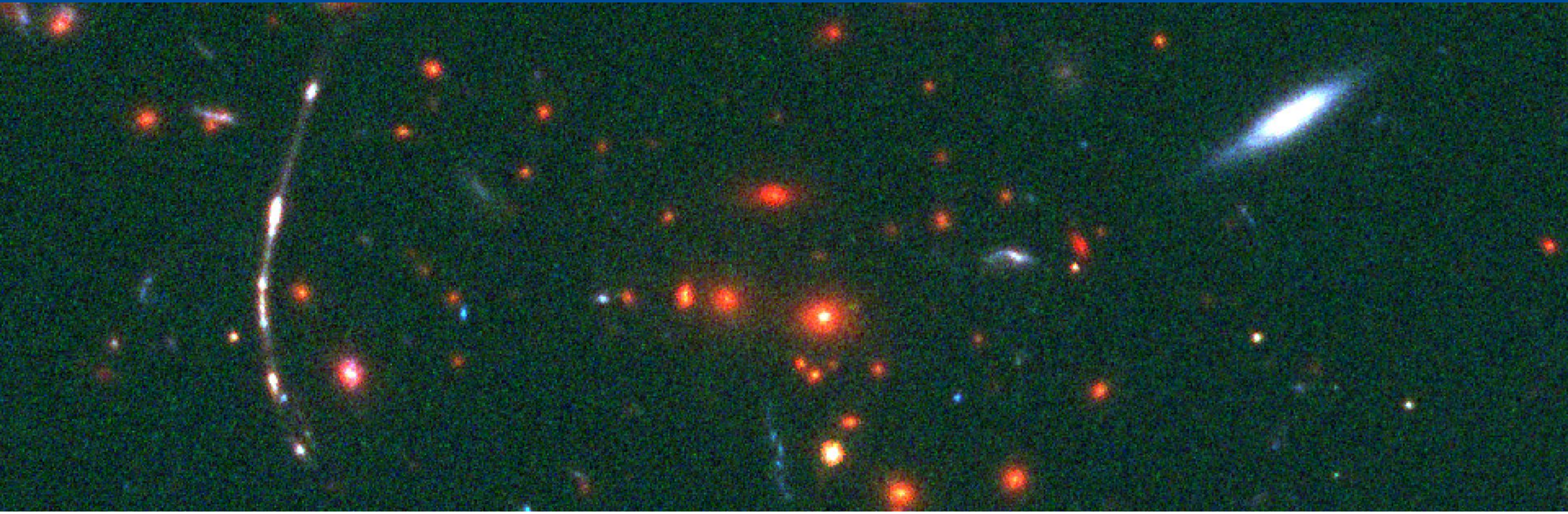


SOAR Integral Field Spectrograph Observations, Spectrograph Fiber Positioner R&D

Finian Ashmead

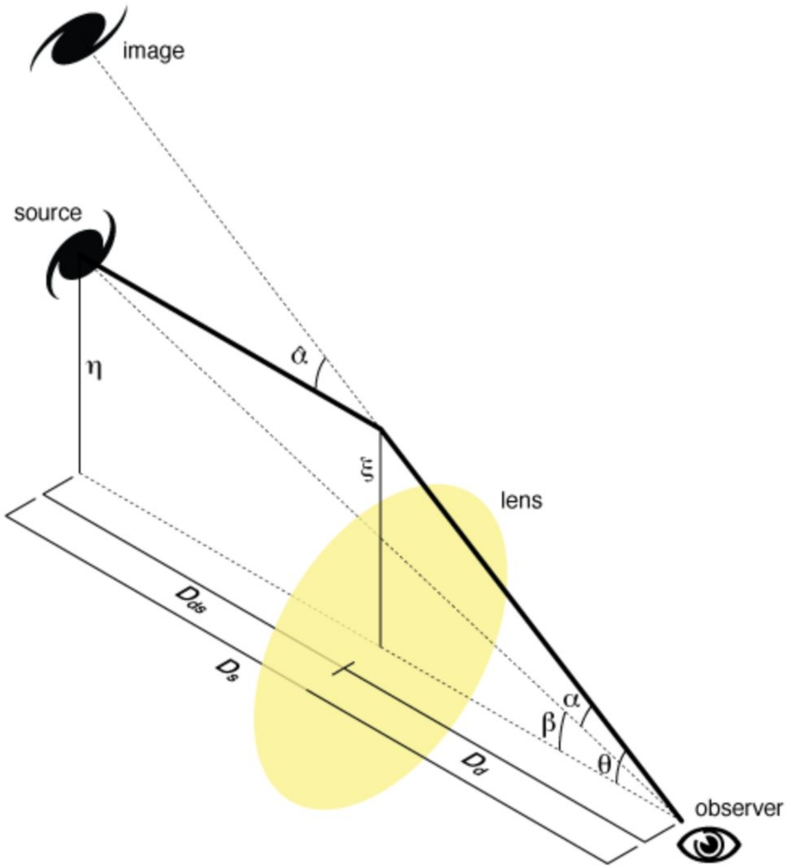
SULI Presentation

26 April 2023

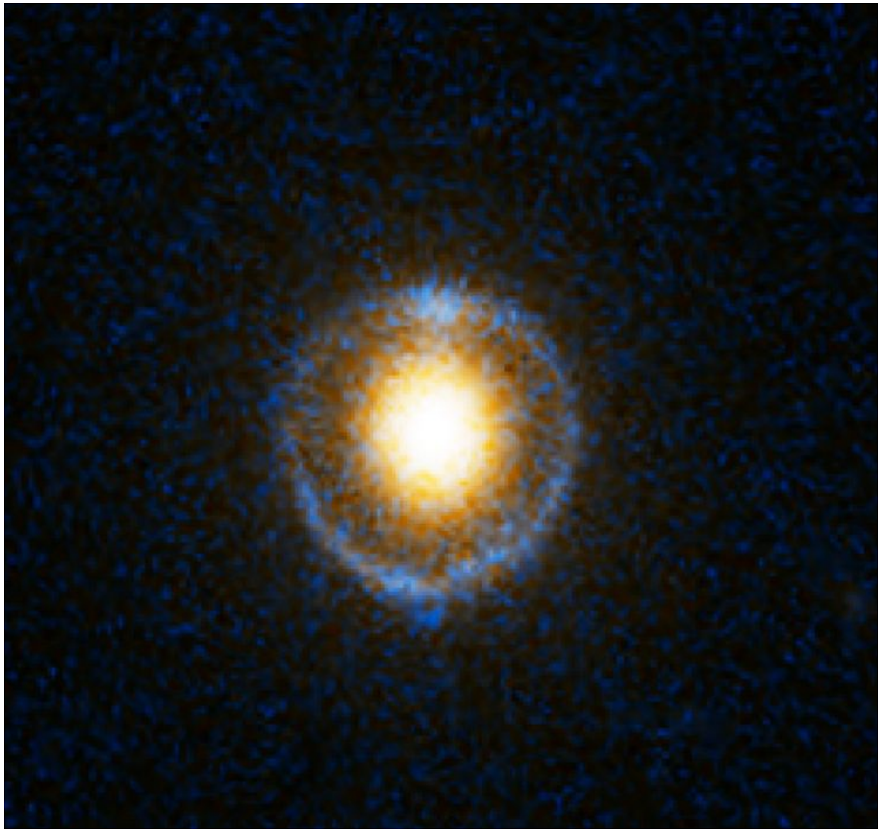
Strong Gravitational Lensing

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

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

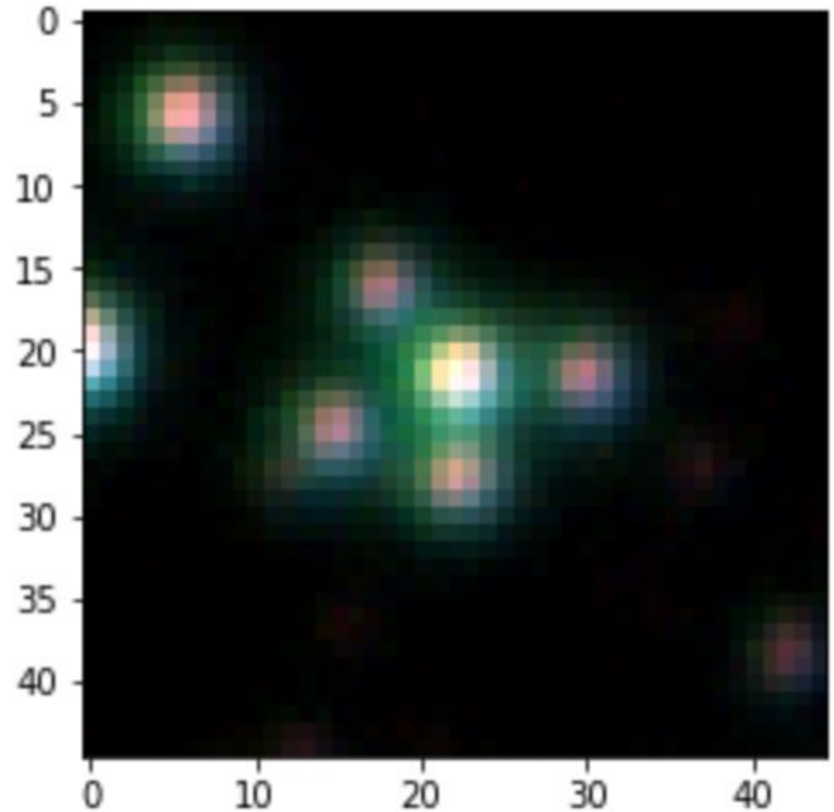


Strong Lensing Examples: Quasar and Galaxy-Galaxy



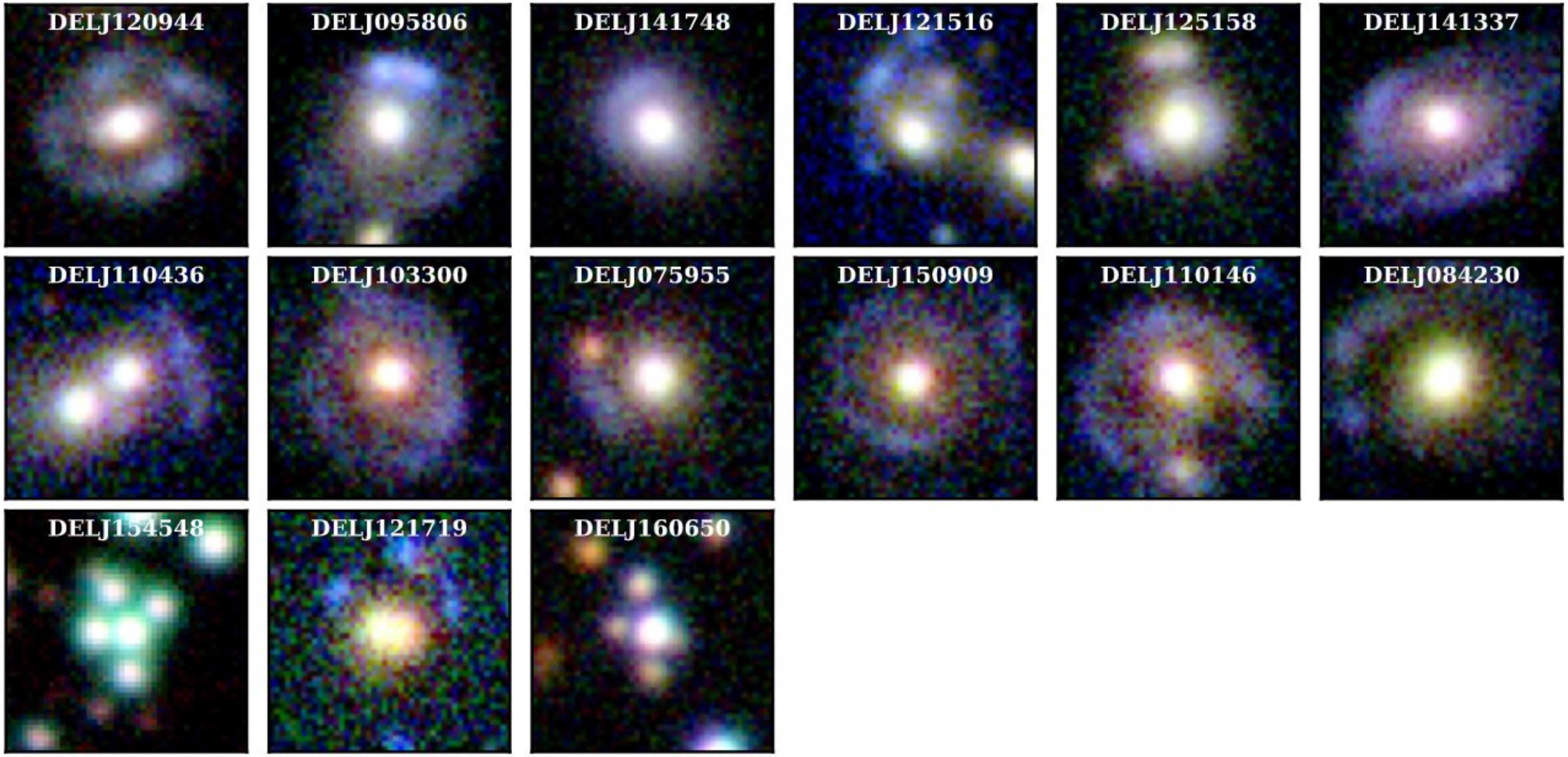
- Galaxy-galaxy strong lenses are a simpler configuration than the cluster-scale lenses, and are what my strong lensing work at FNAL was focused on. An “Einstein ring” is perfectly aligned to produce the ring image.

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



Fermilab

Follow-up Proposal: SIFS

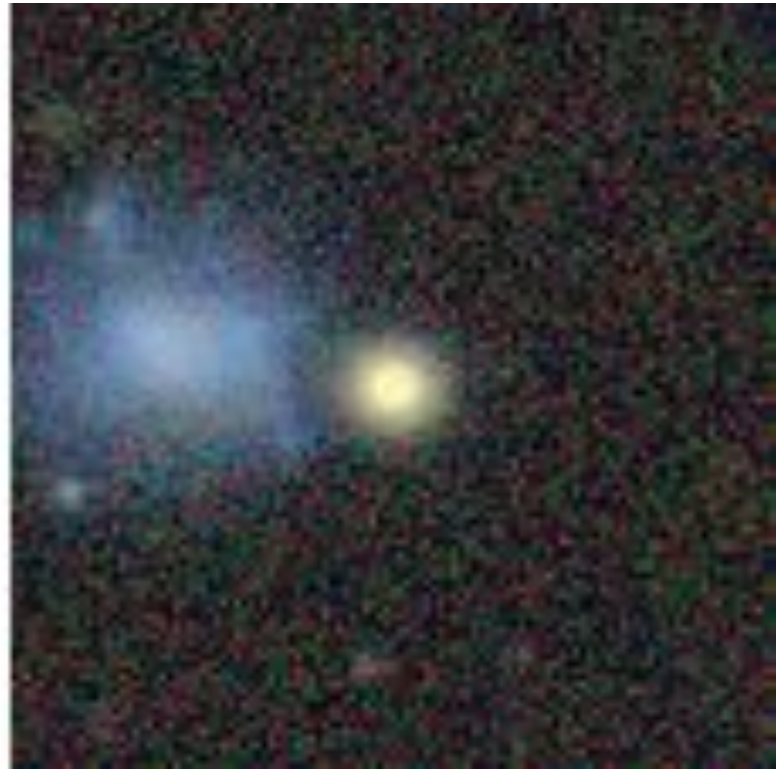


- Follow-up spectroscopy of these candidates would give us accurate redshifts, confirming them as lenses.

Side-by-Side DECaLS Comparison Example

