MULTIFREQUENCY WINDOWS ON SPIRAL GALAXIES.
II: THE A262 AND CANCER CLUSTERS.

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Abstract

We present new photometrical data (U, B, V and H bands) for about 100 spiral galaxies in the A262 and Cancer clusters. The data are used to study the dependence of radio continuum to H band and FIR to H band ratios on the color index U-B, taken as an indicator of the star formation history in galaxy disks. Both parameters are found to increase in bluer galaxies, in agreement with the results obtained for other clusters or field galaxies. The radio continuum activity of spiral galaxies in the Cancer cluster is not enhanced like in other cluster spirals. A study of the reliability of CCD surface photometry is reported, based on the comparison of two sets of observations obtained with different telescopes.

KEY WORDS: Clusters: of Galaxies - Photometry

1. Introduction

Models of galaxy formation and evolution can be constrained using observations taken in a number of "windows" spanning from the radio to the X-rays bands. Just to mention a few major processes and their correspondent observational counterparts, centimetric radio observations (21 cm HI line) provide us with the measurement of the primordial gas reservoir out of which galaxies are formed. Millimetric radio data enable us to observe the gas collapsed in molecular clouds and to trace the regions where star formation takes place. This activity, in turns, can be observed in the visible band by studying several recombination lines emitted in the regions immediately surrounding the forming stars. Furthermore the star formation activity can be traced by several less direct indicators, such as the heating of dust (observed in the far infrared), or the acceleration of cosmic rays taking place in the explosion of newly born massive stars (and consequent emission of synchrotron radiation which manifests itself in the radio domain). Near infrared observations provide us with quantitative measurements of the older, evolved stellar population. Understanding galaxy evolution means understanding the complex feedback processes which govern these and other mechanisms, such as those possibly induced by the galaxy environment.

With the aim of trying to get deeper insights into these questions using a data-base as complete as possible we are continuing a multifrequency survey of galaxies in 9 nearby clusters by collecting photometric measurements in the radio continuum, 21 cm HI line, far infrared, near infrared and visible of spiral galaxies (see also Gavazzi 1990). Some preliminary results have been published in previous works of this series (Gavazzi & Trinchieri 1989; Gavazzi et al. 1990a, hereafter GGB; Gavazzi et al. 1990b; Gavazzi et al. 1991a, hereafter GBK).

Here we report UBV and H aperture photometry of galaxies in A262 and in the Cancer cluster and CCD observations in A262. Most of the data presented here have been already used in a study of the Tully-Fisher relation (Tully & Fisher 1977 and Aaronson et al. 1979) in seven cluster by Gavazzi et al. (1991b; hereafter GSBT), and are the base for a thorough investigation of the velocity-distance relation in A262 (Gavazzi et al. 1992). The data reduction and the analysis procedures are similar to those in previous papers. Here we study the radio and FIR properties of galaxies in A262 and Cancer, also in relation with those in other clusters and outside clusters (Sect 3.2). A brief discussion on the color correction at low galactic latitudes is given in §3.1. The reliability of galaxy surface brightness determinations using CCD observations is analyzed in Appendix A.

2. Observations and data reduction

We present new UBV aperture photometry for 84 galaxies, infrared H band photometry for 48 galaxies, selected among the 102 objects enclosed in the contour drawn in the CGCG (Zwicky et al. 1961-1968) to define A262 and among the 57 galaxies in the Cancer cluster region $8^h 11^m 18^s < \alpha < 8^h 25^m 00^s$; $20^o 29' 00" < \delta < 23^o 00' 00"$, and CCD V and B images of 20 galaxies in A262. UBV and H aperture photometry have been obtained at the TIRGO 1.5 m telescope at Gornergrat (with 3 objects observed at the Kitt Peak 1.3 m telescope). Imaging was done at the Loiano 1.5 m telescope and at the 2.1 m telescope at San Pedro Martir.

Table 1 lists the parameters of the A262 and Cancer galaxies, organized as follows:

Column 1,2,3: Galaxy name, from CGCG, UGC (Nilson 1973) and NGC/IC (de Vaucouleurs et al. 1976, hereafter RC2).

Column 4 and 5: 1950 celestial coordinates, from Santagata et al. (1987), when available, or measured by us with a few arcsecond accuracy using the Bologna X-Y measuring engine.

