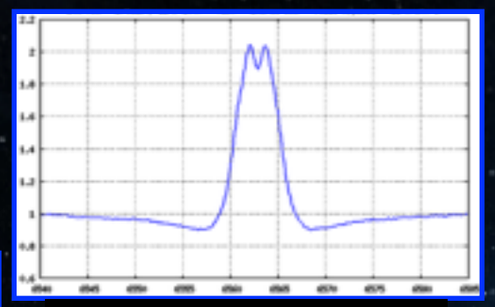
Search for Be stars in Star Clusters



25 Tau B8IIIe

21 Tau B8V

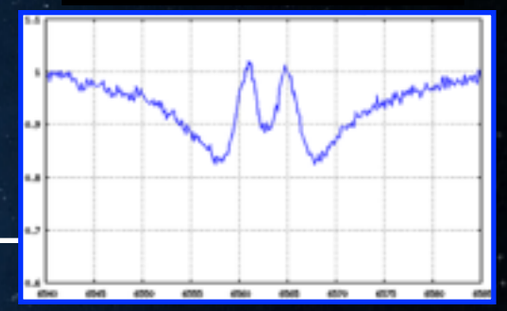
20 Tau B8III

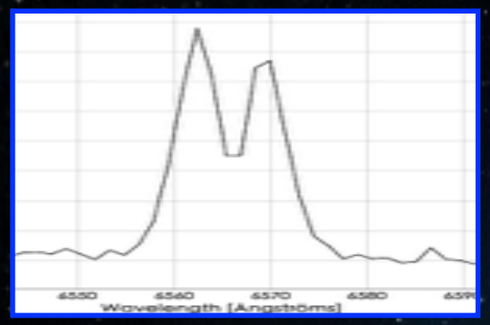
18 Tau B8V

19 Tau B6IV

16 Tau B7IV

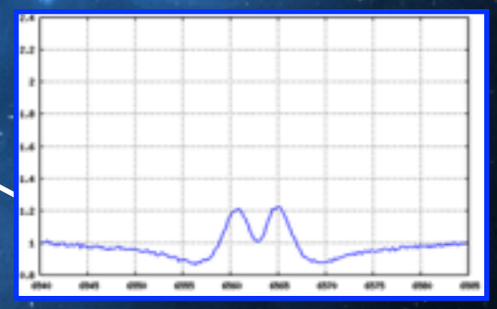
17 Tau B6IIIe





28 Tau B8IVe

27 Tau B8III



23 Tau B6IVe

M45

Roger C.C. Lin[1] (林建爭), J.L. Hou[1], L. Chen[1], Z.Y. Shao[1], and P.C. Yu[2], C.D. Lee[2] etc

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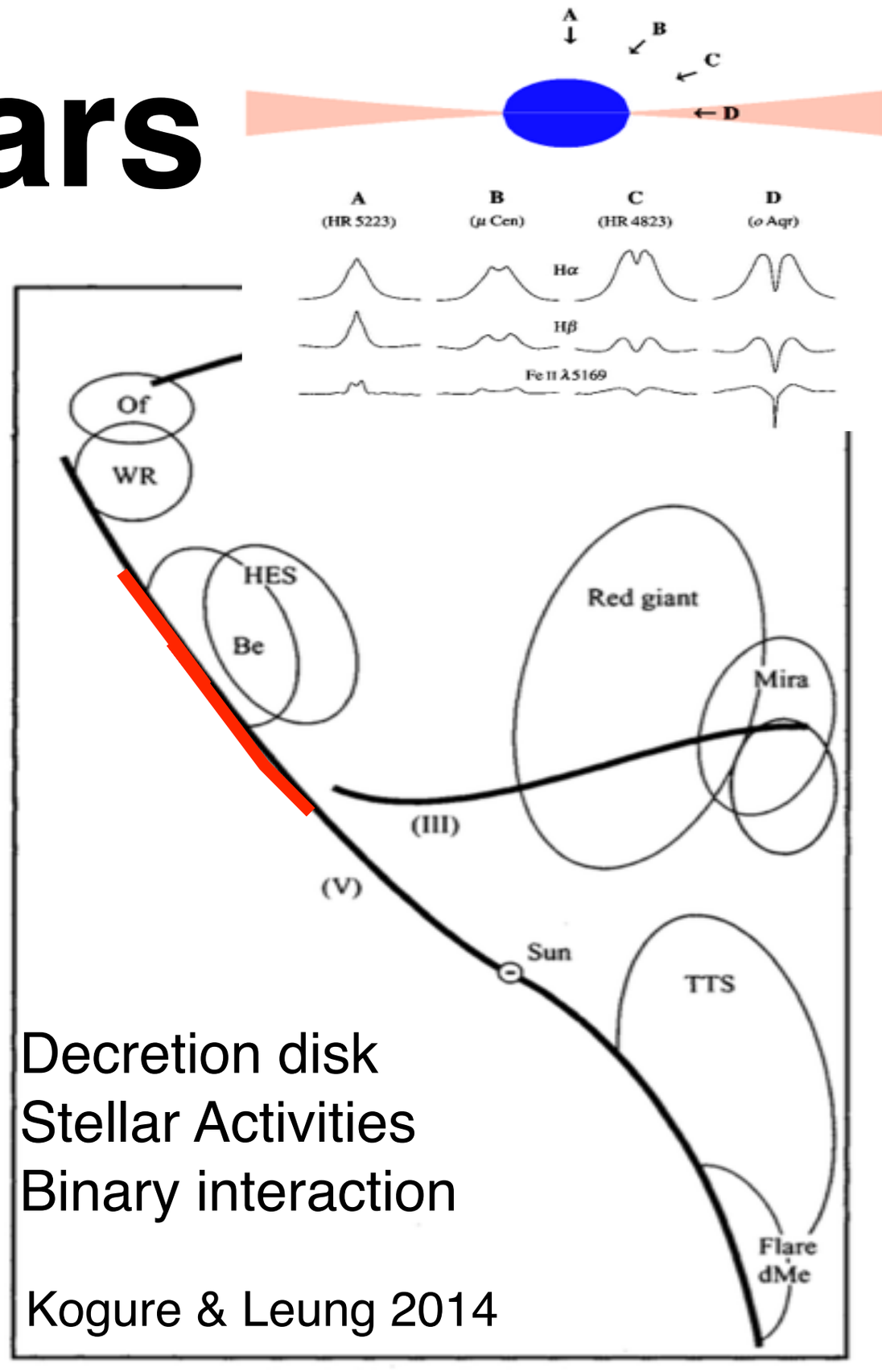
Be Stars

- **The first Be star (γ Cas) was classified by Father Angelo Secchi in 1866.**
- **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.**
- **B -> Be**
  - **evolution process?**
  - **environments?**



