Scalable Interaction with Parallel Applications

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Outline

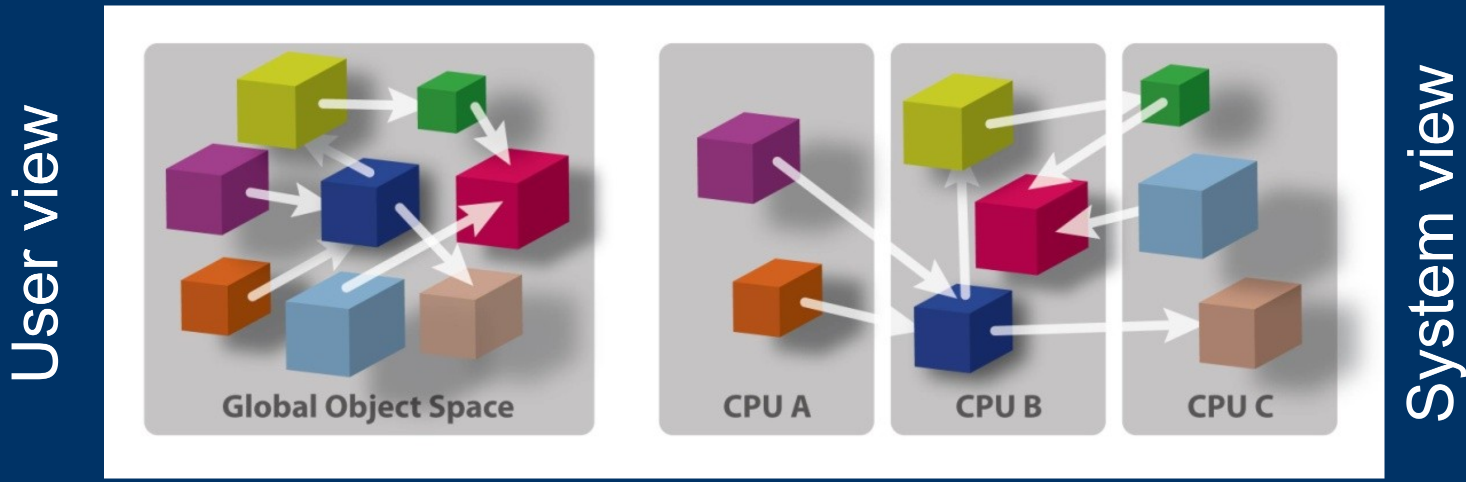
- Overview
  - Charm++ RTS
  - Converse Client Server (CCS)
- Case Studies
  - CharmDebug (parallel debugger)
  - Projections (performance analysis tool)
  - Salsa (particle analysis tool)
- Conclusions

Overview

- Need for real-time communication with parallel applications
  - Steering computation
  - Visualizing/Analyzing data
  - Debugging problems
- Long running applications
  - Time consuming to recompile the code (if at all available)
  - Need to wait for application to re-execute
- Communication requirements:
  - Fast (low user waiting time) → Scalable
  - Uniform method of connection

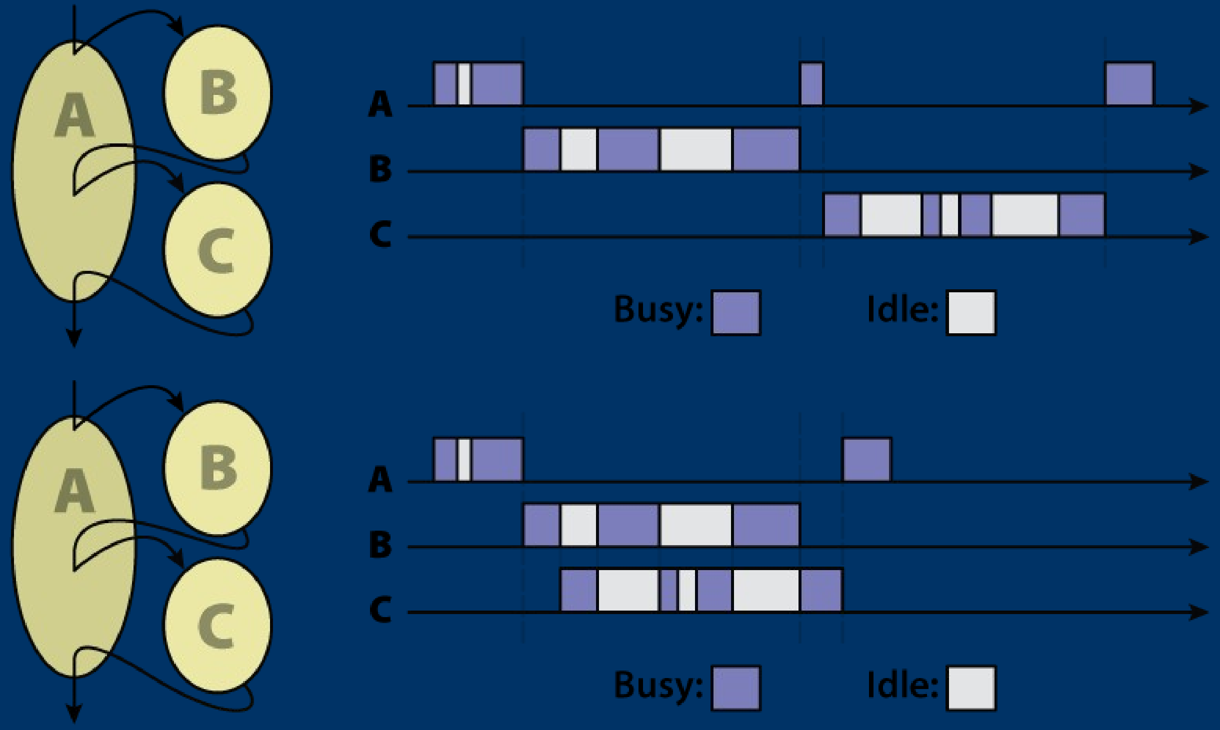
Charm++ Overview

- Middleware written in C++
  - Message passing paradigm (asynchronous comm.)
- User decomposes work among objects (*chare*s)
  - The objects can be virtual MPI processors
- System maps chares to processors
  - automatic load balancing
  - communication optimizations



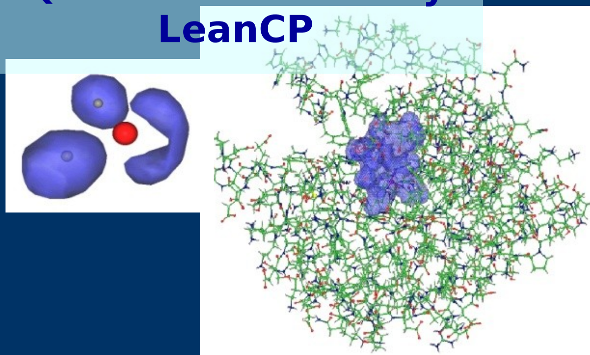
Adaptive overlap and modules

- Allow easy integration of different modules
- Automatic overlap of communication an computation