Column 6: Galaxy type, taken from the literature or estimated by us on the available plate material. Types are coded as: 0=E, 1=S0, 2=S0a, 3=Sa, 4=Sab, 5=Sb, 6=Sbc, 7=Sc, 8=Irr, 9=S...

Column 7: recessional velocity corrected for virgocentric infall (Kraan-Korteveg 1985).

Column 8 and 9: Galaxy major and minor blue axes, in arcmin, from the UGC or consistently measured by us on the POSS.

Column 10: photographic magnitude, from the CGCG.

Column 11: Telescope(s) used in this work: T=TIRGO, for UBV photometry; L=Loiano; S=San Pedro Martir, for CCD; H=TIRGO, for H photometry; K=Kitt Peak for UBV photometry.

Column 12: flag for additional photometry available in the literature: O=optical, I=IR, from Bothun et al. (1985); Longo et al. (1983; 1985); Gavazzi et al. (1990b); GBK.

CCD frames were taken for spiral galaxies in A262 that had been previously detected either in radio or in the Far Infrared by IRAS. UBV and H aperture measurements were taken only of objects, primarily spirals, that were visible on the TV camera attached to the telescope, to ensure accurate pointing and centering of the objects. Including the data presented in this paper, photometry is available for 78% and 58% of the galaxies in the two surveyed regions, respectively in the UBV and in the Infrared, as specified in Table 2.

2.1. *U, B, V multiaperture photometry*

Multiaperture UBV photometry of 59 galaxies in A262 cluster and of 22 in the Cancer Cluster was obtained during three photometric nights in November 1989 at the 1.5 m Italian telescope TIRGO (Infrared Telescope at Gornergrat) with the optical photometer described in Baldetti et al. (1987). The photometer is based on the EMI 9893B/350 phototube and is equipped with 8 apertures ranging from 6.7 to 176 arcsec and with the Johnson filters U, B and V. Three additional galaxies (522023, 522023S, 522073) were observed at the 1.3 m telescope at Kitt Peak in the U, B, V bands using the MarkIII photometer.

UBV observations were done in general through three apertures of diameter smaller or comparable to the galaxy diameters. Typical integration time was of 20 seconds in each band. For the faintest galaxies we integrated for 30 seconds to improve the signal to noise ratio. All galaxies were seen on the TV camera, allowing us to center them accurately and to avoid contamination from unwanted objects both in the object and in the reference beam. Sky subtraction was accomplished by pointing the telescope to empty regions of the sky. Standard stars from the catalogue of Landolt (1983) were observed every hour for calibration. All stars were observed through a fixed aperture for 10 seconds in each band.

The zero point uncertainty derived from the calibrators is 0.01 mag in V, 0.02 mag in B-V and 0.03 mag in U-B in all nights. However, repeated measurements of the faintest objects gave $\lesssim 0.1$ mag differences in V. Consequently we estimate the effective uncertainty on the V magnitudes to be 0.1 mag. For some galaxies the uncertainty on B-V and on U-B in a given aperture is dominated by the poor statistics achieved with the measurements in the B, and even more in the U band. To obtain colors with ~ 0.1 uncertainties, we have averaged the color indices in the various apertures.

Two objects (522050 and 522071) are severely contaminated by bright stars superposed on them, therefore their UBV data will not be used in the following analysis.

Table 3 gives the results of these observations.

Column 1: galaxy name

Column 2: aperture diameter (arcsec)

Column 3: V magnitude in the individual apertures

Column 4: B-V averaged on the various apertures

Column 5: U-B averaged on the various apertures

Total magnitudes, at A/D=1 (D=UGC major diameter), are calculated adopting growth curves determined from the light profiles derived from CCD observations when available (see later), otherwise using standard growth curves from the RC2.

2.2. *H band multiaperture photometry*

Multiaperture H band photometry was obtained for 48 galaxies in three photometric nights of October, 1990 at the TIRGO telescope, using the Arcetri InSb detector.

The observing technique is described in Gavazzi & Trinchieri (1989): circular apertures of 27, 31.5 and 35 arcsecond diameter in the H (1.6 μm) broad-band filter were used for all the objects (two of them also through a 19 arcsecond aperture). The chopping throw was typically of 1.5 arcmin in the East-West direction, with a few exceptions, to avoid unwanted objects in the reference beam. Three calibration stars (Elias et al. 1982; Hunt et al. 1987) have been measured several times each night at comparable air masses (1.0-1.5) as the objects. The typical uncertainty in the zero point determination is 0.04 mag.

