Is NGC 300 a pure exponential disk galaxy?

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ABSTRACT

NGC 300 is a low-mass disk galaxy in the Sculptor group. In the literature, it has been identified as a pure exponential disk galaxy, as its luminosity profile could be well fitted with a single exponential law over many disk scale lengths (Type I). We investigate the stellar luminosity distribution of NGC 300 using *Hubble Space Telescope* (HST) archive data, reaching farther and deeper than any other previous studies. Color magnitude diagrams show a significant population of old red giant branch (RGB) stars in all fields out to $R \sim 19$ kpc (32′), as well as younger populations in the inner regions. We construct the density profiles of the young, intermediate-aged, and old stellar populations. We find two clear breaks in the density profiles of the old RGB and intermediate-aged stars: one down-bending (Type II) at $R \sim 5.9$ kpc, and another up-bending (Type III) at $R \sim 8.3$ kpc. Moreover, the old RGB stars exhibit a negative radial color gradient with an up-bending at $R \sim 8$ kpc, beyond which the stellar populations are uniformly old (>7 Gyr) and metal-poor ([Fe/H] $= -1.6^{+0.2}_{-0.4}$ dex). The outer stellar component at $R \gtrsim 8$ kpc is, therefore, well separated from the inner disk in terms of the stellar density and stellar populations. While our results cast doubt on the currently established wisdom that NGC 300 is a pure exponential disk galaxy, a more detailed survey should be carried out to identify the outskirts as either a disk or a stellar halo.

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The very outskirts of disks form sensitive test areas for models, because their evolution is more extreme due to the low disk self-gravity and the lack of gas for star formation.

- Most exponential disk formation models have difficulty explaining very extended stellar disks, because gas densities are too low for star formation and any interactions would quickly destroy these tenuous disk outskirts. However, observations have shown that there is a population of galaxies that have an exponential light profile traceable out to 10 disk scale-lengths with no sign of a break or a separate halo component.

К истории вопроса

- Схема формирования диска “inside-out” имеет ограниченную область приложения

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COLOR PROFILES OF SPIRAL GALAXIES: CLUES ON OUTER-DISK FORMATION SCENARIOS

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ABSTRACT

We have explored radial color and stellar surface mass density profiles for a sample of 85 late-type spiral galaxies with deep (down to ∼27 mag arcsec^{-2}) SDSS g' and r' band surface brightness profiles. About 90% of the light profiles have been classified as broken exponentials, exhibiting either truncations (Type II galaxies) or antitruncations (Type III galaxies). The color profiles of Type II galaxies show a “U shape” with a minimum of $(g'-r') = 0.47 \pm 0.02$ mag at the break radius. Around the break radius, Type III galaxies have a plateau region with a color of $(g' - r') = 0.57 \pm 0.02$. Using the color to calculate the stellar surface mass density profiles reveals a surprising result. The breaks, well established in the light profiles of the truncated galaxies, are almost gone, and the mass profiles now resemble those of the pure exponential (Type I) galaxies. This result suggests that the origin of the break in Type II galaxies is more likely due to a radial change in stellar population than being associated with an actual drop in the distribution of mass. Type III galaxies, however, seem to preserve their shape in the stellar mass density profiles. We find that the stellar surface mass density at the break for truncated galaxies is $13.6 \pm 1.6\ M_{\odot}\mathrm{pc}^{-2}$ and for the antitruncated ones is $9.9 \pm 1.3\ M_{\odot}\mathrm{pc}^{-2}$ for the antitruncated ones. We estimate that the fraction of stellar mass outside the break radius is ∼15% for truncated galaxies and ∼9% for antitruncated galaxies.

Subject headings: galaxies: evolution - galaxies: formation - galaxies: photometry - galaxies: spiral - galaxies: structure

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SPATIALLY RESOLVED SPECTROSCOPIC STAR FORMATION HISTORIES OF NEARBY DISKS: HINTS OF STELLAR MIGRATION*

