Clues to the evolution of massive stars from young stellar clusters

Ben Davies (Leeds)

Outline

- Introduction:
  - Massive star - SN progenitors - post-SN remnants
  - Studying massive stellar evolution using clusters

- Reviews of recent results:
  - The Arches, RSGC1, Cl 1900+14
  - Implications for stellar evolution & SN progenitors

- Possibilities with an ELT

- Summary

Introduction:

Massive stars, Supernovae, and post-SN remnants

- SN1987A - Type II-P, blue not red - stellar merger?
- Progenitors of luminous Type IIn SNe - LBVs..?

(e.g. SN2006gy - Smith et al (2007) ApJ 666, 1116,
Trundle et al (2008) A&A 483, 47;
SN2005gl - Gal-Yam & Leonard (2009), Nature 458, 865)

- Lack of Type II-Ps with progenitor masses above $17M_\odot$

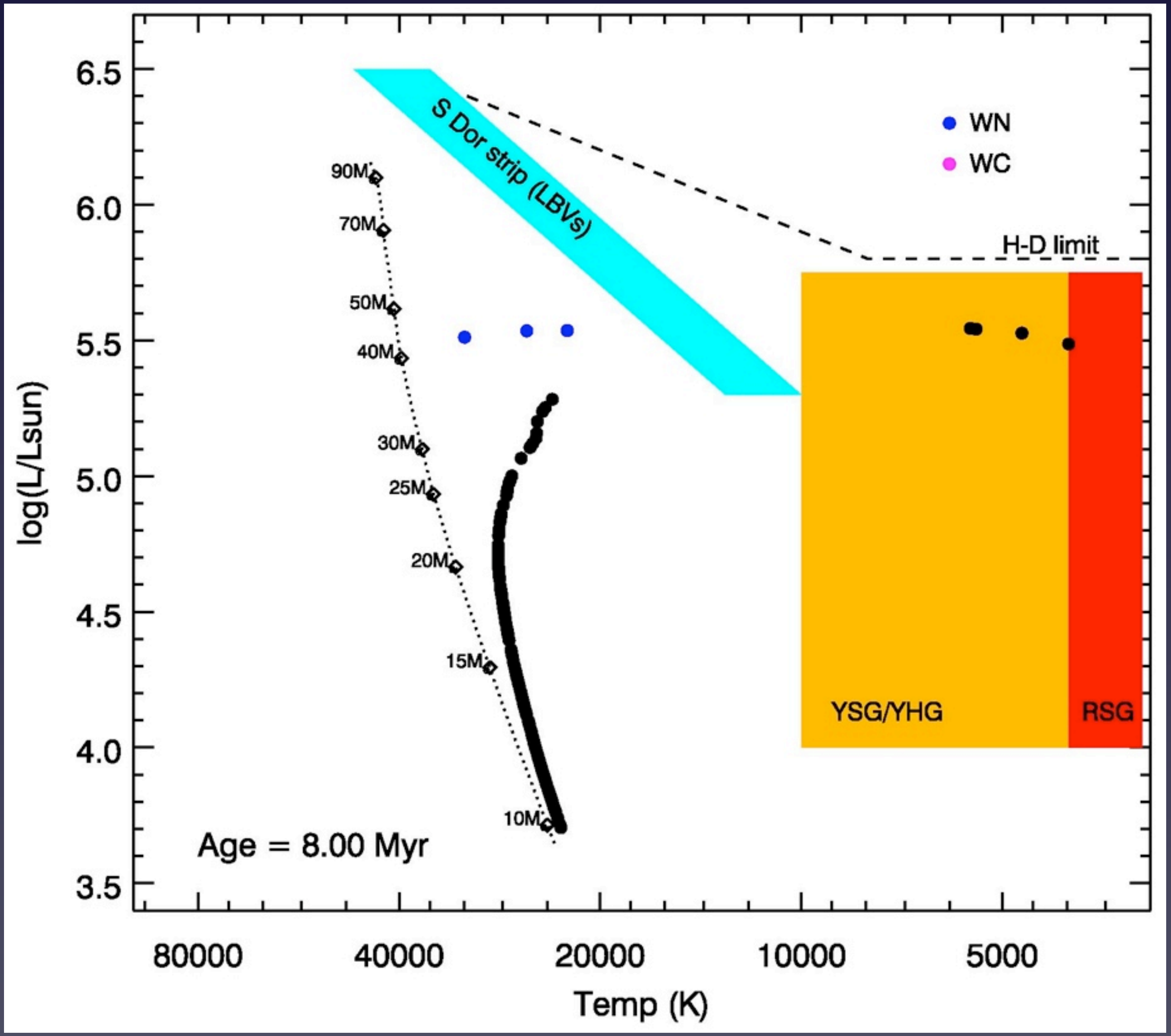
(Smartt et al 2009 MNRAS 395, 1409)

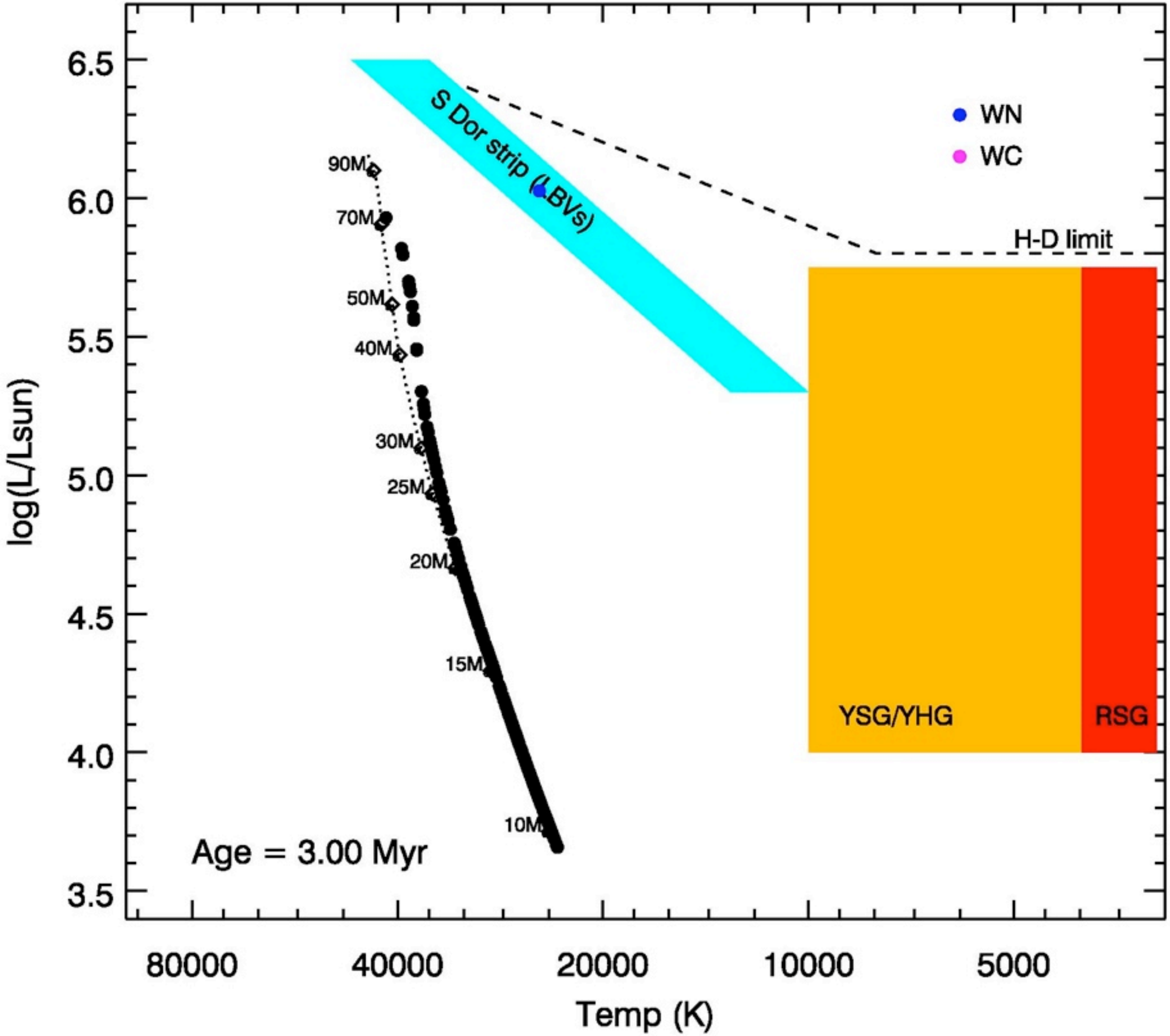
Introduction

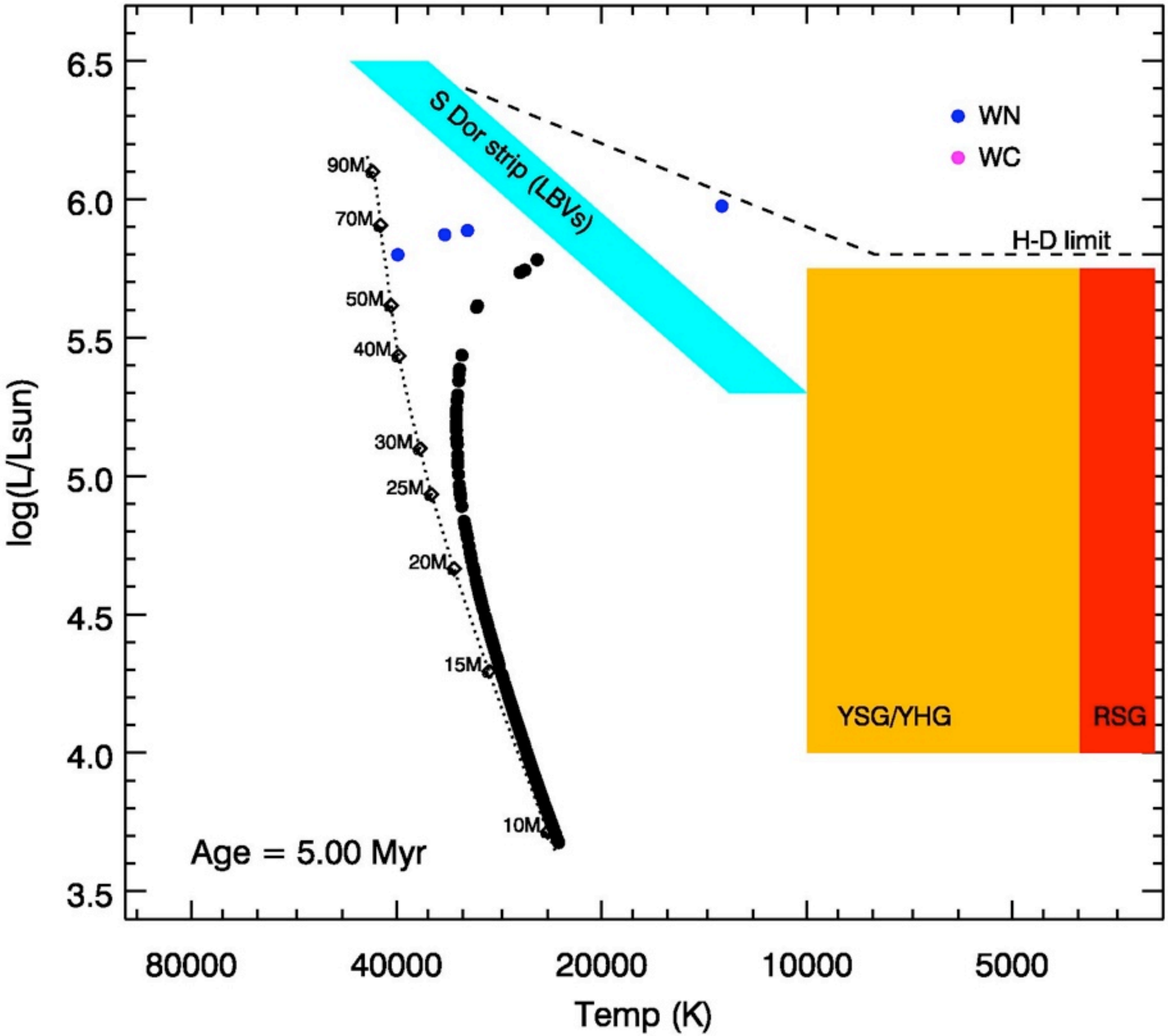
By observing young massive clusters with a range of ages, we can make direct links between stellar initial masses and..