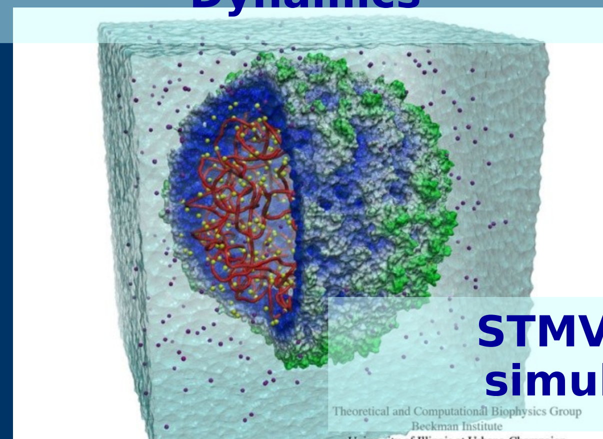


Develop Abstractions in Context of Full-Scale Applications

Quantum Chemistry LeanCP

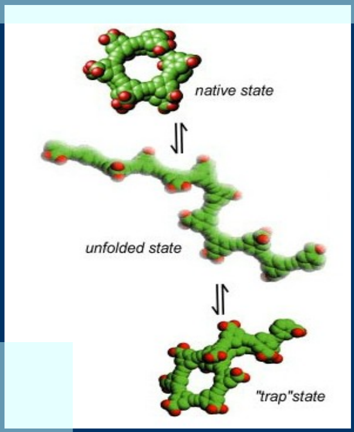


NAMD: Molecular Dynamics

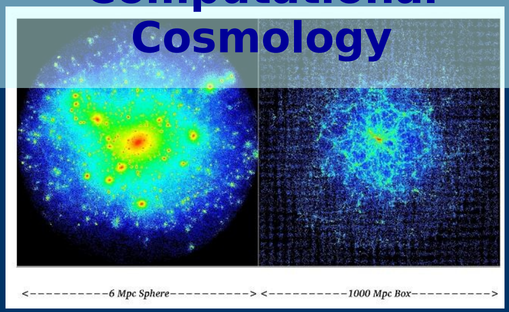


STMV virus simulation

Protein Folding



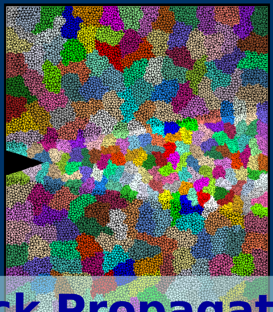
Computational Cosmology



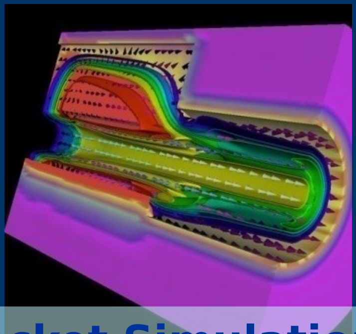
Parallel Objects,

Adaptive Runtime System

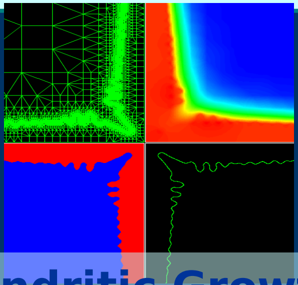
Libraries and Tools



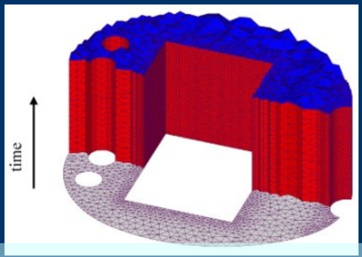
Crack Propagation



Rocket Simulation

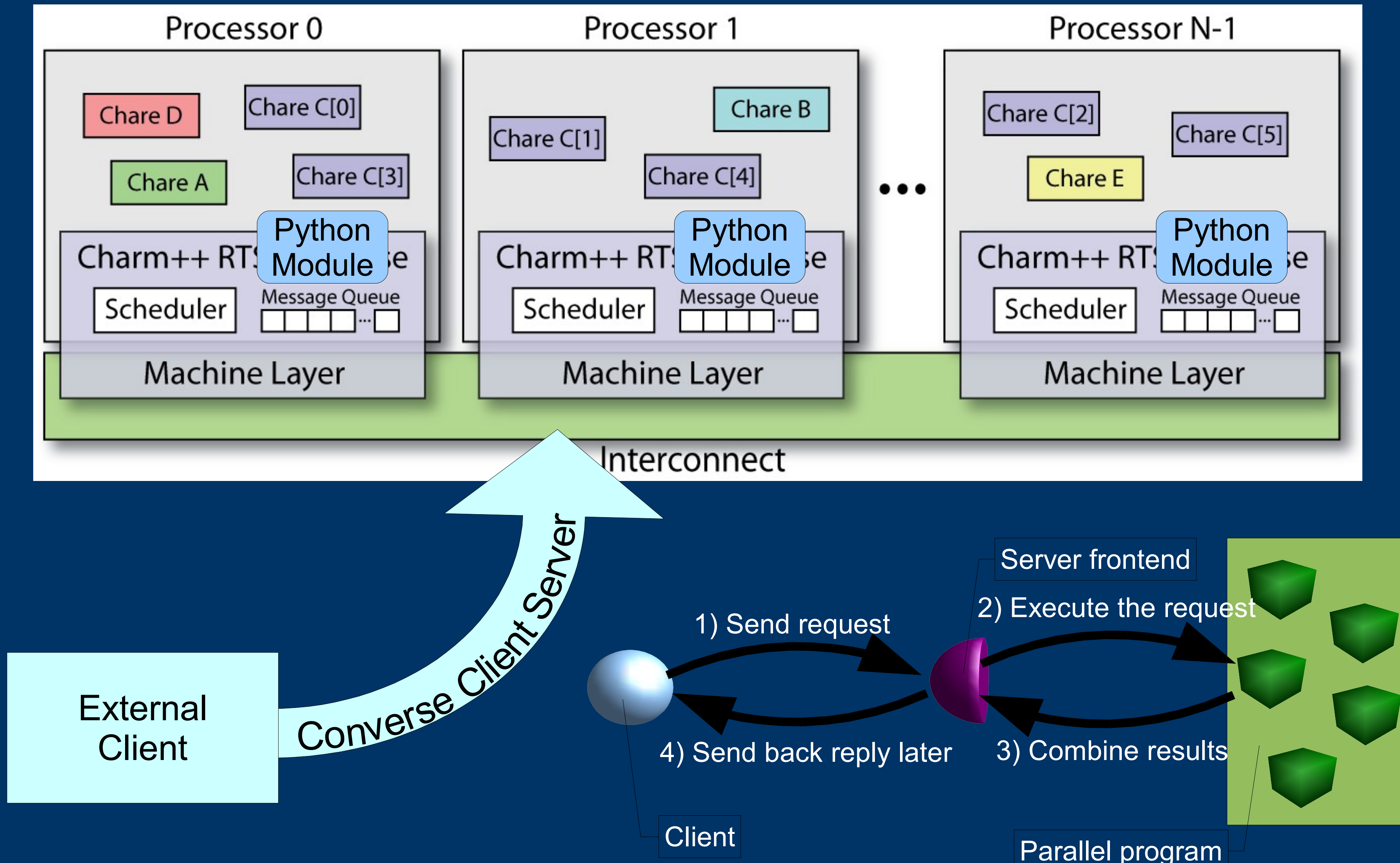


Dendritic Growth



Space-time meshes

Charm++ RTS



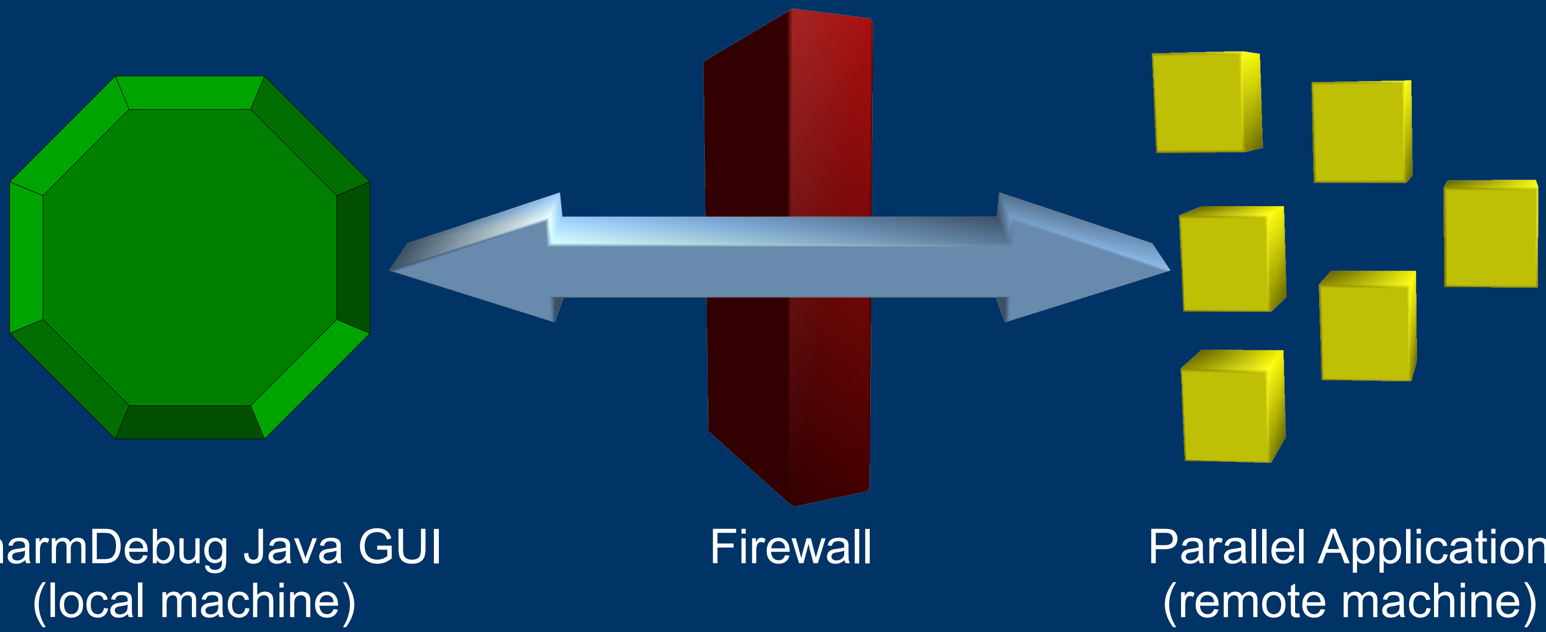
Processor 0
Chare D
Chare C[0]
Chare A
Chare C[3]
Python Module
Scheduler
Message Queue
Machine Layer
Processor 1
Chare C[1]
Chare B
Chare C[4]
Python Module
Scheduler
