***N*Tropy**: A Framework for Analyzing Massive Astrophysical Datasets

Harnessing the Power of Parallel Grid Resources for Astrophysical Data Analysis

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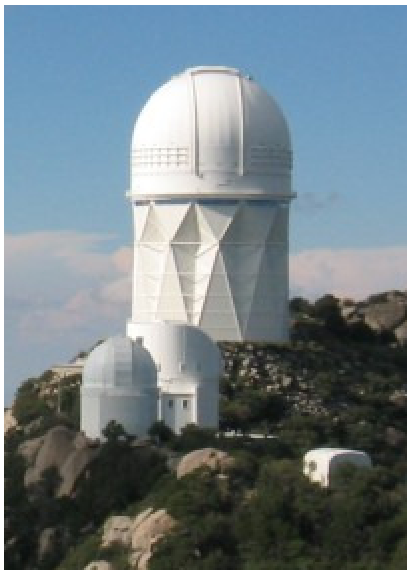
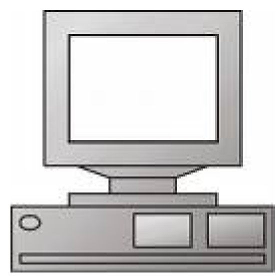
How to turn observational data into scientific knowledge

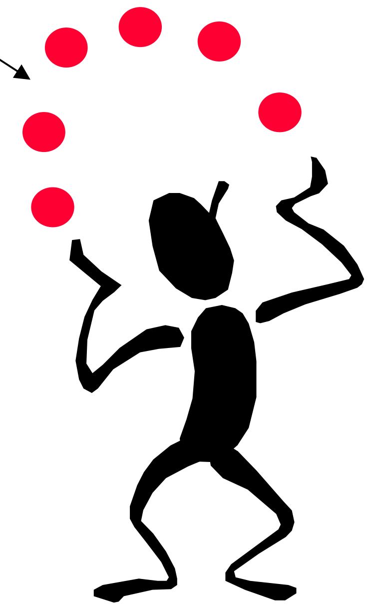


Step 1: Collect data



Step 2: Analyze data
on workstation

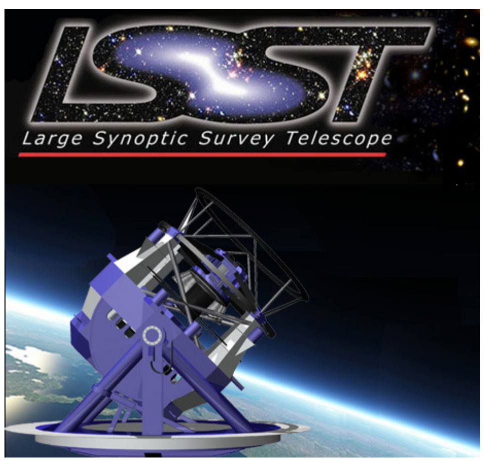
(happy astronomer)

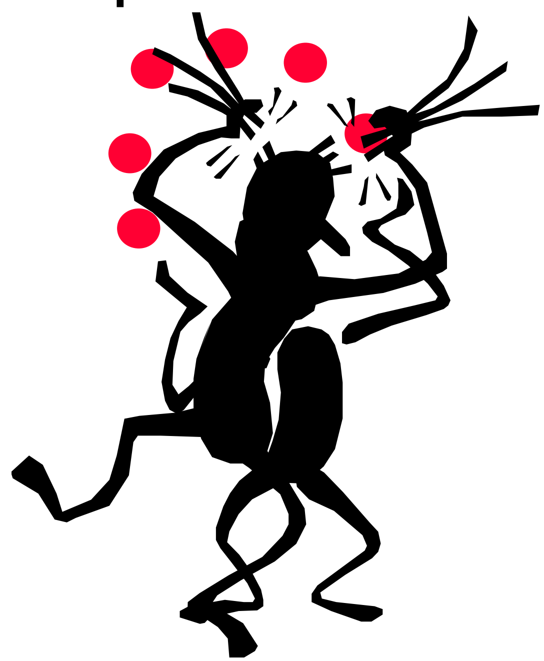


Step 3: Extract meaningful
scientific knowledge

The Era of Sky Surveys

- Paradigm shift in astronomy: Sky Surveys
  - Available data is growing at a much faster rate than computational power.



