Project 8
Star-Formation Efficiency & Timescales: Globally to 100 pc Scales

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GISM2 - 2023

Motivation

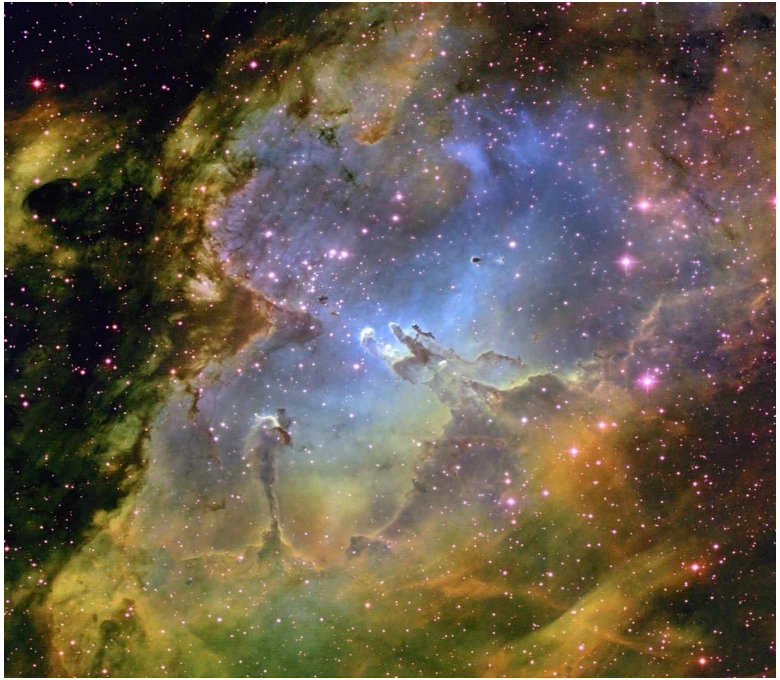
Depletion time

Star formation efficiency

$\varepsilon_{SF} = t_{GMC}/t_{dep}$

Molecular cloud lifetime

- What is star formation?
- Where does it happen?
- Relation between t_{dep} and t_{GMC}

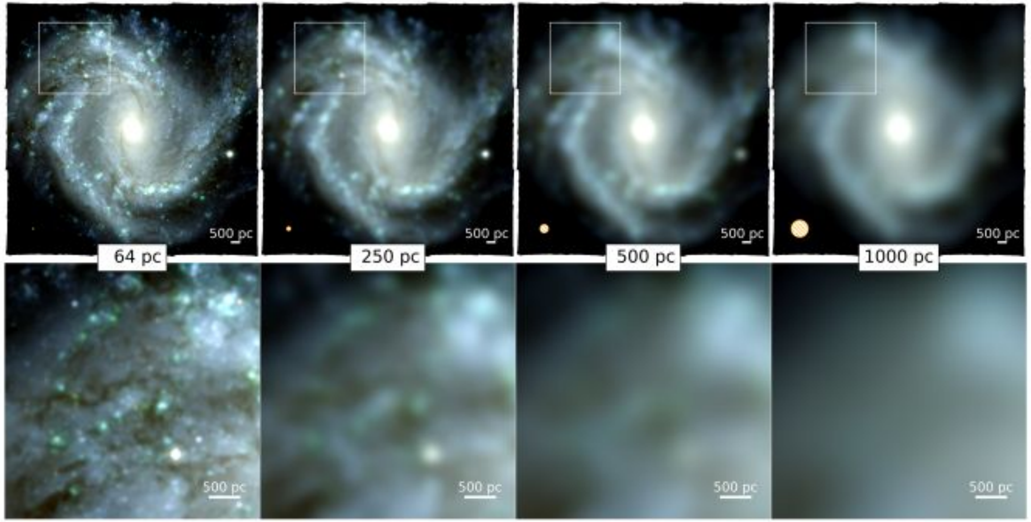


Credit: T. A. Rector & B. A. Wolpa, NOAO, AURA

Data sample: PHANGS

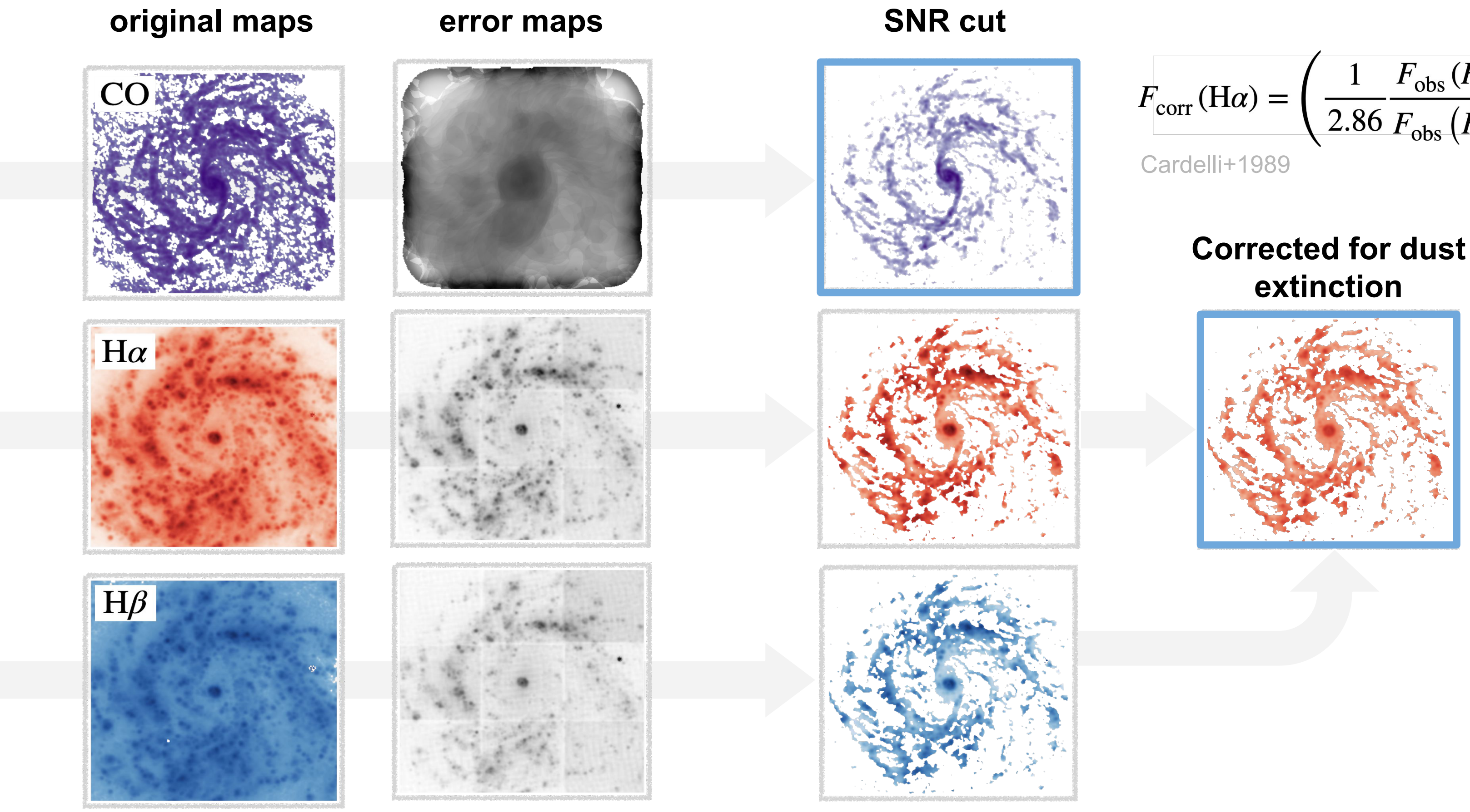
- 19 nearby galaxies (< 20 Mpc), mostly face-on
- ALMA CO(2-1) observations → Molecular cloud intensity maps
- VLT/MUSE H_α and H_β observations → Star formation rate maps

Spatial resolutions capable to distinguish HII regions and cloud scales (~100 pc)



Emsellem+2022

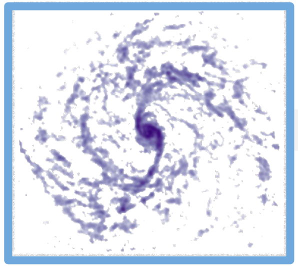
Image Processing



$$F_{\mathrm{corr}}(\mathrm{H}\alpha) = \left(\frac{1}{2.86} \frac{F_{\mathrm{obs}}(H\alpha)}{F_{\mathrm{obs}}(H\beta)} \right)^{2.36} F_{\mathrm{obs}}(\mathrm{H}\alpha)$$

