遠方大質量銀河のダスト放射と銀河形成問題

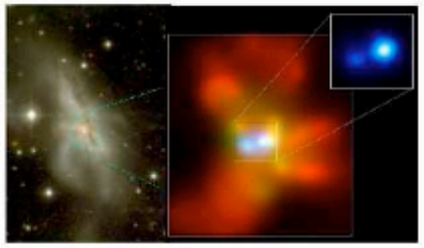
高木俊暢
宇宙研（学振PD)

Hopkins et al.

(c) Interaction/"Merger"

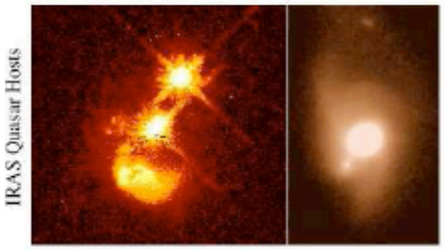
- now within one halo, galaxies interact & lose angular momentum
- SFR starts to increase
- stellar winds dominate feedback
- rarely excite QSOs (only special orbits)

(d) Coalescence/(U)LIRG



- galaxies coalesce: violent relaxation in core
- gas inflows to center: starburst & buried (X-ray) AGN
- starburst dominates luminosity/feedback, but, total stellar mass formed is small

(e) "Blowout"



- BH grows rapidly: briefly dominates luminosity/feedback
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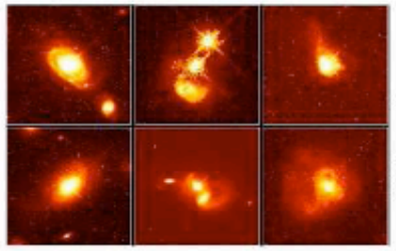
- get reddened (but not Type II) QSO: recent/ongoing SF in host high Eddington ratios merger signatures still visible

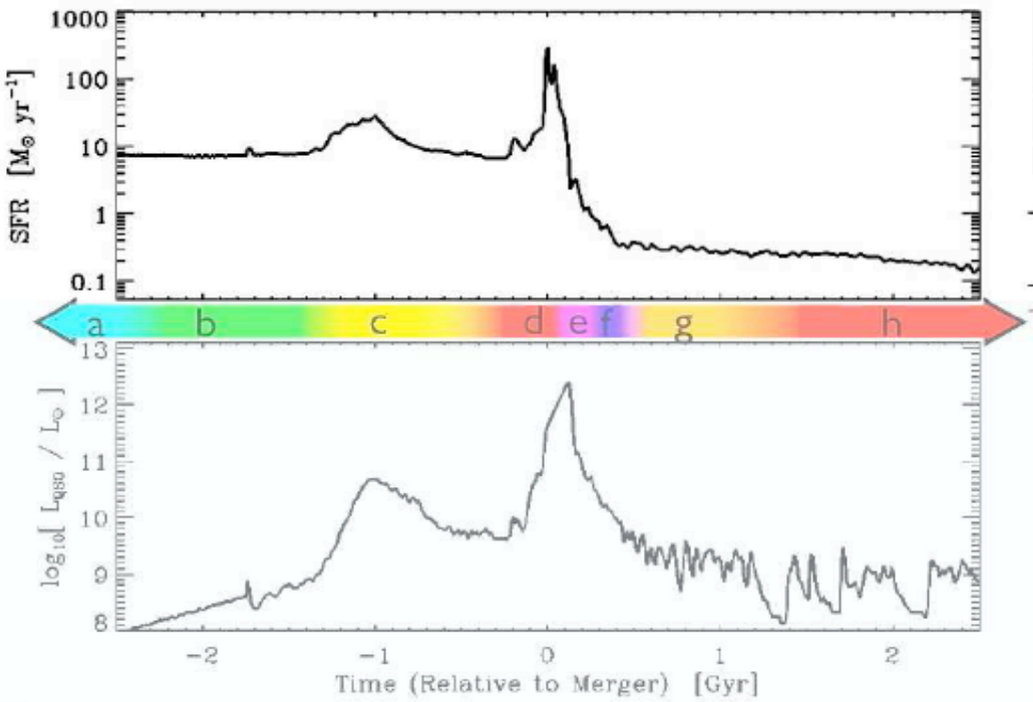
(f) Quasar



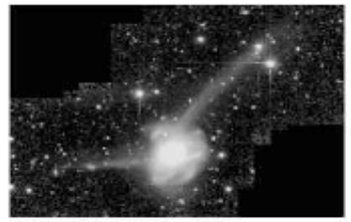
- dust removed: now a "traditional" QSO
- host morphology difficult to observe: tidal features fade rapidly
- characteristically blue/young spheroid

(b) "Small Group"

- halo accretes similar-mass companion(s)
- can occur over a wide mass range
- M_{halo} still similar to before: dynamical friction merges the subhalos efficiently



(g) Decay/K+A



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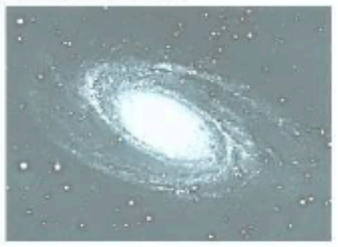
- "hot halo" from feedback
  - sets up quasi-static cooling

(a) Isolated Disk



- halo & disk grow, most stars formed
- secular growth builds bars & pseudobulges
- "Seyfert" fueling (AGN with M_B>-23)
- cannot redden to the red sequence

(h) "Dead" Elliptical

- star formation terminated
- large BH/spheroid - efficient feedback
- halo grows to "large group" scales: mergers become inefficient
- growth by "dry"[illegible]

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FIG. 1. — An schematic outline of the phases of growth in a "typical" galaxy undergoing a gas-rich major merger. *Image Credit:* (a) NOAO/AURA/NSF; (b) REU program/NOAO/AURA/NSF; (c) NASA/STScI/ACS Science Team; (d) Optical (left): NASA/STScI/R. P. van der Marel & J. Gerssen; X-ray (right): NASA/CXC/MPE/S. Komossa et al.; (e) Left: J. Bahcall/M. Disney/NASA; Right: Gemini Observatory/NSF/University of Hawaii Institute for Astronomy; (f) J. Bahcall/M. Disney/NASA; (g) F. Schweizer (CIW/DTM); (h) NOAO/AURA/NSF.

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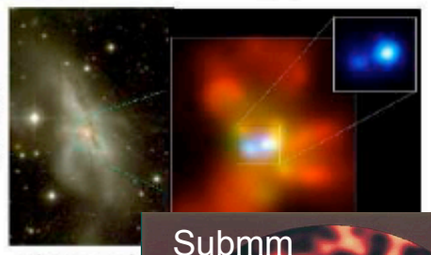

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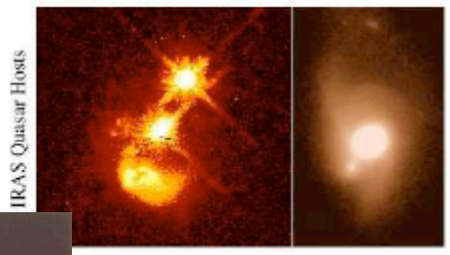

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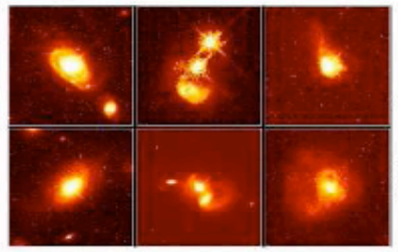

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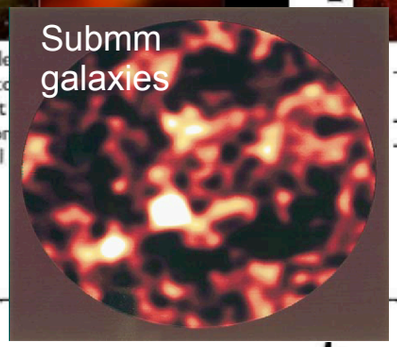
Submm galaxies



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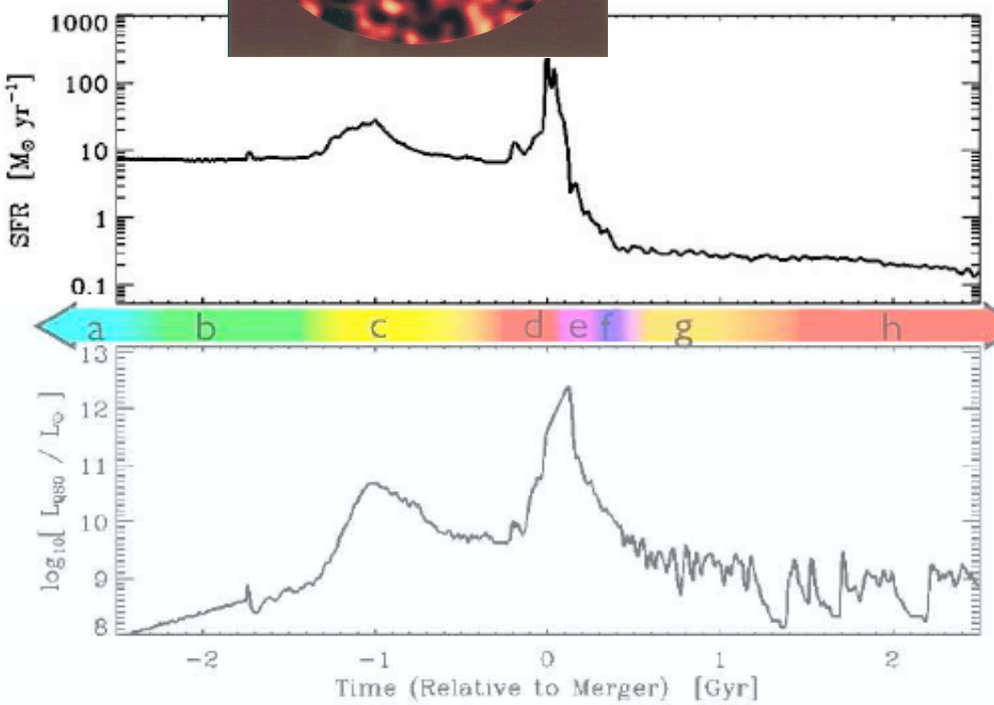

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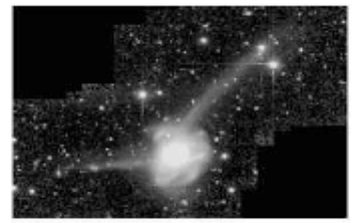

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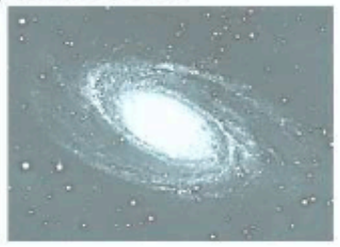

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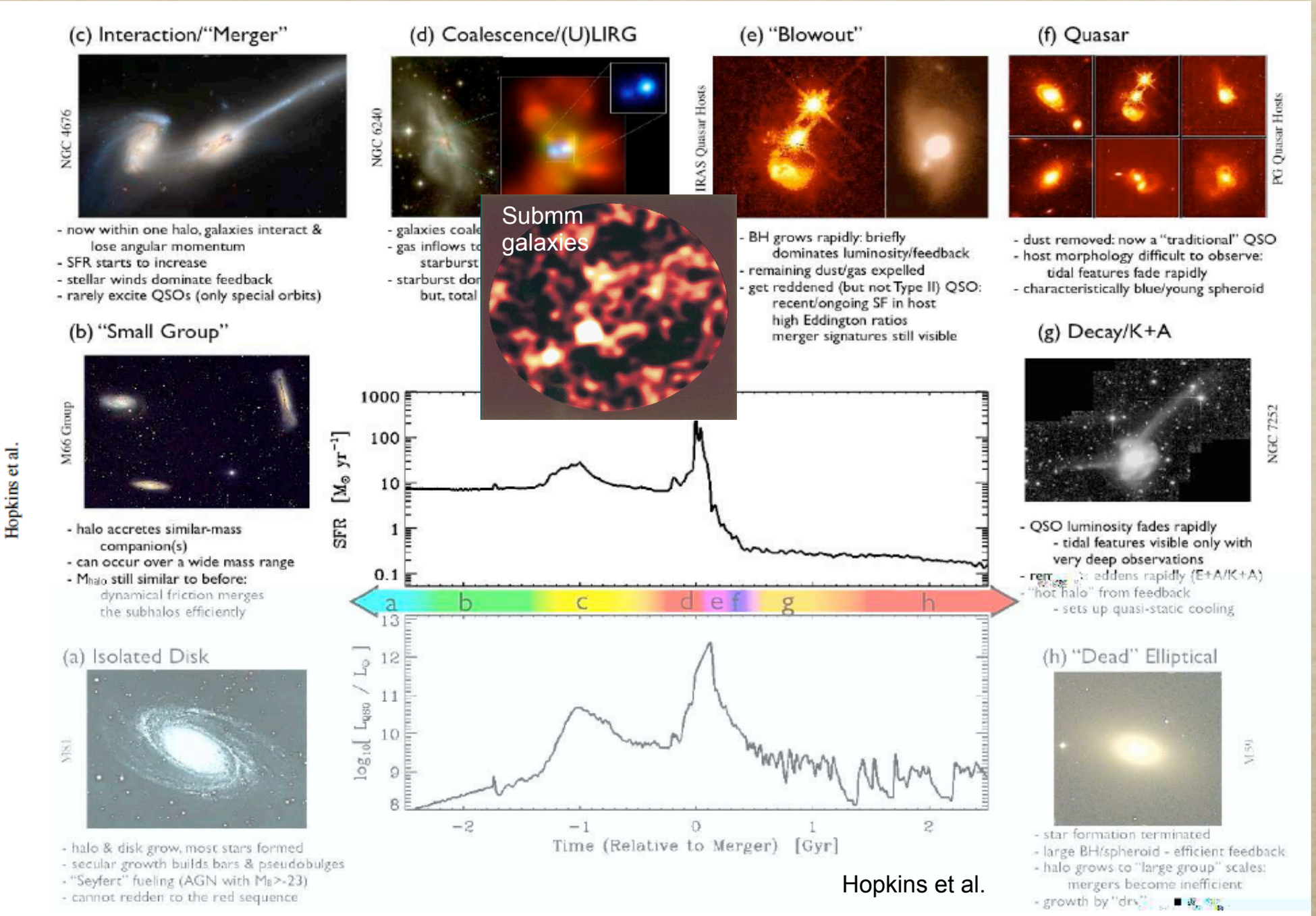

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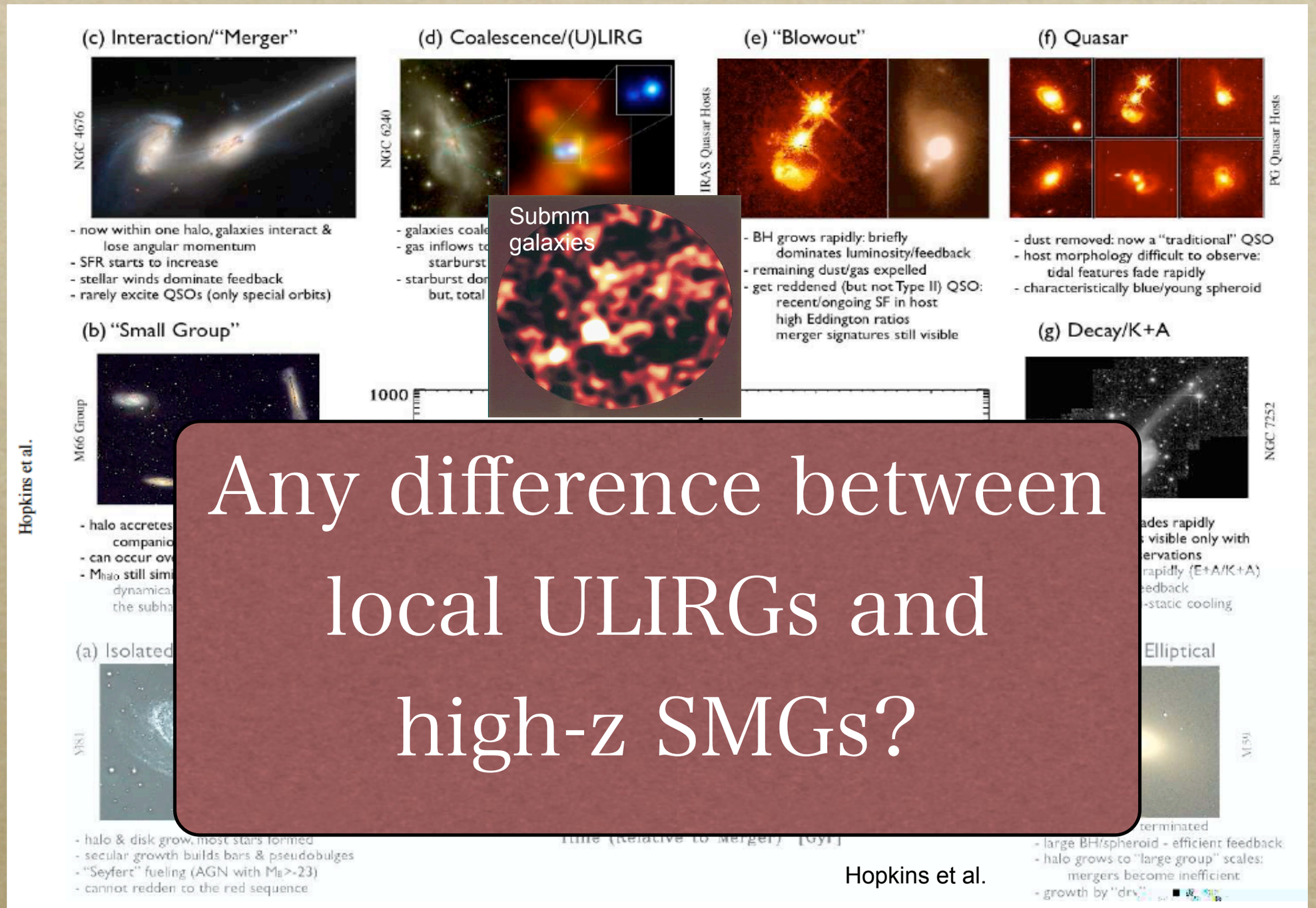
- Merging is a fundamental process to make massive early-type galaxies
- The most active star-formation phase is observed as dusty starbursts



Any difference between local ULIRGs and high-z SMGs?

