Modeling the Evolution of the Point-Symmetric Planetary Nebula IC 4634 Using a Three-Dimensional Morpho-Kinematic Model

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IC 4634 is a planetary nebula with a striking double-S shape, whose curved arcs and distant knots preserve a record of its outflow history. This study presents the first 3D morpho-kinematic reconstruction of IC 4634 that resolves its structure into multiple distinct ejection events over time. Using a Hubble [N II] image, seven position-velocity (PV) diagrams, and SHAPE modeling, the geometry and velocity structure of the nebula are mapped. PV diagrams simulated from the 3D model are used to verify that it accurately reproduces the observed kinematics of the nebula. The reconstruction reveals multiple partial arcs embedded within the S-shaped structure, along with a distant string of knots, each formed during separate ejection episodes. Velocity measurements show that the inner arcs expand faster than the outer arcs and knots, establishing a clear sequence of outflows. Bow-shock-like features trace regions where faster material collided with previously ejected gas. The structure reflects repeated, time-variable outflows that shaped the nebula over time. The independent motion of the equatorial component further supports the presence of a binary central star driving this process. This work provides the first 3D reconstruction that directly links IC 4634's observed structure to its evolutionary history, offering new insight into how complex planetary nebulae form beyond standard interacting stellar wind models.

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