10th Hel.A.S Conference
Ioannina, 5-8 September, 2011
CONTRIBUTED POSTER

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

S. Akras[1] *and W. Steffen*[1,2]
[1]Instituto de Astronomia Universidad National Autónoma de Mexico, Ensenada, Mexico
[2]Institut für Computergraphik, Technische Universität Braunschweig, Germany

Abstract:

Images and high–resolution spectra from the literature are used in order to construct a 3–D model of BD +30 3639 using the morpho–kinematic code SHAPE. We find that two homologous expansion laws are needed for the [N II] and [O III] shell. A cylindrical velocity component is used to replicate the high–speed bipolar collimated outflows. We also present a new kinematic analysis technique called "distance mapping". It uses the observed proper motion vectors and the 3–D velocity field to generate maps that can be used as a constraint to the morpho–kinematic modeling with SHAPE as well as improve the accuracy for distance determination. It is applied to BD+30 3639 using 178 internal proper motion vectors from Li et al. ([?]) and our 3–D velocity field to determine a distance of 1.52 ± 0.21 kpc. Finally, we find evidence for an interaction between the eastern part of nebula and the ambient H_2 molecular gas.

1 Introduction

The fraction of spherical and non–spherical PNe in our Galaxy has been found at 19% and 81%, respectively ([?],[?]). Spatially resolved spectroscopic observations have revealed that the seemingly spherically symmetric PNe can show more complex structures along the line of sight. An example is the Ring Nebula ([?]) or BD +30 3639 ([?]). Therefore, finding the orientation of PNe poses a crucial problem to recognize the true 3–D structure ([?]). The morphology of PNe is likely to be related to the presence of magnetic fields or binary central stars. It is therefore, necessary to study the complete 3–D structure and velocity field in as many PNe as possible in order to understand the formation processes.

Knowledge of the 3–D structure and velocity field of PNe can also yield a significant improvement in accuracy of distance determination, which still poses a key problem in PNe research. The lack of a reliable general method to determine the distance of PNe still remains a great problem. Although, many attempts have been made to evaluate the distance of PNe using several methods like the trigonometric parallax, expansion parallax and statistical, their results are often discrepant.

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. The software SHAPE ([?]) is used to generate a suitable model of BD +30 3639 based on optical images and PV diagrams as well as 178 internal proper motion measurements by Li et al. ([?]).

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 ([?]) and PV diagrams ([?]) for [N II] and [O III] lines. The observed and modeled images and the corresponding PV diagrams are presented in figures 1 & 2. The [O III] shell reveals bright wings with expansion velocities up to 80 km s^{-1} in both directions, whereas the main nebula expands with 35–40 km s^{-1}. The [N II] shell expands with

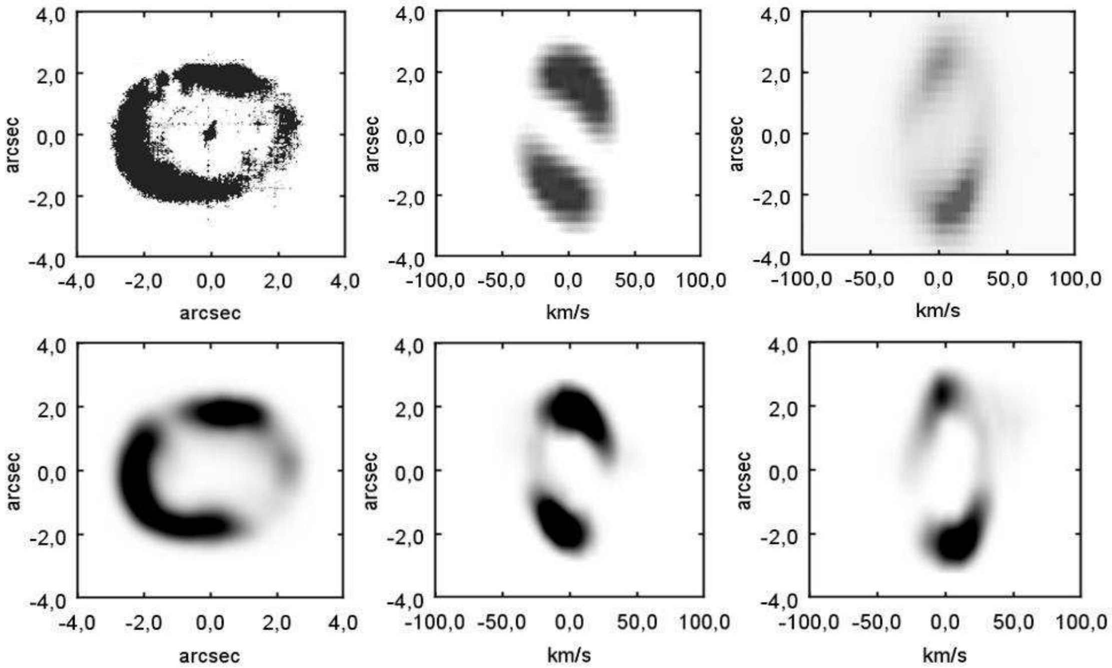

Figure 1: The observed (upper panels) and modeled (bottom panels) images and PV diagrams of [NII] emission line. The slit orientation of the PVs is vertical and horizontal for the middle and right panel, respectively.