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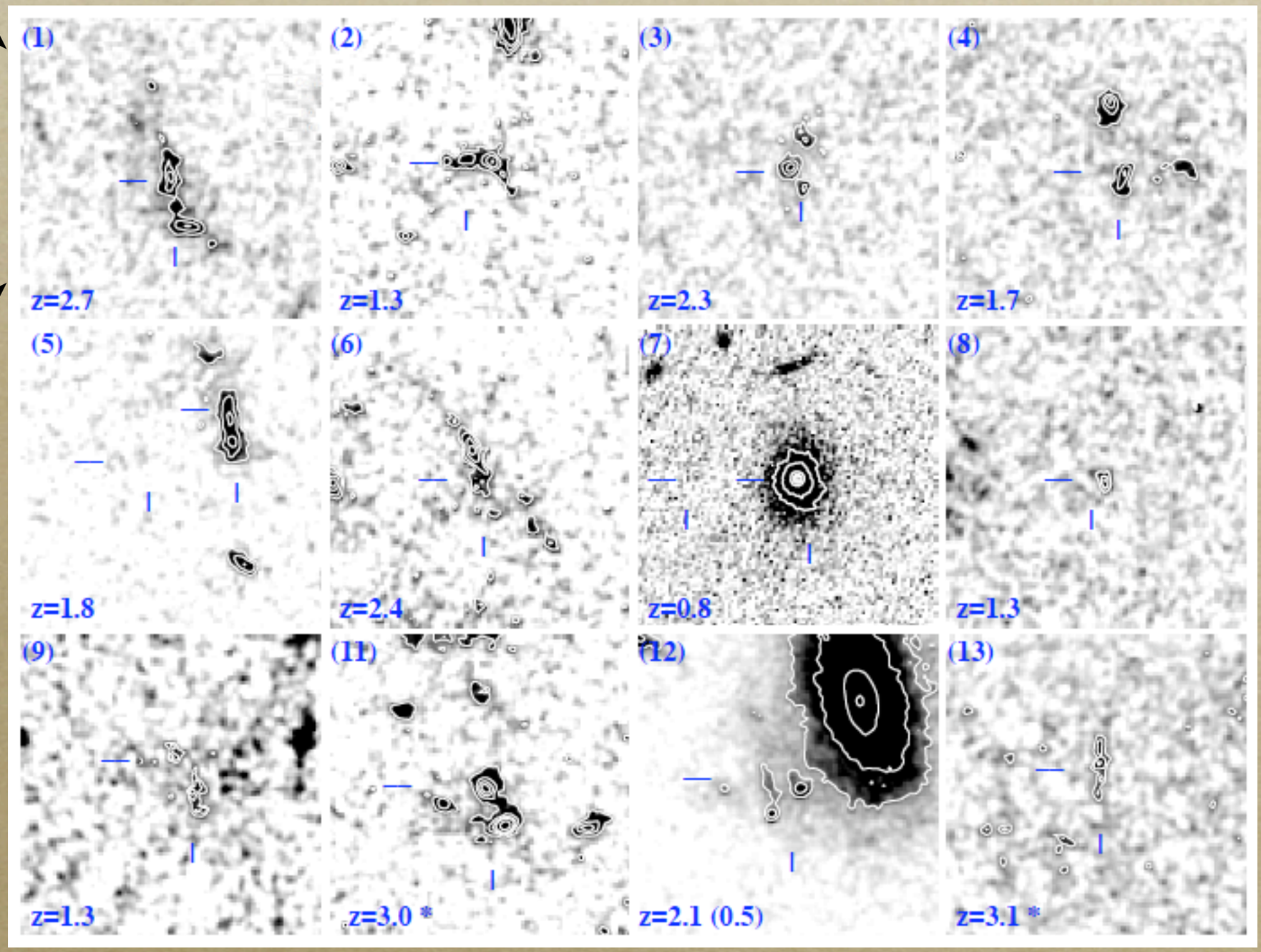
Comparison of physical properties

	local ULIRGs	SMGs (z~2)
Luminosity	$10^{12.1\pm0.1}\ L_\odot$	$10^{13.1\pm0.14}\ L_\odot$
Mass $\langle M_{t1/2}\rangle$	$6\times10^9\ M_\odot$	$6\times10^{10}\ M_\odot$
SFR	~200 $M_\odot$/yr	~900 $M_\odot$/yr
Size $\langle R_{1/2}\rangle$	~ 0.6 kpc	~ 2 kpc
$\langle v_c\rangle$	200 - 260 km/s	~400 km/s
Matter Density	350 cm^{-3} / 4900 $M_\odot$ pc^{-2}	~100 cm^{-3} / 5000 $M_\odot$ pc^{-2}
f_g	0.16	~0.4
NUMBER Density	10^{-8} Mpc^{-3}	10^{-6} Mpc^{-3}

Tacconi et al. (2006)

Morphology of SMGs



Chapman et al. (2003)

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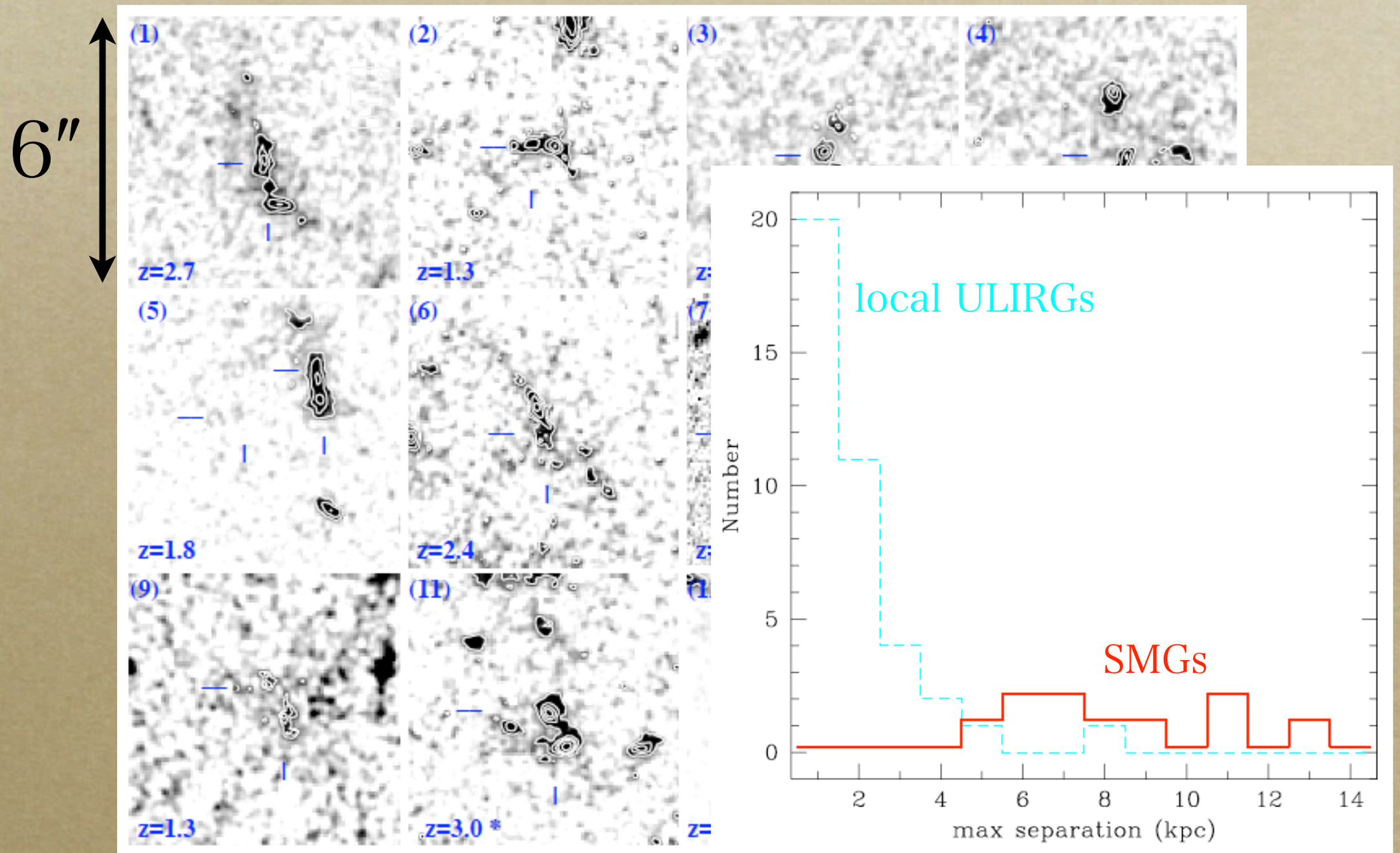

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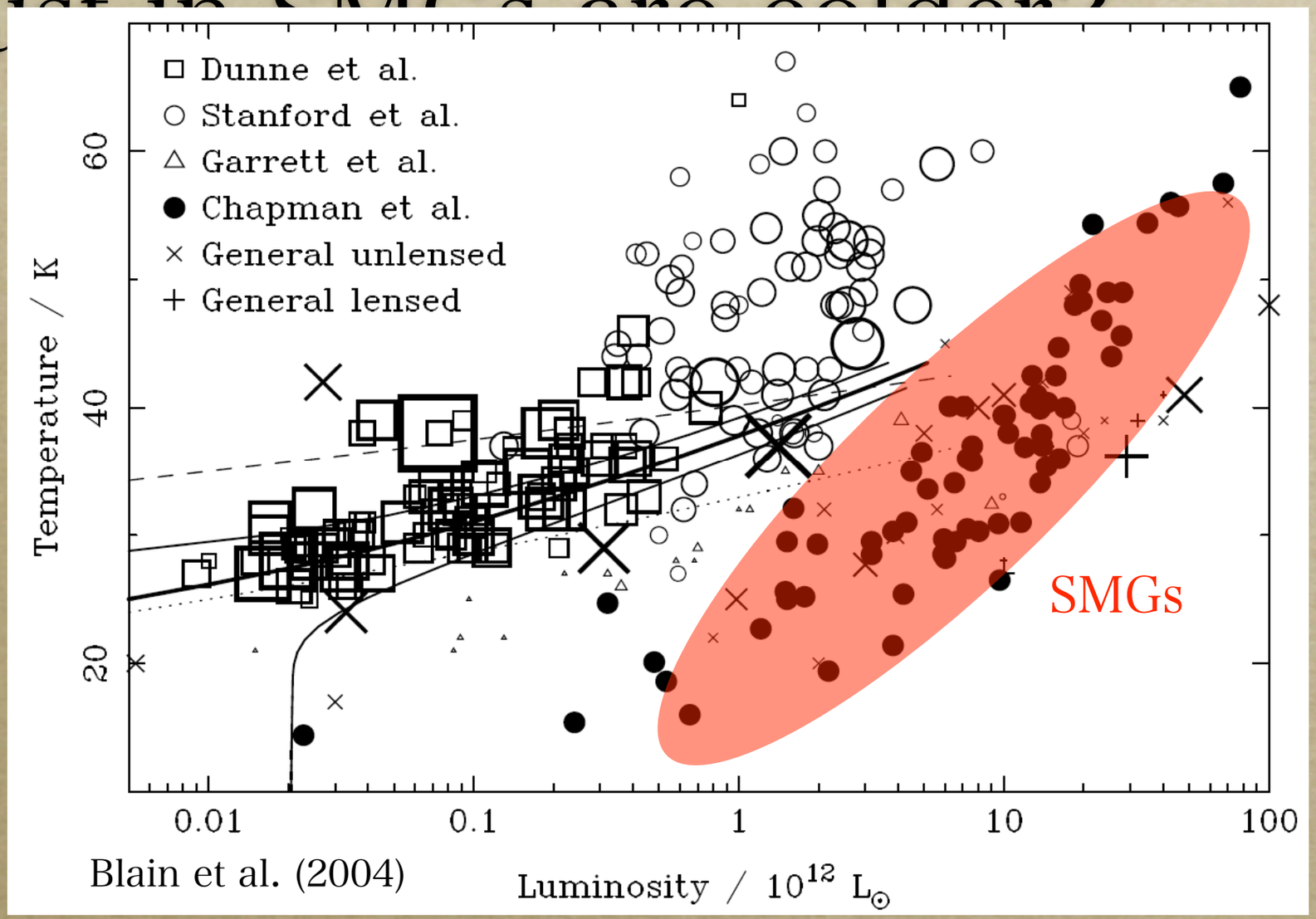

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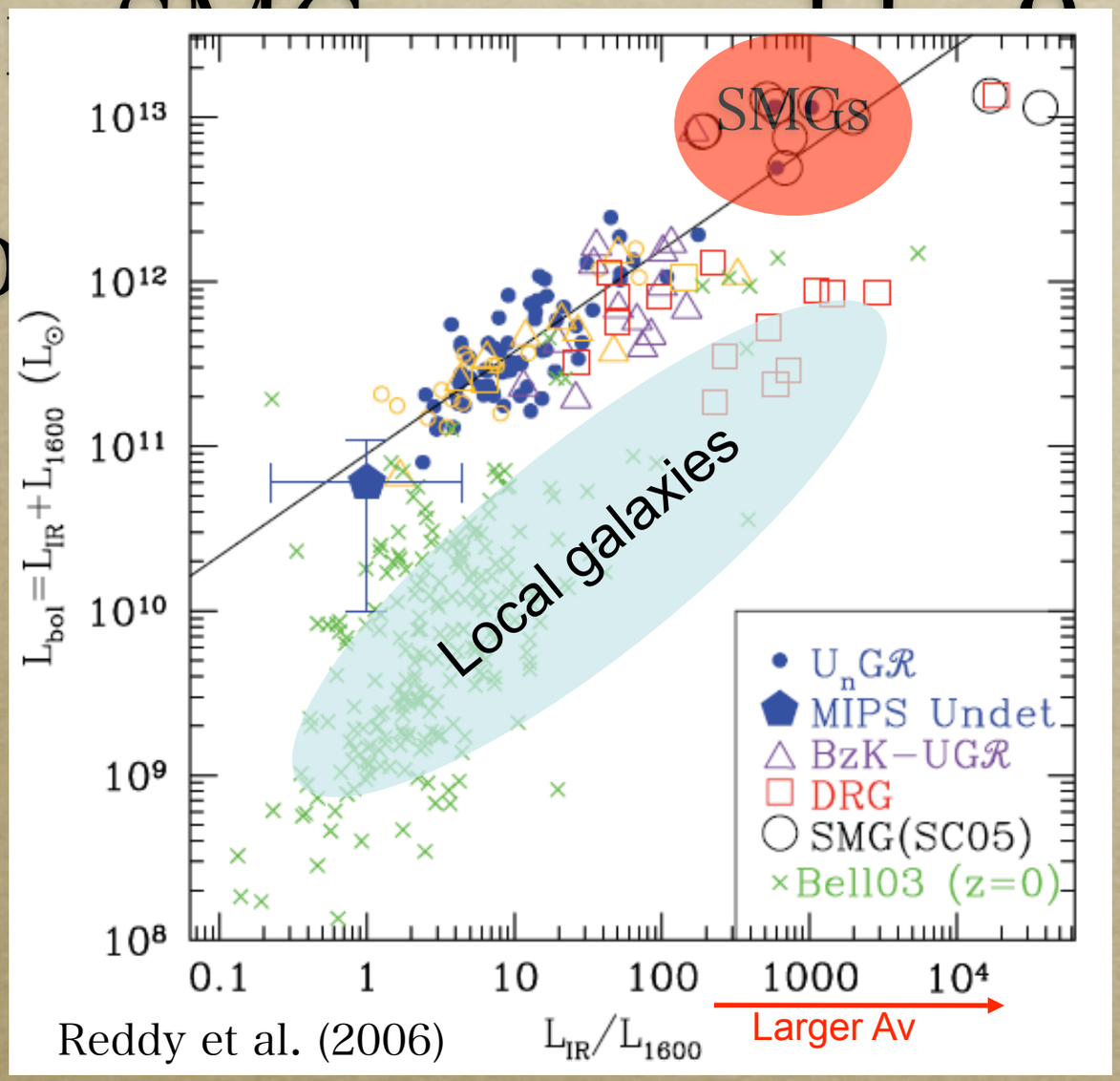

Reddy et al. (2006)

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- Strong PAH emission?

