LETTERS TO NATURE

PHYSICAL SCIENCES

Origin of Broad Emission Lines from Quasistellar Objects

THE optical spectra of QSOs exhibit very broad high-excitation emission lines. The broadest of these in the visible region for typical redshifts are the resonance lines Ly α λ 1216, CIV λ 1550 and MgII λ 2798 (ref. 1). Previous suggestions for the origin of the breadth of these lines include electron scattering and Doppler shifts due to turbulence or other mass motions in clouds of gas.

We have recently proposed a radially-streaming-proton model that gives an excellent fit to profiles of the broad H α emission lines from three different Seyfert galaxy nuclei (ref. 2 and our unpublished work). We suggest here that a similar idea will also explain the observed width of QSO emission lines. In the model, suprathermal protons slow down as they stream radially through a hydrogen gas that is at rest with respect to their source at the centre. Hydrogen emission from these protons occurs when they have slowed to speeds less than about 5,000 km s⁻¹ (about twice the speed of an electron in the first Bohr orbit), and are able to carry an electron for an appreciable fraction of the time. Thus the hydrogen emission profiles are predicted to all have overall Doppler widths at near zero intensity of about 10,000 km s⁻¹.

Fig. 1 Profile of Lyman alpha resulting from a radially-streaming-proton model for three different values of the transparency of the emitting region. The parameter Λ is the ratio of the photon mean free path to the radius of the emitting sphere: —, $\Lambda = \infty$; ---, $\Lambda = 5.0$; - · -, $\Lambda = 2.0$.

In Fig. 1 we display three profiles for Ly α computed in such a model using our (unpublished) atomic cross sections. The profiles differ only in the assumed transparency of the region where the emission originates, which is the only parameter in the model that changes the profile. The overall width is deter-

mined by atomic constants; the width of the profile, measured between the two inflexion points at complete transparency, amounts to $\Delta\lambda/\lambda$ equal to 3.3 times the fine structure constant. The total emission in Ly α from the streamers is computed to vary from about 600 photons per proton when the gas is neutral, to about 6 photons per proton at 90% ionization for the gas.

We have made preliminary calculations of profiles for CIV λ 1550, again assuming that the carbon nuclei are decelerating as they stream radially through a hydrogen gas. The necessary atomic cross sections are known with less certainty than for the Ly α case so the width is less well defined. It is clear, however, that the shape of the CIV resonance line should resemble the Ly α profile, especially in the wings, but be broader by a factor of approximately the square root of the ratio of the ionization potentials of CIV and hydrogen (about 2.2). Because it is primarily the speed of the outermost electron of the ion that determines the behaviour of the atomic cross sections for charge transfer and ionization, the widths of profiles of resonance lines of other ions can be predicted by the same scaling procedure.

There seem to be very few published high-resolution profiles of the broad emission lines from quasistellar objects, but those we have seen³ seem to agree with what we have calculated. Low resolution observations have been made on several QSOs by Oke^{4,5}. A detailed comparison of calculated and observed profiles is not meaningful at this resolution (about 50 to 100 Å), but it is interesting that the hydrogen lines are typically quite broad with a full-width at zero intensity on the order of 10,000 km s⁻¹, and the resonance line of CIV seems to be broader still. The data for 3C273 are consistent with half-half widths of the Balmer lines of about 2,500 km s⁻¹, which is what one expects from our model. What is needed for a good test is a determination of these profiles with a resolution of a few angstroms.

Because of apparent association of QSOs of different redshifts, the failure of QSOs to conform to the same Hubble law as known galaxies and the different redshifts of emission and absorption lines in the same QSO, it has been suggested that new physical laws may be required to describe them (ref. 6 and G. Burbidge, unpublished). If the profiles we have computed agree with QSO emission profiles as well as they do with the hydrogen emission profiles of Seyfert galaxies, then it will be strong evidence that at least the fine structure constant must have the same value in a QSO as it does in the Solar System.

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Received February 26, 1973.

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