

Interactions and star formation



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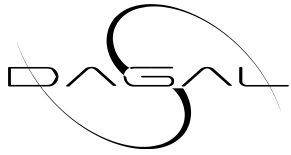
Mauricio Cisternas (IAC)
Miguel Querejeta (MPIA)

EWASS, Tenerife
22 June 2015



Galaxy interactions

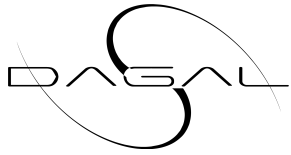
- ◆ Many galaxies interact, practically all galaxies have close neighbours (e.g., Milky Way: Magellanic Clouds)
- ◆ Interactions can stimulate enhanced star formation, particularly in extreme cases (e.g., ULIRGs)
- ◆ But do interactions, or the presence of a close companion, systematically and significantly increase the star formation rate (SFR), and/or the SFR per unit mass (specific SFR, SSFR, EW)?



SFR increase limited...

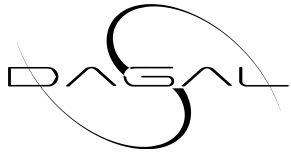


- ◆ Di Matteo et al. (2008) find from many simulations that SFR enhancement is only factor of a few, and lasts for a few hundred million years only
- ◆ This limited SFR increase is supported by many observational results, from Bushouse (1987) to the present day
- ◆ Knapen & James (2009 ApJ): SFR increased by factor of around 2 in presence of close companion – sample size only 300



SFR, SSFR, and EW

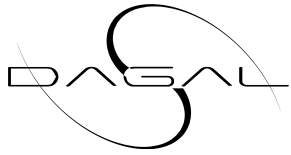
- ◆ SFR = Star Formation Rate, calculated from UV, $H\alpha$, or IR flux of whole galaxy
- ◆ *SFR measures current massive SF*
 - ◆ EW = Equivalent Width: $H\alpha$ flux normalized by continuum emission (R -band)
 - ◆ Specific SFR (SSFR) is SFR normalised by galaxy mass
- ◆ *EW & SSFR measure relative importance of SFR compared to galaxy mass*



S⁴G: many nearby galaxies



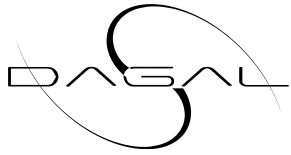
- ◆ Spitzer Survey of Stellar Structure in Galaxies (S⁴G) – imaging in 3.6 and 4.5 μ m for 3000 nearby galaxies (Sheth et al. 2010)
- ◆ Bright, big, nearby galaxies: $d < 40$ Mpc; $m_B < 15.5$; $D_{25} > 1.0$ arcmin
- ◆ Also obtained deep optical imaging, mostly from SDSS, for 2/3 of sample (Knapen et al. 2014)
- ◆ All data publicly available



Ingredients



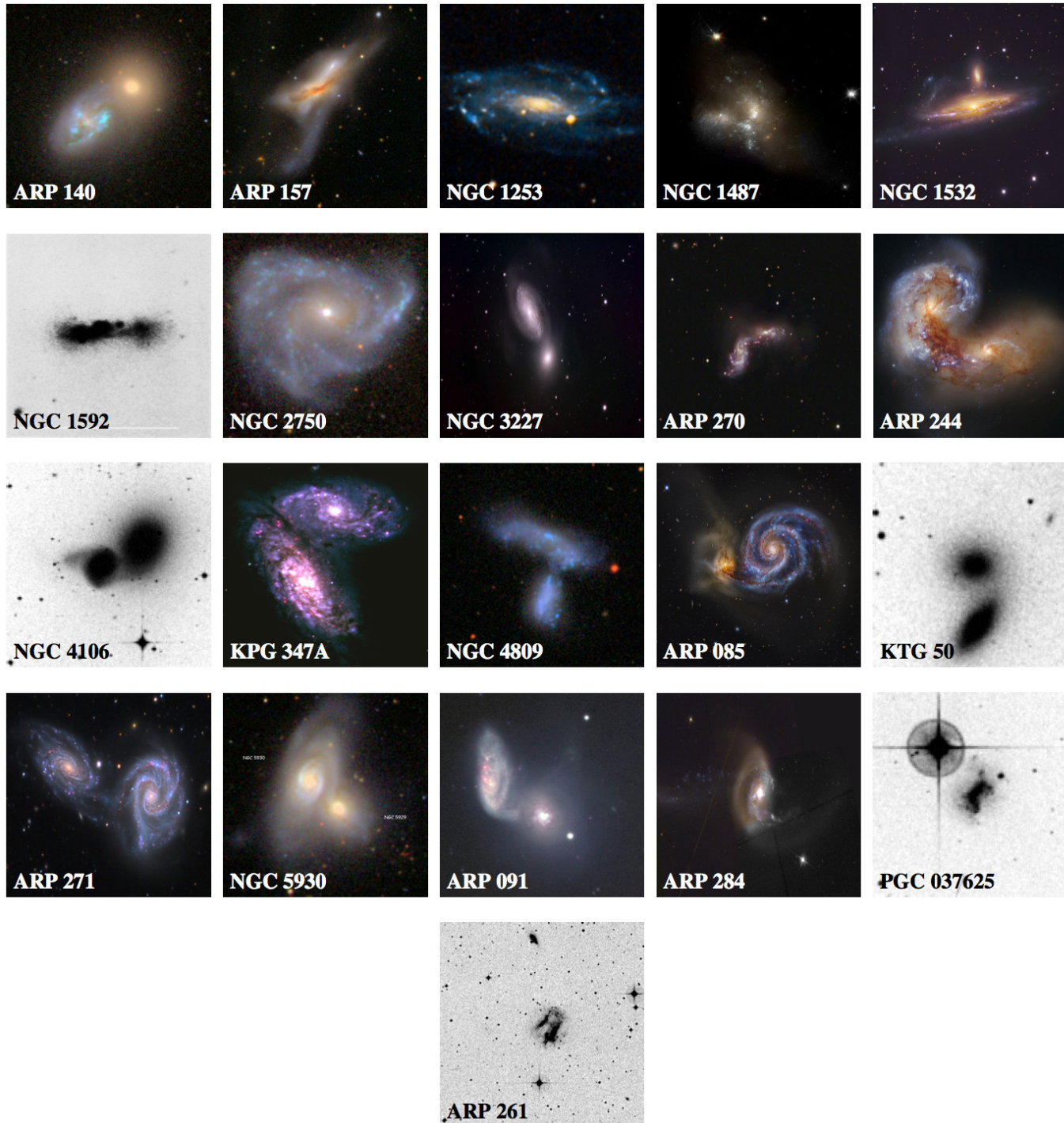
- ◆ Thanks to the S⁴G project, we can combine the following ingredients for 1500 galaxies:
 - ◆ Presence of companions and interaction class (Knapen et al. 2014 A&A, 569, 91)
 - ◆ SFR from IRAS 60 and 100 micron following Larsen & Richtler 2000 (Querejeta et al. 2015),
 $SSFR = SFR / \text{Mass}$
 - ◆ Stellar mass from 3.6 μm total magnitudes (corrected to be only from old stars, Querejeta et al. 2014) and $M/L=0.6$ from Meidt et al. (2014), see also Röck et al. 2015 MNRAS
 - ◆ Type from LEDA



