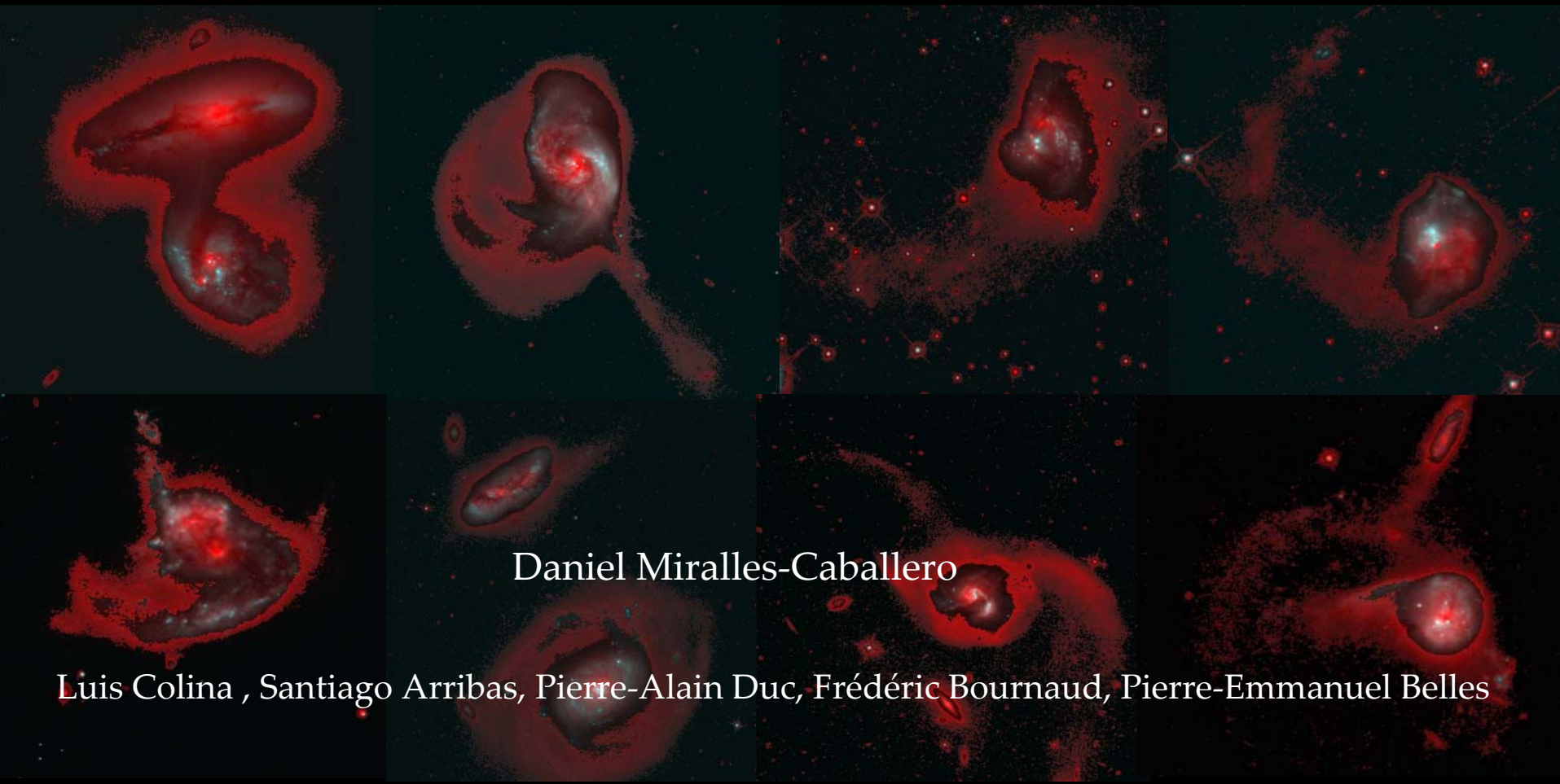
D. Miralles-Caballero

Characterization of star forming regions in (U)LIRGs

A significant fraction of (U)LIRGs are known to constitute interacting and merging systems, where star formation is triggered within the galaxies and along the tidal features that usually form. A systematic analysis of almost 3000 star forming regions in a representative sample of 32 (U)LIRGs has been performed by means of high angular resolution ACS/HST B and I images. This talk presents the results of the photometric characterization of these star forming regions as a function of the luminosity of the systems, the interaction phase and the distance to the nucleus. Characteristics such as sizes, colors, magnitudes and the luminosity function will also be compared with those of clusters observed in less luminous interacting galaxies such as the Antennae.

"Characterization of star forming regions in (U) LIRGs"

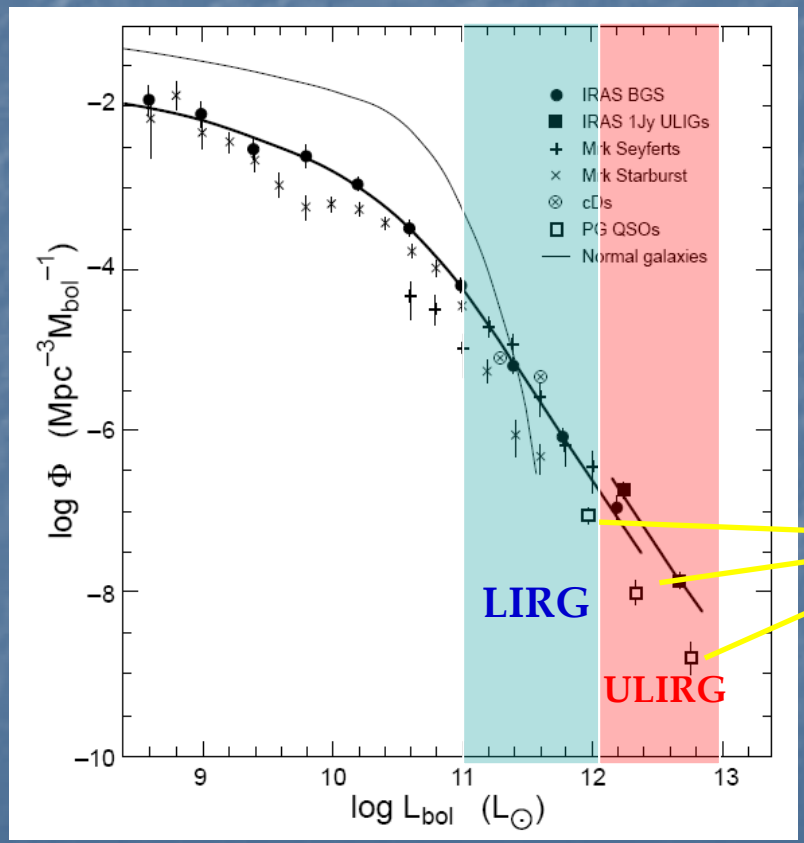


Daniel Miralles-Caballero

Luis Colina , Santiago Arribas, Pierre-Alain Duc, Frédéric Bournaud, Pierre-Emmanuel Belles

(U) LIRGs, extreme ...

