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ABSTRACT

As a result of bidimensional spectroscopy of the central parts of two nearby lenticular galaxies, NGC 1023 and NGC 7332, undertaken with the Multi-Pupil Field Spectrograph of the 6 m telescope of the Special Astrophysical Observatory, their chemically decoupled stellar nuclei are found to be substantially younger than the surrounding bulges: the mean age of the nuclear stellar populations is 7 Gyr in NGC 1023 and 2.5 ± 0.5 Gyr in NGC 7332. The morphological analysis undertaken by Seifert & Scorza for NGC 7332 and by us for NGC 1023 has revealed a existence of separate circumnuclear stellar disks with the radius of 80 pc in NGC 1023 and of 400 pc in NGC 7332; probably, the intermediate-age stellar populations are related to these structures.

Key words: galaxies: nuclei — galaxies: individual (NGC 1023, NGC 7332) — galaxies: evolution — galaxies: structure

1. INTRODUCTION

Early-type galaxies, both ellipticals and lenticulars, are usually thought to be very old stellar systems (see the classic works of Tinsley 1968; Tinsley 1972; Tinsley 1978; Faber 1973). Their red integrated colors are consistent with the mean stellar population age almost as large as that of the universe, T ≥ 15 Gyr. Meantime, early-type galaxies with prominent Balmer absorption lines in their integrated nuclear spectra indicating a mean age of a few gigayears were observed long ago. Historically, they were found in an intermediate-redshift cluster and were first treated as strongly evolving objects (Dressler & Gunn 1983). Later, the similar population of galaxies was noted in the rather peculiar Coma cluster, and therefore the phenomenon of “E+A” or “K+A” galaxies was related to the environment influence (Caldwell et al. 1993). But Zabludoff et al. (1996) have tested the latter hypothesis using a homogeneous sample of nearby galaxies and have found that “~75% of nearby “E+A” galaxies lie in the field, well outside of clusters and rich groups.” An overall fraction of “E+A” galaxies selected by Zabludoff et al. (1996) in the LCR Survey is low, only 0.2% of the total list of galaxies; but they have applied a very extreme selection criterion, <H> > 5.5 Å. Meantime evolutionary synthesis models (e.g., Worthey 1994) imply that even if having EW(Hβ) > 2 Å the stellar population may have the mean (luminosity-weighted) age less than 5 Gyr. Zabludoff et al. (1996) noted that diminishing their <H> low limit only to 4.5 Å increases the sample of “E+A” galaxies by a factor of 3. So we must admit that a substantial fraction of relatively young stellar nuclei may be an intrinsic property of the population of present-day early-type galaxies. We made just this conclusion several years ago, when among ~30 very nearby lenticular galaxies about 10 hosts of the nuclei 5 Gyr old or even younger have been found (Síl’chenko 1993a).

The next question is a question of discreteness. Fisher et al. (1996) in their detailed investigation of a sample of nearby lenticular galaxies have also made the conclusion that the nuclei are on average younger than the bulges by several gigayears; but they prefer to discuss a smooth age increasing outward, a kind of smooth radial gradient that is characteristic for galaxy formation by a dissipative collapse. Meantime there may exist another interpretation: a decoupled nucleus. Seifert & Scorza (1996) have found separate circumnuclear stellar disks in seven lenticular galaxies—in half of all galaxies considered by them. We (Síl’chenko et al. 1992) have found chemically decoupled, metal-rich stellar cores in the lenticular galaxies NGC 1023 and NGC 7332. If the chemically decoupled nuclei are products of secondary star formation bursts in the centers of early-type galaxies, a difference of the mean stellar age between the nuclei and the main galactic bodies must exist: the nuclei must be younger. The present paper is devoted to searching for the age difference between the chemically decoupled nuclei and the surrounding bulges in the nearby lenticular galaxies NGC 1023 and NGC 7332.