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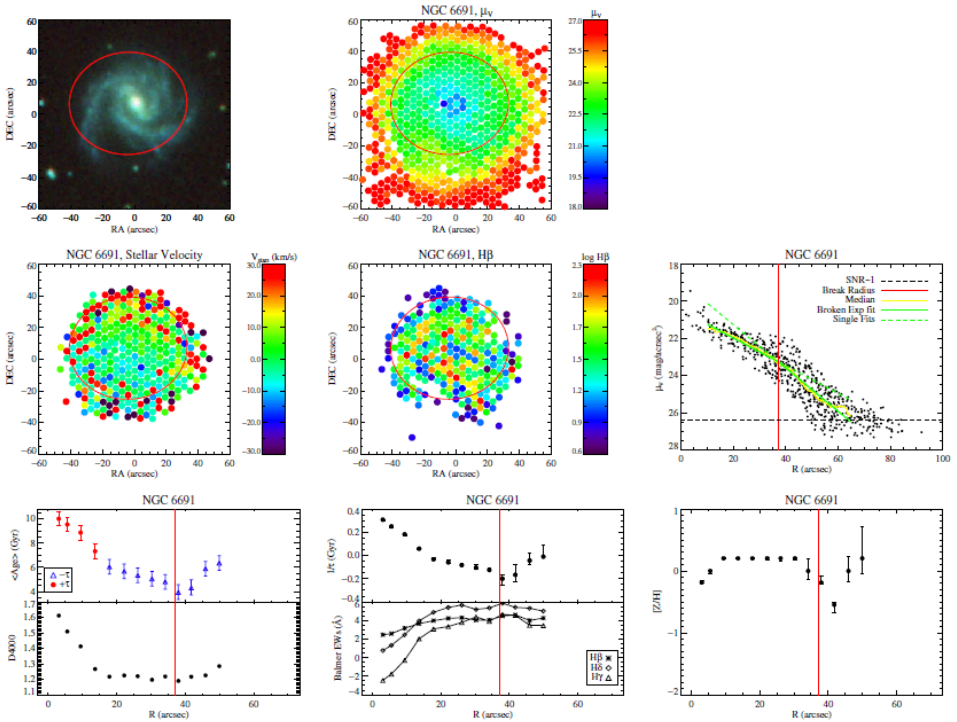
ABSTRACT

We use the Mitchell Spectrograph (formerly VIRUS-P) to observe 12 nearby disk galaxies. We successfully measure ages in the outer disk in six systems. In three cases (NGC 2684, NGC 6155, and NGC 7437), we find that a downward break in the disk surface brightness profile corresponds with a change in the dominant stellar population with the interior being dominated by active star formation and the exterior having older stellar populations that are best fit with star formation histories that decline with time. The observed increase in average stellar ages beyond a profile break is similar to theoretical models that predict surface brightness breaks are caused by stellar migration, with the outer disk being populated from scattered old interior stars. In three more cases (IC 1132, NGC 4904, and NGC 6691), we find no significant change in the stellar population as one crosses the break radius. In these galaxies, both the inner and outer disks are dominated by active star formation and younger stellar populations. While radial migration can contribute to the stellar populations beyond the break, it appears that more than one mechanism is required to explain all of our observed stellar profile breaks.



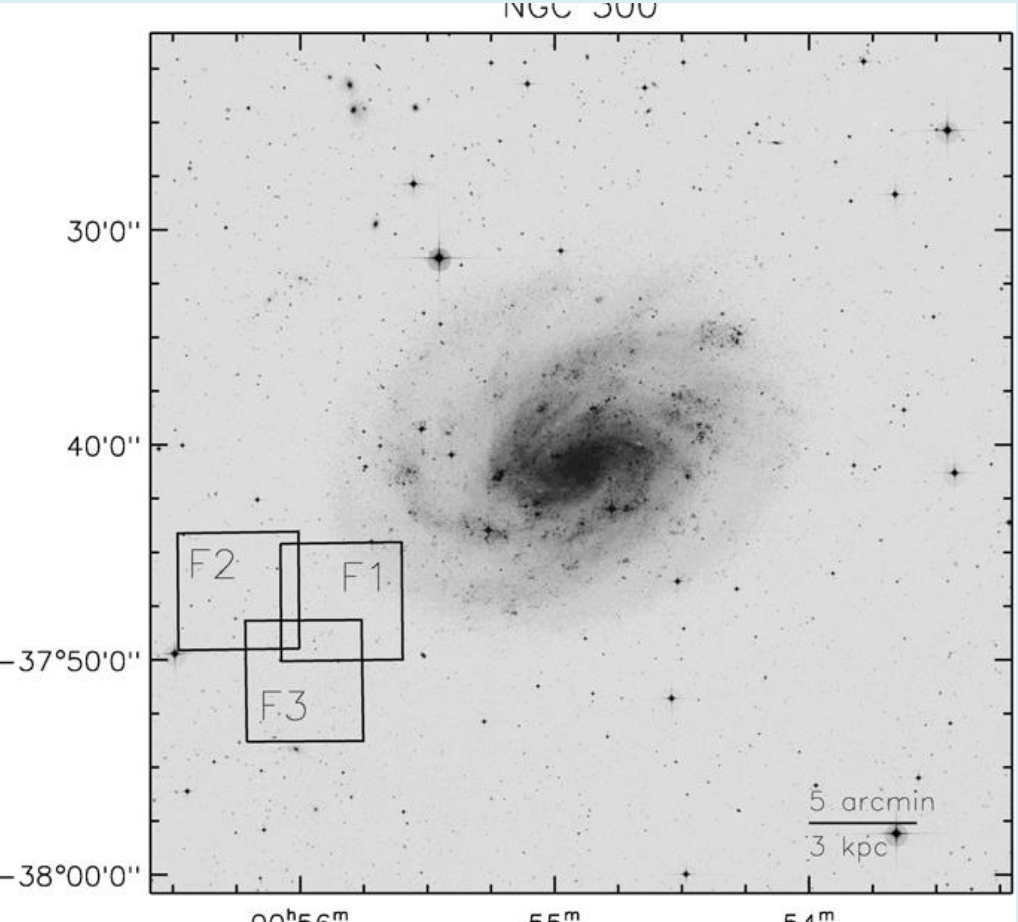
- Важно, минуя моделирование спектров, проследить изменение звездного состава по отдельным звездам.
- Минусы:

а) только для близких галактик

б) проблема учета фона

Предыдущая работа по отдельным звездам во внешнем диске NGC300

- M. Vlajic´, J. Bland-Hawthorn, and K. C. Freeman, 2009



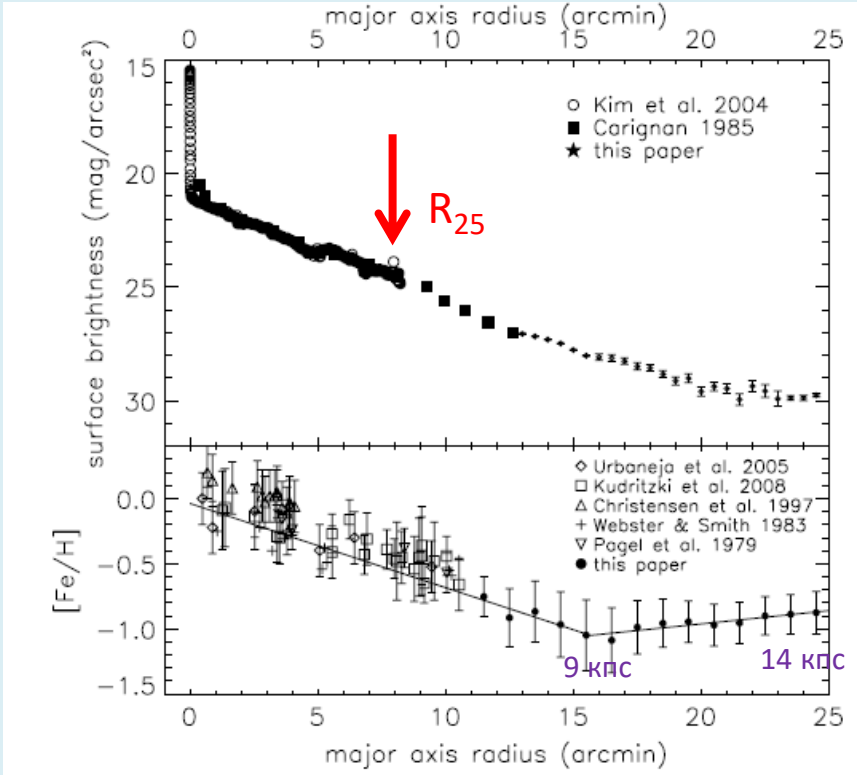


Figure 13. Top: surface brightness profile of NGC 300. Bottom: metallicity gradient in the disk of NGC 300. Inner disk data points are from the spectroscopic abundance studies listed in the figure. Filled circles are outer disk binned mean metallicities and solid lines are the linear fits to these values as calculated in Figure 12.