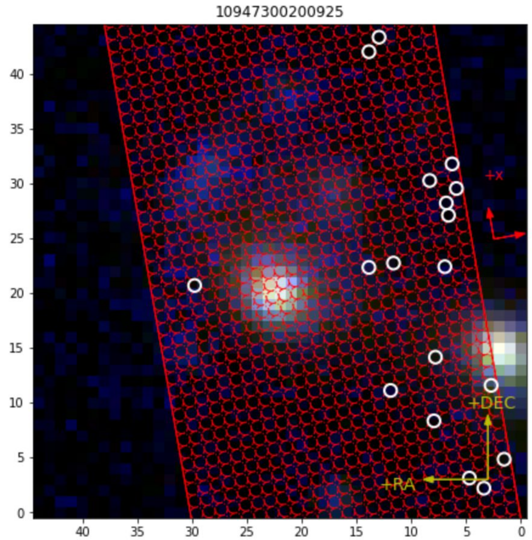
- In this example, the wider FOV and higher quality of the DECaLS image reveals that what appears to be a central lensing galaxy and multiple lensed images in the DELVE DR1 cutout is likely an individual spiral galaxy with blue outer regions.

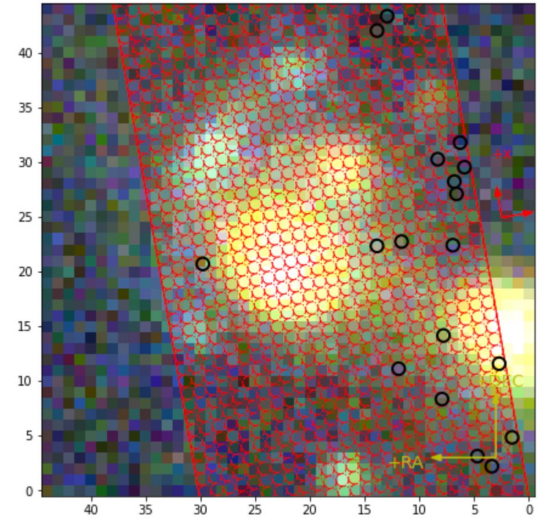
Side-by-Side DECaLS Comparison Example



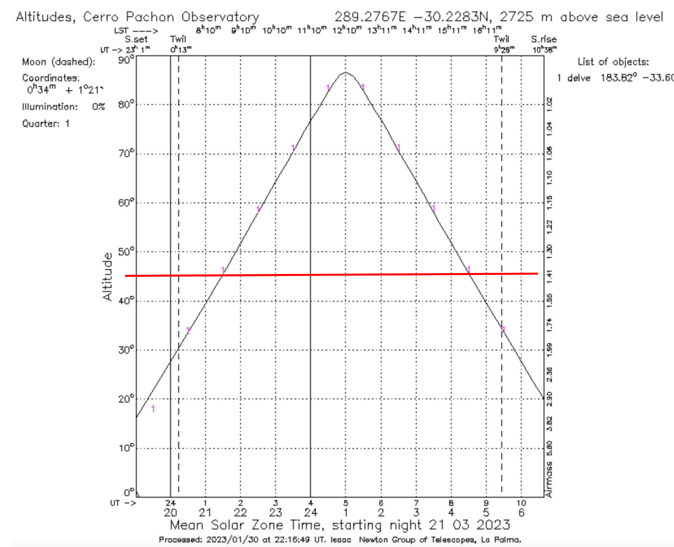
- In this example, the wider cutout image from DECaLS reveals a blue galaxy adjacent to the central galaxy, confused for a lensed arc in the smaller DELVE DR1 cutout image.

SIFS Initial Observation Planning





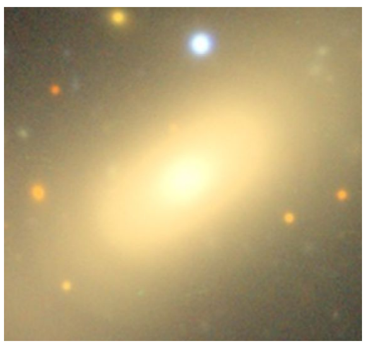
- I built a code to overplot a diagram of the SIFS on our cutout images, in order to plan the position and position angle to use, and to account for dead fibers.
- Together with the trajectory on the sky and the photometric magnitudes of the targets, these were used to select targets for our observing nights, and plan their sequence.

