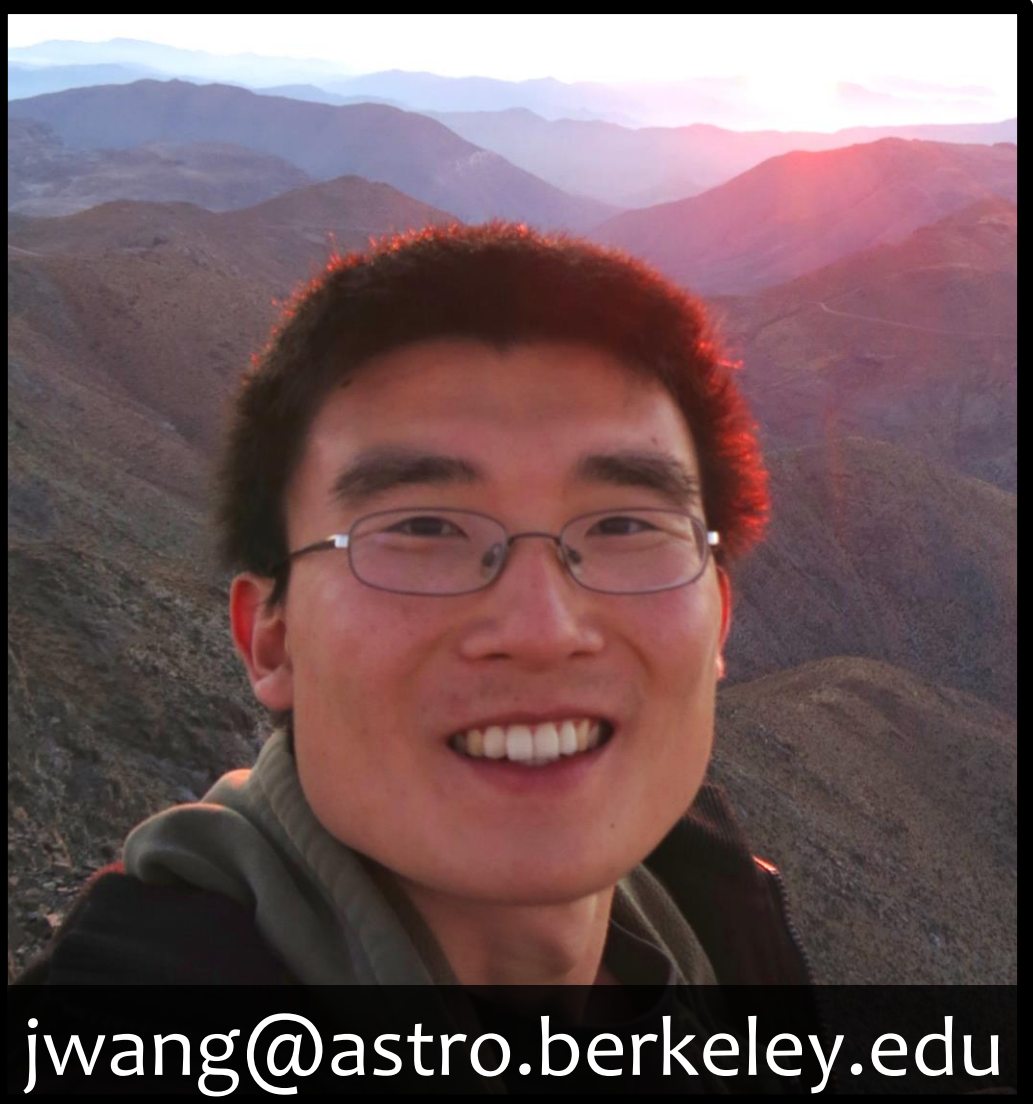




# Gemini Planet Imager Observational Calibrations VIII: Characterization and Role of Satellite Spots

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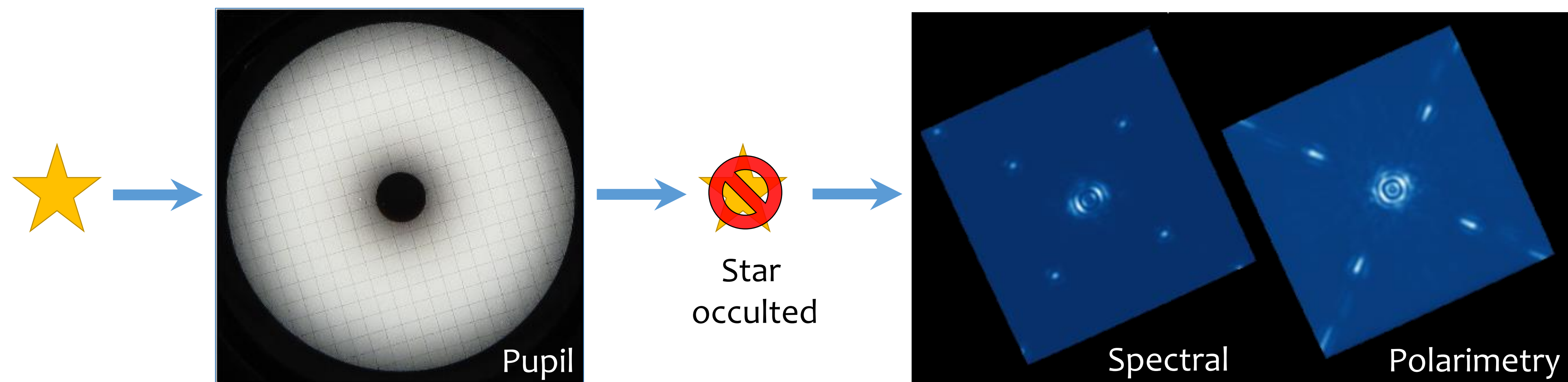


## Summary:

- Satellite spots are diffraction phenomena that allow us to measure the properties of the occulted star in GPI coronagraphy mode.
- The GPI Data Reduction Pipeline has routines that utilize the satellite spots for both astrometric and spectrophotometric calibration.
- The relative astrometric precision of the satellite spots to locate the central star is 0.05 pixels (~0.7 mas) and is best for satellite spots with a signal to noise ratio (SNR) > 20.
