Nuclear discs in external galaxies and the Milky Way: building "bulges" without mergers

Dimitri Gadotti
(ESO/CEA - Durham)
on behalf of the TIMER team

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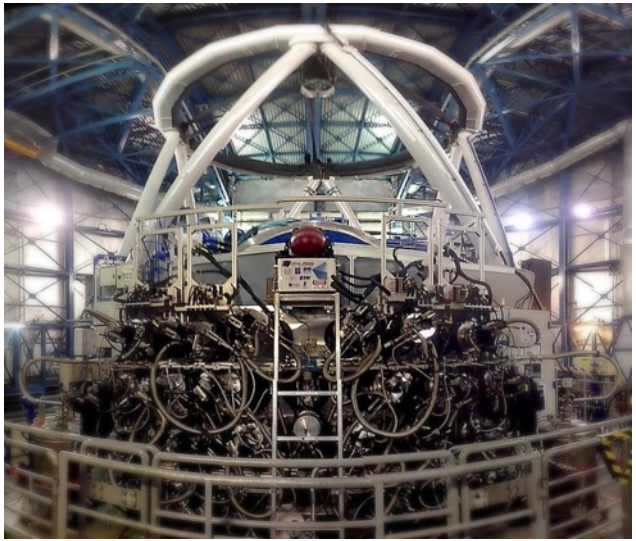
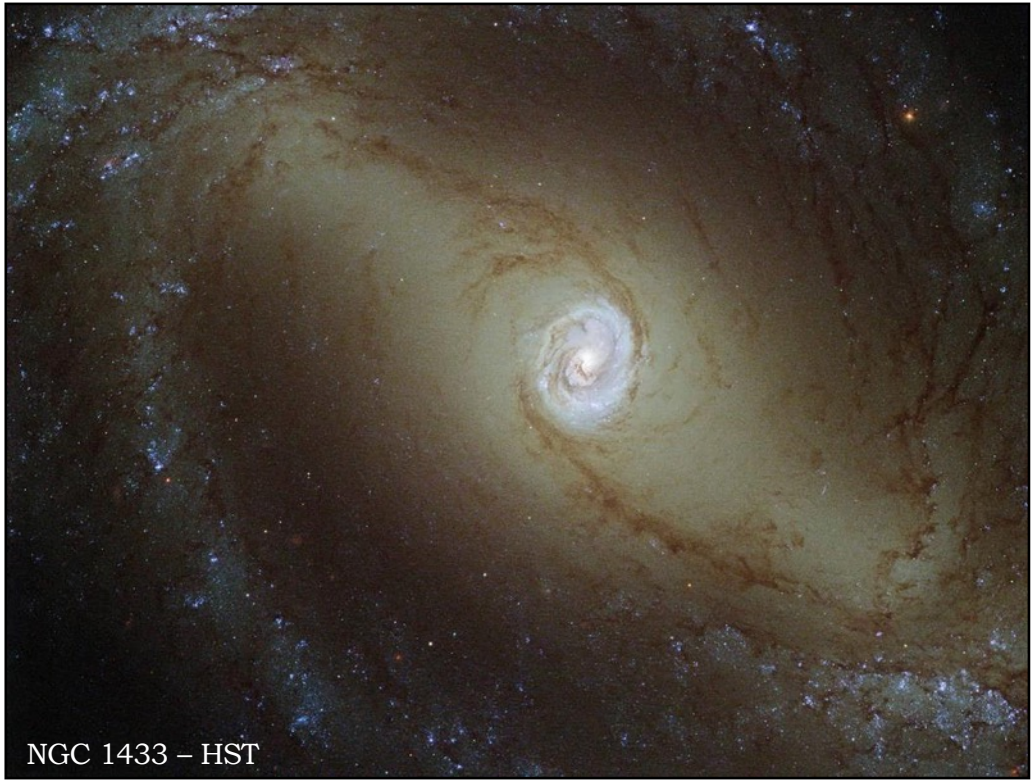


Multi Unit Spectroscopic Explorer on the VLT

- 1 arcmin squared
- 0.2” spaxels
- 90 000 spectra per pointing
- from 480 to 930nm
- R from 1770 to 3590

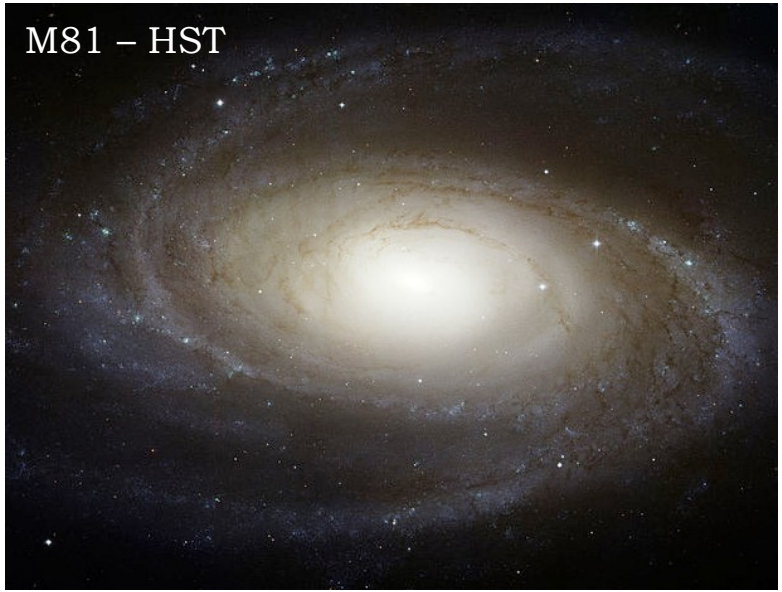
- **T**ime **I**nference with **M**USE in **E**xtragalactic **R**ings (Gadotti+2019)
  - A survey of the central few kpc of 24 nearby barred galaxies with MUSE
  - All galaxies with visually identified central structures reminiscent of discs, such as nuclear rings, nuclear spiral arms and inner bars