Previous Works

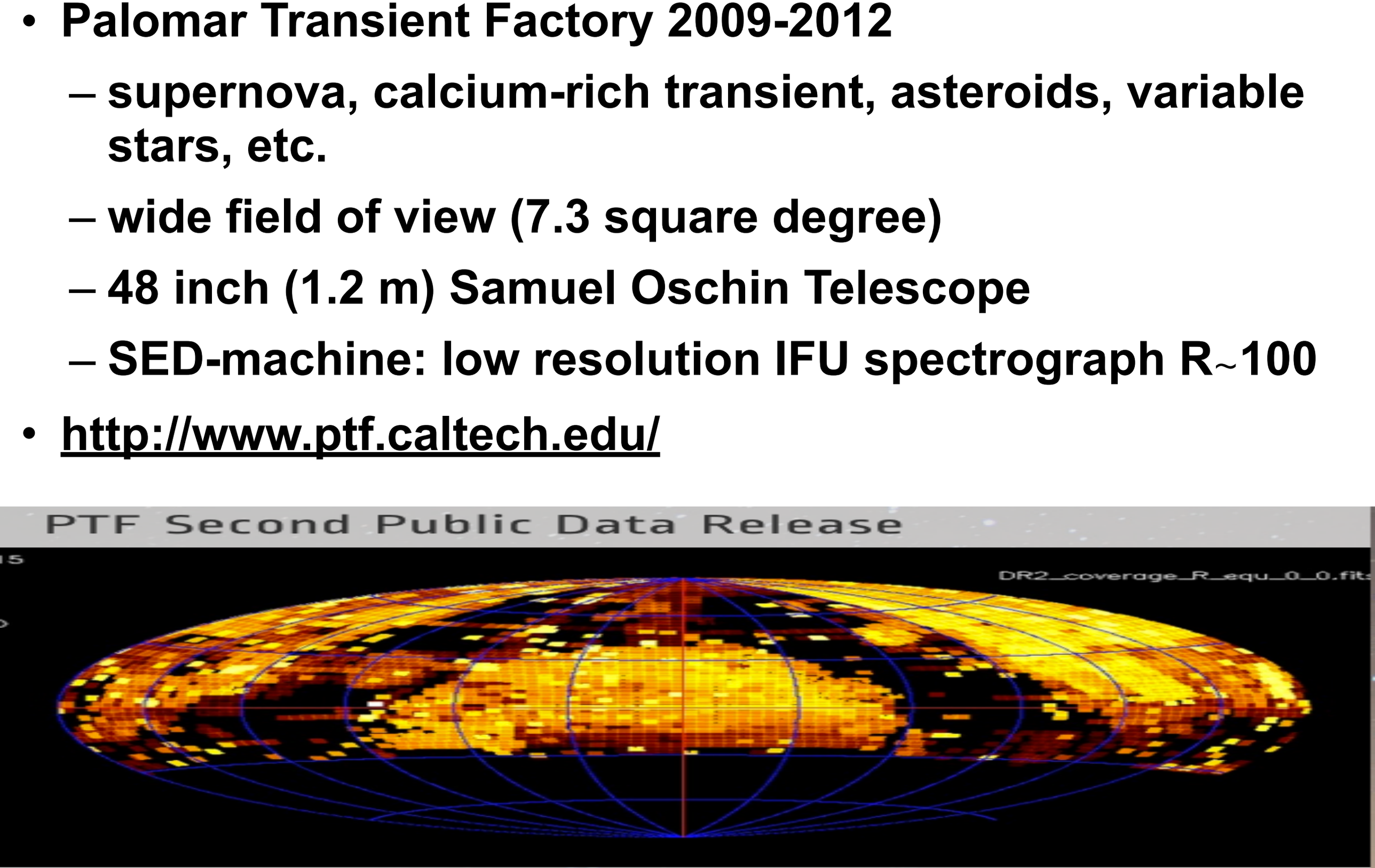
- **Be stars surveys in SMC, LMC, MW: (Mathew & Subramaniam 2011; Drew+ 2005; Drew Chojnowski+ 2015; Raddi+ 2015; Lin+ 2015)**
  - **Evolve to Be and fast rotators after ZAMS**
    - **28 clusters (Fabregat & Torrejon 2000)**
    - **double clusters (Keller+ 2001)**
    - **Be spun-up in 55 clusters (McSwain & Gies 2005)**
  - **Born with Be phenomena**
    - **Be candidates in young clusters of LMC & SMC (Wisniewski & Bjorkman 2006)**

Be Stars in Star Clusters

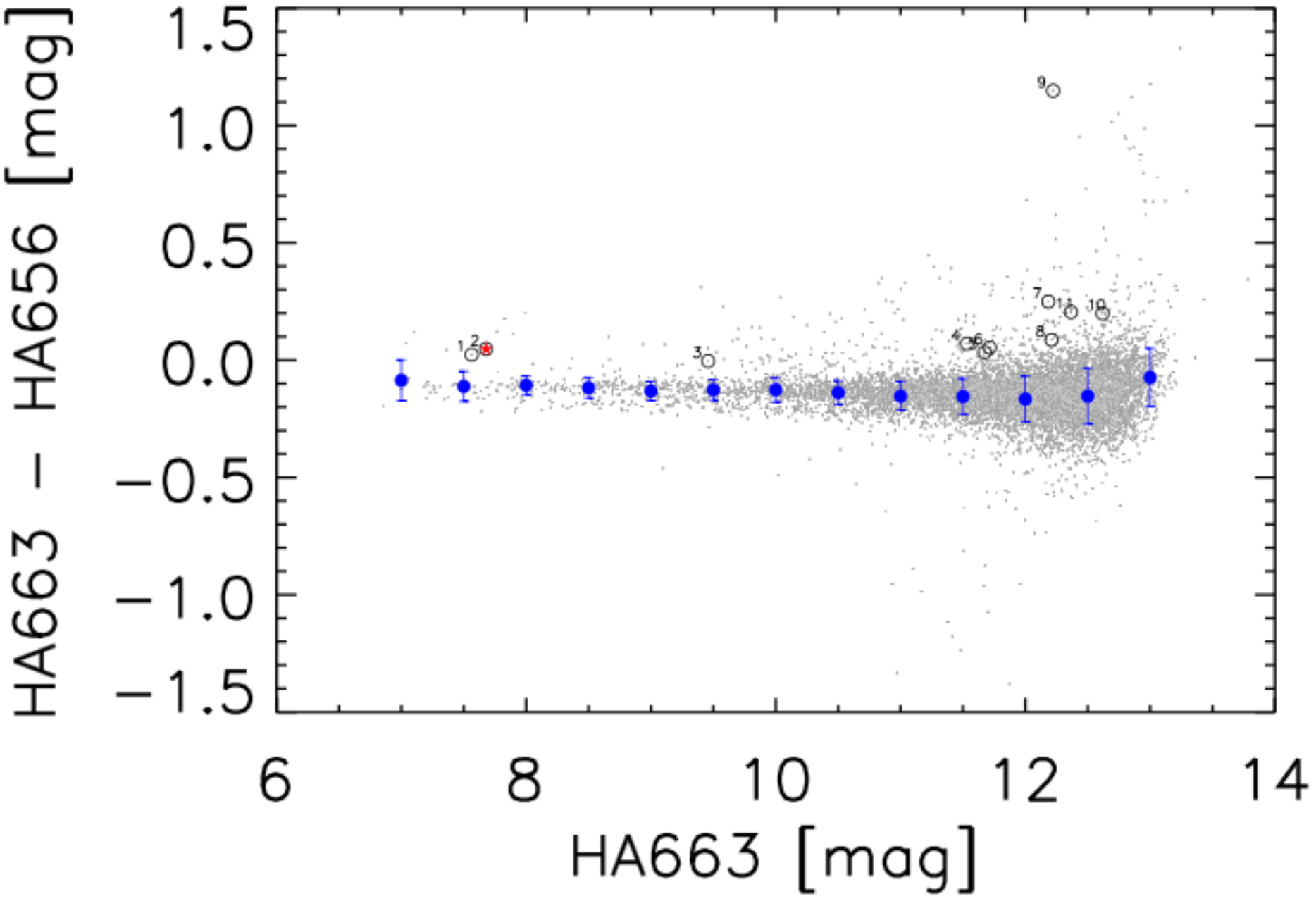
- **The sample is not complete:**
  - **a comprehensive spectroscopic survey is time consuming**
  - **spectroscopic surveys are often limited to bright stars**
  - **some Be-phenomena are transient events**
- **Pilot study: NGC 663 & NGC 6830 (Yu et al. 2015)**
  - **With PTF, 4 new Be stars, 1 known excluded in NGC 663. [N(Be)/N(*)] ~3.5%, [N(Be)/N(B)] ~4.5%, lower than that of NGC 7419, NGC 2345 > 10%**
  - **With PTF, 2 new Be stars, 1 known re-identified in NGC 6830. Age ~ 125 Myr, low Be stars fraction.**

PTF

- **Palomar Transient Factory 2009-2012**
  - **supernova, calcium-rich transient, asteroids, variable stars, etc.**
  - **wide field of view (7.3 square degree)**
  - **48 inch (1.2 m) Samuel Oschin Telescope**
  - **SED-machine: low resolution IFU spectrograph R~100**
- **http://www.ptf.caltech.edu/**



