JA.

IUCAA -.22/96

June 96

Nuclear Dust and Outer Shells in the Elliptical Galaxy NGC 7562

By

D.K. Sahu, S.K. Pandey, D.K. Chakraborty, Ajit Kembhavi and Vijay Mohan

Inter-University Centre for Astronomy and Astrophysics

An Autonomous Institution of the University Grants Commission

Preprint Request (Please quote the preprint number)
email : preprn@iucaa.ernet.in
Fax : 0212-350760
Post : IUCAA, Post Bag 4, Ganeshkhind, Pune 411 007, India

A&A manuscript no.
(will be inserted by hand later) 4677

Your thesaurus codes are:
11.03.3; 11.05.1; 11.09.1 NGC 7562; 11.09.4; 11.16.1

ASTRONOMY
AND
ASTROPHYSICS
11.6.1996

Nuclear Dust and Outer Shells in the Elliptical Galaxy NGC 7562 *

D. K. Sahu[1], **S. K. Pandey**[1], **D. K. Chakraborty**[1], **Ajit Kembhavi**[2], and **Vijay Mohan**[3]

[1] School of Studies in Physics. Ravishankar University. Raipur. 492 010. India
[2] IUCAA. Post Bag 4. Ganeshkhind. Pune. 411 007. India
[3] Uttar Pradesh State Observatory. Nainital. 263 129. India

Received October 25. 1995. accepted April 11. 1996

Abstract. We present a detailed photometric analysis of the nearby cooling flow elliptical galaxy NGC 7562 observed in the Johnson V and Cousins R and I filters. We derive surface brightness, color-index, ellipticity, and position-angle profiles, as well as geometrical parameters which characterise deviations of isophotes from perfect elliptical shapes. The galaxy is found to have inner boxy and outer pointy isophotes. We report the detection of a dust patch in the nuclear region of the galaxy as revealed from color-index maps and argue that some of the inner boxiness may be due to the presence of dust. We examine the residual image obtained by subtracting a smooth elliptical model galaxy from the original image and report the detection of arc-like brightness enhancements which appear as shells or ripples in the outer regions of the galaxy. This structure could be responsible for the outer pointy isophotes, as the presence of a faint outer disk in the galaxy has been ruled out on kinematic grounds. We briefly discuss the possible origin of the dust and shells in the galaxy.

Key words: Galaxies: elliptical – NGC 7562. Galaxies: cooling flows. Galaxies: interstellar matter. Galaxies: photometry

1. Introduction

Careful analysis of high quality images of elliptical galaxies taken with CCDs has demonstrated that isophotes show small but significant deviation from perfect ellipses (Carter 1978: Lauer 1985: Bender & Mollenhoff 1987: Jedrzejewski 1987: Bender et al. 1988). The isophotal distortions have been attributed to the presence of faint structures embedded in the otherwise smooth galaxies. Indeed the use of various image processing techniques has led to the detection of dust or dust lanes, shells or ripples, tidal extensions, X-structures, plumes and faint stellar disks in elliptical galaxies (Sparks et al. 1985: Lauer 1985: Ebneter et al. 1988: Veron-Cetty & Veron 1988: Scorza & Bender 1990: Forbes & Thomson 1992: Singh et al. 1994: Mahabal et al. 1995). Search for faint structures in these galaxies has received considerable attention in recent years because of the realization that these features can provide useful diagnostics of the structure, dynamics and evolution of galaxies in general, and of elliptical galaxies in particular.

We have undertaken a long term programme of CCD imaging of early-type galaxies in order to perform detailed surface photometric analysis as well as to search for faint non-elliptical structures embedded in them. In this paper we have focussed our attention on the rather well studied bright cooling flow elliptical galaxy NGC 7562. which was observed as a part of this programme. Some of the observational characteristics of this galaxy are given in Table 1.

Previous isophotal studies on this object have shown it to have inner boxy and outer pointy isophotes without any firm detection of faint structures (Lauer 1985: Sparks et al. 1985: Ebneter et al. 1988). Pointy isophotes are usually

Send offprint requests to: Ajit Kembhavi. email: akk@iucaa.ernet.in

* Based on observations taken from UPSO. Nainital. India.

Table 1. Some characteristics of NGC 7562

Type	V_r	$log L_B$	$log L_X$	$log L_{FIR}$	$log L_{5GHz}$	$log L_{HI}$	(v/σ)
E2(T= -5)	3806	10.63	41.10	< 42.93	< 27.76	35.16	0.04

Notes to Table 1. : The radial velocity V_r(km/sec) is taken from Sandage & Tammann (1987). L_B & L_X are taken from Canizares et al. (1987); L_B is expressed in solar units, while L_X is in erg/sec. L_{FIR} is in erg/sec and is derived from IRAS fluxes given by Knapp et al. (1989). L_{5GHz} is taken from Calvani et al. (1989). L_{HI} is expressed in erg/sec after converting the weighed mean HI flux from Bottinelli et al. (1990). The (v/σ) ratio is taken from Busarello et al. (1992).

associated with the presence of a faint stellar disk, but on the basis of its kinematical properties, Nieto & Bender (1989) have ruled out the possibility of NGC 7562 having such a feature.

We report the detection of dust in the vicinity of the nucleus as revealed from quotient images and color-index maps . We estimate the color excess $E(B-V)$ to be ~ 0.059 and the dust mass to be $\sim 9.0 \times 10^4 M_\odot$. An application of the shell finding procedure due to Forbes & Thomson (1992) has led to the detection of faint emission features lying mostly along the major axis of the galaxy. The inner boxiness and outer pointedness can be traced to the presence of nuclear dust and outer shells respectively. This galaxy is the third brightest member of Pegasus I cluster (Mould 1981), and forms an interacting pair with the galaxy NGC 7557 with a projected separation of 3$''$.1 and a radial velocity difference $\Delta V_r \sim 126$ km sec^{-1} (Rampazzo & Buson 1990). We suggest that the dust and shell-like emission features seen in the galaxy are most likely due to accretion of matter from this neighbour or strong tidal interactions with it.

