Enzyme rhythms in model glycogen_storage_dilution - enzymes are activated

Model name: glycogen_storage_dilution

o Optimisation problem
- Protein turnover time 1.8e+03 s = 30 min
- Perturbed parameter(s) : x1
- Perturbation frequency f : 0.00333/s (period 300 s)
- Scored quantity: glucose
- Scored quantity: v4
- Fitness-averaged fitness
- Posttranslational rhythms allowed
- Standard frequency considered f : 0.00333/s (period 300 s)

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

o No beneficial autonomous oscillation found

o Fitness changes after external perturbation at frequency f=0.00333/s
- Change by perturbation alone (xx): -19.7
- Change by adaption synergies (xu): 30.4
- Change by periodic enzyme (uu): -17
- Change by enzyme mean shift (u): -3.66e-07
- Total fitness change : -6.3
- Fitness gain by adaption : 13.4
- Maximum adaptive fitness found (in tested range) at frequency f =3.16e-05/s (period 3.16e+04 s)
- Predicted max. fitness change (adaptive, num. opt, full ampl. constraints) at frequency f =3.16e-05: -0.471
Inactive enzymes found; computing adaptive rhythms with shifted mean values in 1st order approximation

o Autonomous oscillations?

o Numerical calculation (responsive, f=0.00333)
- Fitness change (fitness-averaged): -19.7
- Fitness change (state-averaged): -2.86e-07
o Numerical calculation (adaptive, f=0.00333)
- Fitness change (fitness-averaged): -17.4
- Fitness change (state-averaged): -12.7

