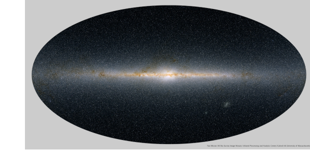
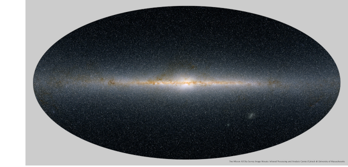


LSP3的改进及反银心方向巡天第二期增值星表

向茂盛
国家天文台，LAMOST冠名博士后

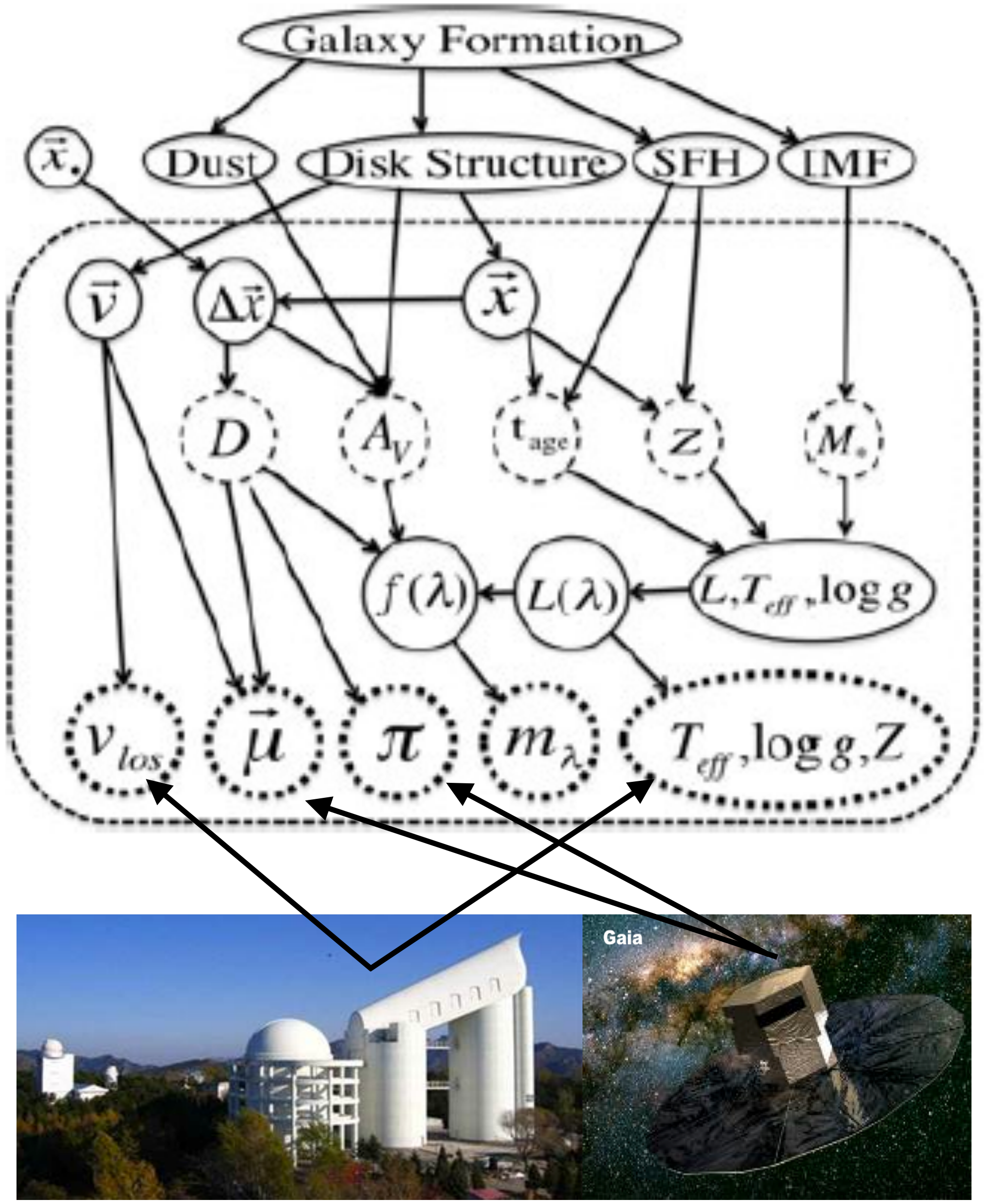
主要合作者：
北京大学：刘晓为、黄样、陈丙秋、王春、田志佳
北京师范大学：苑海波
国家天文台：施建荣、霍志英等

2017-02-18, 昆明



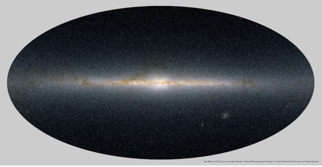
LSP3的动机：银河系结构与演化研究途径

Rix & Bovy 2013, AAR, 21, 61

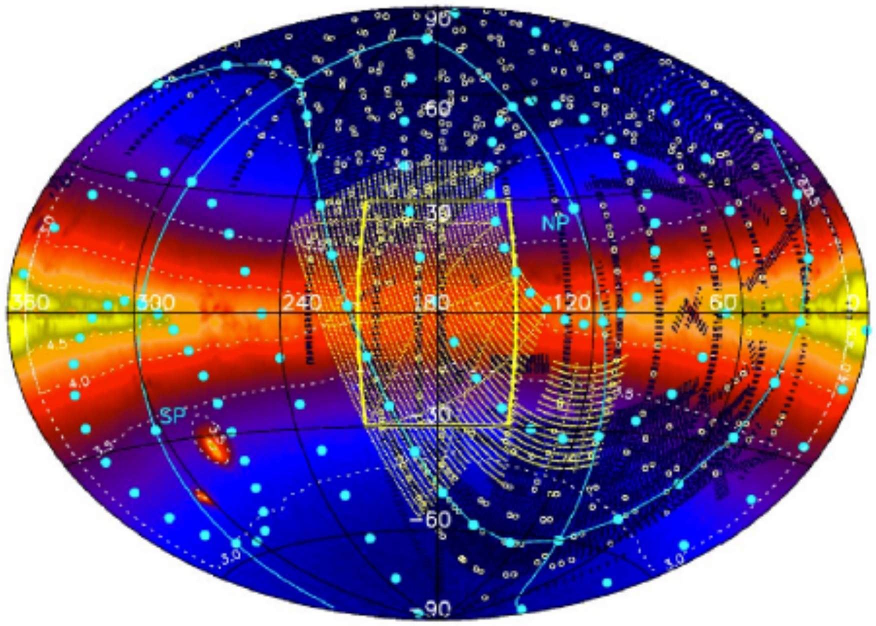


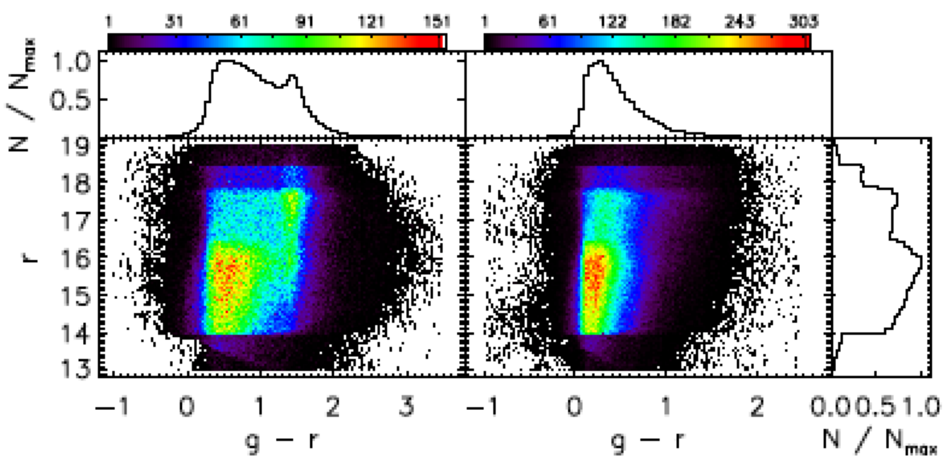
- 银河系结构、起源和演化研究：基础、前沿、热点问题
  - 三维结构（物质分布）、并合和长期演化历史、暗物质
- 银河系结构、起源和演化研究的主要途径：构建大样本恒星的三维空间、三维速度、年龄、元素丰度([Fe/H], [a/Fe], [C/H], [N/H]等)
- **LAMOST恒星光谱数据：**
  - 大样本、多类型
  - 低分辨率、仪器较复杂

LSP3的动机：反银心方向巡天数据特点



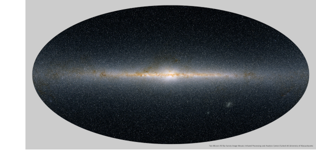
- 星际消光严重、未知
  - 光谱处理－流量定标精度差或处理失败
  - 距离估计精度受限
- 巡天覆盖所有恒星类型
- 缺乏光谱分析软件，已有软件（如SSPP）
  - 适用于有限的恒星类型、参数种类
  - 参数精度有巨大提高空间



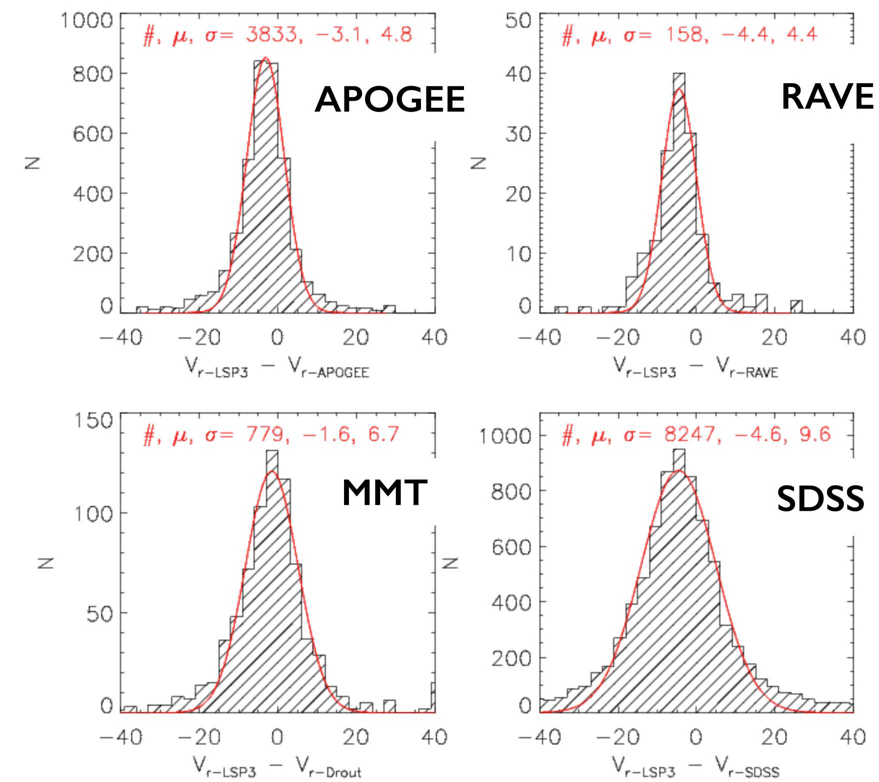


光谱量大＋恒星类型多＋星际消光影响显著
光谱分析软件缺乏
→ **LSP3**

LSP3—LAMOST Stellar Parameter Pipeline at Peking University



- 模版匹配
  - Teff，logg，[Fe/H]: 经验模版库MILES；最小卡方
  - 视向速度：经验模版库ELODIE＋理论模版库Kurucz（高温星）；最大相关系数
- 利用蓝端光谱
- 细致的内部和外部（独立测量）检验



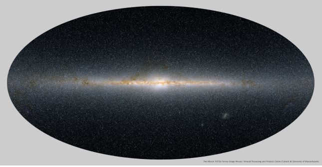
由LSP3得到的反银心方向巡天恒星参数通过增值星表释放（Yuan et al. 2015, MNRAS, 448, 855）

http://lamost973.pku.edu.cn/site/data

LSP3 −	Teff (K)	log *g* (dex)	[Fe/H] (dex)
PASTEL	19 ± 145	−0.03 ± 0.23	0.06 ± 0.13
APOGEE	16 ± 134	−0.02 ± 0.41	0.05 ± 0.17
SDSS	−105 ± 110	0.24 ±0.22	0.12 ± 0.14
LAMOST DR1	7 ± 133	0.02 ± 0.22	0.06 ± 0.14

