CHARACTERIZING DISTANT BLUE GALAXIES WITH HST IMAGES AND KECK SPECTRA.

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Abstract. Keck spectra and HST images have been used to derive characteristic velocity and length scales for an enigmatic component of the faint, blue, field galaxy population: the compact, narrow emission-line galaxies (CNELGs). These galaxies are very luminous, but have been found to be quite low mass systems (with typical masses $\sim 10^9$ $M_\odot$). Their blue colors and strong emission lines indicate that they are undergoing a major burst of star formation. Following the completion of their current burst they will fade, becoming, in the absence of further major bursts, objects very similar to contemporary spheroidal galaxies. With mean sizes $R_e \sim 1.4$ kpc and Gaussian velocity profiles with mean $\sigma = 45$ km s^{-1}, the length scales and velocity widths of CNELGs are also quite consistent with the measured length scales and velocity widths of current spheroidals.

1. Introduction

Studies of distant galaxies have undergone a revolution in the last few years. Examples are the striking results of the deep, distant galaxy survey by Lilly and Le Fèvre and their collaborators (see Lilly, this conference), and the superb images being obtained from HST and the WFPC2 (see Dickinson, this conference). New large telescopes like Keck also allow us to measure velocity widths in distant galaxies.

The blue galaxies that have been studied at Keck to derive velocity widths, and imaged with HST to provide structural length scales, are members of a set of objects known as compact, narrow emission-line galaxies (CNELGs) first identified by Koo and Kron (1988). Those studied to date typically have redshifts $z \sim 0.1 - 0.7$, and were highlighted because of their non-stellar colors, and their unusually small size for galaxies (they are typically unresolved on 4-m survey plates taken in 1-2$''$ seeing).

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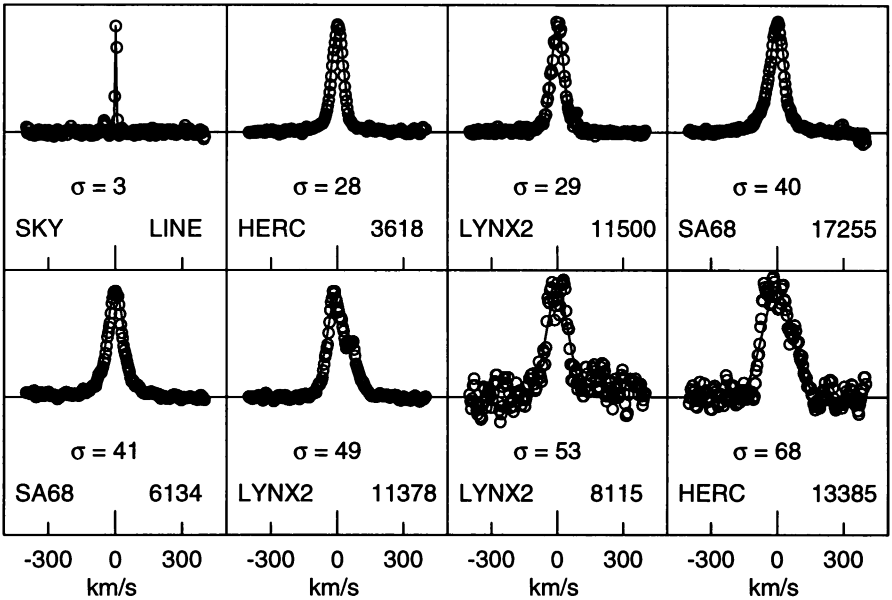

Figure 1. Panel of emission line profiles from a set of CNELGs and compact blue galaxies. The velocity profiles are very well fitted by Gaussians. The instrumental profile is in the upper left. This is a subset of the complete sample.

2. Observations

The HST and Keck Observations of the CNELGs are described in Koo *et al.* (1994), Koo *et al.* (1995) and Guzmán *et al.* (1996). The HST observations were used to derive effective radii, to identify the form of the surface brightness profile and to characterize their morphology. CNELGs can be characterized as centrally concentrated objects, with little substructure, and exponential light profiles. Typical half-light diameters for the seven objects imaged by HST WFPC are 0.65″, corresponding to $R_e \sim 1.4$ kpc ($H_0 = 50$; $q_0 = 0.1$, as used in the above papers).

The Keck spectra were taken with the HIRES spectrograph with a spectral resolution of 8 km s^{-1} FWHM. Velocity widths were measured from the emission lines [OII] 3727 Å, $H\beta$, and/or the [OIII] 4959/5007 Å pair, depending on the line strengths. Since the lines were typically (and interestingly) Gaussian in shape, the velocity width σ was determined by fitting Gaussians (where σ = FWHM/2.35). The sample of seven CNELGs that are the focus of the Guzmán *et al.* (1996) paper have a mean $z = 0.22$, with mean rest frame values of $M_B = -20$, $[U - B]_0 = -0.24$, $[B - V]_0 = 0.39$, and a mean $\sigma = 45$ km s^{-1}.

