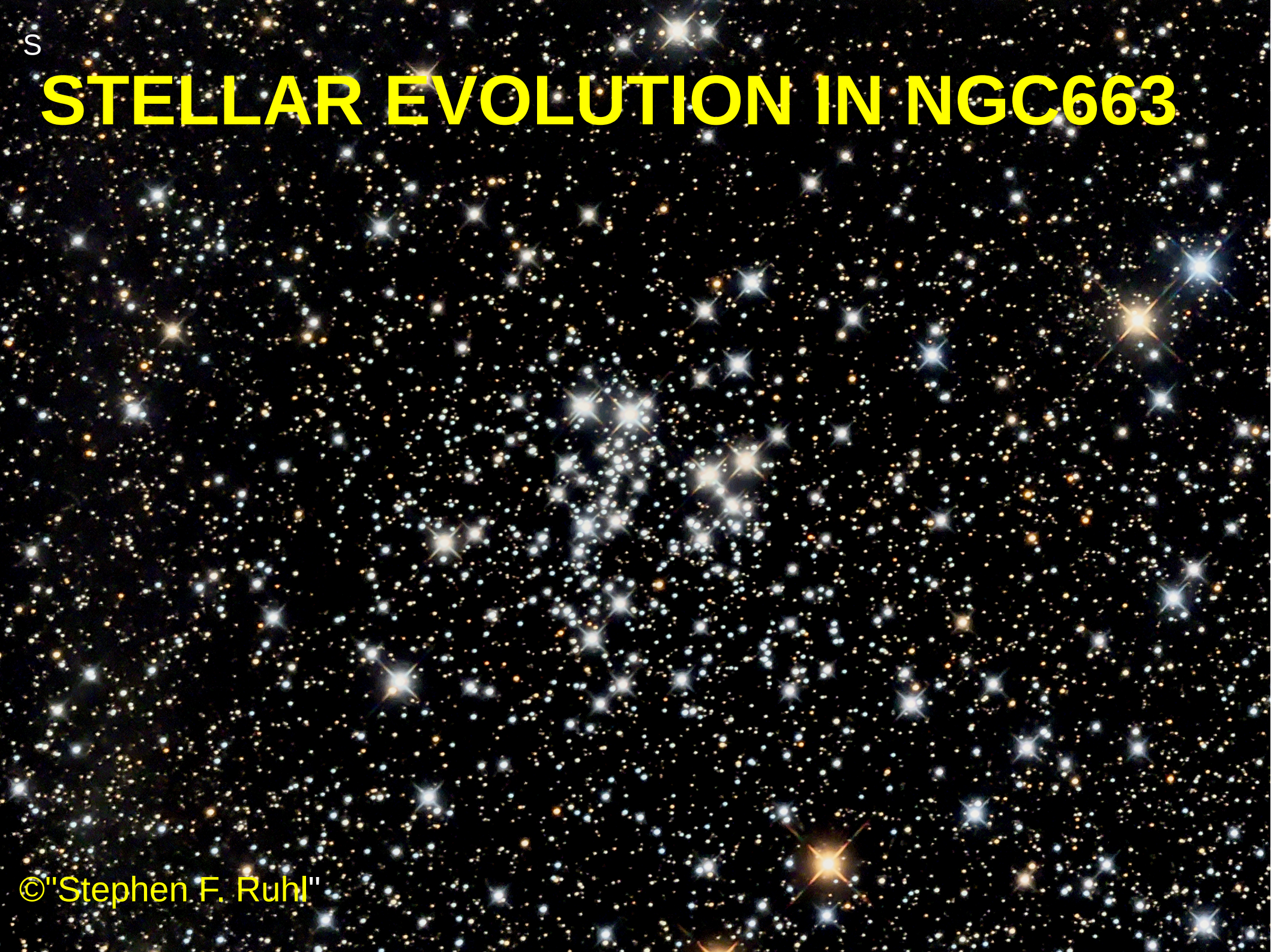
S

STELLAR EVOLUTION IN NGC663



- Amparo Marco (Universidad de Alicante)
- Ignacio Negueruela (Universidad de Alicante)
- Norberto Castro (University of Michigan)
- Sergio Simón-Díaz (IAC)
- Christian Motch (Observatoire de Strasbourg)

Universitat d'Alacant
Universidad de Alicante

LSA ASTRONOMY
UNIVERSITY OF MICHIGAN

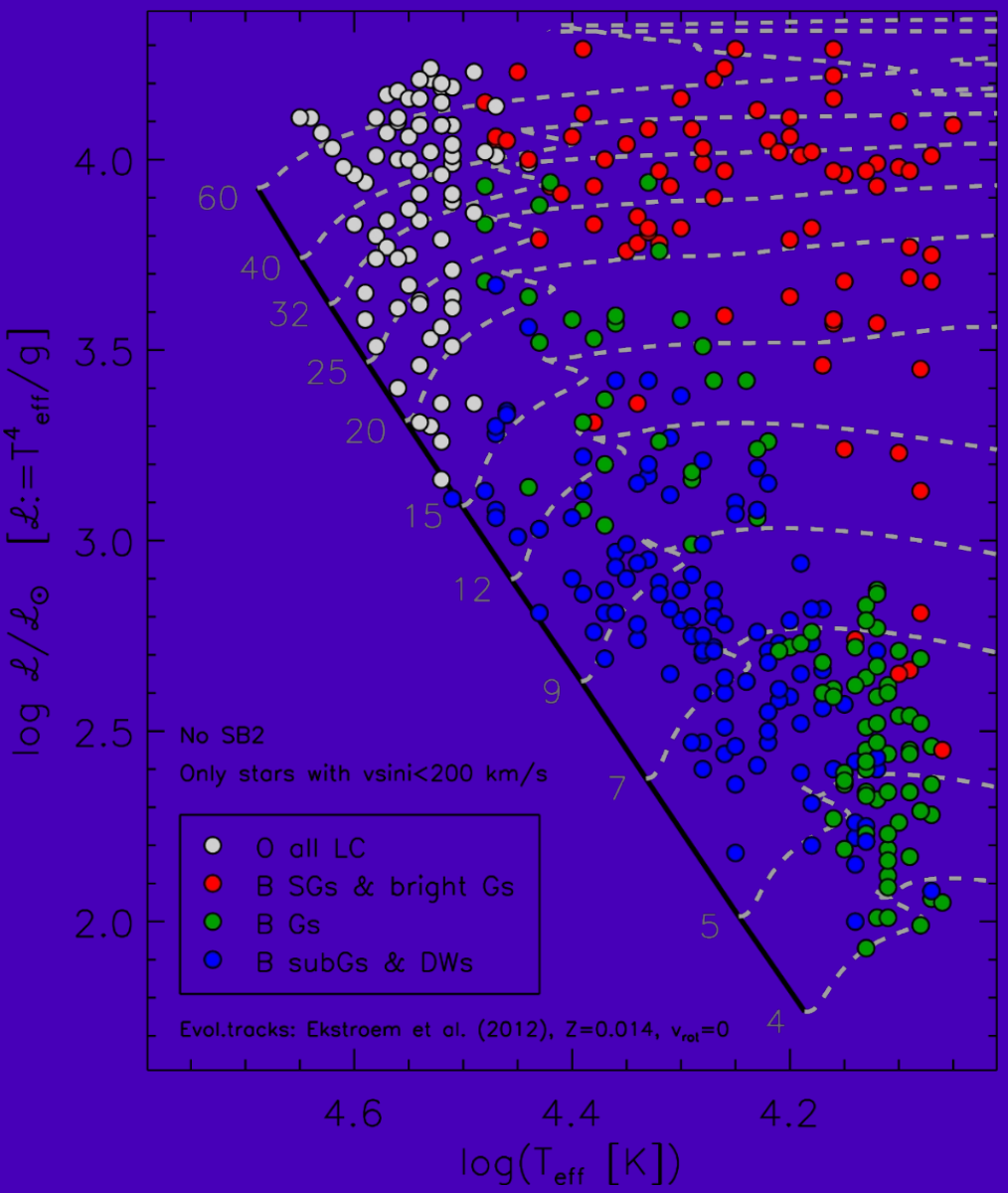
INSTITUTO DE ASTROFISICA DE CANARIAS
IAC

Observatoire astronomique
de Strasbourg

Introduction

- Evolution of massive stars is complex
- The interpretation of HR diagrams is complicated

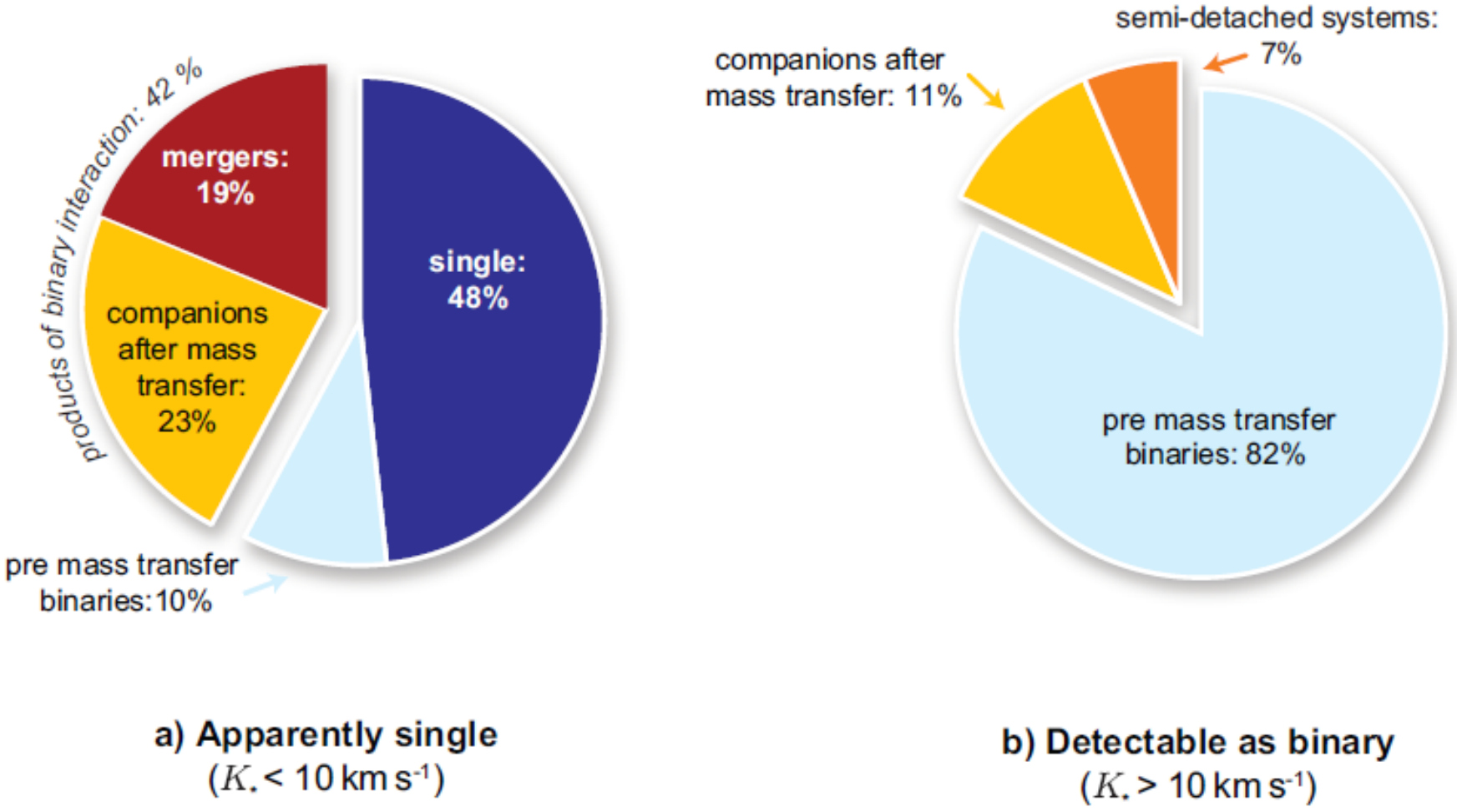
The IACOB spectroscopic database (Simón-Díaz et al. 2015)



