The evolution of massive stars: constraints from surface abundances

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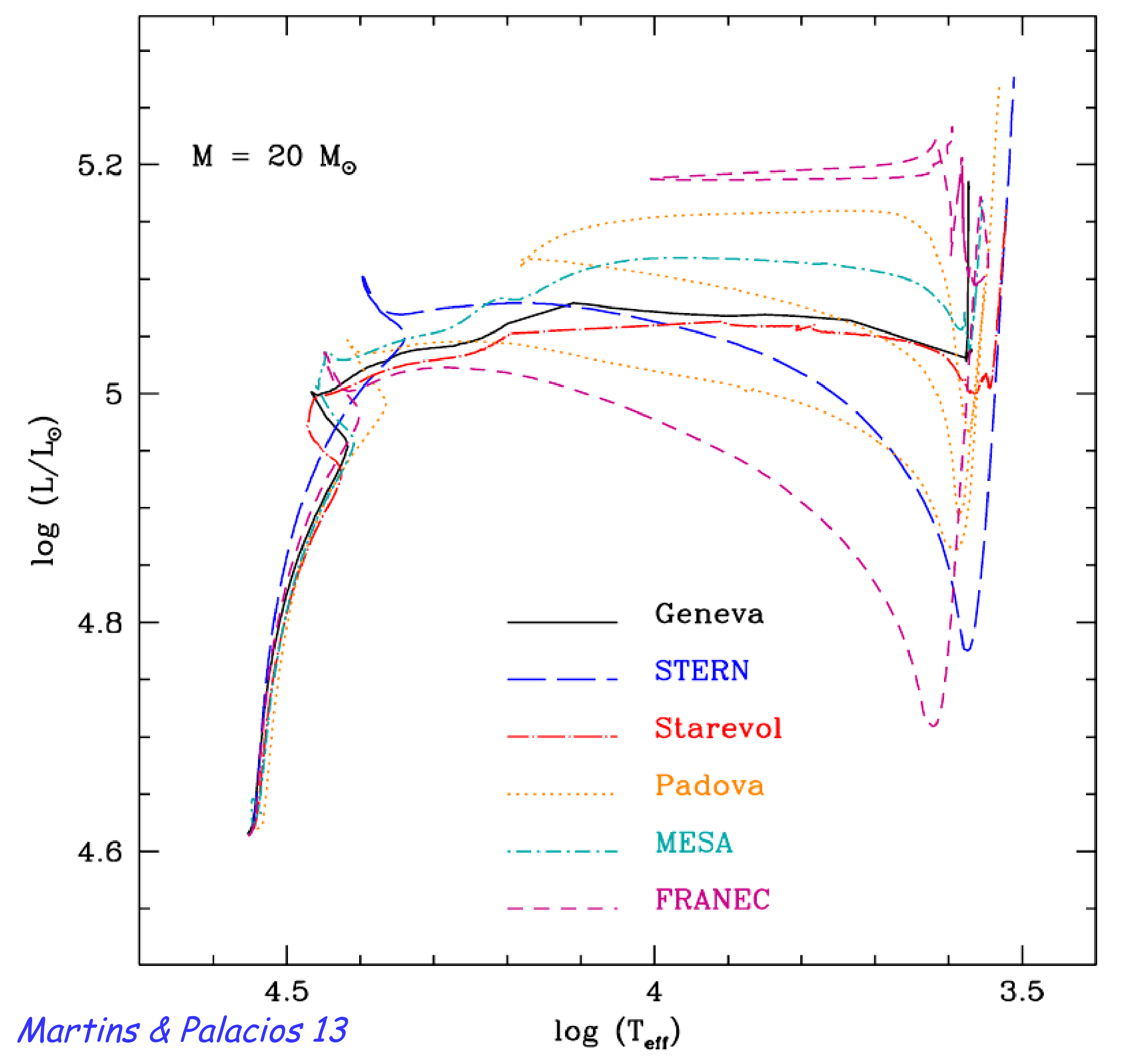
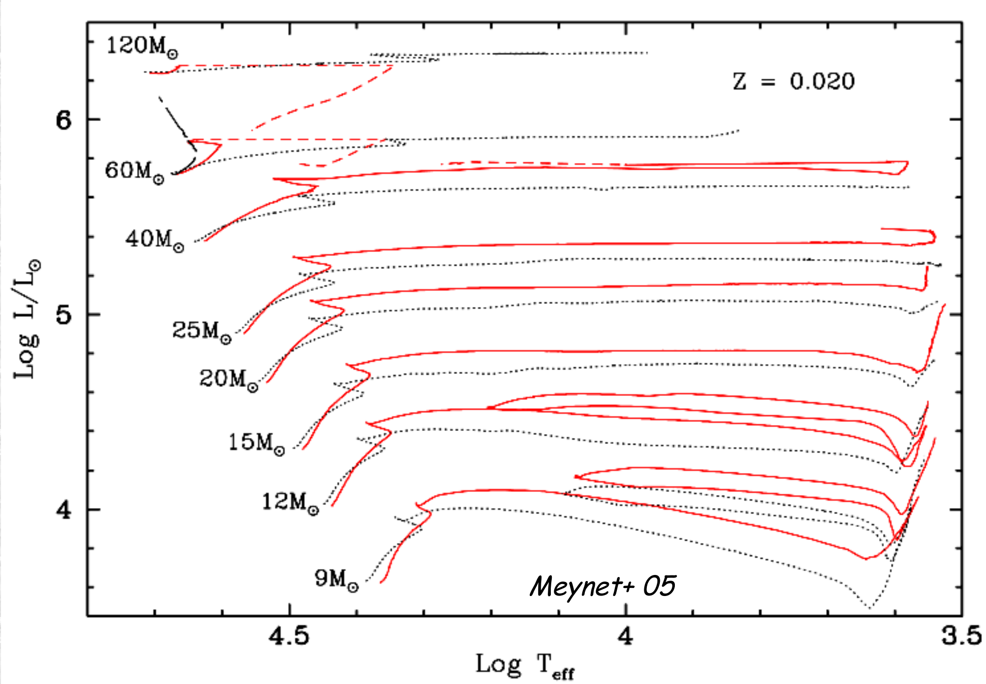
Evolution of massive stars



Martins & Palacios 13

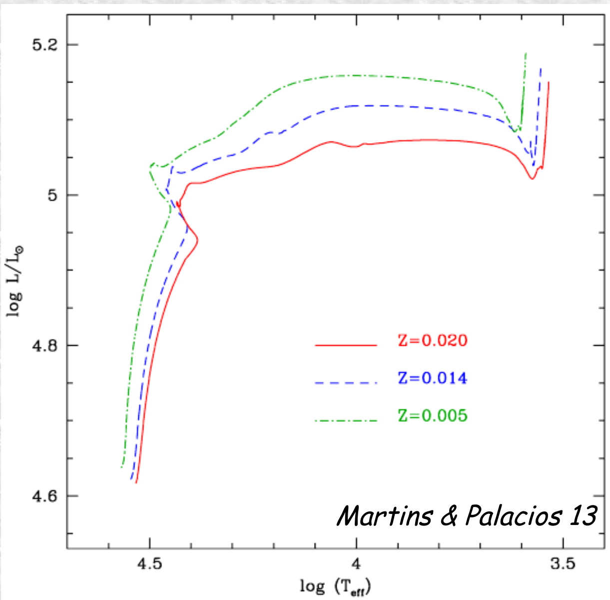
Large uncertainties in predictions of stellar evolution
⇒ need for observational constraints