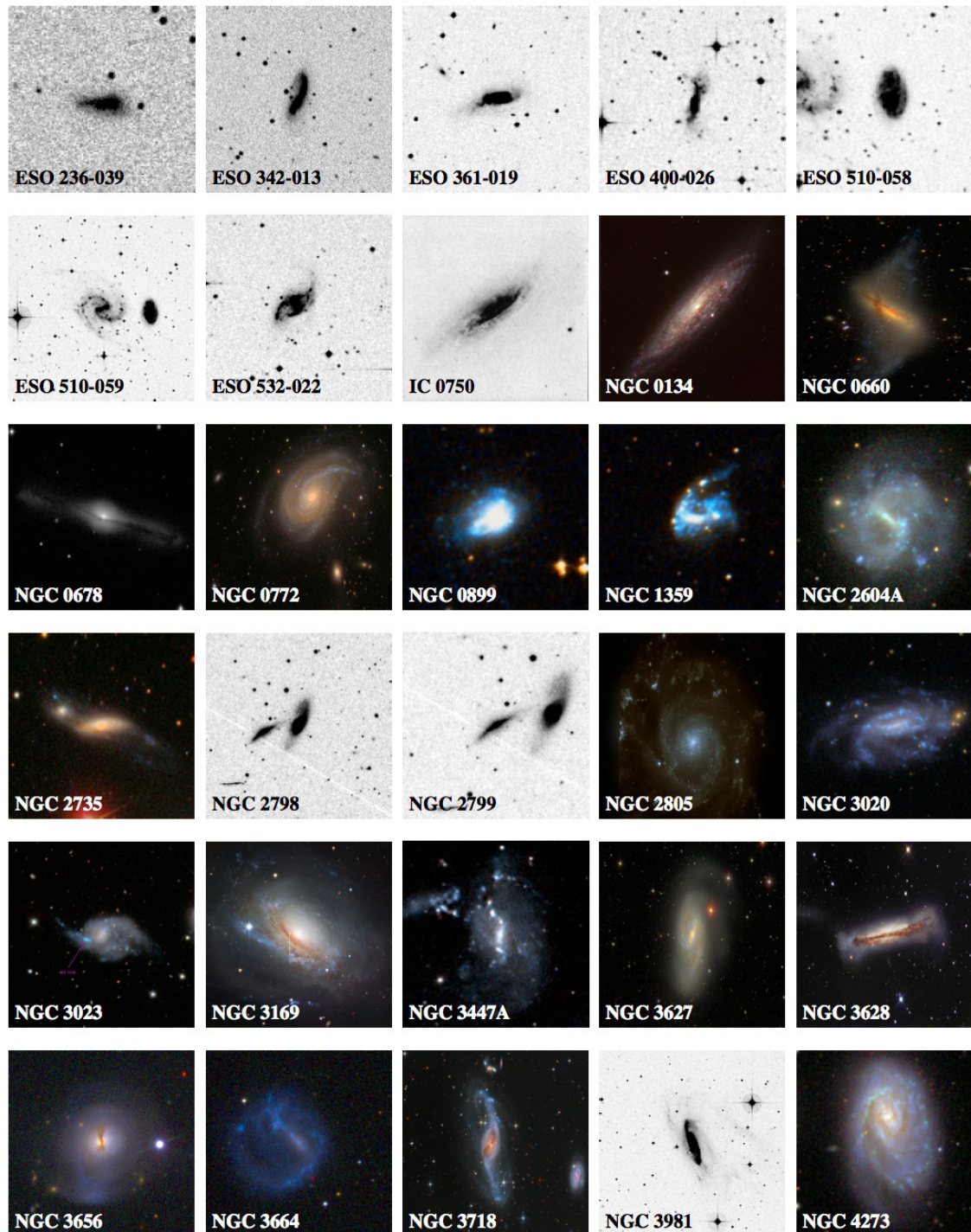
Interactions: 5 Classes

- ◆ A: Mergers: similar size, overlapping, very obviously interacting (16)
- ◆ B: Highly distorted: with morphological hallmarks as tidal arms, or gross distortions of the stellar disk (39)
- ◆ C: Relatively minor distortions of their disk, or minor tidal features (84)
- ◆ 0: Close companion: within 200 km/s in v ; 5 times diameter; and 3 mag (138)
- ◆ N: None of the above (control sample) (1201)

