Where to find exomoons

Xing Wei[1], Doug Lin[2]

1 Beijing Normal University, Beijing, China
2 UCSC, Santa Cruz, USA

Abstract

We study two mechanisms for the retention of exomoons. In the presence of a circumplanetary disk (CPD), by comparison between CPD's inner and outer radii, we find that planets with too strong magnetic fields or too small distance from its host star tend not to host exomoons. During the subsequent CPD-free evolution, we find, by comparison between planet's spindown and moon's migration timescales, that hot Jupiters with periods of several days are unlikely to retain large exomoons, albeit they could be surrounded by rings from the debris of tidally disrupted moons. In contrast, moons, if formed around warm or cold Jupiters, can be preserved.

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Mechanism I: with disk

At first we need to find young planet's magnetic field

$$\partial_t(\rho v^2/2 + B^2/2\mu) = -\boldsymbol{\nabla}\cdot\boldsymbol{A} + \delta\rho\,\boldsymbol{g}\cdot\boldsymbol{v} - D_\nu - J^2/\sigma$$

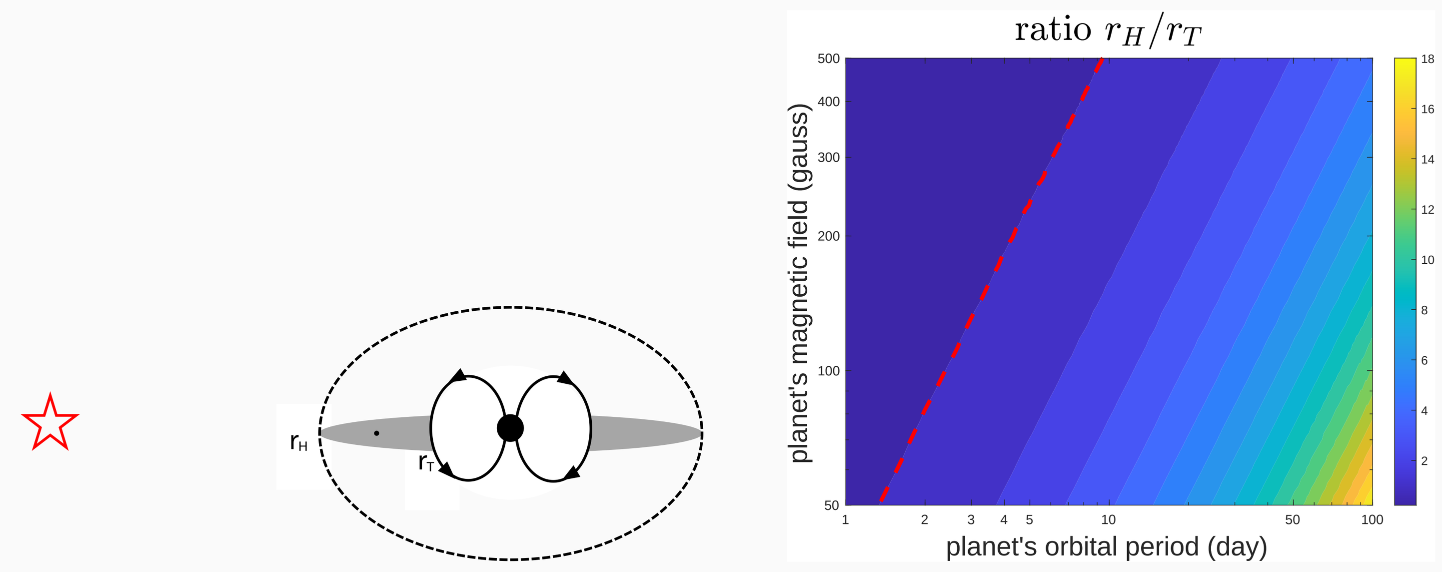
$$\Longrightarrow \langle B^2/\mu\rangle \simeq \beta\rho_m^{1/3}F_s^{2/3} \Longrightarrow \langle B^2/\mu\rangle \simeq 0.115M^{1/3}R^{-7/3}L^{2/3}$$

