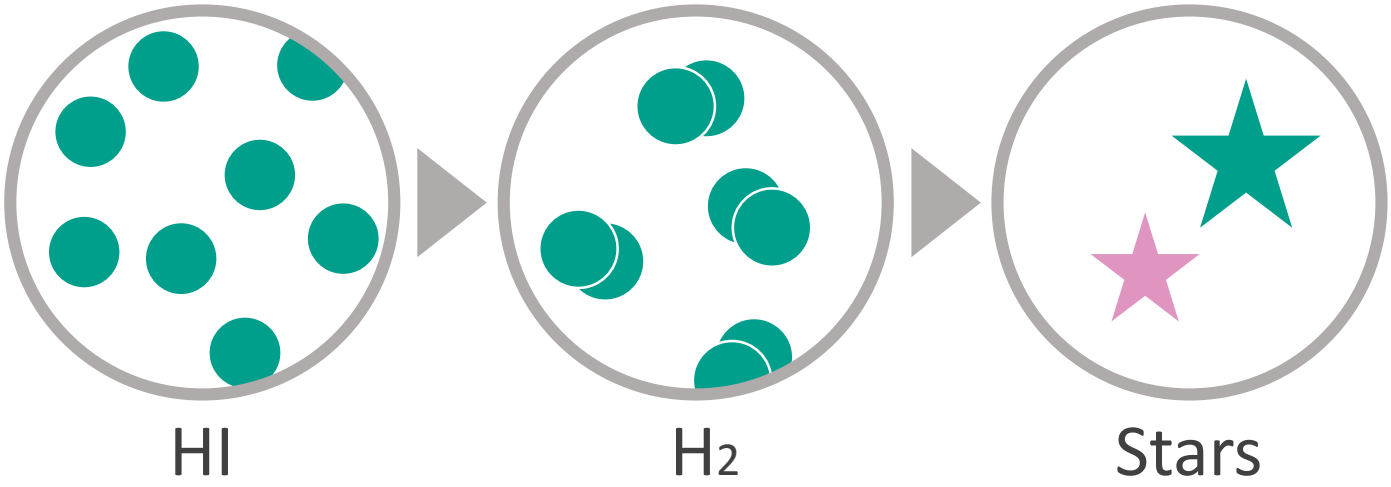
Statistical Study of Star Formation Law in Nearby Galaxies

Moe Yoda (Nagoya University, M2)

Collaborators:
Tsutomu T. Takeuchi (Nagoya University)
COMINGers

Star Formation Activity

Gas converted to stars



Relation between gas and SFR has been studied for a long time

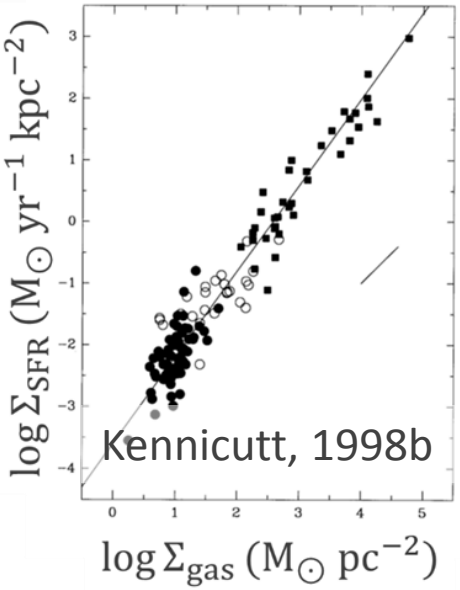
Kennicutt-Schmidt Law

Logarithmic linear relation

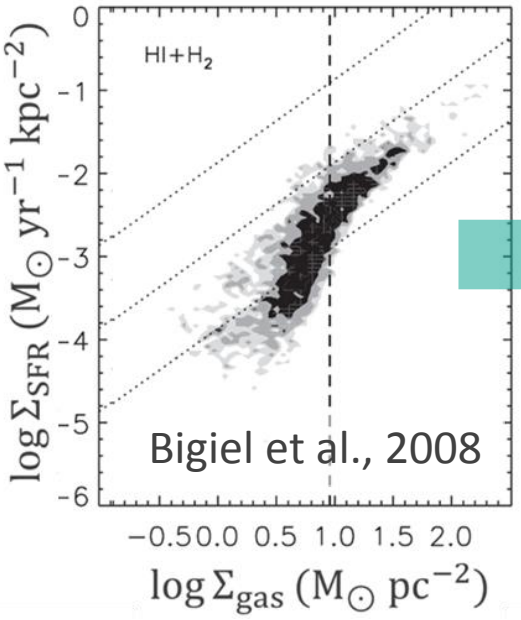
$$\Sigma_{\mathrm{SFR}} \propto \Sigma_{\mathrm{gas}}^{N} \qquad N: 1-2$$

Found at various scales

among galaxies



in a galaxy



Resolved K-S Law

Problems of K-S Law Studies

The meaning of K-S law is **poorly understood**

- The physical meaning of the power-law index *N* is unclear

Many previous resolved K-S law works are **case studies**

- Observation of gas is time-consuming

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However these days …

COMING project enables us to study resolved K-S law statistically

- **CO**-**M**ultiline **I**maging of **N**earby **G**alaxies
- Obtained **140 galaxies' CO maps** using NRO45

