Doppler Tomography in 2D and 3D of the X-ray Binary Cyg X-1 for June, 2007

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ABSTRACT. Two and Three-Dimensional Doppler Tomograms of X-ray binary V1357Cyg=Cyg X-1 were reconstructed on the basis of the spectral monitoring data **in He II 4686A** line at Peak Terskol Observatory (Russia) and Mexican National Astronomical Observatory..

Two and Three-Dimensional Doppler Tomograms of X-ray binary V1357Cyg=Cyg X-1 were reconstructed on the basis of the spectral monitoring data **in He II 4686A** line. The observation profiles were obtained in June 2007 at Peak Terskol Observatory (Russia) with the 2-m telescope and at Mexican National Astronomical Observatory with the 2.1-m telescope. Information **about the gas flows in the directions transverse to the orbital plane has been retrieved for the first time**. The three-dimensional version of Doppler tomography was realized due to the development of the **Radioastronomical Approach (RA)** [1,2] for tomographic reconstruction **in the case of Few Projections** (i.e., when the number of projections is limited).

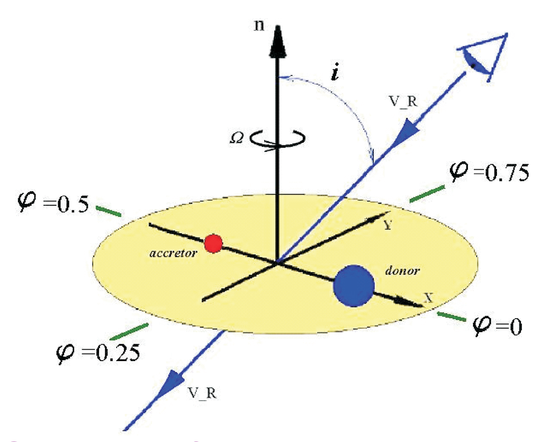

Fig.2. Geometry of binary system observation. It can help understand the process of spectra lines registration in dependence from the radial velocity V**R** that can have three velocity components (Vx, Vy, Vz).

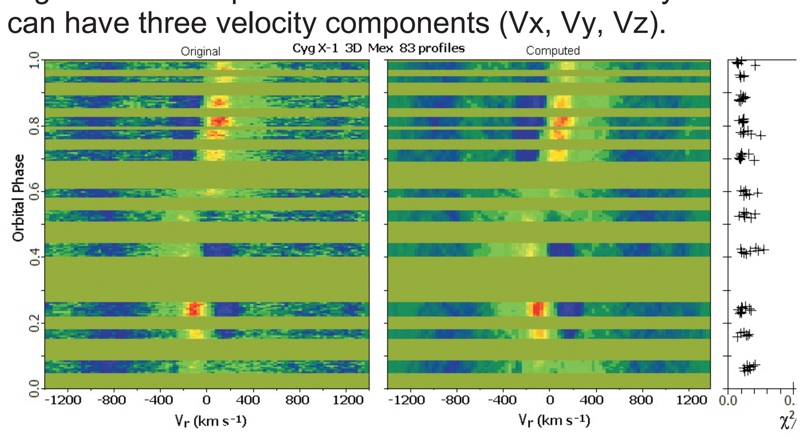

Fig.3. Comparison of two orbital phase sequences of He II 4686A **line profiles – the sequence with 83 observed line profiles (left frame) and the sequence of the ones computed on the base of the constructed 3D Doppler**

A direct comparison was made **between** the **observed** spectra and those **computed** from the constructed 3D Doppler tomogram (**see Fig.3**). **Chi-square statistics** shows a **good quality** of reconstruction.

Two-Dimensional standard Doppler tomograms for 2007 June are similar to the earlier reconstructed tomograms for 1997, 2003 and 2004 [3-4]. They show: **A**) the **emission component** of HeII 4686A line is generated mainly in the outer parts of the accretion structure closest to the donor star (O-supergiant) and out of optically thick accretion disk; **B**) the **absorption component** is the feature of O-supergiant atmosphere.

