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X-RAY EMISSION FROM THE PLANETARY NEBULA NGC 1360

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ABSTRACT

The EXOSAT observatory has detected the nucleus of NGC 1360 in four photometric energy bands. The data rules out that the emission is from blackbody origin. Initial fits made with LTE model atmosphere spectra require the presence of highly ionized Oxygen and Neon in the stellar atmosphere.

INTRODUCTION

Central stars of planetary nebulae are believed to be a short stage in the evolution of a red giant towards a white dwarf. After ejection of the nebula the central star evolves from a relatively cool star (40.000 K) of 1 $R_{\odot}$ into an extremely hot star (150.000 K) of 0.01 $R_{\odot}$. Thereafter it cools down to a white dwarf. Since the discovery of soft X-ray emission from the white dwarf HZ 43 /1/ numerous hot white dwarfs have been detected as X-ray sources. Because of their higher temperature, nuclei of planetary nebulae are expected to be stronger X-ray sources, although sofar nothing has been published.

OBSERVATIONS

EXOSAT observations of NGC 1360 have been carried out on August 20, 1983. All five available filters have been used to obtain maximum spectral information and to be able to correct the data for UV-contamination. Source fluxes have been determined from a circular box of 2 arc minute diameter centered on the source. An annulus of 10 arc minute outer diameter around the source cell defines the background.

The data have been corrected for UV-contamination by making use of inflight calibrations /2/. For the determination of the contamination levels, the ANS-spectrum for NGC 1360 was used /3/. Also an independent check has been made by using the internal consistency of all filter data. The UV-contamination for the data used in the X-ray analysis is at most 7%. Polypropylene data are, due to a higher UV-contamination, not used.
The corrected source fluxes together with 1 σ errors are given in table I.

ANALYSIS AND INTERPRETATION

The X-ray flux is interpreted as surface emission from the central star of NGC 1360. Another interpretation is that the emission originates from shocks induced by the stellar wind, which rams against the nebula. This can be excluded since the high resolution IUE-data don't show any sign of a stellar wind /4/ and our data are consistent with emission from a point source.

The simplest approximation for emission from a stellar surface is blackbody radiation. Confidence levels in the N_h, T_{bb} space have been determined through application of the likelyhood ratio /5/. The 90% confidence contour is given in figure 1. The source

Table I X-ray countrates for NGC1360

Experiment	Filter	Time (sec)	X-ray flux (counts/sec)
LE1	Al/Parylene	5706.4	0.008 ± 0.0015
LE1	Boron	4882.5	0.0054 ± 0.0015
LE2	3000A Lexan	3172.7	0.1834 ± 0.0075
LE2	4000A Lexan	4133.0	0.0834 ± 0.0046
LE2	Polypropylene	3742.7	0.1660 ± 0.0063

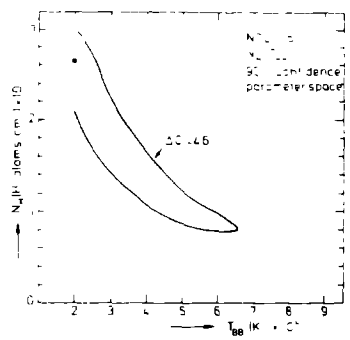

Figure 1: 90% confidence contour for a blackbody fit to the NGC 1360 X-ray data.

intensity, represented by $(R/D)^2$, is given for the N_h, T_{bb} values on the 90% confidence contour in figure 2.

For the interstellar column density in the direction of NGC1360, $(1.4\pm0.1)10^{20}$ H-atoms/cm^2/6/, the blackbody temperature equals 38.000±8.000 K. In case N_h is left free the maximum allowed temperature is 65.000 K. This value is totally inconsistent with temperatures derived sofar. The He II Zanstra temperature equals 85.000 K /7/, while colour temperatures derived from the optical and UV continuum are between 100.000 and 120.000 K /3,4/. The only temperature close to ours is an effective temperature derived from non-LTE model atmosphere fits to absorption line profiles /8/, which results in an effective temperature equal to 65.000 ±15.000 K.

