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INVITED REVIEWS

Stellar Abundance and Galactic Chemical Evolution through LAMOST Spectroscopic Survey *

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Abstract A project of a spectroscopic survey of Galactic structure and evolution with a Large sky Area Multi-Object fiber Spectroscopic Telescope (LAMOST) is presented. The spectroscopic survey consists of two observational modes for various targets in our Galaxy. One is a major survey of the Milky Way aimed at a systematic study of the stellar abundance and Galactic chemical evolution through low resolution ($R = 1000 - 2000$) spectroscopy. Another is a follow-up observation with medium resolution ($R = 10000$) spectrographs aimed at detailed studies of the selected stars with different chemical composition, kinematics and dynamics.

Key words: techniques: spectroscopic – stars: abundances – Galaxy: structure – Galaxy: abundances – Galaxy: kinematics and dynamics – Galaxy: evolution

1 INTRODUCTION

The universe consists of millions of galaxies, in which there is a special one - the Milky Way - where all we stay. The Milky Way is also the subject most concerned by astronomers since it links our knowledge of stellar evolution and some important problems of formation of the universe. It can be used as an ideal laboratory for the studies of large scale structure of the Universe and gas distribution. We can observe more easily the various objects in the Milky Way than those in other galaxies.

The modern study of the Milky Way by the method of star counting was started in late 19th century. Other galaxies were identified to be similar stellar systems as the Milky Way at beginning of 20th century. Considering that the Milky Way is a typical spiral galaxy in which our solar system is located, it is the best sample with which various theoretical models can be checked when we study the formation and evolution of the galaxies. The structure and chemical evolution of a galaxy can be represented by the different distribution and motion of the stars with different metallicities.

There was no exciting progress in the field of Galactic study before 1980's due to the lack of sufficient observational data. Thanks to the rapid development of high resolution spectrographs and some large scale

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surveys, a series of important discoveries in Galactic research has been achieved. Astronomers pay more attention on the studies of the Milky Way due to following reasons:

- **The merging of galaxies.** First, the discovery of the stellar stream in the Centaurus constellation by Ibata et al. (1994) was thought to be evidence of a dwarf galaxy that was swallowed by our Galaxy. The Sloan Digital Sky Survey (SDSS) also confirmed this discovery (Yanny et al. 2000; Ivezic et al. 2000). This is an important contribution to the study of Galactic evolution. Second, the spectacular discovery of debris from the Sagittarius dwarf galaxy shows a complete great circle throughout the sky (Rocha-Pinto et al. 2003). Finding the evidence of the mergence in the Milky Way has a very important meaning since the mergence is one of the main processes in the evolution of galaxies. Another piece of evidence for mergence is a stellar stream from the Magellanic Clouds that shows the Milky Way is accreting material from a companion dwarf galaxy (Pilyugin & Edmunds 1996a, b). Recently, more and more observational evidence have shown that the Milky Way merged and is merging with some small dwarf galaxies.

  The abundance studies of globular cluster in the Galactic halo show that some globular clusters came from dwarf galaxies accreted by the Milky Way (Bassino et al. 1994). The study of field stars indicates that their abundances have the same pattern as the stellar populations in globular cluster from merged dwarf galaxies. This implies that some field stars also came from the merged dwarf galaxies (Kinman et al. 1994). Wyse (1995) and Gilmore (1995) pointed out that the fact of two different populations of thick and thin disk stars in the Galactic disk is a strong support for the assumption of merging galaxies. The study by Beers & Sommer-Larsen (1995) indicates the thick disk comes from an existing disk merged with dwarf galaxies.
- **Galactic chemical evolution.** Since the seminal work of Eggen, Lynden-Bell & Sandage (1962) (hereafter ELS), great progress has been made in understanding the formation and evolution of the Milky Way, both in theory and observation. In the past two decades, a large number of chemical evolution models have been developed, aimed at explaining the various observational characteristics from not only the solar neighborhood but also from the whole disk and halo. Simple chemical evolution models assume gas infall as the main ingredients (e.g. Chiappini et al. 1997, 2001; Goswami & Prantzos 2000; Hou et al. 2000; Francois et al. 2004). Some promising chemodynamical evolutionary models for the Milky Way have also been developed by a few groups (Steinmetz & Mller 1994; Samland et al. 1997; Berczik 1999; Samland & Gerhard 2003) who have adopted different elemental nucleosynthesis rates for the halo, bulge and disk. For the majority of the models, some convergence has been reached within the community. For example, the necessity of substantial gas infall from outer halo, the radial varying timescales for the infall and star formation, and no need for the varying the IMF or strong galactic winds. However, serious differences or uncertainties still exist among various models. For example, how does the disk abundance gradient evolve with time? What is the main mechanism for the large scatter in the abundance pattern for almost all elements? How about the age-metallicity relation? What triggers the formation of the thick disk?

  Observationally, progress comes mainly from the chemical abundances, radial velocities of stars from different populations, and also from star clusters. Earlier and recent extensive work has been concentrated on the $ubvy\beta$ photometric or/and photoelectric surveys of the nearby F and G stars (Olsen 1983, 1993, 1994; Feltzing et al. 2001; Nordstrom et al. 2004). Several groups have been devoted to the high resolution spectroscopy survey for the nearby dwarfs aiming to obtain accurate individual stellar properties. The first systematic spectroscopic studies of chemical abundances of extreme metal-poor dwarfs were made by Chamberlain & Aller (1951), Helfer et al. (1959), Wallerstein et al. (1963), Beers et al. (1985), Magain (1989) and Zhao & Magain (1990). Later, Edvardsson et al. (1993) presented the chemical abundances, age and kinematics for 189 F and G-type nearby Galactic disk stars. Recently, more detailed spectroscopic surveys of the chemical history of selected subsets of stars have been undertaken with several improvements in astrophysical data and computational methods (Fuhrmann 1998; Chen et al. 2000; Mashonkina & Gehren 2001; Bensby et al. 2003).
- **Galactic structure.** The successful launch of the HIPPARCOS satellite enabled us to obtain very accurate stellar position and kinematical parameters with space instruments. The astronomers from America and Europe proposed FAME (Full-sky Astrometric Mapping Explorer) and GAIA (Global Astrometric Interferometer for Astrophysics) projects, respectively. FAME is an astrometric satellite

designed to determine with unprecedented accuracy the positions, distances, and motions of 40 million stars within our galactic neighborhood (*http://www.usno.navy.mil/FAME/MainFrame.html*). FAME will measure stellar positions to less than 50 microarcseconds. GAIA is an ambitious space observatory in astronomy, adopted within the scientific programme of the European Space Agency (ESA) in October 2000. It aims to measure the positions of an extremely large number of stars with unprecedented accuracy. As a result, distances and motions of the stars in our Galaxy will be determined with extraordinary precision, which allows astronomers to determine our Galaxy's three-dimensional structure, space velocities of its constituent stars, and helps us to understand the origin and evolution of our Galaxy (*http://astro.estec.esa.nl/GAIA*). GAIA will measure more than 1 billion stars in a global stellar census of our Galaxy and its nearest neighbours. In addition, it will obtain multi-colour photometry as crucial diagnostic data for all stars observed, along with radial velocities for the brighter objects to complete the kinematical data. Furthermore, many survey data, such as SDSS (*http://www.sdss.org*) and 2MASS (*http://pegasus.phast.umass.edu*), have been released. These data are very important for our understanding of whole picture of Galactic structure and evolution.

