Spatially resolved star-forming main-sequence in local LIRGs

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Abstract

- Luminous Infrared Galaxies(LIRGs) have spatially resolved Star-Formation Main-Sequence(SFMS)
  - locates above the normal galaxies' SFMS
- interacting LIRGs have higher sSFR($=\Sigma_{SFR}/\Sigma_{M*}$) than isolated ones

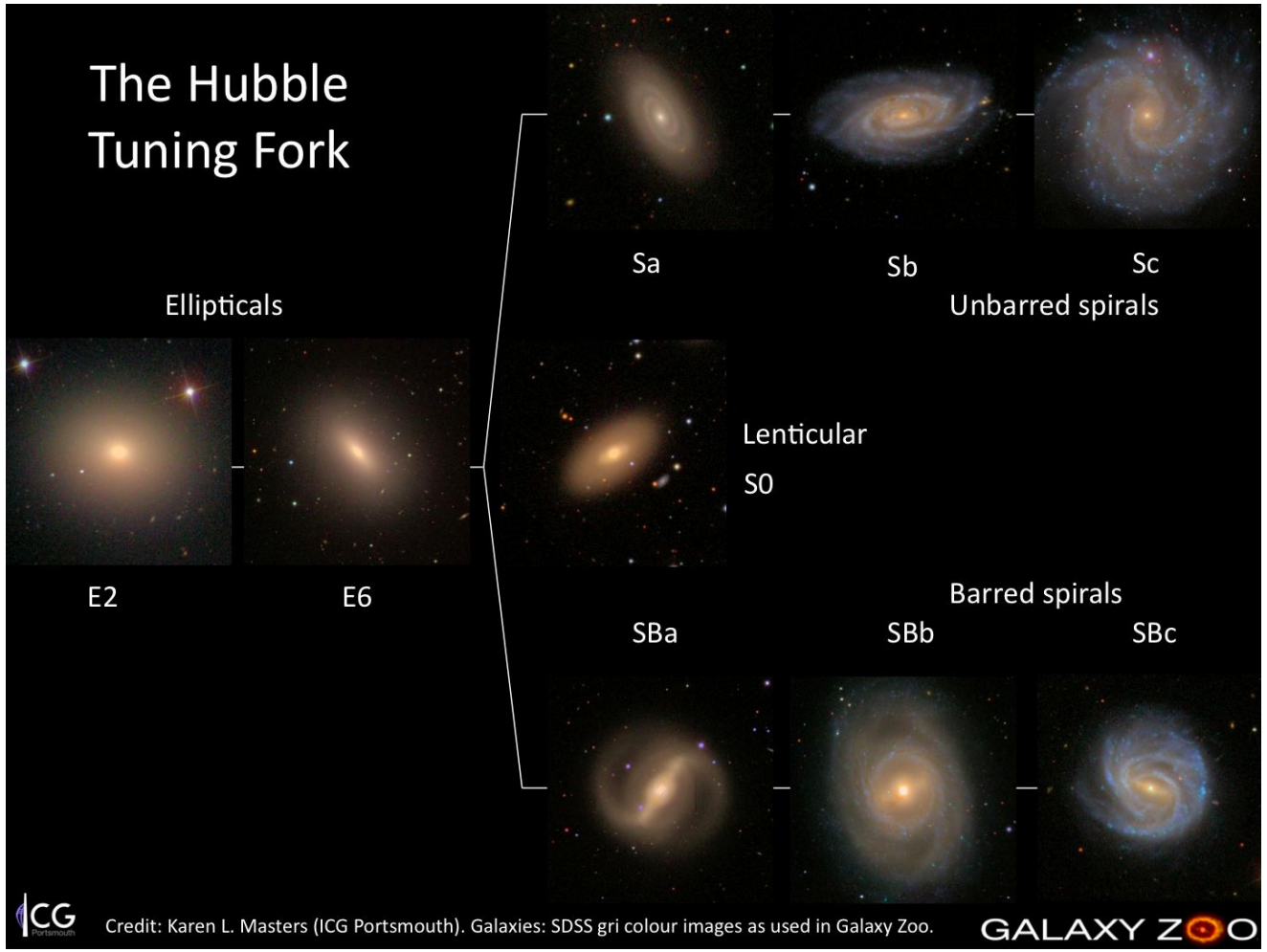
- we haven't reached conclusion, so any comments are welcome!

Outline

1. Introduction
   - Star-Formation Main-Sequence (SFMS)
   - Spatially resolved SFMS
2. Data and Analysis
3. Results
4. Discussion
5. Future Works

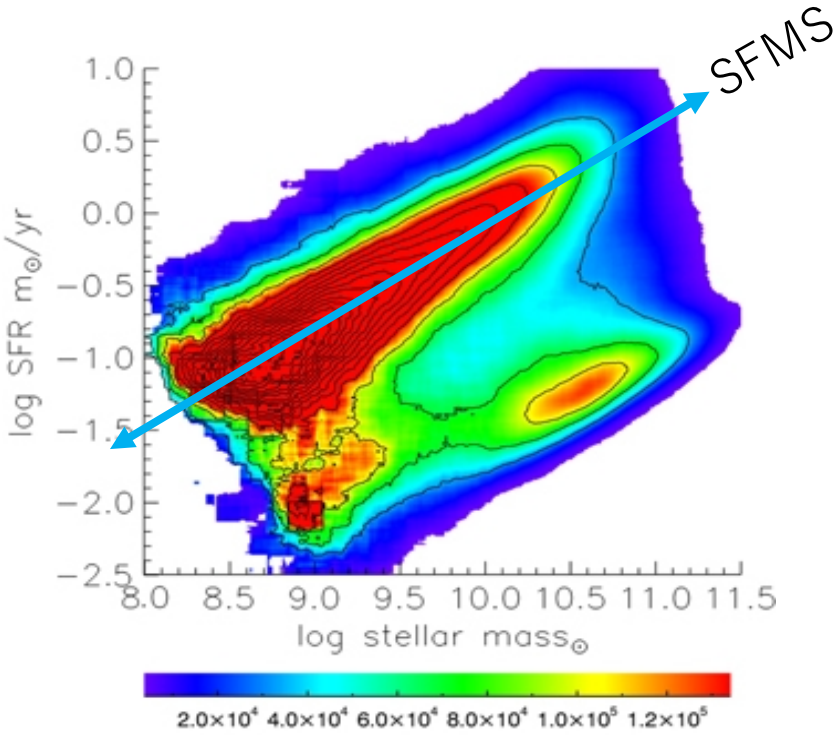
1. Introduction

- The study of galaxies with large samples results in the derivation of statistical and systematic studies

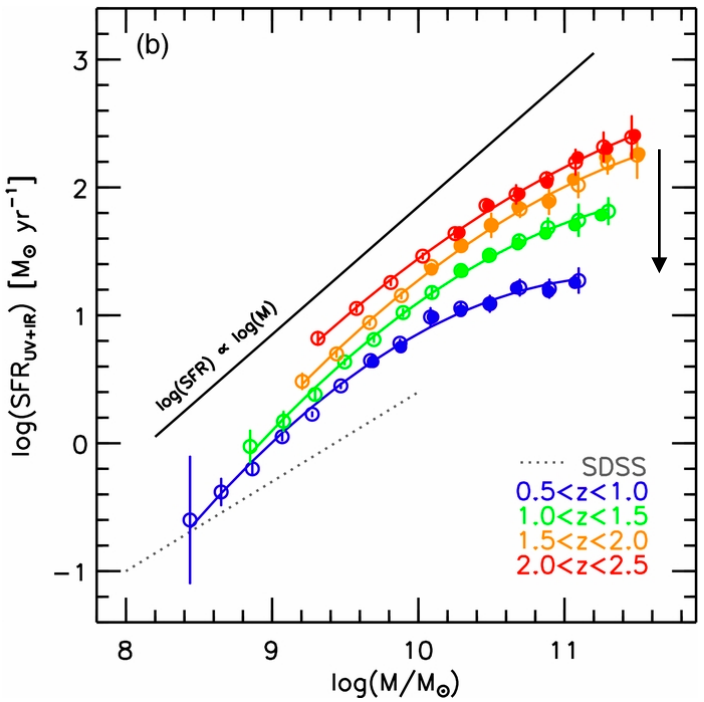


Star-Formation Main-Sequence (SFMS)