2. Observations and Preliminary Data Reduction

Broad band Johnson V and Cousins R and I images of NGC 7562 were taken at the Cassegrain focus (f/13) of the 1m telescope of the Uttar Pradesh State Observatory (UPSO), Nainital, India on the night of October 28, 1992 as a part of a CCD imaging programme on a sample of early-type galaxies. The observations were carried out using a Thomson 384 × 576 CCD camera having 23 μm square pixels in direct imaging mode with 2 × 2 on-chip binning. This gives a scale of 0$''$.72 per pixel and a total field of 140$''$ × 210$''$. We obtained three exposures in V, two of 900s each and one of 600s, two exposures in R of 200s each and two exposures in I of 300s each. Observations were taken under photometric conditions and seeing was in the range 1$''$.7 - 1$''$.9 (FWHM). Several sky flats in each filter and bias frames were taken for pre-processing of the CCD data. Images of comparison stars, chosen close to the galaxy, were taken in each filter sandwiched between successive galaxy exposures. These were used in extinction correction as well as for computing the galaxy magnitude in a differential manner. In addition, several standard stars from the list of Landolt (1983) were observed for photometric calibration. The photometric performance of the CCD system on the 1m telescope at UPSO is described in detail by Mohan et al. (1991). The overall accuracy of the photometric calibration is $\sim$ 0.01mag. To judge the accuracy of the present results we have simulated aperture photometry using circular apertures and compared the results with the similar data in the V band from Longo & de Vaucouleurs (1983) and Poulain (1986). The results are given in Table 2. The rms mean differences between the present and the other two works are 0.029 and 0.011, respectively.

Preliminary reductions of the CCD data like bias subtraction, flat fielding and cosmic-ray event removal were performed using standard tasks within IRAF [1] to obtain clean images. Galaxy frames were aligned to an accuracy better than 0.1 pixel and combined in each filter separately to improve the signal-to-noise ratio. The geometrically aligned images were corrected for the difference in the seeing psf in different filters. These images were used in constructing color-index maps to search for absorption features in the galaxy. The isophotal shape analysis was carried out using the *ellipse* task within STSDAS[2] which is based on the method described in detail by Jedrzejewski (1987). Obvious foreground stars in the galaxy region were masked off and excluded from the ellipse fit. Ellipse fitting was started at 7$''$ from the centre to minimize the effect of seeing. It was continued outward by increasing the semi-major axis length by 10% in each step, and finally terminated at the level where the mean intensity in counts became comparable to three times the standard deviation of the sky background. Likewise, ellipses were fitted inward upto the

[1] IRAF *is distributed by the National Optical Astronomy Observatories (NOAO), which is operated by the Association of Universities, Inc. (AURA) under co-operative agreement with the National Science Foundation.*

[2] *The Space Telescope Science Data Analysis System STSDAS is distributed by the Space Telescope Science Institute.*

Table 2. Aperture photometry for NGC 7562

	V magnitude		
Aperture radius(″)	This work	Longo & de Vaucouleurs (1983)	Poulain (1986)
12.50	12.75	12.67	-
15.60	12.58	-	12.59
18.93	12.45	12.39	-
20.28	12.40	12.29	-
21.68	12.36	-	12.33
27.36	12.23	12.19	-
30.43	12.18	-	12.18
32.15	12.15	12.06	-
40.17	12.04	12.13	-
41.41	12.03	12.08	-

centre by decreasing the semi-major axis length for each successive ellipse by 10%. The ellipticity, position-angle, as well as galaxy-centre were taken to be variable at each stage of the ellipse fit. This procedure gives surface brightness, color-index, ellipticity and position-angle profiles as a function of semi-major axis length in each pass band. The instrumental surface brightness and color profiles thus obtained were corrected for atmospheric extinction and transformed to the Johnson system. The surface brightness, ellipticity, position-angle and fourth order cosine coefficient for the V pass band as well as the color-index profiles are displayed in Figure 1.

3. Detection of nuclear dust and outer shells

3.1. Nuclear Dust

The detection of subtle absorption features superposed on the steep brightness gradient in galaxies presents considerable difficulties, and different techniques have been used for the purpose. In one of the techniques a quotient image is obtained from the division of the original image by its smooth model in the same filter (Lauer 1985; Ebneter et al. 1988). The other method involves examination of color-index images of the galaxies obtained by dividing a blue band image of the galaxy by a red one. The images should be geometrically aligned and corrected for the difference in seeing, if any, before division. Sparks et al. (1985) used a similar technique, but the color-index map was obtained using a smooth model of the red band image. Such two-color images are more appropriate when searching for dust features. Using these techniques a large fraction of elliptical galaxies is found to contain dust features. We have applied all these techniques to NGC 7562 to search for the dust features in it. The quotient-images as well as two-color images created in all manners discussed above reveal the presence of dust absorption features in the central region of the galaxy. For illustration, the color-index map $V - R$ of the galaxy is shown in Figure 2a. It shows a patchy region which is redder than its surrounding (darker tone), covering an area $\sim$ 28 arcsec^2 lying within $\sim 10''$ from the galaxy centre. A cut across the dust patch shown in Figure 2b reveals the presence of an off-centered region having $(V - R)$ color significantly redder than the surrounding region.

The increased reddening seen in color-index maps may be either due to the variation in stellar population or dust absorption or both. The separation of the contribution to reddening due to dust from that due to population changes is quite complex. Qualitatively, by examining the brightness profile in conjunction with color-index maps or color profiles it is possible to decide which one of the two is responsible. Increased reddening, coinciding spatially with decrease in brightness in a single band, points to the presence of dust. Increase in reddening with corresponding increase in brightness, however, indicates an increase in the older population of stars. This distinction would of course work in the case where the amount of reddening seen in the color-index map is significant. For the majority of elliptical galaxies, the density of the older population of stars increases towards the nucleus, giving rise to increase in red color of the galaxy. Against this background, the presence of a small dust patch causing extra reddening is difficult to see in the luminosity profile in a single passband. It seems unlikely that an elliptical galaxy will have an enhanced density of older population of stars occupying a patchy region in the galaxy. Therefore, the redder region seen in color index map is likely to be due to the dust extinction. The amount of reddening is too small to have any discernible effect in the luminosity profile even in the shorter wave band that we have. Since the dust patch is located in the nuclear region where signal-to-noise ratio is very high the detection of dust feature is real.

The presence of dust should also affect the values of b4 coefficient making it color dependent. For this galaxy the color dependence of b4 coefficient is seen but is not very significant. so it is rather difficult to say whether the dust is wholly responsible for the inner boxiness seen in the galaxy. From the analysis of a sample of elliptical galaxies containing dust Forbes (1991) found that dusty ellipticals have tendency to have boxy isophotes.

