Computational Adaptive Mesh Refinement

Matthew Turk

Graduate Research Assistant, KIPAC

Overview

* Astrophysics is a highly multi-scale problem!
* Sophisticated physics needed on all scales
* Eulerian methods with large dynamical range in space and time are possible with embedded meshes
* With appropriate on-the-fly criteria, meshes can be embedded adaptively
* Extreme dynamic range now possible

Multi-Scale Physical Problems

* Primordial stars have formation efficiency of 0.03%!
* Galaxies shaped by stars, star clusters, merger history
* Must be able to adequately resolve large scale structure and small scale in order to develop next-generation subgrid models!

Dynamic Range

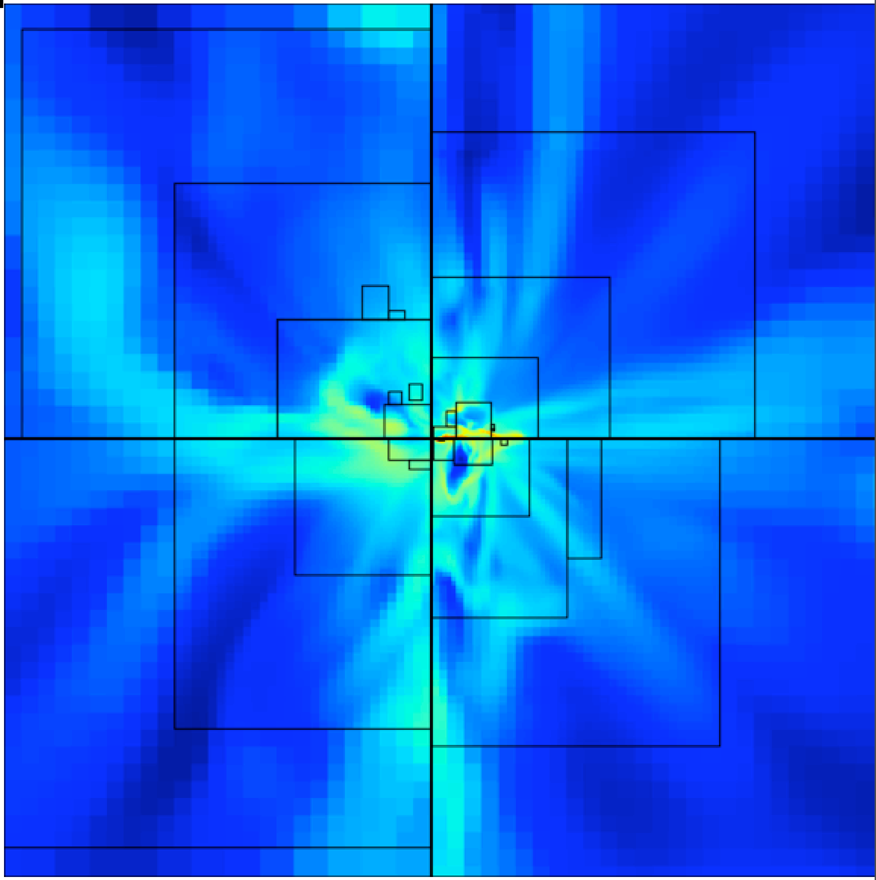
	Size	Relative Size
Visible Universe	1.3×10^{23} km	1.00
Galaxy Cluster	3×10^{19} km	2×10^{-4}
Galaxy	6×10^{17} km	5×10^{-6}
Star Cluster	2×10^{15} km	2×10^{-8}
Star	700,000 km	5×10^{-18}
Earth	6,000 km	5×10^{-20}
Us	0.002 km	1.5×10^{-26}

