X-ray spectra of wind-driven bubbles w/ chemical gradients

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As a tool helping to interpret diffuse X-ray observations of PNe, and as a supplement to our RHD simulations, we have started computing a grid of theoretical X-ray spectra of wind-blown bubbles with temperature and density profiles according to thermal conduction theory. We want to investigate how the X-ray spectra depend on chemical composition (e.g. H-rich vs. H-deficient) and how temperature and abundance determinations reflect temperature gradients as well as chemical gradients 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.

Motivation: The first high-resolution X-ray spectroscopy of a planetary nebula, viz. BD+30º 3639 (Yu et al. 2009, ApJ, 690, 440), opens the possibility to study plasma conditions and chemical compositions of X-ray emitting regions of PNe in much greater detail than before. The data quality enabled Yu et al. to show that an single-component (isothermal) plasma model is insufficient to explain several features of BD+30º 3639's X-ray spectrum simultaneously, demonstrating the existence of temperature gradient(s) within the hot bubble.

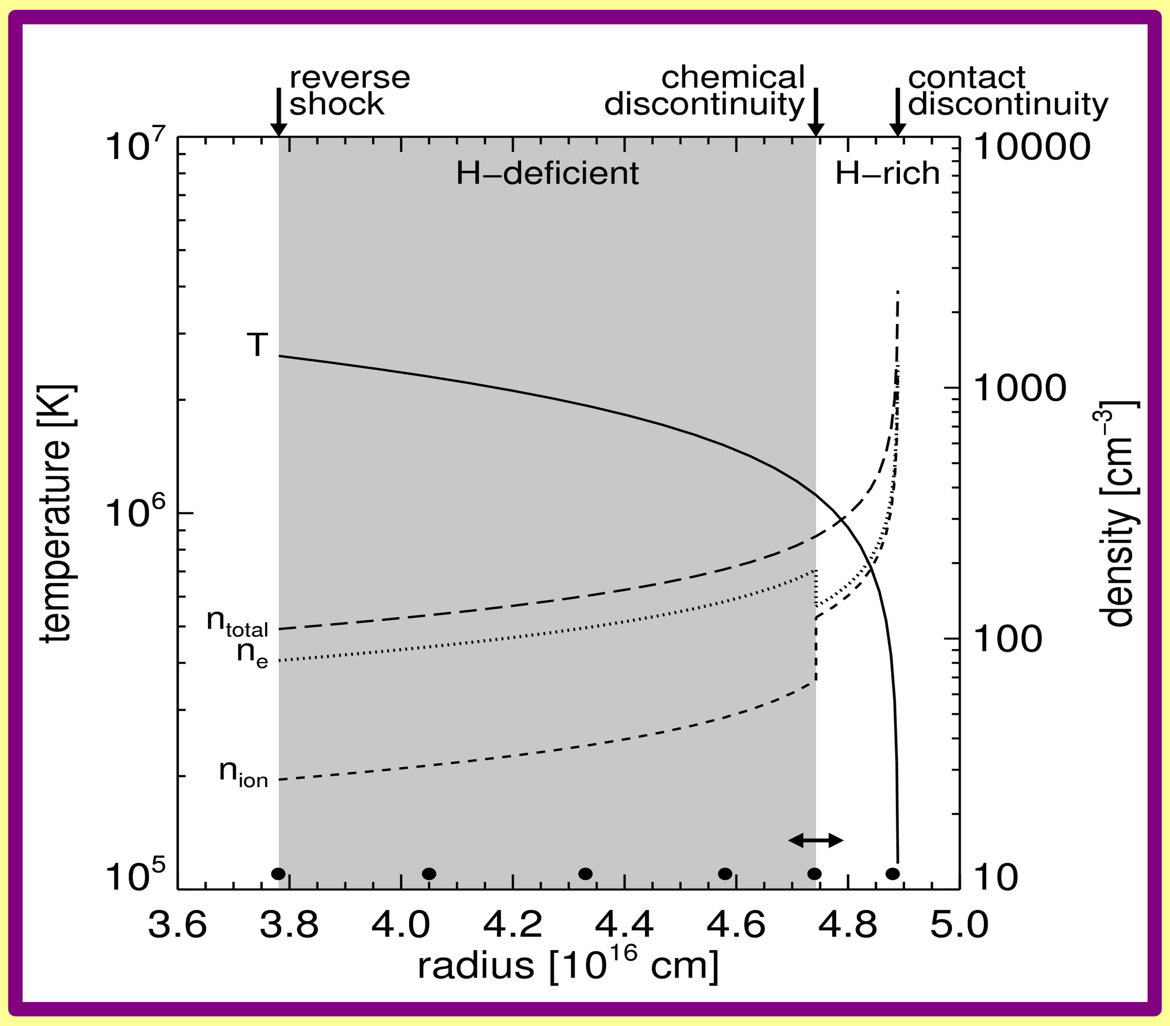
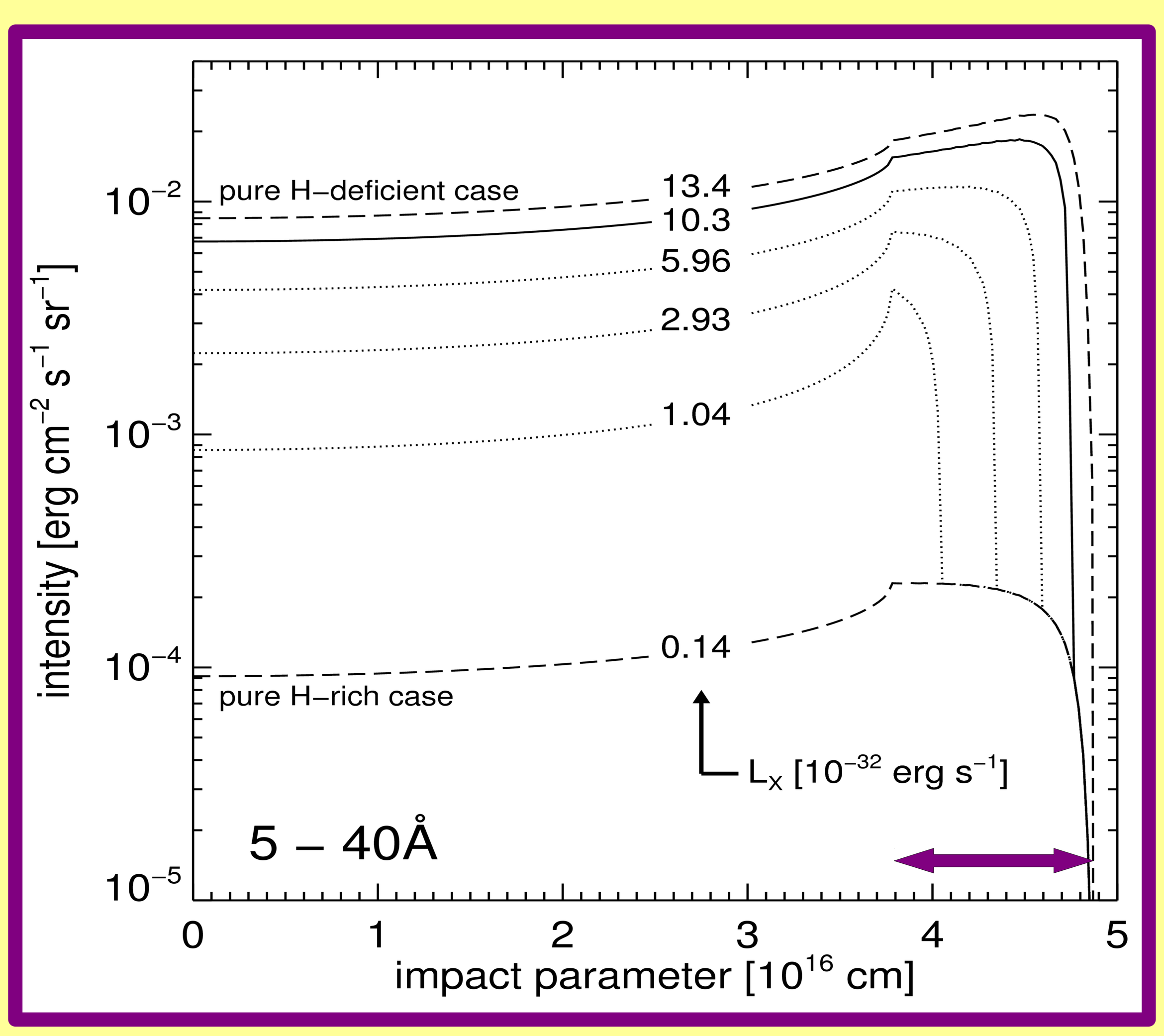


Illustration of a hot bubble model
Bubble formed by interaction of a hydrogen-deficient fast wind with a hydrogen-rich wind. The bubble extends from the wind reverse shock to the contact discontinuity. The H-deficient composition is based on H, He, C, O for BD+30º 3639 from Marcolini et al. (2007, ApJ, 654, 1068). The H-rich matter is of solar composition. The temperature distribution of the isobaric bubble is fixed to determine ion & electron densities for the different chemical compositions.



Radial X-ray brightness distributions
The chemical discontinuity is located at different positions within the bubble (marked by dots above the abscissa in the top figure). The actual hot bubble region is marked by the arrow.

Guide / Central questions:

1. 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 ?

2. How are important diagnostic line ratios, such as O **VIII** / O **VII** or Ne **X** / Ne **IX**, influenced by temperature (and chemical) gradients ?

3. Is a "two-components" - model, such as the one of Yu et al., sufficient ?

4. Do abundance determinations from the central star (CSPN), the hot bubble, and the nebula tell the same story ?

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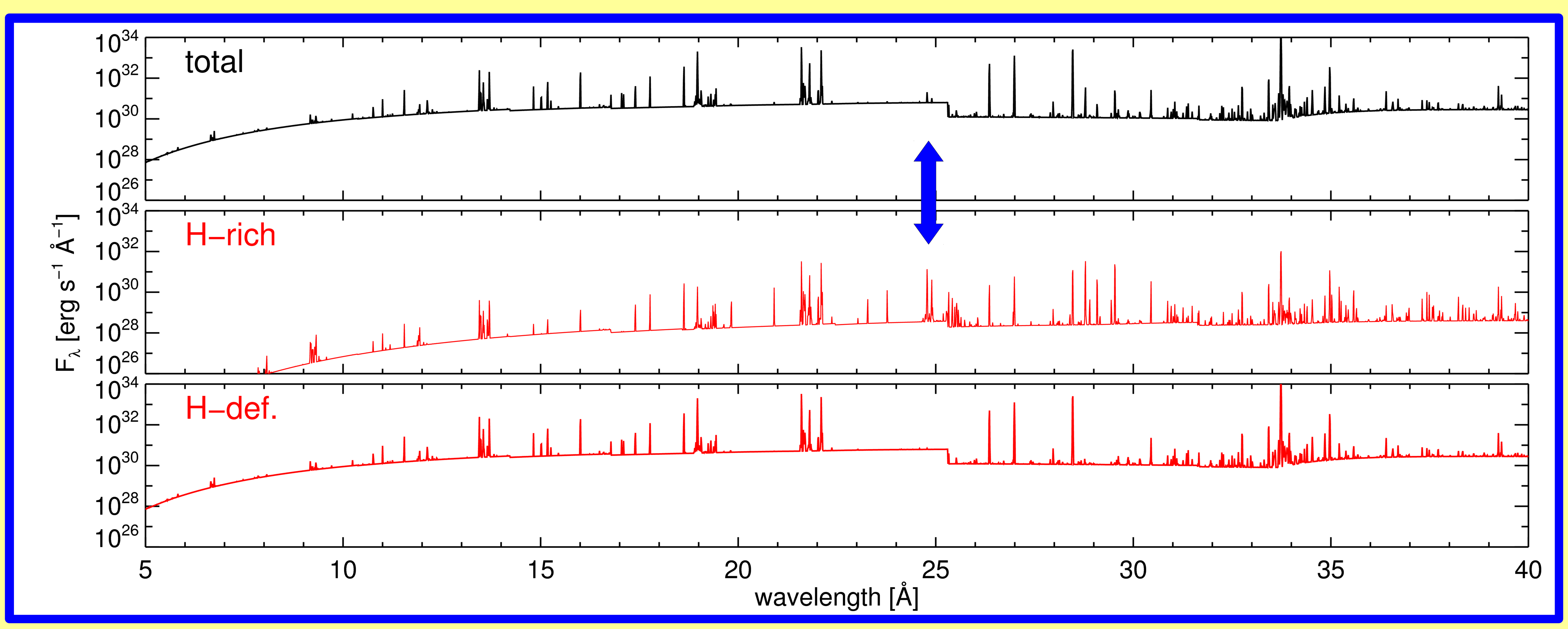
Tool(s) of choice: We employ the self-similar solutions for hot bubbles of spherically symmetric interacting stellar winds of Zhekov & Perinotto (1996, A&A, 309, 648) which include **heat conduction** but no radiative cooling. Their ansatz allows time-dependent CSPN winds. The X-ray emission of these bubble models is computed by means of the well-documented CHIANTI code (v6.0.1, Dere et al. 1997, A&AS, 125, 149; Dere et al., 2009, A&A, 498, 915).

Current task: Building the database of models with widely explored parameter space of fast-wind models, "slow-wind" properties, evolutionary ages (sizes), abundance distributions, positions of chemical discontinuities, that will be subsequently restricted by their mean X-ray luminosities and temperatures.

Example: The study of Zhekov & Perinotto (1998, A&A, 334, 239) only included winds of H-rich CSPN (along evolutionary tracks of Blöcker 1995, A&A, 299, 755). Hence, we first extend their study with modifications introduced by H-deficent winds (➦ poster of Sandin et al., **#25**) 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.



Example of a spectrum of a hot bubble with a chemical gradient
The model is taken from the left side (solid line in the brightness plot). Next to the total spectrum we show the single contributions from the two spherical shells of different chemical compositions. 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 this plots!)