$$\frac{\partial^2 S}{\partial M^2} = \frac{4\pi \left(\sqrt{1-q^2}\right)^3 + 4\pi - 6\pi q^2}{\left(\sqrt{1-q^2}\right)^3}$$

$$\frac{\partial^2 S}{\partial Q^2} = \frac{-2\pi - 2\pi(\sqrt{1-q^2})^{3/2}}{(1-q^2)^{3/2}}$$

$$\frac{\partial^2 S}{\partial M \partial Q} = \frac{2\pi q^3}{\left(\sqrt{1-q^2}\right)^3}$$