3.2. An estimate of the dust mass from optical color excess

In order to investigate the properties of the dust in NGC 7562, we have created extinction maps adopting the procedure of Goudfrooij et al. (1994). A quotient image in each wave band is constructed as described in section 3.1. and then transformed to magnitudes to obtain extinction maps at each wavelength λ, with the extinction in magnitude given by

$$A_\lambda = -2.5 \log(I_{\lambda,obs}/I_{\lambda,model}), \quad (1)$$

where I stands for the intensity(ADUs) of an individual image pixel. The ratio $A_R/A_V \sim 0.71$ which is quite close to its value in our galaxy. Therefore, we may assume that dust properties in the elliptical galaxy NGC 7562 are similar to those in our galaxy. This assumption allows us to use the ratio of neutral hydrogen column density $N(HI)$ to color excess $E(B-V)$ in our galaxy (Bohlin et al. 1978),

$$N(HI) = 5.8 \times 10^{21} \times E(B-V) \text{ atoms cm}^{-2}. \quad (2)$$

We have estimated the color excess in the dusty region from the color-index maps constructed from the direct images in order to avoid the artifacts that may be introduced by the ellipse fitting procedure and modeling algorithms. The mean color excess $E(V-R)$ of the dust patch over the immediate surrounding is 0.046 ±0.01. Using the relation given by Savage and Mathis (1979) the color excess in $(V-R)$ can be converted into the color excess in $(B-V)$ to get $E(B-V) = 0.059$. The total mass of neutral Hydrogen in the dusty region is obtained by integrating the column density over the area of $\sim$ 28 arcsec^2 which is significantly redder (≥ 0.02) than the surrounding region of the galaxy. Adopting a value of 3806 km sec^{-1} (Sandage and Tammann 1987) for the radial velocity of the galaxy, and assuming $H_0 = 50$ km sec^{-1}Mpc^{-1}, we get

$$M_{HI}^{total} = 9.0 \times 10^6 M_\odot \quad (3)$$

Assuming the gas-to-dust mass ratio in NGC 7562 to be 100 as that in our galaxy (Burstein and Heiles 1978), the mass of the dust is

$$M_{dust} = 9.0 \times 10^4 M_\odot \quad (4)$$

The dust patch can have larger extension than presently detected, therefore our estimate provides a lower limit on the dust mass. Forbes (1991) estimated an upper limit of $4.11 \times 10^7 M_\odot$ for the dust mass in NGC 7562 based on FIR flux measurements (Knapp et al. 1989) at 100μm. This is roughly two orders of magnitude larger than the present estimate.

3.3. Outer shells

Faint emission features like shells or ripples embedded in the smooth spheroidal component can significantly distort the isophotes which in turn would appear as non-zero values of one or more of the higher order coefficients in the Fourier expansion. But the faint features can be too faint to be seen in the residual image which is obtained by subtracting the model image from the original frame. In order to delineate the fine emission features that might be present in the galaxy a smooth model is constructed in an alternative way, to better reveal the presence of emission features. In this method, during the course of ellipse fit certain fraction of the brightest pixels are excluded from the fit using the clip parameter available within the *ellipse* routine in STSDAS. A model of the galaxy obtained from the linear interpolation of the fitted ellipses will be smoother than the one constructed without clipping. Therefore the residual image obtained by subtracting this model from the original image is better suited for detection of shells or other emission features that represent additional light superposed on the underlying galaxian light. Forbes and Thomson (1992) and Forbes et al. (1995) have successfully used this technique in the search for shells in several elliptical galaxies.

We have constructed models of the galaxy *with* and *without* the clipping parameter and examined the residual image as well as the profiles of the b4 coefficient for the two cases. To minimize the dust extinction and the night sky emission the R image was chosen. Some additional CCD images of the galaxy in the R band taken during November, 1995 with the same setup as described in the section 2 were also included which improved the image quality considerably in evaluating the statistical significance of the faint features. Figure 3a shows the residual image of the galaxy obtained *with* clipping function. The faint emission features (shells) lying along the apparent major axis on both sides of the centre are seen prominently against the smooth background. The b4 coefficient for the clipped model is shown in the adjoining figure (Figure 3b). It is evident from this figure that isophotes are not significantly boxy or pointy anywhere over the radial range, i.e. the underlying galaxy has nearly perfect ellipses. When clipping function is not used, the entire galaxy light, including the additional light from the embedded faint emission features, is sampled during the ellipse fit, and therefore, in the residual image shown in Figure 3c these faint features are not clearly seen. The profile of the b4 coefficient for the unclipped model is displayed in Figure 3d, which shows that the isophotes are significantly pointy for major-axis length beyond $\sim 25''$. With the available image quality the detection of shells is significant. This observation strengthens our view point in associating the pointy isophotes with the detection of outer shells in the galaxy.

We have made a bulge-to-disk decompositon of the brightness profile of this galaxy, but failed to fit any disk component to it. The observed surface brightness along with the best fit bulge profile are shown in Figure 4. The best fit value for the effective length (r_e) is $29''.1 \pm 3.1$, while Kent (1985) derived $r_e = 24''.1$ from the best fit bulge model, and Busarello et al. (1992) have quoted $r_e = 28''.2$ for this galaxy.

A positive value of the b4 coefficient is usually associated with a weak stellar disk embedded in the smooth galaxy. The presence of a weak disk in elliptical galaxies is also correlated with values of (v/σ), where v and σ are the velocities corresponding to the rotational kinetic energy and kinetic energy of the line of sight component of the random motion, respectively. The value of this parameter for NGC 7562 is ~ 0.04 (see Table 1), which is too small for it to support a disk component (Nieto & Bender 1989). We conclude that the pointy isophote of the galaxy is not due to a faint disk, but due to shells or ripples seen in the outer regions of the galaxy.

Although, the fourth cosine term (b4) is the most commonly used harmonic component in characterizing the isophotal distortions, other higher-order sine and cosine terms (a3, a4 and b3) are also found to be sensitive indicator for the presence of dust absorption and other faint structures in ellipticals (Peletier 1989, Forbes 1994, Goudfrooij et al. 1994). The higher-order harmonics for the galaxy in R filter are shown in Figure 5. We notice that in the region where dust patch has been detected and the isophotes are boxy, the third order sine term (a3) also appears to have small but positive values. Likewise, in the region where shells have been detected and the isophotes are significantly pointy, all other harmonic components exhibit a clear tendency to have non-zero values.