Bar-Driven Processes

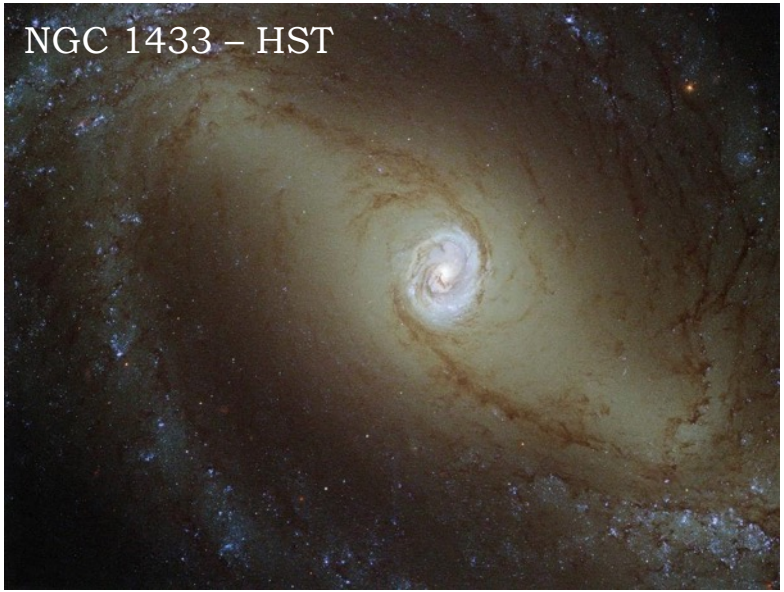


- Estimate the epoch of bar formation (see talk by Camila de Sá Freitas)
- Bar-built nuclear discs are expected to be kinematically cold, in contrast to hot spheroids

Bar-Built Nuclear Structures



Classical bulge – merger-built? Or formation via coalescence of clumps (or clump-driven gas inflow)? (See also talks by Ishibashi and Guo for alternative scenarios.)



Pseudobulge; disc-like bulge; discy bulge… Is it a nuclear disc formed via non-axisymmetric structures?

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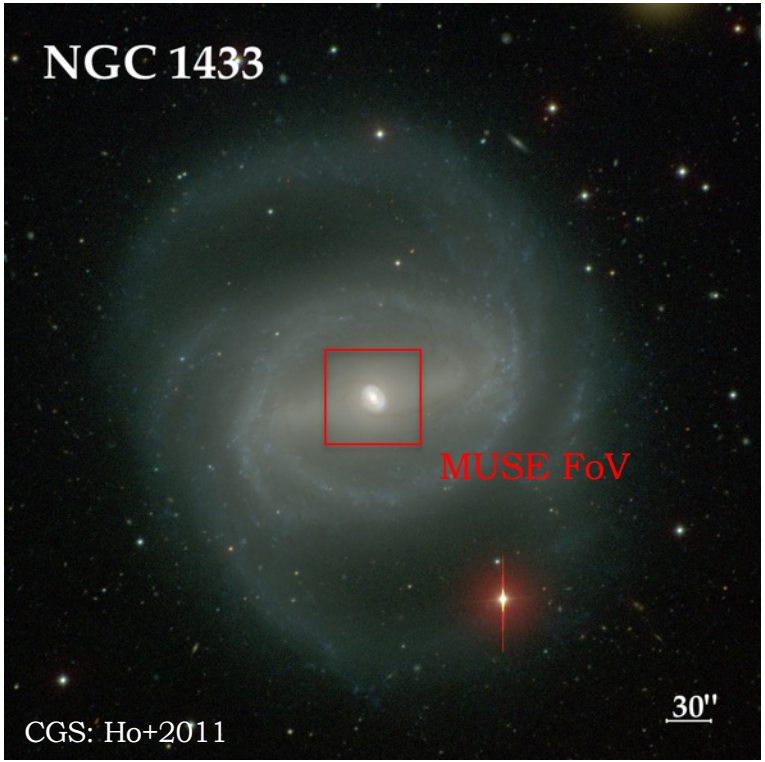

