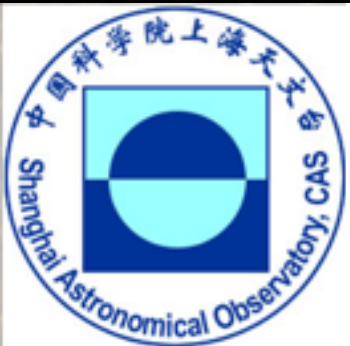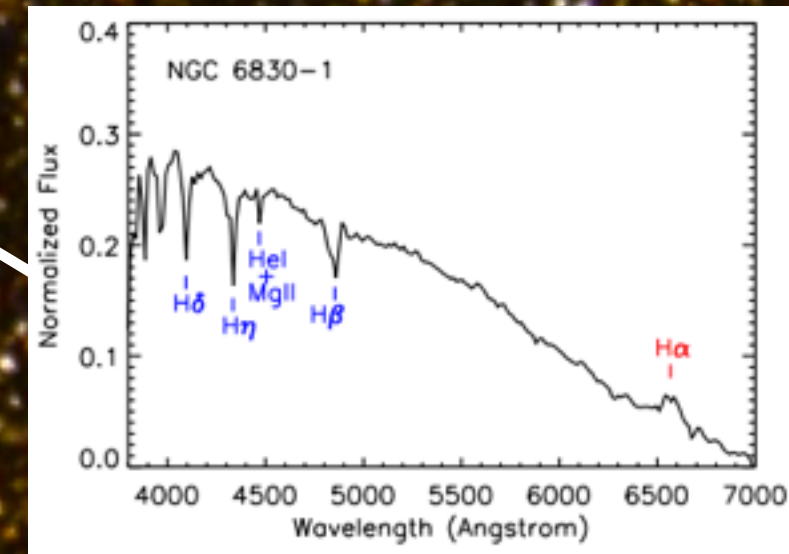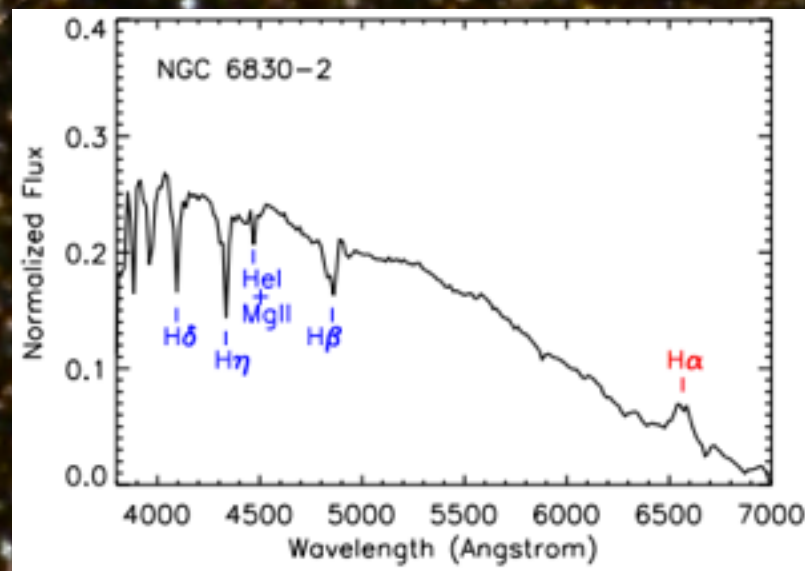# Updates on Searching for Be Stars with LAMOST Data

Roger C.C. Lin (林建爭), SHAO+NCU
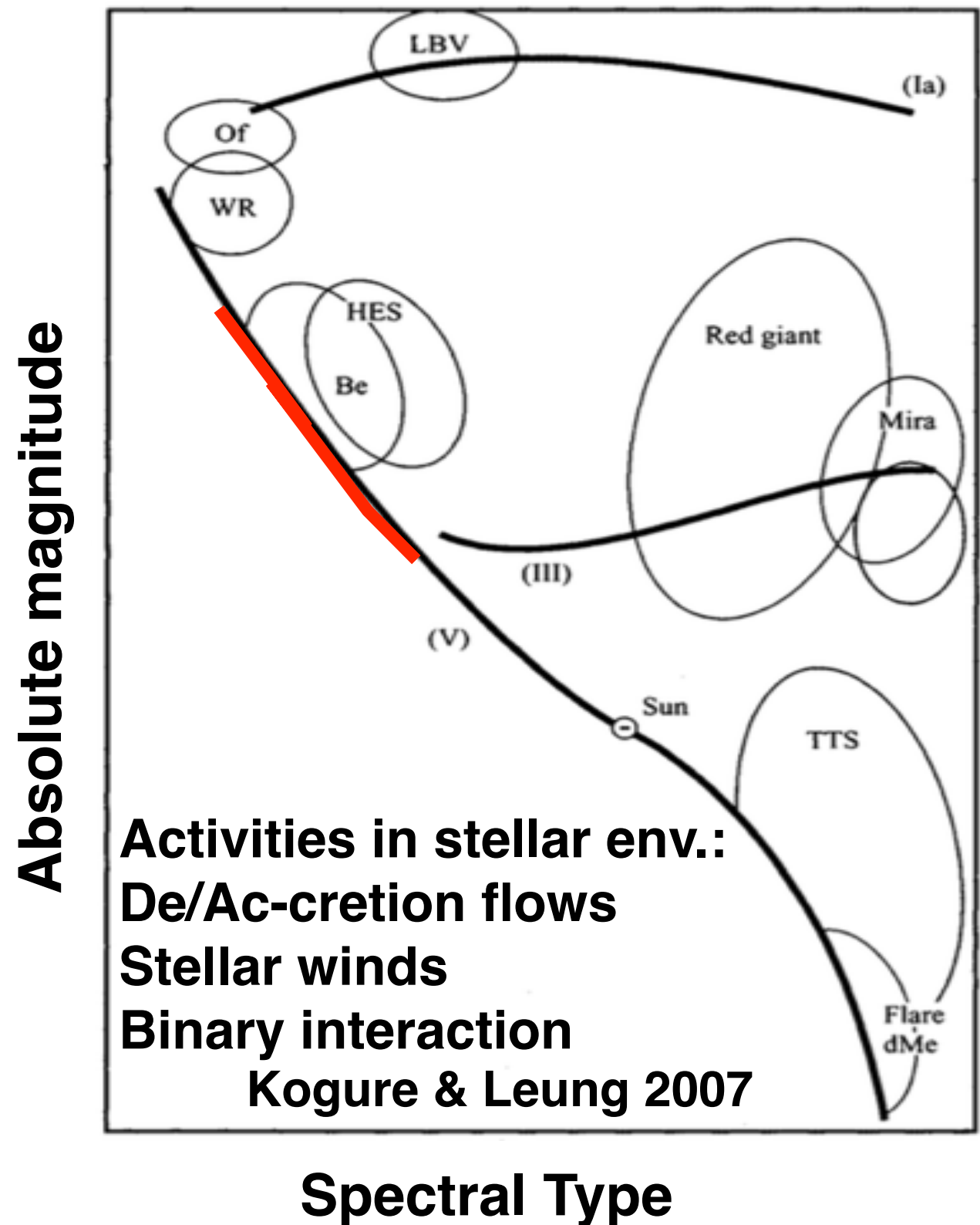1. Shanghai Astronomical Observatory, CAS
2016.03.02@SHAO

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Outline

- **What are Be stars?**
- **How to find Be stars?**
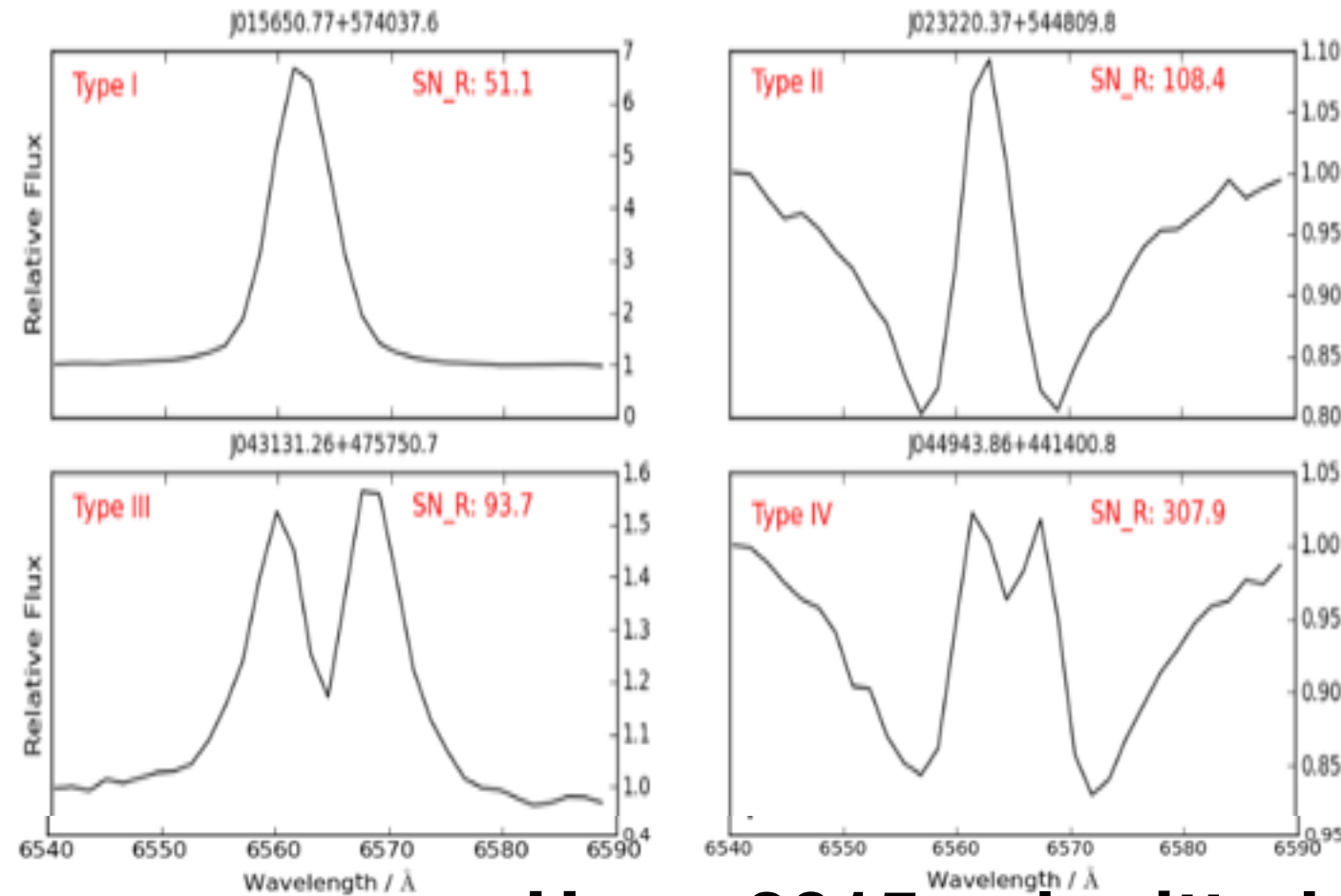- **Be stars in open clusters**
- **Summary**

Emission-Line Stars

- **Emission-line stars are almost in any evolutionary stage:**
  - **Early type stars: Wolf-Rayet star, Of, Oe/Be/Ae stars, Luminous Blue Variables.**
  - **Late type stars: dMe stars, flare stars, red giants, Mira variables.**
  - **Close binaries: Algol stars, cataclysmic variables, symbolic stars.**
  - **Pre-main sequence stars: Herbig Be/Ae stars, T Tauri stars**
- **The first Be star (γ Cas) was classified by Father Angelo Secchi in 1866.**

Absolute magnitude

Spectral Type

Activities in stellar env.:
De/Ac-cretion flows
Stellar winds
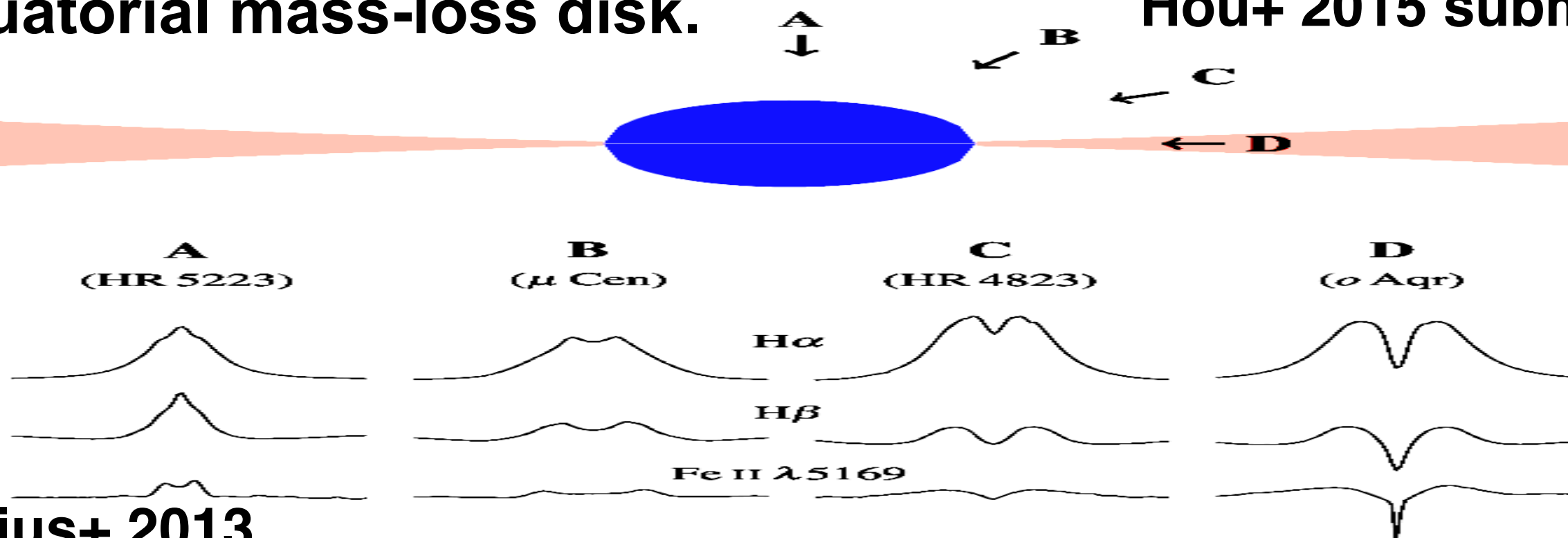**Binary interaction**
Kogure & Leung 2007

