Tracing early-type galaxy assembly with nuclear stellar discs

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Nuclear Stellar Discs

Stellar discs of a few to hundreds of parsecs in diameter have been found in the centre of galaxies more than ten years ago owing to observations with the Hubble Space Telescope (van den Bosch et al. 1994), and have since then recognised as a relatively common feature in early-type galaxies (Rest et al. 2001). Nuclear Stellar Discs (NSD) may also constitute a powerful tool to constrain the assembling history of galaxies since they are sensitive to the epoch when galaxies experienced their last major merging event. NSDs are indeed fragile systems that would not survive a galactic collision, and therefore by studying the fraction and age of NSDs we can test the predictions for the assembly history of early-type galaxies according the current hierarchical paradigm for galaxy formation.

The Census

In Ledo et al. (2010) we have produced the most comprehensive census of Nuclear Stellar Discs in nearby early-type galaxies and found that they are present in approximately 20% of them.

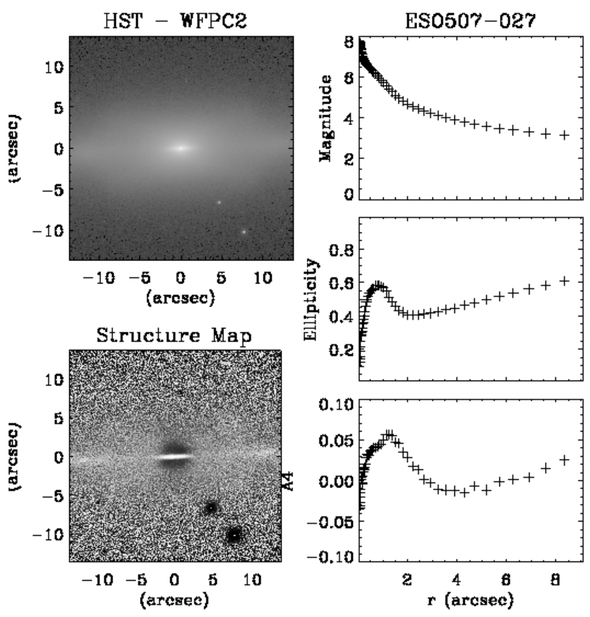

Fig. 1 – HST-WFPC2 image of ESO507-027 with the corresponding Structure Map showing evidence of a disc. On the right are the Magnitude, Ellipticity and a_4 (deviation of a galaxy's isophotes from an ellipse) profiles used to confirm its presence.

- ~20% have NSDs (inclination corrected).

Disc Properties

Following the compilation of the census we focused on retrieving the properties of same of the discs, using an implementation of the method of Scorza and Bender (1995). We performed the disc-bulge decomposition to 12 disc-hosting galaxies, expanding the previous, more limited, sample.

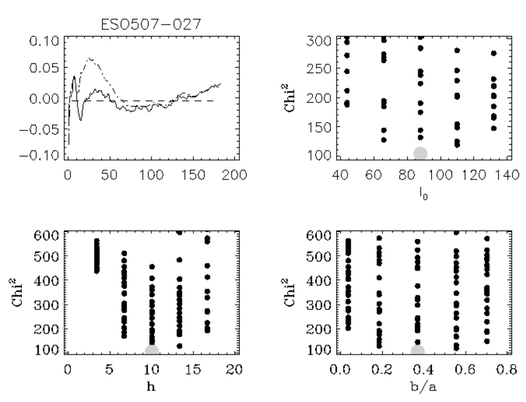

Fig. 2 – On the top left, galaxy a_4 profile before and after subtraction of the best disc model. The three other panels show the best value for Intensity, inclination and axis ratio with the correspondent Chi2.

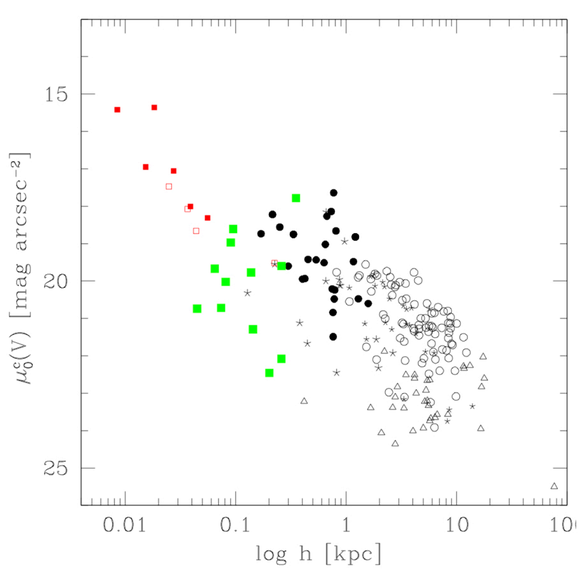

Fig. 3 - Discs μ_0^c – h diagram from Ledo et al. (2010). The open circles correspond to high surface-brightness spiral galaxies whereas low surface-brightness spirals are represented by triangles. Stars denote S0s and filled circles disky ellipticals. NSDs in elliptical and lenticular galaxies are indicated by filled squares and in spirals by open squares. The green squares are those added in this work and the red ones are the pre-existing ones.

