Enzyme rhythms in model four_cycle.speedy - spontaneous oscillations

Model name: four_cycle

o Optimisation problem
- Protein turnover time 1 s = 0.0167 min
- Perturbed parameter(s) : x1
- Perturbation frequency f : 0.444/s (period 2.25 s)
- Scored quantity: v3
- Fitness-averaged fitness
- No posttranslational rhythms allowed
- Standard frequency considered f : 0.444/s (period 2.25 s)

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

o Beneficial autonomous oscillation found
- Maximum principal synergy found (in tested range) at frequency f =0.631/s (period 1.58 s)
- Maximum fitness found (in tested range) at frequency f =0.447/s (period 2.24 s)

o Fitness changes after external perturbation at frequency f=0.444/s
- Change by perturbation alone (xx): -2.22e-08

o autonomous oscillations?
- Maximally autonomous oscillations (in tested range) at f = 0.631, principal synergy 0.0141
- Beneficial autonomous oscillations found at frequency f = 0.444/s (principal synergy = 0.0114)
- Predicted fitness change (autonomous, 2nd order, amplitude below 1/2 of mean) at frequency f =0.444: 0.00123
- Predicted maximal fitness change (autonomous, numeric opt, full amplitude constraints) at frequency f =0.447: 5.33e-06
WARNING: an external rhythm is given and a autonomous rhythm has been found

o Numerical calculation (responsive, f=0.444)
- Fitness change (fitness-averaged): -5.36e-05
- Fitness change (state-averaged): -5.36e-05

o Numerical calculation (autonomous rhythm, amplitude below 1/2 of mean, f=0.444)
- Fitness change (fitness-averaged) : 3.87e-05
- Fitness change (state-averaged): 3.91e-05

