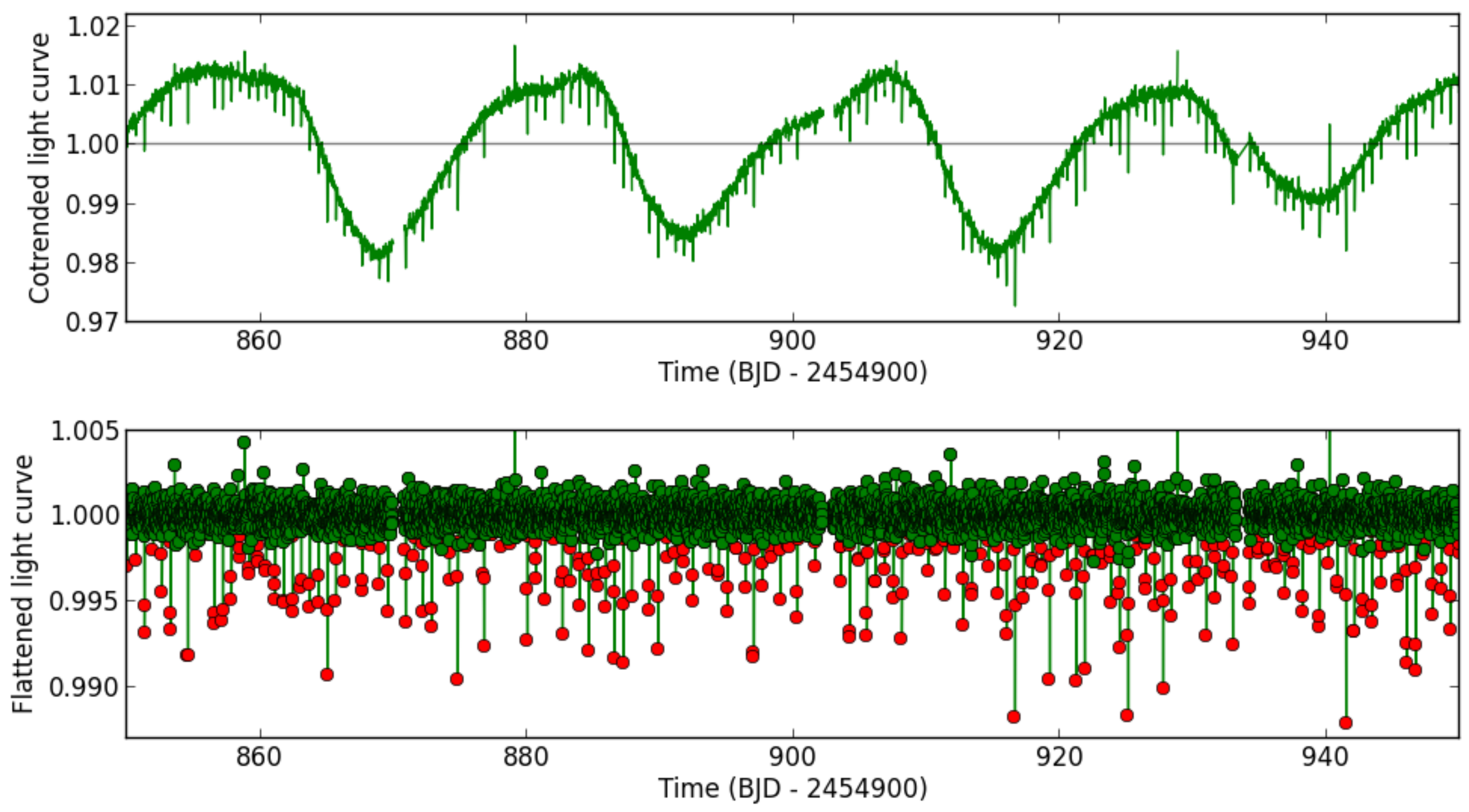
Starspots - Transit Depth Relation of KIC 12557548b

