FY24 R&TD Innovative Spontaneous Concepts (ISC)

Kinematic Lensing with Palomar

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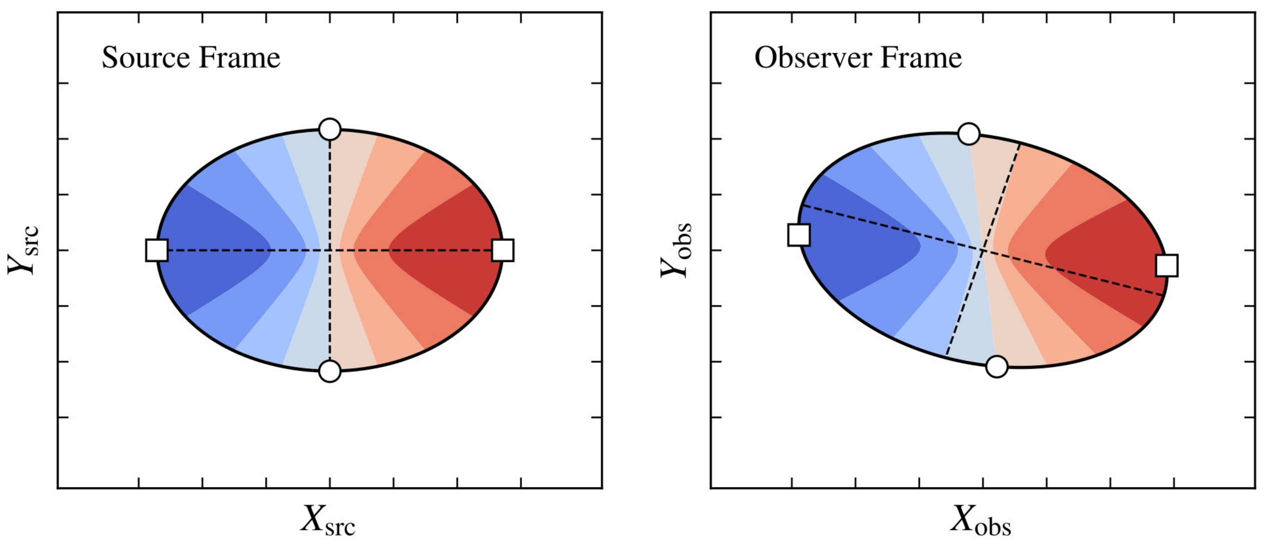
Strategic Focus Area: Innovative Spontaneous Concepts

Objectives

This proposal was intended to produce a first detection of weak gravitational lensing using galaxy kinematics. The team had taken data for this purpose using time previously allocated by JPL on the Hale Telescope at Palomar, and aimed to demonstrate its feasibility with a first detection of the expected effect.

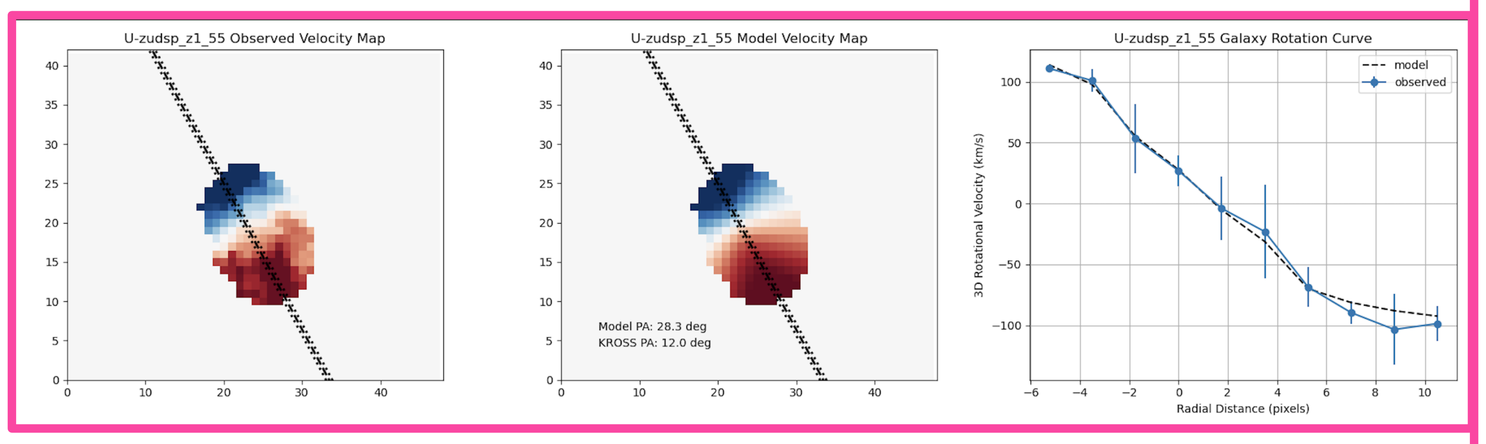


Caption : Map of the line-of-sight velocity field of a galaxy before (source frame) and after (observer frame) weak lensing distortion. With only information about the overall *shape*, the lensing effect is indistinguishable. With accurate measurements of the internal kinematics, we can detectthe mis-alignment between the overall ellipticty and the kinematics.

