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Observing Planet Falling Through Increased Stellar Luminosity

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Abstract

Close-in planets do fall into their stars due to tidal migration, as recent work strongly suggests, but the significance of the energy output remains to be well studied. There is a huge amount of energy made available by falling deep into the star's potential well: Simple calculations show that many of the currently known “hot Jupiters” can potentially produce events as luminous as a small nova. The observability will depend on how rapid the energy release is. There will be two parts to potentially luminous events: the last of the tidal migration, and the destruction of the planet. Even the final rapid tidal infall of the planet can potentially input energy to rival the energy output of the star. The final destruction will release even far more energy. These events are rare enough to explain why there is no undisputed observation of planet accretion, but future transient astronomy surveys such as PTF, Pan-STARRS, and LSST may have a good chance of catching such an event.

Smaller planets may provide less luminous but more common events. Planet formation models frequently refer to protoplanet infall. Comparison with solar system objects shows how these events may be much brighter than seen in ordinary YSO and proto-star variability.

1. Significant Energy Release

Exoplanet tidal migration has become one of the fastest developing areas of exoplanet study, with extraordinarily rapid exchange of new understandings from new observational and theoretical results. Within the last few years there have been enough transiting exoplanets for their parameters to start to show patterns of tidal migration. New theoretical results and observations have brought new insights addressing the question of how do the closest in planets get destroyed by tidally migrating, or “falling”, into their stars. Theoretically, that the destruction of planets by inspiral into the star actually must occur has been shown by recent work that considers the effect of tides induced on the star (eg: Jackson et al. 2009[3], Levrard et al. 2009[2]). Early work on the formation and migration of giant planets showed that migration in the disk could send planets into the star (Masset & Papaloizou 2003[8]; Lin & Papaloizou 1986[6]) The detection of a few unexpectedly close massive planets such as WASP-18b (Hellier et al. 2009[2]) has challenged tidal migration theory to explain the statistics of finding planets with such small semi-major axes, but it appears that planets must continue to migrate towards the star long after formation (Triaud et al. 2010[16]), and thus are likely to be accreted even after the dissipation of the circumstellar disk. While many other questions regarding tidal theory are being addressed, it has not been fully considered how much energy these massive planets will deliver to their stars. Planet consumption has been considered for causing contamination of the star by planetary material (Santos et al. 2010[12], Sandquist et al. 1998 [10], Sandquist et al. 2002[11]), even including planet contamination of white dwarfs (Jura et al. 2009[4]), and the effect of stellar spinup have been considered (Pont 2009[9], Livio & Soker 2002[7]). Planet consumption during late-stage stellar expansion has been widely considered by Soker (Soker & Tylenda 2003[15]) and there has been consideration of the energetics of such consumption (Siess & Livio 1999[13]), and work on the energy release has been done for the case of accretion onto a white dwarf (Shaviv & Starrfield 1988[14]). It is not clear how planet accretion energy will be radiated in most of the many cases.

The orbital energies of the most massive planets is equal to tens of thousands of years of stellar luminosity, as illustrated in Figure 1. It is uncertain how luminous various protoplanet accretion events will be. Less massive planets may slowly release their energy through Roche Lobe Overflow (RLOF). The wide range of planet accretion events will vary, both with planet mass and with when in the stages of planet system evolution the destruction occurs.

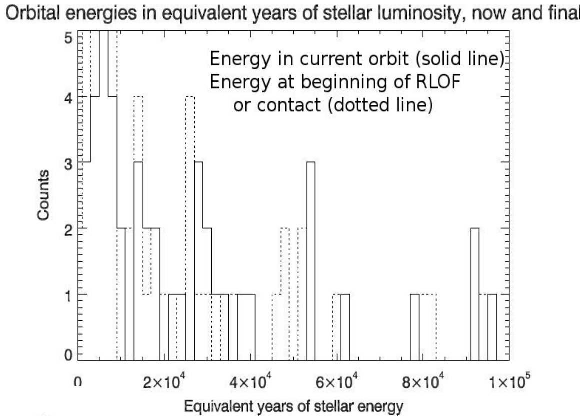

Figure 1: The orbital energies of the transiting planets known as of 2009 June given in terms of equivalent years of stellar luminosity. Solid line is energy of current orbit relative to the stellar radius, and dashed line is energy at RLOF or contact with the stellar radius.

We advocate that work address the questions of how might transient surveys identify observations of planet destruction in both the tidal migration and final destruction stages. During tidal migration, how is the significant energy release of massive planets migrating down many stellar radii released? How does disk extinction affect observations of protoplanet accretion? Final destruction will occur through different density-dependent channels, from RLOF of small planets to orbital merging with the stellar photosphere for the most massive planets. The process of inward migration will be slowed by the planet synchronizing the star, but the speedup of the star's rotation will be reduced or reversed by magnetic braking (Barker & Ogilvie 2009[1]). If the final destruction energy is released quickly enough, upcoming surveys may catch the brightest of these events even in nearby galaxies.

The challenge will be to identify when and how this higher luminosity will produce an observable signature. It will be important to identify signatures identifiable to upcoming transient surveys. We advocate efforts to model and observe what we expect will include the most energetically dramatic events possible in solar systems evolution.

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