Star formation efficiency in galaxy interactions and mergers: a numerical study

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The GalMer Project

Simulations of Galaxy mergers

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Aims:

 simulating galaxy collisions,

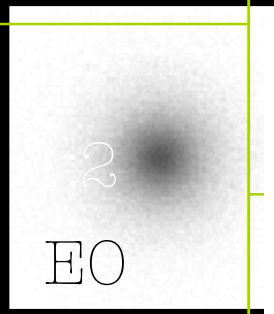
including star formation and metal enrichment

 thousands of galaxy encounters

(varying galaxy Hubble types, mass ratios, orbital parameters)

Library of simulations

Morph	Mass ratios	Inclination	E_{orb} *	R_{per} *	Spin
E0-E0					
E0-Sa	1:1	0°			
E0-Sb					
E0-Sd					
Sa-Sa					
Sa-Sb					
Sa-Sd					
Sb-Sb	1:10				ret
Sb-Sd		90°			
Sd-Sd					

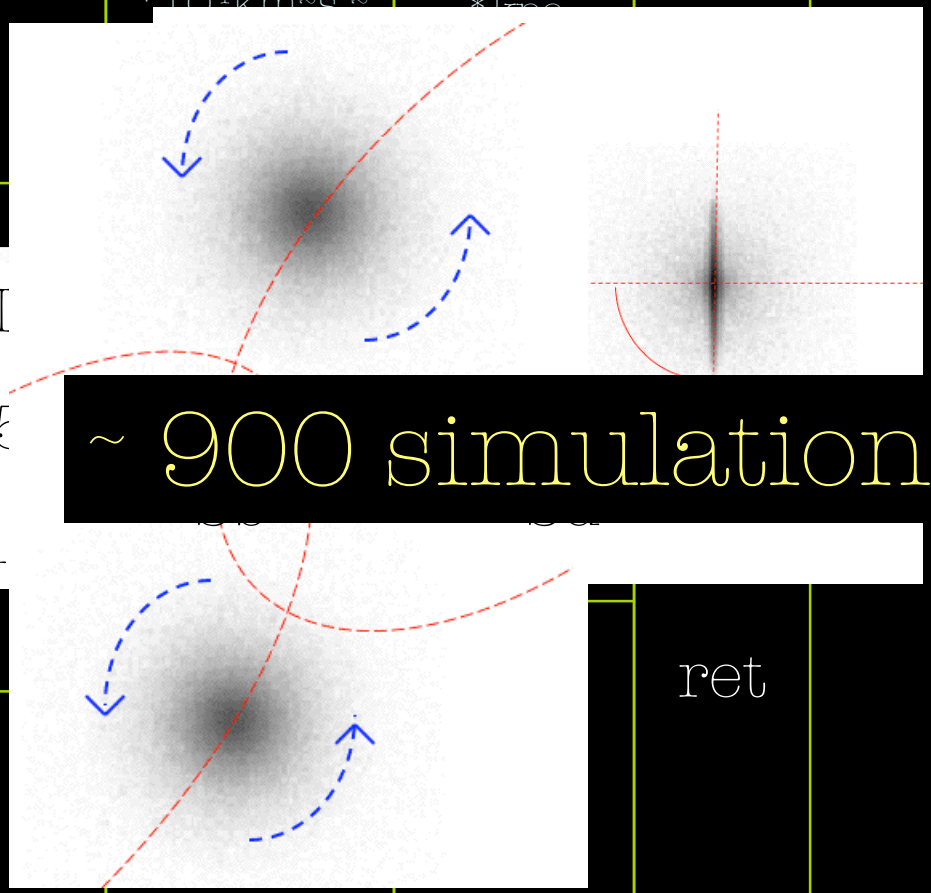


$M_1 = M$

$M_1 = 0.5$

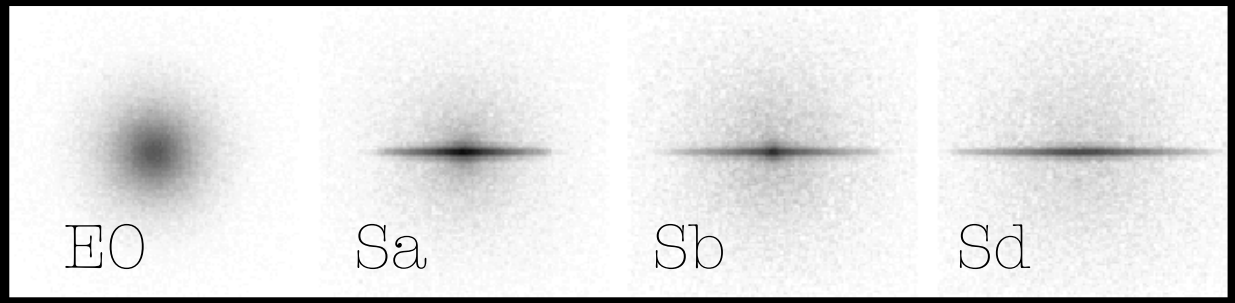
Sa

$M_1 = 0.1$



~ 900 simulations

An Hubble sequence for giant galaxies



Each galaxy is modeled by N=120000 particules, distributed among stars, gas and dark matter

Evolution pour 3 Gyr

	gE0	gSa	gSb	gSd
M_B $[2.3 \times 10^9 M_\odot]$	70	10	5	0
M_H $[2.3 \times 10^9 M_\odot]$	30	50	75	75
M_* $[2.3 \times 10^9 M_\odot]$	0	40	20	25
M_g/M_*	0	0.1	0.2	0.3
r_B [kpc]	4	2	1	–
r_H [kpc]	7	10	12	15
a_* [kpc]	–	4	5	6
h_* [kpc]	–	0.5	0.5	0.5
a_g [kpc]	–	5	6	7
h_g [kpc]	–	0.2	0.2	0.2

Numerical methods

TREE-SPH

Star formation,

Schmidt law

$$\frac{\dot{M}_{gas}}{M_{gas}} = C \times \rho_{gas}^{1/2}$$

Hybrid particules

Feedback:

"velocity kics"

+metal enrichment

Some questions:

- What is the relationship between galaxy interactions and star formation?

- Which are the parameters that determine the star formation rate during interactions?

- How do galaxies respond to tidal effects?

... and:

- What is the frequency of starburst episodes during interactions/mergers?

Question 1.

- What is the relationship between galaxy interactions and star formation?

- Which are the parameters that determine the star formation rate during interactions?

- How do galaxies react to tidal effects ?

Interactions and star formation

Luminous Infrared Galaxies $L_{IR} > 10^{11} L_{\odot}$:

The most luminous objects are all associated to gas rich galaxies in the last phases of an interaction

