

The stellar population of the decoupled nucleus in M 31

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Abstract. The results of a spectroscopic and photometric investigation of the central region of M 31 are presented. An analysis of absorption-index radial profiles involving magnesium, calcium, and iron lines has shown that the unresolved nucleus of M 31 is distinct by its increased metallicity; unexpectedly, among two nuclei of M 31, it is the faintest one located exactly in the dynamical center of the galaxy (and dynamically decoupled) which is chemically distinct. The Balmer absorption line $H\beta$ has been included into the analysis to disentangle metallicity and age effects; an age difference by a factor 3 is detected between stellar populations of the nucleus and of the bulge, the nucleus being younger. The morphological analysis of CCD images has revealed the presence of a nuclear stellar-gaseous disk with a radius of some 100 pc, the gas component of which looks non-stationary, well inside the bulge of M 31.

Key words: galaxies: individual: M 31 – galaxies: nuclei – galaxies: structure – galaxies: stellar content – galaxies: abundances

1. Introduction

The stellar core of the nearby spiral galaxy M 31 is decoupled both dynamically and chemically from the bulge of the galaxy.

Discussion on the dynamical distinctness of the nucleus of M 31 began in 1988 when Dressler & Richstone (1988) and Kormendy (1988) published kinematical data for stars in the center of M 31: the rotation curve reached a sharp maximum at a radius of $1''$ followed by a drop practically toward zero velocity; the stellar velocity dispersion had also a prominent maximum in the center. The dynamical distinctness of the nucleus of M 31 was then explained by the presence of a supermassive black hole. Later the black hole hypothesis was confirmed when an image obtained with the HST revealed that a mass of $3 \cdot 10^7 M_{\odot}$ attached to the dynamically decoupled nucleus is concentrated not in the bright star-like source P1 but in a fainter nucleus P2, $0''.5$ from P1 (Lauer et al. 1993). The true nucleus of M 31, P2, is quite faint optical source, the mass-to-luminosity ratio is high; so the idea of the presence of a supermassive black

hole in the center of M 31 is finally confirmed. However even proponents of the supermassive black hole hypothesis accepted the simultaneous presence of a dynamically decoupled stellar subsystem, namely, of a compact nuclear disk with a radius of $3''$ – $5''$ (10–17 pc). Kormendy (1988) found a zone of low stellar velocity dispersion in the radius range $1'' < r < 4''$, that is, a cold nuclear stellar subsystem embedded into the bulge, and Tremaine (1995) had claimed from dynamical arguments that the "double" nucleus in M 31 can be stable during several billion years as a thick eccentric elliptical nuclear disk which contained the supermassive black hole at one of its foci. So the presence of a *stellar* dynamically decoupled nucleus – or compact disk – in the center of M 31 is also widely accepted.

Interestingly, the chemical distinctness of the nucleus of M 31 was noted some decades earlier than its dynamical distinctness, at the romantic epoch when one photographic spectrum of the galaxy had to be exposed during three nights. Joly & Andriolat (1973) pointed out a change of the Na I, Mg I, CN, and Ca IIK equivalent widths between the nucleus and the bulge; if compared to galactic globular clusters, the magnesium and calcium abundance of the bulge is -0.84 dex, and the nucleus is more metal-rich by 0.6 dex in calcium and by 1.5 dex in magnesium. Surprisingly, the data of Joly & Andriolat (1973) on the iron absorption lines show a prominent equivalent width gradient in the bulge, but the nucleus seems to share this gradient and does not look distinct. A CN break between the nucleus and the bulge of M 31 was also noted by McClure (1969) though not by spectroscopy but by narrow-band photometry: filters with passbands of 83–85 Å were centered on the absorption line CN λ 4165 and on the off-line continuum at λ 4255. Spinrad & Liebert (1975) found another photometric change, $\Delta(U - V) = 0.13 \pm 0.04$; but this colour change corresponds to a very modest metallicity break, not more than 0.2 dex. Morton & Andereck (1976) have confirmed the result of Joly & Andriolat (1973) on the equivalent width change for Ca IIK line – $EW_{nuc}/EW_{bulge} = 1.38 \pm 0.11$, – and Bica et al. (1990) have also noted changes in the Mg I and Ca II lines, but not so prominent as those in the paper of Joly & Andriolat (1973): if calibrated into metallicity, they give a metallicity difference of 0.2 dex between the nucleus and the bulge. Cohen (1979) exposed a long-slit spectrum of M 31 along the east-west direction

by using a linear digital detector; she found changes of the absorption lines NaD and Mgb and, by modelling them with stellar population synthesis, obtained a metallicity difference of four times (0.6 dex). In general, though the existence of metallicity difference between the nucleus and the bulge of M 31 has been established long ago, quantitative estimates range from 0.2 dex to an order of magnitude. Moreover, the studies of abundances of the stellar populations in the center of M 31 in the 60–70 was followed by a long pause, and investigations with modern CCDs have not been undertaken. The only exception is the work of Davidge (1997); but he does not concern the nucleus being concentrated on gradients of absorption-line equivalent widths in the inner bulge. Another, even more recent work of Davidge et al. (1997) treats the properties of the stellar populations in the nucleus of M 31 based completely on photometric data; their C-M diagrams for individual stars being constructed under very good seeing conditions ($FWHM \approx 0''.15$) in the narrow concentric rings with radii of $0 - 1''.4$, $1''.4 - 2''.8$, and $2''.8 - 4''.0$ have allowed to detect a noticeable increase in mean stellar age with radius in the innermost part of the galaxy.