Evolution of massive stars



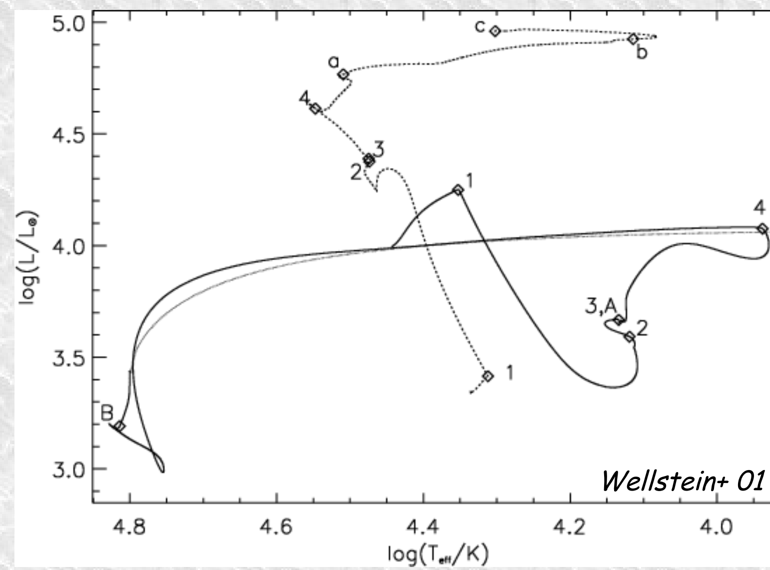
depends on initial mass

depends on **rotation**

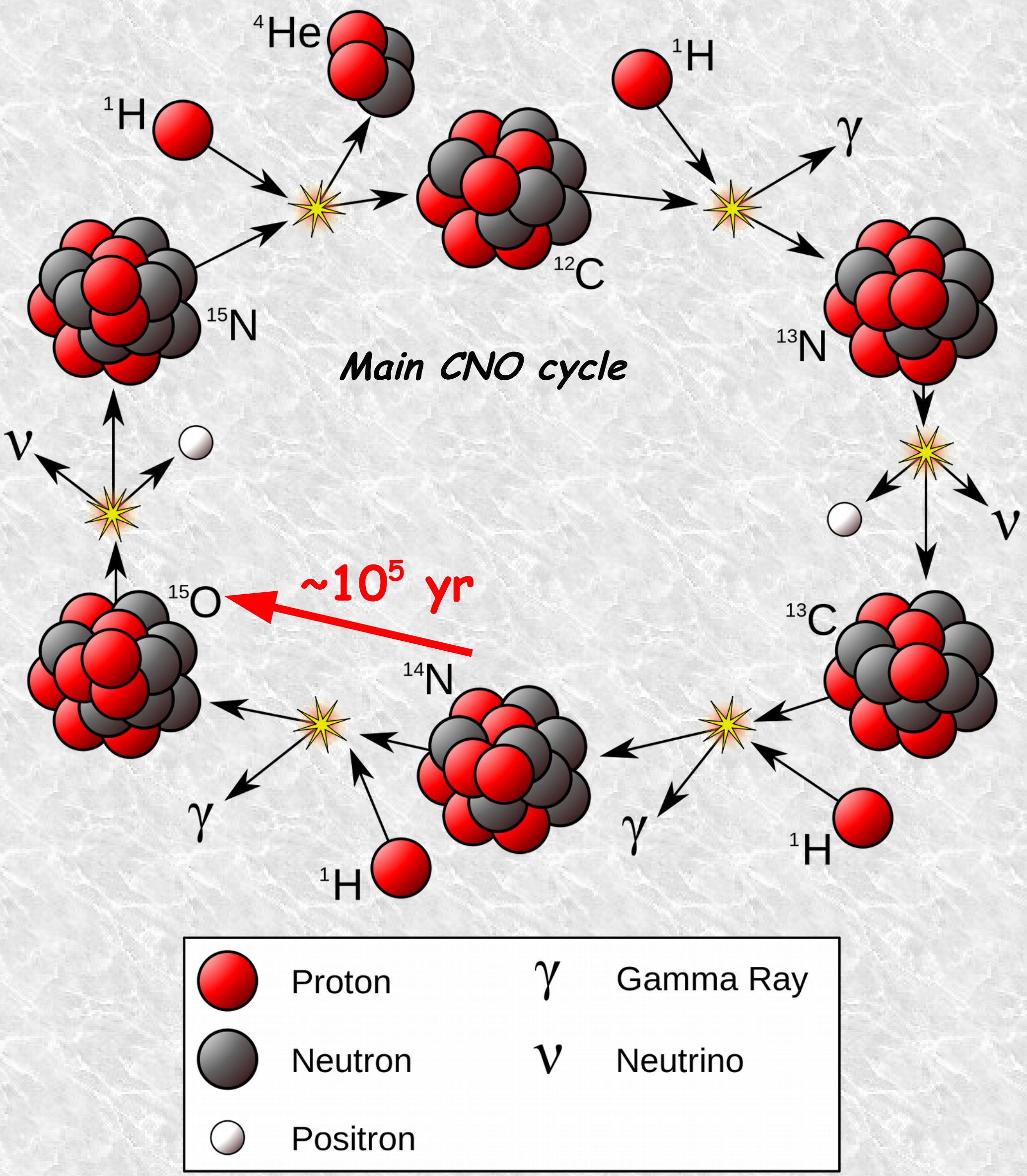


depends on metallicity and mass loss

depends on **binarity**



Surface abundances



H burning through CNO cycle

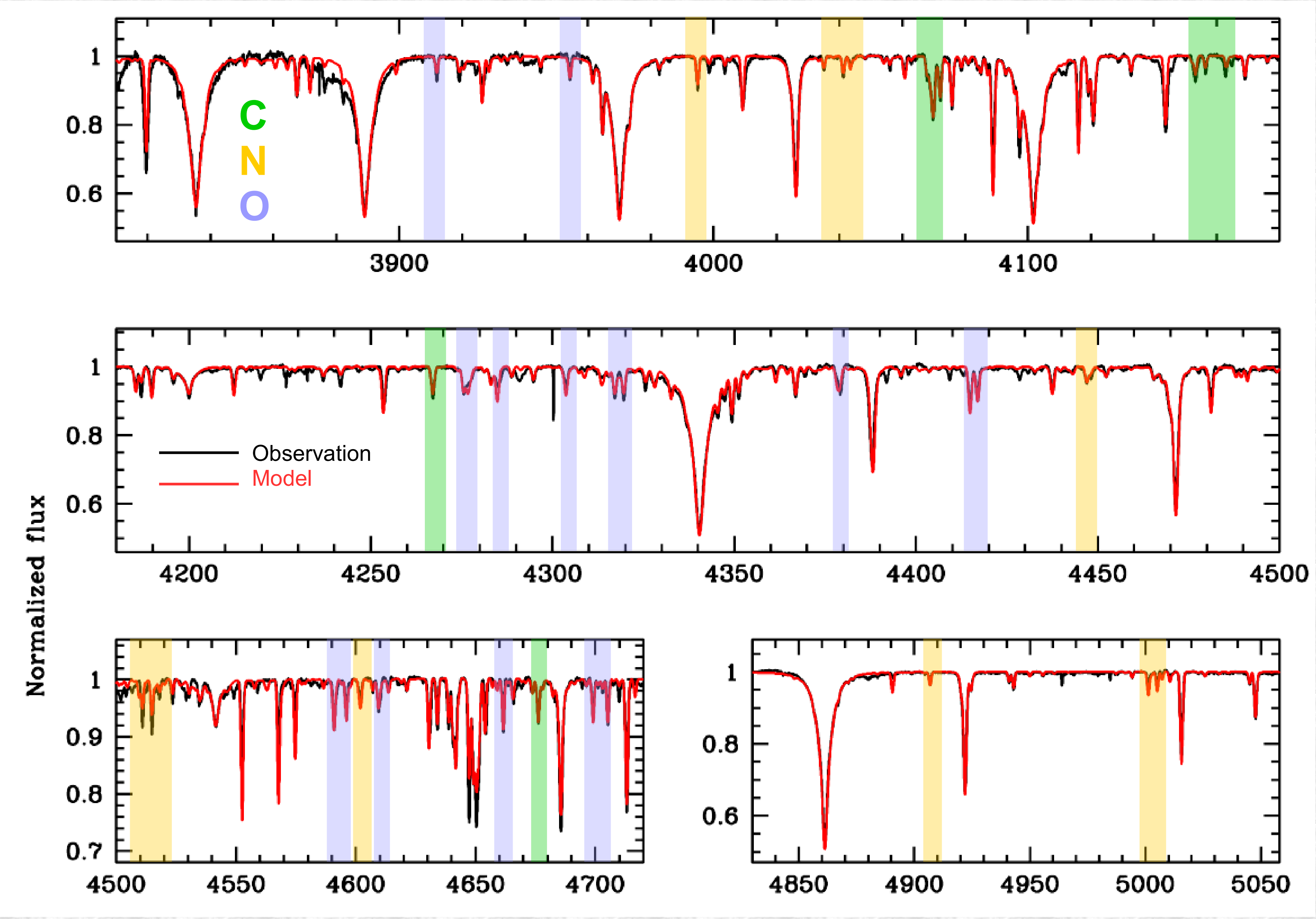
Timescale for nuclear burning longer than mixing timescale (e.g. in rotating stars)

C (and O) converted to N

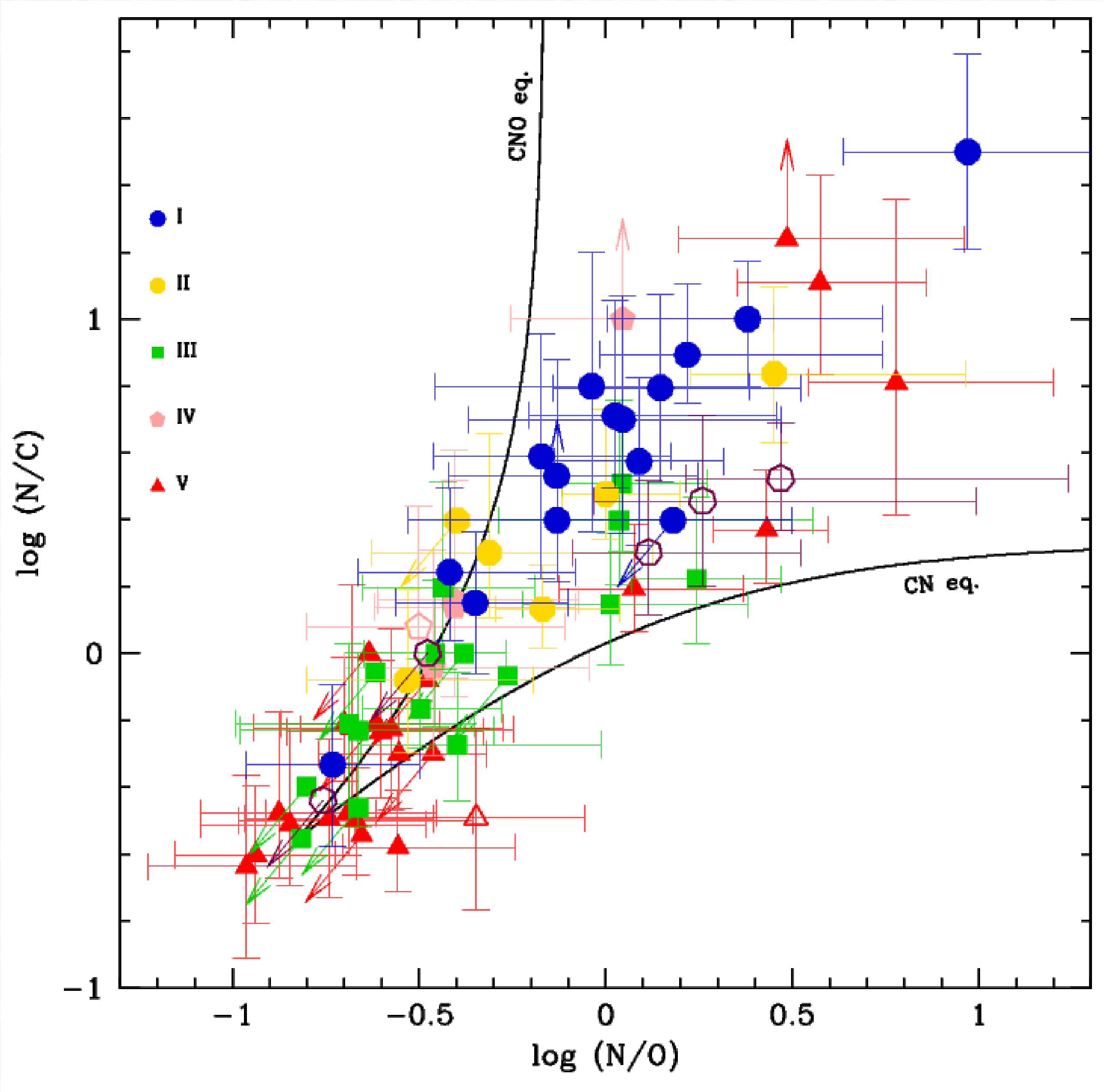
→ *chemical patterns should be observed at surface of stars*

→ *surface abundances = good indicators of mixing processes*

Determination of surface abundances



Surface abundances: origin



Data from the MiMeS survey (ESPaDoNS, NARVAL, HARPSpol optical spectra)

