BCR Work-Precision Diagrams

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The following benchmark is of 1122 ODEs with 24388 terms that describe a stiff chemical reaction network modeling the BCR signaling network from Barua et al.. We use `ReactionNetworkImporters` to load the BioNetGen model files as a Catalyst model, and then use ModelingToolkit to convert the Catalyst network model to ODEs.

```
using DiffEqBase, OrdinaryDiffEq, Catalyst, ReactionNetworkImporters,
      Sundials, Plots, DiffEqDevTools, ODEInterface, ODEInterfaceDiffEq,
      LSODA, TimerOutputs, LinearAlgebra, ModelingToolkit

gr()
datadir  = joinpath(dirname(pathof(ReactionNetworkImporters)),"../data/bcr")
const to = TimerOutput()
tf       = 100000.0

# generate ModelingToolkit ODEs
@timeit to "Parse Network" prnbng = loadrxnetwork(BNGNetwork(), joinpath(datadir,
"bcr.net"))
rn     = prnbng.rn
@timeit to "Create ODESys" osys = convert(ODESystem, rn)

u_0    = prnbng.u_0
p      = prnbng.p
tspan = (0.,tf)
@timeit to "ODEProb No Jac" oprob = ODEProblem(osys, u_0, tspan, p)
@timeit to "ODEProb DenseJac" densejacprob = ODEProblem(osys, u_0, tspan, p, jac=true)
```

```
Parsing parameters...done
Adding parameters...done
Parsing species...done
Adding species...done
Creating ModelingToolkit versions of species and parameters...done
Parsing and adding reactions...done
Parsing groups...done
ODEProblem with uType Vector{Float64} and tType Float64. In-place: true
timespan: (0.0, 100000.0)
u0: 1122-element Vector{Float64}:
 299717.8348854
  47149.15480798
  46979.01102231
 290771.2428252
 299980.7396749
 300000.0
    141.3151575495
      0.1256496403614
      0.4048783555301
```

```
    140.8052338618
      ⋮
      1.005585387399e-24
      6.724953378237e-17
      3.395560698281e-16
      1.787990228838e-5
      8.761844379939e-13
      0.0002517949074779
      0.0005539124513976
      2.281251822741e-14
      1.78232055967e-8
```

```
@timeit to "ODEProb SparseJac" sparsejacprob = ODEProblem(osys, u_0, tspan, p, jac=true,
sparse=true)
show(to)
```

```
                                    Time                    Allocations

      Tot / % measured:            304s / 100%            51.1GiB / 100%

 Section             ncalls     time   %tot     avg     alloc   %tot      a
vg

 ODEProb DenseJac         1     264s  87.0%    264s   42.4GiB  83.0%  42.4G
iB
 ODEProb SparseJac        1    25.4s  8.36%   25.4s   5.24GiB  10.3%  5.24G
iB
 ODEProb No Jac           1    12.3s  4.06%   12.3s   2.80GiB  5.49%  2.80G
iB
 Parse Network            1    991ms  0.33%   991ms    163MiB  0.31%   163M
iB
 Create ODESys            1    859ms  0.28%   859ms    501MiB  0.96%   501M
iB
```

```
@show numspecies(rn) # Number of ODEs
@show numreactions(rn) # Apprx. number of terms in the ODE
@show numparams(rn) # Number of Parameters
```

```
numspecies(rn) = 1122
numreactions(rn) = 24388
numparams(rn) = 128
128
```

0.1 Time ODE derivative function compilation

As compiling the ODE derivative functions has in the past taken longer than running a simulation, we first force compilation by evaluating these functions one time.

```
u  = copy(u_0)
```

```
du = similar(u)
@timeit to "ODERHS Eval1" oprob.f(du,u,p,0.)
@timeit to "ODERHS Eval2" oprob.f(du,u,p,0.)

# force compilation for dense and sparse problem rhs
densejacprob.f(du,u,p,0.)
sparsejacprob.f(du,u,p,0.)

J = zeros(length(u),length(u))
@timeit to "DenseJac Eval1" densejacprob.f.jac(J,u,p,0.)
@timeit to "DenseJac Eval2" densejacprob.f.jac(J,u,p,0.)
```

