HIGH DENSITIES IN QSO AND SEYFERT BROAD-LINE CLOUDS*

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ABSTRACT. While it is widely held that the densities of QSO and Seyfert broad-line regions lie below 10^{11} cm^{-3}, there is a growing body of evidence, indicating that at least some of the broad-line gas has densities equal to or exceeding 10^{11} cm^{-3}. Such evidence includes (1) the presence of a 3μm "bump" in roughly half of all QSOs, (2) the depression of Brγ in several Seyfert galaxies, (3) the broad-line variablity in some objects, and (4) the ability to produce the hydrogen spectrum theoretically.

1. INTRODUCTION

Recently, great strides have been made toward understanding the broad-line emission from QSOs and active galaxies. A fundamental aspect of all recent models is a high density, optically thick emission line region. The most often quoted argument against "extremely" high densities (>10^{10} cm^{-3}) is the presence of broad semi-forbidden emission (e.g. C III] λ1909, N IV] λ1486, O IV λ1402, and O III] λ1663--c.f. Kwan 1984). However, as pointed out by Hubbard and Puetter (1985), the "normal" critical density arguments against the efficient production of these lines relative to permitted lines are inappropriate since the permitted lines also suffer significant collisional effects due to large optical depths. Furthermore, theoretical calculations of the strengths of the semi-forbidden lines have not been done for high density, low ionization parameter conditions, conditions under which acceptable hydrogen line emission may be produced. Thus ruling out high densities may be premature.

2. EVIDENCE OF HIGH DENSITIES

A number of theoretical works (Canfield, Puetter, and Ricchiazzi 1981, Collin-Souffrin, Dumont, and Tully 1982, and Hubbard and Puetter 1985) demonstrate that acceptable hydrogen line emission can result from high density gas, and Hubbard and Puetter (1985) have pointed out that

* Discussion on p.356

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while the multi-element calculations (e.g. Kwan 1984) indicate that the observed semi-forbidden line strengths are inconsistent with high densities and "normal" ionization parameters, trends apparent in these same works indicate that acceptable emission might be obtained at high densities and lower ionization parameter. However, aside from these purely theoretical suggestions that the densities may be high, there are a number of observational results that suggest this as well.

Probabily the most direct indication of high densities comes from time variability studies of the broad-line emission. In Ark 120, for example, Peterson et. al (1985) demonstrate that the line variability constrains the broad-line region to be less than 30 light-days in size. This coupled with the large continuum brightness in this object, requires the densities to lie above 5×10^{10} cm^{-3} in order to have an ionization parameter which will not evaporate the broad-line clouds.

A second piece of observational evidence is the presence of the 3μm bump seen in QSO spectra. This bump could be naturally explained by free-free emission from the broad-line clouds if the densities lie at or above roughly 10^{11} cm^{-3} (Puetter and Hubbard 1985).

A final observational result is the observation by Cutri, Rieke, and Lebofsky (1984) that the Brγ line is depressed relative to Pα in a number of Seyfert galaxies. This observation could also be explained as due to free-free opacity effects. As described by Puetter and Hubbard (1985), preferential destruction of Brγ lines relative to Pα would occur upon conversion of the Brγ line to either 7→6 or 7→5 transitions followed by free-free continuum absorption.

3. CONCLUSIONS

There is mounting evidence of high densities in the broad-line regions of QSOs and active galaxies. The remaining pertinent question is whether all or only part of the emission line gas is at high density. If it becomes clear that most of the gas is at high density, then we may wish to question a number of fundamental aspects of our "cartoon" picture of the broad-line clouds. Indeed, in this case, the outer atmospheres of stars might make a quite viable candidate for the broad-line clouds.

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