Xiang et al. 2015, MNRAS, 448, 822

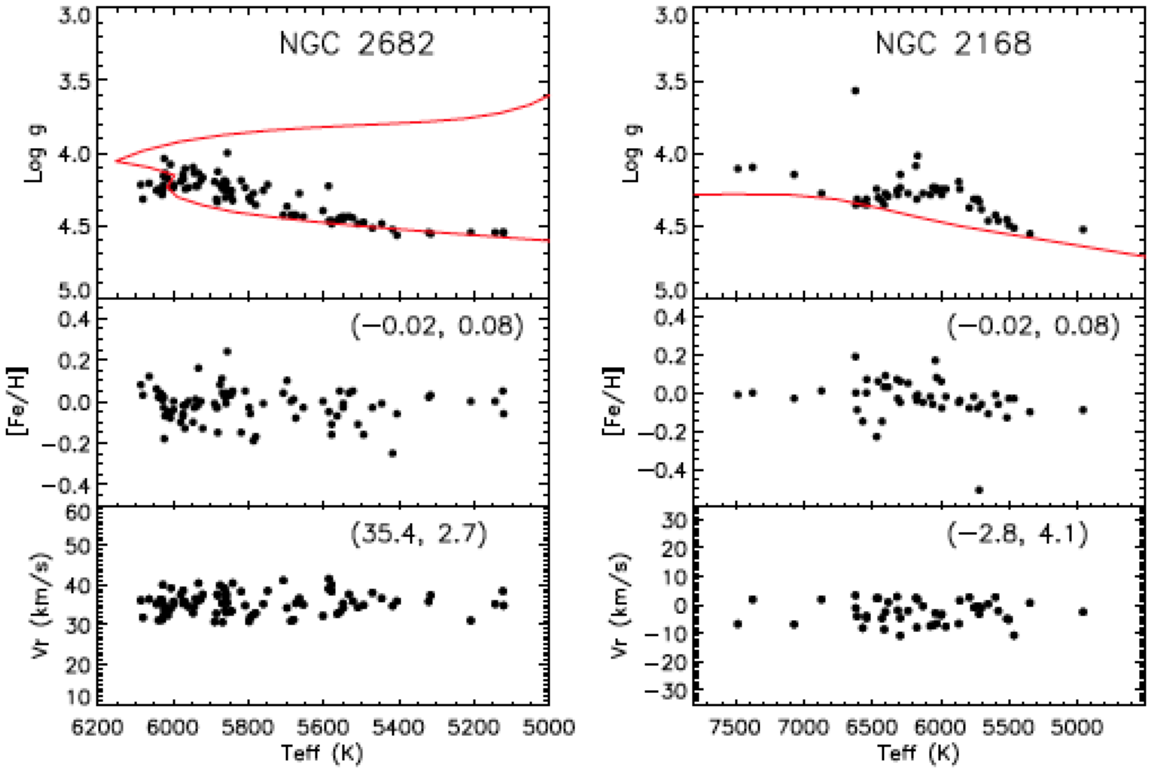
第一版LSP3的不足

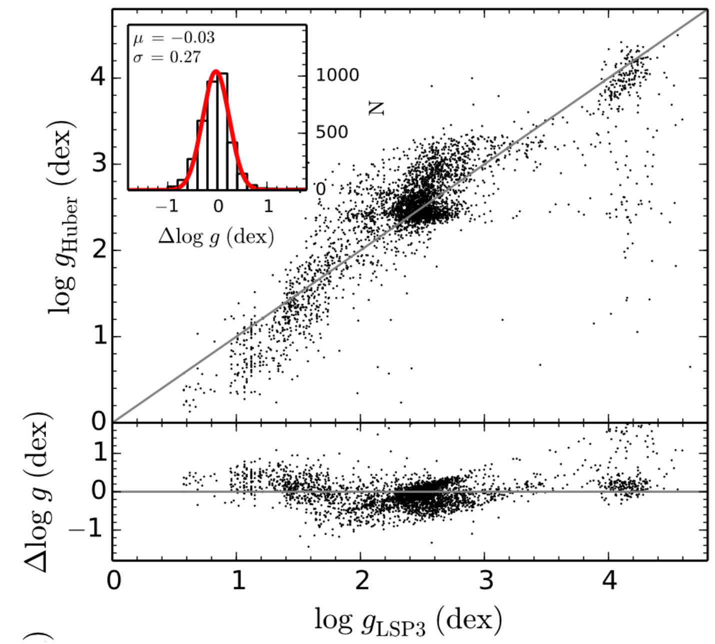


- 表面重力加速度logg误差较大（距离、年龄误差大）
- 缺乏元素α元素, C, N元素等丰度测量
- 仅采用了蓝端光谱，而相当一部分偏红的恒星因蓝端光谱信噪比低而没有参数测量
- 模版不均匀导致一定的参数成团效应，模版边界导致一定的参数测量边界效应

导致这些问题的原因：模版库局限和算法局限

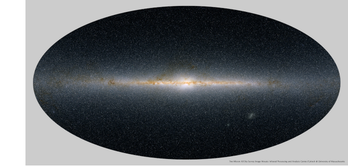
Xiang+2015,MNRAS, 448, 822



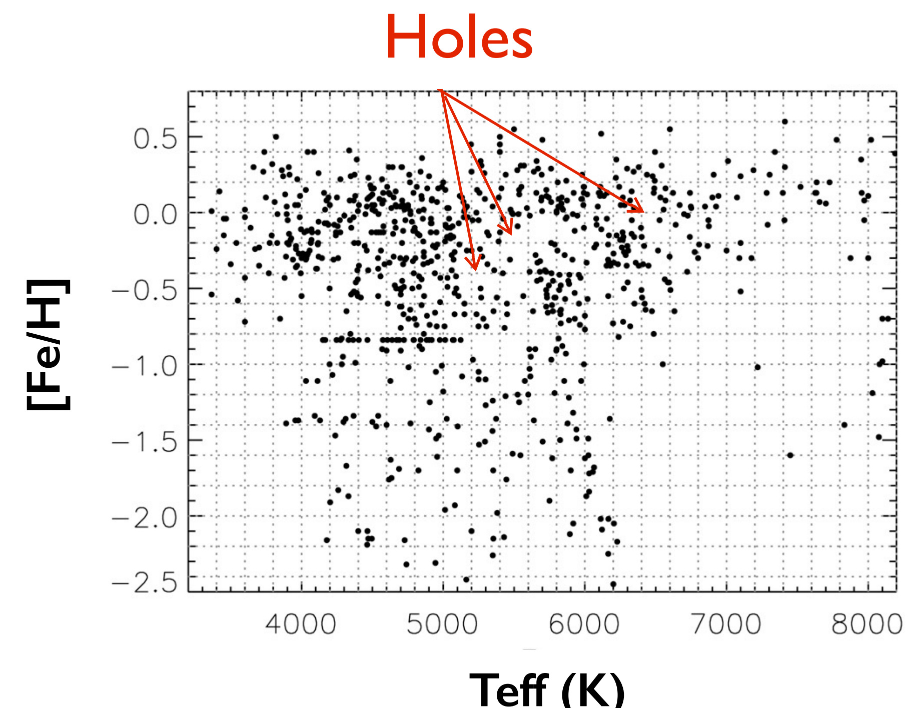


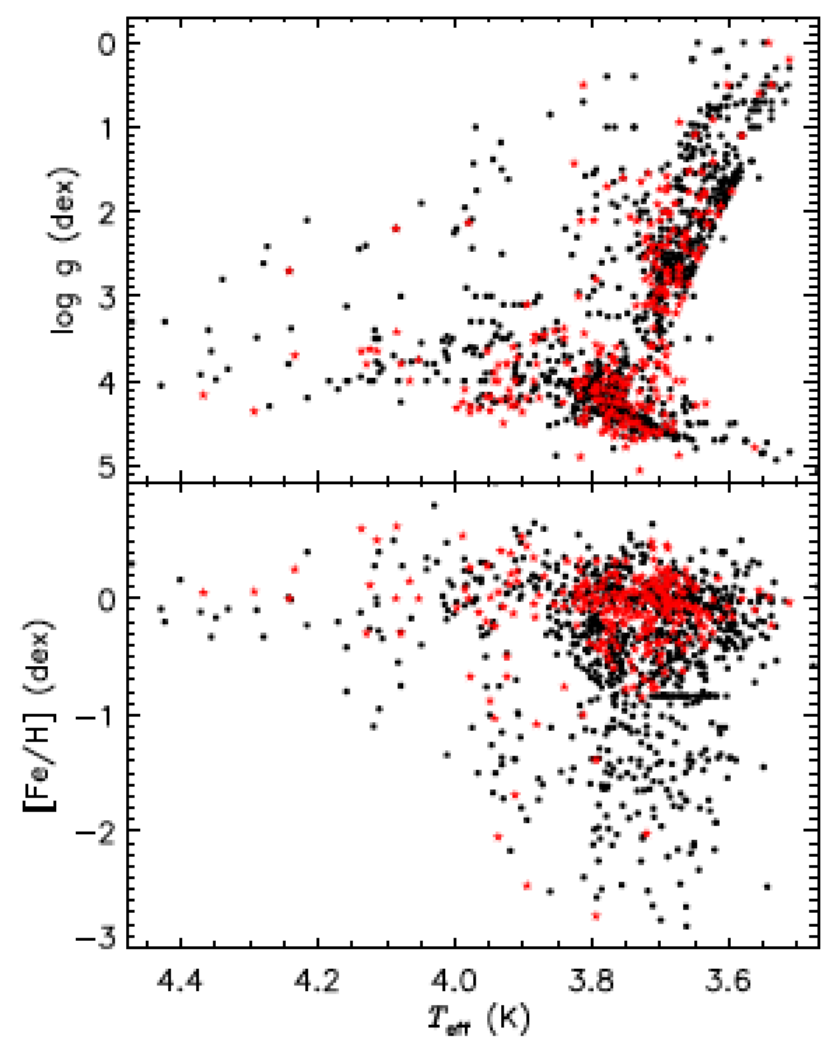
Ren et al. 2016, RAA, 16, 45

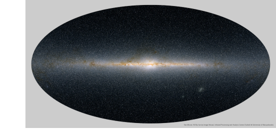
LSP3的改进



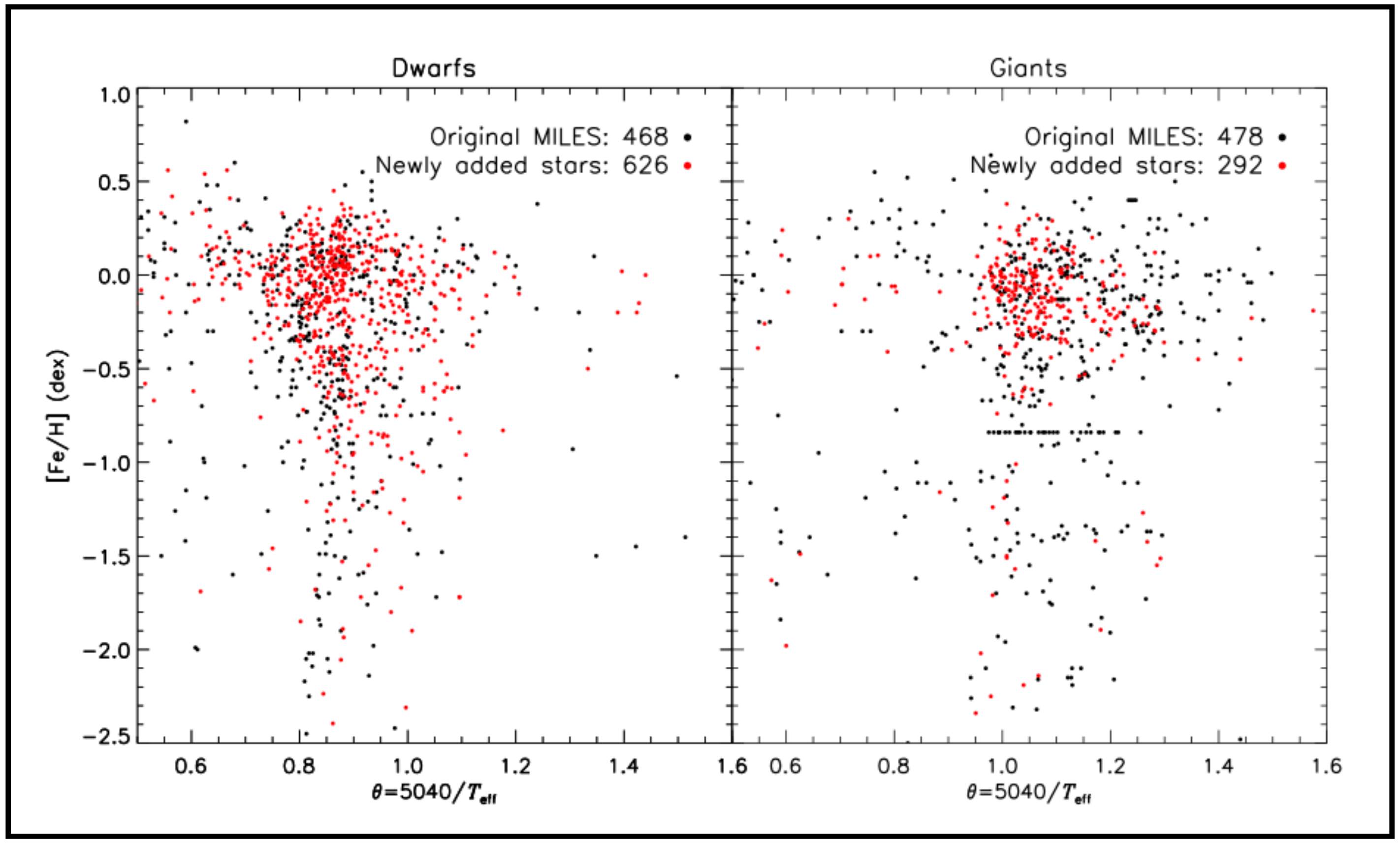
- 利用兴隆2.16m和丽江2.4m望远镜扩充MILES模版库
  - 参数空间覆盖更均匀、更广
  - 红端波长覆盖扩充到9200埃
- 重新定标模版库恒星基本大气参数
- 从LAMOST光谱中选取有精确参数测量的源(LAMOST-Kepler，LAMOST-Hipparcos，LAMOST-APOGEE)作为模版/训练样本, 利用机器学习算法估计参数
- 利用理论光谱库作模版测量[α/Fe]







扩充MILES模版库



- 新增从PASTEL星表选取的918颗恒星（目前已观测820颗）
- 1900颗星的红端光谱（已观测1213颗）

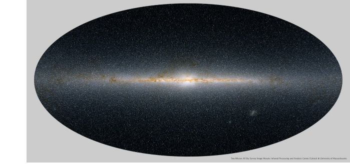
Wang et al. in prep.

