Magnetic Coupling In Giant Planet Circumplanetary Disks

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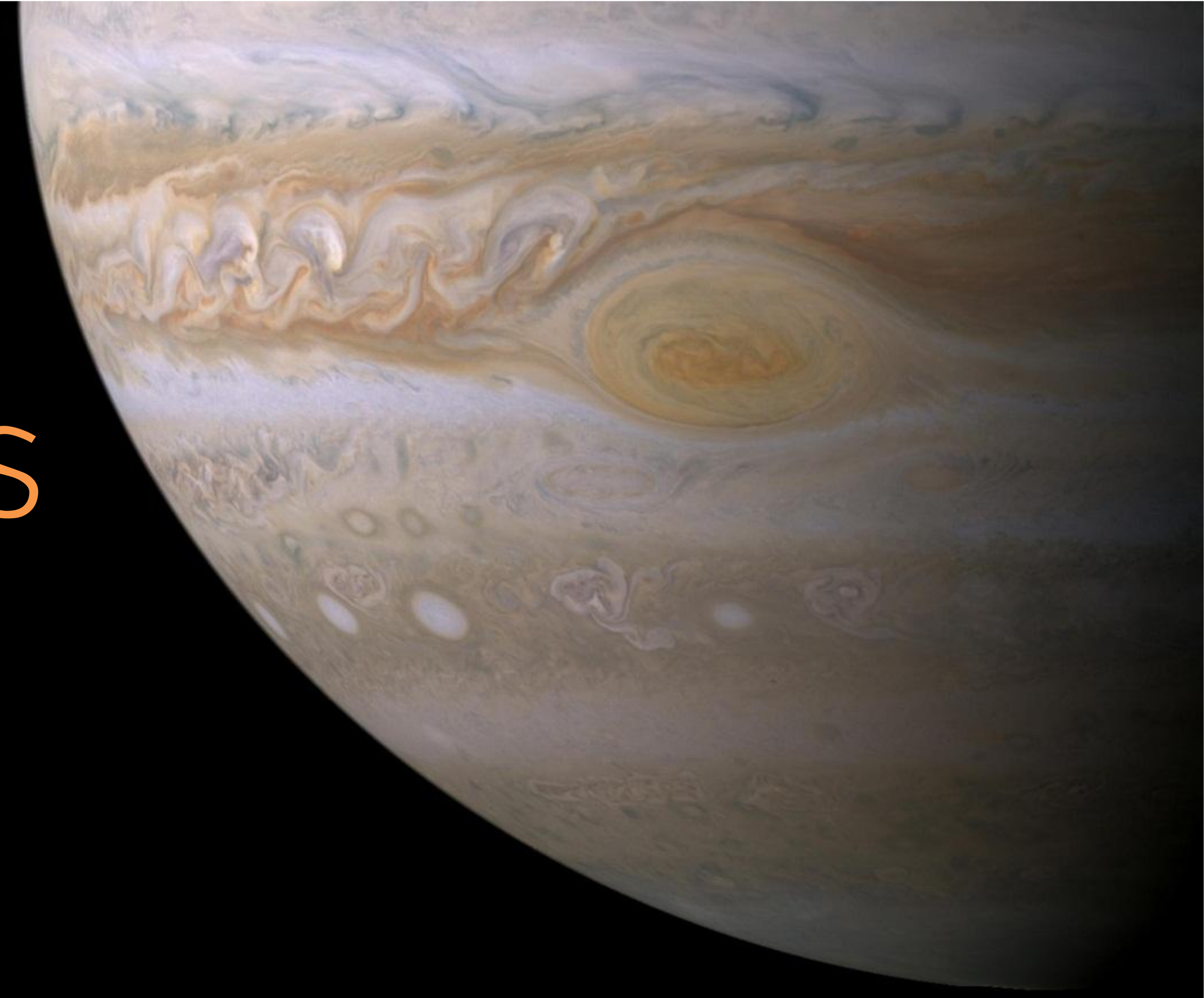
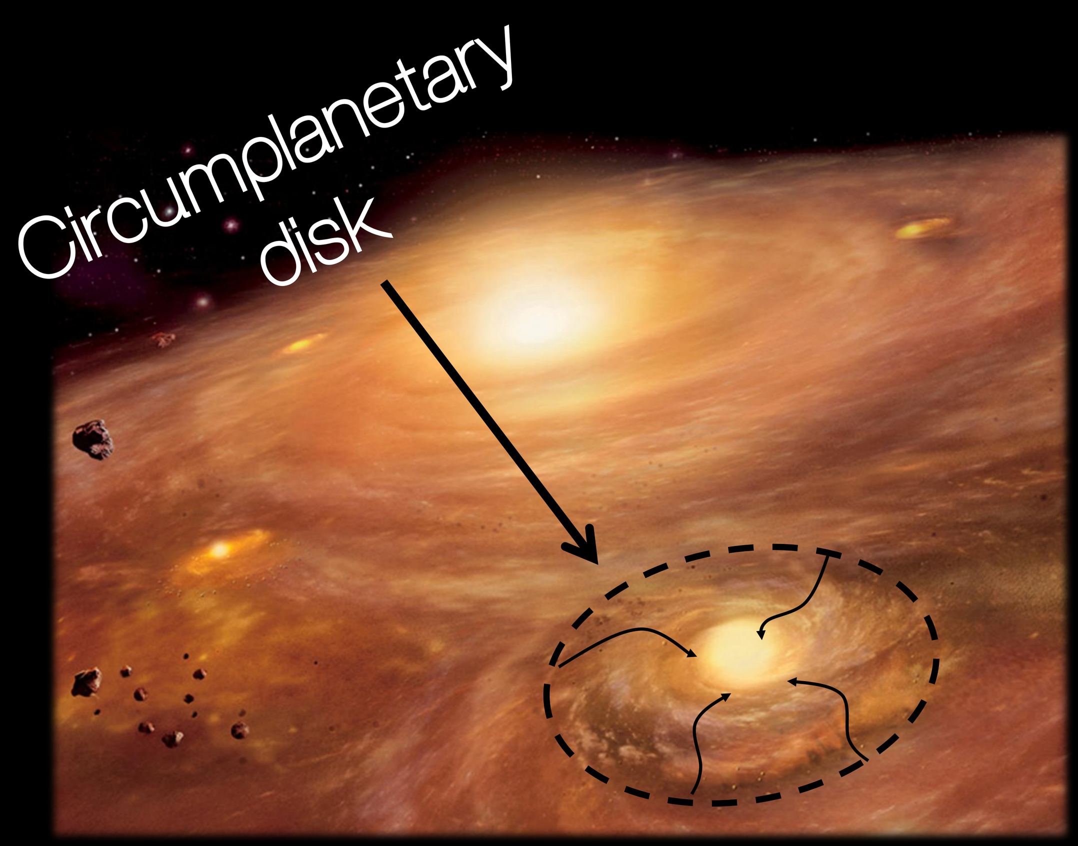


