The M giants classification in the LAMOST DR1

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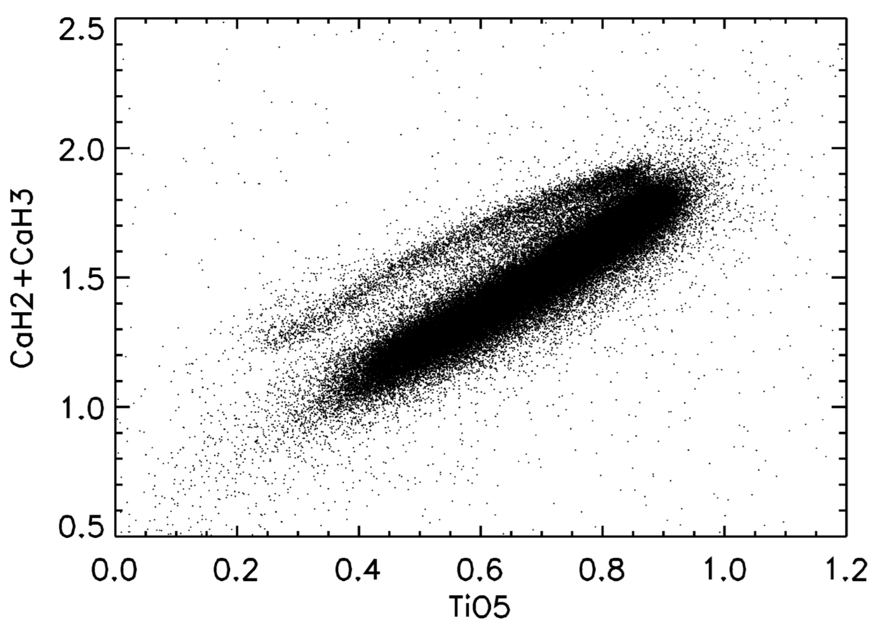
Abstract: We perform a discrimination algorithm by using the spectral index diagram of TiO5 and CaH2+CaH3 to separate M giants and M dwarfs. Using the M giant spectra from the LAMOST DR1, we have successfully assembled a set of M giant templates with high signal-to-noise ratio. Combining with the M dwarf/subdwarf templates in Zhong et al. (2014), we present an extend M-type templates library which includes not only M dwarfs with well-defined temperature and metallicity grid but also M giants sample with temperature from M0 to M6. Then, the template-fit method were used to automatically identify and classify M-type stars from the LAMOST DR1. The result of M-type stars catalog is cross-matched with 2MASS JHKs infrared photometry. In addition, we calculated the heliocentric radial velocity of all M type stars by using the cross-correlation method with the template spectrum in a zero-velocity rest frame. Using the relationship between the absolute infrared magnitude M_J and our classified spectroscopic subtype, we derived the spectroscopic distance of M giants and dwarfs, with uncertainties about 40%. A completed catalog of 10044 M giants and 136251 M dwarfs/subdwarfs is provided.

The Classification Method

Based on the spectroscopic discrimination-method of Mann et al. (2012), the TiO and CaH spectral indices are used to separate M giants and dwarfs in the LAMOST DR1 data. First, we use the template-fitting method (Zhong et al. 2014) to select M type spectra which positively present the characteristic molecular features, e.g., TiO, VO and CaH. Then the spectral indices of TiO5, CaH2 and CaH3, as defined by Reid et al. (1995) and Lépine et al. (2007), were calculated. The right figure shows the spectral indices diagram for all M type stars we identified in the LAMOST DR1. Two populations are clearly shown in this diagram. Giants with weaker CaH band and stronger TiO5 band are located on the upper branch. The number of giant candidates in the upper branch is about 10,000.



Spectral Type	$r-i$
M0.............	0.50-0.65
M1.............	0.60-0.80
M2.............	0.75-0.95
M3.............	0.90-1.15
M4.............	1.00-1.30
M5.............	1.30-1.70
M6.............	1.60-2.00

The left table list the r − i colors as a function of MK spectral subtype, which is mainly based on Covey et al. (2007). Since there is no giant candidate whose r−i color redder than 2.0 mag in our sample, the synthetic M giant templates span the spectral subtype from M0 to M6.