Sanders & Mirabel, 1996, ARA&A, 34, 749

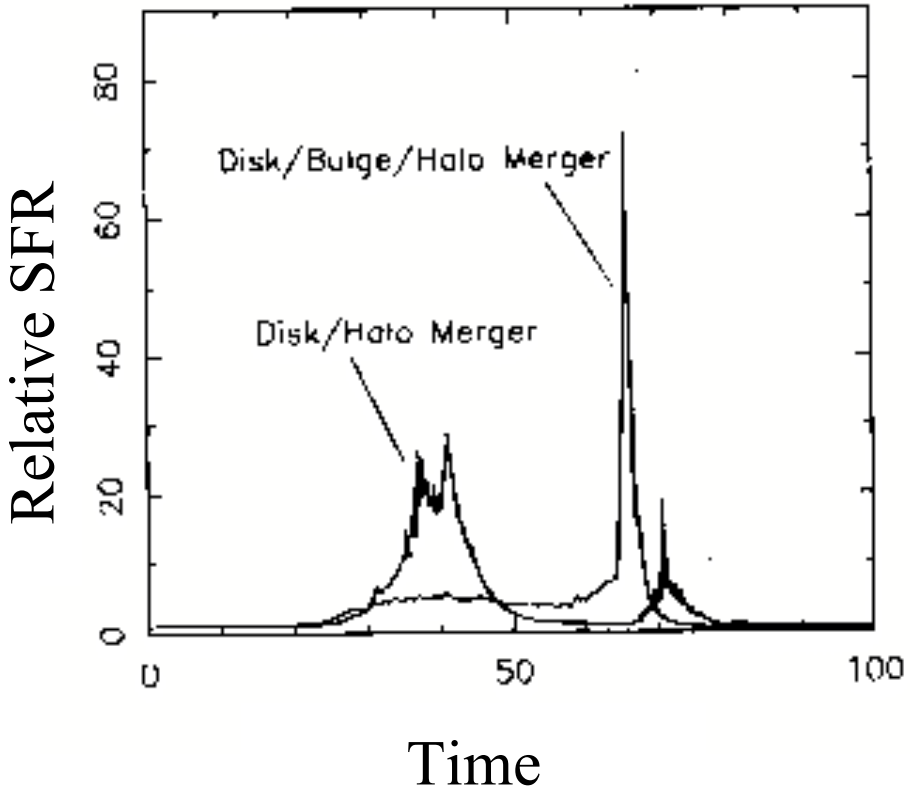
Javier Rodriguez's talk: Star forming histories in Ultraluminous Galaxies

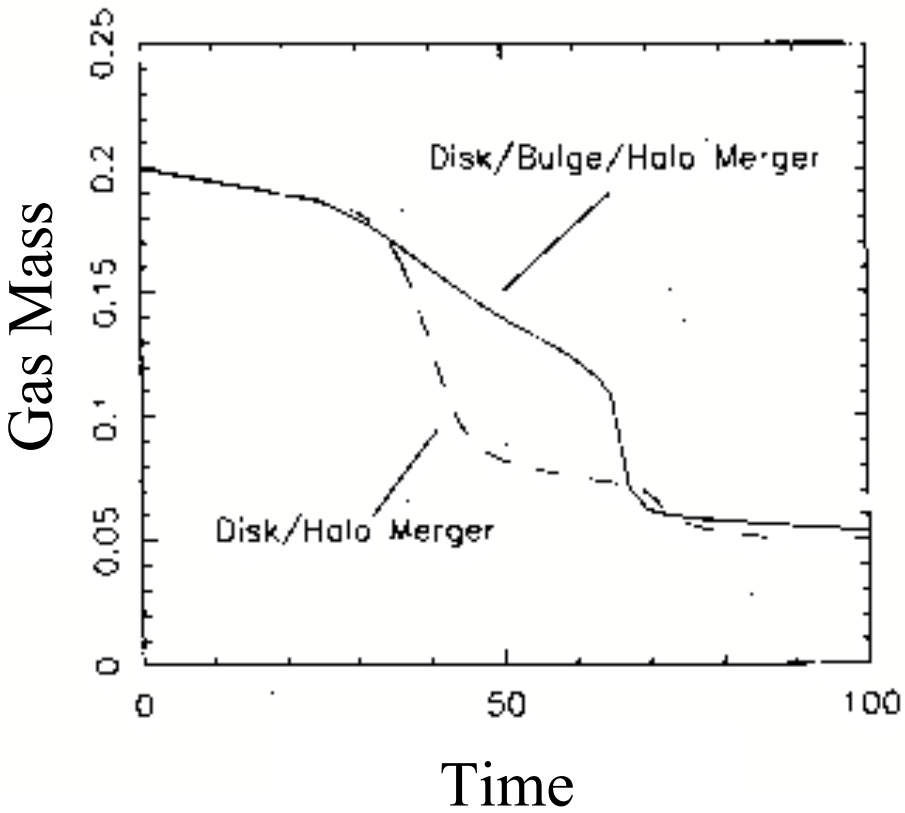
But,

Interacting galaxies that do not show high SFR enhancement (Bergvall et al., 2003, A&A, 405, 31)

Or star formation activity higher than in the past (Johan Knapen's talk)

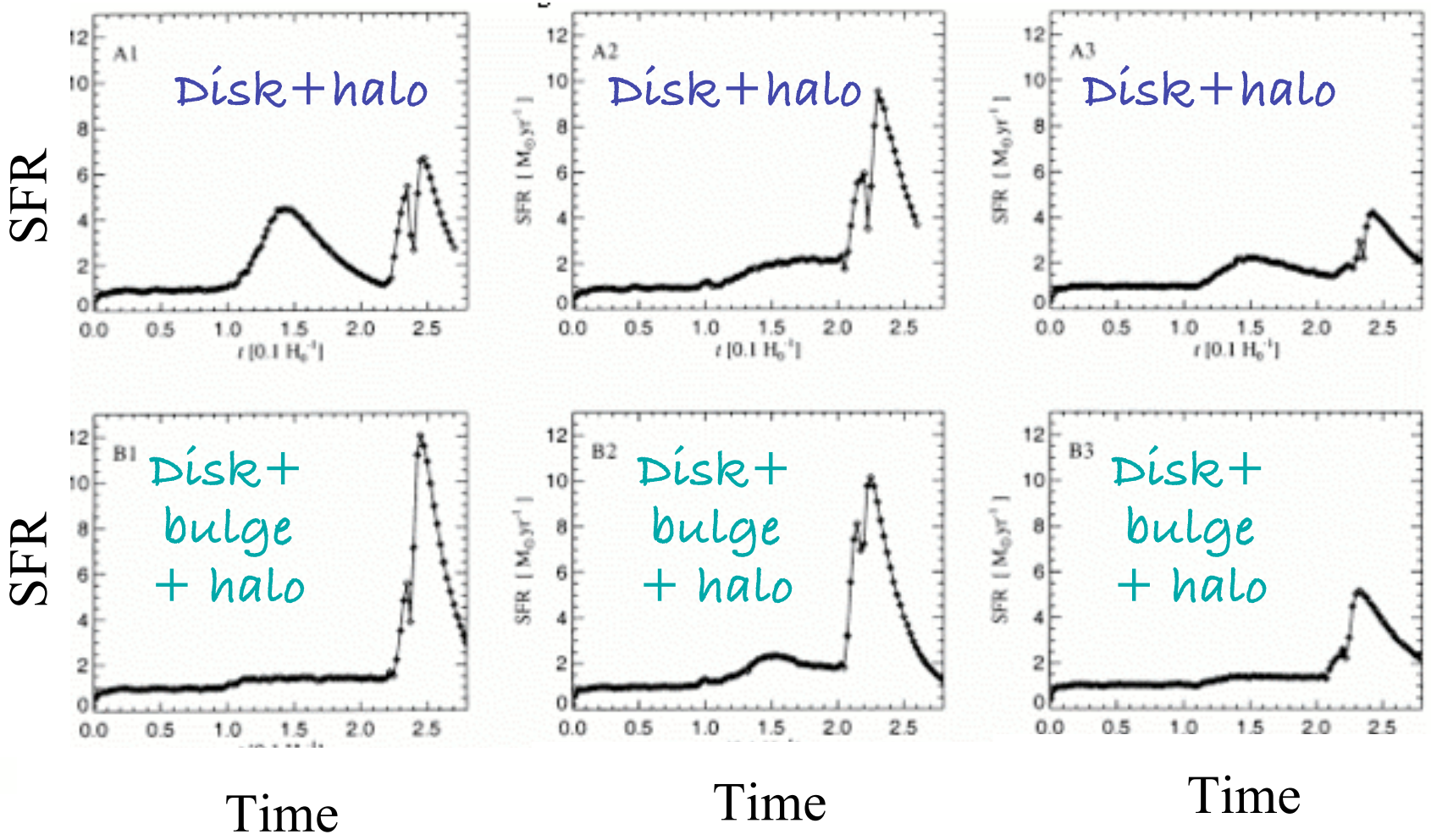
Interactions and star formation





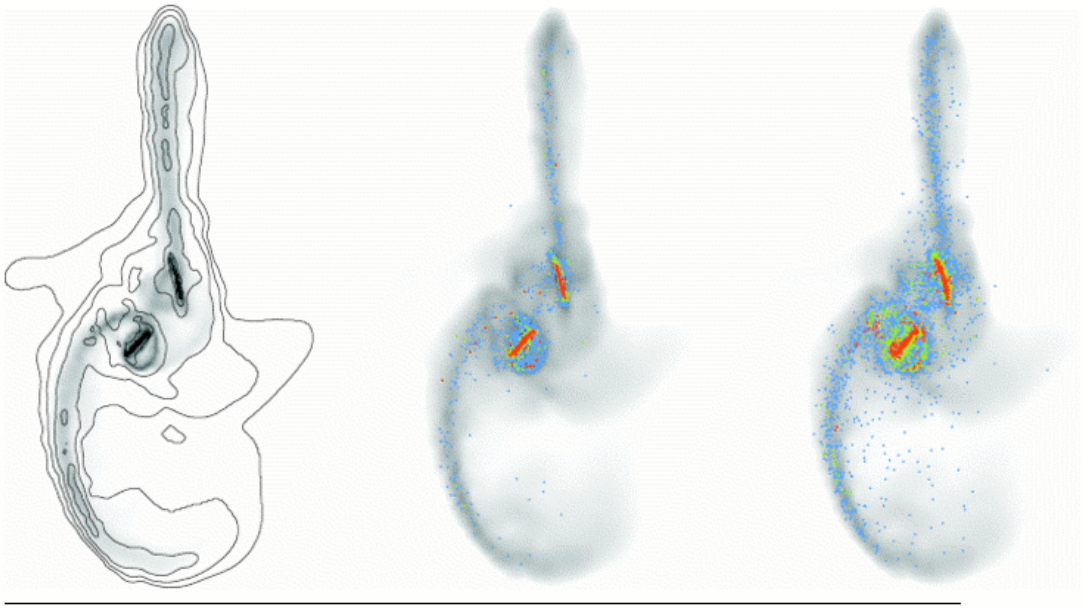
Mihos & Hernquist , 1994, ApJL, 431, 9

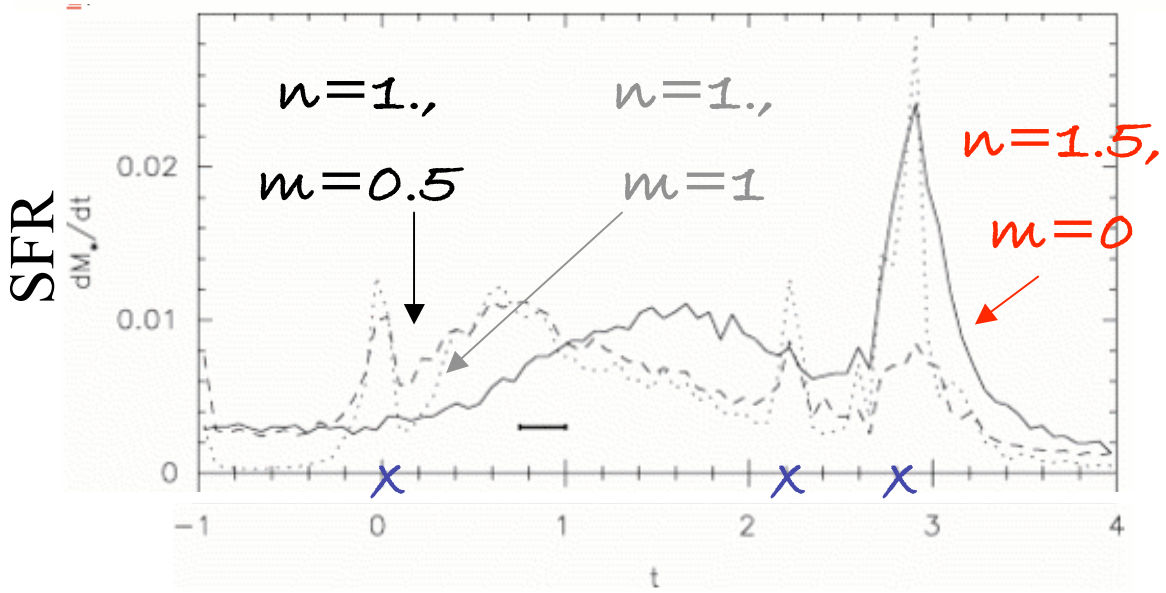
Interactions and star formation



Springel, 2000, MNRAS, 312, 859

Interactions and star formation





Comparison between different star formation laws

$$\rho_* = C_* \rho_g^{n} MAX(\dot{u},0)^{m}$$

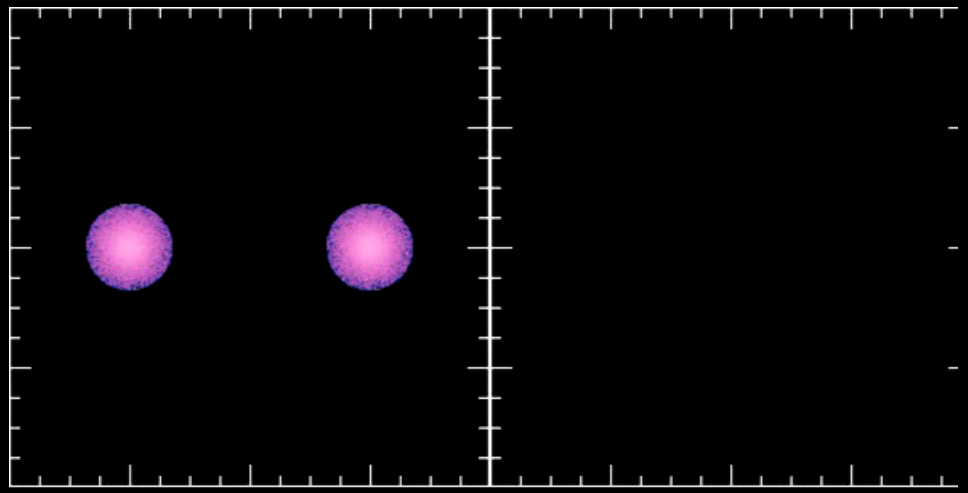
Barnes, 2004, MNRAS, 350, 798

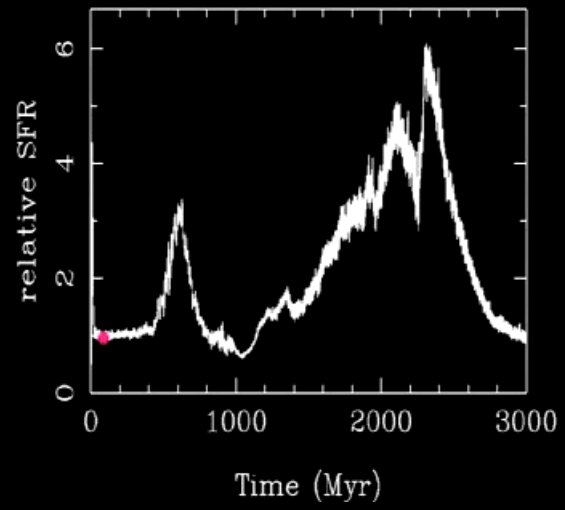
Interactions and star formation

Can the high number of simulations performed tell us something more or new on the relation between interations and star formation?

