

CNO abundances in open clusters

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1st dredge-up (Iben 1965)

^{12}C decreases by 30 %

^{14}N increases by 80 %

^{16}O unaltered

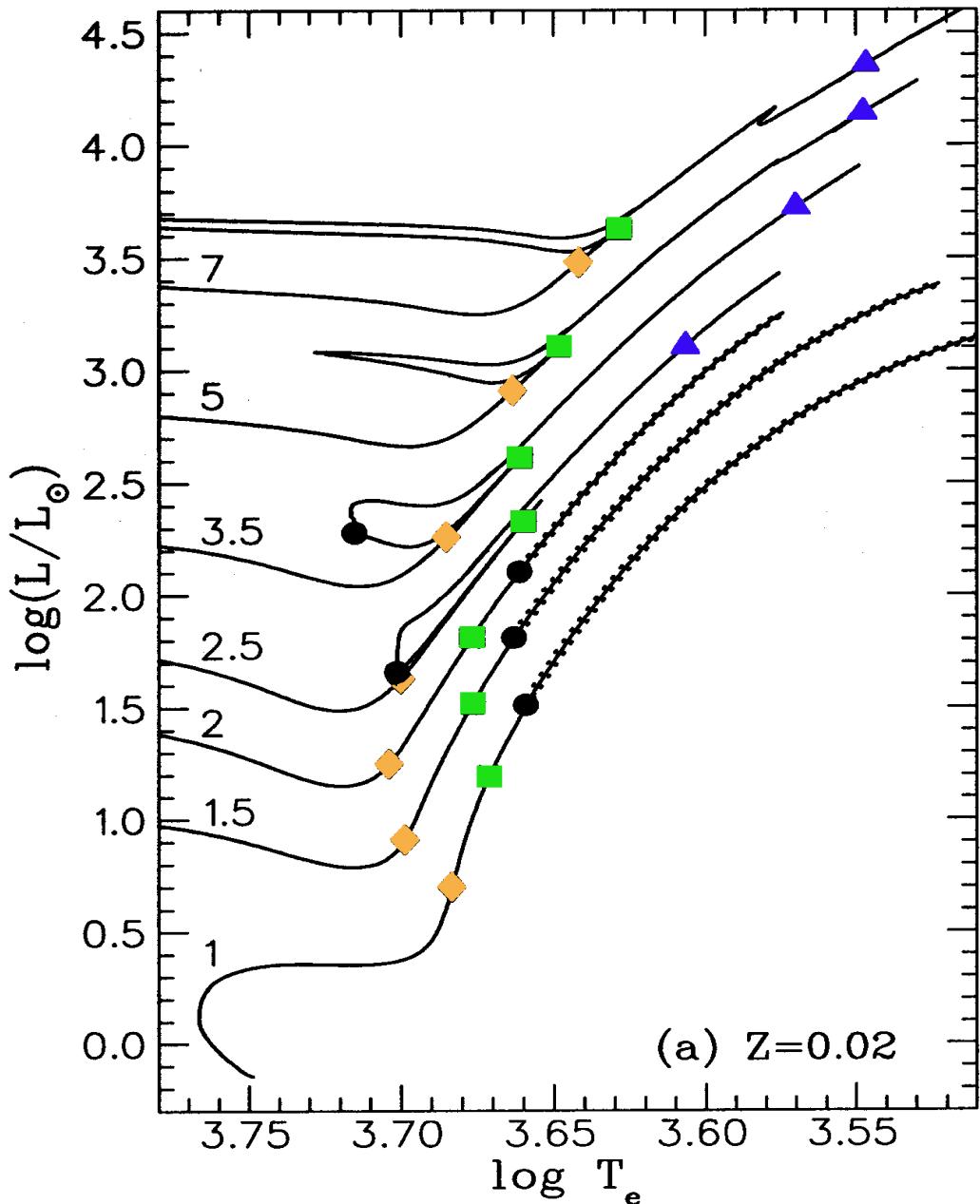
$^{12}\text{C}/^{14}\text{N} = 3.98 \rightarrow 2.0$

$^{12}\text{C}/^{13}\text{C} = 90 \rightarrow 20 - 30$

First discrepancies from the standard theory came when :

- Arcturus was found to have $^{12}\text{C}/^{13}\text{C} = 7.2 \pm 1.5$ (Day et al., 1973)
- The enhancement of CN bands was reported for the clump stars in M 67 (Pagel, 1974)

Boothroyd & Sackman 1999, ApJ, 510, 232



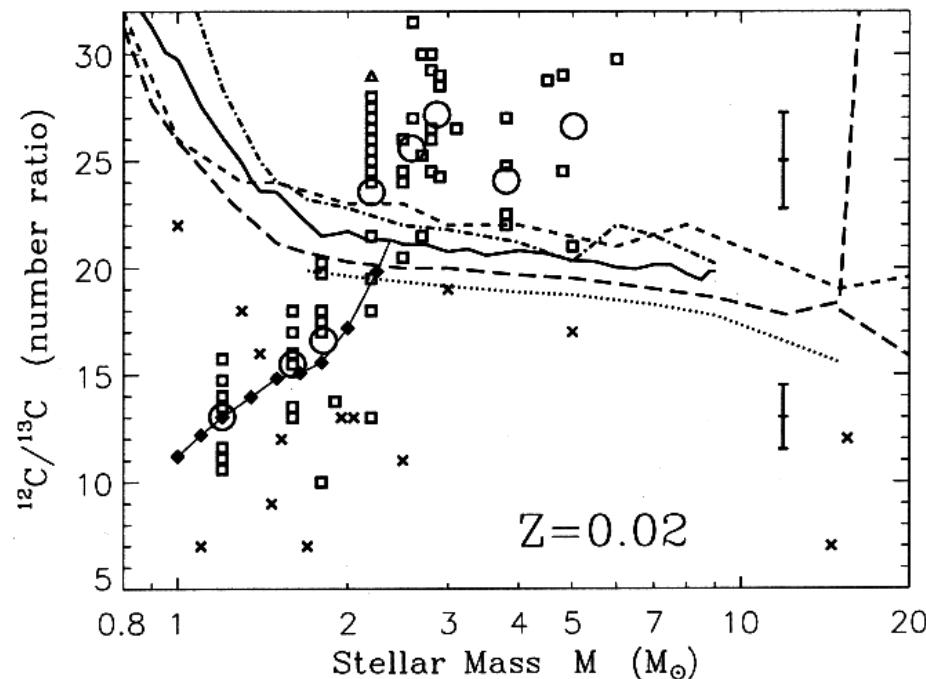


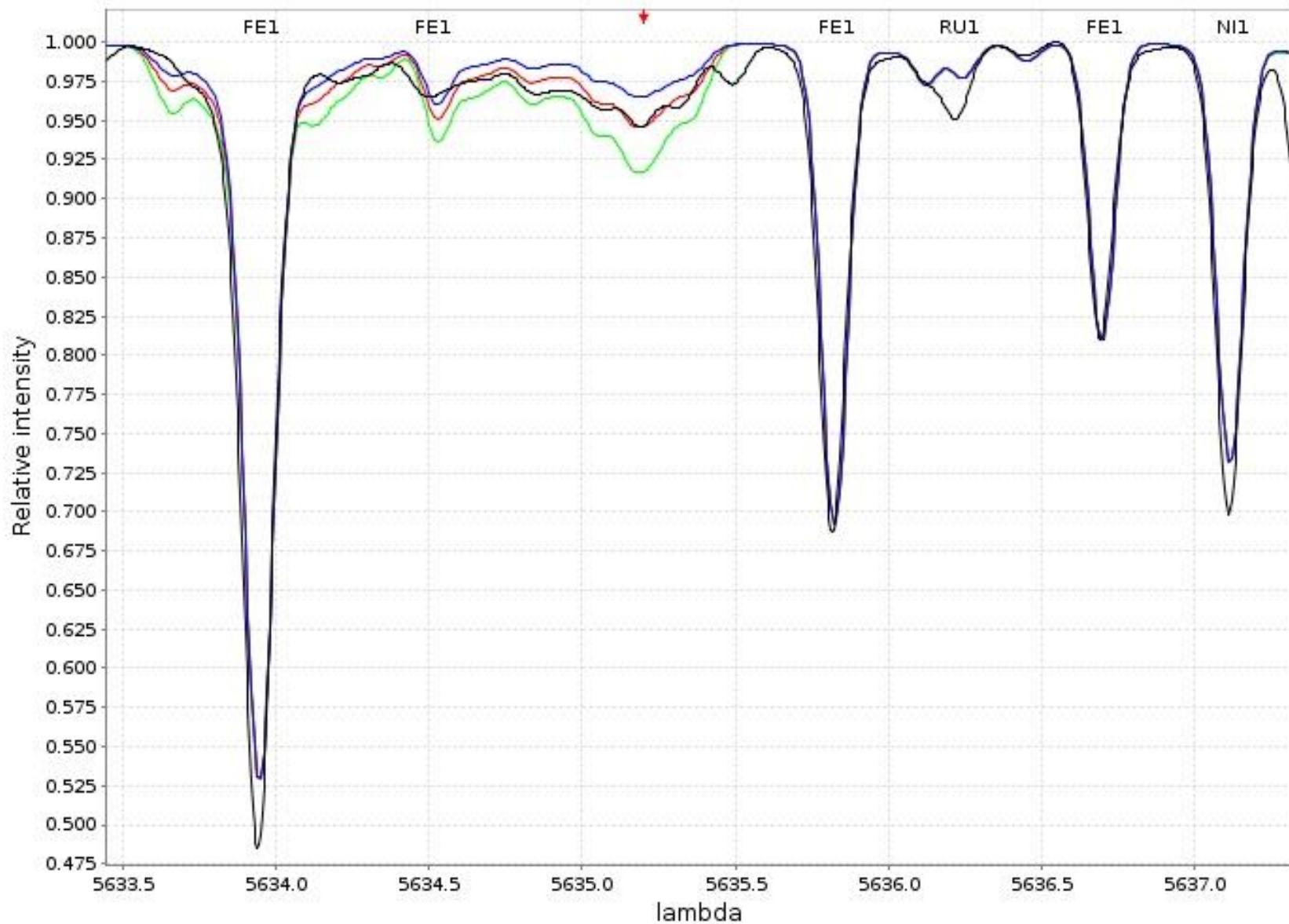
FIG. 3.—Comparison between observations and theory for $^{12}\text{C}/^{13}\text{C}$ in solar-metallicity red giants. *Open squares*: open cluster observations of Gilroy (1989), with open triangle giving lower limit; large open circles give mean values at corresponding masses (error bars at right show typical uncertainties in individual observations). *Crosses*: observations of isolated stars by Harris & Lambert (1984a, 1984b) and Harris et al. (1988), where the stellar masses are also uncertain (by a factor of ~ 2). Theoretical first dredge-up curves: *heavy solid line*: present work; *dotted line*: El Eid (1994); *dot-dashed line*: Bressan et al. (1993); *short-dashed line*: Dearborn (1992); *long-dashed line*: Schaller et al. (1992) (also presented by Charbonnel 1994), where second dredge-up is also shown for masses $\geq 15 M_{\odot}$ where first dredge-up is hard to define. Filled diamonds (connected by light solid line) indicate the abundances from the “evolving RGB” CBP models of the present work (normalized by observations at $1.2 M_{\odot}$: see text).

