**Kepler Transient detector**

Failed approach:

**Light curve detection**

The first and seemingly simplest detection method was to examine light curves for spikes above a threshold from the median and standard deviation. This method proved to be unsuccessful due to the high variability in the pixels selected as the background. Main sources of errors were the target objects slipping into the background pixels and long scale pixel noise sources.

Current approach:

**Pixel analysis**

The second method of examining individual pixels provided a larger control over the detection condition at the cost of a higher computation time. This analysis technique has undergone significant evolution and developed a system of checks and conditions that prove to be fairly successful at preventing false detections from telescope motion, variable stars, long term noise, and to a lesser degree asteroids.

This method works on the basis that an ‘event’ should be bright and present in nearby pixels over several frames. To this end the primary detection criteria exists that the event must be 3 sigma over the median for at least 4 frames. This puts the lower bound on event time to be ~2 hours. The following section details the conditions and cuts placed on the pixels.

Operating code:

1. The object mask is created
   1. A reference frame is selected from a comparison of frame pairs separated by 12 cadences. The pair featuring the lowest standard deviation is selected. This method isn’t ideal as thruster firings don’t occur precisely every 12 frames, however, this appears to be largely inconsequential with the other conditions in place.
   2. The object mask is created by two iterations of removing all points in the reference frame that exceed the median of all pixels, plus the standard deviation. This method appears to be effective at removing overflow pixels around stars and extended sources in galaxies.
2. The mask is applied to the dataset creating the masked data.
3. The thruster flags are identified along with any quality flags.
4. A check is made to remove cadences with terrible pointings.
   1. The median and standard deviation of pixels within the previously defined mask is calculated for all cadences following a thruster reset. Any frame that has less than Med – std is set to NaN.
5. All potential events are identified
   1. The median and std are calculated through all cadences for each unmasked pixel.
   2. All times that pixels exceed Med + 3std identified that are less than the saturation limit of 170000 counts.
   3. To be resistant to spacecraft motion the array of potential points is convolved with a 133 array of ones and all points > 1 are set to 1. Kepler is only permitted to drift by 4’’, which is the width of a single pixel.
   4. The array is convolved with a 511 array of ones and all points 4 are set to 1. This forms an array where all events are represented as 1 and other pixels are 0.
6. The events pass through an analysis to find duration and largest mask size.
   1. A while loop compares an event mask to each of the subsequent event masks. If the masks share similar pixels, they are grouped as the same event and the event time is determined as the separation between the first and last event masks.
   2. If masks share similar features, the mask with the largest number of active pixels is taken as the event mask. This is to ensure that events that occur at the same time can be identified.
   3. If the mask is unique it is removed. This raises the minimum detection time to ~2.5 hours.
7. Each event is analysed to determine if the event mask contains multiple events.
   1. The event mask is convolved with a 133 array of ones and the pixels sharing the maximum value after the convolution are taken as positions for coincident events.
   2. The new event masks are constructed separately by convolving the position with a 133 array of ones.
   3. Event times are found by finding comparing the new mask to event masks in the original event interval. If the event time is one, the event is removed.
8. Events are tested against thruster firings
   1. The event duration must be less than 80% of the total observing time.
   2. The event times start and end are checked for coincidence with thruster firings. If a firing occurs within 3 of the start or end, it is identified.
   3. If there are no thruster firings identified, then a check is made if the start/end coincides within 1 of a quality flag.
   4. All thruster firings what occur within the event are identified. This is used to identify if the event should be treated as short or long.
      1. 3 firings Short event
      2. 3 firings Long event
   5. If the event is short and has no beginning or end flags it is kept.
   6. If the event is long the lightcurve is calculated. The light curve is smoothed according to a boxcar smoothing over 5 cadences and the maximum determined.
      1. The maximum must occur more than 5 cadences from the start and end.
      2. The mean and standard deviation of points in the event light curve following a thruster fire are calculated, along with the mean of points preceding thruster firings.
      3. If the mean pre thruster firings mean +2\*std post thruster firings, the event is accepted.
9. Each event mask is checked to see if any pixel within the mask, including the masked object have a saturation count of 170000. Events that don’t contain saturation pixels are accepted.
10. Each event checked to see if the event is consistently detected through the event duration. If the event appears in > 60% of frames in the event duration it is accepted.
11. Event masks are checked to see if they have shared pixels with other masks and last the same amount of time. If so they are labelled as asteroids and removed from the event list.
12. Events are plotted. Below in a BNS kilonova event injected in a random unmasked pixel at a random time.

/Users/ryanr/Documents/PhD/coding/Kepler/pipelines/Injections/Kilonova/10000000.0ktwo212272599_0.pdf

**Problems**

* This method still has some issues in identifying asteroids, however, a gradient test method is still to be fully explored.
* For bright long duration events the standard deviation obtains a high value, dwarfing the event.
* Some random events still creep through.
* Defining the time sampled is difficult as there are a number of intertwined cuts.