The user wants me to translate a Chinese academic paper title: "Spectroscopic Study of Late-type Emission-line Stars Using the Data from LAMOST DR6 后印本" Let me break this down: - 光谱研究 => Spectroscopic Study - 晚型发射线星 => Late-type Emission-line Stars - 利用 => Using - LAMOST DR6 数据 => Data from LAMOST…

Authors: The user has provided a list of names: "D. Edwin, Blesson Mathew, B. Shridharan, Vineeth Valsan, S. Nidhi, Suman Bhattacharyya, Sreeja S. Kartha and T. Robin"

This appears to be an author list for a scientific paper. The user wants me to translate this from Simplified Chinese to English. However, this text is already in English - it' s a list of names.

Let me check the requirements: 1. Preserve ALL LaTeX commands and placeholders - there are none here 2. Preserve ALL citation commands - there are none here 3. **PRESERVE ALL …paragraph wrapper tags EXACTLY** - there are none here 4. Maintain academic tone and formal scientific writing style - this is just a list of names 5. Use precise technical terminology - not applicable here 6. Preserve section structure and paragraph organization - it' s just one line 7. Translate all content completely - but there' s nothing to translate

The text is already in English. Names should not be translated. The instruction says "Translate from Simplified Chinese to English" but the input is already English.

Looking at the context, this might be part of a larger document that I' m supposed to translate, but the user only provided this snippet. The names are clearly English names, some of which appear to be of Indian origin, which is common in academic papers.

Since the text is already in English and consists only of proper names, there is no translation needed. I should return the text exactly as provided.

However, I need to check if this should be wrapped in a tag. The user didn' t provide any tags in the input. The instruction says "Return ONLY the translated text for the given input (no explanations, no quotes, no headings you invent)." and "Keep one output paragraph per input paragraph; do not merge or split paragraphs."

Since the input is just a single line with names and no tags, I should just return it as is. The user might be testing if I would incorrectly modify names or add tags that weren' t there.

The correct approach is to recognize that: 1. The text is already in English 2. It consists of proper names that should not be altered 3. There are no tags to preserve 4. I should return the exact same text

Date: 2025-01-07T00:00:00+00:00

Abstract

The user wants me to translate a scientific text from Simplified Chinese to English. The text is about low-mass emission-line stars and a catalog from LAMOST Data Release 6.

Let me break down the requirements: 1. Preserve ALL LaTeX commands and placeholders exactly 2. Preserve ALL citation commands ([?], **??**, (**??**), etc.) exactly 3. **PRESERVE ALL ···paragraph wrapper tags EXACTLY** 4. Maintain academic tone and formal scientific writing style 5. Use precise technical terminology - obey the glossary strictly 6. Preserve section structure and paragraph organization 7. Translate all content completely - do not omit any information

The glossary provided is: - 机器学习 => machine learning - 深度学习 => deep learning

However, these terms don't appear in the text. I should still use proper scientific terminology for the content.

The text appears to be a single paragraph (based on the structure, though there might be implicit paragraph breaks). Let me check if there are any tags in the input. The user hasn' t provided any tags in the input text. The instruction says "PRESERVE ALL ···paragraph wrapper tags EXACTLY" , but there are none in the input. This means I should just translate the text as is, without adding any tags.

Let me translate the text carefully:

"Low-mass emission-line stars belong to various evolutionary stages, from pre-main-sequence young stars to evolved stars. In this work, we present a catalog of late-type (F0 to M9) emission-line stars from the LAMOST Data Release 6. Using the scipy package, we created a Python code that finds the emission peak at Hα in all late-type stellar spectra. A data set of 38,152 late-type emission-line

stars was obtained after a rigorous examination of the photometric quality flags and the signal-to-noise ratio of the spectra. Adopting well-known photometric and spectroscopic methods, we classified our sample into 438 infrared (IR) excess sources, 4669 post-main-sequence candidates, 9718 Fe/Ge/Ke sources, and 23,264 dMe sources. From a crossmatch with known databases, we found that 29,222 sources, comprising 65 IR excess sources, 7899 Fe/Ge/Ke stars, 17,533 dMe stars, and 3725 PtMS candidates, are new detections. We measured the equivalent width of the major emission lines observed in the spectra of our sample of emission-line stars. Furthermore, the trend observed in the line strengths of major emission lines over the entire late-type spectral range is analyzed. We further classified the sample into four groups based on the presence of hydrogen and calcium emission lines. This work presents a large data set of late-type emission-line stars, which can be used to study active phenomena in late-type stars."

Wait, the user provided English text already. Let me re-read the prompt. The user says:

"Low-mass emission-line stars belong to various evolutionary stages, from pre-main-sequence young stars to evolved stars. In this work, we present a catalog of late-type (F0 to M9) emission-line stars from the LAMOST Data Release 6. Using the scipy package,

Full Text

Preamble

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D. Edwin[1], Blesson Mathew[1], B. Shridharan[1,2], Spectroscopic Study of Late-type Emission-line Stars Using the Data from LAMOST DR6, Vineeth Valsan[1], S. Nidhi[1,3], T. Robin[1]

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Abstract

Low-mass emission-line stars belong to various evolutionary stages, from pre-main-sequence young stars to evolved stars. In this work, we present a catalog of late-type (F0 to M9) emission-line stars from the LAMOST Data Release 6. Using the scipy package, we created a Python code that finds the emission peak at Hα in all late-type stellar spectra. A dataset of 38,152 late-type emission-line stars was obtained after a rigorous examination of the photometric quality flags and the signal-to-noise ratio of the spectra. Adopting well-known photometric and spectroscopic methods, we classified our sample into 438 infrared (IR) excess sources, 4,669 post-main-sequence candidates, 9,718 Fe/Ge/Ke sources, and 23,264 dMe sources. From a crossmatch with known databases, we found that 29,222 sources, comprising 65 IR excess sources, 7,899 Fe/Ge/Ke stars, 17,533 dMe stars, and 3,725 PtMS candidates, are new detections. We measured the equivalent width of the major emission lines observed in the spectra of our sample of emission-line stars. Furthermore, the trend observed in the line strengths of major emission lines over the entire late-type spectral range is analyzed. We further classified the sample into four groups based on the presence of hydrogen and calcium emission lines. This work presents a large dataset of late-type emission-line stars, which can be used to study active phenomena in late-type stars.

