Jovian and kronian ring currents

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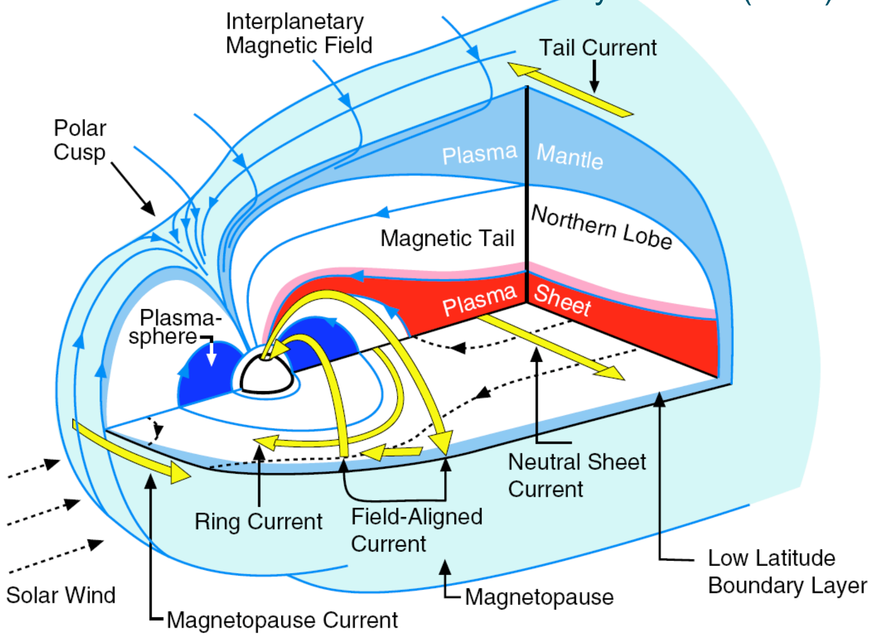
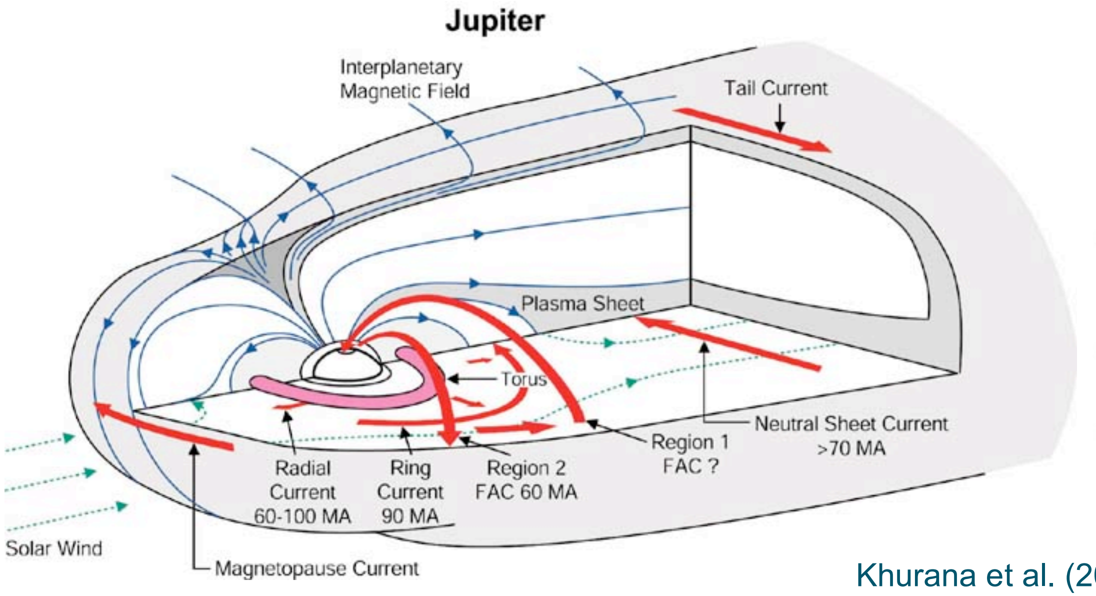
Introduction