Classical Be Stars

- **Non-supergiants B-type stars with/ever with one or more Balmer emission lines (Collins 1987).**

- **Rapidly rotating stars, 70-80% breakup velocity (> 100 km/s) or above (c.f. sun 2 km/s) (Slettebak 1966) ==> equatorial mass-loss disk.**


Hou+ 2015 submitted

Rivinius+ 2013

Be Star Sample is Incomplete

- **The increase fraction of Be stars in star clusters were found with increasing cluster distance from Galactic center (McSwain+ 2005). ==> Lower metallicity region "may have" more Be stars.**

- **B ==> Be phenomenon**
  - **evolution process?**
  - **environments?**

- **A homogenous and comprehensive (age, distance, metallicity, rotation, etc.) Be star sample is needed**
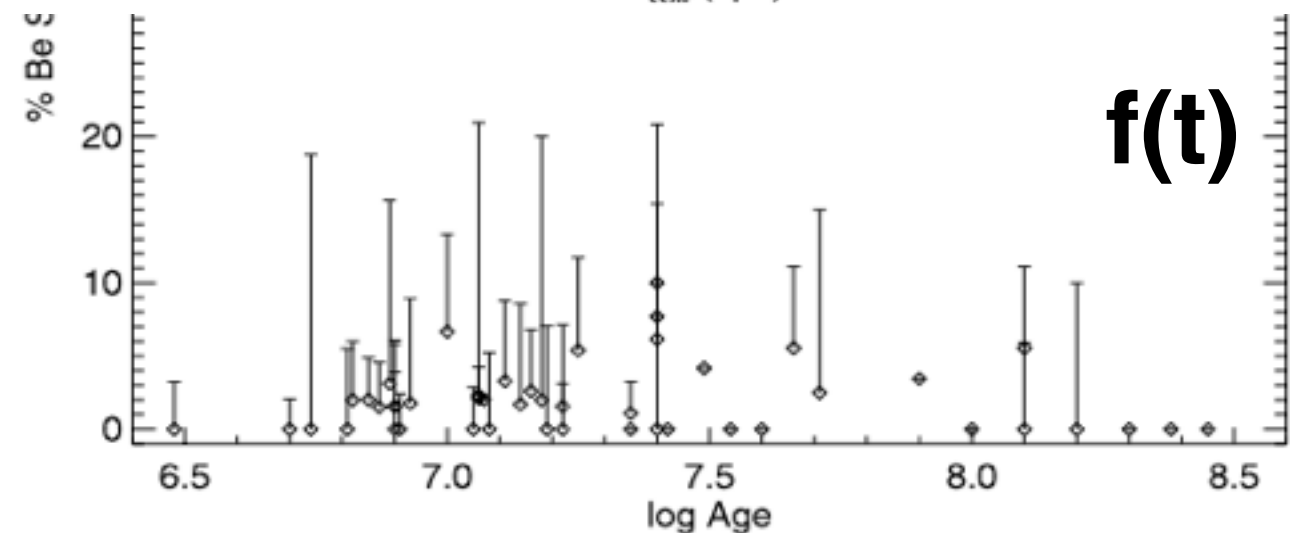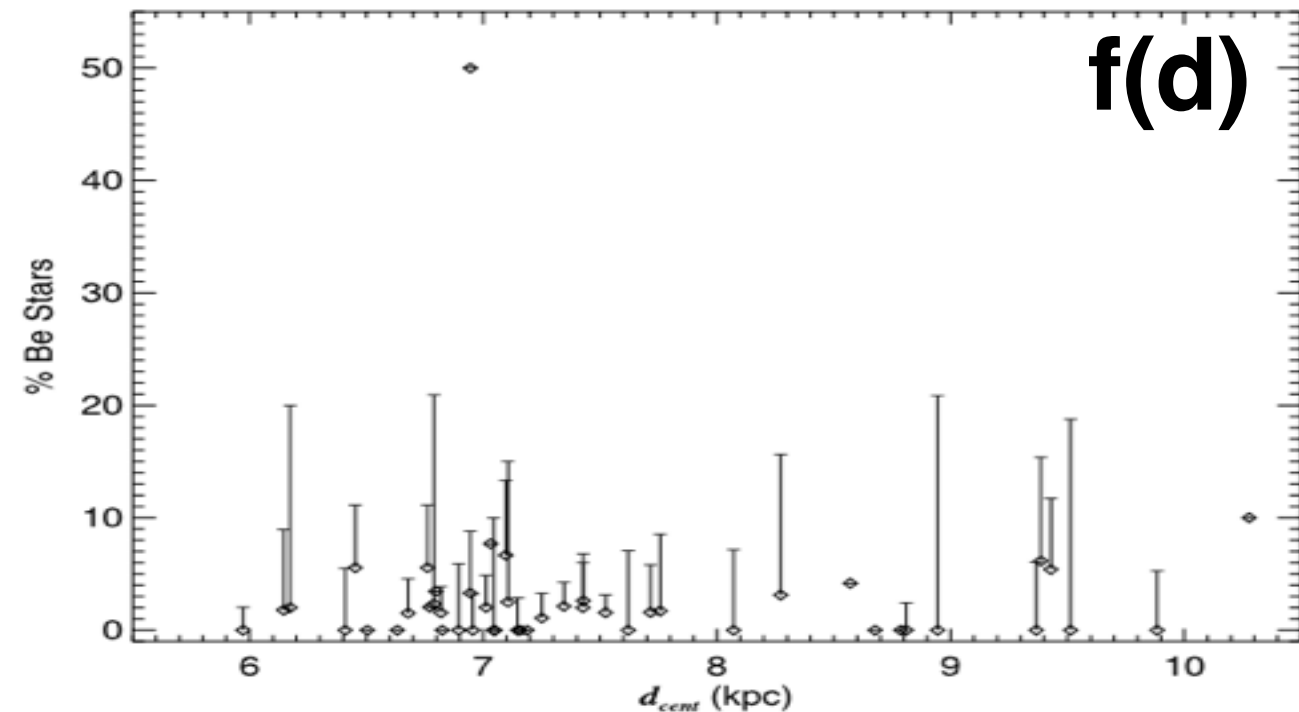
$f(d)$

% Be Stars vs d_{cent} (kpc)

$f(t)$

% Be Stars vs log Age

Outline

- What are Be stars?
- **How to find Be stars?**
- Be stars in open clusters
- Summary

大天区面积多目标光纤光谱天文望远镜

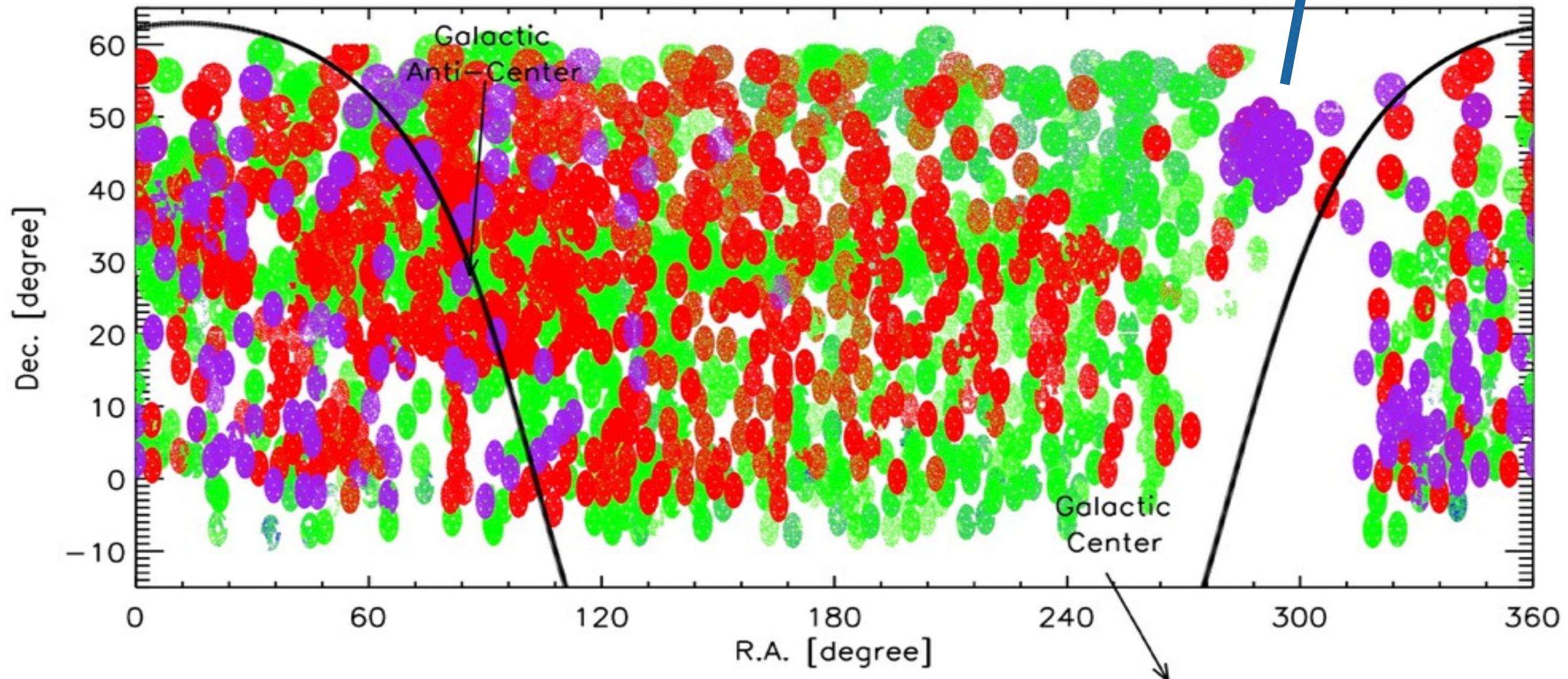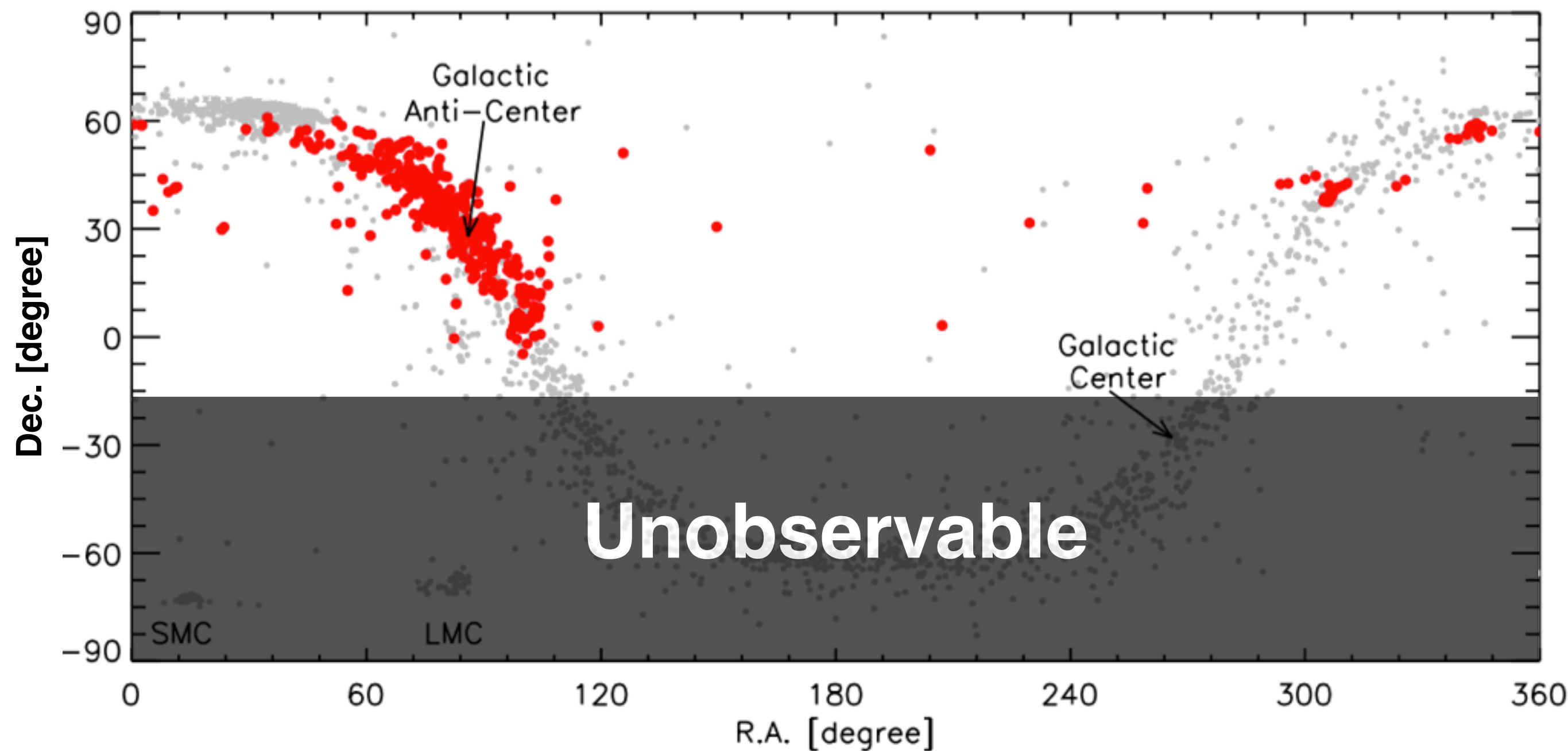Large Sky Area Multi-Object Fiber Spectroscopic Telescope **(LAMOST)**