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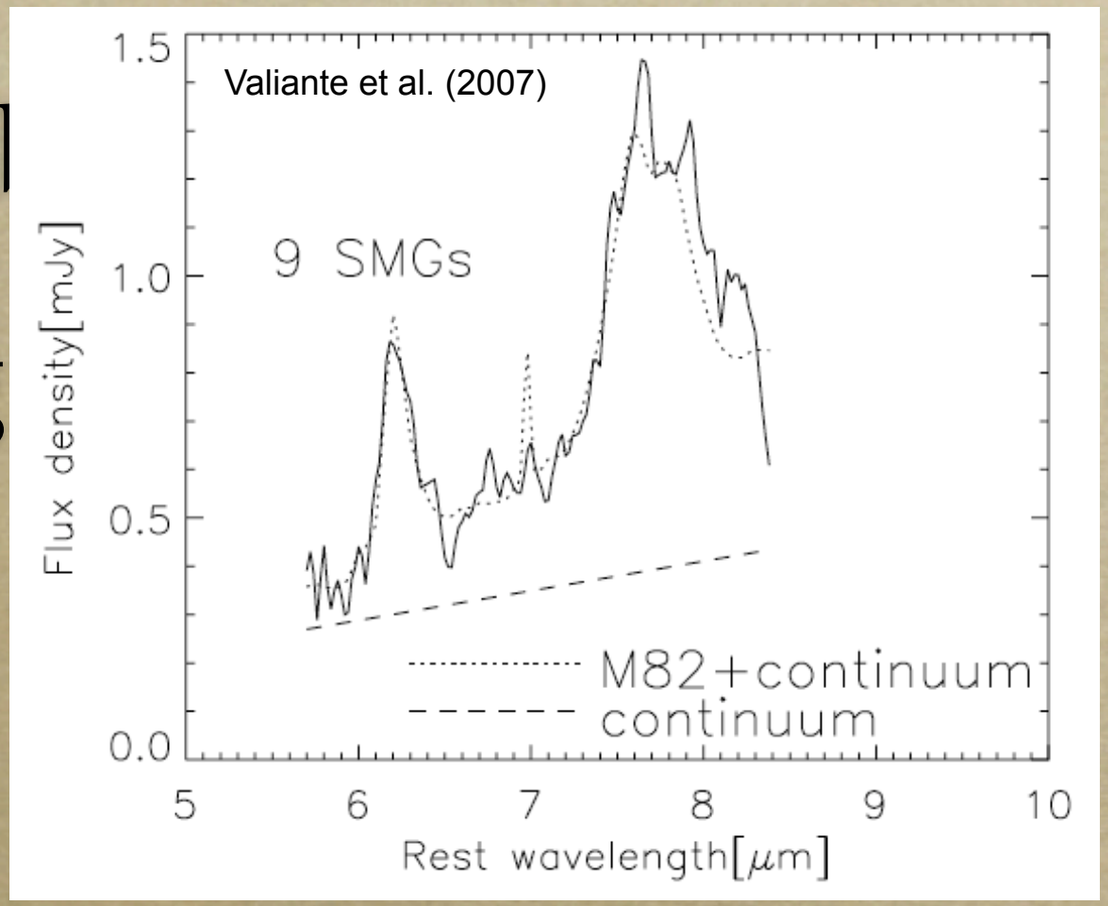
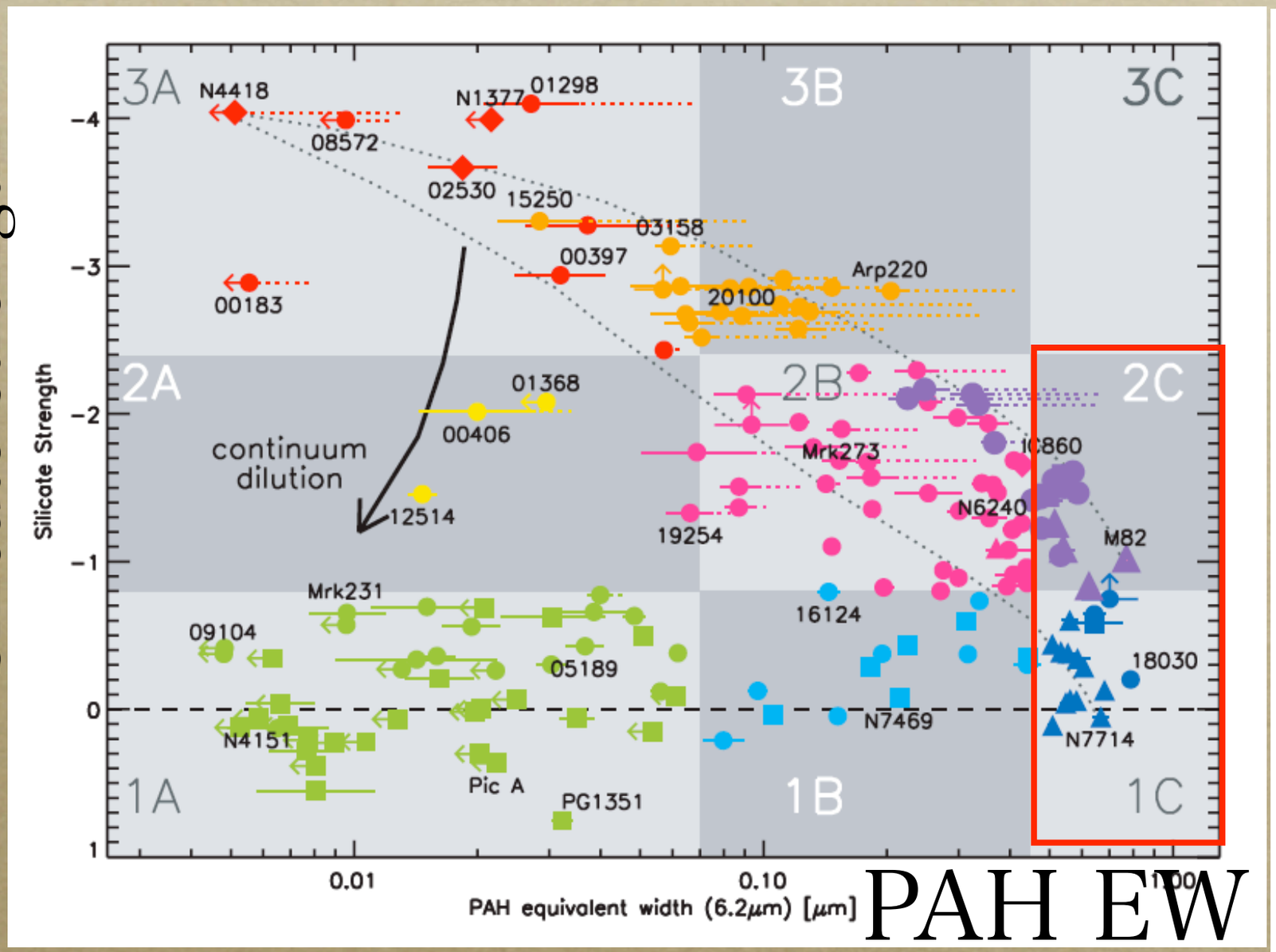
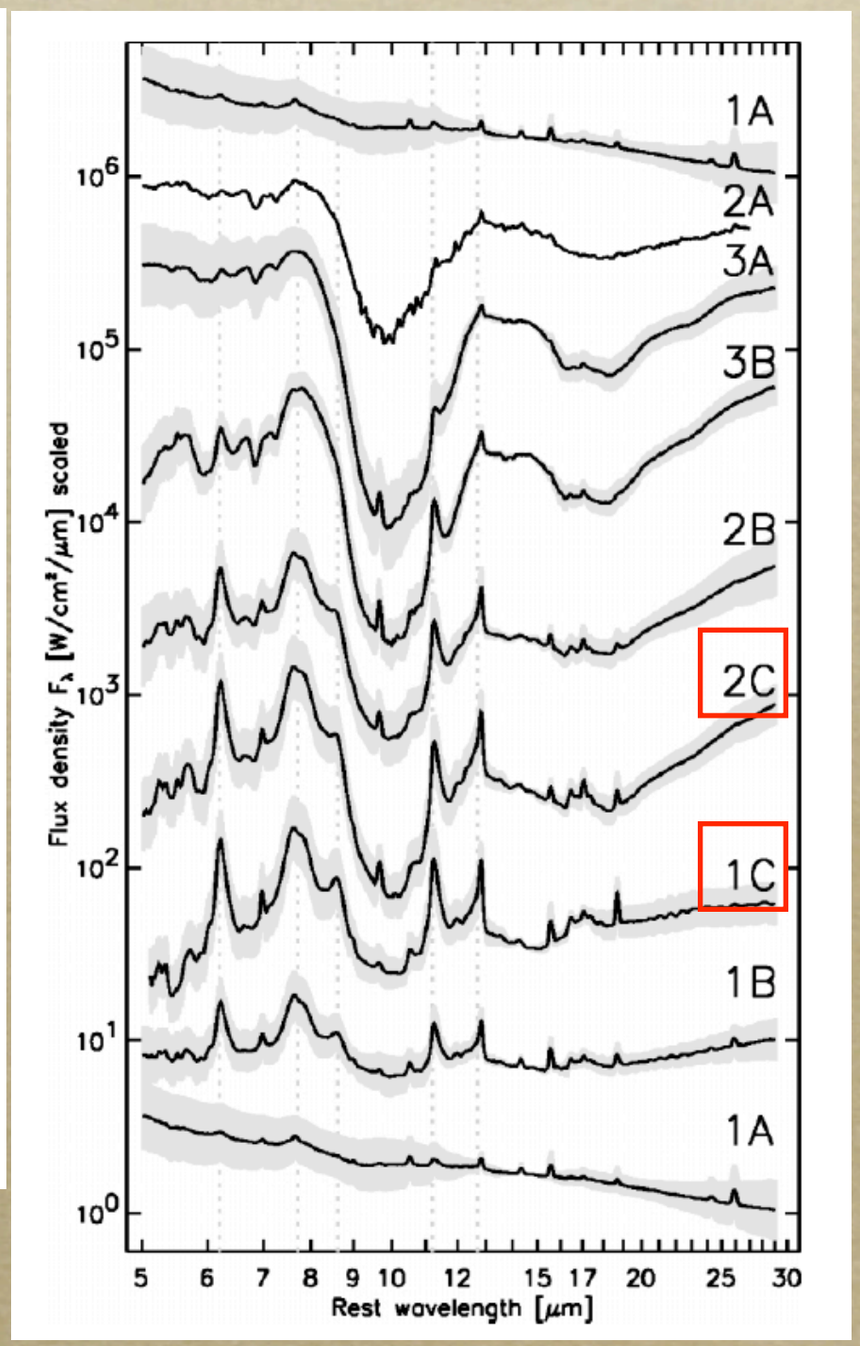


MIR classification of local ULIRGs



Silicate strength

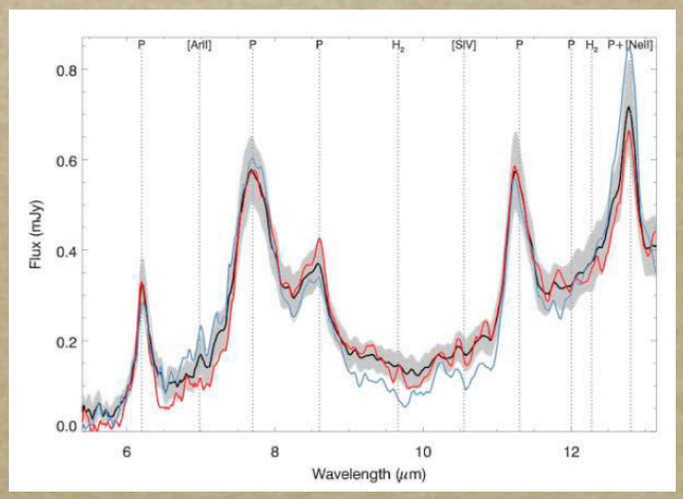
PAH EW



Spoon et al. (2007)

PAH strong HyperLIRGs

- F(24) >500uJy sources
- Bump in IRAC SED
  - ~35 deg^{-2}
- 1.4<Z<1.9
- SFR > 1000 M/yr
- Log L(IR) = 12.9 - 13.8



Farrah et al. (2008)

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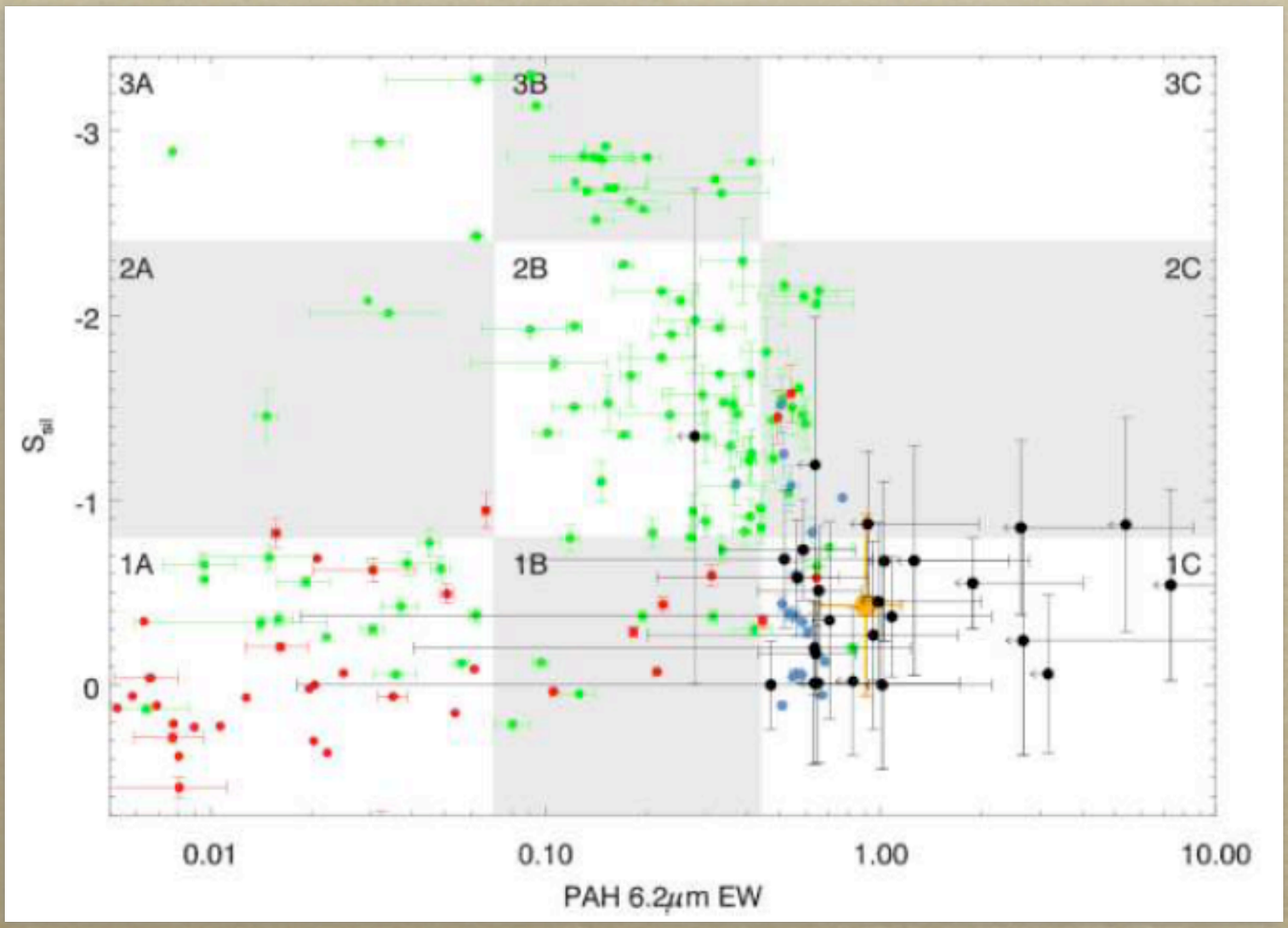

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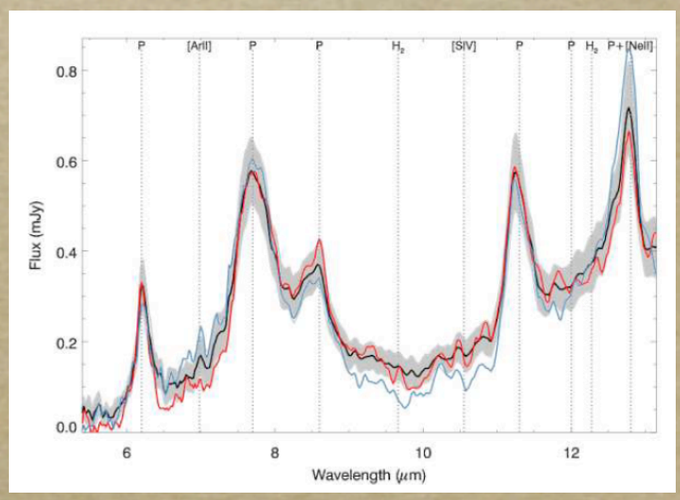

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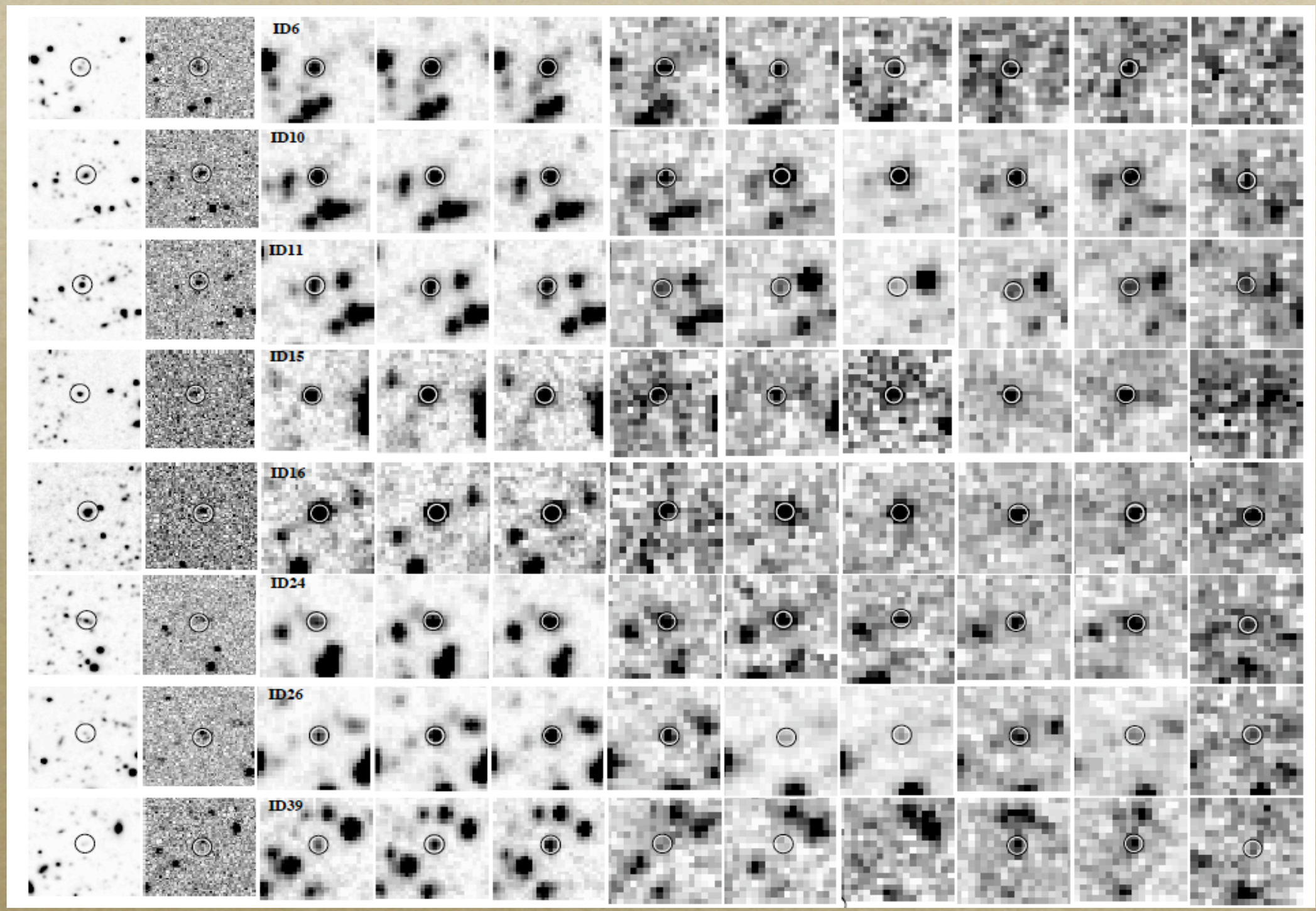
Uniqueness of **AKARI**



