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THE LUMINOSITY-LINEWIDTH RELATION AS A PROBE OF THE EVOLUTION OF FIELD GALAXIES

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I. SUMMARY

The nature of distant faint blue field galaxies remains a mystery, despite the fact that much attention has been devoted to this subject in the last decade. Galaxy counts, particularly those in the optical and near ultraviolet bandpasses, have been demonstrated to be well in excess of those expected in the 'no-evolution' scenario. This has usually been taken to imply that galaxies were brighter in the past, presumably due to a higher rate of star formation. More recently, redshift surveys of galaxies as faint as $B \sim 24$ have shown that the mean redshift of faint blue galaxies is *lower* than that predicted by standard evolutionary models (designed to fit the galaxy counts). The galaxy number count data and redshift data suggest that evolutionary effects are most prominent at the faint end of the galaxy luminosity function. While these data constrain the form of evolution of the overall luminosity function, they do not constrain evolution in individual galaxies.

We are carrying out a series of observations as part of a long-term program aimed at a better understanding of the nature and amount of luminosity evolution in individual galaxies. Our study uses the luminosity-linewidth relation (Tully-Fisher relation) for disk galaxies as a tool to study luminosity evolution. Several studies of a related nature are being carried out by other groups. A specific experiment to test a "no-evolution" hypothesis is presented here.

We have used the AUTOFIB multifibre spectrograph on the 4-metre Anglo-Australian Telescope (AAT) and the Rutgers Fabry-Perot imager on the Cerro Tololo Interamerican Observatory (CTIO) 4-metre telescope to measure the internal kinematics of a representative sample of faint blue field galaxies in the redshift range $z = 0.15$–0.4. The emission line profiles of [OII] and [OIII] in a typical sample galaxy are significantly broader than the instrumental resolution (100–120 km s^{-1}), and it is possible to make a reliable determination of the linewidth. Detailed and realistic simulations based on the properties of nearby, low-luminosity spirals are used to convert the measured linewidth into an estimate of the characteristic rotation speed, making statistical corrections for the effects of inclination, non-uniform distribution of ionized gas, rotation curve shape, finite fibre aperture, etc.. The (corrected) mean characteristic rotation speed for our distant galaxy sample is compared to the mean rotation speed of local galaxies of comparable blue luminosity and colour. The typical galaxy in our distant sample has a B-band luminosity of about $0.25\,L^*$ and a colour that corresponds to the Sb–Sd/Im range of Hubble types. Details of the AUTOFIB fibre spectroscopic study are described by Rix et al. (1996). Follow-up deep near infrared imaging with the 10-metre Keck telescope+NIRC combination and high angular resolution imaging with the Hubble Space Telescope's WFPC2 are being used to determine the structural and orientation parameters of galaxies on an individual basis. This information is being combined with the spatially resolved CTIO Fabry-Perot data to study the internal kinematics of distant galaxies (Ing et al. 1996).

The two main questions addressed by these (preliminary studies) are:

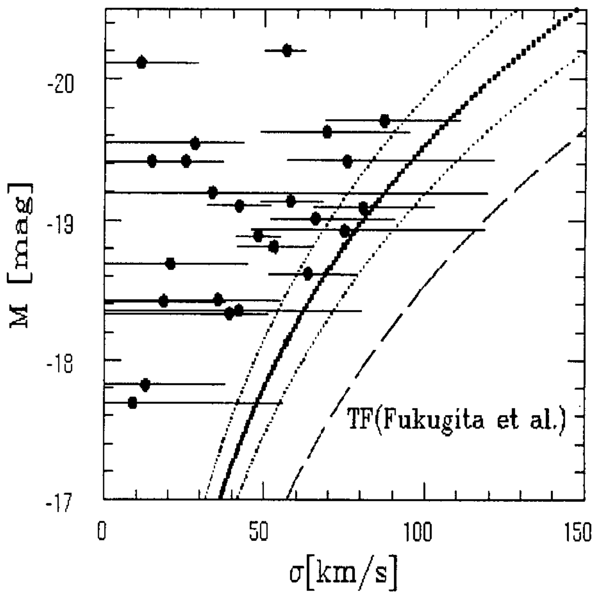

Fig. 1.— Integrated linewidth vs absolute magnitude for a complete sample of $z \sim 0.3$ blue field galaxies from our pilot AUTOFIB study (Rix et al. 1996). The 'best fit' relation (corrected for measurement bias, bold line), is compared to the local relation (dashed line).

