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BALMER LINES IN ACTIVE GALACTIC NUCLEI

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RESUMEN. Se analiza el efecto de un flujo de electrones relativistas en la población de los niveles de hidrógeno. Se comparan los resultados con las observaciones de las líneas de Balmer de los núcleos galácticos activos. El efecto en el decremento de Balmer es similar al enrojecimiento causado por polvo.

ABSTRACT. The effect of a flux of relativistic electrons on the population of hydrogen levels is analyzed. The results are compared to Balmer lines observations of active galactic nuclei. The effect on the Balmer decrement is similar to the reddening caused by dust.

Key words: GALAXIES-NUCLEI — LINE-FORMATION

I. INTRODUCTION

The observed Balmer decrement of AGN is generally different from the radiative value both for the narrow-line and broad line regions (NLR,BLR). The differences are attributed to reddening by dust in NLR and to optical thickness of the emitting gas in BLR.

Relativistic elections are present in radio emitting nuclei and after providing synchroton emission they may affect the physical conditions of the photoionized gas and the emission line intensities (Gruenwald, Viegas-Aldrovandi; 1986). The effect on the Balmer lines is mainly due to collisional excitation of hydrogen levels by these particles and is analyzed in this paper.

II. EQUATIONS

The Balmer decrement is given by:

$$D_n = \frac{I_{n2}}{I_{42}} = \frac{n_n}{n_4}\frac{A_{n2}}{A_{42}}\frac{E_{n2}}{E_{42}}$$

where:

I_{n2}: line emissivity due to transition $n \to 2$

n_n: population of level n

A_{n2}: radiative transition probability $n \to 2$

E_{n2}: transition energy $n \to 2$.

The radiative transition probabilities and the transition energies are given by atomic physics. The level populations are obtained by solving the detailed balance equations for the levels, assuming that the number of transitions populating the level equals that depopulating the level (see, for instance, Brocklehurst, 1971).

Concerning the relativistic electrons, being $\phi(cm^{-2}s^{-1})$ their flux, three terms must be added to the level equations (Andrade, 1986).

(i) Populating term: excitation of level n from lower

levels $\phi \sum_{i<n} n_i \sigma_{in}$

(ii) Depopulating terms:

- excitation from level n to higher levels:

levels $\phi \sum_{j>n} n_n \sigma_{nj}$

- collisional ionization of level n: $\Phi\sigma_n$

The cross sections, σ, are almost independent on the energy of the relativistic electrons (Mott, Massey, 1965) so that a monoenergetic flux has been taken, and the results are not sensitive to the energy.

III. RESULTS

In order to solve the equilibrium equations, the input parameters are:

(a) the temperature, T, and the hydrogen density, n_H, of the gas.

(b) the characteristic size of the emitting cloud, ΔR. If $\Delta R=0$, the gas is optically thin (case A) and if $\Delta R\neq 0$ the gas is optically thick to Lyman lines (case B).

(c)the ionization parameter, U, ratio between the photon flux reaching the cloud and the electron density.

(d) the excitation parameter due to relativistic electrons, Φ/n_H.

The ionization degree of the gas and the electron density are calculated by the ionization equation, considering a purely hydrogen gas cloud ionized by the radiation field and by relativistic electrons.

Several results have been obtained for different values of the input parameters, and will be published elsewhere.

In Figs. 1a,b the behavior of the line ratios Hα/Hβ and Hγ/Hβ are given as a function of ϕ/n_H, for $n_H=10^4 cm^{-3}$, $T=10^4 K$, $\Delta R=0.,10^{18}$ cm and $U=10^7$ cm/s. Dashed lines correspond to case A, and an increase of ϕ/n_H leads to an increase of Hα/Hβ and Hβ/Hγ, since the lower levels are populated due to collisional excitation of the ground level by relativistic electrons. Solid curves correspond to case B and the behavior is related to the optical thickness of Balmer lines. The optical thickness of the Balmer lines, related to the excitation parameter ϕ/n_H by the ionization equations giving the value of the neutral hydrogen abundance, have a maximum at about $\phi/n_H=10^7$ cm/s.