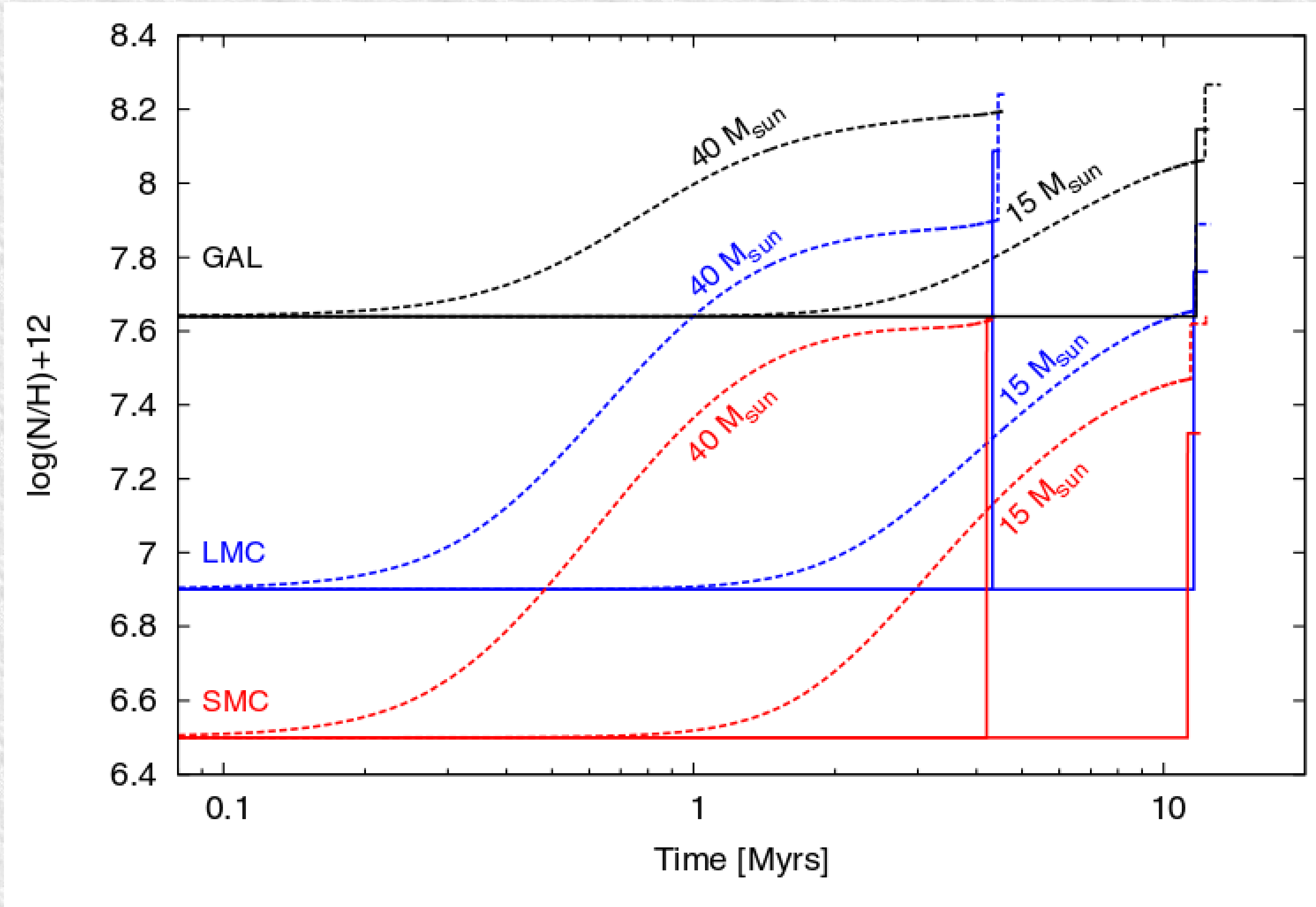
Wade et al. 16

3700-7000+ Å
R > 65000
Echelle spectra
S/N > 300

Martins et al. 15a

See also ***Bouret et al. 12,13****, Rivero Gonzalez et al. 12,Przybilla et al. 10, Maeder et al. 14*

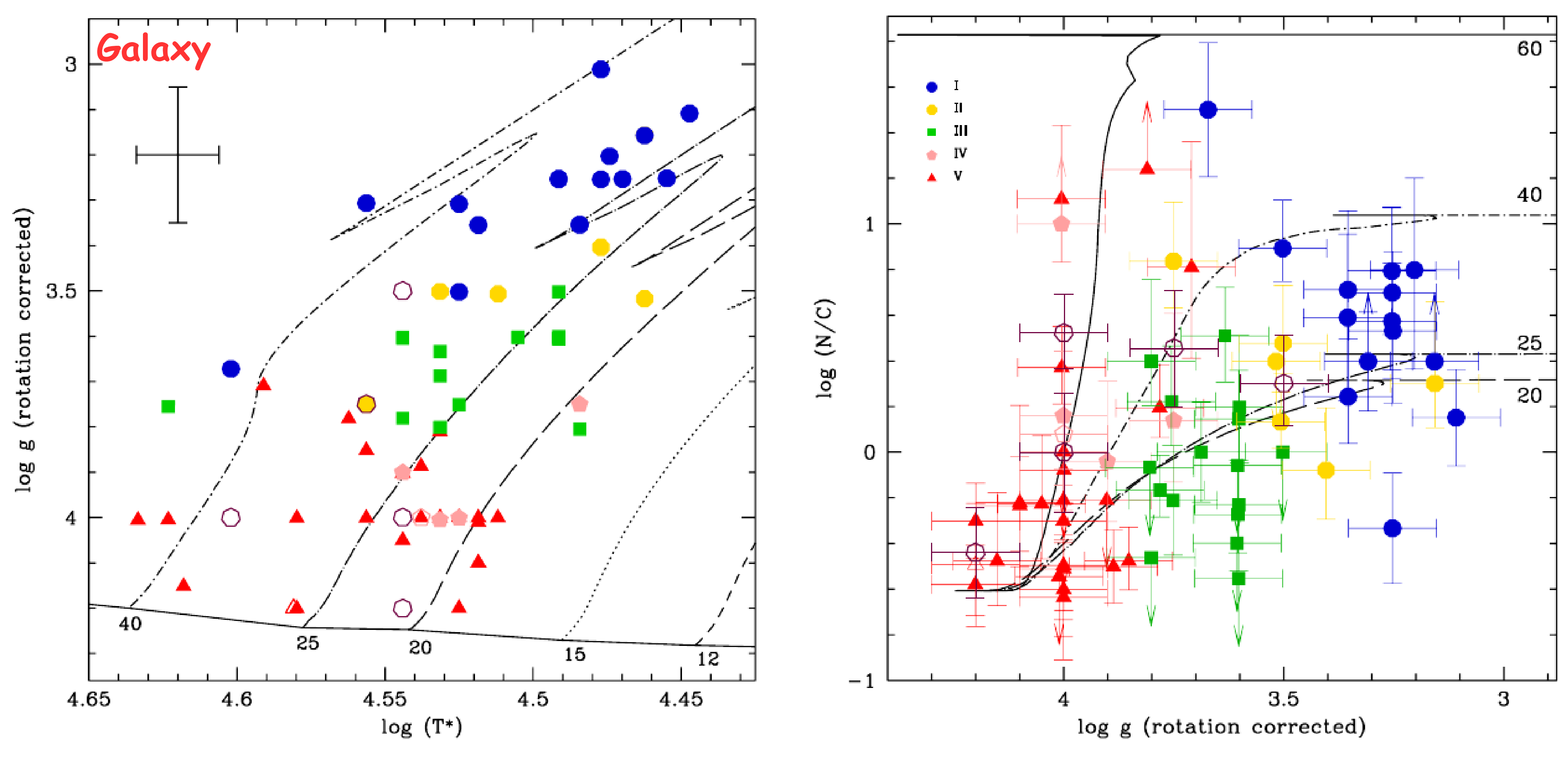
Surface abundances and rotation



Brott et al. 2011
(also: Maeder & Meynet 97, 00, Ekstroem et al. 2012, Georgy et al. 2013, Langer 12...)

Surface abundances depend on 1) initial mass, **2) time**, 3) metallicity, 4) rotation