4. Discussion

It is widely accepted that the FIR emission at 100 μm is due to cool dust. The IRAS flux measurements in NGC 7562 shows that it contains relatively small amount of dust. Our estimate of the dust content is about two orders of magnitude smaller than the upper limit on dust mass obtained from FIR measurements (Knapp et al. 1989). The difference could arise because the dust could be distributed rather diffusely reducing the absorption in the optical wave bands (Goudfrooij & de Jong 1995).

The question of origin of the dust in elliptical galaxies was dealt with in considerable detail by Forbes(1991) using 100 μm fluxes from IRAS co-added data for a sample of elliptical galaxies taken from Bender et al.(1989). The distribution function of the relative dust content from the sample reveals that the dust is not coupled to the stellar content, and that some other process is important in determining the distribution of dust mass among elliptical galaxies. The analysis suggested that the cold phase of the interstellar medium in ellipticals may be the result of an external accretion event. By applying this method to the HI gas content from a sample of 152 ellipticals Knapp et al.(1985) arrived at the same conclusion.

One possible explanation for the external origin of dust in elliptical galaxies is a cooling flow. The cooling of hot gaseous haloes may deposit gas and low-mass stars within the galaxy. The analysis by Forbes(1991), however, demonstrated that the cooling flow is not a significant source of dust or HI gas in ellipticals. In fact, it was shown that the dust content is not related to the hot gas content in both cooling flow and non-cooling flow galaxies.

Another attractive possible mechanism for the acquisition of dust in ellipticals is a merger or interaction. Presence of extensive dust, infalling HI gas, kinematically peculiar cores and shells or ripples are believed to be strong indicators of a merger process. Except for the present detection of a dust patch in the nuclear region and shell-like features in outer regions, the galaxy NGC 7562 is not known to have a peculiar core or to contain infalling HI gas. Several shell galaxies have been reported to possess secondary nuclei, and this provides support for the merger model, but so far a secondary nucleus has not been detected in the galaxy NGC 7562. Therefore, either NGC 7562 never experienced a merger process in its evolutionary history or a merger occurred so long ago that no nuclear traces are left. In that case the dust distribution should have equilibriated.

By virtue of its location in the cluster, and its proximity with another prominent member of the cluster, obviously the environment of NGC 7562 is very conducive for interaction and accretion processes to occur. The accretion of matter from its neighbouring galaxy NGC 7557, therefore, seems to be the most attractive and natural process to explain the observed dust in the galaxy.

A large fraction of elliptical galaxies are found to be blessed with shells and other shell-like fine structures (Malin & Carter 1983; Seitzer & Schweizer 1990), which provide important clues for their structure and evolution. Several models have been proposed to explain the origin of shells (see Forbes et al. 1995). In the accretion model shells are believed to have formed during capture and subsequent disruption of a small secondary galaxy in the gravitational potential of the primary galaxy (Dupraz & Combes 1986; Hernquist & Quinn 1988, 1989). In the merger model proposed by Hernquist & Spergel (1992), the collision between two disk galaxies of comparable mass can lead to formation of shells or other fine structures. In the interaction model, the interaction of the elliptical galaxy with a neighbouring galaxy induces density waves in its thick disk population, which subsequently leads to the formation of shells in the elliptical galaxy (Thomson & Wright 1990; Thomson 1991).

Our analysis here is limited to the detection of shells in the outer regions of the galaxy NGC 7562. For want of good signal-to-noise ratio we have refrained from attempting quantitative measurements on these features. It is therefore not possible for us to determine which one of the three alternative models described above will be operative in creation of shells in the galaxy NGC 7562. Looking into the environment in which NGC 7562 resides, strong tidal interactions with its neighbouring galaxy NGC 7557 seems to provide the most probable explanation for the formation of shells in it.

5. Conclusions

We report for the first time the detection of a nuclear dust patch in the galaxy NGC 7562 covering an area of ~ 28 arcsec^2 and having a mass of $\sim 9.0 \times 10^4 M_\odot$, based on mean optical color excess of the dusty region over the surroundings. Some of the inner boxiness of this galaxy may be attributed to the dust in its nuclear region.

We also report the detection of shells in the outer regions of the galaxy, and associate these with its outer pointy isophotes.

We suggest that both the dust and shells observed in the cooling flow galaxy NGC 7562 are most likely due to accretion of matter from the neighbouring galaxy NGC 7557 or strong tidal interactions with it.

Acknowledgements. One of us (SKP) is an Associate of IUCAA and he expresses his sincere thanks to Professor J. V. Narlikar, Director, IUCAA for providing support and facilities which made this study possible. We are thankful to the Director, UPSO, Nainital for observing time. SKP, DKC, and DKS thank Department of Science and Technology(DST), Govt. of India, New Delhi for financial support through a project grant No. SP/S2/O 25/90. We are also thankful to Dr. Maccagni who refereed the paper and offered his critical comments, and to Professor Tushar Prabhu and Professor Ram Sagar for enlightening discussions.

References

Bender R., Dobereiner S., Mollenhoff C. 1988, A&AS 74, 385.
Bender R., Mollenhoff C. 1987, A&A 177, 71.
Bender R., Surma P., Dobereiner S., Mollenhoff C., Madejsky R. 1989, A&A 217, 35.
Bohlin R.C., Savage B.D., Drake J.R. 1978, ApJ 224, 132.
Bottinelli L., Gouguenheim L., Fouque P., Patrurel G. 1990, A&AS 82 391.
Burstein D., Heiles C. 1978, ApJ 225, 40.
Busarello G., Lomgo G., Feoli A. 1992, A&A 262, 52.
Calvani M., Fasano G., Franceschini A. 1989, AJ 97, 1319.
Canizares C. R., Fabbiano G., Trinchieri G. 1987, ApJ 312, 503
Carter D. 1978, MNRAS 182, 797.
Dupraz C., Combes F. 1986, A&A 166, 53.
Ebneter K., Djorgovski S. Davis M. 1988, AJ 98, 538.
Forbes D.A. 1991, MNRAS 249, 779.
Forbes D. A., Thmoson R. C. 1992, MNRAS 254, 723.
Forbes D. A. 1994, AJ 107, 2017.
Forbes D. A., Reizel D. B., Williger G. M. 1995, AJ 109, 1576.
Goudfrooij P., de Jong T. 1995, A&A 298 784.
Goudfrooij P., de Jong T., Hansen L., Norgaard-Nielsen H.U., 1994, MNRAS 271, 833.
Hernquist L., Quinn P. J. 1988, ApJ 331,682.

