Star Formation History of Local BCDs and those in Voids*

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Abstract

Some Blue Compact Dwarf (BCD) galaxies are found by several surveys inside the cosmic voids, with nearest neighbor distances of $\geq 3\ h^{-1}$ Mpc. If BCDs follow a star formation history of short and intense star bursts preceded by long quiet phases, a considerable number of quiet galaxies should exist in the same voids which have not been found so far. A comparison of the properties of BCDs situated in voids and in sheets shows no significant difference in their distribution of total colors, abundances, and star formation rates. Almost negligible differences for structural parameter and HI contents properties are observed. I conclude that void BCDs and sheet BCDs are the same type of galaxy showing the same type of evolution independent of their local surrounding galaxy density.

HST color magnitude diagram analysis of local (sheet) BCD galaxies has demonstrated that the star formation rate of most BCDs varies only slightly by factors 5 to 15. CMD work and survey statistics show that strong bursts are a rare exception also among BCDs. Recent detailed surface analysis strengthen this view. I therefore conclude that most BCDs stay for a long time in the BCD stage. This scenario avoids the necessity to have large numbers of quiet galaxies in the voids.

1 Introduction

In the mid-eighties, papers devoted to the evolution of large scale structure and the formation of galaxies predicted that low mass galaxies might fill the voids (e.g. Dekel & Silk, 1986) which had been established by mapping the three-dimensional distribution of galaxies in standard catalogues (see Rood, 1988, for an early review or Peebles, 2001, for a recent discussion and references in that paper). While the first prominent voids like the famous Böotes void were found in rather large distances, systematic spectroscopic follow-up of the Zwicky- and UGC catalogues established that regions almost empty of prominent galaxies and with diameters up to 80 h^{-1} Mpc are common features also in the nearby universe ($cz \leq\ 10^4$ km s^{-1}, e.g. CfA survey, Huchra et al. 1990).

Our first approach was that voids might *appear* empty because the used standard catalogues are biased against certain types of (low-mass) galaxies. Standard catalogues are systematically biased against galaxies of low surface brightness (Disney 1976, Davies et al., 1998) and against compact galaxies due to their limits in surface brightness and diameter. This explains the relatively low fraction of dwarf galaxies in these catalogues even though dwarfs are the most numerous galaxies in the local universe (e.g. Schmidt & Boller, 1992). Among the compact galaxies are the Blue Compact Dwarf galaxies (BCD, see Thuan, 1991 for a review), which have small absolute (and thus apparent) diameters, rather low luminosities, and are probably low-mass galaxies. While

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difficult to select by their extension on survey images, they are relatively easy to recognize due to their prominent emission lines in their HII-like spectra (see below).

In the context of this conference on dwarf galaxies and their environment, galaxies in voids are probably the best case of galaxies in very low density regimes. They are highly isolated with nearest neighbor distances $D_{\rm NN}$ of at least 3 h^{-1} Mpc. Thus, a sample of void galaxies is probably the best one to study galaxies with little or even no impact of interaction on their evolution. In the context of cold dark matter cosmoginies, one expect them to be less evolved than those in higher density environments like sheets, or galaxy clusters (e.g. White & Springel 2000).

2 The Heidelberg-Void Survey HVS

As part of the search for galaxies inside voids carried out at the Max-Planck Institut für Astronomie in Heidelberg, we decided to search for emission line galaxies (ELG) towards nearby voids. We used digitized Calar Alto Schmidt telescope objective prism plates of the Hamburg Quasar Survey (Hagen et al. 1995) to select candidates in an objective manner. The selection rules were optimized to select especially BCD galaxies. Candidates were confirmed by follow-up long-slit spectroscopy with the Calar Alto 2.2 m telescope (Popescu et al., 1996, 1998). The detailed discussion of the sample as given by Popescu, Hopp & Elsässer (1997, PHE97) can be summarized as follows: Most of the newly found ELG and BCD are distributed like the already known giant galaxies in the same volumina and follow the well established sheets (see e.g. the wedge diagrams in PHE97 and the discussion of their $D_{\rm NN}$). Very few ELGs were found inside the voids, 17 in total (7% of the survey galaxies, see Tab. 3 of PHE97). Thus, we established a sample of highly isolated galaxies, but a rather small one.