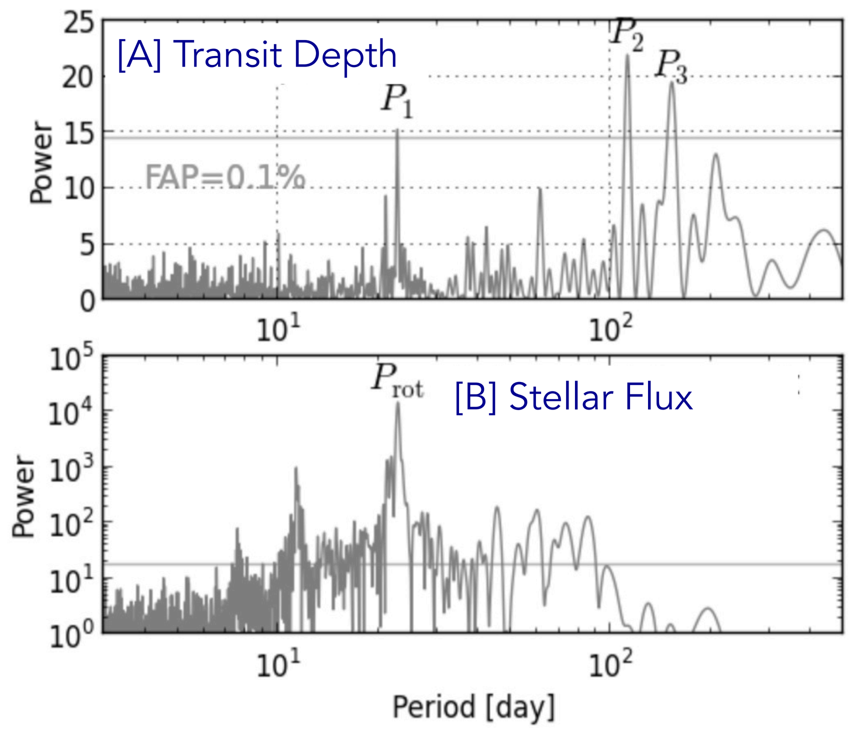
Hajime Kawahara (University of Tokyo) kawahara@eps.s.u-tokyo.ac.jp
With Teruyuki Hirano (titech), Kenji Kurosaki, Yuichi Ito, Masahiro Ikoma (u-tokyo)

KIC 12557548 b : An evaporating planet candidate with violent variation of transit depth

Figure 1. Cotrended and flattened light curves of KIC 12557548 b



KIC 12557548b (KOI 3794 b) has been considered as a disintegrating small planet (Rappaport+12; R12). This object has three distinct features: 1) violent variation of the transit depth (Figure 1), 2) an asymmetric tail of the transit curve and 3) a small bump (Figure 2). The latter two features in the light curve can be interpreted as a shadow of a dusty tail from the evaporating planet and the forward scattering by the dust. Analyzing the intensity of forward scattering, Brogi +12 and Budaj 13 found that the dust expected as an occulter of KIC 12557548 is consistent with sub-micron grains. R12 estimated the mass loss rate of this planet as 1 Earth mass / Gyr. The dominant energy source of the enormous escape still remains unknown. Perez-Becker & Chiang 13 have constructed a radiative-hydrodynamic model assuming a Parker-type wind driven by a hot planetary surface with the equilibrium temperature ~2000 K. They concluded that a planet with mass < 0.02 Earth mass can account for the mass loss rate of KIC 12557548b. The hydrodynamic escape driven by X-ray and ultraviolet (XUV) radiations, as has been discussed for hot Jupiters, is another candidate for the energy source. To explore the nature of the evaporation, we focus on the time-series of the transit depth reanalyzing the *Kepler* data of 3.5 yr.