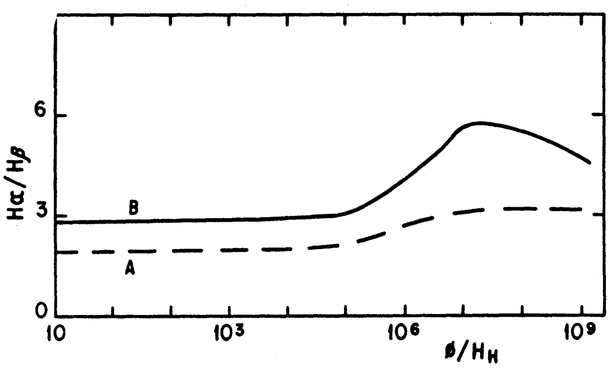


Fig. 1a: $H\alpha|H\beta$ versus $\phi|n_H$

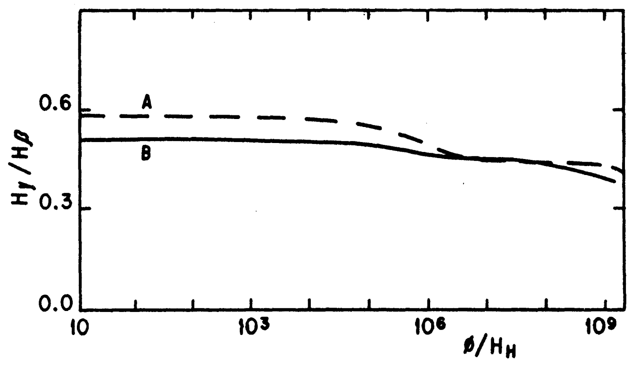
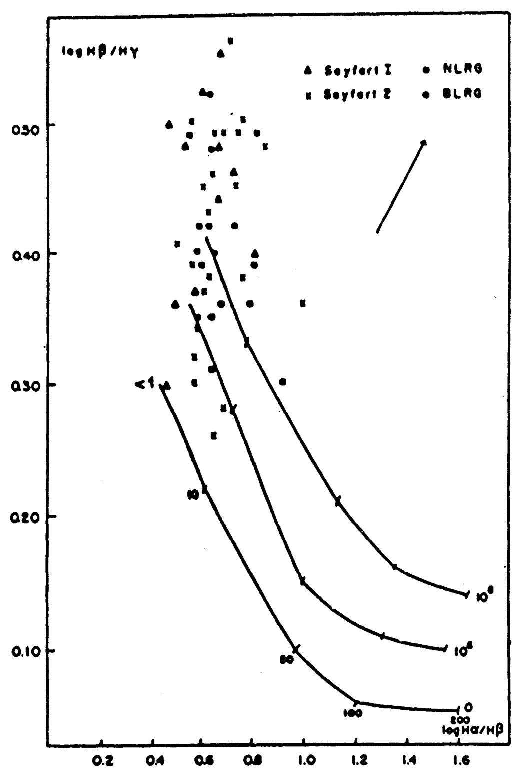


Fig. 1b: $H\gamma|H\beta$ versus $\phi|n_H$

In Fig. 2, the ratios $H\beta/H\gamma$ and $H\alpha/H\beta$ are plotted. The theoretical curves are labeled by ϕ/n_H value and parametized by the optical thickness of $H\alpha$. The results correspond to $T=10^4$K, $n_H=10^4$ cm^{-3} and $U=10^7$cm/s. The observational data (not corrected by reddening) correspond to the narrow Balmer lines and were taken from Cohen (1983), Costero and Osterbrock (1977), Koski(1978), Osterbrock and Miller (1975), Osterbrock et al. (1976), Osterbrock (1981), Shuder (1980), Shuder and Osterbrock (1981). The arrow indicates the reddening.



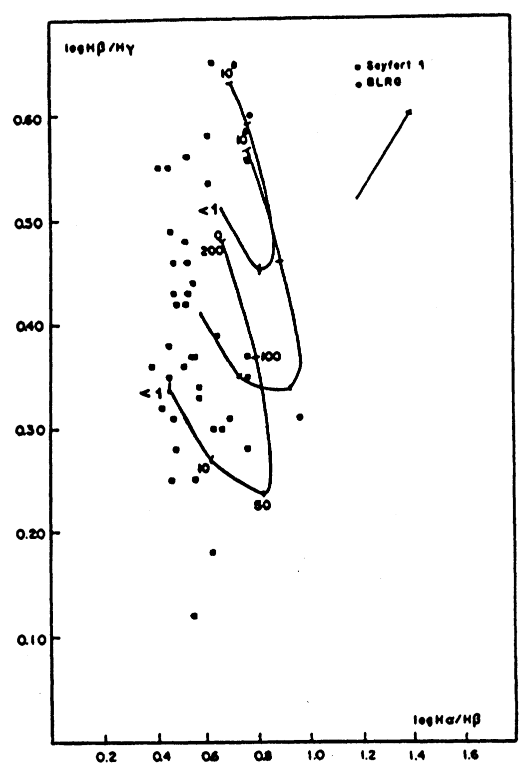


Fig. 2. $H\beta|H\gamma$ versus $H\alpha|H\gamma$ for $T = 10^4$ K, $U = 10^7$ cm/s and $n_H = 10^4$ cm^{-3}.

Fig. 3. $H\beta|H\gamma$ versus $H\alpha|H\gamma$ for $T = 10^4$ K, $U = 10^7$ cm/s and $n_H = 10^8$ cm^{-3}.

For a more dense cloud, the effect of collisional deexcitation of levels changes the theoretical line ratios. Their results are shown in Fig. 3. The hydrogen density is $10^8 cm^{-3}$, $T=10^4 K$ and $U=10^7$ cm/s. The observed broad line ratios are plotted (Anderson, 1970; Osterbrock et al. 1976; Osterbrock, 1977).

The main result of our calculations is that relativistic electrons, which are present in AGN showing radio emission, change the theoretical value of the Balmer decrement and their effect can mimic the presence of dust in AGN. For the broad line components the presence of energetic particles can change the value of the optical thickness of the emitting gas required to explain the observed ratios. In this case the effect on the other permitted lines should be studied as well as results considering higher densities should be obtained. Regarding the narrow component of Balmer lines, for objects where relativistic electrons are present, the accepted reddening by dust may in fact be overestimated.

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