	Stars	Spectra
O stars	182	2312
B stars	461	3420
B (I & II)	96	2408
B (III)	164	378
B (IV and V)	201	634

- Where is the end of the main sequence?
- Why are there so many stars in the Hertzsprung gap?
- What is the role of rotation?
- Which mixing processes are at work?
- What is the origin of Be stars?
- How are Wolf Rayet stars produced?
- Do (some) stars loop back to the blue after being red supergiants?

What is the role of binarity?



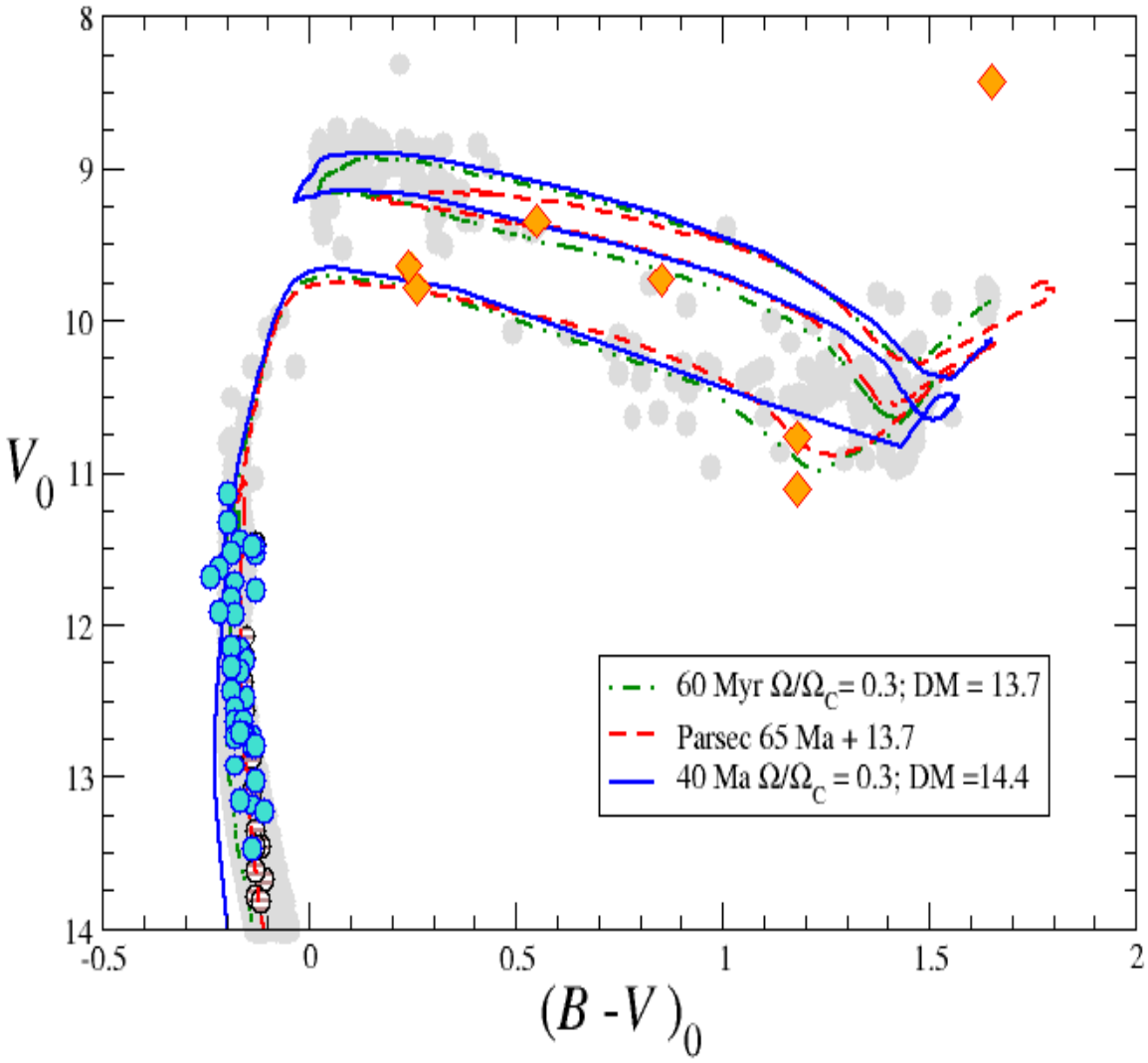
De Mink et al. (2014, ApJ 782, 7)

LARGE DATABASE OF STARS

OR

CLUSTERS

Berkeley 51



D≈5.5 kpc ; Age ~ 60 Ma

4 YSGs and 5 RSGs

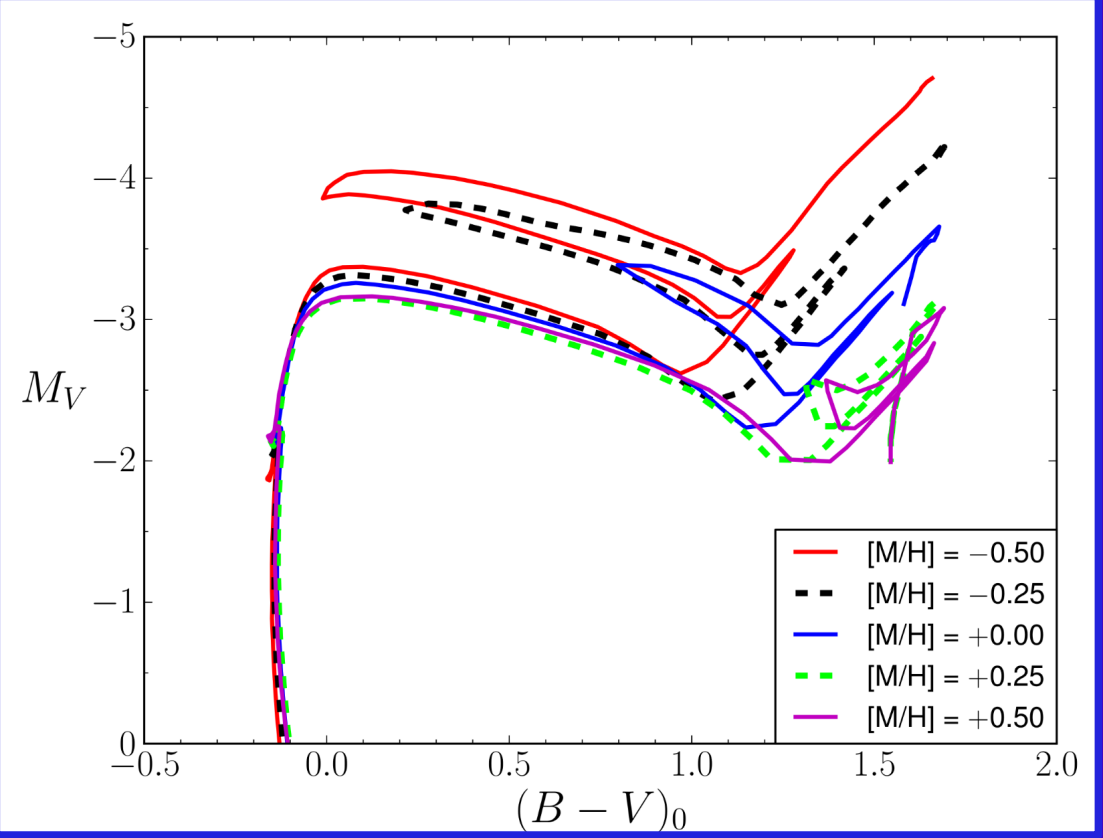
5000 M⊙

20000 intermediate mass

Stars spend the first part of the He-burning phase as rather cool SGs (with spectral types K4 – M0) and the second half as blue (A or F) SGs