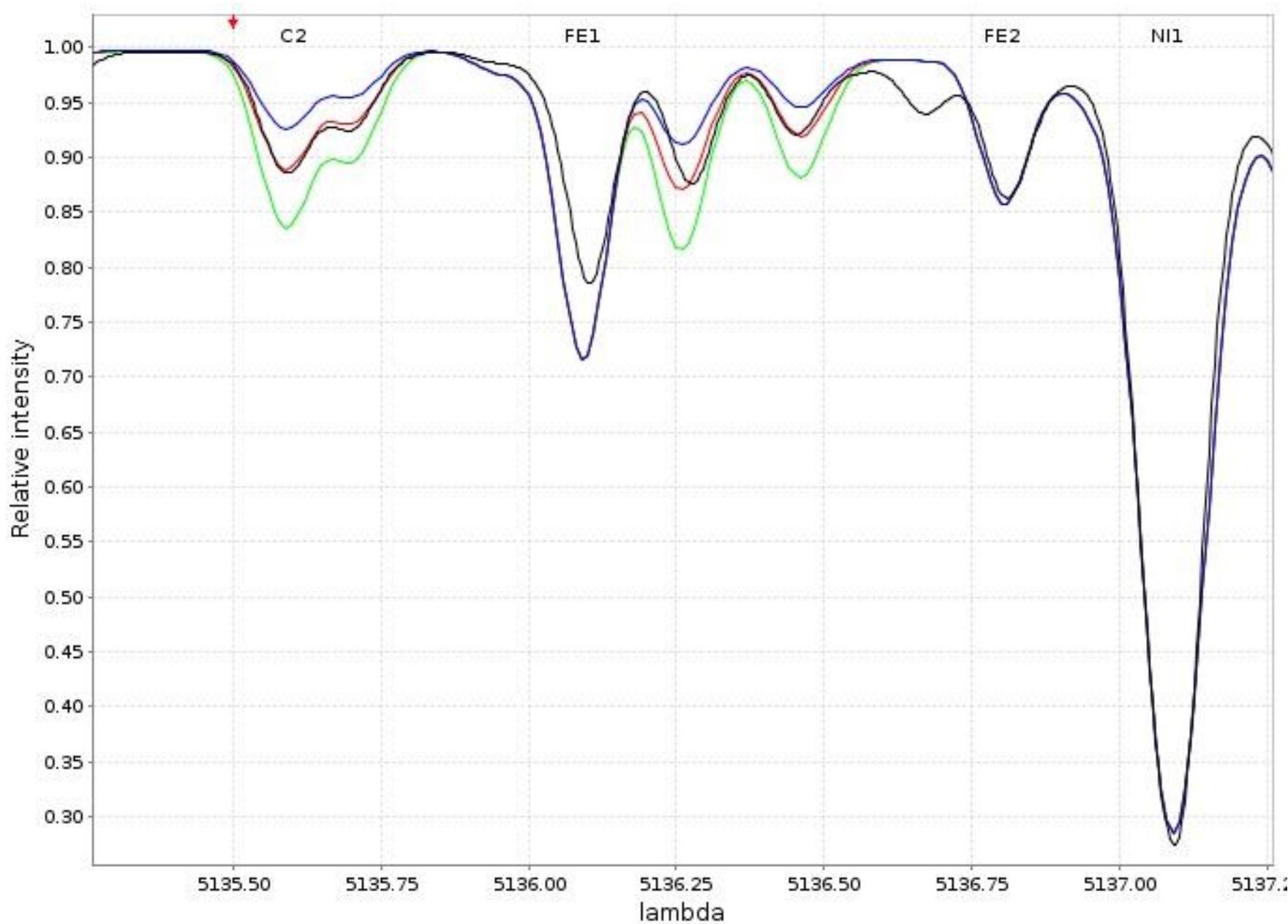
Collaborators

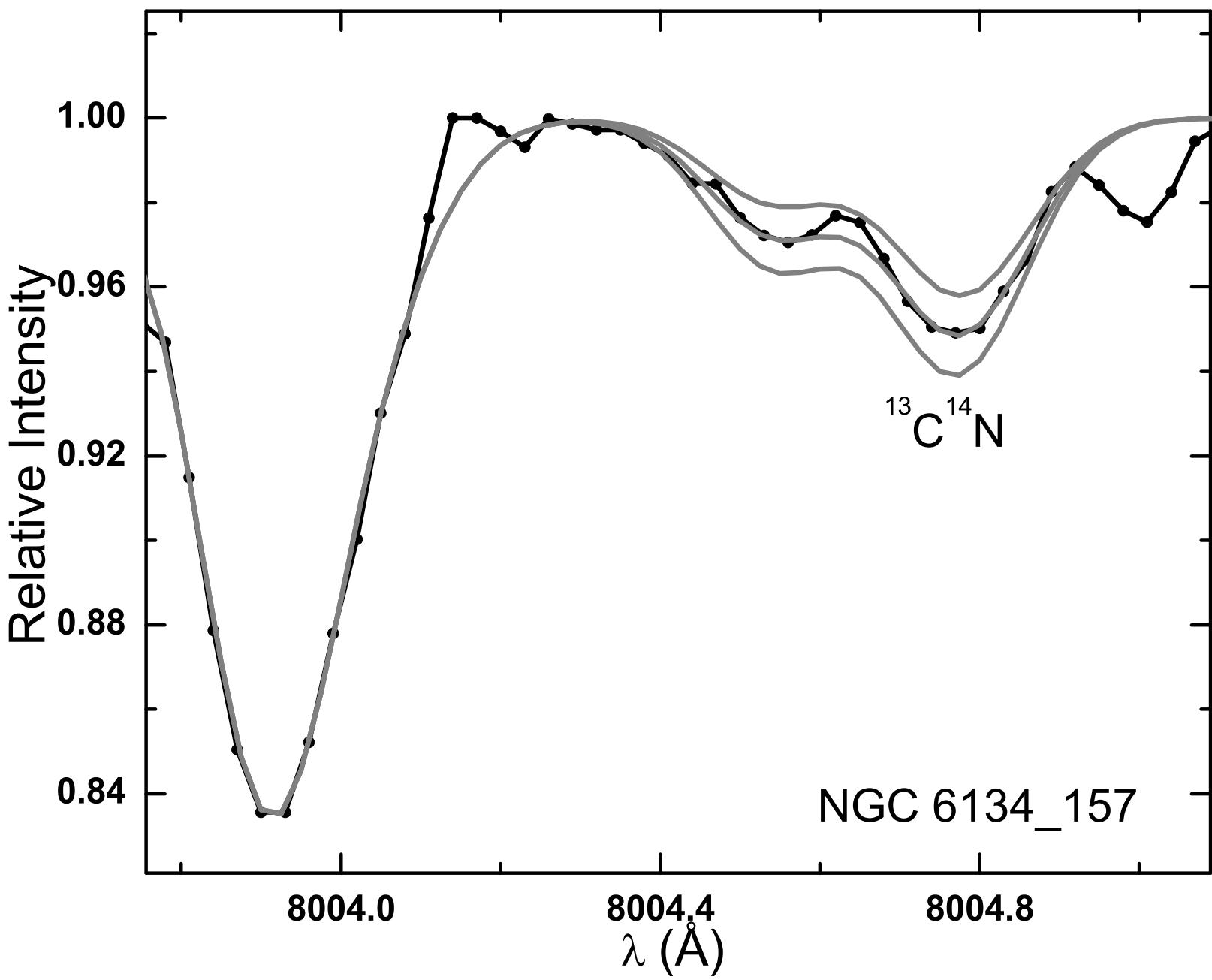


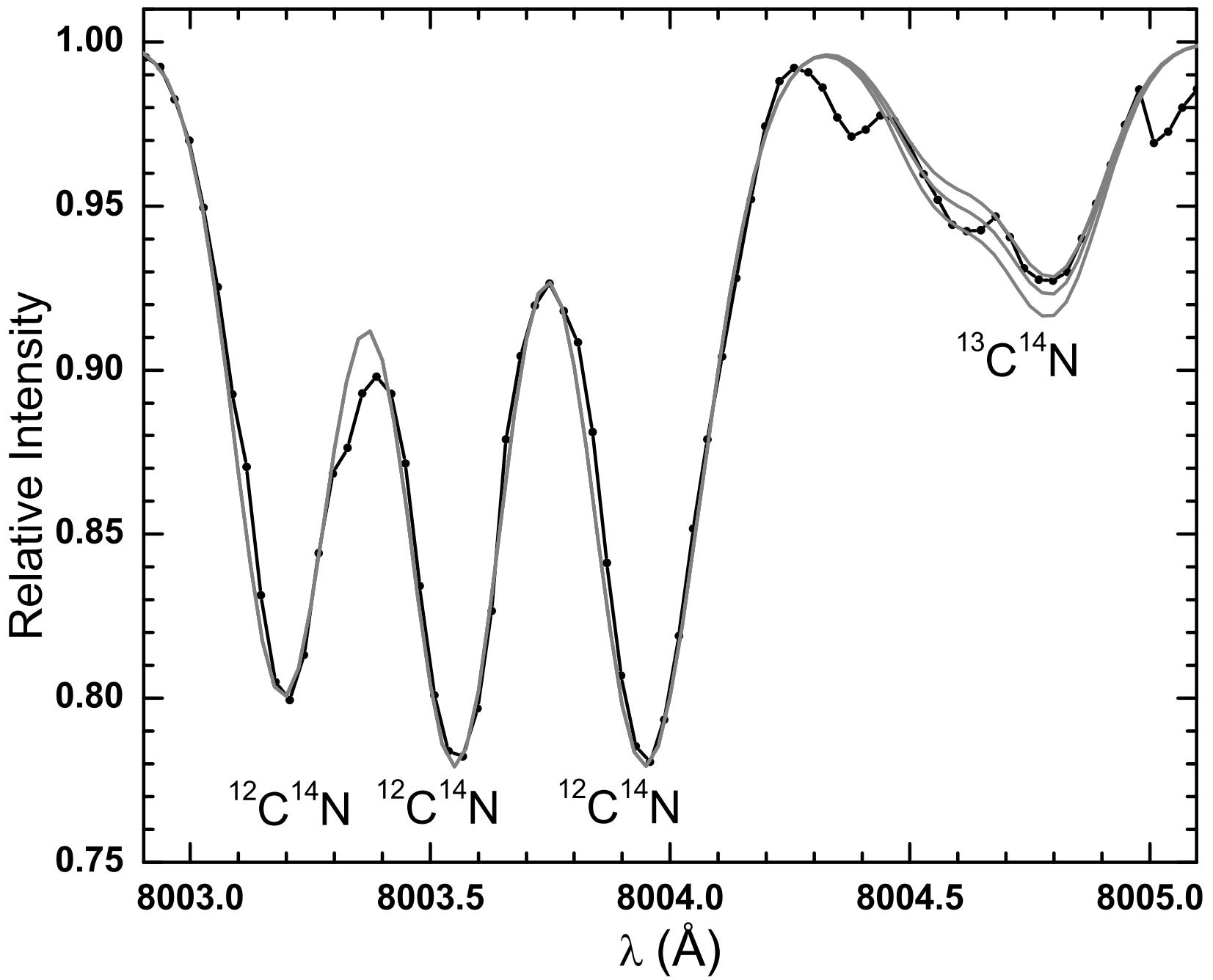
G. Tautvaišiene, S. Mikolaitis, A. Drazdauskas (Lithuania)
B. Edvardsson (Sweden), I. Iljin (Germany), R. Smiljanic (Poland)
A. Bragaglia, E. Carretta, R. Gratton, S. Randich et al. (Italy)

