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Resolving sdB Binary Systems with Adaptive Optics

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Abstract. A snapshot survey of spectroscopic subdwarf B plus main sequence binaries is underway, using high resolution infrared imaging with the NAOMI adaptive optics system at the William Herschel Telescope on La Palma. It is well known that a disproportionally large fraction of the field sdB stars are found in binary systems, and both interacting binary and single star evolutionary scenarios have been proposed for their origin. In the first case, all spectroscopic binaries containing sdBs need to have small separations of the order of 0.1 AU or less, in the other the binaries should have about the same distribution of separations as found for normal stars, i.e. they should be mostly in wide systems. About 100 sdB binary systems brighter than M_V=14.5 are known and have spectroscopic distances between 200 pc and 1200 pc. More than 30% of them should be resolvable on short exposure J-band AO images if the non-interacting evolutionary scenario holds, none in the alternative case. Hence a snapshot survey should yield decisive constraints for the origin of sdB stars.

1. Introduction

Evidence has accumulated that a large fraction of the sdB stars in the field are found in short period binary systems and their formation is easily explained by a common envelope phase. The other "single" sdBs remain a mystery; they can be long period binaries, completely merged stars or genuinely single. Both interacting and non-interacting (single star) evolutionary scenarios have been proposed for their origin (Bailyn et al. 1992). If the first scenario is correct, all spectroscopic binaries containing sdBs need to have small separations of the order of 0.1 AU or less. In the non-interacting case the sdB binaries should have approximately the same distribution of separations as found for normal stars, i.e. there should be mostly wide systems.

2. Observations

The NAOMI adaptive optics system at the William Herschel Telescope on La Palma is capable of producing diffraction limited IR images (0.15") when the natural seeing is average or better (0.5–0.7"). The system requires a natural guide star brighter than V=14.5 for the wavefront sensor, which fits well with the magnitudes of a large sample of known subdwarf B stars with a spectroscopic

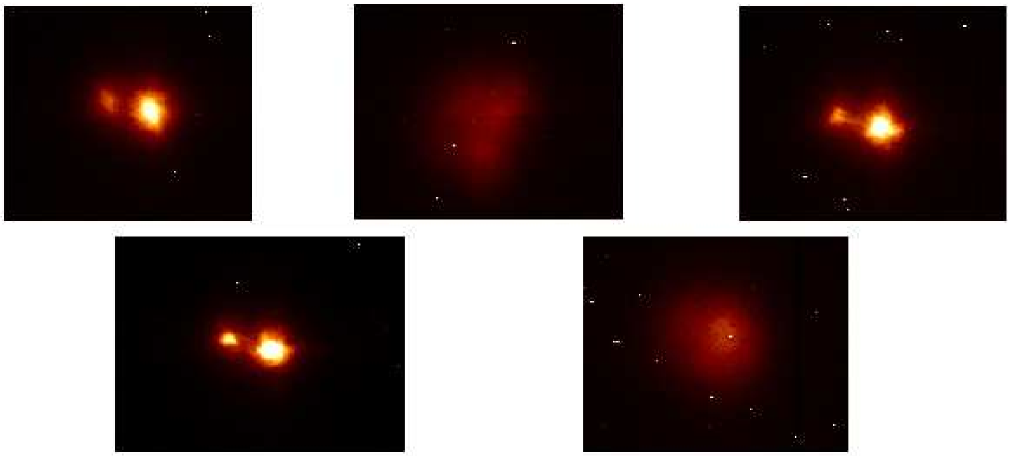

Figure 1. Five individual 5 second H-band images of HD 149382 show the NAOMI system in operation. Due to the poor conditions on this night the system was unable to close the loop for two of the images. The projected separation of the pair is less than one astronomical unit.

companion. The FWHM of NAOMI images are typically better than 0.2 arcsecond for stars brighter than V=12.0, and drops to about half of the natural seeing for stars between 13.0 and 14.5, as the integration time on the wavefront sensor is increased in order to get sufficient signal to close the loop. Useful correction with AO is only possible within about 30 degrees of zenith, which limits the number of accessible targets at any point in time. For more details on the NAOMI system, see `http://www.ing.iac.es/Astronomy/instruments/naomi/`.

3. The Sample

More than 50 sdB binary systems brighter than V=14.5 are known and have spectroscopic distances between 200 pc and 1300 pc. Between half and a third of these should be resolvable on short exposure J-band AO images if the non-interacting evolutionary scenario holds, none in the alternative case (ignoring the occasional triple star systems). Hence, this snapshot survey should tell us whether the cool companions to sdB stars are involved in their formation or not.

This work extends the snapshot survey of sdB stars with cool companions with WFPC2 on HST (Heber et al. 2002). Of the 19 stars observed in that program, 6 were resolved into two or more objects. In four cases the stars are unrelated chance projections, and one is an unresolved binary with a distant second companion. The observation that 18 of these binaries are unresolved shows that they tend to have smaller orbits than solar-type stars. The combination of these data will give us fundamental information on the evolution of sdB stars which we can use to test models of how binary stars evolve and the contribution of sdB stars to the UV excess in old populations of stars.

The sample was put together, first by collecting a list of sdB+F-K stars known from the published spectroscopic surveys, then extending this list with stars which show excess toward the infrared in V-J or J-K. This extends the

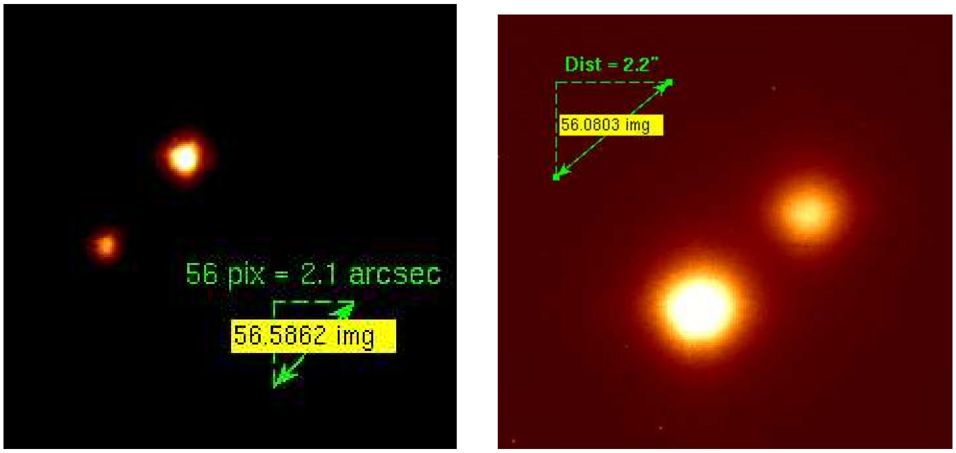

Figure 2. The left figure shows a single image of PG 1629+081, a well separated binary system. The FWHM of this 60 s H-band image is 0.40". The right figure shows a sum of H-band images of PB 8555, which clearly reveals a visual binary with separation of 2.2". The images were taken in poor conditions and the FWHM in these images is no better than 0.75".

numbers in our candidate list past one hundred. However, since the sky area accessible to AO with the WHT, during the summer months when the AO programme is running, is naturally limited, we only expect to be able to observe about two thirds of these stars. Furthermore, whereas the 2MASS IR photometry is well calibrated, the V magnitudes collected from many different sources are of variable quality. The sdB+IR stars therefore needs additional spectroscopic confirmation before they can be considered part of the final sample.

4. First results

Eight stars were observed in the summer of 2002, including the V=8.7 HD 149382 (Fig. 1) and the V=12.8 PG 1629+081 (Fig. 2). HD 149382 was observed again this year, finding the companion at the same separation as two years ago, indicating that it is likely not to b in a close orbit. The conditions during the 2002 run were very poor, and the observations of five of the systems were inconclusive. In 2003, forty stars were observed, most of them in adequate conditions. During one night where the conditions were too poor to close the AO loop, about 20 stars in the sample were observed spectroscopically as a backup programme. This revealed that six of stars in the sample were not sdB stars: PB 6148 (sdF), FBS 1810+389 (HBB), FBS 2158+373 (B), FBS 2204+364 (HBB), FBS 2204+386 (B), FBS 2347+385 (sdF+?). PB 8555 was found to be a well separated binary (Fig. 2), and was also resolved spectroscopically, confirming that the visible companion is an F star and the sdOB star otherwise single. The pulsating binary subdwarf B star KPD 1930+2750 (V2214 Cyg) was also found to be resolved (Fig. 3), but since this star is known to be in a binary system with a period of only about one hour, the resolved companion cannot be the closest companion in this system. More likely, what we see in the NAOMI

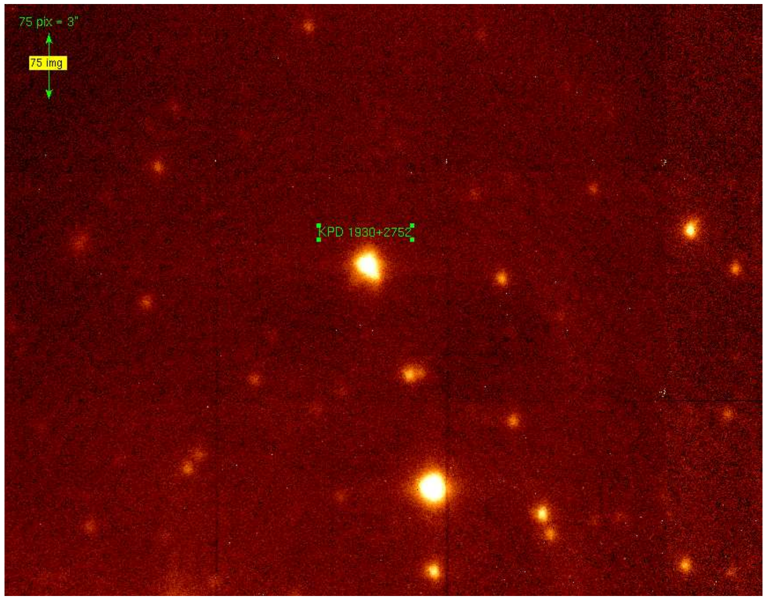

Figure 3. The crowded field of the galactic plane system KPD 1930+2750. At V=13.8 the correction is poor, but the object appears elongated in this sum of nine 60 s frames. Some of the individual images have a FWHM of 0.25”, and show the two objects clearly resolved with a separation of 0.5”.

images is a chance alignment, since the galactic plane field is very crowded. This is in accordance with the assumption that the companion responsible for the ellipsoidal deformation of KPD 1930+2750 is a white dwarf star (Billéres et al. 2000), and the IR excess of the system can be explained by the excess flux from the third object. Our best performance results were obtained in a series of short exposures on the V=10.3 sdOB+F2 system HDE 283048, where most of the images have a FWHM of 0.10 arcsecond. There is no indication of any companion in either the individual or combined images.

5. Conclusions

Although we are still far from reaching the limit intended in our search, the results so far are quite clear. The resolved systems are all wide, and the few close systems we see, are all most likely to be triple systems. This clearly points toward the validity of the interaction scenario for subdwarf B star formation. Further observations will allow us to determine whether the number of resolved systems and their distribution of separations is consistent with the hypothesis that these are triple systems.

References

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