Formation of stellar inner discs and inner rings in spiral galaxies through minor mergers

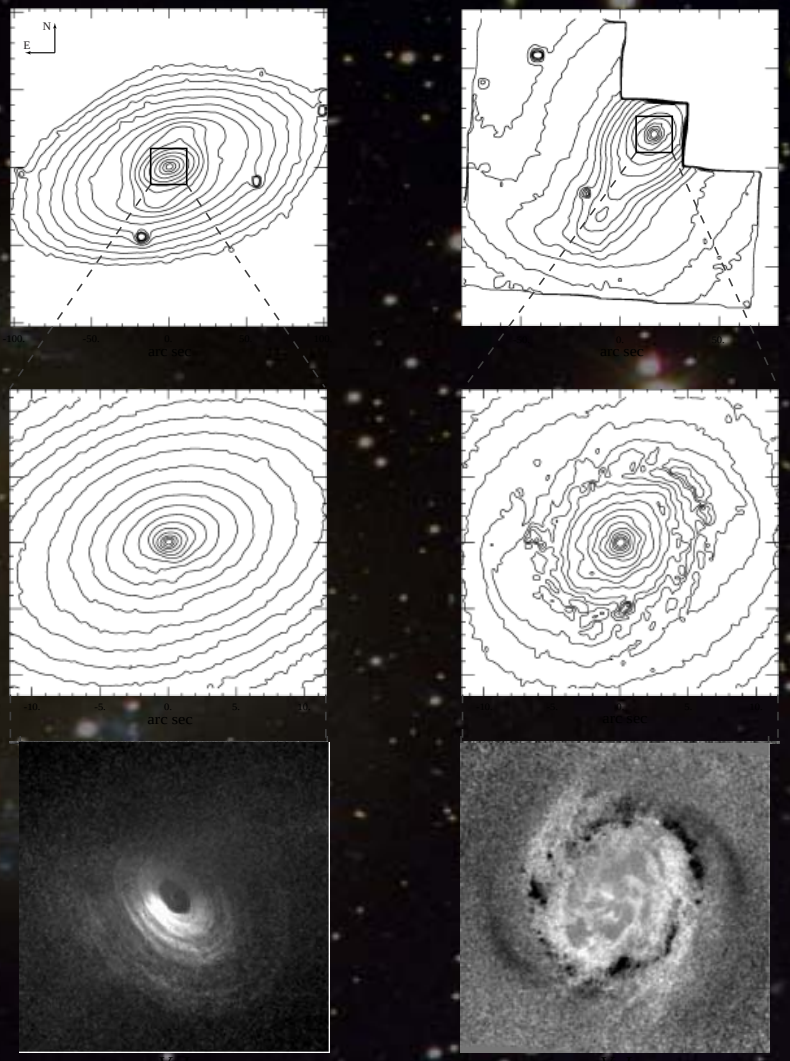
M. Carmen Eliche-Moral
Universidad Complutense de Madrid (Spain)

Collaborators:
C. A. González-García, M. Balcells, J. A. L. Aguerri,
M. Prieto (IAC), J. Gallego, & J. Zamorano (UCM)