Physics Necessary

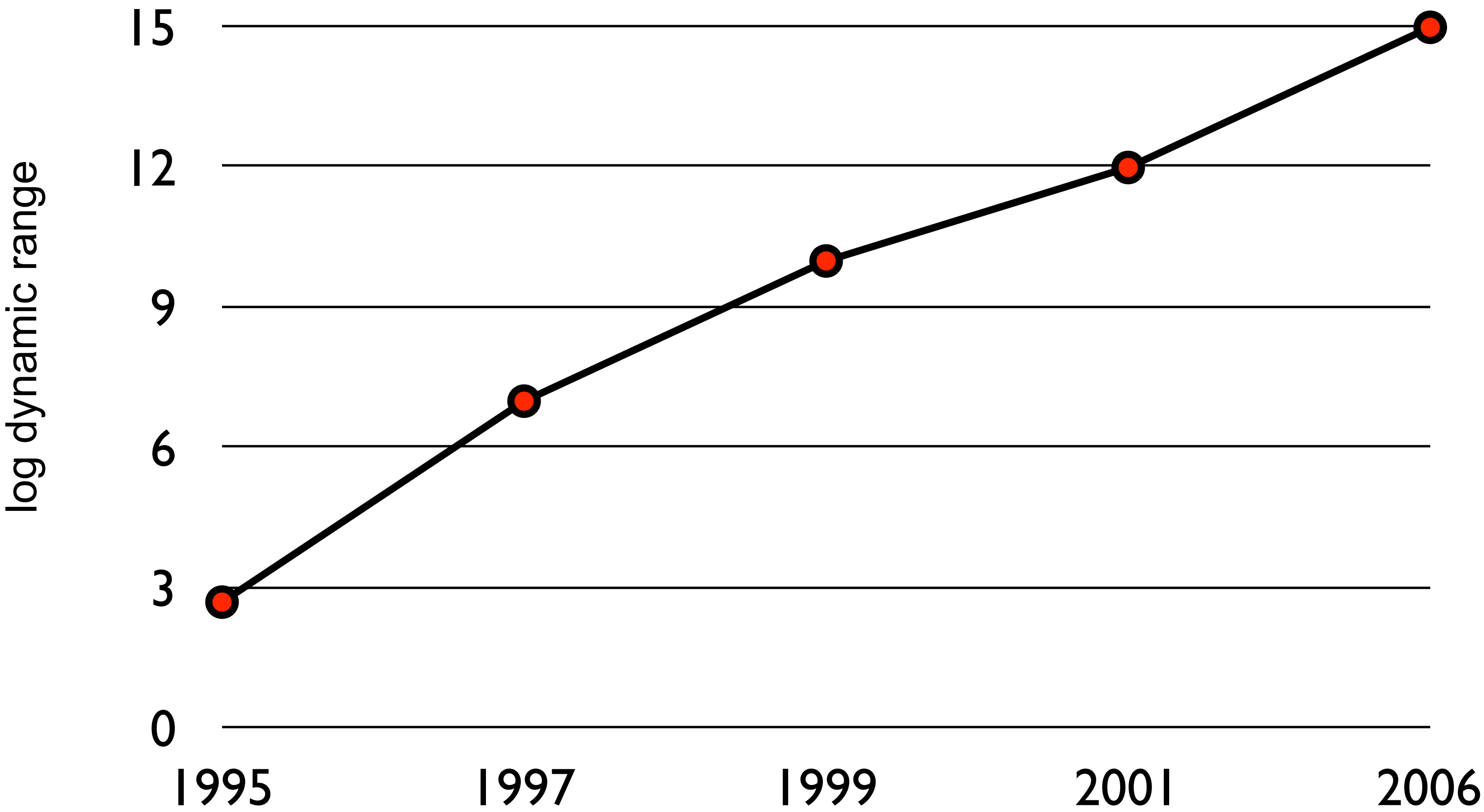
* Radiative cooling
* Ionization physics
* Background radiation
* Multi-species fluids
* Extensible to new subgrid models

Adaptive Mesh Refinement

* Higher-order hydrodynamic schemes
* Interpolate to higher resolution
* Correct fluxes of conserved quantities across boundaries