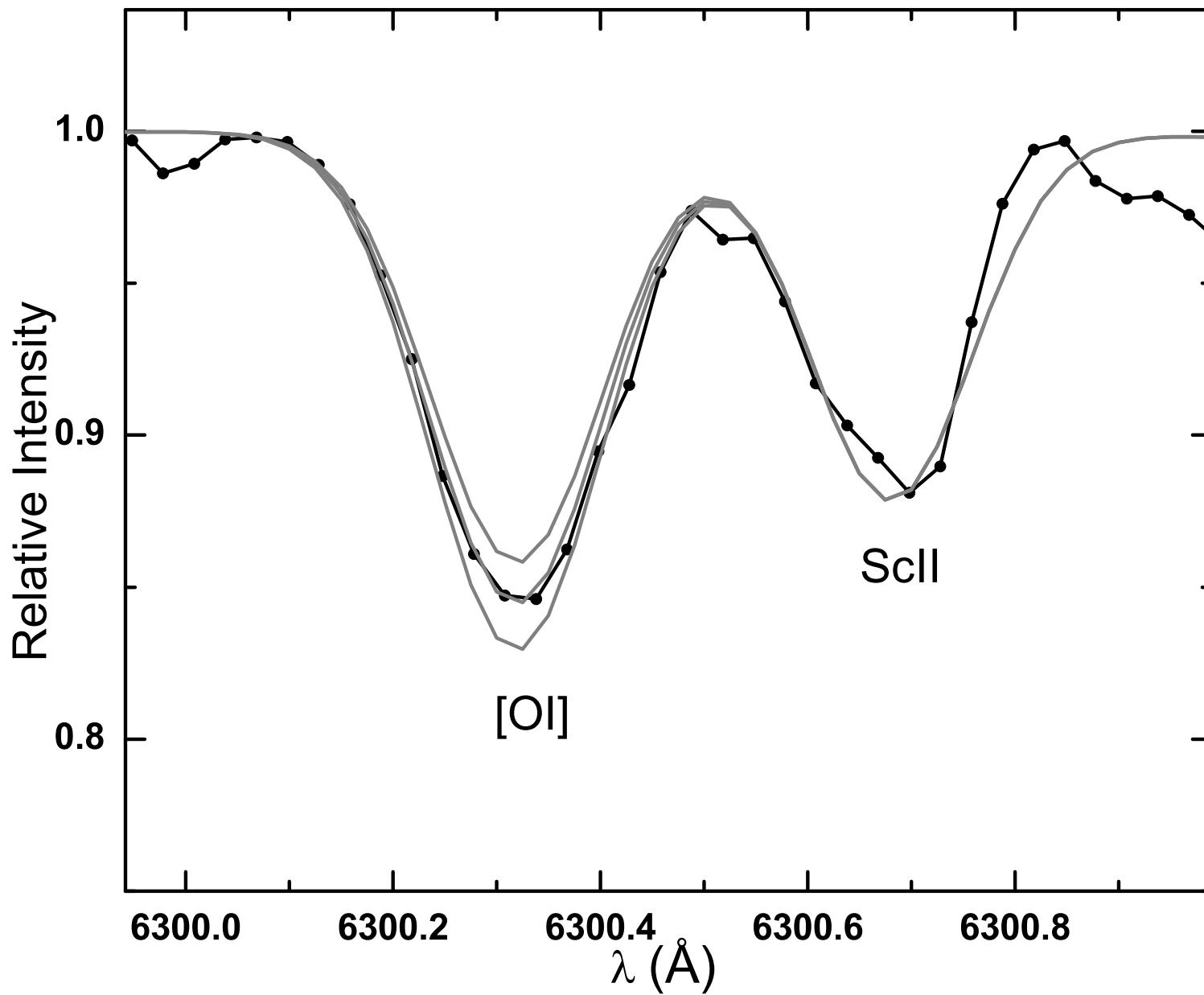
Nordic Optical Telescope, SOFIN spectrograph
Gallileo National Telescope, FERROS spectrograph
VLT, UVES spectrograph...











O M67 giants

● M67 clump stars

(Tautvaišiene et al. 2000)

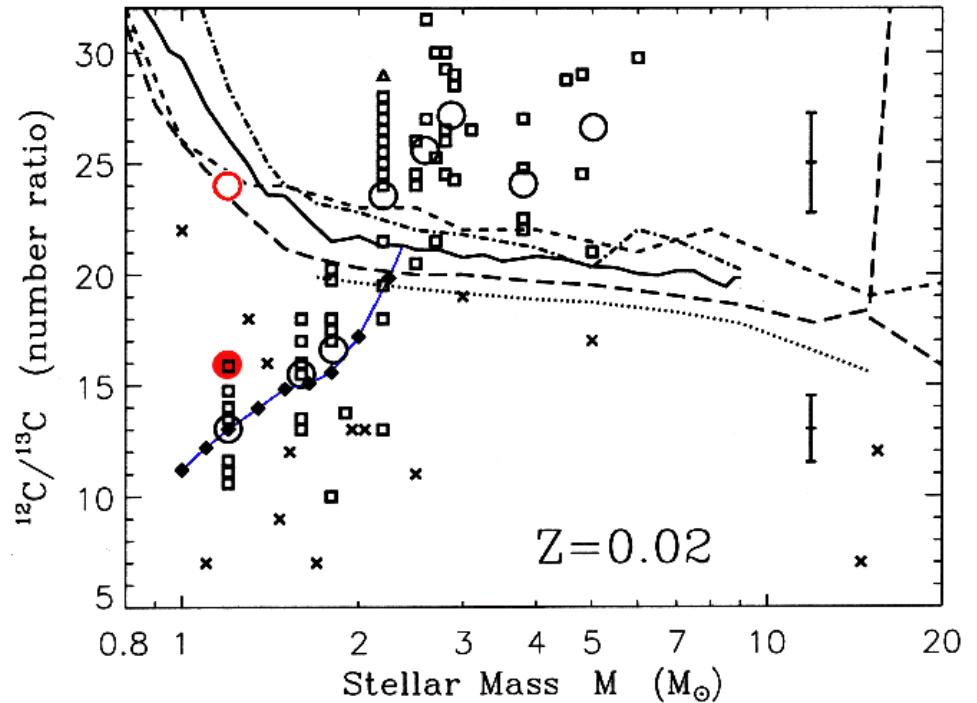
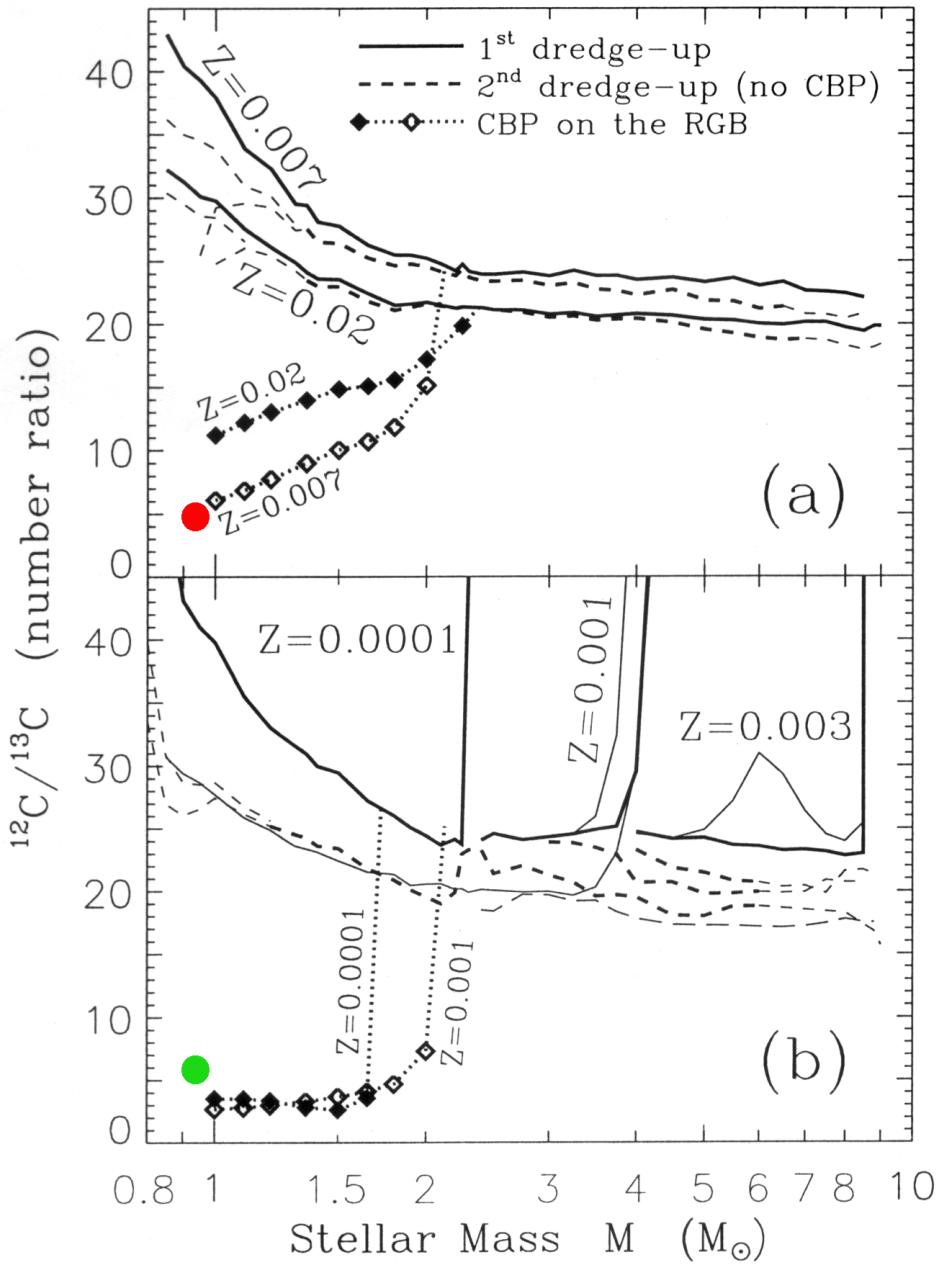
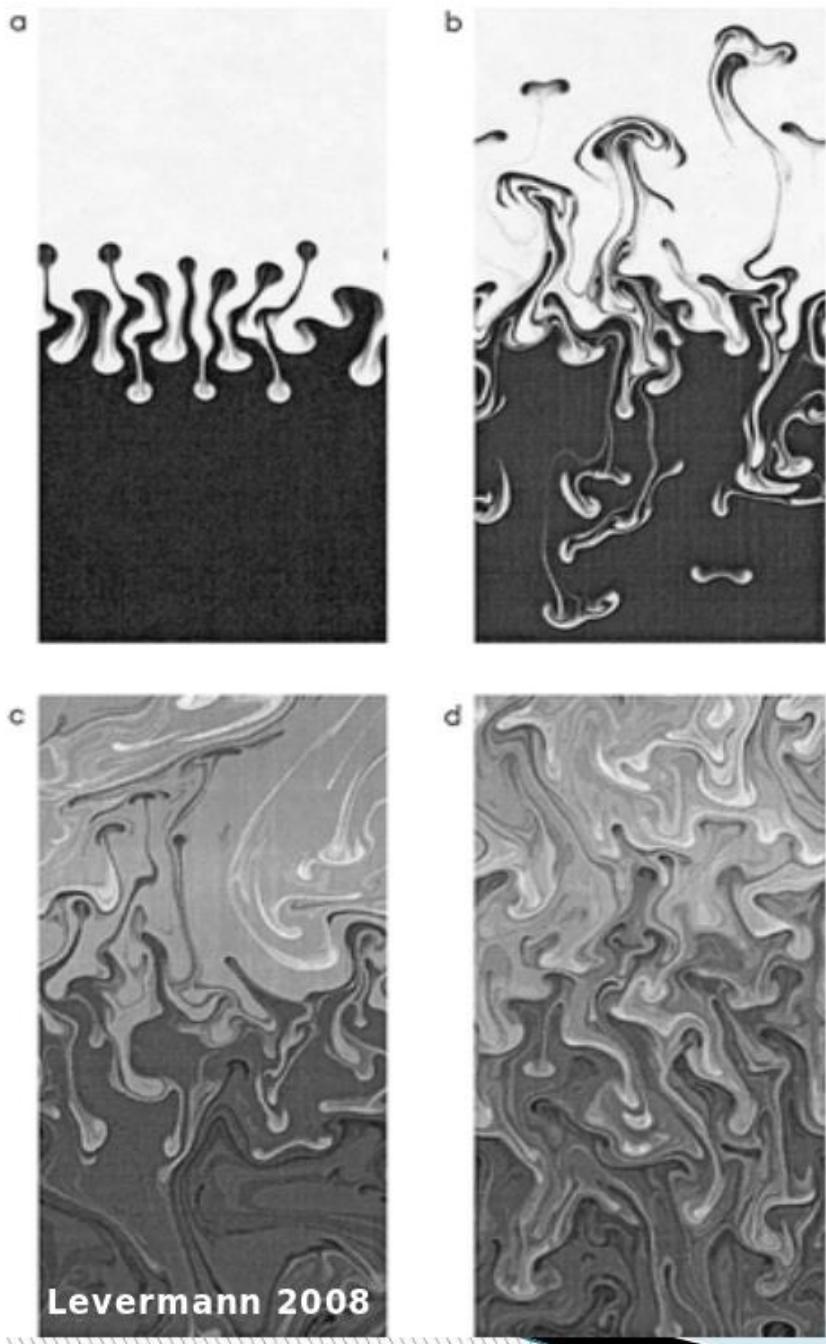


