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Doppler tomography for investigation of binary central stars in planetary nebulae: computer modeling

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Abstract. The radio astronomical approach is applied to 2D and 3D Doppler tomography for close binary central stars in planetary nebulae. It is more effective than the traditional one.

Keywords. binaries: close, planetary nebulae: general, techniques: image processing

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The binarity of the progenitors has an essential influence on the origin and morphology of planetary nebulae. If the orbital period is < 0.35 days and the mass ratio is > 0.5, the central star can be the donor. Is mass exchange at the planetary nebula stage possible? The method of Doppler tomography, presented by Marsh and Horne (1988), is useful to answer this interesting question. In this paper the computer model reconstruction of 2D and 3D Doppler tomograms is carried out using a radio astronomical approach, developed by Agafonov and Sharova (2005). For a demonstration of 2D Doppler tomogram computation, a model has been calculated including a radiating star, a gas stream and an accretion disk around the secondary star. The model parameters are $M_{tot} = 2.0M_{\odot}$, $q = 1.5$, $a = 2.5R_{\odot}$, $M_1 = 0.8M_{\odot}$, $T_{orb} = 0.32$ day. The modeling is carried out on the basis of 30 and 10 lines profiles obtained at regularly spaced orbital phases. To investigate the influence of noise on the reconstruction we have added a random noise signal to the line profiles. The reconstructions have been repeated for two signal to noise ratios, $s/n = 50$ and $s/n = 100$. The tomograms show noise ripple, but the quality of the reconstruction remains good. The model and reconstruction results are shown in Fig. 1, where the errors of reconstruction σ are given. In the case with $s/n = 50$, $\sigma = 8.8\%$ for 30 profiles and 17% for 10 profiles. A simple compact three dimensional model has been used to demonstrate computation of a 3-D Doppler tomogram. It includes two emission areas connected to the stars and two bright details with maxima at $V_z = -46$ km/s and V_z=46 km/s. A reconstruction of the tomogram has been carried out for an inclination $i = 45°$ on the basis of 120 lines profiles calculated at regularly spaced orbital phases. The error of reconstruction is σ=22%, but all details are reproduced. The 3D model and its reconstruction are shown in Fig. 2.

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References

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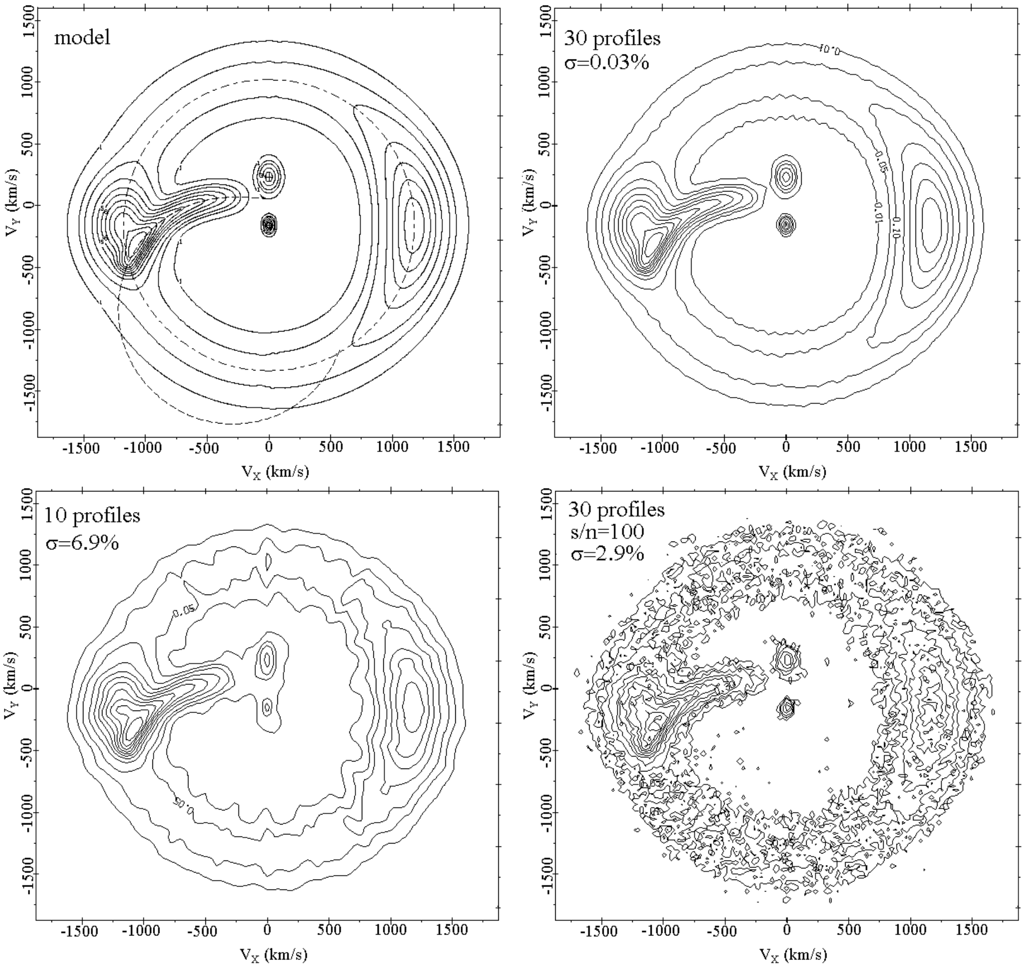

Figure 1. The 2D model with the ballistic trajectory (dashed line) and reconstructions

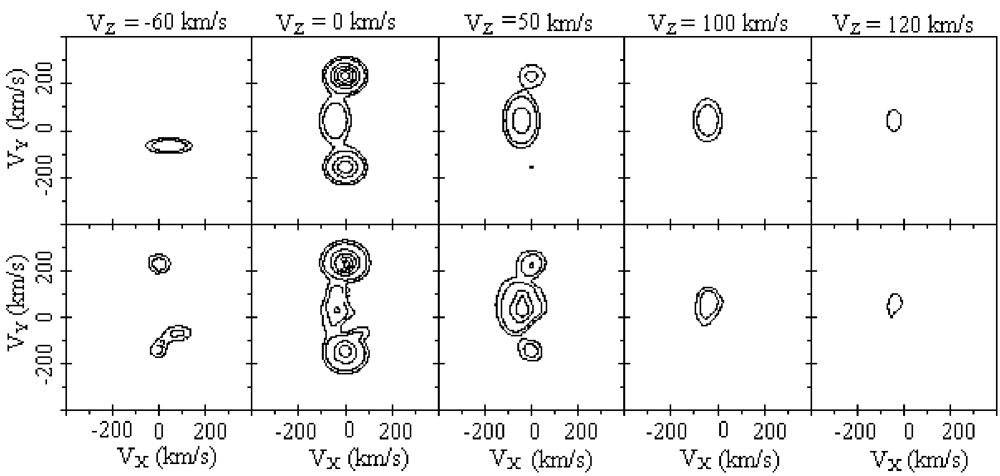

Figure 2. The 3D model (top) and reconstruction (bottom). The panels show slices of various constant out-of-plane velocities V_z

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