Cardelli+1989

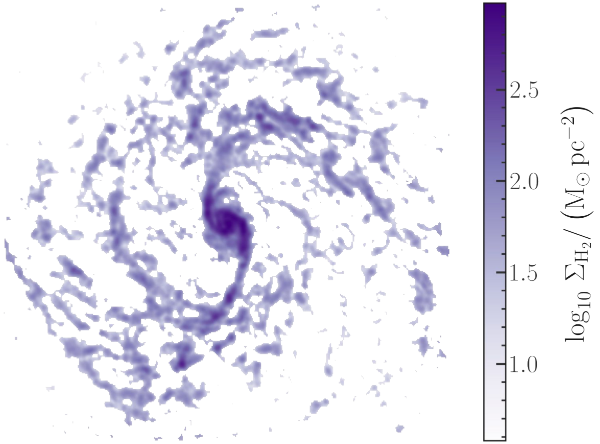
Conversions

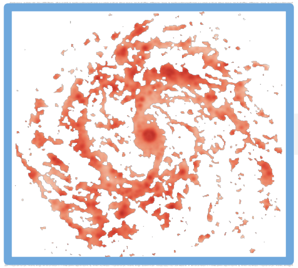


$$CO \Rightarrow H_2$$

$$\alpha_{CO} = 4.35 \, \frac{M_\odot \, pc^{-2}}{K \, km \, s^{-1}}$$

~MW; e.g. Bollato+2013

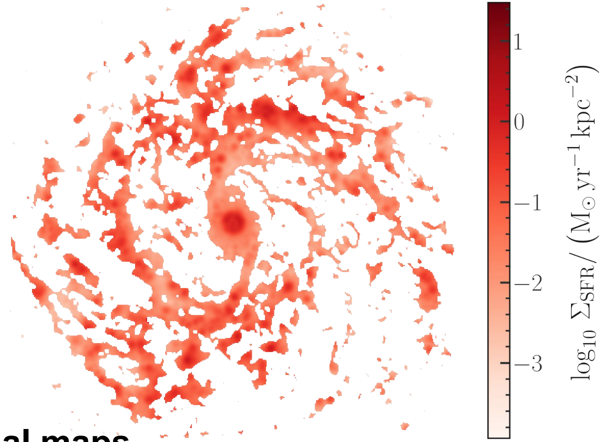




$$H\alpha \Rightarrow SFR$$

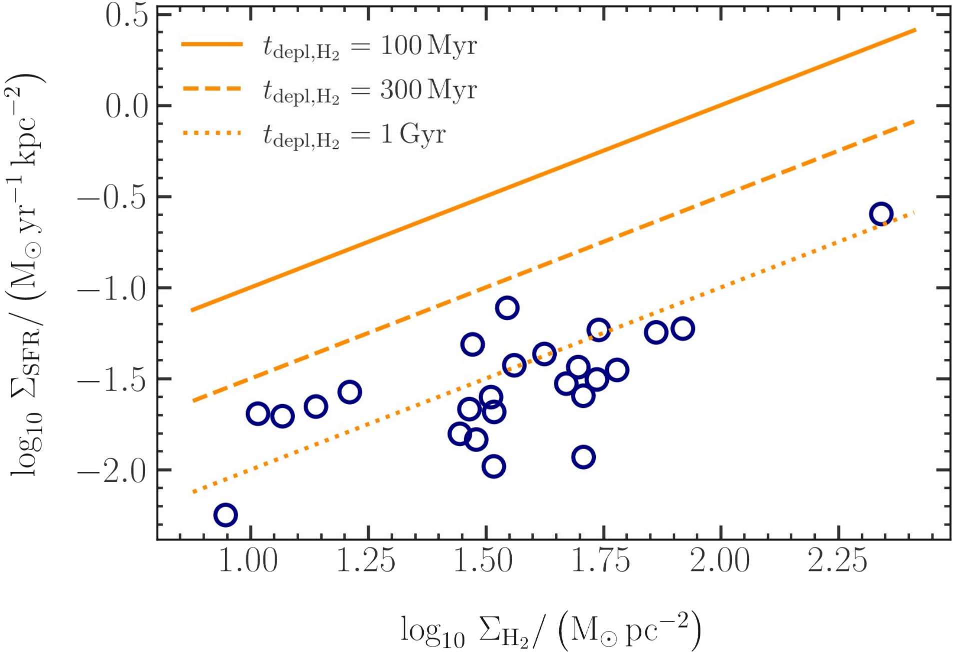
$$\log_{10}\left(\frac{SFR}{M_\odot \, yr^{-1}}\right) = \log_{10}\left(\frac{L_{H\alpha}}{erg \, s^{-1}}\right) - 41.27$$

