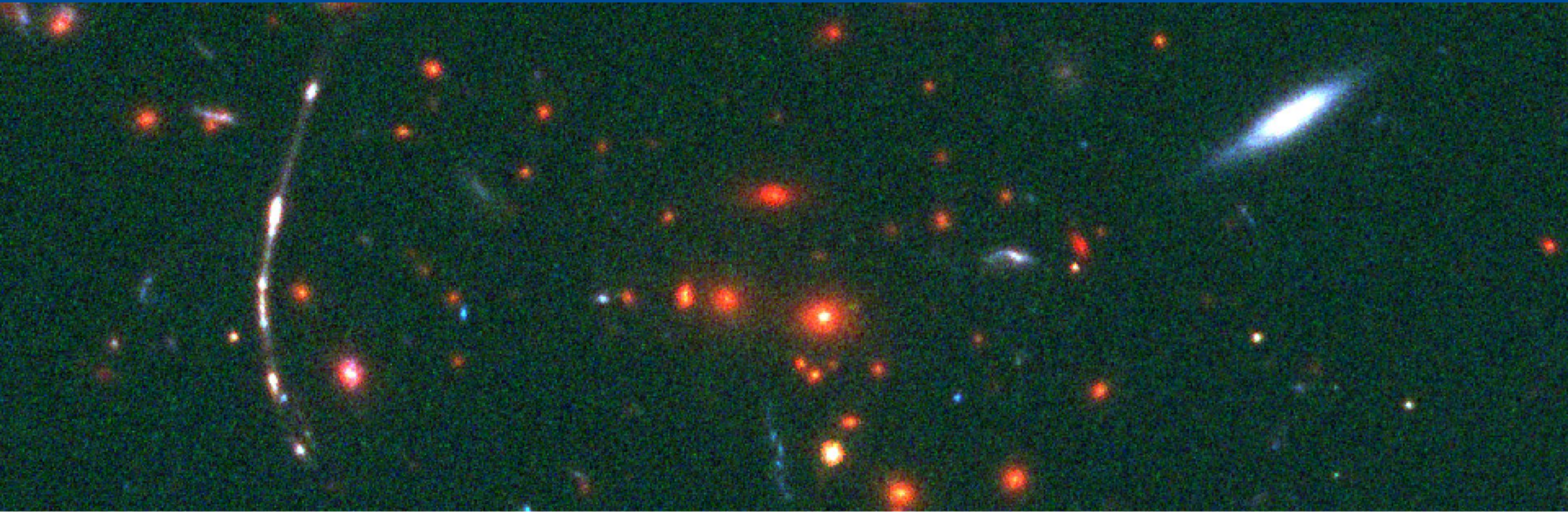


Observational Cosmology; Strong Lensing Analysis, Follow-up Observing Proposals, Spectrograph Fiber Positioner R&D

Finian Ashmead

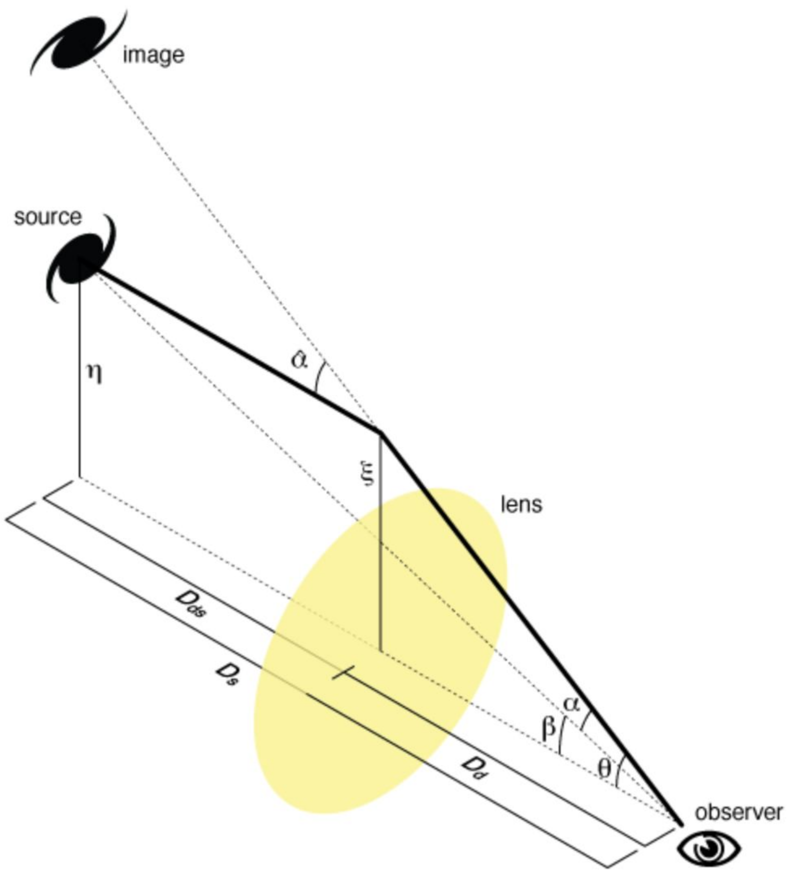
SULI Presentation

7 December 2022

Strong Gravitational Lensing

$$\vec{\beta} = \vec{\theta} - \vec{\alpha}(\vec{\theta}) = \vec{\theta} - \frac{D_{ds}}{D_s}\vec{\hat{\alpha}}(\overrightarrow{D_d\theta})$$

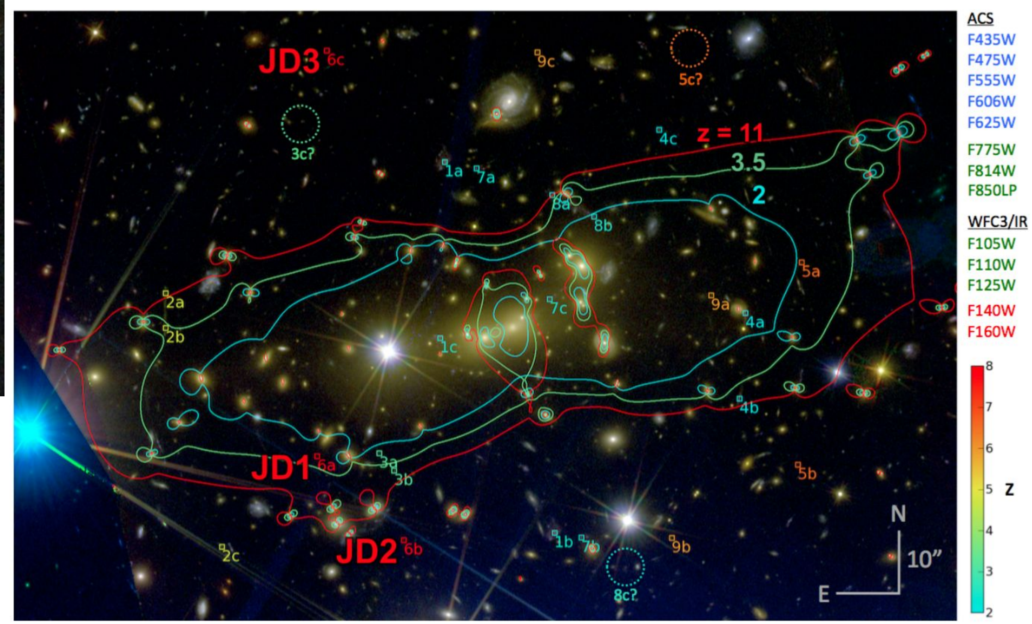
- The deflection of light by a massive source can be predicted by GR.



Science with Strong Gravitational Lensing

- Strong lensing depends only on the mass of the lens, allowing us to directly measure the mass distribution of the foreground galaxy or cluster.

- We receive a flux from the object proportional to the apparent size (solid angle). When galaxies are stretched by strong lensing, we achieve a much greater data quality than would be possible with an equally distant, non-lensed galaxy.