Assume $R \propto t^{-\gamma}$ ($\gamma \approx 0.044$), by virial theorem $L \propto M^2t^{-1}$

$$\Longrightarrow \langle B\rangle \propto M^{5/6}t^{(3/2)\gamma-1/3} \propto M^{5/6}t^{-0.267}$$

typical field of a young Jupiter-mass planet $\approx$ 100 gauss

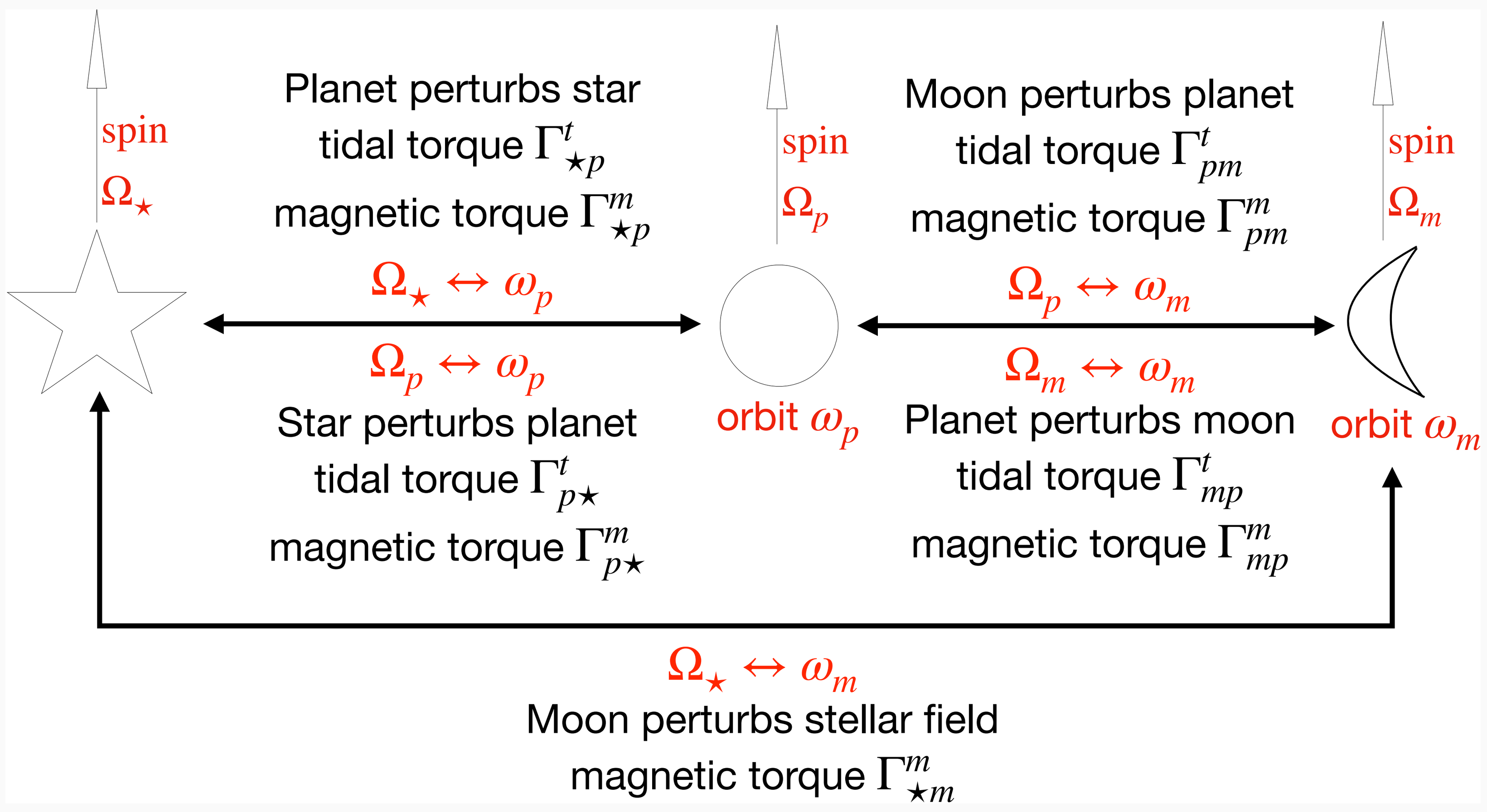
Mechanism I: with disk



Exomoon's retention requires $r_H/r_T > 1$.

$r_H \simeq (M_p/M_\star)^{1/3}a_p \simeq 0.1a_p,\ r_T \simeq (B_p^4R_p^{12}/GM_p\dot{M}_p^2)^{1/7}$