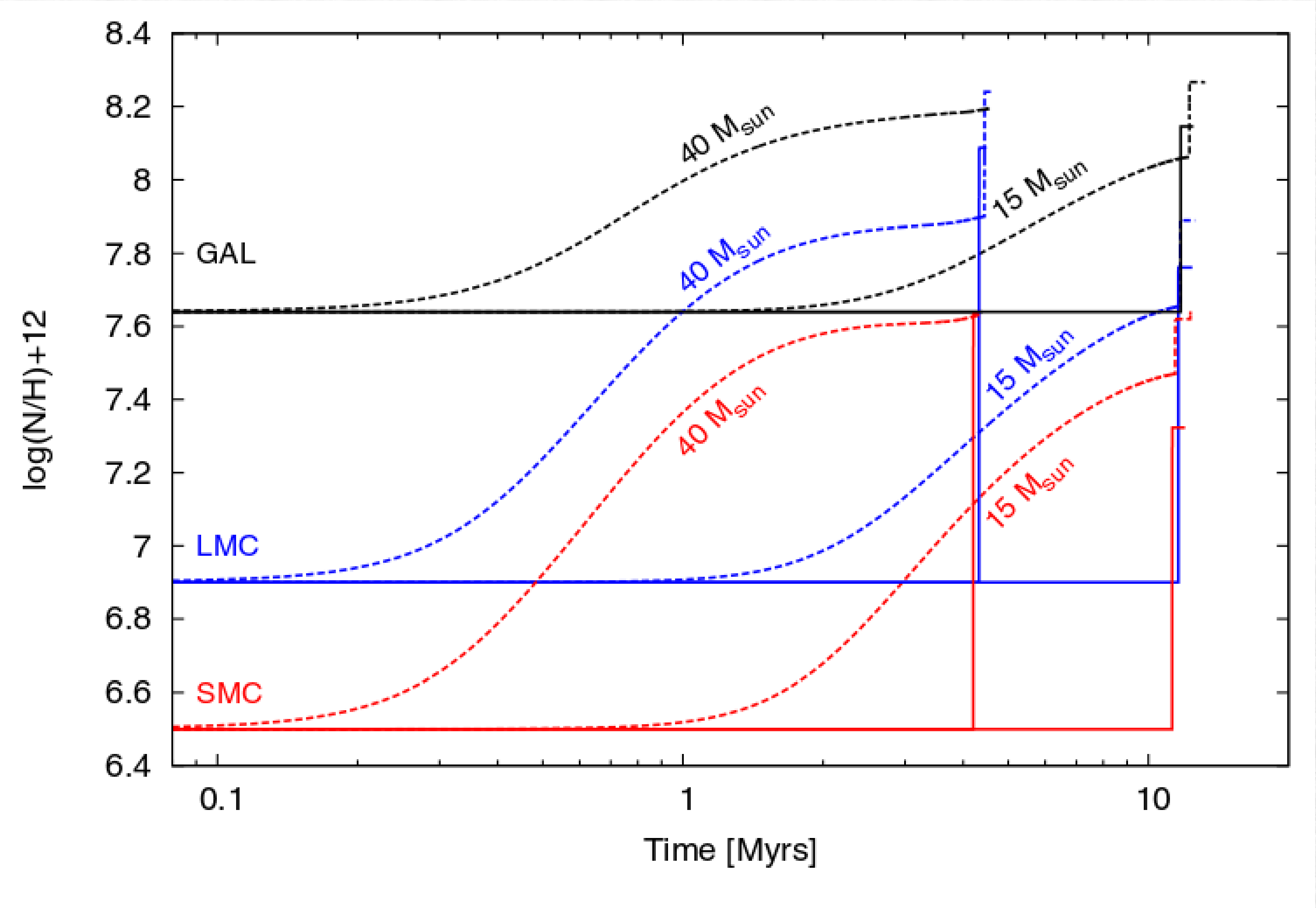
Surface abundances: age effect



Martins et al. 15a
See also Heap et al. 06

More evolved stars have more chemically processed surfaces

Surface abundances and rotation



Brott et al. 2011
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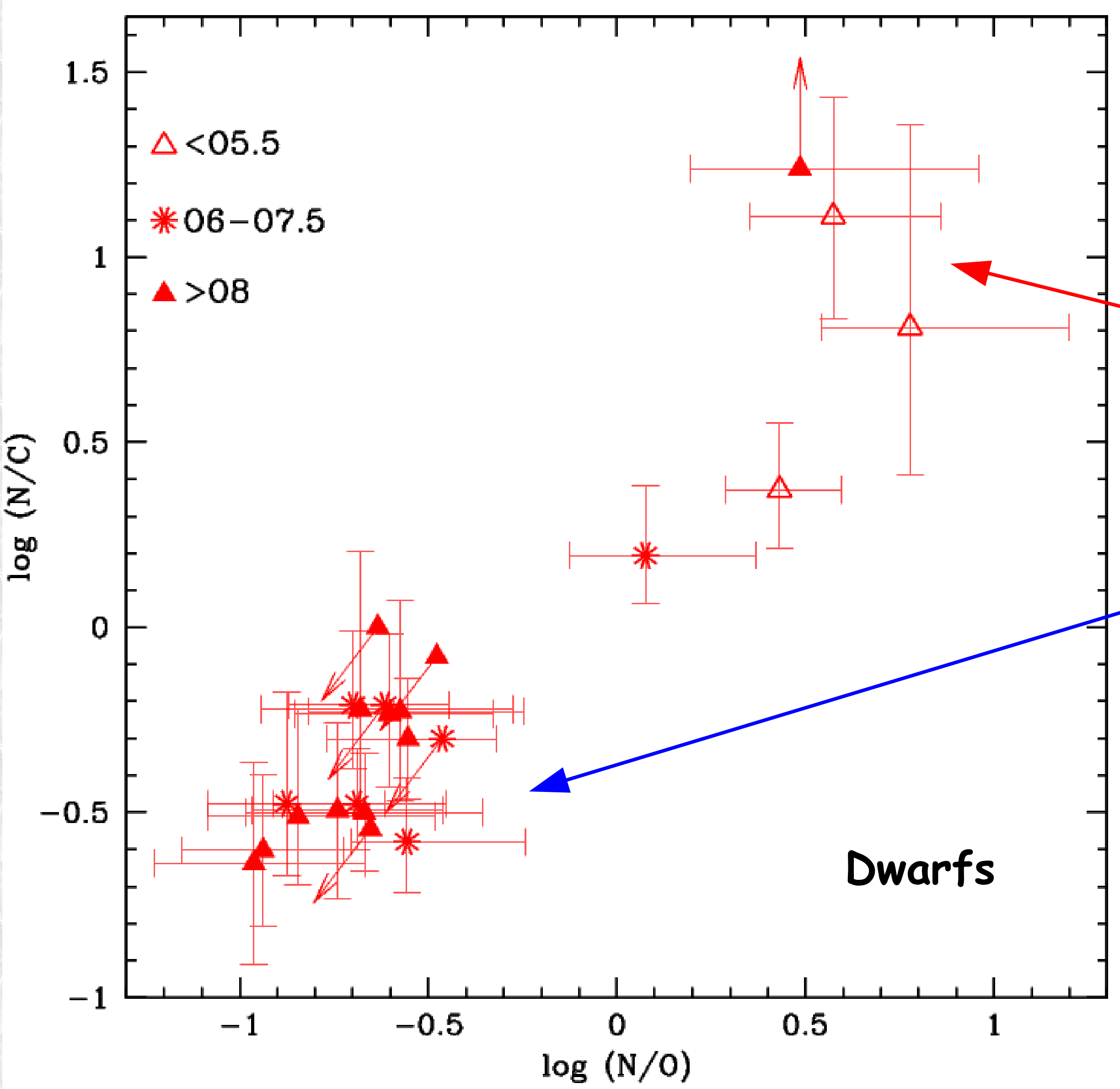
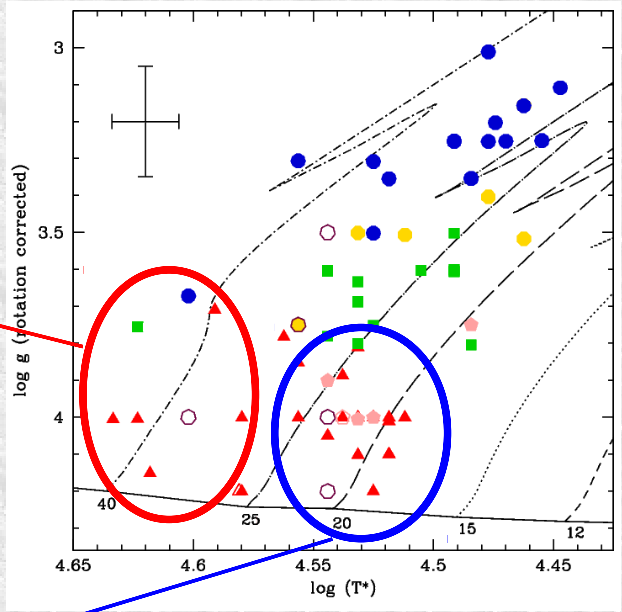
Surface abundances depend on **1) initial mass**, 2) time, 3) metallicity, 4) rotation

Mass effect

Galaxy



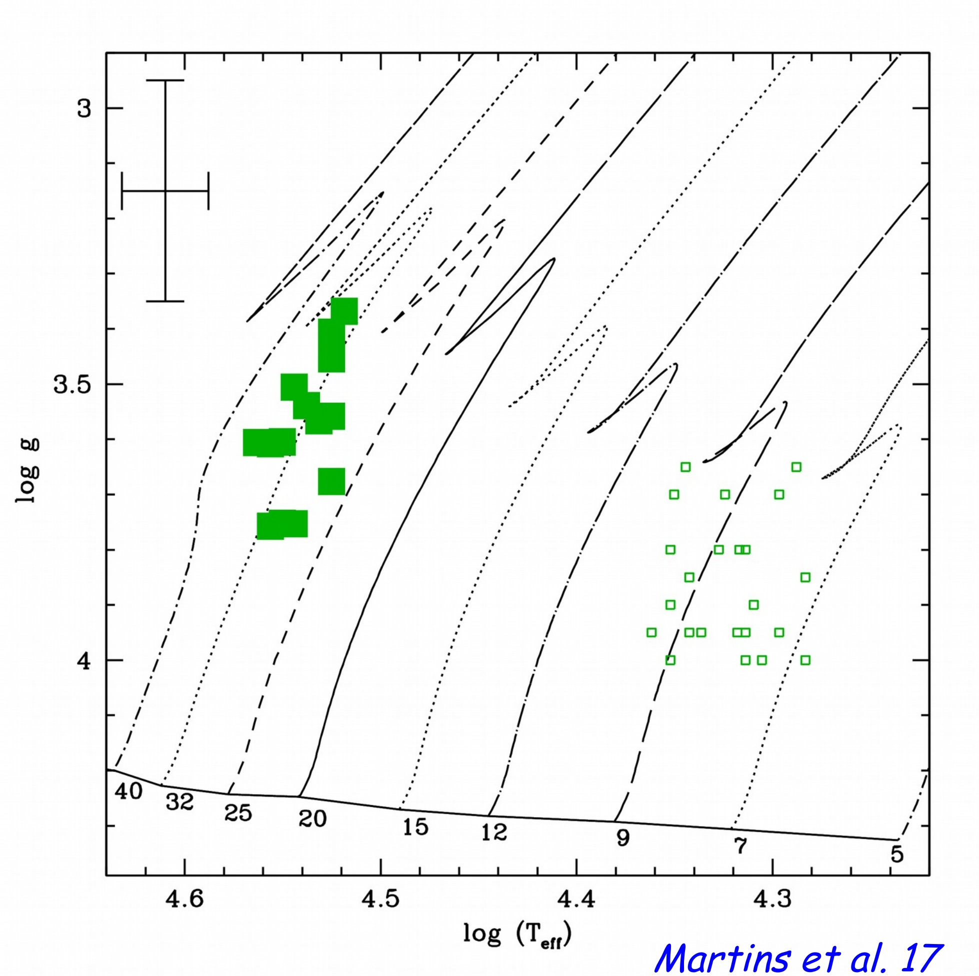


Martins et al. 15a

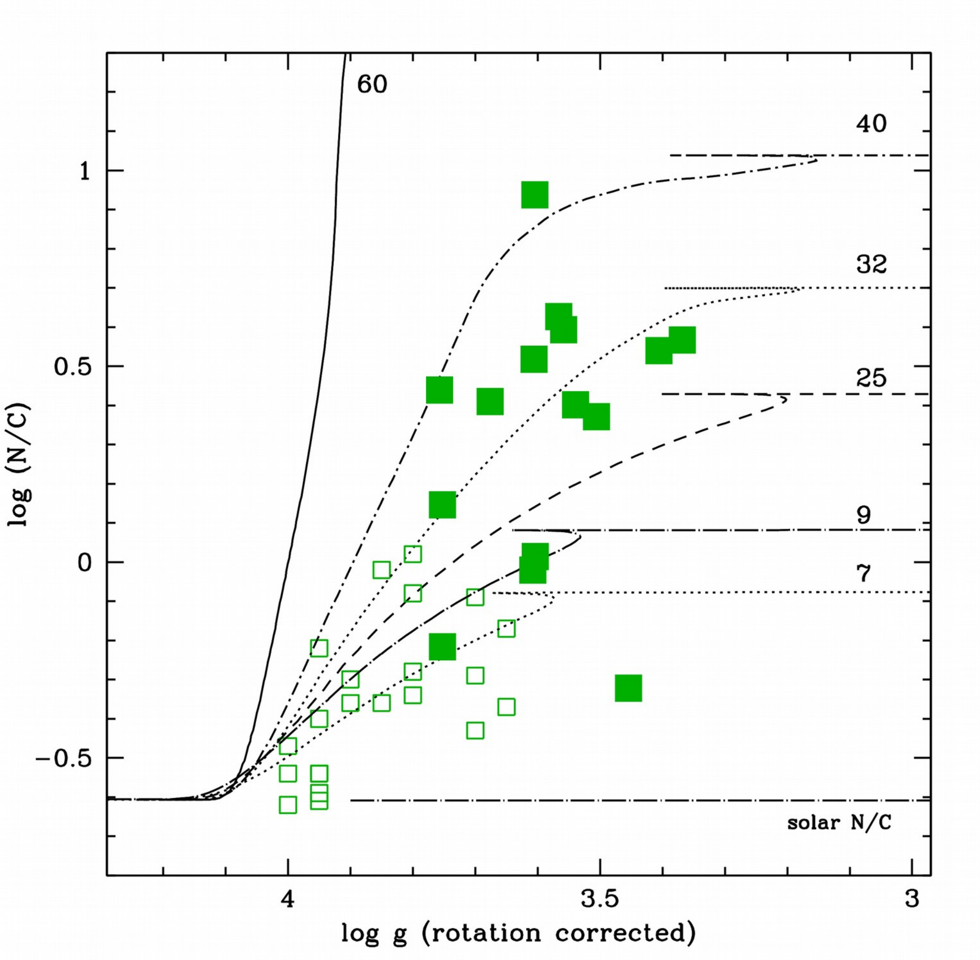
Trend: chemical enrichment depends on mass