Naturally, the isolation of the void galaxies refers to *cataloged* galaxies. Neighboring giant galaxies can be excluded as the standard catalogues are essentially complete for those in the discussed voids. Candidates for neighboring dwarf galaxies which are as bright as the void galaxies are seen only in few cases on our B and R CCD images and spectroscopic follow-up did not identify a single companion so far. Dwarfs of much fainter luminosity ($M_B \leq -12$) and especially pure gaseous companions as found with a frequency of 20% by VLA HI mapping (Taylor, 1997) might be still possible despite the fact that a blind HI survey did not succeed to identify an additional galaxy population (Briggs, 1997).

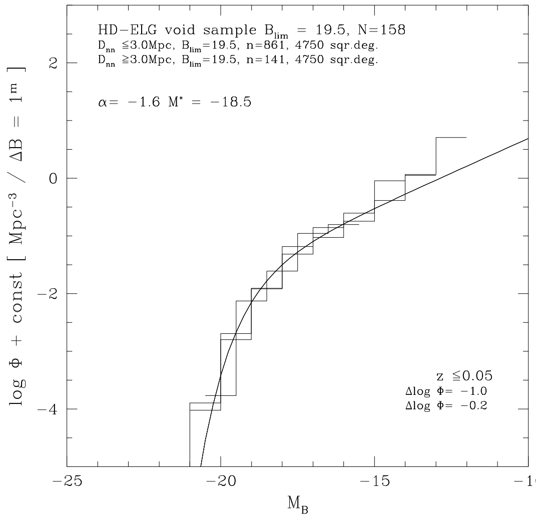

Figure 1: The luminosity function of the HVS, the void ($D_{\rm NN} \geq 3\,h^{-1}$ Mpc) and sheet galaxies of the combined sample of Hopp (1998). The distribution of the void galaxies is shown by the histogram spanning from −20.5 to −15.5 and practically indistinguishable from the histogram of the sheet galaxies except the normalization (see also Grogin & Geller, 1999). The shown Schechter function is not a fit, just an aid to help the eye, parameters in the upper left.

With our rather small number of ELG in voids, any discussion of their sample properties remains difficult. Other groups working on objective prism plates like Salzer and collaborators (University of Michigan survey, see Salzer, 1989, Rosenberg et al. 1994, Lee et al., 2000) or Pustilnik et al. (1995, Second Byurakan Survey) also found a handful of void BCD, each. Pustilnik et al. estimated that up to 20% of their BCDs are situated in voids. To enlarge the sample size, Hopp (1998) combined the samples published at that time assuming that they had very similar selection criteria. This combined sample show no significant difference in the luminosity function for galaxies situated in sheets (several 100 BCDs) and in the void (less than 100 BCDs, Fig. 1, see also Grogin & Geller, 1999). But even this combined sample is rather limited in size.

3 The Hamburg-SAO Survey HSS

This survey attempts to find more BCDs, especially of low gaseous metal abundance and/or those located in voids (Ugryumov et al., 1999). To some extent, it is a follow-up of the HVS: it applies a very similar technique to the Hamburg Quasar Survey data base. It is designed to fill-in the survey gap between the Case survey, the SBS, and the HVS. Slight overlaps with the previous surveys will finally allow to build up a homogeneous sample over a total area of more than 4000 square degree. The limits will be about 19.5 in B and ~ 1.4 nm in equivalent width of the emission line (mostly [OIII] 5007). So far, we identified ~ 1700 candidates in nearly 1700 square degree and obtained spectroscopic follow-up for $\geq 90\%$ of them (Hopp et al., 2000, Kniazev et al., 2001). Having a success rate of $\sim 73\%$, we found ~ 360 new BCD, among them ~ 15 with abundances below 1/15 of solar, including the extreme case HS 0822+3542 ($\sim 1/35$ solar, Kniazev et. al., 2000). A first analysis confirms again the low clustering power of BCDs (Ugryumov et al.,2001).