Three-Dimensional tomograms are reconstructed in 3D velocity space (Vx,Vy,Vz). Their structure shows that the formation of He II 4686A line profiles is also connected both with the **area of accretion structure** (**see Fig.4 and 6**) and with the **donor-star (superqiant).** However, some additional features have been discovered.

A. The first predominant feature is t**he emission component in** the 3D-tomogram located around the central (**Vz~0 km/s**) slice. This area consists **of individual feature components** with different Vz. But all these Vz values lie within the limits of -200 to +160 km/s. Here we can see a combination of three main emission feature components: 1) the **emission of the outer part of the accretion structure** nearby the donor-star; 2) the **elongated feature of the stream emerges** from the point L1 in velocity space; 3) the emission produced by the **stream – accretion structure interaction**.

B. The other predominant feature is visible in **absorption** and is associated with the **supergiant**. It is a **compact** structure. The maximum of absorption

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5. Bochkarev N.G., Karitskaya E.A. Adv.Space Res. 1988, v.8, No.2-3, p.(2)201-(2)203

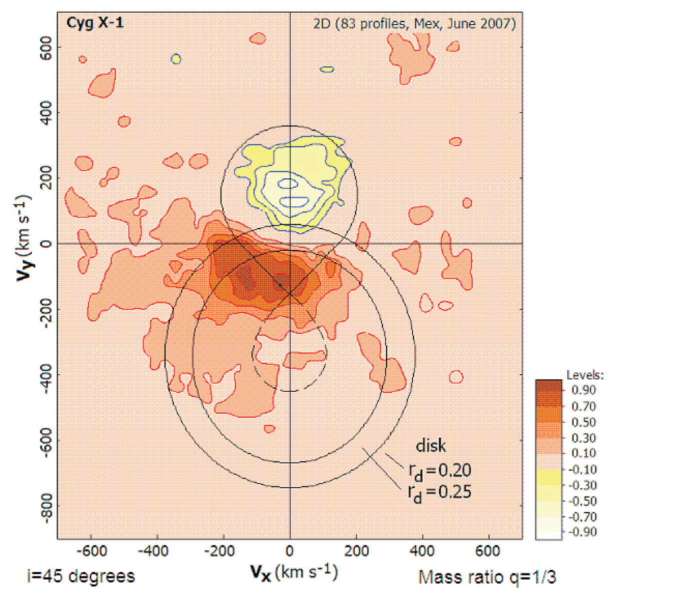

Fig.1. Two-Dimensional Doppler Tomogram of Cyg X-1 is constructed on the basis of 83 spectra line profiles (He II 4686A). These data are result of the spectral monitoring during June, 2007 at the Mexican National Astronomical Observatory with the 2.1-m telescope. The outlines of the Roche lobe of the donor star and the pattern of the outer parts of the accretion disk

