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STARBURSTS IN H II GALAXIES

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RESUMEN

Las galaxias H II están en el límite inferior de la escala de emisión de energía en los brotes de formación estelar. Aún así, son genuinas galaxias "starburst" que producen grandes cantidades de estrellas masivas, a un ritmo que es insostenible a largo plazo. En esta contribución se discuten los efectos de la formación de estrellas en el medio interestelar en estas galaxias enanas y se analiza la posibilidad de que las interacciones sean las responsables del comienzo del brote.

ABSTRACT

H II galaxies fall at the lower end on the scale of the energy output of their starbursts. Still, they are genuine Starburst Galaxies, producing large numbers of massive stars, and at a rate which is unsustainable in the long term. In this contribution I discuss the effects of star formation on the interstellar medium in these dwarf galaxies, and review the possibility that interactions are responsible for the onset of the burst.

Key words: **GALAXIES: COMPACT — GALAXIES: IRREGULAR — GALAXIES: STARBURST – STARS: FORMATION**

1. INTRODUCTION

As was eloquently expressed in the introductory talk by Roberto Terlevich, despite their relatively low, absolute energy output, H II galaxies are important members of the class of Starburst galaxies. On the scale of starbursts such as those occurring in Far Infrared (FIR) luminous IRAS galaxies (Sanders & Mirabel 1996), the objects I will be describing are puny. However, as we will see below, a star formation (SF) event of a magnitude as that currently taking place in the 30 Doradus region in the Large Magellanic Cloud (LMC) can be absolutely catastrophic for a small galaxy.

Also on a more objective scale, the star formation rate in H II galaxies easily qualifies as a starburst. In agreement with Roberto's definition, the luminosity of the current burst of star formation is much greater than the luminosity of the older stellar population ($L_{burst} >> L_{old}$); in fact, some H II galaxies seem to be forming their very first generation of stars (Kunth & Sargent 1986; Thuan, Izotov, & Lipovetsky 1995). Moreover, the current star formation rate (SFR) in these objects is clearly above the average, and it cannot be sustained for a long period of time because of the limited supply of "fuel".

In this paper I will attempt to introduce H II galaxies to a wider audience of starburst addicts, setting the scene for other contributions in these Proceedings which deal with these objects. I will then describe the effects of violent star formation on the interstellar medium (ISM) of H II galaxies. And as the organizers, no doubt with foresight, have scheduled me among those authors advocating interactions as an origin for starbursts, I will review some of the recent evidence which suggest that interactions are (part of) the explanation for the star formation bursts seen in H II galaxies.

Before continuing, let me take a moment to explain some of the acronyms and terminology used:

H II galaxy Actively star-forming dwarf galaxy which, in optical spectra, shows the clear signature of an H II region; when they were discovered they were originally called extra-galactic H II regions (Sargent & Searle 1970).