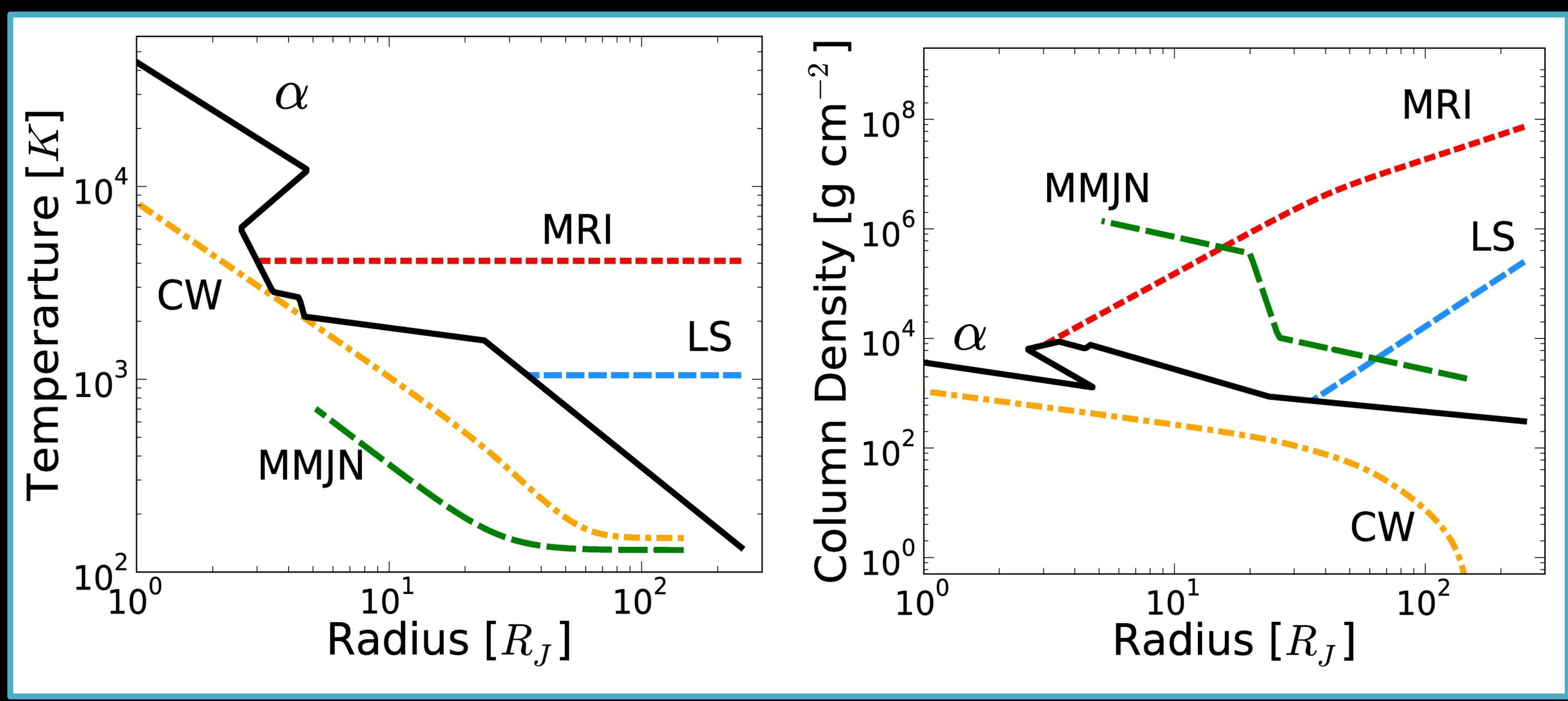


1. INTRODUCTION

During the final growth phase of giant planets, it is thought that accretion is controlled by a surrounding circumplanetary disk. Current models rely on hydromagnetic turbulence as the source of effective viscosity within the disk. However, whether the disk is able to interact sufficiently with the magnetic fields to produce this turbulence remains a key uncertainty. Here, we examine the strength and nature of magnetic coupling in circumplanetary disks to identify active, accreting regions.

