The Nature of the Infrared Excess around WD 0950+139

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WD 0950+139 is an intriguing white dwarf because (1) it is the central star ($T_{\text{eff}} = 110,000$ K) of the large (14′ diameter) planetary nebula EGB 6 (Ellis et al. 1984; Liebert et al. 1989); (2) it has strong nebular emission lines (such as [OIII], Liebert et al. 1989) associated with a resolved companion at a separation of 0.18′ (Bond et al. 1993); and (3) it has a NIR excess suggestive of the presence of a dM companion (Zuckerman et al. 1990, Fulbright & Liebert 1993). Our new Spitzer observations of WD 0950+139 further reveal that the infrared excess extends beyond 35 µm, and has temporal variations on a timescale of a year. Furthermore, our recent ground-based Echelle spectroscopic data reveal a double peaked [OIII] line profile indicative of a Keplerian disk structure around the system. In this paper, we will discuss the nature and origin of the infrared excess around WD 0950+139.
**The Nature of the Infrared Excess around WD0950+139**

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**Planetary Nebula EGB 6 = PN G2215+46 3**

- EGB 6: a large, faint PN discovered by Bond (see Ellis, Grayson & Bond 1984) in Palomar Shy Survey plates. Ground-based CCD (Zuckerman et al. 1989) and TekAO & Keck II (1995) show a brightness enhancement toward the western side of the nebula, suggesting an interaction with the ISM.

**WD0950+139 = CSPN of EGB 6**

- A very hot white dwarf with Teff ~108,390 K, logg ~7.39±0.38, M~0.04 Msun at a distance of 645 pc (Liebert et al. 2005).

**Ground-based UBV, Sloan ugriz and GALEX fuv (0.15 µm) and nuv (0.23 µm) photometry can be well fitted with a WD model atmosphere of Teff~110,000 K with an interstellar extinction Av of ~0.23 µm and an apparent visual Av of ~0.12 mag (See Figure 2).**

**At distance of 645 pc, the WD luminosity is 72 Lsun with a radius of 0.023 Rsun (2.55 R⊕).**

**Our newly obtained Echelle spectrum of WD0950+139 resolved the companion (Figure 3, left) at a separation of 0.18" (~116 AU@645pc).**

**High-resolution HST images (Bond 2009) showed a signpost of a gaseous rotating disk.**

**The infrared excess is evident at λ~1-24 µm.**

**The companion has a luminosity of 0.04 Lsun, and a radius of 0.55 Rsun.**

**Figure 1 – HST image of WD0950+139 by habits, on the right (1995). North is to the top and east is to the left with a dimension of 16.5 arcsec. The outside shell is projected onto the western left, while the western half of the nebula is not seen due to high extinction.**

**The source detected in 11.5 µm showing a radius of 64 pc and an apparent visual Av of 0.5 km. The position is a kinematic age ~11,500 y.**

**The central star, WD0950+139, is marked.**

**The system is complex: (1) a hot WD, emitting lots of UV photons; (2) the nebula has a kinematic age of ~6x104 yr.**

**Possible Origins of the IR Excess**

- The system is complex: (1) a hot WD, emitting lots of UV photons; (2) the nebula has a kinematic age of ~6x104 yr.

**Scenario I (Figure 7)**

- The disk is an optically thin upper disk layer (~300 K, the emitting area, 0.6 µm, is too big for a stellar object. A dust disk/cloud is needed.

**Scenario II (Figure 8)**

- The opaque ring has an inner radius of 0.005 AU (~dust sublimation radius) and an outer radius of 0.5 AU (~the Keplerian radius from the WD). Only small grains can emit efficiently in mid-IR. The thin disk atmosphere is composed of 0.1-10 µm amorphous carbon grains.

**EGB 6: a large, faint PN discovered by Bond (see Ellis, Grayson & Bond 1984) in Palomar Shy Survey plates. Ground-based CCD images (Figure 1 below) by Jacoby & van de Steen (1995) show a brightness enhancement toward the western side of the nebula, suggesting an interaction with the ISM.**

**Figure 2 – The SED of the WD0950+139 mid-IR excess to illustrate ~7 µm Spitzer photometry (IRAC and MIPS 24 µm) and IRS low-resolution spectrum were obtained 1 year ago. The temporal variation is real as the associated errors of these measurements are often smaller to account for the difference.**

**Figure 3 – HST FOC and WFPC2 PC images of WD0950+139. The FWHM of the line is ~44 km/s with the best extending from ~50 km/s to ~150 km/s.**

**[O III] lines show a distinct double-peaked profile, which is usually a signpost of a gaseous rotating disk. The separation between the peaks, ~11 km/s, suggests a disk outer radius of 0.5 AU (1.5 AU) if the companion mass is 0.06 (0.2) Msun.**

**Figure 4 – Echelle spectrum of WD0950+139.**

**Figure 5 – Spitzer images of WD0950+139 along with the Sloan composite color image. All images are in the same physical dimension with N up and E to the left.**

**Figure 6 – The infrared excess SED of WD0950+139. The opaque ring has an inner radius of 0.005 AU (~dust sublimation radius) and an outer radius of 0.5 AU (~the Keplerian radius from the WD). Only small grains can emit efficiently in mid-IR. The thin disk atmosphere is composed of 0.1-10 µm amorphous carbon grains.**

**Figure 7 – SED of Scenario 1.**

- The dust disk is around the WD and heated by both the WD and its companion. The emission can be approximated as a combination of an opaque ring heated by the companion and an optically thin upper disk layer heated by the WD. The opaque ring has an inner radius of 0.005 AU (~dust sublimation radius) and an outer radius of 0.5 AU (~the Keplerian radius from the WD). Only small grains can emit efficiently in mid-IR. The thin disk atmosphere is composed of 0.1-10 µm amorphous carbon grains.

**Figure 8 – SED of Scenario 2.**

- The dust disk is around the WD and heated by both the WD and its companion. The emission can be approximated as a combination of an opaque ring heated by the companion and an optically thin upper disk layer heated by the WD. The opaque ring has an inner radius of 0.005 AU (~dust sublimation radius) and an outer radius of 0.5 AU (~the Keplerian radius from the WD). Only small grains can emit efficiently in mid-IR. The thin disk atmosphere is composed of 0.1-10 µm amorphous carbon grains.