Towards understanding Dust Attenuation of Emission Lines with Illustris TNG Galaxies

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Introduction

- **Emission Line Galaxies** (**ELGs**) are key targets in dark energy surveys such as HETDEX, PFS, and Roman Space Telescope.
- **Dust attenuation** of emission lines such as [OII] λ3727Å and Hα λ6563Å is essential to understand the ELG population.
- Physics on dust attenuation for emission lines is still unclear both theoretically and observationally (see [1] for a review).
- Yet computationally infeasible to fully resolve the physics on dust attenuation (~pc* scale) even in a state-of-the-art cosmological simulation (~100 Mpc scale). [* 1 pc ~ 3 light years]

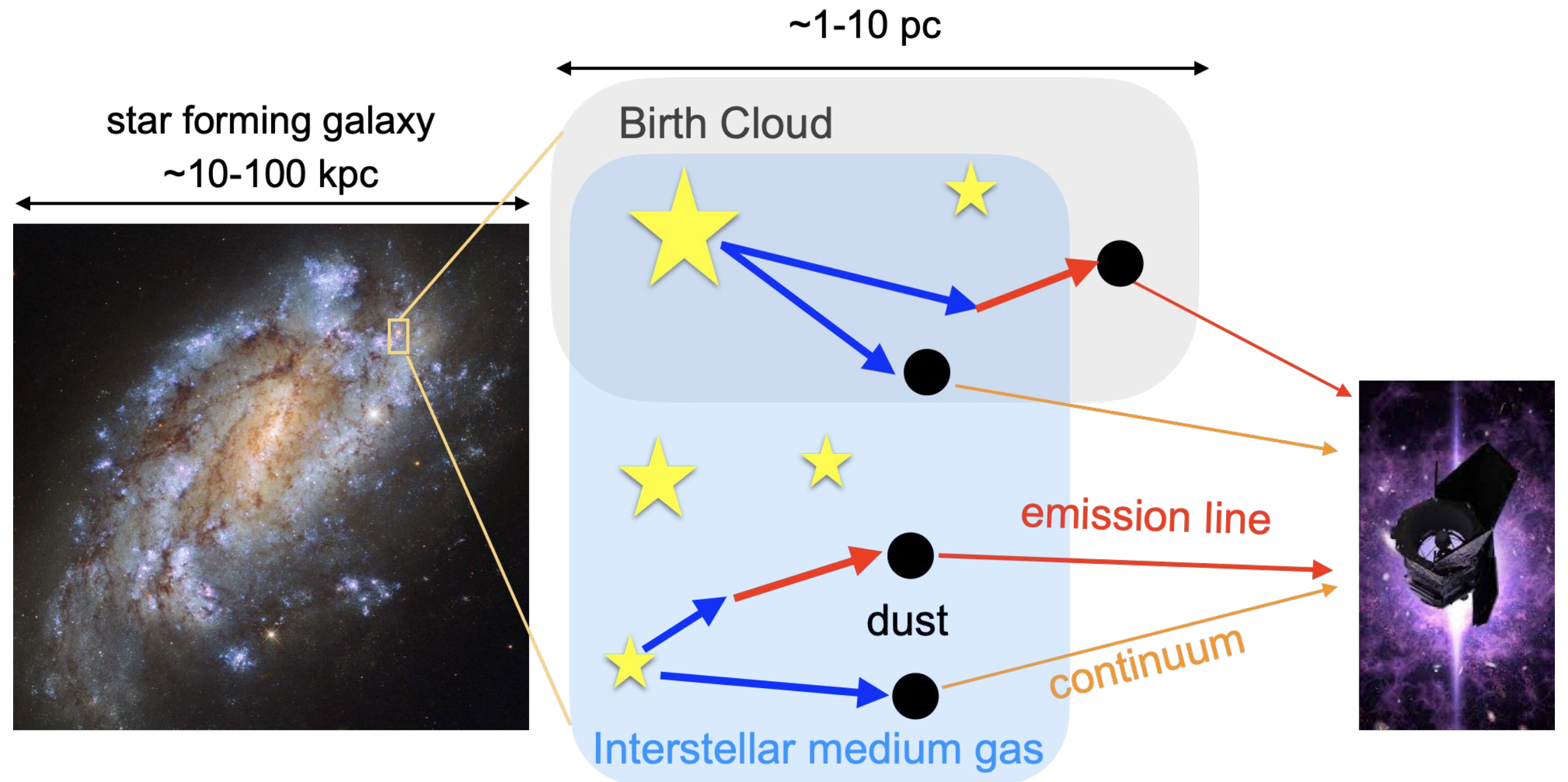


Fig. 1: Schematic illustration of interplay between stellar light (continuum) & emission lines from interstellar medium