Mechanism II: without disk



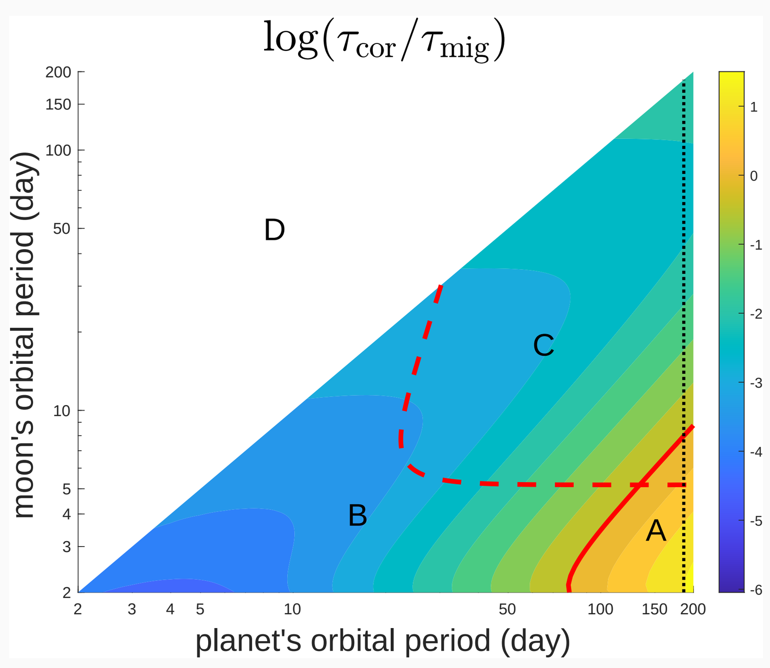
$\Gamma^t_{12} \simeq GM_2^2R_1^5\tau_1(\omega-\Omega_1)/a^6$, $\Gamma^m_{12} \simeq 4\sigma_2B_1^2R_1^6R_2^3(\omega-\Omega_1)/a^4$

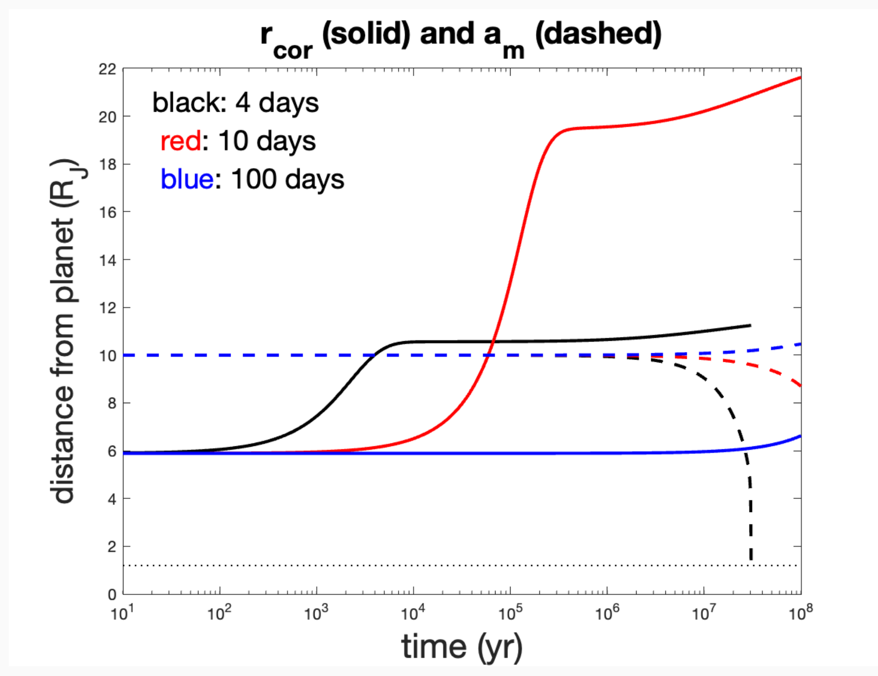
Mechanism II: without disk

$\dot{L}_{\rm p\_obt} = -\Gamma^t_{p\star} - \Gamma^m_{\star p}$, $\dot{L}_{\rm p\_spin} = \Gamma^t_{p\star}$, $\dot{L}_{\rm m\_obt} = -\Gamma^t_{pm} - \Gamma^m_{pm} - \Gamma^m_{\star m}$.

$\tau_{\rm cor} \simeq L_{\rm p\_spin}/|\Gamma^t_{p\star}|$, $\tau_{\rm mig} \simeq L_{\rm m\_obt}/|\Gamma^t_{pm} + \Gamma^m_{pm} + \Gamma^m_{\star m}|$

Exomoon's retention requires $\tau_{\rm cor}/\tau_{\rm mig} > 1$.





Biography

Xing Wei studied PhD at Cambridge and then worked at ETH, Gottingen and Princeton. He is now professor at Beijing Normal University. His interests are fluid dynamics, magnetohydrodynamics and orbital dynamics applied to geophysics and astrophysics.

`xingwei@bnu.edu.cn` `https://xingwei-astro.github.io`

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