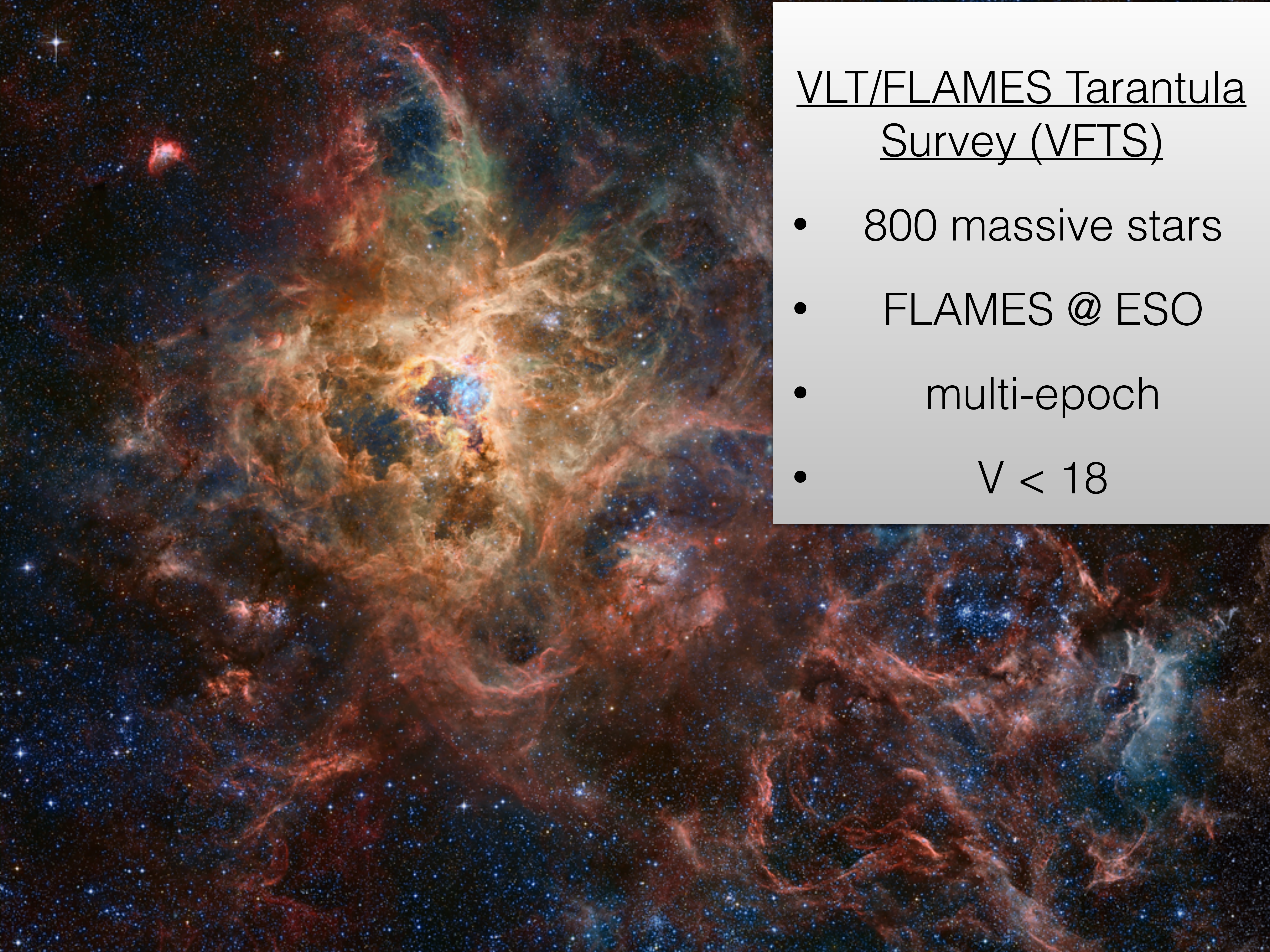
The Tarantula Massive Binaries Monitoring: the double-lined massive systems

Laurent Mahy

H. Sana - L. A. Almeida - M. Abdul-Masih - A. de Koter - N. Langer - TMBM team

KU LEUVEN



VLT/FLAMES Tarantula Survey (VFTS)

- 800 massive stars
- FLAMES @ ESO
- multi-epoch
- V < 18

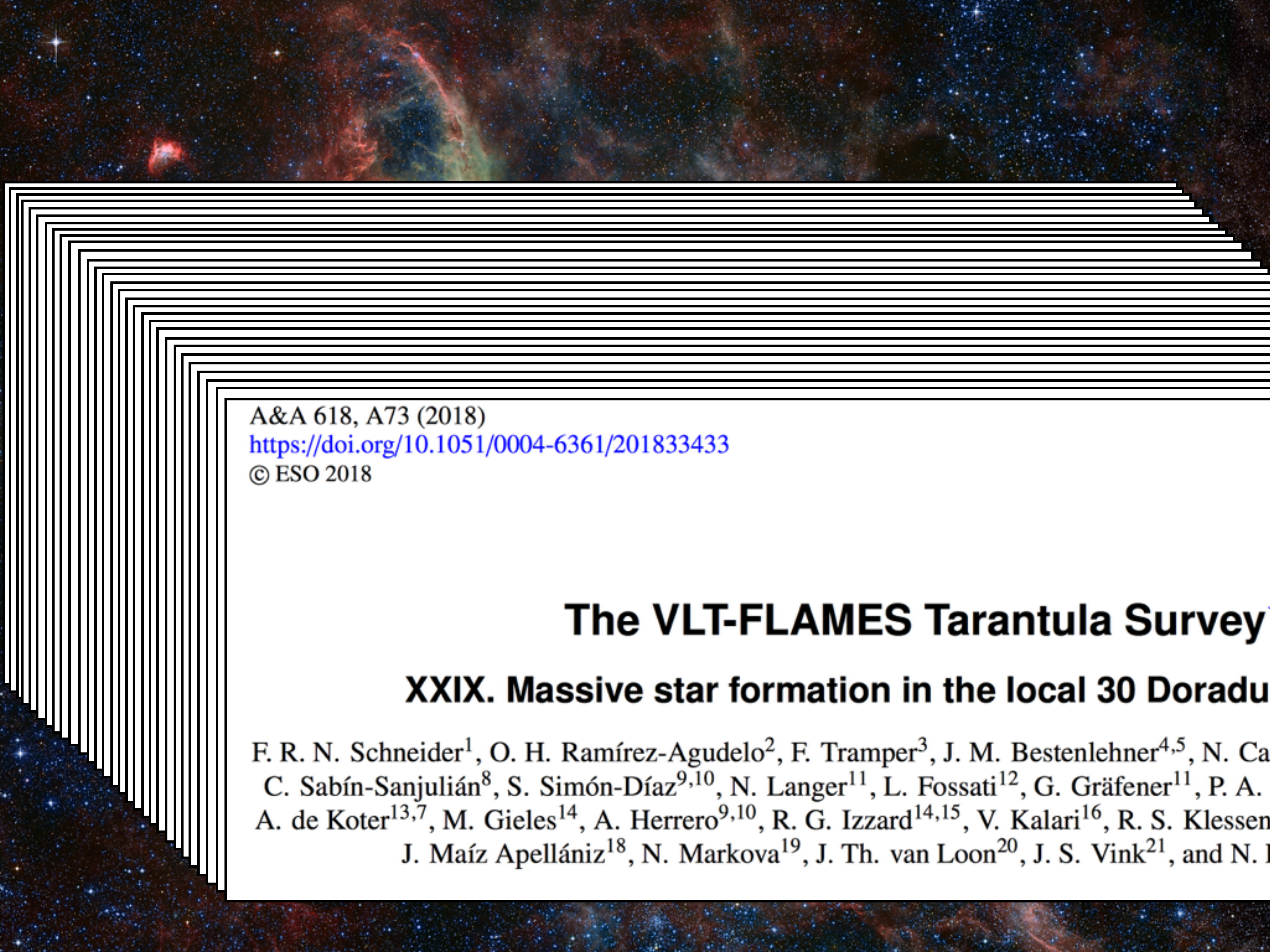
A&A 530, A108 (2011)
DOI: 10.1051/0004-6361/201116782

Astronomy & Astrophysics

The VLT-FLAMES Tarantula Survey

I. Introduction and observational overview[★]

C. J. Evans[1], W. D. Taylor[2], V. Hénault-Brunet[2], H. Sana[3], A. de Koter[3,4], S. Simón-Díaz[5,6], G. Carraro[7], T. Bagnoli[3], N. Bastian[8,9], J. M. Bestenlehner[10], A. Z. Bonanos[11], E. Bressert[9,12,13], I. Brott[4,14], M. A. Campbell[2], M. Cantiello[15], J. S. Clark[16], E. Costa[17], P. A. Crowther[18], S. E. de Mink[19,★★], E. Doran[18], P. L. Dufton[20], P. R. Dunstall[20], K. Friedrich[15], M. Garcia[5,6], M. Gieles[21], G. Gräfener[10], A. Herrero[5,6], I. D. Howarth[22], R. G. Izzard[15], N. Langer[15], D. J. Lennon[23], J. Maíz Apellániz[24,★★★], N. Markova[25], F. Najarro[26], J. Puls[27], O. H. Ramirez[3], C. Sabín-Sanjulián[5,6], S. J. Smartt[20], V. E. Stroud[16,28], J. Th. van Loon[29], J. S. Vink[10], and N. R. Walborn[19]



A&A 618, A73 (2018)
https://doi.org/10.1051/0004-6361/201833433

The VLT-FLAMES Tarantula Survey

XXIX. Massive star formation in the local 30 Doradu

F. R. N. Schneider[1], O. H. Ramírez-Agudelo[2], F. Tramper[3], J. M. Bestenlehner[4,5], N. Ca
C. Sabín-Sanjulián[8], S. Simón-Díaz[9,10], N. Langer[11], L. Fossati[12], G. Gräfener[11], P. A.
A. de Koter[13,7], M. Gieles[14], A. Herrero[9,10], R. G. Izzard[14,15], V. Kalari[16], R. S. Klessen
J. Maíz Apellániz[18], N. Markova[19], J. Th. van Loon[20], J. S. Vink[21], and N.

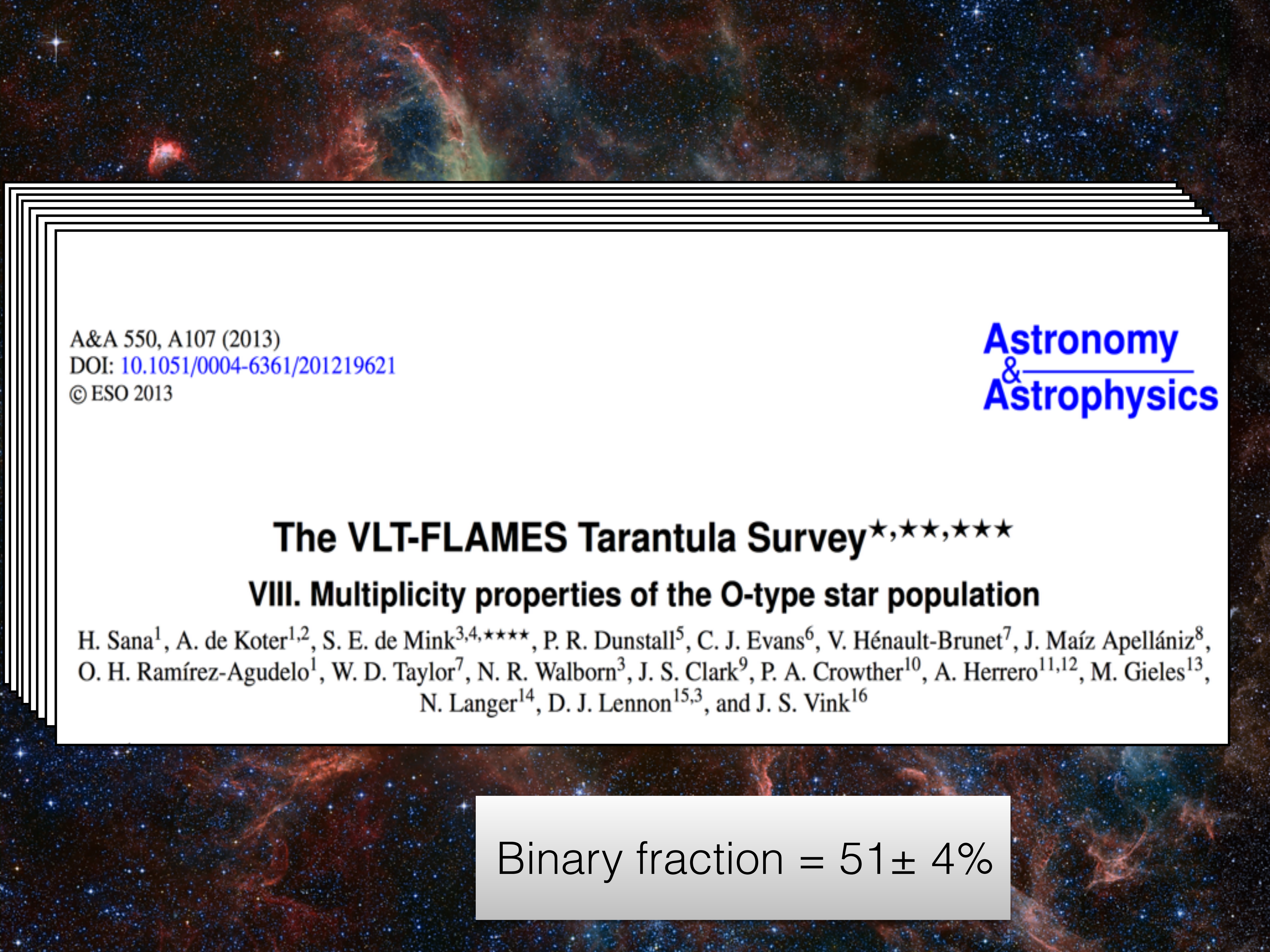
A&A 550, A107 (2013)
DOI: 10.1051/0004-6361/201219621

Astronomy & Astrophysics

The VLT-FLAMES Tarantula Survey⋆,⋆⋆,⋆⋆⋆

VIII. Multiplicity properties of the O-type star population

H. Sana[1], A. de Koter[1,2], S. E. de Mink[3,4,⋆⋆⋆⋆], P. R. Dunstall[5], C. J. Evans[6], V. Hénault-Brunet[7], J. Maíz Apellániz[8], O. H. Ramírez-Agudelo[1], W. D. Taylor[7], N. R. Walborn[3], J. S. Clark[9], P. A. Crowther[10], A. Herrero[11,12], M. Gieles[13], N. Langer[14], D. J. Lennon[15,3], and J. S. Vink[16]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Astronomy & Astrophysics

The VLT-FLAMES Tarantula Survey⋆,⋆⋆,⋆⋆⋆

VIII. Multiplicity properties of the O-type star population

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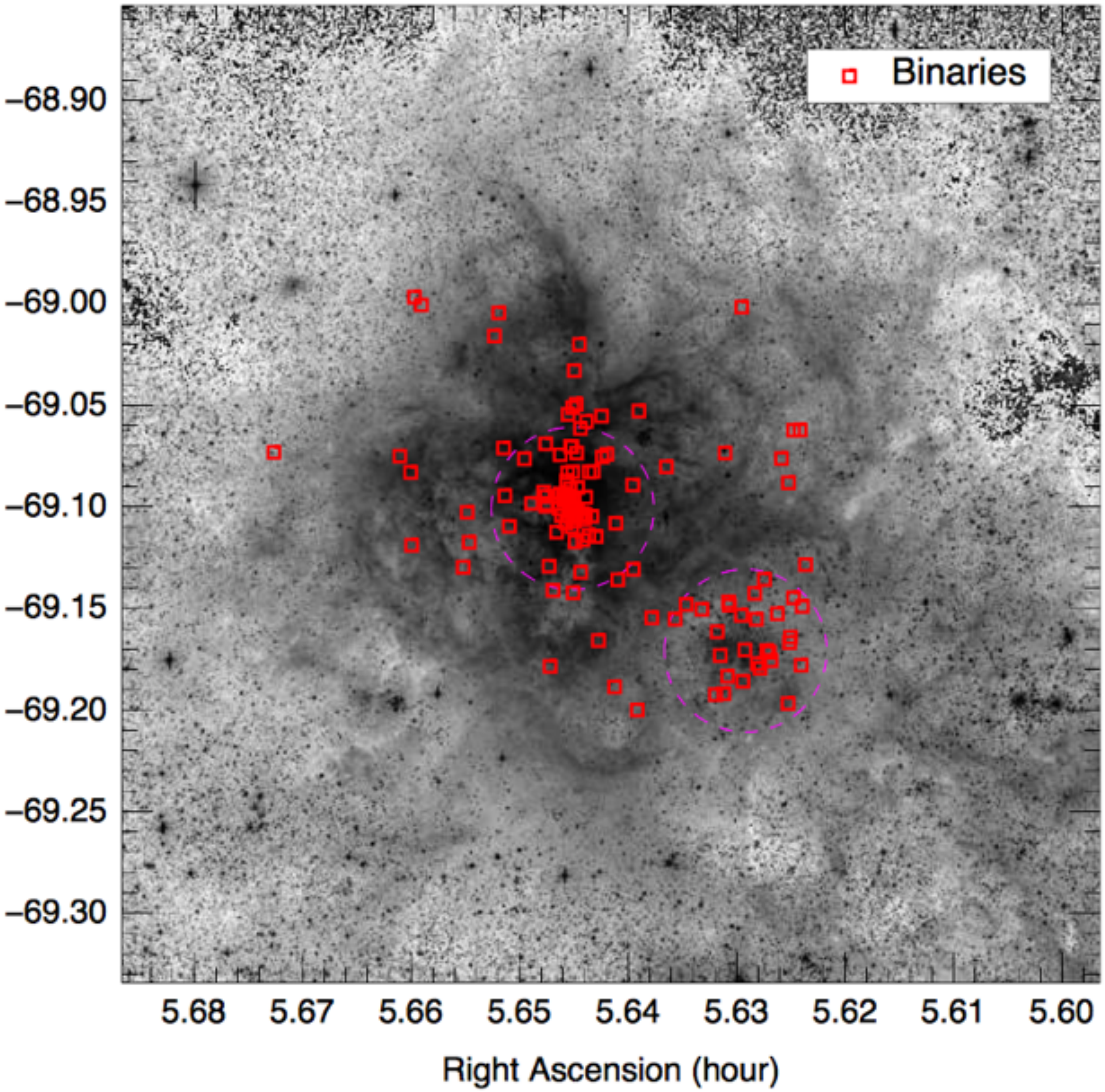
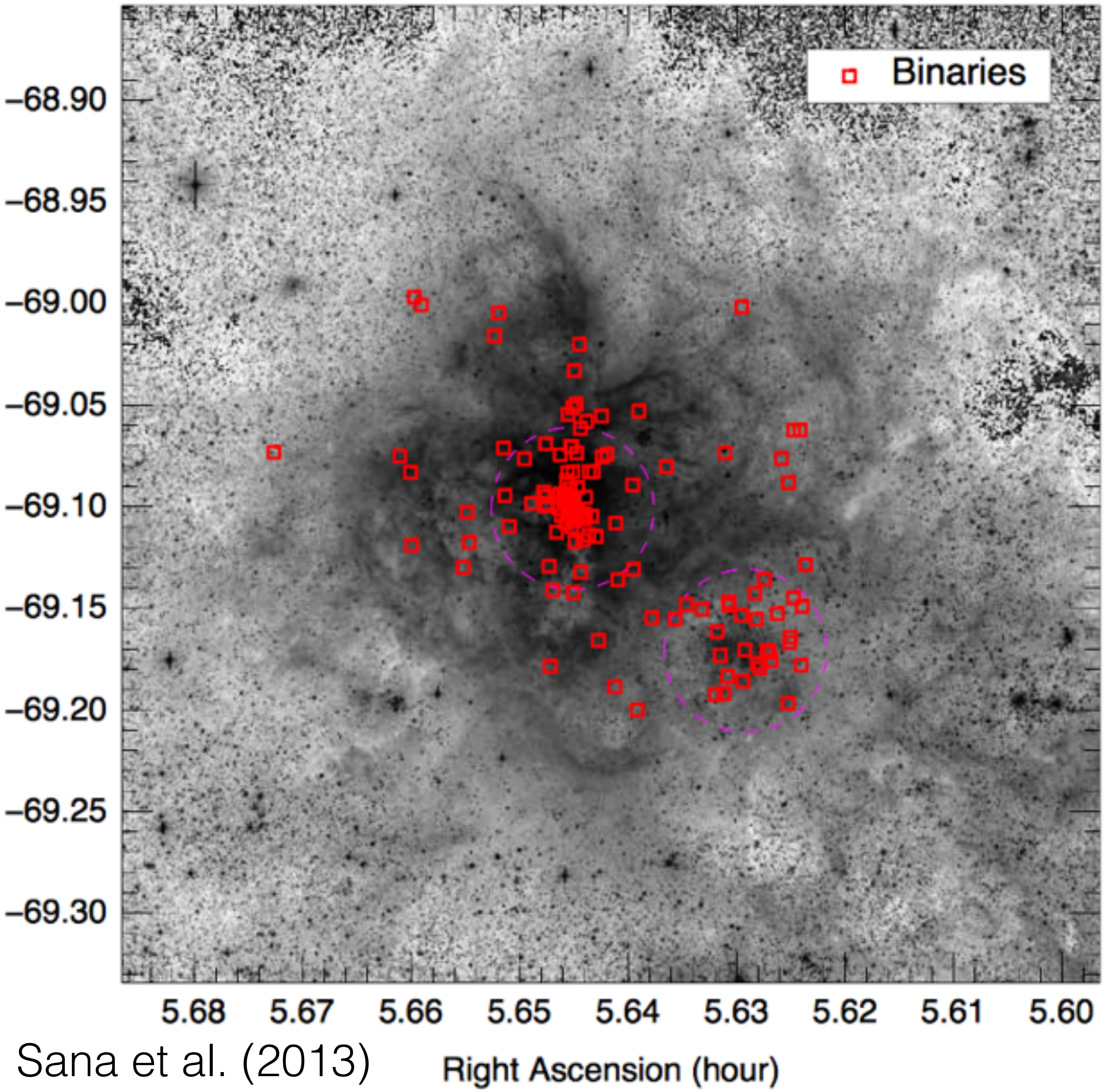


Tarantula Massive Binary Monitoring (TMBM)

- 102 massive stars
- FLAMES @ ESO
- 32 multi-epoch
- [3950 - 4560] A
- 93 O-type binaries
- 7 B-type binaries
- 2 WNh (Shenar et al. 2017)



Sana et al. (2013)

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Almeida et al. (2017) provided orbital solutions for:
51 SB1s and 31 SB2s

Goals

- **Characterize** the physical and chemical properties
- better **understand** the impact of binary interaction on the evolution of massive stars

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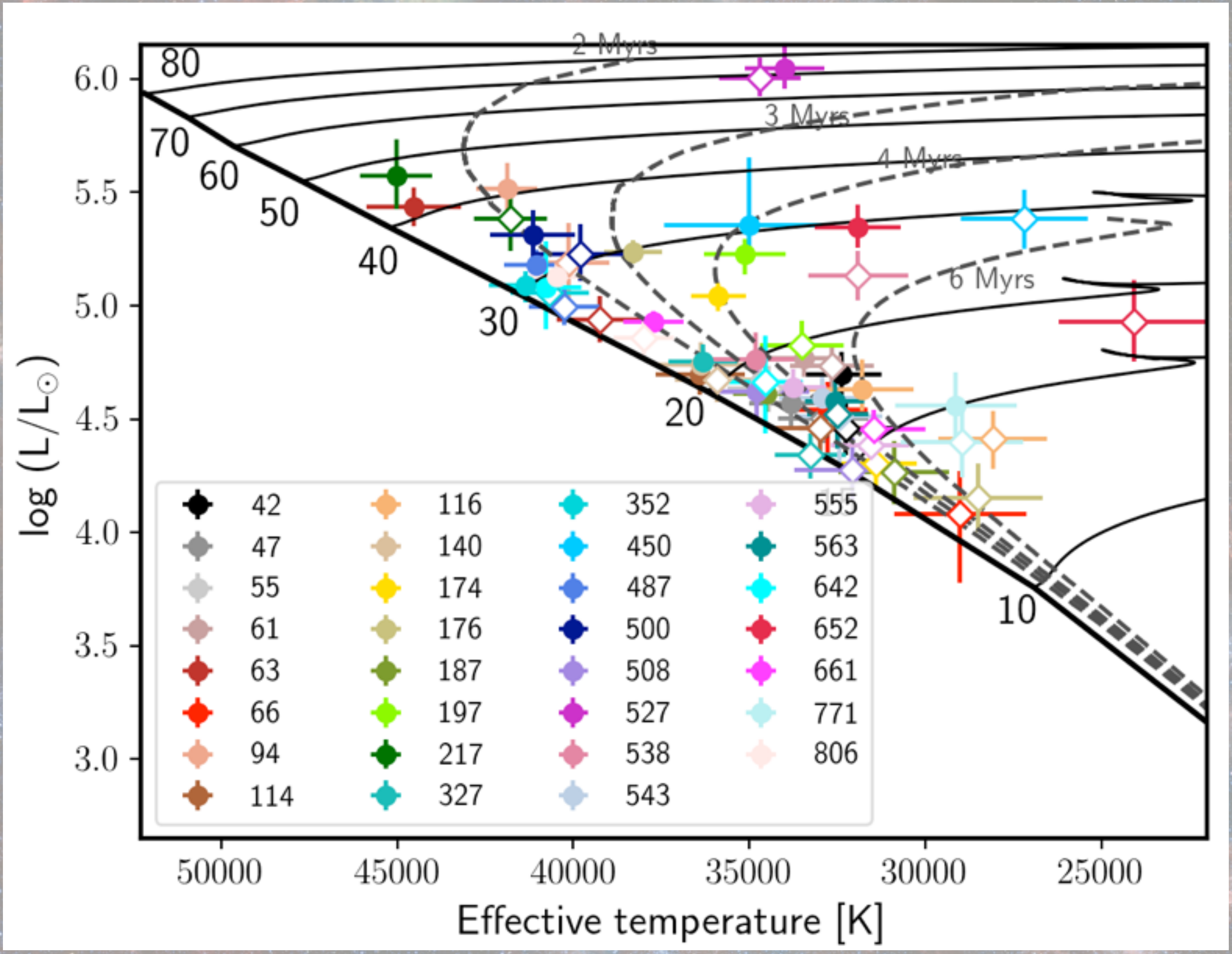
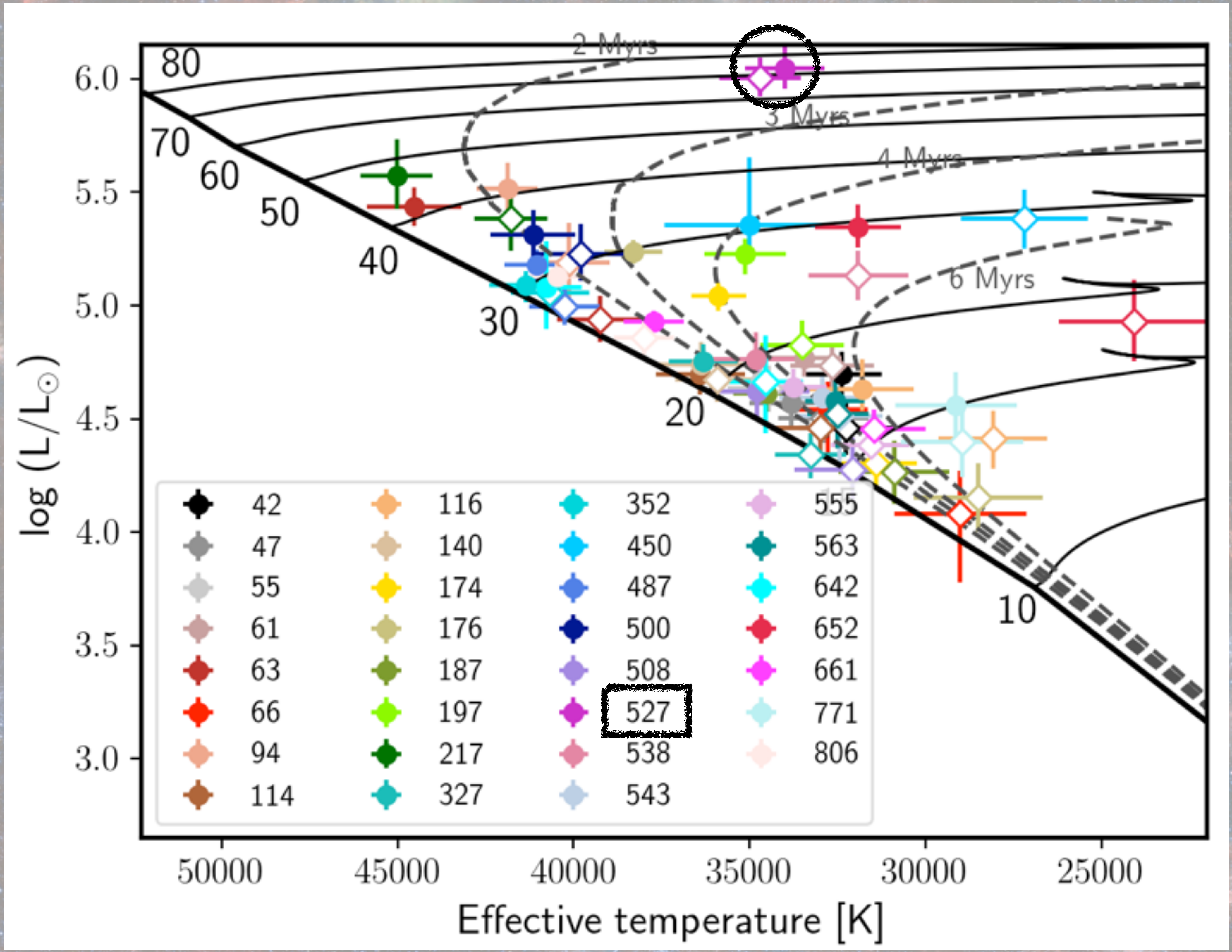
Methodology

