What Fraction of White Dwarfs are Members of Binary Systems?

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Abstract. White dwarfs were originally discovered as the subordinate faint companions of bright nearby stars (i.e. Sirius B and 40 Eri B). Several general categories of binary systems involving white dwarfs are recognized: Sirius-like systems, where the white dwarf may be difficult to detect, binary systems containing white dwarfs and low mass stars, where the white dwarf is often readily discerned; and double degenerate systems. Different modes of white dwarf discovery influence our perception of both the overall binary fraction and the nature of these systems; proper motion surveys emphasize resolved systems, while photometric surveys emphasize unresolved systems containing relatively hot white dwarfs. Recent studies of the local white dwarf population offer some hope of achieving realistic estimates of the relative number of binary systems containing white dwarfs. A sample of 132 white dwarfs within 20 pc indicates that an individual white dwarf has a probability of 32 ± 8% of occurring within a binary or multiple star system.

1. Binary Systems
Binary or multiple star systems containing white dwarfs are important for a number of reasons. For example, in systems such as Sirius and Procyon where accurate binary orbits can be determined it is possible to establish dynamic white dwarf masses which can be compared with the degenerate mass-radius relations. Additionally resolved systems often allow the measurements of gravitational redshifts and in some cases lead to the determination of individual points on the white dwarf initial-final mass relation (Catalán et al. 2007). It is also of interest to understand the frequency of binary systems involving white dwarfs as well as the distribution of companion masses and separations. In close unresolved systems mass transfer may occur which leads to various forms of binary star evolution.

2. The Local Sample
A good place to examine the frequency of white dwarf binary systems is the local sample of degenerate stars within 20 pc of the sun (Holberg et al. 2008). This sample is by definition volume-limited, and can be demonstrated to have a high degree of completeness (∼80%). It is relatively
unbiased with respect to white dwarf luminosity and most of the sample members have been studied extensively over the years.

Since publication in April of 2008, the number of known white dwarfs within 20 pc has grown from 126 individual degenerates to 132. Four additional individual WDs were discovered by Subasavage et al. (2008) and two Sirius-like Systems: GJ86 (WD0210-508) (Mugrauer and Neuhauser 2005) and HD27442 (WD0416-593) (Mugrauer et al. 2007) were subsequently found in the exoplanet literature, where they turned up as close but resolved companions in near IR images of the primary stars containing extra solar planets. The white dwarf around GJ86 is significant since the distance of the system is 10.8 pc, placing it well within the 13 pc subsample from which the local space density of white dwarfs is established. The revised white dwarf space density, including GJ86B, is now $4.9 \pm 0.5 \times 10^{-3}$ pc$^{-3}$. The statistics of the local sample reported here are based on the additional stars included as of July 2008.

Of the 132 WDs in the local sample 92 are single stars and the remainder are members of binary or multiple star systems of various descriptions. This is summarized in Table 1.

### Table 1. The Local White Dwarf Sample

| White Dwarfs | Number | Percent | Comments |
|--------------|--------|---------|----------|
| Single WDs   | 92     | 70      |          |
| WD +dM       | 16     | 12      |          |
| Sirius-Like  | 10     | 8       | 3 contain exoplanets |
| WD + WD      | 7      | 5+5     | 3 resolved, 4 unresolved |
| Total WDs    | 132    | 100     |          |

Thus, on this basis white dwarfs have a $32 \pm 8\%$ probability of occurring in a binary or multiple star system, including double degenerate systems. Note that this should be regarded as a lower limit since the full 20 pc sample is only 80\% complete, which implies that possibly $33 \pm 4$ white dwarfs remain to be discovered and a significant fraction of these will be in binary systems. However, even if 50\% of the remaining white dwarfs are ultimately found in binary systems it is difficult to increase the binary fraction above 35\%. It is also of interest that three white dwarfs (WD0210-508, WD0416-593 and WD1620-391) are members of Sirius-Like Systems that include extrasolar planets, and one white dwarf (WD2326+049 = G29-38) is encircled by a dusty debris disk. Finally, one system, 40 Eri B, is a member of a hierarchical triple system.

### 3. Sirius-Like Systems

One interesting and very under represented type of binary system are Sirius-like systems. In these systems the white dwarf orbits a main sequence star of spectral type K or earlier. In close binary systems the distinction between Sirius-like systems and those composed of a white dwarf and an M dwarf is primarily observational. M dwarf systems are much easier to identify since the white dwarf is generally not dominated by the M dwarf companion. One of the large unknowns about Sirius-like systems is their true frequency.

Historically most Sirius-like systems were discovered as resolved proper motion pairs. Later, with the advent of UV spectroscopy, several unresolved systems were discovered through the presence of UV excesses in the spectra of G and K stars. The largest number, however, were discovered as part of the Extreme Ultraviolet All Sky Surveys of the ROSAT Wide Field Camera and
the Extreme Ultraviolet Explorer (Barstow and Holberg 2003). The author maintains a list of some 75 known Sirius-like systems with companions ranging from B5 to K7. The mean distance for these systems is 101 pc. This would seem to indicate that these are relatively rare systems. However, there is strong evidence that they are quite common. In Table 1 the local sample contains eleven Sirius-like systems, all discovered either as common proper motion companions or recently resolved by near IR imaging. Indeed, one such system (LHS 2231 + WD1009-184) was discovered during the analysis of the 20 pc sample (Holberg et al. 2008).

In Table 2 the 11 known Sirius-like systems within 20 pc are listed along with the composition of the system, the angular separation, estimated period and distance. If the 20 pc sample is representative of the larger solar neighbourhood then we might expect a similar number in the distance interval between 20 pc and 25 pc, which has virtually the same volume. In fact there is only one identified system in this interval. The possible addition to this interval is the recent discovery of an unseen radial velocity companion to Regulus (α Leo) a B8IV star at a distance of 24.3 pc. Gies et al. (2008) argue that this companion is a white dwarf. The dearth of Sirius-like systems beyond 20 pc persists at all distances, as shown in Figure 1, where the number of systems for successive shells of equal volume is plotted as a function of distance. Unless the local sample contains an unusual number of Sirius-like systems then the cumulative number for all bins in Figure 1 should be on the order of 65.

![Figure 1](image-url)

**Figure 1** The observed numbers of Sirius-like systems as a function of distance. Each bin represents a shell containing a volume equal to that of the 20 pc sample.

Clearly many relatively nearby Sirius-like systems are being overlooked. Where might they be found? Considering the separations in Table 1, searches for proper motion companions of nearby bright stars could find over 50% of them. Other potential sources of new systems come from the scrutiny that exoplanet searches are applying to nearby main sequence stars. In terms of radial velocity studies, it is clear that at least three of the systems in Table 2, with orbital periods less than 100 years, could be detected as low level secular drifts in the velocities of the primary star. Another source of potential detections is near IR or adaptive imaging of nearby stars, indeed this is how two such systems were recently discovered. Finally, there may be some systems lurking among the
suspected binaries in the *Hipparcos* catalogue. Ultimately it is probably *Gaia* that will find most of the Sirius-like systems, a decade from now, as resolved proper motion pairs or as unresolved proper motion variables.

**Table 2.** Sirius-Like Systems Within 20 pc

| WD Num.     | Alt. ID | System       | Separation (arc sec) | Period (yrs) | Dist. (pc) |
|-------------|---------|--------------|----------------------|--------------|------------|
| WD0642–166  | Sirius B| A0V+DA2      | 7.5                  | 50.1         | 2.63       |
| WD0736+053  | Procyon B| F5V+DQZ6.5   | 4.27                 | 40.8         | 3.51       |
| WD0413–077  | 40 Eri B | K1V+DA3      | 83.42                | 7700         | 5.04       |
| WD1132–325  | VB04B   | K0V+DC?      | 4.94                 | 270          | 9.56       |
| WD0210–508* | GJ86B   | K1V+DA10     | 1.93                 | 80           | 10.8       |
| WD1620–391* | CD-38° 10980 | G2V+DA2   | 345.05               | 2.3x10^5     | 12.87      |
| WD0743–336  | VB03 B  | G0V+DC9      | 1351.3               | 2.3x10^6     | 15.21      |
| WD1544–377  | HR 5864 B| G6V+ DA4.7   | 15.32                | 3033         | 15.85      |
| WD1009–184  | LHS 2231 B| K7V+DZ7.8   | 399.96               | 5.2x10^4     | 17.18      |
| WD0433+270  | HD283750| K2V+DA9      | 124.05               | 8.8 x10^4    | 17.85      |
| WD0416–593* | HD 27442 B| K2IV+DA3.8 | 12.90                | 3056         | 18.24      |

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