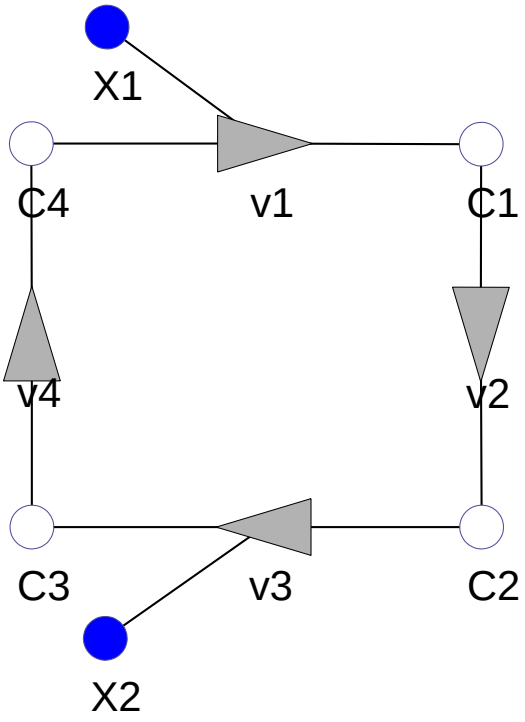

Figure 1: Network and reference flux

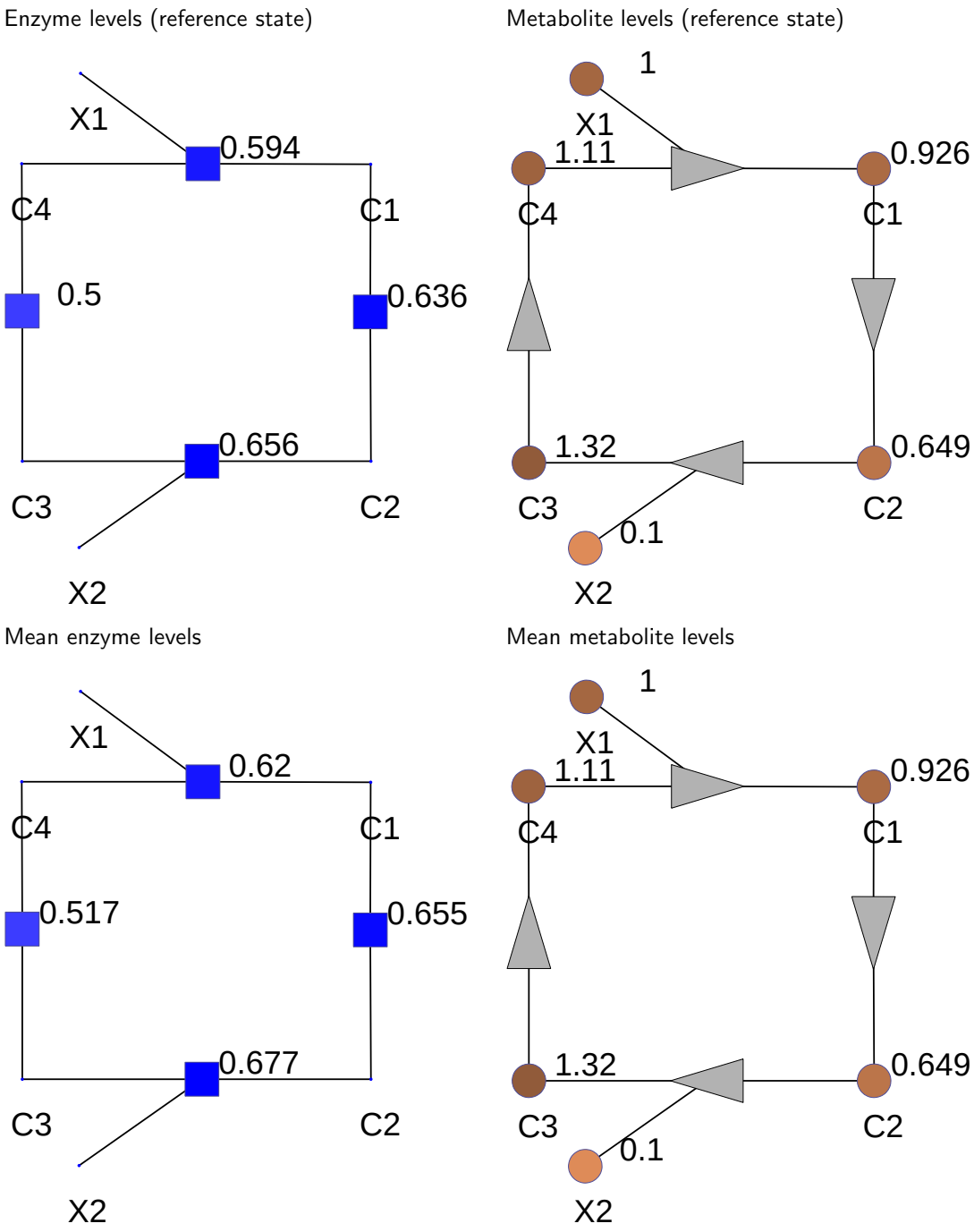

Figure 2: Reference state (top) and mean state during oscillation (bottom).