Objective

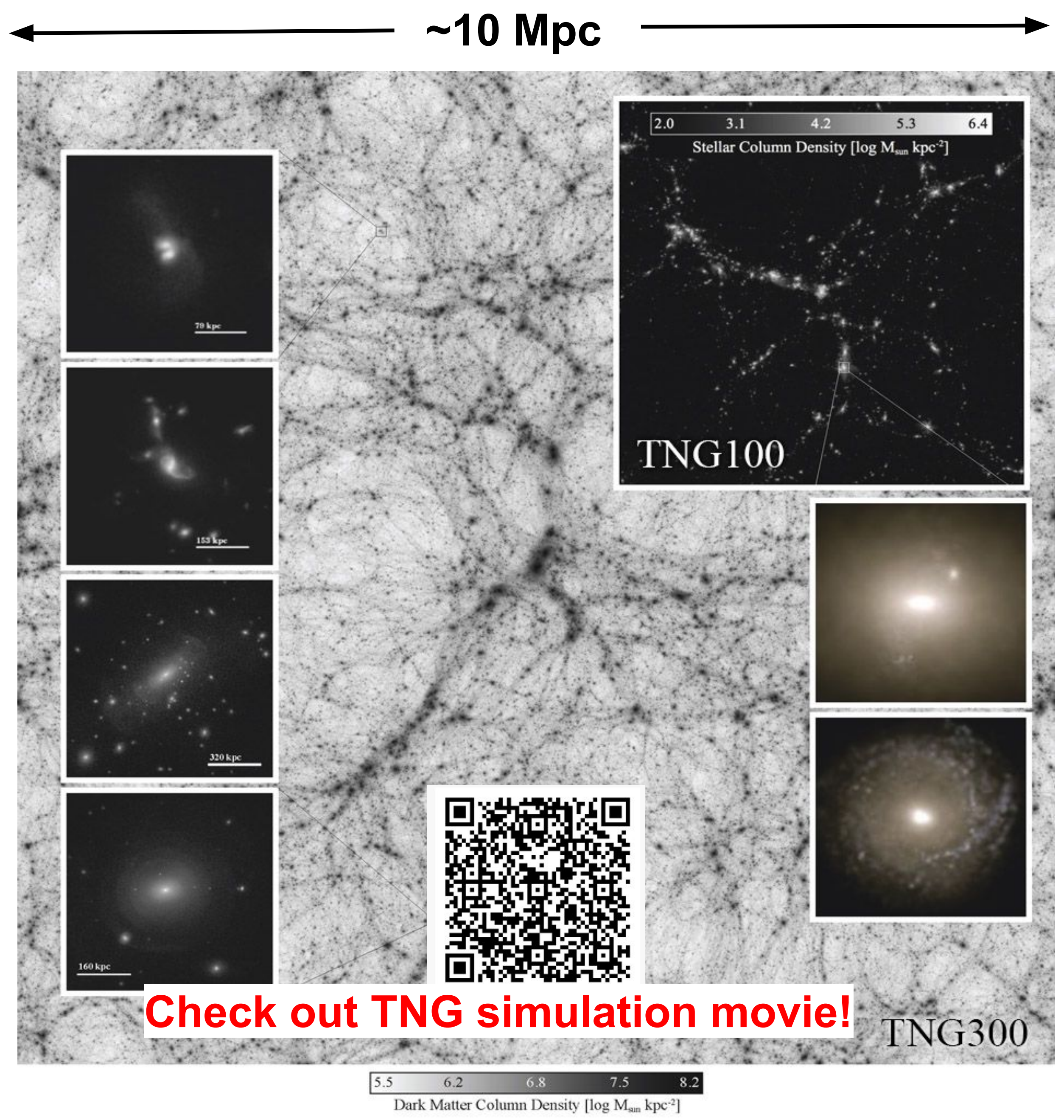
- Understand the impact of dust attenuation model on the **cosmic evolution** of ELG populations.
- Revisit a common method to infer the dust attenuation model from observations.

Method

- Develop a physical model of emission lines, combining the state-of-the-art simulation, **Illustris TNG** [2], with a simple physical dust model on the **PEGASE** code [3], following [4].
- Dust attenuation is characterized by A_λ [1]:

$$f_\lambda / f_{\lambda,\mathrm{w/o\,dust}} = 10^{-0.4A_\lambda} = 10^{-0.4C_\lambda k(\lambda)}$$

  where A_λ is decomposed into the normalization $\boldsymbol{C_\lambda}$ and wavelength dependence $\boldsymbol{k(\lambda)}$.
  Conventionally, the difference of dust attenuation b/w **continuum** and **emission lines** is parametrized by $\boldsymbol{f = C_{\lambda,cont} / C_{\lambda,EL}}$ assuming the same $k(\lambda)$.
- Measure **statistics and its evolution** of the dust attenuation, making full use of the large TNG simulation suite. Compare with a model suggested by observations [5].



Check out TNG simulation movie!

Fig. 2: Galaxies in the Large-Scale Structure in Illustris TNG simulation [2]

Results

- Both Fig 3 (a) & (b): *f* has a wide PDF is not a single value, **evolving over time**. The empirical model suggested by observations [5] is statistically consistent with the PDFs.
- Compare Fig 3 (a) w/ (b): PDFs are not identical, implying a **nontrivial wavelength dependence**.
- Fig 3 (c): Highlights how $\boldsymbol{A_\lambda}$ depends on wavelength for both **continuum** (solid lines) and **emission lines** (points).
  The difference in dust attenuation is correlated with **stellar age**. Young massive stars are surrounded by birth clouds (see Fig.1) which additionally attenuates emission lines depending on number of Lyman-continuum photons and metallicity.

