Luminosity Functions of Planetary Nebulae

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Planetary nebulae have recently been shown to be useful as standard candles (Ciardullo et al. 1989, ApJ, 339, 53; Jacoby 1989, ApJ, 339, 39). Distances to many galaxies have been determined by fitting a planetary nebula luminosity function (PNLF) to observations of the OIII 5007Å line of PNe. Here, the effect of the core mass distribution on the determination of the luminosity function is investigated and a technique for interpolating between model evolutionary tracks is discussed.

Four Schoenberner tracks with central star masses of 0.565, 0.6, 0.644 and 0.835 $M_\odot$ are used to generate normalized curves of luminosity versus time and effective temperature versus time. The normalized functions are found to be remarkably similar, giving us confidence that more evolutionary tracks can be derived by interpolation. Each track consists of 16 grid points in each of the time, luminosity and temperature coordinates, and values between successive points are obtained by linear interpolation. Seven tracks were generated using this method for the following core masses: 0.6, 0.62, 0.63, 0.64, 0.65, 0.66 and 0.68 $M_\odot$.

The nebular expansion is modeled by the momentum conserving equation of the interacting stellar winds model using the following parameters: v=2000 km/s, $\dot{m} = 10^{-8}$ $M_\odot$/yr, V = 10 km/s and a filling factor of 0.6 for all of the tracks. The slow wind mass loss rate is assumed to increase with core mass. The OIII luminosity is calculated at each time interval using the CLOUDY photoionization code. The resulting time evolution of the OIII flux, for each central star mass, is used to generate the PNLF. The OIII flux is given at 100 points between 0 and 40,000 years, and is monitored at shorter intervals near the peak. The flux between successive data points is determined by linear interpolation.

To generate the luminosity function, 100,000 nebulae are selected randomly in age from 0 to 40,000 years, with a core mass chosen according to one of the following distributions:

a. Gaussian core mass distribution: PNLF were generated using gaussian distributions with mean masses of 0.60, 0.61, 0.62, and 0.63 $M_\odot$ and a standard deviation of 0.02 $M_\odot$.

b. Initial-Final mass distribution: Points are selected randomly in initial mass from 1.25 to 9 $M_\odot$, subject to the initial mass function. The final mass is calculated using the initial-final mass relationship of Bryan et al. (1990, ApJ, 365, 301).

The PNLFs generated are compared with the observed M31 data (Ciardullo et al. 1989). While the PNLFs based on the gaussian core mass distribution are similar to those obtained by Jacoby (1989), those generated with realistic initial mass–final mass relationship predict an excess of bright PNe unless there is an upper core mass cutoff of 0.7 $M_\odot$. The possible relationship between the upper core mass limit and the Hubble type and metallicity of the galaxy remains to be investigated.

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