Gas flows in galaxies: mergers and bars

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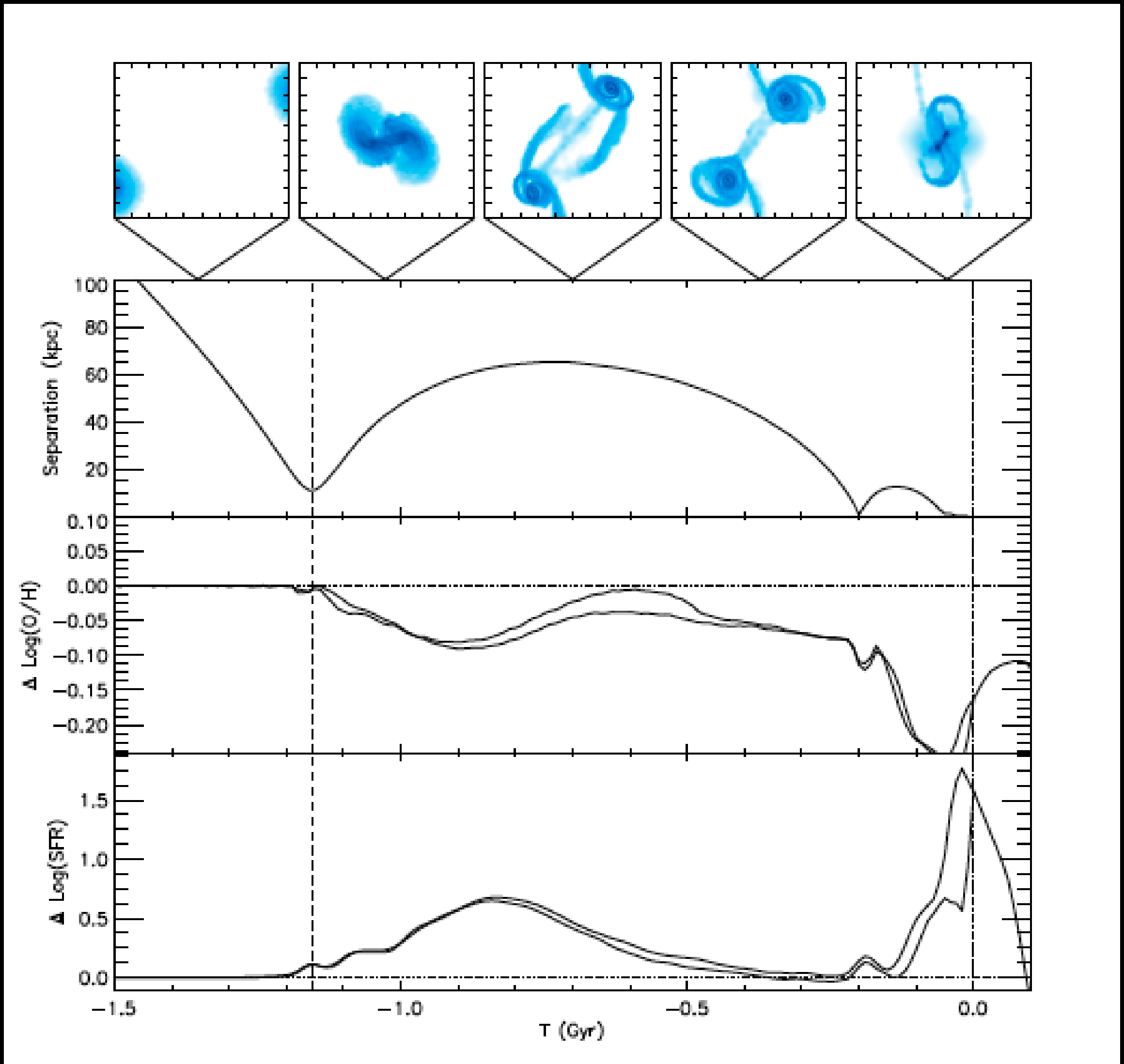
Two main mechanisms for gas inflow to galactic centre to trigger star formation.

Galaxy-galaxy mergers (e.g. the mice)

Galaxy bars (e.g. NGC 1300)

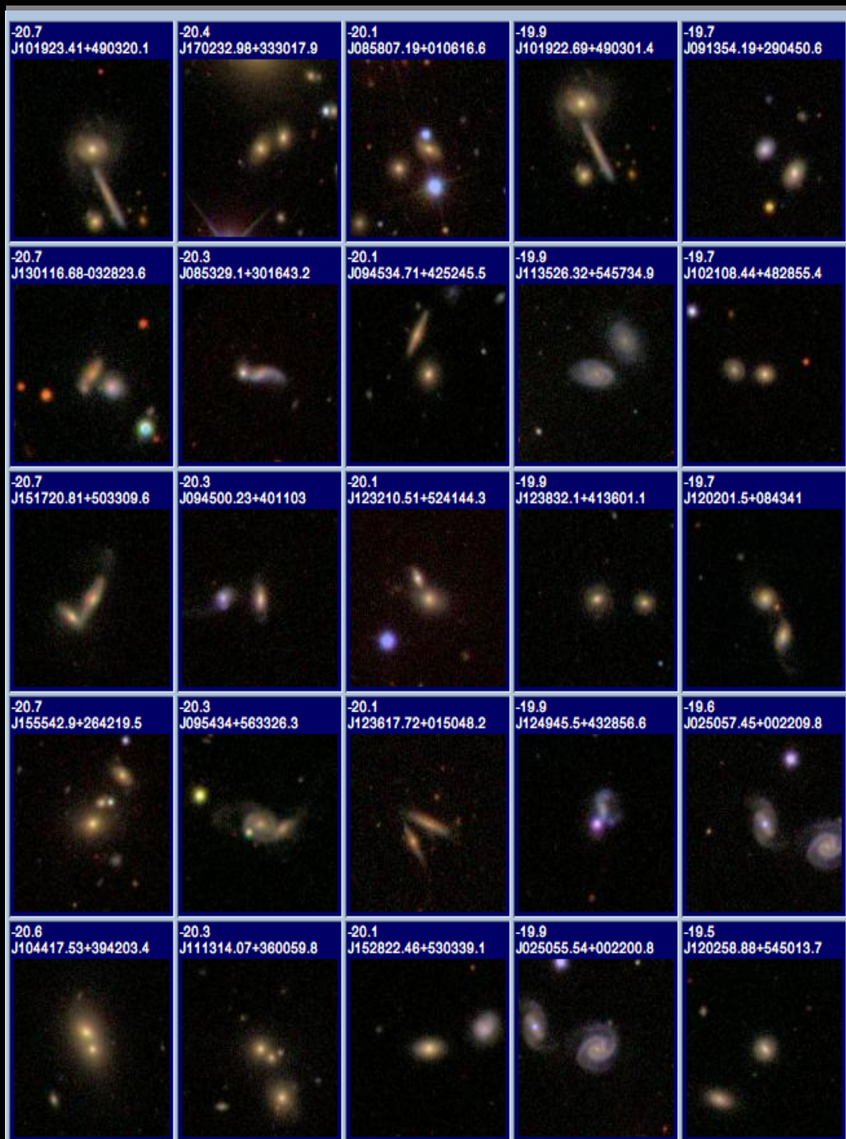
Signatures of gas flows



Simulation by Paul Torrey, in Scudder et al. (in prep).

Metal-poor gas flows to galaxy centre and triggers star formation.
Star formation is accompanied by dilution of metallicity in galaxy centre before eventual enrichment.