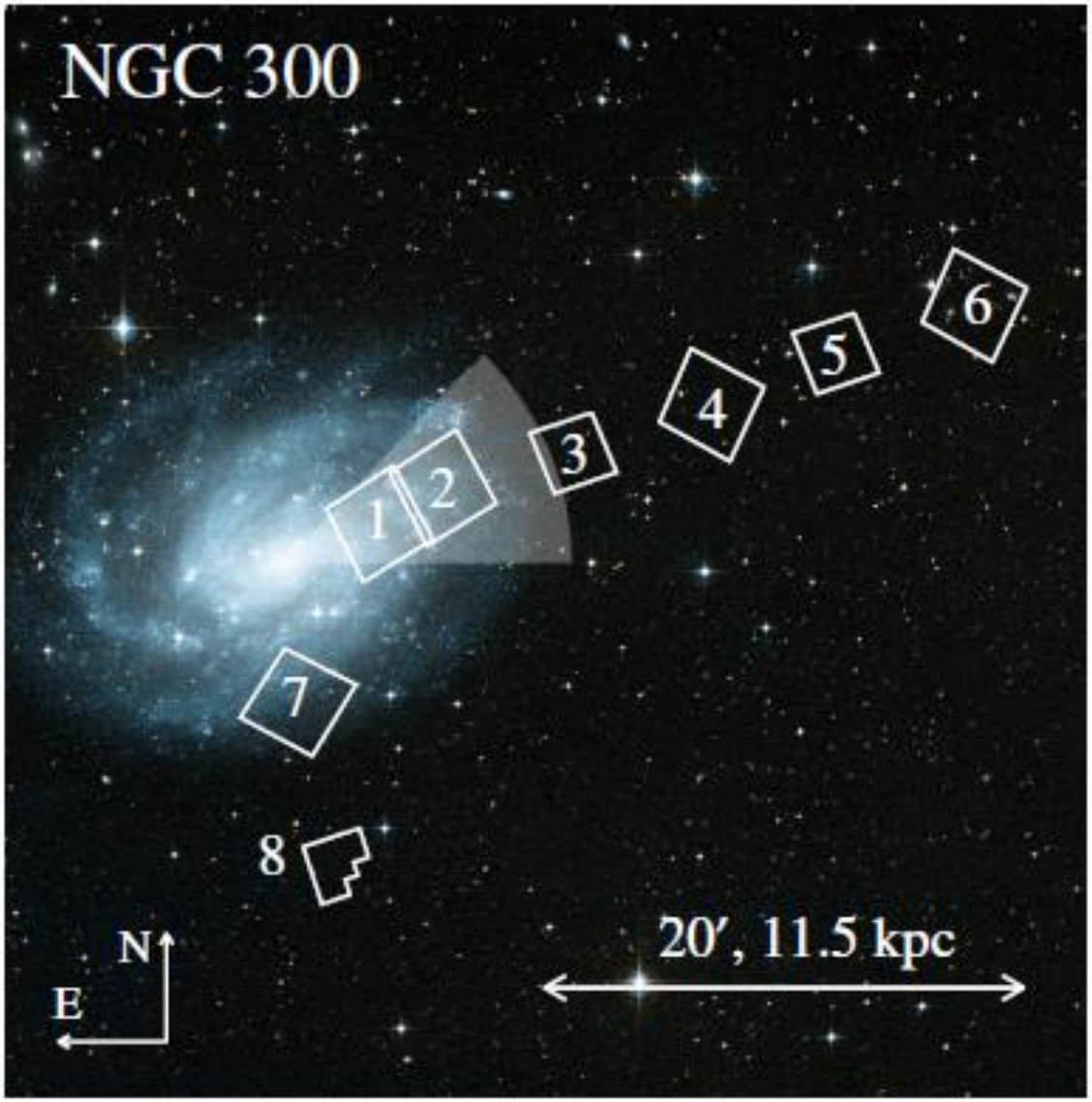
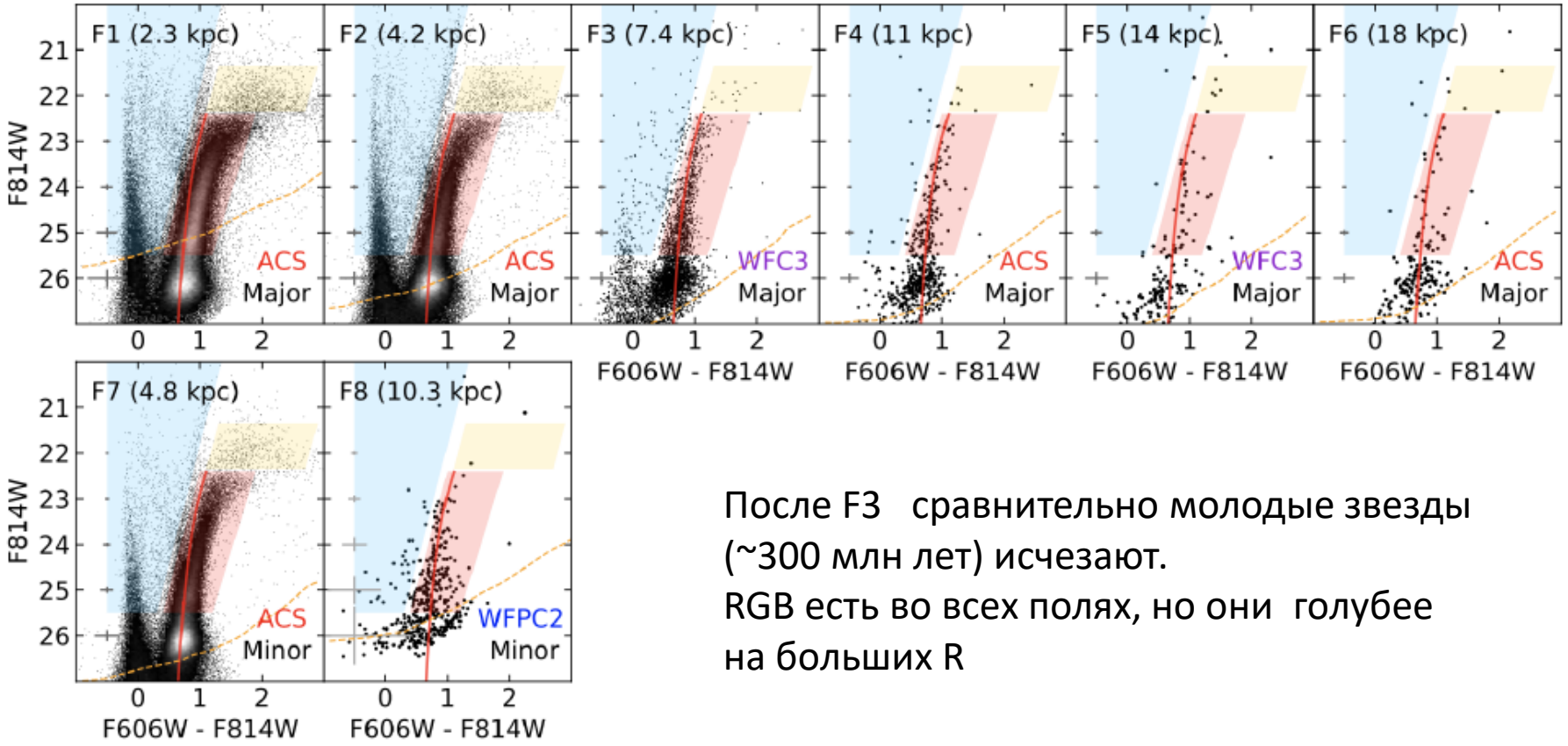