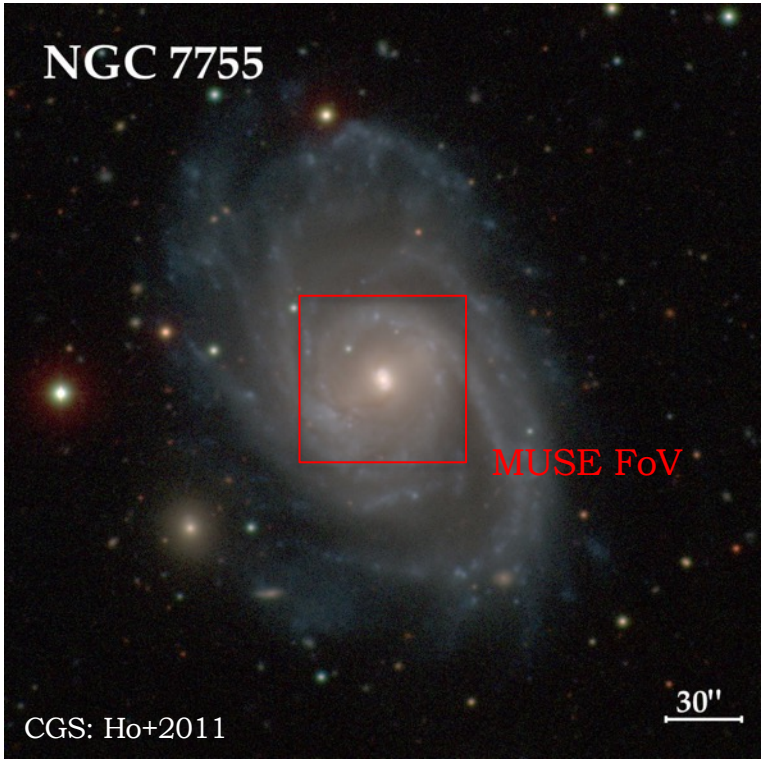

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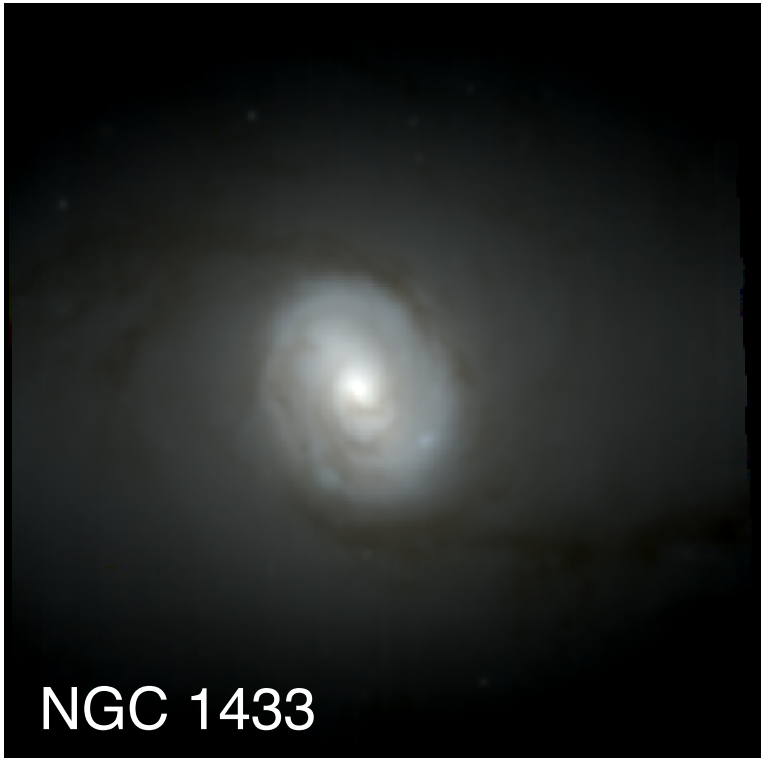
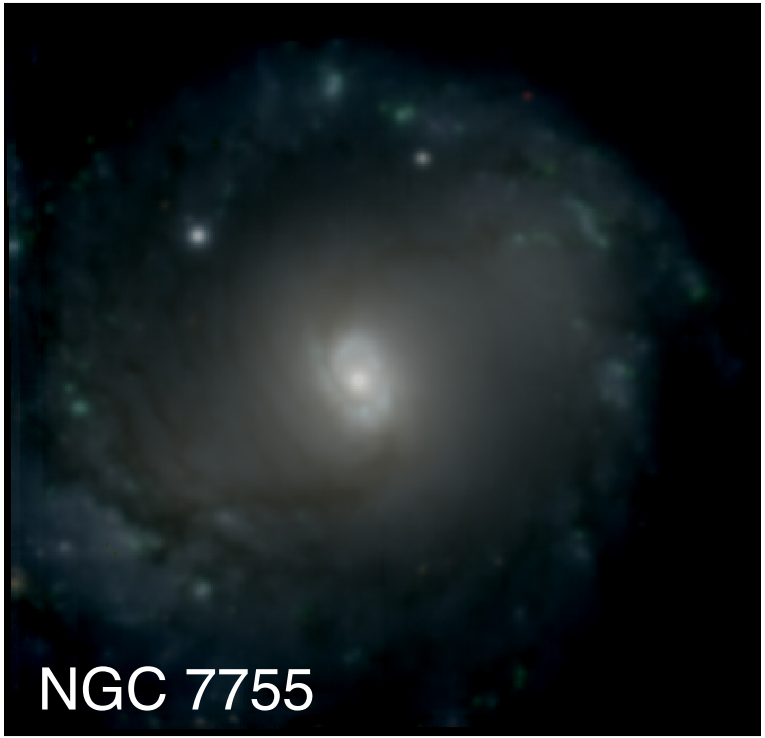
Gadotti+2019