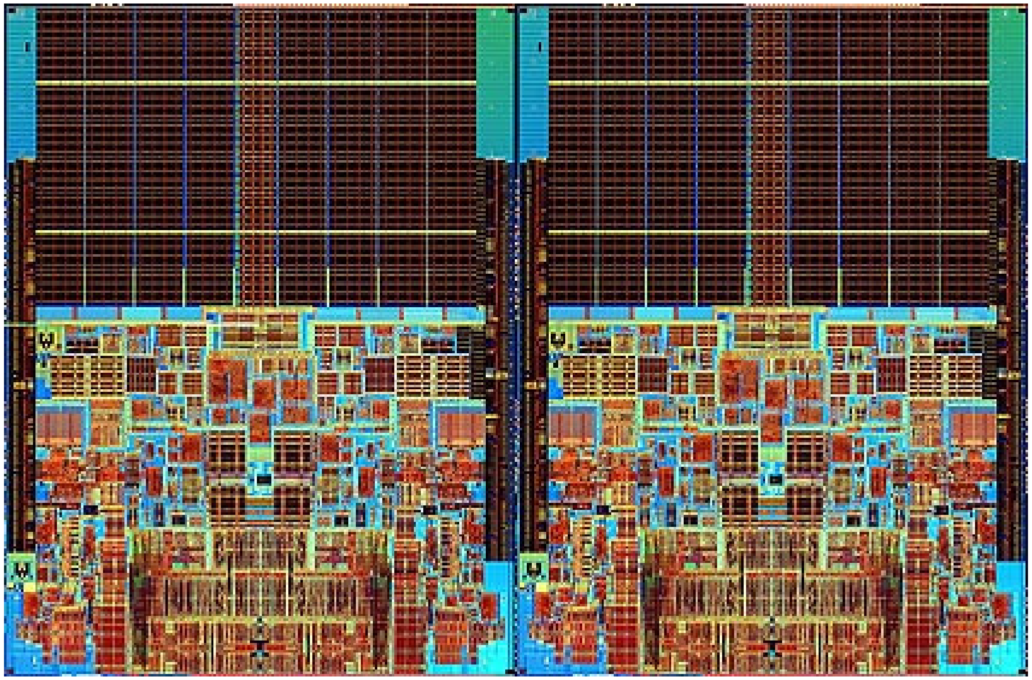


Mining the Universe can be (Computationally) Expensive

- In the future, there will be many problems that will be *impossible* without multiprocessor resources.
- There will be many more problems for which throughput can be substantially enhanced by multiprocessor resources.

Mining the Universe can be (Computationally) Expensive

- In 5 years, even your workstation may have *80 cores!!*



Intel's 4-core Quadro

Good News for "Data Parallel" Operations

- Data Parallel (or "Embarrassingly Parallel"):
  - Example:
    - 1,000,000 QSO spectra
    - Each spectrum takes ~1 hour to reduce
    - Each spectrum is computationally independent from the others
  - There are many workflow management tools that will distribute your computations across many machines.

Tightly-Coupled Parallelism
(what this talk is about)

- Data and computational domains overlap
- Computational elements must communicate with one another
- Examples:
  - Group finding
  - N-Point correlation functions
  - New object classification
  - Density estimation

The Challenge of Data Analysis in a Multiprocessor Universe

- Parallel programs are difficult to write!
  - Steep learning curve to learn parallel programming
- Parallel programs are expensive to write!
  - Lengthy development time
- Parallel world is dominated by simulations:
  - Code is often reused for many years by many people
  - Therefore, you can afford to invest lots of time writing the code.
- *Example:* GASOLINE (a cosmology N-body code)
  - Required *10 FTE-years* of development

The Challenge of Data Analysis in a Multiprocessor Universe

- Data Analysis does not work this way:
  - Rapidly changing scientific inqueries
  - Less code reuse
- Simulation groups do not even write their analysis code in parallel!
- Data Mining paradigm mandates rapid software development!