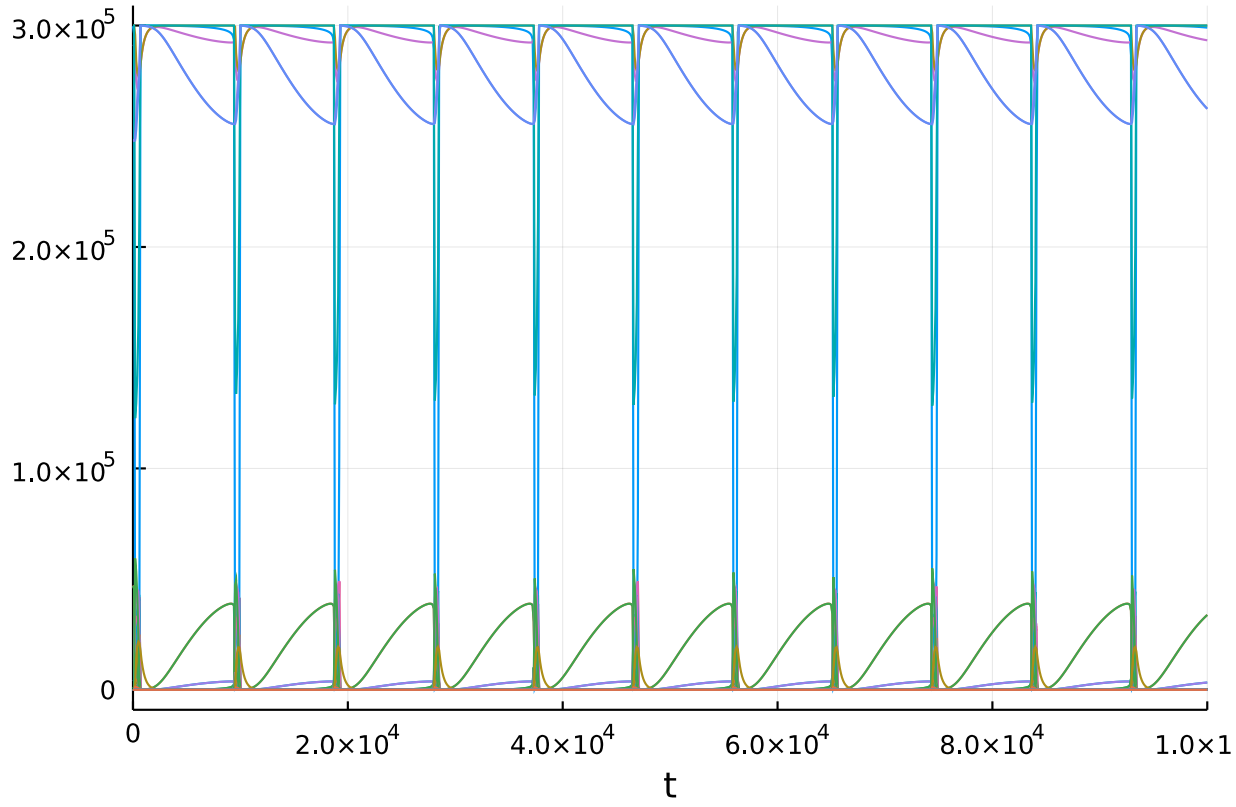
```
Error: syntax: expression too large
```

```
Js = similar(sparsejacprob.f.jac_prototype)
@timeit to "SparseJac Eval1" sparsejacprob.f.jac(Js,u,p,0.)
@timeit to "SparseJac Eval2" sparsejacprob.f.jac(Js,u,p,0.)
show(to)
```

```
Error: syntax: expression too large
```

0.2 Picture of the solution

```
sol = solve(oprob, CVODE_BDF(), saveat=tf/1000., reltol=1e-5, abstol=1e-5)
plot(sol, legend=false, fmt=:png)
```



For these benchmarks we will be using the time-series error with these saving points since the final time point is not well-indicative of the solution behavior (capturing the oscillation

is the key!).

