Cosmological Forecasts for Kinematic Lensing and Multiprobe Strategies in the HLWAS

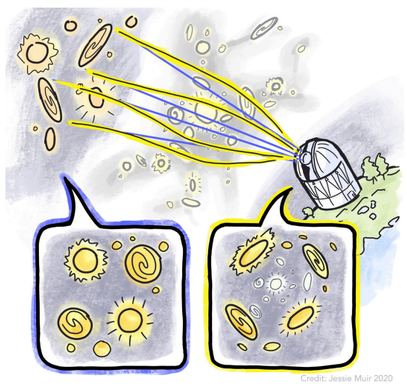
Yu-Hsiu Huang[1], Jiachuan Xu[2], Tim Eifler[1], Elisabeth Krause[1], Pranjal RS[3], Eric Huff[3]
[1]University of Arizona [2]Northeastern University [3]Jet Propulsion Laboratory

Why?

Roman High Latitude Wide Area Survey (HLWAS) will provide overlapping imaging and spectroscopic data over 2415 deg^2. This dataset uniquely enables Kinematic Lensing (KL) and KL-based multiprobe analysis that provides high precision constraints on the dark energy equation of state, allowing us to understand the nature of dark energy.

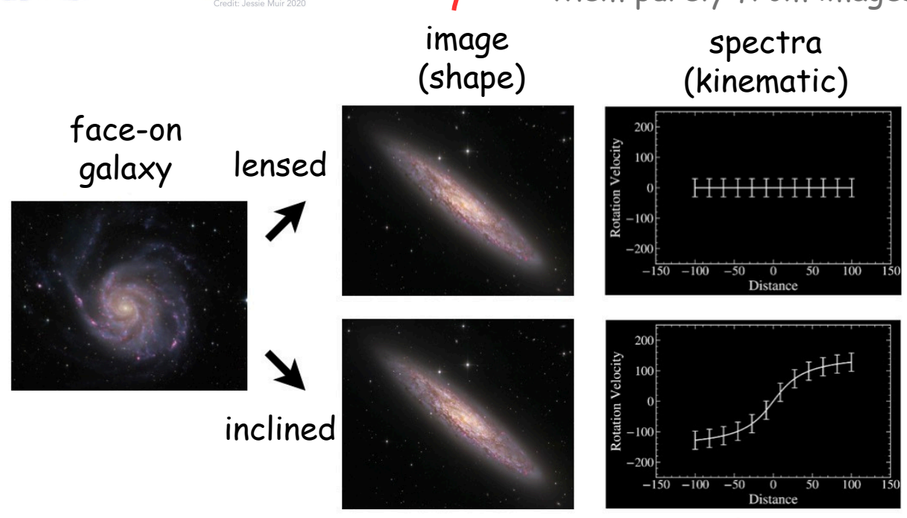
What is Kinematic Lensing?

Kinematic Lensing (KL) is a novel weak lensing technique that uses galaxy kinematics to achieve high-SNR measurements.



Weak lensing (WL) probes the matter distribution through measuring the distortion of images of distant galaxies. It provides a direct measure of the geometry and growth of structure of the universe.

..But the lensing signal is degenerate with galaxy intrinsic inclination. We can't distinguish them purely from images.



For disk galaxies, we can tell the difference by measuring their rotation curves from spectra!

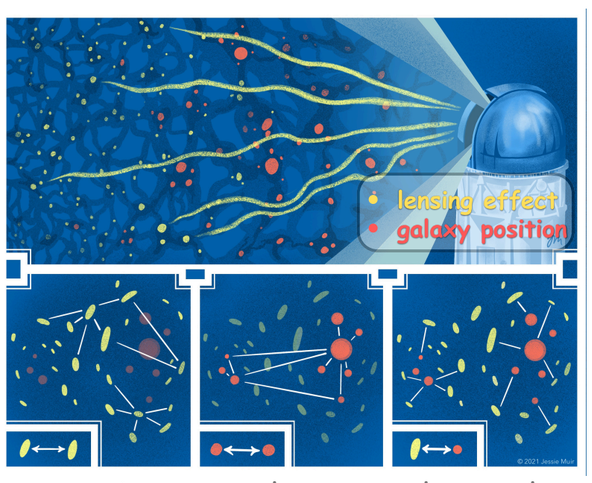
KL jointly analyzes images and spectra to break the degeneracy and hence achieves a lower noise measurement than WL

Check out Eric's talk on Wednesday to learn more about KL!