The range of $(R/D)^2$ in figure 2 is compared with values derived on the basis of m_v /7/ and also on the basis of the surface gravity, log g = 5.2 /8/, the distance D = 350 pc /7/, and a commonly accepted value for the stellar mass, i.e. 0.8 $M_\odot$. The $(R/D)^2$ derived from the X-ray data is one or two orders of magnitude too high.

A blackbody origin can therefore clearly be ruled out. The X-ray data require a stellar flux consistent with a blackbody temperature of at least 85.000 K, while its spectral shape should be as steep as for 38.000 K.

In addition we have investigated a grid of LTE-atmospheres calculated by Hummer and Mihalas /9/. These models include besides H and He also C,N,O and Ne which have absorption edges in the X-ray range.

In figure 3 model atmosphere spectra in the X-ray range are drawn for an effective temperature of 100.000 K, log g=5 and for three different elemental abundances, i.e. the 200 (I), 300 (II) and 400 (III) model spectra series of Hummer and Mihalas. The best fit is obtained for the highest abundance, i.e. the 400-series (Abundance III) spectrum, as indicated by the reduced chi-square. From the spectra in figure 3 it is clear that the

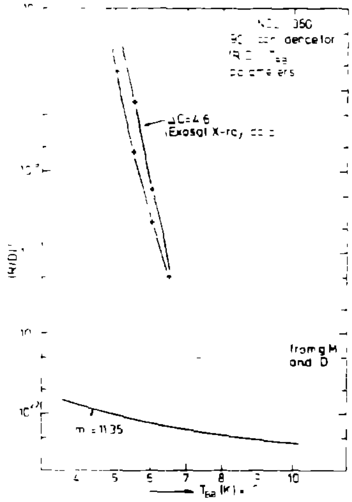

Figure 2: Luminosity, $(R/D)^2$, as a function of blackbody temperature for 90% confidence contour values of temperature and interstellar column density.

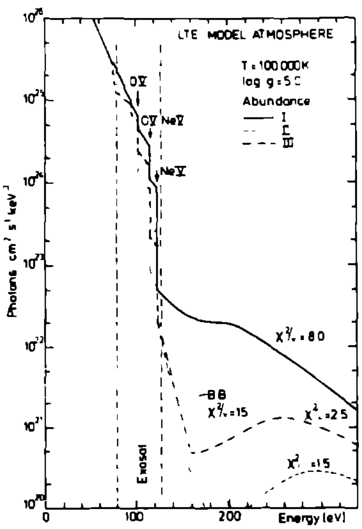

Figure 3: LTE model atmosphere spectra of Hummer and Mihalas /9/ for T_{eff} = 100.000 K, log g = 5 and three different abundances. The quality of the fit to the X-ray data is given by a reduced chi-square.

required steepness of the spectrum in the range observed by EXOSAT is caused by the opacity of the O V and Ne V ions. Those opacities allow for a combination of a large X-ray flux, i.e. high effective temperature, and a steep spectral shape in the spectral range observed.

For objects close to the Eddington limit, like NGC 1360, non-LTE model atmosphere spectra should however be used. Recently a grid of models have been published by Husfeld et al. /10/. These calculations make only use of Hydrogen and Helium. Their spectral shape shortward of 228 A is even flatter than for a blackbody spectrum, so that they don't fit the X-ray data at all. Non-LTE model spectra including abundances of C,N,O and Ne will be required to carry out a more quantative analysis on the available spectral data.

DISCUSSION AND CONCLUSION

The X-ray data cannot be represented by a blackbody spectrum. LTE model atmosphere spectra lead to good fits if opacities from O V and Ne V ions are included. The derivation of abundances for planetary nebula nuclei is very important. White dwarfs are known to have almost pure Hydrogen or Helium atmospheres,which is explained by gravitational settling during the cooling phase. Sofar abundances for planetary nebulae nuclei, just one evolution stage before that of the white dwarf, are unknown.

The X-ray measurements demonstrate the possibility to determine the Oxygen and Neon abundance. Non LTE-calculations with temperature, Helium abundance and gravity fixed to values obtained from optical line profiles /8/ will be carried out in order to extract the abundances of Oxygen and Neon, from the available X-ray data.

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