Enzyme rhythms in model inducilator - spontaneous oscillations

Model name: inducilator

o Optimisation problem
- Protein turnover time 1.8e+03 s = 30 min
- No external perturbation considered
- Scored quantity: v1
- Scored quantity: v2
- Scored quantity: v3
- State-averaged fitness
- Posttranslational rhythms allowed
- Standard frequency considered f : 0.0333/s (period 30 s)

o Model properties:
- inactive_enzymes: 0
- balanced_reference_state: 1
- consider_external_rhythm: 0
- adaptive_rhythm: 0
- spontaneous_rhythm: 1
- spontaneous_rhythm_at_omega: 0
- has_spontaneous_rhythm_and_inactive_enzymes: 0

o Beneficial self-induced oscillation found
- Maximum principal synergy found (in tested range) at frequency f =0.501/s (period 2 s)
- Maximum fitness found (in tested range) at frequency f =0.316/s (period 3.16 s)

o Self-induced oscillations?
- No beneficial self-induced oscillations (2nd order, amplitude below 1/2 of mean) found at frequency f = 0.0333/s (principal synergy = -0.000102): Predicted fitness change -0.000228

o Numerical calculation (self-induced rhythm, amplitude below 1/2 of mean, f=0.0333)
- Fitness change (fitness-averaged) : 2.88e-07
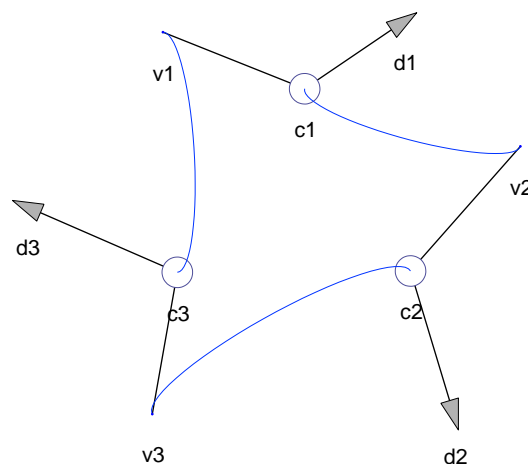- Fitness change (state-averaged): 4.15e-07

Figure 1: Network and reference flux

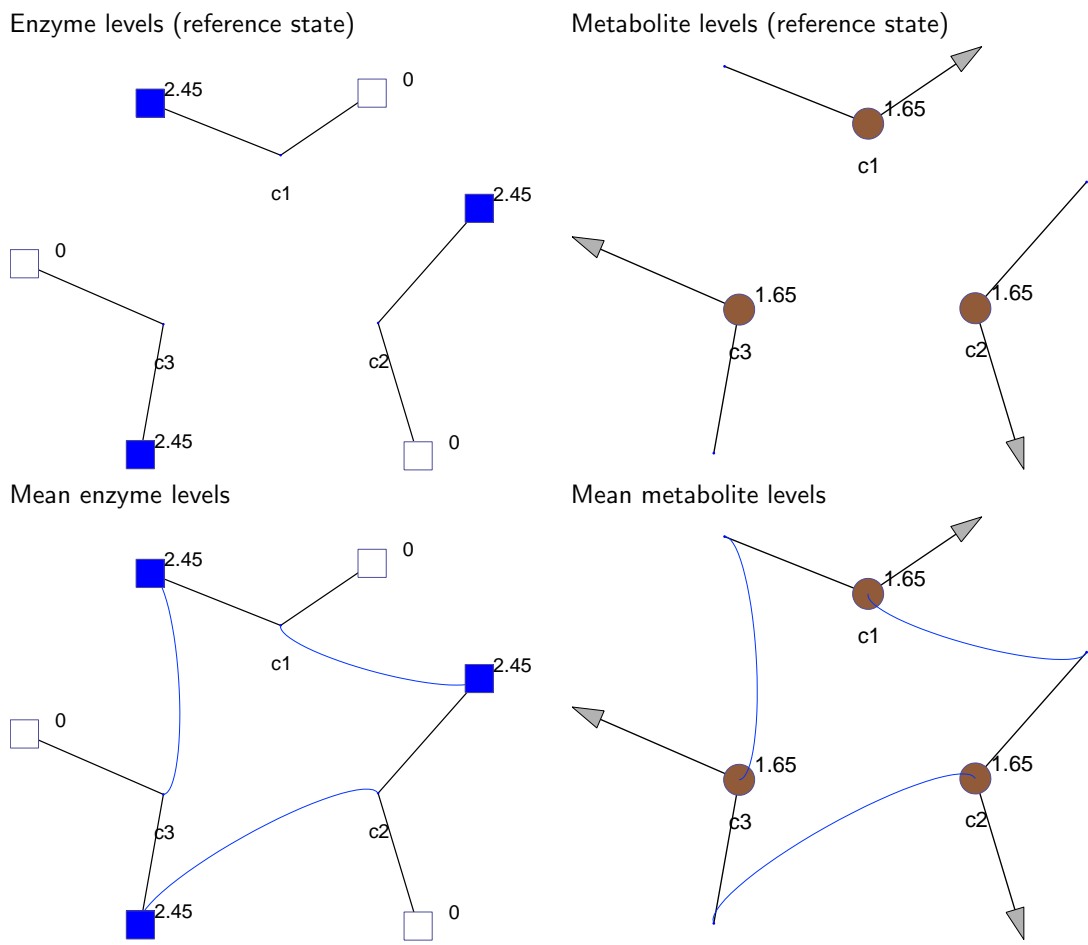Enzyme levels (reference state)

