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Do galactic bars drive the formation of inner/outer rings and spiral arms?

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We study the pitch angles of spiral arms and the frequency and dimensions of inner and outer rings as a function of disk parameters and the amplitude of non-axisymmetries in the S⁴G survey. We provide observational evidence for i) the role of strong bars in ring formation/evolution and ii) the dependence between bar and spiral strengths. Yet, the coupling of rings, spiral arms, and bars is not as robust as predicted by simulations.

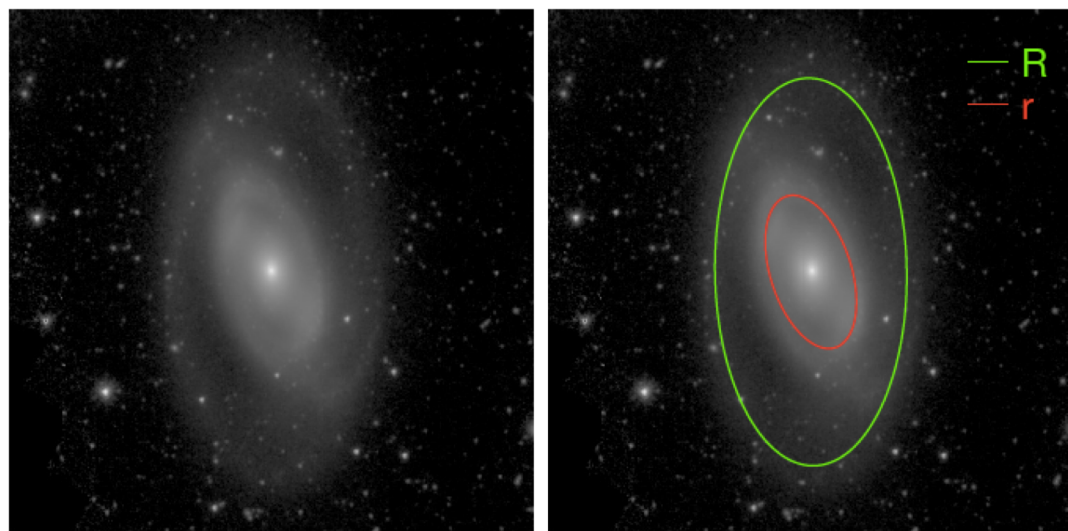
Díaz-García et al. (2019, A&A, 631, A94) [click here](#)

Díaz-García et al. (2019, A&A, 625, A146) [click here](#)



DIMENSIONS OF RINGS

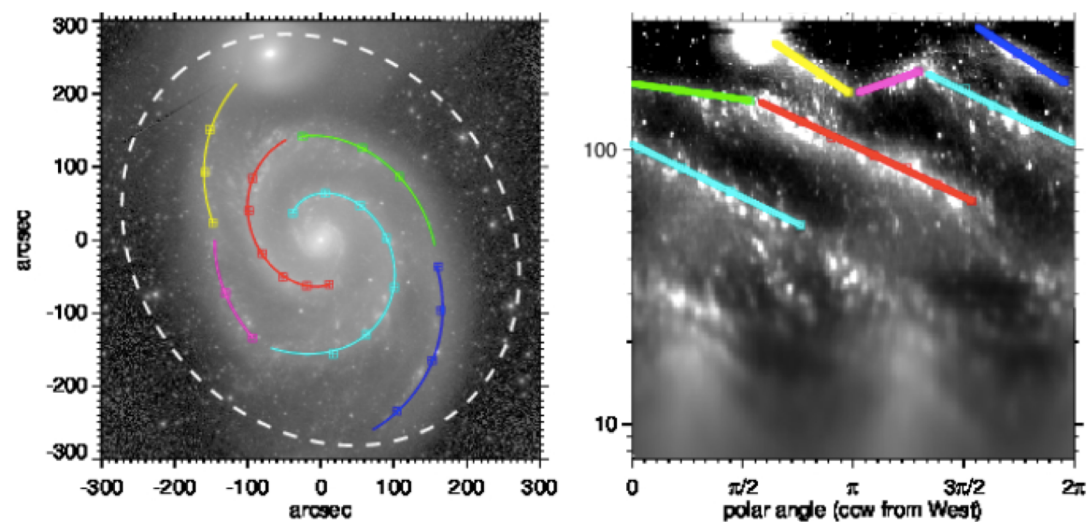
Measurements of sizes and axial ratios of inner and outer rings



Measurements on the 3.6 μm image for NGC 1350. The outline of the ridge of the rings was visually marked and fitted with an ellipse.

