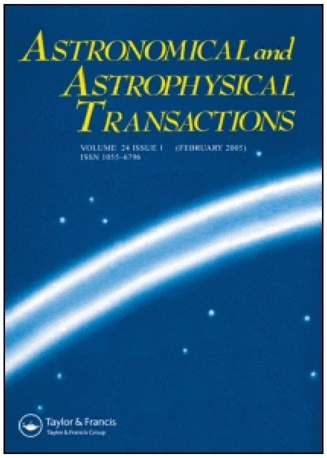

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Three-dimensional Doppler tomograms and detection of motions beyond the orbital plane in close binary systems

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Three-dimensional Doppler tomograms and detection of motions beyond the orbital plane in close binary systems

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The newly developed radioastronomical approach (RA) has been modified for the reconstruction of three-dimensional (3D) Doppler tomograms. The RA permits an unequal space distribution of the views of an object and a reduction in the number of required orbital phases when compared with the filtered back-projection technique. The 3D Doppler tomogram of the close binary system U Coronae Borealis was reconstructed on the basis of 47 spectra of the Hα line. The three strongest Hα emission features found on the map were the accretion annulus, the gas stream moving along the ballistic trajectory, and a high-intensity region moving at high velocity in a direction across the orbital plane. It was not possible to discover this latter feature using standard two-dimensional Doppler tomography. The new RA technique is a useful tool for the subsequent study of gas flows in close binary systems.

Keywords: Doppler tomography; Accretion; Close binary stars

Doppler tomography [1] is the data analysis technique that allows us to obtain indirect images of a variety of objects. This method has been used successfully in the study of binaries. The Doppler map of a binary contains valuable information about accretion structures that cannot be resolved spatially with the largest available telescopes. In this technique, a series of one-dimensional spectra at different orbital phases can be used to yield an emission intensity map in velocity space over the frequency of the observed emission line. Standard Doppler tomography maps only the V_x and V_y components and operates in two-dimensional (2D) velocity space. The procedure used to reconstruct the images is called the filtered back-projection (FBP) method. However, methods based on filtering either result in low spatial resolution or introduce strong distortions in the case of an unequally spaced distribution of the views around the orbit and when the number of projections is small. The directions of the views to the observer always lie on the surface of a cone in the case of rotating binaries; so the distribution of the views in three-dimensional (3D) space is obviously unequally spaced. Thus, the development of 3D Doppler tomography based on the FBP method is faced with fundamental difficulties.

The recently developed radioastronomical approach (RA) [2] has been modified for the reconstruction of 3D Doppler tomograms. The RA permits an unequal space distribution of

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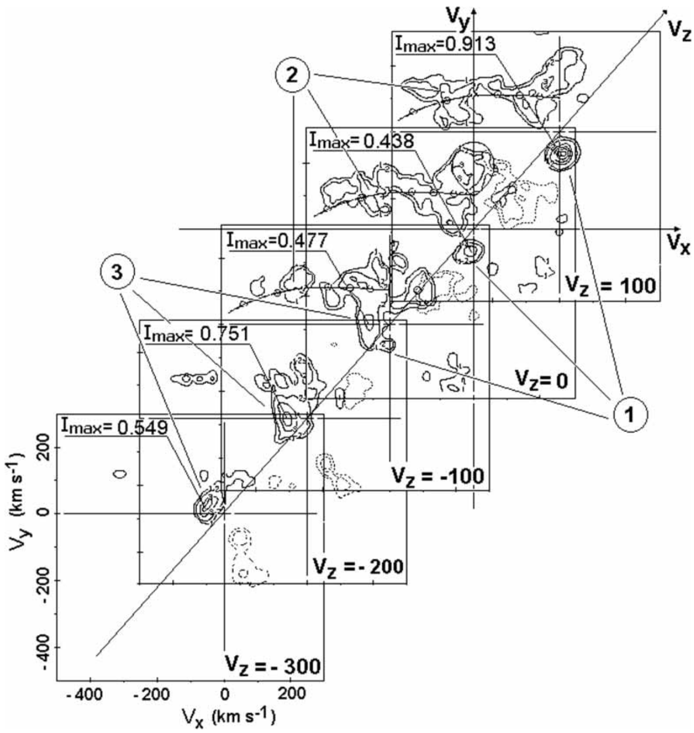

Figure 1. The most interesting five central slices of the 3D Doppler tomogram of U CrB.

the views of an object and a reduction in the number of required orbital phases when compared with the FBP technique. The 3D Doppler tomogram of the close binary system U Coronae Borealis was reconstructed on the basis of 47 spectra of the Hα line (figure 1). The resolution of the resulting distribution of the emission in velocity space (V_x, V_y, V_z) corresponds to velocities (30 km s^{-1}, 30 km s^{-1}, 110 km s^{-1}). The three strongest Hα emission features found on the map were the accretion annuli (labelled 1), the gas streams moving along the ballistic trajectory

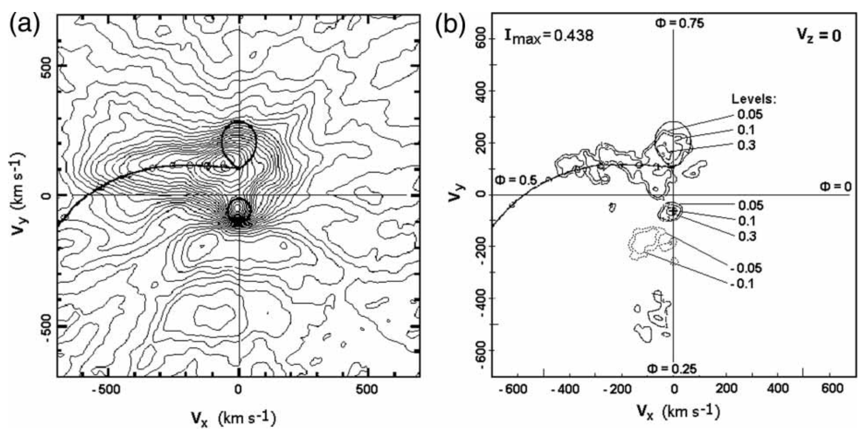

Figure 2. The comparison of (a) the 2D Doppler tomogram [3] and (b) the central slice of the reconstructed 3D Doppler tomogram corresponding to $V_z = 0\,\mathrm{km\,s^{-1}}$.

from the L1 point (labelled 2) and the high-intensity regions moving at a high velocity across the orbital plane (labelled 3). It was not possible to discover this high-velocity structure on the 2D Doppler map [3], which was obtained with the use of the standard Doppler tomography technique (figure 2).

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