- evolutionary phases
- end states

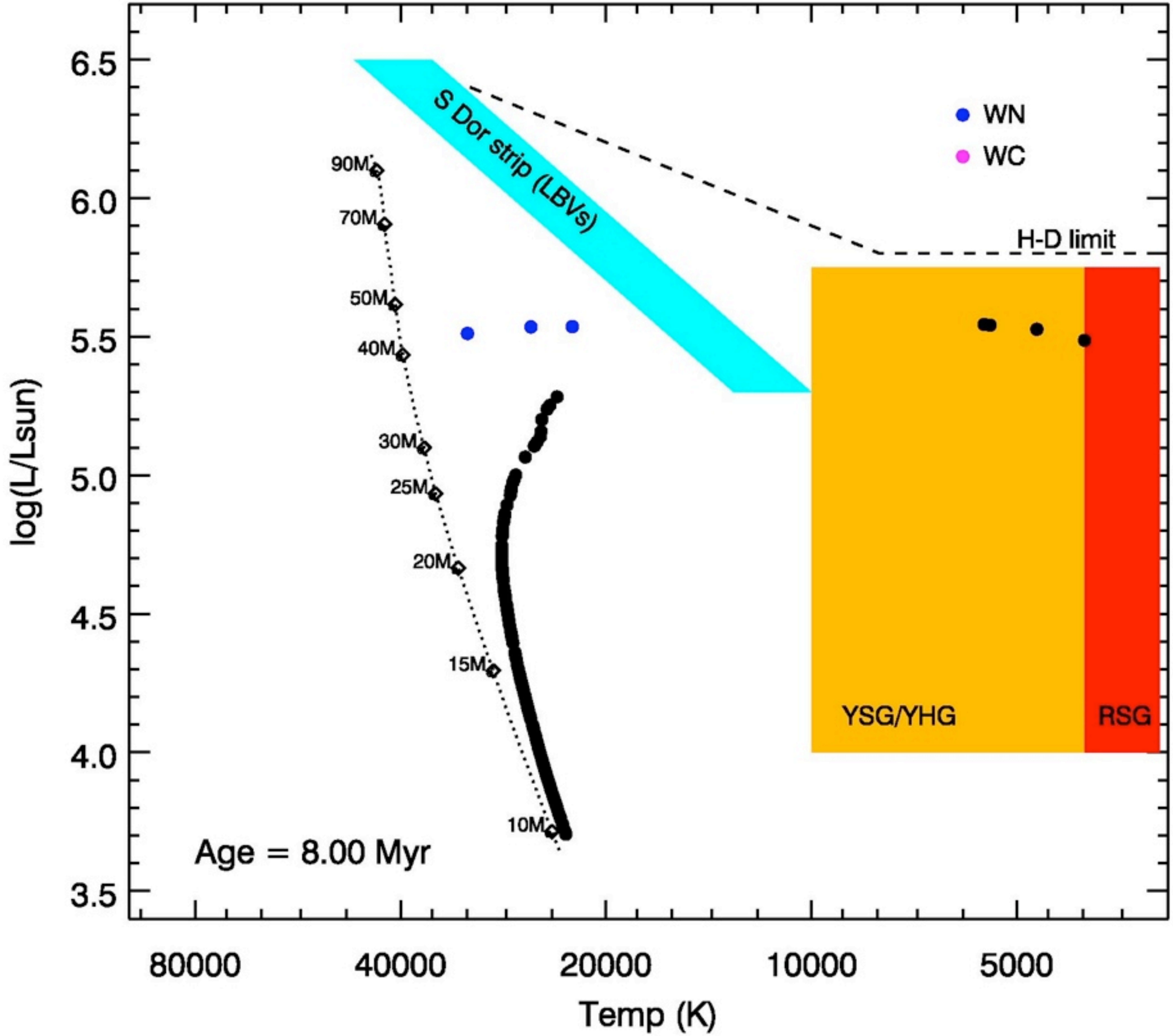
As an illustration, generate a $10^4 M_\odot$ cluster with Salpeter IMF using Geneva rotating tracks (Meynet & Maeder 2000)



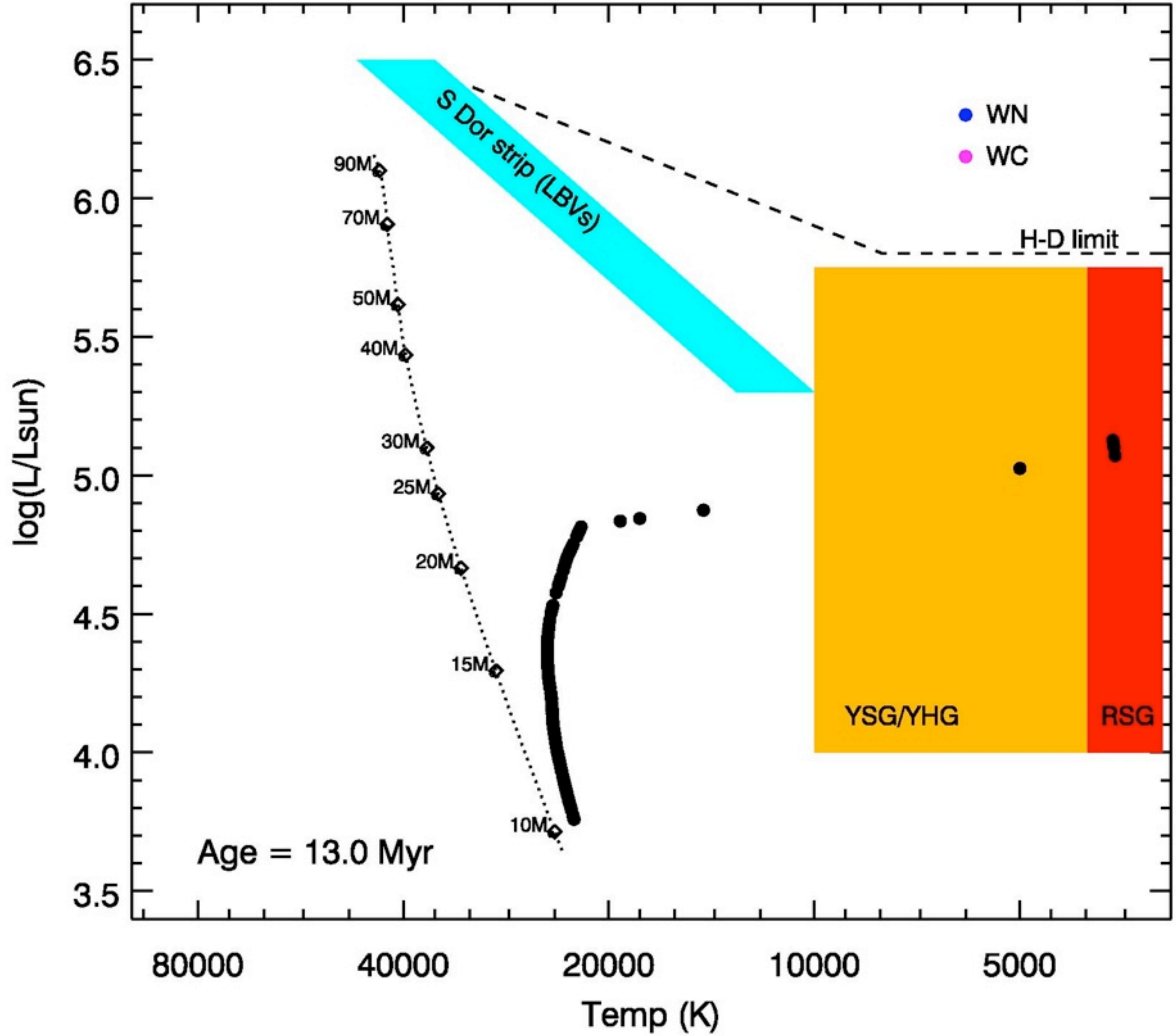

log(L/Lsun)
Temp (K)
6.5
6.0
5.5
5.0
4.5
4.0
3.5
80000
40000
20000
10000
5000
S Dor strip (LBVs)
WN
WC
H-D limit
90M
70M
50M
40M
30M
25M
20M
15M
10M
YSG/YHG
RSG
Age = 3.00 Myr



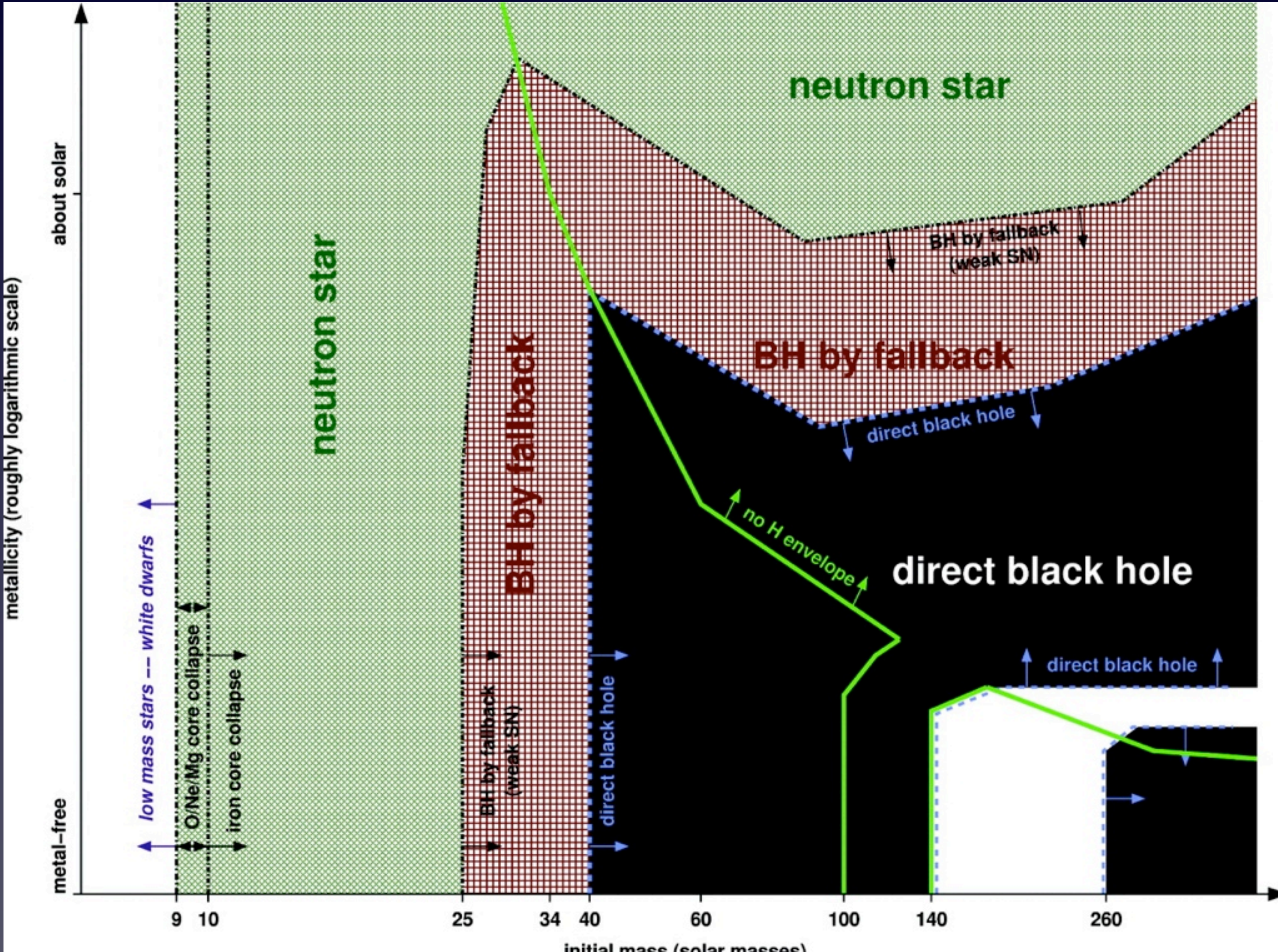
6.5
6.0
5.5
5.0
4.5
4.0
3.5
log(L/Lsun)
80000
40000
20000
10000
5000
Temp (K)
S Dor strip (LBVs)
WN
WC
H-D limit
YSG/YHG
RSG
90M
70M
50M
40M
30M
25M
20M
15M
10M
Age = 5.00 Myr