Hernquist L., Quinn P. J. 1989. ApJ 342. 1.
Hernquist L., Spergel D. N. 1992. ApJ 339. L117.
Jedrzejewski R. I. 1987. MNRAS 226. 747.
Kent S. M. 1985. ApJS. 59. 115.
Knapp G. R., Turner E. L., Cunniffe P. E. 1985. AJ 90. 454.
Knapp G. R., Guhathakurta P., Kim D.-W., Jura M. 1989. ApJS 70. 329.
Landolt A.U. 1983. AJ 88. 439.
Lauer T. R. 1985. MNRAS 216. 429.
Longo G., deVaucouleurs A. 1983. *A general catalogue of photoelectric magnitudes and colors in U. B. V system of 3,578 galaxies brighter than* 16^{th} *V-magnitude (1963-1982).* Texas Monographs in Astronomy 3 (Univ. of Texas).
Mahabal A., Kembhavi A. K., Singh K. P., Bhat P. N., Prabhu T. P. 1995. ApJ (in press).
Malin D.F., Carter. D. 1983. ApJ 274. 534.
Mohan V., Paliwal D.C., Mahra H.S. 1991. Bull Astron Soc India 19. 235.
Mould J. R. 1981. PASP 93. 25.
Nieto J. L., Bender R. 1989. A&A 215. 266.
Peletier R. F. 1989. Ph. D. Thesis. University of Groningen.
Poulain P. 1986. A&AS. 64. 225.
Rampazzo R., Buson L.M. 1990. A&A 236. 25.
Sandage A., Tammann G. A. 1987 *A Revised Shapley - Ames Catalog of Bright Galaxies. Washington D. C.*, Carnegie Institution of Washington.
Savage. B.D., Mathis. J.S. 1979. ARA&A 17. 73.
Scroza C., Bender R. 1990. A&A 235. 49.
Seitzer P., Schweizer. F. 1990. *Dynamics and Interaction of Galaxies*. p.270. ed. Wielen. R., Springer-Verlag. Heidelberg.
Singh. K.P., Prabhu T. P., Kembhavi A. K., Bhat P. N. 1994. ApJ 424. 638.
Sparks W.B., Wall J.V., Thorne D.J., Jorden P.R., van Breda I.G., Rudd P.J., Jorgensen H.E. 1985. MNRAS 217. 87.
Thomson R. C. 1991. MNRAS 253. 256.
Thomson R. C., Wright A. E. 1990. MNRAS 217. 87.
Veron-Cetty M.P., Veron. P. 1988. A&A 204. 28.

This article was processed by the author using Springer-Verlag LaTeX A&A style file *L-AA* version 3.

Caption to the figures

Figure 1 : The V band profiles of surface brightness, ellipticity, position-angle, *b4* coefficient, and color-index profiles.

Figure 2 : (a) V-R color index image of the galaxy NGC 7562: darker shades represent redder regions.

(b) A cut across the dust patch in the color-index image averaged over five rows are plotted around the galaxy center.

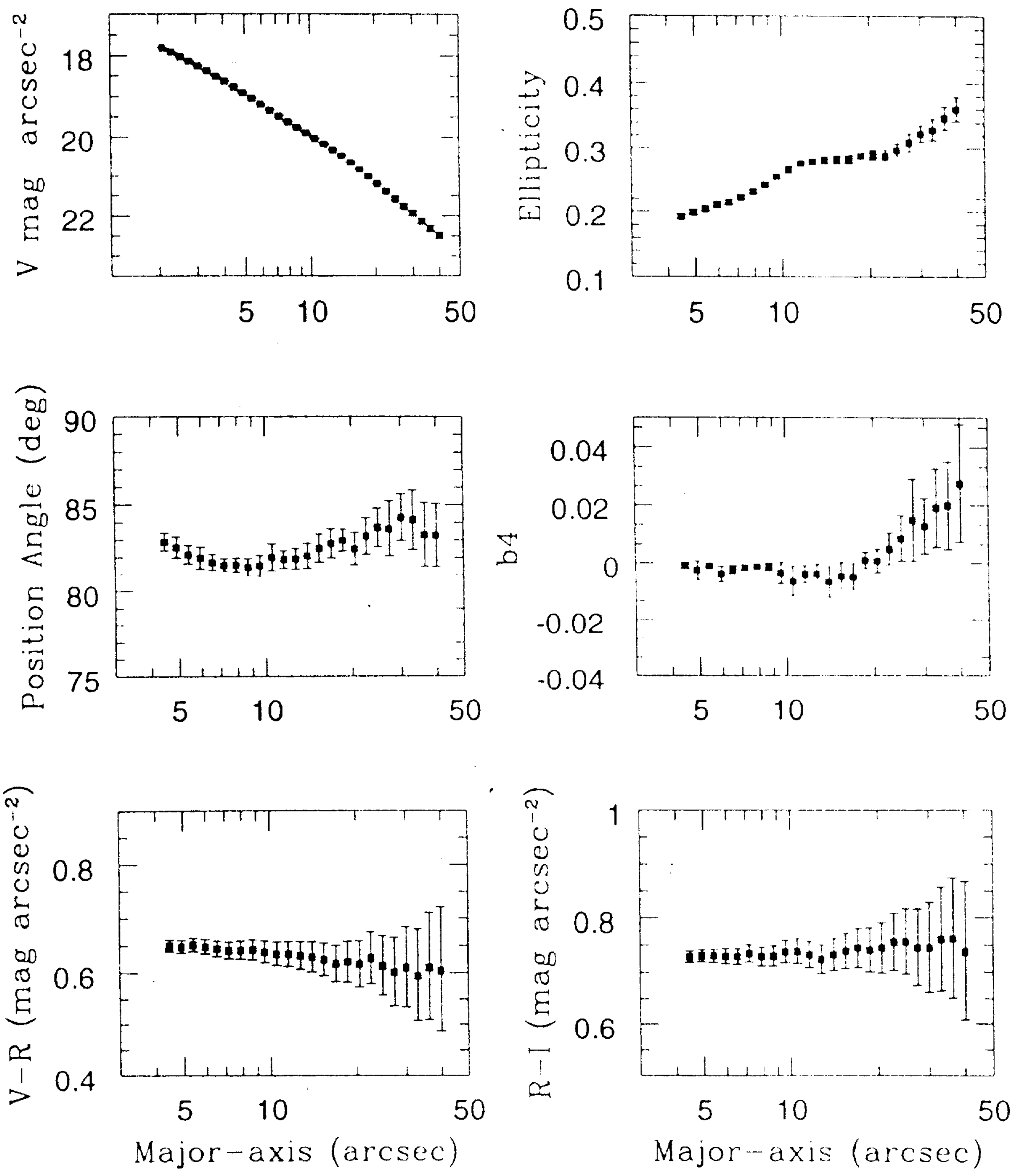
Figure 3 : The residual maps and b4 profiles of the galaxy in the R band :

