Enzyme rhythms in model ox_red_1 - spontaneous oscillations

Model name: ox_red_1

o Optimisation problem
- Protein turnover time 1.8e+03 s = 30 min
- Perturbed parameter(s) : S
- Perturbation frequency f : 0.0333/s (period 30 s)
- Scored quantity: Ana
- 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: 1
- 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 =0.000282/s (period 3.55e+03 s)
- Maximum fitness found (in tested range) at frequency f =0.0001/s (period 1e+04 s)

o Fitness changes after external perturbation at frequency f=0.0333/s
- Change by perturbation alone (xx): 5.35e-05

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 = 7.58e-11): Predicted fitness change 5.26e-12

o Numerical calculation (responsive, f=0.0333)
- Fitness change (fitness-averaged): -0.000441
- Fitness change (state-averaged): -0.000441

o Numerical calculation (self-induced rhythm, amplitude below 1/2 of mean, f=0.0333)
- Fitness change (fitness-averaged) : 2.14e-07
- Fitness change (state-averaged): 2.23e-07

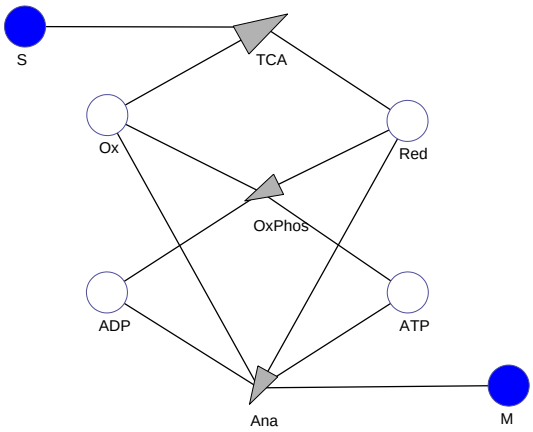


Figure 1: Network and reference flux

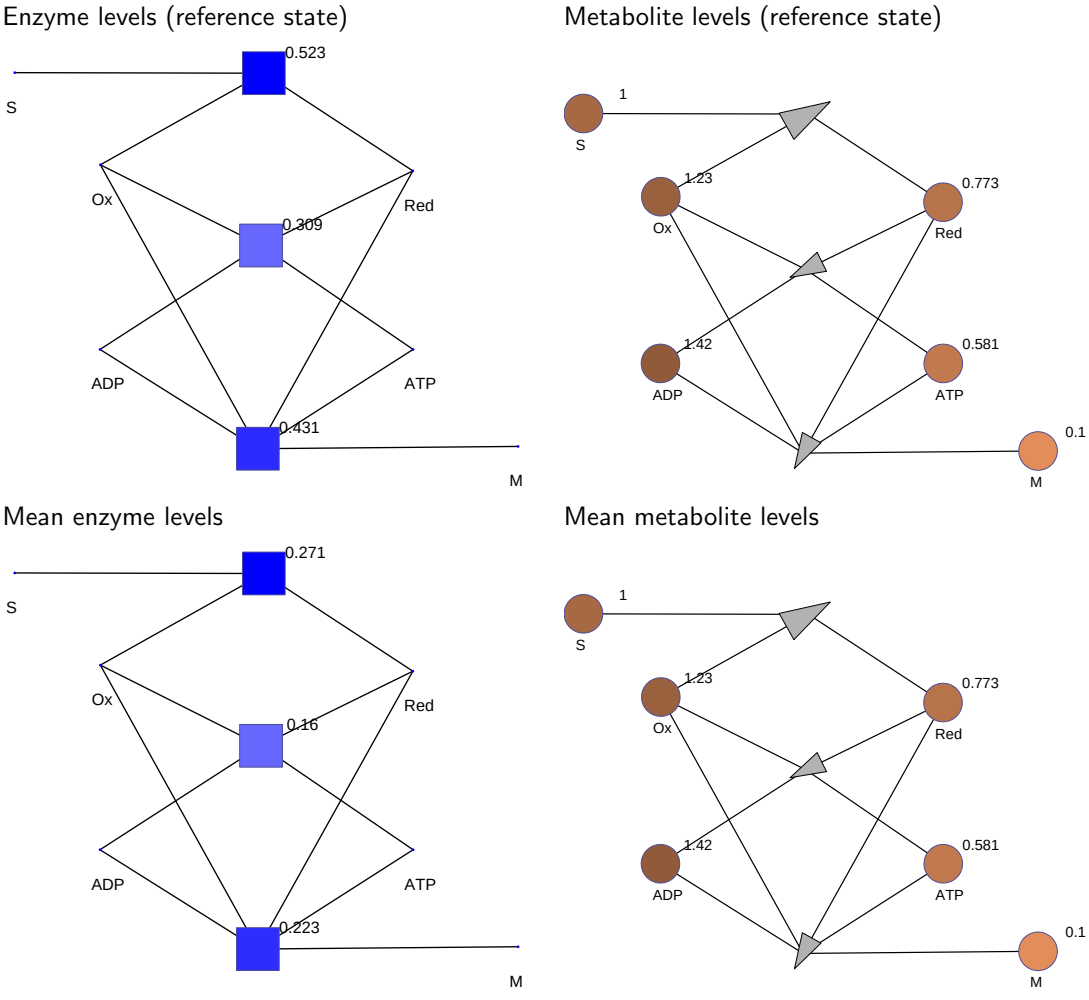


Figure 2: Reference state (top) and mean state during oscillation (bottom).

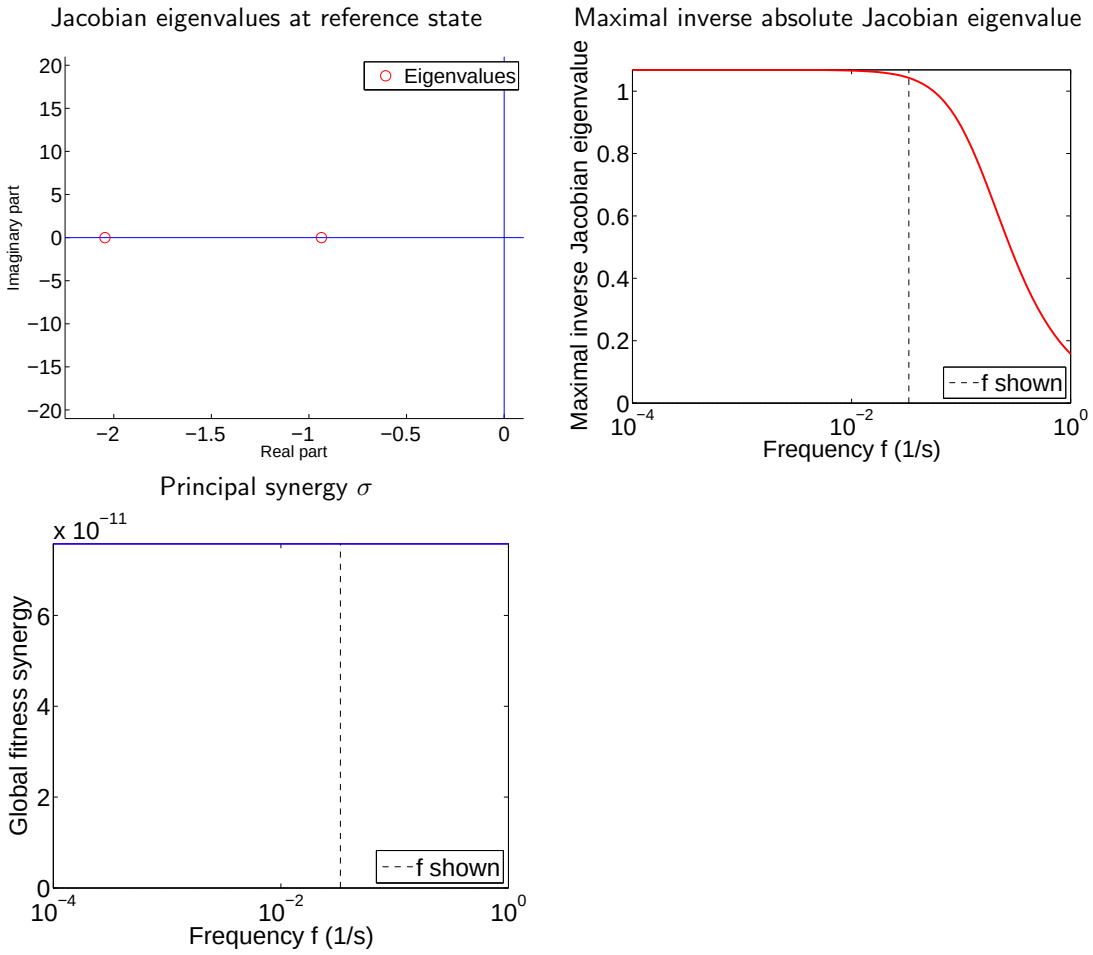
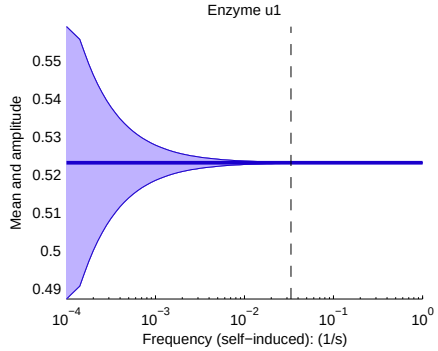
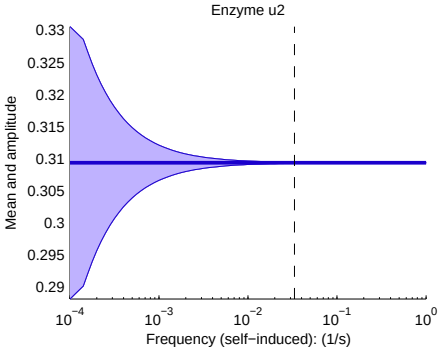
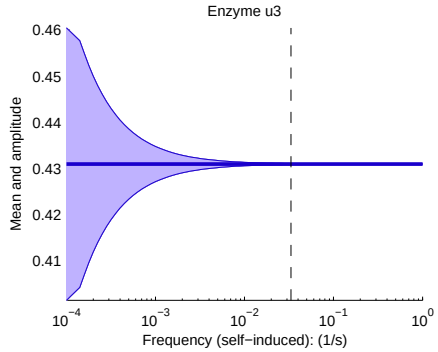


