ATMOSPHERIC CIRCULATION ON GJ1214B: DEPENDENCE ON COMPOSITION AND METALLICITY. T. Kataria[1], A. P. Showman[1], J. J. Fortney[2], M.S. Marley[3], R. S. Freedman[3], [1]University of Arizona, Tucson, AZ (tkataria@lpl.arizona.edu), [2]University of California at Santa Cruz, Santa Cruz, CA, [3]NASA Ames Research Center, Moffet Field, CA.

Introduction: Of the ~750 extrasolar planets detected to date, much of the observational characterization has been for transiting hot Jupiters, Jovian-mass exoplanets that pass in front of their host star at semi-major axes less than 0.1 AU. Observations between transit and secondary eclipse have been obtained from ground- and space-based telescopes (e.g. [1]). One can use these observations (along with radial velocity data) to determine the planet's temperature structure, thus constraining the circulation of their atmospheres (e.g. [2]). The next decade, however, will see a growth in the detection and characterization of terrestrial exoplanets, in particular the "super Earths", planets 1-10 times the mass of Earth. Already, over 60 detections of such planets have been made (e.g. [3], [4]), not including the hundreds of additional planet candidates recently announced by NASA's Kepler mission ([5]). Of particular interest is the detection of super Earths around M-dwarfs, ideal targets for exoplanet surveys because of their small star-planet contrast. The MEarth survey has detected a transiting super-Earth of mass $6M_E$ orbiting M-dwarf GJ 1214A at an orbital distance of 0.014 AU ([3]). We can therefore observe this super Earth by similar techniques used for transiting hot Jupiters, allowing us to characterize the planet's atmosphere. Because the planet is closely orbiting its parent star, it is likely that the planet is tidally locked and synchronously rotating. Thus, like hot Jupiters, one side of the planet will be permanently illuminated while the other will be permanently dark.

Observations of GJ1214b have been obtained by numerous groups to characterize the planet's atmosphere. The first ground-based spectrum obtained by [6] is a generally featureless one, suggesting an atmosphere with a high mean-molecular weight (i.e., not hydrogen- and helium-dominated). Observations obtained by [7], [8] and most recently [9] agree with this result. Still, analysis of other observations favor a H/He dominated atmosphere, particularly if methane is depleted ([10], [11]). The fact that super Earths in general–and GJ1214b specifically–could have either hydrogen-rich or hydrogen-poor atmospheres raises fundamental questions about their atmospheric circulation, since these limits have pressure scale heights differing by an order of magnitude and therefore may exhibit fundamentally differing atmospheric dynamics regimes.

In light of these considerations, we model the atmosphere of GJ1214b using the SPARC/MITgcm, a general circulation model coupled to a fast and efficient radiative transfer scheme applicable to a broad range of atmospheric compositions. Previous studies have investigated the atmospheric circulation of GJ 1214b ([12],[13]), but none using realisitic non-grey radiative transfer. In particular, we focus on the effects of metallicity and composition on the overall temperature structure and dynamical regime.

Model Description: We model GJ1214b's atmosphere using the Substellar Planetary Atmospheric and Radiation Circulation (SPARC) Model, which couples the MITgcm [14] with a plane-parallel, two-stream radiative transfer model by [15] (see [2] for more details). The MITgcm solves for the circulation of the atmosphere using the primitive equations, a simplification of the Navier Stokes equations assuming local hydrostatic balance. Each simulation utilizes a cubed-sphere grid with a horizontal resolution of C32 (64x128 in latitude and longitude) and a vertical pressure range from ~200 bar to ~20 μbar split into 76 levels with even log spacing.

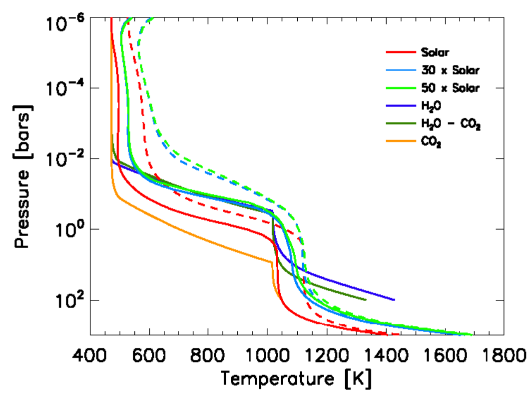

Figure 1: T-P profiles for hydrogen-dominated atmospheres from [16]). The profiles we use for the simulations are given by the red (solar metallicity), blue (30 × solar) and green (50 × solar) solid lines.

