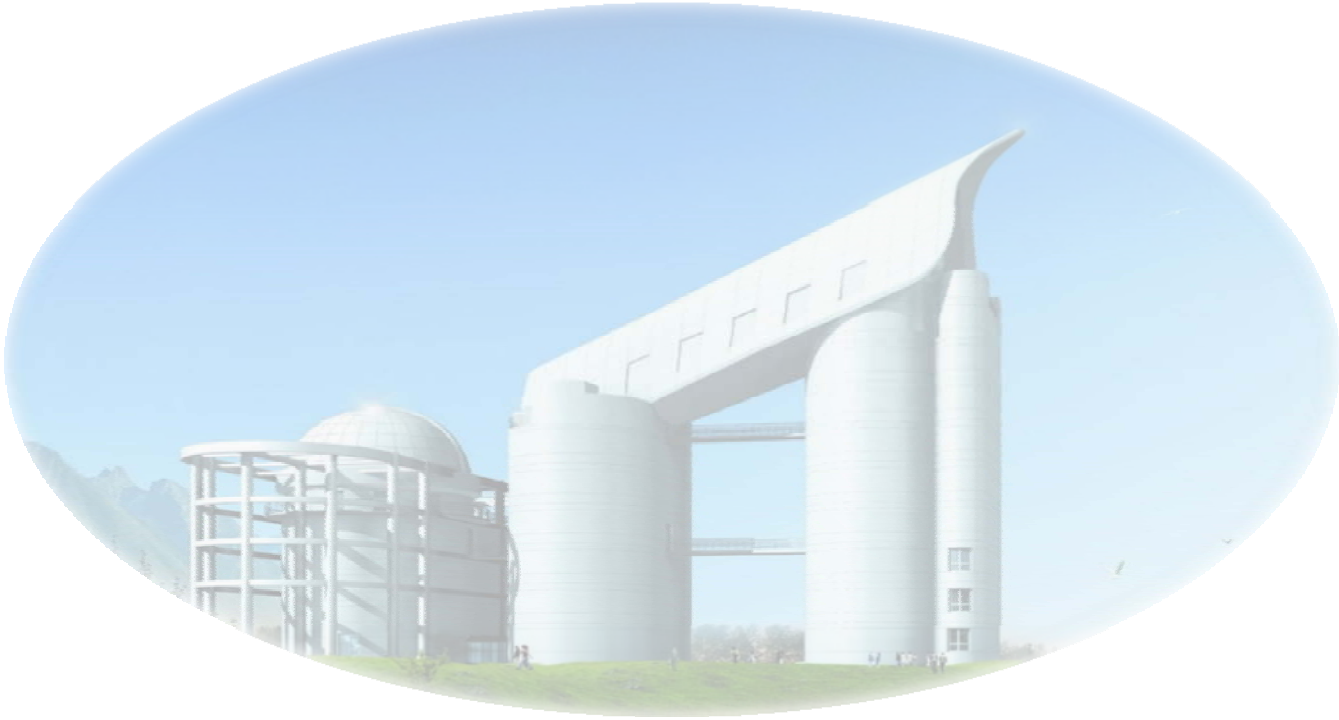
Open Cluster Study in the LAMOST Data



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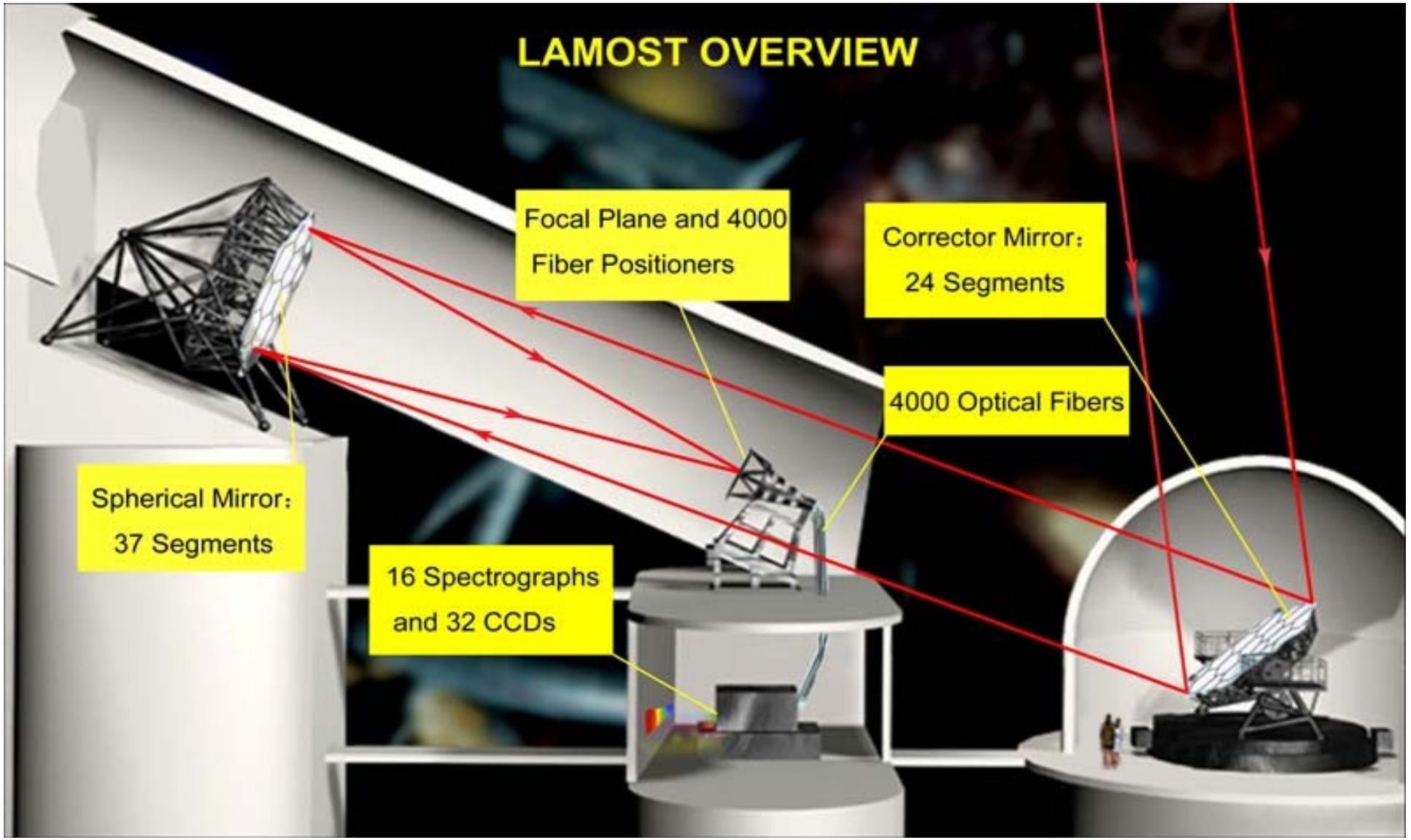
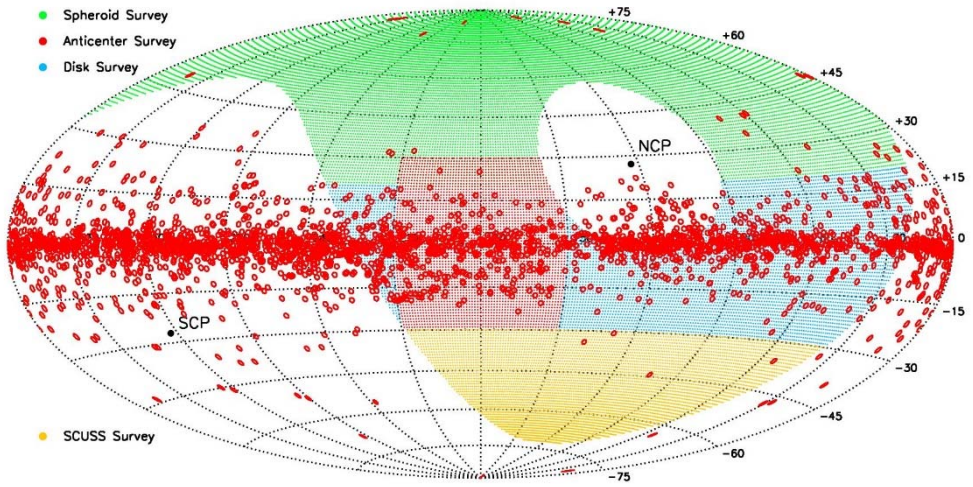
Collaborators: Li Chen, Zhengyi Shao

