Resolving galaxy evolution across cosmic time

Extragalactic Astrophysics Group
Cavendish Laboratory (Department of Physics)
Kavli Institute for Cosmology, Cambridge (KICC)
Extragalactic Astrophysics Group

**Team Co-Lead:** Prof Roberto Maiolino & Dr Sandro Tacchella

**Postdocs:** Dr Francesco D’Eugenio, Dr Mirko Curti (ESO Fellow), Dr Nicolas Laporte (Kavli Senior Fellow), Dr Joanna (Asia) Piotrowska, Dr Jan Scholtz, Dr Charlotte Simmonds, Dr Hannah Übler (Newton Kavli Fellow), Dr Joris Witstok

**Students:** William Baker, Lola Danhaive, Tobias Looser, Gabriel Maheson, William McClymont, Dily Ong, David Puskas, Lester Sandles, Jenny Wan, Callum Witten

...and greatly supported by Steve & Alison!
When, why, and how did the first galaxies form and the Dark Ages end?

How do galaxies regulate and quench star formation? Formation of the first quiescent galaxies?

Which sources reionize the Universe?

How do galaxies chemically enrich?

What are the stellar populations of the first galaxies? PopIII? BH?

When and how do galaxies form their bulge and disk components?
cosmic web (~Gpc)

125 Mpc/h

dark matter halos (~Mpc)

galaxies (~kpc)

1 pc = 3 ly = 3x10^16 m
cosmic web (~Gpc)

dark matter halos (~Mpc)

galaxies (~kpc)

star formation (~pc)

black holes (0.01pc)

1 pc = 3 ly = 3x10^{16} m
cosmic web (~Gpc)

dark matter halos (~Mpc)
gas flow & cooling
magnetic fields
interstellar medium
radiation fields
black hole activity
black hole growth

formation and diffusion of cosmic rays
formation of stars
molecular clouds
supernova explosions
stellar winds
black hole growth

star formation (~pc)
galaxies (~kpc)
black holes (0.01pc)

1 pc = 3 ly = 3x10^{16} m
Progress through observational discoveries

Very Large Telescope at Paranal, Chile

Hubble Space Telescope

ALMA Radio Telescope

Extremely Large Telescope (ELT)
Progress through observational discoveries

- Very Large Telescope at Paranal, Chile
- Hubble Space Telescope
- ALMA Radio Telescope
- MOONS (2023+)
- ANDES (2027+)
- Extremely Large Telescope (ELT)
- James Webb Space Telescope
- JADES (2022+)
About 100,000 galaxies, in 9-14 JWST filters, reaching AB=29. We planned for ~650 hrs in GOODS-S, but only 40% was scheduled in Year 1.
Unprecedented discovery space with MOONS

- MOONS: exceptional combination of large multiplexing, high sensitivity, broad spectral coverage, large area and high fiber density
- Cambridge is part of the MOONS consortium
- MOONRISE: SDSS-like survey around Cosmic Noon (redshift z~1-2.5)
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Our key focus:

- Star-formation variability: what regulates star formation?
- Chemical abundances and star-formation histories
- Which role do black holes play in shutting down star formation?
- How does the environment affect the evolution of galaxies?
Integrated approach between observations & theory

“Precision Galaxy Formation Studies”

Observations
progress through discoveries

Development of new, innovative analysis techniques and testing of tools

Model testing and interpretation of observations: comparison between theory predictions and observations

Theory
numerical and analytical models
Integrated approach between observations & theory

Observations progress through discoveries

Model testing and interpretation of observations: comparison between theory predictions and observations

Development of new, innovative analysis techniques and testing of tools

Theory numerical and analytical models

- numerical simulations
- semi-analytical models
- empirical models

simple ➜ complex

- detailed radiative transfer (MCRT) analysis that include radiative transfer, non-equilibrium thermochemistry, and dust evolution

Smith, Kannan, Tacchella et al. (2022)
Tacchella et al. (2022c)