FIG. 3.—Comparison between observations and theory for $^{12}\text{C}/^{13}\text{C}$ in solar-metallicity red giants. *Open squares*: open cluster observations of Gilroy (1989), with open triangle giving lower limit; large open circles give mean values at corresponding masses (error bars at right show typical uncertainties in individual observations). *Crosses*: observations of isolated stars by Harris & Lambert (1984a, 1984b) and Harris et al. (1988), where the stellar masses are also uncertain (by a factor of ~ 2). Theoretical first dredge-up curves: *heavy solid line*: present work; *dotted line*: El Eid (1994); *dot-dashed line*: Bressan et al. (1993); *short-dashed line*: Dearborn (1992); *long-dashed line*: Schaller et al. (1992) (also presented by Charbonnel 1994), where second dredge-up is also shown for masses $\geq 15 M_\odot$ where first dredge-up is hard to define. Filled diamonds (connected by light solid line) indicate the abundances from the “evolving RGB” CBP models of the present work (normalized by observations at $1.2 M_\odot$: see text).

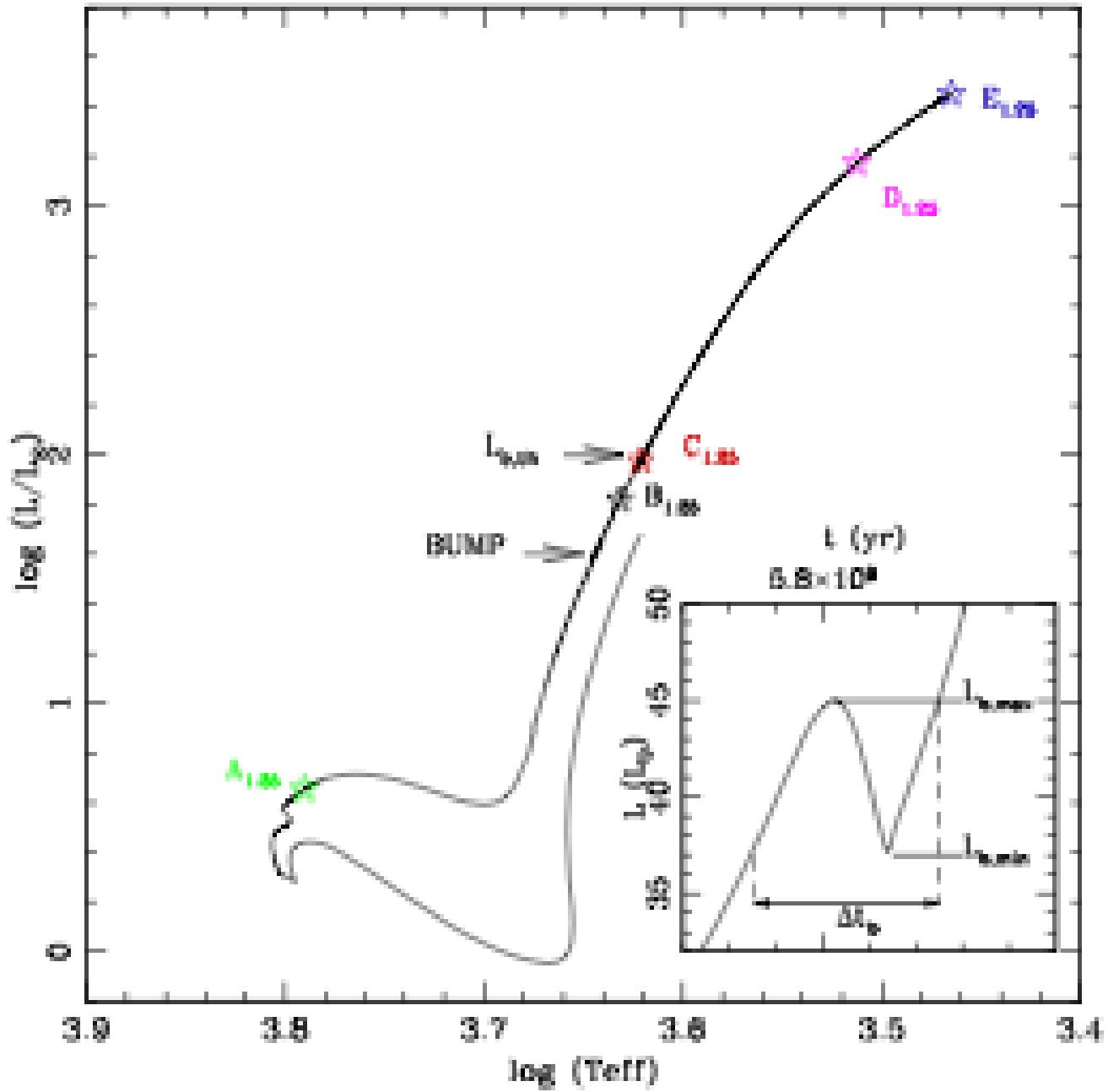
- 10 RHB stars
(Tautvaišiene et al. 2001)
- 6 RHB stars
(Gratton, Sneden, Carretta, Bragaglia 2000)



