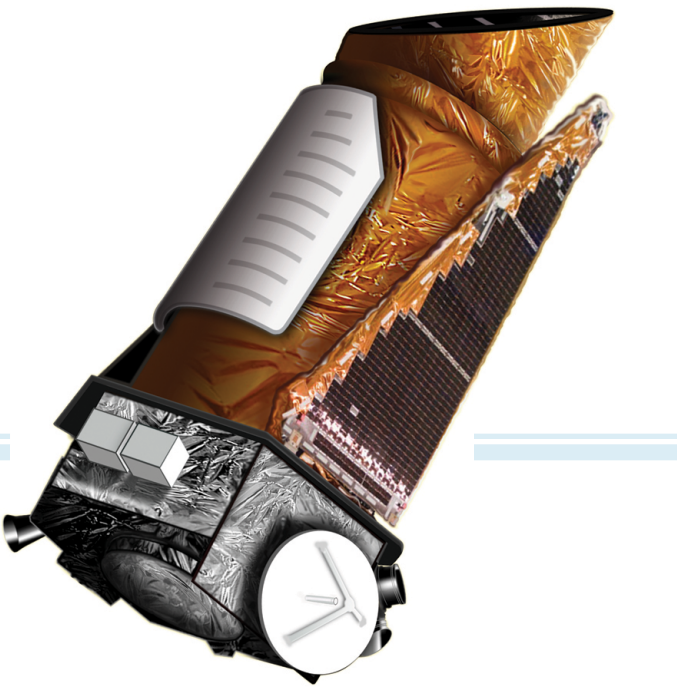




THE KEPLER SKY MODEL METRIC



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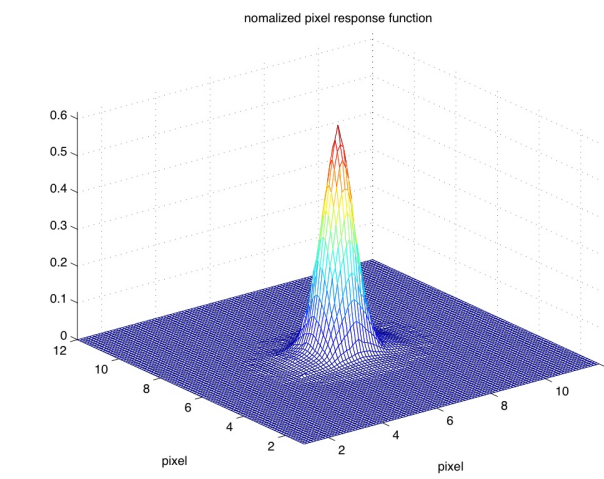
Abstract

The Kepler data analysis pipeline uses various models to extract planetary transit parameters from Kepler data. Some of these models inform the pipeline about the local stellar neighborhood and how starlight is distributed on the Kepler pixels. In particular the Kepler Input Catalog (KIC) the the Pixel Response Function (PRF) models are used to determine the photometrically optimal pixels for aperture photometry and estimate dilution due to crowding. Errors in these models may lead to less than optimal photometry, or errors in the estimate of dilution that can lead to incorrect estimates of transit depths and therefore planet sizes. When individual planet candidates are followed up in detail, flaws in these models can be detected and corrected. But it will be some time before such detailed follow-up is performed for the majority of planet candidates. It is therefore useful to have a metric which indicates when the KIC and PRF models are problematic for individual Kepler targets. We present the Kepler sky model metric, which uses the catalog and PRF models to create a synthetic pixel image for a target star. This synthetic image can be compared to the corresponding observed pixel image, and the Kepler sky model metric measures the magnitude of the difference. When the sky model metric is large, the results of the Kepler data analysis pipeline should be treated with caution. We show the statistics of the sky model metric for Kepler Objects of Interest (KOIs), giving a sense of "nominal" metric values, compared with large outliers that indicate problems. We describe a table that provides sky model metric values for all Kepler target stars. We suggest that statistical analyses of the Kepler planet candidate catalog should take the Kepler sky model metric into account, for example de-weighting planet candidates where the sky model metric is large.