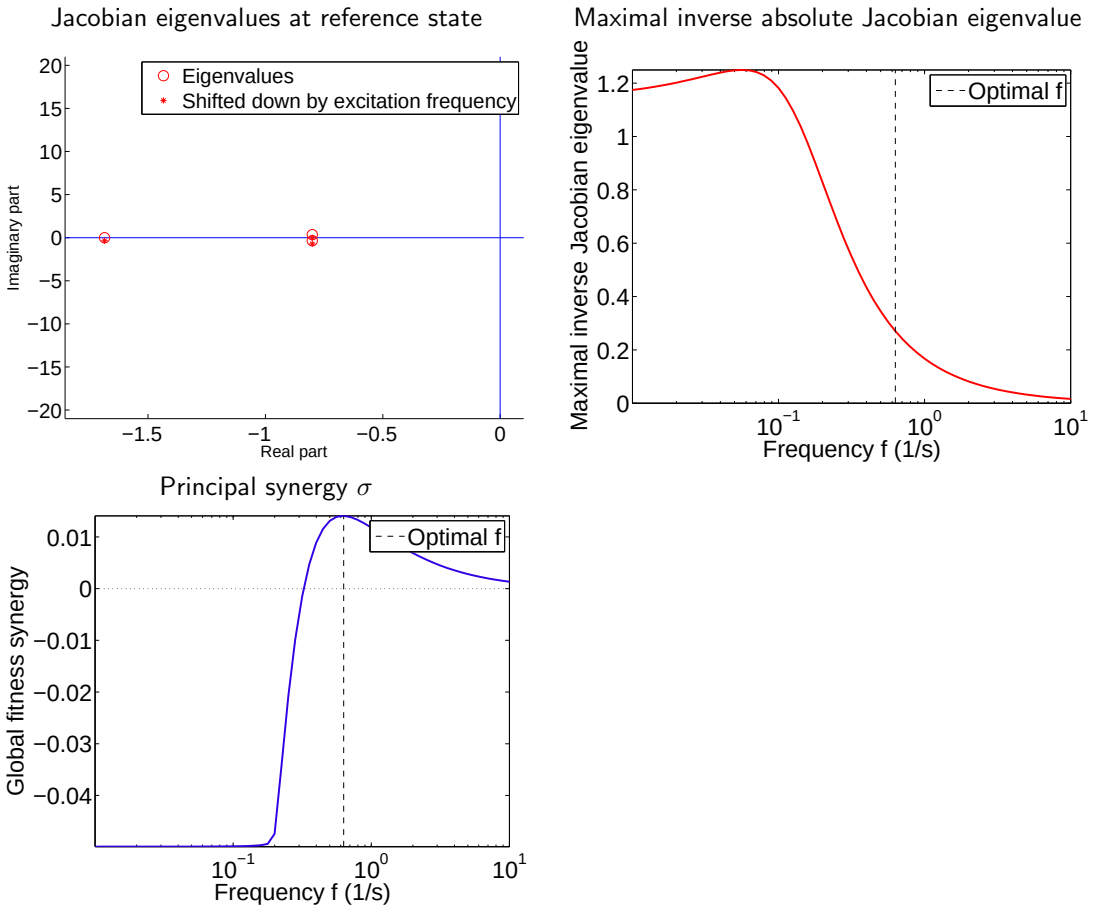

Figure 3: Control analysis: fitness curvatures. Left: Frequency-dependent fitness curvature eigenvalues. Right: relative sizes and phases of the individual enzyme levels (components of the leading fitness curvature eigenvector).