Fig. 1. Finding chart for NGC 300. The eight *HST* fields used in this study are marked on the Digitized Sky Survey image. The shaded area indicates the region we used to derive the integrated light profile from the Spitzer 3.6μm data.



После F3 сравнительно молодые звезды (~300 млн лет) исчезают.
RGB есть во всех полях, но они голубее на больших R

Fig. 2. CMDs of the *HST* fields along the major (top) and minor (bottom) axes of NGC 300. The field IDs and projected galactocentric distance are marked in each panel. The projected distances for the minor axis fields are corrected for the disk inclination ($i = 45°$). Blue, yellow, and pin shaded regions represent selection bins for the young (MS and HeB), intermediate-aged (AGB), and old (RGB) stellar populations, respectively A stellar isochrone for 10 Gyr age with [Fe/H] = −1.6 dex (solid line) and the 50% completeness limit (dashed line) are overlaid in each CMD.

- Blue – MS
- Yellow – intermediate age (AGB)
- Pink – old stars (RGB)

Области фона

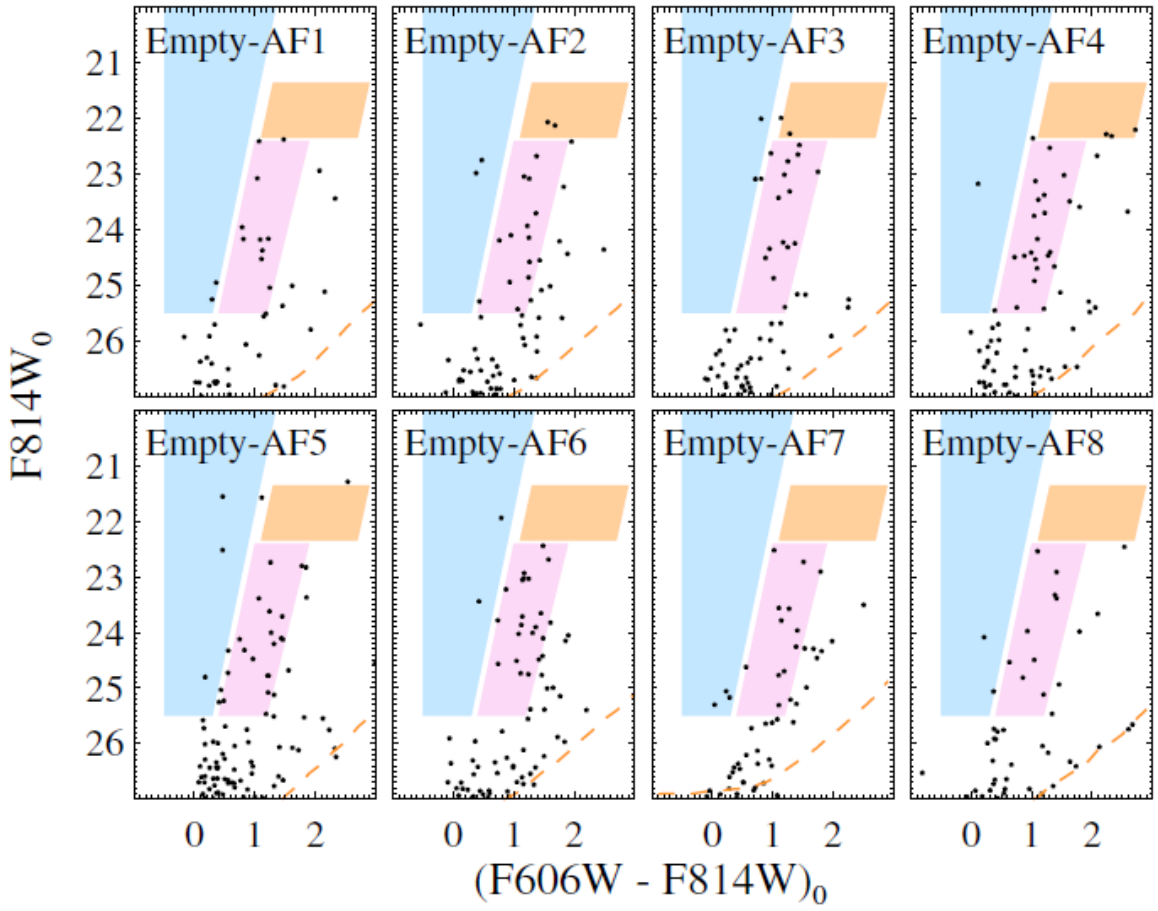


Fig. A.1. CMDs for the selected point sources in the eight empty fields taken with ACS/WFC. We correct for the foreground extinction toward each field using the values in Schlafly & Finkbeiner (2011). Shaded regions are the same as those in Figure 2. Dashed lines represent the 50% completeness limits.

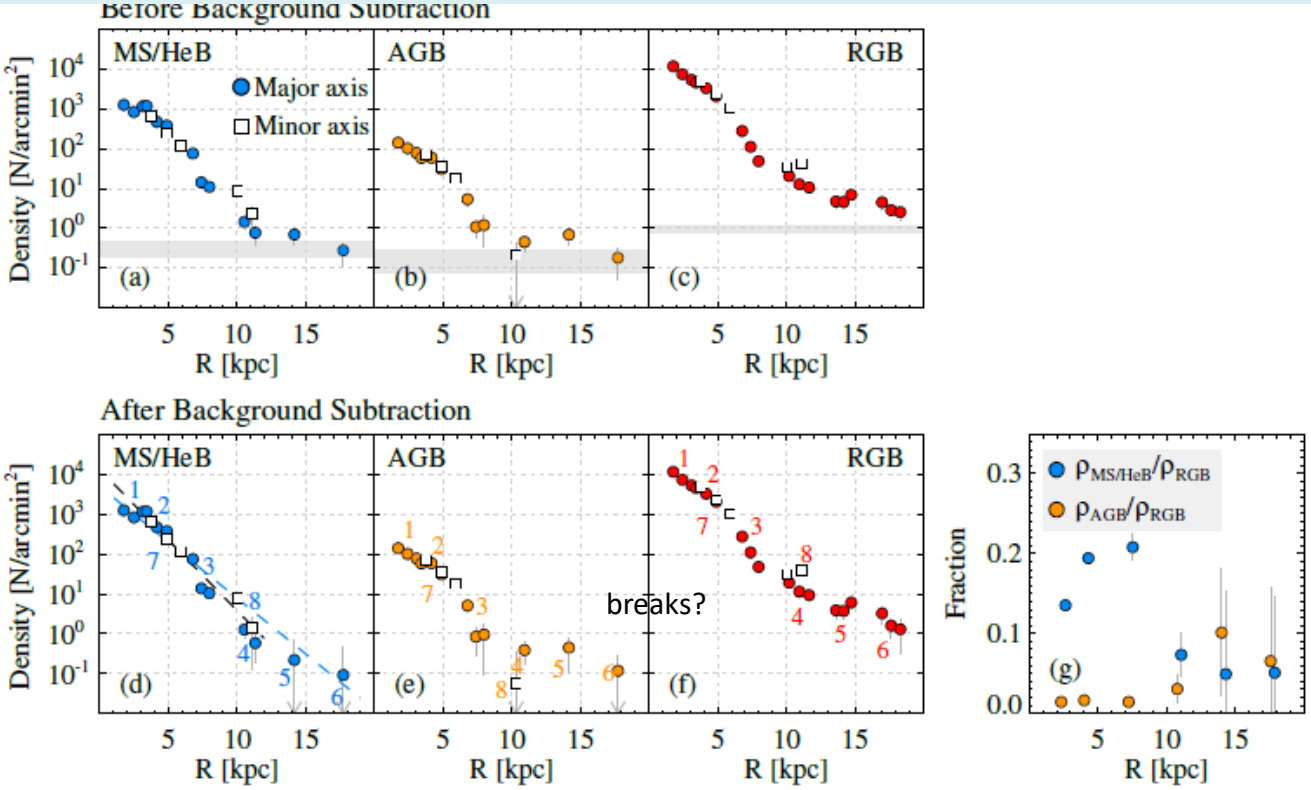


Fig. 3. (Top) Radial star count profiles for the MS/HeB (a), AGB (b), and RGB (c) stars in NGC 300. Circles and squares indicate the profiles along the major and minor axis of the galaxy, respectively. The approximate background levels of each population are marked by shaded regions. (Bottom) Same as top, but after background subtraction. Numbers in each panel indicate field IDs. Dashed lines in panel (d) represent the exponential fit of the major and minor axes profiles. (g) Relative densities of MS/HeB and AGB stars with respect to RGB stars along the major axis.