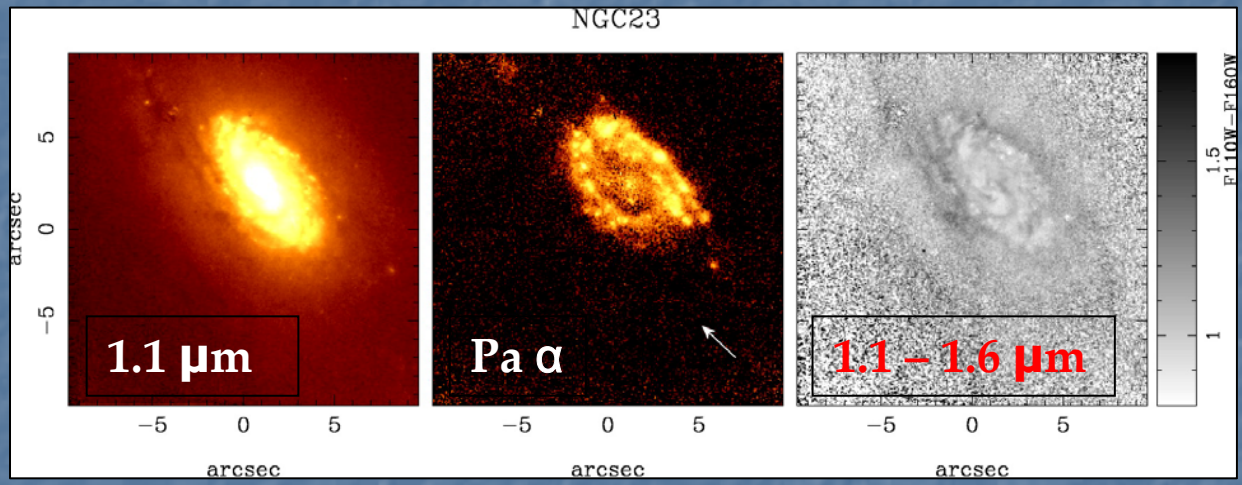
- **Luminous galaxies**

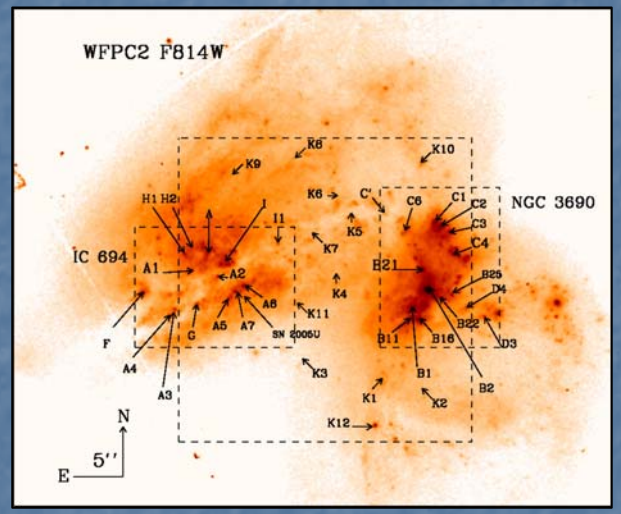


* Sanders & Mirabel 1996, ARAA, 34, 749

(U) LIRGs, extreme ...

- **Luminous galaxies**
- **Star forming galaxies**





* Alonso-Herrero et al. 2006, ApJ 650, 835

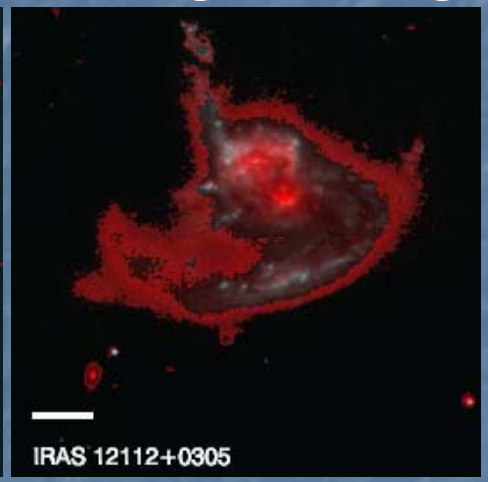
* García-Marín et al. 2006, ApJ 650, 850

SFRs up to hundreds of $M_{\odot}$ yr^{-1}

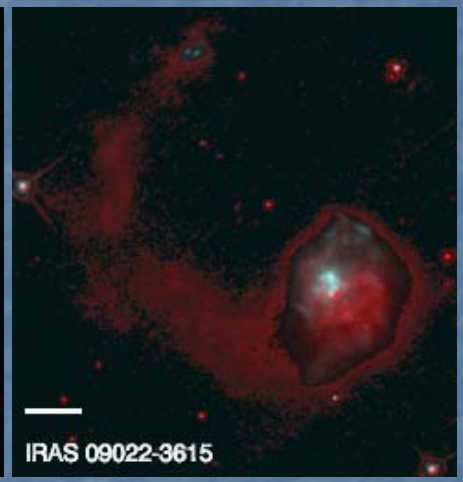
(U) LIRGs, extreme ...

- Luminous galaxies
- Star forming galaxies
- Interactions of gas rich galaxies

Wide pair



Pairs with tails



Single nucleus with tails

Single nucleus

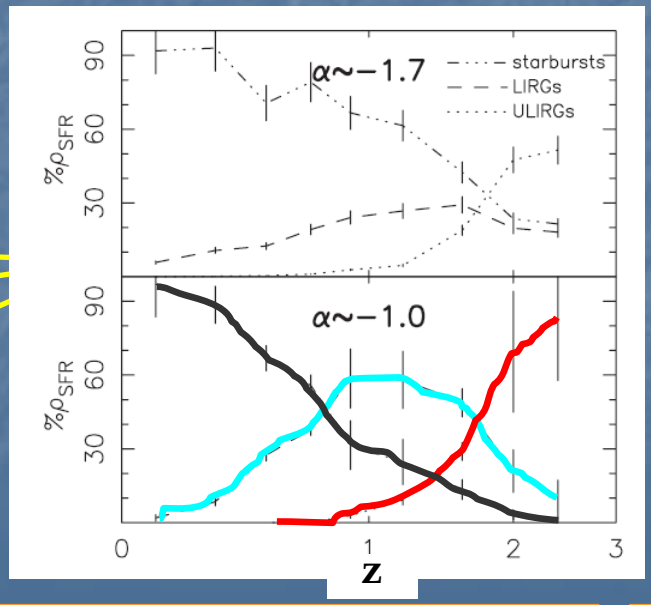
> 60 (95) % of LIRGs (ULIRGs) are mergers or close pairs

(U) LIRGs, extreme ...

