The HST Spectrum of I Zw 1: Implications of the C III* λ1176 Emission Line

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Abstract. I Zw 1 is a well known narrow line quasar with very strong Fe II emission. High S/N spectra obtained with the HST FOS show a remarkably rich emission line spectrum. The C III* λ1176 line is clearly detected in emission for the first time in AGNs. This line arises from radiative decay to the 2s2p3P0, 1, 2 metastable levels of C III. The observed flux is ∼ 50 larger than expected from collisional excitation, or dielectronic recombination, in photoionized gas. The most plausible mechanism for the large enhancement in the C III* λ1176 flux is resonance scattering of continuum photons by C III* ions. This mechanism requires large velocity gradients (∼ 1000 km s⁻¹) within each emitting cloud in the BLR. Such large velocity gradients can be induced by forces external to the gas in the BLR clouds, such as tidal disruption, or radiation pressure.

1. Introduction

A very weak feature at 1176 Å was found by Laor et al. (1995) in three high S/N quasar spectra obtained by HST, and was tentatively identified as C III* λ1176. The rich UV emission line spectrum of the narrow line quasar I Zw 1 obtained by HST (Laor et al. in preparation) allowed us to clearly identify this feature as C III* λ1176. This line was previously detected in AGNs only in absorption (Bromage et al. 1985, Kriss et al. 1992). The line originates from radiative transition of electrons at the 2p23P₀,1,2 levels (17.1 eV above the ground level), down to the 2s2p3P₀,1,2 levels (6.5 eV above the ground level). Given the high energy of the 2p² 3P₀,1,2 levels, the presence of significant C III* λ1176 emission appears surprising.

2. The Calculations

In order to calculate the C III* λ1176 line flux we solved the equilibrium equations for the population of the lowest 10 levels of C III (n=2 levels). Collisional coupling of all levels, and radiative decay to all levels are included. The contributions of recombination (mostly dielectronic) and continuum fluorescence
to the level population were not included since they are not important for the observed line flux.

We find that for typical BLR conditions which are able to generate significant C III λ1909 emission ($n_e \leq 10^{10}$), the $f(1176)/f(1909)$ ratio is at least 50 times smaller than observed.

3. Why is C III* λ1176 strongly enhanced?

3.1. A High Density Component in the BLR?

The observed $f(1176)/f(1909)$ ratio is obtained for $n_e = 11.5$. But this ratio is obtained because λ1909 is strongly suppressed at such a high density, and not because λ1176 is enhanced. A high density component cannot produce the observed λ1176 flux even for a covering factor of $\sim 100\%$

3.2. Dielectronic Recombination?

Dielectronic recombination is ruled out based on line ratios. It predicts a ratio of 2.5 for $f(2297)/f(1176)$, compared with an observed ratio $< 0.2$.

3.3. Collisionally Ionized Gas?

The observed $f(1176)/f(1909)$ is obtained for $T > 2.5 \times 10^4$ K. Such a component was also inferred by Kriss et al. (1992) in NGC 1068, based on the C III λ977 and N III λ990 lines. However, the overall observed emission line spectrum is fit well by photoionization models, rather than collisional ionization models.

3.4. Resonance Scattering?

The EW produced by resonance scattering of continuum photons in the BLR is: $EW = C\Delta v/c \times \min(1, \tau)$, where $C$ is the BLR covering factor, $\Delta v$ is the velocity dispersion within the cloud, and $\tau$ is the line center optical depth (for $\tau \gg 1$, the $EW$ is increased by $\sqrt{\ln \tau}$). The optical depth is $\tau = 1.5 \times 10^6 \Delta v_10^{-1} \Sigma n_i f_{ij}$, where $\Delta v = 10\Delta v_10$ km s$^{-1}$, and the sum is over the 6 permitted transitions contributing to the λ1176 line. We get $\tau = 1000$-$6000\Delta v_10$ for $n_e = 8$-$10$. Thus the observed C III* λ1176 EW of 1.4 Å can be produced if $\Delta v = \text{FWHM}(\lambda 1176) = 1000$ km s$^{-1}$, and $C \sim 0.35$. A similar process of continuum fluorescence was invoked by Ferguson et al. (1995) to explain the strong C III λ977 and N III λ990 lines in NGC 1068.

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