Neutron star evolutions using tabulated equations of state with a new execution model

Matthew Anderson, Thomas Sterling
Center for Research in Extreme Scale Technologies (CREST)
Pervasive Technology Institute at Indiana University
Hartmut Kaiser
Center for Computation and Technology, Louisiana State University
David Neilsen
Brigham Young University

1 April 2012

CENTER FOR RESEARCH IN EXTREME SCALE TECHNOLOGIES
INDIANA UNIVERSITY
Pervasive Technology Institute

Motivation

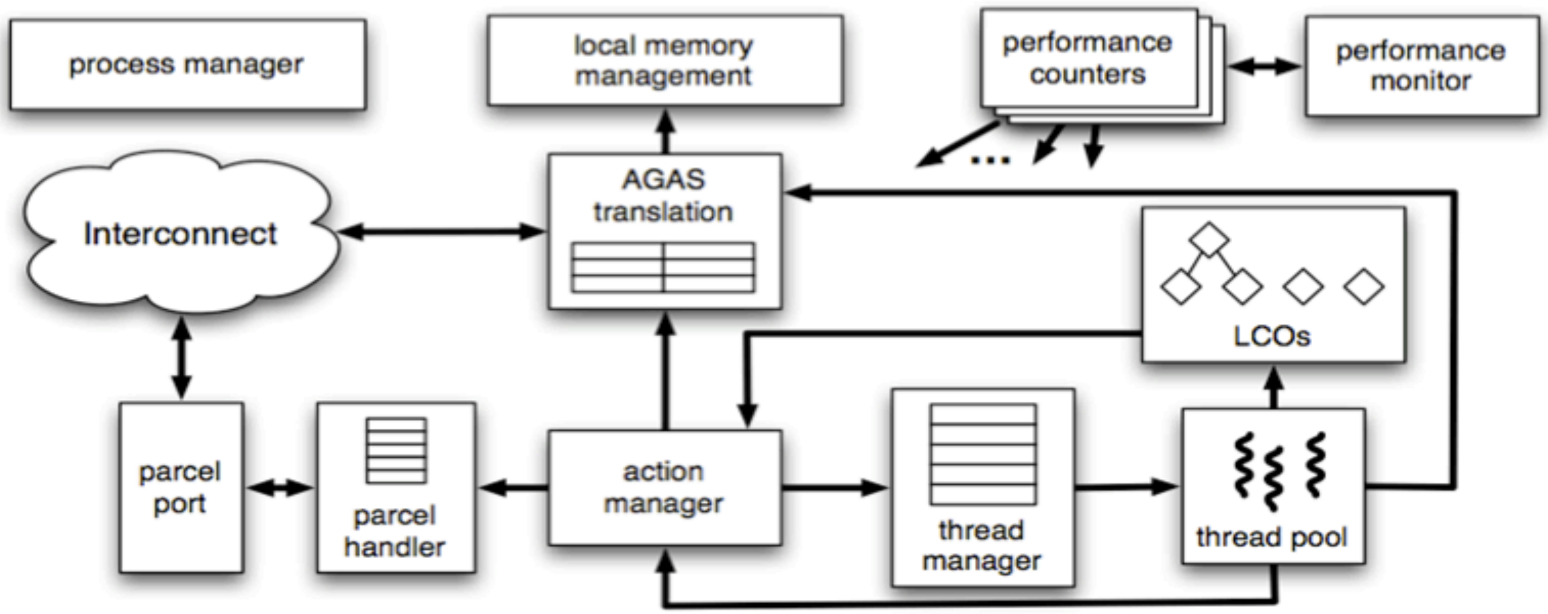
- Adding nuclear and neutrino physics to GR fluid codes gives a more realistic description of hot nuclear matter. Asynchronous nonblocking access to large tables of data is needed.
- Transit the pan-Petaflops performance regime to sustained Exaflops before the end of this decade.
- Improve strong scaling in scaling constrained codes by employing a modern execution model.
- Address issues of programmability in order to realize practical Exascale processing capability

