LUM

Feedback from the use of the largest supercomputer in Europe

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What is LUMI?

- 2978 nodes with
 - 4 AMD MI250x GPUs
 - a single 64 cores AMD EPYC "Trento" lacksquareCPU.
- The aggregated HPL Linpack performance of LUMI-G is 379.70 PFlop/s.





Overview of a LUMI-G compute node

~ 9x Adastra GPU @ CINES





EuroHPC Access Calls

- Granted an allocation for the « extreme scale access mode »
- 3,484,000 GPU h allocated on 1 year

Accessing LUMI

The project « turbulent disks » In collaboration with H. Latter (Univ. of Cambridge, UK)



- Full disk?
- Survival of corrugation modes?
- Dust settling?
- Vortices?

- Full disk?
- Competition with VSI?

Impact of vertical stratification?

- Compressibility effects?
- Survival with curvature?
- Propagation to the midplane?



The challenge

#1: system stability

Gravity: central mass gravitational potential ENABLED with M=1 TimeIntegrator: using 3rd Order (RK3) integrator. TimeIntegrator: Using adaptive dt with CFL=0.8 . TimeIntegrator: will stop after 43.5 hours. Main: Creating initial conditions. Main: Cycling Time Integrator... TimeIntegrator: time cycle TimeIntegrator: 0.000000e+00 0 1.593742e-05 10 TimeIntegrator: TimeIntegrator: 5.727500e-05 20 TimeIntegrator: 1.644940e-04 30 TimeIntegrator: 4.425926e-04 40 1.163909e-03 50 TimeIntegrator: TimeIntegrator: 3.034816e-03 60 TimeIntegrator: 6.519082e-03 70 TimeIntegrator: 1.007368e-02 80 TimeIntegrator: 90 1.362683e-02 TimeIntegrator: 1.717857e-02 100 TimeIntegrator: 110 2.072898e-02 • • • 6.680007e-02 240 TimeIntegrator: TimeIntegrator: 7.033955e-02 250 TimeIntegrator: 7.387860e-02 260 TimeIntegrator: 7.741726e-02 270 • • • TimeIntegrator: 3.213042e-01 960 TimeIntegrator: 3.248379e-01 970 TimeIntegrator: 980 3.283717e-01 TimeIntegrator: 3.319054e-01 | 990 | Main: Reached maximum number of integration cycles. Main: Reached t=0.335439 Main: Completed in 10 minutes 53 seconds and 1000 cycles Main: Perfs are 8.174090e+10 cell updates/second MPI overhead represents 34% of total run time.

| time step | cell (updates/s) | MPI overhead (%) | | |
|--------------|------------------|------------------|--|--|
| 1.000000e-06 | N/A | N/A | | |
| 2.593742e-06 | 1.228411e+11 | 6.229152 | | |
| 6.727500e-06 | 1.263376e+11 | 6.696973 | | |
| 1.744940e-05 | 1.260329e+11 | 6.868502 | | |
| 4.525926e-05 | 1.260741e+11 | 6.713010 | | |
| 1.173909e-04 | 1.258320e+11 | 6.739630 | | |
| 3.044816e-04 | 1.251714e+11 | 6.986361 | | |
| 3.555275e-04 | 1.245450e+11 | 7.566431 | | |
| 3.553797e-04 | 1.238352e+11 | 8.051875 | | |
| 3.552368e-04 | 1.236095e+11 | 8.408736 | | |
| 3.550985e-04 | 1.230930e+11 | 8.999555 | | |
| 3.549738e-04 | 1.191618e+11 | 10.278076 | | |
| | | | | |
| 3.539673e-04 | 8.560018e+10 | 31.998791 | | |
| 3.539236e-04 | 8.455433e+10 | 32.354674 | | |
| 3.538831e-04 | 8.536546e+10 | 31.871857 | | |
| 3.538455e-04 | 8.451818e+10 | 32.560332 | | |
| | | | | |
| 3.533728e-04 | 7.226361e+10 | 39.876328 | | |
| 3.533726e-04 | 7.318458e+10 | 39.556451 | | |
| 3.533725e-04 | 7.281833e+10 | 39.854619 | | |
| 3.533724e-04 | 7.167976e+10 | 40.422609 | | |
| | | | | |

#1: system stability (cont'd)

process #1

Gravity: central mass gravitational potential ENABLED with M=1

TimeIntegrator: using 3rd Order (RK3) integrator.

TimeIntegrator: Using adaptive dt with CFL=0.8 .

TimeIntegrator: will stop after 43.5 hours.

Main: Creating initial conditions.

| Main: Cycling Time Integrator | | | | | | | |
|-------------------------------|--------------|-------|--------------|------------------|------------------|--|--|
| TimeIntegrator: | time | cycle | time step | cell (updates/s) | MPI overhead (%) | | |
| TimeIntegrator: | 0.000000e+00 | 0 | 1.000000e-06 | N/A | N/A | | |
| TimeIntegrator: | 1.593742e-05 | 10 | 2.593742e-06 | 7.951065e+09 | 3.249777 | | |
| TimeIntegrator: | 5.727500e-05 | 20 | 6.727500e-06 | 8.028158e+09 | 3.289534 | | |
| TimeIntegrator: | 1.644940e-04 | 30 | 1.744940e-05 | 8.014591e+09 | 3.362284 | | |
| TimeIntegrator: | 4.425926e-04 | 40 | 4.525926e-05 | 7.998629e+09 | 3.436400 | | |
| TimeIntegrator: | 1.163909e-03 | 50 | 1.173909e-04 | 7.964717e+09 | 3.557654 | | |
| TimeIntegrator: | 3.034816e-03 | 60 | 3.044816e-04 | 7.903785e+09 | 3.754029 | | |
| TimeIntegrator: | 7.327936e-03 | 70 | 4.867873e-04 | 7.863393e+09 | 3.629722 | | |
| TimeIntegrator: | 1.219500e-02 | 80 | 4.866076e-04 | 7.798375e+09 | 3.673882 | | |
| TimeIntegrator: | 1.706028e-02 | 90 | 4.864313e-04 | 7.740056e+09 | 3.972529 | | |
| TimeIntegrator: | 2.192384e-02 | 100 | 4.862645e-04 | 7.717967e+09 | 4.076347 | | |
| TimeIntegrator: | 2.678575e-02 | 110 | 4.861024e-04 | 7.671914e+09 | 4.058943 | | |
| TimeIntegrator: | 3.164608e-02 | 120 | 4.859492e-04 | 7.693121e+09 | 4.226520 | | |
| TimeIntegrator: | 3.650490e-02 | 130 | 4.858028e-04 | 7.691725e+09 | 4.318757 | | |
| TimeIntegrator: | 4.136232e-02 | 140 | 4.856696e-04 | 7.680140e+09 | 4.480481 | | |
| TimeIntegrator: | 4.621844e-02 | 150 | 4.855419e-04 | 7.635158e+09 | 4.922653 | | |
| TimeIntegrator: | 5.107329e-02 | 160 | 4.854182e-04 | 7.480662e+09 | 5.866868 | | |
| TimeIntegrator: | 5.592695e-02 | 170 | 4.853023e-04 | 7.055460e+09 | 8.341483 | | |
| TimeIntegrator: | 6.077947e-02 | 180 | 4.851931e-04 | 6.830506e+09 | 9.758574 | | |
| TimeIntegrator: | 6.563094e-02 | 190 | 4.850902e-04 | 6.774158e+09 | 9.520462 | | |
| TimeIntegrator: | 7.048139e-02 | 200 | 4.849914e-04 | 6.675399e+09 | 10.142318 | | |
| TimeIntegrator: | 7.533088e-02 | 210 | 4.848983e-04 | 6.639014e+09 | 8.720803 | | |
| TimeIntegrator: | 8.017947e-02 | 220 | 4.848107e-04 | 6.534640e+09 | 9.950846 | | |
| TimeIntegrator: | 8.502719e-02 | 230 | 4.847271e-04 | 6.529307e+09 | 9.881086 | | |
| TimeIntegrator: | 8.987411e-02 | 240 | 4.846491e-04 | 6.414888e+09 | 9.832200 | | |
| TimeIntegrator: | 9.472026e-02 | 250 | 4.845747e-04 | 6.354311e+09 | 10.337835 | | |
| TimeIntegrator: | 9.956569e-02 | 260 | 4.845042e-04 | 6.309454e+09 | 10.386557 | | |
| TimeIntegrator: | 1.044104e-01 | 270 | 4.844372e-04 | 6.315063e+09 | 10.402304 | | |
| TimeIntegrator: | 1.092545e-01 | 280 | 4.843735e-04 | 6.211119e+09 | 11.243196 | | |
| TimeIntegrator: | 1.140980e-01 | 290 | 4.843146e-04 | 6.175291e+09 | 10.965431 | | |
| TimeIntegrator: | 1.189409e-01 | 300 | 4.842579e-04 | 6.113392e+09 | 11.152301 | | |
| TimeIntegrator: | 1.237832e-01 | 310 | 4.842048e-04 | 6.023583e+09 | 10.558754 | | |
| TimeIntegrator: | 1.286250e-01 | 320 | 4.841539e-04 | 5.978660e+09 | 11.492593 | | |
| TimeIntegrator: | 1.334663e-01 | 330 | 4.841063e-04 | 5.992310e+09 | 11.478762 | | |
| TimeIntegrator: | 1.383072e-01 | 340 | 4.840615e-04 | 5.931508e+09 | 11.957992 | | |
| TimeIntegrator: | 1.431476e-01 | 350 | 4.840187e-04 | 5.882077e+09 | 11.923003 | | |
| TimeIntegrator: | 1.479876e-01 | 360 | 4.839782e-04 | 5.926814e+09 | 11.963534 | | |
| TimeIntegrator: | 1.528272e-01 | 370 | 4.839398e-04 | 5.821199e+09 | 12.286236 | | |
| TimeIntegrator: | 1.576665e-01 | 380 | 4.839036e-04 | 5.874892e+09 | 11.783085 | | |