S Dor strip (LBVs)
WN
WC
H-D limit
90M
70M
50M
40M
30M
25M
20M
15M
10M
YSG/YHG
RSG
Age = 8.00 Myr
log(L/Lsun)
6.5
6.0
5.5
5.0
4.5
4.0
3.5
80000
40000
20000
10000
5000
Temp (K)



S Dor strip (LBVs)
WN
WC
H-D limit
90M
70M
50M
40M
30M
25M
20M
15M
10M
YSG/YHG
RSG
Age = 13.0 Myr
log(L/Lsun)
6.5
6.0
5.5
5.0
4.5
4.0
3.5
80000
40000
20000
10000
5000
Temp (K)



Heger & Woosley 2003

Part II:
What Young Massive Clusters tell us about massive stellar evolution

RSGC1 -

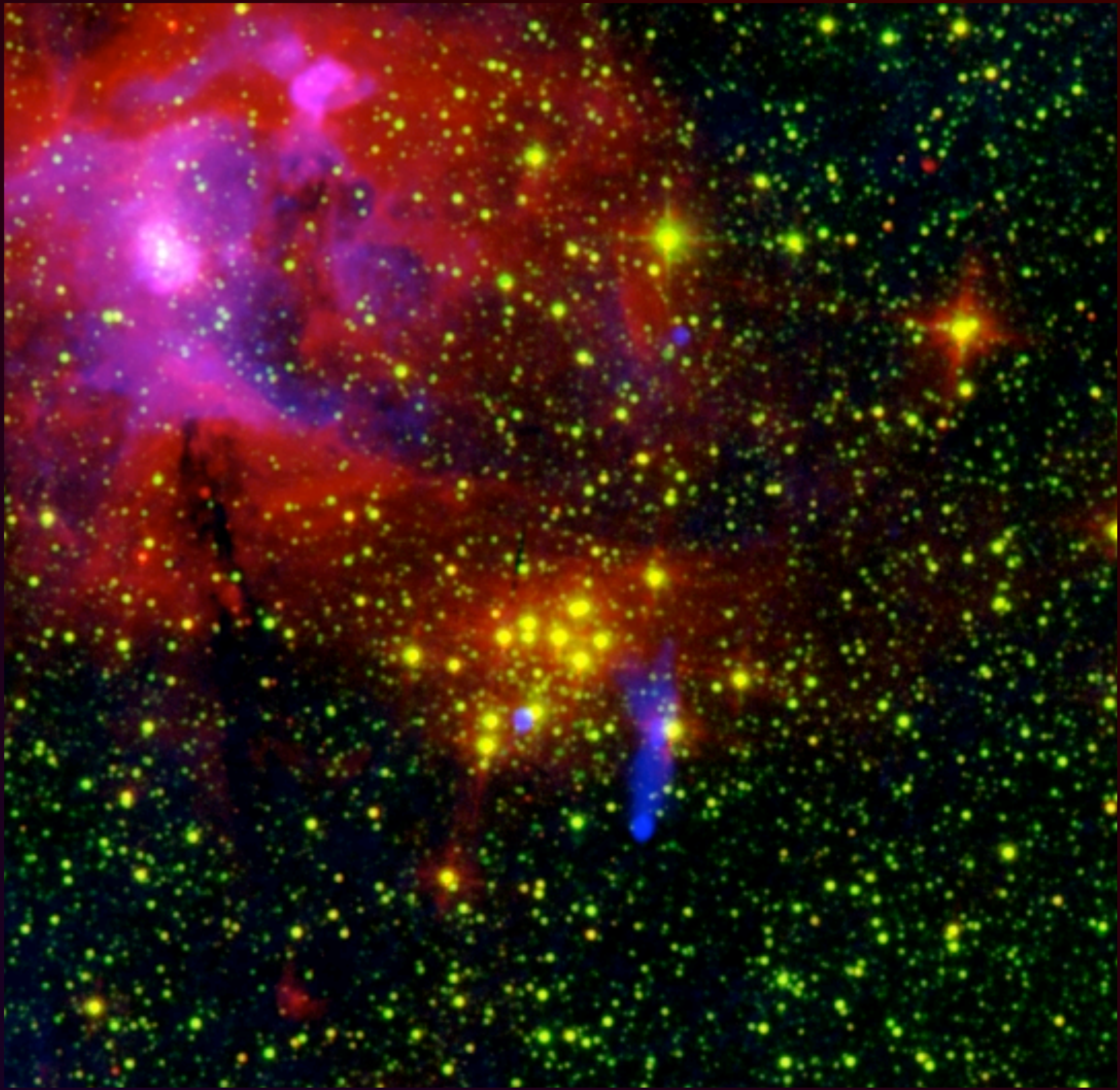
Age = 12 ± 2 Myr

Mass = $3\pm2 \times 10^4\ M_\odot$

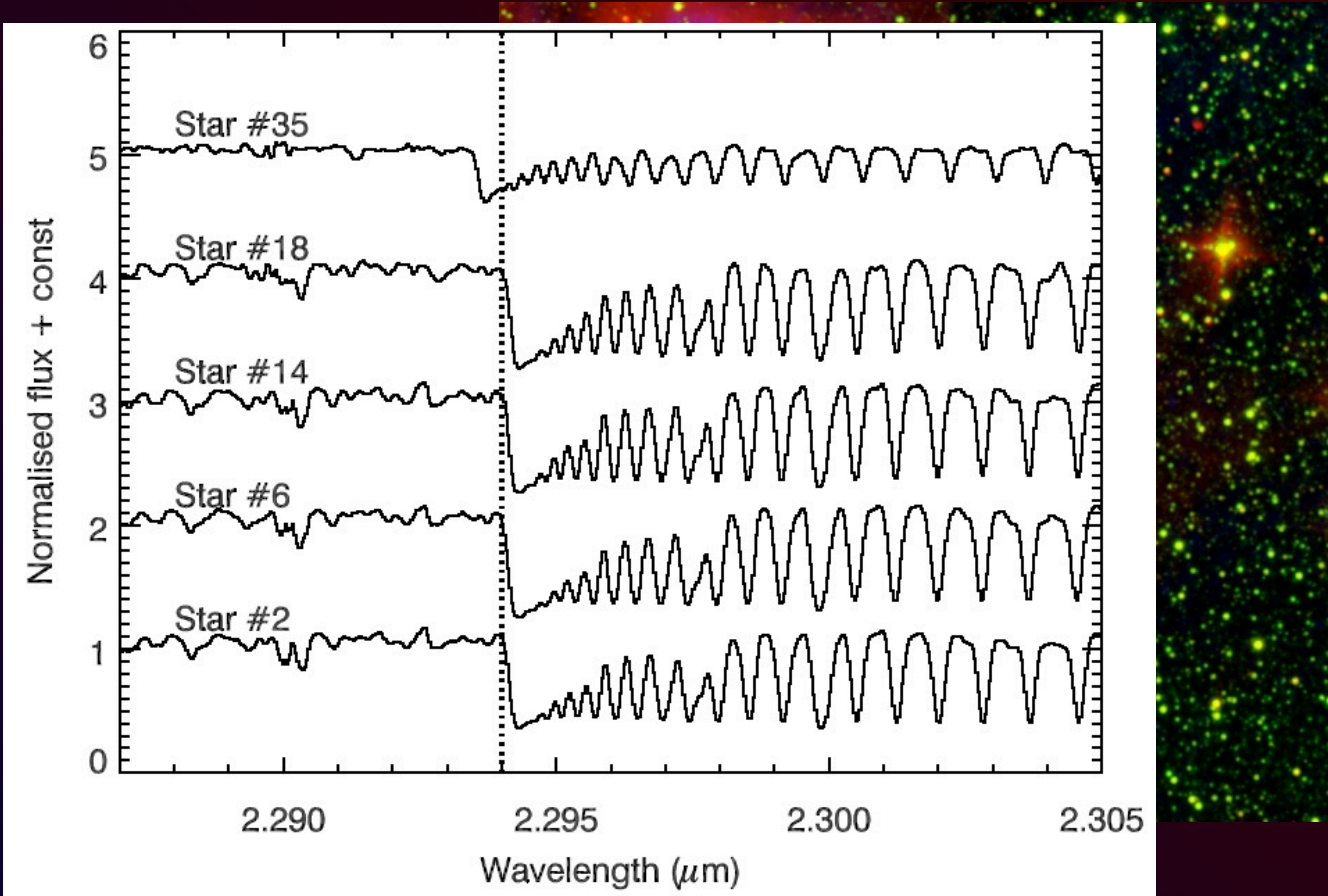
D_{sun} = 6.6 ± 0.9 kpc

A_V = 20

$M_{*,max}$ = $18^{+4}_{-2}\ M_\odot$

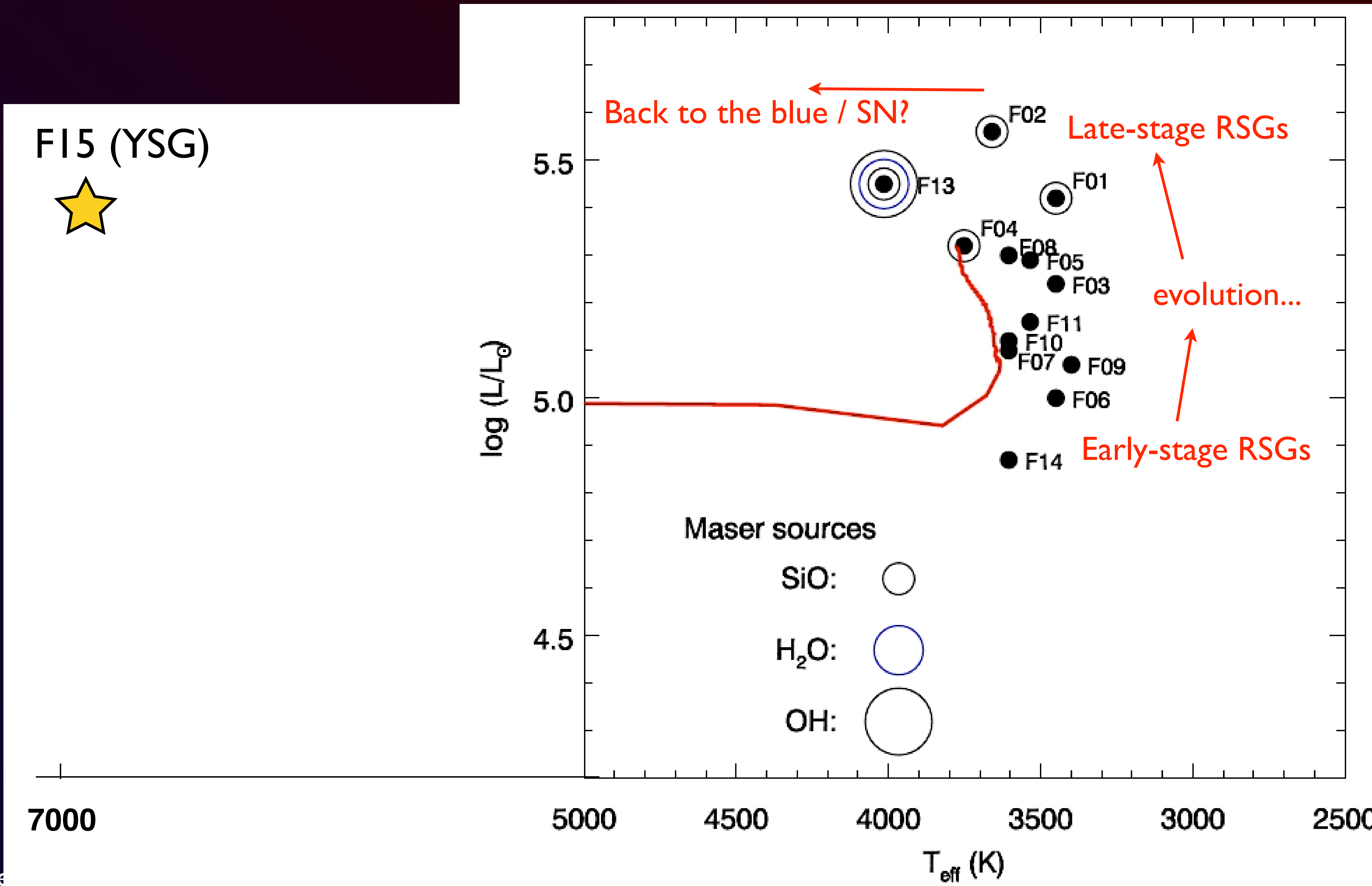


Davies et al 2008 ApJ 676, 1016


Star #35
Star #18
Star #14
Star #6
Star #2
Normalised flux + const
0
1
2
3
4
5
6
2.290
2.295
2.300
2.305
Wavelength (μm)