Mass effect

Galaxy



Martins et al. 17

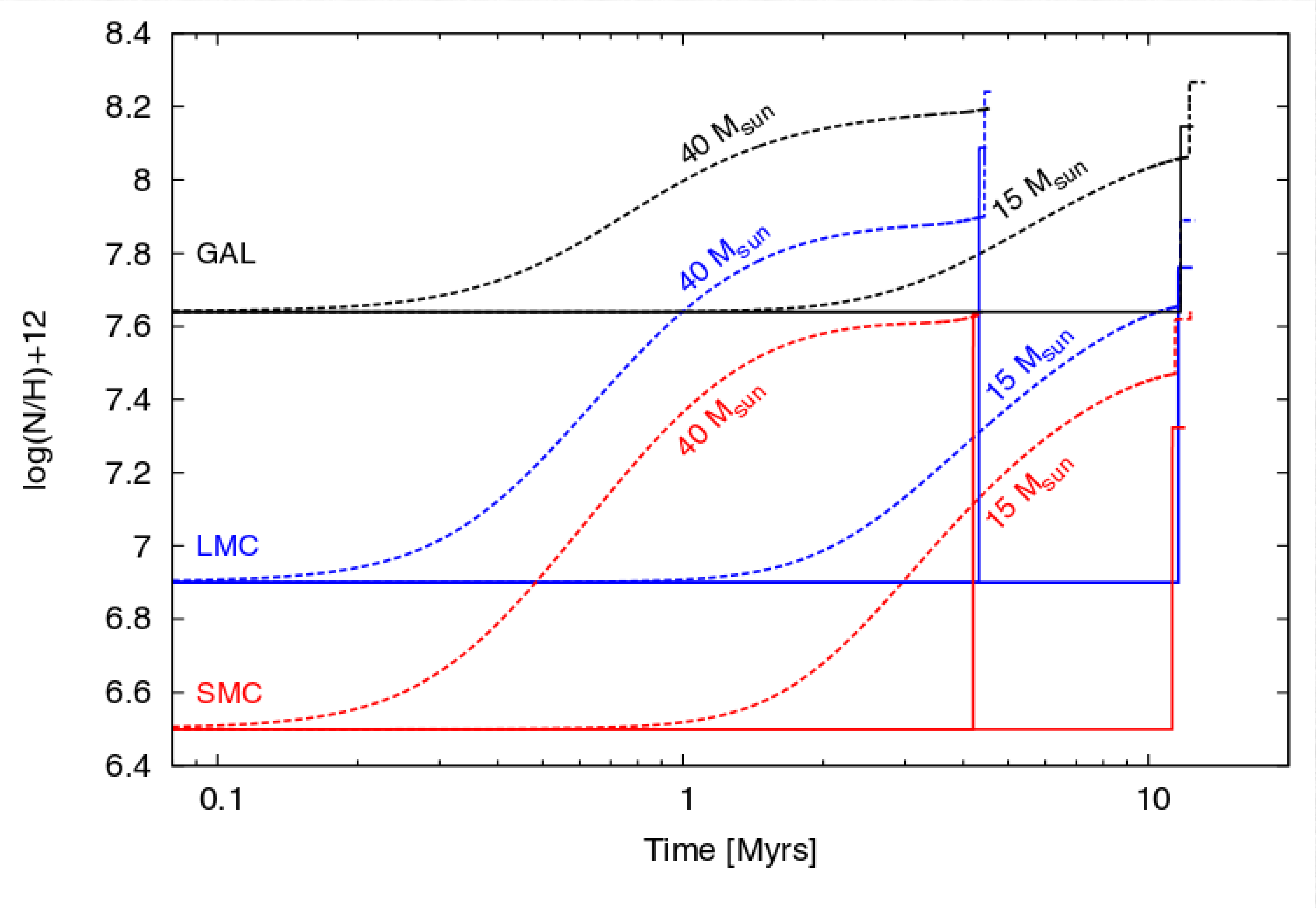


O stars from Martins et al. (2017)

B stars from Hunter et al. (2009) and Nieva & Przybilla (2012)

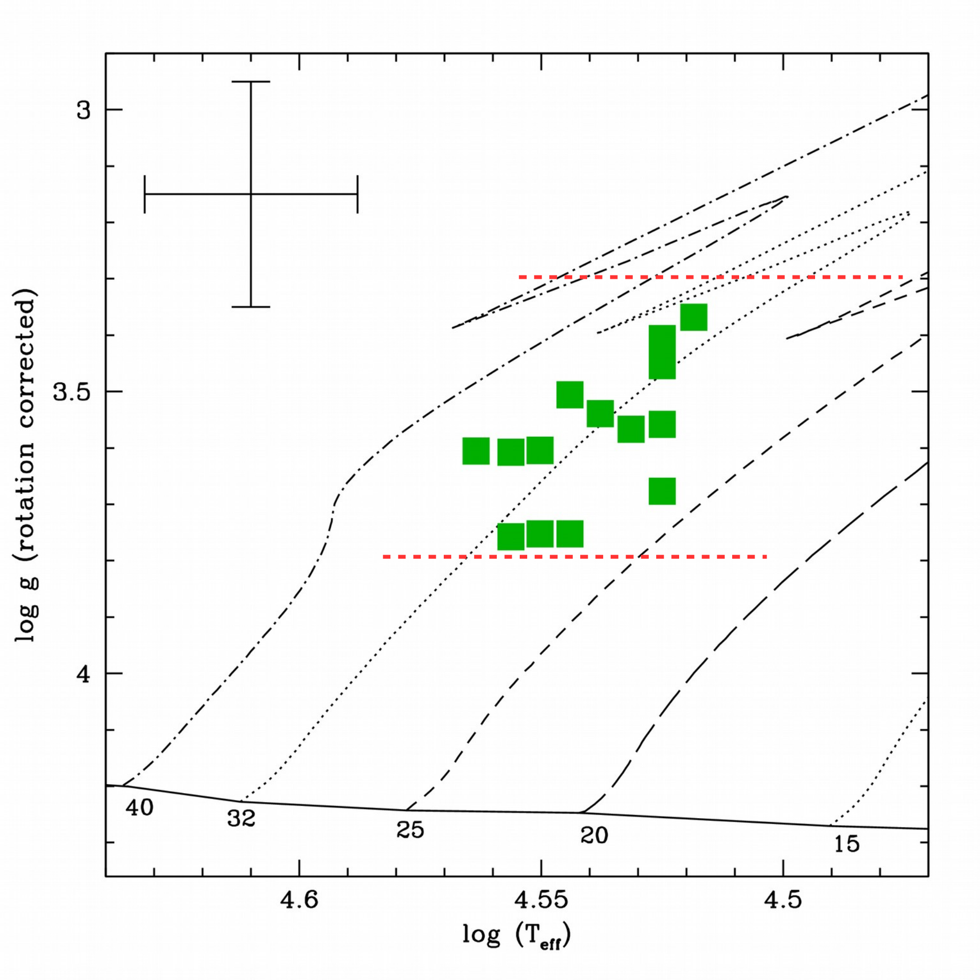
Trend: chemical enrichment depends on mass

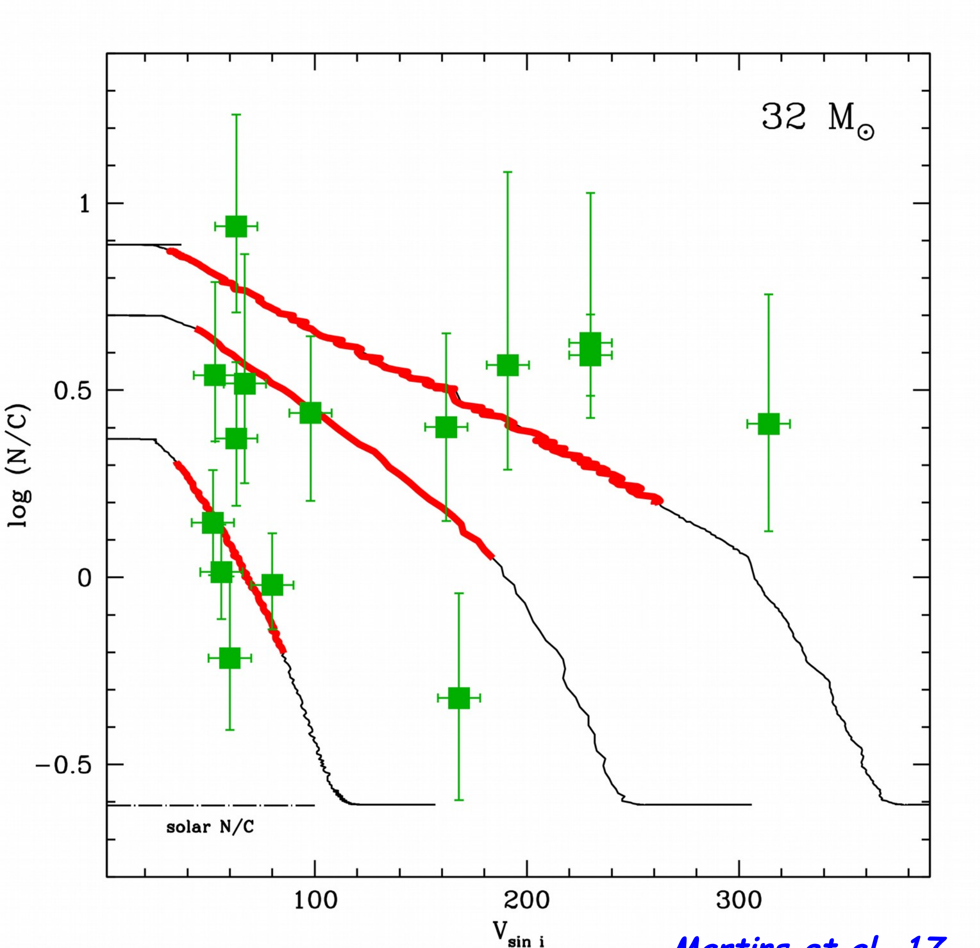
Surface abundances



Surface abundances depend on **1) initial mass**, 2) time, 3) metallicity, 4) rotation

