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Composite Bulges – II. Classical Bulges and Nuclear Discs in Barred Galaxies: The Contrasting Cases of NGC 4608 and NGC 4643

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Исследуемые галактики –”близнецы”

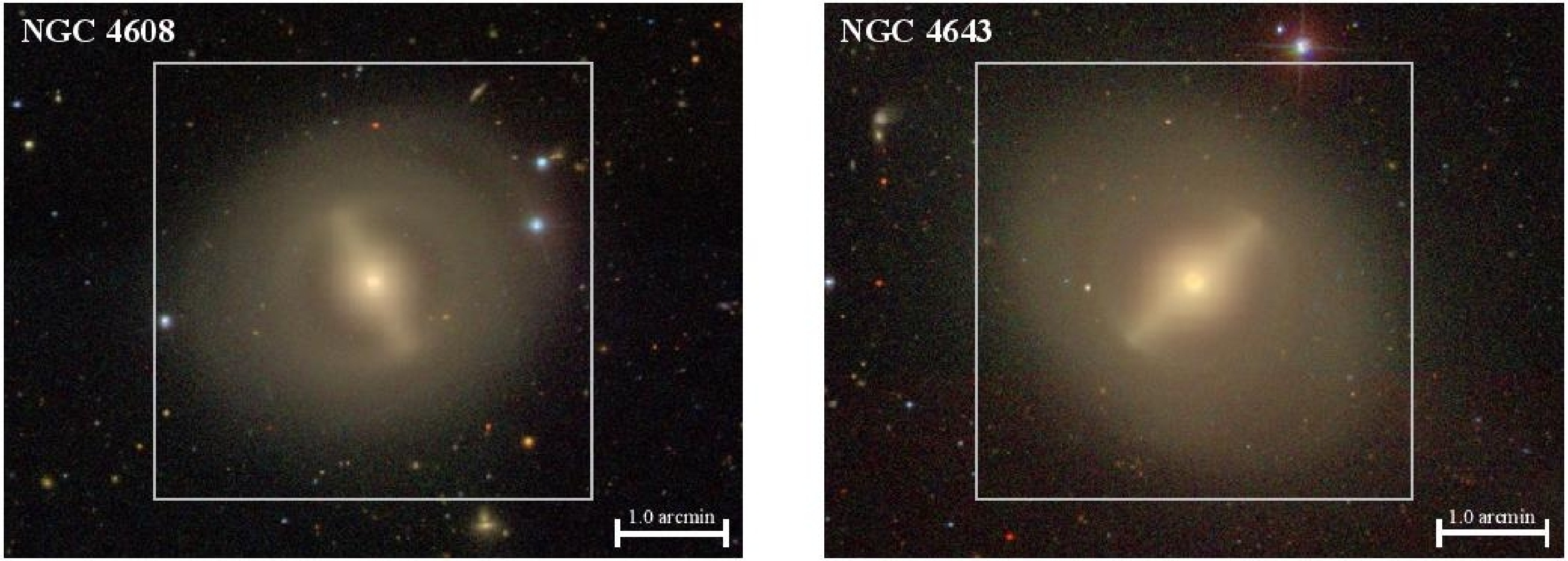

Figure 1. SDSS *gri* colour-composite images (David W. Hogg, Michael R. Blanton, and the Sloan Digital Sky Survey Collaboration) for the two galaxies studied in this paper. The light grey boxes outline the large-scale regions shown (using *Spitzer* IRAC1 isophotes) in the leftmost panels of Figures 2 and 3.