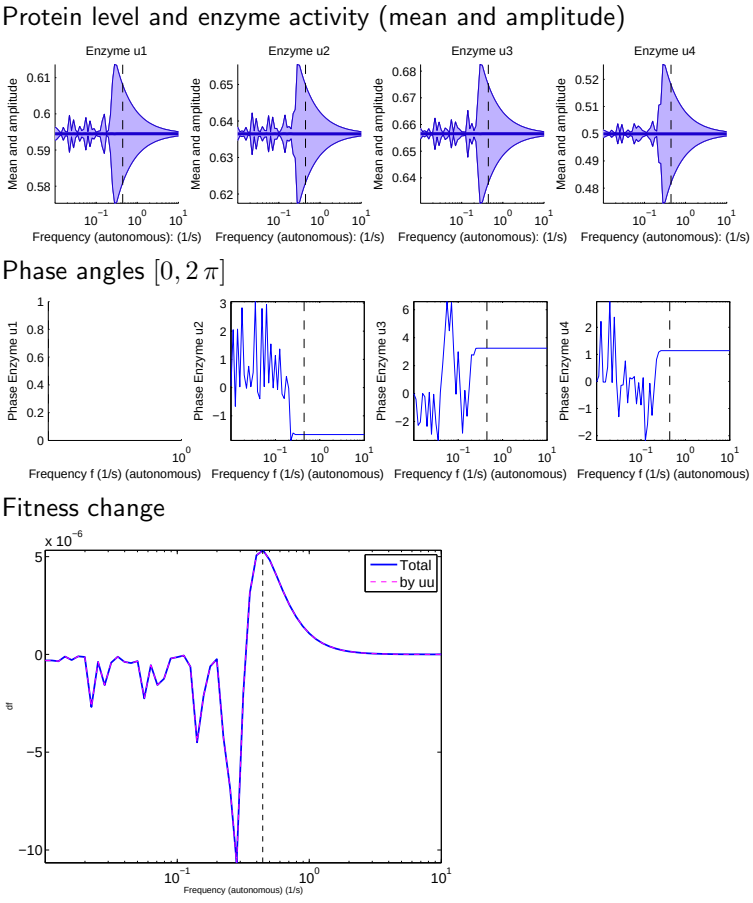

Figure 4: Self-promoting oscillations. Left: amplitudes of protein levels (blue) and modification (grey). Right: phase shifts.

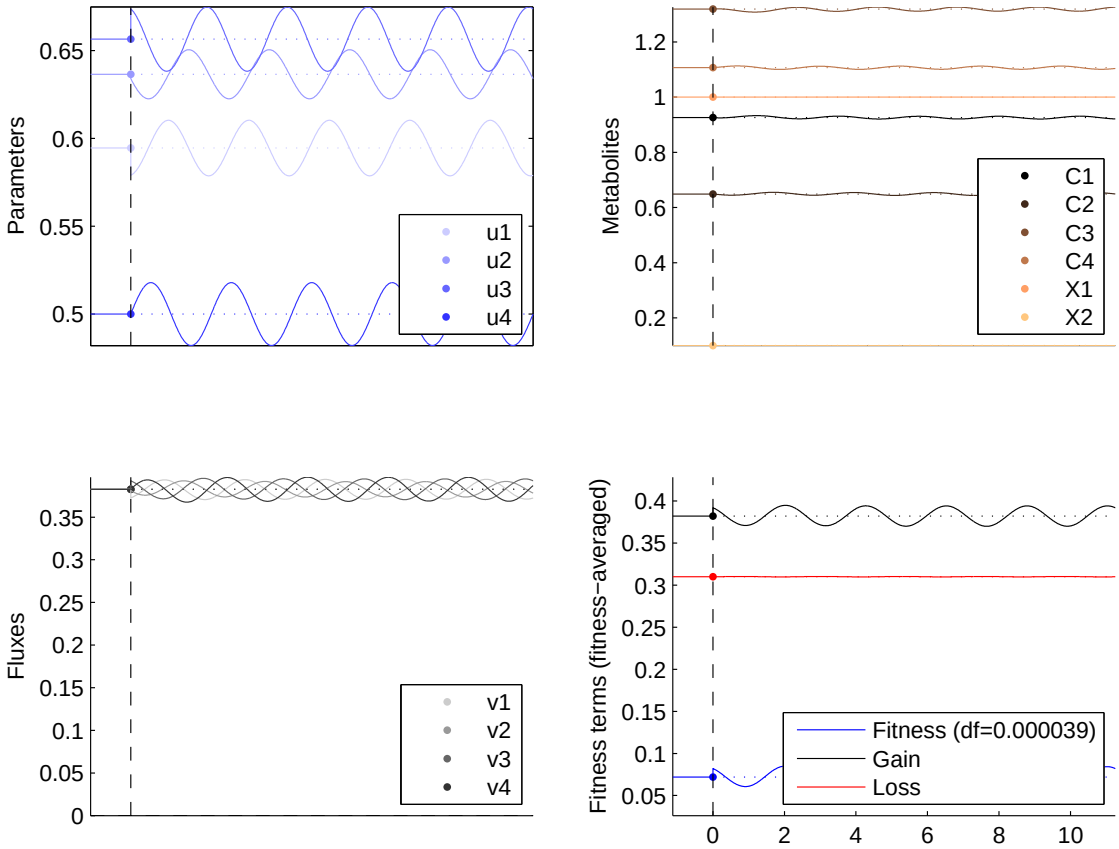

Figure 5: Numerical calculations: spontaneous oscillations. Perturbation frequency see first page.

