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# Statistics of Stellar Variability in Kepler Data with ARC Systematics Removal

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**Abstract.** We investigate the variability properties of main-sequence stars in the first month of Kepler data, using a new astrophysically robust systematics correction. We find that 36% appear more variable than the Sun, and confirm the trend of increasing variability with decreasing effective temperature. We define low- and high-variability samples, with a cut at twice the level of the active Sun, and compare properties of the stars belonging to each sample. We find tentative evidence that the more active stars have lower proper motions. The frequency content of the variability shows clear evidence for periodic or quasi-periodic behaviour in 16% of stars, and highlights significant differences in the nature of variability between spectral types. Most A and F stars have short periods (< 2 days) and highly sinusoidal variability, suggestive of pulsations, whilst G, K and M stars tend to have longer periods (> 5 days, with a trend towards longer periods at later spectral types) and show a mixture of periodic and stochastic variability, indicative of activity. Finally, we use autoregressive models to characterise the stochastic component of the variability, and show that its typical amplitude and time-scale increase towards later spectral types, which we interpret as an increase in the characteristic size and life-time of active regions. Full details will be published shortly.

**Keywords.** stars: activity, stars: rotation, stars: statistics, stars: spots, Galaxy: stellar content

## 1. Systematics Correction

The Kepler pipeline (PDC) is unsuitable for the study of stellar variability so a new Astrophysically Robust Correction for systematics (ARC) was developed. The key feature of our reduction is the removal of a set of basis functions that are found to be present in small amounts across many light curves, therefore effectively removing systematics while leaving the true variability signal unchanged. Full details of this method can be found in Roberts *et al.* (in prep.). The improvement can be seen in Fig. 1, which shows an apparent bimodality in variability where the PDC has removed intrinsic stellar signals at medium variability levels, while the ARC preserves them.

## 2. Variability Statistics

Using the ARC data we revisit and confirm many of the relationships presented by Basri *et al.* (2010), Basri *et al.* (2011) and Ciardi *et al.* (2011) and extend that work to a more thorough study of the periodic and stochastic nature of the variability. We divide the targets into high- and low-variability groups by comparison to the active Sun (top lines in Fig. 1), allowing us to examine the stellar properties of each sample. Using this method, we find that 36% of dwarf stars observed by Kepler appear more variable than the active Sun on a 33-day timescale. We determine the variability statistics and

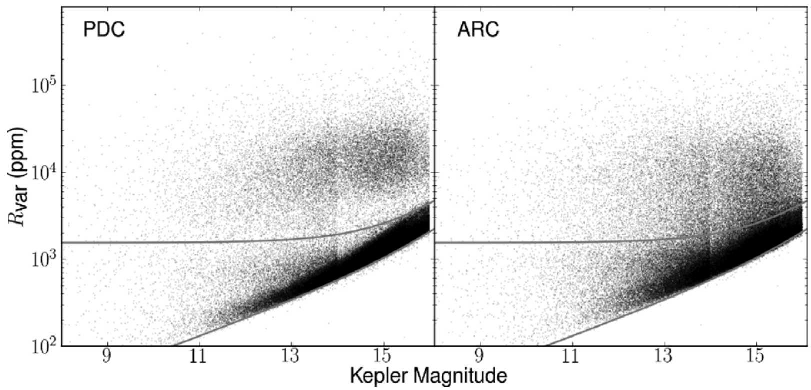


**Figure 1.** Variability (defined as $5^{th} - 95^{th}$ percentile of normalised flux) for the PDC and ARC data, with the photometric uncertainty (lower line) and twice the solar value (upper line).

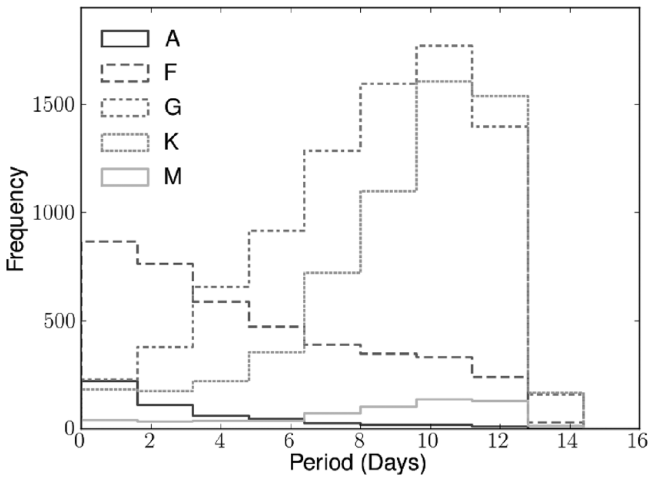


**Figure 2.** Period distribution for each spectral type, for stars displaying a significant period, showing a clear trend towards longer periods for later type stars.

characteristics of each spectral type, and show tenuous evidence that that the high-variability sample typically has lower proper motion. There is evidence for periodic or quasi-periodic behaviour in 16% of dwarf stars, with varying fractions and typical periods for each spectral type (Fig. 2). Specific caveats apply to this distribution, based on dataset length and period selection method.

The stochastic component of variability associated with each spectral type was parameterised by fitting autoregressive models to the periodograms (Aigrain *et al.* 2004). This reveals a trend of increasing amplitude and time-scale towards later types. The spectral density distribution of A and F stars implies small scale, short-lived active regions, whereas for G, K and M stars the active regions appear larger and more stable.

## References

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