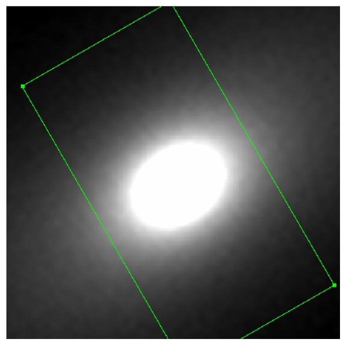


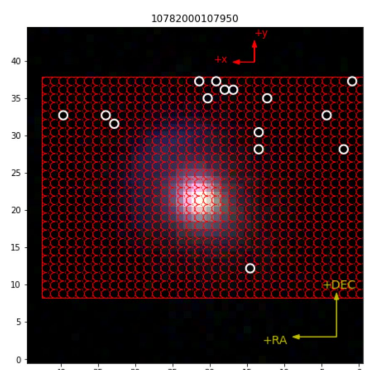
Fermilab

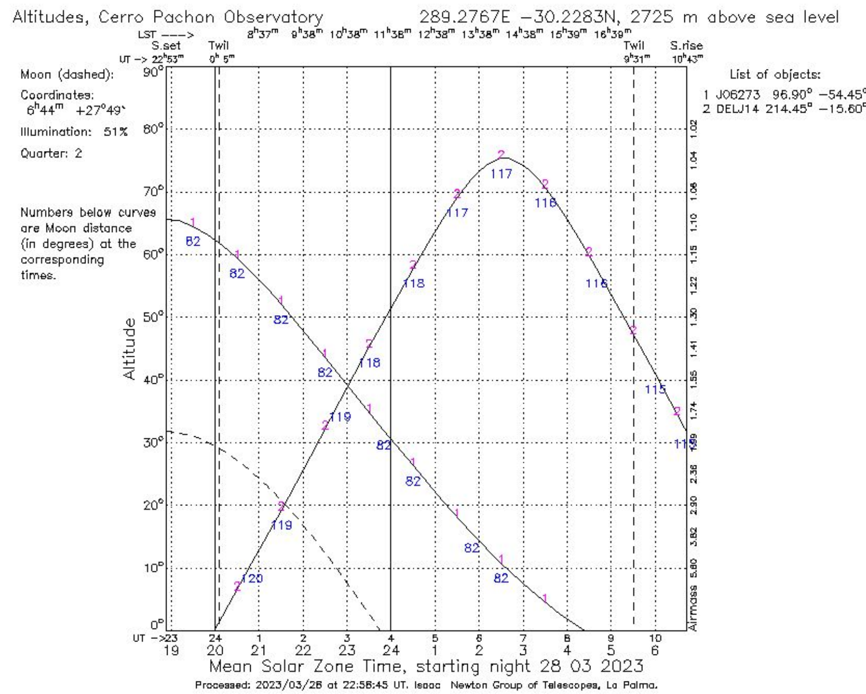
SIFS Observations: 3/28

- J062736 (i_mag = 13.14): observable 24:00-3:00 UTC
  - Gaia DR3 5499641919573921280 ; Gmag ~16.74)
- DELJ141748 (i_mag = 17.09): observable 3:30-9:30 UTC
  - nearby star at Gmag ~16.2 [“Gaia DR3 6297969485409007232”, (214.4462505234, -15.5864598728)]
  - nearby star at Gmag ~15.3 [“Gaia DR3 6297969210531094400”, 214.4806005248, -15.6084378735)]

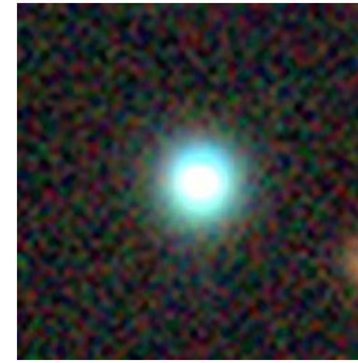






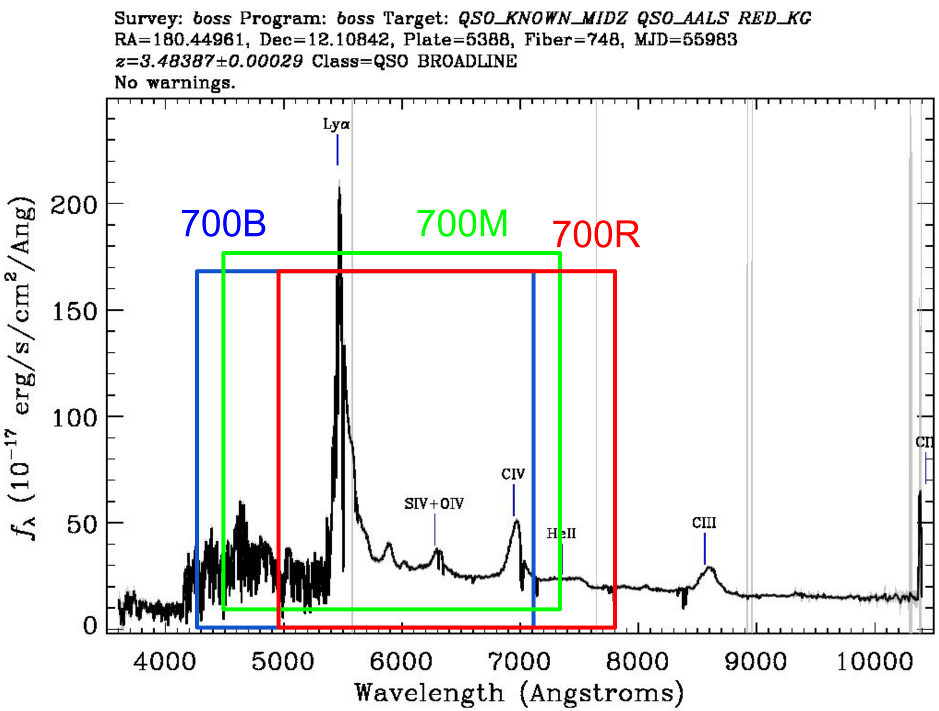


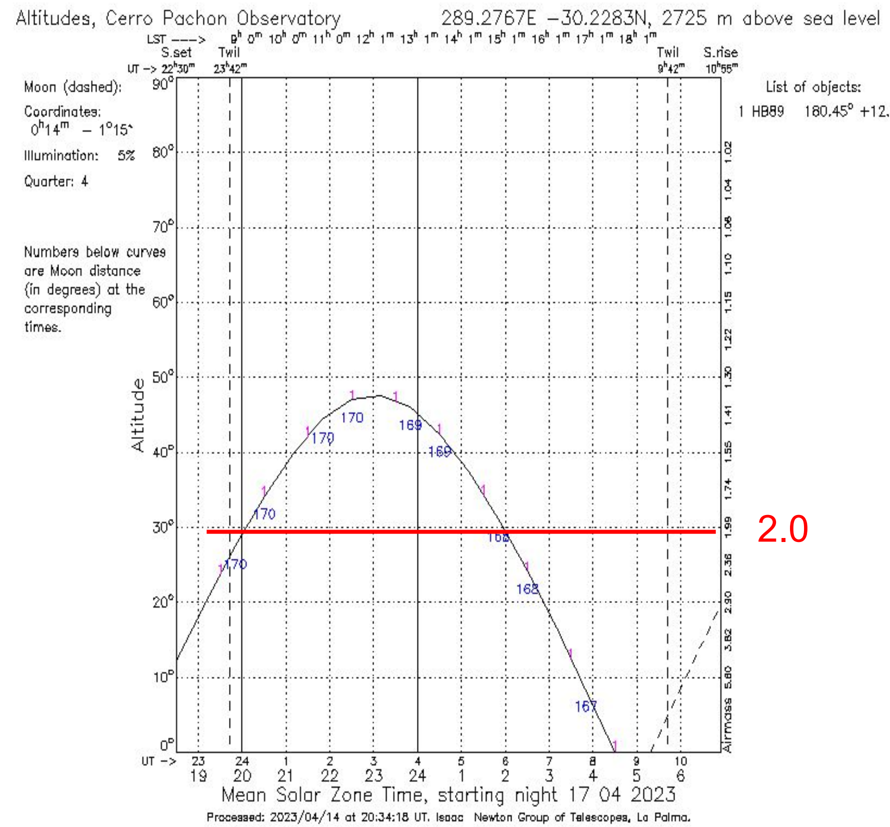
SIFS Observations: New Strategy for 4/17



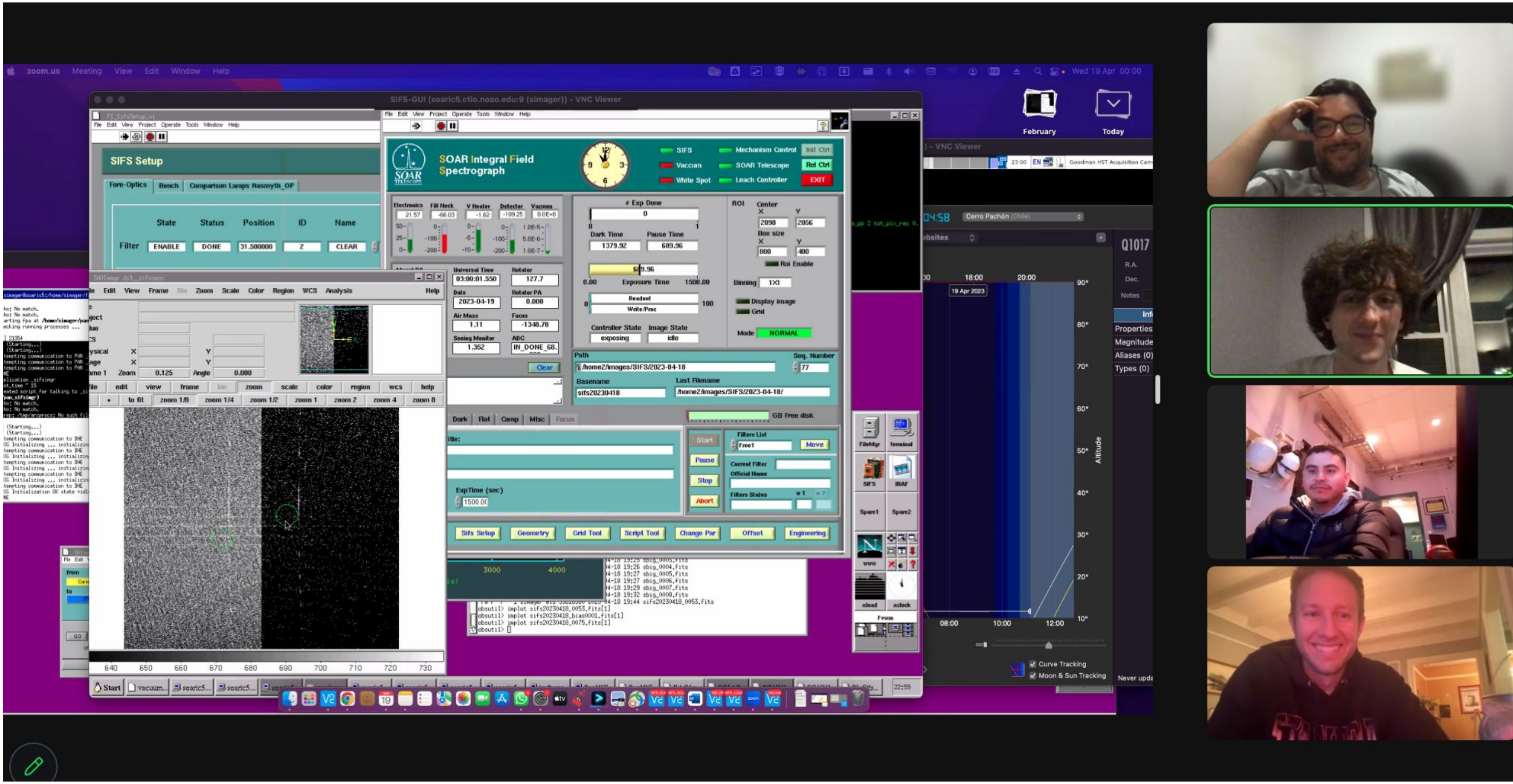
Quasar HB89 1159+123

- Ly-a forest QSO (z=3.522)
- Lines: Ly-a (5500Å), CIV (7000Å)
- Gaia mag_G=17.34 ; DECaLS g=17.94, r=17.34, i=17.37, z=17.12