- ■ DR1 2011.10 - 2013.06 (~2.2 M, 88% stars)
- ■ DR2 2011.10 - 2014.06 (~4.1 M, 91% stars) + DR1
- ■ DR3 2014.09 - 2015.05 (~1.5 M, 92% stars)
- ■ DR4 2015.09 - 2015.11 (~0.5 M, 92% stars)

Kepler Field

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

Galactic Anti-Center

Galactic Center

Dec. [degree]

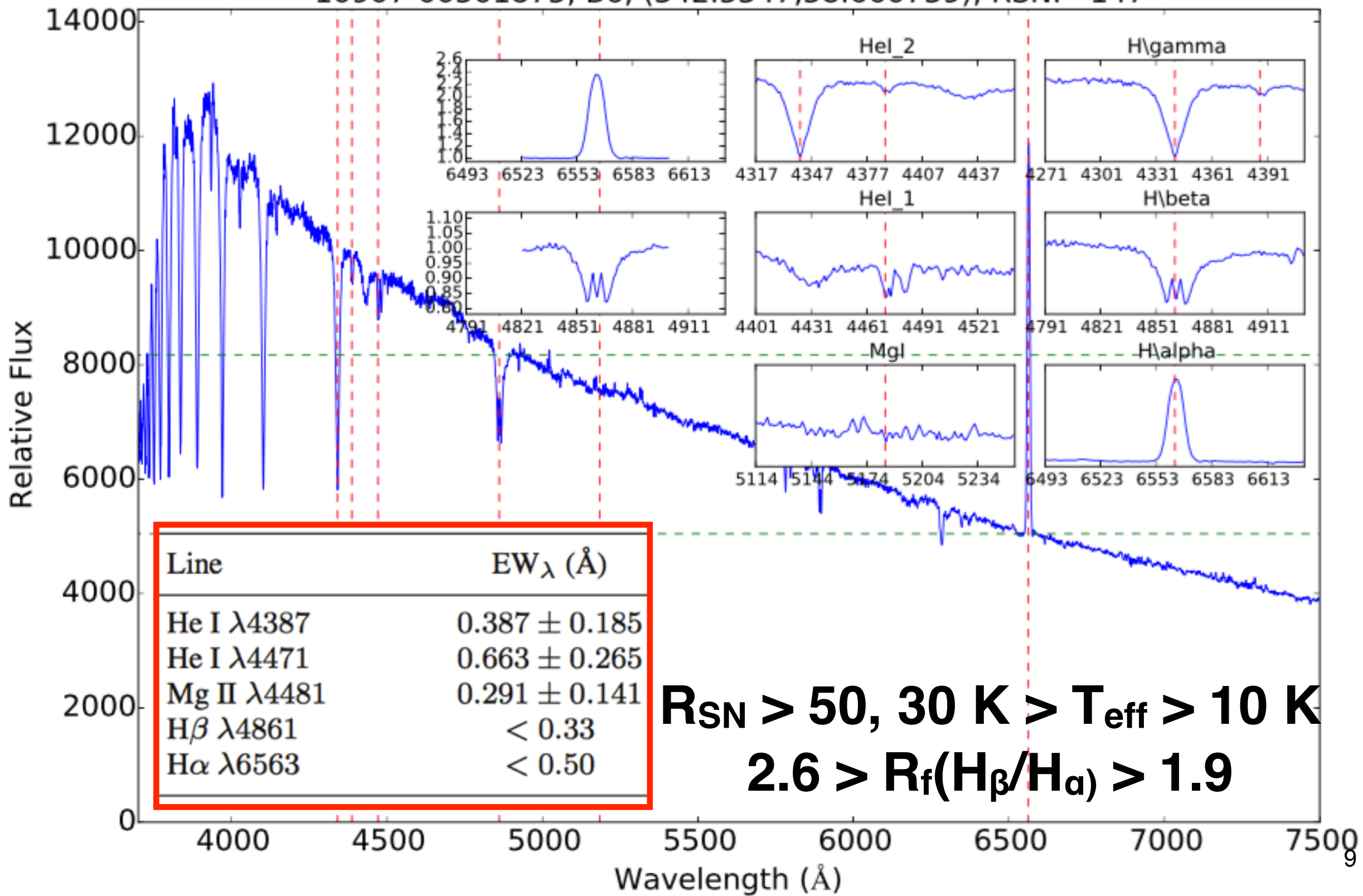**Unobservable**

SMC   LMC

R.A. [degree]

LAMOST observed 202 known Be stars

郭守敬望远镜
Large Sky Area Multi-Object Fiber Spectroscopic Telescope (LAMOST)

10907-00501875, B6, (342.5347,58.660739), RSN: 147

Line	EW_λ (Å)
He I $\lambda 4387$	0.387 ± 0.185
He I $\lambda 4471$	0.663 ± 0.265
Mg II $\lambda 4481$	0.291 ± 0.141
Hβ $\lambda 4861$	< 0.33
Hα $\lambda 6563$	< 0.50

$R_{SN} > 50$, $30\ K > T_{eff} > 10\ K$

$2.6 > R_f(H_\beta/H_\alpha) > 1.9$
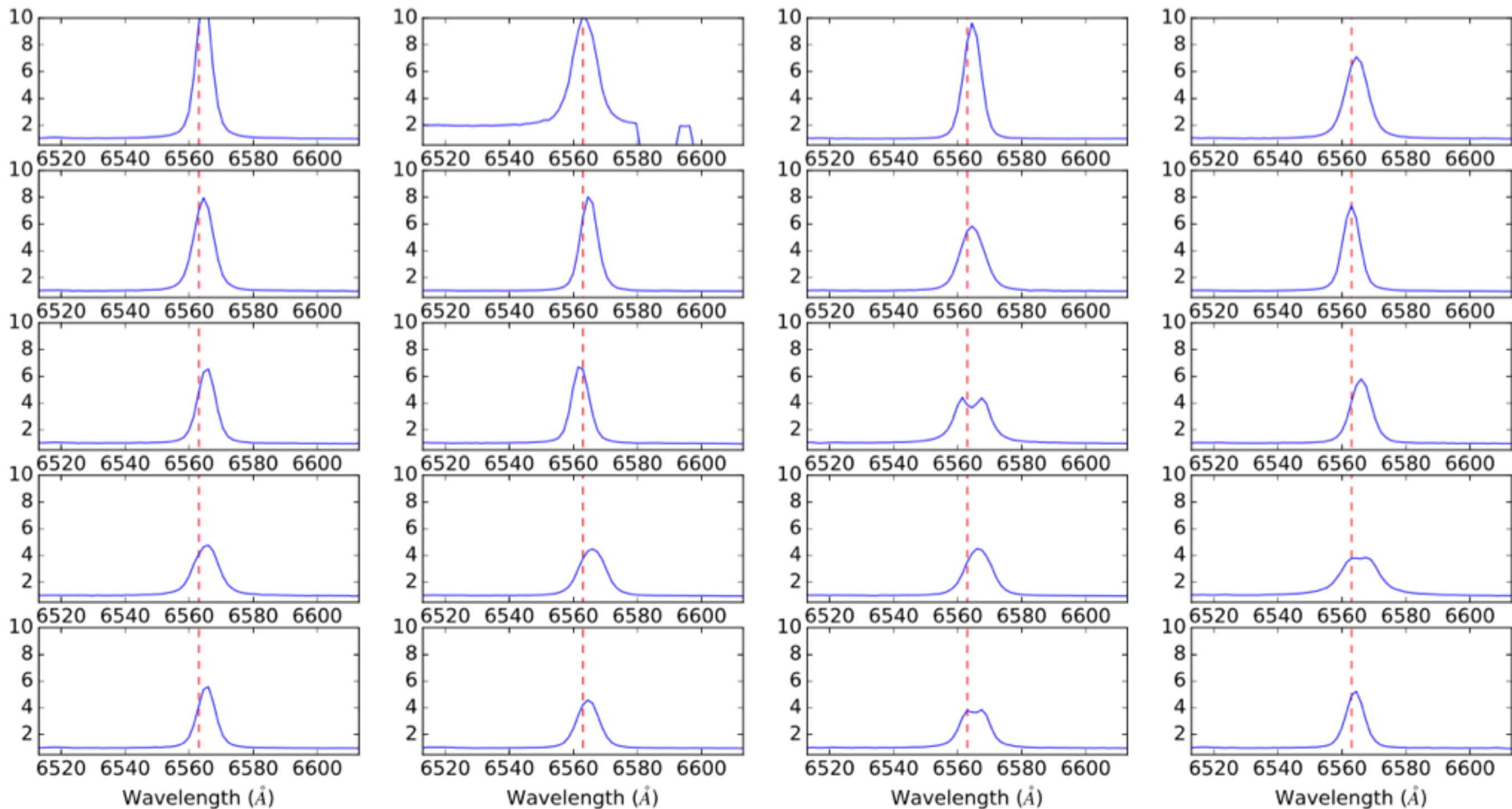
H-alpha normalized flux
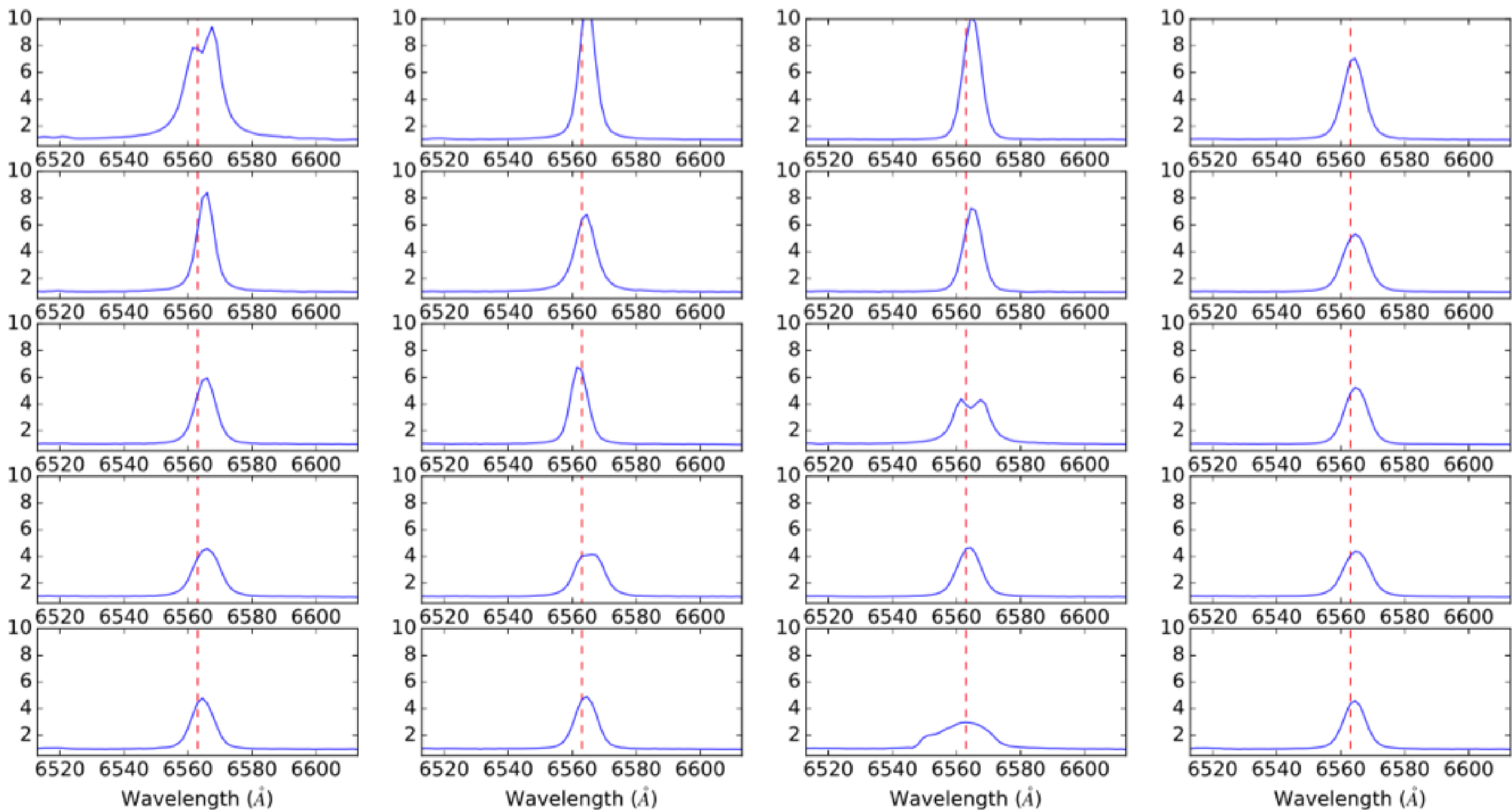
Large Sky Area Multi-Object Fiber Spectroscopic Telescope (LAMOST)

