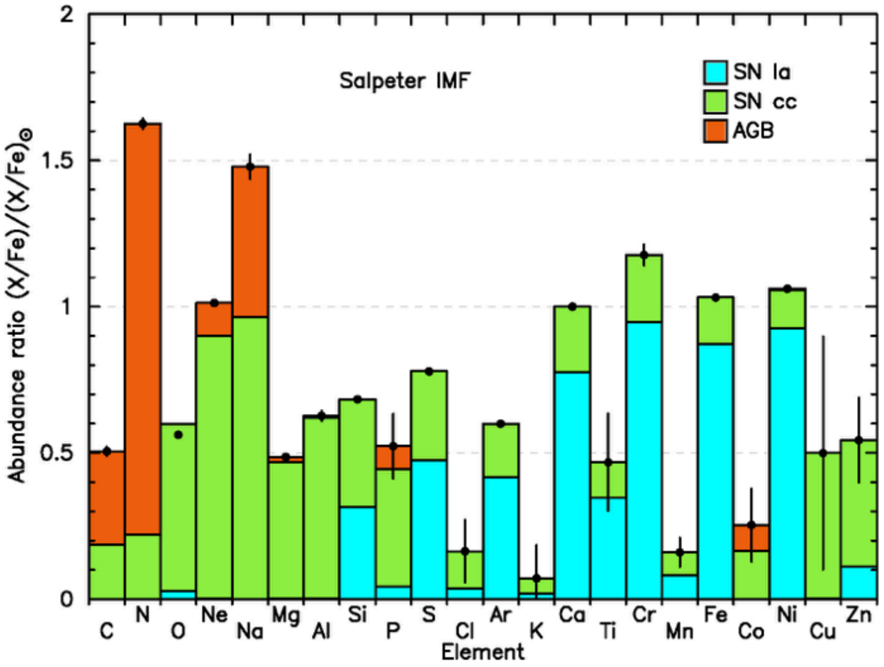
TRACING THE HISTORY AND ORIGIN OF CHEMICAL ELEMENT FORMATION

by Jelle de Plaa. SRON (Netherlands Institute for Space Research) The Netherlands

‘We are made of stardust!’ But when were the building blocks of dust formed? Just after the ‘Big Bang’, about 13.8 billion years ago, the universe consisted only of the simplest elements: hydrogen, helium, and traces of lithium and beryllium. When the first stars formed, hundreds of million years later, heavier elements like carbon, oxygen, silicon and iron were created by (explosive) nuclear fusion in the hot and dense stellar cores. Several generations of stars and billions of years of chemical evolution created the mix of heavier elements that we are made of and that we see all around us in the local universe.

We know that most of the heavy elements form inside stars around the end of their lifetime and are released into space when the stars explode as supernovae. There are various ways in which stars can explode. The way a star ends its life depends on, for example, its mass, composition, and the possible presence of a nearby companion star. In all supernovae, the nuclear fusion reactions that form heavy elements by colliding lighter elements play a major role. The composition of the ejected material therefore tells a lot about the history and properties of the exploded star. Massive stars release mainly lighter elements like oxygen, neon, and magnesium during the explosion at the end of their lives, while the heavy elements end up in the neutron star or black hole that this ‘core-collapse’ supernova explosion also creates. Another type of supernova actually releases the heavy elements, like silicon, calcium and iron, into space. This happens when a relatively light white dwarf star explodes as a result from mass accretion from a neighboring star. Based on their properties in visible light, these explosions were historically classified as type Ia supernovae. But how and when these core-collapse and type Ia explosions form and how many metals they produce is still poorly known.



Expected abundances measured by Athena in a bright ‘local’ cluster of galaxies. The color bars show which fraction of the element is produced by either core-collapse supernovae (SN cc, green), type Ia supernovae (SNIa, blue) or Asymptotic Giant Branch stars (AGB, red). The error bars on the black data points show the expected statistical uncertainty on the measurement.

Using the unprecedented sensitivity and spectral resolution of the X-IFU instrument aboard Athena, we will be able to probe the hot (10 million degree) gas in clusters of galaxies that has been enriched by billions of supernovae over cosmic time. The X-ray spectrum contains the lines of the most important elements from carbon to nickel in the periodic system and allows us to constrain the amounts of the elements with an unprecedented precision. The Athena observatory will not only allow a much more precise measurement, but will also show us lines of rare elements, like sodium, chromium and manganese. Moreover, we will be able to look back in time to clusters that are only about 4 billion years old, and for the first time measure the abundances of elements other than iron, like silicon, sulfur and calcium in such distant objects. When we compare these measurements to models of supernova explosions, we will understand better how the explosions that created the heavy elements, which are crucial for the formation of life, work and when they occur.