- Luminous galaxies
- Star forming galaxies
- Interactions of gas rich galaxies
- (U) LIRGs are major contributors to the SFR density and more common at z ~ 1-2

* Pérez-González et al. 2005, ApJ 630, 82

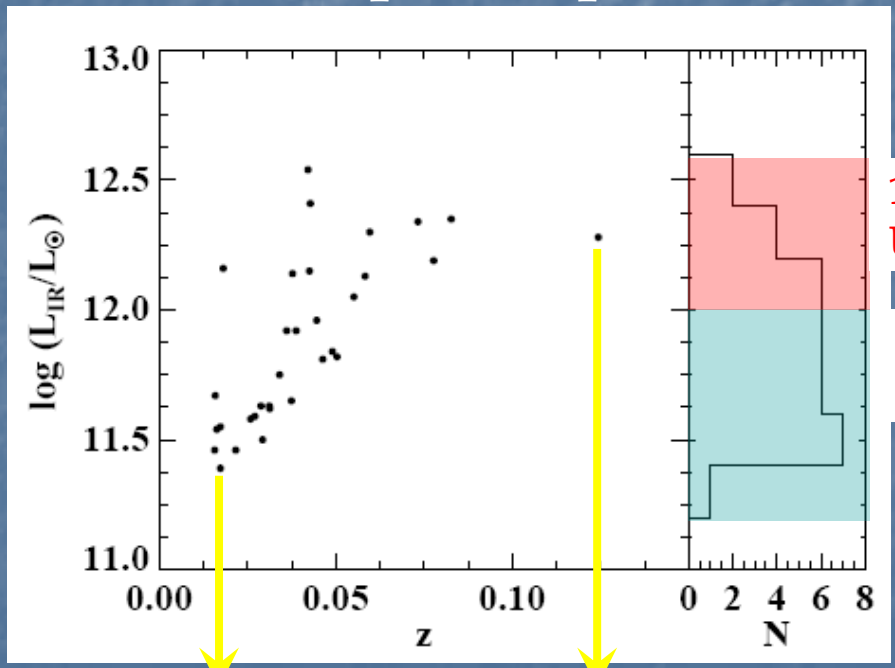
- STARBURSTS
- LIRGs
- ULIRGs



The sample

HST archive -> F435W (~*B*) & F814W (~I) band images

IFS optical spectra (WHT, CAHA & VLT)



- Long-term project: search for TDGs in (U)LIRGS

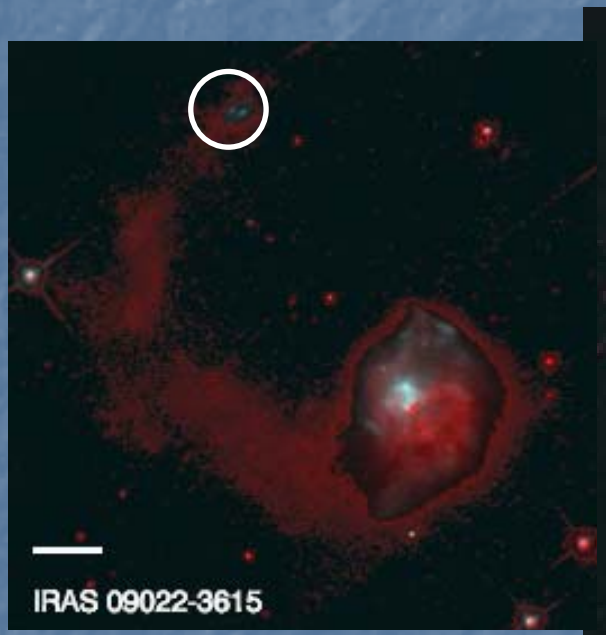
- Representative sample

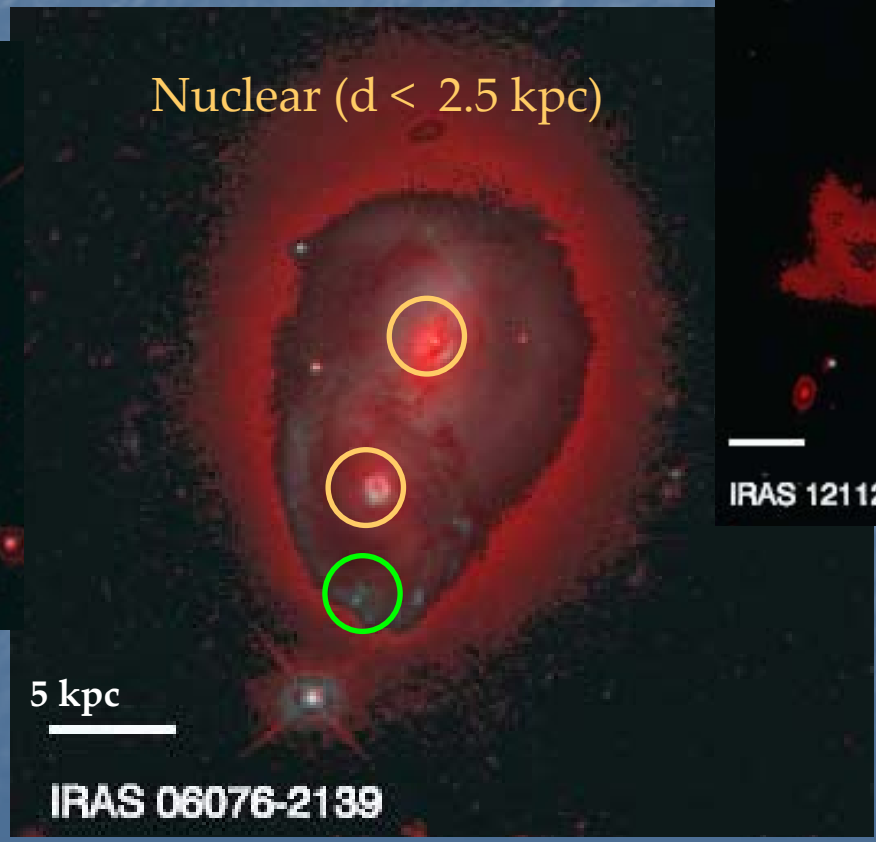
* Mean linear resolution of ~50 pc per pixel