H-alpha normalized flux

H-alpha normalized flux

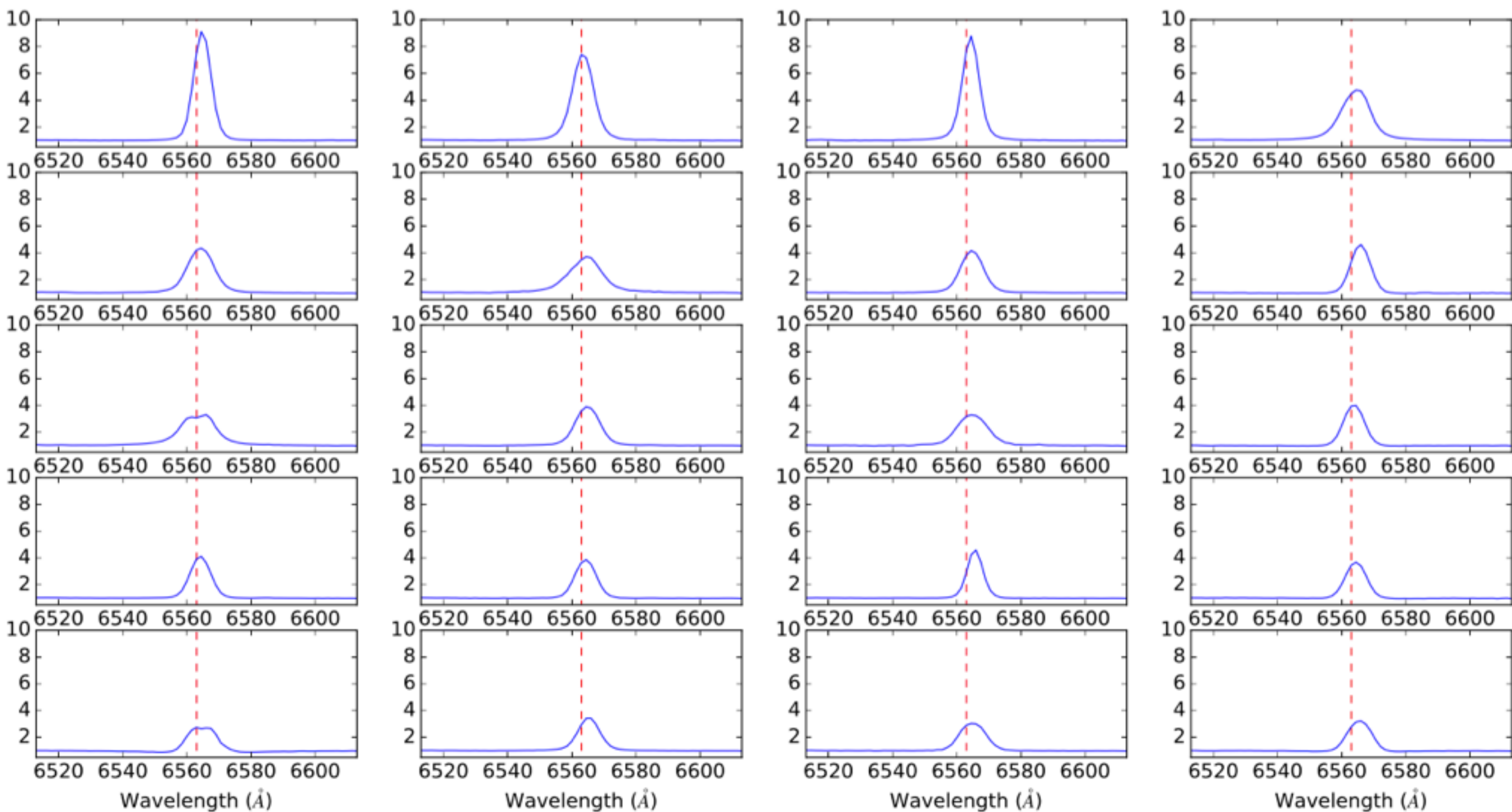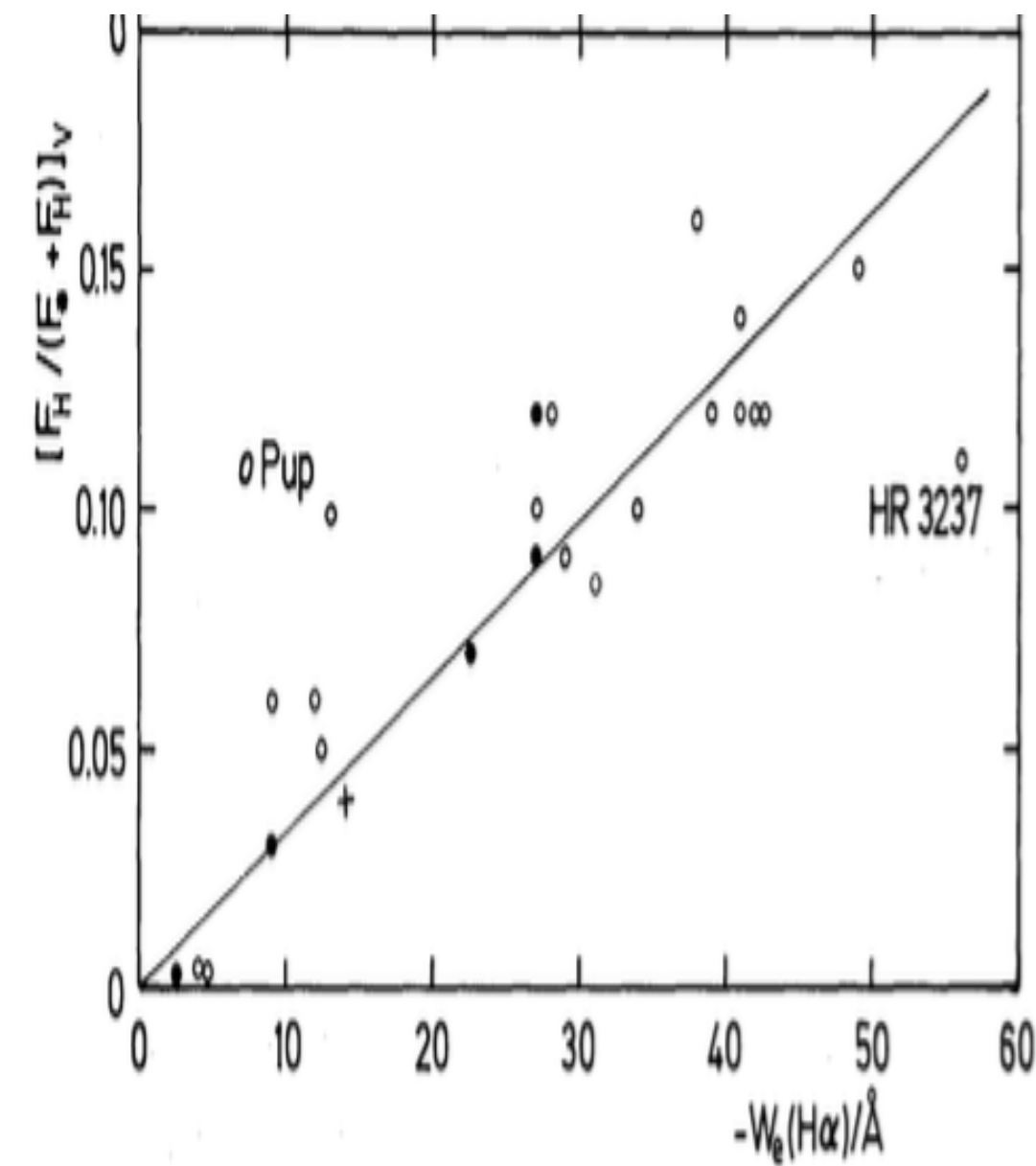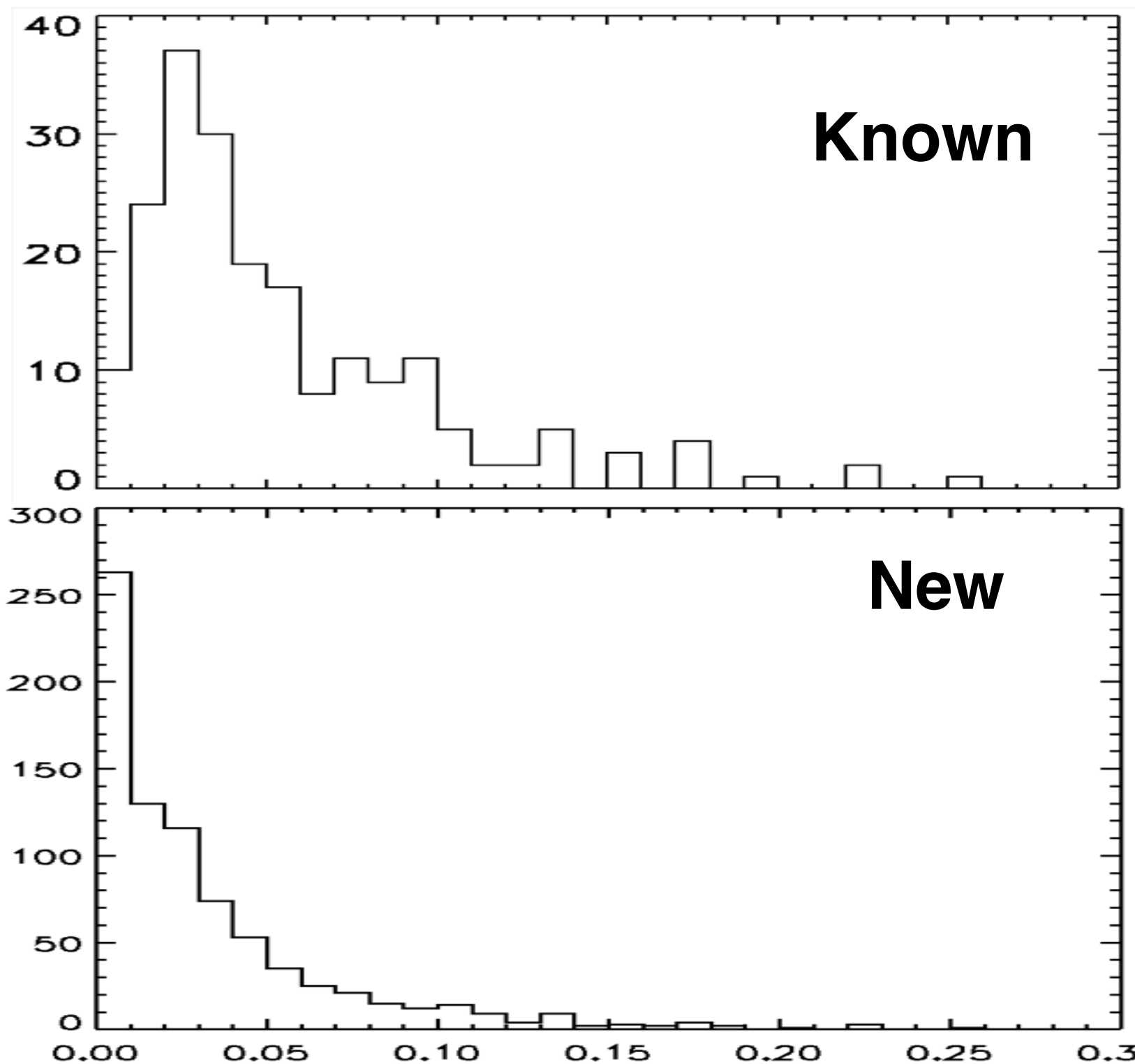Large Sky Area Multi-Object Fiber Spectroscopic Telescope (LAMOST)

$$f_D \simeq 0.1 \times \frac{EW[H\alpha]}{-30\text{Å}}$$

Known

New

Dachs et al. 1988

Envelope Fraction

13

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

543(150 known)