The global parameters of the galaxies under consideration are given in Table 1. These galaxies possess some large-scale peculiarities that may be connected to past merger events. NGC 1023 is rich in neutral hydrogen, and its distribution and velocities resemble those of an accreted material (Sancisi et al. 1984). However, the global star formation is absent in this galaxy (Pogge & Eskridge 1993), and its integrated color is extremely red (see Table 1), as red as that of a luminous elliptical galaxy. A neutral hydrogen content of NGC 7332 is low enough, though nonzero (Knapp et al. 1978); however, it possesses a counter-rotating disk of ionized gas (Plana & Boulesteix 1996; Fisher et al. 1994). Otherwise the galaxies look quite normal, moderate-luminous lenticulars, even non-LINERs. We report our observations and other data in § 2. The radial variations of stellar population age are analyzed in § 3, and the appearance of inner disks probably related with the age-decoupled and chemically decoupled cores is discussed in § 4. In § 5, the two-dimensional stellar velocity fields obtained with the Multi-Pupil Field Spectrograph at the 6 m telescope are presented. Section 6 gives our conclusions.

2. OBSERVATIONS

We have observed NGC 1023 and NGC 7332 in 1996–1997 by using the Multi-Pupil Field Spectrograph (MPFS; Afanasiev et al. 1990; Afanasiev et al. 1996) of the 6 m
telescope of the Special Astrophysical Observatory, Nizhnii Arkhyz, Russia. The journal of the observations is given in Table 2.

MPFS, being the second (after CFHT TIGER system; see Bacon et al. 1995) realization of G. Courtès's (1982) concept of spatial sampling of extended sources by means of a microlens array, is in active operation at the 6 m telescope since 1989. Instruments of this type are providing sufficient gain in investigations of nebulae and galaxies with respect to a classical long-slit spectroscopy due to complete coverage of the studied area, independence of spectral resolution on spatial resolution, absence of slit losses and of the overall problem of object matching.

A set of enlargers, which project the object onto the lens array, provide spatial sampling according to a seeing value—from ≈0.3 to ≈1.6 per lens. Sizes of the used array varied between 8 × 11 and 8 × 16 elements. For this study we have selected the size of a spatial element 1.3 × 1.3. The configurations used in 1996–1997 resulted in 128 spectra per one exposure for NGC 1023 (8 × 16 elements) and in 95 spectra per one exposure for NGC 7332 (8 × 12 elements). The spectral range was 4600–5450 Å for NGC 1023 and 4800–5400 Å for NGC 7332 under the spectral resolution of 4–6 Å (dispersion of 1.6 Å pixel⁻¹). It includes several strong absorption lines, Hβ, Mg b, Fe5270, and Fe5335, which have been used for diagnostics of the stellar population properties. To account accurately for the night-sky background we have separately exposed the blank sky region at 1.5–2′ from the galaxies with an exposure time of half of that for the galaxies; the sky was then (after spectrum extraction and linearization) smoothed and subtracted.

The hollow-cathode lamps filled by HeNeAr or NeXeAr gas mixtures were exposed before and after each exposure in order to provide wavelength calibration of spectral data. Integrations of the twilight sky were carried out for correcting system vignetting and variations of the transmission by the individual lenses.

The primary reduction—bias subtraction, flat fielding, cosmic-ray hit removing, extraction of one-dimensional spectra, wavelength calibration, construction of surface brightness maps—have been fulfilled by using the software developed in the Special Astrophysical Observatory (Vlasyuk 1993). After that, the absorption-line indices Hβ, Mg b, Fe5270, and sometimes Fe5335 have been calculated in the standard Lick system (Worthey et al. 1994). We have checked our consistency with the Lick measurements by observing stars from their list (Worthey et al. 1994) and by calculating the absorption-line indices for the stars in the same manner as for the galaxies. The indices calculated for nine stars are coincident with the data tabulated in Worthey et al. (1994) on average within 0.05 Å. The exposures for the galaxies have been taken long enough to provide signal-to-noise ratios of ≈80–100 in the nuclei and ≈30 near the edges of the frames; the corresponding random error estimations made in the manner of Cardiel et al. (1998) range from 0.1 Å in the center to 0.5 Å for the individual spatial elements at the outermost points. To keep a constant level of accuracy along the radius, we summed the spectra for the galaxies in concentric rings centered onto the nuclei and studied the radial dependencies of the absorption-line indices by comparing them with synthetic models of old stellar populations of Worthey (1994) and Tantalo et al. (1998). We estimate the mean accuracy of our azimuthally averaged indices as 0.1 Å. To give an impression on our data quality, the azimuthally averaged spectra are displayed in Figure 1.