Table 4 lists the H magnitudes obtained in the various apertures. Three objects (522049, 522050 and 522099) are contaminated by stars of comparable brightness projected at small angular distance from the galaxy nuclei. The magnitudes listed in Table 4 were obtained by subtracting the contribution of the stars, determined through an aperture of 14 arcseconds centered on the stars.

Table 4 is organized as follows:

Column 1: galaxy name

Column 2: H magnitude through the 19 arcsec. aperture

Column 3: H magnitude through the 27 arcsec. aperture

Column 4: H magnitude through the 31.5 arcsec. aperture

Column 5: H magnitude through the 35 arcsec. aperture

Total H magnitudes are calculated adopting the same growth curve as in Gavazzi & Trinchieri (1989): a linear function of slope 2.2 in the range -1< $Log(A/D)$ <-0.5 and of slope 1.8 in the range -0.5<Log(A/D)< 0. Due to this choice, $H_{-0.5} = H_{tot} + 0.9$ mag.

2.3. CCD imaging

The CCD observations were done at the 2.1 m reflector at San Pedro Martir (SPM), Baja California, which belongs to the Universidad Nacional Autonoma de Mexico, and at the Cassini 1.5 m reflector at Loiano, Italy, which belongs to the Bologna Observatory. Some specifications of the two telescopes and CCDs are given in Table 5. More details on the CCD attached to the Loiano telescope can be found in Bregoli et al. (1986).

18 galaxies in A262 were observed at Loiano in two nights of October 1989 in the V band (20 min exposure) and in the B band (30 min exposure). 14 galaxies were also observed at SPM in V (15 min exposure) and in B (25 min exposure) during four photometric nights that had been allocated for CCD test time in September, 1989.

The SPM observations were calibrated and transformed into the UBV system using hourly observations of stars from the Landolt (1983) catalogue. The derived nominal photometrical uncertainty is 0.05 mag in V and 0.08 mag in B-V during the whole run.

The Loiano observations were obtained in nearly photometric conditions, but were not calibrated with standard stars. Instead we applied an "a posteriori" calibration using our photometrical data (TIRGO or SPM) as described in GGB.

2.3.1. *Image analysis*

The CCD data reduction procedure is described in GGB. The reader is referred to this paper for details. In short, images were flat-fielded and cleaned from cosmic ray contamination. In each flat-fielded frame the sky was determined with a typical uncertainty of 1%. This represents the dominant source of error in the low surface brightness parts of the galaxy light profiles. SPM frames of four galaxies were found vignetted by the offset-guider mirror. The resulting background gradient ($\simeq$ 5 %) was removed by fitting a bidimensional third order polynomial model to the background.

A growth curve was determined by integrating the counts in concentric circular rings of increasing radii, centered at the object brightest central peak. The growth curves obtained at SPM together with the TIRGO multiaperture photometry were used to calibrate the Loiano frames.

Light profiles were obtained by integrating the brightness distribution in a set of ellipses of fixed center, and of position angle and ellipticity corresponding to the galaxy inclination and orientation in the V frames at the 25th mag arcsec^{-2} isophote.

The V and B band isophotal radii (a_{25}) correspond to the major semiaxes of the ellipses fitted to the 25th magnitude arcsec^{-2} isophotes. The minor semiaxes (b_{25}) are derived from a_{25} and from the ratio R_{25}, i.e. the galaxy aspect ratio at the 25th mag arcsec^{-2} isophote measured on contour plots of the V band frames. The contour plots were obtained after smoothing the images using a 2 pixel FWHM gaussian filter. We assume $R_{25}(V)=R_{25}(B)$.

V and B band magnitudes are derived by integrating the counts within the ellipses which correspond to the 25th mag arcsec^{-2} isophote (V_{25},B_{25}) and within the ellipses having major semiaxes equal to one third of a_{25} ($V_{-0.5}$, $B_{-0.5}$).

The results of the CCD image analysis are summarized in Table 6, arranged as follows (the first line of each entry refers to the V band, the second line to the B band):

Column 1: Galaxy name. Double systems are treated as separate entries.