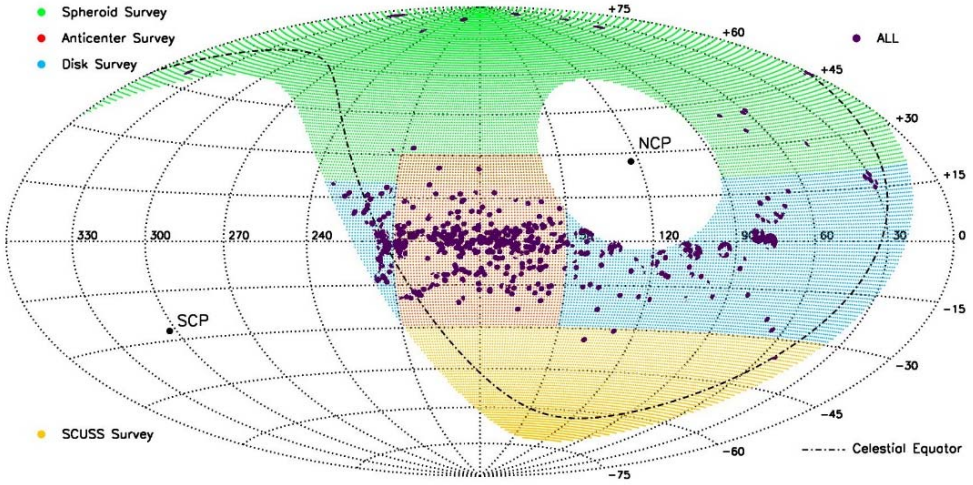
The Large Sky Area Multi-Object Fiber Spectroscopic Telescope (LAMOST)

Large aperture (4m) with a ***Wide FoV*** (20 deg^2)

- 200 Fibers/deg^2, Fiber diameter ~3.3", R~1800







Global survey of star clusters in the Milky Way

(Kharchenko+,2013)

3006 star clusters

	DR1	DR2	DR3
Cluster	381	326	499
Spectra	305398	156890	234206

716 star clusters

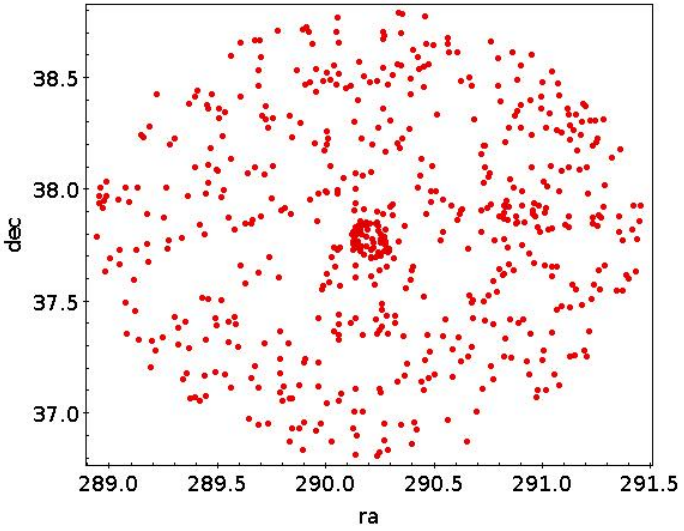
Advantage:

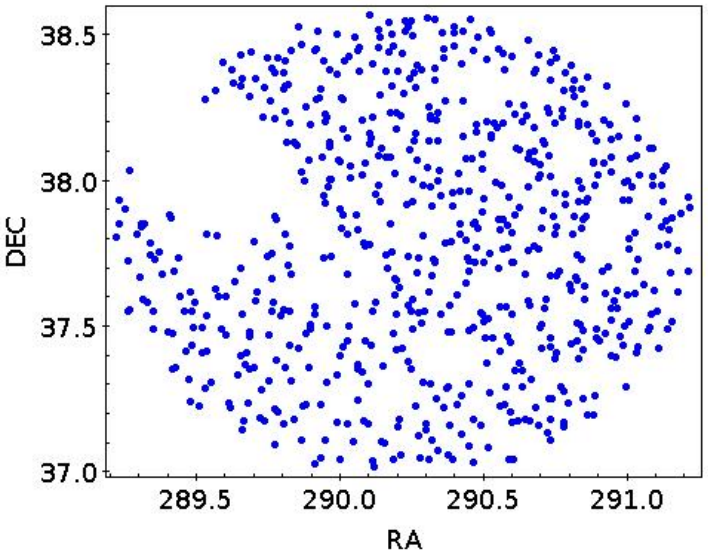
- Large number of spectra in the cluster area
- Coverage of the Galactic disk (Galactic Anti-Center)
- Reliable stellar parameters: RV, FeH, Teff, Logg