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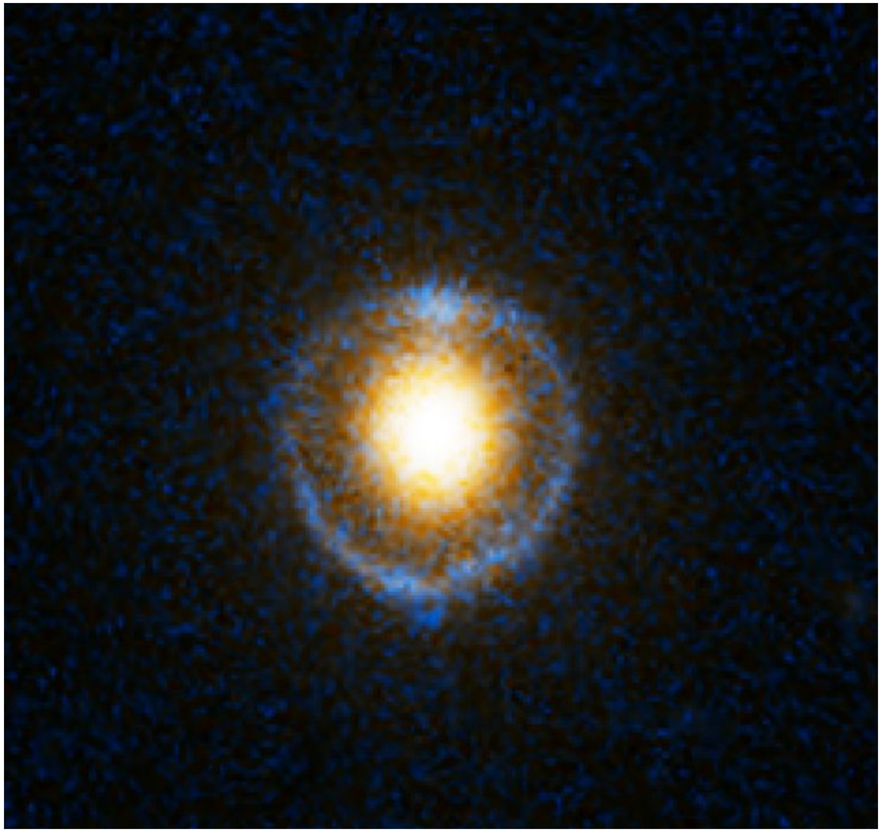
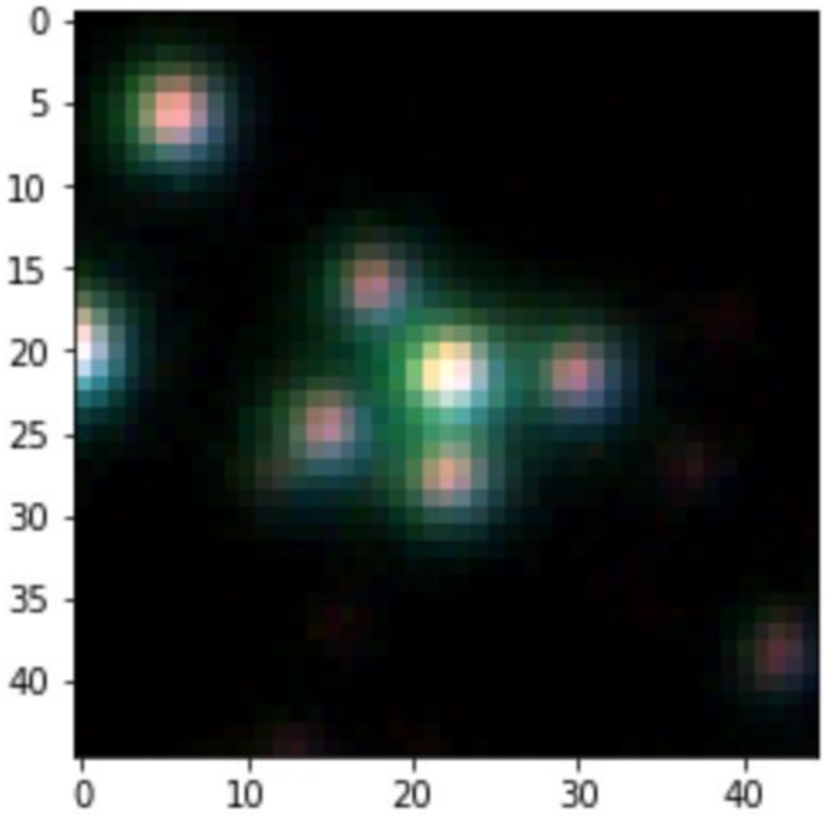
Strong Lensing Examples: Quasar and Galaxy-Galaxy



- Galaxy-galaxy strong lenses are a simpler configuration than the cluster-scale lenses, and are what my strong lensing work at FNAL was focused on. An “Einstein ring” is perfectly aligned to produce the ring image.

- With a multiply-imaged lensed transient such as a quasar, time delays between the images can be used to estimate cosmological parameters.



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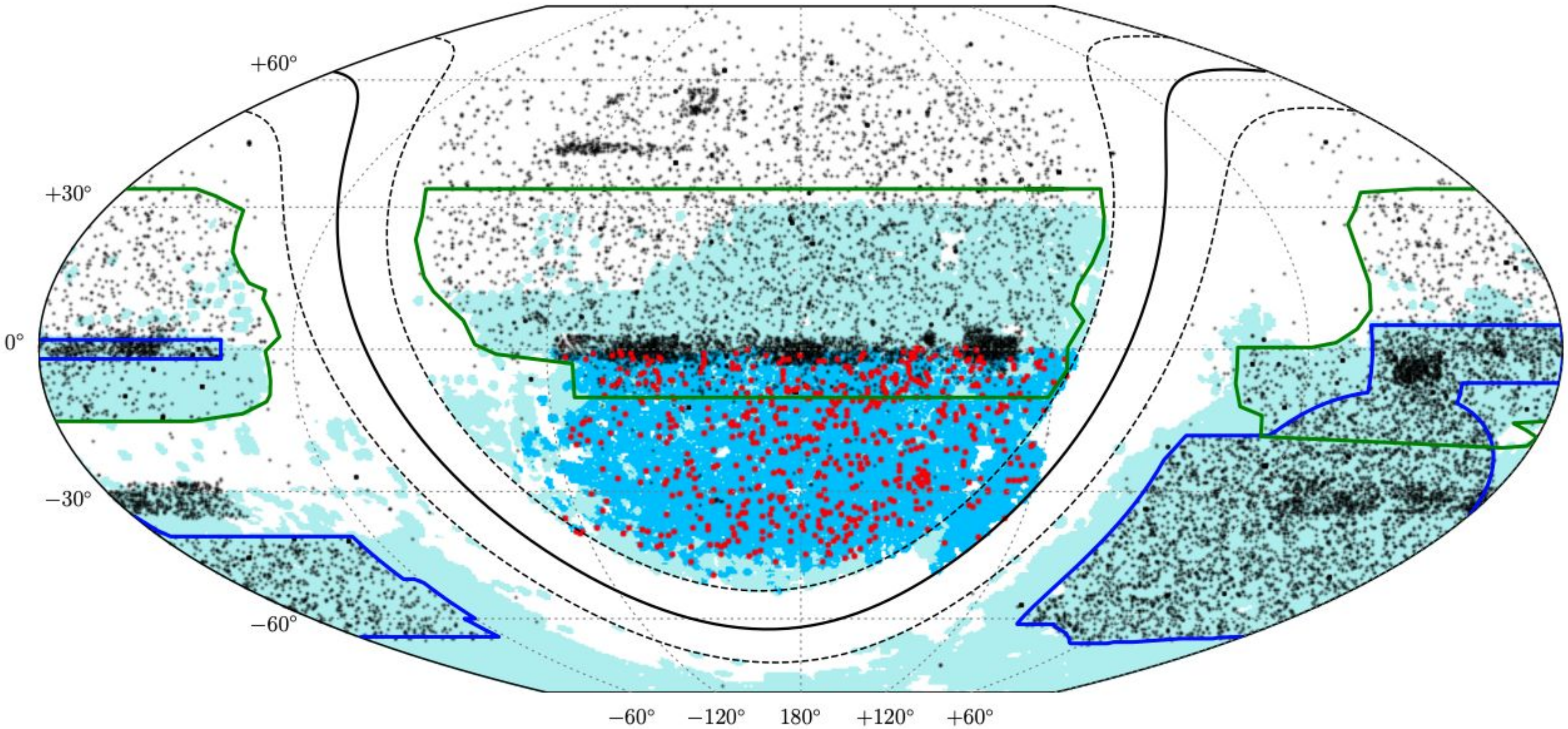
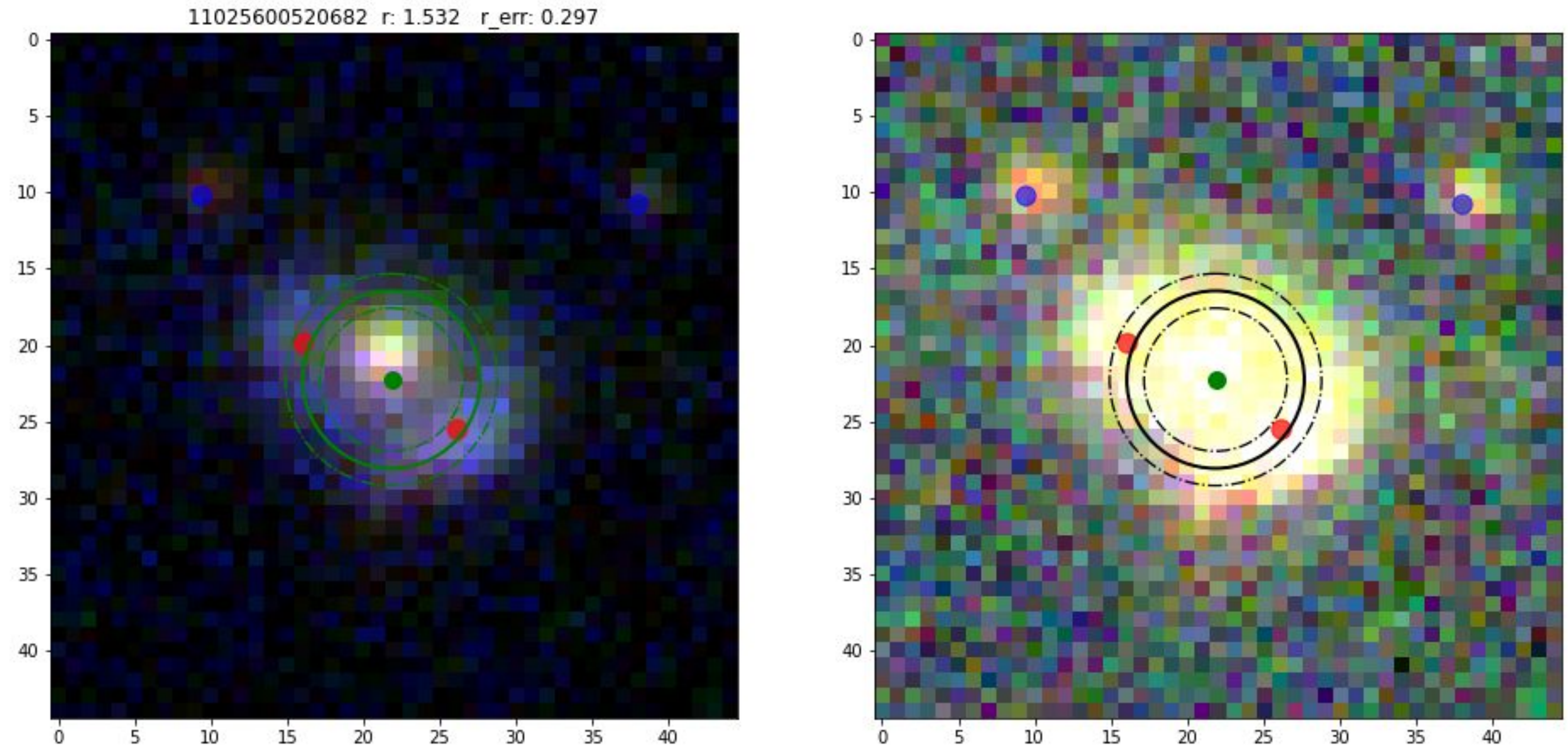
Zaborowski, Drlica-Wagner, Ashmead, et al.: Identification of Galaxy-Galaxy Strong Lens Candidates in the DECam Local Volume Exploration Survey Using Machine Learning