Message Queue
Machine Layer
Processor N-1
Chare C[2]
Chare C[5]
Chare E
Python Module
Scheduler
Message Queue
Machine Layer
Interconnect
External Client
Converse Client Server
Server frontend
1) Send request
2) Execute the request
3) Combine results
4) Send back reply later
Client
Parallel program

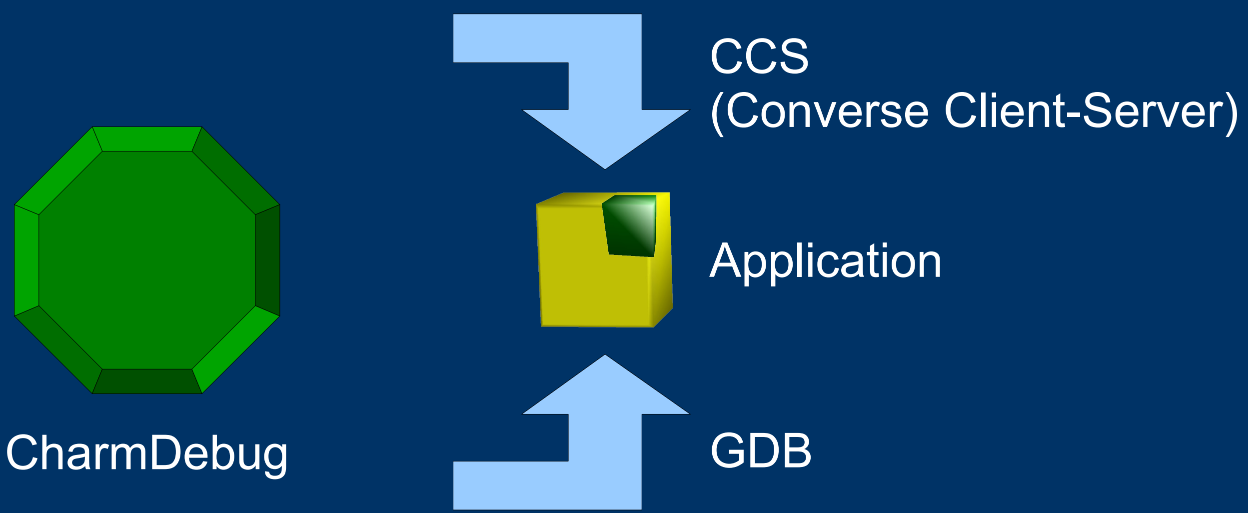
Case study: Parallel Debugging

Large Scale Debugging: Motivations

- Bugs on sequential programs
  - Buffer overflow, memory leaks, pointers, ...
  - More than 50% programming time spent debugging
  - GDB and others
- Bugs on parallel programs
  - Race conditions, non-determinism, ...
  - Much harder to find
    - Effects not only happen later in time, but also on different processors
  - Bugs may appear only on thousands of processors
    - Network latencies delaying messages
    - Data decomposition algorithm
  - TotalView, Allinea DDT