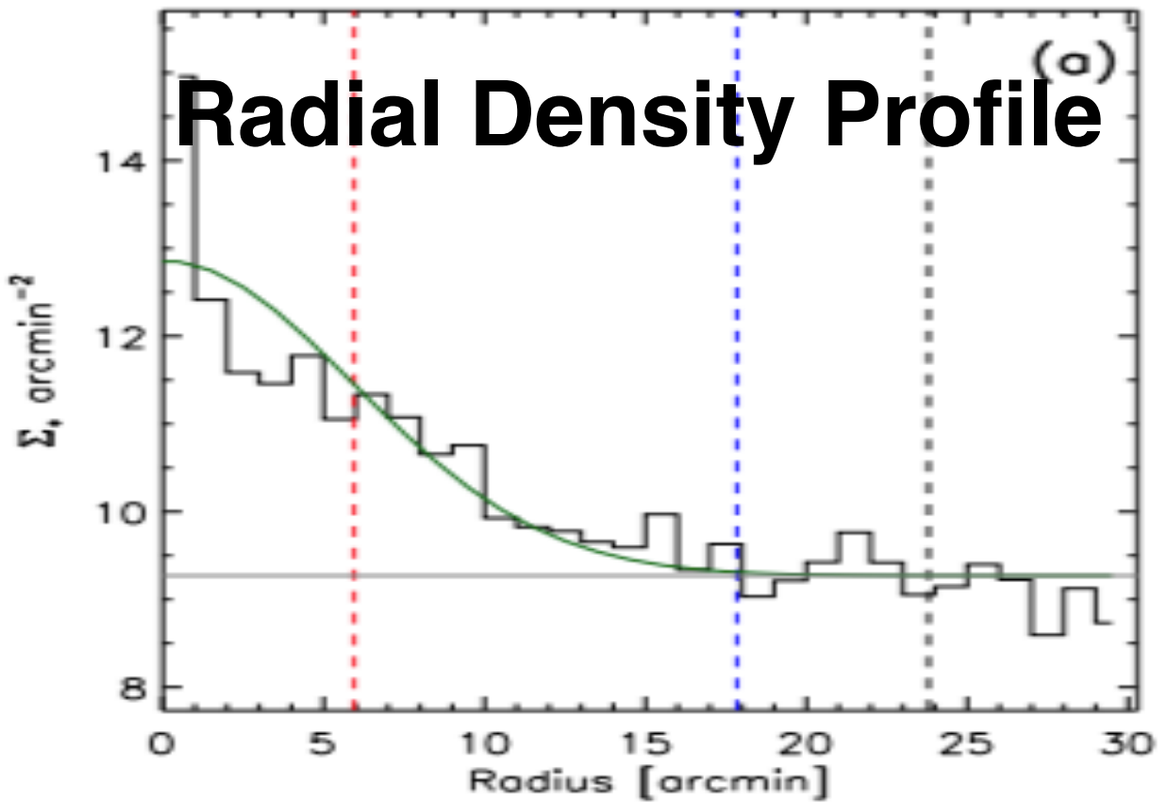
Be Stars Identification



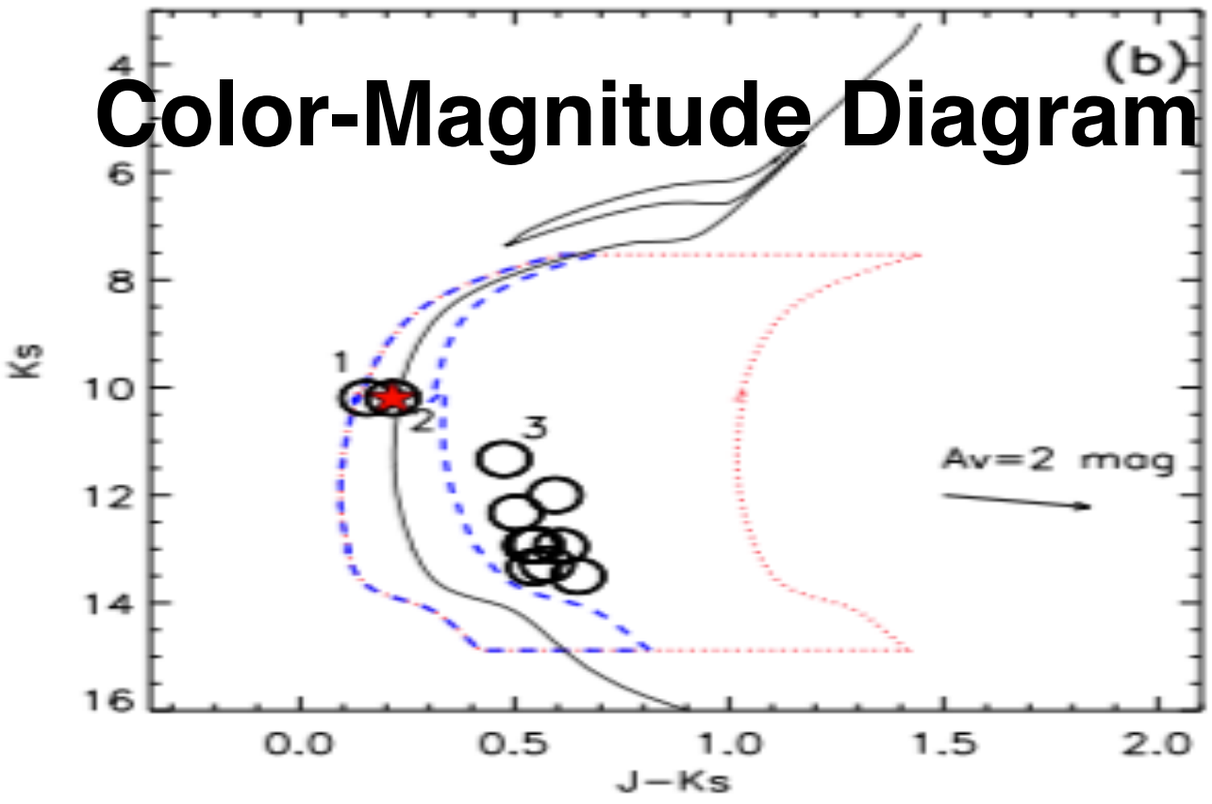
Hα-emitter results

Be Stars Identification Cont.

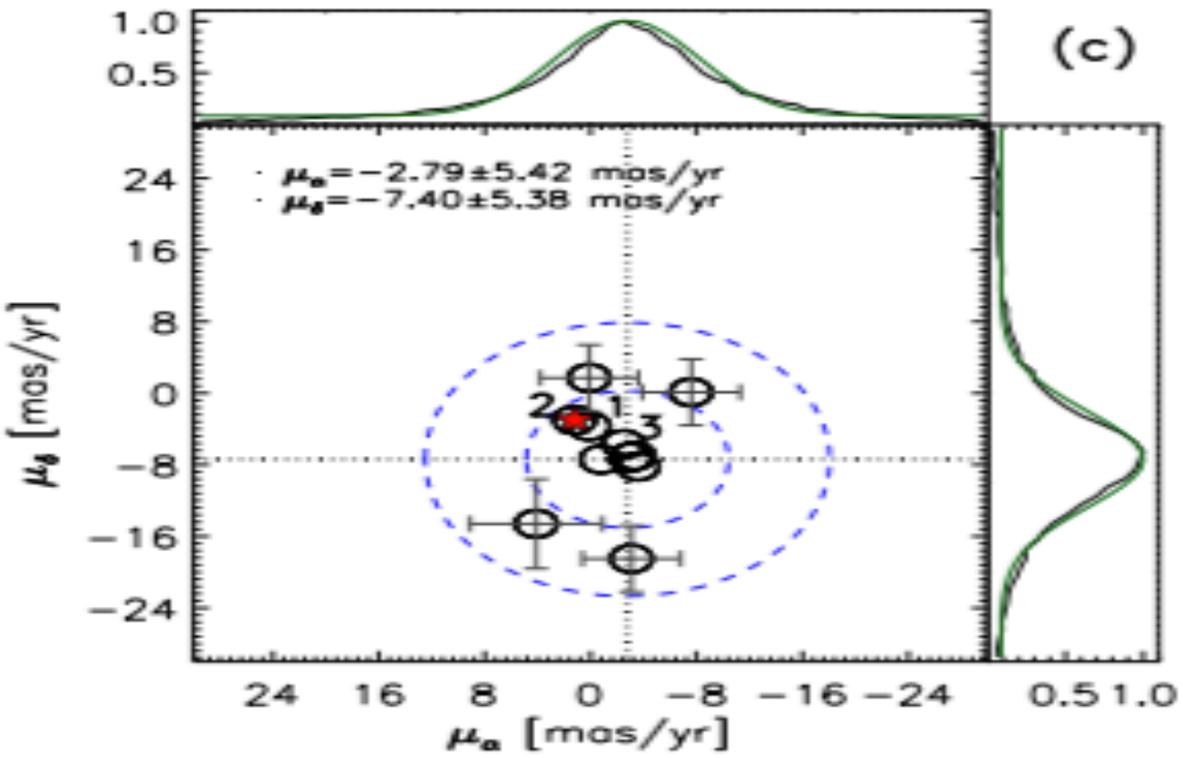
Radial Density Profile



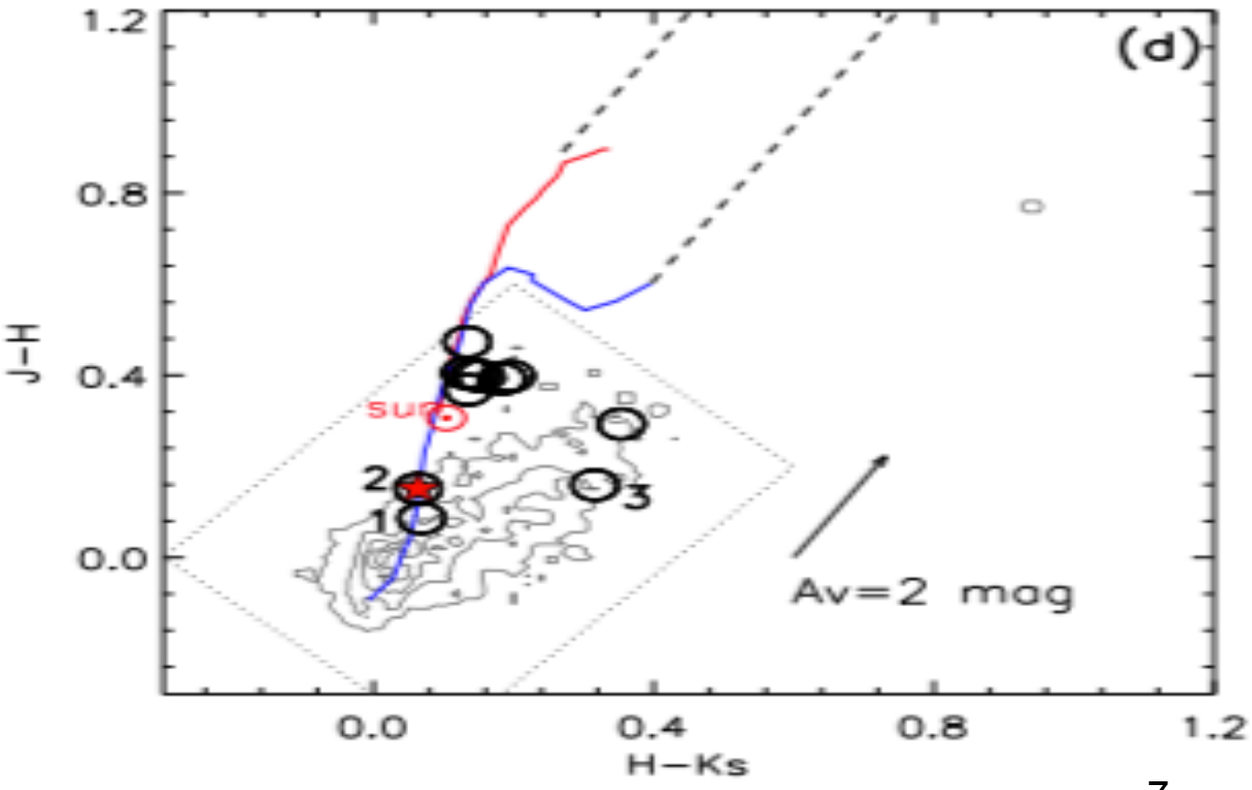
Color-Magnitude Diagram



Proper Motion Diagram



Color-Color Diagram



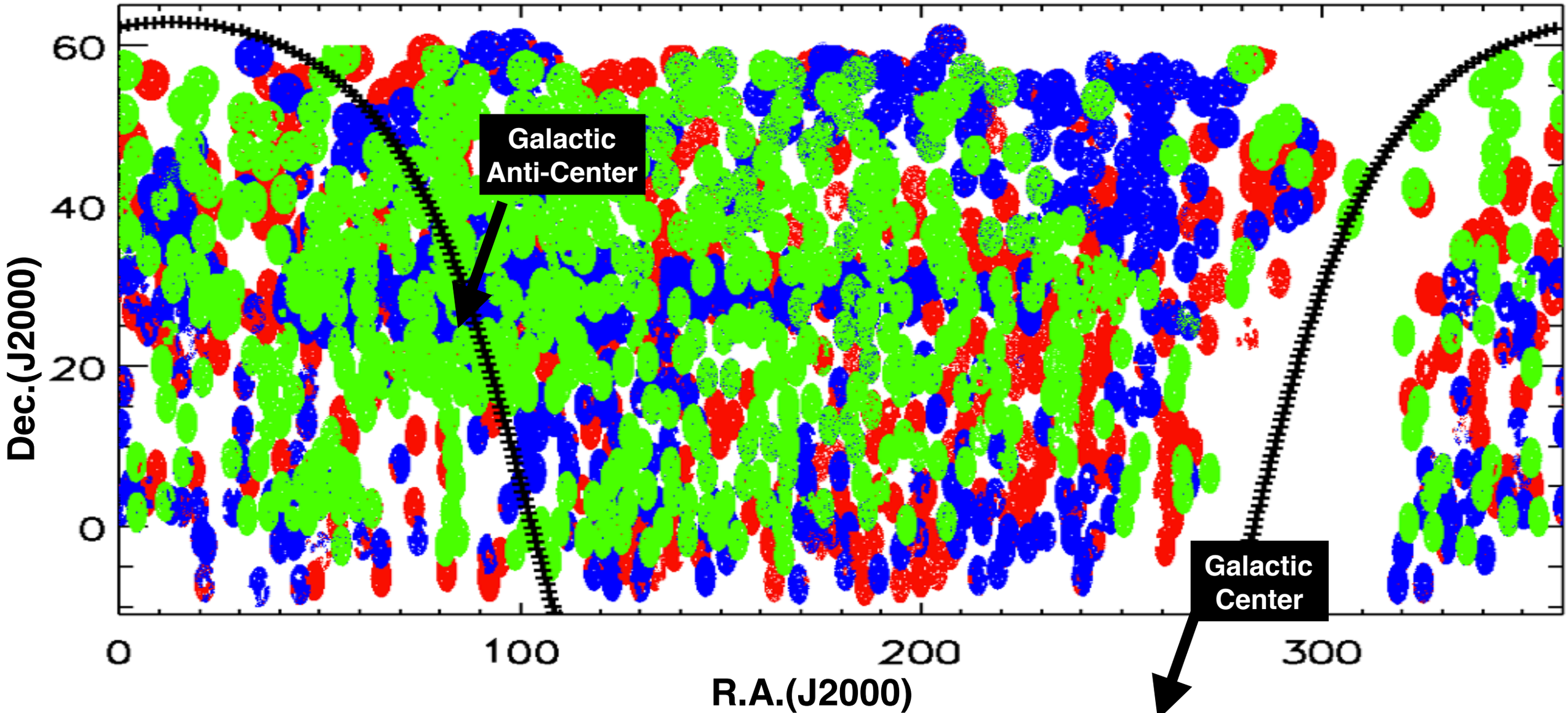
Searching for Be Stars in 100 OCs

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

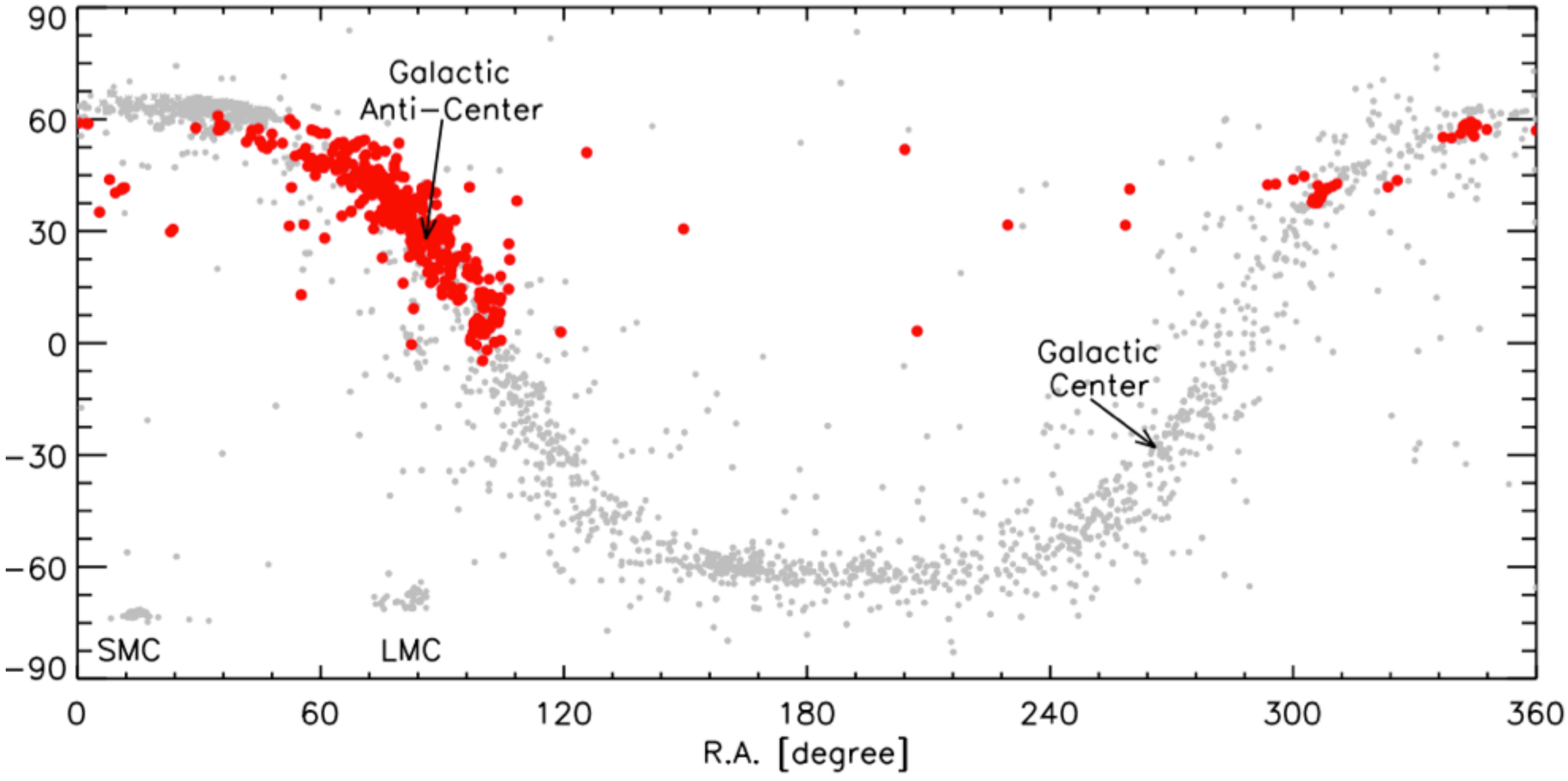
done by C.S. You (游昌憲)