RSGC1 -

Davies et al. (2008) ApJ 676, 1016
Nakashima & Deguchi (2006) ApJ 647, 139



Be

RSGC1 -

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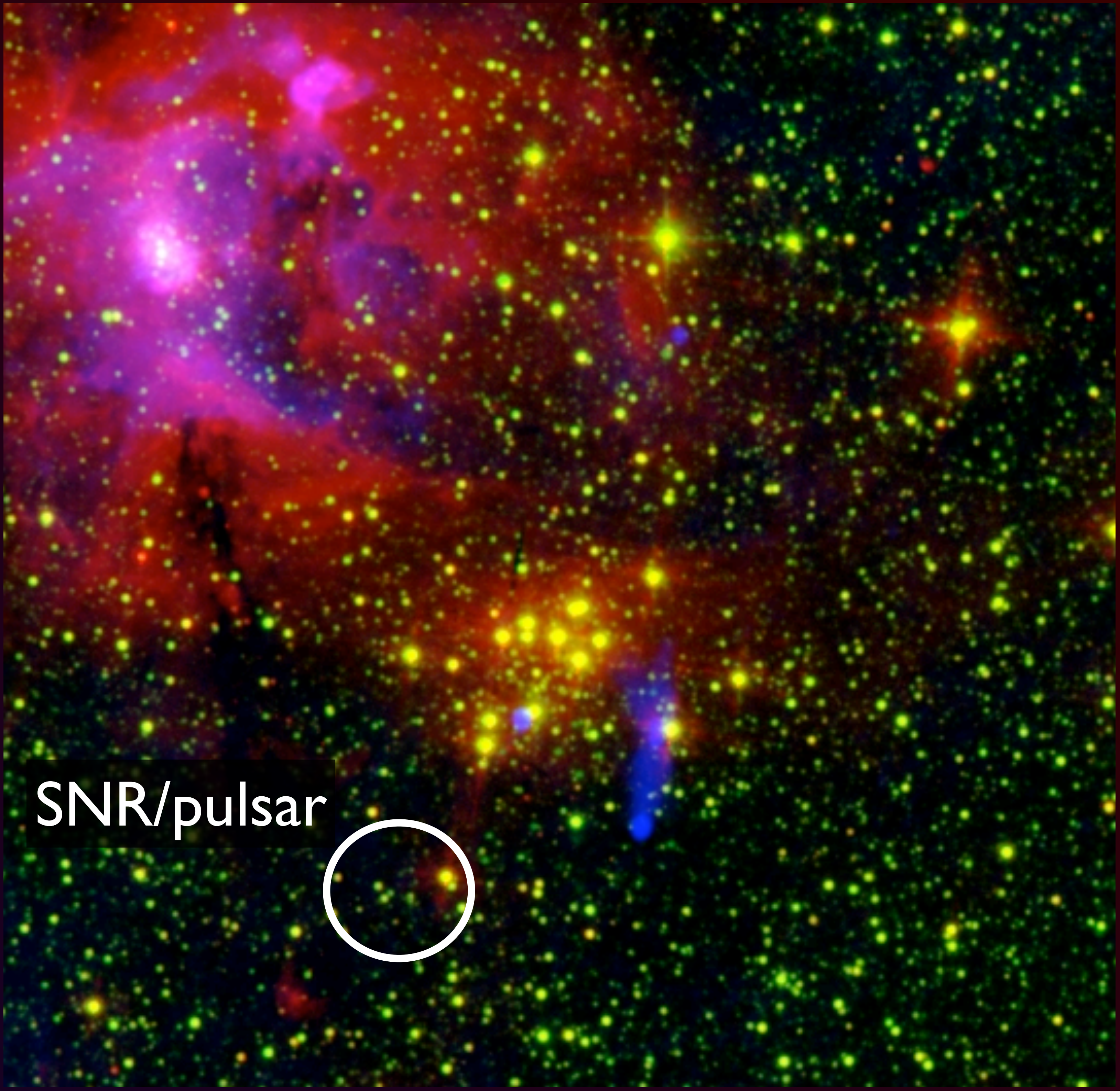


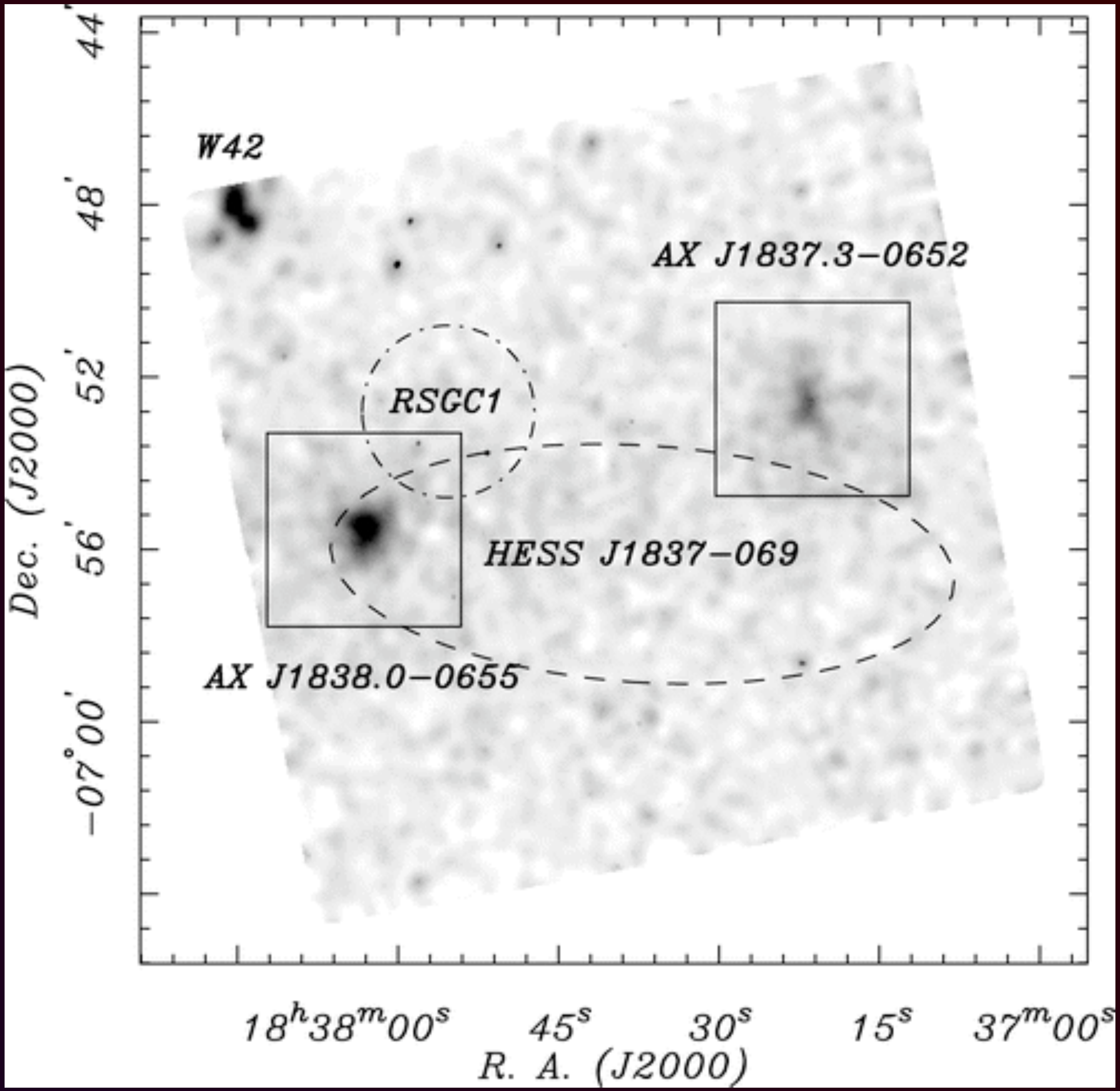
Davies et al 2008 ApJ 676, 1016

RSGC1 -

- Pulsar's characteristic age ~10^4yr *(Gotthelf & Halpern 2008)*
- Suggests that the pulsar's progenitor mass was ~$18M_{\odot}$
- Suggests that, for M_{init} ~ $18M_{\odot}$...

.. RSG ➜ YHG (...WN??) ➜ SN I/II

➜ neutron star (not black hole)



Chandra / ACIS-I image (Gotthelf & Halpern 2008)