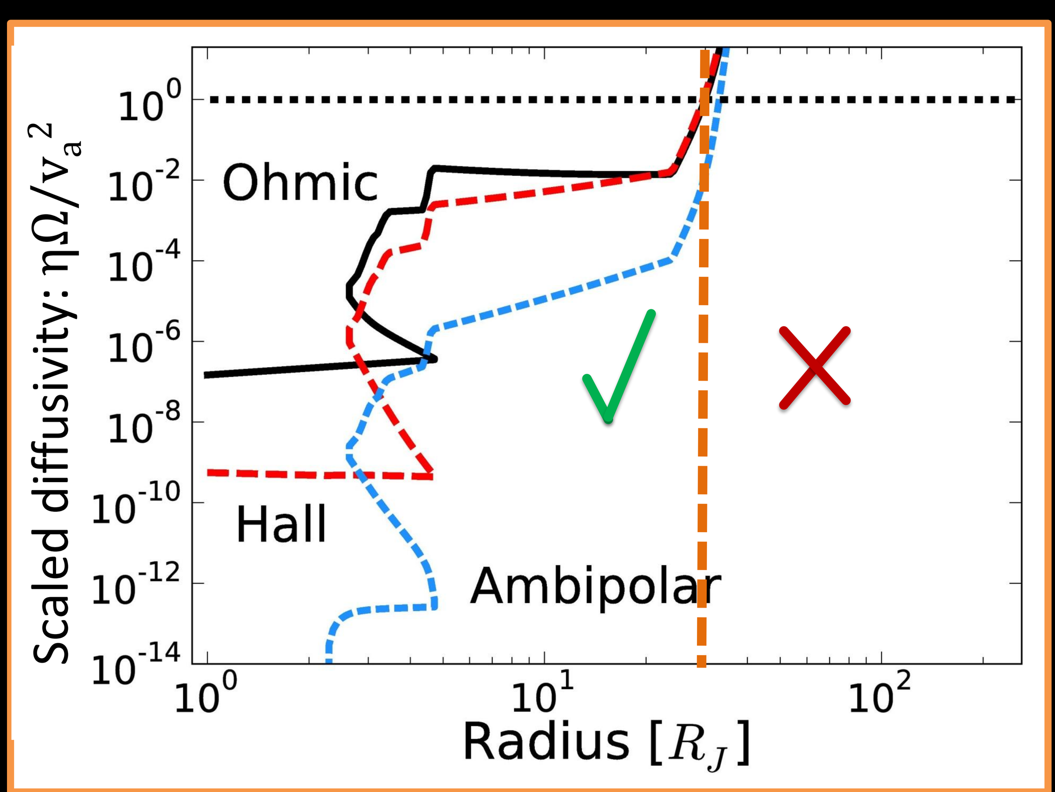
2. METHOD & MODEL

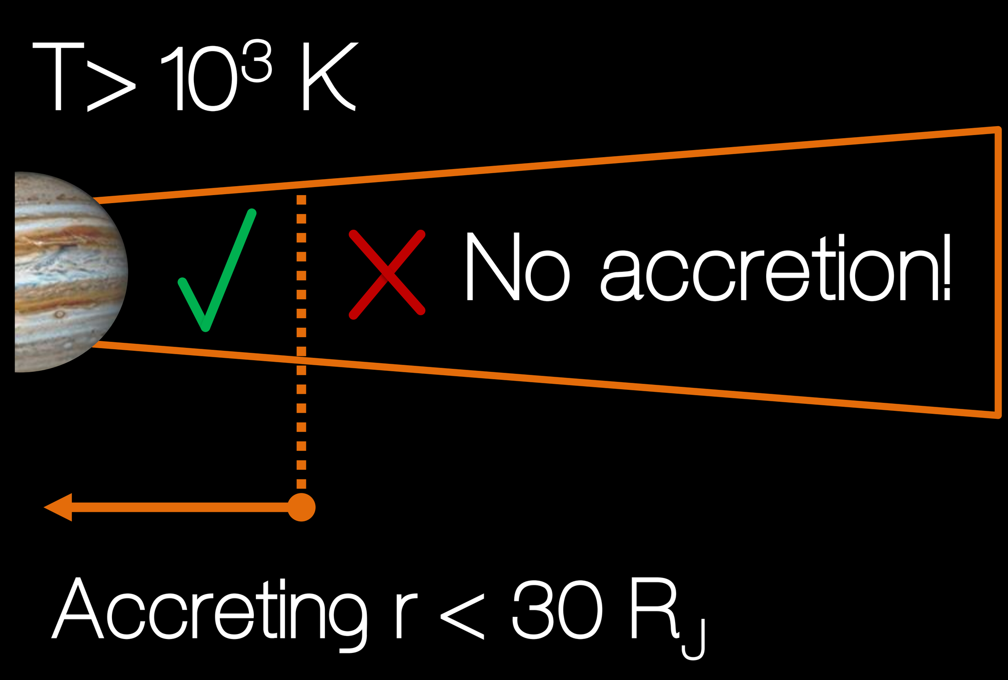
We model the disk as a Shakura-Sunyaev alpha disk, with the Zhu et al. (2009) opacity law. We consider ionisation from thermal ionisation, radioactive decay, cosmic rays, as well as MRI self-sustaining ionisation (Inutsuka & Sano 2005; Muranushi et al., 2012), & penetration of MRI active surface eddies (Ilgner & Nelson 2006, 2008; Turner et al. 2007). We consider both MRI and large scale fields (Wardle 2007, Sano et al. 2004) in driving accretion and determine the strength of coupling between the field and disk using the Ohmic, Hall and Ambipolar diffusivities (Pandey & Wardle 2008; Wardle & Pandey in prep).



