When two commuting isometries are doubly commuting

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A commuting pair $V = (V_1, V_2)$ of isometries on a Hilbert space $\mathcal{H}$ is said be doubly commuting if $V_1^* V_2 = V_2 V_1^*$, where V_1^* denotes the Hilbert space adjoint of V_1. The discussion aims to establish a necessary and sufficient condition for a pair of commuting isometries to be doubly commuting.