- **Spectroscopy** for 31 SB2s + **Photometry** for 13 SB2s
- Fourier spectral **disentangling** (Simon & Sturm 1994, Ilijic et al. 2004)
- **CMFGEN** atmosphere fitting (Hillier & Miller 1998)

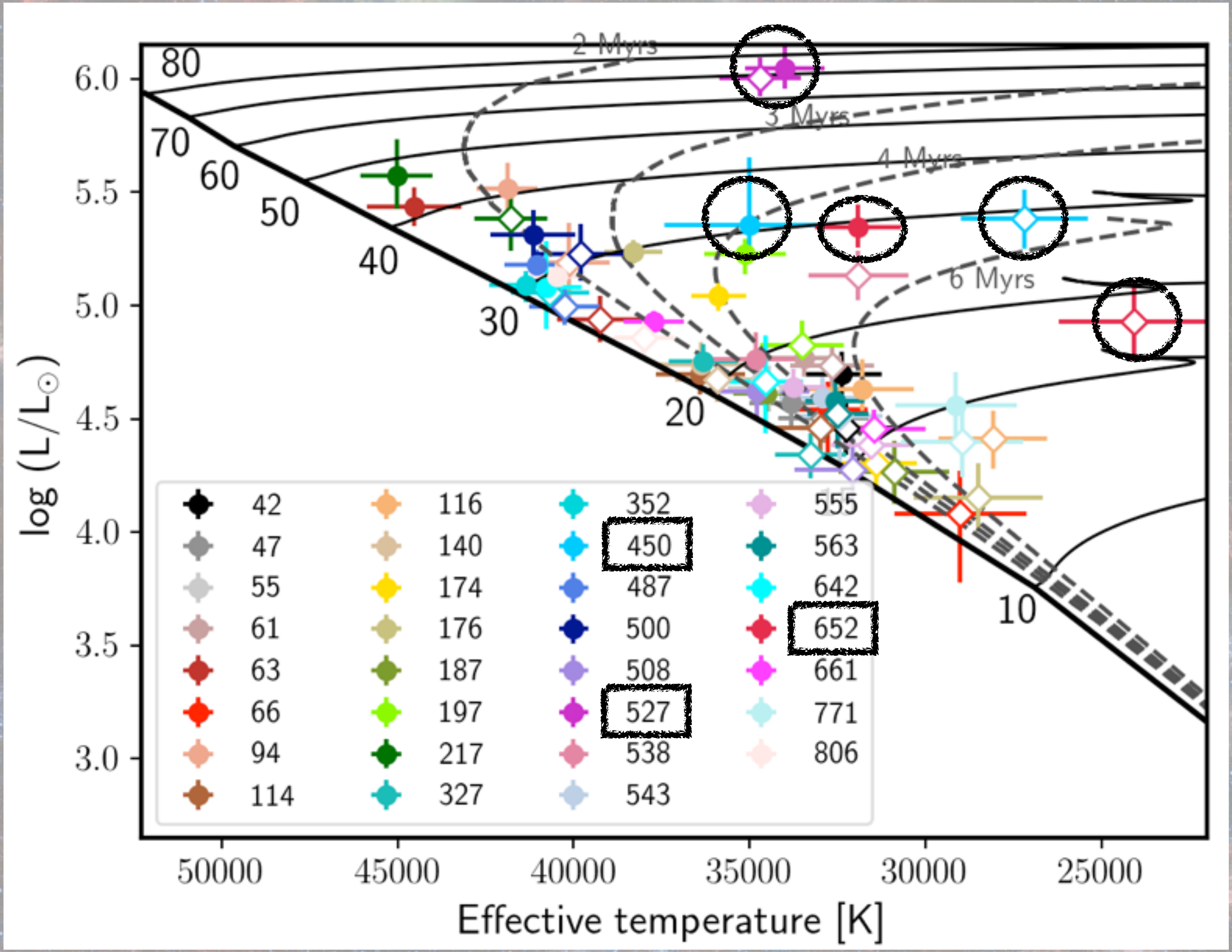
Hertzsprung-Russell diagram



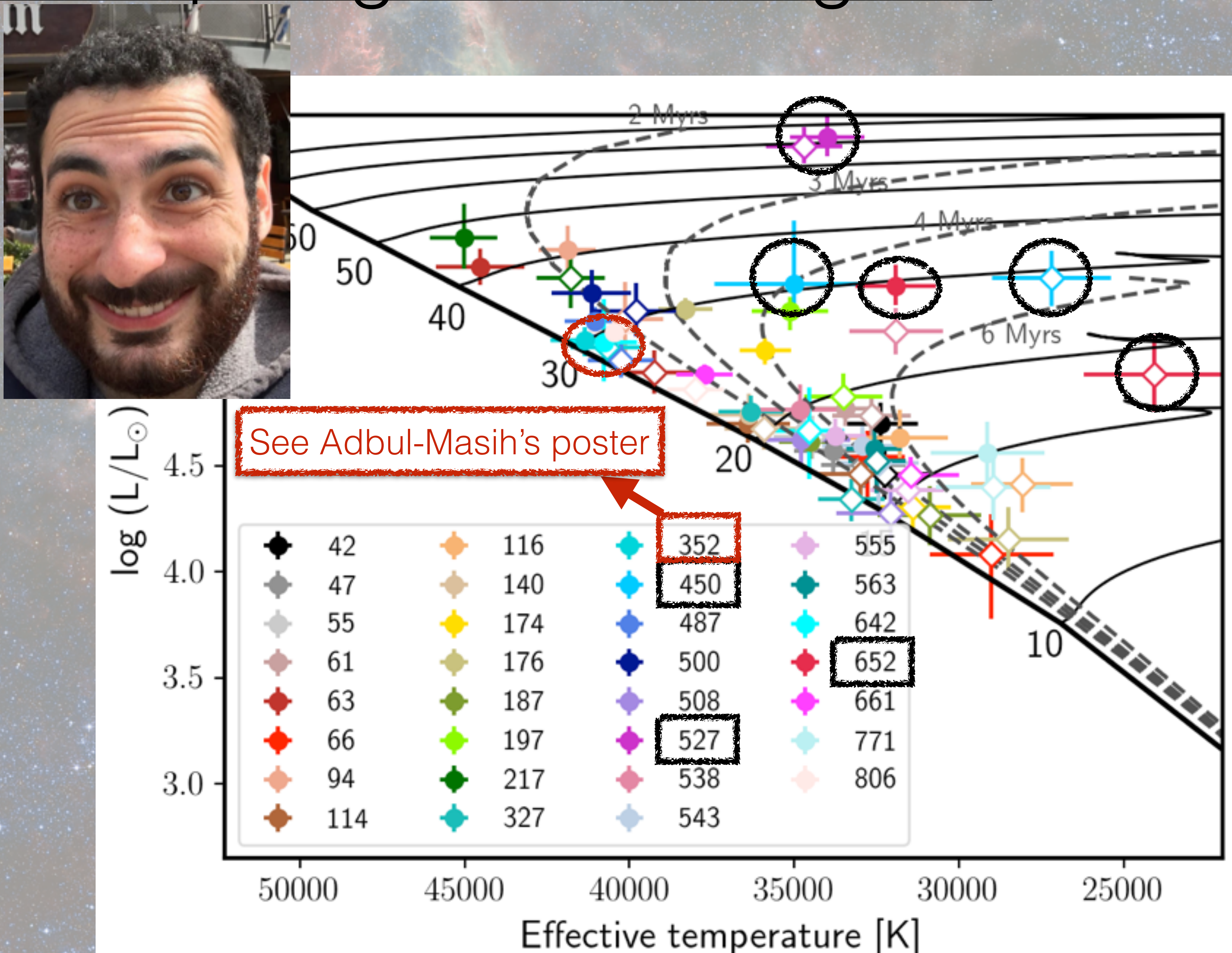
Hertzsprung-Russell diagram

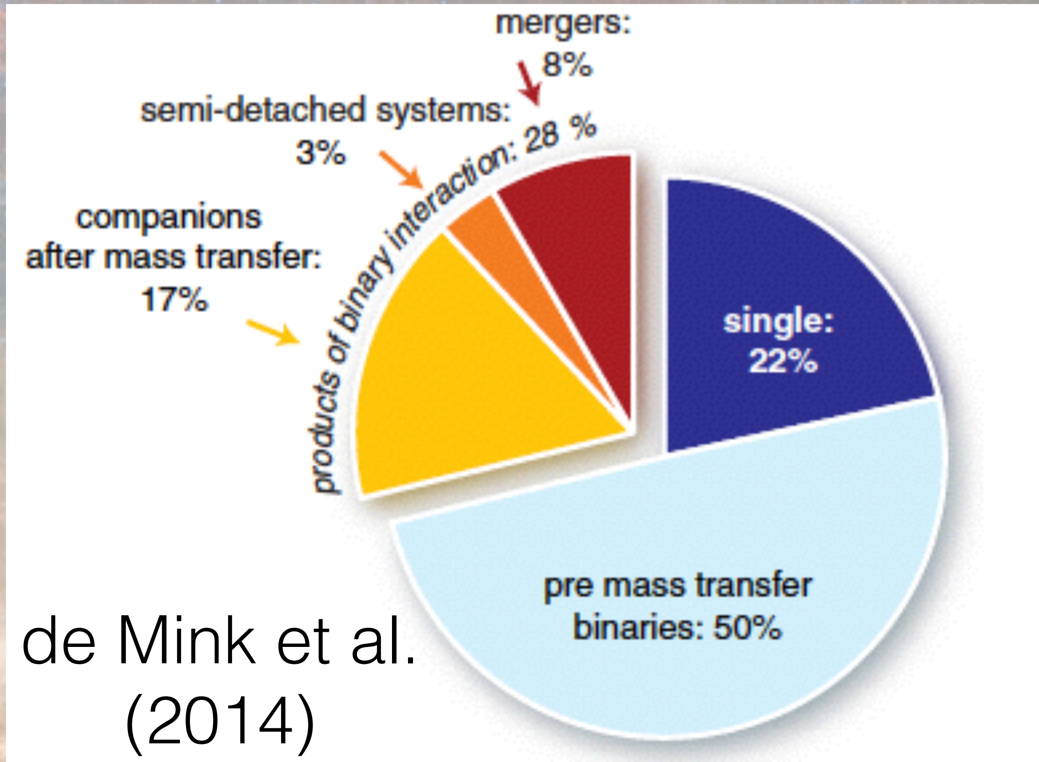


Hertzsprung-Russell diagram



Hertzsprung-Russell diagram

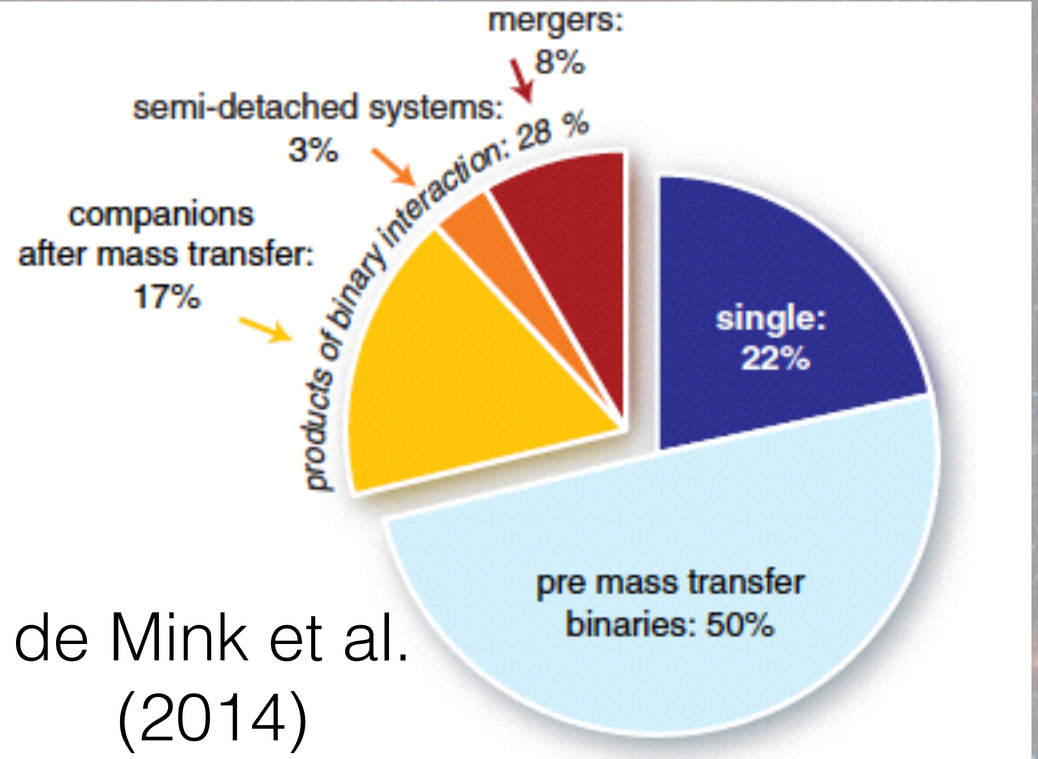




de Mink et al. (2014)