0.3 Generate Test Solution

```
@time sol = solve(oprob, CVODE_BDF(), abstol=1/10^12, reltol=1/10^12)
test_sol  = TestSolution(sol)
```

```
629.982015 seconds (4.71 M allocations: 2.204 GiB, 0.47% gc time, 0.09% com
pilation time)
retcode: Success
Interpolation: 3rd order Hermite
t: nothing
u: nothing
```

0.4 Setups

```
abstols = 1.0 ./ 10.0 .^ (5:8)
reltols = 1.0 ./ 10.0 .^ (5:8);
setups = [
          #Dict(:alg=>Rosenbrock23(autodiff=false)),
          Dict(:alg=>TRBDF2(autodiff=false)),
          Dict(:alg=>QNDF(autodiff=false)),
          Dict(:alg=>CVODE_BDF()),
          Dict(:alg=>CVODE_BDF(linear_solver=:LapackDense)),
          #Dict(:alg=>rodas()),
          #Dict(:alg=>radau()),
          #Dict(:alg=>Rodas4(autodiff=false)),
          #Dict(:alg=>Rodas5(autodiff=false)),
          Dict(:alg=>KenCarp4(autodiff=false)),
          Dict(:alg=>KenCarp47(autodiff=false)),
          #Dict(:alg=>RadauIIA5(autodiff=false)),
          #Dict(:alg=>lsoda()),
          ]
```

```
6-element Vector{Dict{Symbol, V} where V}:
 Dict{Symbol, OrdinaryDiffEq.TRBDF2{0, false, DiffEqBase.DefaultLinSolve, D
iffEqBase.NLNewton{Rational{Int64}, Rational{Int64}, Rational{Int64}}, Data
Type}}(:alg => OrdinaryDiffEq.TRBDF2{0, false, DiffEqBase.DefaultLinSolve,
DiffEqBase.NLNewton{Rational{Int64}, Rational{Int64}, Rational{Int64}}, Dat
aType}(DiffEqBase.DefaultLinSolve(nothing, nothing), DiffEqBase.NLNewton{Ra
tional{Int64}, Rational{Int64}, Rational{Int64}}(1//100, 10, 1//5, 1//5), V
al{:forward}, true, :linear, :PI))
 Dict{Symbol, OrdinaryDiffEq.QNDF{5, 0, false, DiffEqBase.DefaultLinSolve,
DiffEqBase.NLNewton{Rational{Int64}, Rational{Int64}, Rational{Int64}}, Dat
aType, Nothing, Nothing, NTuple{5, Float64}}}(:alg => OrdinaryDiffEq.QNDF{5
, 0, false, DiffEqBase.DefaultLinSolve, DiffEqBase.NLNewton{Rational{Int64}
, Rational{Int64}, Rational{Int64}}, DataType, Nothing, Nothing, NTuple{5,
Float64}}(Val{5}(), DiffEqBase.DefaultLinSolve(nothing, nothing), DiffEqBas
e.NLNewton{Rational{Int64}, Rational{Int64}, Rational{Int64}}(1//100, 10, 1
//5, 1//5), Val{:forward}, nothing, nothing, :linear, (-0.185, -0.111111111
1111111, -0.0823, -0.0415, 0.0), :Standard))
 Dict{Symbol, Sundials.CVODE_BDF{:Newton, :Dense, Nothing, Nothing}}(:alg =
> Sundials.CVODE_BDF{:Newton, :Dense, Nothing, Nothing}(0, 0, 0, false, 10,
 5, 7, 3, 10, nothing, nothing, 0))
 Dict{Symbol, Sundials.CVODE_BDF{:Newton, :LapackDense, Nothing, Nothing}}(
:alg => Sundials.CVODE_BDF{:Newton, :LapackDense, Nothing, Nothing}(0, 0, 0
, false, 10, 5, 7, 3, 10, nothing, nothing, 0))
 Dict{Symbol, OrdinaryDiffEq.KenCarp4{0, false, DiffEqBase.DefaultLinSolve,
 DiffEqBase.NLNewton{Rational{Int64}, Rational{Int64}, Rational{Int64}}, Da
```

