Abstract. A Spitzer IRAC survey of 17 nearby metal-rich white dwarfs, nominally DAZ stars, reveals excess emission from only 3 targets: G29-38, GD 362 and G167-8. Observations of GD 362 with all three Spitzer instruments reveals a warm (≈ 1000 K) dust continuum, very strong silicate emission, and the likely presence of cooler (≈ 500 K) dust. While there is a general similarity between the mid-infrared spectral energy distributions of G29-38 and GD 362, the IRAC fluxes of G167-8 are so far unique among white dwarfs. However, further observations of G167-8 are required before the measured excess can be definitely associated with the white dwarf.
2. Scientific Motivation

The origin of photospheric metals in isolated white dwarfs has long been an astrophysical curiosity (Koester & Wilken 2006; Koester et al. 2005; Zuckerman et al. 2003; Zuckerman & Reid 1998; Dupuis et al. 1993a; Dupuis, Fontaine, & Wesemael 1993b; Dupuis et al. 1992). Since any heavy elements present in the photosphere of a cool white dwarf cannot be primordial (due to gravitational settling), these metal-rich degenerates must be externally polluted. Although accretion from either the interstellar medium or orbiting dust can, in principle, explain the observed abundances, the relatively short dwell times for metals in cool hydrogen atmospheres makes it clear that many of these stars are currently undergoing accretion yet are nowhere near known interstellar clouds (Koester & Wilken 2006; Zuckerman et al. 2003). It may be the case that both mechanisms create polluted white dwarf photospheres – the pristine nature of a nominally pure hydrogen or helium atmosphere makes any contamination readily apparent, regardless of the source. However, recent developments are beginning to shed light on this problem, and there are now a growing number of metal-rich white dwarfs which are confirmed or suspected to harbor circumstellar dust (Jura et al. 2007; Farihi, Zuckerman, & Becklin 2007; Kilic et al. 2006; Mullally et al. 2006; Jura 2006; Becklin et al. 2005; Kilic et al. 2005; Jura 2003).

3. Observations

Between 2004 November and 2005 August, observations of 17 known DAZ white dwarfs were executed with the Infrared Array Camera (IRAC; Fazio et al. 2004) in all four bandpasses: 3.6, 4.5, 5.7, & 7.9 μm. A 20 point cycling dither pattern (medium step size) was used for each target in each bandpass, with 30 second frame times at each position, yielding a total exposure time of 600 seconds at all wavelengths. The data were processed with the IRAC calibration pipeline (versions 10, 11, & 12) to create a single, fully-processed and reduced image upon which to perform photometry. Aperture photometry was executed with standard IRAF tasks, and flux measurements were corrected for aperture size, but not for color.

Additional Spitzer observations of GD 362 were prompted by ground-based observations indicating a high probability of silicate emission around this extremely metal-rich degenerate (Becklin et al. 2005; Kilic et al. 2003). Spectroscopy over the 5–15 μm region was performed with the Infrared Spectrograph (IRS; Houck et al. 2004) in 2006 April. The spectra were taken in the two orders of the short-low module, in staring mode, with a total exposure time of 960 seconds each. The data were processed with IRS calibration pipeline (version 14) and extracted with the SPICE package. Observations at 24 μm were obtained with the Multiband Imaging Photometer for Spitzer (MIPS; Rieke et al. 2004) in 2005 September. The imaging consisted of 20 cycles with the default 14 point dither pattern and 10 second individual exposures, yielding a total exposure time of 2800 seconds. The data were processed with MIPS calibration pipeline (version 12) and aperture photometry was performed with standard IRAF tasks (including appropriate aperture corrections for faint sources).
Figure 1. Spectral energy distribution of GD 362. Shown are data from all three Spitzer instruments.

Figure 2. Spectral energy distribution of G29-38 for comparison. Shown are data from all three Spitzer instruments.
4. Results

Of the 17 observed stars, there are 3 which display excess radiation within their IRAC beams. The case of G167-8 is discussed in some detail below, but both G29-38 and GD 362 show warm (≈ 1000 K) thermal continuum and strong silicate emission in their IRS spectra and therefore are confirmed to harbor dust. Unfortunately, there was a single DAZ target (G21-16) for which accurate fluxes could not be extracted due to source confusion – hence a tentative, preliminary statistic is that at least 2 of 16 targets, or 12.5% have orbiting debris disks. Including all metal-rich white dwarfs observed with IRAC to date, the total which display significant flux excess (this includes G167-8) is 4 of 25 targets, or 16% (Kilic et al. 2005). The full details of the survey, including optical to infrared spectral energy distributions, IRAC 3 − 8 µm fluxes and uncertainties, are forthcoming (Farihi et al. 2007).

4.1. GD 362

The spectral energy distribution of GD 362, together with all its Spitzer data, is displayed in Figure 1. As expected on the basis of ground-based 10 µm data (Becklin et al. 2005), the silicate feature is very prominent – extending even above the peak photospheric flux(!) as well as contributing significantly to the longest wavelength IRAC channel (6.5 − 9.5 µm bandpass, no color correction applied). Plotted in Figure 1 specifically are: IRAC 3 − 8 µm photometry, the 5 − 15 µm IRS low resolution spectrum, and MIPS 24 µm photometry (Jura et al. 2007; Farihi et al. 2007).

For comparison, Figure 2 shows a similar plot for G29-38. Plotted data are: IRAC 3 − 8 µm photometry (Farihi et al. 2007); the 5 − 15 µm IRS low resolution spectrum (downloaded and extracted from the Spitzer archive for this work in a similar manner to the IRS spectrum of GD 362); IRS 16 µm peak-up and MIPS 24 µm photometry (Reach et al. 2005). While the overall similarity (inner dust temperature, silicate emission) between GD 362 and G29-38 is apparent, there are some distinctions beyond the relatively much stronger emission feature of GD 362. The 3 − 5 µm thermal continuum flux of GD 362 is rising rather than falling as for G29-38, likely indicating a difference in the relative amounts of dust cooler than ≈ 1000 K and perhaps partially contributing to the strength of the 8 µm flux of GD 362. Additionally, the 24 µm to 2 µm flux ratio is 0.43 for G29-38 whereas for GD 362 the value is nearly twice as large, 0.73. All of this certainly indicates more emission from cooler (≈ 500 K) dust at GD 362 (Jura et al. 2007). A complete analysis of the dust emission from GD 362, including detailed model fits, mass estimates, temperature distribution, and the sizes and types of the emitting regions is forthcoming (Jura et al. 2007).

4.2. G167-8

Figure 3 displays the IRAC flux measurements for G167-8 resulting from aperture photometry. There are three salient points regarding this unusual, and so far unique, spectral energy distribution. First, there is a source (likely to be extragalactic) within 6′′ of G167-8 seen in all four IRAC channels whose flux has been accounted for in all flux measurements and uncertainties – the error bars in Figure 3 are quite conservative. Only at 8 µm does the flux of this nearby source...
become significant, yet its contamination of the aperture photometry of G167-8 can be accounted for and removed using a number of straightforward methods. Second, it is conceivable that within the $\approx 2''$ IRAC beam of G167-8 there is another background source contributing flux at 5.7 and 7.9 $\mu$m. Ground-based imaging will assist in evaluating this possibility, yet a final decision may not be possible without spectroscopy. Third, G167-8 is a suspected double degenerate – as yet unconfirmed (Liebert et al. 2005; Bergeron et al. 2001). But a careful look at the $BVRIJHK$ data (Zuckerman et al. 2003; Bergeron et al. 2001) plotted in Figure 3 reveals that a single temperature blackbody does not fit the data perfectly; in fact, there appears to be near-infrared excess at $JHK$ (this would become more prominent if a higher temperature model is used to fit $UBVRI$ only).

Any interpretation of the excess flux of G167-8 warrants caution. If real, the infrared emission at G167-8 would be unique among white dwarfs. All confirmed or suspected debris disks around metal-rich white dwarfs give rise to measured excess flux beginning at $2 - 3$ $\mu$m (Kilic et al. 2006; Mullaly et al. 2006; Becklin et al. 2005; Kilic et al. 2005; Reach et al. 2005). If the apparent $5 - 8$ $\mu$m excess is confirmed to be associated with G167-8, then some dust disks may lack warm, opaque debris but harbor only cooler emitting dust.

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