Our paper presents a spectral investigation of the stellar population properties in the nucleus and in the inner bulge of M 31. In contrast to our precursors, we have now the possibility to compare both the mean metallicity and the mean age of stars and to determine in this way a sequence of star formation epochs. The work is undertaken within a large observational project on chemically distinct nuclei in galaxies and on possible relations between chemically and dynamically decoupled galactic nuclei.

2. Observations and data reduction

The observations of M 31 were performed in September 1996, at the 1 m telescope of the Special Astrophysical Observatory of the Russian Academy of Sciences (Nizhnij Arkhyz, Russia) with the long-slit spectrograph UAGS equipped by a 1040×1160 pixel CCD. The slit width was $3''.2$, the seeing quality was similar, about of $4''$. In the night of September 11/12 the galaxy was observed in three position angles, 35° , 80° , and 125° , with total exposure times of 40 minutes for each position angle, and in the night of September 12/13 – in two more position angles, 155° and -10° , with a total exposure time of 30 minutes for each. Each time a blank sky area in 2° from the center of M 31 was exposed; after that the sky spectra were smoothed and subtracted from the spectra of the galaxy. During the observations we used a grating of 651 grooves per mm which provided a dispersion of $1.59 \text{ \AA}/\text{px}$ and a spectral resolution of $3.5\text{--}4 \text{ \AA}$; the spectral range was $3900\text{--}5700 \text{ \AA}$. The scale along the slit was $1''.54/\text{px}$, and as the seeing quality was bad, we binned by 3 rows and studied absorption-line equivalent width variations along the slit with a step of $4''.6$.

Besides our own observations we have used spectral data for M 31 obtained from the La Palma Archive. The galaxy was observed at the 4.2 m William Herschel Telescope on September 19, 1991, with the two-armed long-slit spectrograph ISIS equipped with a 800×1180 pixel CCD. The total exposure time was 1.5 hour. The galaxy was exposed in one position

angle, $P.A. = 55^\circ$, with a slit width of $0''.7$. The dispersion was $0.74 \text{ \AA}/\text{px}$ (spectral resolution of 2 \AA), the blue-arm spectral range which is more interesting for us expanded over $3800\text{--}4700 \text{ \AA}$. The scale along the slit was $0''.34/\text{px}$. The seeing was $0''.9$.

To reduce the spectral data – remove cosmic-ray hits, subtract bias, extract one-dimensional spectra by taking into account the geometry of the images, calibrate wavelengths and linearize the spectra – we have used a software developed by one of us (Vlasyuk 1993). After that we calculated absorption-line indices for the strong lines of calcium, iron, magnesium, and hydrogen (for definition of the indices see Worthey et al. 1994 and Worthey & Ottaviani 1997) and constructed profiles of the indices along the slit. We have used the spectrum of M 31 obtained at the WHT to calculate the indices Ca4227, $H\delta A$, $H\gamma A$, Fe4383, Ca4455, and Fe4531, and our spectra to calculate the indices $H\beta$, Mgb, Fe5270, and Fe5335 missed in the spectral range of the ISIS blue arm. We did not observe standard Lick stars, but our instrumental index system for $H\beta$, Mgb, Fe5270, and Fe5335 is close to the Lick system as the spectral resolution is similar. To demonstrate this fact, we compare our index measurements in $P.A. = 80^\circ$ with the data of Davidge (1997) whose slit was set in the direction of east-west (Fig. 1). Davidge (1997) observed standard stars and transformed his measurements into the Lick system; he needed this procedure because of his spectral resolution of 14 \AA . We see in Fig. 1 that an agreement is excellent inside the claimed accuracy of Davidge's measurements, 0.2 \AA for $H\beta$, 0.3 \AA for Mgb, 0.1 \AA for Fe5270, and 0.2 \AA for Fe5335.

By combining the indices of different chemical elements and by comparing them with models, we are able to reach some conclusions about the stellar population properties at various distances from the center of M 31.

3. Results

3.1. Chemical and age decoupling of the nucleus of M 31

By using the five cross-sections of M 31 obtained by us at the 1 m telescope of SAO RAS, we have calculated index profiles for $H\beta$, Mgb, Fe5270, and Fe5335 up to $70''$ from the center with a step of $14''$. Two iron indices, Fe5270 and Fe5335, were merged into $\langle Fe \rangle \equiv (Fe5270 + Fe5335)/2$. The two halves of each profile, symmetric around the nucleus, were averaged. The results are presented in Fig. 2, the error bars being estimated by point-to-point scatter under binning of $4''.6$.