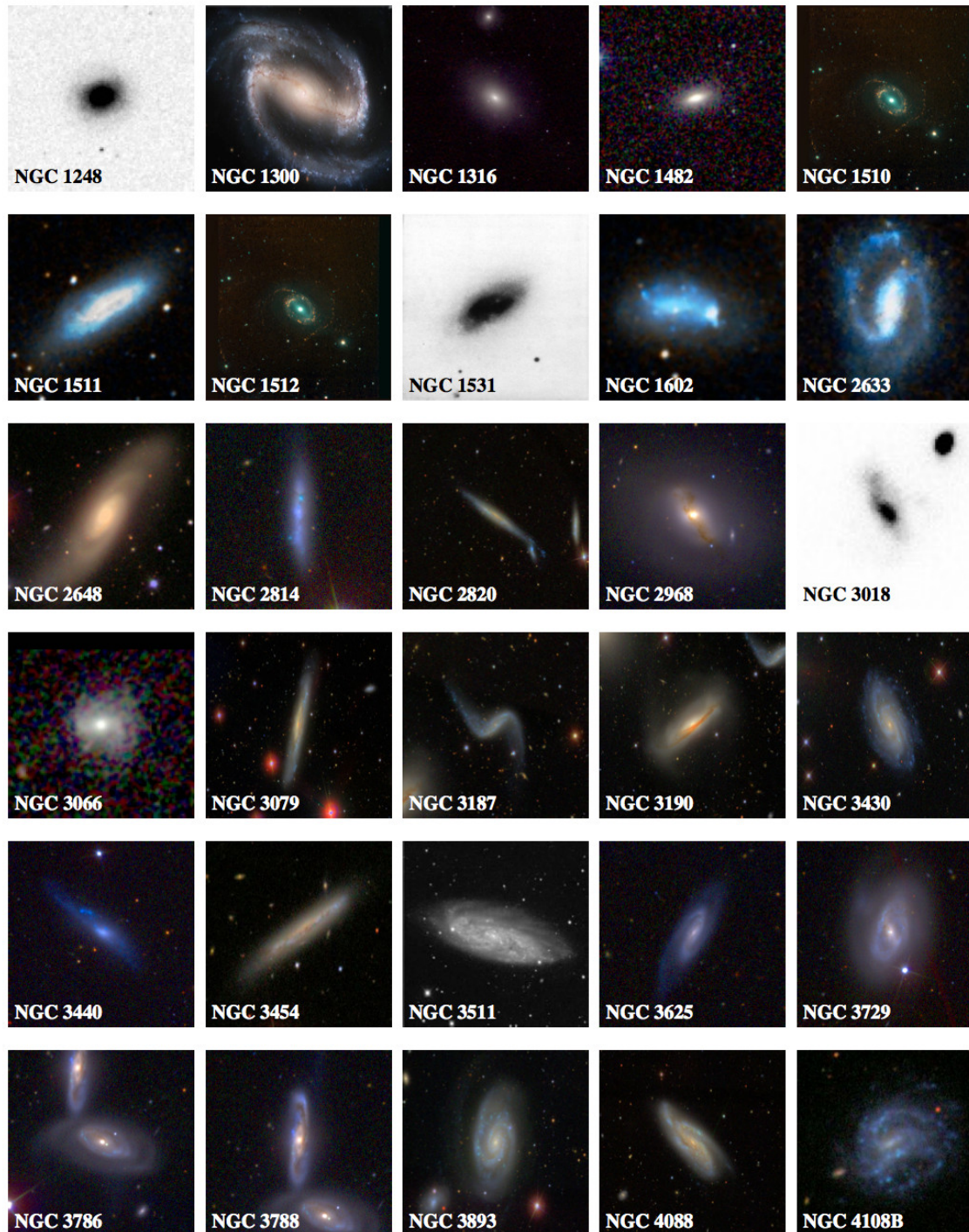
Knapen et al. 2014 A&A



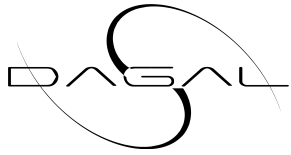
Class A
Knapen et al. 2014



Class B
Knapen et al. 2014



Class C
Knapen et al. 2014

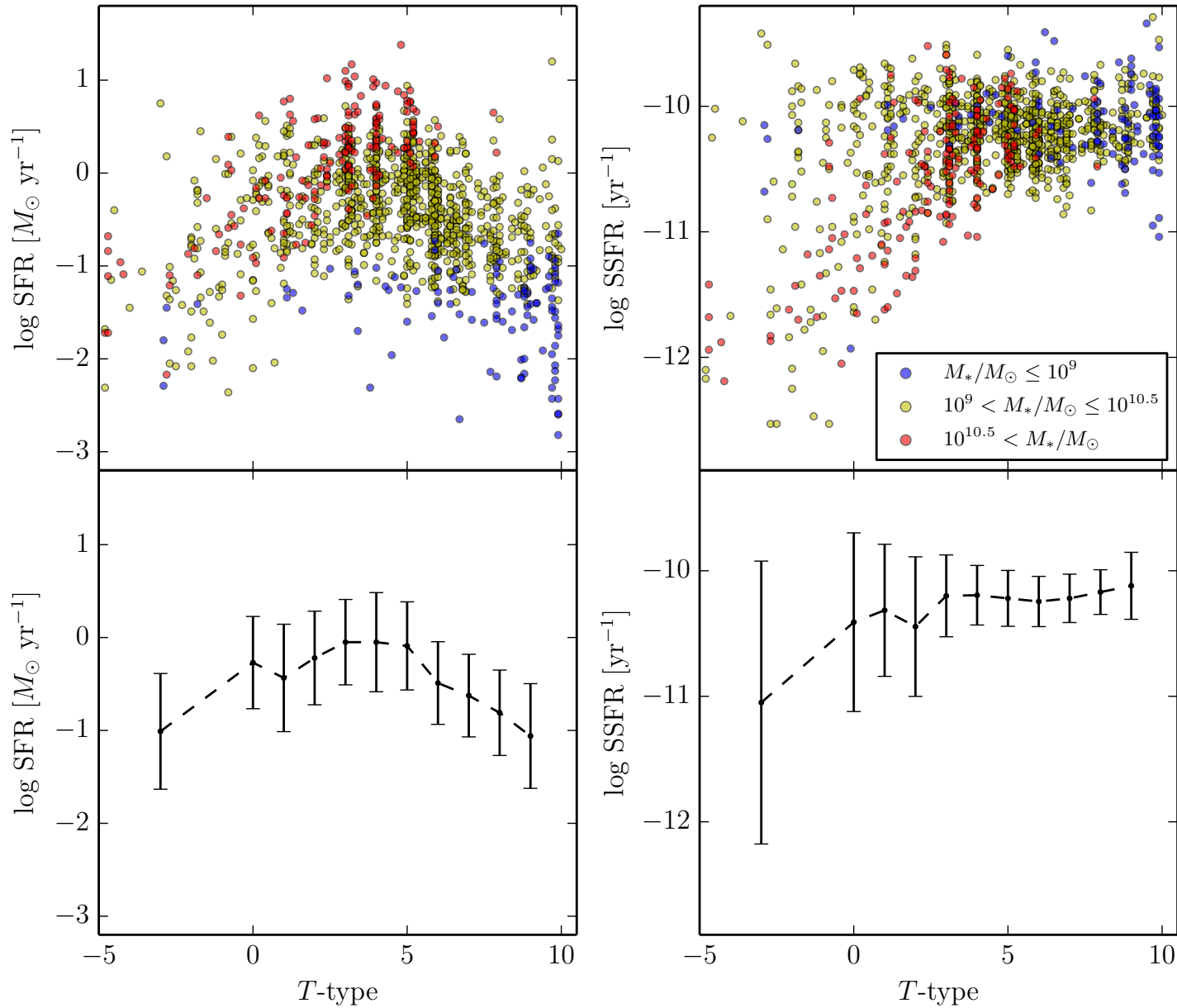


Important advances

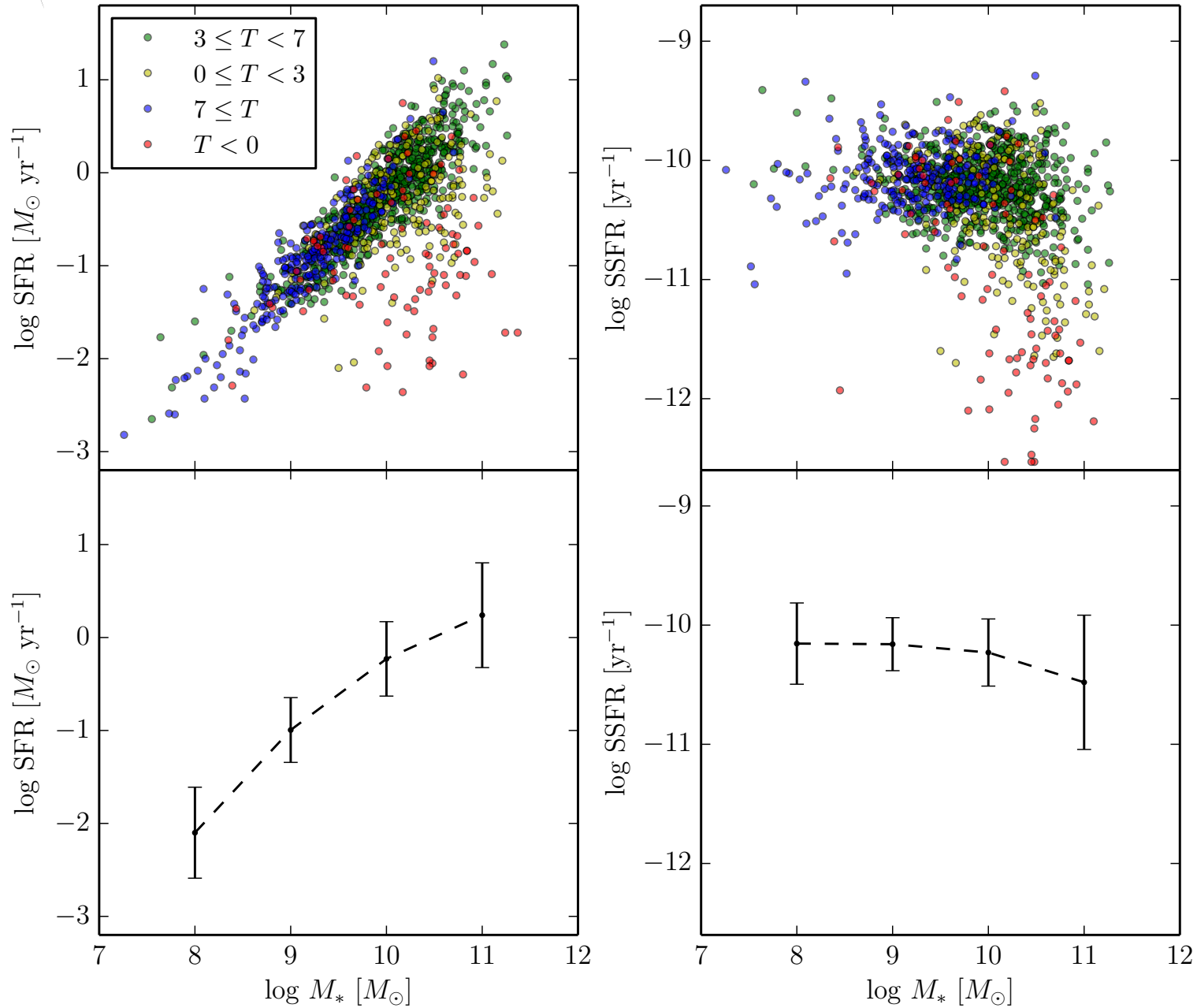


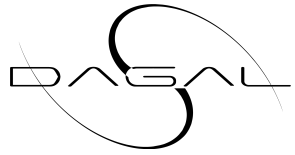