Surface abundances: O stars - effect of rotation





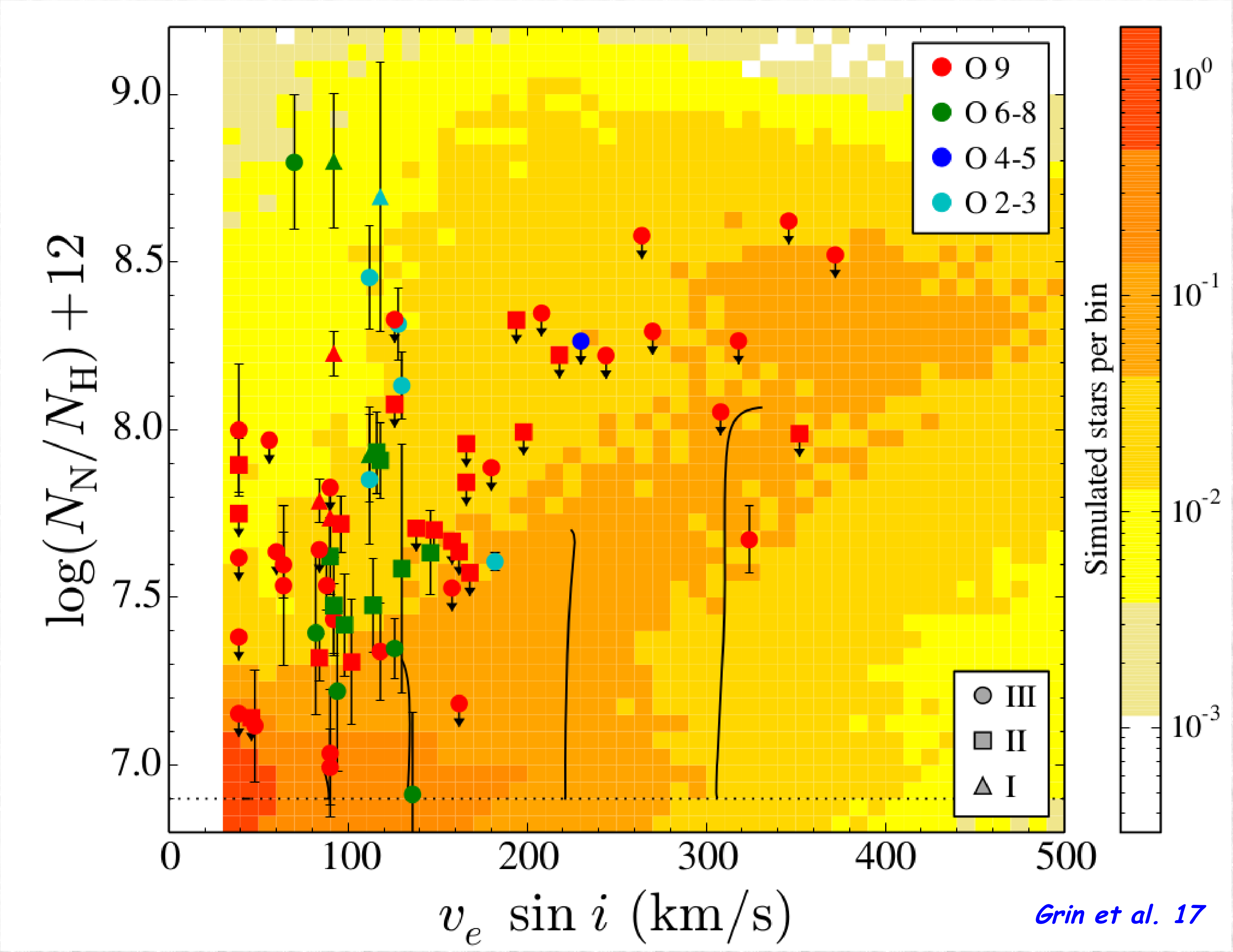
Martins et al. 17

Models of Ekstroem et al. (2012) at solar metallicity account for the distribution of stars in the abundance – vsini diagram.

See also Cazorla et al. 17a, 17b

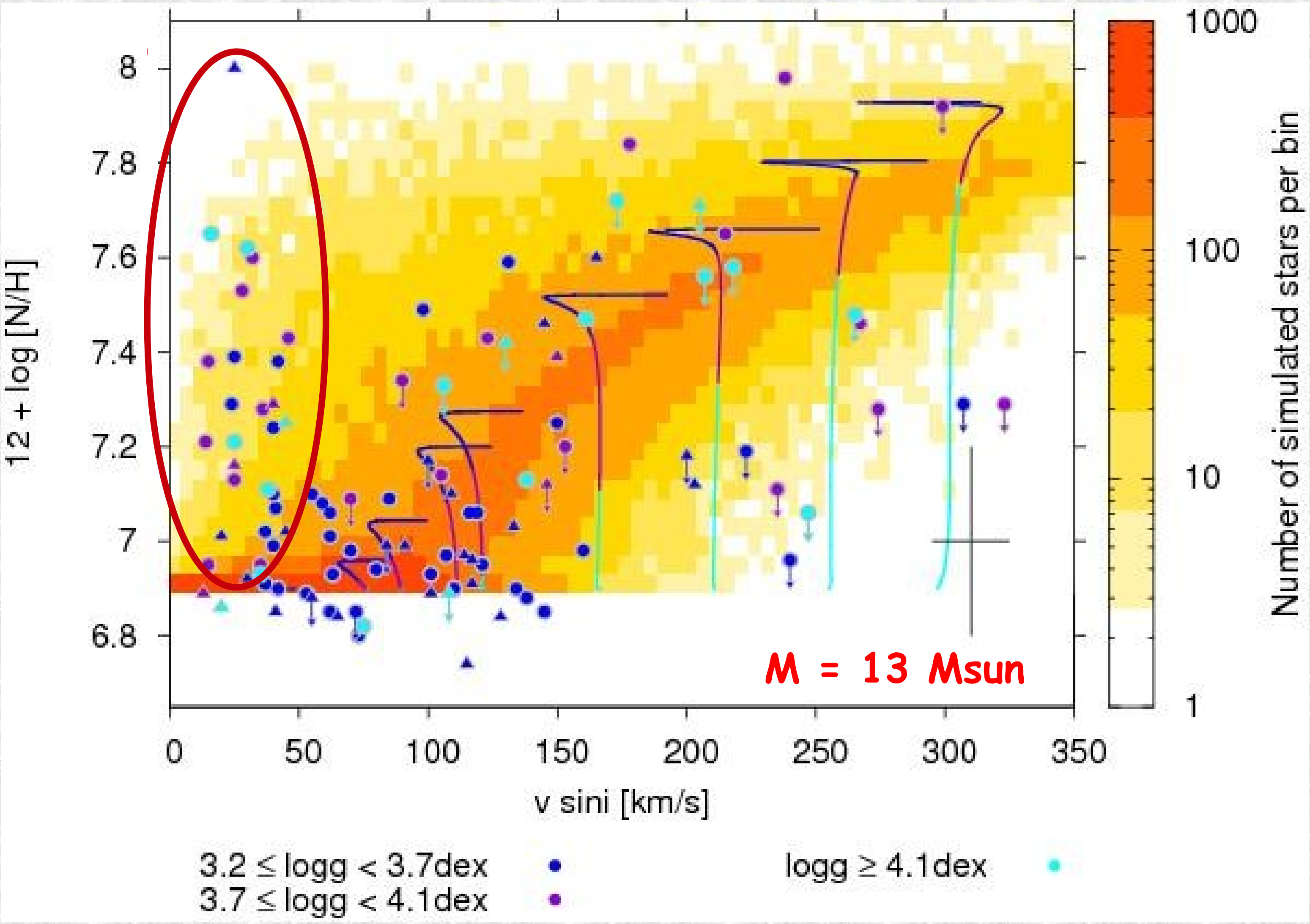
Surface abundances: O stars - effect of rotation

LMC



Models of Brott et al. (2011) at LMC metallicity do not reproduce the distribution of stars

Surface abundances: B stars – effects of rotation



LMC

B-type stars

(M=8-20 Msun)

Hunter et al. 2008
Brott et al. 2011

An uncertain fraction of stars escapes predictions
(10-40% depending on authors, samples...)

Rotation and massive stars evolution

Surface abundances show increasing degree of CNO processing:

✔ with age

✔ with initial mass

- with rotational velocity:
  - ✔ at solar metallicity, above 30 Msun
  - ✘ below 30 Msun and at sub-solar metallicity

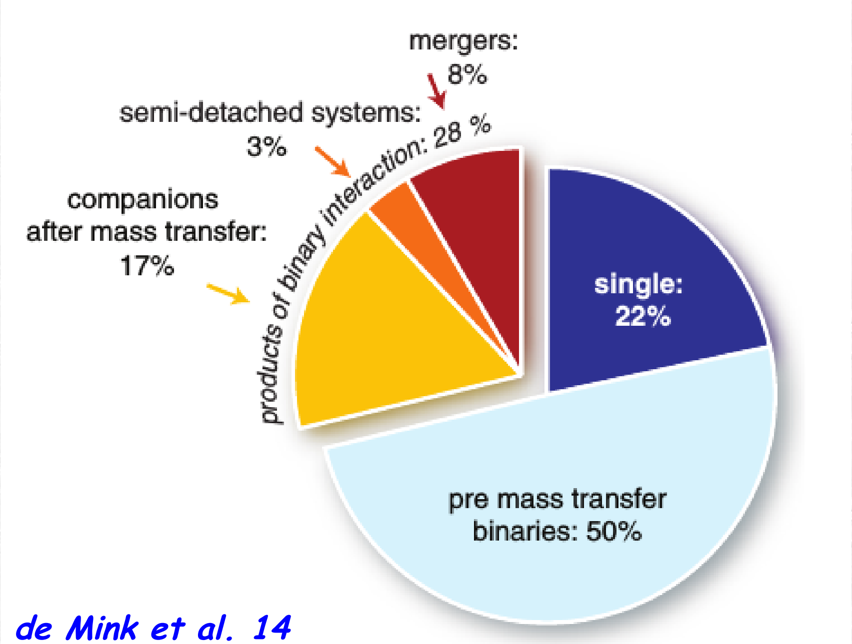
? with metallicity

Results also depend on formalism used to include rotational mixing in evolutionary models

Effect of binarity

Fraction of binary systems among OB stars:

Observed	Bias corrected	
0.56	0.69	*Sana+12*
0.35	0.51	*Sana+13*
0.53	0.91	*Sana+14*
0.35	0.55	*Kobulnicky+14*
>0.21	–	*Mahy+14*
0.30	–	*Pfuhl+14*



de Mink et al. 14

- What is the fraction of massive stars in binary systems?
- Does it varies with environment?
- What are the effects on stellar evolution (compared to single star evolution)?

Effect of binarity

RECONCILING THE STELLAR AND NEBULAR SPECTRA OF HIGH-REDSHIFT GALAXIES*

CrossMark

Charles C. Steidel[1], Allison L. Strom[1], Max Pettini[2], Gwen C. Rudie[3], Naveen A. Reddy[4,6], and Ryan F. Trainor[5,7]
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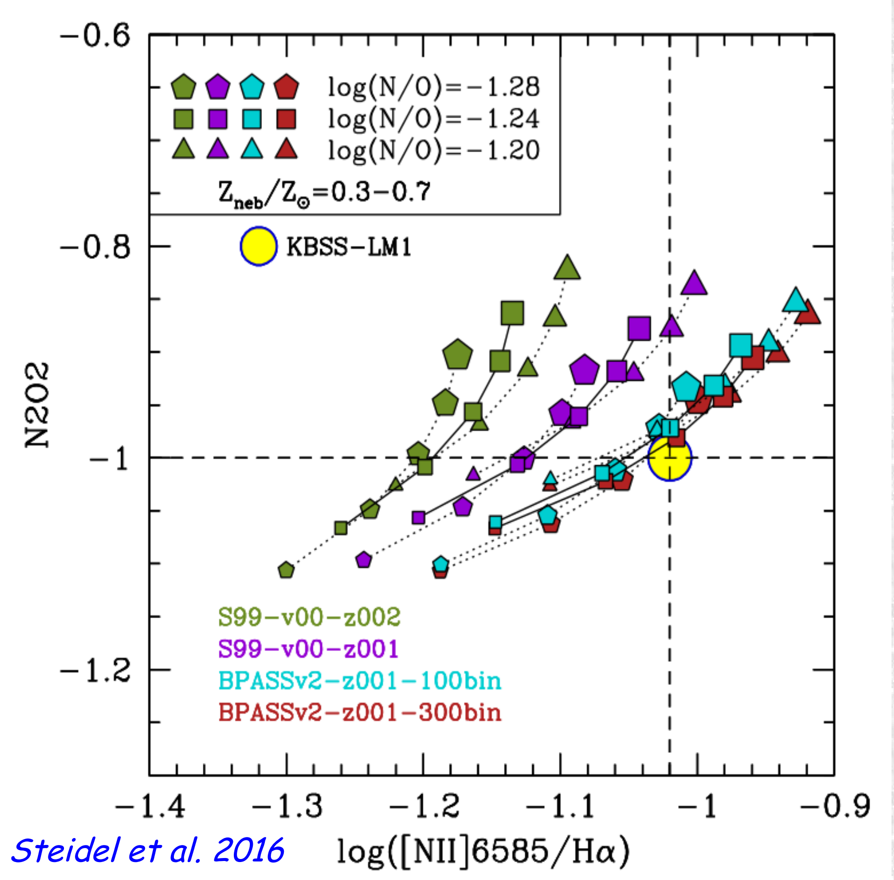
Received 2016 March 28; revised 2016 May 3; accepted 2016 May 19; published 2016 July 28

source in photoionization models—predict all observed nebular emission line ratios. We find that only models including massive star binaries, having low stellar metallicity ($Z_*/Z_\odot \simeq 0.1$) but relatively high nebular (ionized gas-phase) abundances ($Z_{neb}/Z_\odot \simeq 0.5$), can successfully match all of the observational constraints. We show that