>~30% of the He-burning stars should appear as post-RSG A-type SGs

Negueruela et al. 2018, MNRAS, 477, 2976



Thesis Javier Alonso-Santiago 2018

Isochrones: Age=100 Ma

GENEVA: Y⊙=0.266 Z⊙=0.014

Rotation Rate w=Ω/Ω$_{crit}$

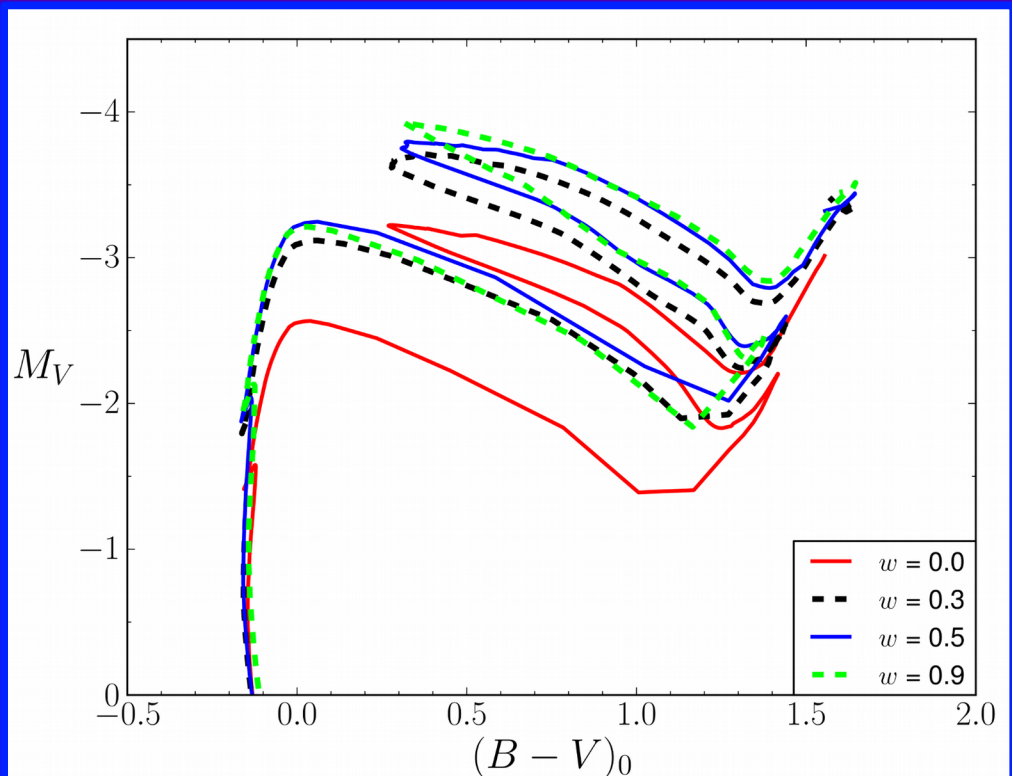
Ekström et al. 2012
Georgy et al. 2013

Isochrones: Age=100 Ma

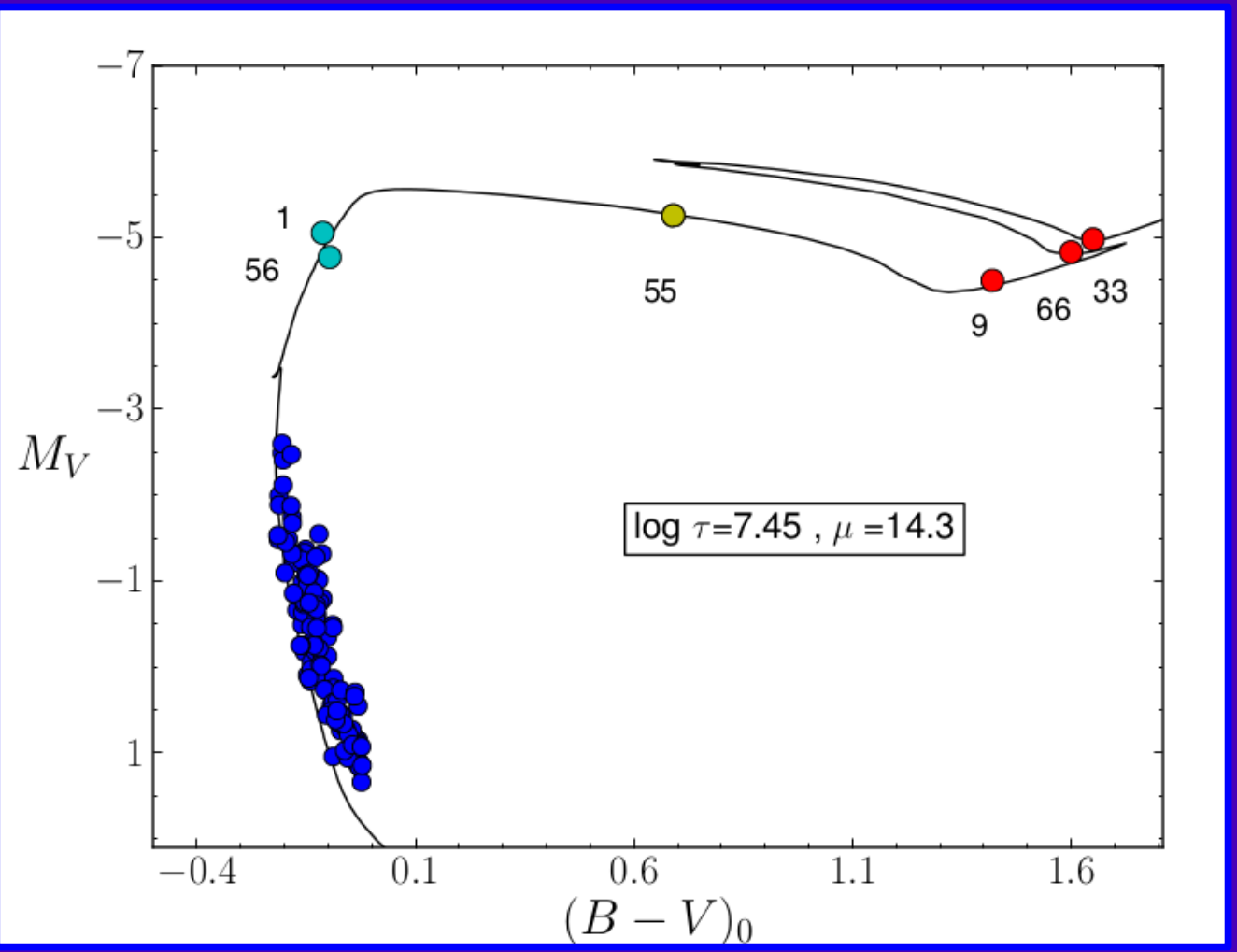
PARSEC: Y⊙=0.276 Z⊙=0.0152

Metallicity [M/H]=log Z/Z⊙

Marigo et al. 2008
Bressan et al.2012



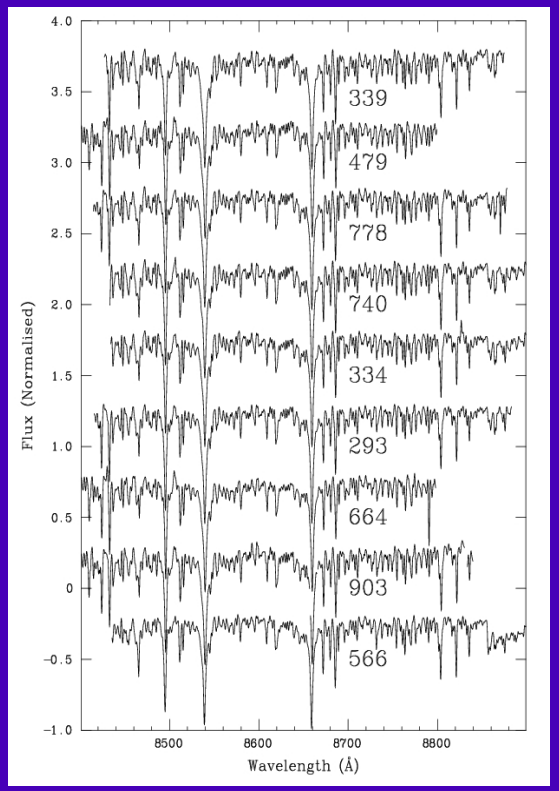
NGC 3105



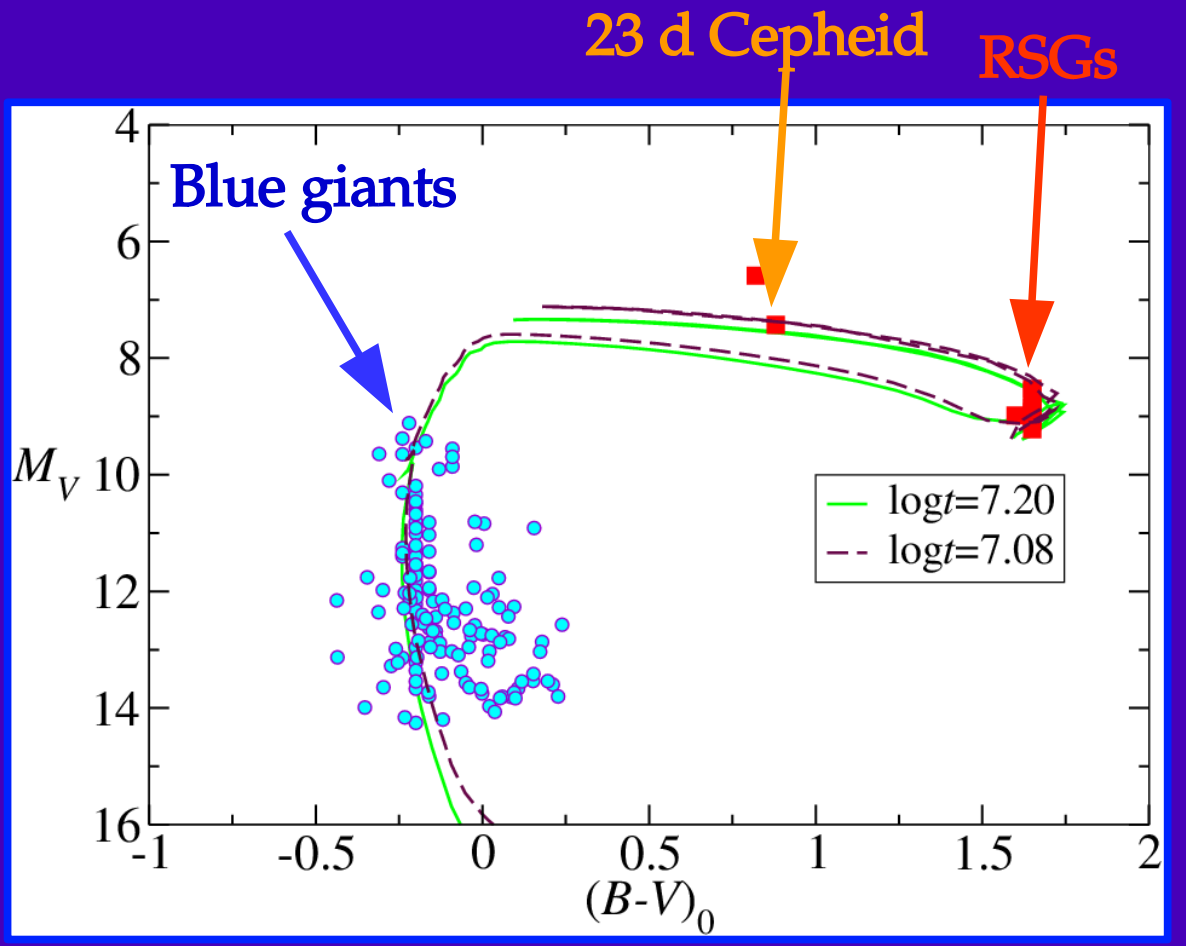
CLUSTER PARAMETERS

E(B-V)	1.03±0.03
d (kpc)	7.2±0.2
Age (Ma)	28±6
[Fe/H]	-0.29±0.22
V_{rad} (km/s)	46.7±0.8
R (arcmin)	2.6±0.6
Mcluster (Msun)	4140±350
M_RSG (Msun)	9.5±0.3

