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Multicolour surface photometry of galaxies : Mrk 35 and Mrk 799

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Abstract. Imaging photometry of two peculiar galaxies Mrk 35 and Mrk 799 has been carried out using a CCD camera and braod band filters. Both the galaxies are highly disturbed and the morphologies of the galaxies are quite complex. The images in different filters show interesting structures which are more clearly visible in the high frequency images obtained by substracting the median filtered image from the original image. In Mrk 35 a stellar nucleus is seen on the western side of the galaxy and an elongated bar is visible to its East. A dust lane appears to be present in the central region. The stellar nucleus is bluer compared to the barred structure. A very interesting feature seen in the colour *(B-R)* map is a U-shaped structure (elongated ring open on one end) situated slightly west of the central nucleus. In Mrk 799 a bright hotspot is seen on one side of the galaxy which is comparable in luminosity to the nucleus but the colour is much bluer which is indicative of the presence of massive young stars.

1. Introduction

Most of the known galaxies are classified according to the Hubble sequence depending on their morphology. But, there are galaxies that contain multiple nuclei, have irregular shapes, show the presence of plumes, tails, jets, hotspots etc. Some galaxies show a high level of nuclear or extra-nuclear activity manifested in the form of thermal or nonthermal radiation. The study of such peculiar galaxies will help us understand the role of mergers and galaxy-galaxy interactions leading to intense stellar activity. The study of the morphology can help in providing hitherto unknown information about galaxy mergers and interactions as also about the activity. In the present paper, we report multiband *(BV RI)* surface photmetry for such disturbed galaxies: *Mrk*35, *Mrk*799.

2. Observations and Analysis

The observations were carried out in May 1994 at the Cassegrain focus of the 104 cm Sampurnanand telescope of the Uttar Pradesh State Observatory, Nainital. A liquid nitrogen

(LN2) cooled, Thomson metachrome coated CCD (384x576 pixels) was used for imaging. Observations have been taken through Johnson's broad band BVRI filters. About 5 to 7 exposures were taken in each filter with typical exposure time being 300 to 600 seconds. Binning of 2 x 2 was employed before recording the images and the resulting plate scale is 0.66 arcsec per pixel. The individual images in each filter were then combined to improve the S/N ratio. Standard stars from Landolt's list (Landolt 1992) were observed for calibration. The analysis was carried out using the IRAF package isntalled on the HP735 work station at Physical Research Laboratory. The images were corrected for bias using the average bias frame and then flat fielded using the master flat. The photometry of the standard stars was carried out using the DAOPHOT task in IRAF. More than fifteen standard stars from Landolt (1992) list having $8^m.0 < V < 15^m.0$ and $-0.20 < B\text{-}V < +1.00$ were observed. With the help of these standard stars, transformation equations were established to convert the instrumental magnitudes to standard system. The errors in the standard magnitudes are $< 0.02^m$. The photometry of the galaxies was carried out as follows: The bias subtracted and flat fielded images of galaxies in different filters were aligned. The images were corrected for sky background using the mode value of the sky determined from the histogram of each image. The sky corrected images were then converted to standard flux values using the transformation coefficients obtained as described above. The calibrated images of the galaxies were further corrected for the following:

a) Galatic reddening : The corrections for the galactic reddening have been taken from Burstein and Heiles, (1984);

b) Extragalactic reddening : The corrections for reddening within the program galaxy were determined using the relation given in the Tully catalogue (Tully 1988);

c) K-corrections : As the redshifts of the two galaxies studied in the present work are low, the K-corrections were found to be very small ($<0^m.001$) and therefore neglected.