Interactions and star formation

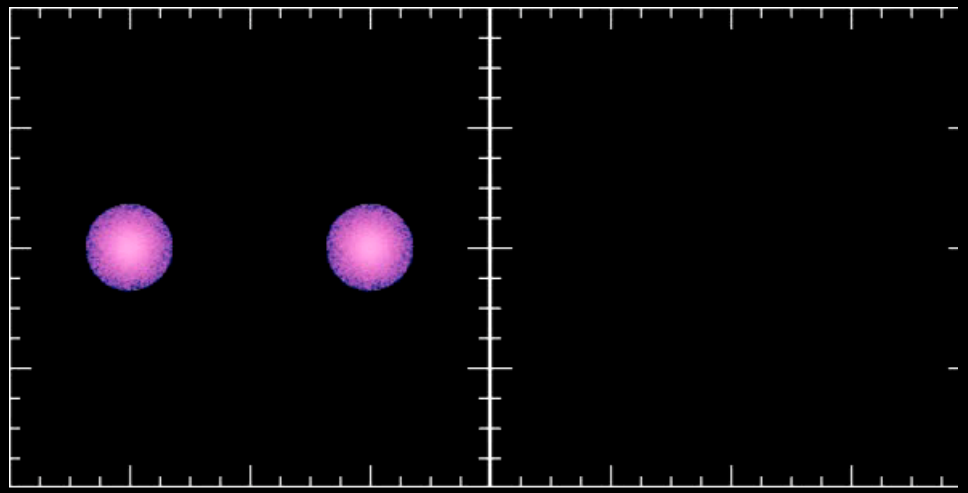
Two late-type galaxies on direct orbits

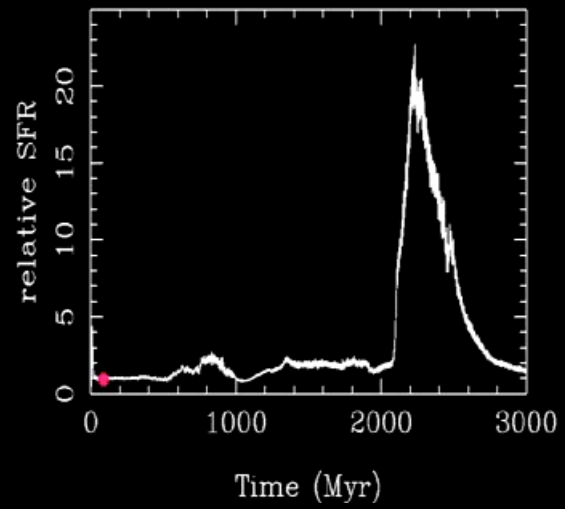




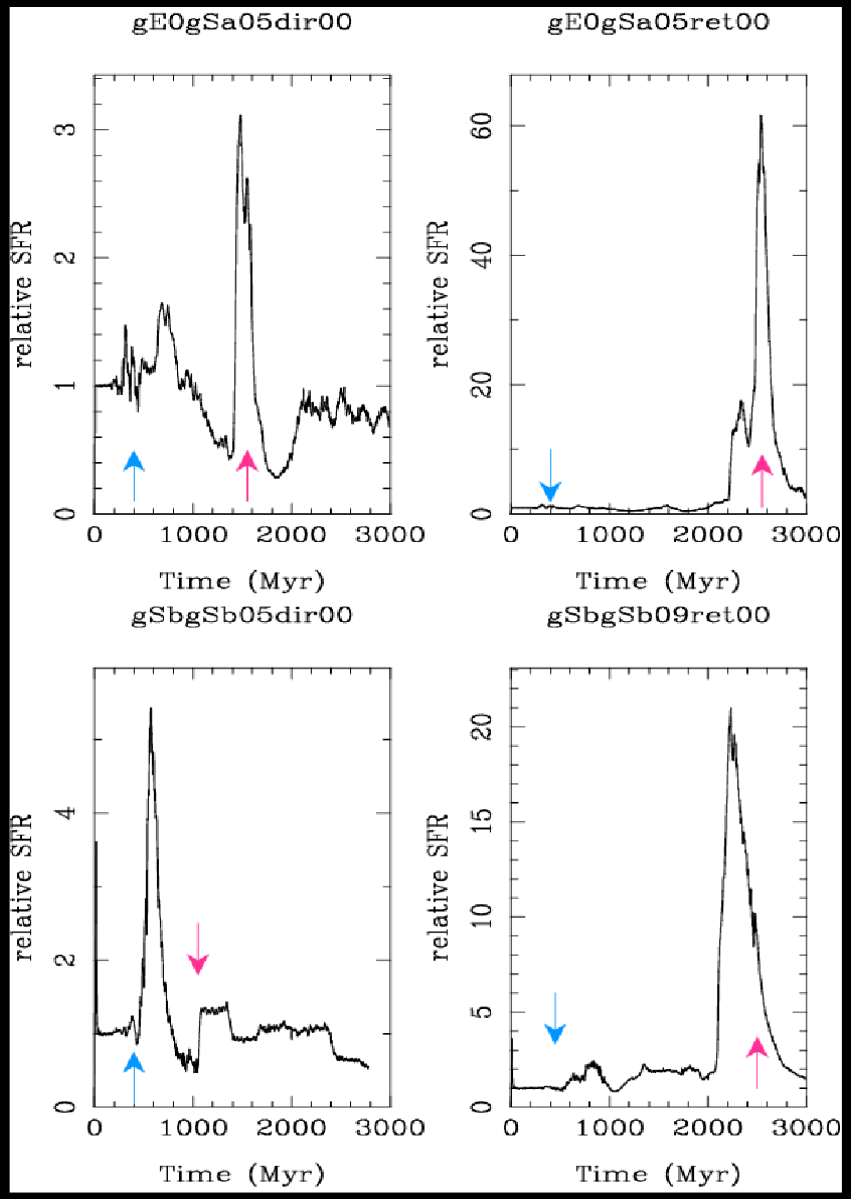
Interactions and star formation

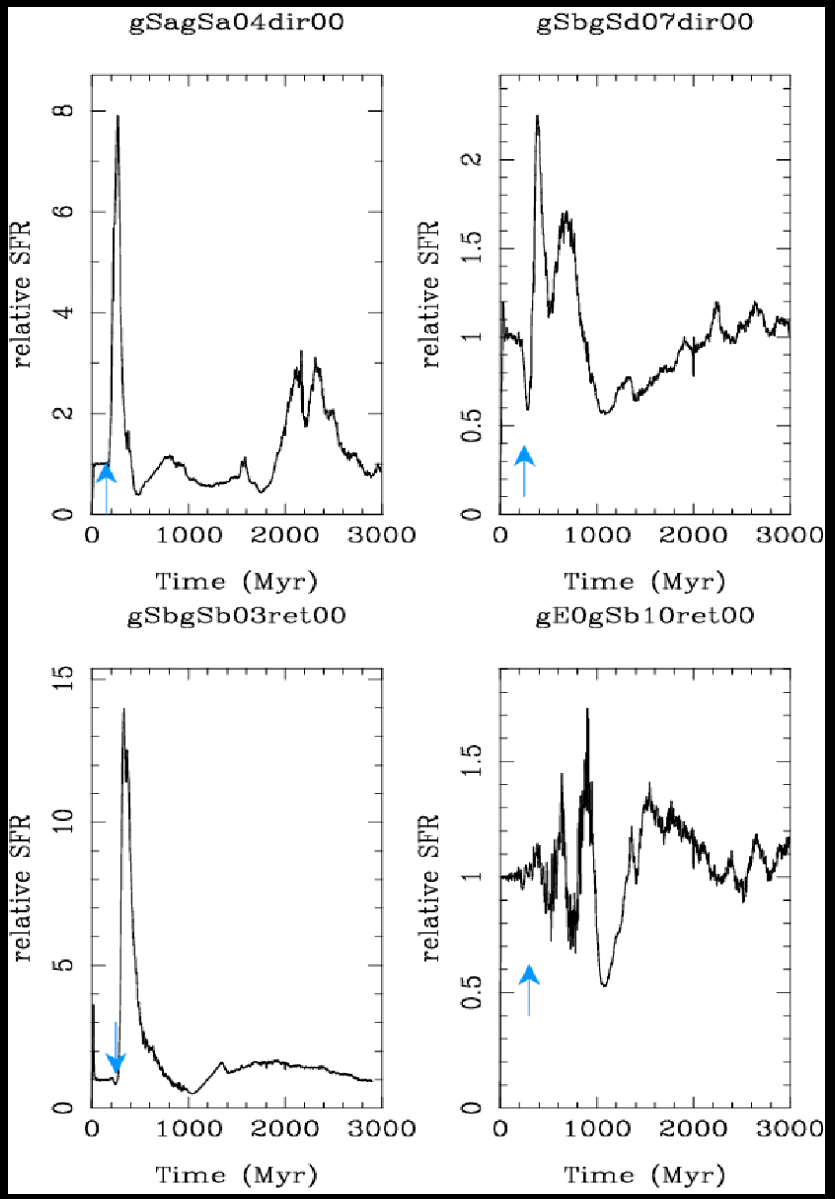
...and on retrograde orbits





Interactions and star formation





Question 2.

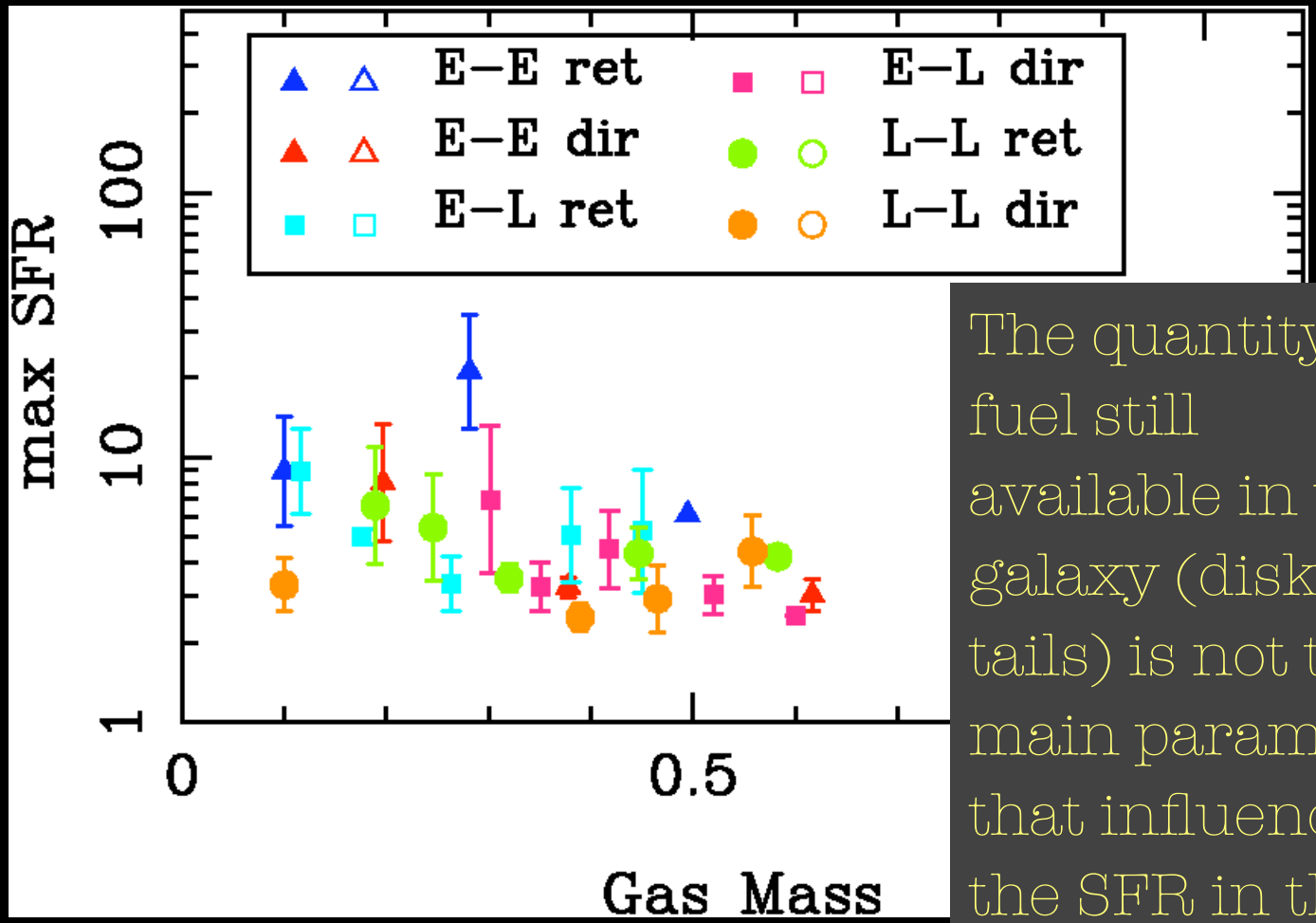