e.g. Kennicutt & Evans (2012)

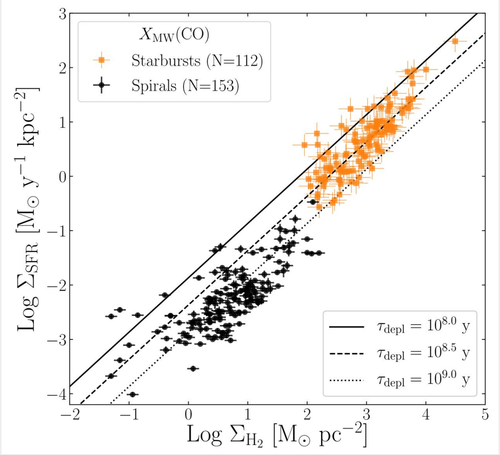


final maps

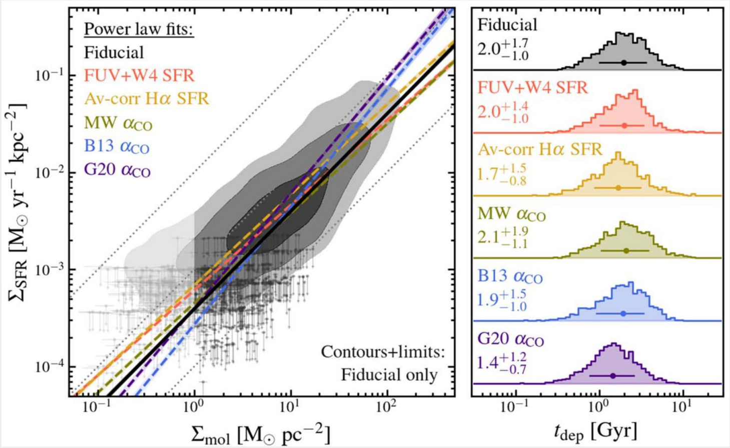
Integrated Kennicutt–Schmidt



Kennicutt & De Los Reyes (2021)