JENAM 2011
St Petersburg,
7/July/2011

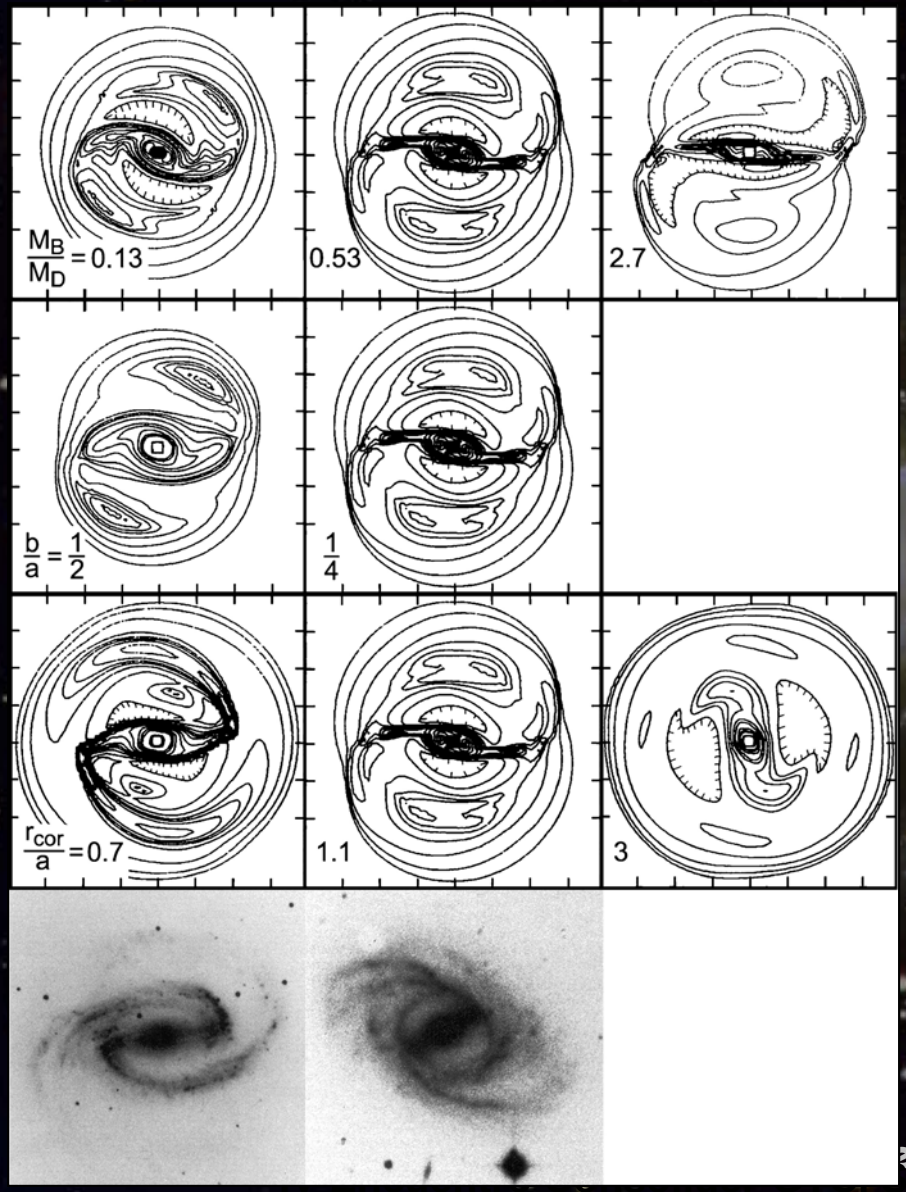
Inner Components (ICs) in Spirals

- Inner components (ICs) are present in **at least** one third of spiral galaxies (Erwin & Sparke02, Falcón-Barroso+06).
- Accounting for the episodic nature of star formation in inner rings, this fraction could be even higher (Sarzi+07).
- Many of them are not directly detectable through imaging, but through the isophotal profiles and kinematical maps (Erwin & Sparke03, Falcón-Barroso+06, Comerón+08, Sil'Chenko10).



Erwin & Sparke (2003)

Mechanisms to form ICs: Bar-related scenarios



Sanders & Tubbs80

- The origin of ICs has been traditionally associated to bars (Simkin+80, Combes92, Böker+08, Athanassoula+09, 10).
- However, recent observations pose that they do not reside preferably in barred hosts (Emsellem+04, Falcón-Barroso+04, Sarzi+06, Comerón+10).
- Many stellar inner disks exist in unbarred galaxies (Buta & Combes96, Muñoz-Tuñón+04, Kormendy+06).
- Mechanisms different to bars are required.

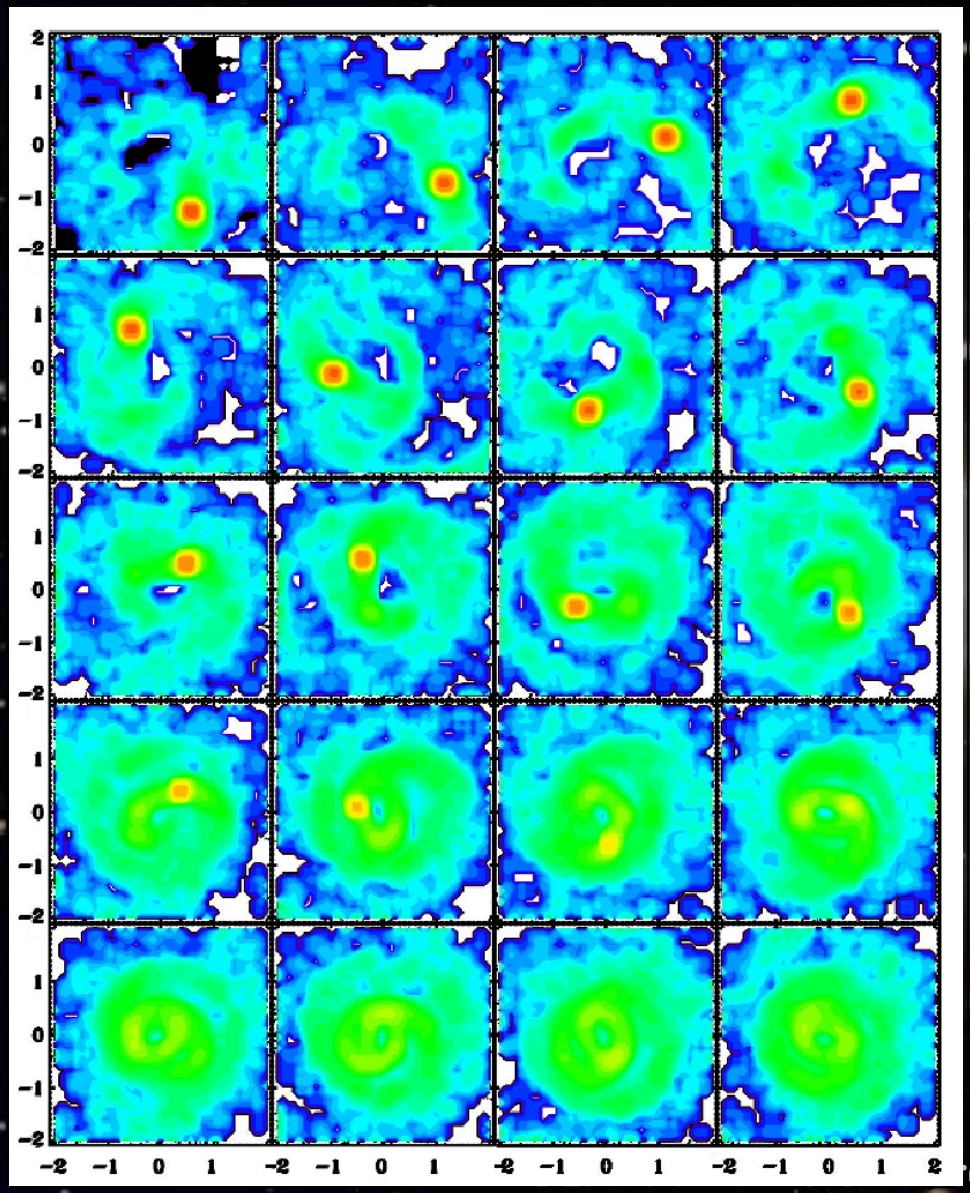
Other formation mechanisms...?

