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MORPHO-KINEMATIC MODELING OF PLANETARY NEBULAE

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RESUMEN

Presentamos una nueva herramienta para desenredar la geometría 3-D y la estructura cinemática de nebulosas gaseosas. El método consiste en combinar software comercial para animación digital para simular la estructura 3-D y el modo de expansión de la nebulosa junto con un software de representación gráfica de imagenes y perfiles de línea diseñado especialmente para el propósito.

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 that produces the final images and long slit spectra which are compared to the real data.

Key Words: **ISM: MODELING**

1. INTRODUCTION

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 2-D geometry of these objects on the sky are usually complex, as are the shape of their spatially resolved emission line profiles but together they provide the key to the 3-D nebular structure.

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 depth or 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. This type of velocity distribution can be expected if the nebula has evolved from its origin as a consequence of a momentum driven expansion (e.g. Steffen & López, 2004, and references therein). In this case, after a sufficiently long time, the velocity becomes proportional to the distance from the center (a "hubble-law") and the expansion of the nebula is said to be self-similar, i.e. the global shape is conserved over time.

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 and this has the advantage that the long-slit spectrum allows a view of the nebula from a direction perpendicular to the line of sight. If the object shows evidence for 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 often provides enough information about the 3D-structure and topology of an object and the modeling with *Shape* can provide 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.

2. *SHAPE*

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 visual world. The modeling with these techniques is mathematically very efficient and a high degree of complexity can be achieved. 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 developed the

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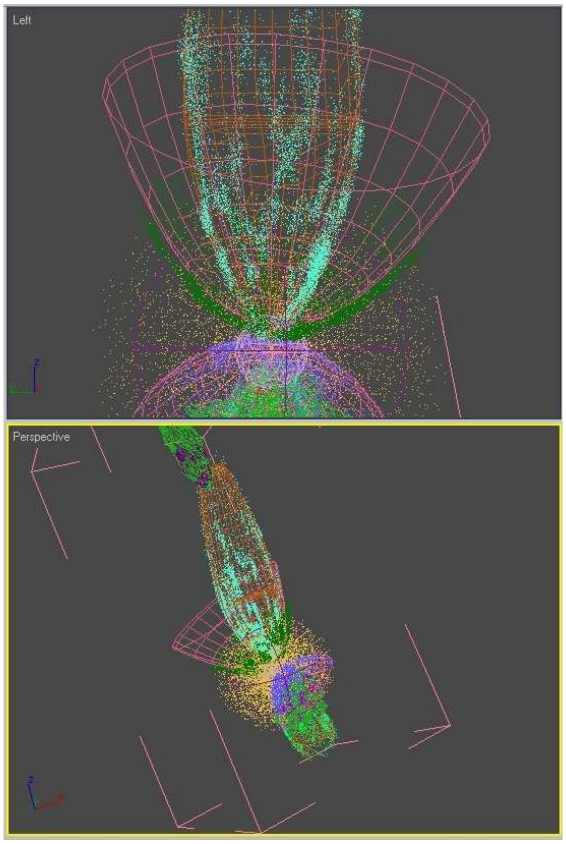

Fig. 1. Screen-shot of the 3D modeling of a complex planetary nebula in *3D Studio Max*.

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* (see the website *www.discreet.com* for detailed software information). 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.

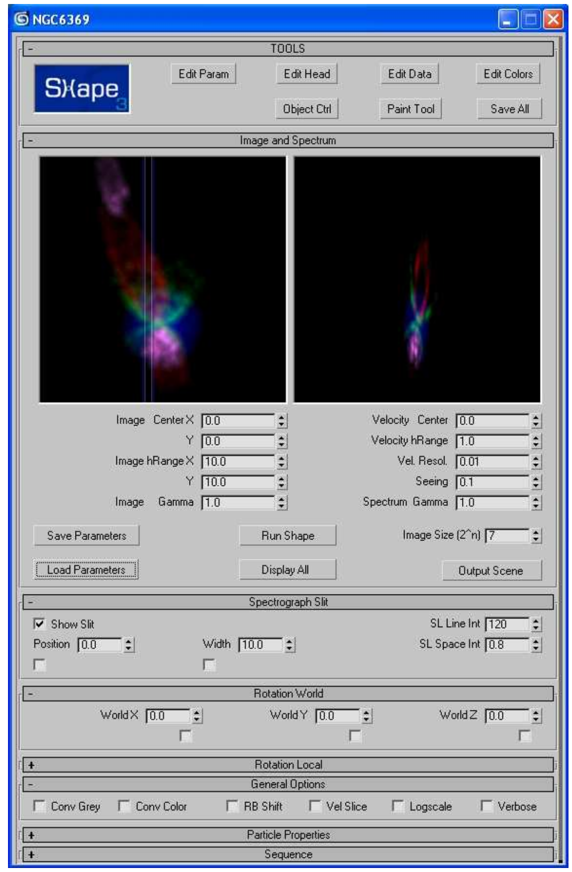

Fig. 2. Screen-shot of the graphical interface of *Shape* with a model image and P-V diagram of NGC 6369 on the left and right, respectively.

For examples of applications of *Shape* to various planetary nebulae see Steffen & López (2006) and references therein. Figure 1 shows a screen-shot of a 3D model for the planetary nebula NGC 6369 (Meaburn et al. 2006), were the number density of particles follows the brightness of a complex system of surfaces. Figure 2 shows the interface of *Shape* with an image and P-V diagram resulting from the 3D model of Figure 1.

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