銀河系の化学力学進化シミュレーション

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利用カテゴリ GRAPE-A

We present the chemodynamical simulations of a Milky Way-type galaxy using a self-consistent hydrodynamical code with supernova feedback and chemical enrichment [1]. In our nucleosynthesis yields of core-collapse supernovae [2], the light curve and spectra fitting of individual supernova are used to estimate the mass of the progenitor, explosion energy, and ejected iron mass. A large contribution from hypernovae is required from the observed abundance of Zn ([Zn/Fe] ~ 0) especially at [Fe/H] $\lesssim -1$. In our progenitor model of SNe Ia [3], based on the single degenerate scenario, the SN Ia lifetime distribution spans a range of $0.1-20$ Gyr with the double peaks at ~ 0.1 and 1 Gyr. Because of the metallicity effect of white dwarf winds, the SN Ia rate is very small at [Fe/H] $\lesssim -1$, which plays an important role in chemical evolution of galaxies.

In the simulated galaxy, the kinematical and chemical properties of the bulge, disk, and halo are consistent with the observations. The bulge formed from the assembly of subgalaxies at $z \gtrsim 3$; 80% of bulge stars are older than ~ 10 Gyr, and 60% have [O/Fe] > 0.3. The disk formed with constant star formation over 13 Gyr; 50% of solar-neighborhood stars are younger than ~ 8 Gyr, 80% have [O/Fe] < 0.3. When we define the thick disk from kinematics, the thick disk stars tend to be older and have higher [α/Fe] than the thin disk stars. The formation timescale of the thick disk is $3-4$ Gyr.

Because the star formation history is different for different components, the age-metallicity relation and the metallicity distribution function are also different. The age-metallicity relation shows a more rapid increase in the bulge than in the disk. In both cases, the average metallicity does not show strong evolution at $t \gtrsim 2$ Gyr, as in the observations. The scatter is originated from the inhomogeneity of chemical enrichment in our chemodynamical model. The observed metallicity distribution function is better reproduced with UV background radiation and hypernovae, but is still problematic. The bulge wind induced by SNe Ia seems to be a good solution to reduce the numbers of metal-rich stars in the bulge and of metal-poor stars in the disk.

The difference in the chemical enrichment timescales results in the difference in the elemental abundance ratios, since different elements are produced by different supernovae with different timescales. We also predict the frequency distribution of elemental abundance ratios as functions of time and location, which will be statistically compared with a large homogeneous sample from galactic archeology surveys such as HERMES, when they become available.

- Because of the delayed enrichment of SNe Ia, α elements (O, Mg, Si, S, and Ca) show a plateau at [Fe/H] ~ -1, and then the decreasing trend against [Fe/H], where [Mn/Fe] also shows the increasing trend. Odd-Z elements (Na, Al, and Cu)

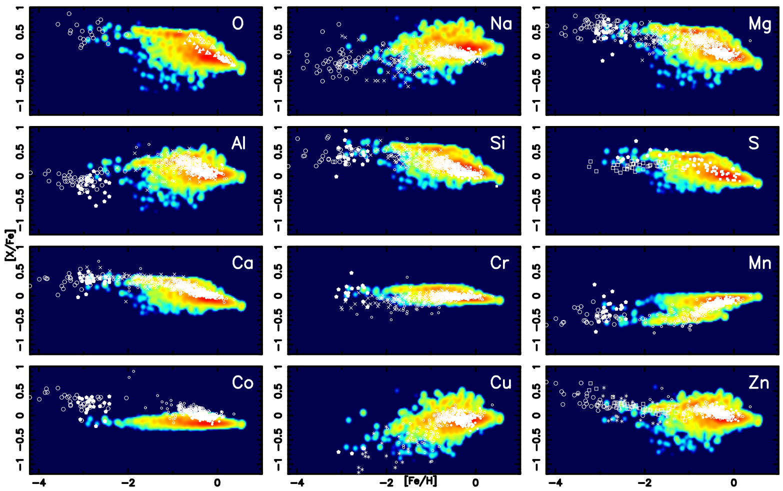

図 1: [X/Fe]-[Fe/H] relations in the solar neighborhood at $z = 0$. The contours show the frequency distribution of stars in the simulated galaxies, where red is for the highest frequency. See [4] for the observational data (white dots) sources.

show the increasing trend at [Fe/H] $\lesssim -1$ because of the metallicity dependence of nucleosynthesis yields. These are in excellent agreement with the available observations.

- In the bulge, the star formation timescale is so short that the [α/Fe] plateau continues to [Fe/H] $\sim +0.3$. Because of the smaller contribution from SNe Ia, the majority of stars shows high [α/Fe] and low [Mn/Fe]. [(Na, Al, Cu, Zn)/Fe] are also high because of the high metallicity in the bulge.

- The stellar population of the thick disk is neither disk-like nor bulge-like. For thick disk stars, [α/Fe] is higher, and [Mn/Fe] is lower than thin disk stars because of the short formation timescale. However, [(Na, Al, Cu, Zn)/Fe] are lower than bulge stars because of the lower chemical enrichment efficiency. This is because half of the thick disk stars have already formed in satellite galaxies before they accrete onto the disk, and the metals have been ejected from the satellite galaxies by the galactic winds.

参考文献

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