3D Scientific Visualization with Blender

Brian R. Kent, Ph.D.

Scientist, National Radio Astronomy Observatory

www.cv.nrao.edu/~bkent/blender

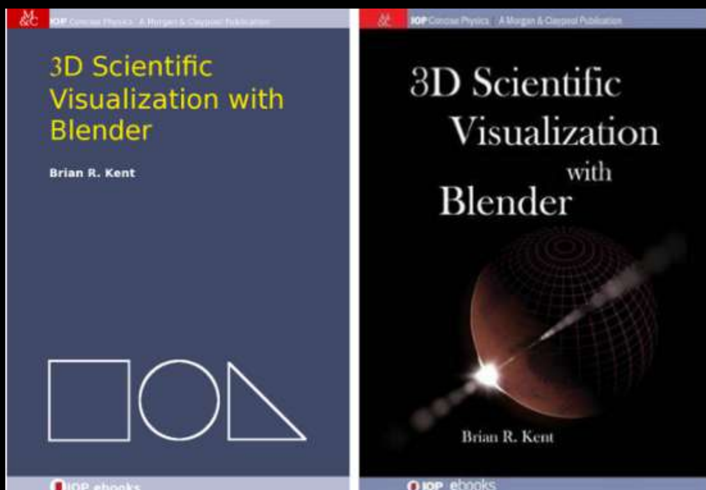
Twitter and Instagram: @VizAstro

NSF AUI NRAO

Watch the live broadcast of this presentation, courtesy of NCSA, at:

https://youtu.be/8FqGNdvEVWo?t=539

Interesting in learning more?



Book and tutorials available at:

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

https://www.youtube.com/VisualizeAstronomy

Twitter and Instagram: @VizAstro

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Overview - 3D Scientific Visualization with Blender

- Science domain and data of astronomy
- What and why we need to visualize data
- All about the visualization tool Blender
- Examples
- Intro to using the interface

NRAO Radio Telescopes

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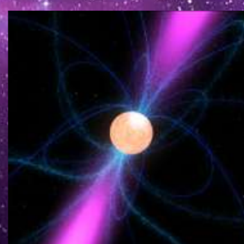
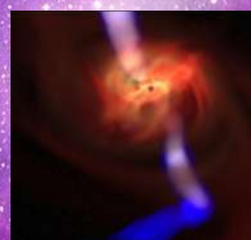
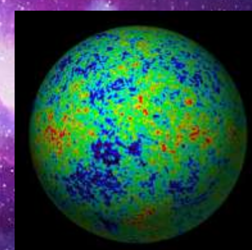
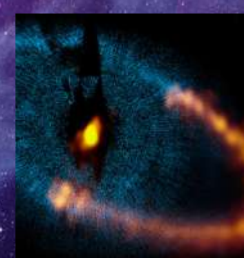
Astrophysical Phenomena