Metabolite levels (reference state)

Mean enzyme levels

Mean metabolite levels

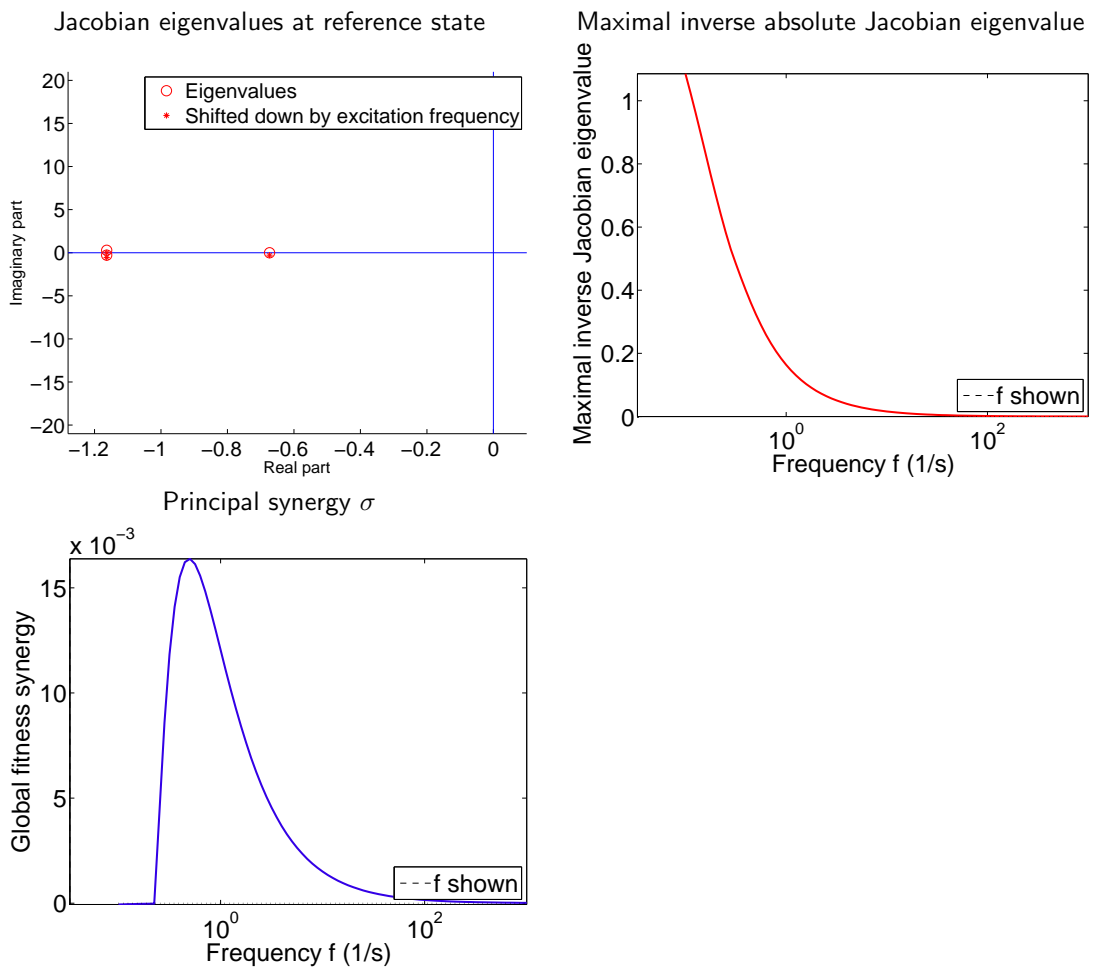Figure 2: Reference state (top) and mean state during oscillation (bottom).