- ◆ High-quality imaging of nearby galaxies, which can be studied one by one and in detail
- ◆ Large sample of 1500 galaxies within some 40 Mpc
- ◆ Reliable SFR and stellar mass measurements
- ◆ Individual control samples: for each galaxy, all similar galaxies from control group

SFR and SSFR vs Type



SFR and SSFR vs Mass



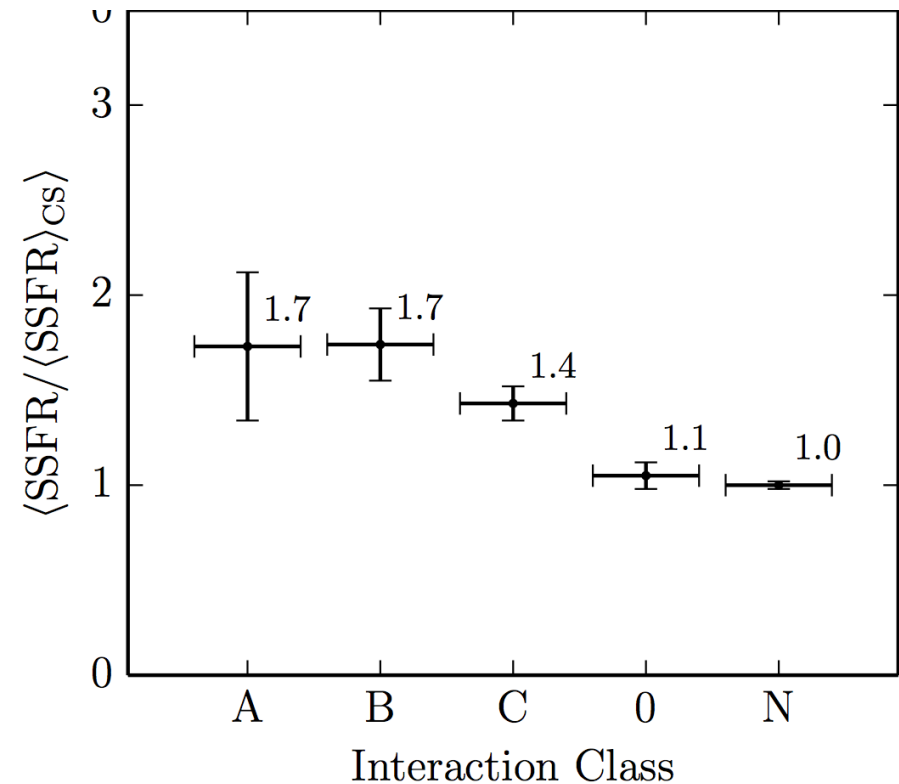
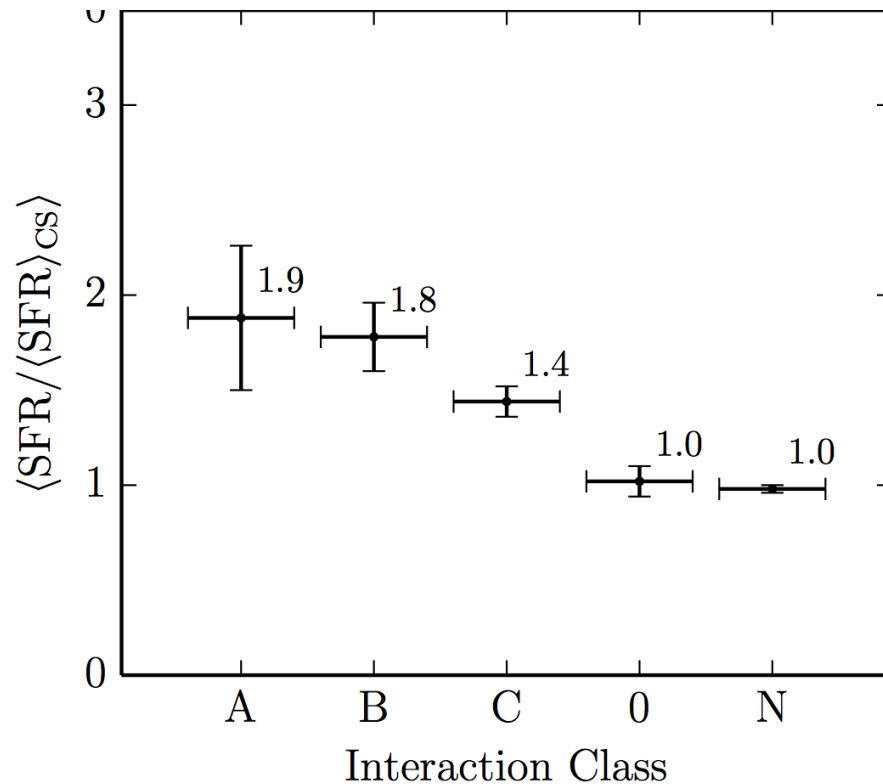


