RevMexAA (Serie de Conferencias), **12**, 148–149 (2002)

THE LBV PHASE OF THE PLANETARY NEBULA LMC-N66[1]

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RESUMEN

Observaciones recientes de la estrella central de la nebulosa planetaria LMC-N66 muestran que el fuerte viento tipo LBV ha estado disminuyendo lentamente, después del violento máximo de 1994. La magnitud actual ($m_V \sim 18.1$ mag) y la probable tasa de pérdida de masa de la estrella son similares a los valores de 1990. A partir de espectros de rendija larga obtenidos con el espectrógrafo STIS del *Telescopio Espacial Hubble*, se han podido analizar algunos datos nebulares.

ABSTRACT

Recent observations of the [WN] central star of the planetary nebula LMC-N66, combined with previous data show that the star has been slowly fading, after its violent LBV-type outburst occurred in 1994. The present stellar brightness ($m_V \sim 18.1$ mag) and the probable mass loss rate are similar to the values observed in 1990. Nebular data from long-slit STIS-*HST* observations allow us to analyze some nebular characteristics.

Key Words: **PLANETARY NEBULAE: INDIVIDUAL (LMC-N66) — STARS: WOLF-RAYET**

1. INTRODUCTION

N66 is well-studied planetary nebula in the LMC, whose central star showed a spectacular outburst, beginning around 1990. It developed impressive WR features first reported by Torres-Peimbert et al. (1993). For 1994 the UV and optical continuum fluxes had increased by factors of about 4 and 25 respectively, and WR features, similar to those of a Population I WN4.5 star, were present. Remarkably, the central star of N66 is the only PN nucleus which has shown a WN type spectrum. All the other known PN nuclei with WR features, in the Galaxy and the Magellanic Clouds, are of WC type (Tylenda et al. 1993; Peña et al. 1997).

Since 1993 we have followed the stellar evolution of N66 from ground-based telescopes and with the *IUE* and *HST* satellites. Analysis of such observations have been reported in Peña et al. (1994, 1995, and 1997). Spectroscopic data show that the strong wind persisted for several years. During this period the stellar emission lines and continuum have undergone important short- and long-time scale variations, getting its maximum stellar brightness in early 1995 ($m_V = 16.4$).

Peña et al. (1997) have presented an extensive analysis of the stellar behavior. Using models for spherically symmetric expanding atmospheres (e.g., Hamann et al. 1993), computed to fit the stellar emission lines and continuum of different epochs, they have shown that the short- and long-term stellar variations can be explained by assuming large changes in the mass-loss rate, which is huge at the stellar maximum ($\dot{M} = 2.5\times10^{-5} M_\odot$ yr^{-1}) and very small at the minimum ($\dot{M} \leq 8\times10^{-7} M_\odot$ yr^{-1} in the pre-outburst epoch). Meanwhile fundamental stellar parameters like bolometric luminosity, radius and effective temperature, remain constant with time. The stellar characteristics, as derived from the models, are: $\log(L_*/L_\odot) = 4.53 \pm 0.10$, $T_* = 93\,300$ K, $R_* = 0.71 R_\odot$. Peña et al. (1997) have proposed that the event taking place in the central star of N66 has been produced by an atmospheric instability similar to those triggering the giant eruptions of Population I LBV stars.

2. RECENT OBSERVATIONS

Ground-based and STIS-*HST* observations have been performed in the last years. The recently acquired data show that since 1995 the central star has been slowly fading with time. In Figure 1 we present a comparison of UV spectra, obtained with *IUE* and *HST* satellites, from 1994 to the present. By the end of 2000, the central star presented a visual magnitude $m_V \sim 18.1$ mag, that is, 1.7 mag fainter than in early-1995 but still half a magnitude brighter than in 1983. WR features, in particular the He II emission lines, are still detectable in the UV and optical spectra.

The analysis of nebular lines shows that the nebular parameters have not changed during the out-

[1]Based on NASA-ESA *IUE* and NASA-ESA *HST* observations.

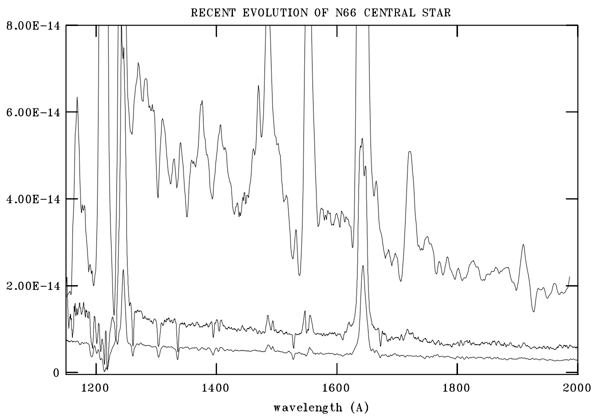

Fig. 1. Comparison of UV spectra of different epochs. At top: *IUE* 1994 (nebular emission is included); middle: FOS-*HST* 1996; bottom: STIS-*HST*, February 1999. Evidently the central star of N66 has been slowly fading, although it has not yet arrived to the low luminosity level of 1983.

burst. N66 was known to be a high excitation, moderately He- and N-rich nebula, with an electron temperature of about 15 000 K and a density around 2600 cm^{-3} and so has remained.

From high-resolution long-slit spectra obtained with STIS we have found that the nebula has a complex kinematics, showing knots moving at velocities of about 80 km s^{-1} relative to the central star. These results confirm previous kinematic data by Dopita et al. (1985).

3. DISCUSSION

Interestingly, Sanduleak (1977) noticed that the irregular variable HV 5967 (reported by Nail & Shapley 1955 with a variation range $\Delta m \approx 0.9$ mag) and N66 are the same object. This could indicate that outbursts similar to the one presented here might have occurred in the past. However, in the 1990 event, the maximum total variation in visual brightness (including nebula and star) did not amount more than 0.3 mag, far from the 0.9 mag reported by Nail & Shapley (1955). For such a large brightness variation of the whole object, the outburst which occurred in the 50's would imply a mass loss rate much larger than the value of $\dot{M} = 2.5 \times 10^{-5} M_\odot$ yr^{-1} computed by Peña et al. (1997). Such a violent mass loss event appears incompatible with the nature of central stars of planetary nebulae, however the recurrence of huge mass-loss events in the central star of LMC-N66 seems to be confirmed.

The recently obtained ground-based and STIS-*HST* spectra will be used to compute improved models of expanding atmospheres, in order to derive the fundamental stellar parameters (bolometric luminosity, effective temperature and radius) as well as the present mass loss rate and other important stellar characteristics. The comparison of such models with those computed for previous epochs will allow to test the hypothesis of atmospheric instabilities triggering the 1990–2000 eruption in the central star of LMC-N66.

The author is very grateful to W.-R. Hamann and M. T. Ruiz for their contributions to the work discussed in this paper. Financial support for this research has been provided by DGAPA-UNAM (project number IN100799) and CONACyT, México (project number 32594-E).

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Ionized Gaseous Nebulae (Mexico City, 21-24 November 2000)
Editors: William Henney, José Franco, Marco Martos, & Miriam Peña