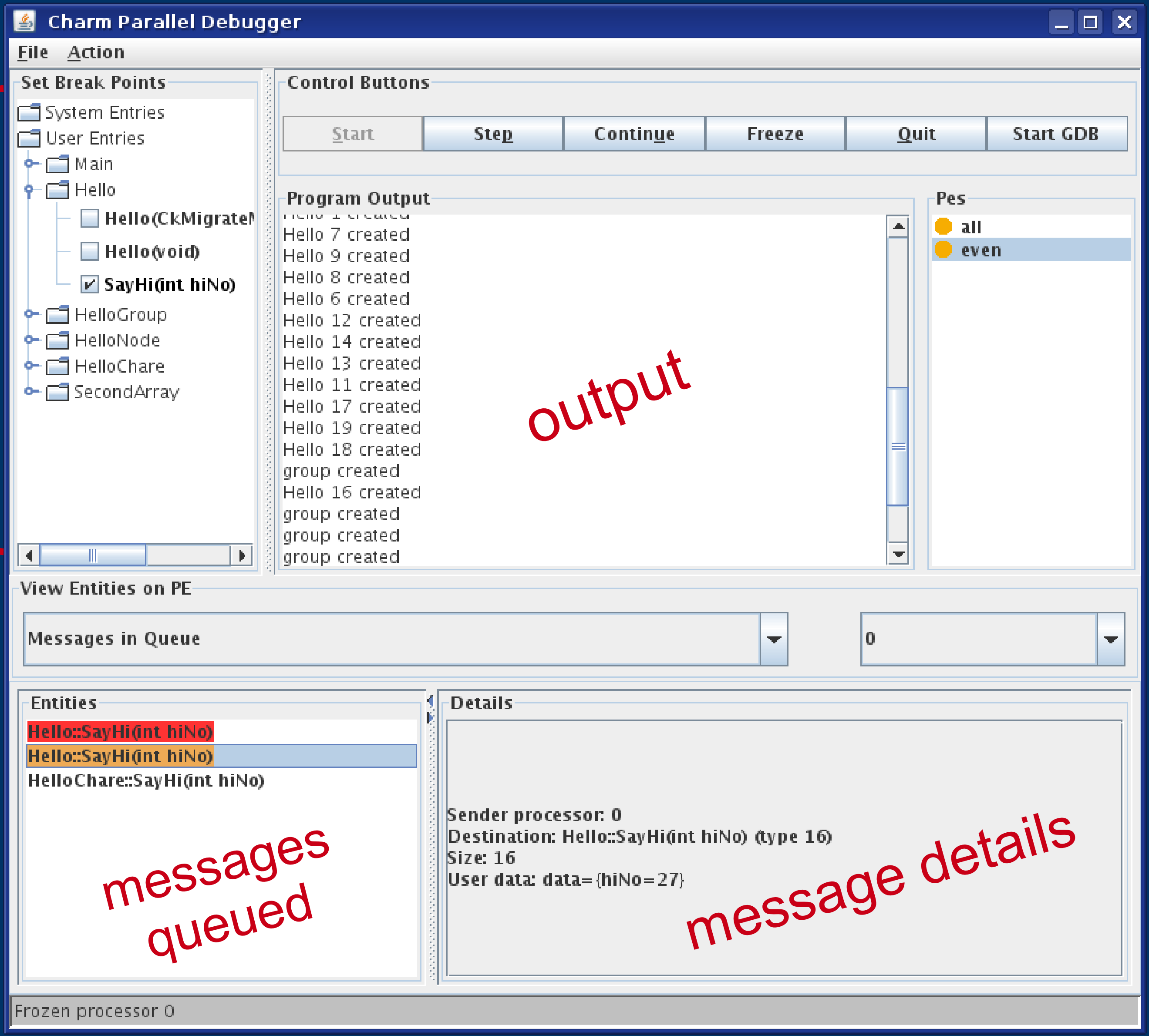
CharmDebug Overview





Main Program View

entry methods

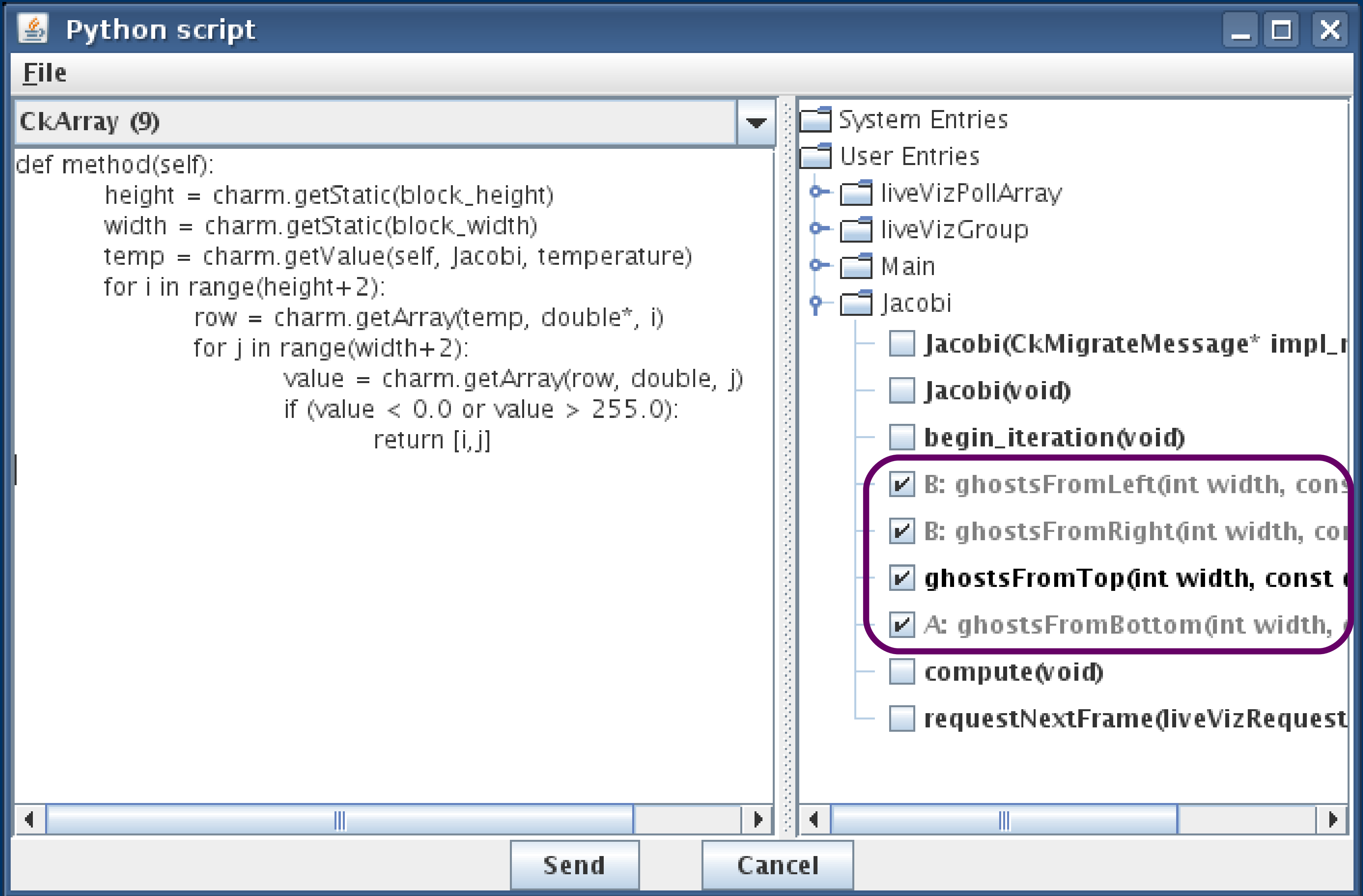


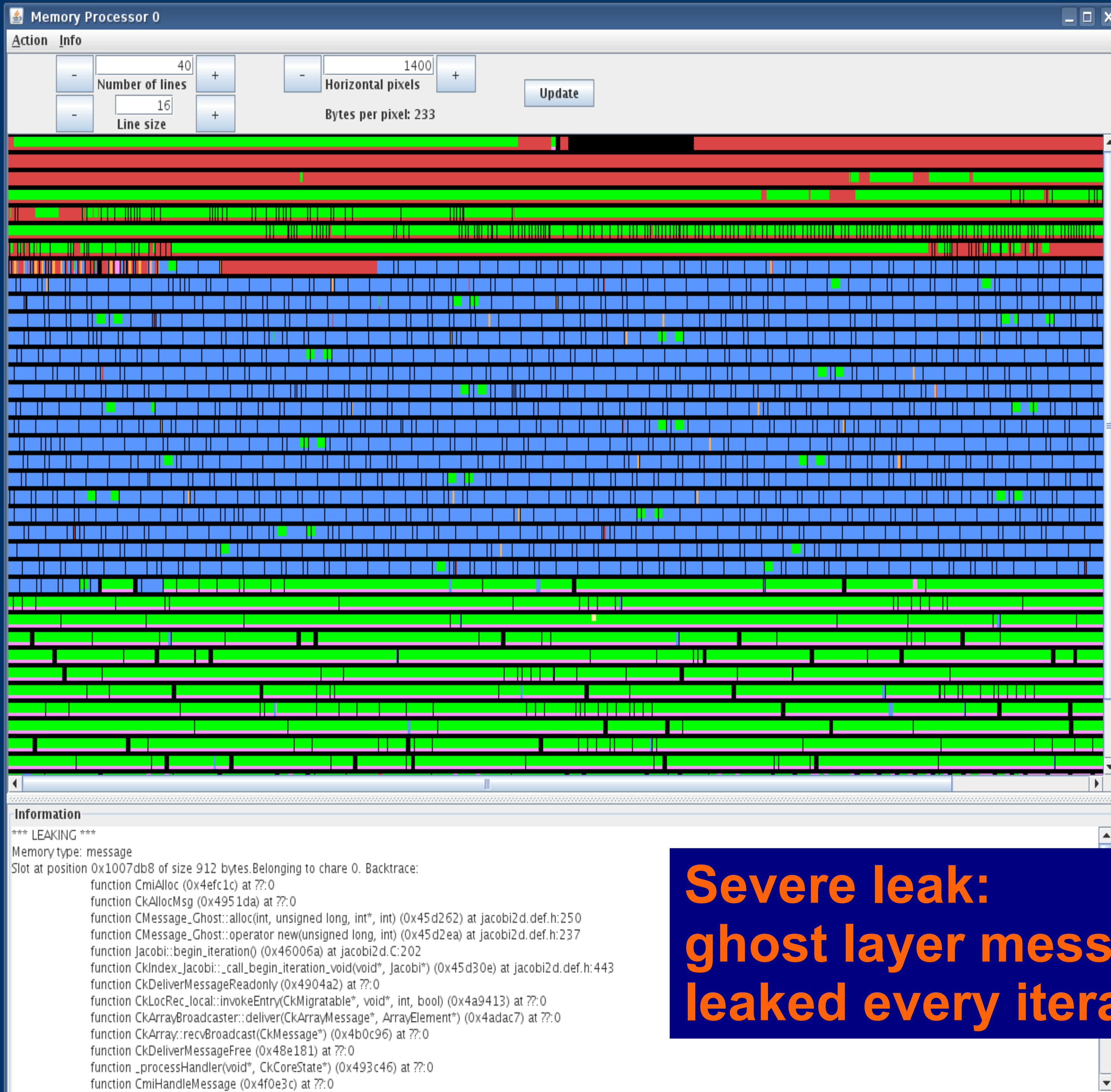
processor subsets

CharmDebug at scale

- Current parallel debuggers don't work
  - Direct connection to every processor
  - STAT (MRNet) not a full debugger
- Kraken: Cray XT4 at NICS
  - Parallel operation collecting total allocated memory
  - Time at the client 16~20 ms
  - Up to 4K processors
  - Other tests to come
- Attaching to the running program took also very little (few seconds)

CharmDebug: Introspection





Severe leak: ghost layer messages leaked every iteration

Case study:
Performance Analysis

Online, Interactive Access to Parallel Performance Data: Motivations

- Observation of time-varying performance of long-running applications through streaming
  - Re-use of local performance data buffers
- Interactive manipulation of performance data when parameters are difficult to define a priori
  - Perform data-volume reduction before application shutdown
    - k-clustering parameters (like number of seeds to use)
    - Write only one processor per cluster

Projections: Online Streaming of Performance Data

- Parallel Application records performance data on local processor buffers
- Performance data is periodically processed and collected to a root processor
- Charm++ runtime adaptively co-schedules the data collection's computation and messages with the host parallel application's
- Performance data buffers can now be re-used
- Remote tool collects data through CCS