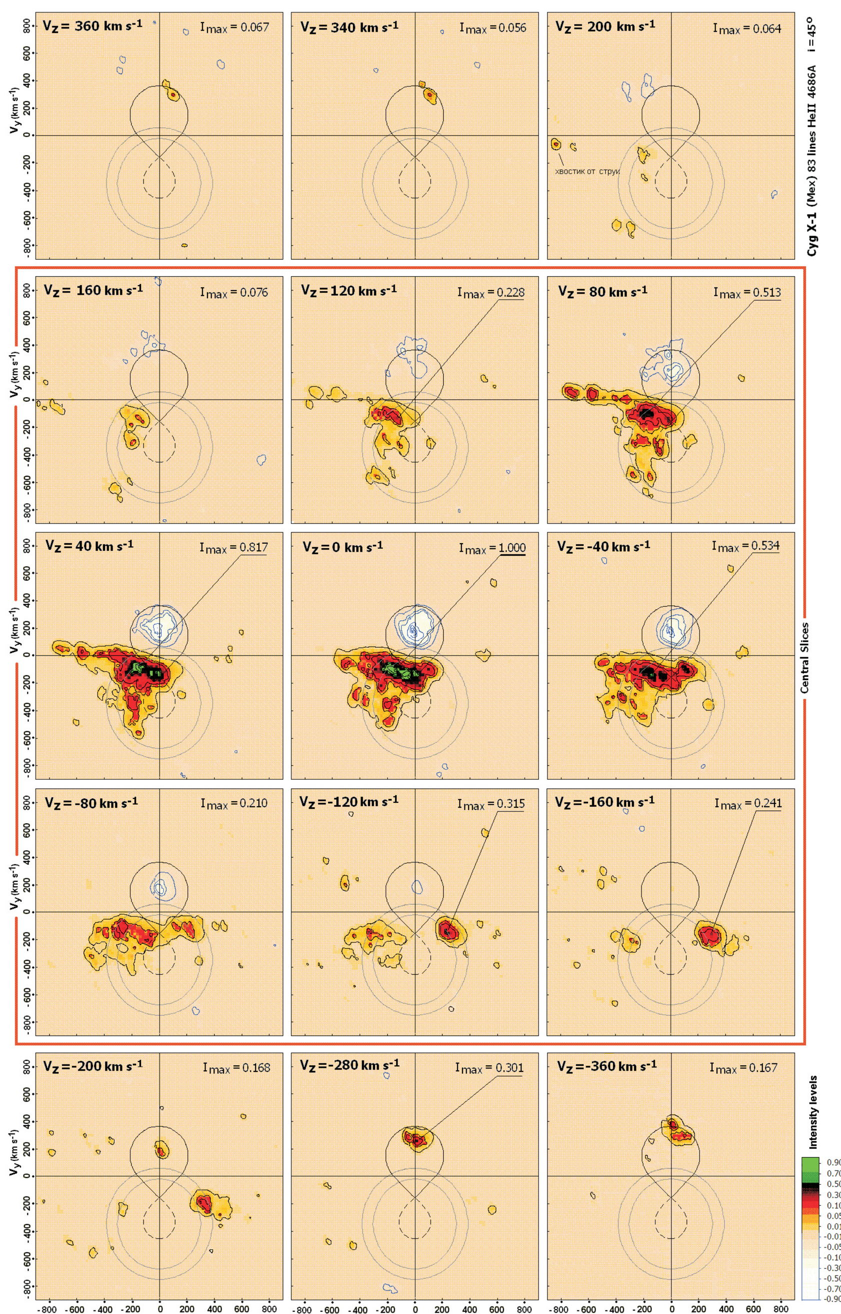

Fig.4. Fifteen (Vx,Vy) slices of Cyg X-1 3D Doppler tomogram for different Vz. The **resolution** along Vx,Vy,Vz axes is **50x50x50 km/s.** 83 He II 4686 A line profiles obtained at the Mexican National Astronomical Observatory in June, 2007 were used for this reconstruction. The features of the structure for the slice Vz=0 move parallel to the orbital plane of the system.

Nine central slices in Vz range -160 to +160 km/s with equal steps **are shown in the frame**. One can see in this slices: the **features with high intensity in emission**
(**1**. the **emission of the outer part of the accretion structure** located near the donor-star; **2**. the **elongated feature of the stream emerging** from the point L1 in velocity space; **3**. the emission due to **stream – accretion structure interaction)** and in **absorption** (the compact area of the **supergiant**).

The distant slices are on the upper and on the lower rows of the figure. An **interesting emission feature** also associated with the donor-star appears in the slices of the low row at Vz= -200, -280, -360 km/s. Its intensity is of about ~20-30% of the maximal intensity of 3D tomogram. That is probably a stream from the donor-star visible in emission flowing almost perpendicularly to the orbital plane (see also Fig.6). A similar symmetrical feature is also seen in the upper row. However, its intensity is weaker (~6-7%).

Fig.5. The comparison of the central slices of the 3D Doppler tomograms of Cyg X-1 based on the 2007 data. Two testing samples: 1) Ter and Mex slices; 2) Slices of Mex(45°) and Slices of Mex(40°).