process #24

| Main: Creating initial conditions. Main: Cycling Time Integrator: TimeIntegrator: N/A M/I TimeIntegrator: 0.0000000+00 0 1.000000-06 N/A N/A TimeIntegrator: 0.303742=05 1.0 2.533742=06 7.951023=+09 3.904353 TimeIntegrator: 5.7275000=05 20 6.727500e=05 8.004786=+09 4.072326 TimeIntegrator: 1.42490=04 30 1.744940=05 8.0004786=+09 4.121089 TimeIntegrator: 1.63090=03 50 1.173909=04 7.951734=+09 4.307905 TimeIntegrator: 7.3273956=03 70 4.8667873=04 7.868538=+09 3.739326 TimeIntegrator: 1.760028=-02 90 4.866456=04 7.739504=+09 3.992650 TimeIntegrator: 2.678575=02 110 4.851024=-04 7.60370e+09 4.21942 TimeIntegrator: 3.166080=02 120 4.856056=04 7.735094=09 4.273643 TimeIntegrator: 3.166080=02 120 4.856036=04 7.632052=049 4 | Gravity: central mass gravitational potential ENABLED with M=1 TimeIntegrator: using 3rd Order (RK3) integrator. TimeIntegrator: Using adaptive dt with CFL=0.8 . TimeIntegrator: will stop after 43.5 bours | | | | | |
|--|---|------------------|-------|--------------|------------------|------------------|
| Main: Cycling Time Integrator time cycle time step cell (updates/s) MPI overhead (%) TimeIntegrator: 0.000000+00 0 1.0000000-06 N/A TimeIntegrator: 0.735020+05 20 6.727500+06 8.028158e+09 4.072326 TimeIntegrator: 1.644940e-04 30 1.744940e-05 8.008421e+09 4.212080 TimeIntegrator: 1.644940e-04 40 1.74990e-04 7.951023e+05 8.008421e+09 4.212080 TimeIntegrator: 1.63990e-03 50 1.173990e-04 7.961734e+09 4.327935 TimeIntegrator: 3.024816e-03 60 3.644816e-04 7.93845e+09 3.979326 TimeIntegrator: 1.219500e-02 80 4.866076e-04 7.738964e+09 3.939560 TimeIntegrator: 2.193284e+02 100 4.862645e-04 7.780894e+09 4.231982 TimeIntegrator: 3.164608e+02 110 4.850492e+04 7.68633e+09 4.273438 TimeIntegrator: 4.65049e+02 130 4.856432e+04 7.69252e+09 4.17367 | Main: Creating ini | tial conditions. | | | | |
| TimeIntégrator: time cycle time step cell (updates/s) MPI overhead (%) TimeIntégrator: 1.593742e-05 10 2.593742e-06 7.951023e-09 3.904353 TimeIntégrator: 1.593742e-05 20 6.727500e-06 7.951023e-09 4.072326 TimeIntégrator: 1.644940e-04 30 1.744940e-05 8.004786e-09 4.122089 TimeIntégrator: 1.16390e-03 50 1.173909e-04 7.961734e-09 4.367905 TimeIntégrator: 3.034816e-03 60 3.044816e-04 7.893845e+09 3.779076 TimeIntégrator: 1.723936e-03 70 4.867873e-04 7.7395467e+09 3.779076 TimeIntégrator: 1.708028e-02 80 4.866313e-04 7.7395467e+09 3.93856 TimeIntégrator: 2.19234e-02 100 4.866345e-04 7.7395467e+09 4.116488 TimeIntégrator: 3.656490e-02 120 4.85392e-04 7.680370e+09 4.116488 TimeIntégrator: 3.656490e-02 130 4.855492e-04 7.692522e+09 | Main: Cvcling Time | Integrator | | | | |
| TimeIntegrator: 0.00000000000000000000000000000000000 | TimeIntegrator: | time | cvcle | time step | cell (updates/s) | MPI overhead (%) |
| TimeIntegrator: 1.593742e-05 10 2.593742e-06 7.951023e+09 3.904353 TimeIntegrator: 5.727500e-05 20 6.727500e-06 8.028158e+09 4.072326 TimeIntegrator: 1.644940e-04 30 1.744940e-05 8.004736e+09 4.121289 TimeIntegrator: 1.63909e-03 50 1.773909e-04 7.951734e+09 4.307905 TimeIntegrator: 7.22796e-03 60 3.044816e-04 7.83845e+09 3.793250 TimeIntegrator: 7.21936e-03 70 4.8667782e-04 7.739504e+09 3.793250 TimeIntegrator: 1.19950e-02 80 4.866076e-04 7.739504e+09 3.93550 TimeIntegrator: 2.192384e-02 100 4.86245e-04 7.680370e+09 4.211648 TimeIntegrator: 3.164608e-02 120 4.855492e-04 7.68205e+09 4.177467 TimeIntegrator: 4.13622e-02 140 4.855492e-04 7.68205e+09 4.177467 TimeIntegrator: 5.167329e-02 160 4.8554182e-04 7.62046e+09 3.774567 TimeIntegrator: 5.167329e-02 160 4.8541 | TimeIntegrator: | 0.000000e+00 | 0 | 1.000000e-06 | N/A | N/A |
| TimeIntegrator: 5.727500e-05 20 6.727500e-05 8.008421e+09 4.212089 TimeIntegrator: 1.644940e-04 30 1.744940e-05 8.008421e+09 4.212089 TimeIntegrator: 1.63909e-03 50 1.173909e-04 7.961734e+09 4.307905 TimeIntegrator: 3.034816e-03 60 3.044416e-04 7.983845e+09 3.920318 TimeIntegrator: 1.219500e-02 80 4.866076e-04 7.73946re09 3.739326 TimeIntegrator: 1.706028e-02 90 4.866076e-04 7.739504e+09 3.993550 TimeIntegrator: 2.192384e-02 100 4.362455e-04 7.708094e+09 4.23182 TimeIntegrator: 3.16408e-02 120 4.85492e-04 7.68037e+09 4.116448 TimeIntegrator: 3.1654990e-02 130 4.358028e-04 7.68205e+09 4.157207 TimeIntegrator: 4.612844e-02 150 4.85632e-04 7.622046e+09 3.920806 TimeIntegrator: 5.06729e-02 160 4.85632e-04 7.622046e+09 3.920806 TimeIntegrator: 5.06729e-02 160 4.8563 | TimeIntegrator: | 1.593742e-05 | 10 | 2.593742e-06 | 7.951023e+09 | 3.904353 |
| TimeIntegrator: 1.644940e-04 30 1.744940e-05 8.008421e+09 4.212089 TimeIntegrator: 1.63390e-03 50 1.73390e-04 7.961734e+09 4.307905 TimeIntegrator: 3.03416e-03 60 3.044316e-04 7.83345e+09 3.920318 TimeIntegrator: 7.32736e-03 70 4.867873e-04 7.6867858e+09 3.73326 TimeIntegrator: 1.219506e-02 80 4.866318e-04 7.733964e+09 3.993550 TimeIntegrator: 2.16284e-02 100 4.862645e-04 7.783964e+09 4.21882 TimeIntegrator: 2.165875e-02 110 4.850248e-04 7.680638e+09 4.23682 TimeIntegrator: 3.164608e-02 120 4.854312e-04 7.680638e+09 4.172648 TimeIntegrator: 3.164608e-02 120 4.856328e-04 7.682065e+09 4.177267 TimeIntegrator: 4.61244e-02 150 4.856319e-04 7.63206e+09 3.774363 TimeIntegrator: 5.107329e-02 160 4.851331e-04 7.63206e+09 4.17237 TimeIntegrator: 5.067329e-02 170 4.85302 | TimeIntegrator: | 5.727500e-05 | 20 | 6.727500e-06 | 8.028158e+09 | 4.072326 |
| TimeIntegrator: 4.425926e-04 40 4.525926e-05 8.004786e+09 4.183434 TimeIntegrator: 1.05300e-03 50 1.17300e-04 7.961734e+09 4.307905 TimeIntegrator: 3.034316e-03 60 3.044316e-04 7.891348e+09 3.720316 TimeIntegrator: 1.219500e-02 80 4.866076e-04 7.739367e+09 3.770076 TimeIntegrator: 1.706028e-02 90 4.861024e-04 7.738904e+09 3.293550 TimeIntegrator: 2.1678575e-02 100 4.861024e-04 7.708094e+09 4.231882 TimeIntegrator: 3.164608e-02 120 4.859492e-04 7.686638e+09 4.157207 TimeIntegrator: 3.164608e-02 120 4.856092e-04 7.6809252e+09 4.157207 TimeIntegrator: 4.621844e-02 150 4.855022e-04 7.699252e+09 4.157207 TimeIntegrator: 4.621844e-02 150 4.854182e-04 7.430682e+09 3.920866 TimeIntegrator: 5.92056e-02 170 4.853023e-04 7.068038e+09 3.132586 TimeIntegrator: 6.63034e-02 160 < | TimeIntegrator: | 1.644940e-04 | 30 | 1.744940e-05 | 8.008421e+09 | 4.212089 |