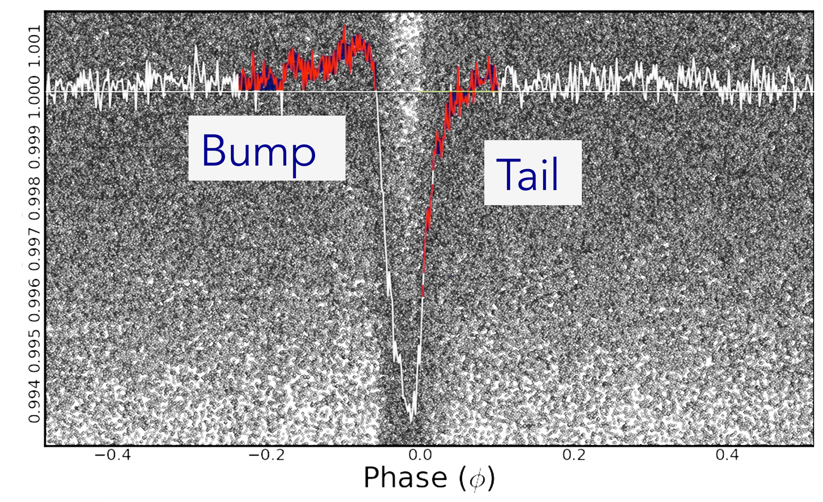
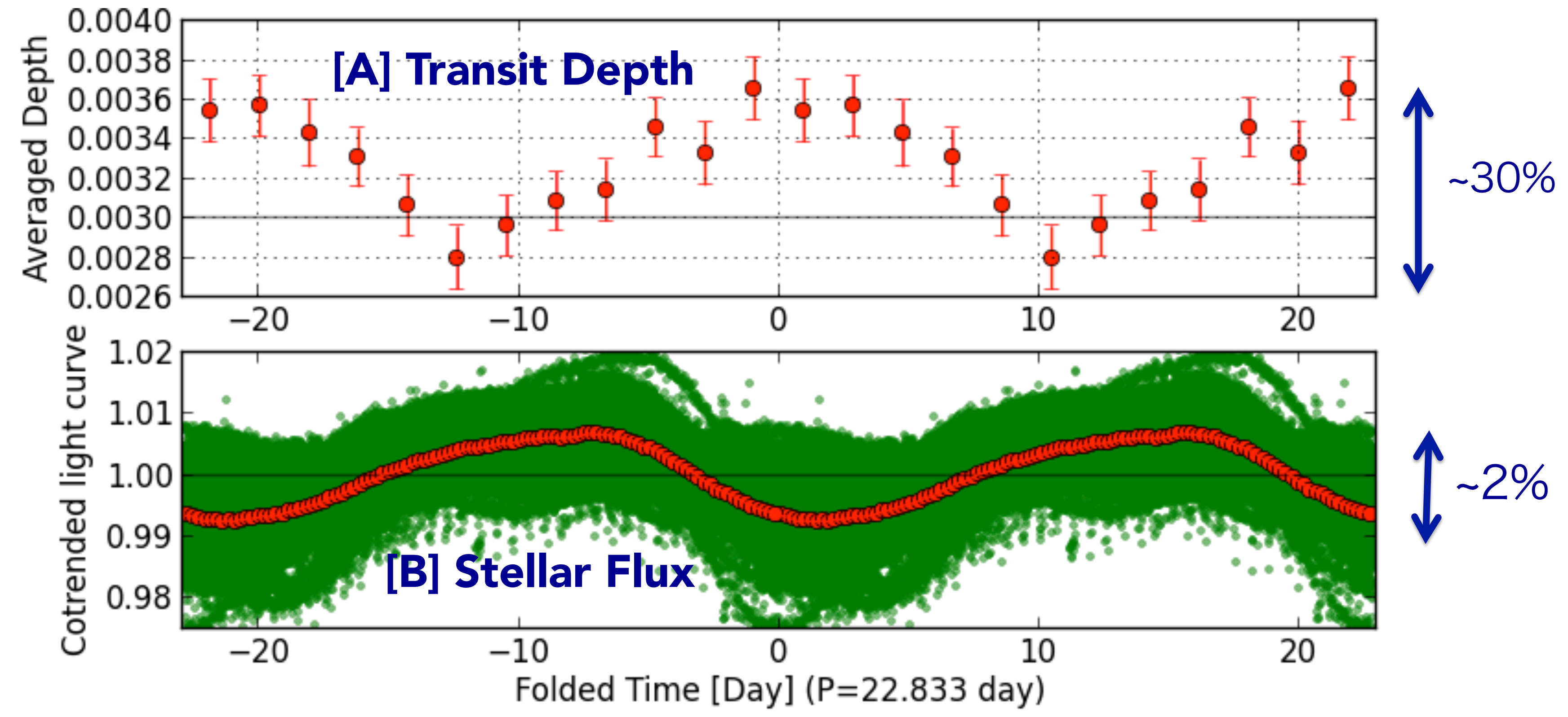