Besides our own spectral data, we have used results of the long-slit observations of NGC 7332 taken from the La Palma Archive. The galaxy has been observed with the spectrograph ISIS, the blue arm, of the 4.2 m William Herschel Telescope (WHT) on 1994 August 3; it was exposed during 30 minutes in the spectral range 3900–5500 Å with the grating R300B (the dispersion of 1.54 Å pixel⁻¹ matched ours exactly). A slit with the width of 1′.0 was aligned with the minor axis of the galaxy (P.A. = 65°). In this case also, the Lick indices Hβ, Mg b, Fe5270, and Fe5335 have been calculated along the slit with binning of 3 pixels (1′).

### TABLE 1

| Parameter       | Source | NGC 1023 | NGC 7332 |
|-----------------|--------|----------|----------|
| Type            | NED    | SB(r)0°- | S0pec   |
| R_{c19} (kpc)   | LEDA   | 13.0     | 10.2     |
| B_{0.5}         | LEDA   | 9.55     | 11.50    |
| M_{B}           | LEDA   | -20.46   | -19.93   |
| B−V             | RC3    | 0.93     | 0.87     |
| U−B             | RC3    | 0.50     | 0.38     |
| V_{0} (radio) (km s⁻¹) | LEDA | 637      | 1300     |
| Distance (Mpc)  | LEDA   | 11       | 19.3     |
| Inclination (deg) | LEDA | 90       | 90       |
| P.A. (deg)      | LEDA   | 87       | 155      |

### TABLE 2

| Date            | Galaxy  | Exposure (min) | Configuration  | Field (arcsec) | P.A. of Long Side (deg) | Seeing (arcsec) |
|-----------------|---------|----------------|----------------|----------------|------------------------|-----------------|
| 1996 Aug 15/16  | NGC 7332| 40             | MPFS+CCD 520 × 580 | 10 × 16        | 72                     | 2.4             |
| 1996 Oct 9/10   | NGC 1023| 60             | MPFS+CCD 1040 × 1160 | 11 × 21        | 122                    | 1.6             |
| 1997 Oct 31/Nov 1 | NGC 7332| 60             | MPFS+CCD 520 × 580 | 10 × 16        | 167                    | 2.0             |
To study the morphology of the central part of NGC 1023, we have used photometric data from the La Palma Archive and from the Hubble Space Telescope (HST) Archive. The galaxy was observed at the 1 m Jacobus Kapteyn Telescope (JKT) on La Palma through the BVRI filters with the CCD GEC (0.3 pixel⁻¹) on 1990 October 24 and on 1991 September 11, under moderate seeing conditions, FWHM₀ = 1.8–2.0. Also it was exposed with the HST WFPC2 through the filters F555W and F814W on 1996 January 27 under the spatial resolution of 0.1 (PI: S. M. Faber; Program ID 6099). All the data have been analyzed with the program of V. V. Vlasyuk (SAO RAS) FITELL.

3. AGES OF THE STELLAR NUCLEI IN NGC 1023 AND NGC 7332

To increase signal-to-noise ratios and to derive more precise radial profiles of the absorption-line indices, we integrate our field measurements in circular concentric rings centered onto the galactic nuclei. But the galactic bulges are rather flattened: the isophote ellipticities in the radius range 3”–8” are nearly 0.2 in NGC 1023 and 0.4 in NGC 7332. Besides, there may be multicomponent photometric structure, perhaps, a noticeable disk influence along the major axes in the edge-on lenticular galaxies under consideration. We would like to be sure that by using the azimuthally averaged radial profiles of the absorption-line indices we compare the nuclei with their surrounding bulges and not to some artificial unphysical units.