- What is the relationship between galaxy interactions and star formation?

- Which are the parameters that determine the star formation rate during interactions?

- How do galaxies react to tidal effects ?

How does the SFR depend on:

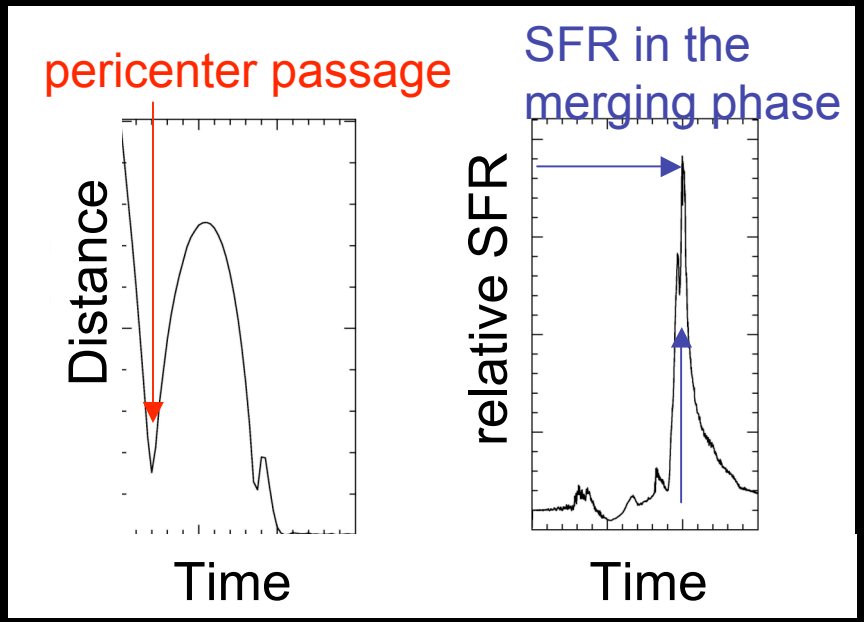
Total amount of gas available



The quantity of fuel still available in the galaxy (disk + tails) is not the main parameter that influences the SFR in the burst phase