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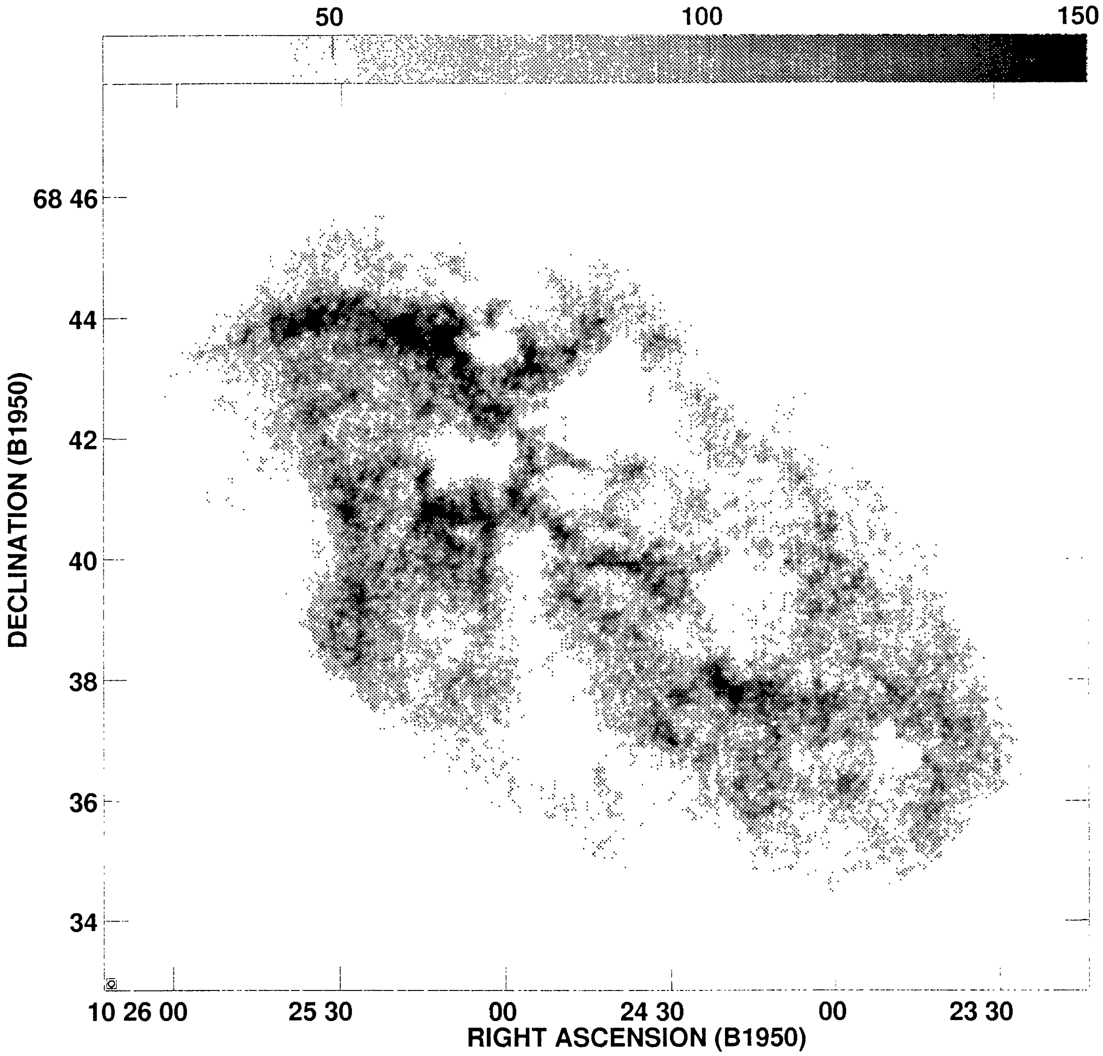

Fig. 1. H I surface brightness map of the galaxy IC 2574. Note the abundance of holes and shells due to the combined effects of stellar winds and supernovae produced by the most massive stars. The beam size is plotted in the lower left hand corner and measures 6.″4 × 5.″9. The velocity resolution is 2.5 km s^{-1}.

BCD Blue Compact Dwarf galaxy. Another name for an H II galaxy, describing its compact optical appearance and blue color, due to the presence of young massive stars.

WR galaxy Wolf-Rayet galaxies are a subset of H II galaxies (or BCDs) which in their optical spectra show the characteristic broad He II 4686Å line due to the presence of WR stars (see e.g., Kunth & Schild 1986; Vacca & Conti 1992).

In general, H II galaxies have blue luminosities of $M_B \geq -17^{mag}$ and linear diameters of a few kpc. They have low heavy element abundance values, ranging between 1/5 to 1/40 solar. This supports the generally accepted view that star formation in these objects is episodic. And this episodic star formation is violent, with a few $\times 10^3$ massive stars (with $M_* > 20\ M_\odot$) being born within a 10–100 pc diameter region. If this description has whetted your appetite, please consult the Proceedings of the ESO/OHP Workshop on Dwarf Galaxies (Meylan & Prugniel 1994) for a more complete account of the current status of dwarf galaxy research.

Why should these objects be at all of interest to you? Well, dwarf galaxies are intrinsically simple systems and, consequently, starbursts should be easier to understand in dwarfs than in more complex environs, such

TABLE 1

SOME GENERAL PROPERTIES

Parameter	H II Galaxy	30 Doradus	NGC604
log L(Hβ) erg s^{-1}	40.63	39.2	38.8
log Q(H°) s^{-1}	53.0	51.5	51.1
No. (O5V)	1840	70	27
M*(10–100 M$_\odot$	4.5 x 10^5	1.6 x 10^4	6.5 x 10^3

as massive mergers. Star forming dwarf galaxies are plentiful and are found relatively nearby, lending them to detailed scrutiny. Also, dwarf galaxies cover a wide range in metallicities, allowing the behavior of starbursts to be probed in different environments. And last but not least, some H II galaxies seem to be forming stars for the very first time and, therefore, might be nearby versions of what happened at larger look back times.