Figure 3: Control analysis: fitness curvatures. Left: Frequency-dependent fitness curvature eigenvalues. Right: relative sizes and phases of the individual enzyme levels (components of the leading fitness curvature eigenvector).
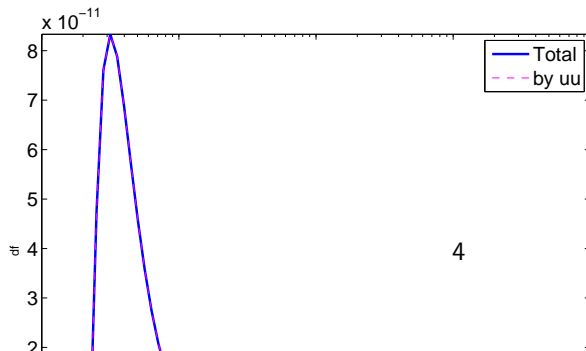
Protein level and enzyme activity (mean and amplitude)

Enzyme u1
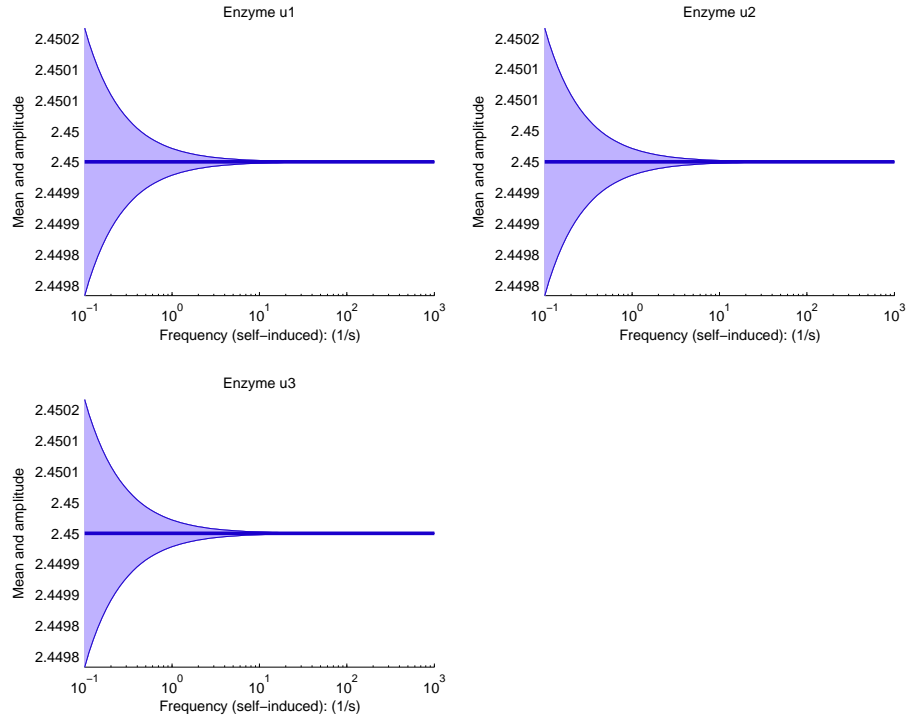
Enzyme u2

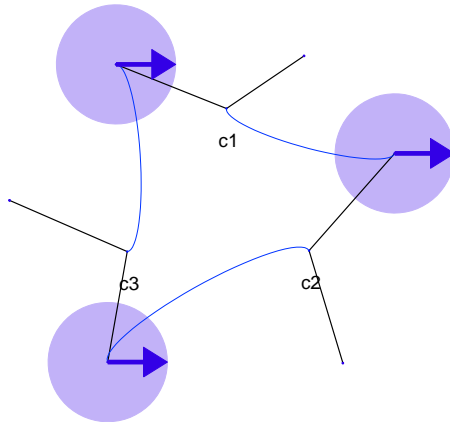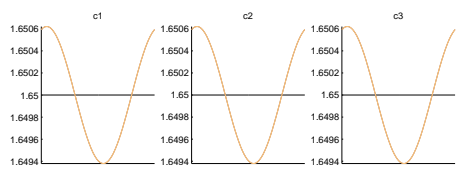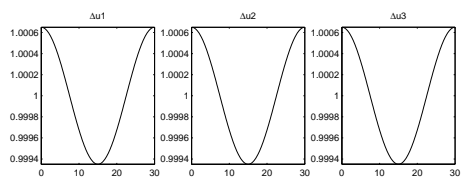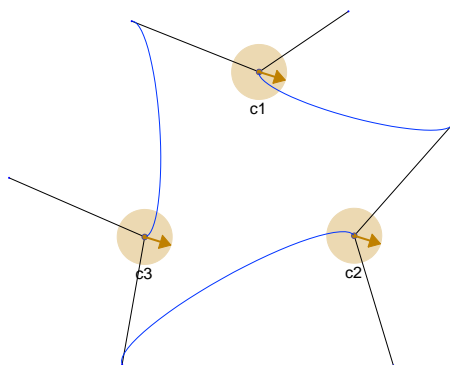### Enzyme u3

