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Observations and NLTE Modeling of the Gaseous Planetary Debris Disk around Ton 345

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Abstract. Debris disks around single white dwarfs are thought to be the remains of planetary bodies disrupted by tidal forces. Ongoing accretion of the hereby produced dust allows to detect the planetary material in the white dwarf photosphere and to conclude on its chemical composition. As an alternative, the composition can in principle be determined directly from the emission lines of the sometimes additionally observed gaseous component of the disks. To this aim, we perform spectral modeling with our non-LTE code for accretion disks. We have obtained new observations of Ton 345 in order to look for long- and short-term variations in the disk line-profiles. We find that the prominent red-violet asymmetry of the Ca II infrared triplet almost disappeared. Line-profile variations during one night are not seen without doubt.

1. Introduction: Metal-rich Gaseous Debris Disks Around White Dwarfs

For several years, there has been a growing number of single white dwarfs (WD) detected showing a high infrared (IR) flux. The picture of an evolved central object shredding and accreting parts of its surrounding planetary system (Debes & Sigurdsson 2002; Jura 2003) became the prevailing explanation for this excess. The high metallicity and mass of the hereby formed dusty debris disks resulting from a destroyed asteroid or minor planet fit the observed data very well (e.g. Farihi et al. 2009). While most of the time spectral analysis of these objects focuses on the accreted material using the WD's atmosphere as a "detector", the discovery of emission lines (e.g. Gänsicke et al. 2006) points towards an additional gaseous disk component and allows the planetary debris to be studied directly.

2. Ton 345

Ton 345 (WD 0842+231) is the first DBZ-type WD ($T_{\rm eff}$ = 18 600 K, $\log g$ = 8.2, Gänsicke et al. 2008) at which the Doppler-broadened Ca II IR triplet (IRT) at $\lambda\lambda$ 8498, 8542, 8662 Å, the hallmark for gaseous debris disks, was discovered by Gänsicke et al. (2008). Two spectra, taken by the Sloan Digital Sky Survey (SDSS) in early 2004 and with the William Herschel Telescope (WHT) in late 2008 (upper two panels in Fig. 1), show a strong decrease of the equivalent widths and a significant red-violet asymmetry of the double-peaked profiles.

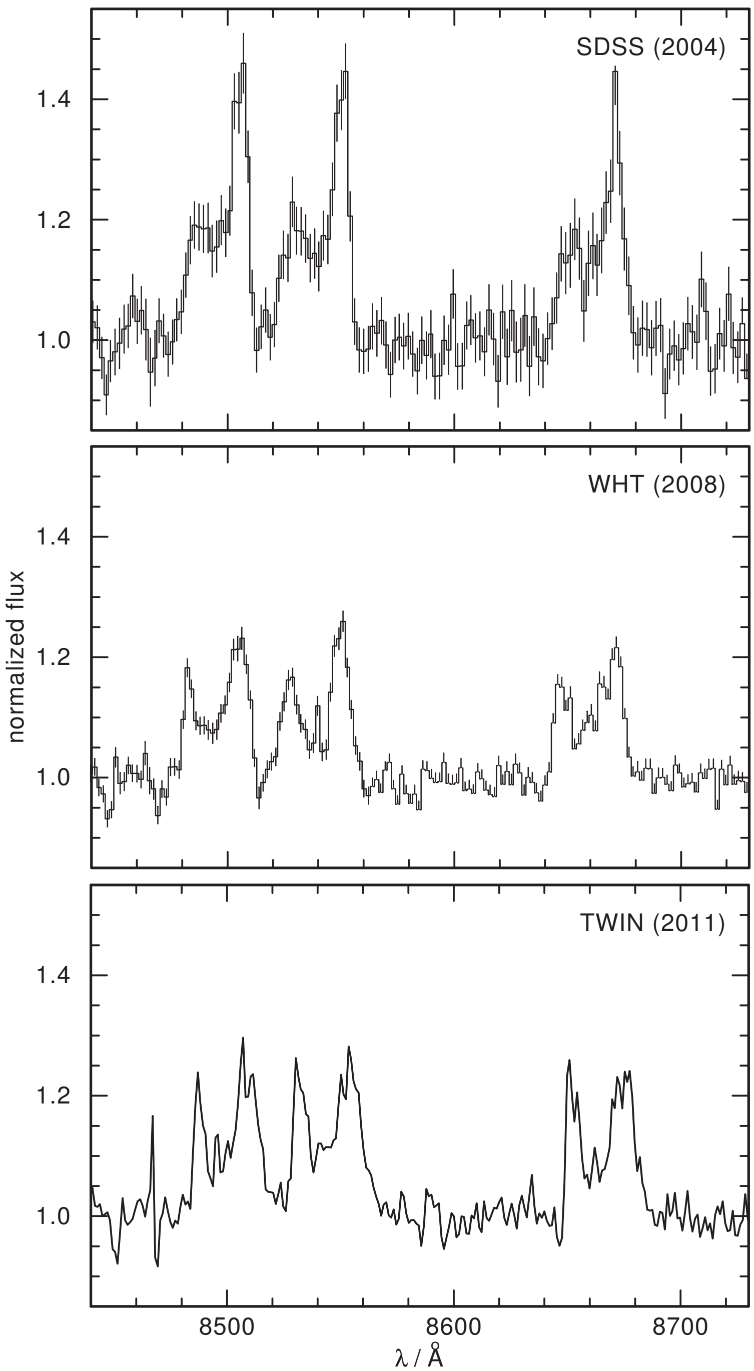

Figure 1. SDSS and WHT spectra (top and center panels; datasets taken from Gänsicke et al. 2008) of Ton 345 in the range of the IRT. The co-added spectrum of the recently obtained Calar Alto data is shown in the bottom panel.

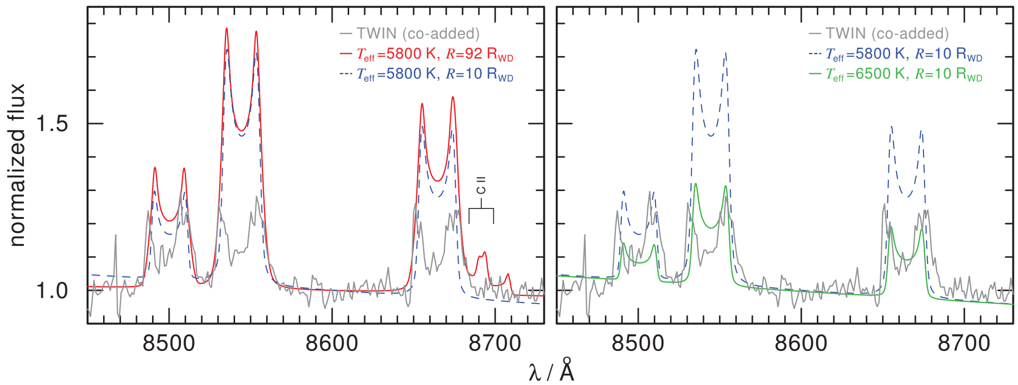

Figure 2. The IRT in the co-added TWIN spectra compared to three different non-LTE disk models. In the left panel both NLTE models have the same constant effective temperature $T_{\rm eff}$ = 5800 K but different radial extent. The models in the right-hand side panel differ in $T_{\rm eff}$ while the radial extent of the disk is kept constant at $R = 10\,R_{\rm WD}$.

3. Calar Alto Observations

The observations were performed with the Cassegrain TWIN Spectrograph at the 3.5 m telescope at Calar Alto Observatory, using gratings T08 for the blue and T04 for the red channel (dispersion 72 Å/mm) to cover the wavelength ranges 3500–6500 Å and 5500–9000 Å, respectively. 17 consecutive spectra were obtained on the night of UTC 2011-04-08, with 900 s integration time each. As conditions were not ideal, the S/N of some spectra is rather poor. The eleven best exposures, i.e. S/N > 6, were co-added (bottom panel in Fig. 1).

To study the disk parameters, we calculated non-LTE radiation-transfer models using our code for accretion disk spectra `AcDc` (Nagel et al. 2004). The models shown in Fig. 2 represent non-stationary, metal-rich gaseous disks with different but constant effective temperature $T_{\rm eff}(r)$ and different radial extent R. The observed line width is best reproduced by using a rather cool ($T_{\rm eff}$ = 5800 K) and widely extended (R = $10\,R_{\rm WD}$) model (left-hand side panel Fig. 2, red solid line). However, to fit the similar relative line strengths of the three IRT components, a model with higher temperature ($T_{\rm eff}$ = 6500 K) and only $R = 92\,R_{\rm WD}$ is necessary (green solid line, right panel Fig. 2).

4. Observed Line-Profile Variations

The frequently observed changes in the IRT of gaseous debris disks around single WDs (e.g. Gänsicke et al. 2008; Melis et al. 2010) give the opportunity to study the dynamical processes occurring within the disk. First attempts to explain the lines' asymmetry by describing the disk geometry in a non-axissymmetric way based on hydrodynamical models might explain the temporal changes (Hartmann et al. 2010, 2011).

In the case of Ton 345, we see in our observations that the long-term trend reported by Gänsicke et al. (2008) continued. The red-violet asymmetry almost disappeared (Fig. 1). Due to insufficient S/N ratio of the single spectra (Fig. 3), a short-term variability in the line-profiles can not be claimed without a doubt. Future observations with a 8 m-class telescope are necessary for more definitive conclusions.

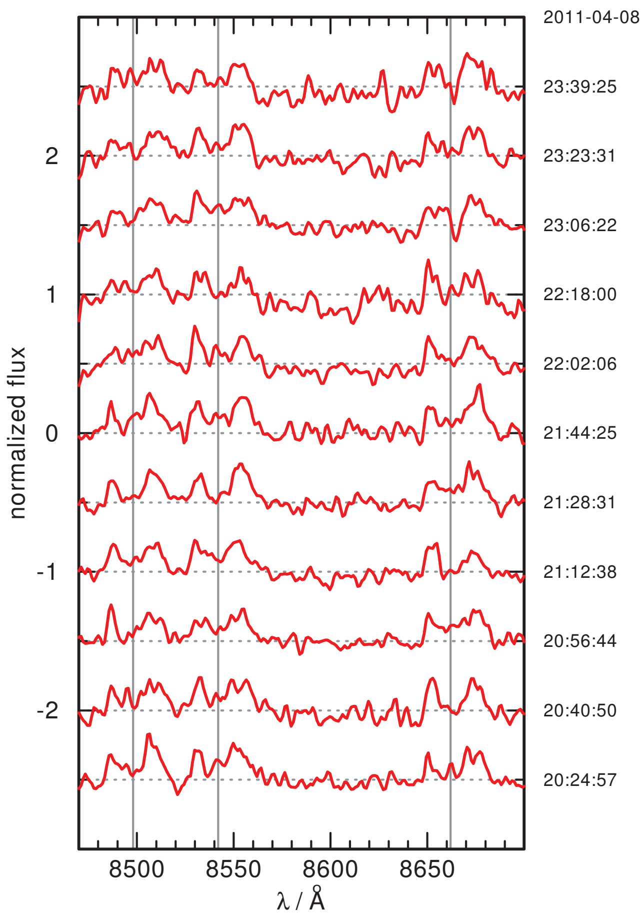

Figure 3. Normalized Calar Alto spectra in chronological order (bottom to top), obtained within about three hours. The vertical lines indicate the rest wavelengths of the IRT components.

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