Kinematic Weak Lensing on “Weighing the Giants” Galaxy Clusters

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Abstract

This research applies ``Kinematic Weak Lensing'', a photometric-spectroscopic approach for breaking the degeneracy between intrinsic shape and cosmic shear noise, which photometric imaging cannot simply accomplish. The research outcomes with galaxy cluster catalogs of intrinsic orientations of galaxy disks, shapes after the effects of cosmic shear, and the velocity fields of the lensed galaxies.

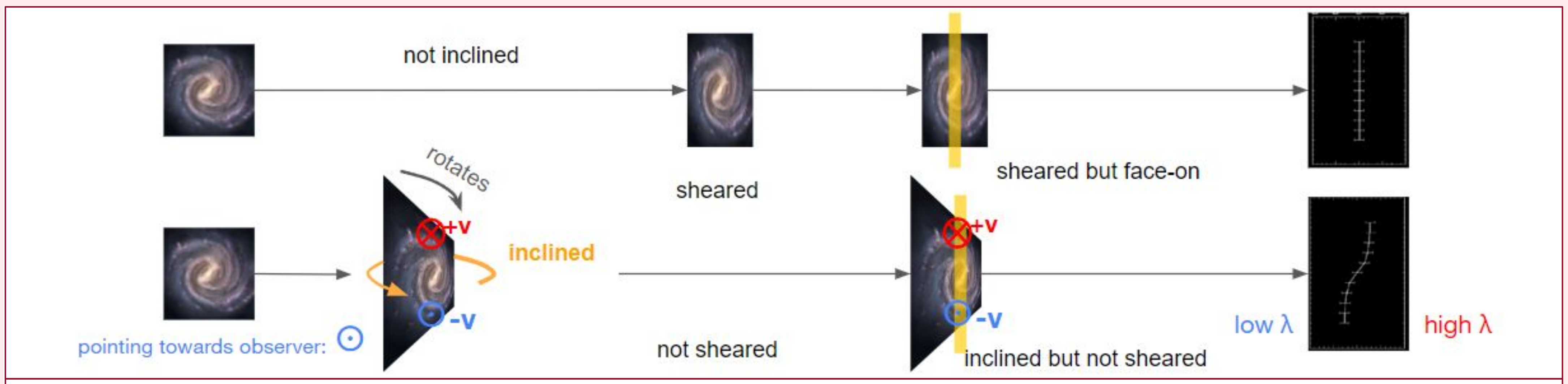


Figure 1. Weak Lensing Signal Noise Formation and Slit-Spectroscopy of Two Cases. Even the original input of upper and lower regimes are both spiral galaxies (Step 1) and observed images are both elliptical (Step 3), we can use emission line shapes from slit-spectroscopy to test the galaxy components' kinematics.

Introduction

Galaxy clusters are massive to become large gravitational lenses that can slightly distort the background galaxy shapes. Such called cosmic shear or “weak lensing” signal is important for constraining the cosmological parameters.

However, it is not sufficient to calculate the galaxy ellipticities of observed galaxy shapes (after lensing) versus intrinsic shapes (before lensing), by only using photometry data and with a shape noise of up to ~26%. It is hard to tell the galaxy's shape is due to:

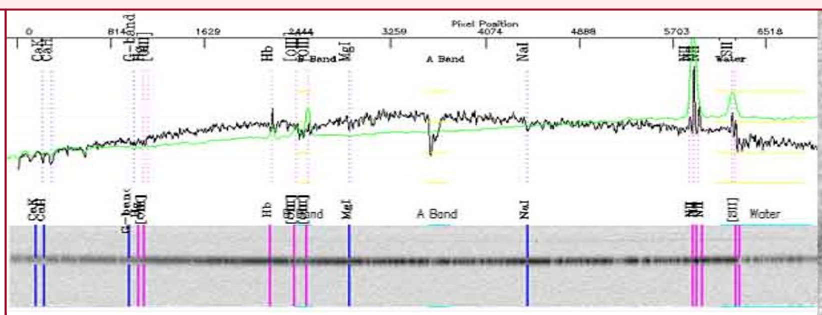
- ❖ an inclination angle along the light of sight, or,
- ❖ it is weak-lensed by cluster

