
Thesis subject

Name of the laboratory: Laboratoire d'Astrophysique de Marseille, Aix-Marseille University

Thesis advisor: Denis Burgarella, Pdt de la Commission IAU *Galaxy Spectral Energy Distributions*

Email and address: denis.burgarella@lam.fr, 38 rue F. Joliot-Curie, 13013 Marseille, France

Tel: 06 07 03 88 06 **Homepage:** <https://people.lam.fr/burgarella.denis/>

Co-advisor: TBD

Subject's title: MODELLING AND OBSERVING DUST AND STARS IN THE FIRST GYR OF THE UNIVERSE

Subject description: The most remote universe, less than 1 Gyr after the big bang, i.e., $6 < z < 15$ is still almost unexplored (Burgarella et al. 2013). During this thesis, you will develop new dust models for galaxies in the early universe where the dust grains are likely to be different from the more local one ($z < 6$). That will allow to perform simulations and to compare them to observations of distant, first galaxies.

Dust absorbs energy in the far-ultraviolet (far-UV) and re-emits it into the far-infrared (far-IR). Dust impacts the observed spectral energy distributions (SEDs) over the entire electromagnetic spectrum from the far-UV to the far-IR and radio. The detection rate of distant galaxies in rest-frame far-IR (with ALMA) is lower than we can presently predict assuming dust properties similar to the local ones (Bouwens et al. 2016; Hirashita, Burgarella & Bouwens. 2017). We still do not understand why. We have to account for the physical and chemical conditions in the early universe to build models adapted to these early times and to solve this issue. This part of the thesis will be carried out in collaboration with people in LAM and in UK, H. Hirashita in Taiwan, A. Inoue and T. Takeuchi in Japan.

The models will be included into our code CIGALE¹. CIGALE (Burgarella et al. 2005; Noll, Burgarella et al. 2009) is one of the leading codes to model and fits galaxy spectral energy distributions.

Beside developing the models, we need observational constraints that are still very rare today. We are involved in some very ambitious observations that are specifically dedicated to detect these early and maybe first galaxies. This part of the work will be carried out with a team of people in France, USA and UK related to JWST, NIKA2 and ALMA (see Fig.). More specifically:

- Member of The *Cosmic Evolution Early Release Science (CEERS²)* Survey. The CEERS project with the James Webb Space Telescope (JWST) was recently accepted. It will cover 100 arcmin² with JWST imaging and spectroscopy. This programme will be followed by other observations. I co-manage the sub-millimetre follow-up with IRAM (because the EGS field is in the North) and co-manage the derivation of the physical parameters via SED fitting, with our code CIGALE.
- Member of the *NIKA2Sky* ANR project³ to detect infrared-bright galaxies in the early universe thanks to deep- and wide-field observations. I also lead some follow-up observations in optical and in the millimetre ranges, e.g., Gemini, IRAM 30m, NOEMA, SMA.

¹ CIGALE : <http://cigale.lam.fr>

² <https://jwst.stsci.edu/news-events/news/News%20items/selections-made-for-the-jwst-directors-discretionary-early-release-science-program>

³ <http://www.agence-nationale-recherche.fr/Project-ANR-15-CE31-0017>

Bibliography:

- Bouwens et al. 2016, ApJ 833, 72, « *ALMA Spectroscopic Survey in the Hubble Ultra Deep Field: The Infrared Excess of UV-Selected $z=2-10$ Galaxies as a Function of UV-Continuum Slope and Stellar Mass* », <https://arxiv.org/abs/1606.05280>
- Burgarella et al. 2013, A&A 554, 70, « *Herschel PEP/HerMES: the redshift evolution ($0 \leq z \leq 4$) of dust attenuation and of the total (UV+IR) star formation rate density* », <https://arxiv.org/abs/1304.7000>
- Burgarella et al. 2005, MNRAS 360, 1413, « *Star formation and dust attenuation properties in galaxies from a statistical ultraviolet-to-far-infrared analysis* », <https://arxiv.org/abs/astro-ph/0504434>
- Hirashita, Burgarella & Bouwens 2017, MNRAS 472, 4587, « *Dust masses of $z > 5$ galaxies from SED fitting and ALMA upper limits* », <https://arxiv.org/abs/1709.02526>
- Noll, Burgarella et al. 2009, A&A 554, 70, « *Analysis of galaxy spectral energy distributions from far-UV to far-IR with CIGALE: studying a SINGS test sample* », <https://arxiv.org/abs/0909.5439>

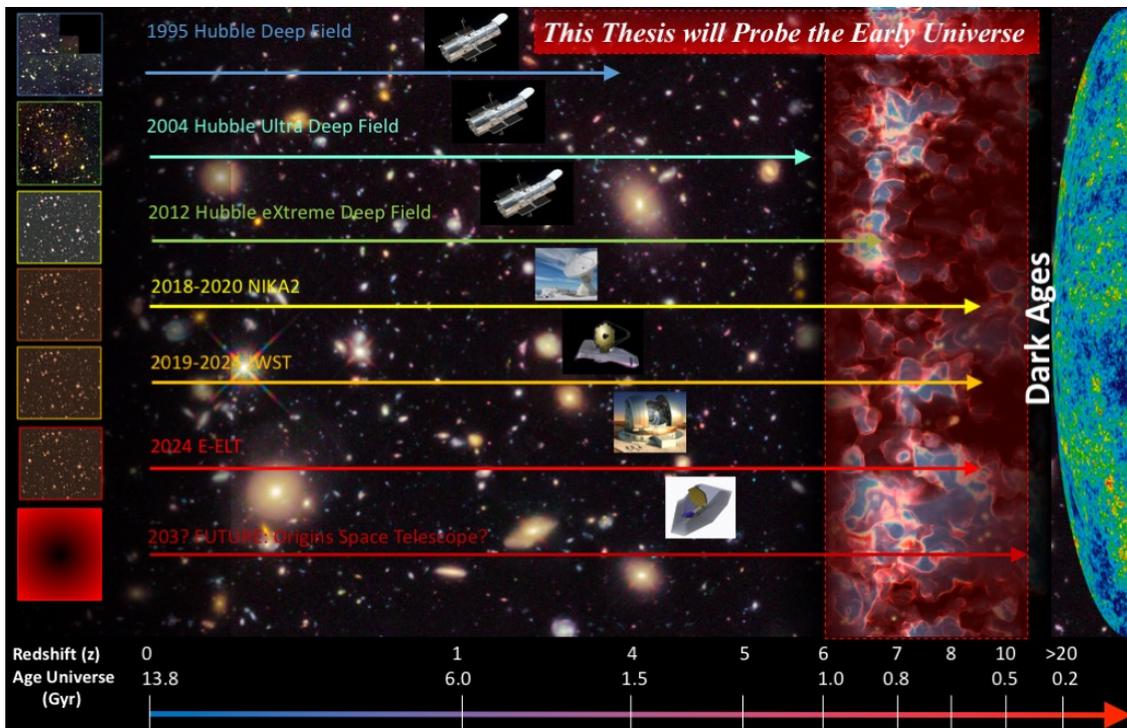


Figure: The reddish area on the right-hand side of the figure is the region that this thesis will probe @ $z > 6$. The models will predict, simulate and be compared to observations from the JWST, from ALMA, NIKA2 and later on the ELT.