- Search for galaxy-galaxy strong lenses in DELVE DR1 data using a convolutional neural network → 617 candidates identified, 599 of which were not previously known
- blue: DELVE DR1 griz footprint ; turquoise DELVE DR2 griz footprint ; red: candidates from this work ; black: previous searches ; black curve: galactic plane

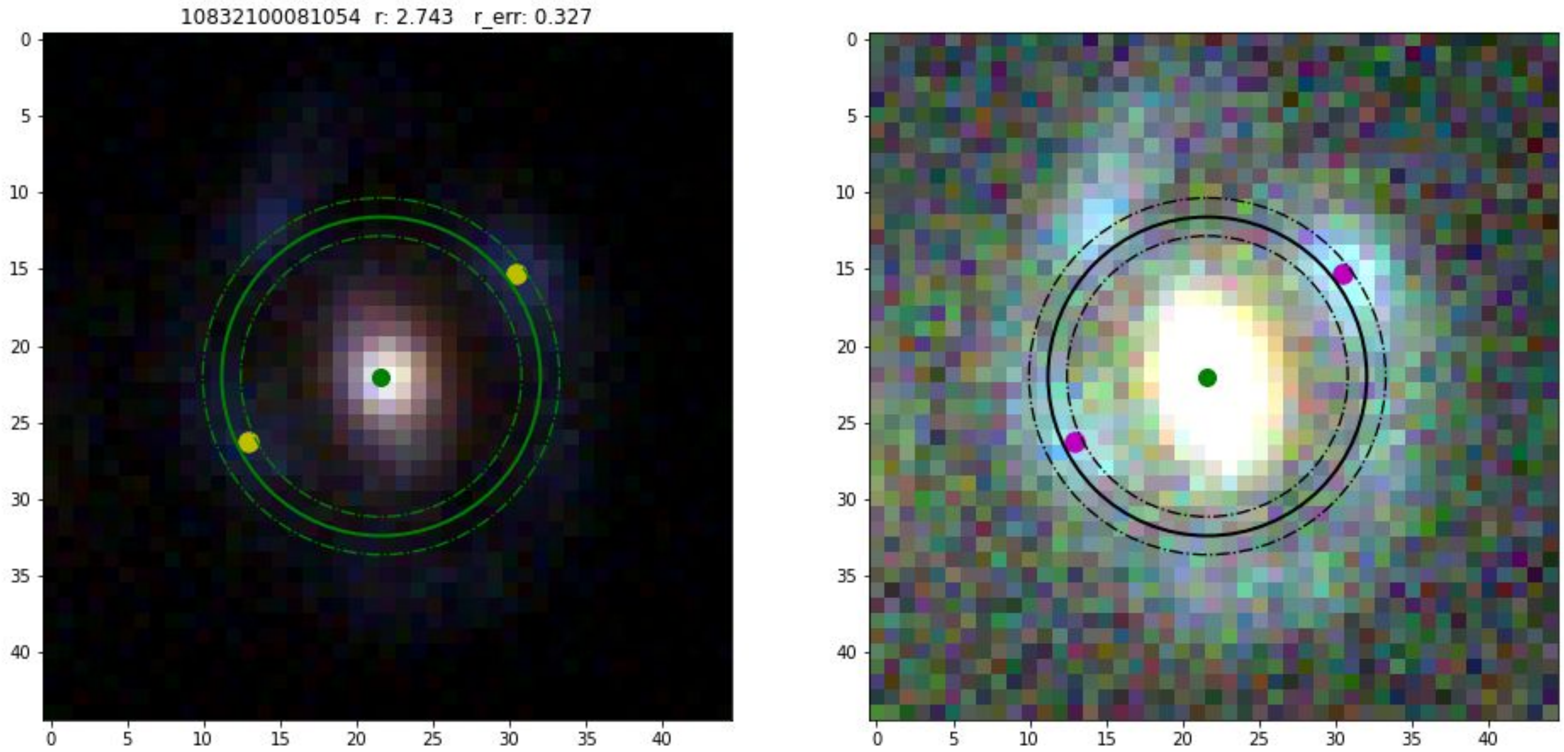
Example candidates from Zaborowski et al.

Einstein Radius Example



- following the procedure of O'Donnell et al. (2022), used the average angular separation between the lens and sources as an estimate of Einstein radius
- calculated error as standard deviation on radius (multiple sources) or 10% of radius (single source) added in quadrature with the pixel scale

Einstein Radius Example



- In this example, there were no DELVE DR1 catalog sources within a 6 arcsecond radius of the lens centroid, so I had to place the source centroids by hand.

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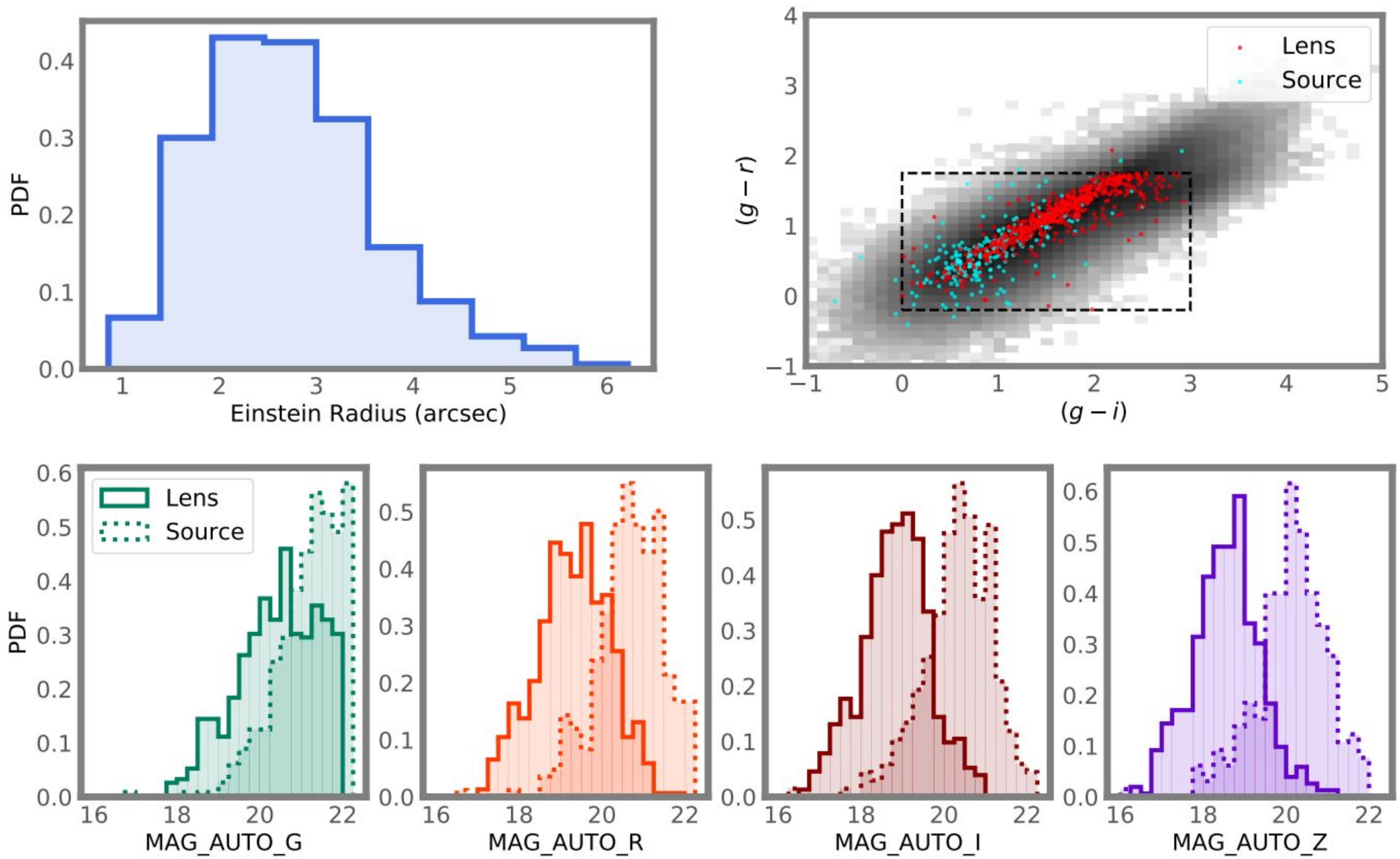
Einstein Radius Distribution, Photometric Properties