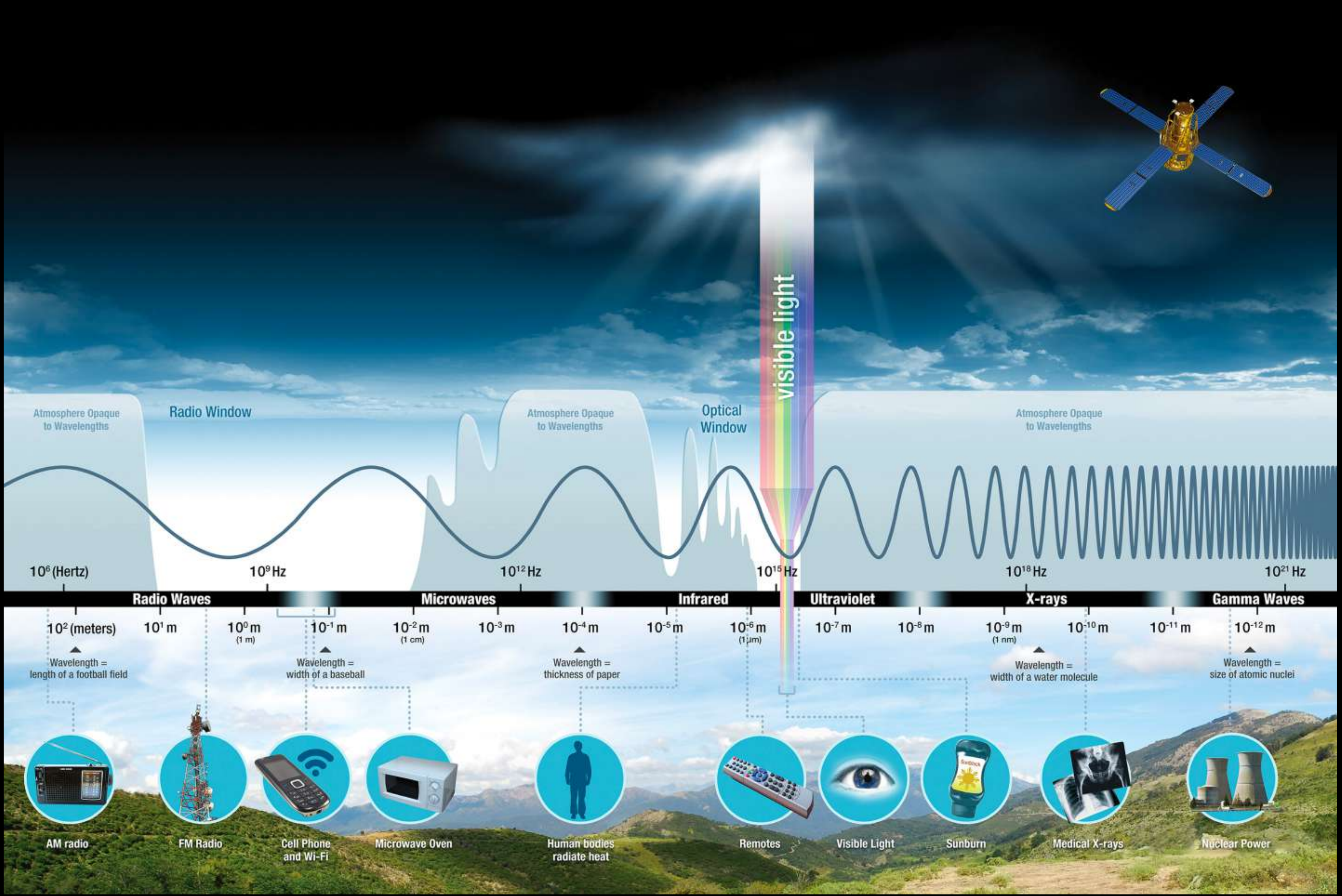








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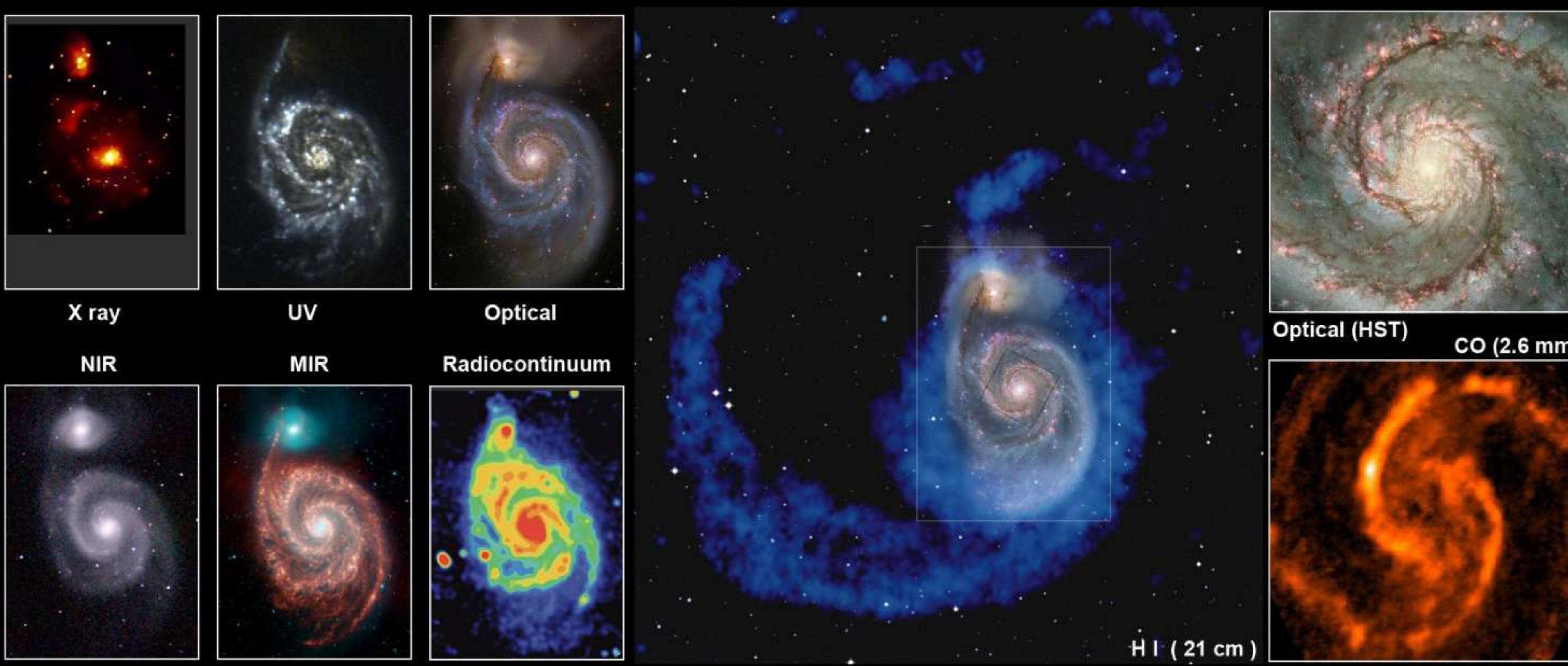

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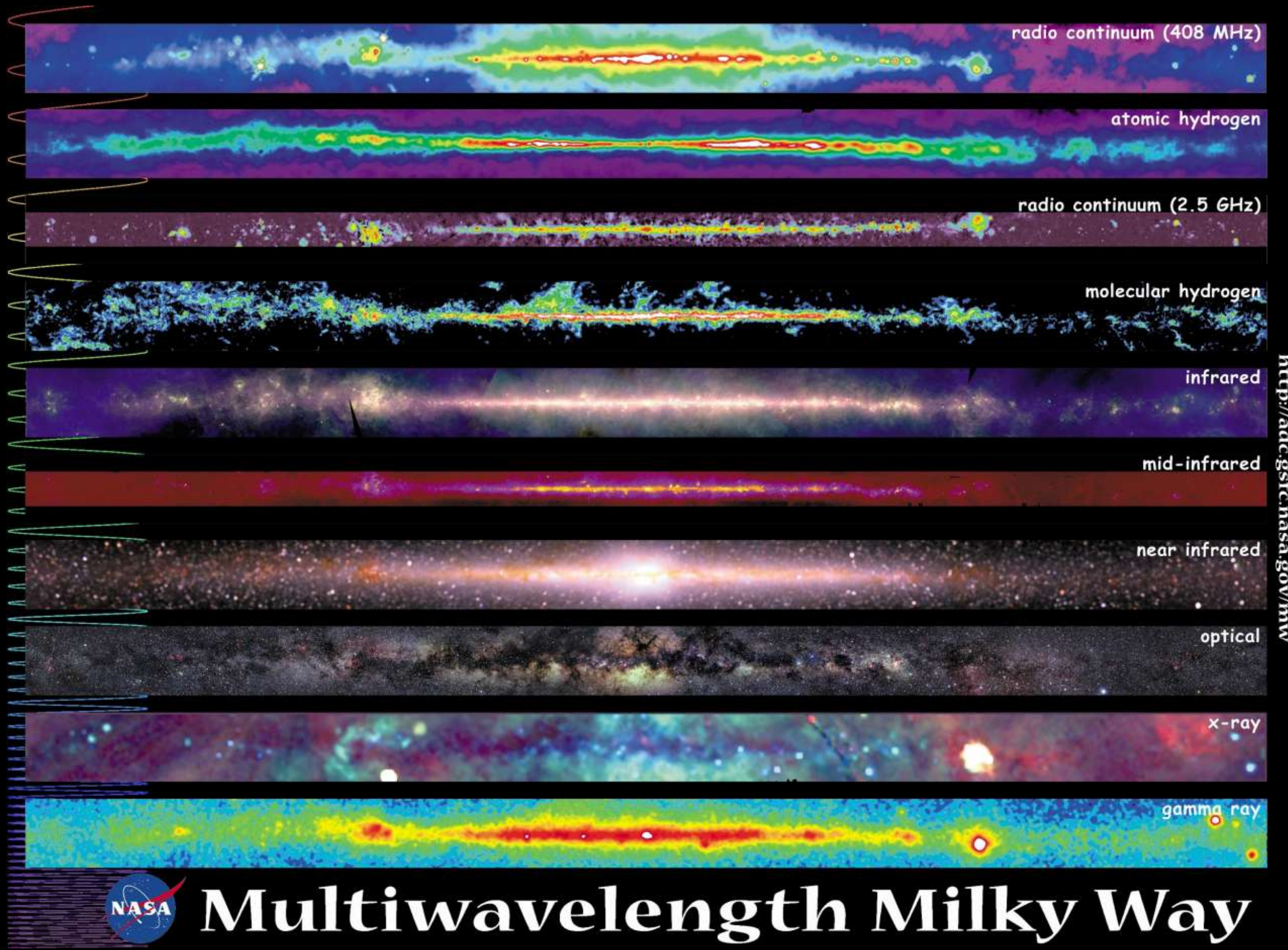

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What do we do in observational astronomy?






Caltech/NRAO/NASA/STScI

Remote sensing and planetary exploration

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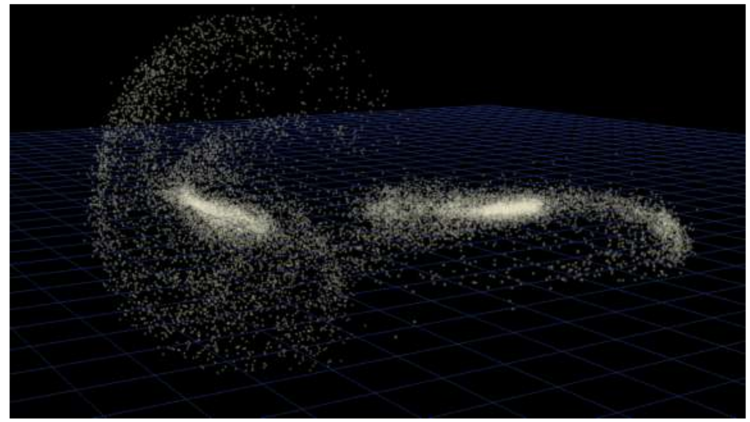
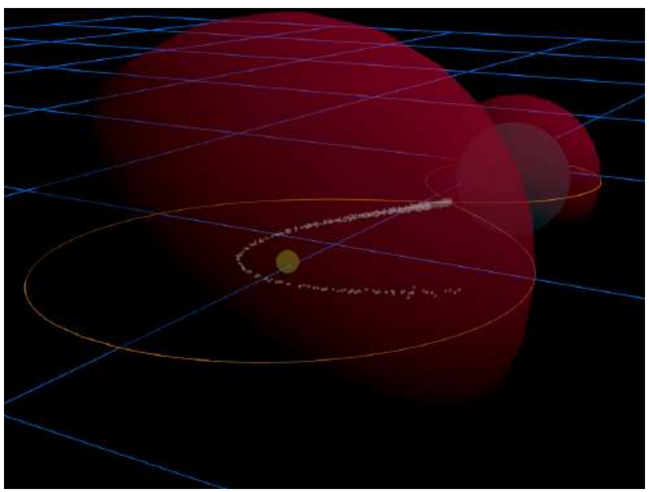
Remote Sensing