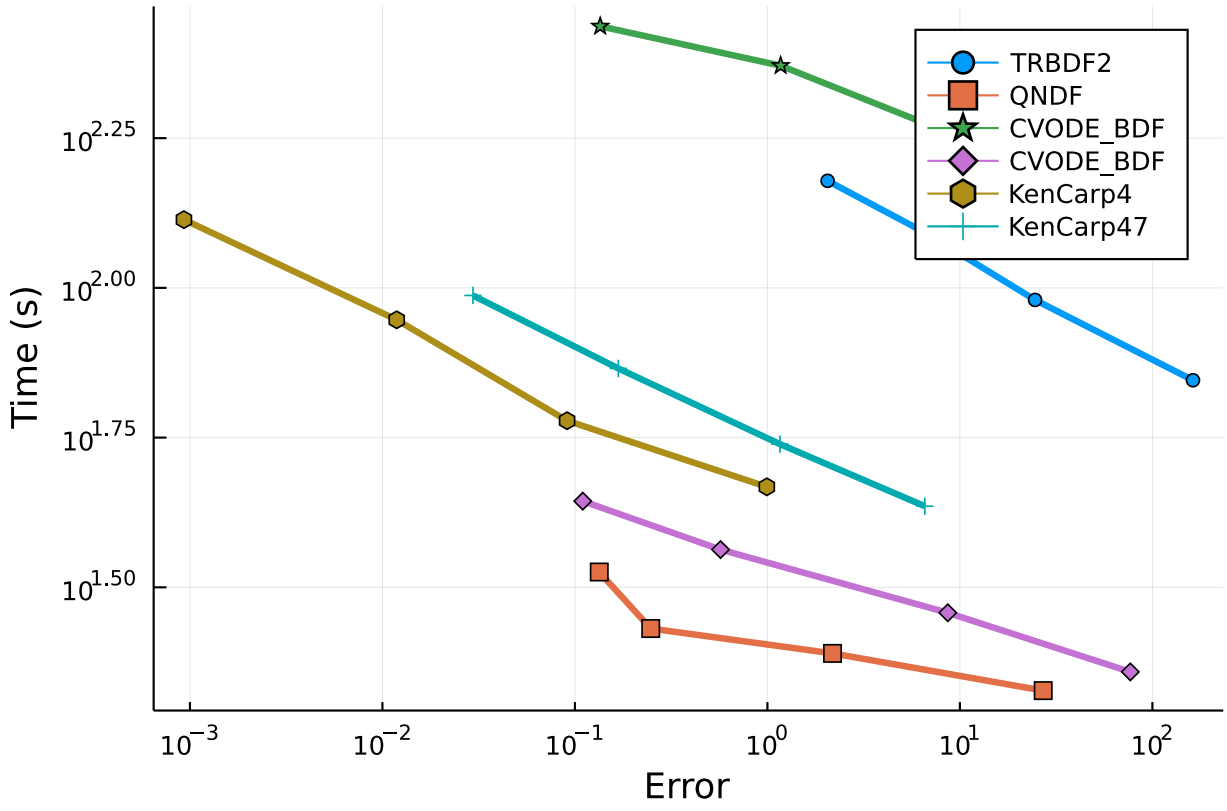
```
taType}}(:alg => OrdinaryDiffEq.KenCarp4{0, false, DiffEqBase.DefaultLinSol
ve, DiffEqBase.NLNewton{Rational{Int64}, Rational{Int64}, Rational{Int64}},
 DataType}(DiffEqBase.DefaultLinSolve(nothing, nothing), DiffEqBase.NLNewto
n{Rational{Int64}, Rational{Int64}, Rational{Int64}}(1//100, 10, 1//5, 1//5
), Val{:forward}, true, :linear, :PI))
 Dict{Symbol, OrdinaryDiffEq.KenCarp47{0, false, DiffEqBase.DefaultLinSolve
, DiffEqBase.NLNewton{Rational{Int64}, Rational{Int64}, Rational{Int64}}, D
ataType}}(:alg => OrdinaryDiffEq.KenCarp47{0, false, DiffEqBase.DefaultLinS
olve, DiffEqBase.NLNewton{Rational{Int64}, Rational{Int64}, Rational{Int64}
}, DataType}(DiffEqBase.DefaultLinSolve(nothing, nothing), DiffEqBase.NLNew
ton{Rational{Int64}, Rational{Int64}, Rational{Int64}}(1//100, 10, 1//5, 1/
/5), Val{:forward}, true, :linear, :PI))
```

0.5 Automatic Jacobian Solves

Due to the computational cost of the problem, we are only going to focus on the methods which demonstrated computational efficiency on the smaller biochemical benchmark problems. This excludes the exponential integrator, stabilized explicit, and extrapolation classes of methods.