| TimeIntegrator: 1.163909e-03 50 1.173909e-04 7.961734e+09 4.307965 TimeIntegrator: 3.034316e-03 60 3.044316e-04 7.839345e+09 3.920318 TimeIntegrator: 1.219500e-02 80 4.867873e-04 7.836658e+09 3.739326 TimeIntegrator: 1.219500e-02 80 4.864313e-04 7.739467e+09 3.79076 TimeIntegrator: 2.105284e-02 100 4.86245e-04 7.708094e+09 4.21382 TimeIntegrator: 3.164608e-02 120 4.85942e-04 7.680370e+09 4.114648 TimeIntegrator: 3.650490e-02 130 4.858028e-04 7.6909252e+09 4.157207 TimeIntegrator: 3.650490e-02 130 4.858028e-04 7.62095e+09 4.177367 TimeIntegrator: 4.61322e-02 140 4.856028e-04 7.63035e+09 4.177357 TimeIntegrator: 5.07329e-02 160 4.851321e-04 7.63159e+09 3.192086 TimeIntegrator: 5.07329e-02 170 4.853028e-04 7.676315e+09 3.103568 TimeIntegrator: 5.592695e-02 170 4.8 | TimeIntegrator: | 4.425926e-04 | 40 | 4.525926e-05 | 8.004786e+09 | 4.183434 |
| TimeIntegrator: 3.034816e-03 60 3.044816e-04 7.893845e+09 3.920318 TimeIntegrator: 7.327356e-03 70 4.867378e-04 7.866658e+09 3.739326 TimeIntegrator: 1.215900e-02 80 4.866378e-04 7.739504e+09 3.936365 TimeIntegrator: 1.20500e-02 90 4.864313e-04 7.739504e+09 3.936365 TimeIntegrator: 2.10234e-02 100 4.861024e-04 7.68094e+09 4.231882 TimeIntegrator: 3.64608e-02 120 4.851024e-04 7.68094e+09 4.273643 TimeIntegrator: 3.650490e-02 130 4.856058e-04 7.690252e+09 4.157207 TimeIntegrator: 4.136232e-02 140 4.856058e-04 7.63005e+09 3.774363 TimeIntegrator: 5.07329e-02 160 4.85112e-04 7.636632e+09 3.920866 TimeIntegrator: 5.59265e-02 170 4.853023e-04 7.076315e+09 4.172325 TimeIntegrator: 6.503094e-02 190 4.859032e-04 6.017109e+09 3.920866 TimeIntegrator: 7.048139e-02 200 4.8 | TimeIntegrator: | 1.163909e-03 | 50 | 1.173909e-04 | 7.961734e+09 | 4.307905 |
| TimeIntegrator: 7.327936e-03 70 4.867873e-04 7.868658e+09 3.739326 TimeIntegrator: 1.219508e-02 80 4.867873e-04 7.73367e+09 3.770076 TimeIntegrator: 1.76028e-02 90 4.864313e-04 7.739504e+09 3.93366 TimeIntegrator: 2.192384e-02 100 4.862645e-04 7.708094e+09 4.231982 TimeIntegrator: 3.650490e-02 120 4.859492e-04 7.668038e+09 4.273643 TimeIntegrator: 3.650490e-02 130 4.858028e-04 7.699252e+09 4.157207 TimeIntegrator: 4.136232e-02 140 4.856038e-04 7.662005e+09 4.177367 TimeIntegrator: 5.107329e-02 160 4.854182e-04 7.430682e+09 3.920086 TimeIntegrator: 5.07329e-02 170 4.850328e-04 7.66159e+09 4.172325 TimeIntegrator: 6.563094e-02 190 4.859032e-04 6.61533e+09 4.108568 TimeIntegrator: 6.563094e-02 190 4.84983ae-04 6.61533e+09 4.16456 TimeIntegrator: 7.648139e-02 200 4 | TimeIntegrator: | 3.034816e-03 | 60 | 3.044816e-04 | 7.893845e+09 | 3.920318 |
| TimeIntegrator: 1.219500e-02 80 4.866076e-04 7.793467e+09 3.770076 TimeIntegrator: 1.706028e-02 90 4.862645e-04 7.739504e+09 3.93650 TimeIntegrator: 2.192384e-02 100 4.862645e-04 7.739504e+09 4.231882 TimeIntegrator: 3.164608e-02 120 4.85042e-04 7.680370e+09 4.114648 TimeIntegrator: 3.164608e-02 120 4.858028e-04 7.680370e+09 4.137364 TimeIntegrator: 3.164608e-02 130 4.858028e-04 7.680370e+09 4.137364 TimeIntegrator: 4.136232e-02 140 4.85696e-04 7.62005e+09 4.157207 TimeIntegrator: 5.107329e-02 160 4.854192e-04 7.632085e+09 3.920086 TimeIntegrator: 5.92695e-02 170 4.853023e-04 7.436832e+09 3.172356 TimeIntegrator: 6.077947e-02 180 4.851931e-04 6.601333e+09 3.103568 TimeIntegrator: 7.533088e-02 200 4.84914e-04 6.691333e+09 3.14286 TimeIntegrator: 7.043308e+02 200 <td< td=""><td>TimeIntegrator:</td><td>7.327936e-03</td><td>70</td><td>4.867873e-04</td><td>7.868658e+09</td><td>3.739326</td></td<> | TimeIntegrator: | 7.327936e-03 | 70 | 4.867873e-04 | 7.868658e+09 | 3.739326 |
| TimeIntegrator: 1.706028e-02 90 4.864313e-04 7.739504e+09 3.993650 TimeIntegrator: 2.192384e-02 100 4.862645e-04 7.78994e+09 4.231982 TimeIntegrator: 2.678575-02 110 4.85092e-04 7.680370e+09 4.114648 TimeIntegrator: 3.164608e-02 120 4.859492e-04 7.680370e+09 4.157207 TimeIntegrator: 3.650490e-02 130 4.858028e-04 7.69252e+09 4.157207 TimeIntegrator: 4.621844e-02 150 4.855419e-04 7.63205e+09 4.177367 TimeIntegrator: 5.107329e-02 160 4.85191e-04 7.63205e+09 3.174363 TimeIntegrator: 5.59265e-02 170 4.853032e-04 7.43682e+09 3.103568 TimeIntegrator: 6.677947e-02 180 4.851931e-04 6.801539e+09 3.103568 TimeIntegrator: 7.048139e-02 200 4.849349e-04 6.61310e+09 3.80033 TimeIntegrator: 7.048139e-02 200 4.849349e-04 6.51710e+09 3.14286 TimeIntegrator: 8.502719e-02 200 4.84 | TimeIntegrator: | 1.219500e-02 | 80 | 4.866076e-04 | 7.793467e+09 | 3.770076 |
| TimeIntegrator: 2.192384e-02 100 4.862645e-04 7.78094e+09 4.231982 TimeIntegrator: 2.678575e-02 110 4.861024e-04 7.680370e+09 4.114648 TimeIntegrator: 3.16408e-02 120 4.859492e-04 7.68638e+09 4.273643 TimeIntegrator: 3.16408e-02 130 4.856082e-04 7.639252e+09 4.157207 TimeIntegrator: 4.136232e-02 140 4.856082e-04 7.624046e+09 3.774363 TimeIntegrator: 5.107329e-02 160 4.854182e-04 7.430632e+09 3.920886 TimeIntegrator: 5.07329e-02 170 4.853023e-04 7.076315e+09 4.172325 TimeIntegrator: 6.077947e-02 180 4.851931e-04 6.801539e+09 3.103668 TimeIntegrator: 7.048139e-02 200 4.849914e-04 6.617100e+09 3.880933 TimeIntegrator: 7.533088e-02 210 4.845983e-04 6.617100e+09 3.84093 TimeIntegrator: 8.07947e-02 220 4.845914e-04 6.545472re+9 3.714286 TimeIntegrator: 8.96741re-02 240 < | TimeIntegrator: | 1.706028e-02 | 90 | 4.864313e-04 | 7.739504e+09 | 3,993650 |