2. STARBURSTS AND THE ISM

Starbursts in dwarf galaxies are violent events, and Table 1 (adopted from Telles 1995) lists some characteristic properties of H II galaxies. Here log L(Hβ) is the Hβ luminosity, log Q(H°) the number of ionizing photons, and M*(10–100 M$_\odot$) the total mass in ionizing stars with $M > 10$ M$_\odot$, assuming the H II region is ionized by an association with a Salpeter IMF and an upper mass limit of 100 M$_\odot$.

The effect of a starburst is devastating as was shown, for example, by Puche et al. (1992) in the case of Holmberg II, a dwarf companion galaxy of M81. These authors showed deep VLA[2] images of the neutral hydrogen gas (H I) distribution at high spatial and velocity resolutions. Giant H I holes and shells, with diameters up to 1000 pc are produced by the combined effects of stellar winds and supernova explosions of the most massive stars. Recently, Fabian Walter and I have started working on similar VLA data of the M81 dwarf companion IC 2574. Figure 1 is a stunning view of this dwarf galaxy, in which massive star formation events completely dominate the morphology of the neutral ISM (earlier maps at lower spatial resolution and with lower sensitivity, based on observations taken with the Westerbork SRT on this object and used, mainly, to study its kinematics, were published by Martimbeau, Carignan, & Roy 1994).

The observations of the neutral, i.e., cool ISM in these galaxies fits well within the notion of a three-phase ISM, as originally proposed by Cox & Smith (1974) and further developed by McKee & Ostriker (1977). A comprehensive review on large scale, expanding structures in galaxies is given by Tenorio-Tagle & Bodenheimer (1988). As shown by Palouš, Tenorio-Tagle, & Franco (1994), the energy injection as a result of massive star formation can, in differentially rotating disks, lead in a natural way to an explanation of the physics of self-propagating star formation. Besides, Silich et al. (1996) show that by making a detailed study of the supershells one can derive the direction of the angular momentum vector.

Both in IC 2574 and Holmberg II the effects of supernovae appear to be much more dramatic than in larger disk galaxies, such as M31 (Brinks & Bajaja 1986). Can we understand this? As argued by Puche et al. (1992), the energy output per Type II supernova is roughly constant. However, for galaxies with decreasing luminosities (or mass, or rotational velocity) there is a decrease in the depth of the gravitational potential. Therefore, a starburst (or its aftermath, really) in a dwarf galaxy has as more disruptive effect than in a nuclear starburst of a more massive spiral galaxy, and is able to expel material into the surrounding intergalactic medium (see Skillman, this volume, for a more complete story). In addition, the lower gravitational pull perpendicular to the disk results in a larger scale height of the H I layer, of order 600 pc instead of the 120 pc observed in large spirals.

3. STARBURSTS AND INTERACTIONS

D. Dultzin-Hacyan (this volume), reviewed our present knowledge, since the seminal work by Larson & Tinsley (1978), on starbursts induced by interactions. In fact, interactions seem to be able to explain almost

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[2] The Very Large Array (VLA) is operated by the National Radio Astronomy Observatory (NRAO), a facility of the National Science Foundation, operated under cooperative agreement by Associated Universities, Inc.