WINDING ANGLE OF ARMS

Pitch angle: visual measurements of logarithmic spiral segments

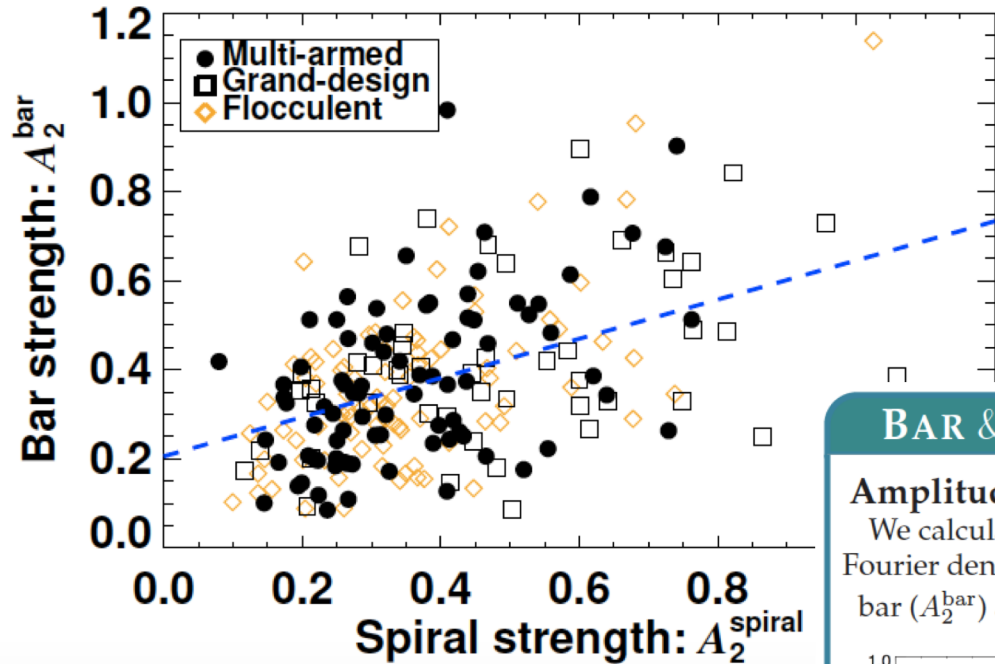


The 3.6 μm image of M 51 in the sky plane (left) and the logarithmic polar plot de-projected to the disk plane (right).

See Herrera-Endoqui et al. (2015, A&A, 528, A86, [click here](#))

BAR-SPIRALS COUPLING

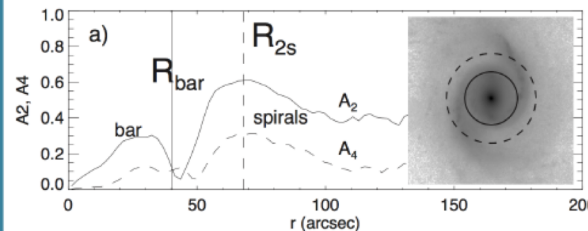
The amplitudes of bars and spirals are correlated: *this supports the role of bars driving the formation of spiral arms.*