- The total satellite spots flux is stable to ~6% and the shape of the spectrum is stable to 2%.

## How Do We Measure a Star Hidden Behind the Occulting Mask?

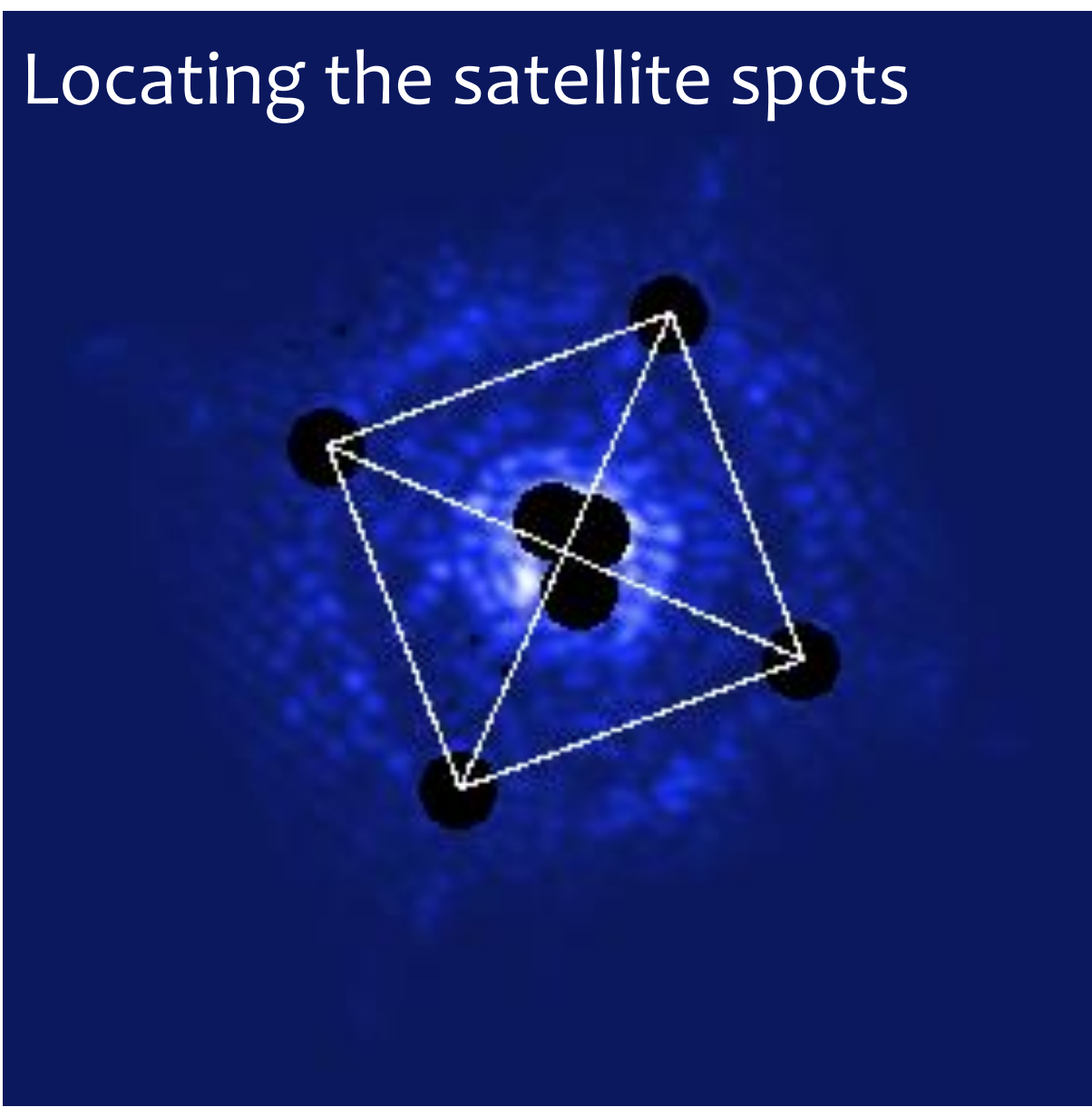
- Starlight is diffracted (pre-occulter) from a square grid printed on the pupil apodizer.
- The grating produces four diffraction spots centered on the location of the star in GPI's field of view.
- In spectral mode, each wavelength slice contains a set of satellite spots.
- In broadband polarimetry images, the satellite spots are smeared into rods extending radially outward from the occulted star.
- The satellite spots are also imprinted with the a fainter copy of the spectrum of the occulted star.