Takagi et al. (2007)

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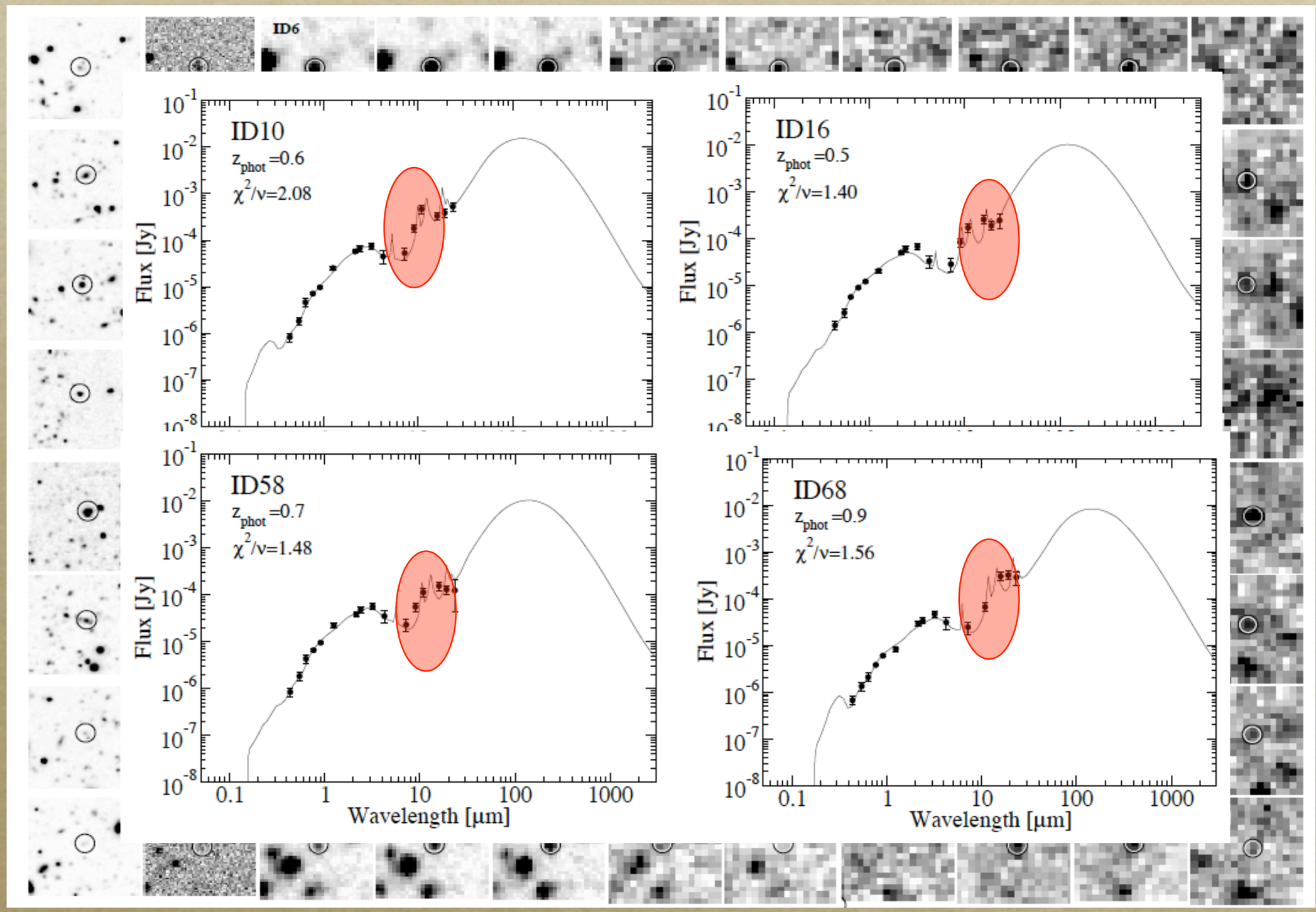
R Ks N2 N3 N4 S7 S9W S11 L15 L18W L24



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How about the specific SFR?

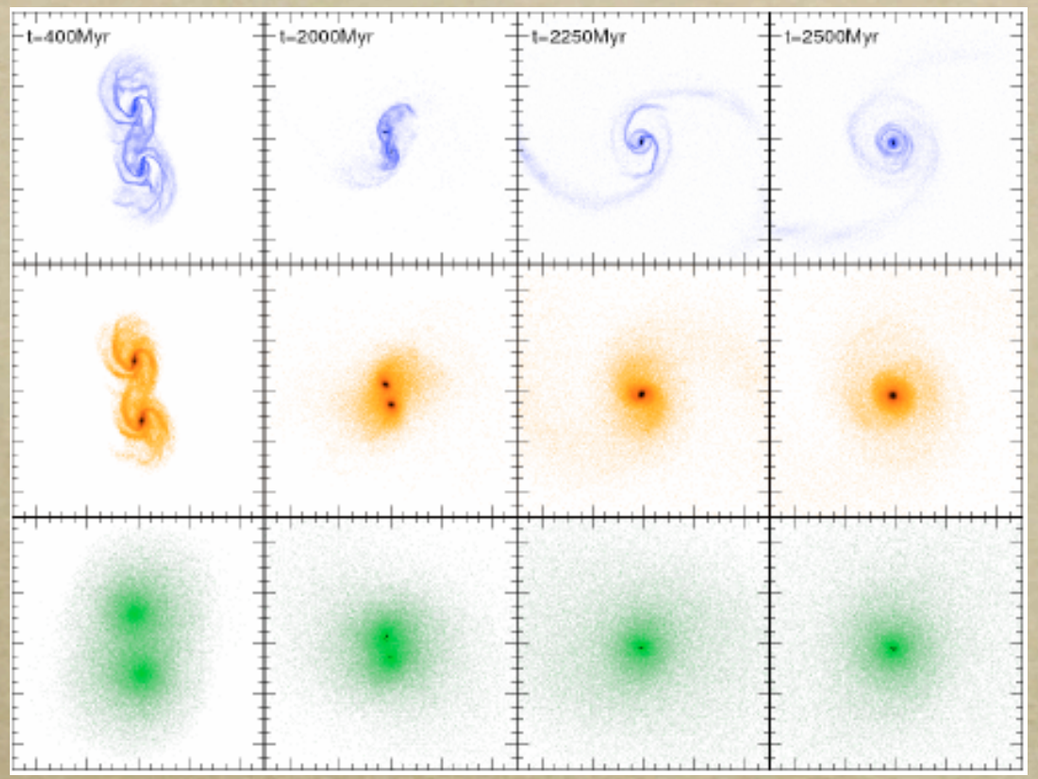
SFR Enhancement

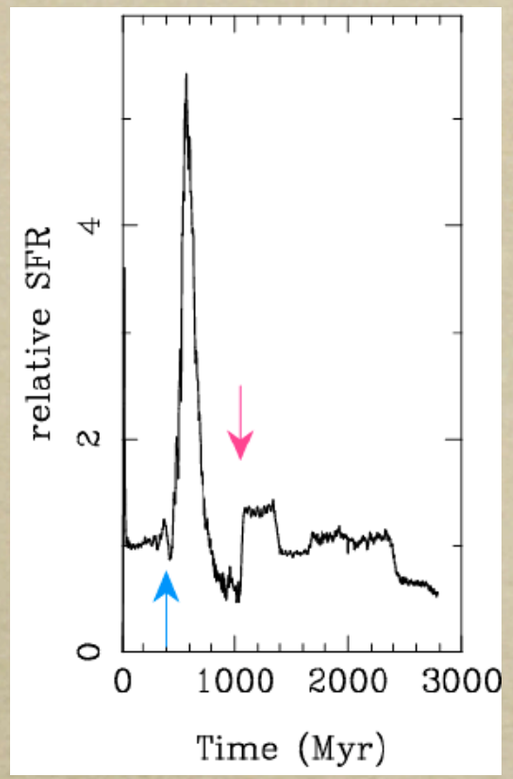
Direct merger

Gas

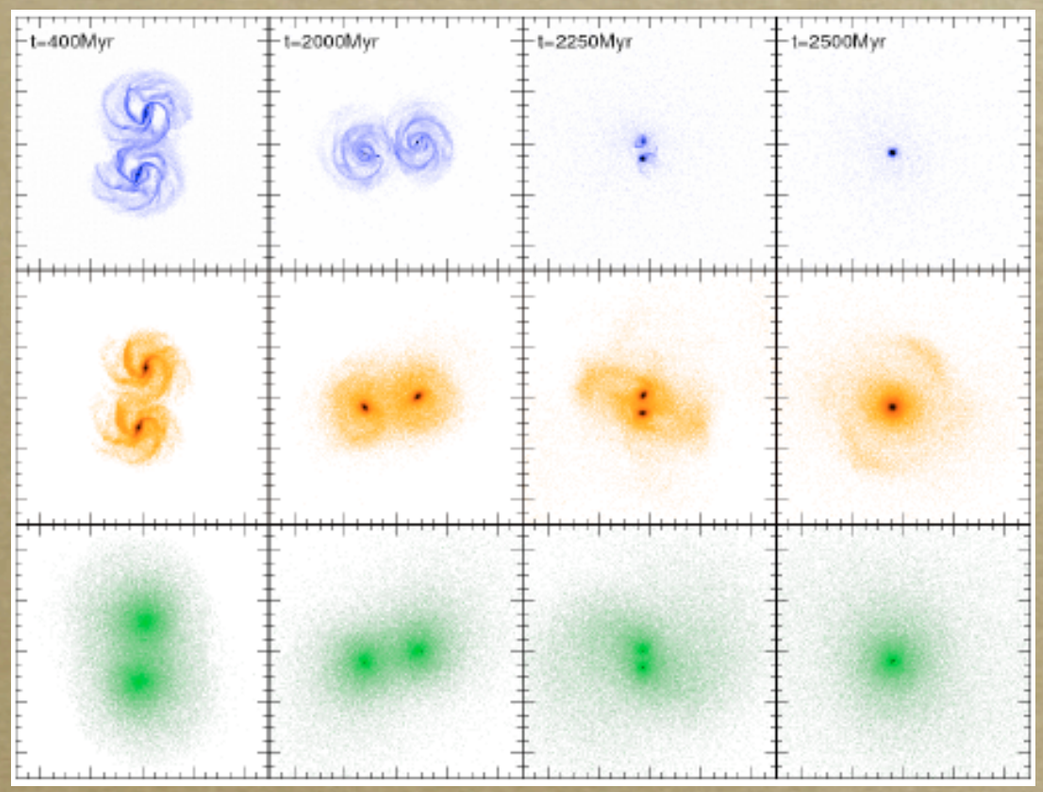
Star

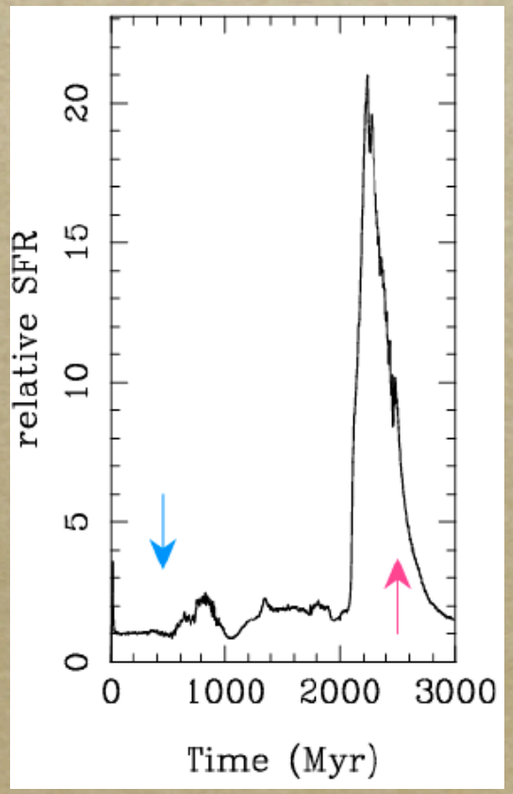
DM





Retrograde merger





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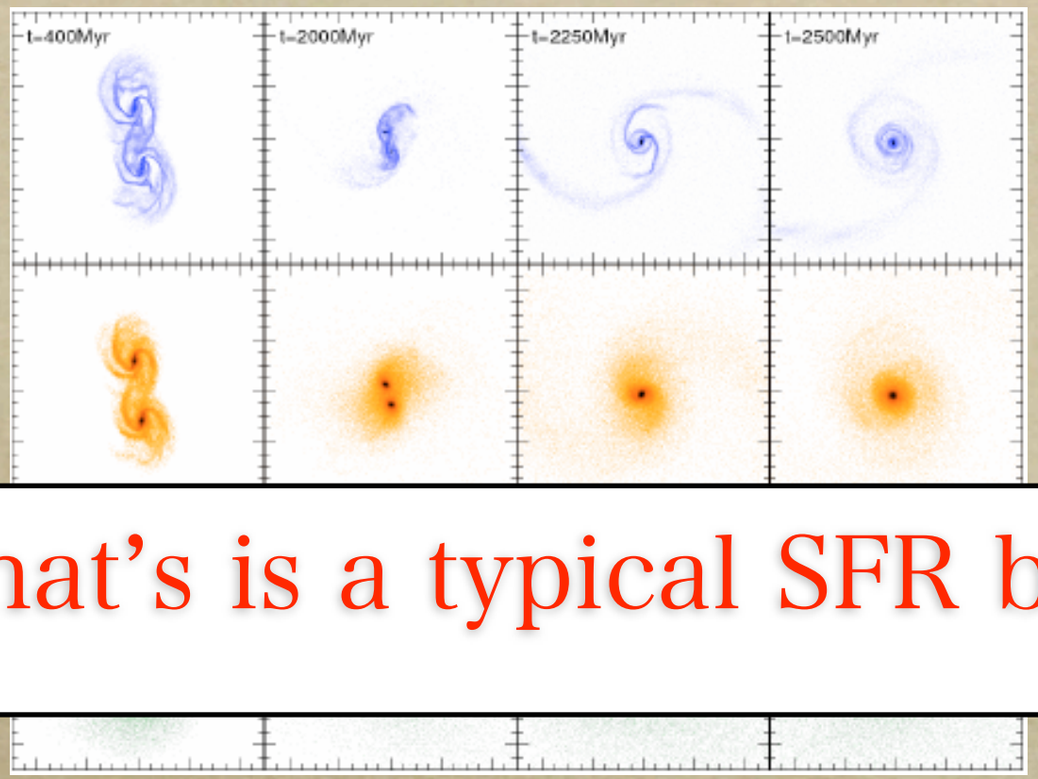
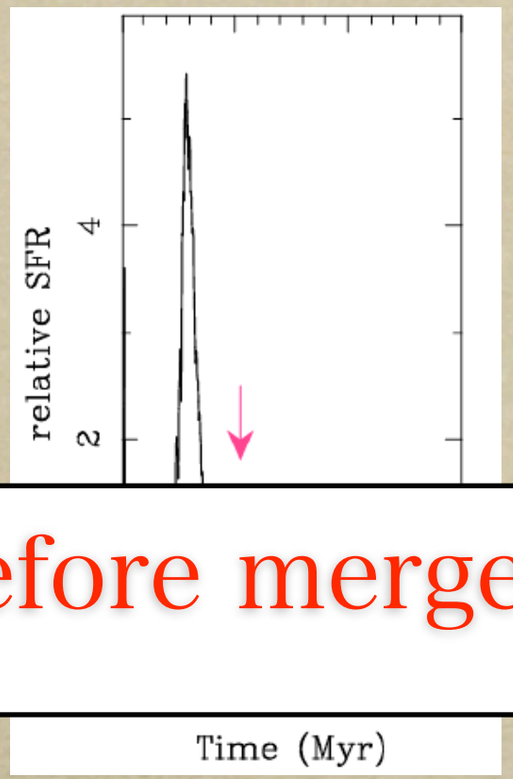
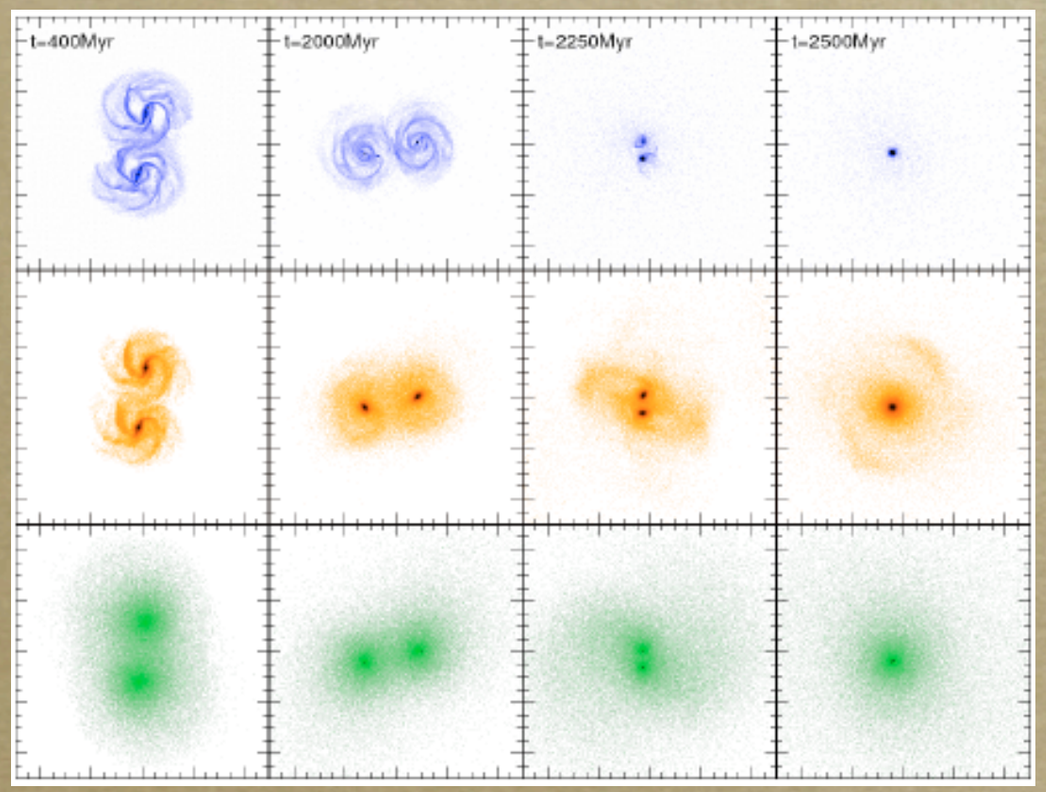




What's is a typical SFR before merger?