Adaptive Mesh Refinement

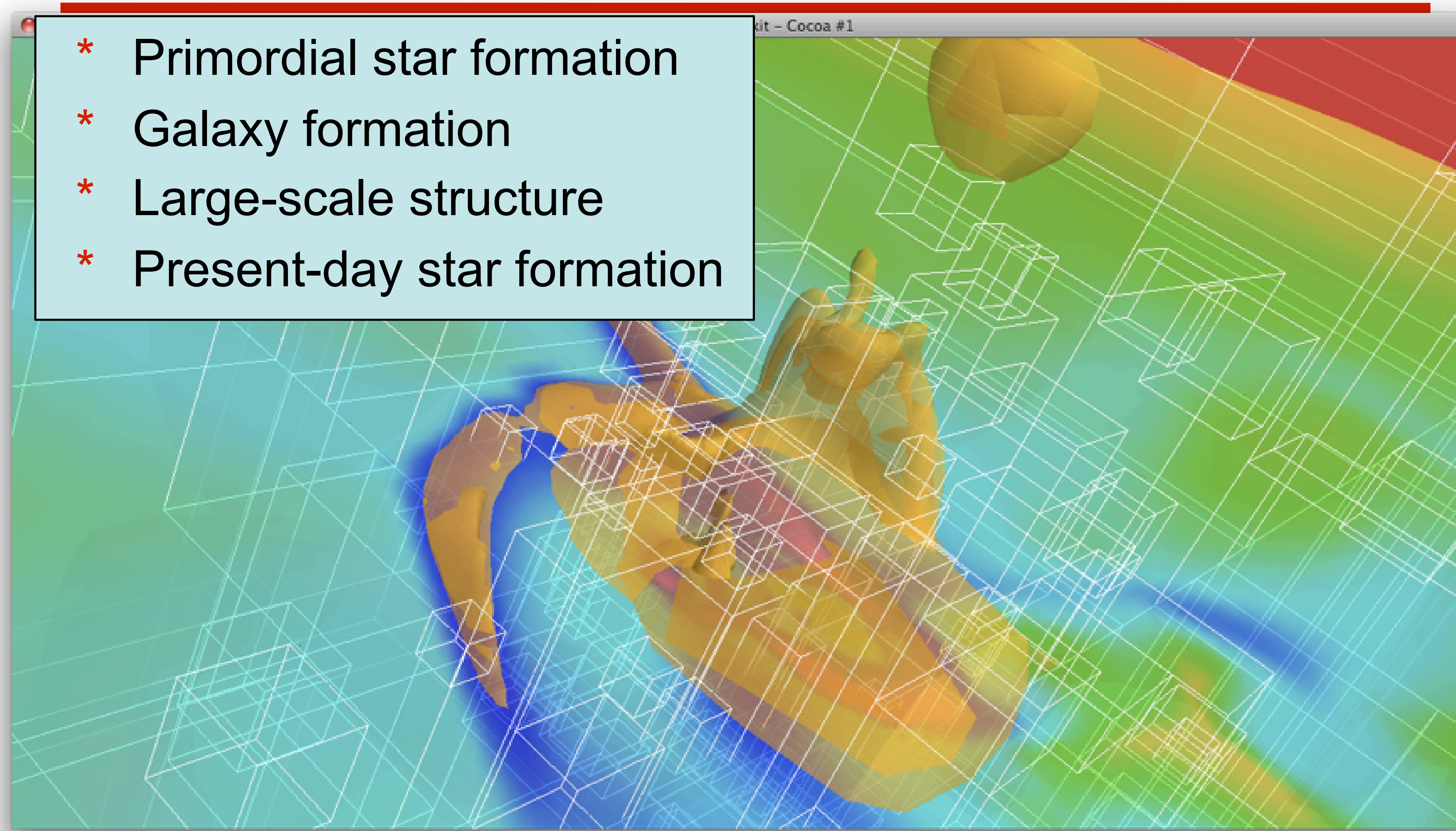


Codes Available

* Diversity of codes:
  - Enzo (SLAC, UCSD, Colorado, Columbia)
  - Orion (LBL, LLNL, Princeton, UCSC)
  - ART (UChicago, Fermilab)
  - Chombo (LBL)
* Enzo code:
  - Wide use in cosmology
  - Freely distributed, community developed
  - Patch-based AMR
  - Piecewise Parabolic Mesh hydro reconstruction
  - 12-species chemistry network

Simulational Domain

* Primordial star formation
* Galaxy formation
* Large-scale structure
* Present-day star formation



Computational Domain Expanding

* Modern simulations run on hundreds if not thousands of processors
* Computational infrastructure at SLAC supports large-scale simulations
* Studying formation of large scale structure with all attendant physics (galaxy feedback, cosmic rays, chemistry, star formation) is nearer than ever
* Galaxy catalogs, simulated observations, lensing studies