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Models and the Kepler Data Analysis Pipeline

The Kepler Pixel Response Function (PRF) models how the pixel values are determined by star light at a particular place on the focal plane. The PRF model is subject to measurement error.



The Kepler Input Catalog (KIC) tells us what stars should appear with flux in the Kepler bandpass. The KIC is subject to magnitude (including stellar variability) and position errors.

Other models include pixel sensitivity, pointing and focal plane geometry. These models are less error prone.

Models are Used To Create Synthetic Images

Synthetic images are created by placing a PRF at the location derived from the catalog RA and Dec and pointing model, scaled by the flux derived from the catalog magnitude and pixel sensitivity model.

These synthetic images are used to

- Determine the photometrically optimal aperture for simple aperture photometry (SAP)
 - Model errors will lead to lower precision from SAP
- Estimate dilution due to crowding ("crowding metric")
 - Model errors will compromise the quality of dilution corrections to the transit depth, which leads to incorrect planet radii

We do not consider models that do not contribute to the synthetic image, such as stellar properties (radius, effective temperature,logg, etc.).

The Kepler Sky Model Metric

A Simple Idea

Because the models drive pipeline results through synthetic images, we simply compare observed pixel values (for example in FFIs) with a synthetic image generated for the time of observation.

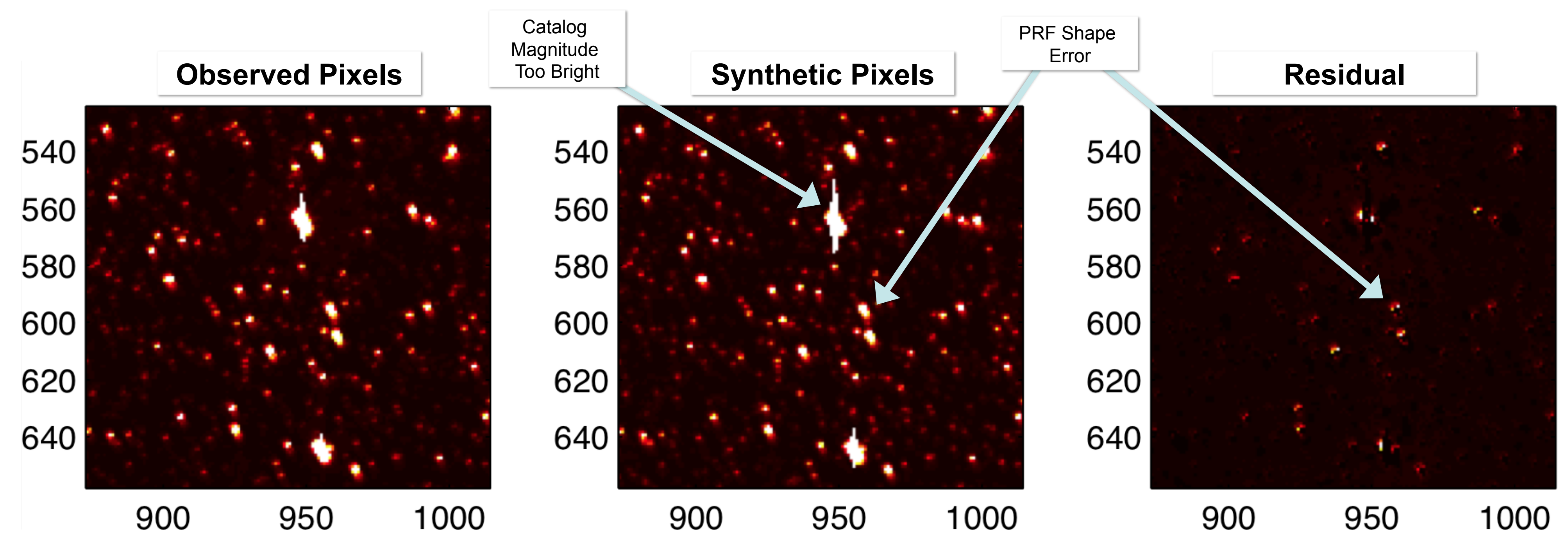
The synthetic and observed images are registered by