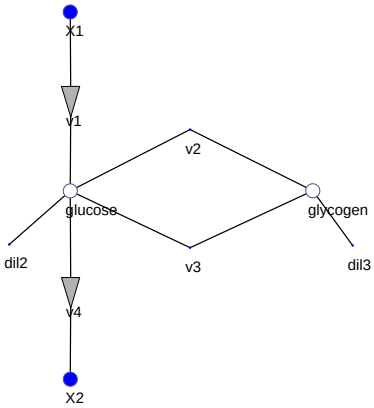

Figure 1: Network and reference flux

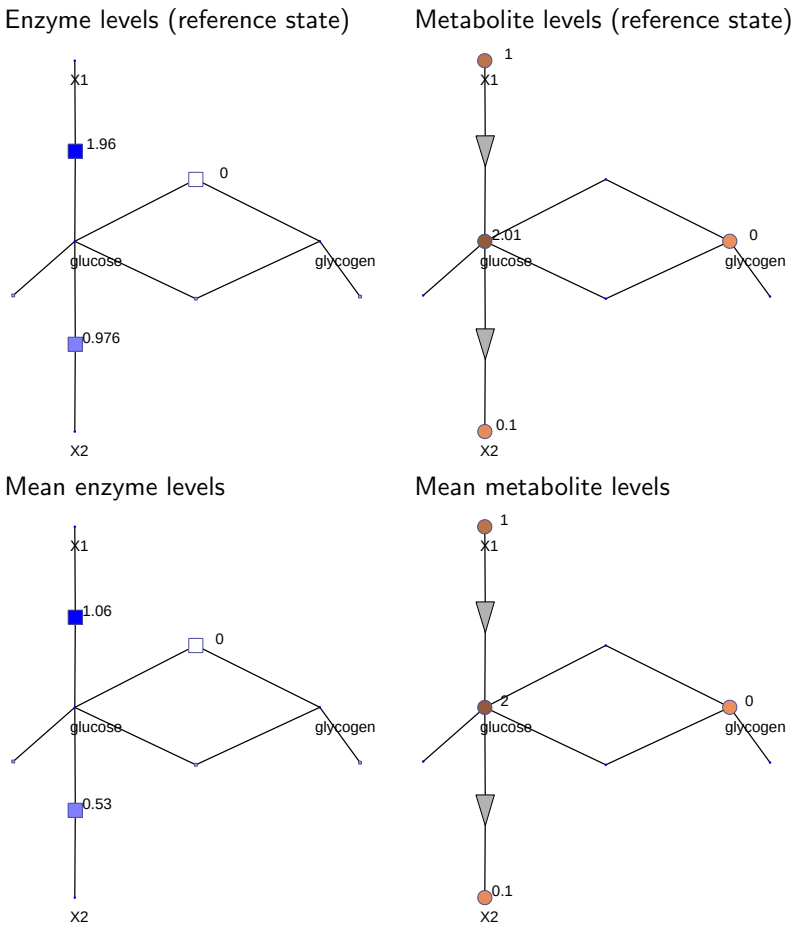

Figure 2: Reference state (top) and mean state during oscillation (bottom).