| TimeIntegrator:2.678575e-021104.861024e-047.680370e+094.114648TimeIntegrator:3.164608e-021204.859492e-047.680370e+094.273643TimeIntegrator:3.650490e-021304.858028e-047.69252e+094.157207TimeIntegrator:4.1621844e-021504.855619e-047.624046e+093.774363TimeIntegrator:5.107329e-021604.854182e-047.430682e+093.920086TimeIntegrator:5.00739e-021604.8551931e-046.801539e+094.172325TimeIntegrator:6.563094e-021904.85902e-046.74842a+094.771410TimeIntegrator:7.048139e-022004.849914e-046.617100e+093.880033TimeIntegrator:7.533088e-022104.848107e-046.554727e+093.714286TimeIntegrator:8.017947e-022204.848107e-046.54727e+093.714286TimeIntegrator:8.987411e-022404.84574re-046.345239e+092.172663TimeIntegrator:9.95659e-022604.84574re-046.317087e+092.240765TimeIntegrator:1.044104e-012704.843735e-046.11079e+092.725292TimeIntegrator:1.04980e-012004.843735e-046.11727e+092.672542TimeIntegrator:1.27332e-013004.842048e-046.11727e+092.672542TimeIntegrator:1.286250e-012004.843735e-046.11727e+092.672542TimeIntegrator:1.27332e-01 | TimeIntegrator: | 2.192384e-02 | 100 | 4.862645e-04 | 7.708094e+09 | 4.231982 |
| TimeIntegrator:3.164608e-021204.859492e-047.686638e+094.273643TimeIntegrator:3.650490e-021304.858028e-047.69252e+094.157207TimeIntegrator:4.136232e-021404.856696e-047.68205e+094.177367TimeIntegrator:4.621844e-021504.855419e-047.624046e+093.774563TimeIntegrator:5.107329e-021604.855419e-047.6315e+093.920086TimeIntegrator:5.502695e-021704.853032e-047.076315e+094.172325TimeIntegrator:6.670947e-021804.851931e-046.801339e+093.103568TimeIntegrator:7.048139e-022004.849914e-046.691332e+093.80033TimeIntegrator:7.533088e-022104.84898e-046.617100e+093.880033TimeIntegrator:8.017947e-022204.848107e-046.556650e+092.458089TimeIntegrator:8.987411e-022404.84691e-046.414570e+092.240765TimeIntegrator:9.955569e-022504.845747e-046.308356e+092.252992TimeIntegrator:1.044104e-012704.844373e-046.210179e+092.679004TimeIntegrator:1.04960e-012004.84373e-046.117275e+092.672542TimeIntegrator:1.237832e-013004.842579e-046.137397e+092.672542TimeIntegrator:1.334663e-013004.842579e-046.117275e+092.46597TimeIntegrator:1.2383072e-01 <td>TimeIntegrator:</td> <td>2.678575e-02</td> <td>110</td> <td>4.861024e-04</td> <td>7.680370e+09</td> <td>4.114648</td> | TimeIntegrator: | 2.678575e-02 | 110 | 4.861024e-04 | 7.680370e+09 | 4.114648 |
| TimeIntegrator:3.650490e-021304.858028e-047.699252e+094.157207TimeIntegrator:4.136232e-021404.856696e-047.632005e+094.177367TimeIntegrator:4.621844e-021504.855419e-047.624046e+093.774363TimeIntegrator:5.107329e-021604.854182e-047.63682e+093.920086TimeIntegrator:5.592695e-021704.853023e-047.076315e+094.172325TimeIntegrator:6.077947e-021804.851931e-046.801539e+093.103568TimeIntegrator:7.048139e-022004.849914e-046.691333e+096.146956TimeIntegrator:7.053088e-022104.848983e-046.617100e+093.880033TimeIntegrator:8.017947e-022204.844914e-046.59650e+092.458089TimeIntegrator:8.907411e-022404.846491e-046.414570e+092.240765TimeIntegrator:9.95650e-022604.845747e-046.38356e+092.25292TimeIntegrator:1.044104e-012704.844373e-046.317087e+092.672942TimeIntegrator:1.092545e-012804.842378e-046.117275e+092.672542TimeIntegrator:1.286250e-013004.842378e-046.117275e+092.672542TimeIntegrator:1.33663e-013004.842378e-046.117275e+092.465897TimeIntegrator:1.33663e-013004.842378e-046.117275e+092.465897TimeIntegrator:1.33663e-01 </td <td>TimeIntegrator:</td> <td>3.164608e-02</td> <td>120</td> <td>4.859492e-04</td> <td>7.686638e+09</td> <td>4.273643</td> | TimeIntegrator: | 3.164608e-02 | 120 | 4.859492e-04 | 7.686638e+09 | 4.273643 |
| TimeIntegrator:4.136232e-021404.856696e-047.682005e+094.177367TimeIntegrator:4.621844e-021504.855419e-047.624046e+093.774363TimeIntegrator:5.107329e-021604.854182e-047.430682e+093.92086TimeIntegrator:5.592695e-021704.853023e-047.076315e+094.172325TimeIntegrator:6.077947e-021804.851931e-046.801539e+093.103568TimeIntegrator:6.563094e-021904.850902e-046.748423e+094.771410TimeIntegrator:7.048139e-022004.849914e-046.691332e+093.80033TimeIntegrator:7.533688e-022104.84893e-046.617100e+093.880033TimeIntegrator:8.017947e-022204.847271e-046.596550e+092.458089TimeIntegrator:8.502719e-022304.847271e-046.365650e+092.240765TimeIntegrator:8.987411e-022404.845042e-046.345239e+092.172663TimeIntegrator:9.956569e-022604.845042e-046.317087e+092.672542TimeIntegrator:1.092545e-012804.843735e-046.117707e+092.672542TimeIntegrator:1.189409e-012904.842579e-046.117275e+092.672542TimeIntegrator:1.23732e-013104.842048e-046.01334e+092.136093TimeIntegrator:1.236250e-013004.841539e-045.98344e+092.136093TimeIntegrator:1.38663e-01< | TimeIntegrator: | 3.650490e-02 | 130 | 4.858028e-04 | 7.699252e+09 | 4.157207 |
| TimeIntegrator:4.621844e-021504.855419e-047.624046e+093.774363TimeIntegrator:5.107329e-021604.854182e-047.43682e+093.92086TimeIntegrator:5.592695e-021704.853023e-047.076315e+094.172325TimeIntegrator:6.077947e-021804.853023e-046.801539e+093.103568TimeIntegrator:6.563094e-021904.850902e-046.748423e+094.771410TimeIntegrator:7.048139e-022004.849914e-046.691333e+096.146956TimeIntegrator:7.53088e-022104.848983e-046.617100e+093.880033TimeIntegrator:8.017947e-022204.848107e-046.554727e+093.714286TimeIntegrator:8.097411e-022204.84574re-046.30835e+092.240765TimeIntegrator:9.472026e-022504.84574re-046.30835e+092.172663TimeIntegrator:9.956569e-022604.845042e-046.317087e+092.252992TimeIntegrator:1.04104e-012704.84373e-046.117275e+092.672542TimeIntegrator:1.189409e-012004.842579e-046.117275e+092.1735128TimeIntegrator:1.237832e-013104.842048e-046.013344e+092.136093TimeIntegrator:1.236250e-013204.841539e-045.993302e+092.037715TimeIntegrator:1.238072e-013004.842048e-046.013434e+092.136093TimeIntegrator:1.336672e-01 | TimeIntegrator: | 4.136232e-02 | 140 | 4.856696e-04 | 7.682005e+09 | 4.177367 |
