**HST** Eclipse Mapping of the Dwarf Nova OY Carinae in Quiescence: An “Fe II Curtain” with Mach \( \approx 6 \) Velocity Dispersion Veils the White Dwarf

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**Abstract.** *HST* observations of the eclipsing dwarf nova OY Car in its quiescent state are used to isolate the ultraviolet spectrum (1150–2500 Å at 9.2 Å FWHM resolution) of the white dwarf, the accretion disk, and the bright spot. The white dwarf dominates the ultraviolet flux, with the disk and bright spot contributions increasing longward of 2000 Å. The white dwarf spectrum has a Stark-broadened photospheric Lyα absorption, but is veiled by a forest of blended Fe II features that we attribute to absorption by intervening disk material. A fit gives \( T_W \approx 16.5 \times 10^3 \)K for the white dwarf with a solar-abundance, \( \log g = 8 \) model atmosphere, and \( T \approx 10^4 \)K, \( n_e \approx 10^{13} \)cm\(^{-3} \), \( N_H \approx 10^{22} \)cm\(^{-2} \), and velocity dispersion \( \Delta V \approx 60 \) km s\(^{-1} \) for the veil of homogeneous solar-abundance LTE gas.

The veil parameters probably measure characteristic physical conditions in the quiescent accretion disk or its chromosphere. The large velocity dispersion is essential for a good fit; it lowers \( \chi^2/778 \) from 22 to 4. Keplerian shear can produce the velocity dispersion if the veiling gas is located a \( R \approx 5R_W \). But this model leaves an unobserved view to the upper hemisphere of the white dwarf, whereas the absorptions are up to 80% deep. The veiling gas may be in the upper atmosphere of the disk near its outer rim, but we then require supersonic (Mach \( \approx 6 \)) but sub-Keplerian (\( \Delta V/V_{Kep} \approx 0.07 \)) velocity disturbances in this region to produce both the observed radial velocity dispersion and vertical motions sufficient to elevate the gas to \( z/R = \cos i = 0.12 \).

1. **Introduction**

The Hubble Space Telescope (*HST*) has high ultraviolet sensitivity and fast photon-counting spectrographs that make it possible to study eclipsing cataclysmic variables in the ultraviolet, providing new information about the spatial structure of the sources of ultraviolet radiation within the accretion flow. Based
on time-resolved ultraviolet spectroscopy of an eclipse of the dwarf nova OY Car obtained with HST's Faint Object Spectrograph (FOS), we decompose the data into white dwarf, bright spot, accretion disk, and flickering components and develop a fit to the observed white dwarf spectrum using a model atmosphere in local thermodynamic equilibrium (LTE) for solar abundance and \( \log g = 8 \) observed through a veil of cooler solar abundance LTE gas that produces a forest of Fe II absorption features. The veiling gas has a supersonic but sub-Keplerian velocity dispersion, and is probably the chromosphere above the outer regions of the disk, the same gas that produces Balmer continuum and line emission in the optical.

2. HST Observations

We used the FOS with the Blue Digicon detector in its RAPID readout mode to obtain a 39m sequence of 234 spectra of OY Car in quiescence on UT 1991 December 4. For details, look for Horne et al. (1993).

![Figure 1.](image1)

![Figure 2.](image2)

Figure 1 shows the eclipse light curve extracted from the time-resolved FOS spectra of OY Car obtained with the G160L grating. The zeroth-order reflection from this grating gives the spectrum from 1150 – 2500 Å at 9.2 Å FWHM resolution. The UV light curves show mainly the sharp eclipse of the white dwarf by the red dwarf companion star. The disk and bright-spot causes the brightness level to be higher before eclipse than after, and also produces a marked ingress and egress feature that is delayed relative to those of the white dwarf. The disk has a broad eclipse and causes the flux that remains at mid-eclipse, when both the white dwarf and bright spot are eclipsed.

Figure 2 shows the UV spectra of OY Car in quiescence obtained for the out-of-eclipse and at mid-eclipse phases of the observation. The white dwarf dominates the out-of-eclipse spectrum, which has a complicated pattern caused
mainly by blended Fe II absorption lines that we think are produced by intervening disk material.

3. Decomposition

We decomposed the data into white dwarf, bright spot, and accretion disk contributions each with a distinct spectrum and light curve. A simple numerical model was used to compute light curves for the eclipse of each component by the Roche lobe of the companion star. Figure 3 shows the fit to the data in selected wavelength bands obtained by scaling the light curves of the three components. The fit residuals show fast flares lasting about a minute that appear to cease during the eclipse of the white dwarf. These flares may represent unstable flows in the boundary layer region where the disk material loses its orbital velocity and settles onto the white dwarf. Figure 4 shows the UV spectra obtained separately for the white dwarf, bright spot, and accretion disk. At each wavelength we obtained the fluxes of the three components by scaling the light curves as in Figure 3. This procedure cleanly isolated the spectra of the three components. Note that the C IV and Lα lines are not correctly modeled by this procedure.

![Figure 3.](image1)

![Figure 4.](image2)

4. Modeling the White Dwarf Spectrum

Figure 5 shows our first attempts to fit the white dwarf spectrum using a log $g = 8$ model atmosphere. A temperature of about 15,000 K is needed to fit the optical UBR fluxes. The pure hydrogen spectrum fits the optical data but lacks the Fe II absorptions needed to fit the HST data. The solar abundance model has line blanketing in the ultraviolet, but the pattern is totally different from what we see in OY Car. If we boost the Fe abundance to 1000 times solar, we obtain Fe II absorptions of roughly the correct depth, but the pattern of these
absorptions is all wrong. We found no combination of temperature, gravity, and composition that could fit the HST spectrum.

Since a bare white dwarf spectrum fails to fit the HST data, we tried models which pass the white dwarf spectrum through a slab of intervening material. Since we view the white dwarf at an inclination of 83°, the line of sight passes through the upper atmosphere of the accretion disk, and hence we expect absorption by gas near the outer rim of the disk. Figure 6 shows a good fit with \( T_W \sim 16.5 \times 10^3 \)K, \( D \sim 100 \) pc for the white dwarf temperature and distance, if we model the intervening material as a slab of LTE gas with \( T \sim 10^4 \)K, \( n_e \sim 10^{13} \text{cm}^{-3} \), \( N_H \sim 10^{22} \text{cm}^{-2} \), and velocity dispersion \( \Delta V \sim 60 \text{ km s}^{-1} \). The absorbing medium has an optical depth of about 0.1 in the Balmer continuum, and is hence likely to be the same gas that produces the Balmer line and continuum emission seen in the optical spectrum. The Mach \( \sim 6 \) velocity dispersion is required for a good fit; it reduces the \( \chi^2/778 \) from 22 to 4. The spectral resolution is only 1500 km s\(^{-1}\), but we can still determine the velocity dispersion accurately because it de-saturates the strongest absorption lines, enhancing their strengths relative to weaker lines. The observed velocity dispersion implies that the vertical structure of the outer disk is supported not mainly by thermal pressure but rather by supersonic but sub-Keplerian disturbances.

![Figure 5](image_url)

![Figure 6](image_url)

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**References**