Constant alpha disk with Shakura-Sunyev viscosity parameter $\alpha=10^{-3}$ (α) and thermally ionised disk driven by an MRI (MRI) or large scale vertical field (LS). For comparison we also show the Minimum Mass Jovian Nebula (Lunine & Stevenson 1982; Mosqueira & Estrada 2003; MMJN) and Canup & Ward alpha-disk (2002, 2006; CW).

3. CONSTANT-ALPHA DISK



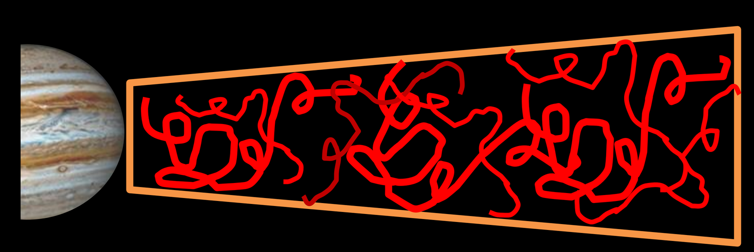


The standard constant-alpha disk is ionised and coupled to the field within $30R_J$, where the temperature T>1000K. However, ionisation is low in the outer regions and strong magnetic diffusivity prevents magnetic coupling so that accretion cannot proceed through the bulk of the disk.

4. THERMALLY IONISED DISK

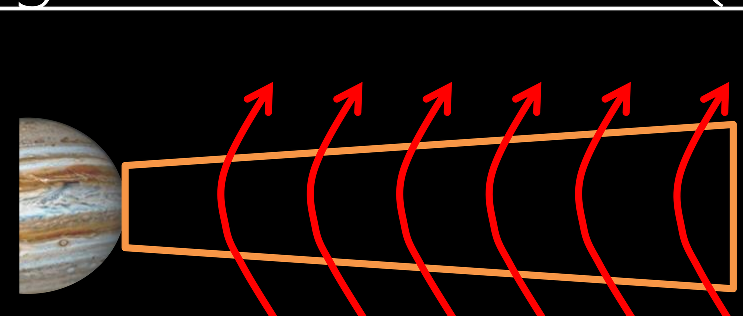
As the constant-alpha disk fails to produce accretion consistent with its viscosity we drop the assumption of constant-alpha & present an alternate model in which the entire midplane is thermally ionised. This is achieved by fixing a minimum temperature, which determines the required column density and alpha, and depends on the magnetic field geometry (MRI or large scale vertical field). While this achieves coupling throughout the disk, the disk is massive and self-gravitating. Large scale fields are favoured as a less extreme disk is needed for coupling.

MRI field (MRI)



T_{min} = 4000 K
$\alpha_{min} \approx 10^{-8}$
(!) $M_{disk} \approx 379\ M_J$ (!),
with $M_{disk} = M_J$ for r < $46R_J$

Large scale vertical field (LS)



T_{min} = 1000 K
$\alpha_{min} \approx 3\times10^{-7}$
$M_{disk} \approx M_J$

✓ Coupled across entire midplane

See temperature & column density profiles for MRI and LS models above in §2.