Scientists produce a 3D morpho-kinematical model of the planetary nebula NGC 2440

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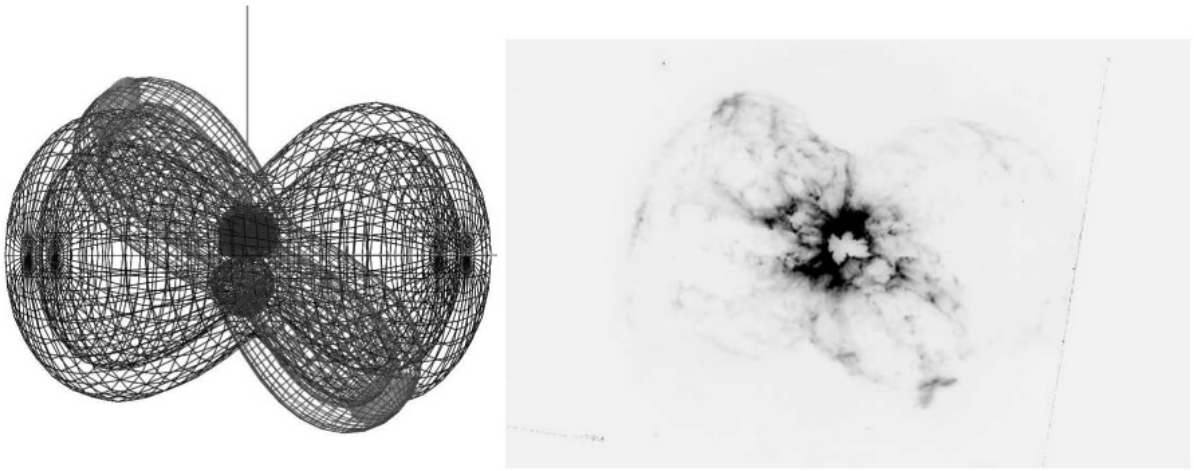

Mesh model to NGC 2440 built with SHAPE (left) and reference HST image (right). Credit: Paulo Lago/Roberto Costa, 2016.

(Phys.org)—Astronomers from the Institute of Astronomy, Geophysics and Atmospheric Sciences (IAG) in Brazil have developed a 3D model of the planetary nebula NGC 2440, describing the kinematics and morphology of this interesting object. The model, introduced in a paper published on June 3 on the arXiv pre-print server, could shed new light on the origins and formation processes of planetary nebulae.

Discovered by William Herschel in 1790, NGC 2440 is one of the most well-known planetary nebulae in our Milky Way galaxy. The object is located in the Puppis constellation and its central star, designated HD 62166, is possibly the hottest known white dwarf to date.

While studying NGC 2440, Paulo Lago and Roberto Costa of IAG, were particularly interested in the nebula's core. The central region has drawn attention of the astronomers due to its complexity and a wealth of microstructures.

In order to create a model that would showcase the nebula's complicated structure, the scientists used high-resolution spectra and position-velocity diagrams of NGC 2440. The high angular resolution images required for modeling purposes were selected from the Hubble Space Telescope's (HST) Wide Field Planetary Camera (WFPC2), available in different filters.

The astronomers utilized the SHAPE software to construct the 3D model. This tool allows researchers to reconstruct the 3D structure of a planetary nebula in great detail, taking into account projection effects, using high angular resolution images such as those from the HST, and high resolution spectra. SHAPE is capable of building a mesh model inside a 3D environment in order to analyze the morphology and kinematics of planetary nebulae.

"SHAPE modeling requires a mesh model and a set of physical parameters such as velocity fields and density distributions derived from the observational data. In general, the larger is the database, the better is the model due to the increase in the number of independent constraints," the researchers noted in the paper.

According to the newly developed 3D model, NGC 2440 is a multi-polar nebula with at least two bipolar components. The larger structure has a

position angle of 85 degrees, while the smaller one has a position angle of 35 degrees; thus, they are tilted 50 degrees apart. These findings suggest the presence of a toroidal structure surrounding the core of the planetary nebula.

"This torus is inside the inner bipolar structure at position angle of 35 degrees, however, it is very hard to distinguish such a feature in the high angular resolution images from HST due to filaments and 'secondary' morphological structures," the paper reads.

Moreover, based on the observational data and the 3D model, the scientists found that a toroidal structure not only exists but is also strongly interacting with the environment or the radiation field.

NGC 2440 was found to showcase a molecular emission of carbon monoxide, particularly in the bipolar component, with a position angle of 35 degrees. According to the research, the presence of fast carbon monoxide components in the core region points to the destruction of a neutral and dense torus by the out flow at the moment of the lobes formation.

"From our models and the observational data, we conclude that a segmented toroidal structure is a good description for the inner part of NGC 2440. The model based upon this hypothesis provides a good reproduction of the observed position-velocity diagrams, therefore it can be said that a torus, segmented at least in three parts, is in good agreement with the observational data. This result agrees with that of Wang et al. (2008), who detect a molecular outflow in NGC 2440, aligned with the optical bipolar lobes," the astronomers concluded.

The authors of the paper also managed to derive the distance to NGC 2440. According to their estimates, this nebula is located about 5,900 light years from the Earth. Previous calculations indicated a 4,000-light-

year distance.

More information: NGC 2440 : A morpho-kinematical model, arXiv:1606.01234 [astro-ph.SR] arxiv.org/abs/1606.01234

Abstract

This work describes the modelling of the 3D structure and position-velocity (P-V) diagrams of NGC 2440, a well known planetary nebula, aiming to describe the morphology of this object, specially its core. We have used high resolution spectra and P-V diagrams to reproduce the 3D structure of the nebula using SHAPE, a software that allows 3D modelling. HST high angular resolution images were used as reference to the model.

The observational data point to a segmented core, and the simulations confirm this assumption; the best model for the nebula is a torus segmented in three pieces. The simulated P-V diagrams agree with the observations. We suggest that the torus was torn apart by interaction with the surrounding medium, either as winds or the radiation field.

For the two bipolar lobes, orientation angles to the plane of the sky of 27±5 and −5±3 degrees, respectively for the bipolar components with PA of 85 and 35 degrees, were derived. No additional bipolar lobes were required to model the observed features of NGC 2440. A distance of 1.8±0.5 kpc was derived for the nebula using our velocity field for the toroidal structure. These results are the first derived for NGC 2440 from modelling in a 3D environment.