First we test using auto-generated Jacobians (finite difference)

```
wp = WorkPrecisionSet(oprob,abstols,reltols,setups;error_estimate=:l2,
                      saveat=tf/10000.,appxsol=test_sol,maxiters=Int(1e5),numruns=1)
plot(wp)
```



0.6 Analytical Jacobian

Now we test using the generated analytic Jacobian function.

```
wp = WorkPrecisionSet(densejacprob,abstols,reltols,setups;error_estimate=:l2,
                      saveat=tf/10000.,appxsol=test_sol,maxiters=Int(1e5),numruns=1)
plot(wp)
```

```
Error: syntax: expression too large
```

0.7 Sparse Jacobian

Finally we test using the generated sparse analytic Jacobian function.

```
setups = [
          #Dict(:alg=>Rosenbrock23(autodiff=false)),
          Dict(:alg=>TRBDF2(autodiff=false)),
          Dict(:alg=>QNDF(autodiff=false)),
          #Dict(:alg=>CVODE_BDF(linear_solver=:KLU)), # Fails!
          #Dict(:alg=>rodas()),
          #Dict(:alg=>radau()),
          #Dict(:alg=>Rodas4(autodiff=false)),
          #Dict(:alg=>Rodas5(autodiff=false)),
          Dict(:alg=>KenCarp4(autodiff=false)),
          Dict(:alg=>KenCarp47(autodiff=false)),
          #Dict(:alg=>RadauIIA5(autodiff=false)),
          #Dict(:alg=>lsoda()),
          ]
wp = WorkPrecisionSet(sparsejacprob,abstols,reltols,setups;error_estimate=:l2,
                      saveat=tf/10000.,appxsol=test_sol,maxiters=Int(1e5),numruns=1)
plot(wp)
```

```
Error: syntax: expression too large
```

0.8 Appendix

These benchmarks are a part of the SciMLBenchmarks.jl repository, found at: https://github.com/SciML/
For more information on high-performance scientific machine learning, check out the SciML
Open Source Software Organization https://sciml.ai.

To locally run this benchmark, do the following commands:

```
using SciMLBenchmarks
SciMLBenchmarks.weave_file("benchmarks/Bio","BCR.jmd")
```

Computer Information:

```
Julia Version 1.6.2
Commit 1b93d53fc4 (2021-07-14 15:36 UTC)
Platform Info:
  OS: Linux (x86_64-pc-linux-gnu)
  CPU: AMD EPYC 7502 32-Core Processor
  WORD_SIZE: 64
  LIBM: libopenlibm
  LLVM: libLLVM-11.0.1 (ORCJIT, znver2)
```

```
Environment:
  JULIA_DEPOT_PATH = /root/.cache/julia-buildkite-plugin/depots/5b300254-1738-4989-ae0a
```

Package Information:

```
      Status `/var/lib/buildkite-agent/builds/amdci3-julia-csail-mit-edu/julialang/scim
  [479239e8] Catalyst v6.12.1
  [2b5f629d] DiffEqBase v6.62.2
  [f3b72e0c] DiffEqDevTools v2.27.2
  [7f56f5a3] LSODA v0.7.0
  [961ee093] ModelingToolkit v5.17.3
  [54ca160b] ODEInterface v0.5.0
  [09606e27] ODEInterfaceDiffEq v3.10.0
  [1dea7af3] OrdinaryDiffEq v5.56.0
  [91a5bcdd] Plots v1.15.2
  [b4db0fb7] ReactionNetworkImporters v0.8.0
  [31c91b34] SciMLBenchmarks v0.1.0
  [c3572dad] Sundials v4.4.3
  [a759f4b9] TimerOutputs v0.5.9
```