- More than doubled number of NSDs with photometric properties.

Assembly History of NGC4458

When disentangling a superposition of stellar populations, the degeneracy between age and mass poses a problem. We propose a new method that we have applied first to NGC4458 (Ledo et al. to be submitted), in which we combined VIMOS integral field spectroscopy with disc properties derived from the disc-bulge decomposition to constrain the disc light fraction. This has allowed us to constrain more precisely the epoch of this galaxy's last major merger (>8Gyr)

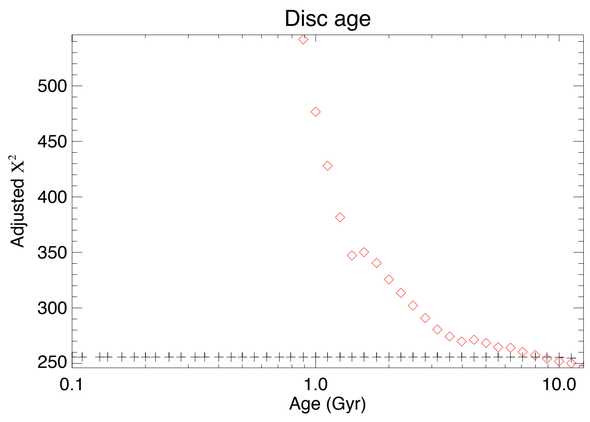

Fig. 4 – Age determination of the disc present in NGC4458. The black crosses show the results when the contributions from the disc and bulge are let free. On the other hand, using our new method, we can place a lower limit on the age of the galaxy.

Disc Fragility

We addressed the disc fragility problem by means of N-body simulations where we explored 1 to 1, 1 to 5 and 1 to 10 mergers at various inclinations. In these simulations we set up a 200 pc disc orbiting a SMBH and embedded in a bulge. We then let loose a second SMBH to simulate a colliding galaxy and explore the results of such collision (Fig. 5).

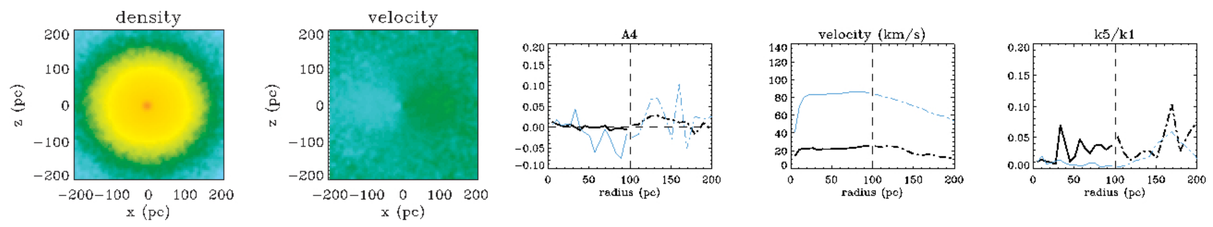

Fig. 5 – This figure is representative of the results we obtained for each simulation. Here we see the last step of the simulation. On the left panels we have the density and velocity maps of a region around the centre and, on the three right panels we have the A_4 coefficient, velocity and k_5/k_1 (analogous to A_4, but for velocities. Low values show disc-like rotation). In blue are disc values and, in black, the total (disc + bulge). The solid line shows the region of the original disc.

- NSDs survive collisions with mass rations ≤ 1 to 5 and are destroyed in 1 to 1.

Conclusions

- Nuclear Stellar Discs can be used as tools to constrain the merging history of galaxies.
- We have produced the first **census of Nuclear Stellar Discs in early-type galaxies**. **Present in ~20%** (with inclination correction).
- We have derived the **properties of 12 such discs** and revealed a not so tight central surface brightness – disc size relation.
- We propose a **new method** to better constrain the epoch of the last major merger that combines *a priori* knowledge of the disc properties together with IFU data.
- **NGC4458** has assembled over 8 Gyr ago.
  With **numerical simulations** we have shown that NSDs are always **fragile against major mergers** and should survive minor mergers.

Future Work

The next steps will be to apply this method to a sample of galaxies with different size/mass and environment characteristics and compare the results with predictions from semi-analytical models such as the ones from Khochfar and Silk (2006a,b). For such a study, instruments like MUSE will be of particular interest.
We will also use of the method applied for NGC4458 in other situations, such as extended discs and rings.

References

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