In accordance with numerous results of earlier investigations, the center of M 31 is remarkable by the higher equivalent widths of magnesium and iron lines. The measurements at $r = 9''$ may be affected by seeing (let us remind that the seeing during our observations was not better than $4''$). At larger distances from the center, in the radius range of $23''\text{--}65''$, radial index gradients if they exist are negligible with respect to the index changes between the nucleus and the bulge. The mean index values in the bulge averaged over all the five cross-sections in the radius range $23''\text{--}65''$ are $Mgb(\text{bulge}) = 4.25 \pm 0.02$

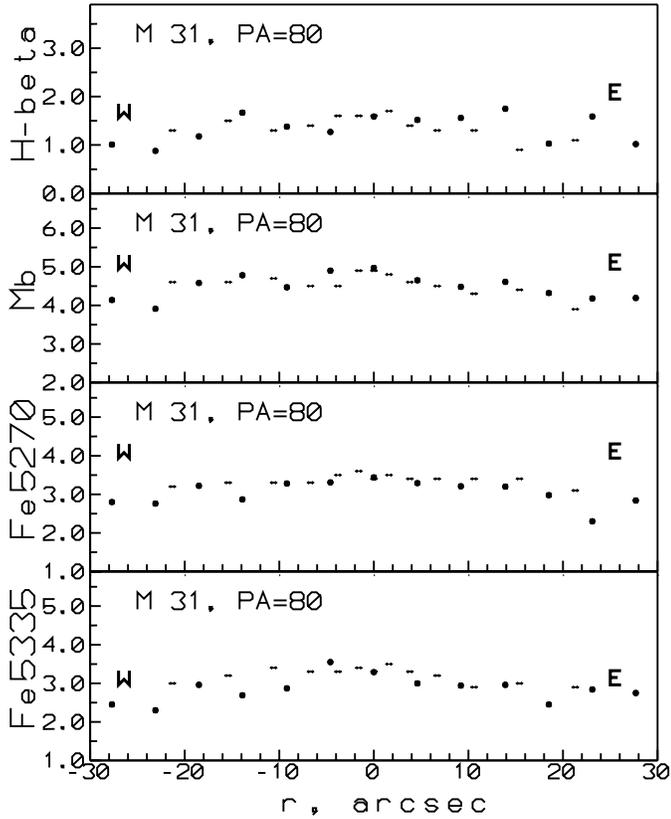


Fig. 1. Radial profiles of absorption-line indices $H\beta$, Mgb , $Fe5270$, and $Fe5335$ in $P.A. = 80^\circ$ (points) compared to the data of Davidge (1997) in $P.A. = 90^\circ$ (two-sided arrows)

and $\langle Fe \rangle$ (bulge) = 2.56 ± 0.01 . If we approximate the radial index dependencies by linear laws and extrapolate them to $r = 0$, we would obtain central bulge index values $Mgb(\text{bulge}) = 4.37 \pm 0.06$ and $\langle Fe \rangle$ (bulge) = 2.68 ± 0.03 . For the nucleus we have measured $Mgb(\text{nuc}) = 5.11 \pm 0.06$ and $\langle Fe \rangle$ (nuc) = 3.21 ± 0.05 . Therefore, the differences between the nucleus and the bulge are $\Delta Mgb = 0.86 \pm 0.10$ and $\Delta \langle Fe \rangle = 0.65 \pm 0.06$ (or $\Delta Mgb = 0.74 \pm 0.12$ and $\Delta \langle Fe \rangle = 0.53 \pm 0.08$, if we use linear index radial dependencies for the bulge). Let us note that due to strongly increased stellar velocity dispersion in the nucleus of M 31 the absorption lines there may be broadened out of the index measuring ranges; so the nuclear indices may be underestimated, and the real index differences between the nucleus and the bulge may be even larger. Application of models of Worthey (1994) for an old stellar population under the assumption of equal bulge and nucleus ages and of a solar $[Mg/Fe] = 0$ gives an estimate of metallicity difference, 0.42 ± 0.05 dex (or 0.35 ± 0.06 dex with a linear gradient in the bulge), the same for magnesium and iron. But are the assumptions of equal ages for the nucleus and bulge stellar populations and of solar magnesium-to-iron ratio valid in this particular case?