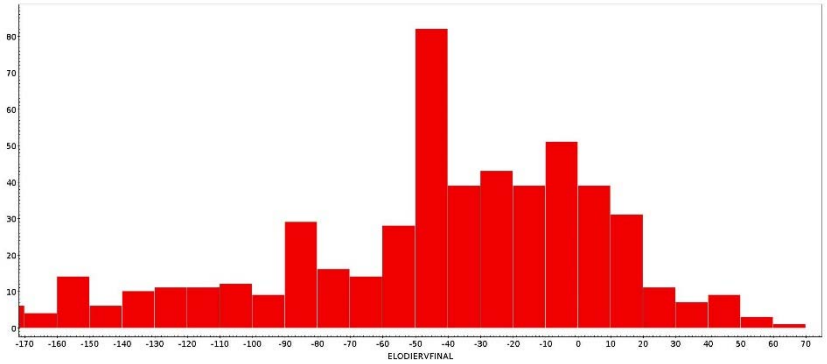
SDSS

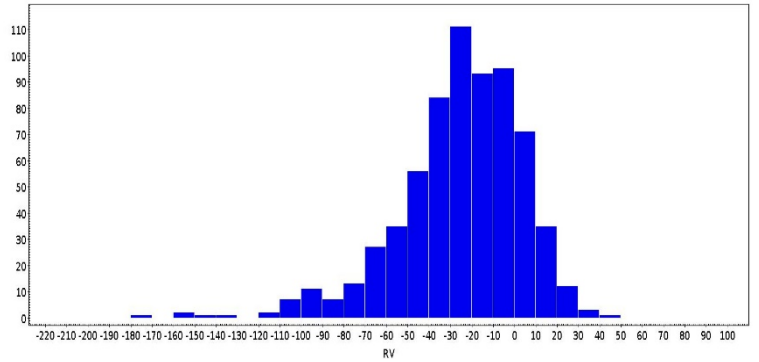
NGC6791

LAMOST





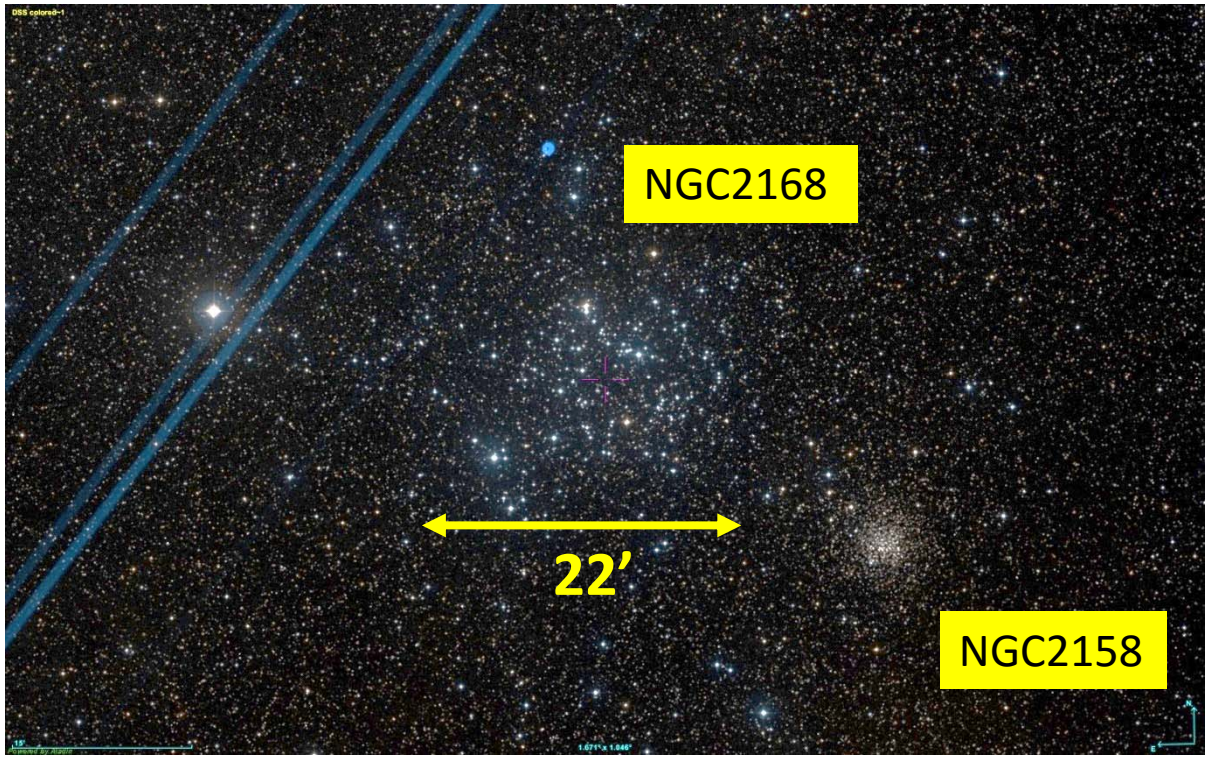




Disadvantage:

- Uniform observation
- Inadequate cluster members
- Field stars contamination

NGC2168 (M35)



Galactic coordinate:
[186.597, 2.26]

Radius: 0.98 deg
Distance: 938 pc
Age: 180 Myr
FeH: -0.16 dex

Kharchenko et al,2013

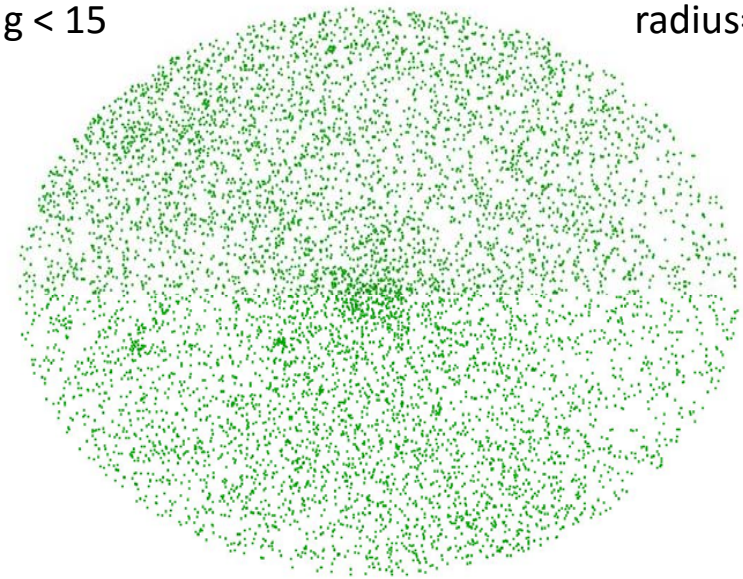
Reference	Distance (pc)	Age (Myr)	$E(B-V)$ (mag)	[Fe/H]
Reimers & Koester (1988)		70–100		
Sung & Bessell (1999)	832 ± 39	200^{+200}_{-100}	0.255 ± 0.024	
Barrado (2001)		180		
Barrado et al. (2001a)		>125		−0.21 ± 0.10
Kalirai et al. (2003)	912^{+70}_{-65}	180		
Steinhauer & Deliyannis (2004)				−0.143 ± 0.014
Meibom et al. (2009)		134–161		
Geller et al. (2010)		133		
McNamara et al. (2011)	732 ± 145			

