National Aeronautics and Space Administration

Next-Generation Weak Lensing with Hyperspectral Imaging Surveys

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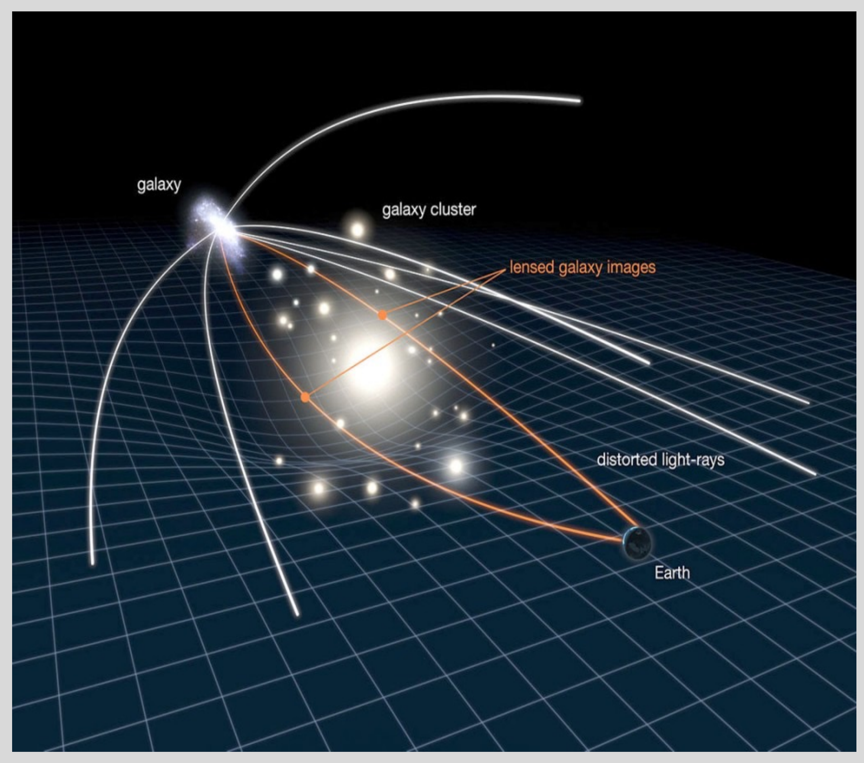
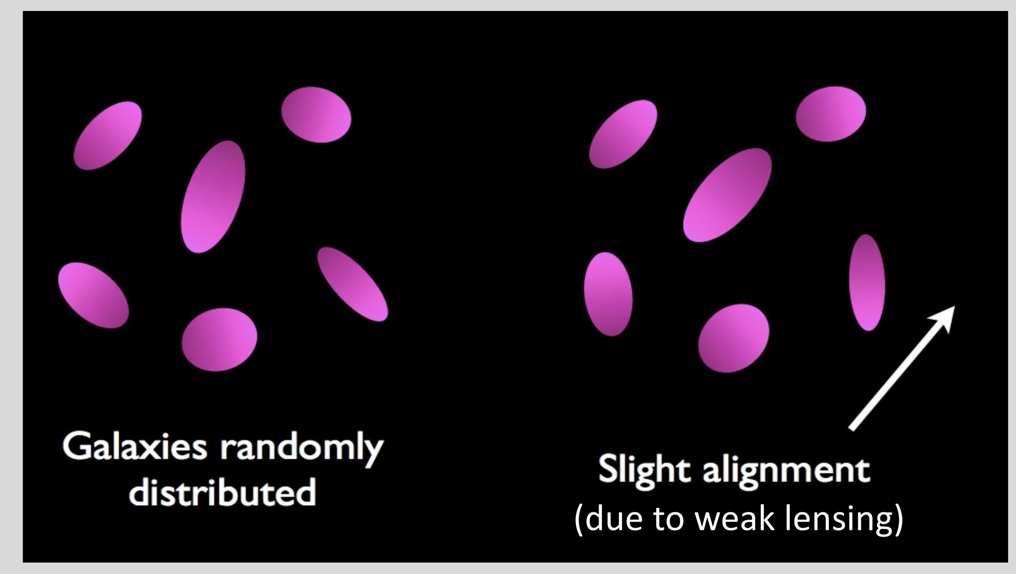
Program: FY22 R&TD Topics
Strategic Focus Area: Origin, evolution, and structure of the universe

Background:

Weak gravitational lensing (WL) measurements are one of the primary available probes of dark energy and the configuration of dark matter. The dominant noise source in WL measurements is the effective noise in the measurement that arises from the random, unknown intrinsic shapes and orientations of the lensed galaxies (shape noise).