If the nucleus is chemically decoupled, it would be natural to suggest that the epochs of basic star formation in the nucleus and in the bulge are different. So the mean ages of the

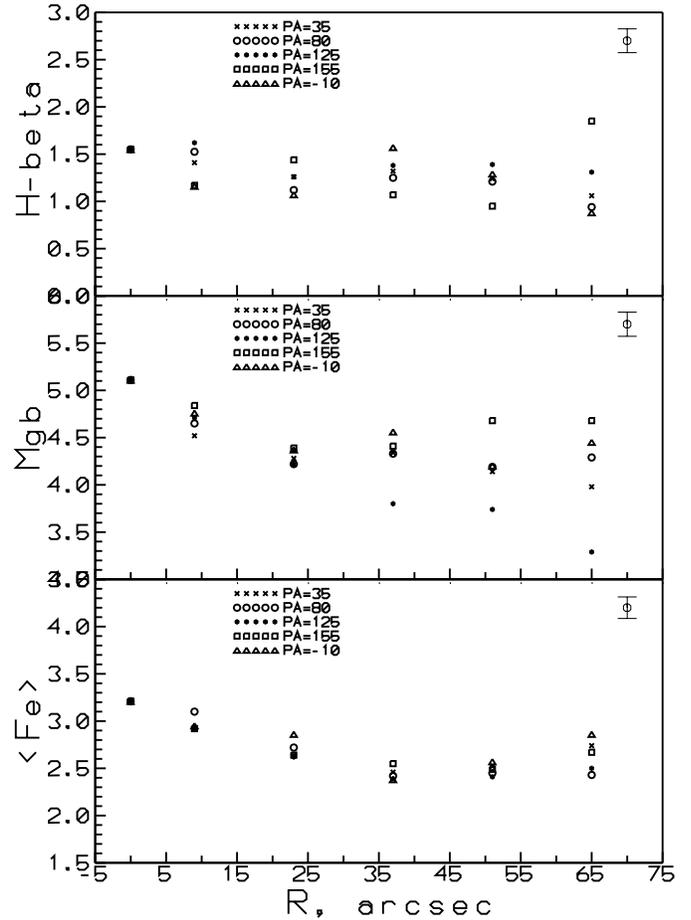


Fig. 2. Radial profiles of absorption-line indices $H\beta$, Mgb , and $\langle Fe \rangle$ in five position angles, averaged over radius intervals of $14''$. Typical error bars are shown in the upper right corners of the frames; they are somewhat smaller for measurements closer to the nucleus and somewhat larger at the edge

stellar populations in the nucleus and in the bulge are expected to be different. It is known that the hydrogen absorption lines are much more sensitive to age than to metallicity, so by confronting a Balmer line index with a magnesium or iron index one can disentangle age and metallicity effects. Such attempts were undertaken for example by Worthey (1994) and Worthey & Ottaviani (1997) in the case of a fixed solar magnesium-to-iron ratio. Recently Tantalo et al. (1998) have presented new model calculations and have written a system of three linear equations allowing to determine differences in metallicity, age, and magnesium-to-iron ratio from the $H\beta$, Mg_2 , and $\langle Fe \rangle$ differences. We have taken the index differences between the nucleus of M 31 and the bulge at $r = 23''$ (Fig. 2), have used the relation $Mgb \approx 15Mg_2$ (Worthey 1994), and from the equations of Tantalo et al. (1998) we have derived differences of the parameters: $\Delta[Mg/Fe] = +0.12$, $\Delta \log(Z/Z_\odot) = +0.53$ and $\Delta \log t = -0.52$. This means that the magnesium-to-iron ratios are close and the nucleus is three times more metal-rich and three times younger than the bulge at $23''$ from the center. As for absolute values, the model of Tantalo et al. (1998) which

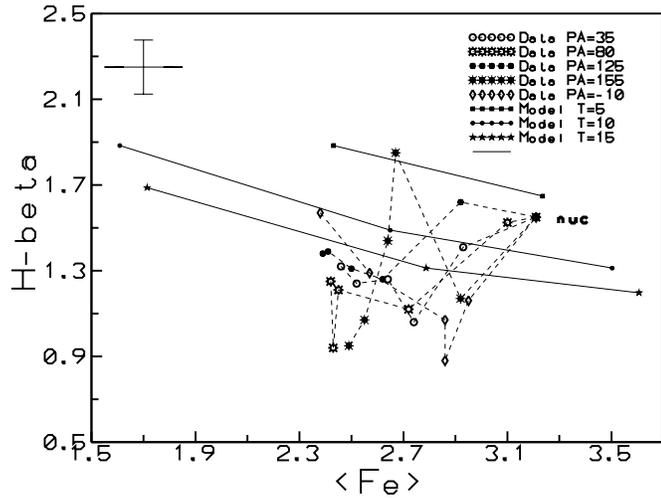


Fig. 3. The diagram ($H\beta$, $\langle Fe \rangle$) for our data on M 31 in five position angles; the nucleus is marked by 'nuc', other points along the radius are connected by dashed lines. The solid lines present the models of Tantalo et al. (1998) for $[Mg/Fe]=+0.3$, the ages of the models are given in billion years. The typical error bar for our measurements is shown in the upper left corner of the frame

