THE FIRST COSMIC EXPLOSIONS:

PROBING EARLY GALAXIES THROUGH GAMMA-RAY BURST AFTERGLOWS

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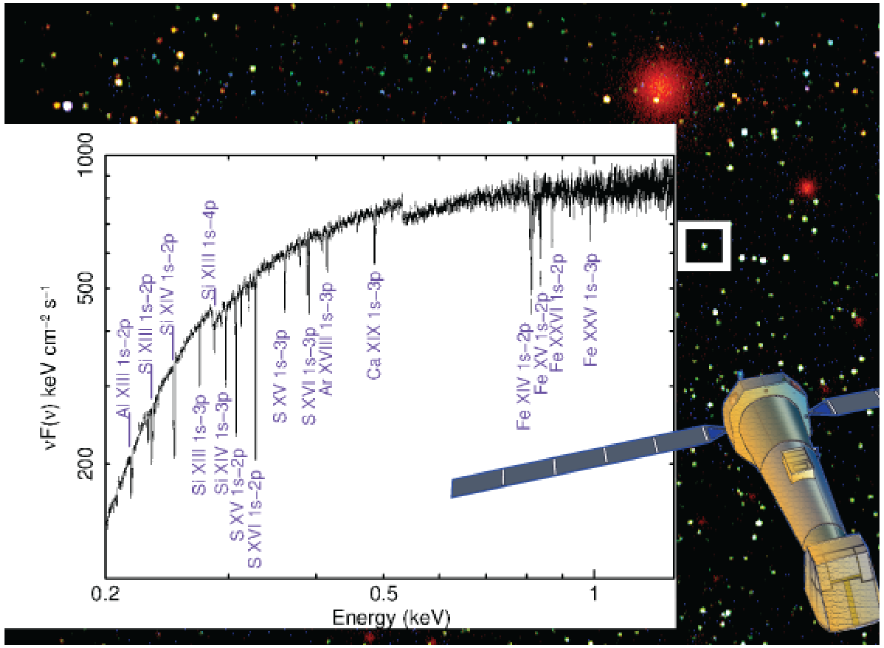
When galaxies began to grow in the early Universe the first generations of stars within them would have been massive, many tens of times the mass of the Sun. Unlike low mass stars, such as the Sun, massive stars live short lives and end as cosmic explosions. These violent stellar deaths are seen as supernovae, but in a small fraction of cases another, much brighter, phenomenon occurs: a Gamma-Ray Burst (GRB). Due to their extreme luminosity – for a brief time, as much as all the stars in a million Milky Way galaxies - GRBs can be seen at any distance, and hence act as unique, luminous probes of the distant Universe. Long duration GRBs in particular can stay bright for hours or days and are associated with the death of massive stars, the engines that drive galaxy chemical enrichment across cosmic time. Beginning with the earliest "metal free" stars, the cycle of metal enrichment started when their final explosive stages injected the first elements beyond Hydrogen and Helium into their pristine surroundings, quickly enriching the gas. These ejecta created the seeds for the next generation of stars.

Finding and mapping the earliest star formation sites is one of the top priorities for future astrophysical observatories such as Athena. Athena will play a unique role in this endeavour. Such assemblies of protostars are so dim that they can hardly be detected in emission, thus the only way to find them is to have a bright beacon, a GRB, pinpointing their locations. Furthermore, the copious GRB high energy photons will "X-ray" these early sites of star formation, thus allowing to characterize, with absorption studies, their properties.



Spectrum: A simulated X-IFU X-ray spectrum of a medium bright (fluence=4 x 10^{-7} erg cm^{-2}) afterglow at z=7, characterized by deep narrow resonant lines of Fe, Si, S, Ar, Mg, from the gas in the environment of the GRB. An effective column density of 2 x 10^{22} cm^{-2} has been assumed.
Composition: ACO Team.

Indeed, as their name implies, GRBs emit most of their light at high energies. They are many orders of magnitude brighter in X-rays than even the most massive accreting black holes (the quasars), albeit for a relatively short period. In the early Universe, within the first billion years or so after the Big Bang, the contrast in brightness is greater as the most massive black holes have not yet grown. GRBs, therefore, are the brightest sources of light with which to probe early galaxies. Athena will have the fast response time, collecting area and spectral resolution necessary to make use of the GRB light.

X-ray spectroscopy has the unique capability of simultaneously probing all the elements (C through Ni), in all their ionization stages. Utilizing the light from GRBs, the exquisite sensitivity and resolution of the Athena/X-IFU can resolve and measure the X-ray absorption features coming from gas close to the GRB location, much of which is expected to be ionised and thus expected to be only accessible by observing narrow X-ray absorption lines. The Athena/X-IFU will be able to measure metal abundance patterns for a variety of many ions for a large sample of GRBs to probe the sites of the first stars which are crucial for understanding cosmic re-ionization, the formation of the first black holes, and the dissemination of the first metals in the Universe.