In this study, we model three atmospheric compositions: hydrogen-dominated, water-dominated, and CO_2 -dominated. For the hydrogen-dominated cases, we model cases with solar metallicity, 30 × solar, and 50 × solar as presented in [16] (**Figure 1**). Opacities for each case are binned using the correlated-k method ([17]). These various compositions affect not only the atmospheric opacities (hence absorption of starlight and emission of infrared radiation) but also the mean molecular weight, hence atmospheric scale height, dry adiabatic lapse rate, and other factors.

Results: As seen in previous work by [18] and others, enhanced metallicity (and hence opacity) leads to shallower atmospheric heating. This affects the atmospheric temperature gradients and winds of the planet as a function of altitude. **Figure 2** illustrates this, plotting the zonal-mean zonal (east-west) wind as a function of pressure and latitude for the 1 × solar, 30 × solar, and 50 × solar metallicity cases. At solar metalllicity, the circulation of the planet is dominated by deep (≤1 bar) eastward jets at the midlatitudes (~60° N and S), with a shallow (<10 mbar) eastward jet at the equator. At enhanced metallicities, the flow is dominated by deep superrotation at the equator, with peak speeds exceeding 2000 m/s. However, the overall eastward wind structure becomes shallower with increasing metallicity; at 50 × solar the winds only penetrate to ~100 mbar.

Overall, a dynamical regime shift occurs from solar to enhanced metallicity, likely due to to changes in latitudinal and day-night heating/forcing. This day-night forcing generates standing Rossby and Kelvin waves which lead to equatorial superrotation and perhaps to equatorial instabilities forming the midlatitude superrotating jets. Ultimately, we will diagnose the mechanisms that drive this forcing, and understand how they depend on atmospheric composition and metallicity. In exploring the effect of atmospheric composotion, we will test water-dominated and CO_2-dominated atmospheres. Furthemore, we will generate synthetic lightcurves and spectra to see which of these best match current observations. Results thus far show that temperatures at photospheric levels have little variation from the dayside to nightside regardless of metallicity, which will have implications for resultant lightcurves. This work serves as a first step towards characterizing the circulation regime and temperature structure of GJ1214b and other super Earths.

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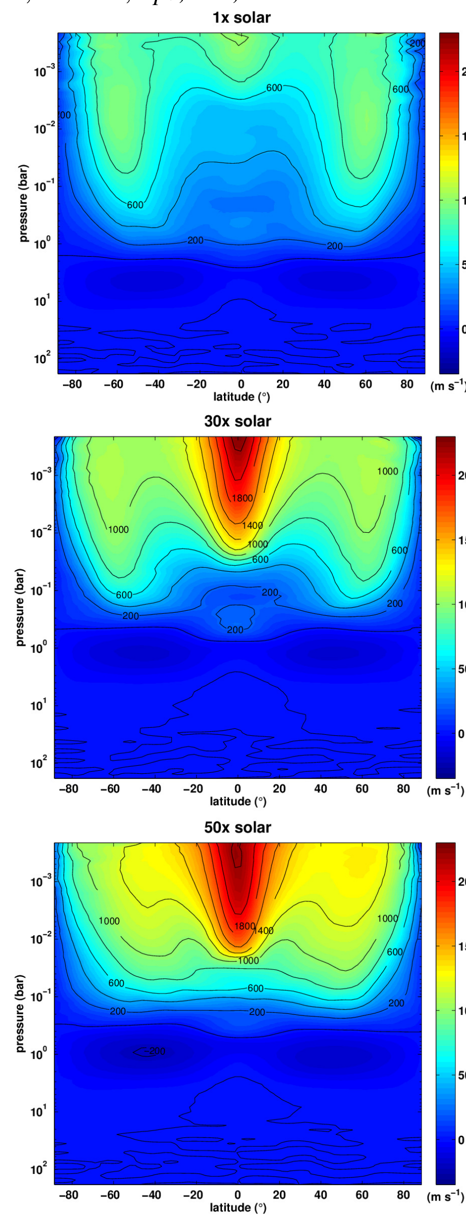

Figure 2: Zonal-mean zonal (east-west) wind as a function of pressure and latitude for GJ1214b with a atmospheric composition of 1 × solar (top), 30 × solar (middle) and 50 × solar (bottom). Note that the colorscales are the same for each figure.