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Morpho-kinematic modeling of planetary nebulae with *SHAPE*

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Abstract. We present a powerful new tool to disentangle the 3-D geometry and kinematic structure of gaseous nebulae. The method consists of combining commercially available digital animation software to simulate the 3-D structure and expansion pattern of the nebula with a dedicated, purpose built rendering software and graphical user interface that produce the final images and long slit spectra which are compared to the real data.

Keywords. stars: winds, outflows, planetary nebulae: general, methods: miscellaneous

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1. SHAPE

In recent years, the discovery of a variety of complex structures in planetary nebulae that markedly depart from rotational symmetry, such as the presence of collimated outflows, poly-polar and point-symmetric structures and rings has opened many questions regarding the origin and evolution of these objects. The correct interpretation of their 3-D geometry and kinematic structure is key to the understanding of the dynamics ruling their evolution.

The projected image on the sky of an extended nebula provides bidimensional spatial information of its structure. On the other hand, the velocity field provides information regarding the radial component of the velocity vector along the line of sight and thus conveys limited but useful information on its third spatial dimension. However, given that the location of a volume element of the nebula is related to the integral of its velocity, a knowledge of the full 3-D structure requires knowledge of the velocity history of that element. The simplest case occurs if the velocity is constant over most of the expansion time. In this case the velocity becomes proportional to the distance from the center (a "hubble-law"). Under these conditions, the shape of the nebula along the line of sight is mapped directly into the long-slit spectrum to within a fixed scaling factor such that the long-slit spectrum allows a view of the nebula from a direction perpendicular to the line of sight. If the object has a significant degree of symmetry, the full 3D-structure and kinematics can be deduced. Even if a simple "hubble-law" expansion is not present, the kinematics as observed in long-slit spectra may provide enough information about the 3D-structure and topology of an object such that the modeling with *Shape* provides a good approximation to the true 3-D structure. In this paper we present a new 3-D modeling tool called *Shape* that combines the ability of commercial modeling software with a purpose-built rendering module for application in astrophysical research.

Recently, photo-realistic 3D-graphics has generated a new way of producing feature films and computer games. Most of this work is based on computationally efficient mathematical representations of the complex visual world. However, these general purpose 3D-graphics modeling codes do not produce a physical description of the world and do not provide spectral information from the kinematics of the model. We have therefore

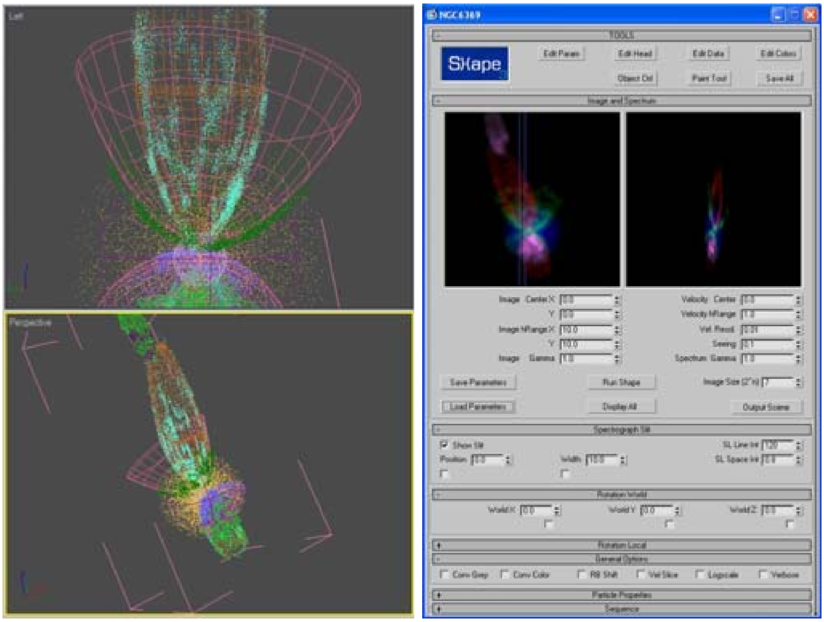

Figure 1. Screen-shot of the 3D modeling of a complex planetary nebula in *3D Studio Max* [left]. The graphical interface of *Shape* with the rendered model image and P-V diagram of NGC 6302 on the left and right, respectively.

developed the rending code *Shape* which produces the images and long-slit spectra using the information from such a modeling code. A special interface has been programmed to control *Shape* from within the modeling software. This interface allows the display of the images and spectra as well as to specify the rendering parameters such as the orientation of the object with respect to the line of sight, spectral slit position and width, seeing values, spectral resolution, colors and others.

As our 3D-modeling software we use *Autodesk 3DS Max 7*. We apply any available tools of the software to create a particle and velocity distribution in space and time in order to model an object. In particular we use the *ParticleFlow* particle system to generate particle distributions which are then exported and rendered in *Shape*. Note that the code does not perform any physical radiation transport or line emission calculation based on the physical conditions in space. What it does is to directly assign a relative emissivity distribution.

For examples of applications of *Shape* to various planetary nebulae see Steffen & López (2006) and references therein. Figure 1 shows a 3D model for the planetary nebula NGC 6302 (Meaburn *et al.* 2006), were the number density of particles follows the brightness of a complex system of surfaces. The user interface of *Shape* with an image and P-V diagram is also shown.

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References

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