From de Mink et al. (2014), assuming 100% binaries:

- 71% of pre mass transfer
- 24% of after mass transfer
- 5% of semi-detached systems



de Mink et al. (2014)

From de Mink et al. (2014), assuming 100% binaries:

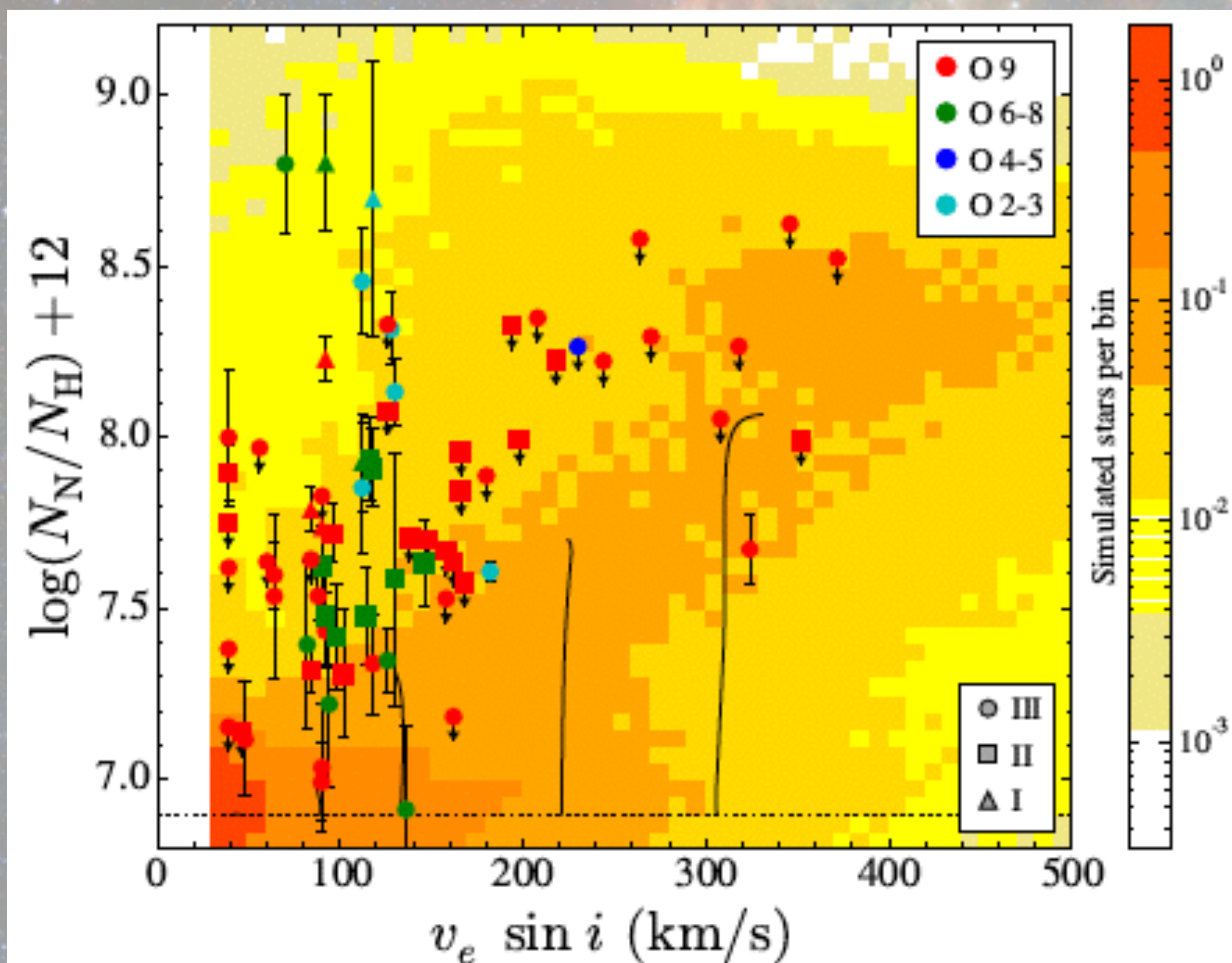
- 71% of pre mass transfer
- 24% of after mass transfer
- 5% of semi-detached systems

From our sample:

- 23 pre mass transfer (~ 74%)
- 6 semi-detached/mass transfer (~ 19%)
- 2 (over-)contact systems (~ 7%)

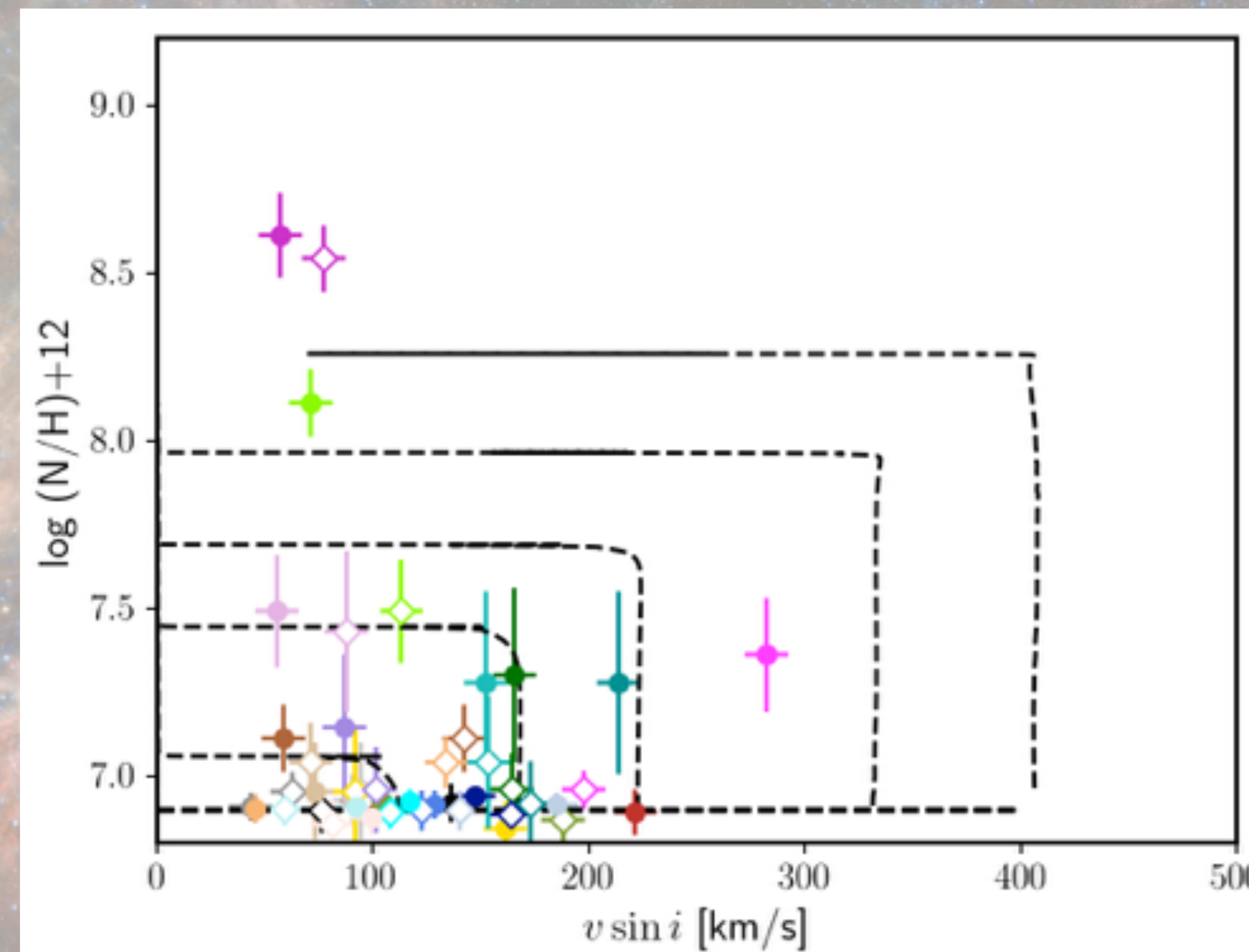
Rotational mixing

Single giants/supergiants



Grin et al. (2017)

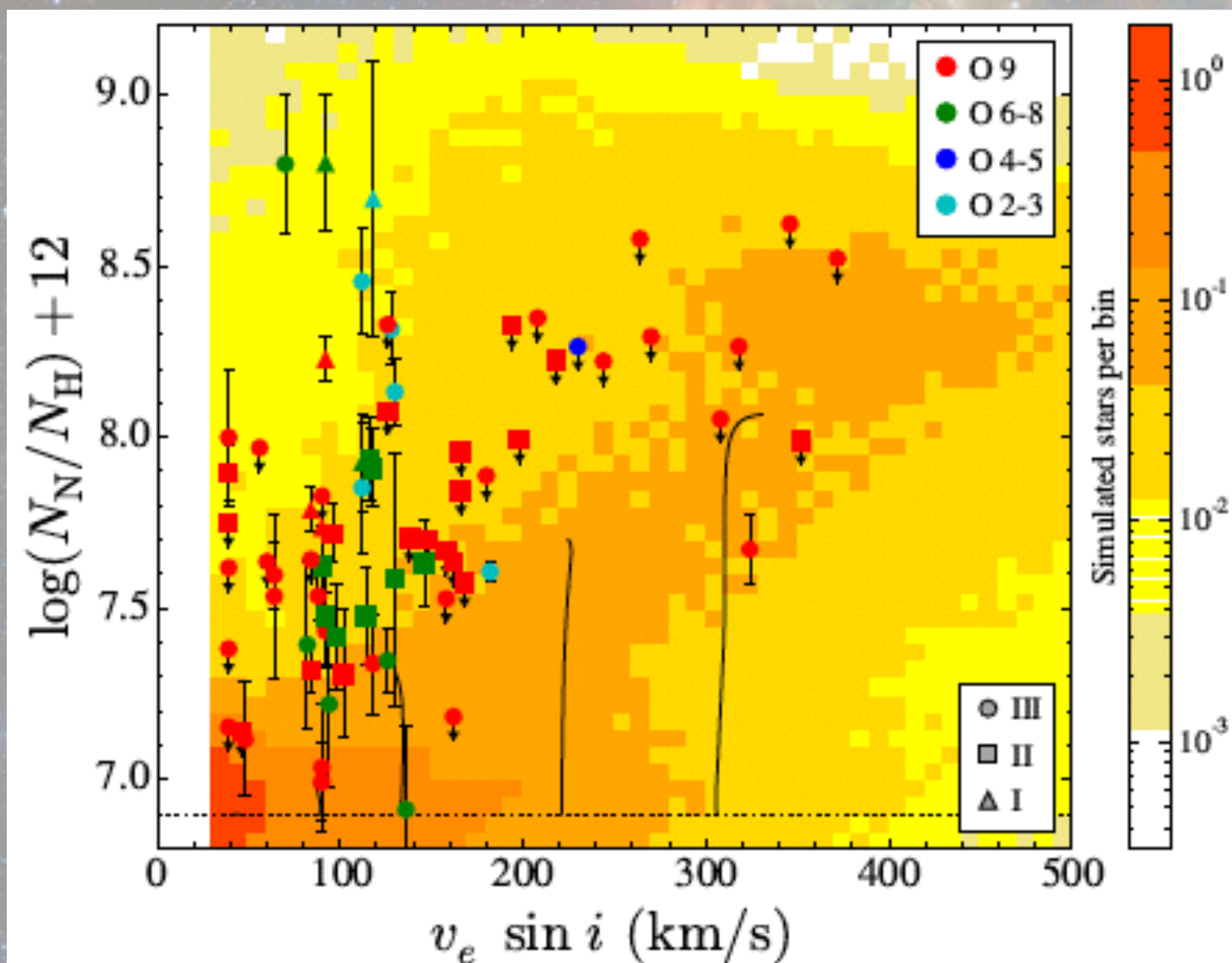
Detached binaries



Mahy et al. (in prep.)