(Sorai et al. in prep)

Aim of the Study

Obtain resolved K-S laws for many galaxies

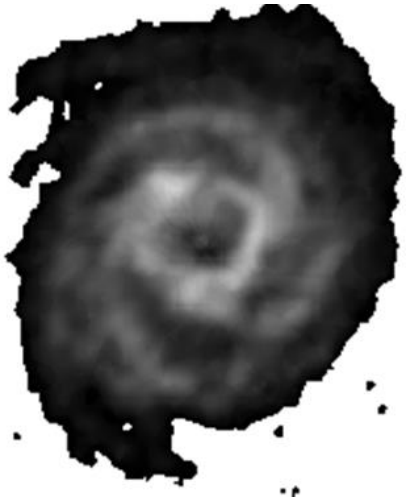
Reveal the physical meaning of K-S law
using statistical method

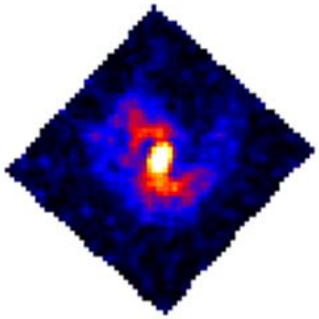
Key of this study

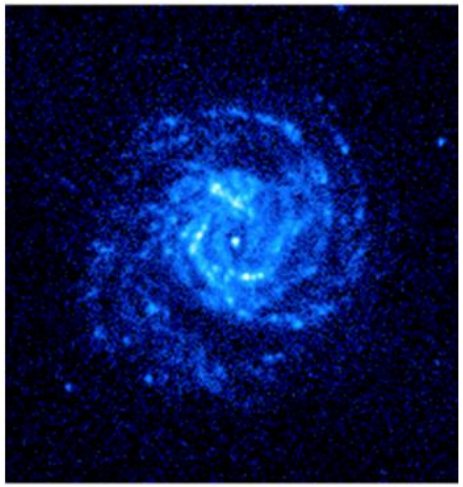
Uses **the largest sample**
compared with previous studies