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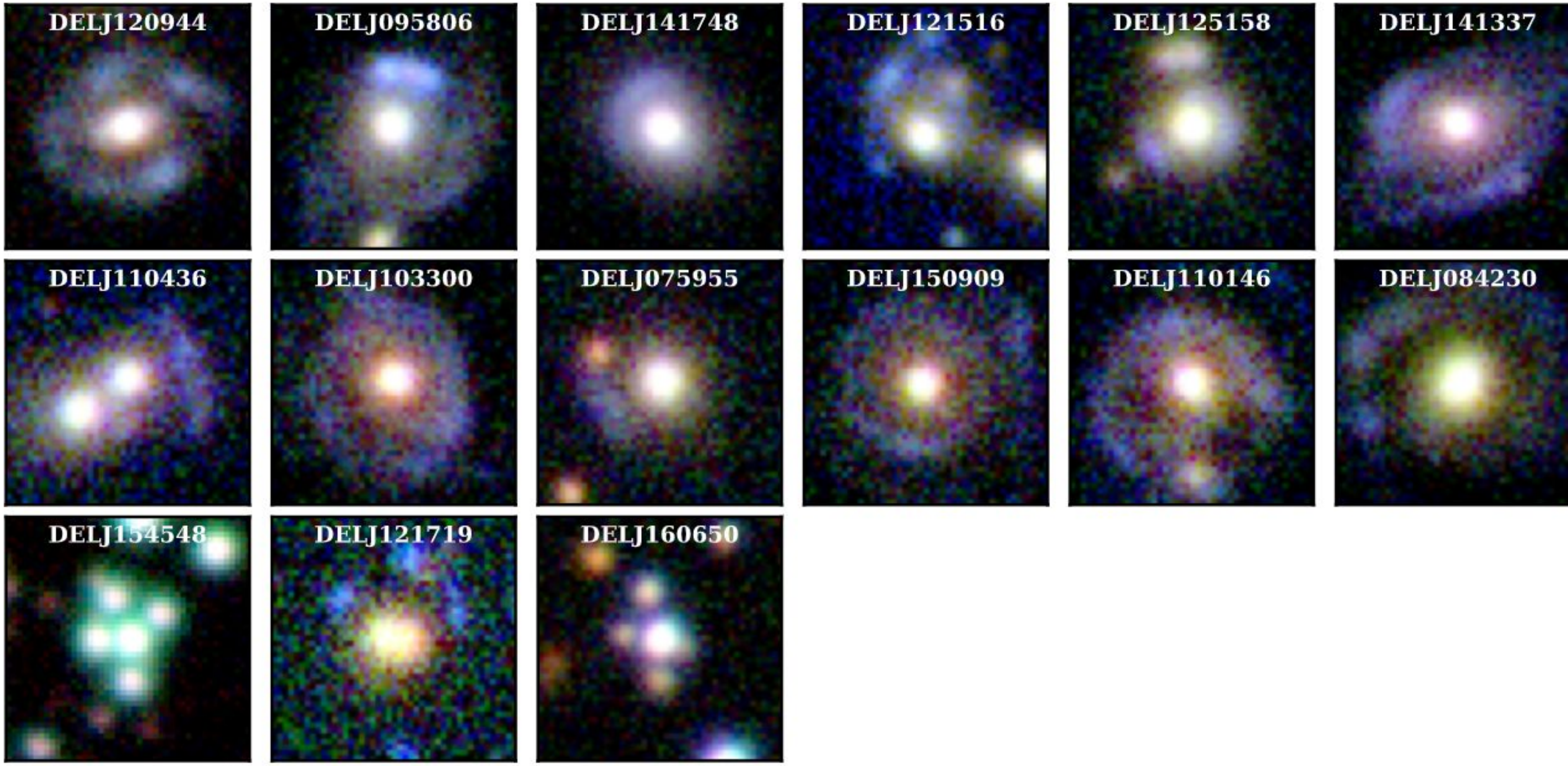
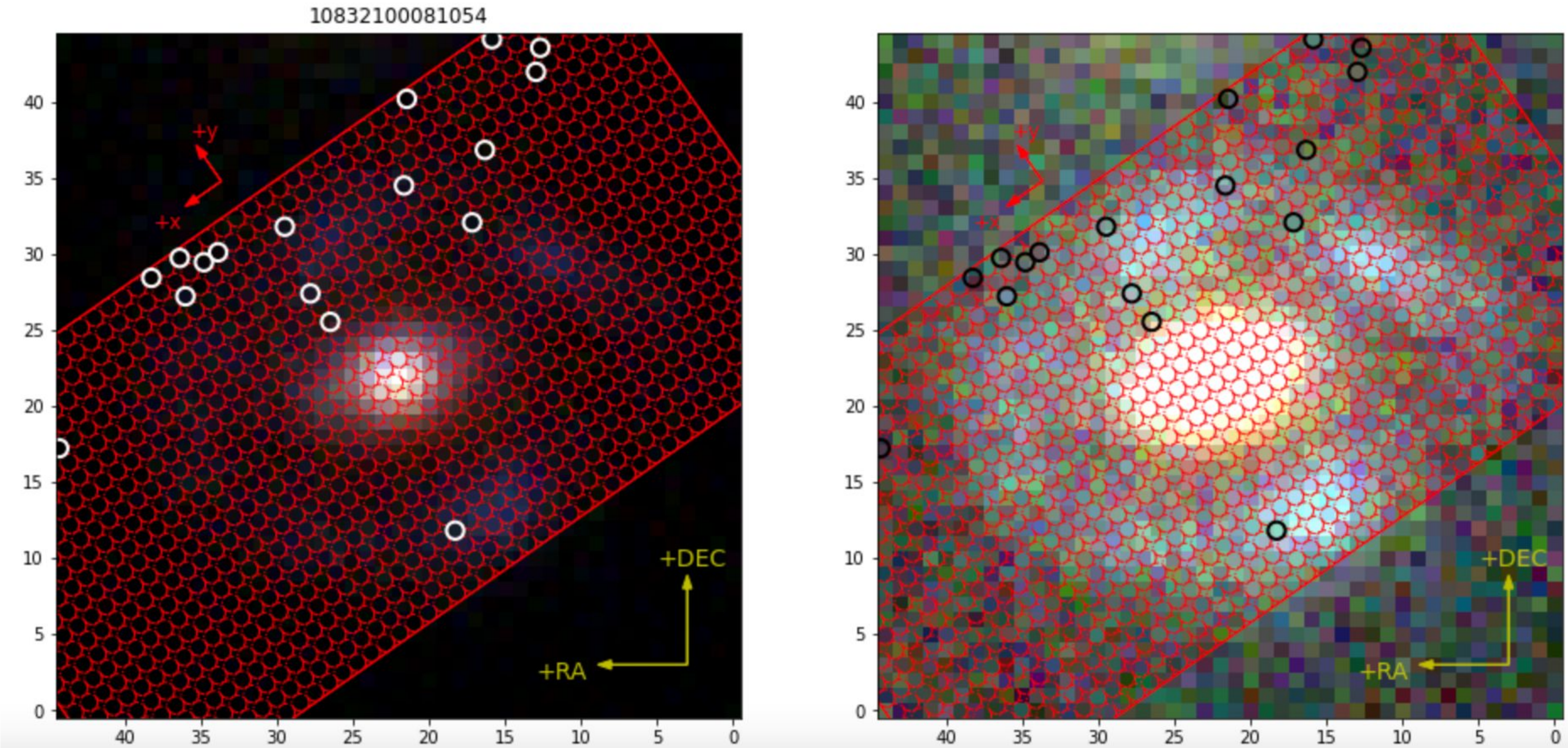
Follow-up Proposal: SIFS



- Follow-up spectroscopy of these candidates will give us accurate redshifts, confirming them as lenses.

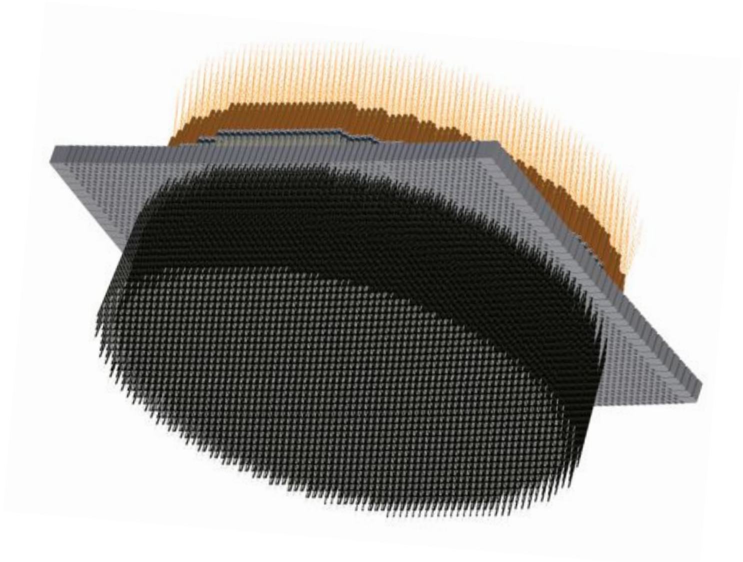
SIFS Observation Planning

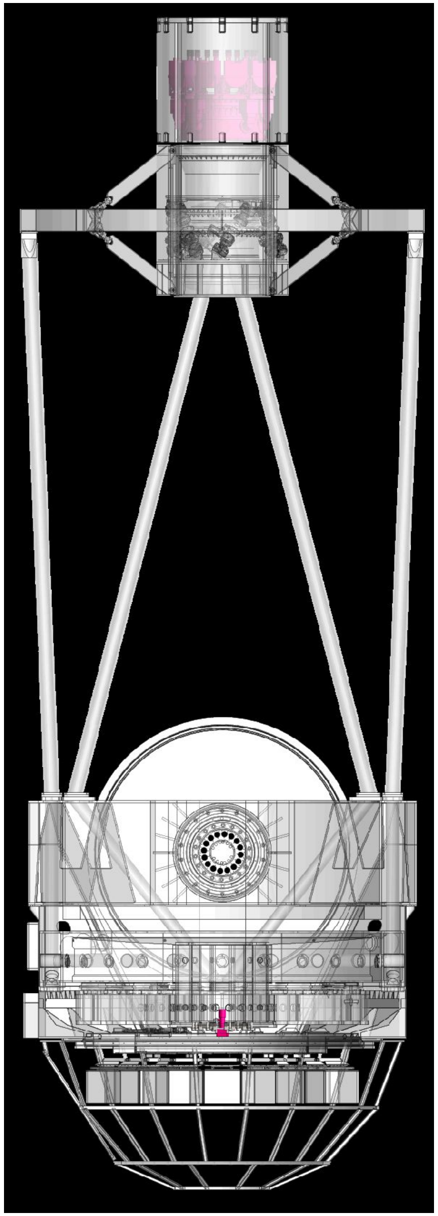
(RA, DEC): (182.44036472413933, -20.607248842823303) angle: 35.0 degrees



- I built a code to overplot a diagram of the SIFS on our cutout images, in order to plan the position and position angle to use, and to account for dead fibers.