4 The Problem

BCD galaxies are often described to be in a star burst phase preceded by a longer quiet phase of very low star formation rate (see the review of Kunth & Östlin, 2000). This started with the discovery papers of the first two BCDs which later turned out to be rather extreme cases - II Zw 40 and I Zw 18 (see Searle & Sargent, 1972)! This assumption is either based on a comparison of the recent star formation rate (SFR) as deduced from the Hα flux, the still available gas (from HI), and the already formed stellar mass (e.g. B-flux); or tries to explain the low chemical abundances found in many BCDs. The word 'burst' is badly defined in the literature and used for (slightly) enhanced SFR to extremely strong SFR. In the following, I will use it for strong, isolated peaks, but not for SFR variations of factors of a few (compare the prediction for dwarf galaxy $SFR(t)$ by Gerola, Seiden & Schulman 1980). Models developed to describe the star burst evolution are often in good agreement with integral measures like colors, optical fluxes, or spectra (e.g. Krüger et al., 1991, Leitherer et al. 1999). A common model prediction is a dimming of several magnitudes after the burst, a long quiet phase preceding and following the burst(s), a duty cycle of $10^{8..9}$ yr, and a burst phase of a few 10^6 yr (Mas-Hesse & Kunth, 1999). The details depend on the burst strength, the IMF of the newly formed stellar population, the chemical abundances, and the properties of the host galaxy.

Given the numbers of BCDs found inside voids, and the duty cycle of the burst models, there should be much more 'quiet' void members (= sleeping BCDs) than BCDs themselfs! Tyson & Scalo (1988) proposed that BCD might dim to low surface brightness galaxies (LSBG) and are therefore absent in standard catalogues. So far, quiet void BCDs were not found in dedicated searches: Binggelli, Tarenghi & Sandage (1990); Bothun, Impey & McGaugh (1997 and references), Mo, McGaugh & Bothun (1993); Kuhn, Hopp & Elsässer (1997); see also Davies et al. (1998). The limits of these LSBG survey are deep enough that BCD burst amplitudes of ~ 2 mag. (corresponding to a ratio of recent SFR to average SFR $b' \sim 15$) are not a problem: BCDs in the flux range of the recent ELG surveys of nearby voids would dim to surface brightness and total magnitudes which are still well inside the search limits. A BCD dimming corresponding to ≥ 4 mag. ($b' \geq 150$) would yield a quiet object which might escape detection. Indeed, so far, even in sheets, no secure candidate for quiet BCDs have been identified (Kunth & Östlin 2000, Legrand et al 2000).

Thus, either, there are no quiet BCDs even though they are required within the above mentioned burst description of BCDs, or, the burst amplitude is rather huge (which introduces other difficulties), or, the BCDs found inside voids differ from the ones found in higher density regions like sheets.

5 A Comparison of Sheet and Void BCDs

To test the last possibility, I present a couple of comparisons between the properties of BCDs found in the voids and those found in sheets. Vennik, Hopp & Popescu (2000) presented total and surface photometry in B and R. Their total magnitudes and colors do not indicate any systematic difference between void and sheet BCDs. This point is further strengthened by the data shown in Fig. 2. By cross-correlating the HVS catalogue and the one of the 2MASS survey as presented on the IPAC homepage, JHK colors were derived for the brighter BCDs in our sample. The sheet BCDs (dots) and the void BCDs (circles) show essentially the same distribution despite the very few (5) void galaxies identified in the 2MASS data base. The outlying object has rather large errors as it is at the sensitivity limit of the data.