重新定标/测量模版库恒星参数(Huang et al. in prep.)

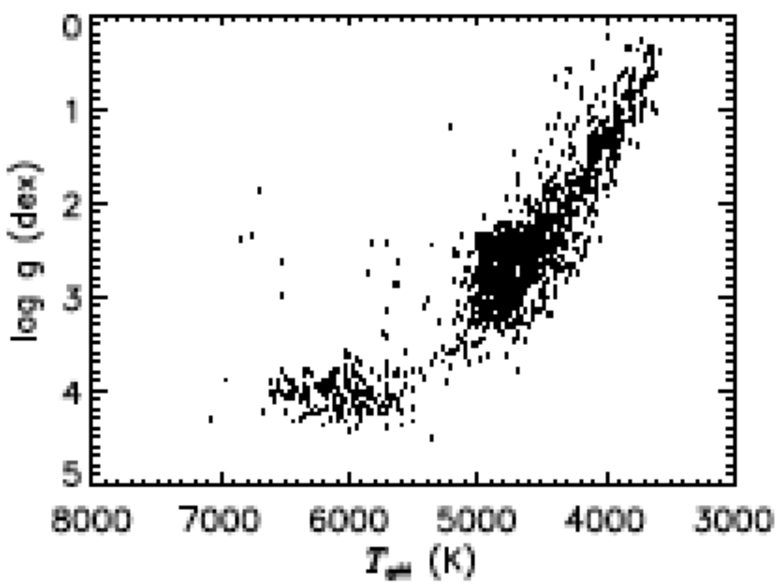
有效温度：颜色-金属丰度-有效温度关系

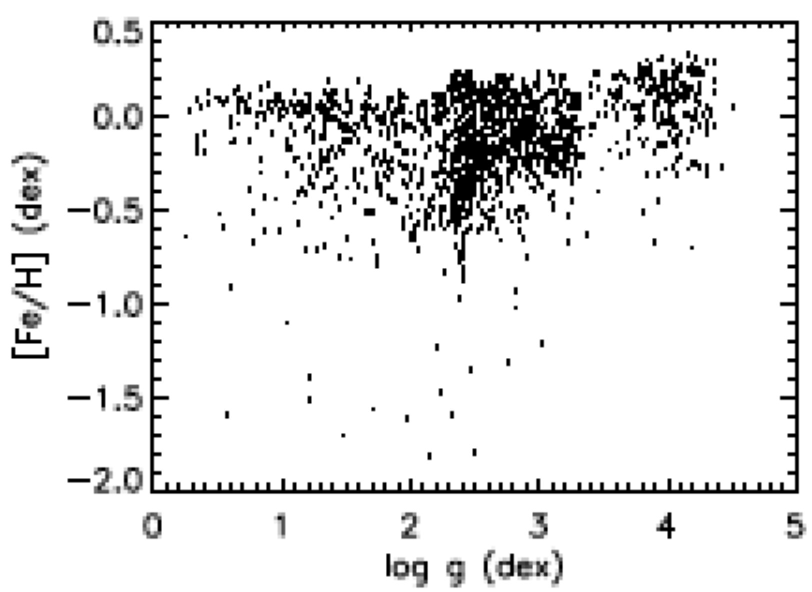
表面重力加速度：三角视差 + 恒星演化模型

金属丰度：高分辨光谱结果(PASTEL)，定标到Gaia-ESO标准星

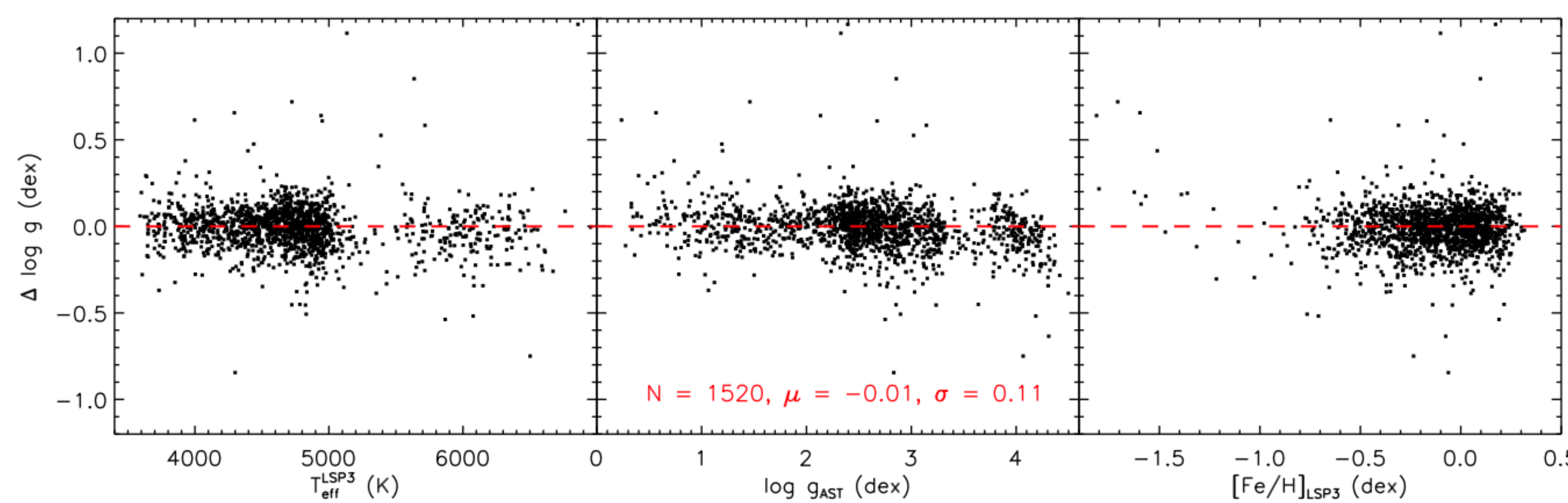


利用LAMOST-Kepler共同源估计巨星logg



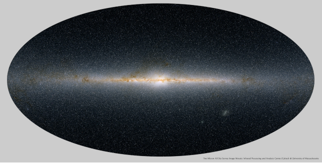


- 星震学给出的巨星logg精度优于0.05dex (e.g. Gai et al. 2011, Hekker et al. 2013, Chaplin et al. 2014)
- LAMOST-Kepler巡天获得数千颗具有星震学logg测量的巨星
- 选取其中一半作为训练样本，利用基于核主成分分析(KPCA)的多变量回归方法估计logg（适用于[Fe/H]>-1.0)

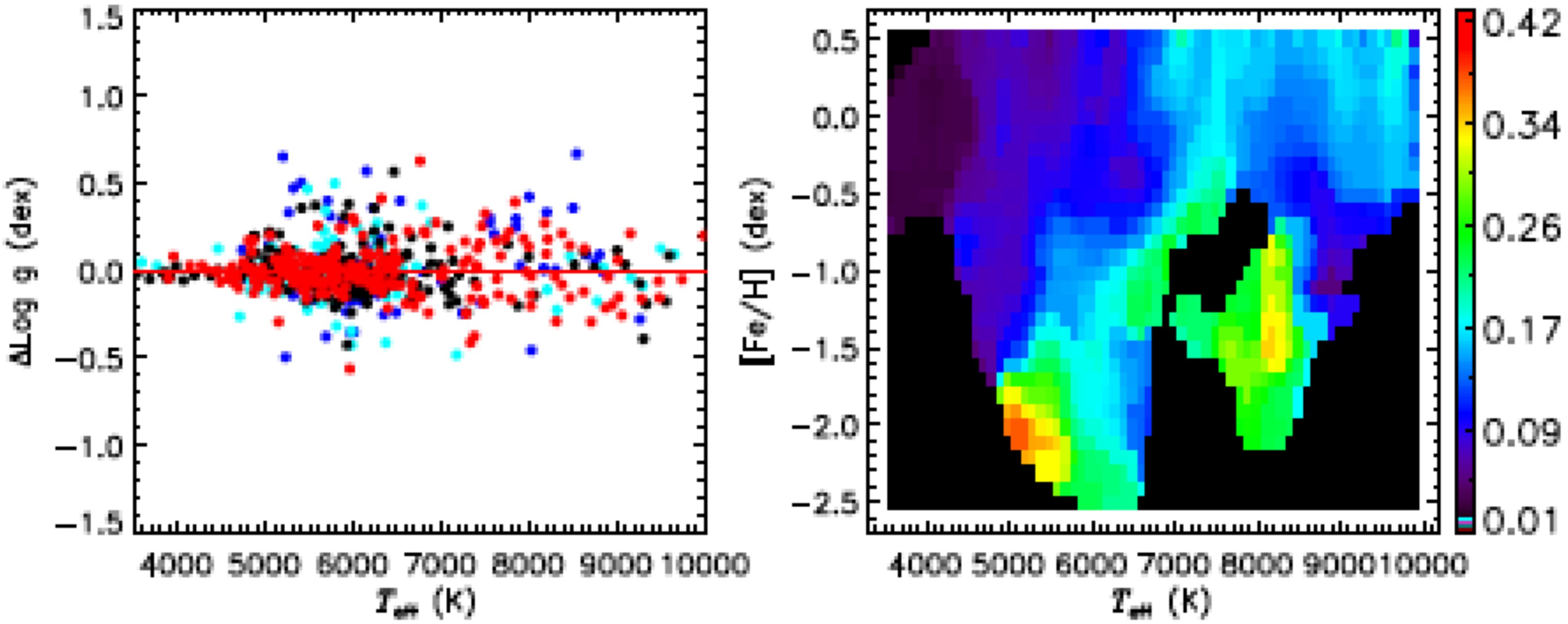


由此方法得到的logg可达0.1dex (SNR>50)

