# Stellar initial mass function varies with metallicity and age of stars, say astronomers

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New research reveals that the mass of newly born stars (yellow, orange, and red circles stand for stars from higher to lower mass) varies with their metal abundances and their birth time (inner circle means born earlier). Credit: Wu Kun

In the vast and diverse universe, the initial mass distribution at the birth

of a new population of stars determines the fate of galaxies. This relationship is described by the initial mass function (IMF). For more than half a century, astronomers have assumed that the IMF is a universal relationship, i.e., it is uniform throughout the universe.

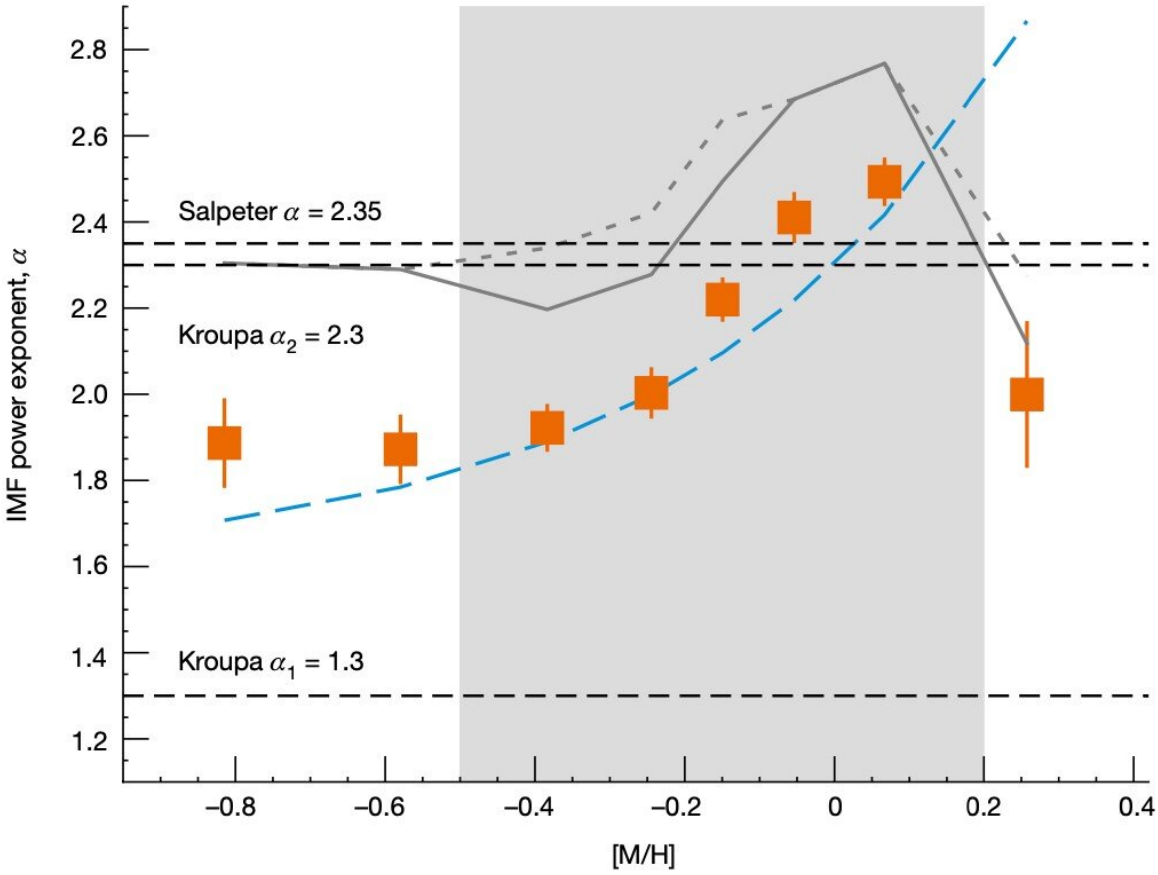
However, in recent years, some indications suggest that in some galaxies where star formation is particularly active, the IMF may be of a different form than is often assumed in the Milky Way. But to fully verify these results, astronomers will need to find more direct observational evidence in the Milky Way.

Now, based on the Large Sky Area Multi-Object Fiber Spectroscopic Telescope (LAMOST, also known as the Guo Shou Jing telescope), a research team led by Prof. Liu Chao from the National Astronomical Observatories of the Chinese Academy of Sciences (NAOC) has found a crucial piece of direct evidence on how the IMF varies with different environments.

This study was published in *Nature* on Jan. 18.

"The IMF varies with levels of metal elements, and populations of stars born earlier in the universe's history contain fewer low-mass stars than younger populations," said Li Jiadong, a Ph.D. student at NAOC and first author of the study.

Counting stars in a given volume is a direct and classical way to measure the IMF of low-mass (red dwarf) stars, whose mass distribution does not evolve with time; this approach is essentially independent of models or assumptions.




The stellar initial mass function (IMF) describes the distribution of the initial mass of new stars in a population. Credit: NAOC

"Although many previous studies applied star counting to derive the IMF, two problems have not been solved. One is that only a small number of stars were counted in previous work. The second is that previous studies did not measure the metallicity of stars," said Prof. Zhang Zhiyu, co-author of the study.

LAMOST has provided spectra that contain information about the chemical composition, temperature and luminosity of millions of stars, enabling the researchers to measure the metallicity of nearby red dwarf

stars.

By selecting about 93,000 red dwarf stars in catalogs from both LAMOST and the Gaia survey, the researchers were able to group stars according to their metallicity and calculate the distribution of stellar mass in each group.

The study has revealed the variable abundance of low-mass stars in our galaxy, the Milky Way, and established a powerful benchmark for models of star formation. The findings may also affect the results of models of chemical enrichment of distant galaxies, as well as estimates of galaxy mass and the efficiency of planet formation.

"For instance, the total stellar mass of galaxies is often estimated by assuming that the IMF is invariant, but if the IMF is variable, this could change the total mass estimates of galaxies and potentially alter the field of Galactic astronomy," said Prof. Liu.

Prof. Pavel Kroupa, an authority on the IMF at the University of Bonn, Germany, commented on the results: "On the basis of a large ensemble of well-observed stars, the authors report that the IMF of late-type stars in the local Galactic disk is metallicity- and age-dependent. These results are highly important for addressing how universal the stellar IMF is and enable an in-depth understanding of the possible shifts in stellar populations that formed at different times and under different conditions in the Galaxy."

**More information:** Chao Liu, Stellar initial mass function varies with metallicity and time, *Nature* (2023). DOI: 10.1038/s41586-022-05488-1. www.nature.com/articles/s41586-022-05488-1