How does the SFR depend on:

the effects of tidal forces



$$T_p = \log 10\left[\frac{M_{comp}}{M_i}\left(\frac{D}{R_p}\right)^3\right]$$

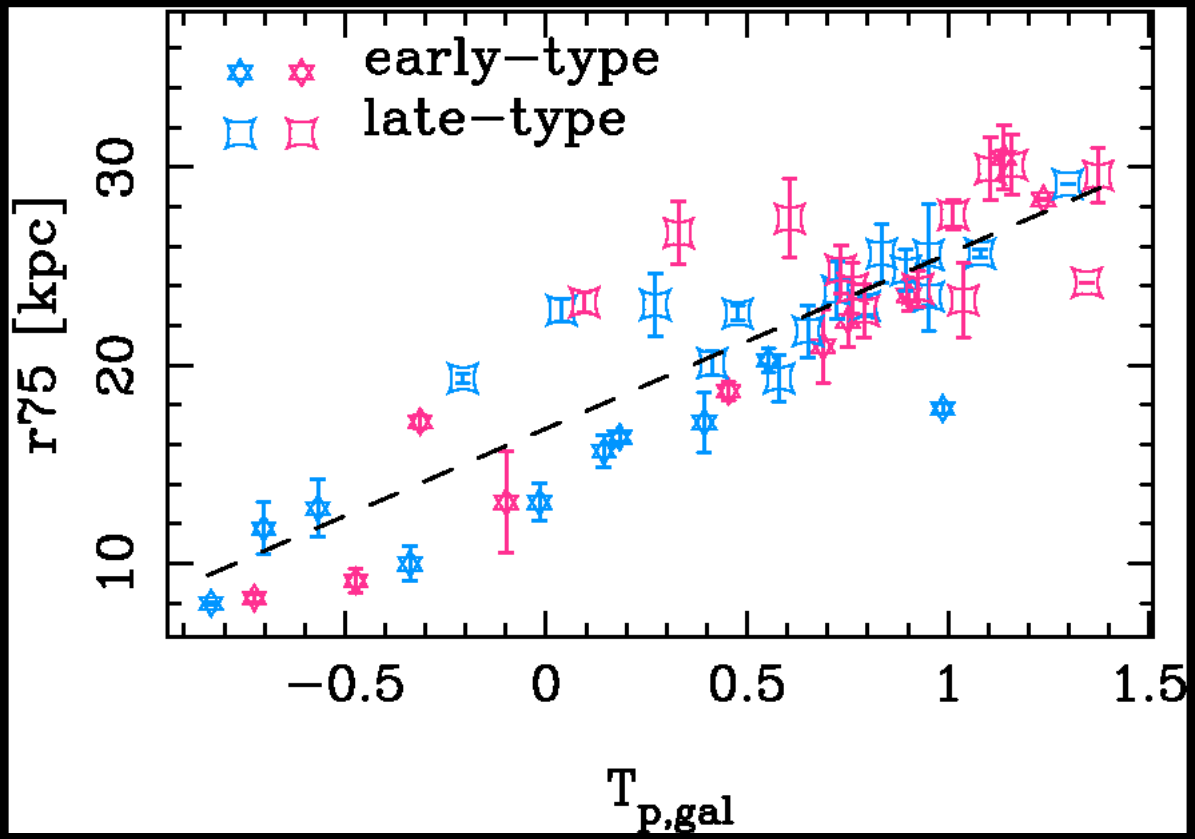
Question 3.

- What is the relationship between galaxy interactions and star formation?

- Which are the parameters that determine the star formation rate during interactions?

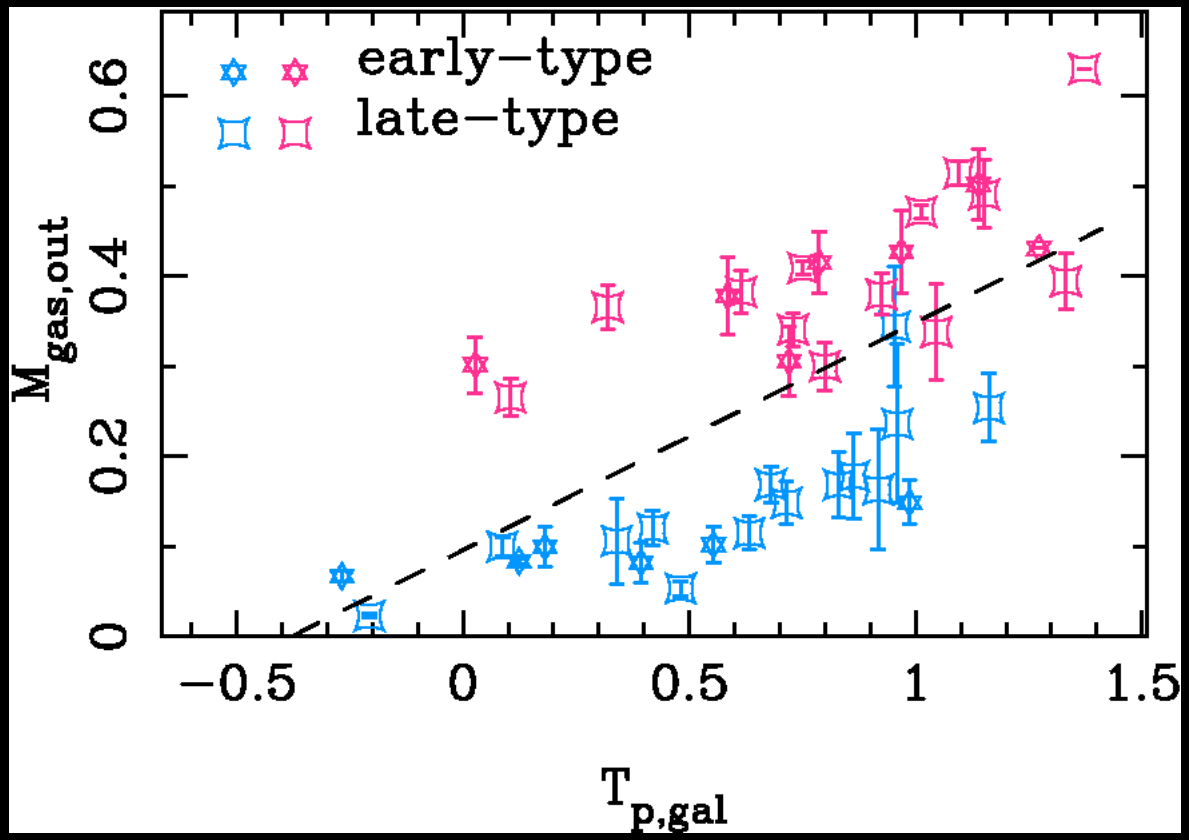
- How do galaxies respond to tidal effects ?

Tidal effects



The strongest the interaction at the pericentre passage, the greatest the subsequent expansion of the system

