Subdwarf B stars as tracers of binary evolution

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ABSTRACT

Subdwarf B stars are a superb stellar population to study binary evolution. In 2001, Maxted et al. [3] found that 21 out of the 36 subdwarf B stars they studied were in short period binaries. These observations inspired new theoretical work that suggests that up to 90 per cent of subdwarf B stars are in binary systems with the remaining apparently single stars being the product of merging pairs (Han et al. 2003 [1]). This high binary fraction added to the fact that they are detached binaries that have not changed significantly since they came out of the common envelope, make subdwarf B stars a perfect population to study binary evolution. By comparing the observed orbital period distribution of subdwarf B stars with that obtained from population synthesis calculations we can determine fundamental parameters of binary evolution such as the common envelope ejection efficiency.

1. SUBDWARF B STARS

Subdwarf B stars are helium burning stars with $\sim 0.5\,M_\odot$ helium cores and very thin hydrogen envelopes ($\sim 0.02\,M_\odot$) [2]. Their formation is easily explained by evolution within a binary system. Recent theoretical studies predict that in fact all of them are the result of binary evolution, and that up to 90% should still have a binary companion [1].

Subdwarf B binaries are detached systems -there is no mass transfer at present between the binary components- which means that their detection is not correlated with their orbital period. This implies that they are not plagued by detection biases, which makes the comparison between observations and theory possible.

2. PROJECT AIMS

We are carrying out a long term observational study of subdwarf B stars. Its aim is to determine:

- the proportion of subdwarf B stars in binaries
- their orbital period distribution
- fundamental binary evolution parameters, by comparing observations with theoretical predictions.

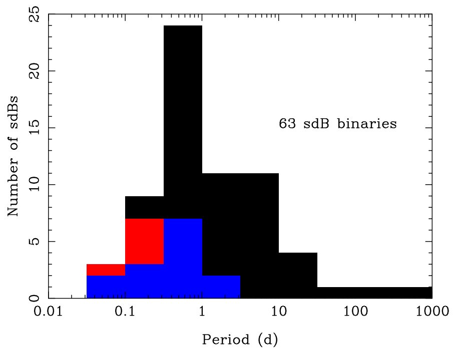
These findings are of great relevance as they can be applied to any binary system, and these are ubiquitous in our and other galaxies.

3.a OBSERVATIONS versus THEORY

Observations

BINARY FRACTION: We measure radial velocity variations in the spectral lines of the subdwarf B star to establish its belonging to a binary system. Maxted et al. 2001 [3] and Morales-Rueda et al. 2003 [4] find that ~70% of the subdwarf B stars in the Palomar-Green survey are in binaries. Using the same method but looking at the sample of subdwarf B stars from the SPY survey, Napiwotzki et al. (2004) [6] find a smaller binary fraction, ~42%. Morales-Rueda et al. 2006 [5] also find a smaller binary fraction, 48%, in the Edinburgh-Cape survey. These discrepancies are probably due to different selection effects in the different surveys but we are still not certain that this is the only reason.

ORBITAL PERIOD DISTRIBUTION: The following histogram shows the distribution of published orbital periods for the subdwarf B binaries together with those from our Edinburgh-Cape study. In most cases we do not know the nature of the companions to the subdwarf B stars. In others -mainly the short period systems- we can determine whether the companion is a white dwarf (blue) or a main sequence star (red).



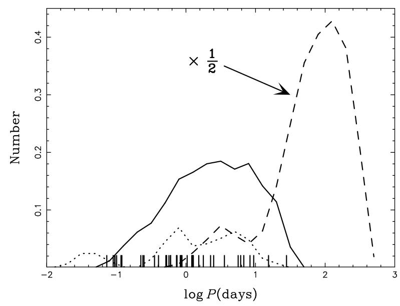
3.b OBSERVATIONS versus THEORY

Theory

BINARY FRACTION: Theoretical predictions for the present binary fraction of subdwarf B stars range between 45 and 90% [1]. The rest of the subdwarf B stars would have formed from a merger of the two stars in a binary and now appear as single.

ORBITAL PERIOD DISTRIBUTION: The orbital period distribution determined from population synthesis calculations is shown in the figure below [1]. The 3 different curves represent different binary formation scenarios. All the subdwarf B stars represented by the dotted line have white dwarf companions, the rest have main sequence companions.

Theory predicts that most subdwarf B stars should be in long period binaries and have main sequence companions. This long period population is missing from the observations (there are only two candidates at present). We believe this is caused by biases in our observing sample: 1. early type companions will swamp the light of the subdwarf B star, 2. long period binaries will show smaller amplitude radial velocities therefore higher resolution spectra is needed to find them, 3. longer time baselines are required to measure periods of a few hundred days. We have therefore changed our approach to search for these long period systems.



4. BINARY EVOLUTION

The Common Envelope is a fundamental phase of binary evolution which most binaries with a compact object must have gone through. During this phase, both stars are engulfed by one common atmosphere that is eventually ejected thanks to the release of orbital energy as the stars spiral closer to each other. The common envelope phase is very difficult to study because it only lasts a short time (1-100 years).

By comparing the observations with theoretical predictions, we find that the Common Envelope ejection efficiencies in subdwarf B stars must be very high [1].

References

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