Сравнение модельной и наблюдаемой CMD.

- Red Clump слабеет с удалением от центра.

Самые далекие области: F4-5-6

The NGC300 outskirts is older than 7 Gyr and probably as old as 10 Gyr.

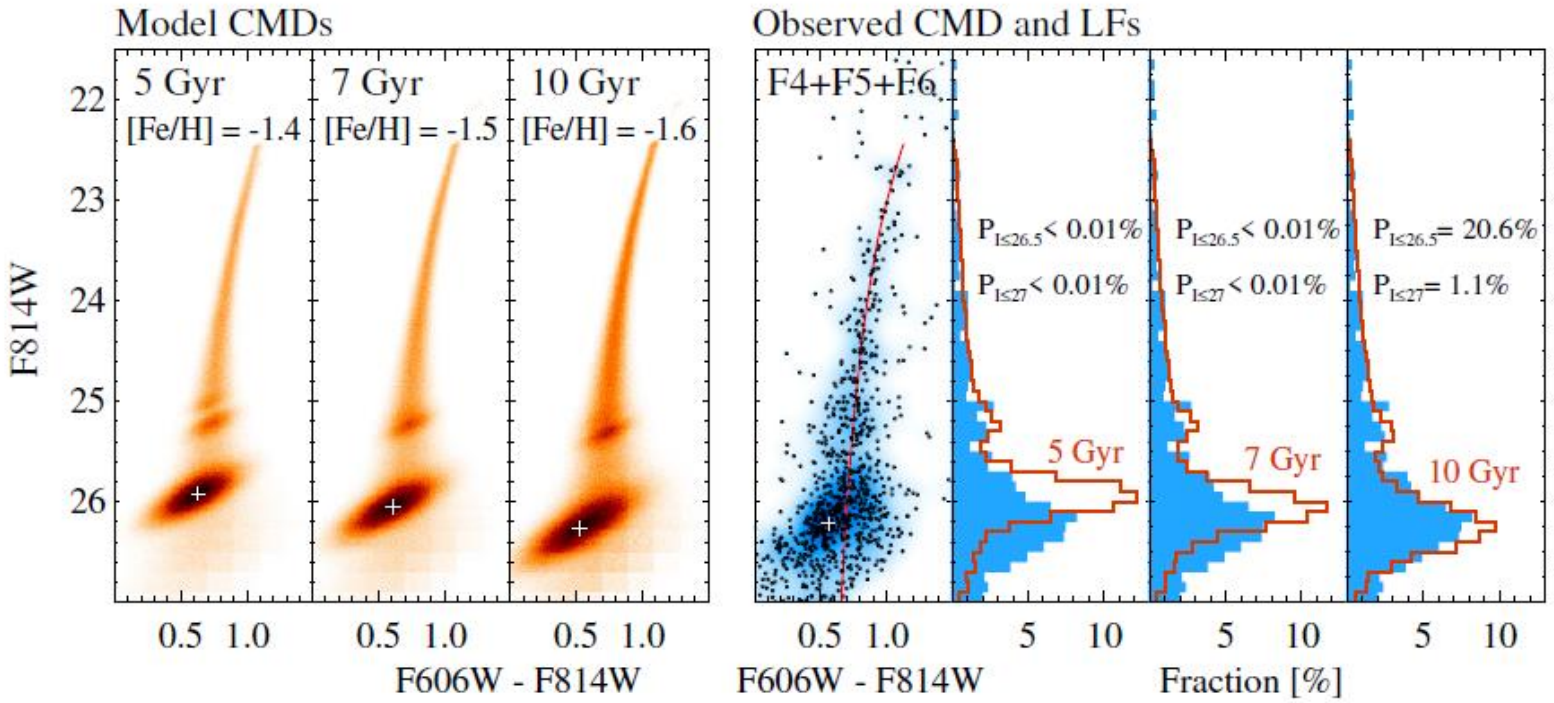


Fig. 4. (Left three panels) Hess diagrams for the simulated 5, 7, and 10 Gyr simple stellar populations at the distance of NGC 300. The highest density regions of the RC are marked by crosses. Note the gradual change of the RC magnitudes as a function of age. (Right four panels) Observed CMD of F4, F5 and F6 and its LF (filled histograms) overplotted with the model LFs (open histograms). The red curved line in the CMD represents the stellar isochrone for age = 10 Gyr and [Fe/H] = −1.6 in the Padova models. The probability (P) of the Kolmogorov-Smirnov test for the stars brighter than F814W = 26.5 and 27 mag are marked in the panels with LFs.