M-type stars catalog

DR1 2204696 spectra → Template fitting method → 10044 M giants / 136251 M dwarfs

The M-type stars catalog (*Twenty lines for example*):

TABLE 5
M-TYPE STARS CATALOG,INCLUDING ASTROMETRY,PHOTOMETRY, SPECTROSCOPIC DISTANCES AND ESTIMATED SUBTYPES

RAJ2000[1] deg	DEJ2000 deg	CaH2[2]	CaH3	TiO5	S/N	J[3] mag	H mag	K_s mag	e_J[4] mag	e_H mag	e_K_s mag	RV [5] km/s	Dist[6] parsec	Class	SpTy
334.09132	0.4682330	0.5705	0.8635	0.6613	2.856	15.52	14.85	14.61	0.054	0.063	0.070	63.818	507	dM	2.5
332.79007	-0.624800	0.5938	0.8290	0.6126	2.286	14.85	14.28	13.97	0.042	0.037	0.055	3.7572	447	dM	1.5
295.41125	39.316722	0.7300	0.9155	0.5549	61.95	6.625	5.725	5.519	0.020	0.018	0.021	-56.91	1285	gM	2.0
330.92885	1.7753160	0.7134	0.9553	0.8948	2.163	16.00	15.74	15.67	0.095	0.156	0.216	110.76	1205	dK	7.0
110.45346	29.405001	0.5068	0.8692	0.3552	109.7	—	—	—	—	—	—	-29.80	—	gM	5.0
330.65934	-1.515705	0.5555	0.8029	0.6220	1.996	15.45	14.65	14.25	0.056	0.066	0.075	-22.93	537	dM	2.0
98.33946	31.981045	0.6891	0.8350	0.8038	10.48	15.40	14.56	14.41	0.046	0.043	0.068	31.996	759	dM	0.0
158.97049	26.502544	0.8751	0.9260	0.8886	105.3	11.77	11.12	10.98	0.021	0.020	0.017	21.950	171	dK	7.0
294.62473	37.837033	0.8500	0.9195	0.7327	45.55	9.425	8.698	8.487	0.022	0.030	0.024	-14.76	3828	gM	0.0
210.35855	19.021133	0.8362	0.8968	0.9084	2.175	11.82	11.34	11.25	0.020	0.021	0.022	-10.58	76	esdK	7.0
121.64525	-7.513990	0.9350	0.9693	0.8367	137.8	9.707	8.904	8.685	0.023	0.025	0.022	68.434	4359	gM	0.0
224.00471	37.649753	0.7037	0.8504	0.7192	19.70	12.46	11.83	11.65	0.019	0.016	0.021	-1.202	179	dM	0.5
10.660100	41.322700	0.9257	0.9728	0.8799	35.13	—	—	—	—	—	—	-230.0	—	gM	0.0
217.78651	29.487778	0.4726	0.7627	0.5968	1.677	14.71	14.16	13.91	0.033	0.037	0.048	-41.31	418	dM	1.5
214.39177	29.187283	0.3241	0.6259	0.2768	3.068	13.68	13.09	12.81	0.025	0.024	0.023	-7.891	77	dM	5.0
224.12532	35.657233	0.4759	0.7277	0.4922	27.53	11.68	11.12	10.79	0.021	0.030	0.019	-10.21	57	dM	3.5
43.315960	0.0523900	0.4579	0.7326	0.4819	28.51	11.55	11.03	10.77	0.023	0.022	0.019	42.304	53	dM	3.5
45.381083	-1.991005	0.5600	0.8165	0.5750	26.60	12.69	12.14	11.92	0.023	0.027	0.028	-22.35	151	dM	2.0
10.791600	41.37760	0.9269	0.9768	0.8701	14.51	—	—	—	—	—	—	-168.2	—	gM	0.0
121.22428	-8.574169	0.8503	0.9621	0.6926	29.13	10.69	9.841	9.592	0.021	0.023	0.028	139.80	7610	gM	1.0

[1] Celestial coordinates in decimal degree,epoch 2000.0.
[2] Spectral indices as defined by Reid et al.1995.
[3] Infrared J, H, and K_s magnitudes from the 2MASS catalog (Skrutskie et al. 2006).
[4] Mean error of J, H, and K_s magnitudes from the 2MASS catalog (Skrutskie et al. 2006).
[5] Heliocentric radial velocity estimated by the classification pipeline.
[6] Spectroscopic distance base on the absolute magnitude(Mj)(Covey et al.2007).