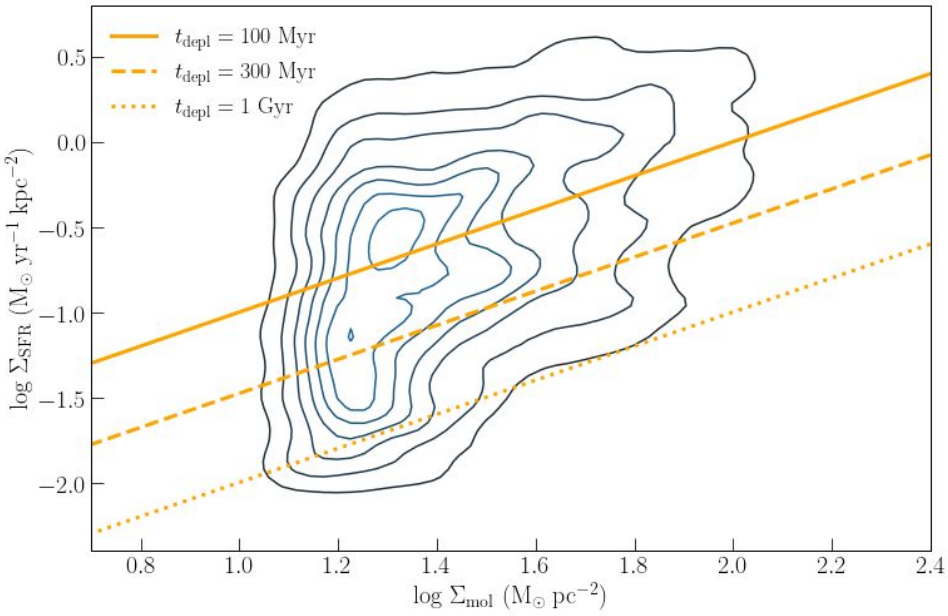


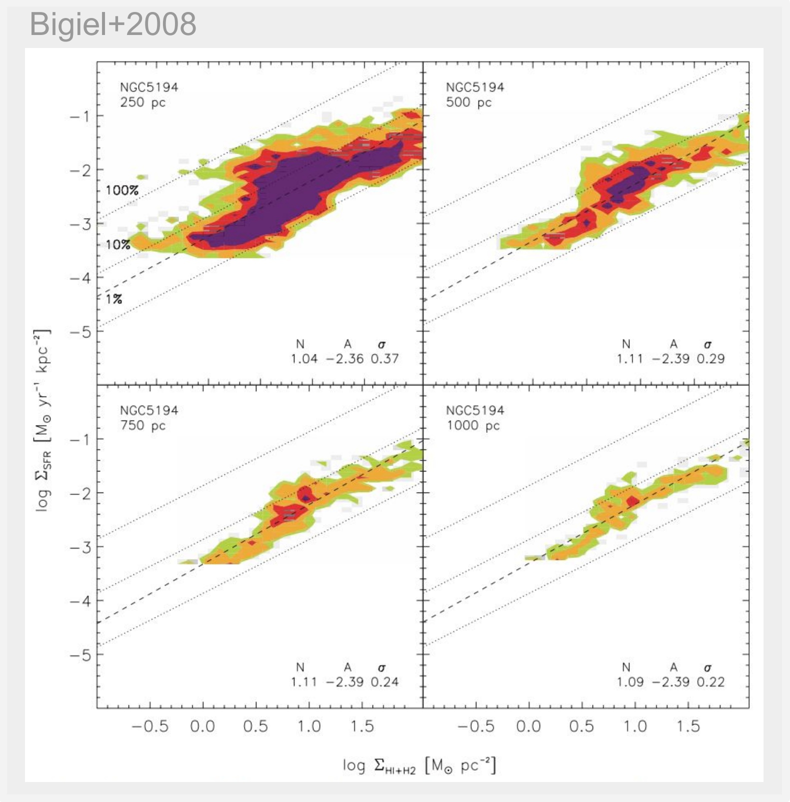
Sun+2023



The fit to the integrated K-S relation gives an estimate of the depletion time

Observed Scatter





- K-S Relation breaks down on smaller scales
- See scatter because of dependence on cloud and star lifetimes
- We can’t directly measure star formation efficiency with this