Фотометрия NGC 4608

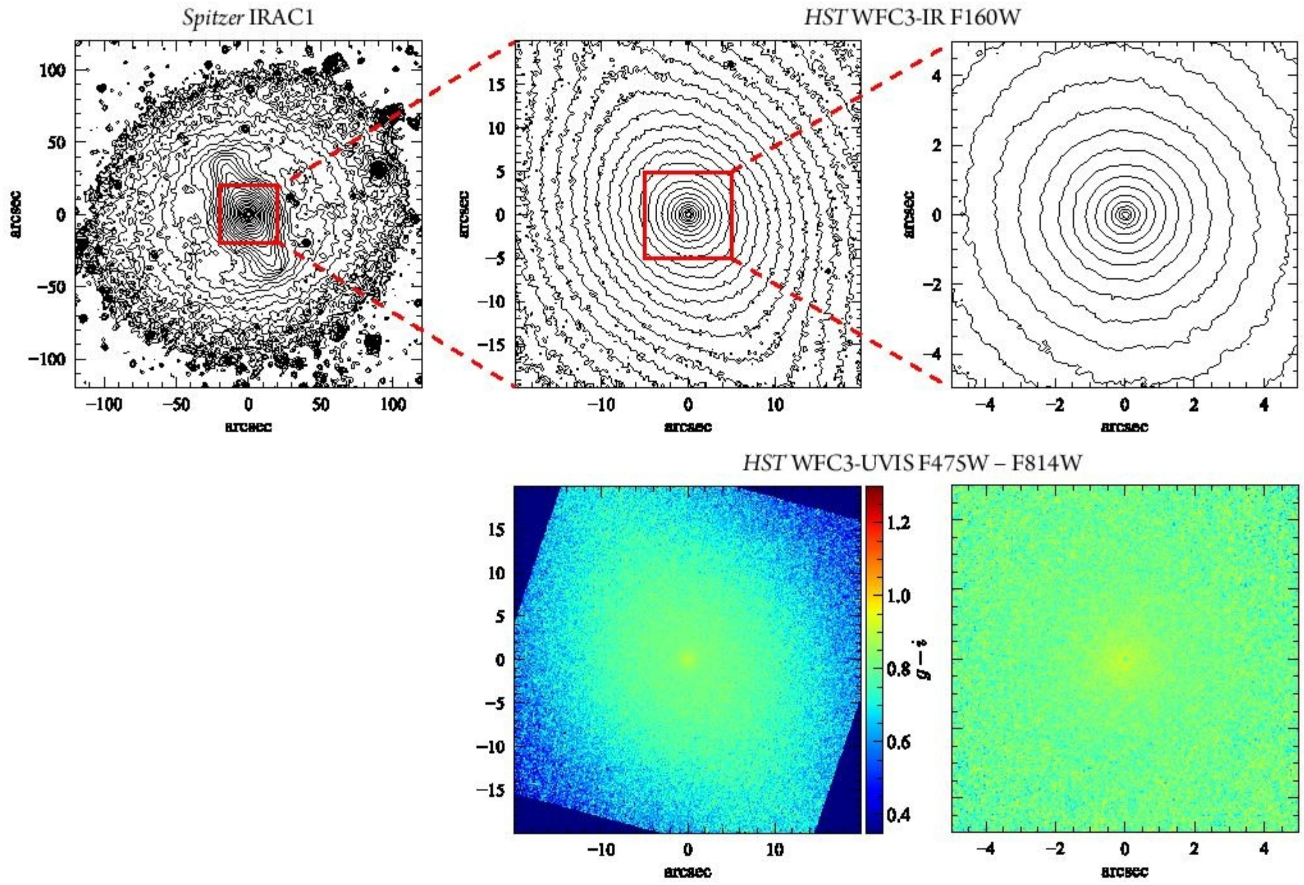

Figure 2. Imaging overview of NGC 4608. Top row: from left to right, logarithmically spaced *Spitzer* IRAC1 isophotes (left, median-smoothed with widtl