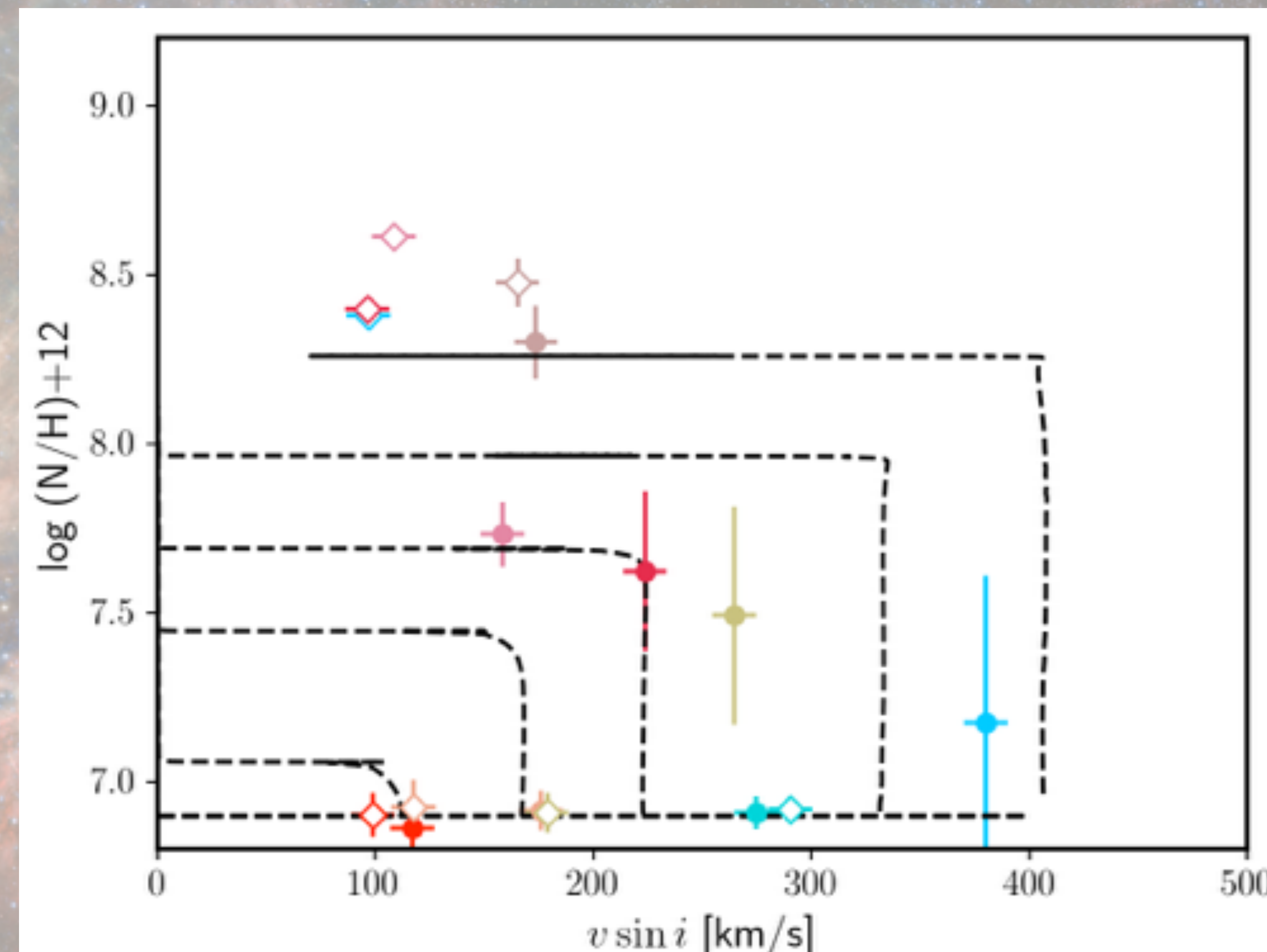
Rotational mixing

Single giants/supergiants



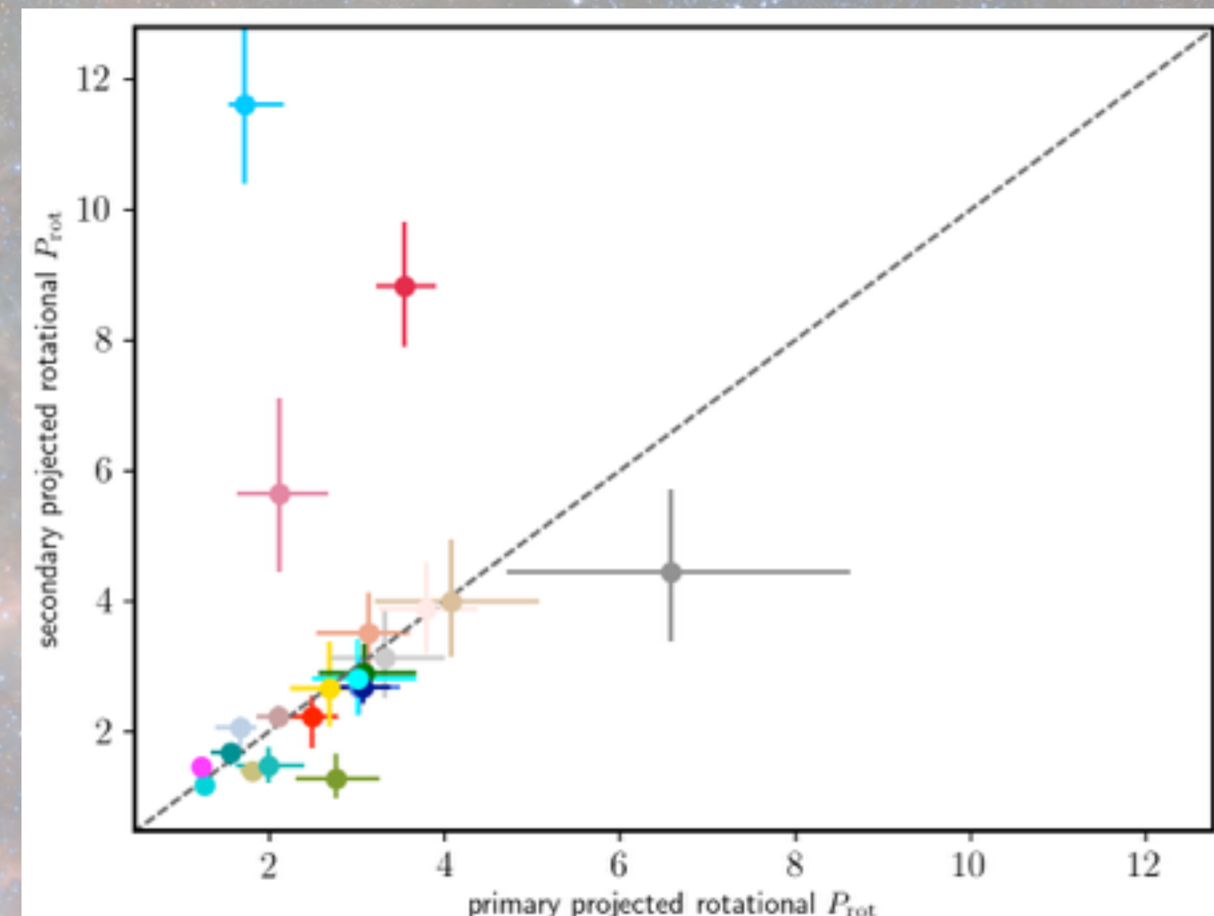
Grin et al. (2017)

Interacting binaries

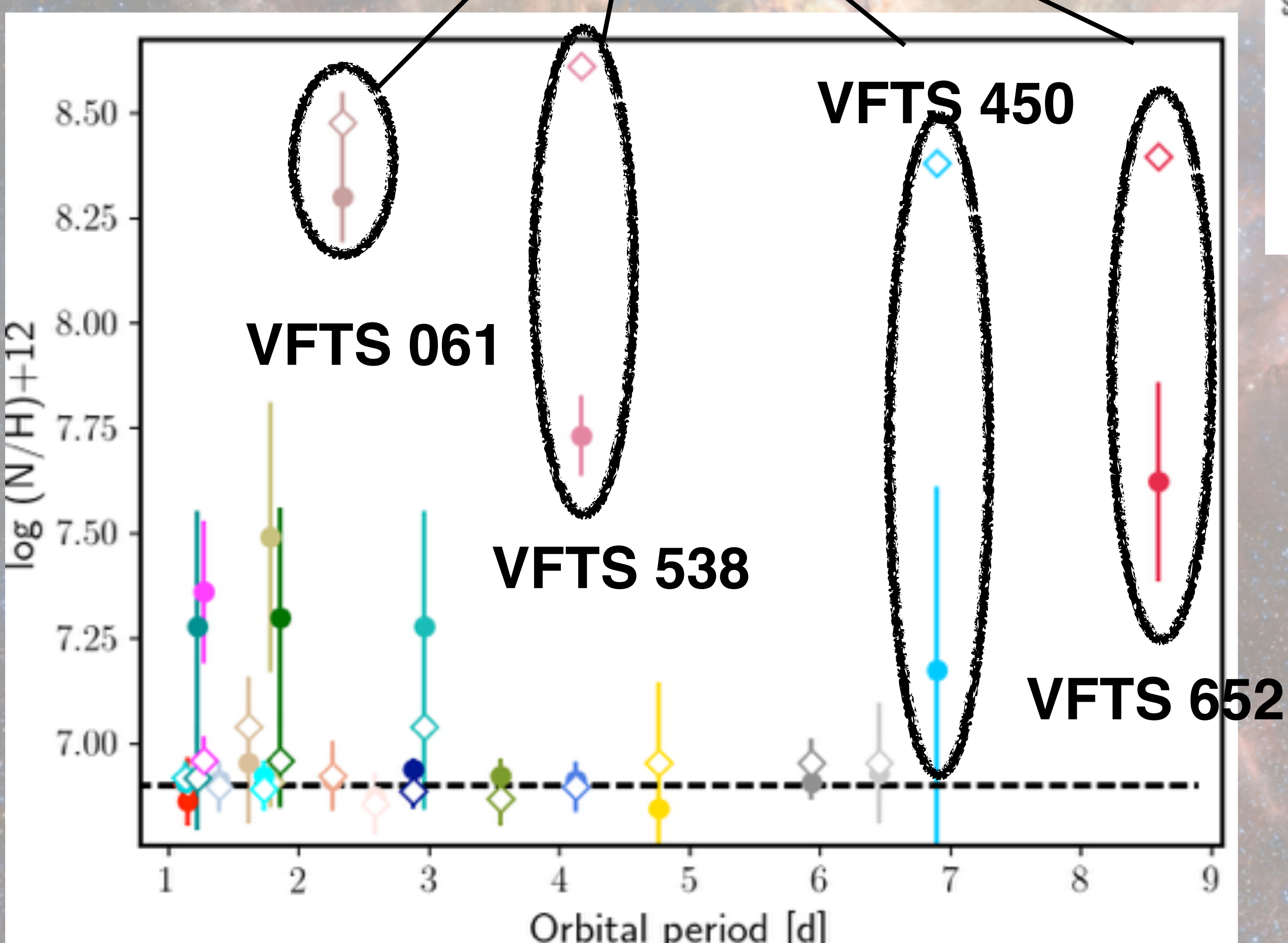


Mahy et al. (in prep.)