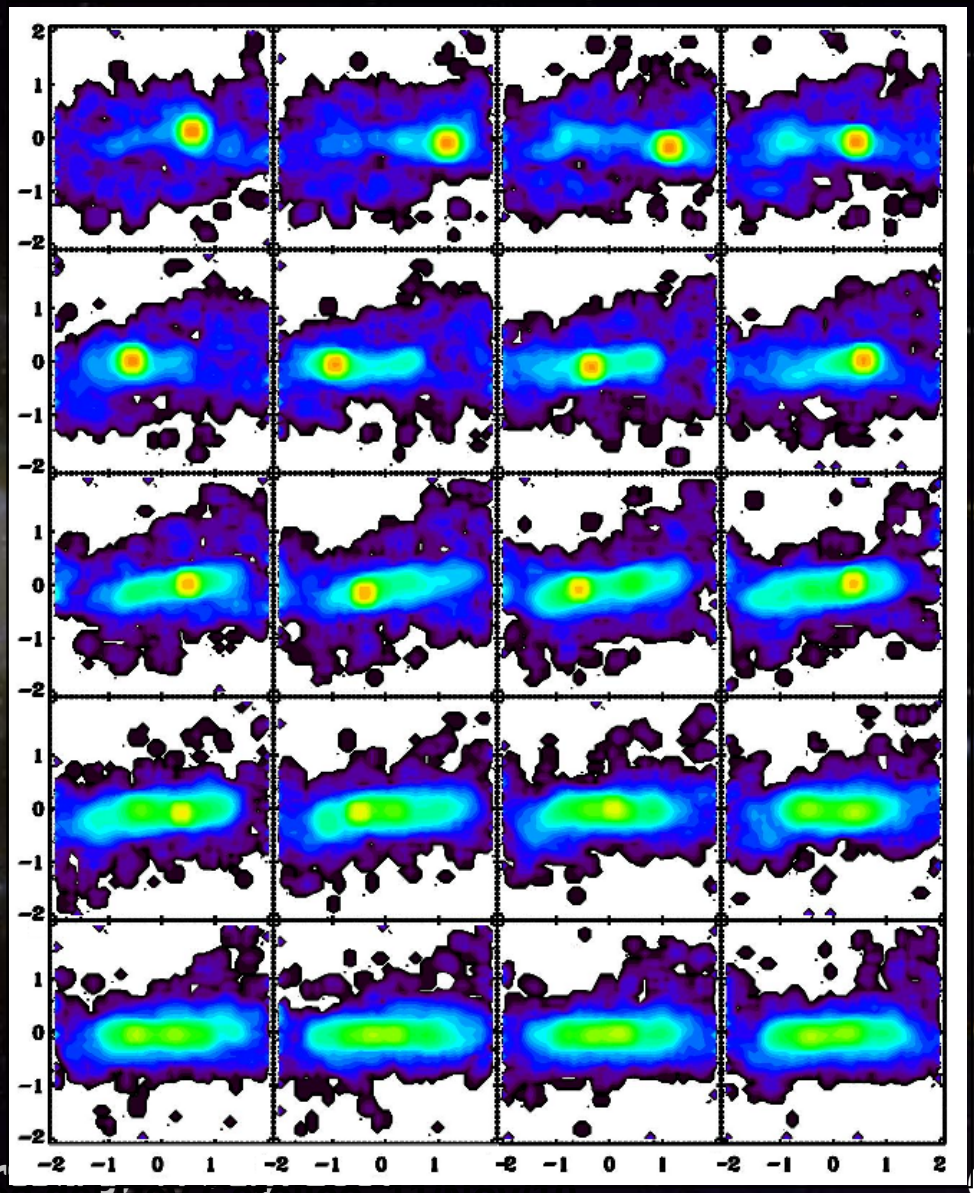
- For gaseous inner rings: It is easy → Disk instabilities, tidal interactions, gas infall, mergers (Thakar+97,98,Naab+06,Aumer+10).
- Radial migration of SF inner rings towards the galaxy center, dilution of nested bars, gas infall (Combes+92, Regan & Teuben03, Sil'Chenko & Smirnova10).
- But stellar inner disks are not **so easy** to form (Thakar+98).
- Major mergers → kinematically-decoupled ICs (Jesseit+07, Di Matteo+08).
- Straightforward alternative mechanism: stellar minor mergers (Bertola+99, EM+06, Sil'Chenko & Moiseev06, Brosch+10).
- Although widely invoked, their capability to form inner disks still to be tested (Aguerri+01, Helmi+11).

...What about minor mergers?

- EM+06 → minor merger simulations to analyse bulge growth.
- Satellite core material is deposited in circular orbits in the remnants.
- What sort of structures does the disrupted satellite material form?
- We have extended the set of collisionless N-body simulations of minor mergers onto disk galaxies (EM+11, A&A in press, arXiv:1105.5826).
- Mass ratios: 1:6, 1:9, 1:18.
- Different orbits (longer pericenters, direct and retrograde orbits).
- Different initial primary galaxies (Sab and Sc).
- Key point: a realistic scaling between satellite and primary galaxy, based on Tully-Fisher relation.

