High-redshift galaxies: an eye towards the future from the ground

The characterization of galaxies at the highest redshifts remains one of the central goals in contemporary astrophysics and huge progress has been made thanks to ALMA and JWST observations. However, the majority of individual galaxies are invisible to ground-based observatories, and possibly even to our best space satellites. The most powerful way to define directly the characteristics of the neutral gas, one of their primary ingredients which contains the majority of metals, is through absorption lines detected in the spectrum of a background bright source. For the last two decades, GRBs have been heralded as an effective diagnostic to probe the interstellar medium (ISM) of high-redshift faint star-forming galaxies and their metal content. An opportunity to fulfill this promise was provided by the bright GRB 210905A at redshift $z=6.3$ and by the recent blast of GRB 240218A at redshift $z=6.8$.

VLT/X-shooter optical spectroscopy of GRB afterglows allowed to detect and characterize in detail neutral-hydrogen, low-ionization, high-ionization and fine-structure absorption lines. Metallicity, kinematics, chemical abundance pattern, dust depletion and dust-to-metal mass ratio could be determined for the ISM of the GRB host galaxies. The results that I will present show the powerful potential of GRBs to access detailed information on the chemical properties of high-redshift galaxies, i.e. $z>6$, and provide unique insights into the metal enrichment history of the Universe, rivaling and complementing JWST surveys. Furthermore, they motivate pursuing GRBs dedicated space missions, such as SVOM and hopefully THESEUS, to fully exploit the possibility to use GRBs to explore the high-redshift Universe, in synergy with ground-based telescopes, such as the future ESO/ELT equipped with the ANDES high-resolution spectrograph. The ANDES spectral coverage and the collecting power of ELT will allow us to resolve narrow metal absorption features, reach the signal-to-noise levels needed to study the faint high-redshift sources, carry out detailed chemical studies of high-redshift absorbers, constrain key elements column density, and study relative abundances in individual gas components and giving access to single gas clouds information. The next-generation ground-based telescopes will facilitate in-depth host galaxy characterization and probe the existence of very massive Pop III stars in the early Universe.