LUMEN: A novel method for emission lines from resolved HII regions in cosmological simulations

Preliminary

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Introduction

We present a novel framework for modelling spatially resolved line emission arising from the usually unresolved HII regions in cosmological simulations. This enables robust emission line predictions out to high-z, providing a basis to assess the impact of processes like α-enhancement, LyC leakage and radiation from binary stars.

Method

Using the cluster mass function from high-resolution GRIFFIN[2] simulation (Fig. 1), we re-distribute mass from young star particles in IllustrisTNG50[3] simulation (Fig. 2a) into star clusters and connect them to the densest gas particles (Fig. 2b).

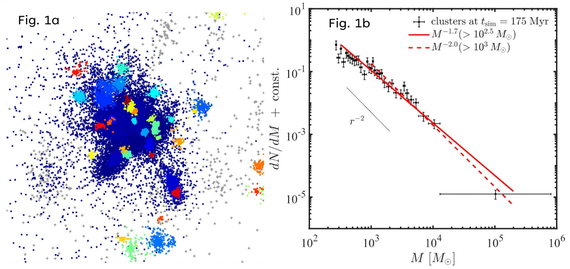

Fig. 1: a) Bound cluster particles (coloured points) and unbound stellar particles (gray). b) Cluster mass function from GRIFFIN simulation.

The ionisation parameter (logU) and Strömgren radii are computed self-consistently via the rate of ionising photons from stellar population models, the gas density, and the filling factor ("clumpiness" of the ionised gas), which is scaled according to the gas density profile of each galaxy. Coupling to photoionisation models, we obtain spectra of individual HII regions (see Hα emission map in Fig. 2c).

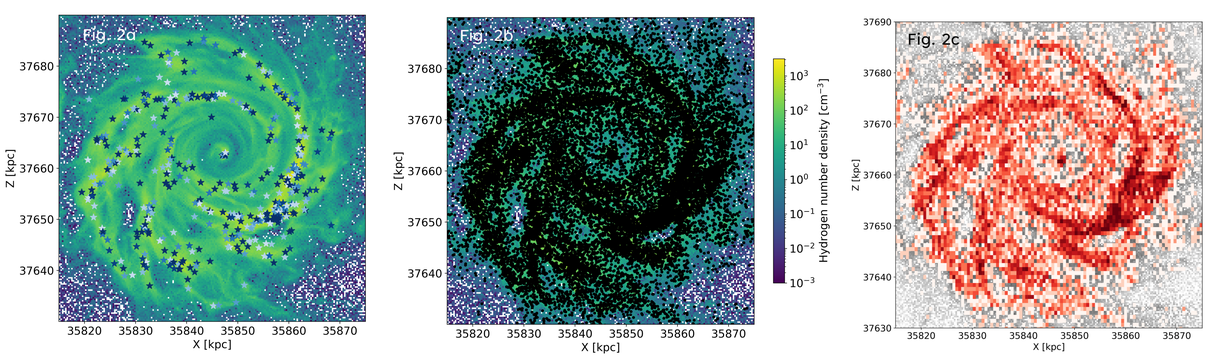

Fig. 2: a) Young stellar particles in TNG50 galaxy, b) resampled star clusters in dense gas, c) Hα emission map.

Validation at z=0

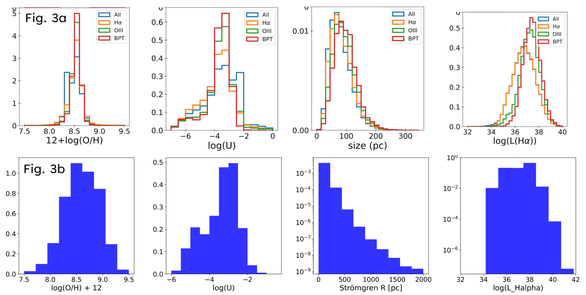

Fig. 3: Cluster properties from a) PHANGS and b) LUMEN.

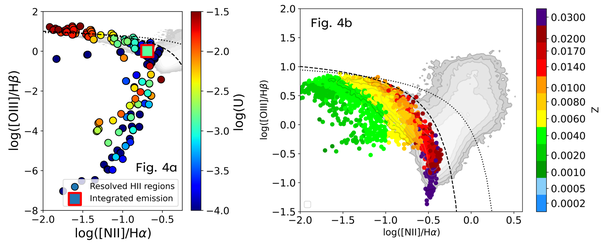

Fig. 4:
a) Spatially resolved BPT diagram for example TNG50 galaxy.
b) BPT diagram of all integrated emission line ratios for ~6300 galaxies.

Properties of the resolved HII regions match the observed size and logU distributions from the PHANGS[4] sample (Fig. 3). Computing integrated emission line ratios for ~6300 TNG50 galaxies from all spatially resolved clusters per galaxy (Fig. 4a), we find a perfect match to SDSS data in the BPT diagram (Fig. 4b).

Predictions out to z=7

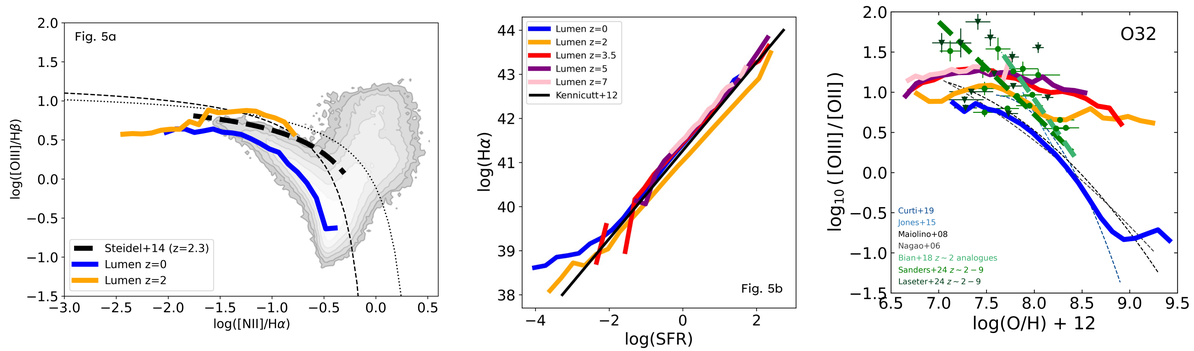

Fig. 5: a) BPT diagram at z=2 compared to Steidel+14, b) Hα-SFR relationship between z=0-7, c) [OIII]/[OII] ratio against O/H abundance between z=0-7.

LUMEN reproduces the observed increase of [OIII]/Hβ at fixed [NII]/Hα (Fig. 5a). The Hα-SFR relationship is robust up to high redshifts (Fig. 5b). Metallicity diagnostics, like [OIII]/[OII] (O32), show an evolution in line with new high-z observations (Fig. 5c).

References:
[2]Lahén et al. (2020), [3]Pillepich et al. (2018), [4]Congiu et al. (2023)

[1]EPFL, Galspec

GALSPEC EPFL