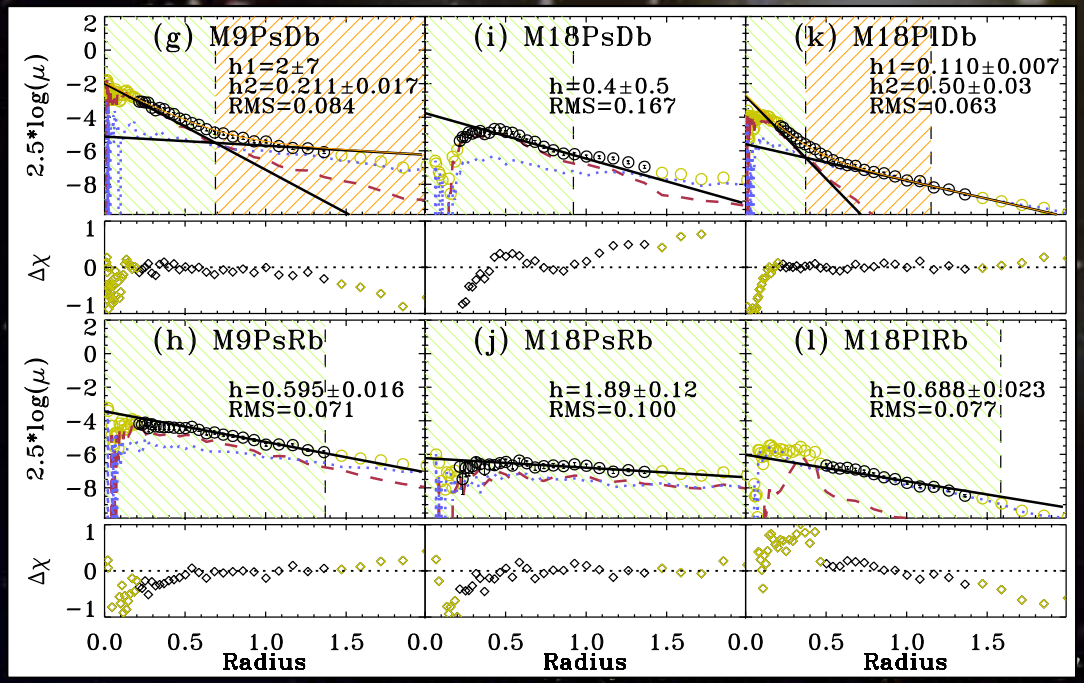
ICs made out of disrupted satellite material are formed