(a, b) The residual image and b4 profile for the clipped model.

(c, d) The residual image and b4 profile without clipping.

Figure 4 : The observed surface brightness profile in R band in magnitudes arcsec^{-2} shown with the fitted bulge profile.

Figure 5 : The higher order Fourier coefficients in the R band.



V mag arcsec^{-2}
18
20
22
5
10
50
Ellipticity
0.5
0.4
0.3
0.2
0.1
Position Angle (deg)
90
85
80
75
b4
0.04
0.02
0
-0.02
-0.04
V−R (mag arcsec^{-2})
0.8
0.6
0.4
R−I (mag arcsec^{-2})
1
Major−axis (arcsec)
Major−axis (arcsec)

Figure 1.

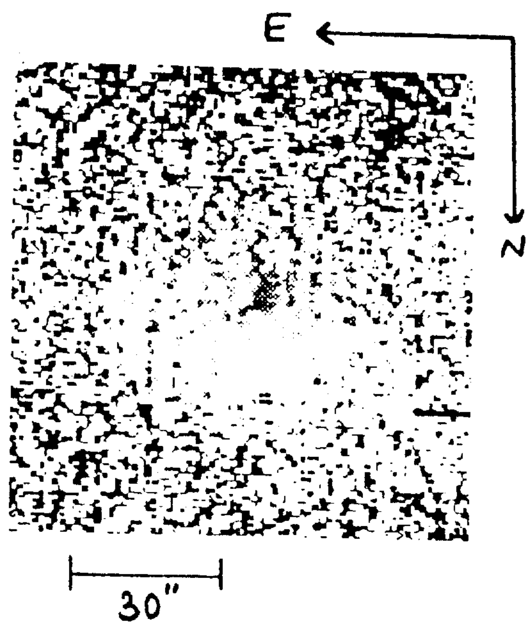


Figure 2(a)

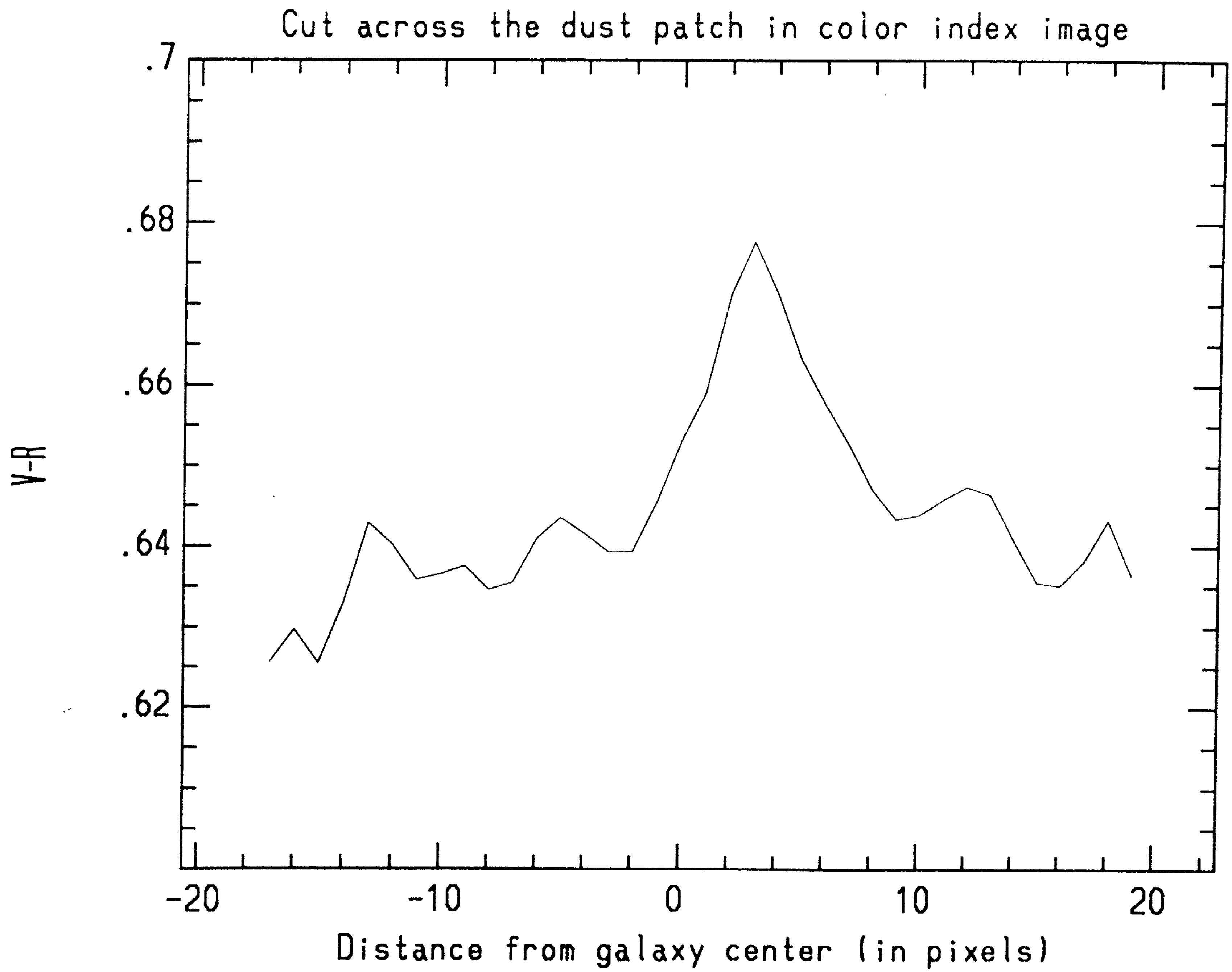

Cut across the dust patch in color index image
.7
.68
.66
.64
.62
V-R
-20
-10
0
10
20
Distance from galaxy center (in pixels)