Normalised to control sample



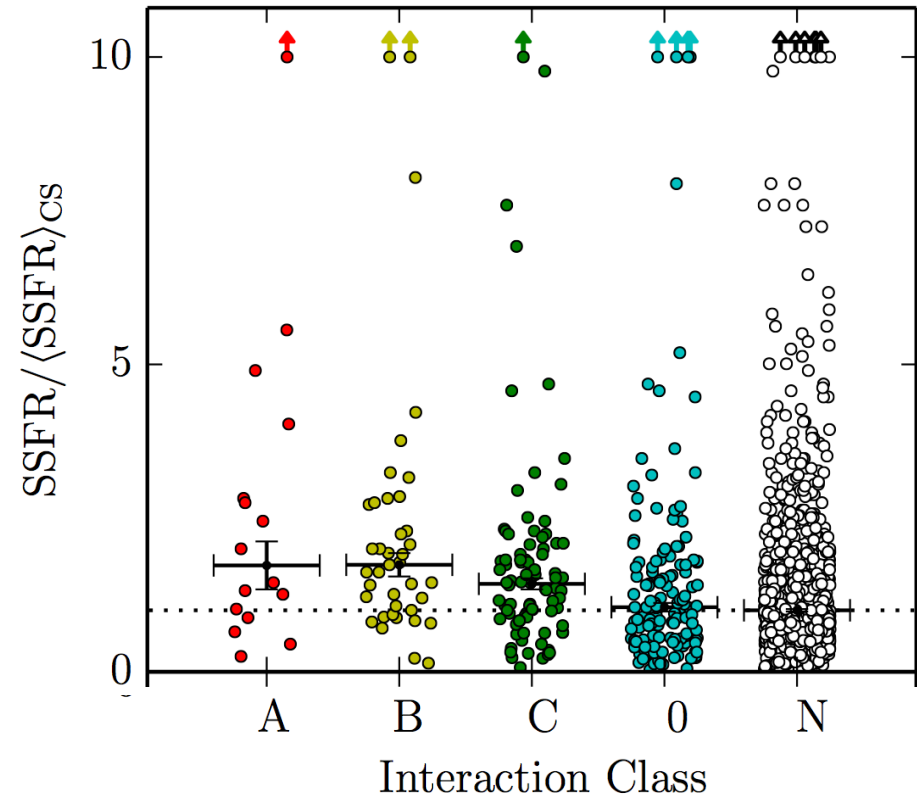
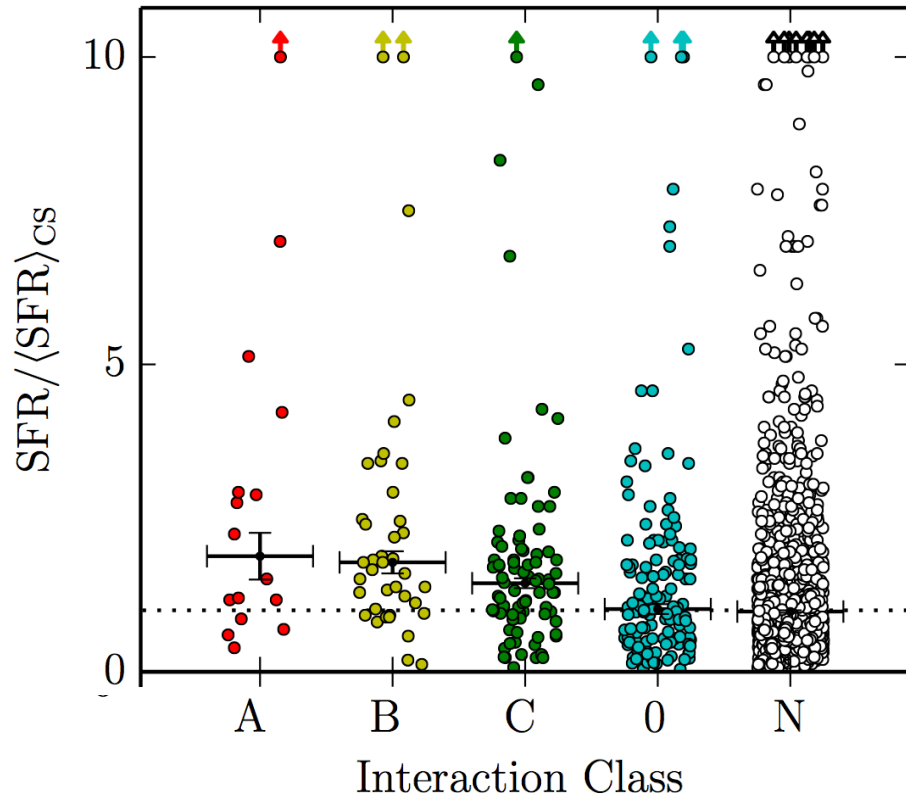
- ◆ Control: median SFR and SSFR of all galaxies from control class (N) with Type ± 1 and Mass $\pm 0.5 \log(M_{\text{Sun}})$
- ◆ We plot median enhancement wrt to control

Normalised to control sample

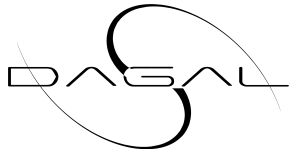


- Moderate increases in both SFR and SSFR – factor of 2
- Higher increases for stronger interactions
- Control sample technique works!