LAMOST Footprints

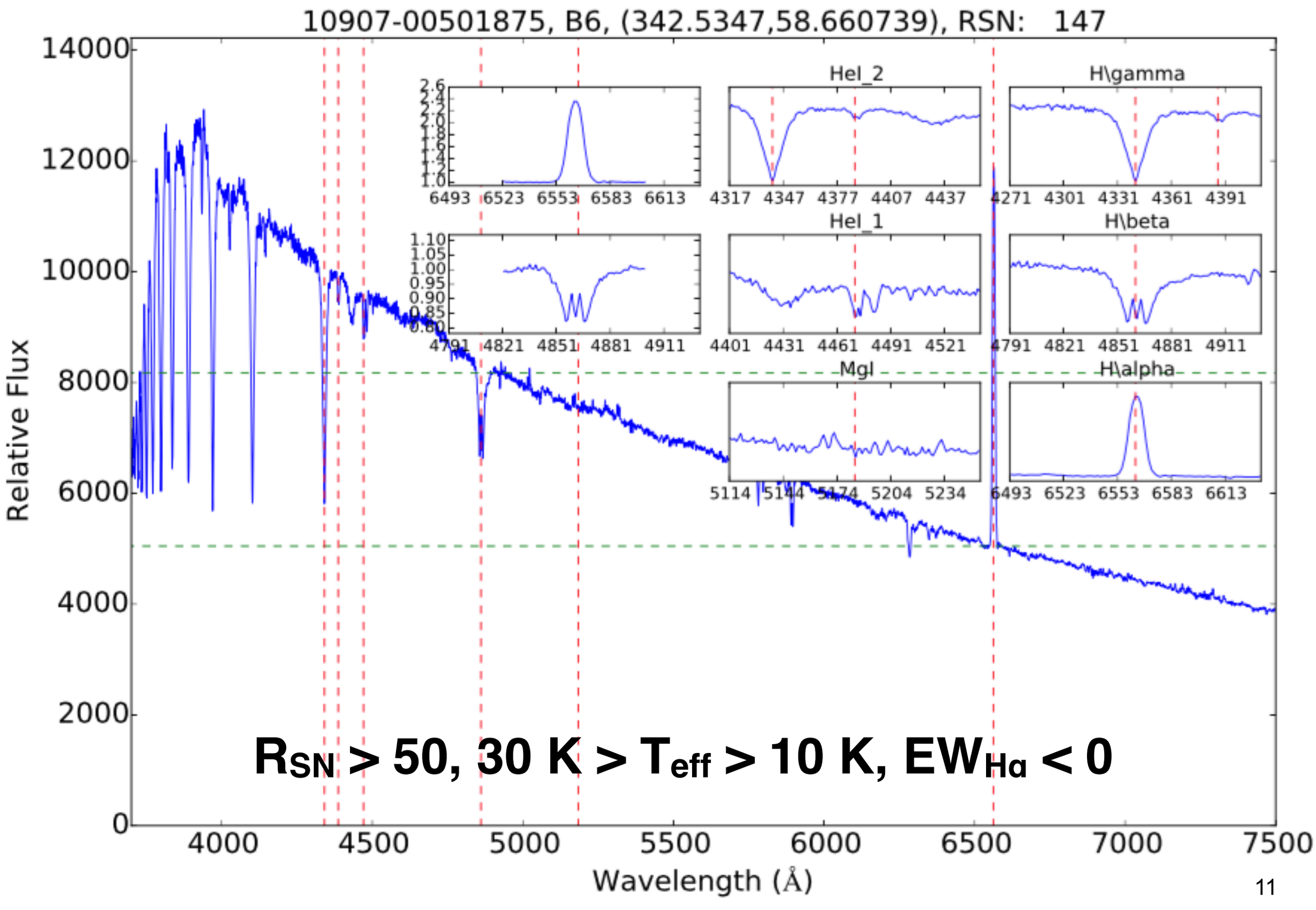
- DR1 2011.10 - 2013.06 (~2.2 M, 88% stars)
- DR2 2011.10 - 2014.06 (~4.1 M, 91% stars)
- DR3 2014.09 - 2015.05 (~1.5 M, 92% stars)



