NOAO Observing Proposal
Date: September 20, 2007

Panel: *For office use.*
Category: Galactic - Other

Observing high red shift galaxies for Tully Fisher relationship

PI: Steven Janowiecki **Status:** U **Affil.:** CWRU
11311 Euclid Ave., Cleveland, OH 44106 USA
Email: spj4@cwru.edu Phone: ________ FAX: ________

Abstract of Scientific Justification *(will be made publicly available for accepted proposals)*:

We propose to study the Tully-Fisher (TF) relationship over a range of red shifts to better calibrate this correlation for future use. This relation in spiral galaxies between rotational velocity and absolute luminosity has been well studied and is typically employed to find distances to galaxies with measured spectra. In studying the TF relation up to a redshift of 1 we can better calibrate it and make it useful for a wider range of observations. Higher red shifts not only correspond to greater distances, but also earlier times. Thus we will also be examining the effects of evolution on spiral galaxies. Through the TF relationship we get an independent distance estimate and a look into kinematic evolution of these galaxies. Our sample of 10 galaxies has already been photometrically observed and fully reduced. However, since the TF relationship requires kinematic information, we are requesting 4 nights on the 4m to do spectroscopy on each galaxy. With this spectroscopic data, we will complete our study and determine the effects of redshift on the TF relationship.

Summary of observing runs requested for this project

Run	Telescope	Instrument	No. Nights	Moon	Optimal months	Accept. months
1	KP-4m	Spectrograph 1	4		Sep - Nov	Sep - Nov
2						
3						
4						
5						
6						

Scheduling constraints and non-usable dates *(up to four lines)*.

Scientific Justification *Be sure to include overall significance to astronomy. For standard proposals limit text to one page with figures, captions and references on no more than two additional pages.*

The Tully-Fisher (TF) relationship (Tully & Fisher 1977) is a widely used and powerful tool that relates the intrinsic luminosities and rotational velocities of spiral galaxies. These parameters correlate tightly enough that, with a zero point and slope for the relationship, measurements of rotational velocities can yield estimates for intrinsic luminosities. A distance to the spiral galaxy can be obtained by comparing this intrinsic luminosity with an observed apparent magnitude. Since independent estimates of distance are few, this relationship provides an important means for studying galaxies. It is not simply a rule of thumb, though, as it has a clear physical basis. In spiral galaxies the stars are orbiting the center, and maintain these orbits due to their motion. This clear and organized rotation dynamically supports the galaxy and allows the assumption that rotational velocity is coupled with dynamical mass (the mass of the stars that are orbiting in the galaxy). These stars also have certain mass to light ratios, which correlate the estimate of mass with an estimate of light emitted from that mass. The TF relationship is the combination of these connections: a measure of rotational velocity yields an estimate of luminosity.

As mentioned, this relationship has a zero point and slope which need to be calibrated. These calibrations are most useful when they are performed on a particular sub-sample of spiral galaxies, such as distant galaxies in clusters (Bamford et al 2005), distant galaxies in the field (Bamford et al 2006), as well as nearby galaxies. (In a large sample, there are so many sources of intrinsic scatter that the relationship is very hard to convincingly fit.) For the local galaxy sample, the distance to each is known independently of TF parameters, i.e. from Cepheids or Supernovae, etc. It is from these local well-measured galaxies that the zero point and slope of the TF relationship are established, and then are applied to more distant galaxies to derive their distances (Pierce & Tully 1992). For the galaxies in clusters, the dynamic history of each individual galaxy plays a significant role in its current observed TF relationship. If a galaxy is perturbed or has recently interacted, it will not be entirely supported by rotation, and the connection between rotational velocity and mass will be weakened. There will still be a correlation, but the scatter in the fit will be much greater for a sample of galaxies in a cluster.