For NGC 7332 we can make our verification by comparing our azimuthally averaged profiles with the linear cross section along the minor axis (and so with the “pure” bulge). Figure 2 presents the results of this comparison. First of all, we would like to note a good agreement between both sets of measurements with the MPFS: the differences inside $R \approx 5''$ do not exceed 0.2 Å, confirming our estimate of the index accuracy, 0.1 Å. Second, the long-slit measurements along the minor axis, being less accurate than the azimuthally averaged data, however, follow the MPFS profiles rather well; at least there is no systematic difference between

![Graphs showing radial profiles of absorption-line indices for NGC 7332.](image-url)
two kinds of profiles. We should only add that in the external parts of the profiles, $R > 5''$, where our data of 1996 and of 1997 somewhat diverge, the long-slit measurements confirm the 1997 version, particularly, of the H$\beta$ and Fe5270 profiles.

For NGC 1023, with its high surface brightness in the center, we have been able to calculate two-dimensional maps of the absorption-line indices. The maps for Mg $b$ and Fe5270 slightly smoothed at $R \geq 2''$ (by a two-dimensional Gaussian with $\sigma = 1.0')$ are presented in Figure 3. Surprisingly, they look different: if the isolines on the Fe5270 map are elongated similar to the isophotes and may be attributed to the effect of the (probable) metal-rich circumnuclear stellar disk, the isolines on the Mg $b$ map are completely decoupled and may be described as elongated, too, but prominently turned. So the analysis of the two index maps prevents us from a selection of any particular ellipsoidal trajectories of index averaging. Taking into account the results of both considerations, for NGC 7332 and for NGC 1023, we conclude that the use of the circularly averaged absorption-line index profiles for comparison of the nuclei with the underlying bulges is the most reliable way as well as the simplest way.

The next figures are “index-index” diagrams where we compare the nuclei of NGC 1023 and NGC 7332 to the surrounding bulges. To compare our measurements to the stellar population models based on summation (with some weights) of spectra of stars, we must made corrections for the stellar velocity dispersion in galaxies that broaden absorption lines and “degrade” a spectral resolution in such way. We have calculated the corrections by smoothing the spectra of K0-K3 III giants from the list of Worthey et al. (1994), which we have observed and by measuring the absorption-line indices of the smoothed spectra. We have found that the index H$\beta$ is quite insensitive to the velocity dispersion when $\sigma_v$ remains to be less than 230 km s$^{-1}$; for metal-line indices, we have found that the corrections are

- 0.1 Å for $\sigma_v = 130$ km s$^{-1}$ (NGC 7332; Simien & Prugniel 1997);
- 0.3 Å for $\sigma_v = 180$ km s$^{-1}$ (circumnuclear regions of NGC 1023; Simien & Prugniel 1997); and

![Fig. 3a](image1)

![Fig. 3b](image2)

![Fig. 3c](image3)
0.4 Å for \( \sigma_v = 215 \text{ km s}^{-1} \) (the nucleus of NGC 1023; Lyon-Meudon Extragalactic Database).

All the figures beginning from Figure 4 contains the corrected indices; for comparison, the data from Trager et al. (1998) for the nuclei of NGC 1023 and NGC 7332 are plotted too—though they are less accurate than ours, the agreement within their errors is good.

The diagrams (Fe5270, Mg b) are intended to check whether the magnesium-to-iron ratios are solar. We want to check it because the most age-metallicity diagnostics are calculated for the solar elemental ratios; besides that, the magnesium-to-iron ratio is important itself because it characterizes a duration of the main star formation epoch. We know that luminous elliptical galaxies are mostly magnesium-overabundant (Worthey et al. 1992); but as for lenticulars, there were discordant opinions: we (Sil'chenko 1993b) found that spectroscopic observations of bright S0 galaxies through a 4'' x (1''–2'') aperture revealed mostly solar magnesium-to-iron ratios, while Fisher et al. (1996) found the brightest S0 galaxies to have magnesium-overabundant nuclei, just as ellipticals. This problem is resolved in Figure 4 with respect to NGC 1023 and NGC 7332. The former has an obviously magnesium-overabundant nucleus; but starting from \( R \approx 1.3 \) all the bulge measurements follow tightly the model sequences for \([\text{Mg/Fe}] = 0\). So we conclude that in the nucleus of NGC 1023 \([\text{Mg/Fe}] \approx +0.3\) and in the bulge \([\text{Mg/Fe}] \approx +0.1\). As for NGC 7332, we can surely state that it has a solar magnesium-to-solar ratio in the nucleus, because we have measured the nuclear indices very accurately. The bulge measurements follow the \([\text{Mg/Fe}] = 0\) model sequences up to \( R \approx 4''\); after that two measurement sets diverge: the data of 1996 continue to follow the model sequences while the data of 1997 show a slight magnesium overabundance. Though the long-slit measurements support rather the results of 1997 in this radius range (see Fig. 2), we would prefer to conclude that the bulge of NGC 7332 demonstrates a nearly solar magnesium-to-iron ratio, just as the nucleus.