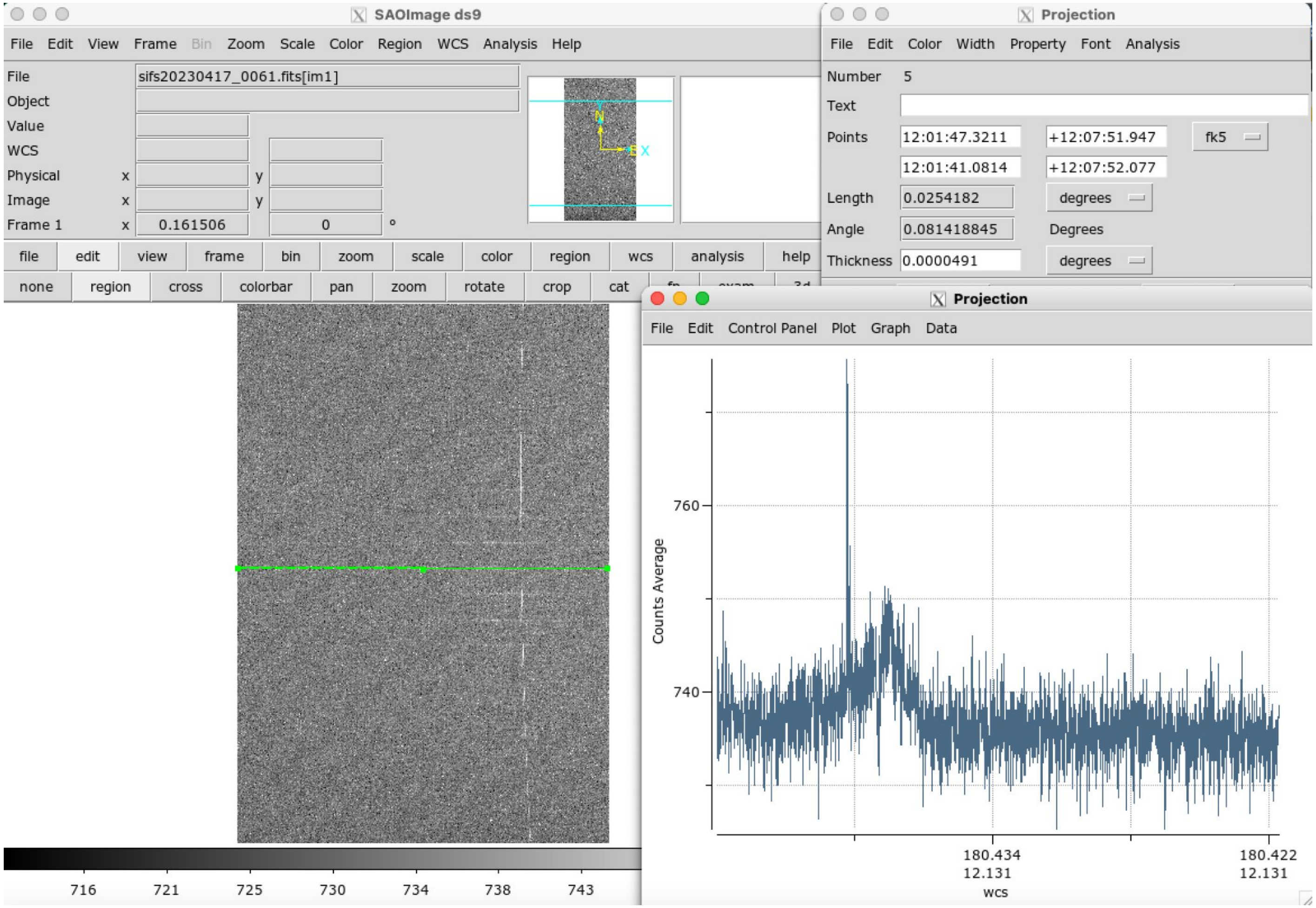


SIFS Observations



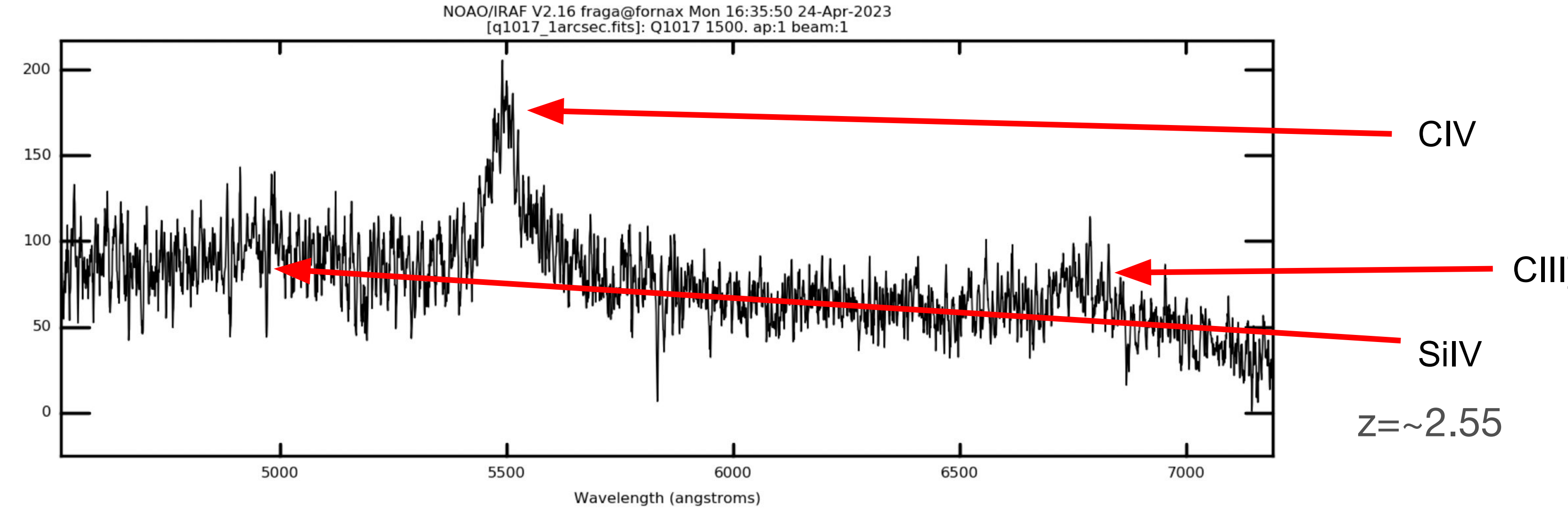
SIFS Observations: 4/17 Results

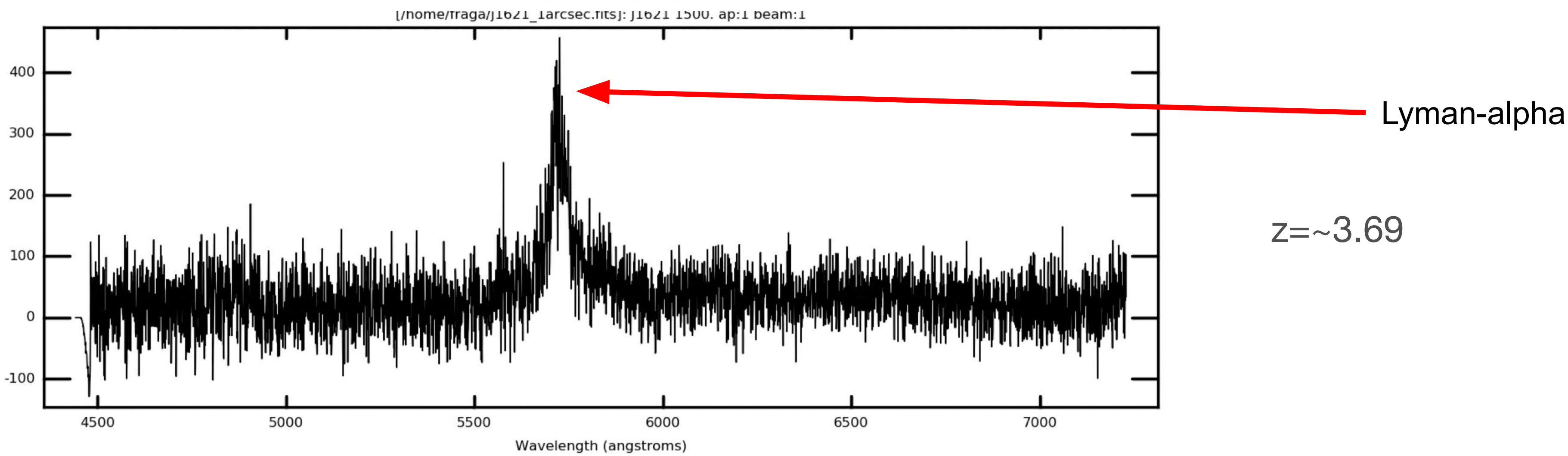
- We observed targets HB89, Q1017, DELJ141748, J1621 (along with standard stars, calibrations, etc.)
- I produced a rough spectrum of HB89 using DS9:



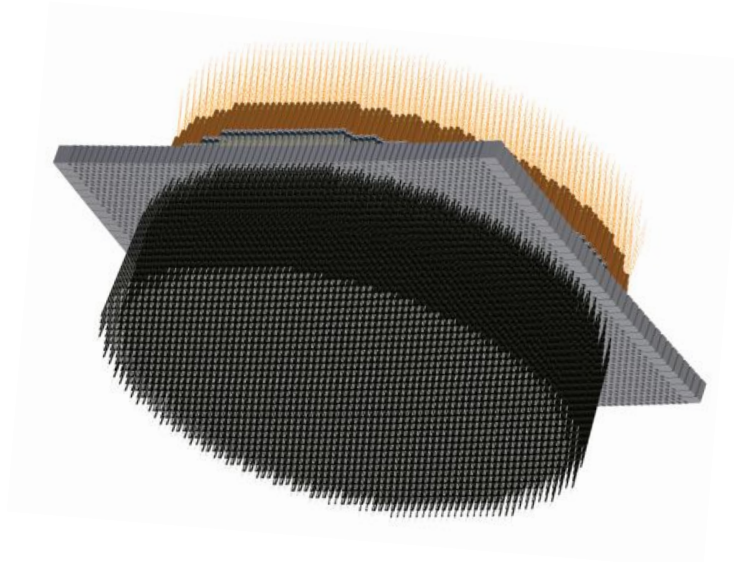
SIFS Observations: 4/17 Results

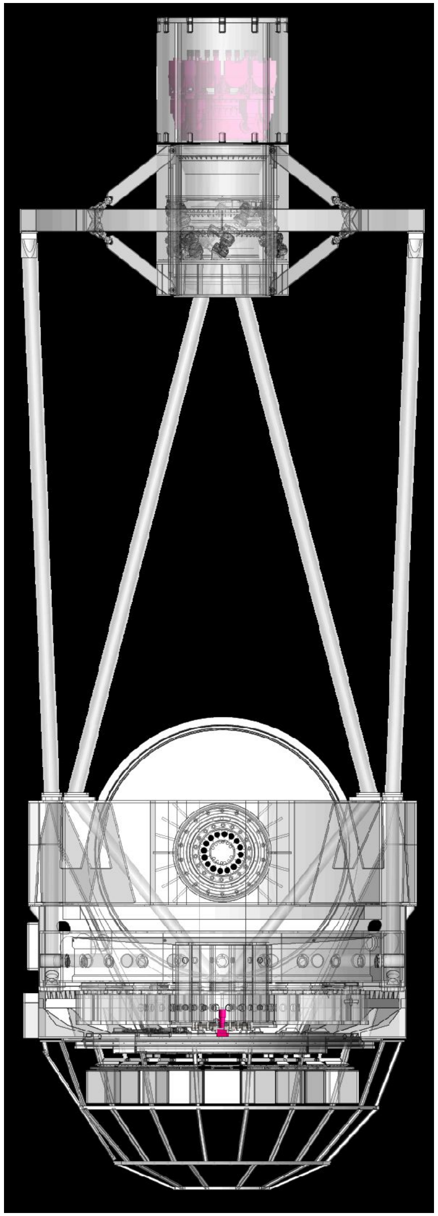
- Spectra of Q1017 and J1621 (data reduced by instrument scientist Luciano Fraga)





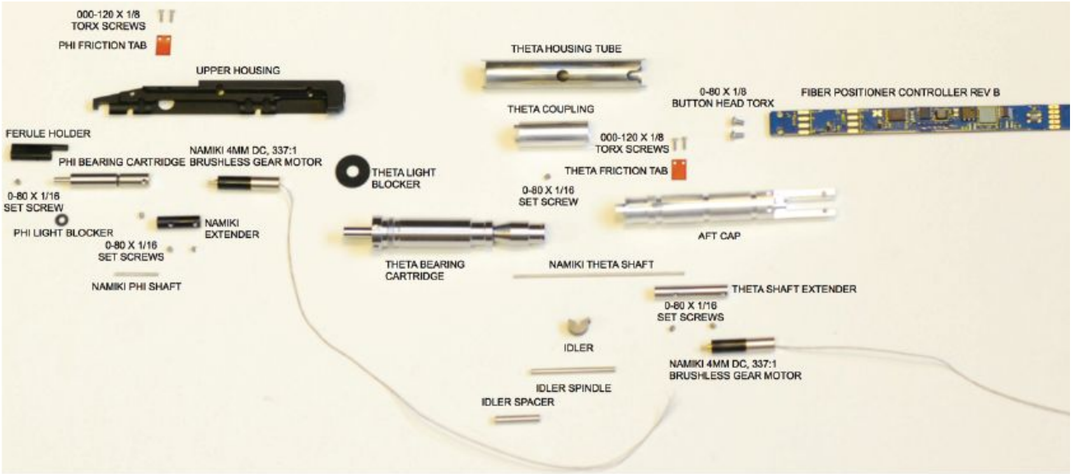
Spectrograph Fiber Positioner

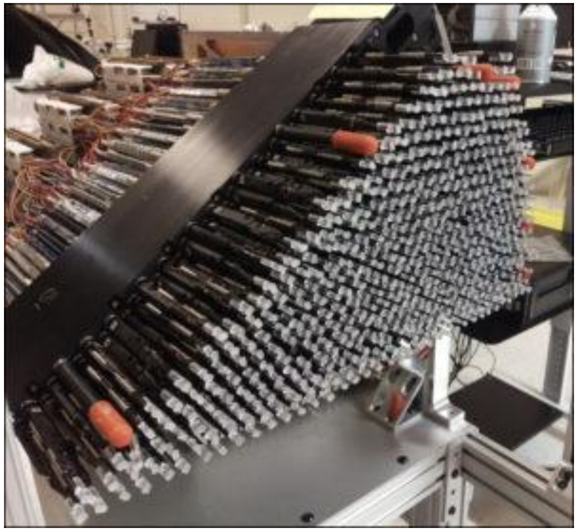




- R&D for a tilting-spine spectrograph fiber positioner
- The goal is to be able to independently position 20,000 optical fibers to take spectra of up to 20,000 astronomical sources in the field of view

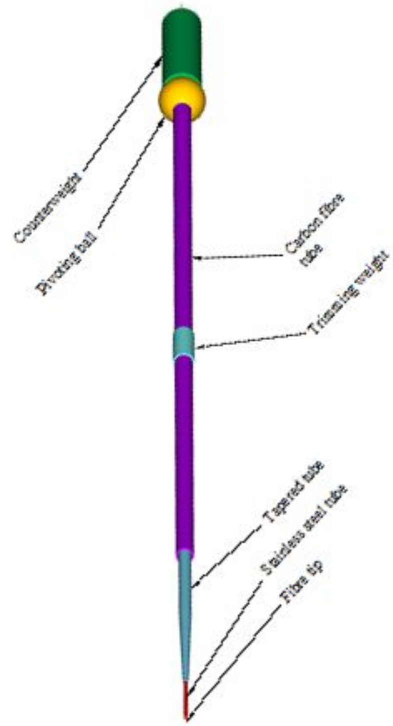
DESI, Twirling Post Fiber Positioners

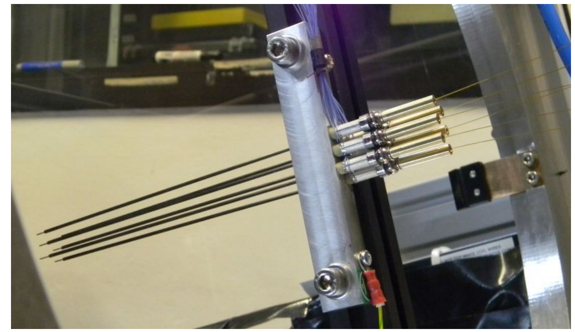


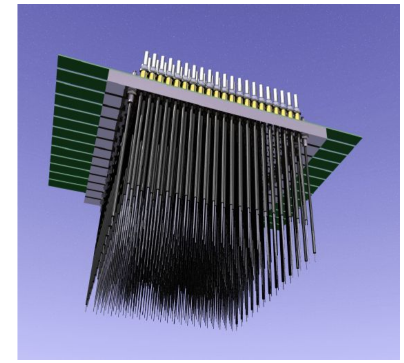


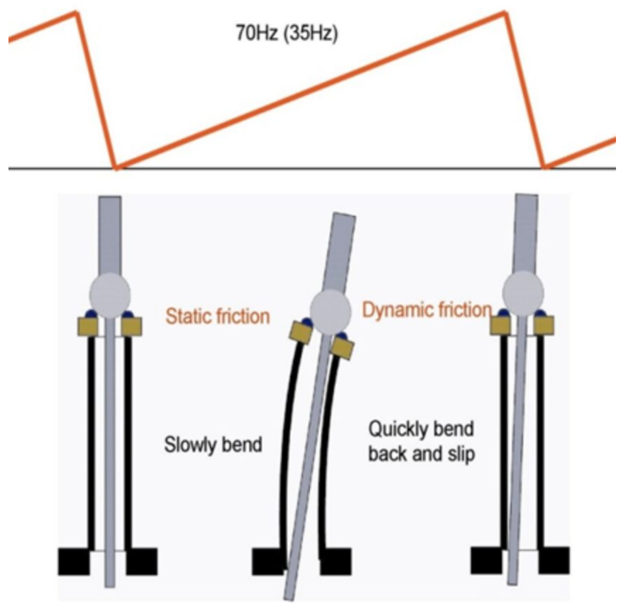
- The Dark Energy Spectroscopic Instrument (DESI) uses twirling post fiber positioners to capture up to 5,000 spectra
- This type of fiber positioner is limited by its large size and many small moving parts, including DC Brushless Gear Motors