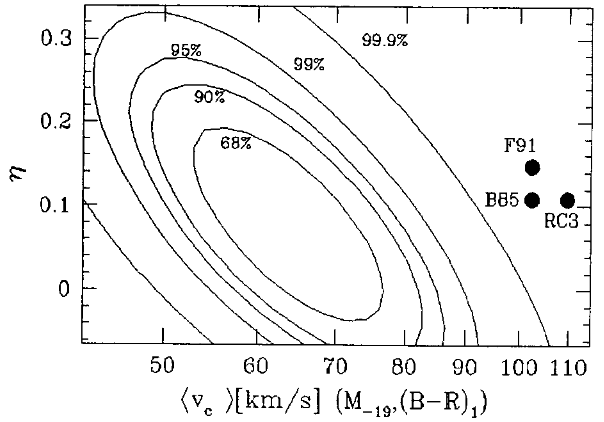

Fig. 2.— Likelihood contours for $v_c(-19,1)$, the mean rotation speed of galaxies with M_B=−19 and B–R=1, and η, the slope of the linewidth–luminosity relation. The corrected rotation speed of $\langle z\rangle$=0.3 galaxies is 35% smaller than that of local galaxies of comparable luminosity, $v_{\rm circ}$ = 100 km/s (bold dots).

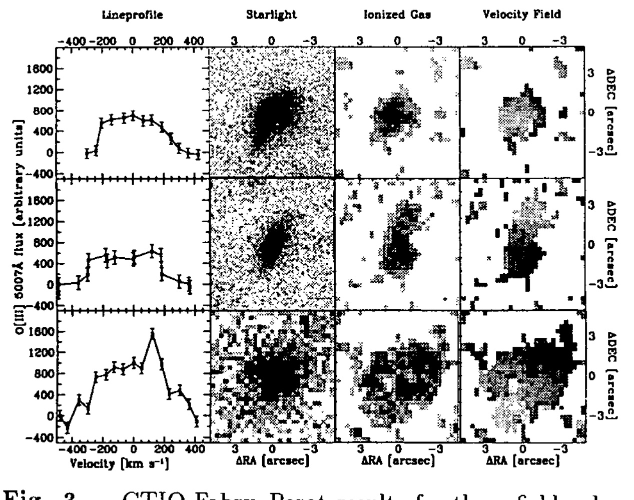

Fig. 3.— CTIO Fabry–Perot results for three field galaxies at $z \sim 0.35$: **L→R**—Global [OIII] emission line profile; Starlight: Keck/NIRC H-band image (top, middle) and CTIO continuum image (bottom); Spatial distribution of [OIII] flux; and [OIII] velocity maps. Light and dark colors in the velocity fields represent redshifted and blueshifted gas, respectively.

1. *Do galaxies of a given luminosity and colour have the same characteristic rotation speed in the distant and local Universe?* The distant galaxies in our AUTOFIB sample have a mean characteristic rotation speed of $\sim$ 70 km s^{-1} after correction for measurement bias (Fig. 1); this is inconsistent with the characteristic rotation speed of local galaxies of comparable photometric properties (105 km s^{-1}) at the > 99% significance level (Fig. 2). A straightforward explanation for this discrepancy is that faint blue galaxies were about 1–1.5 mag brighter (in the B band) at $z \sim 0.25$ than their present-day counterparts.

2. *What is the nature of the internal kinematics of faint field galaxies?* The linewidths of these faint galaxies appear to be dominated by the global disk rotation. The larger galaxies in our sample are about 2″–5″ in diameter so one can get direct insight into the nature of their internal velocity field from the $\sim$ 1″ seeing CTIO Fabry-Perot data. A montage of Fabry-Perot data is shown in Fig. 3. The linewidths are too large (by 5σ) to be caused by turbulence in giant HII regions.

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