

Stellar Variability Observed with *Kepler*

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Abstract. The *Kepler* photometer was launched in March 2009 initiating NASA's search for Earth-size planets orbiting in the habitable zone of their star. After three years of science operations, *Kepler* has proven to be a veritable cornucopia of science results, both for exoplanets and for astrophysics. The phenomenal photometric precision and continuous observations required in order to identify small, rocky transiting planets enables the study of a large range of phenomena contributing to stellar variability for many thousands of solar-like stars in *Kepler*'s field of view in exquisite detail. These effects range from <1 ppm acoustic oscillations on timescales from a few minutes and longward, to flares on timescales of hours, to spot-induced modulation on timescales of days to weeks to activity cycles on timescales of months to years. Recent improvements to the science pipeline have greatly enhanced *Kepler*'s ability to reject instrumental signatures while better preserving intrinsic stellar variability, opening up the timescales for study well beyond 10 days. We give an overview of the stellar variability we see across the full range of spectral types observed by *Kepler*, from the cool, small red M stars to the hot, large late A stars, both in terms of amplitude as well as timescale. We also present a picture of what the extended mission will likely bring to the field of stellar variability as we progress from a 3.5 year mission to a 7.5+ year mission.

Keywords. techniques: photometric, stars: activity, stars: flare, stars: spots, stars: rotation

The launch of the *Kepler* Mission in March 2009 opened up a new window on the detailed photometric behavior of $\sim 190,000$ stars on timescales from a few minutes to a few years and longer with ultra high precision of ~ 30 ppm for a G2V star at a *Kepler* magnitude $K_p = 12$ in 6.5 hours. *Kepler* observes $\sim 150,000$ stars at half hour intervals and up to 512 stars at 1 minute intervals. With this level of precision and data completeness above 90%, *Kepler* is a near perfect stellar variability observatory. *Kepler* was awarded an extended mission with operations continuing through September 2016, significantly enhancing the timescales available for study. The number and type of astrophysical phenomena contributing to stellar variability observed with *Kepler* include:

- Acoustic p-mode oscillations in hundreds of solar-like stars and red giants on timescales of minutes to hours and up (see Chaplin, Kjeldsen, Christensen-Dalsgaard, *et al.* 2011)
- Flares on timescales of hours (see, e.g., Balona 2012, Walkowicz, Basri, Batalha, *et al.* 2011)
- Gravity waves in red giants that have already begun to fuse Helium in their core (Mosser, Goupil, Belkacem, *et al.* 2012)
- Spot signatures (see, e.g., Désert, Charbonneau, Demory, *et al.* 2011, Sanchis-Ojeda, Fabrycky, Winn, *et al.* 2012)

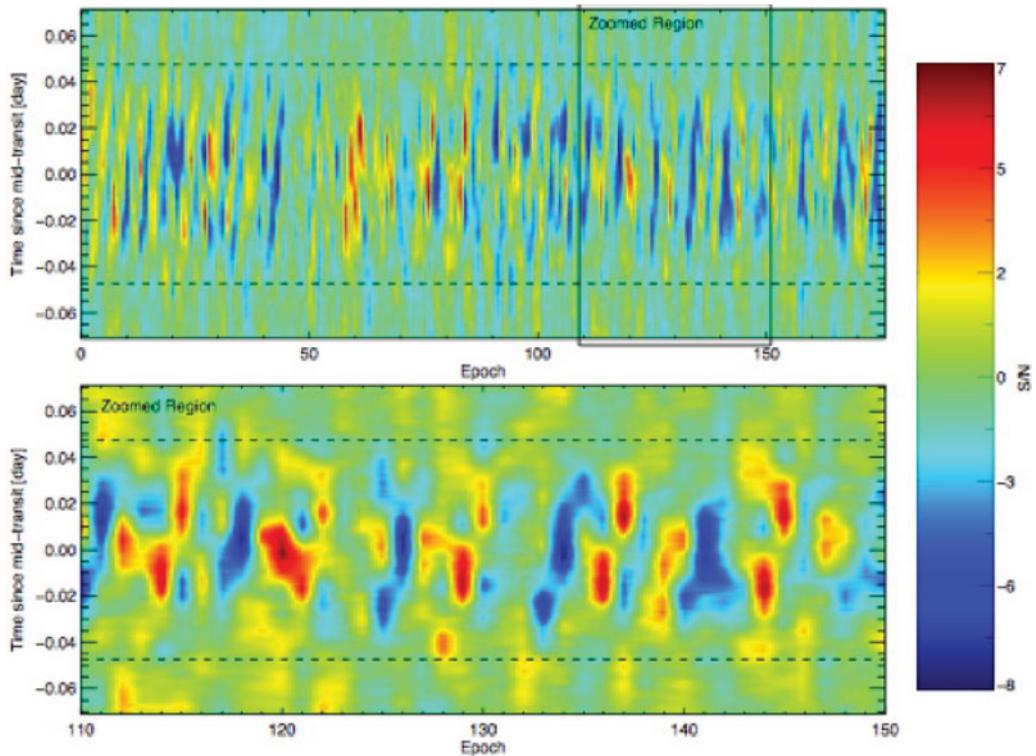


Figure 1. Spatio-temporal map of the surface of the star Kepler-17 scanned stroboscopically by its transiting planet, which has an orbital period exactly $1/8^{\text{th}}$ that of the star (Sanchis-Ojeda, Fabrycky, Winn, *et al.* 2012). This time-map image corresponds to the scatter (S/N) measured across the residuals in each transit epoch, relative to mid-transit as a function of the epoch.

- Stellar rotation and gyrochronology for star clusters from 0.5 to 9 GY (Meibom, S., Barnes, S. A., Latham, D. W., *et al.* 2011)
- Stellar variability of solar-like stars (Gilliland, Chaplin, Dunham, *et al.* 2011)
- Stellar cycles (in the 7.5-year extended mission)

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