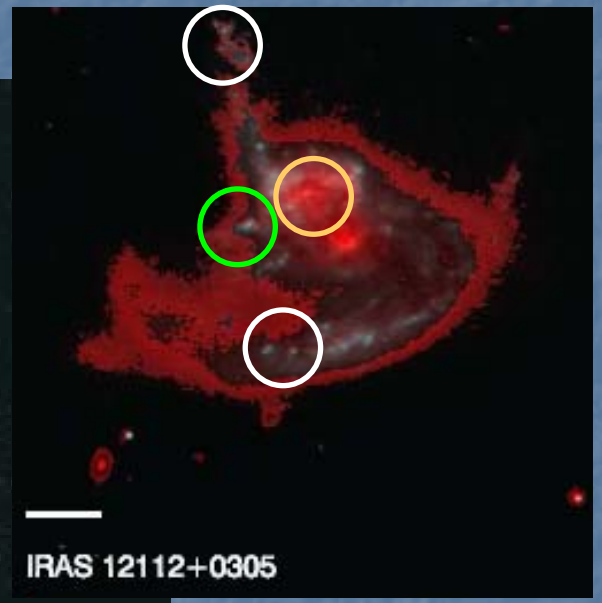
$L_{IR} \equiv \log (L_{IR}(L_\odot))$

The sample

Star formation at all scales





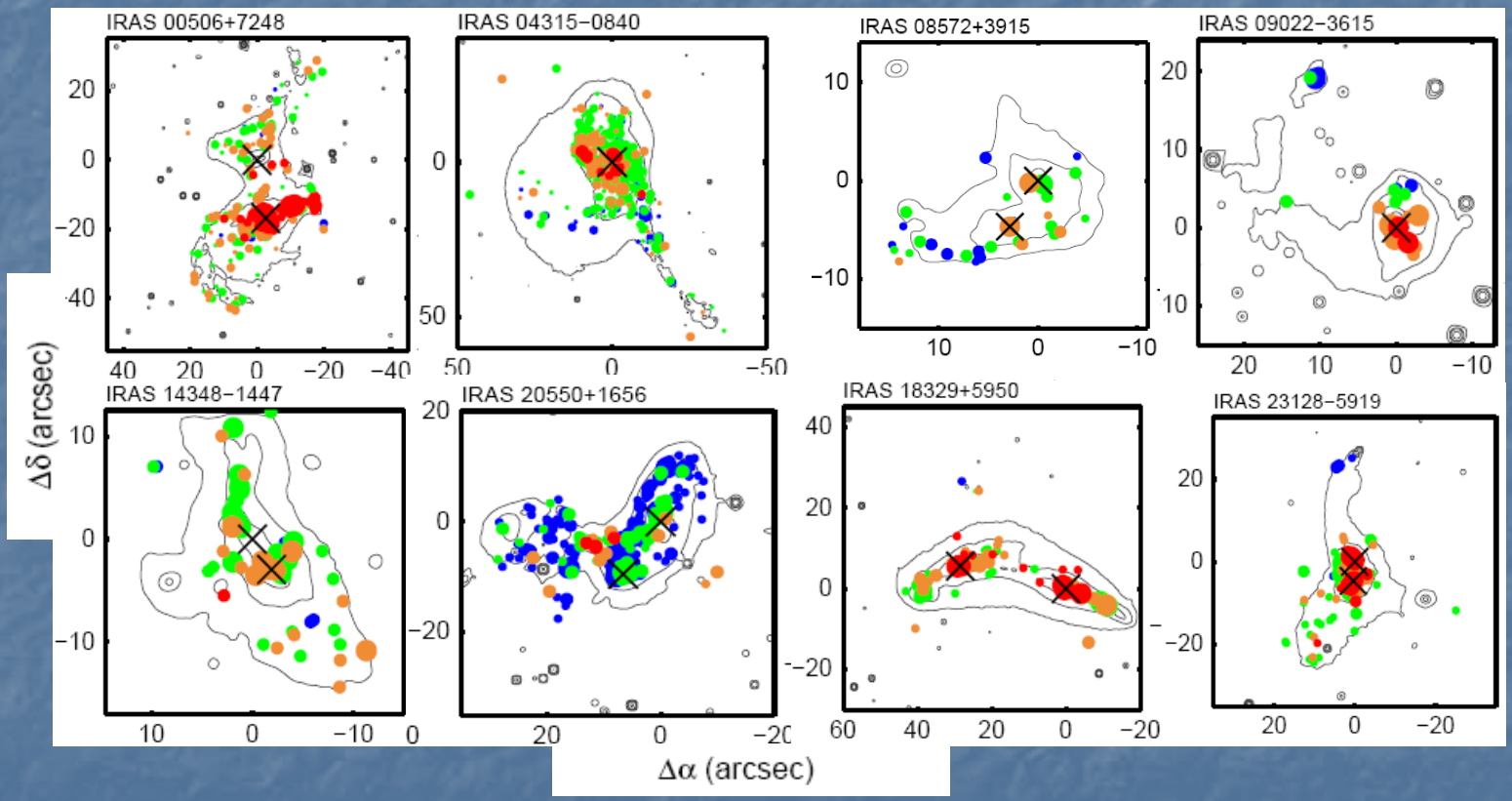


Extra-nuclear
(d = 2.5-20 kpc)

- 32 galaxies
- close to 3000 SF regions (knots)