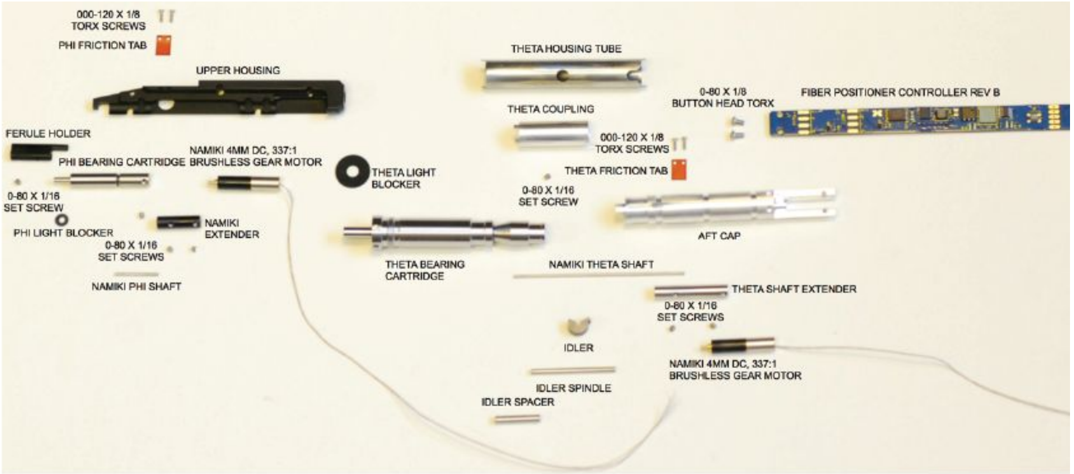
Spectrograph Fiber Positioner

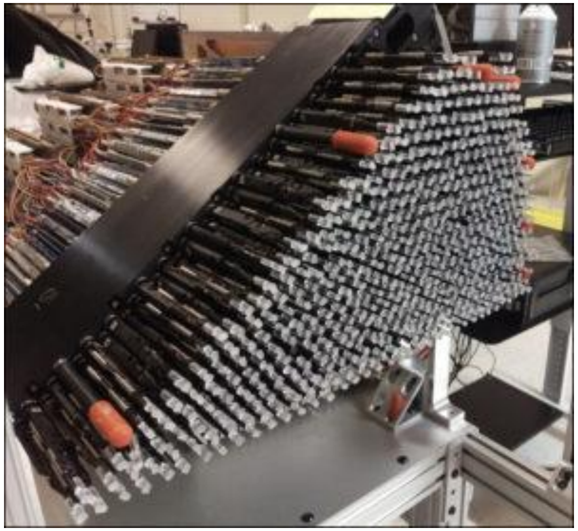




- R&D for a tilting-spine spectrograph fiber positioner
- The goal is to be able to independently position 20,000 optical fibers to take spectra of up to 20,000 astronomical sources in the field of view

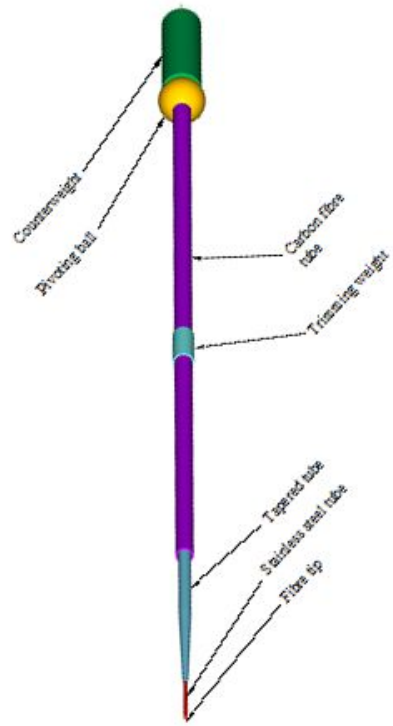
DESI, Twirling Post Fiber Positioners

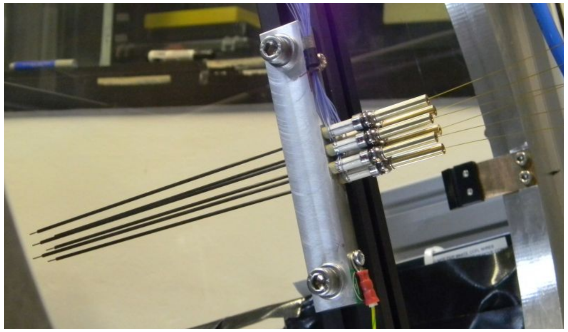


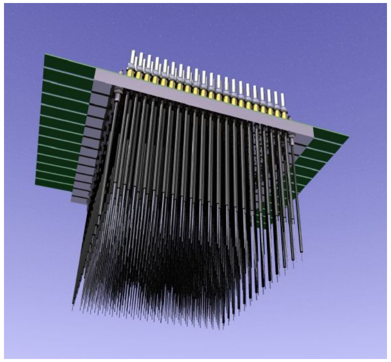


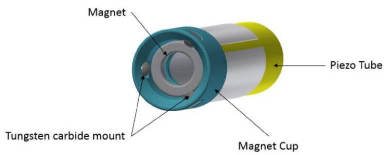
- The Dark Energy Spectroscopic Instrument (DESI) uses twirling post fiber positioners to capture up to 5,000 spectra
- This type of fiber positioner is limited by its large size and many small moving parts, including DC Brushless Gear Motors

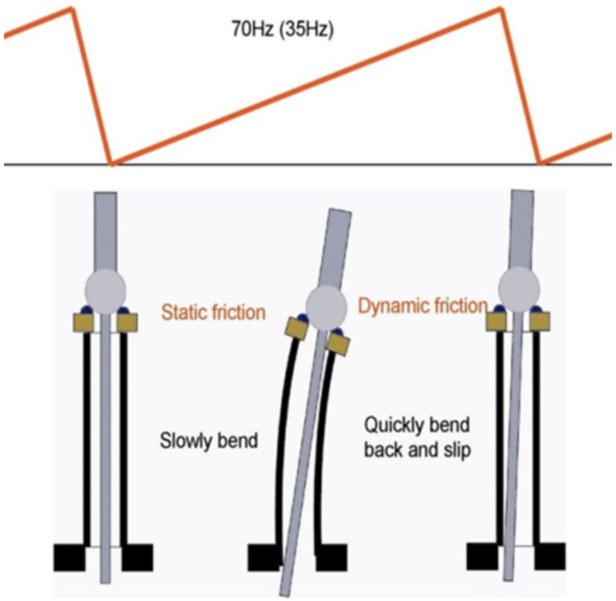
Tilting Spines





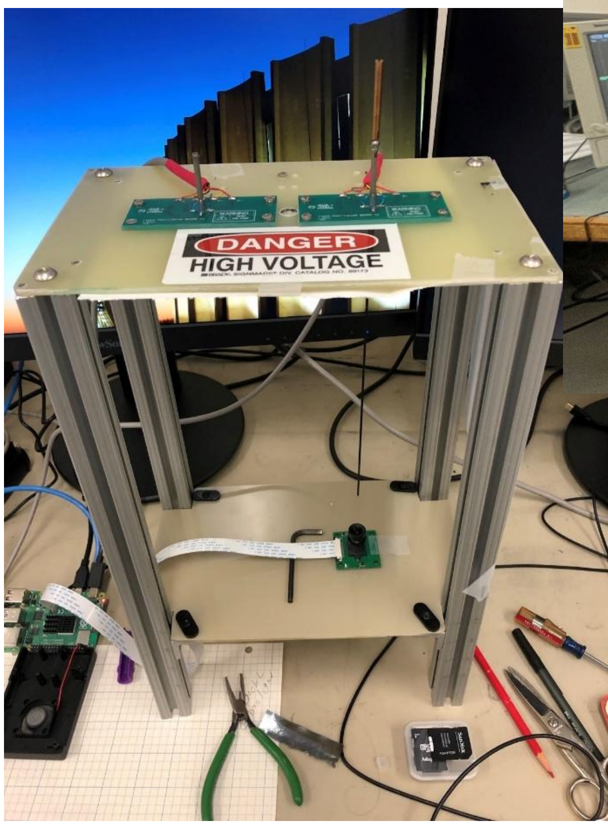




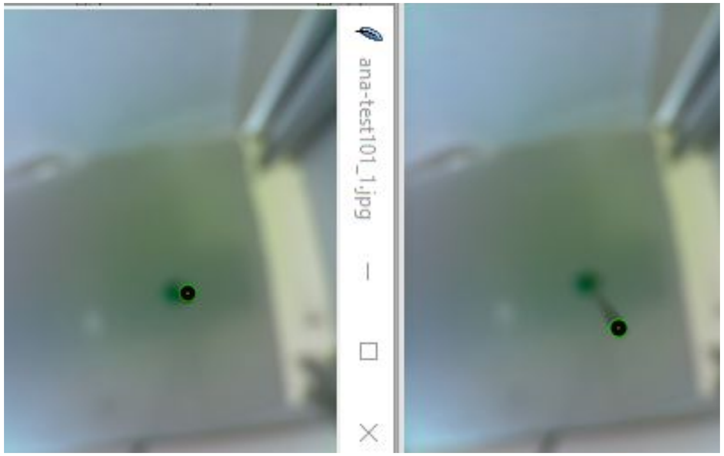


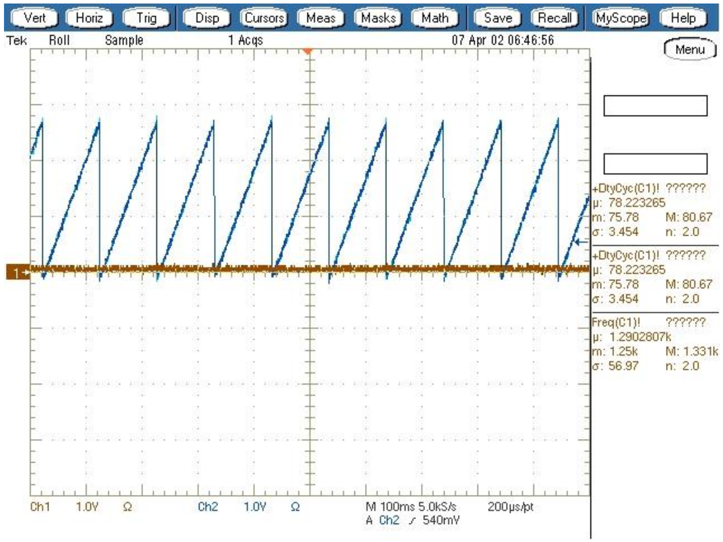
- Piezo tube and magnetic cup fits over the ball on the spine. One moving part.
- FMOS (400), 4MOST (2436), DESpec (4000), MSE (4332)
- Can get them closer together than Twirling Posts