All images were scaled to 0.5 arcsec per pixel for plotting purpose. All the images and contour plots are in this format.

i) Mrk 35 (NGC 3353) : Mrk35 is an irregular amorphous galaxy. The galaxy images were taken in four filters BV RI. Figure 1a shows the galaxy image in B filter. The galaxy appears disturbed at shorter wavelengths and gradually smoothens towards the longer wavelengths I. In general, peculiar galaxies show interesting structures within the galaxy. In direct images, the structures hidden in the galaxy are in general not visible. To extract the structures embedded in the galaxy, high frequency images of the galaxy in all the filters were obtained by substracting the (5 x 5) median filtered image from the original images. The high frequency image in filter B is shown in Figure 1b. This image shows a stellar nucleus towards the north west with respect to the geometric center and an elongated bar lying along the south east direction. Two blobs are also visible towards the south-west. A stellar nucleus is seen towards the western side of the galaxy and an elongated bar is visible to its east and along the SW-NE direction. In addition to this two more structures are seen to the SW of this elongated feature. The bar appears

brighter in longer wavelengths. The colour images of Mrk35 in B – R and V – 1 were constructed. The contour map of the B – R colour image is shown in Figure 2. A very interesting U-shaped structure (elongated ring open on one end) located slightly west of the central part of the galaxy is clearly seen in the colour image. In general the B – R colour along the U–structure is blue compared to the average galaxy colour. There are sub structures within the U–structure. Various structures are named as a, b, c, d, e in Figure 2. Structure a coincides with the stellar nucleus and lies in the eastern arm of the U, for which B – R = + 0.36. The bluest region lies in the neck of the U-structure and does not coincide with any structures seen in the filter images. The bar is the reddest region which may be either due to the presence of a large number of old population stars present or due to heavy obscuration of the young stars.

ii) Markarian 799 (N 5430, U 8937) : Mrk 799 has been classified as a Sb type spiral galaxy undergoing a starburst (Mazzarella *et al.* 1982). Figure 3 shows the galaxy image in B filter. The galaxy shows a bright central nucleus and a hotspot at the end of the central bar. The bright region lies 40 arcsec (8 kpc) to the south east of the nucleus. Photometric measurements of the nucleus hotspots were made through an aperture of 4 arcsecs. The distribution of fluxes in the filters B, V, R, I through this aperture of 4 arcsecs is shown in Figure 4. The hotspot is bluer than the nucleus. In the nucleus, the flux values increase very steeply from B to R but the increase from R to I is gradual. Figure 5 shows the V magnitude contour. Table 2 gives the colours of the nucleus and the hotspot.

Table 1. Photometric colours of various structures shown in Figure 2 in Mrk 35.

Structure	Position from a	B – V	B – R	V – I
a	—	0.12	0.36	– 0.01
b	2" to the NW	0.06	0.56	0.42
c	4" to the NW	0.11	0.41	0.14
d	3" to the NW	0.10	0.32	0.06
e	4" to the SE	0.17 to 0.31	0.62 to 0.73	0.65 to 0.80

Table 2. Photometric colours of the nucleus and hotspot in Mrk 799.

Colour	Nucleus	Hotspot
B – V	0.73 ± 0.09	0.05 ± 0.20
B – R	1.24 ± 0.12	0.22 ± 0.24
V – R	0.51 ± 0.04	0.17 ± 0.06
V – I	1.18 ± 0.10	–0.05 ± 0.06