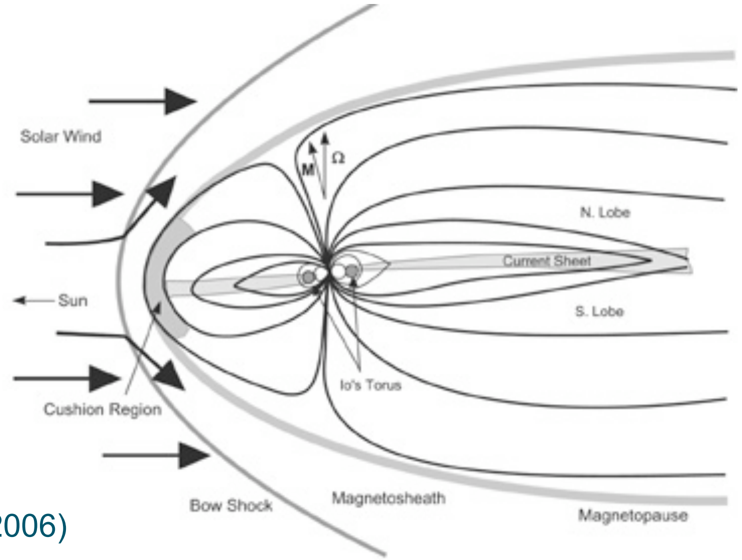
- Earth's ring current produces a magnetic field that doesn't severely change the largely dipolar magnetic field produced by the planet.

- The jovian ring current strongly distorts the shape of the field into a disc-like configuration called the magnetodisc.

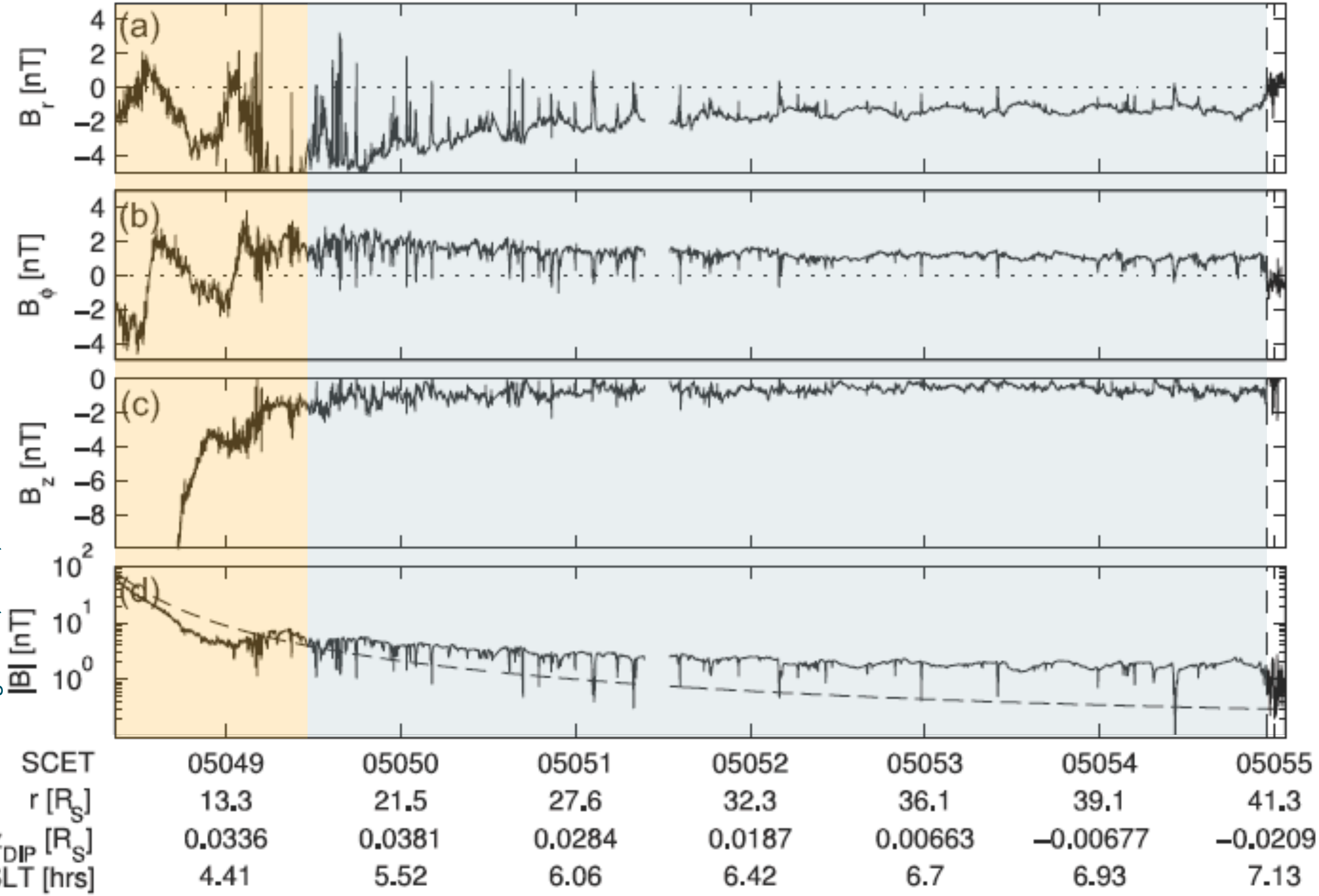
De Keyser et al. (2006)







