Asymmetric Planetary Nebulae 5
(Ebrary, Cambridge, USA),
A.A Zijlstra, I. McDonald, eds.

The role of thermal conduction in WR-type Planetary Nebulae

Christer Sandin

Astrophysikalisches Institut Potsdam, An der Sternwarte 16, Potsdam, D-14482, Germany

M. Steffen, D. Schoenberner, U .RÜhling, W.H. Hamann

Thermal conduction plays an important role to the interpretation of X-ray spectra of planetary nebulae. Models including this effect so far only used a theoretical formulation that assumes a pure hydrogen composition. To permit modeling of objects with other compositions, such as Wolf-Rayet stars, we have now extended the thermal-conduction description in our models. We will present the outcome of our study in terms of how these changes affect the new models and the predicted X-ray emission spectra.

The role of thermal conduction in Wolf-Rayet-type planetary nebulae

Christer Sandin, Matthias Steffen, Detlef Schönberner, Ute Rühling[1], Wolf-Rainer Hamann[1]

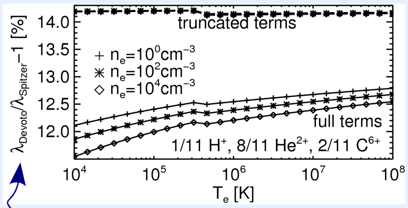
Astrophysikalisches Institut Potsdam, Germany; [1]Univ. Potsdam, Germany

Thermal conduction plays an important role in the formation of X-ray spectra of planetary nebulae (PNe). Models including this effect so far only assumed a pure hydrogen composition. To permit modeling of objects with other compositions we have now extended the thermal-conduction description in our radiation-hydrodynamic models. We present the latest outcome of our study in terms of how we model the physical structure of the hydrogen-poor object BD+30°3639 that has a Wolf-Rayet central star, and also calculate an X-ray emission spectrum.

Inclusion of a modified description of thermal conduction in H-poor envelopes

Steffen et al. (2008, A&A, 489, 173) use a pure hydrogen plasma according to the general Fokker-Planck-based theory of Spitzer (1962); it also works for other compositions. We made a comparison with the Chapman-Enskog-Burnett version of the theory of Devoto (1966–1967, Physics of Fluids). For typical sets of H-poor compositions we found **small differences** (see example in the right-hand side figure) – we then chose the simpler formulae of Spitzer (1962).

For our H-poor composition, the diffusion coefficient is about two times lower compared to a pure hydrogen plasma.



Ratio of diffusion coeff. of Devoto/Spitzer

Modeling the diffuse X-ray emission of BD+30°3639

Without thermal conduction the bubble forms earlier, and, hence, closer to the star. The bubble has a very high temperature ($T_X > 10^7$K) and it is more stretched out, with a lower electron density ($\langle n_{e,\mathrm{bubble}}\rangle < 10\,\mathrm{cm}^{-3}$).

With thermal conduction the bubble forms later. It has a much lower temperature than when thermal conduction is neglected, $2\cdot10^6 < T_X < 4\cdot10^6$K, and the electron density is higher ($\langle n_{e,\mathrm{bubble}}\rangle \approx 50\,\mathrm{cm}^{-3}$). The line ratio OVIII λ18.967/ OVII λ18.627 compares well with the observed ratio of Yu et al. 2009 – our spectrum below shows that the ratio is about 2.

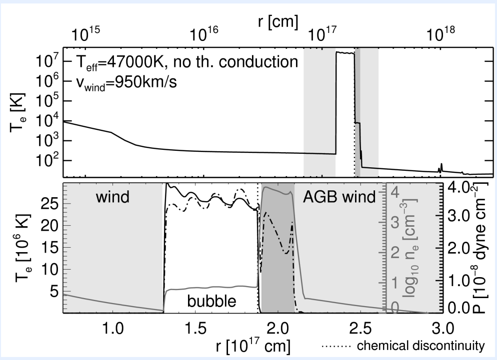
BD+30°3639 (PN G64.7+05.0)

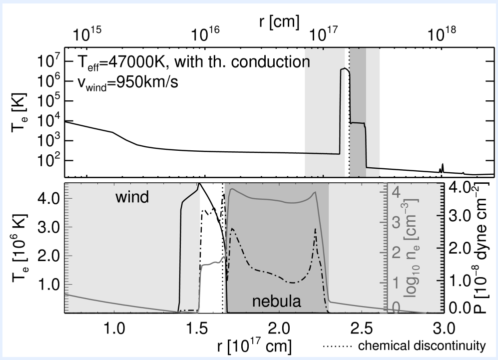
Central star: [WC9], $T_{\mathrm{eff}} \sim 47{,}000 - 48{,}060$ K (Leuenhagen et al. 1996 – Marcolino et al. 2007)

Fast wind: v=700 – 900 km/s, $dM/dt = 10^{-4.87}\,M_\odot$/yr (Leuenhagen et al. 1996 – Guerrero et al. 2009)

X-ray props.: $T_X \sim 2.7\cdot10^6$ K, $L_X \sim 1.6\cdot10^{32}$ erg/s (d = 1 kpc) (Kastner et al. 2000)

Composition of the fast wind (by mass): 51% C, 43% He, 6% O, 2% Ne (Marcolino et al. 2007)





We calculated a spectrum for both models using the CHIANTI atomic database (version 6.0.1). We have indicated some of the lines observed by Yu et al. 2009.