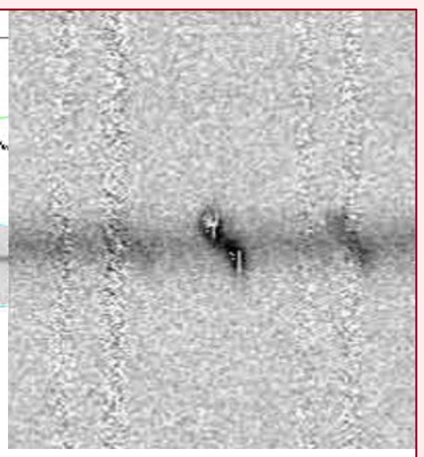
(Velocity) Rotation Curve

- ➢ Take spectrum for a lensed galaxy
- ➢ Use a slit of a position angle
- ➢ Examine emission lines if tilted
- ➢ Obtain light-of-sight rotational speed as a function of galaxy radius

Rotation curves from multiple slit angles can yield a velocity field and a precise intrinsic shape of the galaxy before the weak lensing.

It combines weak lensing with kinematics, which is also called “kinematic lensing” (KL), greatly reducing the shape noise down to ~4% reported from the recent mock observations.





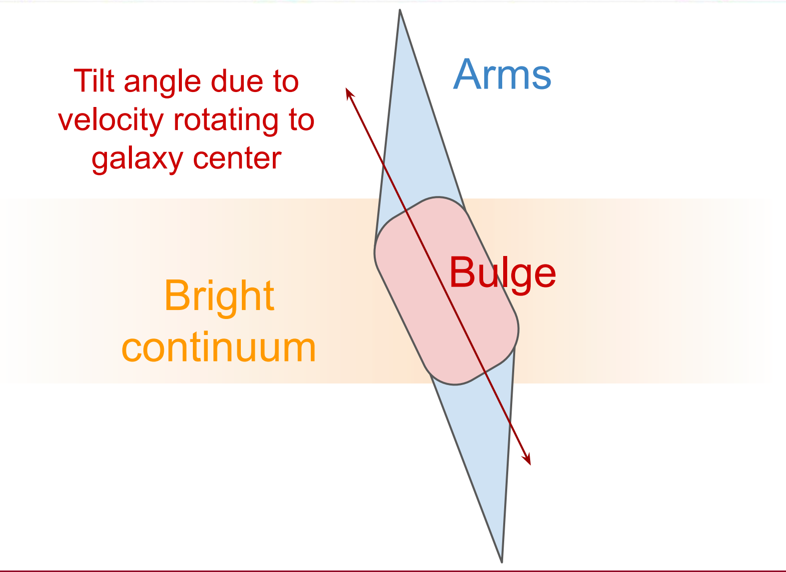


Figure 2. (Upper-left) Example 1D+2D Spectra for Slit #42 in Cluster A611.

Figure 3. (Upper-right) Zoom-in NII, H-alpha, and [SII] emission lines in 2D Spectrum.

Figure 4. (lower) Schematic Illustration of emission line structure caused by galaxy components' kinematics.

