DISTANT COMPACT NARROW EMISSION LINE GALAXIES AS PROGENITORS OF TODAY'S SPHEROIDAL GALAXIES

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1. Introduction

Dwarf galaxies at high redshifts are important to study for a variety of reasons. By dwarf, we mean galaxies with low-mass, though galaxies with low-luminosities or small sizes are also commonly referred to as dwarfs. Several groups have suggested that such galaxies may be major contributors to faint blue galaxies, whose nature remains unclear. Dwarfs are viable candidates for faint blue galaxies if many undergo strong bursts of star-formation at redshifts $z \sim 1$ (Babul and Ferguson 1996) or even lower redshifts $z \sim 0.3$ (Cowie, Songaila, and Hu 1991; Broadhurst et al. 1988) and fade or disappear by today; if they have a much steeper luminosity function (Driver et al. 1994) than generally adopted in faint galaxy models; or if they represent small pre-merger fragments of larger galaxies today (Guiderdoni and Rocca-Volmerange 1990; Broadhurst, Ellis, and Glazebrook 1992), as might be expected in standard cold dark matter models with hierarchical galaxy formation.

2. Observations

As one approach to find distant dwarfs, we have been studying a sample of distant, very compact galaxies. They were originally discovered serendipitously as part of a survey for QSO's, with candidates selected on the basis of being stellar-like in apparent size (i.e., unresolved on ground-based images) and of having colors atypical of Galactic stars (Koo and Kron 1988). These candidates had very blue colors, and from low-resolution spectra gathered at Kitt Peak National Observatory, they were found to have moderate redshifts ($0.1 < z < 0.7$) and thus luminosities close to that of typical (L^*) galaxies. Since they had very strong, narrow emission lines more indicative of active star formation than of AGN's, we have dubbed these objects as compact narrow emission line galaxies (CNELG).

More recently, we have exploited the Wide Field Cameras (I and II) on the Hubble Space Telescope to measure their tiny sizes and to examine the morphology of CNELG's (Koo et al 1994, Guzmán et al. 1996, Guzmán et al. 1997b). With a spectral resolution of 8 $\mathrm{km\,s^{-1}}$ and using the Keck 10-m Telescope, the HIRES echelle spectrograph (Vogt et al. 1994) provides the most powerful diagnostic, namely high resolution kinematics. The vast majority of CNELG spectra reveal very narrow velocity widths of 30-70 $\mathrm{km\,s^{-1}}$ in the strong emission lines (Koo et al. 1995). Although winds, dust obscuration, and poor representation of the gravitational potential by the luminous star formation regions may all invalidate the use of the emission line widths for probing the gravitational potential, the available data to date shows a fairly tight ratio of 0.7 +/- 0.1 between such optical line-width measures and radio measures of HI motions (Telles and Terlevich 1993). The HI kinematics presumably sample most of the true potential. Making the assumption that our line widths, after an upward correction of 40%, are meaningful measures of the true potential, and when combined with HST size data, we are able to obtain a direct measure of mass to determine whether they are low-mass dwarfs or more massive but very compact galaxies.

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3. Results

We now highlight the key findings of our CNELG project. Despite their relatively high luminosities ($M_B \sim -21$), CNELG's are found to be genuine dwarfs, i.e., with low masses of about 10^9 $M_\odot$ or 1% that of equally luminous galaxies. Moreover, HST data indicate that their half-light radii of 0.3 to 0.4 arcsecs correspond to 1-3 kpc, again qualifying CNELGs as dwarfs by their sizes. Although CNELGs are nominally some of the best candidates for the bursting dwarfs proposed by Babul and Ferguson (1996), most CNELGs are brighter than the most luminous of the predicted bursting dwarfs by nearly a factor 10.

So what are CNELGs? To decipher their nature and relationship to various types of galaxy classes, their basic galaxy properties of luminosity, size, surface brightness, velocity dispersions, mass, M/L, etc., have been compared to that found for known local populations of galaxies. Evidence from these scaling relations are then combined with line ratios and strengths and very blue colors that support a strong burst of star formation; radial profiles that resemble exponentials; redshifts that imply a wide range of lookback times of several to many Gyr; and rough volume densities of about 1% of galaxies. In other words, a consistent picture emerges. We find that CNELGs are not blue compact dwarfs, clumpy irregulars, or starbursts, but resemble instead the more luminous and compact subset of the class known as H II galaxies. As discussed by Guzmán (in these proceedings), the CNELGs also appear to be a subset of the much larger pool of faint, blue, high surface brightness galaxies selected from the Hubble Deep Field Flanking Fields and studied by Phillips et al. (1997) and Guzmán et al. (1997a). The CNELGs may also be the lower-luminosity counterparts to the compact galaxies found at very high redshifts $z \sim 3$ by Steidel et al. (1996) and Lowenthal et al. (1997). Assuming that the past integrated star formation does not overwhelm the new stars, CNELGs are expected to fade by several magnitudes. This fading places the CNELGs squarely on top of the locations of the spheroidals in the parameters of luminosity vs. size or surface brightness vs. velocity width (Koo et al. 1995; Guzmán et al. 1996)

4. Summary

Kormendy and Bender (1994) have highlighted the importance and mystery of the origin of spheroidal galaxies like NGC 205, while Skillman and Bender (1995) have emphasized a "crisis" in understanding why some low mass systems become or remain irregulars while others become spheroidals. Our HST and Keck work on CNELGs, which have luminosities comparable to that of Andromeda but tiny sizes and *masses* like that of its companion NGC 205, strongly support the possibility that some, if not all, of these distant, strongly-starbursting dwarfs will eject their remaining gas and fade to become today's spheroidals like NGC 205. The underlying physical cause for the intense starburst remains, however, a puzzle.

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