- **Searching for extra-solar planetary systems.** The existence of extra-solar planetary systems was proposed long before the first detection of the candidate of such an object (Mayor & Queloz 1995). The first observation of a transit of host stars confirmed the existence of planets (Henry et al. 2000). At present, the search for extrasolar planets is a hot topic in astronomy and it has attracted many eyes from the public. Moreover, increasing numbers of planets are found to surround not only main sequence stars but also late type G giants (Sato et al. 2003). Some astronomers attempt to search planet host stars among metal-poor stars and stars in globular clusters. Excitingly, planets with size of the order of the Earth were detected very recently (Rivera et al. 2005) and some projects are launched to detect habitable planets like our Earth. It is possible that planet formation is a frequent phenomenon in astrophysics. We may expect to find planets around different kinds of stars located everywhere in the universe. The detailed study of extra-solar planetary systems is not only the base of search for the formation of the solar system and extraterrestrial civilization, but also plays an important role in the study of Galactic evolution. It is significant to compare solar-like field stars with and without planets to see if their surface abundances are affected by planetary systems (e.g. Fuhrmann et al. 1997; Zhao et al. 2002a, b; Gonzalez 2003). The detection and study of extra-solar planetary systems can provide more information for Galactic evolution since there are many such kinds of stars in our Galaxy.
- **Metal-poor stars and the early history of the Galaxy.** Metal-poor stars provide the "fossil record" of the creation and evolution of the elements from the earliest times, and thus they play a very important role in the study of the early Galactic chemical evolution. In particular, the most metal-deficient stars presumably provide information on Pop. III progenitors and such objects must have existed in the past, and perhaps still exist in the Galactic halo. In order to further these kinds of studies, a dedicated survey effort is needed to expand the number of such stars known, especially for stars below [Fe/H] $= -2.0$. A sample of stars selected in the survey should cover a wide range of stellar spectral types and temperatures. Their visual magnitudes should be bright enough for high resolution follow-up observations. The numerous samples of the candidate enable us to give the trends and scatter of elemental species. Two kinds of stars are suitable for such survey, namely dwarfs and giants. The former are relatively warm and generally un-mixed stars; the latter are relatively cool and generally mixed stars. An advantage is that these stars are located throughout the Galaxy, which can give us important information on the structure and evolution of the Milky Way. The systematic discovery of metal-poor stars began with the search for high-velocity objects in catalogs of high proper motion stars. The deliberate search for extremely metal poor stars by objective-prism surveys began with Bond (1970), who recognized the importance of such stars as relics of the earliest Galactic evolution. The method was later extended to fainter stars by adding an interference filter that isolates the Ca II H and K lines with wavelength coverage of 15 nm (Preston & Shectman 1977; Beers 1999). The HK prism survey was finished by using the 0.6 m Burrell Schmidt telescope in the northern hemisphere and the 0.6 m Curtis Schmidt telescope in the southern hemisphere. The survey limited by relatively "bright" magnitude limit of B < 15.5. Beers and his collaborators (Beers & Christlieb 2005) found about 1000 stars with [Fe/H] < -2.0 by visual detection of Ca II H and K lines. Rhee et al. (1999) re-analyzed the data from objective prism spectroscopic survey by the method of a combination of automated scans and 2MASS colors. They found about 2000 stars with [Fe/H] < -2.0 through Artificial Neural Network analysis. Another large scale objective-prism

survey is the Hamburg/ESO Survey (HES), which started in 1989 with aim of finding bright quasars ($B_J > 17.5$) with the ESO 1m Schmidt telescope. This survey is ideal for searching for metal-poor stars because of the low star number density at high latitude ($|b| > 30°$). There are total of 383 plates with a $5° \times 5°$ coverage each. This deep wide-field objective prism survey of the southern sky gives a 7500 square degree area. With machine scanned and an automatically classified method, Christlieb et al. (2001a, b) analyzed a total of 4 000 000 stellar spectra. They found about 10 000 metal-poor star candidates with [Fe/H] < -2.0 from these spectra since the methods used are a highly efficient selection of metal-poor, FHB/A stars, carbon-enhanced stars, etc.

The LAMOST project (see Fig. 1) provides a wonderful chance to improve our understanding on these exciting topics of the Galaxy. This review paper will give readers a general idea about the LAMOST instrument and its scientific motivations in the Galactic astronomy. In Sections 2.1 and 2.2 we give a brief description of the performance of the LAMOST low-resolution spectrograph (hereafter LRS) and medium resolution spectrograph (hereafter MRS), respectively. In Section 3 we propose and emphasize some important potential scientific subjects related to stellar abundances and the Galactic chemical evolution, which will be taken with the LAMOST spectroscopic survey. The concluding remarks concerning the project are presented in the last section.

Fig. 1 LAMOST model. Left: exterior view; Right: optical part with encloser.

2 THE STRATEGY OF LAMOST SPECTROSCOPIC SURVEY ON GALACTIC ASTRONOMY

LAMOST is a national key project started in 1997. Its main features are unique in combining large aperture (4-meter) with wide field of view (5-degree) and equipped with unprecedentedly large number of a 4000-fiber spectrograph. There are two important technical innovations in LAMOST: the active optics for the segmented thin mirror and the parallel controllable fiber positioning. LAMOST can provide 4000 spectra of objects down to V$\sim$ 20.5 with 1 nm spectral resolution in a 1.5-hour exposure, which break through the bottleneck of ever-increasing need for spectroscopic observations in astronomy.

2.1 Low Resolution Spectroscopic Survey with LAMOST

There are total of 16 LRSs with two 4K × 4K CCD (9 μm/pixel) each attached to LAMOST. We present the main characteristics of the low resolution spectrographs in Table 1. The consequent columns are the slit width, the resolving power and the wavelength coverage for the blue and red arms, respectively. The optical design of the LAMOST LRS is given in Figure 2.

One of the aims of LAMOST low resolution spectroscopic survey is to unravel the Galactic structure, the formation history of the Galaxy, the chemical and dynamical evolution of the Galaxy, and dark matter distribution in the Galaxy. With this motivation, we plan to observe about 5 million stellar objects with 16

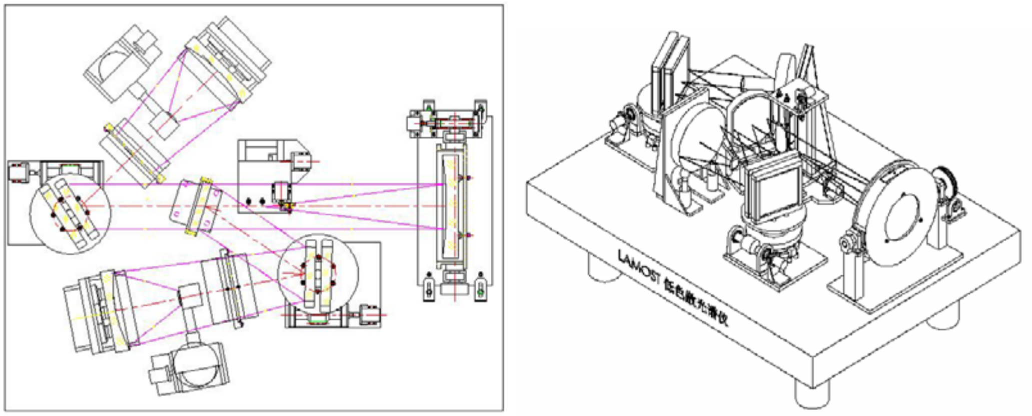

Fig. 2 Left: the optical path of LAMOST LRS. Right: the scheme of LAMOST LRS.

Table 1 Main Characteristics of Low Resolution Spectrographs (LRS)

	Blue Arm		Red Arm	
	R	Wave. range (nm)	R	Wave. range (nm)
Full slit	1000	370–590	1000	570–900
1/2 slit	2000	370–590	2000	570–900

LRS within three years. Through such a survey, various stellar objects can be observed with either of two resolution modes ($R = 1000$ and 2000), and a new star catalogue with Sp-type and [Fe/H] can be achieved.

One of the most important goals of this survey is the search for metal-poor star candidates based on LAMOST low resolution spectroscopic survey ($R = 1000 - 2000$). These extensive amounts of data of low resolution spectra will stimulate a revolution in the exploration of Galactic halo. Metallicities of stars may change in radial direction from the inner halo to the outer halo if the original sites of stars are different. Metallicity histograms of halo stars as a function of Galactocentric distance would allow models of halo formation to be developed and tested.

2.2 Medium Resolution Spectroscopic Survey with LAMOST

A medium resolution spectroscopic study for interesting stars with $R = 10\,000$ is a follow up observation based on all interesting candidates determined by the LAMOST low resolution spectroscopic survey. Especially, this kind of survey of metal-poor stars can unravel some important astrophysical problems, such as light element constraints on Big Bang nucleosynthesis, alpha- and iron-peak abundances of metal-poor stars, carbon formation in early-generation stars, the direct measurement of elemental yields of Type II SN, identification of astrophysical site(s) of the neutron-capture formation processes, efficiency of mixing processes in the early Galaxy, likely dominance of individual SN II, and the age of our Galaxy and the Universe.

A MRS consists of a LRS with a normal grating replaced by a volume phase holographic grating. We give the main characteristics of MRS in Table 2. The consequent columns in the table are the same as in Table 1.

Up until to now only 7000 stars were observed (one at a time!) with a spectral resolving power $R > 15\,000$ during the past 20 years. We plan to observe all metal-poor star candidates with B magnitude brighter than 18.5 m determined in the LAMOST low resolution spectroscopic survey. We can expect the number

Table 2 Main Characteristics of Medium Resolution Spectrographs (MRS)

	Blue Arm		Red Arm	
	R	Wave. range (nm)	R	Wave. range (nm)
Full slit	5000	510–550	5000	830–890
1/2 slit	10 000	510–550	10 000	830–890

of metal-poor stars with relatively high resolution spectra ($R \sim 10\,000$) will be increased by at least 1–2 orders of magnitudes through such a survey project.

3 STELLAR ABUNDANCE AND GALACTIC CHEMICAL EVOLUTION BASED ON LAMOST SPECTROSCOPIC SURVEY

Based on high resolution, high signal-to-noise ratio spectra obtained with CES of the 2.16 m telescope of the Xinglong station (Zhao & Li 2001), the Chinese astronomers achieved some valuable results through the abundance analyses for a large sample of halo and disk dwarf stars -"fossil" of Galactic evolution, in recent years (e.g. Zhao et al. 2000; Chen et al. 2004; Shi et al. 2004; Zhang & Zhao 2005). As a national key project, the LAMOST spectroscopic survey is expected to provide the most complete data about the stellar abundances and radial velocities in the Milky Way, and yielding great improvements in our understanding of the chemical and dynamical evolution of the Galaxy. The special design of LAMOST is suitable for wide field and large sample astronomy. Therefore, we propose a large scale spectroscopic survey project with this unique facility. Below, we present some scientific subjects related to Galactic astronomy that will be mainly considered in the survey.

3.1 The Distribution of Different Populations and Galactic Evolution

The origin and evolution of galaxies, such as our Milky Way, and of their associated dark matter halos are among the major outstanding questions of astrophysics. Modern theory of galaxy formation suggests that galaxies are formed from the processing of the merging of many small dwarf galaxies (e.g. White & Rees 1978). Our Galaxy might have accreted many such dwarf galaxies. These dwarf galaxies have their own origins and chemical evolution histories. The star formation history and merging history of the Galaxy are written in its stellar populations. Thus it is possible to understand the characteristics of different populations in the Galaxy by studying the chemical abundances, kinematics, and ages of a large sample of stars. Furthermore, low-resolution spectra of even larger sample of stars, combining their spatial distributions, provide us with useful information on the Galactic structure and the merging relics of our Galaxy with dwarf galaxies.

With the data from the LAMOST spectroscopic survey, one can investigate the Galactic structure and evolution by determining the abundances and the radial velocities of huge numbers of stars. Besides providing valuable data to the international astronomical community, this survey, combining with the future GAIA data, gives a powerful way to describe the spatial positions and other properties for stars with different abundances. With these data, stellar kinematics can be calculated and the metallicity distribution function in the Galaxy will be obtained. These provide important constraints on the present models of the Galactic structure, formation history, kinematical and dynamical evolution, chemical evolution, and the dark matter distribution in the Milky Way. This will also be an ideal data set for tracing the transitions from thin disk to thick disk, and to halo.

The finding of the extreme low metallicity stars with [Fe/H] < -5.3 (Christlieb et al. 2002; Frebel et al. 2005) indicates that at least some low mass stars could have been formed out of extremely low-metallicity gas. With LAMOST it will be productive to carry out a survey for metal-poor stars in the Galaxy. Systematic analysis of a large sample of spectra of metal-poor stars gives the metallicity distribution of halo stars and initial mass function, which will improve our understanding on the early evolution of the Galaxy. By studying the abundance patterns we can distinguish from the theoretical yield calculations. Furthermore, by quantitatively comparing the observed patterns with simulations, it should be possible to reconstruct the supernova yield ratios. At present, the first generation stars formed after the Big Bang have not been found and this is one of our main goals with a great effort to search for it. If some first generation stars still remain, their lifetimes should be longer than 14 Gyr and thus they are unevolved and record the primordial information on the formation and evolution of the Galaxy. Through this survey plan, the number of metal-poor stars will be increased considerably.

3.2 The Spectroscopic Study of the Galactic Thick Disk Stars

The existence of a population of stars with kinematics, ages, and chemical abundances between the characteristic values for the halo and the disk populations is a long-standing problem in studies of Galactic structure and evolution.

Observational works from the 1980's showed that the Galaxy has two disk-like components. The first evidence for the second disk population was claimed by Gilmore & Reid (1983) who discovered that the stellar number density distribution as a function of distance from the Galactic plane was well fitted by two components with scale heights of 300 pc and 1300 pc, respectively. The latter component was identified as a Galactic thick disk, as a complement to the more well-known thin disk. Following this work, it has been intensively discussed whether the thin and thick disks are discrete components of our Galaxy or if there is a more continuous sequence of stellar populations connecting the Galactic halo and the thin disk.

The formation scenario of the Galactic thick disk is an unresolved problem (Majewski 1993). There are essentially two major formation scenarios for the Galactic thick disk: the pre-thin disk (top-down) models and the post-thin disk (bottom-up) models. Much more work on stellar ages, kinematics, and abundances has to be carried out before we can be sure about the basic scenario for the formation and evolution of our Galaxy.

The study of chemical abundances in long-lived dwarf stars of thin and thick disks provides information of Galactic disk formation and becomes an active area in recent years. A strong indication of the thin and thick disks as discrete populations with respect to kinematics and age came from Edvardsson et al. (1993). The following works showed systematic differences between the chemical composition of the thin and thick disk stars (e.g. Fuhrmann 1998, 2004; Mashonkina & Gehren 2001; Bensby et al. 2003; Gehren et al. 2004). There has been much effort expended in this field in the last decade. Although the abundance differences of some elements for the thin and thick disks stars are quite compelling (see the comprehensive review paper by Nissen 2003), the evidence from these studies points in conflicting directions. Due to a large number of factors involved, it is necessary to study a large sample of stars in a relatively homogeneous way. One should note that some studies mentioned above have selected stars with extreme kinematics to make it possible to classify stars as belonging to either the thin or thick disk populations. Thereby, the conclusions may be affected by a kinematical bias. It would be very interesting to make in situ studies of abundances and kinematics of stars in the various places of the thin and thick disks, such as the low-resolution spectroscopic survey of the stars situated at 0.5–5 kpc from the Galactic plane (Gilmore et al. 2002) and the spectroscopic study based on SDSS survey (Allende Prieto et al. 2006).

The spectroscopic survey with LAMOST covers stellar objects with brightness down to $V{\sim}20.5$ and comprises a large number of F- and G-type stars with a scale height of 0.5–2 kpc that essentially belong to the thick disk of the Galaxy. In such a sample no kinematic bias would be present as at these heights the thick disk dominates over the thin disk and stars could be chosen without selections based on kinematics probabilities. Starting from the spectra of the stars, the radial velocities are measured and the stellar atmospheric parameters (effective temperature, surface gravity, and [Fe/H]) are directly disentangled with reasonable accuracy through spectral analysis, and even the abundance ratios of chemical elements or groups of elements also are determined. Stellar evolution theory allows us to constrain interesting stellar parameters such as masses, radii, and ages, once the atmospheric parameters have been derived. The element abundances combined with the ages, kinematics, and space densities of the unbiased thick disk sample will set substantially tighter constraints on the models of Galactic thick disk formation and evolution.

3.3 Extremely Metal-poor Stars and Nucleochronology by Radioactive Elements

The most metal-poor stars carry the "fossil" record of the chemical composition of the Galaxy, and hence allow one to study the earliest epochs of Galactic chemical evolution. The crude metallicity (or heavy elements) for stars can be obtained from low resolution spectra so that a large sample of candidates of the extremely metal-poor (hereafter EMP) stars can be selected by the LAMOST spectroscopic survey. Specifically, we plan to probe the age scatter, kinematical grouping and abundance diversion for a very large sample of EMP stars selected by LAMOST. In addition, EMP stars are among the oldest stellar objects known; they can be used as natural laboratories for testing the theory of stellar evolution.

Meanwhile, EMP and other interesting stars identified through LRS spectra will be observed at high resolution. LAMOST will be equipped with an $R \sim 60\,000$ high resolution spectrography (hereafter HRS) which enables us to obtain the high resolution and high signal-to-noise spectra of bright EMP stars. In cooperation with international large telescopes, it has become feasible to derive abundances of heavy elements for a large sample of fainter EMP stars in a reasonable time. Our main goals are threefold. First, it is important to investigate the scatter in the element-to-element abundance ratios for EMP stars, which might reveal a wealth of data for nucleosynthesis. For example, a very large scatter in [Sr/Fe] for EMP stars is not found in other elements that can be produced by the s-process. A proper understanding of this scatter requires a large number of sample stars and high precision abundance analysis. Second, abundances of many interesting heavy elements, such as Mo, Lu, Au, Pt, Pb, Ga, Ge, Cd and Sn, are lacking and the [X/Fe] vs. [Fe/H] trends have not been well established. LAMOST may provide enough samples of such stars for this purpose. Last, the relative contribution ratios of r-process to s-process at low metallicities, which provides hint on the characteristics of early SNe, can be studied by some special neutron-capture elements (e.g. Ba and Eu). In this respect, interesting stars, such as those extremely rich in r-process elements and some extreme CH stars, which can be used to study the s-process, are useful to explore this problem.

Furthermore, there are two cosmological applications for EMP stars: (i) the determination of the primordial lithium abundance constraining the baryon density parameter, and (ii) individual age determinations setting a lower limit to the age of the Universe. It is interesting to investigate the Li abundances for large samples of extremely metal-poor dwarf stars with [Fe/H]< -3.0 because WMAP recently gave a primordial Li abundance by 0.4 dex higher than the Li plateau than that obtained from metal-poor stars with temperatures higher than 5600 K. Our second emphasis will focus on the age determinations. The abundances of certain long-lived radioactive elements, such as thorium and uranium, act as nuclear chronometers and provide direct age determinations of EMP stars. Presently, there are still large uncertainties in chronometric age estimates. The reliability can be improved by two ways. One is enlarging the numbers of stellar detections of Th and/or U and the stable third r-process peak elements necessary to constrain theoretical predictions. Another is improving the precision of abundance determinations. The present models for both stellar interiors and stellar atmospheres should be revised theoretically and empirically besides obtaining high quality spectra observationally. For example, the stellar atmospheric model with the opacity distribution function should be tested by comparison with solar observations before the model can be used for abundance analysis. On this basis, by improving the quality of stellar spectra and adopting new analysis methods, it is possible to determine the stellar ages of EMP stars and provide the lower limit to the age of the Universe with relatively high precision.

3.4 NLTE Effects in Atmospheres of Late Type Stars

With the improvements to the signal-to-noise ratios of the stellar spectra and the accuracy of the oscillator strengths of the atomic lines, the assumption of the local thermodynamic equilibrium (LTE) is becoming a very important problem in the field of abundance analysis. Since many elements deviate from the LTE assumption, the precision and the reliability of using these elements as tracers of the evolution of the Galaxy are greatly reduced. Departures from LTE are commonplace and often quite serious, in particular for stars with low surface gravities or metallicities. Stars with minority species and low-excitation transitions being the most vulnerable (Asplund 2005). As mentioned above, the NLTE effect has significant influences on the determination of the age of the Universe when using metal-poor stars. If this effect depends on $\log g$ and [Fe/H], the NLTE will affect the accuracy of $\log g$ determination by altering the ionization equilibrium of Fe II and Fe I lines. Therefore, the first solution to the determination of stellar positions in the HR diagram with a high precision is the NLTE problem. In particular it is important to investigate the NLTE effects for neutral lines of Li, O, Na, Mg, Al, K and Fe.

Lithium plays several important roles as a diagnostic of stellar and Galactic evolution. As lithium has a low ionization potential, the NLTE effects can be expected to be important (Carlsson et al. 1994; Asplund et al. 2003). Recently, Barklem et al. (2003) found the collisional excitation and de-excitation

($\mathrm{Li}^*+\mathrm{H}\rightleftharpoons\mathrm{Li}^*+\mathrm{H}$) reactions are negligible for the line formation process, while the charge transfer reactions ($\mathrm{Li}^*+\mathrm{H}\rightleftharpoons \mathrm{Li}^++\mathrm{H}^-$) are of importance in thermalizing lithium. It is found that the NLTE effects are negligible for metal-poor stars (Shi et al. 2006). However, it is important for lithium rich stars (Carlsson et al. 1994). Particular care must be exercised in analyses of sodium, aluminum, and potassium, especially with the resonance Na I D lines at 589 nm, Al I at 396 nm and K I at 770 nm. The NLTE abundance correction for Na I D lines is about -0.05 for the Sun, but reaches -0.15 for dwarfs with [Fe/H]~ -1 (Shi et al. 2004; Takeda et al. 2003). Taking into account these NLTE effects, a significant underabundance of sodium at low [Fe/H] was found (Gehren et al. 2004). Analyses adopting the LTE assumption for Al and K are often widely misleading. At solar [Fe/H], the NLTE abundance corrections for the Al 396 nm resonance line are about $+0.1$ dex but they reach $+0.4$ dex for dwarfs with [Fe/H] < -1; the corrections approach $+0.8$ dex for mildly metal-poor turn-off stars (Gehren et al. 2004). The NLTE corrections of [K/Fe] are around -0.10 to -0.50 dex for metal-poor stars (Zhang et al. 2006). For the elements, oxygen and magnesium, it has long been suspected that the most commonly used permitted O I triplet lines at 777 nm are not formed in LTE (Eriksson & Toft 1979). For the Sun the NLTE corrections for these lines are about -0.2 dex (Asplund et al. 2004), while it is reduced to about -0.1 dex when the hydrogen collisions from Drawin (1968) are included (Takeda 2003). The NLTE abundance corrections become larger toward higher T_{eff} and lower $\log g$. The most acute oxygen problem is found in metal-poor stars. The literature on the topic is extensive, and different results are obtained from different diagnostics. This problem is still unresolved. The NLTE effects for magnesium are small in the Sun. As expected, the corrections increase with decreasing metal abundance, and they increase slightly with decreasing surface gravity. For extremely metal-poor stars the abundance corrections approach 0.23 at [Fe/H] ~ -3.0 (Zhao et al. 1998, 2000).

The outstanding role of iron has made it a reference element for all astronomical research related to stellar nucleosynthesis and chemical evolution of the Galaxy. There is no doubt that Fe I lines are not formed in LTE in solar-type stars; the question is how severe are these departures. Using an extended iron atomic model, Thévenin & Idíart (1999) found that the NLTE effects are significant, and they depend on [Fe/H]. The abundance corrections reach to about $+0.3$ at [Fe/H]$= -3$. However, they did not consider the hydrogen collisions (S_{H} = 0). In contrast, Gratton et al. (1999), based on a much smaller iron atom model with exceedingly efficient hydrogen collisions (S_{H}= 30), found NLTE abundance corrections are negligible even at low metallicities, except at low gravities. Gehren and his collaborators instead tried to calibrate S_{H} using solar line profiles and ionization balances of stars with well-determined surface gravities (Gehren et al. 2001a, b; Korn et al. 2003). The scaling factor S_{H} is determined to be 3. The resulting NLTE effects are small: about $+0.03$ dex for the Sun and two halo stars (HD 140283 and HD 84937). When the hydrogen collisions are not included, the corrections are as large as $+0.46$ and $+0.40$ dex for those two metal-poor stars, respectively.