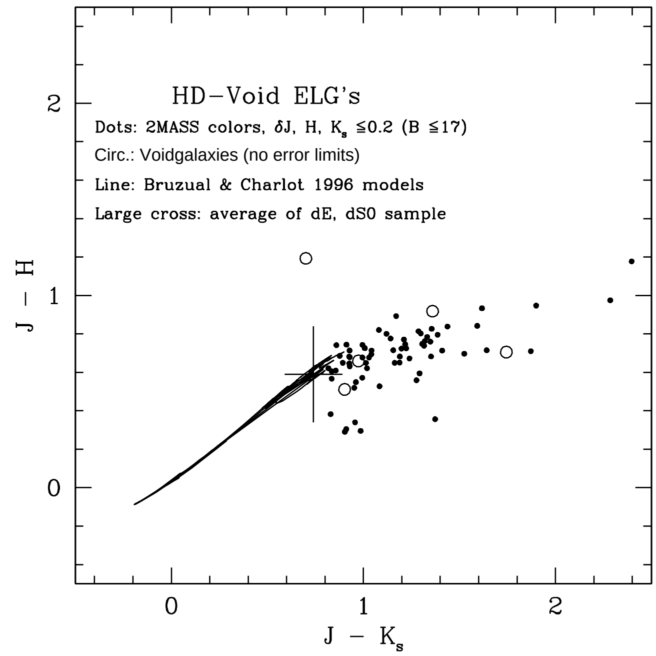

Figure 2: The near infrared colors of the BCDs in the Heidelberg-void survey. The NIR data of the HVS galaxies have been taken from the 2MASS survey (IPAC data base). Sheet galaxies are shown only when relatively good photometry exists (according to the 2MASS error estimates) while all five void galaxies identified in the 2MASS catalogue are shown (by circles). For comparison, the Bruzual & Charlot (1996) simple stellar population models are shown as straight line for various metalicities. The large cross give the average value and 1 σ dispersion of a small sample of dE and dS0 galaxies which I measured with the 2.2m Calar Alto telescope. For detail see text.

In Fig. 2, a mean value (and its 1-σ variance) of a small sample of 10 dE and dS0 galaxies is shown for comparison. The dE and dS0 galaxies were observed with the MAGIC NIR camera of the Calar Alto 2.2m telescope. Galaxies of these type are supposed to have a stellar population very similar to the host underlying the central BCD event. While the dE and dS0 data are in good agreement with the simple stellar population synthesis models of Bruzual & Charlot (1993, but 1996 code used, shown by lines), the data of the BCD galaxies scatter to much redder colors in $J-K$ while the bluest slightly overlap with the distribution of the dE and dS0 dwarfs. As show by Schulte-Ladbeck et al. (1999b), the young red supergiants formed in the recent star formation event have a strong influence on the NIR colors of BCDs and thus hamper the use of total NIR fluxes for stellar mass estimates.

Vennik, Hopp & Popescu (2000) also derived structural parameters from their surface photometry. A comparison indicates only marginal differences between void and sheet galaxies. While the distribution in surface brightness is the same for both density regimes, there is a tendency for void galaxies to have slightly larger scale length than the sheet BCDs at a given luminosity. HI studies of our void sample galaxies (Huchtmeier, Hopp & Kuhn, 1997, Hopp 1998) show a trend that void galaxies have a slightly higher $L_{\rm B}/M_{\rm HI}$ for given luminosity, but the differences are small.

Popescu, Hopp & Rosa (2000) and Popescu & Hopp (2000) studied the optical spectra of a complete HVS sub-sample. They found indistinguishable distributions for void and sheet BCDs for many properties, among them the chemical abundances of the HII regions, the star formation rate and the burst strength. In particular, the void BCD cover the whole range from rather low to high abundances. The authors emphasized that their sample was selected identically in the void and sheet regions and showed the same type mixture. They thus concluded that the star formation properties are not correlated to the surrounding density of galaxies. This finding is in contradiction to Vilchez (1995) who concluded from a comparison of cluster, field and void emission line galaxies that the star formation history in high density regimes differs from that in lower density regimes. While Vilchez had the advantage to include higher density regimes than we did, his sample mix depend on density. Further, his abundance values were meanwhile revised and the effect almost vanishes (Lee et al. 1998). Finally, tidal dwarfs with their special abundances (Duc et al., 1998) can confuse the results in high density samples.