BAR & SPIRAL STRENGTH

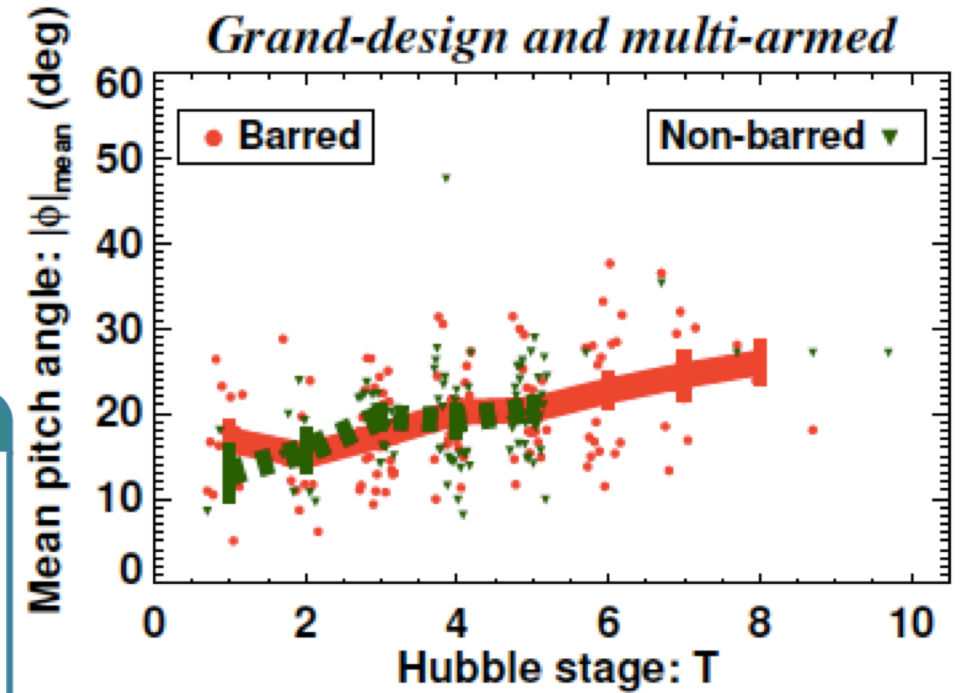
Amplitudes of non-axisymmetries:

We calculate the maximum of the $m = 2$ Fourier density amplitudes associated to the bar (A_2^{bar}) and to the spiral arms (A_2^{spiral}).



Bar/spiral force calculation on NGC 1566 (Salo et al. 2010).

However, the distribution of pitch angles for barred and non-barred galaxies is roughly the same when $1 \leq T \leq 5$.

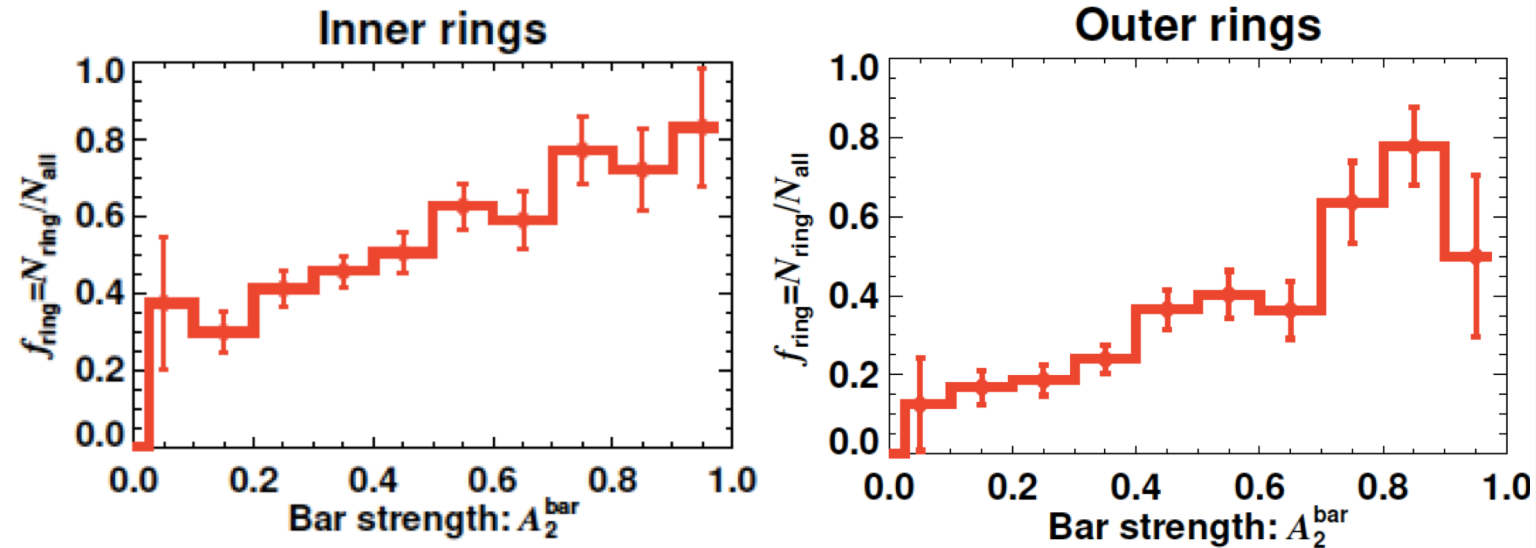


See also Díaz-García et al. (2016, A&A, 587, A160, [click here](#))

