λ Andromeda: All dredged−up?

Bill Ball, Jeremy Drake, John Eldridge

Harvard Smithsonian Center for Astrophysics, MS−3, 60 Garden st., Cambridge, MA 02138

A mystery star trained in the art of deception.

• The subgiant of the RS CVn system λ And is exhibiting an interesting C/N ratio: **this is at odds with its position on evolutionary tracks**.

• We find λ And's C/N ∼ 3 (solar) and similar to that of ϵ Eri, a MS dwarf. But λ And lies on the vertical giant branch from its stellar parameters, where dredge-up should have ensured a low C/N ratio ∼ 1.

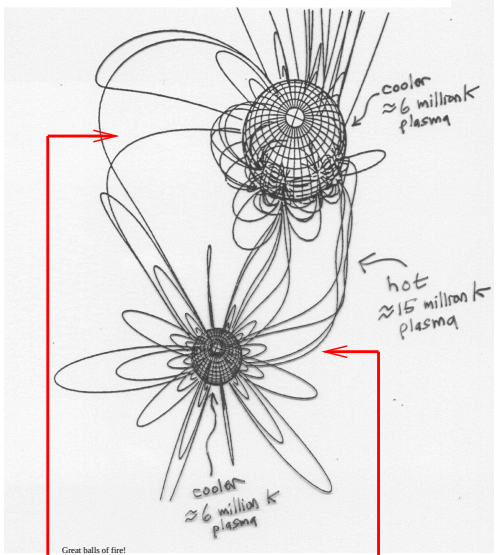
• It's C/N ratio is *dissimilar* to other similar RS CVns: UX Ari (K0 IV + G5 V) and HR 1099 (K1 IV + G5 V).

• We used the Drake (2003) method to calculate the C/N ratio for λ And: $C/N = 1.85 \times \frac{(I_c/11.6)}{(I_n/15.2)}$, where I_c and I_n are the number of counts in the C VI (24.7 Å) and N VII (33.7 Å) lines, respectively. The values 11.6 and 15.3 (cm^2) are the effective area normalising factors at the appropriate wavelengths (Pease et al. 2002).

• The spectra were obtained with the Low Energy Transmission Grating Spectrometer (LETG). Observational data were obtained from the public Chandra Data Archive (http://asc.harvard.edu/cda).

• The data were reduced using the CIAO software package v. 2.2 and the data analysis, including line identification and fitting using β profiles, was performed using the PINTofALE suite of IDL tools (Kashyap & Drake 2000).

λ And: G8 III−IV + ?



Subgiant primary

White dwarf, low−mass MS, brown dwarf secondary?

Table 1. Summary of photometric and dervied properties for λ And.

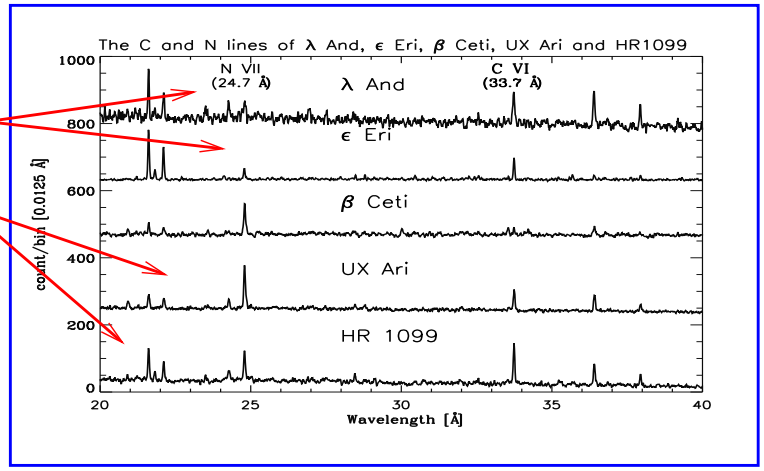
Star	M_{bol}	B-V[1]	V-R	R-I	M_p[2] ($M_\odot$)	[Fe/H][3]	Log n(Li)	Log T_{eff} (T)	Log (L/$L_\odot$) (K)
λ And	1.25±0.25	1.01	0.78	0.57	$0.65^{0.6}_{0.3}$	-0.4	≤-0.5[4]	3.68±0.01	1.4

