

近傍銀河の分子ガス撮像観測 プロジェクトCOMINGで探る分子 ガスと星生成

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1. BACKGROUND

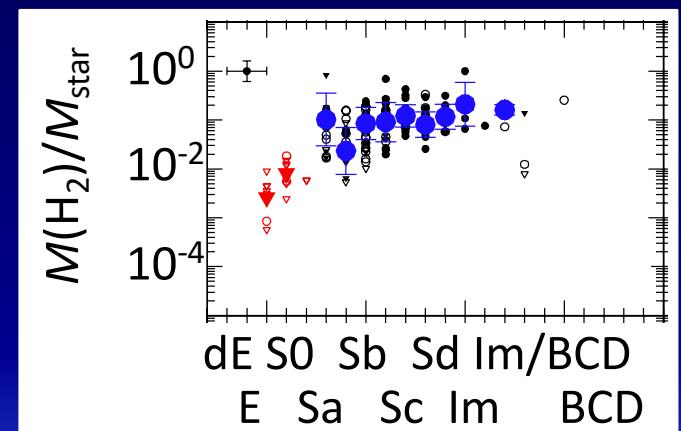
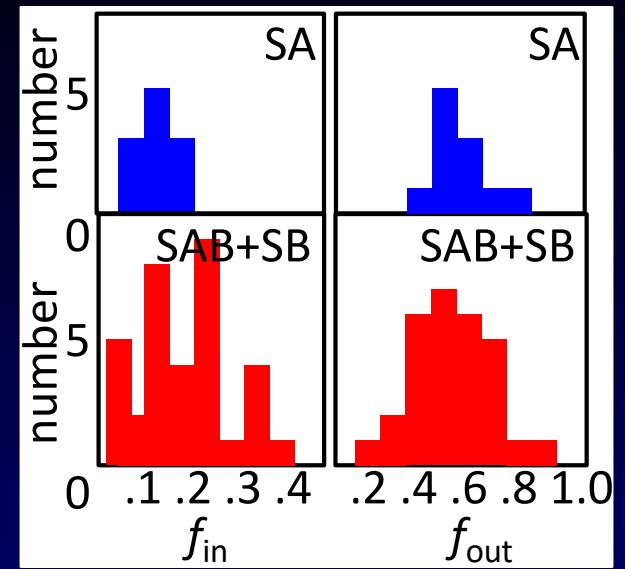
COMING
CO MULTI-LINE IMAGING OF NEARBY GALAXIES

Why CO in galaxies?

- Galaxies have evolved through forming stars from gas.
- We have to know
 - Where stars form in galaxies?
 - How stars form in galaxies?
- CO is a tracer of cold molecular gas.
 - ← Cold H₂ cannot emit electromagnetic waves.

Gas Distribution & Morphology

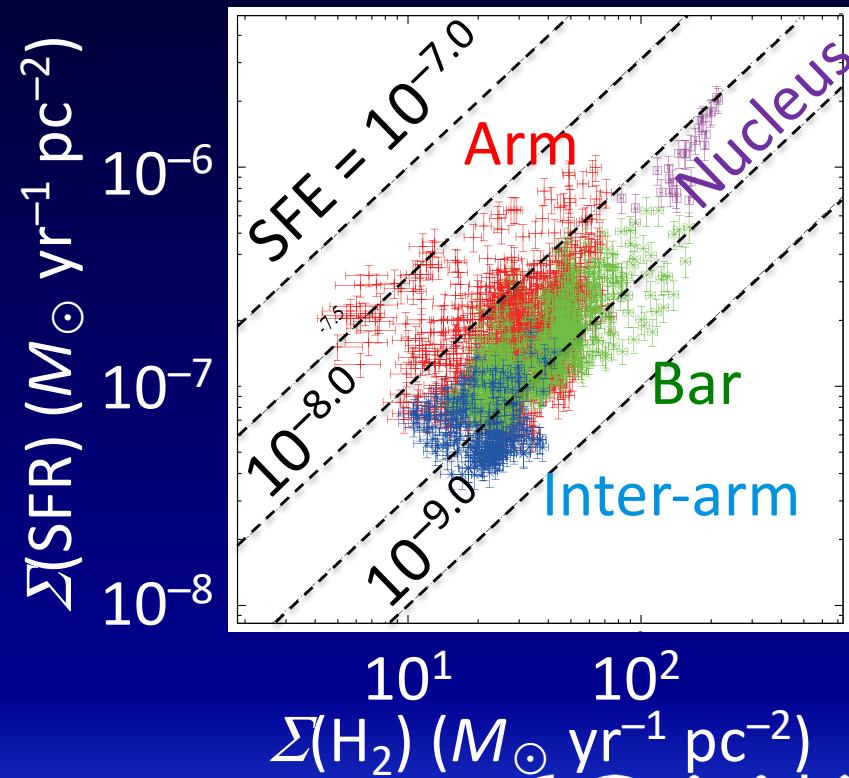
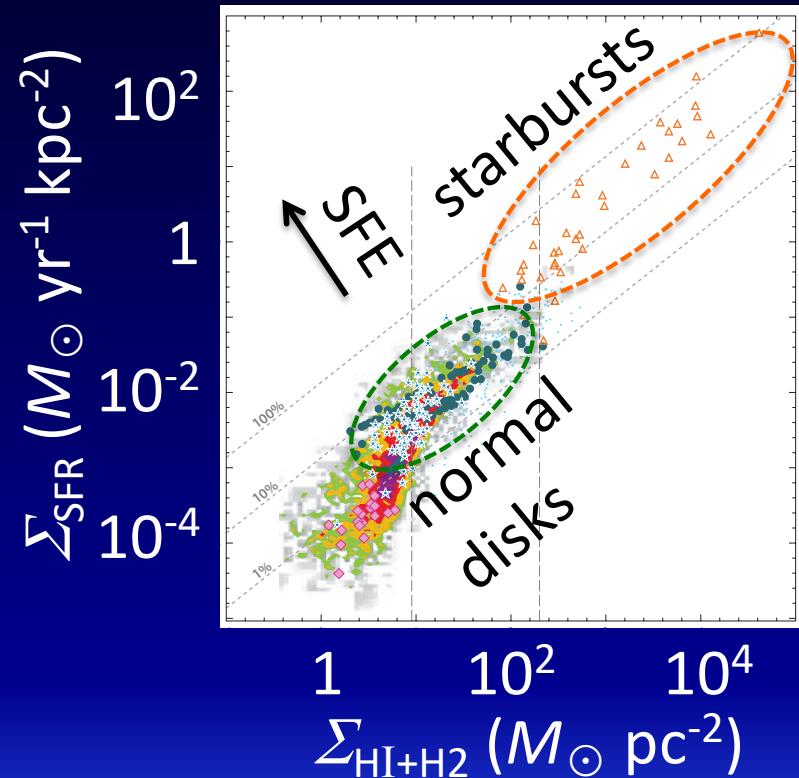
- central concentration of molecular gas by bar
(Sakamoto+ 99; Sheth+ 05;
Kuno+ 07)
- molecular gas mass fraction
 - no clear tendency along the Hubble sequence
(Young & Scoville 91;
Boselli+ 14b)



(revised from Kuno+ 07; revised from Boselli+ 14b)

Kennicutt – Schmidt Relation

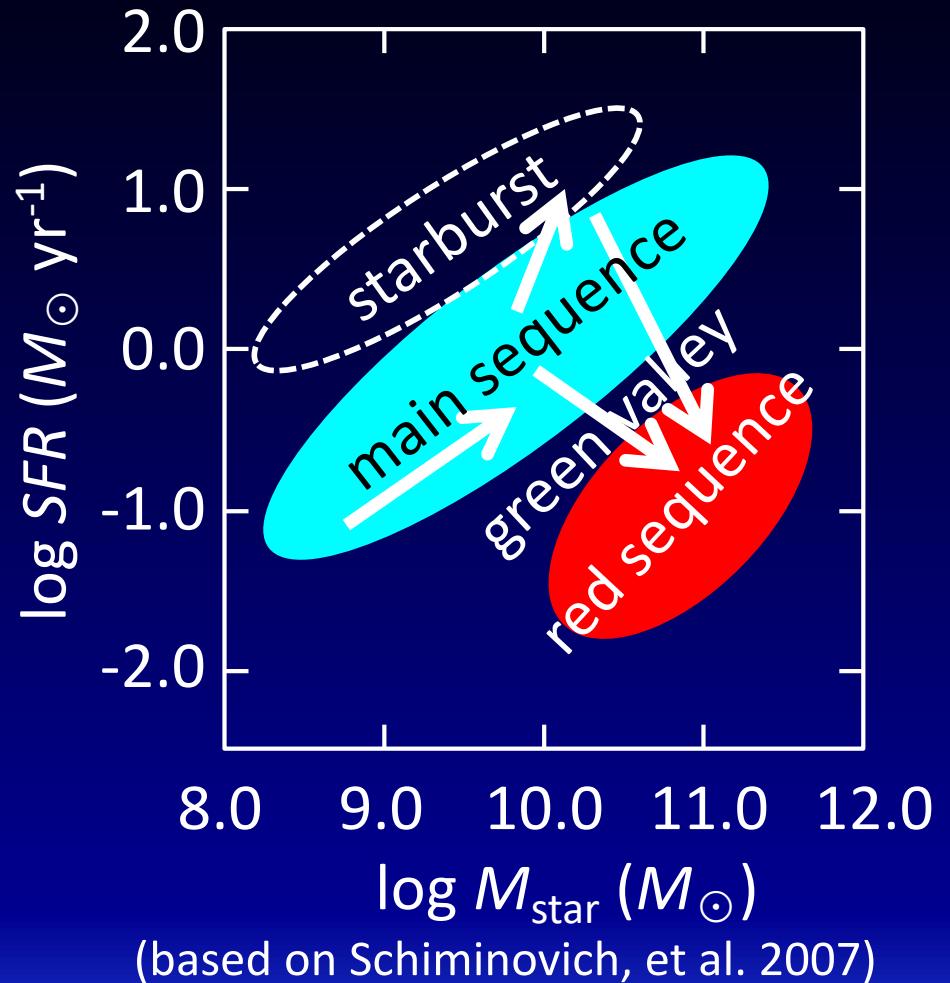
- $\Sigma(\text{SFR}) \propto \Sigma(\text{H}_2)^N$ ($1 \leq N \leq 2$)
- Star formation efficiency (SFE) is not constant.



(revised from Kennicutt & Evans 12; revised from Momose+ 10)

On the Road of Galaxy Evolution

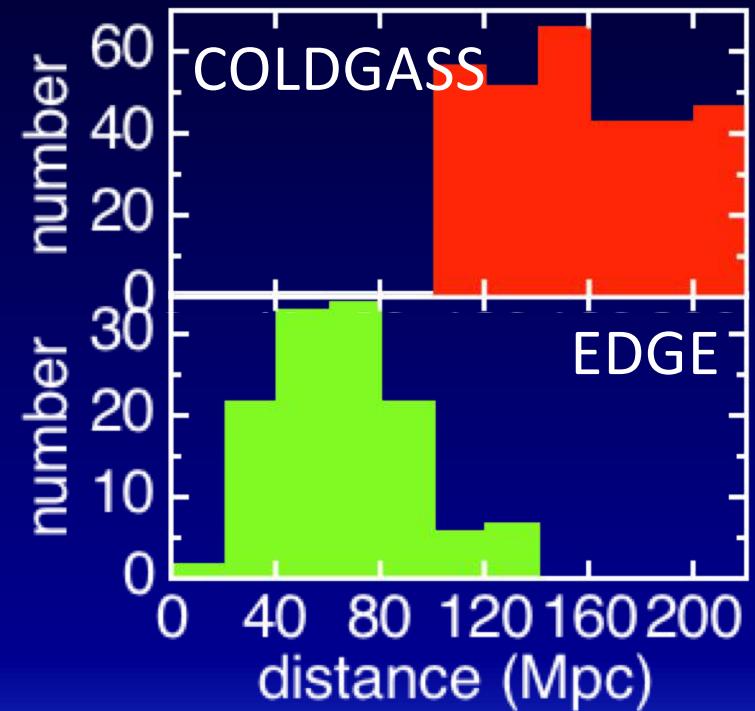
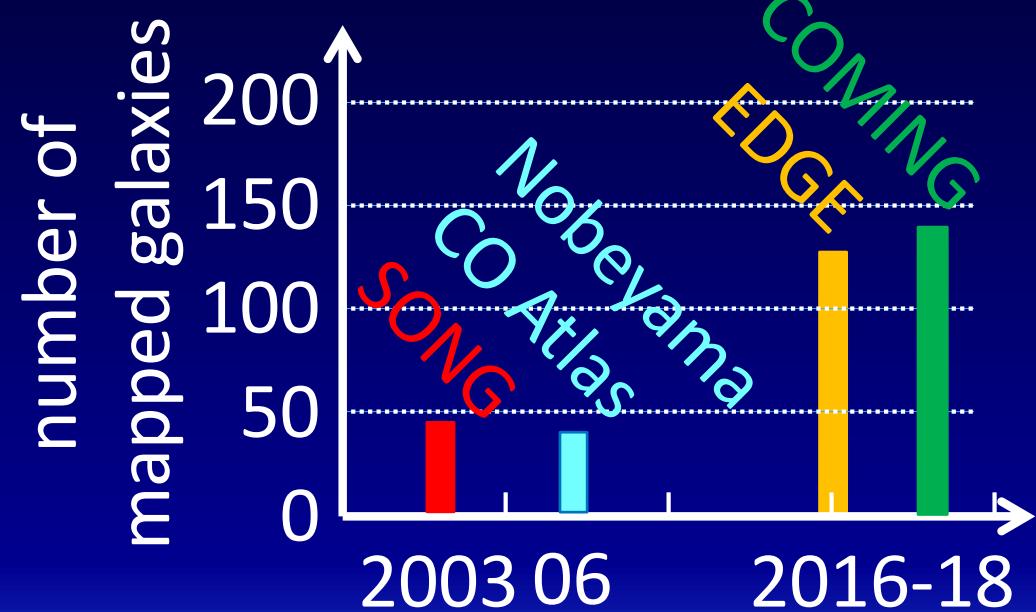
- integrated over the whole galaxy
→ What happens within a galaxy?
- lack of molecular gas information



(based on Schiminovich, et al. 2007)

Previous CO Surveys

Information of molecular gas has been deficient,
in especial, spatially resolved images.



2. COMING PROJECT

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The Team COMING

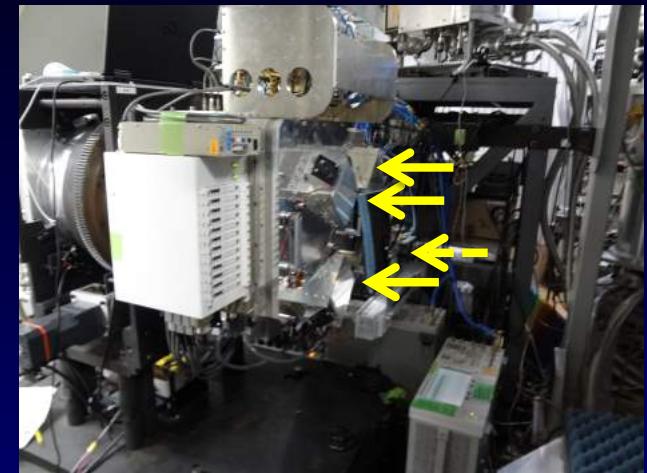
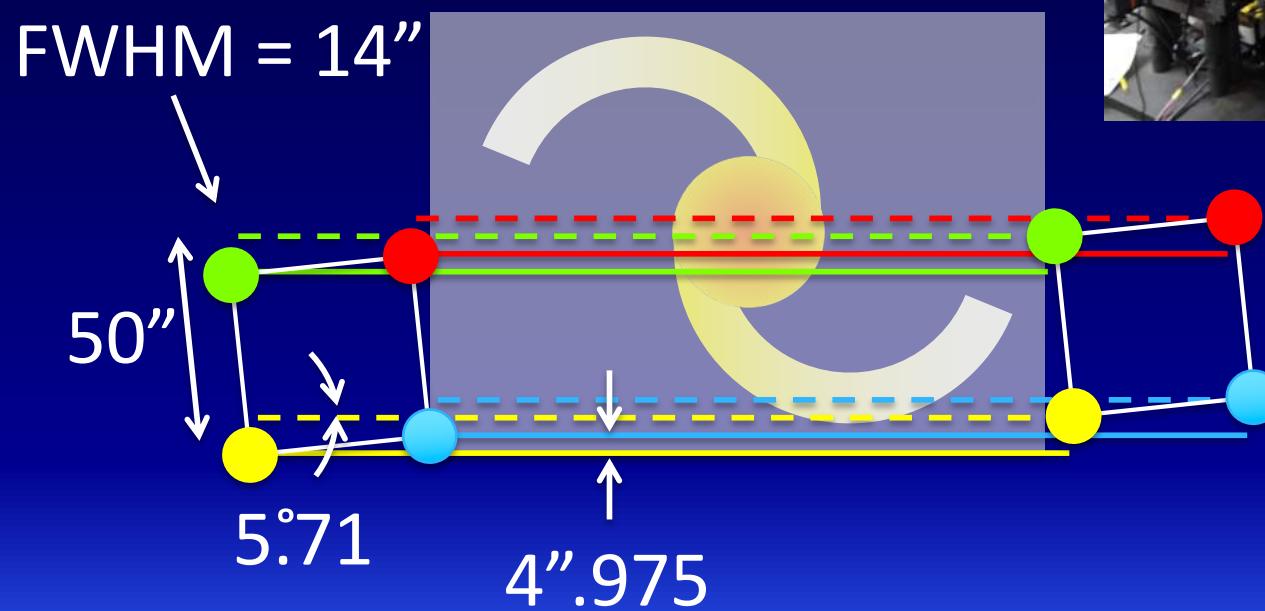


(* : 卒業/修了生)

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On-The-Fly Mapping w/ FOREST

- FOREST (receiver) on the 45-m telescope
 - 4 beams in 50" separation
 - beam size of 14" at 115 GHz (frequency of ^{12}CO)

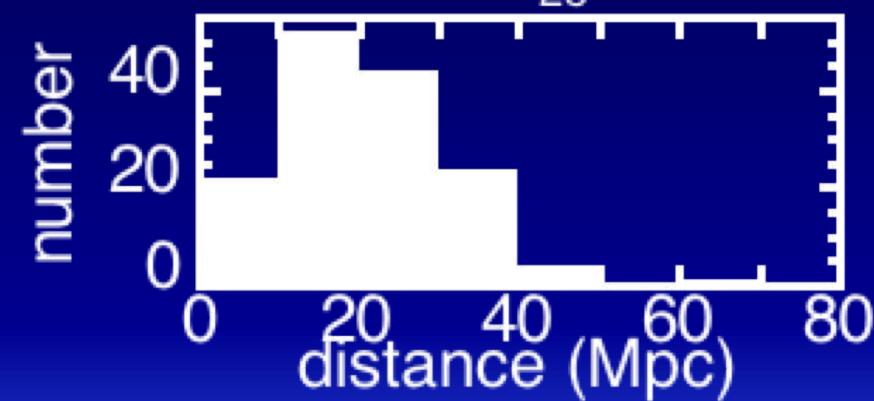
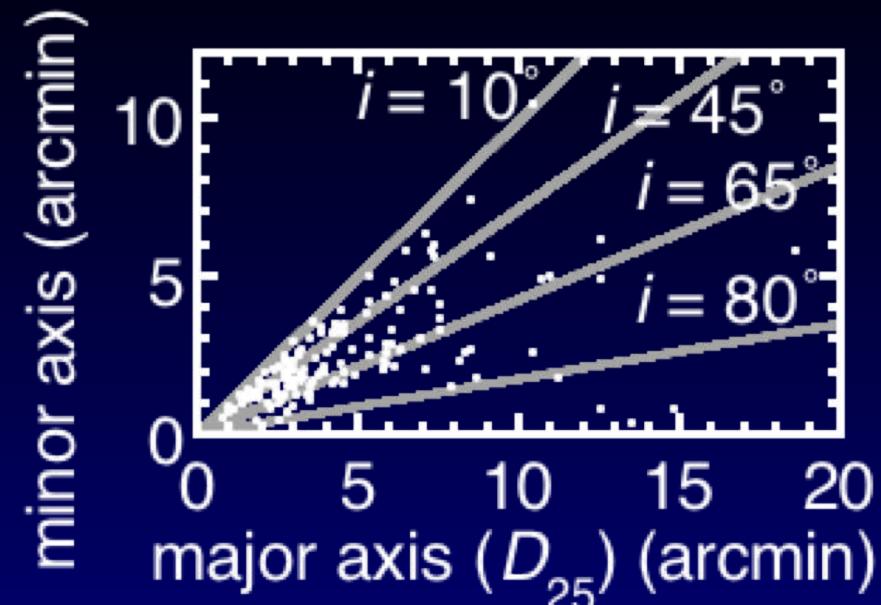
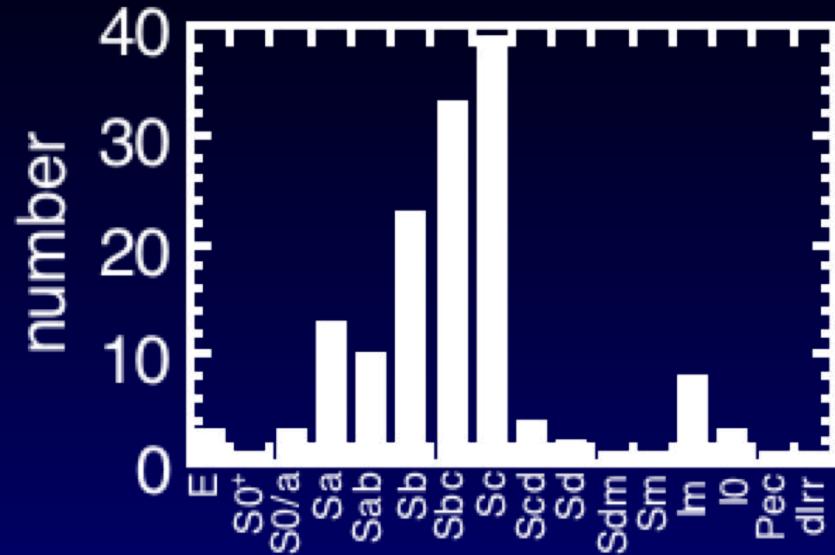


Observations

- OTF with **the 45-m telescope** w/ **FOREST**
- 2015, Apr. – 2018, Mar.
- ^{12}CO , ^{13}CO , C^{18}O $J=1-0$ (simultaneously)
- $\Delta v = 10 \text{ km s}^{-1}$
- $\Delta T_A^* = 30 \text{ mK}$
- mapping area: **70% of D_{25}**
- observed targets: **146** galaxies
(~61 % of the original samples)



Final Samples (146 galaxies)

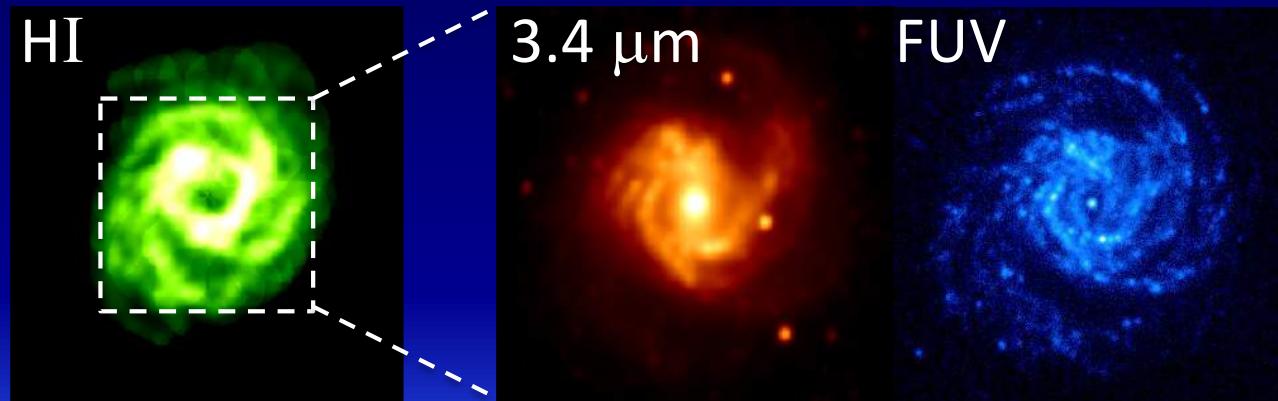


Summary of the Sample

- FIR bright galaxies (\leftarrow maybe CO bright)
- closer than the EDGE sample (comparable resolution)
- the final samples of 146 << the original targets of 238
 - impossible to categorize into the Hubble types
- lack of apparently large galaxies
(e.g., NGC 253, NGC 1097, NGC 1365, NGC 2403, NGC 5033)
 - restricted to several galaxies for resolving galaxy structures

Complementary Data

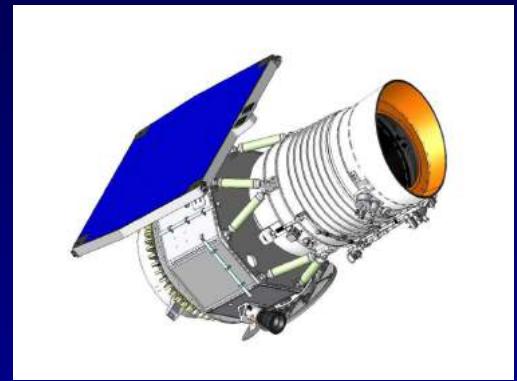
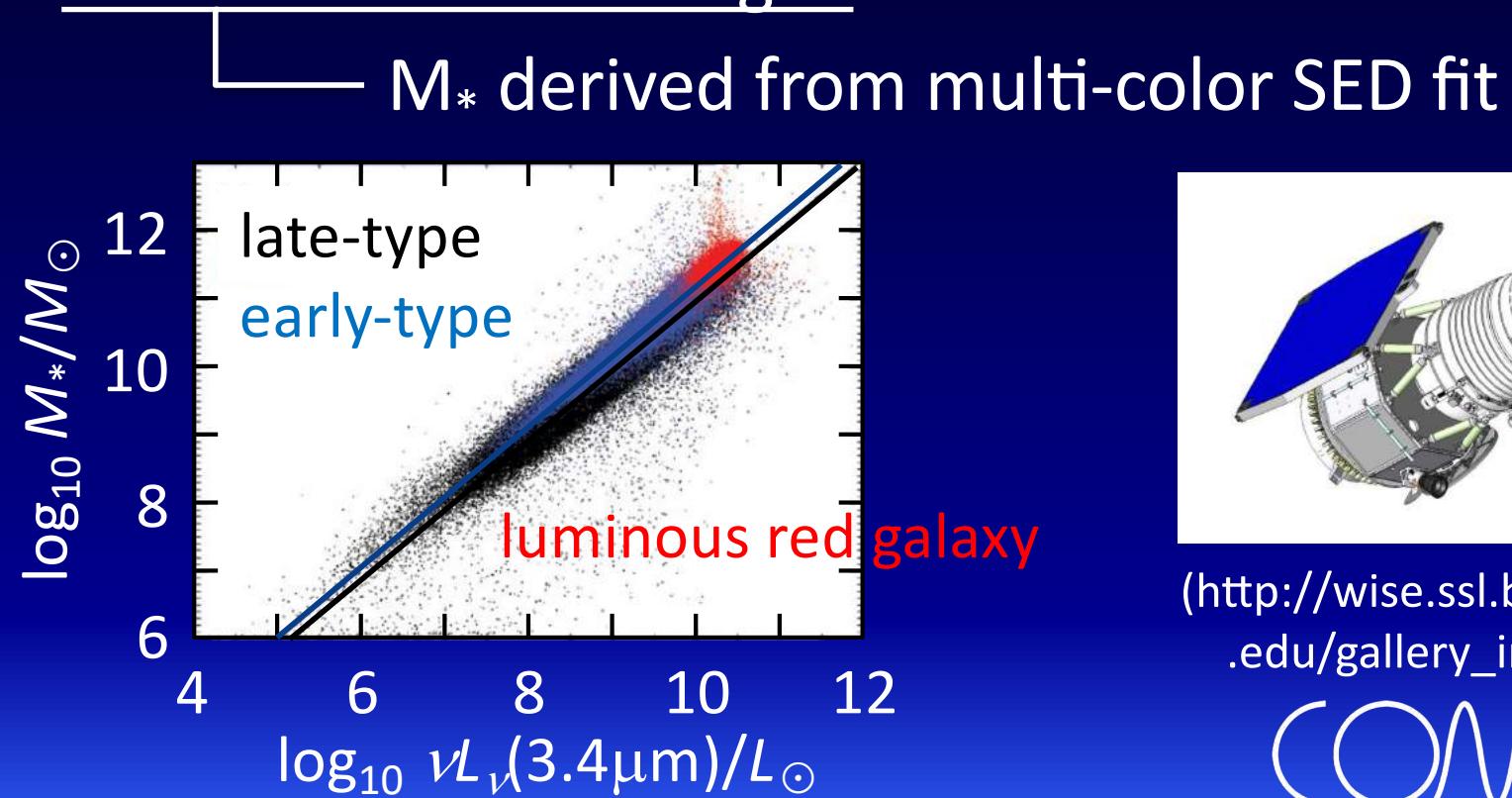
- already usable
 - HI (atomic gas) 66 galaxies
 - GALEX FUV (SFR) 99 galaxies
 - WISE 3.4 μm (stellar mass) 146 galaxies
 - Herschel (dust) ~ 20 galaxies



Deriving Stellar Mass

Wen+ 13

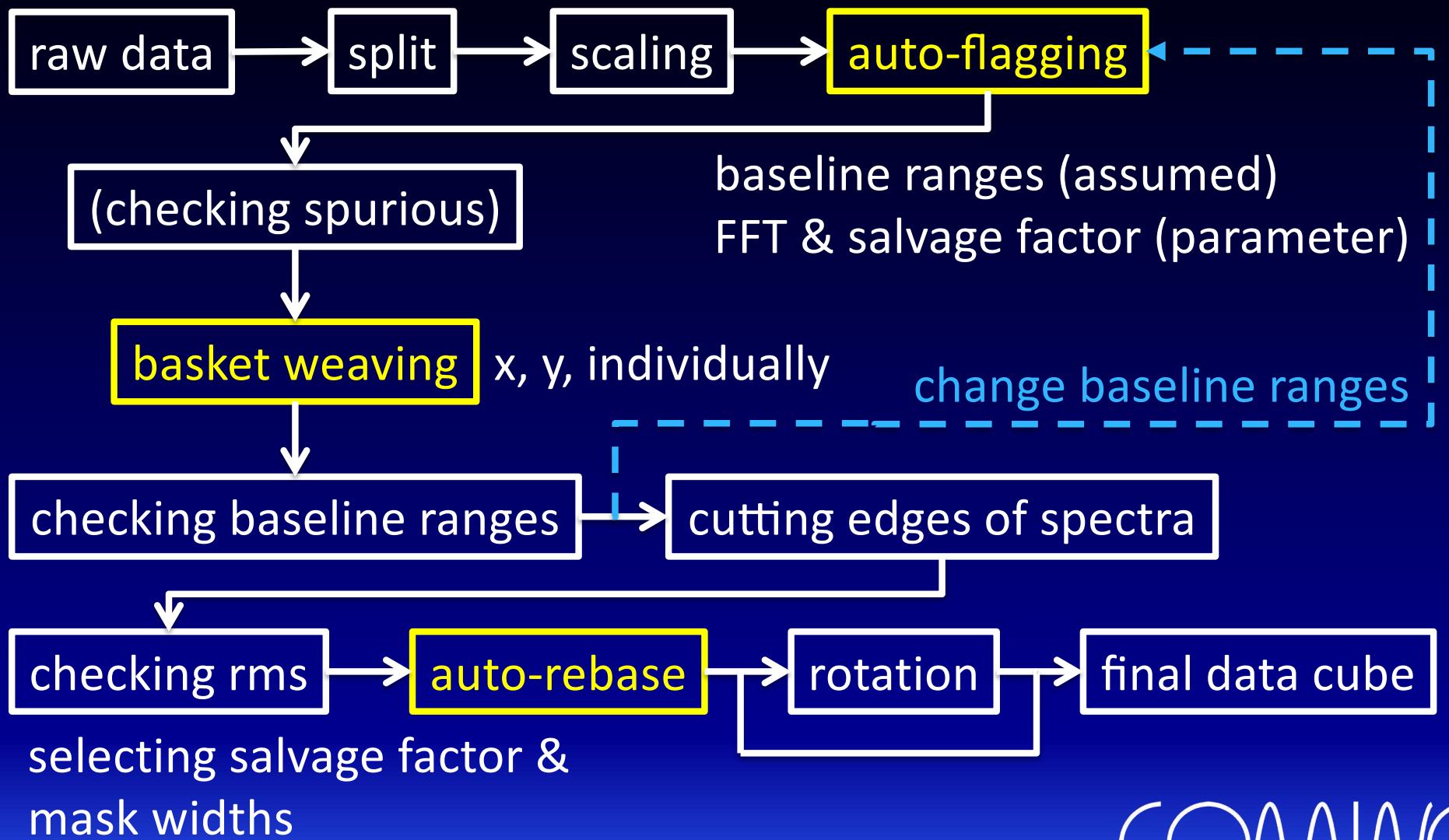
WISE 3.4 μm ($\sim 8''.3$) for 542757 galaxies @ $z \lesssim 0.35$
in MPA-JHU SDSS catalogue



(http://wise.ssl.berkeley.edu/gallery_images/)

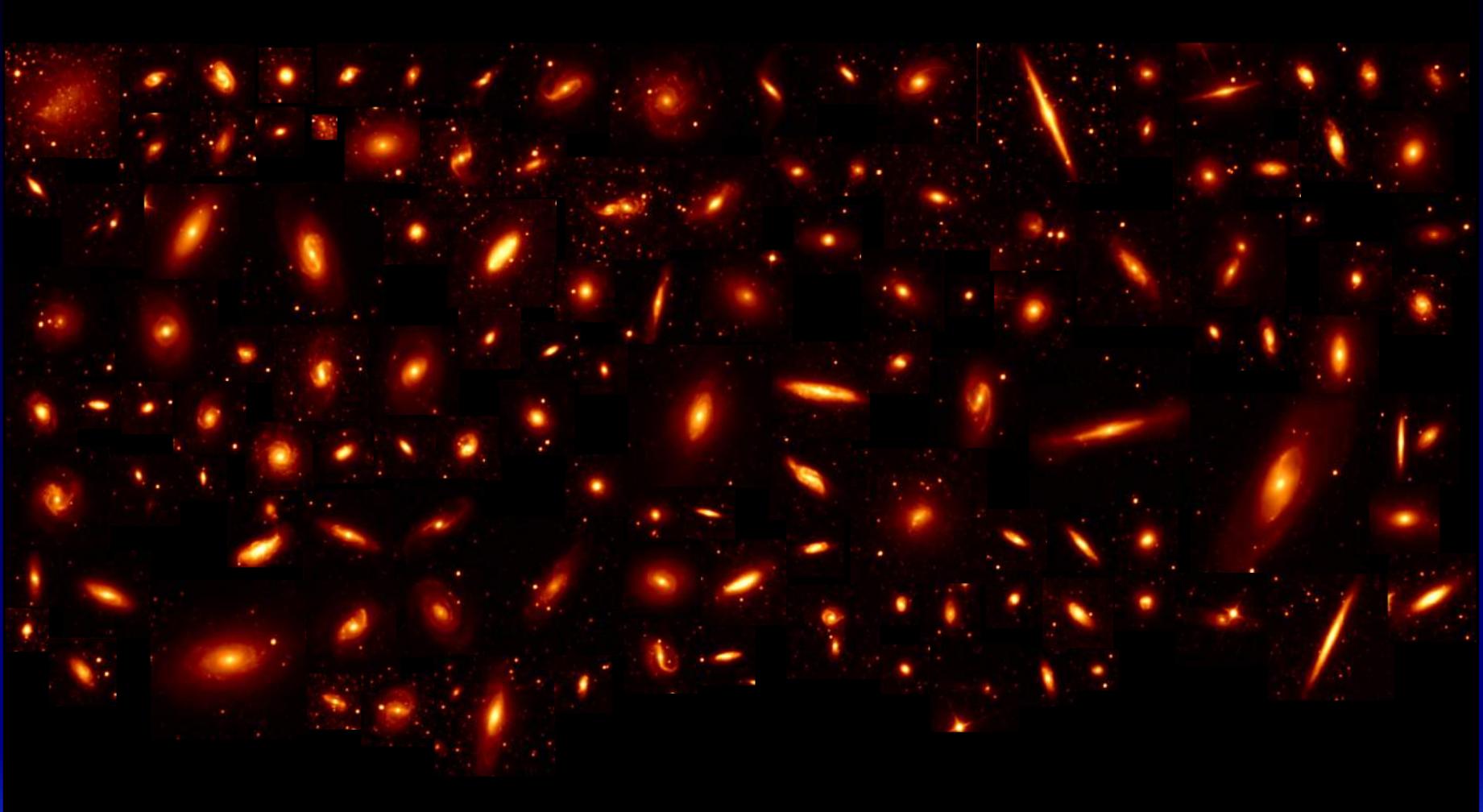
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Auto-Reduction Tool (*COMING ART*)



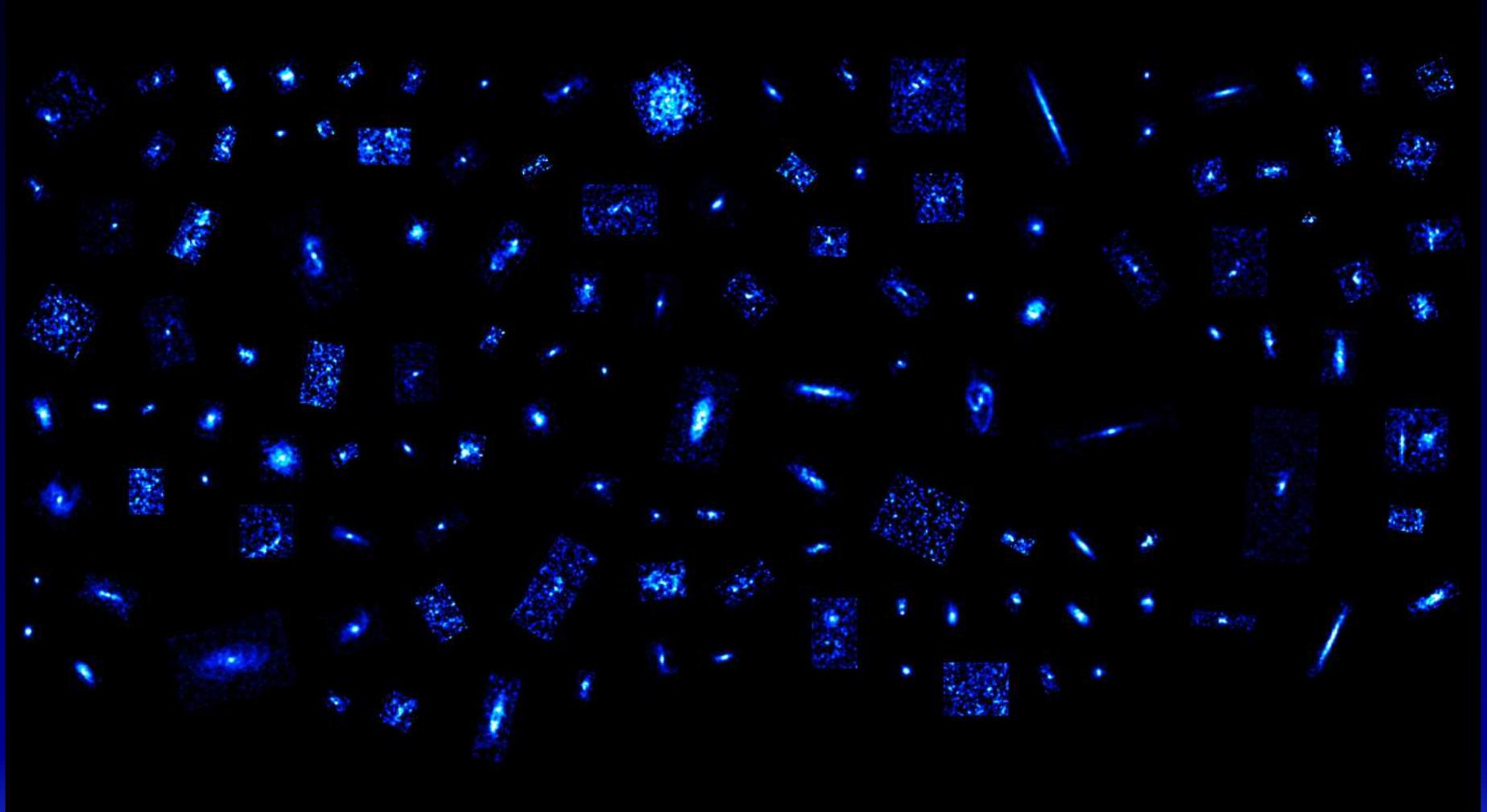
3. RESULTS

COMING Galaxies (WISE 3.4 μm)



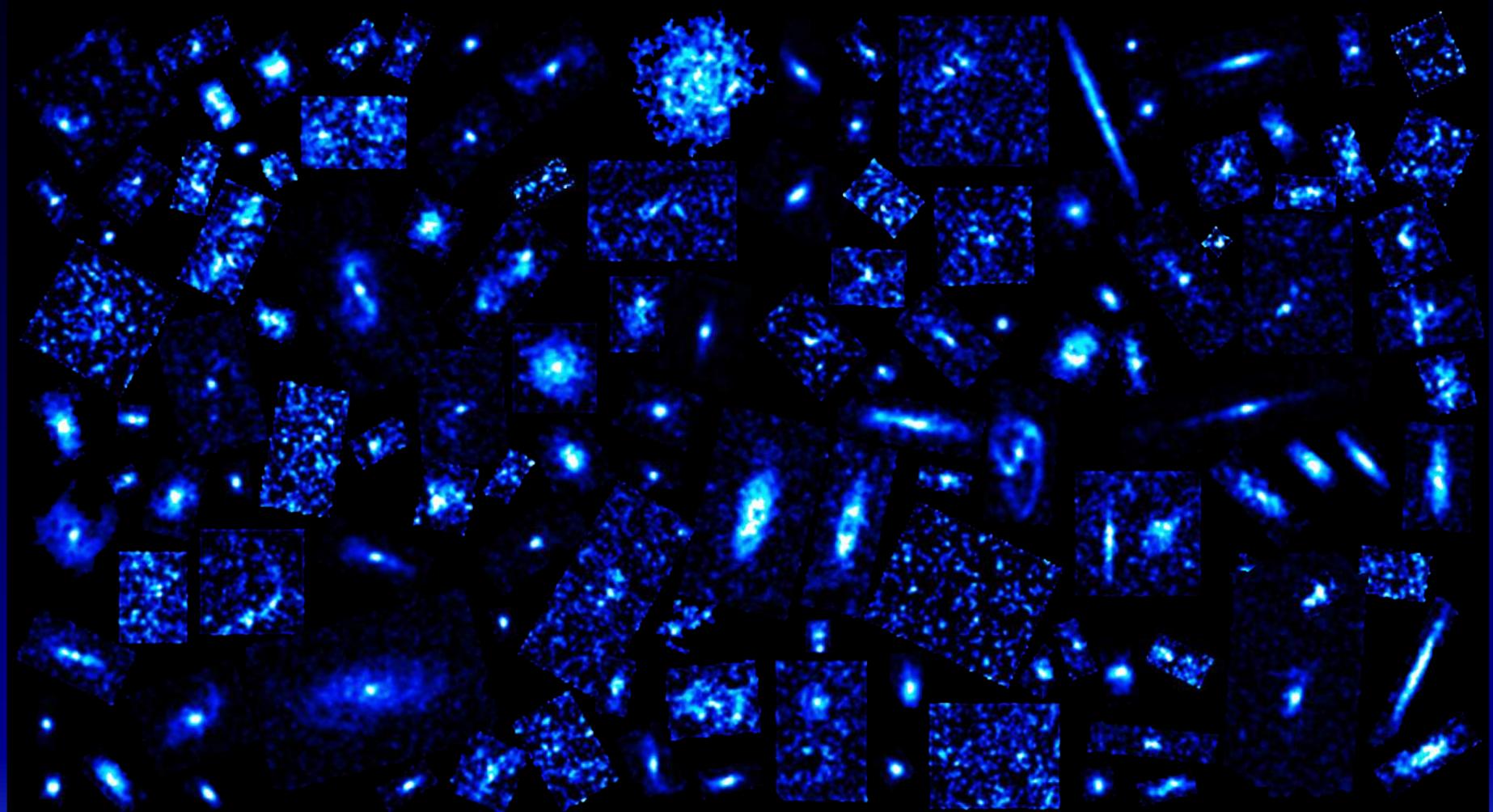
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COMING Galaxies ($^{12}\text{CO } J=1-0$)



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COMING Galaxies (zoom in)



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Molecular Gas Mass Fraction

no clear tendency (consistent with previous works)

preliminary results



SFR – Stellar Mass Relation

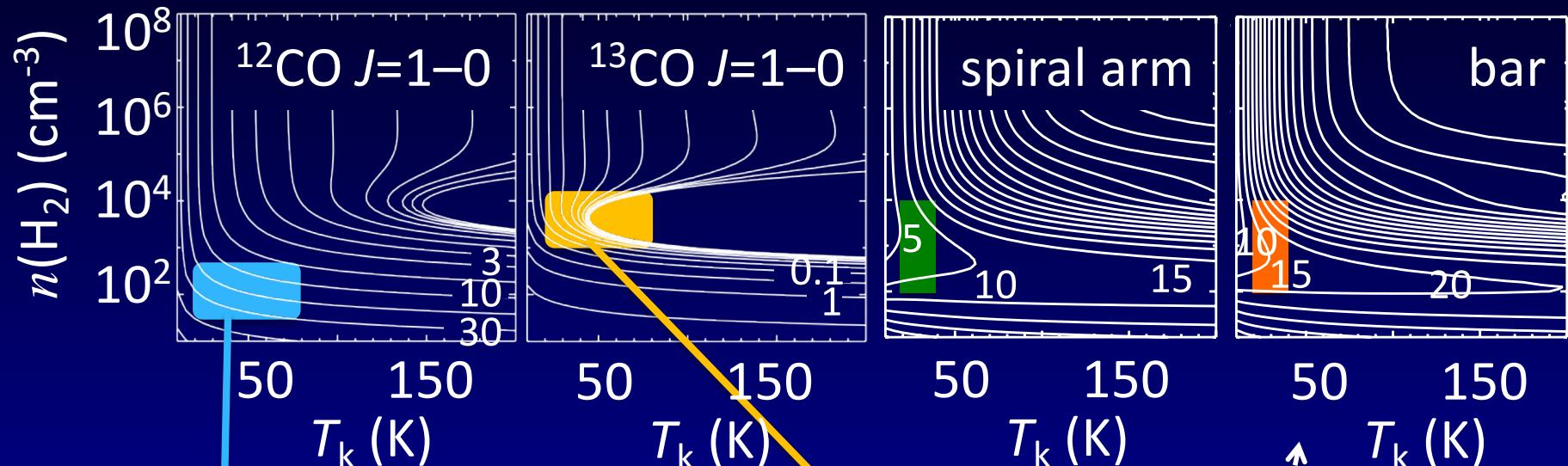
preliminary results



4. DISCUSSION

Multi-Line Analysis

optical depth and intensity ratio calculated with
RADEX (van der Tak+ 07)



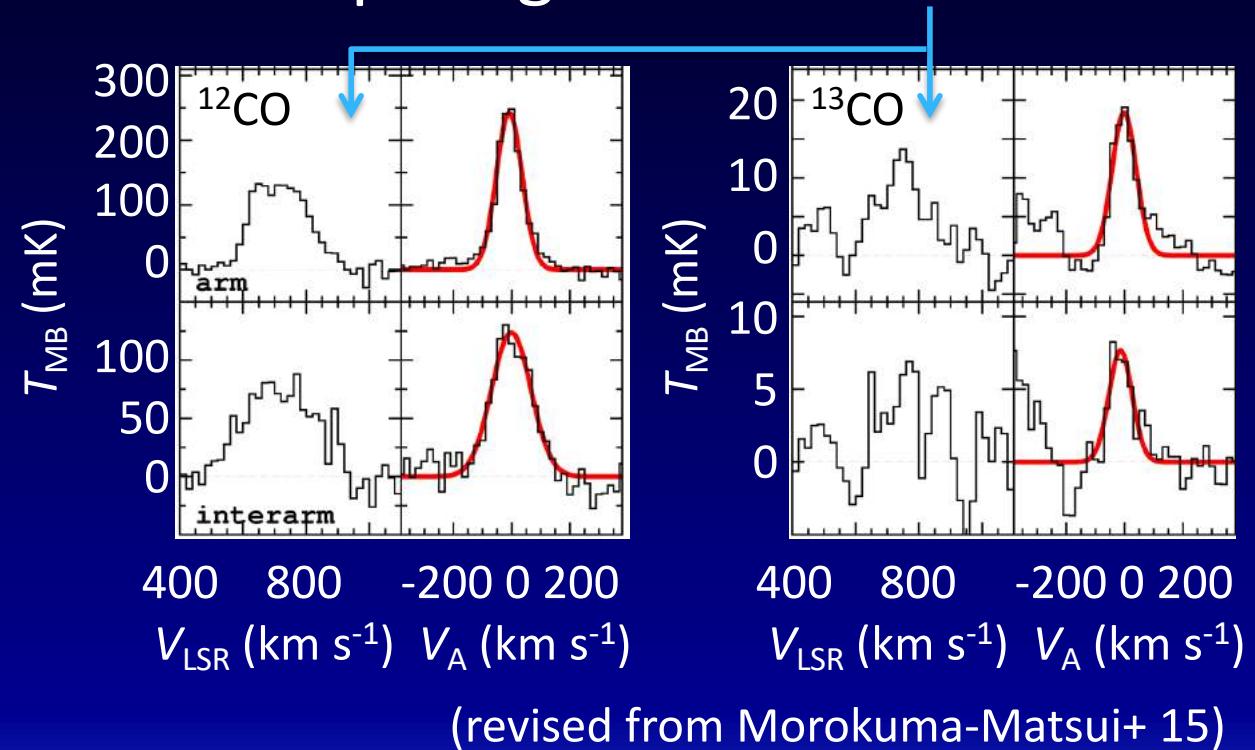
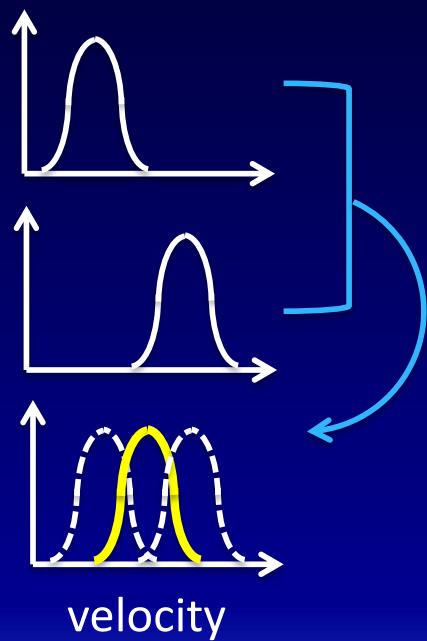
$$\tau(^{12}\text{CO } J=1-0) \gg 1 \gtrsim \tau(^{13}\text{CO } J=1-0)$$

larger velocity dispersion, rather diffuse

Weak Emission Revealed by Stacking

NGC 3627 (Morokuma-Matsu+ 15)

improving S/N of 3.2 comparing with normal
stacking



(revised from Morokuma-Matsu+ 15)

Promotion/Suppression of SF



(revised from Yajima+ 2018)

SFE & Molecular Gas Property

no clear dependency on $I(^{12}\text{CO})/I(^{13}\text{CO})$



preliminary results

→ The intensity ratio does not reflect gas density for galaxy integrated data.

SFE & Molecular Gas Property

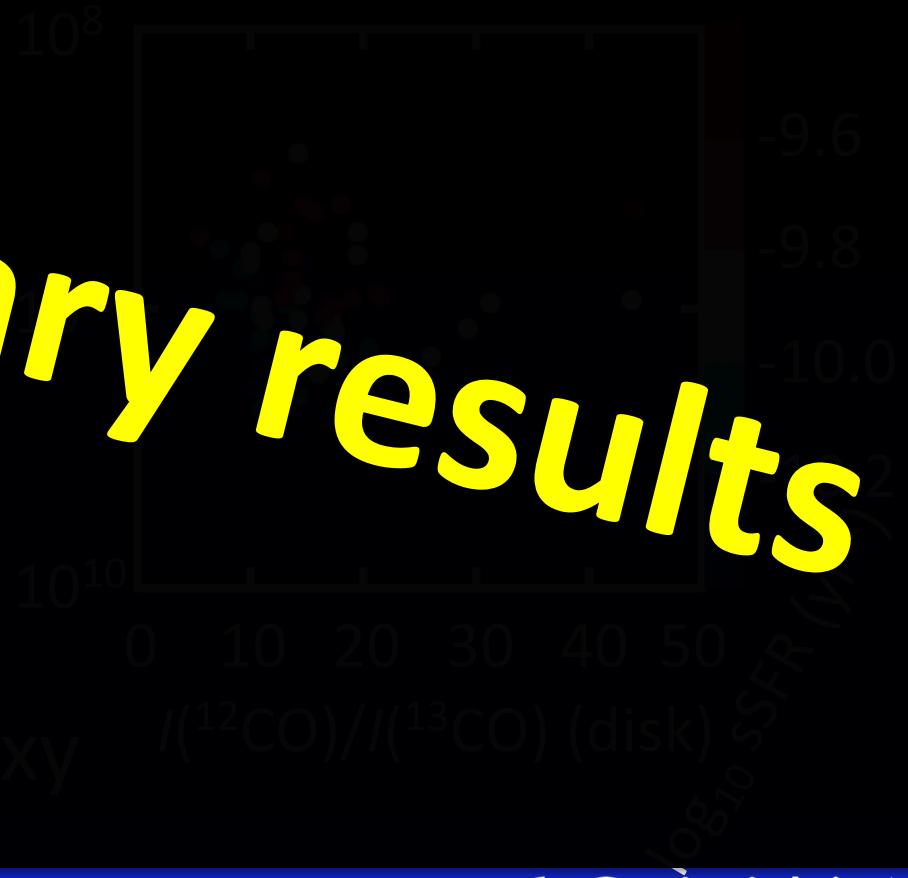
sSFR ↘ (= SF time scale ↗), $I(^{12}\text{CO})/I(^{13}\text{CO})$ ↘
at the same SFE (?)

preliminary results

effect (?)

^{13}C formed by
low/intermediate
mass stars

→ checking within a galaxy



5. SUMMARY & FUTURE WORKS

Status of the COMING Project

- COMING observed **146 galaxies**.
 - the largest CO imaging survey in the world!
 - (stacked) ^{13}CO data
- Star formation is not uniform among galaxies and within a galaxy.
- Gas motion seems to promote and suppress star formation.

Future Works

- HI and cloud formation
- cloud-scale study with ALMA data
- comparison with distant galaxies
- observations of multi-CO lines & dense gas tracers
- observations of low-z galaxies