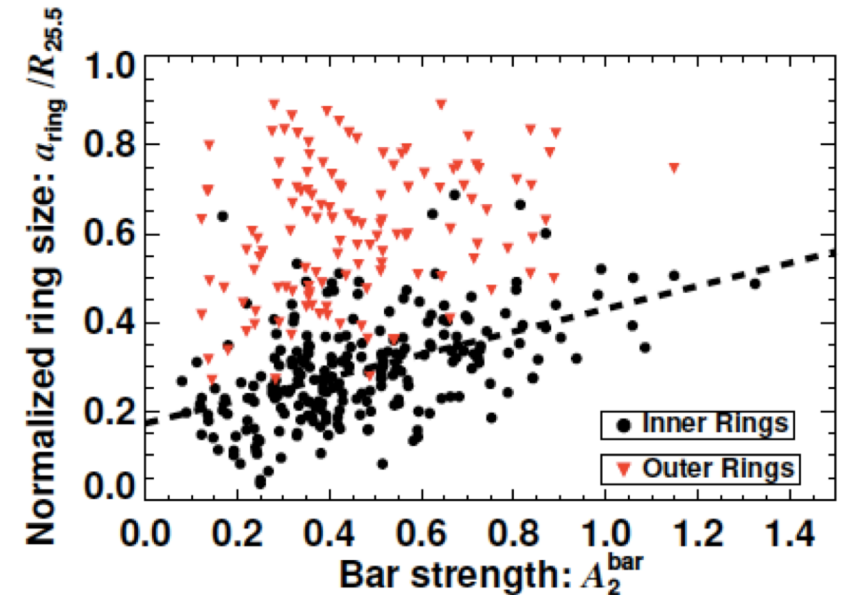
GROWTH OF BARS & RINGS

Ring fraction increases with increasing bar strength:

this can be interpreted as evidence for the role of bars in ring formation.



The sizes of inner rings are correlated with bar strength: *this is probably linked to the radial displacement of the I4R resonance while the bar grows and its rotation speed decreases.*