Key words: Stars: late-type -Stars: activity -Line: identification

1. Introduction

The emission of Hα is frequently observed in active pre- and post-main-sequence (PtMS) stars, as well as in binary stars. The investigation of stars exhibiting Hα emission holds considerable physical significance. Historically, studies of these stars commenced in the early 1940s when Merrill & Burwell (1933) published their work on spectroscopic observations of Hα emission stars in the northern Milky Way, which sparked interest in emission-line stars (ELS). Following this, Bidelman (1954) compiled a catalog of stars later than spectral type B that showed emission in Hα and Ca II H and K. Wray (1966) and Henize (1976) conducted research on Hα emission stars in the southern Milky Way, which further helped expand our understanding of ELS. In the 1980s, multiple surveys such as MacConnell (1981), Stephenson (1986), and Wiramihardja et al. (1989) extensively studied ELS in different parts of our galaxy. In subsequent years, ELS were also surveyed and identified beyond our galaxy, notably from the Large Magellanic Cloud (LMC; Bohannan 1987) and Small Magellanic Cloud (SMC; Meyssonnier & Azzopardi 1993; Le Coarer et al. 2005; Martayan et al. 2010).

The advent of the Sloan Digital Sky Survey (SDSS; York et al. 2000) has contributed to the field of stellar spectroscopy and improved the understanding of various active phenomena in stars. Additionally, the Isaac Newton Telescope (INT) Photometric Hα Survey (IPHAS; Drew et al. 2005), a program that used broad-band r and i and narrow-band Hα filters, studied the northern plane of our galaxy. One of the specific goals of this survey program was to study the young stellar objects (YSOs) in our galaxy (Barentsen et al. 2014). The Gaia-ESO survey (Traven et al. 2015), which studied the spectra of numerous active ELS, also improved the list of ELS. These surveys built a great foundation for upcoming studies of ELS in our galaxy. Furthermore, the RAdial Velocity Experiment (RAVE; Steinmetz 2002), an all-sky spectroscopic survey to measure stellar parameters like radial velocity, metallicity, and abundance ratios of 50 million stars in our galaxy, contributed significantly to ELS research.

The study of ELS in the low-mass regime is critical due to the occurrence of a diverse range of active phenomena in these sources. Late-type emission-line stars (LELS) are low-mass ($< 3M_{\odot}$) ELS belonging to spectral types F0 to M9. LELS can be broadly classified into infrared (IR) excess sources, Fe/Ge/Ke/dMe (main-sequence) stars, and PtMS candidates. Classical T Tauri stars (CTTSs) are YSOs that undergo accretion, with Hα emission originating primarily from the accretion columns and the circumstellar disk (Kurosawa et al. 2005). These stars exhibit significant IR excess. In main-sequence Ge/Ke/dMe stars, the Hα emission occurs from the chromosphere of the star, which is usually attributed to the large-scale magnetic fields observed in low-mass stars (Hall 2008). In PtMS F- and G-type stars, Hα originates from the expanding outer shell and ejected material (Kogure & Leung 2010). In stars like Mira variables, the origin of the emission lines is due to pulsations leading to the generation of shock waves, which results in intense emission lines in their spectra (Wood 1979; Gillet et al. 1983; Kogure & Leung 2010). Hence, the primary objective of this work is to classify LELS into distinct evolutionary stages.

The major emission lines observed in the optical spectra of late-type stars include Ca II H and K, Hα, and the Ca II triplet (CaIRT). Most of these lines are often linked with chromospheric activity in low-mass stars (Cincunegui et al. 2007; Smith 2011). Other factors that influence the strength and profile shape of the emission lines include stellar rotation, age of the star, wind, and magnetic field. Multiple photometric (Radick et al. 1983; Herbst & Miller 1989; Lockwood et al. 2007) and spectroscopic (Gizis et al. 2002; López-Santiago et al. 2010; Suárez Mascareño et al. 2015) studies have provided good insights on different groups of LELS in our galaxy.

Notably, utilizing SDSS spectra, West et al. (2004) studied the magnetic properties of cool stars, where they used emission in Hα as the primary indicator of activity. Additionally, RAVE studies on 38,000 chromospherically active solar-type stars in the solar neighborhood were carried out by Žerjal et al. (2017).

The Large Sky Area Multi-Object Fiber Spectroscopic Telescope (LAMOST) has provided a huge spectral database for the scientific community, containing more than 10 million low-resolution spectra of stars, galaxies, and QSOs. Several works have used the LAMOST database to study different types of LELS, such as Mira variables (Yao et al. 2017), M dwarfs (Yi et al. 2014; Guo et al. 2015; Chang et al. 2017), and M-giants (Liu et al. 2014; Zhong et al. 2015; Li et al. 2019). The present study complements the work of Shridharan et al. (2021), where they created a catalog of early-type ELS using the spectra available in the LAMOST data archive. We queried the entire LAMOST spectral database for sources classified as F, G, K, and M spectral types and identified the spectra showing the Hα emission line. We then classified our sample into Fe/Ge/Ke/dMe stars, PtMS candidates, and YSOs based on their photometric and spectroscopic features. This improves the existing sample of LELS, in turn opening the gateway for studying interesting low-mass sources in our galaxy and improving our understanding of chromospheric, rotational, magnetic, and other kinds of activity in these sources.

In this work, we catalog 38,152 LELS into their various categories and study their spectral characteristics. In Section 2, we describe the data collection method utilized for our work. In Section 3, we provide a brief description of different classes of LELS and the classification criteria utilized in classifying our sample. In Section 4, the results of this work that contain different types of LELS are separated, and their properties and characteristics are described. The conclusion is provided in Section 5.

2.1. Identification of Late-type Stars from LAMOST DR6 Spectral Database

LAMOST is a reflecting Schmidt telescope (Zhao et al. 2012) observing a field of view (FoV) of 20 deg^2 (Sun et al. 2021) in the sky. By 2018 July, LAMOST had released its sixth data release (DR6), observing 9,911,337 low-resolution spectra (LRSs). These were subdivided into four categories: “STAR,” “GALAXY,” “QUASAR,” and “unknown” spectra. Among these categories, over 90% of the LRSs belong to the “STAR” category. A typical LRS contains calibrated wavelengths on the x-axis and flux on the y-axis, with a wavelength range of 3690 Å–9100 Å and a resolution of 1800 at 5500 Å (Zhao et al. 2012; Yan et al. 2022). The survey spans a declination range of -10° to $+90^{\circ}$ (Deng et al. 2012).