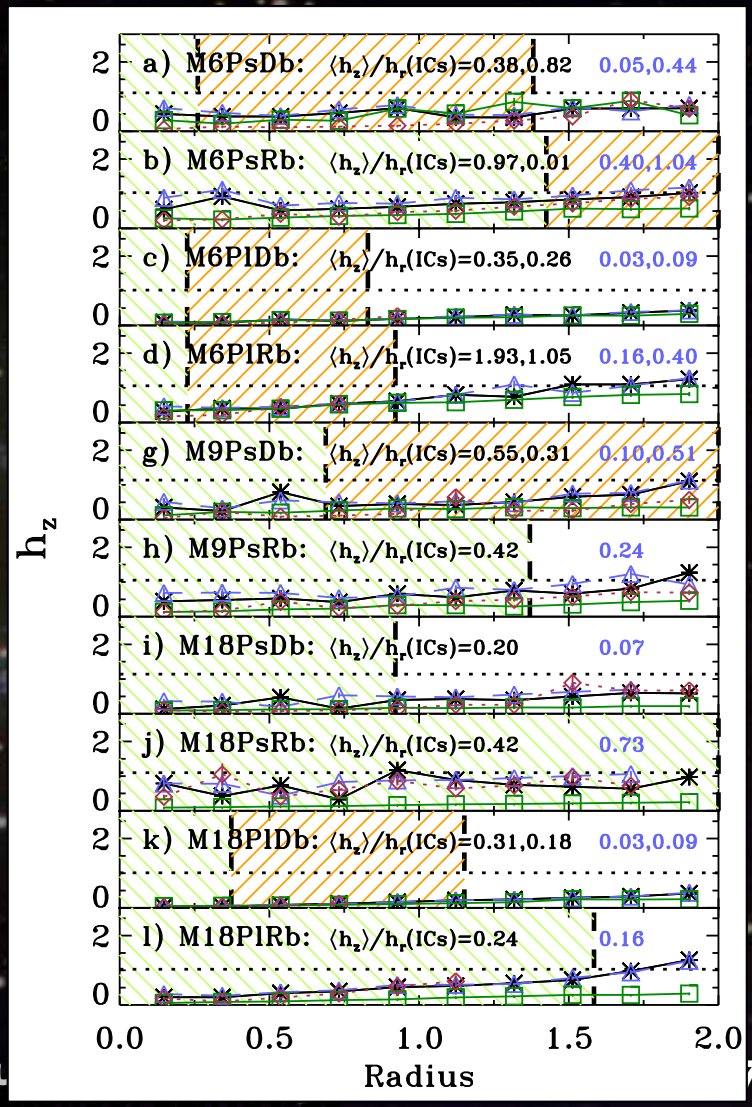




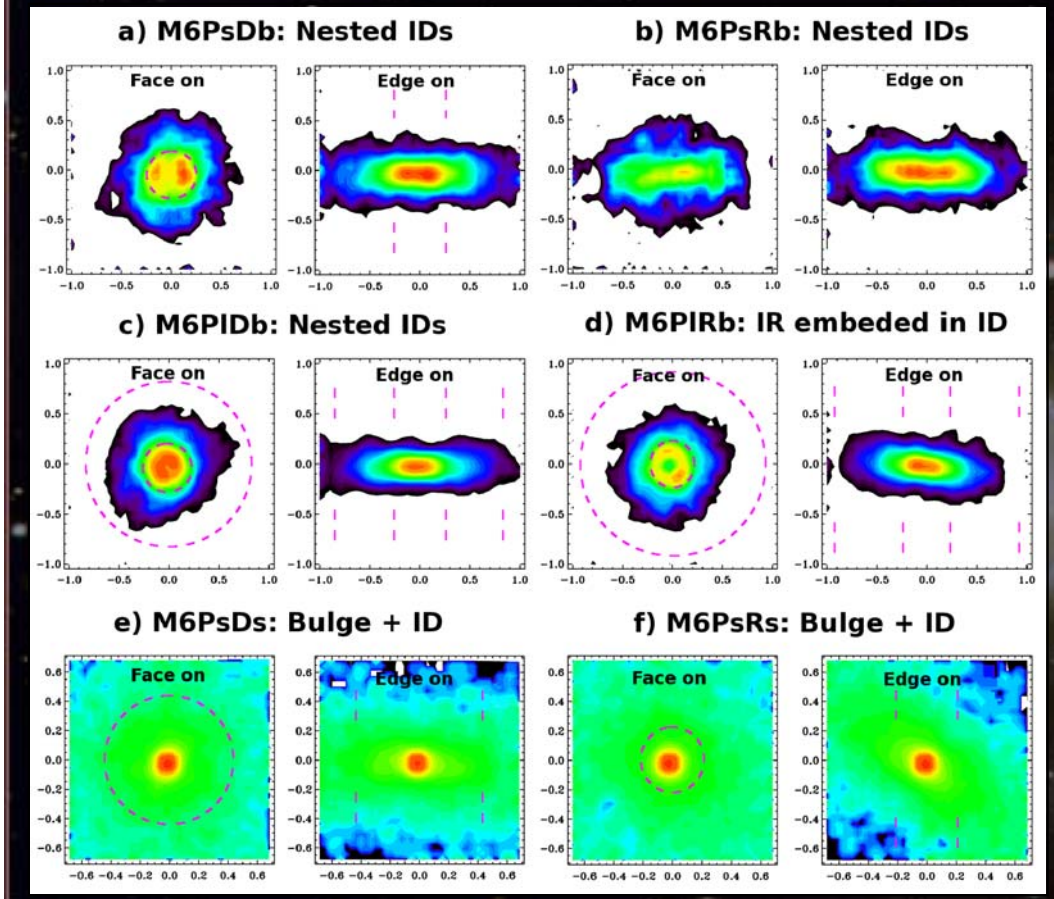
The ICs can be described as nested and single inner disks and rings

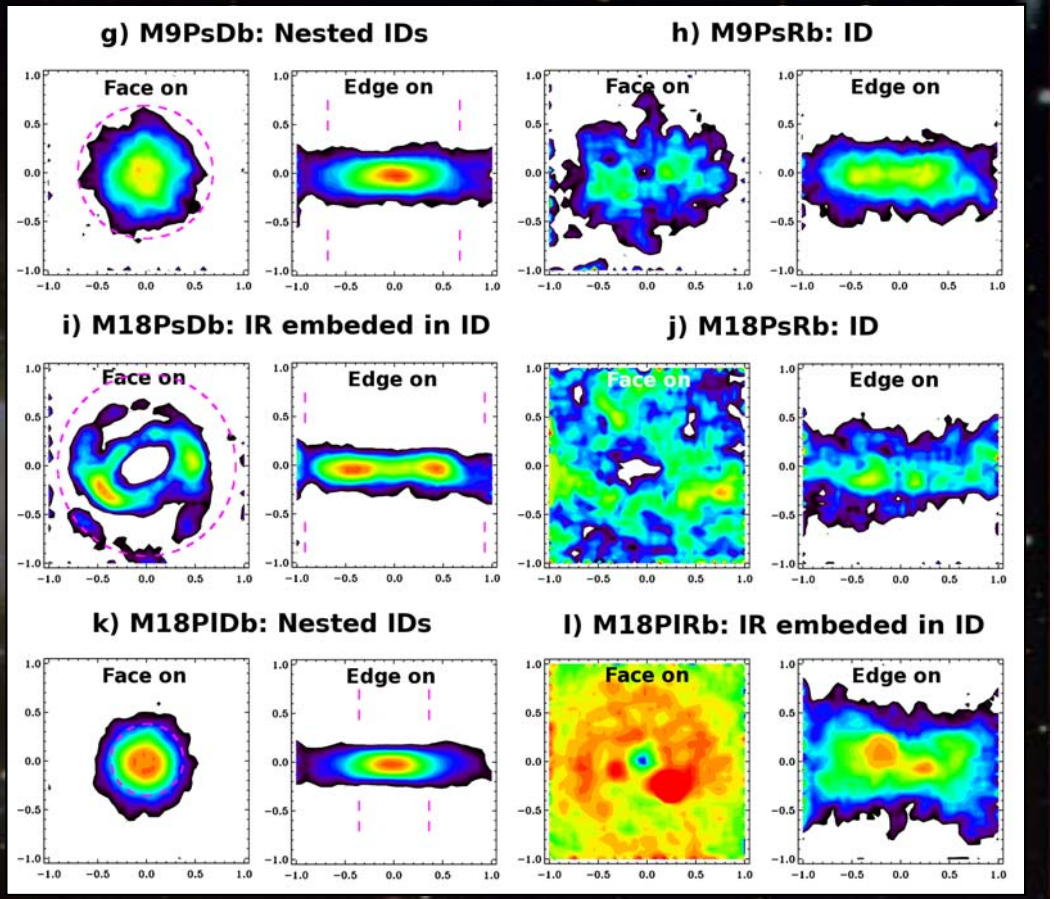
- The minor mergers have given place to thin single or nested inner discs, pseudobulges, thick discs, thin disks embedded into thick ones.
- All disks are flared (See Chilingarian's and di Matteo's talks).
- All ICs are aligned to better than 5° with the main disc of the remnant.