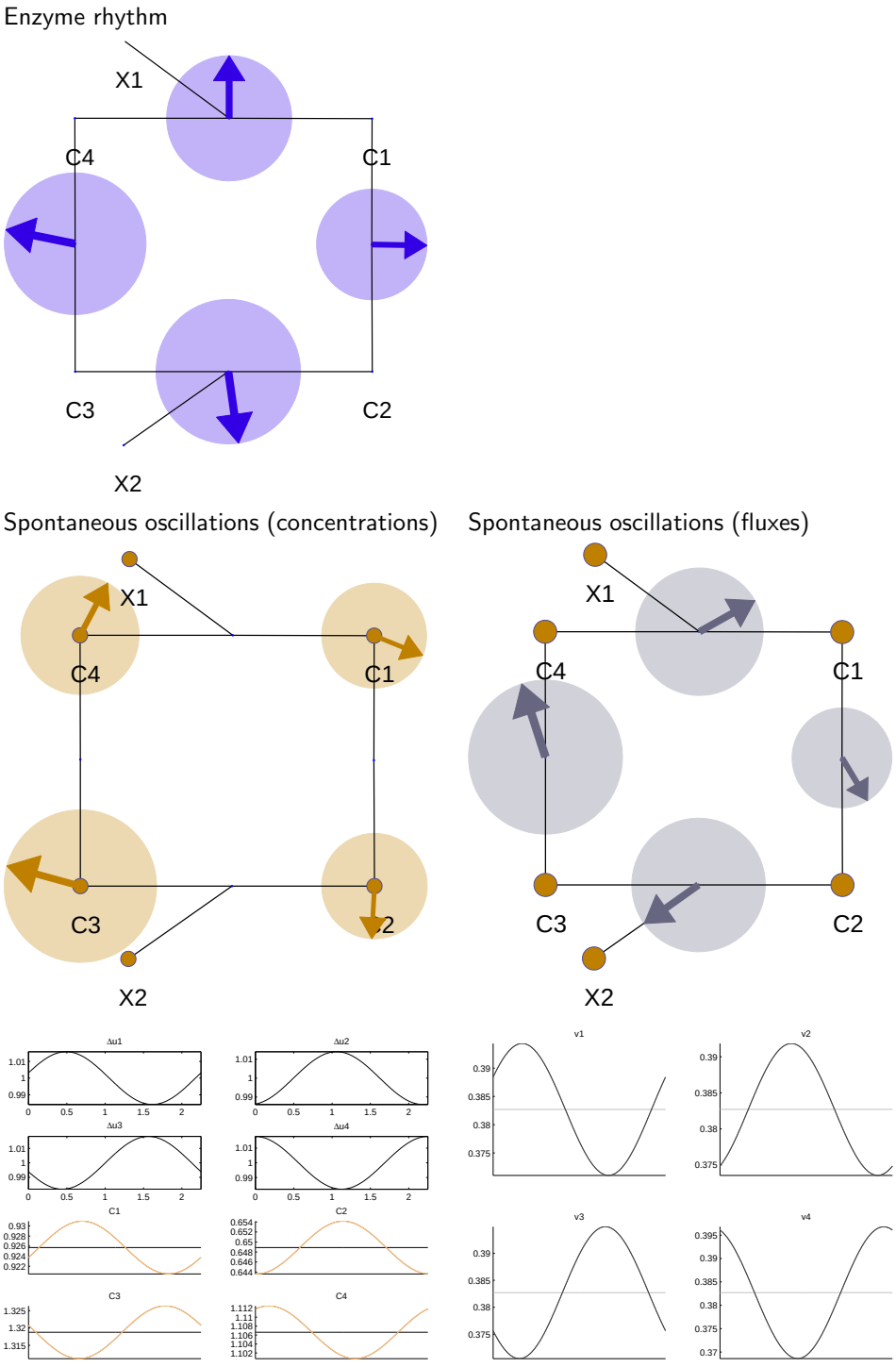

Figure 6: Spontaneous oscillations (local expansion; arrows: absolute changes). Perturbation frequency see first page.