The host cluster of the magnetar SGR 1900+14

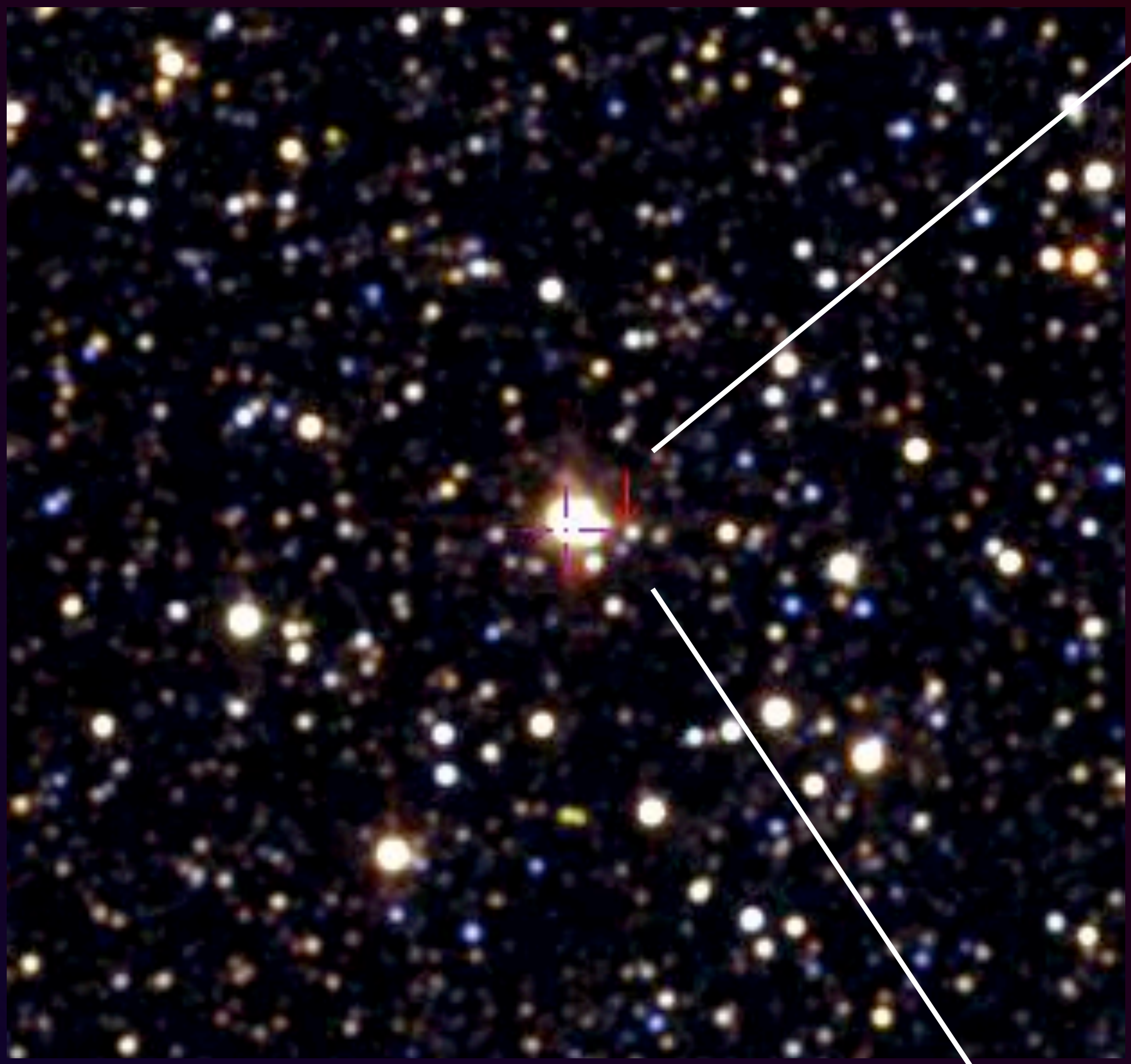
2MASS JHK

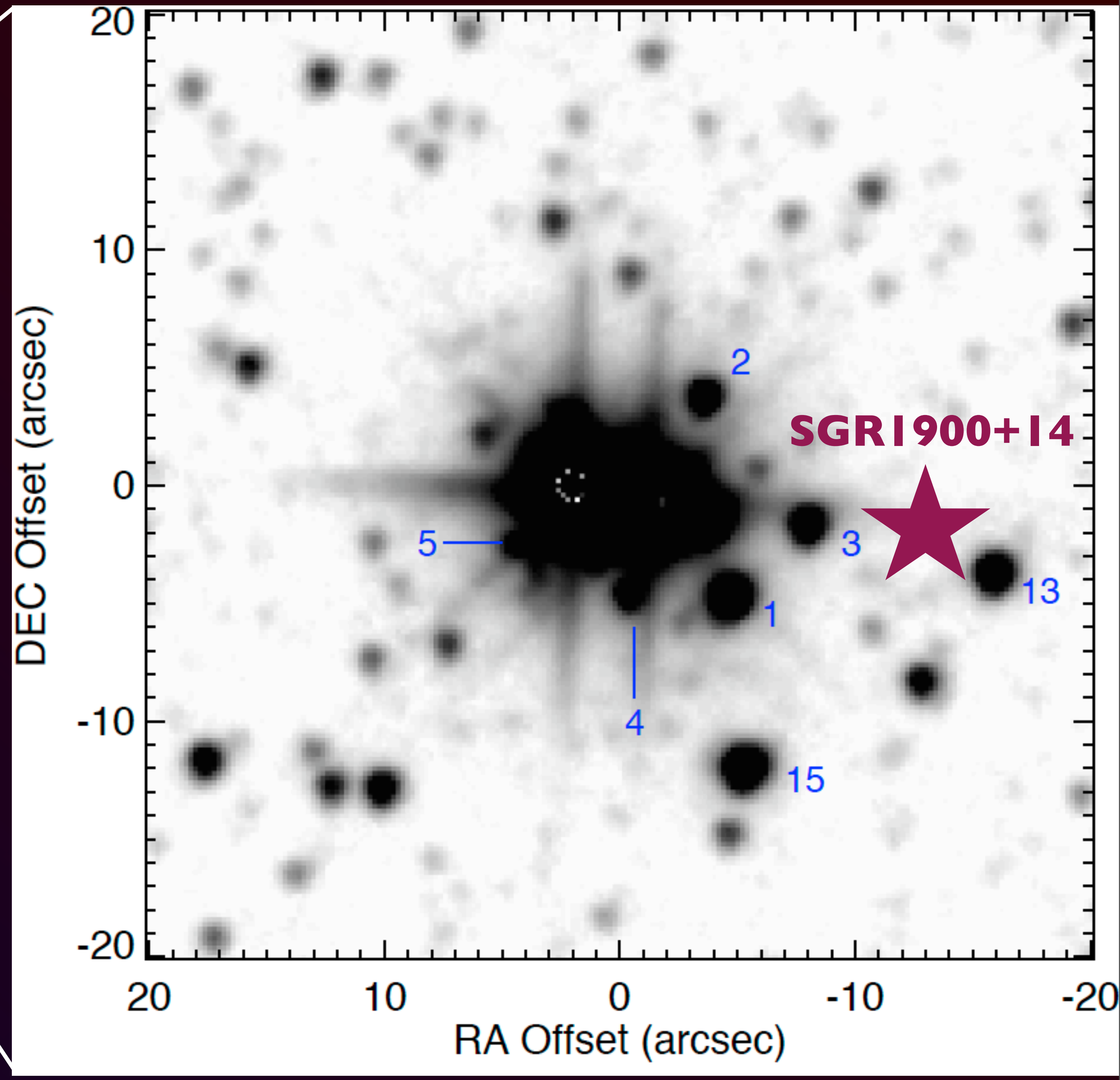
The host cluster of the magnetar SGR 1900+14

Object [+ cluster]	**$M_{prog}/M_\odot$**	**Remnant**	**B ($\times 10^{14}$G)**
SGR 1806-20	48^{+20}_{-8}	Magnetar	2-8
CXO J164710.2-455216 [Wd 1]	40±5	Magnetar	<1.5
IGR J18135-1751 [Cl 1813-18]	25±5	Pulsar Wind Neb	0.1-1
AX J1838-0655 [RSGC1]	18±2	Pulsar Wind Neb	0.02
SGR 1900+14	???	Magnetar	2-8

➜ magnetic fields of neutron stars some function of initial stellar mass..?

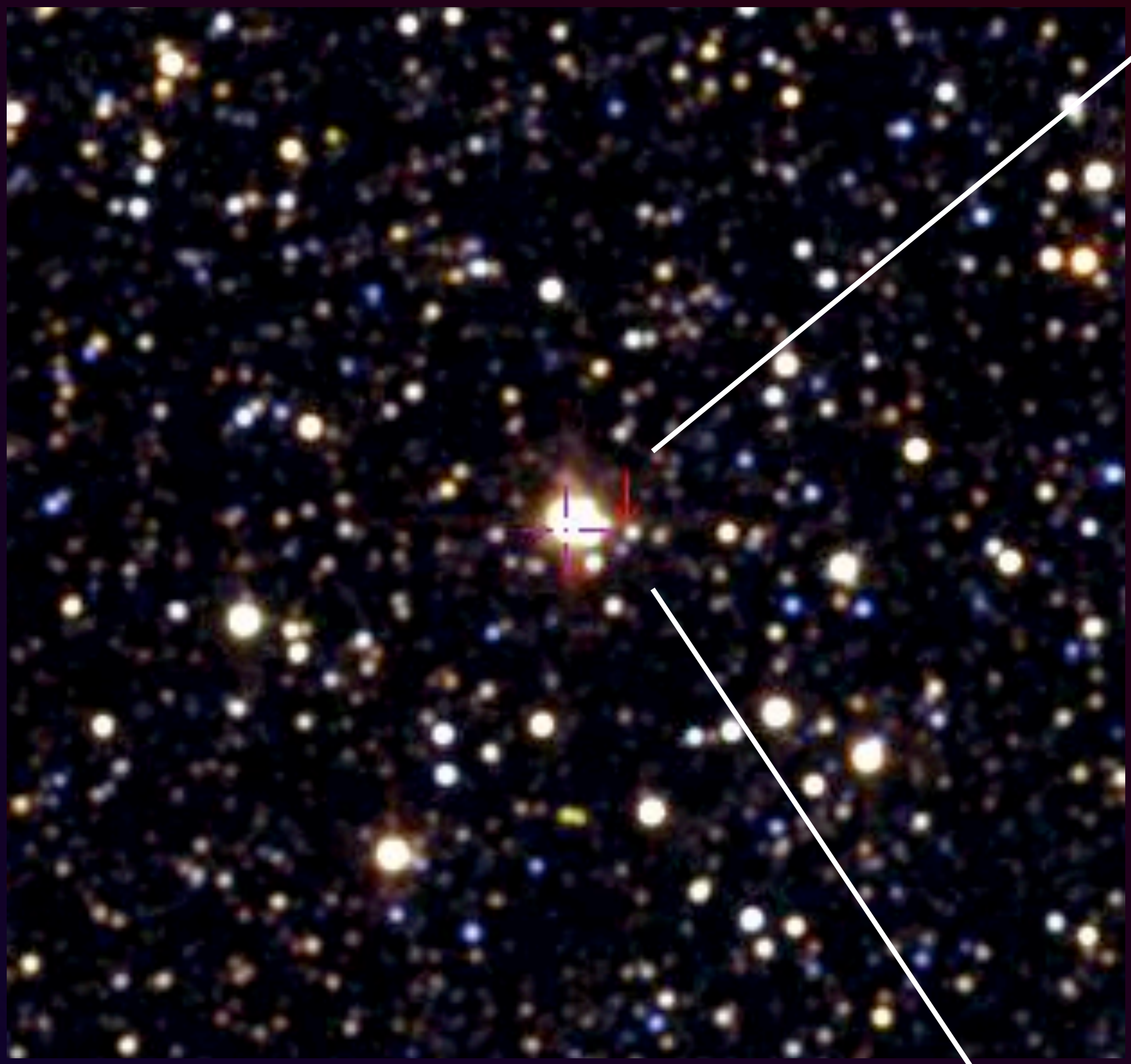
The host cluster of the magnetar SGR 1900+14

