State-of-the-art of chemodynamical simulations: The Origin of Elements and their Evolution in Galaxies

Chiaki Kobayashi[1,2]

[1]Centre for Astrophysics Research, School of Physics, Astronomy and Mathematics, University of Hertfordshire, Hatfield AL10 9AB, UK
[2]Kavli Institute for the Physics and Mathematics of the Universe, Chiba 277-8583, Japan

State-of-the art of chemical evolution modelling has provided deeper understanding of the origin of elements as well as the evolution of galaxies [1]. We have been running hydrodynamical simulations of galaxies including detailed chemical enrichment from core-collapse supernovae, Type Ia supernovae, AGB stars, super AGB stars, and neutron star mergers. With our chemodynamical simulations of Milky Way-type galaxies [2], we have predicted the bimodal distribution in the [alpha/Fe]-[Fe/H] diagram and its radial and vertical gradients in the disk, which are now seen also in observational data such as APOGEE. Unlike classical "one-zone" models, in chemodynamical simulations, chemical enrichment takes place inhomogeneously, which results in a significant contribution from long time-delay sources (e.g., AGB stars) in metal-poor environments. Because of this effect, we succeed in reproducing the observed N/O-O/H relations in nearby star-forming galaxies [3]. However, even with this effect, it seems not possible to explain the observed distribution of neutron capture elements with neutron star mergers only, and a significant contribution from magneto-rotational supernovae is necessary, especially at very low metallicity [4]. With recent observational techniques, metallicities and elemental abundance ratios can also be estimated within external galaxies. These are also in good agreement with our predictions from cosmological simulations with feedback from super-massive blackholes that originate from the First Stars in the Universe [5,6]. We also predict the evolution of elements that will be explored with James Webb Space Telescope in near future [7].

[1] Kobayashi, C. 2016, Nature, 540, 205
[2] Kobayashi, C., Nakasato, N. 2011, Astrophysical Journal, 729, 16
[3] Vincenzo, F., Kobayashi, C. 2018, Monthly Notices of the Royal Astronomical Society, 478, 155
[4] Haynes, C. J., Kobayashi, C. 2019, Monthly Notices of the Royal Astronomical Society, 483, 5123
[5] Taylor, P., Kobayashi, C. 2014, Monthly Notices of the Royal Astronomical Society, 442, 2751
[6] Taylor, P., Kobayashi, C. 2017, Monthly Notices of the Royal Astronomical Society, 471, 3856
[7] Vincenzo, F., Kobayashi, C. 2018, Astronomy & Astrophysics Letter, 610, 16