EPSC Abstracts
Vol. 13, EPSC-DPS2019-1505-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Aerosols in exoplanet retrieval models: validating parameterization

Joanna Barstow (1), Stefan Lines (2), Nathan Mayne (2), James Manners (3), Ian Boutle (3), Graham Lee (4), Patrick Irwin (4) and Christiane Helling (5,6)

(1) University College London, UK (2) University of Exeter, UK (3) Met Office, Exeter, UK (4) University of Oxford, UK (5) University of St Andrews, UK (6) SRON, Utrecht, Netherlands (j.barstow@ucl.ac.uk)

Abstract

It is becoming increasingly apparent that aerosols play a significant role in exoplanet atmospheres, especially regarding their effects on transmission spectra obtained during transit. However, we know very little *a priori* about the composition and structure of condensational clouds and photochemical hazes in exotic hot Jupiter atmospheres. Retrieval approaches provide a relatively agnostic method for extracting atmospheric information from observed spectra, but models used in retrievals are necessarily simple and complex structures such as cloud decks are parameterised. We here present results of parameterized aerosol retrievals on synthetic spectra generated from 3D Global Circulation Models incorporating microphysical cloud schemes. We demonstrate that the synthetic spectra can be well reproduced by the parameterized model, and compare the retrieval output with the known input characteristics of aerosols.

1. Introduction

Exotic, highly-irradiated, gas giant exoplanets (hot Jupiters) can be observed when they transit their parent stars. Several hot Jupiters now have relatively complete transmission spectra, and these objects are suitable targets for spectral retrieval methods. Retrieval schemes combine iterative sampling and fitting algorithms such as non-linear optimal estimation (Rodgers, 2000) or MultiNest (Feroz & Hobson, 2008; Feroz et al., 2009, 2013) with simple, parameterized, 1D radiative transfer models. The retrieval approach allows atmospheric information to be inferred directly from the spectra, with minimal prior assumptions; however, the requirement for parameterization means that atmospheric features and processes are highly simplified. Whilst we lack ground truth for exoplanets, sophisticated 3D circulation models incorporating physically based cloud microphysics schemes (Lines et al., 2018) are readily available. Synthetic observations generated from these models provide an important benchmark for retrieval schemes, both in terms of ability to reproduce the observation and ability to recover key aspects of the input atmospheric state.

2. Modelling

We perform this benchmarking exercise using the NEMESIS retrieval scheme (Irwin et al., 2008) against outputs from the Met Office Unified Model, a 3D GCM (Lines et al. 2018 and references therein). The GCM has been coupled to two alternative cloud microphysics schemes, DIHRT (Lee et al. 2016 and references therein; Helling et al. 2008) and EddySed (Ackerman & Marley, 2001). We test several different aerosol parameterizations within NEMESIS, including models based on those used in Barstow et al. (2017) and MacDonald & Madhusudhan (2017). Generally, each aerosol model is restricted to having five parameters or fewer; parameters used include total aerosol opacity, a specification for the wavelength dependence of the scattering efficiency, cloud top/base pressures, and the aerosol fraction over the terminator. Examples of the effects of changing various aerosol parameters are shown in Figure 1. NEMESIS uses PyMultiNest (Buchner et al., 2014) to sample the posterior and provide a marginalized solution for these aerosol parameters (Krissansen-Totton et al., 2018).

3 Preliminary findings and future work

We find that simple parameterized models are capable of producing an excellent fit to cloudy spectra generated from the 3D GCM, using the DIHRT microphysics scheme. A comparison of the GCM atmospheric state with the retrieval output for our initial test indicates discrepancies in the retrieved gas