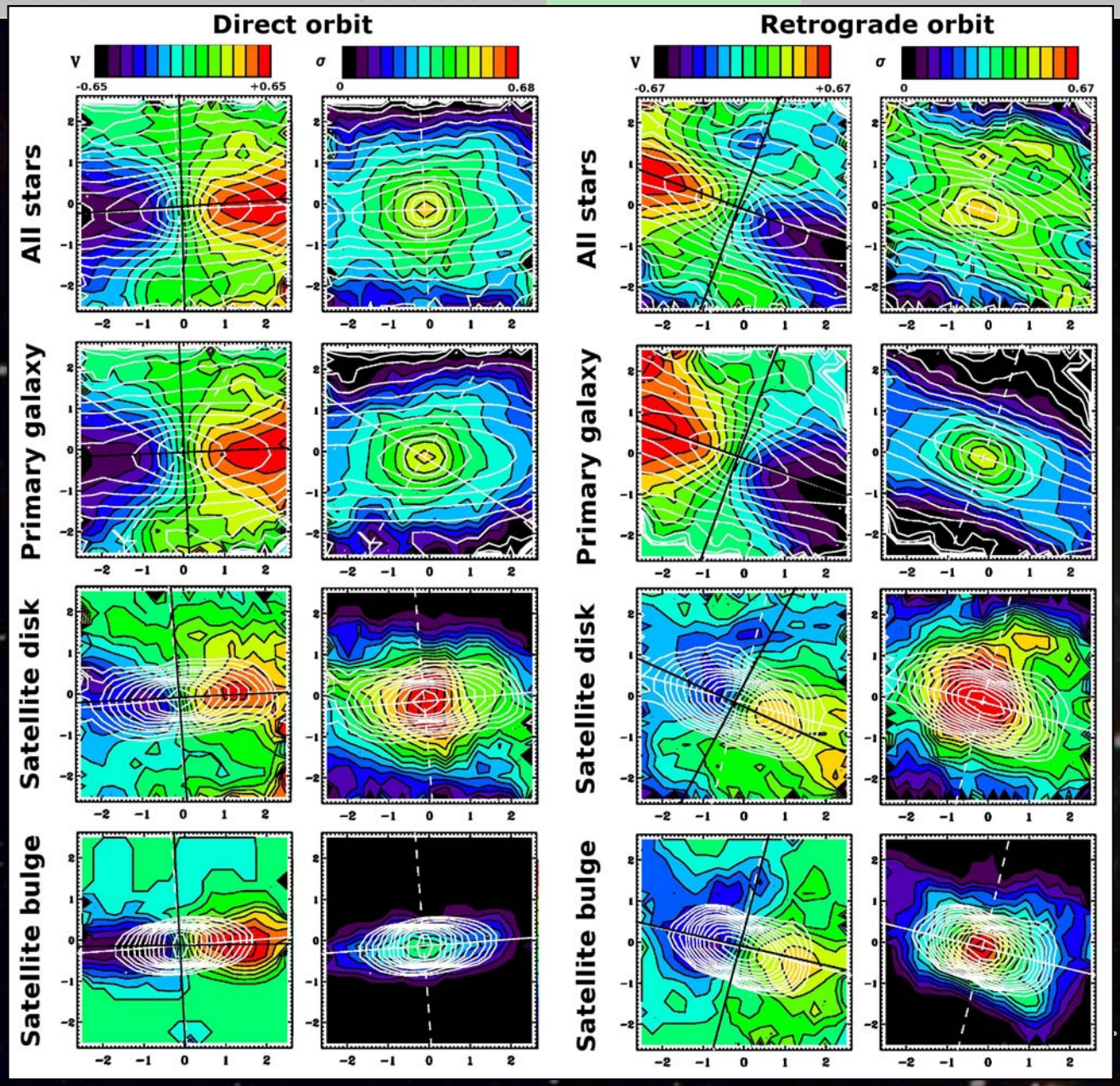


Morphological zoo of ICs





The ICs are supported by rotation

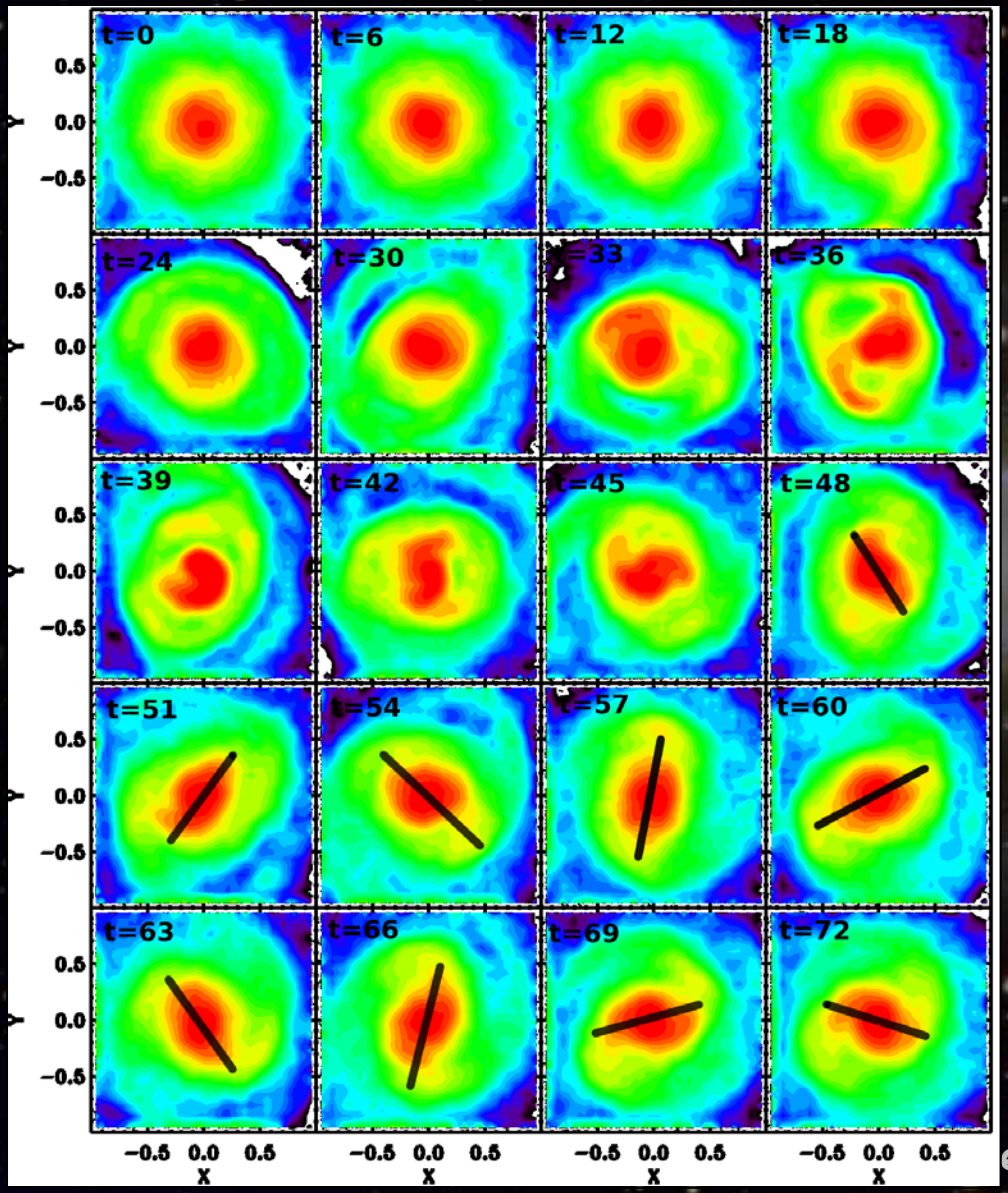


Co-rotating ICs

Counter-rotating ICs

- No dissipative component is required to produce dynamically-cold ICs.