Hα emitters

Be stars

Av=7 mag
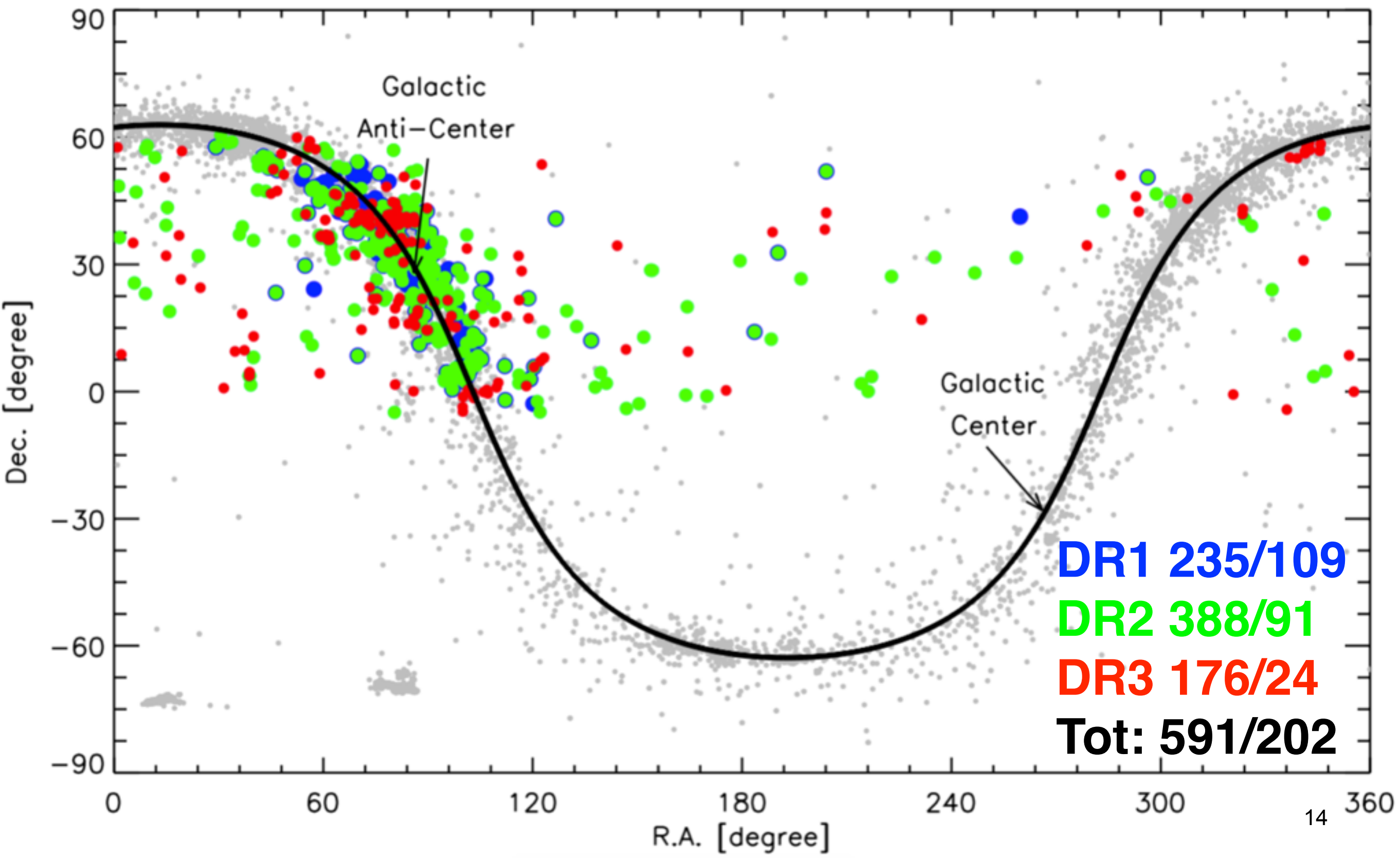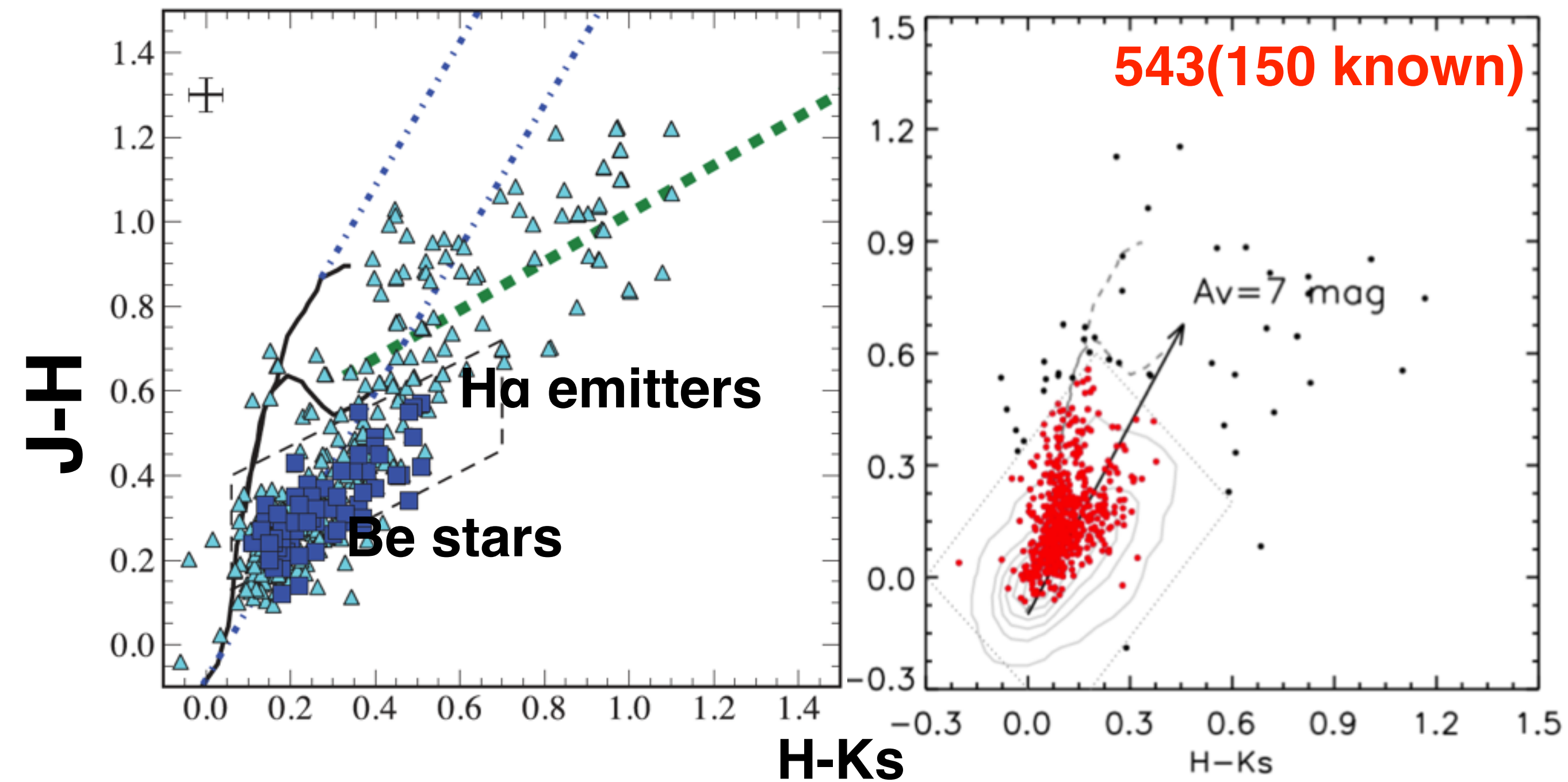
IPHAS: Raddi+ 2013
100 deg², 181 Be stars

Zhang+ 2005, Neiner+ 2011
> 3000+ Be stars 15

郭守敬望遠鏡
Large Sky Area Multi-Object Fiber Spectroscopic Telescope **(LAMOST)**

d > 12-31 kpc

**d > 7 kpc
edge of GAC**

**M$_J$ of B0-B1: < -1 mag
M$_J$ of B2-B5: -0.3 ~ 0.8 mag
M$_J$ of B5-B7: > 0.9 mag**

Npt

J-mag

Large Sky Area Multi-Object Fiber Spectroscopic Telescope **(LAMOST)**
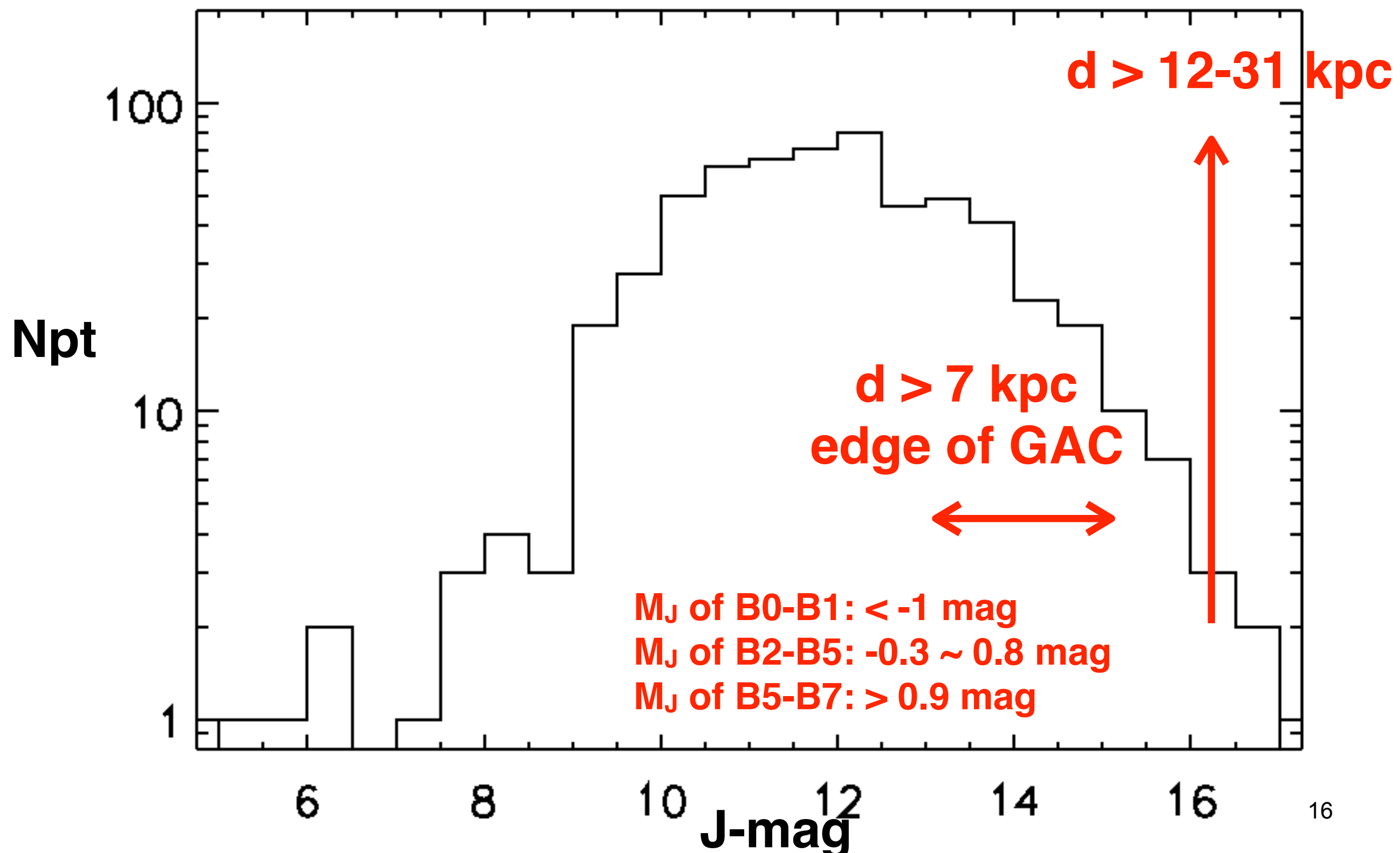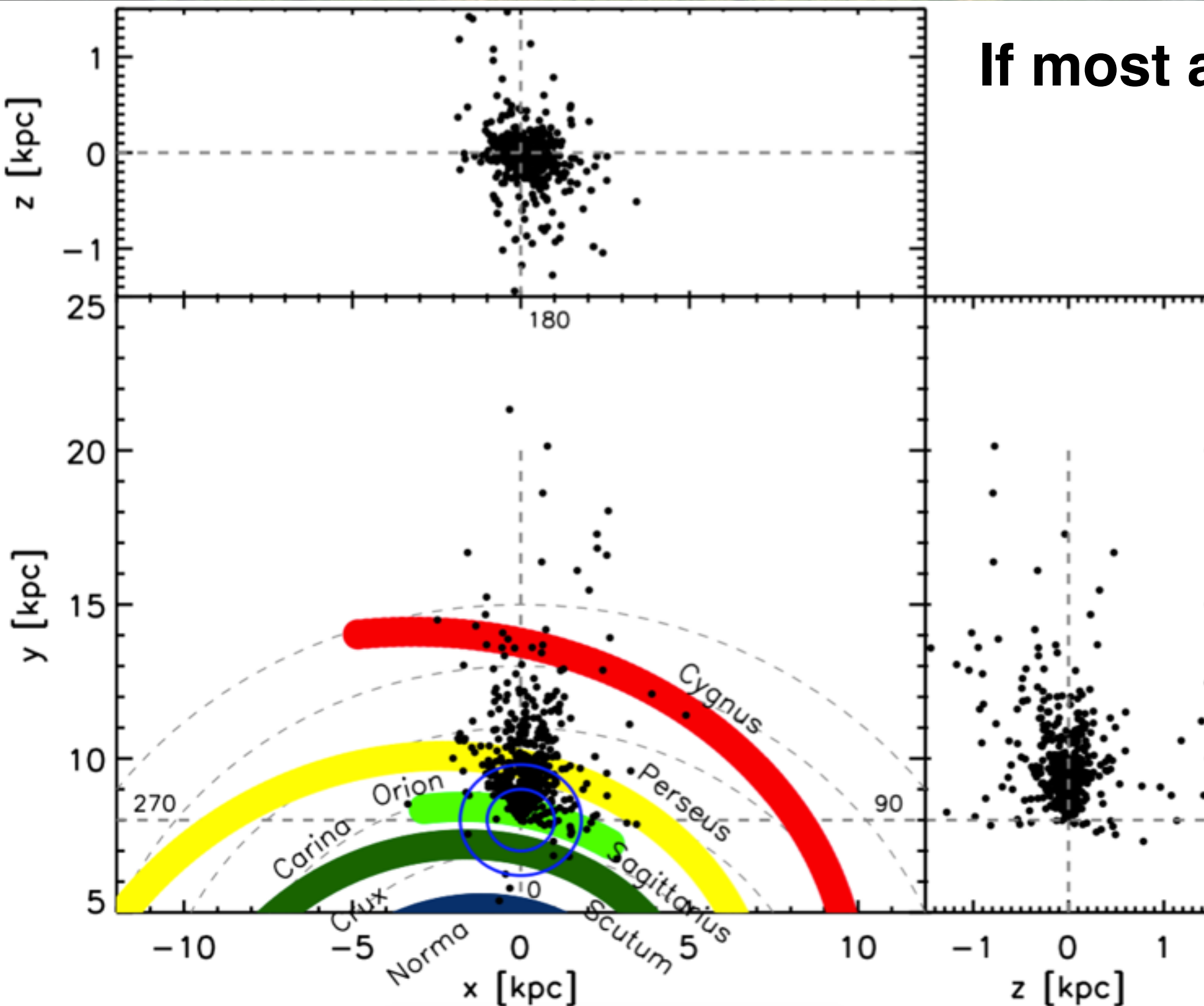
If most are late type Be