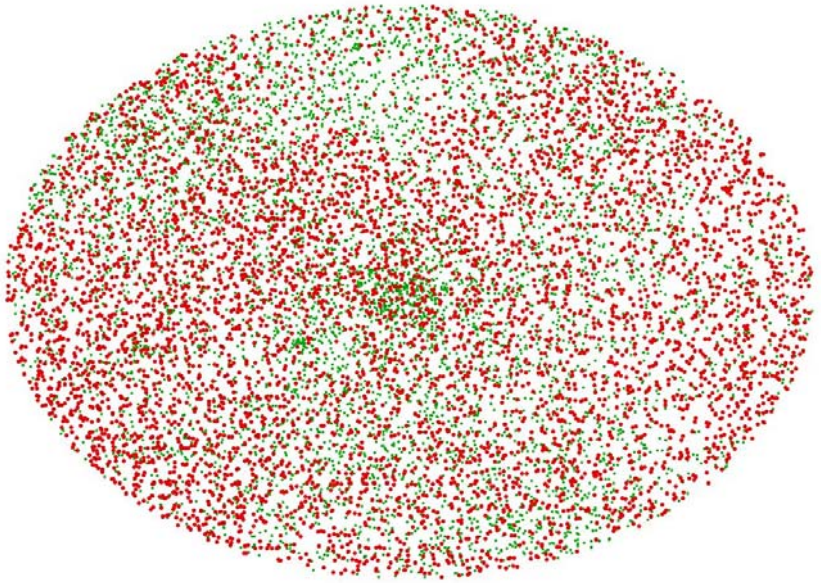
Bouy et al,2015

LAMOST Observation in NGC2168

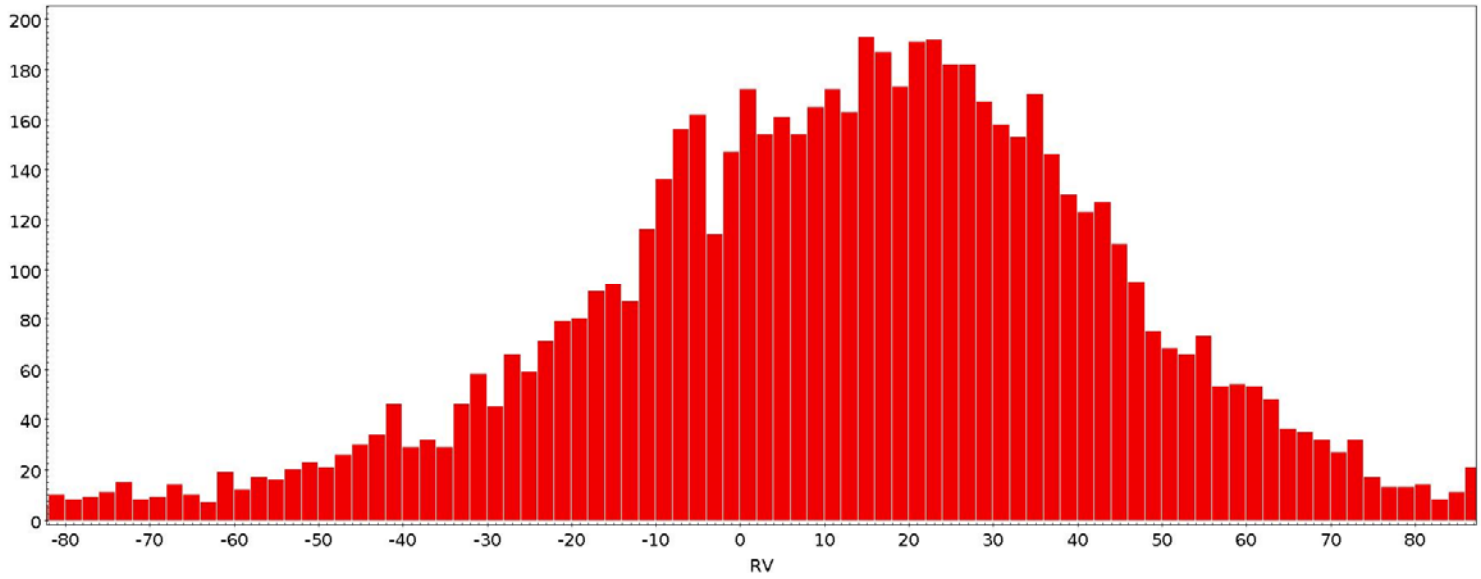
g < 15

radius=1.5°

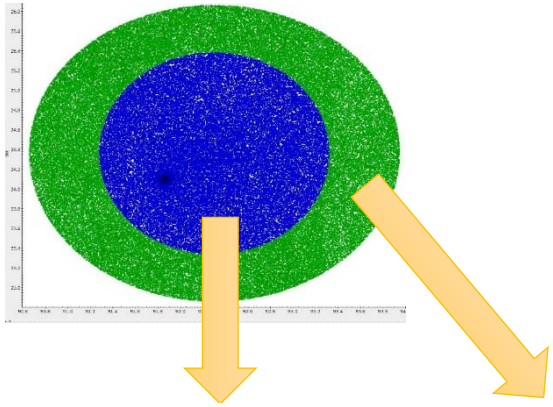




LAMOST spectra： 6926



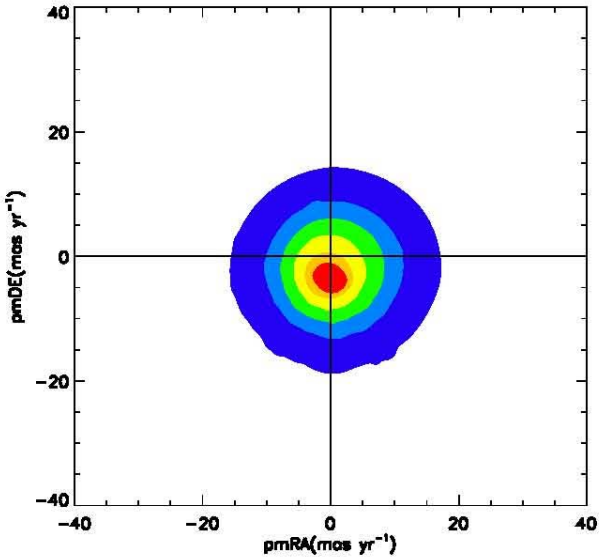
Proper Motion Subtraction

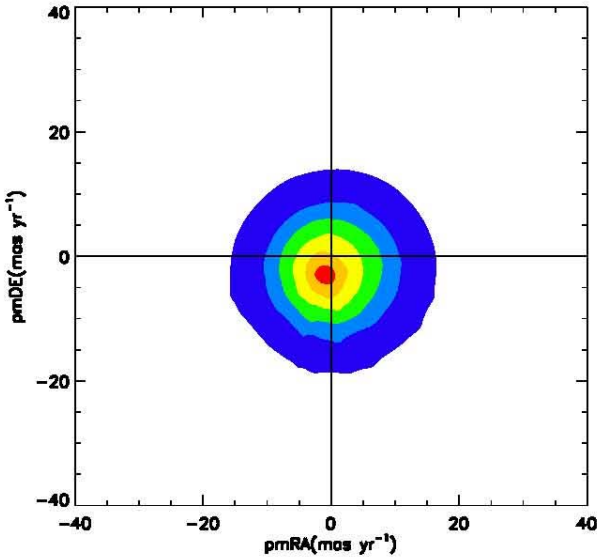


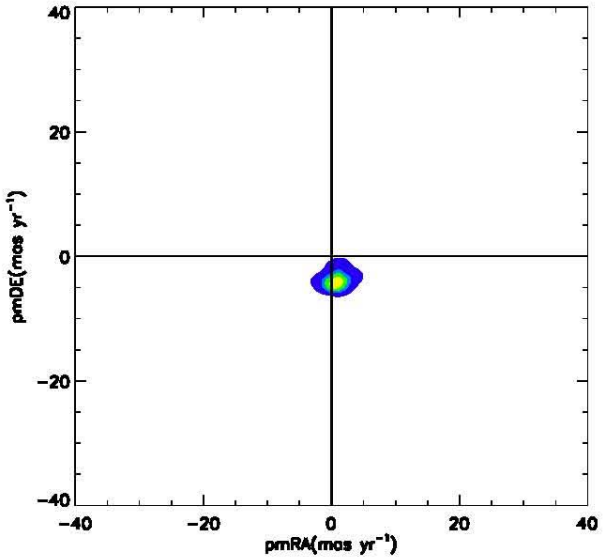
$$\mathrm{N}(i,j) = \sum_{k=1}^{n} f_k(i,j)$$

cross-match with UCAC4:

|pmra| < 40 , e_pmra < 15
|pmde|< 40 , e_pmde < 15







	μ_{pmRA}	μ_{pmDE}	σ_{pmRA}	σ_{pmDE}
Cluster	0.74±0.18	-4.12±0.13	1.55±0.17	1.23±0.14
Field	-0.27±0.19	-2.47±0.19	5.91±0.13	6.19±0.12

The frequency function for the *i*-th star of a cluster :

Cluster

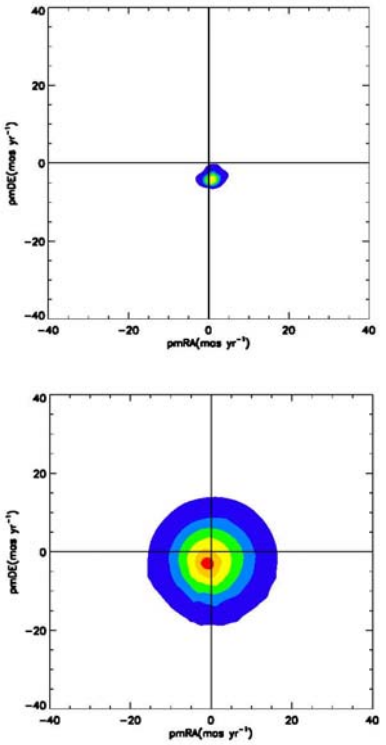
$$\Phi_{\rm c}^{\boldsymbol{v}} = \frac{1}{2\pi(\sigma_{\rm c}^2+\epsilon_{xi}^2)^{1/2}(\sigma_{\rm c}^2+\epsilon_{yi}^2)^{1/2}} \exp\left\{-\frac{1}{2}\left[\frac{(\mu_{xi}-\mu_{x\rm c})^2}{\sigma_{\rm c}^2+\epsilon_{xi}^2}+\frac{(\mu_{yi}-\mu_{y\rm c})^2}{\sigma_{\rm c}^2+\epsilon_{yi}^2}\right]\right\}$$

$$\Phi_{\rm c}^{\boldsymbol{r}} = \frac{1}{2\pi r_{\rm c}^2}.\exp\left\{-\frac{1}{2}\left[\left(\frac{x_i-x_{\rm c}}{r_{\rm c}}\right)^2+\left(\frac{y_i-|y_{\rm c}}{r_{\rm c}}\right)^2\right]\right\}$$

Field

$$\Phi_{\rm f}^{\boldsymbol{v}} = \frac{1}{2\pi(1-\gamma^2)^{1/2}(\sigma_{x\rm f}^2+\epsilon_{xi}^2)^{1/2}(\sigma_{y\rm f}^2+\epsilon_{yi}^2)^{1/2}} \exp\left\{-\frac{1}{2(1-\gamma^2)}\left[\frac{(\mu_{xi}-\mu_{x\rm f})^2}{\sigma_{x\rm f}^2+\epsilon_{xi}^2} - \frac{2\gamma(\mu_{xi}-\mu_{x\rm f})(\mu_{yi}-\mu_{y\rm f})}{(\sigma_{x\rm f}^2+\epsilon_{xi}^2)^{1/2}(\sigma_{y\rm f}^2+\epsilon_{yi}^2)^{1/2}}+\frac{(\mu_{yi}-\mu_{y\rm f})^2}{\sigma_{y\rm f}^2+\epsilon_{yi}^2}\right]\right\}$$