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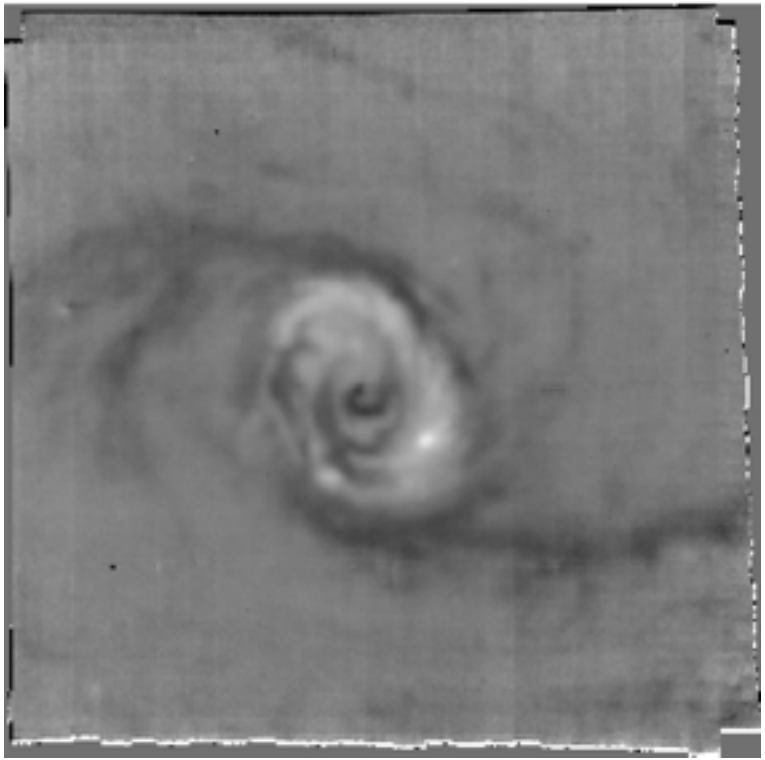
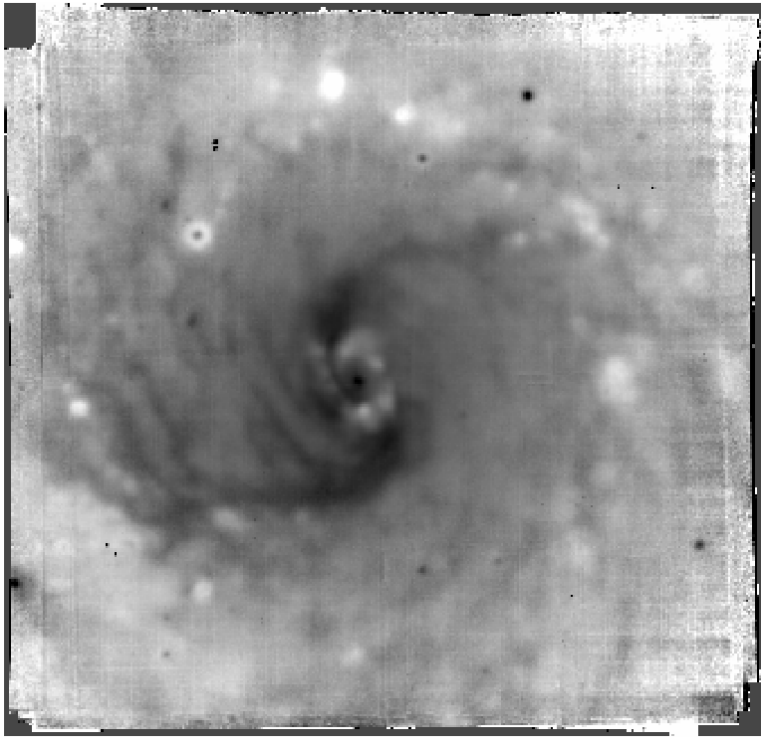
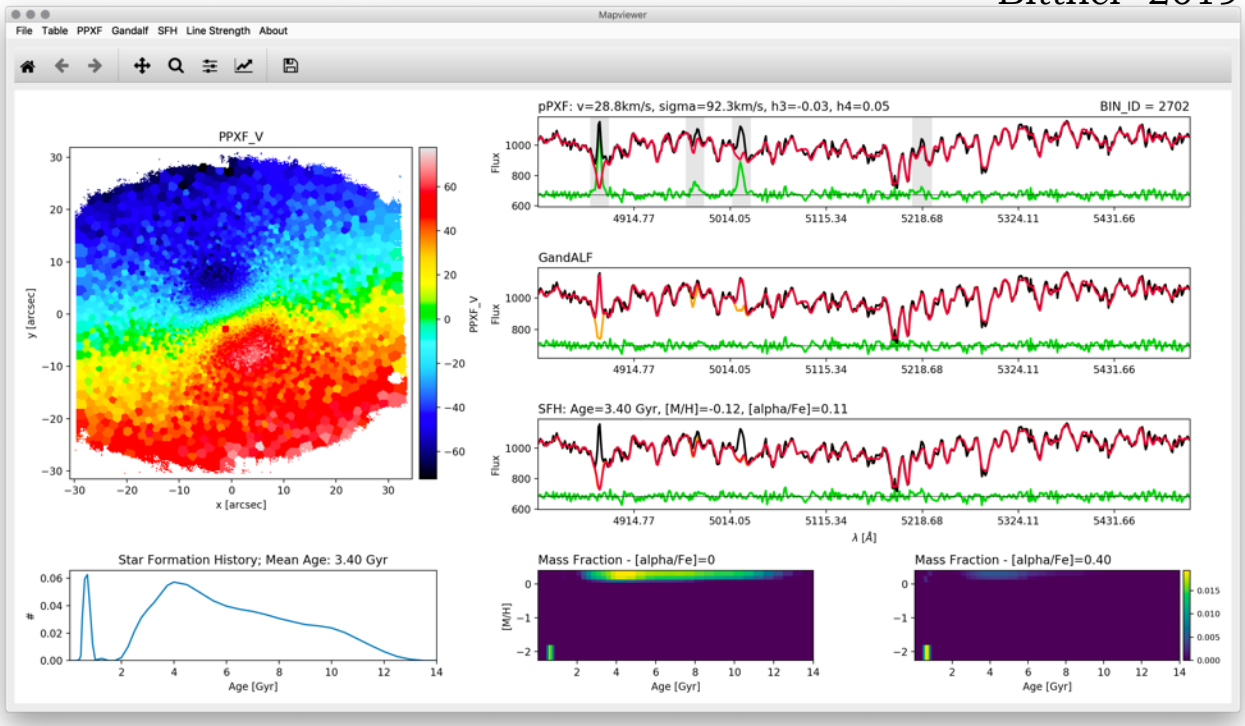




