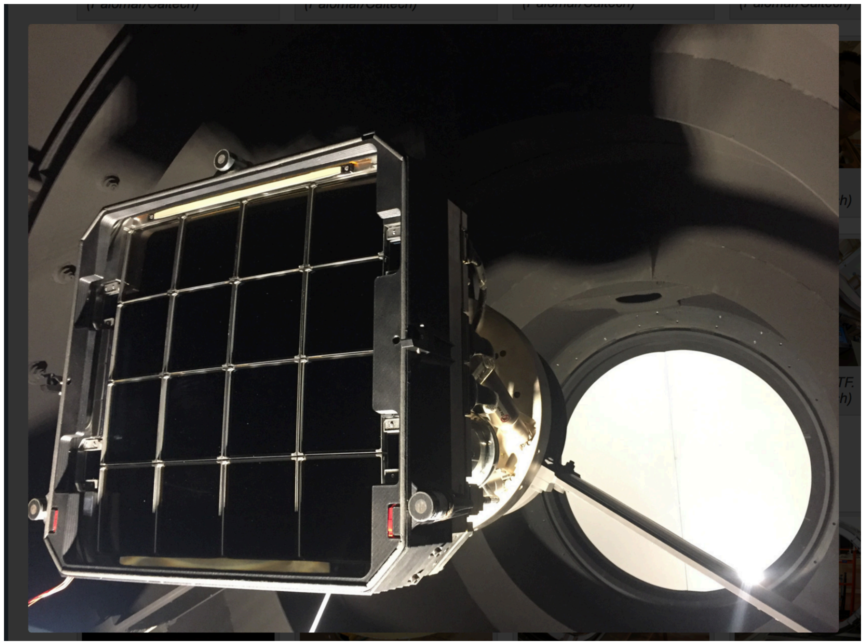
Part I: Correcting for the Nonlinearity in ZTF

Background:

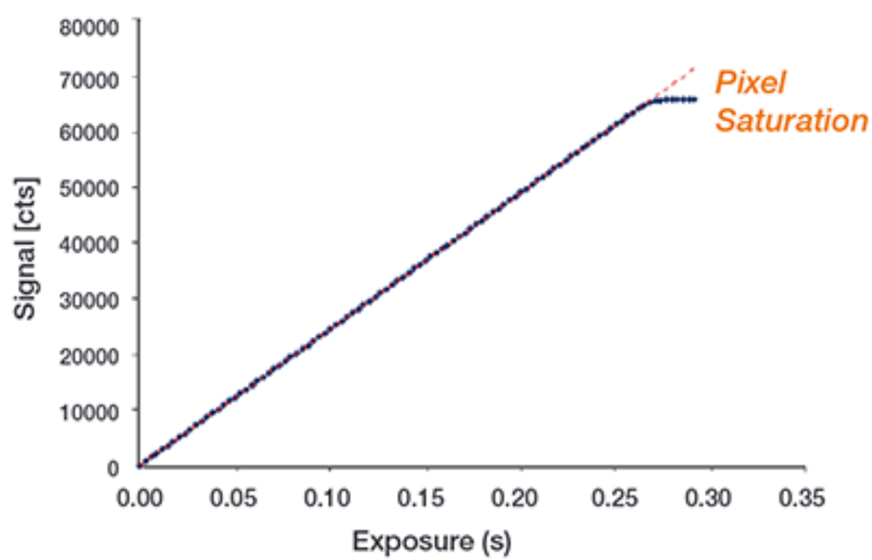


Photons in should be proportional to electrons out

ZTF: ~6 e-/ADU

Become nonlinear when saturating
- at ~60,000 ADU

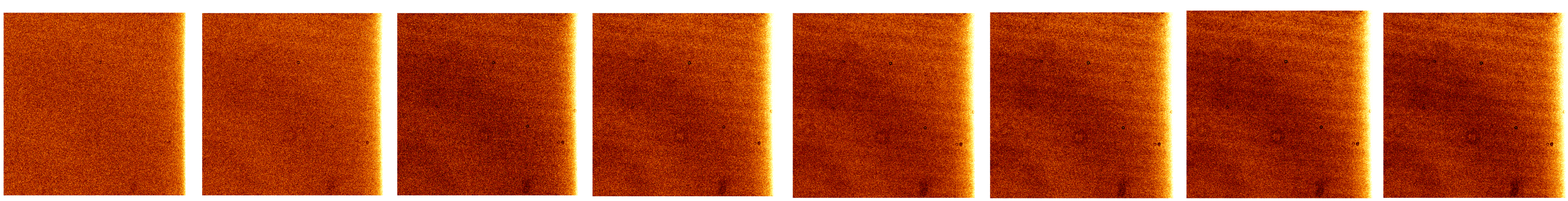
Can lead to inaccurate photometry



http://www.astro.caltech.edu/palomar/media/oschinmedia.html

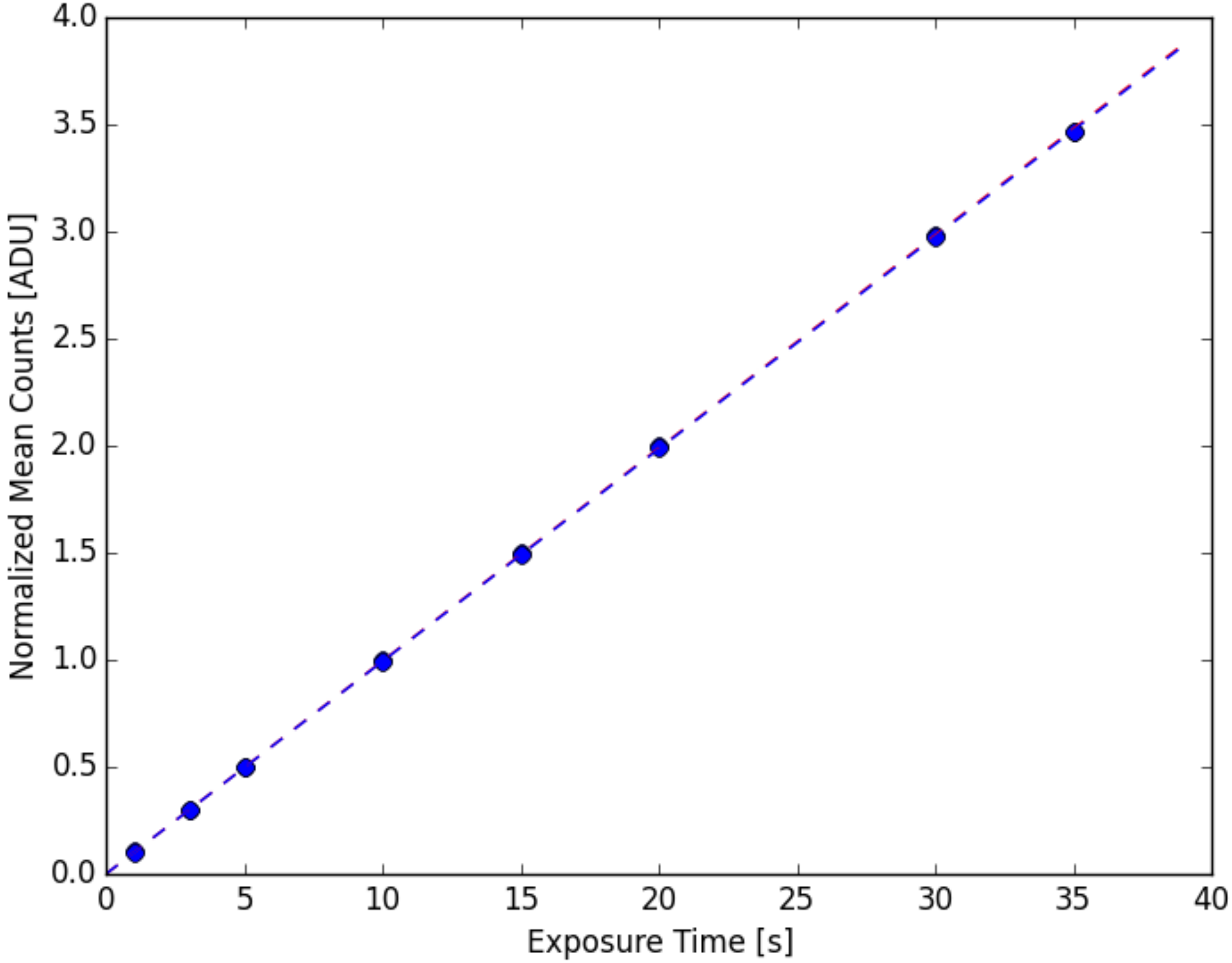
Experiment Description:

1. Take flats of increasing exposure time (1, 3, 5, 10, 15, 20, 30, and 35s)
2. Between each step take a 10 sec exposure to normalize
3. Measure the flux of the light source at low signals (far from saturation)
4. Use this flux to find the expected number of counts, as if perfectly linear
5. Find the measured / expected counts for each exposure time