Retrograde merger



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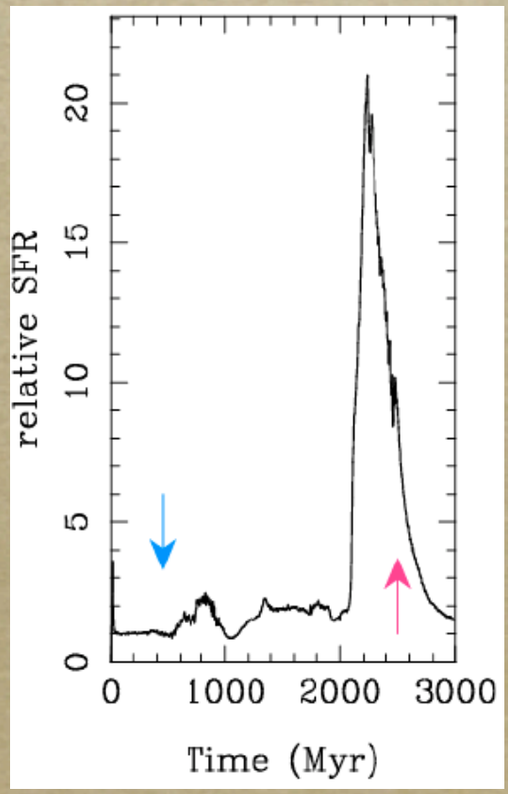
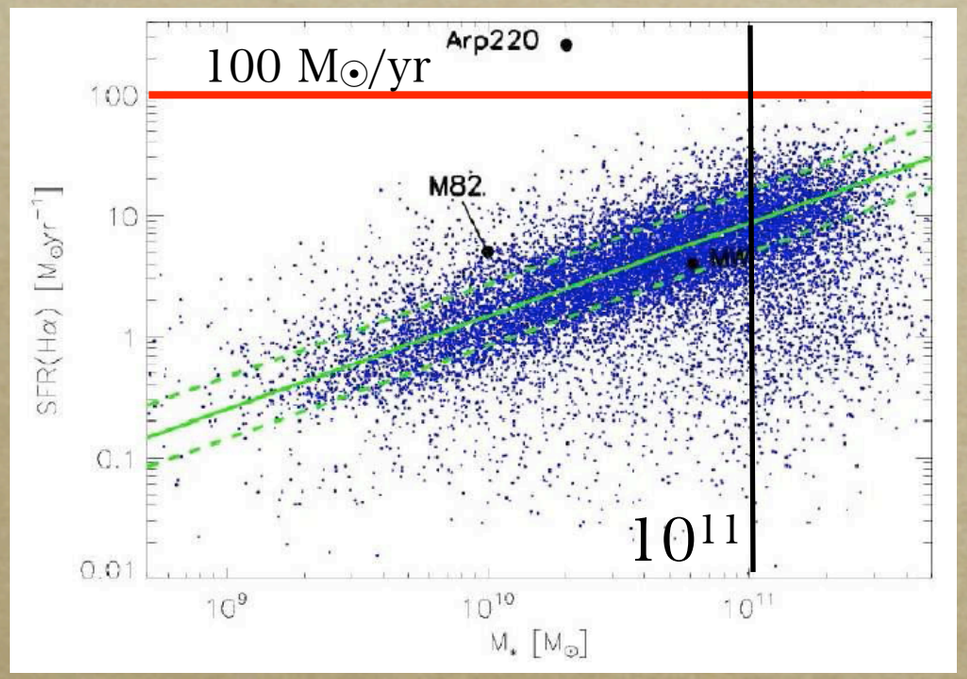


The SFR-M⋆ relation at z≤1

z~0



Elbaz et al. (2007)

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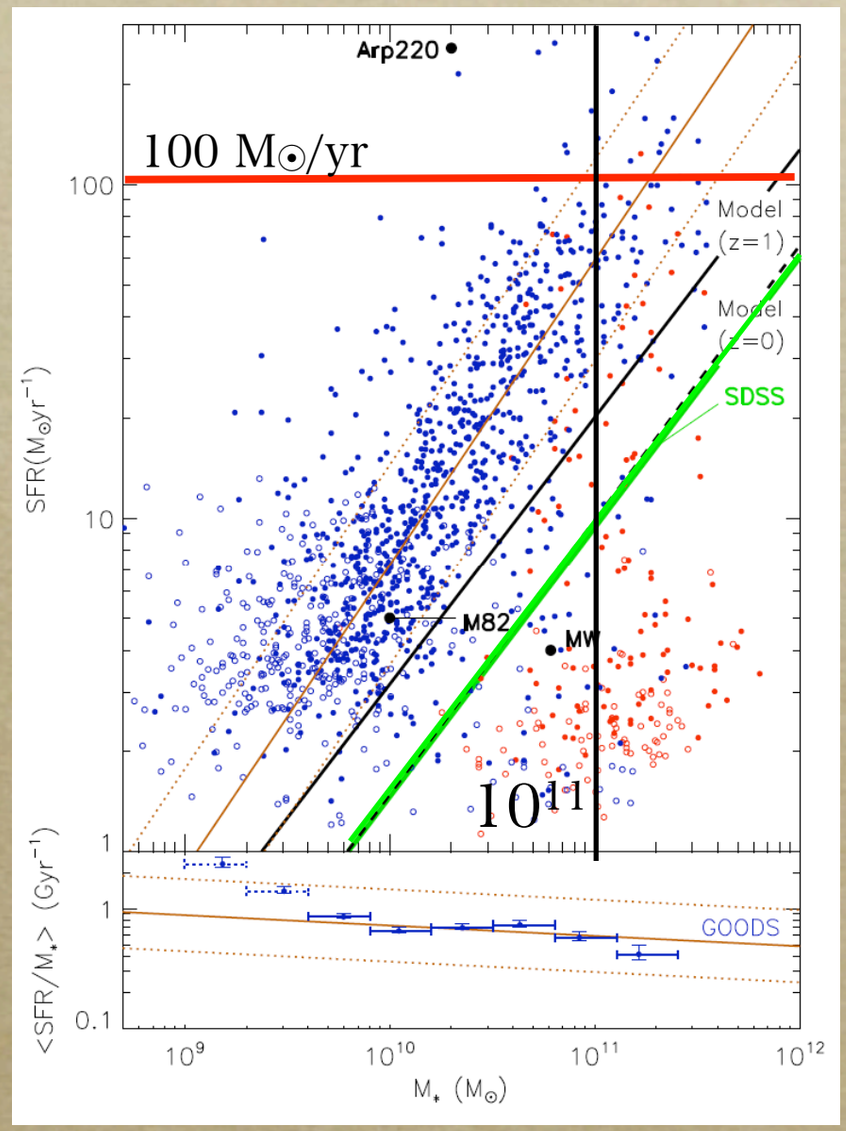


- ULIRGs are strong outlier

The SFR-M⋆ relation

- At $M_\star = 10^{11} M_\odot$,

  z~2

  - SFR = 200 M⊙/yr

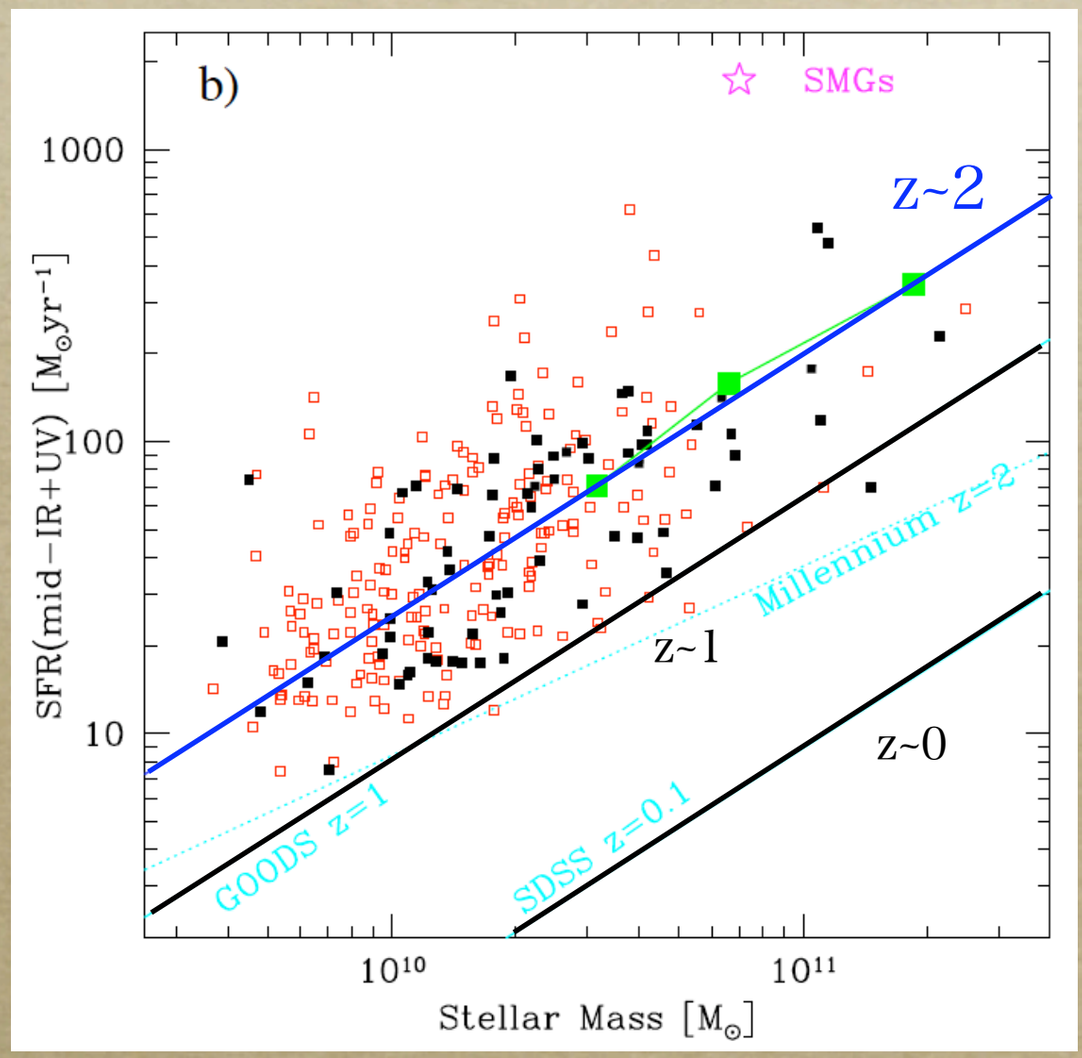
  z~1

  - SFR = 60 M⊙/yr

  z~0

  - SFR = 9 M⊙/yr

BzK-selected galaxies



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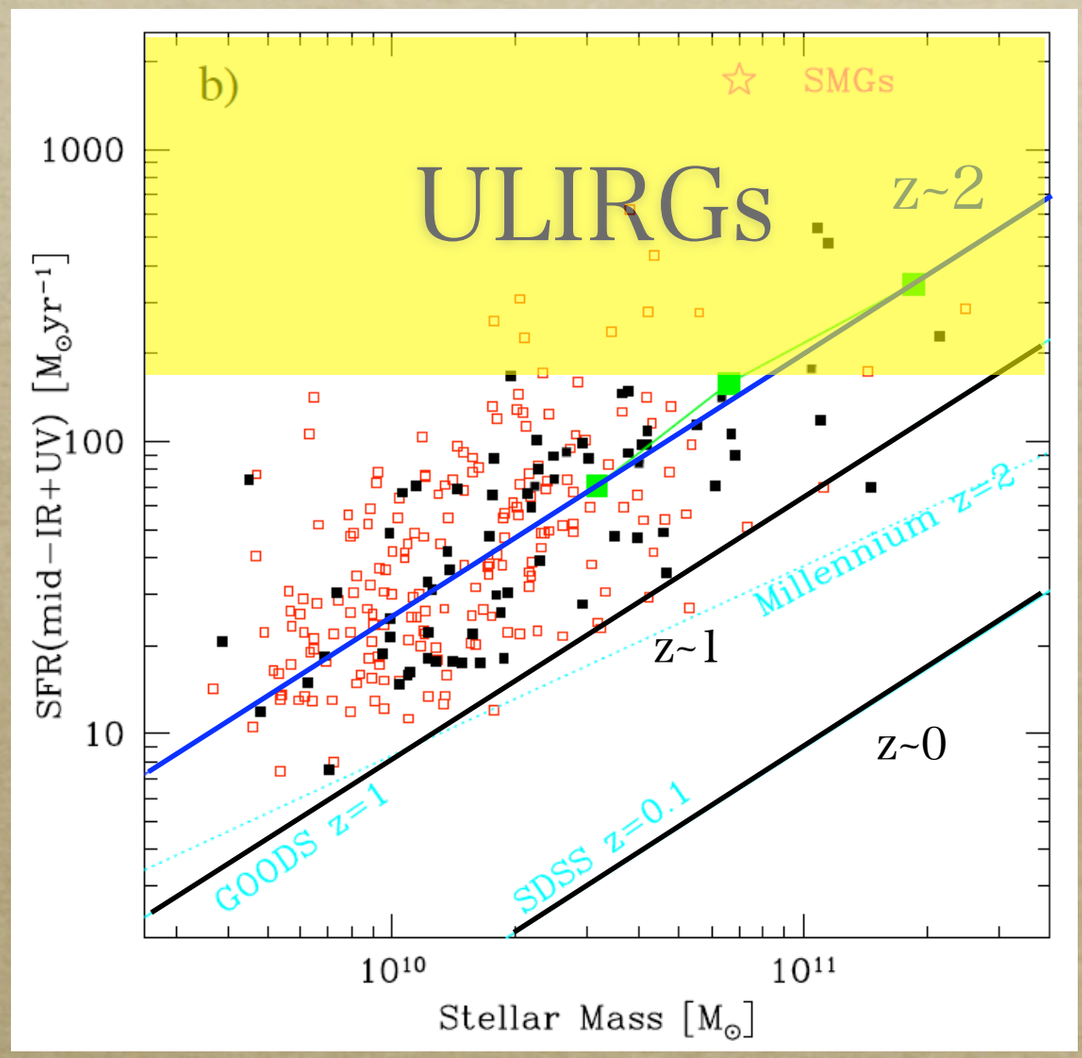

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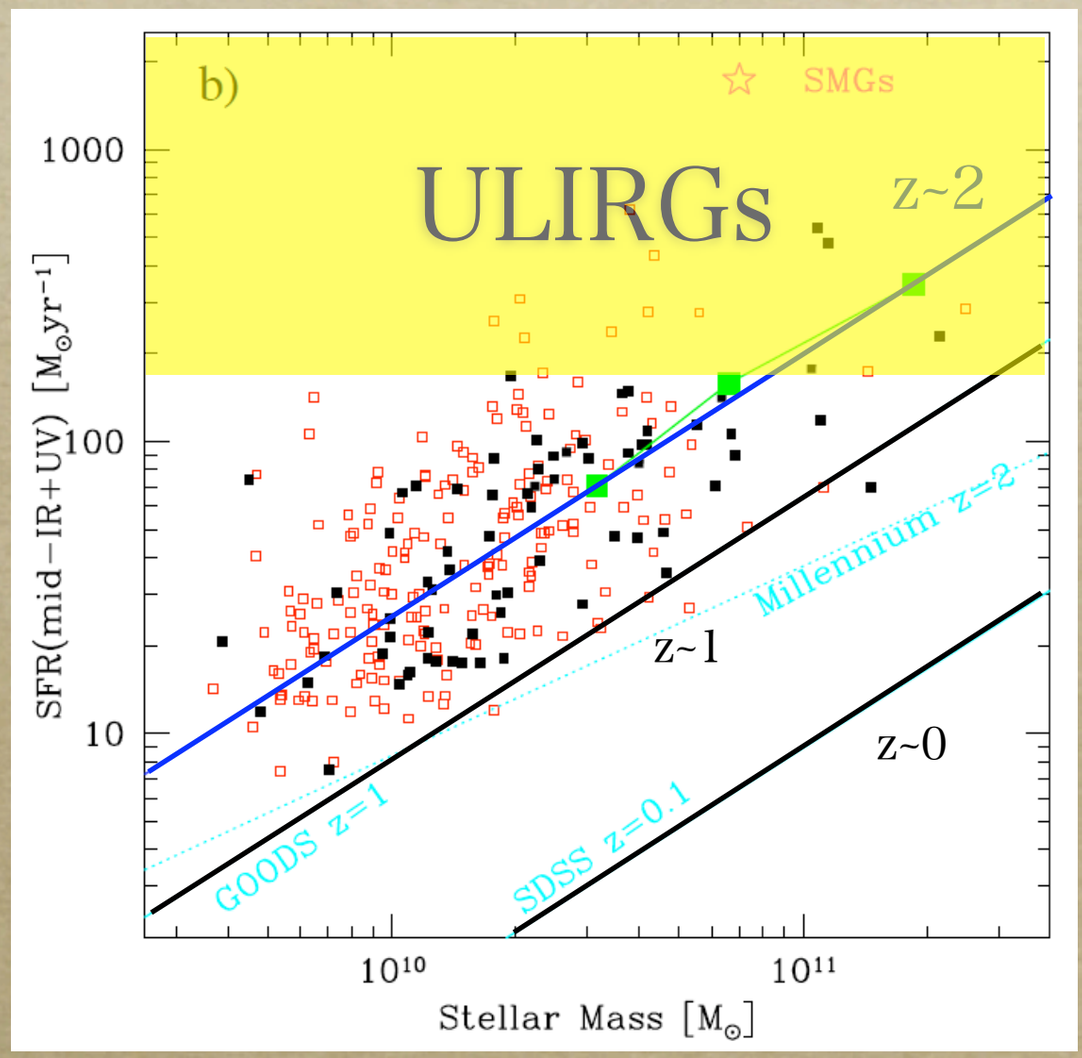
  - SFR = 9 M⊙/yr

What is the difference between BzKs and SMGs?

