
The distance to the Planetary Nebula M 2-43

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Summary. We obtain the distance to the Planetary Nebula (PN) M2-43 using the angular expansion technique. Using high quality radio continuum observations in two epochs at 3.6 cm with the Very Large Array toward the planetary nebula M2-43. The time separation between the two epochs was 4.07 years. The comparison of the two epochs clearly shows the expansion of the planetary nebula with an angular rate of 0.61 ± 0.09 mas year⁻¹. Assuming that the expansion velocity in the plane of the sky and the expansion velocity along the line of sight are equal, we find a distance to the planetary nebula of 6.9 ± 1.5 kpc. Once we have the distance we can derive the physical parameters of the nebula, such as the ionized mass, electronic density, the emission measure and the kinematic age.

Key words: ISM–planetary nebulae: individual (M 2-43)–stars: distances–techniques: interferometric

1 Introduction

We present an angular expansion study of the PN M 2-43. This technique measures the angular expansion parallax of a PN, from two epochs of radio interferometric data obtained over a period of a few years. The measurement of the angular expansion parallax of a PN, provides an accurate method to estimate their distances [12]. Masson was the first to use this technique to measure the distance to NGC 7027 using interferometric data taken with only 2.8 years between the observations.

This technique has been applied with success in several PNe, [12], [13], [14], [5], [7], [8], [9], [6], [4]. In the next table we show a summary of all these contributions. The angular expansion technique has also been used for Hubble Space Telescope WFPC2 data in several PNe [17], [15].

We made an angular expansion study of the PN M 2-43, using Very Large Array (VLA) data taken at 3.6 cm with a time baseline of 4.07 years. Our goal was to detect for the first time this expansion and use it to obtain an accurate distance estimate to this PN. The planetary nebula M 2-43 (=PN G027.6+04.2) has been detected at radio wavelengths, showing a compact size with a diameter of 1''5 for its major axis and ellipsoidal morphology [2], [10]. >From the literature we find that the

Table 1. Distances to PNe using this technique

Name	θ (mas/yr)	D (kpc)	Reference
BD+303639	1.69 +/- 1.30	2.80 +/- 3	Masson (1989)
BD+303639	1.73 +/- 0.51	2.68 +/- 0.81	Hajian et al. (1993)
NGC 3242	13.2 +/- 4.7	0.42 +/- 0.16	Hajian et al. (1995)
NGC 6302	1.7 +/- 0.3	1.60 +/- 0.6	Gómez et al. (1993)
NGC 6210	3.10 +/- 0.42	1.57 +/- 0.40	Hajian et al. (1995)
NGC 6572	2.51 +/- 0.76	1.49 +/- 0.62	Hajian et al. (1995)
NGC 7027	4.7 +/- 7	0.94 +/- 0.2	Masson (1986)
NGC 7662	5.6 +/- 5	0.79 +/- 0.75	Hajian y Terzian (1996)
VY 2-2	1.13 +/- 0.12	3.60 +/- 0.4	Christiano y Seaquist (1998)
M 2-43	0.61 +/- 0.09	6.9 +/- 1.5	Guzmán et al. (2006)

expansion velocities for M 2-43 measured with different ions are in the range from 26 to 30 km s⁻¹ [1], [16]. Acker et al. (2002) found spectral evidence for turbulent velocities in [WC]-type PNe superimposed on a constant expansion velocity pattern. The modelling made by Acker et al. (2002) toward M 2-43, taking into account the turbulence, gives an expansion velocity of 20 km s⁻¹ with a turbulent component of 10 km s⁻¹. We also find that M 2-43 has a high radial velocity value (with respect to the local standard of rest) of $+111.6 \pm 5$ km s⁻¹ [18]. Previous estimates of the distance to M 2-43 have been made using statistical methods and range from 1.4 kpc [3] to 5 kpc [1]. An accurate distance value for M 2-43 is very important for a better estimate of the physical parameters and evolutionary stage of the PN.