Фотометрия NGC 4643

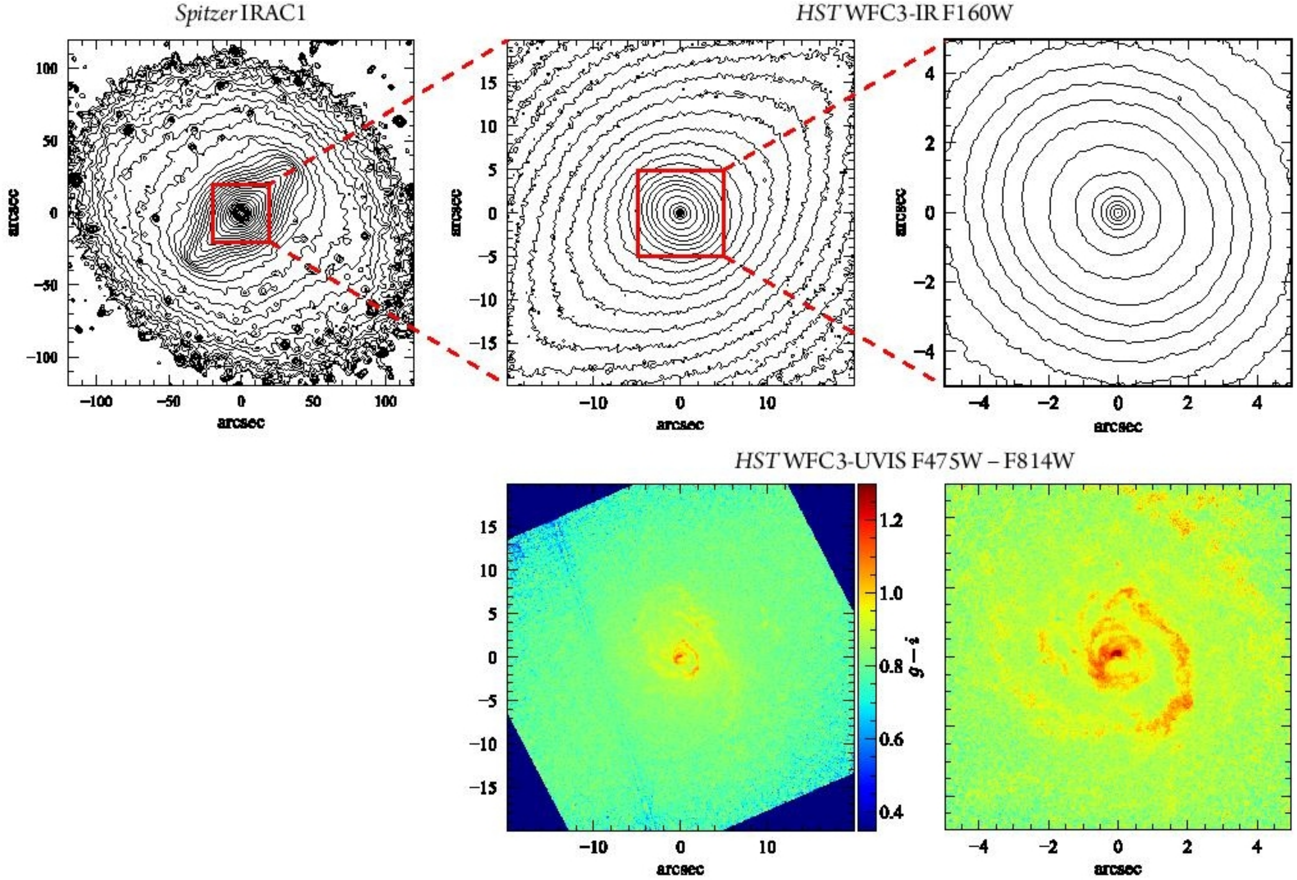

Figure 3. Same as Figure 2, but now showing NGC 4643

Анализ NGC 4608

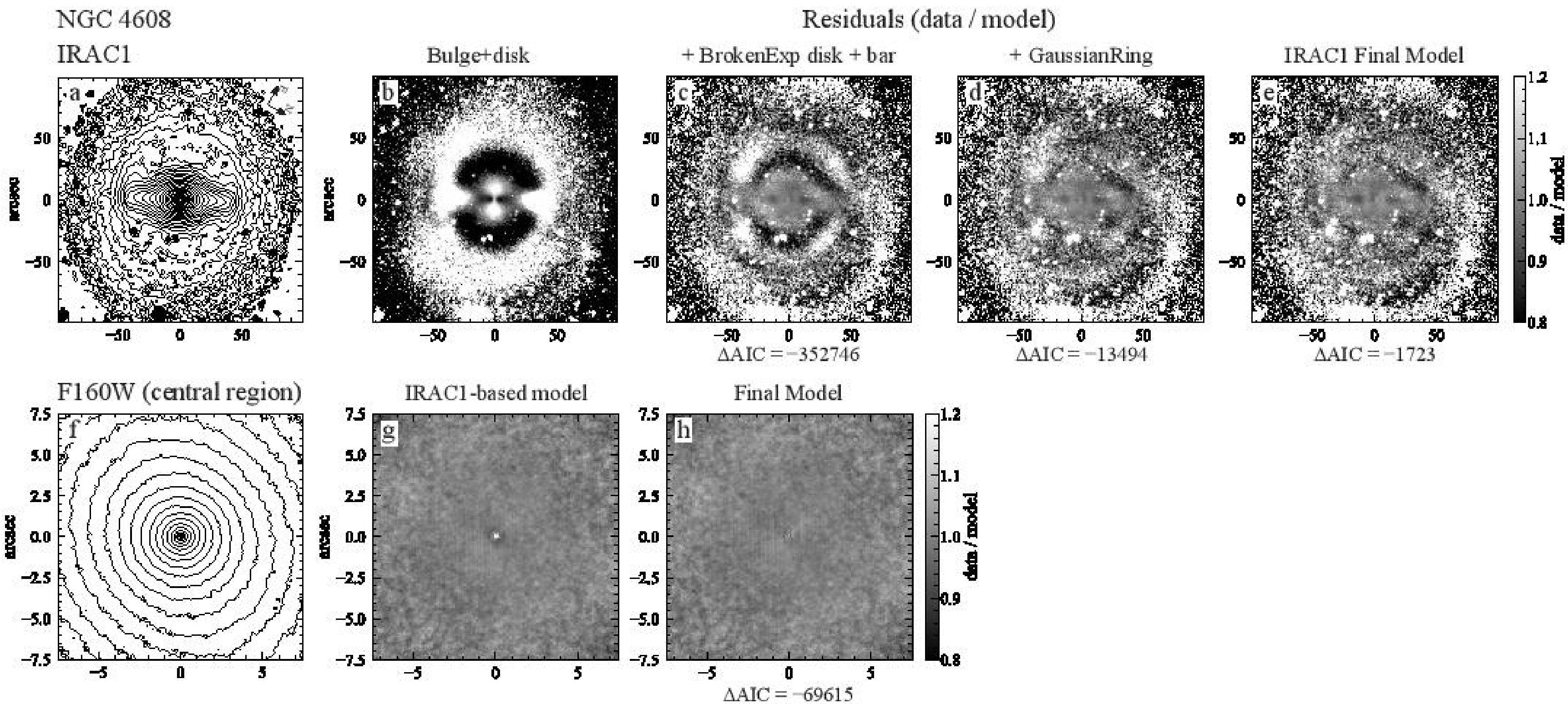

Figure 5. Progressively more complex and accurate 2D image modeling of NGC 4608. **Upper row:** logarithmically spaced, median-smoothed isophotes of the fitted region of the *Spitzer* IRAC1 image (a) and "residual-ratio" images (data / model) from models fit to this image (b–e). These are, from left to right: simple bulge/disc (Sérsic + exponential) model (b); addition of our two-component bar model (Appendix B) and replacement of exponential (disc) with BrokenExponential component (c); addition of GaussianRing component to model the inner ring surrounding the bar (d); and replacement of the GaussianRing with a GaussianRingAz (Appendix C) component (e). Numbers below each image show the relative improvement of the fit (change in Akaike Information Criterion [AIC] relative to the previous fit). Note that image orientation in this row is as observed. **Lower row:** Isophotes from the inner region of the *HST* WFC3-IR F160W image (f) and residual-ratio images from fits to the (full) F160W image. From left to right, these are: the "final model" from the IRAC1 fits (g) and addition of a central Gaussian component to represent a nuclear star cluster (h). Note that in this row, image orientation is standard (N = up, E = left).