17

If most ar

Outline

- What are Be stars?
- How to find Be stars?
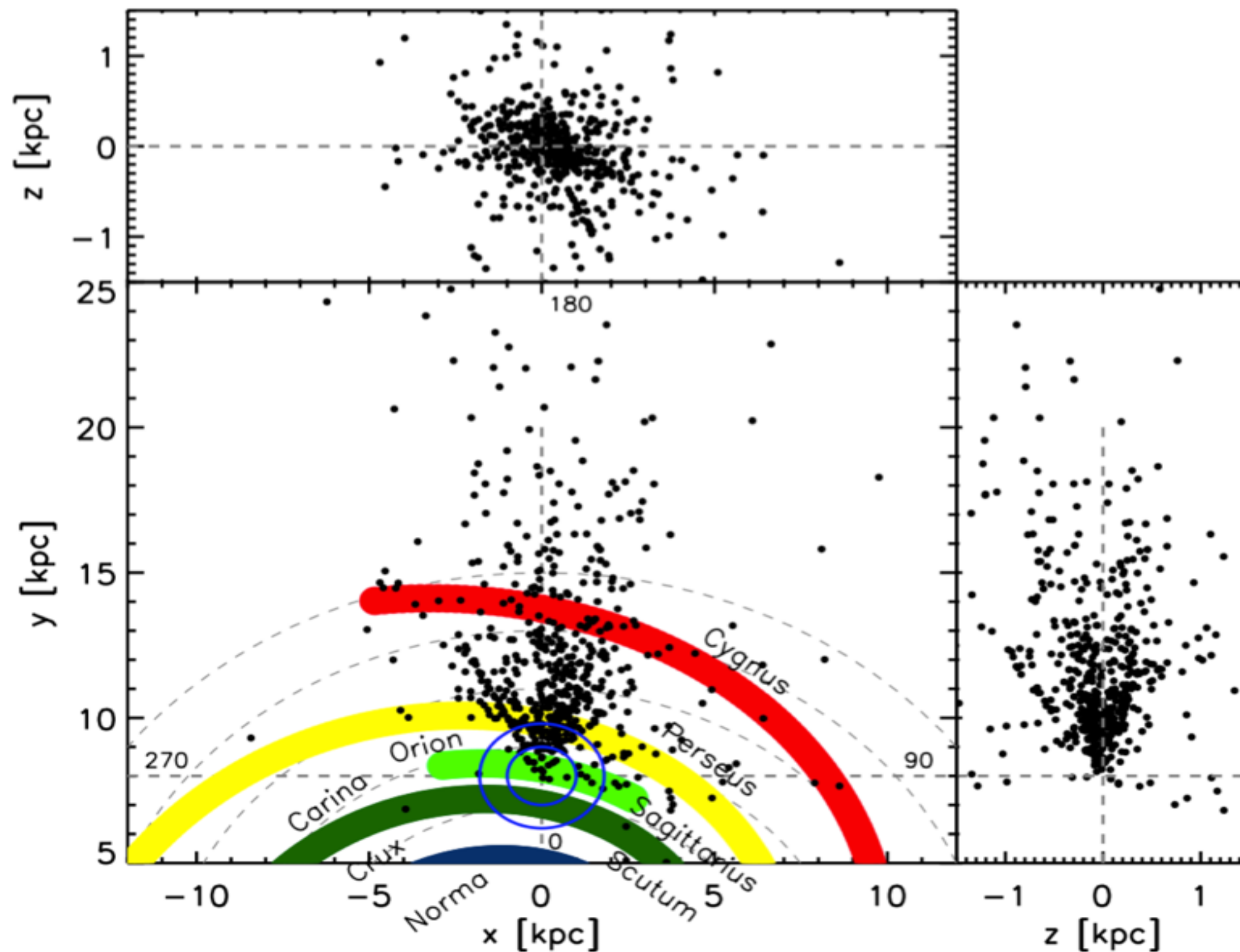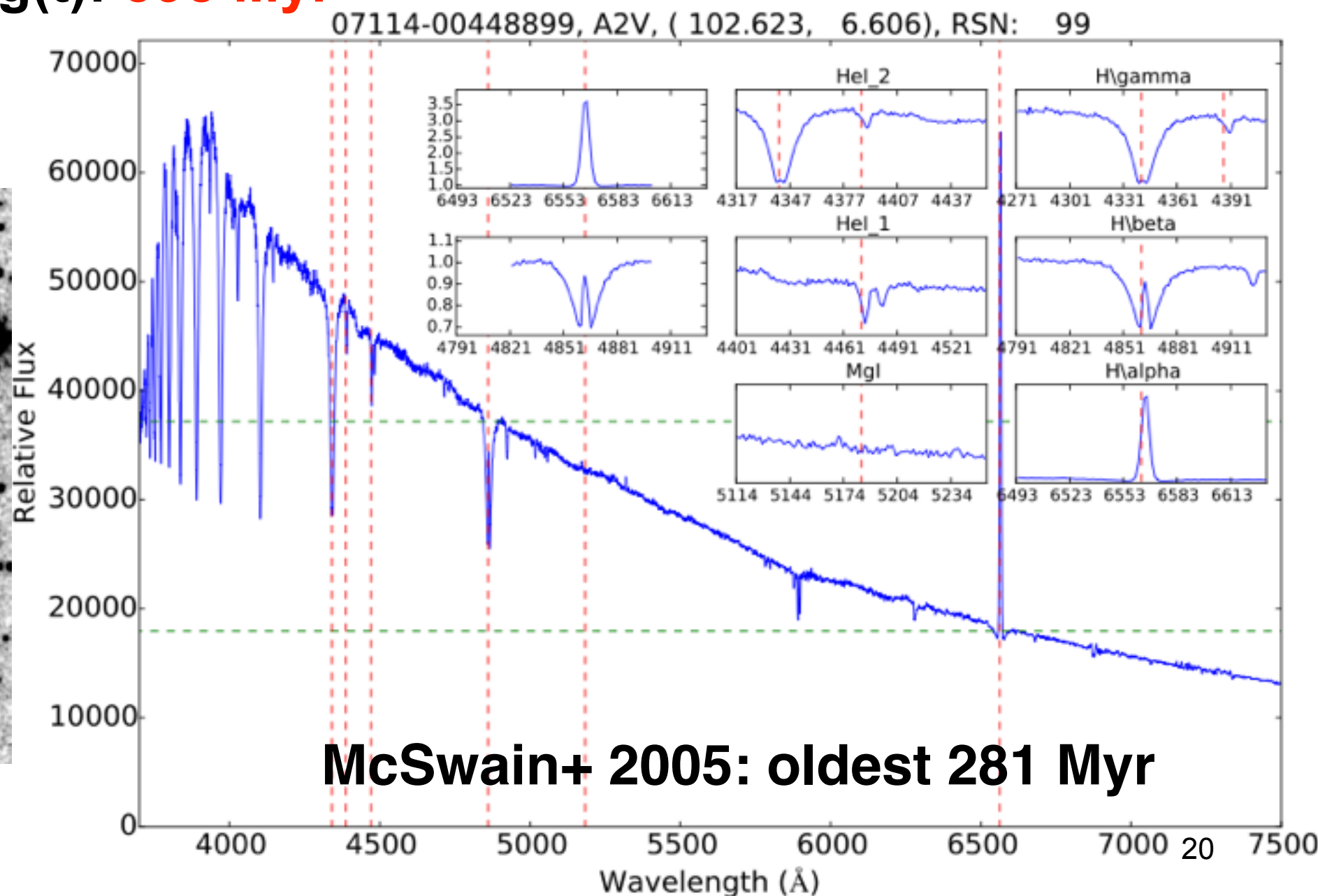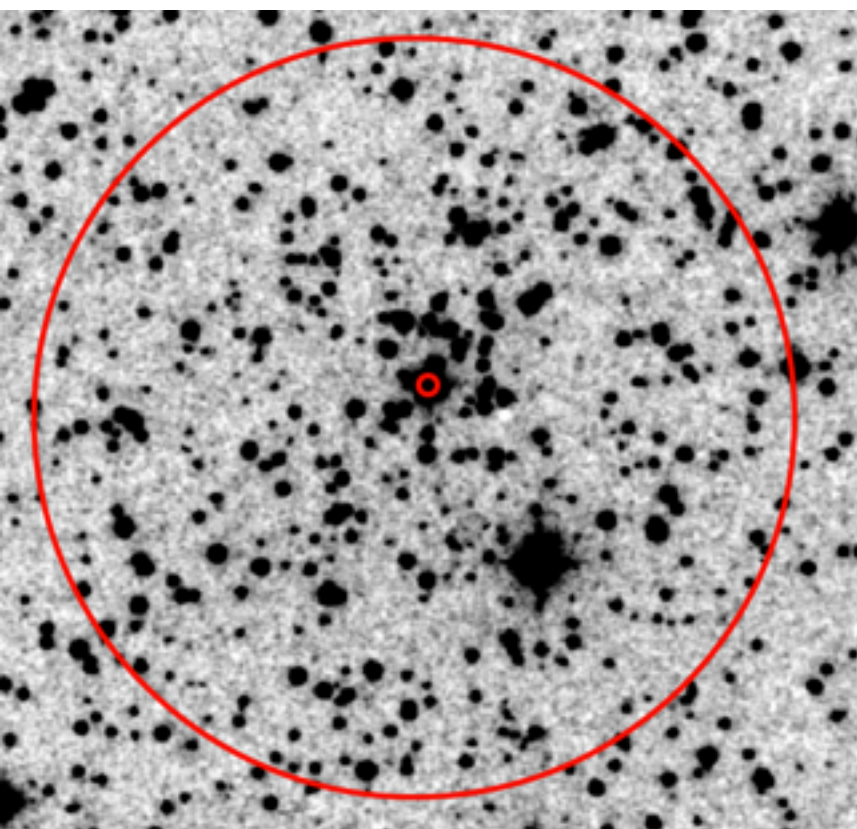- **Be stars in open clusters**
- Summary

2 Be Stars in OCs by LAMOST

- α, δ (J2000): (102.625, +06.600) deg

- μα, μδ = (-1.65, -1.70) mas/yr

- Radius: 4', Distance: 2095 pc

RAJ2000 deg △▽	DEJ2000 deg △▽	pmRA mas/yr △▽	pmDE mas/yr △▽	Jmag mag △▽	Kmag mag △▽
102.622640	+06.605820	-1.4	-0.5	10.453	10.328

- E(B-V): 0.3 mag, log(t): **398 Myr**

FSR 1025

07114-00448899, A2V, (102.623, 6.606), RSN: 99

McSwain+ 2005: oldest 281 Myr

Be Stars in Star Clusters

- **Difficulties to complete the sample of Be stars in star clusters:**

  - **a comprehensive spectroscopic survey is time consuming (5 years)**

  - **spectroscopic surveys are often limited to bright stars (R < 18 mag)**

  - **some Be-phenomena are transient/various events**

    - **short term: hourly to few days (Hubert+ 1997)**

    - **medium term: few years (Vakili+ 1998)**

    - **long term: few decades**

PTF Hα and r images

- **Palomar Transient Factory 2009-2012 (Law et al. 2009)**

  - **supernova, asteroids, variable stars, etc.**

  - **wide field of view (7.3 square degrees)**

  - **48 inch (1.2 m) Samuel Oschin Telescope**

  - **With HA 656 (Hα) and HA 663 (r) narrow-band filters**

  - **SED-machine: low resolution IFU spectrograph R∼100, mounted on the Palomar 1.5-m telescope**