| TimeIntegrator:5.107329e-021604.854182e-047.430682e+093.920086TimeIntegrator:5.592695e-021704.853023e-047.076315e+094.172325TimeIntegrator:6.077947e-021804.851931e-046.801539e+093.103568TimeIntegrator:6.563094e-021904.850902e-046.748423e+094.771410TimeIntegrator:7.048139e-022004.849914e-046.601333e+096.146956TimeIntegrator:7.533088e-022104.849914e-046.617100e+093.880033TimeIntegrator:8.017947e-022204.847271e-046.506650e+092.458089TimeIntegrator:8.50719e-022304.84771e-046.306550e+092.458089TimeIntegrator:9.472026e-022504.84574re-046.31708re+092.240765TimeIntegrator:9.956569e-022604.84374re-046.31708re+092.679004TimeIntegrator:1.092545e-012904.843146e-046.158299e+092.735128TimeIntegrator:1.189409e-012904.843146e-046.013434e+092.136093TimeIntegrator:1.286250e-013204.841539e-045.980344e+092.037715TimeIntegrator:1.334663e-013304.841063e-045.93302e+092.220177TimeIntegrator:1.334072e-013404.84018re-045.933302e+092.202197TimeIntegrator:1.431476e-013504.84018re-045.985458e+091.836741TimeIntegrator:1.52872e- | TimeIntegrator: | 4.621844e-02 | 150 | 4.855419e-04 | 7.624046e+09 | 3.774363 |
| TimeIntegrator:5.592695e-021704.853023e-047.076315e+094.172325TimeIntegrator:6.077947e-021804.851931e-046.801539e+093.103568TimeIntegrator:6.563094e-021904.869092e-046.748423e+094.771410TimeIntegrator:7.048139e-022004.849914e-046.69133e+096.16953TimeIntegrator:7.053088e-022104.84993e-046.617100e+093.880033TimeIntegrator:8.017947e-022204.848107e-046.554727e+093.714286TimeIntegrator:8.017947e-022204.847271e-046.50650e+092.458089TimeIntegrator:8.987411e-022404.846491e-046.414570e+092.240765TimeIntegrator:9.472026e-022504.845747e-046.305356e+092.252992TimeIntegrator:1.044104e-012704.843373e-046.210179e+092.679004TimeIntegrator:1.092545e-012804.842373e-046.158299e+092.75242TimeIntegrator:1.189409e-013004.842579e-046.117275e+092.465897TimeIntegrator:1.237832e-013104.84063e-045.980344e+092.037715TimeIntegrator:1.336072e-013204.84163e-045.993302e+092.202197TimeIntegrator:1.338072e-013604.84063e-045.993302e+092.202197TimeIntegrator:1.625250e-013204.84163e-045.993302e+092.202197TimeIntegrator:1.638072e-01 <td>TimeIntegrator:</td> <td>5.107329e-02</td> <td>160</td> <td>4.854182e-04</td> <td>7.430682e+09</td> <td>3.920086</td> | TimeIntegrator: | 5.107329e-02 | 160 | 4.854182e-04 | 7.430682e+09 | 3.920086 |
| TimeIntegrator:6.077947e-021804.851931e-046.801539e+093.103568TimeIntegrator:6.563094e-021904.850902e-046.748423e+094.771410TimeIntegrator:7.048139e-022004.849914e-046.691333e+096.146956TimeIntegrator:7.533088e-022104.848983e-046.617100e+093.880033TimeIntegrator:8.017947e-022204.848107e-046.55650e+092.458089TimeIntegrator:8.502719e-022304.847271e-046.56656e+092.240765TimeIntegrator:9.972026e-022504.845747e-046.308356e+092.240765TimeIntegrator:9.956569e-022604.845042e-046.308356e+092.252992TimeIntegrator:1.09245e-012704.844372e-046.317087e+092.679004TimeIntegrator:1.092545e-012804.843735e-046.210179e+092.735128TimeIntegrator:1.189409e-013004.842579e-046.117275e+092.465897TimeIntegrator:1.237832e-013104.842048e-046.013434e+092.136093TimeIntegrator:1.334663e-013304.841539e-045.933302e+092.207715TimeIntegrator:1.334663e-013504.840187e-045.933302e+092.20177TimeIntegrator:1.479876e-013604.839782e-045.929866e+092.268091TimeIntegrator:1.479876e-013604.839782e-045.818551e+094.272906TimeIntegrator:1.479876e- | TimeIntegrator: | 5.592695e-02 | 170 | 4.853023e-04 | 7.076315e+09 | 4.172325 |
| TimeIntegrator:6.563094e-021904.850902e-046.748423e+094.771410TimeIntegrator:7.048139e-022004.849914e-046.691333e+096.146956TimeIntegrator:7.533088e-022104.848983e-046.617100e+093.880033TimeIntegrator:8.017947e-022204.848107e-046.554727e+093.714286TimeIntegrator:8.502719e-022304.84721e-046.50650e+092.458089TimeIntegrator:8.987411e-022404.846491e-046.414570e+092.240765TimeIntegrator:9.472026e-022504.845747e-046.345239e+092.172663TimeIntegrator:9.956569e-022604.845042e-046.310787e+092.67904TimeIntegrator:1.092545e-012804.84373e-046.11727e+092.672542TimeIntegrator:1.140980e-012004.843146e-046.117275e+092.465897TimeIntegrator:1.237832e-013104.842048e-046.013434e+092.136093TimeIntegrator:1.2366250e-013204.841539e-045.980344e+092.037715TimeIntegrator:1.334663e-013304.841063e-045.979734e+091.836741TimeIntegrator:1.431476e-013504.840187e-045.985458e+091.841658TimeIntegrator:1.479876e-013604.83982e-045.929866e+092.268691TimeIntegrator:1.432476e-013604.839782e-045.913302e+092.268691TimeIntegrator:1.431476e-0 | TimeIntegrator: | 6.077947e-02 | 180 | 4.851931e-04 | 6.801539e+09 | 3.103568 |
| TimeIntegrator:7.048139e-022004.849914e-046.691333e+096.146956TimeIntegrator:7.533088e-022104.848983e-046.617100e+093.880033TimeIntegrator:8.017947e-022204.848107e-046.554727e+093.714286TimeIntegrator:8.502719e-022304.847271e-046.506650e+092.458089TimeIntegrator:8.987411e-022404.846491e-046.414570e+092.240765TimeIntegrator:9.472026e-022504.845747e-046.345239e+092.252992TimeIntegrator:9.956569e-022604.845042e-046.317087e+092.679004TimeIntegrator:1.092545e-012804.843735e-046.117275e+092.672542TimeIntegrator:1.149980e-012904.843579e-046.117275e+092.465897TimeIntegrator:1.286250e-013004.842579e-046.013434e+092.136093TimeIntegrator:1.334663e-013304.841063e-045.9933302e+092.037715TimeIntegrator:1.334663e-013304.84063e-045.9933302e+092.202197TimeIntegrator:1.338072e-013404.840187e-045.885458e+091.83654TimeIntegrator:1.431476e-013504.840187e-045.992866e+092.268691TimeIntegrator:1.479876e-013604.839782e-045.929866e+092.268691TimeIntegrator:1.479876e-013604.839782e-045.929866e+092.268691TimeIntegrator:1.5282 | TimeIntegrator: | 6.563094e-02 | 190 | 4.850902e-04 | 6.748423e+09 | 4.771410 |
| TimeIntegrator:7.533088e-022104.848983e-046.617100e+093.880033TimeIntegrator:8.017947e-022204.848107e-046.554727e+093.714286TimeIntegrator:8.502719e-022304.847271e-046.506650e+092.458089TimeIntegrator:8.987411e-022404.846491e-046.414570e+092.240765TimeIntegrator:9.472026e-022504.845747e-046.308356e+092.252992TimeIntegrator:9.956569e-022604.845942e-046.317087e+092.679004TimeIntegrator:1.044104e-012704.844372e-046.11708re+092.672542TimeIntegrator:1.092545e-012804.843735e-046.11727e+092.672542TimeIntegrator:1.140980e-012904.843146e-046.117275e+092.465897TimeIntegrator:1.237832e-013104.842048e-046.013434e+092.136093TimeIntegrator:1.334663e-013204.841639e-045.980344e+092.037715TimeIntegrator:1.334663e-013304.841063e-045.979734e+091.836741TimeIntegrator:1.334663e-013504.840187e-045.885458e+091.841658TimeIntegrator:1.431476e-013504.840187e-045.885458e+091.841658TimeIntegrator:1.479876e-013604.839782e-045.92866e+092.268691TimeIntegrator:1.479876e-013604.839782e-045.818551e+094.272906TimeIntegrator:1.672676 | TimeIntegrator: | 7.048139e-02 | 200 | 4.849914e-04 | 6.691333e+09 | 6.146956 |