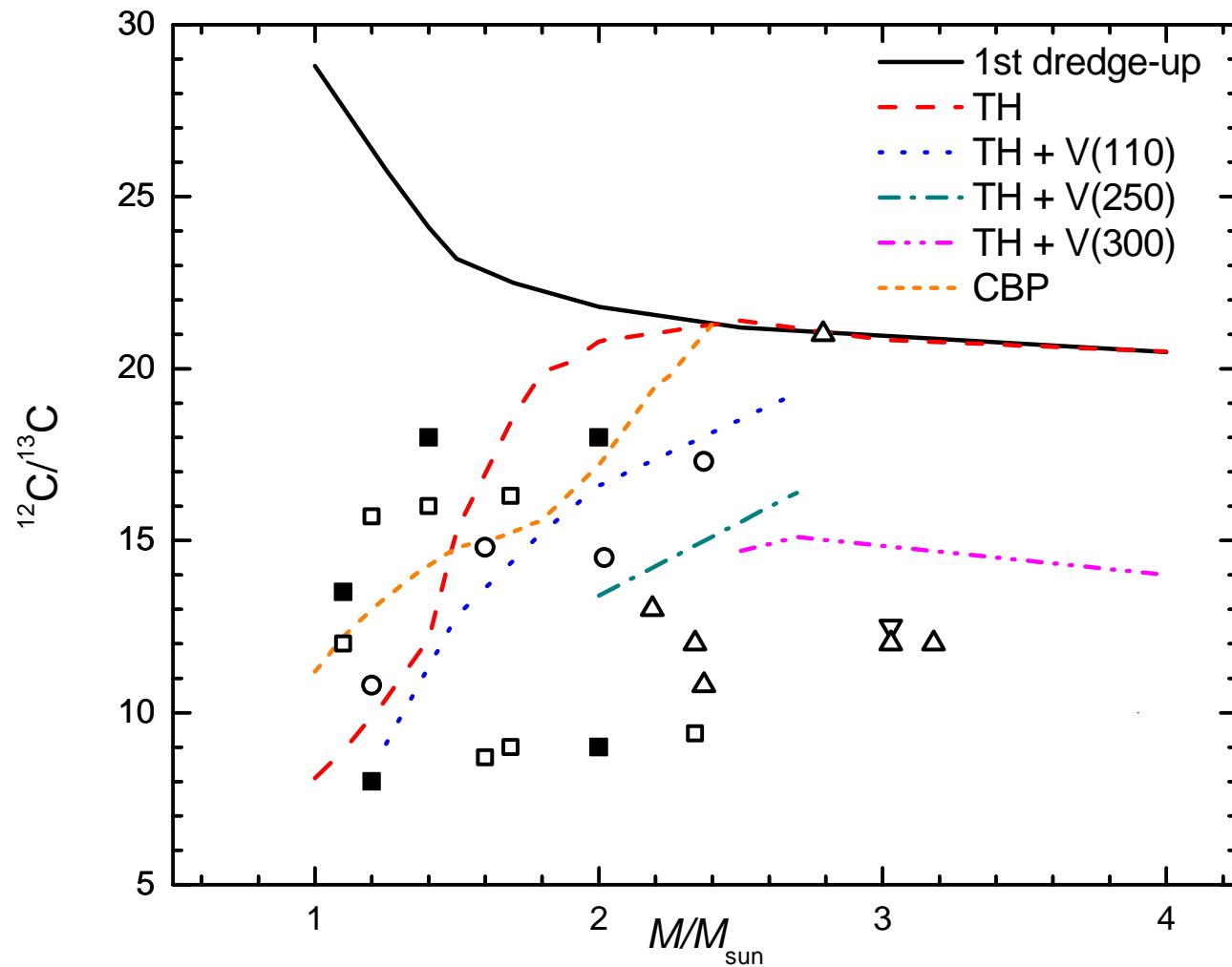
Thermohaline mixing



Charbonnel &
Lagarde, 2010,
A&A, 522, 10

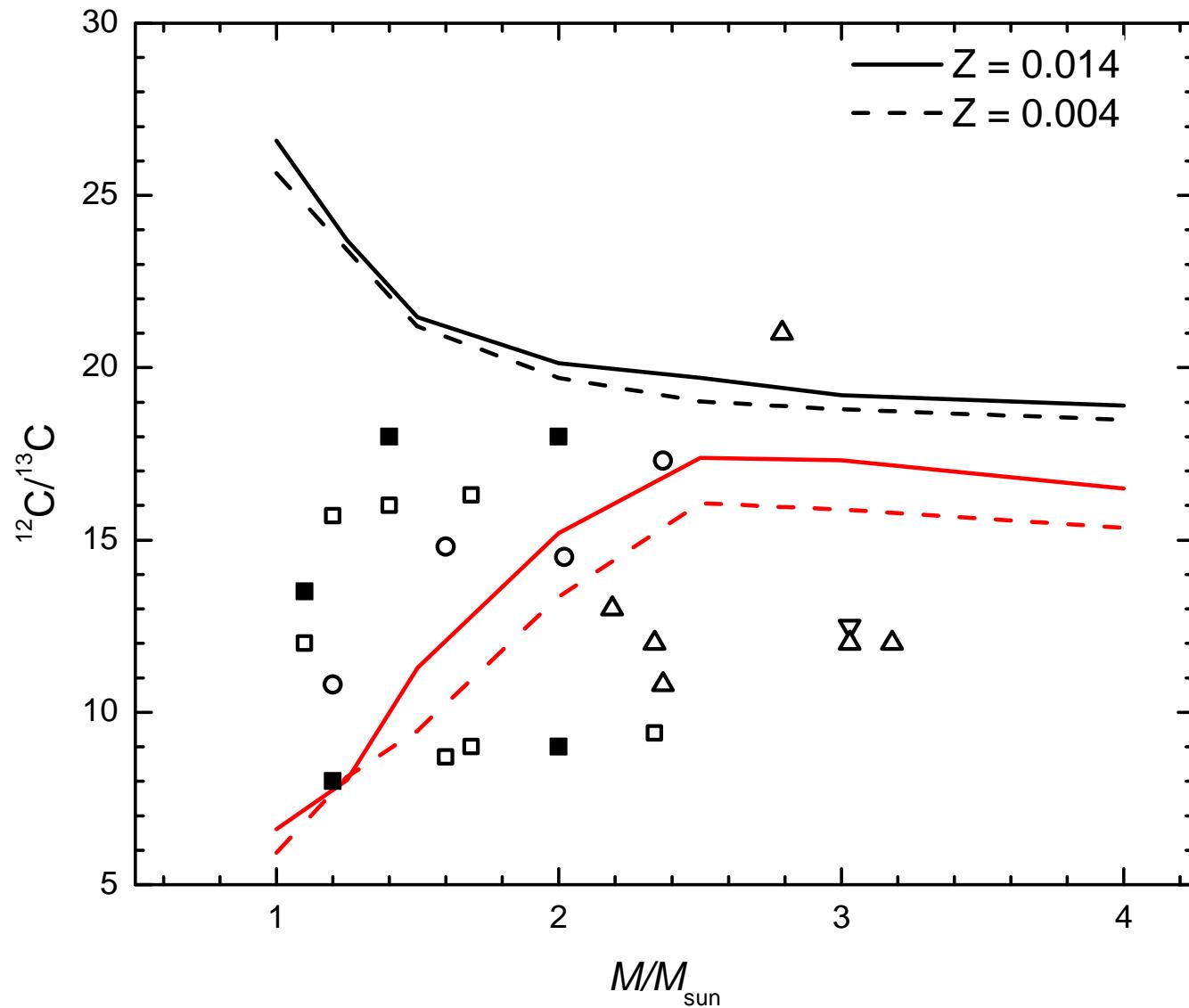


Models: Boothroyd & Sackmann (CPB, 1999)
Charbonnel & Lagarde (TH, 2010)



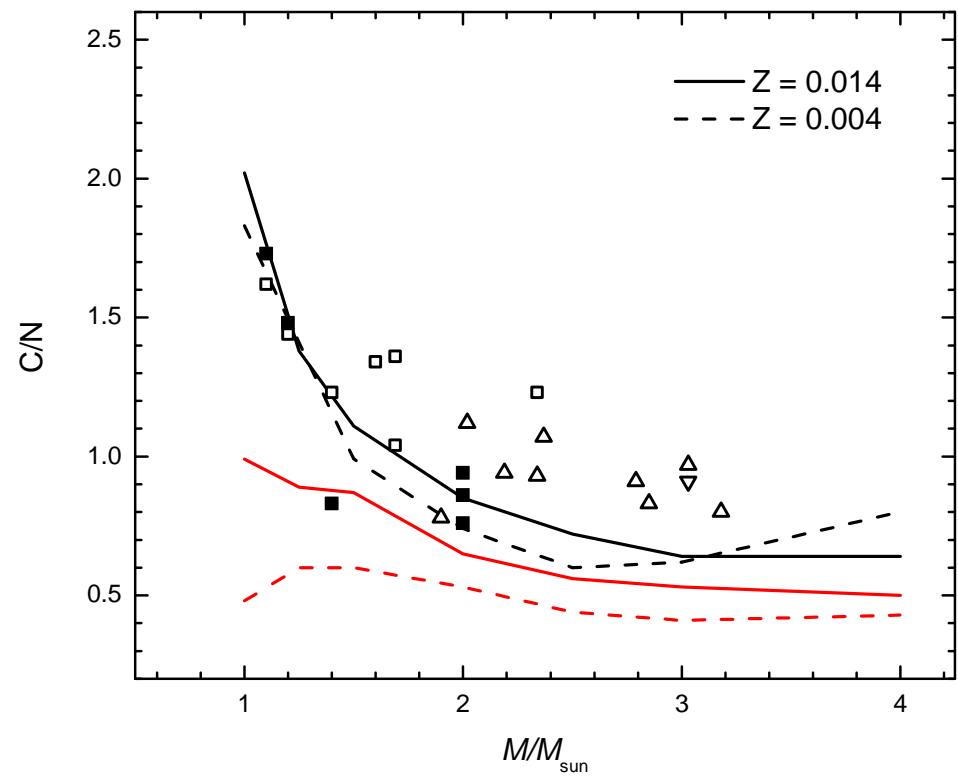
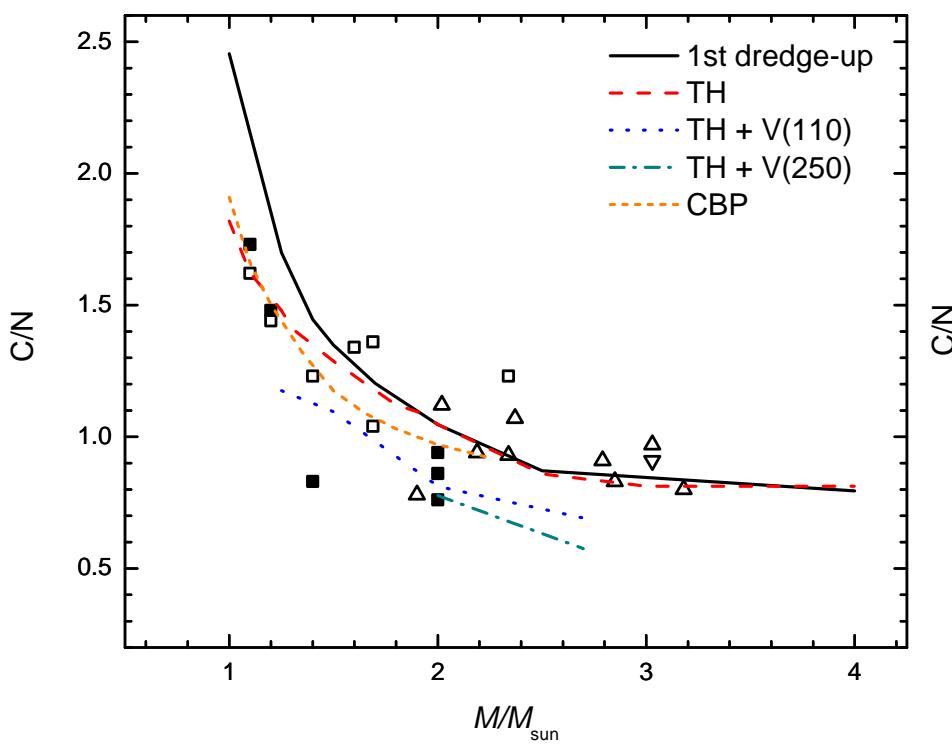
Observations: Tautvaišiūnė et al. Mikolaitis et al.
Smiljanic et al. (2009), Gilroy (1989), Luck (1991)

