1. Science Justification

1.1. Cluster Mass Mapping

The mass distribution in galaxy clusters is a crucial test of our cosmological paradigm. Total halo masses probe the amplitude of matter fluctuations and growth of structure in the Universe, and the abundance of substructure within halos is sensitive to the history of hierarchical assembly and potentially the interaction cross section of dark matter (e.g., Natarajan et al. 2002a,b; Voit 2005; Clowe et al. 2006). Gravitational lensing has played an important role in mapping dark matter within halos, primarily by exploiting the distortion of images of background galaxies. On small scales inside lensing clusters, strong distortions produce extended arcs and multiple images enabling the production of detailed mass maps, while on larger scales the distortions are weaker and require averaging the shapes of many background galaxies over a broad area to extract a shear signal.

We propose to map the projected mass distribution in the massive cluster Abell 2261 with a new lensing techinque that uses kinematic measurements of background sources to drastically improve the signal-to-noise (S/N). The typical weak lensing shear signal averaged within the virial radius of a massive cluster ($\gamma_t \sim 0.05$) is small compared to the distribution of intrinsic shapes in imaging (which has scatter $\sigma_\gamma \sim 0.25$). Kinematic information can be used to infer the intrinsic shape and orientation of the background galaxies, potentially reducing the shape noise per galaxy by a factor of ten. This enables S/N $\gtrsim 1$ measurements of shear with individual galaxies. With such precision we will improve the spatial resolution of mass maps and extend the precision of strong lensing out to the weak regime near the virial radius of the cluster. We discuss this technique and its potential for improving both the precision and accuracy of future large-scale lensing experiments in the next section. Additionally, the repeat slit spectra taken for hundreds of sources behind A2261 will provide two-dimensional kinematics of emission line disk galaxies, greatly enhancing the sample size at that redshift for studying evolution of galaxy kinematics and the Tully-Fisher relation (TFR).

1.2. Kinematic Weak Lensing

The utility of kinematic maps for weak lensing was originally described by Blain (2002) and Morales (2006), who forecasted constraints from high S/N, high spatial resolution observations with future radio arrays. The basic idea for the kinematic shear observables is as follows. In an image, a rotating circular disk with some inclination toward the observer has elliptical isophotes. When the image of this galaxy is sheared, the isophotes remain elliptical (in the weak shear limit, $|\gamma_t| \ll 1$) with a new axis ratio and positional angle. New photometric axes are inferred from this ellipse in the sheared image, and information about the original axes is lost. The case is different however, with kinematic measurements. The unsheared circular disk has kinematic axes that are perpendicular to one another and are aligned with the unsheared photometric axes. This cross shape becomes skewed when the velocity map is sheared; the kinematic axes are no longer perpendicular and they are misaligned with the photometric axes inferred from the sheared isophotal ellipse in the imaging data. Figure **??** demonstrates this idea.

Disk galaxies are inclined at random with respect to the line of sight to the observer, so the measured rotation velocity is related to the true circular velocity of the disk by $v_{\rm obs} = v_{\rm circ} \sin i$. Correcting for the effects of inclination has been an important obsevational complication inherent in TFR studies to date. Typically observers model the galaxy as a thin disk and estimate $\sin i$ from the ellipticity of the image.

After inclination correction, estimates for the intrinsic fractional scatter in $v_{\rm circ}$ at fixed luminosity or stellar mass are typically .05 dex or less. If the TFR is regarded as known, then a galaxy's velocity offset from the relation becomes a estimator for its true unlensed ellipticity. Properly weighted, the scatter in the ellipticity estimated this way is only .015 – in other words, knowledge of the disk inclination controls for 95% of the variation in the observed shape of the disk. This quantity is sensitive to measurement errors in $v_{\rm circ}$, as shown in figure 1; in general, rotation curve errors of 10 km/s reduce the disk galaxy shape noise by an order of magnitude.

1.3. A Pilot Study for a Stage V Dark Energy Experiment

Weak gravitational lensing has been widely touted as a powerful probe of cosmology. It is a major science driver for several large imaging surveys, such as the Dark Energy Survey (DES) the Large Synoptic Survey Telescope (LSST), and space missions such as Euclid and the Wide-Field Infrared Survey Telescope (WFIRST). Weak lensing is weak, however, and all current measurements are limited by the scatter in galaxy shapes, which is an order of magnitude or more greater than the typical weak lensing signal. This means that weak lensing analyses must average over every available galaxy image, pushing the analysis to include faint and poorly-resolved galaxies for which unbiased measurements of galaxy shapes are difficult. Precision estimates of galaxy redshifts from photometry is crucial for these analyses, as the current generation of ongoing surveys will entail sample sizes of a few $\times 10^8$ galaxies, which is two orders of magnitude beyond the size of the largest existing spectroscopic samples. Percent-level biases in the photometric redshifts will have a large impact on the error budgets for this next generation of surveys.

Here we propose a pilot study for a new weak lensing measurement technique that uses the Tully-Fisher relation (TFR) to obviate the photo-z and shear calibration problems while offering a very large reduction in the effective lensing noise.

