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The role of gas in SFGs in the largest surveys: deriving the gas content from optical spectra

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WHY? Gas has been shown to be a key parameter in understanding the physics of galaxy evolution ①. However, reliable direct gas measurements are available only for a very limited sample and the technology to deliver the orders of magnitude larger sample sizes needed are decades away. Therefore, reliable proxy gas measurements from optical spectra are instrumental to the study of the role of gas in galaxy evolution.

HOW? In this project we study galaxies using photoionization models, which gives us information, for example about metallicity, dust attenuation and gas content ②. These models describe the physics underlying the emission lines we observe. We use Simulation Based Inference (SBI) to speed up the model-inference process③. This allows us to apply this procedure to millions of spectra.

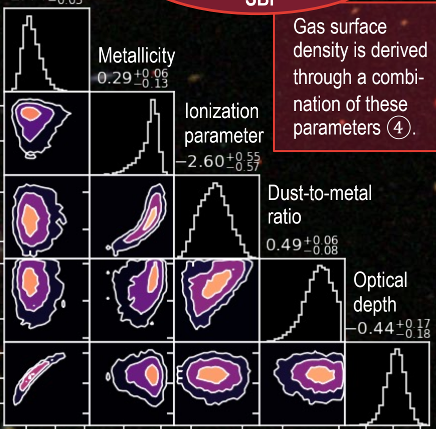
THE BASICS Gas surface density measurements from optical spectra rely on the measurement of dust attenuation of emission lines in the spectra. The Balmer decrement (ratio between the H-alpha and H-beta emission lines) is used for this measurement because the unattenuated flux ratio of these lines is constant*. From the dust attenuation we can estimate the dust surface density and by extension the gas surface density with a dust-to-gas conversion ratio.

* In most physical conditions in star forming galaxies.

Emission line flux observations

SDSS DESI

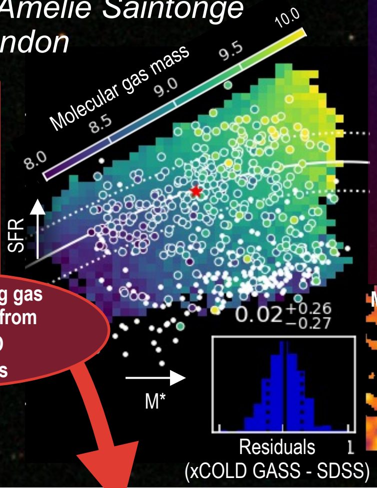
Fit photoionization models to observations using SBI



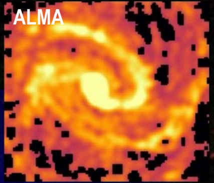
Gas surface density is derived through a combination of these parameters ④.

Calibration using gas measurements from sub-mm CO observations

We get very good agreement between xCOLD GASS (dots) and SDSS (pixels) derived gas masses over a wide range of the M*-SFR plane! ⑤

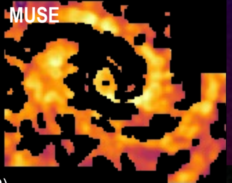


THE BONUS The technique also works on spatially-resolved observations.

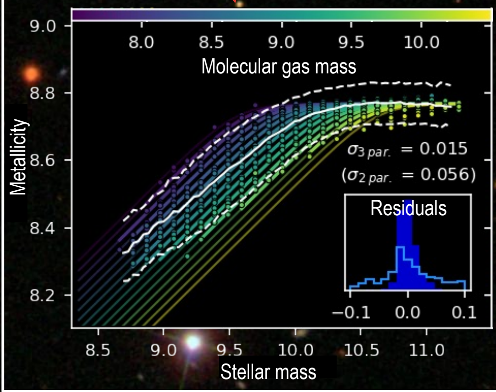


Using the PHANGS-ALMA/MUSE surveys we have developed an extension to the method described here that can be applied to resolved observations ⑥.

To do so we need to take into account the resolution dependence of the relation between optical depth and gas surface density.



We compare the gas surface density maps we predict for the MUSE spectroscopy to ALMA CO (2-1) gas measurements.



What can we use this for? We study the comparative roles of gas and star formation in the scatter of the relation between stellar mass and gas phase metallicity (MZR) ⑦.

These parameters are closely linked as gas is the fuel for star formation. They also relate to physical processes such as the inflow of pristine gas into galaxies and the expulsion of enriched gas by supernovae.

Which of these processes is the most fundamental process defining the scatter in the MZR? In our measurements the residuals are reduced the most for parameters related to gas, such as the total molecular gas mass.

① Tinsley (1980), ② Charlot and longhetti (2001); Byler et al. (2017), ③ Greenberg et al. (2019); Tejero-Cantero et al. (2020), ④ Brinchmann et al. (2013), ⑤ Saintonge et al. (2016); Kauffmann et al. (2003); Brinchmann et al. (2004), ⑥ Leroy et al. (2021); Emsellem et al. (2021), ⑦ Tremonti et al. (2004), Ellison et al. (2008), Mannucci et al. (2010), Bothwell et al. (2013, 2016)