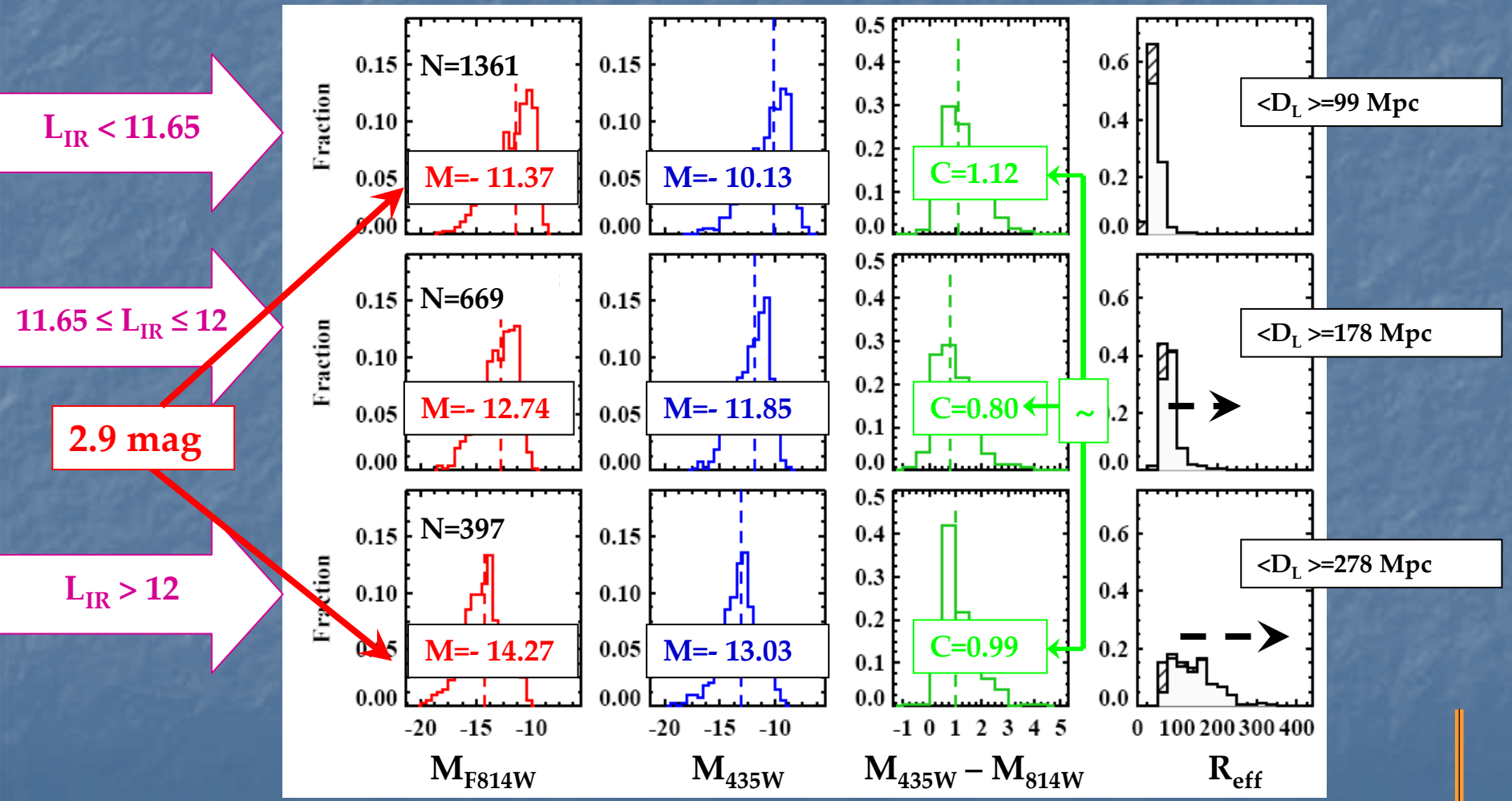
Photometry : colors and magnitudes

- **Spatial distribution**



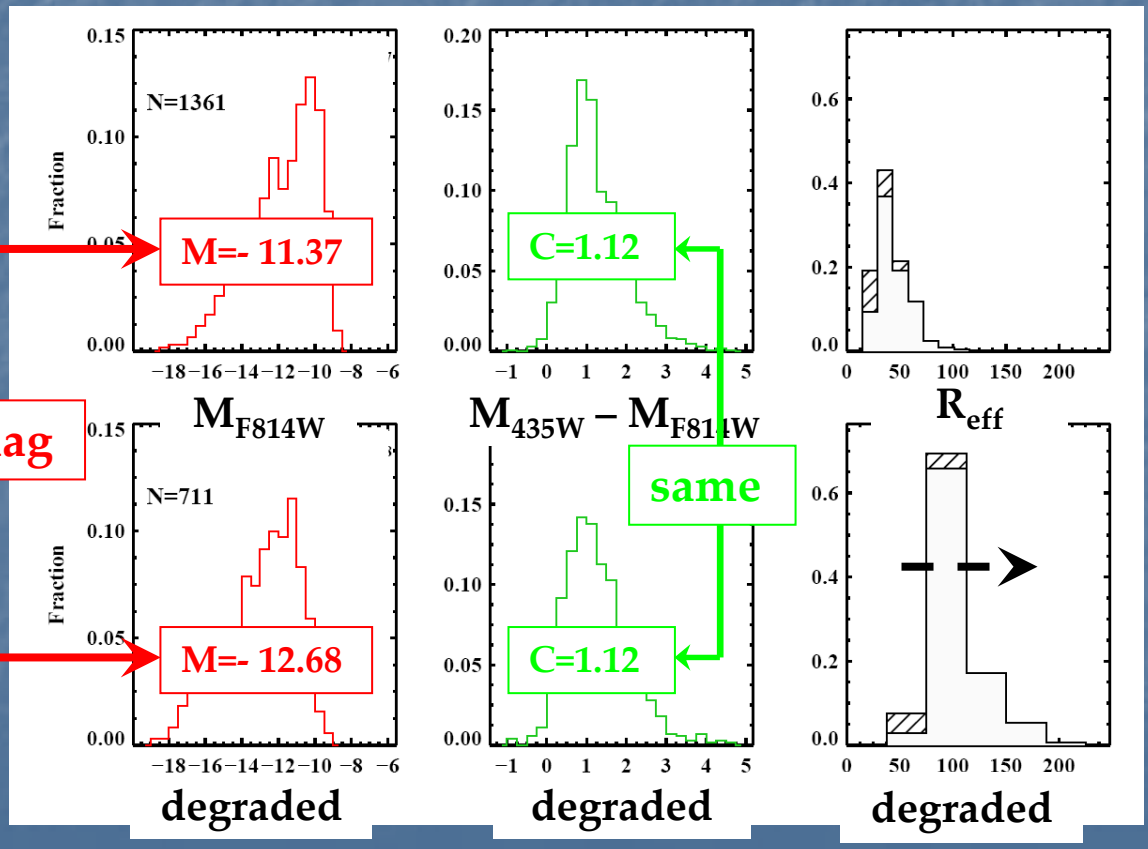
- Redder objects in the innermost regions -> Extinction gradient?
- Some blue and bright knots along and at the tip of the tidal tails

Properties as a function of L_{IR}



Properties as a function of L_{IR}

- **Simulation of distance effect**



* 1.3 mag due to distance effect

* 1.6 mag brighter & similar colors:

- Greater density of clusters
- More massive clusters

(similar age and extinction range)

Properties as a function of L_{IR}

- **Comparison with nearby interacting galaxies**

The Antennae (Whitmore et al. 1999, AJ, 118, 1551)