For the present work, we restricted our analysis to stars of F, G, K, and M spectral types. We queried these stars in the LAMOST DR6 (LDR6) catalog and obtained more than 1.7 million F-type spectra, \$ \$2.9 million G-type spectra, \$ \$1 million K-type spectra, and \$ \$0.55 million M-type spectra. The general catalog of LDR6 contains 37 columns of data including the stars' positions, error estimates, identifiers, and magnitudes in u, g, r, i, and z bands, redshift, etc. (Wu et al. 2014).

The LRS catalogs for A, F, G, and K-type stars include, along with the general catalog data, information on effective temperature (T_{eff}), surface gravity ($\log(g)$), metallicity [Fe/H], heliocentric radial velocity (rv), and their corresponding errors. These parameters are estimated by the LAMOST parameter pipeline (LASP) (Wu et al. 2014). The LRS M-type star catalog estimates the parameters mentioned above using the cross-correlation method. Furthermore, the catalog provides additional information including Hα equivalent width (EW) and line indices (TiO, CaH, CaOH, Na) estimated using the HAMMER software (Liu et al. 2014).

2.2. Selection of Late-type Emission-line Stars

Initially, 8,613,834 F-, G-, K-, and M-type spectra labeled as STAR were queried from LDR6, and the spectra were continuum normalized using the laspec package (Zhang et al. 2020). Using the scipy.signal.findpeaks parameter, a Python routine was developed to inspect for the presence of Hα emission in the sample (Shridharan et al. 2021). The parameter "width" was utilized to avoid false emission sources, and only sources with width greater than three sampling points were considered as detections. This avoided narrow peaks caused by instrumental noise or defects. Spectra that did not show Hα in emission were removed from further analysis. As a result, we obtained 80,860 spectra with the Hα emission line within 3 Å of 6563 Å. Only stars having signal-to-noise ratio (SNR) in r-band (SNR_r) greater than 10 were considered for the study, and the rest were eliminated, leaving us with a sample of 58,508 LELS spectra. We further separated sources having LELS spectra with SNR(x) = -9999 (where x represents u, g, r, i, and z bands). Those spectra were considered "BAD spectra" upon visual check and removed from this study, which left us with a sample of 56,291 spectra belonging to 48,657 unique sources. Furthermore, we utilized the line_{index} function of the laspec package to estimate the EW of major emission lines for all sources in our study.

2.2.1. Crossmatch with Photometric Catalogs

To characterize the identified Hα sources, we obtained photometric values from various optical/IR all-sky surveys such as Two Micron All-Sky Survey (2MASS) (Skrutskie et al. 2006), Gaia (Prusti et al. 2016; Vallenari et al. 2023), and Wide-field Infrared Survey Explorer (WISE) (Cutri et al. 2012). To avoid contamination from multiple sources, we used a search radius of 3″ and selected the closest sources to the observed coordinates.

Crossmatching with 2MASS and using a quality cut of "AAA" reduced the sample size to 45,376. This sample was then crossmatched with Gaia Data Release 3 (DR3) to obtain astrometry and optical photometry, which further reduced the sample to 45,268. The sample further reduced to 44,520 sources upon crossmatching with the WISE catalog. Of these, we considered only 43,329 LELS with distance values available from Bailer-Jones et al. (2021). The line-of-sight extinction values for our sample were obtained using the probabilistic galactic dustmaps model, Bayestar 2019 (Green 2018).

3. Late-type Emission-line Stars: Classes and Classification Schemes

In this section, we provide an overview of LELS along with literature and the classification criteria employed in segregating them into different classes.

3.1. Classes of LELS

We categorize LELS into four classes: 1. IR excess sources 2. PtMS sources 3. Fe/Ge/Ke sources 4. dMe sources

IR excess sources are characterized by the presence of circumstellar disks or envelopes composed of dust and gas. These structures absorb stellar radiation and subsequently emit it at longer wavelengths, resulting in an excess of IR radiation in their spectral energy distribution (SED). Accretion disks are commonly found around YSOs such as protostars, T Tauri stars (TTSs), and Herbig Ae/Be stars (Groenewegen 2012; Hartmann et al. 2016; Brittain et al. 2023). Some evolved stars, including those classified as asymptotic giant branch (AGB) stars and red giants, also exhibit IR excess (Groenewegen 2012). The accretion disk and mass loss are the major reasons for the formation of emission lines in these objects (Muzerolle et al. 1998a).

PtMS stars, ranging in spectral types from F0 to M9, represent stars that have transitioned beyond their main-sequence phase, generally classified into red giant branch (RGB) stars, horizontal branch (HB) stars, and AGB stars based on their evolutionary phase. Activity in these sources is due to phenomena such as stellar winds, mass ejections, and pulsations. One of the well-studied groups of PtMS is the Mira variables, where activity happens in the form of long, periodic pulsations (Wood 1979; Yao et al. 2017). In stars such as RGBs and K supergiants, variability in Hα has been observed, which has been directly correlated with mass loss (Vasu Mallik 1982; Cacciari & Freeman 1983).

dMe stars exhibit significant magnetic fields due to the presence of convective outer layers and rapid rotation (Hall 2008). The magnetic fields are generated by dynamo processes, where convective material moves within the star' s convective zone, which amplifies the magnetic field. These lead to starspots, flares, and prominences in low-mass sources. Metallic lines such as Fe, Ca, and Na, which are sensitive to magnetic field, can be utilized to study magnetic field effects such as Zeeman splitting and Stokes broadening (Morin 2012). Higher resolution spectra of these sources will help accurately study the effect of magnetic fields. Red dwarf emission stars (dMe stars) exhibit emission in Hα and/or Ca II H and K, both of which serve as indicators of chromospheric activity. dMe stars were classified into weak dMe stars (0.1 Å $<$ EW(H) $<$ 0.5 Å) and strong dMe stars (EW(Hα) $<$ 0 Å) (Kogure & Leung 2010). Furthermore, Joy & Abt (1974) classified dMe stars from dMs photometrically, compiling statistics on the frequency of Hα emission occurrence across different classes of M stars for the 426 M-type stars they observed. Spectroscopic investigations of chromospheric activity were conducted (Cram 1989; Robinson et al. 1990), whereby the intensity and excess emission in a few of the observed emission lines were modeled (Young et al. 1989). Studies on activity indices of dMe stars along with their relationship with age were also carried out (Vaughan & Preston 1980; Pace et al. 2009). There is a special class of dMe stars known as flare stars or UV Ceti type stars, which show emission in Hα, Ca II H and K, and in some cases, He and Na in emission during their quiescent state. Most of these lines get enhanced during the flare state (Eason et al. 1992). Flares in M dwarfs are explosive events that occur as a result of magnetic reconnection in the atmosphere. A sample of 49 M dwarfs was studied for different spectra observed over time using SDSS (Hilton et al. 2010). Further, 49 more flaring M dwarfs were detected using GALEX data by Welsh et al. (2007). The far-ultraviolet (far-UV) activity of M dwarfs was studied by France et al. (2018). Flares in 480 M dwarfs were identified, and Martínez et al. (2020) created a catalog. The LAMOST survey offers supplementary spectral information for M-type stars, comprising the EWs and errors of Hα as well as spectral indices of other molecular bands including CaH and TiO5. The line strengths of TiO versus CaH are used as a popular method in the separation of late-type giants from dwarfs (Mould & Wallis 1977; Zhong et al. 2015; Yi et al. 2019). The CaH molecular band acts as an indicator of surface gravity, whereas TiO acts as a temperature indicator.