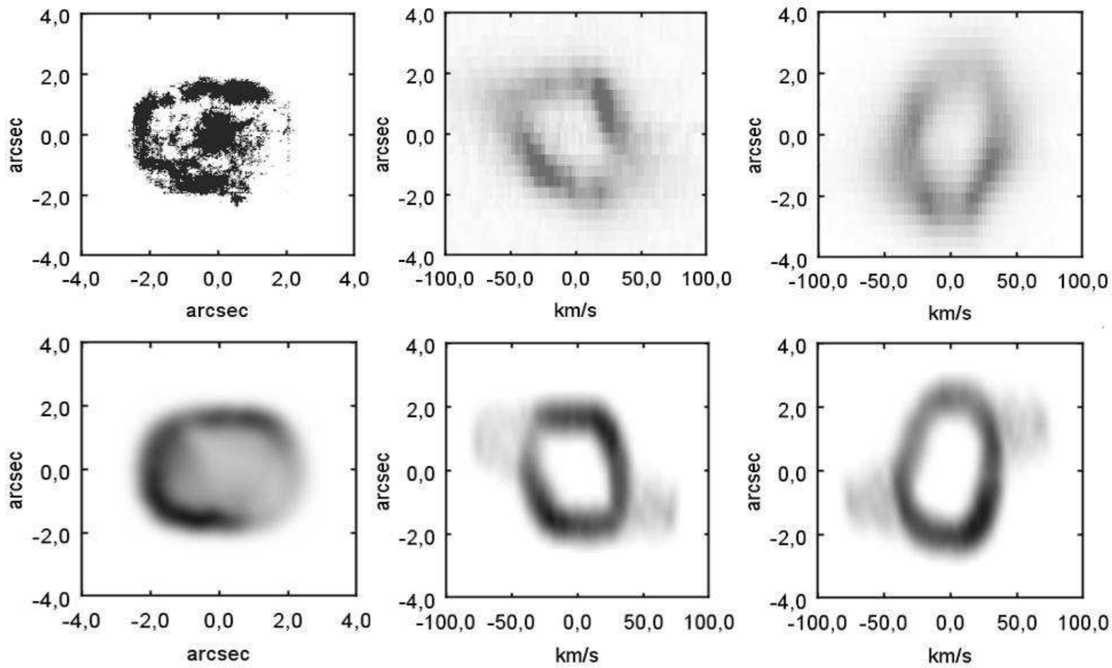

Figure 2: The observed (upper panels) and modeled (bottom panels) images and PV diagrams of [O III] emission line. The slit orientation of the PVs is vertical and horizontal for the middle and right panel, respectively.

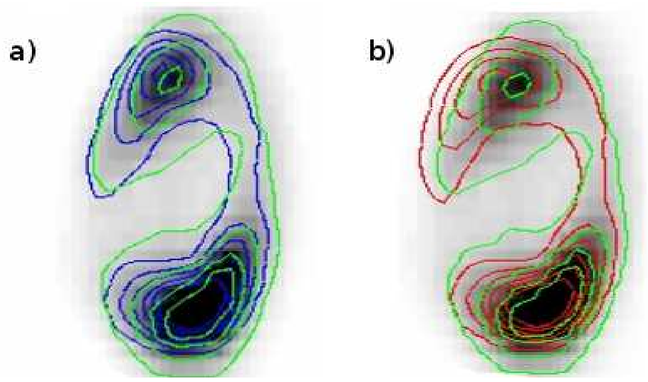

Figure 3: The observed PV diagram of [N II] with the contours of modeled PV diagram with the velocity of the western region being 20 km s^{-1} less (a) and without (b). (See the electronic version for a color version of these images).

velocities of 25–30 km s^{-1}. The simultaneous reconstruction of the [N II] and [O III] PV diagrams was therefore not possible with one homologous velocity law for both. Thus, two velocity laws are used (V=28 r/r_o km s^{-1} for the [N II] line and V=40 r/r_o km s^{-1} for the [O III] line, where r is the distance from the central star and r_o is the radius of the [N II] shell).