Tidal mixing & Mass transfer

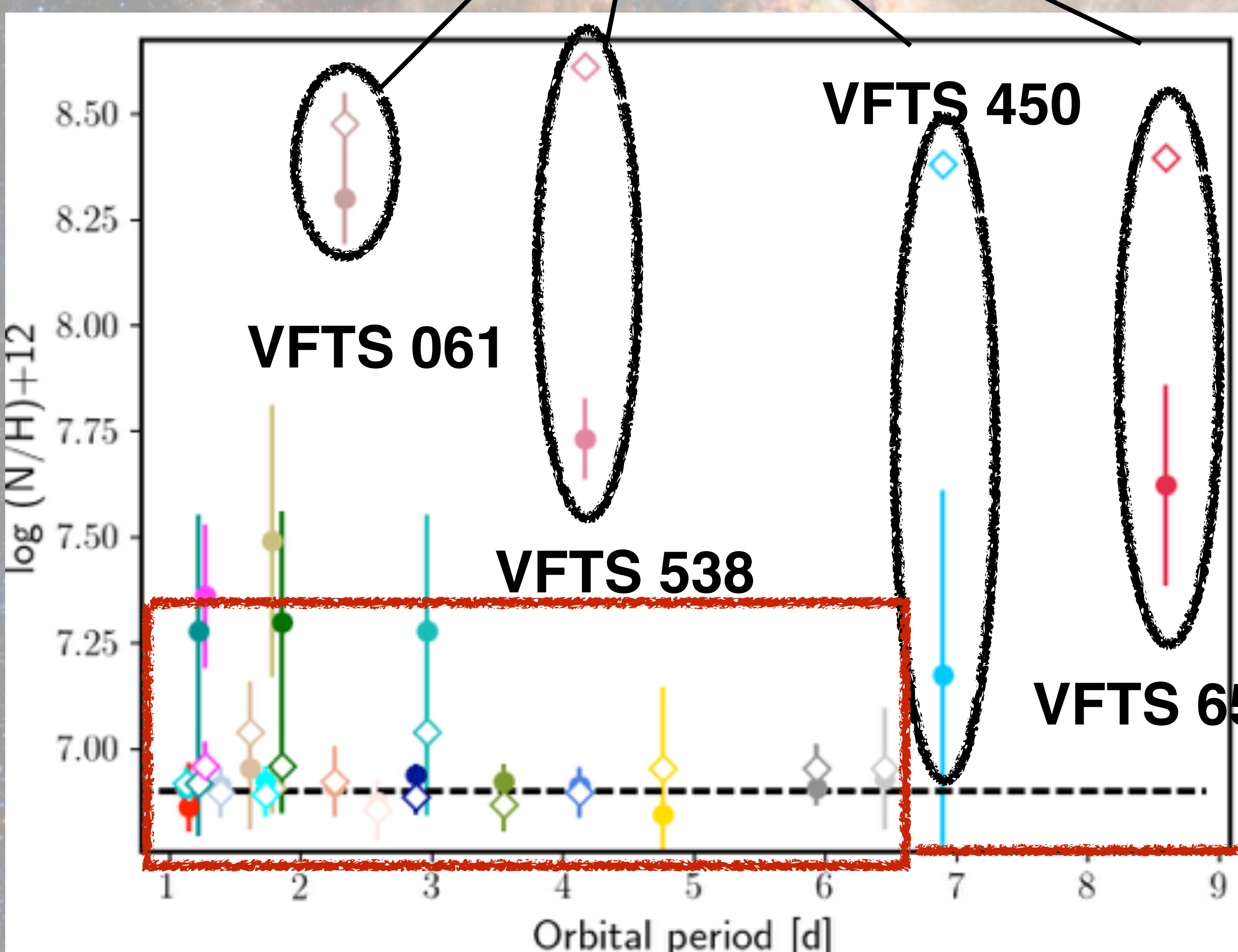


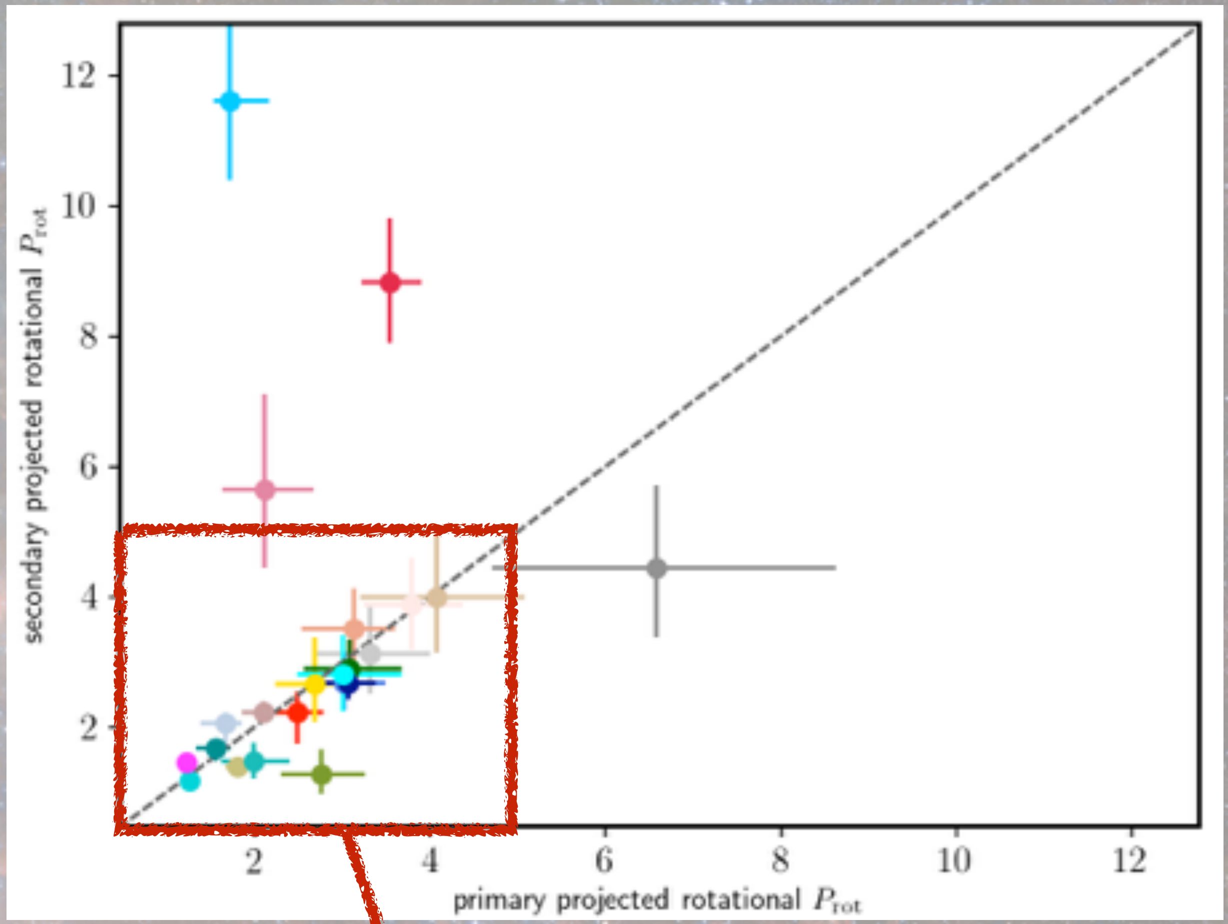
MASS TRANSFER



Tidal mixing & Mass transfer

MASS TRANSFER



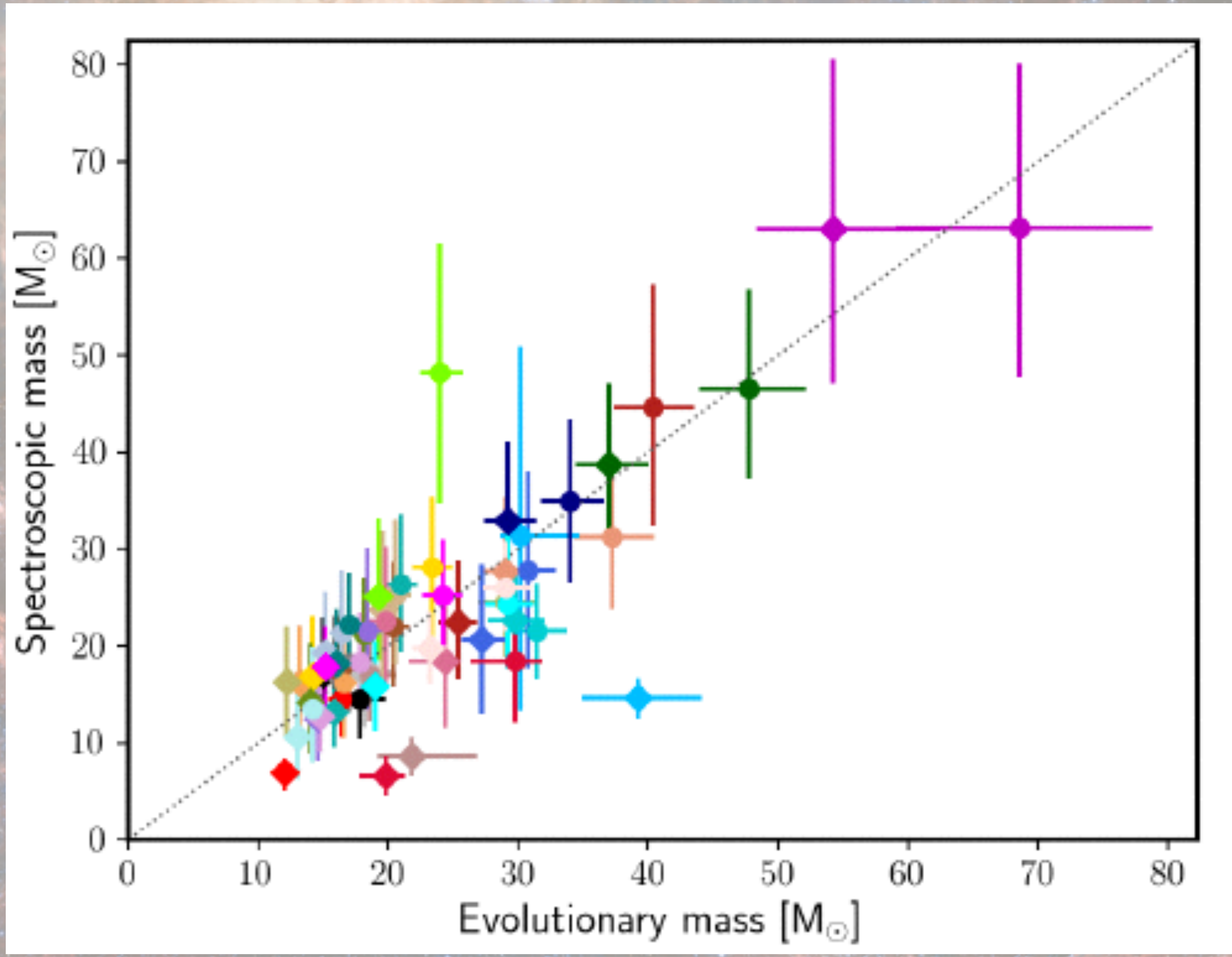


Rotational mixing
+ Tidal mixing

Mass discrepancy

Spectroscopical mass - surface gravity and radius
Evolutionary mass - coming from the BONN models

Brott et al. 2011, Kohler et al. 2015
BONNSAI (Schneider et al. 2014)

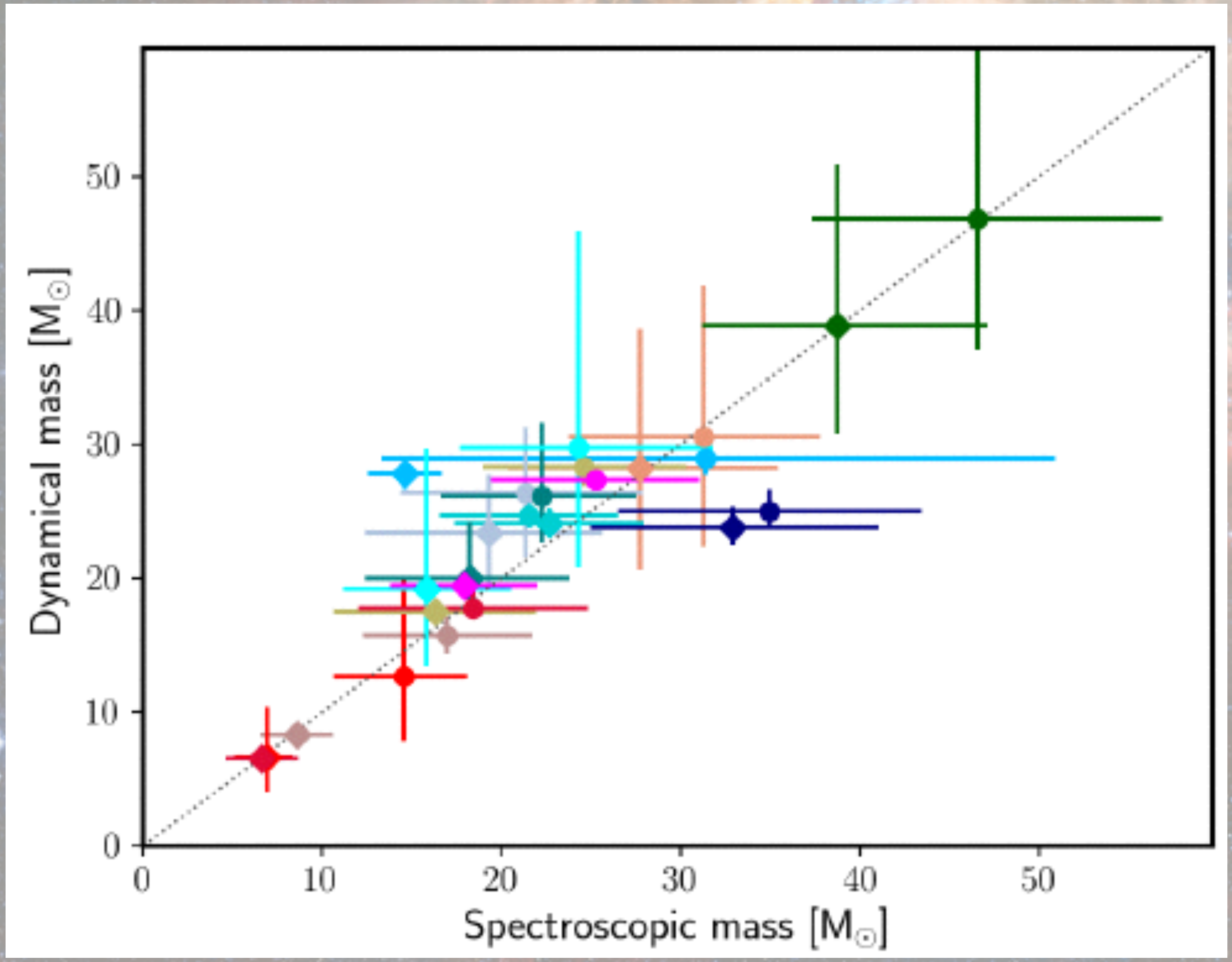


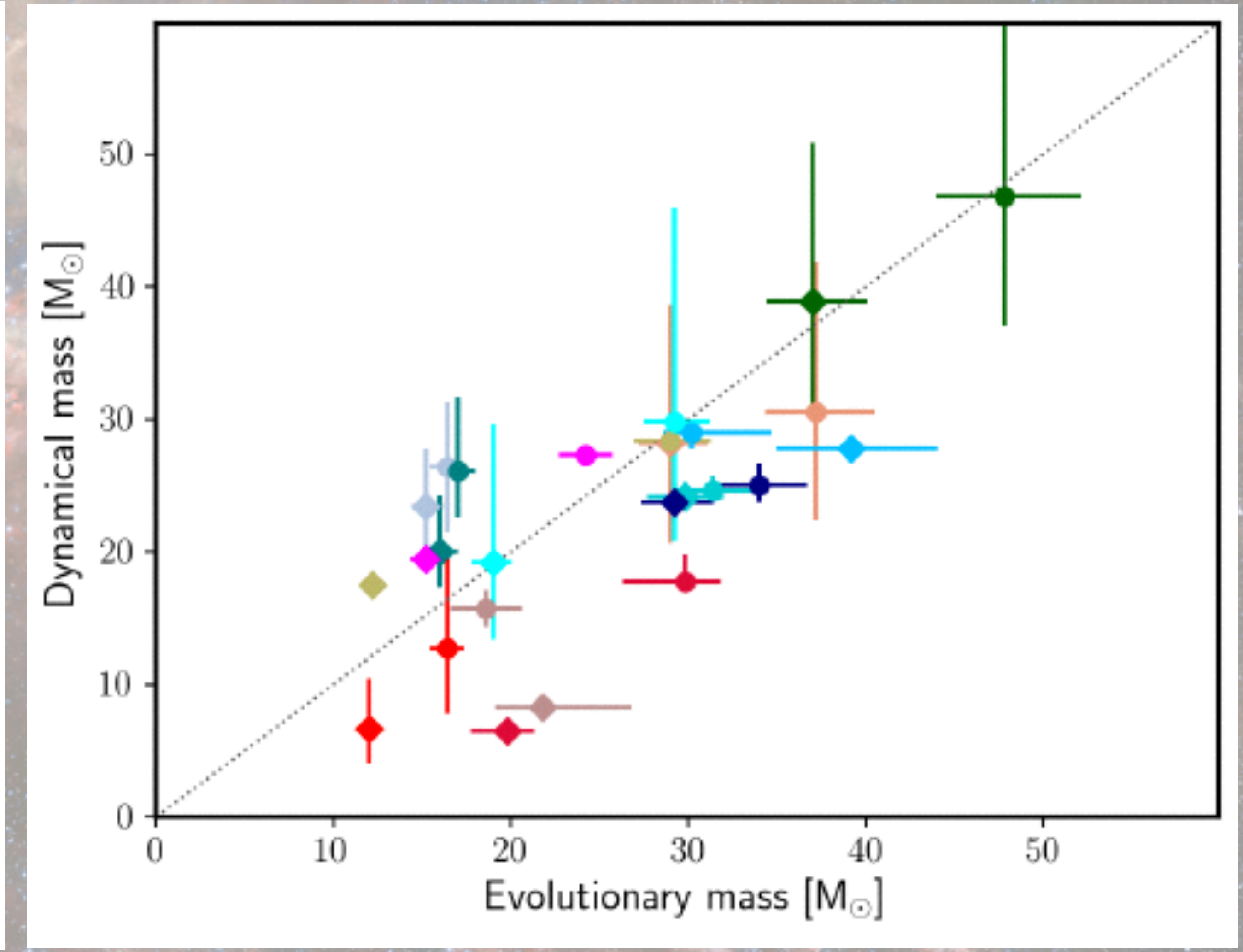
Mass discrepancy

Spectroscopical mass - surface gravity and radius
Evolutionary mass - coming from the models