Multiprobe strategies: 3x2pt

With KL replacing the WL, the KL-3x2pt is expected to have even tighter constraints than typical 3x2pt by reducing (1) the shot noise and (2) redshift uncertainty.

Because KL has spectroscopic sample!



3x2pt analysis combines two tracer fields: weak lensing and galaxy positions. This multiprobe approach nulls the incoherent systematics and breaks parameter degeneracy.

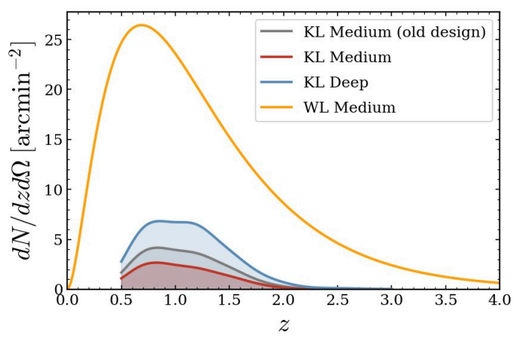
Achieve better dark energy constraints

How?

The forecasts are simulated likelihood analysis done within CosmoLike-CoCoA framework.

Design	Area (deg^2)	$N_{\rm gal}^{\rm KL}$ (arcmin^{-2})
Roman Medium	2415	2.474
Roman Medium Y1	700	2.474
Roman Deep	19.2	7.05

The galaxy redshift distributions are estimated from COSMOS[1] and CANDELS[2] following ROTAC report[3]

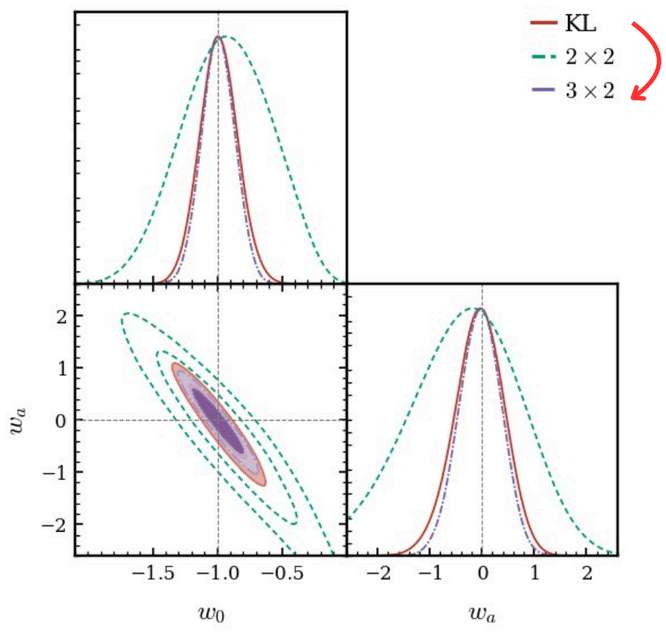


1. Generating data vectors and covariance matrices
2. Perform simulated likelihood analysis

Parameter posterior distributions aka constraining power

Forecast

KL outperforms WL by a factor of ~2.9 in constraining the dark energy equation of state*. Extending the analysis from KL to KL-3×2 yields an additional ~1.5x improvement in constraining power.



The 1.5x improvement comes from breaking parameter degeneracy when including galaxy positions.

Our forecasts also suggest that KL using HLWAS Year 1 data (700 deg²) achieves constraining power comparable to that of WL using Year 5 data (2415 deg²).

Take Home

KL is a powerful cosmological probe for Roman HLWAS

*We use dark energy figure of merit as the metric.

Reference
[1] Jouvel et al 2009, A&A, 504, 359
[2] Grogin et al 2011, ApJS, 197, 35
[3] arXiv:2505.10574

Images: Wei-Hao Wang, Jessie Muir

Check out my papers on KL-related topics

Astrophysical Systematics of KL
2404.00197

One-component Cosmic Shear
2510.18011