# Animation Techniques in Astronomy

... aka a Smorgasbord of Data Management, Coding Hacks and Stuff I've Been Working on in Houdini/Blender/VR in the context of the larger problems we face in Astronomy

# Who Are you?

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Ph.D. from UCSC, BS from UCLA

Alyssa Goodman
& Glue Team

Donna Cox's Group
&
Matt Turk

# Terms

Visualization = Animations and/or pictures (in 2D and 3D)

analysis/analysis plots = images with axis that have numbers

# Some Structural Problems Facing Astronomy

New instruments
=
more data

New high resolution/cadence instruments = lots more data

… an example

How fast galaxy is moving away from us

Hubble's Law

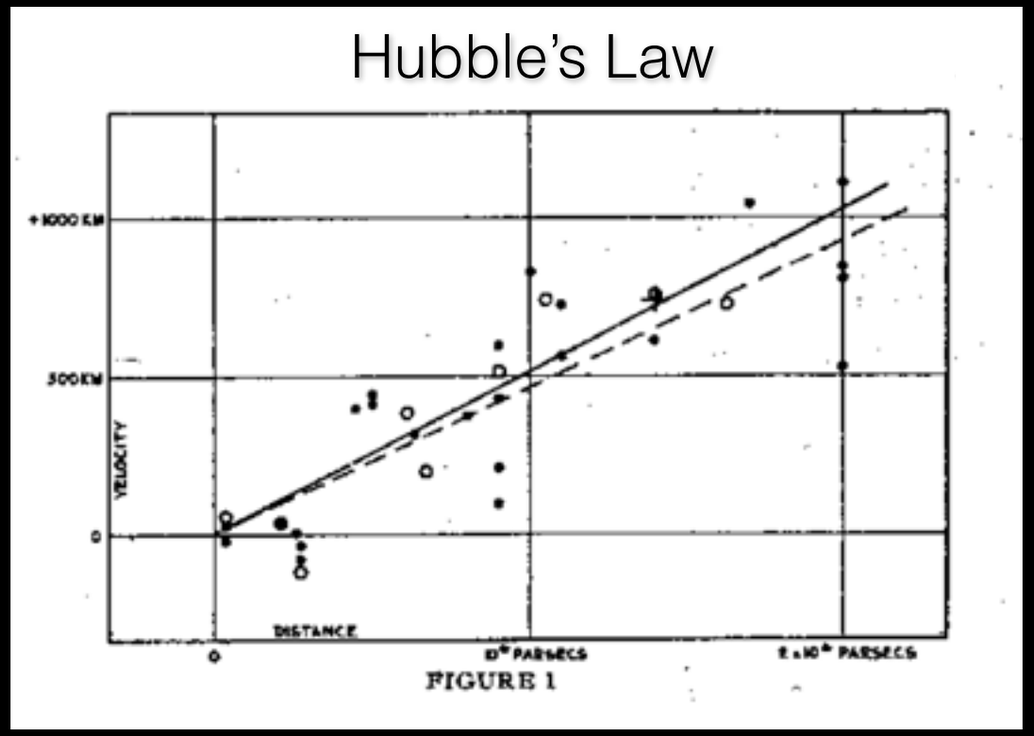

FIGURE 1

How far away a specific galaxy is

Things further away from us are moving away from us more quickly

The universe is expanding in every direction

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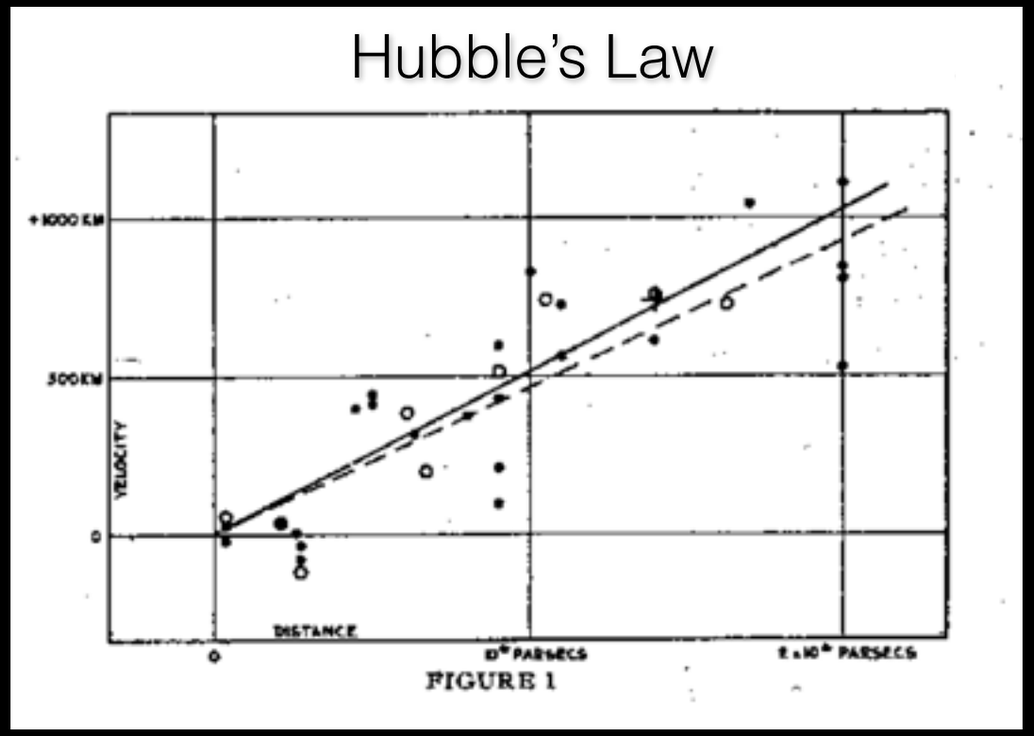

FIGURE 1

How far away a specific galaxy is

Things further away from us are moving away from us more quickly

The universe is expanding in every direction

If you run time backwards space is smooshed together

=

The Big Bang

This was a Big Discovery!

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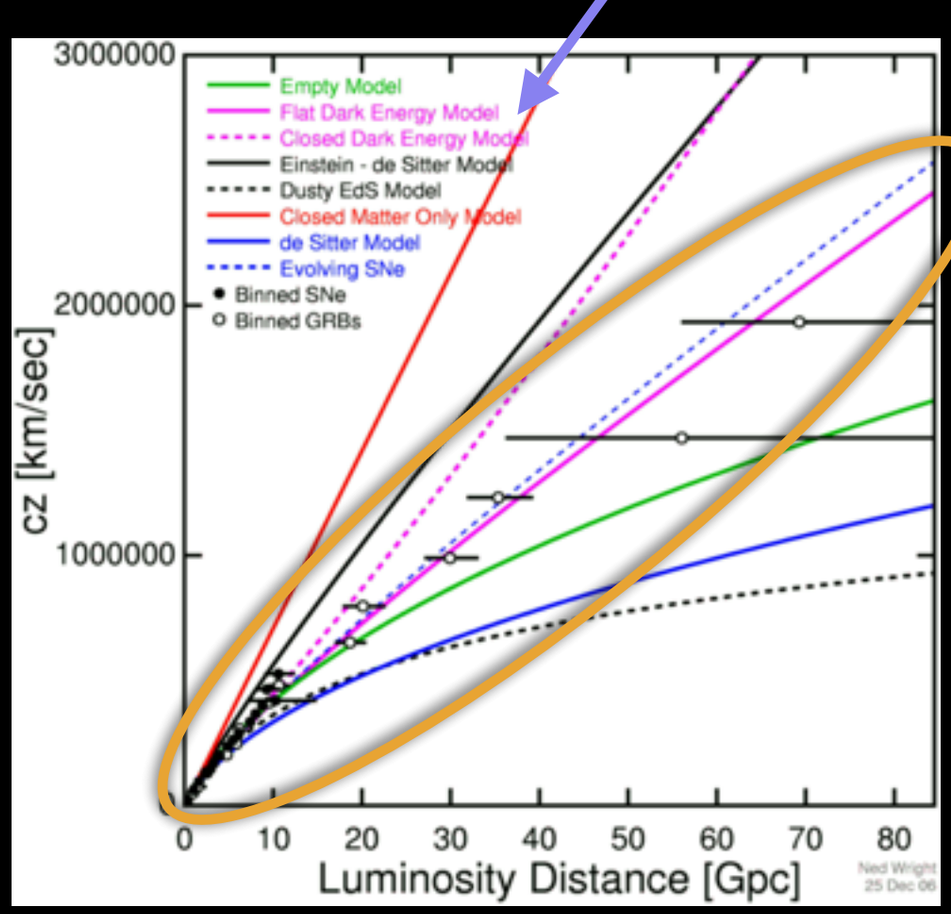
… an example

Models that require DE for acceleration




How fast galaxy is moving away from us

How far away a specific galaxy is

Better telescopes
=
New data which shows expansion is accelerating
=
discovery of Dark Energy

But what is Dark Energy?

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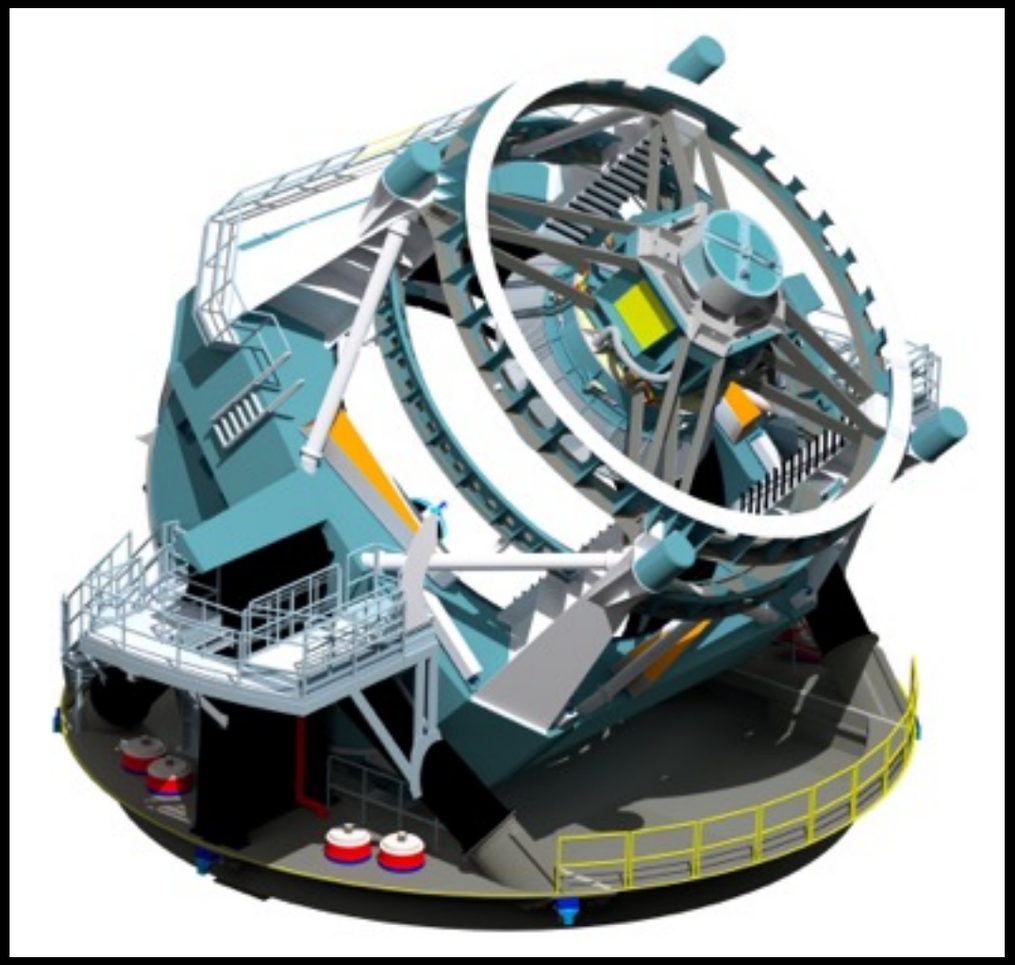

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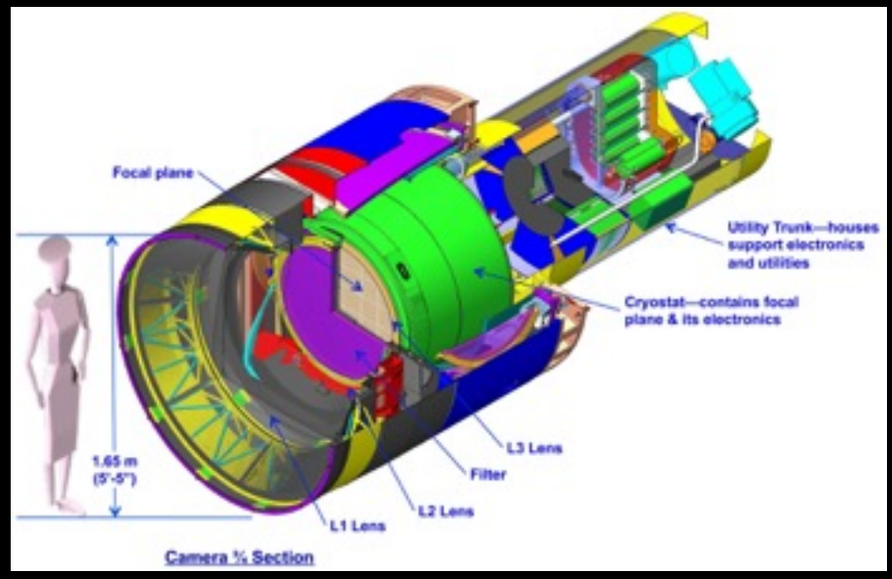
… an example

Large Synoptic Survey Telescope (LSST): searching for answers about Dark Energy (and Dark Matter, and on and on!)




GIGANTIC camera with 3.2 gigapixels (3,200,000,000 pixels)

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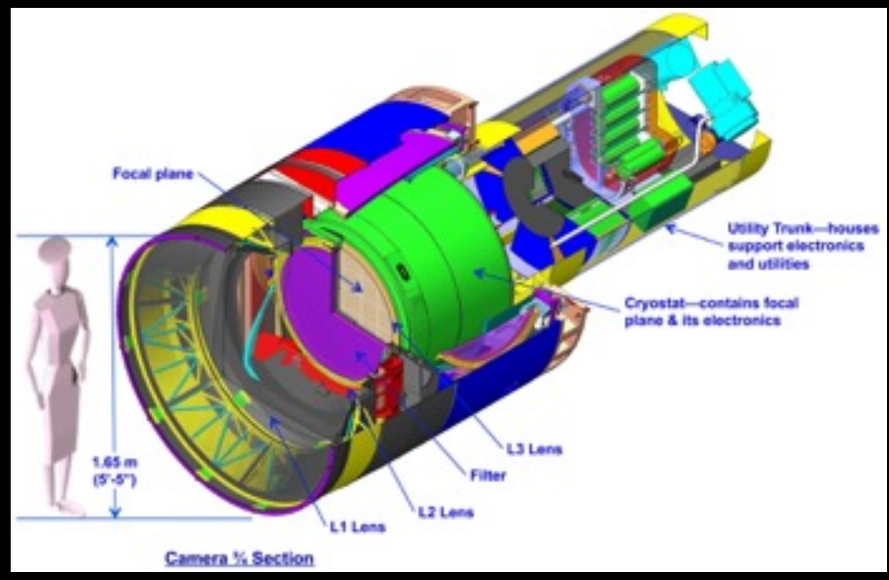
… an example

Large Synoptic Survey Telescope (LSST): searching for answers about Dark Energy (and Dark Matter, and on and on!)

200PB/decade expected (200,000 Jill's laptop's storage)

How are we possibly sift through all this data for the interesting bits??

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New high resolution/cadence instruments = lots more data

… an example

LSST: 200PB/decade expected (200,000 Jill's laptop's storage)

Sloan Digital Sky Survey (SDSS): ~120TB

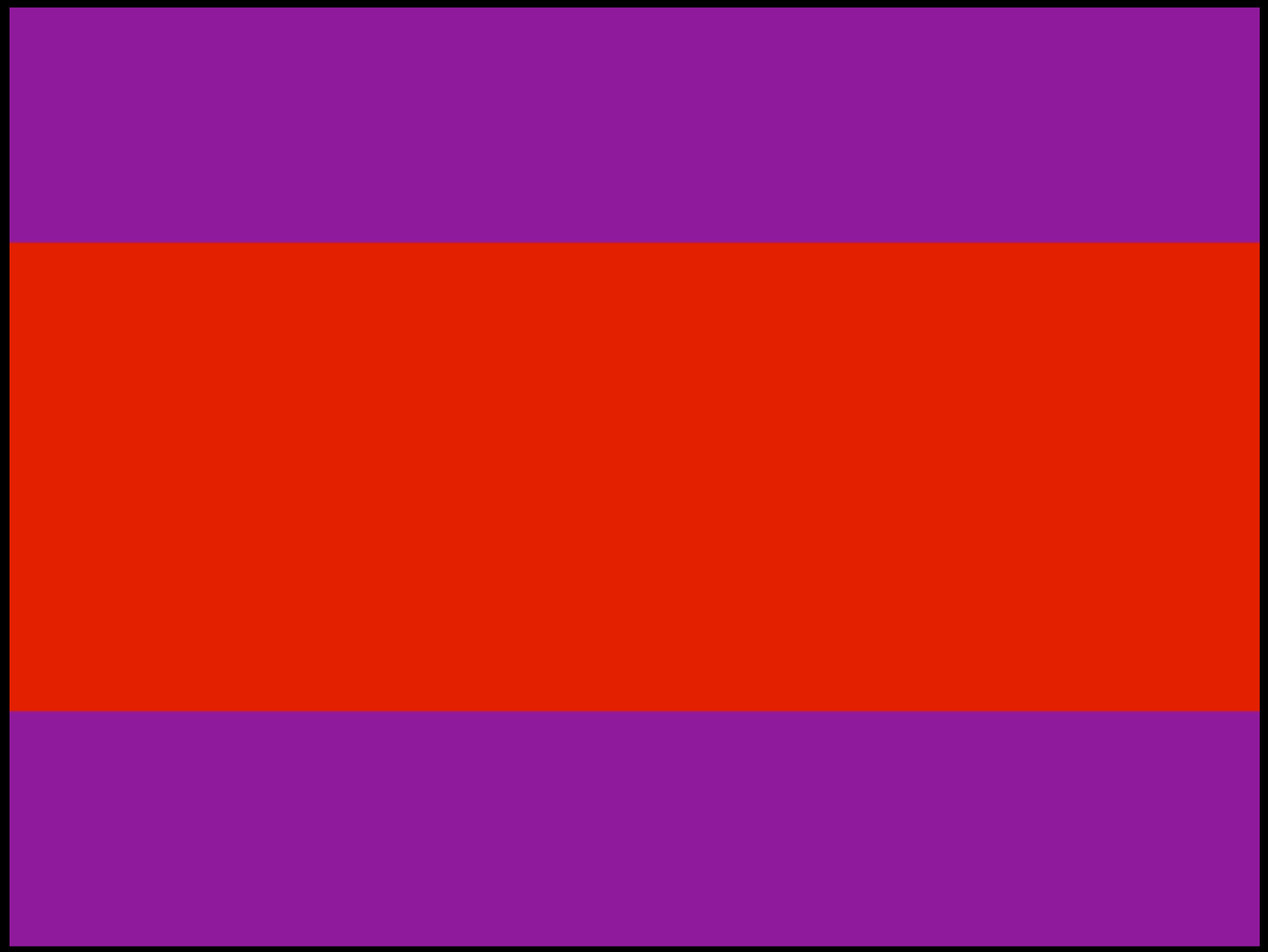
Dark Energy Survey (DES): ~200GB/night, ~PB in last decade.