- Imaging from the ground or space of phenomena that we can’t physically reach
- The entire physical Universe is our laboratory
- Spectroscopy
    - Dynamics and kinematics, chemistry
- Imaging
    - Earth looking out, and from orbit looking at planets
- Time-series
    - Asteroid identification, light-curves for planet finding, and pulsar timing for general relativity

Astrophysical Simulations

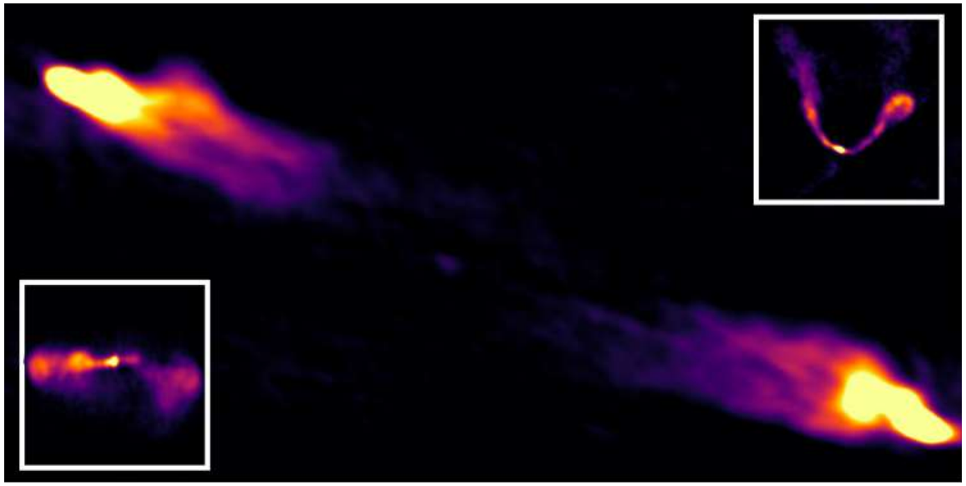
- N-body simulations
- Smoothed Particle Hydrodynamics
- Numerical Relativity
- Models of…
  - Interacting Binary Stars
  - Active Galactic Nuclei Jets
  - Black Holes
  - Interacting Galaxies



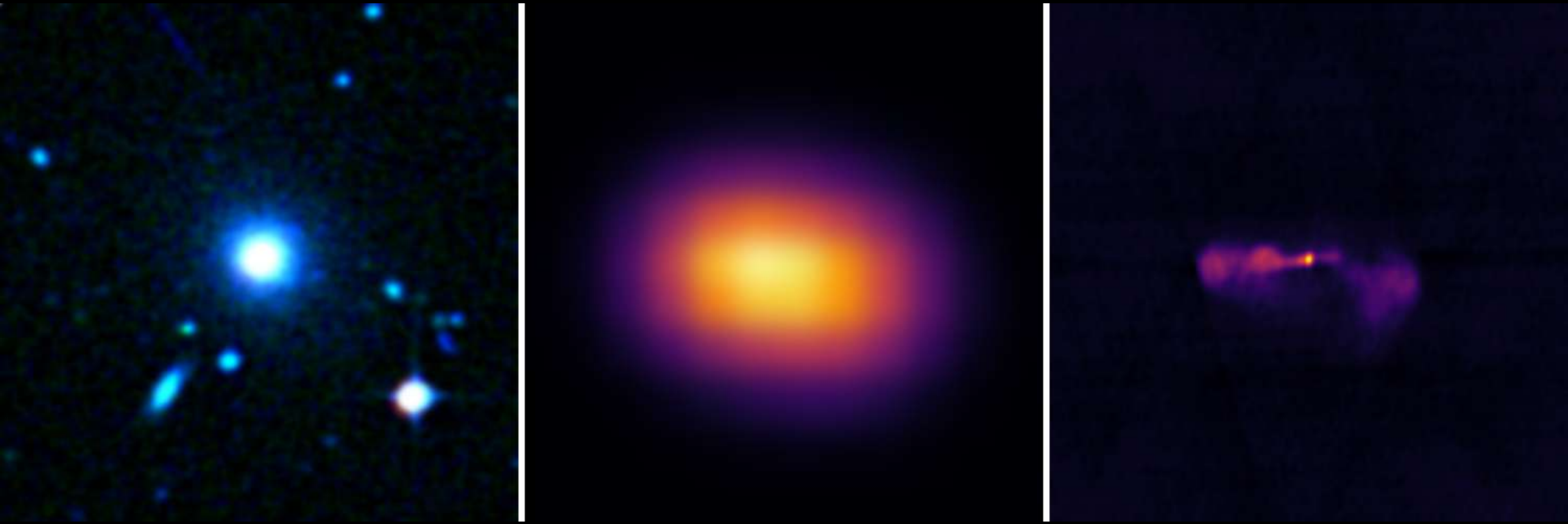


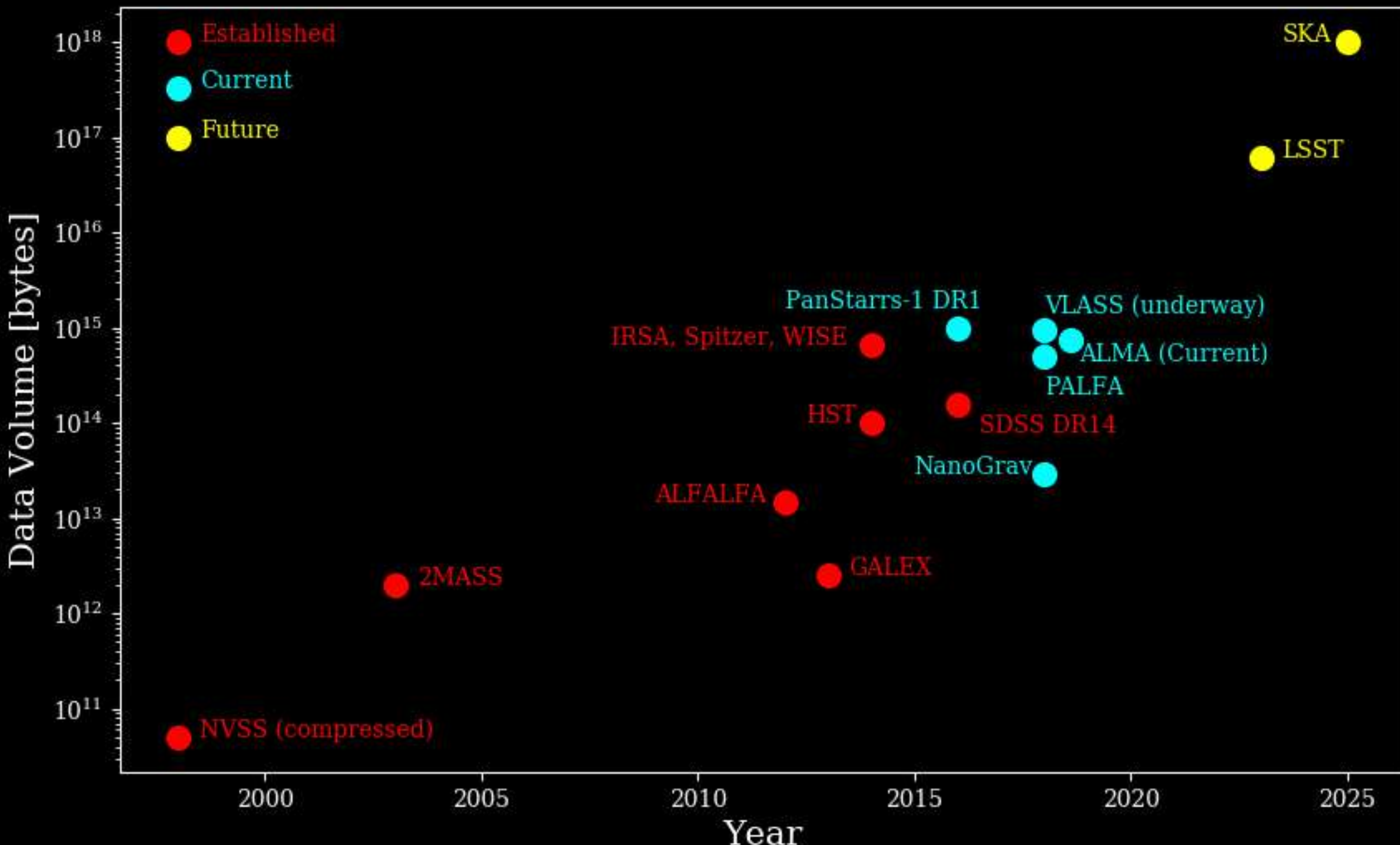
Data from Matt Wood, Texas A&M University-Commerce

Data Rates in Astronomy



- The Atacama Large Millimeter Array (ALMA) in Chile has produced:
    - over 1300 Terabytes of total data in 2014.
    - over 2700 Terabytes of total data in 2016
- The Very Large Array in New Mexico has the capability of producing a million simultaneous frequency channels.
- Current VLA Sky Survey generates 300 GB of raw data in four hours.