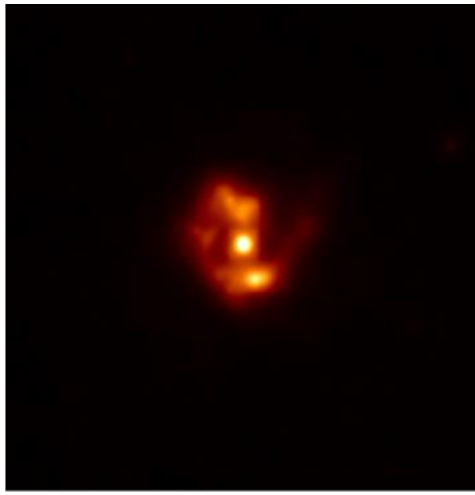
Method

Data









Σ_{HI}

VLA

21 cm line

Σ_{H2}

NRO45

$^{12}\mathrm{CO}(1-0)$

$\Sigma_{\mathrm{SFR(FUV)}}$

GALEX

FUV

$\Sigma_{\mathrm{SFR(FIR)}}$

WISE

22 μm

Σ_{gas}

Σ_{SFR}

Sample Selection

61 Molecular K-S law

32 Total gas K-S law

COMING sample

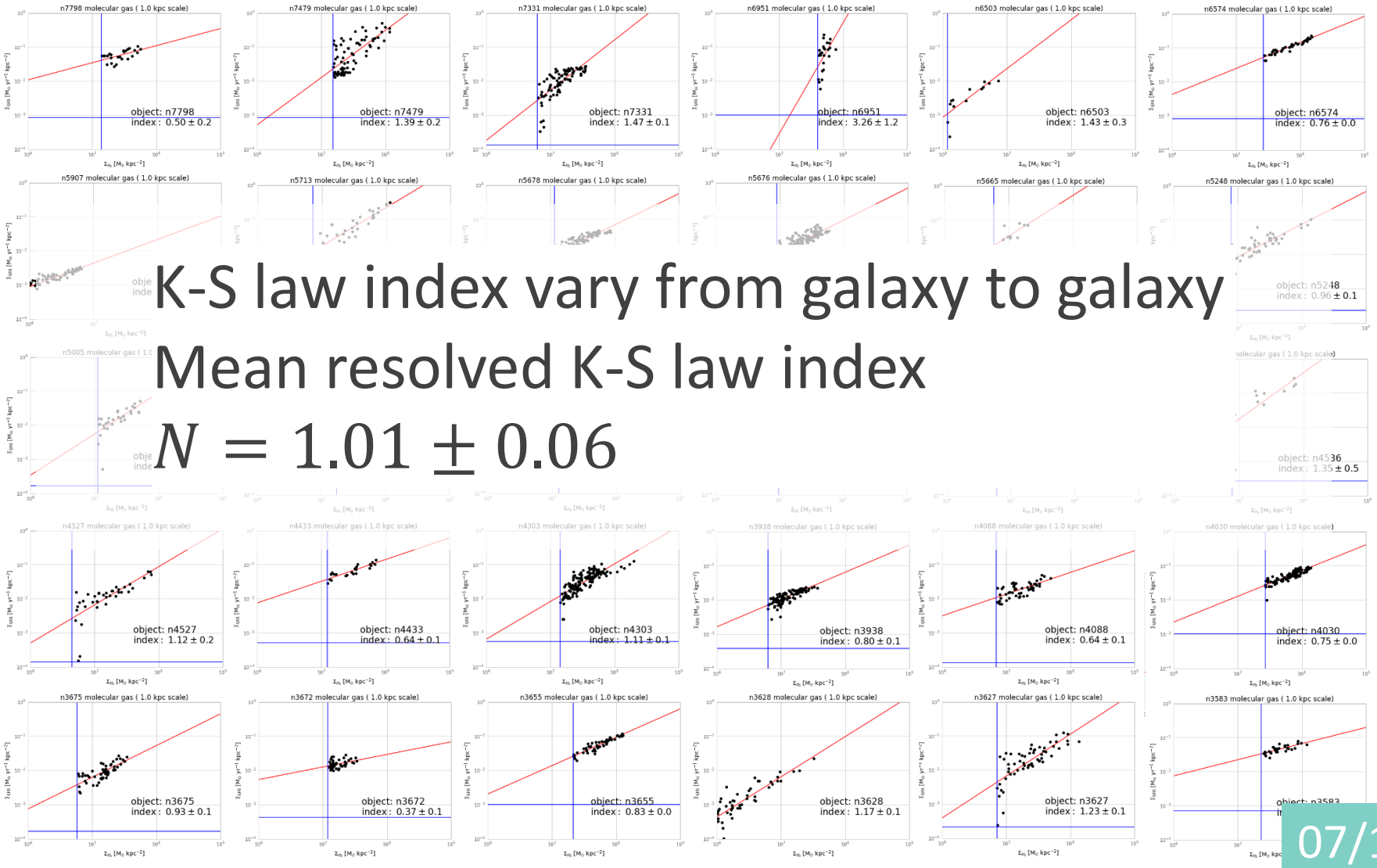
Observed by GALEX and WISE

Isolated galaxy

Enough data points at 1 kpc scale

Result

Resolved Molecular Gas K-S Law



K-S law index vary from galaxy to galaxy

Mean resolved K-S law index

$$N = 1.01 \pm 0.06$$

Discussion

Relations between K-S Law and Galaxy's Properties