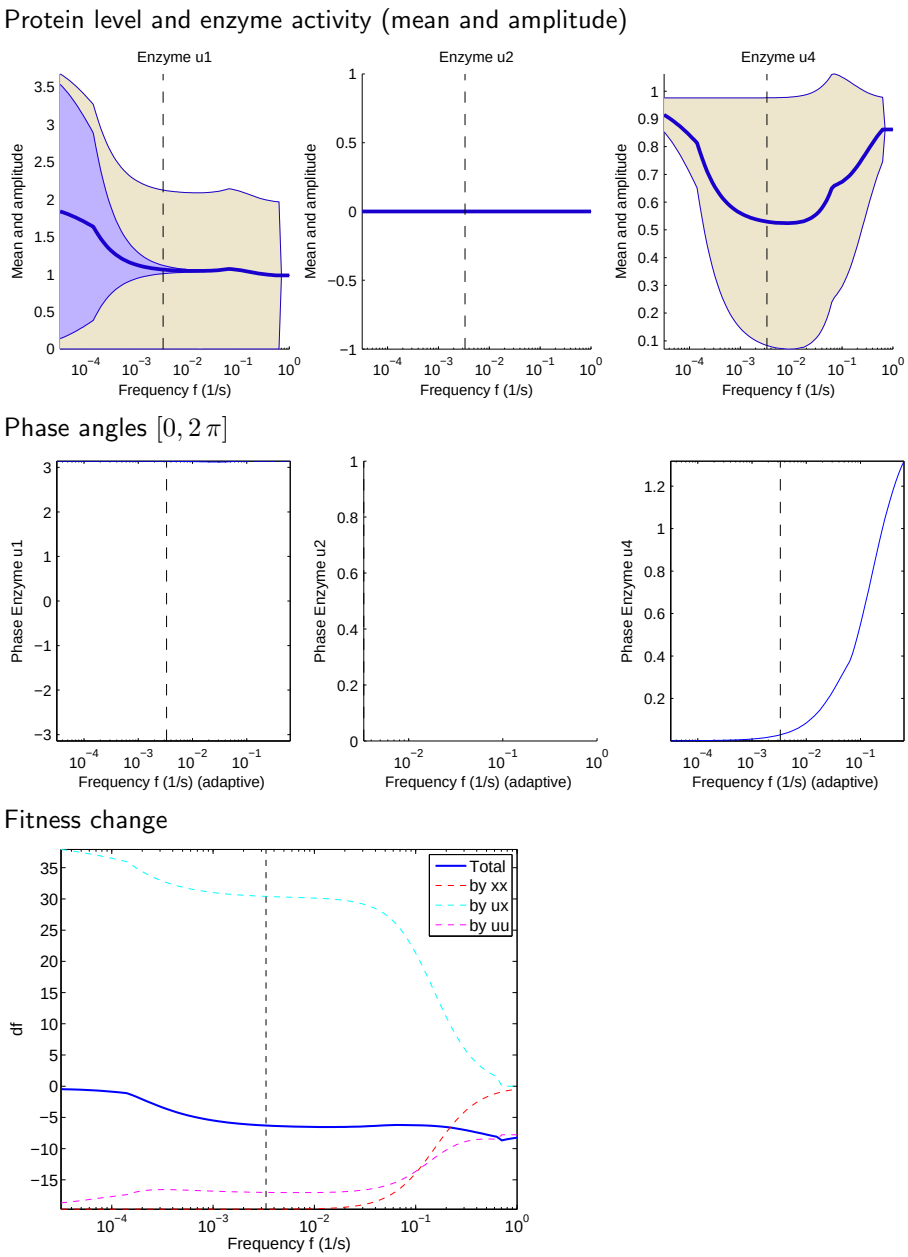

Figure 3: Adaptive oscillations. Left: amplitudes of protein levels (blue) and modification (grey). Right: phase shifts.

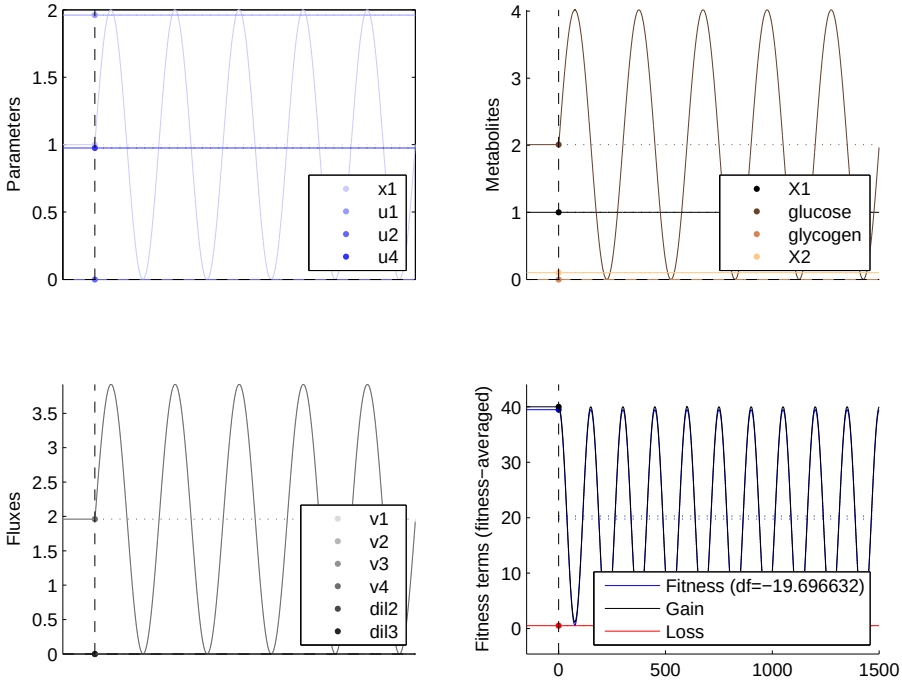

Figure 4: Numerical calculations: responsive oscillations (curves). Dynamic effects of oscillations. The panels show different types of variables: (i) Optimal periodic enzyme levels; (ii) internal metabolite levels; (iii) reaction fluxes; (iv) fitness, benefit, and cost.