The M giant templates

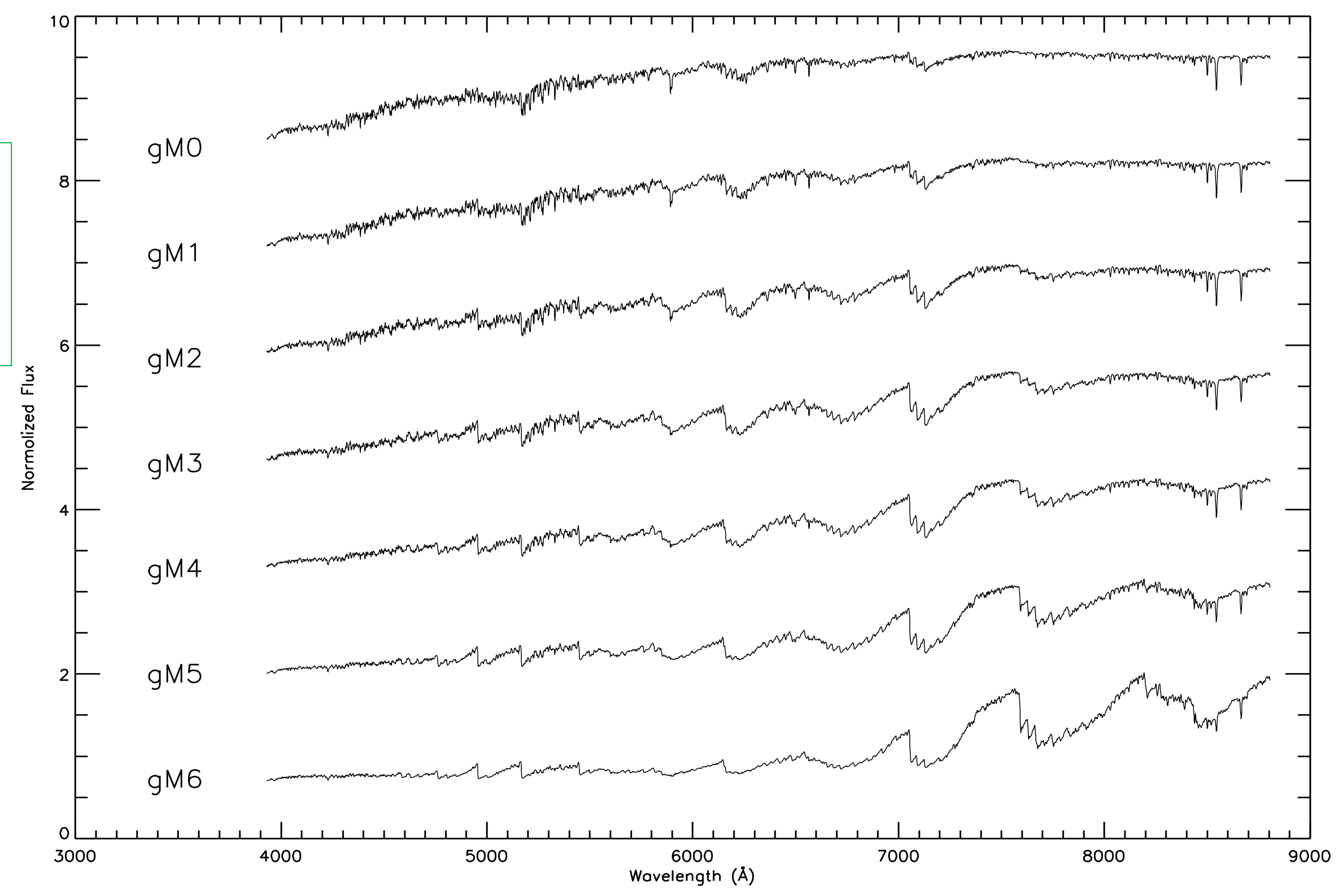
High SNR (S/N > 20)
Good photometry (SDSS)
No sky line contamination
No serious reddening
No flux missing

↓

RV calibration
(IRAF rv.rvidlines)

↓

184 LAMOST Standard spectra



The M giant templates from M0 to M6. We defined seven different giant subtypes according to the r-i colors, as proposed in the upper table. Each template spectrum is assembled from at least five LAMOST standard spectra which are confirmed by manual assignment. From top to bottom, the increasing strength of molecular bands, such as CaH, TiO and VO, reflect decreasing temperature of giant spectra.

The template-fitting method

- Use the wavelength range from 6000-8000Å for the template-fitting.
- For each target spectrum, calculate the chi-square for the jth template spectrum as:

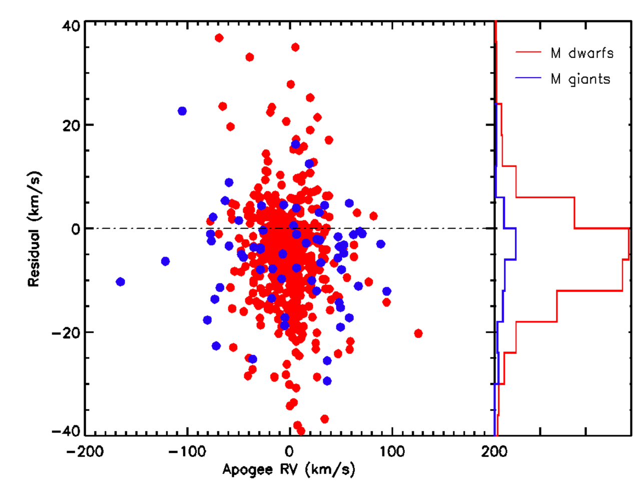
$$\chi_j^2 = \sum_{i=1}^{N} \left(\frac{L_i - T_{ij}}{\sigma_i}\right)^2$$

where L_i is the LAMOST spectral flux for each of the i=1,N pixels, T_{ij} is the flux of the jth template spectrum for every corresponding pixel i, and σ_i is the error for the LAMOST spectral flux at each pixel i.