Examining galaxies at high reds hifts provides not only a very distant sample but also a less-evolved sample, since objects at higher redshift are generally younger than objects at a redshift z = 0. Thus in our study of high red shift galaxies we will be separating effects caused by the distance and effects resulting from the different states of evolution. Both of these phenomena will change the slope and zero point, but in predictable ways. Bohm et al. (2004) observes that the TF slope gets shallower at $z \sim 0.5$, and accounts for this with a different mass to light ratio, which results from the galaxy being less evolved. Similarly, galaxies observed at great distances will begin to be noticeably altered by cosmological effects. While these effects will be dominated by the evolutionary changes, there may still be some extra reddening or other distortions in the observations that are redshift dependent. This will become obvious in our reduction and analysis.

In order to better study the effects of redshift on the TF relation, we have selected 10 galaxies to observe, with red shifts between 0 and 1.1. There is a chance that the galaxies selected will be biased at higher red shifts, due to the fact that galaxies get dimmer. In selecting galaxies at high red shifts, there is a bias toward picking the brighter galaxies. Thus, if we observe a trend as a function of redshift, it may only be a trend that goes with increasing luminosity, and not actually red shift. Our chosen sample of galaxies was selected to avoid this bias. Similarly, we may encounter a bias toward star-forming galaxies, as those, too, are brighter and more likely to be observed. Still, we will at least be able place an upper limit on the TF relation for this sample of galaxies, even if they are only representative of the bright end and not a uniform sample.

For our selection of galaxies, we have already obtained high quality optical imaging, and have derived the necessary inclination angles (to correct for projected rotation velocity, discussed below) and apparent magnitudes (Janowiecki 2007). All that remains is to obtain a spectrum for each galaxy in order to compute its rotation velocity. While this computation is a well-established procedure for nearby galaxies, it becomes a more complicated problem at high redshifts where the galaxies are quite small on the sky. Chiu et al (2007) obtained similar spectra and Figure 1 shows some of their imaging and spectral data for reference. The example spectra are for a particular emission line along a alit through the galaxy. It is clear in the spectra that one side of the galaxy is rotating toward us (blue-shifted, relative to the galaxy) and the other side is rotating away from us (red-shifted, galaxy relative). However, there is not enough resolution to simply find the rotation velocity as a function of radius and obtain a rotation curve, so we instead rely on an alternative method of analysis. The spectral data is processed with a routine developed by Simard & Pritchet (1998) called ELFIT2D. It creates synthetic emission line models and guesses at rotation curves until the observed spectra is reproduced. This technique has been successfully applied in similar data sets (Chiu et al 2007). These rotation curves asymptote (or reach their maximum at) the value we use for rotation velocity. Once this rotation velocity has been computed from the spectra, we still have to correct it to account for the observed inclination of the galaxy. The spectra only measure the component of velocity that is radial to us, and not the true rotation velocity. As a galaxy is tilted further away from us, the projected velocity scales as the sine of the inclination angle until it is face on, and has no projected rotation velocity. In some of the galaxies that are nearly edge on, estimates will be made for the absorption from dust within the galaxy, which would dim the galaxy and skew the TF relationship.

The spectra derive from ELFIT2d will also permit us to re-compute red shifts for the sample, providing another distance measure and allowing us to look for redshift trends in the TF relation. Bamford et al. (2006) has undertaken a similar study of TF slope as a function of redshift, and their results are unable to make a claim about any redshift dependence (Figure 2). Other groups have claimed to find significant effects that depend on the evolution (as determined through red shift), but there are many publications on both sides of the issue (Vogt et al 1997 or Simard & Pritchet 1998). We expect our results to have smaller uncertainties and to more tightly constrain the TF relationship at high redshifts, in order to make a stronger statement about the TF slope's dependence of redshift. Still, much of the scatter in this relation is not a result of instrumental uncertainties, but rather is from physical processes in the galaxies, such as the evolution, perturbation, lack of total rotation support, or geometric alignment factors. Still, our calibration of the TF slope and zero point will server first as a tool to be used in future high redshift observations as a distance estimate, and will also help reveal more of the kinematics of spiral galaxies at various states of evolution in a variety of environments.

