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CRISS-CROSS MAPPING BD+30 3639: A NEW KINEMATIC ANALYSIS TECHNIQUE

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We introduce a new method to analyze proper motion data. The method is called "criss-cross" mapping. It emphasizes regions where proper motion vector extensions cross or converge. From a superposition of lines through the vectors, a map is generated which helps to interpret the kinematic data. The new mapping technique is applied to the young planetary nebula BD+30 3639. The data are approx. 200 internal proper motion measurements from Li, Harrington, & Borkowski (2002). From the criss-cross mapping of BD+30 3639, we conclude that the kinematic center is approximately 0.5 arcsec offset to the South-East from the central star. The mapping also shows evidence for a non-homologous expansion of the nebula that is consistent with a disturbance aligned with the bipolar molecular bullets.

We define the criss-cross mapping by the following procedure: replace proper motion vectors with a thin line that extends over the complete area covered by the nebula. Assign a finite constant brightness to every line. Generate an image by adding together all lines. The result is convolved with a suitable kernel like a gaussian with a width that is larger than the average separation between the vectors. In the regions where vectors converge the image will increase in brightness and reveal where most velocity vectors meet.

Our numerical scheme determines whether an image pixel (i, j) is on a line going through the vector indexed k. If so, then the weight value w_k is added to the pixel

$$I_{\mathrm{d}\ i,j} = \sum_{k=1}^{\mathrm{n}_k} w_k\ \delta(d_{i,j;\ k,s}) \qquad (1)$$

where i, j are the indices of the image pixels, k is the velocity vector index and the total number of velocity vectors is n_k. The distance of the image pixel i, j to the vector line k is $\mathrm{d}\, i, j$. In equation (1) $\delta(d)$ is a top-hat function with a value of 0 or 1. The total width of the top-hat function –which represents the line width– is s.

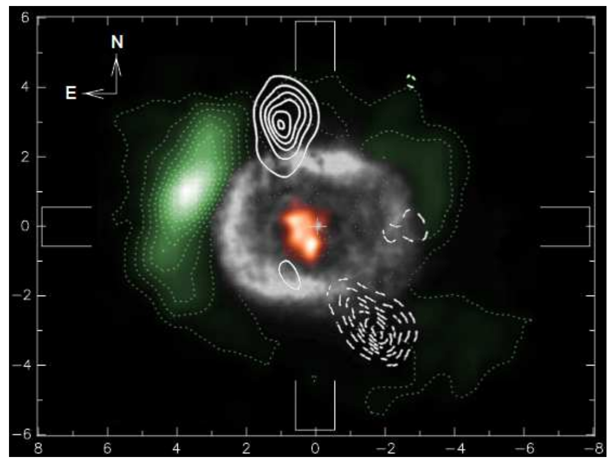

Fig. 1. Several types of maps have been combined: optical (grey, from LHB2002), H_2 (contoured green, from Shupe et al. 1998), CO (white contour, from Bachiller et al. 2000) and the criss-cross map (red, this work).

We have implemented the procedure in the morpho-kinematic 3D modeling software *Shape* (Steffen et al. 2011, freely available from `http://www.astrosen.unam.mx/shape`). It allows one to generate criss-cross maps from observations and models.

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