Galaxy pairs

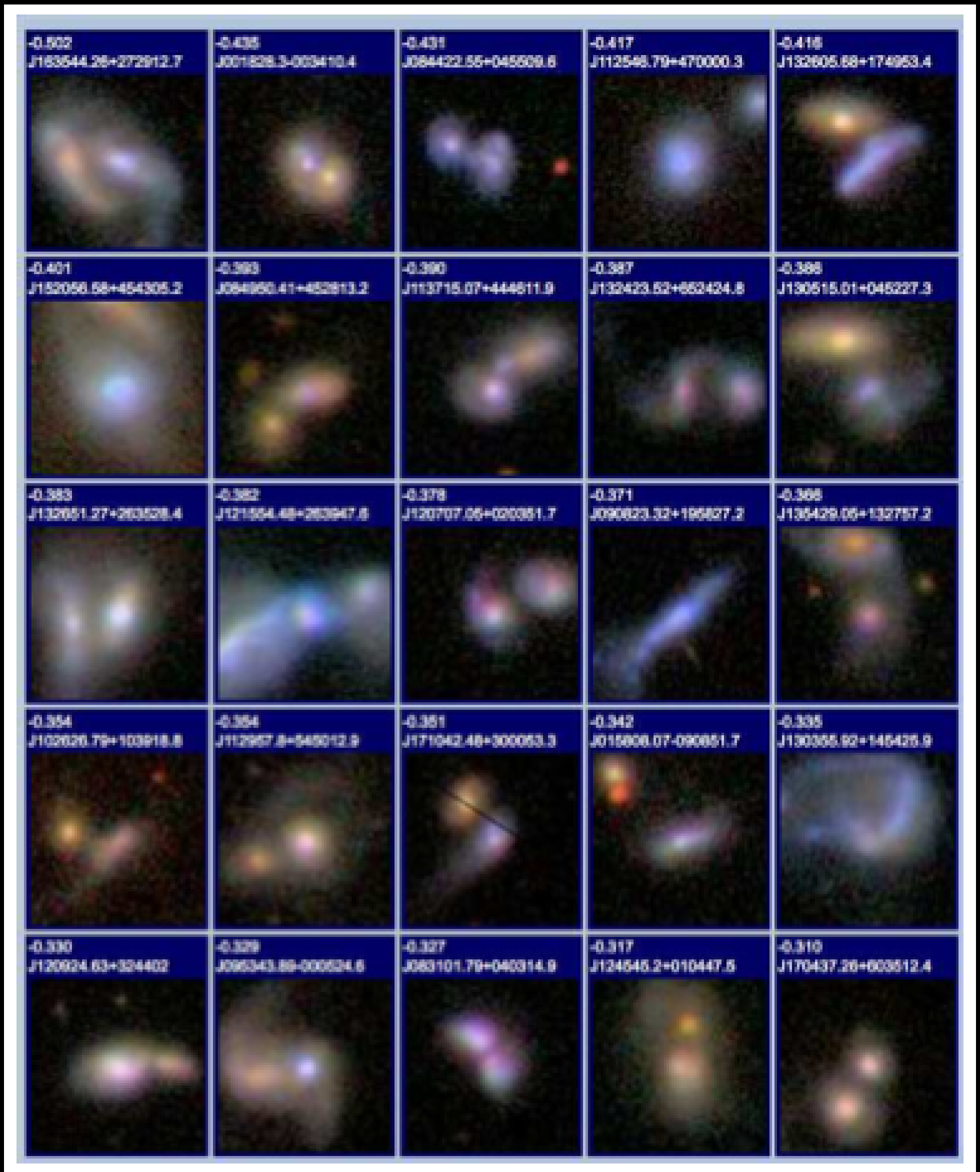


DR7 full pairs sample:
Projected separation <80 kpc
ΔV <10,000 km/s
Mass ratio 0.1 - 10

Yields: 22,777 galaxies in pairs (use a subset with ΔV<500 km/s for mergers).

Construct control samples that are matched in mass and redshift, typically 10 control galaxies per pair.

Photometry of close pairs

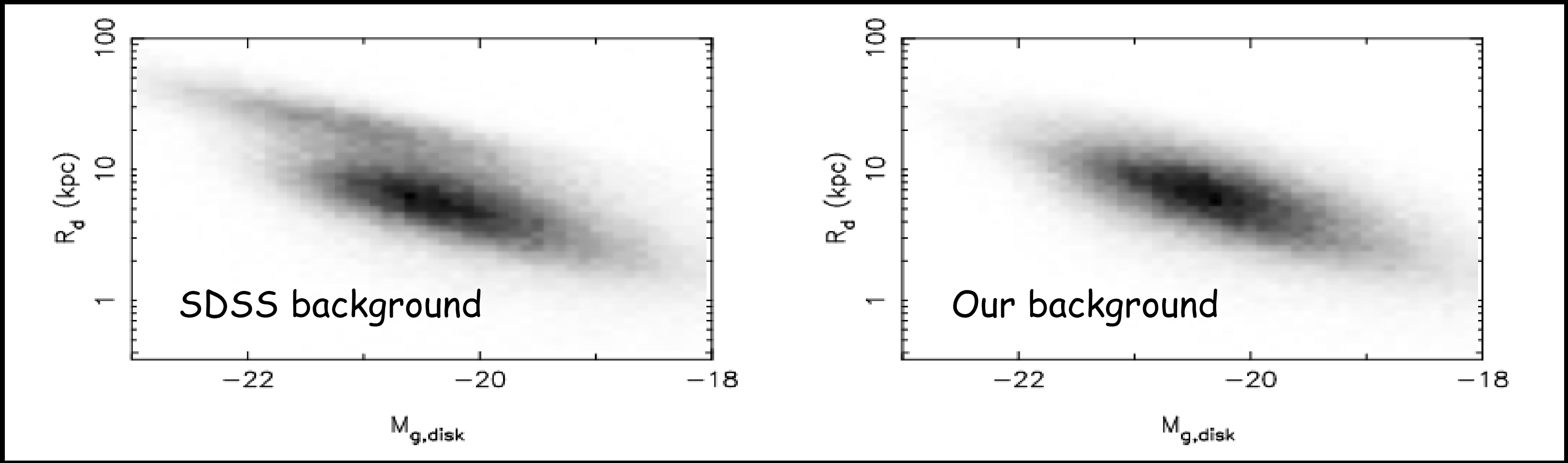


Several improvements made to SDSS photometry, which has problems in crowded environments:

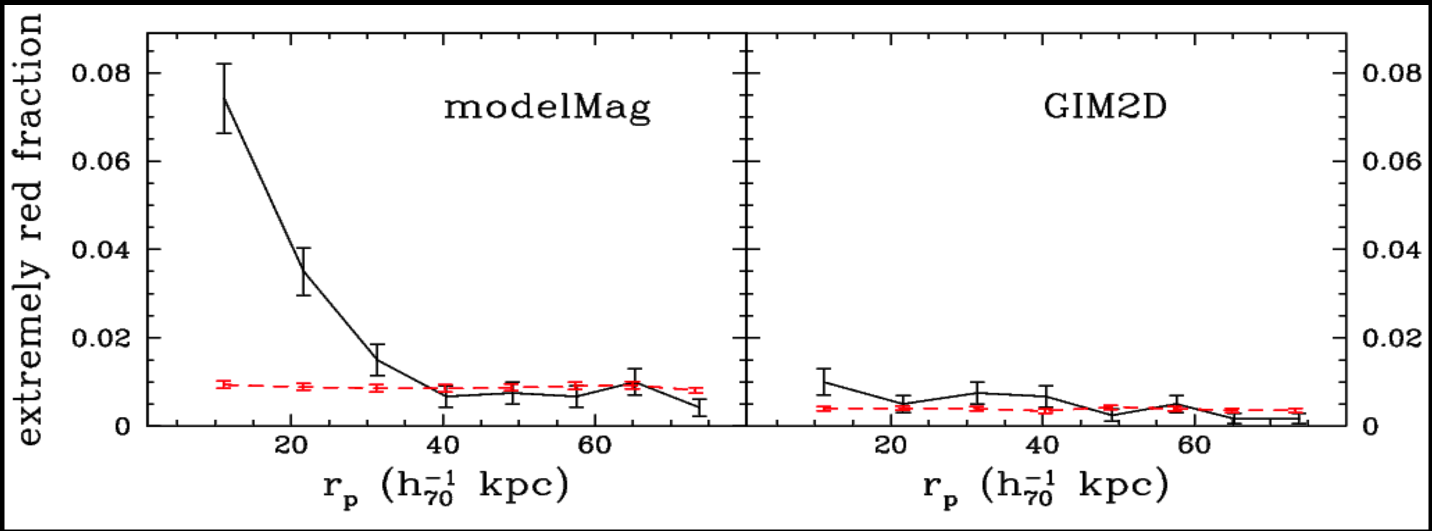
- Sextractor deblending
- Local sky determination
- Simultaneous r+g fits

Public catalog available: Simard et al. (2011)

Poor background determination can lead to extended disks:

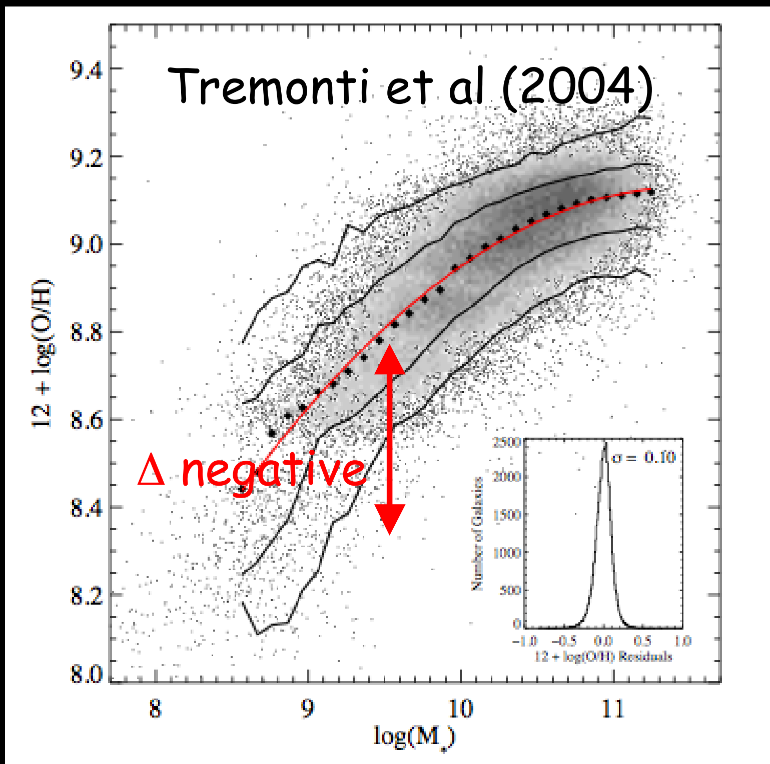


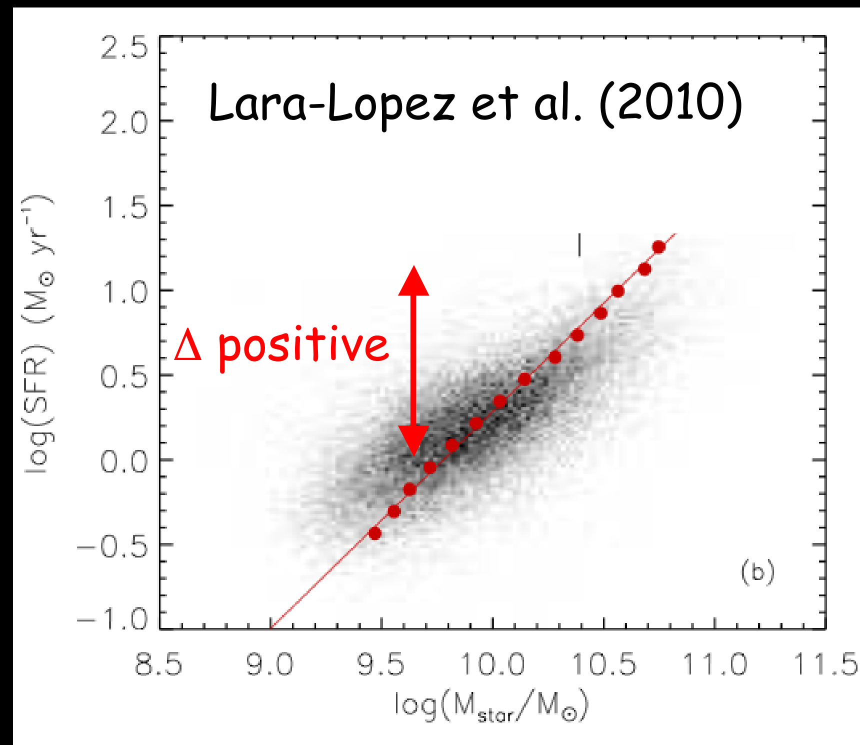
Poor object definition leads to spuriously red colours:



Full SDSS data release of 1.12 million galaxies: Simard et al. (2011)

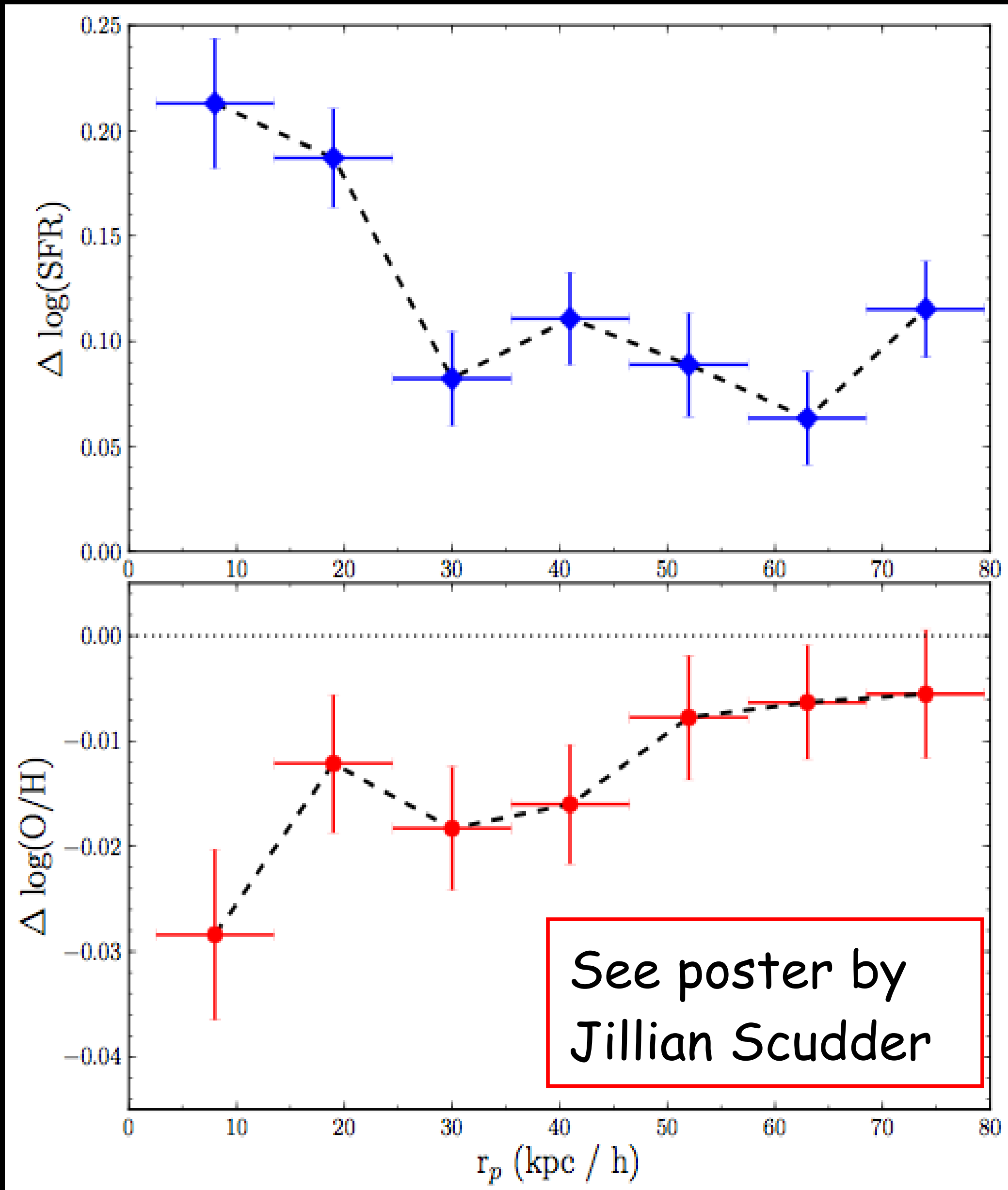
Quantify SFR and metallicity enhancements by looking for offsets from the mass-SFR and mass-metallicity relations of control galaxies.



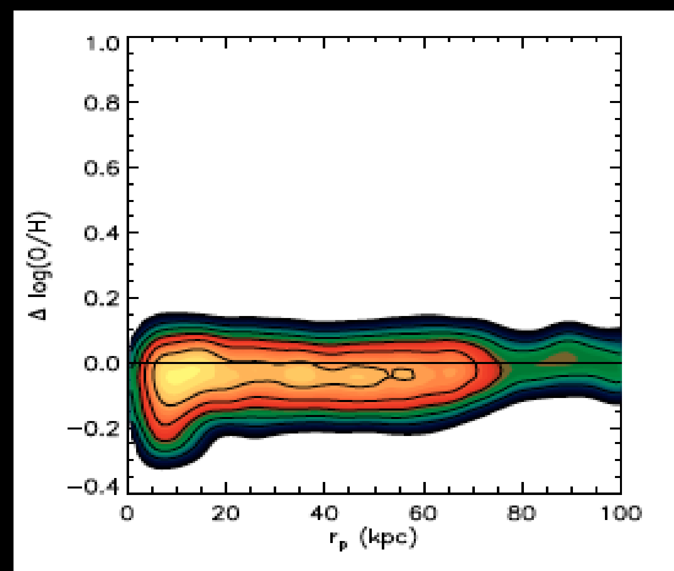


Δ O/H = log O/H - log O/H$_{predict}$

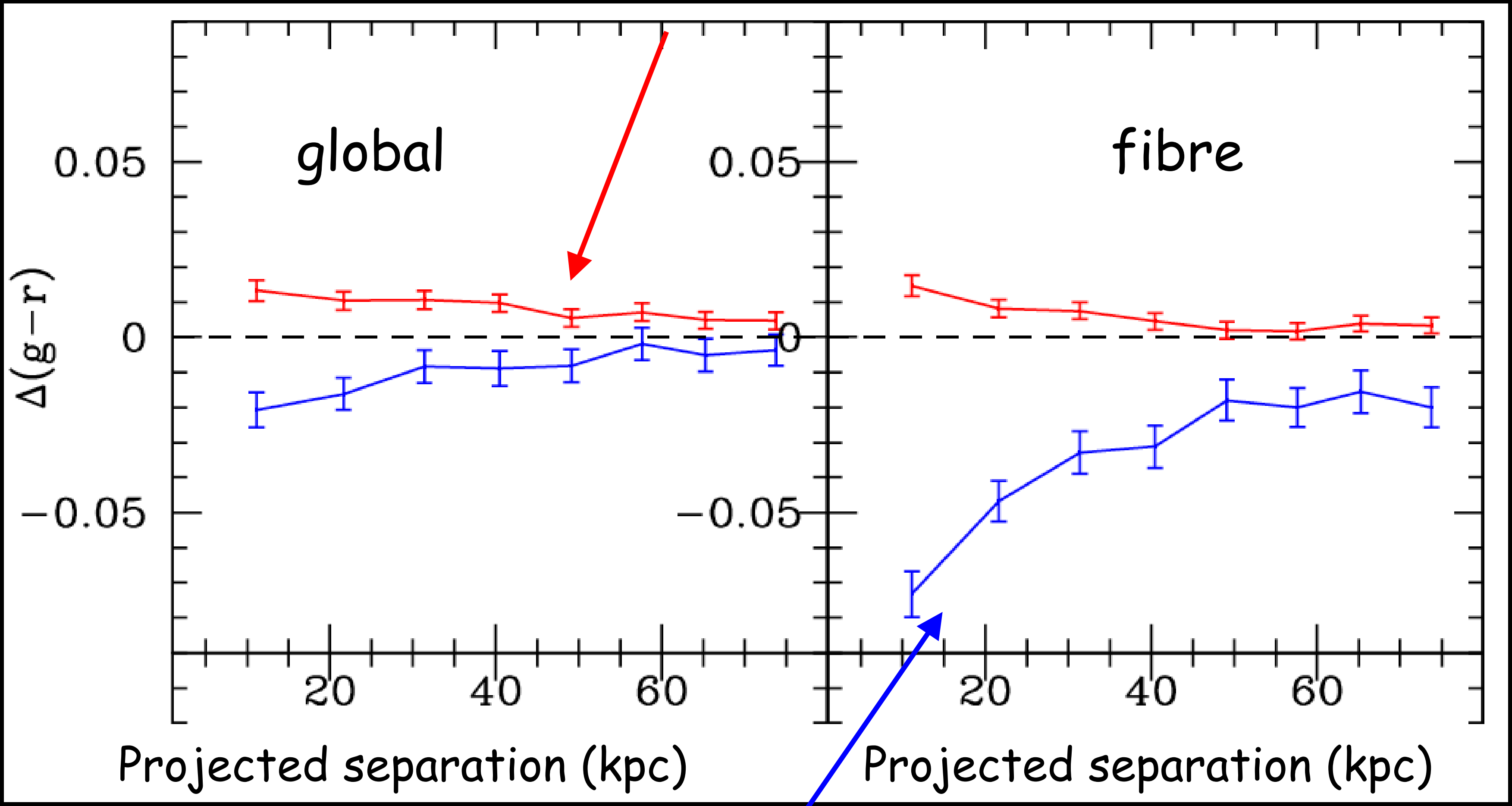
Δ SFR = log SFR - log SFR$_{predict}$



SFR increases and metallicity decreases in close pairs and remains offset from the field even out to 80 kpc (Scudder et al. in prep). General agreement with simulations.