Xiang et al. 2017a, MNRAS, 464, 3657



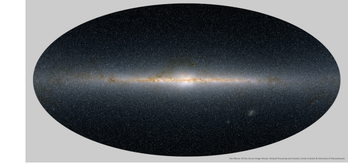
利用MILES光谱库和KPCA方法估计矮星logg

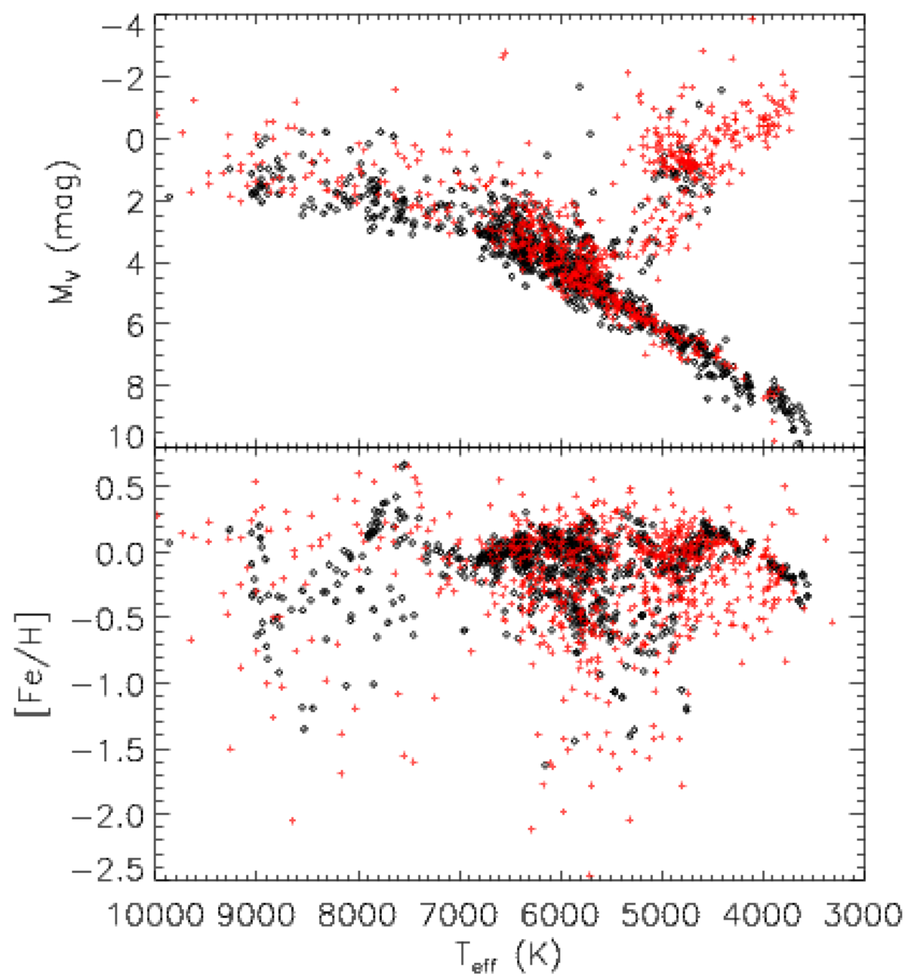


矮星：太阳类型恒星的logg精度可达0.1dex

Xiang et al. 2017a, MNRAS, 464, 3657

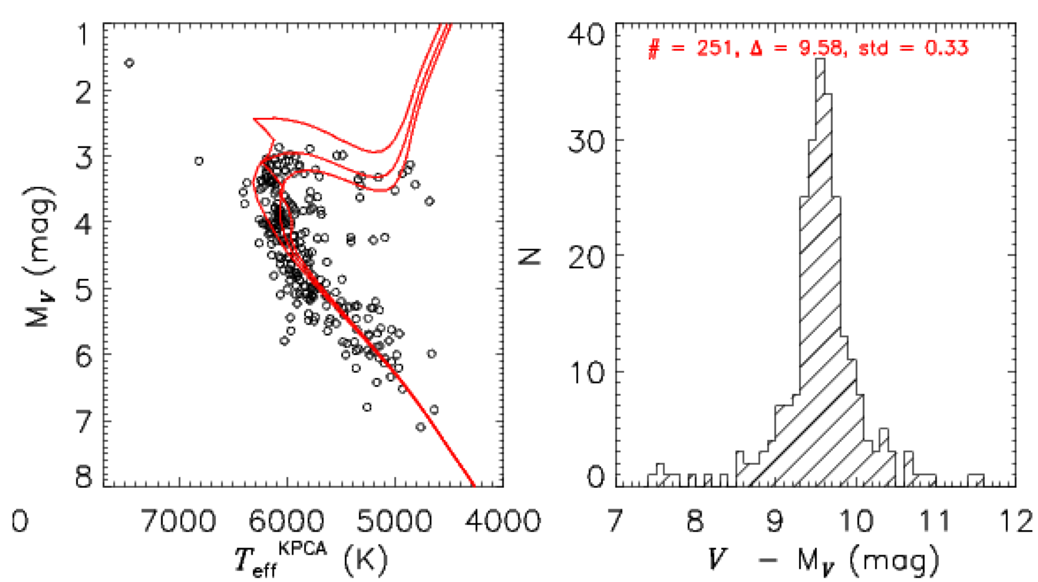
利用LAMOST-Hipparcos共同源估计绝对星等





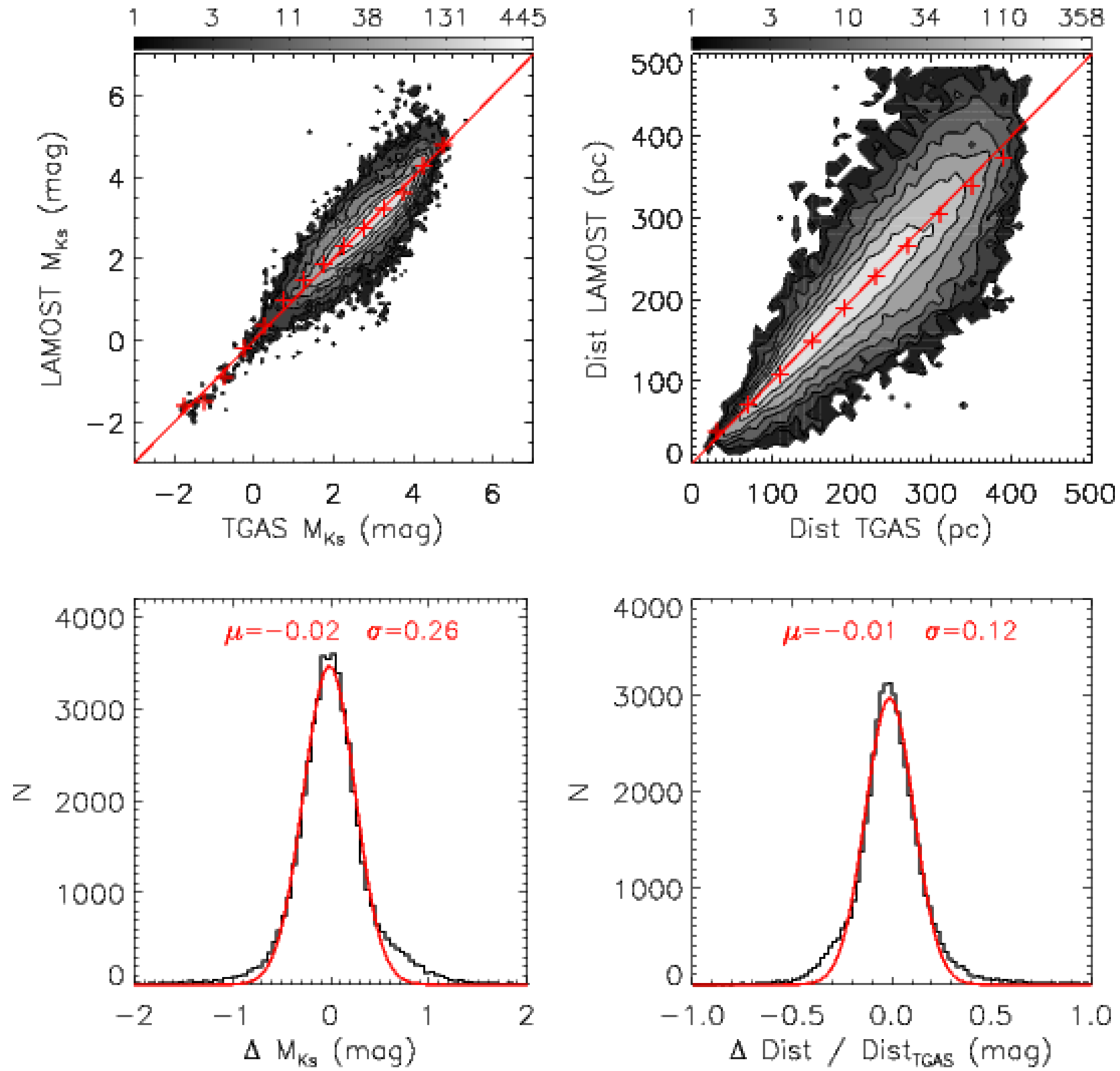
训练样本：LAMOST与HIPPARCOS
共同源＋MILES恒星

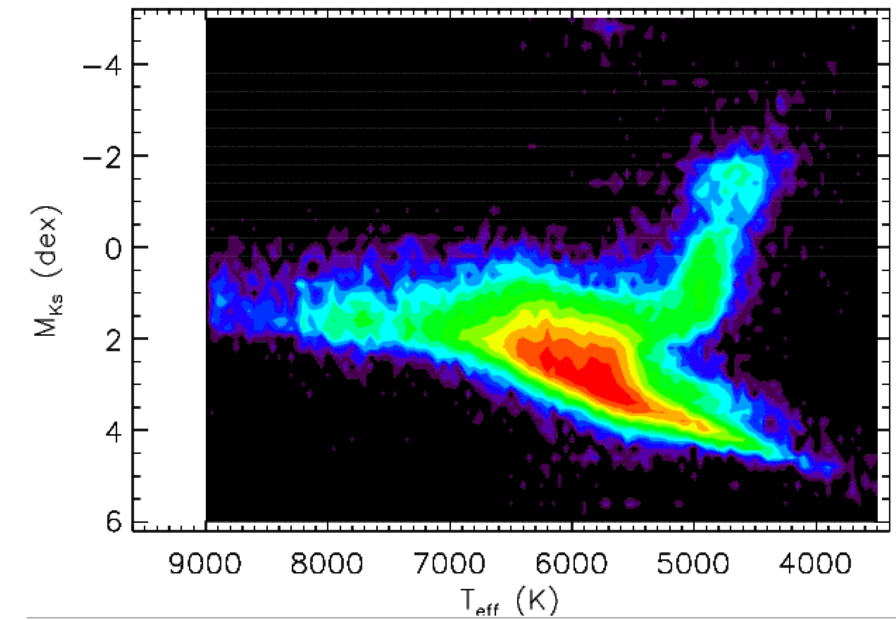
绝对星等的精度达0.3mag (SNR>50)

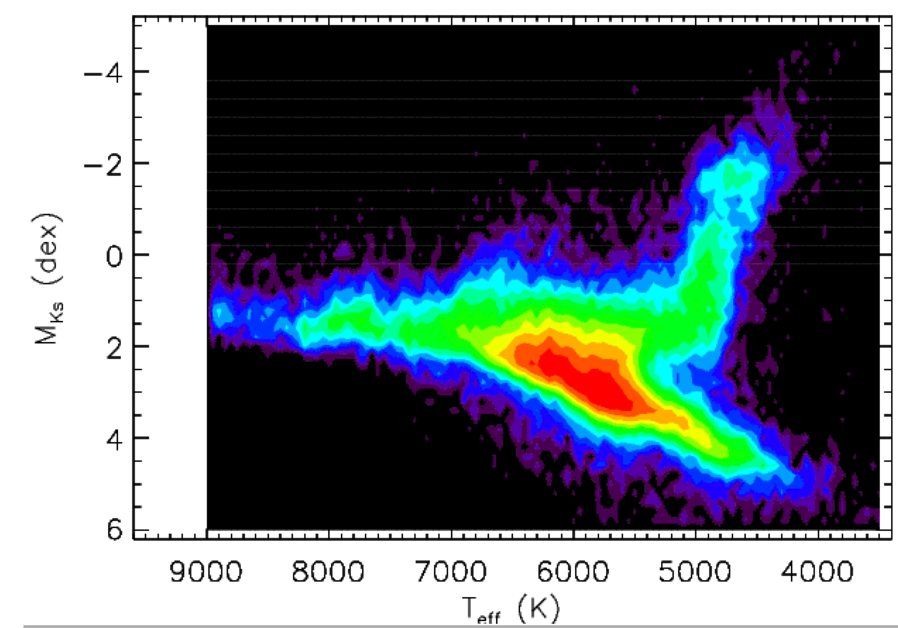


首次通过经验地方式直接从大
样本光谱得到精确距离估计

绝对星等—与Gaia TGAS比较

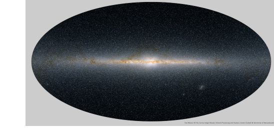


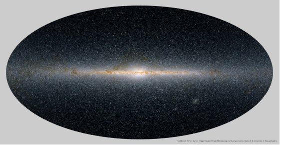




绝对星等精度优于0.3mag，对应距离误差约10%

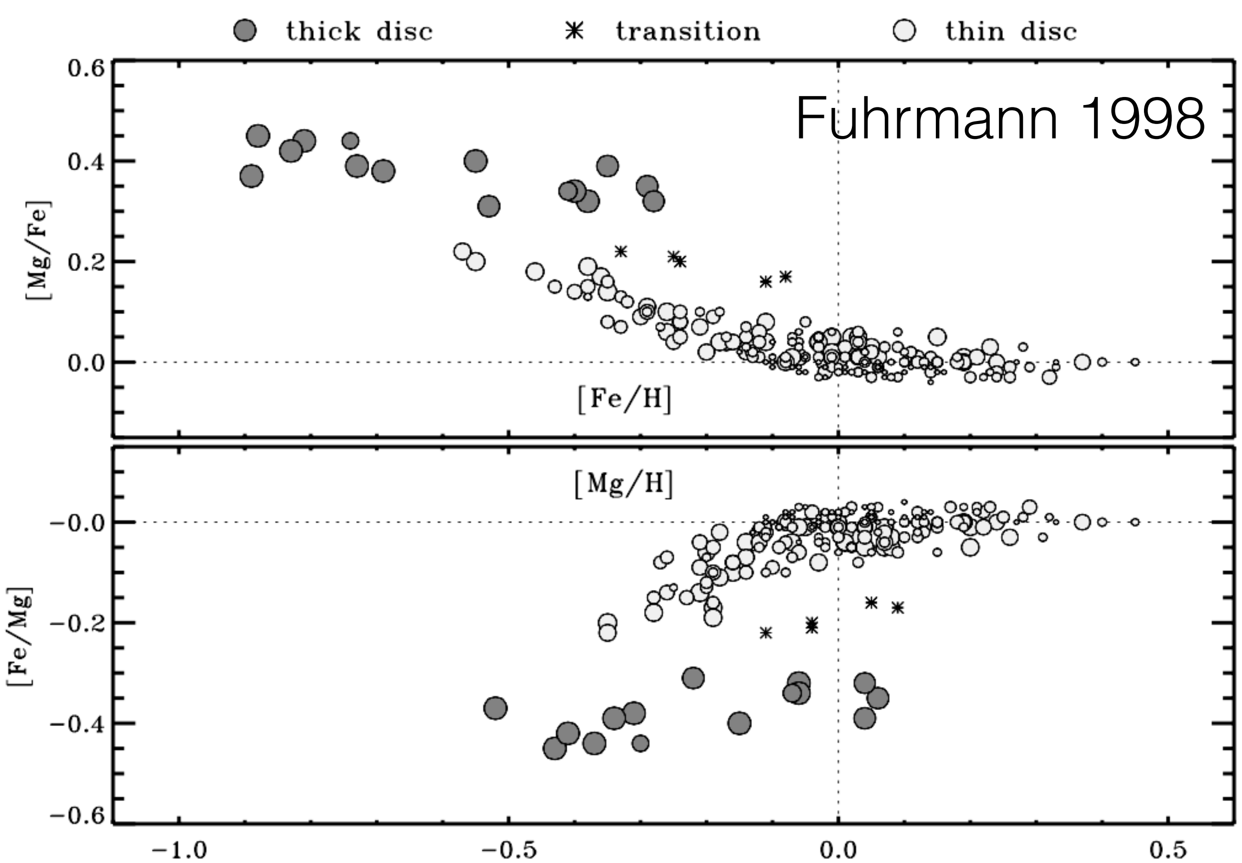
Xiang et al. 2017b, MNRAS, in press, arXiv:1701.05409





测量[α/Fe]