- Shift each LAMOST spectrum towards the blue or red by a number of pixels, and recalculate the chi-square value against each template spectrum.
- The combination of pixel shifting and jth template spectrum which has the minimum chi-square value is selected as the best fit.

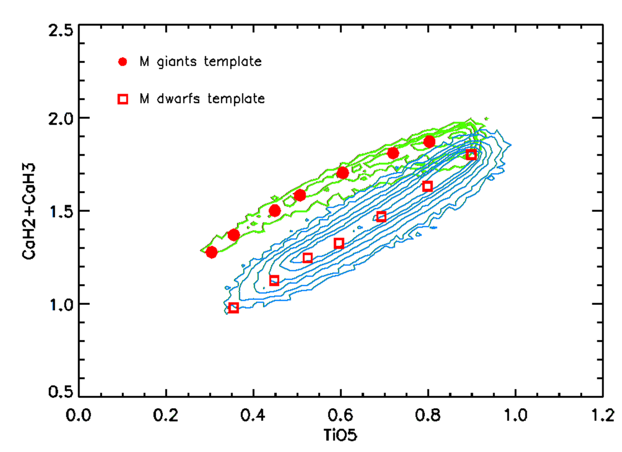
Conclusion & Discussion

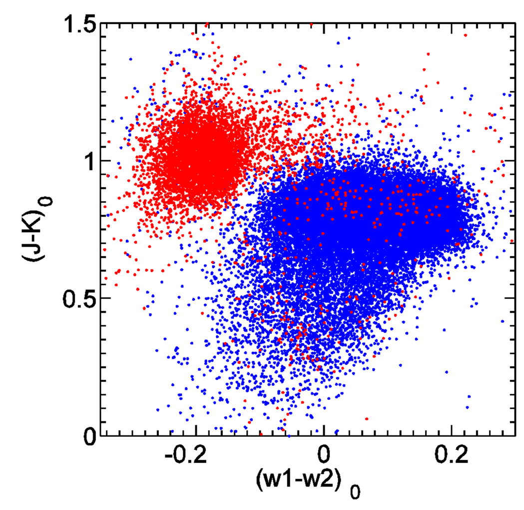
We have successfully assembled a set of M giant templates from M0 to M6 by the LAMOST DR1 spectra. After combining the M giant templates and M dwarf/subdwarf templates as a new M-type spectral library, we re-run the updated classification pipeline to identify and classify M-type stars in the LAMOST DR1. The completed catalog of 10044 M giants and 136251 M dwarfs/subdwarfs is provided. In this catalog, we present the celestial coordinates, spectral indices, JHKs infrared magnitudes in 2MASS, heliocentric radial velocity, spectroscopic distance and derived spectral subtypes.



Distribution of RV residual for all common stars with the LAMOST DR1 and the APOGEE data. The left panel shows the RV residual distribution of 59 M giants (blue dots) and 416 M dwarfs (red dots). The right panel shows the histogram distribution of M giants (blue lines) and M dwarfs (red lines). All the LAMOST spectra we measured have the SNR greater than 10. The σ of RV residual in our measurement are 11.1 km/s for giants and 8.1 km/s for dwarfs.

The right diagram shows the spectral indices distribution of all M type stars in our catalog. The green contour represent the M giants distribution and the blue contour represent the M dwarfs distribution. From right to left, the template subtypes are from M0 to M6, which means the CaH and TiO molecular absorption bands in late-type template are deeper than the early-type template. The distribution of giant templates shows that our template spectra are consist with the M giants branch, and define a reliable temperature grid.





Using the M-type stars sample, we find M giants and dwarfs located on two distinct regions in the WISE and 2MASS color-color diagram for the first time (Li et al. in prep). The infrared color distribution of M-type stars is shown in the left diagram. The red dots are M giants and the blue dots are M dwarfs, of which both were classified by our classification pipeline. The dwarfs contamination in the M giants sample is about 4.7%.

Reference: Covey, K. R Ivezić, Ž, Schlegel, D., et al. 2007, AJ, 134, 2398
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Li et al.in prep

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