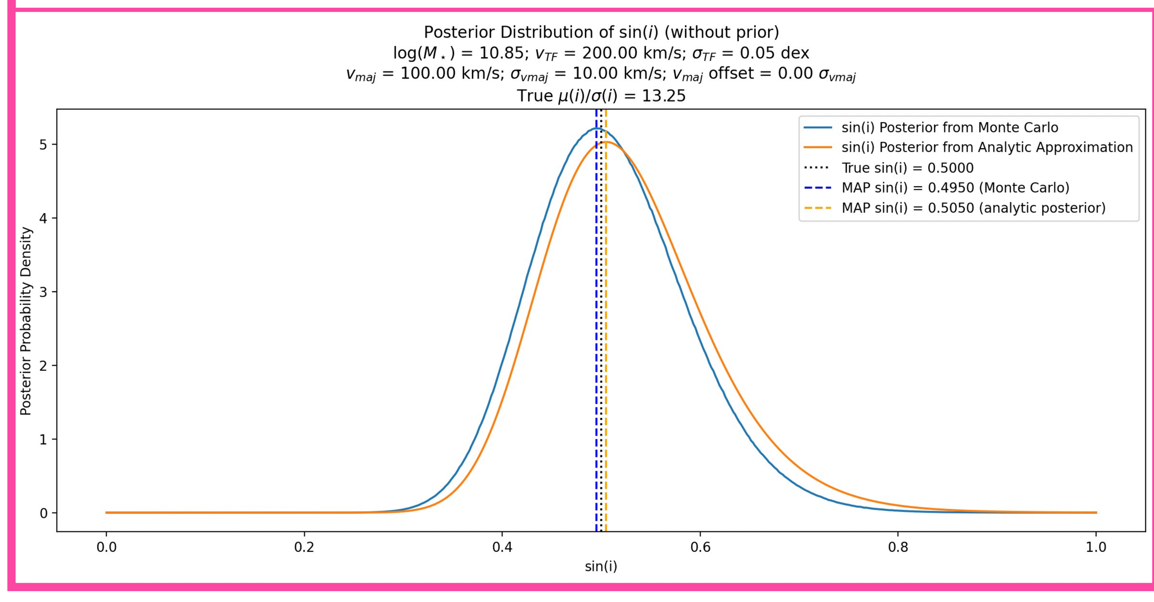
Approach and Results

The Palomar data themselves suffered from unexpected problems due to corrupted data produced by the instrument, which we were not able to resolve during the period of the award.

However, the team did work to develop analysis tools to extract 2D and 1D spectroscopy from CWI-like data and measure the KL signal. We sought and found Palomar-like data from archival sources (see right), and validated their performance on Palomar-like data from the Very Large Telscope's MUST integral field spectrograph.



The computational complexity of the kinematic lensing inference has proved to be a significant bottleneck; many potential sources from the VLT data have been excluded due to our cost of fitting a sufficiently complex parameterized model to capture realistic galaxies.



To address this, we developed an hybrid analytic approach with an anlaytic Bayesian estimator for some of the galaxy properties the that allows us to derive accurate kinematics with a less complex model. The performance of this analytic posterior as compared to more complex simulations is shown at left. The analytic result, which reduces the computational cost of KL inference by orders of magnitude, introduces a negligible bias in the result.