Column 2: Galaxy position angle (in degrees) measured counterclockwise from North.

Column 3: exposure time (in minutes).

Column 4, 5, 6: measured major (a_{25}) and minor (b_{25}) axes (in arcseconds) and their ratio R_{25} determined at the 25th magnitude isophote, not corrected for inclination. For B band we give

a_{25} and assume the same R_{25} as in the V band.

Column 7 and 8: observed integrated magnitudes at the 25th mag arcsec^{-2} isophote: m_{25}, and those at $a_{25}/3$: $m_{-0.5}$, not corrected to the face-on value.

2.3.2. *Light profiles*

Fig. 1 contains the images and the light profiles of the galaxies observed in this work. 9 level gray pictures of the V band frame are shown in panel a. Since images taken at SPM are somewhat degraded due to a slight misalignment of the optics, and consequently have poorer resolution (FWHP=2.0") than those taken at Loiano (FWHP=1.5"), in Fig. 1 we give the images taken at Loiano for the galaxies observed with both telescopes.

Panel b and c give the differential profiles in mag arcsec^{-2} and the integral profiles respectively, obtained by azimuthal integration along elliptical annuli. The data points in the differential and integral profiles are plotted down to $\sim$ 5 mag below the sky brightness ($\sim$ 4 mag in the color diagram). At this level the photometric error is dominated by the uncertainty in the sky subtraction and it is estimated to be 0.12 mag (see appendix A). Galaxy 522068 could not be properly calibrated, and no light profiles were derived.

2.3.3. *Color maps*

The differential B-V profile is given in panel d of Fig. 1. To obtain a B-V color image, the B frame was first aligned as accurately as possible with the V frame using pointlike objects in the field as reference. Slight residual image misalignments produce spurious colors in regions where light gradients are more pronounced. To partially remove these artificial features, the images were smoothed using a gaussian filter of 2 pixels FWHM, before taking their ratio. In each frame, the data were truncated four magnitudes below the sky level so that our color determinations are affected by uncertainties < 0.2 mag.

The nuclear regions show systematically redder colors than disks and spiral arms, as expected from the more centrally peaked distribution of the old stellar population. Two galaxies, 522014 and 522058, show an interesting color distribution. Their bidimensional B-V color maps are given in Fig. 2. A prominent dust lane south of the nucleus can be seen in 522014. 522058, also in the Markarian list of galaxies (Mkn 2; Markarian 1967), shows normal disk colors, but has a blue nucleus, 0.25 mag bluer than the disk.

3. Discussion

The photometrical parameters derived in this work and those available from the literature are listed in Table 7 as follows:

Column 1: galaxy name

Column 2: total H magnitude. No absorption correction is applied, since it is assumed that the extinction, both in our galaxy and in the target object, is negligeable in this band (Aaronson et al. 1979). A correction 1.9 ·z has been applied according to Aaronson et al. (1980).

Column 3: total V magnitude, corrected for reddening both internal and from our galaxy and for K dimming using the prescriptions of the RC2.

Column 4 and 5: B-V and U-B total colors, averaged over individual apertures, and corrected for internal reddening, for absorption due to our galaxy and K dimming using the prescriptions of the RC2.

Column 6 and 7: radio continuum flux normalized to the V and H band fluxes. The radio continuum measurements are from Fanti et al. (1982) (1.4 GHz), Righetti et al. (1988) (327 MHz), Perola et al. (1980) (0.6 GHz) and Salpeter & Dickey (1987) (1.4 GHz). All fluxes are converted to 1.4 GHz using power law spectra with α=-0.8. Magnitudes are converted into fluxes using: $H_{flux} = 1.03 \cdot 10^6 10^{(-H/2.5)}$ and $V_{flux} = 3.81 \cdot 10^6 10^{(-V_c/2.5)}$

Column 8 and 9: 60μm FIR flux from Corbelli et al. (1991) and from Bicay & Giovanelli (1987), normalized to the V and H fluxes.

3.1. *Color corrections*

Since both clusters are at relatively low galactic latitude (b^{II}= +29 for Cancer and b^{II}= -25 for A262), where the reddening from our Galaxy is significant, we have checked the corrections applied to the color indices by comparing the observed and corrected B-V color distributions with those obtained in the Coma supercluster, near the North galactic pole (both data sets have been corrected for galactic and internal absorption and K dimming). Early type galaxies (E,S0,S0a) are separated from the spirals to remove differences in the clusters population. The observed color distribution is indeed about 0.1 mag redder in the low galactic latitude sample both for early and late type galaxies, but with the correction applied, the two color distributions become consistent.