With the high quality spectra from the HRS of LAMOST, we will attempt to obtain high quality spectra for a sample of late type stars and carry out the NLTE calculations for those interesting elements. Specifically, the statistical equilibrium processes for the neutral lines of Li, O, Na, Mg, Al, K, and Fe have to be calculated in order to estimate their NLTE effects. The key problem in this study is to establish a reliable atomic model for NLTE line analyses. This procedure requires a large amount of updated empirical atomic data and computing time. With these improvements, reliable abundances and NLTE corrections for above elements can be derived by profile fitting to the observed spectra for stars with different parameters. The NLTE corrections are then tabulated as a grid in terms of stellar parameters. Then NLTE effects can be corrected for stellar abundances determined from the medium resolution spectra of LAMOST and LTE models by interpolating in this grid according to the stellar parameters.

3.5 The Abundances of Planetary Host Stars

The investigation of planetary host candidates is currently one of the hottest topics in astrophysics. Most studies of abundance analyses of planetary host stars indicate that their metallicities are higher than the mean value of normal field stars in the solar neighborhood. It is suspected either stars with high metallicity are favored to form the planetary system, or the formation process of planetary system enhances the surface metallicity of the host stars The abundance patterns of the planetary host stars will provide a way to test these two mechanism (e.g., Fuhrmann 1997; Chen & Zhao 2001). In addition, age, kinematics, and other information can be used to study the main properties of such stars (Chen & Zhao 2002).

Unfortunately, the number of currently-known planetary host stars is around 150 and it is difficult to obtain some statistical meanings from such a sample. As mentioned above, planet formation may be a widespread phenomenon in the universe and the present technique of planet search is limited by their low efficiency. Fortunately, astronomers have recently developed a new technique by using a dispersed fixed-delay interferometer (FDI) which enables us to detect planet stars with very high efficiency (Ge 2002). The design of wide field and multiple objects of the LAMOST telescope, equipped with FDI, is wonderful for the survey of planetary host stars. In addition, the extension of SDSS survey will focus on the search for planetary host stars with FDI technique. Therefore, in the coming years, we can expect that the number of such stars will be increased dramatically.

The MRS of LAMOST are desirable to obtain the spectra of very large samples of planetary host stars. Ages, kinematics and abundances can be derived and they will provide the characteristics of their properties and nature. It is possible that planetary formation may have different scenarios, and these observational data can be used to distinguish different formation processes and the fraction of planetary formation in each scenario.

With LAMOST HRS, it will be interesting to determine accurate abundances of a large samples of planetary host stars and to discover important information on planet formation. The differential analysis between planetary host stars and stars without detected planets will be fruitful, even if there are only small differences in abundances of the two different kinds of stars. In view of this, we will attempt to derive abundances of elements for as many as possible of the 50–100 typical planetary host stars formed by different scenarios. Moreover, after we understand the nature of planetary host stars, we can estimate how the chemical evolution of our Galaxy is affected by the presence of a large sample of planetary host stars. For example, planetary host stars with different locations may have different probabilities and different influences of the chemical abundance in local regions. Finally, it will be interesting to investigate how stellar evolution is affected by the presence of planets, and thus provides new constraints on the theory of stellar evolution.

3.6 The Radial Velocity and Abundance of Open Clusters

Open clusters (OCs) have long been used to trace the structure and evolution of the Galactic disk (Friel 1995). Since open clusters have relatively large age spans while the cluster ages can be relatively accurately dated and one can see them to large distances, their [Fe/H] values serve as excellent tracers of the abundance gradient along the Galactic disk, as well as many other important disk properties, such as the age-metallicity relation (AMR), abundance gradient evolution, disk age, and so on (Carraro et al. 1998; Hou et al. 2002; Chen et al. 2002).

In comparison, the field disk populations are also able to trace the disk evolution. Indeed, the extensive studies by Edvardsson et al. (1993) and by Chen et al. (2000), who concentrate on disk F and G stars, showed an overall radial gradient that is nearly independent of age. Those results are based on stars mainly restricted to the solar neighborhood. However, results from these studies are strongly affected by selection effects and rely on the techniques for determining individual stellar distances that are heavily dependent on the adopted Galaxy potential model; those techniques are much less reliable than those used to obtain cluster distances. Moreover, the effect of orbital diffusion of stars makes a gradient shallower over time, and the cluster population offers a more viable means for finding detailed structure within the recent Galactic abundance gradient.

Recently, Chen et al. (2003) have compiled a most complete open cluster sample with metallicities, ages, and distance data, as well as kinematic information available, from which an iron radial gradient of about 0.063 ± 0.008 dex kpc^{-1} is derived. This is quite consistent with the recent determinations of the oxygen gradient in nebulae and young stars. By dividing clusters into age groups, they showed that the iron gradient was steeper in the past, which is consistent with the results from Galactic planetary nebulae data. Their result supports the inside-out Galactic disk formation mechanism, in which the invoked star formation rate and infall timescale vary with radius.

However, the sample of open clusters with determinations of distances, ages, and chemical or kinematical properties available is quite small, namely less than about 10% of the total known open clusters. Currently the paucity of metallicities of very old open clusters makes it impossible to give a definite conclusion about the age-metallicity relation. Also, the lack of inner- and outer-disk region candidates increases the difficultly to judge the radial flow effect on the current Galactic chemical evolution models. In particular, more old and far away cluster samples with abundance values are needed to derive a much better disk metallicity gradient.

With the great ability of spectroscopic observation with LAMOST, one will expect to explore a much larger sample of open clusters, about 600 in number, to obtain stellar radial velocities as well as abundance information of stars brighter than $R \sim 16$ in each cluster field, for about 10^6 stars in total. This large amount of up-to-date homogeneous data would lead to the most reliable membership determination for sample clusters, using accurate radial velocity data. These, then will significantly purify the color-magnitude diagrams of hundreds of open clusters and provide the best basis for obtaining the essential parameters of clusters, such as distances and ages.

From this observational database, we can investigate the disk metallicity gradient as well as its spatial variation and temporal evolution, thus providing key constraints on the chemical evolution model of the Galaxy. Furthermore, the Galactic age-metallicity relation, the kinematic and dynamical characters of the Galactic disk as well as their relation to the chemical properties will also be improved greatly.

3.7 Interstellar Extinction and Abundances

In 1922, Heger observed two broad absorption features centered at 578.0 nm and 579.7 nm, conspicuously broader than atomic interstellar absorption lines. This marked the birth of a long standing astrophysical mystery – the diffuse interstellar bands (DIBs). Not until the work of Merrill (1934) were the interstellar nature of these absorption features established. So far, over 300 DIBs have been detected from the near infrared to the near ultraviolet, with the best studied being at 442.8, 578.0, 579.7, 617.7, 628.4 and 862.0 nm. Despite 83 years of effort, no definite identification of the carrier(s) of DIBs have been found (see Li 2005a for a review).