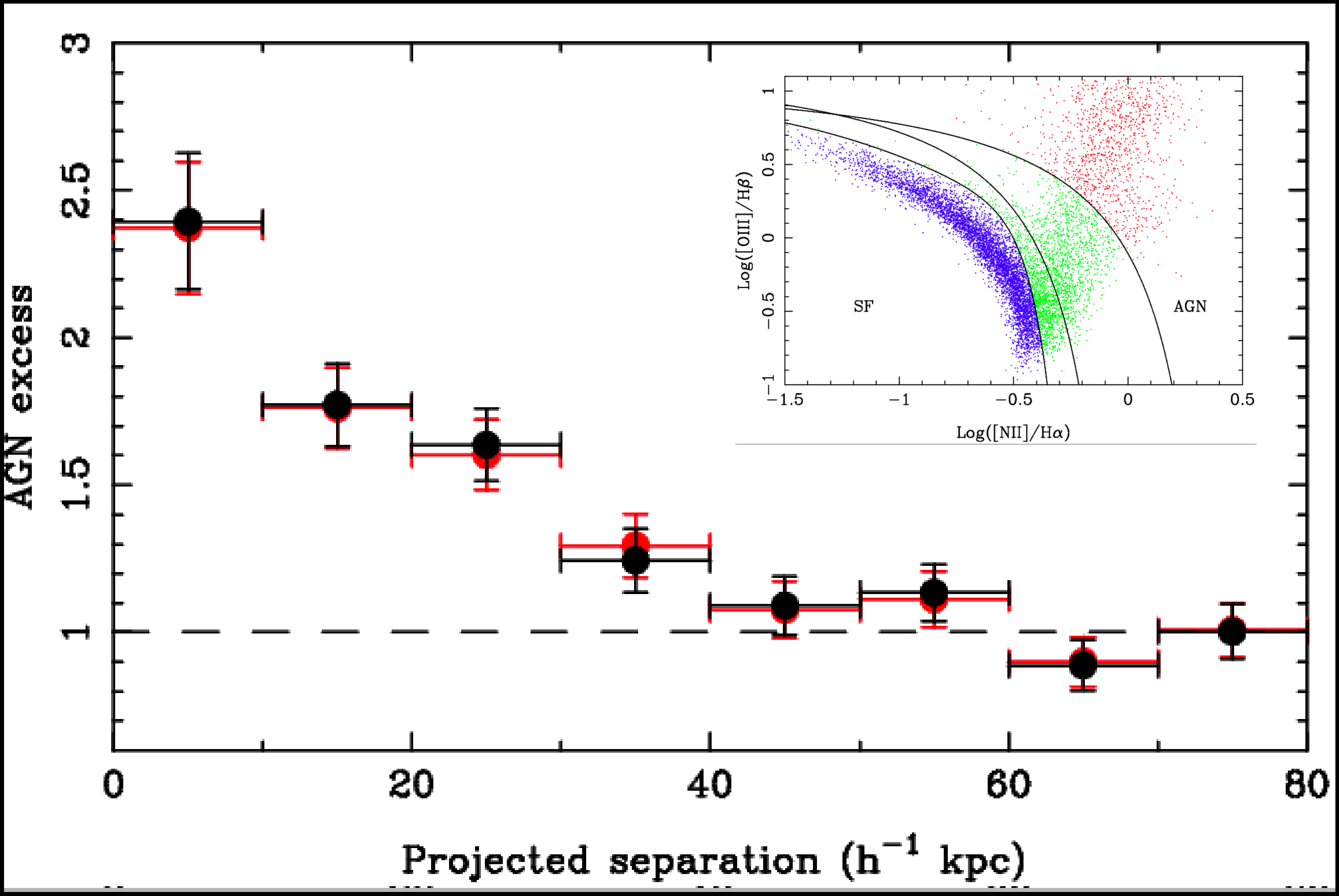
Red pairs slightly redder than control, likely due to environment.

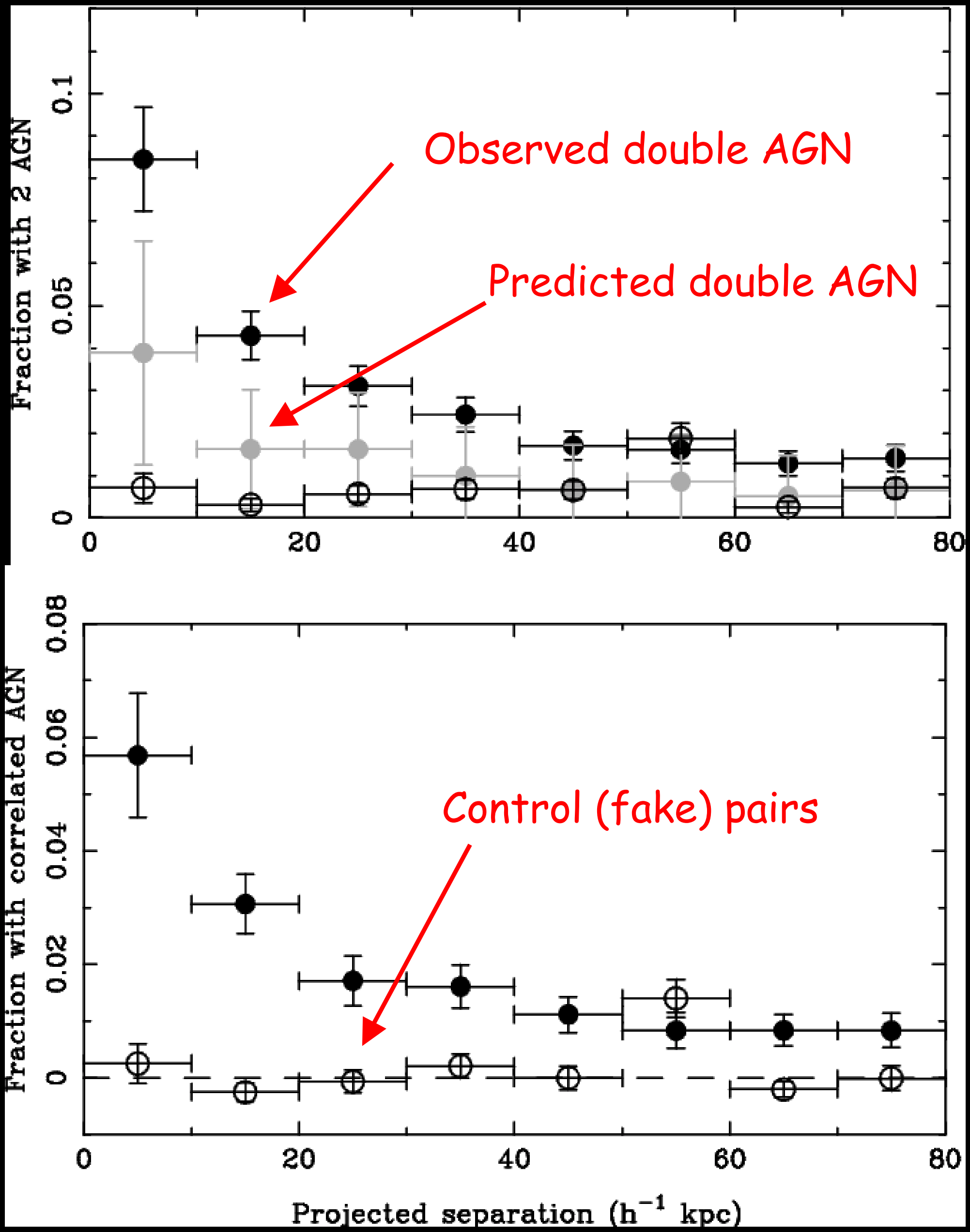


Blue galaxies get bluer than their controls at small separations, dominated by changes in their central regions: star formation is nuclear.

Patton et al. (2011)

In addition to changes in star formation and metallicity, expect that gas inflows may trigger AGN: find up to 2.5 times more AGN in close pairs. Ellison et al. (submitted - ask me for a copy if you're interested).