Overview

- A little about ParalleX
- Performance comparisons using ParalleX for the EOS routines and tables found at http://stellarcollapse.org/equationofstate (O'Connor and Ott)
- Towards Radial pulsation frequencies

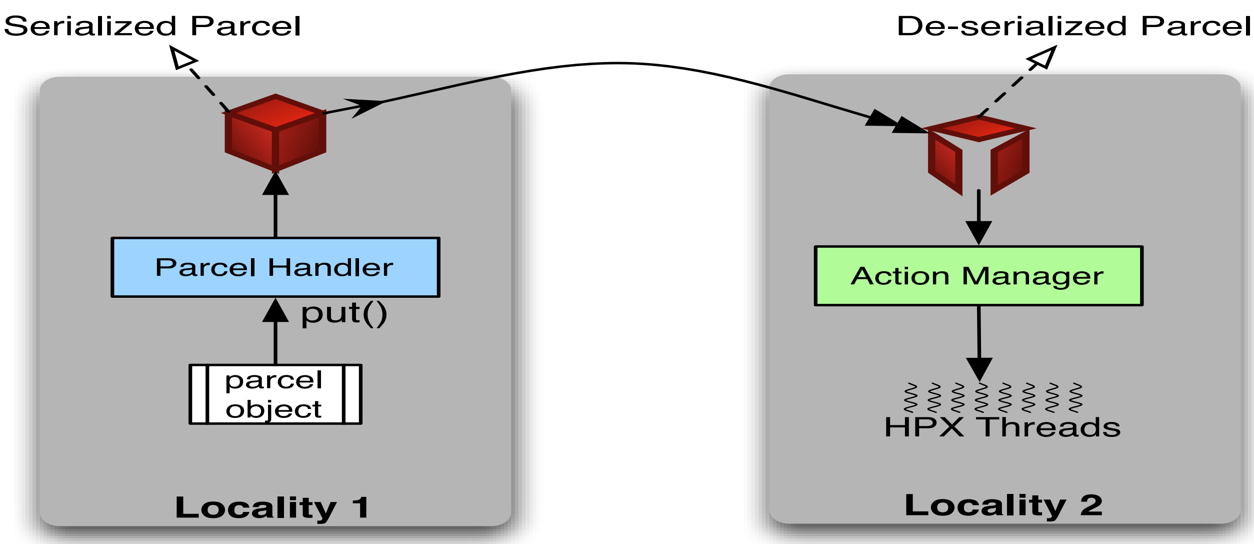
ParalleX

- Establishes a global address space that is active in the sense that a virtually addressed object may migrate across nodes without having to change its address



