Optical Spectroscopy of GRO J1655−40

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abstract

We have obtained optical spectra of the soft X-ray transient GRO J1655−40 during different X-ray spectral states (quiescence, high-soft and hard outburst) between 1994 August and 1997 June. Characteristic features observed during the 1996–97 high-soft state were: a) broad absorption lines at Hα and Hβ, probably formed in the inner disk; b) double-peaked He II λ4686 emission lines, formed in a temperature-inversion layer on the disk surface, created by the soft X-ray irradiation; c) double-peaked Hα emission, with a strength associated with the hard X-ray flux, suggesting that it was probably emitted from deeper layers than He II λ4686. The He II λ4686 line profile appeared approximately symmetric, as we would expect from a disk surface with an axisymmetric emissivity function. The Balmer emission, on the other hand, appeared to come only from a double-armed region on the disk, possibly the locations of tidal density waves or spiral shocks. The observed rotational velocities of all the double-peaked lines suggest that the disk was extended slightly beyond its tidal radius.

Three classes of lines were identified in the spectra taken in 1994 August–September, during a period of low X-ray activity between two strong X-ray flares: broad absorption, broad (flat-topped) emission and narrow emission. We have found that the narrow (single-peaked or double-peaked) emission lines cannot be explained by a conventional thin accretion disk model. We propose that the system was in a transient state, in which the accretion disk might have had an extended optically thin cocoon and significant matter outflow, which would also explain the systematic blue-shift of the narrow emission lines and the flat-topped profiles of the broad emission lines.

After the onset of a hard X-ray flare the disk signatures disappeared, and strong single-peaked Hα and Paschen emission was detected, suggesting that the cocoon became opaque to optical radiation. High-ionization lines disappeared or weakened. Two weeks after the end of the flare, the cocoon appeared to be once again optically thin.