Анализ NGC 4643

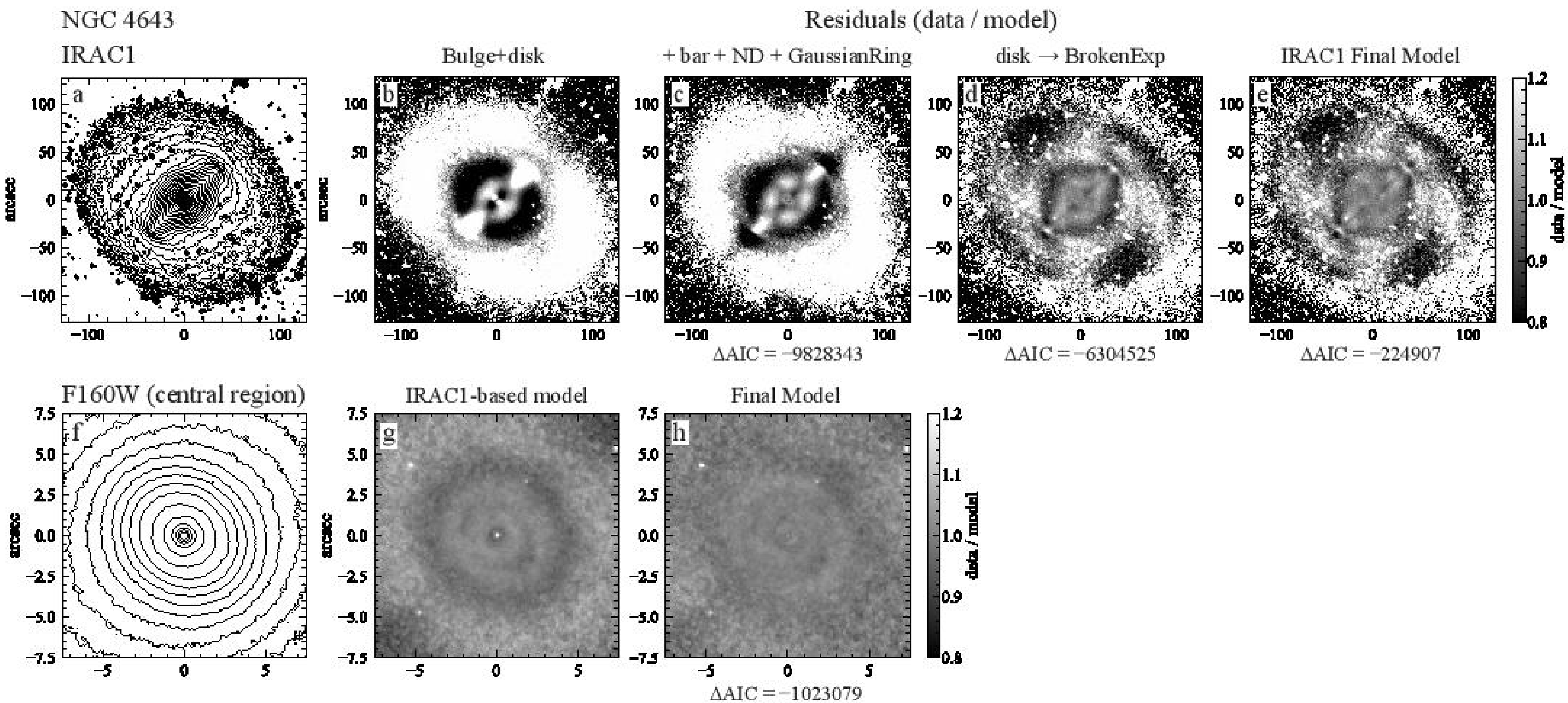

Figure 8. As for Figure 5, but now showing progressive modeling of NGC 4643. **Upper row:** logarithmically spaced, median-smoothed isophotes of the fitted region of the *Spitzer* IRAC1 image (a) and "residual-ratio" images (data / model) from models fit to the image (b–e). These are (from left to right): simple bulge/disc (Sérsic + exponential) model (b); addition of bar + nuclear disc + nuclear ring (c); replacement of outer exponential with BrokenExponential (d); replacement of exponential B/P-bulge component with Sérsic component (e). **Lower row:** Isophotes from the *HST* WFC3-IR F160W image (f) and residual-ratio images from fits to the (full) image. From left to right, these are: the "final model" from the IRAC1 fits (g) and replacement of inner exponential + GaussianRing with BrokenExponential + Sersic components to better model nuclear disc and compact classical bulge (or NSC) (h).

Результаты анализа

Our final model for NGC 4608 uses the combination of IMFIT's BrokenExponential component and the new GaussianRingAz component (Appendix C) for the disc and the inner ring surrounding the bar; the new FlatBar component for the outer part of the bar and a mildly elliptical Sersic_GenEllipse component for the inner, B/P part of the bar; a central round Sérsic component; and a compact, circular Gaussian. Table 1 summarizes the best-fitting parame-

Our final model for NGC 4643 uses IMFIT's BrokenExponential component for the main disc; the new FlatBar component for the outer part of the bar and a mildly elliptical Sersic_GenEllipse component for the inner, B/P part of the bar; another BrokenExponential component for the nuclear disc; and a central compact, nearly circular Sérsic component. Table 2 summarizes the best-fitting parameter

Сравнение центральных областей

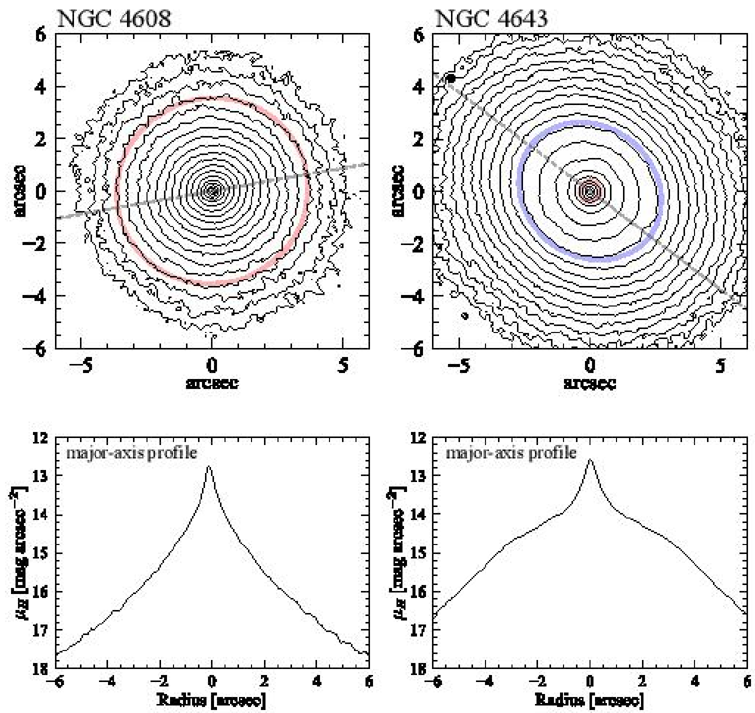

Figure 12. Isolation of the central stellar components of NGC 4608 and NGC 4643. **Upper left:** The classical bulge (+ NSC) in NGC 4608. Contours show logarithmically spaced isophotes from the *HST* WFC3-IR F160W image after subtracting the best-fitting model components corresponding to the disc and bar. The red circle marks the effective radius ($R_e = 3.67'' = 310$ pc) of the Sérsic component from the full fit; the dashed grey line indicates the galaxy major axis. **Upper right:** Same, except now showing the nuclear disc and compact classical bulge/NSC in NGC 4643. The blue ellipse marks the break radius of the broken-exponential component from the full fit ($a_{\rm brk} = 2.86'' \approx 270$ pc), while the small red circle marks the effec-

