1 Science Justification

Weak Lensing with the Tully-Fisher Relation. 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.

Here we propose a pilot study for a new weak lensing measurement technique that uses the Tully-Fisher relation (TFR) to produce a very large reduction to the lensing noise. The TFR is a tight empirical correlation between the luminosity and rotation velocity ($v_{\rm circ}$ of disk galaxies. These 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 known, however, then a galaxy's velocity offset from the TFR is a estimator for its true unlensed ellipticity**. Properly weighted, the scatter in the ellipticity estimated this way is reduced from 0.4 to .015 – in other words, knowledge of the disk inclination controls for 95% of the variation in the observed shape of the disk. This reduction is a necessary consequence of the small scatter observed in the TFR after inclination corrections. The amount of this reduction is sensitive to measurement errors in $v_{\rm circ}$, as shown in figure 1; in general, keeping rotation curve measurement errors less than 10 km/s reduces the disk galaxy shape noise by an order of magnitude. With this level of noise, a spectroscopic survey with a target density of 1 galaxy arcmin^{-2} **will substantially exceed in weak lensing signal-to-noise any existing or planned imaging survey, from ground or space**. Such a spectroscopic survey would also eliminate the need to rely on photometric redshifts for background sources, removing a major source of systematic error in lensing analyses.

1.1 Abell 2261: Precision Lensing of a Dissociative Galaxy Cluster

The reduction in the shape noise promised by this technique will substantially improve weak lensing measurements of the mass distribution in massive galaxy clusters. For the case of Abell 2261, the proposed target,

1.2 A Pilot Study for a Stage V Dark Energy Experiment

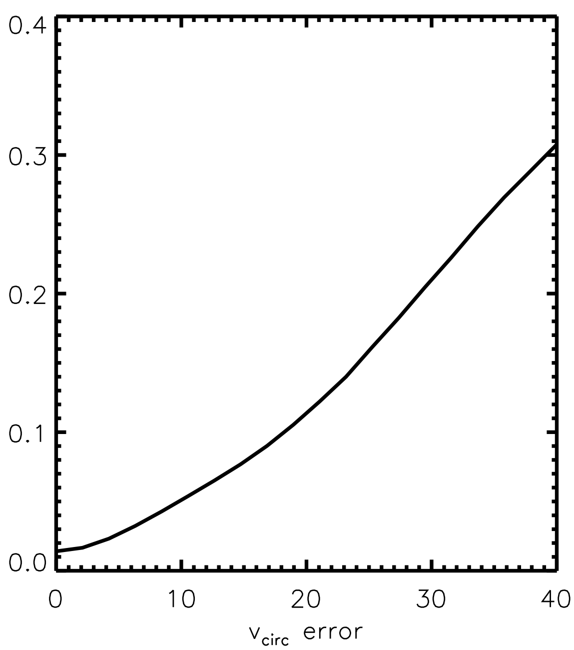

Figure 1: Effective shape noise σ_{TF} as a function of the measurement error on the disk circular velocity.