Collin Dabbieri

Assignment 16

2. Observations and Analysis

Planetary nebulae were randomly selected and images were obtained with HST in H-alpha and [OIII]. For each object VLT spectra were also obtained. Of the 36 bulge planetary nebulae observed, 21 had a central structure with a clear extension, and of those 21, only 6 had classic bipolar lobes. These 6 objects were the only ones with both axial- and point- symmetry, which reduces the computational time of the simulation. Those 6 objects were analyzed along with 2 additional objects which showed a post-bipolar lobe phase.

Due to seeing, the spectra were able to probe the central arc second of each structure, meaning the velocities near the center are observable, but the velocities in the extended regions are unknown. The model does both kinematic and photoionization calculations. The photoionization part of the code computes a series of 1-D cloudy models for different radial directions. Eight separate angles were used, where the angle and the slab start radius for each run were determined by the results of the previous run. Axial- and point- symmetry is utilized to project results from one quadrant onto other quadrants and missing locations in the 3-D grid of the calculated quadrant are determined through interpolation. The calculated structure was projected onto the night sky to return a model image, or what the model says we would have observed. This can be compared with the actual observed image.

To simplify the model, velocities were restricted to only point radially with respect to the central star. The magnitude of the velocity depends linearly on the radial distance of the star. Trial and error convinced the authors to also add an inner region with constant velocity, whose radius can be determined by the model. The observed lines indicate higher velocities in outer regions, corresponding to lower ionization, so the model was also restricted to increase linearly with increasing radius outside of the constant velocity region.

The dense torus dominates line emission. Therefore if the symmetry axis is in the plane of the sky, most of the material will be moving either toward or away from the observer, resulting in an emission profile that is clearly split. However, if the torus lies in the plane of the sky, most of the material will be moving perpendicular to the observer, causing the line to narrow and the split to disappear. One can use the observed line profile then to determine the inclination angle. The authors claim to be able to do this to within an uncertainty of roughly 10 degrees.