It is known that both age and metallicity decreases result in the bluer color and weaker metal absorption lines in the integrated spectra of the stellar populations. However, there are methods to disentangle age and metallicity effects. Particularly, comparing Balmer line and metal-line indices, one can determine simultaneously both parameters. The most popular present models that provide a lot of various absorption-line indices for old stellar populations \((T > 1 \text{ Gyr})\) are the models of Worthey (1994); however, they are calculated for \([\text{Mg/Fe}] = 0\). Recently, some advanced models have been published; among them we take the results of Tantalo et al. (1998), which are expanded to \([\text{Mg/Fe}] = -0.3\) and \([\text{Mg/Fe}] = +0.3\). In NGC 1023 only the starlike nucleus has \([\text{Mg/Fe}] \approx +0.3\), and the rest of the region under consideration has \([\text{Mg/Fe}] \approx 0.0\). So we need both sets of calculations for the age-metallicity diagnostics. To determine an age of the starlike nucleus, we must use the Figure 5a where the models of Tantalo et al. (1998) for \([\text{Mg/Fe}] = +0.3\) are plotted. We see that the nucleus itself is \(\approx 7 \text{ Gyr old}\) and has more than solar global metallicity. Figure 5b, which contains the comparison with the models of Tantalo et al. (1998) calculated for \([\text{Mg/Fe}] = 0.0\), evidences that the ring at \( R = 1.3 \) is young, nearly 5 Gyr old, and has more than solar global metallicity; the bulge is \(\approx 15 \text{ Gyr old}\) and moderately metal-poor. Figure 5c presents a comparison to Worthey’s models, so it is valid for the measurements except the nucleus. One can see once more that the point at \( R = 1.3 \) confirms the rather young age of the stellar population in the nearest vicinity of the nucleus, namely, \( T \leq 5 \text{ Gyr} \); the more outer bulge, at \( R > 2''\), is old, \( T \approx 17 \text{ Gyr} \). So we conclude that there exists a compact, marginally resolved stellar structure in the center of NGC 1023, with the radius of \( R \leq 1.5 \), which is significantly younger than the surrounding bulge. There is also a modest metallicity difference between the two: the nuclear plus circumnuclear stellar population has \([m/H] \approx +0.3\), while in the central bulge we see \([m/H]\) from 0.0 to \(-0.3\).

The work of Tantalo et al. (1998) proposes also a possibility to quantify differences of stellar population properties basing on the index differences. A set of three linear equations, connecting \(\Delta[\text{Mg/Fe}], \Delta \log Z, \text{ and } \Delta \log T\) to the \(\Delta m2, \Delta (\text{Fe}), \text{ and } \Delta H\beta\), is proposed. We apply these equa-
Age-diagnostics diagrams for NGC 1023. (a) $\text{H}_\beta$ vs. $\langle \text{Fe} \rangle$ for $[\text{Mg/Fe}] = +0.3$ (the models of Tantalo et al. 1998), valid for the nucleus. (b) $\text{H}_\beta$ vs. $\langle \text{Fe} \rangle$ for $[\text{Mg/Fe}] = 0$ (the models of Tantalo et al. 1998), valid for all the points except the nucleus. (c) $\text{H}_\beta$ vs. $[\text{MgFe}]$ for $[\text{Mg/Fe}] < 0$ (the models of Worthey 1994), valid for all the points except the nucleus. The measurements are azimuthally averaged and taken along the radius with the step of $\Delta R = 0.3$. The nuclear measurements from Trager et al. (1998) are plotted for comparison with their error bar. The ages of the models are given in gigayears. The metallicities for the Worthey’s models are $[\text{Mg/Fe}] = 0.50, 0.25, 0.00, 0.22, 0.50, 1.00, 1.50, 2.00$, if one takes the signs from the right to the left. For the models of Tantalo et al., they are $[\text{Mg/Fe}] = 0.4, 0.0, 0.7$.