D_L=19.4 Mpc, L_{IR}=11

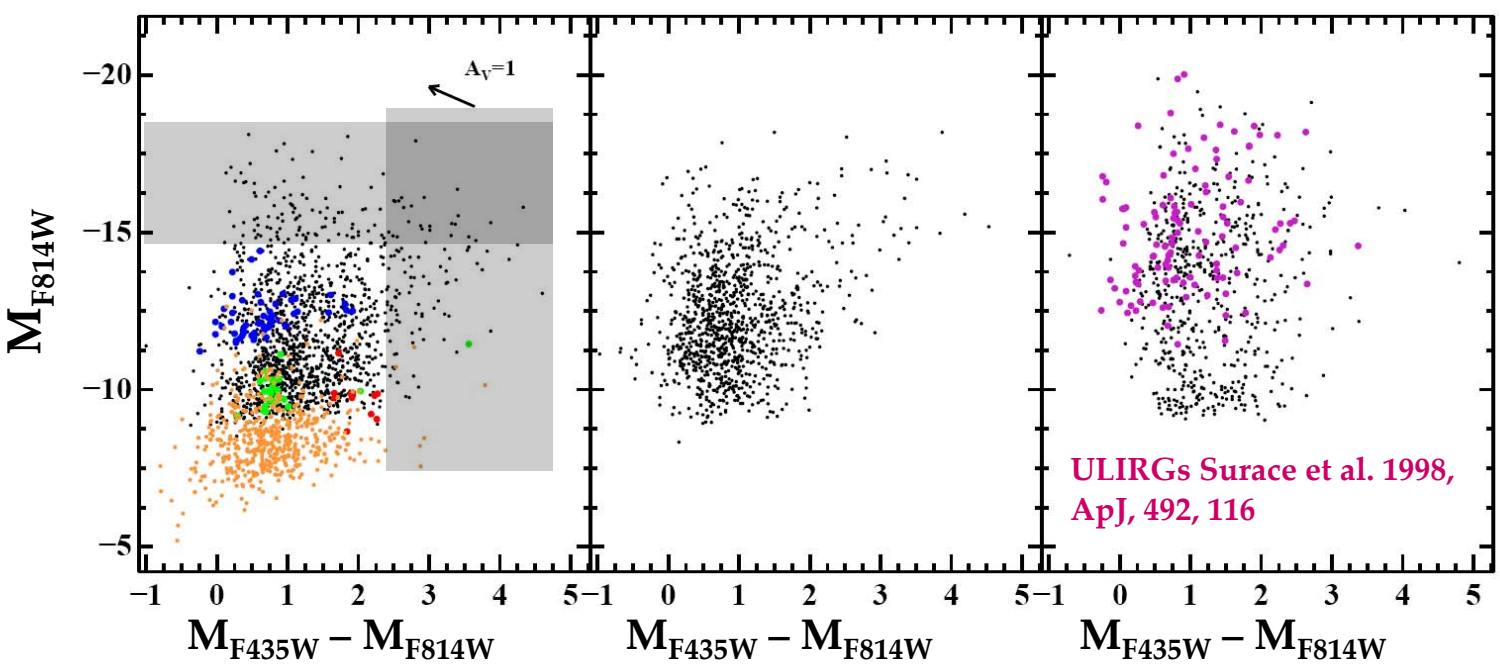
Age < 30 Myr
M_I=-12.3, *B-I=0.5*

250 Myr <Age < 1 Gyr
M_I=-9.8, *B-I=0.7*

Age > 1 Gyr
M_I=-9.7, *B-I=1.8*

M51, (Bik et al. 2003, A&A, 397, 473)

D_L=10.6 Mpc, L_{IR}= 10



- In general, similar color range (> 90% of the knots)

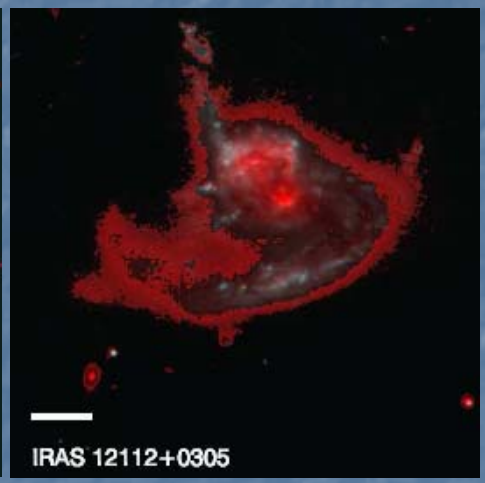
* Up to 5 mag brighter than clusters in nearby interacting galaxies

Properties as a function of interaction phase

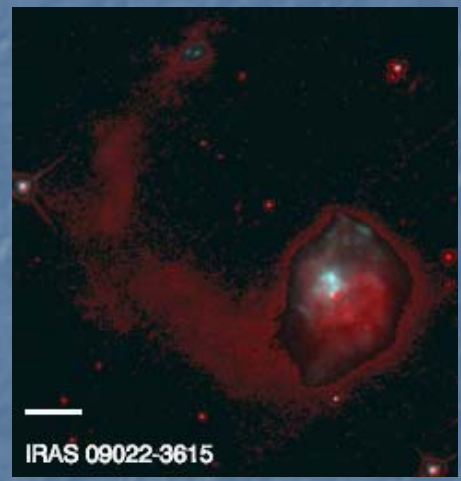
- Morphological classification

* Based on classficiation of Veilleux et al. 2002, ApJS, 143, 31; but simplified

First approach (wide pair, no tails) [1]



Pre-merger (pair, tails) [2]



Merger (single nucleus, tails) [3]

Post-merger (isolated, no tails) [4]

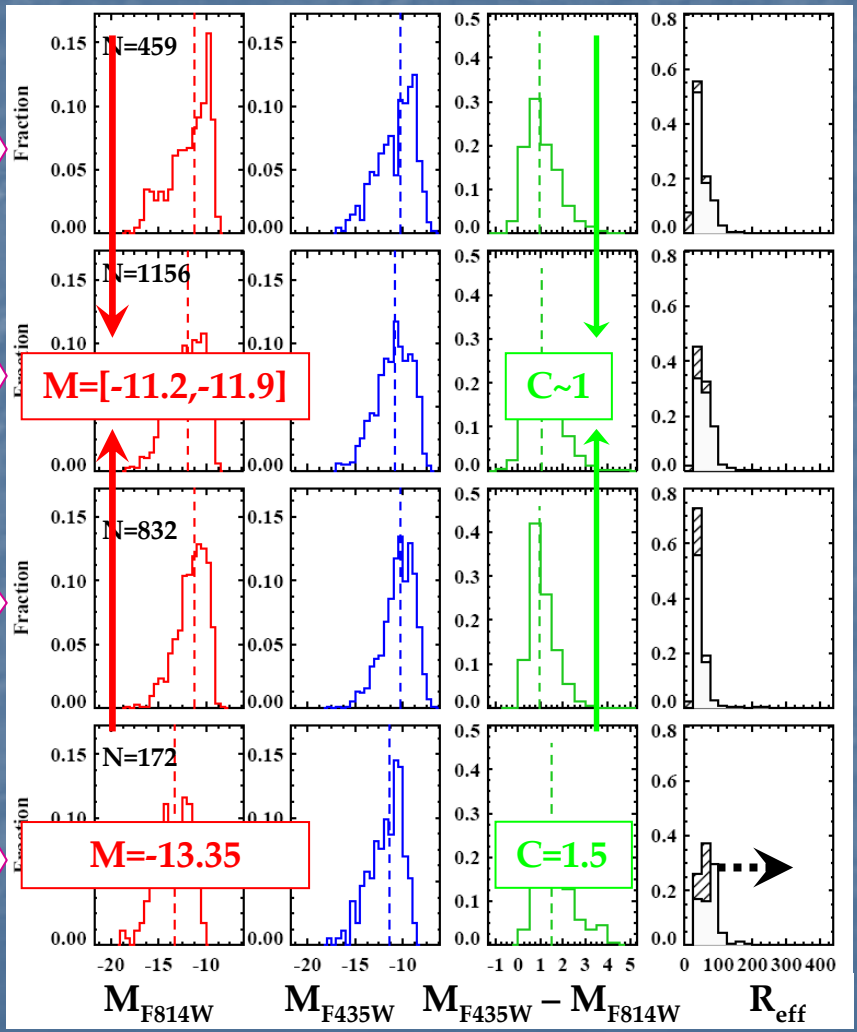
Properties as a function of interaction phase