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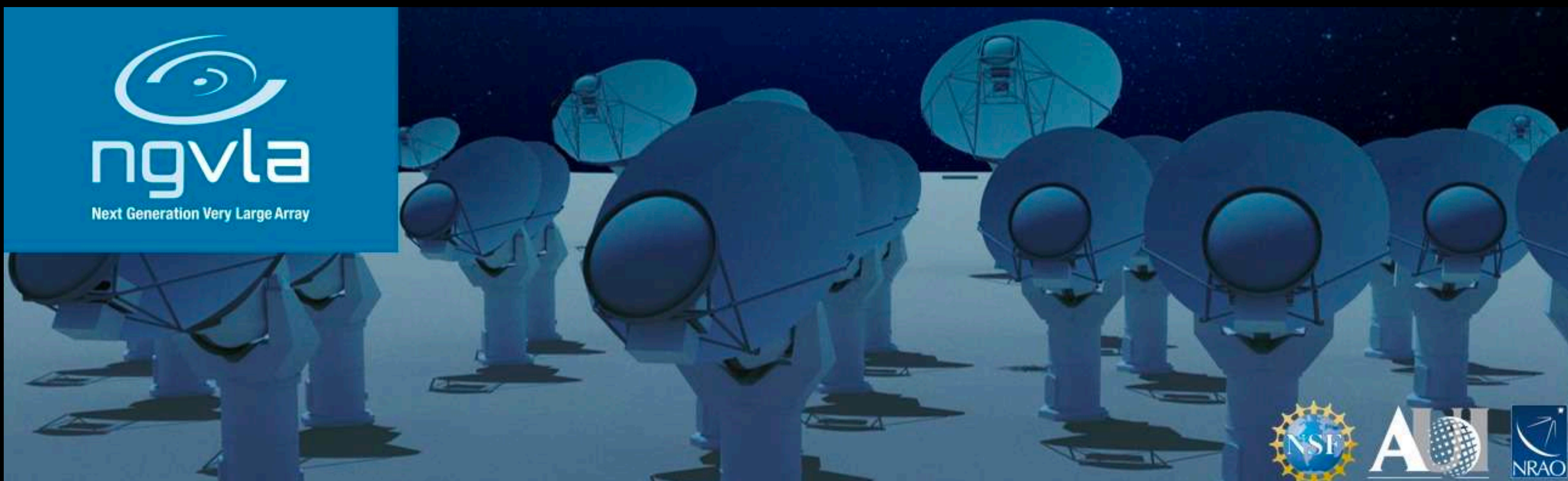
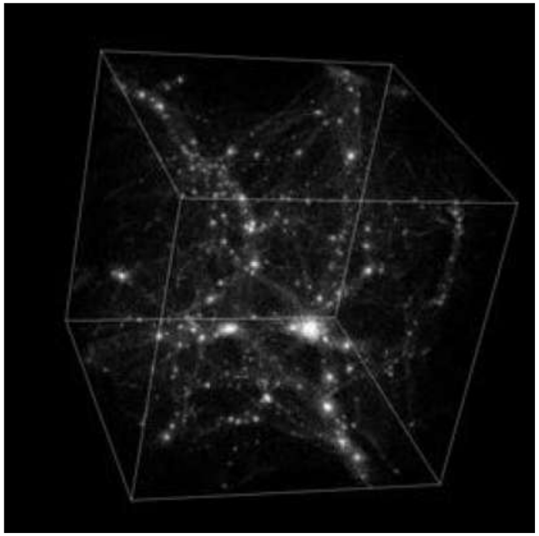
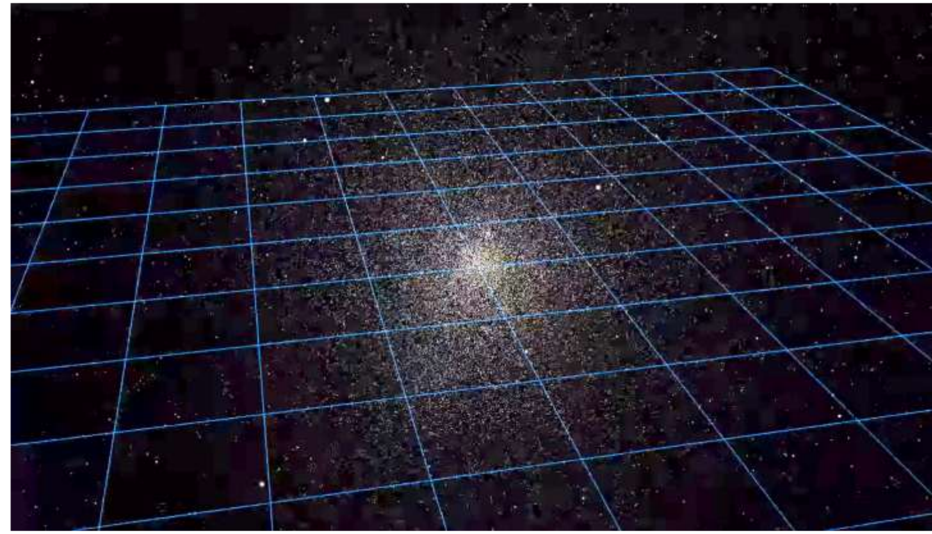
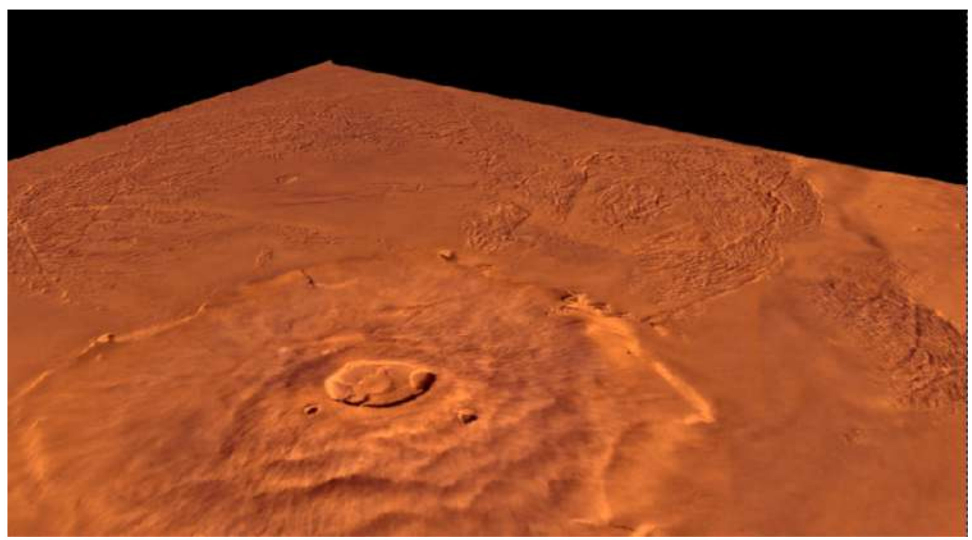

