PLANETARY NEBULAE: THEIR EVOLUTION AND ROLE IN THE UNIVERSE
IAU Symposium, Vol. 209, 2003
S. Kwok, M. Dopita, and R. Sutherland, eds.

Dust Extinction and Elemental Abundances of NGC 7027

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1. Introduction

Extinction toward NGC 7027 has been extensively studied. Seaton (1979) found the extinction across the nebula is variable and presented a two-component model to explain the radio and infrared observations. Middlemass (1990) presented a wedge-shaped extinction model, assuming the extinction increases linearly across the surface of the nebula. Walton et al. (1988) obtained an extinction map and found a mean extinction of $E_{B-V} = 1.02$, and a lower extinction of $E_{B-V} = 0.8$ towards the central star (CS). Based on high-resolution imaging, Robberto et al. (1993) and Wolff et al. (2000) obtained higher extinction of $E_{B-V} = 1.07$ and 1.10 towards the CS, respectively.

We have obtained deep optical spectra of NGC 7027 by uniformly scanning a 2 arcmin long slit across the nebula. The observations yield average optical spectra for the whole nebula. We have also measured fluxes of lines detected in the archival *IUE* UV spectra and in the *ISO* infrared spectra. The data from the UV to the far IR have been used to derive the extinction curve towards NGC 7027 and the nebular thermal and density structures and elemental abundances.

2. Results and Discussion

Figure 1 shows the extinction curve derived from the H I and He II recombination lines. A few forbidden line ratios were also used. Note that the two data points near 1600 Åwere derived from [Ne IV] λ1602 and O III] λ1665. Due to relatively large observational errors of the two weak lines and the fact that the reddening derived from them is sensitive to the adopted T_e and N_e, they should be treated with caution. The IR and optical results are consistent with both the standard Galactic ISM extinction curve and that predicted by the Middlemass model. In the UV, the extinction curve predicted by the Middlemass model is steeper than the standard ISM law and seems to be supported by the observations, in particular the data point derived from the He II λ1640 line which should be reliable. The steeper extinction in the UV could be caused by the local dusts. In Fig. 1, data points from Seaton (1978) are also plotted. The radio and IR anomalies claimed by Seaton were not obvious in our current data set and

https://doi.org/10.1017/S0074180900208929 Published online by Cambridge University Press

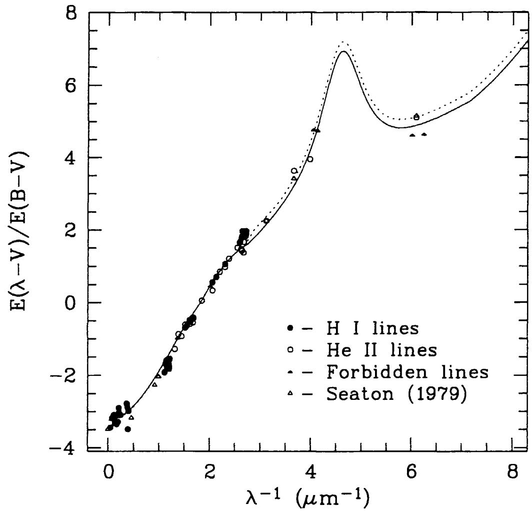

Figure 1. Extinction curve towards NGC 7027. The solid and dashed curves are respectively the standard ISM reddening law for $R = 3.2$ and that predicted by the model of Middlemass (1990).

could be spurious. Our data yield a mean extinction of $E_{B-V} = 0.85$, in good agreement with the value found by Salas et al. (2001) using radio/Hβ method.

Our plasma diagnostics yields a mean electron density of 47 000 cm^{-3}, an [O III] forbidden line temperature of 12 600 K and a Balmer jump temperature of 12 800 K. Table 1 presents the element abundances derived from optical recombination lines (ORLs) and from collisionally excited lines (CELs). The discrepancies between these set of results are small, so is the difference between the [O III] and the Balmer jump temperatures, consistent with the results of Liu et al.(2001) who find that the ORL/CEL abundance ratio is positively correlated with difference between the [O III] and Balmer jump temperatures.

Table 1. Element Abundances in units such that log$N$(H) = 12.0

	He	C	N	O	Ne	Mg	S	Cl	Ar	Fe
ORLs	11.00	8.93	8.37	8.79	8.76	7.59	-	-	-	-
CELs	-	8.57	8.01	8.56	8.12	7.61	6.65	5.12	6.27	5.45

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