Unit 22

Red-Giant Branch Morphology

22.0.1 RGB properties

Here we discuss the main RGB features on various physical and chemical parameters. The main morphological features are it's location on the H-R diagram, the luminosity when the bump occurs, and the luminosity at the tip of the RGB.

The main drivers of these features are the star's mass, it's He core mass, the composition (Y, Z), and convective efficiency.

22.1 RGB location

- The main determinator of the RGB location is the size of the convective envelope.
- With decreasing mass, the RGB is cooler.
- An increase in He content reduces the opacity, causing a shrinking of the convective envelope, and thus a hotter RGB.
- An increase in metallicity produces a deeper convection zone (higher opacity, cooler temps) and a cooler RGB.
- An increase in the convective efficiency, such as an increase in the mixing length, the RGB shifts to hotter effective temperatures.
- If the mixing length parameter is set to zero, the RGB disappears and expands until it falls apart.

22.2 RGB bump luminosity

- This phenomenon depends most strongly on the location of the H-abundance discontinuity after the first dredge up.
- The bump luminosity decreases as this location moves deeper into the star, as it will encounter it at earlier times.
- A decrease in He, or increase in metals, pushes this location deeper, and reduces the bump luminosity.
- More efficient convection, decreases the mass extent of the outer convection zone and the bump occurs at higher luminosity.

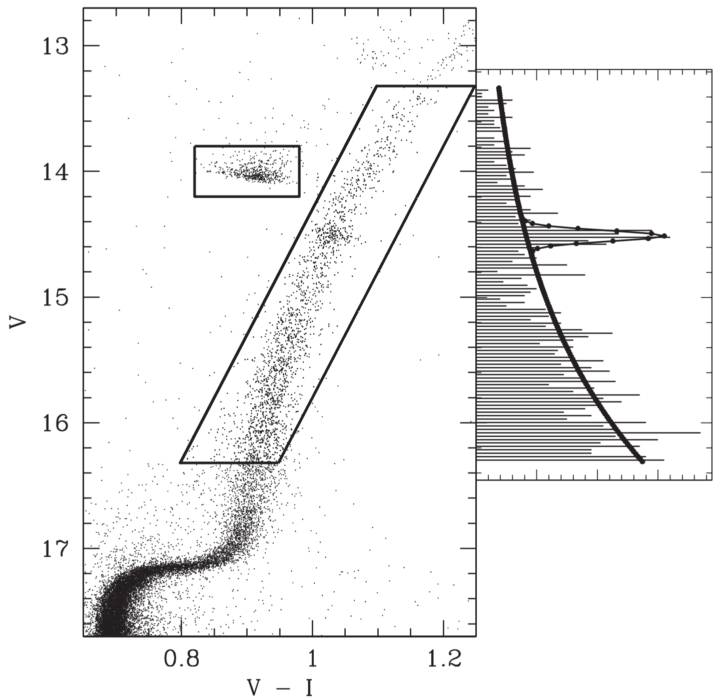

Figure 22.1: Left panel: the color–magnitude diagram of HST data for the globular cluster 47 Tuc. The RGB (including the RGBB) and the HB are all contained within their respective color–magnitude selection boxes. Right panel: magnitude distribution of RG stars. The RGBB stands out as a prominent and significant peak at $V = 14.51$, with a normalization of (122 ± 14) stars. From Nataf et al. [2011], where they show the lifetime of the RGBB is different for different He amounts in the cluster stars.

- Another prediction of stellar evolution theory is that the *lifetime* of the RGBB is decreased as the He content increases.
- Empirical support for this is alluded to in Figure 22.1 and the associated article.

22.3 RGB tip luminosity

- The luminosity at the tip of the RGB occurs when He is ignited.
- This typically happens at a well defined He core mass.
- For stars less massive than about $1.8M_\odot$, the mass of the He core at the flash does not depend on the overall mass that much, and they all develop about the same amount of electron degeneracy in the core.
- So the luminosity at the flash is about the same for these stars (all things otherwise being equal).
- For higher masses (about less than $3M_\odot$), the mass of the core is smaller and degeneracy is at lower levels, so the luminosity is reduced at the tip (ignition occurs earlier).
- For higher masses still, the luminosity starts to increase again as a result of the mass of the He core increasing again.
- An increasing He content increases interior temperatures and decreases electron degeneracy leading to lower He core mass and a lower tip luminosity.

- An increasing metallicity also helps lower the He core mass, because shell H burning is more efficient.
- This heats the He core faster; however, the luminosity is higher with increasing metals since L is strongly affected by the H-burning shell.
- Convection changes do not affect the tip luminosity since these don't really change the mass of the He core.