Lagarde et al. 2012

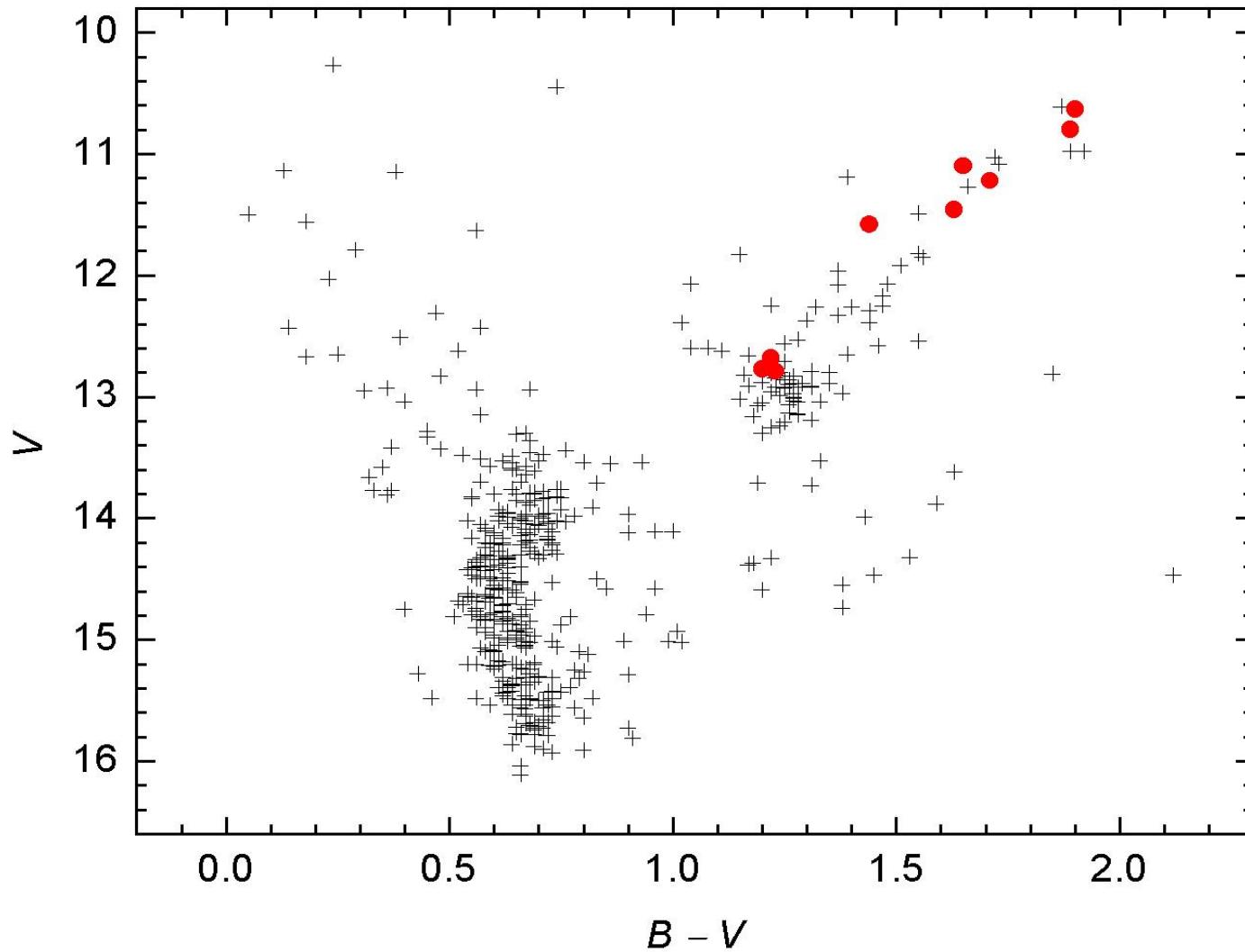


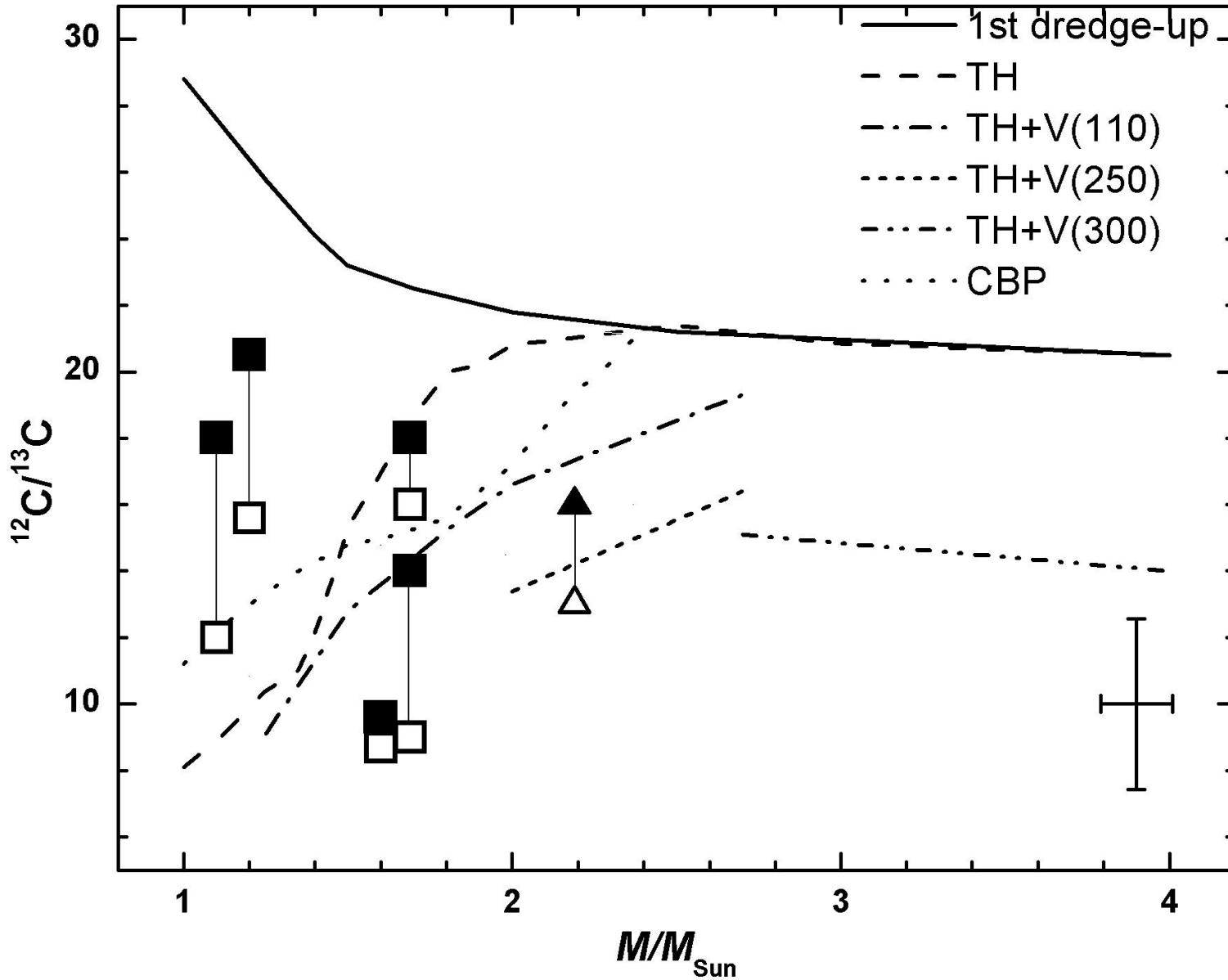
Boothroyd & Sackmann 1999
Charbonnel & Lagarde 2010

Lagarde et al. 2012

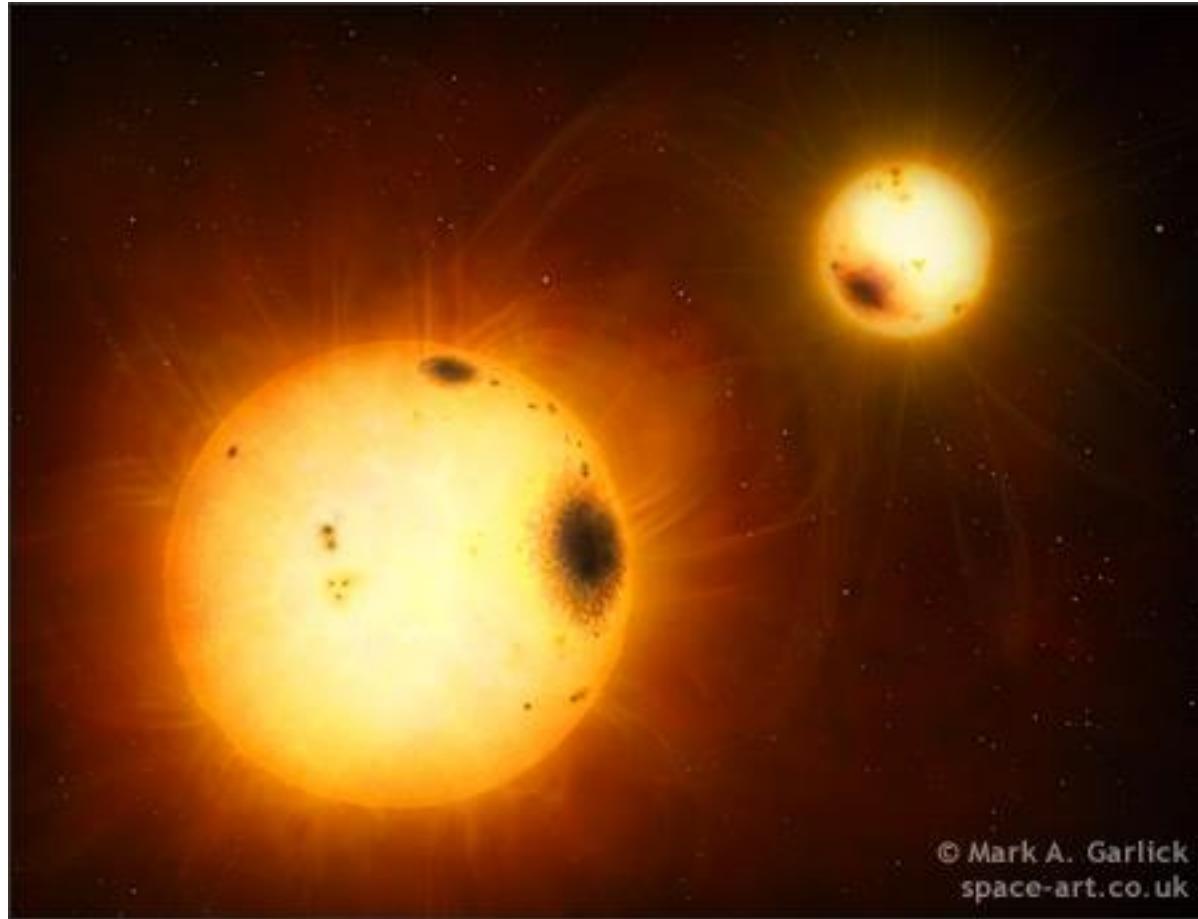


Open Clusters (NGC 7789)