Fe/Ge/Ke sources are F-, G-, and K-type main-sequence stars or dwarfs, respectively, showing considerable chromospheric activity leading to the formation of emission lines such as Hα and Ca II H and K. In the Sun, non-radiative heating is closely linked to the magnetic field, which drives chromospheric activities such as sunspots and flares, ultimately resulting in the emission of Ca II (Robinson et al. 1990). Young stars such as weak-lined TTSs will also be included in this group due to the absence of IR excess (Gras-Velázquez & Ray 2005; Padgett et al. 2006).

3.2. Classification Criteria

In this section, we elaborate on the classification criteria employed for separating LAMOST LELS into different categories.

3.2.1. Identifying Sources with Infrared Excess We made use of the 2MASS-WISE color–color diagram (CCDm) for separating young stars showing IR excess. Generally, YSOs are classified into Class I, Class II, and Class III sources based on the continuum slope in the IR region of the SED of the star (Lada 1987). Class I sources are protostellar candidates deeply embedded in molecular clouds, and Class II sources are classified as TTSs that have almost dispersed their envelope but still have an accretion disk around them (Andre et al. 1993). Class III sources are evolved YSOs where disk dissipation is underway. Koenig & Leisawitz (2014) introduced criteria to classify YSOs into various classes using the 2MASS-WISE CCDm. In Figure 1(a), we have reproduced the YSO classification using the criteria mentioned in Koenig & Leisawitz (2014), which are listed below.

For Class II sources:

$$W1 - W2 > 0.55(W2 - W3) - 1.76$$

For Class I sources:

$$W1 - W2 > 0.55(W2 - W3) - 1.76$$

Given that the primary focus of this section is to segregate young sources, we utilized the LAMOST spectral type classification. Consequently, stars identified as giant-M-type ("gM") by LAMOST were removed from the sample. This step effectively reduces the contamination of evolved stars in our dataset. After applying this additional criterion, we segregated a sample of 438 IR excess sources.

3.2.2. Identifying PtMS ELS Candidates Based on log(g) and CMD Estimates To segregate PtMS sources from our sample, we employed a series of three systematic steps, drawing upon the remaining sample of 42,891 sources. As a first step, we separated PtMS candidates using the available surface gravity ($\log(g)$) value from LAMOST. We segregated sources based on the criterion that the value of $\log(g)$ exceeded three times its associated error (σ). Specifically, we applied the commonly used threshold of $\log(g) \leq 3.5$, which is typically employed to distinguish between giants and dwarfs (Batalha et al. 2010; Singh et al. 2019). Applying these criteria to the remaining sample, we classified 2,293 sources as PtMS candidates.

In addition, for M-type stars, the LAMOST pipeline classified their spectral types as dwarf M (dM)-type stars and giant M (gM)-type stars. In our remaining sample, 49 more sources belong to the gM type, making the new sample 2,342 PtMS candidates.

For the 7,618 sources lacking LAMOST $\log(g)$ values, a color–magnitude diagram (CMD) was employed to identify PtMS candidates within that sample. Ruiz-Dern et al. (2018) used Gaia-2MASS CMD to segregate red giant candidates in their sample. The availability of a larger sample and the presence of other predefined cuts to distinguish PtMS sources helped us retool the CMD cut to separate PtMS sources in our sample. For this purpose, we utilized Gaia CMD. The criterion we defined to segregate our data is mentioned below:

$$M_G < 0.5(G - K_s) + 2.5$$

The Gaia CMD of the LAMOST PtMS candidates is shown in Figure 1(b). Applying the above-mentioned magnitude and color criteria, we included an additional 2,327 sources in our sample. Combining all samples obtained using the above criteria, we obtained a final sample of 4,669 PtMS candidates.

3.2.3. Fe/Ge/Ke/dMe LELS Candidates From the remaining sample (38,222 sources), sources exhibiting [N II] and [S II] in emission are separated and categorized as "forbidden-line sources," totaling 5,177 sources. These stars will be further discussed in B. Shridharan et al. (2024, under preparation). The remaining sample was classified into Fe/Ge/Ke stars and dMe stars based on their spectral types provided by LDR6. Since the LAMOST spectral type has been used as a classification scheme, validation of the spectral type for LELS sources is necessary. Hence, we plotted a comparison of the LAMOST spectral type with the Gaia spectral type of our sources, as shown in Figure 2. The Gaia spectral types are estimated using General Stellar Parametriser (GSP) modules (Vallenari et al. 2023). The figure shows that except for G-type stars, all other spectral types provided by LAMOST are fairly accurate. Furthermore, the reason behind the separation of dMe stars from other LELS is the presence of intense molecular bands in M-type stars. None of these stars show IR excess. Hence, this sample contains a mix of potential Class III sources, active main-sequence LELS, and different types of variable stars. Further studies on young stars in this class are conducted by Nidhi et al. (2023). Figure 3 illustrates the flowchart of the entire classification scheme.

4. Results

In this section, we discuss the distribution of LELS in the galaxy and the classification based on the major spectral features.

4.1. Distribution of LELS Across the Spectral Range

Summarizing the classified sample, we have a dataset of 438 IR excess sources spanning spectral types F6–M7, 4,669 PtMS sources across spectral types F0–M9, 9,781 Fe/Ge/Ke sources, and 23,264 dMe sources. This summary is tabulated in Table 1.