Formation mechanism of ICs

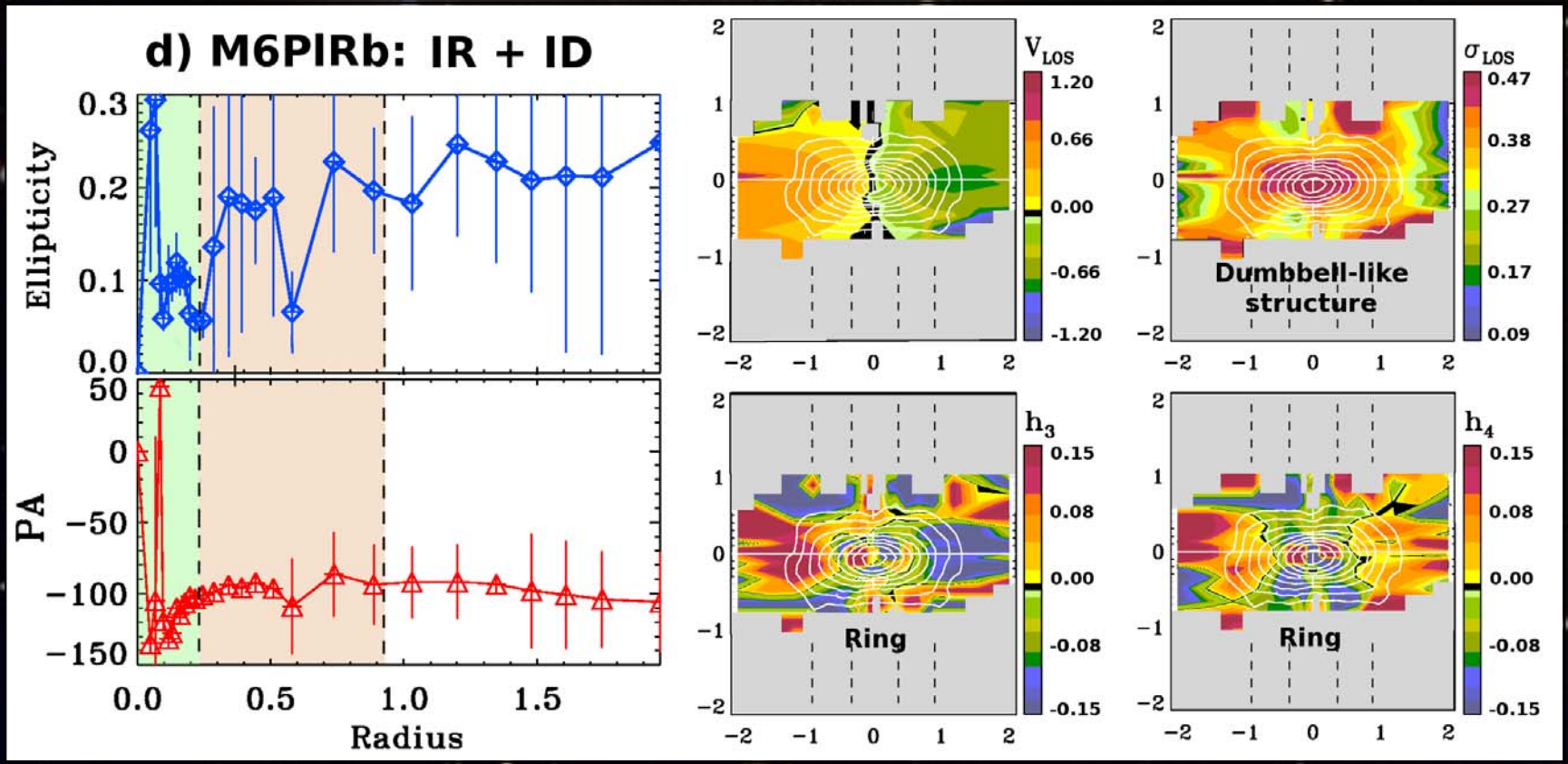


- Disk resonances triggered by the encounter couple with the disrupted satellite material (Tutukov & Fedorova06).
- No bar is formed in the primary disk (just oval distortions).