- Matching the median pixel values by adding a constant offset to one image
- Moving the common median to zero by subtracting it from both images
- Multiplying the observed image by the constant scale factor that minimizes the difference between the two images in a least-squares sense

These images are subtracted to form a residual, which measures the quality of the model.

An Example Region of the Sky

This example is towards the edge of the field of view, where the PRF is broad and has a complex shape

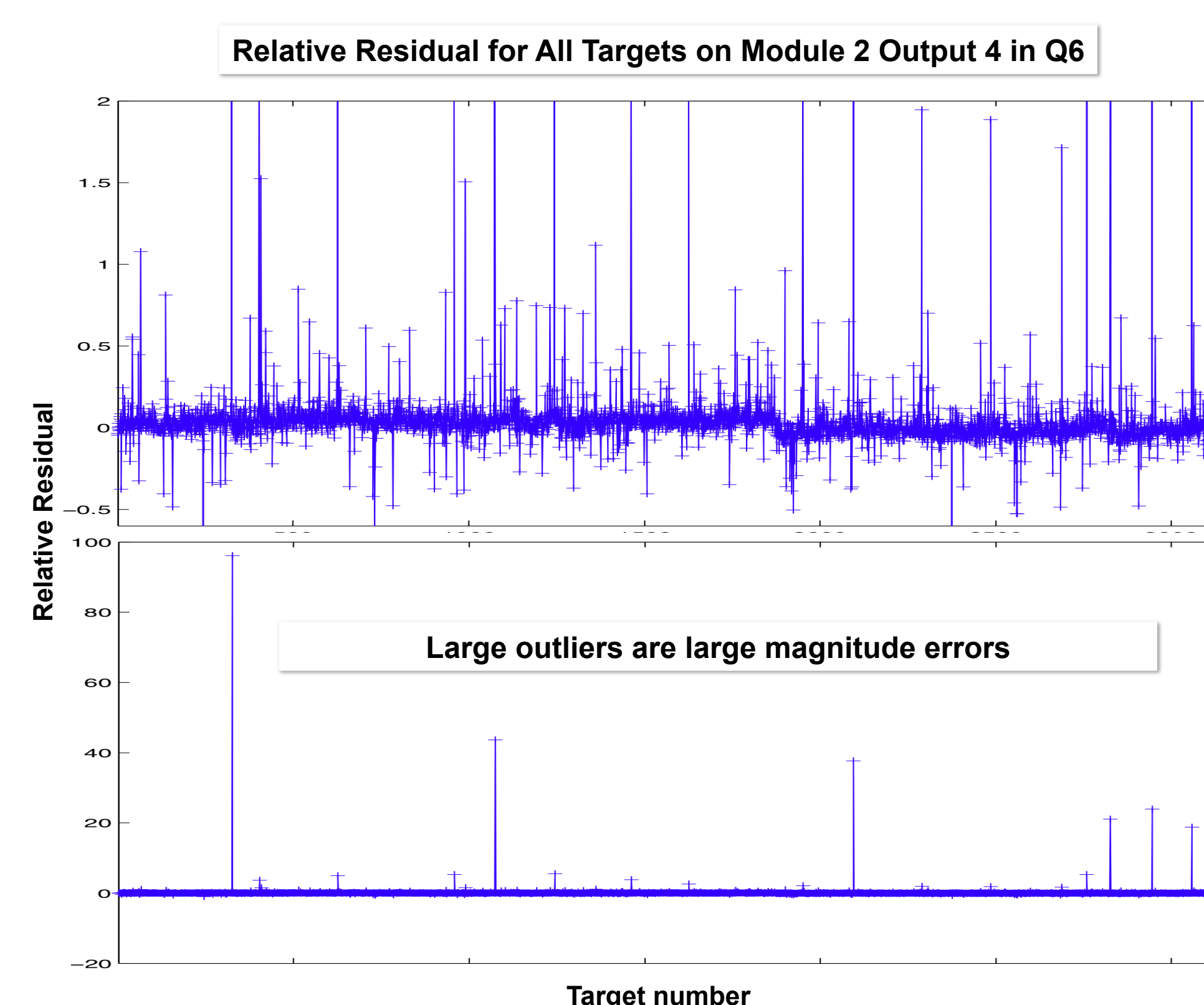
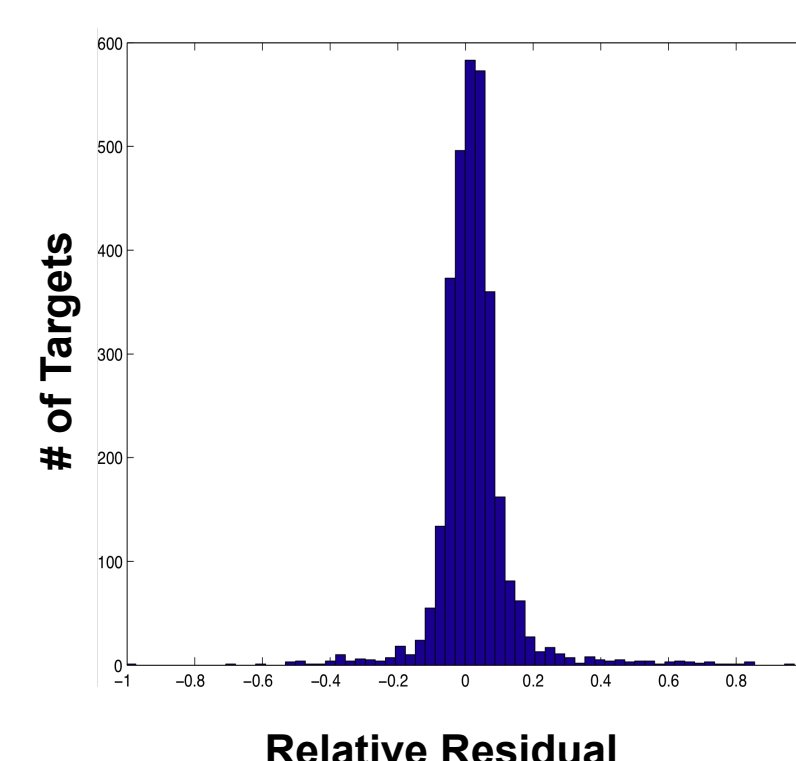


