NOAO Observing Proposal
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Panel: *For office use.*
Category: Galactic - Other

Observing high redshift galaxies for Tully Fisher relationship

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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 redshifts to better calibrate this correlation for future use and to study the evolution of galaxies as a function of lookback time (as determined by redshift). 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 redshifts 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 in patterns such as spiral arms. 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, their distances are known independently, 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. The scatter in the correlation will be much greater for cluster galaxies.

Examining galaxies at high redshifts 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 redshift 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. As the spiral galaxy evolves, it increases its metallicity, and its mass to light ratio increases. This effect is particularly strong for high-mass spirals, which are the type we are more likely to observe at high redshift. Similarly, galaxies observed at great distances will begin to be noticeably altered by cosmological effects. These effects may necessitate a K correction to make sure the measured flux is correct, as well as the evolution correction mentioned above, since galaxies will also get redder with age. While these overall observational 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 redshifts between 0.77 and 1.1. There is a chance that the galaxies selected will be biased at higher redshifts, due to the fact that galaxies appear dimmer at greater distances, and so it is easier to see the brighter galaxies. Thus, if we observe a trend as a function of redshift, it may only be a trend as a function of luminosity, and not actually redshift. Our chosen sample of galaxies was selected to avoid this bias by picking a sample with much greater variation in brightnesses than in redshifts. Similarly, we may encounter a bias toward star-forming galaxies, as those are also brighter and more likely to be observed. Still, we will 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 small on the sky. Chiu et al (2007) observed similar high redshift galaxies and Figure 1 shows some of their imaging and spectral data for reference. Their spectra are for a particular emission line along a slit through the galaxy. It is clear from 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 fit the rotation velocity as a function of radius and obtain a rotation curve, so we instead rely on an alternative method of analysis. The spectra are processed with a routine developed by Simard & Pritchet (1998) called ELFIT2D. It creates synthetic emission line models and tries rotation curves until the observed spectra are reproduced. This technique has been successfully applied in similar data sets (Chiu et al 2007). These generated rotation curves will asymptote (or reach their maximum at) the value we use for rotation velocity. Once this rotation velocity has been computed, we still have to correct it to account for the inclination of the galaxy relative to us. The spectra only measure the component of velocity that is radial to us, and not the true circular 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 also be made for the absorption from dust within the galaxy, which would dim the appearance of the galaxy and skew the TF relationship.

The spectra derived from ELFIT2d will also permit us to re-compute redshifts 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 redshift), but there are many publications on both sides of the issue (Vogt et al 1997 or Simard & Pritchet 1998). These evolution effects will be especially pronounced in our high redshift galaxies, since they will be substantially less evolved ($z \sim 0.5$ corresponds to a lookback time of almost 8 Gyrs, assuming standard CDM cosmology). With this very early look into these galaxies, the high redshift TF relation should reflect the changing properties of the galaxies, especially the different mass to light ratio at younger ages. The bright young stars in the earlier galaxies will emit more light per mass than the more evolved galaxies will. Our TF fit will show how these galaxies are evolving, in terms of their mass to light ratio and their kinematic structure - the key parts of the TF relation

We expect our results to have smaller uncertainties than previous work 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 or measurement uncertainties, but rather is from physical processes in the galaxies, such as the evolution, perturbation, lack of total rotation support, or geometric alignment factors. Even so, our calibration of the TF slope and zero point will be useful 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.

References

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

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

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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. The galaxies range in rotational velocities up to about 200 km/s. In order to obtain velocity uncertainties around 20 km/s (comparable with Chiu et al (2007)), this S/N will be acceptable, as it yields a velocity accuracy of about 20 or 25 km/s.

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.: