Stellar Variability in the Kepler Q1 Data

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We investigate the variability properties of main sequence stars in the Kepler Q1 data, using a new astrophysically robust systematics correction (ARC). We show that 60% of dwarf stars appear more variable than the active Sun, and demonstrate relationships between variability and stellar properties, including significant differences in the nature of variability between spectral types. We present evidence for clear periodic or quasi-periodic behaviour in 16% of the dwarf stars observed, and examine the period distribution and stochastic component of variability for each spectral type.

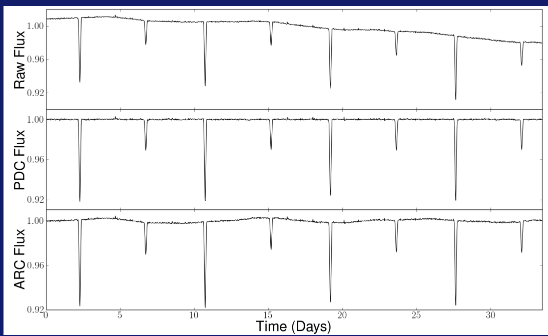

Figure 1. Comparison of the PDC and ARC for a single light curve.

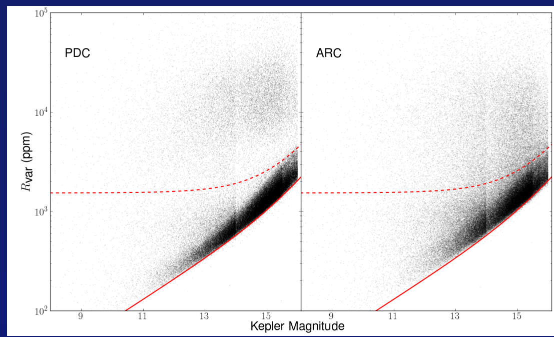

Figure 2. Variability for the PDC and ARC data, with photometric uncertainty (solid line) and twice solar value (dashed line).

Astrophysically Robust Correction (ARC)

The Kepler pipeline (PDC) corrects systematics effectively for use in transit searches but is not suitable for the study of stellar variability, since it can also remove stellar signals. We therefore developed the ARC method[1], which removes a set of basis functions, determined to be present in small amounts across many light curves, therefore removing systematics while preserving real variability. The apparent dearth of stars with intermediate variability levels in the PDC panel of Figure 2 results from the removal of real variability.

Variability Statistics

Using the ARC data we revisited and extended previous Q1 variability studies[2,3,4], comparing the variability statistic R_{var} (5th – 95th percentile of flux) to stellar properties. The dwarf stars were divided into high- and low-variability samples at twice the level of the active sun (dashed line in Figure 2), allowing comparison of their stellar properties.

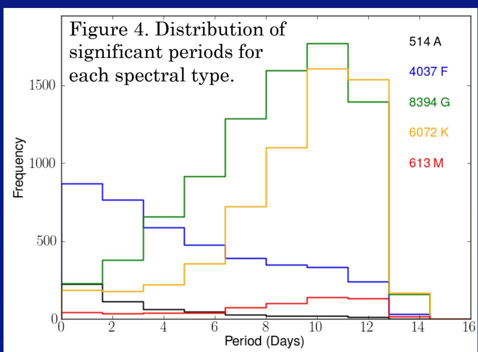

Figure 4. Distribution of significant periods for each spectral type.

Variability Trends

Higher variability is seen to correlate with lower temperatures[4], a result we also see in the ARC data. We looked for evidence that the high and low samples may belong to different stellar populations, and found tentative evidence that the high variability sample have lower proper motions (Figure 3), although giant contamination may introduce similar effects.

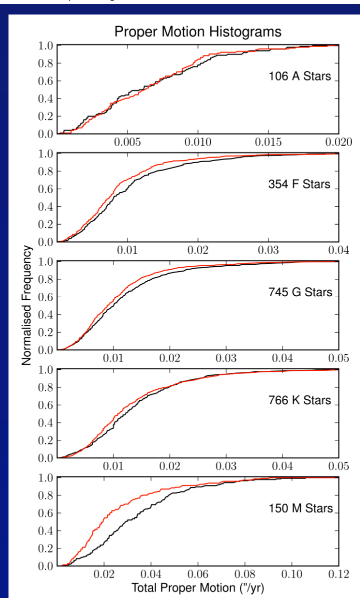

Figure 5. Proper motion distribution for high (red) and low (black) variability samples.

Periodicity

Figure 4 shows a trend of longer periods towards later spectral types, for maximum periodogram peaks above the significance threshold and within the valid frequency range. The stringent period selection method prevents false detections close to the maximum range, but also leads to a truncation of the histograms in this region. We find clear periodic or quasi-periodic behavior in 16% of stars.

Stochasticity

The stochastic component of variability was parameterised by fitting autoregressive models to the average PSD for each spectral type[5] (Figure 3). This reveals a trend of increasing amplitude, timescale and slope towards later types. The power distribution is indicative of the size and timescale of the active regions.

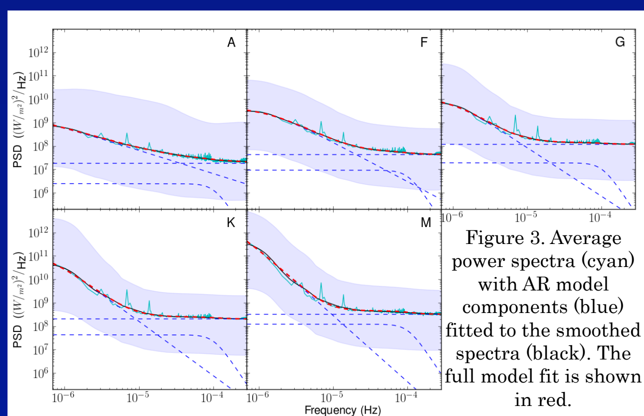

Figure 3. Average power spectra (cyan) with AR model components (blue) fitted to the smoothed spectra (black). The full model fit is shown in red.

Summary

The amplitude of variability appears to be correlated with temperature and proper motion. Most A and F stars have short periods (< 2 days) and highly sinusoidal variability, suggestive of pulsations. They are accompanied by small scale, short lived active regions. 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. For these late type stars the activity regions also appear larger and more stable. We find 60% of dwarf stars are more variable than the active Sun on 33 day timescales. The majority of Kepler dwarf stars appear more variable than the Sun on 6.5 hr timescales[6] when using the PDC data, and we are currently investigating this effect with the ARC data.

For more details, see McQuillan et al. 2012 (A&A in press, arXiv:1111.5580)

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References

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