In conclusion, there is little to no evidence that void BCD galaxies differ in their properties from those at higher density. Grogin & Geller (2000) derived similar conclusions from a study of the CfA2.

6 Star formation rate of the HVS galaxies

Popescu, Hopp & Rosa (2000) measured the star formation rate SFR of their complete sample, using the Hβ line and following the recipes of Kennicutt (1998). The values range from ~ 2.2 to $0.01~\mathrm{M_\odot yr^{-1}}$ with a clear rise towards the lower bound. 2/3 of the sample have a SFR $\leq 0.3~\mathrm{M_\odot yr^{-1}}$ (Fig. 3). I used these data to compute the ratio of the volume densities ρ of BCDs with high SFR and those with a low one: $\rho(SFR \geq 0.8~\mathrm{M_\odot yr^{-1}})/\rho(SFR \leq 0.3~\mathrm{M_\odot yr^{-1}}) = 0.1$. Thus, the HVS sample indicates that high SFR are *rare* among BCDs.

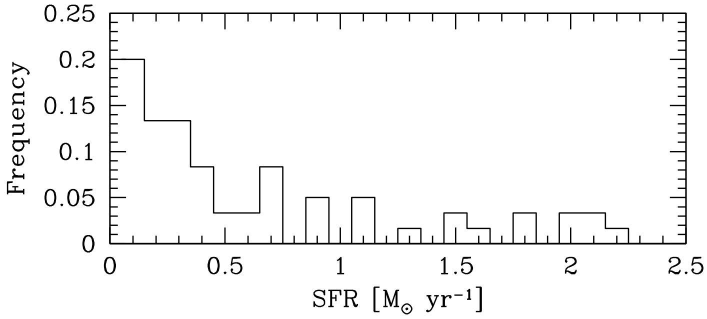

Figure 3: Star formation rate distribution of the HVS sample Popescu, Hopp & Rosa (2000).

7 Star formation history of local BCDs

As discussed in more detail by Schulte-Ladbeck et al. in this proceedings, we have investigated the SFR of very local BCDs through HST investigations of their color magnitude diagrams. Individual stars were resolved either in the optical (Schulte-Ladbeck, Hopp & Crone, 1998, Lynds et al., 1998, Schulte-Ladbeck et al., 1999a) or in the NIR (Schulte-Ladbeck et al., 1999b, 2000, 2001). The conclusion from the CMD discussion (including simulations) of VII Zw 403, Mrk 178, and I Zw 36 can be summarized as follows: These sheet BCDs, all belonging to the morphological Loose-Thuan (1986) subtype iE, a) have all relatively low SFR and b) had only slightly varying SFR in the last few 100 Myr, typically $b' \sim 5$. Over several Gyr, $b' \sim 8$ to 15. Note, that the range where these CMD reconstructions of the $SFR(t)$ have a good time resolution (≤ 1 Gyr) corresponds to the depth of the discussed voids surveys ($z \leq 0.1$). Crone et al. (2000, also this proceedings) showed evidence that a morphologically different BCD behaves very similarly while Drozdovsky et al. (2001, this proceedings) analyzed HST data of the local void BCD NGC 6789 and found again a CMD pattern very similar to VII Zw 403. Independently, Tosi (this proceedings) derived very similar conclusions for NGC 1705 (see also Annibali et al. and Sabbi et al., both this proceedings).

The only local galaxy, where we have relatively clear evidence for a strongly episodic $SRF(t)$ is the Carina dwarf galaxy which might have been a BCD with a SFR of ~ 0.8 $M_\odot$/yr some 7 Gyr ago (Hurley-Keller et al., 1998). The other well known case of a strong fluctuation in SFR which might be a real burst is NGC 1569 (Greggio et al., 1998, Tosi, this proceedings).