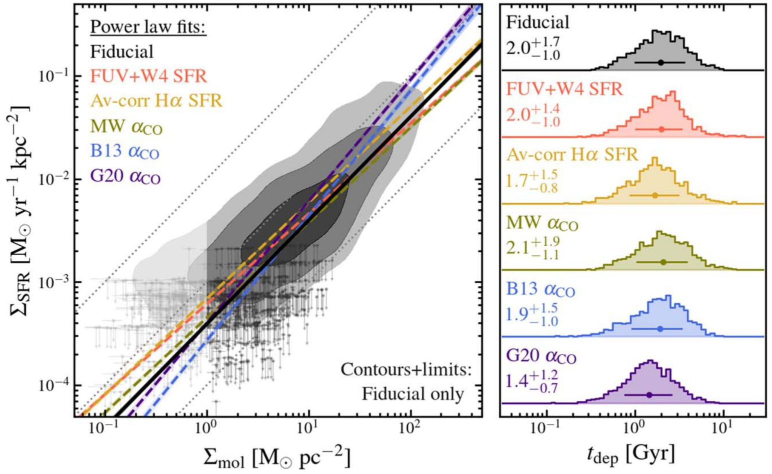
Star-Formation Efficiency

Star formation efficiency

$\varepsilon_{SF} = t_{GMC}/t_{dep}$

Depletion time

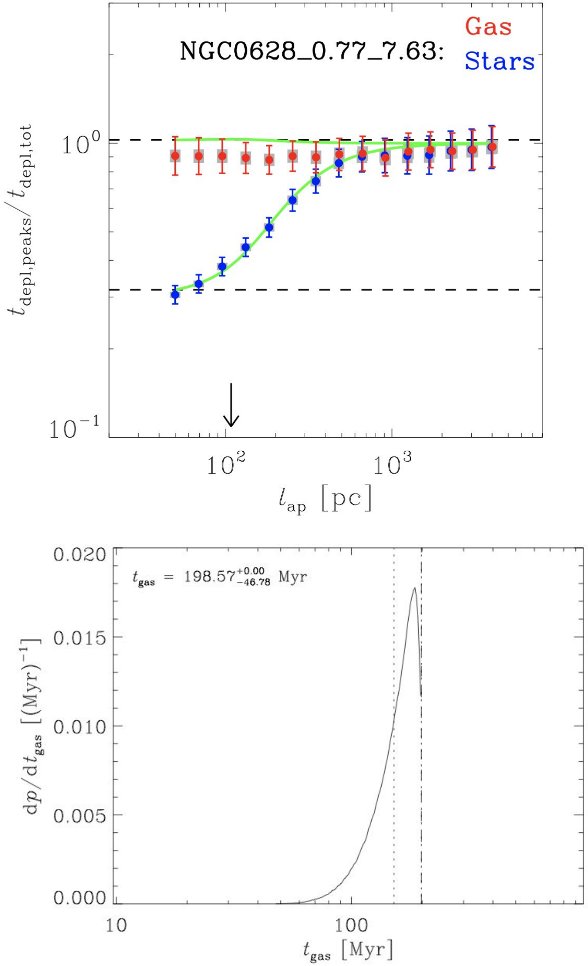
Molecular cloud lifetime



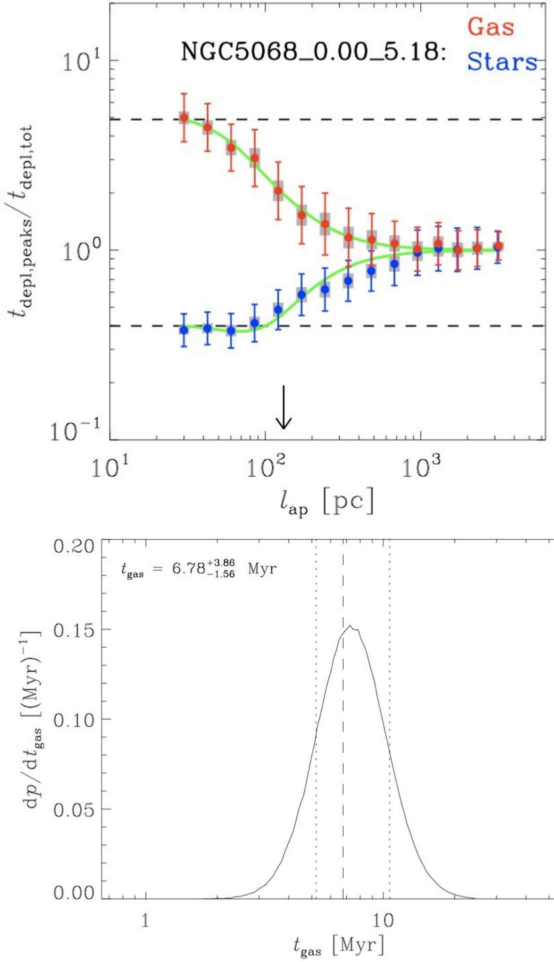
Finding t_{GMC}

- Heisenberg code
- Total 5 galaxies, 7-20 Myrs lifetime
- Gas-to-SFR as a function of spatial scale
- NGC0628: high metallicity
  NGC5068: low metallicity