And the full manifest:

```
      Status `/var/lib/buildkite-agent/builds/amdci3-julia-csail-mit-edu/julialang/scim
  [c3fe647b] AbstractAlgebra v0.16.0
  [1520ce14] AbstractTrees v0.3.4
  [79e6a3ab] Adapt v3.3.0
  [ec485272] ArnoldiMethod v0.1.0
  [4fba245c] ArrayInterface v3.1.15
  [9e28174c] BinDeps v1.0.2
  [fa961155] CEnum v0.4.1
  [00ebfdb7] CSTParser v2.5.0
  [479239e8] Catalyst v6.12.1
  [d360d2e6] ChainRulesCore v0.9.44
  [b630d9fa] CheapThreads v0.2.5
  [35d6a980] ColorSchemes v3.12.1
  [3da002f7] ColorTypes v0.11.0
  [5ae59095] Colors v0.12.8
  [861a8166] Combinatorics v1.0.2
  [a80b9123] CommonMark v0.8.1
  [38540f10] CommonSolve v0.2.0
  [bbf7d656] CommonSubexpressions v0.3.0
  [34da2185] Compat v3.30.0
  [8f4d0f93] Conda v1.5.2
  [187b0558] ConstructionBase v1.2.1
  [d38c429a] Contour v0.5.7
  [a8cc5b0e] Crayons v4.0.4
  [9a962f9c] DataAPI v1.6.0
```

```
[864edb3b] DataStructures v0.18.9
[e2d170a0] DataValueInterfaces v1.0.0
[2b5f629d] DiffEqBase v6.62.2
[f3b72e0c] DiffEqDevTools v2.27.2
[c894b116] DiffEqJump v6.14.2
[77a26b50] DiffEqNoiseProcess v5.7.3
[163ba53b] DiffResults v1.0.3
[b552c78f] DiffRules v1.0.2
[b4f34e82] Distances v0.10.3
[31c24e10] Distributions v0.24.18
[ffbed154] DocStringExtensions v0.8.4
[e30172f5] Documenter v0.26.3
[d4d017d3] ExponentialUtilities v1.8.4
[e2ba6199] ExprTools v0.1.3
[c87230d0] FFMPEG v0.4.0
[7034ab61] FastBroadcast v0.1.8
[9aa1b823] FastClosures v0.3.2
[1a297f60] FillArrays v0.11.7
[6a86dc24] FiniteDiff v2.8.0
[53c48c17] FixedPointNumbers v0.8.4
[59287772] Formatting v0.4.2
[f6369f11] ForwardDiff v0.10.18
[069b7b12] FunctionWrappers v1.1.2
[28b8d3ca] GR v0.57.4
[5c1252a2] GeometryBasics v0.3.12
[d7ba0133] Git v1.2.1
[42e2da0e] Grisu v1.0.2
[cd3eb016] HTTP v0.9.9
[eafb193a] Highlights v0.4.5
[0e44f5e4] Hwloc v2.0.0
[7073ff75] IJulia v1.23.2
[b5f81e59] IOCapture v0.1.1
[615f187c] IfElse v0.1.0
[d25df0c9] Inflate v0.1.2
[83e8ac13] IniFile v0.5.0
[c8e1da08] IterTools v1.3.0
[42fd0dbc] IterativeSolvers v0.9.1
[82899510] IteratorInterfaceExtensions v1.0.0
[692b3bcd] JLLWrappers v1.3.0
[682c06a0] JSON v0.21.1
[98e50ef6] JuliaFormatter v0.13.7
[7f56f5a3] LSODA v0.7.0
[b964fa9f] LaTeXStrings v1.2.1
[2ee39098] LabelledArrays v1.6.1
[23fbe1c1] Latexify v0.15.5
[093fc24a] LightGraphs v1.3.5
[d3d80556] LineSearches v7.1.1
[2ab3a3ac] LogExpFunctions v0.2.4
[bdcacae8] LoopVectorization v0.12.23
```

```
[1914dd2f] MacroTools v0.5.6
[739be429] MbedTLS v1.0.3
[442fdcdd] Measures v0.3.1
[e1d29d7a] Missings v1.0.0
[961ee093] ModelingToolkit v5.17.3
[46d2c3a1] MuladdMacro v0.2.2
[ffc61752] Mustache v1.0.10
[d41bc354] NLSolversBase v7.8.0
[2774e3e8] NLsolve v4.5.1
[77ba4419] NaNMath v0.3.5
[8913a72c] NonlinearSolve v0.3.8
[54ca160b] ODEInterface v0.5.0
[09606e27] ODEInterfaceDiffEq v3.10.0
[6fe1bfb0] OffsetArrays v1.9.0
[429524aa] Optim v1.3.0