- the relation between stellar mass and SFR
- studied with various wavelength and in various redshifts



Renzini & Peng 15



redshift evolution

Whitaker+14

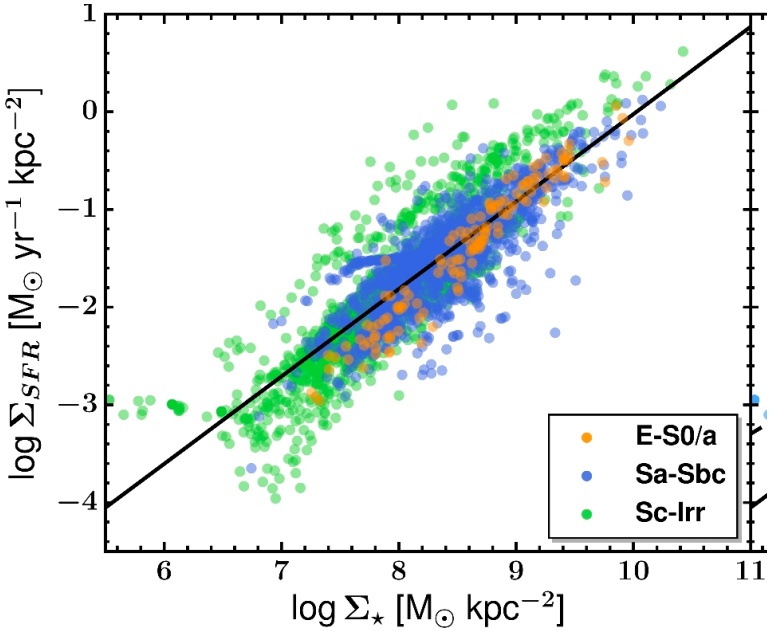
Star-Formation Main-Sequence (SFMS)

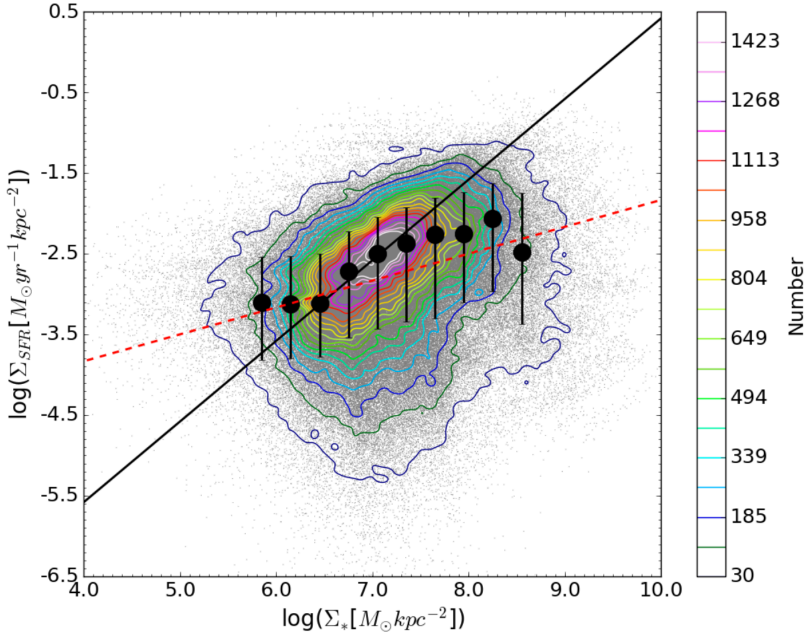
- What's the physical origin of SFMS?
  - combination of various processes in various scales
    - pc scale : molecular cloud, HII region, …
    - kpc scale : disk, halo, …
    - Mpc scale : outflow, accretion, …

- many teams are trying to reconcile SFMS by cosmological simulation
  - e.g. Sparre+15(Illustris simulation), Torrey+14
  - but more sophisticated treatment of feedback or resolution is necessary

Spatially Resolved SFMS

- the tight relation of Σ_{mass} and Σ_{SFR} also exists in sub-kpc scale





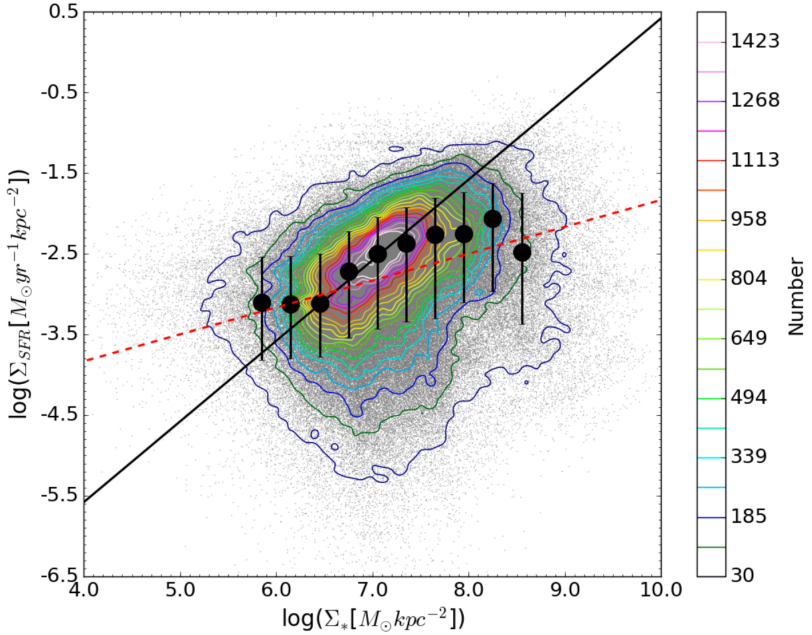
Maragkoudakis+17
Σ_* ← 3.6um
Σ_{SFR} ← 8um

Abdurro'uf+17
Σ_* , Σ_{SFR} ← SED fitting

Spatially Resolved SFMS

- the tight relation of Σ_{mass} and Σ_{SFR} also exists in sub-kpc scale
- $\log(SFR) = \alpha \log(M_*) + \beta$

resolved SFMS @z~0	α	β	σ
Cano-Diaz+16	0.72	-7.95	0.23
Maragkoudakis+17	0.91	-9.01	0.31
Abdurro'uf+17	1.00	-9.58	NA
global SFMS @z~0	**α**	**β**	**σ**
Cano-Diaz+16	0.81	-8.34	0.20
Renzini & Peng 15	0.76	-7.64	NA
Whitaker+14	0.70	-6.97	0.34