Figure 2. Folded transit light curve of KIC 12557548 b (short cadence data).

Figure 3. Lomb-Scargle Periodograms of the time-series of the transit depth and stellar visibility.

Transit depth negatively correlates with starspots

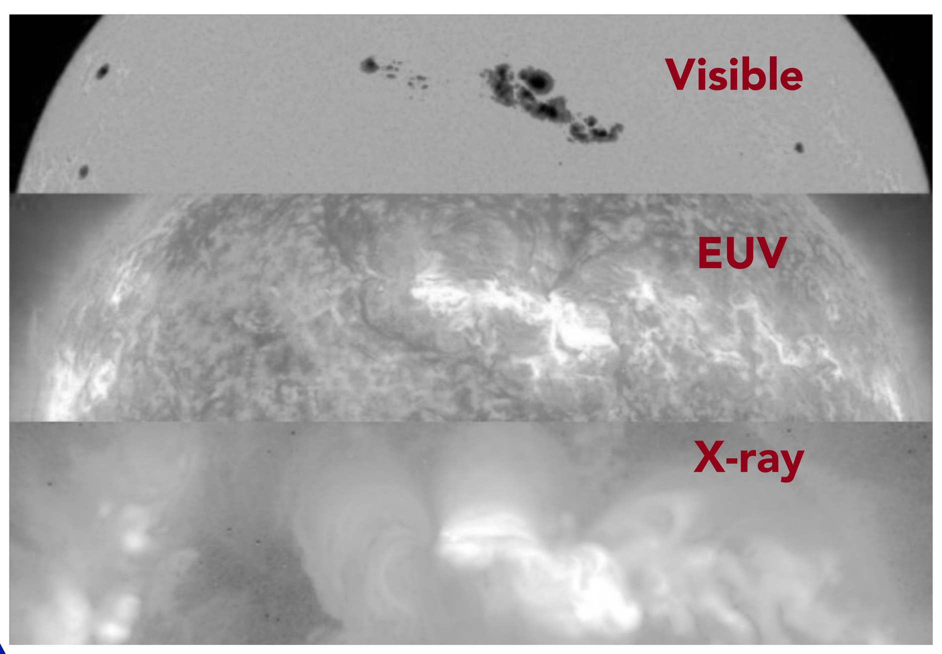
Figure 4. Folded time-series of the transit depth and stellar visibility with P1=22.8 day .



We created the time-series of the transit depths and performed the periodogram analysis. We found that the transit depth variation has three values of specific periodicity above FAP=0.1 % and that the shortest one P1 = 22.83 ± 0.21 days is consistent with the stellar rotation period estimated by visibility modulation (Figure 3). The mean value of binned data has ~ 30 % variation (Figure 4 top). We also fold the cotrended light curve with P1 (Figure 4. bottom) and find that the folded cotrended light curve is negatively correlated with the folded depth variation. A large starspot can survive for many years (Berdyugina 2005). The 2% variation of the folded light curve can be interpreted as long term variation due to a large starspot associated with a local active area. Hence, our interpretation of the anti-correlation is that the planet tends to make deeper occultation when facing the large starspot.