ngvla
Next Generation Very Large Array
NSF
AUI
NRAO

Types of Data in Astronomy







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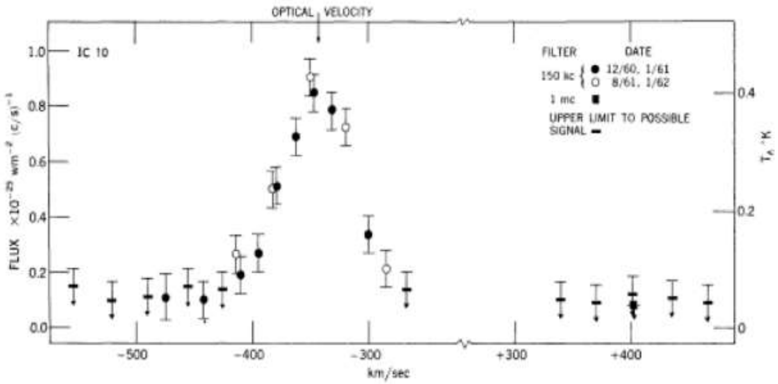
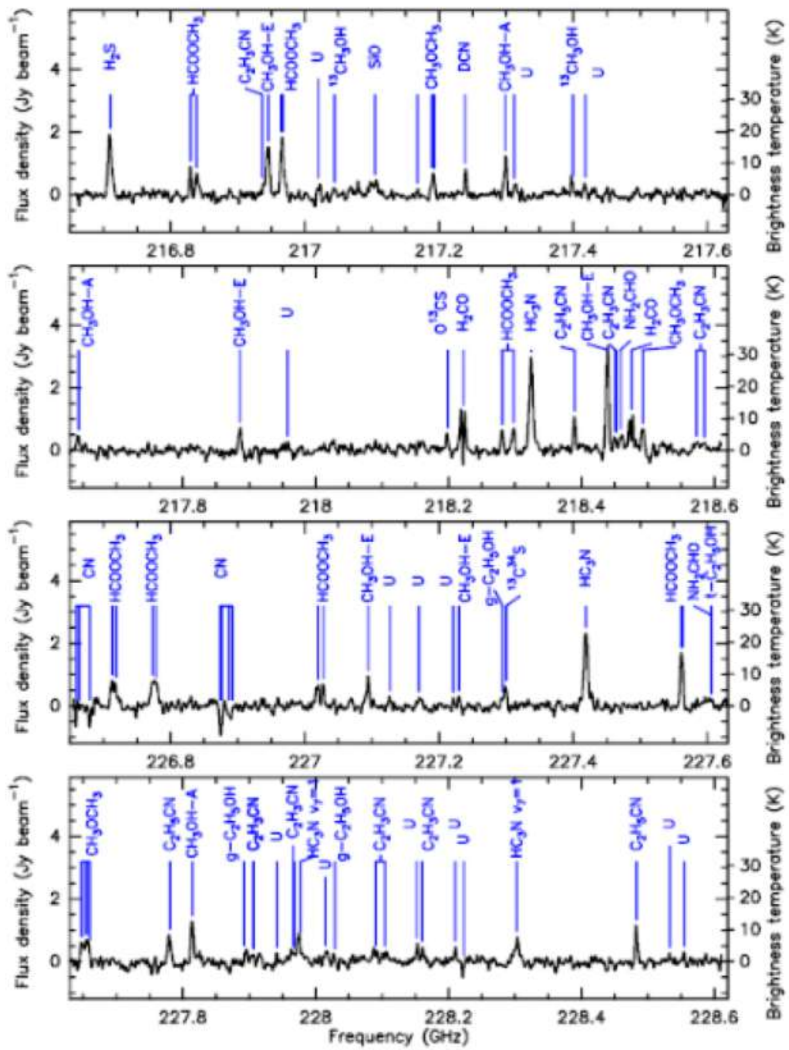
Why do we need to visualize?



In addition to increasing data rates, data are becoming increasingly complex. We have moved from

- the paradigm of studying a single spectral line to thousands of lines
- the paradigm of single galaxy dynamics to millions of galaxies



The parameter space continues to increase - efficient database usage, signal extraction, and visualization methods are required.

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High-performance computing

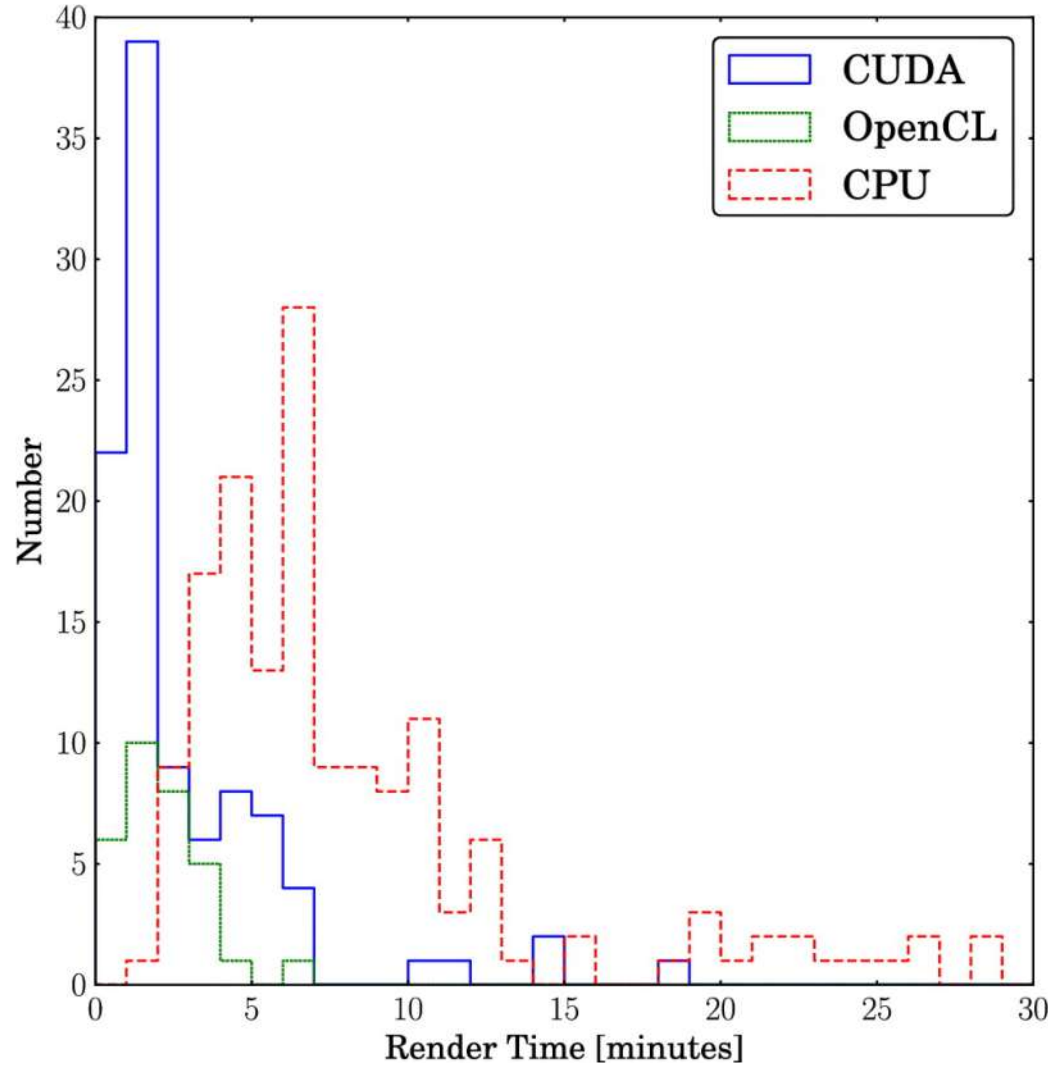
TABLE 2

RENDERING TIME BENCHMARK COMPARISON

Render	Samples N	Mean (minutes)	Median (minutes)	$SE_{\bar{x}}$
NVidia CUDA	100	2.82	1.49	0.31
OpenCL	31	2.17	1.99	0.22
CPU	154	8.30	6.48	0.47

NOTE.—Rendering time for a Blender session in the Cycles engine at a resolution of 960×540 pixels with rendering tile sizes of 8×8 pixels. The benchmark test consisted of 6 camera views and 12 mesh objects totaling 86,391 polygons and 91,452 vertices. The last column describes the standard error of the mean.