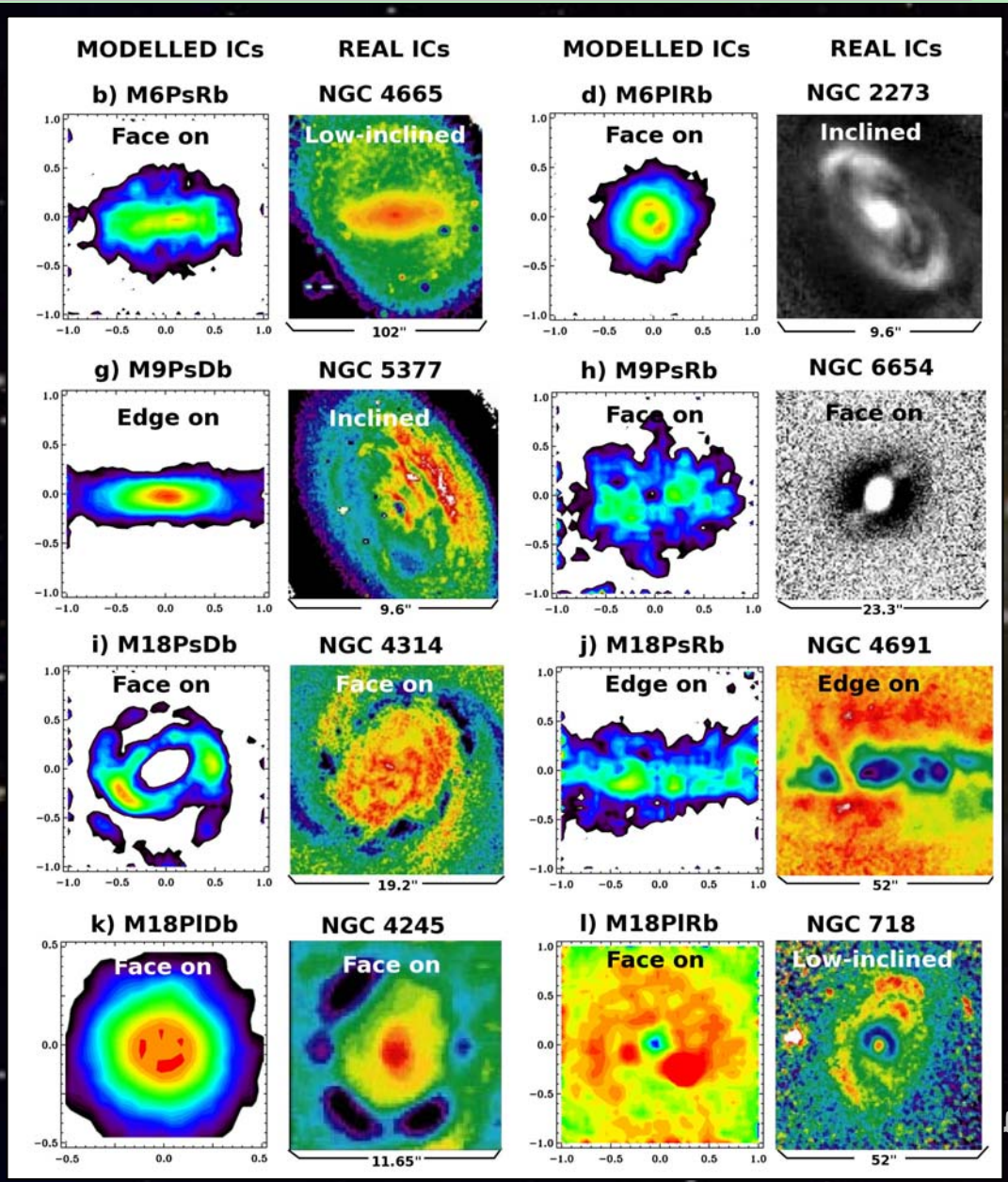
The combination of resonances, disruption, and orbital circularization gives place to highly-aligned dynamically-cold ICs in the remnant center.

Comparison to observations: Structure and kinematics (I)

- Ellipticity and PA profile trends similar to observations (Erwin&Sparke+02,03).
- Kinematic features similar to observations: S-shaped kinematic twist, σ and h_4 peaks, dumbbell-like σ structures, stretching of iso-v contours (Falcón-Barroso+06, Sarzi+06, Krajnovic+08).



Comparison to observations: Morphology (II)



- Morphologies similar to those observed (Erwin & Sparke03, Sil'Chenko+11).
- Sizes similar to those observed in real galaxies (R~0.4-2.5 kpc).
- Low misalignment of ICs in spirals (Krajnovic+11).
- Explain the existence of dynamically-cold thin stellar ICs in unbarred galaxies.

Summary

Minor mergers are an efficient mechanism to form rotationally-supported stellar ICs in spiral galaxies, without requiring either strong dissipation or the development of noticeable bars.

These models indicate that minor mergers can account for the existence of stellar inner disks and rings in unbarred spirals.

The role of minor mergers in the formation of ICs may have been much more complex than just bar triggering.