- **http://www.ptf.caltech.edu/**

PTF Second Public Data Release

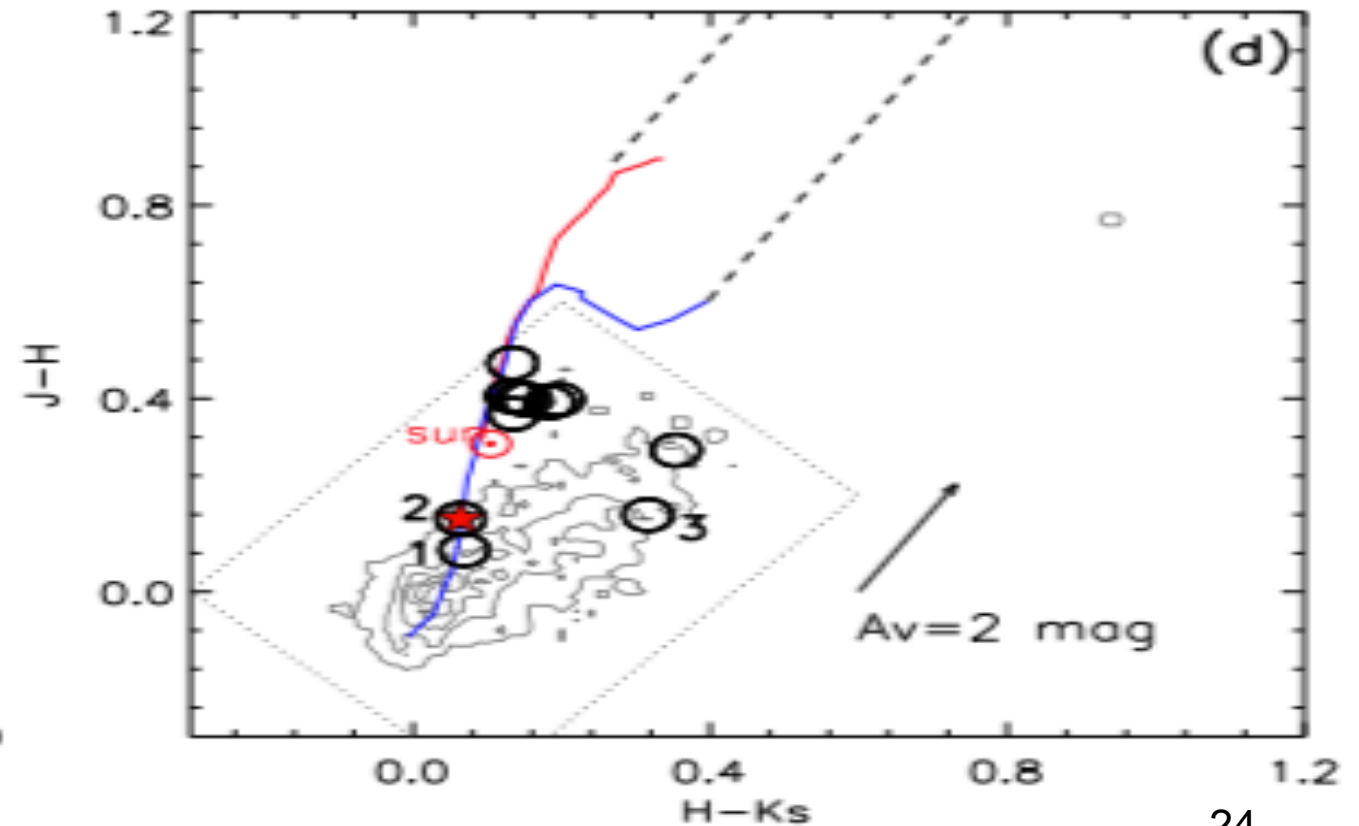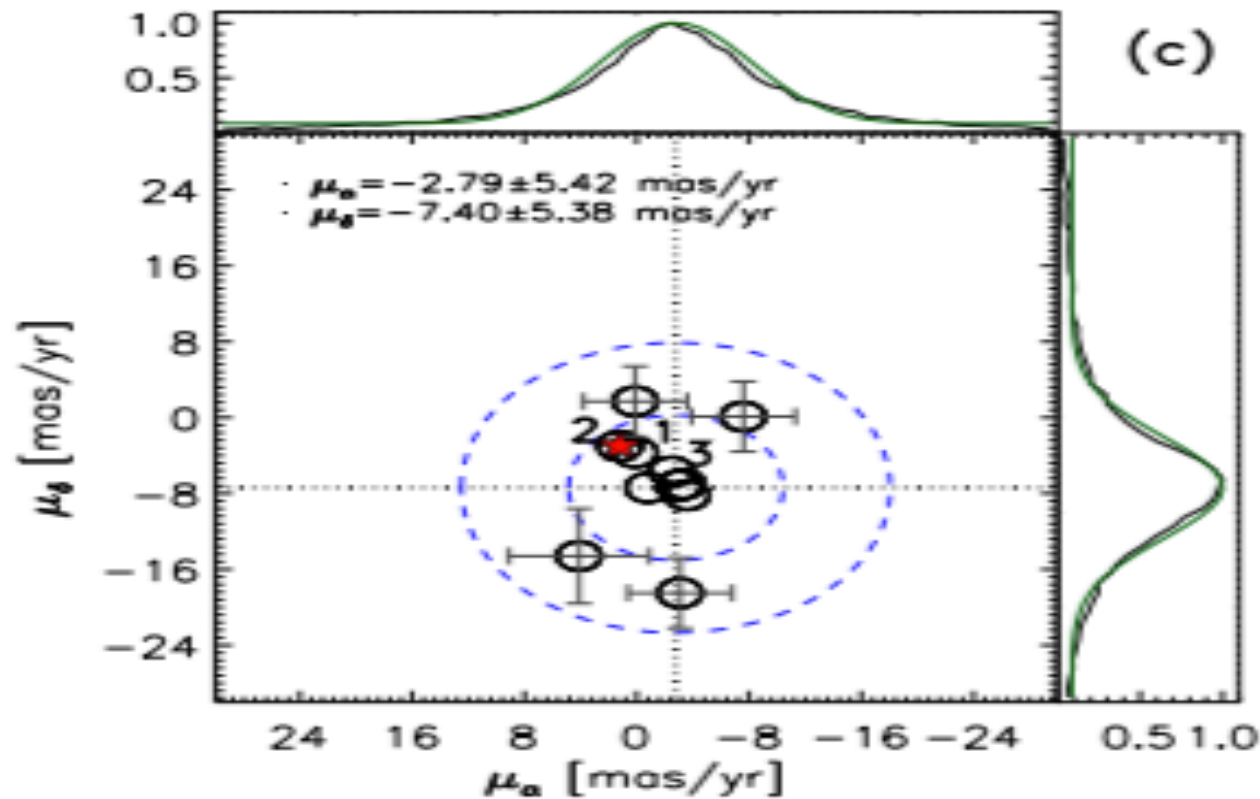15   DR2_coverage_R_equ_0_0.fits
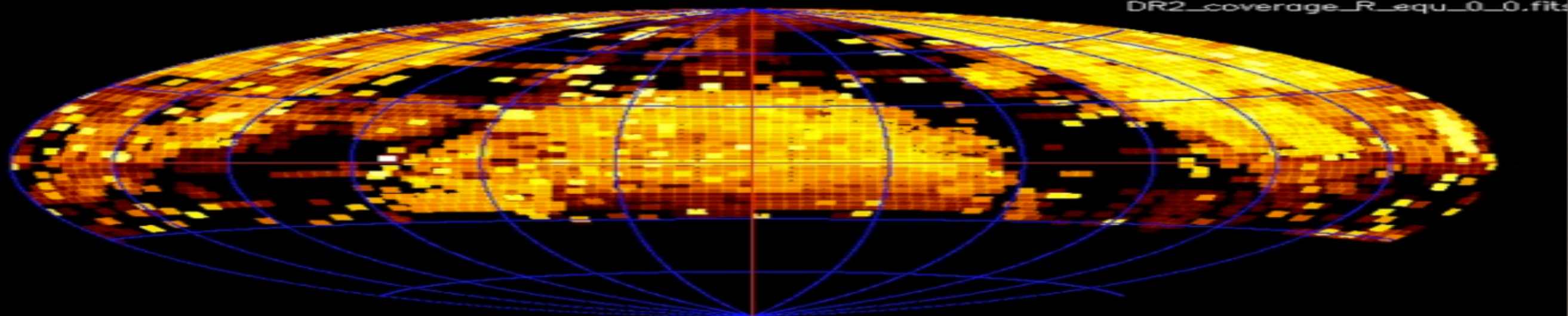
Ha emitters with PTF
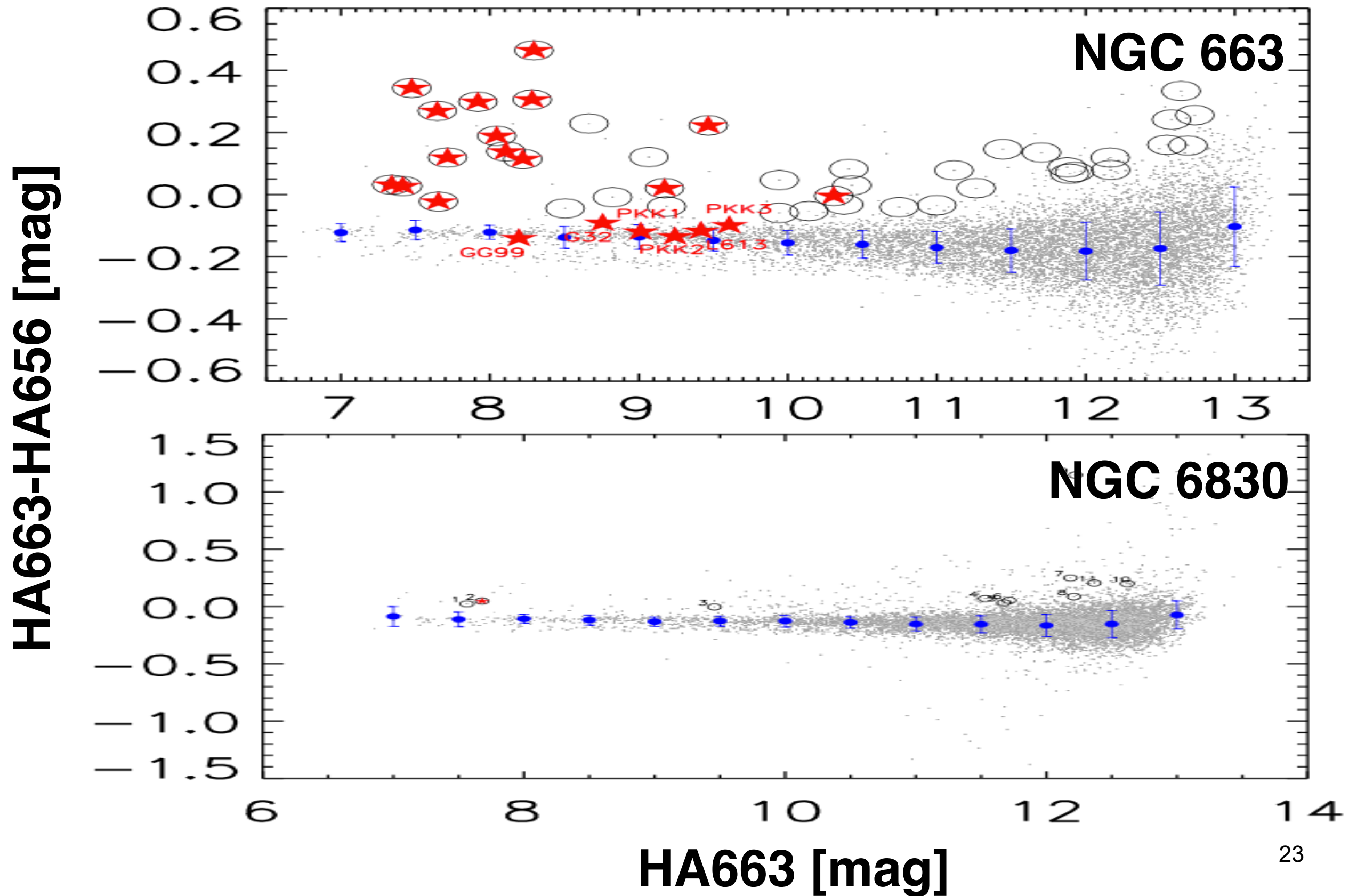
Membership Identification

Radial Density Profile (a)

Color-Magnitude Diagram (b)
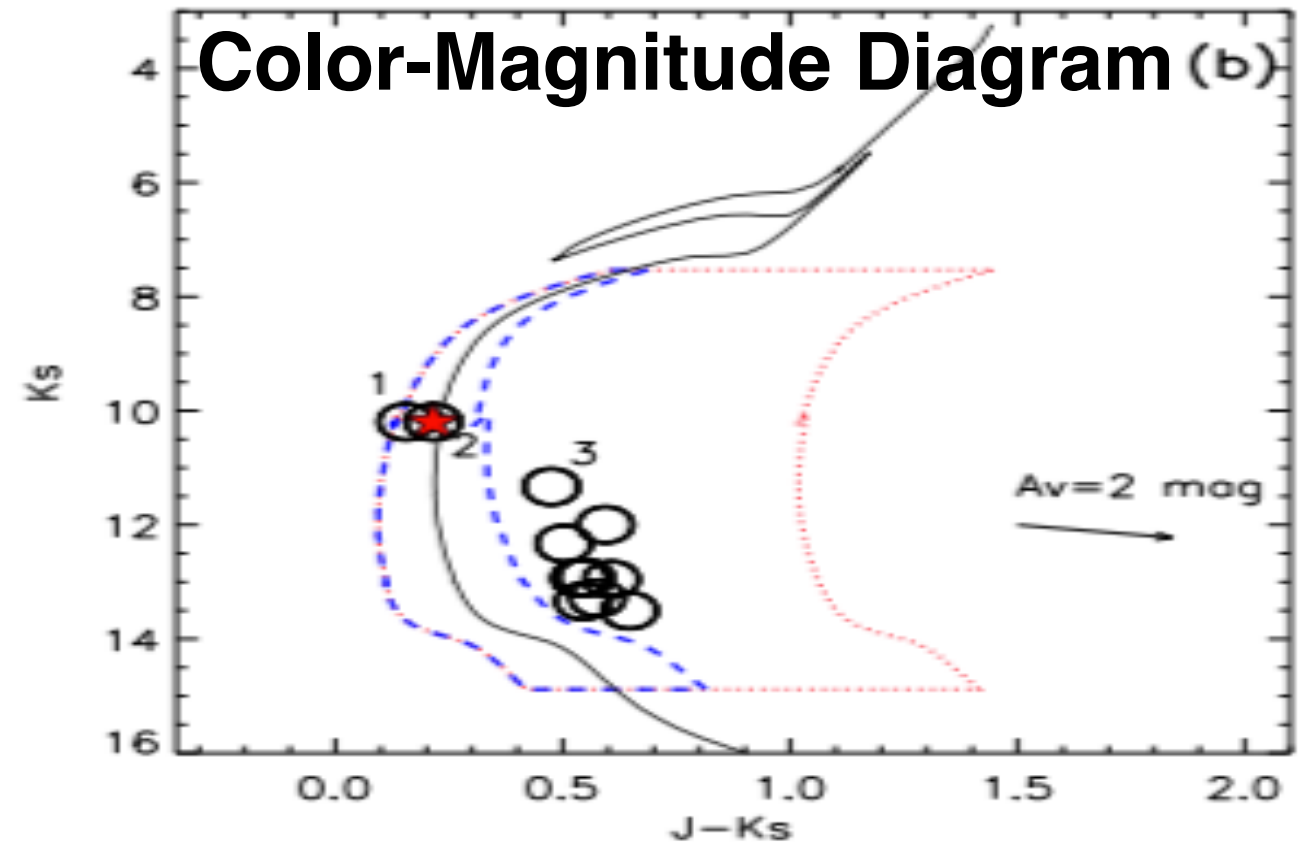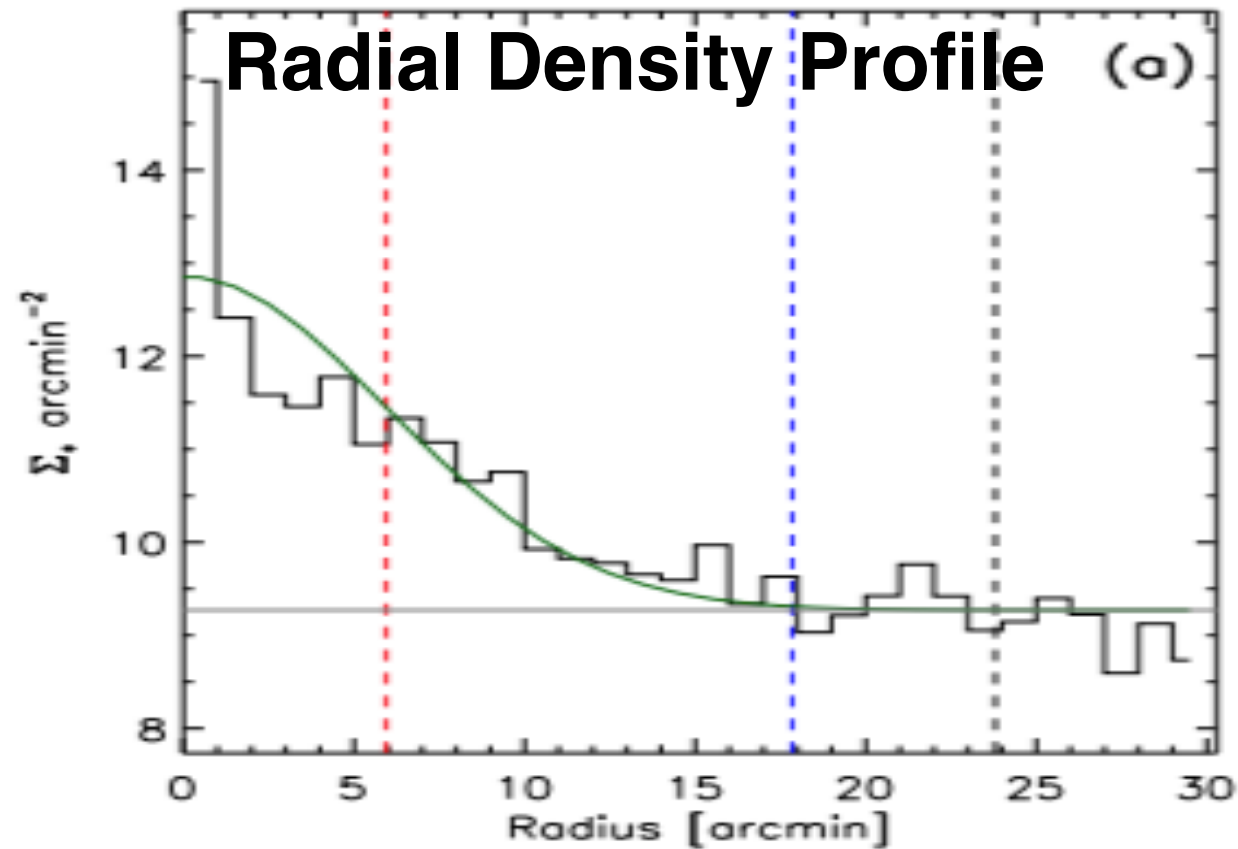
Proper Motion Diagram