ZAMS: a PARSEC isochrone of 10 Ma computed at the cluster metallicity



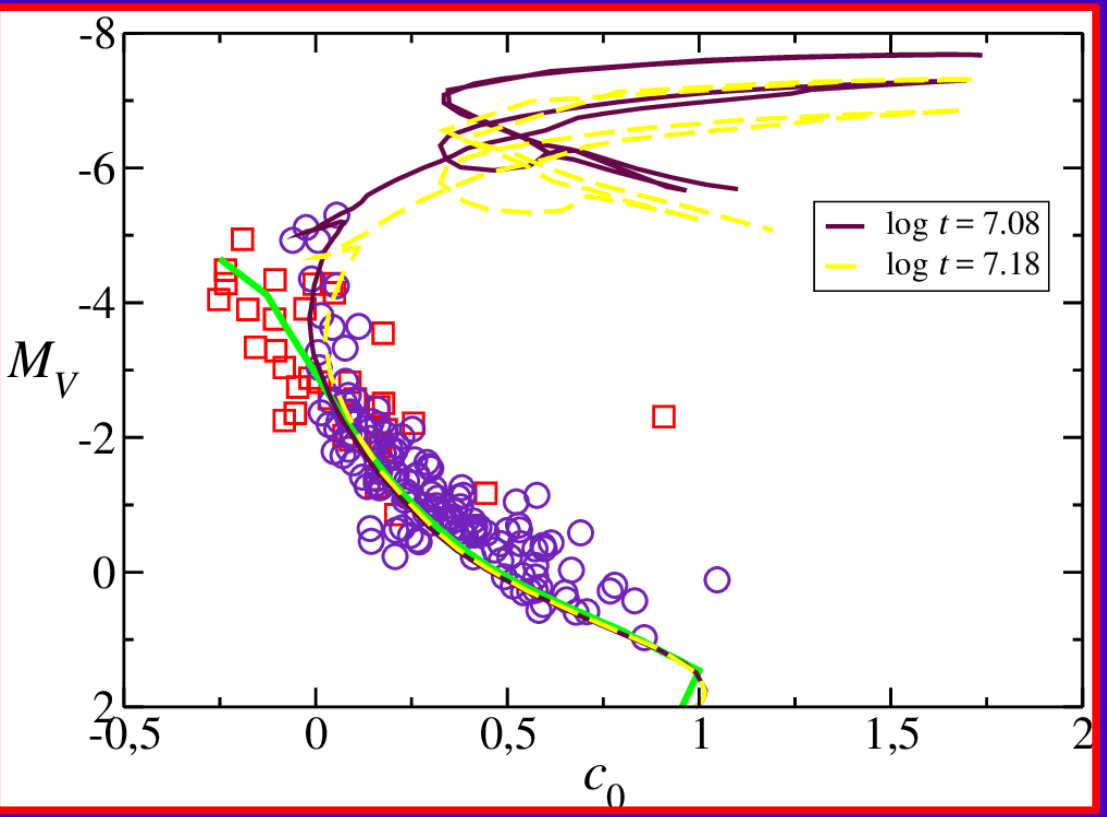
VdBH 222



ℓ = 349°

- Age ~18 Ma
- Distance 6 kpc
- Mass ~2x10^4 $M_\odot$
- $A_V \approx 7.5$
- v_{LSR}= -100±3 km/s

Marco et al. 2014; A&A 567, A73

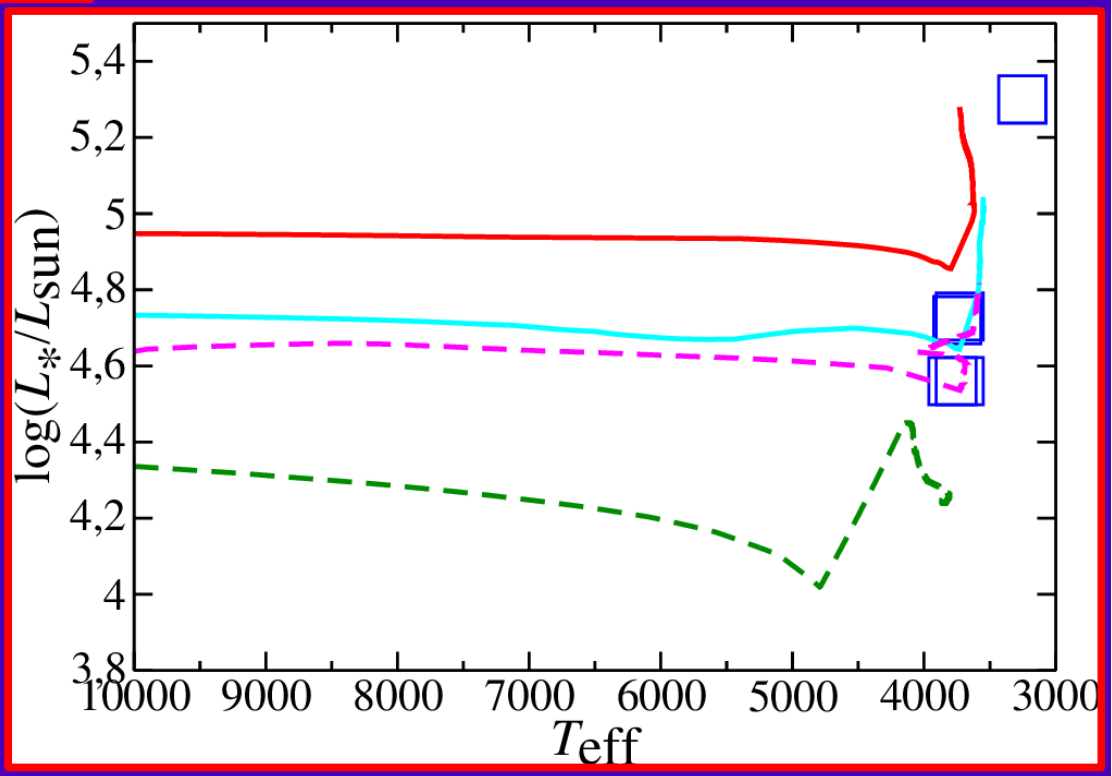


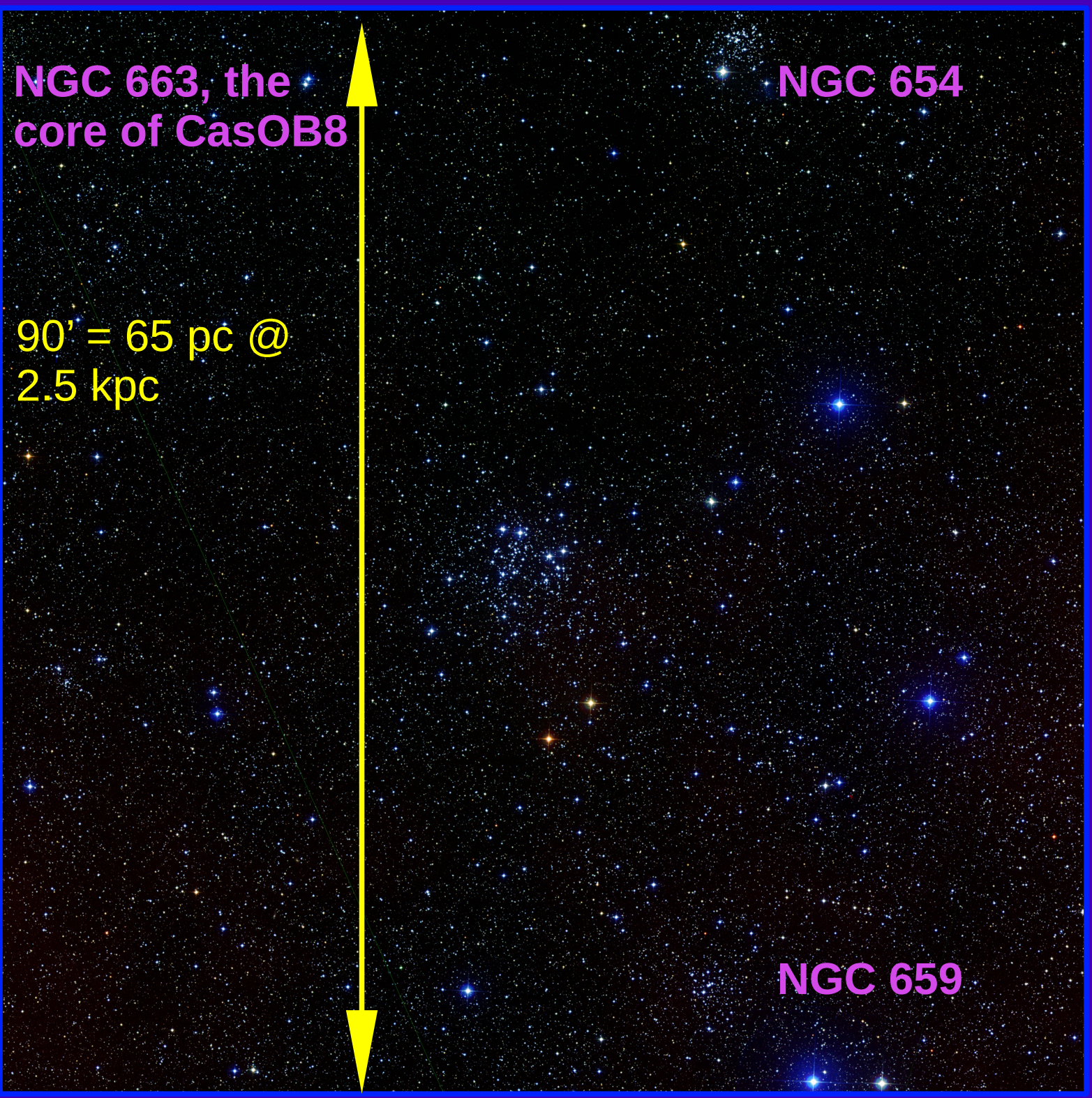
NGC 7419

1) Be stars and 5 RSGs
2) 4 ± 0.4 kpc and 14 ± 2 Ma
3) 7000-10000 M⊙
4) Testbed for theoretical predictions
5) Template to compare more obscured clusters

BSGs outnumber RSGs by a factor ~3 (Eggenberger et al. 2002) in Galactic open clusters.