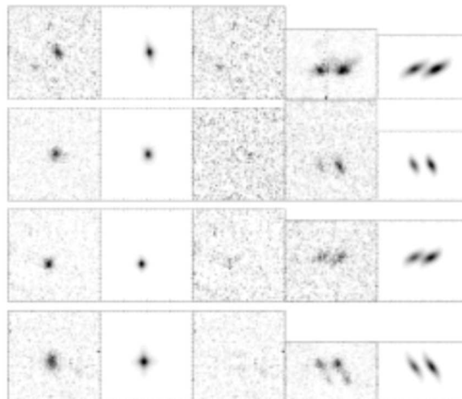

Figure 1: Imaging and spectral observations of similar galaxies to those in this proposal. Columns: (a) optical image, (b) modelled galaxy, (c) model-subtracted, (d) observed spectra, (e) best fit synthetic model. The optical images are 12" x 12". Both spectra are 9" (25 Å) across and contain the flux at the 3727 Å[OII line] best fit. While they are not identical to traditional rotation curves, the kinematic information can still be extracted from them. These galxies are at redshifts around 0.8. (Chiu et al. 2007, Figure 2)

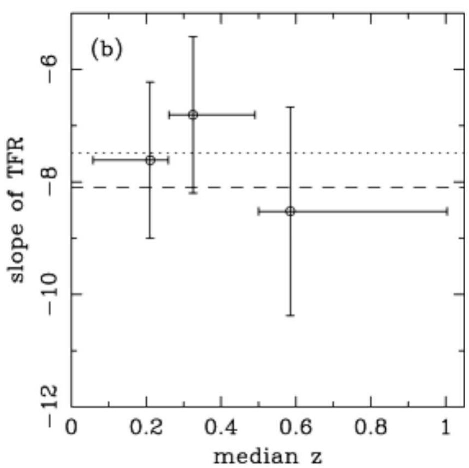

Figure 2: TF slope as a function of (binned) redshift. While this graph does not show a significant trend over redshift, our observations will have improved sensitivity and less uncertainty. (Bamford et al. 2006, Figure 6b)

References

Bamford, S. P., Milvang-Jensen, B., Aragon-Salamanca, A., Simard, L., 2005, MNRAS, 361, 109

Bamford, S. P., Aragon-Salamanca, A.,Milvang-Jensen, B., 2006, MNRAS, 366, 308

Bohm, A., et al. 2004, A&A, 420, 97

Chiu, K., Bamford, S. P., Bunker, A., 2007, MNRAS, 377, 806

Janowiecki, S. P., 2007, private communication

Pierce, M. J., Tully, R. B., 1992, ApJ, 387, 47

Simard L., Pritchet C.J., 1998, ApJ, 505, 96

Tully R. B., Fisher J.R., 1977, AAP, 54, 661

Vogt, N. P. et al, 1997, ApJ, 479, L121

Observing Run Details for Run 1:

Technical Description *Describe the observations to be made during this observing run. Justify the specific telescope, the number of nights, the instrument, and the lunar phase. List objects, coordinates, and magnitudes (or surface brightness, if appropriate) in the Target Tables section below (required for queue and Gemini runs).*

The targets for this observation are 10 galaxies from the DEEP2 spectroscopic survey (Cuillandre et al 2001), following the selection criteria of Chiu et al (2007). They are inclined enough to prevent most of the interference from dust, but not inclined so much as to alter the inclination correction (from projection) to the rotation velocity measurement. These galaxies are at redshifts between 0.77 and 1.1, with apparent I-band magnitudes from 21 to 21.6, and angular sizes between 2 and 4 arcseconds. In order to obtain a S/N of ~ 10, we will expose for 3 hours on each galaxy, using Setup 2 on the spectrograph.

Cullandre, J.-C. et al., 2001, in Clowes R., Adamson A., Bromage G., eds, ASP Conf. Ser. Vol. 232, The New Era of Wide Field Astronomy. Astron. Soc. Poc. San Francisco, p. 398

Instrument Configuration

Filters:	Slit: 1”	Fiber cable:
Grating/grism:	Multislit:	Corrector:
Order:	λ_{start}:	Collimator:
Cross disperser:	λ_{end}:	Atmos. disp. corr.: