Summary of the Analysis on Counter-Moving Ghosts in ZTF

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1 Goal

Create a method to predict the approximate location, sizes, and shapes of counter-moving ghosts from bright stars in the ZTF focal plane. These ghosts can then be masked by Frank within the IPAC pipeline.

2 Experiment

Data for this experiment was taken on Nov 1, 2017. The goal was to cycle Beta Peg through each quadrant on the focal plane (and also along locations just outside the FOV) to provide a sample set of ghosts as a function of parent star position. In addition to this set of ghosts, I also examined data from the nights of Oct 22 and Oct 27 for bright stars which just so happened to be in the field of view and included them in my analysis. These additional stars varied in magnitude from ∼2 to ∼6 and greater (V-band).

3 Ghost Properties

All counter-moving ghosts have approximately the same shape – an elongated ellipse tilted at an angle. I used DS9 to measure the ellipse properties (in units of pixels) for ghosts from parent stars of varying magnitude (2.6 to 5.4 in V-band). See Figure 1 for an example.

4 Predicting the Ghost Locations

In all cases the CCD and quadrant of the ghost can be found by simply identifying the CCD and quadrant of the parent star. **The ghosts always reflect across the approximate center of the ZTF focal plane**. For example, a parent star in CCD1 Q4 will always produce a ghost in CCD16 Q2, and vice versa.

To predict the pixel location of the ghost within a quadrant I created Figure 2. Here I've over-plotted all the parent star and ghost pixel locations onto one quadrant. The reflection point within the quadrant is actually a little southwest of the central pixel.

So the steps to predict the location of a ghost are:

1. Identify the CCD of the ghost by reflecting across the center of the focal plane (CCD6 $\leftrightarrow$ CCD11 and CCD13 $\leftrightarrow$ CCD4, etc)

2. Identify the quadrant of the ghost by a similar process (i.e., Q1 $\leftrightarrow$ Q3 and Q2 $\leftrightarrow$ Q4).

3. Pretend that the ghost will appear in the same quadrant as the parent. Reflect the parent's position across the point noted by the diamond in the plot (**at (x,y) position (1565,1580)**).

4. The ghost will appear at this pixel position but in the CCD and quadrant identified in steps 1 and 2.

5 Masking the Pixels

After the location of the ghost is identified then we can use an ellipse shape to mask pixels that may be associated with the ghost. **Conservative values for the semi-major and semi-minor axis of the ellipse mask are 600 and 200 pixels. The ellipse should also be at an angle of -15 degrees.**

If the translation between CCD and quadrant of the parent star vs ghost is hardcoded then the only input needed to predict the location of the counter-moving ghost is the (x,y) location of the parent in pixels. Any differences due to the varying magnitudes of the parent stars can be accounted for by using conservative values for the ellipse size.

6 Impact to the total ZTF Field

Only parent stars with magnitude V$\leq$6 produce noticeable ghosts. Given there are $\sim$5000 stars equal to or brighter than this across the sky and if we assume they are uniformly distributed across the sky then we can expect to see $\sim$6 ghost-producing stars per ZTF field. If I use the conservative mask properties stated above then this means about $\sim$0.4% of the entire ZTF field on average will be covered by a mask.

Although probably the stars are not uniformly distributed and instead are concentrated near the galactic plane, so if we ignore stars within $\pm$10 degrees of the plane then the number of ghost-producing stars reduces to $\sim$3600. Then you'd expect to see $\sim$4 stars per field which means $\sim$**0.28% of pixels are masked** when looking outside the Galactic plane.

7 Other thoughts / issues

- Sometimes for parent stars located on the corner CCDs there can exist a second, smaller ellipse (Figure 3). These are harder to predict because their location relative to the primary ghosts depends upon which corner of the field the parent lives.

- This analysis only accounts for the counter-moving ghosts and does not include the masking of the co-moving ghosts. Co-moving ghosts are independent of parent star magnitude and so are masked by simply identifying a circle of radius 350 pixels centered on the parent star. Masks from co-moving ghosts would cover between 2.4 and 3.6% of the total field of view.