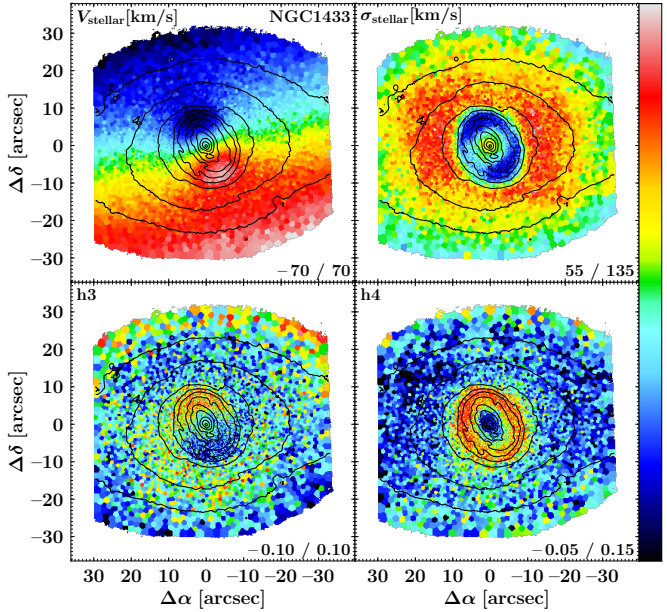
The GIST Pipeline

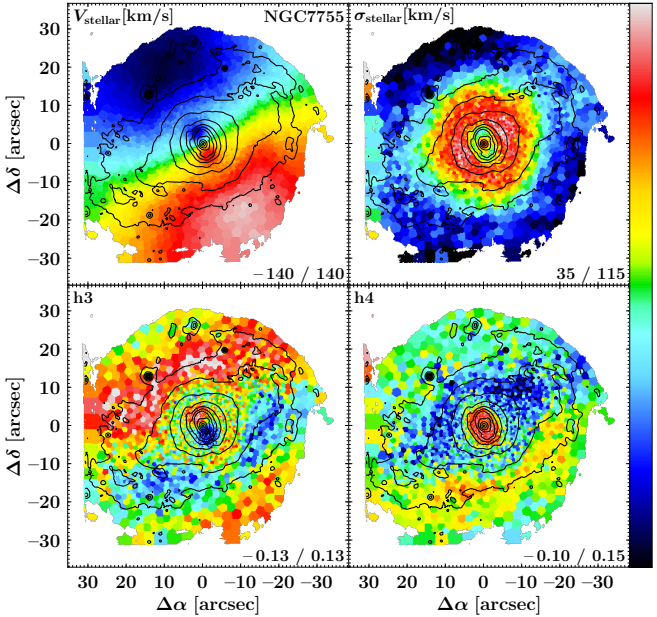
Bittner+2019



Stellar Kinematics

Gadotti+2020

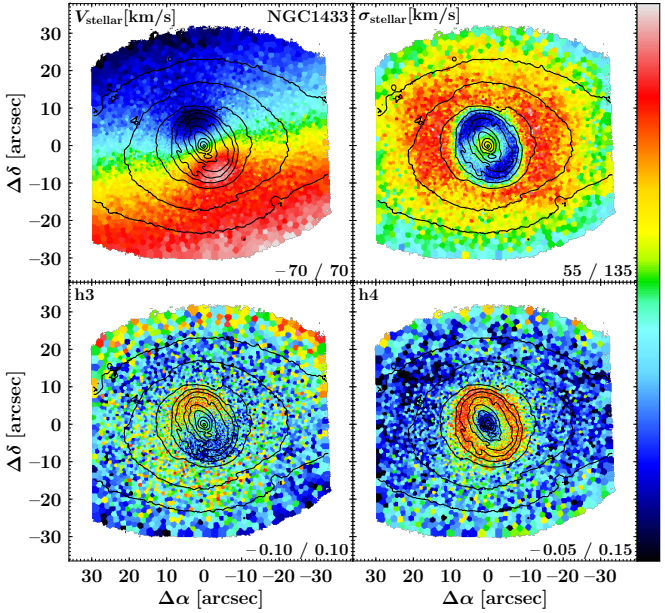


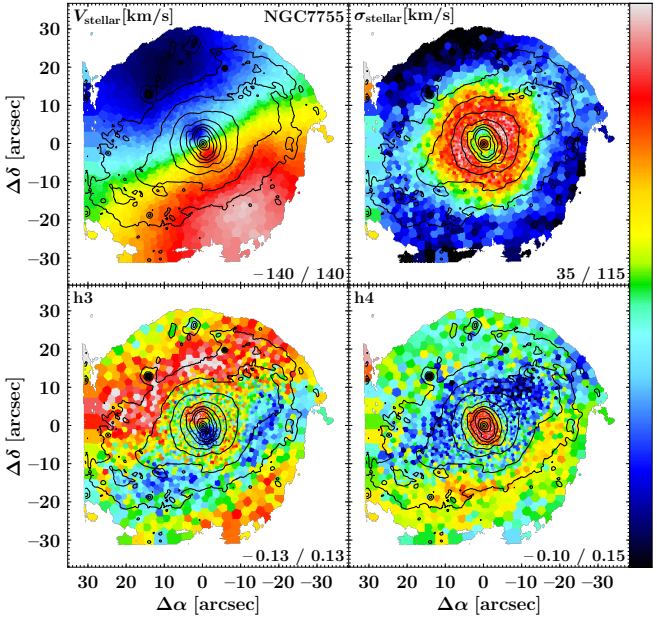


- In virtually all galaxies, nuclear structures are rapidly-rotating, with low velocity dispersion
- Have v-h_3 anti-correlation, a signature of near-circular orbits
- High values of h_4: they are a component distinct from the main underlying disc