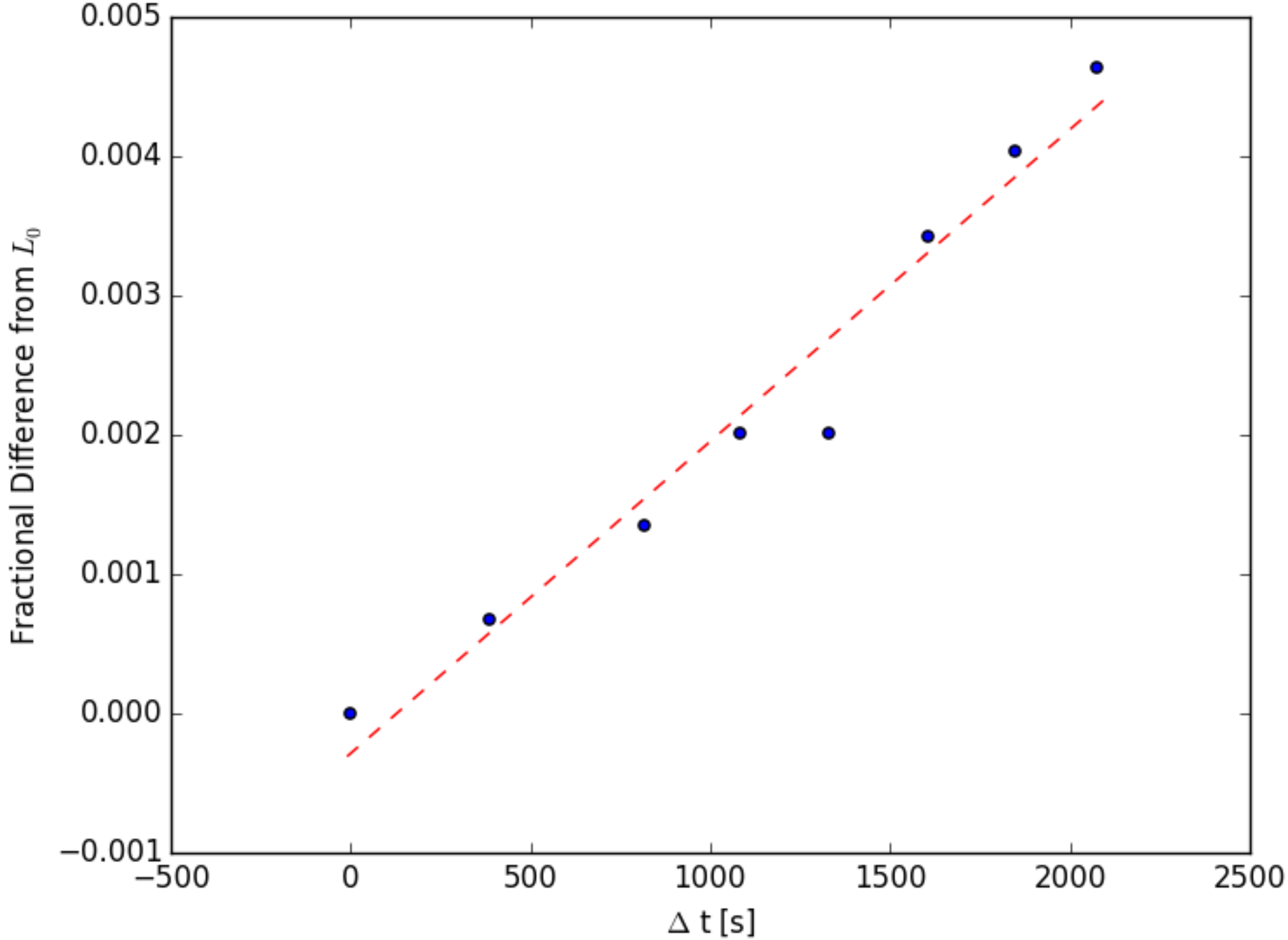


1s 3s 5s 10s 15s 20s 30s 35s

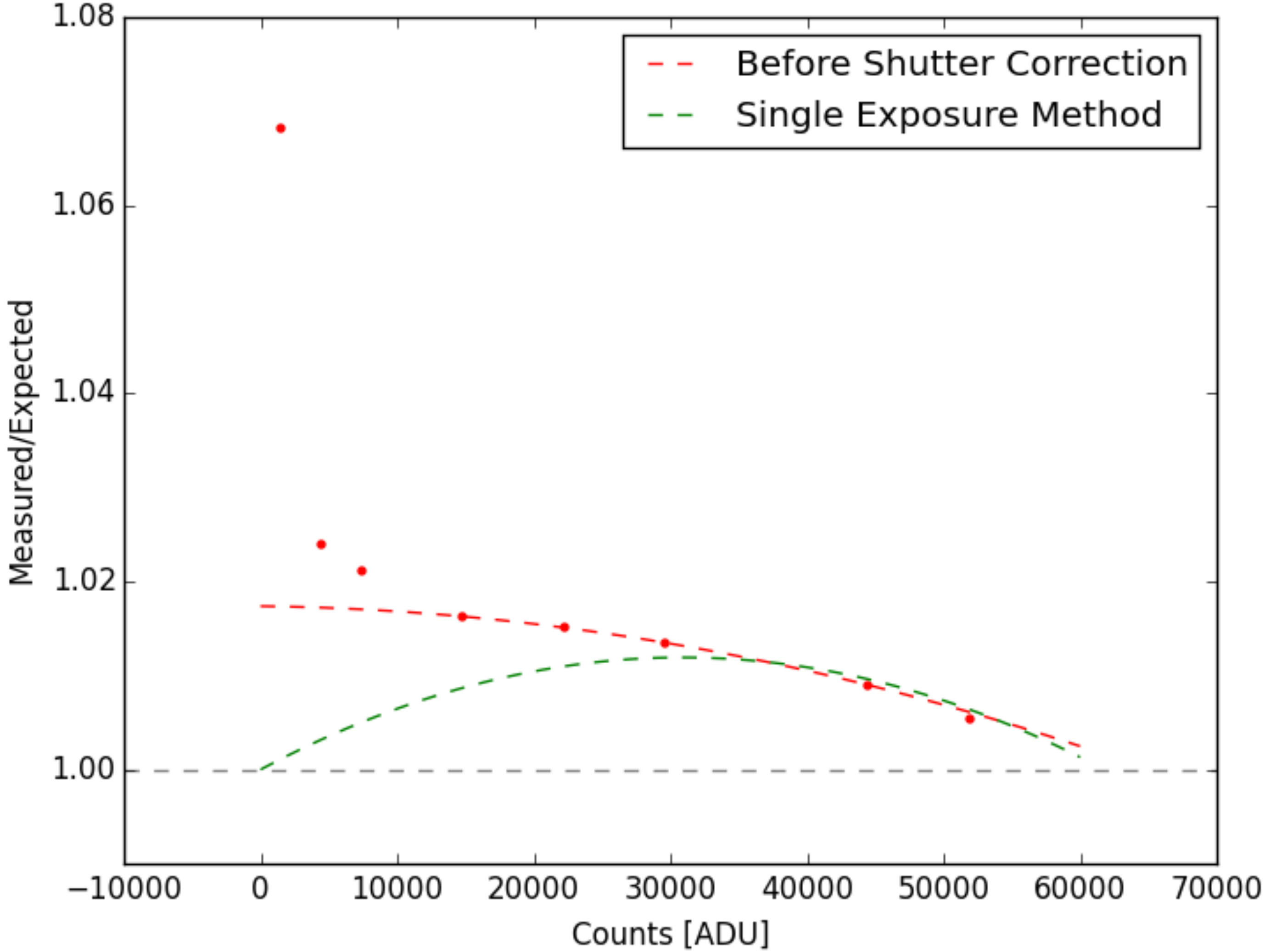
Step 1: Take flats of increasing exposure time



