Magnetically Driven Wind from Hot Jupiters

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Abstract

Recently theoretical studies on thermal evolution of hot Jupiters invoke Ohmic dissipation to account for extraordinary large radii of some objects. Those analyses suggest the existence of significantly strong magnetic fields in hot Jupiters. To test this hypothesis it is important to investigate possible consequence of magnetic fields in gaseous giant planets. Since gaseous giant planets are supposed to have large convection zones, magnetic field mediates energy transfer from the interior to the exterior of the atmosphere.

Atmospheric escape from hot Jupiters have been observed in some exoplanets by using transit method. But there are no previous works about magnetically driven wind from a gaseous planet.

In this poster we develop a model of magnetically driven wind from a gaseous planet and investigate the resultant mass loss.

We apply the theory of mass loss from the Sun to calculate mass loss rate from gaseous planet, especially from hot Jupiters. We get mass loss rate which is consistent with observational mass loss rate when we use parameters which are assumed to be typical value for hot Jupiters.

This work may provide a possible consistency check of theories with observation of hot Jupiters.

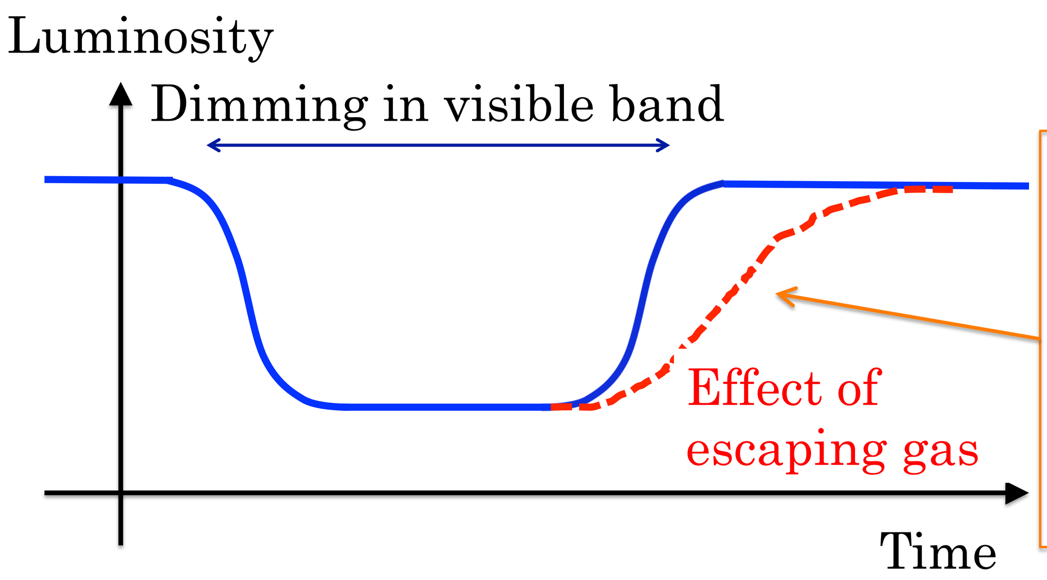
■ Introduction

Hot Jupiter ➔ Close-in gaseous giant planet
Typical semi-major axis ~0.05AU

High surface temperature due to strong irradiation from central star ~1000K
➔ Large amount of mass loss from atmosphere is expected

From observation..
- Rare atmosphere extends out to several planetary radii
- Mass loss from atmosphere

☆Mass loss from hot Jupiter can be detected by using transit method



Comet-like tail of escaping high temperature atmosphere creates distinctive structure in light curve in UV band

This structure is observed in light curve of HD 209458b
Estimate value of mass loss rate (lower limit)
~10^{10} g/s (Vidal-Madjar et al. 2003)

What is the driven mechanism of mass loss?
➔Mass loss driven by magnetohydrodynamic wave
➔Energy of turbulent at surface drives "planetary wind" through magnetic field
There are no previous work about the relation between mass loss and magnetic activities in gaseous planets.