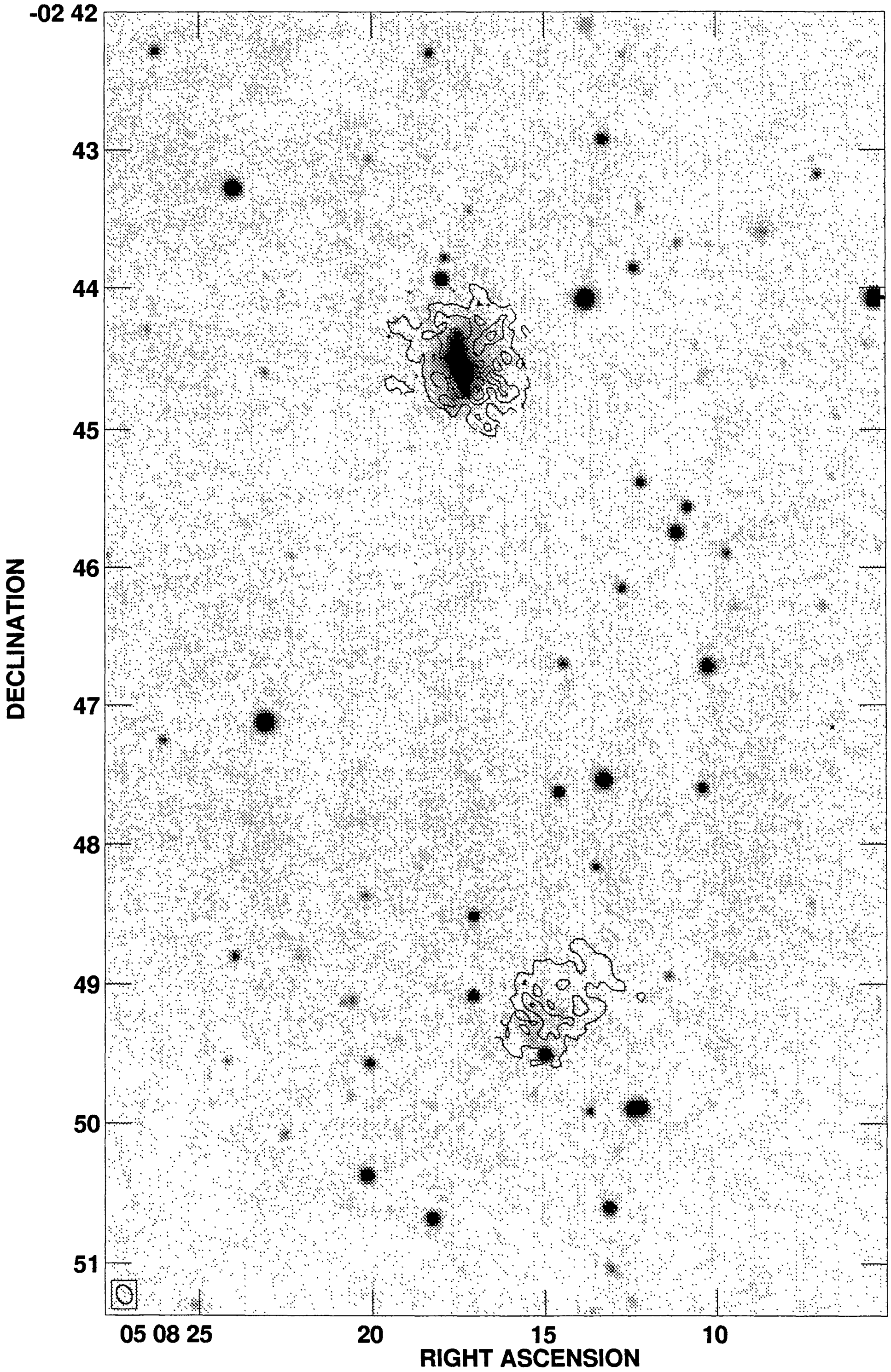

Fig. 2. H I surface brightness map of II Zwicky 33 (North) and its gas rich companion (South) overlaid on an optical image. The VLA beam size of 8″.5 × 6″.4 is indicated in the lower left hand corner. The H I contour levels are drawn at 6, 18, 30, and 42 $\times 10^{20}$ atoms cm^{-2}.

anything these days! As I will argue below, I think that interactions also play an important role in the evolution of dwarf galaxies. Once triggered, stochastic self-propagating star formation will keep the star formation process going, possibly for many generations (Gerola, Seiden, & Schulman 1980). There seems to be a need, though, for an external trigger to initiate the very first starburst or a new sequel of star formation once the stochastic process has died down.