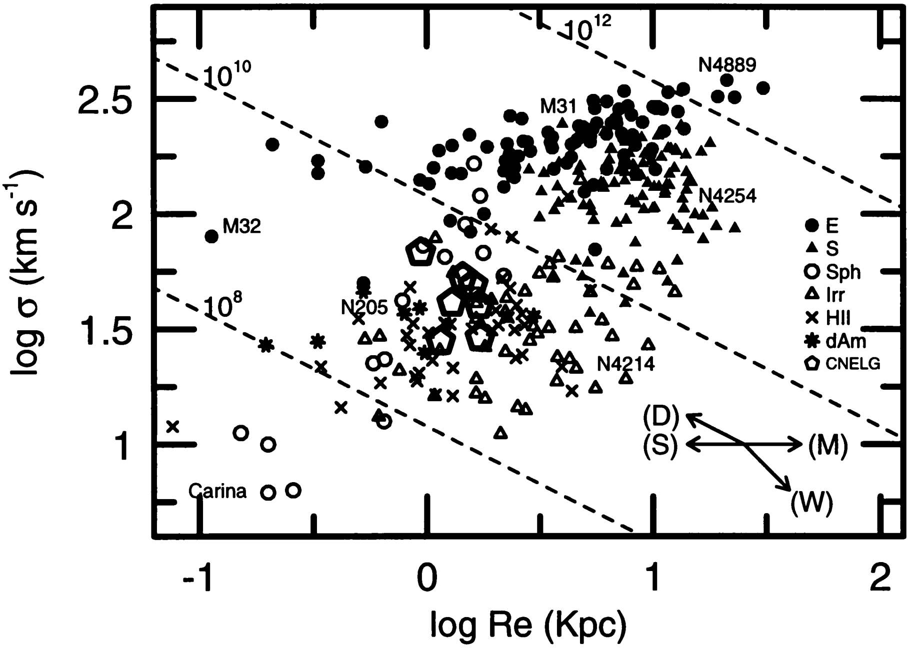

Figure 2. Length scale – velocity width relation (R_e *vs.* σ) comparing the CNELGs with a sample of nearby galaxies from ellipticals to spheroidals. The dashed lines indicate masses of 10^8, 10^{10} and 10^{12} $M_\odot$; surface densities are highest to the upper left. The CNELGs have typical masses around 10^9 $M_\odot$, and clearly fall amongst the local dwarf population in their $R_e - \sigma$ properties. The labelled arrows correspond to a variety of physical processes that could change the location of galaxies in this figure (namely, mergers – M, tidal stripping – S, galactic winds – W, and dissipation – D). As discussed in Guzmán *et al.* (1996), none of these processes are likely to displace the observed values far enough to move them out of the contemporary dwarf galaxy regime.

3. Results and Discussion

Comparison of the properties of the CNELGs, namely, their high luminosities, low velocity widths, small sizes, strong emission lines, and their very blue colors, with those of nearby galaxies suggests a close link to the HII galaxies, a set of low mass, extreme star-forming galaxies (Salzer *et al.* 1989). Koo *et al.* (1995) argued from simple burst models that the velocity widths, luminosities and surface brightnesses suggested a close link between CNELGs and current-day spheroidals. This link has been strengthened with the combined dataset of length scales and velocity widths now in hand for seven CNELGs. A comparison in the $R_e - \sigma$ plane shows that the CNELGs are unambiguously related to contemporary dwarf galaxies in size and velocity scales, and hence in mass. The details of the arguments can be found in Guzmán *et al.* (1996). These data provide an excellent example of the power of HST, and telescopes such as Keck, for clarifying the nature of the generic faint blue galaxy population at intermediate and high redshifts.

I would especially like to acknowledge David Koo for his realization that the Keck HIRES could measure velocity widths in such faint galaxies, and his efforts to assemble the observing program on very short notice when LRIS failed just before our Keck run. In addition, Rafael Guzmán also deserves special mention for his considerable efforts on this project, one of the first to be completed as part of the DEEP program. DEEP is a project sponsored by the Center for Particle Astrophysics at UC Berkeley. Funding for this work was provided by NSF grants AST91-20005 and AST-8858203 and NASA grants GO-2684.04-87A and GO-2684.05-87A.

References

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Questions and Answers

P. Guhathakurta: What fraction of all $20 < B < 23$ galaxies do CNELGs represent?
G. Illingworth: Very small; roughly $\sim$ 1-2% to $B \sim 21$.
E. Khachikian: According to your data (spectra) it seems to me that your objects look like Liners or Superassociations (Giant HII regions)?
G. Illingworth: They are more like the latter, and not Liners, since the spectra are typical of those seen for giant, star-forming complexes.
I. Appenzeller: Can you say something about the relative frequency or space density of the class of blue galaxies described in your talk, and (if these objects are indeed the precursors of the Dwarf Spheroidals) can one perhaps estimate from such data the poorly known space density of the Dwarf Spheroidals outside the local group.
G. Illingworth: These objects are a few percent of the blue galaxy population. At this stage I think it would be very difficult to use CNELGs to provide any useful constraints on the spheroidal space density because it is likely that they formed over a very wide range of redshifts, and we are only sampling a modest range in redshift. The formation rate probably varied considerably and we have not made any estimate for the formation rate function, nor would any estimate be very reliable at this time.
A. Oemler: It gives me great pleasure to hear that Dave Koo now believes in evolution, but it gives me even greater pleasure to say that I don't believe it. You have shown that the high redshift blue compact emission line galaxies are identical to nearby objects, but it is only an astrophysical inference from gas loss mechanisms to expect that they might evolve.
G Illingworth: It is my mistake if I did not make the argument very clear during my talk. What I wanted to emphasize was that there is a very good set of arguments that indicate that such low-mass bursting galaxies could well be the progenitors of spheroidal galaxies, but that *there is no reason to suggest that the intermediate redshift epoch was unique as the time of formation of such objects.* Since local counterparts to CNELGs exist, it is likely that spheroidals have formed over a large range of epochs. These data tell us little about evolution; surveys such as those of Lilly and Le Fèvre will provide more definitive answers on this.