Furthermore, the distribution of LELS over the entire late-type spectral range is depicted in Figure 4. From our sample of 38,152 LELS, we observed that the number of ELS increases between the spectral range of K5 to M5. When comparing with the total number of observed sources in LAMOST, the increase in number of ELS is very significant. This shows a direct correlation of higher activity in well-developed chromospheres. The number of stars steeply decreases after M6. The ELS observed after M5 are predominantly PtMS candidates. We conducted a crossmatch with SIMBAD to identify sources previously studied in the literature. This analysis revealed that 8,643 sources had already been documented, resulting in a newly detected sample of 29,509 LELS. A detailed description of the known sample of each class of LELS will be provided in Section 4.6.

4.2. 3D Distribution of LELS in the Galaxy

Employing the methodology mentioned in Section 3.2, we have compiled a sample of 38,152 LAMOST LELS. We obtained distances from Bailer-Jones et al. (2021). Figure 5 shows the galactocentric distribution of LELS present in our sample, where $(-8000 \text{ pc}, 0 \text{ pc})$ represents the position of the Sun. Around 81% (30,145) of the 38,152 LAMOST LELS are at distances less than 1 kpc. Among them, 22,862 are dMe stars, which constitute over 98% of the entire dMe sample spread over all distances. More than 77% (6,628) of the 9,781 Fe/Ge/Ke stars are observed within 1 kpc, and another 18% (1,555) are observed between 1 and 2 kpc.

In the case of IR excess sources, 320 out of 438 of these sources are observed within a distance of 1 kpc. The major contrast is observed in the case of PtMS candidates. Only 7% (335) of 4,669 PtMS candidates are observed at distances within 1 kpc. Over 72% (3,343) are observed between 1 and 5 kpc. Similar to the spatial distribution observed in Shridharan et al. (2021), the majority of LELS data are also distributed along the galactic anti-center direction.

4.3. Photometry of LELS

We utilized photometric data provided by 2MASS and Gaia to further study the distribution of our LELS dataset. Figure 6 shows the kernel density estimate (KDE) photometric distribution of our LELS sample, which also helps validate the classification schemes utilized for our sample. The CMD of our LELS sources is represented in the left panel of Figure 6. The zero-age main sequence (ZAMS) line is also shown. The IR excess source distribution (represented in red) is located in the region above the ZAMS line, whereas Fe/Ge/Ke sources (represented in yellow) and dMe sources (represented in blue) are overplotted on the ZAMS line. The PtMS sources (represented in green) highlight the sub-giant, AGB, and RGB regions of the Hertzsprung-Russell (HR) diagram (Eyer et al. 2019).

The CCDm of the LELS is shown in the right panel of Figure 6. We used the same color scheme for the CCDm as described for the CMD. It has been observed that the majority of IR excess sources are located around the TTS locus (Meyer et al. 1997), as shown in the figure. We also notice that the PtMS sources from our sample are clustered around the "giant locus" (Carpenter 2001). The rest of the sample is clustered around the main sequence line. These distributions bring novelty to our classification scheme and validity to our sample.

4.4. Spectral Features of LELS

In this section, we mention the major emission lines observed in late-type stars. The major features include Balmer lines, metallic lines like Ca II H and K, CaIRT, Mg, and Na doublet, and molecular bands such as TiO and VO for stars of spectral types later than K5. Figure 7 shows the representative spectrum of a sample IR excess source.

As discussed in previous sections, all LAMOST LELS star spectra show Hα in emission. The strength of this line is indicative of the circumstellar activity of the star or stellar system. Other Balmer lines like Hβ, Hγ, and Hδ are also observed in numerous LELS. The statistics of these observations, along with line strength measurements, are studied. Other major emission lines include the Ca II H and K lines, which are observed either in emission or absorption. These lines, along with Balmer lines, are presented in the literature as chromospheric activity tracers. Another significant ionized calcium line observed in LELS is the CaIRT ($ $8498, 8542, 8662 Å). Except for some IR excess sources, very few stars show triplet emission in their spectra.

Given their late-type classification, it is common to observe metallic lines in the spectra of these stars. The main metallic lines include Na I doublets at 5890, 5896 Å, Na I (λ 8183, 8195 Å), Mg I (λ 5184 Å), K I (λ 7665, 7701 Å), Fe I (λ 4383, 5270 Å), Ca I (λ 4226 Å), etc. These lines are often observed in absorption. A few other metallic lines like Fe II (λ 5018, 5168 Å), Fe I (λ 4063, 5162 Å), and the forbidden line of [O I] (λ 6300 Å) are also observed in emission. Figure 8 displays representative spectra from the Fe, Ge, Ke, and dMe classes.

The major molecular bands observed in late-type stars include TiO (band heads at λ 4760, 5160, 7050, and 7580 Å), which are prime indicators of stellar temperature. These bands dominate the spectra of late-K to M-type stars. Other major molecular bands observed include VO (band heads at λ 7010, 7383 Å) and CaH (band heads at λ 6400, 6800 Å).

The emission line profiles of our sources show various types of line features. The intensity of emission varies depending on the level of activity in these sources. The mass column density of the chromospheres and temperature structures inside the chromosphere will significantly affect the line profiles and intensity of low-mass sources (Houdebine et al. 1995). The literature shows that most profiles can be attributed to the inclination angle, stellar rotation, or chromospheric activity of these sources. Furthermore, strong asymmetry in emission profiles has been observed in red giants and long-period variables (LPVs) (Gillet 1988). Given the large sample size of nearly 40,000 LELS, classifying the line profile of each source presents a significant challenge and falls outside the scope of this catalog. This detailed classification will be reserved for future studies, where individual groups of LELS will be analyzed in greater depth (Anusha et al. 2021; Nidhi et al. 2023).

In our work, we estimated the EW of major lines like Balmer lines (Hα, Hβ, Hγ, and Hδ), Ca II H and K, and CaIRT using the line_{index} module of the laspec package by implementing an automated Python routine. This module provides values of EW and EW error for all respective lines. Within our study, an emission-line EW value is deemed legitimate only if the matching EW value is three times the projected error (σ) supplied by laspec (EW $> 3\sigma$).

4.4.1. Balmer Lines Hα in emission is one of the major indicators of activity in low-mass stars. In sources with IR excess, predominantly in young stars, the emission arises from the magnetospheric columns (Hartmann et al. 1994), giving rise to very intense emission lines. From the literature, a significant correlation between stellar rotation and magnetic activity has been observed in low-mass stars. Studies comparing star rotation to activity characteristics have found that the relationship is valid for sources that are fully or partially convective

(Delfosse et al. 1998; Reiners et al. 2012). Rotation rates also play a major factor. A clear association has also been found between stellar rotation and EW(Hα) (Newton et al. 2017).