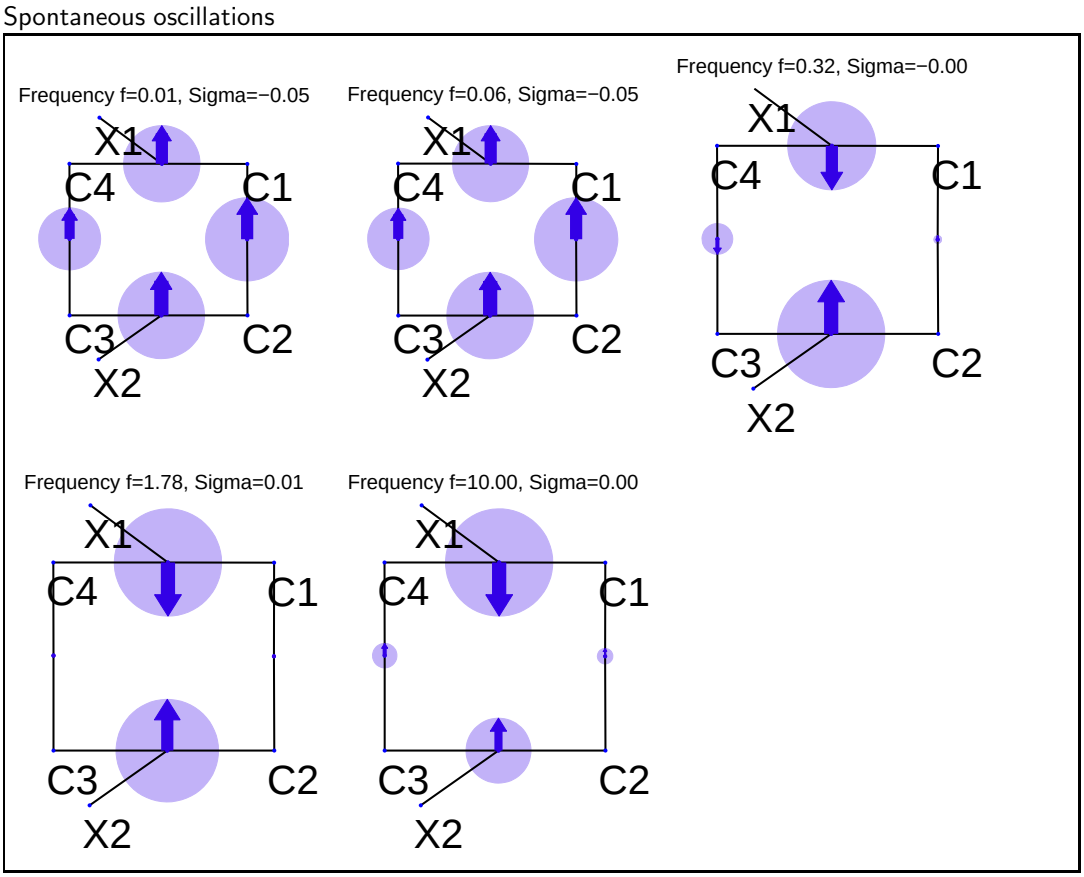

Figure 7: Spontaneous oscillations (or tendencies towards them) for various circular frequencies ω. If the maximal fitness curvatures λ is positive, the rhythm is beneficial (local expansion; arrows: absolute changes).