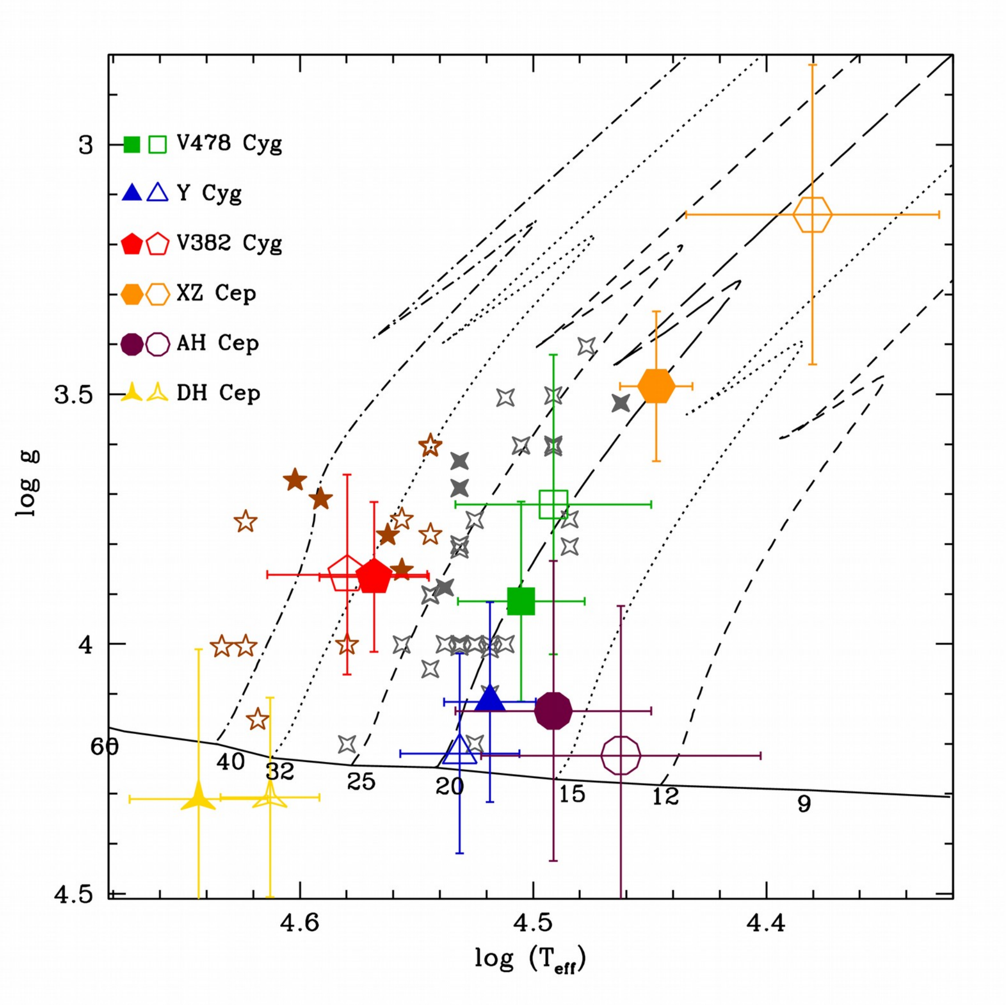
Impact on interpretation of
star forming galaxies at z~2-3

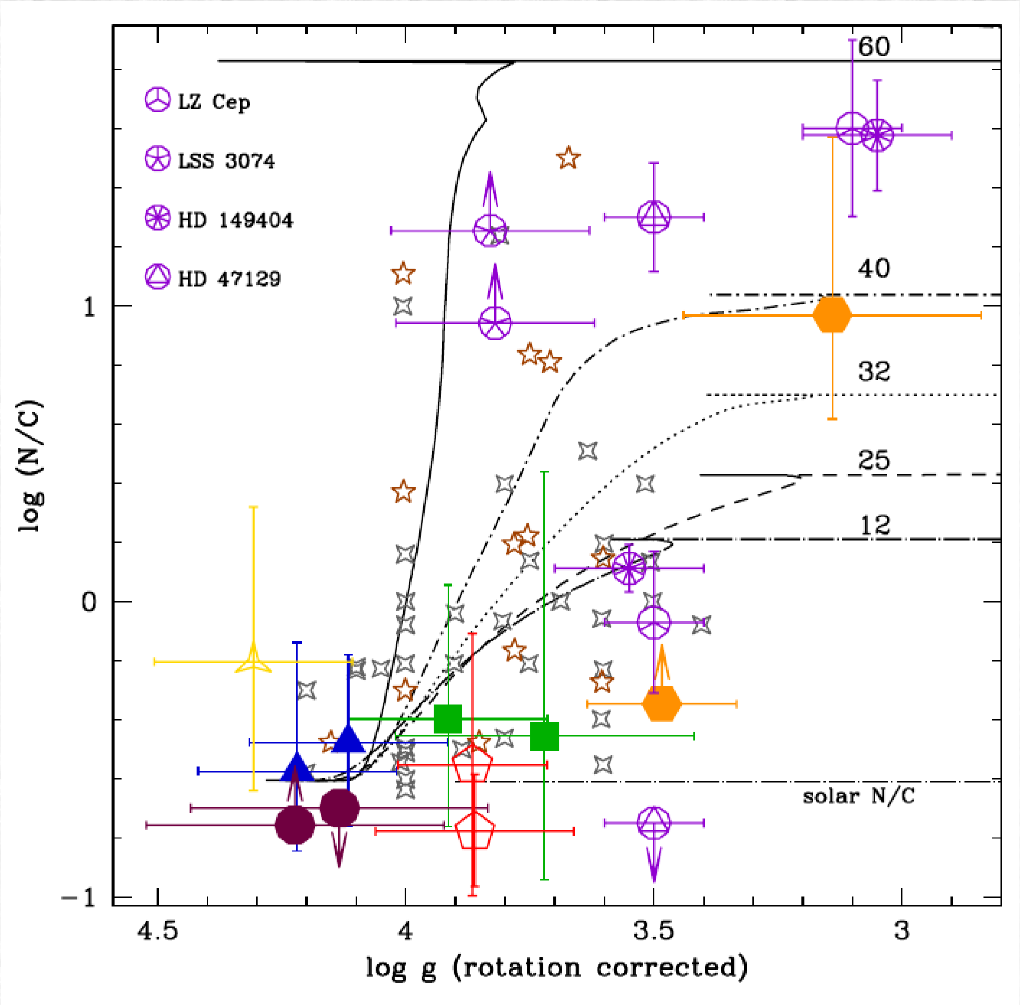
→ *Binary models favored over single star models*