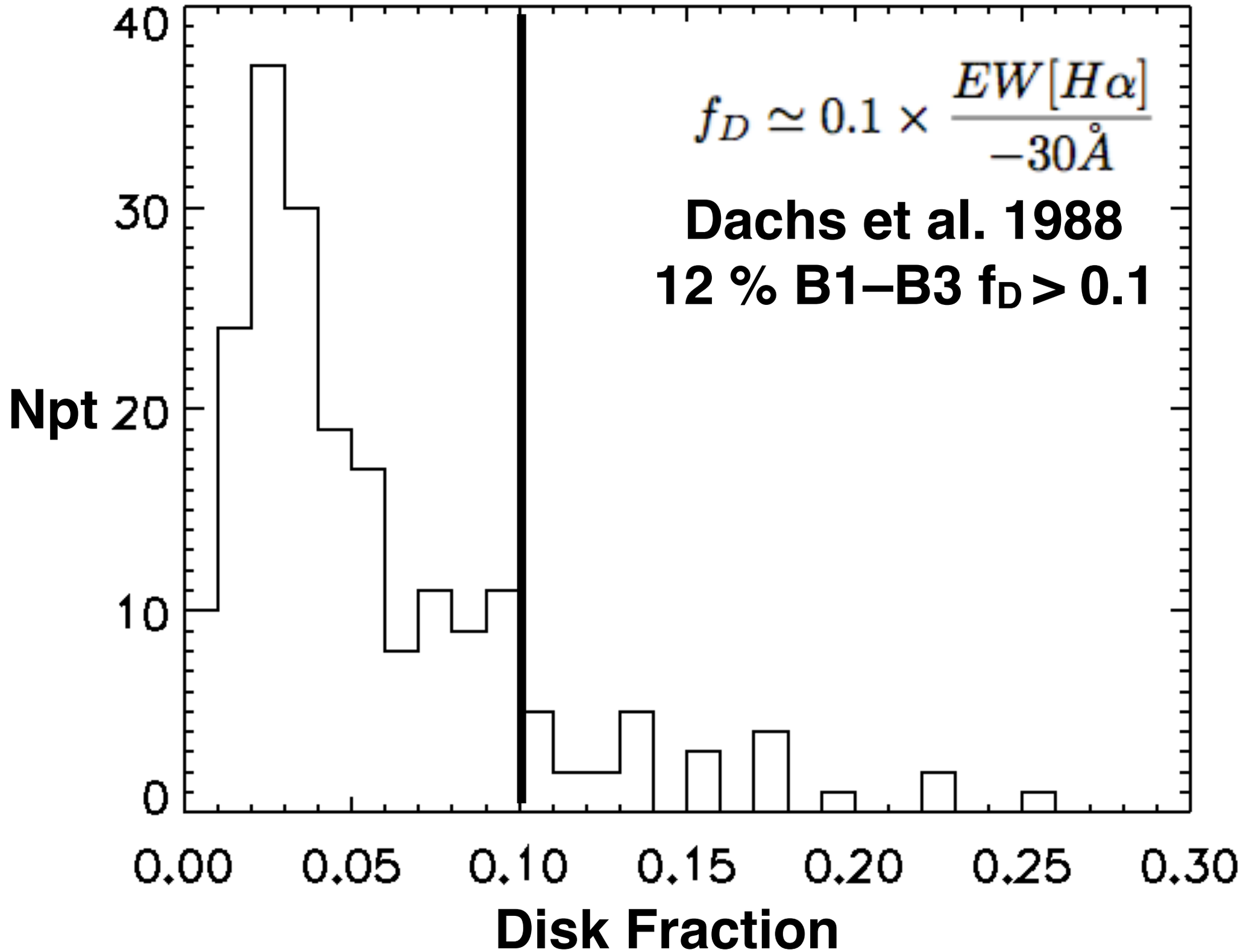
LAMOST 202 Known Be Stars



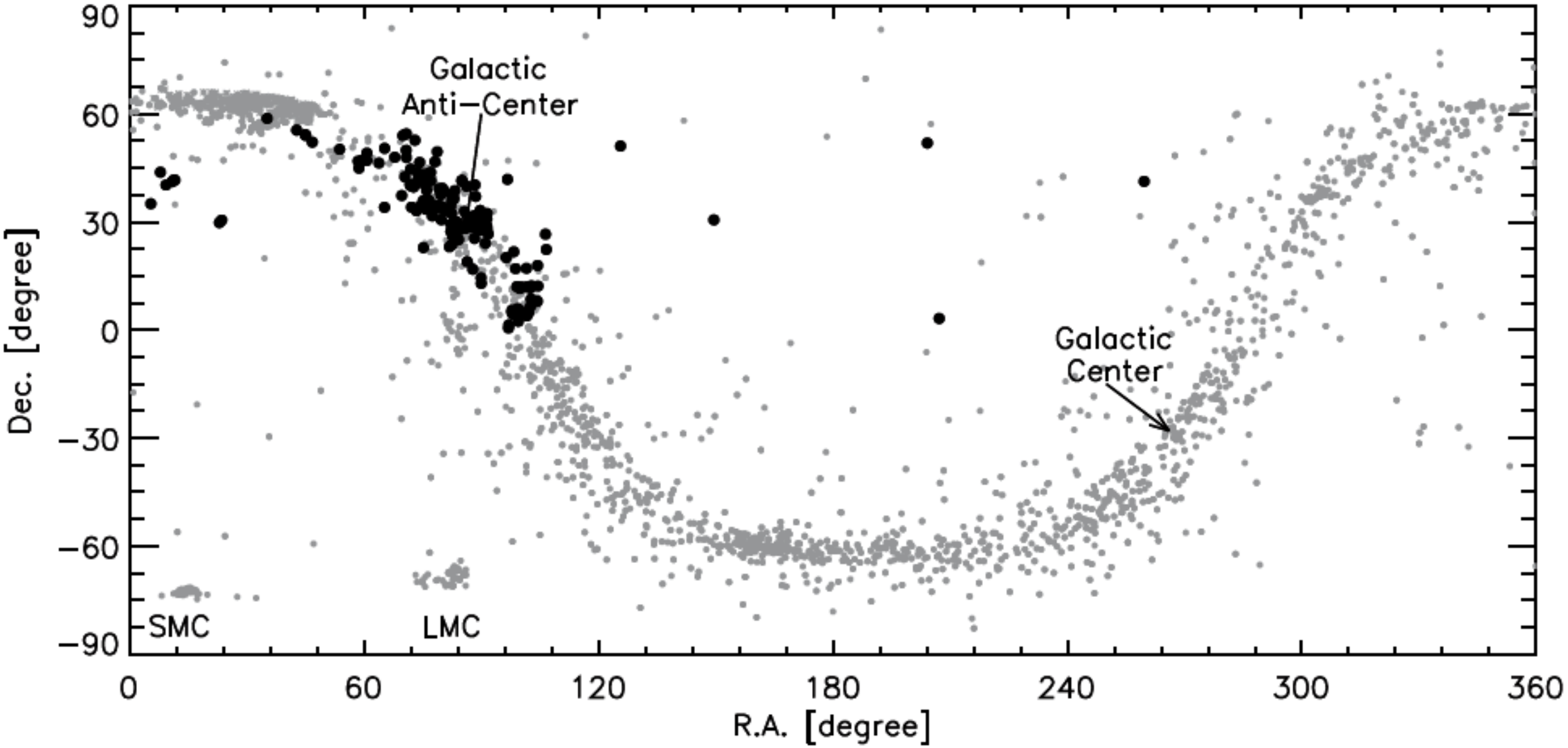
LAMOST 202 Known Be Stars



LAMOST 202 Known Be Stars



LAMOST DR1 192 Be Candidates



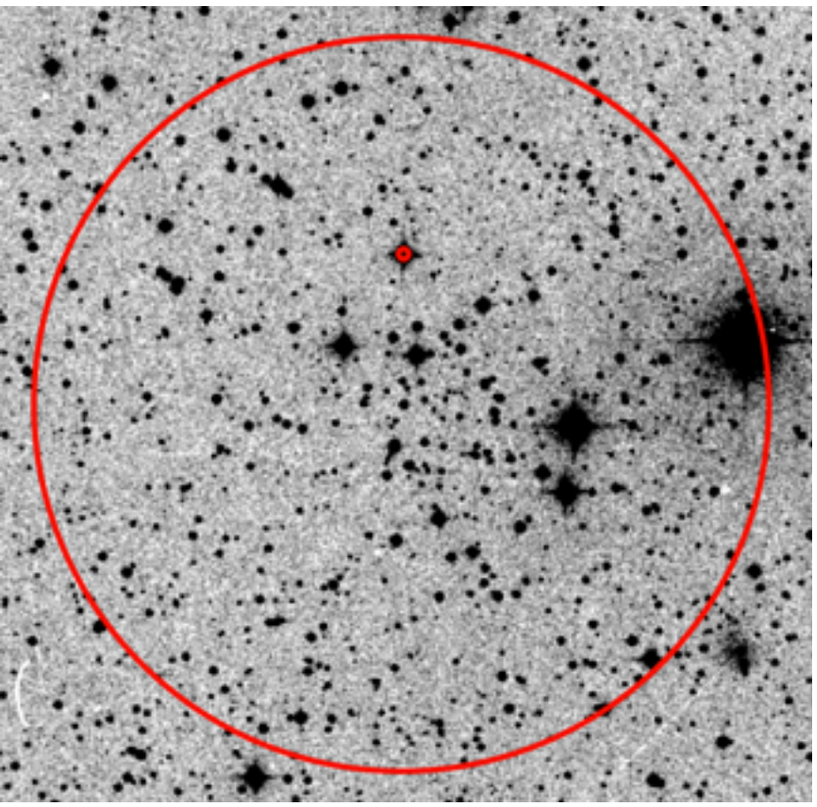
due to the observing strategy used for LAMOST