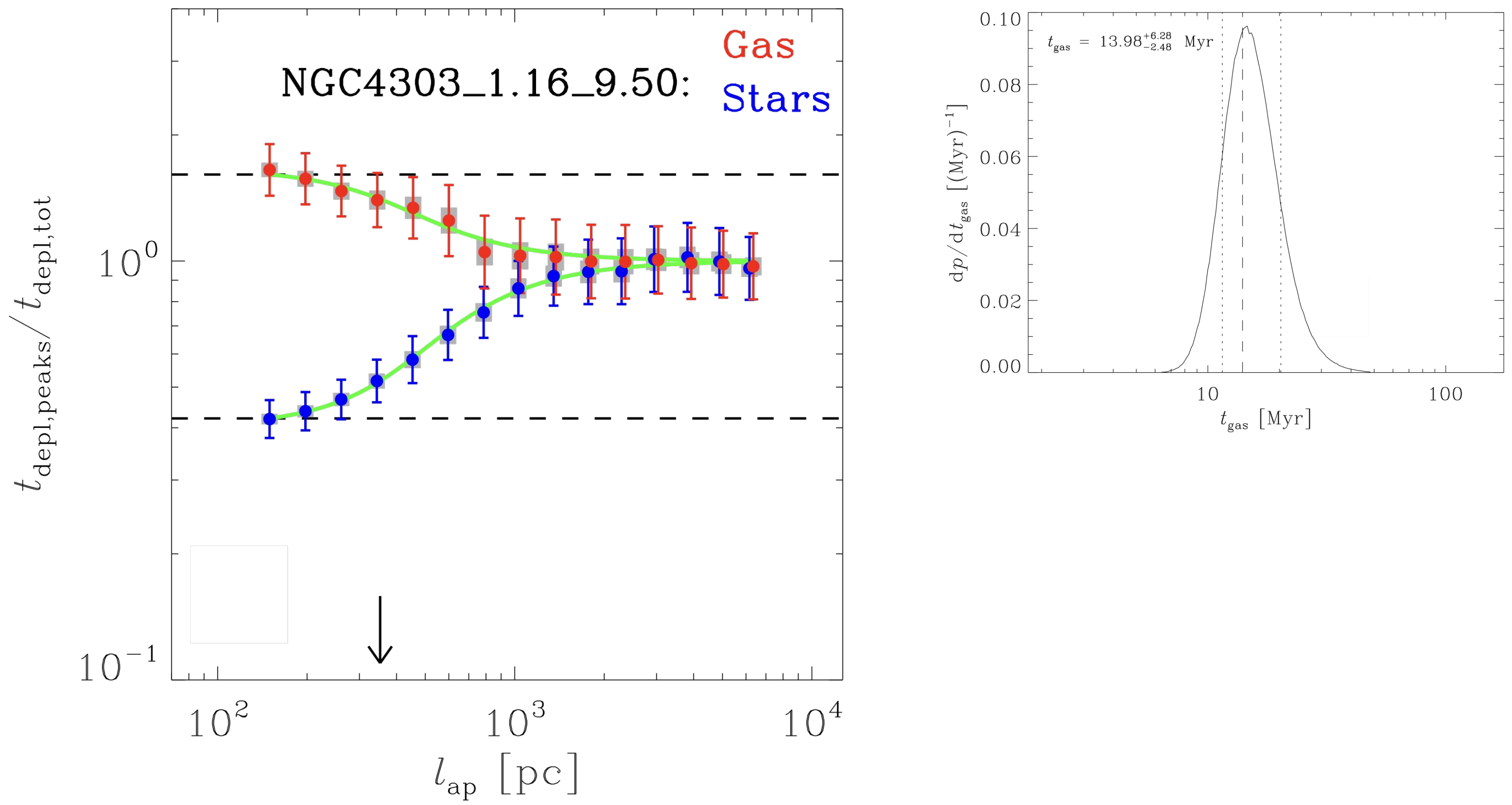
Reference: Kruijssen et al. 2018



With diffuse gas



without diffuse gas



NGC4303_1.16_9.50:
Gas
Stars
$t_{\rm depl,peaks}/t_{\rm depl,tot}$
10^0
10^{-1}
10^2
10^3
10^4
$l_{\rm ap}$ [pc]
$t_{\rm gas}$ = $13.98^{+6.28}_{-2.48}$ Myr
0.10
0.08
0.06
0.04
0.02
0.00
$dp/dt_{\rm gas}$ [(Myr)$^{-1}$]
10
100
$t_{\rm gas}$ [Myr]

Conclusions

- We measure t_{dep} = 1 Gyr and t_{GMC} = 10 Myr, so ε_{SF} = 1%
- We estimated star formation efficiency using the PHANGS sample, but this problem is difficult!
- We learned how to:
  - Use FITS files
  - Reduce data
  - Run Heisenberg (kind of 😆)
  - Work in a team