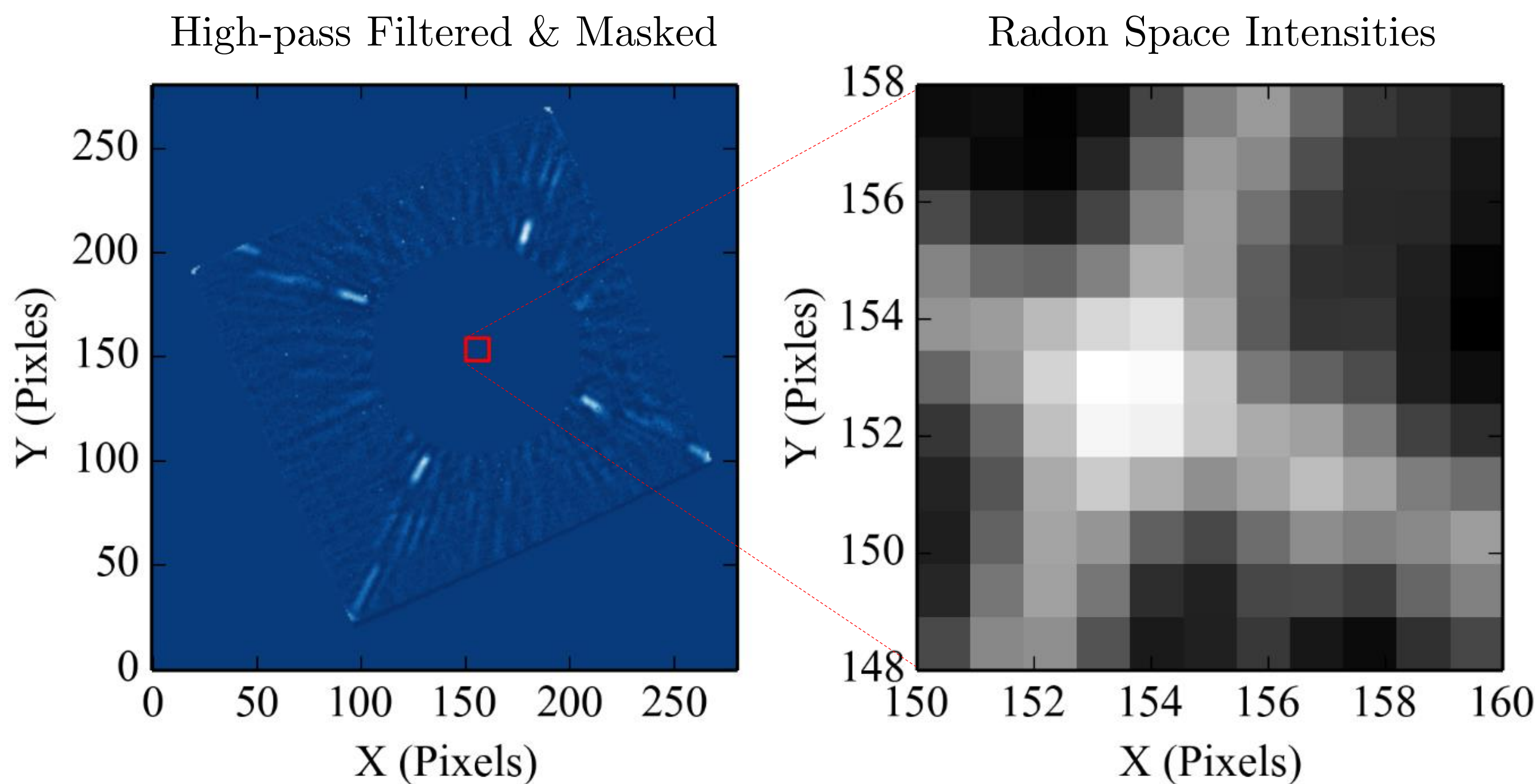
## Locating and Measuring the Satellite Spots in the GPI Pipeline