+

Dynamical mass for 26 objects





Conclusions

- 31 massive systems at LMC metallicity
- 4 systems showing hints of mass transfer
- The effect of tides on chemical mixing is limited, whereas the mass transfer leads to the appearance of chemically processed material at the surface (also see Martins et al. 2017)
- No mass discrepancy is observed except for interacting systems
- Papers are in preparation - Mahy et al. - **Stay tuned !!!**

Thanks

Back up slides

Mass - Luminosity relation

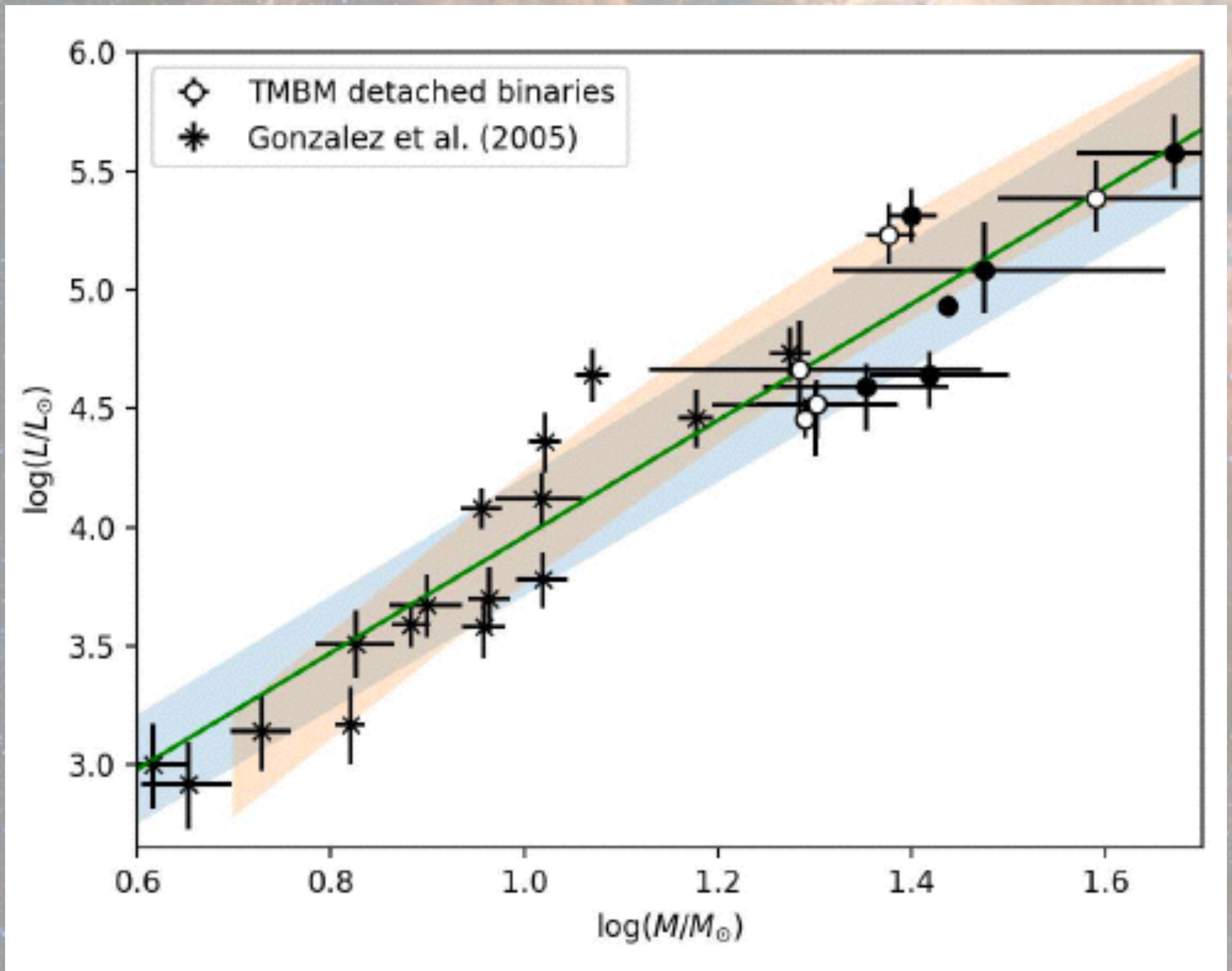
For 6 Msun < M < 50 Msun

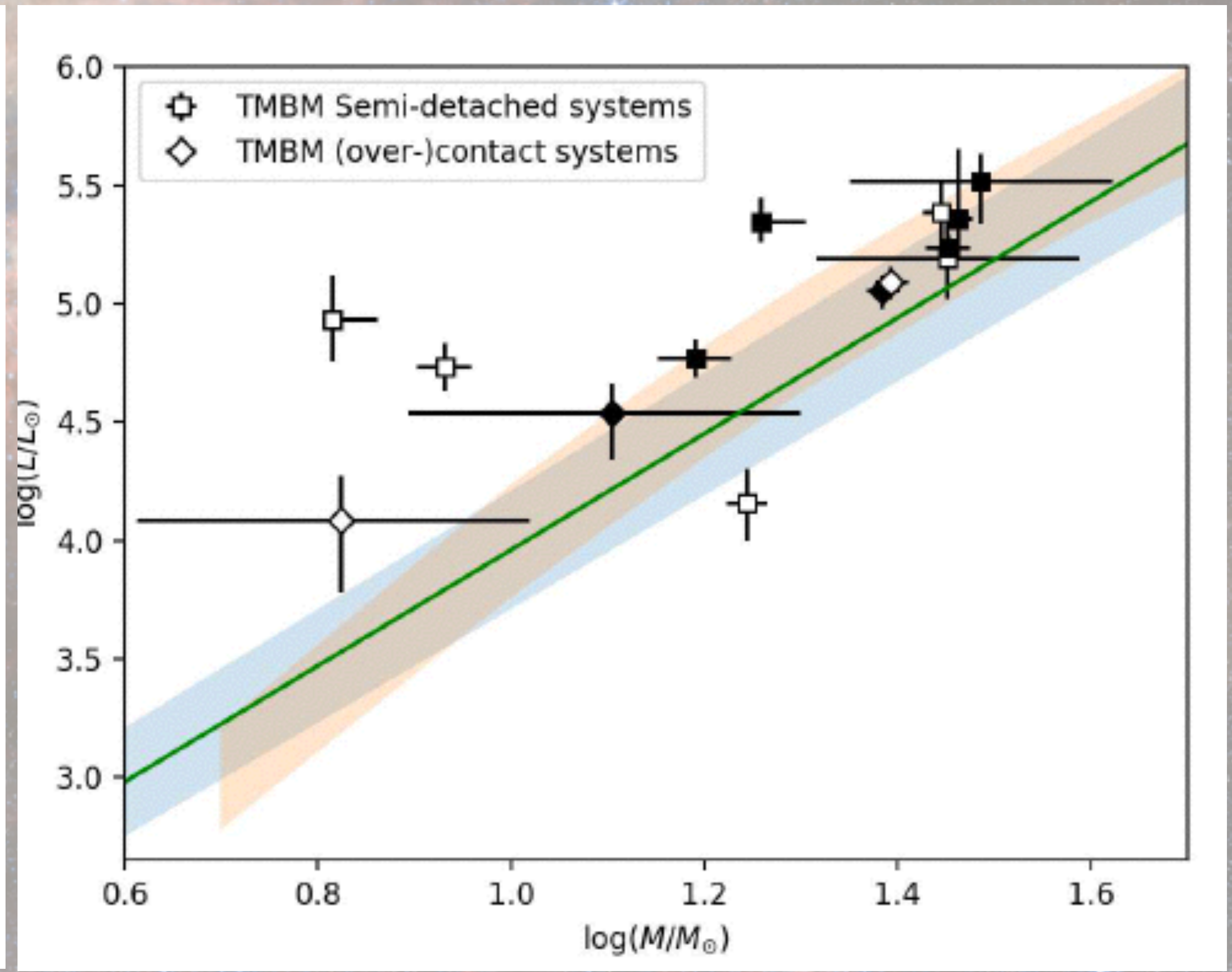
$$\log(L/L_\odot) = [2.45 \pm 0.04]\log(M/M_\odot) + [1.51 \pm 0.20]$$

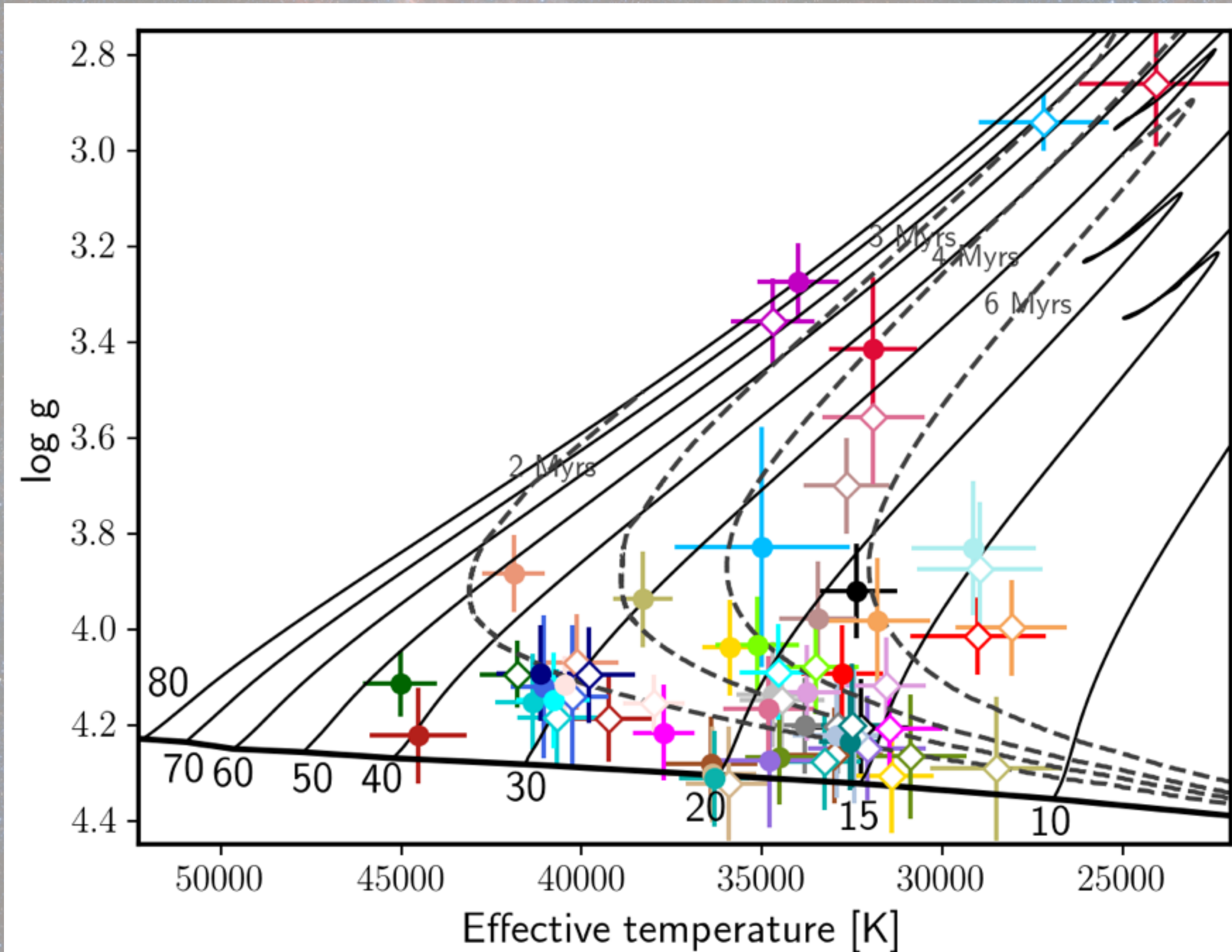
For 4 Msun < M < 20 Msun

$$\log(L/L_\odot) = 3.09\log(M/M_\odot) + 0.89.$$

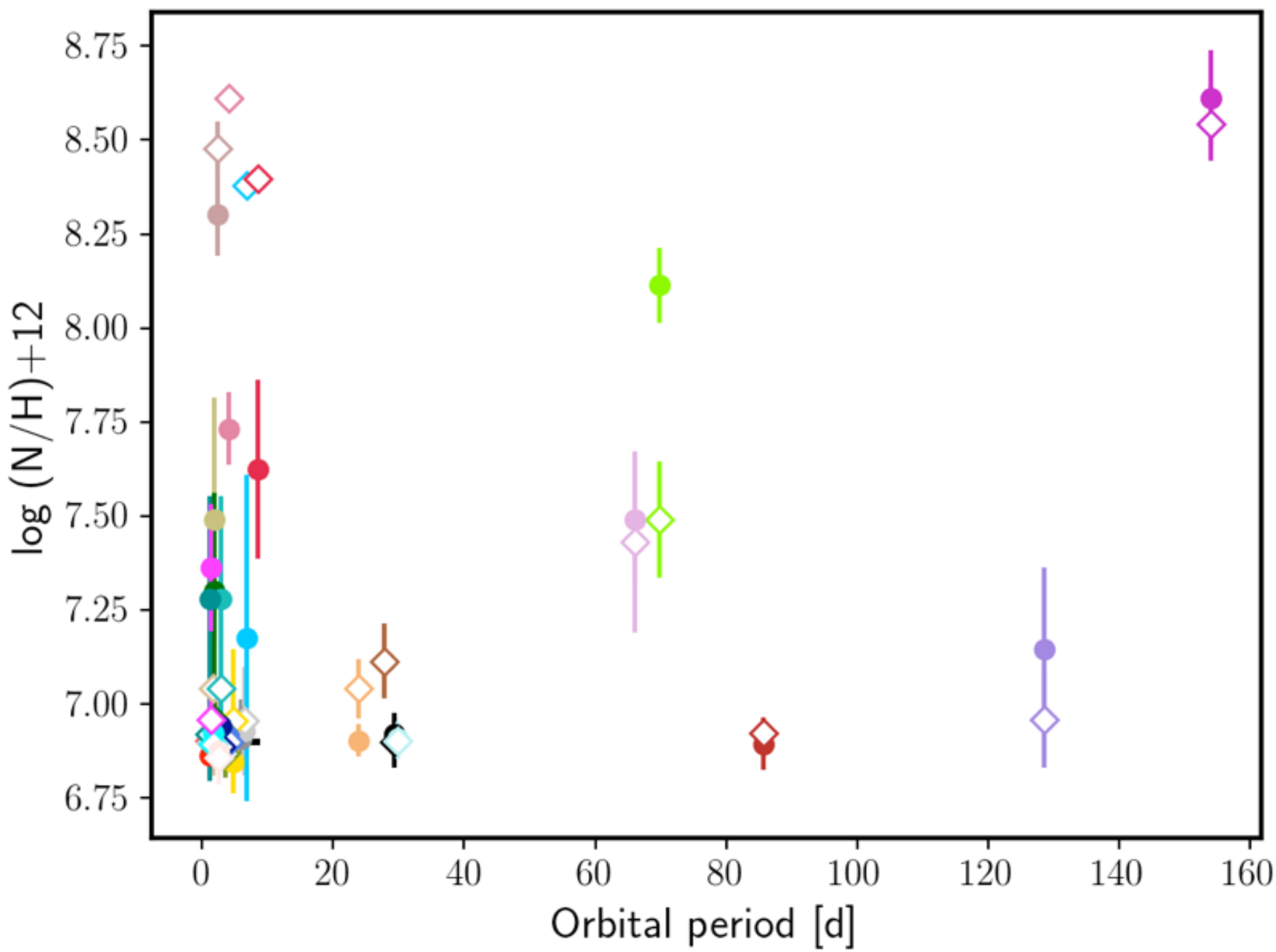
Gonzalez et al. (2005)



