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Stellar subsystems of edge-on disk galaxies[†]

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Based on the stellar photometry of the Hubble Space Telescope images we analyze the stellar populations of edge-on disk galaxies: IC 1959, IC 2233, IC 5052, NGC 4631, NGC 5023 and ESO115-G121 with the goal of quantifying their spatial distribution, vertical extent and structure. We find that there is a profound change in the slope of the number density profiles of the evolved RGB stars at extraplanar height of 4–8 kpc that possibly reflects a truncation of the thick disk and reaching the 2–3 times more extended oblate stellar halo.

Keywords: Nearby galaxies; Stellar photometry; Stellar content of galaxies; Thin and thick disks

1 Introduction

Understanding the structure of the stellar component of disk galaxies is an important step for unraveling their formation and evolution. The extraplanar stellar content around galaxies is a potentially important probe of the most ancient stellar populations, as well as of the role that different external and internal processes play in the evolution of modern galaxies, such as: merging of neighbour galaxies, accretion of metal-poor gas, disk heating or the ejection of gas from the underlying disk. The stellar outskirts around some large spiral galaxies have been extensively studied over the last years and revealed faint stellar envelopes in many of them. We selected six edge-on spiral galaxies (Fig. 1, left) for a study of their stellar structure. The choice of high-inclination galaxies ensures minimal contamination by stars belonging to the dominant galactic disk component and provides a more robust separation of the thick disk and halo stellar populations.

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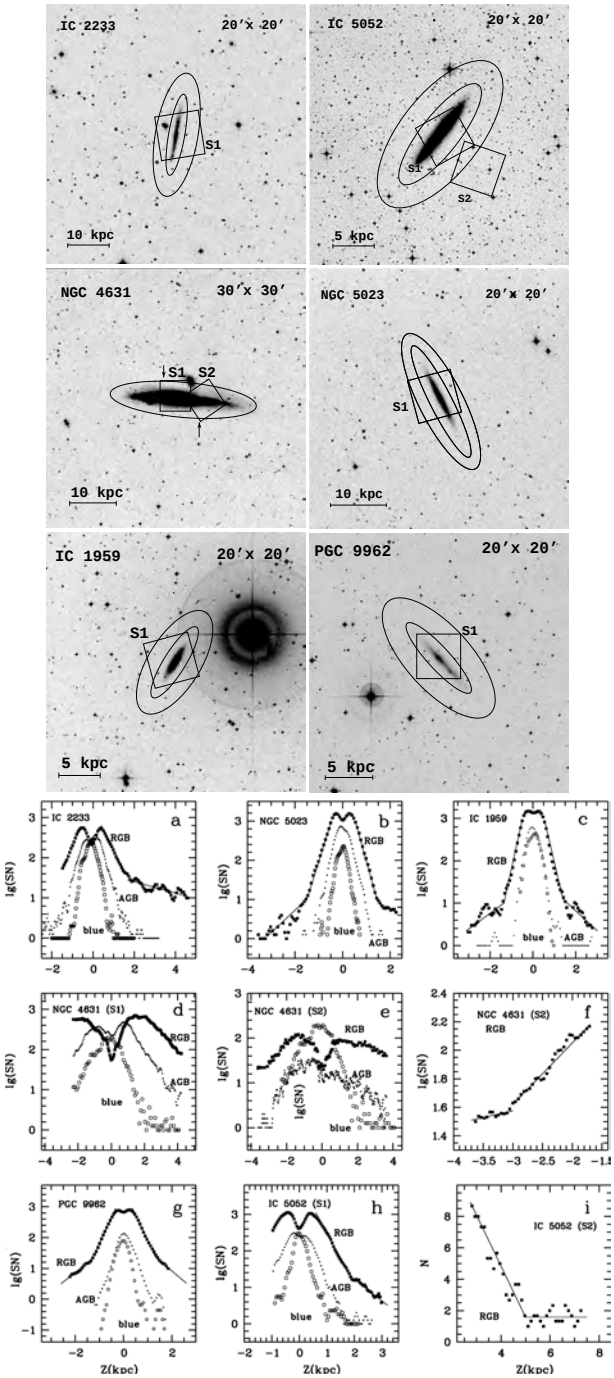


Figure 1 *Left:* The DSS-2 images of the galaxies with the ACS/WFC footprints superposed. The edge of thick disk and halo extent are shown by the ellipses. *Right:* The surface number density distribution of RGB (filled squares), AGB (dots) and blue stars (empty squares) along the extraplanar Z-axis.