gives the best set for the index combination in the nucleus corresponds to $Z = 0.05$ (or $2.5Z_{\odot}$), $[Mg/Fe]=+0.3$ and $t = 6 - 7$ billion years. Consequently, in the bulge the stellar population metallicity is slightly below the solar one, and its age is over 15 billion years. Fig. 3 presents the combination of a theoretical diagram ($H\beta$, $\langle Fe \rangle$) for $[Mg/Fe]=+0.3$ from the work of Tantalo et al. (1998) and of our data for M 31 from Fig. 2. One can see immediately that the locations of the nucleus and of the bulge measurements in the diagram ($H\beta$, $\langle Fe \rangle$) imply a significant difference of stellar population mean ages: the nucleus has an age about of 7 billion years, and the bulge measurements over the whole radius range of $23'' - 65''$ are below the model sequence of 15 billion years, so the bulge stellar populations are everywhere older than 15 billion years. One danger always exists when one makes such an analysis: the $H\beta$ absorption line equivalent width may be affected by emission. We know (see e. g. Ciardullo et al., 1988) that at $R > 5''$ emission lines are seen in the spectra of M 31. Unfortunately, we have not found quantitative estimates of their equivalent widths in the literature. But a visual analysis of the Figs. 7 and 8 in the paper of Ciardullo et al. (1988) allows us to estimate roughly that the equivalent width of the $H\alpha$ emission line is less than 1 \AA in the radius range of $20'' - 60''$. It means that a correction for the emission which must be applied to the $H\beta$ absorption indices in Fig. 3 is less than 0.3 \AA , and therefore the estimate of the bulge stellar population mean age still remains larger than 10 billion years, and the age difference between the nucleus and the bulge remains substantial.

M 31 is known to have two nuclei (Lauer et al. 1993). Therefore it would be important to localize the chemically distinct entity more exactly. For this purpose we have used the long-slit data from the 4.2 m WHT obtained under much better seeing conditions than our observations. Fig. 4 presents the absorption-line

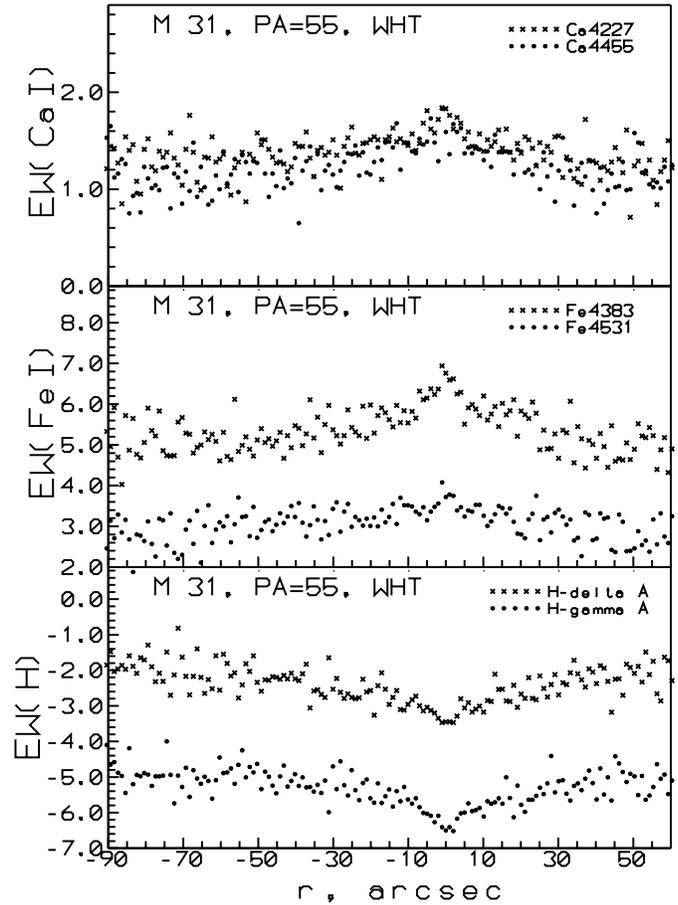


Fig. 4. Radial profiles of calcium, iron, and hydrogen absorption-line indices according to the WHT data, averaged over radius intervals of $1''$

index variations along the slit for Ca I (Ca4227 and Ca4455), Fe I (Fe4383 and Fe4531) and hydrogen ($H\gamma A$ and $H\delta A$) in the position angle $P.A. = 55^\circ$, very close to the line connecting two nuclei of M 31 ($43^\circ \pm 1^\circ$, Lauer et al. 1993).

Again we can see an outstanding nucleus with increased metal-line indices and decreased hydrogen indices and also a slight index drift along the radius. The dependencies of indices on r look like linear ones, so we have approximated them by linear formulae in the radius range of $5'' - 60''$, have extrapolated the formulae to $r = 0$, and have subtracted the fitted linear laws from the measured profiles. The results of this subtraction averaged over the indices of every element are presented in Fig. 5 together with the continuum profile along the slit (the continuum is taken around $\lambda \approx 4400 \text{ \AA}$); only the central part of the profiles, $r \leq 12''$, is shown.