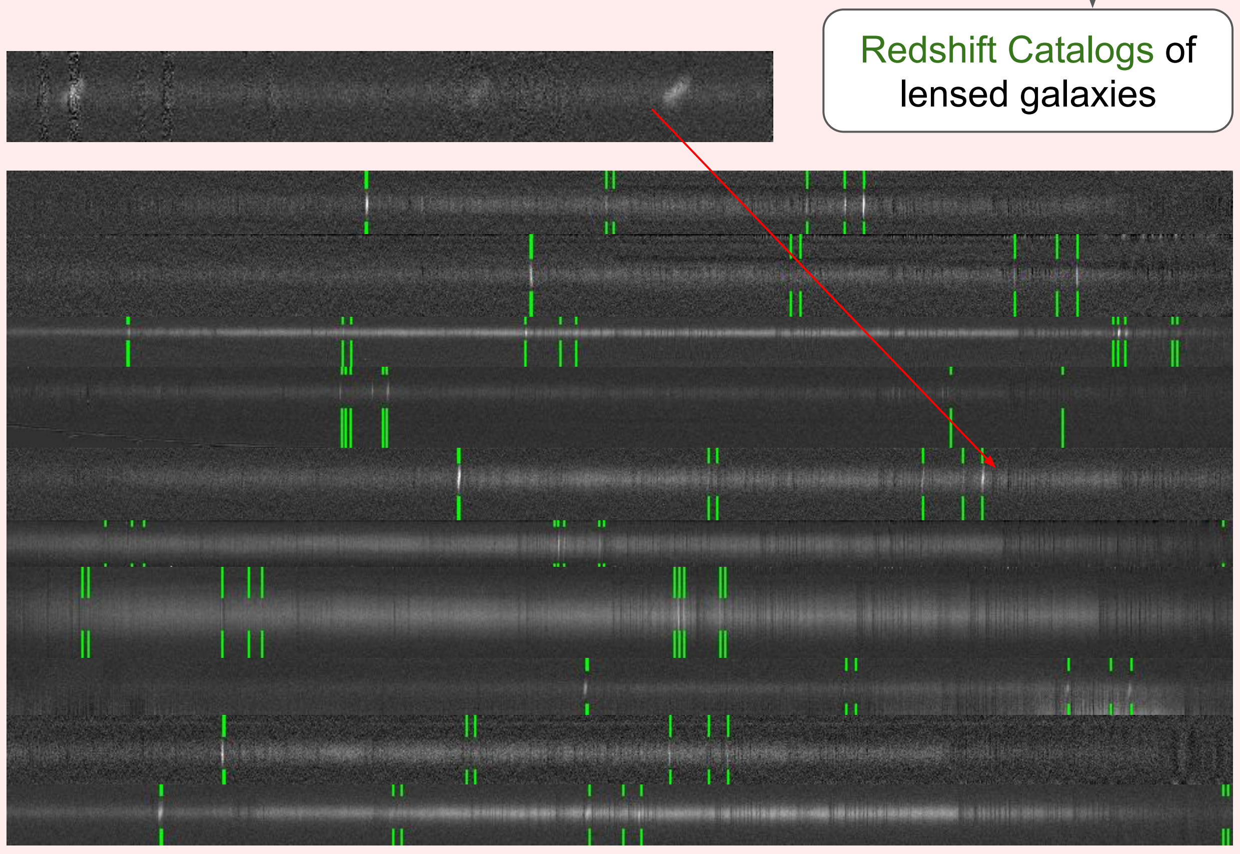
Data

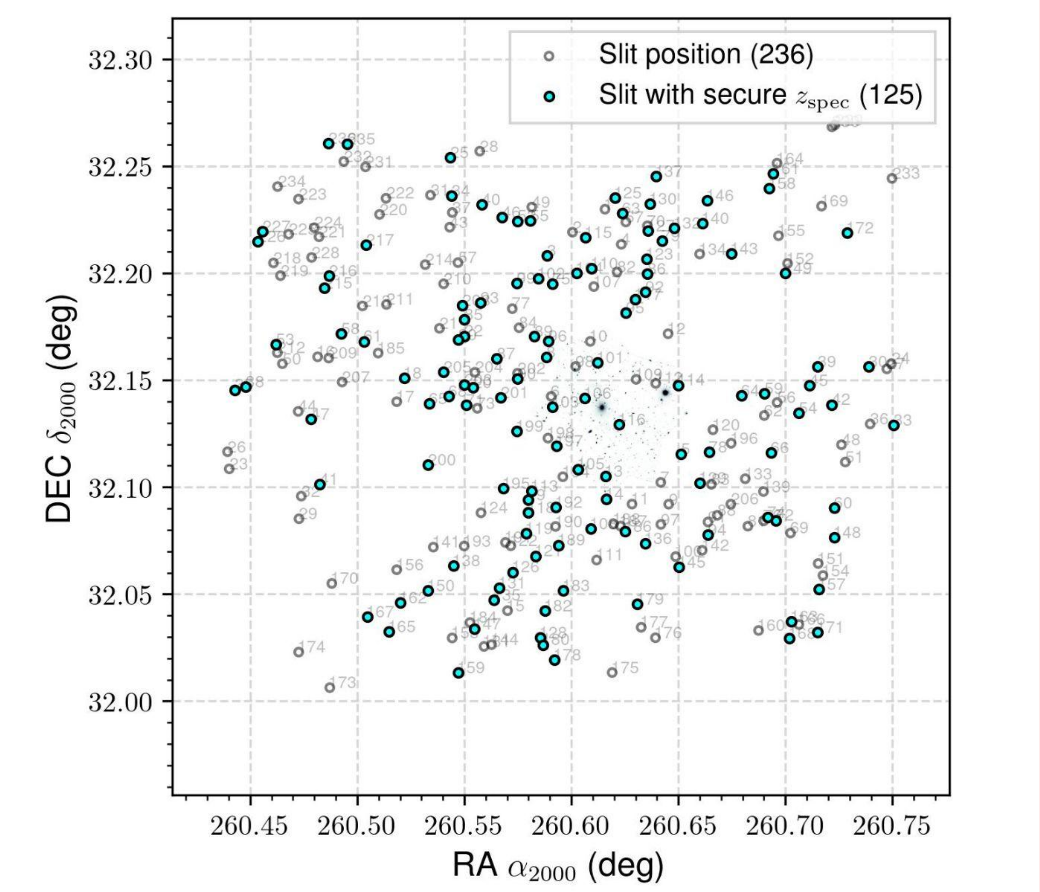
Totally 51 galaxy clusters in Project “Weighing the Giants” with known X-ray weak lensing masses:
Spec: Keck/DEIMOS and VLT/VIMOS spectra + Optical: images of lensed galaxies