Study from Kent (PASP) 2013



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Software for 3D graphics

MAYA

LightWave 11

3DS MAX

HOUDINI

CINEMA 4D

blender™

PIXAR's RenderMan

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Blender

3D Graphics and Visualization

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What is Blender?

Blender is:

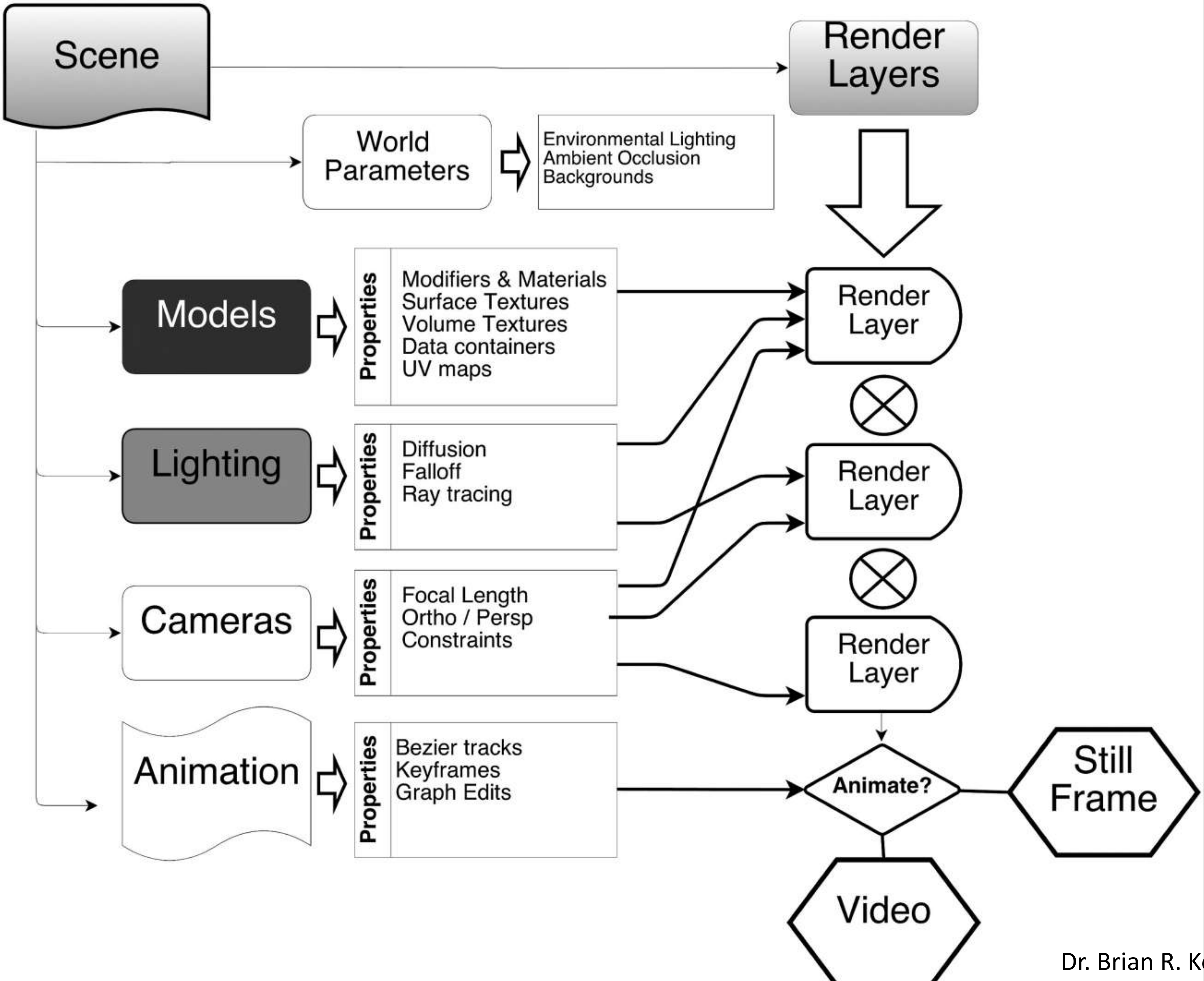
- 3D graphics software for modeling, animation, and visualization
- Open-source
- A real-time 3D viewer and GUI
- A Python scriptable interface for loading data

http://www.blender.org

Elements of 3D Graphics

We need to consider:

- Models - physical or data containers?
- Textures - 2D, 3D, and projections?
- Lighting - illumination of data - physical or artistic
- Animation - How will the model move and change?
- Camera control - lens selection, angle, image size, and movement and tracking
- Rendering - backend engine choice
- Compositing - layering final output



