A normal form of your dynamical system

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Generally, the lowest order, most important, terms are near the end of each expression.

off echo;

Specified dynamical system

$\dot{x}_1 = -\varepsilon x_1 y_1$

$\dot{y}_1 = \sigma w_1 + \varepsilon(x_1^2 - 2y_1^2) - y_1$

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Time dependent normal form coordinates

$y_1 = 4\sigma\varepsilon \mathrm{e}^{-1t} \star w_1 \, Y_1 + \sigma \mathrm{e}^{-1t} \star w_1 \, + \varepsilon(X_1^2 + 2Y_1^2) + Y_1$

$x_1 = \sigma\varepsilon \mathrm{e}^{-1t} \star w_1 \, X_1 + \varepsilon X_1 Y_1 + X_1$

Result normal form DEs

$\dot{Y}_1 = 8\sigma^2\varepsilon^2 \mathrm{e}^{-1t} \star w_1 \, w_1 Y_1 - 4\sigma\varepsilon w_1 Y_1 - 2\varepsilon^2 X_1^2 Y_1 - Y_1$

$\dot{X}_1 = 2\sigma^2\varepsilon^2 \mathrm{e}^{-1t} \star w_1 \, w_1 X_1 - \sigma\varepsilon w_1 X_1 - \varepsilon^2 X_1^3$