1.4. 2-d Disk Kinematics at $z \sim 0.5$

REFERENCES

Blain, A. W. 2002, ApJ, 570, L51

Clowe, D., Bradač, M., Gonzalez, A. H., Markevitch, M., Randall, S. W., Jones, C., & Zaritsky, D. 2006, ApJ, 648, L109

Morales, M. F. 2006, ApJ, 650, L21

Natarajan, P., Kneib, J.-P., & Smail, I. 2002a, ApJ, 580, L11

Natarajan, P., Loeb, A., Kneib, J.-P., & Smail, I. 2002b, ApJ, 580, L17

Voit, G. M. 2005, Reviews of Modern Physics, 77, 207

2. Technical Remarks

2.1. Targets and Exposures

2.2. Backup Program

2.3. Supplementary Observations

2.4. Status of Previously Approved Keck Programs

2.5. Path to Science from Observations

2.6. Technical Concerns

2.7. Experience and Publications

2.8. Resources and Publication Timescale

This preprint was prepared with the AAS LaTeX macros v5.2.

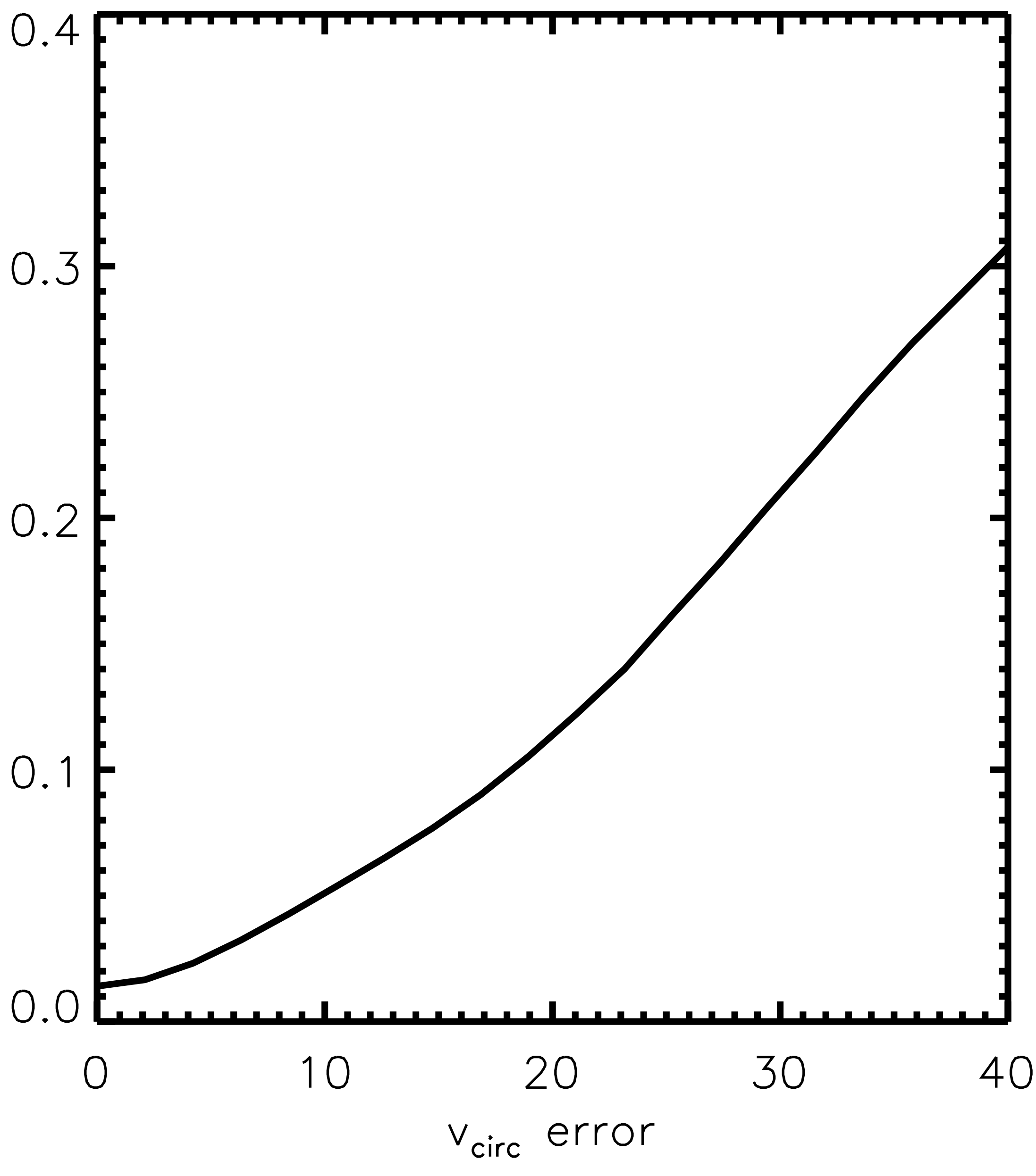

Fig. 1.— Effective shape noise σ_{TF} as a function of the measurement error on the disk circular velocity.