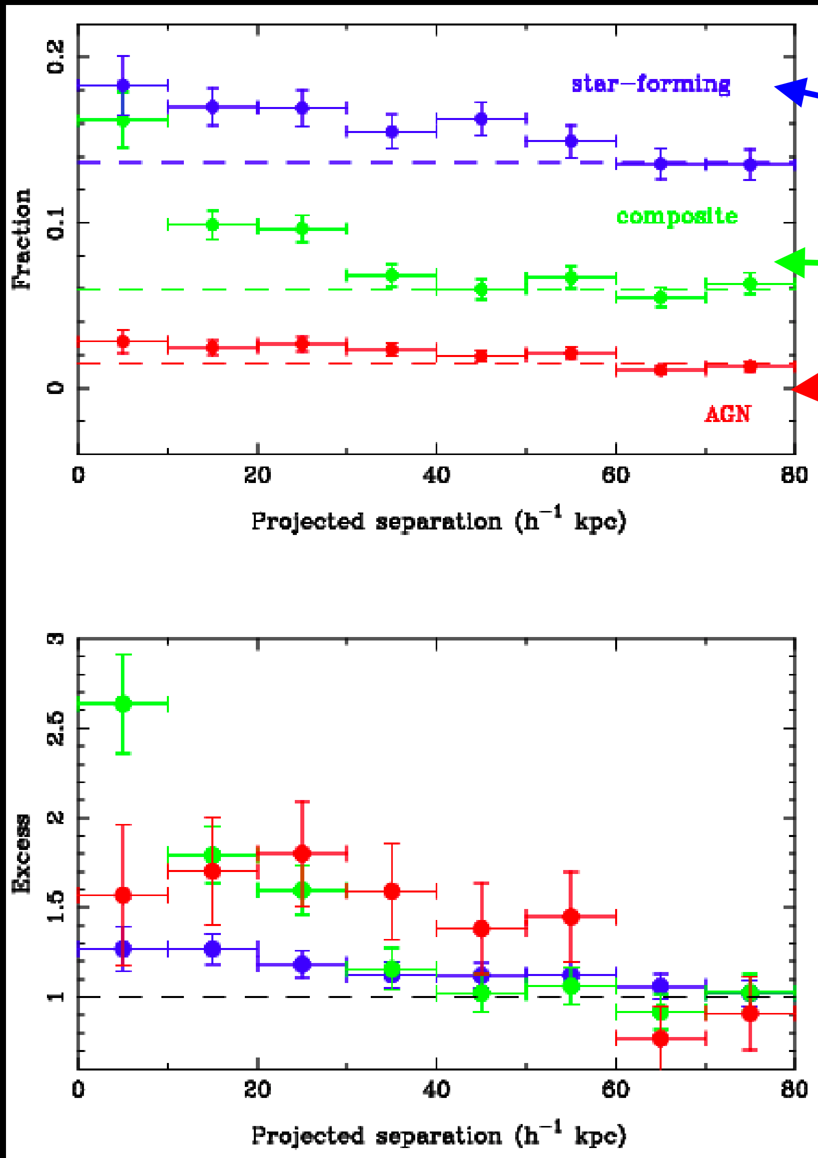


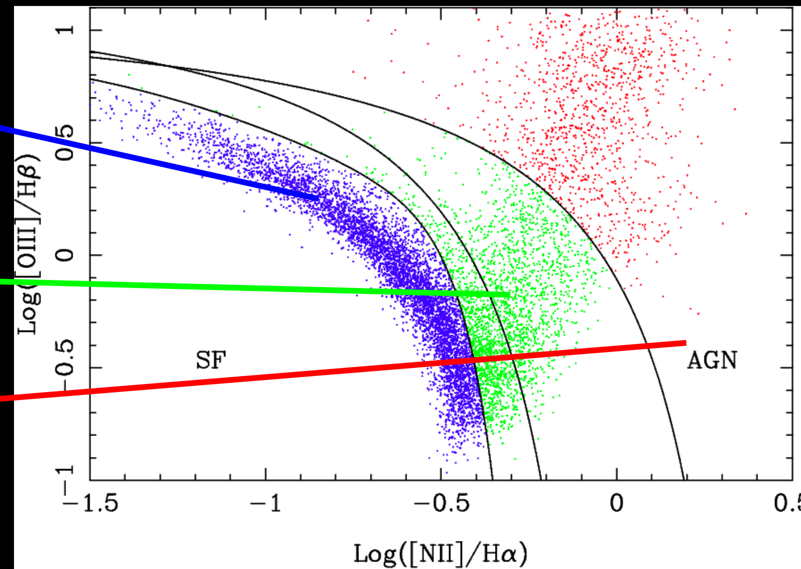


Fraction of double AGN is twice what we would expect from a random occurrence.

Calculate what fraction of the double AGN can be accounted for from a random occurrence and hence what fraction are correlated. Excess of correlated pairs at small separations: SYNCHRONIZED AGN TRIGGERING.

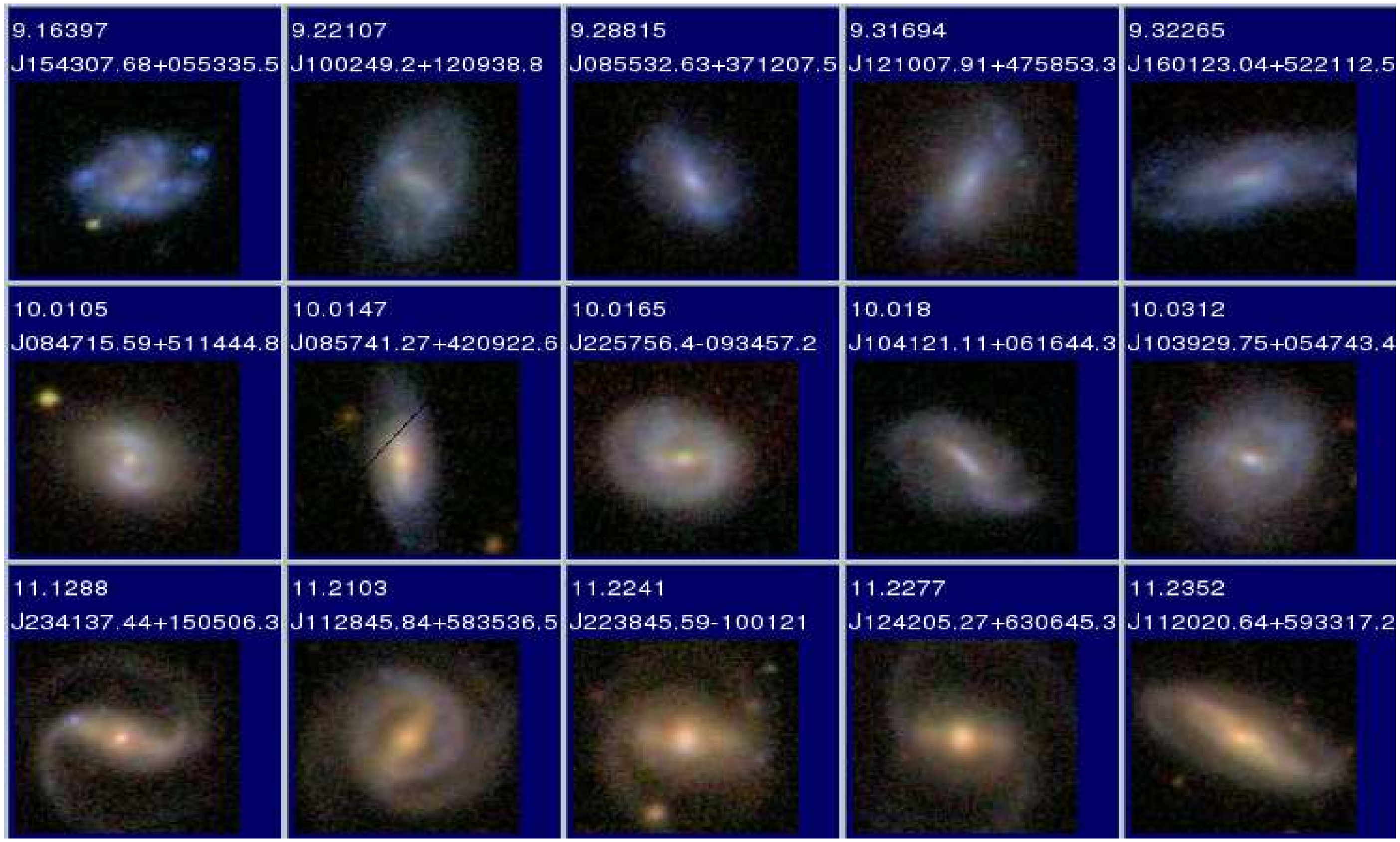
Ellison et al. (submitted).