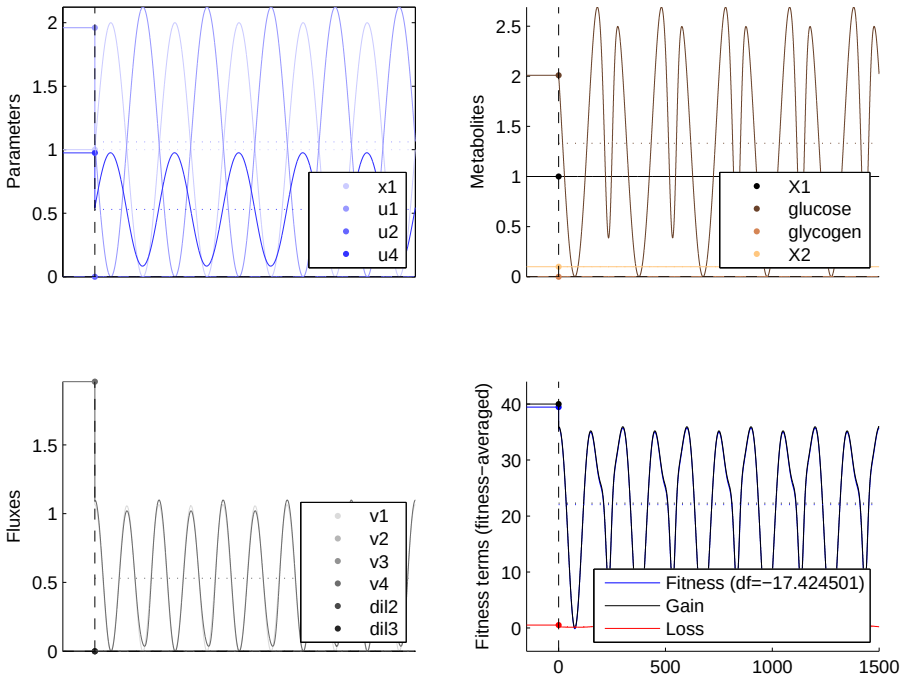

Figure 5: Numerical calculations: adaptive oscillations (curves). Dynamic effects of oscillations. The panels show different types of variables: (i) Optimal periodic enzyme levels; (ii) internal metabolite levels; (iii) reaction fluxes; (iv) fitness, benefit, and cost.