3.2. *Radio continuum and FIR properties*

The photometrical data are used to study the dependence of the radio continuum and FIR properties of disk galaxies in A262 and Cancer on their star formation rates and to compare them with those observed in other clusters (cf. GBK). Since we are interested in the diffuse component, we restrict the analysis to galaxies of types later or equal to Sa, to ensure the least possible contribution from nuclei.

The following analysis makes use of the 1.4 GHz radio continuum and of the 60μm FIR fluxes normalized to the H flux (Radio/H; FIR/H). The normalization is done to remove the obvious effect: "bigger galaxies have more of everything", and the infrared is chosen because this is perhaps the best indicator of the luminous mass in galaxies (Rieke and Lebofsky 1979), and is the least affected by reddening effects, both internal and along the line of sight. We use the corrected U-B color index as an indicator of star formation, since Kennicutt (1983) has shown that Hα equivalent width (present star formation rate) is correlated to the optical color indices (star formation history). For galaxies with B and V and without U measurements (522024, 522025, 522084), U-B)c as been derived from the general relation between B-V)c and U-B)c reported in GBK.

The relation between the Radio/H (or FIR/H) and the star formation index U-B)c for the subsample of the detected galaxies are shown in Fig. 3 a and b. The best fits found by GBK are plotted with the data for reference.

There is a clear dependence of the radio and FIR luminosity on galaxy color in the sense that bluer galaxies show relatively higher radio and FIR luminosities. The FIR emission of 522093 is exceptional for its color. It would not be surprising if the excess were associated with a nuclear component. These relations are consistent with the results of GBK, based on a much larger sample of both cluster and non-cluster objects.

Inspection of Fig. 3a further indicates that the radio activity of galaxies in the Cancer region is not enhanced as that of cluster objects, in agreement with the dynamical study of Bothun et al. (1983) who concluded that this is a loose aggregate of groups (see also GSBT). The radio excess observed in two galaxies, 119080W and 119055, is probably of nuclear origin. In 119080W it can be induced by the interaction with its companion 119080E (Hummel et al. 1987). 119055 is a peculiar object, with a prominent dust lane and a bright emission line nucleus (Tifft et al. 1973). The statistics in A262 is too poor to conclude that these galaxies have enhanced radio emission consistent with the average of the cluster objects. However, there is evidence that the radio enhancements of both 522024 and 522041 is indeed coming from the disk, as indicated by the slightly extended radio emission reported in Fanti et al. (1982).

More data are needed to definitely confirm these results, and in particular to address the problem of environmental influence over star formation related emission in A262. Of particular interest it would be the possibility of obtaining H_α data to better quantify the star formation rate in these galaxies.

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Appendix

The determination of reliable galaxy light profiles at surface brightness well below the sky level is a severe problem in surface photometry (see Capaccioli & de Vaucouleurs 1983). To derive an objective estimate of the accuracy achieved in photometric measurements obtained with CCDs we briefly analyze the differences between the photometry of nine objects, observed using two different telescopes (Loiano and San Pedro Martir) equipped with slightly different focal plane detectors. For each of these objects we obtained two independent light profiles (Llp and Slp). To remove possible residual zero point differences, we offset the Llp in order to match as closely as possible the Slp in the inner 5-20 arcsec. Subtracting the offsetted Llp from the Slp, we obtain the radial distribution of the differences between the two sets of photometric measurements. Fig. 4 shows the results for our best five objects (e.g. frames uncontaminated from bright nearby stars and with no flat fielding problems).

The differences are marginal up to $0.75 \cdot a_{25}$, then they increase rapidly reaching as much as 1 mag arcsec^{-2}. At a_{25} the standard deviation of the mean difference is 0.17 magnitudes. Assuming that the errors affecting the two curves are equal, the uncertainty of our photometry at a_{25} (neglecting the error in the zero point) is of 0.12 mag. If only the five objects of Fig. 4 are considered, the dispersion at a_{25} reduces at 0.13 magnitudes, hence the photometric error at a_{25} reduces to 0.1 magnitudes.