2 Stellar photometry

To study the resolved stellar population of galaxies, we obtained ACS/WFC images available in the HST archive. Stellar photometry was carried out with DAOPHOT II in MIDAS [1]. The results are presented as colour-magnitude diagrams (CMD). On these CMDs we can see the branches of blue and red supergiants, of intermediate age stars (AGB) and a branch of red giants. For our spatial structure analysis we used only stars with magnitudes above the 50% completeness level that occurs at about $I = 27.^m5$ in these diagrams.

3 Stellar spatial distributions

Using CMDs, we separate different stellar populations and analyze their spatial distribution.

The surface number density profiles such as the ones presented in Fig. 1(right) show that distribution of different stellar populations has quite different scale-lengths and truncation radii. The distribution of the faint stars shows a decline toward the galaxy planes due to the increase of stellar crowding and bright background. The majority of young stars of thin disks are bright enough to be detected even near the mid-plane of galaxies and, therefore, they do not show the same drop-out as less luminous stars (AGB and RGB).

Farther above the thick disks, a density of the RGB stars declines with a shallower slope. By fitting the exponential law, we extrapolated stellar halos out to $Z =$ 5–15 kpc. Unless there is an additional outermost stellar component not covered by the ACS/WFC field, the relatively small extent of the stellar halo in comparison with apparent large axis length (planar extent) indicates that stellar halo might be represented by oblate ellipsoid.

4 Model of the stellar structures of a disk galaxy

Comparing the inferred parameters for the thin and thick disk and halo with our and other published results, we compose a scale 3D model of the stellar structures of a typical disk galaxy (Fig. 2). This model relies on the star number counts in edge-on and face-on spiral galaxies. We would like to note that massive irregular galaxies such as IC 10 and M 82 show all kinds of stellar structures, including thick disk and halo. The spatial distribution of stars along and perpendicular to a disk galaxy plane are alike.The young stars are mostly confined to the thin disk of the galaxy, while older stars are more spread out with oldest stars being traced outermost.

5 Discussion

Relying on the star number counts in the six edge-on disk galaxies, we examine the extraplanar spatial distribution of young and evolved stars in their disks and halos. All

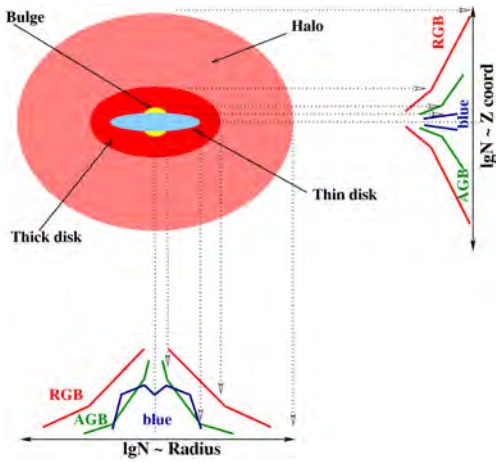


Figure 2 A scaled 3D representation of the stellar components of the typical spiral galaxy and results of their projection as a stellar density for a face-on (bottom plot) and edge-on (right) galaxy.

galaxies show the similar morphological properties, thin and thick disks and halos, but relative sizes of these structures are different in each galaxy. Combining this work with results obtained for other galaxies we suggest that most of the massive disk galaxies have not only a thick disk but also an extended halo, consisting mainly of evolved stars. The ratio of the halo-to-thick disk size is relatively constant, $R_{\rm halo}/R_{\rm thick\,disk} = 2.5$. It might reflect the overall rotation of the galaxy, including flatten stellar halo.

The stellar populations of the bulge, thin and thick disks and halo have likely been formed by different mechanisms, especially considering the differences in ages and metallicities. The thick disk and halo may cast light on the most ancient structure formation, and are therefore extremely important for the understanding of early history of galaxy formation and evolution.

6 Summary

On the basis of the stars count method, we have analyzed extraplanar stellar structures in six large high-inclination galaxies. Main results can be summarized as follows:

The extended stellar thick disks and halos have been detected in all galaxies.

There are clear differences between surface density gradients of evolved stellar populations assigned to the thick disks and halos, which allowed us to detect the edge of the thick disk.

The spatial distribution of stellar populations of these six galaxies provide more confidence for the unified model of three-dimensional structure of large disk galaxies and motivate follow-up spectroscopic study to constrain the kinematic characteristics of the stellar components.

References

[1] Stetson, P., 1994, Users Manual DAOPHOT II