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PN G135.9+55.9: A NEW, EXTREMELY OXYGEN-POOR PLANETARY NEBULA IN THE GALACTIC HALO

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RESUMEN

Mostramos que SBS 1150+599A es una nebulosa planetaria localizada en el halo de la Galaxia (que se llamaría PN G135.9+55.9). Modelos de fotoionización indican que su abundancia en oxígeno es menor que 1/100 del valor solar.

ABSTRACT

We show that SBS 1150+599A is most probably a planetary nebula located in the Galactic halo (becoming PN G135.9+55.9). Our photoionization models indicate that its oxygen abundance is lower than 1/100 solar.

Key Words: **GALAXY: HALO — PLANETARY NEBULAE: GENERAL — PLANETARY NEBULAE: INDIVIDUAL (SBS 1150+599A, PN G135.9+55.9)**

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1. INTRODUCTION

SBS 1150+599A belongs to the list of stellar-like objects from the Second Byurakan Survey (SBS, see Balayan 1997; Stepanian et al. 1999). It was first thought to be a Cataclysmic Variable (CV). Our study shows that it is most probably a peculiar halo Planetary Nebula (PN). A full account of this work is given in Tovmassian et al. (2001).

2. OBSERVATIONS

We secured low-resolution spectrophotometry from different sites between 1998–2000. Several spectra with FWHM resolution of 5 to 13 Å were obtained at the 2.1-m telescopes of OAN and Cananea in México and at the 6-m telescope of Russia in the 4000–8000 Å wavelength range. A 1.5 Å FWHM resolution spectrum was taken at the 2.5-m INT at La Palma in a short wavelength range around Hβ.

The spectrum shows a blue continuum with strong narrow emission lines of H I, He II and marginally detected [O III]. No trace of He I or lines from singly ionized ions are seen. The shape of the continuum suggests a hot source ($T_* > 50\,000$ K). It does not change from epoch to epoch. The 1.5 Å FWHM resolution spectrum demonstrates that the emission lines are relatively narrow. The emission lines are blueshifted by -190 ± 2 km s^{-1} (after heliocentric correction). They are spatially extended, with an edge-to-edge width corresponding to $\approx 10''$ in the direction perpendicular to the dispersion.

TABLE 1

MEASUREMENTS OF SPECTRAL LINES

Spec. Line	EW (Å)	Flux[a]	Relative Flux	FWHM (Å)	Shift (Å)
Hϵ	−3–5	0.13	0.11–0.14	···	···
Hδ	−6–12	0.3	0.23–0.34	···	···
Hγ	−16–18	0.67	0.41–0.57	···	···
Hβ	−50–80	1.19	1.0	2.0	−2.83
Hα	−400–600	3.01	2.46–2.9	···	···
He II	−30–44	1.09	0.7–0.92	1.84	−2.68
[O III]	−2–3	0.037	0.03–0.035	···	···
He I	···	···	< 0.01	···	···
[N II]	···	···	< 0.005	···	···
[S II]	···	···	< 0.005	···	···

[a]Fluxes based upon the wide-slit SPM 2000 observations (units: 10^{-14} erg cm^{-2} s^{-1}).

3. NATURE OF THE OBJECT

Although SBS 1150+599A was originally classified as a CV by the authors of the SBS, a careful examination of the spectra leads us to reject such an interpretation. In CVs one expects much wider line profiles, due to the presence of an accretion disc or accretion flow. A CV with emission lines shifted up to 3 Å would be a high inclination system, thus in a time span of several hours it should show significant radial velocity variations.

The spectrum of SBS 1150+599A looks more like that of a symbiotic star, but apart from having high ionization emission lines it does not satisfy any other

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criteria established by Bełczyński et al. (2000). Neither our spectra nor available IR surveys provide any evidence for the presence of a late giant in the immediate neighborhood of the object. The 6825 Å emission feature, which appears in a few symbiotics with no cool star, is not observed either.

Since the object is blue shifted, if it were a galaxy it would necessarily belong to the Local Group. From the observed Hβ flux, we deduce that the total Hβ luminosity would be $< 2 \times 10^3 L_\odot$, much less than the typical Hβ luminosities of H II galaxies. The most compelling argument against SBS 1150+599A being a blue compact galaxy, developed by Tovmassian et al. (2001), is that the continuum is much bluer than observed in BCGs.

While the spectrum of our object is by no means similar to that of a typical PN, since it shows only one forbidden line, there are examples of PNe in which the lines lacking in the spectrum of SBS 1150+599A are very weak (Aller & Czyzak 1983). At first sight, our spectra can be interpreted as pertaining to a PN with a hot exciting star (to produce significant He II emission), density bounded (so that no He I, [N II] and [S II] lines are seen), and either of very low metallicity or in a very high ionization state (to ensure a very small [O III]/Hβ). The observed heliocentric velocity is indeed compatible with SBS 1150+599A belonging to the Galactic halo (Beers & Sommer-Larsen 1995). With the nomenclature of the Strasbourg-ESO catalogue of planetary nebulae (Acker et al. 1992) SBS 1150+599A becomes PN G135.9+55.9.

4. A PHOTOIONIZATION MODEL FOR PN G135.9+55.9

Given the small number of observational constraints, we adopt a very simple model consisting of a homogeneous gaseous sphere surrounding a hot star. We computed series of photoionization models in which we specify the stellar temperature, T_*, the rate of ionizing photons Q, the gas density n, and the filling factor ϵ. The integration starts from the center and stops when the equivalent width of Hβ, EW(Hβ), becomes equal to the observed value. We do not have to consider all possible combinations of Q, n and ϵ since for a fixed T_* and a given EW(Hβ) the nebular ionization structure depends only on the combination $Qn\epsilon^2$. We find that there is quite a range of input parameters compatible with our observational constraints. While models with $T_* =$ 80 000 K are not compatible with the lack of detection of He I 5876 Å, models with T_* between 100 000 K and 200 000 K are consistent with the observed constraints in a range of metallicities that depend essentially on the value of the ionization parameter.

From the observed angular extent and Hβ flux we estimate the distance assuming a certain mass and filling factor. Being a density-bounded object, such a procedure (the Shklovsky method) provides a reasonable estimate. Taking the canonical values $M_{\rm neb} = 0.2 M_\odot$ and $\epsilon = 0.2$ it gives $d = 20.4$ kpc, which is within acceptable distances for a halo object. The value of n is then ~ 50 cm^{-3}. For a star of given T_*, the observed EW(Hβ) can be obtained by a whole family of models sharing the same value of $(M_{\rm neb} n/Q)$. We can then readily infer the value of Q that corresponds to a given $M_{\rm neb}$, thus restricting the range of possible oxygen abundances. The accepted values still span a large range, but oxygen abundances over one fiftieth of solar are clearly eliminated. This makes of SBS 1150+599A by far the most oxygen-poor PN known.

From the measured expansion velocity and nebular size, we estimate an expansion age of $\sim 10\,000$ yr. Using the post-AGB evolution tracks of Blöcker (1995), we then estimate a central star mass of ~ 0.58–$0.59 M_\odot$ and $T_* \sim 150\,000$ K . This further constrains the oxygen abundance of SBS 1150+599A to be $\log {\rm O/H} + 12 \sim 5.8$–$6.8$.

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