Phase angles $[0, 2\pi]$

Fitness change

4
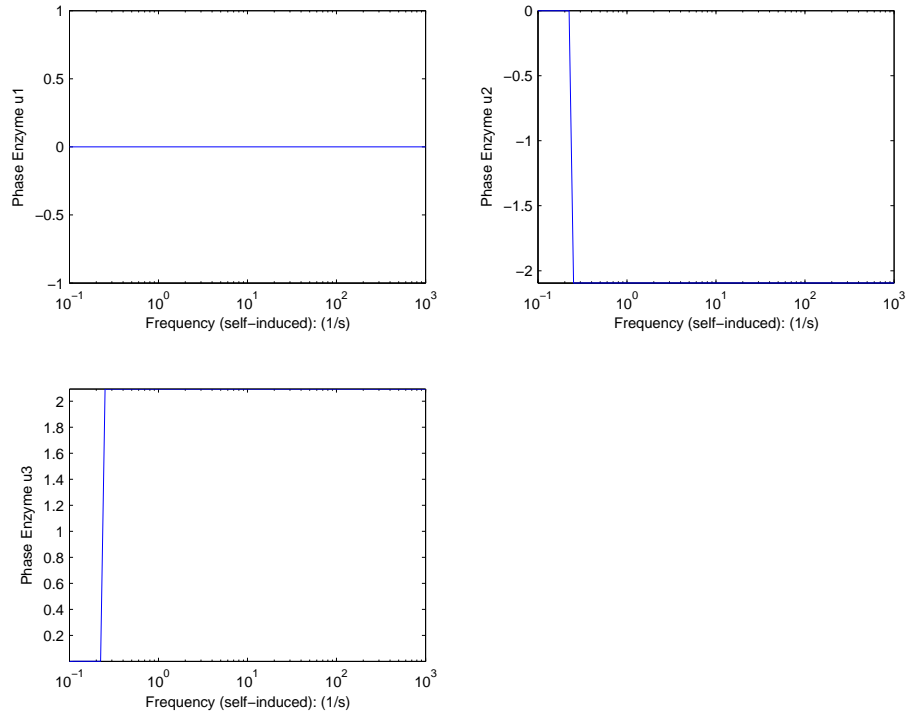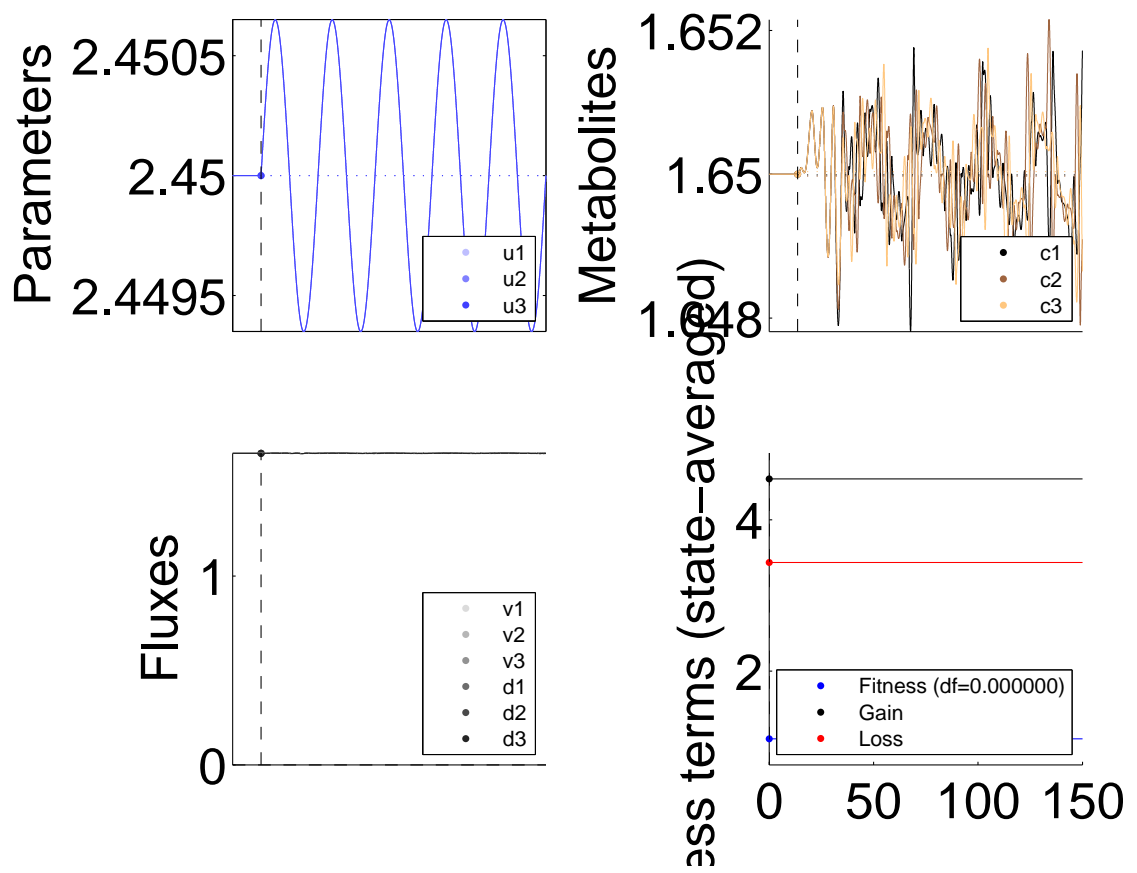
Figure 5: Numerical calculations: spontaneous oscillations. Perturbation frequency see first page.
