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General Circulation and Variability of Close-In Exoplanet Atmospheres

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Abstract

Many exoplanets are on close-in orbits and are likely tidally synchronized. Scaling arguments and simulations indicate that this type of planets may occupy a regime where atmospheric flow structures (jets/vortices) are large, making their possible time variability crucial to observations (if they are coupled to the temperature field). Time variability affects assumptions when interpreting observations, but also offers an opportunity to extract additional information about the atmospheres from the time modulation of the signals. The goal of our study is to constrain the conditions under which time variability can be expected and understand mechanisms likely to cause or quench variability on tidally locked exoplanets.

We use a general circulation model, solving the primitive equations with thermal relaxation. We have explored the parameter space relevant for tidally synchronized planets, using the super-Earth GJ1214b as a reference planet. For a large range of conditions, robust features include a small number of jets and large-scale vortices. The vortices often exhibit time variability, associated with planetary scale waves, with corresponding variability in the position of relative hot and cold regions.

These results make a strong case for mission concepts such as NASA's FINESSE and ESA's EChO, that emphasize repeated measurements of a given planet, enabling feedback between observations and modeling that can yield new insights for exoplanet atmospheres. Furthermore, it is already becoming possible to extract information about latitudinal as well as longitudinal structure of transiting exoplanet atmospheres, so knowledge about the extent of spatial and temporal variability can soon be within reach.