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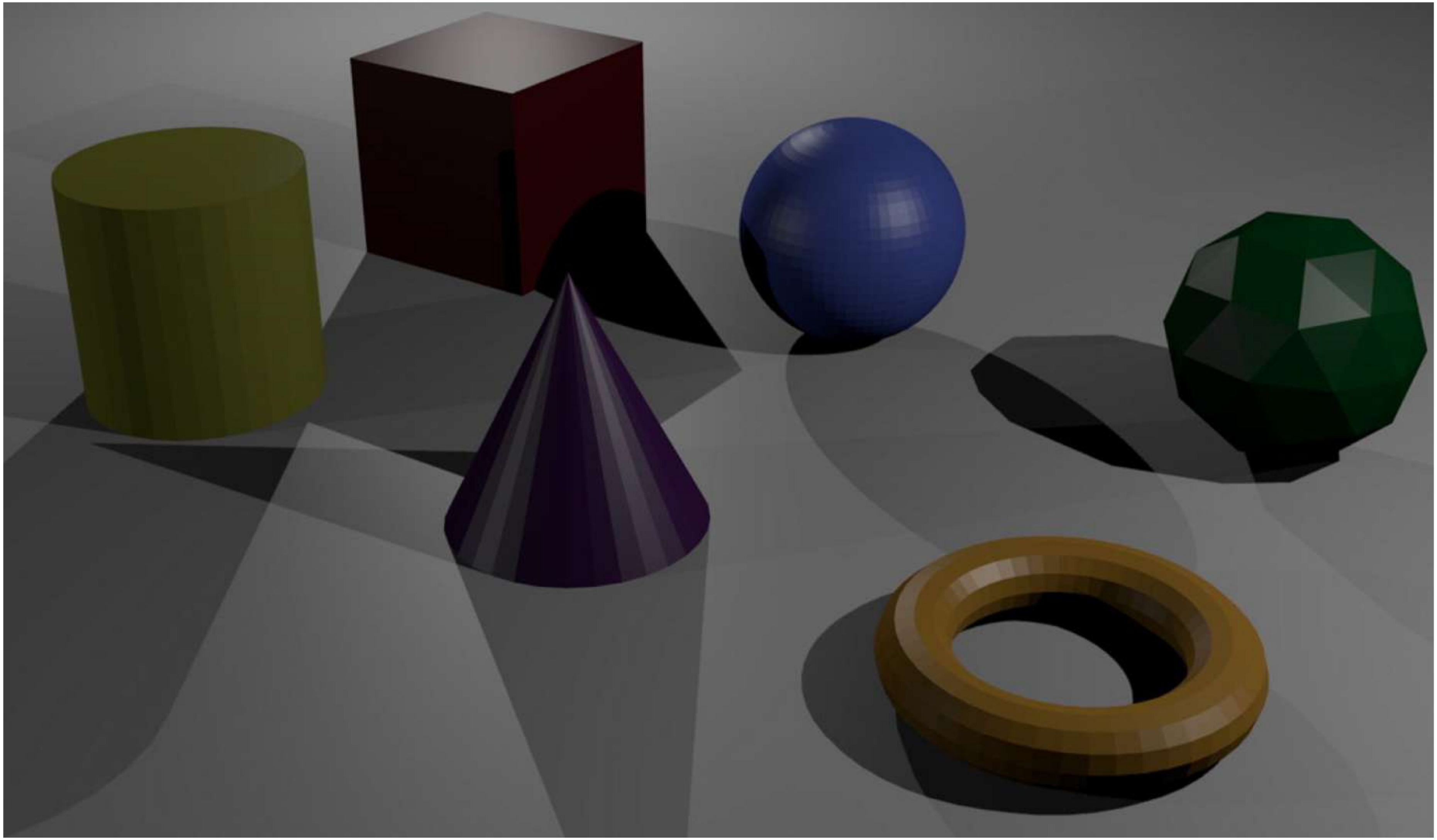
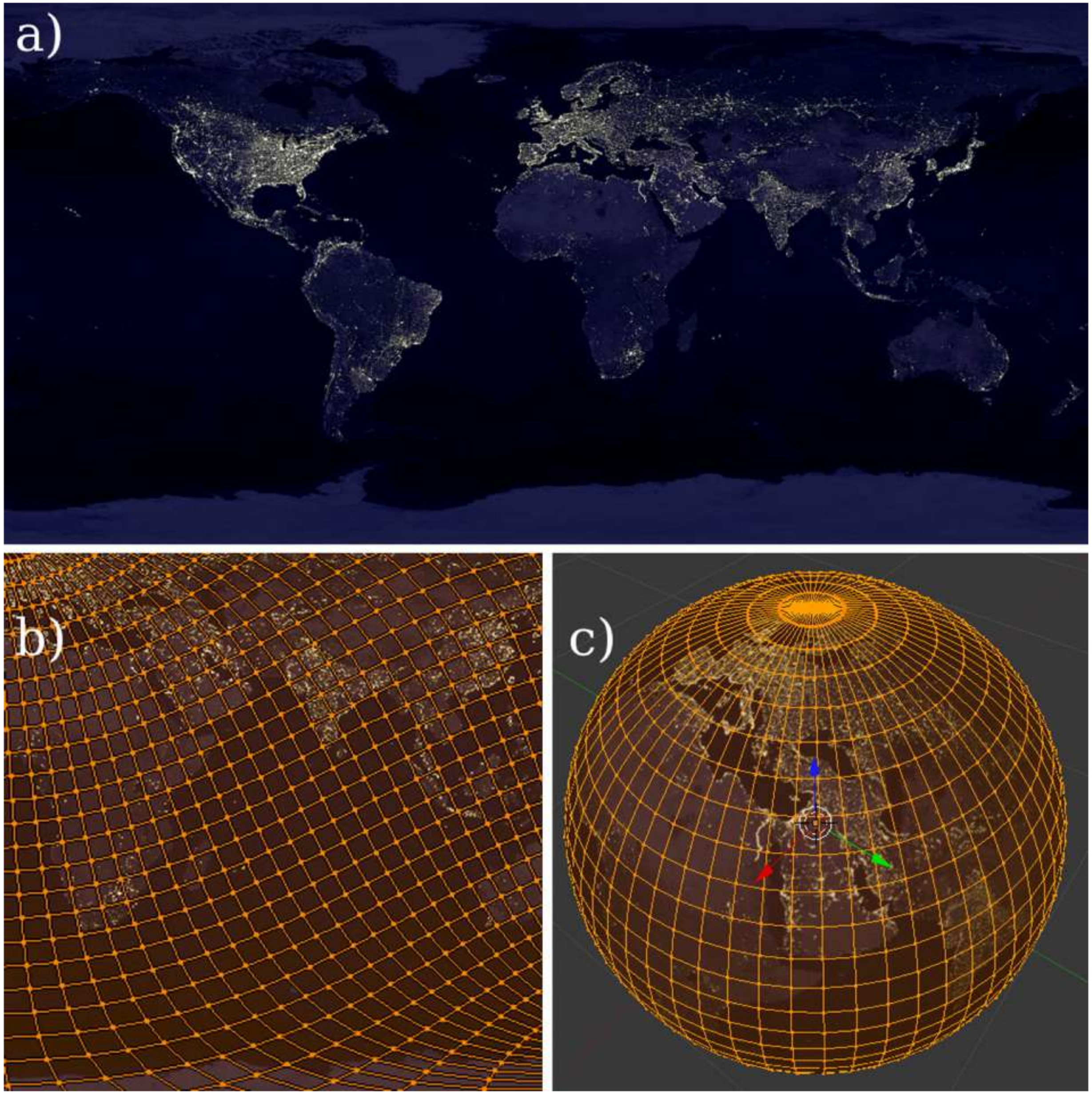
Modeling



Texturing and Mapping



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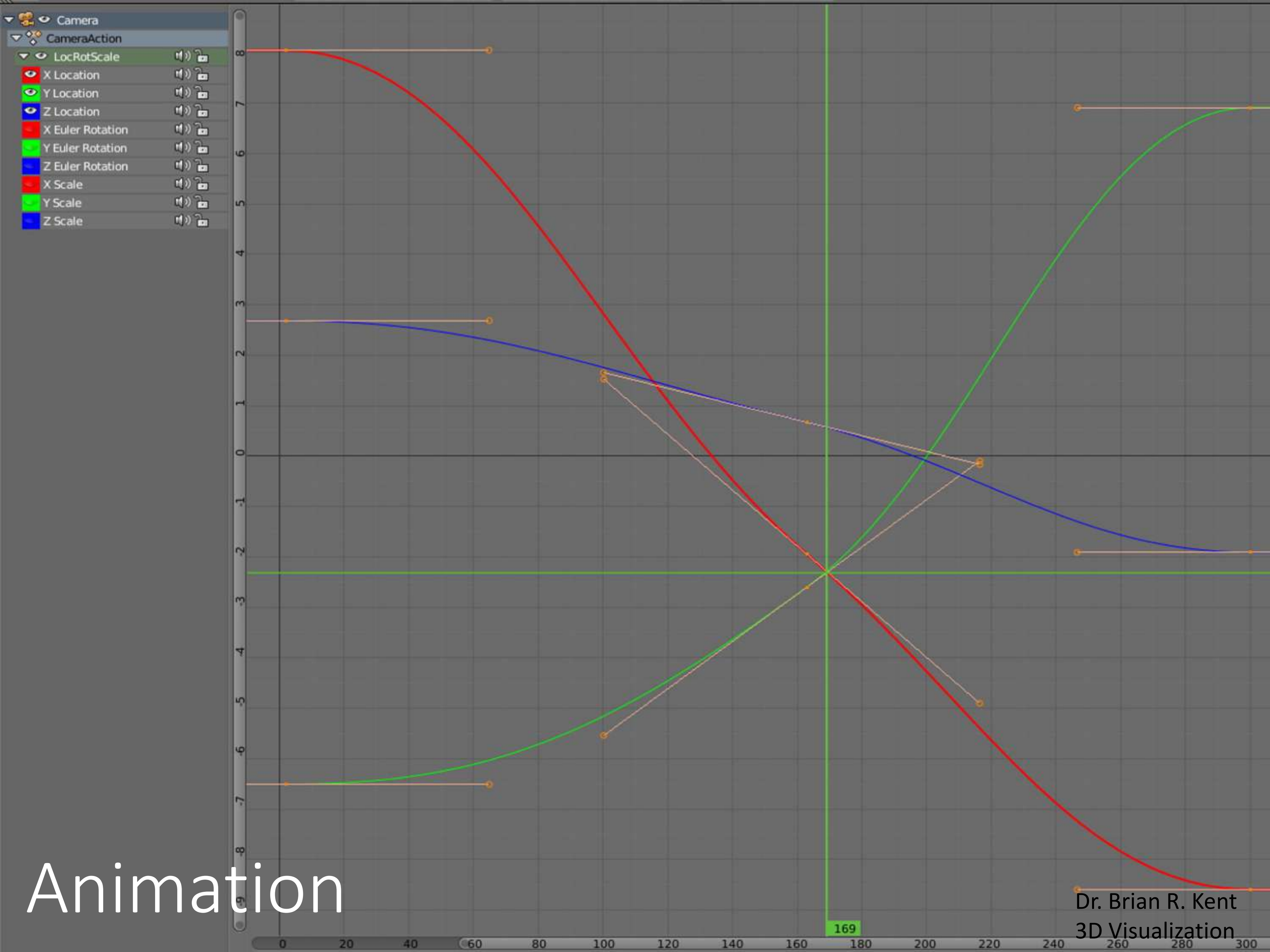