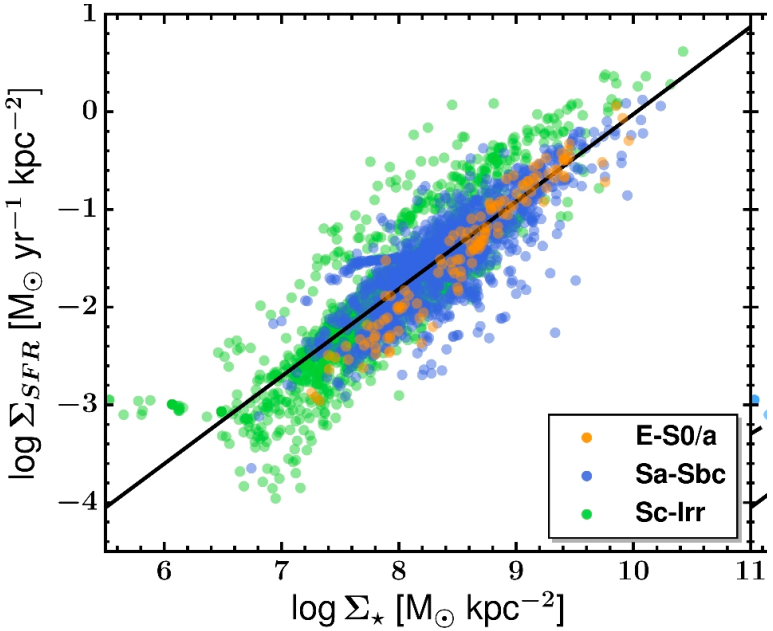
IMF, SFR tracer, extinction curve etc. can explain the difference.
(Speagle+14)

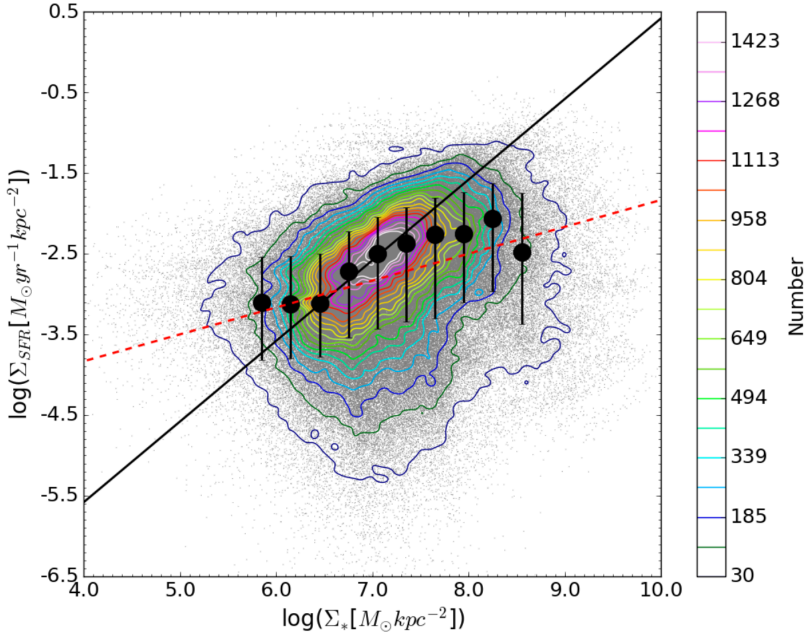
Abdurro'uf+17
Σ_* , Σ_{SFR} ← SED fitting

Spatially Resolved SFMS

- the tight relation of Σ_{mass} and Σ_{SFR} also exists in sub-kpc scale

- limited wavelength
  - ➢spatial resolution
  - ➢few studies





Maragkoudakis+17
Σ_* ← 3.6um
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Abdurro'uf+17
Σ_* , Σ_{SFR} ← SED fitting

Spatially Resolved SFMS in LIRG

<u>LIRG (Luminous Infrared Galaxy)</u>

- most of them are merging or interacting
- actively star-forming (≧10Msun/year)
- high dust extinction (Av~4mag)
- possible to spatially resolve

➢Pa α (λ =1.875um) is a good tracer of spatially resolved SFMS

- Apa α ~0.6

Outline

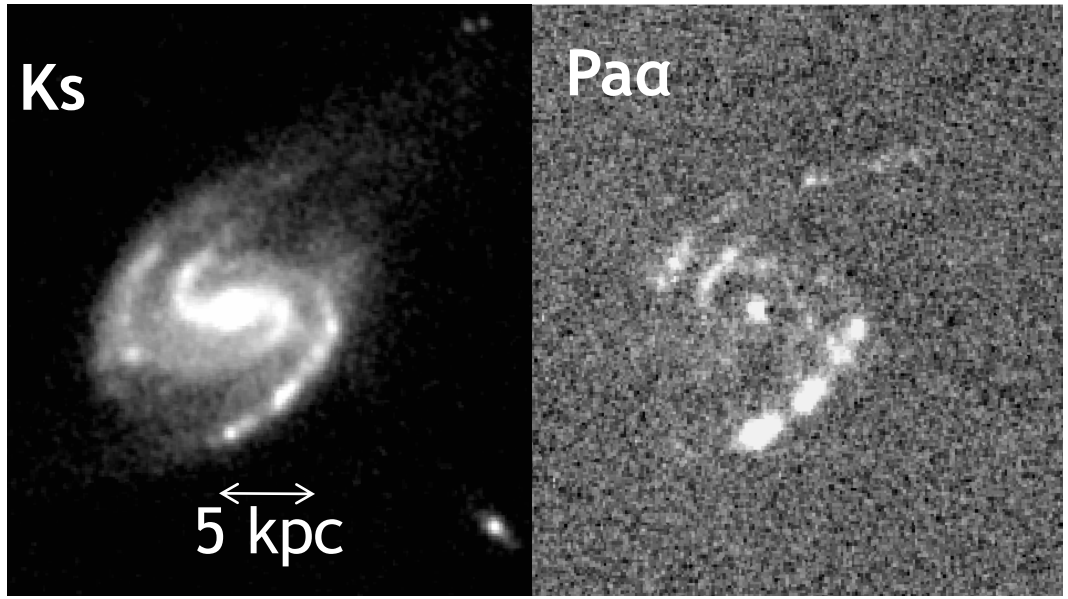
1. Introduction
2. Data and Analysis
   - Data
   - Analysis
3. Results
4. Discussion
5. Future Works

Data

- 19 LIRGs were observed by mini TAO/ANIR in Ks and Pa α
  - no AGN, D ~ 80Mpc(z~0.005)
  - 7 are interacting (merging, merger remnant, etc.)
  - 3 are isolated
  - 9 are to be determined
  - some of them have CO(1-0) data obtained by ALMA

- 17 LIRGs with AGN
  - assume pixels @r>1.2” is not affected by AGN

- spatial resolution
  - 0.6”(=0.24kpc) ~ 2.9”(=1.2kpc)



NGC5257; Tateuchi+15, interacting LIRG

Analysis

- mass surface density
  - ➢$\Sigma_{M_*}/\Sigma_{M_{sun}} = 0.8\,\Sigma_{L_*,K}/\Sigma_{L_{sun}}$ (Bell+03)
- SFR surface density
  - ➢$\Sigma_{SFR} = 6.4 * 10^{-41}\,\Sigma_{\mathrm{Lpa}\alpha}$ [Msun/yr/kpc^2] (Rieke+09)

extinction is not corrected

- not follow uniform dust screen model (Kobayakawa+16)
- extinction map is necessary