Stellar Kinematics

Gadotti+2020

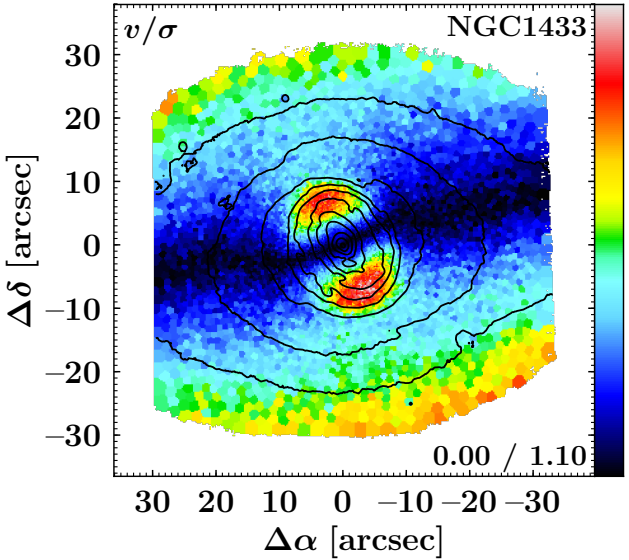


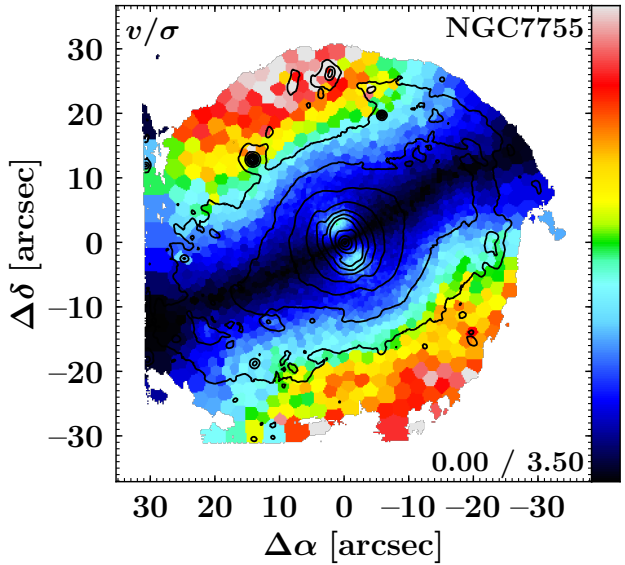


➢ All exactly as expected for bar-built nuclear discs

Stellar Kinematics

Gadotti+2020

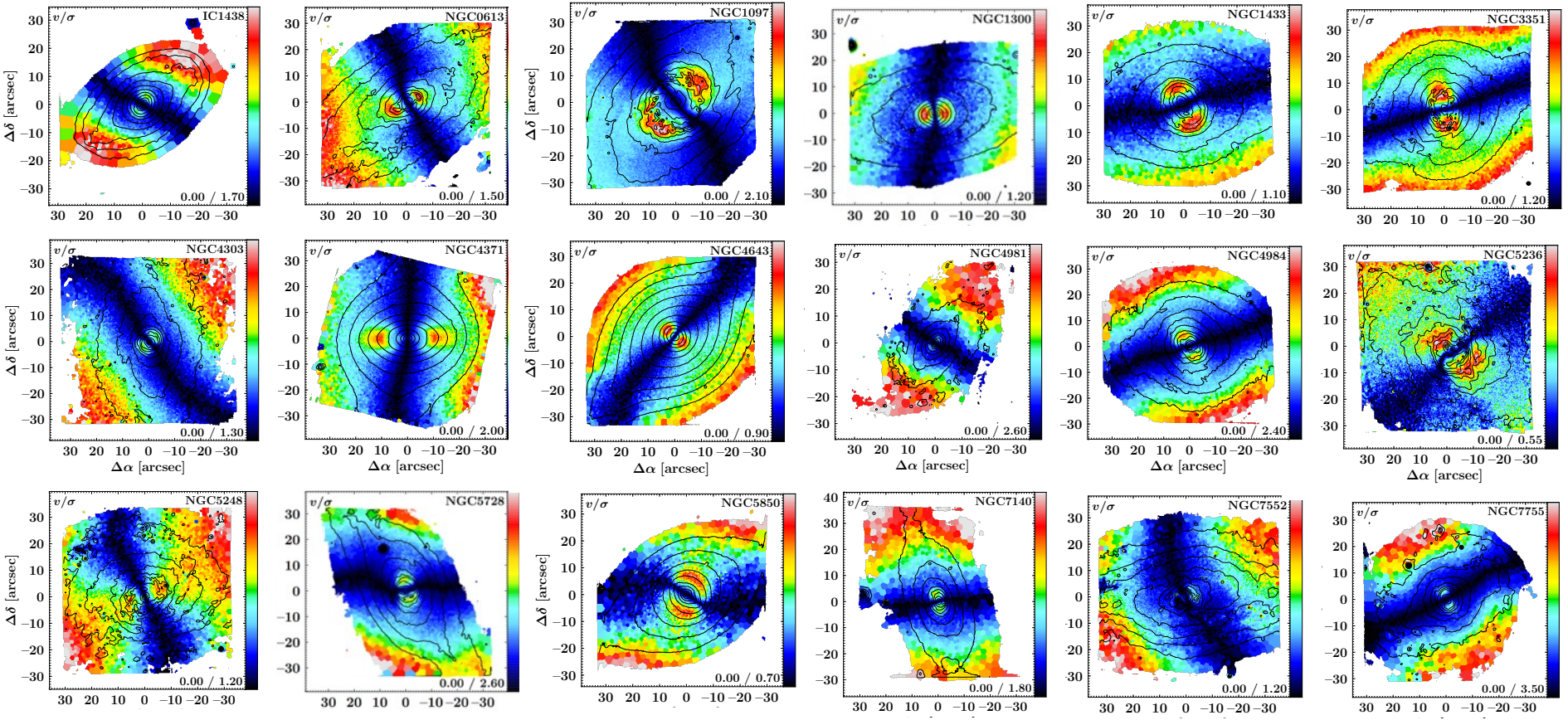




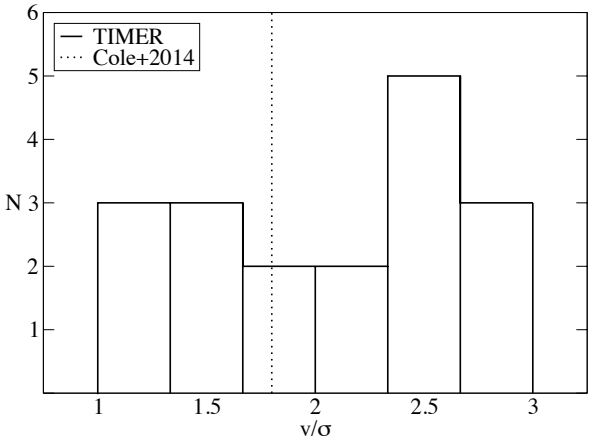
- Nuclear discs have more rotational support than main disc at the same radii and are aligned with main disc