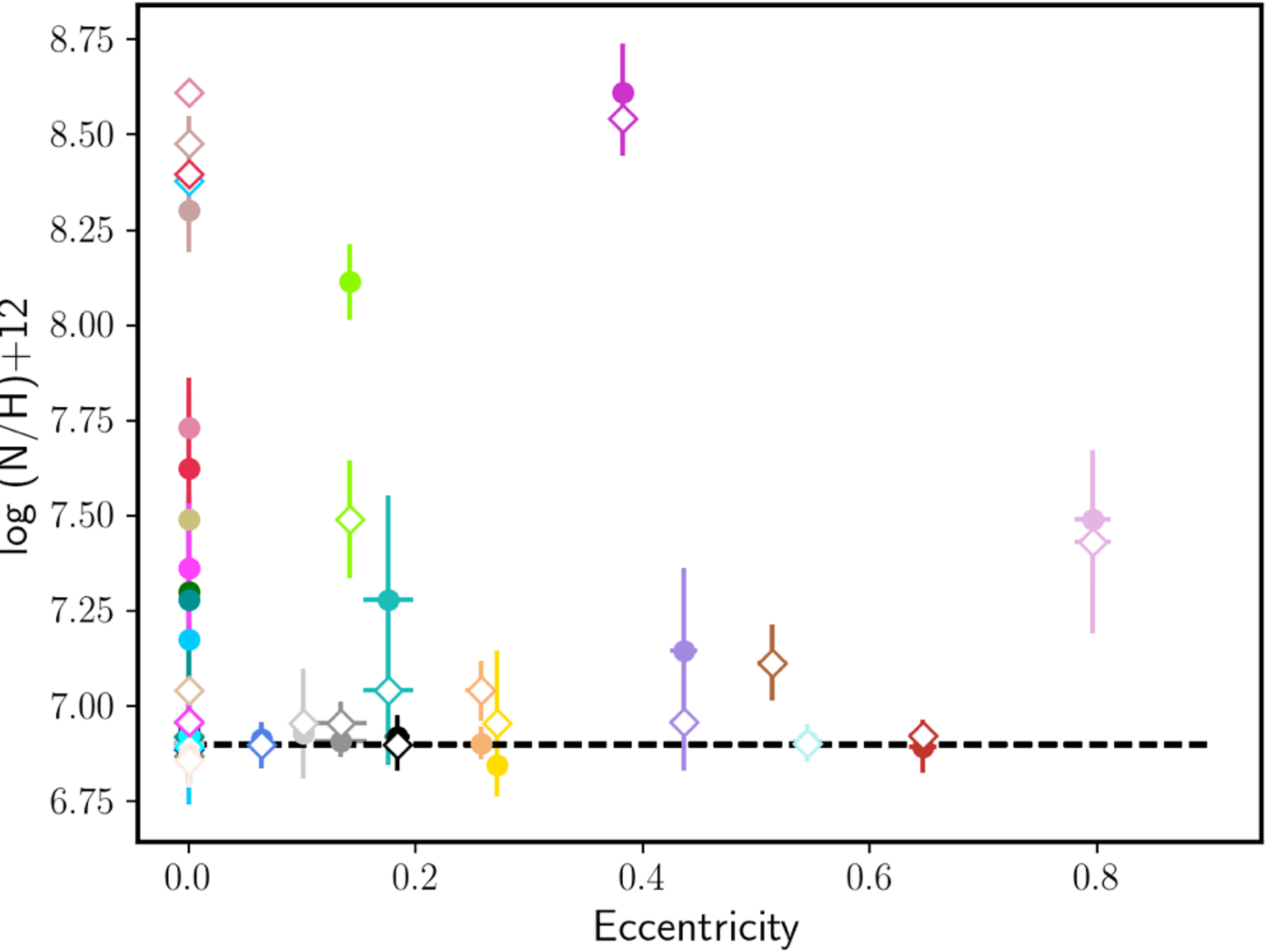




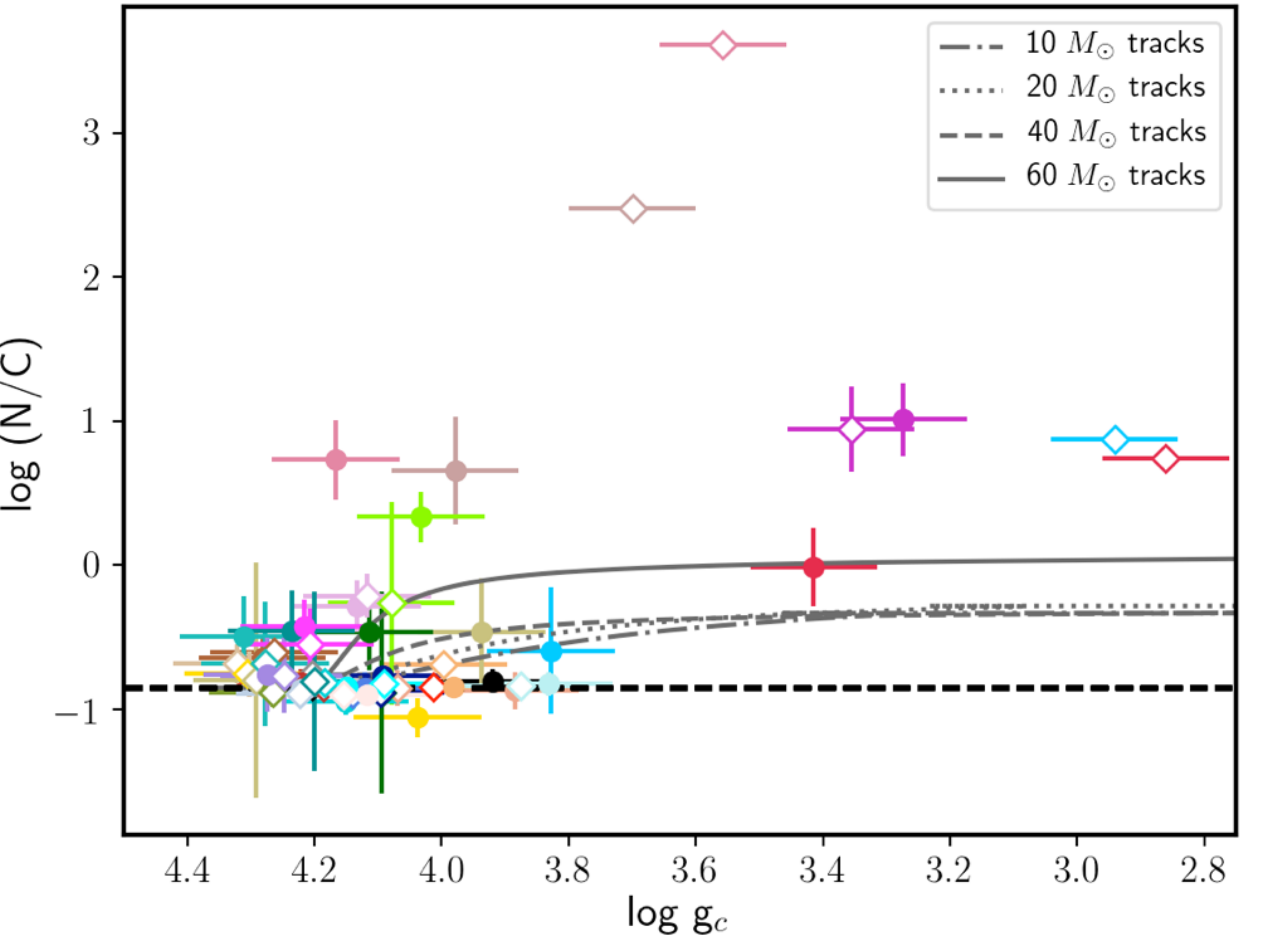
2.8
3.0
3.2
3.4
3.6
3.8
4.0
4.2
4.4
log g
50000
45000
40000
35000
30000
25000
Effective temperature [K]
2 Myrs
3 Myrs
4 Myrs
6 Myrs
80
70
60
50
40
30
20
15
10

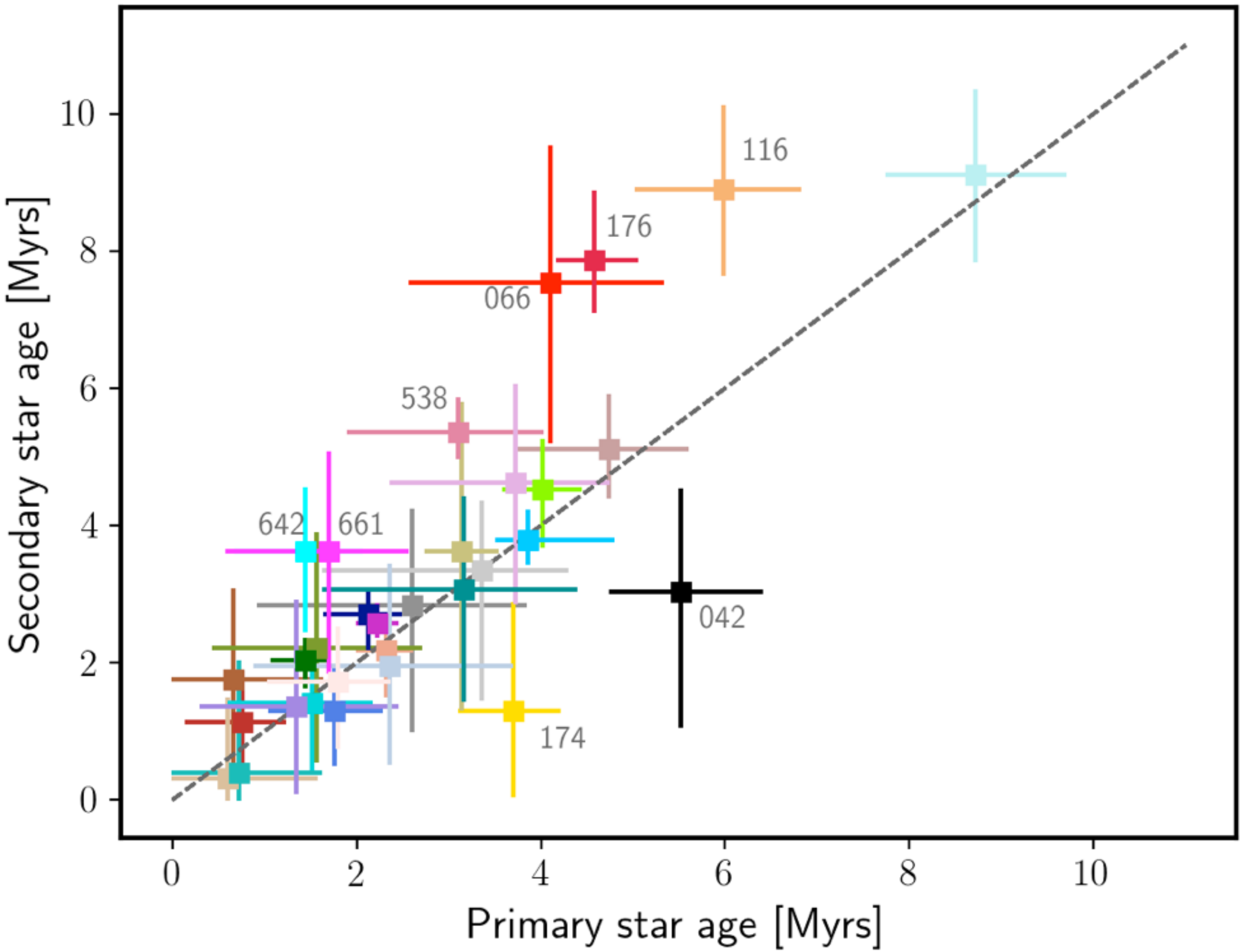


log (N/H)+12
8.75
8.50
8.25
8.00
7.75
7.50
7.25
7.00
6.75
0
20
40
60
80
100
120
140
160
Orbital period [d]



8.75
8.50
8.25
8.00
7.75
7.50
7.25
7.00
6.75
log (N/H)+12
0.0
0.2
0.4
0.6
0.8
Eccentricity


10 $M_\odot$ tracks
20 $M_\odot$ tracks
40 $M_\odot$ tracks
60 $M_\odot$ tracks
log (N/C)
log g$_c$
3
2
1
0
−1
4.4
4.2
4.0
3.8
3.6
3.4
3.2
3.0
2.8



Secondary star age [Myrs]
Primary star age [Myrs]
0
2
4
6
8
10
116
176
066
538
642
661
042
174