The Challenge of Data Analysis in a Multiprocessor Universe

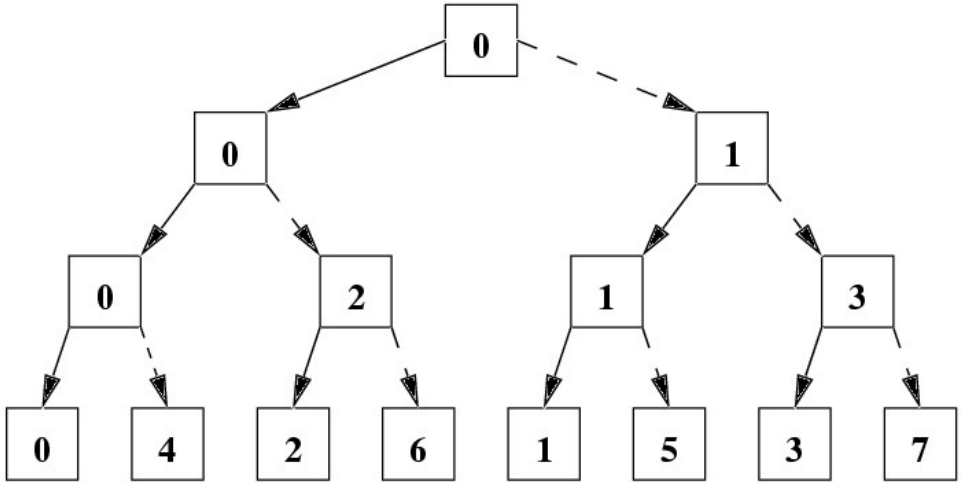
- Build a framework that is:
  - Sophisticated enough to take care of all of the nasty parallel bits for you
  - Flexible enough to be used for your own particular data analysis application

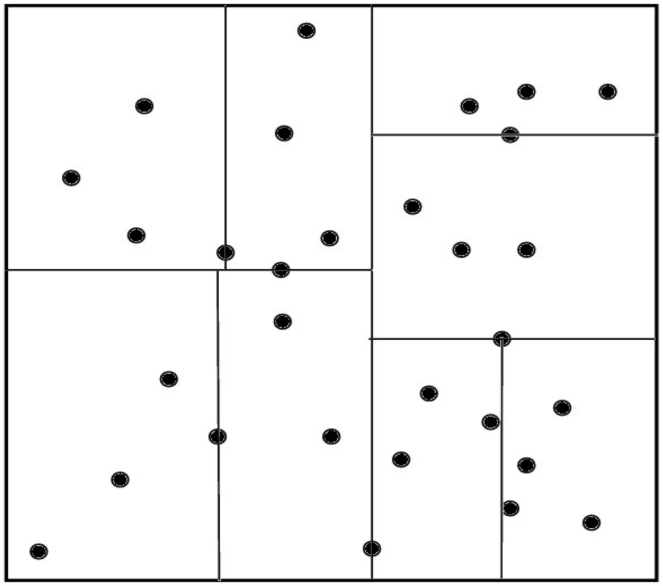
N tropy: A framework for multiprocessor development

- GOAL: Minimize development time for parallel applications.
- GOAL: Enable scientists with no parallel programming background (or time to learn) to still implement their algorithms in parallel by writing only serial code.
- GOAL: Provide seamless scalability from single processor machines to massively parallel resources.
- GOAL: Do not restrict inquiry space.

