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SURFACE PHOTOMETRY OF BLUE COMPACT DWARF GALAXIES FROM THE BYURAKAN LISTS*

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The surface photometry of 23 ultraviolet excess galaxies from the two Byurakan surveys (FBS and SBS), selected to be Blue Compact Dwarfs candidates, has been made in *B* and *R* colors. A remarkable fraction of the sample exhibit a projected brightness distribution following the same de Vaucouleurs law as the bright spheroidal objects of the field (ellipticals and bulges of spirals). The other most frequent morphological type has an exponential brightness distribution, therefore similar to usual dwarf Magellanic irregulars. From their small absolute dimensions and average high effective surface brightness, the studied objects are indeed "compact" in the usual empirical sense.

1. *Introduction.* We present some preliminary results of CCD imaging and suface photometry on a sample of blue compact dwarf galaxies (hereafter BCDGs) selected from the two surveys of ultraviolet excess galaxies conducted at Byurakan Observatory. This work is part of a large observational multispectral investigation on Byurakan star - forming galaxies conducted as an international collaborative project between Armenian and western European astronomers.

2. *Observations.* 23 galaxies have been selected from First Byurakan Survey (Markaryan et al. 1967 and follow) and second Byurakan Survey (Markaryan and Stepanyan 1983, hereafter SBS) as BCDGs candidates, based on their small angular diameter, low redshift, low absolute magnitude ($M_b \geq$- 16.5) and high surface brightness. The redshifts and estimates of absolute magnitudes used for the selection of the candidates were taken from Mazzarella and Balzano (1986) and Stepanyan (1993, private communication). Imaging in

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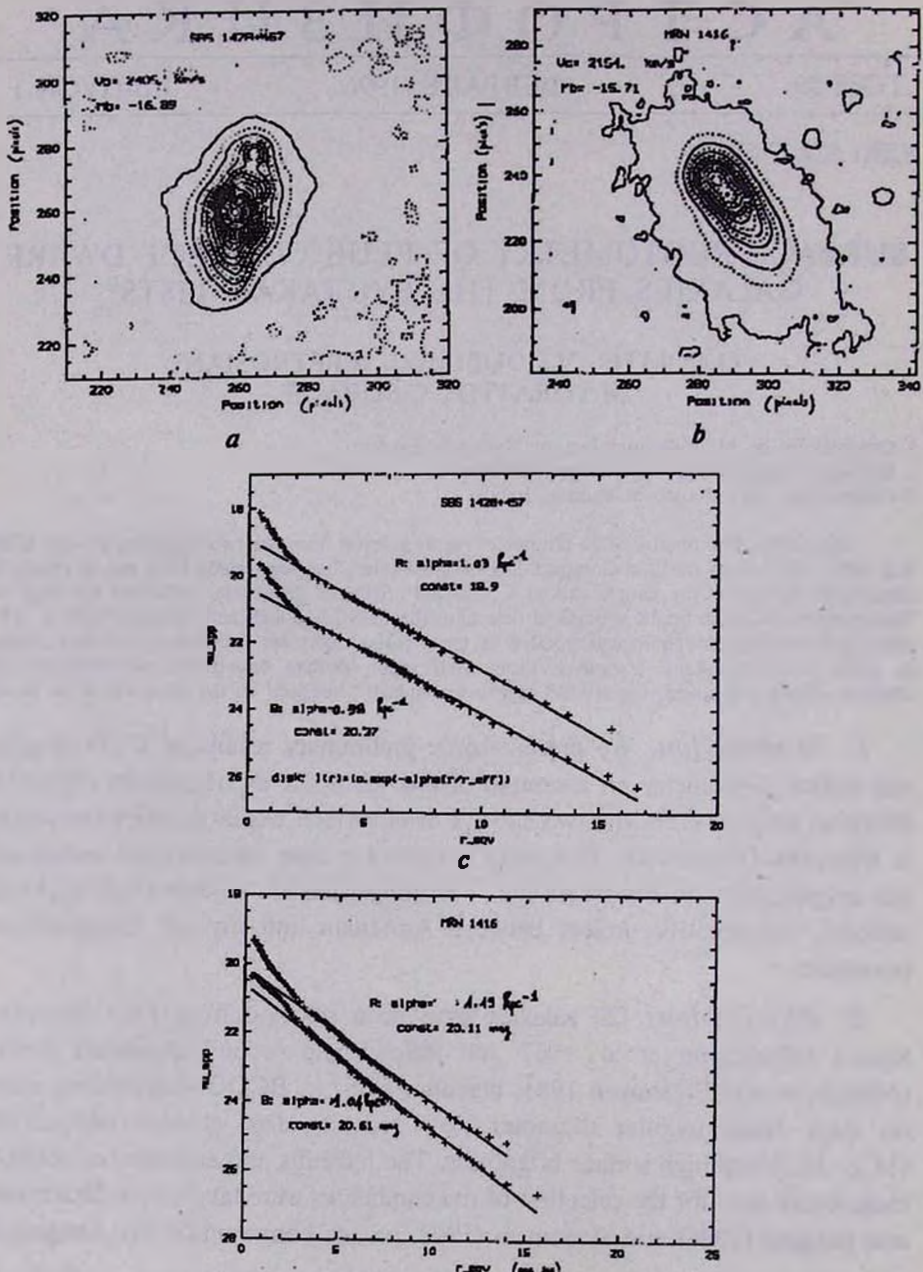
a
b
c
d
SBS 1428+457
Position (pixels)
MRK 1416
Vc= 2154. km/s
Mb= -15.71
Position (pixels)
R: alpha=1.03 kpc^-1
const= 18.9
B: alpha=0.98 kpc^-1
const= 20.37
disk: I(r)=Io.exp(-alpha(r/r_eff))
mu_app
r_eqv
R: alpha= 1.15 kpc^-1
const= 20.11 mag
B: alpha= 1.04 kpc^-1
const= 20.61 mag