$$\Phi_{\rm f}^{\boldsymbol{r}} = \frac{1}{\pi r_{\rm max}^2}$$



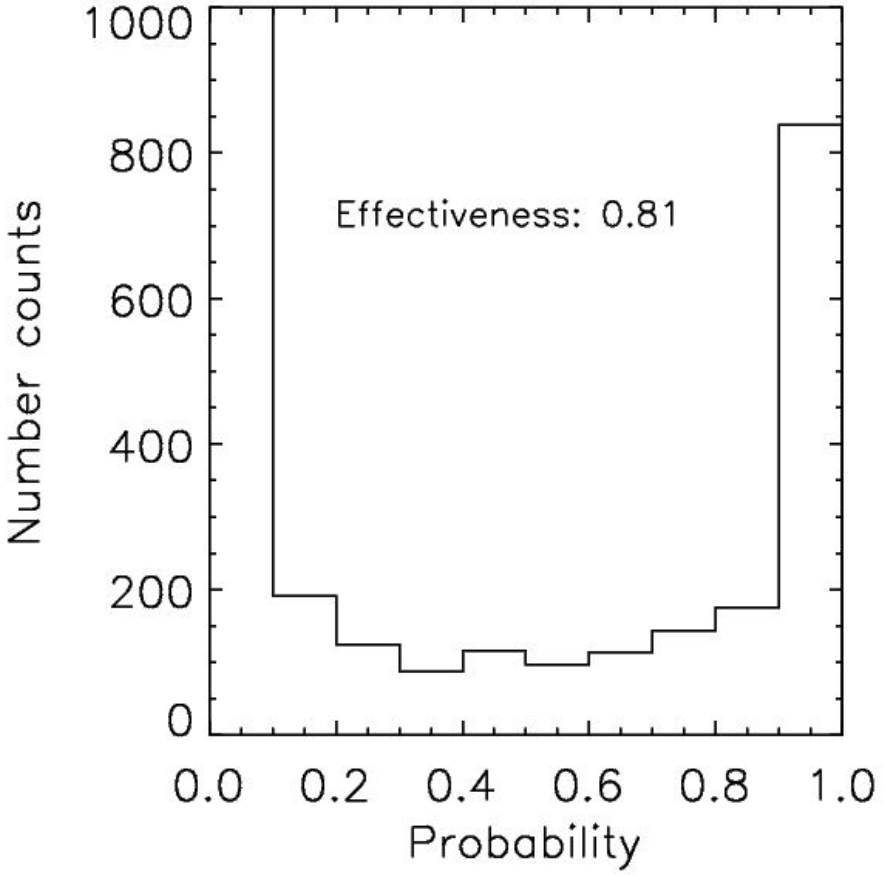
The membership probabilities of the *i*-th star belonging to the cluster :

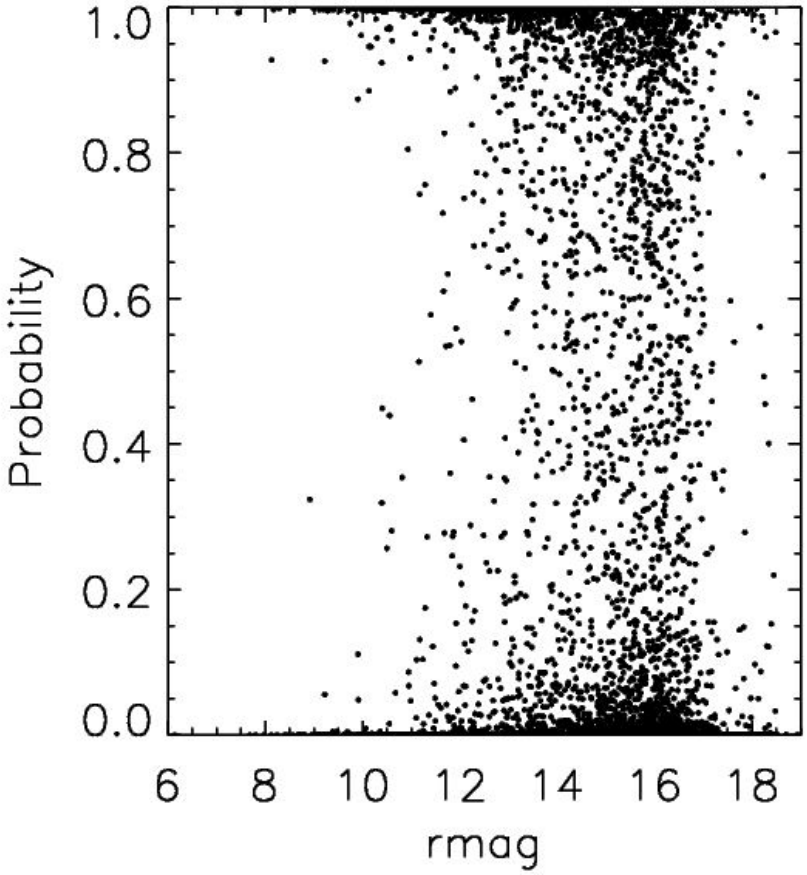
$$P_{\rm c}(i) = \frac{\Phi_{\rm c}(i)}{\Phi(i)}$$

$$\Phi = \Phi_{\rm c}+\Phi_{\rm f} = n_{\rm c}\cdot\Phi_{\rm c}^{\boldsymbol{v}}\cdot\Phi_{\rm c}^{\boldsymbol{r}} + n_{\rm f}\cdot\Phi_{\rm f}^{\boldsymbol{v}}\cdot\Phi_{\rm f}^{\boldsymbol{r}}.$$

Balaguer-Nunez et al.1998

Membership Distribution

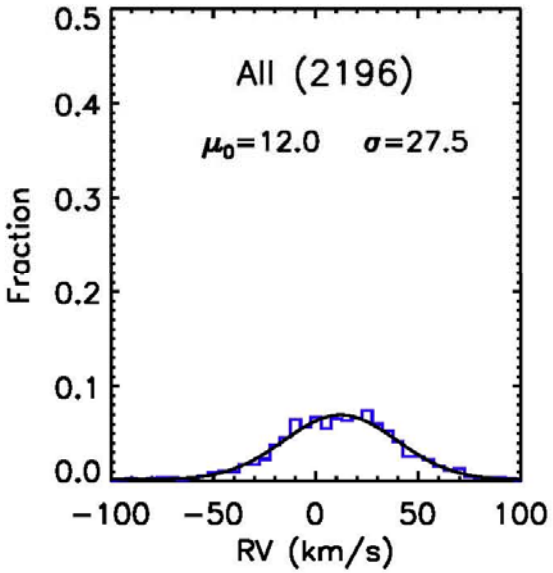


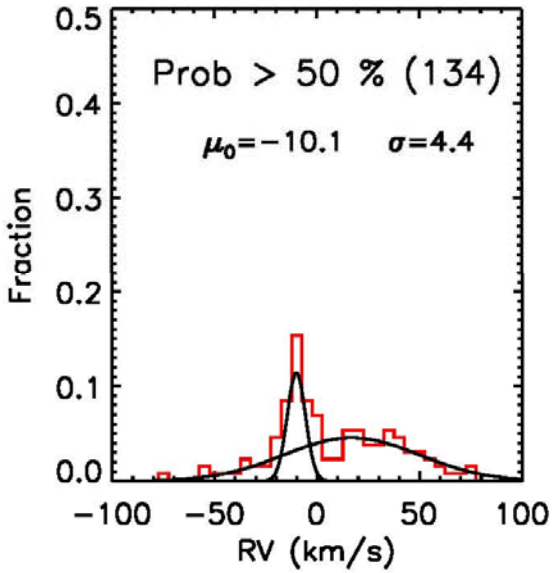


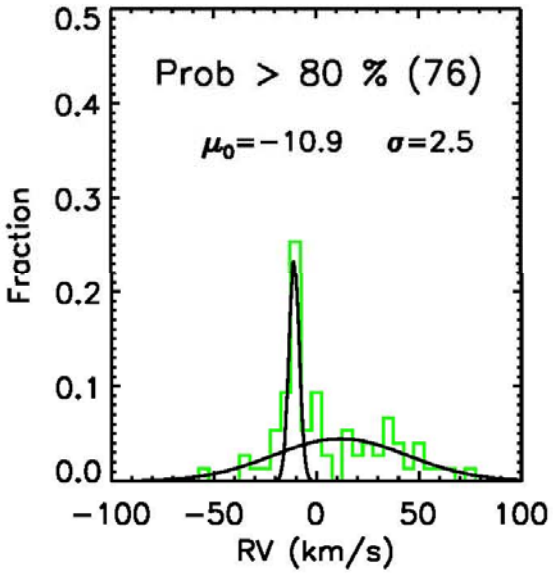
$$E = 1 - \frac{N \sum_{i=1}^{N} \{P(i)\,[1 - P(i)]\}}{\sum_{i=1}^{N} P(i) \sum_{i=1}^{N} [1 - P(i)]}$$