恒星的[α/Fe]是银河系星族和化学增丰历史的重要的指针



1，与理论光谱进行模版匹配

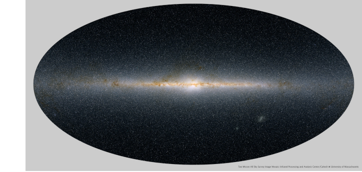
Li et al. 2016, RAA, 16,110

基于Kurucz恒星大气模型构建格点密的理论光谱库

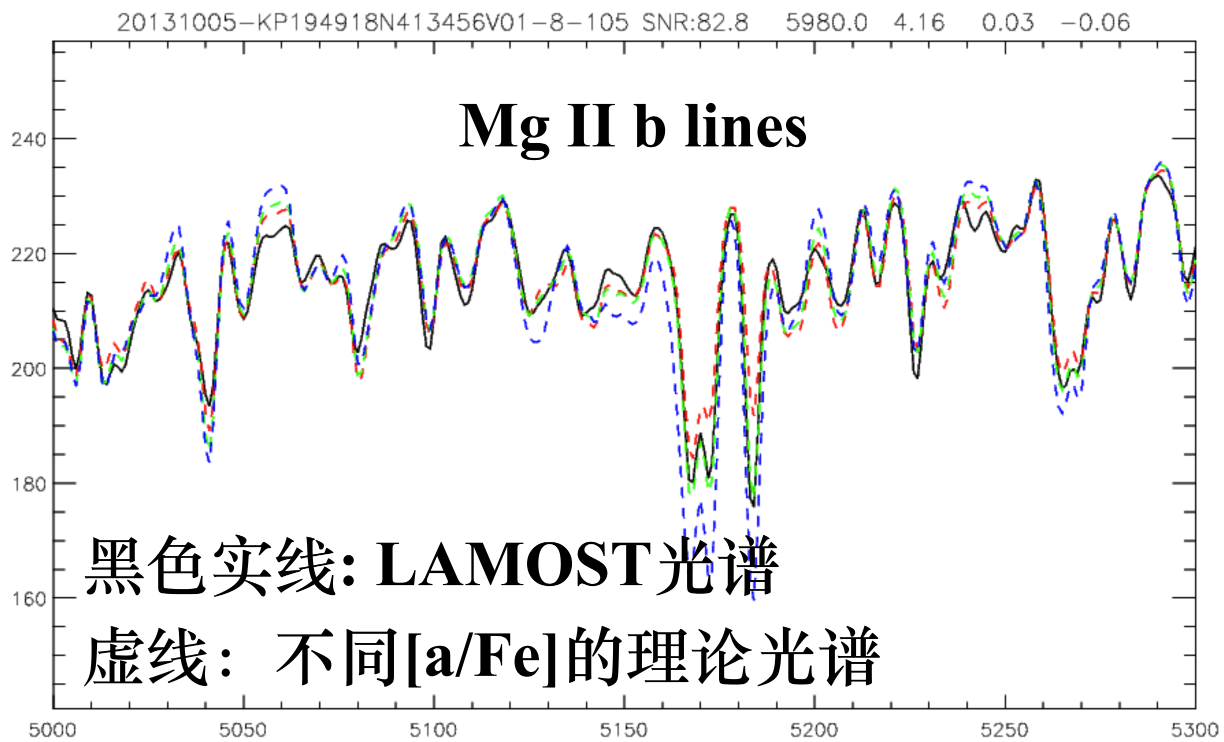
2，KPCA方法（巨星）

Xiang et al. 2017a, MNRAS, 464, 3657

利用LAMOST-APOGEE恒星作为训练样本; 同时，还测量了[C/H], [N/H], [Mg/H], [Ca/H]



利用理论模版估计[α/Fe]

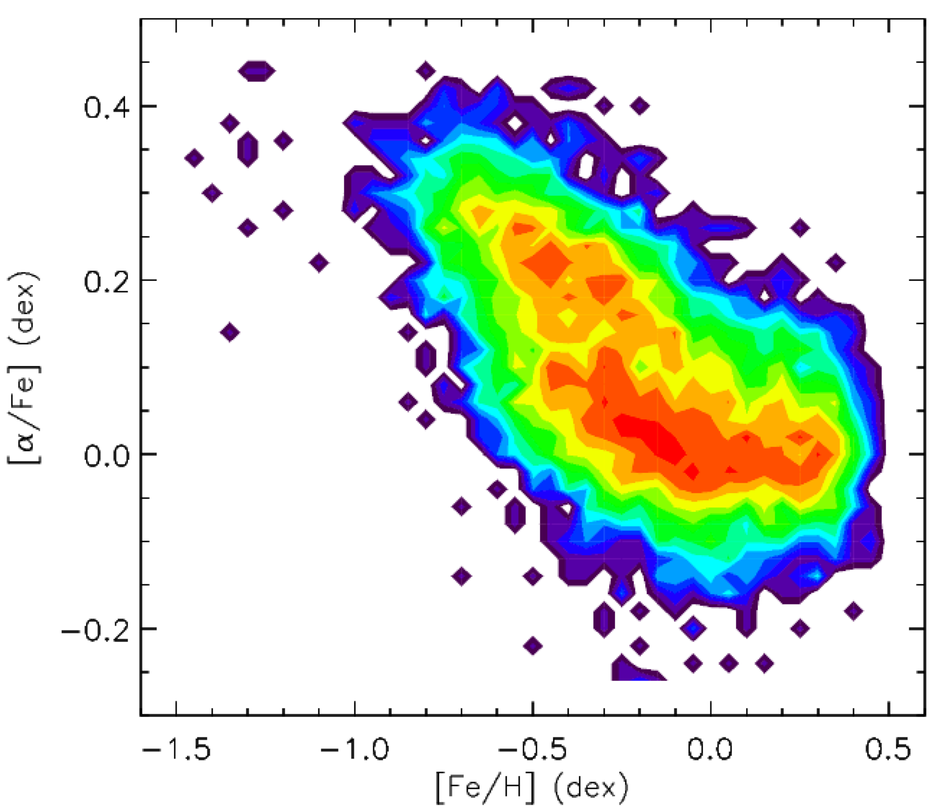


利用包含Mg, Ti谱线的光谱段
最小卡方匹配

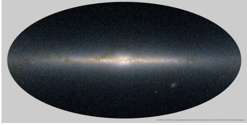
Li et al. 2016, RAA, 16,110

光谱信噪比大于50时，矮星[α/Fe]
测量的精度达0.05dex

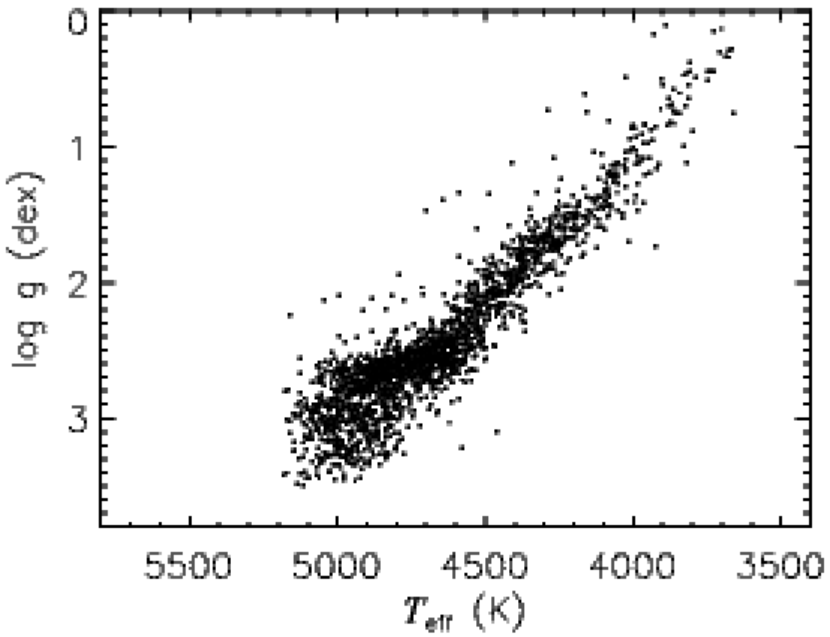
Xiang et al. 2017b, MNRAS, in press, arXiv:1701.05409



高精度元素丰度测量—从化学丰度上区分薄盘、厚盘星，以研究薄盘、厚盘大样本恒星的统计性质

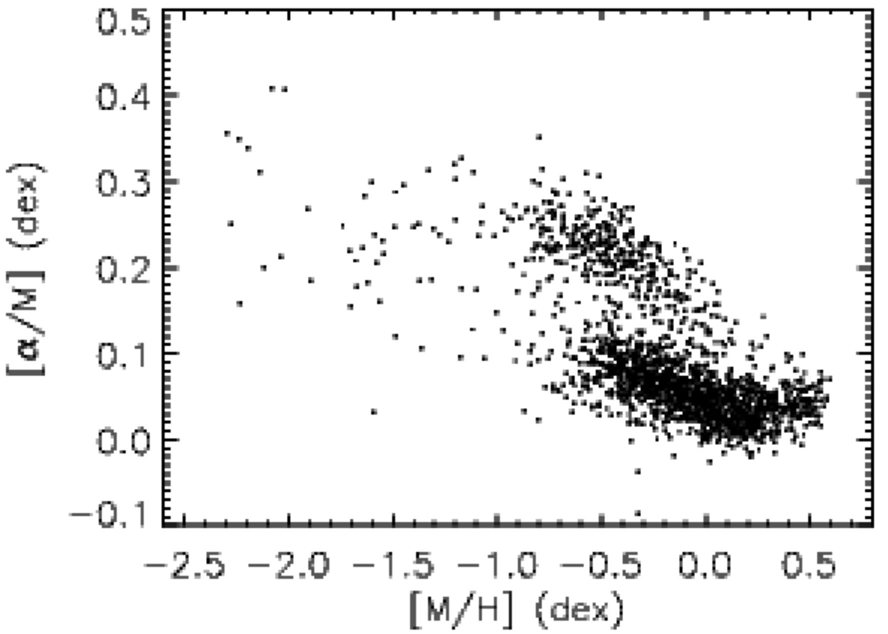


利用LAMOST-Kepler共同源估计巨星的[α/Fe]



SDSS-III/APOGEE: 分辨本领R~22500红外光谱(1.51 – 1.70μm)

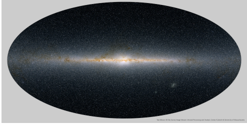
10万颗巨星的Teff, log g, [M/H], [C/M], [N/M] and [α/M]及15种元素丰度(Holtzman et al. 2015)