| TimeIntegrator:8.017947e-022204.848107e-046.554727e+093.714286TimeIntegrator:8.502719e-022304.847271e-046.506650e+092.458089TimeIntegrator:8.987411e-022404.846491e-046.414570e+092.240765TimeIntegrator:9.472026e-022504.845747e-046.345239e+092.172663TimeIntegrator:9.956569e-022604.845042e-046.308356e+092.252992TimeIntegrator:1.044104e-012704.844372e-046.317087e+092.679004TimeIntegrator:1.092545e-012804.843735e-046.117275e+092.672542TimeIntegrator:1.189409e-013004.842579e-046.013434e+092.136093TimeIntegrator:1.286250e-013204.841539e-045.980344e+092.037715TimeIntegrator:1.334663e-013304.841063e-045.979734e+091.836741TimeIntegrator:1.383072e-013404.840615e-045.933302e+092.202197TimeIntegrator:1.431476e-013504.840187e-045.885458e+091.841658TimeIntegrator:1.479876e-013604.839782e-045.929866e+092.268691TimeIntegrator:1.479876e-013604.839782e-045.818551e+094.272060TimeIntegrator:1.479876e-013604.839398e-045.818551e+094.272060TimeIntegrator:1.528272e-013704.839398e-045.818551e+094.272060TimeIntegrator:1.5282 | TimeIntegrator: | 7.533088e-02 | 210 | 4.848983e-04 | 6.617100e+09 | 3.880033 |
| TimeIntegrator:8.502719e-022304.847271e-046.506650e+092.458089TimeIntegrator:8.987411e-022404.846491e-046.414570e+092.240765TimeIntegrator:9.472026e-022504.845747e-046.345239e+092.172663TimeIntegrator:9.956569e-022604.845042e-046.308356e+092.252992TimeIntegrator:1.044104e-012704.844372e-046.317087e+092.679004TimeIntegrator:1.092545e-012804.843735e-046.210179e+092.672542TimeIntegrator:1.140980e-012904.843146e-046.117275e+092.465897TimeIntegrator:1.237832e-013104.842048e-046.013434e+092.136093TimeIntegrator:1.334663e-013204.841063e-045.980344e+092.037715TimeIntegrator:1.333072e-013404.840615e-045.933302e+092.202197TimeIntegrator:1.431476e-013504.849187e-045.885458e+091.841658TimeIntegrator:1.479876e-013604.839782e-045.929866e+092.268691TimeIntegrator:1.479876e-013604.839782e-045.929866e+092.268691TimeIntegrator:1.479876e-013704.839398e-045.818551e+094.272906TimeIntegrator:1.479876e-013704.839398e-045.818551e+094.272906TimeIntegrator:1.479876e-013704.839398e-045.818551e+094.272906TimeIntegrator:1.4798 | TimeIntegrator: | 8.017947e-02 | 220 | 4.848107e-04 | 6.554727e+09 | 3.714286 |
| TimeIntegrator:8.987411e-022404.846491e-046.414570e+092.240765TimeIntegrator:9.472026e-022504.845747e-046.345239e+092.172663TimeIntegrator:9.956569e-022604.845042e-046.308356e+092.252992TimeIntegrator:1.044104e-012704.844372e-046.317087e+092.679004TimeIntegrator:1.092545e-012804.843735e-046.210179e+092.672542TimeIntegrator:1.140980e-012904.843146e-046.158299e+092.735128TimeIntegrator:1.237832e-013004.842048e-046.013434e+092.136093TimeIntegrator:1.286250e-013204.841063e-045.980344e+092.037715TimeIntegrator:1.334663e-013304.841063e-045.933302e+092.202197TimeIntegrator:1.431476e-013504.840187e-045.885458e+091.841658TimeIntegrator:1.479876e-013604.839782e-045.929866e+092.268691TimeIntegrator:1.528272e-013704.83938e-045.9129866e+092.268691TimeIntegrator:1.528272e-013704.83938e-045.918551e+094.272906TimeIntegrator:1.528272e-013704.839398e-045.9129866e+092.268691TimeIntegrator:1.528272e-013704.839398e-045.9129866e+092.268691TimeIntegrator:1.528272e-013704.839398e-045.9129866e+092.268691TimeIntegrator:1.52 | TimeIntegrator: | 8.502719e-02 | 230 | 4.847271e-04 | 6.506650e+09 | 2.458089 |
| TimeIntegrator:9.472026e-022504.845747e-046.345239e+092.172663TimeIntegrator:9.956569e-022604.845042e-046.308356e+092.252992TimeIntegrator:1.044104e-012704.844372e-046.317087e+092.679004TimeIntegrator:1.092545e-012804.843735e-046.210179e+092.672542TimeIntegrator:1.140980e-012904.843146e-046.158299e+092.735128TimeIntegrator:1.189409e-013004.842579e-046.117275e+092.465897TimeIntegrator:1.237832e-013104.842048e-046.013434e+092.136093TimeIntegrator:1.286250e-013204.841539e-045.980344e+092.037715TimeIntegrator:1.334663e-013304.841063e-045.979734e+091.836741TimeIntegrator:1.431476e-013504.840187e-045.885458e+091.841658TimeIntegrator:1.479876e-013604.839782e-045.929866e+092.268691TimeIntegrator:1.528272e-013704.839398e-045.818551e+094.272906TimeIntegrator:1.528272e-013704.839398e-045.818551e+094.2268691TimeIntegrator:1.528272e-013704.839398e-045.818551e+094.272906TimeIntegrator:1.528272e-013704.839398e-045.818551e+094.272906TimeIntegrator:1.528272e-013704.839398e-045.818551e+094.272906 | TimeIntegrator: | 8.987411e-02 | 240 | 4.846491e-04 | 6.414570e+09 | 2.240765 |
| TimeIntegrator:9.956569e-022604.845042e-046.308356e+092.252992TimeIntegrator:1.044104e-012704.844372e-046.317087e+092.679004TimeIntegrator:1.092545e-012804.843735e-046.210179e+092.672542TimeIntegrator:1.140980e-012904.843146e-046.158299e+092.735128TimeIntegrator:1.189409e-013004.842579e-046.0117275e+092.465897TimeIntegrator:1.237832e-013104.842048e-046.013434e+092.136093TimeIntegrator:1.286250e-013204.841539e-045.980344e+092.037715TimeIntegrator:1.334663e-013304.841063e-045.979734e+091.836741TimeIntegrator:1.431476e-013504.840187e-045.885458e+091.841658TimeIntegrator:1.479876e-013604.839782e-045.929866e+092.268691TimeIntegrator:1.528272e-013704.839398e-045.91202052.202197TimeIntegrator:1.528272e-013704.839398e-045.9129866e+092.268691TimeIntegrator:1.528272e-013704.839398e-045.918551e+094.272906TimeIntegrator:1.528272e-013704.839398e-045.918551e+094.272906TimeIntegrator:1.528272e-013704.839398e-045.918551e+094.272906 | TimeIntegrator: | 9.472026e-02 | 250 | 4.845747e-04 | 6.345239e+09 | 2.172663 |