■ Model of Mass Loss from Planets

Apply the previous study of solar wind acceleration (Suzuki & Inutsuka 2005, 2006) to gaseous planets (1D MHD calculation)
- Perturb magnetic field lines at surface

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- MHD waves propagate and dissipate

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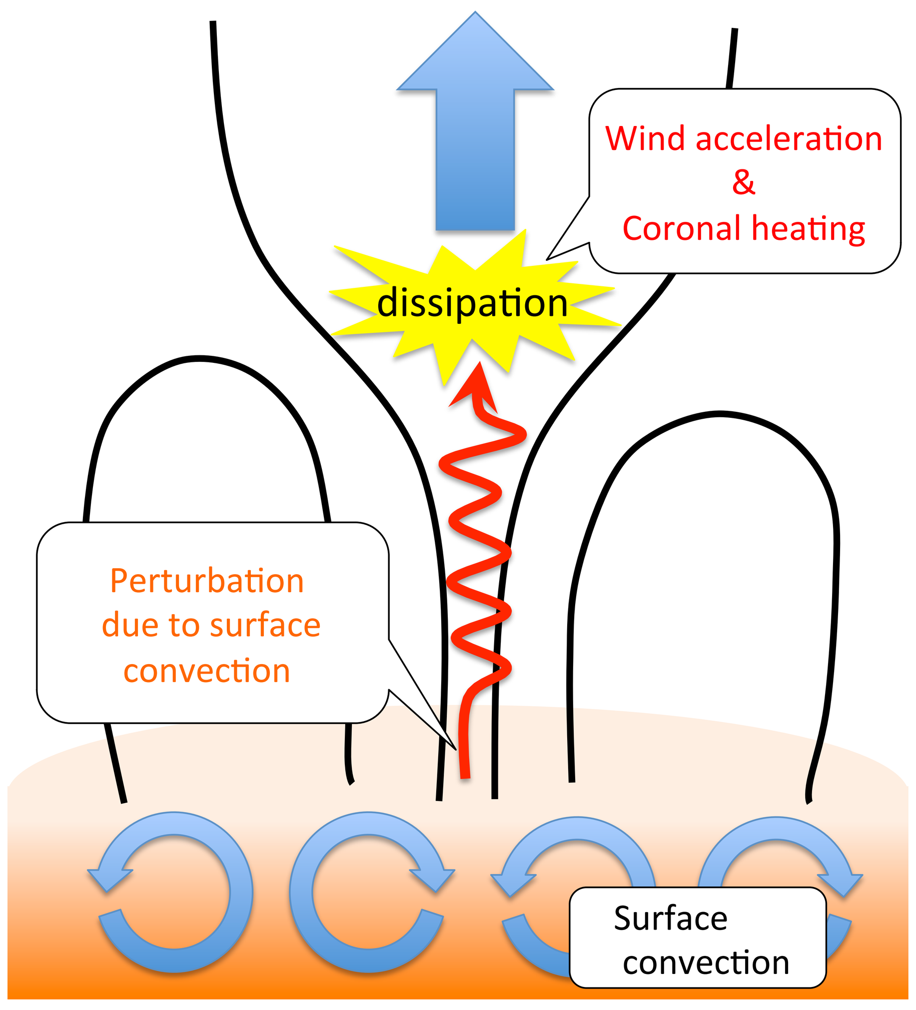
- Acceleration of wind
- Creation of coronal region



Apply this model to Jupiter-mass objects and calculate mass loss rate

■ Result

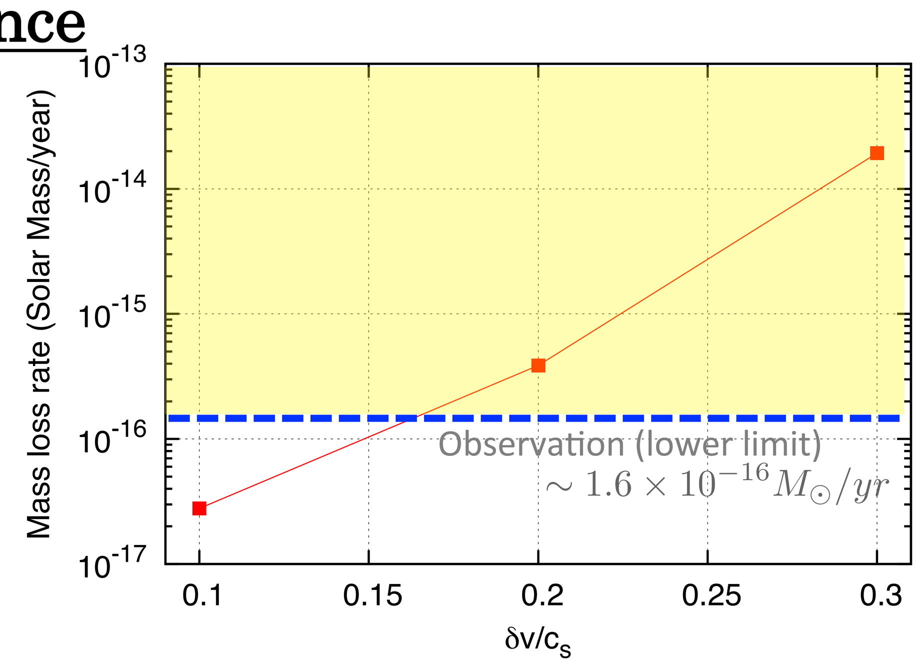
☆Parameters
Amplitude of velocity dispersion, radius & mass of planet
Surface temperature is fixed to 1000K