Khurana et al. (2006)



Arridge et al., 2007, submitted

Force balance responsible for the magnetodisc

- In MHD terms the ring current arises from the force balance in the magnetosphere:

$$\rho(\mathbf{u}\cdot\nabla)\mathbf{u} = -\nabla\cdot\mathbf{P} + \mathbf{j}\times\mathbf{B}$$

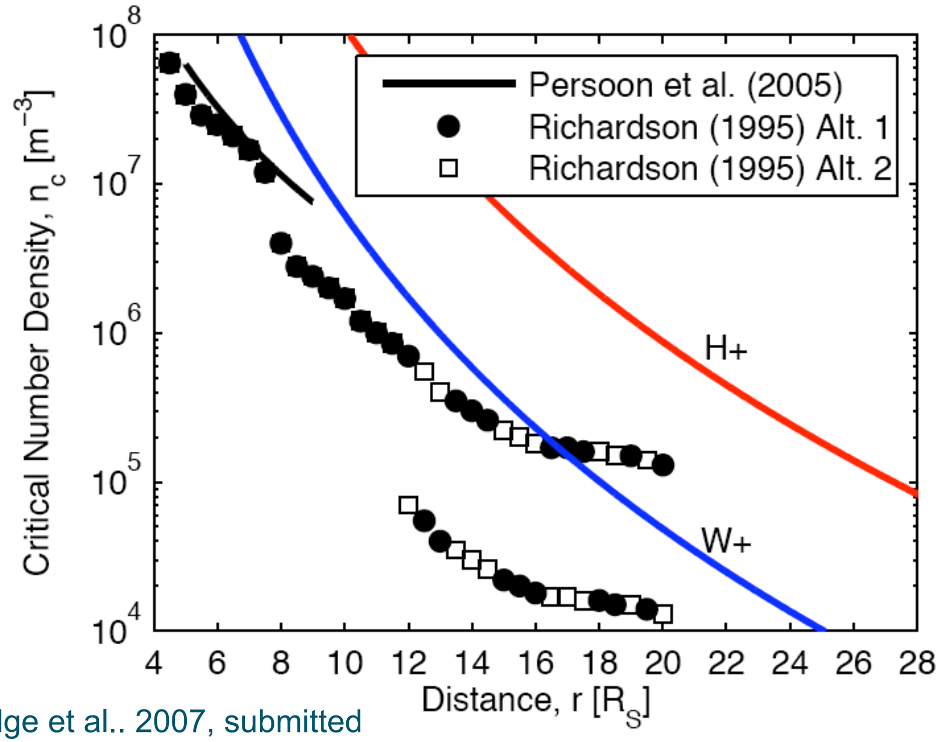
- In establishing the magnetodisc nature of Saturn's ring current we can investigate the forces required to produce a disc.