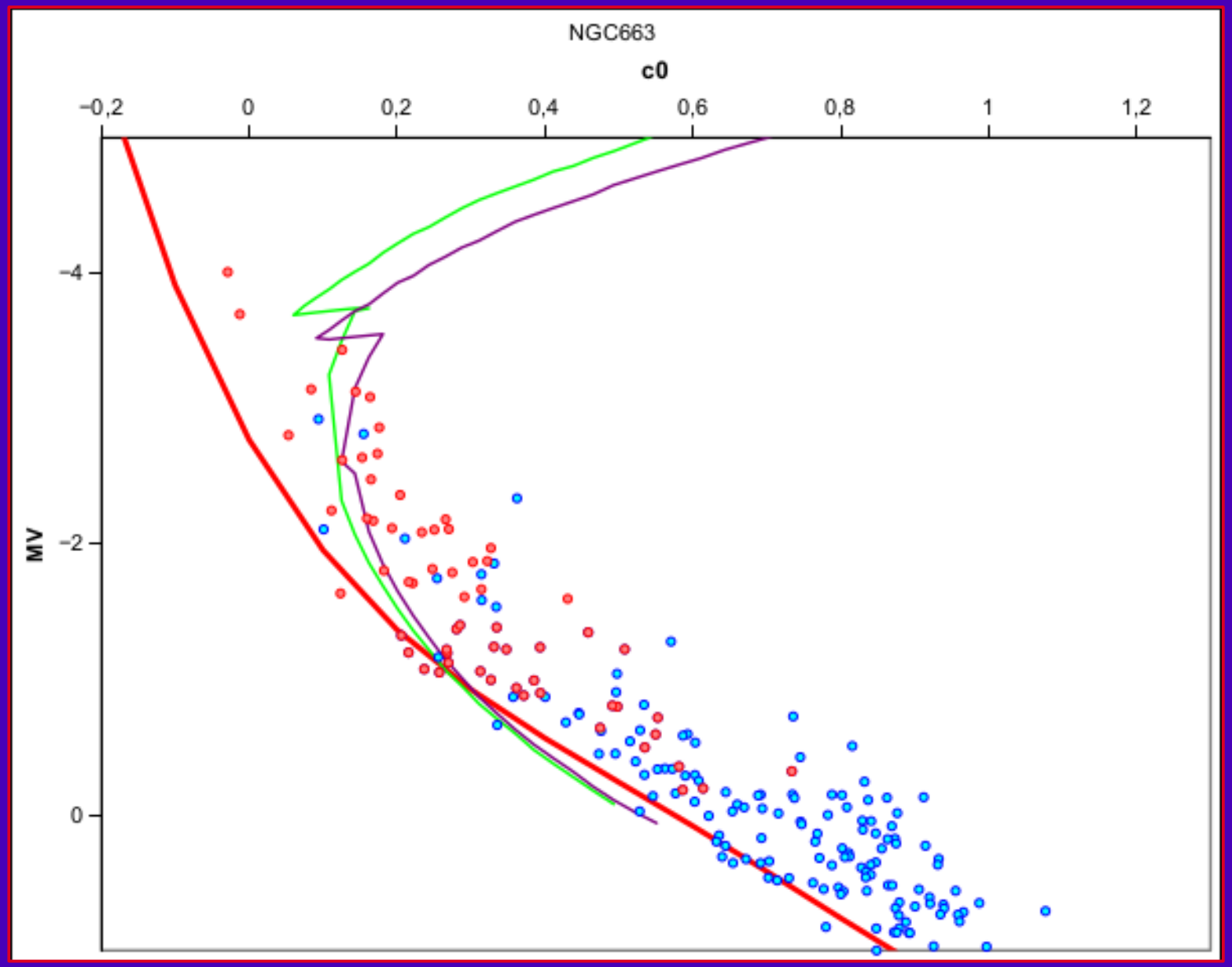
Marco & Negueruela, 2013, A&A 552, A92





- Perseus Arm
- Most massive at 20 Ma in the MW
- BSGs and Be stars

STRÖMGREN PHOTOMETRY



236 members

65 members with spectra

DM=12.2±0.2

$D=2.80\pm^{0.27}_{0.24}$

Log t=7.3-7.4

Age=(20-25)Ma

Turn-off at B2

Spectroscopy

- 151 stars at classification resolution (R=1000-2000; 4000):

  1 O9.5V(binary?)

  1 B0III

  1 B0.5IVe

  2 B1III

  10 B2V; 5 B2Ve; 4 B2IV; 3 B2IVe; 3B2IIIe

  12 B2.5V; 6 B2.5Ve; 9 B2.5IV; 1 B2.5IVe; 3 B2.5III; 1 B2.5IIIe; 1 B2.5IIIe

  13 B3V; 4 B3Ve; 3 B3III; 1 B3IIIe

  9 B4V; 2 B4Ve; 2 B4Ib

  9 B5V; 2 B6V; 1 B6Ve; 5 B7V; 6 B8V; 2 B8Ve; 1 B8Ib

  1 B9V; 1 B9.5Ib; 1 A0V; 1 A0Ib

Spectroscopy

- 9 stars at high resolution:

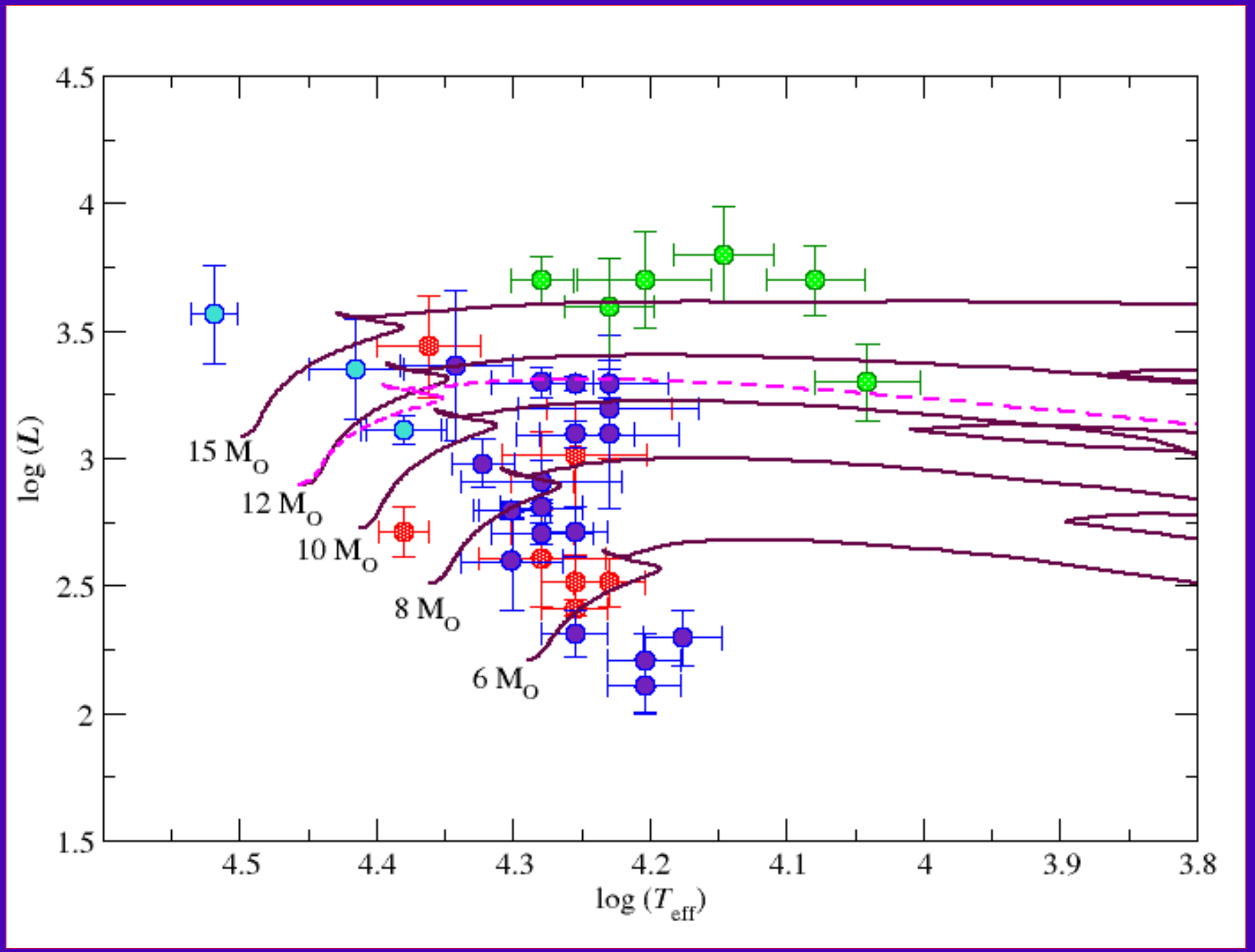
  2 B4Ib

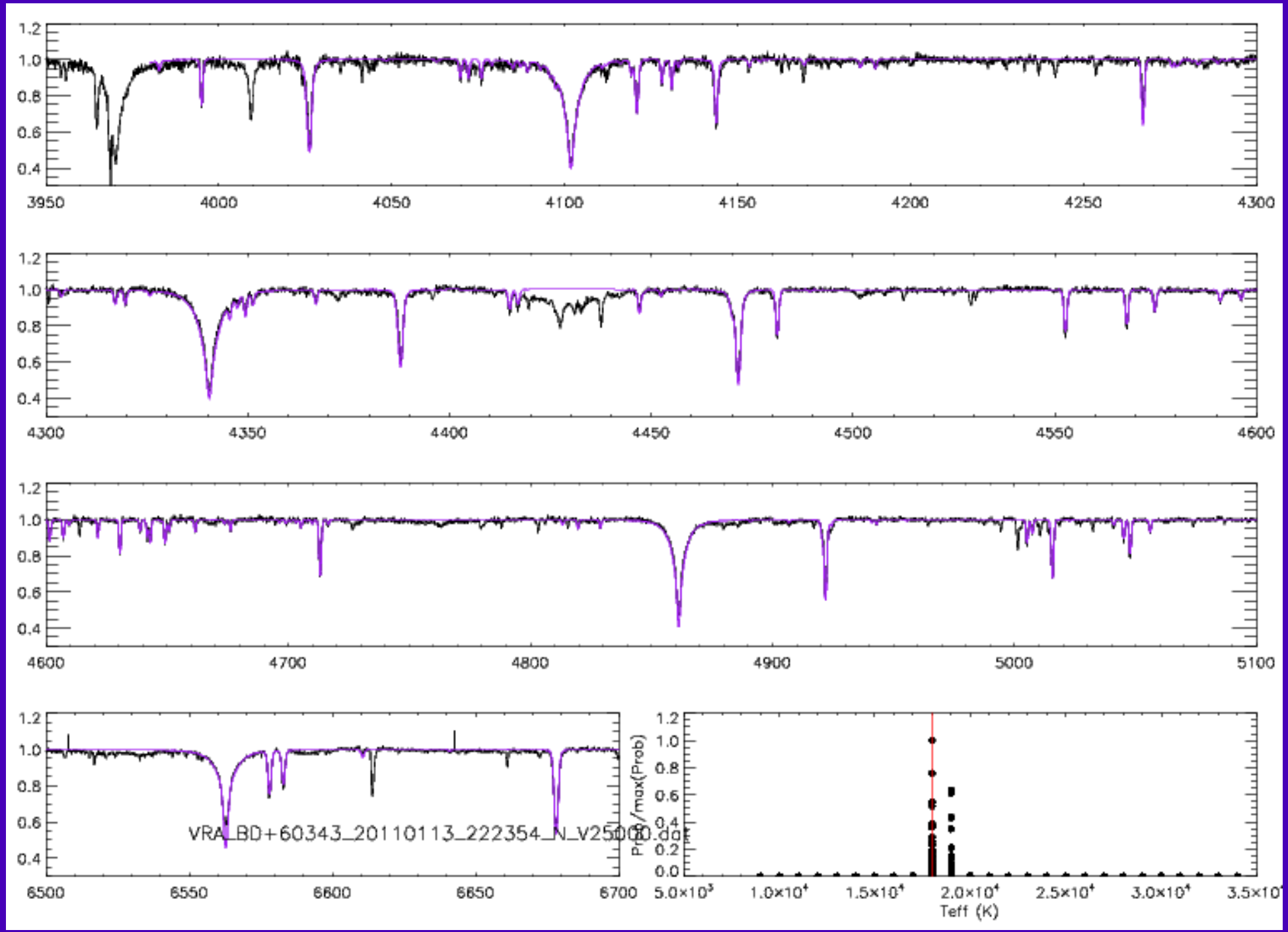
  1 B8Ib

  1 B9.5Ib

  1 B3II

  1 B2.5Ib-II

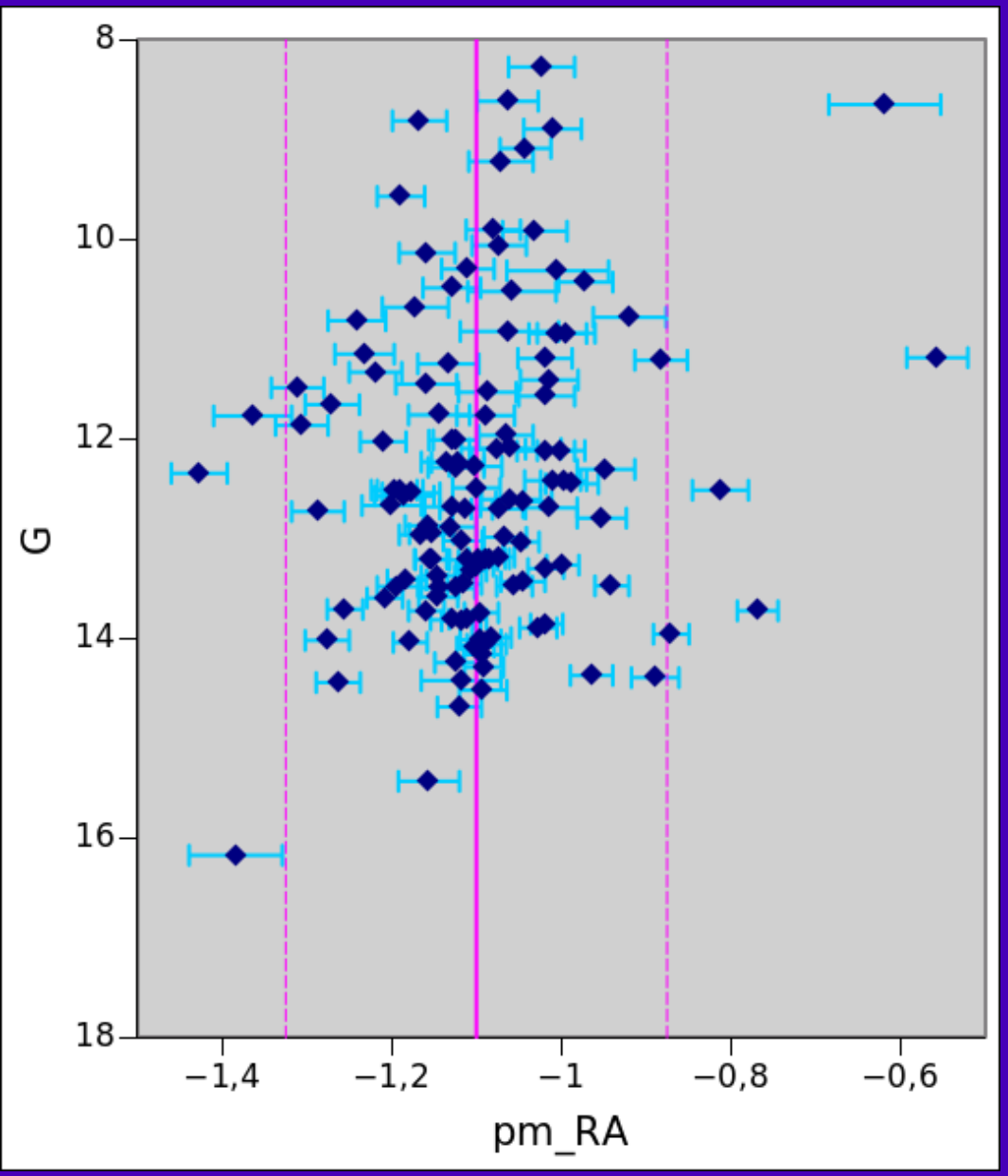

4.5
4
3.5
3
2.5
2
1.5
log (L)
15 M_O
12 M_O
10 M_O
8 M_O
6 M_O
4.5
4.4
4.3
4.2
4.1
4
3.9
3.8
log (T_eff)