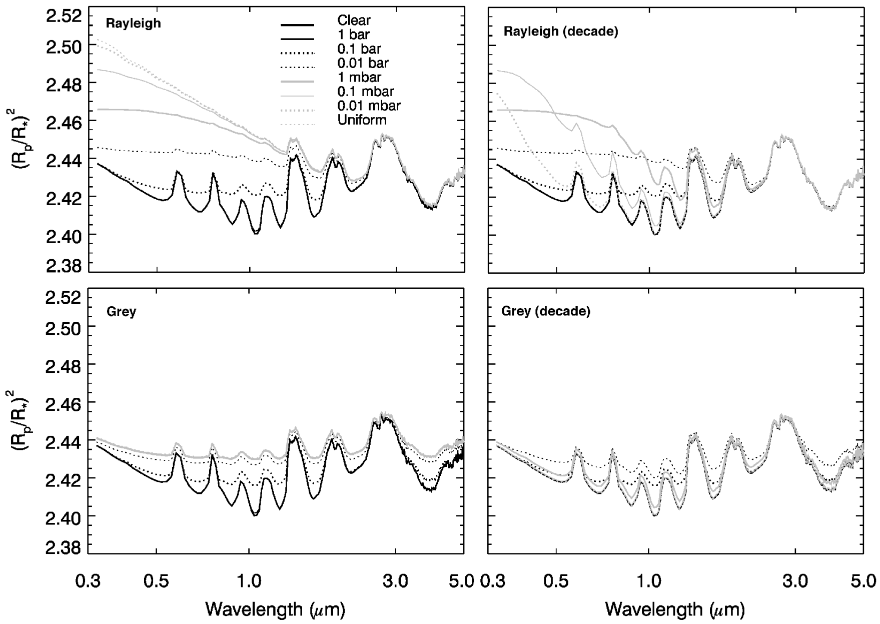

Figure 1: Synthetic spectra generated using NEMESIS, showing the effects of changing various cloud parameters. The plots on the left hand side show spectra for cloud extending from the cloud top to the bottom of the model atmosphere. The plots on the right hand side show spectra for cloud extending over a decade in pressure only. This figure was originally presented in Barstow et al. (2017).

abundances, which we attribute to the assumption in NEMESIS that the temperature profile is isothermal above 0.1 bar, when the GCM temperature structure is non-isothermal in this region. In subsequent work, a more flexible parameterization for the temperature profile will be used. The retrieved aerosol model favours small, Rayleigh scattering particles, which is in good agreement with the GCM cloud, indicating that the aerosol properties most critical for transmission spectra can be recovered. We will next perform a comprehensive study, testing a variety of aerosol parameterizations on spectra generated using both the DIHRT and EddySed cloud microphysics schemes, the results of which will be presented.

Acknowledgements

JKB is supported by a Royal Astronomical Society Research Fellowship.

References

Rodgers, C. D. 2000, Inverse Methods for Atmospheric Sounding (World Scientific)

Feroz, F., Hobson, M. P., & Bridges, M. 2009, MNRAS, 398, 1601

Feroz, F., & Hobson, M. P. 2008, MNRAS, 384, 449

Feroz, F., Hobson, M. P., Cameron, E., & Pettitt, A. N. 2009, arxiv

Lines, S., Manners, J., Mayne, N. J., et al. 2018, MNRAS, 481, 194

Irwin, P. G. J., Teanby, N. A., de Kok, R., et al. 2008, Journal of Quantitative Spectorscopy and Radiative Transfer, 109, 1136

Lee, G., Dobbs-Dixon, I., Helling, Ch., Bognar, K. & Woitke, P. 2016, A&A, 594, 48

Helling, Ch., Woitke, P. & Thi, W.-F. 2008, A&A, 485, 547

Ackerman, A. S., & Marley, M. S. 2001, ApJ, 556, 872

Barstow, J. K., Aigrain, S., Irwin, P. G. J., & Sing, D. K. 2017, ApJ, 834, 50

MacDonald, R. J., & Madhusudhan, N. 2017, ApJL, 850, 15

Buchner, J., Georgakakis, A., Nandra, K., et al. 2014, A&A, 564, A125

Krissansen-Totton, J., Garland, R., Irwin, P., & Catling, D. C. 2018, AJ, 156, 114