Figure 3: Control analysis: fitness curvatures. Left: Frequency-dependent fitness curvature eigenvalues. Right: relative sizes and phases of the individual enzyme levels (components of the leading fitness curvature eigenvector).

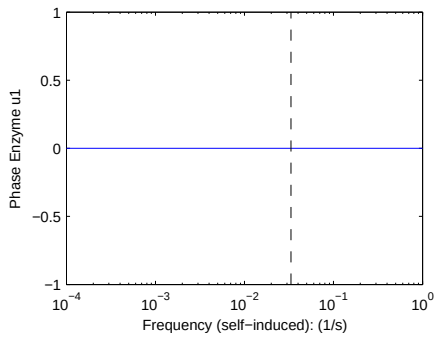
Protein level and enzyme activity (mean and amplitude)

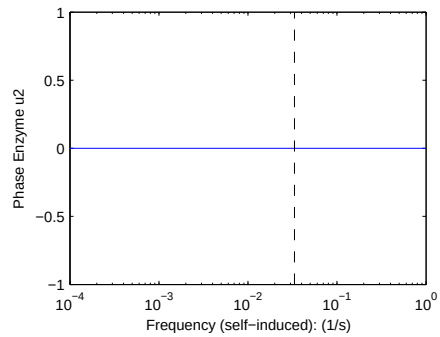


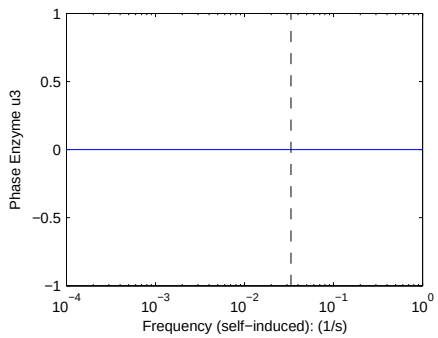




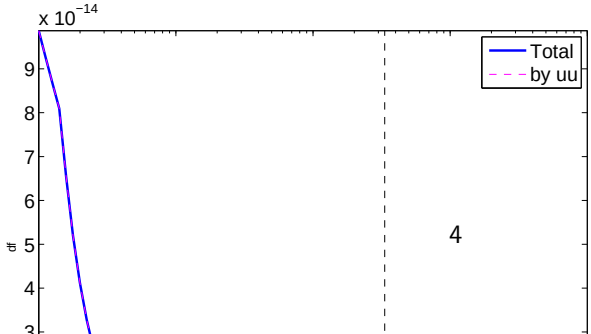
Phase angles $[0, 2\,\pi]$







Fitness change



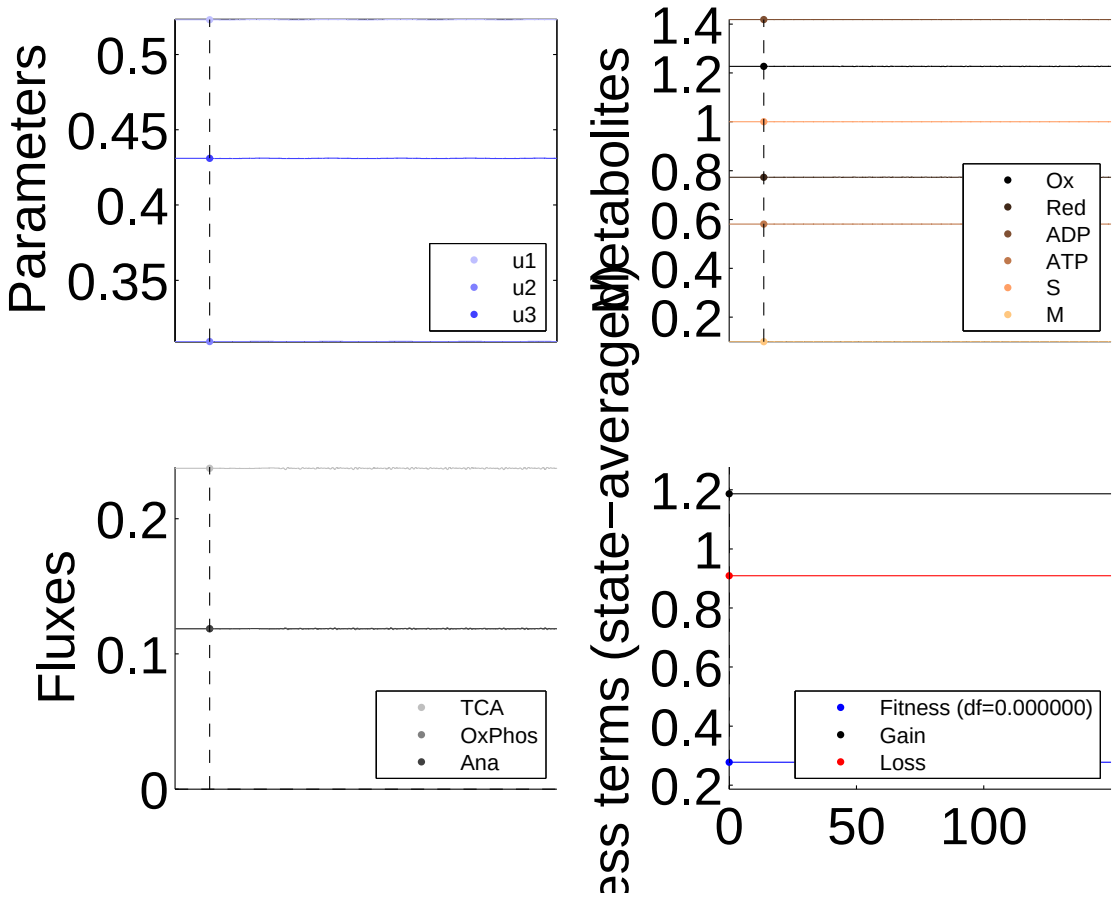


Figure 5: Numerical calculations: spontaneous oscillations. Perturbation frequency see first page.

