Theoretical modeling of hydrogen line emission from accreting gas giants: comparison with observations of LkCa15b and PDS70b

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Recent direct imaging observation has detected some forming protoplanets. Although most of such observations used infra-red bands, also visible band observation, which covers H-alpha line, detected two protoplanetary candidates, LkCa15b and PDS70b. The observed luminosities of IR photon from the protoplanets correspond to the emission from the gas of thousands K. This is a reasonable temperature for photosphere of accreting protoplanets. On the other hand, the detected H-alpha luminosities exceed the emission of thousands K and correspond to tens of thousands of K. Such a hot gas originates in shock-heated gas. According to numerical simulations of hydrodynamics around forming planets, gas accreting towards protoplanets goes through several shocks. At some of the shocks, its flow velocity exceeds gas sound speed by several orders of magnitude. Thus, the shock heats the gas to tens of thousands of K, and the shock-heated gas can emit H-alpha of observable intensity. However, such a hot gas rapidly cools by hydrogen line radiation. Since the temperature changes with electron transitions proceeding, the hydrogen electron level distribution, which determines hydrogen line emission and extinction, never reaches its equilibrium state. Therefore, in this study, we modeled hydrodynamics of cooling flow after the shock, radiative transfer of hydrogen lines, and electron level transitions at the same time. Using this model, we estimated hydrogen line intensity as a function of gas velocity and mass flux at the shock. By comparing the results with the observational results, we will discuss the preferred picture of gas accretion towards protoplanets.

Keywords: LkCa15b, PDS70b, Shock heating, Hydrogen line, Hα

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