The Sky Model Metric for Individual Targets

The optimal aperture pixels for a Kepler target are extracted from the observed and residual images. The relative residual for the target is defined as

$$\frac{\sum_{\text{optimal aperture pixels}} \text{residual}}{\sum_{\text{optimal aperture pixels}} \text{observed pixel values}}$$

Most targets have a small relative residual: the MAD of our example channel is 0.004. Large outliers indicate candidates for catalog corrections

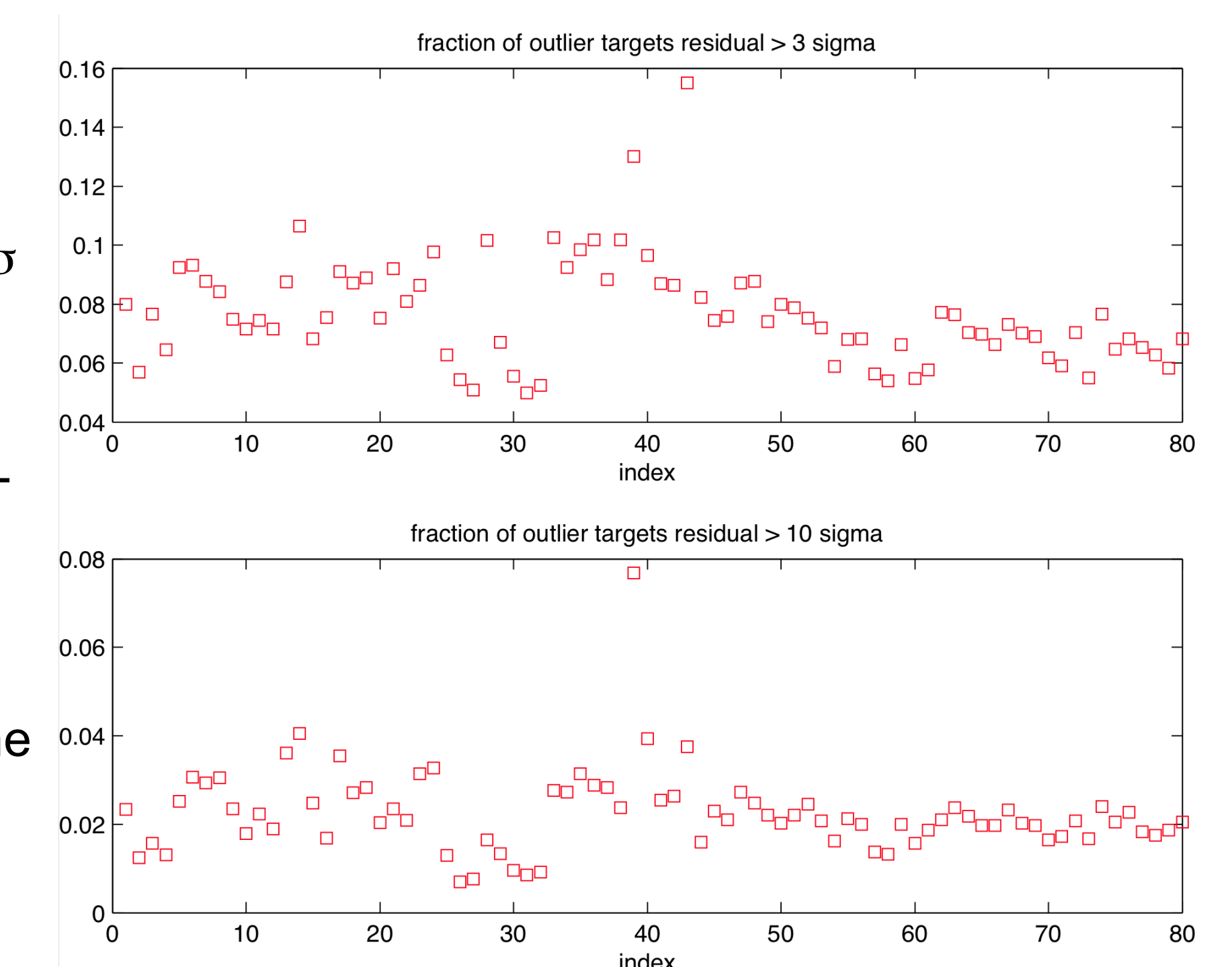


Full Target Set Statistics (in Q6)

< 10% of all targets (5.5% of all KOIs) have residuals > 3σ
< 4% of all targets (1.4% of all KOIs) and have residuals > 10σ
Pipeline results for these targets should receive extra scrutiny.

Analysis based on adding UKIRT stars to the catalog indicates that dilution due to crowding may be underestimated by at least 1% near the Galactic plane

A table of Kepler Sky Metrics will be published in 2014.



Discovery Mission 10 - Launched 2009 - <http://Kepler.NASA.gov>