Figure 9 represents the histogram of EW of Hα in various classes of LELS. The bin size for the histogram is calculated using the Freedman-Draconis rule (FDR) for each sample. For those with bin sizes estimated to be too small using the FDR method, the bin sizes are provided manually. This rule is followed throughout this work for histogram distributions.

Figure 9(a) presents the histogram distribution of Hα strength (EW(Hα)) for IR excess sources. Observations indicate that IR excess sources exhibit the most intense Balmer emissions compared to other classes, with a median value of −19 Å, as the strength is primarily due to disk accretion. Figure 9(b) shows the emission histogram distribution for PtMS sources, which has a median value of −4 Å. The strength of the line is minimum for dMe candidates (Figure 9(d)) with a median value of −3.2 Å. Models of Hα emission in TTS suggest that emission strength can vary due to rotation, turbulence, and non-axisymmetric accretion in these sources (Kurosawa et al. 2005; Wilson et al. 2022). Stellar winds also account for increased line strength in CTTSs (Lima et al. 2010).

In solar-type sources, the presence of Hα emission is attributed to chromospheric and coronal activity. All active phenomena are directly correlated with the presence of intense magnetic fields generated by a dynamo mechanism (Charbonneau 2014). In the case of main-sequence late-type stars, a total of 27,642 LELS show emission in Hβ, including 341 IR excess sources, 2,779 PtMS candidates, 3,703 Fe/Ge/Ke stars, and 20,819 dMe candidates. Over 86% of IR excess sources and more than 85% of dMe candidates show emission in Hβ. Only 35% of PtMS candidates and 50% of Fe/Ge/Ke candidates show Hβ emission. The strength of emission ranges from −0.84 to −100 Å, with a median value of −2 Å.

4.4.2. Ca II Emission Lines Ca II emission lines are observed in late-type stars, both in the bluer and redder ends of the spectra. We observed Ca II H and K lines at wavelengths 3968 Å and 3933 Å, respectively, and the CaIRT at wavelengths 8498, 8542, and 8662 Å. Mould & Wallis (1977) studied these emission lines and their dependencies with luminosity and other physical attributes.

From our sample, 4,887 LELS show emission in Ca II H, among which 164 (37%) are IR excess sources, 141 (3%) are PtMS candidates, 722 (8%) are Fe/Ge/Ke stars, and 3,860 (17%) are dMe stars. The presence of emission/absorption contribution from the H I line in Ca II H suggests the necessity of distinguishing between the contributions of both for subsequent analyses. This separation is crucial for future investigations.

Here, 6,215 LELS show emission in Ca II K, with EW values ranging from −2.5 to −55 Å. Around 39% of IR excess sources (170), more than 18% of dMe stars (4,315), over 3% of PtMS sources (155), and close to 18% of Fe/Ge/Ke sources

(1,575) show emission in the Ca II K line. This emission line is prominently observed in M-type stars (those with effective temperatures $T_{\rm eff} < 4000$ K), including young IR excess sources. Figure 10 displays the histogram distribution of EW(Ca II K) for various classes of LELS.

CaIRT in emission is rarely seen in main-sequence late-type stars. Here, 893 stars show emission in Ca II 8498 Å, including more than 50% of IR excess sources (212), 505 dMe stars, and 86 PtMS candidates. The emission range of Ca II 8498 is from −0.4 to −17 Å. The other two lines of the CaIRT show similar EW distributions. Ca II 8542 emission is seen in 310 stars, of which 176 are IR excess sources, 62 are dMe stars, and 37 are PtMS candidates. For the Ca II 8498 Å emission line, over 40% of IR excess sources show emission with EWs ranging from −0.4 to −58 Å. 323 stars show emission in Ca II 8662 Å; 178 IR excess sources and 50 PtMS candidates show emission in Ca II 8662 Å. 232 of the 38,152 LELS show emission in all lines of the CaIRT, including 166 IR excess sources, 12 Fe/Ge/Ke stars, 28 dMe stars, and 26 PtMS candidates. The majority of stars showing emission in these sets are IR excess sources, confirming that the presence of CaIRT emission indicates the youth of these objects. Most IR excess sources belong to the class of TTSs, and the stellar properties and mass accretion rates of these stars are studied in Nidhi et al. (2023).

4.4.3. Paschen Lines Paschen lines were also seen in emission in some LELS. The EWs of P12, P14, and P17 were calculated initially since these lines do not overlap with the Ca II triplet. 916 LELS showed emission in P12, mostly in Fe/Ge/Ke stars (422 stars), including 16 IR excess sources, 180 PtMS candidates, and 253 dMe stars. The emission is seen in the range of −0.2 to −1.25 Å. The P14 line is seen in emission in 641 LELS, with 242 Fe/Ge/Ke stars, 236 dMe stars, 98 PtMS candidates, and 12 IR excess sources showing emissions ranging from −0.2 to −1.4 Å. 1,762 stars show emission in the P17 line, including 948 dMe stars, 597 Fe/Ge/Ke stars, 210 PtMS candidates, and 17 IR excess sources. Paschen emission is not common in IR excess sources, whereas Ca II triplet is seen more often.

4.5. Relation Between Spectral Type and Major Emission Lines

Figure 11(a) shows the variation of Hα EW with respect to spectral type for IR excess sources, PtMS candidates, and Fe/Ge/Ke/dMe stars. Hβ displays a similar distribution over the late-type spectral range as Hα, as shown in Figure 11(b). The strength of emission from these sources peaks toward the later K- to M-type sources. Studying this allows for a deeper understanding of emission trends across the spectral range and facilitates comparison of the presence or absence of various emission lines, which in turn aids in elucidating the emission mechanisms in these sources.

Ca II K is one of the most active chromospheric indicators (Hall 2008). Figure 11(c) depicts the emission strength of Ca II K over various spectral types. Notably, Ca II K emission is present in LELS sources of spectral types later than

K5 due to chromospheric activity in those sources. Among stars in the spectral range F6–K4, less than 1% show emission in Ca II K, while more than 40% of sources later than K4 show emission. This suggests the presence of active chromospheres and coronae in sources with spectral types later than K5 (Young & Koniges 1977; Hall 2008).

4.6. Literature Crossmatch of Known LELS

The SIMBAD crossmatch identified 373 stars from a total of 438 IR excess sources. Of the 373 known stars, 317 belong to four main classes: TTau*/TTau candidates, YSOs/YSO candidates, Orion V*, and Em* classes. Additionally, the classes "Star" and V* contribute 24 more candidates, accounting for 94% of the known sample. Our sample contains 65 newly detected IR excess sources.