Outline

1. Introduction
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3. Results
   - global SFMS
   - spatially resolved SFMS
4. Discussion
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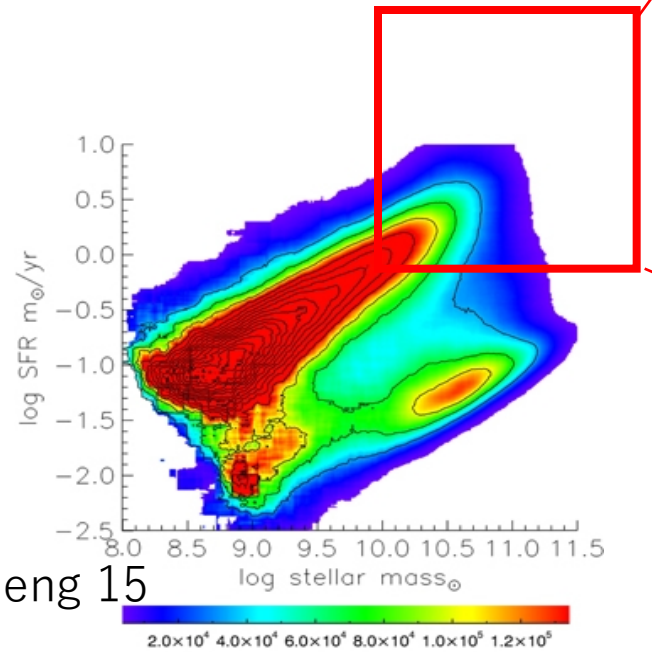
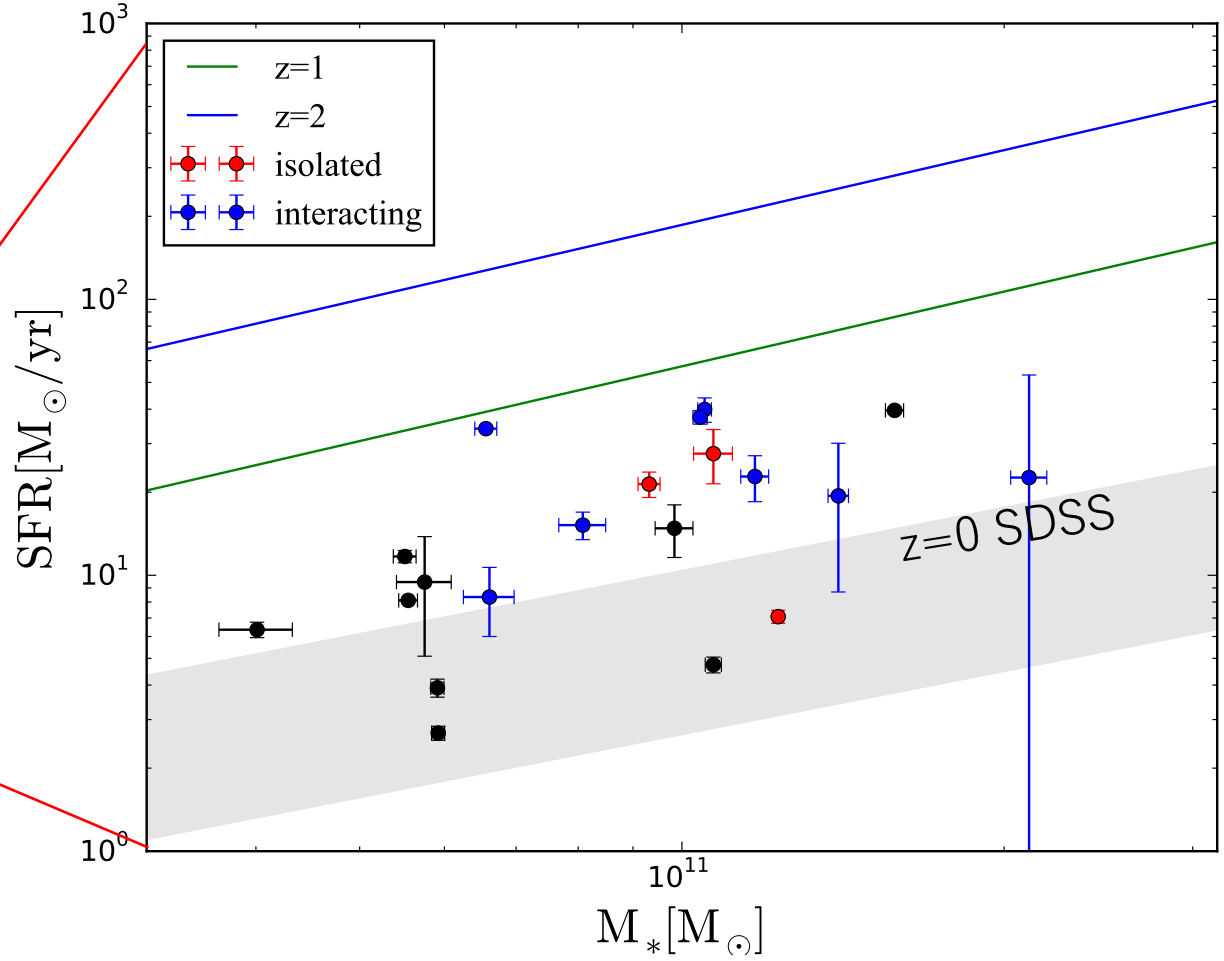
Results 1. global SFMS