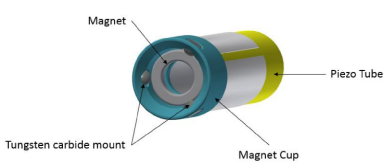
Tilting Spines





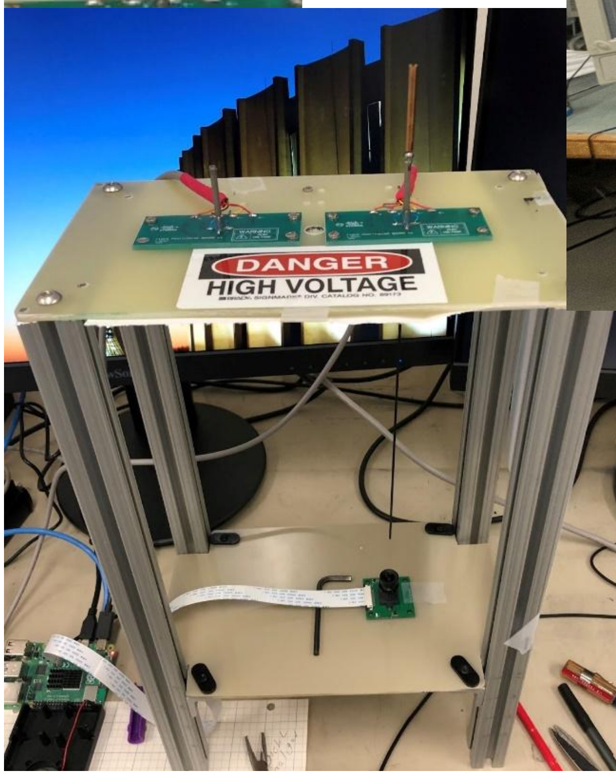


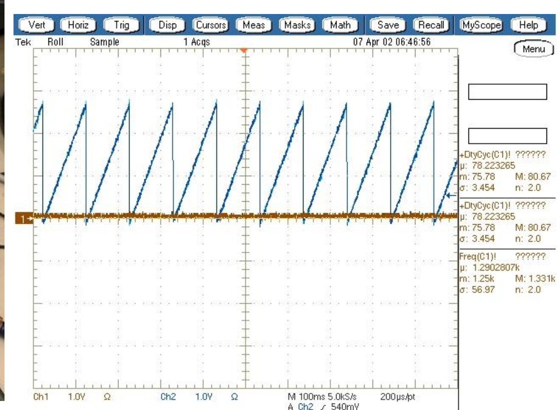


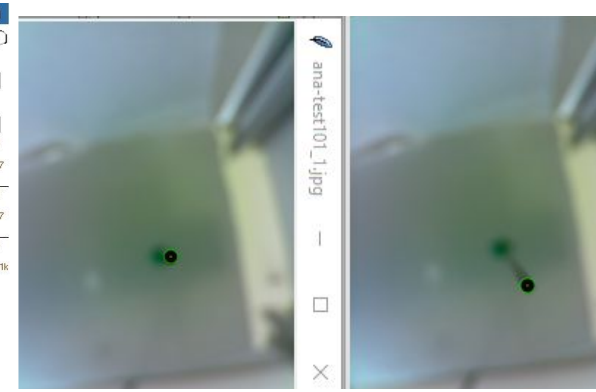


- Piezo tube and magnetic cup fits over the ball on the spine. One moving part.
- FMOS (400), 4MOST (2436), DESpec (4000), MSE (4332)
- Can get them closer together than Twirling Posts