Step 2: Normalize counts with stability flats

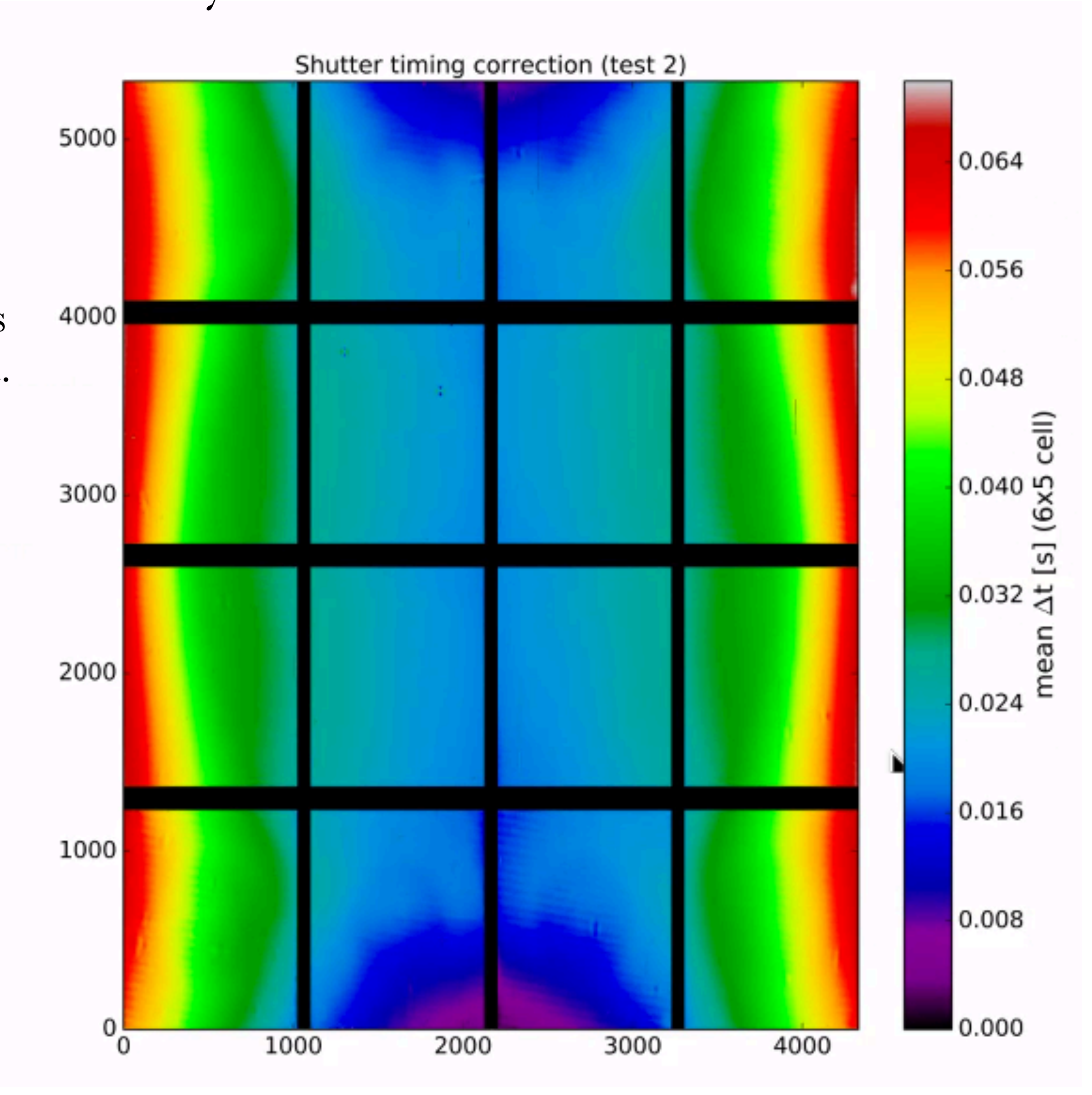


Step 3-5: Find ratio of measured to expected counts

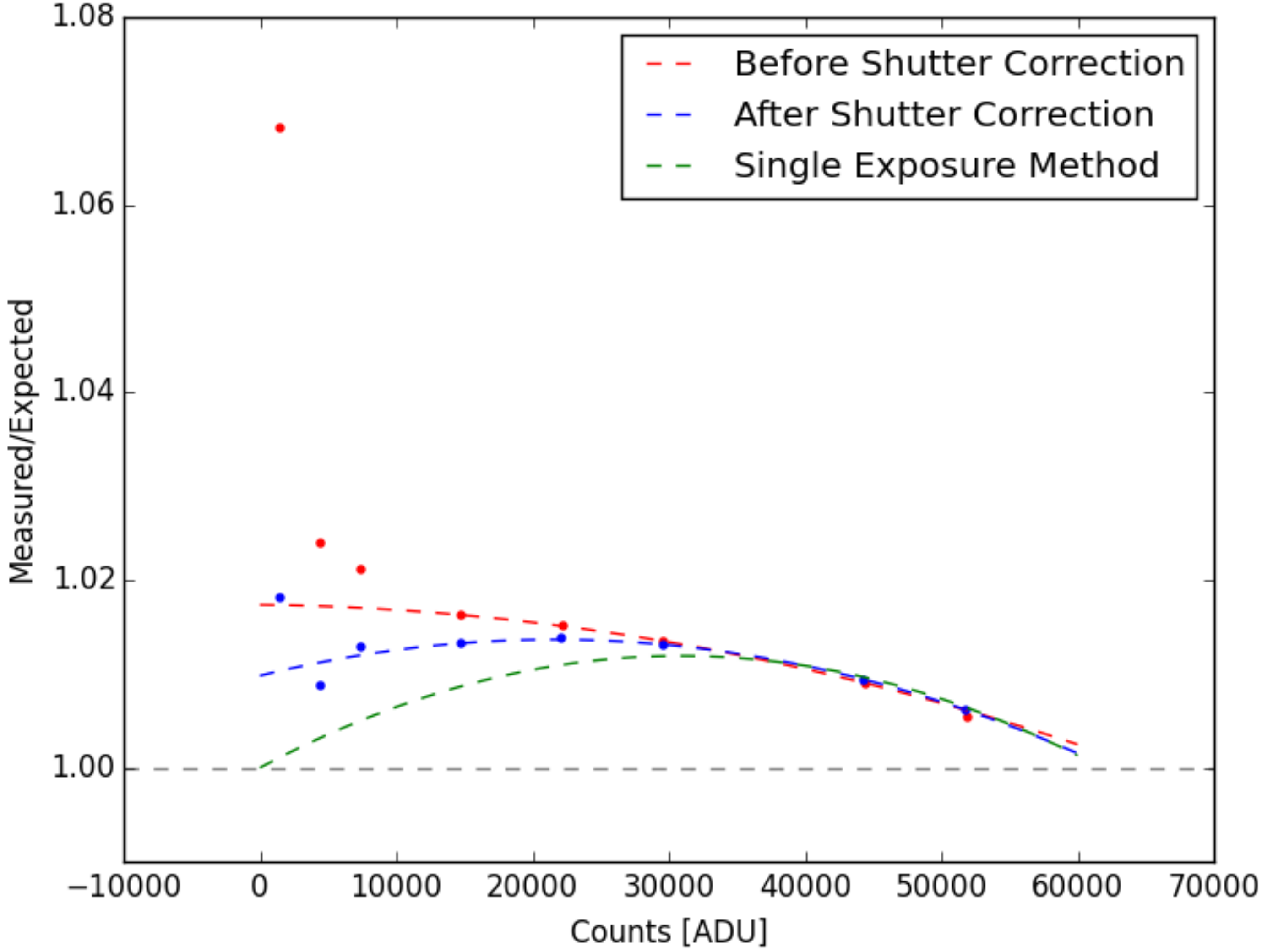


Shutter Correction by Matteo Giomi:

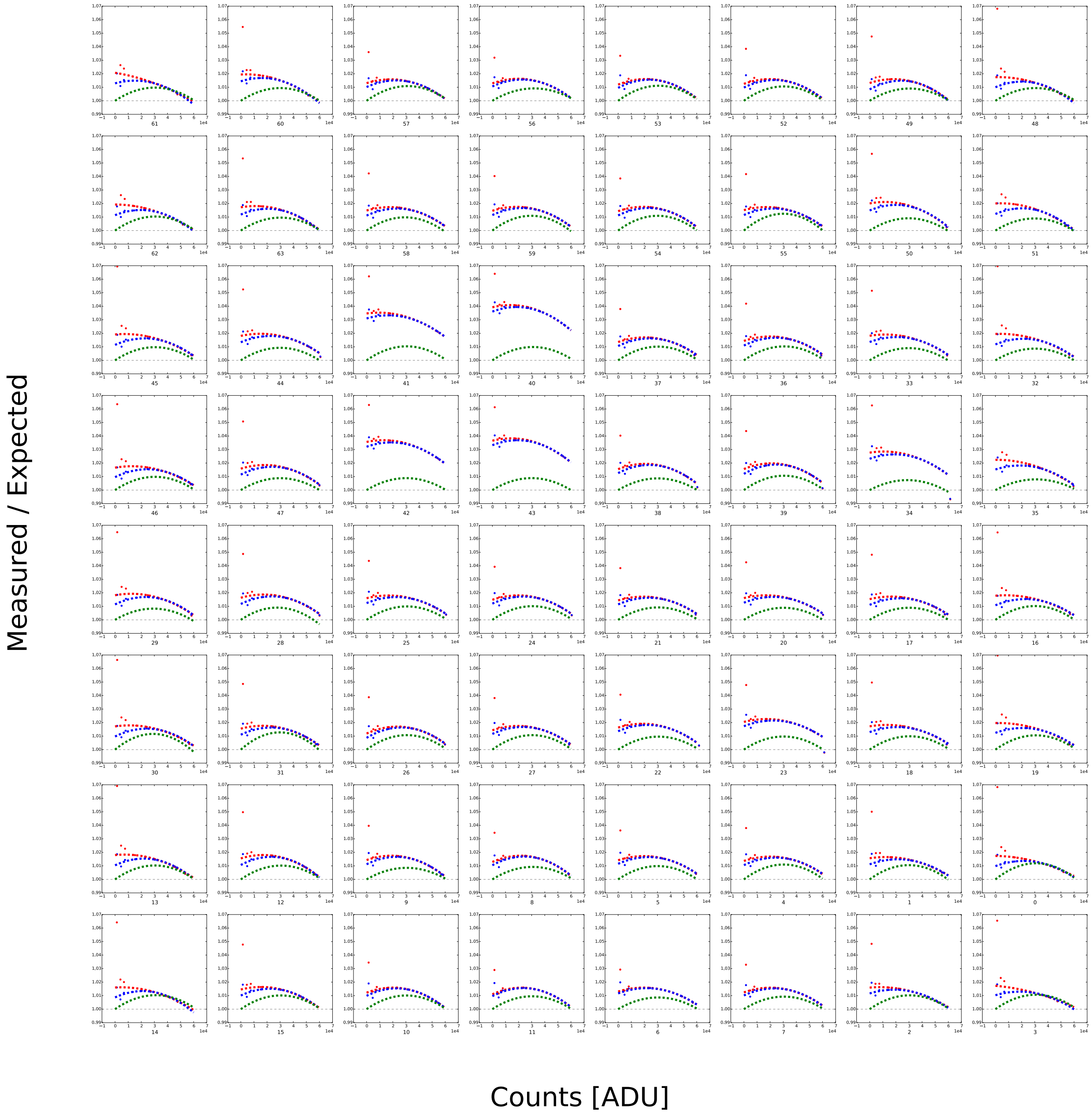
Must account for lost counts due to non-instantaneous shutter movement.



After incorporating shutter timing correction:



Repeat for all 64 Quadrants:



Summary of Results:

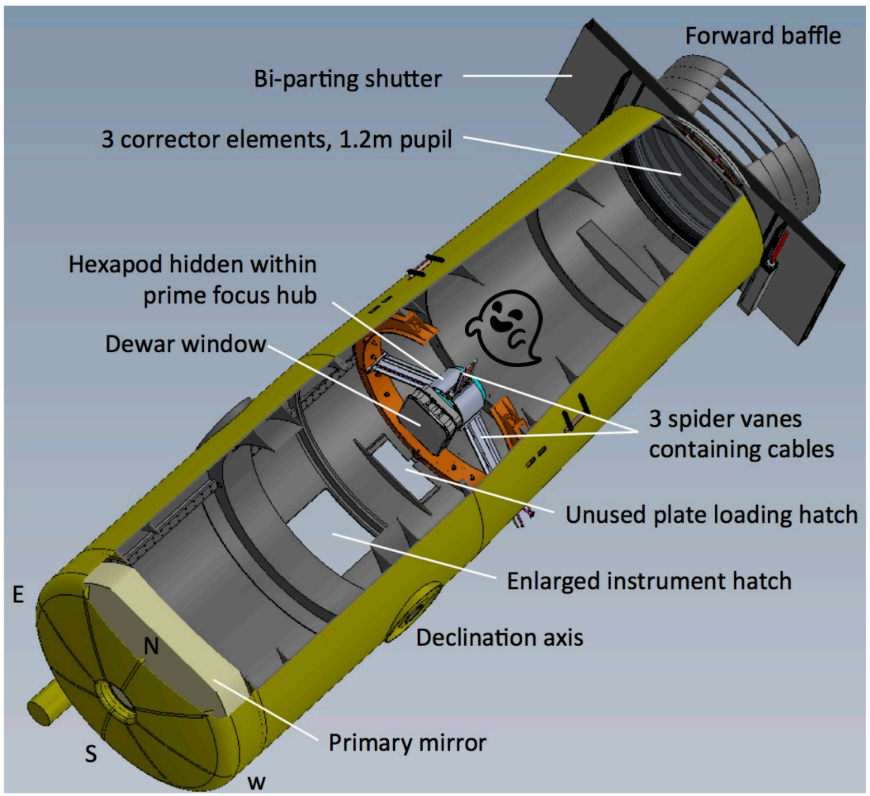
- ZTF is linear to 1-2% level with traditional method – But analysis is still ongoing
- Single exposure method shows nonlinearity is marginal
- We are not reproducing the results we expected - unclear why there are deviations at low signal level
- Shutter timing error is significant
- Single exposure method is already implemented into pipeline