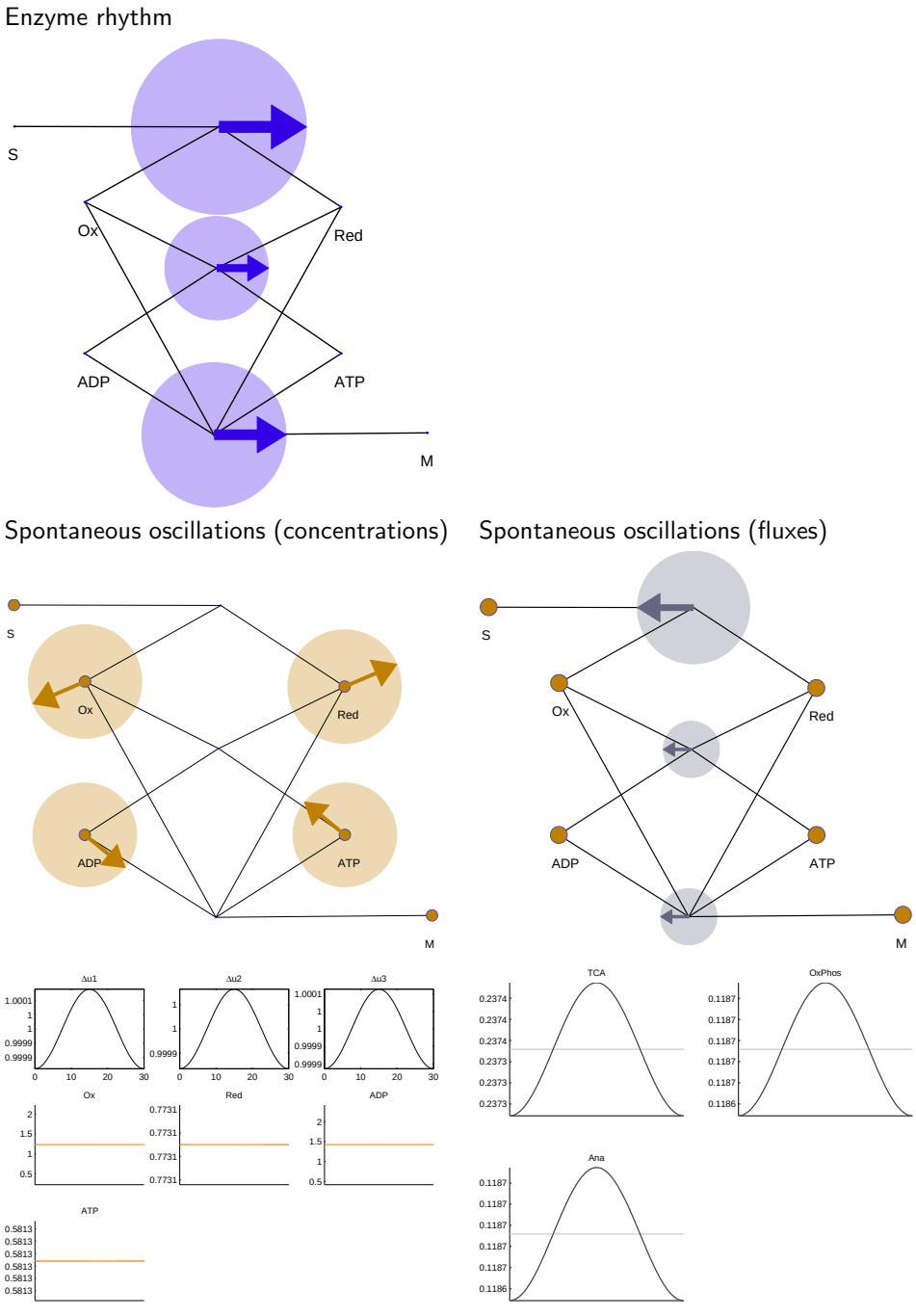


Figure 6: Spontaneous oscillations (local expansion; arrows: absolute changes). Perturbation frequency see first page.