- LIRGs lie above the local SFM



Renzini & Peng 15

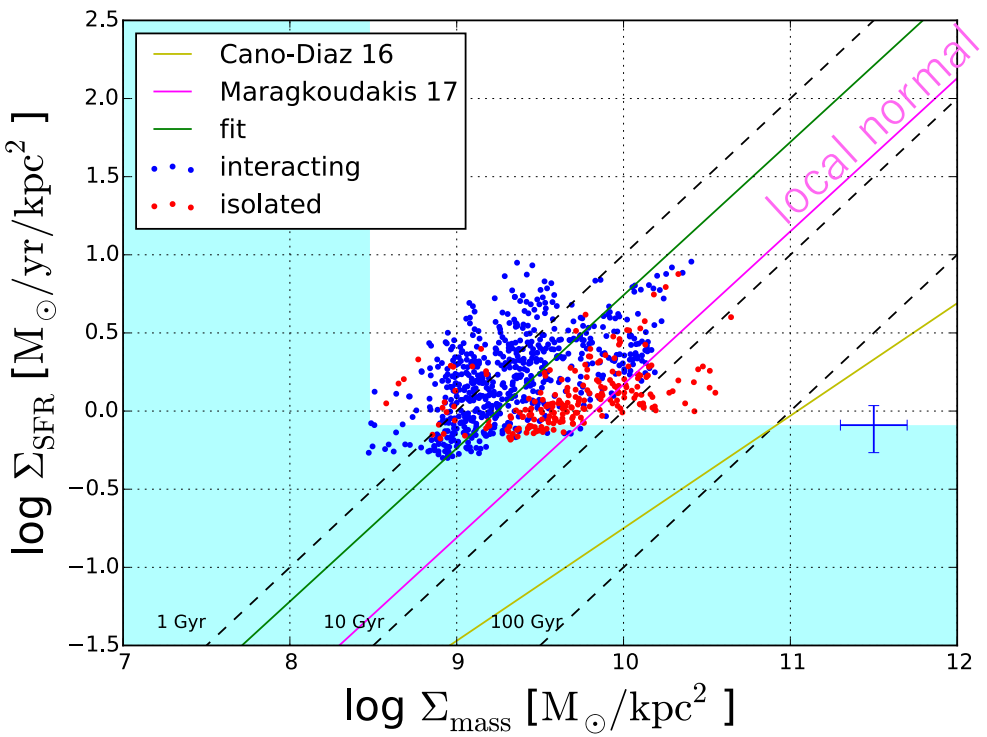


- LIRGs are heavy and starburst

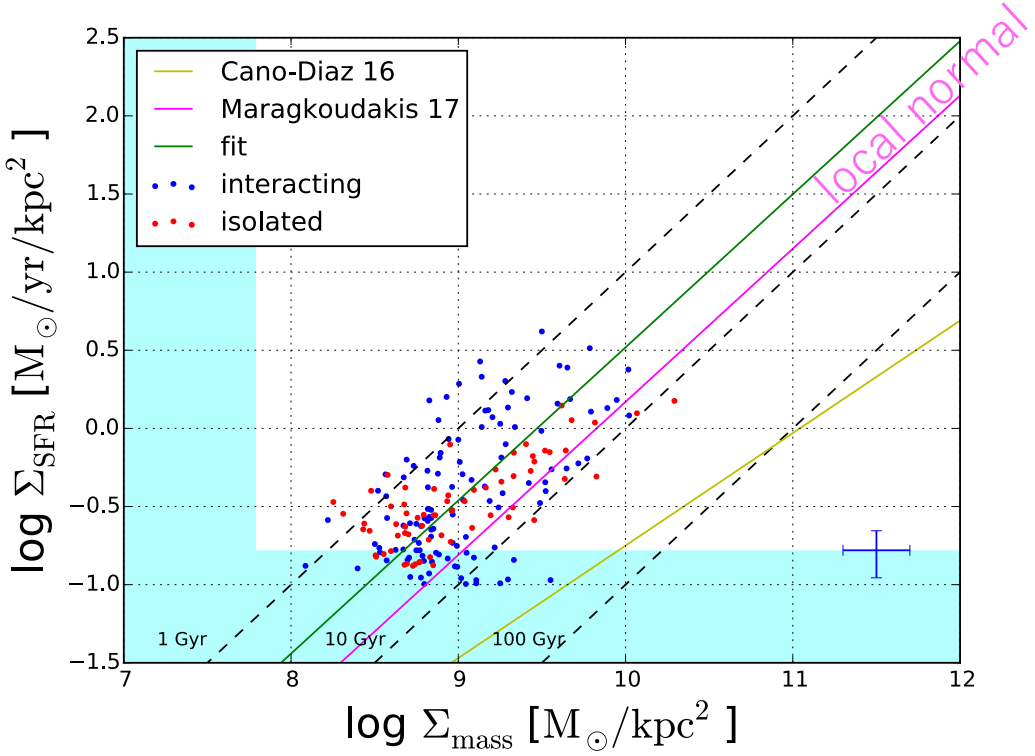
Results 2. Spatially Resolved SFMS

- LIRGs also lie above the local SFMS

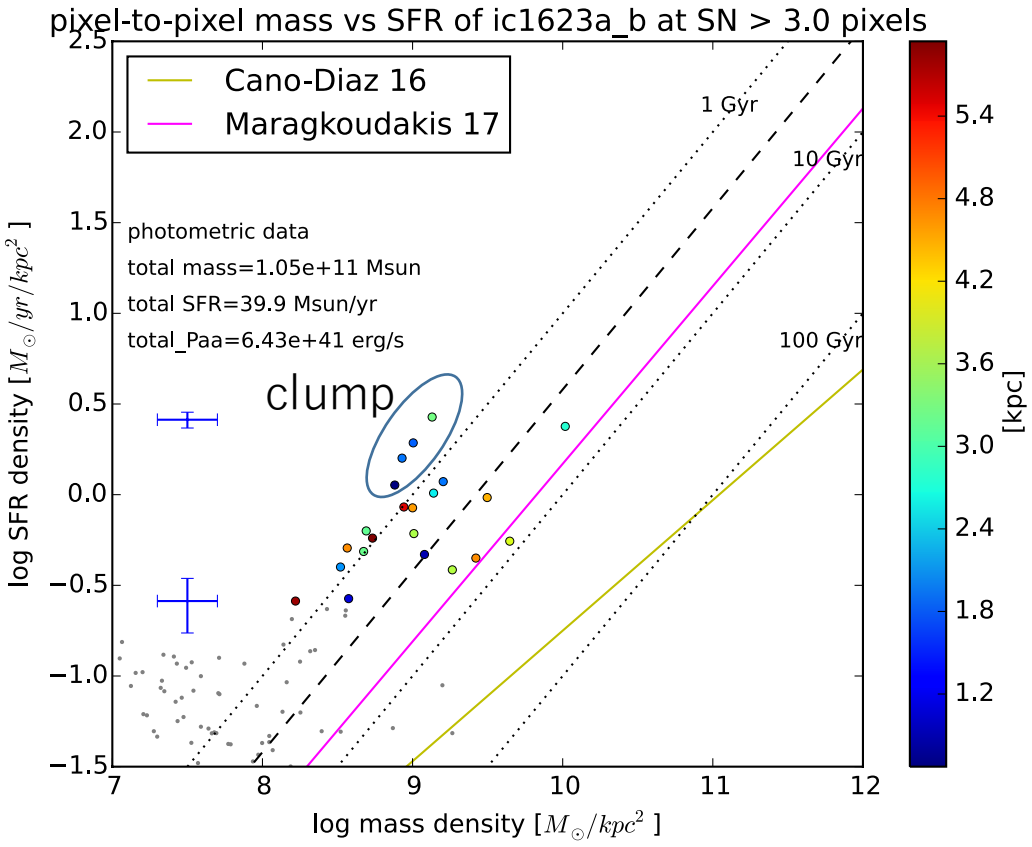
resolution ~ 0.24 kpc



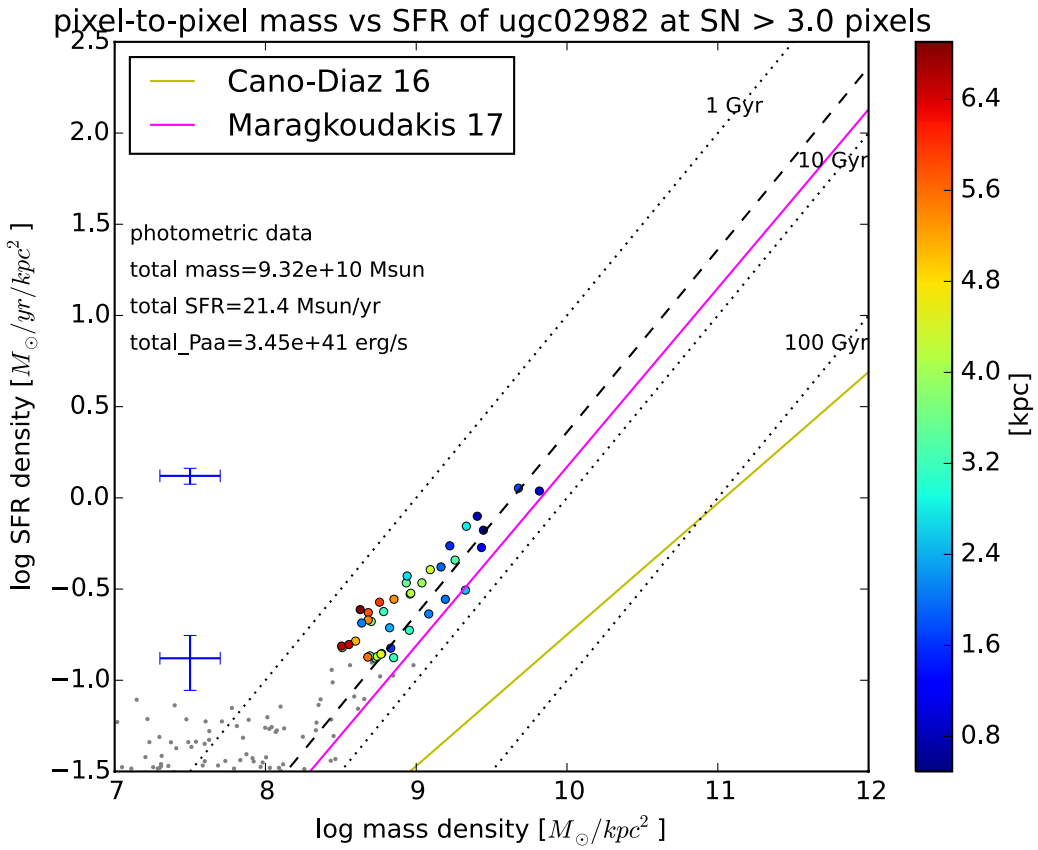
resolution ~ 1.2 kpc



Results 3. SFMS in each galaxy



ic1623, merging

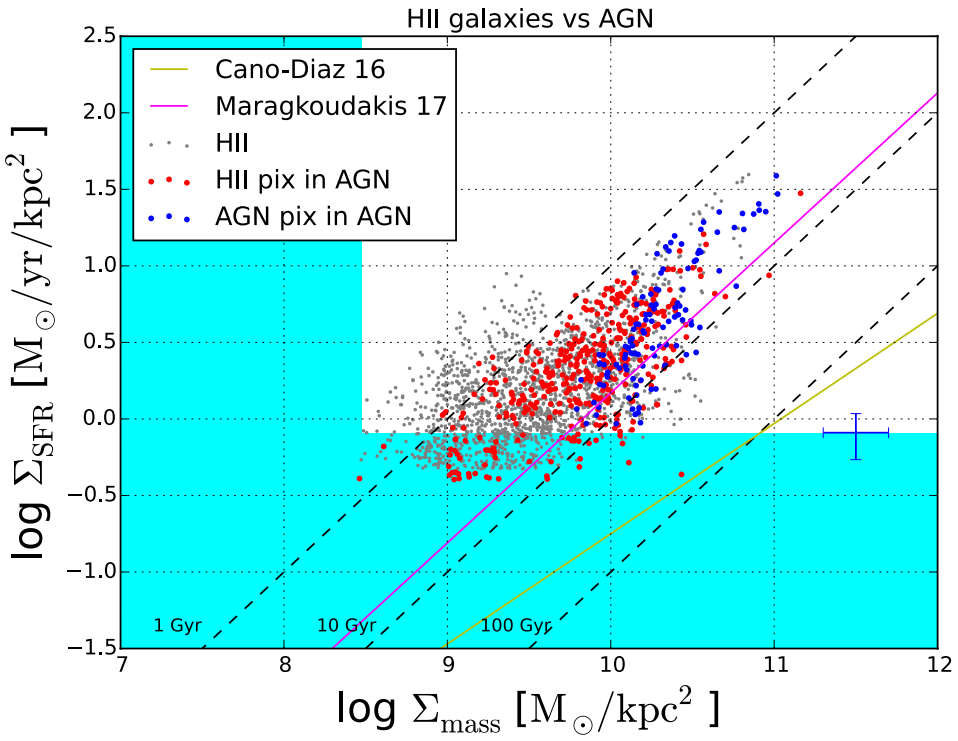


ugc02982, isolated galaxy

Results 4. SFMS of normal pixels in AGN