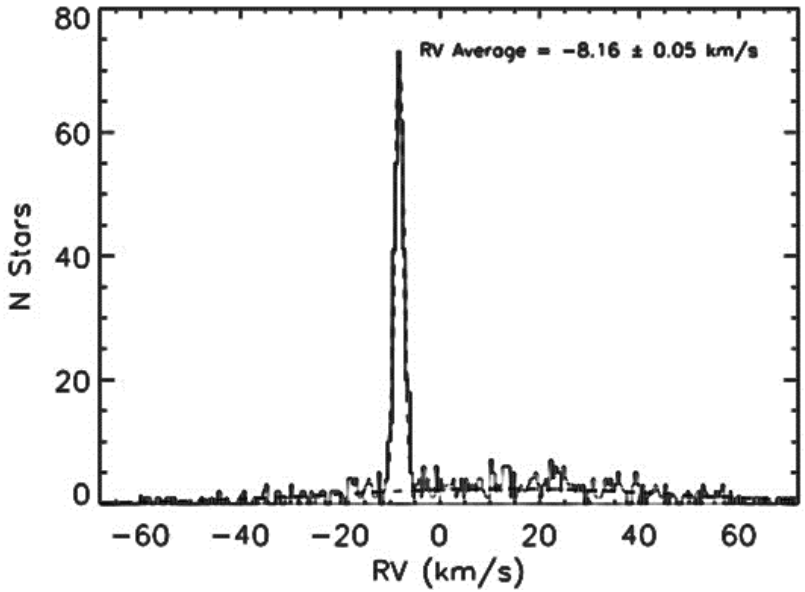
Shao & Zhao et al.1996

Radial velocity distribution





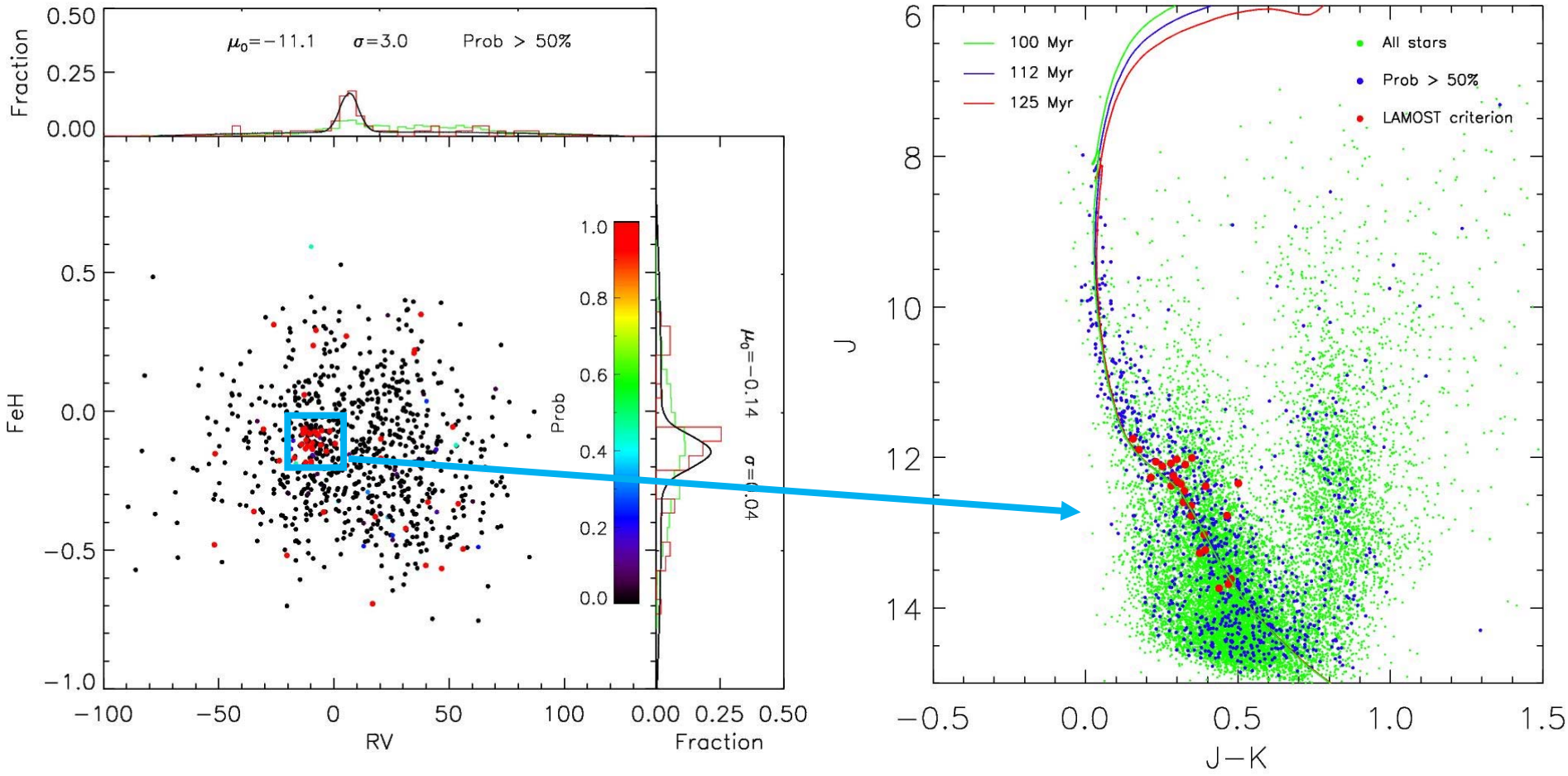




WIYN study in NGC2168:

- 3.5m telescope
- 1144 stars
- 5201 RV measurements
- Observed since 1997
- Precision of 0.5 km s^{-1}

Geller et al.2010



The radial velocity and metallicity of member candidates in the LAMOST are useful to study the Open Cluster.

NGC2168	LAMOST	WIYN	Steinhauer+2004	Kalirai+2003	Barrado+2001	Sung+1999
RV (km/s)	-10.9±2.5	-8.16±0.05				
FeH	-0.14±0.04	-0.2	-0.143±0.014		-0.21±0.1	
Age(Myr)	112±12			180	>125	200
Distance(pc)	912			912		832
E(J-K)	0.15					