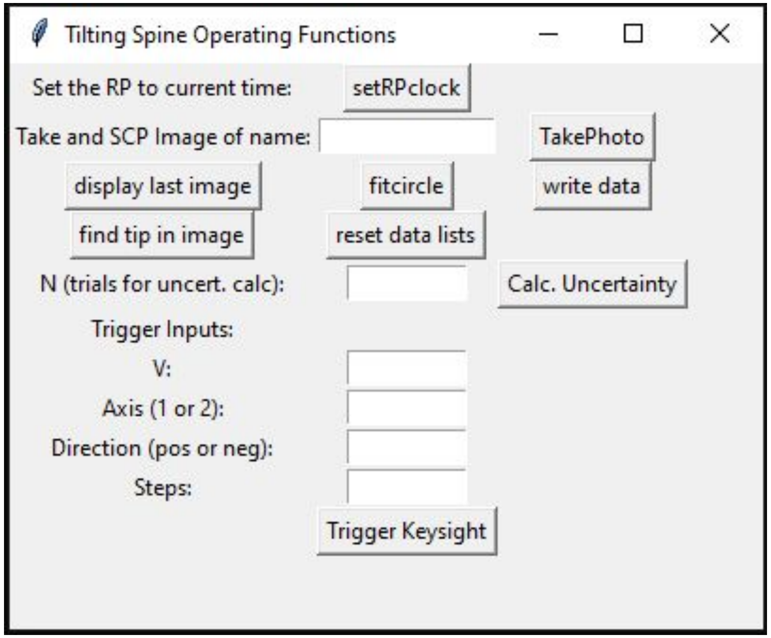
Test Stand Setup



Apparatus Controls and First GUI







- Programmed waveforms in 2-channel waveform generator
- Integrated code for taking the picture, identifying the fiber tip, and calculating the range of motion into a GUI, along with new code controlling the waveform generator

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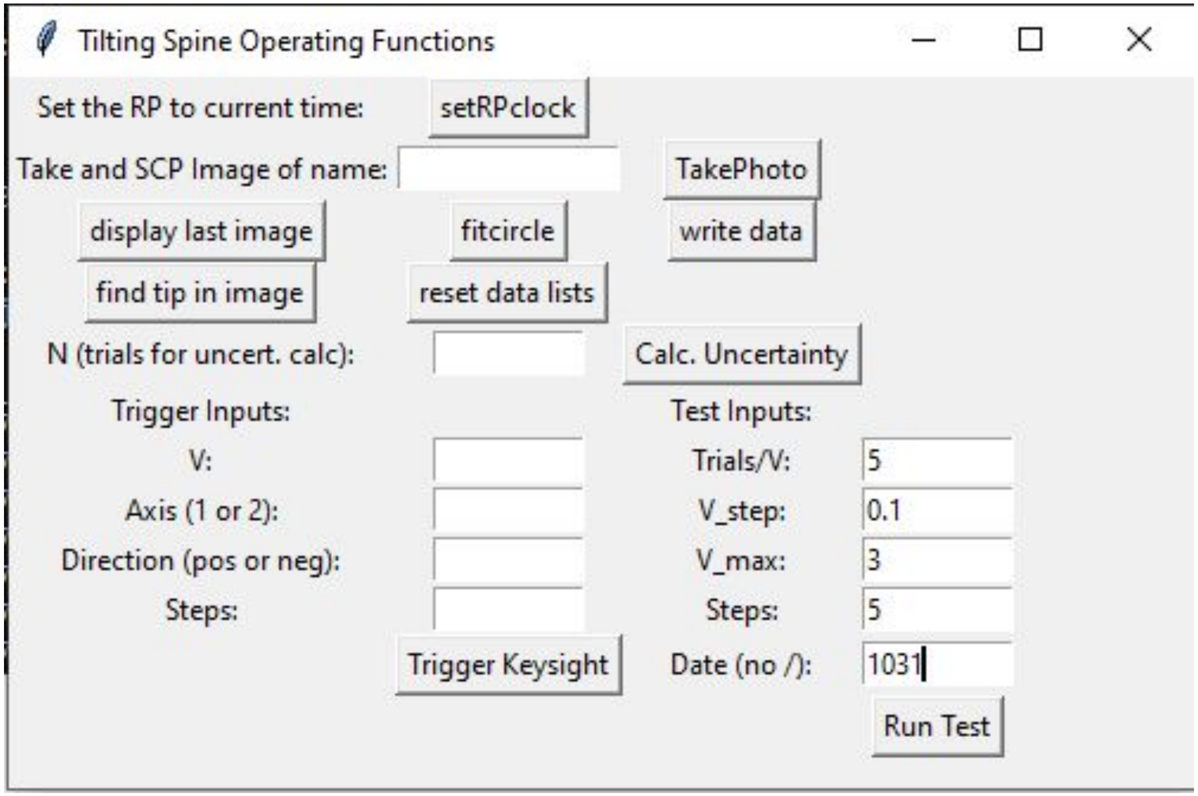
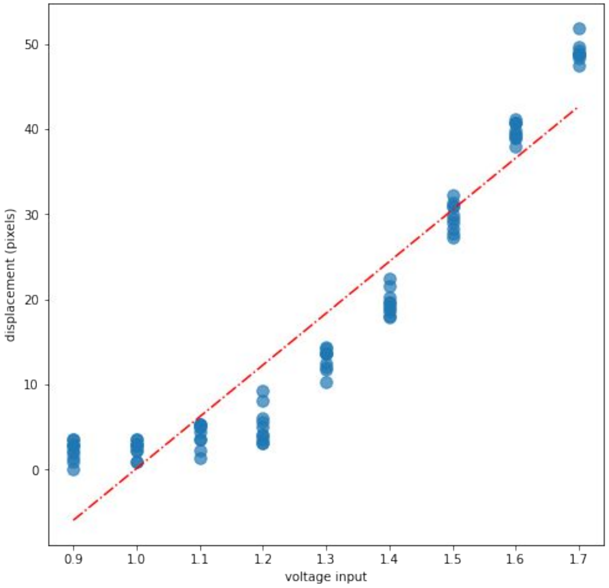
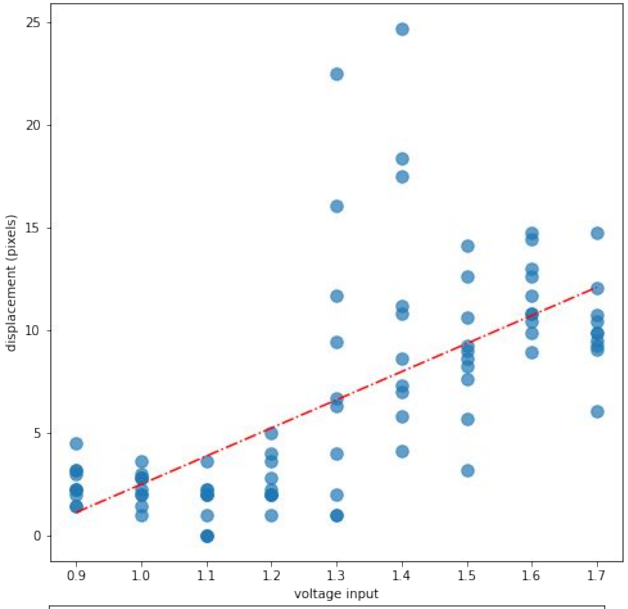
Second GUI and Automating Large Tests

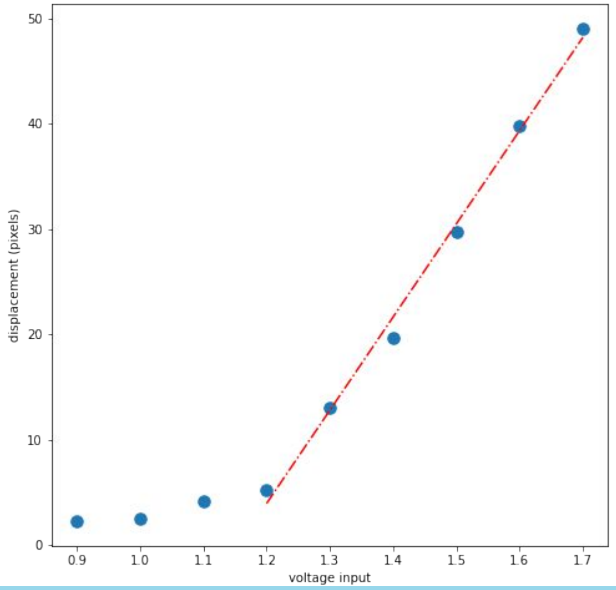


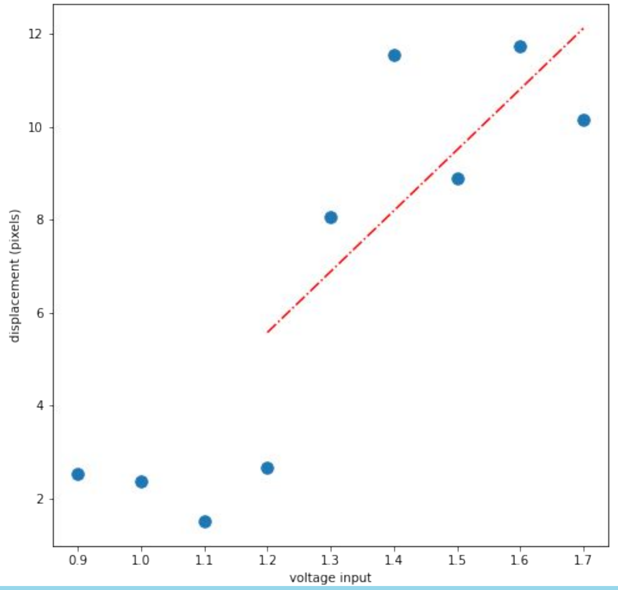
- Designed a code to run an automated systematic test of motion.

