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Age Distribution of AGB Stars and Central Stars of Planetary Nebulae

W. J. Maciel, R. D. D. Costa, and T. E. P. Idiart

Astronomy Department, University of São Paulo, Brazil

Abstract. We discuss three methods to estimate the age distribution of central stars of planetary nebulae (CSPN) and their progenitor stars. These methods include the use of an age–metallicity relation that also depends on the galactocentric distance, an age–metallicity relation for the Galactic disk, and the determination of ages from the central star masses obtained from the observed nitrogen abundances. We conclude that most CSPN in the Galactic disk have ages under 6 Gyr, and their age distribution is peaked around 2–4 Gyr. These results have been successfully compared with the age distributions of white dwarf stars based on their mass distribution, and on available mass determinations of CSPN.

1. Introduction

AGB stars and planetary nebulae (PN) are the offspring of intermediate-mass stars with main-sequence masses between 0.8 and 8 $M_\odot$, approximately. As a consequence, their properties reflect different physical conditions depending on the stellar masses, and therefore ages, which makes these objects extremely important in the study of the chemical evolution of the Galaxy. In this work, we discuss three methods to estimate the ages of the PN progenitor stars, based both on the observed nebular properties and on some properties of the stars themselves. For details see Maciel, Costa, & Idiart (2010).

2. Age Determination of CSPN and AGB Stars

The first method, or Method 1, was developed by Maciel, Costa, & Uchida (2003). Using the oxygen abundance measured in the nebula, a relation between the metallicity [Fe/H] and the oxygen abundance, and the age–metallicity–galactocentric distance relation by Edvardsson et al. (1993), the stellar ages can be estimated. This method was applied to a sample of 234 well-observed disk PN and the results show that the age distribution has a prominent peak, located around 4–5 Gyr, similar to the age of the Sun, suggesting that most PN come from stars having masses close to one solar mass on the main sequence.

Method 2 is based on the age–metallicity relation for the Galactic disk derived by Rocha-Pinto et al. (2000) from chromospheric ages and accurate metallicities. From this relation the stellar lifetimes can be determined once the metallicity is fixed. We can apply the same procedure as in the previous method, and obtain [Fe/H] from the oxygen abundance. The derived age distribution is flatter than in the previous method, but most stars have ages under 6 Gyr in both cases.

Method 3 was also employed by Maciel et al. (2003) and assumes a relationship between the central star mass and the N/O abundance. In order to obtain the stellar mass on the main sequence, we adopted a simple initial mass–final mass relation as in Maciel et al. (2003). Simple mass–age relations have also been adopted (case A), as well as the well known mass–age relation by Bahcall & Piran (1983) (case B). The results for a sample of 122 PN are similar to the age–metalllicity–radius method, in that most objects have ages lower than about 6 Gyr, and there is a sharp maximum in the probability distribution. However, its location depends on the lifetimes as a function of the main-sequence mass, being around 3–7 Gyr for Case A and 1–4 Gyr for Case B.

3. Discussion

Assuming that the star formation rate in the Galaxy has remained approximately constant, the age distribution of the CSPN can be estimated from the mass distribution of their progenitor stars. The AGB phase is of short duration (cf. van Winckel, these proceedings), so that the expected age distribution of CSPN and AGB stars can be obtained by analyzing the mass distribution of the white dwarf stars, most of which are essentially CSPN which have already entered the cooling track. In a first approximation, the mass distribution of the CSPN and AGB stars must be similar to that of the white dwarfs, except for the very low mass stars which are not expected to form PN, as the corresponding stars probably go directly to the white dwarf phase. Using a recent mass distribution of white dwarfs by Madej, Należyty, & Althaus (2004), we obtain a distribution strongly peaked at 0.56 $M_\odot$. From empirical determinations of the CSPN masses by Gesicki & Zijlstra (2007) and adopting the same hypotheses as before, we find that the CSPN and white dwarf distributions peak around 0.6 $M_\odot$, although the white dwarf distribution shows a broader mass range. The derived CSPN age distributions have peaks at approximately 4–6 Gyr (Case A) and 2–4 Gyr (Case B). At face value, the age distributions of Method 3 are very similar to the results obtained from the probability distributions, especially if Case B is considered, as seems more appropriate. This is also in agreement with the conclusion by Groenewegen & Blommaert (2005) that bulge Miras have masses in the range of 1.5–2.0 $M_\odot$, with maximum ages of about 3 Gyr for most objects. Although the estimated uncertainty of Method 3 is larger, it is reassuring that the average distribution shows such remarkable agreement with the expected age distribution of CSPN.

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