Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PPS21-28 Room:304 Time:May 21 10:00-10:15

Effects of Evaporation of Hot-Jupiters on Exoplanets Population

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As the number of observed exoplanets increases, statistical discussions have been possible. It has been pointed out that there are correlations between semi-major axes (or orbital periods) of planets and planetary masses, surface gravities, or densities (Mazeh et al., 2005; Southworth et al., 2007; Jackson et al., 2012). One possible mechanism to account for the correlations is XUV-driven atmospheric escape due to the heating of upper atmosphere by stellar XUV (e. g., Lammer et al., 2003; Jackson et al.,2012).

Previous works which test the hypothesis neglected thermal cooling and evolutions of planetary radii or densities due to mass-loss. Also, the energy-limited escape was simply assumed. However, the changes of planetary radii and densities can result in a runaway mass-loss (Braffe et al., 2004). The Roche-lobe overflow might contributes to mass-loss in such a runaway regime. In addition, under an intense XUV environment which is possible in earlier stages of a host star, the thermal escape is in the recombination-limited regime (Murray-Clay et al., 2009; Owen and Jackson et al., 2012), not in the energy-limited regime as assumed in previous works on mass-loss evolutions. In this study, we develop a model to calculate the thermal evolution and the mass-loss evolution simultaneously taking the Roche-lobe overflow and the recombination-limited escape into account.

As a result, we show that a total evaporation of an envelope occurs for planets orbiting close to the host star (~0.015 AU for a Jupiter-mass planet) and the evaporation is in the recombination-limited regime, not in the energy-limited regime. The mass-loss results in an expanding of the planetary radius and it is followed by the runaway mass-loss. The mass-loss evolution finally causes the Roche-lobe overflow. Because it strongly depends on the initial mass of the planet whether the planet experiences the runaway mass-loss or not, we can define a critical mass for a planet to lose whole envelope as a function of the semi-major axis. We show a comparison of the semi-major axis - critical mass relation obtained by our calculation and the observed population of exoplanets. Our results for Hot-Jupiters which have a small core of ~10 Earth mass are consistent with the observation.

Keywords: exoplanet, atmospheric escape, gas planet, Hot-Jupiter, stellar XUV