Mex – 3D-tomogram based on 83 Mexican National Astronomical Observatory spectra lines.

Ter – 3D tomogram based on 51 Peak Terskol Observatory spectra lines.

Middle column - b. Only (Mex) slices. Five slices (Vx,Vy) in color together with the isolines of the 3D Doppler tomogram (Mex).

Left column - a. (Ter) and (Mex) slices. Five slices (Vx,Vy) in **isolines of 3D Doppler tomogram (Ter)** superimposing the **color slices of 3D Doppler tomogram (Mex)**. The comparison shows that the main features on the slices are similar. As a result, the features discovered in the 3D Doppler tomogram (Mex) are the main, more reliable, information source. That is because the 3D-tomogram (Mex) was constructed on the base of 83 spectra profiles that have more equidistant phase distribution across all the phases from 0 to 1.0 than the (Ter) observation distribution. Then, the number of (Mex) observation profiles (83) is larger than the 51 (Ter) spectra. The results of 3D-Doppler tomogram (Ter) are like a test that confirms the existence of the main features discovered in the central part of the 3D-tomogram.

Right column - c. The slices of the 3D-tomogram (Mex) in the **isolines for the inclination angle i=40°** are superimposed on the color slices **for the inclination angle of i=45°** of the 3D-tomogram (Mex). This test is very useful because it allows estimating the

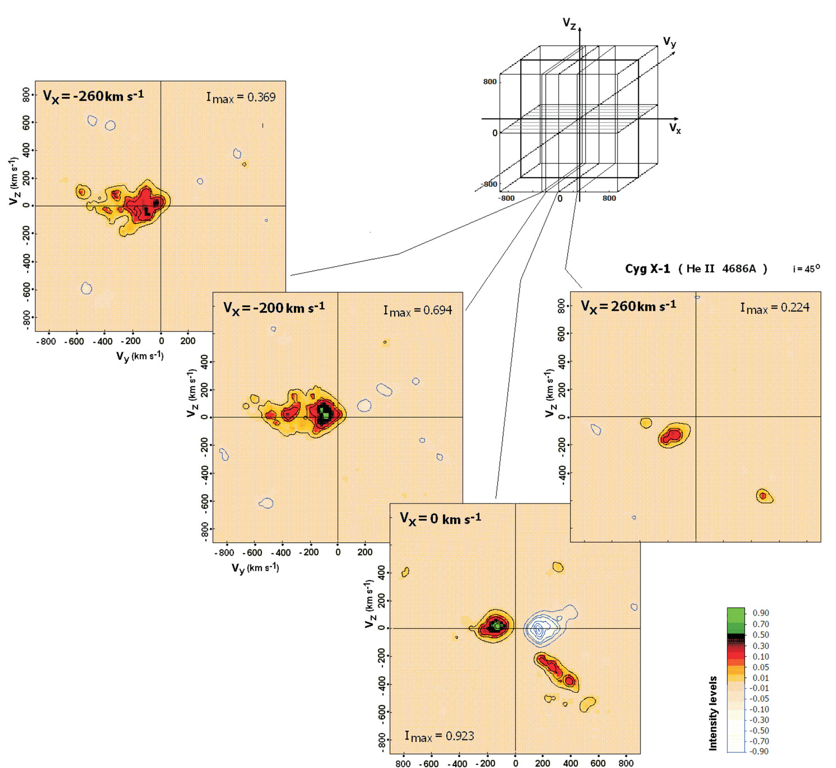

Fig.6. Cross-sections (Vy,Vz) of the 3D Doppler tomogram of the X-ray binary Cyg X-1. The slices for four values of Vx velocity component. The cube in the upper part of the Figure shows the geometry of the arrangement of the slices in 3D velocity space (Vx,Vy,Vz).

CONCLUSIONS:

1. The 3D Doppler tomograms of X-ray binary Cyg X-1 are constructed **for the first time.** The discovered features of the structure visible in He II (4686A) are identified.