LAMOST will provide us with an excellent opportunity to obtain a large data sample of DIBs. This will allow us to derive the interstellar extinction throughout the Galaxy based on the close correlation between the strength (equivalent width) of DIBs with the interstellar reddening (e.g., see Munari 2000), and probably also help constrain the nature of the carrier of DIBs.

Elements in the interstellar medium (ISM) generally exist in the form of gas or dust. The interstellar gas-phase abundances of elements can be measured from their optical and ultraviolet spectroscopic absorption lines. The elements "missing" from the gas phase are bound up in dust grains - this phenomenon is often called "interstellar depletion". The determination of the dust-phase abundances ("depletion") is indirect and more complicated. One usually relies on the interstellar extinction modelling or the solid-state spectral feature analysis. Both methods require an explicit assumption of the nature, such as grain composition, size and geometry, and the physical characteristics of the grains, such as their optical properties and the strengths of their characteristic vibrational bands usually determined from their laboratory analogs. More commonly, the dust-phase abundance of an element is derived by assuming a reference abundance - total abundance of this element (both in gas and in dust) for the ISM, and then from subtracting off the observed gas-phase abundance (see Li 2004 for a review).

Interstellar depletions allow us to extract important information about the composition and quantity of interstellar dust (see Li 2004 for details). Apparently, in interstellar depletion and dust composition studies the knowledge of interstellar reference abundances is critical. Historically, the solar abundances have been taken to represent the total interstellar abundances. It has recently been suggested that the interstellar abundances might be better represented by those of B stars due to their young ages, which are just 60–70% of the widely adopted solar values ("subsolar"). On the other hand, the most recent estimates of the solar carbon and oxygen abundances are also close to those of B stars. If the interstellar abundances are indeed "subsolar" like B stars or the newly-determined solar C, O values (Asplund et al. 2005), there might be a lack of raw material to form the dust to account for the interstellar extinction (see Li 2005b).

The LRS and MRS spectra from LAMOST will be capable of measuring the gas phase abundances of some dust-forming elements of various types of stars and the ISM itself. This will allow us to study the interstellar reference abundances and to infer possible grain composition.

3.8 The Merging History of Our Galaxy

One of the most famous formation scenarios of our Galaxy is ELS model. In this scenario, the Galaxy was formed from a huge gas ball with uniform density and high collapse velocity, and the halo stars were formed in the early stage during the collapse process; then the disk stars were formed in the later stage. However, Searle & Zinn (1978) suggested another scenario, in which the Galaxy was formed through the collision of dozens of small galaxies. More and more observational data have been published, leading us to propose the general accepted scenario about the formation of the Galaxy. That is, the outer halo was formed by collision and accretion of small galaxies, and the inside part was formed by the rapid collapse with dissipation.

The Galactic halo is the best place to study the merging history of our Galaxy. Several groups have undertaken large-scale surveys to uncover substructure in the halo. These include, among others, the "Spaghetti" survey (Morrison et al. 2000), the APM (Automatic Plate Measuring) carbon star survey (Totten & Irwin 1998; Totten et al. 2000; Ibata et al. 2001a) and the SDSS (Yanny et al. 2000; Ivezic et al. 2000; Ibata et al. 2001b). The Milky Way is merging with at least one satellite galaxy at the present day, namely the Sagittarius dwarf spheroidal galaxy (Ibata et al. 1994). This tidal interaction has produced, and is producing, thin streams, or tidal arms, that can be traced across the sky (Majewski et al. 2003). The APM carbon star survey, a sky survey that is almost all high-latitude, revealed the existence of a gigantic band of these intermediate-age ($\sim$ 6 Gyr) stars around the sky. Based on the second incremental data release of 2MASS, Ibata et al. (2002) processed a pole-count analysis of M-giant stars selected by color, which revealed a strong stream of stars along the orbit of the Sagittarius dwarf galaxy. Future radial velocity measurements of these C and M-stars will easily allow us to discriminate stream from halo or foreground stars. Our LAMOST survey will greatly improve the number of faint halo sources and allow us to identify individual streams from their kinematic signatures with the accuracy of 10 km s $^{-1}$ obtained by using the MRS spectroscopy. Moreover, the detailed chemical abundance studies of these stars, if they are available, will help much to explore the collision history of other dwarf galaxies with the Galactic halo. Recently, the studies based on SDSS database have made important progress on the mergering history of our Galaxy. Juric et al. (2005) mapped the three-dimensional number density distribution in the Galaxy on the basis of the distances of $\sim$48 million stars estimated using the photometric parallax method, and they found a remarkable density enhancement covering over a thousand square degrees of sky detected towards the constellation of Virgo. Based on the color-magnitude diagram (CMD) of F turnoff stars, Newberg et al. (2002) pointed out that four among the five overdensity structures may be pieces of the Sagittarius stream, and the new structure could be a new dwarf satellite of the Milky Way. Xu et al. (2006) studied the Galactic structure using star counts on the basis of the SDSS-DR4 database. They found that the direct statistics of the data in 10 strips at Galactic latitude of +60° show that the surface densities of l from 180° to 360° are systematically higher than those from 0° to 180°, defining a region of oversensity (in the direction of Virgo) and another one of underdensity (in the direction of Ursa Major) with respect to an axisymmetric model, and the star counts are performed using a theoretical triaxial halo model. The medium resolution spectrograph attached to LAMOST will provide spectra for large set of halo stars, which enables us for the first time to obtain the detailed abundances of large samples of such stars. The observable magnitude limit will be deeper than the SDSS, and the medium resolution spectrograph for elemental abundances could help us to study more about the merging and accretion processes of the Galaxy.

Furthermore, we can study the merging history of our Galaxy through the Galactic chemical evolution model. The merging processes of dwarf galaxies with the Milky Way are the building blocks of the formation and evolution of galaxies and they play crucial roles on frontier of many research fields, such as the structure and evolution of the Galaxy and the searching for the first generation stars. One of the main tasks of LAMOST is to identify the populations caused by the accretion events of the Galaxy from satellite galaxies. Notice that the merging of the Galaxy with nearby dwarf galaxies will greatly reduce the probability of the detection of the unevolved first generation stars; until now we have not detected any such stars. Based on the fact that the Galaxy is merging with dwarf galaxies and on the chemical evolution model of the Galaxy, we suggested that the chemical enrichment resulted from both the self-enrichment within the Galaxy and the merging events with dwarf galaxies. As compared with the observational results, we can obtain the probability of the detection of the first generation stars, the metallicity distribution of metal-poor stars, and the total number of satellite galaxies in the local group of galaxies. At present it is difficult to carry out directly the spectral observations of the merged dwarf galaxies; the average metallicity of such galaxies can only be obtained through the method of the population synthesis. With our knowledge of the Milky Way, it is possible to investigate the chemical evolution of dwarf galaxies and to establish a reasonable and consistent model for the dwarf galaxies which will provide the theoretical basis for the identification of accreting populations by the Galaxy with the LAMOST spectroscopic survey in the near future.

