Dynamic Meteorology at the Photosphere of HD 209458b

Curtis S. Cooper and Adam P. Showman

We discuss here simulations of the meteorology of the transiting extrasolar planet HD 209458b. Radiative transfer models to date consider only simple redistribution geometries for the stellar radiation absorbed and reemitted by the planet. In particular, radiation models treat only two special cases: (1) complete (global) redistribution of heat, and (2) redistribution of heat over the planet's dayside only. The simulations presented here represent a major advance in our understanding of the heat transfer problem of close-in giant planets.

Our atmospheric model of HD 209458b solves the primitive equations of dynamical meteorology on an Eulerian grid within the planet's extended radiative zone. Dynamics are driven by perpetual irradiation of one hemisphere of this tidally locked planet. The HD 209458b nominal model predicts global temperature contrasts of 500 – 600 K at the photosphere and the development of a steady superrotating jet. The jet extends from the equator to mid-latitudes and from the top model layer at 1 mbar down to 10 bars at the base of the heated region. Equatorial speeds exceed 4 km s^{-1} at 300 mbar. The hottest regions of the atmosphere are blown downstream from the substellar point by $\sim 60^{\circ}$ of longitude. We will describe the various uncertainties of these models and discuss the sensitivity of our predictions to the initial conditions of the simulation.

We predict from our simulations a factor of $\sim$2 between the maximum and minimum infrared radiation from the planet over a full orbital period, with peak infrared emission preceding the time of the secondary eclipse by about 14 hours. We will demonstrate several other observational implications of these results. Recent direct detections of photons from the transiting planets TrES-1 and HD 209458b make the predictions of these simulations highly relevant for guiding near-future observational programs.