Звездная кинематика NGC 4608

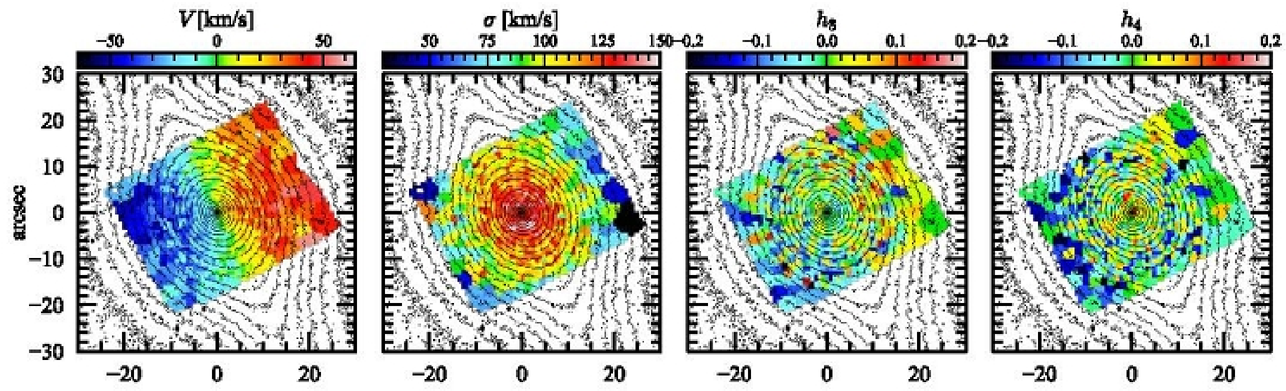

Figure 13. NGC 4608 SAURON kinematic maps, with data from ATLAS[3D] (colour) plotted on top of *HST* F160W isophotes. In the h_3 panel, there is evidence for a weak asymmetry: negative h_3 on the left side, positive h_3 on the right. This matches the velocity pattern in the first panel; such a V-h_3 correlation is a signature of bar orbits.

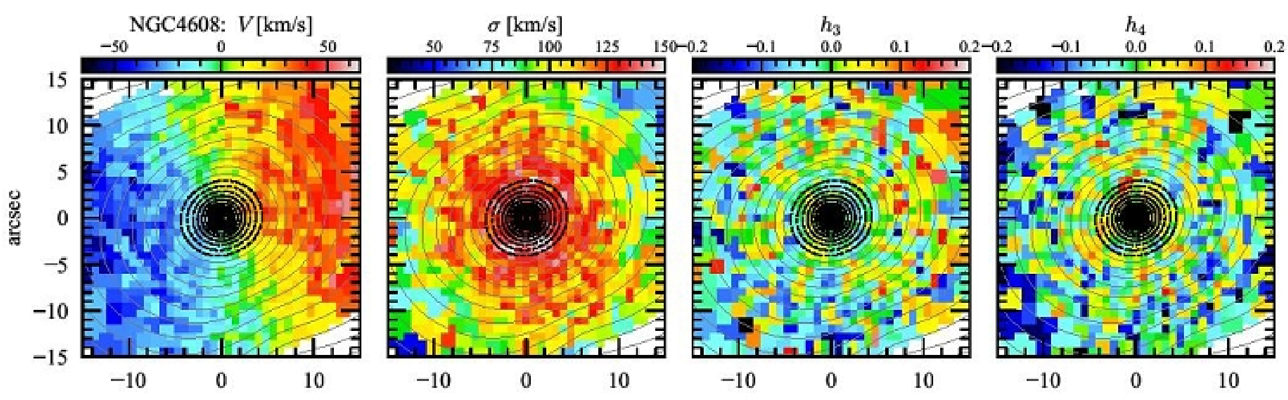

Figure 14. A close-up of Figure 13, but with contours now showing the ratio of the classical-bulge (Sérsic) component to the rest of our best-fitting model of NGC 4608 (e.g., Figure 7). Solid black contours indicate where the classical-bulge component is brighter, dashed black contours where its brightness is 50–100% of the rest of the model, and thin grey contours where it is fainter. The region dominated by the bulge component has almost no rotation, centrally increasing velocity dispersion, and little or no signature in h_3 or h_4; this is suggestive of a classical bulge.