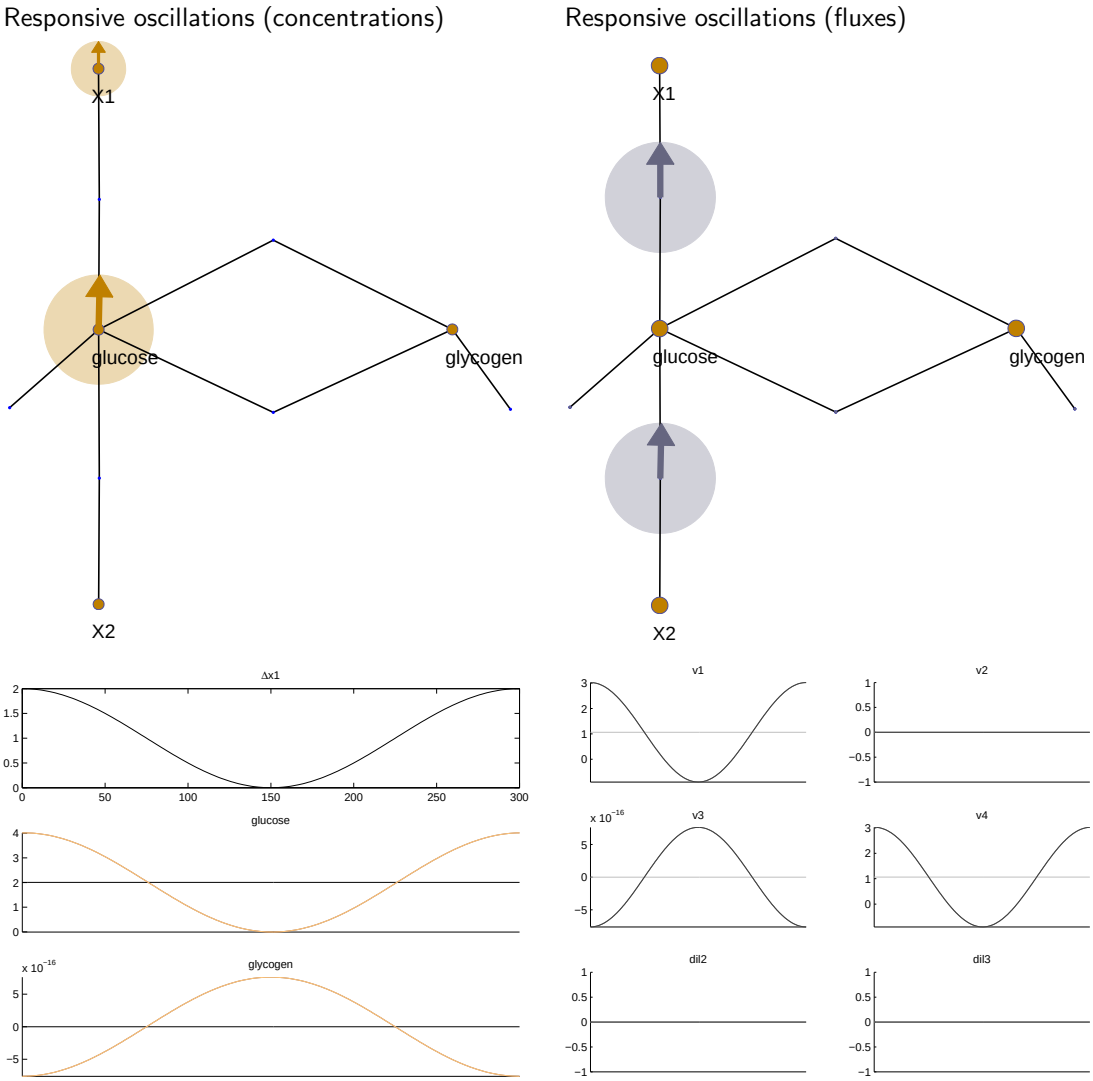

Figure 6: Responsive oscillations (local expansion; arrows: absolute changes)

