Emission Lines in Active Galaxies: New Methods and Techniques
ASP Conference Series, Vol. 113, 1997
B.M. Peterson, F.-Z. Cheng, and A.S. Wilson (eds.)

Čerenkov Line Radiation: An Important Line Mechanism in the Broad-Line Region[1]

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1. Introduction

Observations (Espey et al. 1989, Carswell et al. 1991, Marziani et al. 1996) at high resolution have shown relative shifts between the Balmer lines and the C IV line in a number of QSOs. In this paper, we suggest that in the BLR there are many cloudlets with dense gas that is optically thick, and the BLR is not only illuminated by UV-X radiation, but also by relativistic electrons. Therefore the Čerenkov line radiation has to be taken into consideration, and we calculate the Čerenkov line redshifts and the profiles.

2. The Redshifts and Profiles of Čerenkov Lines

The basic formula for calculating the Čerenkov line redshift U_t is

$$\Delta z^c \equiv U_t \equiv \frac{\Delta\lambda_t}{\lambda_{lu}} = \frac{1}{C_0^{-1}\gamma_c^{-2} + \sqrt{C_0^{-2}\gamma_c^{-4} + (C_3/C_2)}}. \quad (1)$$

Here γ_c is the characteristic electron energy in a given source, and the constants C_0, C_2, and C_3 are given by You & Cheng (1986). For the very dense gas (say, $N_{\rm H} \approx 10^{16}\,{\rm cm}^{-3}$) that we are interested in, eq. (1) can be simplified as

$$\Delta z_c \equiv U_t \simeq \sqrt{\frac{C_2}{C_3}} = 1.04 \times 10^{-11} \sqrt{\lambda_{lu} A_{ul} \Gamma_{lu} \left(\frac{g_u}{g_l}\right) R_l R_p^{-1} p^5 \xi}, \quad (2)$$

where $\xi = N/N_{\rm H}^0$ is the number density ratio of relevant atomic (ion) species to neutral hydrogen, $N_{\rm H}$ is the number density of hydrogen atoms, N is the number density of the relevant atom (ion), g_u and g_l are the degeneracy of the upper and lower levels respectively, $R_l \equiv N_l/N$ denotes the fractional population of the lower level l of relevant atom (ion), and $R_p \equiv N_{{\rm H}p}^0/N_{\rm H}^0$ is the fractional population at the lowest photoionization level p of the hydrogen atom.

As an example, we calculate the redshifts of the Čerenkov Hβ line, for which $A_{42} = 3.33 \times 10^7\,{\rm sec}^{-1}$, $\lambda_{24} = 4.861 \times 10^{-5}\,{\rm cm}$, $\Gamma_{24} = 7.44 \times 10^8\,{\rm sec}^{-1}$, $p = 3$, taking $R_2 \simeq 10^{-2}$ (the population in level 2 is anomalously increased due to Lyα trapping), and taking $T = 1.5 \times 10^4$ K. Taking the density of hydrogen gas N as

[1]This work is supported by National Natural Science Foundation of China.

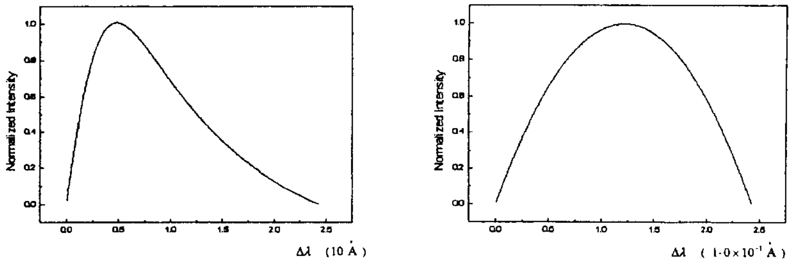

Figure 1. The Čerenkov line Hβ profiles at $T = 1.5 \times 10^4\,$K. *Left:* $N = 10^{16}\,\mathrm{cm}^{-3}$. *Right:* $N = 10^{14}\,\mathrm{cm}^{-3}$.

a free parameter, the calculated the redshifts of Čerenkov Hβ line are shown in Table 1. The profiles are shown in Fig. 1.

Table 1. Čerenkov Line Hβ Redshifts

Density N (cm^{-3})	Δz^c
10^{16}	9.55×10^{-4}
10^{14}	2.50×10^{-5}
10^{12}	2.50×10^{-7}

3. Conclusions and Discussion

From eq. (2) we see that Δz^c is dependent on R_l and R_p, the particle population at different energy levels. Therefore Δz^c is related to the temperature. The calculated Δz^c (Hβ) is about 10^{-3} (for very dense gas), which is in agreement with the observations. According to eq. (1), the different Čerenkov lines have different redshifts, even for the lines of the same atomic species. So it is not difficult to understand the redshift difference between the Hα and Hβ lines, etc.

References

Carswell, R. F., et al. 1991, ApJ, 381, L5.
Espey, B. R., et al. 1989, ApJ, 342, 666.
Marizini, P., et al. 1996, ApJS, 104, 37.
You. J. H., & Cheng, F. H. 1986, Phys. Rev. A, 34, 3015.

https://doi.org/10.1017/S0252921100040136 Published online by Cambridge University Press