrum complete with error bars. Tau-REx is then used to fit the spectrum and retrieve the atmospheric parameters. This process is graphically summarised in Figure 1.

[1]https://github.com/ucl-exoplanets/pylightcurve

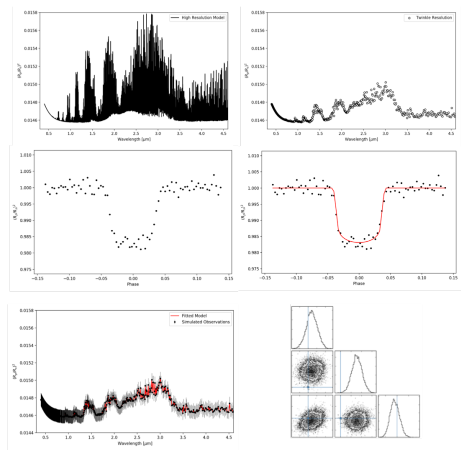

Figure 1: Overview of the structure of Terminus. Top left: Input spectrum generated by TauREx. Top Right: Binning of spectrum to instrument resolution. Middle Left: Creation of light curves. Middle Right: Fitting of light curves. Bottom Left: Retrieved spectrum. Bottom Right: Retrieved atmospheric composition.

2. Summary and Conclusions

Terminus will have the capability to simulate exoplanet transits and will be particularly suited to observatories in low-Earth orbits. Terminus will allow for gaps in the light curve due to Earth obscuration to be added and the subsequent effect studied. The simulator has been baselined on Twinkle, an upcoming space-based telescope capable of visible and infrared spectroscopy, which will operate in a low Earth, Sun-synchronous orbit [2].

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References

[1] Baraffe, I., Homeier, D., Allard, F., and Chabrier, G.: New evolutionary models for pre-main sequence and main sequence low-mass stars down to the hydrogen-burning limit, Astronomy & Astrophysics, Vol. 557, pp. A42, 2015

[2] Billy Edwards, Malena Rice, Tiziano Zingales, Marcell Tessenyi, Ingo Waldmann, Giovanna Tinetti, Enzo Pascale, Giorgio Savini and Subhajit Sarkar: Exoplanet Spectroscopy and Photometry with the Twinkle Space Telescope, Experimental Astronomy, 2018

[3] Gordon, I., Rothman, L. S., Wilzewski, J. S., Kochanov, R. V., Hill, C., Tan, Y. and Wcislo, P.: HITRAN2016 : new and improved data and tools towards studies of planetary atmospheres, AAS/Division for Planetary Sciences Meeting Abstracts #48, 2016

[4] Rothman, L. S. and Gordon, I. E.,: Status of the HITRAN and HITEMP databases, 13th International HITRAN Conference, 2014

[5] Waldmann, I. P., Tinetti, G., Rocchetto, M., Barton, E. J., Yurchenko, S. N. and Tennyson, J.: Tau-REx I: A Next Generation Retrieval Code for Exoplanetary Atmospheres, ApJ, Vol. 802, pp. 107, 2015

[6] Waldmann, I. P., Rocchetto, M., Tinetti, G., Barton, E. J., Yurchenko, S. N. and Tennyson, J.: Tau-REx II: Retrieval of Emission Spectra, ApJ, Vol. 813, pp. 13, 2015

[7] Yurchenko, S. N. and Tennyson, J. : ExoMol: molecular line lists for exoplanet and other atmospheres, EAS Publications Series, Vol. 58, pp. 243-248, 2012