| TimeIntegrator:1.044104e-012704.844372e-046.317087e+092.679004TimeIntegrator:1.092545e-012804.843735e-046.210179e+092.672542TimeIntegrator:1.140980e-012904.843146e-046.158299e+092.735128TimeIntegrator:1.189409e-013004.842579e-046.117275e+092.465897TimeIntegrator:1.237832e-013104.842048e-046.013434e+092.136093TimeIntegrator:1.286250e-013204.841539e-045.980344e+092.037715TimeIntegrator:1.334663e-013304.841063e-045.979734e+091.836741TimeIntegrator:1.383072e-013404.840615e-045.933302e+092.202197TimeIntegrator:1.431476e-013504.840187e-045.985458e+091.841658TimeIntegrator:1.528272e-013704.839398e-045.818551e+094.272906TimeIntegrator:1.528272e-013704.839398e-045.818551e+094.272906TimeIntegrator:1.528272e-013704.839398e-045.818551e+094.272906 | TimeIntegrator: | 9.956569e-02 | 260 | 4.845042e-04 | 6.308356e+09 | 2.252992 |
| TimeIntegrator:1.092545e-012804.843735e-046.210179e+092.672542TimeIntegrator:1.140980e-012904.843146e-046.158299e+092.735128TimeIntegrator:1.189409e-013004.842579e-046.117275e+092.465897TimeIntegrator:1.237832e-013104.842048e-046.013434e+092.136093TimeIntegrator:1.286250e-013204.841539e-045.980344e+092.037715TimeIntegrator:1.334663e-013304.841063e-045.979734e+091.836741TimeIntegrator:1.383072e-013404.840615e-045.933302e+092.202197TimeIntegrator:1.431476e-013504.840187e-045.885458e+091.841658TimeIntegrator:1.479876e-013604.839782e-045.929866e+092.268691TimeIntegrator:1.528272e-013704.839398e-045.818551e+094.272906TimeIntegrator:1.528272e-013704.839398e-045.818551e+094.272906 | TimeIntegrator: | 1.044104e-01 | 270 | 4.844372e-04 | 6.317087e+09 | 2.679004 |
| TimeIntegrator:1.140980e-012904.843146e-046.158299e+092.735128TimeIntegrator:1.189409e-013004.842579e-046.117275e+092.465897TimeIntegrator:1.237832e-013104.842048e-046.013434e+092.136093TimeIntegrator:1.286250e-013204.841539e-045.980344e+092.037715TimeIntegrator:1.334663e-013304.841063e-045.979734e+091.836741TimeIntegrator:1.383072e-013404.840615e-045.933302e+092.202197TimeIntegrator:1.431476e-013504.840187e-045.885458e+091.841658TimeIntegrator:1.479876e-013604.839782e-045.929866e+092.268691TimeIntegrator:1.528272e-013704.839398e-045.818551e+094.272906TimeIntegrator:1.52665e.012004.03023e-045.07025e+002.268691 | TimeIntegrator: | 1.092545e-01 | 280 | 4.843735e-04 | 6.210179e+09 | 2.672542 |
| TimeIntegrator:1.189409e-013004.842579e-046.117275e+092.465897TimeIntegrator:1.237832e-013104.842048e-046.013434e+092.136093TimeIntegrator:1.286250e-013204.841539e-045.980344e+092.037715TimeIntegrator:1.334663e-013304.841063e-045.979734e+091.836741TimeIntegrator:1.383072e-013404.840615e-045.933302e+092.202197TimeIntegrator:1.431476e-013504.840187e-045.885458e+091.841658TimeIntegrator:1.479876e-013604.839782e-045.929866e+092.268691TimeIntegrator:1.528272e-013704.839398e-045.818551e+094.272906TimeIntegrator:1.526665e012004.8309398e-045.818551e+094.272906 | TimeIntegrator: | 1.140980e-01 | 290 | 4.843146e-04 | 6.158299e+09 | 2.735128 |
| TimeIntegrator:1.237832e-013104.842048e-046.013434e+092.136093TimeIntegrator:1.286250e-013204.841539e-045.980344e+092.037715TimeIntegrator:1.334663e-013304.841063e-045.979734e+091.836741TimeIntegrator:1.383072e-013404.840615e-045.933302e+092.202197TimeIntegrator:1.431476e-013504.840187e-045.885458e+091.841658TimeIntegrator:1.479876e-013604.839782e-045.929866e+092.268691TimeIntegrator:1.528272e-013704.839398e-045.818551e+094.272906TimeIntegrator:1.528272e-013704.820266e-045.0100550002.202197 | TimeIntegrator: | 1.189409e-01 | 300 | 4.842579e-04 | 6.117275e+09 | 2.465897 |
| TimeIntegrator:1.286250e-013204.841539e-045.980344e+092.037715TimeIntegrator:1.334663e-013304.841063e-045.979734e+091.836741TimeIntegrator:1.383072e-013404.840615e-045.933302e+092.202197TimeIntegrator:1.431476e-013504.840187e-045.885458e+091.841658TimeIntegrator:1.479876e-013604.839782e-045.929866e+092.268691TimeIntegrator:1.528272e-013704.839398e-045.818551e+094.272906TimeIntegrator:1.528272e-013704.839398e-045.910055+0002.201014 | TimeIntegrator: | 1.237832e-01 | 310 | 4.842048e-04 | 6.013434e+09 | 2.136093 |
| TimeIntegrator:1.334663e-013304.841063e-045.979734e+091.836741TimeIntegrator:1.383072e-013404.840615e-045.933302e+092.202197TimeIntegrator:1.431476e-013504.840187e-045.885458e+091.841658TimeIntegrator:1.479876e-013604.839782e-045.929866e+092.268691TimeIntegrator:1.528272e-013704.839398e-045.818551e+094.272906TimeIntegrator:1.526665e-013704.839398e-045.818551e+094.272906 | TimeIntegrator: | 1.286250e-01 | 320 | 4.841539e-04 | 5.980344e+09 | 2.037715 |
| TimeIntegrator:1.383072e-013404.840615e-045.933302e+092.202197TimeIntegrator:1.431476e-013504.840187e-045.885458e+091.841658TimeIntegrator:1.479876e-013604.839782e-045.929866e+092.268691TimeIntegrator:1.528272e-013704.839398e-045.818551e+094.272906TimeIntegrator:1.526665e-013704.839398e-045.818551e+094.272906 | TimeIntegrator: | 1.334663e-01 | 330 | 4.841063e-04 | 5.979734e+09 | 1.836741 |
| TimeIntegrator: 1.431476e-01 350 4.840187e-04 5.885458e+09 1.841658 TimeIntegrator: 1.479876e-01 360 4.839782e-04 5.929866e+09 2.268691 TimeIntegrator: 1.528272e-01 370 4.839398e-04 5.818551e+09 4.272906 TimeIntegrator: 1.526665e 01 200 4.839398e-04 5.818551e+09 4.272906 | TimeIntegrator: | 1.383072e-01 | 340 | 4.840615e-04 | 5.933302e+09 | 2.202197 |
| TimeIntegrator: 1.479876e-01 360 4.839782e-04 5.929866e+09 2.268691 TimeIntegrator: 1.528272e-01 370 4.839398e-04 5.818551e+09 4.272906 TimeIntegrator: 1.576665e-01 370 4.839398e-04 5.818551e+09 4.272906 | TimeIntegrator: | 1.431476e-01 | 350 | 4.840187e-04 | 5.885458e+09 | 1.841658 |
| TimeIntegrator: 1.528272e-01 370 4.839398e-04 5.818551e+09 4.272906 TimeIntegrator: 1.576665e.01 200 4.020026e.04 5.070025e.00 2.00011 | TimeIntegrator: | 1.479876e-01 | 360 | 4.839782e-04 | 5.929866e+09 | 2.268691 |
| | TimeIntegrator: | 1.528272e-01 | 370 | 4.839398e-04 | 5.818551e+09 | 4.272906 |
| immetricegrator: 1.570005e-01 380 4.839036e-04 5.878025e+09 🌉 2.621614 | TimeIntegrator: | 1.576665e-01 | 380 | 4.839036e-04 | 5.878025e+09 | 2.621614 |