Square Kilometre Array (SKA): 1000 PB per year expected

# Some Structural Problems Facing Astronomy

New instruments
=
more data

Faster Computers
=
more (fake) data



AREPO - http://wwwmpa.mpa-garching.mpg.de/~volker/arepo/

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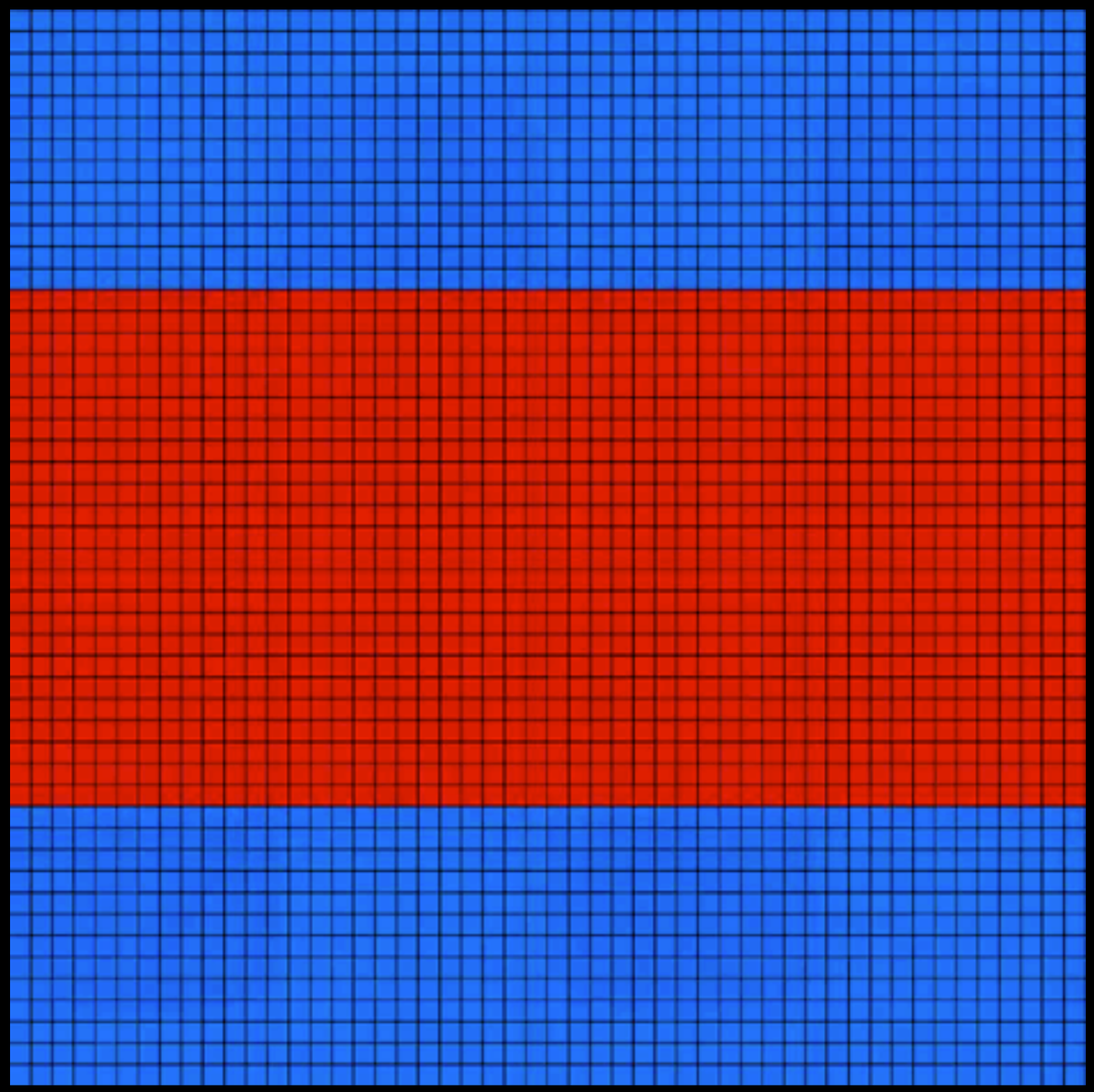

AREPO - http://wwwmpa.mpa-garching.mpg.de/~volker/arepo/

# Some Structural Problems Facing Astronomy

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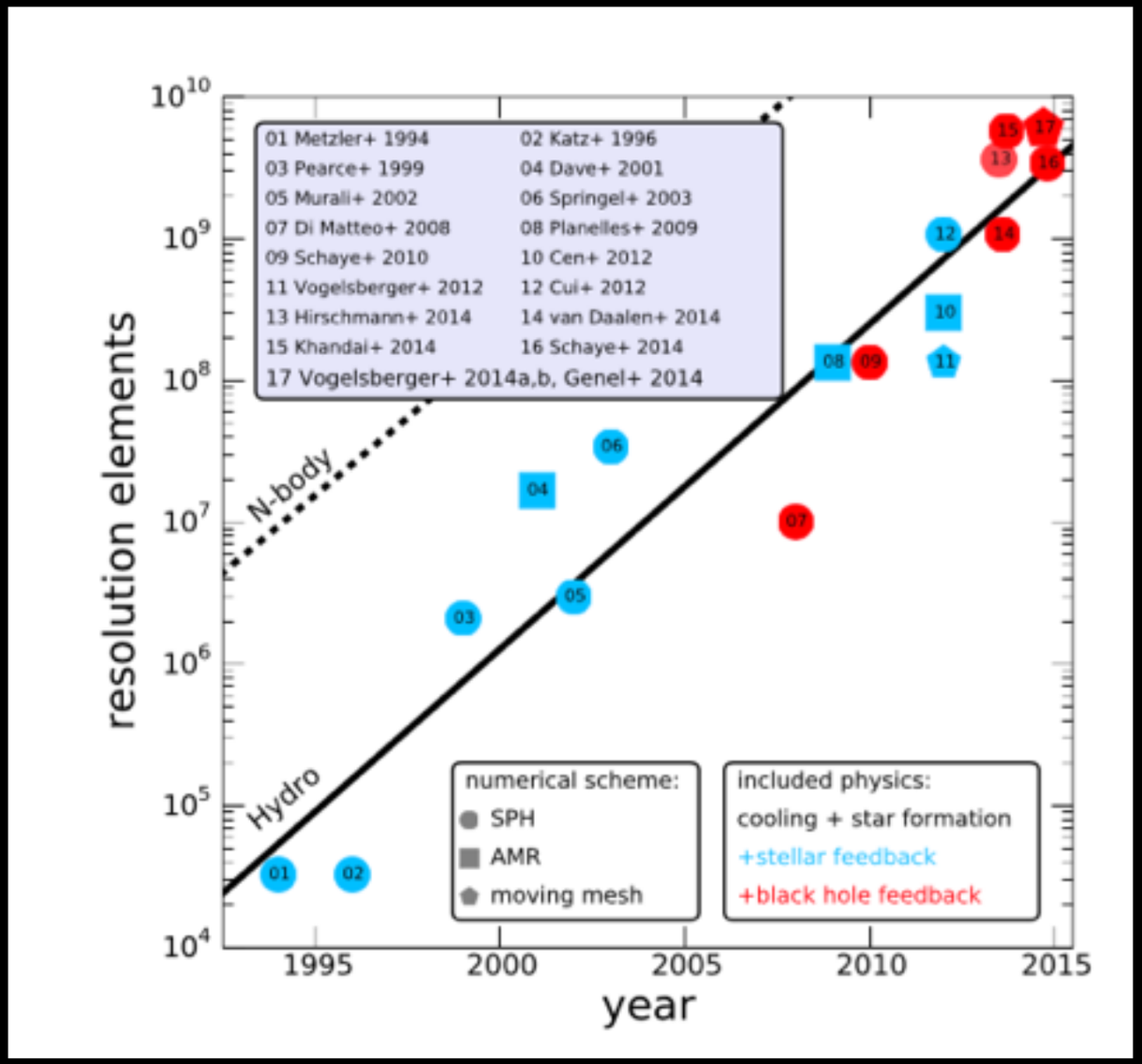
How many little grids can we break up our simulation into?

## "Moore's Law for Astronomy"




Again: How are we possibly sift through all this (fake) data for the interesting bits?

# Some Structural Problems Facing Astronomy

New instruments
=
more data

Faster Computers
=
more (fake) data

Scientific illiteracy

~1 in 4 think Sun goes around Earth

~1 in 2 think antibiotics kill viruses as well as bacteria

~1 in 4 think all radioactivity is human-made

Indicates a failure of scientific education/communication.

NSF - http://www.nsf.gov/statistics/seind14/content/chapter-7/chapter-7.pdf

# Some Structural Problems Facing Astronomy

New instruments
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Scientific brain-drain

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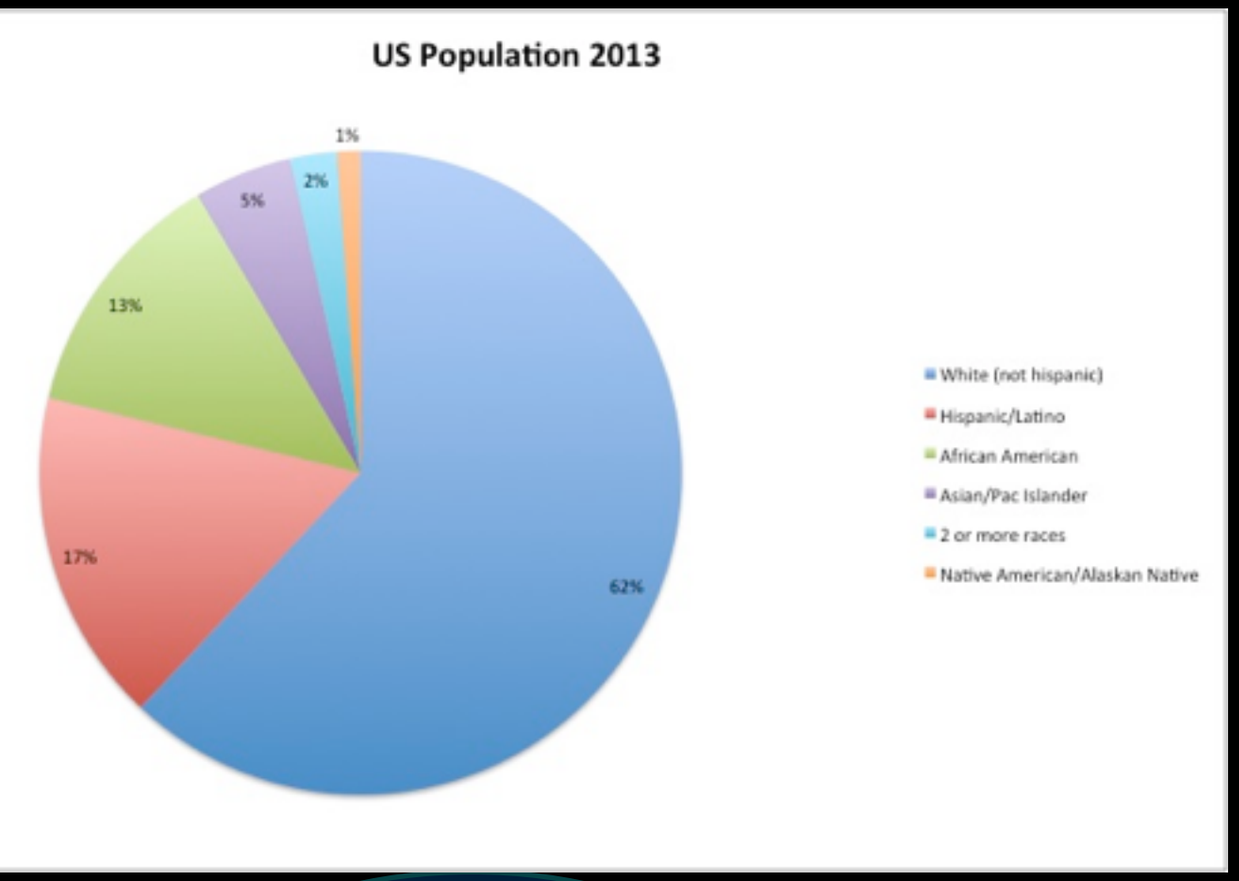
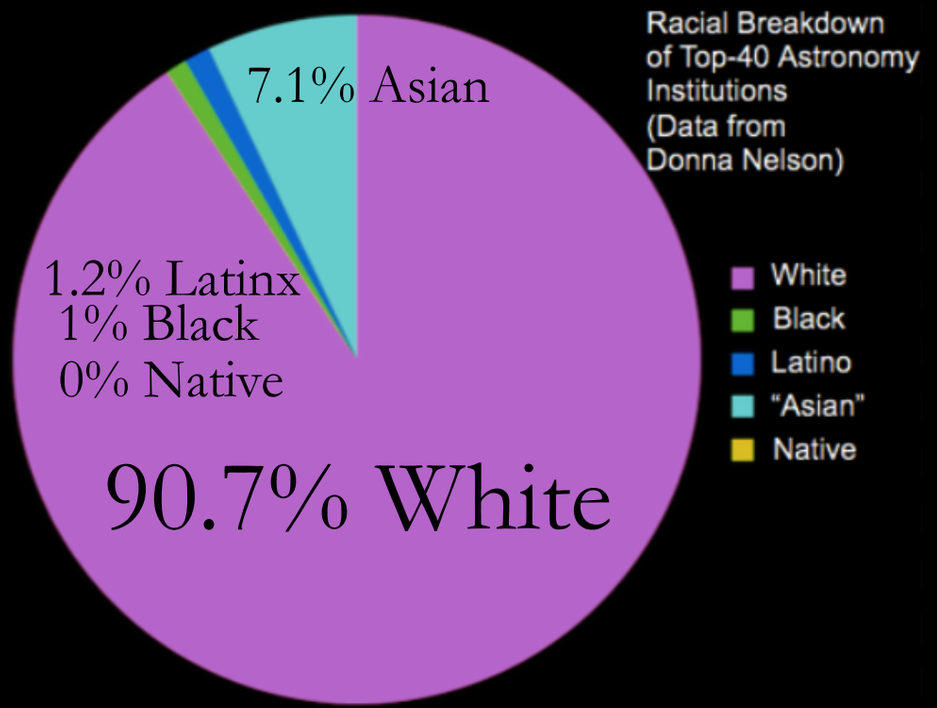


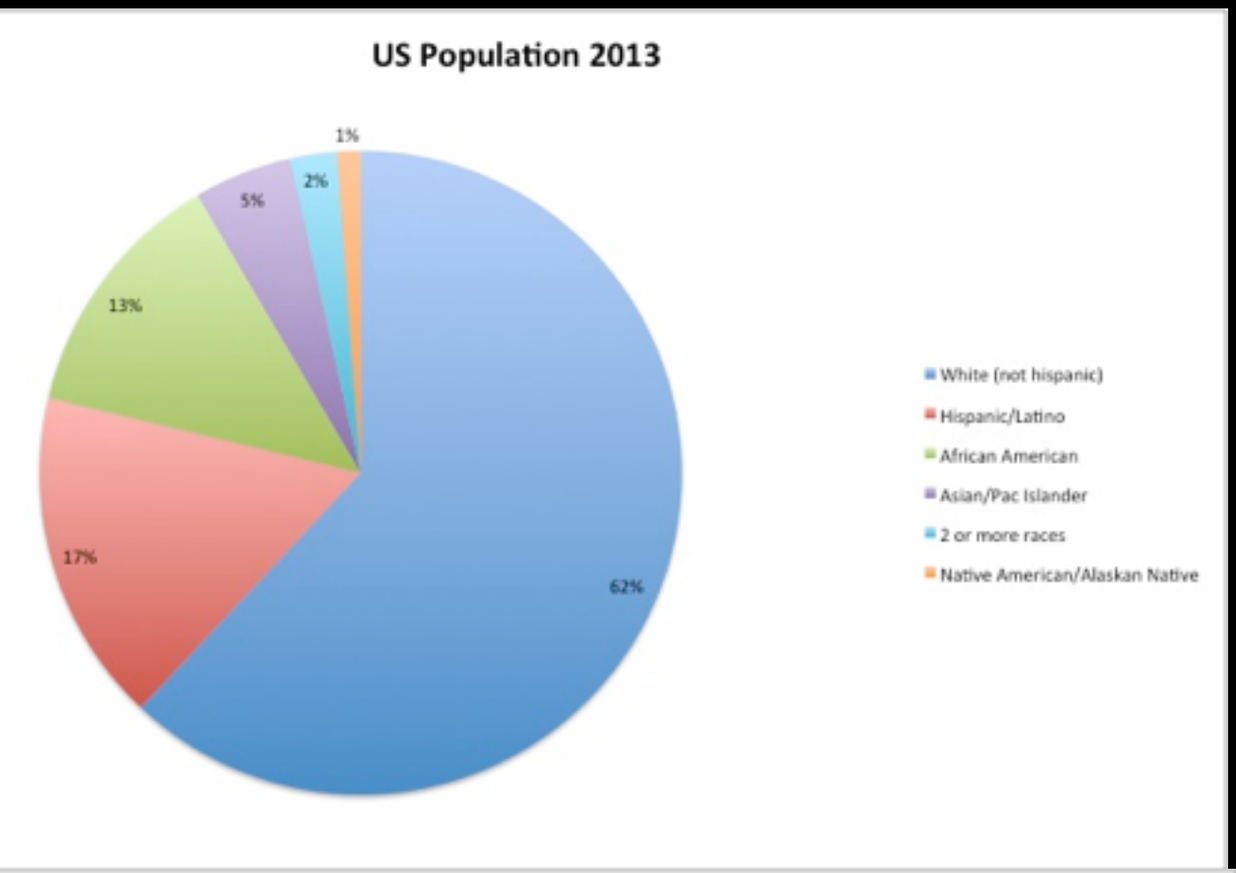



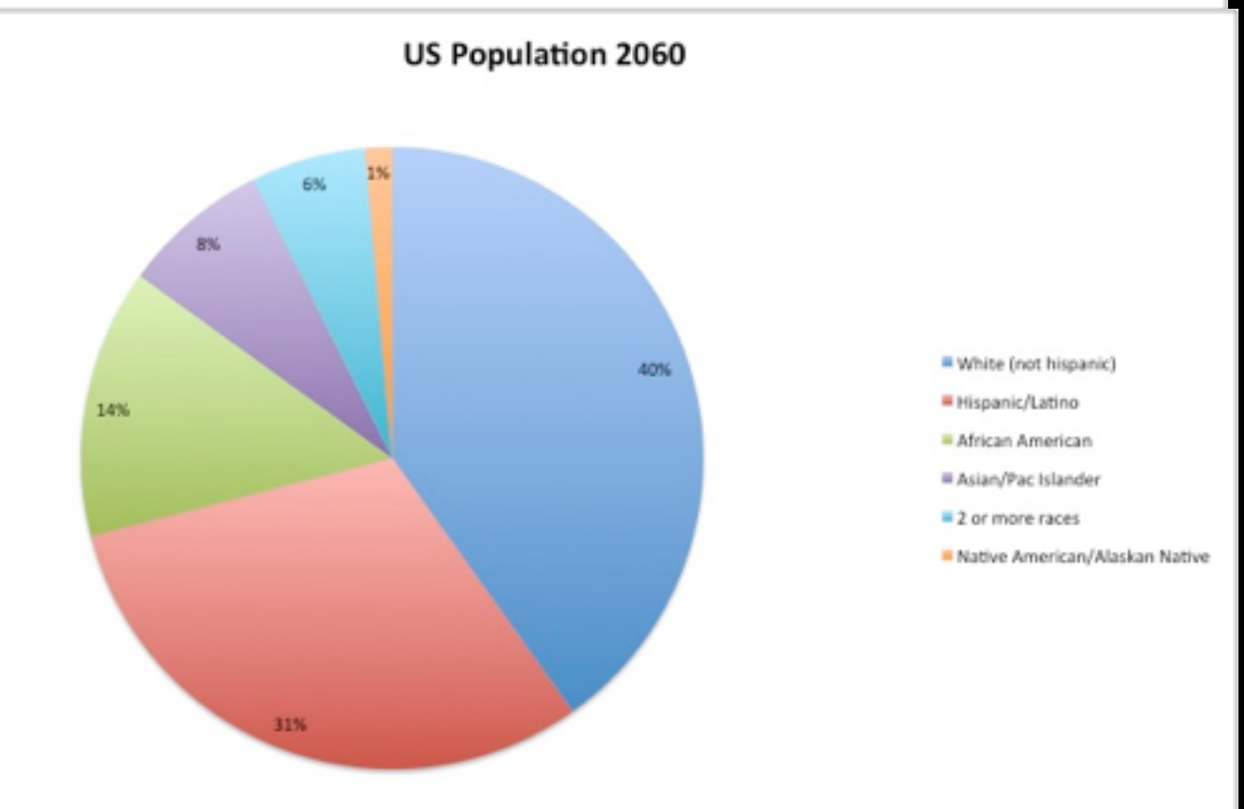

Faster Computers
=
more (fake) data

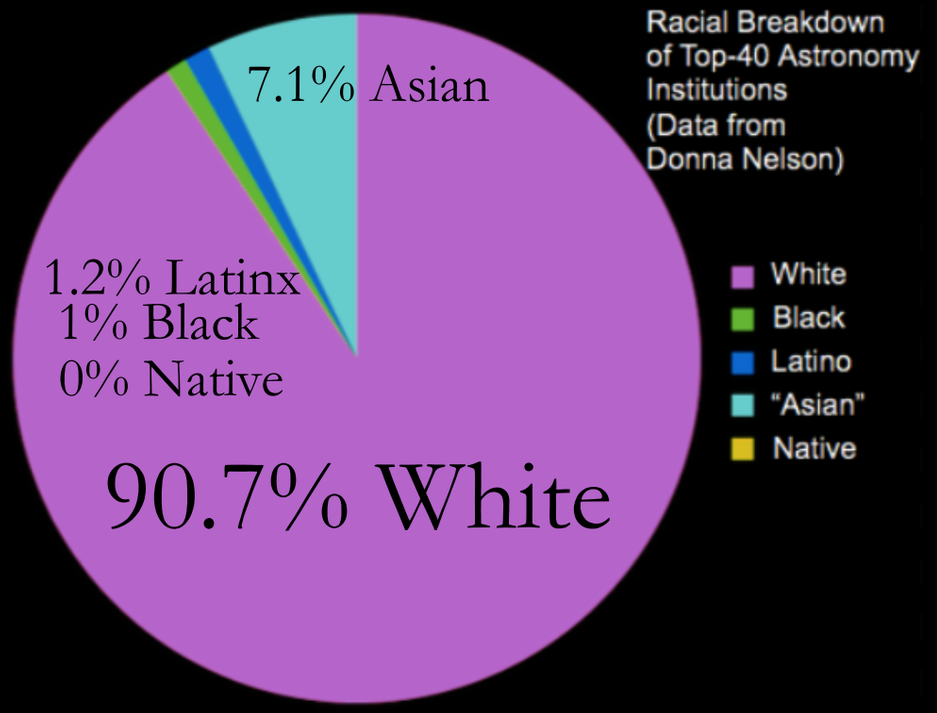
Scientific brain-drain

Other access issues:
socioeconomic status, gender, etc

# Some Structural Problems Facing Astronomy



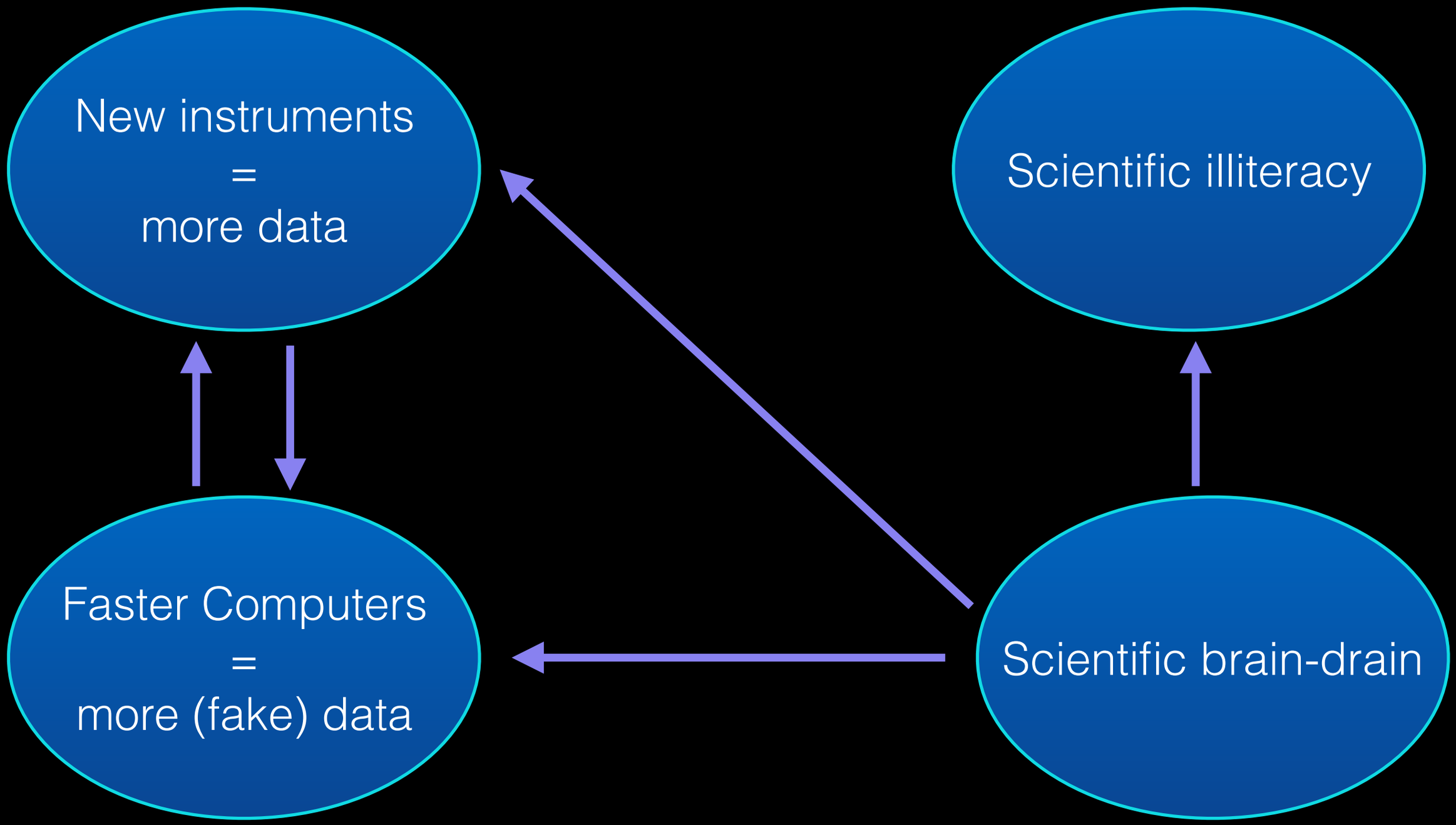



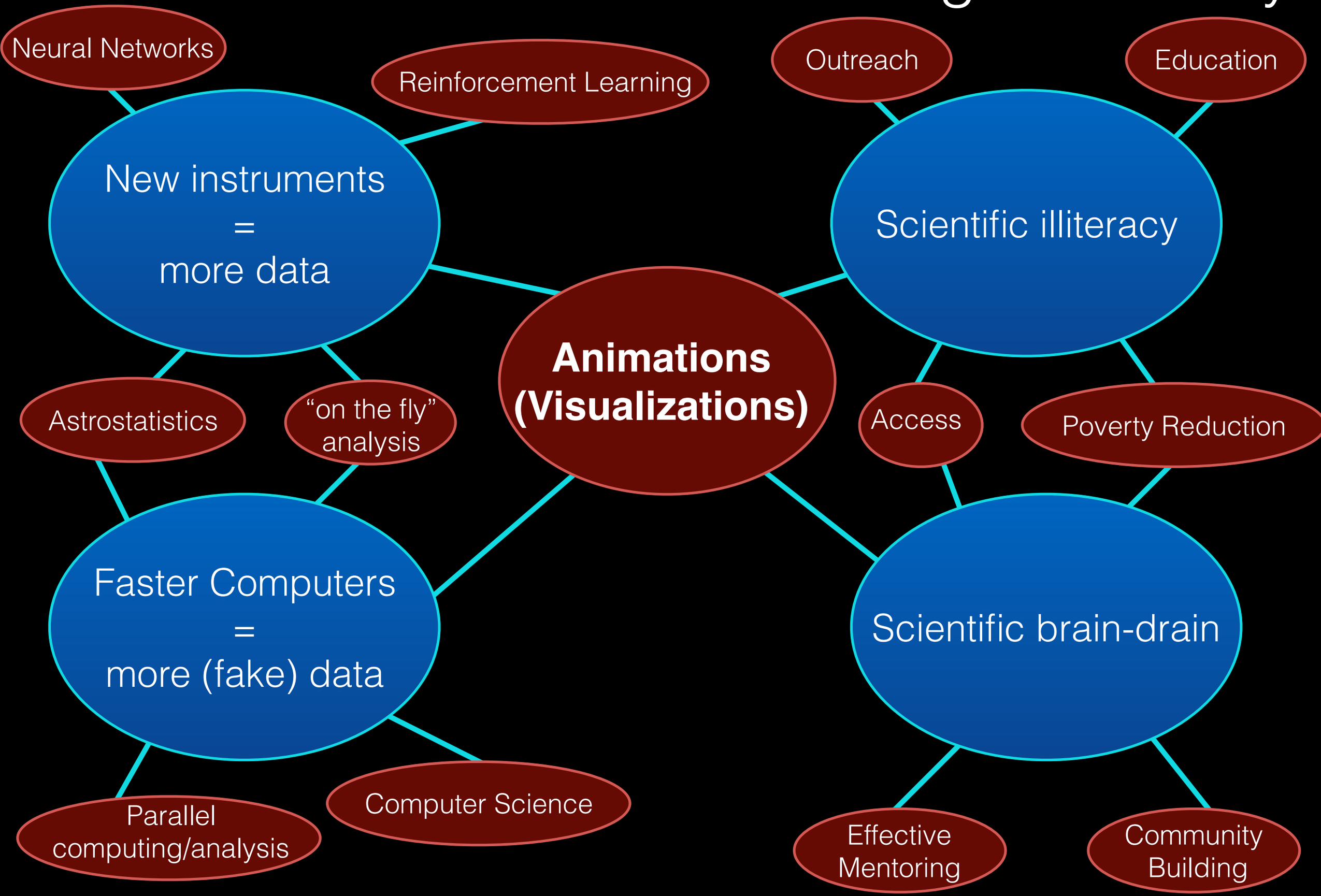

Scientific brain-drain

How can we tap into the greater pool of great scientific minds?

# Some Structural Problems Facing Astronomy



# Some Structural Problems Facing Astronomy



# Some Structural Problems Facing Astronomy

Neural Networks

Reinforcement Learning

Outreach

Education

New instruments
=
more data

Scientific illiteracy

**Animations (Visualizations)**

Astrostatistics

"on the fly" analysis

Access

Poverty Reduction

Faster Computers
=
more (fake) data

Scientific brain-drain

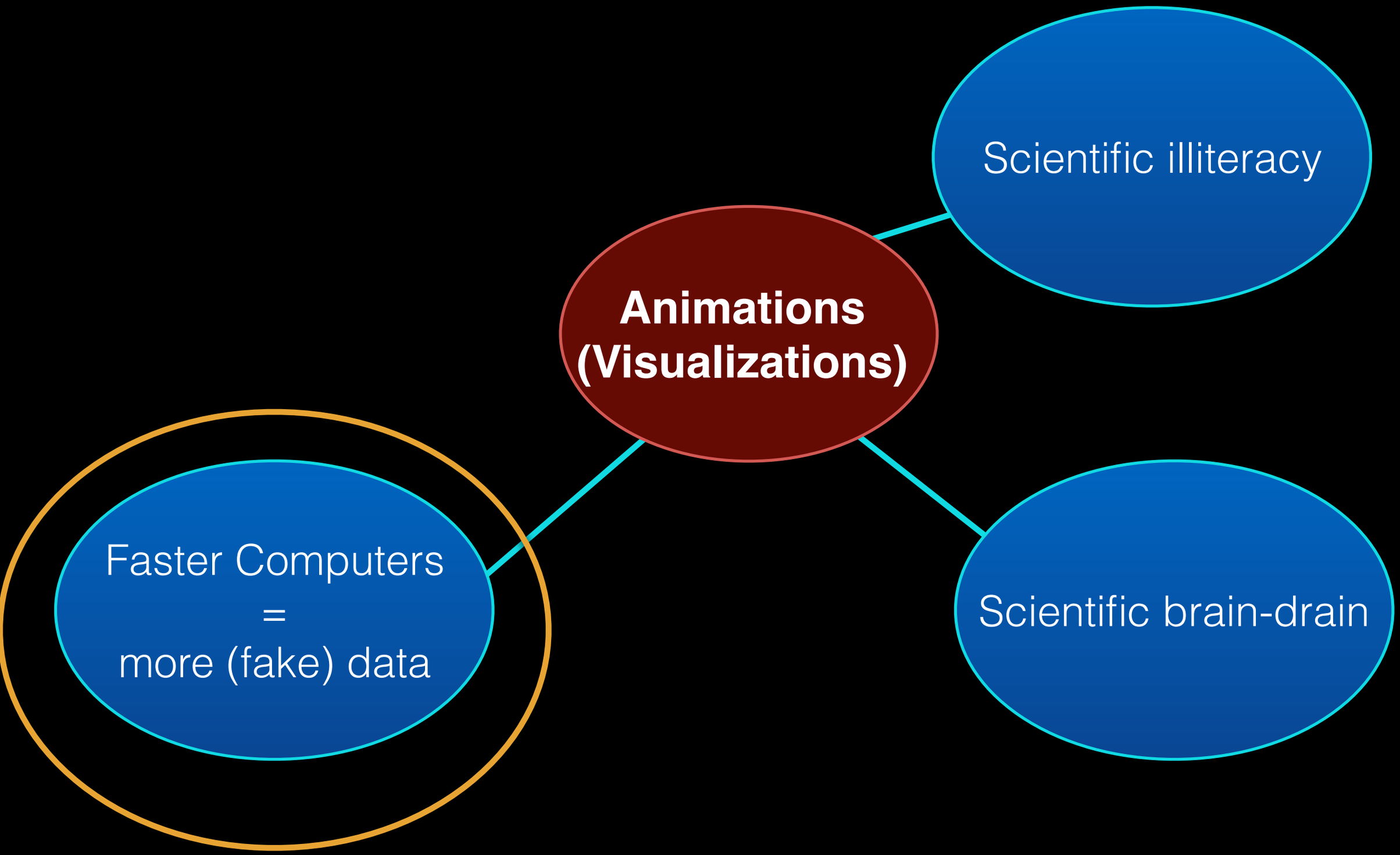
Parallel computing/analysis

Computer Science

Effective Mentoring

Community Building

# Some Structural Problems Facing Astronomy

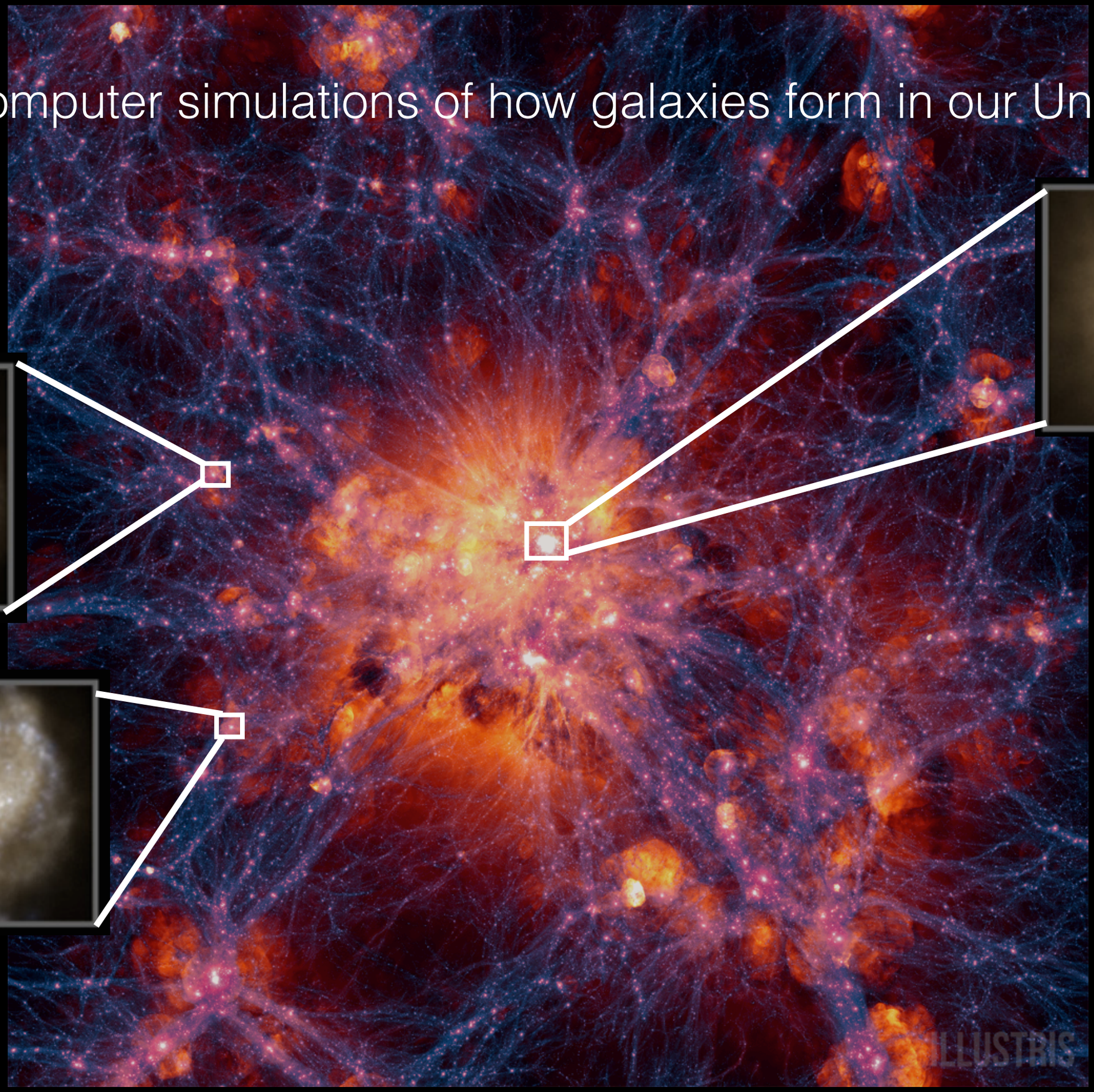


# What I Do*

* NOT made with Blender/Houdini… yet

# What I Do

- Super computer simulations of how galaxies form in our Universe



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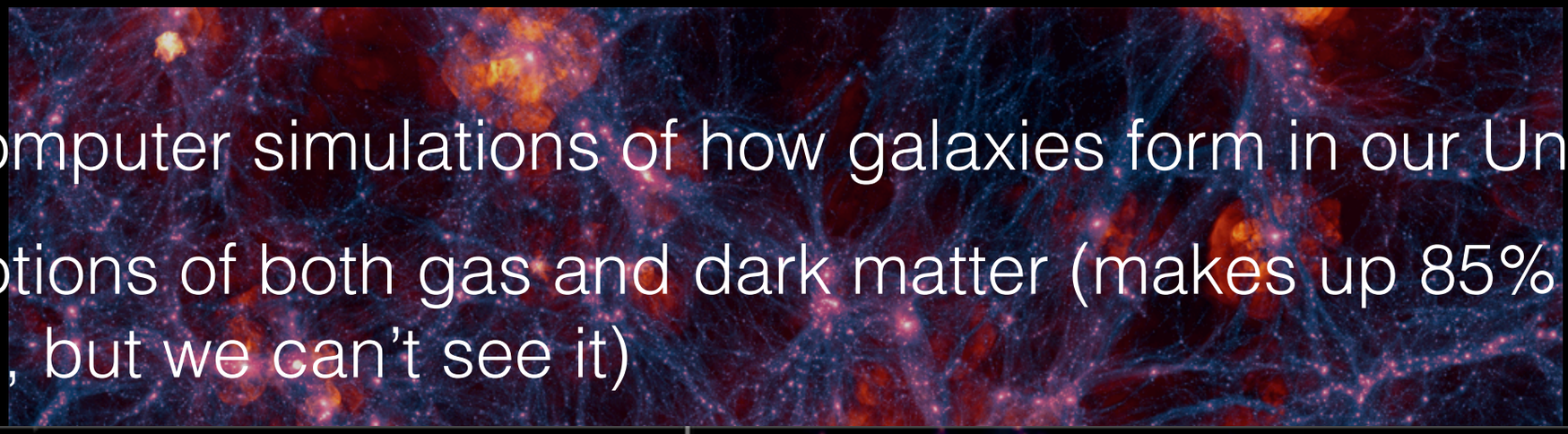
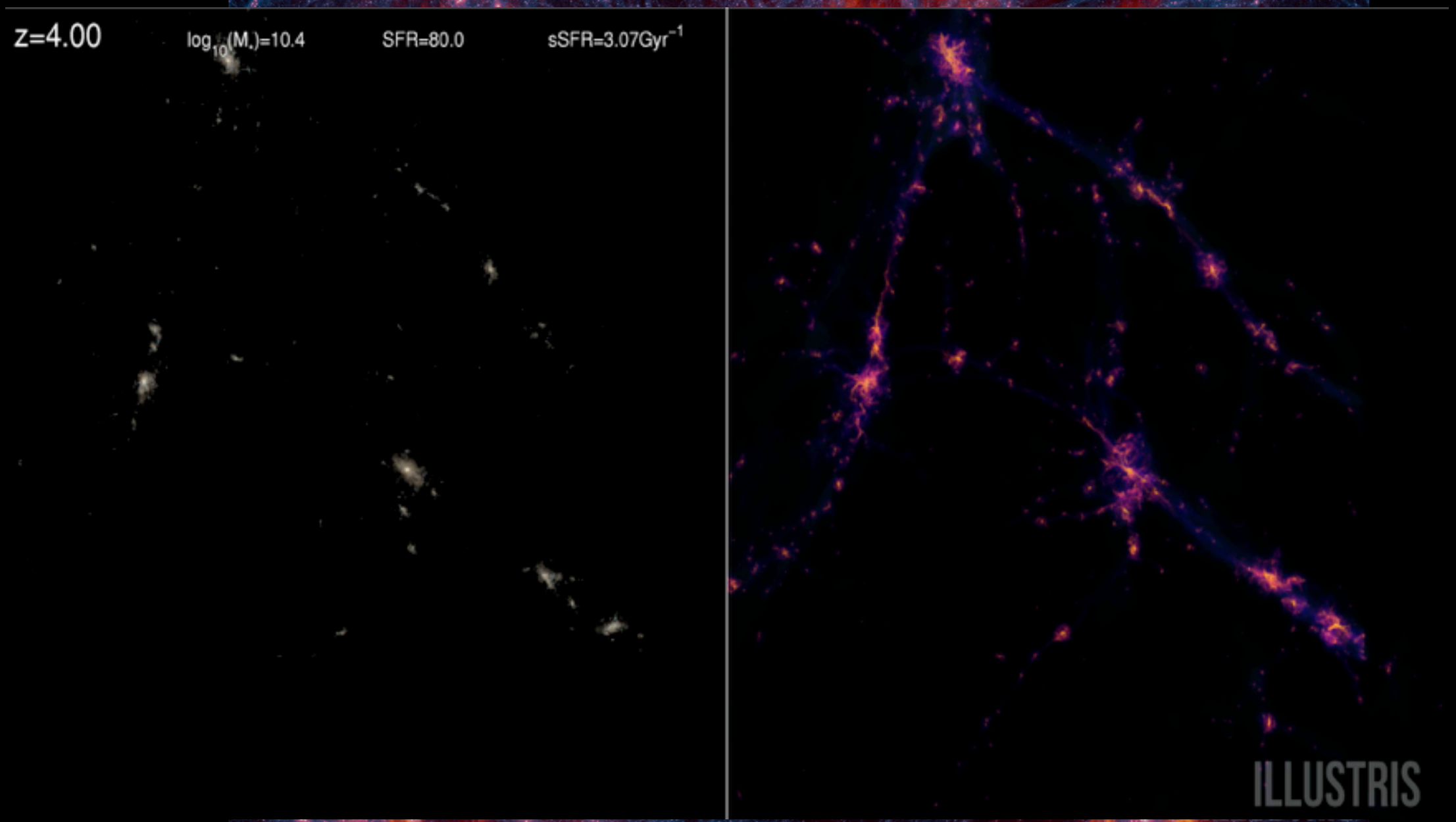


- Super computer simulations of how galaxies form in our Universe
- Track motions of both gas and dark matter (makes up 85% of the Universe, but we can't see it)



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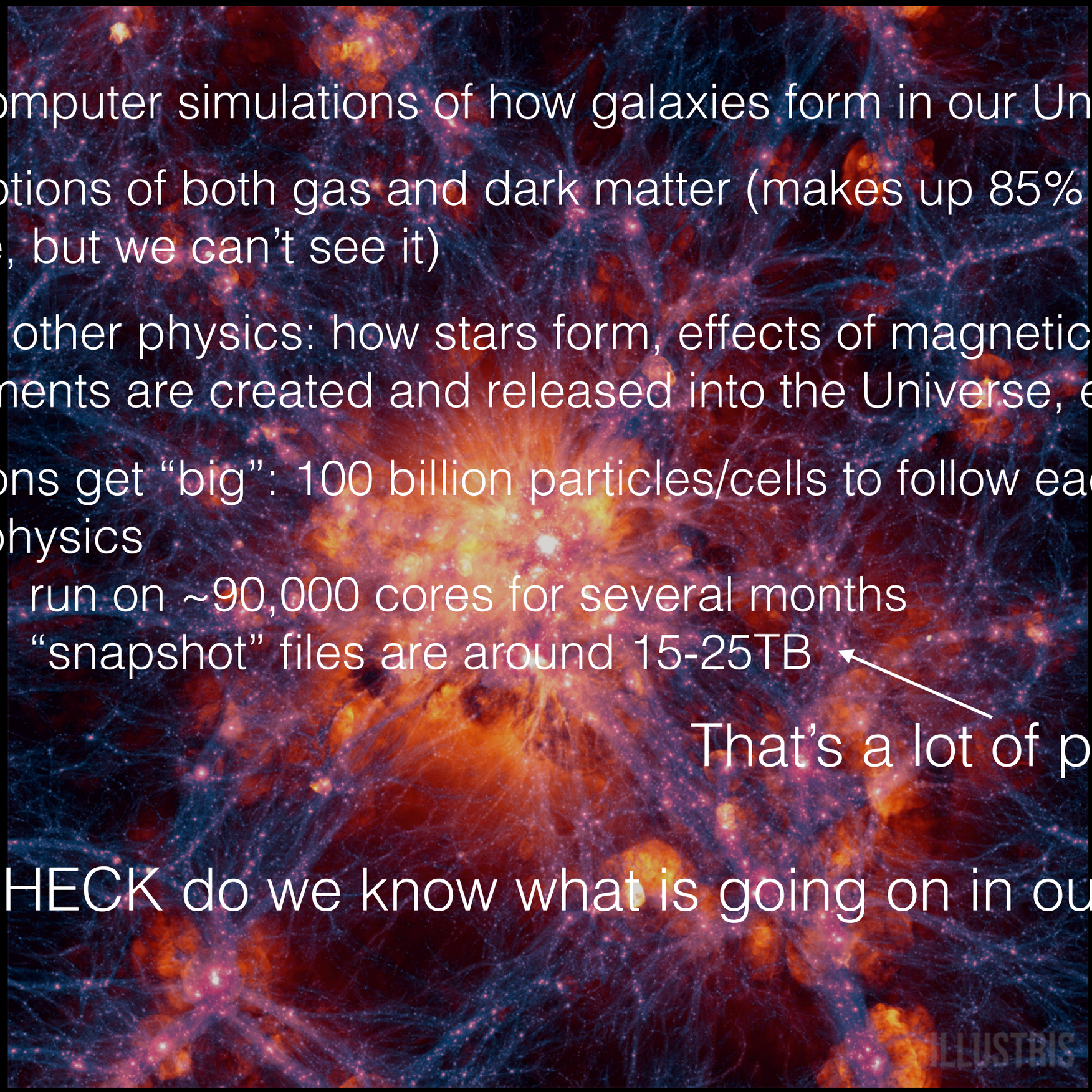
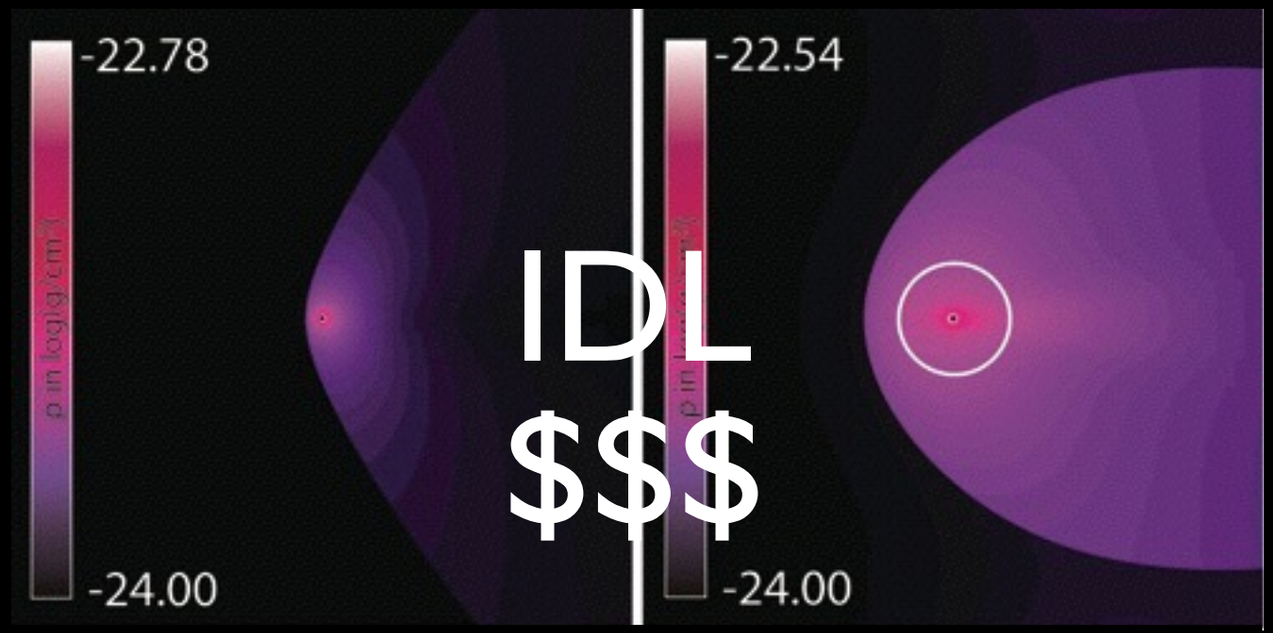


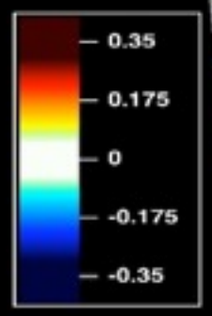

- Super computer simulations of how galaxies form in our Universe
- Track motions of both gas and dark matter (makes up 85% of the Universe, but we can't see it)
- Includes other physics: how stars form, effects of magnetic fields, how elements are created and released into the Universe, etc
- Simulations get "big": 100 billion particles/cells to follow each with its own physics
  - run on ~90,000 cores for several months
  - "snapshot" files are around 15-25TB

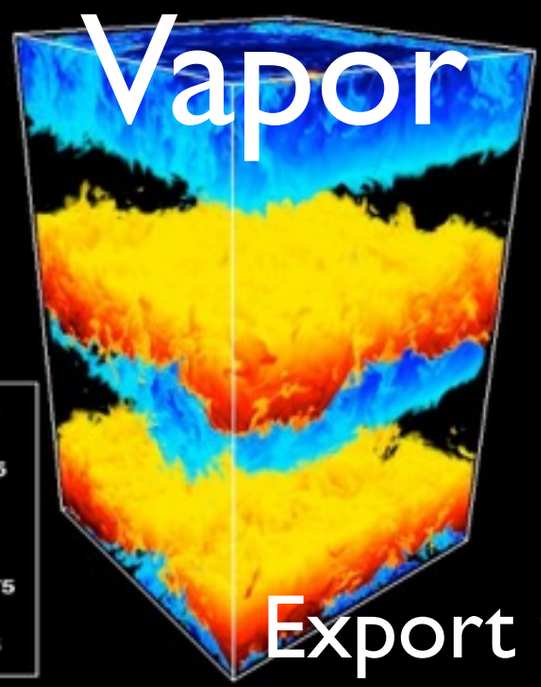
That's a lot of polygons!

How the HECK do we know what is going on in our data?

# Other Scientific Animation Codes:

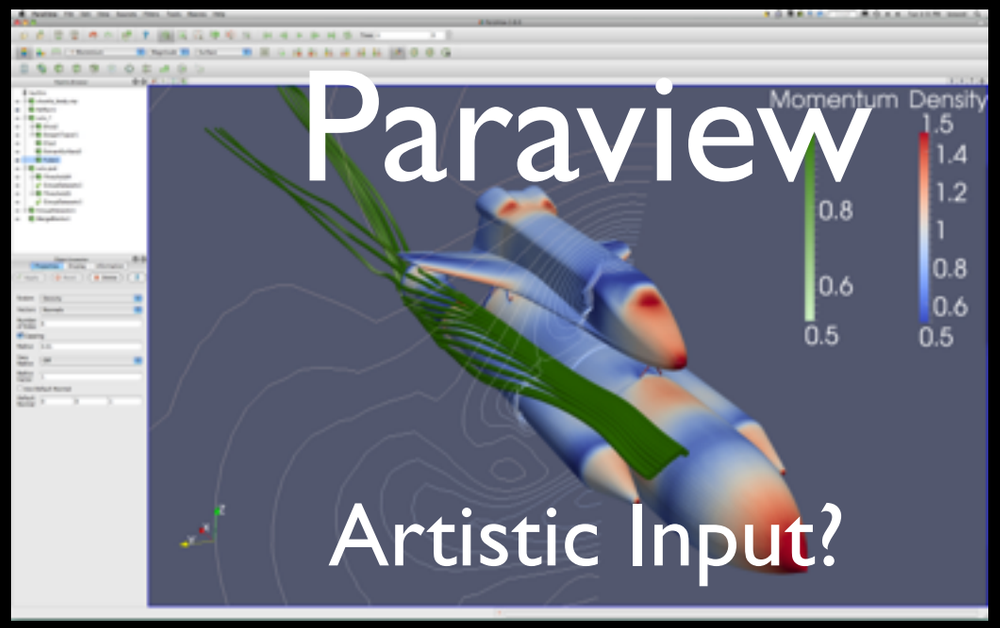


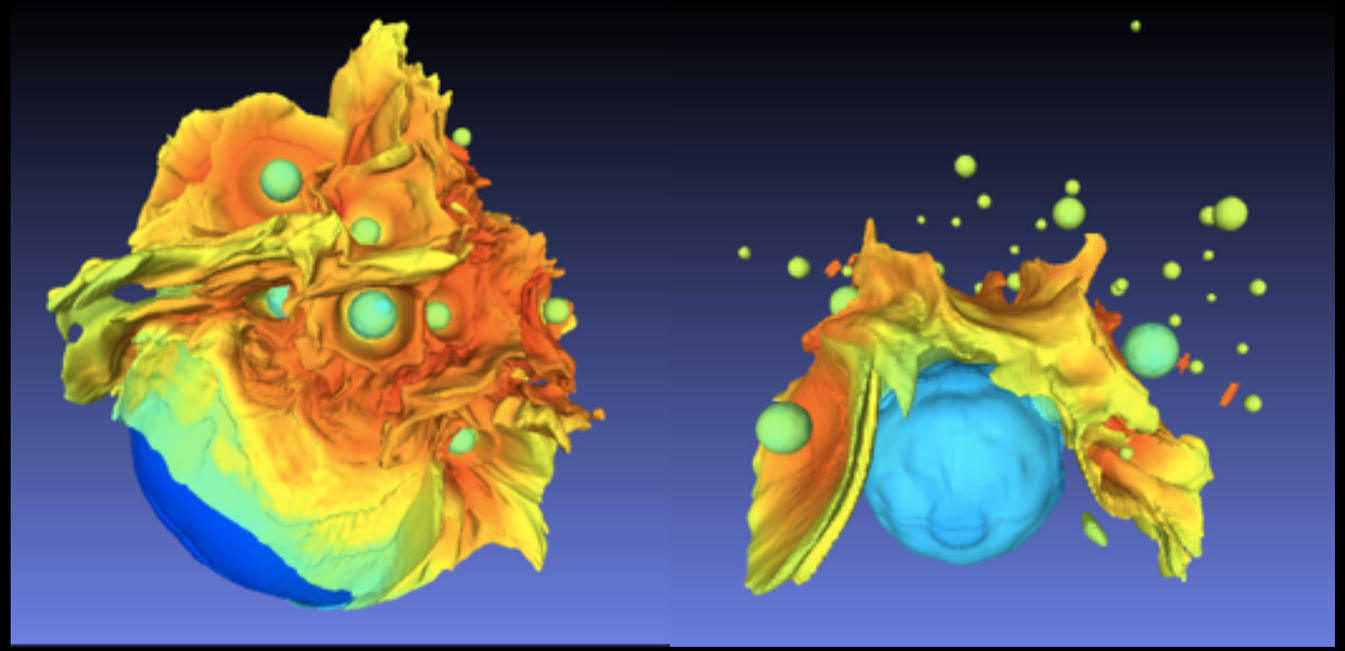




## VisIt

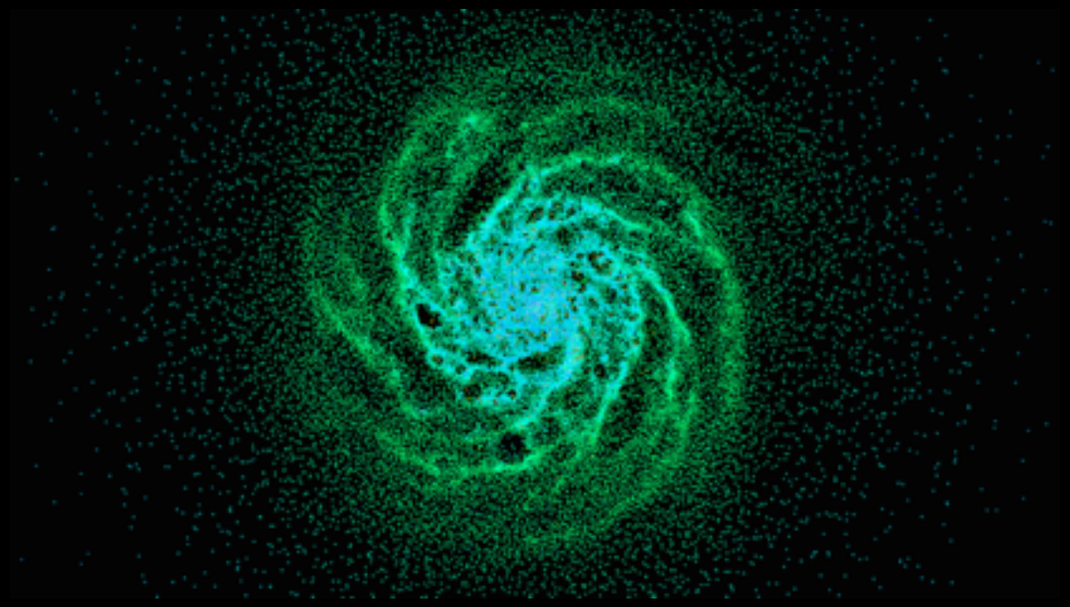
User interface?



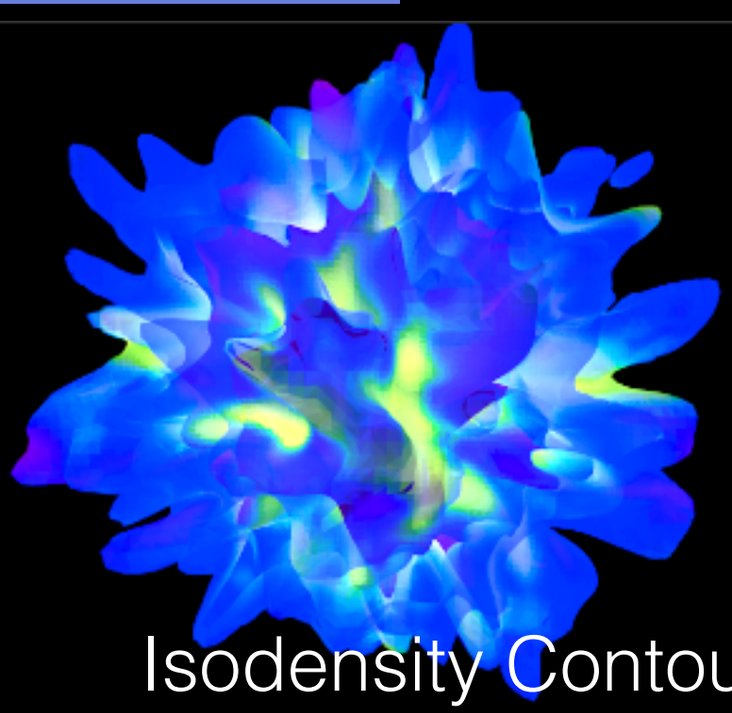
# AstroBlend: An Astrophysical Animation Tool



Isodensity Contours colored by temperature



Galaxy particle simulation (colors = temperature)

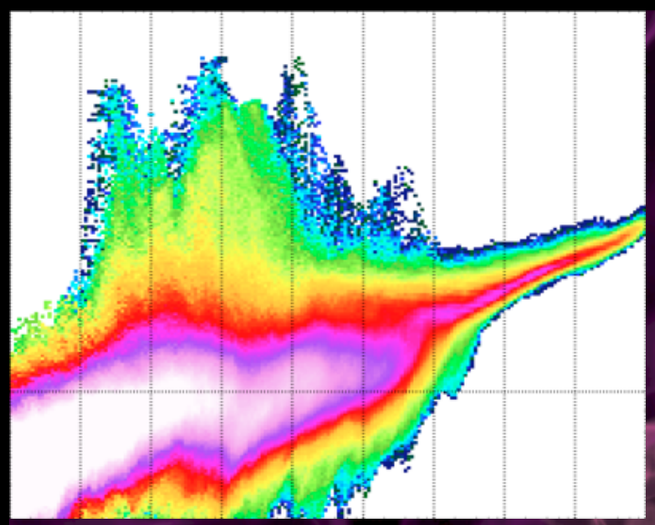


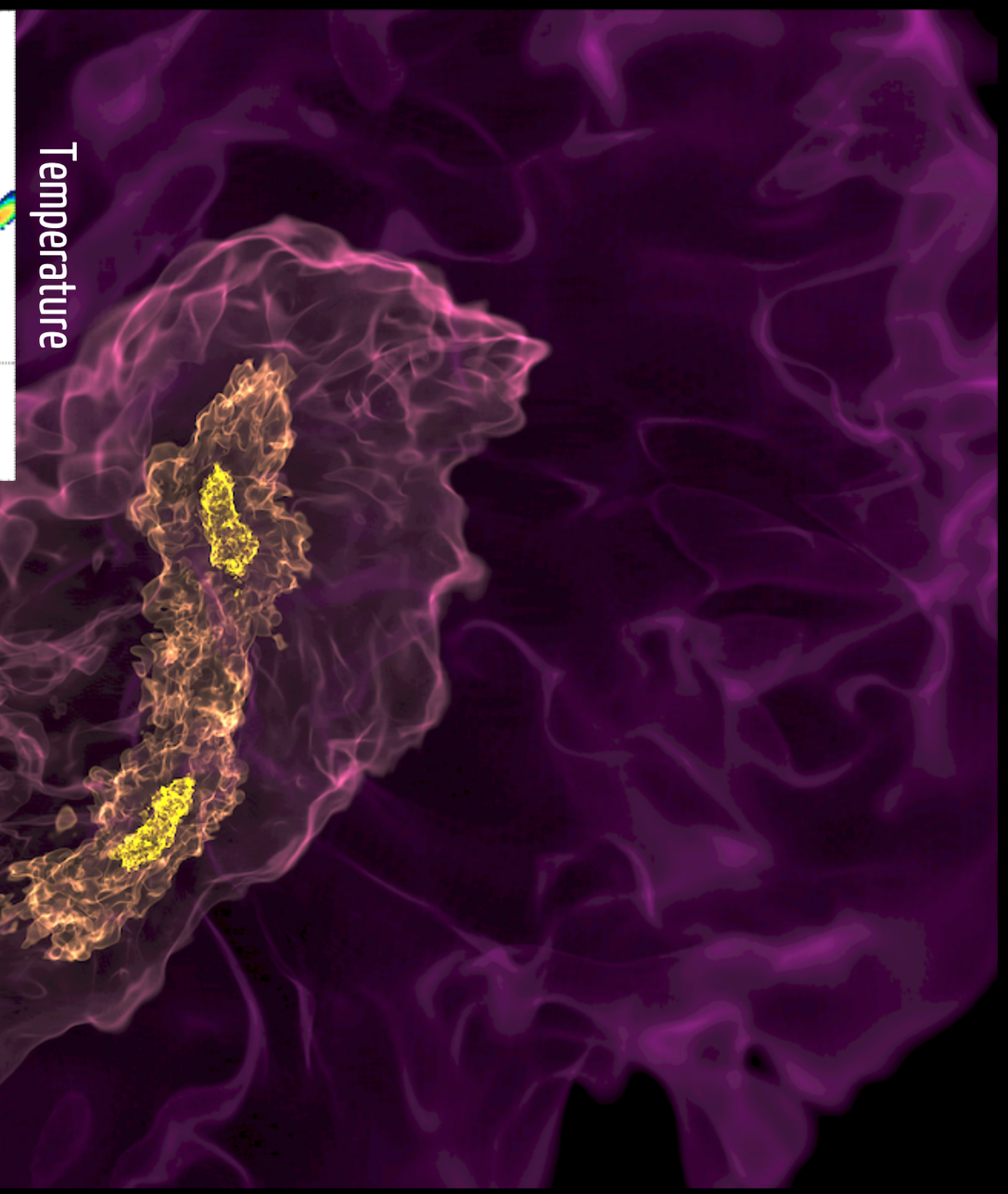
Isodensity Contours colored by temperature, glowing based on physics

# AstroBlend: As A Frontend to YT

From the yt website:

"yt is a python package for analyzing and visualizing volumetric, multi-resolution data from astrophysical simulations, radio telescopes, and a burgeoning interdisciplinary community."



Turk et al 2009

Simulation gas collapsing and forming two dense cores that will become some of the first stars in our Universe.

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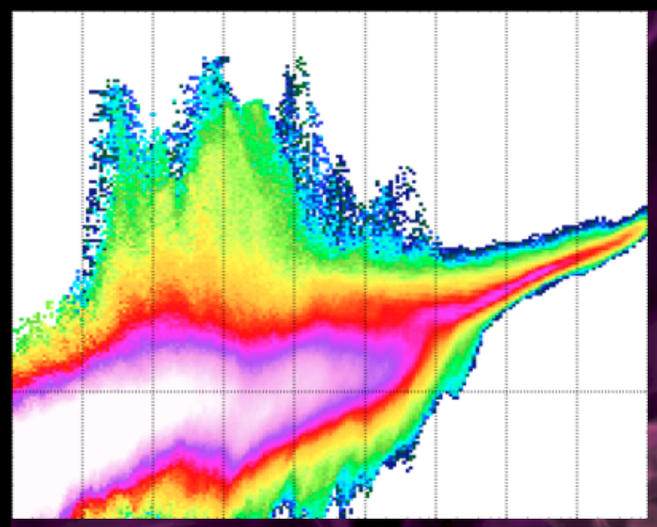


Turk et al 2009

Used for both analysis and visualization

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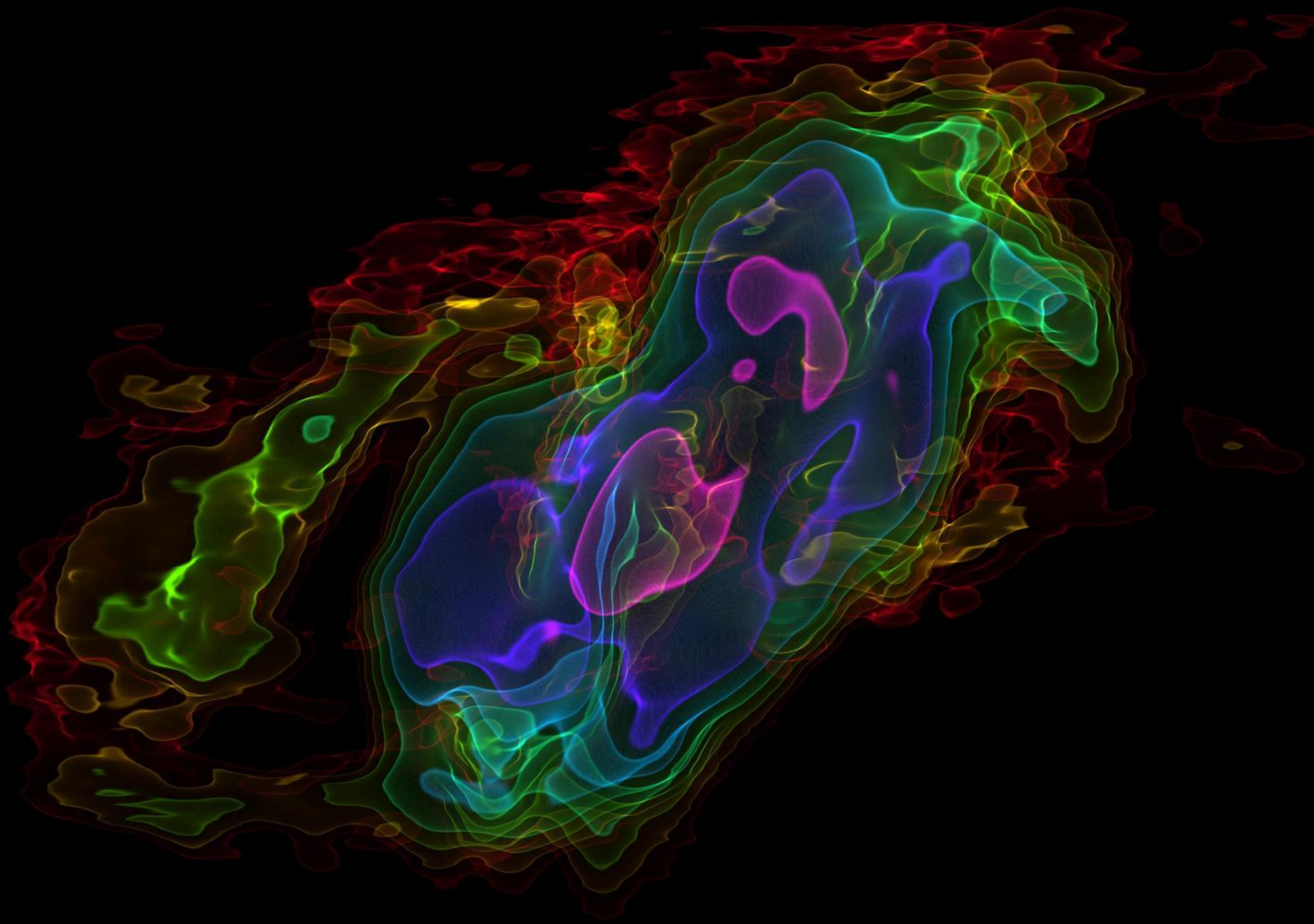

Image Credit: Erik Rosolowsky & ALMA

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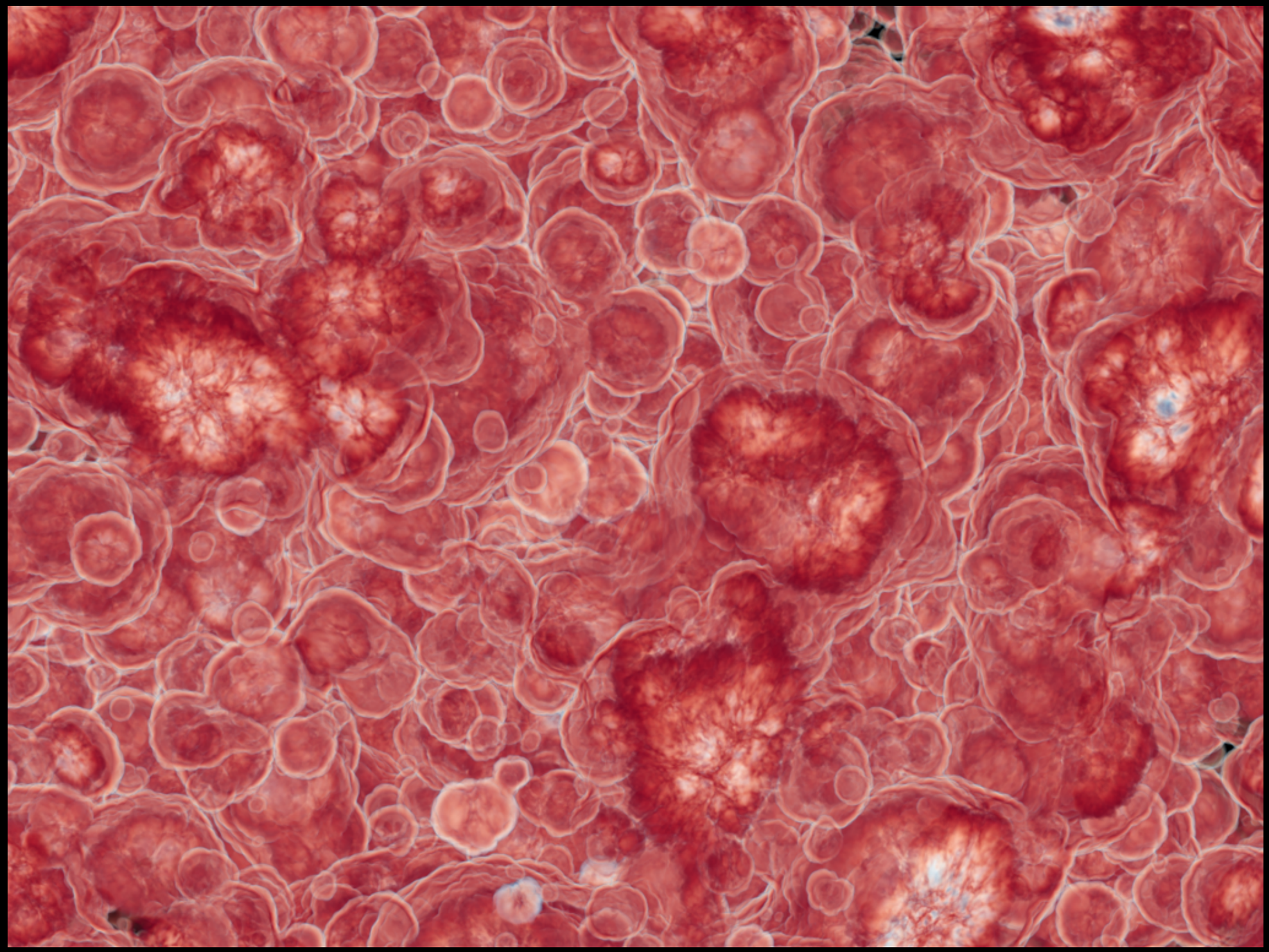
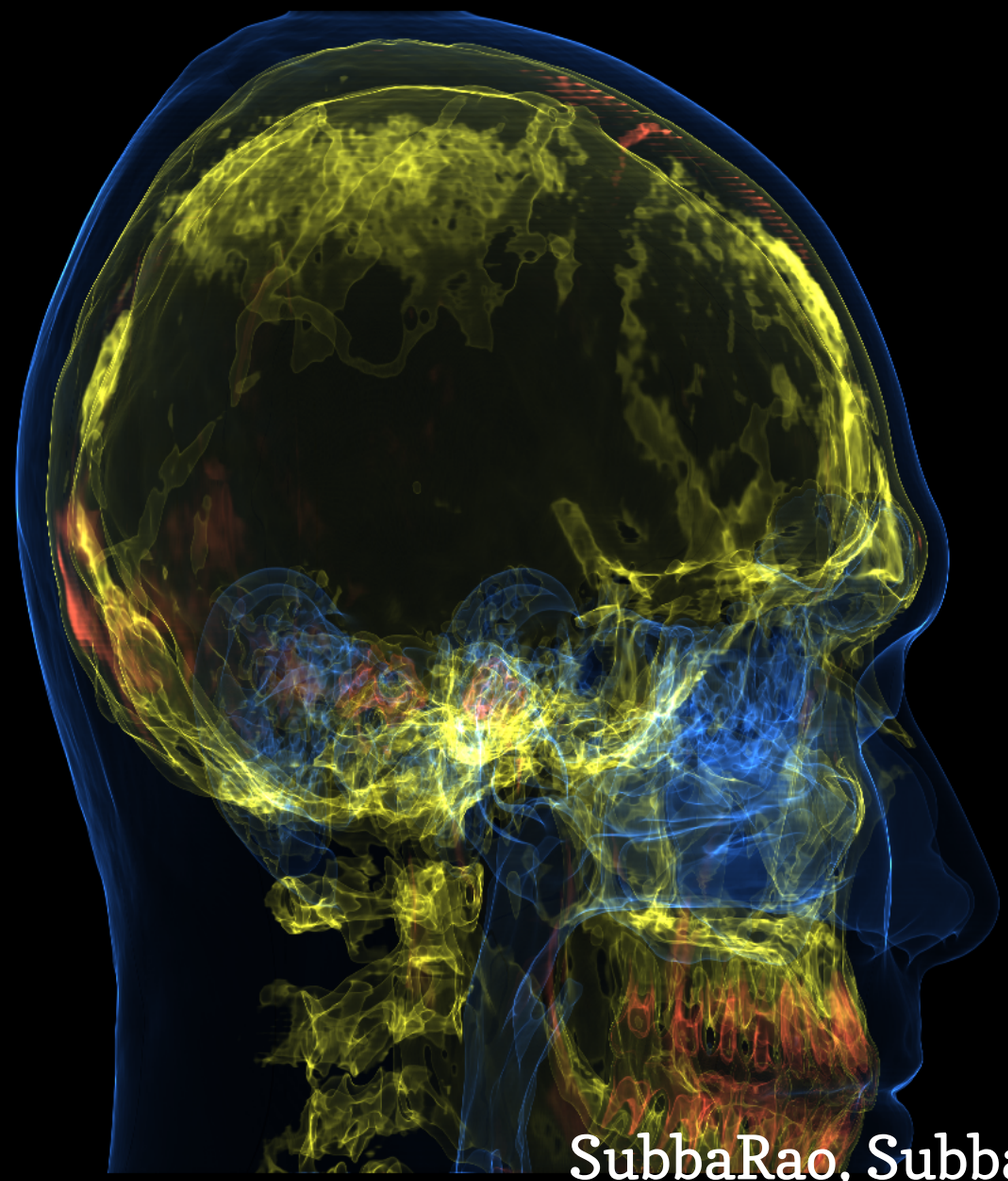


# AstroBlend: As A Frontend to YT

NeuroDome



SubbaRao, SubbaRao & Fisher

# AstroBlend: As A Frontend to YT

## Pretty pictures but… what about 3D interactions with the data?

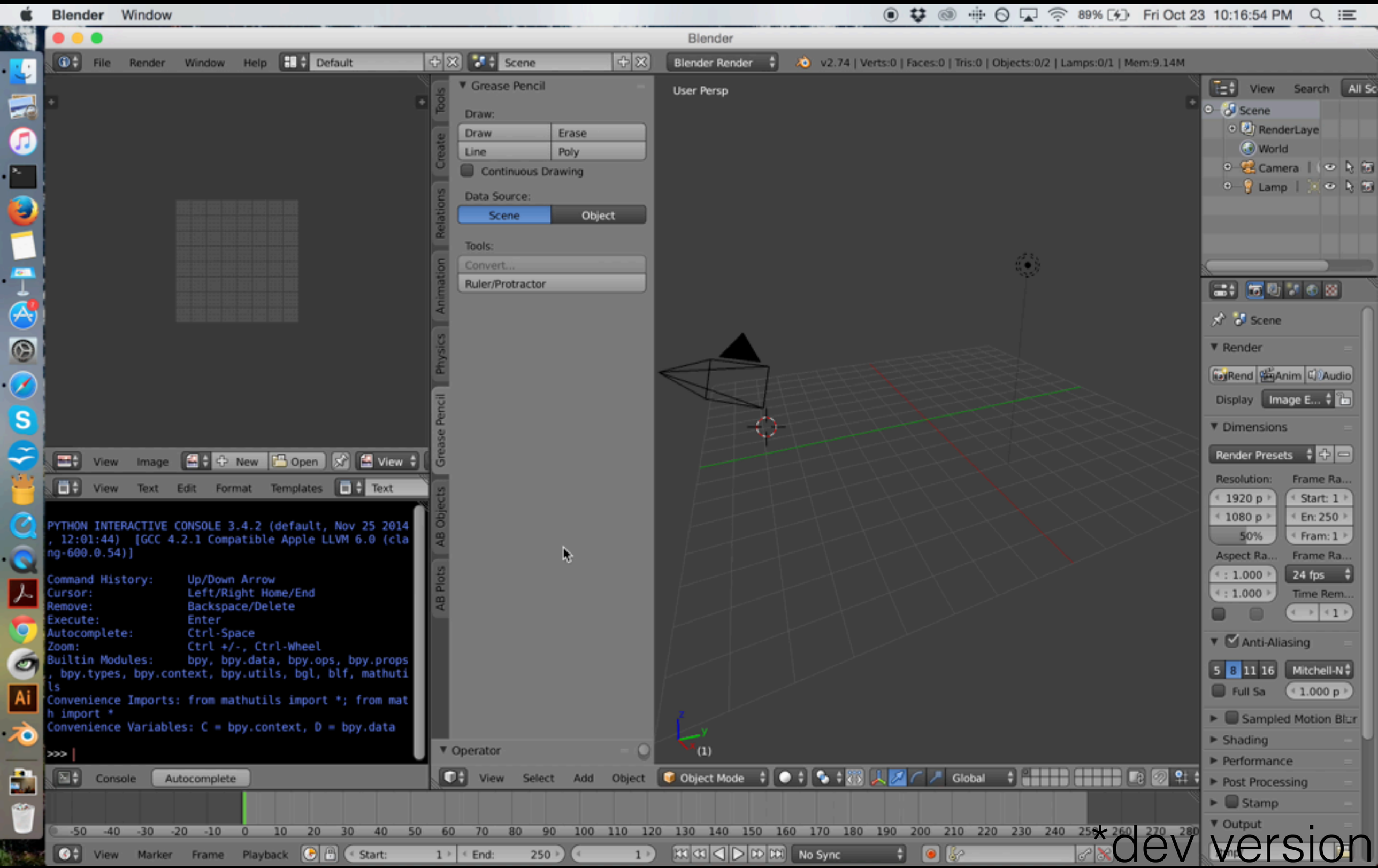
Image Viewer

One of Blender's Selection panels

3D Viewer

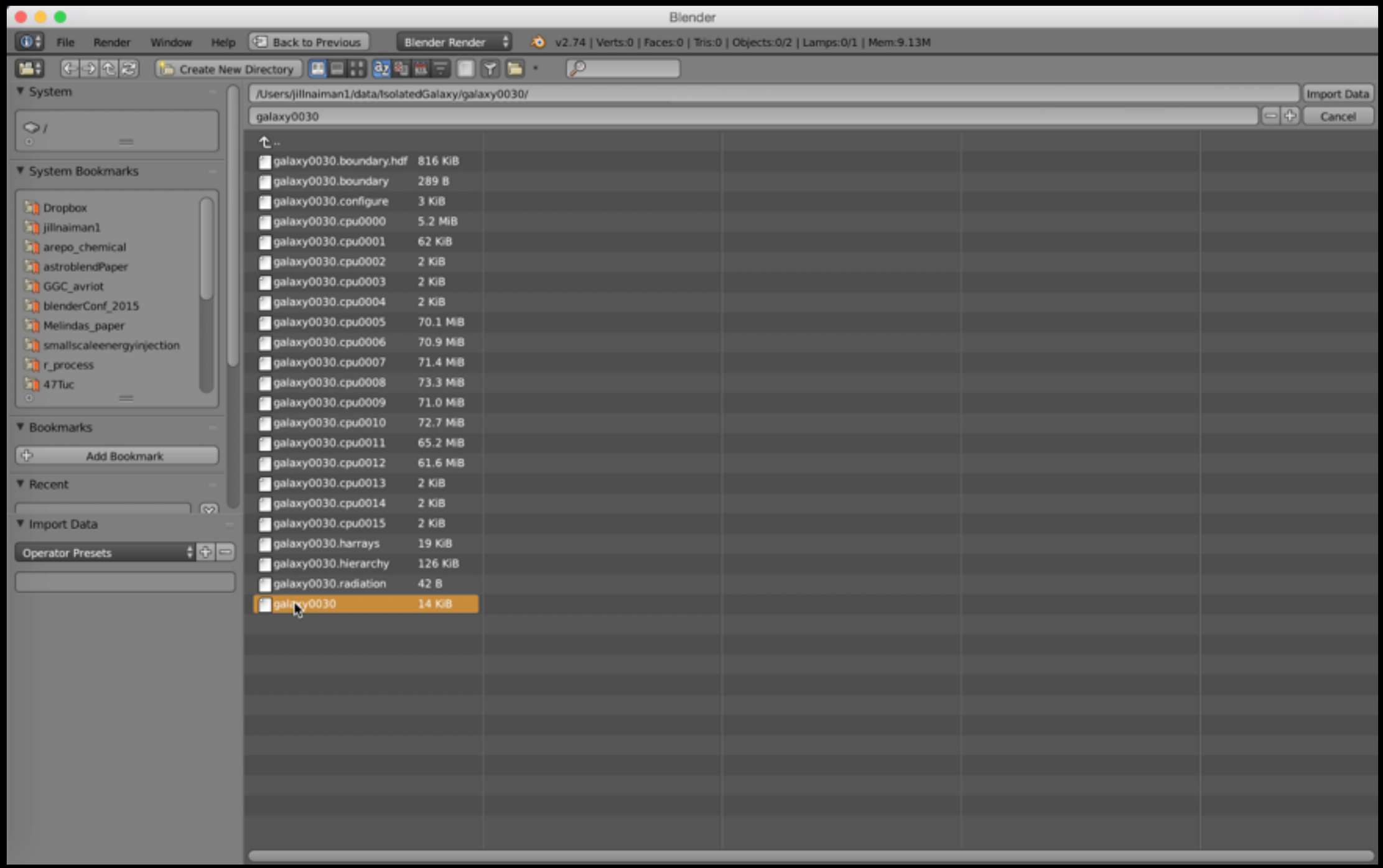
# AstroBlend: As A Frontend to YT

## Pretty pictures but… what about 3D interactions with the data?



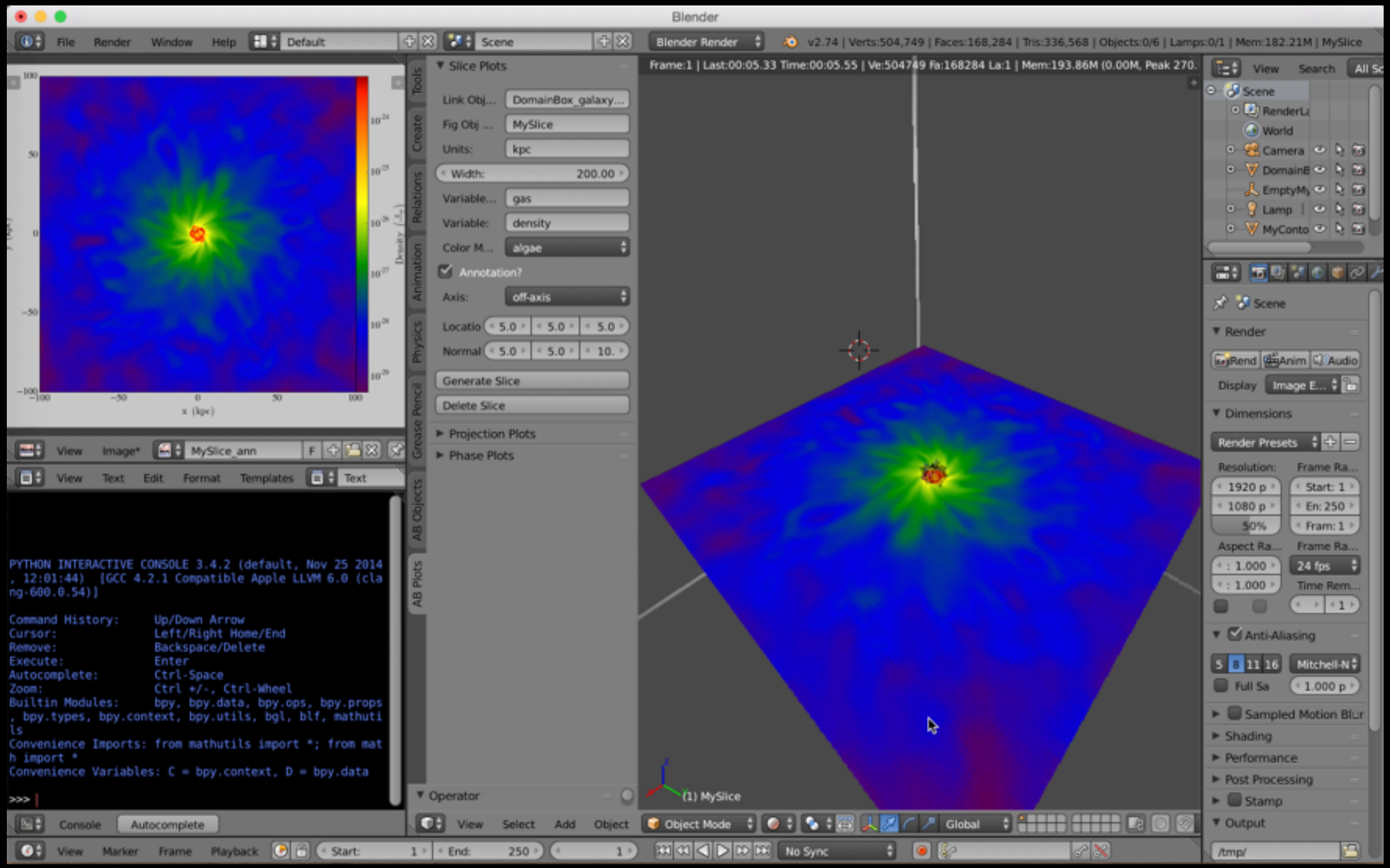

*dev version

# AstroBlend: As A Frontend to YT



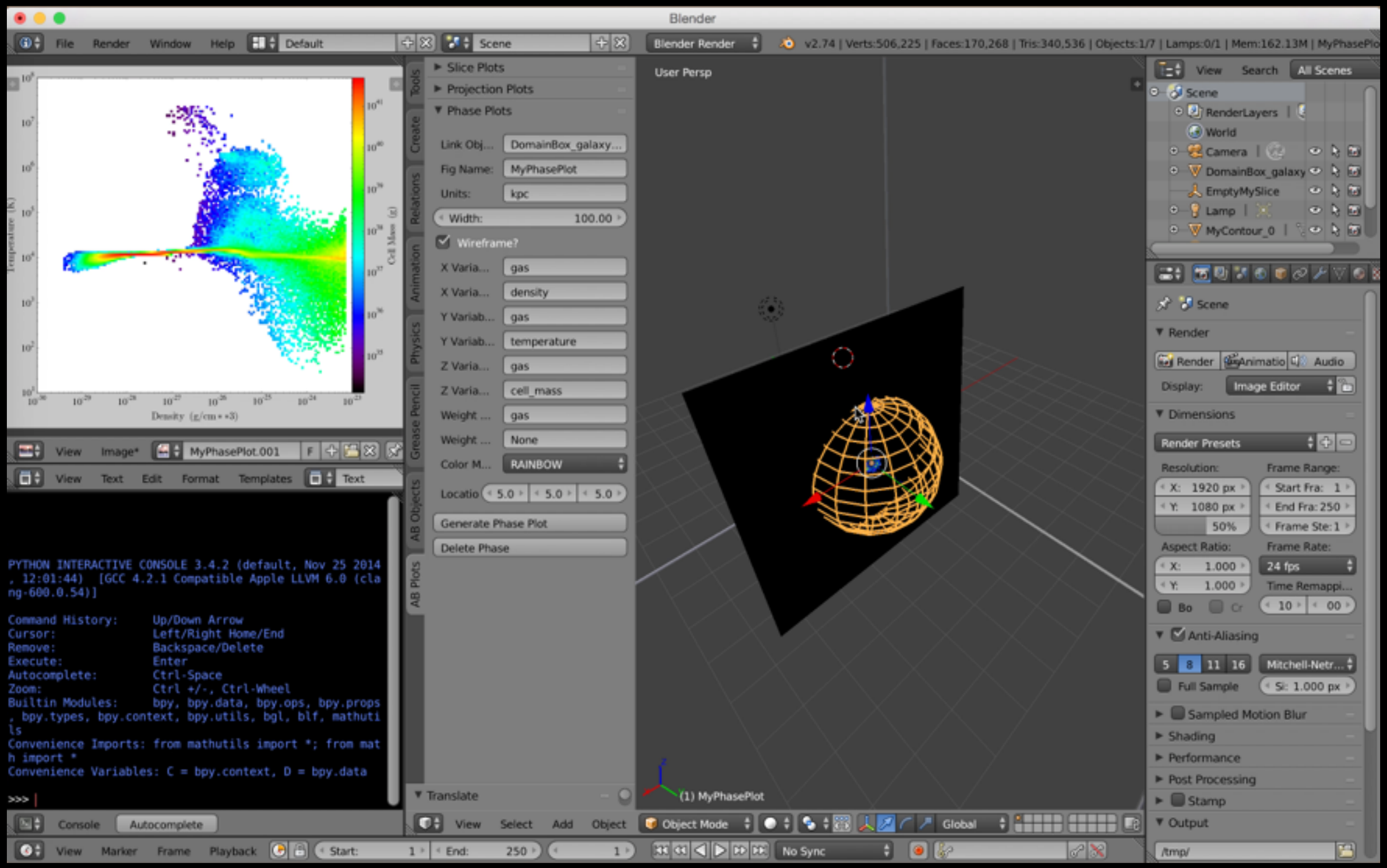

With this library Blender can now “read” astrophysical data

# AstroBlend: As A Frontend to YT



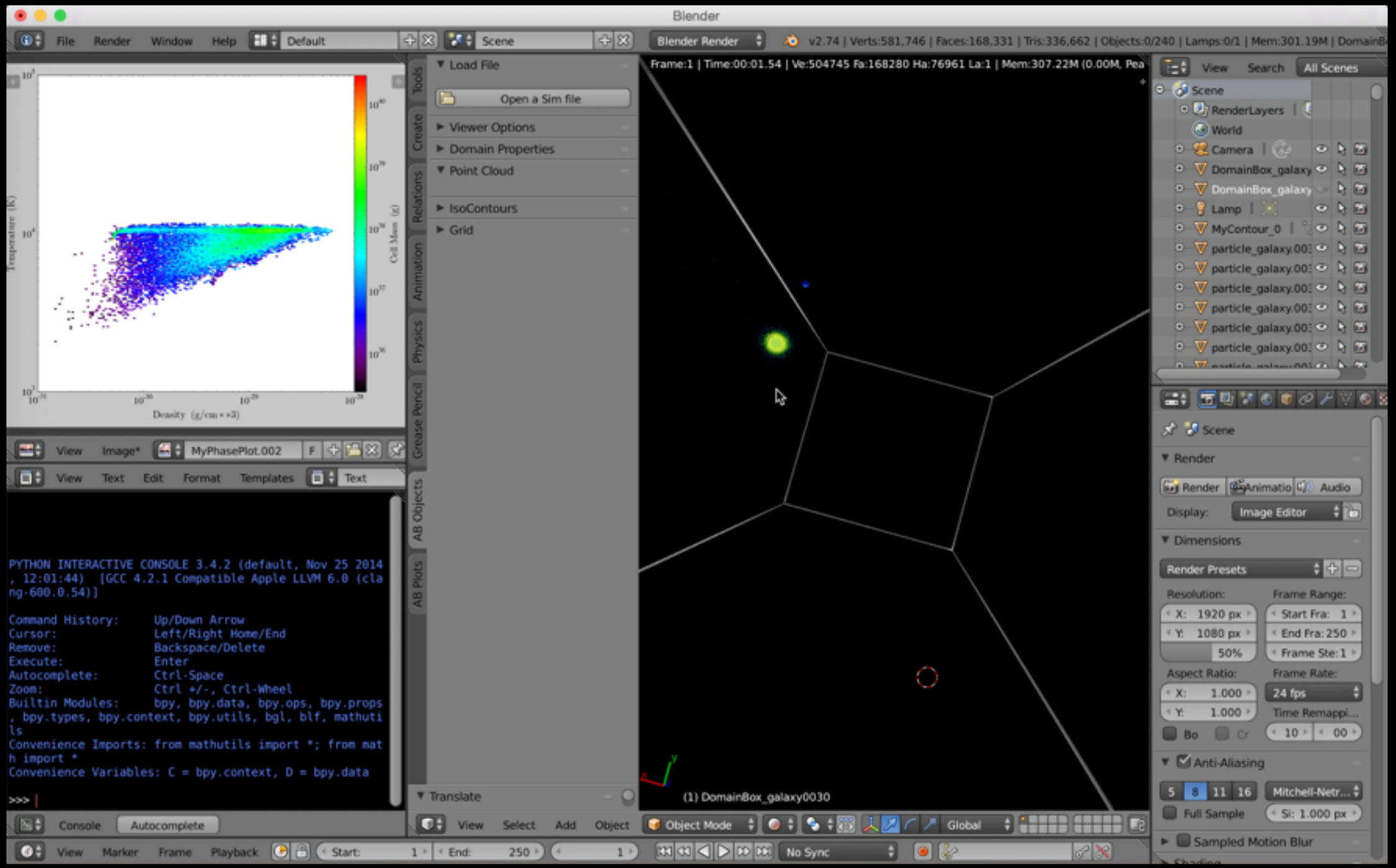

3D data objects and analysis plots are put in physical context with each other

# AstroBlend: As A Frontend to YT



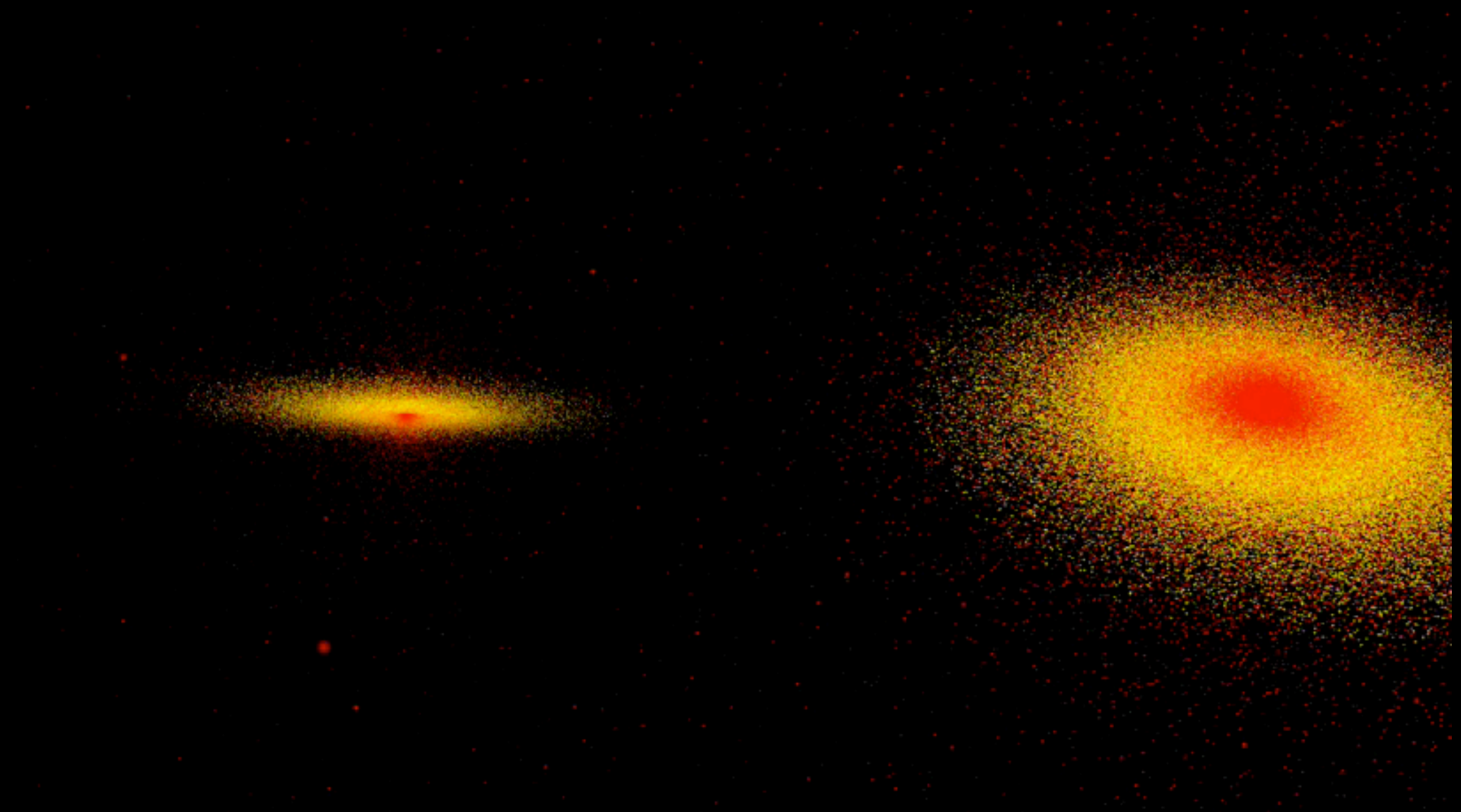

Analysis plots are made to be interactive

# AstroBlend: As A Frontend to YT




Can easily combine different data sets in physical space

# AstroBlend: Gratuitous Movies!



~4.6 billion particles

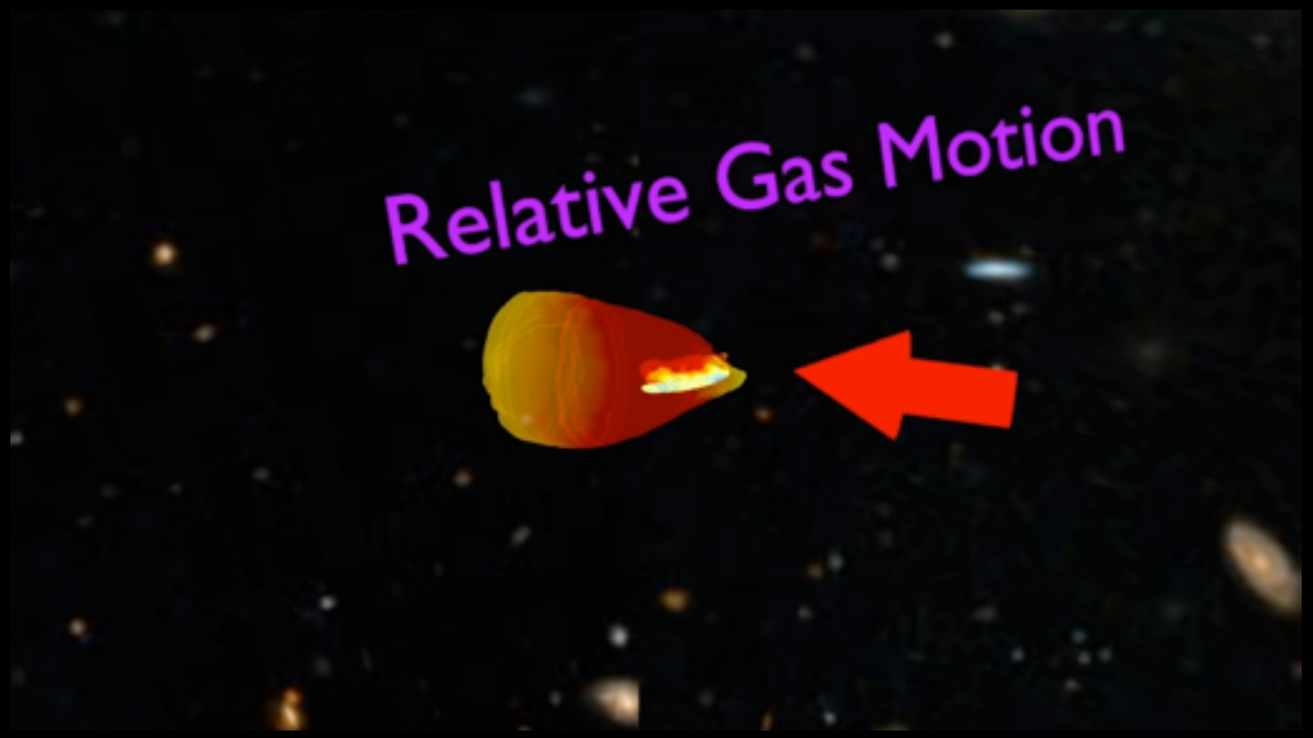
# AstroBlend: Gratuitous Movies!


Made (nearly) entirely with Python in Blender

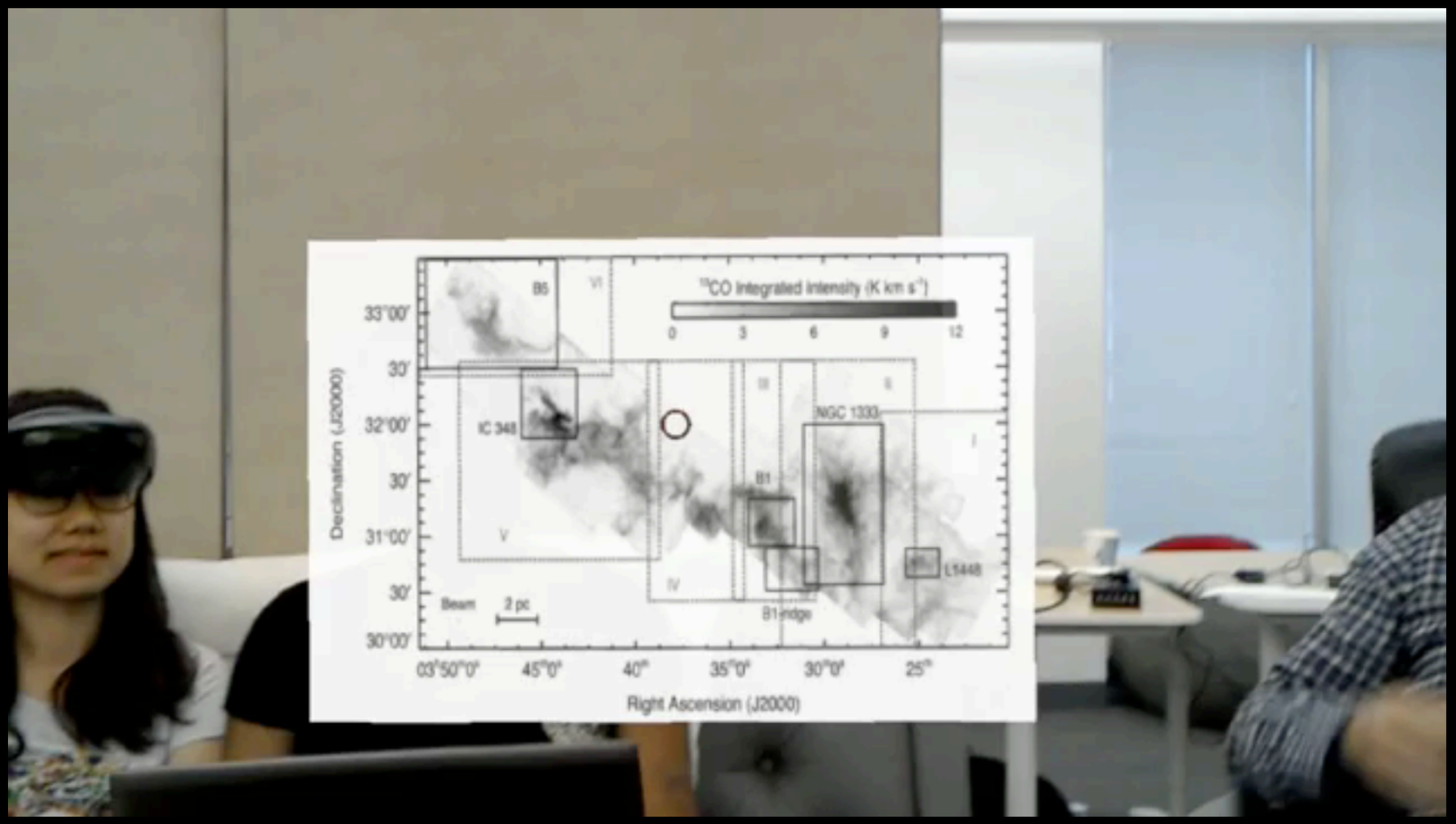
# AstroBlend: Gratuitous Movies!


Can combine artistic models with observed astrophysical data

Can place simulated data in context with observations and artistic models



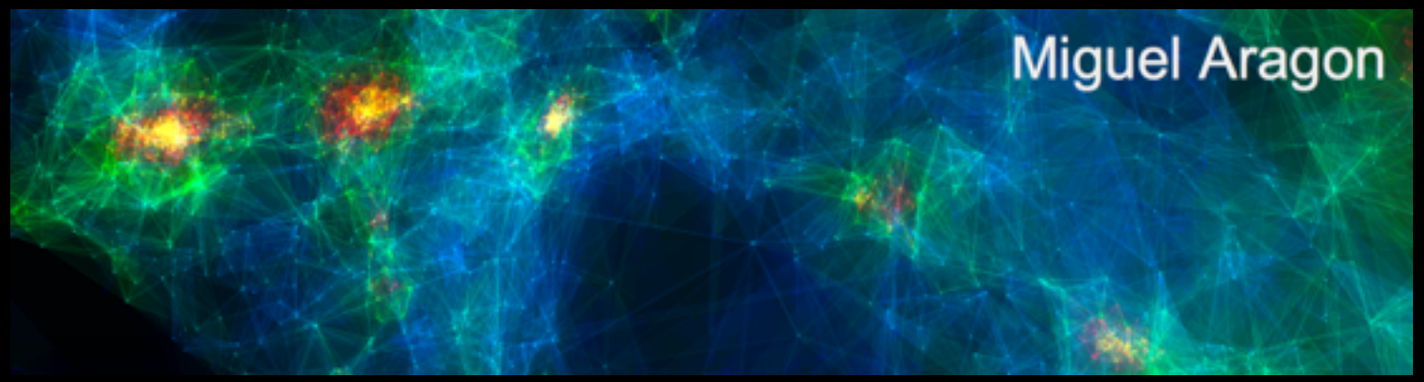
# The Future…




video from Glue team: http://www.glueviz.org/en/stable/

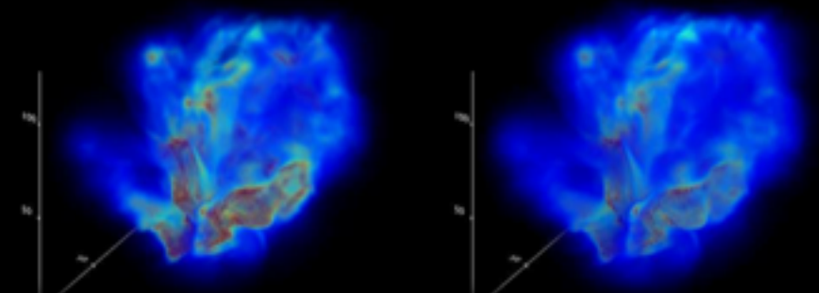
# The Future… bonus

# Other Astrophysicists working in Blender:



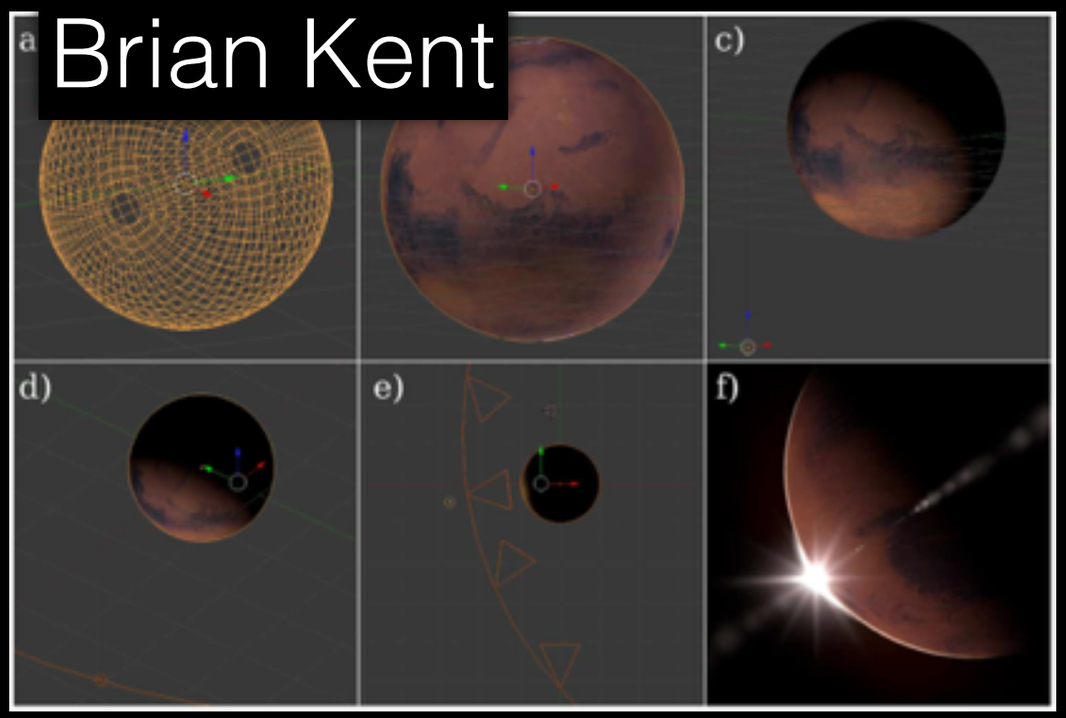

http://skysrv.pha.jhu.edu/~miguel/visualization.html

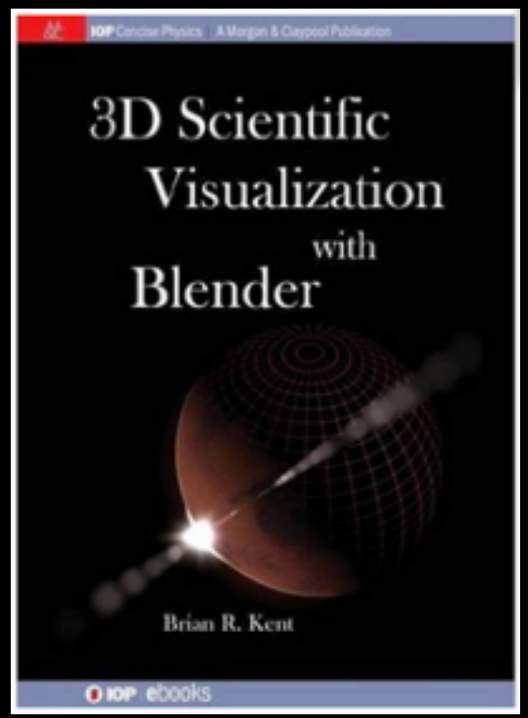
## Rhysy Taylor



FRELLED - volume rendering
http://www.rhysy.net/frelled.html

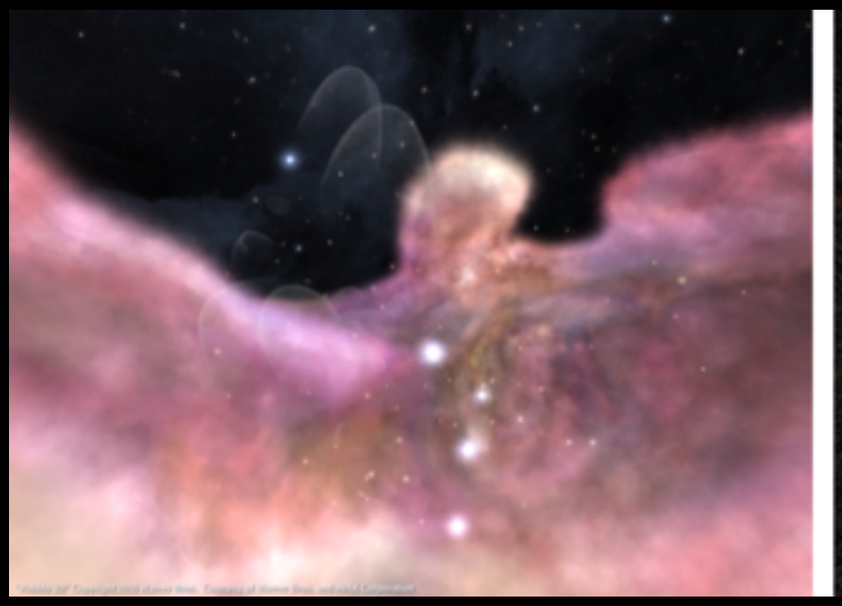
## Brian Kent

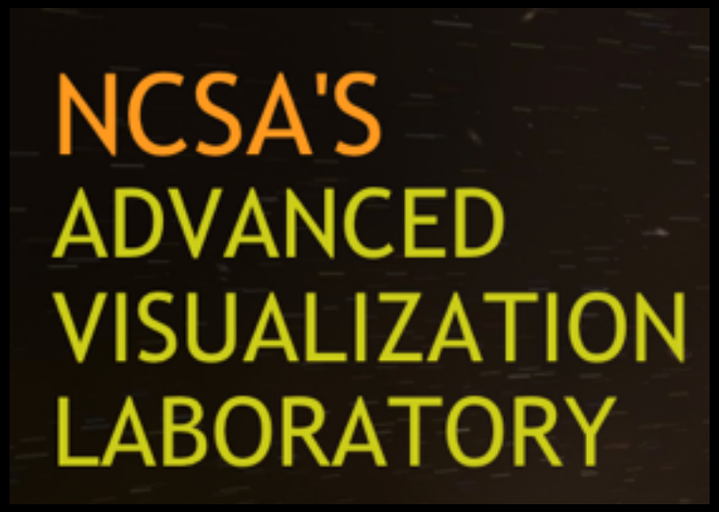


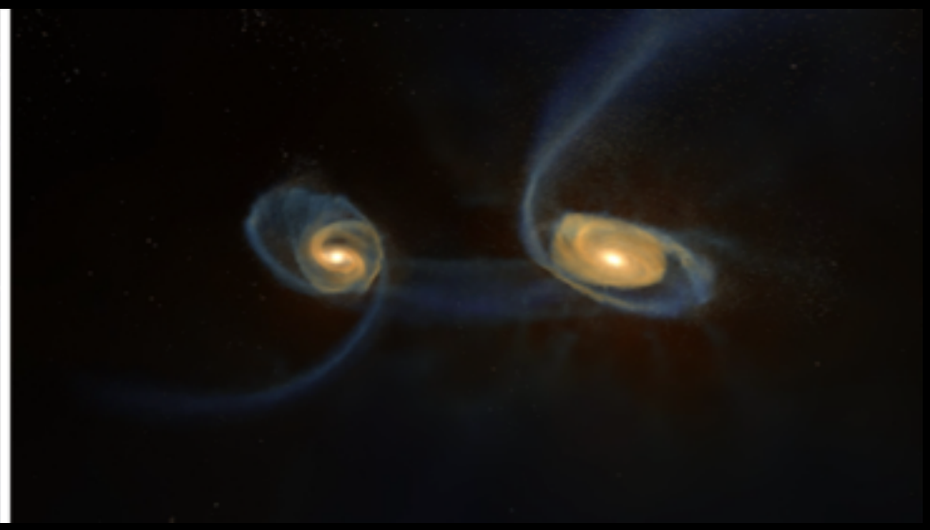



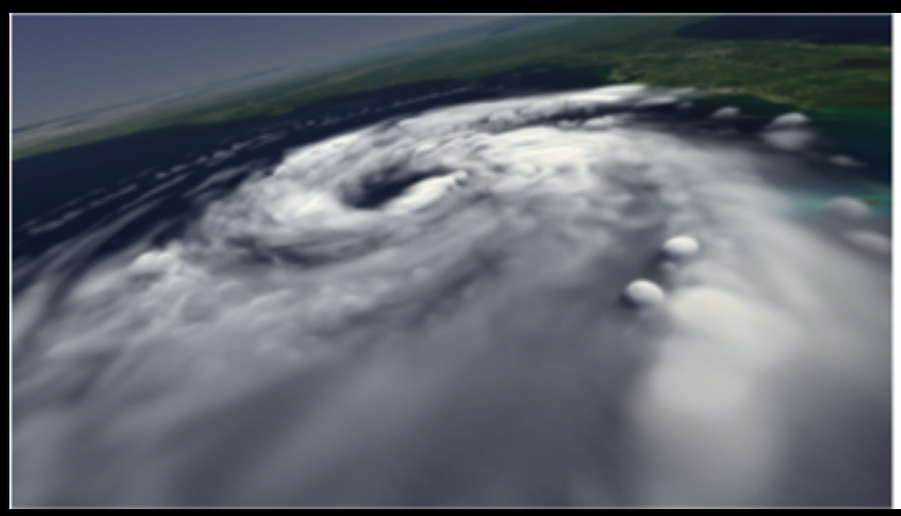

http://www.cv.nrao.edu/~bkent/blender/index.html

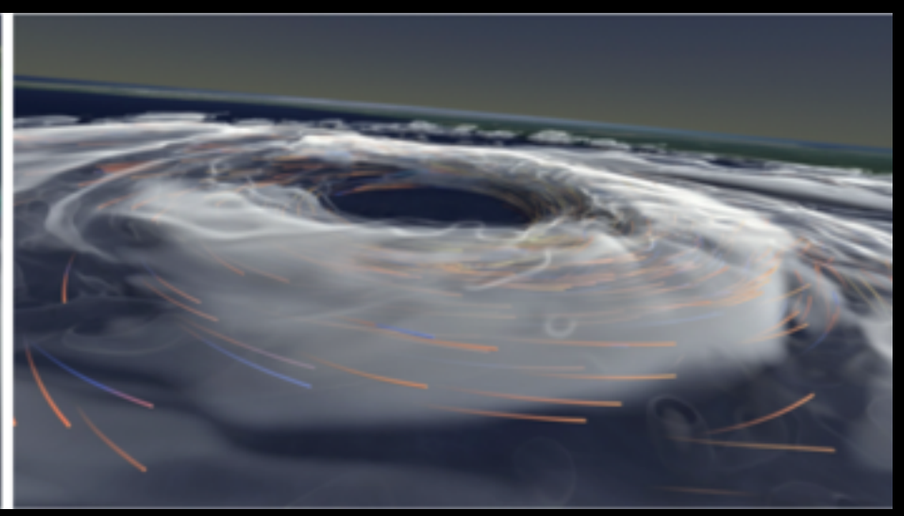
# Beginning to work in Houdini





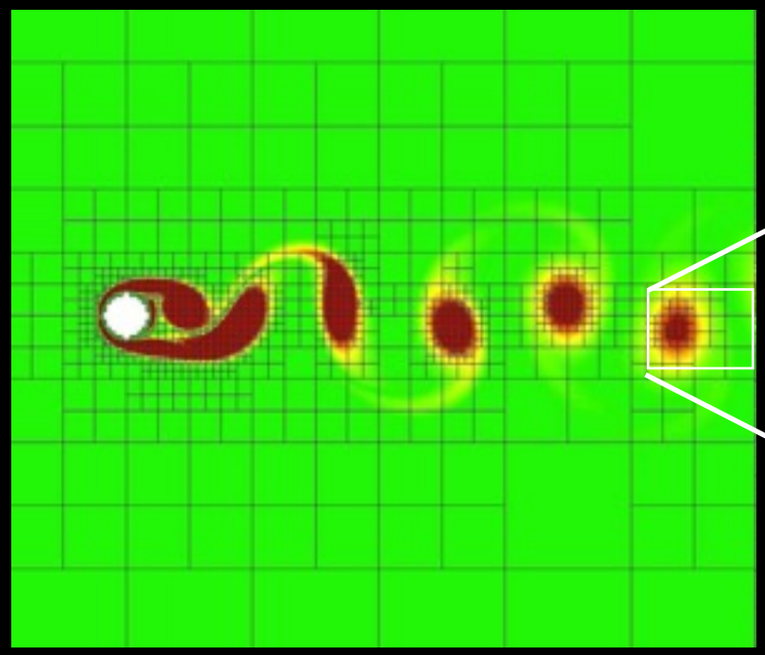





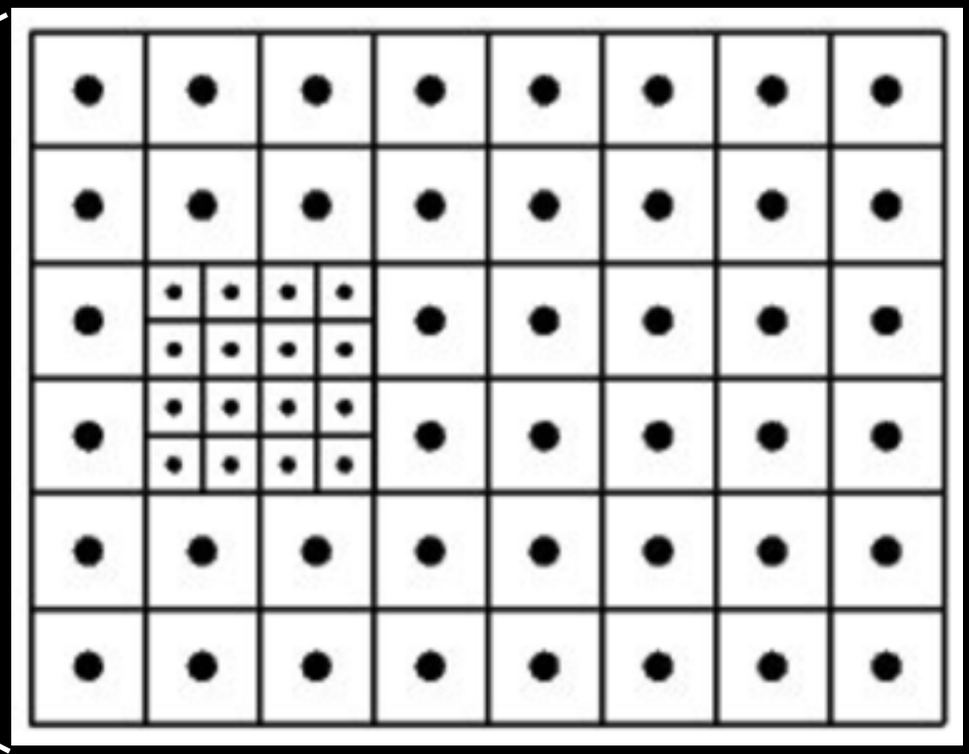


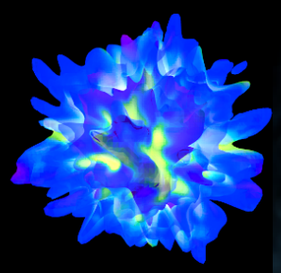
# Beginning to work in Houdini: The Issues

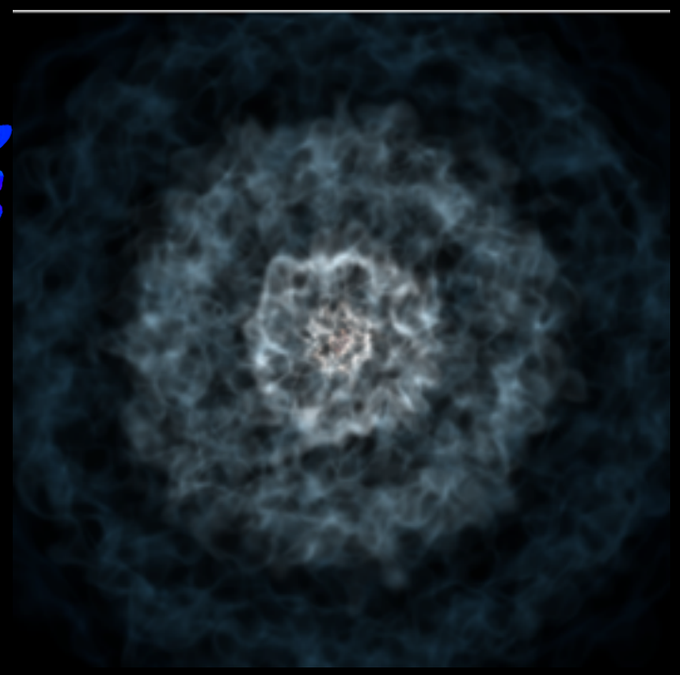
Our data sometimes looks like this:



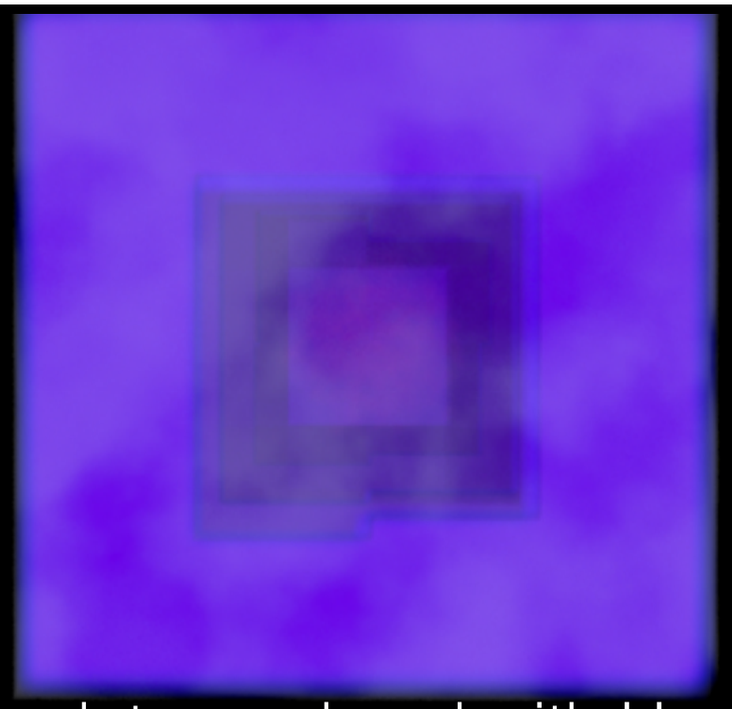
Grid is not uniform:
some areas are finer meshed







data rendered into image with yt



same data rendered with Houdini

# Beginning to work in Houdini: Some Fixes

- More efficient data storage (VDB)
- Messing with how edges of volume rendering boxes are treated (box filter width)
- Data loading based on camera position (on the fly data processing)

# Beginning to work in Houdini: Some Fixes


Can load & process high resolution data more efficiently…
but there is still so much data not shown!

# Beginning to work in Houdini: Some Fixes


Can load & process high resolution data more efficiently…
but there is still so much data not shown!

# Some final thoughts on increasing access to science

How to provide animation/visualization tools to young astronomers so that they can tell their own stories with their data?

# Some final thoughts on increasing access to science

HARVARD UNIVERSITY HARVARD.EDU

BANNEKER INSTITUTE
AZTLÁN INSTITUTE

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What are the Institutes?

The Banneker Institute—established by Dr. John Johnson of Harvard University—and the Aztlán Institute—established by Dr. Jorge Moreno of California State Polytechnic University, Pomona—form a partnership. Both institutes offer a summer program hosted at the Harvard-Smithsonian Center for Astrophysics (CfA).

## About Banneker & Aztlán

### Why Banneker?

The program and its name draw on the pioneering inspiration of Benjamin Banneker, a surveyor best known for accompanying Andrew Ellicott in his original land survey of what would become Washington, D.C. Banneker was also an accomplished astronomer, which drove the success of his series of almanacs. As a forefather to Black American contributions to science, his eminence has earned him the distinction of being the first professional astronomer in America.

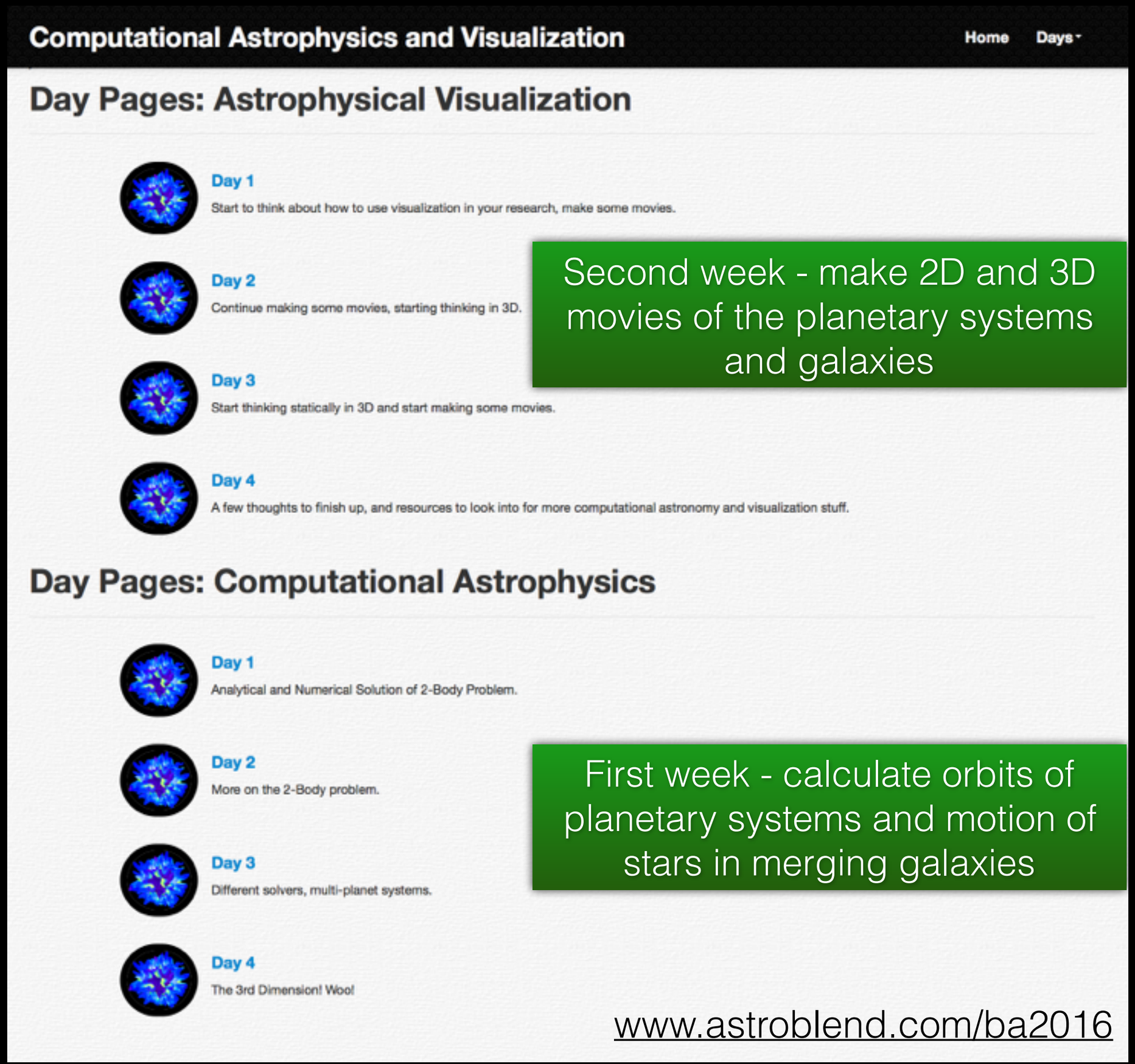
### Why Aztlán?

Aztlán is the legendary ancestral home of the Aztec peoples. The historical and cultural significance of the name led to its adoption by indigenous and Chicano civil rights movements in the United States. The Aztlán Institute honors this tradition as the partner program to Banneker by promoting the advancement of AZTronomy among LAtinx and Native students.

Download Our One-Pager


http://bannekerinstitute.fas.harvard.edu/about

# Some final thoughts on increasing access to science

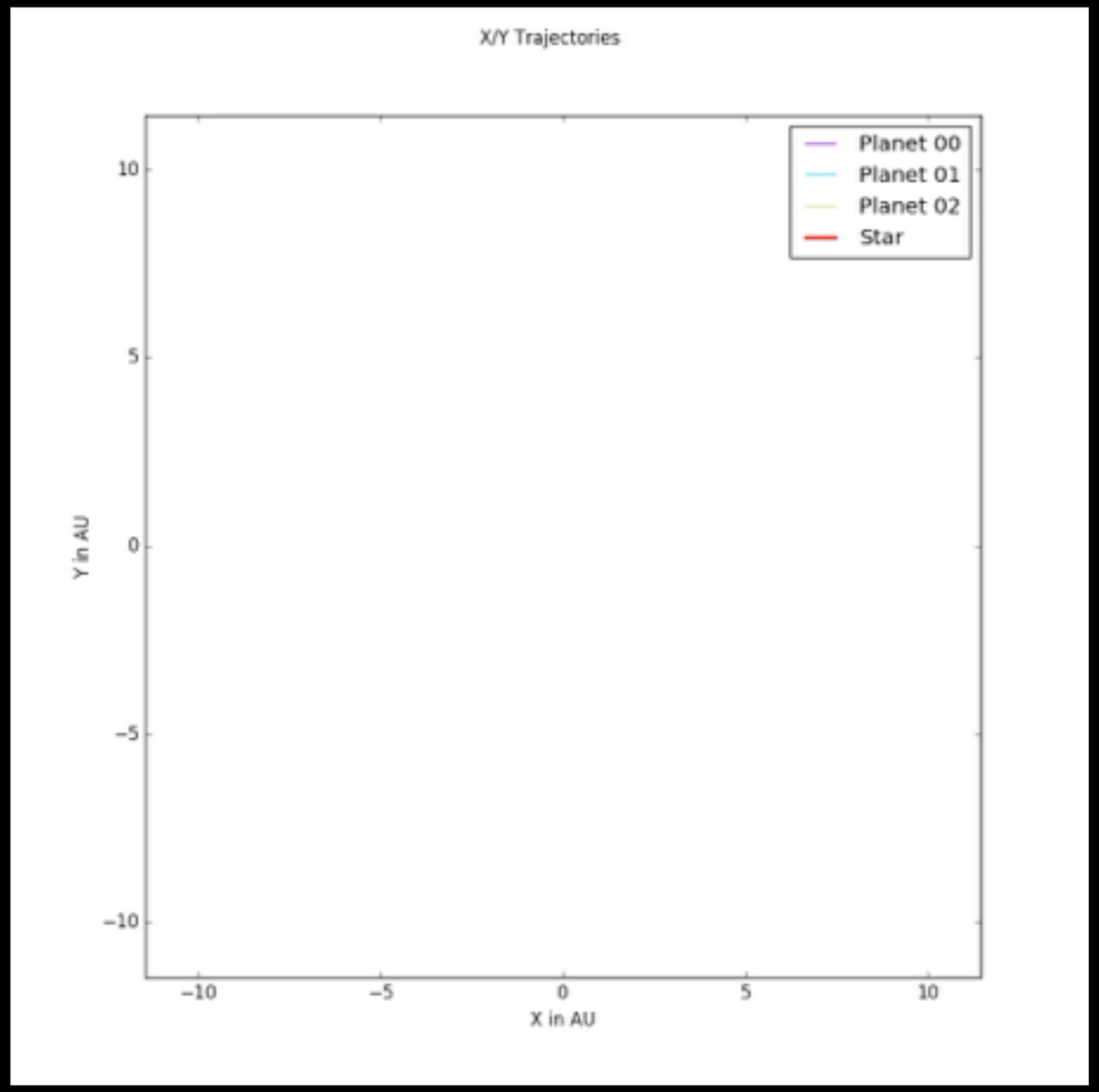


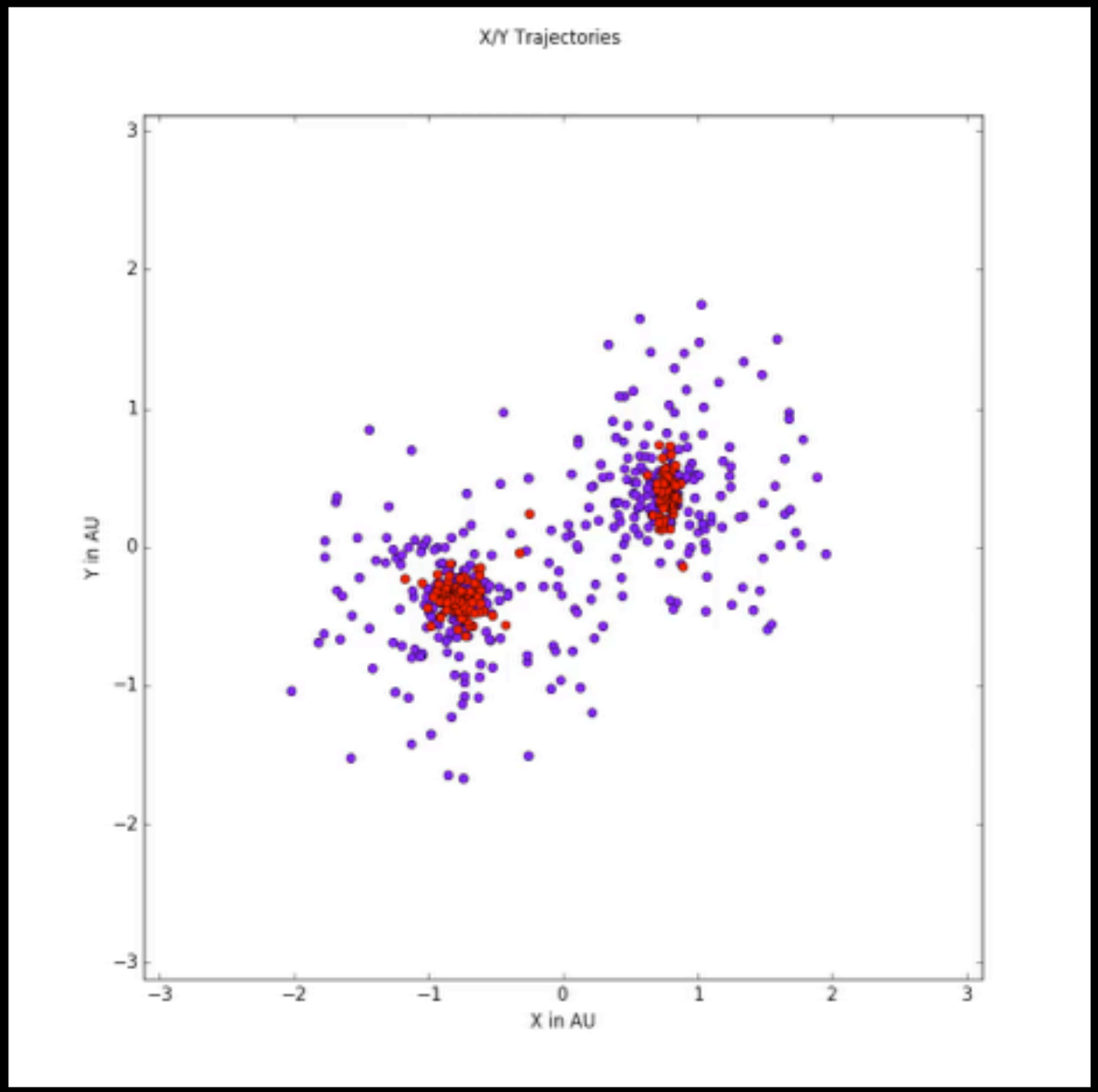

Second week - make 2D and 3D movies of the planetary systems and galaxies

First week - calculate orbits of planetary systems and motion of stars in merging galaxies

www.astroblend.com/ba2016

# Some final thoughts on increasing access to science



# Some final thoughts on increasing access to science

Moved on to:

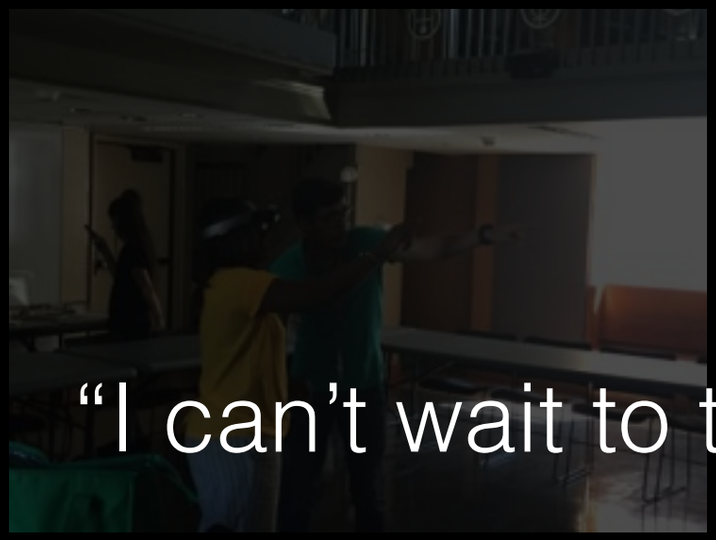
3D Planets https://skfb.ly/RyZo

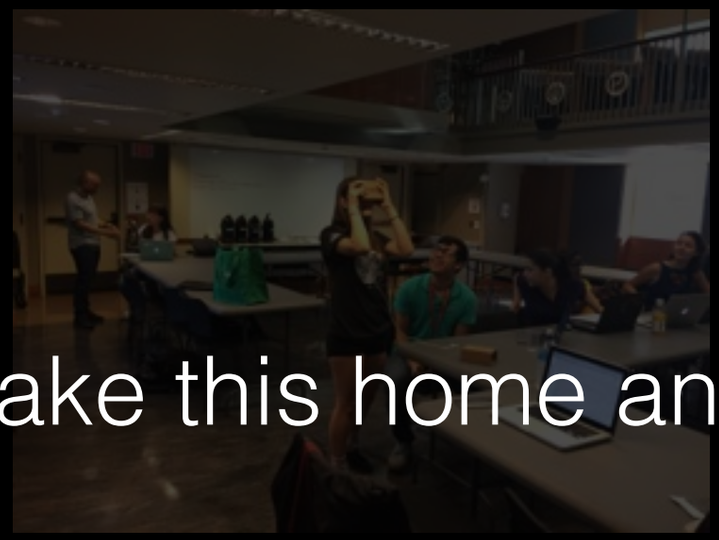
3D Galaxies https://skfb.ly/QHwx

# Some final thoughts on increasing access to science

Used Hololense & Google Cardboard
+ Sketchfab to view 3D models

# Some final thoughts on increasing access to science



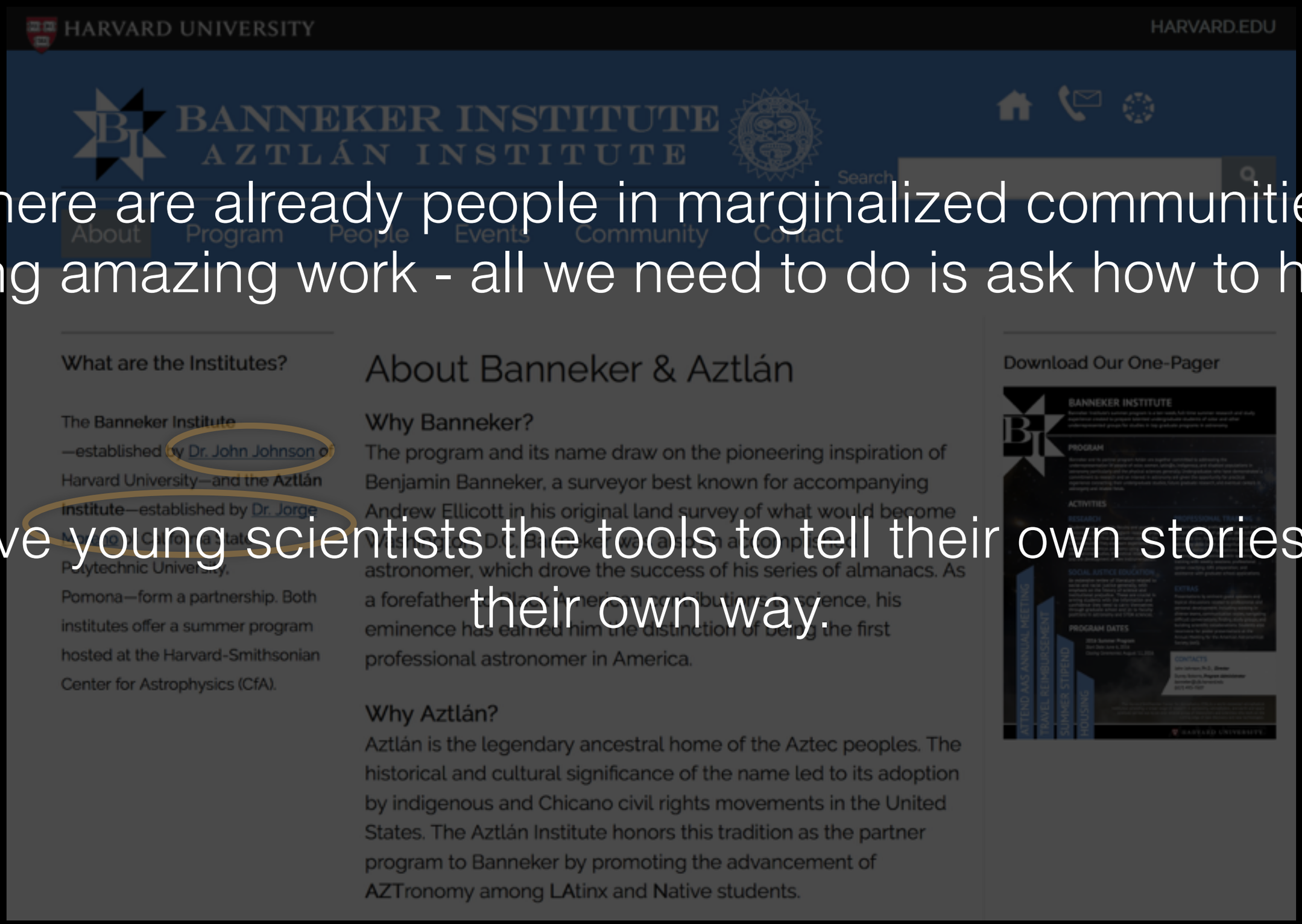


"I can't wait to take this home and show my little sister."

"I'd like to figure out a way to use this stuff with my own research."

Used Hololense & Google Cardboard
+ Sketchfab to view 3D models

# Some final thoughts on increasing access to science




There are already people in marginalized communities doing amazing work - all we need to do is ask how to help!

Give young scientists the tools to tell their own stories in their own way.

http://bannekerinstitute.fas.harvard.edu/about

# Thank you!

jill.naiman@cfa.harvard.edu

- www.astroblend.com
- http://yt-project.org/
- http://bannekerinstitute.fas.harvard.edu/about
- http://www.ncsa.illinois.edu/
- www.sketchfab.com/jnaiman

# What do artists gain from scientific visualization?

- Easier access to scientists! (Either a good thing… or a bad thing…)
- Easier access to scientific data: http://yt-project.org/data/
  - also: National Data Service - www.nationaldataservice.org/about/vision.html
- Cool things to print!