Spectra from FIES at R=25000; B2.5Ib-II

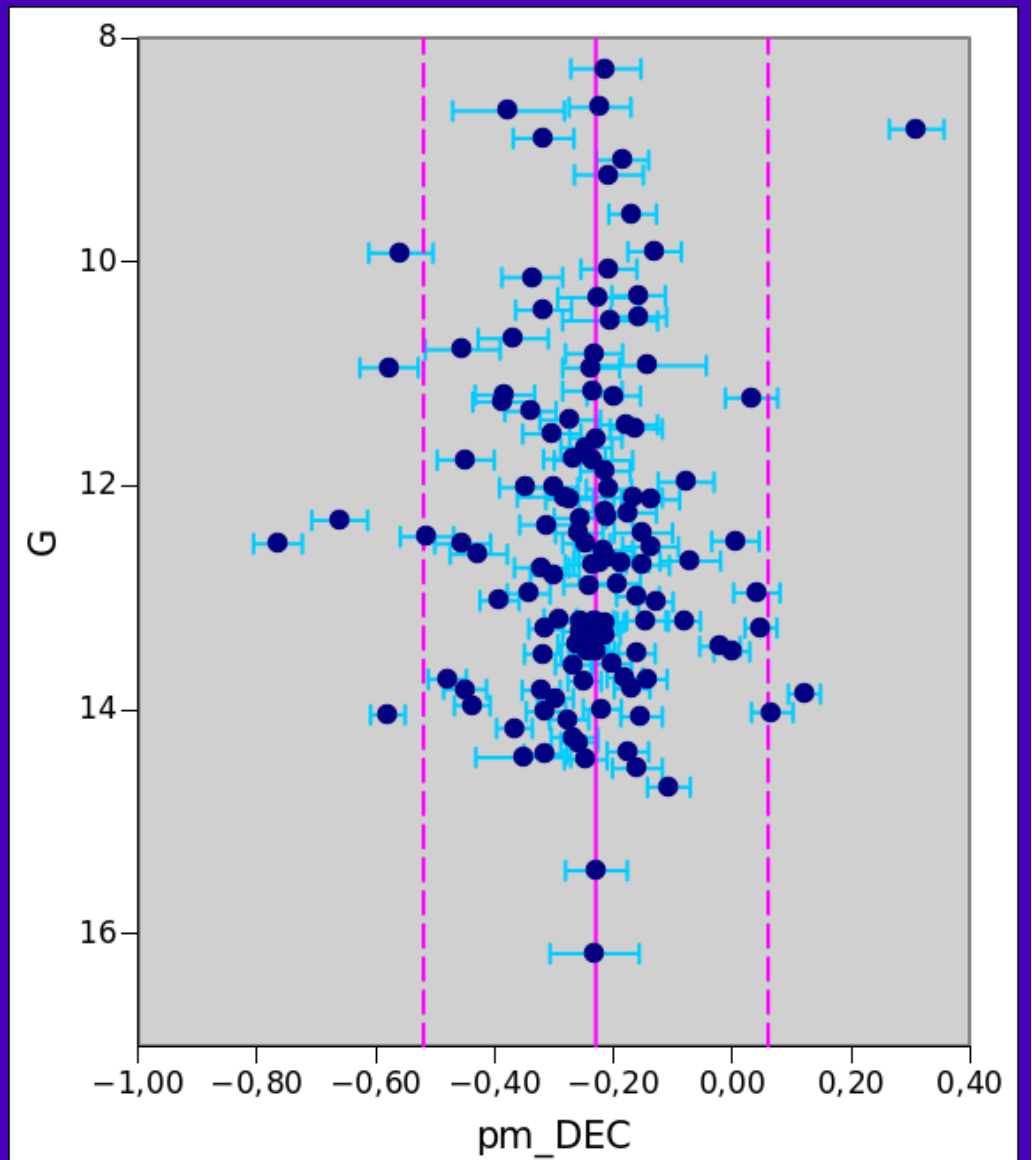
Analysis with Gaia data

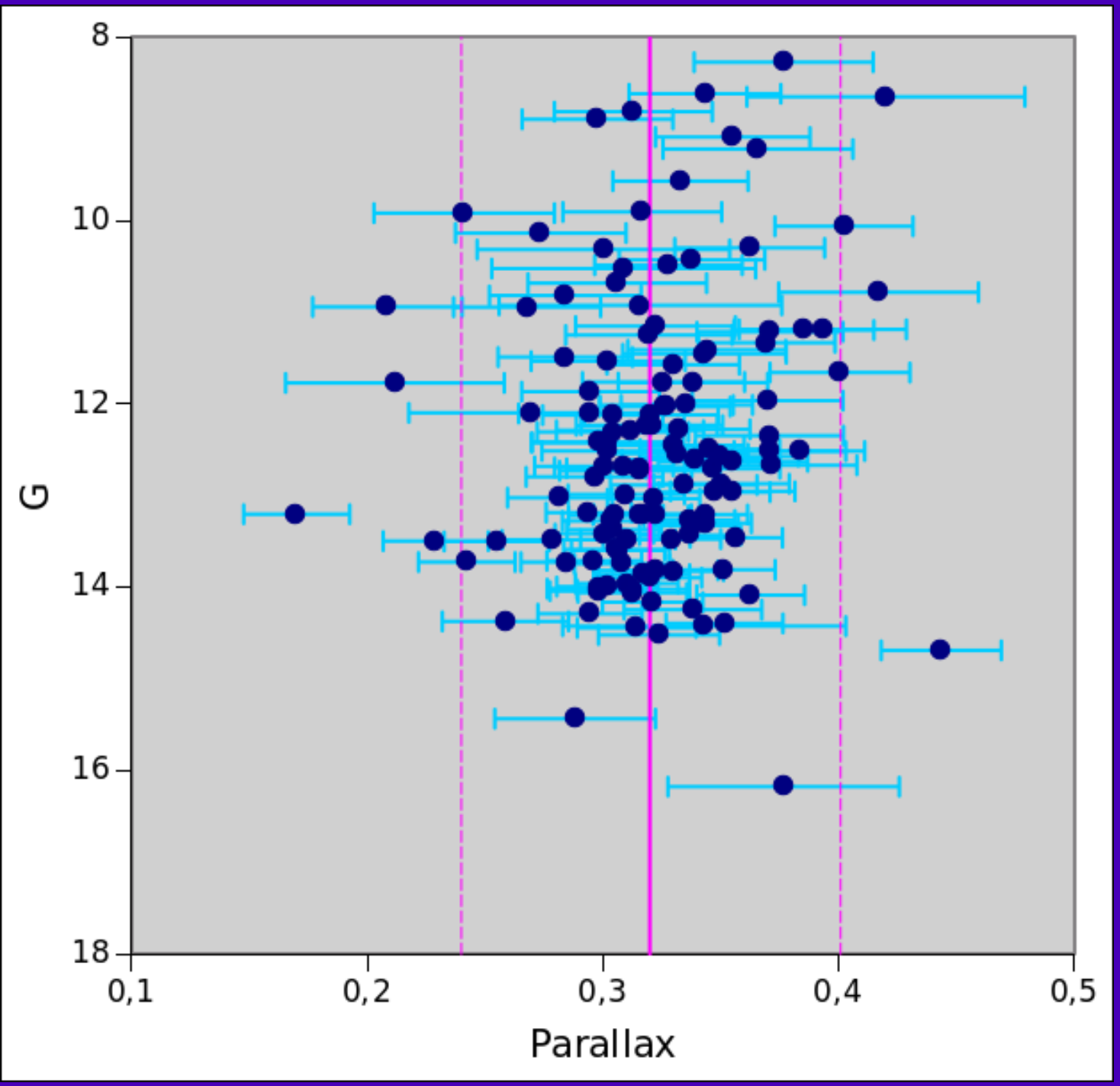
- 149 stars with spectral types (B-type stars)
- G_Plx = 0.32±0.04 ;
- G_pmRA = -1.10±0.11;G_pmDE = -0.23±0.14
- 119 members
- 14 non-members (late type stars)
- 9 with only one bad measurement ?
- 7 with 2 bad measurements ?



pm_RA= -1.10±0.11

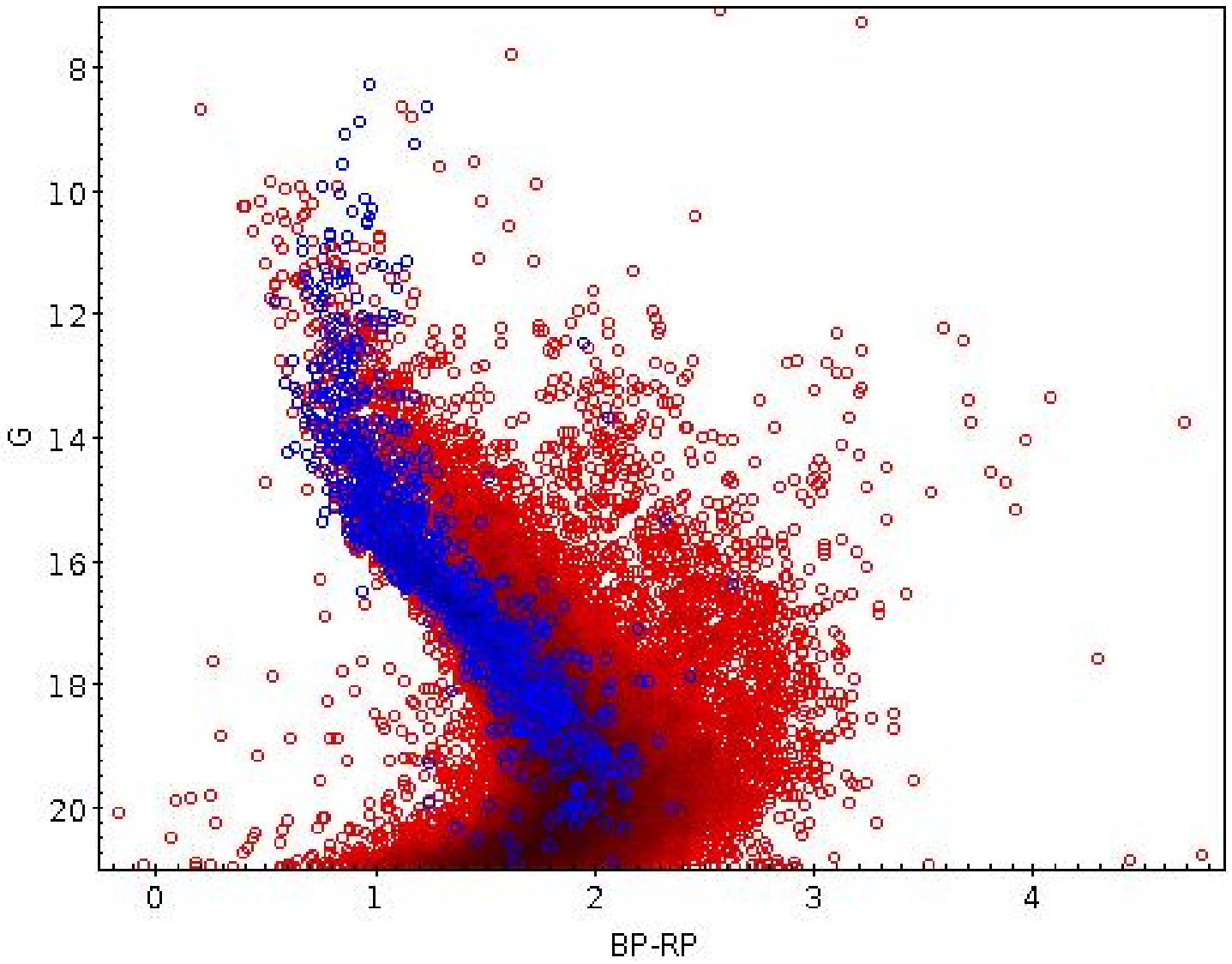
pm_DE=-0.23±0.14





Parallax=0.32±0.04

GAIA PHOTOMETRY



25 arcminute:

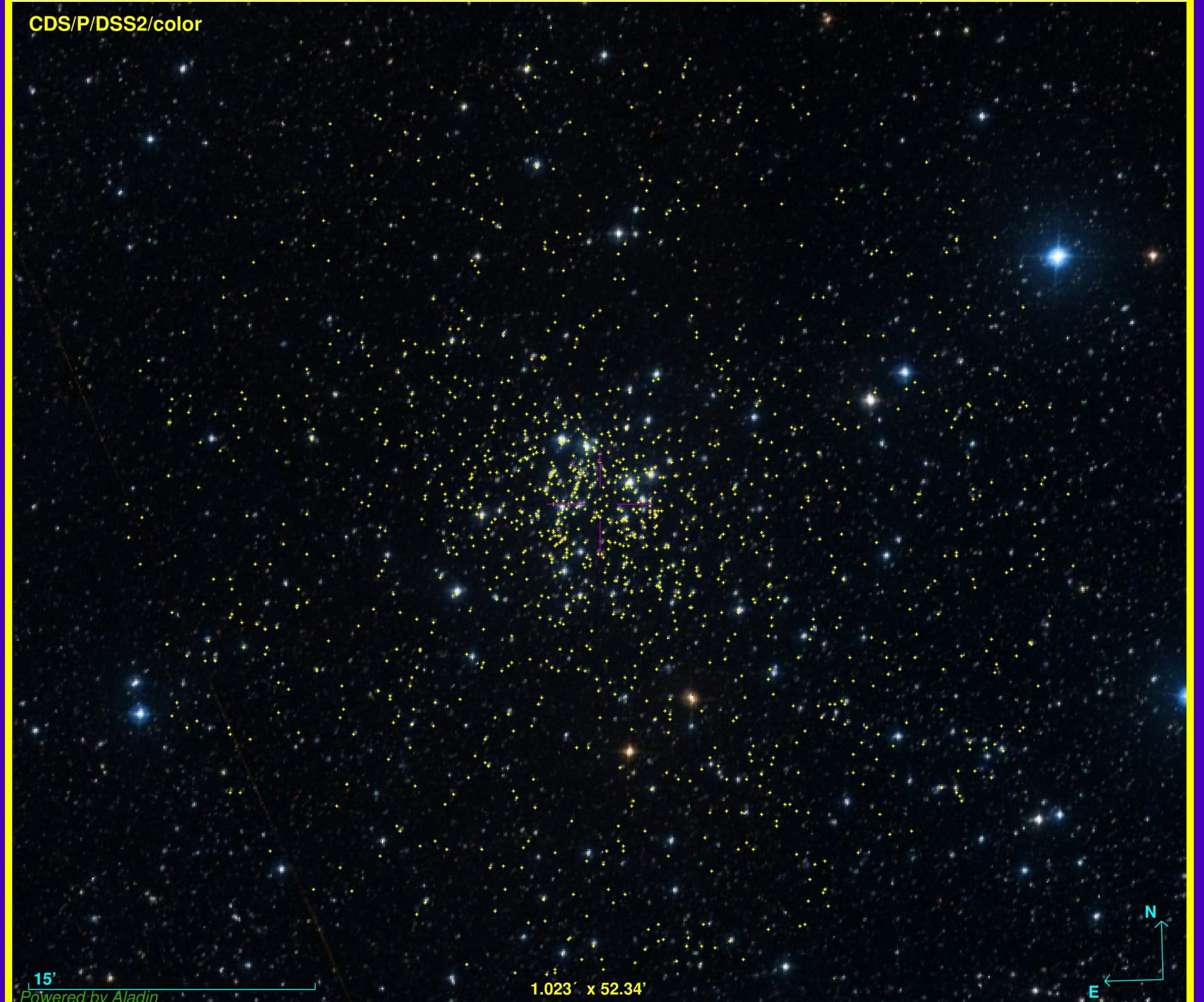
36785 stars in red

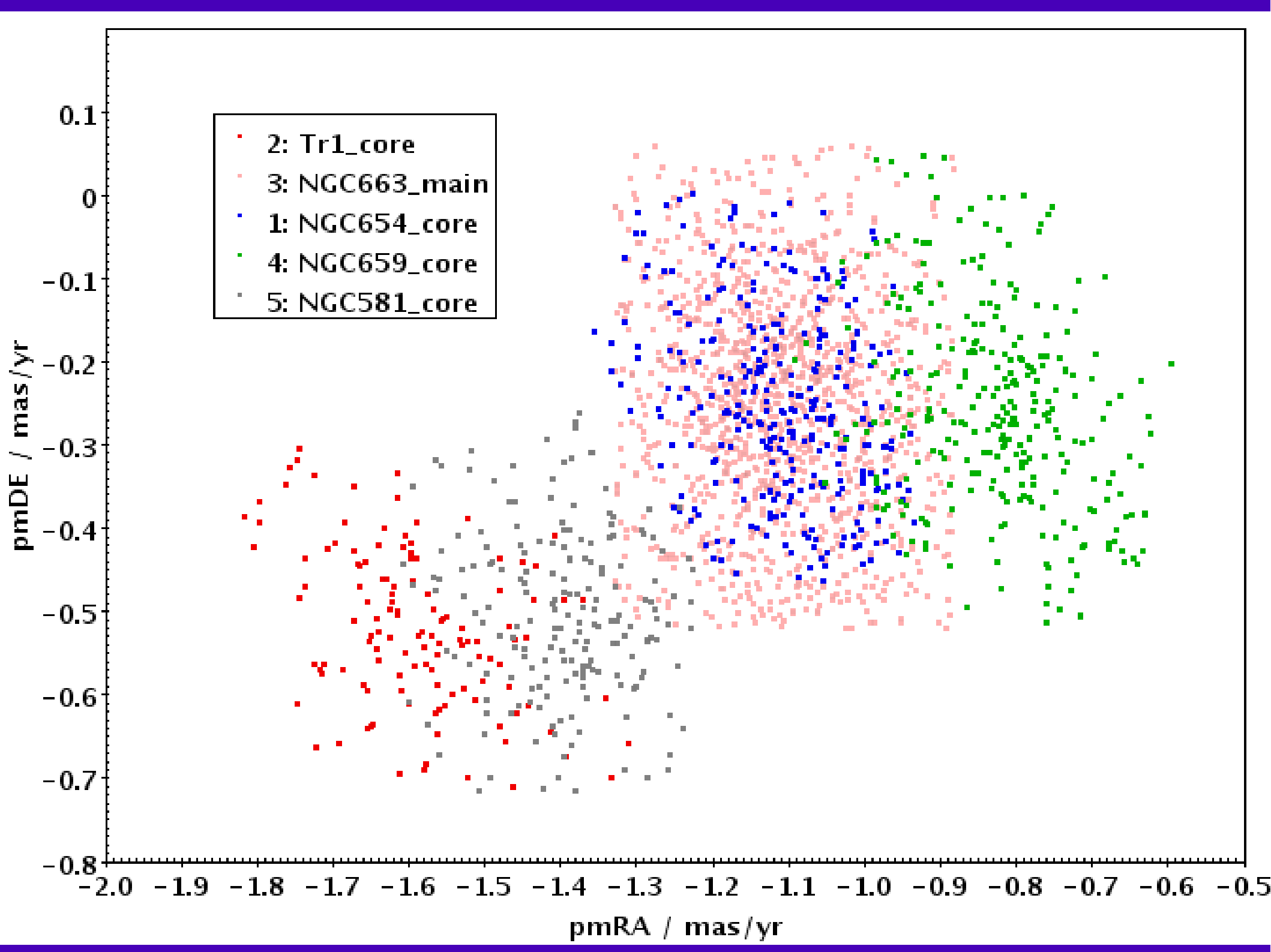
Selection:
-1.33<pmRA<-0.88
-0.52<pmDE<0.06
0.24<Plx<0.40

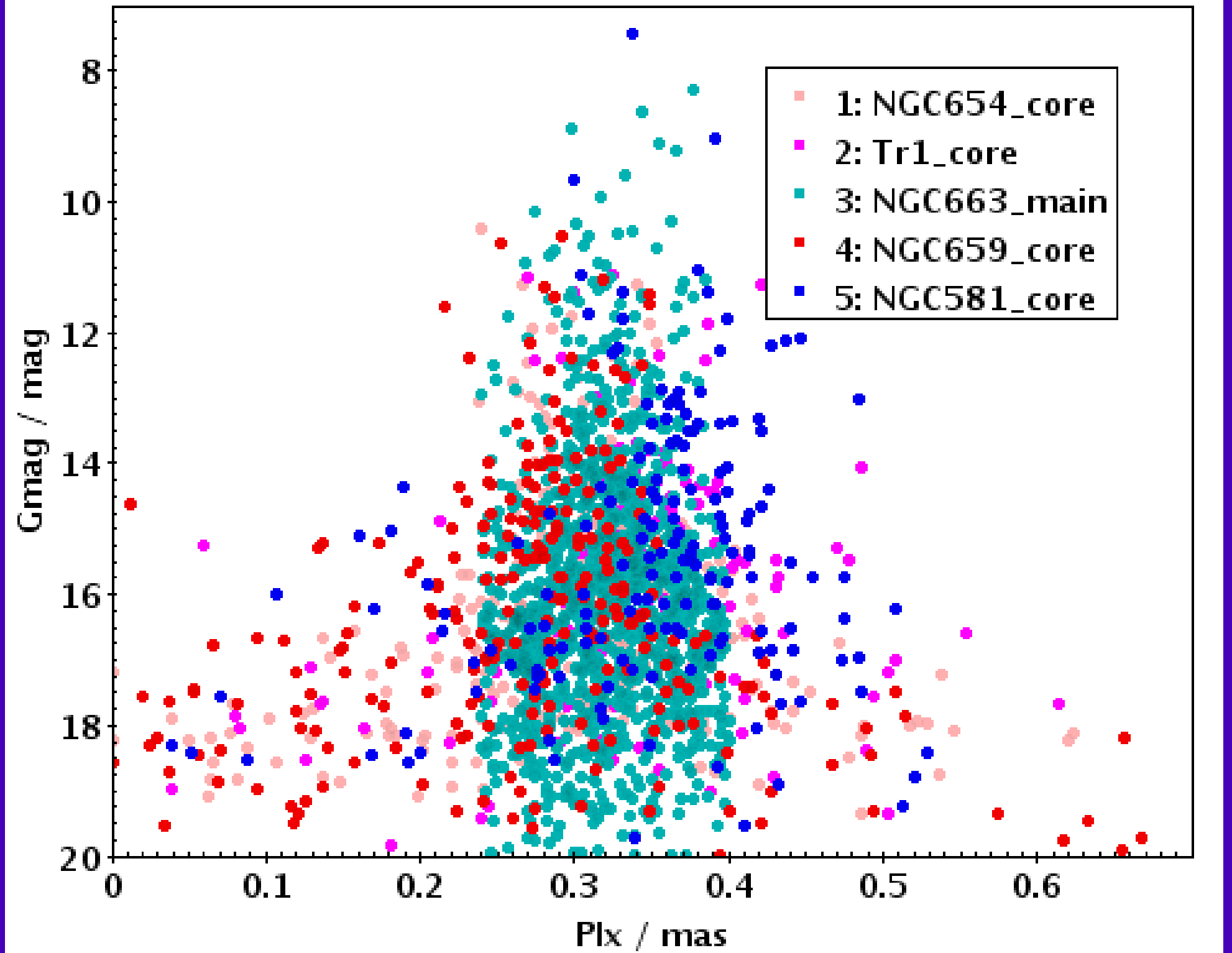
1231 stars in blue

Parallax=0.32±0.04

Distance=3.1±0.4 kpc


CDS/P/DSS2/color
15’
Powered by Aladin
1.023´ x 52.34’
N
E


2: Tr1_core
3: NGC663_main
1: NGC654_core
4: NGC659_core
5: NGC581_core
pmDE / mas/yr
pmRA / mas/yr
0.1
0
−0.1
−0.2
−0.3
−0.4
−0.5
−0.6
−0.7
−0.8
−2.0
−1.9
−1.8
−1.7
−1.6
−1.5
−1.4
−1.3
−1.2
−1.1
−1.0
−0.9
−0.8
−0.7
−0.6
−0.5


1: NGC654_core
2: Tr1_core
3: NGC663_main
4: NGC659_core
5: NGC581_core
Gmag / mag
Plx / mas
8
10
12
14
16
18
20
0
0.1
0.2
0.3
0.4
0.5
0.6

What we know from Gaia

- Gaia confirm the membership of blue stragglers and supergiants
- Gaia confirm the membership of BeX system

  (LSI +61 235)
- Gaia shows the physical connection between the clusters belonging to Cas OB8
- The two massive clusters (NGC 663 and NGC 654) have indistinguishable proper motions and parallaxes
- With more than 100 stars between (10-5) M⊙ is a very massive cluster