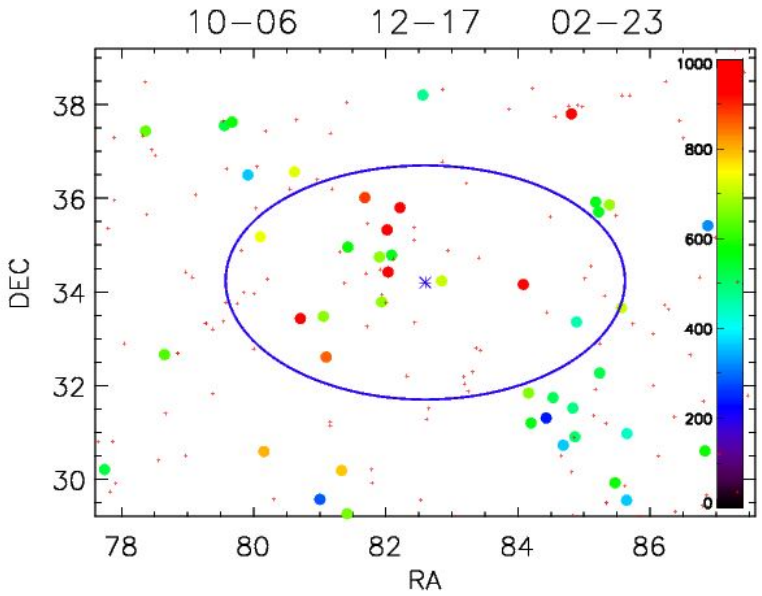
基于LAMOST现有数据：

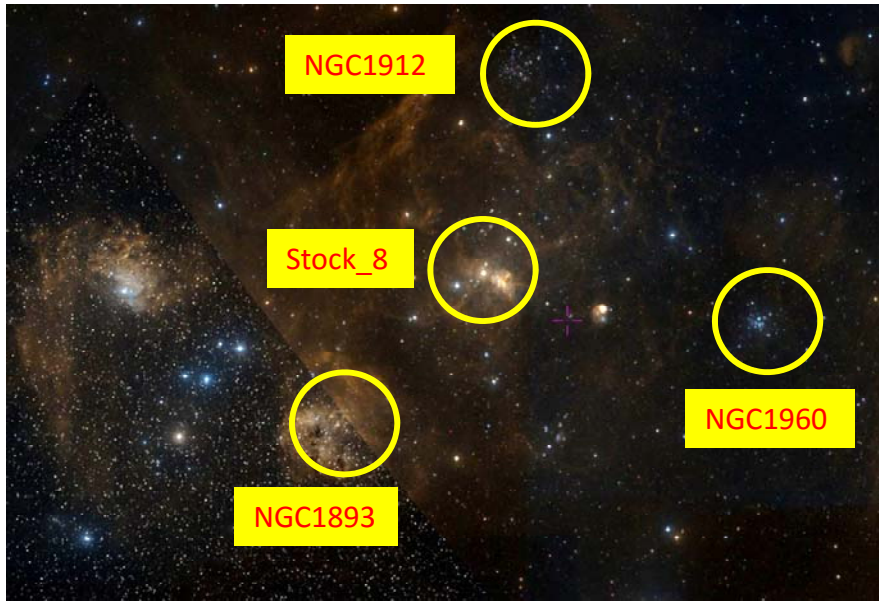
- 近邻星团，投影面积大
- 有可靠的自行数据
- 星团区域有过多次观测

小天区星团观测计划

小天区星团观测计划

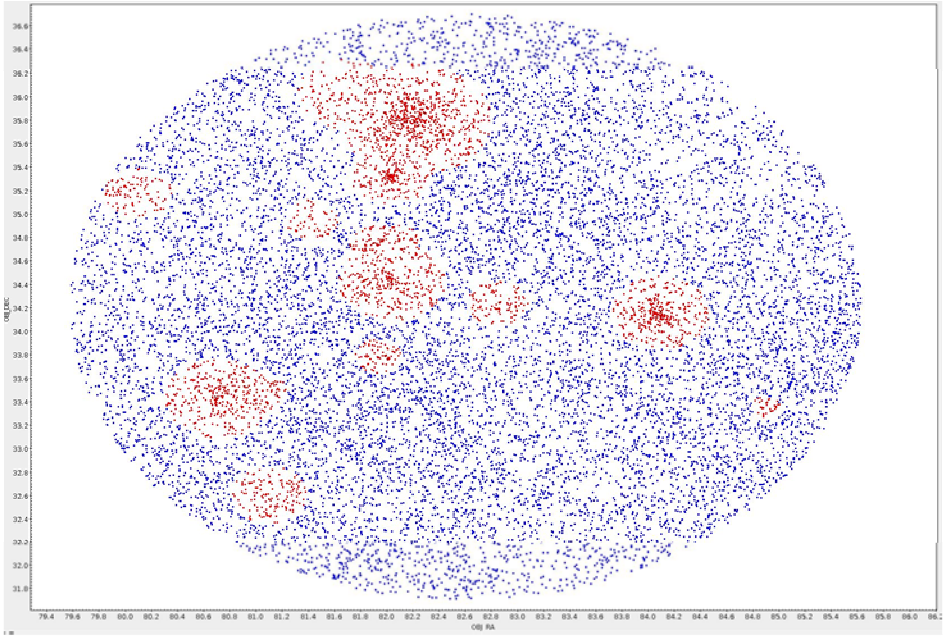
- 星团密集天区
- 多次不同目标观测
- 星团成员星高优先级
- 测试时段观测（亮月夜）
- 观测星等9~14mag（r波段）





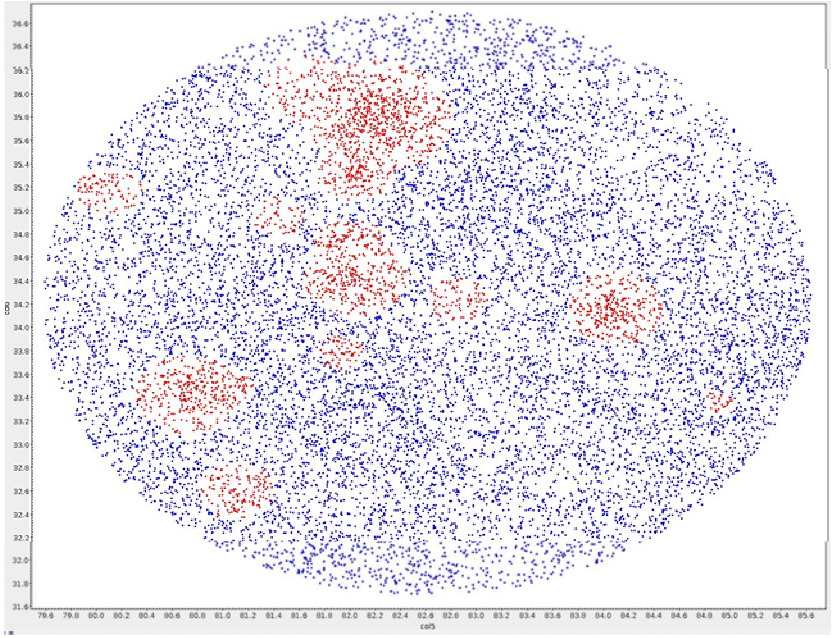
FNAME	RA	DEC	GL	GB	RD	VNUM	BNUM
0507_ASCC_14	80.10000610351562	35.18	171.851	-1.078	0.175	89	412
0516_NGC_1893	80.7074966430664	33.43	173.577	-1.66	0.28	332	1227
0529_SAI_48	81.05549621582031	33.477	173.702	-1.394	0.125	80	267
0532_Berkeley_69	81.09749603271484	32.608	174.44	-1.853	0.205	169	661
0536_FSR_0775	81.42449951171875	34.957	172.648	-0.31	0.14	38	261
0543_Czernik_21	81.6824951171875	36.015	171.888	0.456	0.25	182	722
0546_FSR_0777	81.90450286865234	34.748	173.041	-0.1	0.13	88	265
0548_Dolidze_20	81.9375	33.785	173.857	-0.612	0.125	77	304
0552_NGC_1907	82.0199966430664	35.325	172.614	0.299	0.21	233	865
0553_Stock_8	82.03499603271484	34.424	173.371	-0.19	0.28	360	1320
0555_Kronberger_1	82.08749389648438	34.785	173.094	0.046	0.1	47	185
0557_NGC_1912	82.21499633789062	35.8	172.307	0.695	0.39	892	2702
0564_NGC_1931	82.8449935913086	34.233	173.899	0.262	0.16	91	395
0594_NGC_1960	84.08250427246094	34.158	174.518	1.081	0.26	390	1108
0625_Koposov_27	84.88800048828125	33.358	175.552	1.218	0.077	30	126

