Anticipating the unexpected

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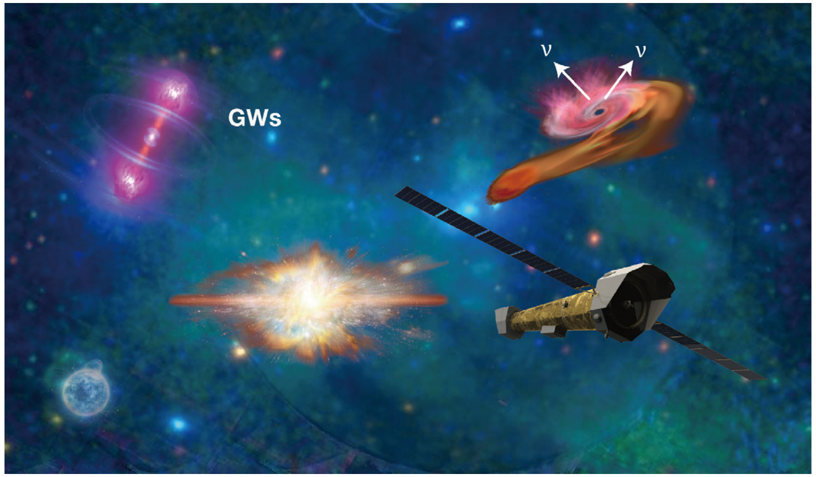

Thanks to its Target of Opportunity mode, *Athena* will be able to observe sudden and unpredictable flashes of X-ray radiation coming from the most extreme environments. For example, magnetars outbursts, exploding massive stars, rupting supermassive black holes, and neutron star mergers. Credit: Background: XMM-Newton; *Athena* satellite: ESA/IRAP/CNRS/UT3/CNES/Fab&Fab; Insets: Brian Monroe -NASA VE (top-left); ESA/C. Carrue (top-right); NRAO (middle); XMM-*Newton* (bottom-left).

Ancient cultures depicted the night sky as an immutable ensemble of fixed stars. Modern astronomy facilities reveal to us a richly dynamic and ever-changing sky. The X-ray sky is no exception, as it hosts some of the most violent and energetic phenomena: from the explosive death of massive stars to the catastrophic collisions of neutron stars, from the ejection of relativistic outflows at the center of galaxies to the tragic end of stars devoured by the heaviest black holes. These events allow us to explore the most extreme environments through multiple cosmic messengers (such as photons, neutrinos, cosmic rays, and gravitational waves) and to reach the earliest epochs of our universe, when the first stars and galaxies were formed.

To catch these sudden and unpredictable fireworks of X-ray radiation, *Athena* must quickly readjust its plans and turn its instruments to look at the right place in the sky. This observational capability, known as Target of Opportunity (ToO), is key to unlocking the discovery potential of time-domain astronomy. As an example, let's consider the case of a long duration Gamma-Ray Burst (GRB) illuminating the infant universe with its bright but very fast-fading X-ray afterglow. Long GRBs are produced by the gravitational collapse of the most massive stars. The *Athena* X-ray Integral Field Unit (X-IFU) will use the GRB afterglow as a backlight to snap a detailed picture of the gas content in the immediate surroundings of the GRB explosion. By showing how the X-ray light is absorbed, high-resolution spectroscopy will probe the birthplaces of the very first stars, revealing their gas metallicities, abundance pattern, and fraction of neutral hydrogen. However, X-ray afterglows are short-lived and their brightness can drop by a factor of a hundred in just a few hours. To use them as cosmic beacons, *Athena* must observe while they shine.

This is only an example, and many other scientific cases need this mode of observation. Other examples are supernova shock breakouts, marking the first escape of photons related to the explosion (all core-collapse supernovae are expected to show a X-ray/ultra-violet flash upon break out), and tidal disruption events signalling that a dormant black hole is cannibalising a star that has come too close. Basically, the ToO mode offers *Athena* the opportunity to react to any new phenomenon that could not be foreseen in the observation planning. The *Athena* Ground Segment will allow us to communicate with the spacecraft every few hours, and to alert it of any new important event that needs to be rapidly observed. *Athena* will send us the data within 4 hours for 40% of the events anywhere in the sky.