BzK-selected galaxies

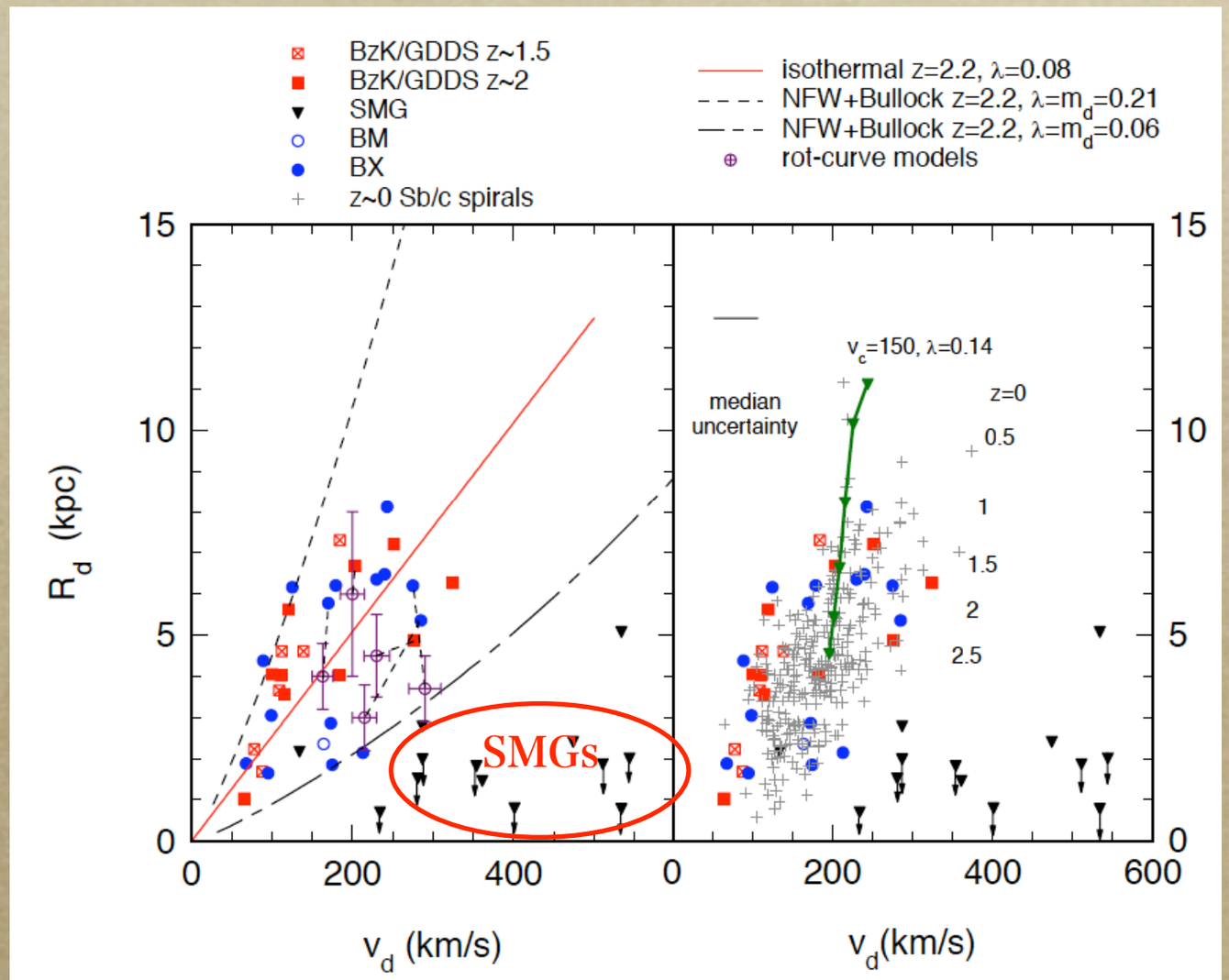


Daddi et al. (2007)

Kinematic properties at z~2

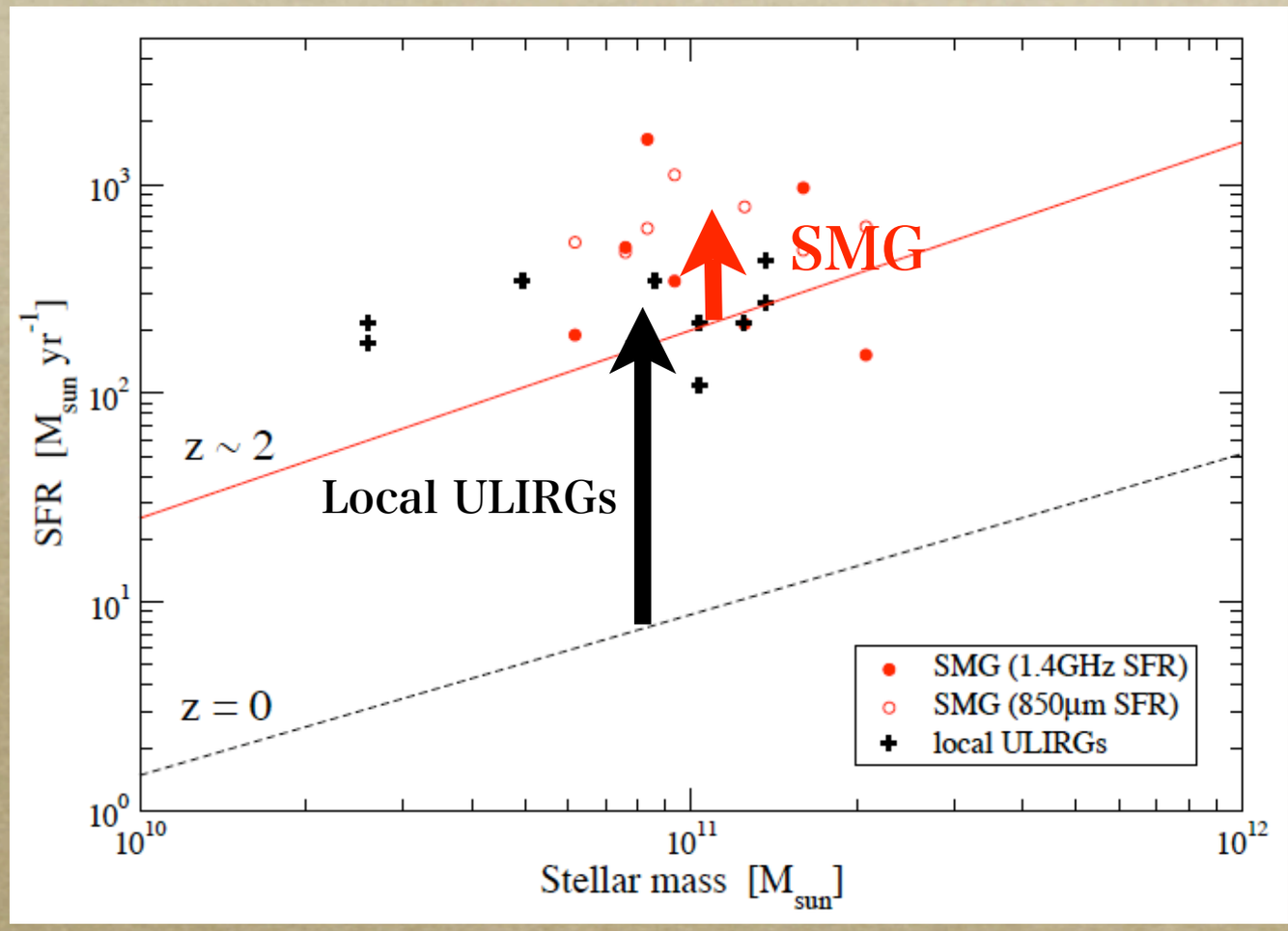
- The size-velocity of BzKs are similar to local spiral
  - BzKs = Disk (ULIRGs)
- SMGs are compact and have large velocity
  - SMGs = Merger

SMGs are merging BzKs?



Bouche et al. (2007)

SFR enhancement (1)



Takagi et al. in prep

SFR enhancement (1)

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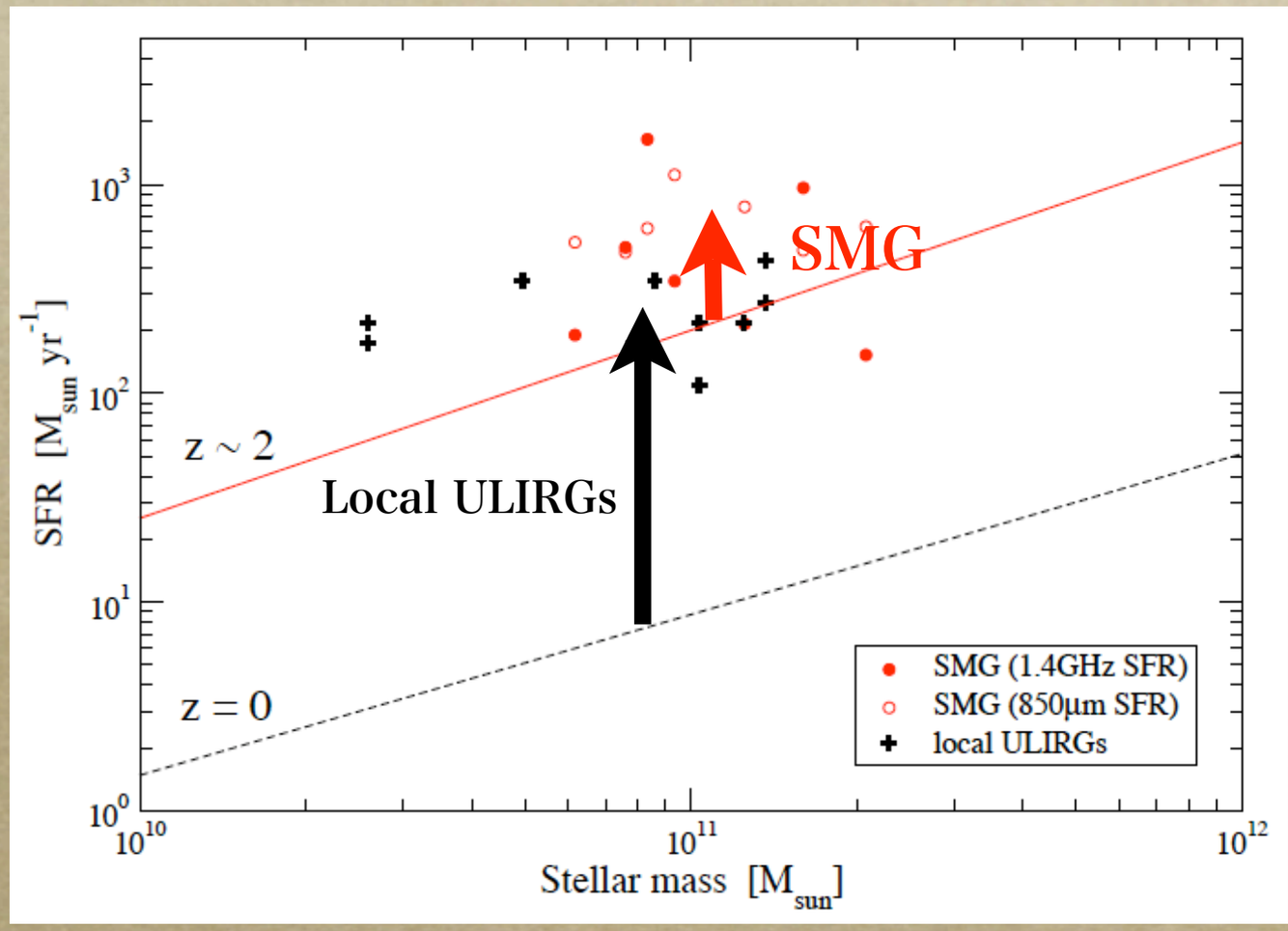

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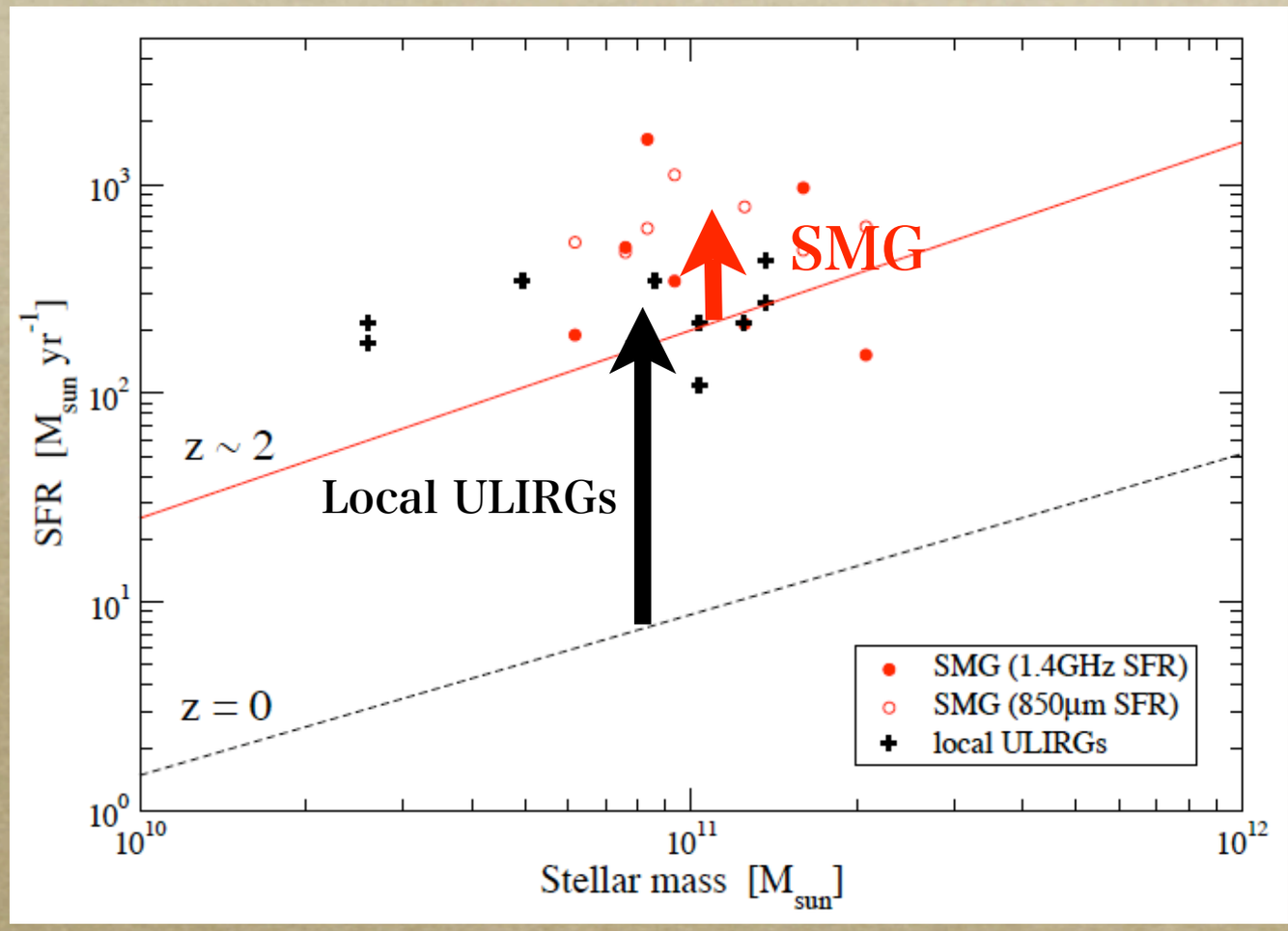