待观测成员星： 3663



Obs

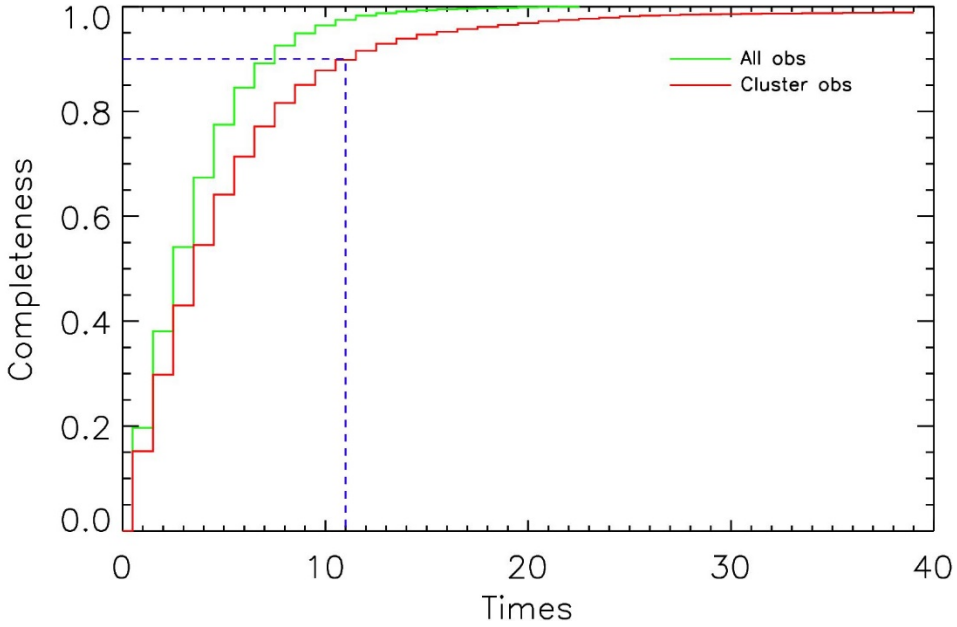
模拟观测成员星： 3291

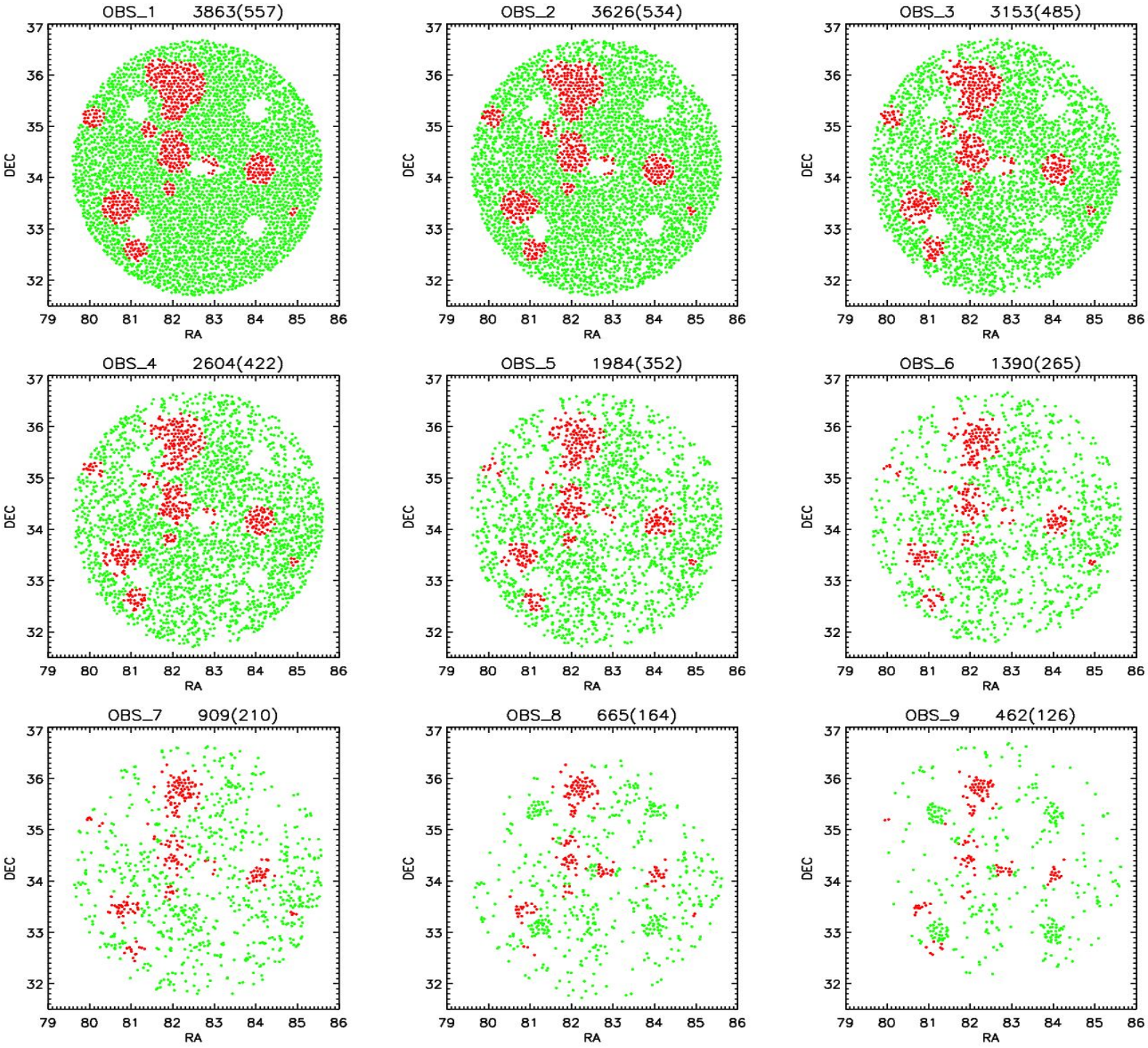


Sim

SSS_V2.47 模拟光纤分配结果：

11次观测后星团区域的恒星采样率达到90%




OBS_1 3863(557)
OBS_2 3626(534)
OBS_3 3153(485)
OBS_4 2604(422)
OBS_5 1984(352)
OBS_6 1390(265)
OBS_7 909(210)
OBS_8 665(164)
OBS_9 462(126)
DEC
RA
37
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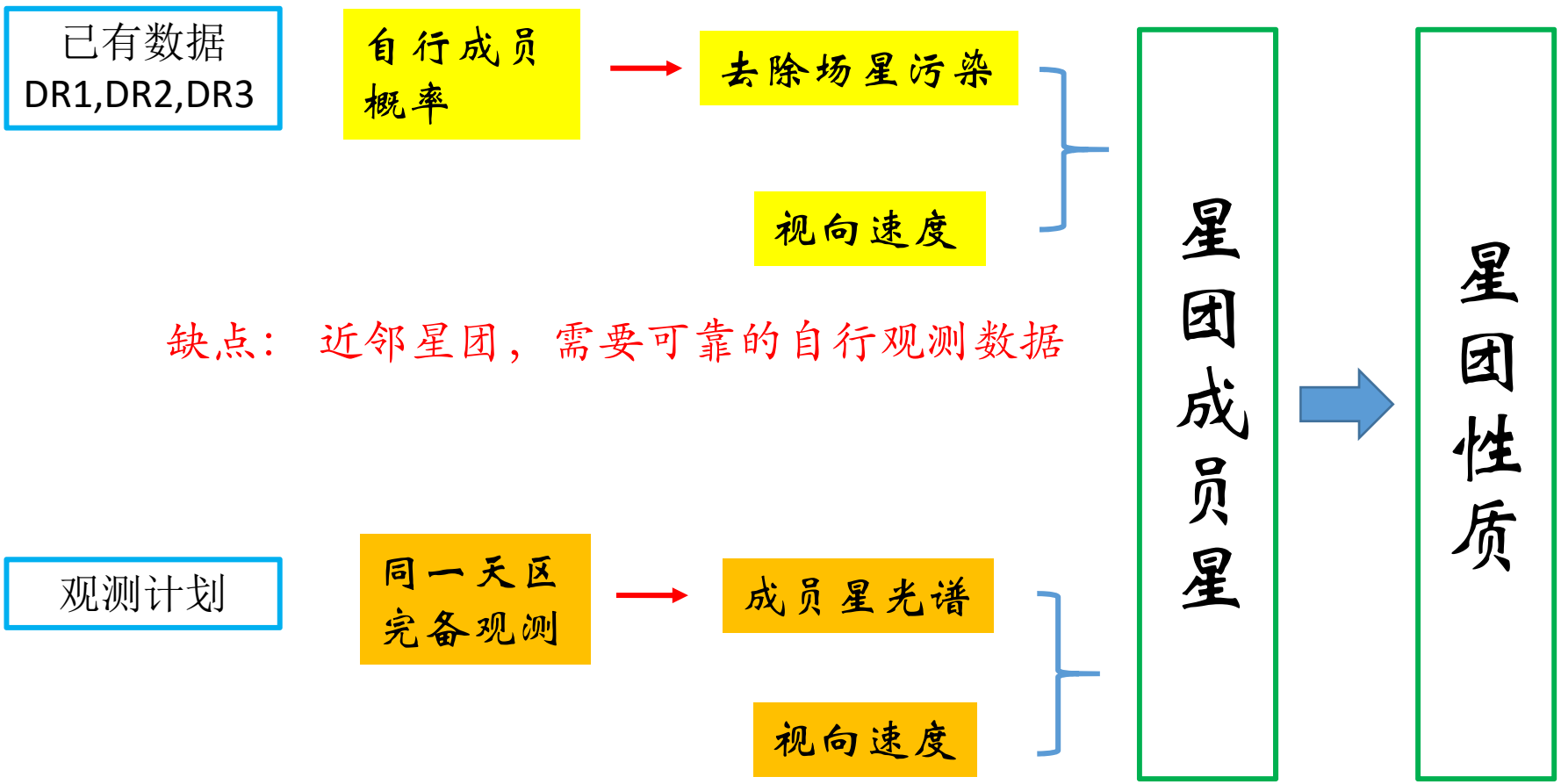
86

总结



缺点： 近邻星团，需要可靠的自行观测数据

优点： 不受星团自行数据的限制，可研究的星团数目大大增加