Large spread!



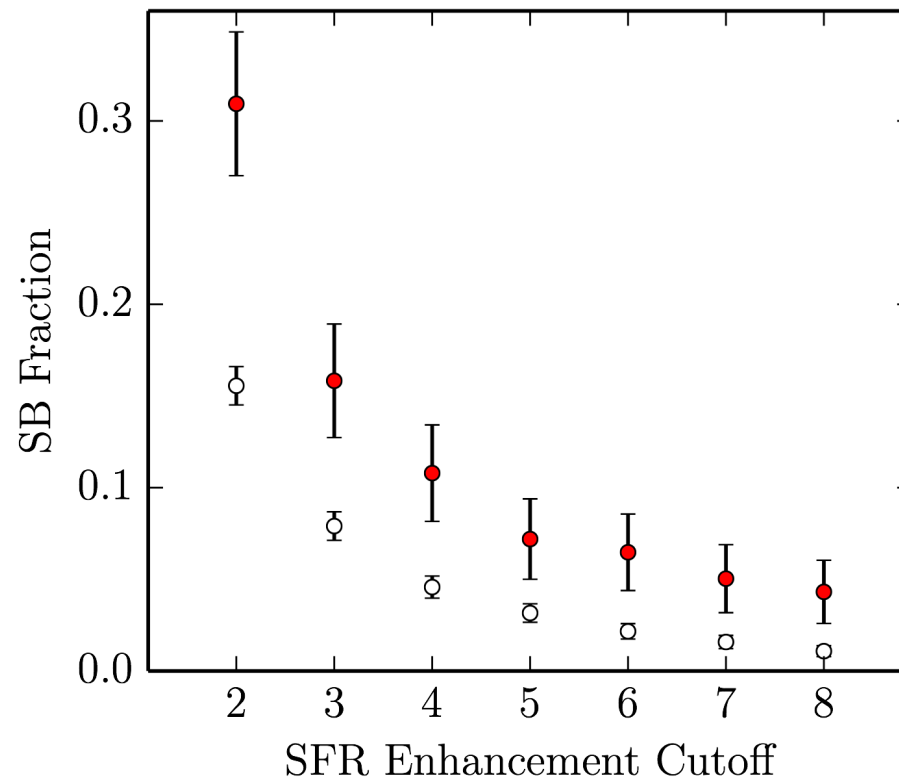
- Extremes occur in all classes
- Even most interacting galaxies can be below-average in (S)SFR
- Most interacting galaxies do not have enhanced (S)SFR



More 'Starbursts' among interacting galaxies



Starburst
fraction

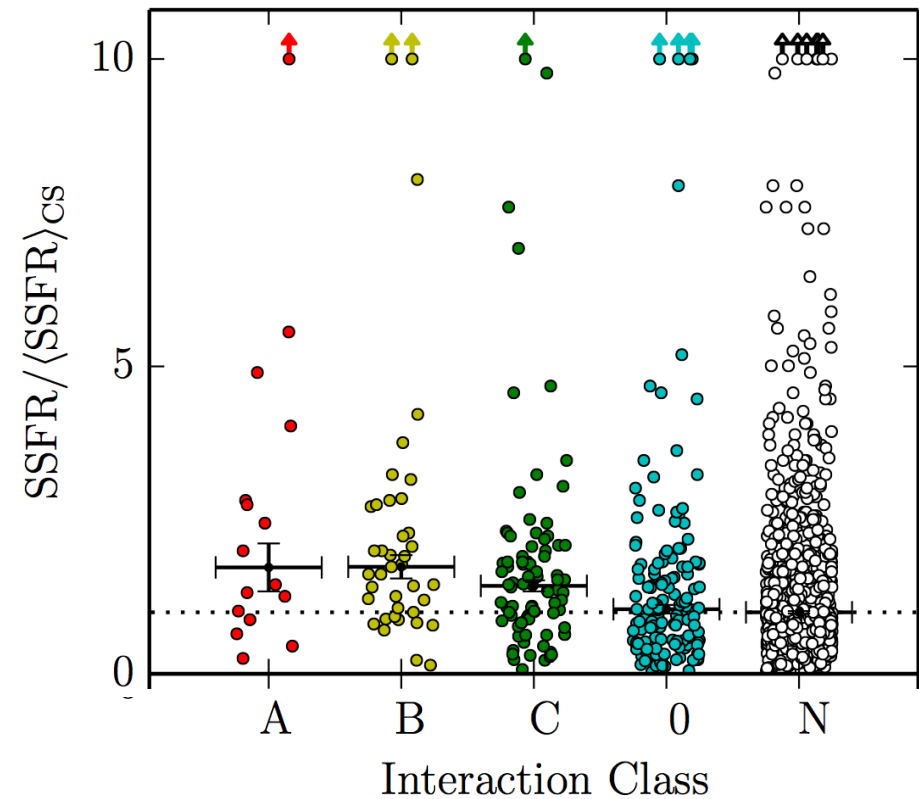
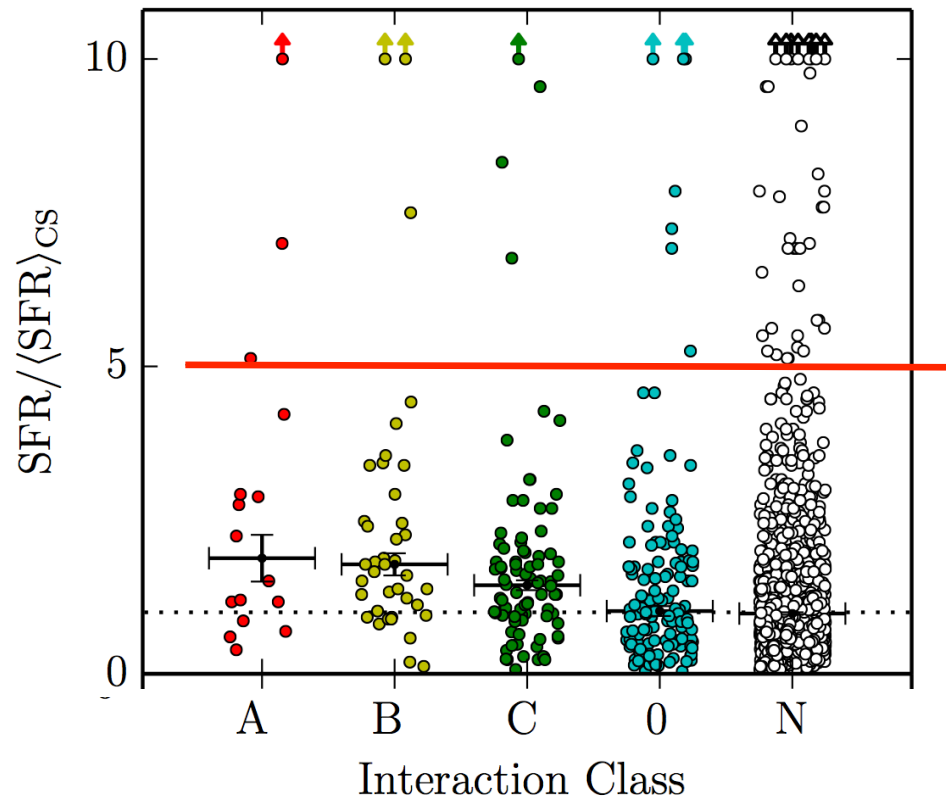