Звездная кинематика NGC 4643

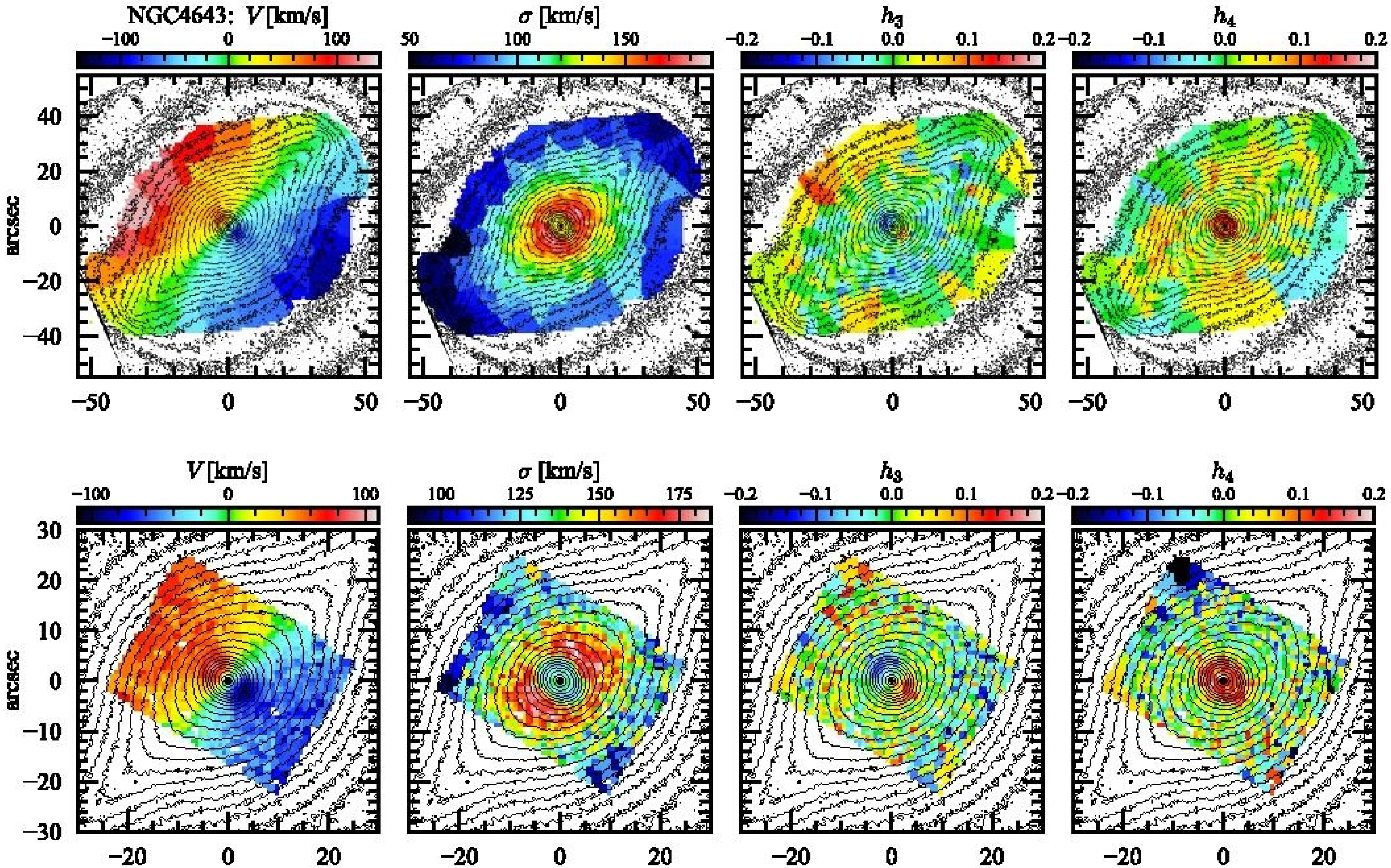

Figure 15. NGC 4643 SAURON kinematic maps, plotted on top of *HST* F160W isophotes. Top panels show maps from Seidel et al. (2015), bottom panels

NGC 4643: MUSE

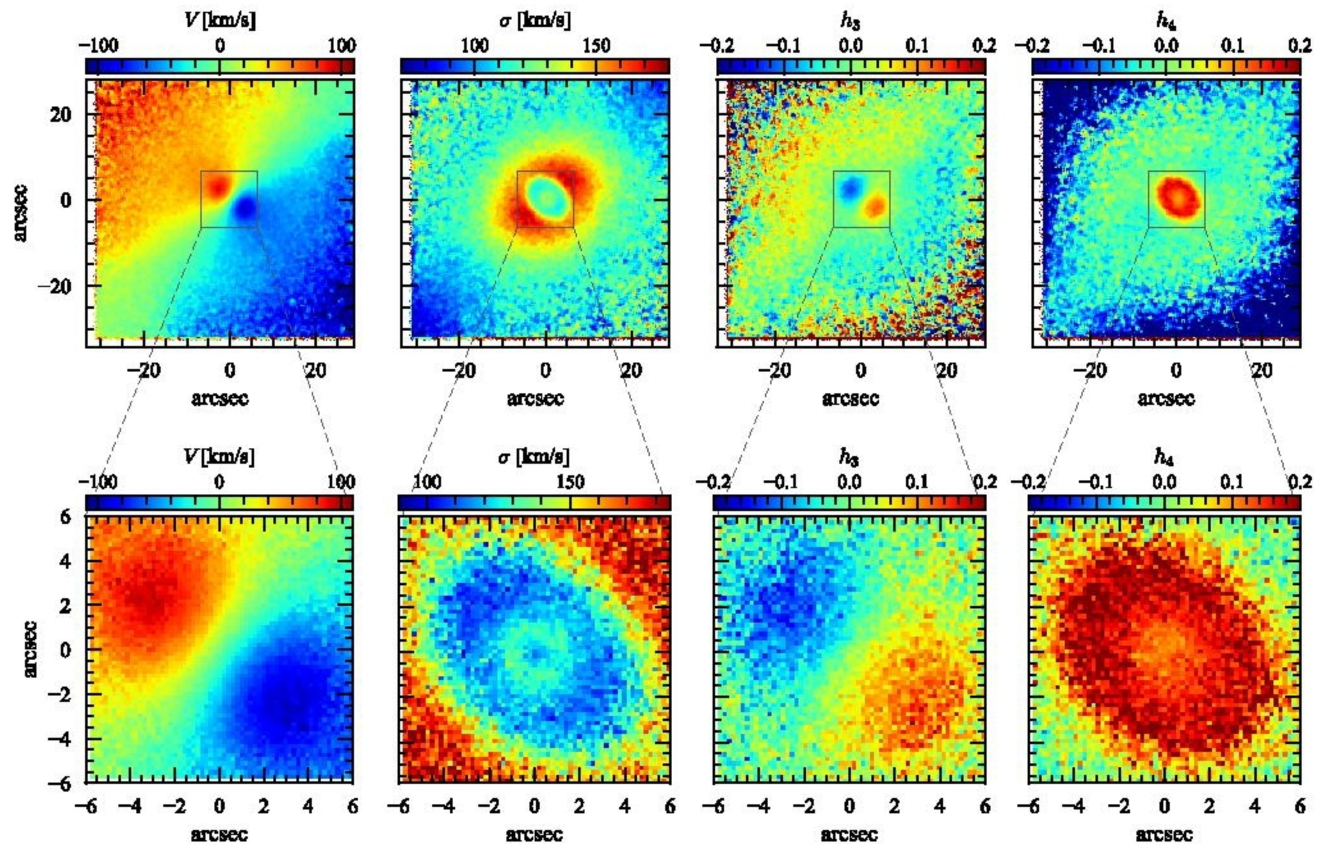

Figure 17. MUSE stellar kinematics for NGC 4643. **Top panels**: Isophotes from IRAC1 and F160W images of NGC 4643. **Middle panels**: Median-smoothe

Идейный вывод

- Если вписывать двухкомпонентную фотометрическую модель, то обе галактики – bulge-dominated (50% NGC 4608, 60%-70% NGC 4643), и балджи - классические.
- На самом деле, скромный, 12%, классический балдж есть только у NGC 4608; и у обеих – заметные (30%) peanut-box псевдобалджи.