Figure 2(b)

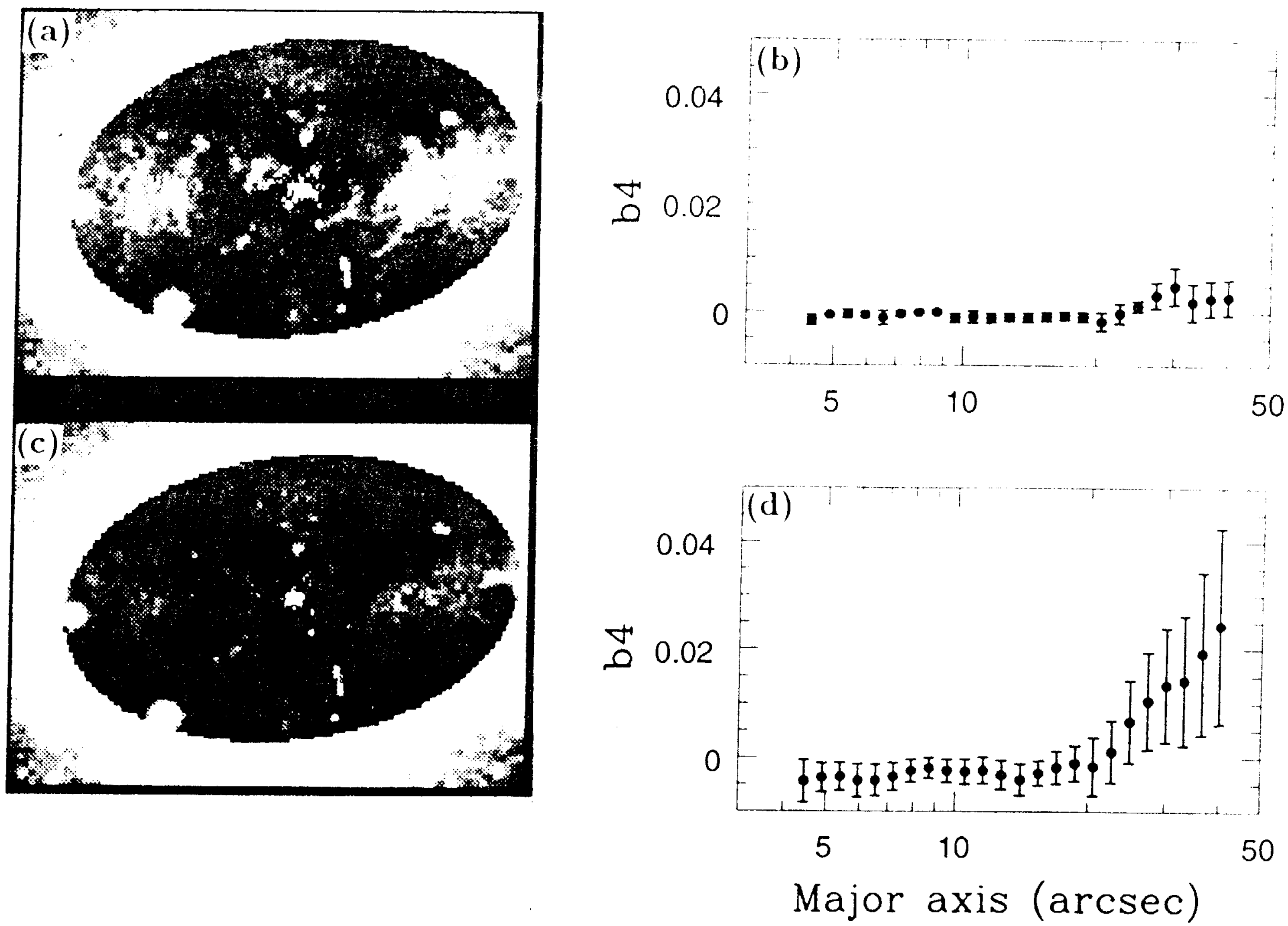


Figure 3

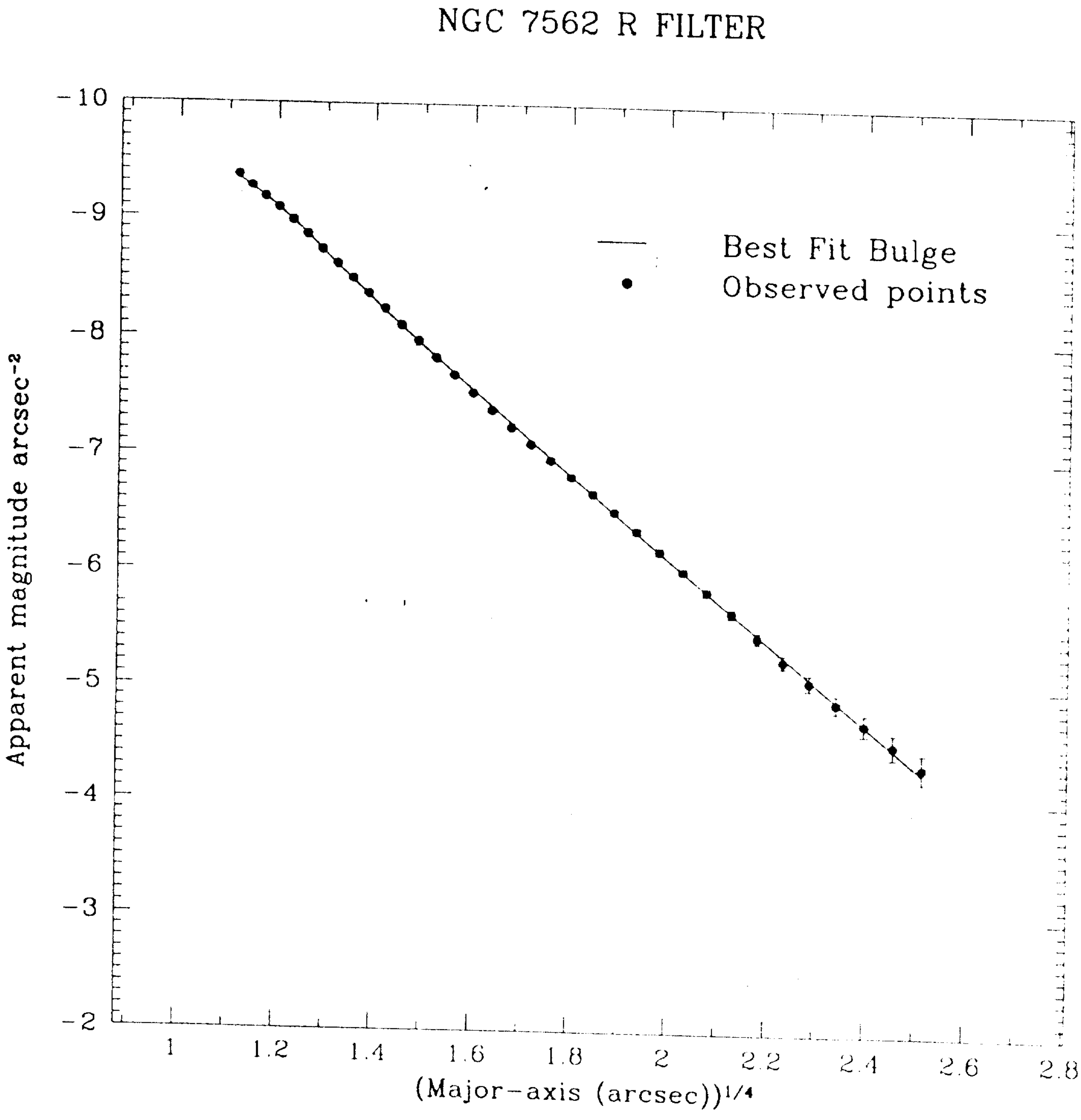

NGC 7562 R FILTER
Best Fit Bulge
Observed points
Apparent magnitude arcsec^{-2}