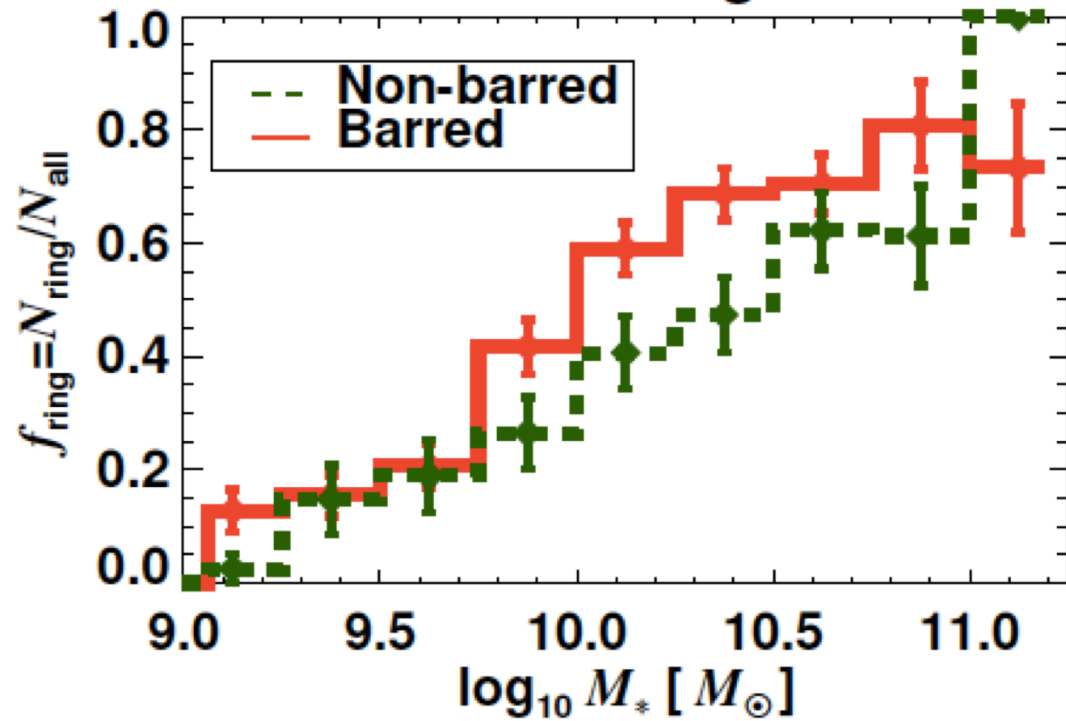


Outer ring sizes do not correlate with bar strength: *larger timescales are required for outer ring formation from gas redistributed by bars, whose potential might have changed.*

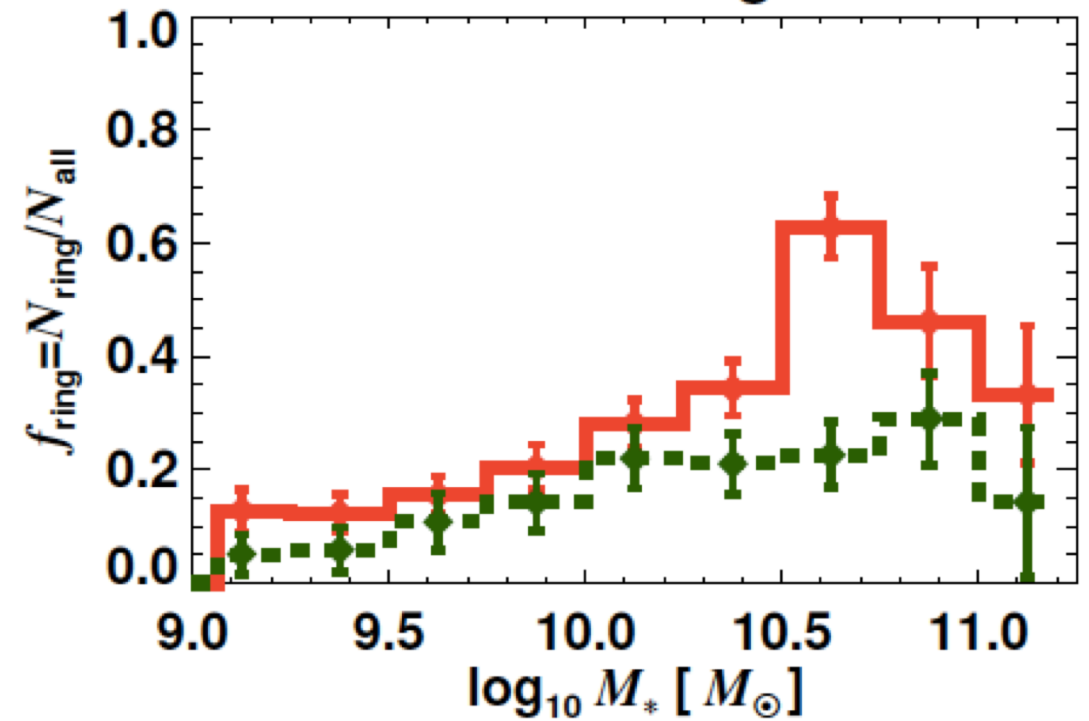
However, $\sim 1/3$ ($\sim 1/4$) of the galaxies hosting inner (outer) rings are not barred, thus:

1. some bars dissolve after ring formation (implausible based on numerical models) or,
2. other mechanisms may as well be responsible for ring creation (e.g. spiral modes or interactions).

Inner rings



Outer rings



Some concluding remarks

Bars play a role in inner/outer ring formation. However, the coupling between bars and rings is not as robust as expected from numerical models.

Coupling between bar and spiral amplitudes (grand design, multi-armed, flocculent):
Disks prone to development of strong bars are also reactive to the formation of prominent spirals.

Spirals are not necessarily bar-driven: barred & non-barred galaxies have similar pitch angles.

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreements No 893673 and 721463