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A prediction on the age of thick discs as a function of the stellar mass of the host galaxy

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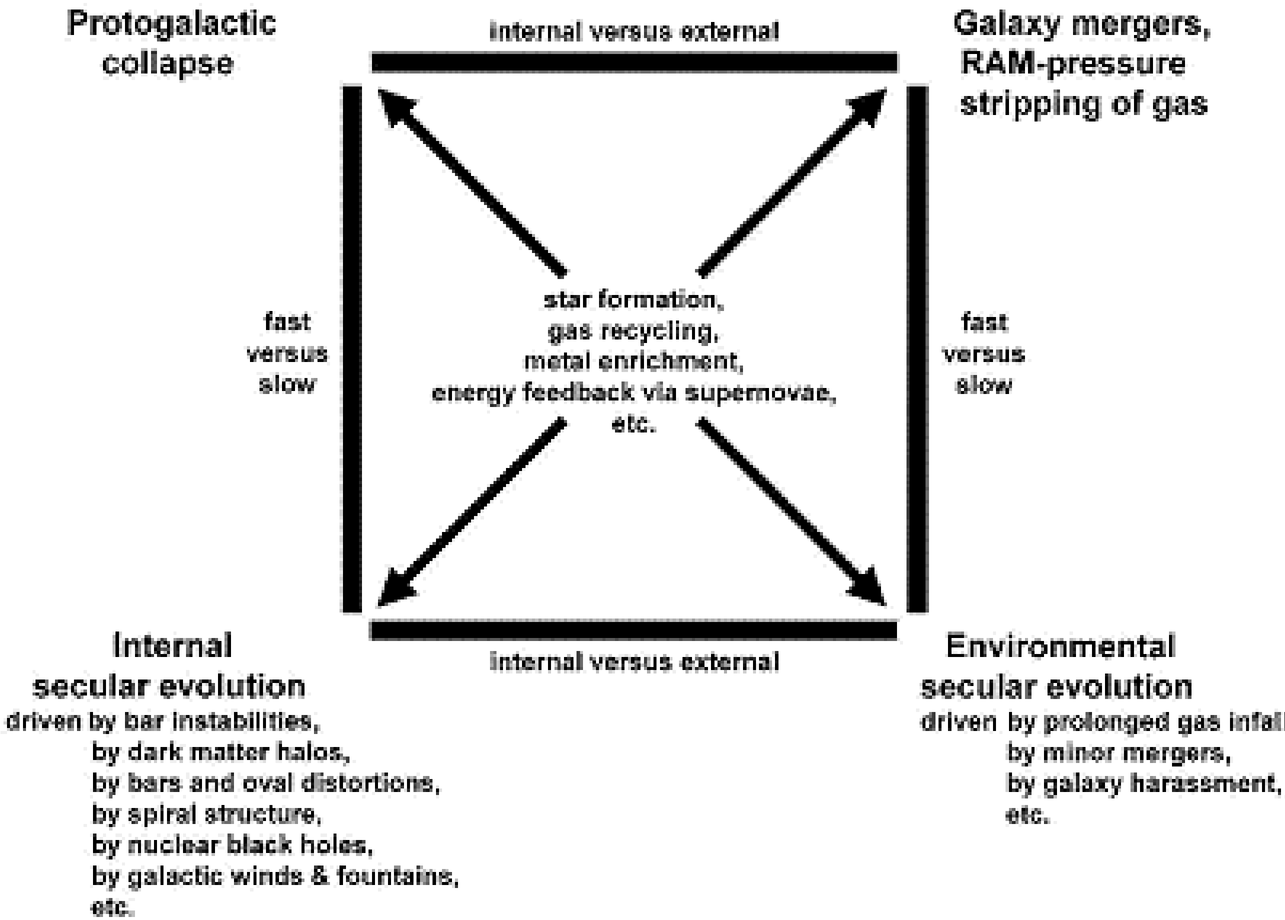
ABSTRACT

One of the suggested thick disc formation mechanisms is that they were born fast and in-situ from a turbulent clumpy disc. Subsequently, thin discs formed slowly within them from left-overs of the turbulent phase and from material accreted through cold flows and minor mergers. In this letter, I propose an observational test to verify this hypothesis. By combining thick disc and total stellar masses of edge-on galaxies with galaxy stellar mass functions calculated in the redshift range $z \leq 3.0$, I derive a positive correlation between the age of the youngest stars in thick discs and the stellar mass of the host galaxy; galaxies with a present-day stellar mass $\mathcal{M}_\star(z=0) < 10^{10}\,\mathcal{M}_\odot$ have thick disc stars as young as $4-6$ Gyr, whereas the youngest stars in the thick discs of Milky-Way-like galaxies are ~ 10 Gyr old. I test this prediction against the scarce available thick disc age estimates, all of them of galaxies with $\mathcal{M}_\star(z=0) \gtrsim 10^{10}\,\mathcal{M}_\odot$ and find that field spiral galaxies seem to follow the expectation. On the other hand, my derivation predicts too low ages for the thick discs in lenticular galaxies, indicating a fast early evolution for S0 galaxies. I propose to conclusively test whether thick discs formed fast and in-situ by obtaining the ages of thick discs in field galaxies with masses $\mathcal{M}_\star(z=0) \sim 10^{9.5}\,\mathcal{M}_\odot$ and checking whether they contain ~ 5 Gyr-old stars.

Динамическая эволюция



Kormendy & Kennicutt 2004

«Фишка» Себастьяна Комерона

hot=bulge+thick disk

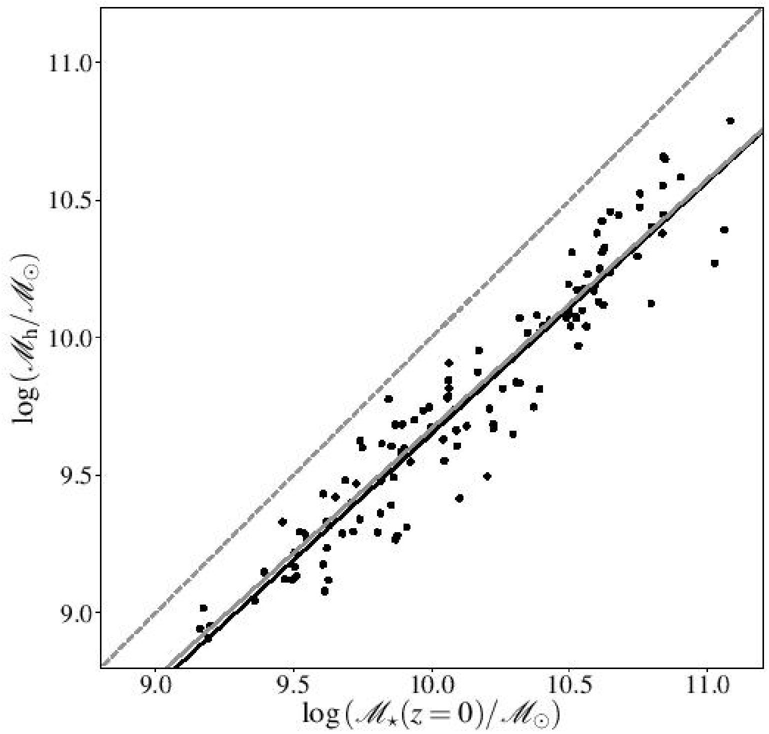


Fig. 1. Scatter plot of the sum of the masses of the thick disc and the classical bulge (dynamically hot components; $\mathscr{M}_h$) versus the total stellar mass of the galaxy, $\mathscr{M}_\star(z = 0)$, for the 124 galaxies with a fitted thick disc in Comerón et al. (2018). The black continuous line indicates the linear fit to all the data, whereas the continuous grey line indicates the fit to the data points corresponding to galaxies in the Virgo and Fornax clusters only. The dashed grey line indicates a one-to-one relation.