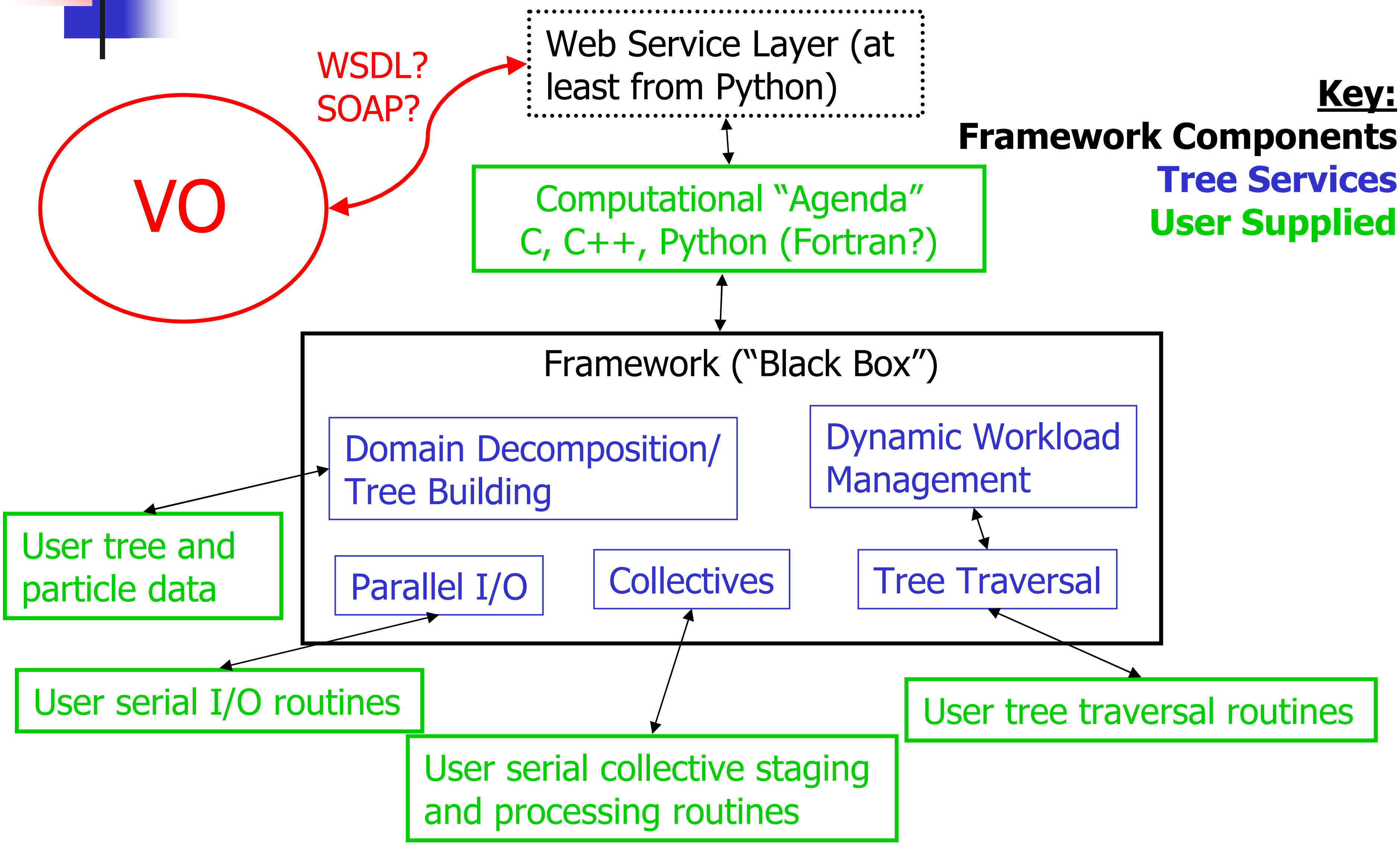
N tropy Methodology

- Limited Data Structures:
  - Astronomy deals with point-like data in an N-dimensional parameter space
  - Most efficient methods on these kind of data use space-partitioning trees.
- Limited Methods:
  - Analysis methods perform a limited number of fundamental operations on these data structures.