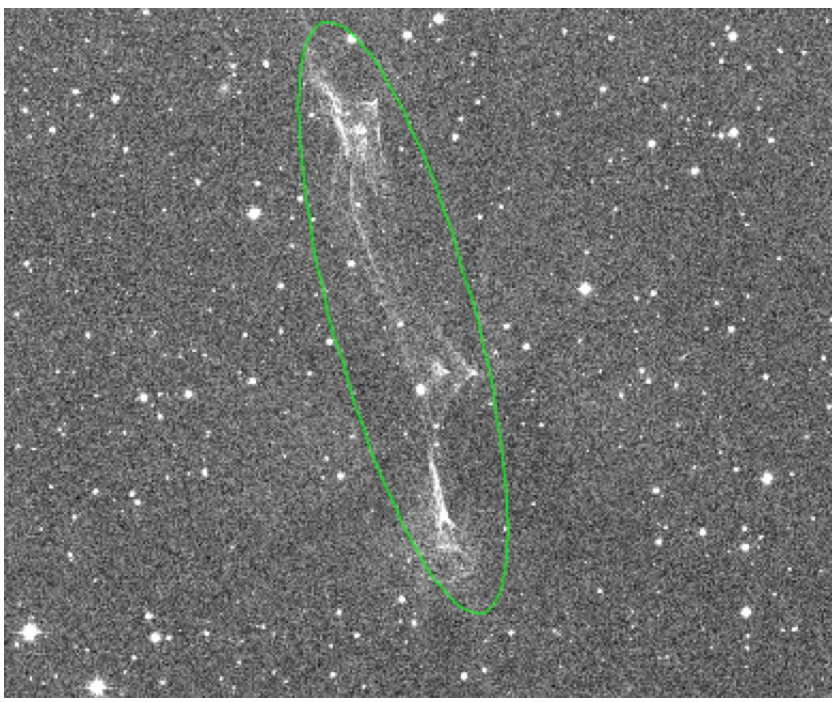

Figure 1: A ghost from a 3.0 mag parent star.