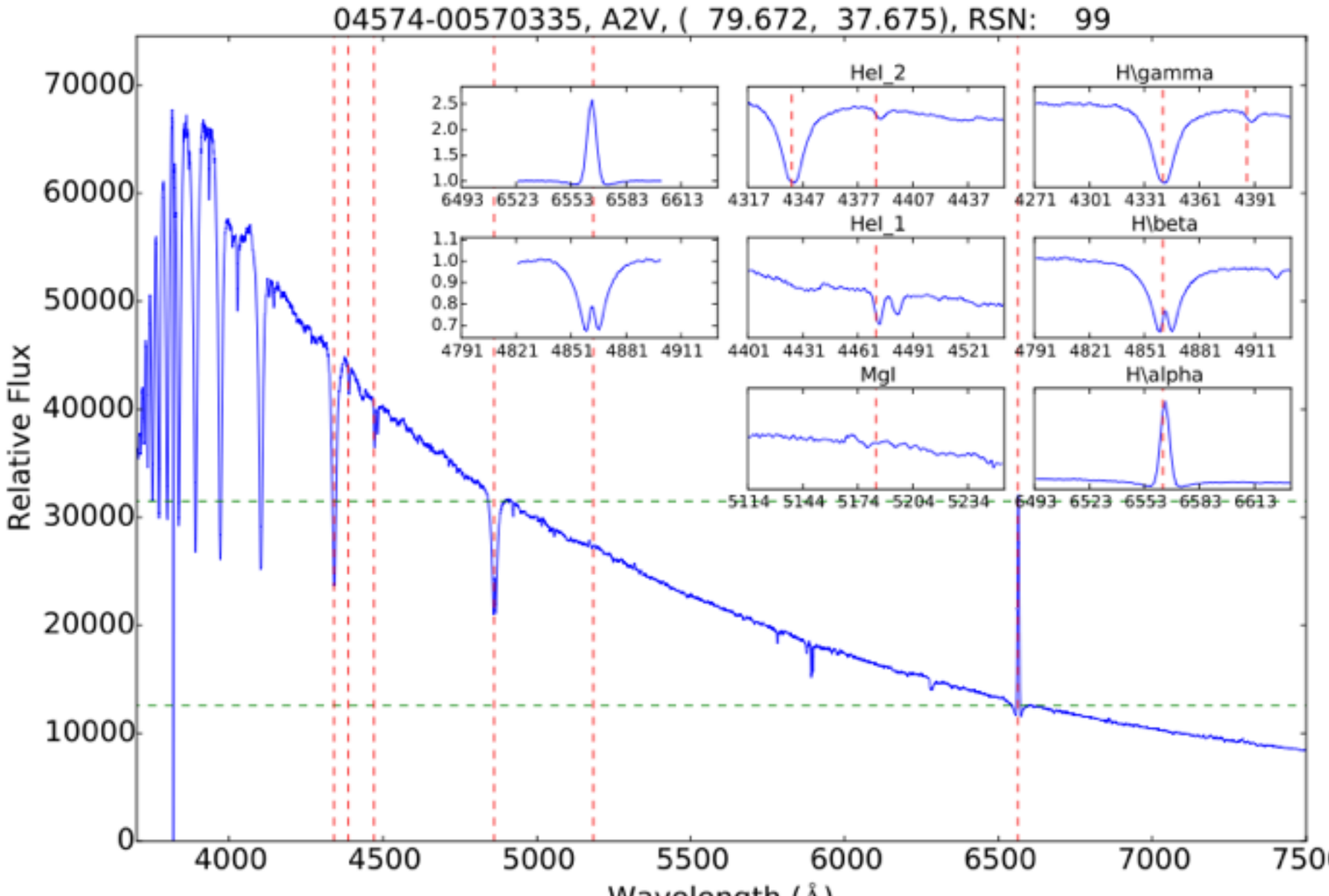
Fig.3 The spatial distribution of CBes. The small gray dots are known CBes from Zhang et al. (2005), Neiner et al. (2011) and Raddi et al. (2015). The large dots are the CBe candidates from LAMOST DR1. The Galactic Center/Anti-Center and Magellanic Clouds are marked. **(Lin+ 2015)**

Kronberger_18

- α, δ (J2000): (079.672, +37.630) deg
- μα, μδ = (-4.29, -6.70) mas/yr
- Radius: 6’, Distance: 2700 pc
- E(B-V): 0.7 mag, log(t): 15.8 Myr

RAJ2000 deg	DEJ2000 deg	pmRA mas/yr	pmDE mas/yr	Jmag mag	Kmag mag
079.672049	+37.675018	-3.7	-4.0	10.975	10.946

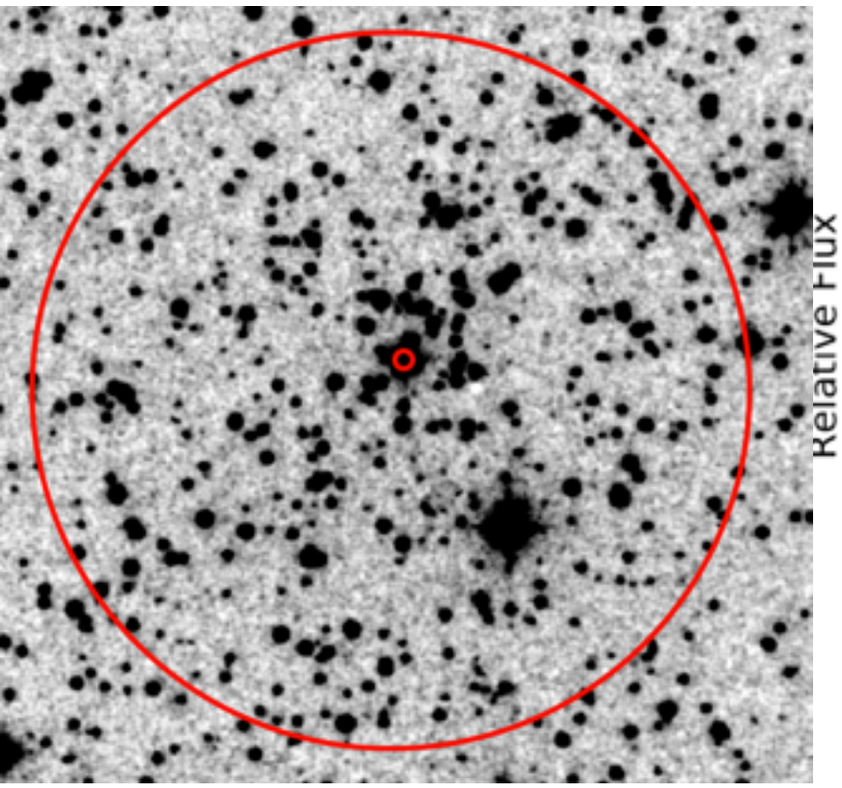


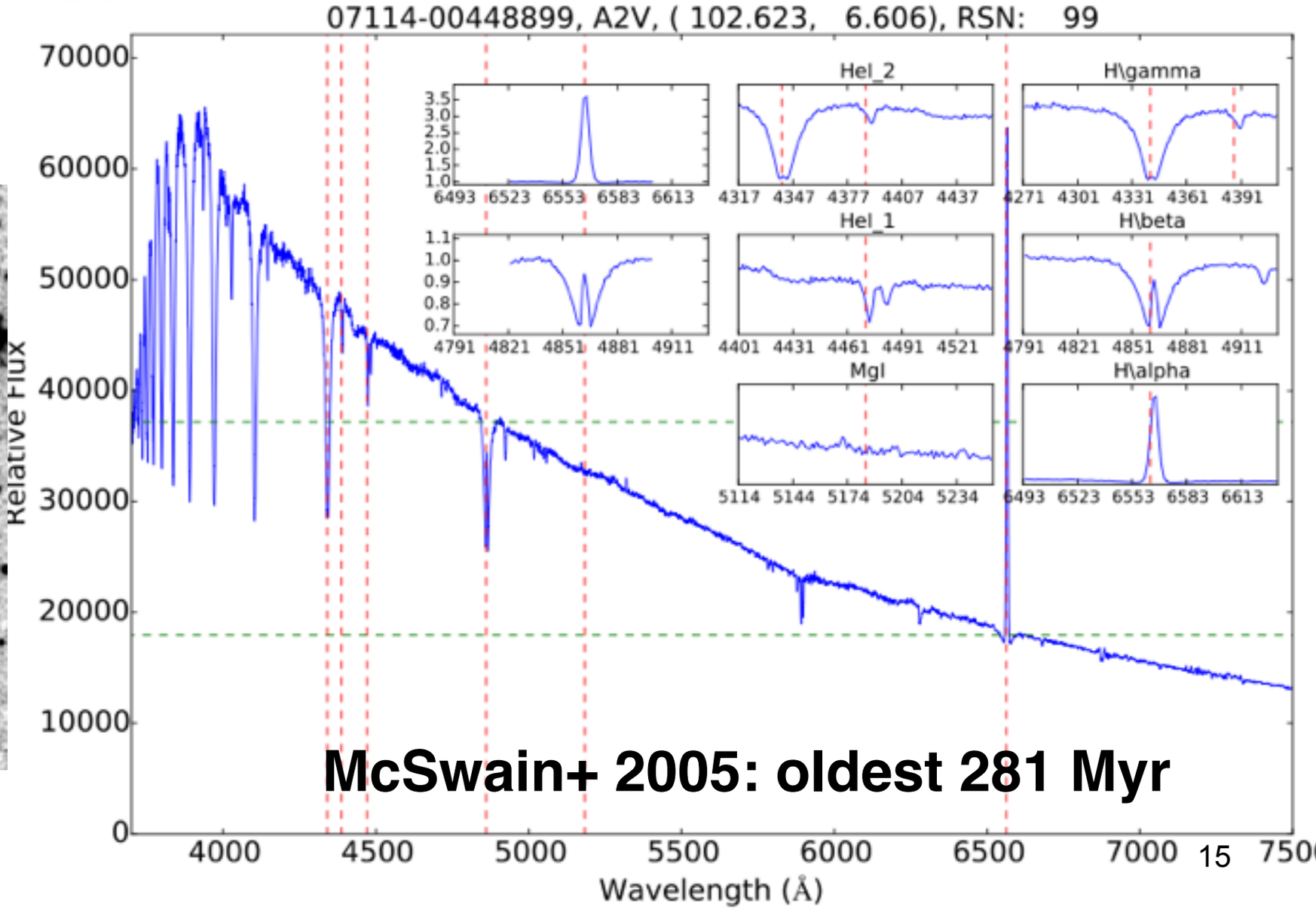


FSR_1025

- α, δ (J2000): (102.625, +06.600) deg
- μα, μδ = (-1.65, -1.70) mas/yr
- Radius: 4’, Distance: 2095 pc
- E(B-V): 0.3 mag, log(t): 398 Myr