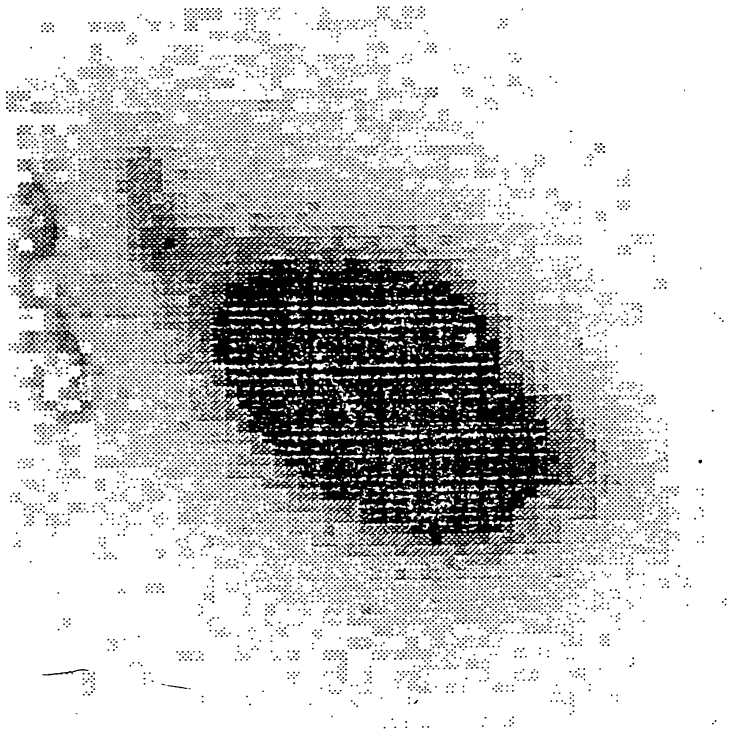

Figure 1a. B filter image of Mrk 35.