We note that the [N II] PV diagram reveals a noticeably asymmetric velocity ellipse (fig. 1, right panels) which is hardly seen in [O III]. The western bright section shows lower expansion velocities than the eastern counterpart. We find that the model improves considerably when the velocity of the western region is reduced by 20 km s^{-1}. This asymmetry might have been caused by the interaction of the western region of the nebula with the H_2 molecular gas around it. The H_2 emission overlaps with the western part of the nebula, suggesting that it might decelerate the expansion of the nebula in this direction. In fig. 6, we present the contour maps of modeled [N II] PV diagrams with the velocity of the western region being 20 km s^{-1} less (6a; blue contours) and without (6b; red contours) overlay of the observed PV diagrams (green contours).

3 Distance mapping technique

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 more precise and direct determination of the distance. This information can be derived from observations of internal proper motion using high quality data combined with a 3–D morpho-kinematic model.

We use our 3–D velocity field and 178 internal proper motion measurements by Li et al. ([**?**]). 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 ($d = 211\frac{V_t}{d\theta/dt}$), 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.

We, finally, evaluate the distance of BD +30 at 1.58±0.21 kpc. However, from previous distance determinations, we point out that the distance of BD +30 is clearly less than 3.00 kpc and therefore, distance values higher than 3.00 kpc can be exluded from the calculation of the final value. Distance values higher than 3.00 kpc might have been resulted by individual inaccurate proper motion measurements. The final value of distance is re-calculated at 1.52±0.21 kpc consistent with previous studies ([**?**]).

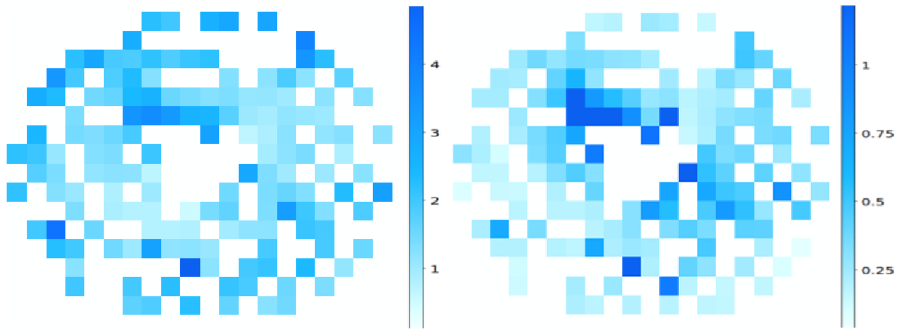

Figure 4: The distance map (left) and the error map (right) of BD +30 3639. The scale bars correspond to the ranges indicated in units of kpc.

4 Conclusions

We obtained a 3–D morpho–kinematic model that includes the main morphological and kinematical characteristics reproducing the 2–D images and the PV diagrams. We found that two homologous velocity laws are necessary to model the whole structure of BD +30 (V=28 r/r_o km s^{-1} for the [N II] line and V=40 r/r_o km s^{-1} for the [O III] line). We concluded therefore that the internal velocity field of BD +30 is a decreasing function of the distance from the central star over the range of the [O III] and [N II] shells. The inclination and position angle were found to be 22±4 degrees for the [N II] and the [O III] shell, respectively, with the respect to the line of sight. We also found that the [N II] velocity ellipse in the west–east slit direction is non-symmetric in velocity and displays low expansion at the western region, probably due to the interaction of main nebula with the ambient H_2 molecular gas.

A new kinematic analysis technique called "distance mapping" was developed based on the 3–D velocity field and internal proper motion measurements. We concluded that if the size of boxes becomes bigger, the distance will be systematically higher and it has to be chosen carefully. Furthermore, distance mapping technique can be used as a constraint of the SHAPE model and reveals deviations from the true velocity field. The final distance of BD +30 was found at 1.52±0.21 kpc in agreement with previous studies.

Acknowledgements: This work has been supported by grant from UNAM PAPIIT IN 100410. S. A. acknowledges a postdoctoral scholarship from UNAM-DGAPA.

References

[1] Balick B., Frank A., 2002, ARA&A, 40, 439

[2] Bryce, M. & Mellema, G., 1999, MNRAS, 309, 371

[3] Bryce M., Balick B., Meaburn J., 1994, MNRAS, 266, 721

[4] Harrington, J. P., Lame, N. J., White, S. M., & Borkowski K. J., 1997, AJ, 113, 2147

[5] Kawamura J., Masson C. R., 1996, ApJ, 461, 282

[6] Li, J., Harrington, J. P. & Borkowski, K. J., 2002, ApJ, 123, 2676

[7] Miszalski B., Parker Q. A., Acker A., Birkby J. L., Frew D. J., Kovacevic A., 2008, MNRAS, 383, 525

[8] Parker, Q. A., et al. 2006, MNRAS, 373, 79

[9] Steffen, W., Koning, N., Wenger, S., Morisset, C. & Magnor, M., 2011, Transactions of Computer Graphics and Visualization, 17, 454