The integrated light profile was scaled to the RGB density using the Padova stellar models.

We can convert this median color to metallicity using the relation by Streich et al. (2014) with[α/Fe] = 0.3, which results in [Fe/H] = -1.6pm0.3 dex.

The Type II break we find at R~10' in the AGB and RGB profiles is also supported by a down-bending in the UV profile of NGC300 found by Roussel et al. (2005) and Gil de Paz et al. (2007). Taken at face value, the youngest stellar disk of the galaxy is also likely truncated.

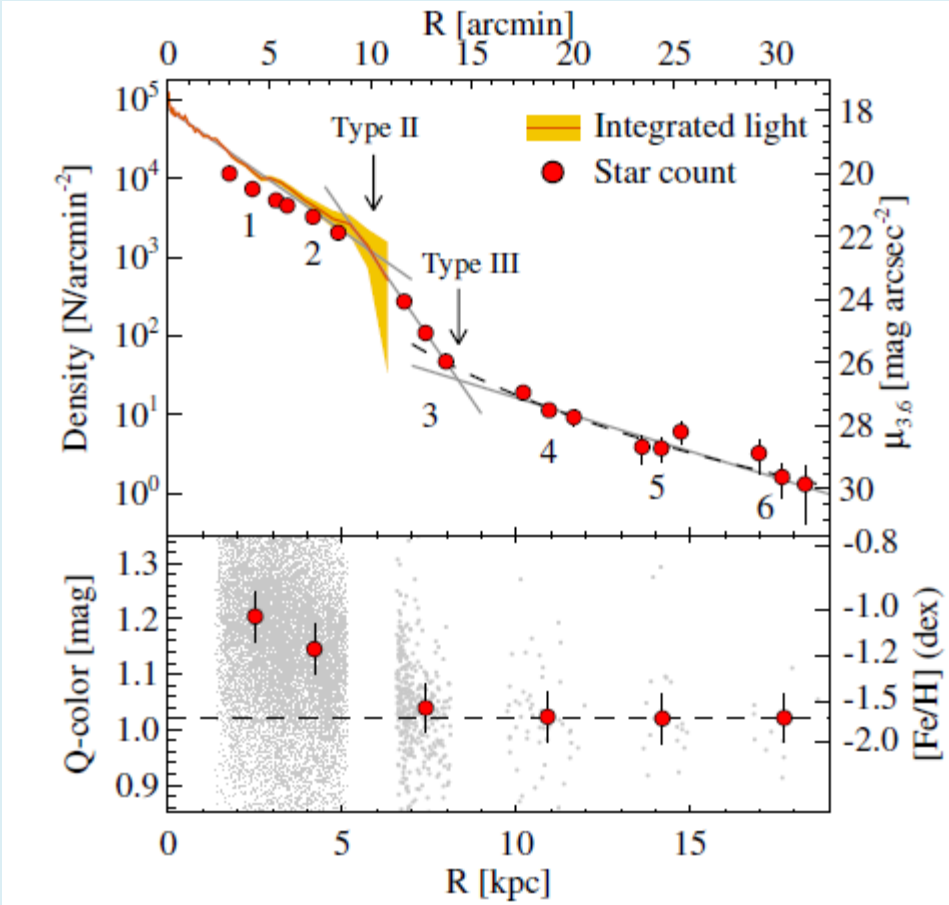


Fig. 5. (Top) Stellar density profile along the NGC 300 major axis. RGB star counts are shown by circles. The orange line with a shaded region indicates the integrated light profile in the Spitzer 3.6μm band. Surface brightness is shown on the right y-axis, which can be converted to V-mag by adding ~2.0 mag. Solid lines indicate fits to the resulting three regions using exponential-law models. Also shown is a fit to the outermost component with a power-law (dashed line). (Bottom) The Q-color distribution of the bright RGB stars with $F814W \leq 24.5$ mag. Individual stars and their median colors are indicated by gray dots and red circles, respectively.

- Таким образом,

The stellar populations beyond the Type III break radius become predominantly old (>9 Gyr) and metal-poor ([Fe/H]=-1.6), well separated from the inner disk regions.

Extended disk or stellar halo?

Если это протяженный диск:

- HI наблюдается до 20 кпс – в пользу диска.
- Как появились звезды на таком расстоянии? Perturbations by accretion or minor mergings?

Если это гало:

- ρ_{halo} ~$R^{-4.2}$ и M_{halo}(10-19kpc) = 3 $10^7 M_s$ =1.5% M_{gal}
- Полная масса гало ~ несколько % по массе.

Such a massive stellar halo would be very unusual in current low-mass disk galaxy models.

- *It is expected that wide-field imaging with ground based large telescopes would be useful to map out the global structure of the extended stellar component, providing evidence to the formation history of NGC300*