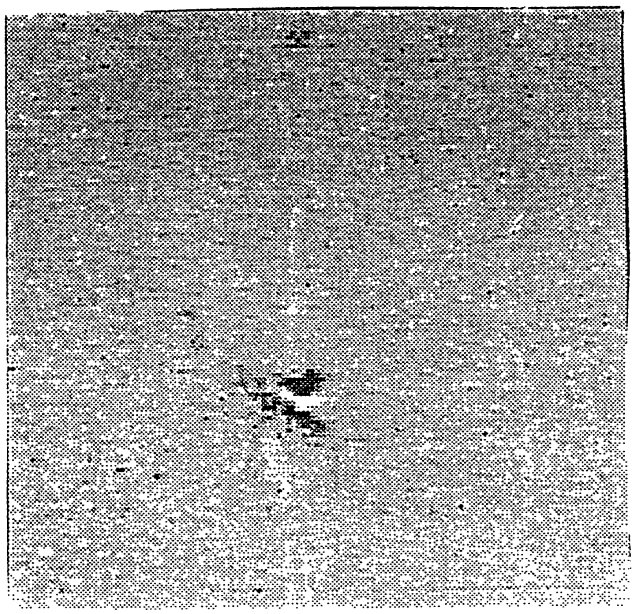

Figure 1b. High frequency image of Mrk 35 in B filter

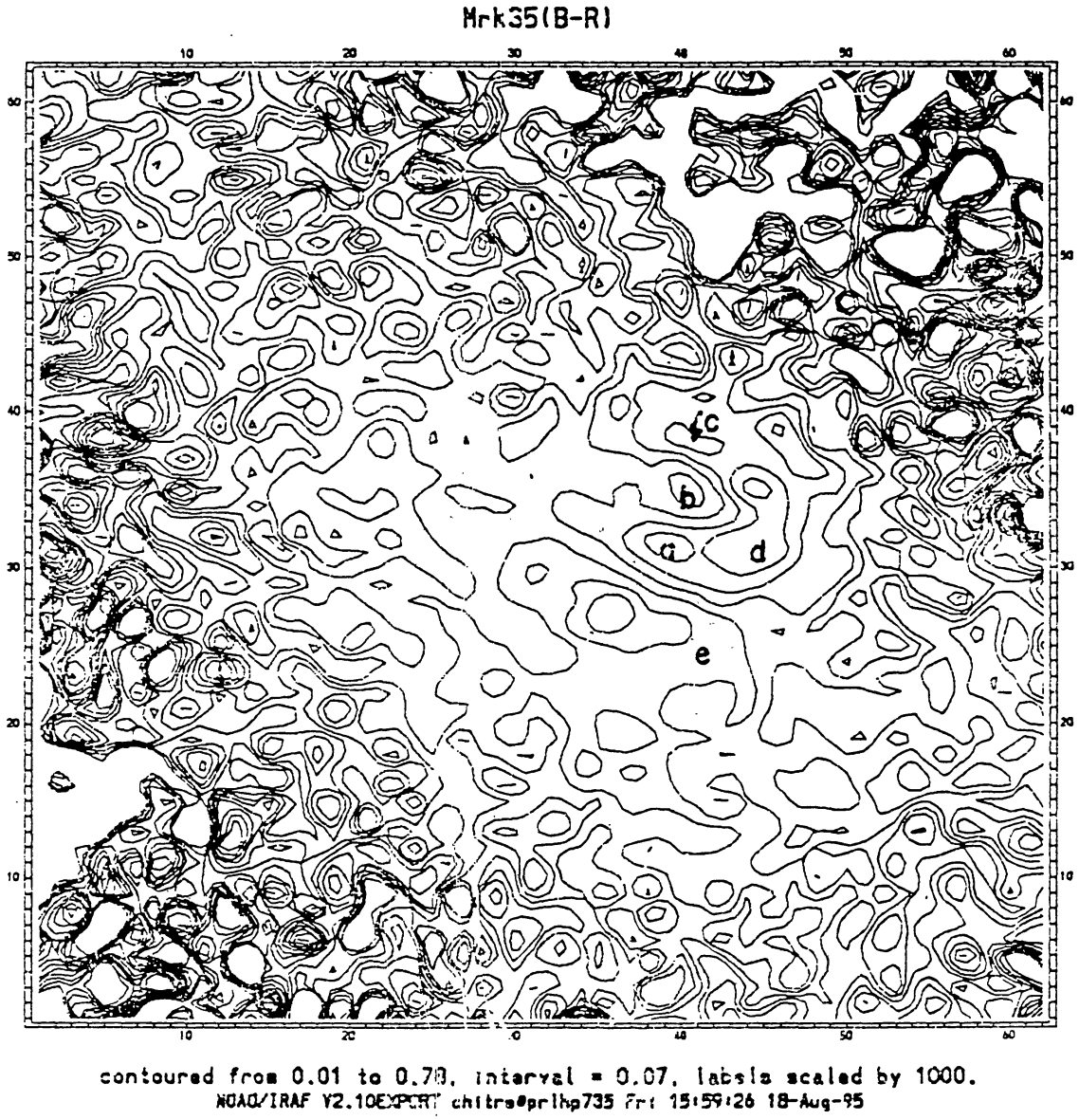

Figure 2. (B – R) colour map of Mrk 35 contoured from 0.01 to 0.78.