[bac558e1] OrderedCollections v1.4.1
[1dea7af3] OrdinaryDiffEq v5.56.0
[90014a1f] PDMats v0.11.0
[d96e819e] Parameters v0.12.2
[69de0a69] Parsers v1.1.0
[ccf2f8ad] PlotThemes v2.0.1
[995b91a9] PlotUtils v1.0.10
[91a5bcdd] Plots v1.15.2
[e409e4f3] PoissonRandom v0.4.0
[f517fe37] Polyester v0.3.1
[85a6dd25] PositiveFactorizations v0.2.4
[21216c6a] Preferences v1.2.2
[1fd47b50] QuadGK v2.4.1
[74087812] Random123 v1.3.1
[fb686558] RandomExtensions v0.4.3
[e6cf234a] RandomNumbers v1.4.0
[b4db0fb7] ReactionNetworkImporters v0.8.0
[3cdcf5f2] RecipesBase v1.1.1
[01d81517] RecipesPipeline v0.3.2
[731186ca] RecursiveArrayTools v2.11.4
[f2c3362d] RecursiveFactorization v0.1.12
[189a3867] Reexport v1.0.0
[ae029012] Requires v1.1.3
[ae5879a3] ResettableStacks v1.1.0
[79098fc4] Rmath v0.7.0
[47965b36] RootedTrees v1.0.0
[7e49a35a] RuntimeGeneratedFunctions v0.5.2
[476501e8] SLEEFPirates v0.6.20
[1bc83da4] SafeTestsets v0.0.1
[0bca4576] SciMLBase v1.13.4
[31c91b34] SciMLBenchmarks v0.1.0
[6c6a2e73] Scratch v1.0.3
[efcf1570] Setfield v0.7.0
[992d4aef] Showoff v1.0.3
```

```
[699a6c99] SimpleTraits v0.9.3
[b85f4697] SoftGlobalScope v1.1.0
[a2af1166] SortingAlgorithms v1.0.0
[47a9eef4] SparseDiffTools v1.13.2
[276daf66] SpecialFunctions v1.4.1
[aedffcd0] Static v0.2.4
[90137ffa] StaticArrays v1.2.0
[82ae8749] StatsAPI v1.0.0
[2913bbd2] StatsBase v0.33.8
[4c63d2b9] StatsFuns v0.9.8
[7792a7ef] StrideArraysCore v0.1.11
[09ab397b] StructArrays v0.5.1
[c3572dad] Sundials v4.4.3
[d1185830] SymbolicUtils v0.11.2
[0c5d862f] Symbolics v0.1.25
[3783bdb8] TableTraits v1.0.1
[bd369af6] Tables v1.4.2
[8290d209] ThreadingUtilities v0.4.4
[a759f4b9] TimerOutputs v0.5.9
[0796e94c] Tokenize v0.5.16
[a2a6695c] TreeViews v0.3.0
[30578b45] URIParser v0.4.1
[5c2747f8] URIs v1.3.0
[3a884ed6] UnPack v1.0.2
[1986cc42] Unitful v1.7.0
[3d5dd08c] VectorizationBase v0.20.11
[81def892] VersionParsing v1.2.0
[19fa3120] VertexSafeGraphs v0.1.2
[44d3d7a6] Weave v0.10.8
[ddb6d928] YAML v0.4.6
[c2297ded] ZMQ v1.2.1
[700de1a5] ZygoteRules v0.2.1
[6e34b625] Bzip2_jll v1.0.6+5
[83423d85] Cairo_jll v1.16.0+6
[5ae413db] EarCut_jll v2.1.5+1
[2e619515] Expat_jll v2.2.10+0
[b22a6f82] FFMPEG_jll v4.3.1+4
[a3f928ae] Fontconfig_jll v2.13.1+14
[d7e528f0] FreeType2_jll v2.10.1+5
[559328eb] FriBidi_jll v1.0.5+6
[0656b61e] GLFW_jll v3.3.4+0
[d2c73de3] GR_jll v0.57.2+0
[78b55507] Gettext_jll v0.20.1+7
[f8c6e375] Git_jll v2.31.0+0
[7746bdde] Glib_jll v2.59.0+4
[e33a78d0] Hwloc_jll v2.4.1+0
[aacddb02] JpegTurbo_jll v2.0.1+3
[c1c5ebd0] LAME_jll v3.100.0+3
[aae0fff6] LSODA_jll v0.1.1+0
```

```
[dd4b983a] LZO_jll v2.10.1+0
[dd192d2f] LibVPX_jll v1.9.0+1
[e9f186c6] Libffi_jll v3.2.2+0
[d4300ac3] Libgcrypt_jll v1.8.7+0
[7e76a0d4] Libglvnd_jll v1.3.0+3
[7add5ba3] Libgpg_error_jll v1.42.0+0
[94ce4f54] Libiconv_jll v1.16.1+0
