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Spectral analysis of mid-IR excesses of central stars of planetary nebulae

Jana Bilikova[1], You-Hua Chu[1], Kate Y.L. Su[2], Robert Gruendl[1], et al.

[1]Dept. of Astronomy, University of Illinois,
1002 West Green Street, Urbana, Illinois, 61801, USA
email: jbiliko2@illinois.edu

[2]Stewart Observatory, University of Arizona,
Tucson, AZ 85721, USA
email: ksu@as.arizona.edu

Abstract. In our Spitzer 24 μm survey of hot white dwarfs (WDs) we found 9 WDs with IR excesses, 7 of them are still central stars of planetary nebulae (CSPNs). We have thus carried out a Spitzer archival survey of CSPNs, and found additional objects with IR excesses. To date, a total of 13 CSPNs show IR excesses from Spitzer observations. These mid-IR excesses are indicative of the presence of circumstellar dust, which could be produced by collisions or disruption of sub-planetary objects. To further assess the nature of these IR excesses, we have obtained Spitzer IRS, Gemini NIRI and Michelle, and KPNO 4m echelle spectra of these objects. In this poster, we summarize the spectroscopic observations and discuss the nature of these IR excesses.

Keywords. planetary nebulae: general, infrared: stars, circumstellar matter

1. Introduction

Spitzer Space Telescope MIPS 24 and 70 μm observations of Helix Nebula's hot ($T_{\rm eff}$ $\sim$110,000 K) CSPN revealed a compact source coincident with the central WD. Its follow-up Spitzer IRS spectrum confirmed that the mid-IR emission originates from a 90-130 K dust continuum with an emitting area of 4-40 AU^2, located between 40 and 100 AU from the CSPN. Such location corresponds to that of the Kuiper Belt in our Solar System, and the dust disk was suggested to originate from collisions among Kuiper Belt-like objects, dynamically rejuvenated in the AGB and post-AGB evolutionary stages (Su *et al.* 2007).

2. CSPNs with IR Excesses

To find more dust disks similar to that of the Helix Nebula's CSPN, we have surveyed 71 hot WDs for excess 24 μm emission with *Spitzer's* MIPS camera. We have found 9 cases of IR excess, in 7 cases the star is still in PN (Chu *et al.* 2011). We have also searched the Spitzer archive for other incidences of CSPNs with IR excesses, and found 19 CSPNs with clear/likely IR excesses. Among these, eight are WC stars, one is a nova, and two have companions that can account for the observed excess emission. For the remaining cases, a dust disk is required to explain the IR excess. To assess the nature of these IR excesses, we have obtained Spitzer IRS, Gemini NIRI and Michelle spectra of some of these objects. The CSPNs with dust disks, and the basic characteristics, nature, and models of the excess emission are summarized in Table 1.

Figure 1 shows multi-wavelength images, SED, IRS spectrum, and dust disk model of an example CSPN with IR excess at 24 μm, Sh 2-216. The excess emission originates

Table 1. Hot White Dwarfs and CSPNs with IR Excesses

WD Name	Spec Type	$T_{\rm eff}$ (K)	JHK excess	IRAC excess	24μm excess	Excess Nature[a]	Known Comp	$T_{\rm dust}$ (K)	$L_{\rm IR}/L_*$
CSPN Abell 21	PG1159	130,000			✓			150	1.7×10^{-5}
CSPN DeHt 5	DAO.86	76,500		8μm	✓			190	5.9×10^{-5}
CSPN EGB 1	DA.34	150,000		8μm	✓	C		190	1.3×10^{-5}
CSPN EGB 6	DA.46	110,000	✓	✓	✓	C[b]	✓	150+500	4.6×10^{-4}
CSPN K 1-22	CSPN	141,000	✓	✓	✓	C	✓	150+700	1.1×10^{-4}
CSPN NGC 2346	CSPN	100,000	✓	✓	✓	C,E	✓	250+1000	2.3×10^{-2}
CSPN NGC 2438	CSPN	114,000		✓	✓	C,E		150+1100	4.7×10^{-4}
CSPN NGC 6804	CSPN	86,000	✓	✓	✓	C,E		200+630+1500	1.0×10^{-3}
CSPN NGC 6853	DAO.46	108,600		8μm	✓			150	2.4×10^{-4}
CSPN NGC 7139	CSPN	125,000		✓		C		1500	6.3×10^{-4}
CSPN NGC 7293	DAO.49	110,000		8μm	✓	C		120	2.5×10^{-4}
CSPN Sh 2-216	DA.61	83,000			✓	C		150	3.7×10^{-6}
CSPN Sh 2-188	DAO.49	102,000		✓	✓			150+900	6.6×10^{-5}

[a] C stands for continuum, E for emission lines
[b] A Compact nebulosity is coincident with WD's companion

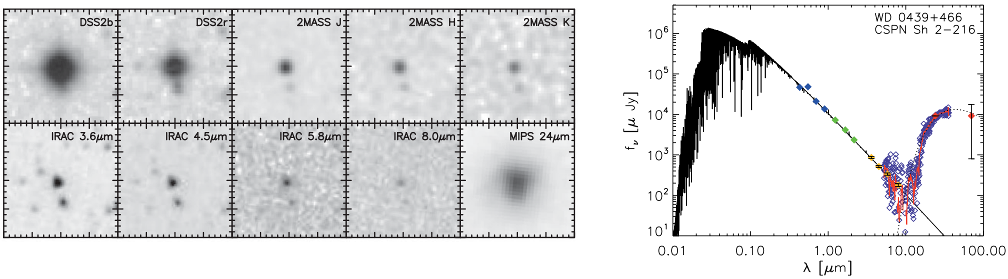

Figure 1. Images (left) and the SED (right) of CSPN Sh2-216. The Spitzer IRS spectrum is shown in the SED as open diamonds, and the smoothed spectrum is shown in thick line. The spectrum is dominated by featureless continuum emission, which starts rising at ∼10 μm. The dust model is shown as a dotted curve.

from a T ∼150 K dust continuum located between ∼30-35 AU from the CSPN, with an emitting area of ∼0.5 AU^2, and a mass of ∼0.001 Earth mass.

3. Possible Origins of IR excesses

Apart from collisions among planetesimals, other origins for the observed dust disks need to be considered. Stable Keplerian-rotating dust disks are common among binary post-AGB stars (de Ruyter *et al.* 2006). The CSPNs have just evolved past the post-AGB stage, and some of our targets have known binary companions, or have SEDs that do not eliminate the possibility of a companion; it is thus possible that dust disks around CSPNs may be related to those around post-AGB stars. However, it is not yet known how and whether the post-AGB binaries with dust disks evolve into the PN stage. Further observational and theoretical studies are necessary to distinguish between the two origins.

References

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