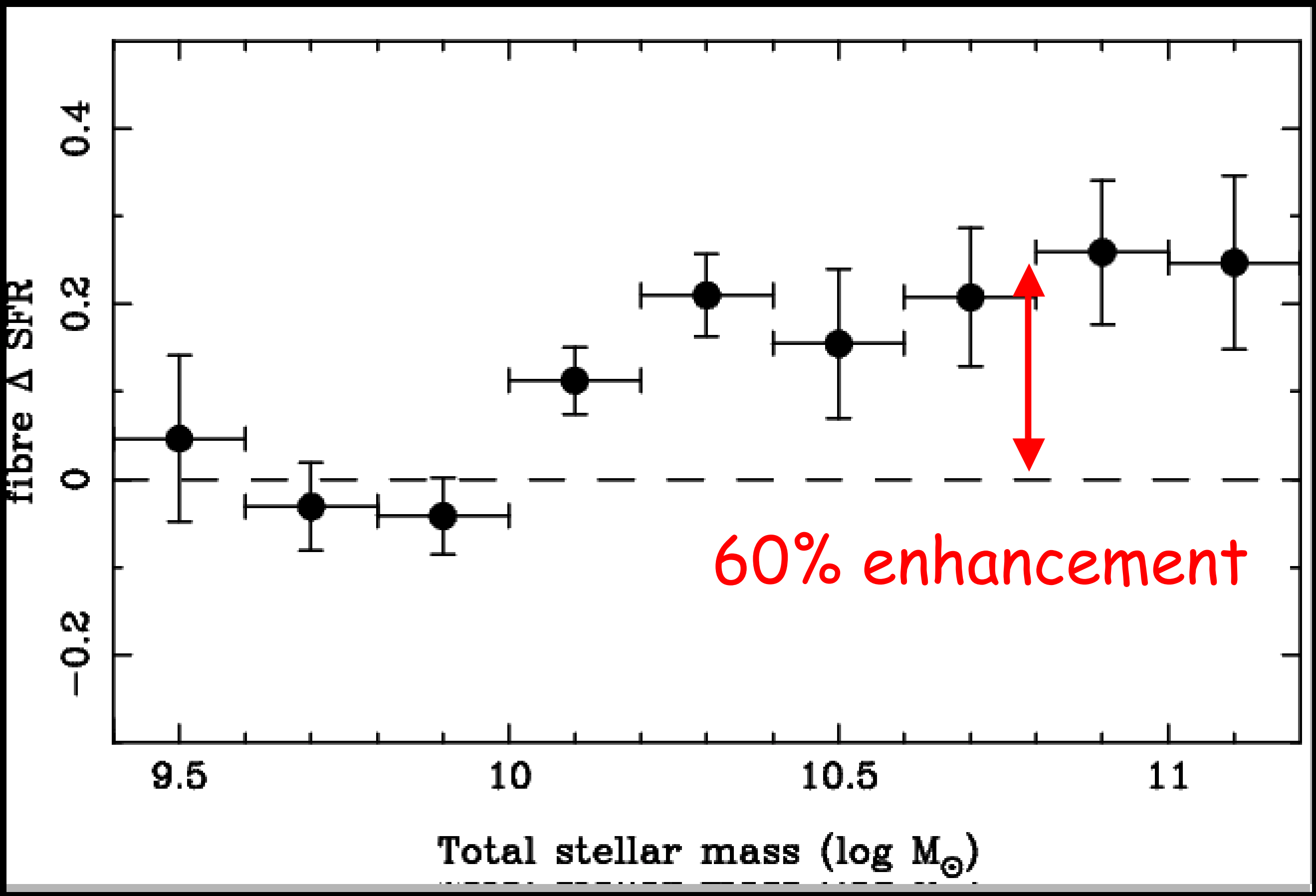
In addition to the expected increase in star-forming fraction, and our detection of increase in AGN fraction, we find the biggest increase is in the fraction of composite galaxies.

Barred galaxies



311 visually selected bars with z<0.1, *g*<16 from DR4 spectroscopic sample (Nair & Abraham 2010).

Star formation rates in bars

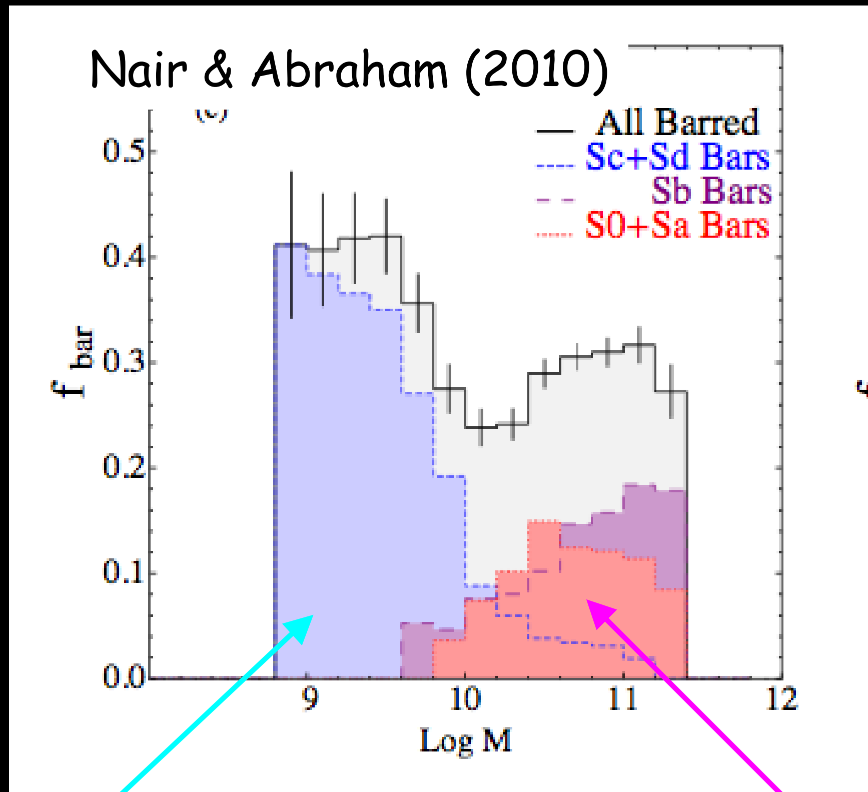


60% enhancement in fibre SFR in barred galaxies with Log M > 10 M_{sun}.

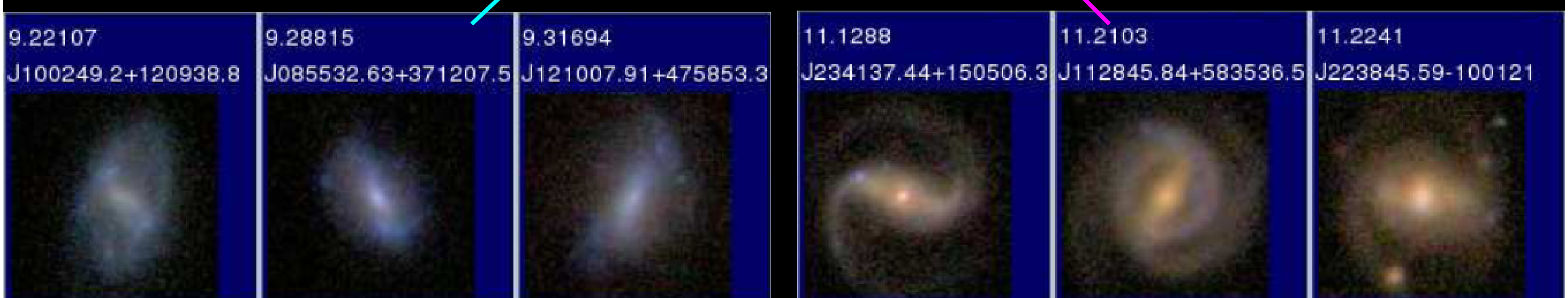
Ellison et al. (2011)

Mass of 10^{10} M_{sun} corresponds to morphological transition

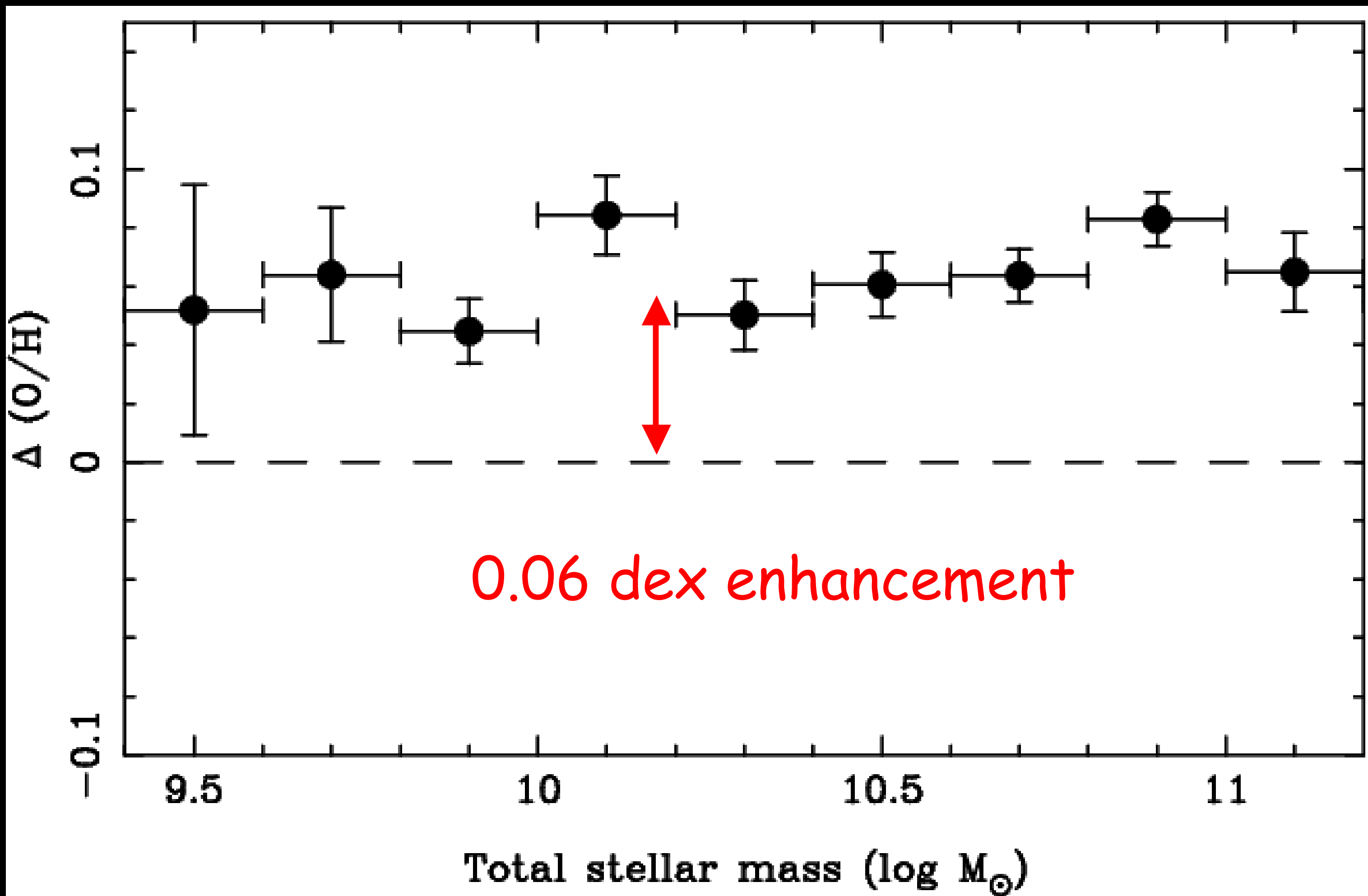
Low mass bars are mostly late-types (Sc and Sd)