- Ignoring ∇•P we can expand the radial component:

$$\rho\Omega^2 r = j_\phi B_z = \frac{B_z \Delta B_r}{\mu_0 D}$$

- When $\Delta B_r > B_z$ the field is disc-like and the density corresponding to such a configuration is:

$$n_c = \frac{B_z^2}{\mu_0 D m_p M_i \Omega^2 r}$$

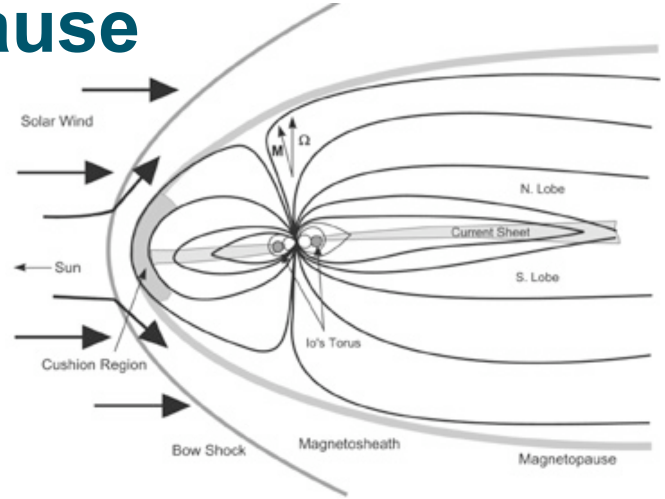


Arridge et al.. 2007, submitted

Ring current and the magnetopause

- The location of the magnetopause depends on a pressure balance across the boundary:

$$kP_{SW} = \frac{B^2}{2\mu_0}$$



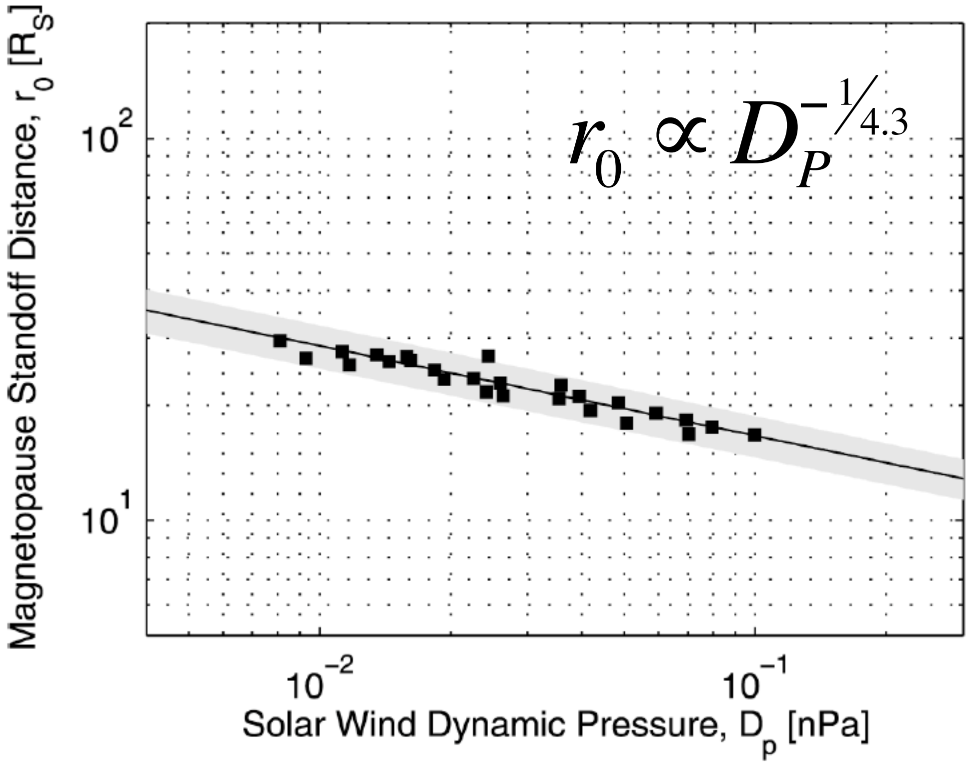
- Assuming a vacuum dipole, $B=B_P r^{-3}$

$$r_0^6 = \frac{B_P^2}{2\mu_0 k} D_P^{-1}$$

$$r_0 = \left(\frac{B_P^2}{2\mu_0 k}\right)^{1/6} D_P^{-1/6}$$

- The Earth's magnetopause actually follows this 1/6th law quite closely (Shue et al. 1997).

