Search for Disks in Binary Systems with White Dwarf

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ABSTRACT

Circumstellar disks seem to be present at every stage of stellar evolution, beginning from proto-stellar cores, through evolutionary advanced stages, like first-ascent, asymptotic giant branch (AGB) stars, post-AGB objects, and ending on isolated white dwarfs (WDs). WDs are relatively recent addition to this track. The nature of disks around evolutionary advanced objects is still a matter of debate. Disks around pre-main sequence stars are very likely to be sites of planets formation. We do not know yet whether protoplanets can be formed in disks around evolutionary advanced stars. Therefore, understanding the creation, evolution and survival of such disks is a matter of primary importance. We propose a study of known disks around isolated white dwarfs and of possible disks around binary systems that contain WD component with the SAFARI instrument on board of the *SPICA* satellite.

1. INTRODUCTION

The first white dwarf, G29-38, exhibiting near-infrared (NIR) excess that was not associated with a stellar companion has been discovered by Zuckerman & Becklin (1987). The crucial argument that this NIR excess is not related to the emission from a brown dwarf companion follows the discovery of additional excess at 10 micrometres (Tokunaga et al. 1990). Moreover, an additional constraint came from a detection of many metals in the atmosphere of G29-38, which has been interpreted as the evidence of the current accretion of the material from the flat dusty debris disk (Jura 2003) by the white dwarf (Koester et al. 1997).

At the end of 2010, about 20 isolated white dwarfs with circumstellar disks were known (Farihi 2011, Table 5.1). However, no binary systems with WD are known so far to have circumstellar disk. We do not know any isolated WD with planets neither, except GJ 3483 that hosts a Y type brown dwarf. However, more than 10 eclipsing binary systems containing WD with planet candidates inferred from the interpretation of O-C diagrams are known. An example of such

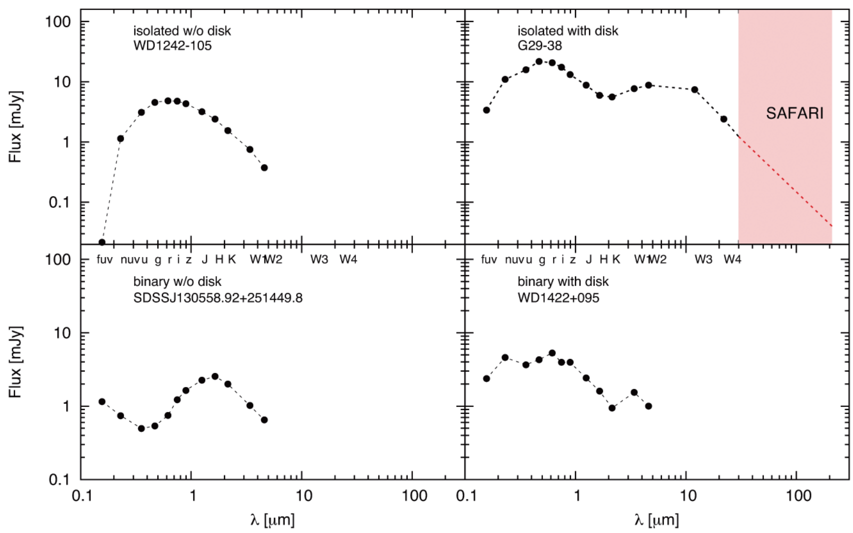

Figure 1. SEDs of: isolated WD without a disk (top-left), binary system with WD without a disk (bottom-left), isolated WD G29–38 with a disk (top-right) and binary system with WD and a disk candidate (bottom-right). Photometric measurements were obtained from GALEX (FUV and NUV), SDSS (u, g, r, i and z), 2MASS (J, H and K) and *WISE* (W_1, W_2, W_3 and W_4) surveys. In the case of G29–38 (top-right panel) the infrared excess due to disk presence is clearly visible. The SED's Rayleigh-Jeans extrapolation for SAFARI detection range is also shown. Estimated flux values are as follows: 30 μm – 1360 μJy, 100 μm – 130 μJy, 150 μm – 70 μJy and 210 μm – 40 μJy. Therefore, this source will be detected with S/N > 5 σ within one hour of observations even at the wavelengths longer than 150 microns.

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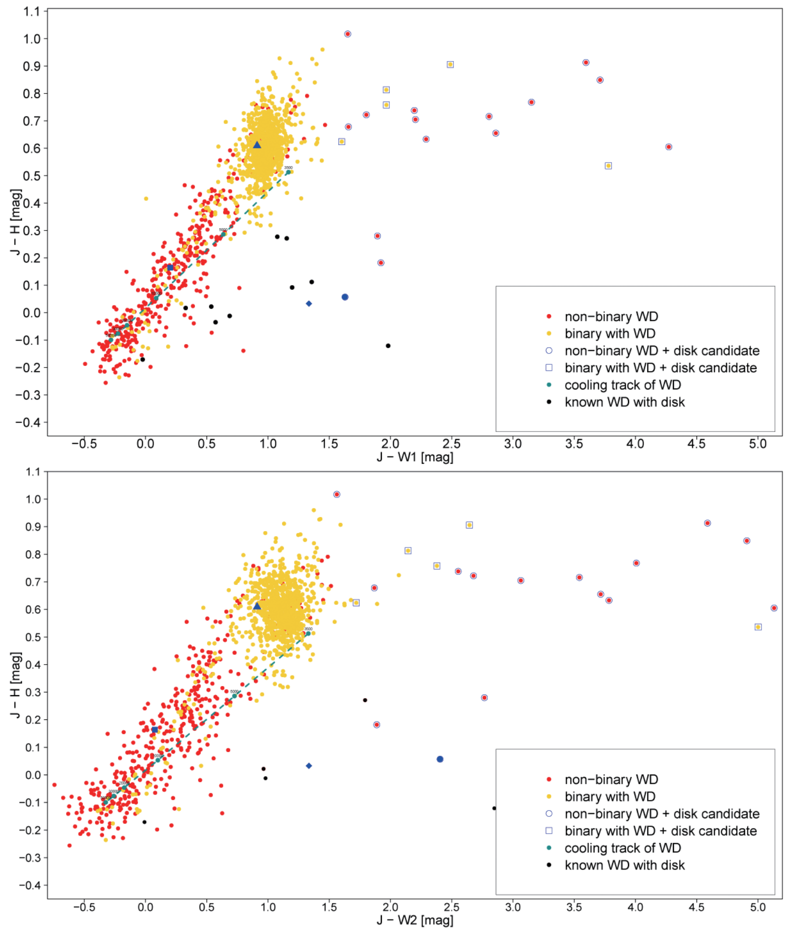

Figure 2. $J - H$ vs. $J - W_1$ (top panel) and $J - H$ vs. $J - W_2$ (bottom panel) colour-colour diagrams for non-binary WDs (red dots) and binary systems with WD (yellow dots). Black filled circles mark known isolated WDs with dusty debris disks (Farihi 2011, Table 5.1). Blue circles and squares mark non-binary WDs and binary systems with WD disk candidates, respectively. Cooling track was modelled as in Renedo et al. (2010) for the final white dwarf mass of $M_f = 0.6\ \mathrm{M}_\odot$ and metallicity of Z = 0.01, using the black-body atmosphere model. For WDs with temperatures lower than 5,000 K there is a strong evidence for the departure of isolated WDs from the cooling track towards the higher values of $J - H$. This is caused by the so called collision induced absorption (CIA, Borysow et al. 1997) which depends on the H/He ratio in the WD atmospheres, $T_{\rm eff}$ and g. Special symbols that denote four individual objects: blue square is for WD 1242–105 — an isolated WD without disk, blue rhombus is for SDSS J130558.92+2514598 — a binary system with WD without disk, while blue filled circle and blue triangle are for G29–38 (an isolated WD) and WD 1422+095 (binary system with WD) with disk or disk candidate, respectively. SEDs of these four objects are presented in Figure 1.

a system is HU Aqr that likely hosts a planet of 7 Jupiter masses on the circumbinary orbit with the orbital period of 10 years (Goździewski et al. 2012; Słowikowska et al.). Therefore, we propose a study of known and candidate disks around isolated and especially binary systems with the SAFARI instrument. We aim to understand a possibility of planet formation in circumstellar/circumbinary disks.

2. SAMPLE SELECTION AND DISK CANDIDATES

We have selected a sample of white dwarfs from following three catalogues: *The White Dwarf Catalogue of Villanova University* (McCook & Sion 1999), *SDSS DR7 White Dwarf Catalog* (Kleinman et al. 2013), *Post-common envelope binaries from SDSS - XIV. The DR7 white dwarf-main-sequence binary catalogue* (Rebassa-Mansergas et al. 2012).

We gathered 22,756 objects from the above catalogues, among which 2,972 are classified, mostly based on the analysis of the SDSS spectra, as binaries. It turns out that the optical spectra (e.g. SDSS) are not always available, so the classification may not be adequate. While preparing our WD database we took into account proper motion since some close WDs have very high angular change in position over time. Examples of typical spectral energy distribution (SED) of an isolated WD and binary system with WD without (left panels) and with a disk or a disk candidate (right panels), are shown in Figure 1.

From our database (Rybicka et al. 2013) we selected a sample that obeys the following conditions: 2MASS J and H, as well as *WISE* W_1 and W_2 photometry is available for all 4 filters and for all of them it has a quality flag “A”. There are 413 non-binary WDs and 990 WDs in binary systems which sum up to 1,403 objects that fulfil the applied criteria. Obtained sample was extended with objects from the Farihi’s list (Farihi 2011, Table 5.1). We tried to include all 20 objects, however for some of them the photometric (J, H, W_1, W_2) data were missing. Figure 2 illustrates two kinds of colour-colour diagrams, i.e. $J - H$ vs. $J - W_1$ (upper panel) and $J - H$ vs. $J - W_2$ (bottom panel) for non-binary and binary WDs. In addition to objects with colours similar to the known isolated WDs with disks, we marked by blue circles and squares disk candidates that have $J - W_1 > 1.5$ for non-binary WDs and binary systems with WD, respectively. These objects are also shown on $J - W_2$ diagram.

3. CONCLUSIONS

A detection of circumbinary disks around binary systems with WD is a matter of great importance, as yet no such disks are found. Discovery of a disk around close binary could establish a missing link in the binary system evolution that leads to circumbinary planet creation. It would be especially interesting in a case of close binaries that are suspected of hosting planets on circumbinary orbits. Our broadband photometric analysis allowed us to select promising candidates that might have disks. There are several non-binary WDs as well as binary systems with WD in our sample that meet our selection criteria and are bright enough to be detected with SAFARI.

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