Tidal effects



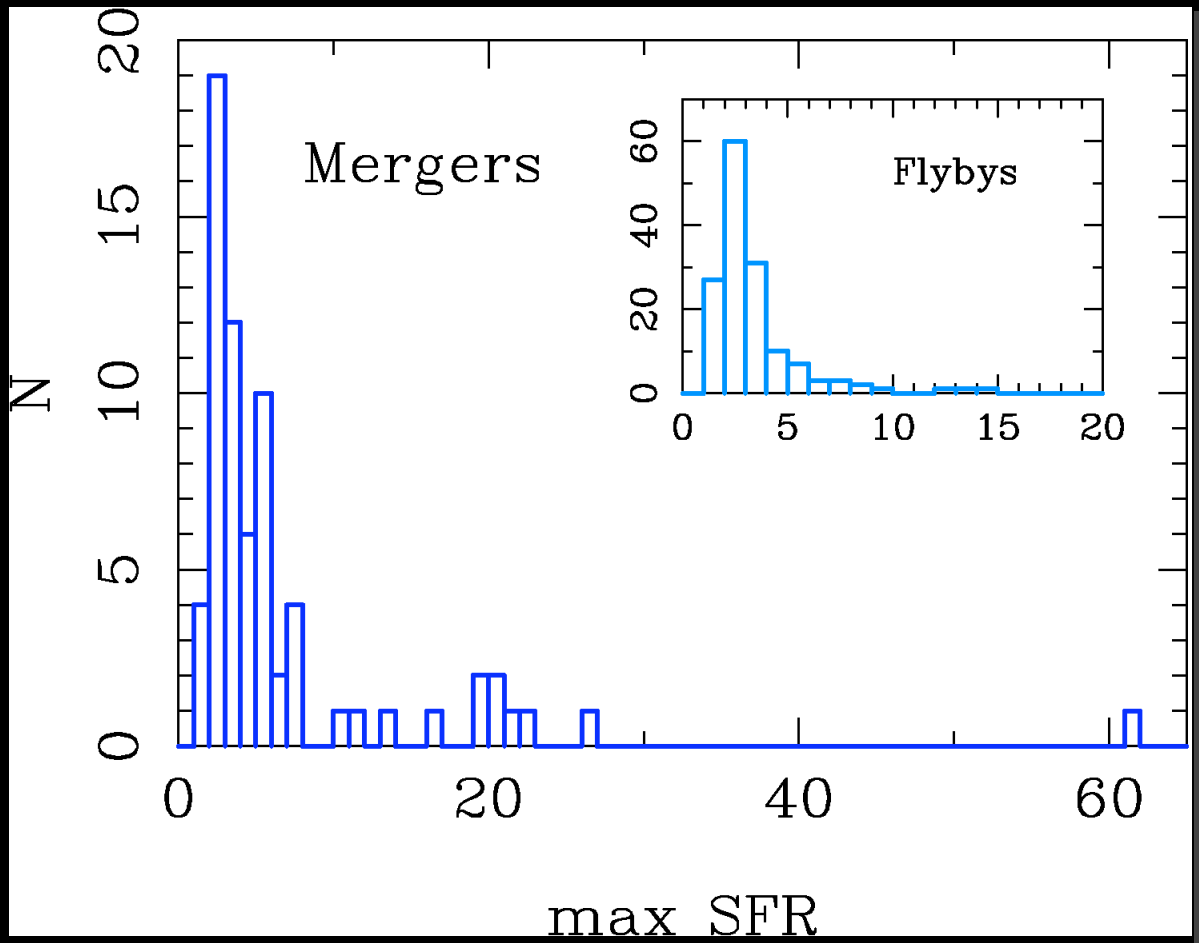
The strongest the interaction at the pericenter passage, the greatest the gas amount ejected from the disk

Different behaviour for direct and retrograde orbits

Question 4.

- What is the frequency of starburst episodes during interactions/mergers?

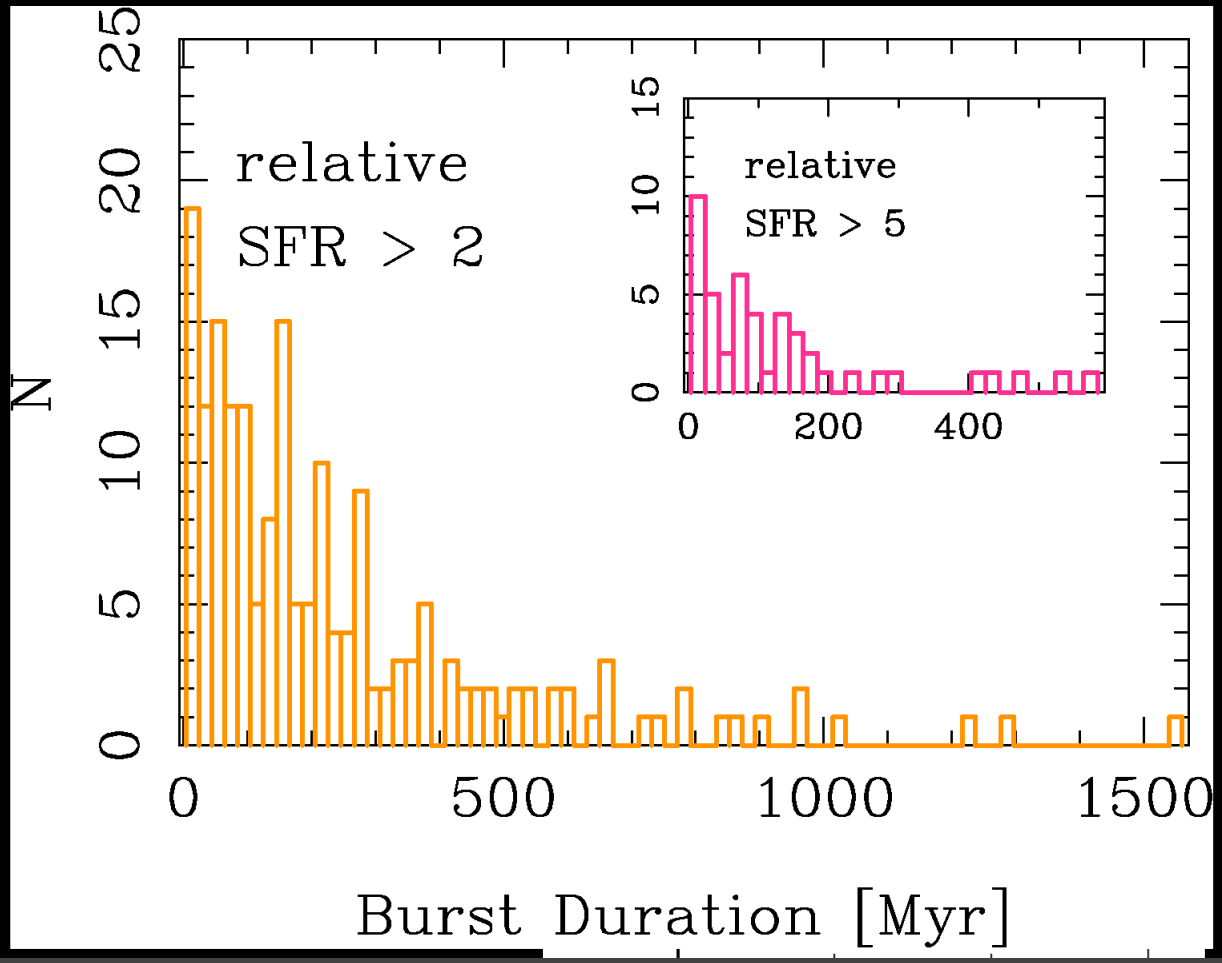
Starburst frequence



17% of the merger sample has a SFR at least 10 times greater than those of isolated galaxies, but 50% of the sample show only a moderate enhancement

Mergers are not always starburst triggers

Burst duration

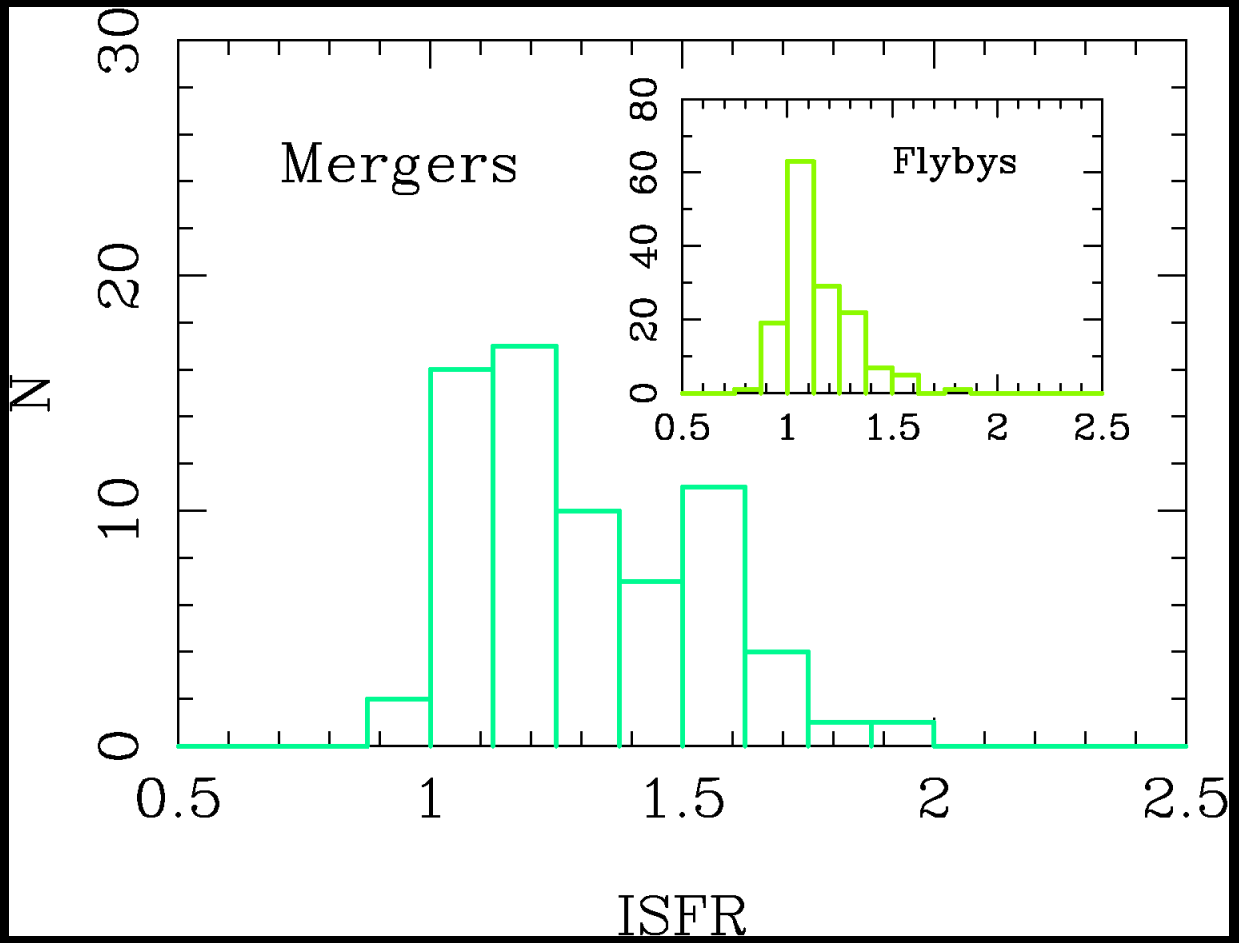


36% of the whole sample has SFR ≥ $2SFR_{iso}$ for T≥500 Myr.

But only 20% shows SFR ≥ $5SFR_{iso}$ for T≥200 Myr

High SFR not only less frequent but also characterized by the shortest duration times

Integrated star formation rate



$$ISFR = \frac{\int_{t=0}^{t=3Gyr} SFR(t)dt}{\int_{t=0}^{t=3Gyr} SFR_{iso}(t)dt}$$

Interactions do not always convert high mass quantities into new stars

Conclusions

Previuos numerical investigations partially confirmed: major galaxy interactions CAN trigger strong nuclear starbursts,

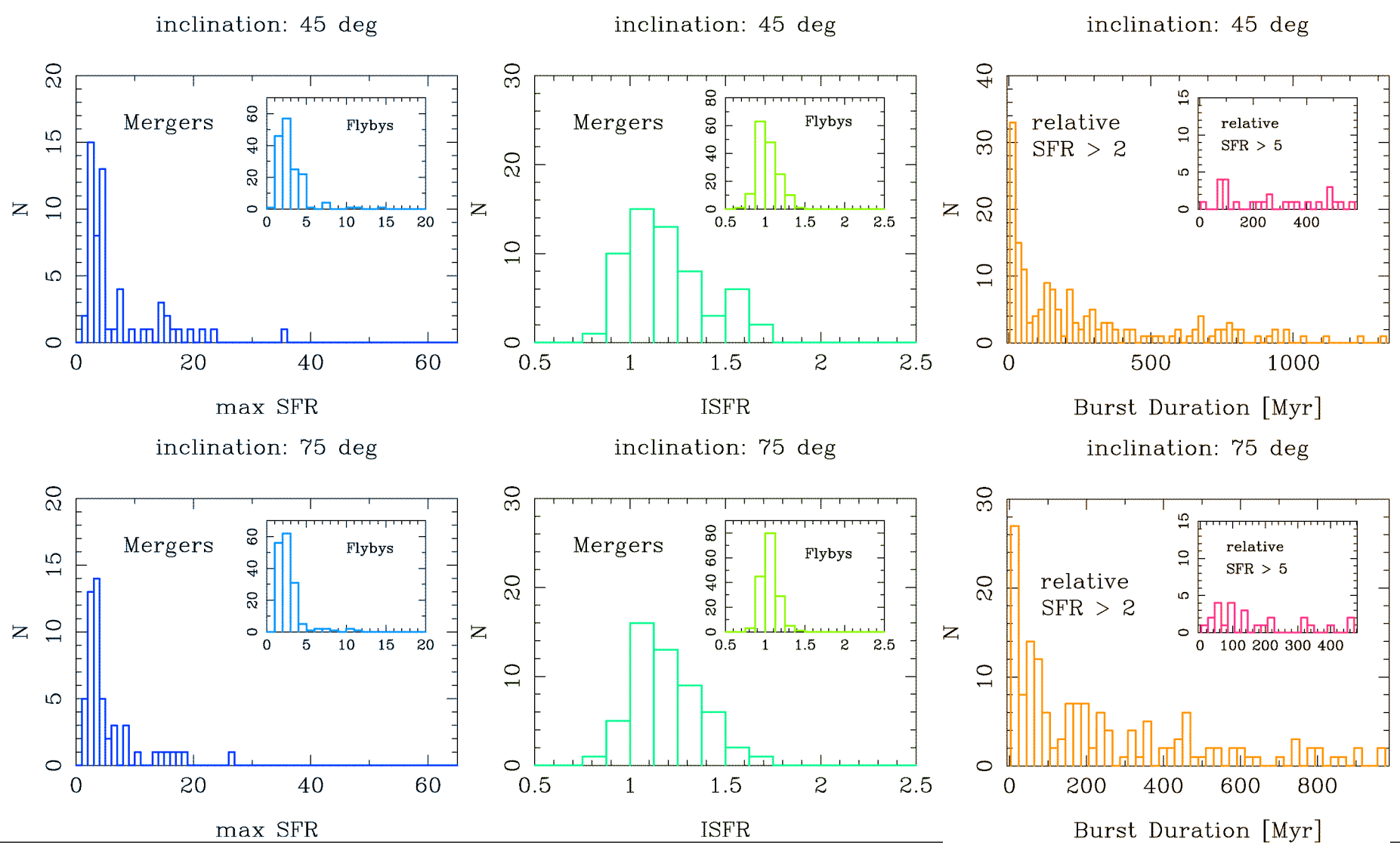
BUT

MERGERS are NOT ALWAYS STARBURST TRIGGERS and GALAXY INTERACTIONS DO NOT ALWAYS CONVERT LARGE QUANTITIES OF GAS MASS INTO NEW STARS

Di Matteo, P., Combes, F., Melchior A.L., Semelin, B. 2007, A&A, 468, 61

What's going on now…

Varying disk inclinations (216+432=648 simulations)



What's going on now…

* Compare these results with those obtained adopting different numerical codes and different star formation recipes (with F. Bournaud and M. Martig, CEA, Saclay, France): it seems promising.....

* How the results depend on the fraction of gas mass available in the disk?