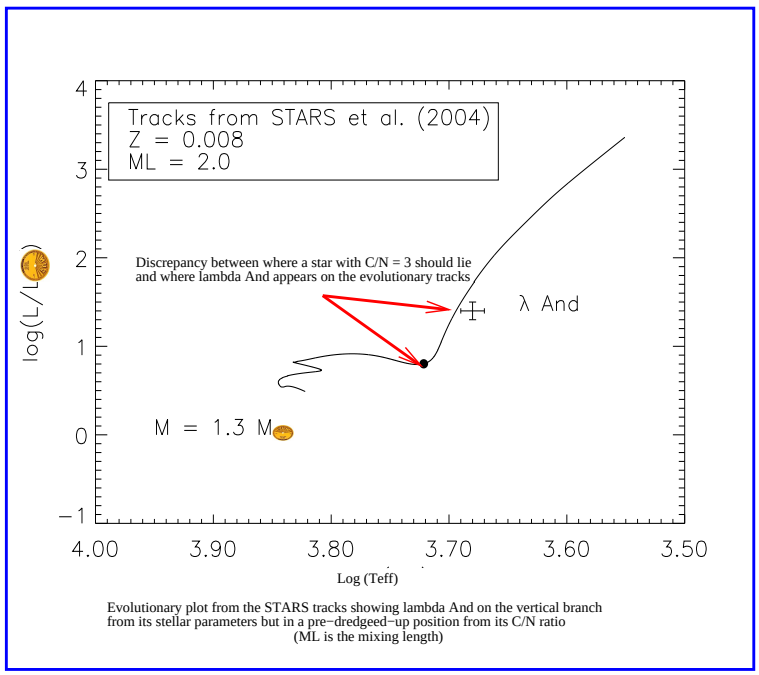
[1]All photometric values are taken from Strassmeier et al. 1993.

[2]Mass estimate taken from Donati et al. 1995.

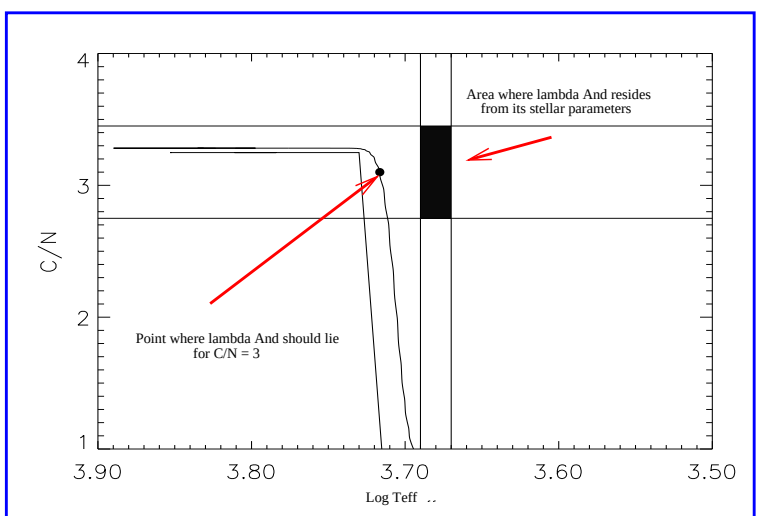
[3]$[Fe/H] \equiv \log \frac{[Fe/H]_*}{[Fe/H]_\odot}$

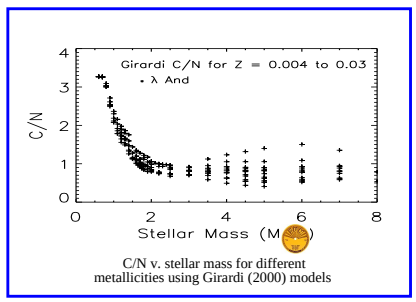
[4]Randich et al. (1994)





Evolutionary plot from the STARS tracks showing lambda And on the vertical branch from its stellar parameters but in a pre−dredgeed−up position from its C/N ratio (ML is the mixing length)





C/N v. stellar mass for different metallicities using Girardi (2000) models

Dredge-up

Theories of stellar evolution predict that when a star evolves off the main sequence and up the giant branch, its outer convection envelope extends inwards and probes the CN-processed region in the hydrogen envelope, propagating the processed elements up to the stellar surface. This causes ^{13}C and ^{14}N to be transported to the surface, whilst ^{12}C is assigned to the interior. The net result of this 'dredge-up' is to decrease the $^{12}C/^{13}C$ and $^{12}C/^{14}N$ ratios on the stellar surface (Iben 1967, Shadick et al. 1986). These ratios are therefore sensitive indicators of the amount of mixing in red giants, and hence their evolutionary status. This theoretical predictions in giants have generally been confirmed by Lambert & Ries (1981), Gratton (1985) and Cottrell & Sneden (1986). There are some exceptions, (e.g. Gilroy & Brown 1991) and λ And seems to be one of them.

Possible explanations

• *Pollution onto the subgiant from the (unseen) companion:* the system in the past could have been a MS star and a giant in close tidal interaction; the latter dumping C onto the common envelope which was picked up during first dredge-up. This could also possibly explain the (still unexplained) circularity of λ And's orbit.

• *Mixing parameter (α_{MLT}):* it has been shown that within binaries with accurately-known masses, age discrepancies of a factor 2 have been found (e.g. Popper 1997). Lastennet et al. (2003) explored the influence of the mixing length, α_{MLT}, and found that fixing it to its solar value for both components (a common hypothesis assumed in most stellar evolutionary models) may not be correct. We are currently investigating altering the α_{MLT} parameter for low-mass stars within the STARS code at Cambridge, UK, to see if there are significant changes in the evolutionary tracks.

• *Stellar models:* we note that stellar models assume no interaction between binary components; not necessarily the case for λ And.

• *Convection theory:* there is still not a complete description of convection and Ventura & D'Antona (2005) have found some C and N abundance prediction discrepancies in intermediate mass metal-poor AGB (asymptotic giant branch) stars.

λ And has left the building. Thank you very much

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