Several authors (Brinks & Klein 1988; Brinks 1990; Campos-Aguilar, & Moles 1991; Campos-Aguilar, Moles, & Masegosa 1993) proposed that interactions might be important in the evolution of H II galaxies and have looked for evidence. Campos-Aguilar & Moles (1991) selected their objects from the *Spectrophotometric Catalogue of H II Galaxies* published by Terlevich et al. (1991). Using the CfA catalogue, they checked for massive optical companions, within a projected distance of 1 Mpc and a redshift difference of 500 km s^{-1}, to their sample objects. Campos-Aguilar et al. (1993), using a larger sample, have confirmed that more than 64% of their objects are isolated; the 13% with a massive galaxy within the search volume do not show any evidence for tidal interaction. Telles & Terlevich (1995), using the same *Spectrophotometric Atlas*, but using the NASA/IPAC Extragalactic Database to search for giant companions, searched within a projected distance of 1 Mpc and a velocity difference of 250 km s^{-1}. They reached the same conclusion: there are no indications for interactions with larger (L*) galaxies. In fact, they found the somewhat counterintuitive result that those objects which seem most disturbed, based on their optical morphology (their type 1 objects), have no neighbors.

What all these studies have in common is that they look for companions in the optical. Brinks (1990) however showed that there exist objects like II Zwicky 33 which have a low surface brightness, gas rich companion. The following results are taken from Walter et al. (1996) who give a more complete and updated description of this system. II Zwicky 33 has a blue luminosity of 3.3×10^9 $L_{B\odot}$ and a mass of 1.1×10^9 $M_\odot$ in H I gas. It's companion is about as heavy in neutral gas, 0.6×10^9 $M_\odot$, whereas it is very weak in the optical with an estimated blue luminosity of only 0.3×10^9 $L_{B\odot}$ (assuming a distance of 37.8 Mpc). Figure 2 shows the H I surface brightness map overlaid on an optical image. So, there seem to be low mass, gas rich objects which are companions to H II galaxies and which likely play a role in their star formation history.

With this in mind, Taylor et al. (1993, 1995, 1996a; see also Taylor 1996) started a project to search for gas rich companions to H II galaxies. In Taylor, Brinks, & Skillman (1993, Paper I) they discuss a sample of nine H II galaxies, four of which have an unambiguous companion. Taylor et al. (1994, Paper II) present follow-up observations with as one of the results that one of the target galaxies, Haro 26, which was found to have one companion in low resolution H I maps, proved to have a second, closer companion when inspected at higher spatial resolution. In their Taylor et al. (1995, 1996a; Paper III) paper they study a statistically complete sample of H II galaxies, culled from the lists of Salzer, MacAlpine, & Boroson (1989a, b). Searching within a 125 kpc radius around each dwarf galaxy and within a velocity difference of 500 km s^{-1} they find that out of 20 objects, 12 have at least one companion. In a control sample of 17 Low Surface Brightness dwarf galaxies, i.e., currently not actively star forming galaxies, chosen to be as similar as possible to the H II galaxy sample, and searching a similar volume, Taylor et al. (1996b; Paper IV) find that only 4 objects have at least one companion. Contrary to what was found in Paper III, in which companions to H II galaxies were shown to be objects of similar dimensions or smaller, three out of the four companions to the LSB dwarf galaxies are galaxies which are much larger than the target objects. A more complete analysis of the project, reviewing the evidence provided by Papers I, III, and IV is given by Taylor (1996).

In support of Taylor et al.'s results it is worth noting that there is plenty of anecdotal evidence for interactions being the underlying cause for the starbursts in dwarf galaxies. As a recent example I would like to highlight maps published by Wilcots, Lehman, & Miller (1996). In a survey of five barred Magellanic Irregular galaxies they find, again, that 4 out of 5 galaxies have a dwarf companion. Wilcots et al. speculate that the companions, which are clearly interacting with the barred galaxies and which have no counterpart on the Digitized Sky Survey, have been instrumental in inducing the bar in these systems.

4. SUMMARY

I hope that it will be clear from this brief review that we can learn an awful lot by studying starbursts in H II galaxies. Based on the articles and studies listed above we can conclude that:

- Because of the shallow gravitational potential well, the H I layer in H II galaxies is thicker (scale height of order 600 pc) than in spiral galaxies. Consequently, H I shells can grow to a larger size in dwarf galaxies before they burst. And, because dwarf galaxies rotate like a solid body (at least throughout most of their observed area), these structures are longer lived than in differentially rotating disk galaxies.