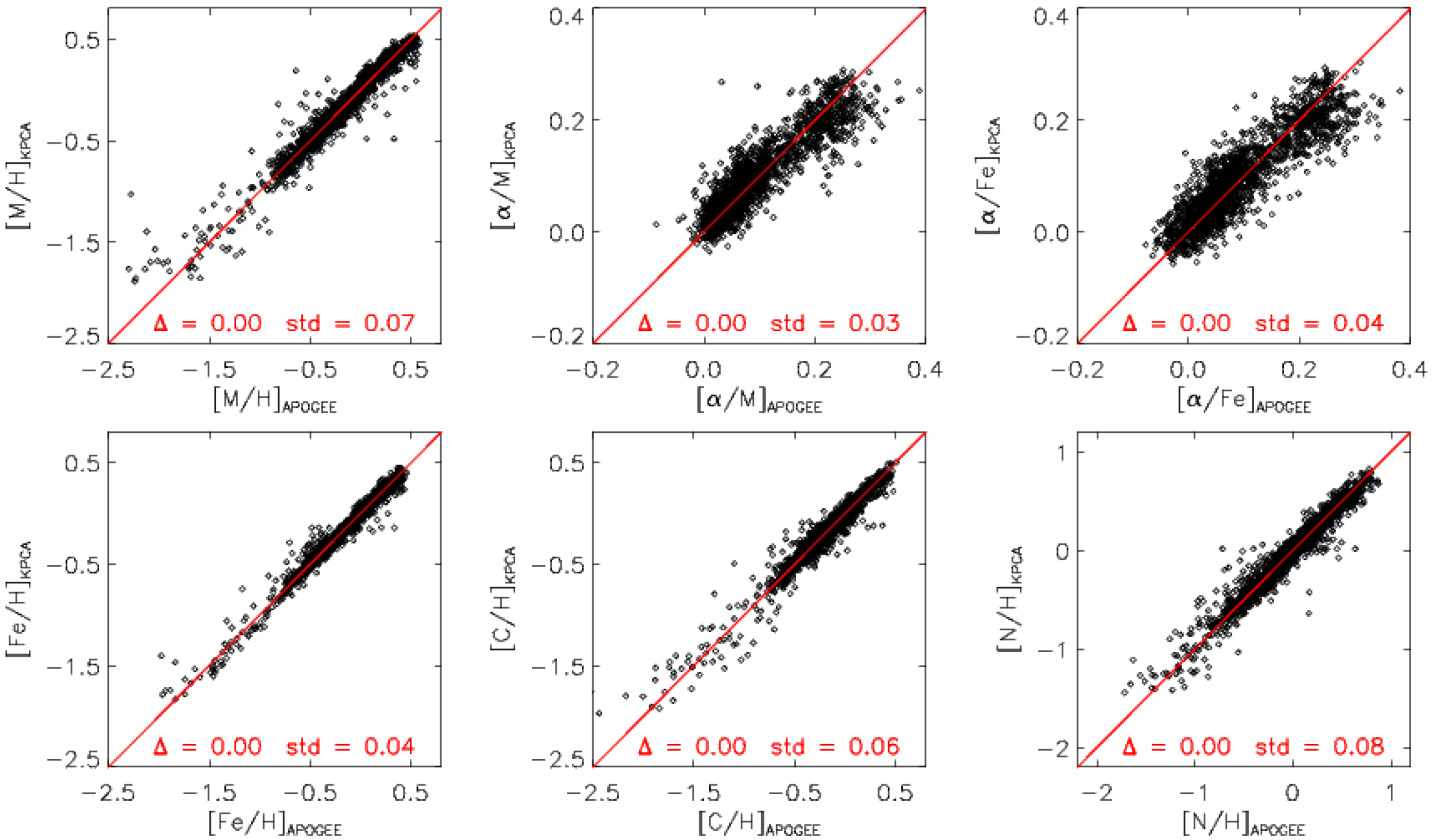


3500多颗信噪比大于50的共同源，取其中一半作为训练样本

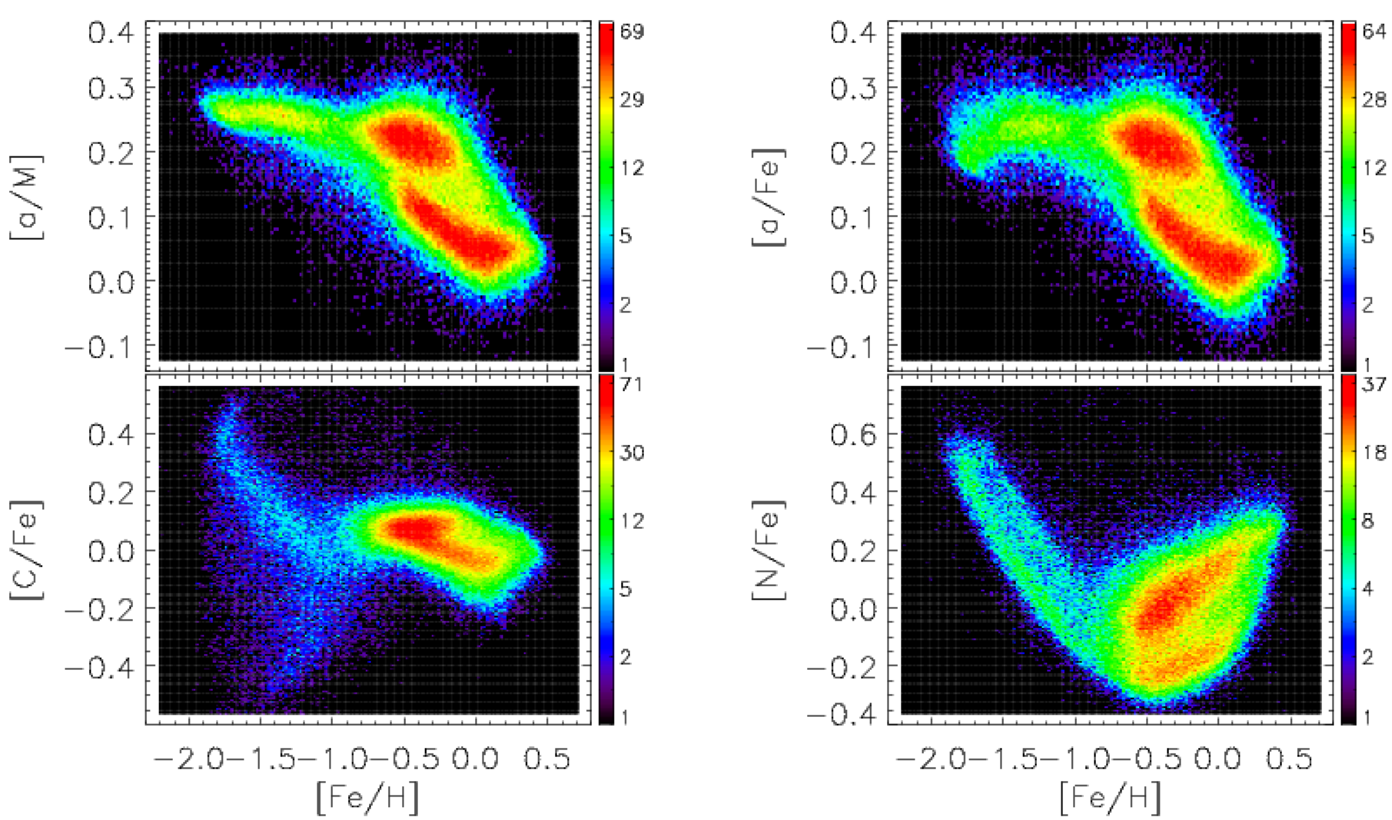
Xiang et al. 2017a, MNRAS, 464, 3657

利用LAMOST-Kepler共同源估计巨星的[α/Fe]





从LAMOST光谱提取的丰度与从APOGEE光谱得到的丰度精度相当

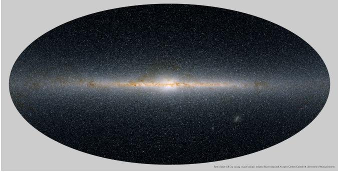


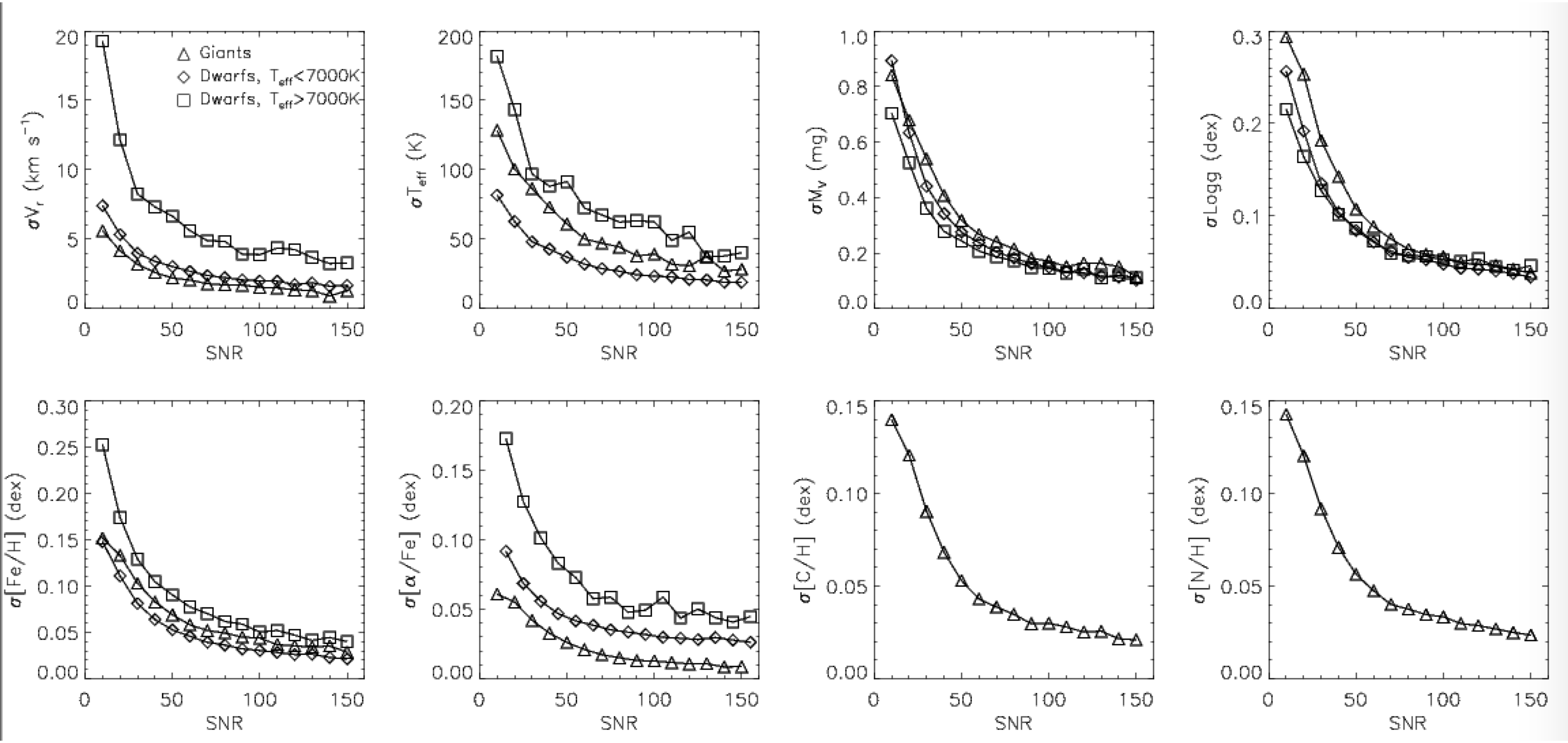
|b|>30； SNR>20

高精度丰度测量使得薄盘、厚盘、晕族恒星能够被显著区分开

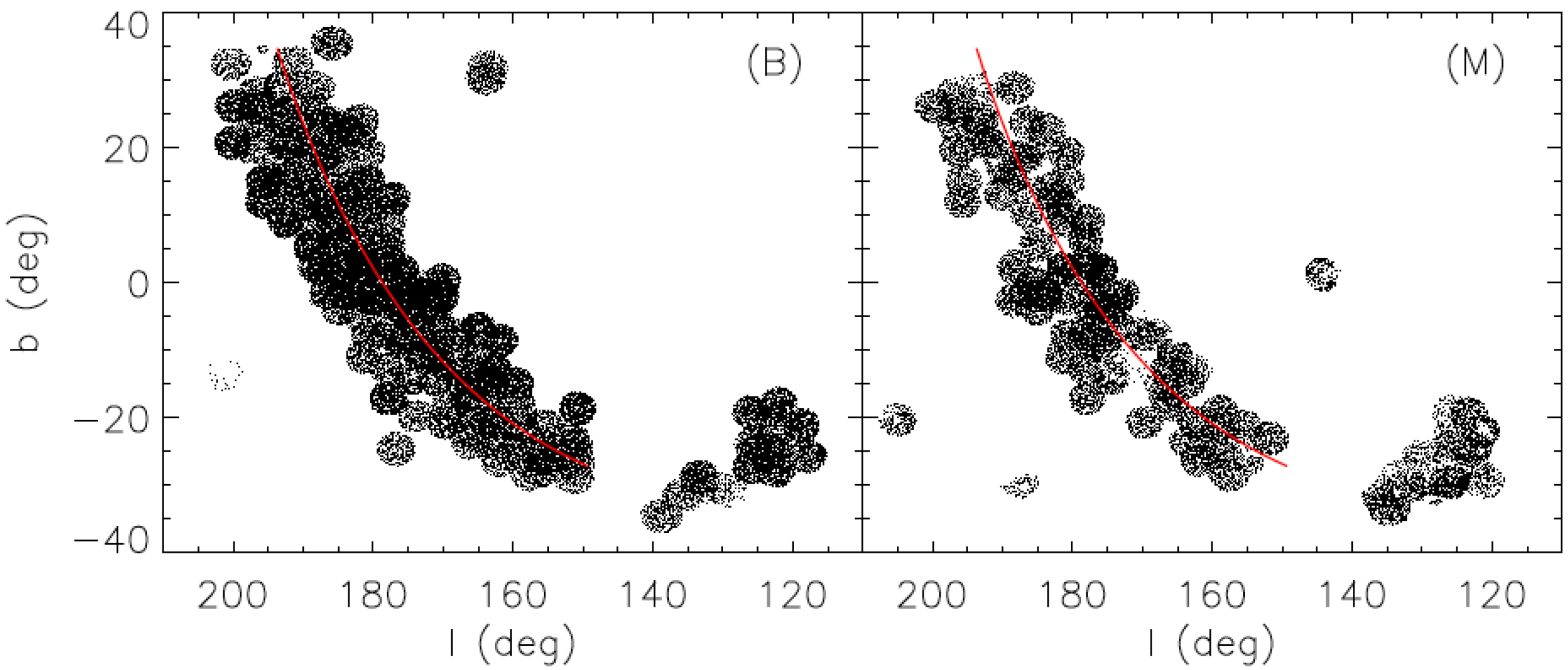
Xiang et al. 2017a, MNRAS, 464, 3657

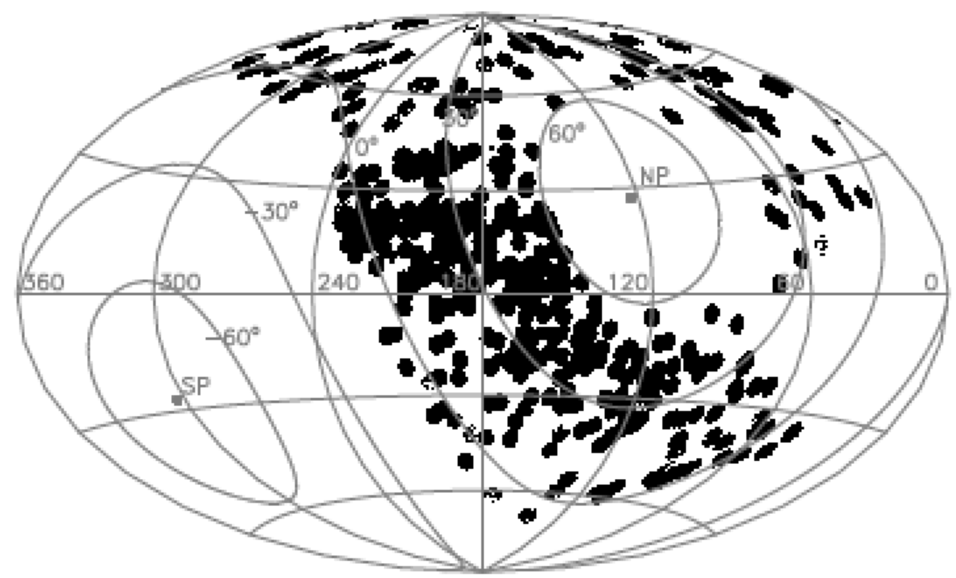
基本参数的测量精度随信噪比及恒星类型的变化





反银心方向巡天第二期增值星表





2011.9-2014.6

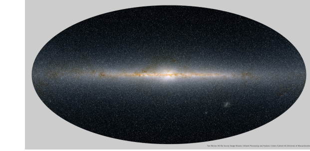
	LSS-GAC Main Survey	M31/M33 Survey	VB Survey
All SNRs	1,332,812 (948,361)	305,226 (171,259)	1,944,525 (1,431,219)
SNR (4650Å) > 10	510,531 (423,503)	91,921 (65,841)	1,194,367 (922,935)
SNR (7450Å) > 10	688,459 (572,438)	68,380 (58,197)	1,358,618 (1,050,143)
SNR (4650Å) > 10 or SNR(7450) > 10	763,723 (618,924)	113,597 (80,452)	1,397,538 (1,075,677)