The main sources of error in the magnitude determination are: the Poissonian error on the pixels counts, the uncertainty in the determination of the mean sky background around each object, and the error due to large scale fluctuations of the background across the frame. The Poissonian counts error is the square root of the pixel counts divided by the electrons per digital unit conversion factor. The constant sky value n_{bg} is determined within 0.1 counts per pixel by imposing that the differential radial count density distribution converge to zero at large radii. The error due to the large scale fluctuations of the background is assumed to be the standard deviation of the mean sky level determined in several 20 pixel $\times$ 20 pixel boxes around the frame. These three errors are statistically independent.

For a magnitude m at a radius r we have:

$$m(r) = -2.5 log(f(r)) + Z_p \tag{1}$$

where the flux density f(r) is

$$f(r) = \frac{1}{tS}(\frac{\sum_i n_i(r)}{N} - n_{bg}) \tag{2}$$

The summation refers to an ellipsoidal annulus of N pixels. t is the exposure time in minutes, S the area of the pixel in arcsec^2, n_i the effective count in pixel i, and n_{bg} the mean sky background per pixel. Z_p is the zero point from the calibration. By differentiating equation (1) we obtain the error on the determination of the magnitude :

$$\sigma_m^2 = (2.5\frac{1}{f(r)}Loge)^2\sigma_f^2 = \frac{1.178}{(f(r))^2}\sigma_f^2 \tag{3}$$

The error σ_f on the flux density, obtained differentiating equation (2) is:

$$\sigma_f^2 = \frac{1}{(tS)^2}(\frac{\sigma_n^2}{N} + \sigma_{bg}^2) \tag{4}$$

where $\sigma_n^2 = \frac{1}{c.f.} < n(r) >$ is the Poissonian error, c.f. is the electron to digital units conversion factor, $< n(r) >$ is the average counts per pixel corresponding to radius r, and $\sigma_{bg}^2 = \sigma_{<bg>}^2 + \sigma_{lsf}^2$ is the sum of the errors on the mean background and on the fluctuations of the background itself. Neglecting the uncertainty on the zero point and substituting equation (4) into equation (3) we have:

$$\sigma_m^2 = 1.178\frac{1}{[< n(r) > -n_{bg}]^2}[\frac{1}{N}\frac{< n(r) >}{c.f.} + \sigma_{<bg>}^2 + \sigma_{lsf}^2] \tag{5}$$

Equation (5) gives the radial distribution of the expected error on m(r). The error $\sigma(r)$ on the difference between Llp and Slp for a given galaxy is obtained by adding in quadrature equation 5 for Llp with Eq. 5 for Slp. This value $\sigma(r)$ is reproduced with a solid line in Fig. 5 together with the observed difference $\Delta m(r)$. The agreement between the predicted and the measured uncertainties is satisfactory, implying that the model adopted is a realistic representation of the photometrical uncertainties.

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Figure Captions

Fig. 1. **a** Surface brightness distribution of the observed galaxies from the CCD data. The 9 gray lavels are from 24 mag arcsec^{-2} in steps of 0.5 mag. A 30" bar is given. South is at the top, East to the left. **b and c** Differential and integral profiles in the V band (+) and in the B band (•) along the galactocentric distance (in arcsec) measured along the major axis of the ellipse. **d** Differential B-V profile

Fig. 2. B-V color image of 522014 (left) and 522058 (right). 9 gray levels (from white to black), from B-V = 0.4 to 1.2 (522014), and 0.1 to 0.9 (522058), in steps of 0.1, are given

Fig. 3. **a** The relation between the radio continuum emission normalized to the H band and (U-B)c for the subsample of galaxies detected in the radio continuum. The lines plotted are from GBK, and represent the best fit for : clusters (dashed line) $Radio/H = -0.58 - 1.58(U-B)_c$, non-cluster (solid line) $Radio/H = -1.16 - 1.41(U-B)_c$, **b** Same as **a** for FIR/H, for the galaxies detected in FIR. The line is derived from cluster and non cluster objects by GBK: $FIR/H = 1.17 - 1.60(U-B)_c$

Fig. 4. Difference between the light profiles obtained at SPM and Loiano for the 5 best common galaxies

Fig. 5. Same as Fig. 4 for each individual object. The solid line represents the 1 $\sigma(r)$ uncertainity expected from the error analysis discused in the appendix