NLTE Analysis of the Ultra-short Period White-dwarf Binary RX J0806.3+1527

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Abstract. RX J0806.3+1527 is suspected to be a double-degenerate white dwarf binary. We present first results of our NLTE analysis of its optical spectrum. The VLT/FORS1 data show a composite spectrum consisting of a blue continuum and superimposed emission lines of the He II Pickering series and, possibly, the H Balmer series. Our models are based on hot white dwarf atmospheres and include illumination effects onto the secondary star. The physical parameters and chemical abundances derived from the comparison of the observed spectrum with a grid of model atmospheres provide constraints on the true nature of this enigmatic binary and on the models proposed so far.

1. Introduction

RX J0806.3+1527 is a remarkable object discovered during the ROSAT all-sky survey (Beuermann et al. 1999). Its soft X-ray flux is \( \approx 100\% \) modulated with a period of 321.54 s (Israel et al. 1999; Burwitz & Reinsch 2001). If this is the orbital period of a double-degenerate close binary system as suggested by Israel et al. (2002) and Ramsay et al. (2002) it would lie close to the theoretical minimum period of white dwarf binaries and would imply the presence of a He-rich donor star.

The spectral energy distributions in the optical and X-ray windows reveal two distinct components with black body temperatures of \( \approx 40\,000\,\text{K} \) and \( \approx 750\,000\,\text{K} \) which could be attributed to the donor star or an accretion disk and to an accretion spot on the primary, respectively (Israel et al. 2003). As a crucial test to distinguish between the double-degenerate scenario and competing models (e.g. Norton et al. 2004) for RX J0806.3+1527 we have started an abundance analysis of the optical spectrum presented by Israel et al. (2002).

2. Spectral Analysis of RX J0806.3+1527

The optical spectrum of RX J0806.3+1527 obtained with FORS1 at the ESO VLT shows a composite of a blue continuum and superimposed emission lines of the He II Pickering series and, possibly, the H Balmer series. For the spectral analysis, we utilize a grid of theoretical spectra calculated with an NLTE model atmosphere code for white dwarf photospheres with a range of effective temperatures \( T_{\text{wd}}, (\text{He/H}) \) abundance ratios, and isotropic irradiation (Werner & Dreizler 1999; Dreizler 2003; Werner et al. 2003). Here, we present a study of the influence of the three main parameters on the spectrum.
2.1. Illumination Parameter

In our models, irradiation is treated as black body emission with effective temperature \( T_{\text{irr}} = 500000 \text{ K} \) from a spherically symmetric shell around a white dwarf with \( T_{\text{wd}} = 30000 \text{ K} \) and an abundance ratio \((He/H) = 1.0\). The distance between the irradiating source and the photosphere is represented by a free “illumination” parameter \( i \). It has been varied from \( 10^{-1} \) to \( 10^{-10} \) with a more detailed study in the parameter range which leads to the occurrence of significant emission lines in the spectrum (Fig. 1). Depending on \( i \), our models produce three phenomenologically different types of spectra:

\[
10^{-10} < i < 10^{-5} : \text{Absorption lines are gradually filled by emission}
\]

\[
2 \cdot 10^{-5} < i < 2 \cdot 10^{-4} : \text{Emission lines with central absorption in He II } \lambda \text{ 4686 Å}
\]

\[
2 \cdot 10^{-4} < i : \text{Featureless spectrum except for He II } \lambda \text{ 4686 Å absorption}
\]

![Figure 1](image.png)

Figure 1. Observed spectrum of RX J0806.3+1527 in comparison to a selection of models with different illumination parameters \( i \) (from top to bottom: observation, models with \( i = 0.0002, 0.0001, 0.00005, 0.00002 \), and model without irradiation. For comparison with the models, the observed spectrum has been arbitrarily offset in flux units.

2.2. \((He/H)\) Abundance Ratio

In order to estimate the chemical composition of RX J0806.3+1527 we have calculated models with different \((He/H)\) abundance ratios between \((He/H) = 0.01\) and \((He/H) = 100\). The irradiation and photospheric temperatures have been fixed at \( T_{\text{irr}} = 500000 \text{ K} \) and \( T_{\text{wd}} = 30000 \text{ K} \), respectively, and the illumination parameter has been set to \( i = 0.0001 \) (see Fig. 2).
Based on our analysis, we can reject He-deficient atmospheres, \((\text{He}/\text{H}) \leq 0.01\), as well as models with strong He overabundances, \((\text{He}/\text{H}) \geq 1.0\). The latter fail to reproduce the observed spectrum, especially around the \(\text{He} \mathbin{\text{II}} \lambda 4540\text{Å}\) line. Proper fits to the observational data can be obtained with abundances \(0.1 \leq (\text{He}/\text{H}) \leq 0.3\).

### 2.3. White Dwarf Temperature

As a third parameter, we varied the effective temperature of the illuminated photosphere in the range \(30\,000\,\text{K} \leq T_{\text{wd}} \leq 50\,000\,\text{K}\) with fixed parameters \(i = 0.0001\) and \((\text{He}/\text{H}) = 1.0\) (see Figure 3).

Our models show that photospheric temperatures between 30,000 K and 35,000 K seem to be more realistic than higher temperatures, in agreement with the overall spectral energy distribution of RX J0806.3+1527.

### 3. Results and Future Work

Our parameter study has shown that the optical spectrum of RX J0806.3+1527 can be quantitatively reproduced with our irradiated white dwarf atmosphere model. The model spectra provide some evidence against a He-white dwarf nature of the donor star implied by the double-degenerate binary scenario. Noting that illumination is the dominant effect in modeling the optical spectrum of RX J0806.3+1527, our approach of an isotropic irradiation of a high-gravity
Figure 3. Sequence of models with different white dwarf temperatures $T_{\text{wd}}$ (from top to bottom: $T_{\text{wd}} = 50,000\,\text{K}$ to $30,000\,\text{K}$ in steps of $5,000\,\text{K}$) and observed spectrum of RX J0806.3+1527 (lowermost curve). For comparison with the models, the observed spectrum has been arbitrarily offset in flux units.

atmosphere may, however, be too simplistic. Further work will be required to investigate models with non-isotropical irradiation and irradiated accretion disks.

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