Geophysical Research Abstracts
Vol. 13, EGU2011-3523, 2011
EGU General Assembly 2011

Tidal instability in exoplanetary systems evolution

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The role of tides in the evolution of systems composed of a star and a close-in companion has been investigated in several studies recently, in order to tentatively explain for instance: i) the spin-up of stars with hot jupiters (Pont 2009), ii) the radius anomaly of strongly irradiated planets (Leconte et al 2010), iii) the synchronisation or quasi-synchronisation of the stellar spin (Aigrain et al 2008)... Such studies always account for the static tides. Most recent observations have attracted our interest to add a new ingredient in this study, the tidal instability. The star tau-Boo has a massive planet in short orbit (4.5 MJup minimum mass and 3.31-day period), and the remarkable property of a stellar surface rotating synchronously with the planetary orbit. It is possible that tides from the planet onto the star have synchronised the thin convective zone of this F7 star, since the mass ratio between the planet and the convective zone is more than 10. Recurrent spectropolarimetric observations have allowed to reconstruct the global magnetic topology of the star since 2006, and its evolution. Two polarity reversals have been observed in two years (Donati et al, 2008, Farès et al, 2009), an evidence for a magnetic cycle of 800 days, much shorter than the Sun's (22 yrs). The role of the planetary tides on the star in this short activity cycle was questioned; a strong shear may take place at the bottom of the convective zone, triggering a more active and rapidly evolving dynamo.

The misalignement of one third of transiting hot jupiters (Winn, 2010) also questioned the role of tides in such systems, since the tides are responsible for alignement of the planes, circularization of the orbit and synchronisations of periods. The classical idea of planet formation and migration within a disk was also challenged by such observations. Tidal instabilities may cause the rotational axis of both bodies in the system to change orientation with time, at a relatively short timescale. Misaligned systems could thus show unstable rotation axes of stars, rather than tilted orbital planes of the planet. Tidal implications on the internal structure of planets were already reported (Leconte et al 2010). Since the power dissipated by tides could generate radius anomaly, then the additional power generated by tidal instabilities should also be taken into account in planet modeling.

Based on theoretical, experimental and numerical works, we estimate the growth rate of the instability for hot-jupiter systems, when the rotation period of the star is known (Cebron et al, 2011). We present the physical process, its application to stars, and preliminary results obtained on a few dozen systems, summarized in the form of a stability diagram. Most of the systems are trapped in the so-called "forbidden zone", where the instability cannot grow. In some systems, the tidal instability is able to grow, at short timescales compared to the system evolution. Implications are discussed in the framework of mis-aligned transiting systems, as the rotational axis of the star would be unstable in systems where this elliptical instability grows.

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