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NGC 6826- Integrated Study of the Planetary Nebula and Central Star Properties

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Abstract:- *This study provides a comprehensive analysis of NGC 6826, focusing on the structural, kinematic, and spectroscopic properties of its planetary nebula and the characteristics of its central star. By integrating multi-wavelength observational data, we examine the nebular morphology, ionization structure, and chemical composition, which reveal insights into the evolutionary processes shaping the nebula. Additionally, we analyze the central star's luminosity, temperature, and spectral features to understand its role in driving the observed nebular dynamics. Our findings contribute to the broader understanding of planetary nebula formation, central star evolution, and the interaction mechanisms at play. This integrated approach underscores the importance of studying planetary nebulae in a holistic context to unravel the complexities of stellar evolution.*

Keywords: *NGC 6826, planetary nebula, central star, kinematics, stellar evolution, spectroscopy*

1. Introduction

Low and intermediate mass stars (0.8 to 8.0 $M_\odot$) eventually form planetary nebulae (PNe). The gas shells encircling the nucleus of the The stellar remnant is sufficiently hot for the progenitor star to release photons that can ionize the atmosphere around them. Numerous intricate PNe or center star models CSPNs (planetary nebulae) have been created independently; nonetheless, there aren't many pieces that combine the examination of the center star in the nebula. Authors offer a way to produce a self-consistent planetary nebula and its center star model.

2. A UNIFIED MODEL IS NEEDED

Several models can replicate the observations of the same star in the case of central stars (CSPN) of galactic planetary nebulae, according to data published in the literature. The largest issue is the tremendous degree of uncertainty surrounding these objects' distances. Two examples of stellar models with varying parameters from the literature are displayed in Table 1.

In contrast, photoionization models often use atmospheric or black body (BB) models as ionization sources. All that is required to determine a BB's temperature is the quantity of ionizing photons required to replicate the ionization state in the nebular gas. In order to replicate the nebula's ionization state, Teff and luminosity are altered while some parameters are taken from other sources when using an atmospheric model. These investigations do not take into account the stellar wind. The nebular spectrum data can be replicated by a number of nebular models thanks to the degradation distance-luminosity. Two nebular model examples from the literature with varying parameters are displayed in Table 1.
Few studies fit the CS and PN parameters at the same time (Morisset & Georgiev 2009). Using the atmospheric model as input to the

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photoionization model is one method of connecting the two objects (CS and PN). The CS model ought to replicate the stellar spectrum, including wind-related P-Cygni patterns. The nebular model adapts to variations in the star's Teff and luminosity by altering the degree of ionization. Although creating a stellar-nebular model involves more work than creating a stellar or nebular model alone, the extra observational restrictions placed on the model limit the number of potential models and lower the parameter uncertainty.

Table-1 Parameter of NGC 6826

Reference	**TeffT_{\text{eff}}Teff (kK)**	**log⁡g\log glogg**	**M˙\dot{M}M˙ (10−8^{-8}−8 M⊙M_{\odot}M⊙/yr)**	**v∞v_{\infty}v∞ (km/s)**	**L/L⊙L/L_{\odot}L/L⊙**	**Distance (kpc)**
Pauldrach et al. 2004 (stellar model)	44	3.9	18	1200	15,848	3.18
Kudritzki et al. 2006 (stellar model)	46	3.8	7.94	1200	12,882	2.6
Kwitter & Henry 1998 (nebular model)	50	-	-	-	186,200	-
Surendiranath & Pottasch 2008 (nebular model)	47.5	3.75	-	-	1,640	1.4
This work (stellar-nebular model)	45.0±2.5 45.0 \pm 2.545.0±2.5	3.65±0.2 3.65 \pm 0.23.65±0.2	1.50±11.50 \pm 11.50±1	1100±1001100 \pm 1001100±100	6000±5006000 \pm 5006000±500	0.80±0.2 0.80 \pm 0.20.80±0.2

3. DISTANCE DEGENERATION IN LUMINOSITY

The determination of the absolute brightness is a challenging topic because the distances to the Galactic PNe are not well established. Due to this issue, multiple models with various combinations of L, R, and M values can replicate the observations. The luminosity-distance degeneration causes degenerations in numerous other parameters.

However, the size (Rin, Rout) and amount of gas emitted by the nebula are directly impacted by changes in distance. Models of photoionization that vary the ionizing source's temperature, brightness, and distance can replicate the observations.

4. ENDING DEGENERATION

To break the degeneracy between the star and nebula parameters, the key factor is the distance. To minimize uncertainty in the distance, we utilized the evolutionary tracks from Vassilidis & Wood (1994) along with the dynamic age of the nebula.

The effective temperature (T_{eff}) of the central star can be constrained using the line ratio of the same element in two consecutive ionization stages (e.g., the C IV λ1169 / C III λ1176 ratio). Distances from previous studies provide a range for the distance to the nebula. The dynamic age is determined from the nebula's expansion velocity, based on observational data for a given distance. By assuming a maximum distance of 3.18 kpc and a minimum expansion velocity of 10 km/s, we calculated an upper limit for the dynamic age of 30,150 years. The lower limit was set at 3,700 years, assuming a minimum distance of 0.7 kpc and a maximum expansion velocity of 18 km/s.

By knowing the dynamic age and the temperature of the central star, it is possible to place it within the evolutionary tracks. We use the evolutionary tracks from Vassiliadis & Wood (1994) for this purpose. Potential solutions lie within the region defined by the ranges of T_{eff} and dynamic age. Each point within this region corresponds to a combination of luminosity, T_{eff} and dynamic age. By assuming the average expansion velocity from the available data, we can determine a distance for each model under study.

Multiple potential solutions were investigated within the region defined by the evolutionary tracks. Several models for the central star were generated, with the best-fitting models selected based on their ability to reproduce the observed spectra. These models were then used as input for photoionization models to simulate the ionization state of the nebula.

Table 2 Supplementary Parameters for NGC 6826

Parameter	Value (Stellar)	Value (Nebular)	Solar Value	Units
Rotational v×sin i	70±1570	70±1570	-	km/s
Age	5000±10005000	5000±10005000	-	years
Nebula Radius (R_{neb})	0.07±0.010.07	0.07±0.010.07	-	pc
He	11.04±0.1511.04	11.04±0.1511.04	10.93±0.1510.93	-
C	8.00±0.308.00	8.00±0.308.00	8.30±0.308.30	-
N	8.18±0.308.18	8.18±0.308.18	7.78±0.307.78	-
O	8.60±0.308.60	8.60±0.308.60	8.60±0.308.60	-

5. Conclusion

Table 1 presents various parameters derived from a preliminary model of NGC 6826, alongside comparisons with values from other studies. Table 2 lists additional parameters determined in this work. Apart from carbon, the stellar and nebular abundances are consistent within the margin of error. The solar values provided are based on Asplund et al. (2005).

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