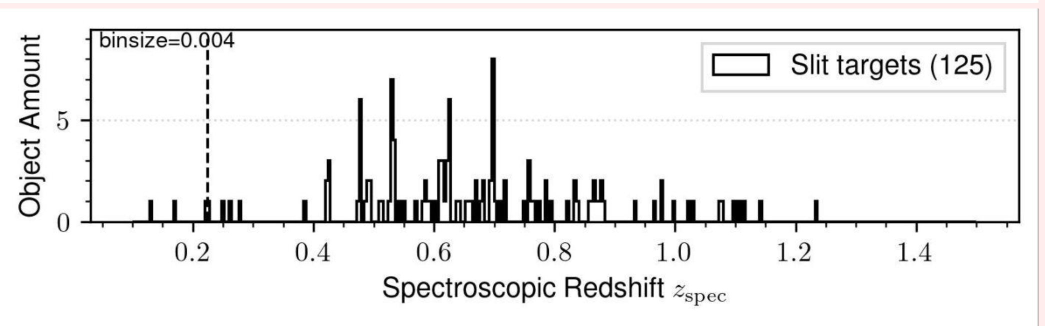
- Spectrum Data from Observatory Archives (e.g. Keck/DEIMOS, VLT-UT3/VIMOS) → Raw spectrum `fits` data → (`PypeIt`) → Wavelength calibrated, coadded spectra on CCD → An original pipeline: `pypeit_to_specpro`
- → assemble 1D+2D spec combos sliced from `PypeIt`'s output → (`SpecPro`) → Rotation curves of emission lines → Galaxy's intrinsic morphology (True inclination angle, trinsic ellipticity) → Provide samples to lensing model training
- assemble 1D+2D spec combos sliced from `PypeIt`'s output → (`SpecPro`) → Redshift Catalogs of lensed galaxies

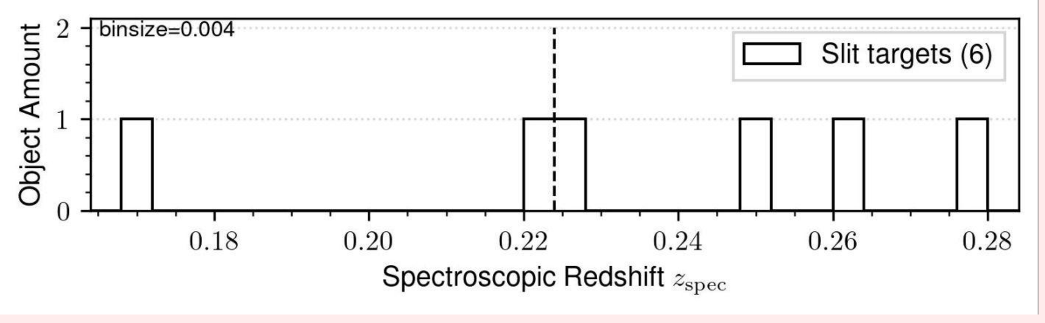
Results

- ★ A few (10+) rotation curves for each of A2261, MACS J1115.8+0129, and MS0451.6-0305 clusters which:
  - ○ Redshifts of galaxies is higher (Δ>0.1) than cluster ⇒ Treat as background ⇒ lensed galaxies
  - ○ Sufficient amount of slit PAs were found to construct velocity field.
- ★ Catalogs of foreground rotation curves for trainings of velocity field recoveries.









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