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EXPANSION PARALLAX OF THE PLANETARY NEBULA IC 418

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RESUMEN

Presentamos observaciones en dos épocas en radio contínuo de la nebulosa planetaria IC 418, las observaciones están separadas por más de 20 años y fueron realizadas usando el arreglo muy largo, o VLA. Estos datos nos permiten mostrar que la tasa de expansión angular del frente de ionización en IC 418 es 5.8 ± 1.5 msa año^{-1}. Si la velocidad de expansión del frente de ionización es igual que la velocidad de expansión del gas en la línea de visión, medida usando espectroscopía óptica, entonces para la velocidad de expansión de 30 km s^{-1}, obtenemos una distancia a IC 418 de 1.1 ± 0.3 kpc. Si tomamos en cuenta que el frente de ionización podría estar expandiéndose 20% más rápido que el gas, entonces la distancia a IC 418 incrementaría a 1.3 ± 0.4 kpc.

ABSTRACT

In this paper, we present radio continuum observations of the planetary nebula IC 418 obtained at two epochs separated by more than 20 years using the Very Large Array. These data allow us to show that the angular expansion rate of the ionization front in IC 418 is 5.8 ± 1.5 mas yr^{-1}. If the expansion velocity of the ionization front is equal to the expansion velocity of the gas along the line of sight as measured by optical spectroscopy, then using the value of 30 km s^{-1} for the expansion velocity, we obtained a distance to IC 418 of 1.1 ± 0.3 kpc. If we take into account that the ionization front may be expanding about 20% faster than the material, then the distance to IC 418 would increase to 1.3 ± 0.4 kpc.

Key Words: planetary nebulae: individual (IC 418) — radio continuum: stars

1. IC 418

The Spirograph Nebula (IC 418, G215.2-24.2) has a rather simple morphology: both at optical and radio wavelenghts, it has an elliptical ring shape, with a major axis of 14″ and a minor axis of 10″. It is surrounded by a low-level ionized halo, which is itself enshrouded in a neutral envelope with an angular size of about 2″ (Taylor & Pottasch 1987; Taylor et al. 1989). Widely discrepant estimates of the distance to the planetary nebula (PN) IC 418 have been obtained using different statistical methods. To our knowledge, the shortest distance ever proposed is 360 pc (Acker 1978), whereas the largest one is 5.74 kpc (Phillips & Pottasch 1984). In recent years, the most popular value appears to have been 1 kpc (Meixner et al. 1996; Pottasch et al. 2004), although the reason for this is not entirely clear.

2. RESULTS AND DISCUSSION

The data were taken using the Very Large Array (VLA) of the NRAO[4] at 6 cm (5 GHz) in its second most extended (B) configuration on June 28, 1986 (1986.49) and November 6, 2007 (2007.85). This is a time separation of 21.36 yr. The resulting images are shown in Figure 1.

The difference image between the two epochs, shown in the bottom left panel of Figure 1 was produced following Guzmán et al. (2006). We estimated the expansion rate of the nebula by comparing the difference image of the data with the model. To generate the model difference, we image the data twice. The first image was made using a fixed pixel size of 0.″1, whereas the second one was made using pixel sizes of $(1 + \epsilon) \times 0.''1$, with $\epsilon \geq 0$, but $\epsilon \ll 1$. See Guzmán et al. (2009) for more detail. To identify the best model, we repeated the procedure described above for a set of values of ϵ. For each value, we compared the model difference with the real difference. The best model clearly corresponds to the situation where the two differences are as similar to each other as possible. The best value for ϵ that we obtained was $\epsilon = 0.018 \pm 0.005$. Using the image of the second

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