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

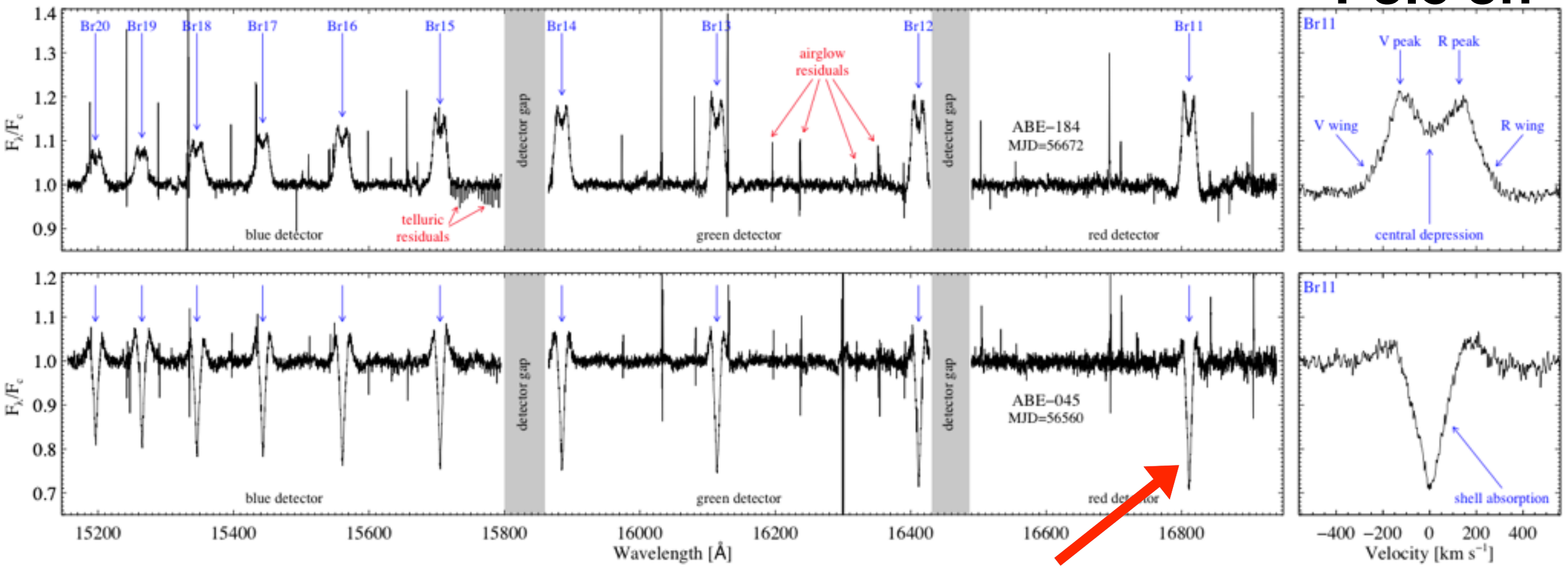




SDSS APOGEE

- R~22,500, 2.5-m telescope
- H-band : 15145-15808, 15858-16443, 16474-16955λ
- 1 hr exposure times for H~11 mag
- 24 x 1 hr for H~13.8 mag

Pole on



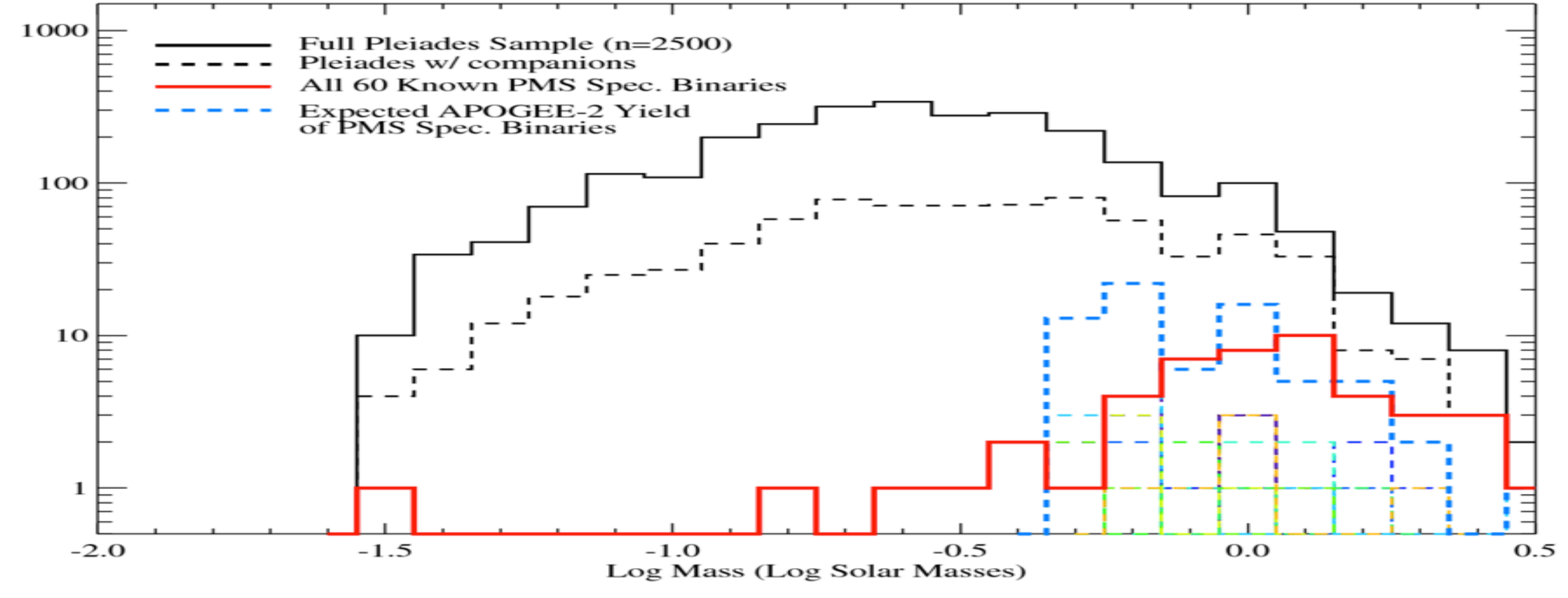
Brackett series n =4, Inner disk tracers

Edge on

Drew Chojnowski, et al. 2015

SDSS-IV APOGEEII

Name	RA (deg.)	Dec. (deg.)	l (deg.)	b (deg.)	radius (deg.)	dist. (pc)	age (Myrs)	total mass ($M_\odot$)	half-mass radius (pc)	n_{stars} w/ H<12.5 (#)	H=12.5 mass-limit ($M_\odot$)
NGC 1333	52.225	31.322	158.283	-20.533	0.15	350	1.5	79	0.49	120	0.2
Orion	83.86	-5.18	-151.15	-19.25	3[a]	480	3	1100	3.8	1500	0.35
IC 348	56.125	32.28	160.4	-17.7	0.15	320	4	160	0.47	225	0.2
NGC 2264	100.27	9.68	-156.86	2.123	0.5	913	4	2000	1.1	250	0.7
W40	277.83	-2.066	28.794	3.525	0.5	495	2	300?	0.5	158	0.35
Lupus III	240.8	-42.1	-23.3	7.833	0.5	120	2	50	1	80	0.2
Cha I	166.5	-77.5	-62.8	-15.818	0.75	140	3	100	2	200	0.2
Upper Sco	241.75	-22.5	351	20	6	145	10	2000	28	600	0.2
NGC 2547	122.52	-49.26	264.5	-8.6	0.3	361	35	370	1.2	250	0.5
Alpha Per	122.5	49.1	170.0	32.7	2	170	85	200	9	450	0.5
Blanco 1[a]	1.25	-30.04	14.25	-79.40	1	207	132	200	3	105	XX



Summary and Discussion

- **We have searched for Be stars in 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.**
- **The LAMOST DR1, DR2, and DR3 contain ~7.8 M spectrums (> 90% are stars and with stellar parameters). A total of 192 objects were identified as Be candidates and mostly distributed near Galactic Anti-Center due to the survey strategy. Only 2 Be stars are in star clusters with age 15 Myr and 398 Myr, respectively.**
- **Star clusters and Be stars studies with SDSS-IV APOGEEII.**