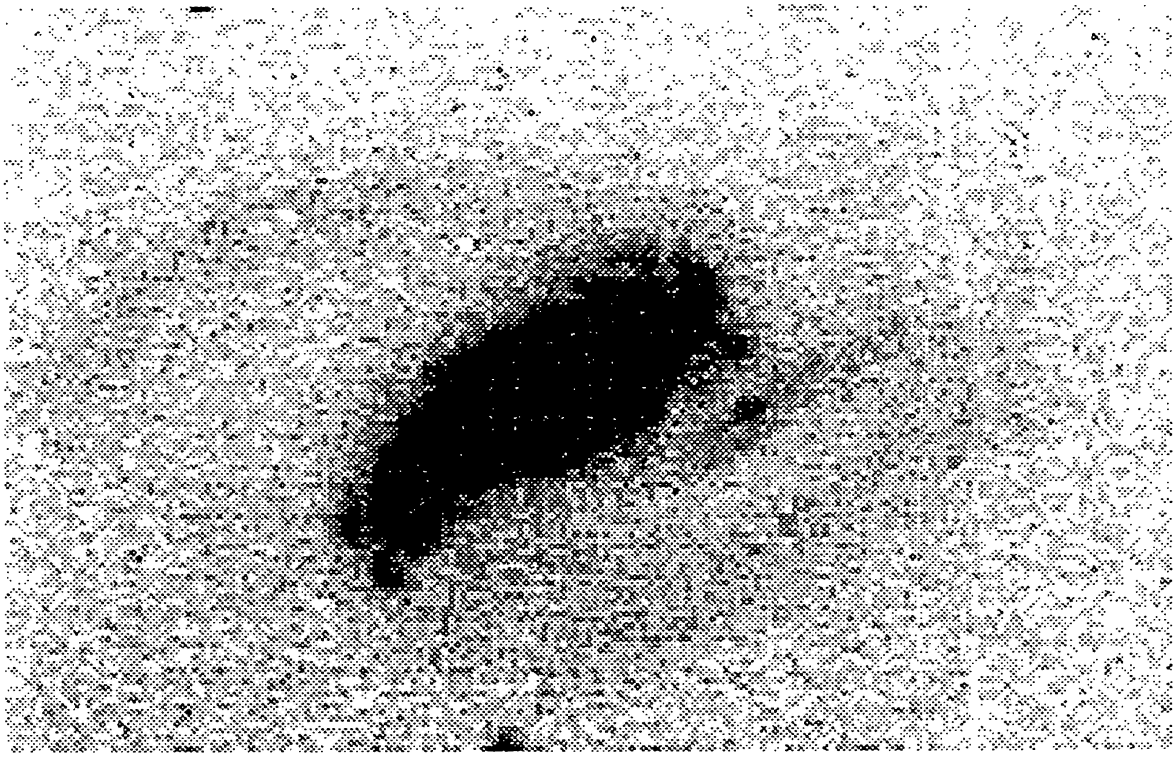

Figure 3. B filter image of Mrk 799.

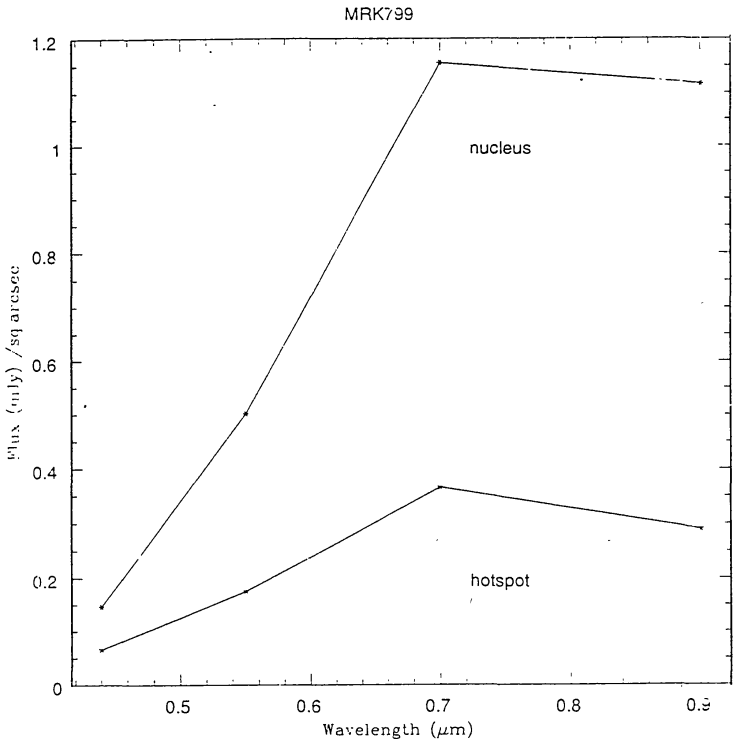

Figure 4 . Flux distribution in the optical region for the nucleus and hotspot of Mrk 799