1.8M/1.4M

2.3M/1.8M

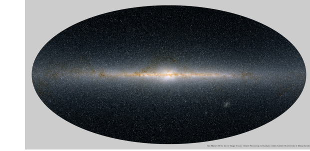
Xiang et al. 2017b, MNRAS, in press, arXiv:1701.05409

反银心方向巡天第二期增值星表

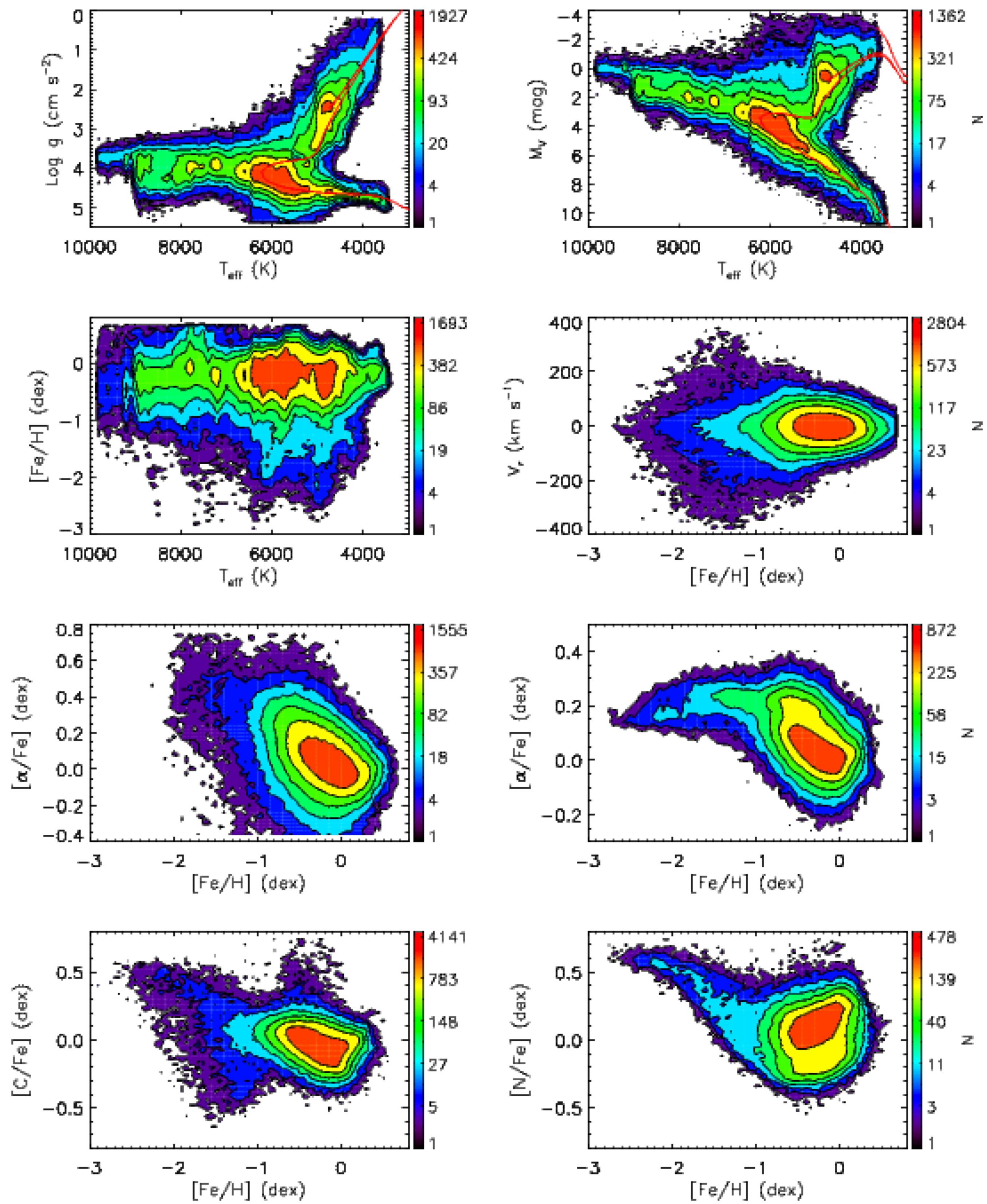


Parameter	Method	Effective range
Effective temperature		
$T_{\rm eff}$_1	Weighted-mean template matching	All
$T_{\rm eff}$_2	KPCA with the MILES training set	$T_{\rm eff}$_1 $<$ 10000 K
$T_{\rm eff}$ (recommended)	$T_{\rm eff}$_1	All
Surface gravity		
Logg_1	Weighted-mean template matching	All
Logg_2	KPCA with the MILES training set	$T_{\rm eff}$_1 $<$ 10000 K, Logg_1 $>$ 3.0 dex
Logg_3	KPCA with the LAMOST-*Kepler* training set	$T_{\rm eff}$_1 $<$ 5600 K, Logg_1 $<$ 3.8 dex or Logg_2 $<$ 3.8 dex
Logg (recommended)	Logg_1	$T_{\rm eff}$_1 $>$ 10000 K
	Logg_3	$T_{\rm eff}$_1 $<$ 5600 K, Logg_1 $<$ 3.8 dex or Logg_2 $<$ 3.8 dex
	Logg_2	Otherwise
Metallicity		
[Fe/H]_1	Weighted-mean template matching	All
[Fe/H]_2	KPCA with the MILES training set	$T_{\rm eff}$_1 $<$ 10000 K
[Fe/H]_3	KPCA with the LAMOST-APOGEE training set	$T_{\rm eff}$_1 $<$ 5600 K, Logg_1 $<$ 3.8 dex or Logg_2 $<$ 3.8 dex
[Fe/H] (recommended)	[Fe/H]_1	$T_{\rm eff}$_1 $>$ 10000 K
	[Fe/H]_2	Otherwise
α-element to iron abundance ratio		
[α/Fe]_1	Template matching using spectra of 3900 – 3980, 4400 – 4600 and 5000 – 5300 Å	4000 $<$ $T_{\rm eff}$_1 $<$ 8000 K
[α/Fe]_2	Template matching using spectra of 4400 – 4600 and 5000 – 5300 Å	4000 $<$ $T_{\rm eff}$_1 $<$ 8000 K
[α/Fe]_3	KPCA with the LAMOST-APOGEE training set	$T_{\rm eff}$_1 $<$ 5600 K, Logg_1 $<$ 3.8 dex or Logg_2 $<$ 3.8 dex
[α/Fe] (recommended)	[α/Fe]_3	$T_{\rm eff}$_1 $<$ 5600 K, Logg_1 $<$ 3.8 dex or Logg_2 $<$ 3.8 dex
	[α/Fe]_1	Otherwise
Other elemental abundances		
[M/H]		
[α/M]	KPCA with the LAMOST-APOGEE training set	$T_{\rm eff}$_1 $<$ 5600 K, Logg_1 $<$ 3.8 dex or Logg_2 $<$ 3.8 dex
[C/H]		
[N/H]		
Absolute magnitudes		
M_V_1	KPCA with the LAMOST-Hipparcos training set	
M_{K_s}_1	using 300 PCs	$T_{\rm eff}$_1 $<$ 12000 K
M_V_2	KPCA with the LAMOST-Hipparcos training set	
M_{K_s}_2	using 100 PCs	$T_{\rm eff}$_1 $<$ 12000 K
M_V (recommended)	M_V_1	
M_{K_s} (recommended)	M_{K_s}_1	$T_{\rm eff}$_1 $<$ 12000 K

Xiang et al. 2017b, MNRAS, in press, arXiv:1701.05409



反银心方向巡天第二期增值星表



HR图与Isochrone符合较好

盘星主导: [Fe/H]<-1的源仅占1.8%

样本参数误差中值

Vr: 5.7km/s

Teff: 112K

logg: 0.17dex

[Fe/H]: 0.14dex

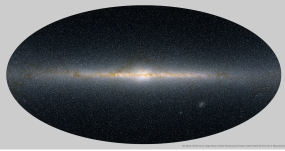
[a/Fe]: 0.03dex(giant),

0.1dex(dwarf)