Impact of Online Performance Data Streaming

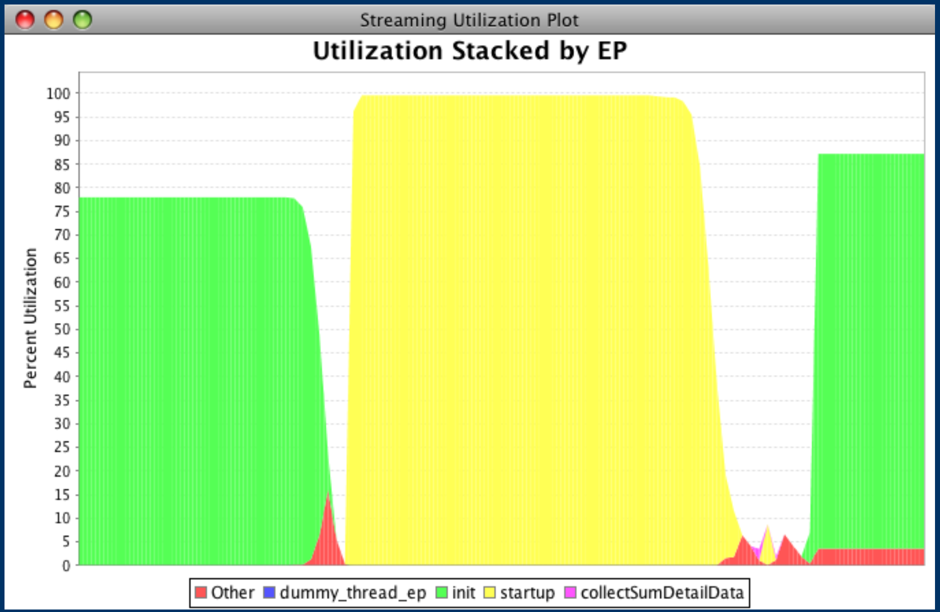
Simple Charm++ Parallel Application (Iterations of Work + Barriers)		
# Cores	Exec Time in seconds (no Data Collection and Streaming)	Exec Time in seconds (with Data Collection and Streaming*)
4095	21.44s	21.46s
8191	37.84s	37.71s

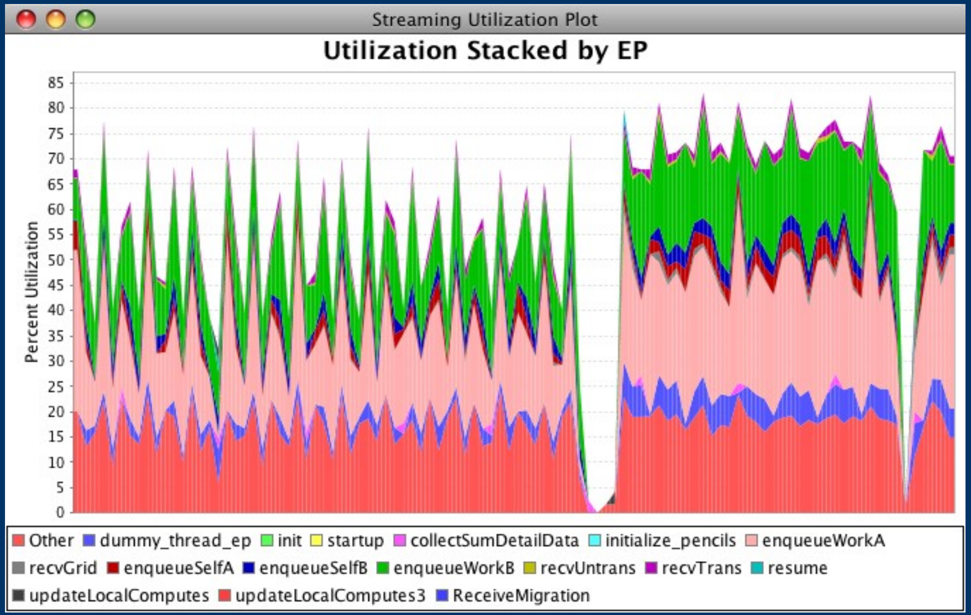
* Global Reduction of 8 kilobyte messages from each processor every second.

NAMD 1-million atom simulation (STMV)					
# Cores	512	1024	2048	4096	8192
Overhead (%) no Data Collection and Streaming to visualization client.	0.69%	0.55%	-3.44%	1.56%	1.29%
Overhead (%) with Data Collection and Streaming@	0.30%	0.43%	-3.94%	3.47%	6.63%

@ Global Reductions per second of between 3.5 to 11 kilobyte messages from each processor. The visualization client receives 12 kilobytes/second.

Online Visualization of Streamed Performance Data





- Pictures show 10-second snapshots of live NAMD detailed performance profiles from start-up (left) to the first major load-balancing phase (right) on 1024 Cray XT5 processors
- Ssh tunnel between client and compute node through head-node

