$$\begin{cases} \frac{dx}{dt} &= v_x \\ \frac{dy}{dt} &= v_y \\ \frac{dv_x}{dt} &= -Gm\frac{x}{r^3} \\ \frac{dv_y}{dt} &= -Gm\frac{y}{r^3} \end{cases}$$

$$r = \sqrt{x^2 + y^2}$$

$$\frac{d}{dt}\begin{pmatrix} x \\ y \\ v_x \\ v_y \end{pmatrix} = f\begin{pmatrix} x \\ y \\ v_x \\ v_y \end{pmatrix} = \begin{pmatrix} 0 & 0 & v_x & 0 \\ 0 & 0 & 0 & v_y \\ \frac{-Gmx}{r^3} & 0 & 0 & 0 \\ 0 & \frac{-Gmy}{r^3} & 0 & 0 \end{pmatrix}$$

$$u = (x, y, v_x, v_y)$$

$$\frac{\partial f}{\partial u} = \begin{pmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ Gm\left(\frac{x^2}{r^3} - \frac{1}{r}\right) & Gm\left(\frac{xy}{r^3}\right) & 0 & 0 \\ Gm\left(\frac{xy}{r^3}\right) & Gm\left(\frac{y^2}{r^3} - \frac{1}{r}\right) & 0 & 0 \end{pmatrix}$$

wartości własne:

$$\sigma = \left\{0,\, 0,\, -i\sqrt{\frac{Gm}{r}},\, i\sqrt{\frac{Gm}{r}}\right\}$$

$$\Delta t \leq \text{const}\, \sqrt{\frac{r}{Gm}}$$