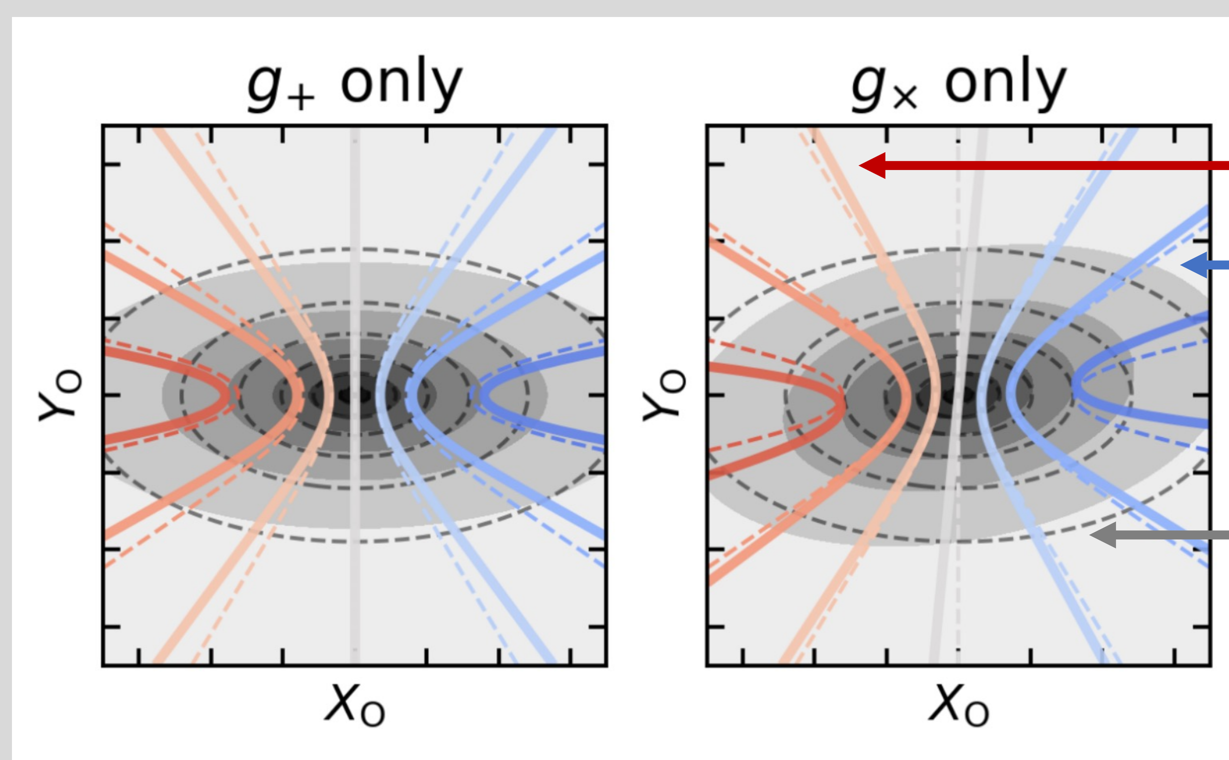




Lensing allows us to probe dark matter on cosmic scales (**left**). It subtly changes the shapes of galaxies, but requires large statistical samples to measure (**top**).

Objective:

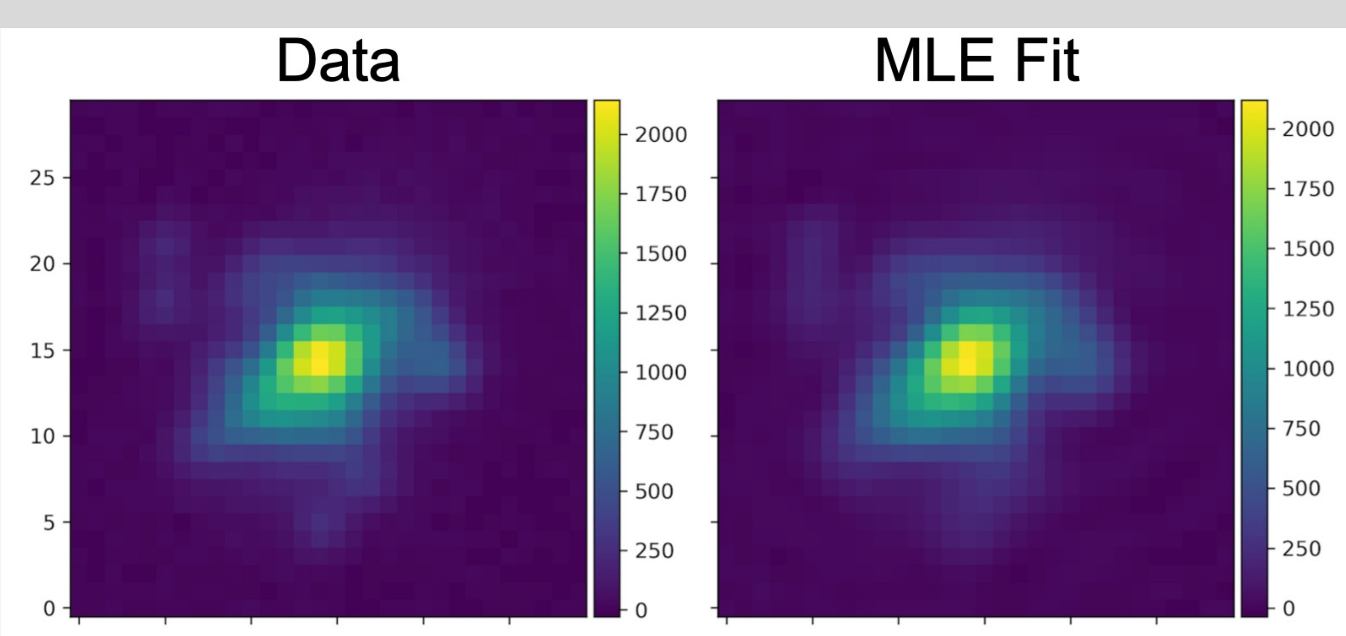
The objective of this work was to demonstrate a new technique for measuring weak gravitational lensing from cosmic structures. This technique, called kinematic lensing (KL), makes use of spatially-resolved spectroscopy of distant galaxies to largely eliminate shape noise. Weak lensing produces a subtle misalignment between the kinematics and the image of a galaxy (see figure at right). ***If this effect can be accurately measured, kinematics for a single galaxy can provide as much information as 100 traditional WL measurements.***