### Spectral Mode

**Astrometry**  
Approximately locate a set of four point sources in the image that forms a square (right). Centroid on each spot by using a matched filter with a Gaussian PSF of fixed width. The star is in the middle of the four satellite spot positions.



**Photometry**  
Fit a Gaussian template to each of the satellite spots: calculate the full width half maximum (FWHM) to fix the width of the Gaussian and fit for height of the Gaussian to extract the peak flux.



### Polarimetry Mode

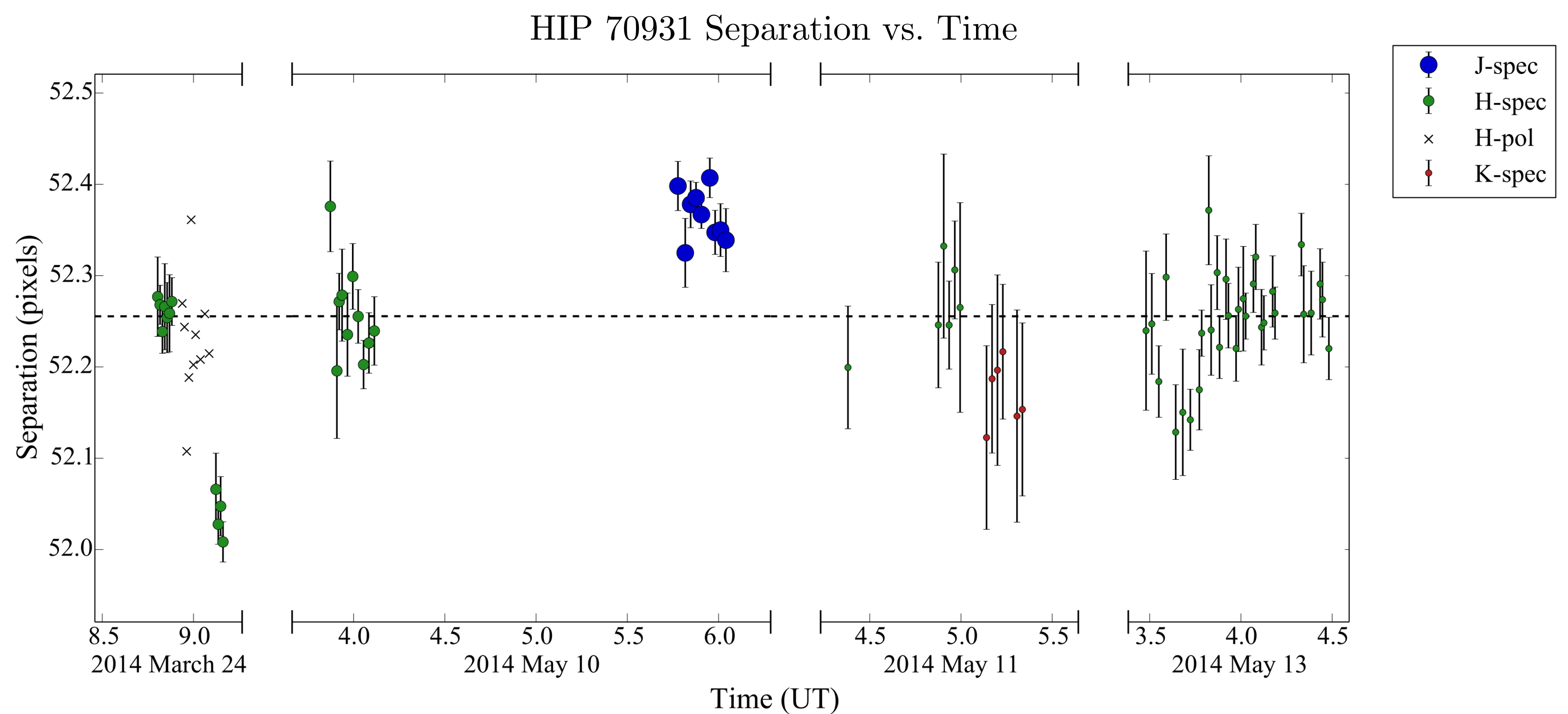
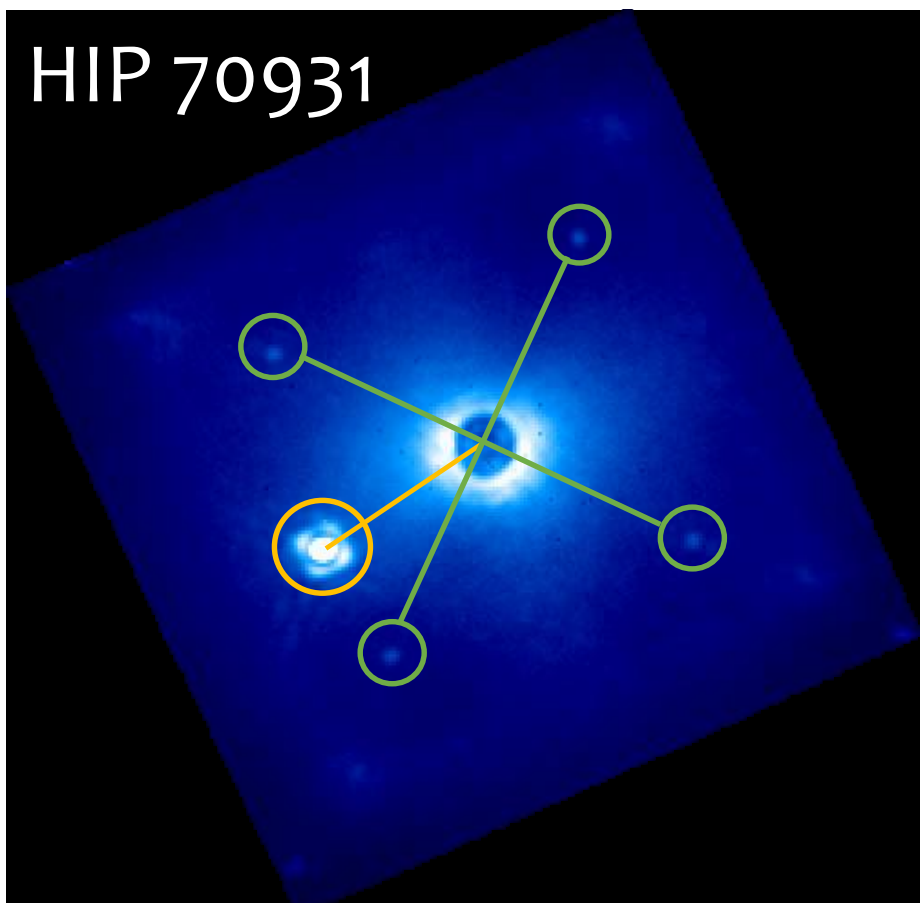
**Astrometry**  
Radon Transform method (left): for each pixel, take the sum of the flux through all straight lines that pass through that point. Pixel with most flux harbors the center star.