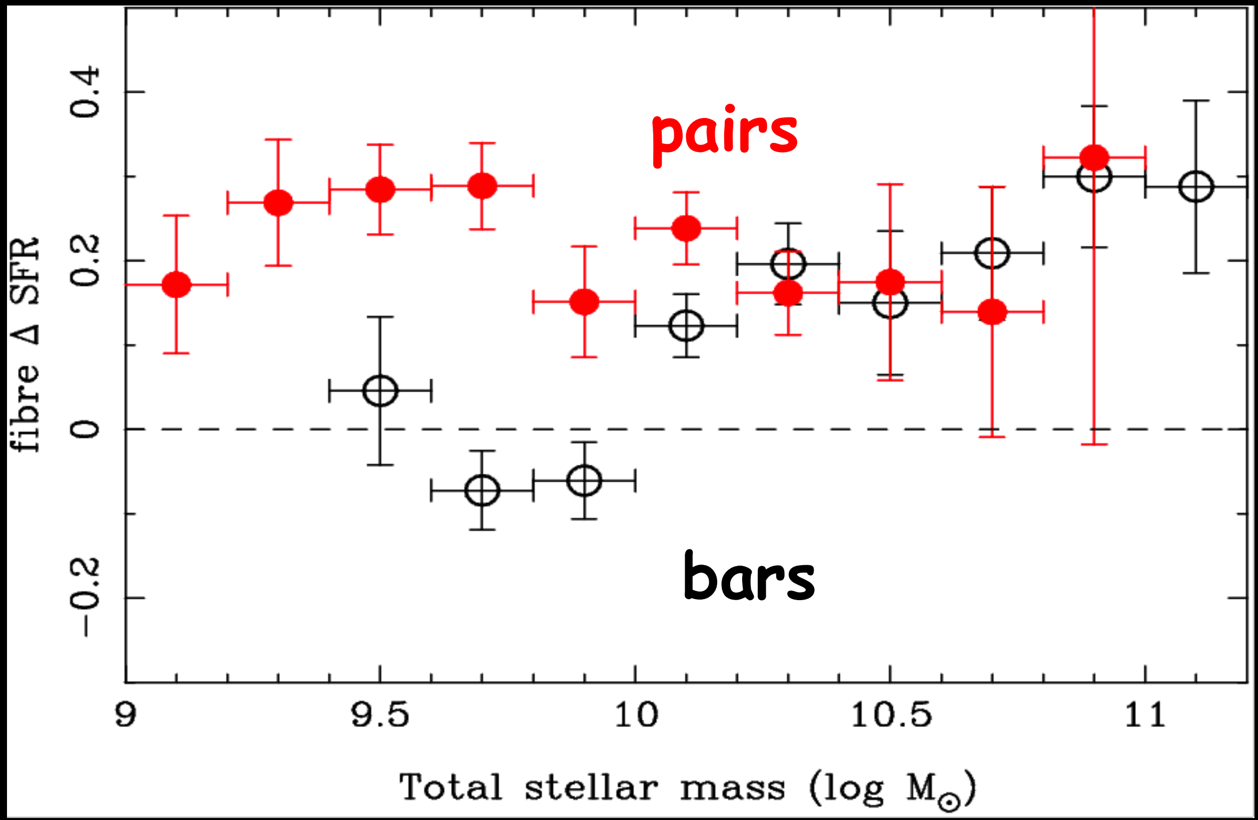
High mass bars are mostly early-types (SO-Sb)



Metallicities in barred galaxies

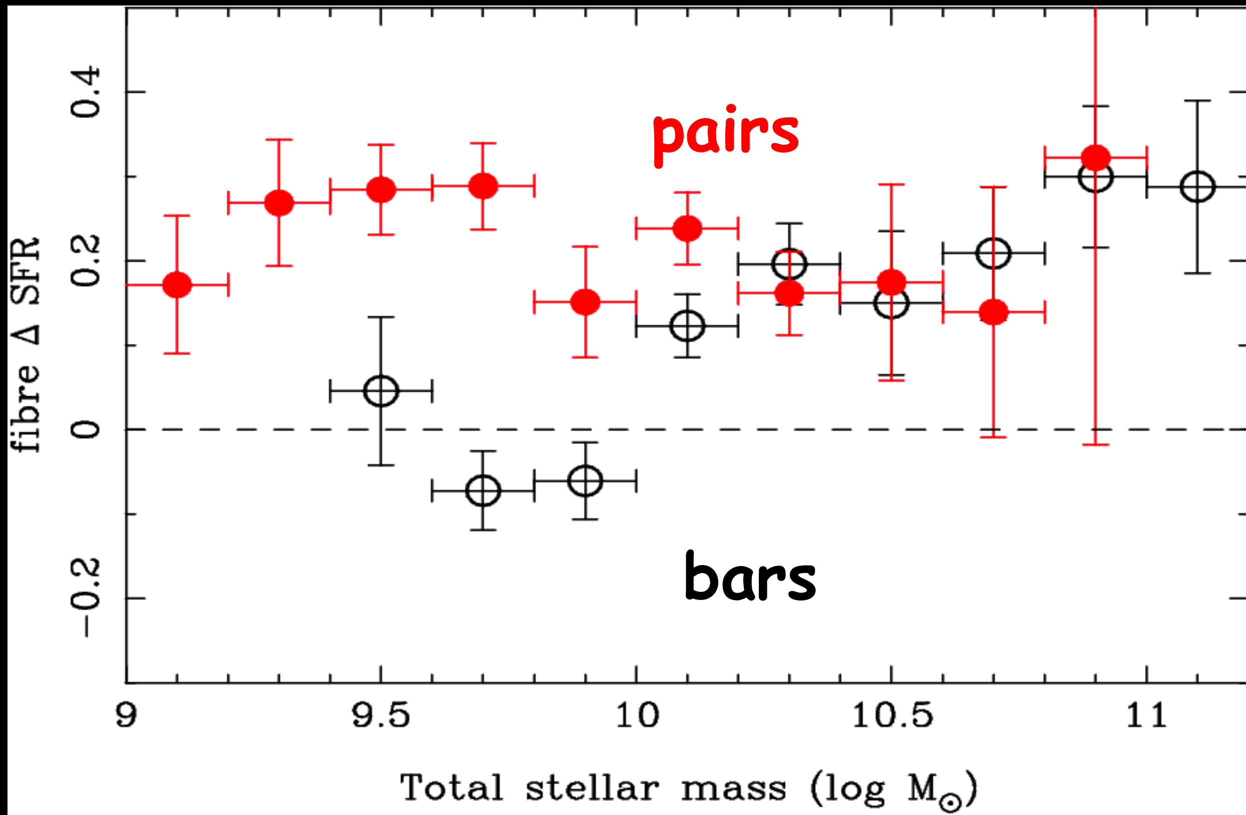


Barred galaxies more metal-rich at all masses. Bars sufficiently long lived to show enrichment, even after SF.



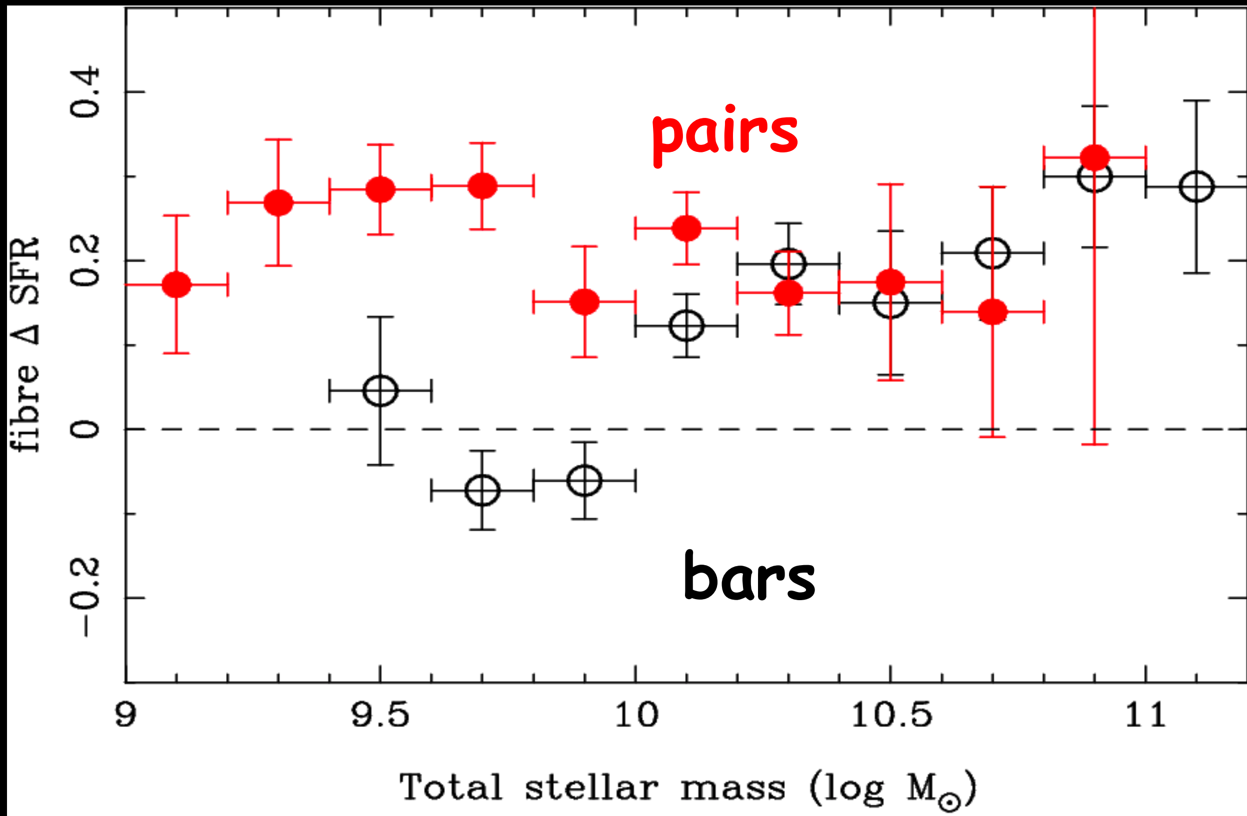
$$\epsilon_{b/p} = \frac{f_b}{f_p} \times \frac{f_{b,\star}}{f_{p,\star}} \times \frac{10^{\Delta SFR_b}}{10^{\Delta SFR_p}}$$

Ratio of enhanced star formation coming from bars and pairs.