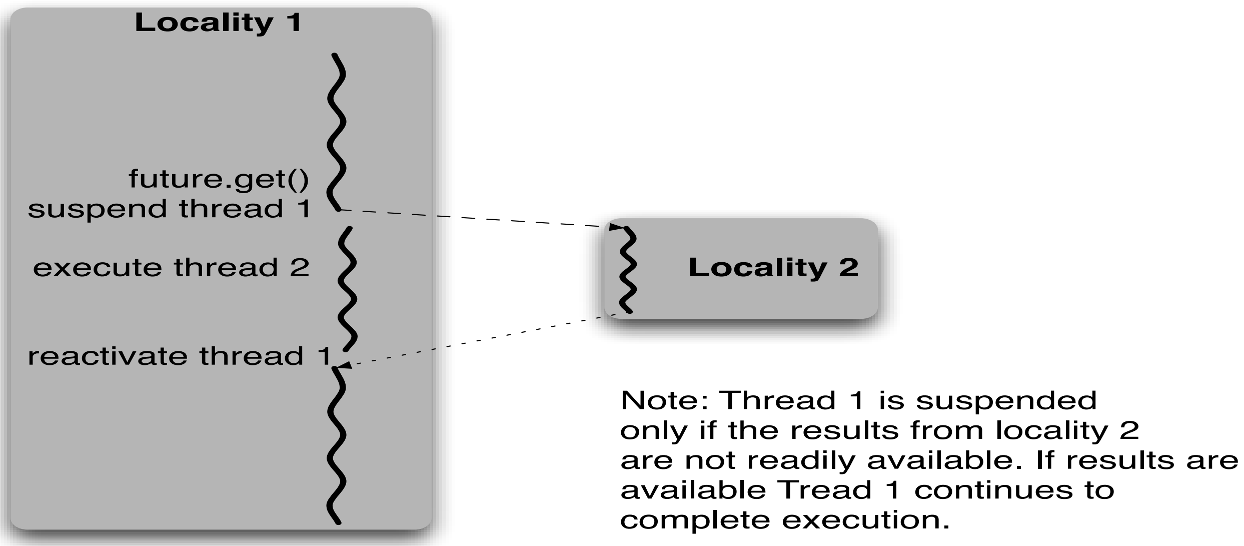
ParalleX

- Communicates by parcels (an advanced form of active messages) that moves both work and control state to the data as well as conventional asynchronous gathers of data to the work



ParalleX

- Supports Local Control Objects (LCOs) for lightweight synchronization to eliminate global barriers and manage asynchronous compound actions to reduce overhead and expose additional parallelism



ParalleX

- Defines contexts of data and tasks that provide protected abstract domains across multiple system nodes.
- Thread manager implements work stealing (compare to Cilk)
- Open source implementation: HPX
- http://stellar.cct.lsu.edu/
- Shen EOS component used for this talk is available for download
- AMR code with tapered boundaries also available

Finite Temperature Equation of State

- Putting in the right nuclear physics (polytropes don't have the right compactness).
- To do anything with neutrinos, you need a temperature: neutrino cooling, dynamics of hypernova
- To do anything with radiation, you need a physical temperature
- This is a spring-board for new astrophysics and microphysics

Equations of State come in tables

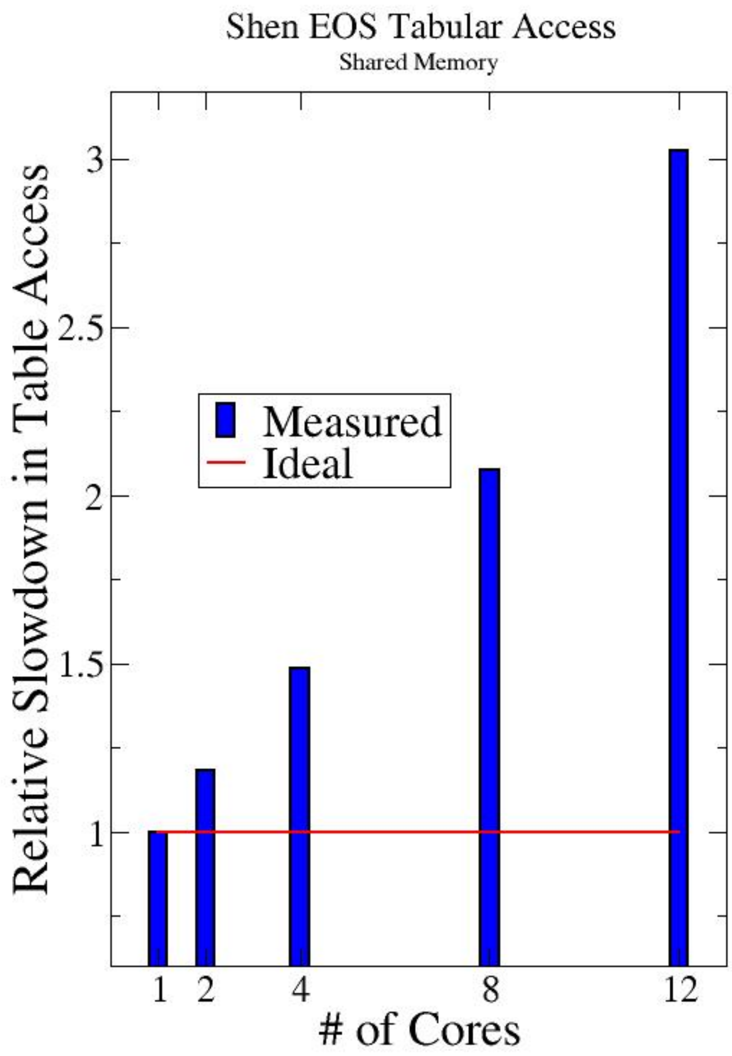
- Not practical to do EOS calculation in place; it's best to use a look-up table
- The table covers a lot of physics for you
- In high energy astrophysics:

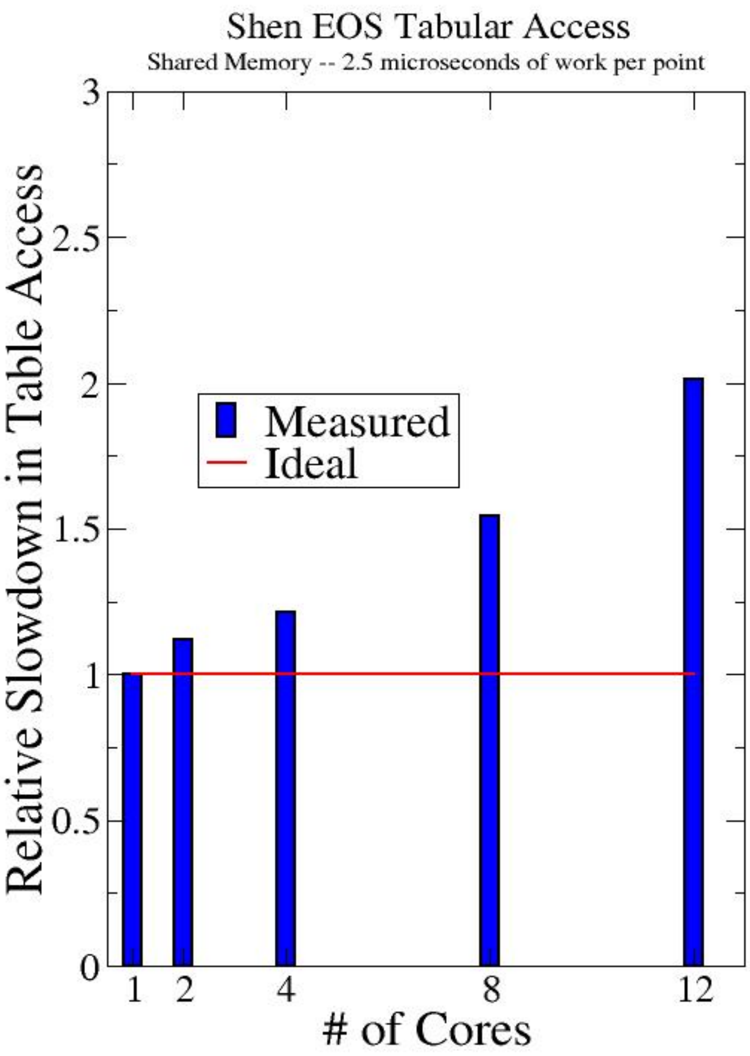
Temperatures vary from 0 to > 100 MeV

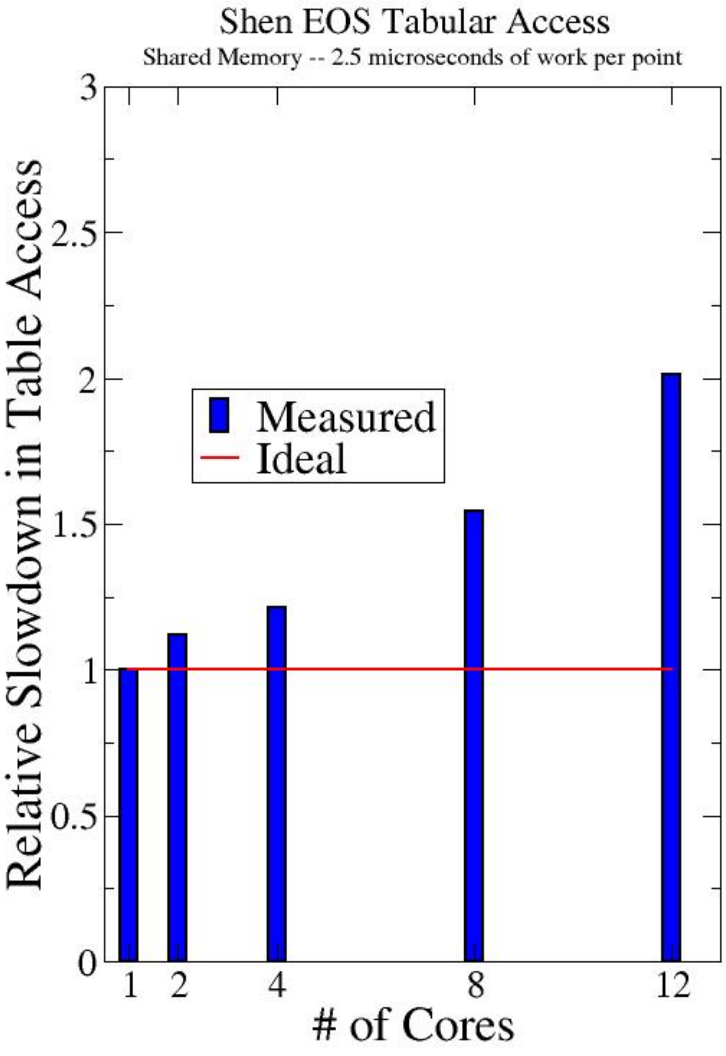