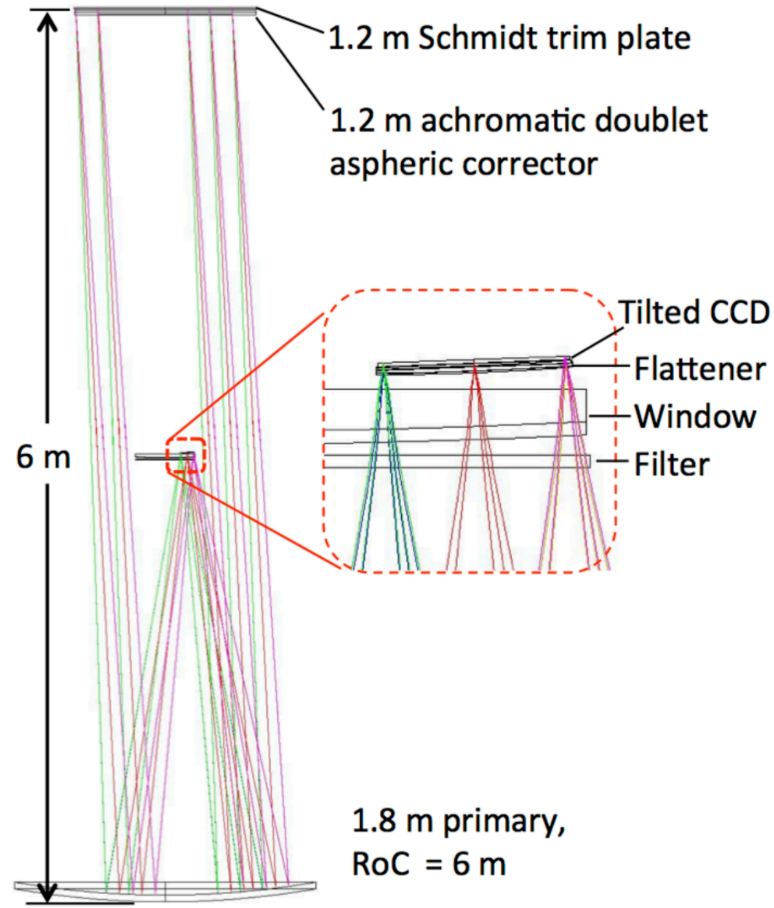
Future Work:

- Comparison between the traditional and single exposure methods still needs work, they should agree

Part II: Hunting for Ghosts in ZTF

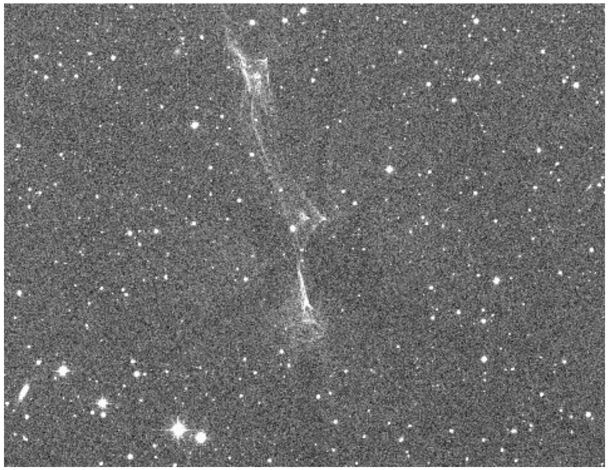
Ghosts are caused by internal reflections from bright, saturated parent stars





Ghosts Come in Two Flavors:

	Co-moving (halos):	**Counter-moving (reflections):**
Caused by:	Saturation of pixel full-well capacity	Internal reflections between optics
Locations:	Approx. symmetric around parent star	Reflected across center of focal plane
Distortions:	Vignetting, central obscurations	Sagging trim plate, obscurations



Why are ghosts a problem?

They are bad:

- for high-precision photometry in crowded fields
- for long exposures where stars saturate
- if stars fall inside a ghost, may find inaccurate magnitude
- and most importantly at the moment, **may be mistaken for real transients**

Goal:

To identify pixel locations of ghosts so that they can be masked in image processing and will not be mistaken for a real transient.

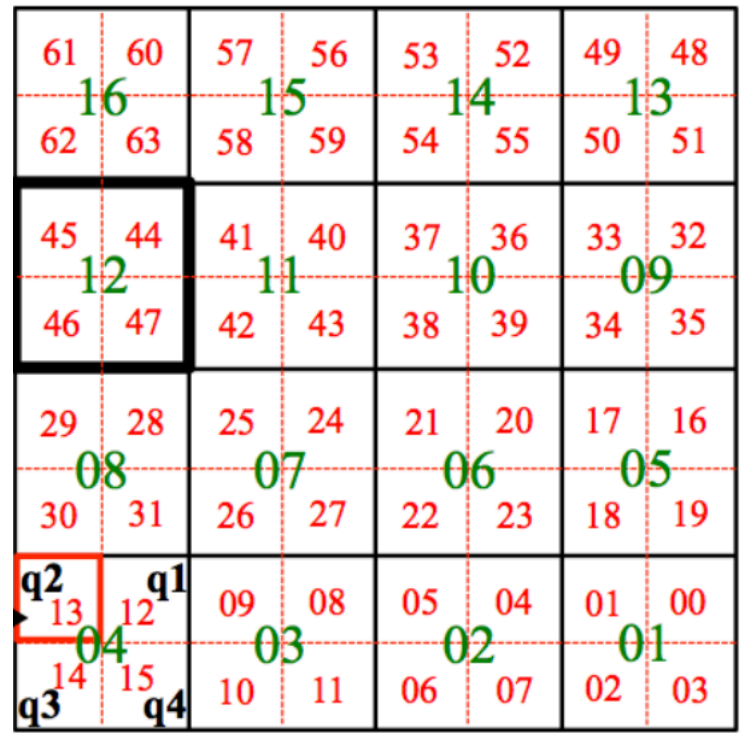
We choose an empirical approach as distortions in the CCDs can inhibit an analytical model of ghost predictions

Experiment Description:

Image bright parent star with each of the 64 quadrants (and outside of focal plane too, for counter-moving ghosts)

2nd Magnitude Parent (Beta Peg)

30 s exposures (single)



Co-moving Ghosts:

Uniform:

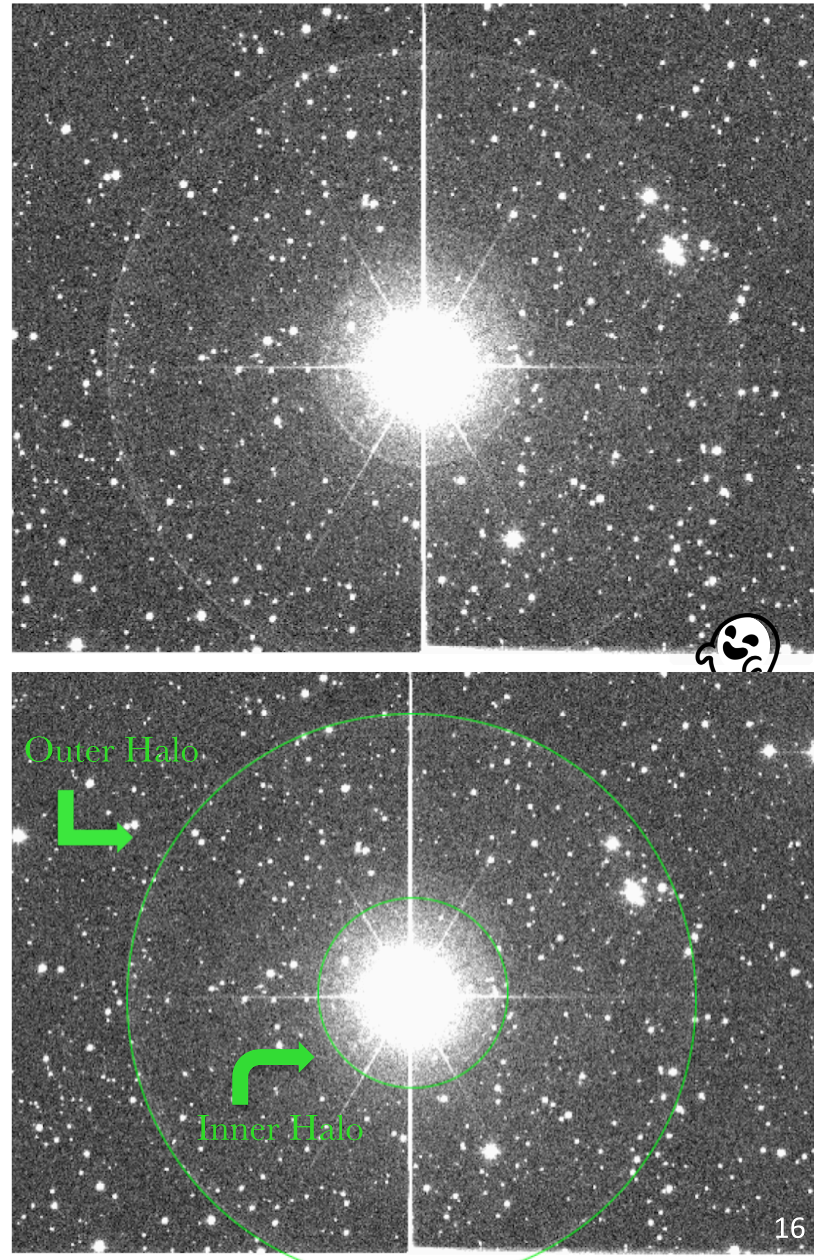
- Independent of parent brightness
- Independent of parent location on focal plane

Two components

- Outer halo: 350 pixel radius
- Inner halo: 130 pixel radius

Exists for parent stars up to 6th magnitude

There are some deviations but we use a conservative value for halo radius to account for this.