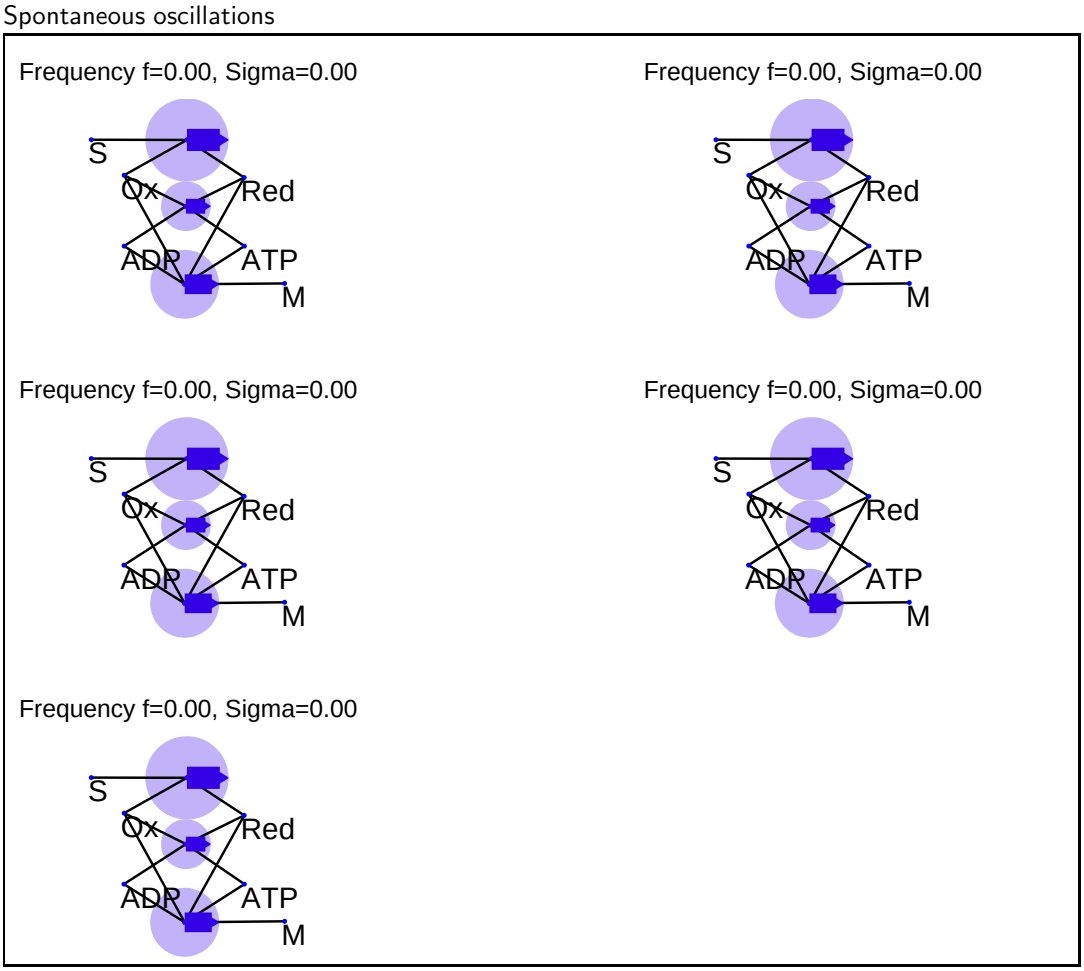


Figure 7: Spontaneous oscillations (or tendencies towards them) for various circular frequencies ω. If the maximal fitness curvatures λ is positive, the rhythm is beneficial (local expansion; arrows: absolute changes).