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Distance mapping technique and the 3-D structure of BD +30°3639

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Abstract. We present a new kinematic analysis technique called distance mapping. It uses the observed proper motion vectors and the 3-D velocity field to determine the distance for each vector. From this information we generate maps that can be use as a constraint to morpho-kinematic modeling with SHAPE. It is applied to BD +30°3639, using the internal proper motion measurements by Li *et al.* (2002). We determine its distance at 1.40 kpc ± 0.15 kpc.

Keywords. ISM: jets and outflows, ISM: kinematics and dynamics, methods: numerical, planetary nebula: individual (BD +30°3639)

1. Introduction

The distance parameter is a key problem in PNe research. Knowledge of the observed angular expansion rate and the true internal 3-D velocity field can yield a direct determination of the distance. This information can be derived from observations of internal proper motion and Doppler-shift of the gas, combined with a 3-D morpho-kinematic model. We used the software SHAPE (Steffen *et al.* 2011) to generate a suitable model based on optical images and PV diagrams as well as 178 internal proper motion measurements by Li *et al.* (2002).

2. SHAPE modeling

In order to reconstruct the 3-D structure and obtain the appropriate velocity field of BD +30°3639, we use the morpho-kinematic code SHAPE , optical images (Harrington

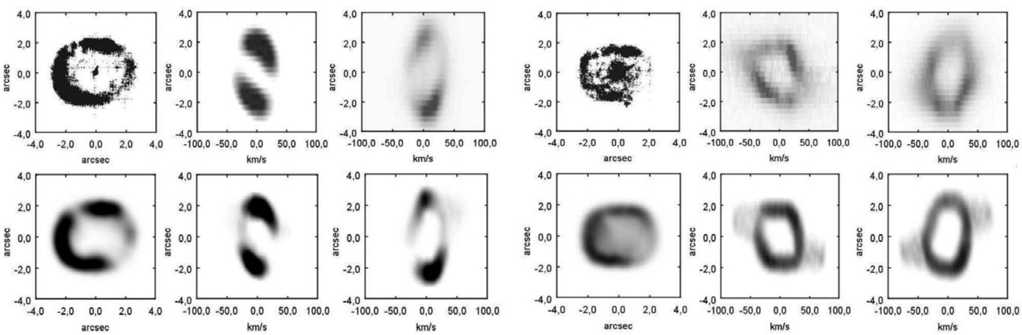

Figure 1. The observed (upper panels) and modeled (bottom panels) images and PV diagrams of [NII] (left) and [O III] (right) emission lines. The slit orientation of the PVs is vertical and horizontal for the middle and right, respectively.

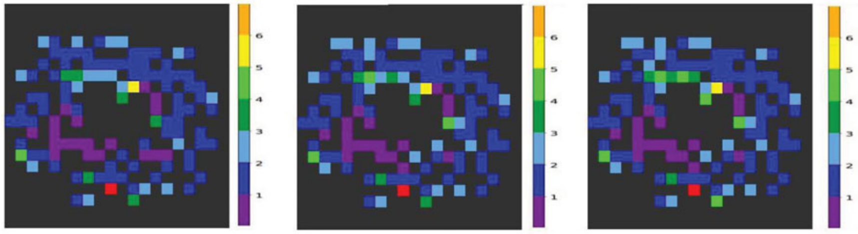

Figure 2. The distance maps from three models with the same homologous expansion law and different maximum cylindrical velocity (0 km/s (left), 30 km/s (middle) and 45 km/s (right)). The scale bars correspond to the ranges indicated in units of kpc.

et al. 1997) and PV diagrams (Bryce & Mellema 1999) for [N II] and [O III] shells. The observed and modeled images and the corresponding PV diagrams are presented in Figure 1.

3. Distance mapping technique

To determine the distance, we use our 3-D model velocity field and 178 internal proper motion measurements by Li *et al.* (2002). We divide the nebula's image in small boxes and calculate the distance and the standard deviation (SD) for each box separately, from the equation ($d = \frac{V_t}{d\theta/dt}$), where d is the distance in kpc, V_t is the modeled tangential velocity in km/s, and $d\theta/dt$ is the observed proper motion in mas/yrs.

From these data, we are able to construct the map of the resulting distance and its formal error. Since the distance for each box should be the same, the resulting distance map should result in a uniform value within the noise limits. Any systematic deviations hint towards deviations of the model velocity field from the true field. The distance map can thereby be used as a constraint for morpho-kinematic modeling. The top panels of Figure 2 display the distance maps from three models with the same homologous expansion field but different maximum cylindrical velocity (0, 30 and 45 km/s). The maximum cylindrical velocity of BD +30°3639 should be at 30 km/s.

4. Conclusions

1) The distance of BD +30°3639 was estimated at 1.40 ± 0.15 kpc for maximum cylindrical velocity component of 30 km/s. 2) If the cylindrical velocity component gets higher, the distance will be bigger. 3) If the size of boxes becomes bigger, the distance will be systematically higher and it has to be chosen carefully. 4) Distance mapping technique can be used as a constraint of the SHAPE model and reveals deviations from the true velocity field.

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