Both the metal-index profiles exhibit maxima shifted to the south-west with respect to the continuum maximum. The continuum peak marks the position of the brighter nucleus, P1, which is not the isophote center nor the dynamical center. The continuum profile looks asymmetric, and a Gauss analysis reveals a presence of two components, a point-like one at $r = 0$ and an extended one ($FWHM = 7''$) at $r = -0''.4$. It is the latter, the southern-western component that must contain the second,

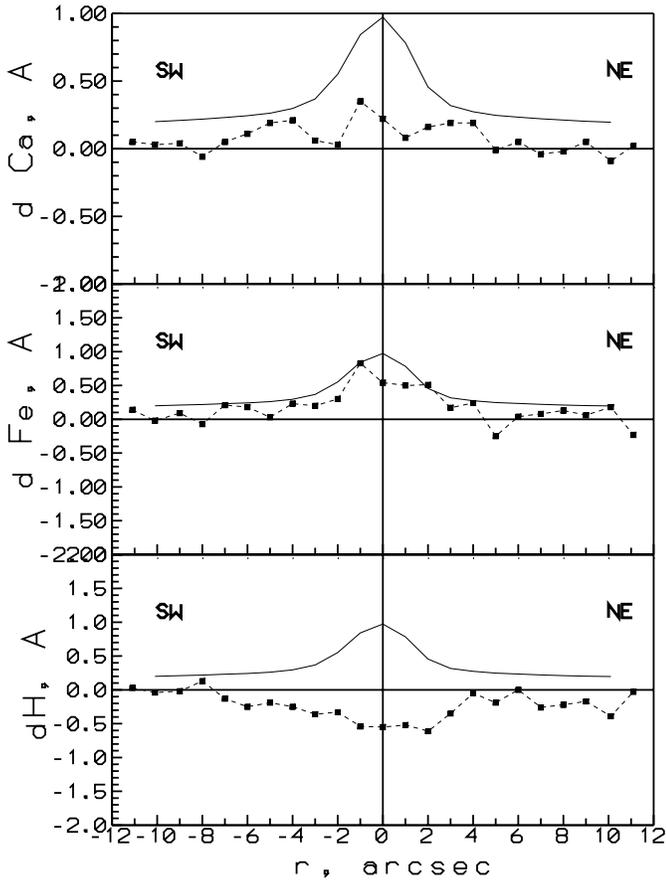


Fig. 5. Radial profiles of $(\Delta\text{Ca}4227 + \Delta\text{Ca}4455)/2$, $(\Delta\text{Fe}4383 + \Delta\text{Fe}4531)/2$, and $(\Delta H\gamma A + \Delta H\delta A)/2$ indices after removing linear radial trends; the solid line shows continuum profile near $\lambda \approx 4400 \text{ \AA}$, the positions of the brightest continuum points are marked by vertical lines

fainter nucleus of M 31, P2, which corresponds to the photometric and the dynamical centers of the galaxy (Lauer et al. 1993). Therefore we conclude that P2 is the chemically and age decoupled nucleus of M 31 (though due to the flatness of the Balmer line index minima inside $r < 5''$ we may suspect that the nuclear disk mentioned by Kormendy (1988) has also a metal abundance enhancement). Let us remind that P2 is dynamically decoupled (Kormendy 1988). This result, though impressive, was not unexpected. King et al. (1995) obtained an image of M 31 at $\lambda = 1750 \text{ \AA}$; they had found that P2 is brighter in the ultraviolet than P1, in contrast to the visible. They have immediately interpreted this fact as an evidence for P2 metallicity overabundance because there exists a correlation between UV excess and metallicity in elliptical galaxies. However, we must note that Davidge et al. (1997) have found that P1 and P2 have roughly equal colours $H - K$; but the formal error estimates, 0.1–0.2 mag, can hide a metallicity difference as large as a factor 10 (Worthey 1994).