Fig. 1.

Johnson B and Gunn R bands has been performed during several runs at Pic-du-Midi Bernard Lyot 2m telescope (France), using ISARD focal reducing camera (Lemaitre et al. 1996) and Cima Ekar 1.82m telescope (Italy). Both instruments were used with CCD detectors, giving respective scales of 0".48 and 0"39 per pixel. The reduction to standard B and Cousins R photometric system was done by means of regular nightly observations of standart stars (Landolt 1983) and stellar clusters (M67: Gilliland et al., 1993, Chevalier and Ilovaisky 1993 and NGC 7790: Odewahn et al., 1993)

Surface photometry was performed using isophotal integration of the flux in the galaxy images following the classical "equivalent radius" method of de Vaucouleurs (1959). At each step, the quantities produced by the reduction software package (based on MIDAS specially written macroprocedures) are the equivalent radius (radius of the circle of same area as the isophotal contour), the integrated magnitude and the isophotal surface brightness. An extrapolation of the integrated magnitude growth curve produces the "total" (asymptotic) magnitude from which one derives the "effective" equivalent radius (corresponding to the isophote that contains half the total luminosity of the galaxy). This effective radius is a metric quantity independent of the level of the night sky background. For each galaxy, the surface brightness radial distribution was constucted. Additional parameters were derived from the data as average surface brightness inside characteristic radii, concentration indexes, etc... Full details on the procedure and an atlas of isophotal maps and surface brightness distributions will be found elsewhere (Doubiler et al., 1996).

3. *Archetypes of BCDGs.* The analysis of the surface brightness distributions and isophotal maps shows that the sample may be classified roughly along a threefold scheme. We discuss some typical cases in the following.

3.1 Exponential brightness distributions. Fig 1a shows the isophotal B map of SBS 1428+457 (V_0=2405 km s^{-1}, M_B=-16.89 for H_0=75km s^{-1} Mpc^{-1}). This galaxy has an ellipsoidal general shape with a bright central region and a secondary brightness peak detached from the center. The internal isophotes exhibit distortions from regular ellipses. Fig. 1b displays the isophotal map of Mrk 1416 (V_0=2154 km s^{-1}, M_B=-15.71). The isophotes are elongated, and the brightness maximum is cleary displaced with respect to the geometrical center of the outermost contours. The central bright star-forming region is elongated across an extent of some 800 pc.

Figs. 1c and 1d show the brightness distributions of these two objects in apparent surface brightness versus equivalent radius. Both show a consistently