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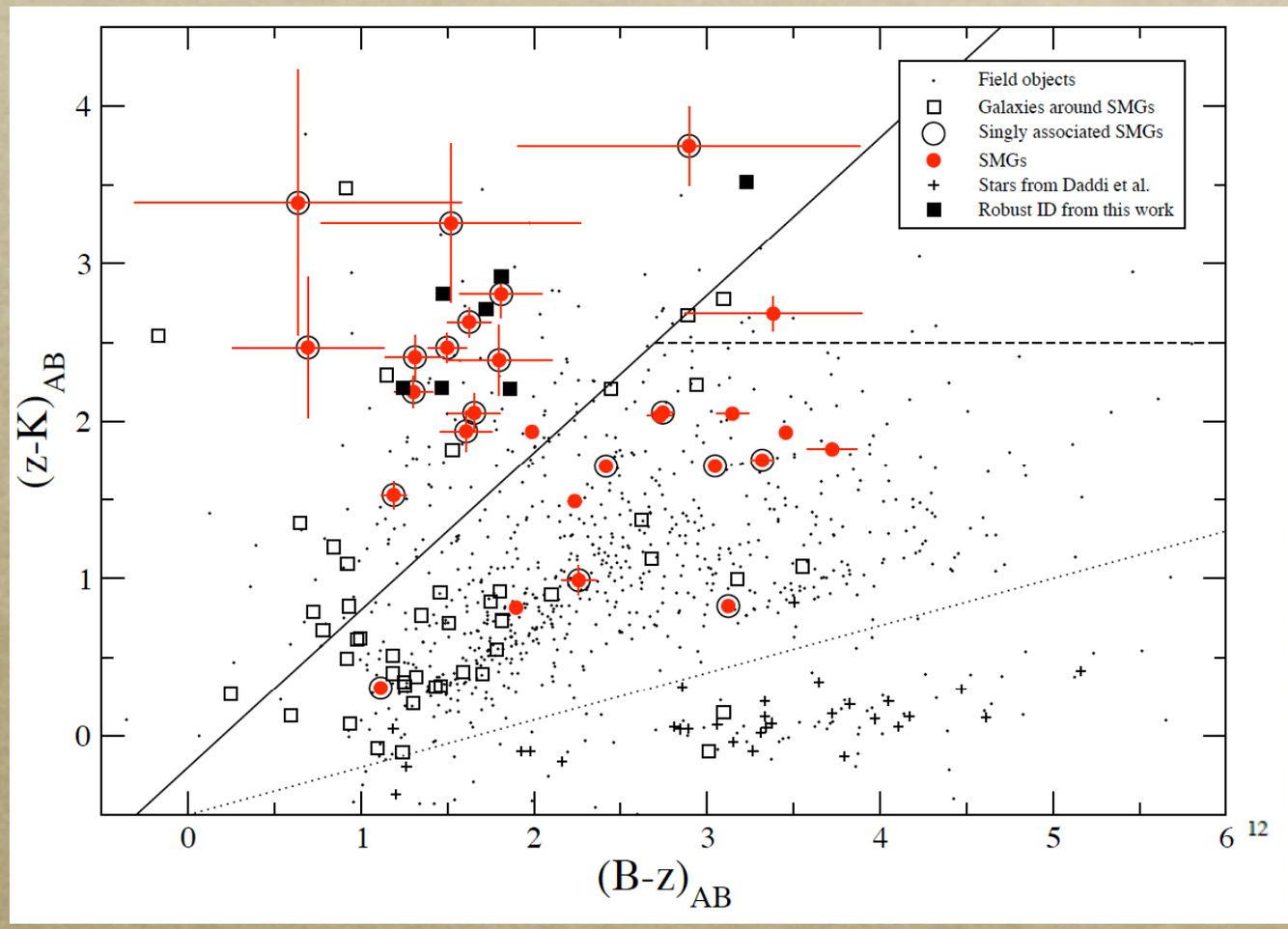

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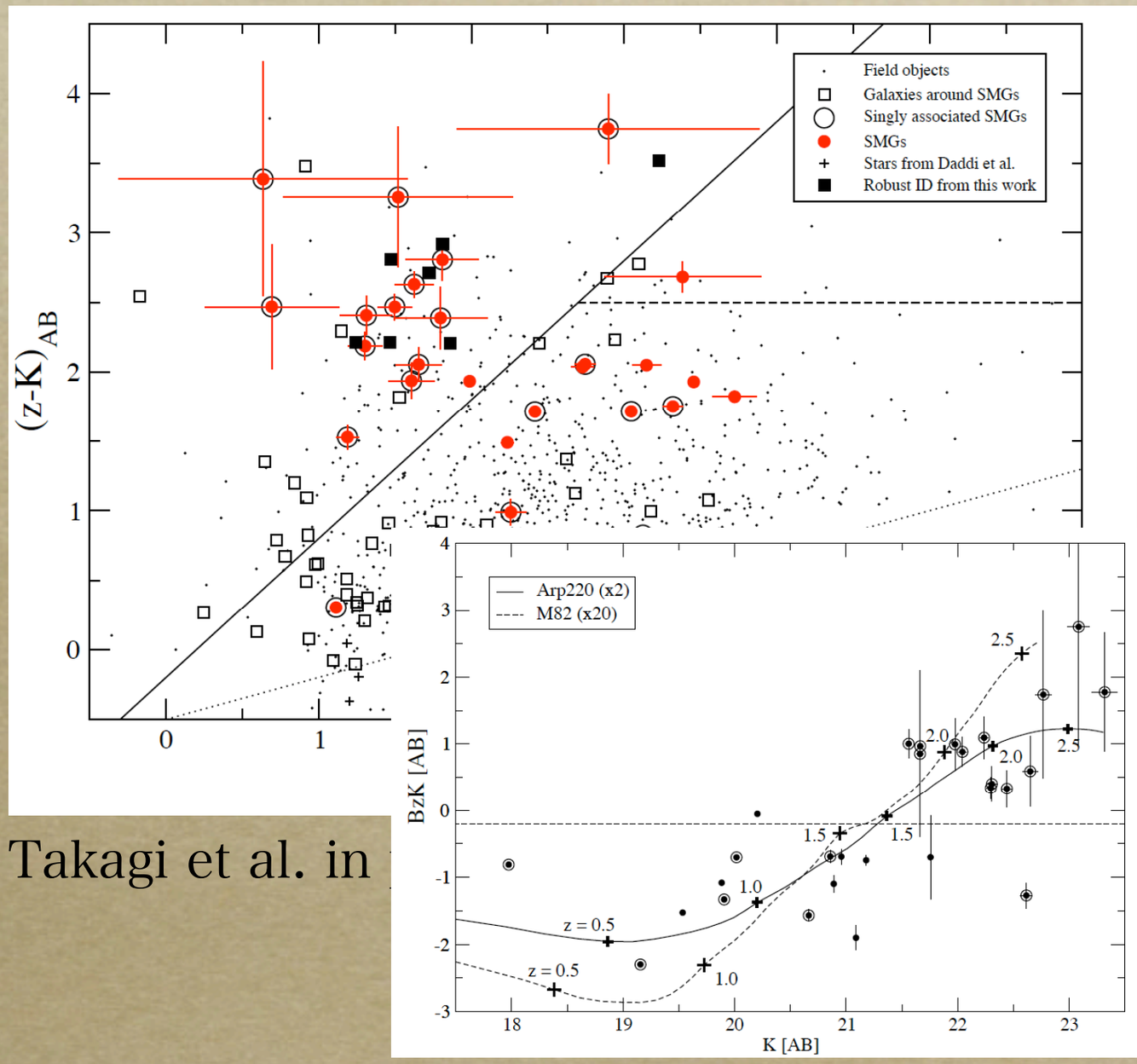

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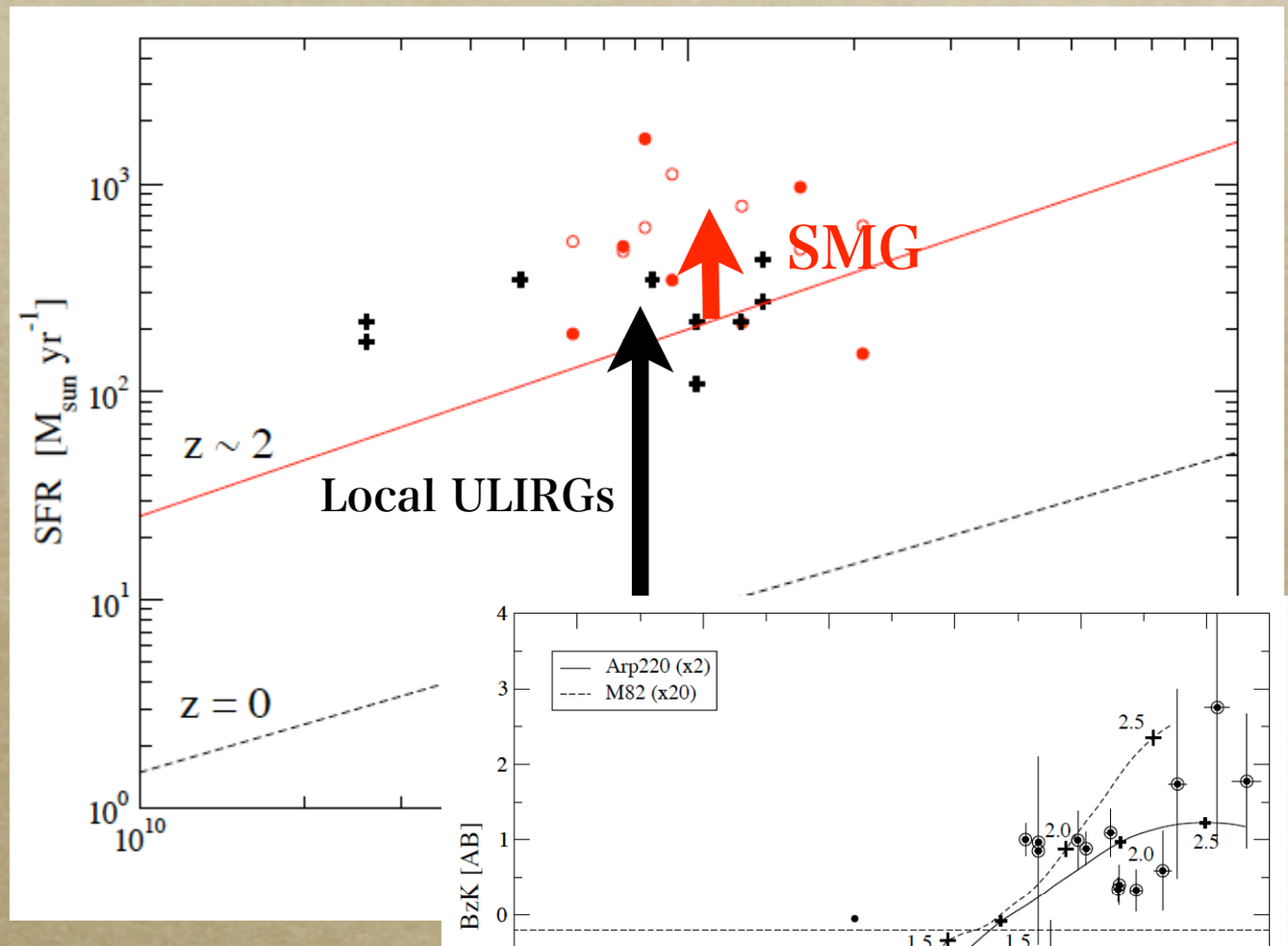

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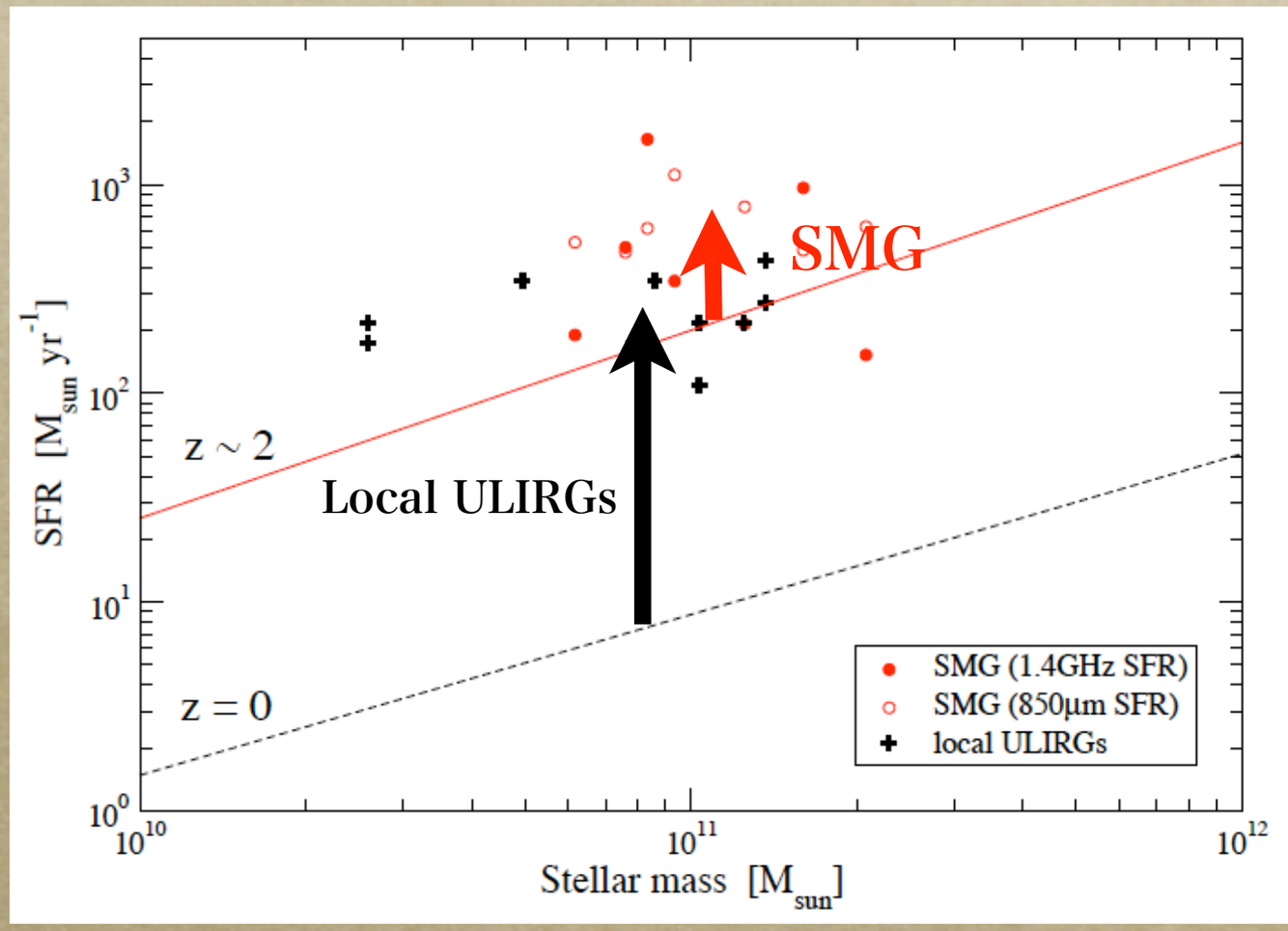