K-S relations vary from galaxy to galaxy

Estimate
correlation coefficient

$$\frac{\log \overline{\Sigma_{\mathrm{gas}}}\ \log \overline{\Sigma_{\mathrm{SFR}}}}{\left|\log \Sigma_{\mathrm{gas}} - \overline{\log \Sigma_{\mathrm{gas}}}\right|^2 \left|\log \Sigma_{\mathrm{SFR}} - \overline{\log \Sigma_{\mathrm{SFR}}}\right|^2}$$

Resolved K-S law index

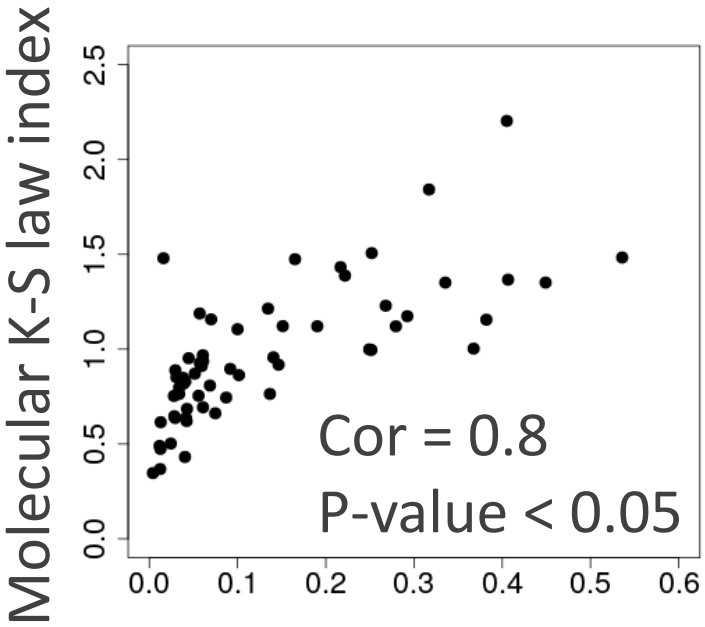
HI saturation threshold

Dust extinction

Morphology

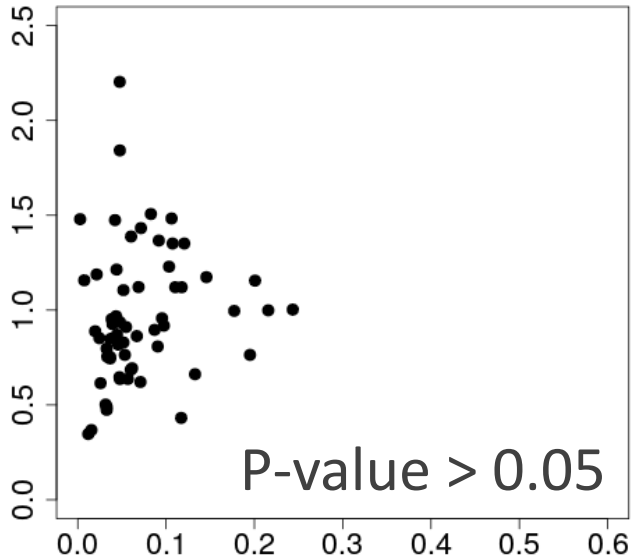
Index and Galaxy's Properties

Index of molecular K-S law has significant correlation with $\left|\log \Sigma_{SFR} - \overline{\log \Sigma_{SFR}}\right|^2$



Variance of **SFR** density

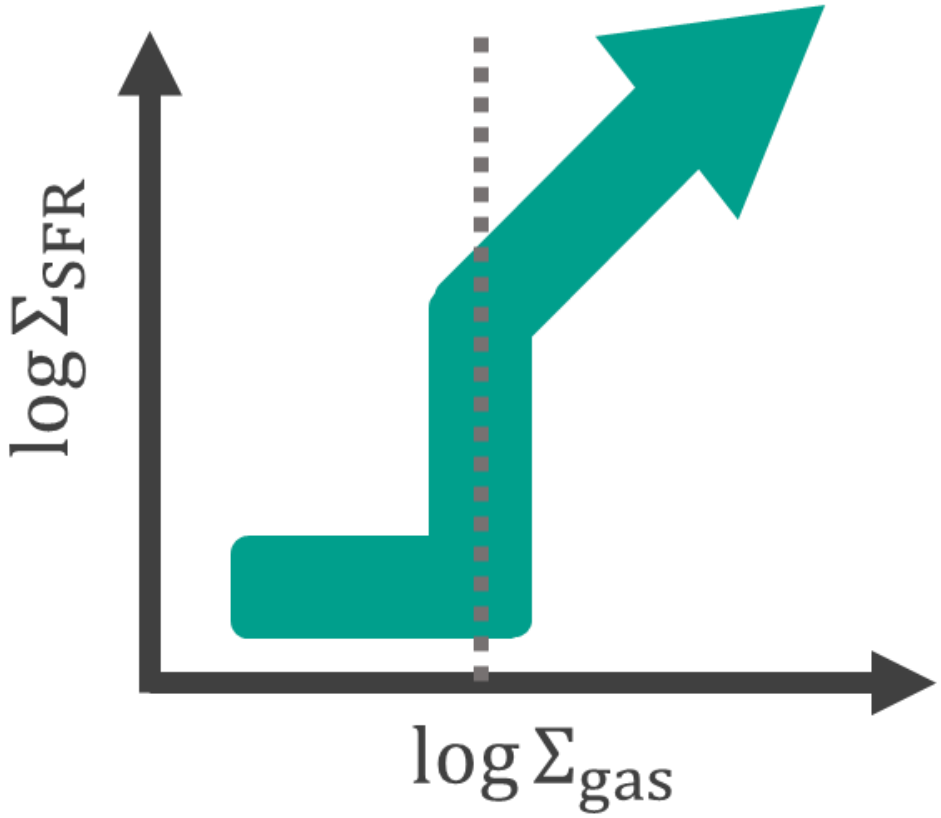
Strong correlation



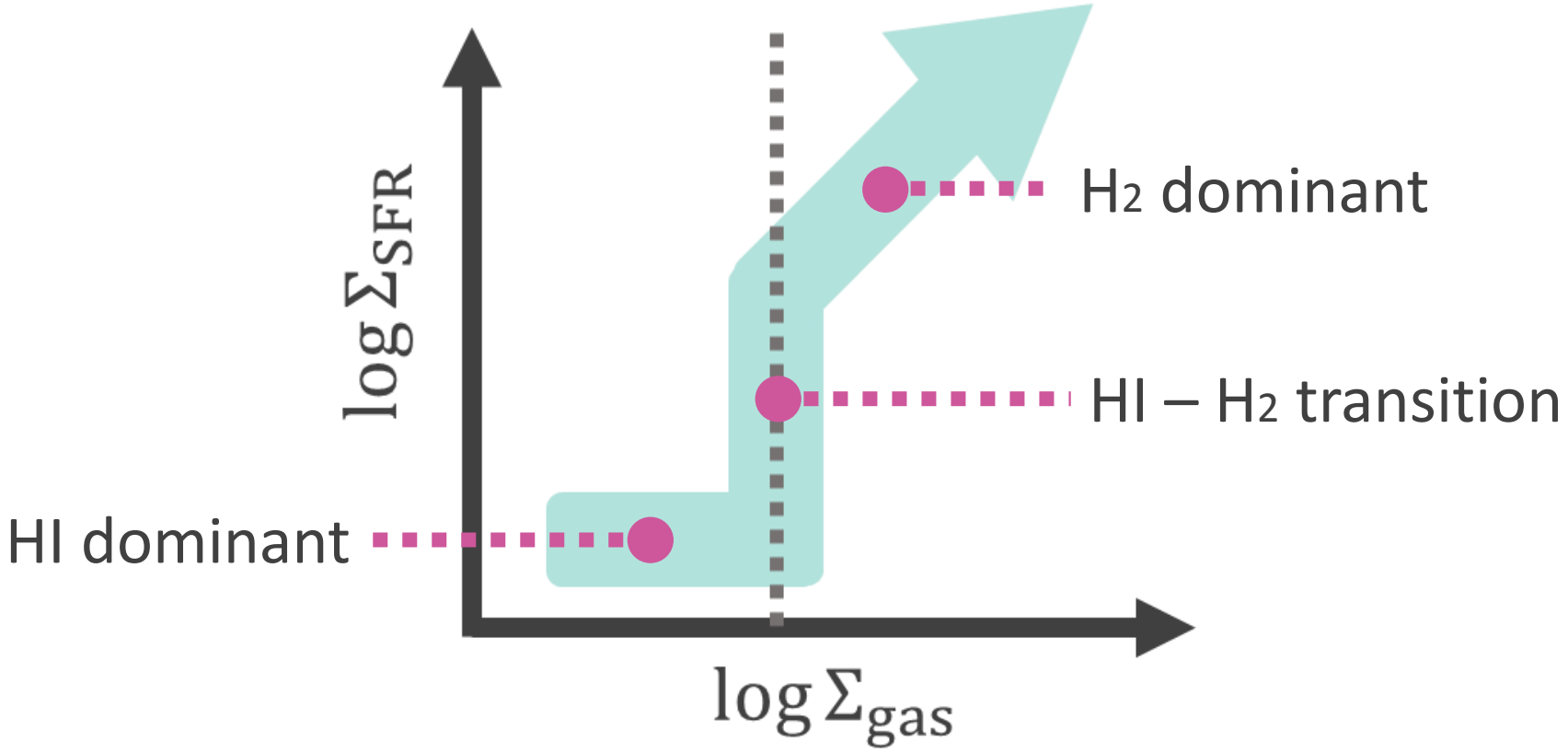
Variance of H_2 density

No significant correlation

One Possible Model of K-S Law



One Possible Model of K-S Law



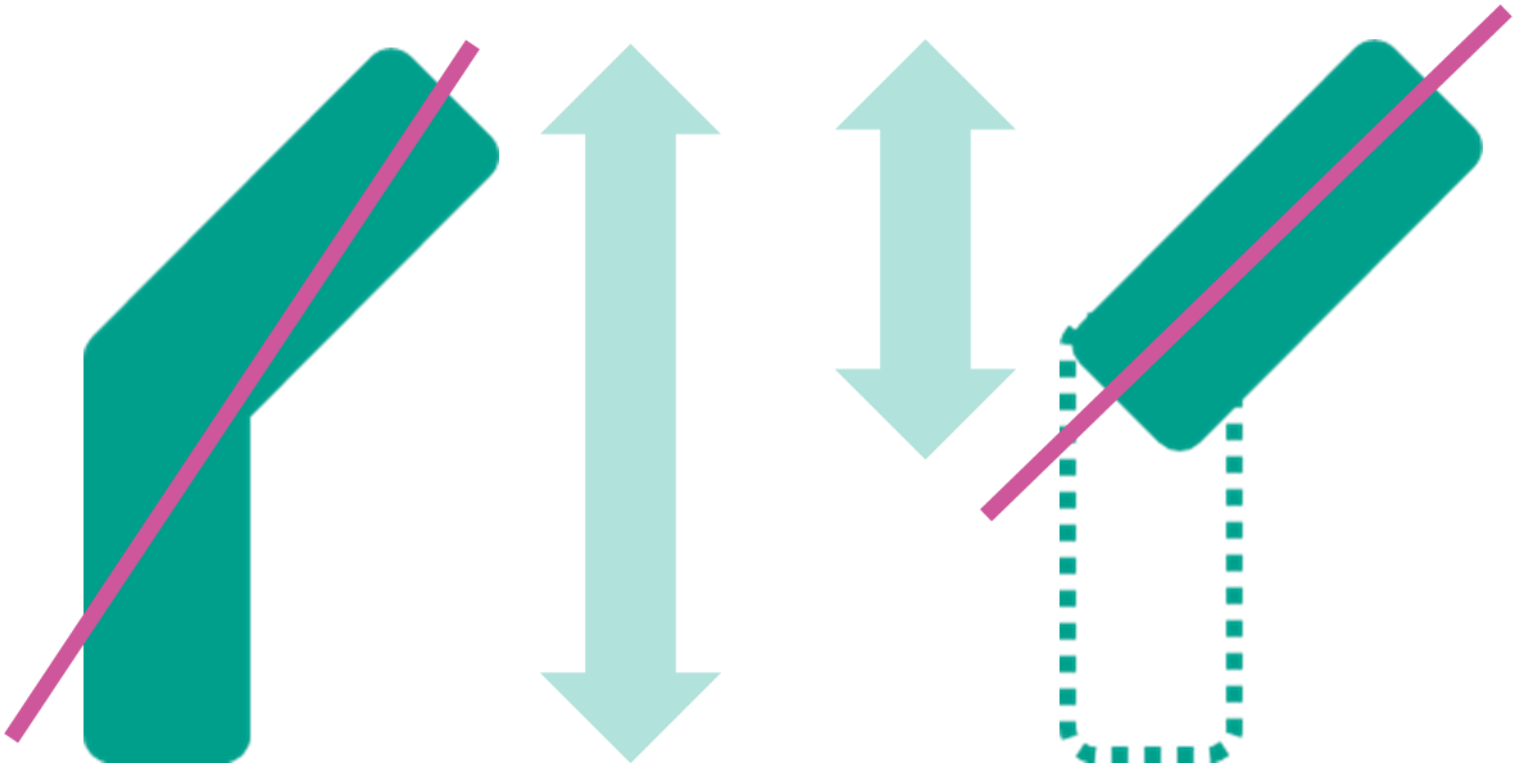
One Possible Model of K-S Law

Large Σ_{SFR} variance

Large index

Small Σ_{SFR} variance

Small index



Summary

Kennicutt-Schmidt law is a relation between gas and SFR surface density

Obtain **61 galaxies** resolved K-S law

Index of molecular K-S law has significant correlation with variance of SFR density

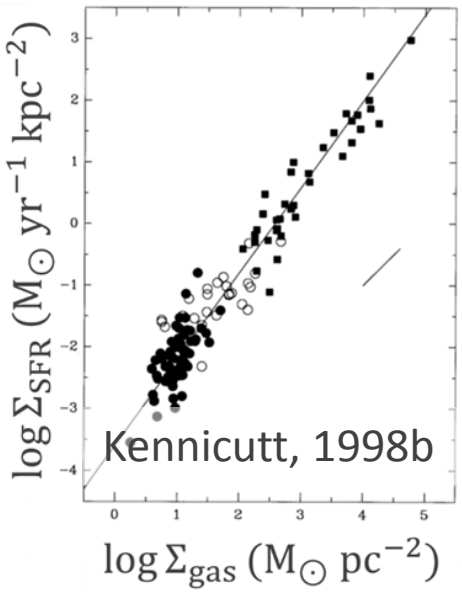
Future Study

Explain the results physically

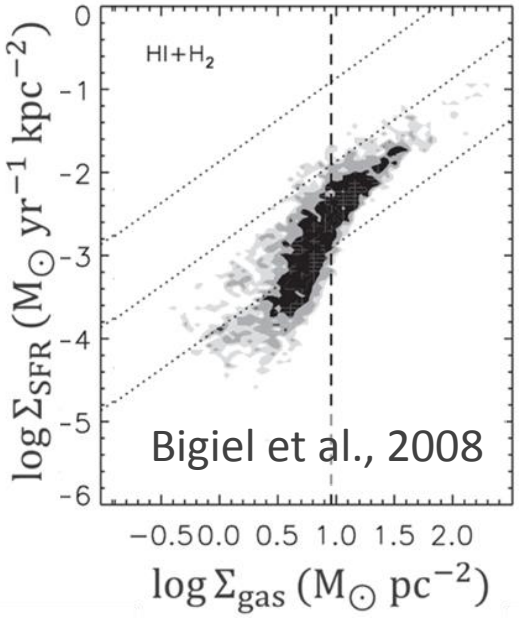
Appendix

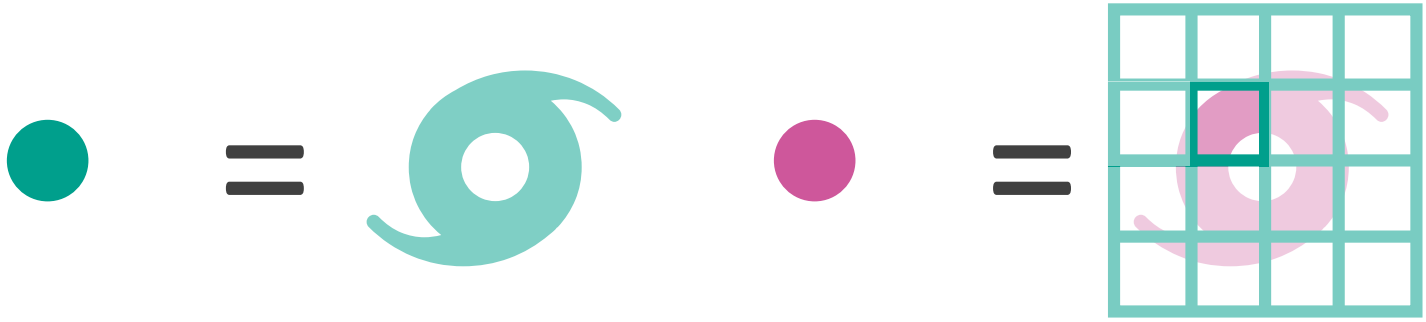
Kennicutt-Schmidt Law

Global K-S law

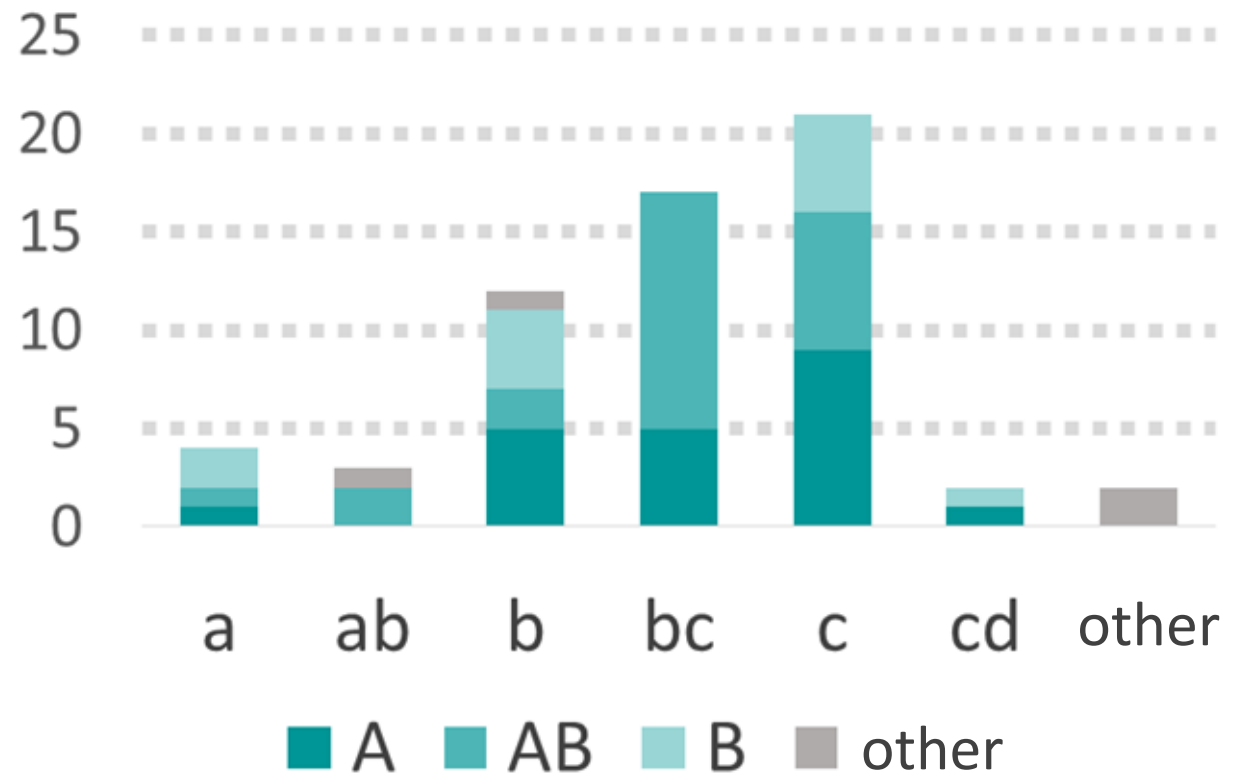


Resolved K-S law





Sample Morphology



Enough Data Points

Estimate **correlation coefficient's p-value** between Σ_{gas} and Σ_{SFR}

If a galaxy does not have enough data points, the p-value will be > 0.05

We adopted the galaxies which have **p-value < 0.05**

Formulae

HI

$$M(\mathrm{HI})\left[\mathrm{M}_{\odot}\right] = 2.356 \times 10^{5} S_{\mathrm{HI}}\ [\mathrm{Jy\ km\ s^{-1}}](D[\mathrm{Mpc}])^{2}$$

H2

$$\Sigma_{\mathrm{H_2}}\left[\mathrm{M}_{\odot}\ \mathrm{kpc}^{-2}\right] = 3.21 \times 10^{6} \times \cos(i)\ \left(\frac{I_{12\mathrm{CO}(1-0)}}{\mathrm{K\ km\ s^{-1}}}\right)$$

$$X_{\mathrm{CO}} = 2.0 \times 10^{20}\ [\mathrm{cm^{-2}\ (K\ km\ s^{-1})^{-1}}]$$

SFR(FUV)

$$\Sigma_{\mathrm{SFR_{FUV}}}\left[\mathrm{M}_{\odot}\ \mathrm{yr}^{-1}\ \mathrm{kpc}^{-2}\right] = 8.1 \times 10^{-2} \times I_{\mathrm{FUV}}[\mathrm{MJy\ sr^{-1}}] \times 1.59$$

SFR(22um)

$$\Sigma_{\mathrm{SFR_{22}}}\left[\mathrm{M}_{\odot}\ \mathrm{yr}^{-1}\ \mathrm{kpc}^{-2}\right] = 3.2 \times 10^{-3} \times I_{22}[\mathrm{MJy\ sr^{-1}}] \times 1.59$$

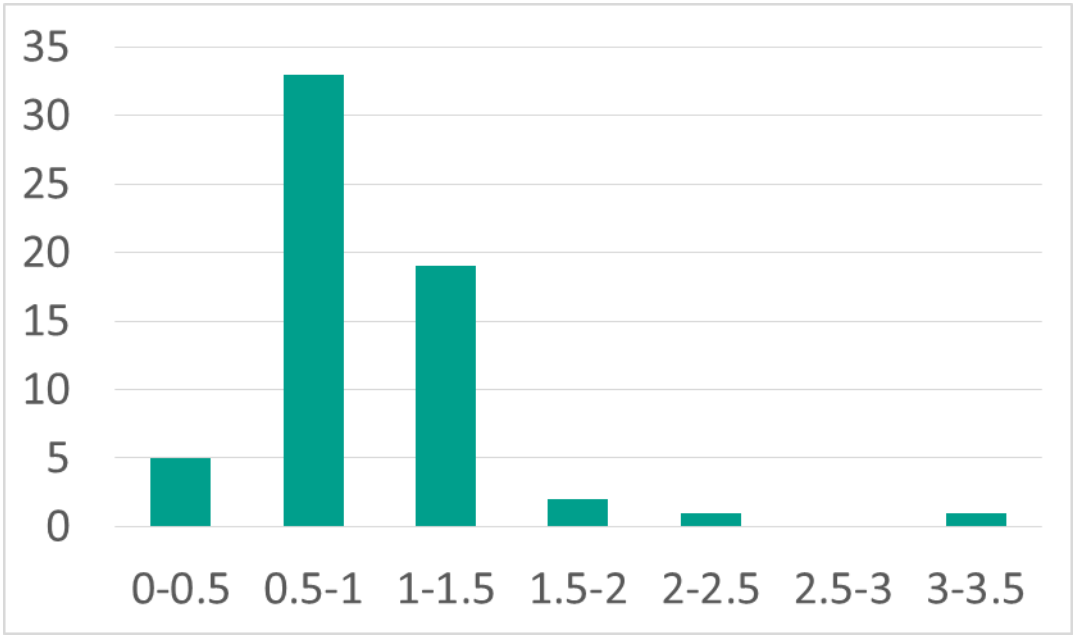
Casasola et al., 2017

Analysis

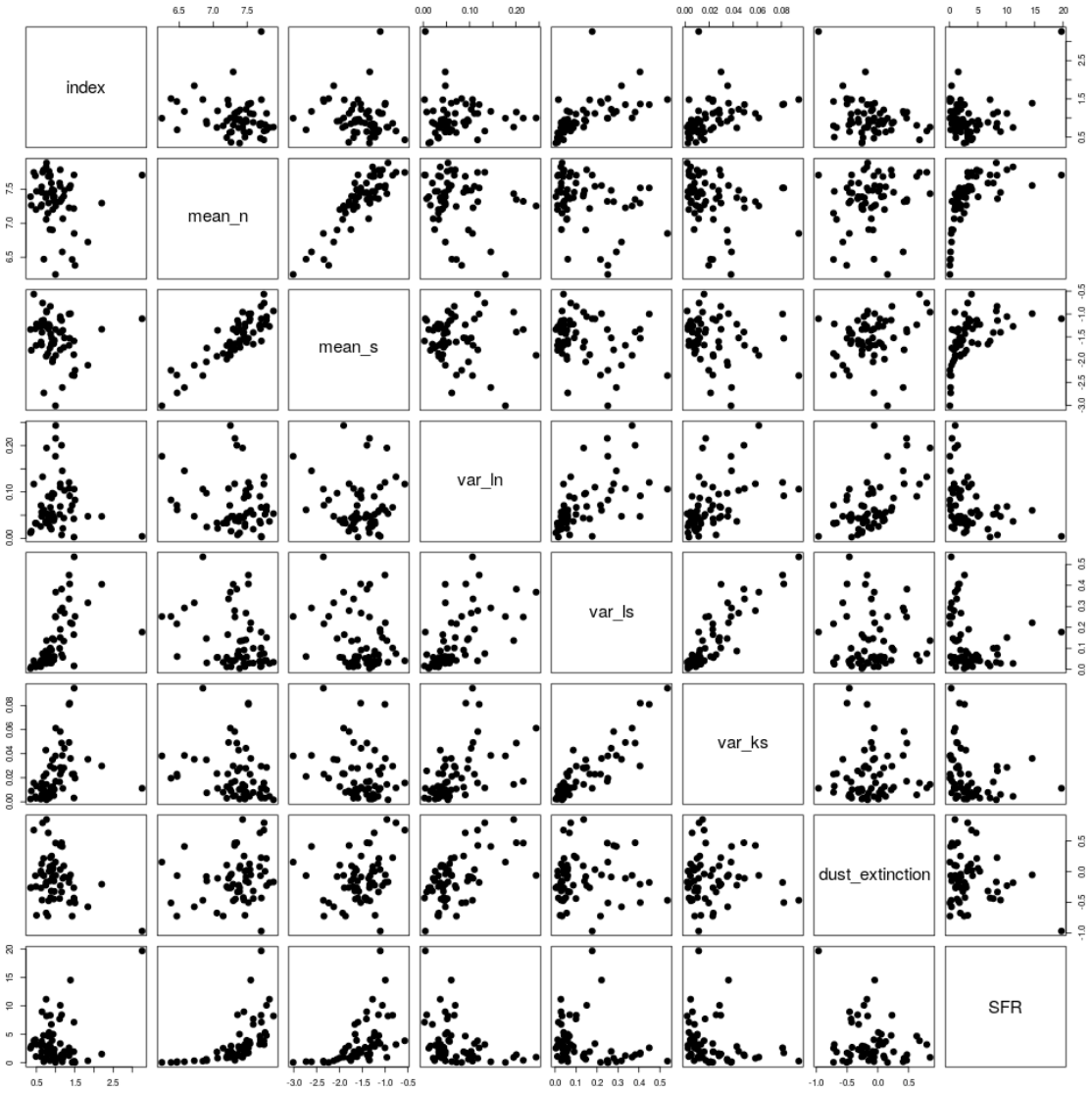
1. Convolution
2. Making 1 kpc-grid maps
3. Fitting with least square method

$$\log \Sigma_{\mathrm{SFR}} = N \times \log \Sigma_{\mathrm{gas}} + A$$

Molecular K-S Law Index



Molecular K-S Law's Properties



Total Gas K-S Law's Properties