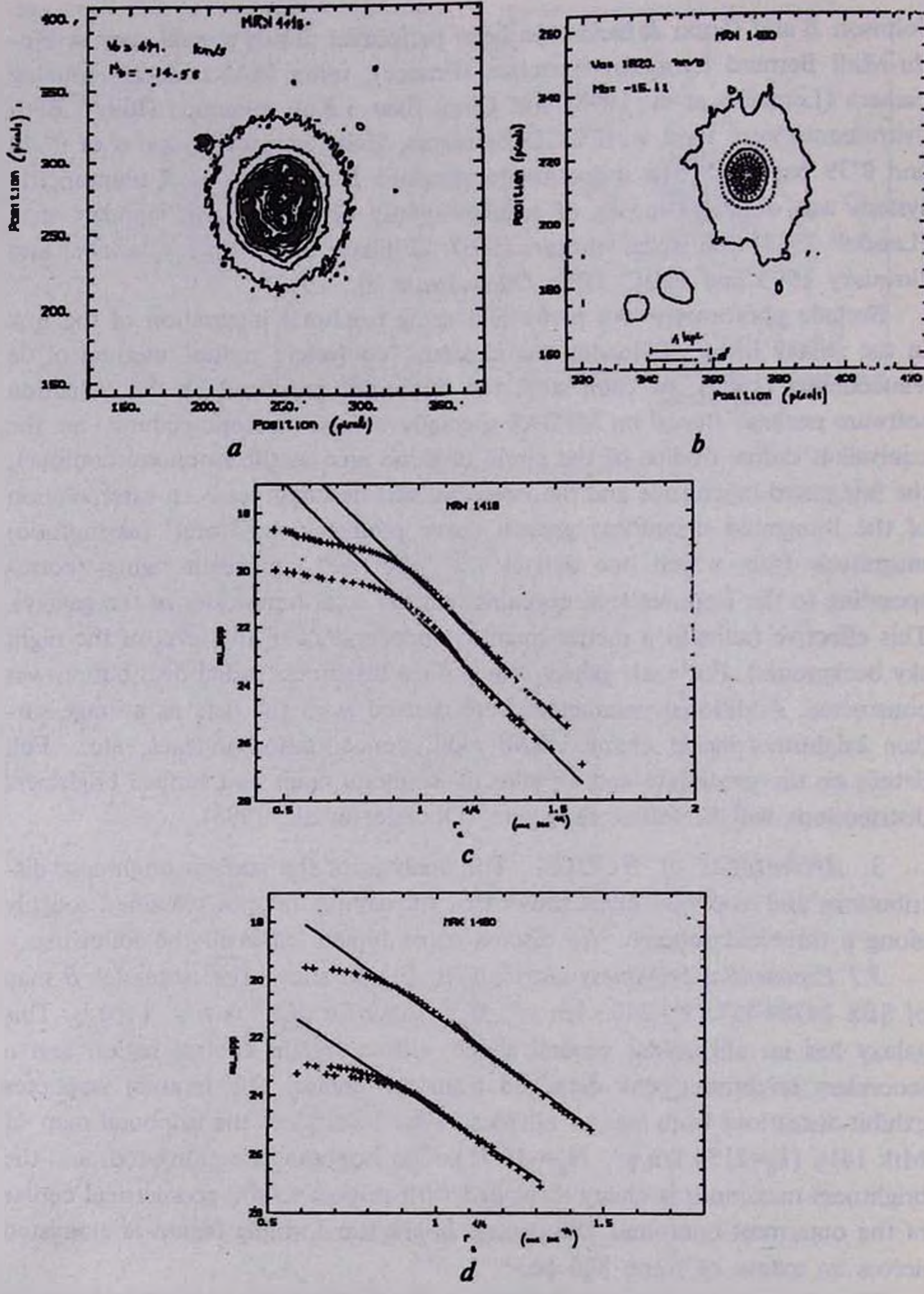

Fig. 2.

linear brightness distribution across most of the observed range of equivalent radius, that is, their projected light intensity distribution is well fitted by an exponential law, as is the case for flattened disk dominated galaxies, such as giant normal spirals or Magellanic irregulars. A local central excess of light with steep gradient is obvious in both objects, corresponding to the area affected by the active star-forming "center". Mrk 1416 also shows a weak color gradient, its outer envelope being redder than its central parts (contrary to the classical case of normal spirals). The brightness gradient of Mrk 1416 is much steeper than that of SBS 1428+457, making it more "compact" in appearance.

We think that there is some evidence that this class of objects corresponds to active (in stellar formation) counterparts of normal dwarf Magellanic irregulars. BCDGs of this type have simply a substantially higher star formation rate than typical dwarf Magellanics of the field (examplified for instance by DDO objects). One may notice that, considering the important excess of light due to the presently observed starburst, these objects, when seen in a more quiescent phase, should have absolute magnitudes in the range - 14 to - 15 typical of DDO dwarfs in the neighbourhood of the Galaxy. Their scalelengths (measured for instance by their effective radii) are normal with respect to well - studied Magellanic dwarfs.