- HII pixel in HII galaxies
- HII pixel in AGN : r>1.2” (~FWHM of PSF x2)
- AGN pixel : r<1.2”

- there is no big difference
  - no AGN feedback?
  - stellar feedback dominates?

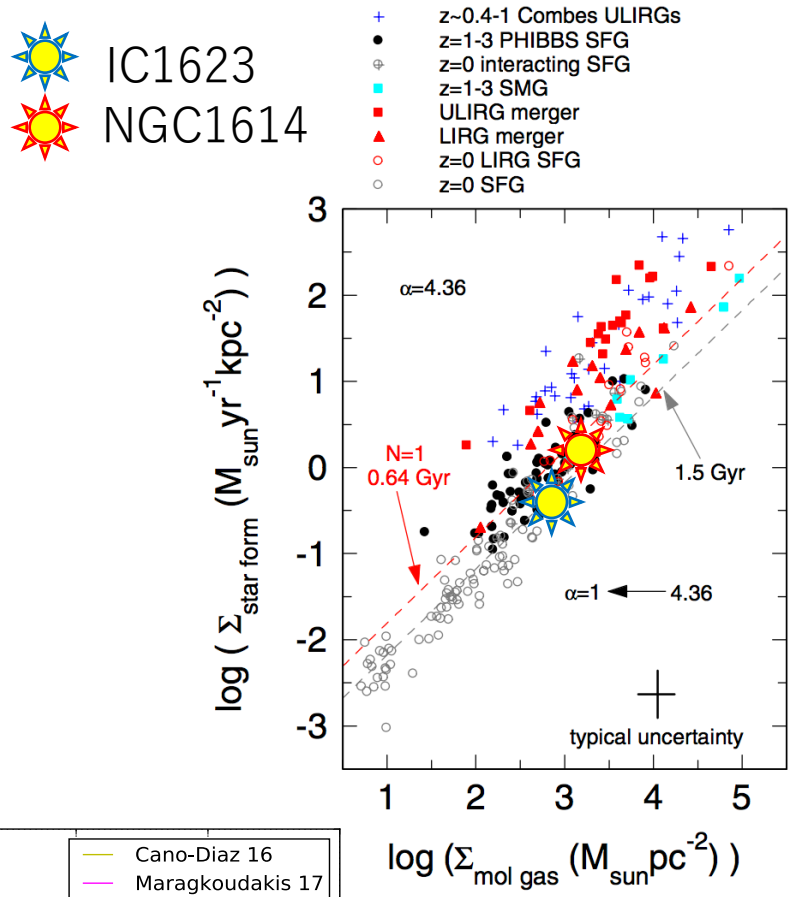


Discussion

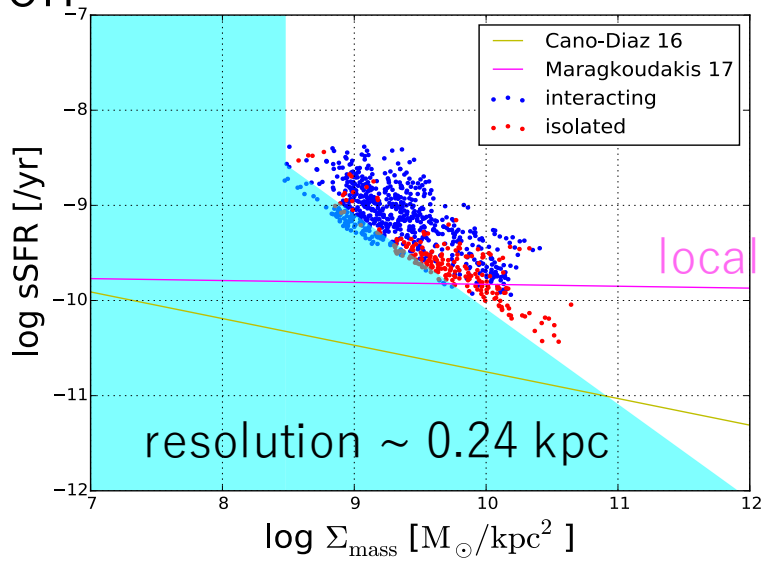
✓interacting LIRGs have high sSFR

- 0.3dex above isolated LIRGs

1. locally have more molecular gas? (=high f_{gas})
2. high SFE?
   - ✓gravitational tidal torque (Hopkins+09)
   - ✓shock-induced gas compression (Saitoh+09)
3. miss align with gas and stellar?