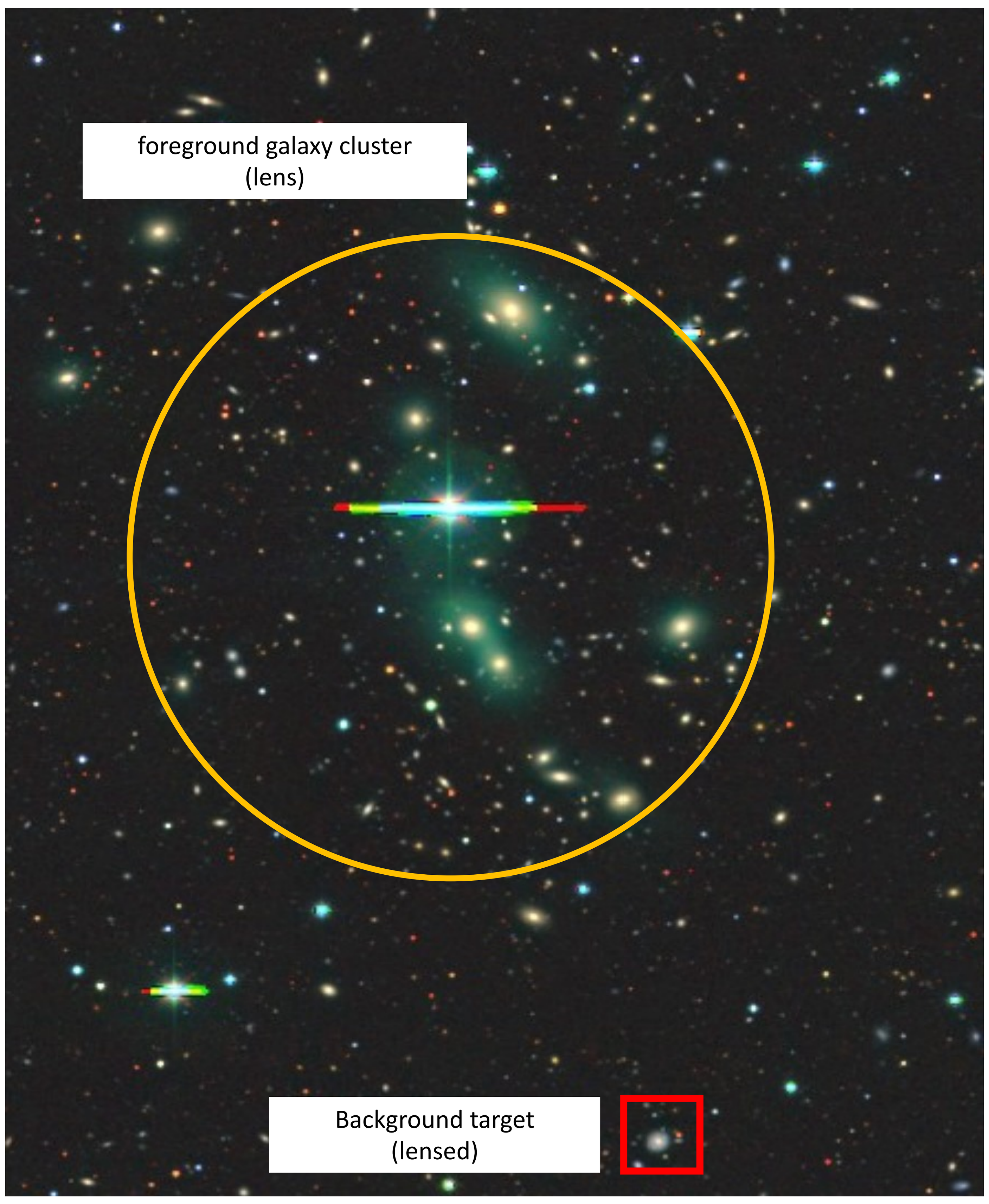
Background

Weak gravitational lensing is our only direct probe of the distribution of dark matter. Because of this, weak lensing measurements are one of the primary methods by which current and future cosmological probes, such as the Nancy Grace Roman and Euclid missions, will determine the properties of dark matter and dark energy.

Weak Lensing measurements are notoriously challenging. This effect produces a tiny (<1%) change to the *ellipticity* of a galaxy distant galaxy. For any single galaxy, this is indistinguishable from variation in the intrinsic, unlensed shape of the galaxy.

This team had previously demonstrated a new method for detecting weak lensing using measurements of galaxy kinematics (see figure above). Prior work suggested that using spectroscopic observations of galaxy internal motions (kinematics), it should be possible to independently determine both the intrinsic shape of the galaxy and the weak lensing signal.

We were awarded time to perform these measurements on the Hale telescope at Palomar. A typical target is shown at right, with the massive foreground lens and target galaxy indicated. The purpose of this work was to analyze these data.



Significance

Due to unexpected complications, the Palomar data turned out to require more time and labor to fully analyze than the scope of this award permitted.

Despite this, we found comparable archival data, and used those data to refine tools and methods, and are working towards a future detection.

This progress from early FY24 has already enabled preliminary detections on other data sources.

Successful deployment of the kinematic weak lensing technique piloted here will improve the sensitivity of future cosmological probes by an order of magnitude.

Benefits to JPL and NASA

The nature of dark energy will remain a priority topic for astrophysical exploration for many years to come. The observables powering current missions (ESA's Euclid, NASA's Nancy Grace Roman) have limited potential for future improvement.

This method may be a viable successor to current cosmological probes, and a candidate driver for future cosmological mission concepts.

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