Velocity contours with (solid) and without (dashed) weak lensing effect.

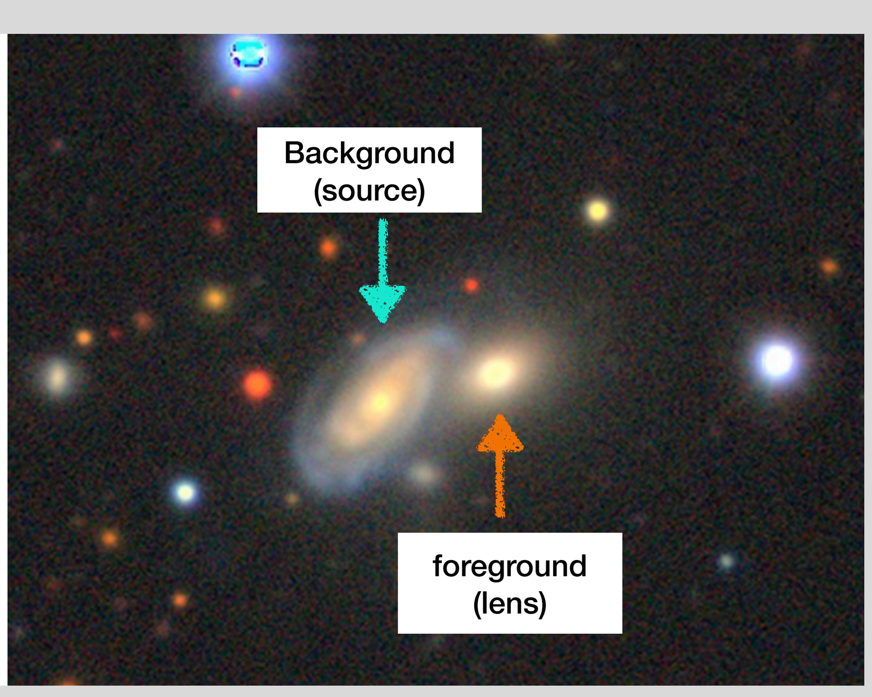
Image contours with (solid) and without (dashed) weak lensing effect.

Measurements of the internal motions of galaxies can be used to distinguish intrinsic shape from gravitational lensing.



Top: Demonstration of our technique for fitting arbitrarily complex galaxy emission-line intensity patterns with a fast, flexible Sersiclet basis function approach.

Right: First target for our 2022 Palomar observing run. This lens-source pair was observed on September 20, 2022.



Approach:

- We built a Bayesian forward-modeling retrieval pipeline to fit realistic hyperspectral imaging data from galaxies and extract the shear.
- We extensively tested this pipeline on simulations, and showed that it can fit complex galaxy morphologies while accounting for realistic observational effects.
- On the strength of our simulated results, we applied for and were granted 6 nights in Fall 2022 on the Hale telescope's Cosmic Web Imager to carry out a first KL measurement. This program is ongoing.

Results:

- On simulations, we are able to reduce the intrinsic noise floor in weak lensing observations by a factor of ~10. [1]
- On simulated Roman Space Telescope grism imaging, we and our collaborators found that a KL analysis of the Roman survey data would improve the key Roman mission's cosmological parameter constraint figure of merit by a factor of ~3. [2]

Benefits to JPL and NASA:

- Dramatically increases power of future measurements of dark energy, dark matter from Roman Space Telescope, where JPL is aims to lead science.
- Opens new discovery space for future astrophysics missions.

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Publications:

[1] S., P.R., Krause, E., Huang, H.-J., et al. 2022, arXiv:2209.11811 (submitted to MNRAS)
[2] Xu, J., Eifler, T., Huff, E., et al. 2022, arXiv:2201.00739 (submitted to MNRAS, in review)

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