Planetary Nebulae in our Galaxy and Beyond
Proceedings IAU Symposium No. 234, 2006
M. J. Barlow & R. H. Méndez, eds.

doi:10.1017/S1743921306003449

Non-LTE model for the wind of the NGC 6543 central star

L. N. Georgiev[1], D. J. Hillier[2], M. G. Richer[1] and A. Arrieta [3]

[1]Instituto de Astronomía, UNAM, México; [2]Physics and Astronomy Department, University of Pittsburgh PA, USA; [3] Universidad Iberoamericana, México

Abstract. We present non-LTE models of the wind for the central star in NGC 6543. The models suggest that the star is hydrogen-rich. The iron composition is solar, which, in turn, suggests that the hot X-ray emitting gas is of nebular origin.

Keywords. stars: winds, stars: abundances, (ISM:) planetary nebulae: individual (NGC 6543)

1. Introduction

NGC 6543 is one of the few planetary nebulae which shows diffuse X-ray emission (Chu *et al.*, 2001). The conditions of the plasma, as determined by the X-ray data, are such that it should emit the coronal line Fe XIV 5303 sufficiently strong to be detectable, but attempts to observe this line in a few objects were unsuccessful (Georgiev *et al.*, 2006). We interpreted the missing emission as a consequence of the reduced iron composition of the hot X-ray emitting gas. Now, the question is: "why is the gas iron depleted?" One possibility is that the wind of the star is iron-poor. In this paper we present a model of the wind of the central star of NGC 6543 in order to determine its iron abundance.

2. The observed spectrum, the model and basic stellar parameters

The optical spectrum was obtained with the echelle spectrograph at the Observatorio Astronómico Nacional in San Pedro Mártir, México. We used the same optical spectrum as in Georgiev *et al.* (2006). The stellar spectrum was corrected for the nebular contribution. Due to the relatively high resolution of the spectrograph (R 17000), the stellar hydrogen lines are clearly visible, since they are much broader than the nebular lines. The spectrum between 1150 and 1400 Å consists of the HST/STIS o8o707010 and o8o707020 spectra. The rest of the UV spectrum comes from IUE spectrum swp55982. All data were normalized to the continuum level.

We used the well-established code CMFGEN (Hillier and Miller, 1998) which is designed to calculate nLTE models of spherically symmetric winds with multi level atoms. The model contains H, He, CNO, Si and Fe. Fig. 1 presents the comparison of the calculated and observed spectra in various wavelength regions.

The effective temperature, the stellar radius and the luminosity of the star are related. We adopted a luminosity of $L = 5200L_\odot$ as in de Koter *et al.* (1996). We adjusted the stellar radius until the OIV 1338/43 Å, OIV 3560/63 Å, and OV 1371 Å lines were reproduced. The mass loss rate $\dot{M}$ was determined from the intensities of HI and HeII optical lines. The clumping factor was fixed to $f = 0.1$ which is a typical value for massive stars. Finally, the terminal velocity V_∞ was determined from the blue edges of the UV P Cyg lines. Our best model has $R = 0.6R_\odot$, $T_{\rm eff} = 63000$K, $\dot{M} = 0.6 \times 10^{-7} M_\odot$ and $V_\infty = 1600$ km/s. Taking into account the clumping, our basic parameters are in good agreement with those of de Koter *et al.* (1996).

Table 1. Abundances of the chemical elements relative to hydrogen (by number)

He/H	0.1	C/H	1×10^{-3}
N/H	1.2×10^{-4}	O/H	1×10^{-3}
Si/H	3.5×10^{-5}	Fe/H	3.5×10^{-5}

3. Chemical composition

The standard method for determination of hydrogen composition in massive WR stars is the study of the intensity decrement of the Pickering ($n \rightarrow 4$) HeII lines. The lines with even n have a wavelength similar to the hydrogen Balmer lines. A hydrogen-poor star shows a smooth Pickering decrement. In contrast, the observed HeII 5411Å line is much weaker than H_β and H_α. From Fig. 1, it is clear that the star cannot be hydrogen-poor. C, N, O and Si lines are reproduced acceptably well. The iron abundance is determined by the lines in the region between 1250 and 1450 Å. These lines are relatively well reproduced with solar iron abundance. We conclude that the iron abundance should be very close to the solar value. Table 1 summarizes the derived composition.

4. Conclusions

The central star of NGC 6543 is a hydrogen-rich star. The chemical composition of the wind is normal (solar abundance ratios), except that carbon is overabundant. The iron is of solar abundance and therefore the star itself cannot be responsible for the iron deficit of the hot X-ray emitting gas (Georgiev *et al.* 2006). Consequently, the hot gas should originate from the nebular material, where the iron could condense into dust grains. If so, that points to a cooling mechanism for the X-ray gas related to evaporation of the cold nebular gas into the interface region.

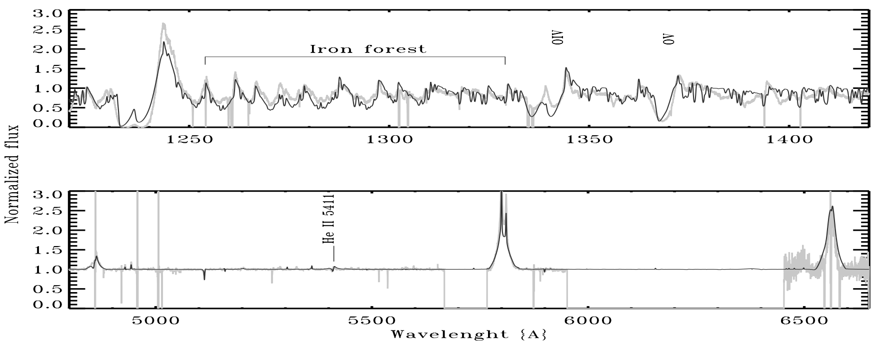

Figure 1. Comparison between calculated (black thin line) and observed (grey thick line) flux in UV and optical regions

Acknowledgements

This work was supported by CONACyT grants 42809, 43121, and 46904 and UNAM/DGAPA grants IN112103, IN108406-2, and IN108506-2.

References

Chu, Y.-H.,Gerrero, M., Gruendl, R., Williams, R., & Kaler, J., 2001, *ApJ*,553,L67.
Georgiev, L., Richer, M. G., Arrieta, A., & Szhekov, S., 2006,*ApJ*,639,185.
de Koter, A., Heap, S., Hubeny, I., & Lanz, T., 1996,*ASPC* 96,141.
Hillier, D. J., & Miller, D., 1998, *ApJ*, 496, 407.