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# X-ray spectra of wind-driven bubbles with chemical gradients

**Ralf Jacob, Christer Sandin, Detlef Schönberner and Matthias Steffen**

Leibniz-Institut für Astrophysik Potsdam,
An der Sternwarte 16, D–14482 Potsdam, Germany
email: rjacob@aip.de

**Abstract.** As a tool helping to interpret diffuse X-ray emission of PNe, and as a supplement to our RHD simulations, we have started to construct a grid of theoretical X-ray spectra of wind-blown bubbles with temperature and density profiles according to thermal conduction theory. We investigate how the X-ray spectra depend on chemical composition (e.g. H-rich vs. H-deficient) and how temperature and abundance determinations reflect gradients of temperature and chemical composition within the bubbles. These synthetic models shall allow to quickly perform detailed parameter studies without the need for dedicated hydrodynamical simulations. We report on ideas and goals.

**Keywords.** conduction, hydrodynamics, planetary nebulae: general, X-rays: stars

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Our project is motivated by the first high-resolution X-ray spectroscopy of a planetary nebula, viz. BD+30° 3639 (Yu *et al.* 2009), which opens the possibility to study plasma conditions and chemical composition of X-ray emitting regions of PNe in much greater detail than before. The data quality enabled Yu *et al.* to show that a single-component (isothermal) plasma model is insufficient to explain several features of BD+30° 3639's X-ray spectrum simultaneously, demonstrating the existence of temperature variations within the hot bubble.

Central questions addressed by our study are:

- How does evaporation of H-rich matter into the hot bubble formed by a wind of a H-deficient CSPN influence the bubble's X-ray spectrum and abundance determinations based on it ?
- How are important diagnostic line ratios, such as O VIII/O VII or Ne X/Ne IX, influenced by temperature (and chemical) gradients ?
- Is a *two-component* model, such as the one of Yu *et al.*, sufficient ?
- Do abundance determinations from the central star (CSPN), the hot bubble, and the nebula tell the same story ?

We employ the self-similar solutions for hot bubbles of spherically symmetric interacting stellar winds of Zhekov & Perinotto (1996) which include heat conduction but no radiative cooling (Fig. 1 left). Their Ansatz allows for time-dependent CSPN winds. The X-ray emission of these bubble models (Fig. 1 right) is computed by means of the well-documented CHIANTI code (v6.0.1, Dere *et al.* 1997, 2009).

The study of Zhekov & Perinotto (1998) only included winds of H-rich CSPN along evolutionary tracks of Blöcker (1995). Hence, we first extend their study with modifications introduced by H-deficient winds (see contribution of Sandin *et al.*, this volume) colliding with H-rich PNe. Next to diagnostic line ratios we study whether the two different chemical compositions produce distinct or unique features in the spectra (Fig. 2).

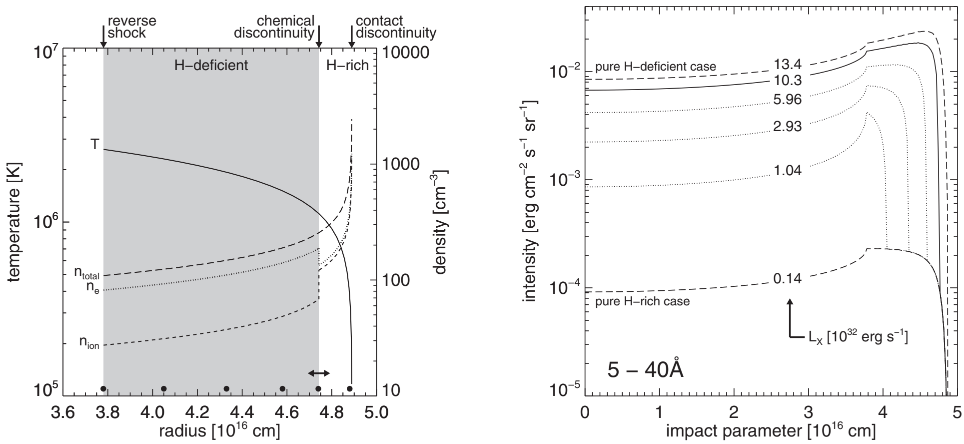


**Figure 1.** *Left*: Illustration of a hot bubble model. The bubble is formed by interaction of a hydrogen-deficient fast wind with a hydrogen-rich slow wind. The bubble extends from the wind reverse shock to the contact discontinuity. The H-deficient composition is based on H, He, C, O for BD+30° 3639 from Marcolino *et al.* (2007). The H-rich matter is of solar composition. The temperature distribution of the isobaric bubble is fixed to determine ion and electron densities for the different chemical compositions. *Right*: Radial X-ray brightness distributions for the bubble structure of the left figure (solid) and five cases where the chemical discontinuity is located at different positions within the bubble (marked by dots above the abscissa in the left figure). Note the difference in surface brightness and $L_X$ between the pure H-rich and H-deficient cases (about a factor 100).

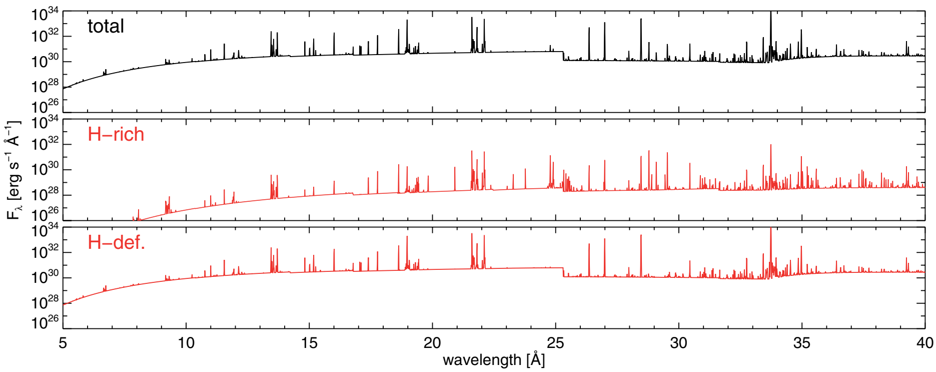


**Figure 2.** Example of a spectrum of a hot bubble with a chemical discontinuity. The model is taken from Fig. 1 (solid line in the brightness plot). Next to the total spectrum we show the single contributions from the two spherical shells of different chemical composition. The N VII 24.77Å feature will be of particular interest since it originates only from the H-rich matter. (However, note the logarithmic scale in these plots!)

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