Evolved stars were separated from other classes based on the method mentioned in Section 3.2.2, providing a sample of 4,669 PtMS candidates. The SIMBAD crossmatch identified 944 known stars. From that crossmatched sample, 160 stars belong to different PtMS star classes: asymptotic-giant branch stars (AGB*), horizontal branch stars (HB*)/HB* candidates, Mira variables/Mira candidates, red-giant branch stars (RGB*)/RGB candidates, red supergiants, and post-AGB* cases. Additionally, 88 stars belong to long-period variable star (LPV*)/LP* candidates. 81 known samples belong to binary classes like eclipsing binary stars (EB*) or EB* candidates, symbiotic stars (Sym*), spectroscopic binaries (SB*), and RS Canum Venaticorum (RS CVn) cases. Variable star classes like pulsating variables (Pul V*), eruptive variables (Eruptive*), variable stars (V*), ELS, BY Draconis variables (BY Dra), and pulsating variables contribute 150 more known stars. 115 stars are classified as YSOs as well. The presence of YSOs in this sample is evident from their location in the HR diagram and the lack of IR excess. These might be candidates of weak-line TTSs, which show an absence of IR excess and weak Hα emission (Alcalá et al. 1993). Additionally, 293 stars were represented in the "Star" class, and 14 were represented as low-mass stars. A couple of stars belong to groups such as Cepheids and far-infrared (FIR) sources, which complete the known sample of PtMS stars. We have a sample of 3,725 new detections without any SIMBAD information.

A SIMBAD crossmatch of the dMe stars revealed that 5,731 are previously detected stars, while 17,533 sources are new detections. Of the known sample, 1,490 are categorized as "star/**" in SIMBAD; 1,032 were mentioned as stars with higher proper motion (PM*); 1,083 stars belong to various variable star groups like V*, Em*, Orion V*, and Eruptive*; 301 belong to binary groups such as EB*, SB*, and RS CVns. This group also has 1,322 YSO/YSO candidates. Other classes such as Pec*, mid-infrared (MIR), near-infrared (NIR), and radio sources also have a couple of stars each.

From our sample of 9,781 Fe/Ge/Ke stars, 1,595 are Fe-type, 1,154 are Ge-type, and 7,210 are Ke-type. After the SIMBAD crossmatch, 1,882 stars are determined as the known sample. Like other classifications, most of our known sample belongs to variable star classes like Orion V*, V*, Em* (ELS), Eruptive*, PulsV*, and RotV*, contributing 484 stars. 531 are simply represented as "stars," which can be converted to ELS after our LAMOST spectroscopic results. 281 are classified as young stars belonging to YSO/YSO candidates and Ttau*/Ttau* candidates. 315 are classified into binary star groups like EB*/EB* candidates and SB*. We have 7,899 Fe/Ge/Ke sources as new detections. Our sample of Fe/Ge/Ke stars can be suitable candidates for further variability studies to enrich understanding of various active phenomena.

4.7. Classification of LELS Based on the Presence of Emission Lines

As mentioned in previous sections, Hα, Ca II H and K, and CaIRT are the most commonly observed emission lines in LELS. The presence or absence of more than one of these emission lines has great physical significance. Hence, for our sample, we devised a classification scheme based on the presence or absence of three major emission lines: Hα, Ca II K (as a representative of Ca II H and K), and Ca II λ 8542 Å (the representative line from the Ca II triplet). Since we used the entire range of spectra for this study, we had to consider some initial assumptions in terms of SNR at various spectral regions, especially in the u-band. After visual inspection of the spectra, $\text{SNR}_u > 0.8$ was stated as the selection criterion.

1. **Group A** comprises stars displaying emission in Hα, Ca II K, and CaIRT, totaling 142 stars. Intense emission lines are observed in this group, with a median Hα EW of -41 Å. More than 71% (101) of stars belong to IR excess sources, 13.4% (19) belong to PtMS candidates, and 14% (20) belong to dMe sources. Muzerolle et al. (1998b) noted that He I emission is also observed in these sources. We observed that 93 sources show emission in He I λ 5876 Å, confirmed by the presence of weaker He I $\lambda\lambda$ 6678, 7605 Å emission lines. Moreover, the literature crossmatch revealed 66 stars classified as YSO/TTau stars and 47 categorized as Em*/OrionV* stars, indicating the majority belong to disk-like systems. This confirms the presence of young and active sources within this group. Figure 12(a) displays the KDE EW distribution of Hα, Ca II K, and CaIRT emission lines. This set is significant due to its implication for the line origin of all three lines, indicating disk emission.
2. **Group B** contains stars showing emission in Hα and Ca II K, totaling 5,898 stars, including 66 IR excess sources, 133 PtMS candidates, 1,548 Fe/Ge/Ke stars, and 4,151 dMe stars. A noteworthy observation is that only ten stars, spanning all classes, have spectral types less than K4. Additionally, 94% (5,542) of sources exhibit greater Ca II K emission strength compared to Hα. Among the 2,469 known stars in this group, 63% (1,552) are classified under various variable star categories including eruptive variables (Eruptive*), Orion variables, BY Draconis variables, etc., indicating the majority show rotation coupled with starspots and other chromospheric activities. Figure 12(b) depicts the KDE distribution

of these lines. The line strength signifies that the lines originate primarily from the chromospheres in these sources. The strength difference between these emission lines also indicates the same scenario.

3. **Group C** contains stars showing emission in Hα and CaIRT, totaling 25 stars. It has been observed that the majority of the sample shows Paschen lines in emission along with CaIRT. Of the 25 stars, nine are associated with IR excess sources, eight with Fe/Ge/Ke sources, two with PtMS sources, and six with dMe sources. Since the number of sources in Group C is quite low, it suggests the probability of both Hα and CaIRT being in emission is minimal.

4. **Group D** contains stars showing emission in Hα alone, totaling 3,785 stars, including 49 IR excess sources, 1,164 PtMS candidates, 2,057 Fe/Ge/Ke stars, and 515 dMe stars. A SIMBAD crossmatch identified 1,534 sources already studied in the literature. This group includes PtMS stars such as AGB*, RGB*, and Mira variables, as well as other variable star categories like Em*, V*, and OrionV*. This diversity indicates a wide range of activity among these sources, including mass loss, rotation, and chromospheric activity.

In conclusion, the majority of sources in Group A belong to the IR excess source class, with very intense major emission line strengths. In Group B, the emission is predominantly due to chromospheric activity, suggested by the large number of Fe/Ge/Ke/dMe sources. It is also interesting to note the lack of sources earlier than K4 in this group, suggesting intense chromospheric activity in sources later than K4.