А это позаимствовано из COSMOSa

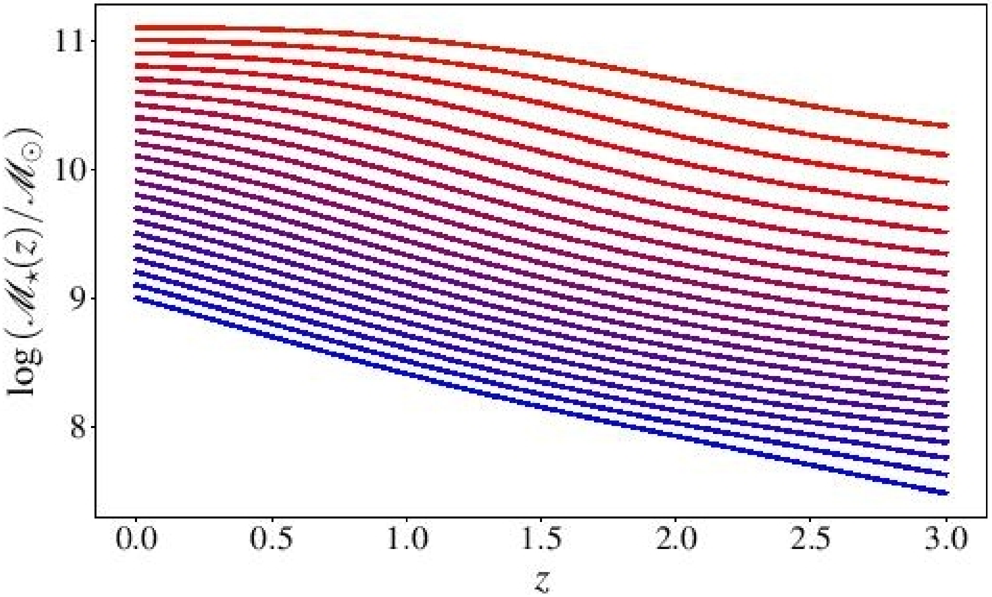


Fig. 2. Stellar mass as a function of redshift for galaxies with present-day stellar masses between 10^9 and $10^{11.2}$ $\mathscr{M}_\odot$ (in 0.1 dex intervals) calculated using the continuity model from Leja et al. (2020).

Результат: что не так с S0

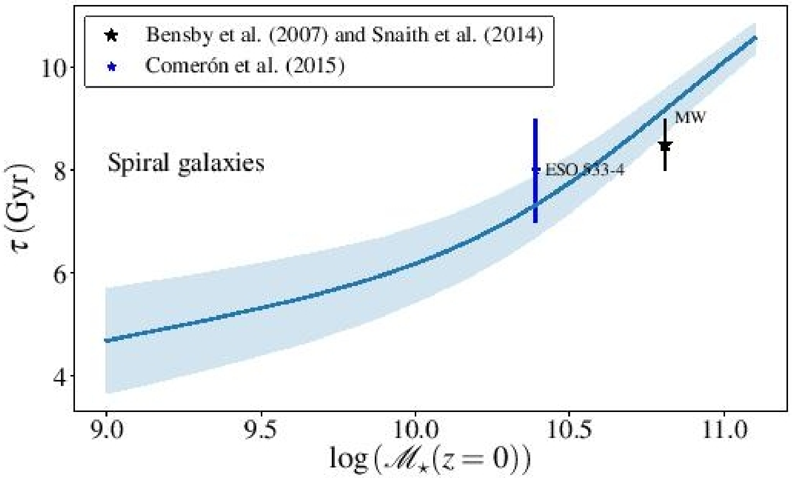


Fig. 3. Predicted age of the youngest stars in thick discs as a function of the total present-day stellar mass of the host. The error bands correspond to one-σ confidence intervals. The symbols correspond to spiral galaxies with thick disc stellar ages and masses reported in the literature

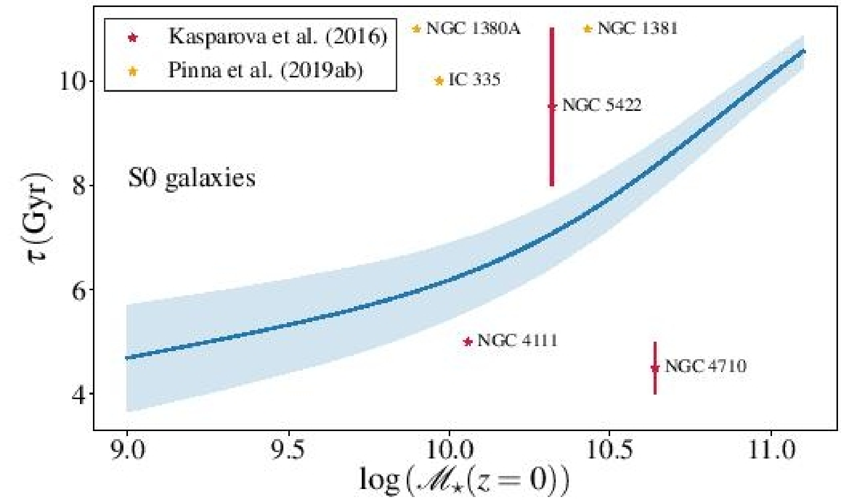


Fig. 4. As Fig. 3, but with data points corresponding to S0 galaxies.