**Photometry**  
Not yet implemented

## On Sky Performance

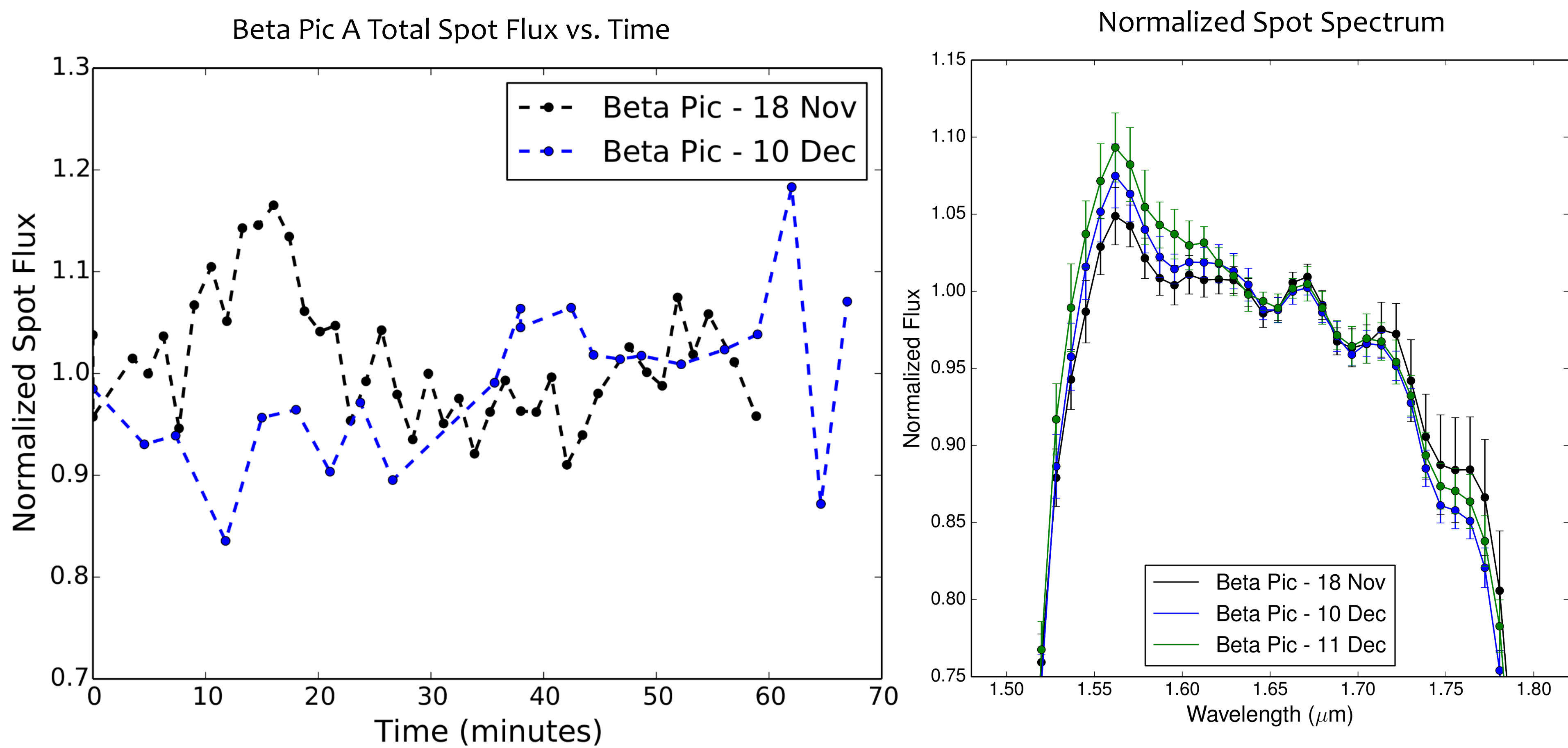
### Astrometric Precision in Locating the Occulted Star

- We could not find a target suitable to perform an absolute astrometric calibration so we characterize the relative precision by examining the reproducibility of the measured separation of a non-astrometric binary (HIP 70931).
- In *H*-band, the relative RMS uncertainty of the occulted star position is 0.05 pixels (0.7 mas) for a single data cube.
- Systematic errors dominate the uncertainty and vary in time.
- Locating the occulted star position works best when the signal-to-noise ratio of an individual satellite spot is > 20.



### Spectrophotometric Stability of the Satellite Spots

- The average flux of all four satellite spots is the most stable photometric measurement.
- Within an observing sequence, the combined flux from all four satellite spots varies ~6%.
- The shape of the spectrum of the satellite spots is stable to 2% between exposures.
- The brightness of the satellite spots scales linearly with the brightness of the star.



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