Research Highlights

Proof of the Origin of the Heavy Elements

DAWN researchers led the way in discovering the astronomical origins of most of the periodic table. The heaviest two thirds of the chemical elements, including gold, platinum, and uranium, were the last elements to have an unidentified origin. Our *Nature* paper, (Watson et al. 2019) detected freshly synthesized heavy elements for the first time, proving that they are forged in the extreme heat of the collisions of neutron stars. That heavy elements were formed in neutron star collisions was hypothesized already in 1982, but has not been verified experimentally until now.

In 2017, the first gravitational wave signature from the collision of two neutron stars was detected, and we managed to quickly observe the galaxy in which this collision occurred, obtaining good quality spectra of the explosion resulting from this neutron star collision. This new type of explosion is now referred to as a kilonova. At the time, there was a lot of excitement about the fact that this kilonova might indicate that large amounts of heavy elements were produced. However, because of the enormous velocities of the explosion that smeared and shifted the spectral lines and the complexity of heavy element spectra with billions of individual atomic lines expected, no one at the time could show evidence for any individual element. Over the next two years, we worked on deciphering the spectra, and we succeeded. We found clear evidence for the element strontium, one of the lightest of the heavy elements, proving that neutron star mergers were definitively the origin of the heaviest elements.

Discovery of the Most Distant “Dying” Cosmic Giants

The majority of stars in the nearby universe are part of gigantic spheroidal, red, and dead old galaxies, with little or no formation of new stars to keep them alive. These cosmic “dead” giants are thought to be among the first objects to reach a full maturity in the universe: following the collision and merging of smaller gas-rich galaxies, they form stars at furious rates (several hundred times faster than our Milky Way), assembling most of their final mass in a few hundred, dramatic million years. This might be connected to their sudden death, followed by billion years of passive evolution, during which they mainly grow in size by swallowing smaller satellites in their surroundings due to the gravitational attraction.

Working with our international collaborators, we discovered the most distant cosmic dying giant discovered so far: a galaxy which is already “dead” just 1.5 billion years after the Big Bang. Surprisingly, the motion of stars within the distant galaxy -- a proxy of the total dynamical mass of the system and a fundamental probe for our models -- is similar to what is observed in closer objects of the same type, showing that no substantial evolution is present for several billion years of the history of these massive galaxies. Moreover, a statistical analysis shows that this galaxy is not so extreme, but rather similar to typical star-forming galaxies at Cosmic Dawn.

The team led by Francesco Valentino further showed that state-of-the-art cosmological hydrodynamical simulations can accommodate a significant number of massive quiescent objects as being “normal” in the distant universe and they predict their ``normal'' past history. However, this agreement becomes uncomfortably poor for the closest galaxies to the Big Bang. If an extremely distant one of these dying cosmic giants were found in upcoming JWST observations, it may be necessary to substantially revise current models of galaxy evolution.