2 Observations

We made observations toward M 2-43 with the VLA of the NRAO¹ at 3.6 cm in the A configuration. The observations were made in 1995 August 24 (epoch 1995.65) and 1999 September 19 (epoch 1999.72), the time interval between observations was of 4.07 years with an angular resolution of $\sim 0''.3$ with natural weighting. The data was reduced using the standard VLA procedures and then cross-calibrated in phase and amplitude using the procedure of Masson (1986; 1989). In Figure 1 we show a panel of the individual images for each epoch including the difference image that clearly shows the signature of expansion with the outer parts of the source appearing as positive and the inner parts of the source appearing as negative and the model. The details of this work can be seen in Guzmán et al. 2006.

3 Results

We modeled the difference map (Fig.1:bottom-left) following Gómez, Rodríguez, & Moran (1993). A first image was made concatenating the two epoch data sets and

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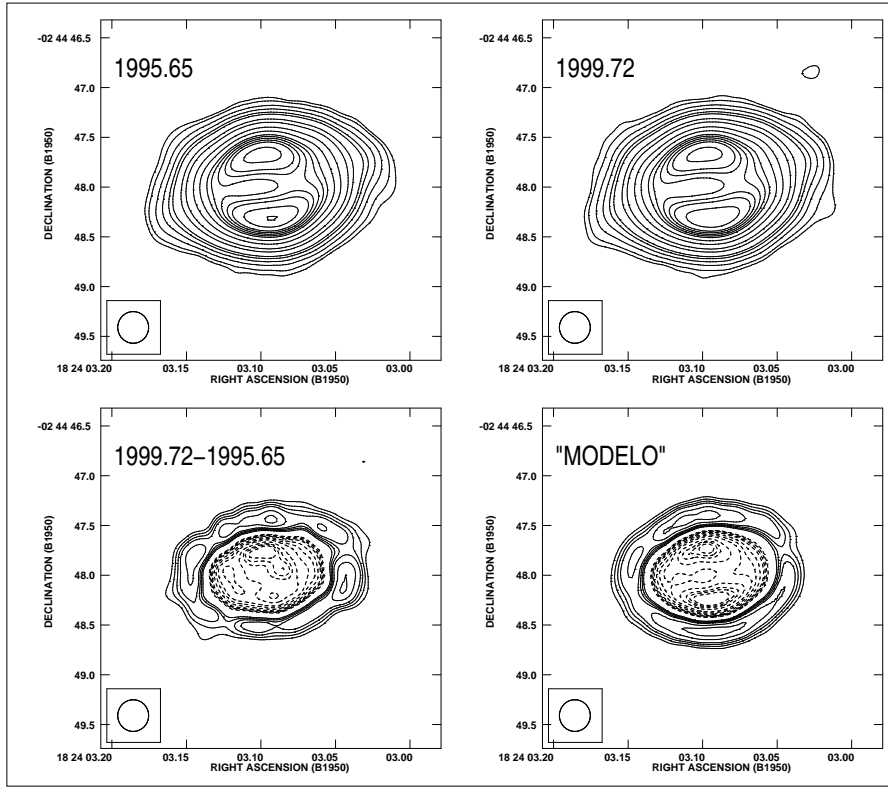


Fig. 1. Top: contour images of the 3.6 cm continuum emission from M 2-43 for 1995.65 (left) and 1999.72 (right). The contours are -4, 4, 8, 20, 40, 70, 100, 200, 300, 500, 700, 900, 1000, 1100, 1200, 1300, 1500, and 1700 times $15 \mu\text{Jy}$, the average rms noise of the images. Bottom: contour images of the 3.6 cm difference image (left) and of the “model” (right) obtained as described in the text. The contours are -19, -18, -17, -15, -12, -10, -8, -6, -5, -4, -3, 3, 4, 5, 6, 8, 10, 12, 15, and 17 times $22 \mu\text{Jy}$, the rms noise of the difference image. The restoring beam ($0''.32 \times 0''.31$ with a position angle of 0°) is shown in the bottom left corner of each image.