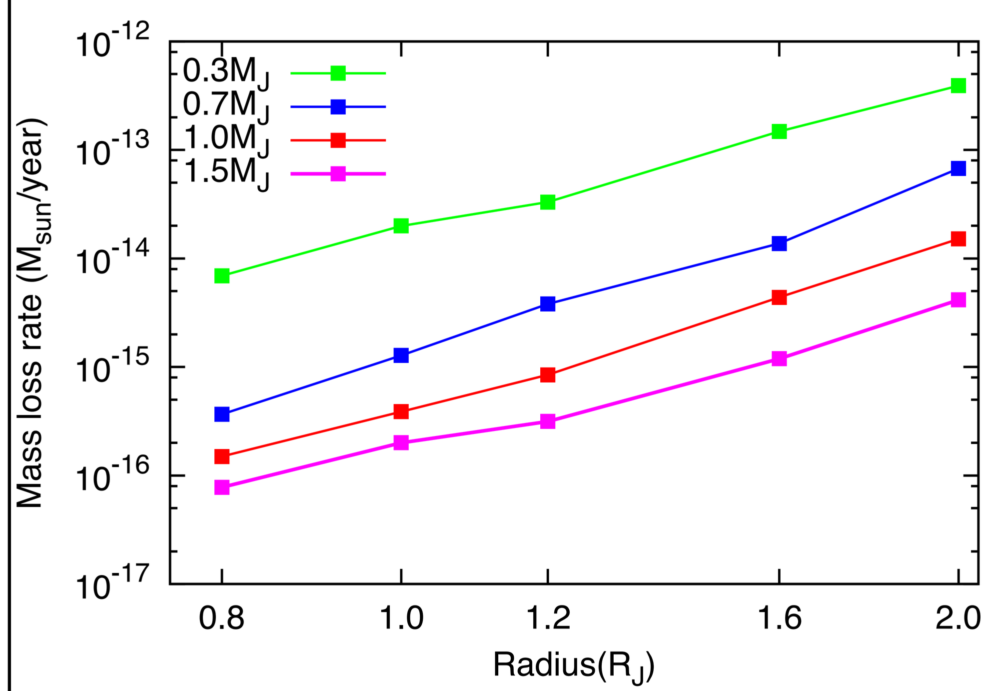
☆Velocity dispertsion dependence
(Jupiter radius and mass)

When $\delta v = 0.2 c_s$,

$$\dot{M} \simeq 3.87 \times 10^{-16} M_{\odot}/yr$$

➔ Consistent with observational value





☆Radius and Mass
(fix dv to 0.2c_s)

Larger radius and smaller mass
➔Larger mass loss rate

Depend strongly to radius of planet

■ Parameter Dependence

Approximate expression of radial density profile at upper atmosphere is

$$\rho/\rho_0 = \exp\left(-\frac{r-R}{H_0}\frac{R}{r}\right) \qquad H_0 = \frac{N_A k_B T}{\mu g_0} \text{ (Scale height)}$$

Proportional relation of energy of planetary wind is

$$\frac{1}{2}\dot{M} v_{esc}^2 \propto 4\pi R^2 \rho(r_c)\, v_w \langle \delta v^2 \rangle$$

Lhs ➔ Kinetic energy transported by wind per unit time
Rhs ➔ Energy flux at nozzle point of planetary wind

From these two equation, we can get

$$\dot{M} \propto \frac{R^3}{M} \exp\left(-\frac{G}{c_s^2}\frac{r_c - R}{r_c}\frac{M}{R}\right)$$

Parametric dependence of mass loss rate

➔Consistent with simulation

Conclusion & Discussion

We can get consistent mass loss rate if we assume that mass loss is driven by magnetohydrodynamic wave due to surface convection. ➔ **Planetary wind is driven by magnetic field**
Derived parametric dependence

Dependence on surface temperature
Relation with interior or formative process } ➔Future works