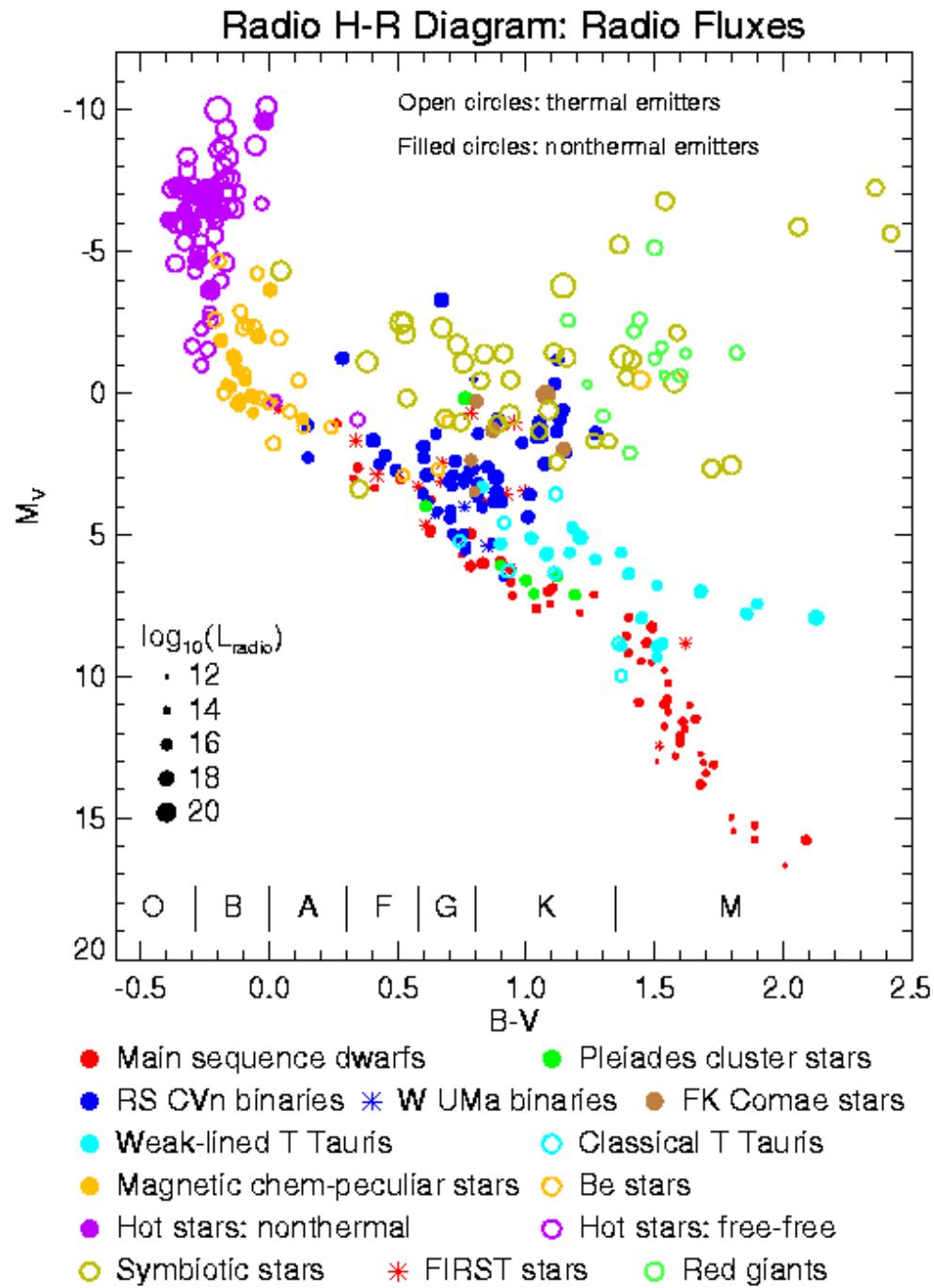


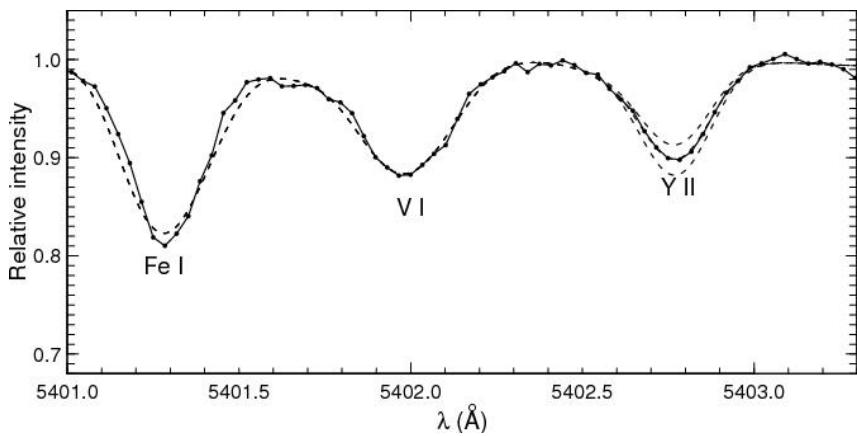
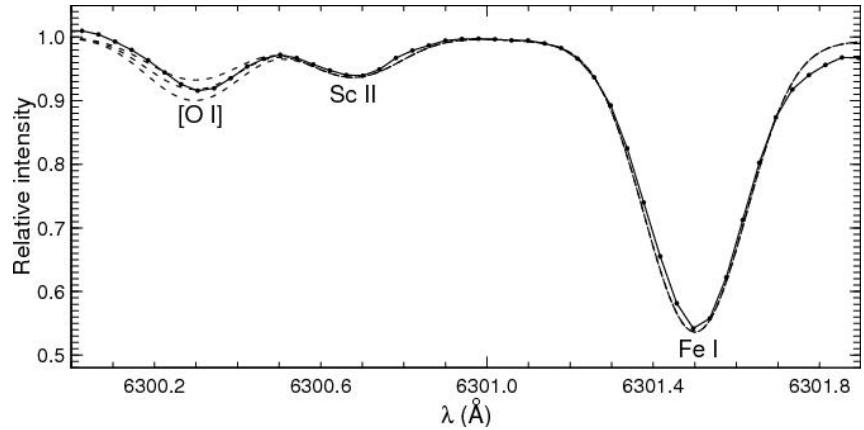
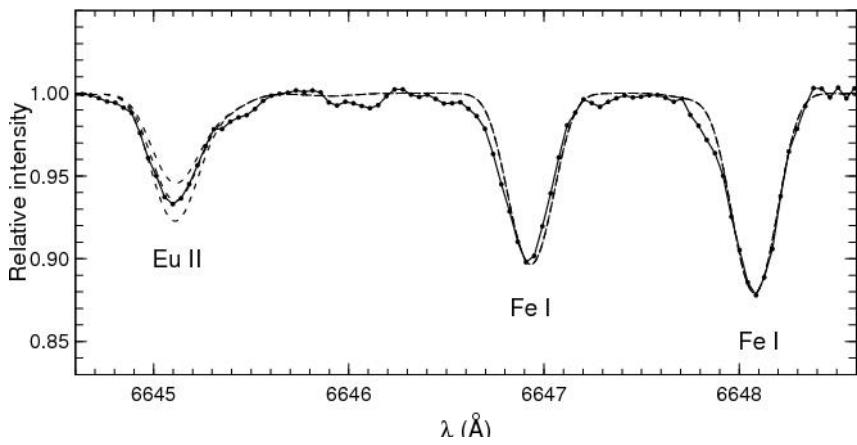
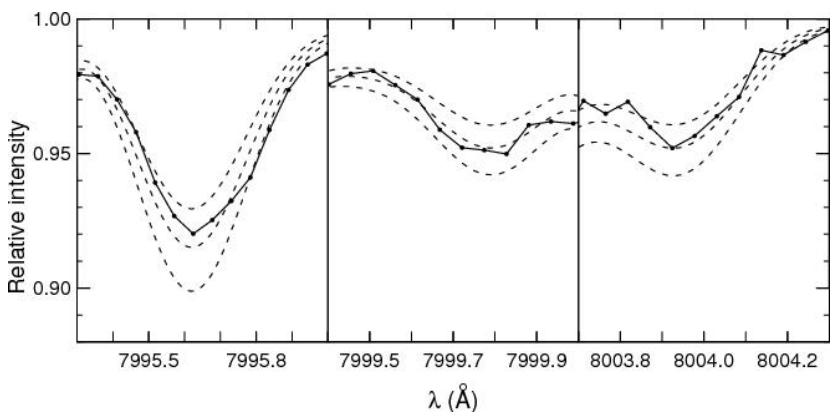
Cromospherically active stars: RS CVn



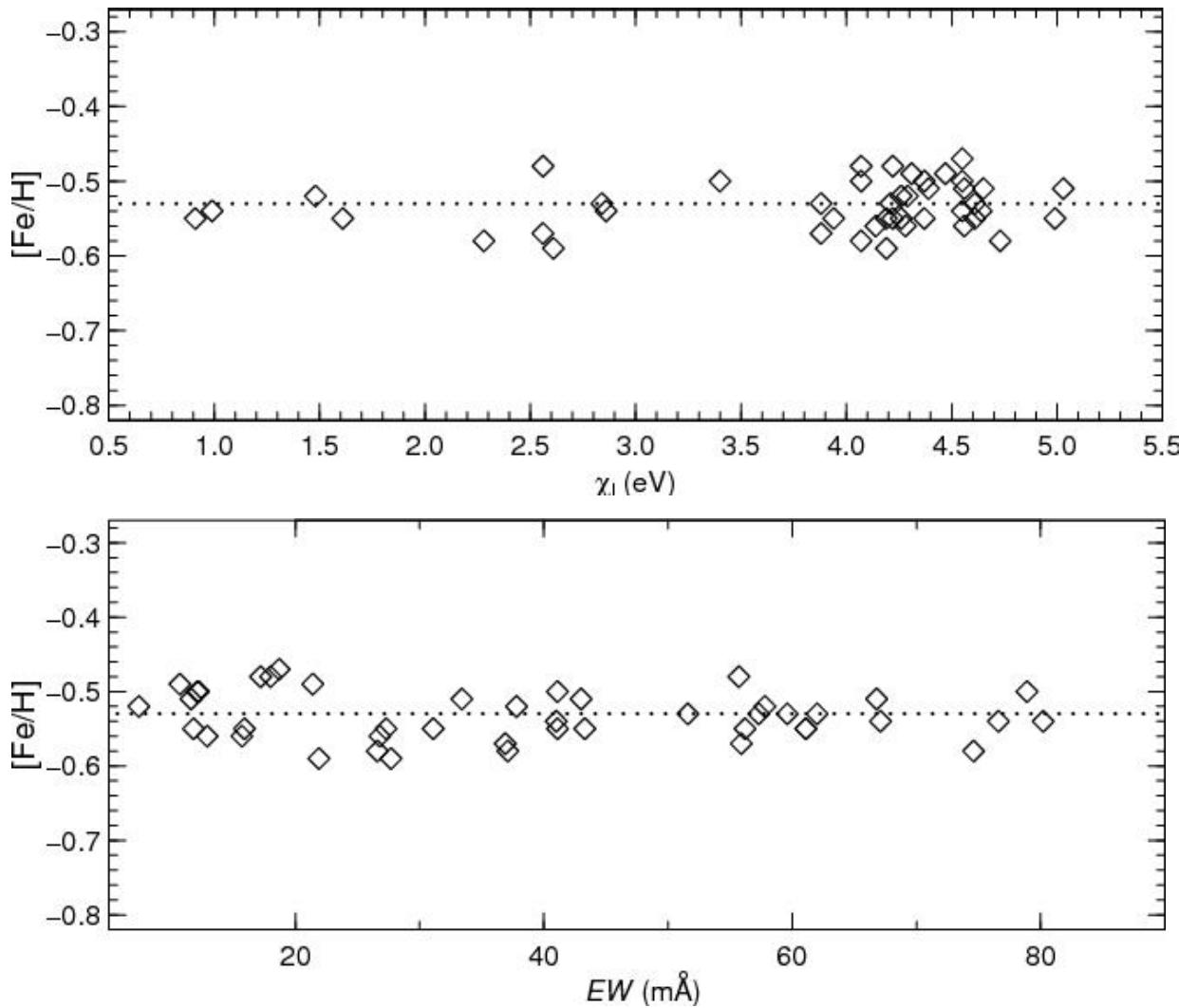
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Tautvaišienė et al. 1992, 2011, 2013
Barisevičius et al. 2010a,b, 2012