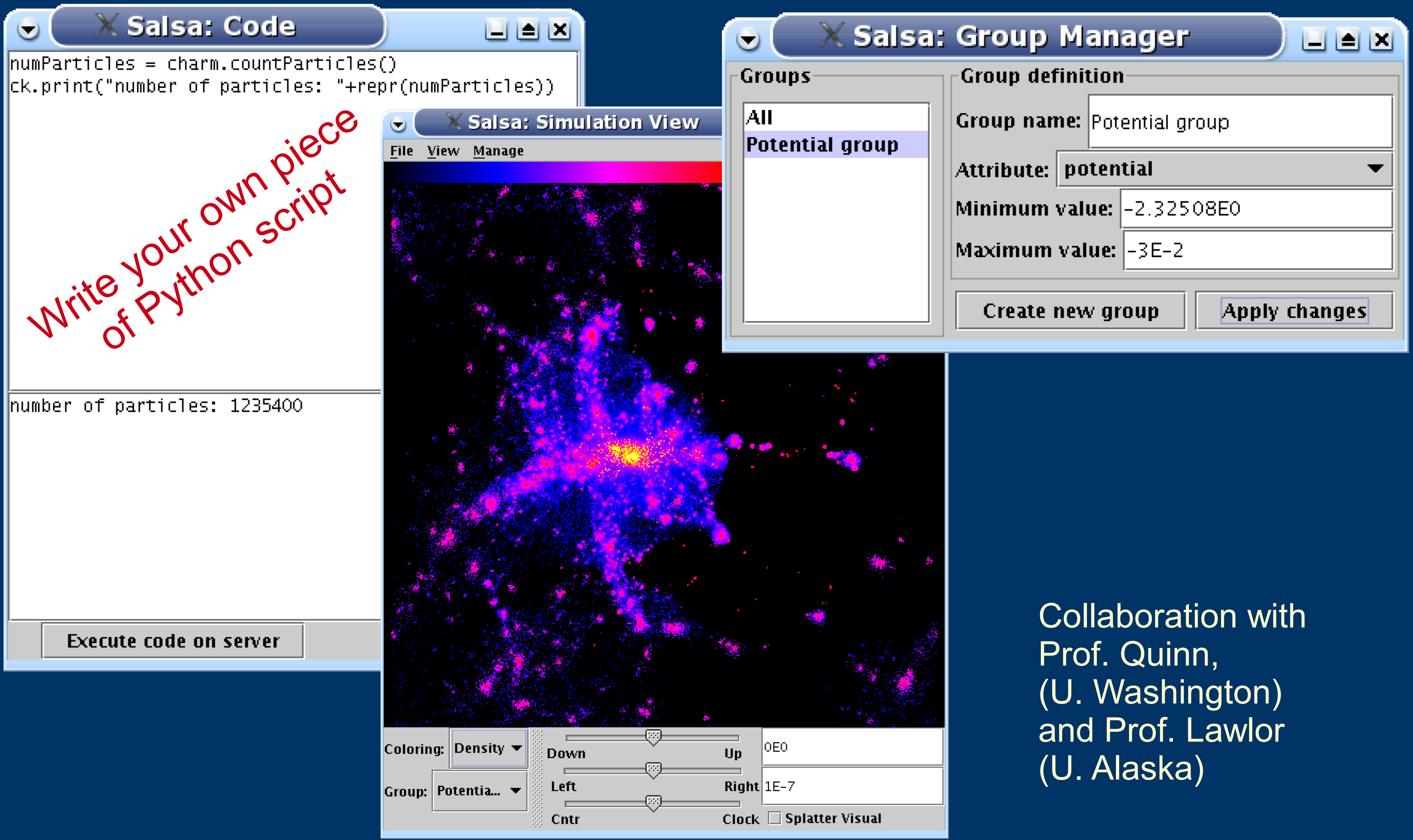
Case study:
Cosmological Data Analysis

Comsological Data Analysis: Motivations

- Astronomical simulations/observations generate huge amount of data
- This data cannot be loaded into a single machine
- Even if loaded, interaction with user too slow

- Need to parallel analyzer tools capable of
  - Scaling well to large number of processors
  - Provide flexibility to the user

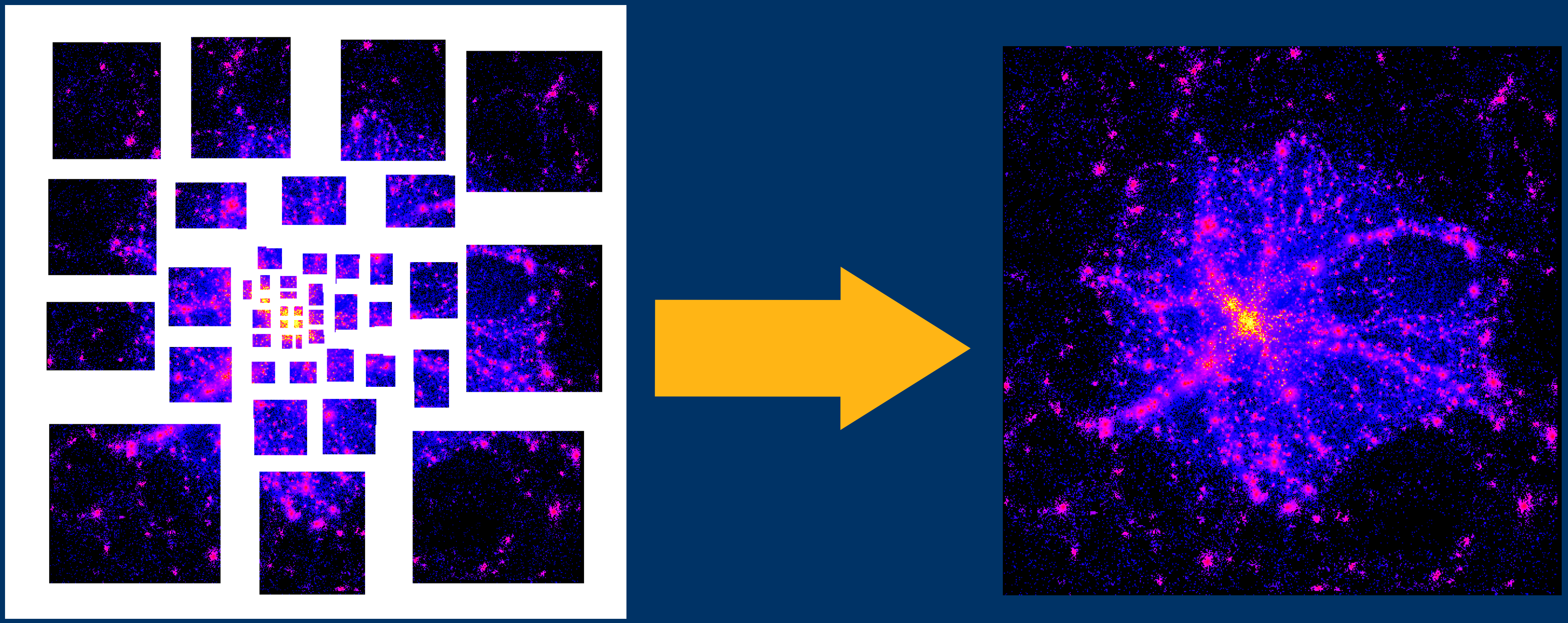
Salsa



Collaboration with Prof. Quinn, (U. Washington) and Prof. Lawlor (U. Alaska)

LiveViz

- Every piece is represented by a chare



- Under integration in ChaNGa (simulator)

How well are we doing?