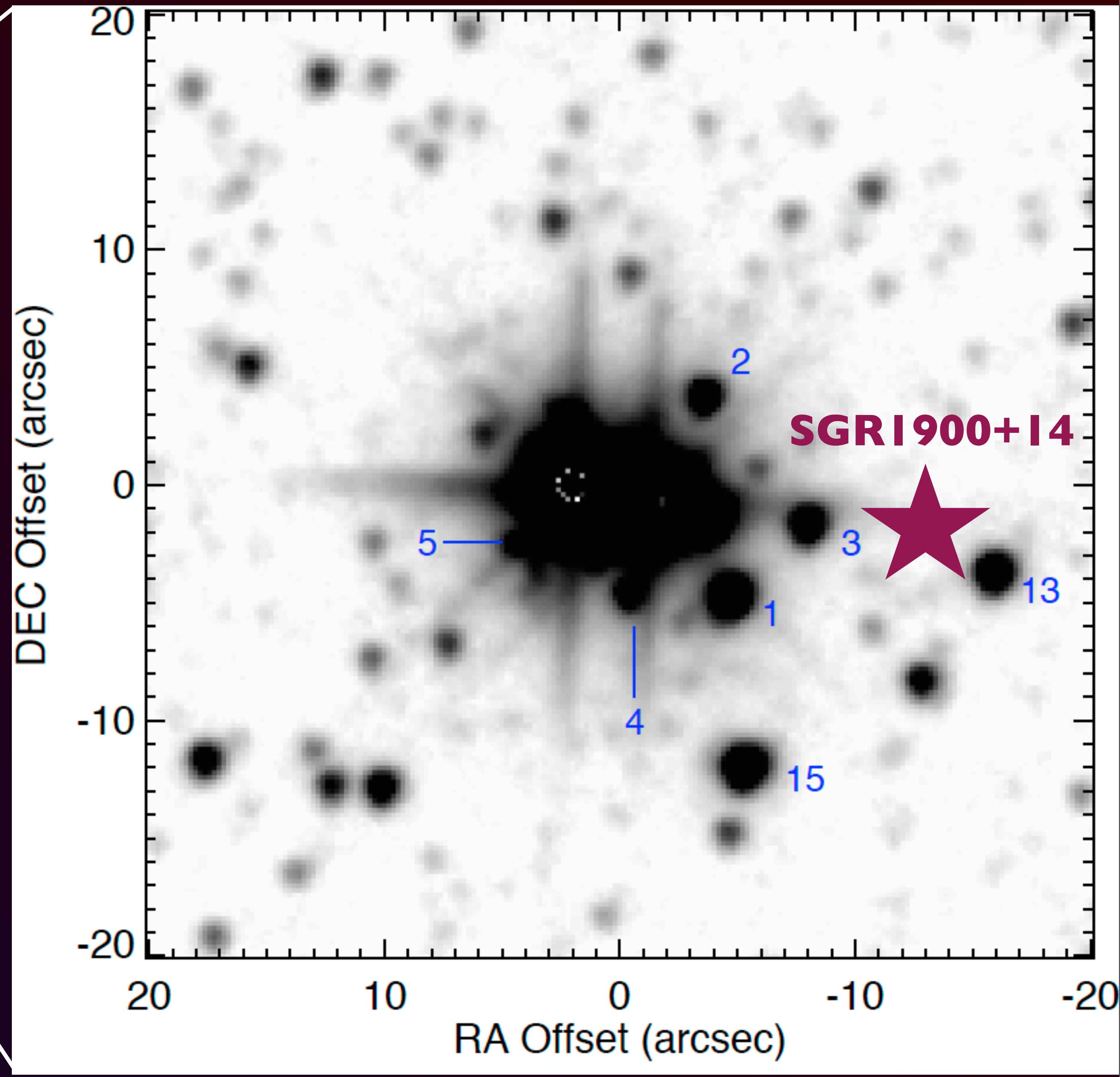




UKIDSS H-band

The host cluster of the magnetar SGR 1900+14





UKIDSS H-band

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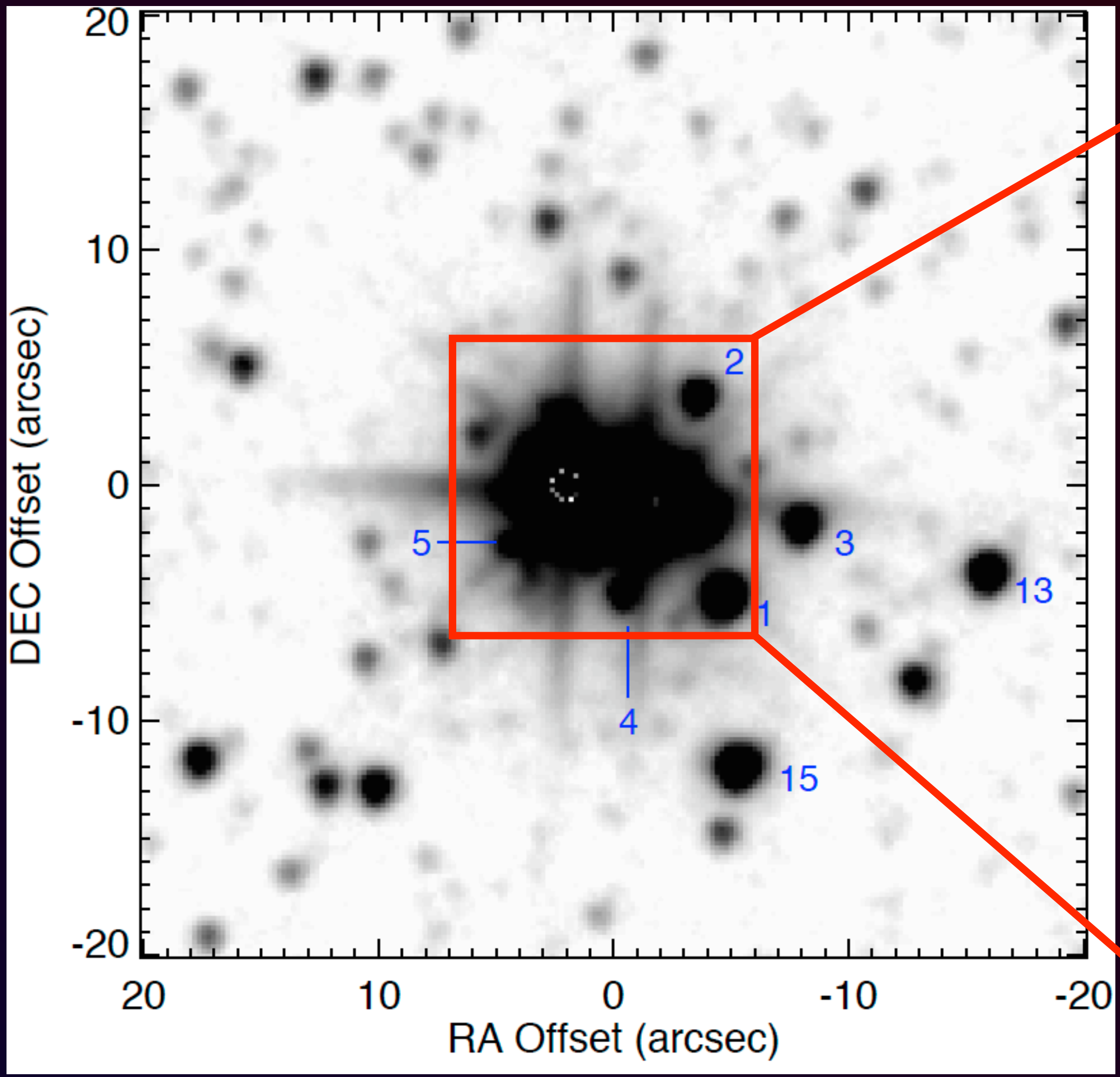
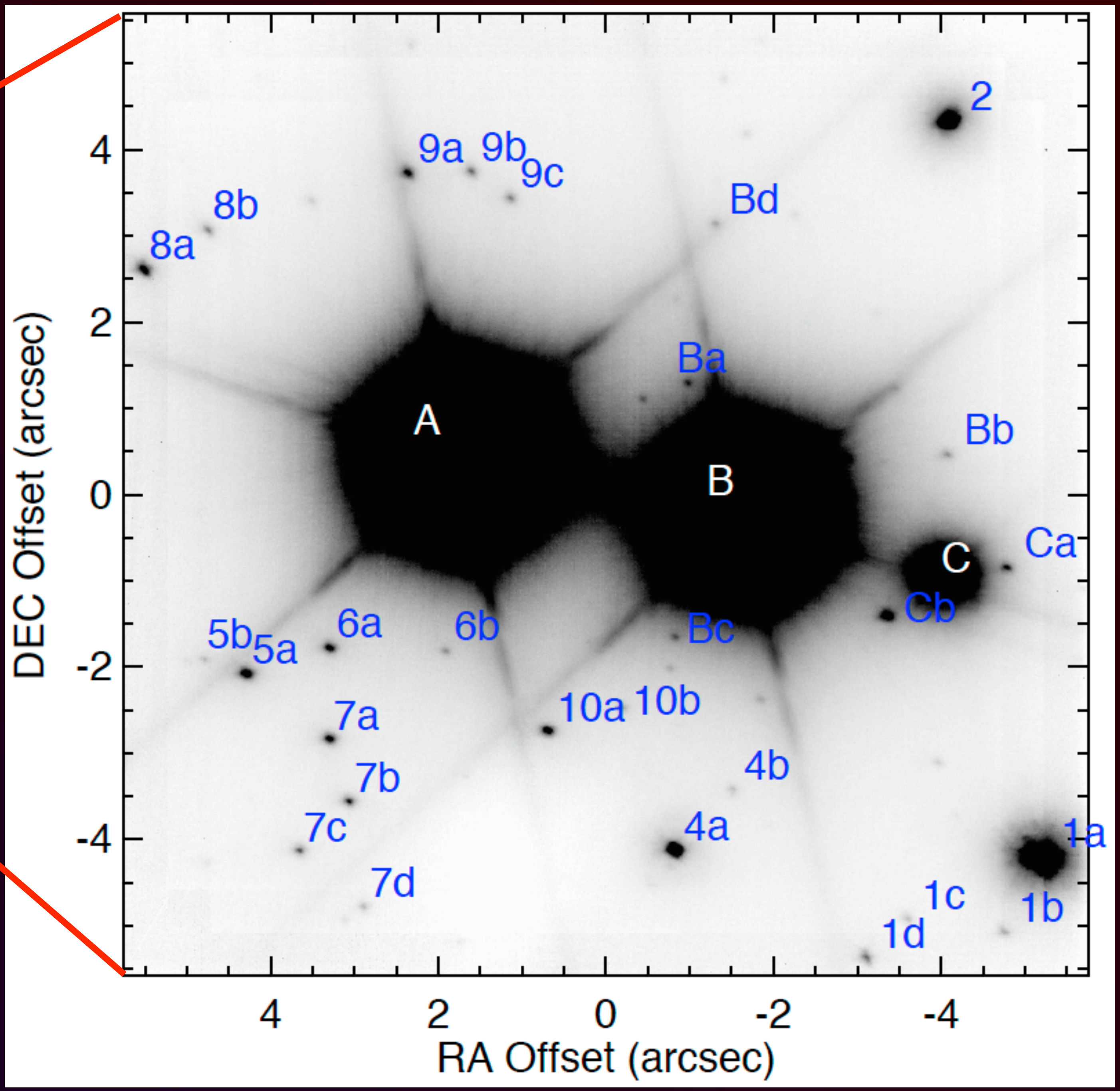