Among the 23 observed BCDGs from the Byurakan lists, 9 objects fall in this category. This class has also previously been identified as "iI" by Loose and Thuan (1986). Kunth et al. (1988) have identified several other candidates with disk - like brightness distributions (Tol 2, Tol 3).

3.2. $r^{1/4}$ brightness distributions. Fig 2a shows the isophotal *B* map of Mrk 1418 (V_0=1418 km s^{-1}, M_B=-14.56), a close - by object with a small linear apparent diameter. Its outer contours are elliptically shaped and regular, but there is a lot of structure in the central region, with several protruding "blobs" and very much perturbed isophotal contours. Fig. 2b shows the isophotal R map of Mrk 1480 (V_0=1820 km s^{-1}, M_B=-15.11), which exhibits a quite regular ellipsoid shape with a central brightness peak displaced from the geometrical center of outermost contours.

Figs. 2c and 2d show the brightness distibutions of these two galaxies in apparent surface brightness plotted against the 0.25 power of the equivalent radius. Note that up to r $^{1/4}$=0.8 to 0.9, the measure of the surface brightness is subject to blurring by seeing effect, and no information can be derived in this area without applying complex deconvolution algorithms. Beyond this range, the brightness distribution closely follows a linear relationship, analogous to that obeyed by normal giant ellipticals or bulges of giant spirals and S0 galaxies, well-known as de Vaucouleurs' law (1948).

It is quite surprising that a galaxy exhibiting as much structure as Mrk 1418 is so well fitted by an $r^{1/4}$ law. This implies in fact that relaxation processes in the dynamical state of the galaxy are very powerful.

10 objects (among 23) have been found to obey a de Vaucouleurs law along most of the observed range of equivalent radius. The presence of excess light above the $r^{1/4}$ law at large radius (i.e. extended envelopes) is found to be quite common. Many authors suggest that this could be due to past tidal interaction. Another possibility is that it could reflect the residual presence of an extended disk of weak surface brightness. As regards the isophotal shapes, most of the $r^{1/4}$ objects exhibit distortions (boxy internal isophotes, offset position of the brightness maximum with respect to the outer contours, elongated "nuclei", isophote rotation). The geometrical shape and real dynamical nature of these galaxies is worth a deep investigation, but needs extensive observations (in particular the velocity fields of gaseous and stellar components), since apparently they represent a very singificant fraction of the BCDG population. This is consistent with previous findings reported by Loose and Thuan (1986) and Kunth et al. (1988).

3.3. Other types. 4 objects in the sample are supposed, from the shape of their brightness distribution, to be representative of galaxies in which the flattened disk (exponential brightness distibution) and a central spheroid (de Vaucouleurs law in $r^{1/4}$) coexist. As could be expected, these objects are rather luminous with respect to the remaining of the sample. 2 more objects escape any classification in what could be called the "natural" (i.e. dynamical) preceding categories. The shapes of their brightness disributions are peculiar, possibly because of large dominance of an abundant newborne population in a non-stabilized dynamical state (e.g. SBS 1331+493).

4. *Remarks on integral photometric quantities.*

4.1 Linear size. We have constructed the histogram of the effective radius in kpc, assuming distances derived from the corrected Galactocentric velocity and H_0=75 km s^{-1} Mpc^{-1}. Most objects have r_{eff} 1kpc and half of the sample has r_{eff} 0.5 kpc. The observed galaxies have small average absolute dimensions. Remind that normal spirals and luminous irregulars have r_{eff} 2 kpc. A plot of the logarithm of the effective diameter versus absolute magnitude shows that the sample obeys a reasonable linear relationship with a slope of 3.7 (+ or -

1.1). This is not inconsistent with the slope of 5 expected for a "normal" luminosity - diameter relation because strong selection effects towards high surface brightness objects are present at the low luminosity end.

4.2 Surface brightness. We have also studied the distribution of the average surface brightness inside the effective isophote. The normal field galaxies would show a much more extended distribution, with a weaker median value of this average brightness. This, coupled with the small linear size, translates into the apparent "compacity" of the objects. Note that the surface brightness is a tracer of both the stellar density along the line of sight and the average luminosity of the stellar population. In B band, objects dominated by a starburst producing a rich main - sequence of high and intermediate mass stars are likely to appear brighter than a normal evolved population (which, on the contrary, will dominate at near - infrared wavelengths).

4.3 Color. Finally, the B - R color distribution (uncorrected for reddening) as seen integrated inside the effective (B) isophote, shows that the bulk of the sample is cleary blue, with a mean value at $(B - R)_{eff}$=1.09. The average value for normal spirals is around 1.3 and 1.6 for field ellipticals.