Red: interactions
Open: control

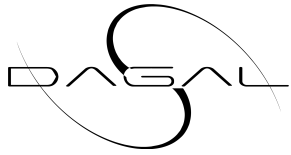
Knapen & Cisternas
2015 ApJL, arXiv:
1506.00656

- Fraction of starbursts ~ 2 x as high in interacting (red dots) as in control galaxies (open circles)
- More galaxies classified as starbursts for less restrictive definitions (left in diagram) – obvious result

Large spread!



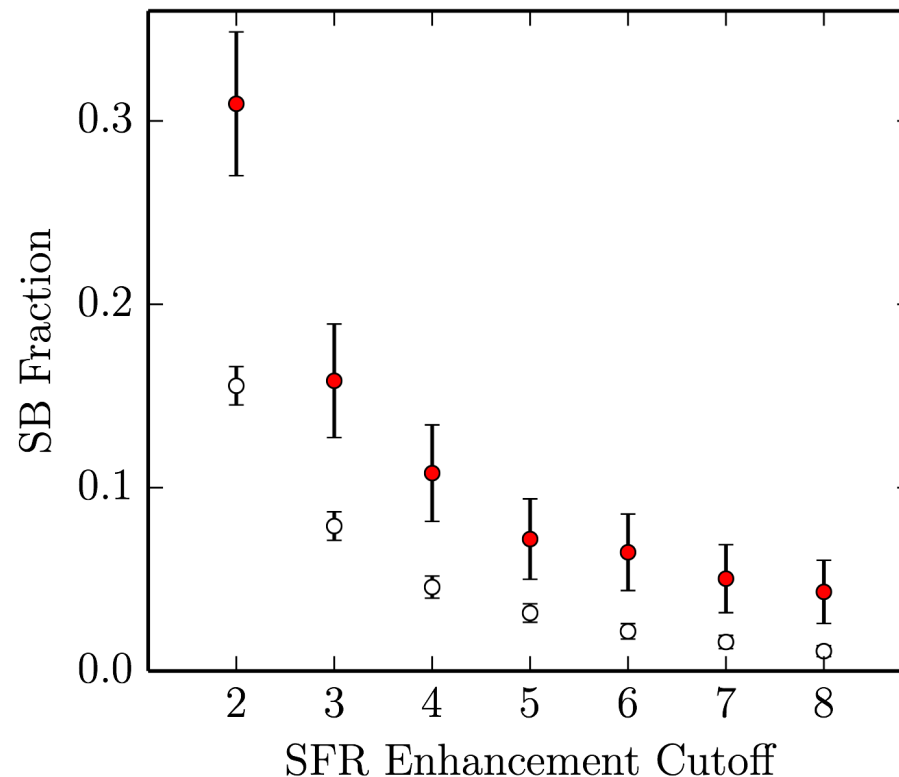
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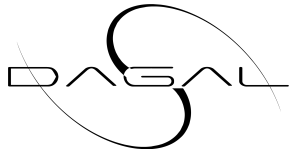
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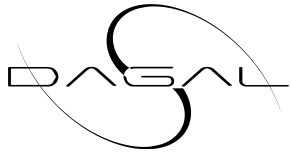
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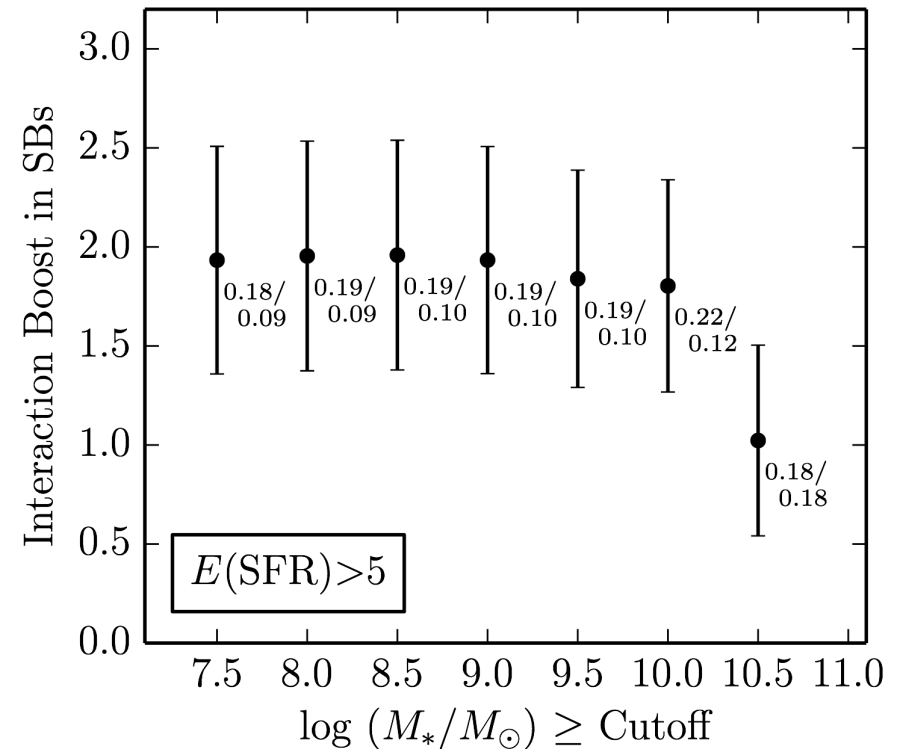
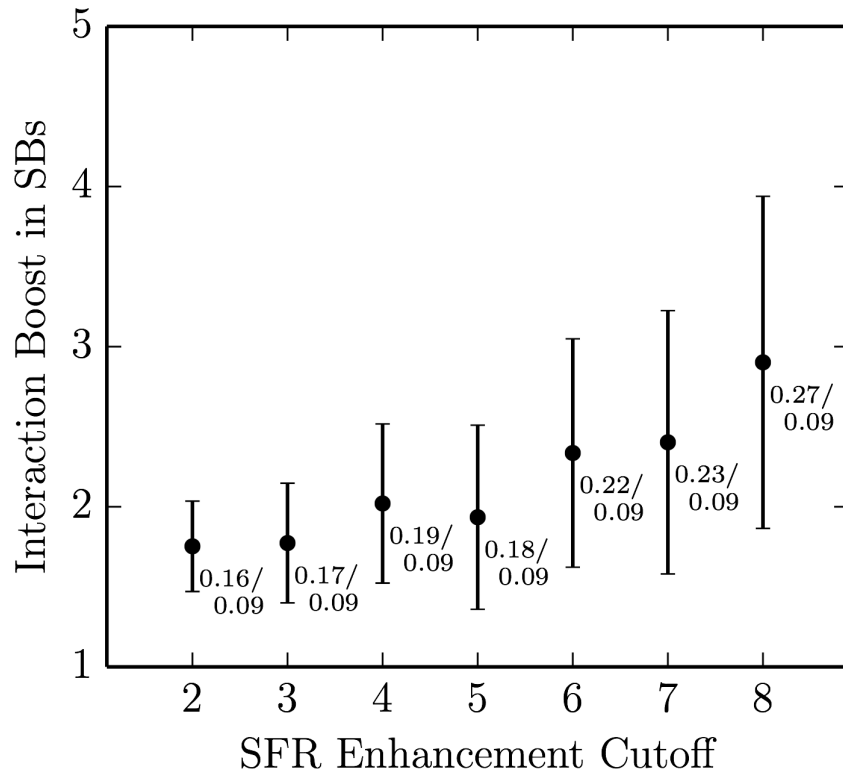
Starbursts - interactions