#1: system stability (cont'd)

Every 0,1s: rocm-smi -t

| | == | ===== ROCm Syste | m Ma Temp | nagement Interface == | ====== |
|---|----|---|--------------|--------------------------|--------|
| GPU[0] | | Temperature (Sen | sor | edge (C): 88.0 | |
| GPU[0] | : | Temperature (Sen | sor | iunction (C): 96.0 | |
| GPU[0] | : | Temperature (Sen | sor | memory) (C): 93.0 | |
| GPU[0] | : | Temperature (Sen | sor | HBM 0) (C): 92.0 | |
| GPU[0] | : | Temperature (Sen | sor | HBM 1) (C): 91.0 | |
| GPU[0] | : | Temperature (Sen | sor | HBM 2) (C): 90.0 | |
| GPU[0] | : | Temperature (Sen | sor | HBM 3) (C): 93.0 | |
| GPU[1] | : | Temperature (Sen | sor | edge) (C): 78.0 | |
| GPU[1] | : | Temperature (Sen | sor | junction) (C): 92.0 | |
| GPU[1] | : | Temperature (Sen | sor | memory) (C): 92.0 | |
| GPU[1] | : | Temperature (Sen | sor | HBM 0) (C): 89.0 | |
| GPU[1] | : | Temperature (Sen | sor | HBM 1) (C): 88.0 | |
| GPU[1] | : | Temperature (Sen | sor | HBM 2) (C): 91.0 | |
| GPU[1] | : | Temperature (Sen | sor | HBM 3) (C): 92.0 | |
| GPU[2] | : | Temperature (Sen | sor | edge) (C): 72.0 | |
| GPU[2] | : | Temperature (Sen | sor | junction) (C): 73.0 | |
| GPU[2] | : | Temperature (Sen | sor | memory) (C): 74.0 | |
| GPU[2] | : | Temperature (Sen | sor | HBM 0) (C): 72.0 | |
| GPU[2] | : | Temperature (Sen | sor | HBM 1) (C): 70.0 | |
| GPU[2] | : | Temperature (Sen | sor | HBM 2) (C): 72.0 | |
| GPU[2] | : | Temperature (Sen | sor | HBM 3) (C): 74.0 | |
| GPU[3] | : | Temperature (Sen | sor | edge) (C): 66.0 | |
| GPU[3] | : | Temperature (Sen | sor | junction) (C): 72.0 | |
| GPU[3] | : | Temperature (Sen | sor | memory) (C): 74.0 | |
| GPU[3] | : | Temperature (Sen | sor | HBM 0) (C): 67.0 | |
| GPU[3] | : | Temperature (Sen | sor | HBM 1) (C): 70.0 | |
| GPU[3] | : | Temperature (Sen | sor | HBM 2) (C): 71.0 | |
| GPU[3] | : | Temperature (Sen | sor | HBM 3) (C): 74.0 | |
| GPU[4] | : | Temperature (Sen | sor | edge) (C): 83.0 | |
| GPU[4] | • | Temperature (Sen | sor | junction) (C): 95.0 | |
| GPU[4] | : | Temperature (Sen | sor | memory) (C): 92.0 | |
| GPU[4] | | Temperature (Sen | sor | HBM 0) (C): 91.0 | |
| GPU[4] | | Temperature (Sen | sor | (C): 91.0 | |
| | : | Temperature (Sen | sor | HBM 2) (C): 91.0 | |
| | : | Temperature (Sen | SOF | (C): 92.0 | |
| | | Temperature (Sen | SOL | iupction (C): 00.0 | |
| GPU[5] | | Temperature (Sen | sor | $memory) (C) \cdot 93.0$ | |
| GPU[5] | | Temperature (Sen | sor | $HBM(0) (C) \cdot 91(0)$ | |
| GPU[5] | | Temperature (Sen | sor | HBM 1) (C) 93.0 | |
| GPU[5] | : | Temperature (Sen | sor | HBM 2) (C): 90.0 | |
| GPU[5] | | Temperature (Sen | sor | HBM 3) (C): 89.0 | |
| GPU[6] | | Temperature (Sen | sor | edge) (C): 64.0 | |
| GPU[6] | ; | Temperature (Sen | sor | junction) (C): 70.0 | |
| GPU[6] | : | Temperature (Sen | sor | memory) (C): 74.0 | |
| GPU[6] | : | Temperature (Sen | sor | HBM 0) (C): 72.0 | |
| GPU[6] | : | Temperature (Sen | sor | HBM 1) (C): 70.0 | |
| GPU[6] | : | Temperature (Sen | sor | HBM 2) (C): 70.0 | |
| GPU[6] | : | Temperature (Sen | sor | HBM 3) (C): 74.0 | |
| GPU[7] | : | Temperature (Sen | sor | edge) (C): 65.0 | |
| GPU[7] | : | Temperature (Sen | sor | junction) (C): 68.0 | |
| GPU[7] | : | Temperature (Sen | sor | memory) (C): 72.0 | |
| GPU[7] | : | Temperature (Sen | sor | HBM 0) (C): 72.0 | |
| GPU[7] | : | Temperature (Sen | sor | HBM 1) (C): 72.0 | |
| GPU[7] | : | Temperature (Sen | sor | HBM 2) (C): 68.0 | |
| GPU[7] | : | Temperature (Sen | sor | HBM 3) (C): 70.0 | |
| ======================================= | | ======================================= | ==== | | |

nid005705: Sat Mar 2 12:06:08 2024

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- On some GPUs, the cooling was inefficient (growth of « biology » in the pipes = algae)
- To avoid overheating, these GPUs were slowed down automatically by the system.
- The MPI processes running on those « hot » GPUs were always lagging behind
- All the other processes had to wait for the hot one to finish their task

MPI overhead was increasing on every processes but the hot ones

#1: system stability (end)

Addition of an MPI balance diagnostic in Idefix, to quickly identify these problems.



#2 file size

- VTK files are typically above 1TB (NB: idefix is efficient: ~320s to write one of the above VTK file)
- How to open such a large file? (Paraview won't, unless with a lot or RAM)
- We don't have the ressources to directly load these files...

Solution: on-the-fly VTK slices (i.e. 2D slices of the 3D domain). See this afternoon

-rw-rw---- 1 lesurg l-ipag 2.2T Mar 29 22:13 data.0017.vtk -rw-rw---- 1 lesurg l-ipag 2.2T Apr 6 00:10 data.0018.vtk -rw-rw---- 1 lesurg l-ipag 2.2T Apr 23 04:52 data.0019.vtk -rw-rw---- 1 lesurg l-ipag 2.2T Apr 25 17:49 data.0020.vtk -rw-rw---- 1 lesurg l-ipag 2.2T May 4 22:06 data.0021.vtk -rw-rw---- 1 lesurg l-ipag 2.2T May 11 23:29 data.0022.vtk -rw-rw---- 1 lesurg l-ipag 2.2T May 29 17:21 data.0023.vtk -rw-rw---- 1 lesurg l-ipag 2.2T Jun 11 06:51 data.0024.vtk -rw-rw---- 1 lesurg l-ipag 2.2T Jun 23 06:52 data.0025.vtk



#3 node failure

MPICH ERROR [Rank 3284] [job id 6471201.0] [Mon Mar 25 16:22:20 2024] [nid006342] - Abort(1009397903) (rank 3284 in comm error in PMPI_Waitall: Other MPI error, error stack: PMPI_Waitall(378)...... MPI_Waitall(count=2, req_array=0x14bf148, status_array=0x7ffe3211d520) failed MPIR_Waitall(167)..... MPIR_Waitall_impl(51)..... MPID_Progress_wait(201)..... MPIDI_Progress_test(97)..... MPIDI_OFI_handle_cq_error(1067): OFI poll failed (ofi_events.c:1069:MPIDI_OFI_handle_cq_error:Input/output error - UNDEL • • • srun: error: Node failure on nid005989 srun: Force Terminated StepId=6471201.0 slurmstepd: error: *** JOB 6471201 ON nid005280 CANCELLED AT 2024-03-25T16:29:07 DUE TO NODE FAILURE, SEE SLURMCTLD LOG ***

... this happens a lot



#3 node failure (cont'd)

After 2 months of intense exchange with LUMI support:

I have been discussing failure rate with the SysAdmins team and it is approximately 3 random GPU node failures per day observed (there are almost 3000 GPU nodes in total). This rough statistics gives at least some understanding of expected level of reliability or mean time to failure. I have been also again instructed these failures do not share any common characteristics. In other words, current diagnosis is "bad luck".

In other words, a job running on 1000 GPUs for 24h is expected to fail

Solution(s):

- self-erasing dump files (but not satisfactory: significant I/O overheads)

- Idefix should rely on a resilience library (e.g. kokkos resilience): is it enough?





VSI=vertical shear instability



$$R\Omega)| \sim \epsilon |q|\Omega,$$

A high resolution VSI run

- Idefix code on AMD Mi250 GPUs (LUMI, Finland)
- 70pts/H, 3 directions
- High order reconstruction (LimO3)
- Fargo scheme
- Large aspect ratio ($R_{out}/R_{in}=25$)
- 4 dust size (pressure less fluid)



Time=4869.5693



α and kinetic energy



Average properties

Accretion rate

linscale = 1, vmin =-0.1, vmax = 0.1),)

```
plt.yscale('log')
plt.xlabel('$t$ (orbits @ R=1)')
plt.ylabel('$R$')
plt.title(r'\log_{10}[z_\rbot{H}])
plt.colorbar(c)
```

<matplotlib.colorbar.Colorbar at 0x152e0c7b1390>



```
Sigma_org=Sigma[:,0]
```

pattern



RMS turbulent velocity @ 3H



Turbulence



-0.72



No radial dependence?

Dust settling

Settling under-estimated in the innermost regions.

Conclusion

- Idefix runs efficiently on pre-exascale European machines. However:
 - These machines are very sensitive to heating problems, leading to reduced performances and imbalanced computations
 - The failure rate is high, impacting significantly the runs when using more than 100 nodes (+1000GPUs)
 - File size is huge

• But eventually, it works :-)