[C/H],[N/H]: 0.1dex

E(B-V): 0.04 mag

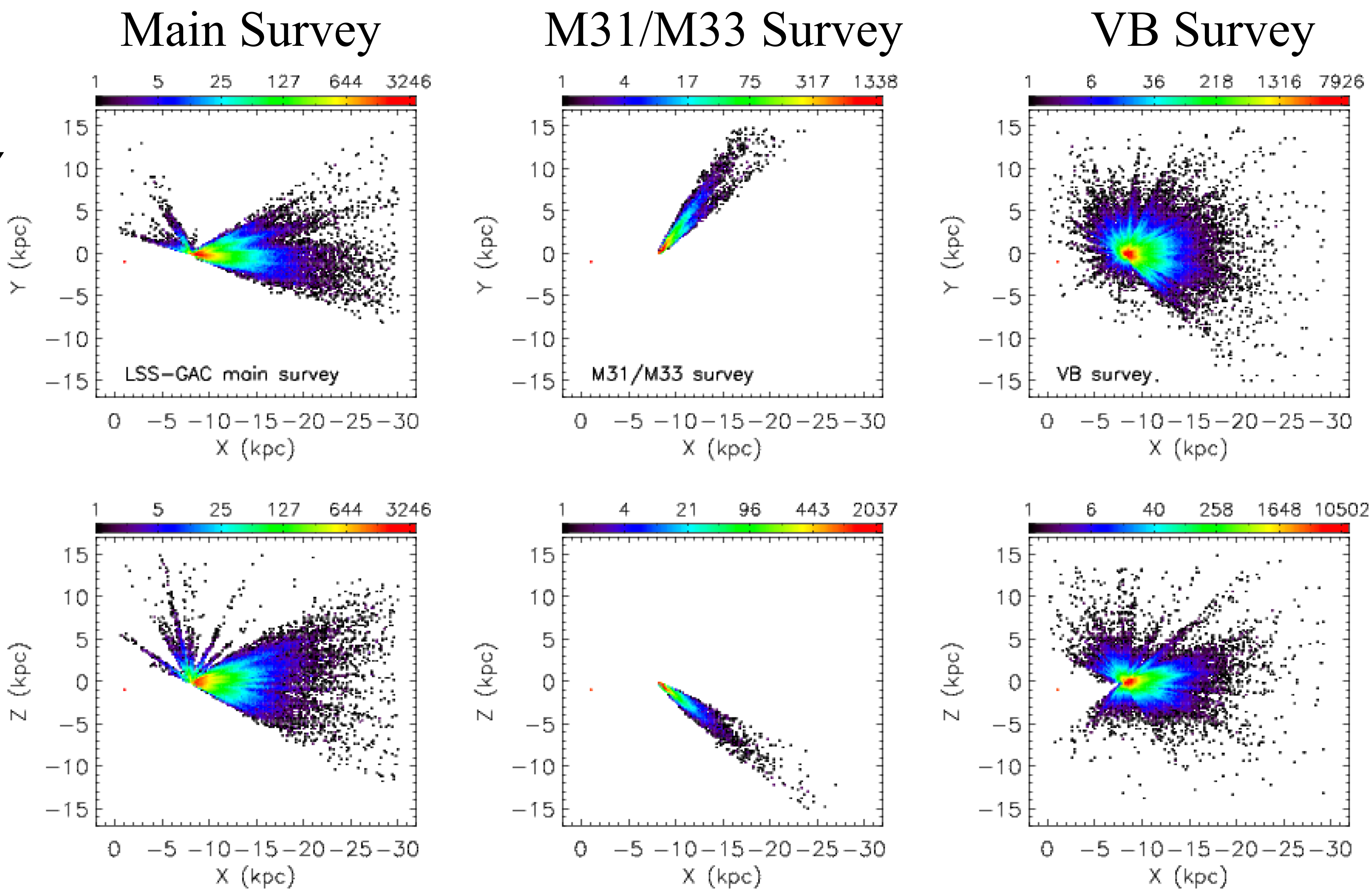
Distance: 16%



反银心方向巡天第二期增值星表

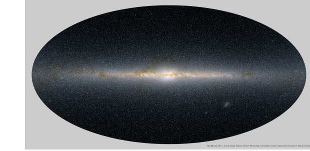
X-Y

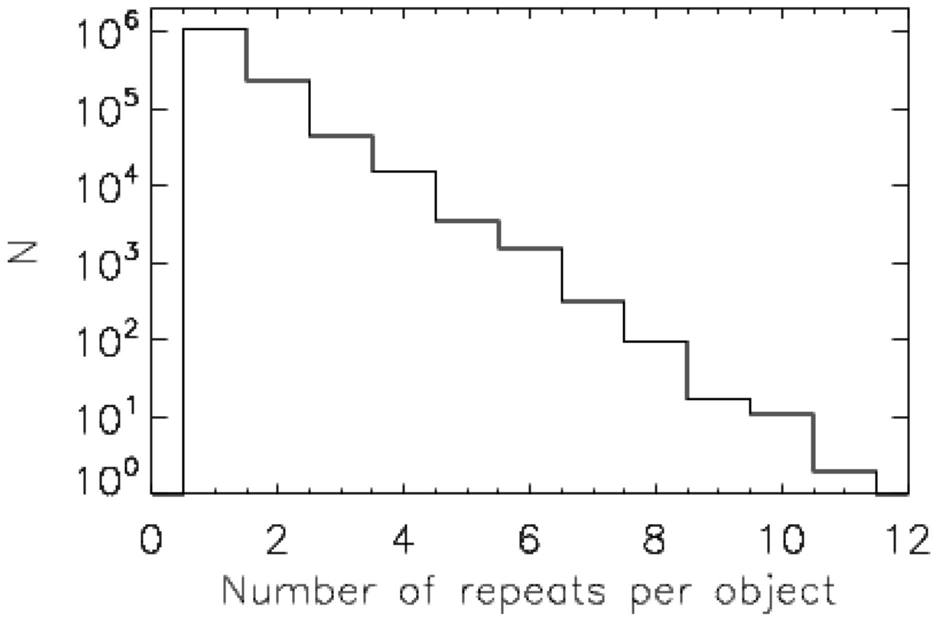
X-Z

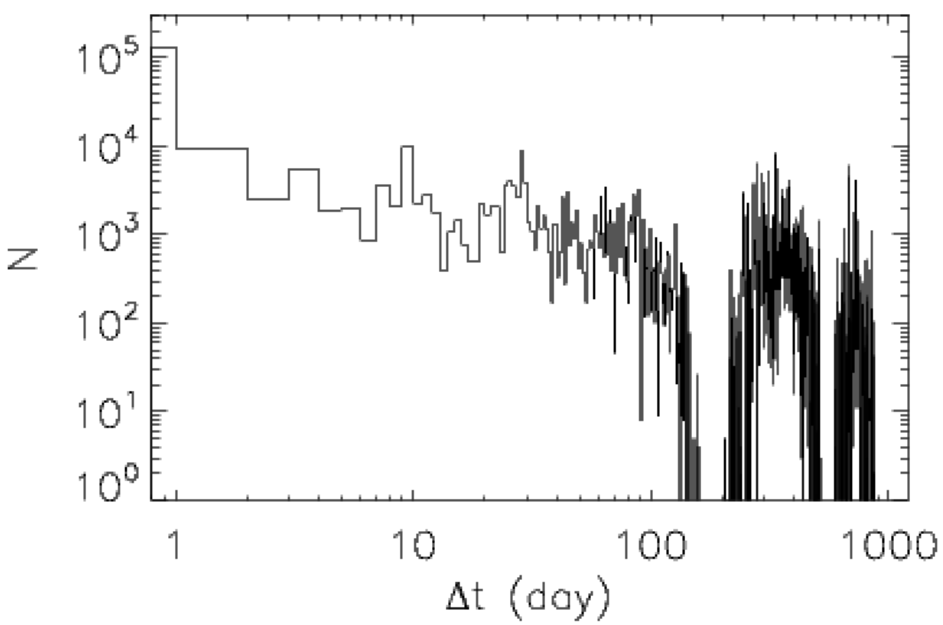


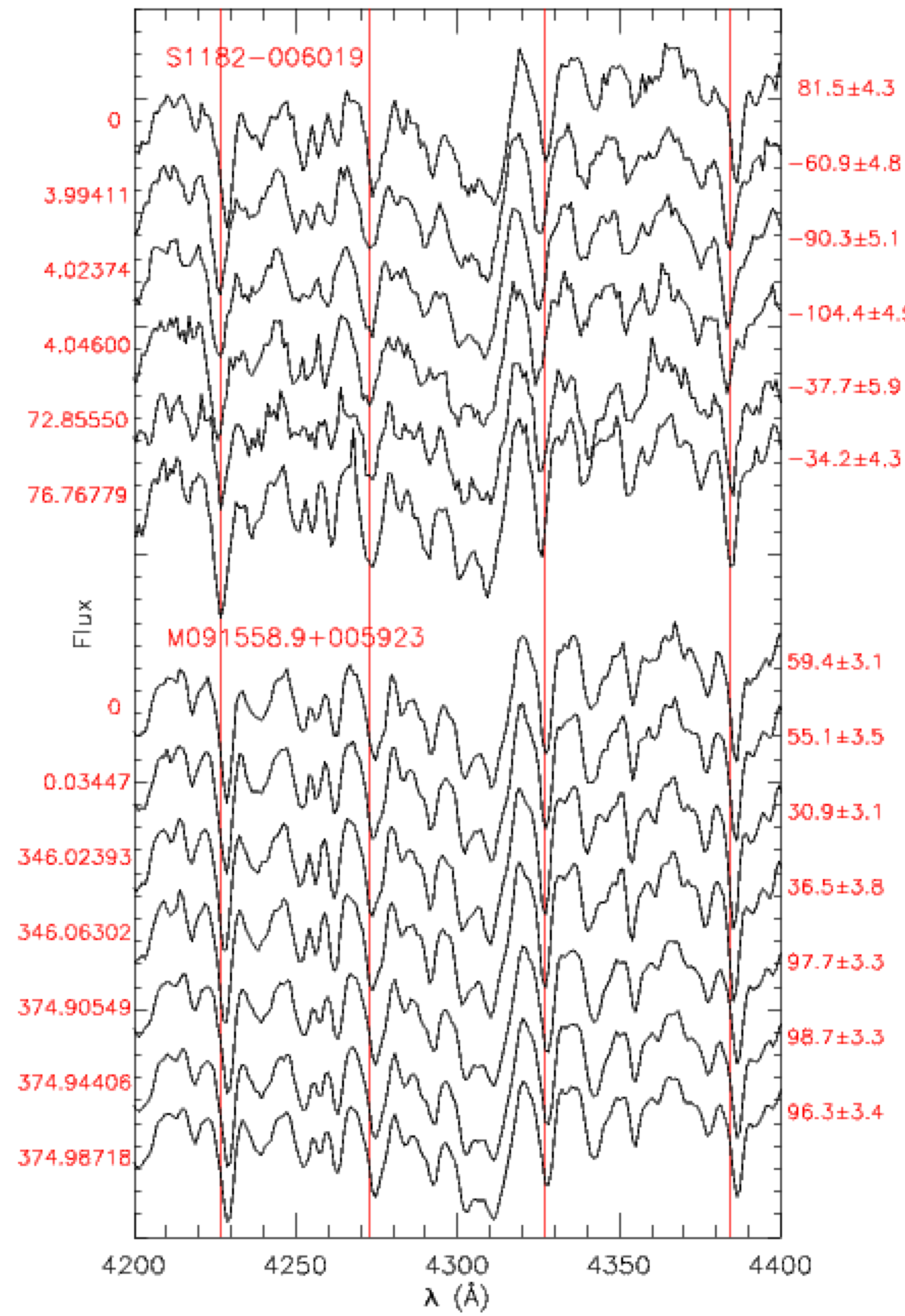
对外盘和太阳附近银盘采样连续

反银心方向巡天第二期增值星表



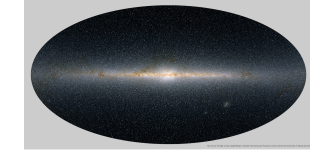






30%恒星具有多次观测

可开展时变恒星物理研究



Flag	Type	N
1	Normal star (single; AFGKM)	757
2	Pre-main-sequence star	1
3	L/T-type star	9
4	O/B-type star	19
5	S star	6
6	Carbon star	5
7	Blue supergiant star	6
8	Red supergiant star	3
9	Evolved supergiant star	1
10	Horizontal branch (HB) star (not including RCs)	27
11	Asymptotic giant branch (AGB) Star	6
12	Post-AGB star (proto-PN)	4
13	Planetary nebula (PN)	1
14	Star in nebula	3
15	Emission-line star	2
16	Pulsating variable star	5
17	Semiregular pulsating star	22
18	Classical Cepheid (delta Cep type)	10
19	Variable star of beta Cep type	4
20	Variable star of RR Lyr type	5
21	Variable star of BY Dra type	28
22	Variable star of RS CVn type	12
23	Variable star of alpha2 CVn type	23
24	Variable star of delta Sct type	21
25	Variable star of RV Tau type	1
26	Rotationally variable star	4
27	T Tau-type star	1
28	Flare star	10
29	Peculiar star	4
30	Long-period variable star	13
31	Spectroscopic binary	80
32	Eclipsing binary of Algol type (detached)	7
33	Eclipsing binary of beta Lyr type (semidetached)	2
34	Symbiotic star	2
35	Star with envelope of CH type	7
36	Variable star (unclassfied)	78
37	Double or multiple star	79
38	WD (DA)	3

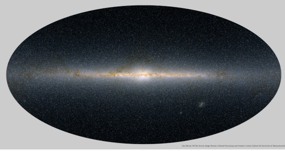
观测条件—月相、月亮距离、望远镜指向，光纤性能好坏

数据质量—目标源信号与天光强度比，饱和情况，光纤交叉污染情况

最佳匹配模版光谱的类型—普通恒星、变星、双星、特殊恒星等

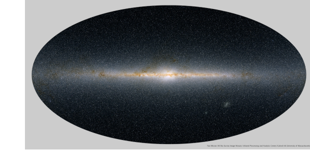
多波段测光数据—紫外(Galex)到红外(WISE)

自行(UCAC4, PPMXL, Xuyi-2MASS)和**轨道参数**



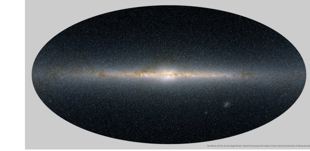
Col.	Name	Description
1	spec_id	LAMOST unique spectral ID, in format of date-plateid-spectrographid-fibreid
2	date	Date of observation
3	plate	LAMOST plate ID, not necessarily unique
4	sp_id	LAMOST spectrograph ID, ranging from 1 to 16
5	fibre_id	LAMOST fibre ID for a given spectrograph, ranging from 1 to 250
6	objid	Object ID in the input catalogues
7	objtype	Initial object type from the survey input catalogues
8	ra	Right ascension of J2000.0 (°)
9	dec	Declination of J2000.0 (°)
10	l	Galactic longitude (°)
11	b	Galactic latitude (°)
12	jd	Julian days at the middle time of the first exposure
13	moonphase	Moon phase at the middle time of the first exposure
14	monodis	Moon distance at the middle time of the first exposure
15	airmass	Airmass at the middle time of the first exposure
16	alt	Altitude (in degrees) of the telescope at the middle time of the first exposure
17	az	Azimuth angle (in degrees) of the telescope at the middle time of the first exposure
18	ha	Hour angle (in degrees) of the telescope at the middle time of the first exposure
19	badfiber	Is it a bad fibre? (yes – 1, no – 0)
20	satflag	Is the spectrum saturated? (yes – 1, no – 0)
21	brightflag	Are there bright stars (snr_b > 300) in the nearby five fibres (yes – 1, no – 0)
22	brightsnr	Largest snr_b in the nearby five fibres
23	object_sky_ratio	Object to sky flux ratio
24	snr_b	S/N(4650 Å) per pixel
25	snr_r	S/N(7450 Å) per pixel
26	uqflag	Uniqueness flag. If the target has been observed n times, then uqflag runs from 1 to n, with 1 denoting the spectrum of the highest snr_b
27	vr	Radial velocity yielded by LSP3, after corrected for a systematic offset of -3.1 km s^{-1} (km s^{-1})
28	err_vr	Error of radial velocity yielded by LSP3 (km s^{-1})
29	teff	Recommended $T_{\rm eff}$ (K)
30	err_teff	Error of the recommended $T_{\rm eff}$
31	teff_from	Which method is the recommended $T_{\rm eff}$ adopted
32	logg	Recommended log g (cm s^{-2})
33	err_logg	Error of the recommended log g
34	logg_from	Which method is the recommended log g adopted
35	mv	Recommended absolute magnitude in V band
36	err_mv	Error of M_V
37	mv_from	Which method is the recommended M_V adopted
38	mk	Recommended absolute magnitude in K_s band
39	err_mk	Error of M_{K_s}
40	mk_from	Which method is the recommended M_{K_s} adopted
41	feh	Recommended [Fe/H] (dex)
42	err_feh	Error of the recommended [Fe/H]
43	feh_from	Which method is the recommended [Fe/H] adopted
44	afe	Recommended [α/Fe] (dex)
45	err_afe	Error of the recommended [α/Fe]

http://lamost973.pku.edu.cn/site/data

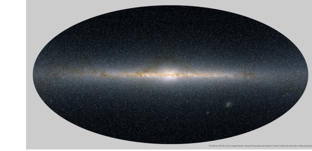
总结

- 改进了logg测量精度，信噪比大于50时，巨星和太阳类型矮星精度接近0.1dex
- 测量了[α/Fe]，信噪比大于20时，巨星精度优于0.05dex; 信噪比大于50时，矮星精度达0.05dex
- 测量了巨星的C, N丰度，精度达0.1dex
- 直接从LAMOST光谱估计绝对星等，信噪比大于50时，精度优于0.3mag, 距离精度接近10%, 系统误差小
- 释放了反银心方向巡天第二期增值星表，包含140万颗恒星的三位位置、三维速度、金属（元素）丰度、轨道参数；28%的恒星具有多次测量，可用于时变恒星物理研究



讨论与展望

- 恒星基本参数测量
  - 充分利用红端光谱估计恒星大气参数
  - 利用LAMOST-TGAS共同源作为模版进一步改进恒星基本参数及距离测量
  - 进一步优化基本参数估计方法，提高精度
- 增值星表
  - LSS-GAC DR3
- 基于大样本数据的银河系结构和演化研究



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谢谢！