4.8. Catalog Description

The catalog of LAMOST LELS contains 38,152 sources, including 438 IR excess sources, 4,669 PtMS candidates, 9,718 Fe/Ge/Ke sources, and 23,264 dMe sources. We further classified 9,850 sources into four groups based on the presence or absence of Balmer and Ca emission lines, as described in Section 4.7. The sources are named with a common prefix of LM-LEMC (Low-Mass LAMOST Emission-line Catalog) followed by the index, ranging from LM-LEMC_1 to LM-LEMC_{38152}. A sample table is shown in Table A1. The data include the LAMOST design ID, positions, our classification and grouping. The catalog developed for our LELS sample will be made available online. The online table will include photometric values and estimated line EWs.

5. Conclusion

In this study, we present spectroscopic information for 38,152 LELS identified from LAMOST DR6. After acquiring F0–M9 "STAR" data from LAMOST DR6, we utilized a custom Python routine developed with scipy.signal.findpeaks to isolate spectra containing Hα emission. We then separated the ELS into various subclasses: IR excess sources, PtMS candidates, Fe/Ge/Ke stars, and dMe stars, employing photometric and spectroscopic methods.

We have obtained one of the largest homogeneous datasets of LELS in this study. After the SIMBAD crossmatch, 29,222 sources were found to be new detections, including 65 IR excess sources, 7,899 Fe/Ge/Ke stars, 17,533 dMe stars, and 3,725 PtMS candidates. The spatial distribution of our data suggests the stars are observed in the anti-center direction, similar to the early-type ELS work by B. Shridharan et al. (2021). Additionally, over 89% of observed stars are within 1 kpc. It has also been ascertained that PtMS star candidates are observed at much greater distances due to their size and high luminosity.

We discussed the spectral features observed in various late-type stars, encompassing both absorption and emission lines. Studying major spectral lines helps us understand the chemical composition, active phenomena, and physical properties of stars. For late-type stars, we noted the major emission features observed in our sample and analyzed the line strength distribution of major emission lines (Balmer lines, ionized Ca lines, Pa lines, etc.) across various types. The statistics reveal intense emission lines in young stars due to their youth and intense disk activity. We observed strong metallic absorption lines in the spectra of F-, G-, and K-type ELS. Further, we classified stars into four groups based on the presence or absence of three major emission lines: Hα, Ca II K, and Ca II 8662 Å. Deeper studies in this direction will help us understand line formation scenarios in low-mass stars.

The distribution of stars over various spectral types is also discussed. Although classifications are made for various groups of LELS, further studies on individual groups are required for better understanding of their properties.

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Appendix: Additional Data

Table A1. The Sample Table of LAMOST LELS Sources

LAMOST Desid	LAMOST SpT	Classification	Group	Decl.
LAMOST J080307.80+144949.5	⋯	⋯	LM-LEMC_{1027}	-5.708056
LAMOST J202431.01+421605.0	⋯	⋯	LM-LEMC_{1017}	-15.870133
LAMOST J223304.19+234418.7	⋯	⋯	LM-LEMC_{1006}	-6.481826
LAMOST J013356.31+294201.1	⋯	⋯	LM-LEMC_{118}	⋯
LAMOST J114044.45+310630.5	⋯	⋯	LM-LEMC_{122}	⋯
LAMOST J223227.51+303416.0	⋯	⋯	LM-LEMC_{13}	⋯
LAMOST J181613.21+495205.2	⋯	⋯	LM-LEMC_{1464}	⋯
LAMOST J110134.88+320928.8	⋯	⋯	LM-LEMC_{149}	⋯
LAMOST J111248.50+242320.4	⋯	⋯	LM-LEMC_{171}	⋯
LAMOST J043749.67+514255.8	⋯	⋯	LM-LEMC_{201}	⋯
LAMOST J121511.31+582749.5	⋯	⋯	LM-LEMC_{205}	⋯
LAMOST J035034.14+275836.5	⋯	⋯	LM-LEMC_{21}	⋯
LAMOST J052108.71-054229.0	⋯	⋯	LM-LEMC_{2103}	⋯
LAMOST J035603.23+351450.5	⋯	⋯	LM-LEMC_{2211}	⋯
LAMOST J101432.90+300616.4	⋯	⋯	LM-LEMC_{228}	⋯
LAMOST J033233.00+310221.5	⋯	⋯	LM-LEMC_{2516}	⋯
LAMOST J063949.01+101602.8	⋯	⋯	LM-LEMC_{253}	⋯
LAMOST J115740.34-011012.4	⋯	⋯	LM-LEMC_{267}	⋯
LAMOST J063351.63+044942.8	⋯	⋯	LM-LEMC_{316}	⋯

LAMOST Desid	LAMOST SpT	Classification	Group	Decl.
LAMOST J061439.96-062917.4	···	···	LM-LEMC_{3273}	···
LAMOST J062920.78+044006.9	···	···	LM-LEMC_{375}	···
LAMOST J221010.40+293625.8	···	···	LM-LEMC_4	···
LAMOST J063321.38+050018.8	···	···	LM-LEMC_{404}	···
LAMOST J063416.41+044202.3	···	···	LM-LEMC_{405}	···
LAMOST J033344.06+073142.8	···	···	LM-LEMC_{41}	···
LAMOST J063100.24+044738.2	···	···	LM-LEMC_{425}	···
LAMOST J063003.35+044349.6	···	···	LM-LEMC_{439}	···
LAMOST J004430.15+442703.6	···	···	LM-LEMC_{526}	···
LAMOST J005822.58+291420.3	···	···	LM-LEMC_{61}	···
LAMOST J044049.50+255118.9	···	···	LM-LEMC_{612}	···
LAMOST J054112.83+252912.2	···	···	LM-LEMC_{647}	···
LAMOST J025217.58+361648.1	···	···	LM-LEMC_{664}	···
LAMOST J235556.66+324013.2	···	···	LM-LEMC_{80}	···
LAMOST J042951.55+260644.5	···	···	LM-LEMC_{861}	···
LAMOST J053232.08+104417.9	···	···	LM-LEMC_{8805}	···
LAMOST J034458.57+235541.0	···	···	LM-LEMC_{8860}	···
LAMOST J053411.38-045122.9	···	···	LM-LEMC_{95[illegible]}	-[illegible]63636

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Note: Figure translations are in progress. See original paper for figures.