Test Stand Setup

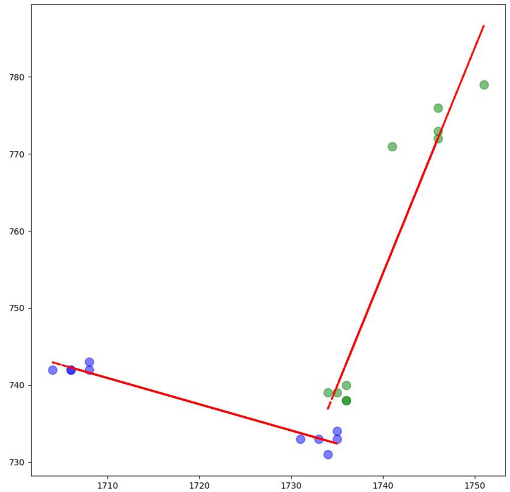


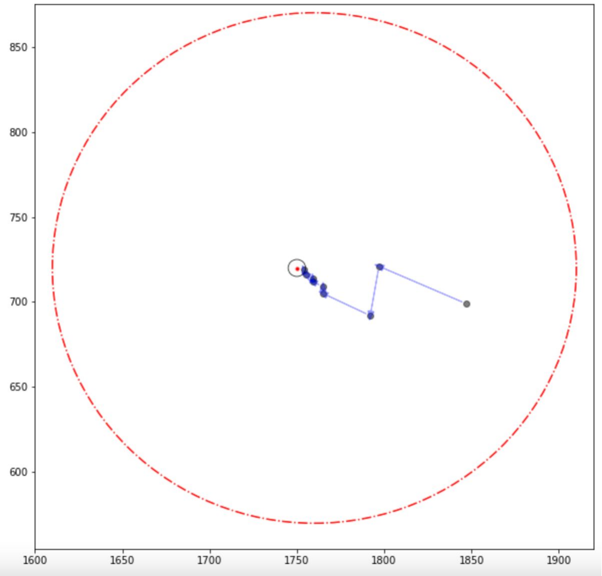


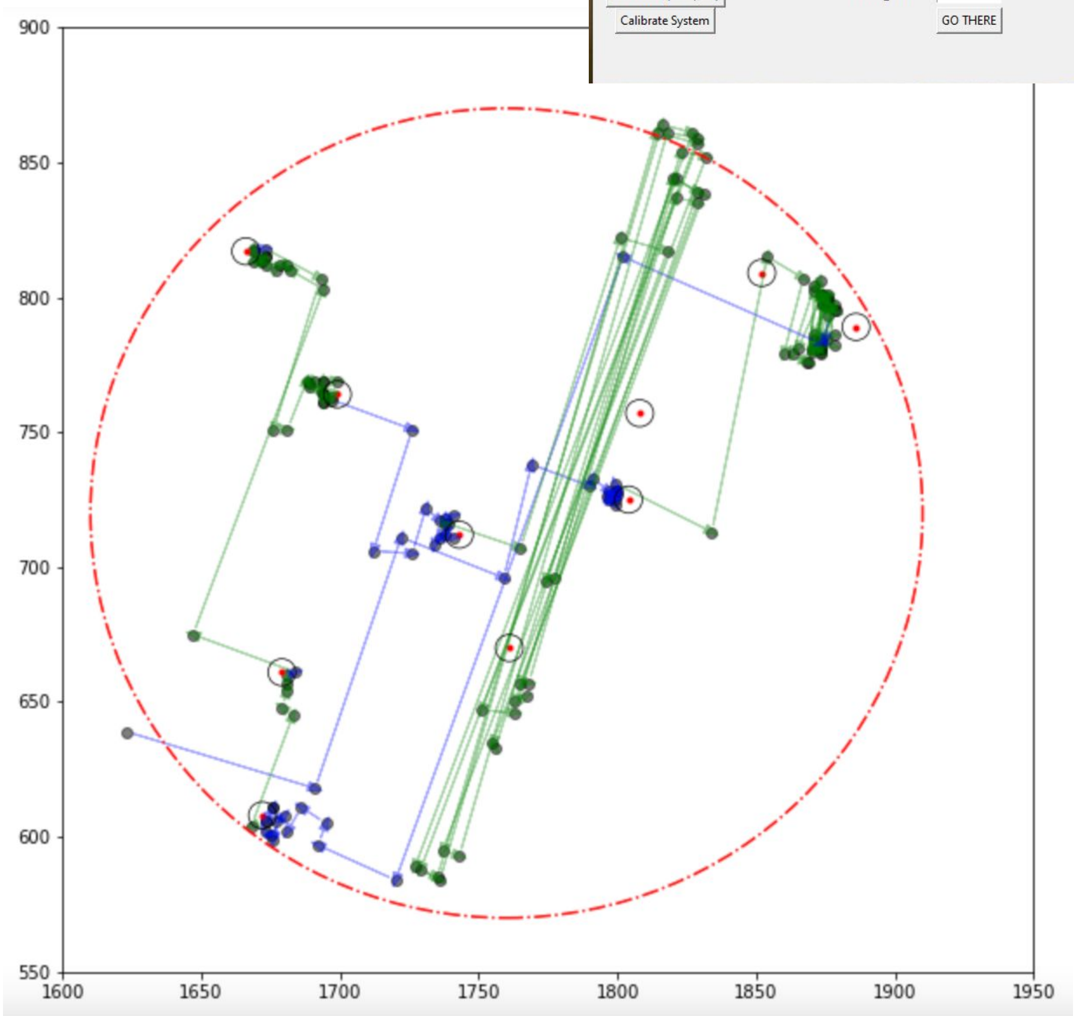


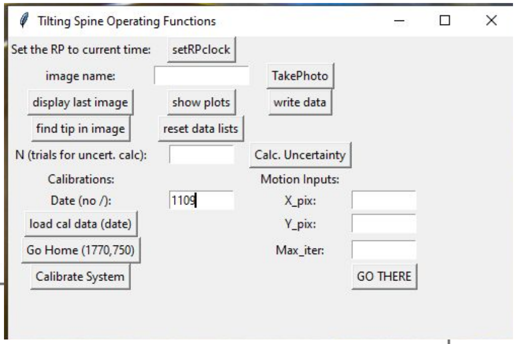
Fermilab

Location-Seeking Algorithm

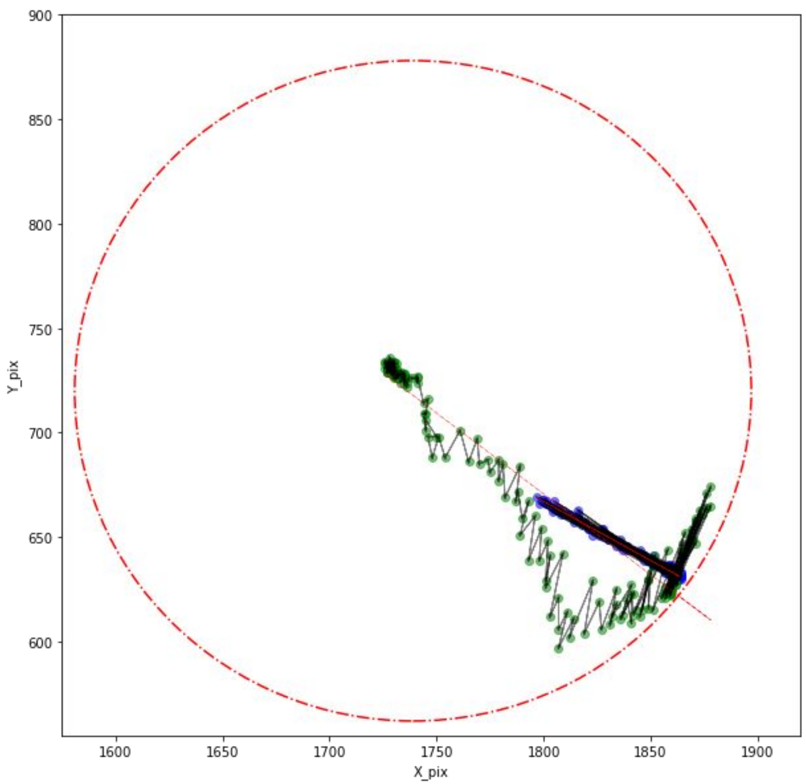


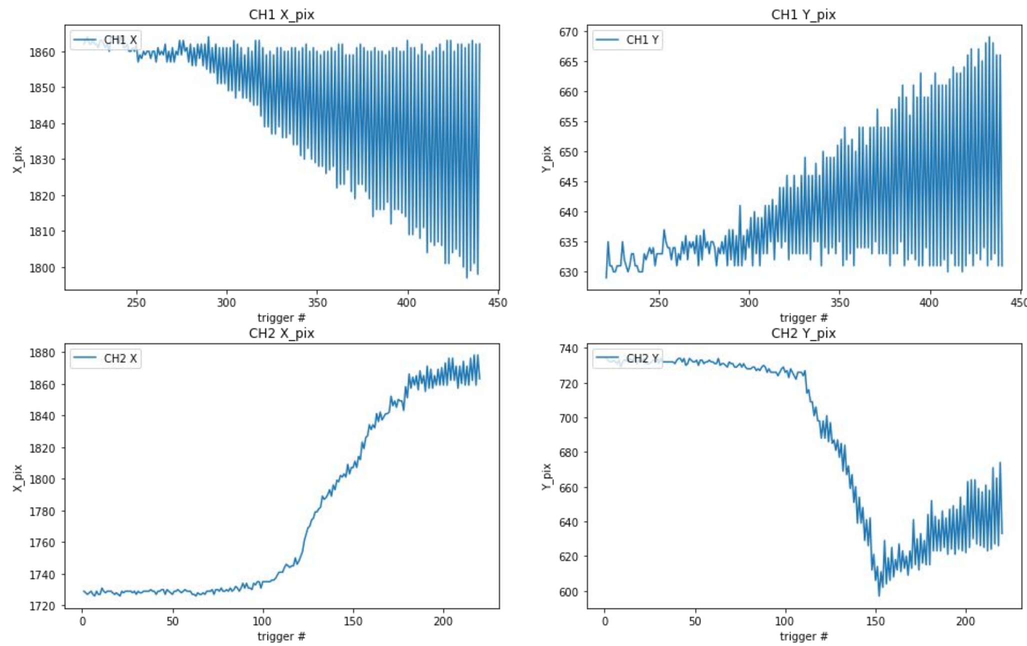


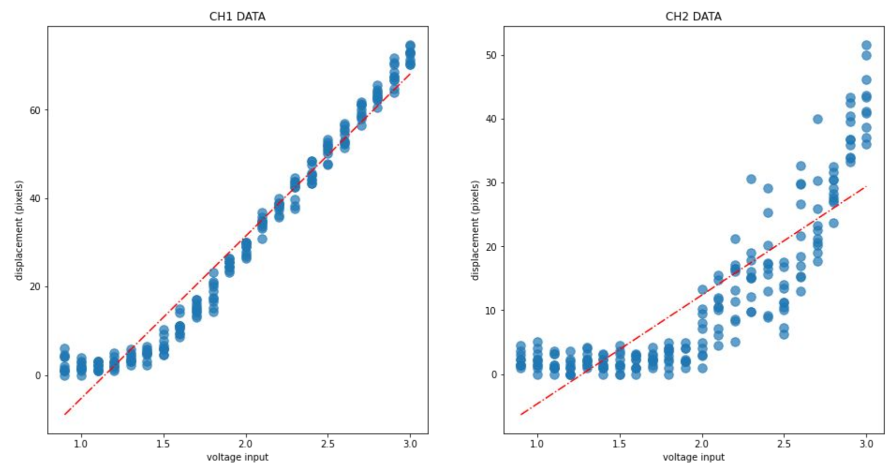




Inconsistencies Between the Channels

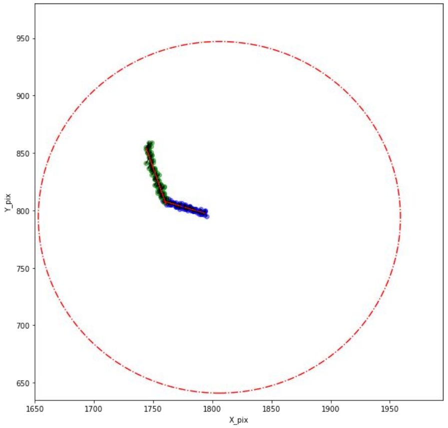




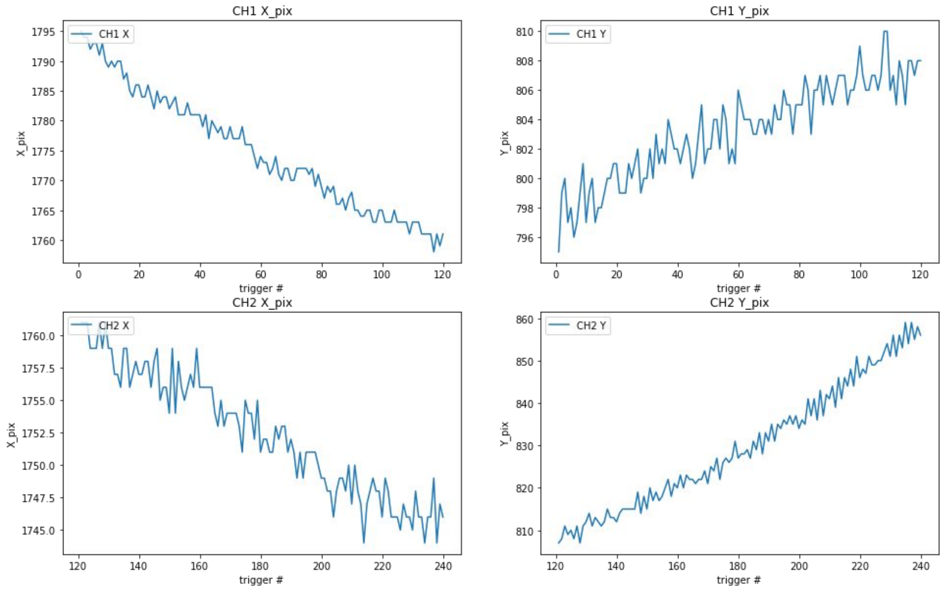


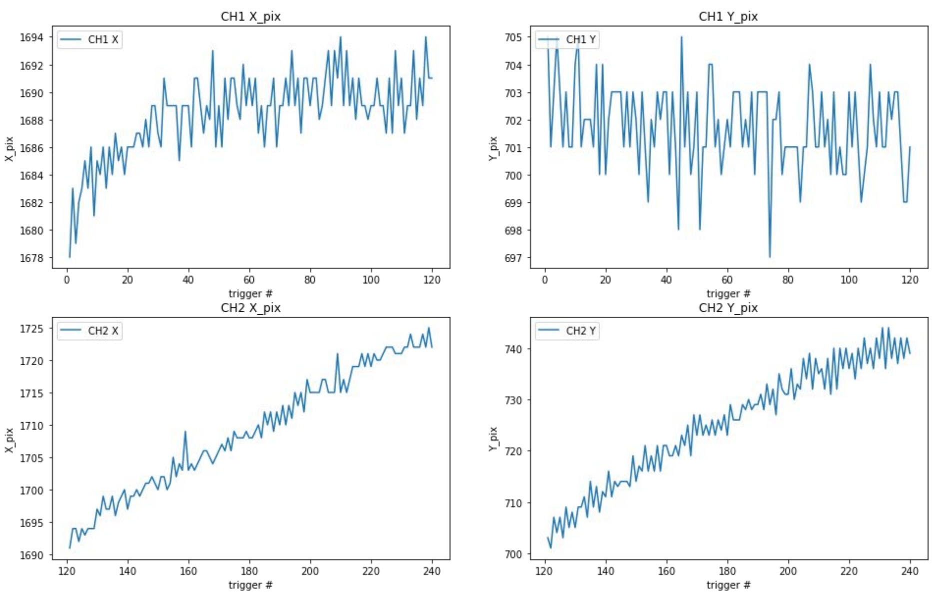
- In this data from January, CH1 (blue) is behaving approximately as it should, while CH2 (green) showed a strong drift towards high-X, low-Y before hitting the edge of the range of motion.
- Relative performance of the channels is known to depend on angle of fiber assembly.