Differences to the differences between the nucleus and the bulge or between the nucleus and circumnuclear structure (the ring at $R = 1.3'$) in NGC 1023; the bulge is taken by integrating the rings at the following values of radius, $r = 2.6, 3.9, 5.2$. Having performed the set of calculations, we have obtained the following parameter differences: for the difference “circumnuclear ring minus nucleus” $\Delta [\text{Mg/Fe}] = -0.20$, $\Delta \log Z = +0.09$, and $\Delta \log T = -0.19$; and for the difference “bulge minus nucleus” $\Delta [\text{Mg/Fe}] = -0.27$, $\Delta \log Z = -0.27$, and $\Delta \log T = +0.26$. It means that the bulge is twice as old and twice as times as metal-poor as the nucleus; the circumnuclear structure is almost as metal-rich as the nucleus but is younger by a factor of 1.5. Interestingly, the Mg/Fe ratios are almost equal in the circumnuclear structure and in the bulge, but the nucleus is outstanding by its magnesium over-abundance. The bulge has a solar magnesium-to-solar ratio, as one can see from Figure 4a; then the nucleus has $[\text{Mg/Fe}] \approx +0.3$, and the age estimate for it obtained from the diagram Figure 5a is valid.

For NGC 7332 we can use the models with $[\text{Mg/Fe}] = 0$ for the nucleus and for the bulge as well. But there are some other restrictions: the data of 1997 lack extended $\langle \text{Fe} \rangle$ measurements though their $\text{H}_\beta$ indices are more accurate at $R \geq 4''$ (see Fig. 2). So we give three variants of $\text{H}_\beta$, metal index diagrams to disentangle age and metallicity effects in NGC 7332. Figure 6a reveals a strong age gradient in the radius range $0''-5''$; outside $R \approx 5''$ the age of the stellar population remains constant and older than 17 Gyr. Figures 6b and 6c confirm the age increase by a factor of 6 between $R = 0''$ and $R = 5''$. And all three diagrams show surely that the mean age of the nuclear stellar population in NGC 7332 is less than 3 Gyr. Moreover, as we have three independent high-quality nucleus measurements (see Fig. 2), we can calculate the $\text{H}_\beta$ index value very accurately: $\langle \text{H}_\beta \rangle = 2.20 \pm 0.05 \text{Å}$ (and the metal-line indices also: Mg $b = 3.82 \pm 0.04 \text{Å}$ and $\langle \text{Fe} \rangle = 2.95 \pm 0.03 \text{Å}$). It lets a very precise estimate of the nuclear stellar population age: $T = 2.5 \pm 0.5$ Gyr with the range of $[m/H]$ from $+0.3$ to $+0.4$. This age is unexpectedly low for a regular gas-poor lenticular galaxy. A metallicity drop between the nucleus and the bulge at $R \approx 5''$ is also very prominent: from $+0.3$ to $-0.5$ or $-0.7$, almost an order of magnitude. Therefore, in NGC 7332 the age- and metallicity-decoupled circumnuclear structure is extended, with $R \approx 5''$ (it is a somewhat overestimated value due to our moderate seeing quality);
outside it we see an unusually metal-poor bulge with the old stellar population.

4. MORPHOLOGY OF THE CENTRAL PARTS OF NGC 1023 AND NGC 7332

There are several photometric studies of NGC 7332 that have been made recently with CCD detectors under rather good seeing conditions and followed by a sophisticated mathematical analysis (Fisher et al. 1994; Seifert & Scorza 1996). The paper of Fisher et al. (1994) is fully devoted to the dynamics and structure of NGC 7332. The photometric data obtained with the 3 m Lick Telescope have allowed them to decompose the radial brightness profile into a bulge, an extended exponential disk, and a third component, "something flat" in the radius range of 14\"--24\". The kinematical data have revealed a presence of counter-rotating ionized gas, but nothing unusual in the rotation of the stellar component. Meantime, the stellar velocity dispersion has a prominent minimum in the center of the galaxy that cannot be consistent with the dominance of the hot spheroidal bulge. Seifert & Scorza (1996) have made a two-dimensional decomposition of the surface brightness map of NGC 7332, together with other lenticular galaxies. They have found two disks in this galaxy: the inner one has a maximum surface brightness at \( R \approx 3.5 \) and the outer one at \( R \approx 23 \)\". Between two disks there is a gap: at \( R \approx 10 \)\" only a spheroidal component is detected. We would like to note that the radius ranges for the inner disk photometric incidence and for the region of the strong age gradient reported in the previous section are roughly the same.

