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Distance determination to PNe using the extinction-distance method

Silvana G. Navarro[1,2], Romano L. M. Corradi[2] and Antonio Mampaso[2]

[1]Instituto de Astronomía y Meteorología, Universidad de Guadalajara
Av. Vallarta 2602, Col. Arcos Vallarta, Guadalajara, Jal., México
email: silvana@astro.iam.udg.mx

[2]Instituto de Astrofísica de Canarias
Via Láctea s/n, La Laguna, Tenerife, España,
email: rcorradi@iac.es, amr@iac.es

Abstract. We present individual distances to three PNe: NGC 6537, NGC 6781 and NGC 7027, determined by the extinction-distance method. These objects are part of a larger sample (35) of PNe that we observed at ORM. In order to apply this method, and to obtain accurate distances, we determined the spectral type of 40 to 60 stars in the line of sight of each PNe. This implied the necessity of classifying few thousands of stellar spectra with S/N ratio between 10 and 60. To solve such need we developed an ANN system to perform automatic spectral classification which could classify spectra with S/N ratio as low as 20 with an accuracy better than 2 spectral subtypes. In this poster we compare the accuracy of such distances with previous distance determinations using other methods. We conclude that it is possible to use this method to obtain the distance of a large number of PNe with better precision.

Keywords. Stars: distances, planetary nebulae: general, planetary nebulae: individual (NGC 6537, NGC 6781, NGC 7027)

1. Introduction

Individual and statistical distance determination to PN differ by factors of 3 or more (Terzian 1993). This implies uncertainties by a factor greater than ten for the fundamental properties of PNe. The methods that could provide accurate distances for this type of object are individual determinations using: trigonometric parallaxes, spectroscopic parallaxes, expansion distances measured from radio images, binary central stars, extinction-distance method. The applicability of almost all these methods are limited to very few objects. The extinction-distance technique appears to be the only method useful for determining accurate distances for a significantly large number of PNe, and which is independent of statistical assumptions about the physics of the nebulae and/or of their central stars. We use this method to determine the distances in a sample of 35 PNe. We present here the results for the first three objects. This method have been used more or less successfully for more than 30 years (Lutz 1973; Acker 1978; Gathier *et al.* 1986; Giammanco *et al.* 2011) to determine distances to PNe. The method consists of determining the reddening-distance relation in the line of sight of each object and, using the reddening measured on the spectra of the PN, it is possible to obtain its distance. This method demands a large number of observations: photometry and spectroscopy of stars near the line of sight of each PNe and its own spectroscopy.

Table 1. Distances obtained in this work and by other authors using statistical methods (Stat. Dist.) or individual determinations (Indiv. Dist.).

Object	E(B-V)	Stat. Dist.	Indiv. Dist.	This Work
NGC 6781	00.768 (Liu *et al.* 2004)	0.7–0.9 kpc	<1000 pc	0.83 ± 0.24 kpc
NGC 7027	<0.33 (Navarro 2005)	0.32–0.63 kpc	0.65–0.94 kpc	$d < 1.15$ kpc
NGC 6537	1.12 (Tylenda *et al.* 1992)	0.6–3 kpc	2.4±0.6 kpc	2.81 ± 0.45 kpc

2. Observations

Observations were made at ORM in 1997 and 1998 at the JKT, INT and WHT telescopes. Near the line of sight of each of the 35 observed PNe, 40 to 60 stars were selected, all of them nearer than 3 arcmin from the PN in order to minimise the effect of small scale variations in the interstellar medium (Dickey *et al.* 1979). All the PNe selected for this project are near the galactic plane ($b < 5^o$).

Spectral Classification: In order to determine an accurate spectral classification of the stars near the line of sight of each of the PNe, we obtained the spectra of these stars at the WHT, using the LDSS2 multi-object spectrograph with a resolution of 6 Å. To determine the spectral type of the stars in each field, we developed an Artificial Neural Network System which is able to classify spectra with signal to noise ratio (S/N) as low as 20 with an accuracy better than 2 spectral subtypes (Navarro 2005; Navarro *et al.* 2011). The neural networks were trained with the measurement of 35 spectral lines that are sensitive to spectral type and luminosity class. The spectral database used to train the ANNs was obtained from the Jacoby *et al.* 1984 spectral catalogue adding a wide range of noise levels.

Photometry: The B, V photometry of the objects presented in this paper were obtained at JKT by Pollaco and Vassiliadis using a CCD TeK 1024×1024 with a 0.33″ pixel size.

3. Results

Table 1 shows the distances determined by this method (Col. 5) and the comparison with previous determinations by other methods: statistical (Col. 3) and individual (Col. 4). (The complete references for these distances are listed in Navarro 2005) The source for the extinction value in each case is listed in the second column. As can be seen, the distances obtained with extinction-distance method have better or similar precision as that obtained by other individual methods. This method has great potential, especially in the near future when data from large surveys like GAIA and other data sets available through the Virtual Observatory (VO) will make it possible to determine the distance to most of the PNe near the galactic disk (Navarro & Larson 2010).

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