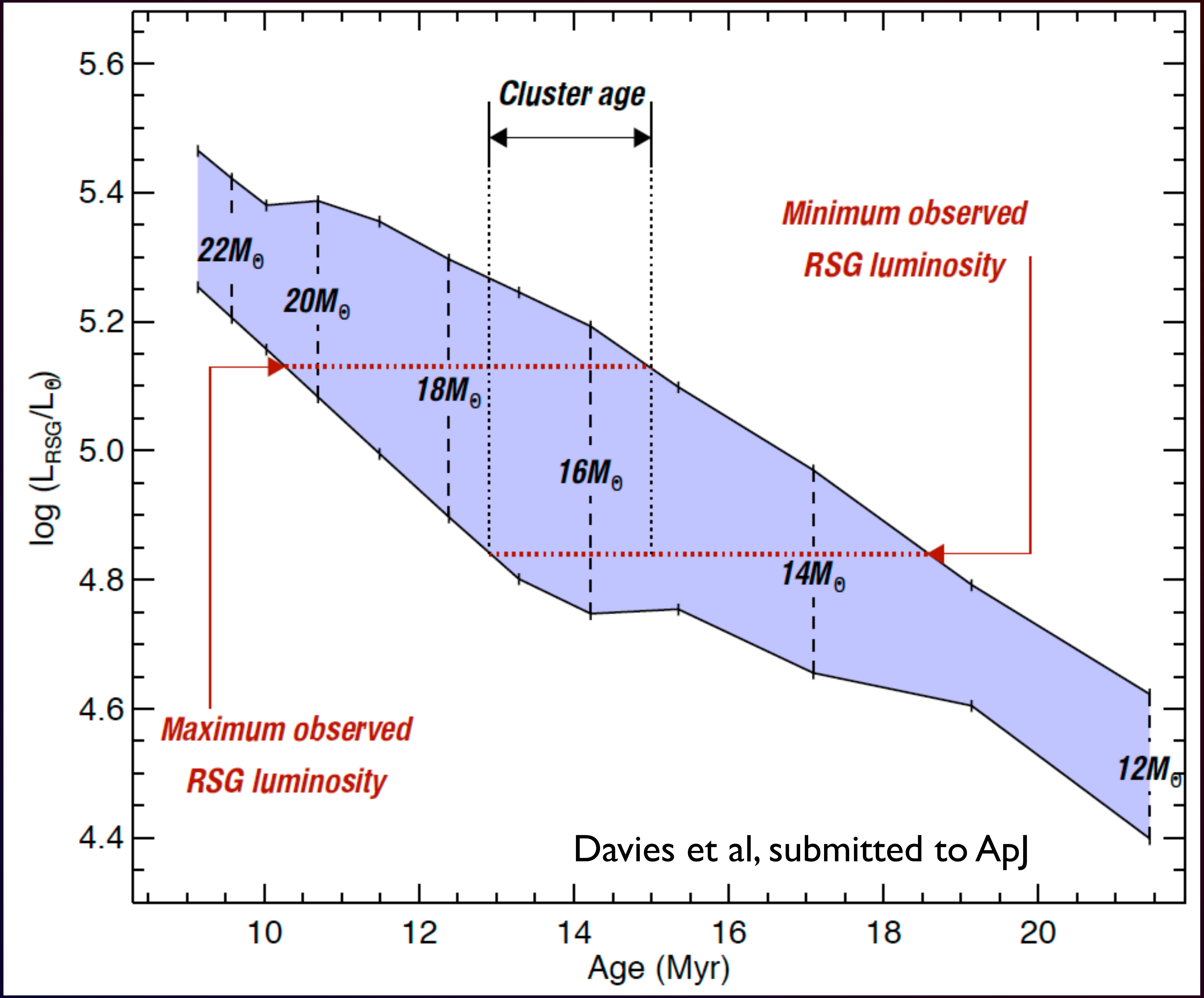
UKIDSS H-band



Keck/NIRC2 H-band

Davies et al, submitted to ApJ

The host cluster of the magnetar SGR 1900+14



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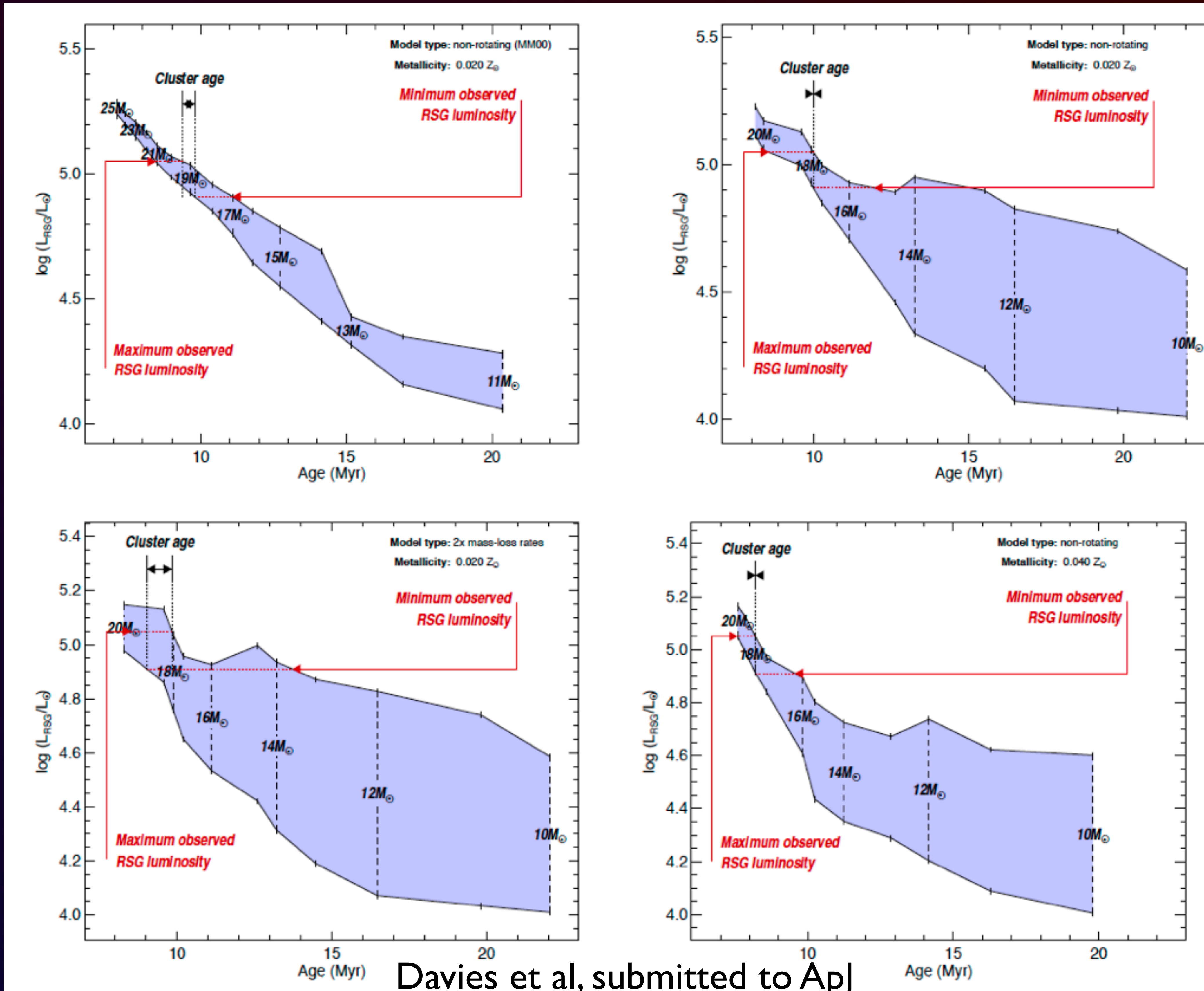

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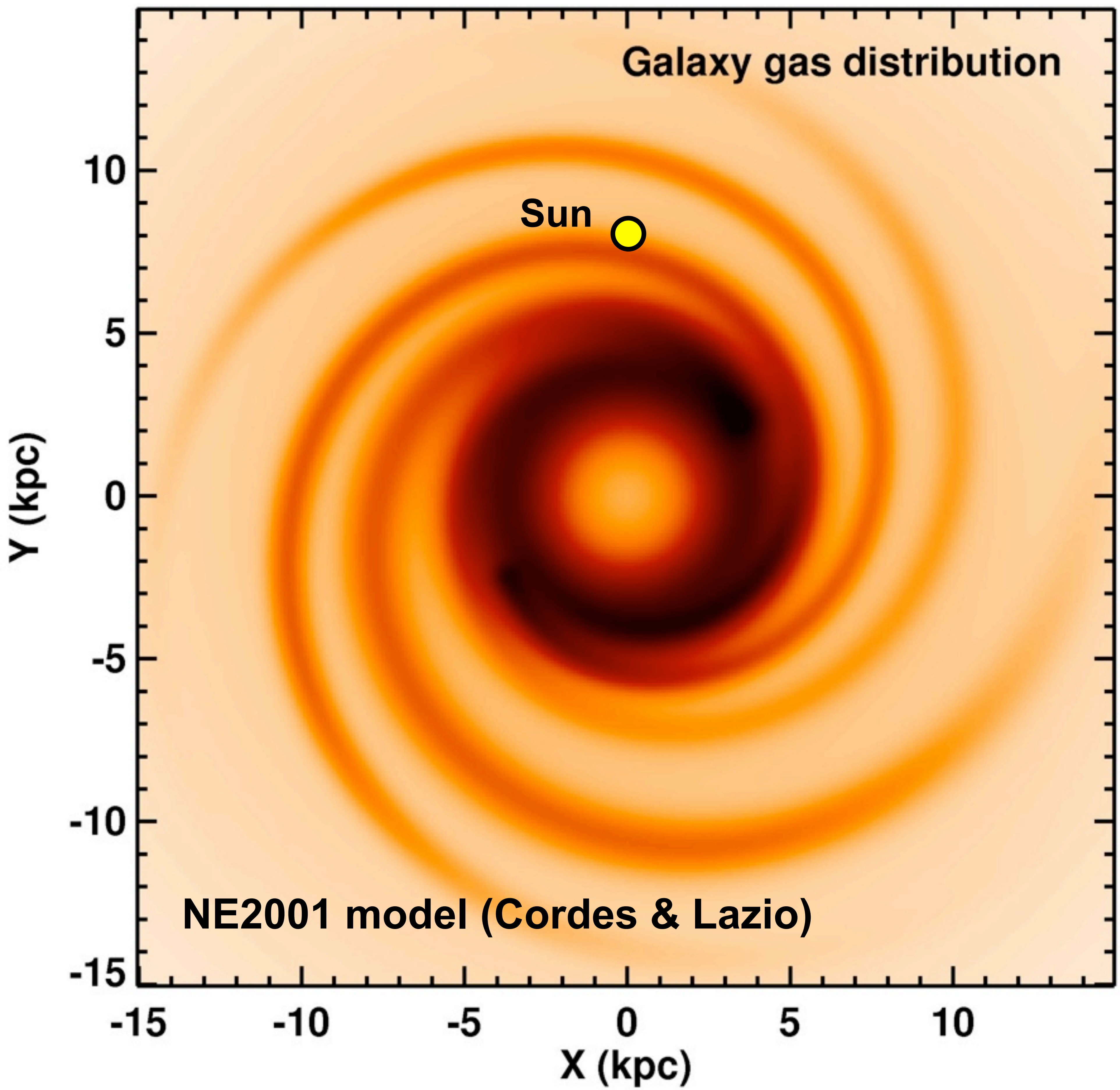
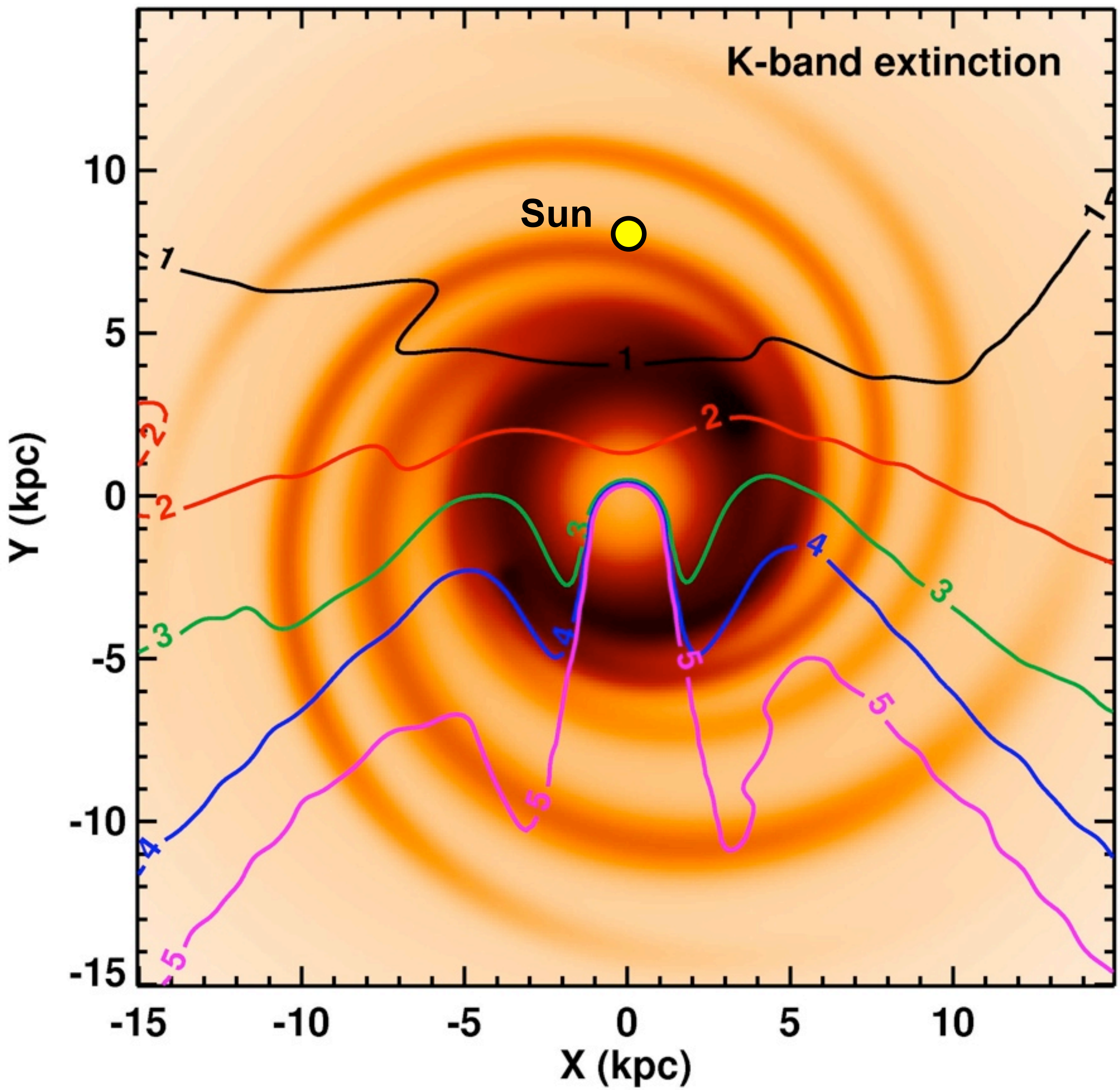
➜ magnetic fields of neutron stars depend on factor other than initial mass..?