NGC 1023, being brighter and larger than NGC 7332, was intensively studied in the epoch of photographic photometry. Probably, a general impression that Barbon & Capaccioli (1975) and Gallagher & Hudson (1976) have made all the observations possible prevented an investigation of NGC 1023 with digital detectors. Barbon & Capaccioli (1975) have derived three-component structure of the radial surface brightness profile: de Vaucouleurs bulge at \( R \leq 0.5 \), an exponential disk at \( R \geq 1 \), and a lens between them—a picture very similar to the structure of NGC 7332 derived by Fisher et al. (1994). But a two-dimensional analysis a la Seifert & Scorza (1996) was still needed.
Figure 7 presents some results of such analysis, which we have undertaken by using the photometric data from the archives of the HST and La Palma. One can see that the HST data are more precise (though limited by a smaller radius range), but in general the agreement between the different telescope and different passband results exists. High spatial resolution of the HST observations enables us to detect a very compact distinct structure in the center of NGC 1023. It manifests itself as a local maximum of ellipticity at $R \approx 1''$. Since the fourth cosine Fourier coefficient is larger than $+1\%$ inside $R = 1'5$, we can conclude that this distinct subsystem is a compact nuclear stellar disk. We have subtracted pure elliptical surface brightness distribution from the HST image of NGC 1023; the result is shown in Figure 8. Even though we have ascribed the ellipse parameters affected by the disk presence to our model image, the residual map still demonstrates a presence of the thin edge-on disk with a radius of $\sim 1'5$. The orientation of the nuclear disk, P.A. $\approx 84^\circ - 85^\circ$, is very close to the global line of nodes, P.A. $\approx 86^\circ$ (Barbon & Capaccioli 1975), though the bulge itself—or rather, the lens, if it dominates at $R = 35'' - 40''$—reveals some misalignment, by $10^\circ - 12^\circ$, with respect to the outermost disk. If we deal in this radius range with some triaxial subsystem—NGC 1023 is classified as SB0—this misalignment transforms in the plane of the galaxy into a very prominent turn taking into account that the galaxy is seen almost edge-on ($i = 80^\circ$, Barbon & Capaccioli 1975). If this lens is a dislikle subsystem, which is implied by high values of $a_2$ between $R = 20''$ and $R = 40''$, it demonstrates a strange local "warp" scarcely explicable in the inner region of the early-type galaxy, which is dominated by an oblate spheroid. Detailed kinematical data are needed to classify this subsystem intermediate between the bulge and the main disk. But inside $R \approx 14''$ the structure seems to be clear: the compact circumnuclear disk limited by $R \approx 1'5$ is embedded into the pure ellipsoidal bulge. This morphology is quite consistent with the age trend detected in the previous section: the entity with more than solar metallicity and the age younger than 10 Gyr appears to be a nuclear stellar disk. The bulge is old and moderately metal-poor.

