National Aeronautics and Space Administration

Next-Generation Weak Lensing with Hyperspectral Imaging Surveys

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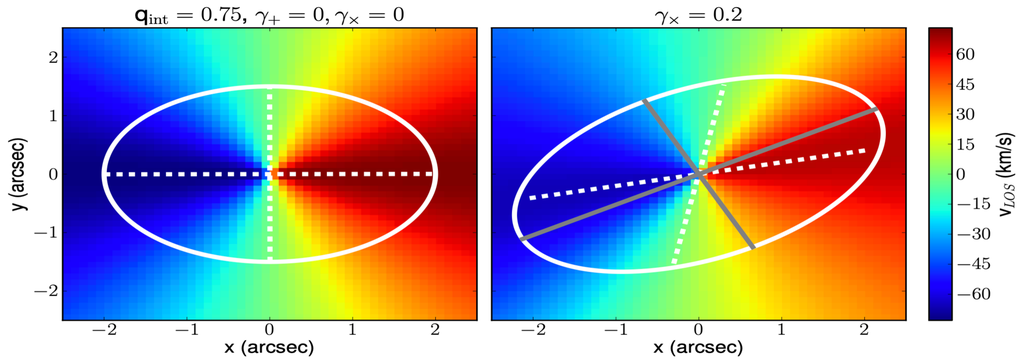
Program: FY21 R&TD Topics **Strategic Focus Area: Origin, evolution, and structure of the universe**

Objectives

This project will demonstrate that **measurements of galaxy kinematics**, made with **hyperspectral imaging**, can **reduce the noise** in our best cosmological probe **by an order of magnitude**.



White contours trace this galaxy's image; colored maps show its line-of-sight velocity field, measurable with spectroscopy. The **left** panel shows the unlensed galaxy; the **right**, the effect of an exaggerated lensing distortion, which mis-aligns the velocity and image axis.

Background

Maps of large-scale cosmic structure are sensitive probes of the nature of dark energy, which drives the accelerated expansion of the Universe. Most of the structure is dark matter, and can only be indirectly observed with gravitational lensing.
Lensing measurements are thus crucial for modern cosmology. They're also intrinsically very challenging, with a noise floor set by the intrinsic scatter in real galaxy properties.

When a galaxy is lensed by foreground structures, its image and velocity field appear inconsistent. Those inconsistencies can be exploited to infer the magnitude and direction of the lensing signal. Using velocity information in this way controls for the intrinsic orientation of the galaxy; simulations indicate that this reduces the noise in the measurement by an approximately an order of magnitude.

If this works, it represents a major breakthrough, and could allow cosmic structures to be mapped with lensing at much higher precision than was previously possible. The benefits for science prioritized by JPL and NASA would be considerable…

…but first we have to show that that it works in real data.

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Approach and Results

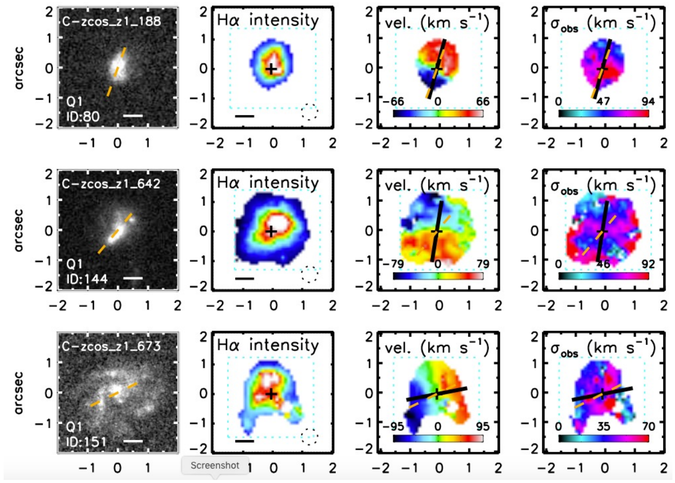
Focus: archival data from KMOS Redshift One Spectroscopic Survey (KROSS – example data at right)

Well-measured kinematics for 580 disks between 0.6 < z< 1.0

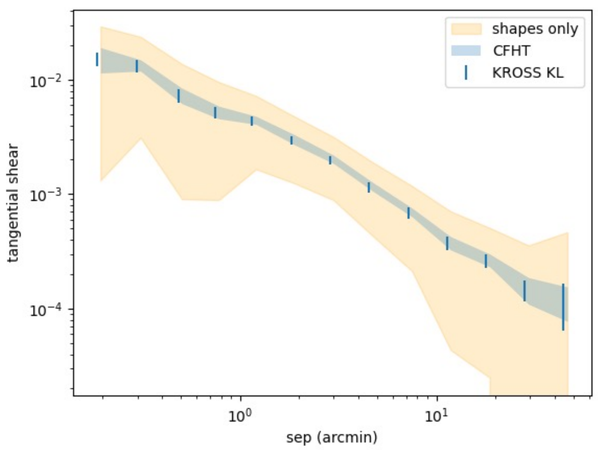
Public catalogs with full data-cubes of H-alpha emission and kinematics

3 northern fields (470 galaxies) covering 2.5 deg^2, overlapping SDSS (foreground lenses)

We have developed a simulation suite and Bayesian forward-modeling retrieval pipeline that permits realistic simulated analyses on KROSS-like data.
These simulated analyses allow us to map out and mitigate noise and systematic errors in the final measurements.
At present, we are able to recover input lensing with a precision of ~0.025, **an order of magnitude improvement over traditional techniques.**



Images and emission-line measures from the KROSS survey, to be used in this analysis..



Forecast for galaxy-galaxy lensing signal from this measurement (KROSS KL) compared with a traditional weak lensing measurement using the same data (yellow shaded region), and the current state of the art from surveys with 100x more data (blue).

Significance for NASA and JPL

Completing a pilot measurement here will open up significant new science opportunities.

Our forecasts suggest we can achieve flagship-level cosmological constraints with KL in a small-aperture (30cm) hyperspectral imaging mission with existing technology.

Publications

None – work still ongoing

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