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The fraction of circumstellar debris at white dwarfs

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Abstract

We present results of the first unbiased *Spitzer* IRAC survey of a homogeneous and well-defined sample of 134 single white dwarfs in search of infrared excesses compatible with the presence of circumstellar dust formed from the disruption of planetesimals. The stars were selected without regard to atmospheric metal content but were chosen to have 1) hydrogen rich atmospheres, 2) $17\,000\,\mathrm{K} < T_{\mathrm{eff}} < 20\,000\,\mathrm{K}$ and correspondingly young post main-sequence ages of 20–120 Myr, and 3) sufficient far-ultraviolet brightness for a corresponding *Hubble Space Telescope* COS Snapshot. We find five white dwarfs that host an infrared bright dust disc, three previously known, and two reported here for the first time, yielding a nominal 3.7% of white dwarfs in this post-main sequence age range with detectable circumstellar material. Remarkably, our complementary *HST* observations indicate this fraction is almost certainly an order of magnitude higher, with the bulk of circumstellar discs currently hidden in the infrared. The presence of narrow and attenuated dust rings, and especially atmospheric pollution, corroborate this interpretation as do the distribution of L_{IR}/L_{*} values as a function of cooling age.

1. Background: Asteroid-Polluted White Dwarfs

In the context of exoplanetary research white dwarfs offer a unique laboratory to study exoplanetary compositions. It is now clear that planetary systems around Sun-like and intermediate-like stars survive, at least in part, the post-main sequence phases of their hosts. Compelling evidence comes from metal polluted white dwarfs that commonly exhibit closely orbiting circumstellar dust and gas discs. Since the discovery of an infrared excess around the white dwarf G29-38 [16] and the subsequent detection of a few metal species in its atmosphere [8] the connection between metal polluted white dwarfs and circumstellar discs has become compelling and such stars offer the only opportunity so far to study in detail the composition of large asteroids in the terrestrial zone via the analysis of the accreted material.

Detailed modelling of the infrared excesses at these stars suggest that the circumstellar dust is arranged in the form of an optically thick but geometrically thin disc, with similar properties to the rings of Saturn [5, 12]. These rings of warm dust are situated within the Roche limit of their host star, as shown empirically by the emission profiles of gaseous debris discovered at dusty white dwarfs and inferred from modelling of the infrared dust emission. These discs are thus likely formed by the tidal disruption of asteroids or minor planets, perturbed by unseen planets [1]. The orbiting dust gradually falls onto the white dwarf surface and contaminates its photosphere. Due to high surface gravity and negligible radiative forces, heavy elements sink on short timescales within the atmospheres of relatively cool ($T_{\mathrm{eff}} \lesssim 25\,000\,\mathrm{K}$) white dwarfs [4, 11] and hence the presence of metals in the atmospheres of cool white dwarfs must be a sign of external accretion [17]. Notably, ultraviolet and optical spectroscopy have shown that metal-contaminated white dwarfs are, in general, refractory-rich and volatile-poor [2, 3, 7, 15], while infrared spectroscopy reveals that the circumstellar dust itself is silicate-rich and carbon-poor [6, 13, 14], and thus similar to materials found in the inner Solar System [10].

After nearly a decade of dust disc discoveries at metal enriched degenerates, there is still a need to determine unbiased statistics for the frequency of the phenomenon. Here we present *Spitzer* observations of a well defined metallicity unbiased sample of 134 young DA white dwarfs in the temperature range $17\,000\,\mathrm{K} < T_{\mathrm{eff}} < 25\,000\,\mathrm{K}$. Metal abundances for 85 of the stars were also determined in a complementary *Hubble Space Telescope* COS Snapshot program [9], and permit the first unbiased statistics of the the frequency of infrared bright and hidden circumstellar discs at young white dwarfs.

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