Unfolding the high redshift Universe with GRBs

The identification and characterization of galaxies at the highest redshifts remains one of the central goals in contemporary astrophysics. The majority of individual galaxies are invisible to ground-based observatories, and possibly even to our best space satellites (e.g. HST, JWST). The most powerful way to define directly the characteristics of the neutral gas, one of their primary ingredient which contains the majority of metals, is through absorption lines detected in the spectrum of a background bright source.

Long gamma-ray bursts (LGRBs) are unique tools to probe first galaxies. They are associated with massive stars and their bright afterglows can be used as powerful background sources capable of unveiling the gas along their line of sight. Afterglow spectroscopy allows detailed studies of the properties of the ISM of star-forming galaxies up to the highest redshift. Furthermore, the LGRB afterglow emission fades quite rapidly, allowing the study of the emission properties of their hosts, independently of their brightness at any wavelength.

In this talk, I will show the results obtained with VLT/X-shooter observation of the afterglow of GRB 210905A at $z = 6.3118$. We detect neutral hydrogen, low-ionization, high-ionization and fine-structure absorption lines, as well as a tentative Lyman-α emission at velocity $> 1000\,\mathrm{km\,s^{-1}}$ from the absorbing gas. We were able to determine the metallicity, kinematics and chemical abundance pattern, dust depletion and dust-to-metal mass ratio of the ISM at $z = 6.3118$.

These results show the very powerful potential of GRBs to access detailed information on the properties of very high-redshift galaxies, independently of the galaxy luminosity. As an enormous telescope equipped with the most advanced facilities, the ESO/ELT will be able to observe these first galaxies and revolutionise our perception of the Universe. The ability of ELT's instruments to obtain high-signal-to-noise, high-resolution spectroscopy will allow us to resolve and study many more metal absorption lines, too weak for current telescopes, and determine significant constraints on key chemical elements.

The synergy between the extremely large ground-based telescopes available at the end of '20s and the future foreseen high-energy satellites devoted to the GRBs science (e.g. SVOM, THESEUS) will provide essential informations to optimise the follow-up, allowing us to monitor the cosmic metal enrichment and chemical evolution to early times, and search for evidence of the nucleosynthetic products of even earlier generations of stars.