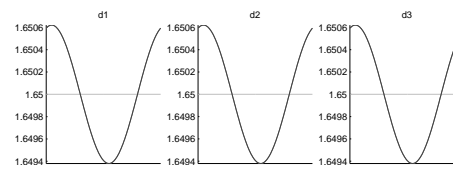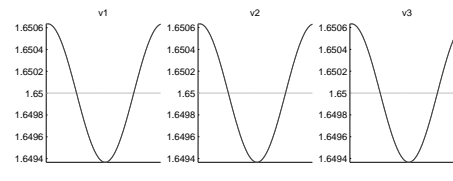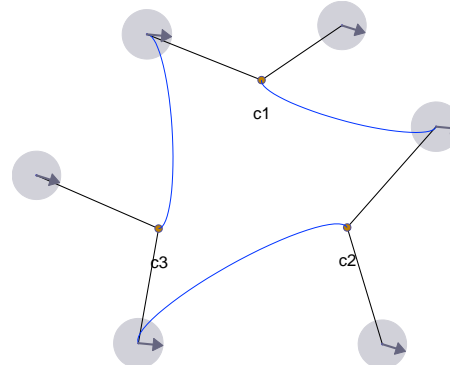
Figure 6: Spontaneous oscillations (local expansion; arrows: absolute changes). Perturbation frequency see first page.
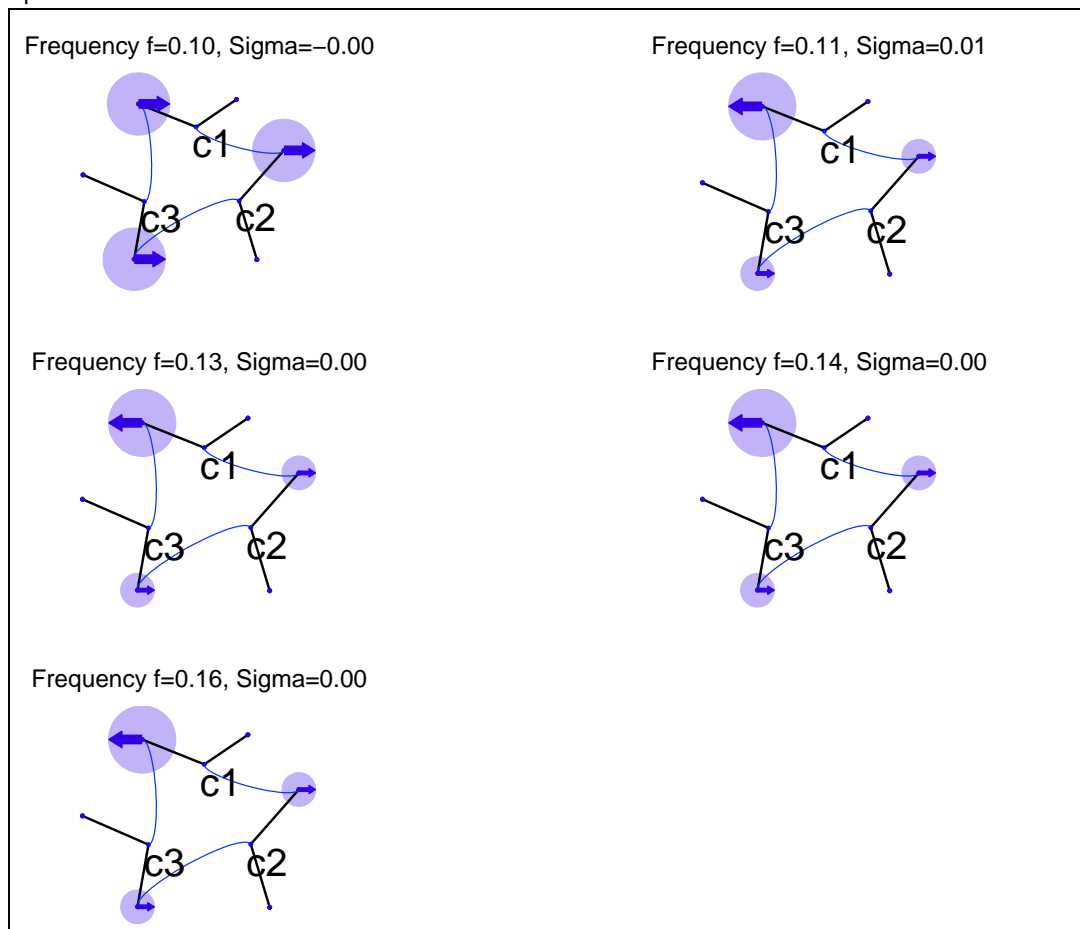
Spontaneous oscillations

Figure 7: Spontaneous oscillations (or tendencies towards them) for various circular frequencies ω. If the maximal fitness curvatures λ is positive, the rhythm is beneficial (local expansion; arrows: absolute changes).