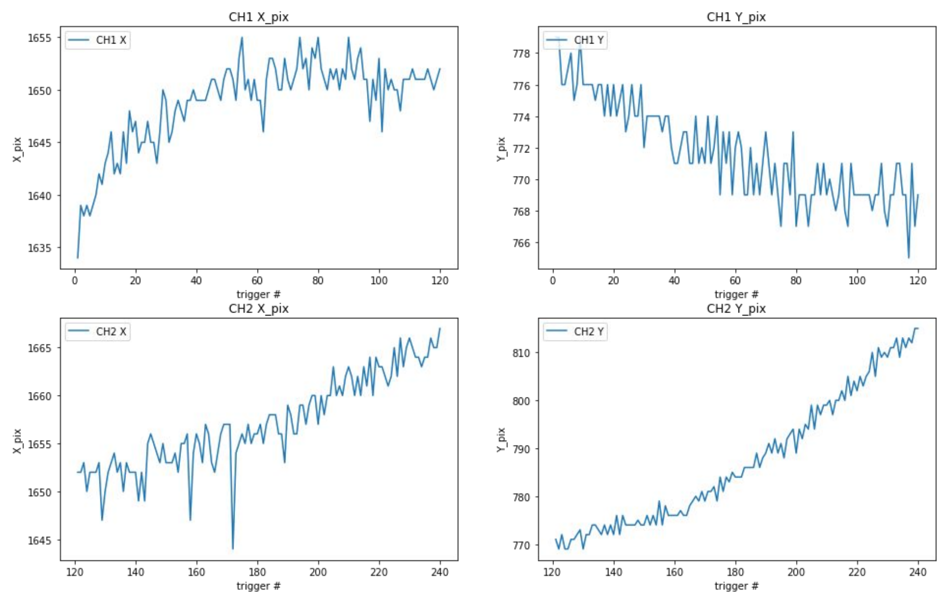
Investigating Drift



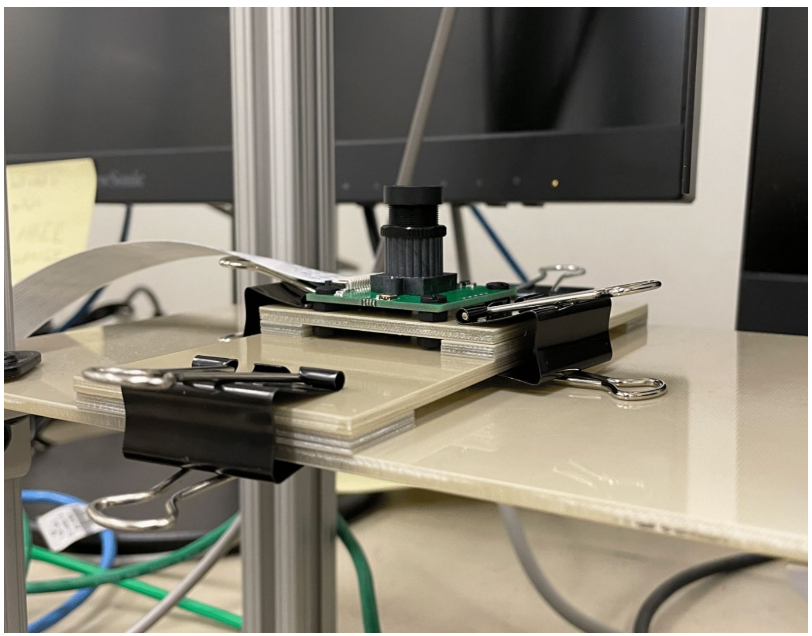
- upper right: 0°
- lower left: +180°
- lower right: +90°

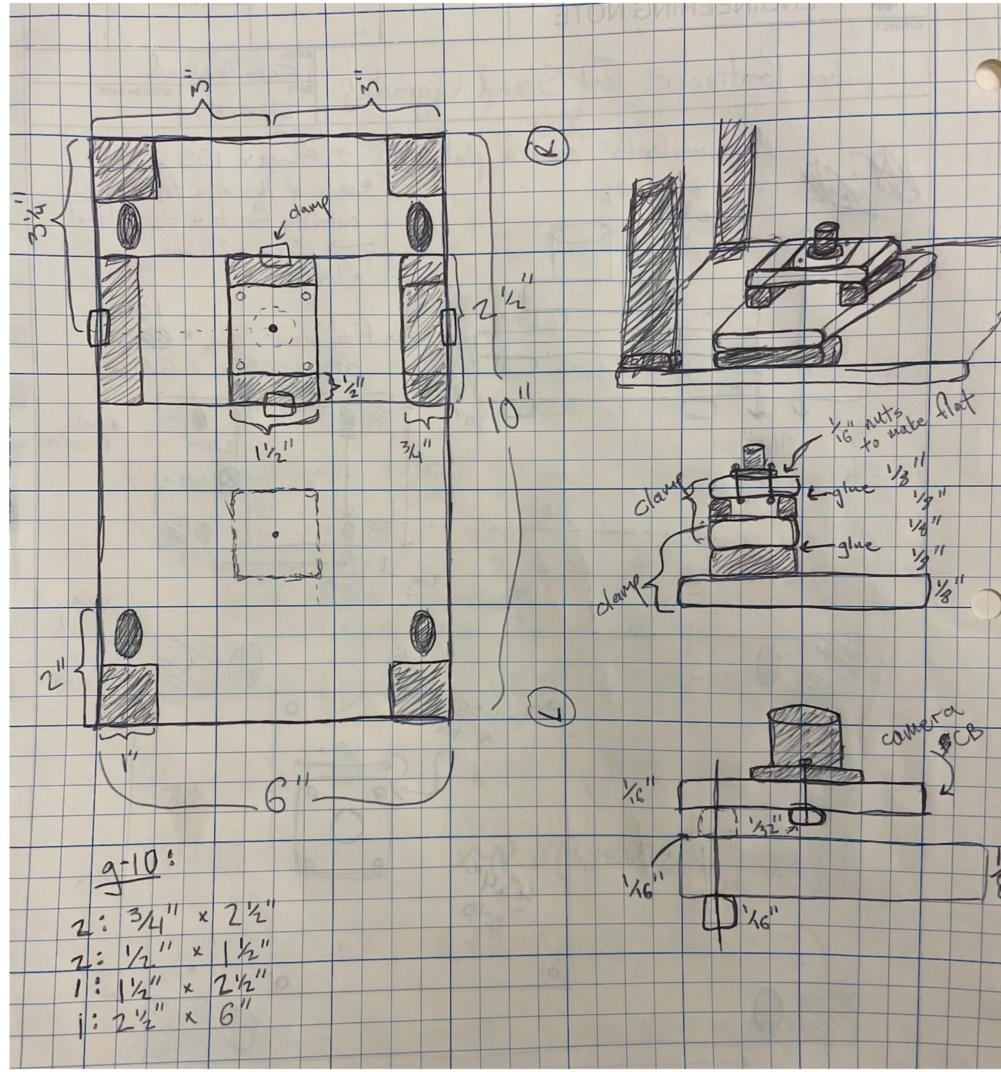






Upgrading the Camera Mount





Fermilab

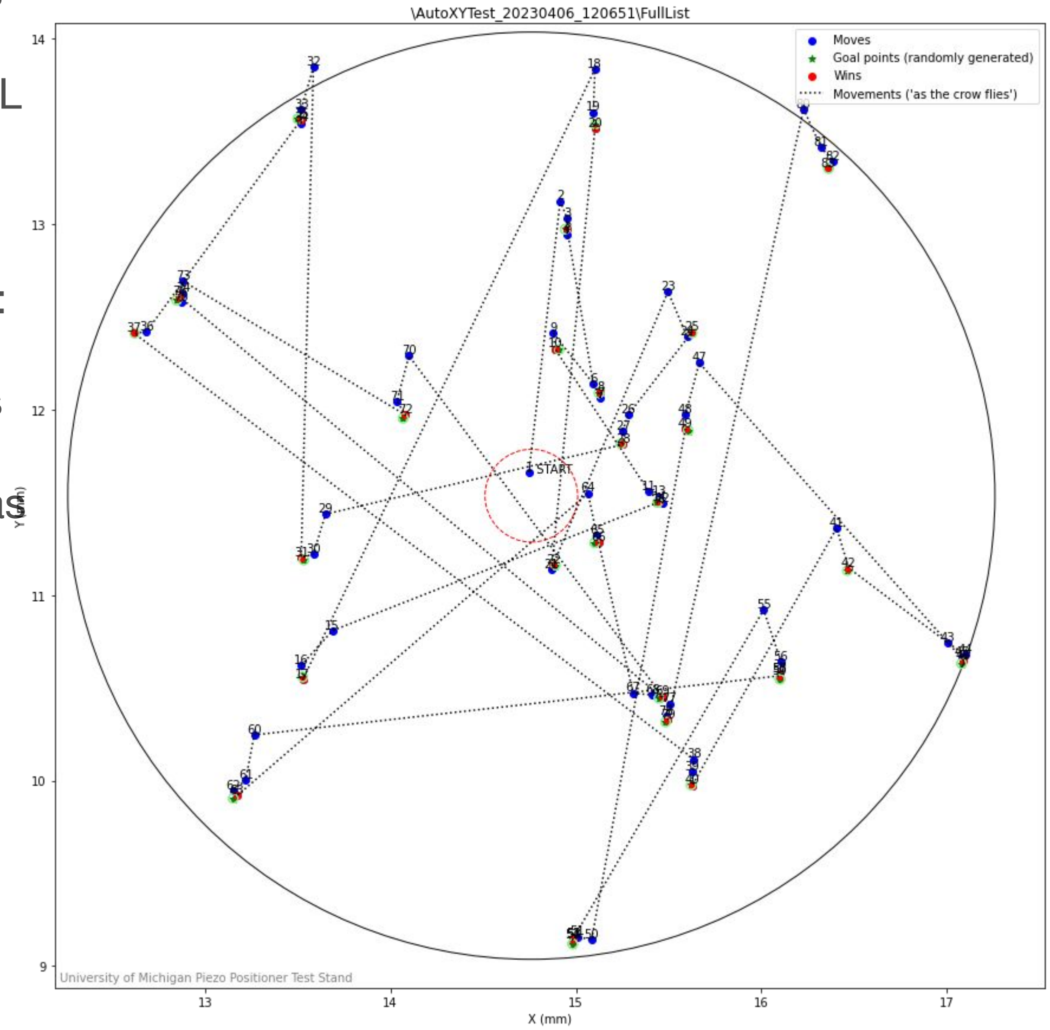
Upgrading Algorithms for Calibration, Finding a Location

- After discarding the imbalance-counterweight hypothesis, I decided to attempt to address the problems indicated in the drift tests by improving the algorithms I use to calibrate how the waveform generator moves the spine and attempt to move it to a desired location.
- The new calibration results indicate this upgrade is worth doing, improvement in performance TBD.

- Tested new calibration with 3V on both channels:
- theta1p=189.9° , theta1n=9.6° , theta2p=87.5° , theta2n=262.0°
- pixel displacement per step at 3V: 1p = 11.1 , 1n = 10.3 , 2p = 12.1 , 2n = 14.0
- d_theta1=0.3° ; d_theta2=5.5° ; d_disp1=0.8pix ; d_disp2=1.9pix

Progress Made by UMich Collaborator Rebekah Sebok

- Our collaborator Rebekah Sebok works at UMich with Marcelle Soares-Santos
- Weekly meetings, Rebekah visited FNAL at the beginning of March
- Rebekah's latest results using new Piezo:
- Final win count: 25 / 25 with an error of: 0.025 mm
- The maximum tries for a single win was 5 and the minimum was 2 .
- The average number of tries per win was 3.28



Fermilab

pixel scale: (1.5mm)/(420pix) = 0.0036 mm/pix = 3.6um/pix ; std.dev. on position ~2pix → ~7 micron uncertainty ; still debugging new location-seeking algorithm ; new calibration still seems worthwhile: pos/neg X and Y directions can be off from 180° by up to about 10°, magnitudes (at 3V) can be off by a few pixels per step

SIFS Observations: 3/28 Results

- explain issues, maybe show fits image with no visible signal (might want one with a strong signal for comparison)

SIFS Observations: 4/17 Results

- HB89 spectra: