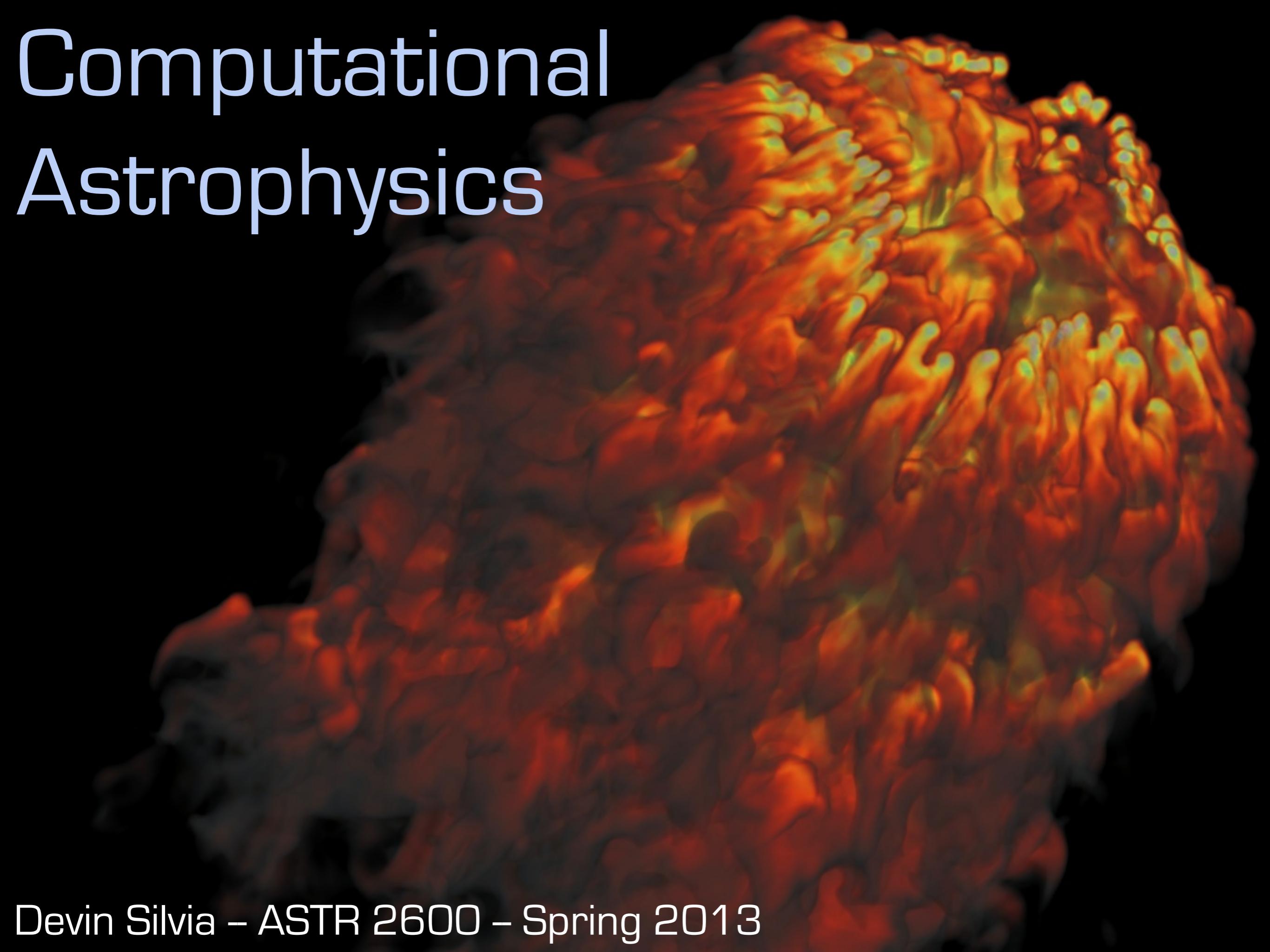


Computational Astrophysics



What is it?

Computational astrophysics
is the use of numerical methods to
solve research problems in
astrophysics on a computer.

James M. Stone (2007), Scholarpedia, 2(10):2419

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What are we trying to solve?

- linear algebra
- nonlinear root finding
- ordinary differential equations (ODEs)
- coupled partial differential equations (PDEs) in multi-dimensions

There is an entire book about this: Numerical Recipes

In what physical scenarios?

- Astrophysical fluid dynamics (hydro and MHD)
- Radiation transfer
- Stellar structure and evolution
- Gravitational dynamics (e.g. orbital dynamics)
- Relativity (e.g. black hole mergers)
- Chemical Networks

Lots o' Codes

WOMBAT

Zeus

Orion

C²-Ray

MESA

Enzo

Ramses

CoCoNuT

GADGET

Nyx

FLASH

ASH

AREPO

Cactus

Mercury

Dengo

Athena

Cloudy

ART

Sunrise

Whisky

AstroBEAR

What do we use?

- Local machines:
 - Laptop (1 - 4 cores, 1-16 GB RAM)
 - Work station (desktop; 4-16 cores, 4 - 64 GB RAM)
 - Department servers (32+ cores, 64+ GB RAM)
- High performance computers:
 - CU's Janus supercomputer
 - NASA Advanced Supercomputing Division
 - NSF XSEDE (collection of machines across US)
 - * 10^5 - 10^6 cores, 10^5 - 10^6 GB RAM, 10^3 - 10^4 TFlops *
 - my laptop: ~5 GFlops
 - factor of $\sim 10^6$

How do we use them?

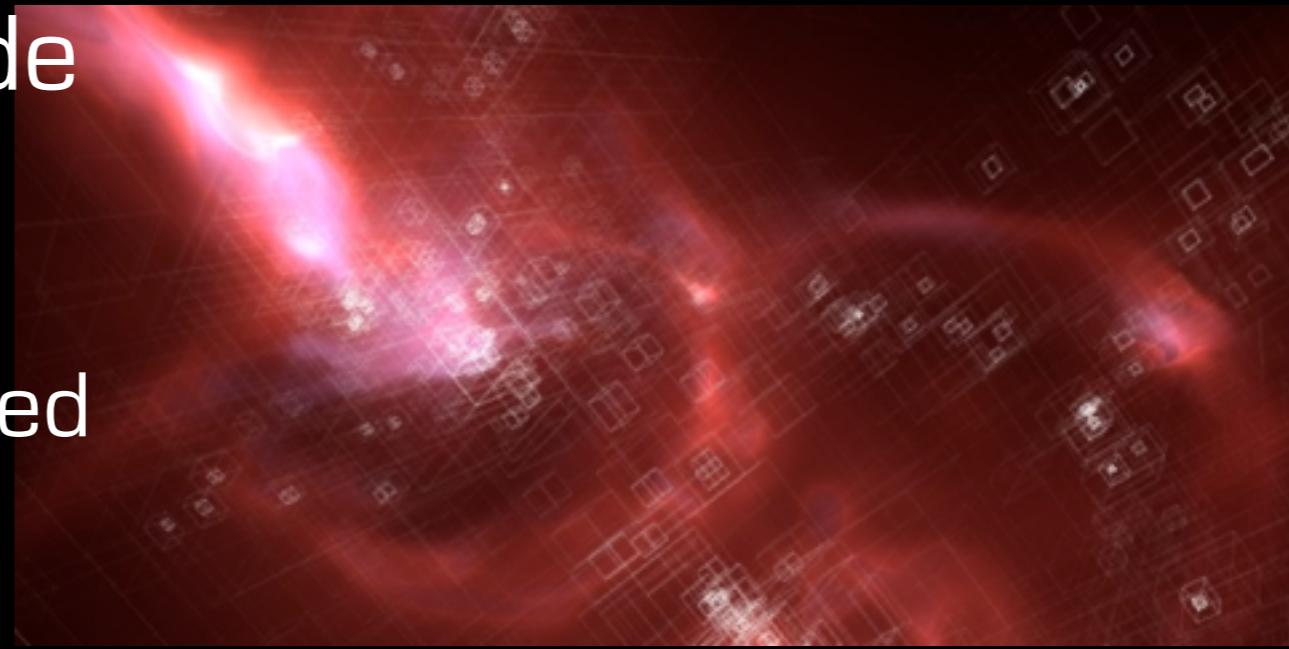
- “Embarrassingly parallel”, many serial tasks simultaneously
 - Often used for parameter space studies
- Truly parallel
 - Large simulations can be divided into “chunks” and spread out across many processors
 - Requires special software packages (MPI, OpenMP)

What do I use?

Enzo: 3D, grid-based, adaptive mesh-refinement,
N-body + hydrodynamics code

- Written in C++, Fortran
- Parallel with MPI and OpenMP
- Publicly available, openly developed
- Uses online repository

<http://enzo-project.org>



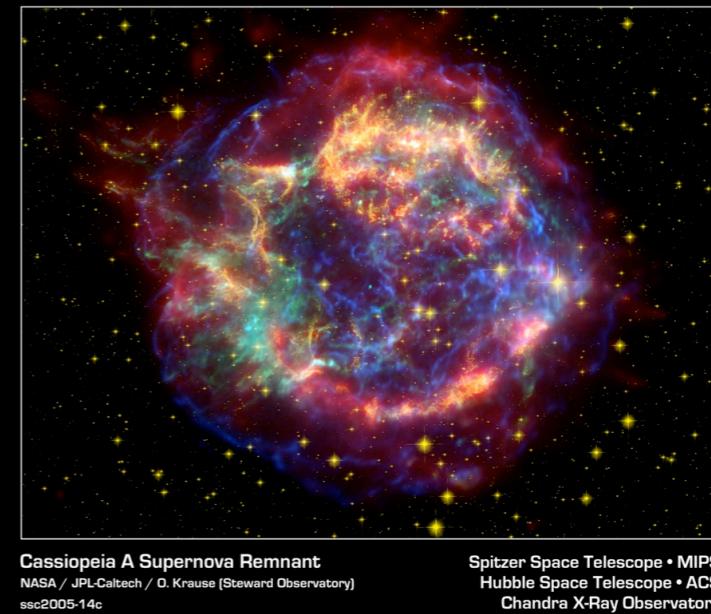
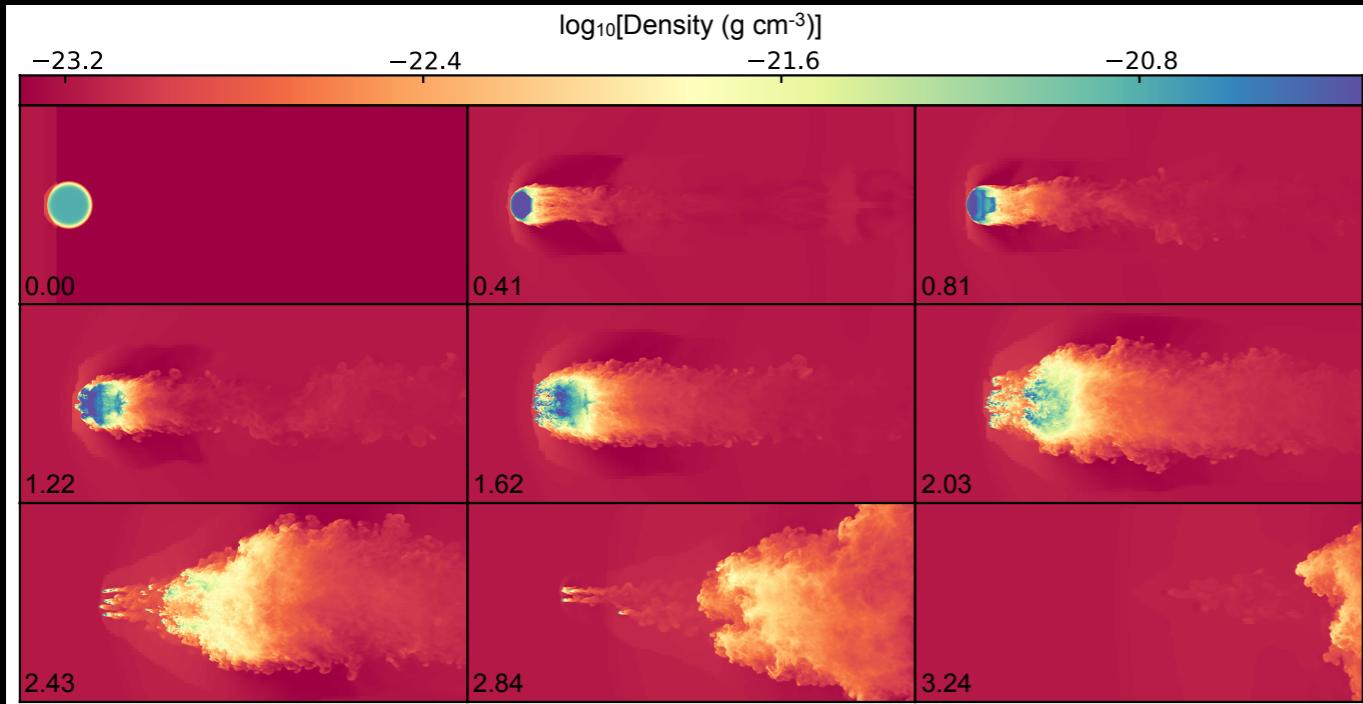
yt: data analysis and visualization software

- Written mostly in Python
- Works with Enzo, Orion, Nyx, FLASH, and more!
- Also publicly available and openly developed

<http://yt-project.org>

What do I study?

Dust destruction in supernova remnants

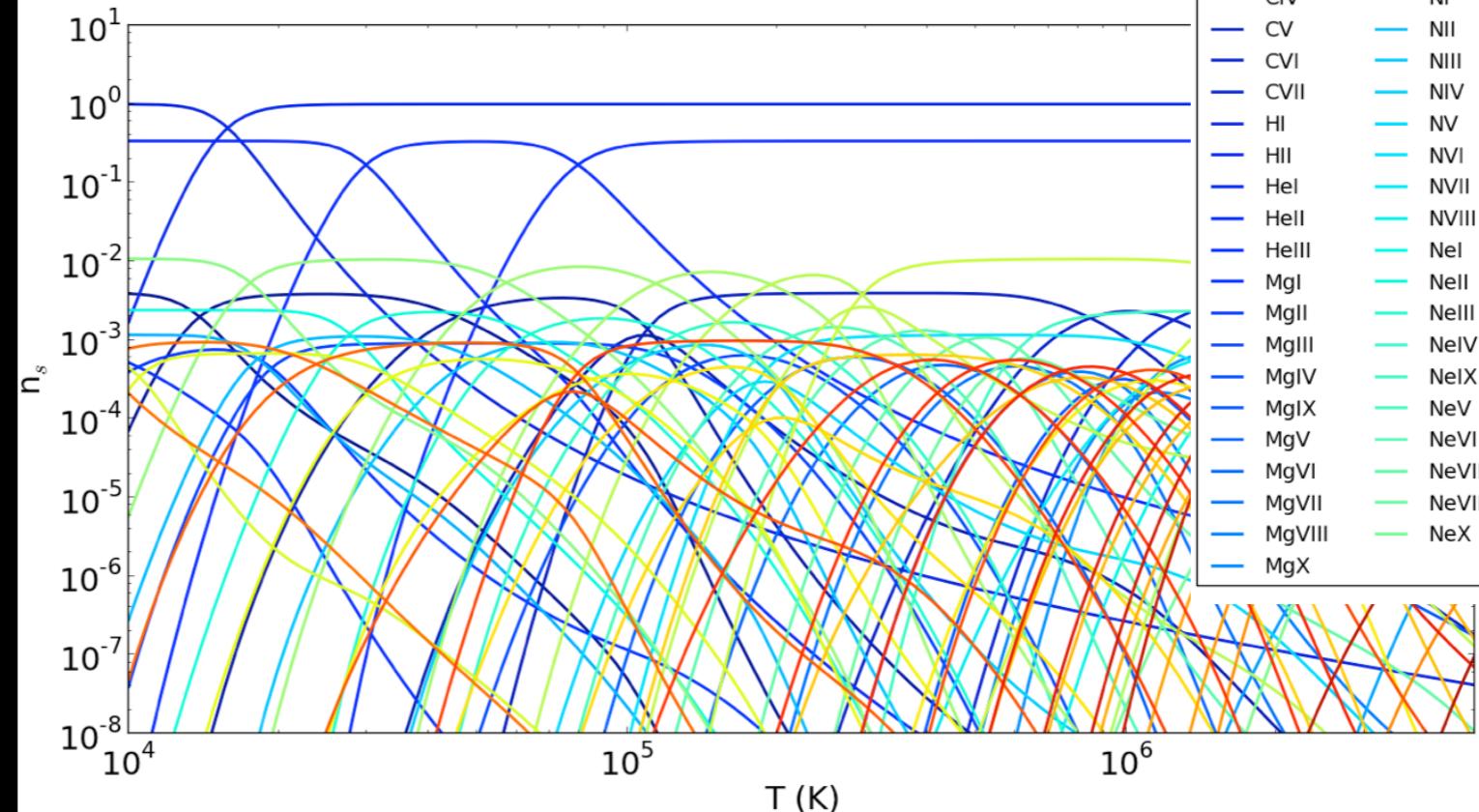


Cassiopeia A Supernova Remnant
NASA / JPL-Caltech / O. Krause (Steward Observatory)
ssc2005-14c

Spitzer Space Telescope • MIPS
Hubble Space Telescope • ACS
Chandra X-Ray Observatory

Non-equilibrium ionization chemistry

Cl	MgXI	NeXI	SXII
ClI	MgXII	OI	SXIII
ClII	MgXIII	OII	SXIV
ClIII	NI	OIII	SXV
ClIV	NII	OIV	SXVI
CV	NIII	OIX	SXVII
CVI	NIV	OV	Sil
CVII	NV	OVI	Sill
HII	NVI	OVII	Silll
HIII	NVII	OVIII	SilV
HeI	NVIII	SI	SiIX
HeII	Nel	SII	SiV
HeIII	Nell	SIII	SiVI
HeII	Nelll	SIV	SiVII
MgI	NelV	SIX	SiVIII
MgII	NelX	SV	SiX
MgIII	NeV	SVI	SiXI
MgIV	NeVI	SVII	SiXII
MgV	NeVII	SVIII	SiXIII
MgVI	NeVIII	SX	SiXIV
MgVII	NeX	SXI	SiXV
MgVIII			
MgX			

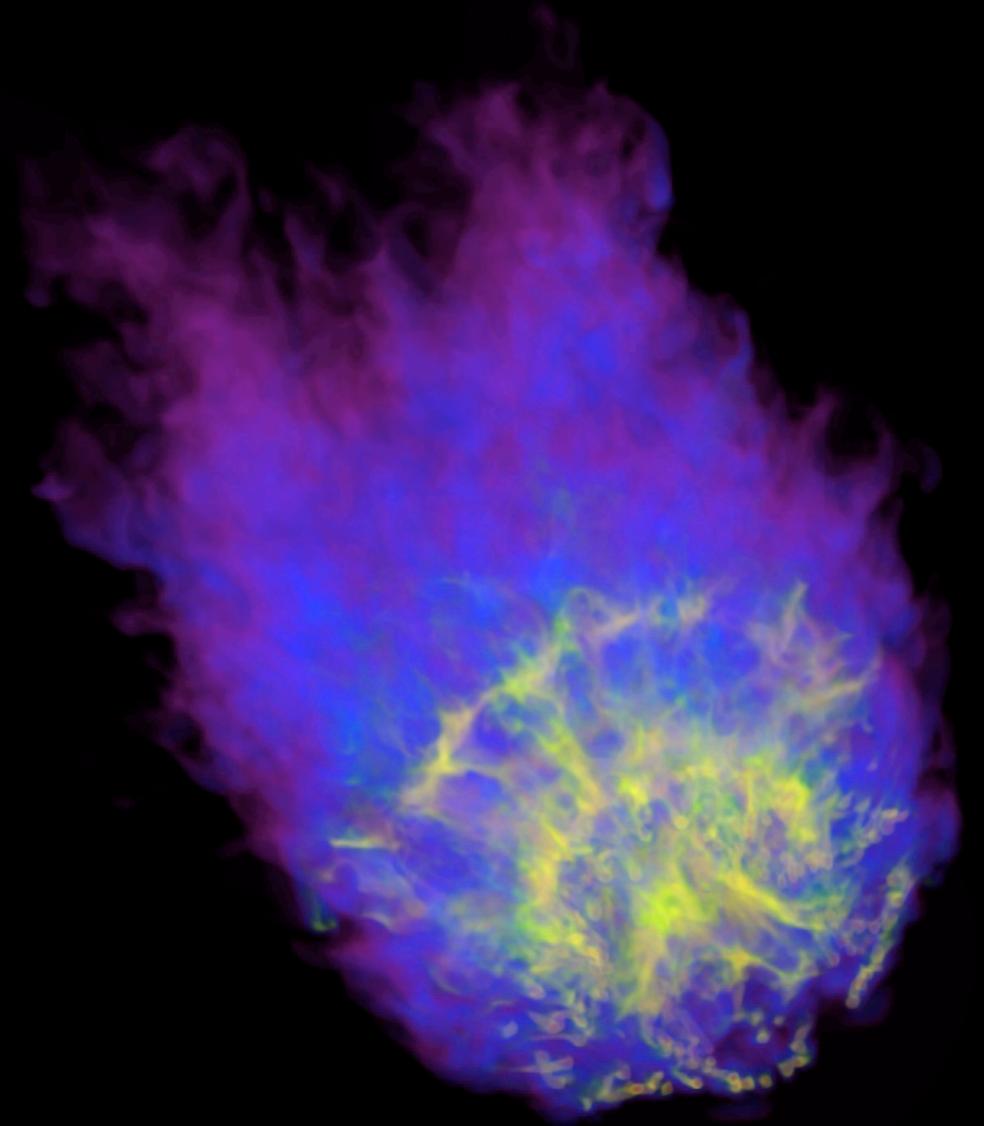


New software module:
Dengo

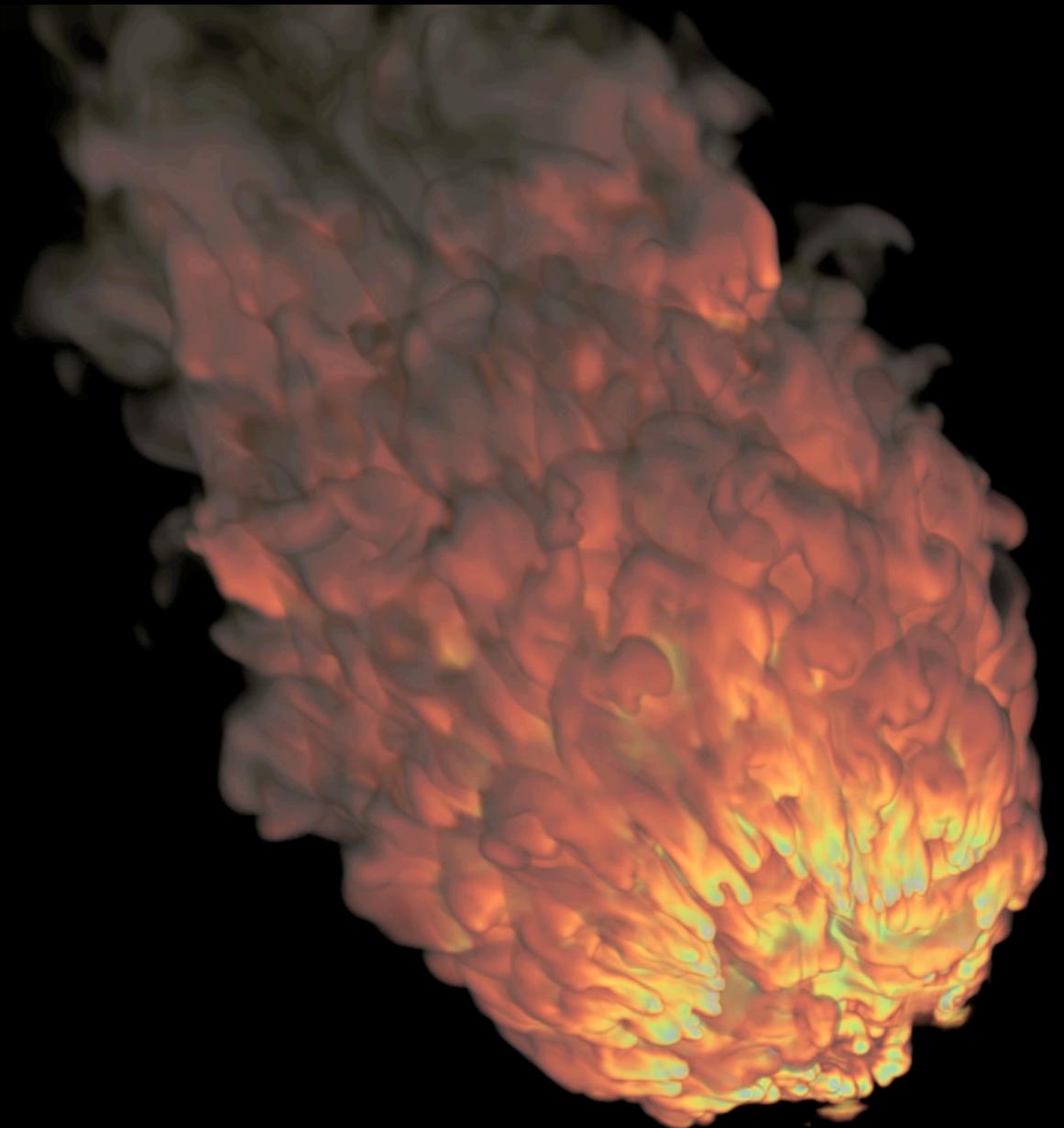
- Solves complex chemical networks
- Python-based
- Not code specific
- Hosted on bitbucket

Movies!

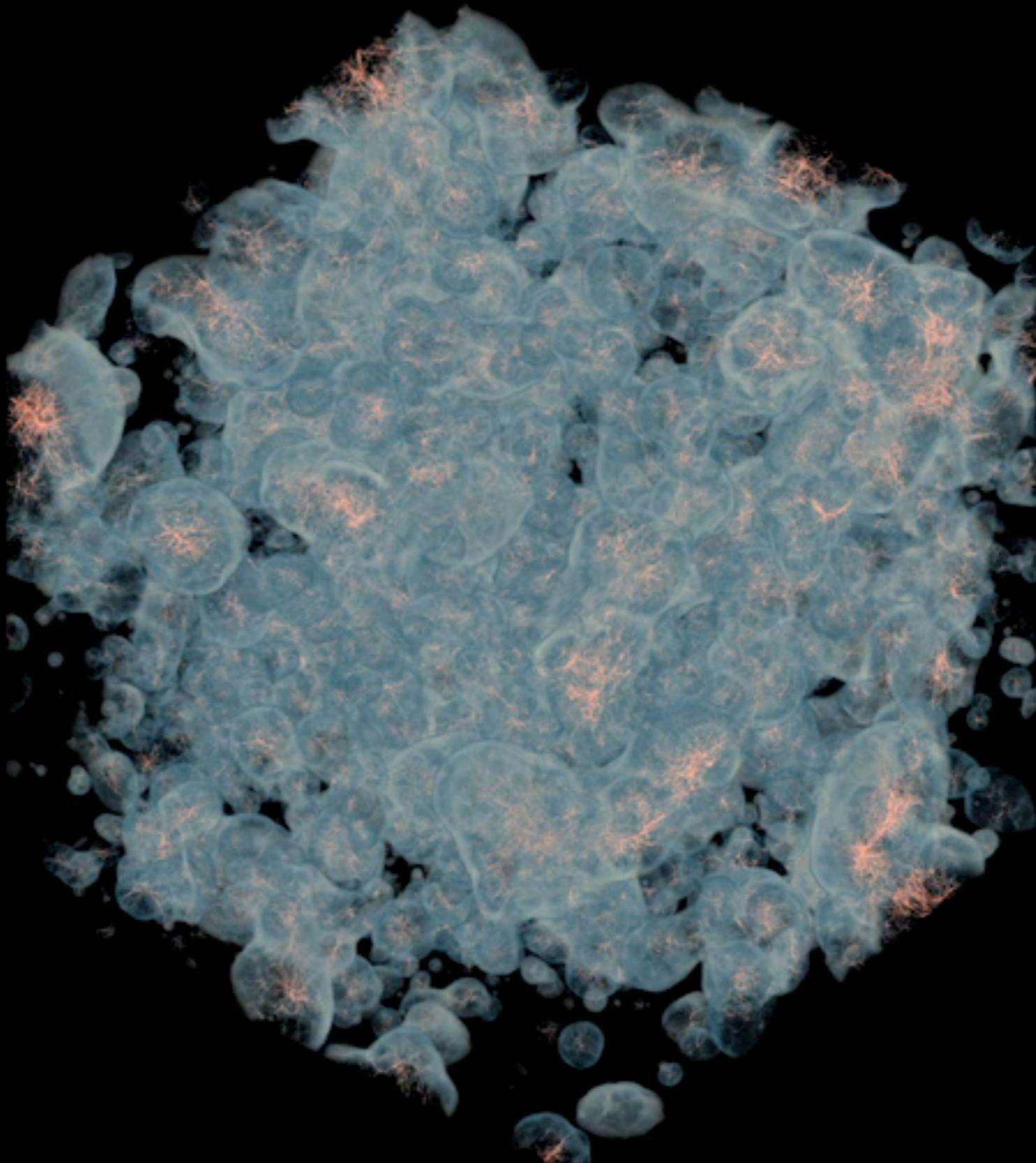
Density



“Dust”



Rendered using `yt`



Courtesy of Sam Skillman
also used `yt`

Questions?

<http://devinsilvia.com>