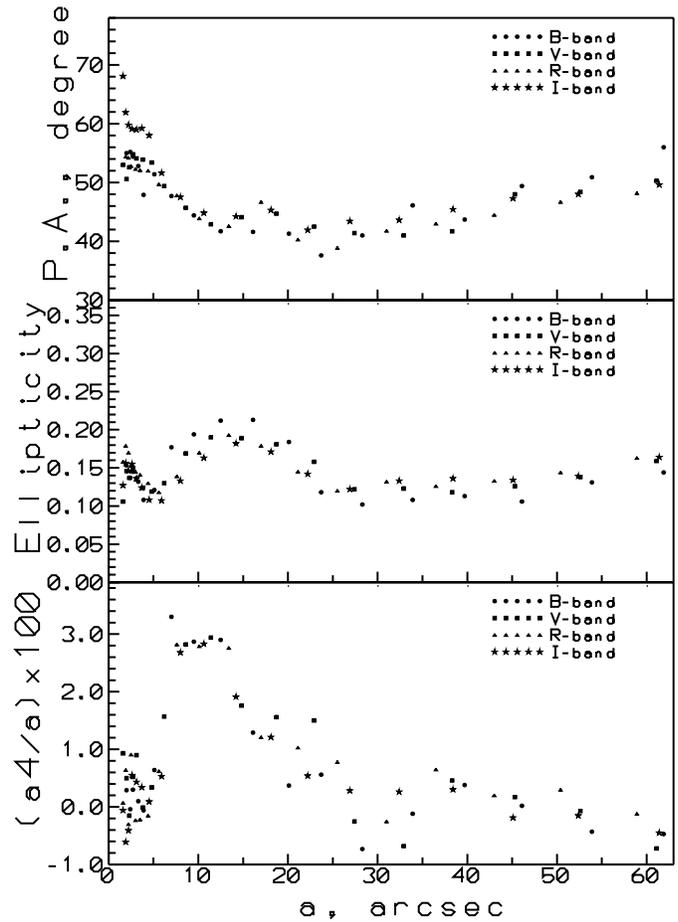


Fig. 6. Radial variations of isophote parameters

3.2. Morphological analysis of the central part of M 31

We have used CCD images of the central part of M 31 obtained from the La Palma Archive to analyze the two-dimensional surface brightness distribution. The galaxy was observed on November 17, 1990, at the 1 m Jacobus Kapteyn Telescope through four filters, $BVRI$, by a 320×512 pixel RCA CCD, with a seeing quality of $1''.5$. After bias subtraction and division by flat fields, the isophotes of the images were approximated by ellipses. Fig. 6 presents the radial variations of the major axis position angles, ellipticities, and fourth Fourier coefficients a_4/a .

Fig. 7 is a "residual map", demonstrating the difference between the observed R image and a modelled one consisting of pure elliptical isophotes. The "residual maps" in all four filters are similar and look like the Fig. 3b from the paper of Wirth et al. (1985) though Wirth et al. subtracted median-smoothed images, not modelled ones. Wirth et al. (1985) have interpreted the spiral absorption features of their Fig. 3b as dust arms. We reach the same conclusion.

Fig. 6 is fully consistent with earlier photometric results for the central part of M 31 (see, for example, CFHT data in the work of Bacon et al. 1994), though we would like to note that boxiness of the inner isophotes of M 31 is shown here for the

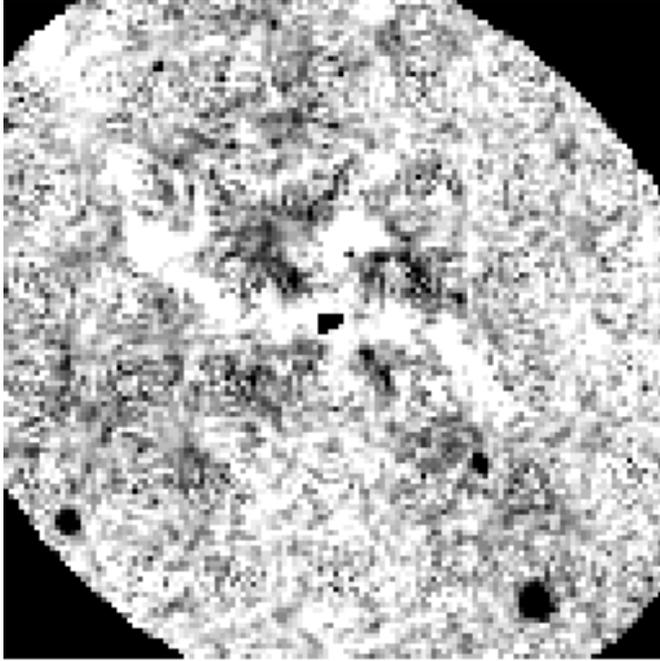


Fig. 7. Map of photometric residuals (after pure elliptical isophote subtraction) in the filter R . The white spots are in reality dark ones. North is up, East is to the left, the picture sizes are $105'' \times 105''$

first time. There are also some details of the radial profiles of $P.A.$ and $(1 - b/a)$ which were not discussed earlier. Over all the four spectral bands the major semi-axis range of $7'' - 25''$ is characterized by a local maximum of ellipticity which reaches 0.2 and by a local minimum in the position angle which oscillates between 40° and 44° close enough to the orientation of the line of nodes of the disk, $P.A. = 38^\circ$. The same radius interval is characterized by a a_4/a higher than +1%; outside, a_4/a is less than +1%. This means that in the radius range of $7'' - 25''$ we see a stellar disk whose plane is close to or even coincides with the global plane of the galaxy. One must keep in mind that the central region of M 31 is photometrically dominated by the bulge (Iijima et al. 1976). At the distance of M 31 the major semi-axis of $25''$ corresponds to a metric radius of 85 pc, therefore we deal with a so called nuclear disk; similar disks were earlier found in some other early-type spiral galaxies, particularly, in NGC 4594 (Burkhead 1991). In Fig. 7 one can see two dark (dust?) spiral miniarms located also in the same radius range. Besides that, over the same radius range a noticeable emission line [OIII] $\lambda 5007$ is seen in our spectra (in the very center of M 31, $r < 5''$, emission lines are absent according to the claims of Bacon et al. 1994). We can conclude that the nuclear stellar disk of M 31 contains also dust and ionized gas. Ionization might be due to shocks because, according to Ciardullo et al. (1988), the nitrogen emission line [NII] $\lambda 6583$ is everywhere stronger than $H\alpha$ inside $r = 1'$.

4. Discussion and conclusions

Though M 31, the most nearby spiral galaxy, has been studied for a long time and with unmatched spatial resolution, the true structure of its central region is still a puzzle. The large amount of accumulated observational data has led to reject many models, even regarded earlier as reasonable ones. Our work contributes to this process.

Two extraordinary features – the strong increase of angular rotation velocity and of stellar velocity dispersion inside a radius of $1''$ and the shift of the bright point-like nucleus with respect to the center of the galaxy – were initially explained in the frames of two equally successful models: a strong anisotropy (end-on tumbling minibar: Gerhard 1988) and an axisymmetric potential distribution with a supermassive black hole in the center (Kormendy 1988). The former model looked preferable because of the isophote twist along the radius of M 31 and because of a noticeable line-of-sight velocity gradient along the photometric minor axis (Ciardullo et al. 1988) – these observational facts had allowed Stark & Binney (1994) to suggest the presence of a large-scale bar in M 31 extended up to $3'$ from the center. However Bacon et al. (1994) observed a central part, $r \leq 5''$, of M 31 with the Integral Field Spectrograph TIGER and could compare the surface brightness map with the line-of-sight velocity field; they have found a coincidence of the dynamical and photometric major axes and in this way proved the circularity of stellar rotation inside a radius of $5''$. The nuclear region of M 31 has appeared to be axisymmetric. After that a model of Tremaine (1995) has become very popular: he has proposed an eccentric disk rotating in accordance with the Kepler's law and having a supermassive black hole in one of its foci, P2. In the frame of this model the bright nucleus P1 is an apocenter where stars decelerate and their orbits crowd, then forming a surface brightness excess. The model of Tremaine (1995) is often cited as the most realistic; however it has been dismissed two years ago. Gerssen et al. (1995) had observed M 31 with a long-slit spectrograph; they had oriented the slit along the minor axis of the nucleus ($P.A. = 148^\circ$) and set its width as $1''/25$, so that the putative disk of Tremaine falls completely within the slit. Due to angular momentum conservation, the luminosity-weighted velocity of a filled Keplerian orbit about a stationary object should be zero; but the analysis of the observations showed the presence of two distinct kinematical components at $r = 0$! Indeed, only one model is not rejected: that of a giant stellar cluster falling to the center of M 31 under the attraction of a black hole (Emsellem & Combes 1997); but such a configuration is unstable and very short-lived, so it implies that M 31 is observed during an unique evolutionary stage.

The results obtained in this work even worsen the situation. Earlier when we discovered a chemically distinct nucleus in galaxies more distant than M 31, we supposed it to be a compact nuclear disk; in several cases where the chemically distinct nuclei appeared to be resolved, our supposition was confirmed by a coincidence of chemically, kinematically and photometrically distinct area radii (NGC 1052 – Sil'chenko 1995, NGC 4621 – Sil'chenko 1997; but note that they are elliptical galaxies). The

case of M 31 has destroyed our presumption: the nuclear disk of M 31 detected by its photometric signature has a radius of 80–100 pc, while the chemically distinct nucleus is unresolved, being less than 3 pc. Moreover, it is not P1 which is chemically distinct, though only P1 is thought to be a giant stellar cluster, but P2 which is assumed to be a supermassive black hole the stellar content around which is not yet known. The central region with a radius of $2''.3$ in Fig. 3 looks three times younger than the bulge; but P2 contributes only a small fraction into the luminosity of this region, namely, 30% if to assume the photometric decomposition model C from the work of Bacon et al. (1994); so we must conclude that the stellar population of P2 is significantly younger than 5 billion years. Hence a relatively recent star formation burst exactly at the dynamical center of M 31 seems indubitable. It may not be the only and last one: dust spiral arms in the nuclear disk of M 31, the local splitting of emission lines in several spots within a dozen arcseconds from the center seen in our data and also in the data of Ciardullo et al. (1988), the bright nucleus P1 which cannot be on a stable orbit – all these facts are evidences in favour of a continuous matter drift to the center of M 31. Though less probable, there exists still another explanation of the observational facts reported by us: if in the proximity of the supermassive black hole located inside P2 the stars have some unusual structure, say, if their external atmospheres are removed by tidal effects, then we see their inner layers which are enriched by metals. In this case the nucleus P2 may look like a chemically decoupled nucleus too.

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