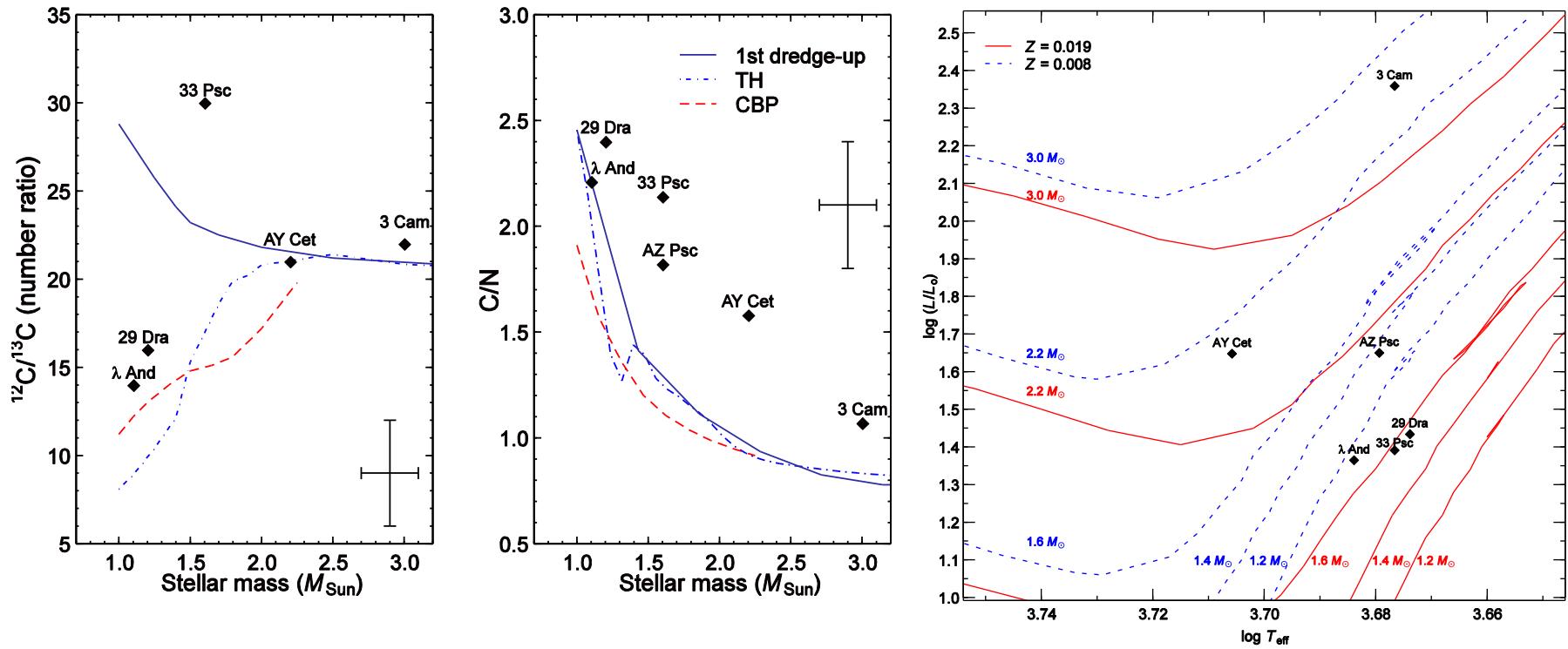




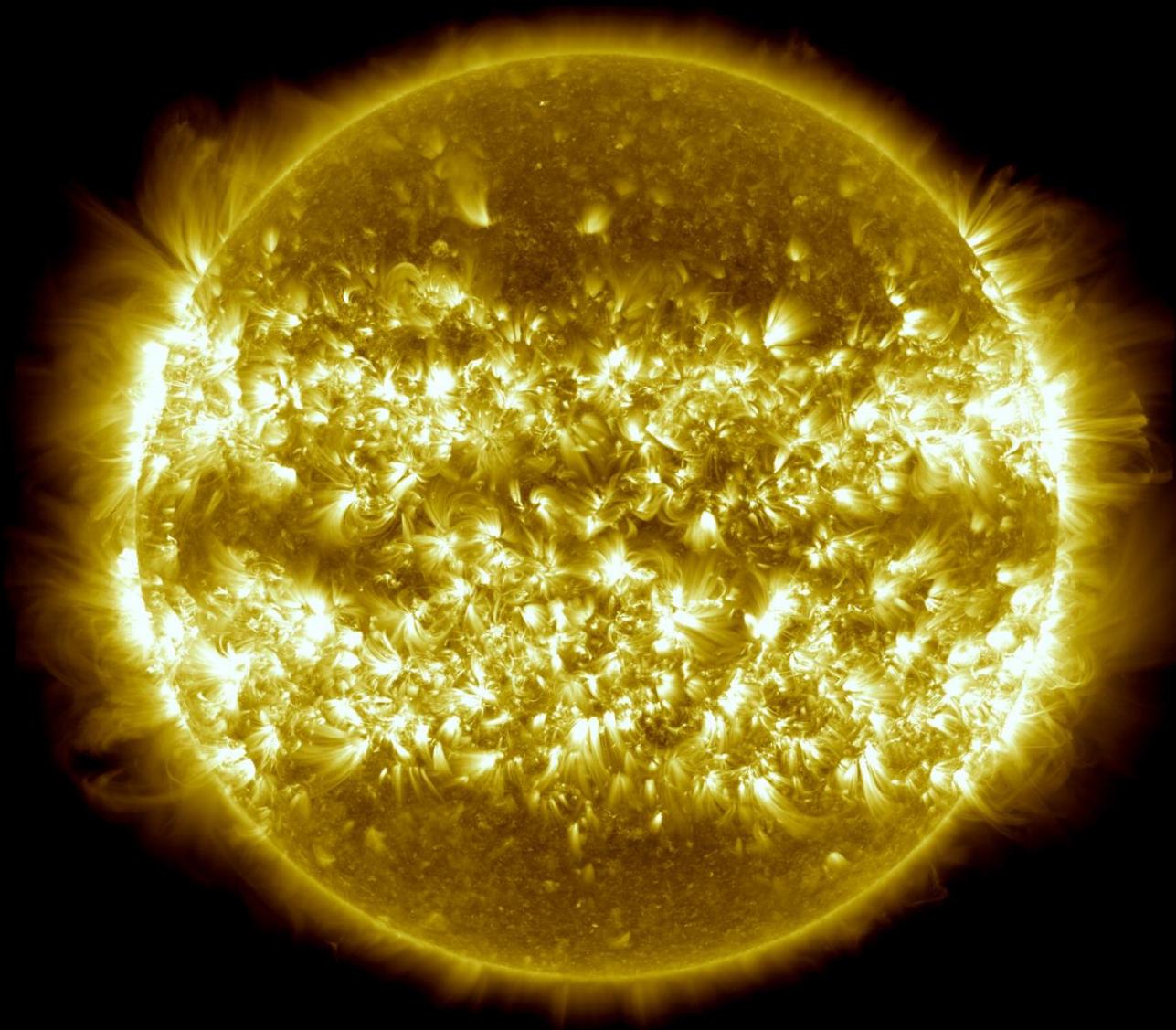
Atmospheric parameters



Chemical composition of photospheres in RS CVn stars



- We determine $^{12}\text{C}/^{13}\text{C}$ ratios in RS CVn stars and compare with theoretical models of the 1st dredge-up and of extra-mixing.
- In low-mass chromospherically active RS CVn stars, such as λ And and 29 Dra, the extra-mixing starts earlier than in non-active giants.
- 33 Psc, which has almost negligible activity, has no extra-mixing.



Thanks for your attention

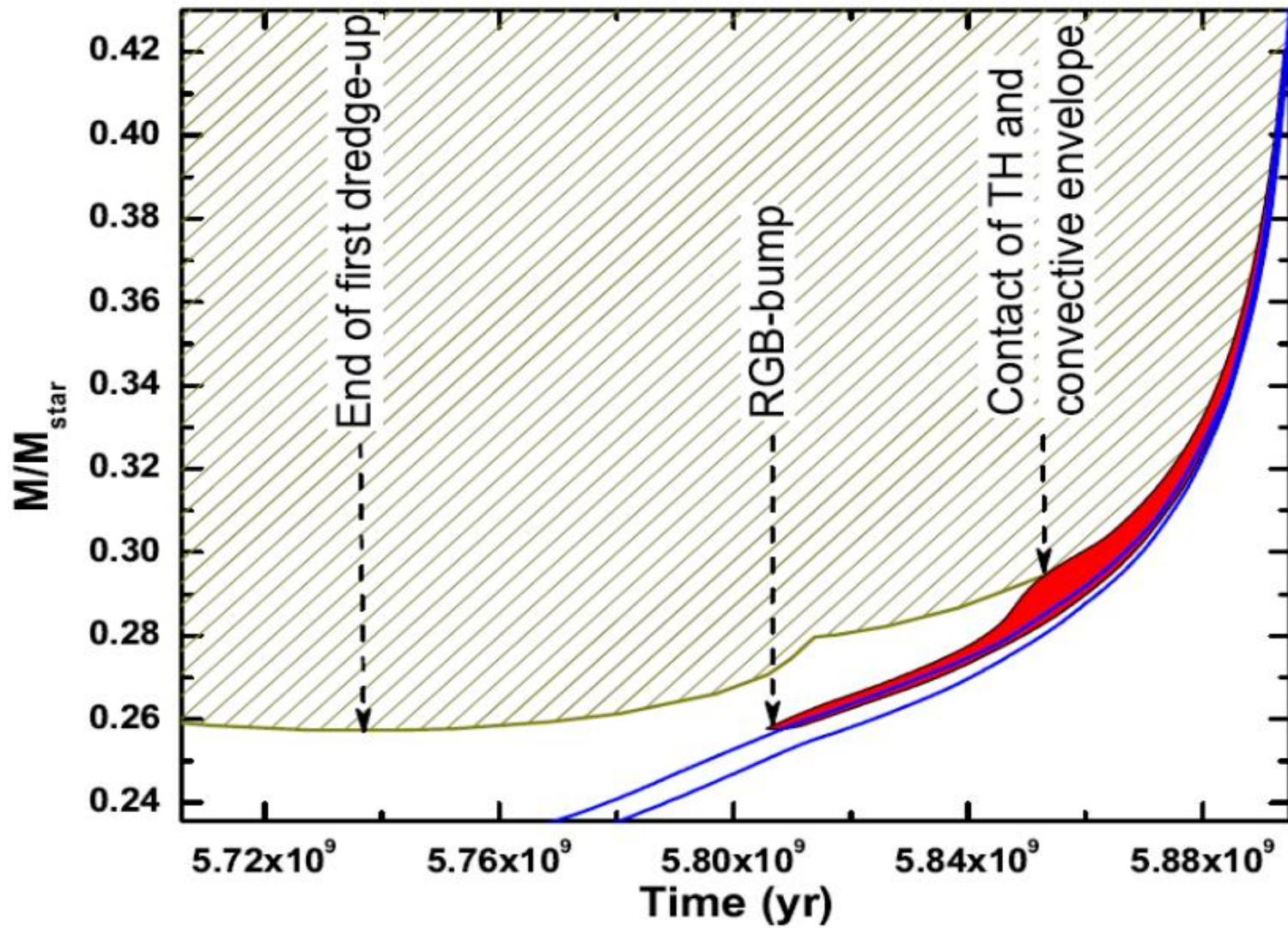


Figure 3.1: Kippenhahn diagram for the $M = 1.25M_{\odot}$ Population I star evolution from the first dredge-up up to the RGB-tip. The brown hashed area indicates the convective envelope. A zone where the thermohaline instability develops is shown in red. Blue lines delimit the hydrogen-burning shell above the degenerate helium core. Diagram is taken from Charbonnel & Lagarde (2010).

Carbon isotope ratios

(Tautvaišiūnė et al. 2010, 2013)