5. STELLAR ROTATION IN THE INNER PARTS OF NGC 1023 AND NGC 7332

The spectral range that has been exposed with the MPFS contains a lot of strong absorption lines. So it has been a possibility to calculate a field of stellar velocities by cross-correlating elementary galactic spectra with spectra of some K-giants, that have been observed the same nights as the galaxies. Two-dimensional line-of-sight velocity maps obtained are presented in Figure 9. Both galaxies are seen nearly edge-on. The stellar velocity field of NGC 1023 (Fig. 9a) can be treated as cylindric rotation, but the stellar velocity field of NGC 7332 (Fig. 9b) is not so conventional: a sure local velocity extremum is clearly seen to the north from the center, which may be a sign of a dynamically decoupled core. In any case, rotational velocities can be derived from major-axis cross sections, which are simulated from the two-dimensional maps and presented in Figure 10. For comparison and to extend the rotation curves, the long-slit data from Simien & Prugniel (1997) are also plotted. To compare them, we have reduced the profiles to the same systemic velocities: in the case of NGC 1023 the difference of the systemic velocity is $37$ km s$^{-1}$, and in the case of NGC 7332, $28$ km s$^{-1}$. But the shapes of the central velocity gradients according to our observations and to those of Simien & Prugniel (1997) are very similar. For NGC 1023 (Fig. 10, top) the agreement is perfect; the combination of the data presented lets to conclude that the central part of the galaxy inside $R \approx 3''$ (it is an upper limit due to finite spatial resolution) rotates much more rapidly than the rest of the galaxy. An analogous conclusion may be made with respect to NGC 7332 if we believe in our MPFS cross section: the velocity profile from Simien & Prugniel (1997) looks somewhat shallower than ours. Since our profile is symmetric and the profile from Simien & Prugniel (1997) is clearly asymmetric and since during long-slit observations there may be difficulties with slit positioning, perhaps, our data are more reliable. So we may conclude that the central parts of NGC 1023 and NGC 7332 appear to be rotating faster than the surrounding bulges and are kinematically decoupled.

6. CONCLUSIONS

We have found chemically distinct, on average relatively young stellar cores in the lenticular galaxies NGC 1023 and NGC 7332. The morphological analysis undertaken by Seifert & Scorza (1996) for NGC 7332 and here by us for NGC 1023 has implied that they are related to the separate circumnuclear stellar disks. The similar conclusion about the secondary formation epoch has been made by de Jong & Davies (1997) for embedded disks of some disky ellipticals, when they have found correlation between $H\beta$ index
Residual brightness map of the central part of NGC 1023 obtained from the HST WFPC2 F814W image by subtracting the pure ellipsoidal brightness distribution. The sizes of the map are $23' \times 21''$, the orientation is P.A.(top of figure) = 120°, the black spot in the center marks the nucleus position, and the light ellipse borders the area where the model has been subtracted.

and the fourth cosine Fourier coefficient of isophotes. By considering stellar rotation curves of NGC 1023 and NGC 7332, we see that the central (chemically decoupled) regions are also distinguished by a fast solid-body rotation, so they can be also described as dynamically decoupled. Interestingly, the borders of the regions distinct by the metallicity, by the age, and by the morphology are approximately the same—that is, $R = 1.5'$, or 80 pc, for NGC 1023, and $R = 4''$, or 400 pc, for NGC 7332. In the case of NGC 7332 we are sure to resolve the decoupled region, and we can state rapid changes of stellar characteristics, especially age, along the radius due to the circumnuclear disk effect, the

Fig. 8.—Stellar isovelocities in the centers of NGC 1023 (a) and NGC 7332 (b). The positions of photometric centers are shown by the crosses.
nucleus being the youngest point. The decoupled substructure in NGC 1023, though very compact, seems to be marginally resolved too. The difference in magnesium-to-iron ratio between the nucleus and the ring at looks convincingly: it is consistent with the age difference of 2 Gyr implying that the secondary star formation burst was short in the nucleus and lasted for several (2–3) gigayears at the periphery of the circumnuclear disk. The coincidence of chemically, morphologically, and dynamically decoupled central regions was also found in another lenticular galaxy, NGC 4816 (Mehlert et al. 1998); in this galaxy the circumnuclear disk is also relatively young, $T \lesssim 8$ Gyr, and very strongly dynamically decoupled (being counter-rotating). Perhaps, in this relation lenticular galaxies are similar to ellipticals where the coincidence of chemically decoupled cores with fast-rotating circumnuclear stellar disks is frequent (Bender & Surma 1992; Surma & Bender 1995; Scorza & Bender 1995; Forbes et al. 1995). In early-type spiral galaxies the situation looks somewhat different: we have found that in M31 (Sil'chenko et al. 1998) and in NGC 4216 and NGC 4501 (Sil'chenko et al. 1999) the chemically decoupled young stellar cores are much more compact than the circumnuclear stellar disks, although both are present.

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