5. *Suggestions for future work and some problems to solve.* In the preceding sections, we have underlined the importance of the $r^{1/4}$ BCDGs as objects that may provide unexpected clues to the understanding of the BCDG phenomen. To our opinion, "exponential" (i. e. disk - dominated) BCDGs are not so difficult to understand: gas clouds inside the disk of a gas - rich Magellanic dwarf irregular, compressed for some reason (tidal interaction with a neighbour, shock from supernova event or stellar superwind, growth of a non - axisymmetric dynamical component as a mini - bar) locally reach the critical density for stellar formation and fuel a burst that may propagate across the object. Although no quantitative simulation of a real galaxy up to now exists, this scheme looks realistic and we wait for subsequent detailed observations (velocity fields, HI mapping, etc..) that will help to build well - constrained models for a few typical objects.

The $r^{1/4}$ BCDGs, on the other hand, are much more difficult to interpret, because of two major problems encountered when one wants to link them with otherwise well - known spheroidal galaxy classes:

1 - normal elliptical galaxies have a small gas content and a very low or even nul star formation rate. In any case, the observed gas content of field ellipticals, scaled to the luminosity of BCDGs, is too low by orders of magnitude to fuel a burst as seen in Byurakan $r^{1/4}$ BCDGs,

or objects like IZw123, observed by Kunth et al. (1988) to be an $r^{1/4}$ galaxy.

2 - dwarf spheroidal systems, present in large numbers in the Universe, exhibit *exponential* brightness distributions. Their light, apparently dominated by old red giant stars, therefore does not trace the dynamical behaviour of the stellar population observed in $r^{1/4}$ BCDGs, and especially does not show any evidence of isothermal relaxation.

We therefore may produce what is merely a catalog of problems to solve, and perhaps would suggest a list of observational recipes.

1) About the galaxies themselves:

a) compare a sample of $r^{1/4}$ BCDGs with a sample of *nucleated* dwarf ellipticals as those identified in numbers by Binggelli et al. (1985) in the Virgo Cluster.

b) search for evidence of star formation sites migration across the objects.

c) study the geometrical (i.e. dynamical) parameters of the old stellar population decoupled from the newborne one. This implies observations in the infrared, where the contribution of the old giant stars should largely dominate the light of the objects.

d) search for, and make detailed studies on dwarf nucleated ellipticals that are red, (i.e. have no ultraviolet excess) and yet are weak H_α line emitters. If such objects exist, may they bridge the gap between dwarf spheroidals and $r^{1/4}$ BCDGs as "dying starbust" galaxies?

e) get the velocity dispersion of stellar population in $r^{1/4}$ BCDGs (use a large telescope!) and search for their location in the fundamental plane of the ellipticals.

f) make models of a dwarf spheriodal accreting a gas cloud that fuels a starburst inside and look into evolution, relaxation of stellar population, characteristic timescales, etc..

2) About the environment of the objects:

a) search for evidence of recent past tidal or merging processes (shells, tails, tidal debris, etc..., also in HI line)

b) identify the environment around the BCDGs, by means of multi - object spectroscopy of every galaxy visible up to 500 kpc in projected distance from a known BCDG candidate for tidal interaction. Check the velocities, etc...

c) search for HI clouds in the vicinity of BCDGs, look into HI distribution across pairs like Mrk 1480 - 81, search for giant common HI envelopes, etc...

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ПОВЕРХНОСТНАЯ ФОТОМЕТРИЯ ГОЛУБЫХ КОМПАКТНЫХ КАРЛИКОВЫХ ГАЛАКТИК ИЗ БЮРАКАНСКИХ СПИСКОВ

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М.ТУРАТО, С.СУРАС

Проведена поверхностная фотометрия в *B* и *R* цветах для 23 галактик с UV - избытком из двух бюраканских обзоров (FBS и SBS), отобранных как кандидаты в голубые компактные карлики. У значительной части выборки распределение яркости в проекции следует закону де Вокулера подобно ярким сфероидальным объектам в поле (эллиптическим галактикам и балджам спиралей). Другой наиболее часто встречающийся морфологический тип имеет экспоненциальное распределение яркости и поэтому похож на обычные карлики типа Магеллановых иррегулярных галактик. По своим малым абсолютным размерам и в среднем высокой эффективной поверхностной яркости исследуемые объекты скорее являются "компактными" в обычном практическом смысле.

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