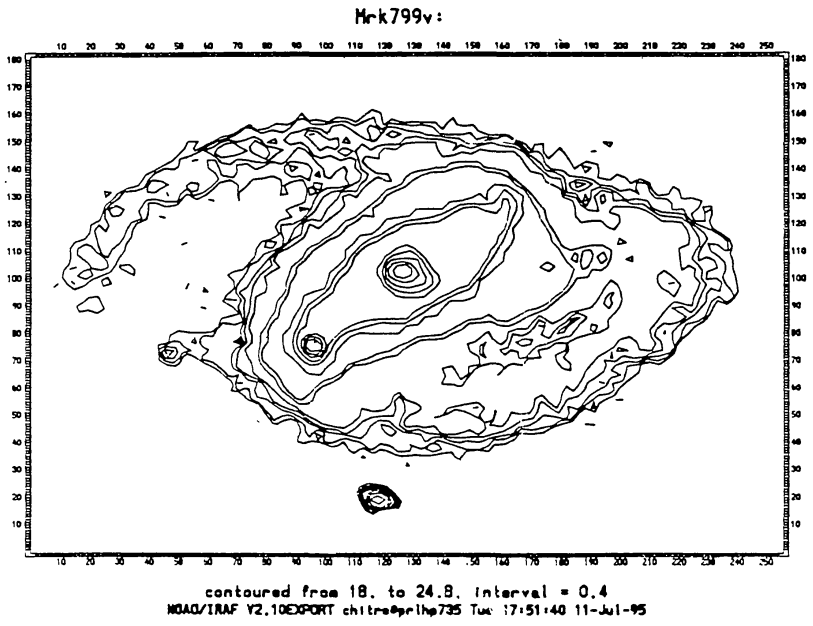

Figure 5. Contour of Mrk 799 in V filter

3. Discussions

As is evident in Table 2, the B – V colours of the hotspot are much bluer than those of the nucleus, indicative of the presence of more bluer stars than those in the nucleus. The B – V colour of the nucleus is similar to that observed in the bulge of normal galaxies or in globular clusters. The typical values of the colours are : B - V = 0.65, B - R = 1.10, V - R = 0.45, V – I = 0.95 (Reed 1985; Reed, Hesser & Shawl 1988; Hesser & Shawl 1985).

Interactions between galaxies are expected to affect the evolution of galaxies in a variety of ways. One of the consequences of the gravitational interaction between galaxies is the enhancement of the star formation rate in them (Joseph & Wright 1985; Bushouse 1987). The enhancement is in general, seen in one of the members (Joseph & Wright 1985). In the present study of Mrk 35 and Mrk 799 also, we find two bright nuclei and one of them is bluer compared to the other. This further supports the finding, by earlier researchers that enhancement of star formation is seen in only one component in a multiple nuclei system.

An empirical relation has been derived by Chini et al. 1992 for calculating the dust temperature from the IRAS data as

$$T_{dust} = 20\ (S_{60} / S_{100}) + 20$$

For Mrk 799, S_{60} = 10.40 Jy and S_{100} = 20.49 Jy. Hence, T_{dust} = 30.15K.

The mass luminosity ratio is a good measure of the starburst activity. The total luminosity from optical and FIR has been estimated using the optical fluxes obtained in the present study and the FIR fluxes taken from IRAS catalog. The total luminosity from optical to FIR has been estimated as $2 \times 10^{-12} W / m^2$. The dust mass is estimated from the FIR fluxes given in IRAS catalog using the method given by Bothun *et al.* (1989). The dust mass is $2.06 \times 10^7 M_\odot$. Young et al. (1986) show hat for spiral galaxies, the ratio of the molecular hydrogen mass to be approx. $1.0^3 \times 10^{10} M_\odot$. The mass-to-luminosity ratio (M / L) thus is estimated to be 0.09 indicating starburst. The small value of M / L is a signature of intense star formation activity in the galaxy. It appears from the comparative study of the colours of the hotspot and nucleus, that most of the young and massive stars are concentrated in the hotspot.

4. Conclusions

The morphology of Mrk 35 and Mrk 799 appears to be quite complex. Both show the presence of more than one nucleus / hotspot. One of the nucleus shows colours that are considerably bluer than the other one. It appears that both the galaxies belong to galaxy merger cases as is evident from the morphology of the galaxies and also from M / L ratio in case of Mrk 799.

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