Surface photometry by various authors (Fig. 4) showed that most BCDs have central blue excess light in the order of 0.5 to 2 mag. The most detailed information was derived by the extremely careful analysis by Papaderos et al. (1996a,b). This central blue excess corresponds rarely to more than half of the optical emission, and - given its low M/L - to much lower masses than the red light of the underlying galaxy. At the same time, an excess produced by the recent or even on-going star formation event of the above order corresponds to variations in SFR of $b' \sim 5$. Several authors have discussed that the structural parameters of the host underlying a BCD differ from those of irregulars (Marlowe et al. 1999, Salzer & Norton, 1999). BCD's tend to have higher surface brightness and smaller scale length for a given luminosity (Fig. 4).

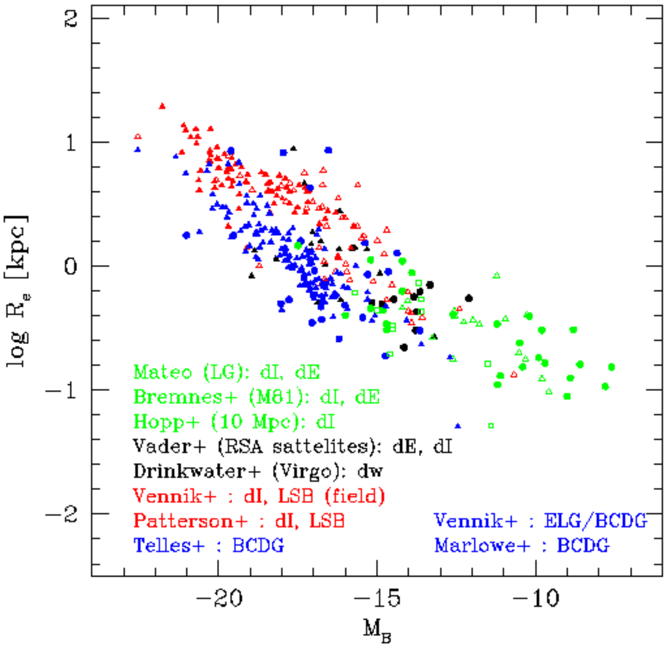

Figure 4: Effective surface brightness vs. total blue magnitude for various dwarf samples, including BCDs.The data were compiled from Bremnes et al., (1998), Drinkwater et al. (1996), Schulte-Ladbeck & Hopp (1998), Marlowe et al. (1999), Mateo (1998), Patterson & Thuan (1998), Telles et al. (1997), and Vennik et al. (1996, 2000). Data are used as published.

8 Discussion and Conclusions

We presented arguments based on BCD objective prism surveys that BCDs in voids and sheets have very similar properties, especially similar abundances and star formation rates. The different galaxy densities of the environments have no impact on the properties. Therefore, due to the isolated position of void galaxies, one has to take into account that the BCD phenomenon does not depend on galaxy interaction but can be triggered internally. So far, it was difficult to show that BCDs show high percentages of galaxy interaction (Telles & Maddox, 2000). We further argued that most BCDs have rather moderate SFR which vary only by factors of a few. Thus, at least for the selection rules used by most surveys, they stay in their class over a long span of their life time until their gas supply is exhausted. Most of them present a 'gaspy' SFR to us (Tosi, 1998) and those showing a real burst like NGC 1569 (Greggio et al., 1998) are pretty rare, about 10% of the BCDs.

If BCDs mostly remain in their class, have a gaspy and not a bursty $SFR(t)$, it is not surprising that so far, no quiet BCDs have been identified, neither in the voids (see above) nor elsewhere (Kunth & Östlin, 2000). One might even turn the argument around. As no quiet void-BCDs are found, most of these galaxies can not follow a bursty star formation history.

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References

Binggeli, B., Tarenghi, M., Sandage, A., 1990, A&A, 228, 42
Bothum, G.D., Impey, C., McGaugh, S., 1997, PASP, 109, 745
Bremnes, T., Binggeli, B., Prugniel, P., 1998, A&AS, 129, 313
Briggs, F.H., 1997, ApJ, 484, L29
Bruzual A., G., Charlot, S., 1993, ApJ, 405, 538
Crone, M.M., Schulte-Ladbeck, R.E., Hopp, U., Greggio, L., 2000, ApJ, 545, L31
Dekel, A. Silk, J, 1986, ApJ, 303, 39
Davies, J.I., Impey, C., Phillipps, S., (eds). 1998, ASP Conf. Ser., 170
Disney, J.M., 1976, Nature, 263, 573
Drinkwater, M. J., Currie, M. J., Young, C. K., Hardy, E., Yearsley, J. M., 1996, MNRAS, 279, 595
Drozdovsky, I. O., Schulte-Ladbeck, R. E., Hopp, U., Crone, M. M., Greggio, L.,2001, ApJ, Letters, in press
Duc, P.-A., Fritze-v. Alvensleben, U., Weilbacher, P., 1998, in: T. Richtler & J.M. Braun (eds.), Proc. of "The Magellanic Clouds and Other Dwarf Galaxies", Shaker Verlag, Aachen, p. 133
Gerola, H., Seiden, P. E., Schulman, L. S., 1980, ApJ, 242, 517
Greggio, L., Tosi, M., Clampin, M., de Marchi, G., Leitherer, C., Nota, A., Sirianni, M., 1998, ApJ, 504, 725
Grogin, N.A., Geller, M.J., 1999, AJ, 118, 2561
Grogin, N.A., Geller, M.J., 2000, AJ, 119, 32
Hagen, H.J., Groote, D., Engels, D., Reimers D., 1995, A&AS, 111, 195
Hopp, U., 1998, in: D. Hamilton (ed.) "The Evolving Universe", Astrophys. & Space Sci. Lib., Vol. 231, 59
Hopp, U., Engels, D., Green, R. F., et al., 2000, A&AS, 142, 417
Huchra,J.P., Geller,M.J., de Lapparent,V., Corwin,H.G., 1990, ApJS, 72, 433
Huchtmeier, W. K., Hopp, U., Kuhn, B., 1997, A&A, 319, 67
Hurley-Keller, D., Mateo, M., Nemec, J., 1998, AJ, 115, 1840
Kennicutt, R. C., 1998, ApJ, 498, 541
Kniazev, A.Y., Engels, D., Pustilnik, S.A., et al., 2001, A&A, 366, 771
Kniazev, A. Y., Pustilnik, S. A., Masegosa, J., et al., 2000, A&A, 357, 101

Krüger, H., Fritze-von Alvensleben, U., Loose, H.-H., Fricke, K.J., 1991, A&A, 242, 343
Kuhn, B., Hopp, U., Elsaesser, H., 1997, A&A, 318, 405
Kunth, D., Östlin, G., 2000, A&AR, 10, 1
Lee, H., McCall, M. L., Richer, M. G., 1998, BAAS, 193, 5304
Lee, J.C., Salzer, J.J., Law, D.A., Rosenberg, J.L., 2000, ApJ, 536, 606
Legrand, F., Kunth, D., Roy, J.-R., Mas-Hesse, J. M., Walsh, J. R., 2000, A&A, 355, 891
Leitherer, C., Schaerer, D., Goldader, et al., 1999, ApJS, 123, 3
Loose, H.-H., Thuan, T.X., 1986, in: D. Kunth, T.X. Thuan & J.T.T. Van (eds.), Star-Forming Dwarf Galaxies and Related Objects, Edition Frontieres, p. 73
Lynds, R., Tolstoy, E., O'Neil., E.J., Hunter, D.A., 1998, AJ, 116, 146
Marlowe, A. T., Meurer, G. R., Heckman, T. M., 1999, ApJ, 522, 183
Mas-Hesse, J.M., Kunth, D., 1999, A&A, 349, 765
Mateo, M.L., 1998, ARA&A, 36, 435
Mo, H.J., McGaugh, S., Bothun, G.D., 1994, MNRAS, 267, 129
Papaderos, P., Loose, H.-H., Thuan, T. X., Fricke, K. J., 1996a, A&AS, 120, 207
Papaderos, P., Loose, H.-H., Fricke, K. J., Thuan, T. X., 1996b, A&A, 314, 59
Patterson, R.J., Thuan, T.X., 1998, ApJS, 117, 633
Peebles, P.J.E., 2001, in press (astro-ph/0101127)
Popescu, C.C., Hopp, U., 2000, A&AS, 142, 247
Popescu, C.C., Hopp, U., Elsässer, H., 1997, A&A, 325, 881 (PHE97)
Popescu, C.C., Hopp, U., Hagen, H.J., Elsässer, H., 1996, A&AS, 116, 43
Popescu, C.C., Hopp, U., Hagen, H.J., Elsässer, H., 1998, A&AS, 133, 13
Popescu, C.C., Hopp, U., Rosa, M., 2000, A&A, 350, 414
Pustilnik, S., Ugryumov, A.V., Lipovetsky, V.A., Thuan, T.X., Guseva, N., 1995, ApJ, 443, 499
Rood,H.J., 1988, ARA&A, 26, 245
Rosenberg, J.L., Salzer, J.J., Moody, J.W., 1994, AJ, 108, 1557
Salzer, J.J., 1989, ApJ, 347, 152
Salzer, J. J.; Norton, S. A., 1999, ASP Conf. Ser., 170, 253
Schmidt, K.-H., Boller, T., 1992, AN, 313, 329
Searle, L., Sargent, W.L.W., 1972, ApJ, 173, 25
Schulte-Ladbeck, R.E., Hopp, U., 1998, AJ, 116, 2886
Schulte-Ladbeck, R.E., Hopp, U., Crone, M.M., 1998, ApJ, 493, L23
Schulte-Ladbeck, R.E., Hopp, U., Crone, M.M., Greggio, L., 1999a, ApJ, 525, 709
Schulte-Ladbeck, R.E., Hopp, U., Greggio, L., Crone, M.M., 1999b, AJ, 118, 2705
Schulte-Ladbeck, R.E., Hopp, U., Greggio, L., Crone, M.M., 2000, AJ, 120, 1713
Schulte-Ladbeck, R.E., Hopp, U., Greggio, L., Crone, M.M., 2001, AJ, June, in press
Taylor, C., 1997, ApJ, 480, 524
Telles, E., Maddox, S., 2000, MNRAS, 311, 307
Telles, E., Melnick, J., Terlevich, R., 1997, MNRAS, 288, 78
Thuan, X.T., 1991, in C. Leitherer, N.R. Walborn, T.M. Heckman & C.A. Norman (eds.): Massive Stars in Starbursts, Cambridge University Press, p. 183
Tosi, M. 1998, in "Dwarf Galaxies and Cosmology", ed. T.X. Thuan, C. Balkowski, V. Cayatte, and J. Tran Than Van (Gif-sur-Yvette: Éditions Frontières), 443
Tyson, N.D., Scalo, J.M., 1988, ApJ, 329, 618
Ugryumov, A. V., Engels, D., Lipovetsky, et al., 1999, A&AS, 135, 511
Ugryumov, A. V., et al., 2001, in: Proc. of "The New Era of Wide Field Astronomy", Preston, Aug. 2000
Vennik, J., Hopp, U., Kovachev, B., Kuhn, B., Elsässer, H., 1996, A&AS, 117, 261
Vennik, J., Hopp, U., Popescu, C. C., 2000, A&AS, 142, 399
Vilchez, J.M., 1995, AJ, 110, 1090
White. S.D.M., Springel, V., 2000, in "The First Stars", ESO Astrophys. Symp., eds. A. Weiss, T.Abel & V.Hill, Springer, 327