3.9 The Chemical Evolution of the Galaxy

The chemical evolution of galaxies can be traced by the trends of elemental abundances with time. It is efficient to establish a simple model of the chemical evolution of galaxies to reproduce the observational phenomena. The Galactic Chemical Evolution (GCE) model has been developed significantly since the "closed-box model" was suggested by van den Bergh (1962) and Schmidt (1963). The subsequent GCE models considered many more details about the formation and evolution of the Galaxy. They are the "prompt initial enrichment of metals model" (PIE model) (Truran & Cameron 1971), the "infall model" (Larson 1972; Liang et al. 2001; Chang et al. 2002), the "double-infall model" (Chiappini et al. 1997; Chang et al. 1999), the "delayed- mixture model" (Thomas et al. 1998), the "chemodynamical model" (Samland et al. 1997), and the "chemo-spectrophotometric model" (Boissier & Prantzos 1999), etc. The basic idea of these GCE models is to understand better the formation and evolution history of our Galaxy by explaining as many as observational phenomena as possible. For example, the standard infall model suggested by Liang et al. (2001) explains well some of the basic phenomena of our Galaxy, such as the age-metallicity relation, the oxygen abundances of field dwarf stars, and the metallicity distribution of G-dwarfs in the solar neighborhood. These observed phenomena can be considered as the basic constraints for the GCE model. Although great progress has been made for GCE model and for the questions it trys to solve, many debates and questions still exist, for the global and some detailed properties of the Galaxy.

Generally, the standard infall models of the GCE mainly include six basic parameters: the initial conditions, the stellar initial mass function (IMF), the star formation rate (SFR), the infall time scale, the stellar life time, and the nucleosynthesis yields of the stars with different masses. In principle, one can focus on any of these parameters to study the GCE models. We will pay more attention on the stellar nucleosynthesis yields and associated IMFs, because only the stellar nucleosynthesis yields can be obtained from the first-hand calculations (Goswami & Prantzos 2000; Liang et al. 2001). Calculations for the yields of different mass stars have been developed in the past years. Also one may need top-heavy IMFs to understand the early evolutionary stage of our Galaxy.

We have studied the sources of CNO elements on the basis of the GCE model by considering the published nucleosynthesis yields of different mass stars (Liang et al. 2001). However, from the present published nucleosynthesis yields, one cannot distinguish clearly whether the main source of carbon in the late Galactic stage is the massive stars ($M > 8M_{\odot}$) alone, or the intermediate- and low-mass stars ($M < 8M_{\odot}$) together with the massive stars of $8M_{\odot} \leq M \leq 40M_{\odot}$ that do not go through the Wolf-Rayet stage. Some recent improvements about the yields of stars have been made and provided new clues for understanding the source of carbon. In particular, stellar rotation and magnetic fields have been considered in the stellar evolution and nucleosynthesis of massive stars (Meynet & Maeder 2005; Hirschi et al. 2005), which changed the yields of CNO elements of massive stars and hence the results of the GCE calculations. Furthermore, the nucleosynthesis yields of Pop. III stars published recently (Picardi et al. 2004; Chieffi & Limongi 2004) will help to trace the chemical evolution of our Galaxy at the extreme early stage by combining with the top-heavy IMF (Akerman et al. 2004). Our LAMOST medium resolution spectroscopic survey will produce a huge set of data for elemental abundances, including carbon, of stars to study the chemical evolution history of our Galaxy. Also, the large database of carbon of stars obtained from this single facility will minimize the effect from the various observing facilities for the large scatter of [C/Fe] abundances at the given [Fe/H] in the previous observational results. We then can focus more on the intrinsic properties.

These published new nucleosynthesis yields will help us to understand better the source of nitrogen as well. Nitrogen consists of primary and secondary components. It will be the primary component when its production does not relate to the original CNO elements; conversely, it will be secondary component if it does so relate. The present observational [N/Fe] vs. [Fe/H] abundance relations of field dwarf stars put the sources of N in a confused situation. If we believe that the present observational results exhibit an independent [N/Fe] on [Fe/H] (see fig. 10 in Liang et al. 2001), then the present nucleosynthesis yields of massive stars and the GCE model cannot provide the "requested" primary components of N; however, if we neglect the big scatter of [N/Fe] of the metal-poor stars caused by some special N-rich stars, the [N/Fe] trend then shows a negative correlation with [Fe/H], which is consistent with the present GCE model result. These N-rich stars may come from three sources: 1) the interior material was mixed to the surface; 2) binary accretion; 3) primordial abundant nitrogen. Some GCE models have tried to explain the recent new N abundances of some metal-poor stars published by Spite et al. (2005). For example, Chiappini et al. (2005) considered rotation of stars to explain the important primary N of these small samples of halo stars. Similar to carbon mentioned above, the large set of homogeneous data from one single highly-efficient facility will minimize the effects of various observing instruments in the scatter of nitrogen abundance at the given metallicity.

Not only for carbon and nitrogen mentioned above in detail, the evolutionary behavior of many other kinds of elements could provide much more information on the evolution of our Galaxy. The GCE model will be a useful tool for this. The numerous data about the abundances of a huge sample of stars that will be obtained by the LAMOST medium resolution spectroscopic survey will provide many more new and strong observational constraints, by which we could study the origins of many kinds of elements, including C, N, O, Na, Mg, Al and neutron capture elements such as Sr, Zr, Ba, and so on, and to understand the formation of Galactic halo and the abundance properties of the thin and thick disk stars. We can also understand more the inside-outside forming scenario of the Galactic disk by studying the abundance trends of the stars following the radius of the disk.

4 CONCLUDING REMARKS

In summary, stars in the Galaxy are the fossil remains of the structure and evolution of the Galaxy. The investigation of a large sample of stars with different types, for example, stars on different evolutionary stages in the Galactic halo, disk and bulge, stars with chemical anomalies and stars with planets, will enrich our understanding of the frontier of fields in modern astrophysics, such as the chemical evolution of galaxies, the structure of Galaxy, stellar nucleosyntheses, etc. The future LAMOST spectroscopic survey will provide us an opportunity to realize above presented ambitious goals.

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