(Major-axis (arcsec))$^{1/4}$
-10
-9
-8
-7
-6
-5
-4
-3
-2
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8

Figure 4.

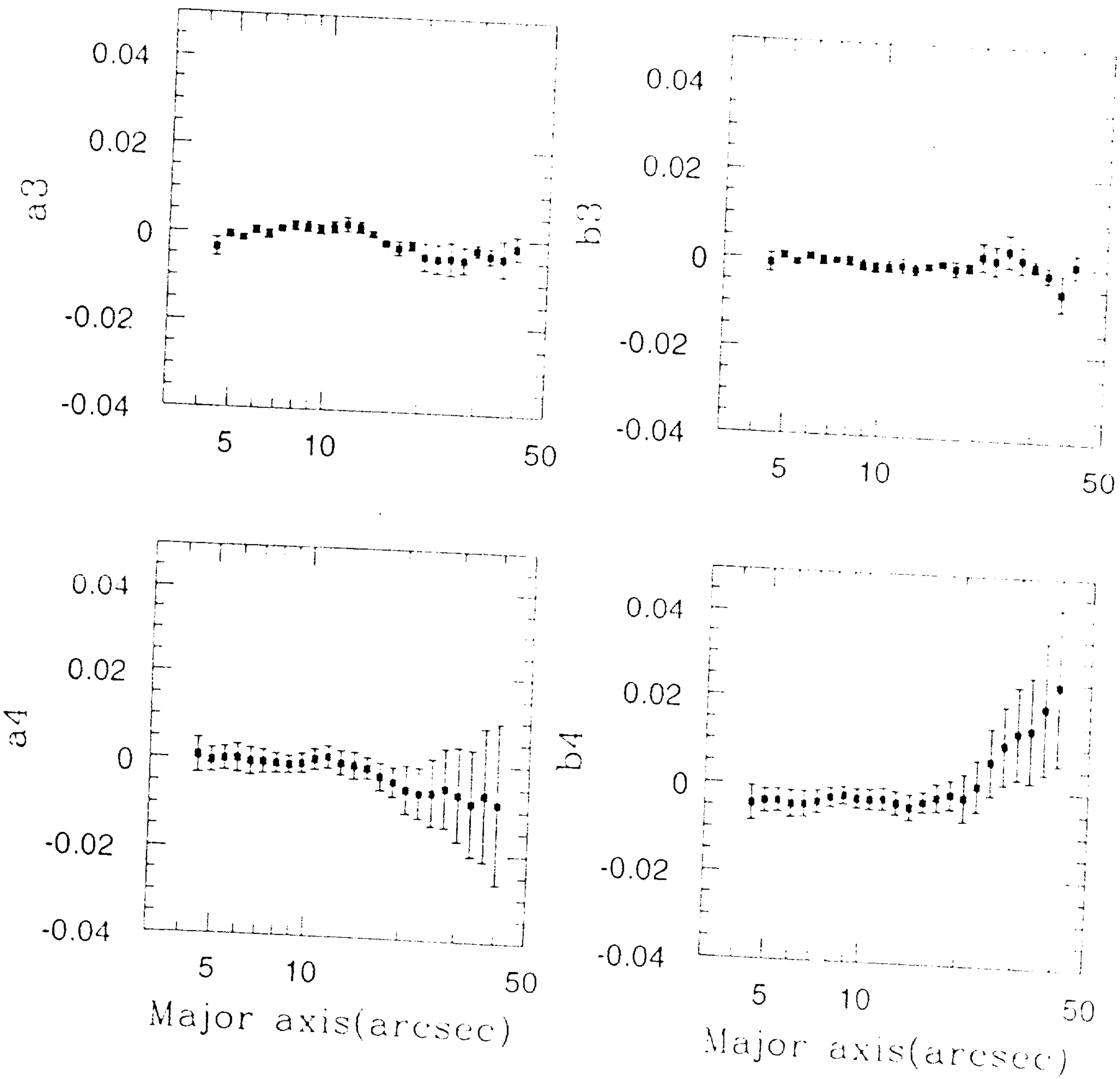


Figure 5.