Color-Color Diagram

Be Stars in the Star Cluster NGC 663

- **Pilot study on NGC 663 with PTF, 2MASS, and PPMXL (Yu+ 2015)**
  - **4 new Be stars, 1 known excluded in NGC 663.**
    - **[N(Be)/N(B)] ~4.5%,**
    - **lower than that of NGC 7419, NGC 2345 (>10%)**
  - **The low fraction of Be stars in NGC 663 might be a consequence of the effects of mass segregation and stellar winds or supernova explosions.**

20x20 arcmin
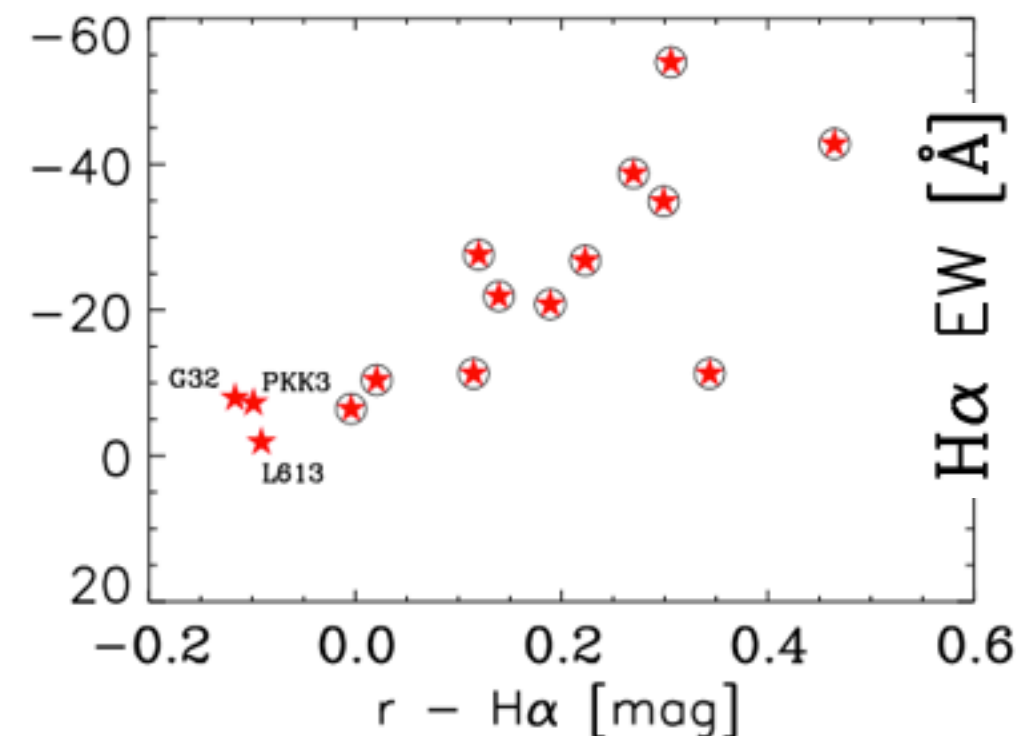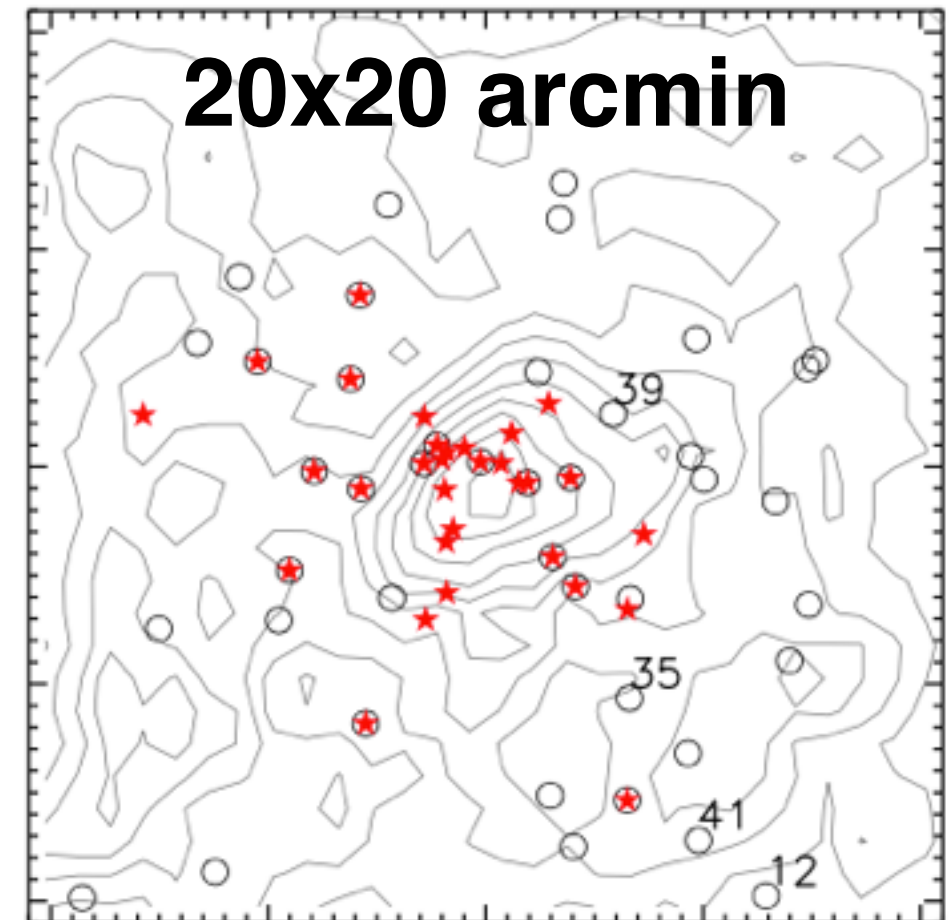
Be Stars in the Star Cluster NGC 6830

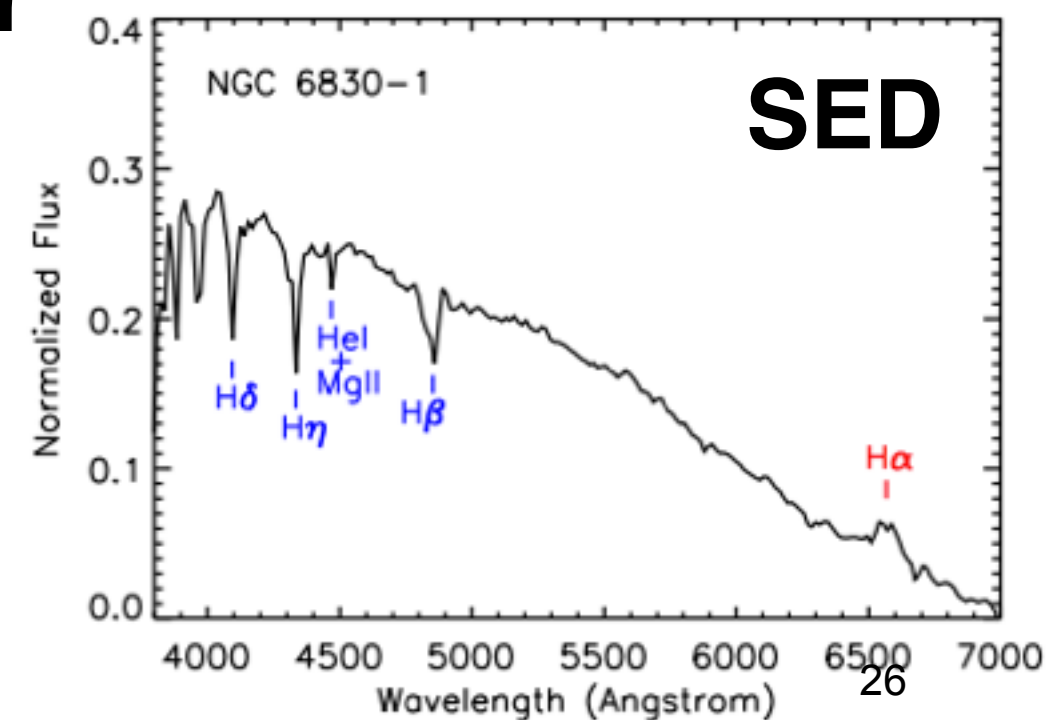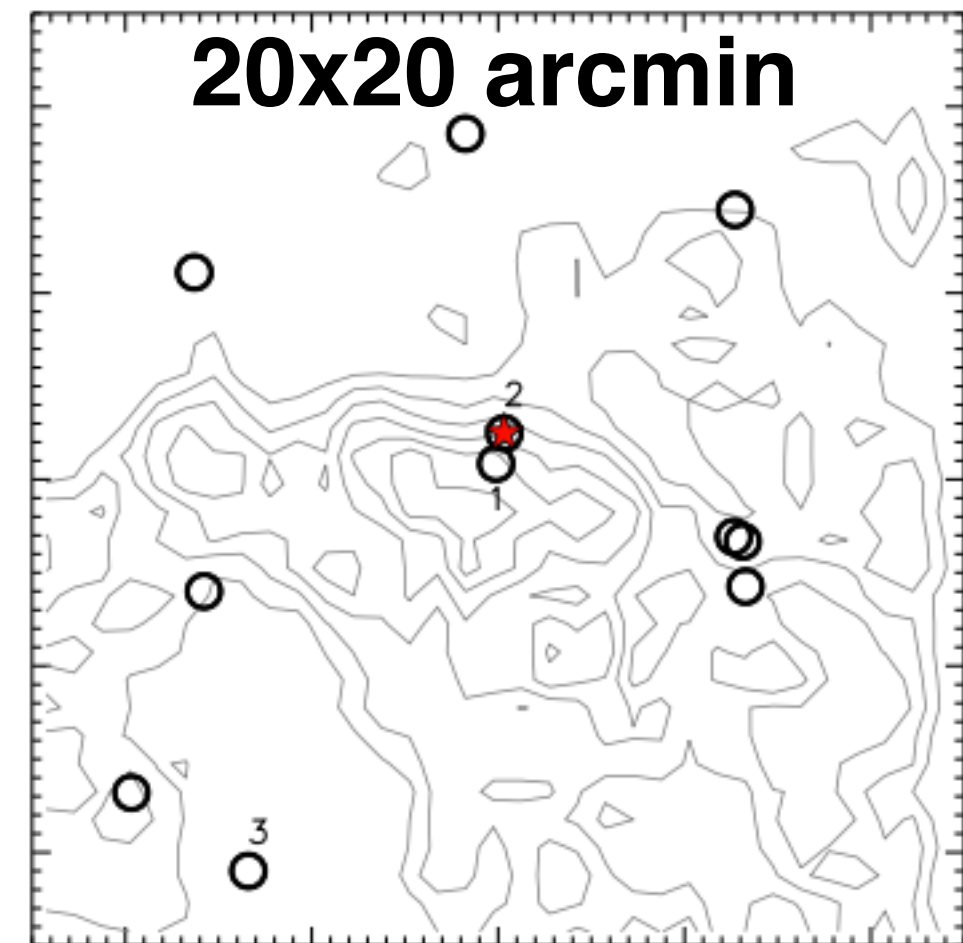- **Program improved on NGC 6830 with PTF, 2MASS, and PPMXL (Yu+ submitted.)**
  - **2 new Be stars, 1 known re-identified in NGC 6830. Age ~ 125 Myr.**
  - **The low fraction of Be stars in NGC 6830 indicates that older open cluster lack Be stars.**
  - **Due to time constraints during the commission runs, we only observed the two brightest candidates**

20x20 arcmin

SED

Searching for Be Stars in 100 OCs

Name	RA	Dec	Distance	log(age)	Candidates
ASCC_3	7.77	55.275	1550	7.729	2
FSR_0106	267.81	11.162	1596	7.95	4
FSR_0771	75.945	32.165	1705	8.515	3
FSR_1102	118.39	5.7	1659	8.77	3
FSR_1147	120.08	1.26	1508	8.72	0
Koposov_12	90.261	35.277	1900	8.91	1
FSR_1139	111.13	-2.884	1964	8.855	0
FSR_0728	67.47	38.5	1816	8.255	0
FSR_0905	98.427	22.288	1786	8.3	0
FSR_1094	92.497	-6.32	1627	8.85	0
FSR_0866	103.81	29.73	1664	9.2	1
FSR_0683	77.16	53.22	1522	9.2	0
FSR_0757	62.47	26.57	1900	9	0

13 OCs have been done by C.S. You (游昌憲), NCU

Summary

- The LAMOST DR1, DR2, and DR3 contain > 5 M spectrums (> 90% are stars and with stellar parameters). More than 500 objects were identified as Be candidates and mostly distributed near Galactic Anti-Center due to the survey strategy. In DR1, only 2 Be stars are in star clusters with age 15 Myr and 398 Myr, respectively.

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- As a pilot project, we have searched for Be stars in 2 star clusters with Hα- and r-band images from PTF survey and confirmed their membership photometrically and kinematically with 2MASS and PPMXL, respectively. Searing for Be star candidates in 100 star clusters is ongoing. The SED machine will efficiently verify Be candidates in the future.

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