we start with our non-dimensional eqns. for mutual repression.

\[
\frac{d\tilde{y}}{d\tau} = \frac{\tilde{y}}{4} (1 - \tilde{y} - \tilde{z}) - \gamma_1
\]

\[
\frac{d\tilde{z}}{d\tau} = \frac{\tilde{z}}{4} (1 - \tilde{y} - \tilde{z}) - \gamma_2
\]

with

\[
\tau = \frac{d\tau}{dt}
\]

\[
\gamma = \frac{d\gamma}{dt}
\]

\[
\tilde{y} = \frac{y}{y_0}
\]

\[
\tilde{z} = \frac{z}{z_0}
\]

\[
F \rightarrow \frac{d\tau}{d\gamma}
\]

what can we learn about the system's dynamics?

we doing much math/simulations?

- Calculate the nullclines

\[
\frac{d\tilde{y}}{d\tau} = \frac{\tilde{y}}{4} (1 - \tilde{y} - \tilde{z}) - \gamma_1
\]

\[
\frac{d\tilde{z}}{d\tau} = \frac{\tilde{z}}{4} (1 - \tilde{y} - \tilde{z}) - \gamma_2
\]

- Calculate \( \gamma(t) \) and \( \tilde{z}(t) \) given some initial cond.

- Plot \( \tilde{y}(t) \) and \( \tilde{z}(t) \) vs. \( t \)

- Plot \( (\tilde{y}, \tilde{z}) \) on the phase portrait.

\[
\tilde{y}(\tau = 2\tau) = \tilde{y}(\tau) + \frac{\tilde{y}}{4 \tilde{z}(\tau) + \tilde{z}} \Delta \tau - \gamma \tilde{y}(\tau) \Delta \tau
\]

\[
\tilde{z}(\tau = 2\tau) = \tilde{z}(\tau) + \frac{\tilde{z}}{4 \tilde{z}(\tau) + \tilde{y}} \Delta \tau - \gamma \tilde{z}(\tau) \Delta \tau
\]

We computed the vector field in Python.

- Plot \( (\tilde{y}, \tilde{z}) \) on the phase portrait.