Proton fraction changes from 0 to 0.6

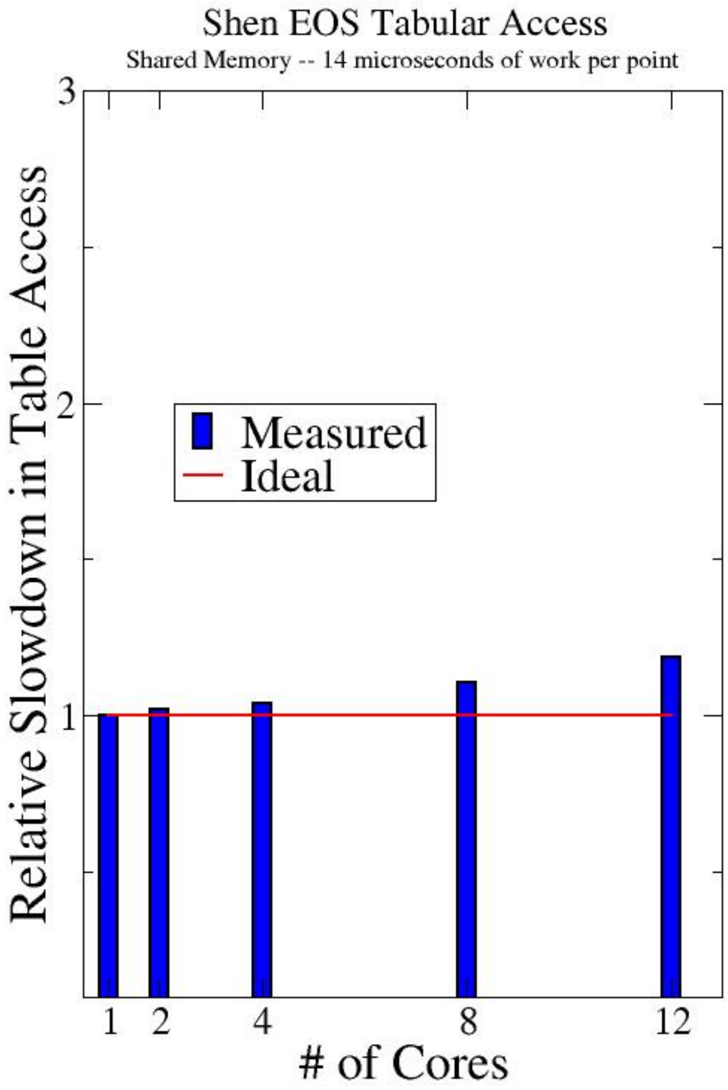
Density varies across 10 orders of magnitude

