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NEBU_3D, A NEW PSEUDO-3D PHOTOIONIZATION CODE

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Most ionized nebulae have complex morphological structures. This is true not only for HII regions, but also for Planetary Nebulae. So far, almost all selfconsistent physical analyses of ionized nebulae have used 1D photoionization codes á la Cloudy. A few 3D photoionization codes now exist (Gruenwald et al. 1996; Ercolano et al. 2003). There are practical difficulties with 3D model fitting of real nebulae: one is the enormous parameter space to consider and another one is the fact that 3D codes are very CPU-time and memory consuming: several hours are needed on clusters or supercomputers to make a full model.

We present here a new pseudo-3D photoionization code (NEBU_3D, Morisset et al. 2005, MNRAS 360, 499), which models aspherical nebulae in a few minutes. The code uses various runs of the 1D photoionization code NEBU (Péquignot 2001) to generate a 3D model. Its associated visualization tool, VISNEB_3D, allows one to easily rotate and project the data cube to obtain emission line maps.

Emission line profiles can be used to put constraints on the morphology and kinematics of PNe. The profiles are directly connected to the density and velocity distributions along the line of sight. Using the output of NEBU_3d (or any 3D photoionization code), we compute emission line profiles with the VELNEB_3D tool (Morisset et al., 2005, submitted) in the following way: in each cell of the cube, we compute elementary emission line profiles, using a velocity vector defined by a linear expansion law. Thermal broadening is taken into account and turbulence may be added. An integration of these elementary profiles inside a specific slit provides the observed line profile. The observed profile is strongly dependent on the size, shape and location of the slit. Very complex profiles can be obtained, even using a very simple velocity law, especially if the slit is off-center. Figure 1 presents the emission line maps for four lines, with the aperture used to compute the emission line profiles superimposed. Figure 2 presents

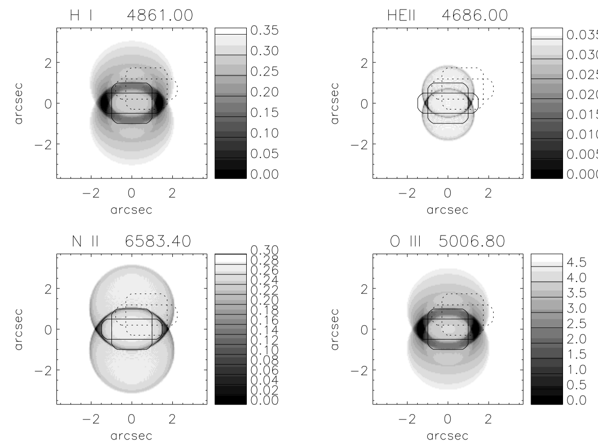

Fig. 1. Emission line maps for the bipolar model, for H_β, He II 4686, [N II] 6583 and [O III] 5007. The apertures used to compute the emission line profiles are superimposed.

results in the case of a bipolar nebula. The nebula has its polar axis making an angle of 45 degrees with the plane of the sky. The expansion law is linear, reaching 40 km/s at the polar recombination front. A small turbulence is added (0.5 km/s). The first two lines of plots in Fig. 2 describe the model and the three last lines show emission line profiles, for 3 lines (H_β, [O III] 5007, [N II] 6583, one line for each column) seen through various apertures, the size of which being reported on the top of each plot (the last line of plots is the profile for the whole nebula). Each plot shows the results for a centered aperture and an off-center aperture (solid and dotted lines resp.). The complicated profile obtained is only due to the bipolar shape, as the expansion law is linear. The wings observed in the last line of plots could be mistaken for the contribution of turbulence, while this is only the velocity gas.

More details are found in Morisset et al. 2005, submitted.

We plan to make the NEBU_3D, VISNEB_3 and VELNEB_3D tools publicly available in the near future, using Cloudy as 1D photoionization code.

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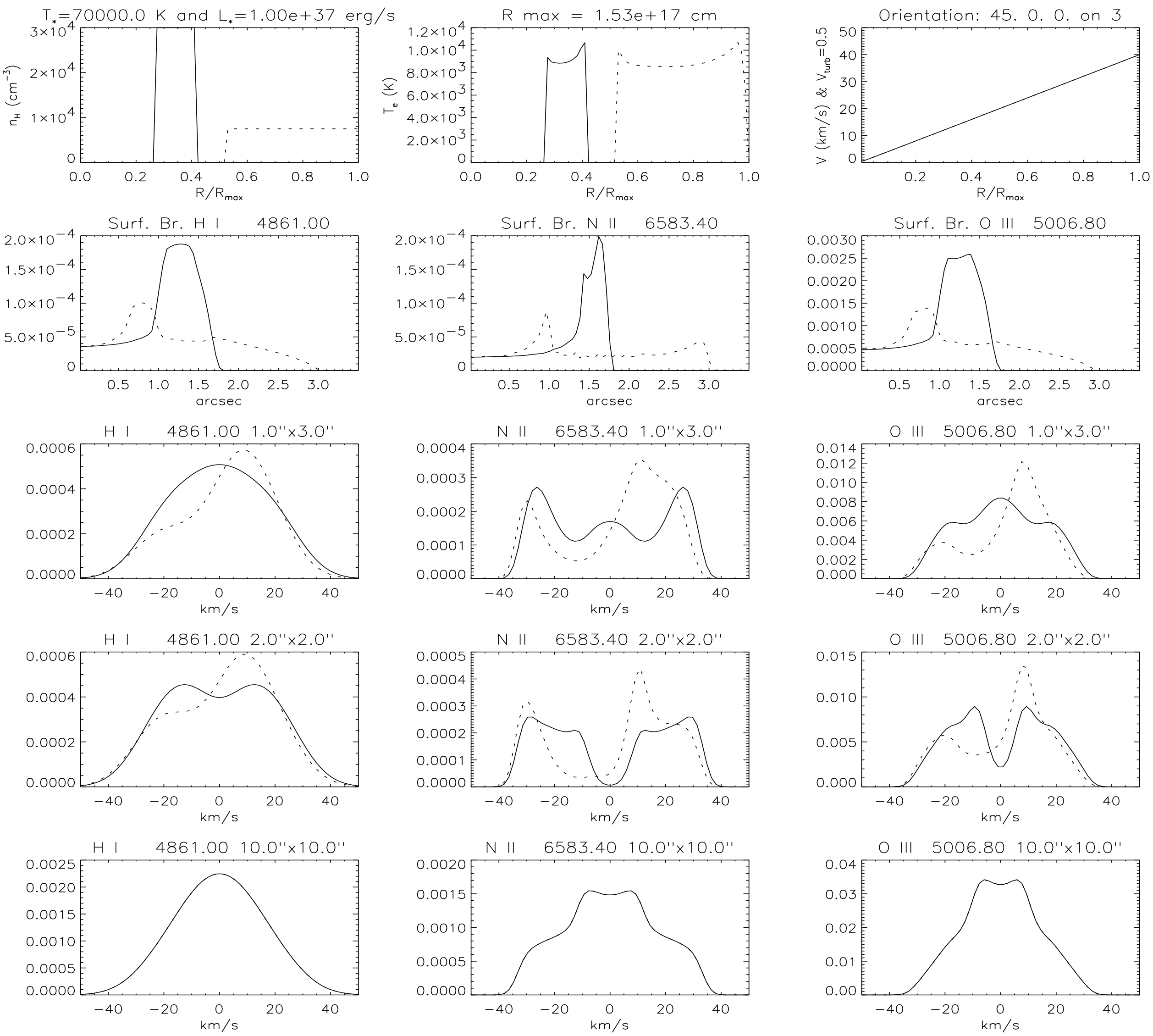

Fig. 2. Upper line plots, variation of some parameters versus the distance to the ionizing star: left: Hydrogen density distribution (solid and dashed lines: in the equatorial and polar directions respectively), middle: electron temperature distribution, right: velocity law. Second line plots: surface brightness for three emission lines (namely H_β, [O III] 5007, [N II] 6583), solid and dashed lines being in the equatorial and polar directions respectively. Units are arbitrary, but the same for the three plots. Last three lines of plots: profiles for the same three emission lines, through apertures, the size of the aperture being specified on top of each plot. The solid and dotted line plots are obtained through centered and off-center apertures respectively. The positions of the apertures are shown in Fig. 1. Intensity units are arbitrary, but the same for all the plots.

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