CH1 vs. CH2: Displacement per input voltage

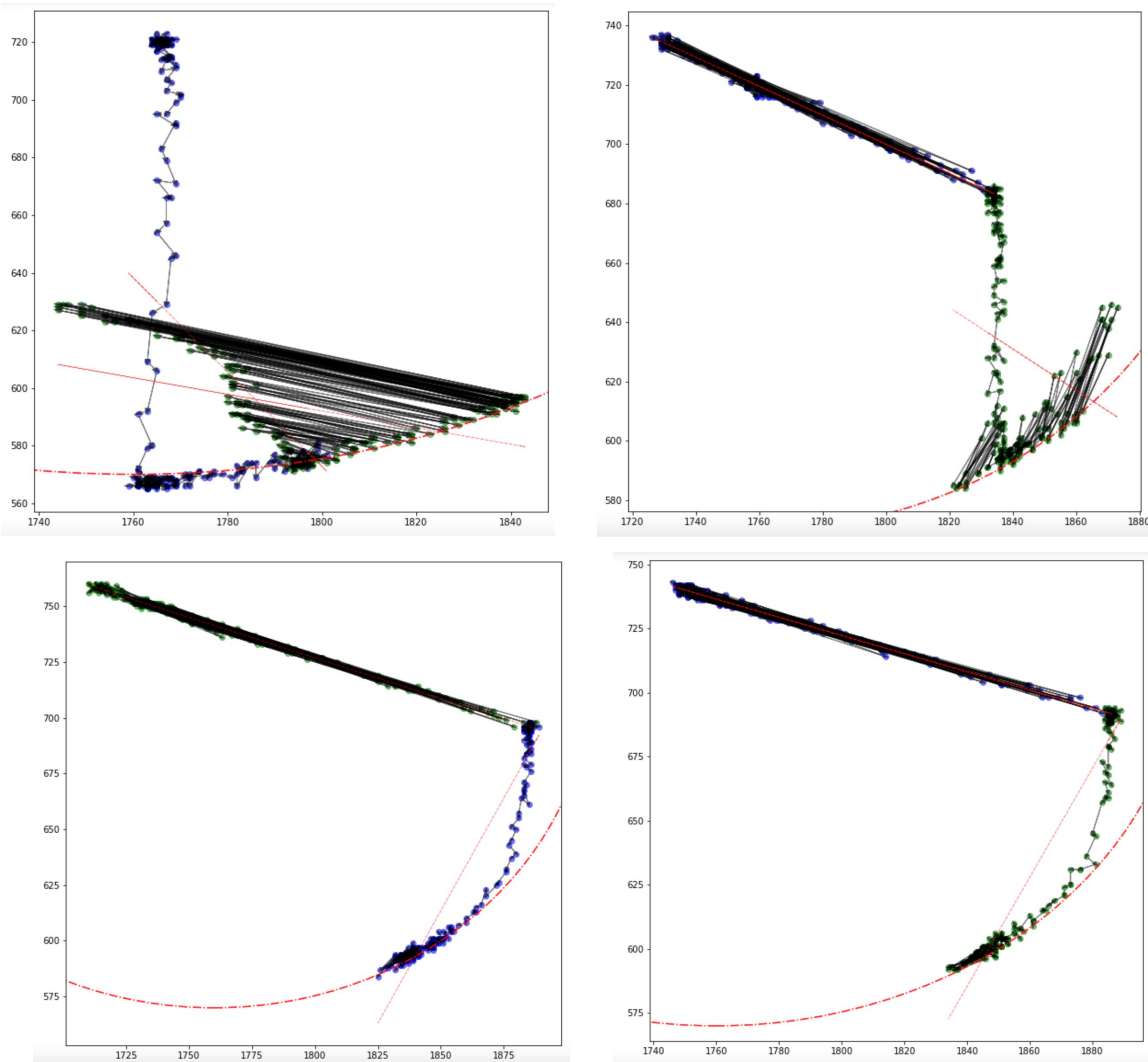




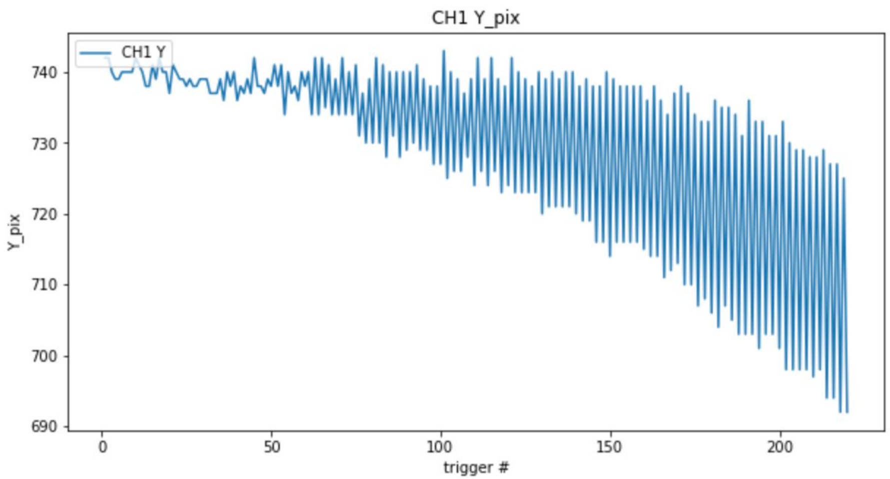


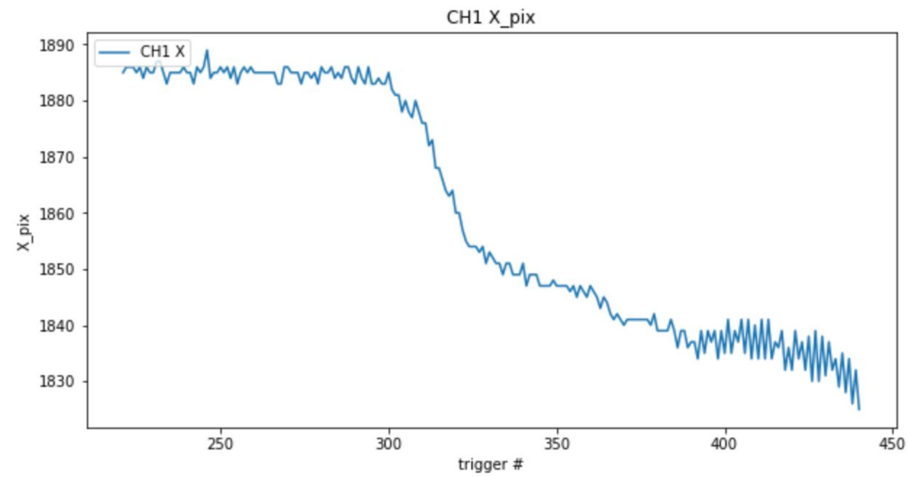


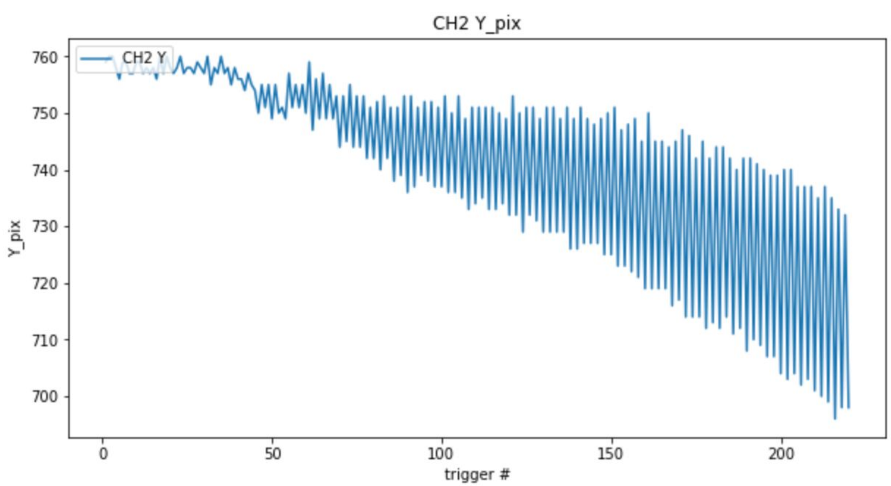
CH1 vs. CH2: Position scatterplots

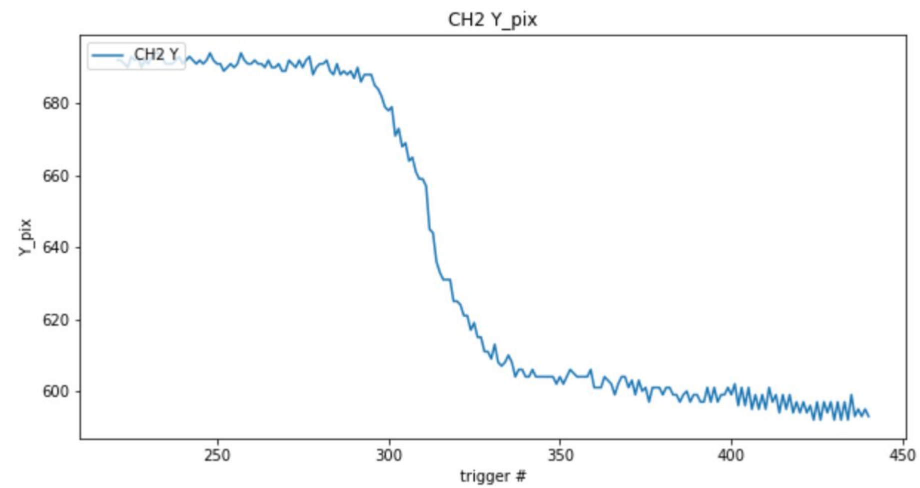


CH1 vs. CH2: Position scatterplots

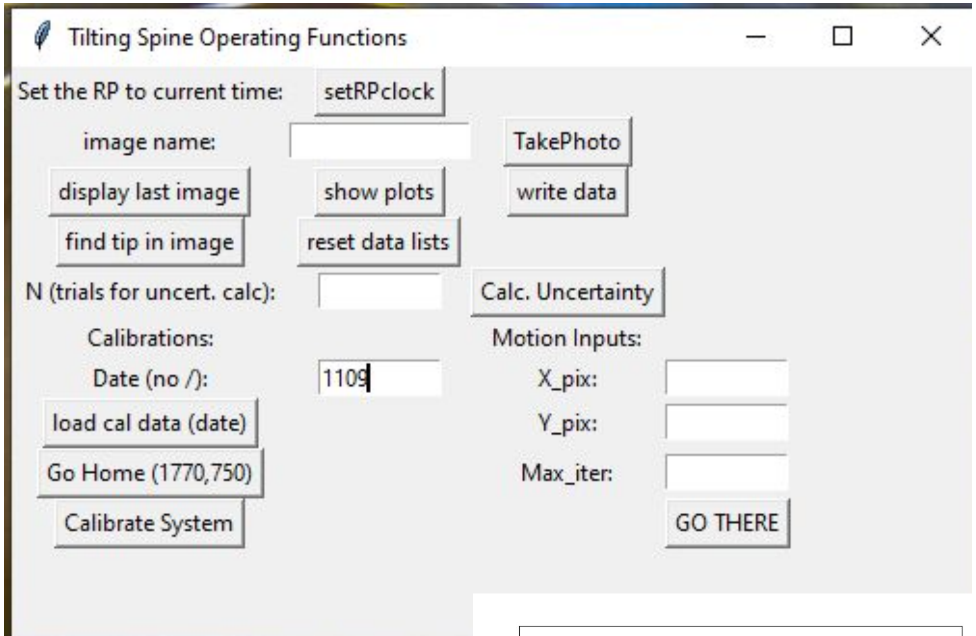


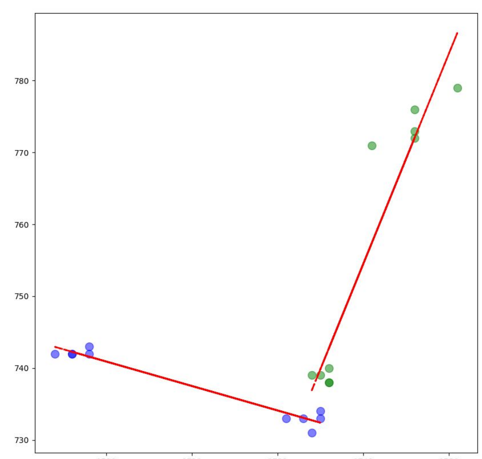




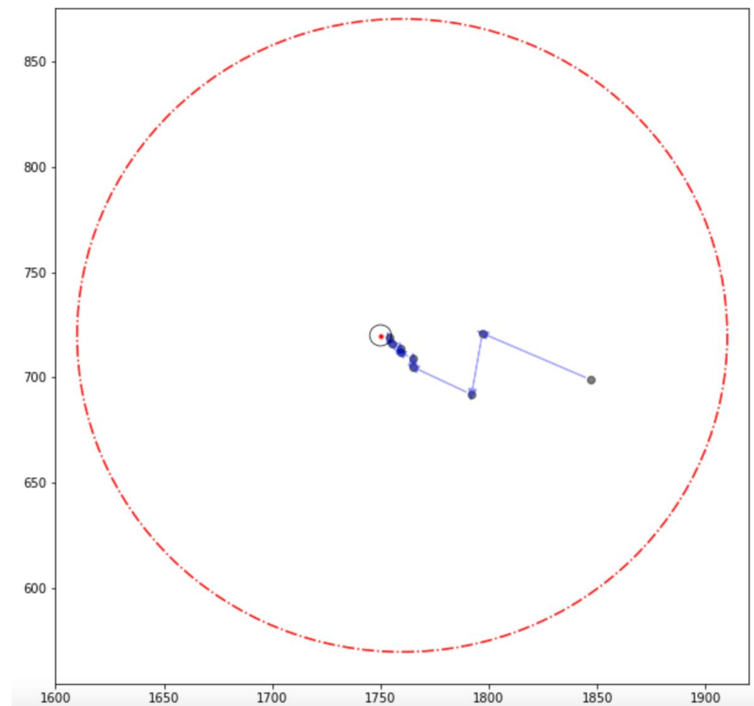


Second GUI, Calibration Code, Motion Calculating Code

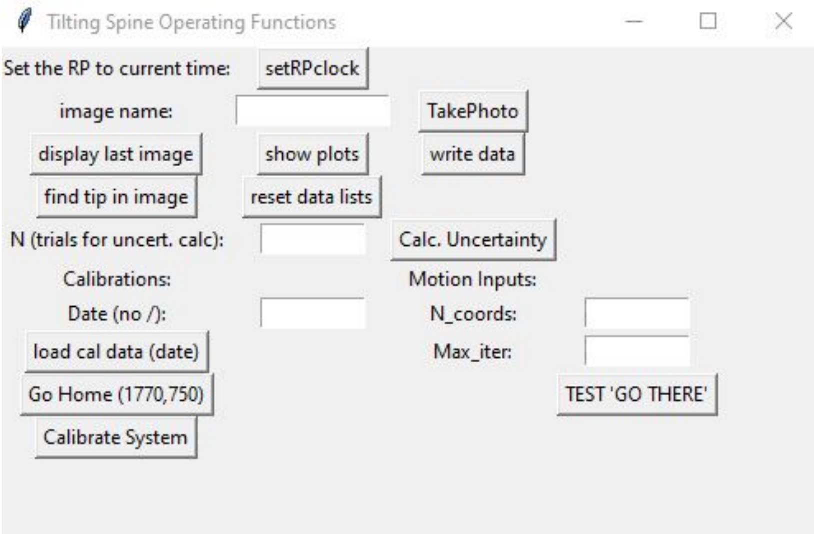




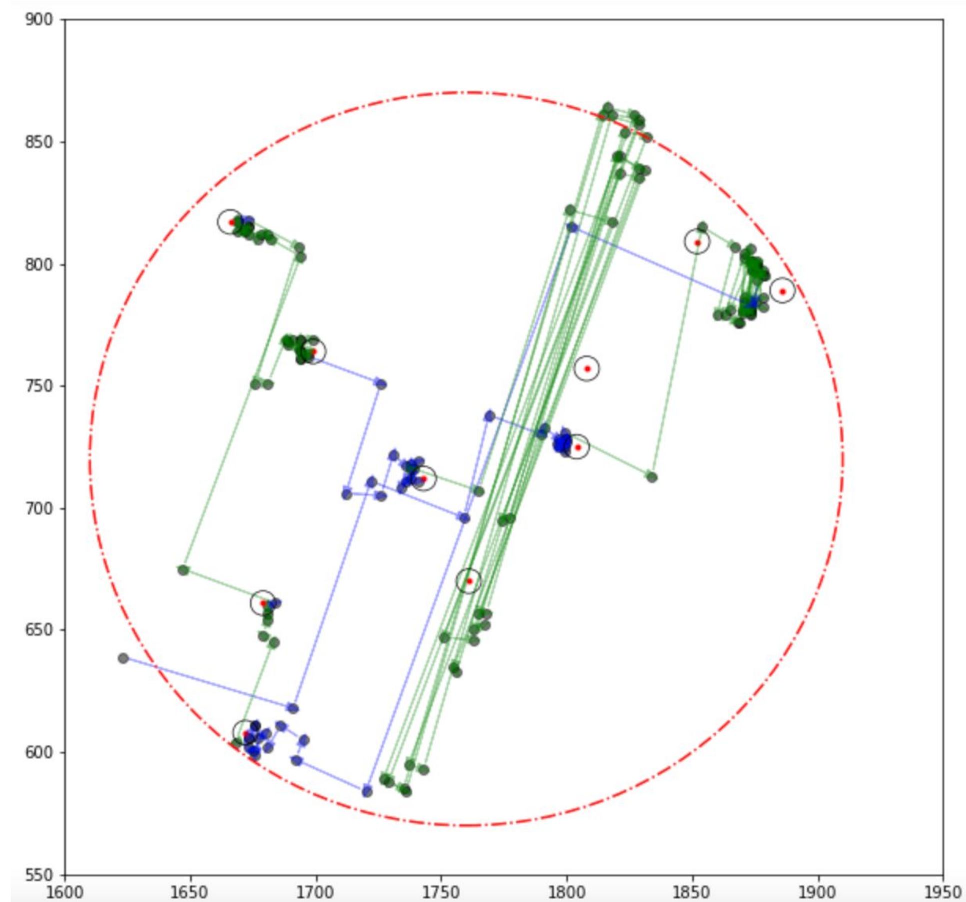
- This GUI controls an algorithm that runs a calibration code to determine the direction and magnitude of a voltage pulse, then calculates the number of pulses needed in each channel to reach an input pixel coordinate.



Third GUI, New Automated Test Loop



- This GUI triggers an algorithm to generate a specified number of random coordinates, and move the spine to them in order, with a set number of iterations allowed for each location.



Next Steps

- Test with tighter displacement criteria
- Certain changes to the calibration code, like adding data to the calibration as the spine is being moved, or calibrating the positive and negative directions of each channel separately.
- Test an array of multiple spines