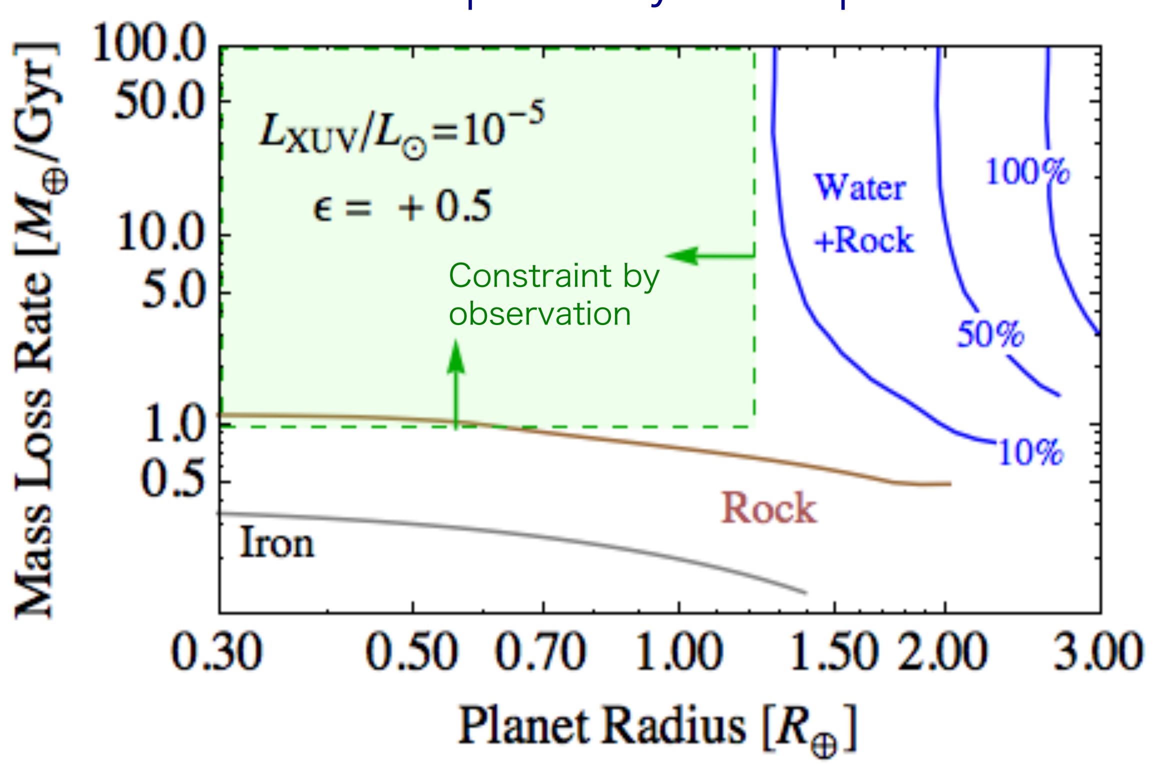
Energy-limit evaporation from a rocky planet by X-ray & UV ?

Figure 5. Visible, EUV, and X-ray images of Solar Active Region AR 9393 (Credit: NASA)



NASA SOHO/MDI/EIT Consortium/Yohkoh/SXT
http://apod.nasa.gov/apod/ap010419.html

Figure 6. Theoretical curves of terrestrial planets in Mass loss rate – planetary radius plane.



Strong XUV radiation is often related to stellar spots since the XUV flares originate from magnetic loops (Figure 5). The X-ray and/or UV periodicity with rotation were found in several stars (e.g., DeWarf et al. 2010; Scandariato et al. 2013). But is the input energy sufficient to account for the mass loss rate ? We revisit this problem using the theoretical mass–radius (M-R) relation of sub/super- Earths with several different compositions. Using the M-R relation with tide, we show that the massive escape of a rocky planet driven by XUV is possible if assuming high XUV flux and high efficiency (Figure 6). The energetic electrons released by the magnetic reconnection proposed by Lanza 13 is another possible scenario.

References

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We used the *PyKE* to process the *Kepler* data (Still & Barclay 2012).