the second image was made taking the first image and expanding it in a self-similar way by a factor of $(1 + \epsilon)$, where $\epsilon \ll 1$. The first image was then subtracted from the second one for different values of ϵ to produce a set of “model” images. The best agreement with the difference image was obtained for $\epsilon = 0.0075 \pm 0.0008$ (see Fig.1:bottom-right). The radius of maximum emission, θ , is estimated to be $0''.33 \pm 0''.03$ from the images of the full free-free emission (top part of Fig. 1). The angular expansion rate of this radius of maximum emission is:

$$\dot{\theta} = \frac{\theta \epsilon}{\Delta t},$$

and from our measurements we find $\dot{\theta} = 0.61 \pm 0.09 \text{ mas yr}^{-1}$. The distance to the planetary nebula will then be given by,

$$\left[\frac{D}{pc}\right] = 211 \left[\frac{v_{exp}}{km\ s^{-1}}\right] \left[\frac{\dot{\theta}}{mas\ yr^{-1}}\right]^{-1},$$

where v_{exp} is the expansion velocity of the nebula at the point of maximum emission. Then adopting the modelling made by Acker et al. (2002) for the expansion velocity of $20 \pm 3\ km\ s^{-1}$ for M 2-43 in combination with our angular expansion rate we estimate a distance of $6.9 \pm 1.5\ kpc$. Using the fact that we have the radial LSR velocity for M 2-43 is $+111.6 \pm 5\ km\ s^{-1}$ [18] and knowing that the dispersion velocity deviation with respect to their respective local standard of rest is around $40\ km\ s^{-1}$ for PNe [11], we can plot this velocity as a function of the distance to the Sun (see Fig. 2). The kinematic distance obtained in Fig. 2 and the angular expansion distance are consistent with the distance of $6.9 \pm 1.5\ kpc$ for M 2-43.

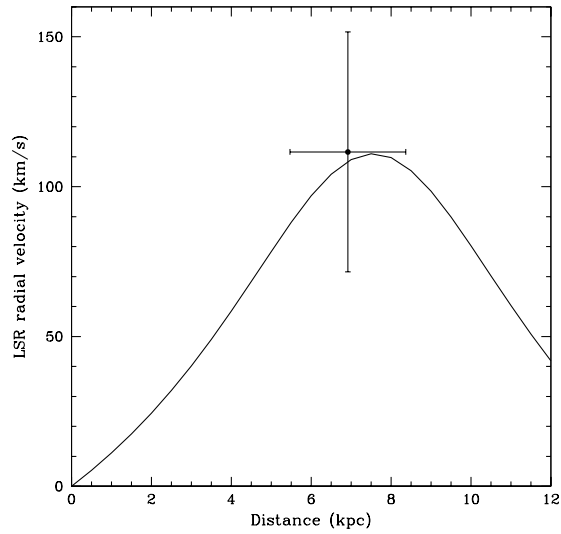


Fig. 2. In this figure we show (solid line) the expected LSR radial velocity as a function of distance to the Sun in the direction of M 2-43 for the galactic rotation model of Brand & Blitz (1993). The point marks the estimated distance and the observed LSR radial velocity for M 2-43.

4 Conclusions

We presented VLA observations made at 3.6 cm of the planetary nebula M 2-43 during two epochs separated by 4.07 years. Assuming a self-similar expansion for the ionized gas we determine an angular expansion rate for M 2-43 of $0.61 \pm 0.09\ mas\ year^{-1}$ and using an expansion velocity of $20\ km\ s^{-1}$ imply a distance to the

nebula of 6.9 ± 1.5 kpc. This distance estimate is in agreement with the high radial LSR velocity reported for this nebula. Adopting a distance of 6.9 kpc we derive a ionized mass of $0.035 M_{\odot}$ and a kinematic age of 500 years for M 2-43, suggesting that it is a very young and relatively remote planetary nebula. This is the most distant PN that has been measured using this technique.

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