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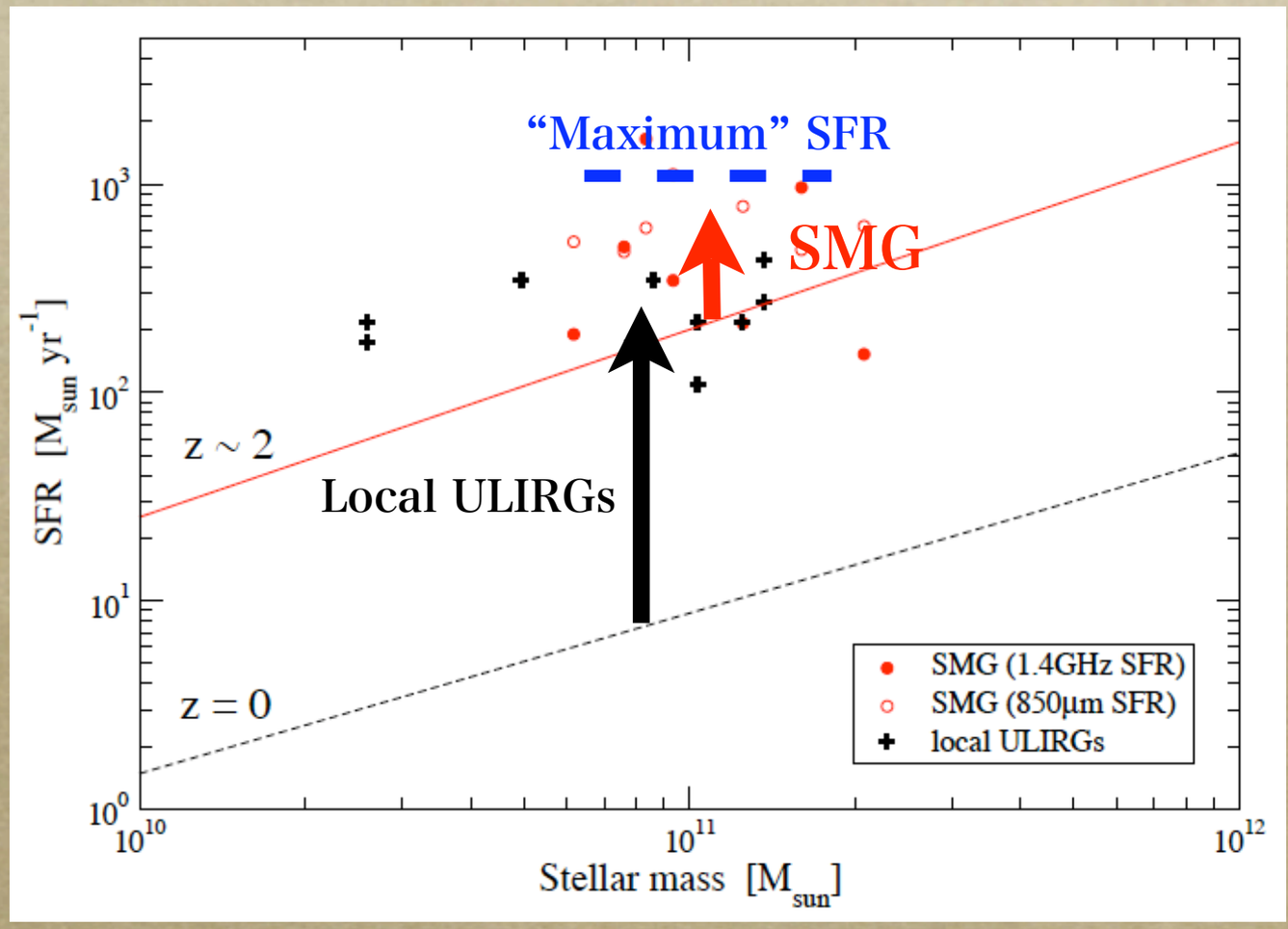
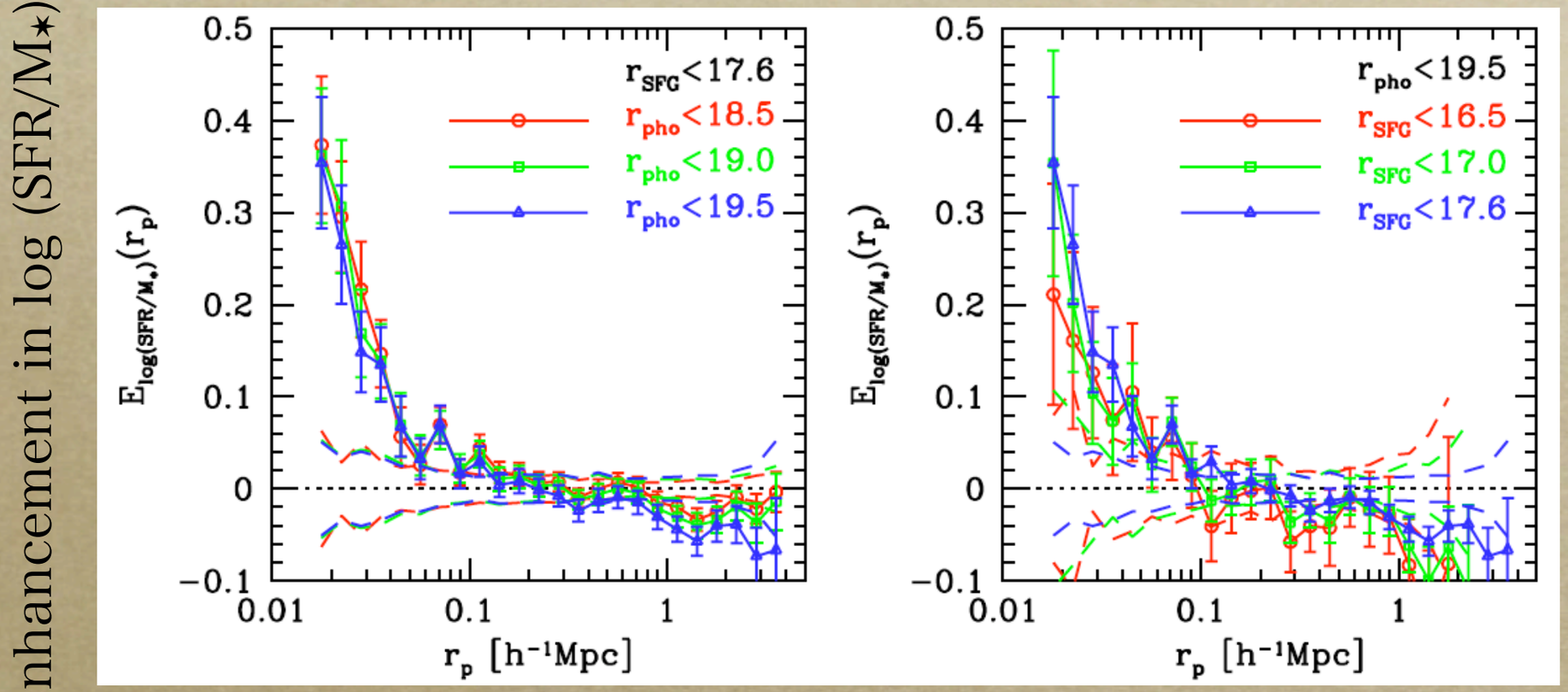


Takagi et al. in prep

SFR enhancement (2)

10^5 star-forming galaxies from SDSS



Li et al. (2008)

- Typical enhancement is 2~3× for r<20 kpc

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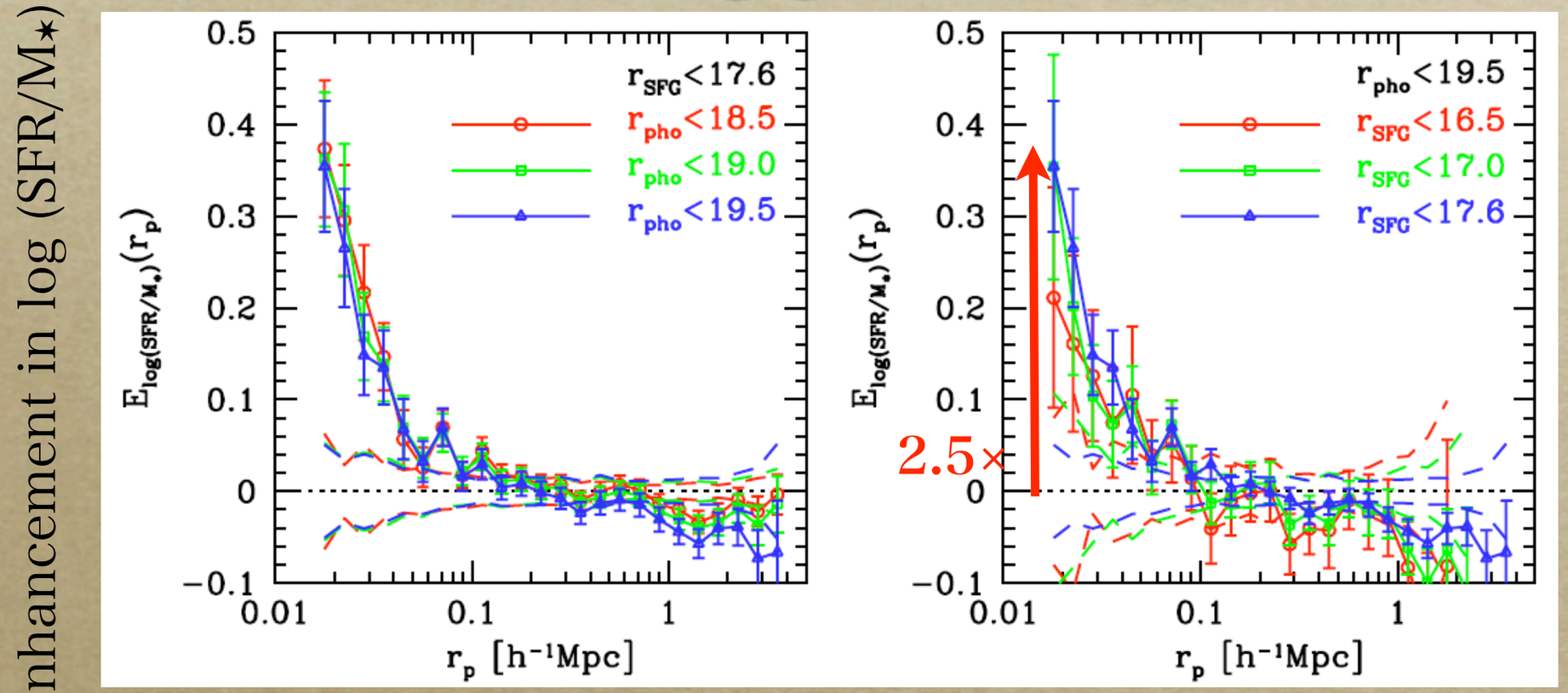

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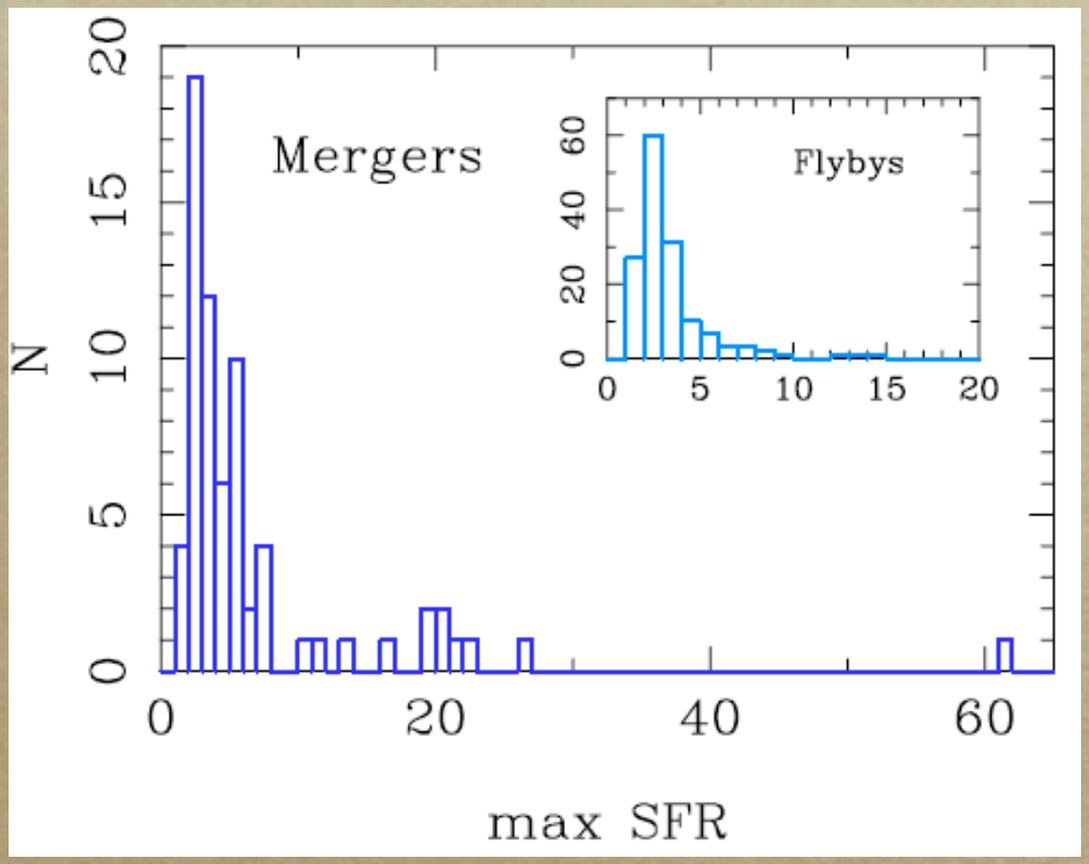
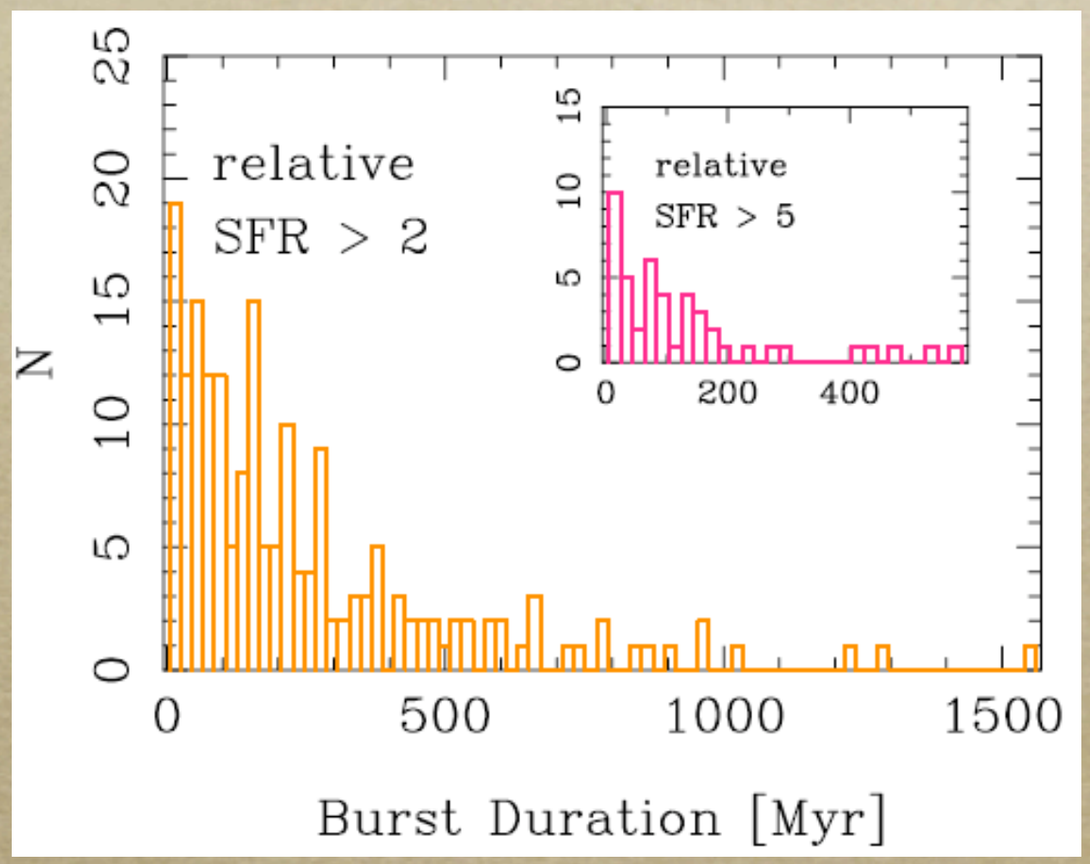
SFR enhancement (3)

SPH numerical simulation





Di Matteo et al. (2007)

- Typical enhancement is <5×
- Strong bursts have shorter lifetime (<200 Myr)
- ULIRGs are very rare, SMGs are popular?

Number density comparison

Number density Mpc^{-3}	Progenitor	Major merger	SFR enhancement
z~0	Spiral: 10^{-3}	ULIRGs: 10^{-8}	30
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- What makes SMGs special in kinematic sense? Multiple mergers?

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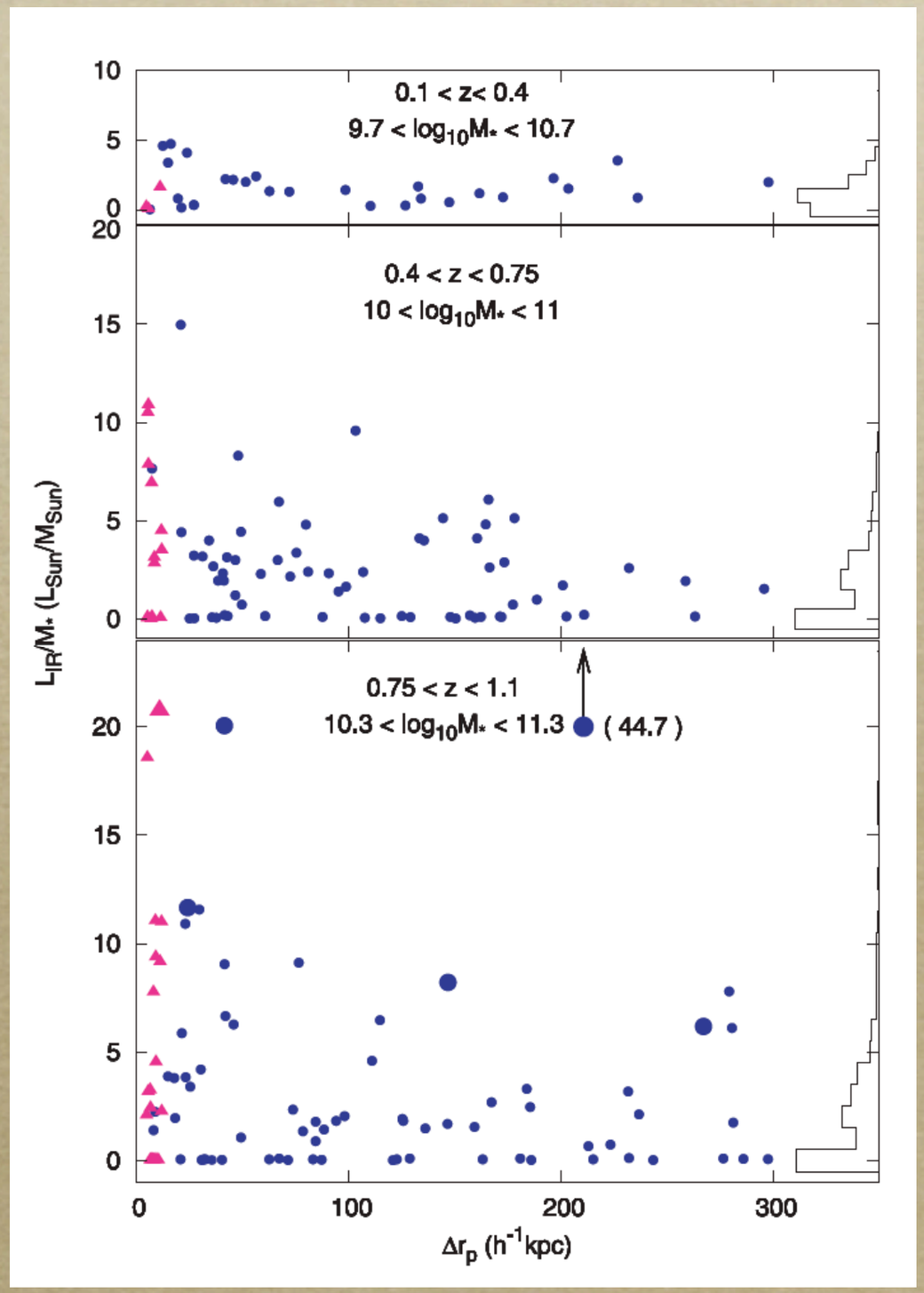
- We need to understand galaxy interaction/merger.
  - What is a physical explanation for the fraction of ULIRGs at various redshifts?

The End


0.1 < z< 0.4
9.7 < log10M* < 10.7
0.4 < z < 0.75
10 < log10M* < 11
0.75 < z < 1.1
10.3 < log10M* < 11.3
(44.7)
LIR/M* (LSun/MSun)
Δrp (h-1kpc)
0
5
10
15
20
100
200
300