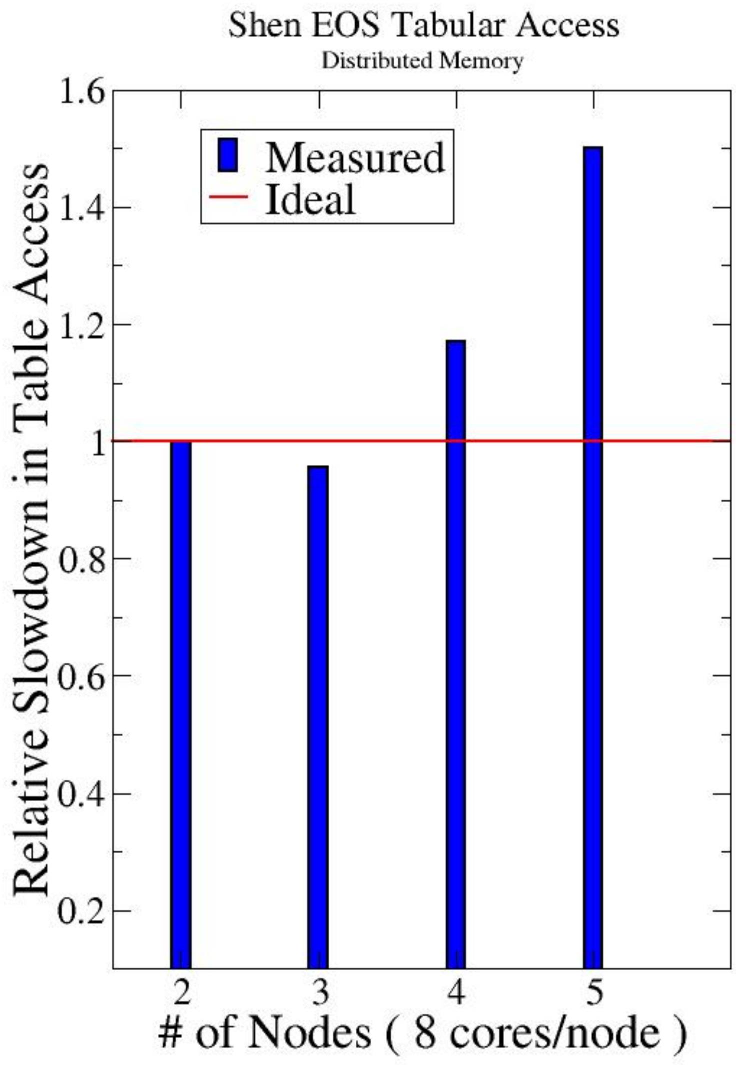
- Finer grid tables are better for accuracy
- Tables need to cover a wide variety of conditions: black hole formation, neutron star mergers, nucleosynthesis


Shen EOS Tabular Access
Shared Memory
Relative Slowdown in Table Access
# of Cores
Measured
Ideal
1
1.5
2
2.5
3
1 2 4 8 12


Shen EOS Tabular Access
Shared Memory -- 2.5 microseconds of work per point
Relative Slowdown in Table Access
# of Cores
Measured
Ideal
0
0.5
1
1.5
2
2.5
3
1 2 4 8 12


Shen EOS Tabular Access
Shared Memory -- 2.5 microseconds of work per point
Relative Slowdown in Table Access
# of Cores
Measured
Ideal
0
0.5
1
1.5
2
2.5
3
1
2
4
8
12

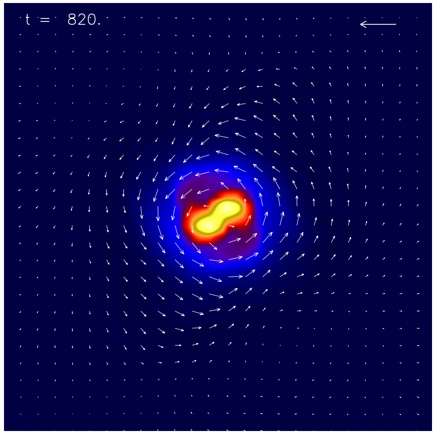

Shen EOS Tabular Access
Shared Memory -- 14 microseconds of work per point
Relative Slowdown in Table Access
# of Cores
Measured
Ideal
1
2
3
1
2
4
8
12



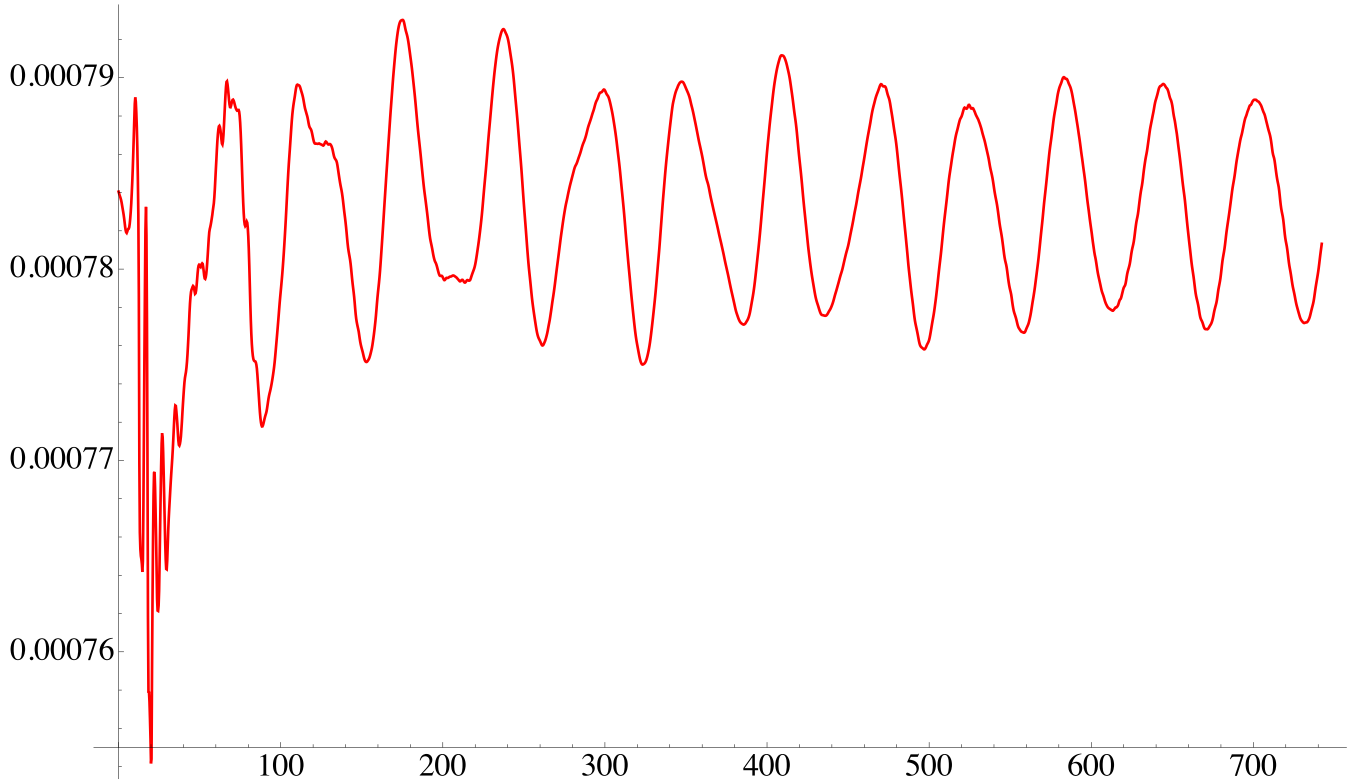
Shen EOS Tabular Access
Distributed Memory
Relative Slowdown in Table Access
# of Nodes (8 cores/node)
Measured
Ideal
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
2
3
4
5

MHDe Code Tests

- All C++
- PPM Reconstruction with HLLE Numerical Flux
- AMR
- Equations described in http://arxiv.org/abs/gr-qc/0605102



Preliminary Radial Pulsation Frequencies



Conclusions

- Big look-up tables are coming or are already here (EOS, opacity, etc)
- Exaflops computing is coming
- Modern execution models provide tools key for improving scaling constrained codes
- Stay tuned for more