National Aeronautics and Space Administration

Kinematic Lensing: A New Method for Weak Gravitational Lensing Measurements

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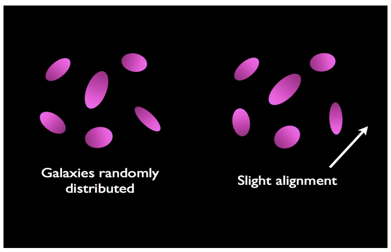
Program: SURP

Motivation

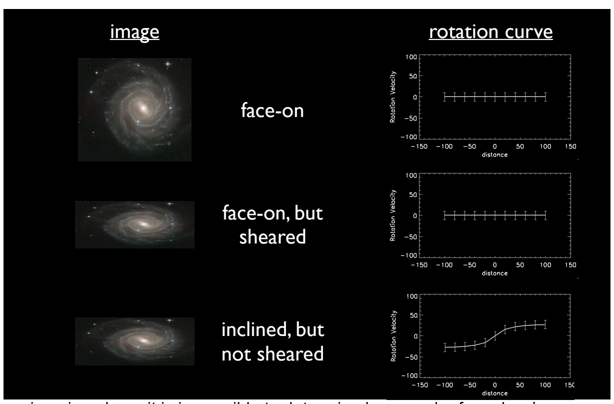
Weak gravitational lensing is the most powerful observational probe of the origin and large-scale structure of the universe, and one of the primary science drivers for a wide range of large missions including **WFIRST** and **Euclid.** Lensing measurements are typically very noisy, and require large volumes of data with exquisite quality control to be successful. Here we report on an attempt to use spectroscopic measurements of galaxy rotation to **boost the lensing signal, potentially by as much as an order of magnitude**. We present a progress report on an analysis using spectra from the Keck telescope taken on targets behind the massive galaxy cluster Abell 2261 that will make the first **kinematic lensing** measurement.

I. Why weak lensing measurements are so challenging



Lensing produces a coherent alignment in galaxy shapes, but this effect is much smaller than the random variation in intrinsic shapes. As a result, successful weak lensing measurements require vast statistical samples, and the low signal-to-noise ratio makes validating measurements particularly difficult.

II. Why spectroscopy is a game-changer.

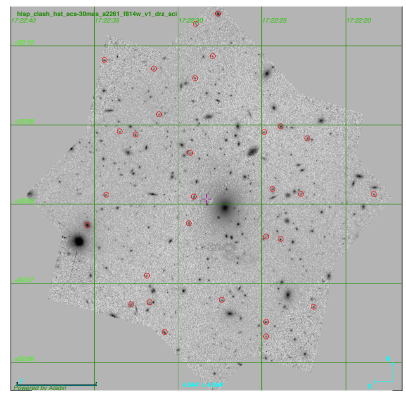


From imaging alone, it is impossible to determine how much of a galaxy's apparent shape is due to orientation, and how much is due to lensing. With a rotation curve, typically measured using slit spectroscopy, it is possible to disambiguate lensing and intrinsic shape, **leading to a large increase in the statistical power of the shear measurement**.

Benefits to NASA and JPL:

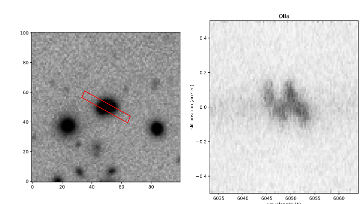
Kinematic Lensing is a strong candidate for future cosmological missions. With this pilot study, we are aiming to establish its viability as a mission science driver in the **post-WFIRST** era.

III. Lensing by Abell 2261

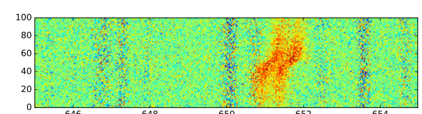


Abell 2261 (right) is a massive galaxy cluster at redshift 0.224. It was a target of ground- and spaced-based weak lensing studies by the Cluster Lensing and Supernova survey with Hubble (CLASH). As a well-studied cluster, **it is an excellent testbed for our proposed kinematic lensing technique.**

We have used the DEIMOS instrument on the Keck telescope to obtain spectra disk galaxies in the cluster background; **in this field, our targets are shown in red**.



DEIMOS slits, aligned with the galaxy, produce spectra that are distorted by the velocity field of the galaxy. A zoom-in image of one of our targets, with the slit angle superposed, is shown in the left panel. **The right panel shows the OII doublet, distorted by rotation.**

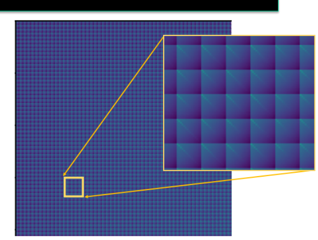


To extract the lensing signal, we need a parameterized model for the shear galaxy spectrum. **We have completed development of a generative model for lensed DEIMOS spectra**; a simulated galaxy spectrum generated with this model is shown at right.

IV. Recent Progress

Accurate modeling of the lensing signal requires computation of the likelihood function *L*, which connects the data (D) to the theoretical model (M) accounting for the noise in the measurement with a covariance matrix (C). The UA group has computed a stable, accurate C for kinematic lensing this year with further development of the *CosmoLike* cosmological modeling framework developed by Eifler and collaborators previously at JPL.

$$L(\mathbf{D}|\mathbf{p}) \propto \exp\left(-\frac{1}{2}\left[(\mathbf{D}-\mathbf{M}(\mathbf{p}))^T \mathbf{C}^{-1}(\mathbf{D}-\mathbf{M}(\mathbf{p}))\right]\right)$$



Our new model covariance matrix, including contributions fom measurement errors and cosmic structure, is shown at right, for an 1100-element kinematic lensing power spectrum data vector.

This object will form the core of a forecasting and modeling task in the next year of this award.

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