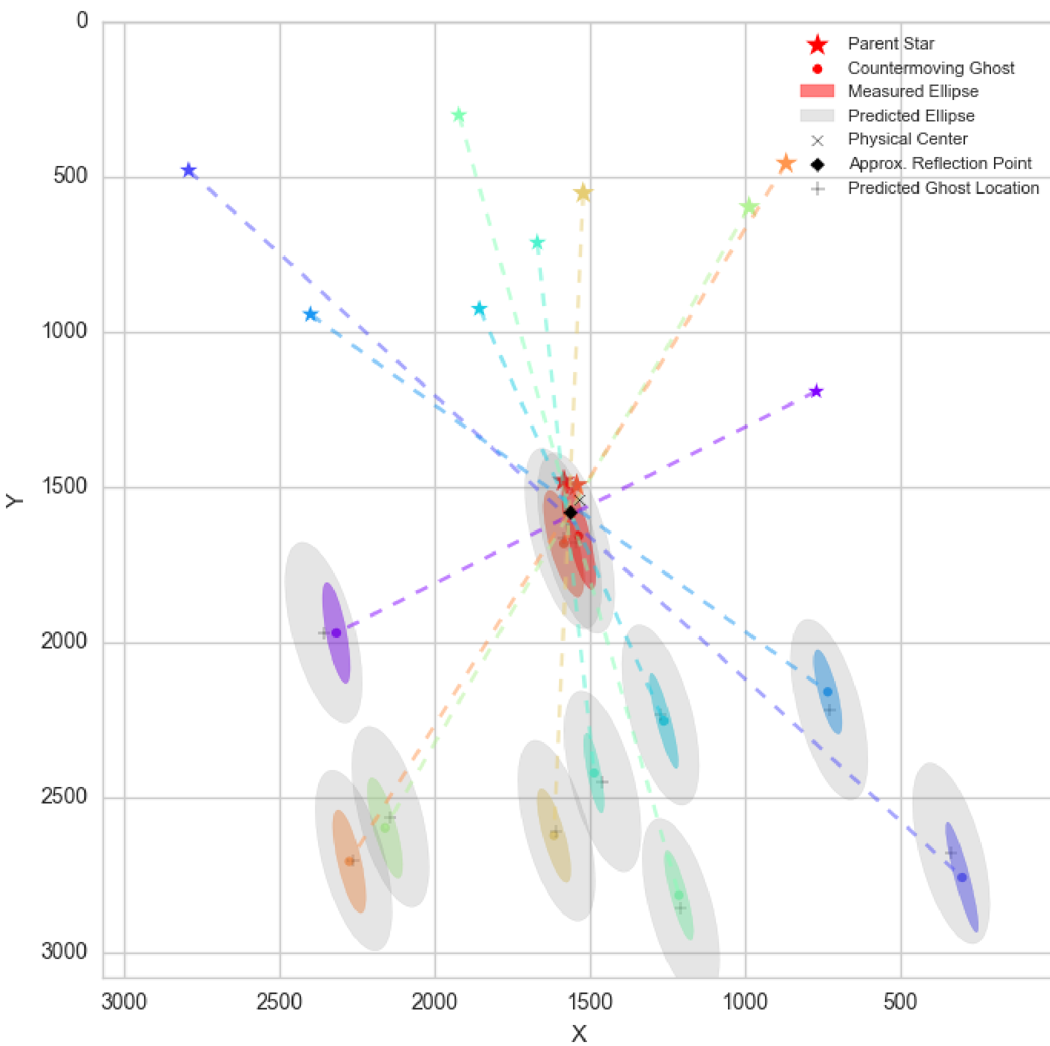

Figure 2: Locations of parent stars and their counter-moving ghosts.

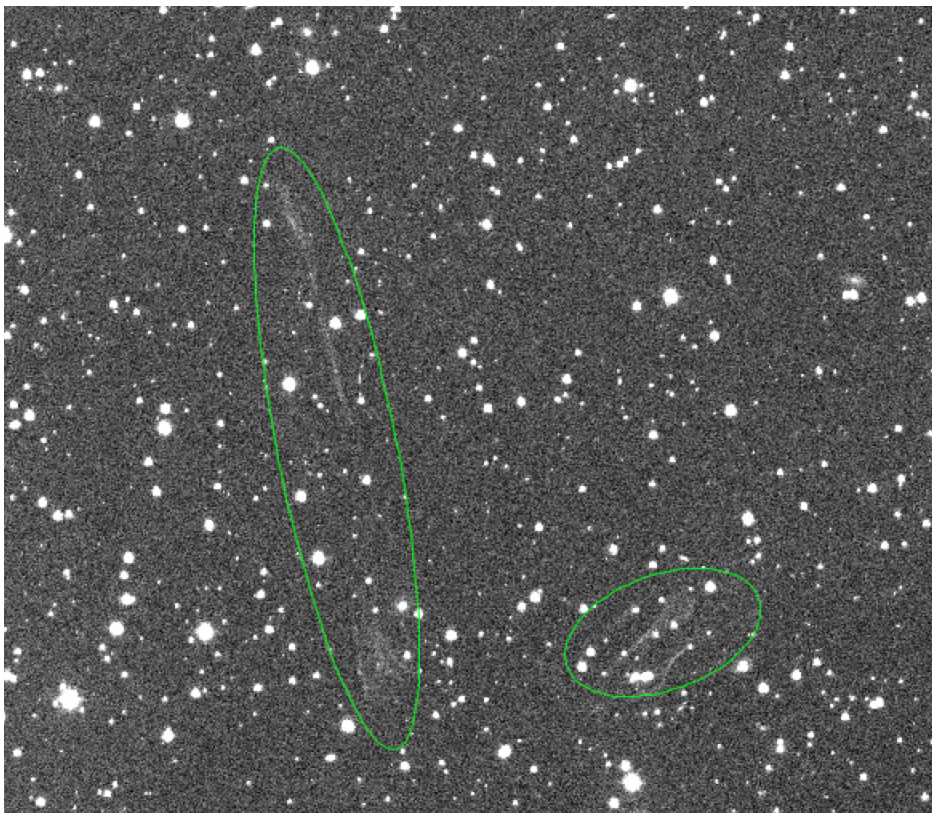

Figure 3: Example of the ghosts from parent stars on corner CCDs.