- But a 1/4th law was found for Jupiter (Slavin et al. 1985; Huddleston et al. 1998) and also recently for Saturn (Arridge et al. 2006).



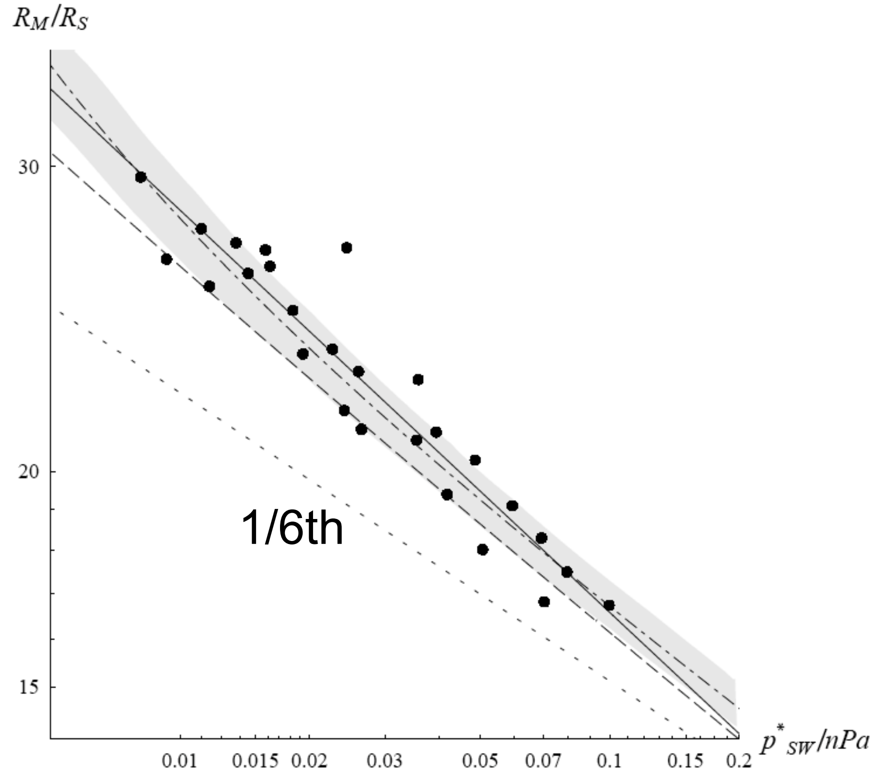
Ring current effect on the magnetopause

- Using a simple model current sheet to represent the ring current, an empirical model for the variation of the ring current with system size was established by Bunce et al. (2007).

- The azimuthal drift relative to the ExB flow is given by: $$v_{d\phi} = \frac{1}{qB}\left(mr\Omega^2 - \frac{W_\perp}{B}\frac{dB}{dr}\right)$$

- The magnetic moment associated with this current loop is:

$$\mu_{TOT} = \frac{mr^2\Omega^2}{2B} + \frac{W_\perp}{B}\left(1 - \frac{r}{2B}\frac{dB}{dr}\right)$$



- Bunce et al. (2007) shows that the inertial term varies much more strongly with system size than the thermal term.
  - A pressure-gradient-dominated ring current will not modify the 1/6th law
  - When inertial terms are important the magnetosphere will be more more compressible.

Questions, outstanding issues and discussion points

- What is the nature of the transition/interaction between a terrestrial-type magnetotail and magnetodisc?
  - Surely depends on the maintenance of (sub)corotation which in turn depends on the magnetosphere-ionosphere coupling?

- What physical processes occur at the transition to the magnetodisc?
  - Plasma flows, changes in stress balance, corotation breakdown
  - Is the importance of the acceleration current a requirement for a magnetodisc?? Some think so, some don't…

- When the solar wind pressure is high, producing a quasi-dipolar dayside and a highly asymmetric magnetodisc, what are the form and properties of the FAC ensuring $\nabla \bullet \mathbf{j}=0$ and their place in global force balance? - or do they close along the magnetopause?