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A Cat's Eye view of the Eskimo from Saturn

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Abstract. The 3-D and kinematic structure of the Eskimo nebula, NGC 2392, has been notoriously difficult to interpret given its complex morphology, multiple kinematic components and its nearly pole-on orientation along the line of sight. Here we present the most comprehensive high resolution spectroscopic mapping of the Eskimo planetary nebula to date. The data consist of 21 spatially resolved, long-slit echelle spectra tightly spaced over the Eskimo and along its bipolar jets. This data set allowed us to construct a velocity-resolved [NII] channel map of the nebula with a resolution of 10 km/s that disentagles the differente kinematic components of the nebula and reveals clearly for the first time the kinematic expansion pattern for each of the components. The spectroscopic information is combined with a HST image to construct the first detailed three dimensional model of the Eskimo with the code SHAPE. With this model we demostrate that the Eskimo is nearly a twin to the Saturn nebula, but rotated 90^{o} to the line sight. Furthermore, we show that the main characteristics of our model apply to the general properties of the group of elliptical planetary nebulae with ansae, once the orientation is considered.

Keywords. planetary nebulae: individual (NGC 2392, NGC 7009, NGC 6543), ISM: kinematics and dynamics, techniques: spectroscopy

1. Introduction

NGC 2392 (Eskimo nebula, PN G197.8+17.3) is a spectacular planetary nebula (PN), which presents a complex morphology: bright inner bubble, low-ionization cometary knots and FLIERS, spherical outer shell and bipolar flows. In an attempt to explain the morphology and kinematic of the Eskimo nebula, several authors have used direct image, slit spectra, velocity cube data and models. O'Dell *et al.* (1990) used kinematic data to modeled the structure of Eskimo, they found that the central ellipsoid represents the proyection of a prolate structure with the long axis oriented along the line of the sight.

In this work, we present a comprehensive set of spatially resolved, high spectral resolution, long-slit spectra to investigate in detail the kinematics of NGC 2392, as well as the model 3D of NGC 2392 which was made using the code SHAPE.

2. Observations and Data Analysis

Long-slit echelle spectroscopic observations of the Eskimo planetary nebula were obtained at the Observatorio Astronómico Nacional at San Pedro Mártir, (SPM), México, on 2002, January 7–10 (21 pointings). These observations were taken using the Manchester Echelle Spectrometer (MES-SPM) on the 2.1 m telescope in a $f/7.5$ configuration. We reduced the data using standard task of IRAF. All spectra presented in this work are corrected for heliocentric velocity. To distangle the different components of the nebula, we construct a three-dimensional velocity cube of the nebula from the optical emission line [N II] 6584 Å.

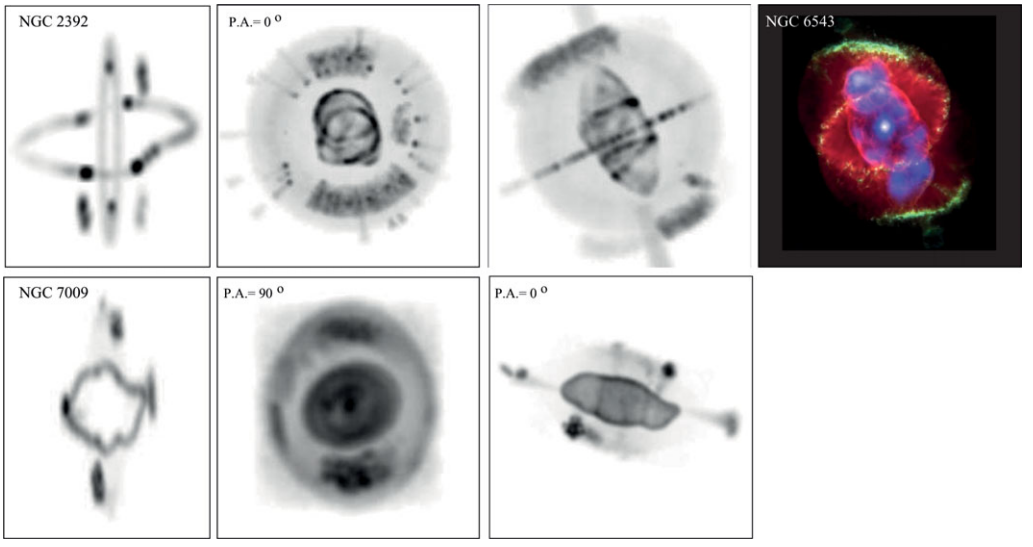

Figure 1. *Upper panels, from left*: the synthetic line profile for the central slit j. *Next*, the Eskimo image, as seen on the sky, derived from the model. *Next*: the previous image rotated 90º, note here the similarity with the Saturn nebula and the Cat's Eye nebula, shown on the last panel. *Lower panels*: the central panel is the image from the SHAPE model of the Saturn nebula (Steffen *et al.* 2009) as it would be seen pole-on. *To the left* is the synthetic line profile from a slit located at the center of the pole-on view. The last image to the right shows the model image of the Saturn image as seen on the sky

3. 3-D Model and Conclusion

Taking the observed PV arrays and an image from the HST we were able to contruct a 3-D model from the Eskimo using the code *SHAPE* (Steffen and López, 2006). SHAPE is a morpho-kinematic modeling tool that allows the user to reconstruct the 3D structure and observed spectral line profiles using several expanding geometrical forms, a velocity field and a brightness distribution to each mesh structure. The resultant 2-D image and spectral information are then rendered from the 3-D model and compared with the real data. Figure 1 shows a comparison of the Eskimo model, the Saturn model (Steffen *et al.* 2009) and Cat's Eye nebula. The objects shown here have a similar morphology structure and in the case of the Eskimo and Saturn also similar kinematic behavior.

The 3-D model presented here for the Eskimo is able to replicate all its main components in kinematic and morphological terms. It is also shown to apply well in general terms to the common characteristics of the group of elliptical PNe with FLIERS. Full details of this work will be published soon.

References

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