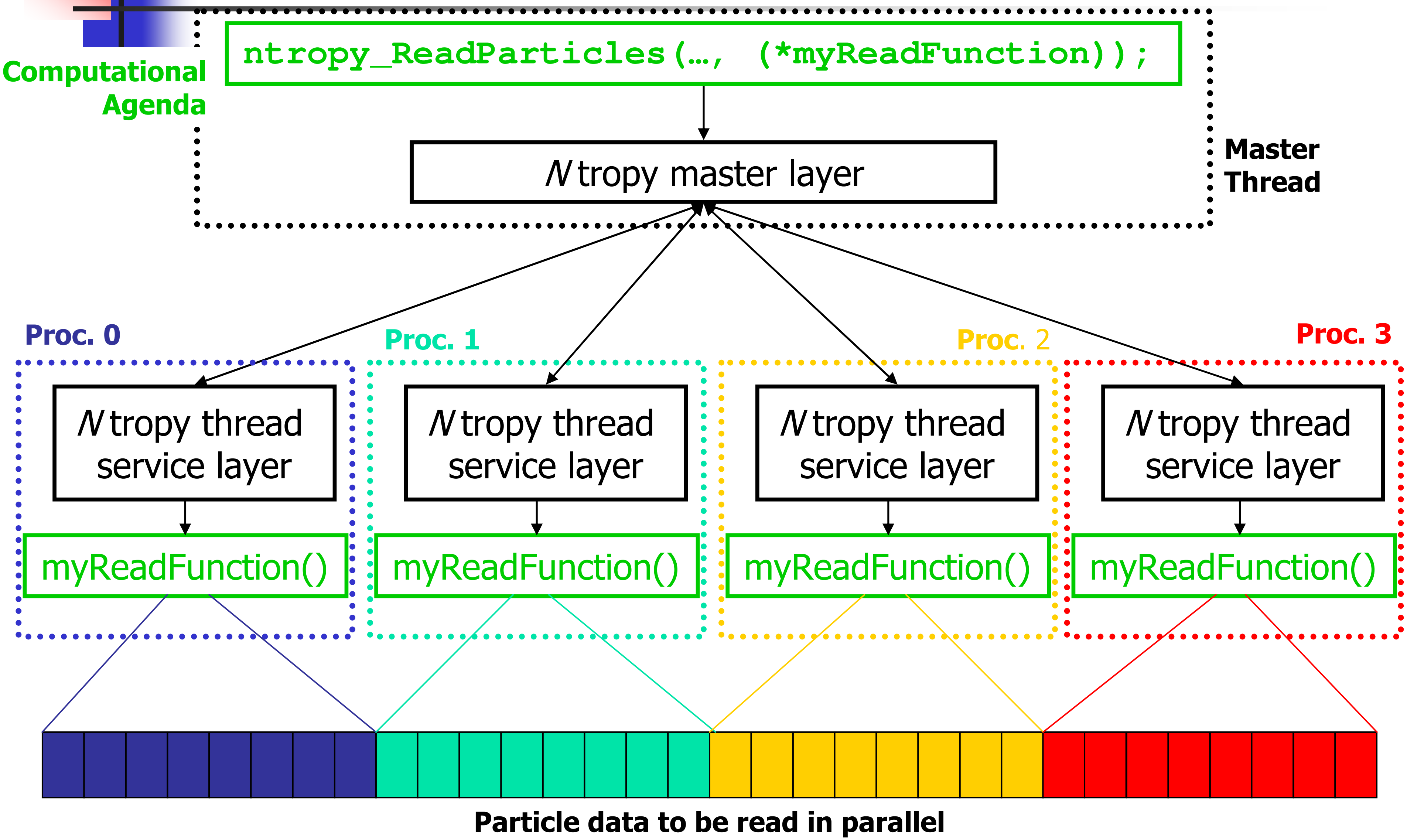




N tropy Conceptual Schematic



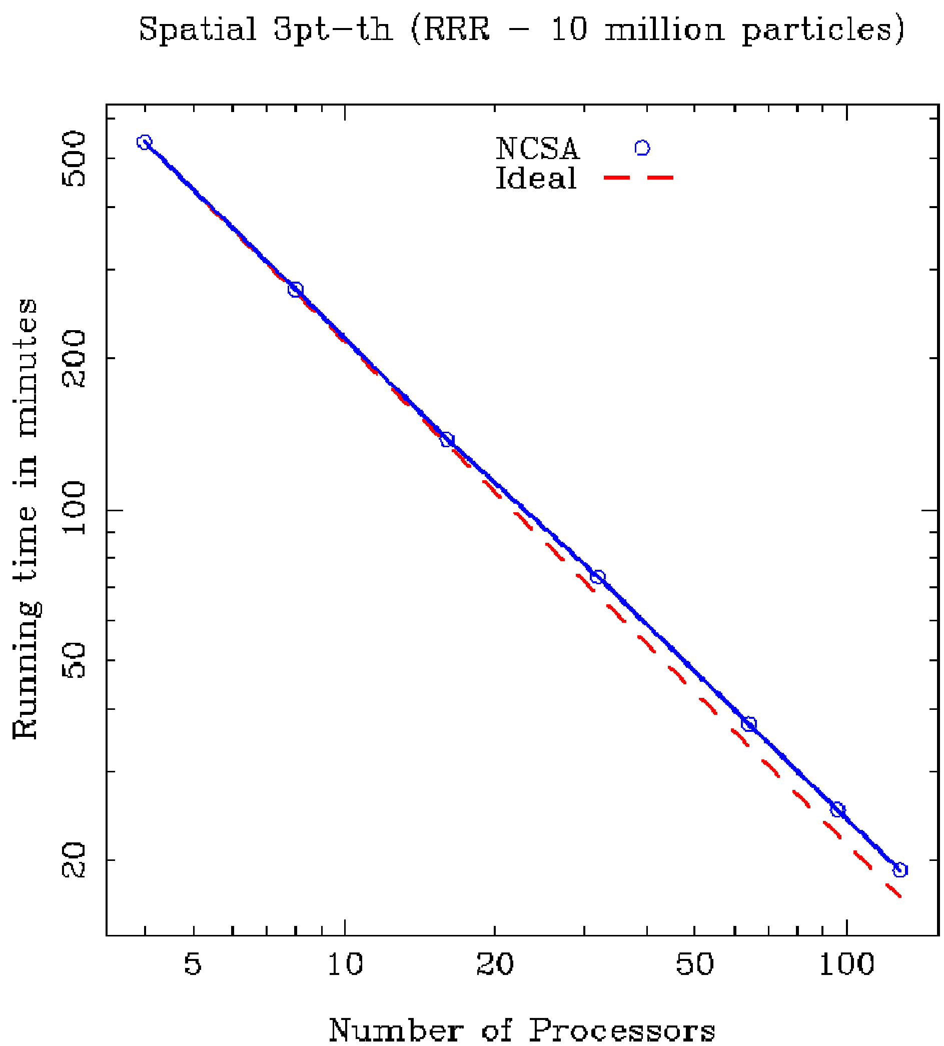
A Simple *N*tropy Example



N tropy Performance

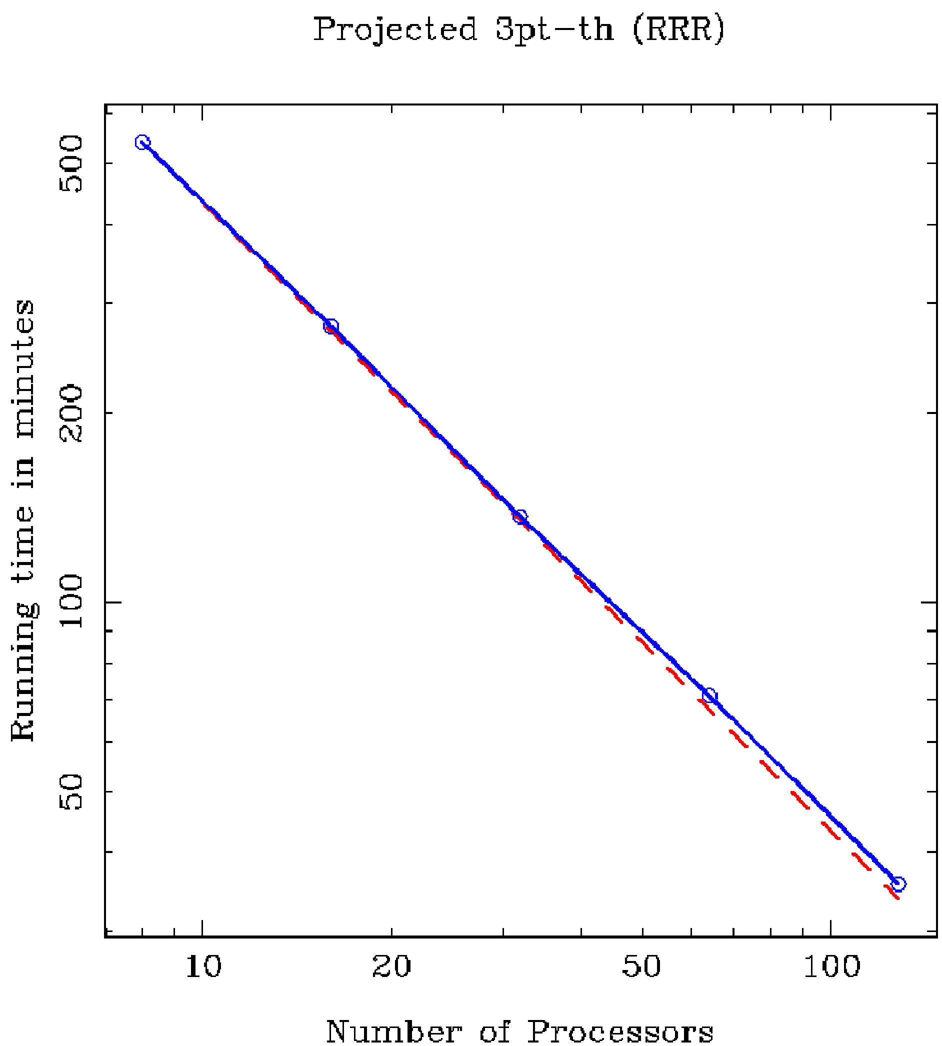
10 million particles
Spatial 3-Point
3->4 Mpc

(SDSS DR1 takes less than 1 minute with perfect load balancing)



N tropy Performance

10 million particles
Projected 3-Point
0->3 Mpc



Serial Performance

- *N* tropy vs. an existing serial n-point correlation function calculator:

N tropy is 6 to 30 times faster *in serial!*

- In short:

1. Not only does it takes much less time to write an application using *N* tropy,
2. You application may run *faster* than if you wrote it from scratch!

N tropy “Meaningful” Benchmarks

- The purpose of this framework is to minimize development time!
- Development time for:
  1. *Parallel* N-point correlation function calculator
     - 3 months
  2. *Parallel* Friends-of-Friends group finder
     - 3 weeks
  3. *Parallel* N-body gravity code
     - 1 day!*

*(OK, I cheated a bit and used existing serial N-body code fragments)

Conclusions

- Astrophysics, like many sciences, is facing a deluge of data that we must rely upon multiprocessor compute systems to analyze
- With *N* tropy, you can develop a tree-based algorithm in less time than it would take you to write one from scratch:
  1. The implementation may be even faster than a "from scratch" effort
  2. It will scale across many distributed processors
- More Information:
  - Go to Wikipedia and seach "Ntropy"