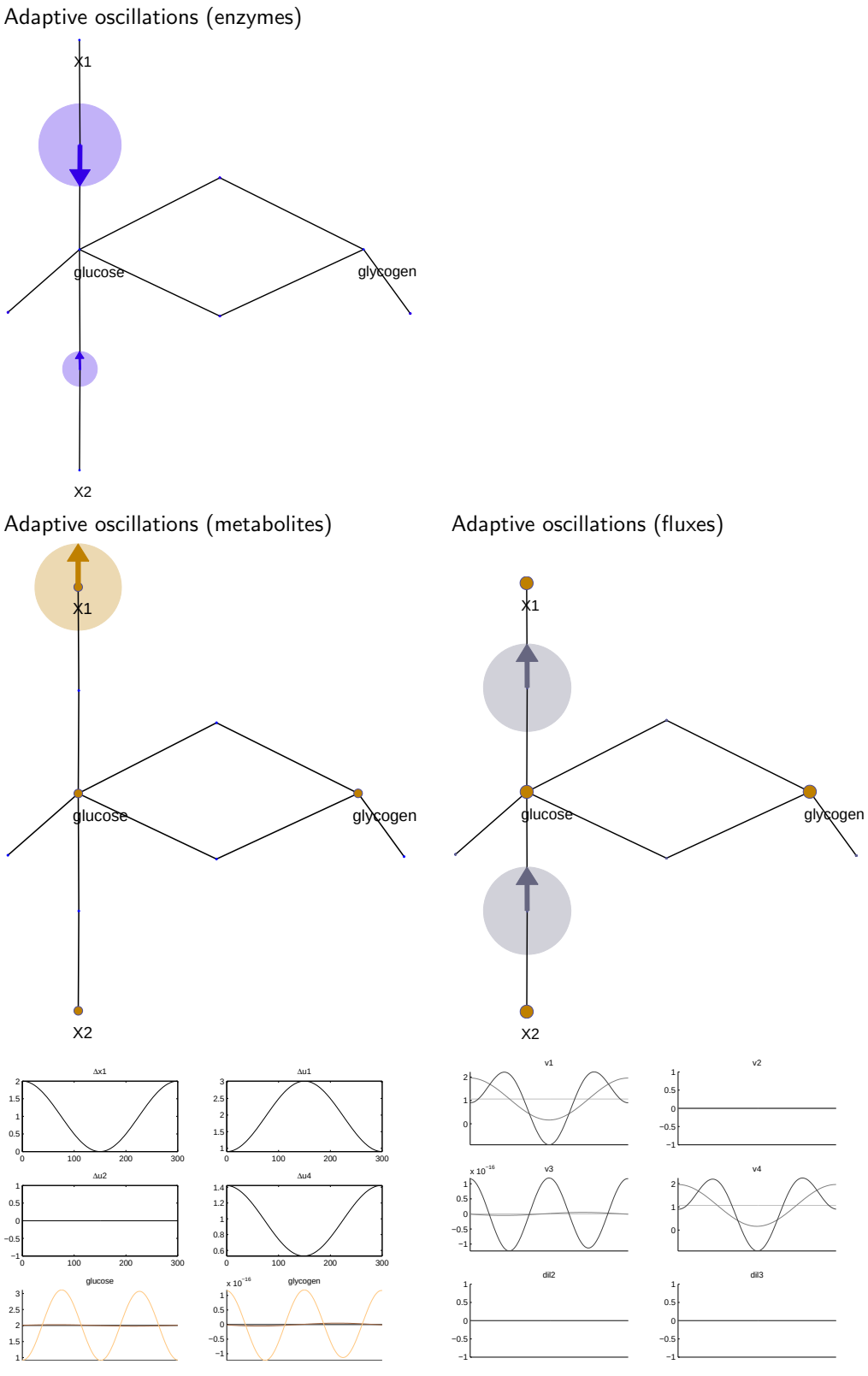

Figure 7: Adaption to forced oscillations (local expansion; arrows: absolute changes)

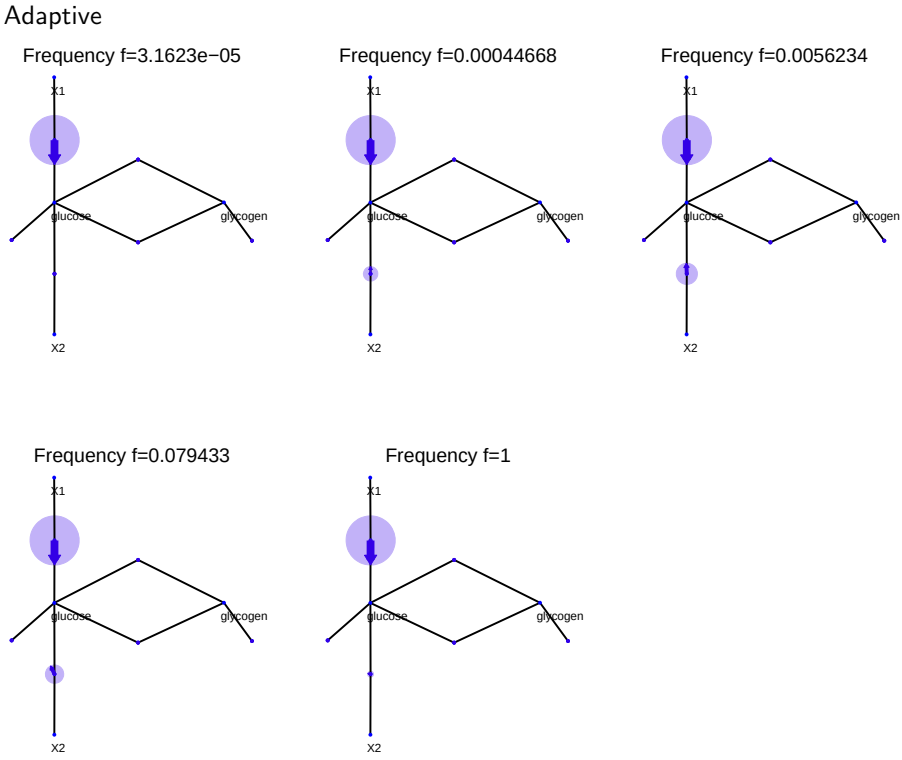

Figure 8: Adaptive oscillations for several frequencies (from local expansion).