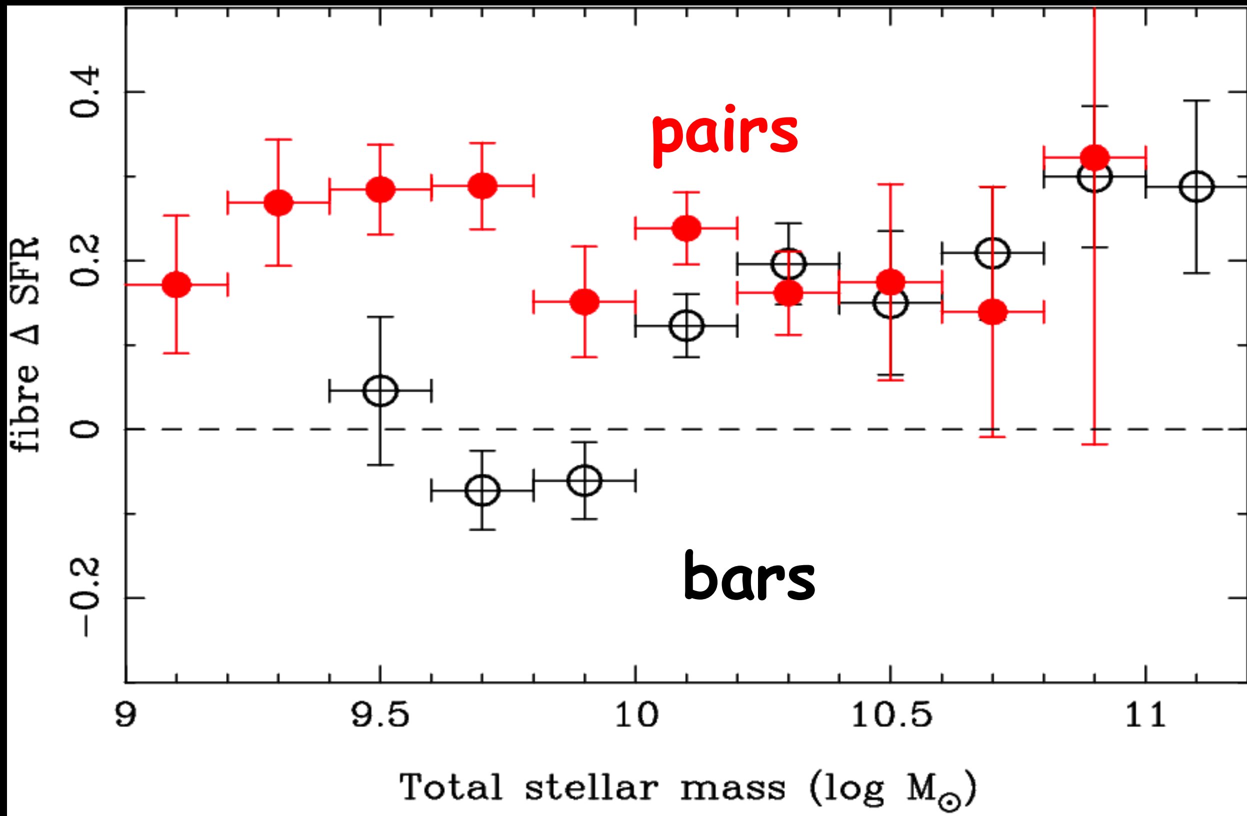
$$\epsilon_{b/p} = \frac{f_b}{f_p} \times \frac{f_{b,\star}}{f_{p,\star}} \times \frac{10^{\Delta SFR_b}}{10^{\Delta SFR_p}}$$

Ratio of bar and pair fraction in galaxy population.



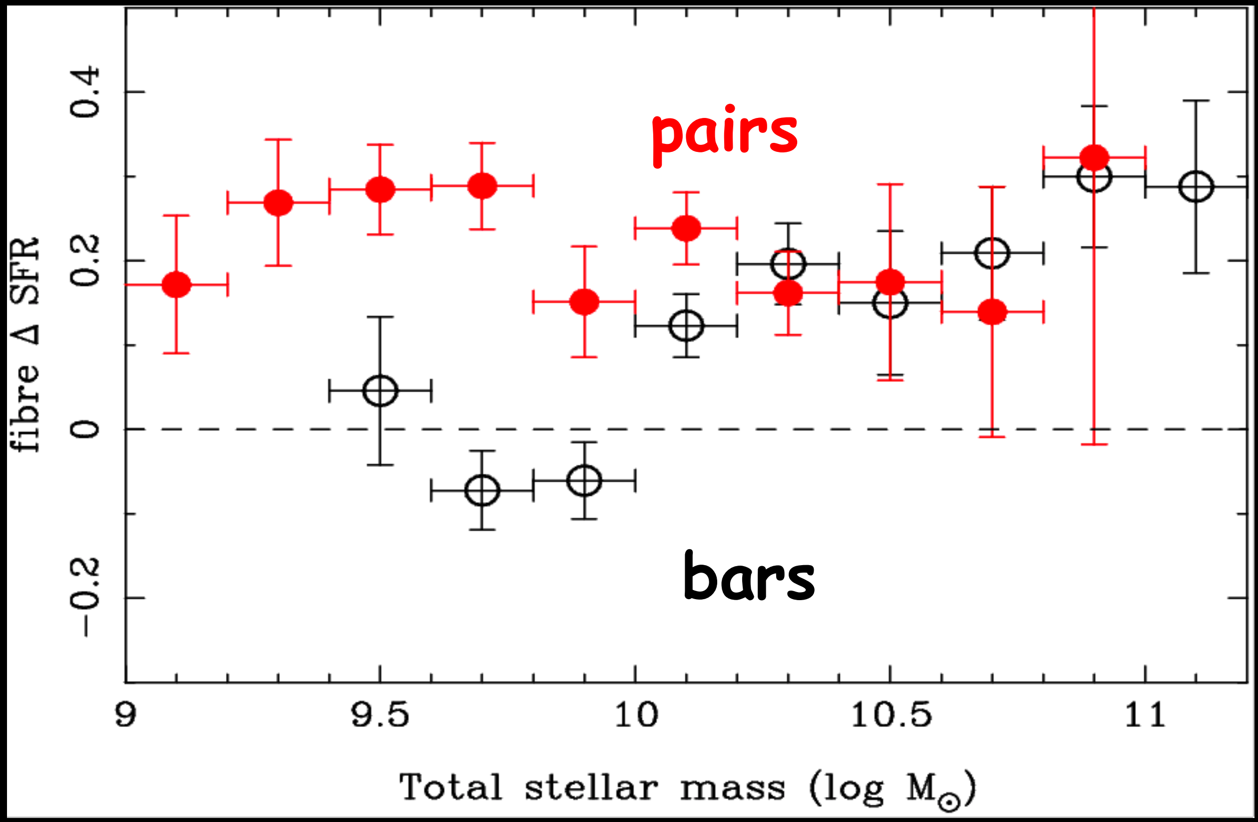
$$\epsilon_{b/p} = \frac{f_b}{f_p} \times \frac{f_{b,\star}}{f_{p,\star}} \times \frac{10^{\Delta SFR_b}}{10^{\Delta SFR_p}}$$

Ratio of bar and pair fraction in star-forming sample.



$$\epsilon_{b/p} = \frac{f_b}{f_p} \times \frac{f_{b,\star}}{f_{p,\star}} \times \frac{10^{\Delta SFR_b}}{10^{\Delta SFR_p}}$$

Ratio of SFR enhancements bar and pair star-forming sample (this ratio ~1).



$$\epsilon_{b/p} = \frac{f_b}{f_p} \times \frac{f_{b,\star}}{f_{p,\star}} \times \frac{10^{\Delta SFR_b}}{10^{\Delta SFR_p}}$$

$\varepsilon_{b/p} > 3$, I.e. at least 3 times more central star formation comes from bars than pairs.

Ellison et al. (2011)

Summary

- Pairs of galaxies experience triggered star formation mostly in blue galaxies, star formation is central and persists out to at least 80 kpc: Ellison et al. (2008, 2010), Patton et al. (2011), Scudder et al (in prep)

- Galaxy pairs are metal-poor for their mass due to gas inflows: Ellison et al. (2008), Scudder et al. (in prep).

- Close pairs of galaxies have ~3 times more AGN. Ellison et al. (submitted)

- Bars also show central SFR enhancements by about 60%, but only at log M > 10 where the population becomes dominated by early-type bars: Ellison et al. (2011).

- Bars have high central metallicities for their mass by ~0.06 dex: Ellison et al. (2011).

- The relatively high bar frequency means that bars contribute to at least 3 times more central star formation than interactions.