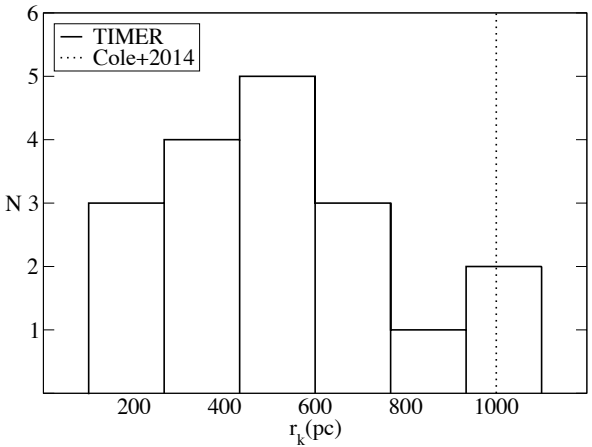
Nuclear Disc v/σ Gallery

Gadotti+2020



Gadotti+2020

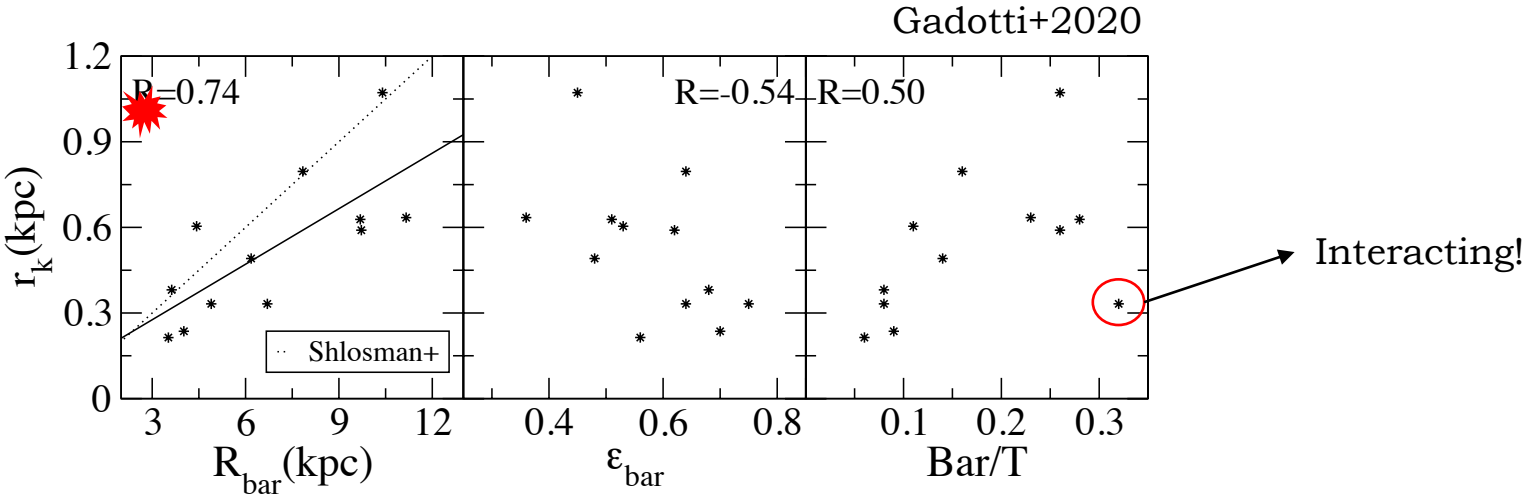




Stellar Kinematics

- Distribution of v/σ values is skewed towards high values, but some are as low as unity
- Sizes from ~100 to ~1000 pc
- Simulation of Cole+2014 fits in observations

