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Temperature and abundance retrieval for exoplanet atmospheres

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We present a retrieval technique for exoplanet atmospheres, and some new results from several applications of the technique. Recently, we demonstrated a statistical temperature and abundance retrieval method for exoplanet atmospheres (Madhusudhan & Seager, 2009, ApJ, 707, 24). Our method facilitates calculating error contours in the space of chemical composition, the 1-D averaged temperature structure, and the day-night energy redistribution in the planet atmosphere, based on photometric and spectroscopic observations. The statistical treatment involves large-scale computation of millions of 1D atmosphere models, spanning the large parameter space allowed by current data. Our model includes a parametric pressure-temperature (P-T) profile coupled with line-by-line radiative transfer, hydrostatic equilibrium, and energy balance, along with prescriptions for non-equilibrium molecular compositions, and day-night energy redistribution. The parametric P-T profile captures the basic physical features of temperature structures in planetary atmospheres (including temperature inversions), and fits a wide range of published P-T profiles, including those of solar system planets. We applied our temperature and abundance retrieval method to Spitzer, HST and/or Kepler observations of several exoplanet atmospheres. We present three prominent results here. Firstly, we place statistical constraints on the atmospheric properties of two exoplanets with the best data, HD 189733b and HD 209458b. For HD 189733b, we find efficient day-night redistribution of energy in the atmosphere, and molecular abundance constraints confirming the presence of water, carbon monoxide, carbon dioxide, and methane. For HD 209458b, we confirm and constrain a thermal inversion in the dayside atmosphere. We also report detection of water, carbon monoxide, carbon dioxide, and methane on the dayside of HD 209458b, from six-channel Spitzer photometry. We report constraints due to individual data sets separately; a few key observations of HD 189733b made at similar wavelengths differ at the 2-sigma level. We, therefore, acknowledge the strong possibility that the atmosphere of HD 189733b is variable. Secondly, we statistically address the question of whether existing observations require thermal inversions in very hot Jupiter atmospheres. Finally, we present new pathways towards characterization of exoplanet atmospheres.