Tacconi+13

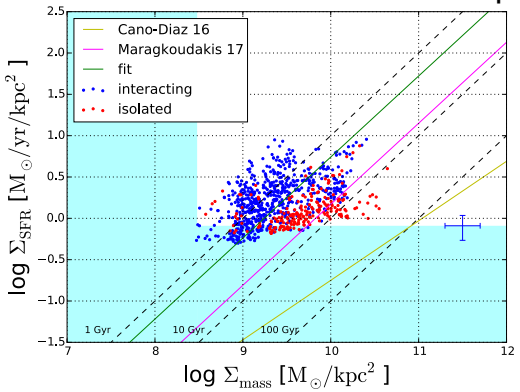


Discussion

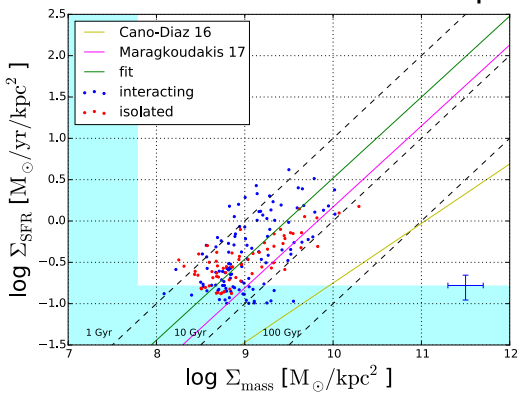
spatial resolution can change the Main Sequence

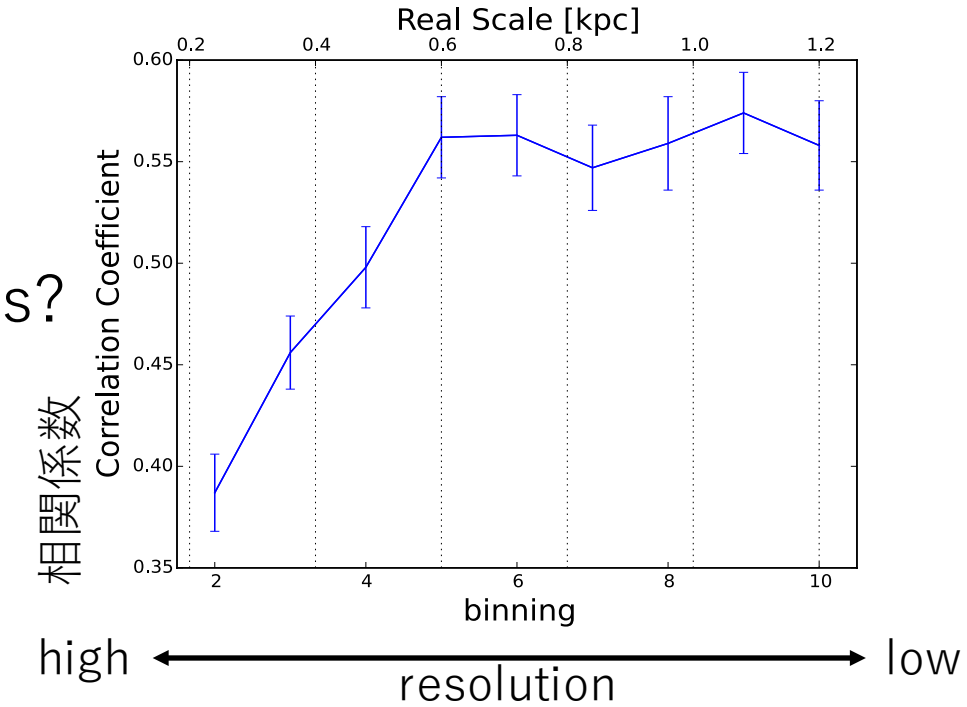
- ✓correlation between Σ_{SFR} and Σ_{M*} fades in high resolution (<0.6kpc)
  - ➢need to check this in normal galaxies
    1. break of KS law?
    2. variety of fgas
    3. unique scale of SF that M_* contributes?

resolution ~ 0.24 kpc



resolution ~ 1.2 kpc





Discussion

1. local KS law

- does not change with resolution in R=300pc~1000pc (Bigiel+08)
- breaks in local LIRG, IC4687 @250pc resolution (Pereira-Santaella+16)

the distribution of CO and ionized gas is different <75pc resolution (Schruba+10)

Bigiel+08

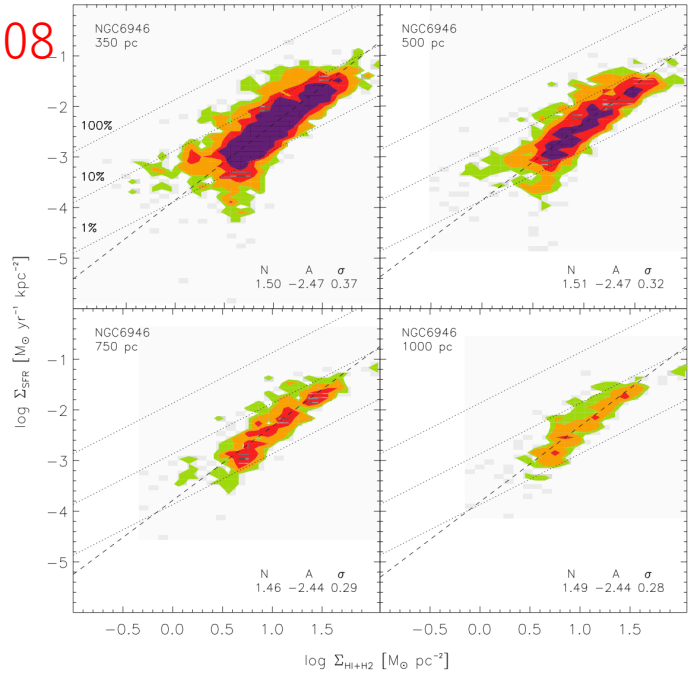
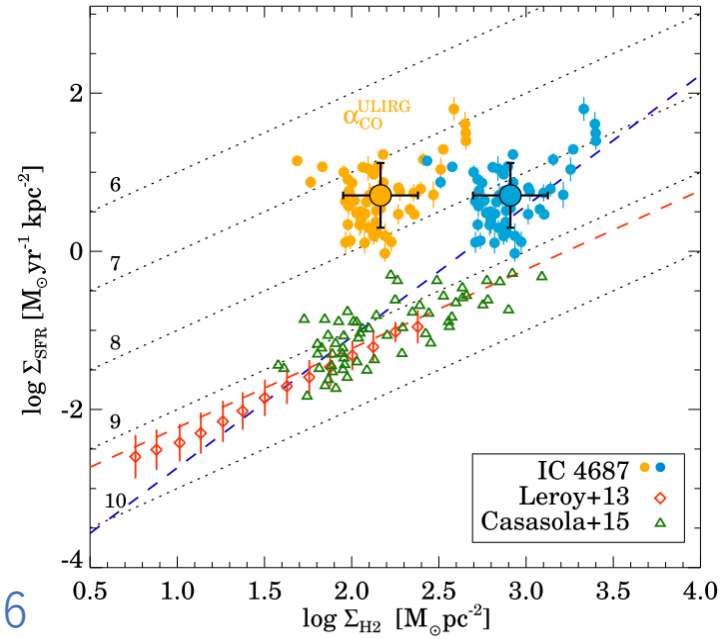


Figure 6. (Continued)



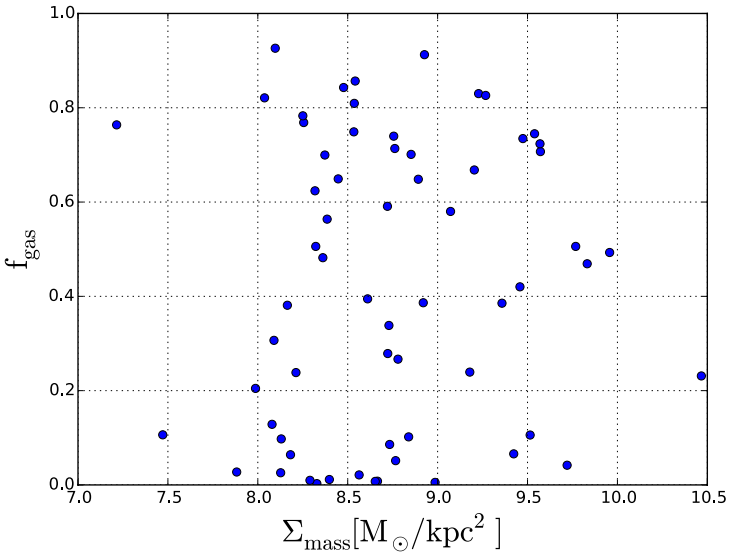
Pereira-Santaella+16

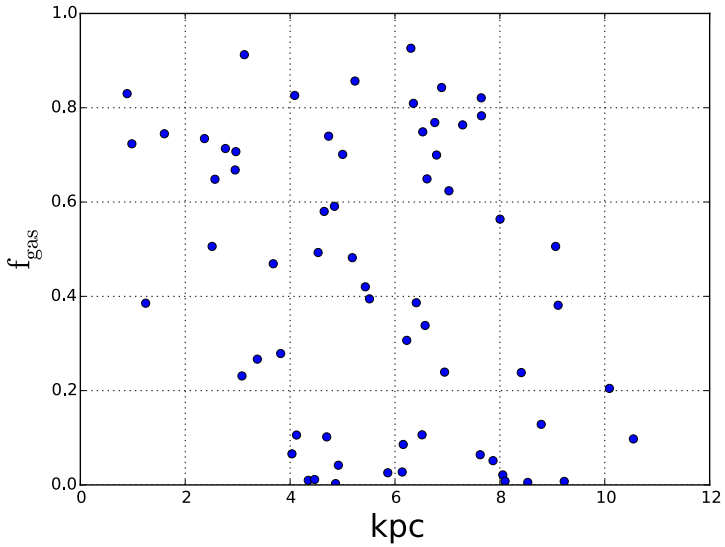
Discussion

2. local gas fraction

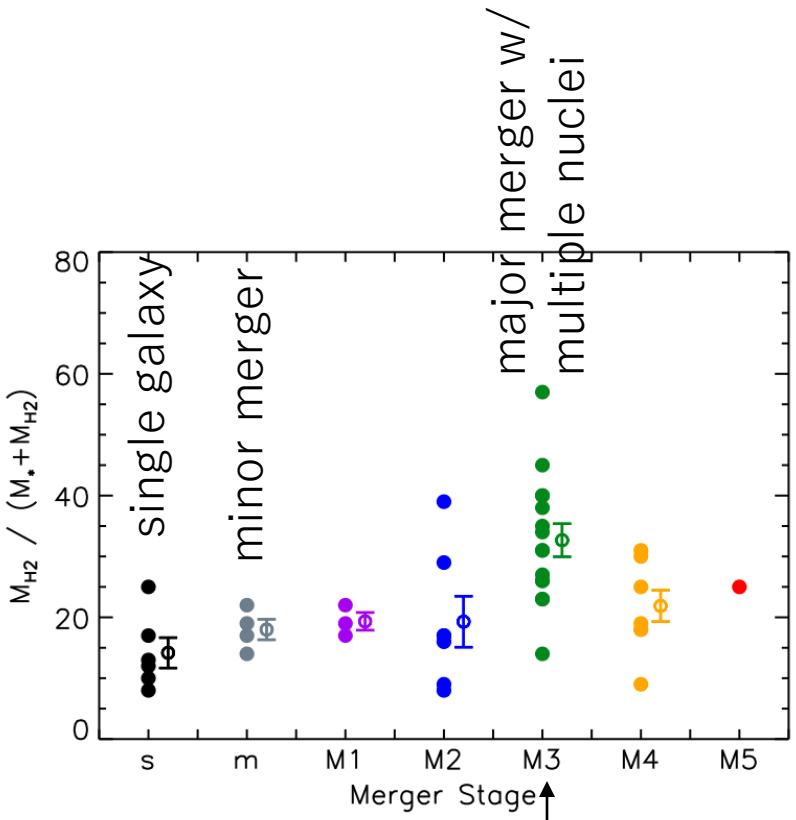
one galaxy have various local $f_{gas} = \Sigma_{gas} / (\Sigma_{gas} + \Sigma_{M*})$

- $\Sigma_{gas} = \Sigma_{CO(1-0)}$





ic1623 @0.8kpc resolution

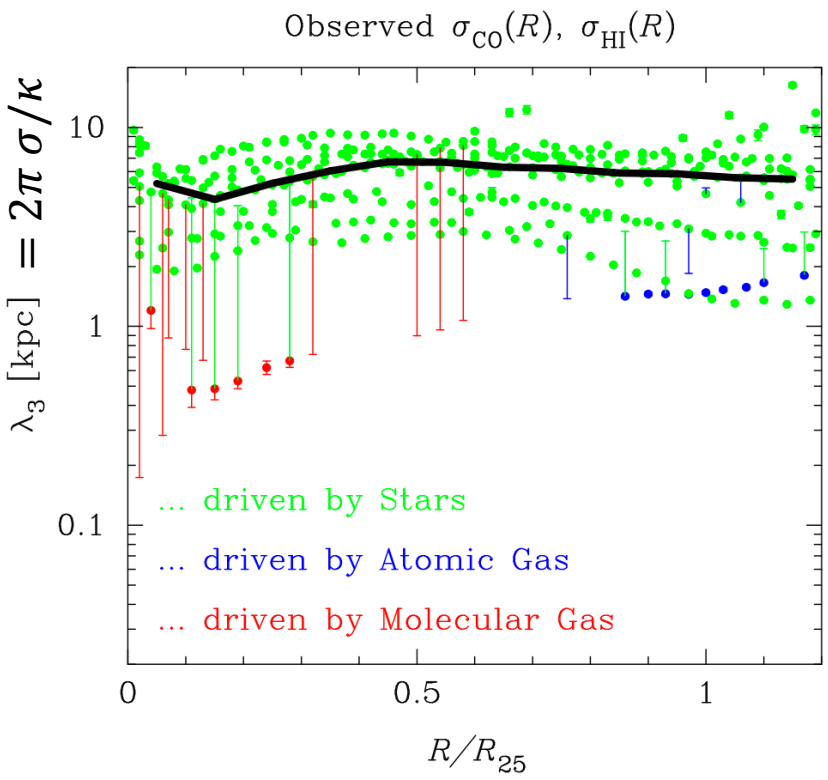


Larson+16

ic1623

Discussion

3. unique scale that M* contributes to SF
   - gravitational instability is driven mainly by Stars (Romeo+17)
   - the scale of instability ≧ 1kpc
     - ➢we could not have enough data points at this resolution
   - at ≦ 1kpc, molecular gas drives instability
     - ➢we need more molecular gas data of LIRG



Romeo+17

Conclusion

- LIRGs lie above the local SFMS

- LIRGs also have spatially resolved SFMS
  - the MS locates 0.3 dex above the local normal one
  - interacting LIRGs locate above isolated LIRGs
    - ➢extinction correction can stands out the difference

- spatial resolution can change the main-sequence

Future Works

- extinction correction
  - ✓make extinction map
  - ✓Balmer decrement with Paα and Paβ or Hα
    - cf. densest region of LIRG have A_K~3 (Pereira-Santaella+16)

- study the local KS law in LIRG
  - ✓high SFE/fgas?
  - ✓ α_{CO} problem