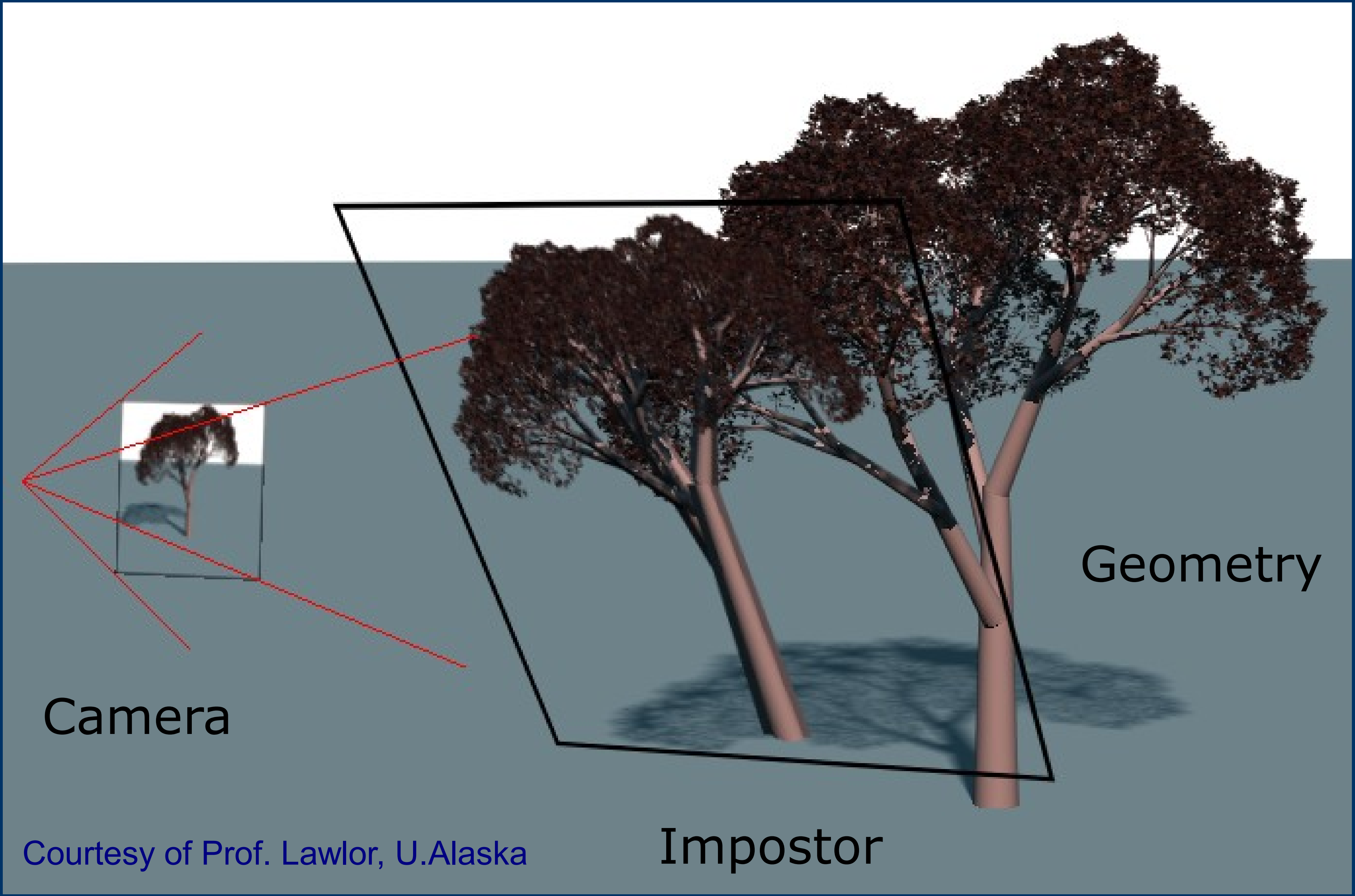
Salsa application framerate

Window size	Gigabit network		2MB/s wireless	
	Bitmap	JPEG	Bitmap	JPEG
256x256	333	25	6	25
512x512	166	24	2	15
1024x1024	50	15	< 1	13
2048x2048	13	4	<< 1	4

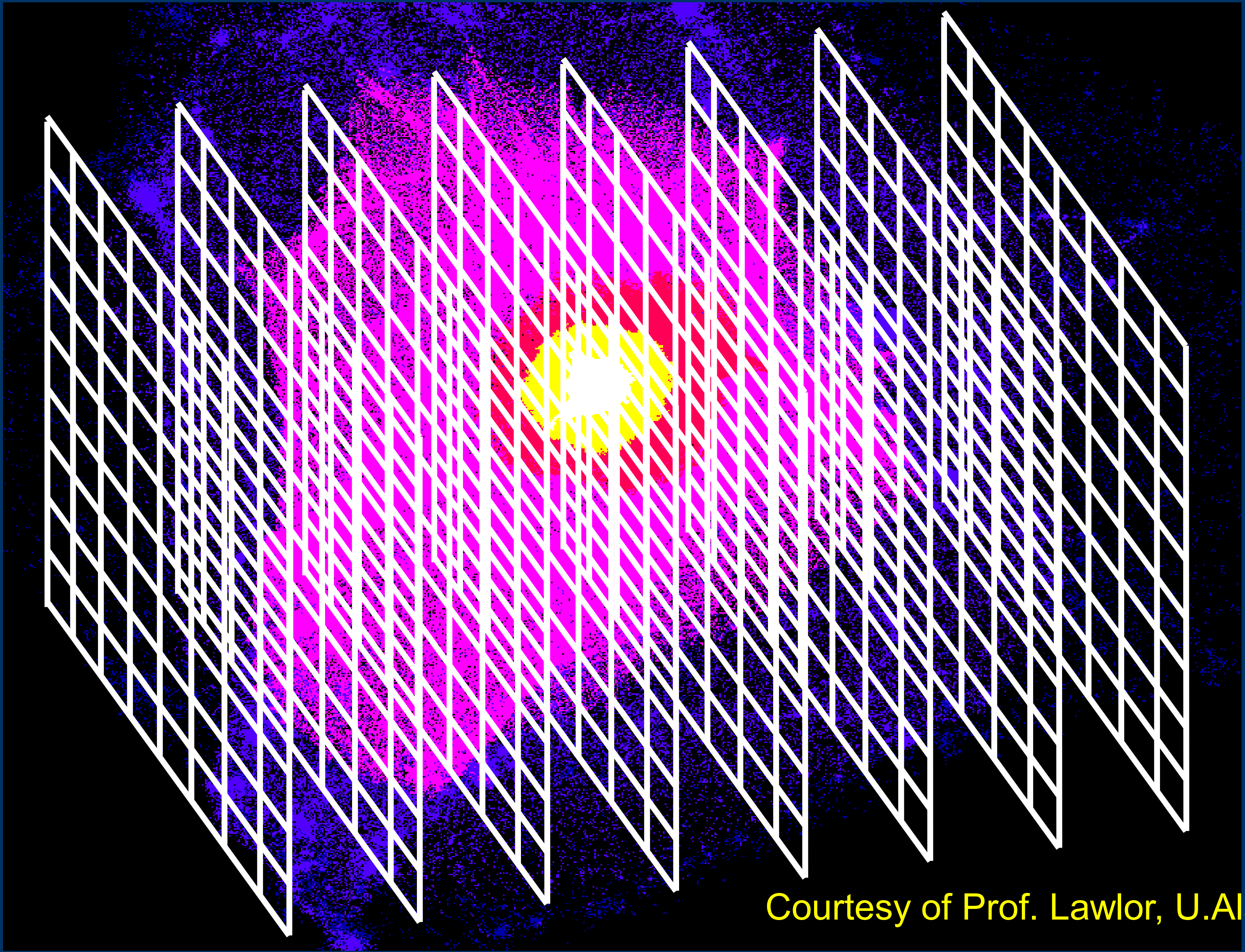
Courtesy of Prof. Lawlor, U.Alaska

- JPEG is CPU bound
  - Inefficient on high bandwidth networks
- Bitmap is network bound
  - Bad on slow networks
- The bottleneck is on the client (network or processor)
  - Parallel application: use enough processors

Impostors: Basic Idea



Particle Set to Volume Impostors



Courtesy of Prof. Lawlor, U.Alaska

Summary

- Generic framework (CCS) to connect to a running parallel application, and interact with it
- Demonstration in different scenarios:
  - Parallel debugging
    - Low response time
  - Performance analysis
    - Low runtime overhead
  - Application (cosmological) data analysis
    - High frame rate
- All code is open source and available on our website

Questions?

Thank you

http://charm.cs.uiuc.edu/