Summary & Scientific significance

- This work presents **the first systematic physical modeling of dust attenuation on emission lines** in a cosmological hydrodynamical simulation.
- A simple physical recipe already implies too simplistic assumptions in observational measurements in terms of **wavelength and time dependence**. The observational measurements need to be revisited.

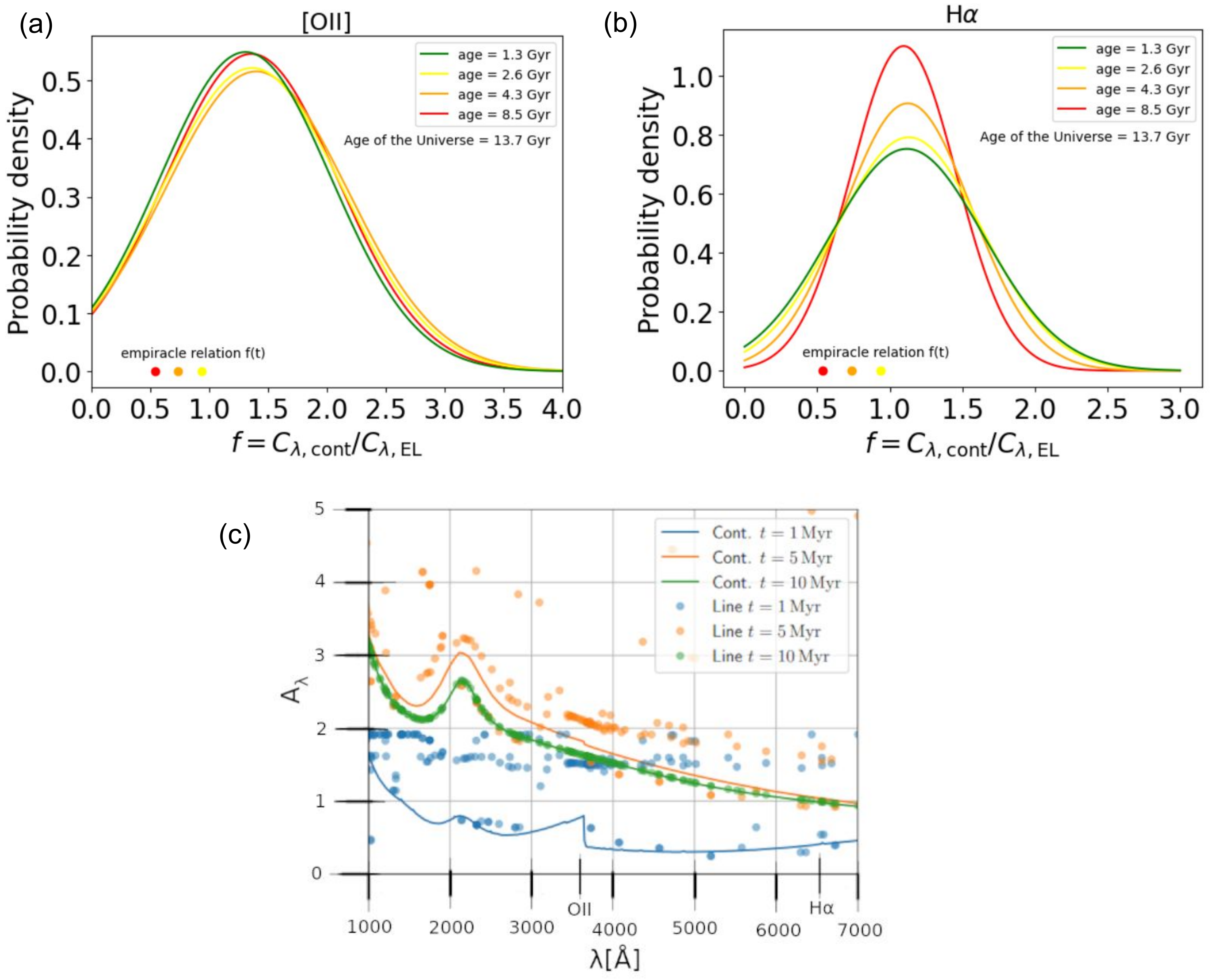


Fig. 3: Main outcomes of this work. (a) & (b) show the PDF of dust attenuation for [OII] and Hα, respectively. (c) shows the PEGASE output as a function of stellar age.

Future work

- Compare the simple model with existing luminosity functions for various emission lines across cosmic time.
- Refine the PEGASE dust model if necessary.
- Revisit the observational measurements of dust attenuation, taking account of the non-trivial wavelength and time dependence.

References & Acknowledgments

1. Salim & Narayanan, ARAA 58, p529 (2020).
2. Nelson et al., CAC 6, 2 (2019).
3. Fioc & Rocca-Volmerange, A&A 623, A143 (2019).
4. Osato & Okumura, MNRAS 519, 2 (2023).
5. Saito et al., MNRAS 494, 1 (2020).

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