- ◆ Now turn it around: first select starbursts, then see how many of those are mergers/interactions
 - ◆ 18% of starbursts are interacting
 - ◆ 9% of all galaxies are interacting
- ◆ Factor 2 enhancement (*Interaction Boost*), very similar to what Luo et al. (2014, ApJL) found from 400k SDSS galaxies at higher redshift
- ◆ Knapen & Cisternas, ApJL in press (arXiv: 1506.00656)



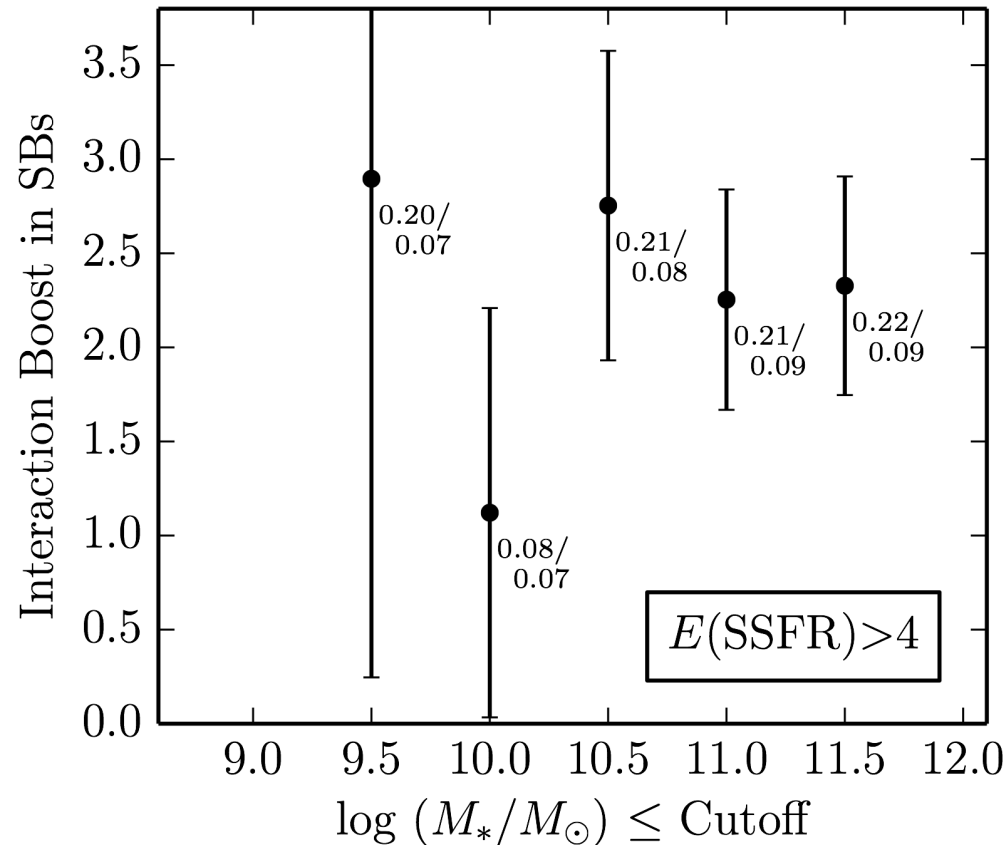
Starbursts - Interactions



Interaction Boost hardly depends on how the starburst is defined (left) or on the mass cutoff of the sample (right)

Knapen & Cisternas 2015 ApJL

Starbursts - Interactions



No evidence for change in behaviour for low-mass galaxies (left side of diagram)

Knapen & Cisternas 2015 ApJL

Conclusions

- ◆ Studied 1500 nearby galaxies – benchmark for high- z studies and simulations
- ◆ SFR and SSFR moderately enhanced by interactions and mergers
- ◆ Both (S)SFR increase and ‘starburst’ fraction go up with strength/prominence of interaction
- ◆ Twice as many starburst galaxies are interacting as non-starbursts, just like at higher redshifts
- ◆ Most interacting galaxies do not have increased (S)SFRs at all (at present...)