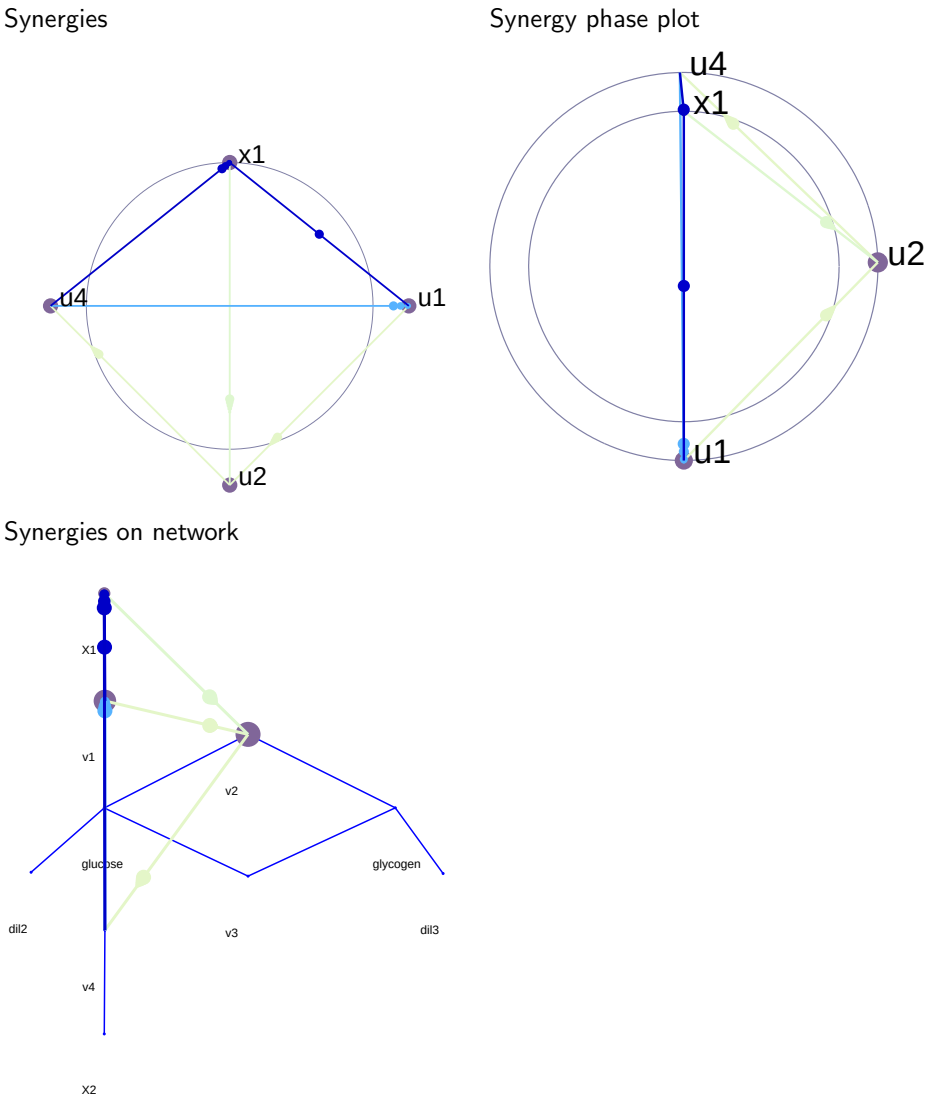

Figure 9: Periodic economic potentials and direct enzyme values.