Counter-moving Ghosts:

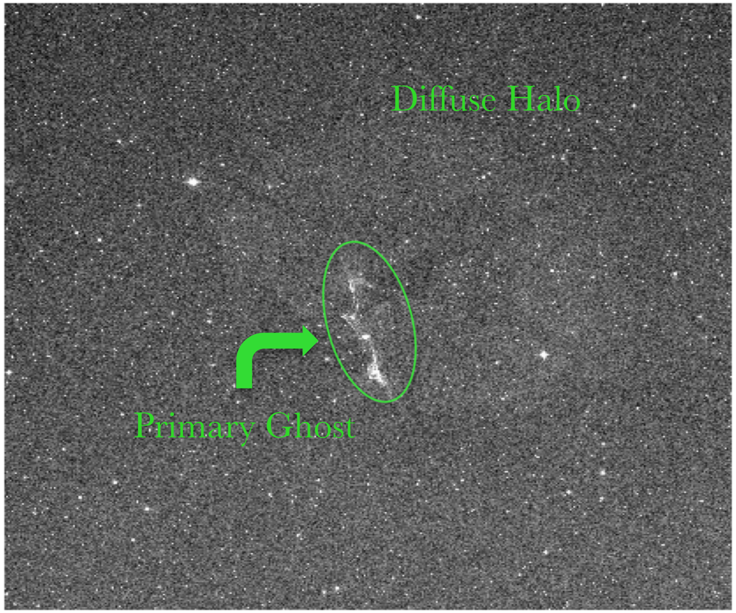
Multiple Components
- Primary ghost
- Diffuse halo
- Secondary ghost

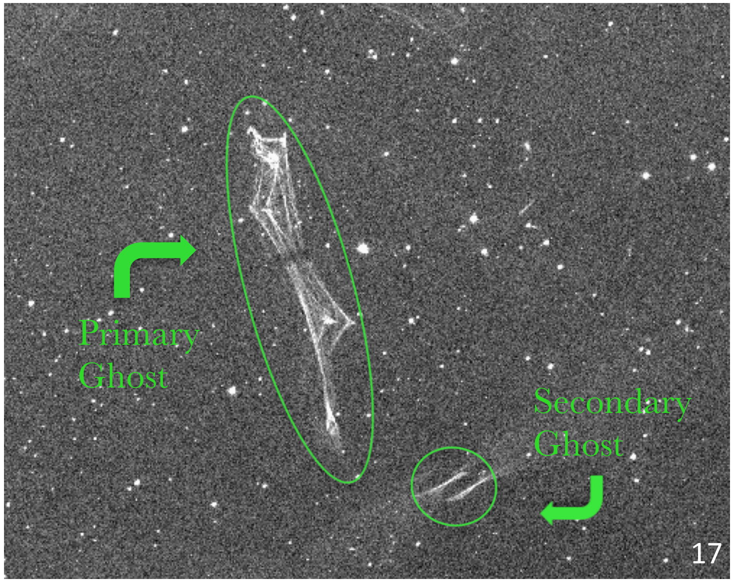
Less Uniform
- Some dependence on parent brightness
- Some dependence of parent location

Harder to predict ghost locations

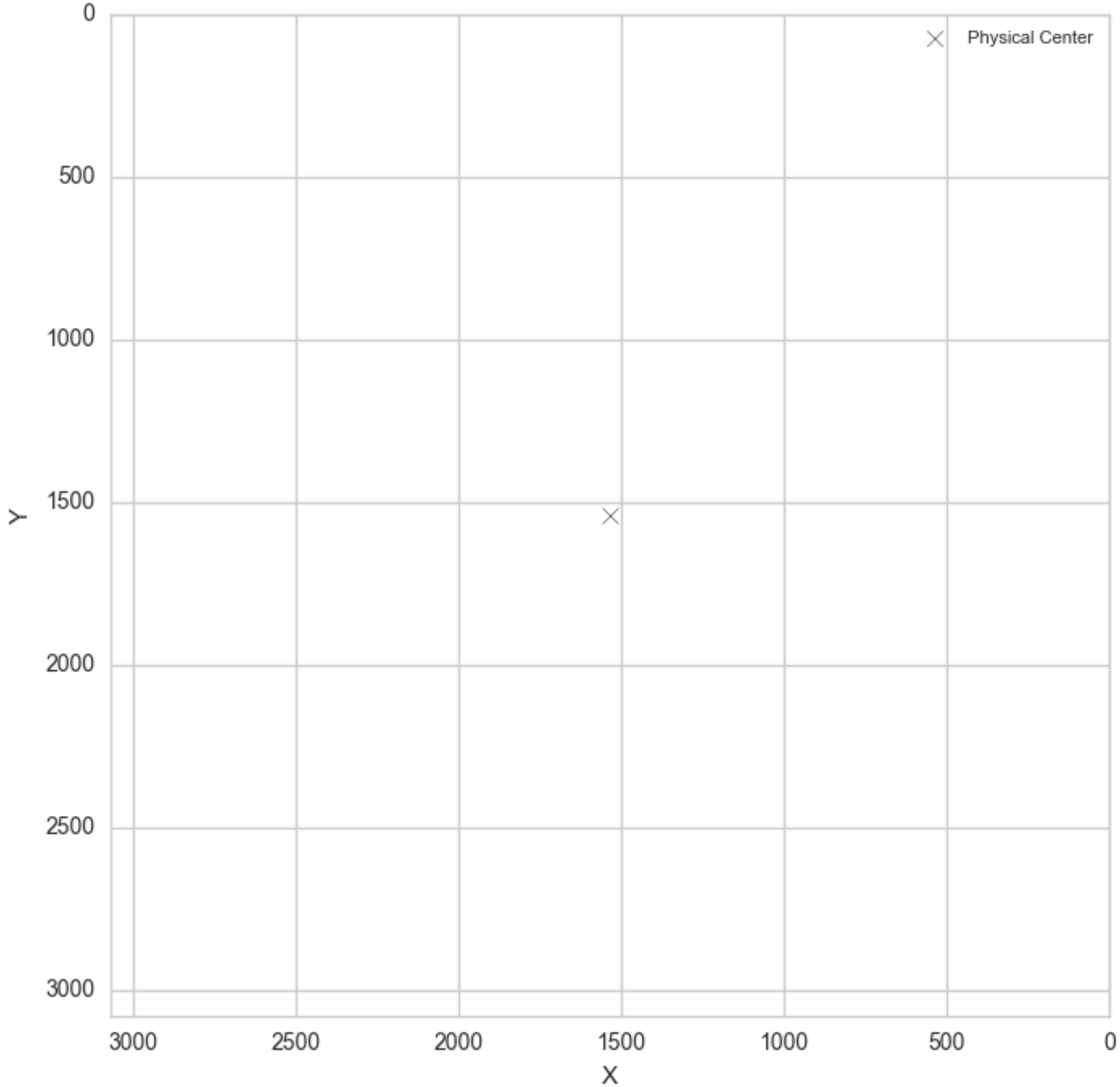
Also exists for up to 6th magnitude parent stars