- Furthermore, because of the reduced gravitational pull, the same amount of kinetic energy deposited by the combined effects of stellar winds and supernova explosions of the most massive stars has a much more disruptive effect in dwarf galaxies than in their larger cousins.
- H II galaxies are in general *not* found near larger (L*) galaxies within a projected distance of 1 Mpc and a radial velocity difference of 500 km s^{-1}. This result stems from surveys in the optical regime.
- H II galaxies *do* have companions, though. They are gas rich, of about equal mass or with masses down to about 1/10 of the mass of the primary galaxy. Some companions are starburst galaxies in their own right, others are inconspicuous when looked at in the optical.
- The frequency of companion occurrence is statistically significant, the observed probability for finding a gas rich companion near an H II galaxy being at least of order 60%.
- LSB dwarf galaxies do *not* have gas rich companions, the probability for encountering companions being only 25% which agrees well with what can be expected from the two point correlation function (Taylor 1996). Besides, the companions to LSB dwarfs are of a different nature altogether then those found near H II galaxies.

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REFERENCES

Brinks, E. 1990, in Dynamics and Interactions of Galaxies, ed. R. Wielen (Heidelberg: Springer), p. 146
Brinks, E., & Bajaja, E. 1986, A&A, 169, 14
Brinks, E., & Klein, U. 1988, MNRAS, 231, 63p
Campos-Aguilar, A., & Moles, M. 1991, A&A, 241, 358
Campos-Aguilar, A., Moles, M., & Masegosa, J. 1993, AJ, 106, 1784
Cox, D., & Smith, B. W. 1974, ApJ, 189, L105
Gerola, H., Seiden, P. E., & Schulman, L. S. 1980, ApJ, 242, 517
Kunth, D., & Sargent, W. L. W. 1986, ApJ, 300, 496
Kunth, D., & Schild, H. 1986, A&A, 169, 71
Larson, R. B., & Tinsley, B. M. 1978, ApJ, 219, 46
Martimbeau, N., Carignan, C., & Roy, J.-R. 1994, AJ, 107, 543
McKee, C. F., & Ostriker, J. P. 1977, ApJ, 218, 148
Meylan, G., & Prugniel, P. 1994, ESO/OHP Workshop on Dwarf Galaxies (Garching: ESO)
Palouš, J., Tenorio-Tagle, G., & Franco, J. 1994, MNRAS, 270, 75
Puche, D., Westpfahl, D., Brinks, E., & Roy, J.-R. 1992, AJ, 103, 1841
Salzer, J. J., MacAlpine, G. M., & Boroson, T. A. 1989a, ApJS, 70, 447
________________. 1989b, ApJS, 70, 479
Sanders, D. B., & Mirabel, I. F. 1996, ARA&A, in press
Sargent, W. L. W., & Searle, L. 1970, ApJ, 162, L155
Silich, S. A., Mashchenko, S. Ya., Tenorio-Tagle, G., & Franco, J. 1996, MNRAS, 280, 711
Taylor, C. L. 1996, AJ, submitted
Taylor, C. L., Brinks, E., & Skillman, E. D. 1993, AJ, 105, 128
Taylor, C. L., Brinks, E., Grashuis, R. M., & Skillman, E. D. 1995, ApJS, 99, 427
________________. 1996a, ApJS, 102, 189, Erratum
Taylor, C. L., Brinks, E., Pogge, R. W., & Skillman, E. D. 1994, AJ, 107, 971
Taylor, C. L., Thomas, D. L., Brinks, E., & Skillman, E. D. 1996b, ApJS, November issue
Telles, E. 1995, Ph.D. thesis, Cambridge University
Telles, E., & Terlevich, R. 1995, MNRAS, 275, 1
Tenorio-Tagle, G., & Bodenheimer, P. 1988, ARA&A, 26, 145
Terlevich, R., Melnick, J., Masegosa, J., Moles, M., & Copetti, M. V. F. 1991, A&AS, 91, 285
Thuan, T. X., Izotov, Yu, I., & Lipovetsky, V. A. 1995, ApJ, 445, 108
Vacca, W. D., & Conti, P. S. 1992, ApJ, 401, 543
Walter, F., Brinks, E., Duric, N., & Klein, U. 1996, AJ, submitted
Wilcots, E. M., Lehman, C., & Miller, B. 1996, AJ, 111, 1575