

# Kepler’s Unparalleled Exploration of the Time Dimension

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## A1. Appendix: Simulating *Kepler II* light curves

A simple code was written to get a feel for what future observations in the *Kepler* field may be like. An observed *Kepler* light curve is input and then degraded by simply multiplying by a noise time series. This allows the noise characteristics already present to remain exactly the same in the simulated data, i.e., Poisson/shot noise, Quarterly sensitivity changes, readout noise, gaps, anomalies, etc., plus any intrinsic stellar variability noise (spots, etc.). The core of the program is to generate the noise vector, which has a mean of 1.0 and small fluctuations about the mean. The assumptions going into the noise model, and their consequences are:

- (1) Raw pixel-to-pixel variations of 1% — this is the flat-field (FF) noise.
- (2) Pointing drift of 2 arcmin/day — this is 30 pixel/day or 0.625 pix/cadence.
- (3) Effective number of pixel per aperture = 4 — the light is spread out over more pixels, but most of the light is concentrated in the central pixels. This is effectively how many pixels the FF noise gets averaged over, and thus the FF noise is reduced by  $\sqrt{4}$  = factor of 2.
- (4) Five cadences before stellar image is on totally independent pixels — assumes an effective PSF FWZI of 3 pix, and a 3 pix shift will occur in 4.8 cadences, so this is rounded up to 5 cadences. This is the correlation time.
- (5) Flat-field calibration noise-reduction factor = 0.2 — we expect that the 1% FF error can be reduced by this amount after a FF correction is applied.
- (6) Daily 1-degree rotation of spacecraft — a jump onto an entirely new set of pixels will occur every 48 cadences.
- (7) Pointing jitter  $\sim 1$  arcsec — other than the systematic drift, the random motion of the light centroid remains well within 1 pixel, and so jitter is ignored.

Limitations: (1) Daily gaps due to spacecraft rotations are not included; it is assumed that the affected data will simply be rejected and omitted, and that the time for rotation is less than 30 minutes. (2) Pixel channel sensitivity drops have not been included. These are intra-pixel drops due to the gate structure of the CCD. It is assumed that this 10calibration. (3) Drifts/rotations off of one CCD and onto another are not included. These will be similar in offset as the current 90-day Quarterly jumps, but they will occur more frequently.

The noise times series  $X_t$  is modelled as a Moving Average (MA) process of order 4, meaning  $X_t = \sum_{i=0}^4 \beta_i Z_{t-i}$  where the  $Z_i$  are Gaussian white noise realizations with variance  $\sigma_Z^2$ . This MA choice produces correlated noise for exactly 5 cadences, at which point the star light is entirely on new pixels. The autocorrelation goes to linearly to zero after 5 cadences and the noise is then white. The variance for a MA process is  $\sigma_N^2 = \sigma_Z^2 \sum_{i=0}^4 \beta_i$ . Since all pixels contribute equally, each  $\beta_i = 1$ . Then  $\sigma_Z^2$  is simply chosen to match the expected fluctuation size as the star drifts from one set of 4 pixels to the next independent set: 0.1%.

Once the noise time series is generated, the observed counts at time  $t$  are multiplied by  $(1 + X_t)$  to generate the simulated degraded light curve. Since the simulated degraded light curve has identical features as the original (eclipse depth, width, period, etc), a direct comparison of the two light curves is possible, which then informs us of the effect of the degraded photometric precision.

This noise model is clearly a crude approximation, but it allows us to estimate the expected degradation of the photometry. The important result is that this simulation can be off by as much as a factor of a few and the science goals (i.e. measuring EB eclipse times) can still be met; for the best cases of larger ETVs, the degradation could be over an order of magnitude more than what is simulated here and the science still done.