FIRST APPROACH

PRE-MERGER

MERGER

POST-MERGER



- Only systems at similar distance

* Brighter (1.5-2 mag), redder (0.5 mag) and tendency towards larger knots in the most evolved phase

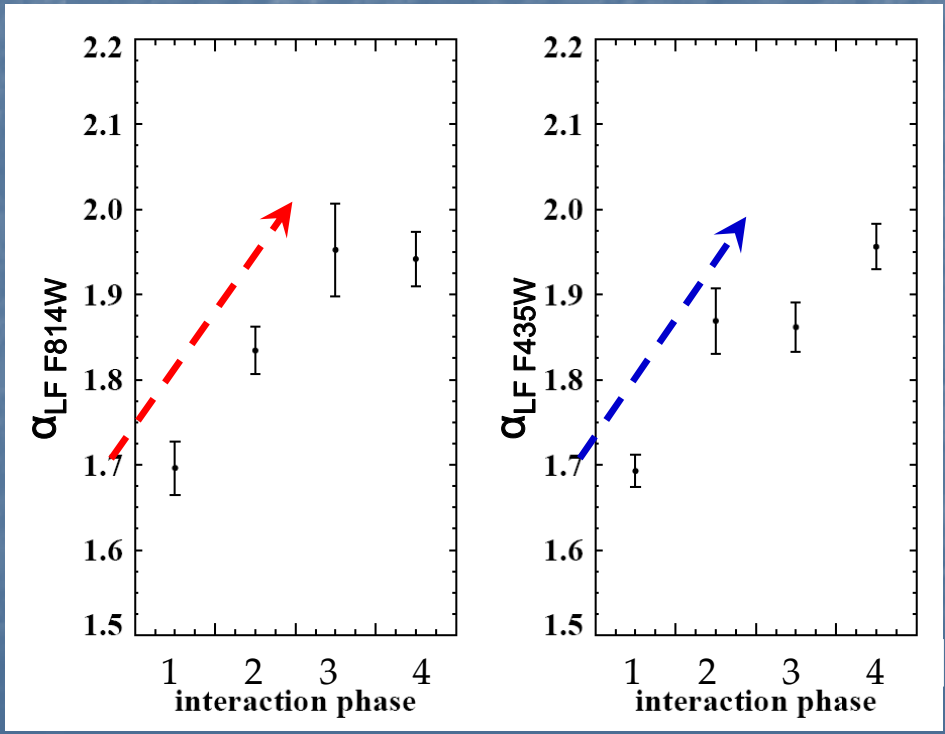
- Merging of superclusters?
(Kroupa 1998, MNRAS, 300,200)

Properties as a function of interaction phase

- **Luminosity Function (LF)**

  $dN \alpha L_\lambda^{-\alpha} dL_\lambda$

  Bins of variable width (Maíz-Apellániz & Úbeda 2005, ApJ, 629, 873)



* Similar slopes than measured in other systems (around α=2), like in the Antennae, M51, Arp 284, NGC 7252, etc

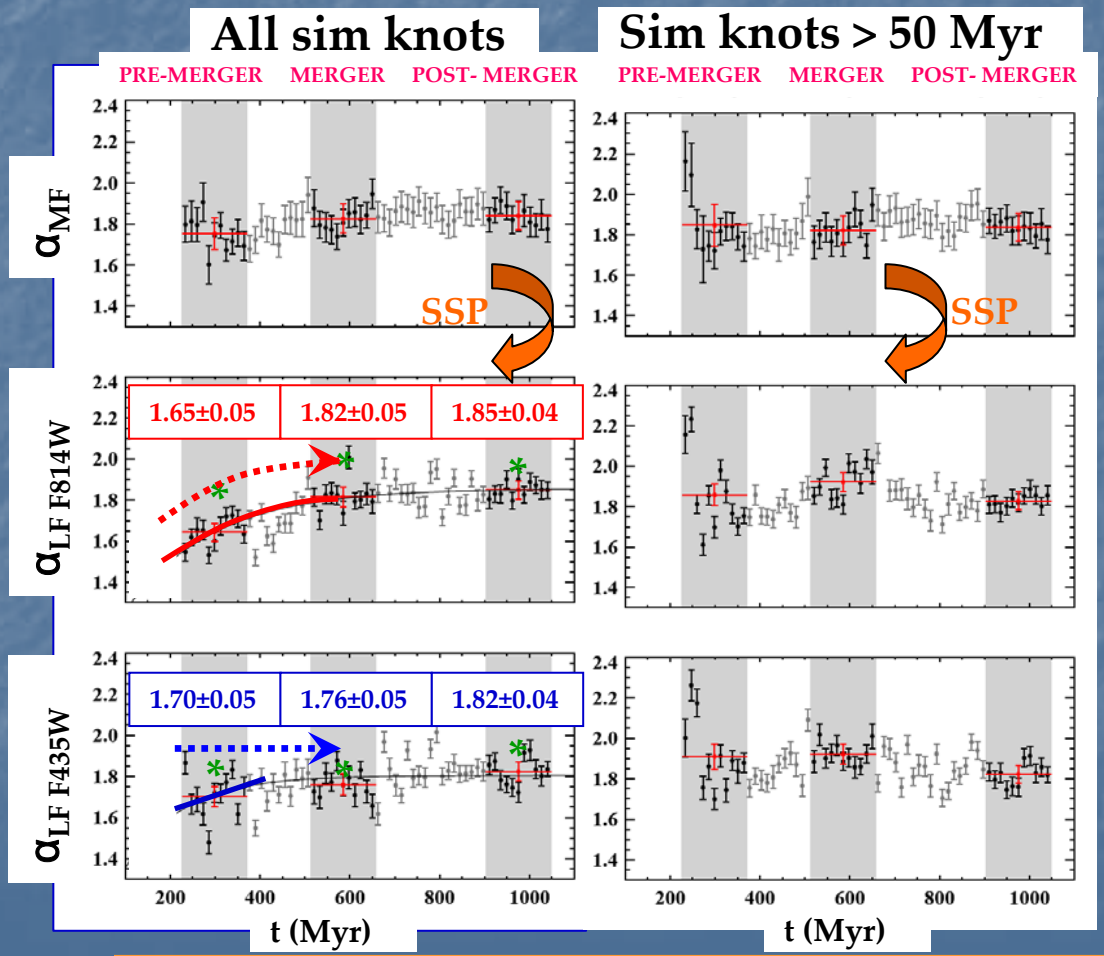
- Though, tendency of evolution of the slope of the LF

