Solving TeraScale Linear Systems

Correspondence between structure of integro-PDE and underlying linear systems...



Neutrino Transport Time Scales

The Need for Exascale Resources

—Dominated by preconditioning of dense blocks.

FLOPS ~ $N_t N_s N_i f N_m^2 \sim 3.5 \times 10^{22} f$

 N_t = number of time steps ~ 1×10⁶ N_s = number of spatial zones ~ 512×512×512 N_i = number of iterations per time step ~ 10 N_m = number of neutrino momentum zones $f \in [1, N_m] = [1, 5120]$

$$N_m = N_v \times N_E \times N_p \times N_a$$

 $N_v = 4$ N_E = number of neutrino energy groups ~ 20 N_p = number of neutrino polar direction angles ~ 8 N_a = number of neutrino azimuthal direction angles ~ 8



Algorithms critical!

Runtime: ~ (4f) days per run on a 1 EF machine (at 10% of peak).

The Need for Exascale Resources

-Dominated by preconditioning of dense blocks.

FLOPS ~ $N_t N_s N_i f N_m^2$ ~ 3.4 × 10¹⁹ f

 N_t = number of time steps ~ 1×10⁶ N_s = number of spatial zones ~ 512×512×512 N_i = number of iterations per time step ~ 10 N_m = number of neutrino momentum zones $f \in [1, N_m] = [1, 160]$

$$N_m = N_v \times N_E$$

 $N_v = 4 \times 2$ N_E = number of neutrino energy groups ~ 20



Algorithms critical!

Runtime: ~ fhours per run on a 1 EF machine (at 10% of peak).

Scientific Workflows: A Different Challenge

In "production mode," managing Workflows has become a paramount issue.

 \Rightarrow Ideally, we would like to automate these workflows.

- ⇒ Data Management and Analysis
- \Rightarrow Networking
- \Rightarrow Visualization



Code	# Variables	Resolution	# Dumps	Data Output	Runtime	Machine
CHIMERA 1.0	~ 200	576X96X192	3000	~50 TB	~ 3 Months	1 PF
CHIMERA 2.0	~ 350	576X96X192	3000	~100 TB	~ 3 Months	20 PF
GenASiS	~5000	512X512X512	3000	~30 PB	?	10 EF

Summary and Outlook

Are core collapse supernovae neutrino driven, magnetically driven, or both?

- Recent progress in 2D indicates robust neutrino-driven explosions are possible.
- 3D multi-physics simulations are ongoing.
- Studies of extreme cases with rapid rotation indicate magnetic fields may be amplified to dynamically significant levels and induce explosion.

Can core collapse supernovae be used as laboratories for neutrino physics?

- Past work gives every indication this will be the case.
- However, past work also demonstrates that our ability to do so will require a full treatment of neutrino mixing, including neutrino-neutrino forward scattering, which presents a significant theoretical and computational challenge.

These are exciting times for neutrino physics, neutrino astrophysics, and core collapse supernova science.

- Advent of exascale computing platforms over the next decade.
- Increasing sophistication of observational capabilities.
- New observational capabilities (e.g., Super-Kamiokande, LIGO)



"Per aspera ad astra."

Lucius Annaeus Seneca Roman Philosopher, Statesman, Dramatist 4 BC – 65 AD