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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 $2s2p\ ^3\mathrm{P}^o_{0,1,2}$ metastable levels of C III. The observed flux is ~ 50 *times 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* ($\sim 1000\,\mathrm{km\,s^{-1}}$) 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 $2p^2\ ^3\mathrm{P}_{0,1,2}$ levels (17.1 eV above the ground level), down to the $2s2p\ ^3\mathrm{P}^o_{0,1,2}$ levels (6.5 eV above the ground level). Given the high energy of the $2p^2\ ^3\mathrm{P}_{0,1,2}$ 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] $\lambda1909$ emission ($n_e \leq 10^{10}\,\mathrm{cm}^{-3}$), 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 $\log n_e = 11.5$. But this ratio is obtained because C III $\lambda1909$ is strongly suppressed at such a high density, and not because $\lambda1176$ is enhanced. A high-density component cannot produce the observed $\lambda1176$ flux even for a covering factor of unity.

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 $T > 2.5\times10^4$ K. Such a component was also inferred by Kriss et al. (1992) in NGC 1068, based on the C III $\lambda977$ and N III $\lambda990$ 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: $EW = C\lambda\Delta v/c \times \min(1,\tau)$, where C is the BLR covering factor, Δv is the velocity dispersion within the cloud, and τ is the line center optical depth (for $\tau \gg 1$, the EW is increased by $\sqrt{\ln\tau}$). The optical depth is $\tau = 1.5\times10^6\Delta v_{10}^{-1}\Sigma_{i,j} n_i f_{ij}$, where $\Delta v = 10\Delta v_{10}\,\mathrm{km\,s^{-1}}$, and the sum is over the 6 permitted transitions contributing to the $\lambda1176$ line. We get $\tau = 1000$–$6000\,\Delta v_{10}^{-1}$ for $\log n_e = 8$–10. Thus the observed C III* $\lambda1176$ EW of 1.4 Å can be produced if $\Delta v = \mathrm{FWHM}(\lambda1176) = 1000\,\mathrm{km\,s^{-1}}$, and $C \approx 0.35$. A similar process of continuum fluorescence was invoked by Ferguson et al. (1995) to explain the strong C III $\lambda977$ and N III $\lambda990$ lines in NGC 1068.

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