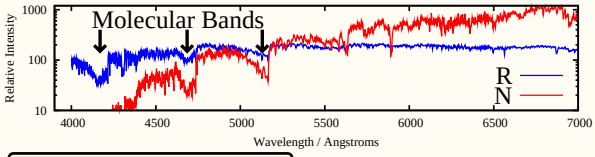
What are The R Stars?

1. History and Observations

Secchi discovered carbon stars in 1868. Most are of the very red "normal" N-type, but some are bluer, like K type stars. Fleming and Pickering labelled these the "R stars" in 1908. Both types are identified by molecular bands in their spectra.



Dominy 1984: R Stars

$[C/Fe] \sim [N/Fe] \sim +0.5$

$[Fe/H] \sim [O/Fe] \sim -0.1$

$^{12}C/^{13}C \sim 6$ ($\sim$ CNO eq.)

$[s/Fe] \sim 0.0$ (i.e. not AGB)

R stars are ~ 1.5mag dimmer than N stars: similar to the "red clump" of core helium burning stars. They are old, from the Galactic thick disk, and chemically normal except for enhanced C & N.

McClure showed in 1997 that all of 22 R stars observed over 15 years are single stars.

R-Star binary fraction: 0%
c.f. Normal GK giants: 20%

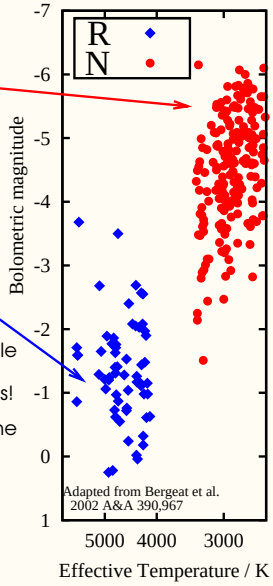
Hipparcos: **R stars are not rare**
$N_R/N_{\text{red clump}} = 0.1\%$
(Knapp et al. 2001 A&A 371,222)

2. Stellar Evolution Mystery

The N-type carbon stars are asymptotic giant branch (AGB) stars, which are cool, bright and relatively well understood:
$T_{\text{eff}} \sim 3500$K $L \sim 10^3 L_\odot$

The R stars are hotter $T_{\text{eff}} \sim 4500$K and dimmer $L \sim 10^2 L_\odot$. Conventional stellar evolution theory cannot explain their excess C or N.

- Why are all the R stars single stars?
  ... They are merged binaries!
- How does the merger affect the chemistry?
- Why only in the R stars?



Introduction

The R stars look like normal K-type giants but are enhanced in carbon and nitrogen and are all single stars. This implies they were once binaries which have now merged. Helium ignition in a rapidly rotating stellar core may cause the C and N anomalies. We have simulated binary populations to investigate the merger rate in binary stars with helium cores which may give rise to the mysterious R stars...

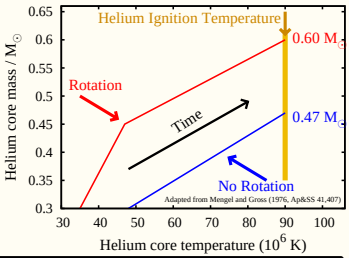
Conclusions

- Binary mergers of stars with helium cores are viable progenitors of the R stars
- Our models make too many R stars, but we included all possible He-core mergers: probably only a subset are true R stars
- We need to better understand the merger process
- More work on helium-core mergers is required

3. Evolutionary Channel

Binary: stars with helium cores →
Stars merge →
Single star: Rotating helium core →
Abnormal helium ignition

When a binary merges, its large orbital angular momentum results in a rapidly rotating single star.
Rotation increases the core mass at helium ignition.



If the core ignites nears its outer edge enough ^{12}C can be mixed into the stellar envelope to make a C-star.
(Paczynski and Tremaine 1977, ApJ 216,57)

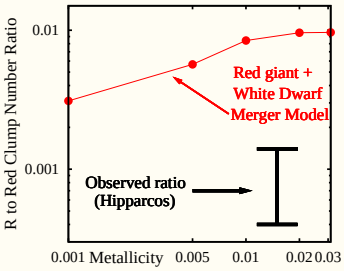
In combination these results give us a route to the R stars: C mixed out of the core must pass through the hydrogen-burning shell, so some is converted to ^{13}C and ^{14}N, as is observed.

The resulting merged single star naturally has the required C and N enhancements and is otherwise a normal core-helium burning star, with $L \sim 10^2 L_\odot$. Is it an R star?

4. Binary Mergers: A Solution?

We modelled populations of binary stars to count the number of helium-core mergers. We compared our results to the Hipparcos R to Red Clump number count ratio.

Our models show that the main merger channel is that of a red giant with a helium white dwarf. This makes more stars than we need, so probably only a subset of these are the R stars. Perhaps some cores do not rotate quickly enough, some are too massive?



For the first time we have constructed a viable model of the R stars with which we can test our ideas regarding common envelope evolution in red giants, stellar mergers and rotation, the helium flash and the origin of these mysterious objects.

Robert Izzard[1], Simon Jeffery[2] and John Lattanzio[3]

1. Sterrenkundig Instituut, University of Utrecht, The Netherlands. E-mail R.G.Izzard@phys.uu.nl
2. Armagh Observatory, Northern Ireland
3. Monash University, Melbourne, Australia

For further details see Izzard, Jeffery and Lattanzio (2007) A&A in press, astro-ph/0705.0894