Studies of young clusters in the E-ELT era

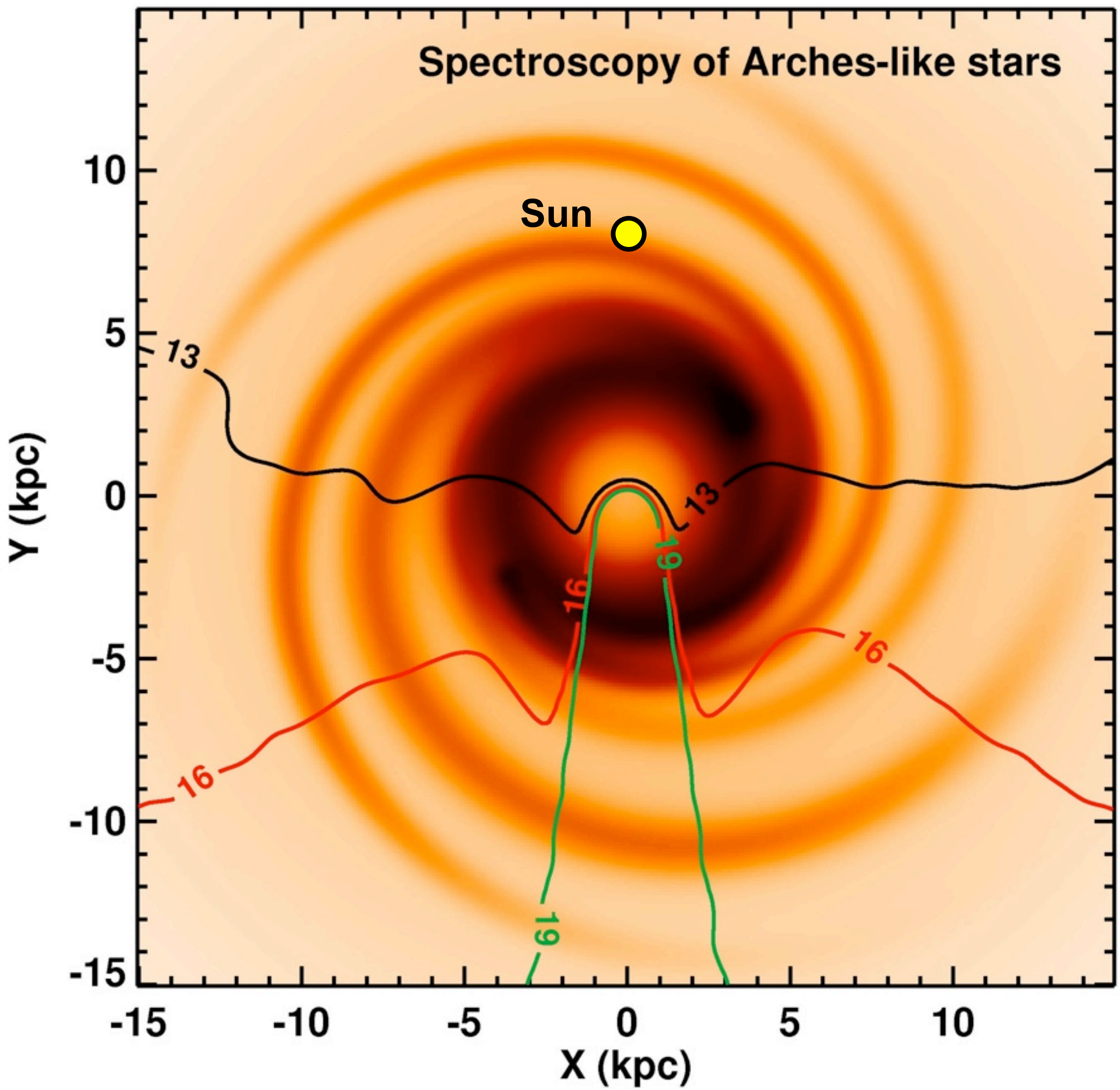
- Current studies of Galactic clusters hampered by extinction, distance.

- What would be possible with an ELT..?


Galaxy gas distribution
Sun
NE2001 model (Cordes & Lazio)
Y (kpc)
X (kpc)
10
5
0
-5
-10
-15
-15
-10
-5
0
5
10

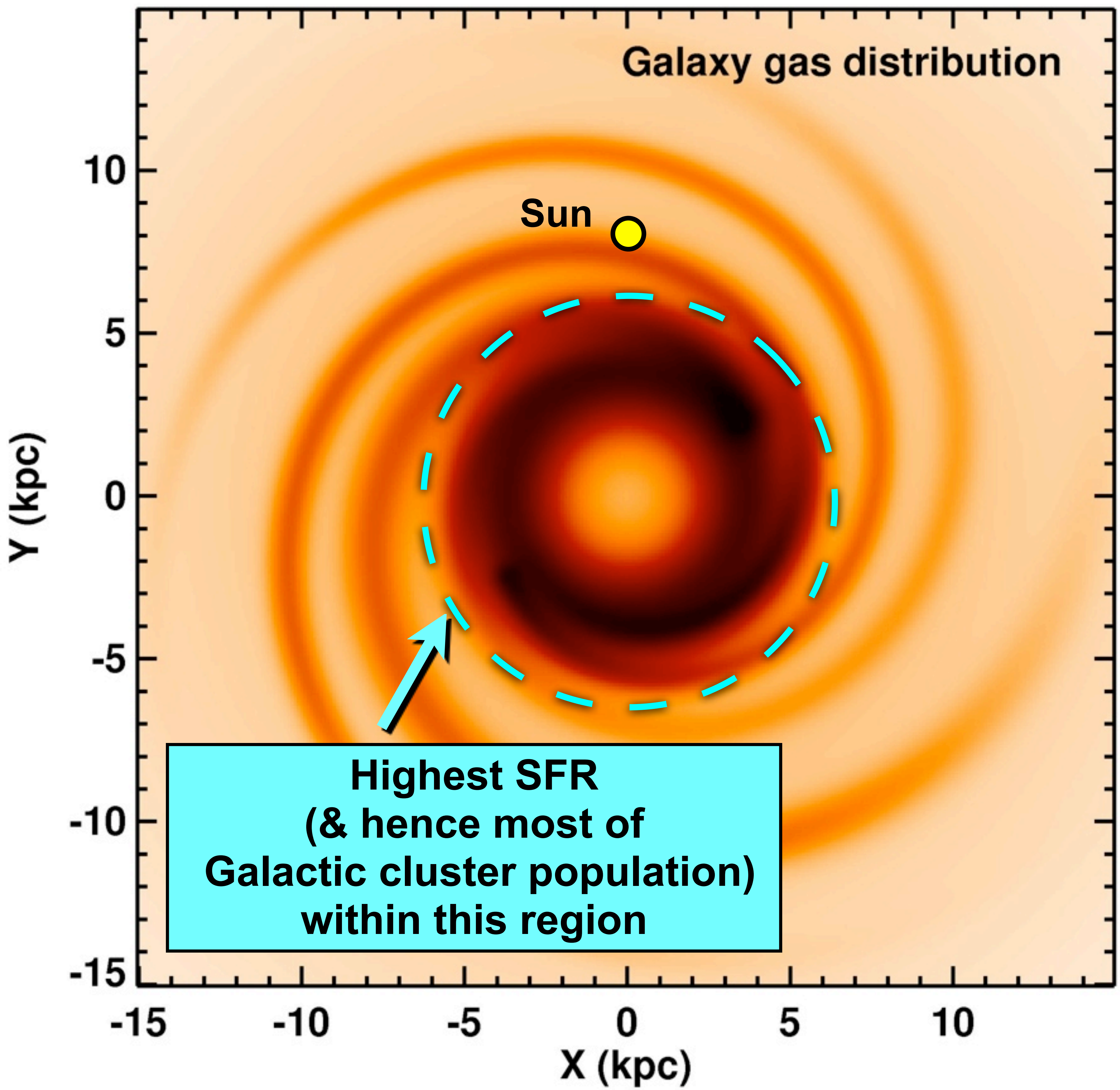


K-band extinction
Sun
Y (kpc)
X (kpc)
10
5
0
-5
-10
-15
-15
-10
-5
0
5
10
1
2
3
4
5


Spectroscopy of Arches-like stars
Sun
13
16
19
Y (kpc)
X (kpc)
-15
-10
-5
0
5
10

Studies of young clusters in the E-ELT era

- Study of clusters: need to know ages and distances.


Galaxy gas distribution
Sun
Highest SFR
(& hence most of
Galactic cluster population)
within this region
Y (kpc)
X (kpc)
10
5
0
-5
-10
-15
-15
-10
-5
0
5
10

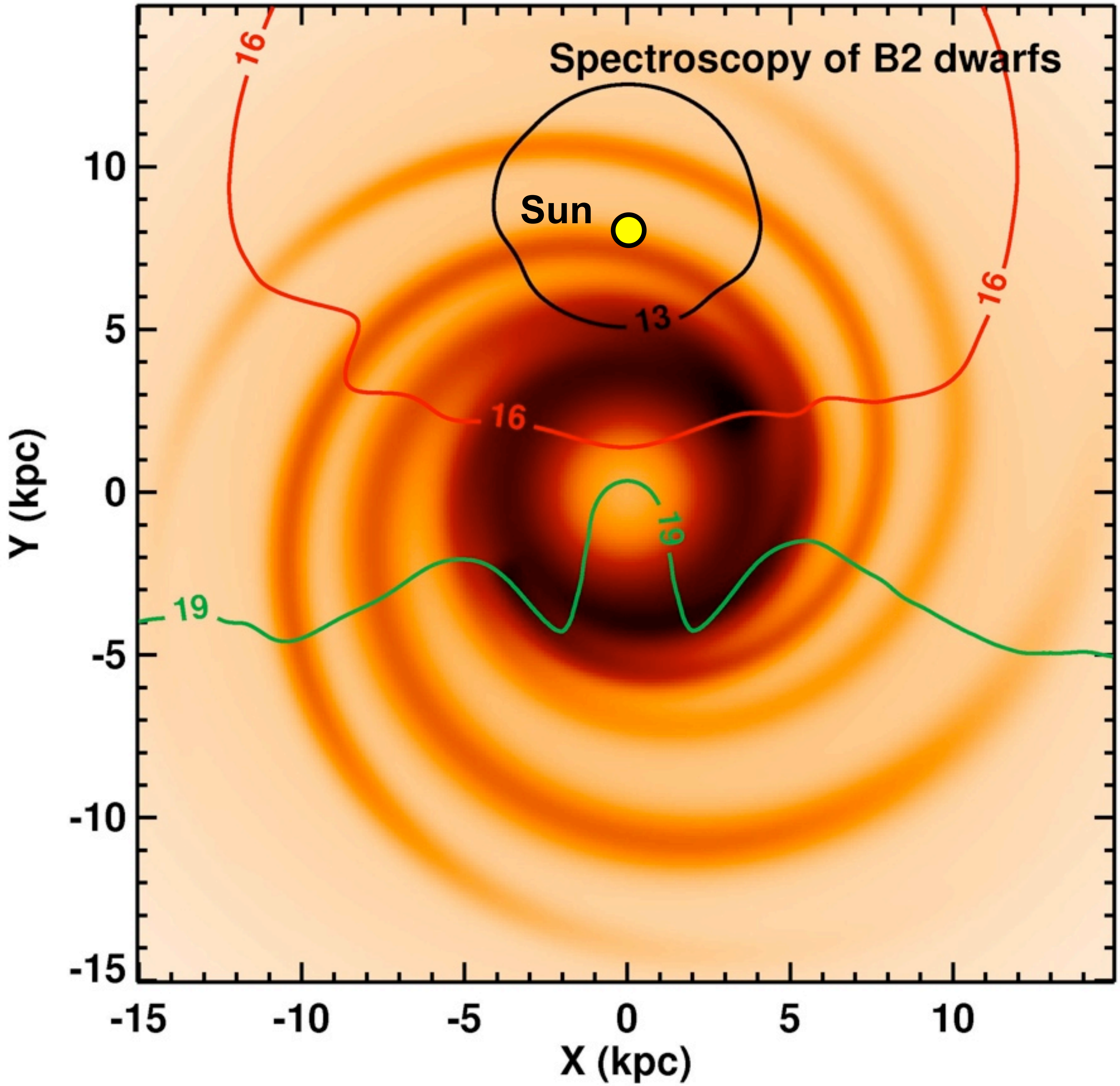
Studies of young clusters in the E-ELT era

- Study of clusters: need to know ages and distances.
- Quantitative spectroscopy of mid-type B stars:

★ accurate spectrophotometric distances.
(remove dependence on Galactic rotation curve)

★ Accurate measure of main-sequence turn-offs.
(ages)

- SNR > 150, R > 4000, T_{exp} < 1hr ...


Spectroscopy of B2 dwarfs
Sun
13
16
16
16
19
19
Y (kpc)
X (kpc)
10
5
0
-5
-10
-15
-15
-10
-5
0
5
10

Summary

Summary

- Young clusters can be used to study massive stellar evolution:
  - ★ direct links between stellar mass, SN progenitors, and post-SN objects.
  - ★ Arches cluster: not all massive stars pass through an LBV-like phase..?
  - ★ RSGC1, Cl1900+14: Stars with $M_{init} \lesssim 18 M_{\odot}$ produce neutron stars, and *can* produce magnetars.

Summary

- Young clusters can be used to study massive stellar evolution:
  - ★ direct links between stellar mass, SN progenitors, and post-SN objects.
  - ★ Arches cluster: not all massive stars pass through an LBV-like phase..?
  - ★ RSGC1, Cl1900+14: Stars with $M_{init} \leq 18 M_{\odot}$ produce neutron stars, and *can* produce magnetars.
- With an ELT:
  - ★ Could do quantitative studies of massive young clusters throughout entire Galaxy.
  - ★ Could get accurate distances to clusters in the inner Galaxy, removing dependance on Galactic rotation curve.