Properties as a function of interaction phase

- **Simulation of a wet merger** **(Bournaud et al. 2008, MNRAS, 389, L8)**
  - ✓ Equal mass merger (total initial stellar mass of $2 \times 10^{11}\ M_{\odot}$)
  - ✓ Linear resolution of 32 pc
  - ✓ Mass resolution of $\sim 10^{5}\ M_{\odot}$
  - ✓ Gas fraction 17 %

Properties as a function of interaction phase

- **Simulation of a wet merger** (Bournaud et al. 2008, MNRAS, 389, L8)

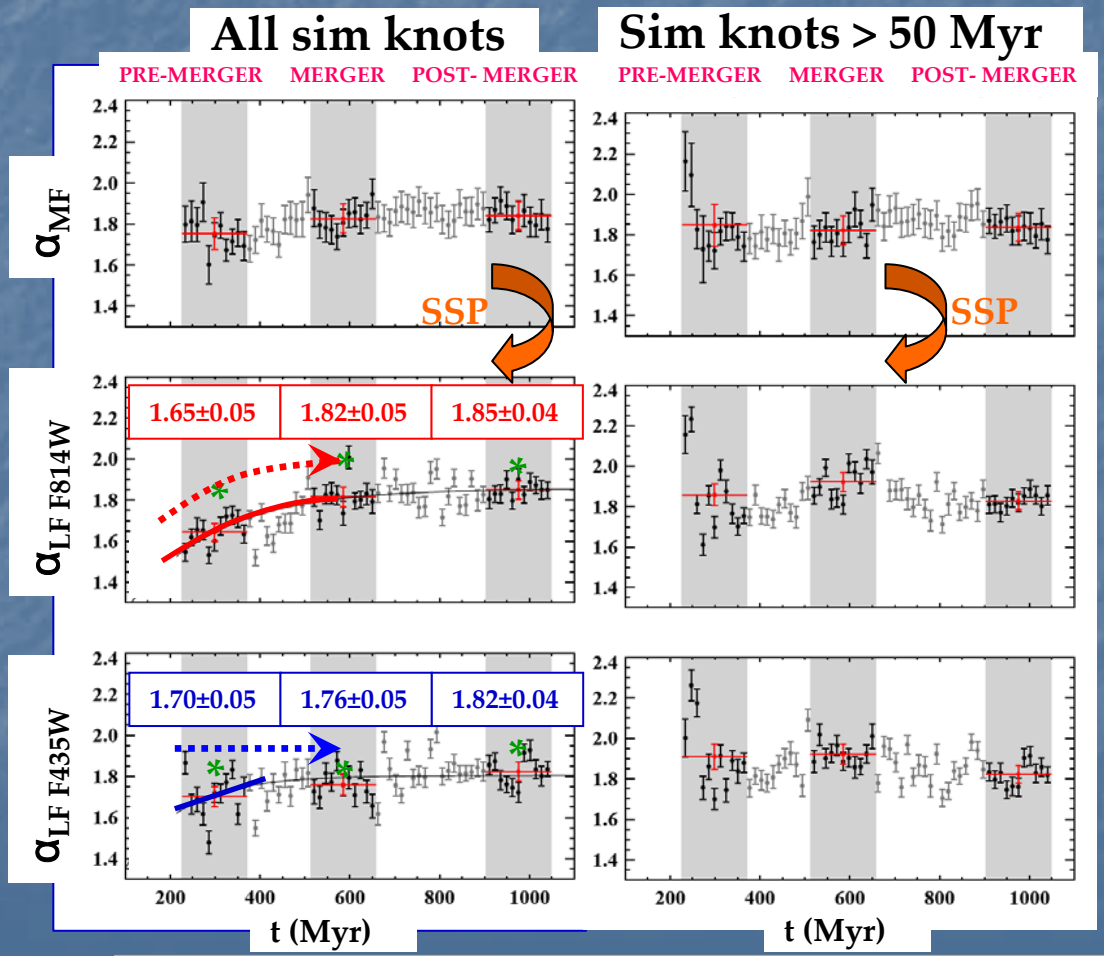


* Slight evolution of the slope of the LF of the red filter up to the merger phase

* Similar behavior than observed systems

Properties as a function of interaction phase

- **Simulation of a wet merger** (Bournaud et al. 2008, MNRAS, 389, L8)



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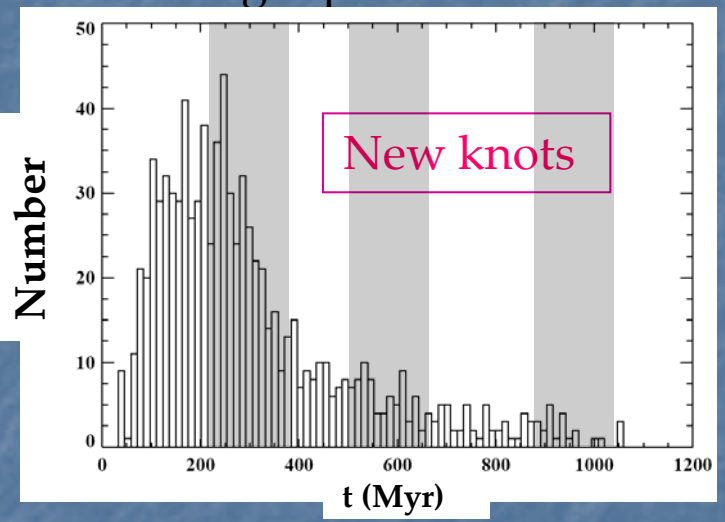

- Higher knot formation rate at early phases

Summary

- ✓ **Systematic photometric study of star forming regions (knots) in a representative sample of 32 low-z (U)LIRGs as extremely luminous starbursts in extreme interactions**
- ✓ **Knots have similar colors than clusters in less luminous interacting galaxies. Few of them redder (i.e lager internal extinction)**
- ✓ **L_{IR} dependence of the properties of the knots: increase in density of clusters and/or their mass as a function of the L_{IR} of the system**
- ✓ **Possible evidence of dynamical evolution of the knots with the interaction: kroupa scenario in (U)LIRGs?**
- ✓ **Slight evolution of the slope of the LF with the interaction: significant contribution of young**