Ignoring secondary ghosts for now

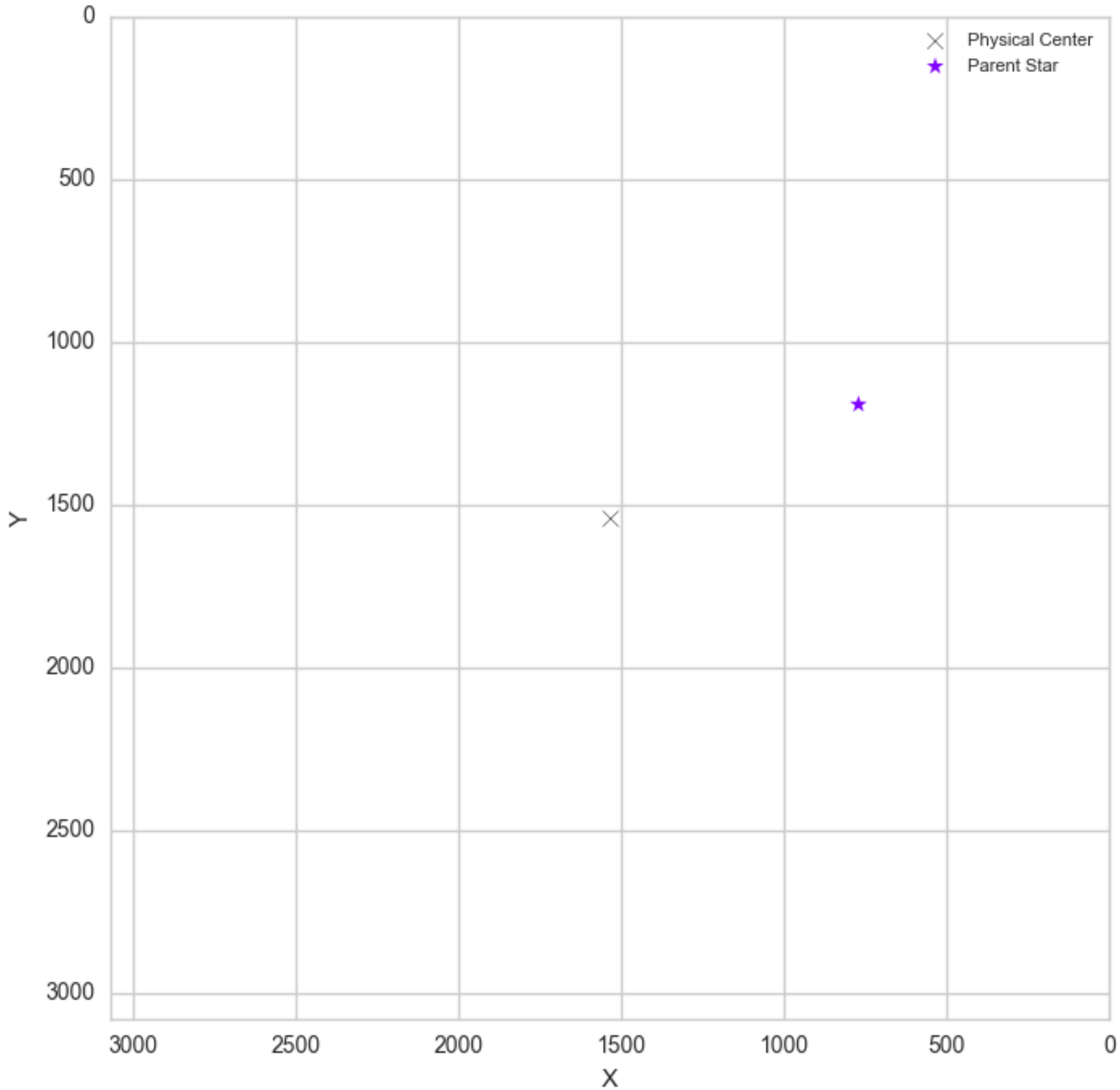




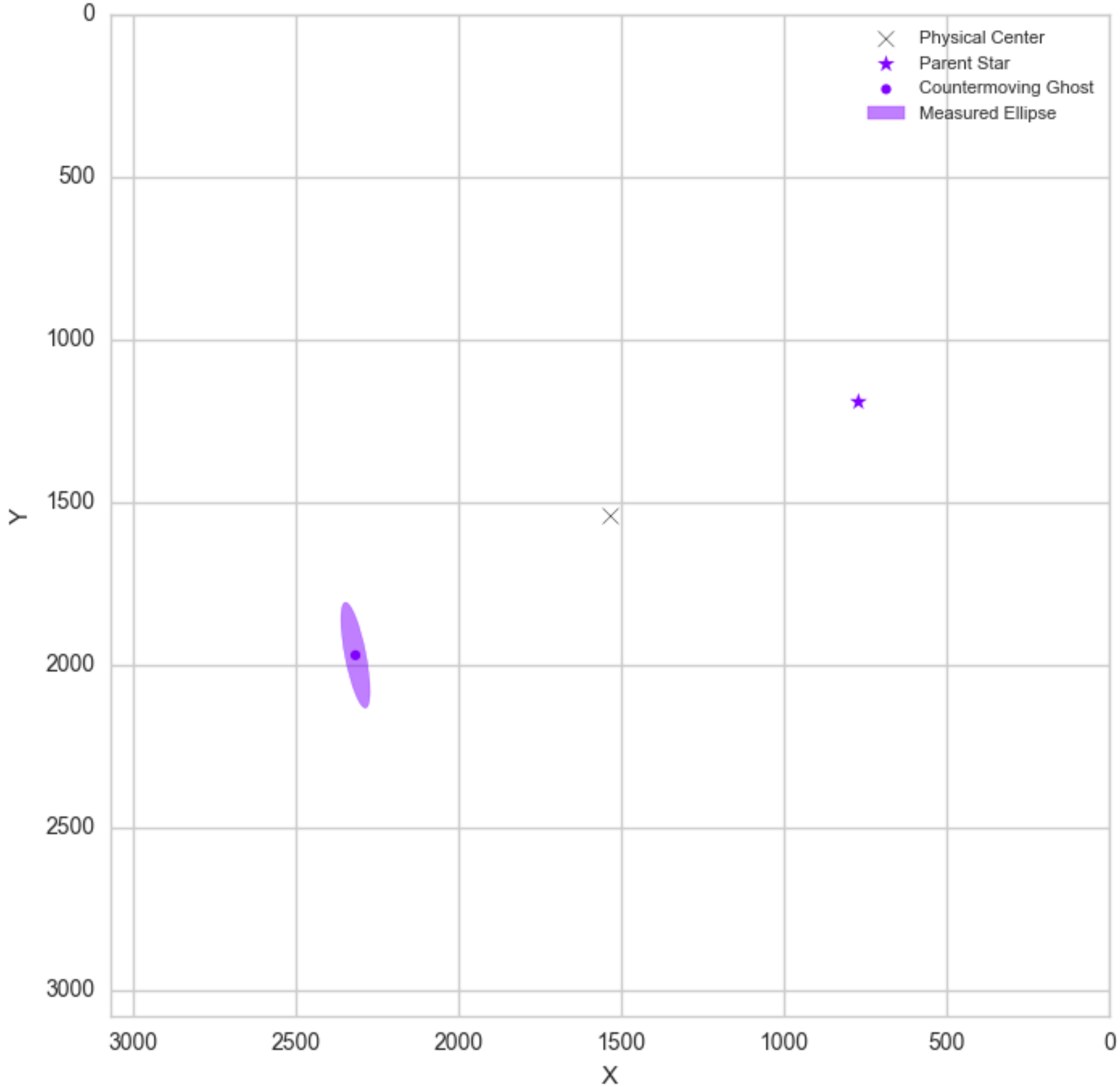
Predicting counter-moving ghost locations:



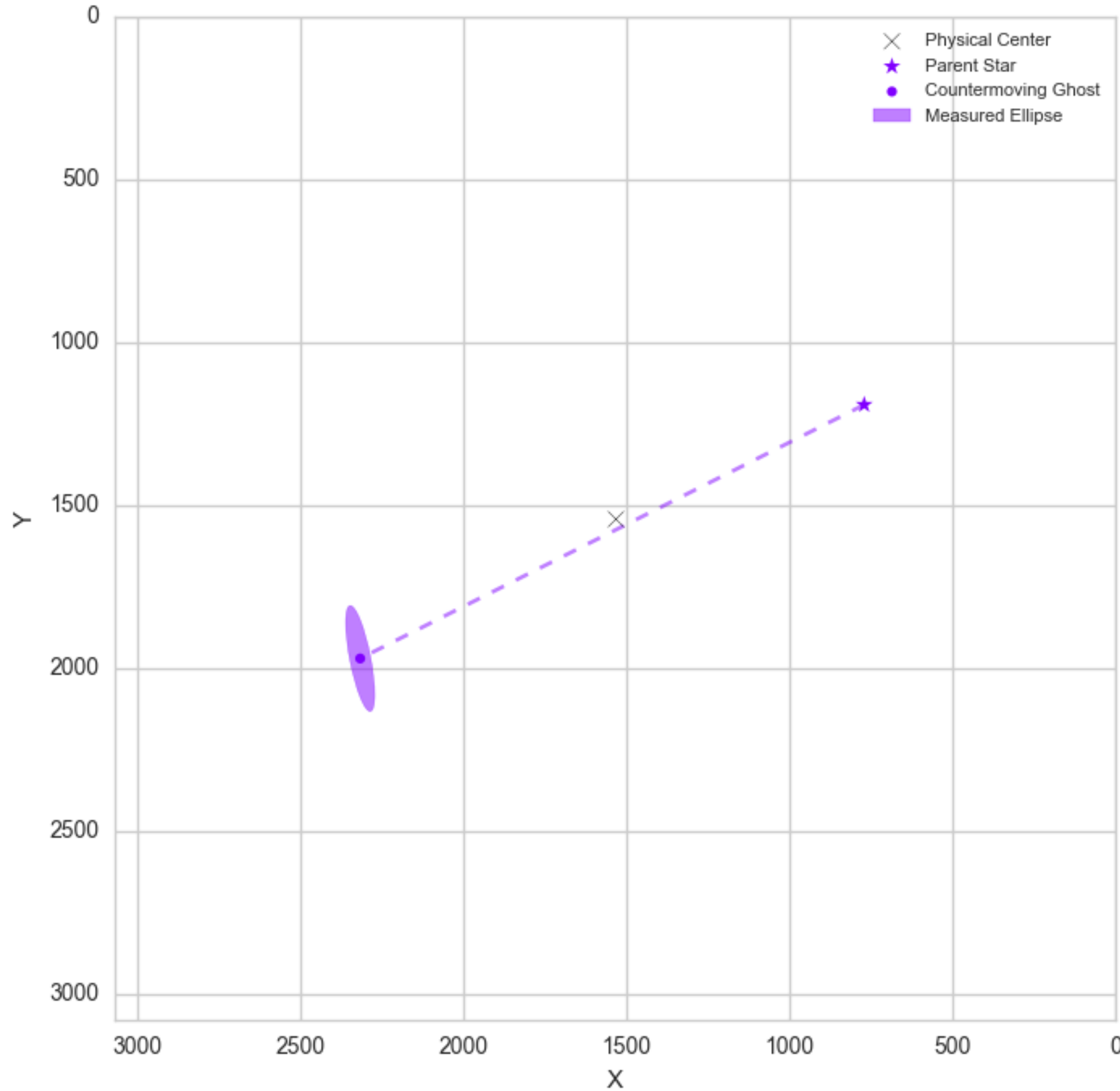
Predicting counter-moving ghost locations:



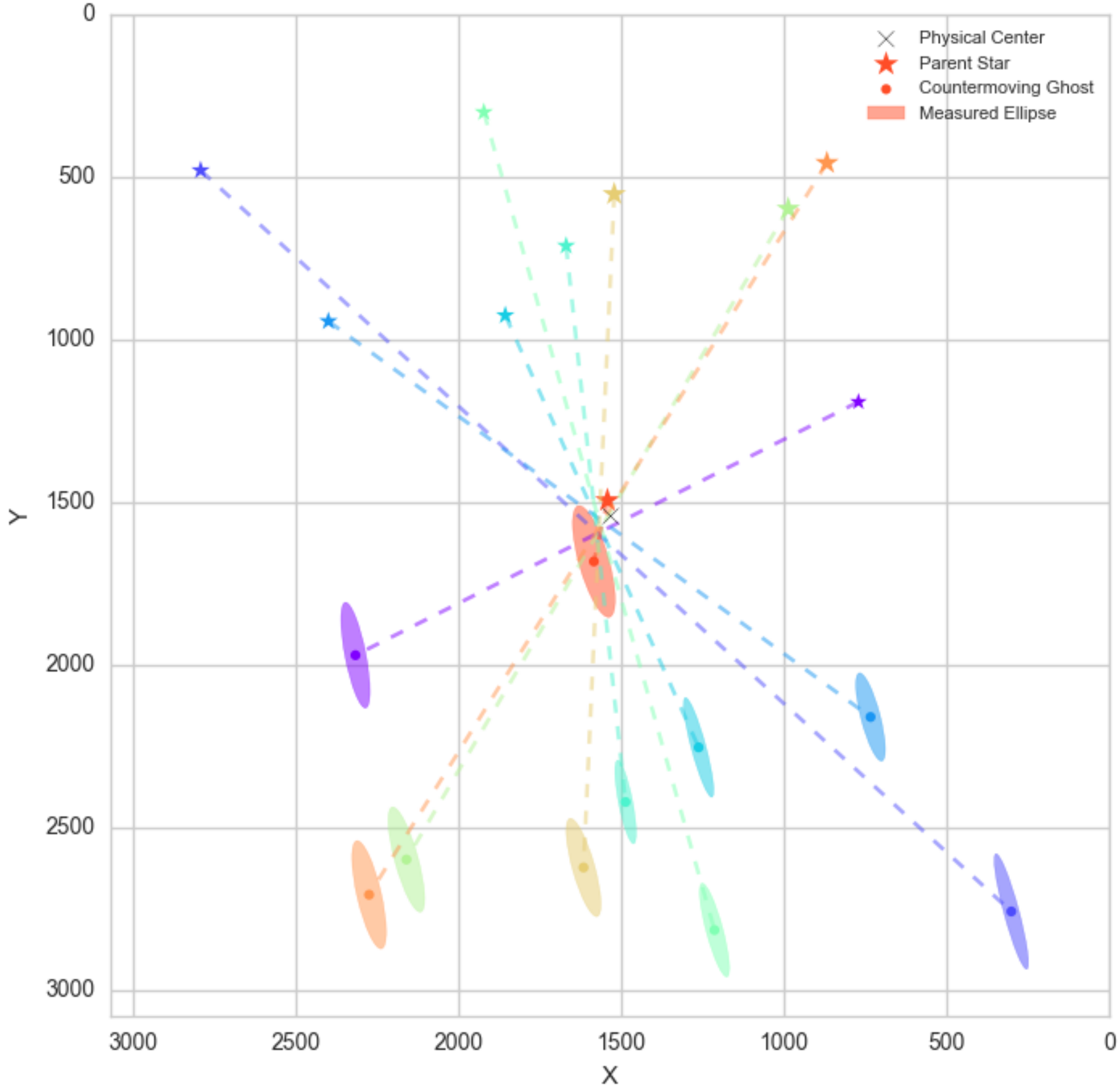
Predicting counter-moving ghost locations:



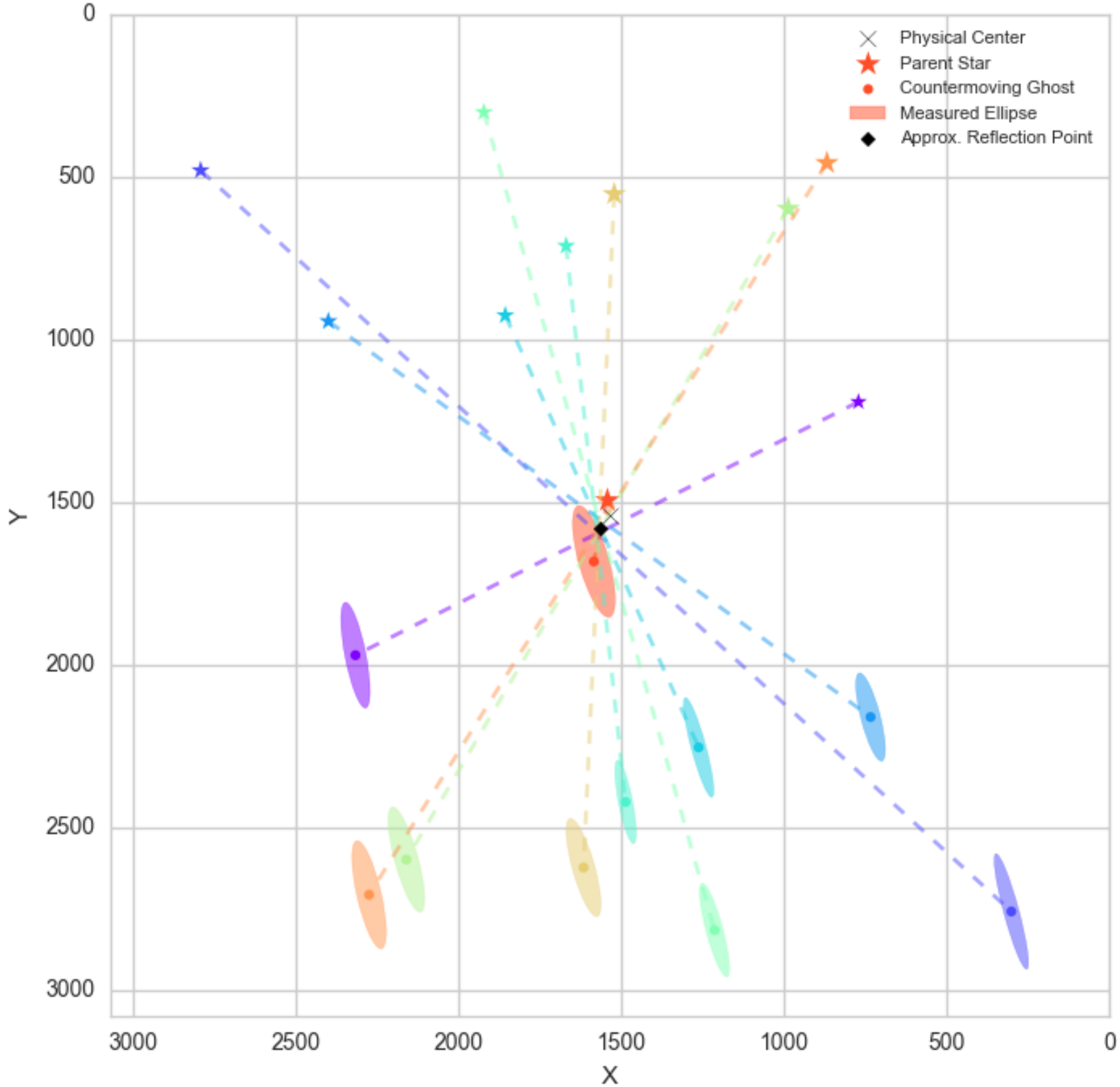
Predicting counter-moving ghost locations:



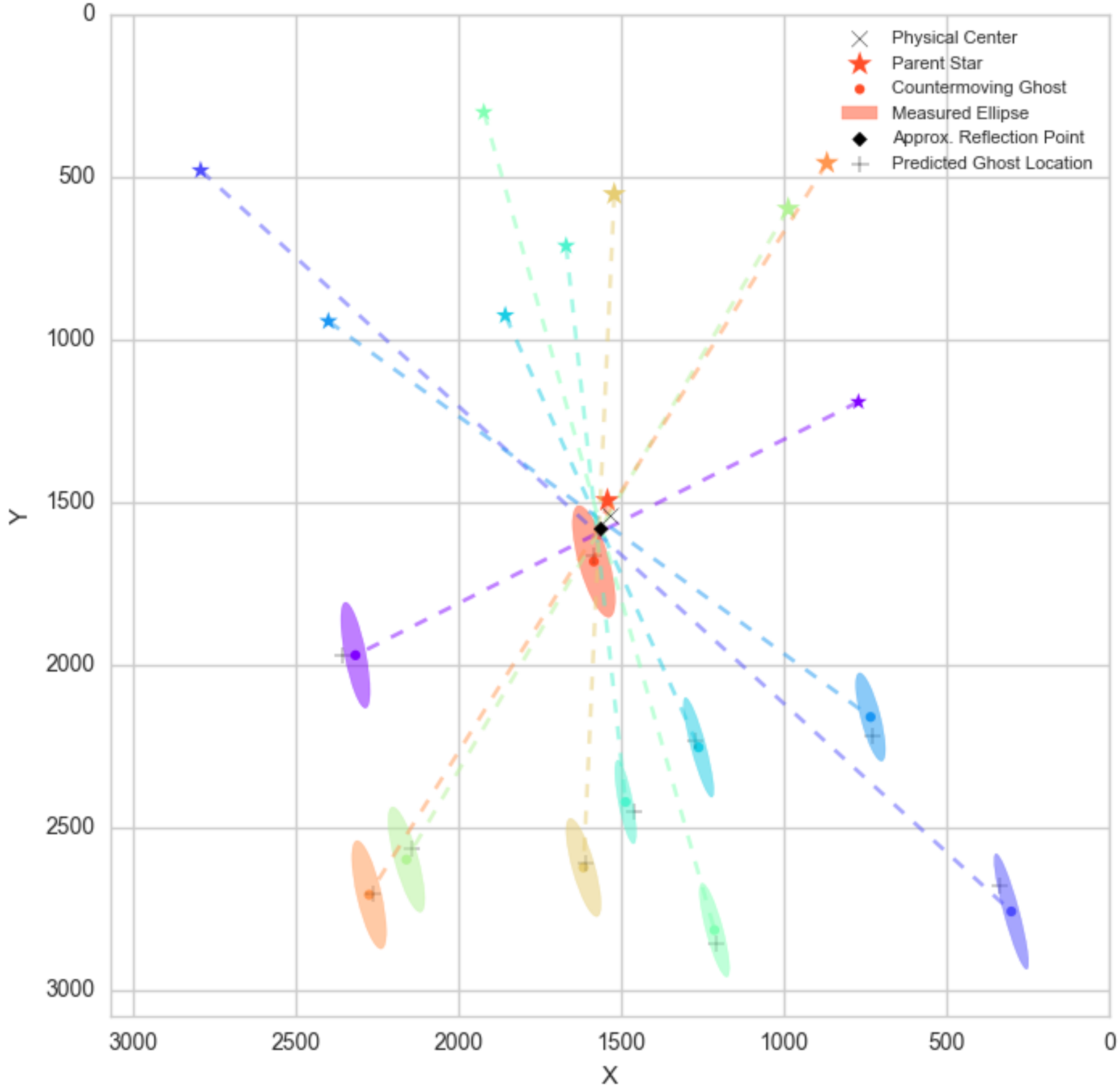
Predicting counter-moving ghost locations:



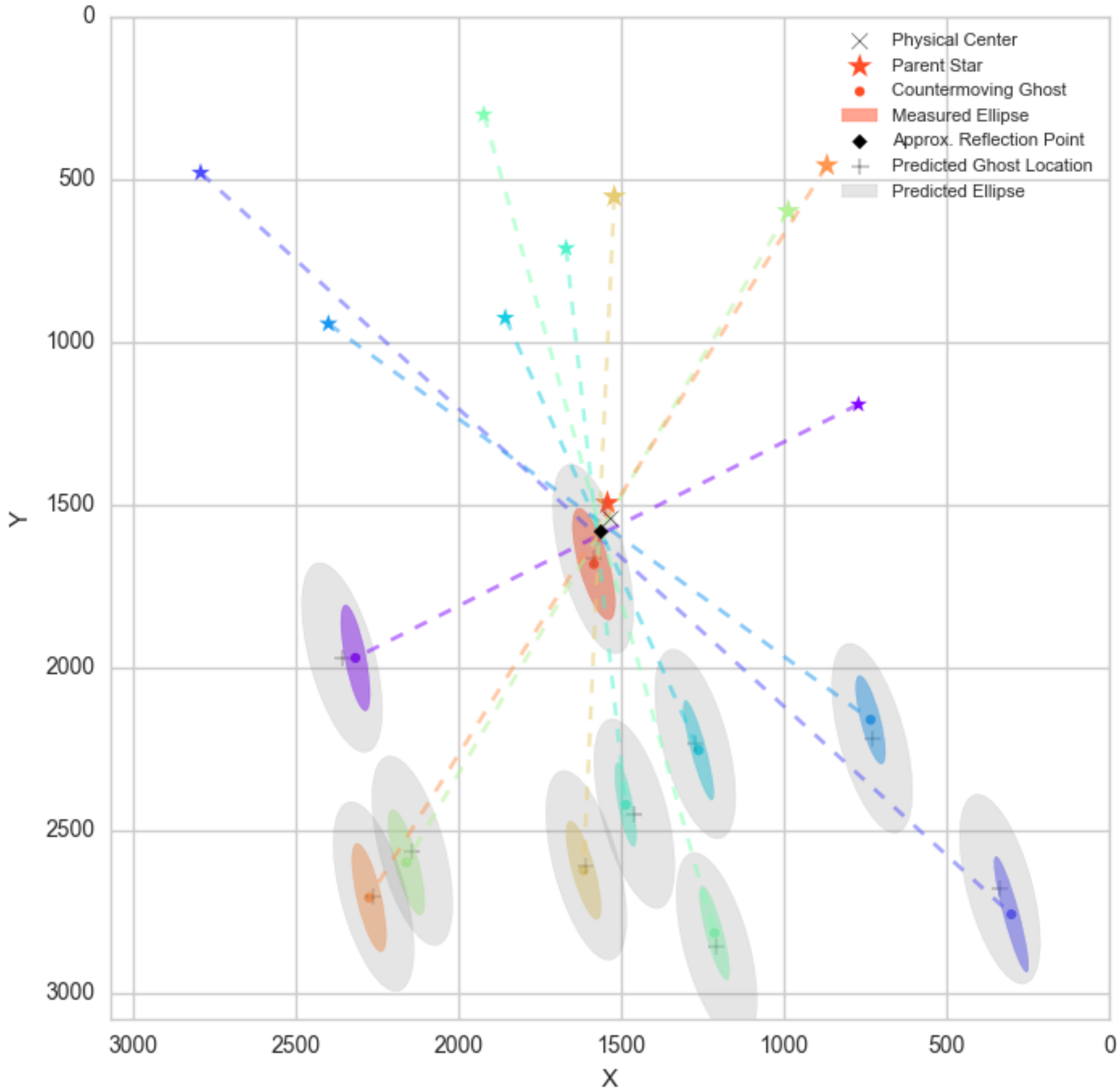
Predicting counter-moving ghost locations:



Predicting counter-moving ghost locations:



Predicting counter-moving ghost locations:



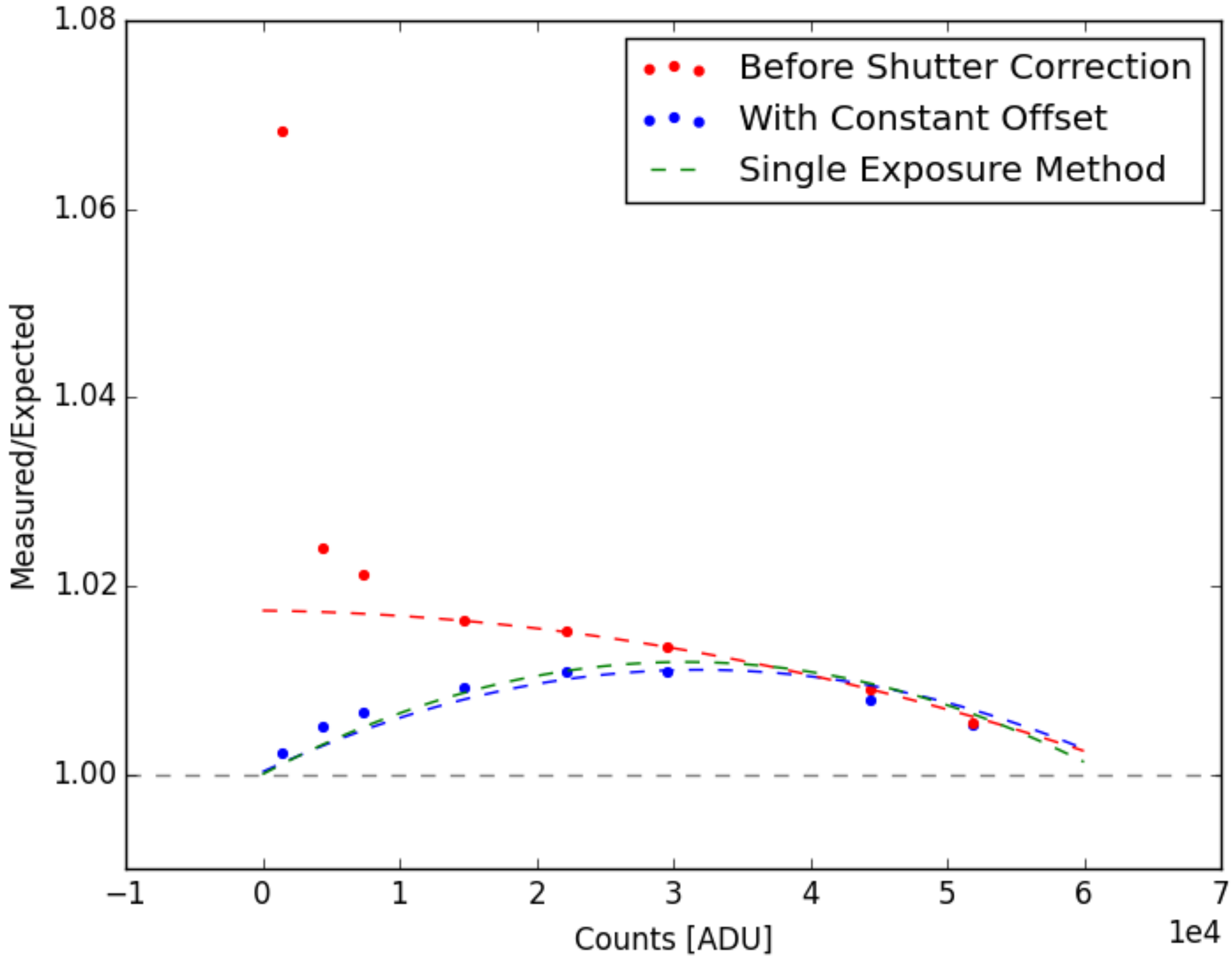
Summary of Results:

- We came up with conservative predictions to identify both co- and counter-moving ghosts from a parent star catalog
- Ghosts in general are fairly uniform and independent of parent star's magnitude
- These results will be implemented into the image processing pipeline and any affected pixels will be masked
- ~0.3% of pixels masked in all images by counter-moving ghosts, ~0.4% for co-moving ghosts

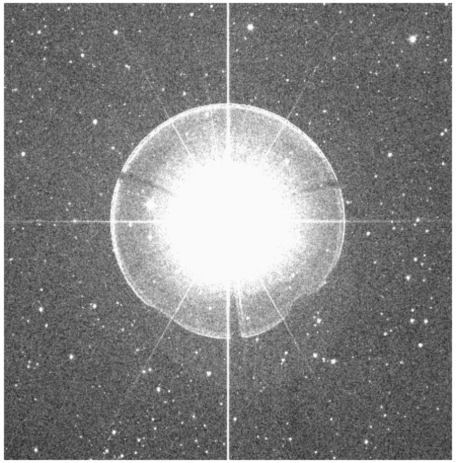
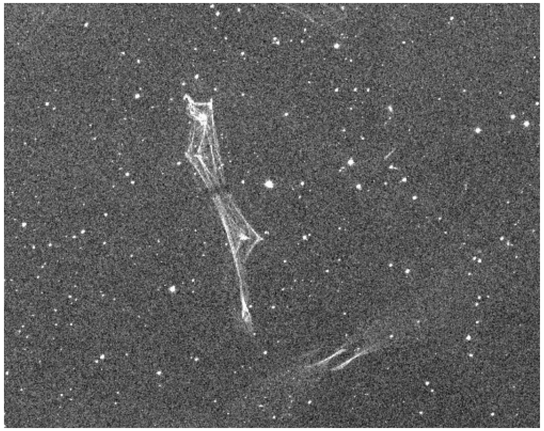
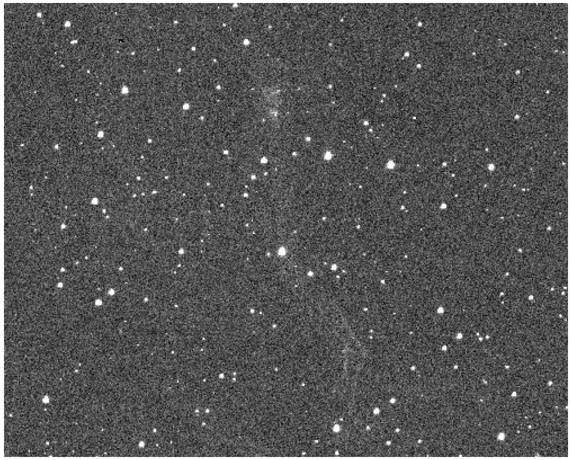
Future work:

- May need to perform experiment again because this was done before ZTF was taken off the mountain in January
- Future second-order predictions would also mask the secondary ghosts

Adding Constant Offset to Results before Shutter Correction:



Bright vs. Faint Ghosts:

	Bright	**Faint**
Co-Moving		
Counter-Moving		

Secondary Counter-Moving Ghosts: