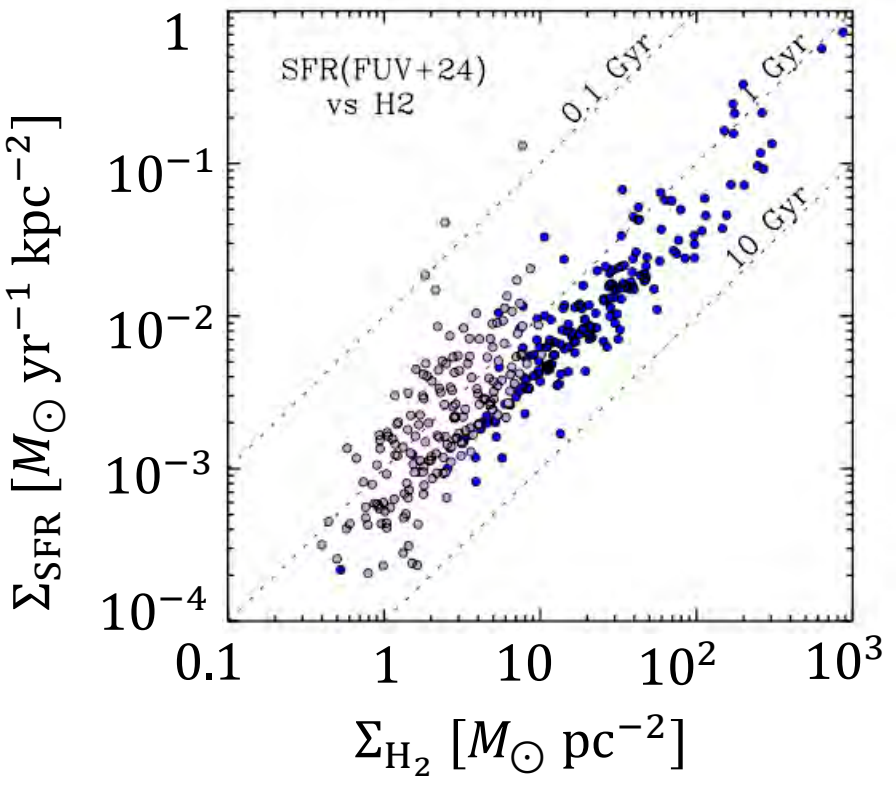
The transition from atomic to molecular gas and the rate–limiting process in star formation in nearby galaxies

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Stars form from molecular gas



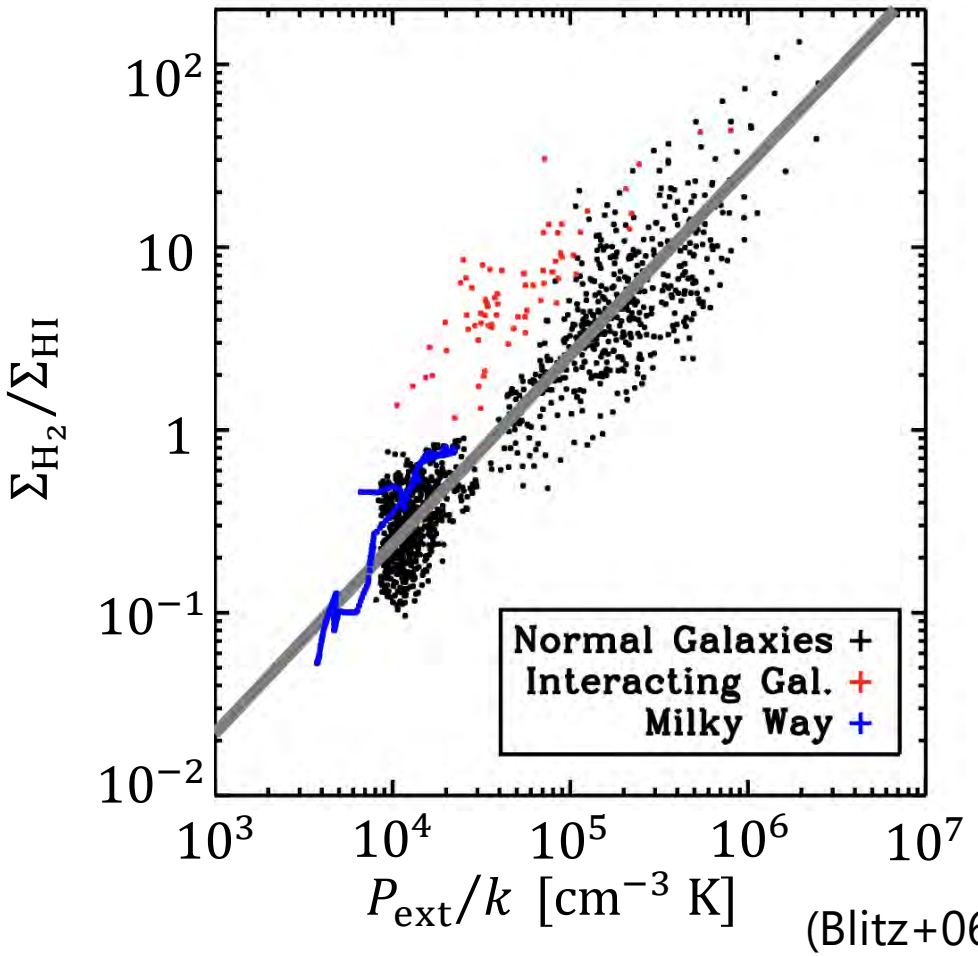
(Schruba+11)

- Molecular gas form under specific physically conditions.

- The star formation process is

atomic gas ⇨ molecular gas ⇨ star

Efficiency of forming molecular gas



(Blitz+06)

- Blitz+06; Eibensteiner+23, etc.
  - $\Sigma_{H_2}/\Sigma_{HI} \propto$ midplane pressure
- Krumholz+09, etc.
  - H_2 fraction primarily set by column density & metallicity
  - Weak dependence on ISRF* intensity

(* Inter Stellar Radiation Field)

Data

COMING Survey (Sorai+19)

COMING
CO Multi-line Imaging of Nearby Galaxies

- The large survey of $^{12}\mathrm{CO}(1-0)$ (~150 galaxies, 17″ resolution)
- A sample with a wide range of galaxy morphologies
- About 1/4 galaxies have observed HI by VLA (C configuration, 14″)
- Stellar mass and SFR of a whole galaxy

☐ In this work, we use **30 non-interacting galaxies**

Sample Galaxies

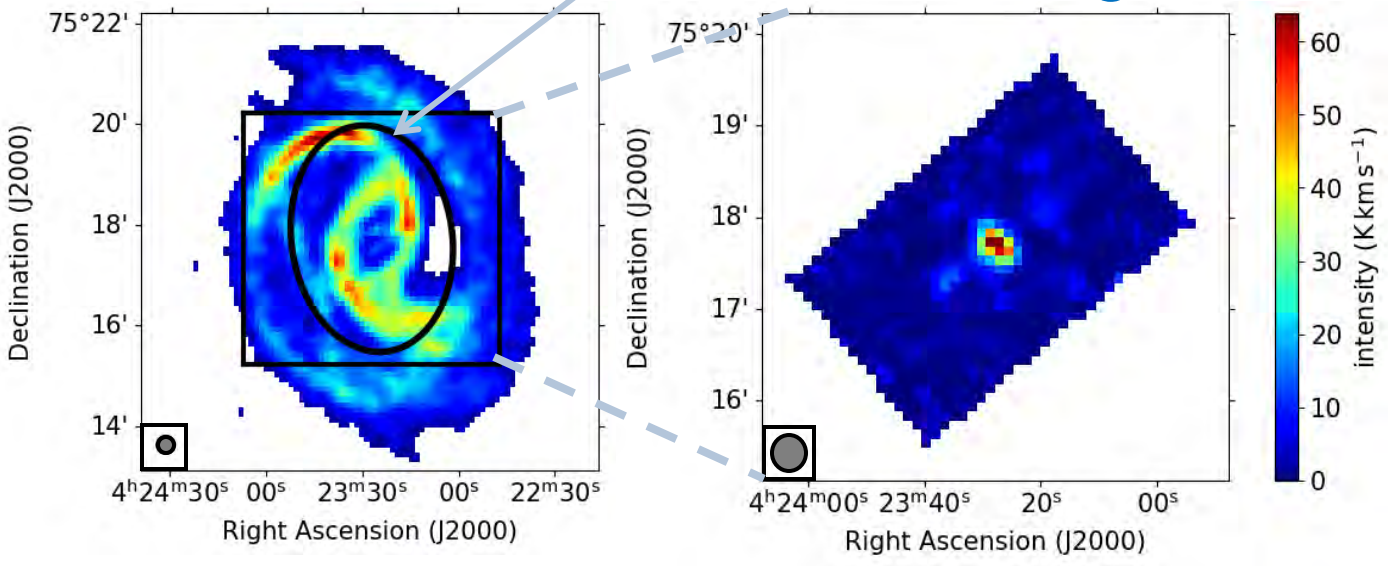


Optical images cited from SDSS

R_{25}; optical radius

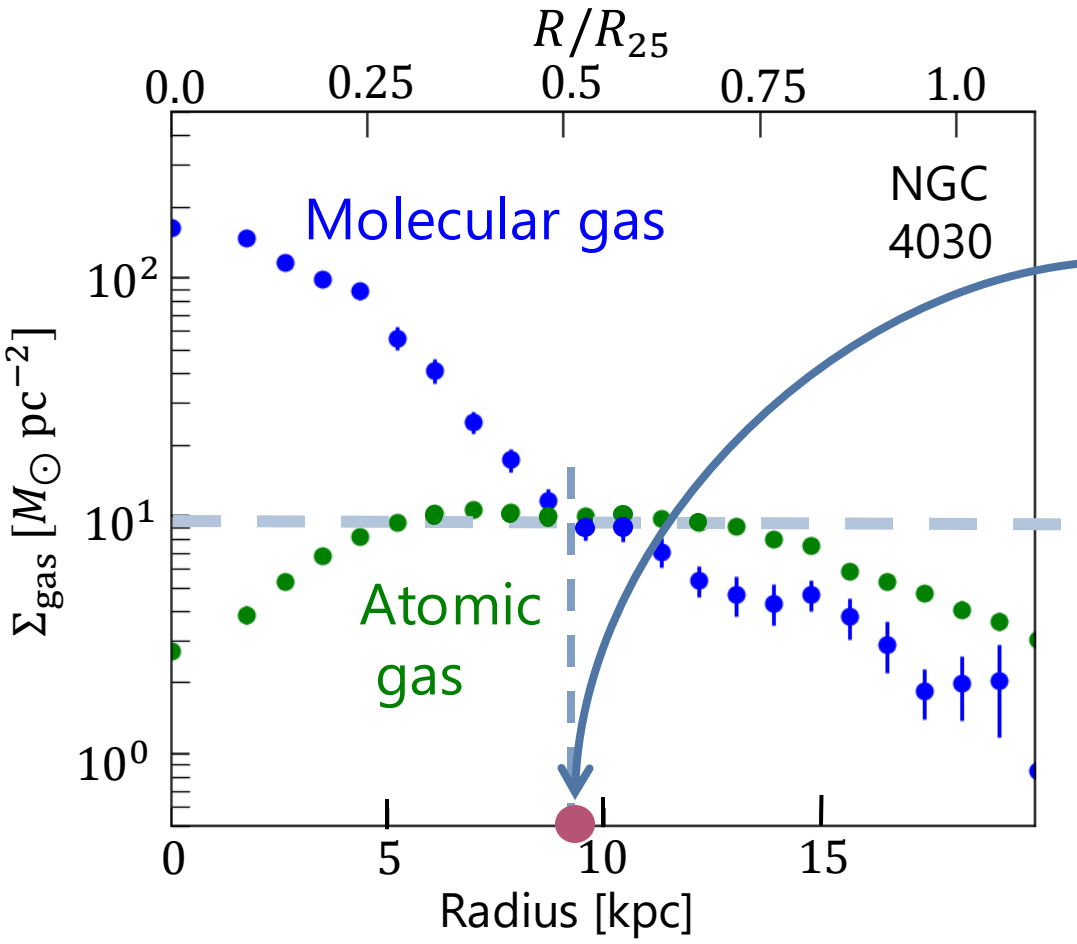
atomic gas

molecular gas



(resolution: 17″)

Radial distribution of gas density

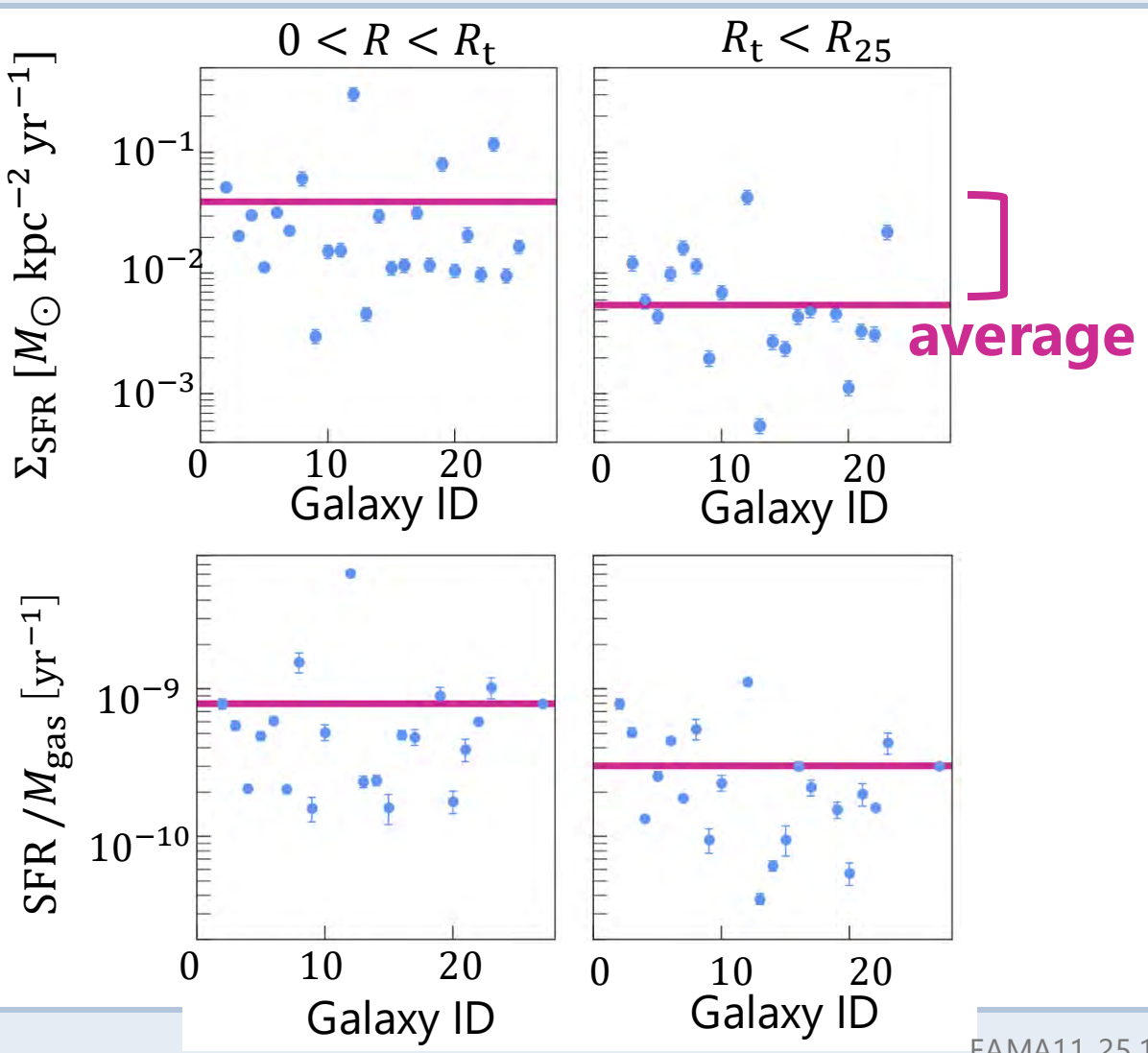


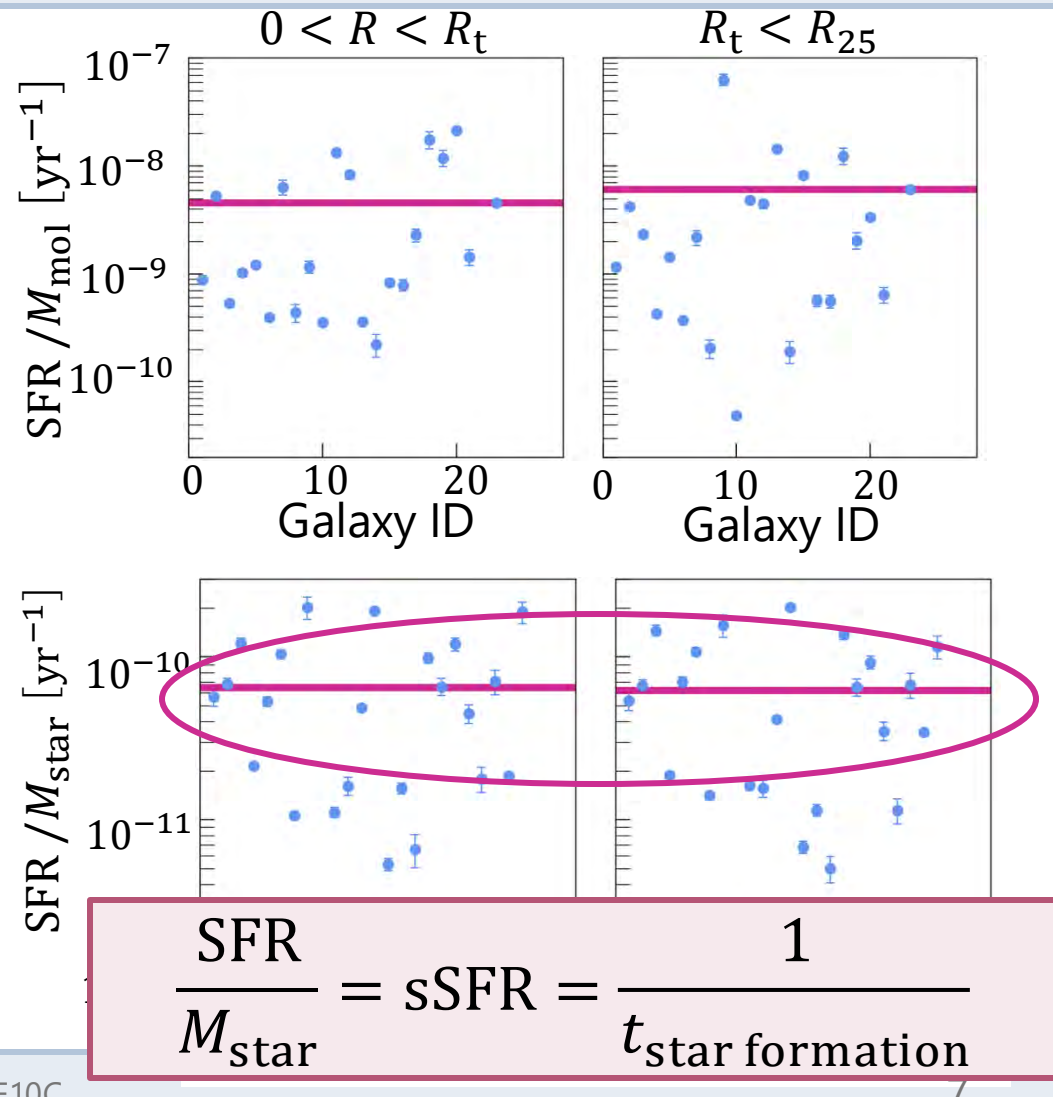
$R_{\rm t}$: Atomic–to–molecular gas transition radius

$$\Sigma_{\rm atom} = \Sigma_{\rm mol}$$

- The median $R_{\rm t}$ $\quad \overline{R_{\rm t}} \cong 0.48\ R_{25}$
- The range of $R_{\rm t}$ $\quad 0.1 < R_{\rm t}/R_{25} < 1.1$

SFR, SFE, and sSFR (=SFR/$M_{\rm star}$)

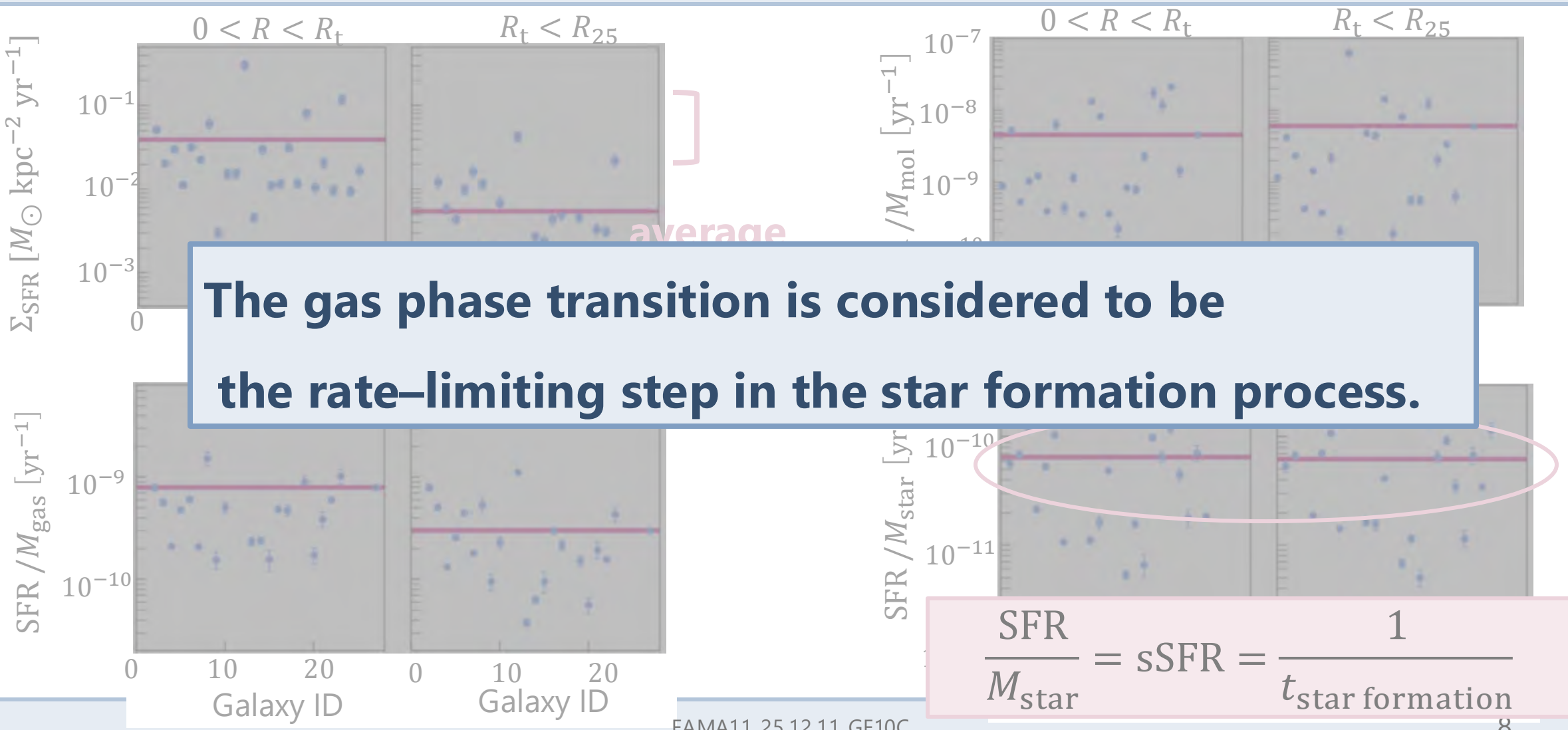




$$\frac{\rm SFR}{M_{\rm star}} = {\rm sSFR} = \frac{1}{t_{\rm star\ formation}}$$

($M_{\rm gas} = M_{\rm atom} + M_{\rm mol}$)

SFR, SFE, and sSFR (=SFR/M_{star})

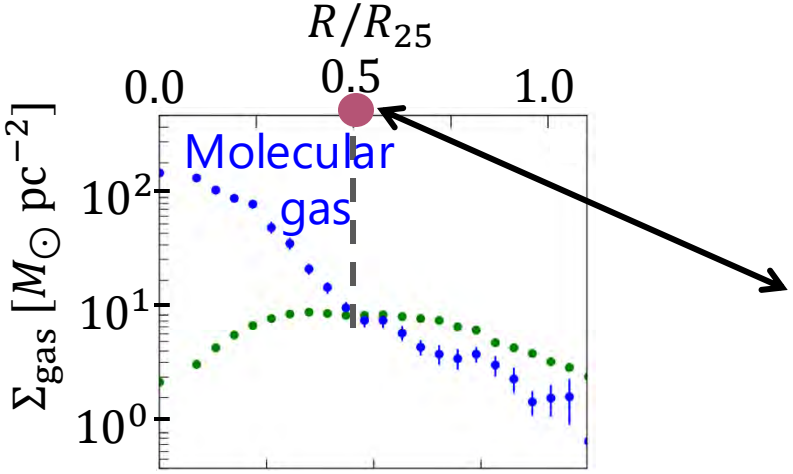


The gas phase transition is considered to be the rate–limiting step in the star formation process.

$$\frac{\mathrm{SFR}}{M_{\mathrm{star}}} = \mathrm{sSFR} = \frac{1}{t_{\mathrm{star\ formation}}}$$

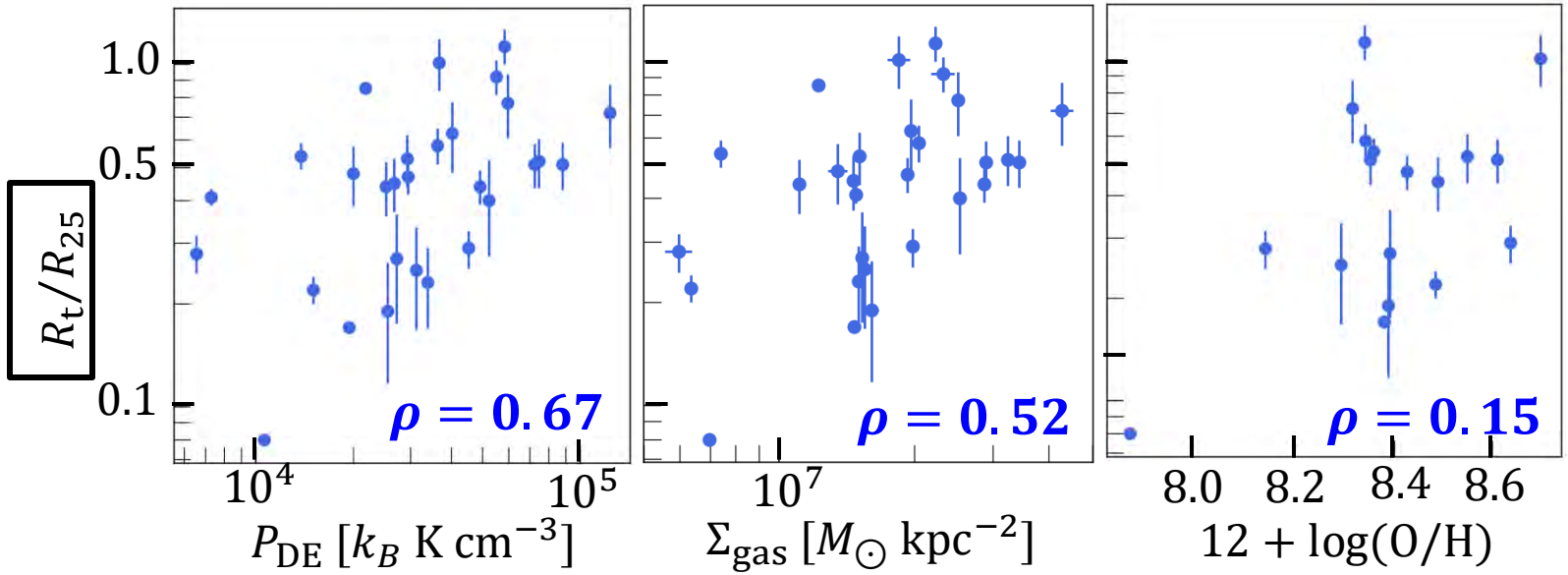
($M_{\mathrm{gas}} = M_{\mathrm{atom}} + M_{\mathrm{mol}}$)

What promotes the transition atomic ⇨ molecular gas in the gas phase?



$$P_{\rm DE} = \frac{\pi G}{2}\Sigma_{\rm gas}^2 + \sigma_{\rm gas}\Sigma_{\rm gas}\sqrt{2G\rho_{\rm star}}$$ (Sun+20a)

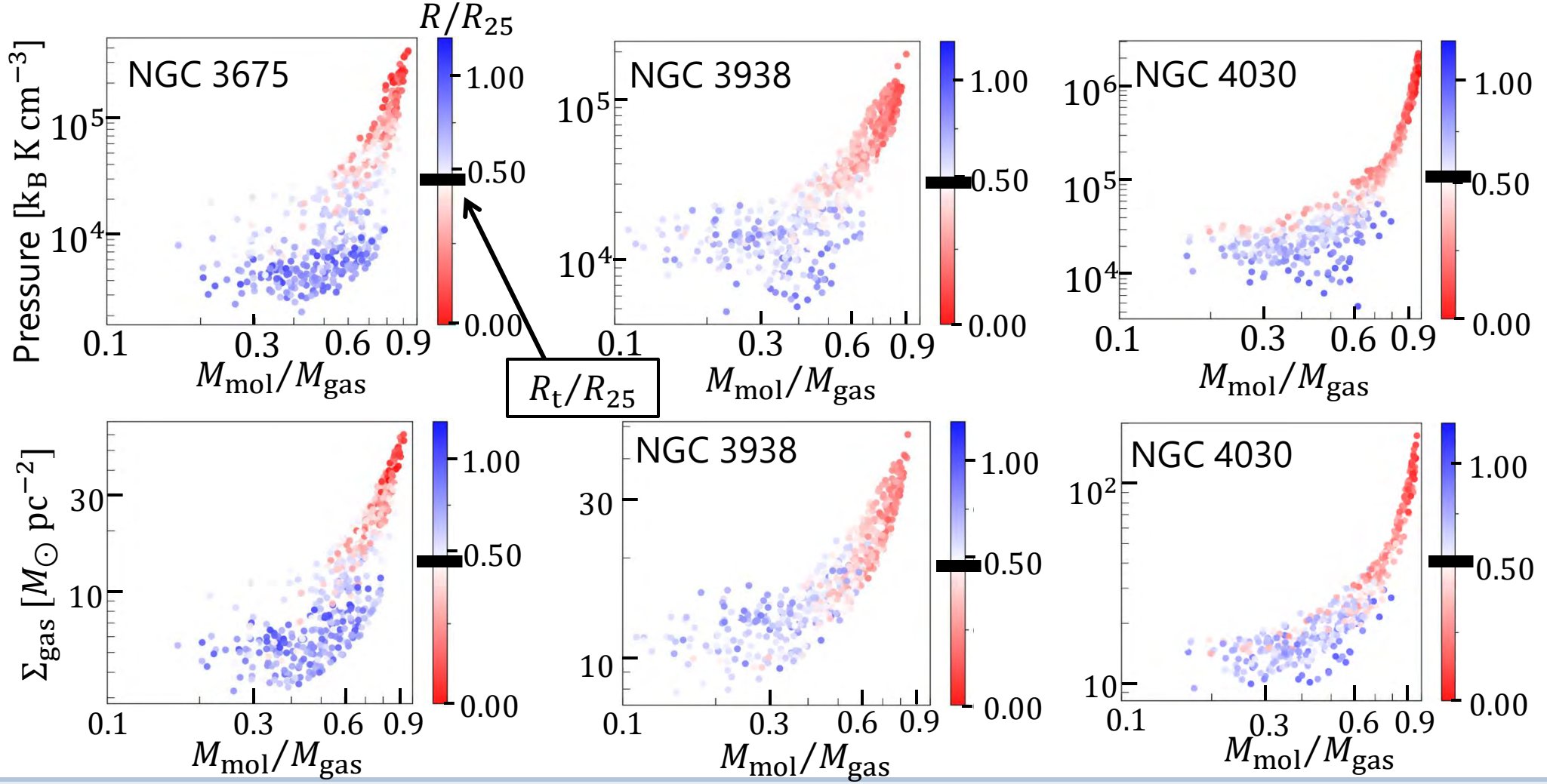
G : gravity constant
$\sigma_{\rm gas}$: gas velocity dispersion
$\rho_{\rm star}$: stellar volume density



$$12 + \log({\rm O/H}) = -0.185(\pm 0.001) \times M_{\rm B} + 5.328(\pm 0.018)$$

($M_{\rm B}$: absolute magnitude)
(Tremonti+04)

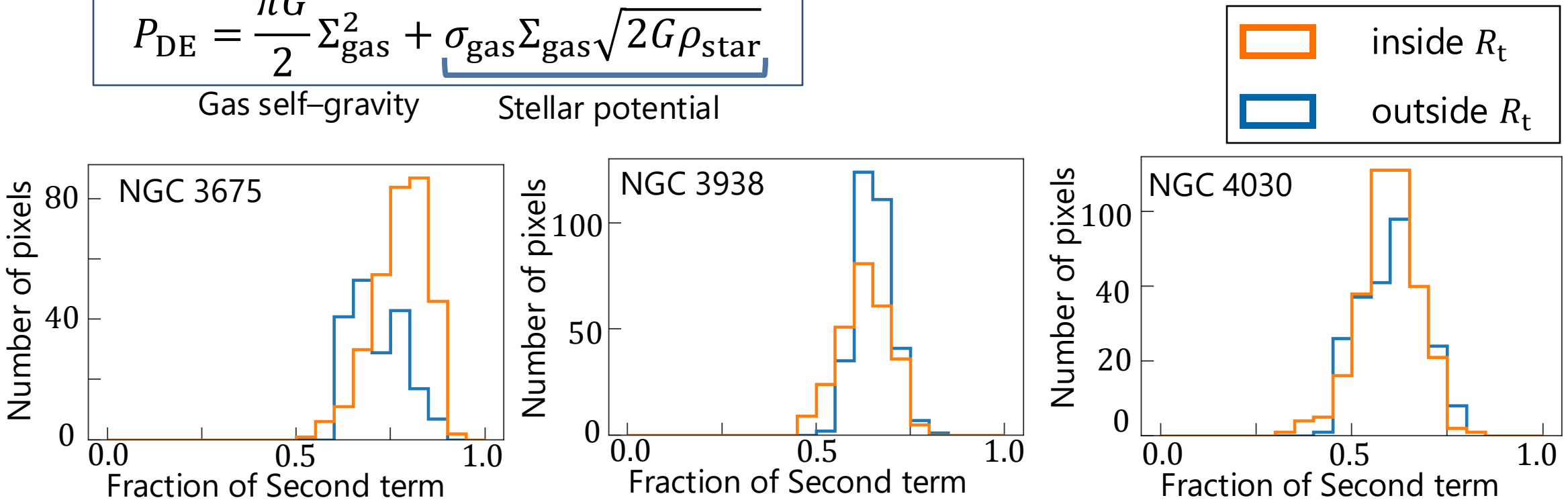
Pixel by pixel analysis for P_{DE} and Σ_{gas}



Pixel by pixel analysis for P_{DE} (pressure)

$$P_{\mathrm{DE}} = \frac{\pi G}{2}\Sigma_{\mathrm{gas}}^2 + \sigma_{\mathrm{gas}}\Sigma_{\mathrm{gas}}\sqrt{2G\rho_{\mathrm{star}}}$$

Gas self–gravity　　Stellar potential



- Pixel–based analysis shows a stronger contribution from the stellar potential

Summary & Conclusion

- The radius where $\Sigma_{\mathrm{atom}} = \Sigma_{\mathrm{mol}}$ is defined as R_{t} ($\overline{R_{\mathrm{t}}} \cong 0.477\ R_{25}$).
- Star formation likely began at roughly the same time inside and outside Rt, but Σ_{SFR} and $\mathrm{SFE}_{\mathrm{gas}}$ are different.
  - The gas phase transition is considered to be the rate–limiting step in the star formation process.
- P_{DE} shows a positive correlation with R_{t}/R_{25}.
  - Pressure also contributes to gas transition in the radial distribution.