Using Time As a Tool, Athena Will Find Rare And Important Types Of Neutron Stars and Black Holes

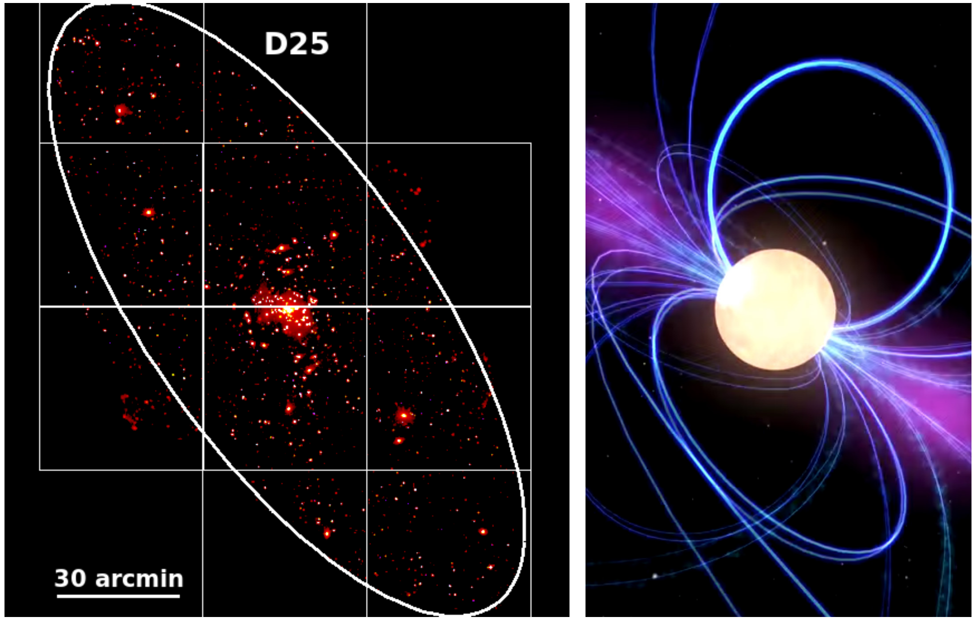
Ann Hornschemeier and Neven Vulic, NASA Goddard Space Flight Center, X-ray Astrophysics Laboratory

It has been more than fifty years since the discovery of a neutron star system emitting X-rays began X-ray astronomy with a sounding rocket flight in 1967, resulting in the 2002 Nobel Prize in Physics to Riccardo Giacconi. However, an enduring challenge to astronomers is moving beyond the initial identification of candidate compact objects (like neutron stars and black holes) and definitively identifying their nature. The simple knowledge of whether or not a compact object is a lower mass neutron star or a higher mass black hole gives astronomers important constraints on how supernova explosions are likely to proceed. Indeed, for the most massive stars, there is a mass range where it is difficult to predict whether a neutron star or black hole will be formed after the supernova. Knowledge of the maximum mass that can be attained by neutron stars is important as it teaches us about the internal structure of these exotic objects, a still open question for fundamental laws of nuclear physics.

How can we tell if an X-ray source that appears to be accreting material from a companion star harbors a neutron star or a black hole? There are multiple techniques that have been employed over the years, one of the most robust tools being precision timing. If the compact object contains a surface, as a neutron star does (but a black hole does not), and the system has a strong magnetic field that funnels the accretion flow to a particular spot on the surface, then pulsations are expected as the neutron star rotates and the spot periodically comes into our view (called a pulsar). Similarly, occasionally the accretion flow can "pile up" onto the surface of a neutron star, achieving a critical mass value that triggers a thermonuclear explosion in the form of a characteristic burst. Detecting either the pulsations or such a characteristic burst is a "smoking gun" for a neutron star.

What about black holes? Here the story can be slightly more complicated. In the types of binary systems expected in galaxies that are active in forming newly born stars (named starburst galaxies), one of the most interesting, yet elusive, is a population of Wolf Rayet X-ray Binaries that are believed to host black holes. X-ray variability of a certain magnitude over periods less than a day characterizes such systems and can be used to spot them. To date, interesting studies in the time domain have been carried out on neutron star and black hole populations, however, these are largely confined to our own Milky Way galaxy.

The *Athena* Wide Field Instrument (WFI) will be able to extend this study to more distant galaxies by mapping their whole population of X-ray sources, and simultaneously complete precision timing for all of them. The nature of the object, a neutron star or a black hole, will be determined by measuring the different temporal behavior as mentioned above. Thus, *Athena* WFI will use time itself as a tool in the X-ray band, taking a census of compact object types, and providing theorists with much more constraining information than ever available before.



Left: Shown is a simulated Athena WFI image of the nearby Andromeda galaxy (M31). The white ellipse labelled D25 represents the size of the galaxy. In a relatively quick scan of ten pointings, Athena WFI will take an inventory of the luminous neutron star and black hole population in the entire Andromeda galaxy. Credit: A. Hornschemeier and N. Vulic, NASA/GSFC. X-ray Astrophysics Laboratory. Right: An illustration of a neutron star with a strong magnetic field, known as pulsars if pulsations are detected. Credit: NASA/GSFC.

Athena X-ray Observaroty
@AthenaXobs
ACO@ifca.unican.es
www.the-athena-x-ray-observatory.eu