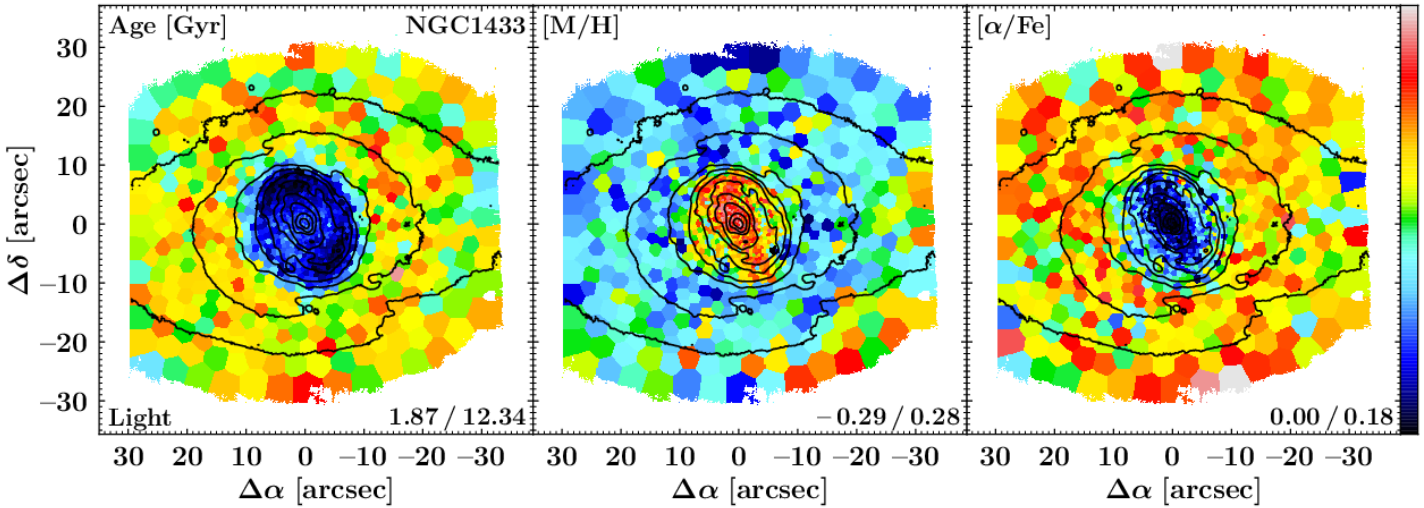
Bar-Driven Origin



- Relations between nuclear disc size and bar properties consistent with bar-driven origin
- Nuclear disc extends to about 10% of the bar length
- Simulation of Cole+2014 produces a nuclear disc that is 3 times too large

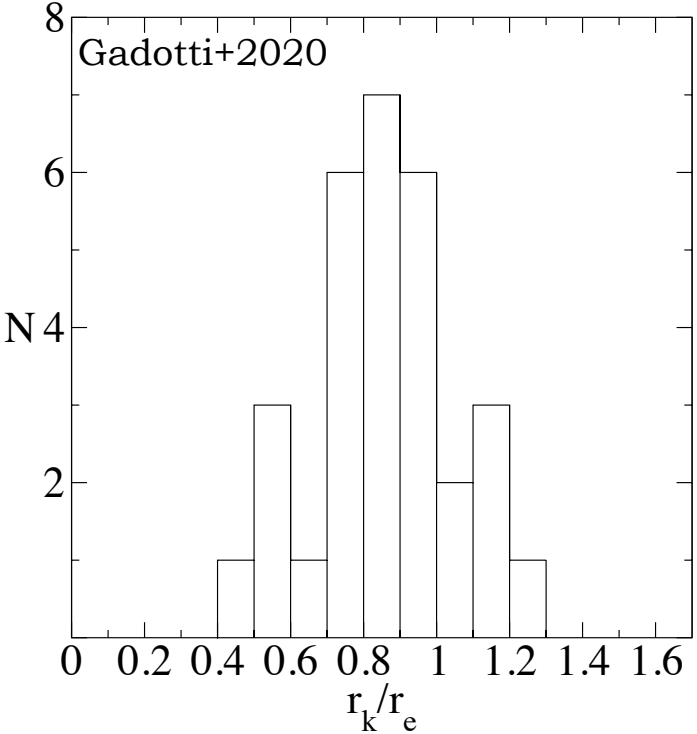
Stellar Population Properties

Bittner+2020



- Relatively young, metal-rich, and showing low values of [α/Fe], as compared to surroundings
- As expected for a bar-driven origin

Nuclear Discs in Photometric Decompositions



- Careful photometric decompositions (from Kim+2014 and Salo+2015) typically indicate exponential light profiles for our nuclear discs
- Physical spatial resolution and appropriate models are crucial
- Half-light radii of exponential components derived by Kim+2014 and Salo+2015 correlate with radii derived kinematically
- Exponential (i.e., with Sérsic n ~ 1) photometric bulges are nuclear discs

The Milky Way Nuclear Disc

- Evidence for it is hard to obtain, but infrared photometry and star counts indicate that the MW has a nuclear stellar disc with (see e.g. Launhardt+2002 and Sormani+2020):
  - Radius of 100-200 pc
  - Scale-height of 45 pc
  - A gaseous outer edge or nuclear ring, aka the Central Molecular Zone
  - An estimated mass of $7 \pm 2 \times 10^8\,\mathrm{M}_\odot$
- Consistent with our observations but on the low side of the size distribution
- Understanding it is still challenging
  - Sormani+2020 report $\sigma_z/\sigma_R > 1$ (but see Sormani+2022)

What does this tell us about bulge formation?

- The stellar kinematics and populations properties of nuclear discs are consistent with a bar-driven formation, in contrast to classical bulges
- Exponential, disc-like “bulges” in photometric studies are indeed rotationally supported, bar-built nuclear discs
- Nuclear discs seem to extend all the way to the centre and to form from inside out

For details check these TIMER papers: Gadotti+2020 and Bittner+2020