3 kpc of the Sun. These methods include the determination of the age distribution of CSPN using (i) an age-metallicity relation that also depends on the Galactocentric distance, (ii) an age-metallicity relation obtained for the disk, and (iii) the central star masses obtained from the observed nitrogen abundances. We concluded that most CSPN in our sample have ages under 6 Gyr, and that the age distribution is peaked around 2–4 Gyr. The average uncertainties were estimated as 1–2 Gyr, and the results were compared with the expected distribution based both on the observed mass distribution of white dwarfs and on the age distribution derived from available masses of CSPN.

In the present work we develop two additional and more accurate methods to estimate the age distribution of the CSPN based on their kinematical properties, namely: (i) a method based on the expected rotation velocities of the nebulae at their Galactocentric distances, which are then compared with the predicted values for a given rotation curve, the differences being attributed to the different ages of the evolved stars; (ii) a method based on the derived U, V, W, velocity components of the stars and their corresponding dispersions. In both cases, the age-velocity dispersion relations from the Geneva-Copenhagen survey are used to infer the age distribution. These methods are applied to two PN samples, (i) the previous sample of disk PN used by Maciel et al. (2010), for which a detailed data set is available, and (ii) a sample containing all PN for which accurate radial velocities are known. The methods are developed in § 2, and the samples used are described in § 3. The main results and discussion are given in § 4.

2. DETERMINATION OF THE AGE DISTRIBUTION OF CSPN

2.1. *Method 1: The PN rotation velocity*

As objects of intermediate age, PN in the disk of the Galaxy describe a rotation curve similar to the one defined by younger objects, such as HII regions, although with a higher dispersion, as discussed in detail by Maciel & Lago (2005). Therefore, the discrepancies between the rotation velocities inferred from the PN radial velocities and distances and the velocities expected from the known rotation curve may be at least partially ascribed to their evolved status. In other words, a given nebula located at a distance d, with galactic coordinates ℓ and b and observed heliocentric radial velocity V_r(hel) can be associated with a rotation velocity $\theta(R)$, after obtaining its Galactocentric distance R and its radial velocity relative to the Local Standard of Rest (LSR), V_r(LSR). Assuming circular orbits, the rotation velocity $\theta(R)$ at the Galactocentric distance R can be written as

$$\theta(R) = \frac{R}{R_o}\left[\frac{V_r(\mathrm{LSR})}{\sin\ell\,\cos b} + \theta_0\right], \qquad (1)$$

where R_0 and θ_0 are the Galactocentric distance and rotation velocity at the solar position (see for example Maciel & Lago 2005; Maciel & Dutra 1992). On the other hand, the expected rotation velocity at the given Galactocentric distance, $\theta_c(R)$, can be obtained from an adopted rotation curve. The difference $\Delta\theta = |\theta(R) - \theta_c(R)|$ can then be considered as proportional to the age difference between the PN and the objects defining the rotation curve. We have adopted the radial velocities from the catalogue by Durand, Acker, & Zijlstra (1998), and two distance scales, those by Maciel (1984) and Stanghellini, Shaw, & Villaver (2008). The first one was based on a relationship between the ionized mass and the radius of the nebulae, while the second is an update of the distance scale by Cahn, Kaler, & Stanghellini (1992), using a modified Shklovksy method following Daub (1982). Since the distances of planetary nebulae in the Galaxy may contain large individual uncertainties, the use of two different scales which are considered as "short" (Maciel 1984) and "long" (Stanghellini et al. 2008) ensures that these uncertainties will not affect the derived age distributions. We have adopted $R_0 = 8.0$ kpc for the distance of the Sun to the centre and $\theta_0 = 220$ km s^{-1} for the rotation velocity at R_0. Slightly different values can be found in the literature (see for example Perryman 2009, and Reid 2010), but the values above are frequently adopted, so that a comparison with other work is made easier. For the "theoretical" rotation curve we have also adopted two possibilities, namely, the PN curve derived by Maciel & Lago (2005), and the HII region curve derived by Clemens (1985). In the first case, the rotation velocity can be written as

$$\theta_c(R) = a_0 + a_1\,R + a_2\,R^2\,, \qquad (2)$$

where the constants are $a_0 = 269.2549$, $a_1 = -14.7321$, and $a_2 = 0.7847$, the Galactocentric distance R is given in kpc and $\theta_c(R)$ in km s^{-1}. For the CO/HII region based Clemens (1985) curve, we have made an adjustment for $R_0 = 8.0$ kpc and $\theta_0(R) = 220$ km s^{-1}, in which case we have

$$\theta_c(R) = \sum a_i\,R^i\,, \qquad (3)$$

where the constants are given in Table 1, with the same units as in equation (2).