[4b2f31a3] Libmount_jll v2.35.0+0
[89763e89] Libtiff_jll v4.1.0+2
[38a345b3] Libuuid_jll v2.36.0+0
[c771fb93] ODEInterface_jll v0.0.1+0
[e7412a2a] Ogg_jll v1.3.4+2
[458c3c95] OpenSSL_jll v1.1.1+6
[efe28fd5] OpenSpecFun_jll v0.5.4+0
[91d4177d] Opus_jll v1.3.1+3
[2f80f16e] PCRE_jll v8.44.0+0
[30392449] Pixman_jll v0.40.1+0
[ea2cea3b] Qt5Base_jll v5.15.2+0
[f50d1b31] Rmath_jll v0.3.0+0
[fb77eaff] Sundials_jll v5.2.0+1
[a2964d1f] Wayland_jll v1.17.0+4
[2381bf8a] Wayland_protocols_jll v1.18.0+4
[02c8fc9c] XML2_jll v2.9.12+0
[aed1982a] XSLT_jll v1.1.34+0
[4f6342f7] Xorg_libX11_jll v1.6.9+4
[0c0b7dd1] Xorg_libXau_jll v1.0.9+4
[935fb764] Xorg_libXcursor_jll v1.2.0+4
[a3789734] Xorg_libXdmcp_jll v1.1.3+4
[1082639a] Xorg_libXext_jll v1.3.4+4
[d091e8ba] Xorg_libXfixes_jll v5.0.3+4
[a51aa0fd] Xorg_libXi_jll v1.7.10+4
[d1454406] Xorg_libXinerama_jll v1.1.4+4
[ec84b674] Xorg_libXrandr_jll v1.5.2+4
[ea2f1a96] Xorg_libXrender_jll v0.9.10+4
[14d82f49] Xorg_libpthread_stubs_jll v0.1.0+3
[c7cfdc94] Xorg_libxcb_jll v1.13.0+3
[cc61e674] Xorg_libxkbfile_jll v1.1.0+4
[12413925] Xorg_xcb_util_image_jll v0.4.0+1
[2def613f] Xorg_xcb_util_jll v0.4.0+1
[975044d2] Xorg_xcb_util_keysyms_jll v0.4.0+1
[0d47668e] Xorg_xcb_util_renderutil_jll v0.3.9+1
[c22f9ab0] Xorg_xcb_util_wm_jll v0.4.1+1
[35661453] Xorg_xkbcomp_jll v1.4.2+4
[33bec58e] Xorg_xkeyboard_config_jll v2.27.0+4
[c5fb5394] Xorg_xtrans_jll v1.4.0+3
[8f1865be] ZeroMQ_jll v4.3.2+6
[3161d3a3] Zstd_jll v1.5.0+0
[0ac62f75] libass_jll v0.14.0+4
[f638f0a6] libfdk_aac_jll v0.1.6+4
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[b53b4c65] libpng_jll v1.6.38+0
[a9144af2] libsodium_jll v1.0.20+0
[f27f6e37] libvorbis_jll v1.3.6+6
[1270edf5] x264_jll v2020.7.14+2
[dfaa095f] x265_jll v3.0.0+3
[d8fb68d0] xkbcommon_jll v0.9.1+5
[0dad84c5] ArgTools
[56f22d72] Artifacts
[2a0f44e3] Base64
[ade2ca70] Dates
[8bb1440f] DelimitedFiles
[8ba89e20] Distributed
[f43a241f] Downloads
[7b1f6079] FileWatching
[9fa8497b] Future
[b77e0a4c] InteractiveUtils
[b27032c2] LibCURL
[76f85450] LibGit2
[8f399da3] Libdl
[37e2e46d] LinearAlgebra
[56ddb016] Logging
[d6f4376e] Markdown
[a63ad114] Mmap
[ca575930] NetworkOptions
[44cfe95a] Pkg
[de0858da] Printf
[3fa0cd96] REPL
[9a3f8284] Random
[ea8e919c] SHA
[9e88b42a] Serialization
[1a1011a3] SharedArrays
[6462fe0b] Sockets
[2f01184e] SparseArrays
[10745b16] Statistics
[4607b0f0] SuiteSparse
[fa267f1f] TOML
[a4e569a6] Tar
[8dfed614] Test
[cf7118a7] UUIDs
[4ec0a83e] Unicode
[e66e0078] CompilerSupportLibraries_jll
[deac9b47] LibCURL_jll
[29816b5a] LibSSH2_jll
[c8ffd9c3] MbedTLS_jll
[14a3606d] MozillaCACerts_jll
[4536629a] OpenBLAS_jll
[efcefdf7] PCRE2_jll
[bea87d4a] SuiteSparse_jll
[83775a58] Zlib_jll
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[8e850ede] nghttp2_jll
[3f19e933] p7zip_jll
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