Steidel et al. 2016

Effect of binarity

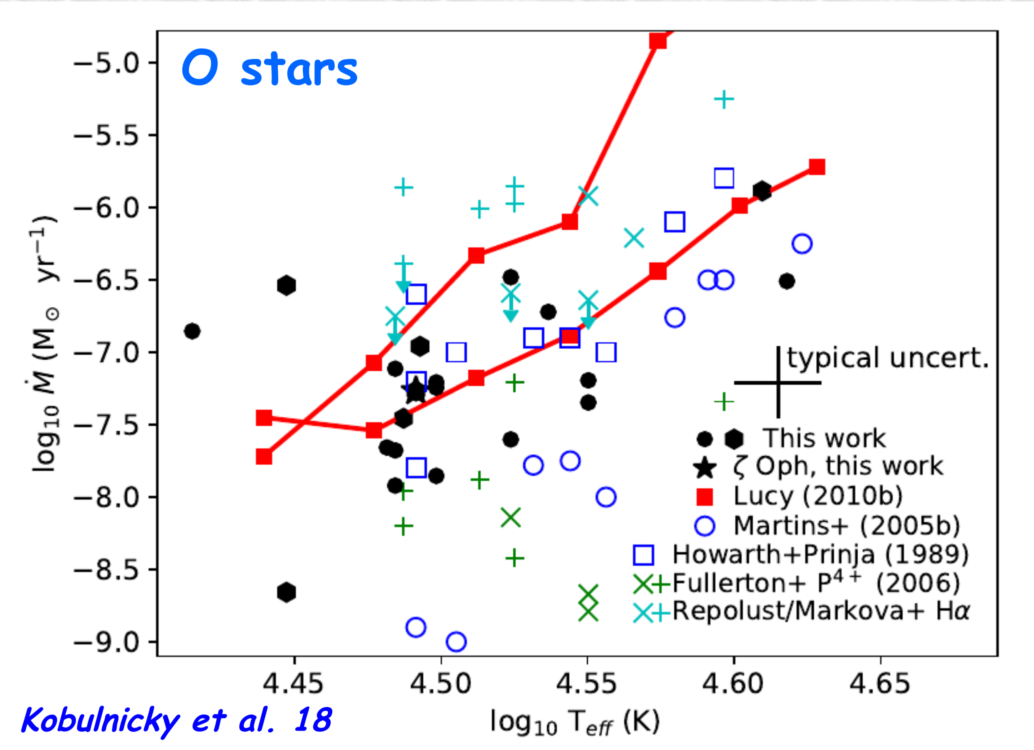


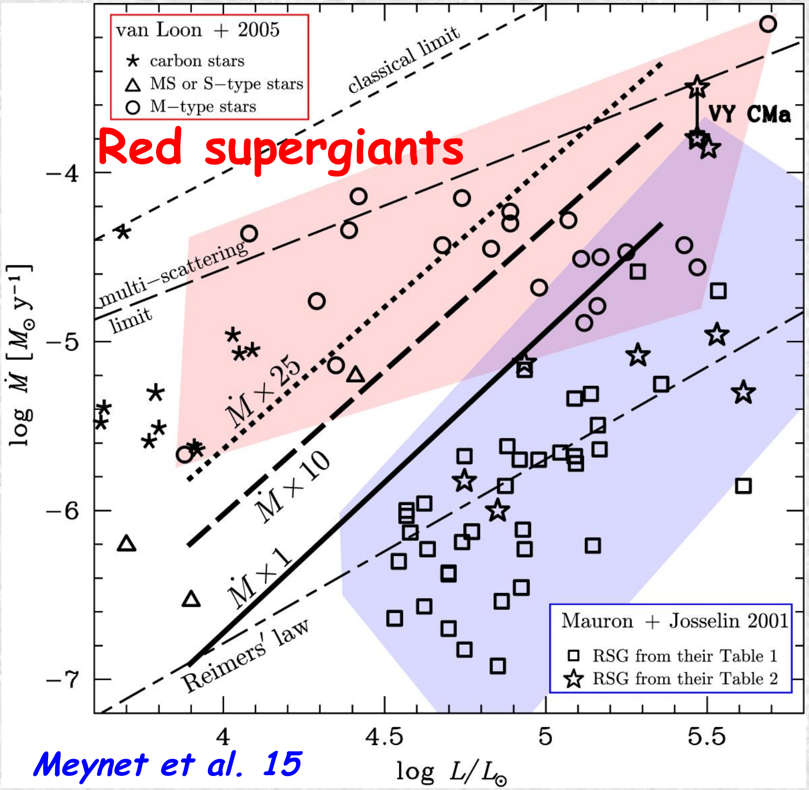


Martins et al. 17b
data from OHP/T193

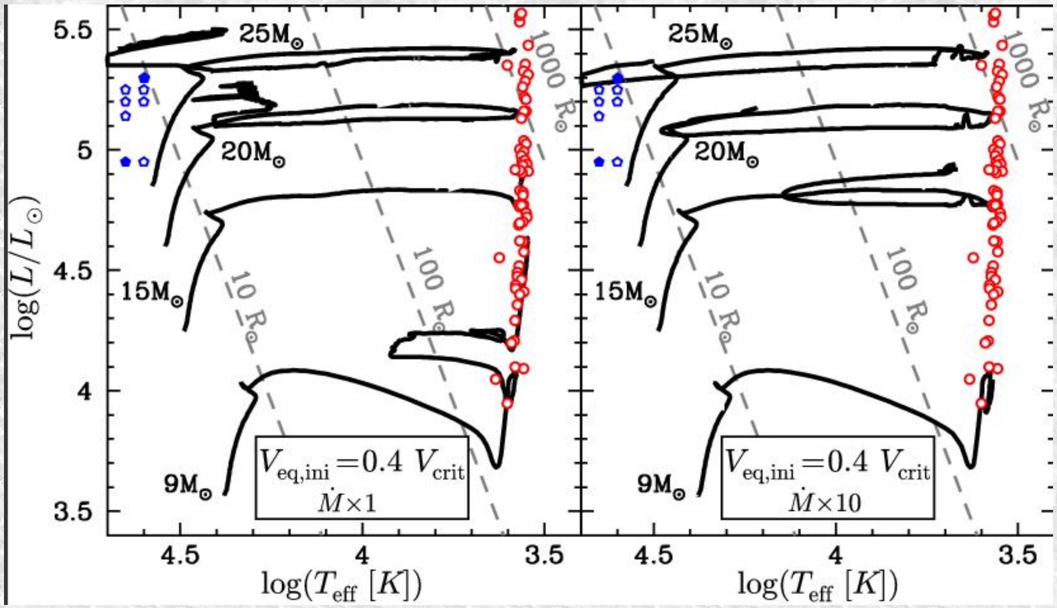
Surface chemical abundances significantly different from single stars only after mass transfer (in donor)

Mass loss and stellar evolution





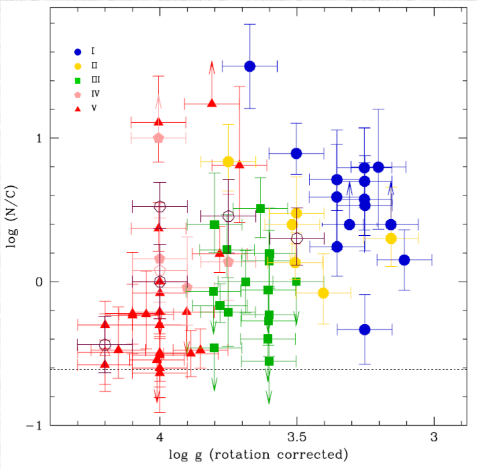
See also Bouret et al. 15



Large uncertainties on mass loss rates for all phases of evolution of massive stars

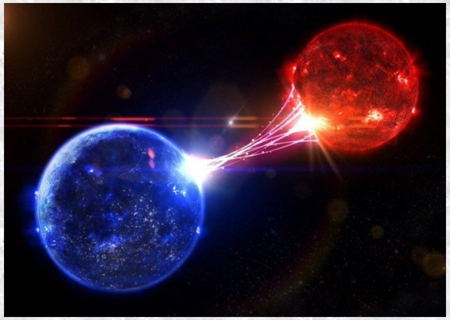
Impact on prediction of stellar evolution, progenitors of SN/BRG + GW emitters

Conclusions / Perspectives



- **Some predictions of stellar evolution with rotation are observed**
  - *surface chemical processing larger at later evolutionary phases and higher masses*

  Others remain to be fully tested
  - *effect of metallicity (including Local Group / ELT)*
  - *trend with rotation*



- **Effets of binarity on surface properties and stellar evolution remain widely unconstrained**

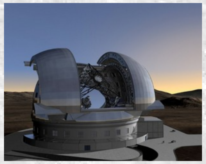
  → *need for observational constraints + evolutionary models*

- **What are the real mass loss rates of (massive) stars at different phases of their evolution?**

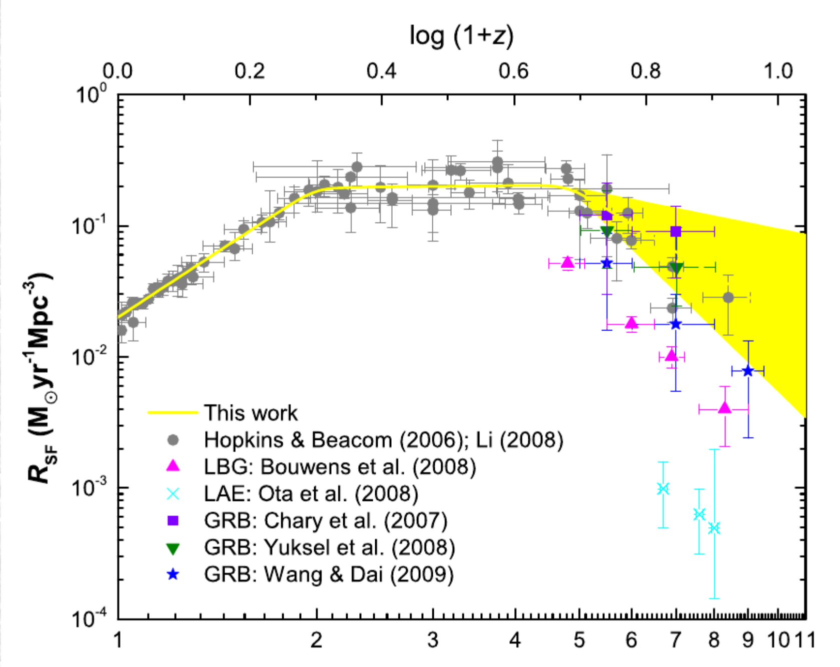
  → *PNPS action on mass loss ?*

Conclusions / Perspectives

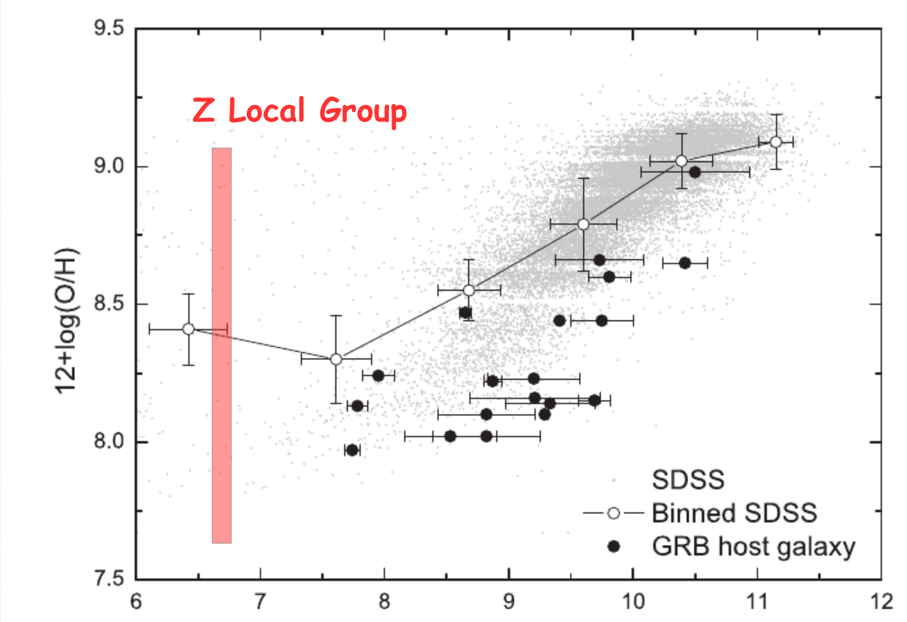
Massive stars in the Local Group resolved with the E-ELT



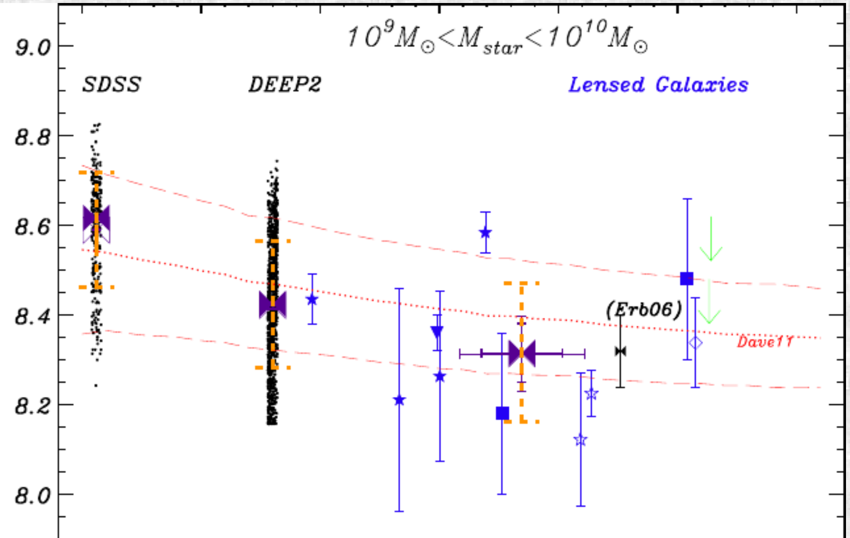
- stellar winds at $Z<Z_{SMC}$ (*see Bouret et al. 15*)
- long-soft GRBs favored at low Z
- massive stars evolution and properties at metallicity typical of redshift of peak of star formation (z~2-3)



Wei et al. 14



Wang & Dai 14



Yuan et al. 12

Atelier aux journées de la SF2A 2018

"Etoiles massives: de la formation aux stades ultimes, un état des lieux des recherches en France"

jeudi 5 juillet après-midi

Contributions bienvenues via le site des journées.

SOC: F. Martins, A. Palacios, S. Vergani, S. Bontemps

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40 ans

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Société invitée:
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SOC: S. Boissier, O. Berné, J. Braine, V. Buat, P. Di Matteo, F. Herpin, E. Lagadec, A. Lançon, F. Lique, C. Reylé, A. Palacios, P. Petit

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