Animation

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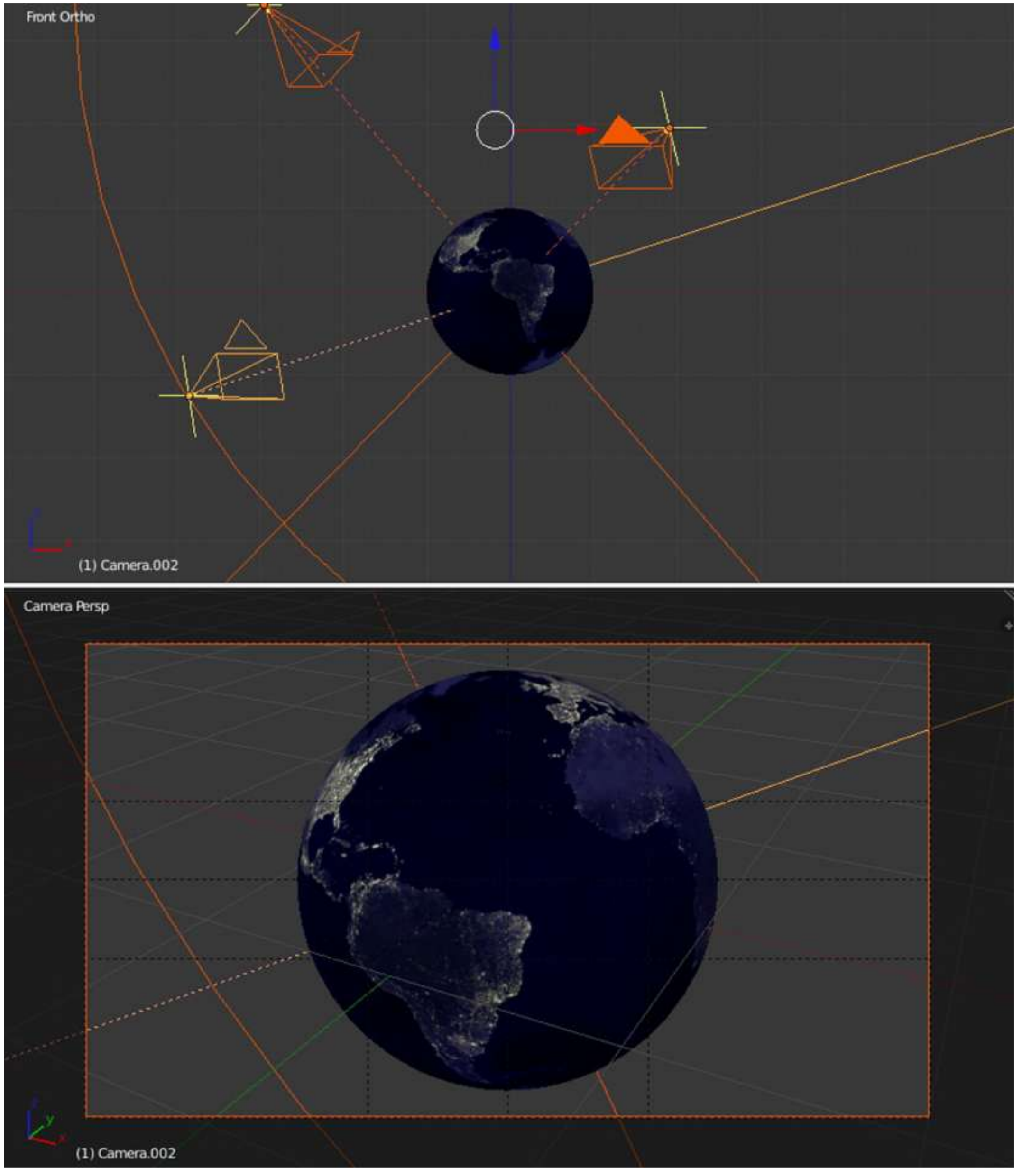
Camera Control and Movement



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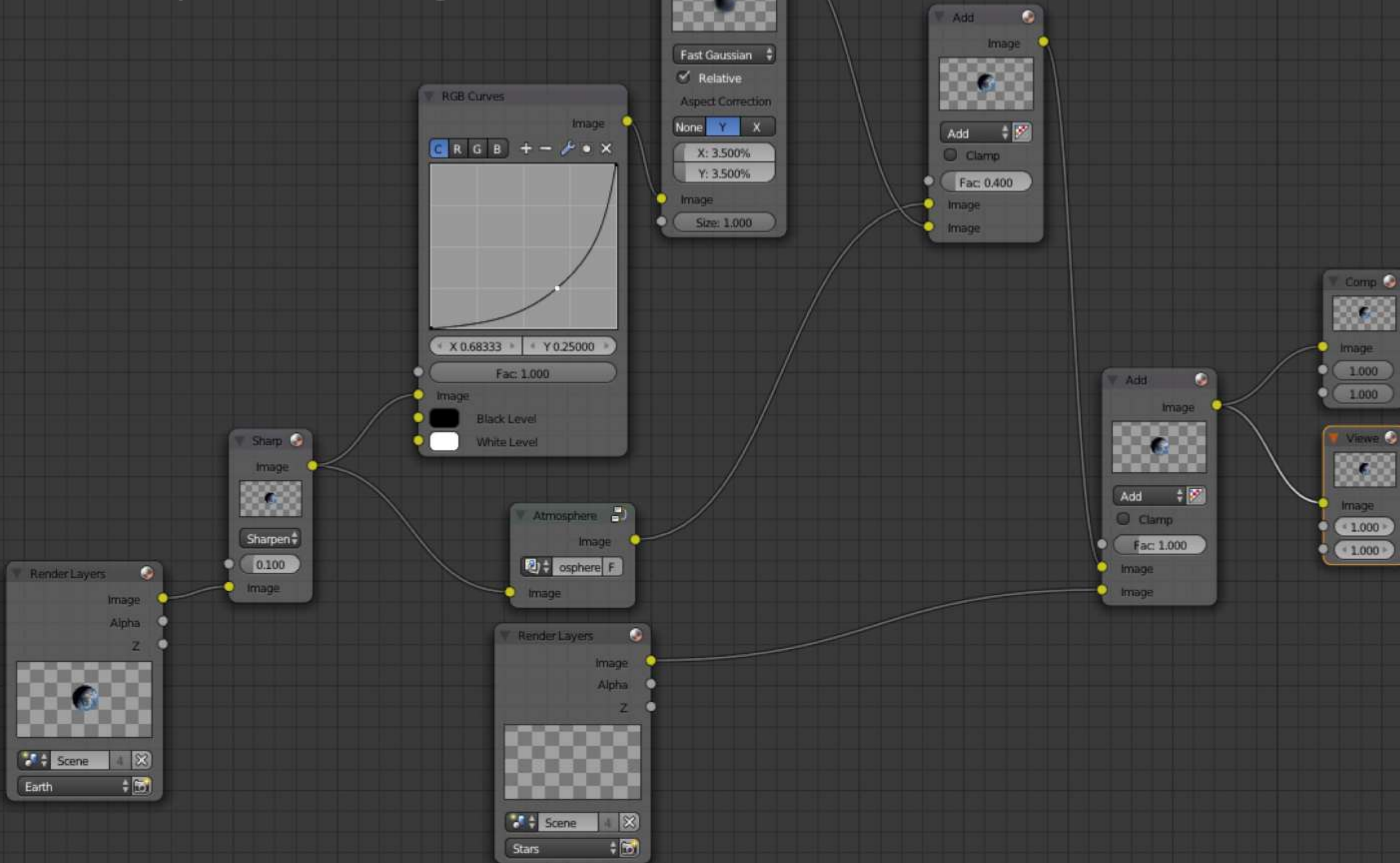
Rendering Engine

- Blender (included)
- Cycles (included)
- Yafaray (open source ray tracing engine http://www.yafaray.org/)
- Luxrender (http://www.luxrender.net/en_GB/index)
- Octane (http://render.otoy.com/)
- Renderman (http://renderman.pixar.com/view/renderman)

Compositing



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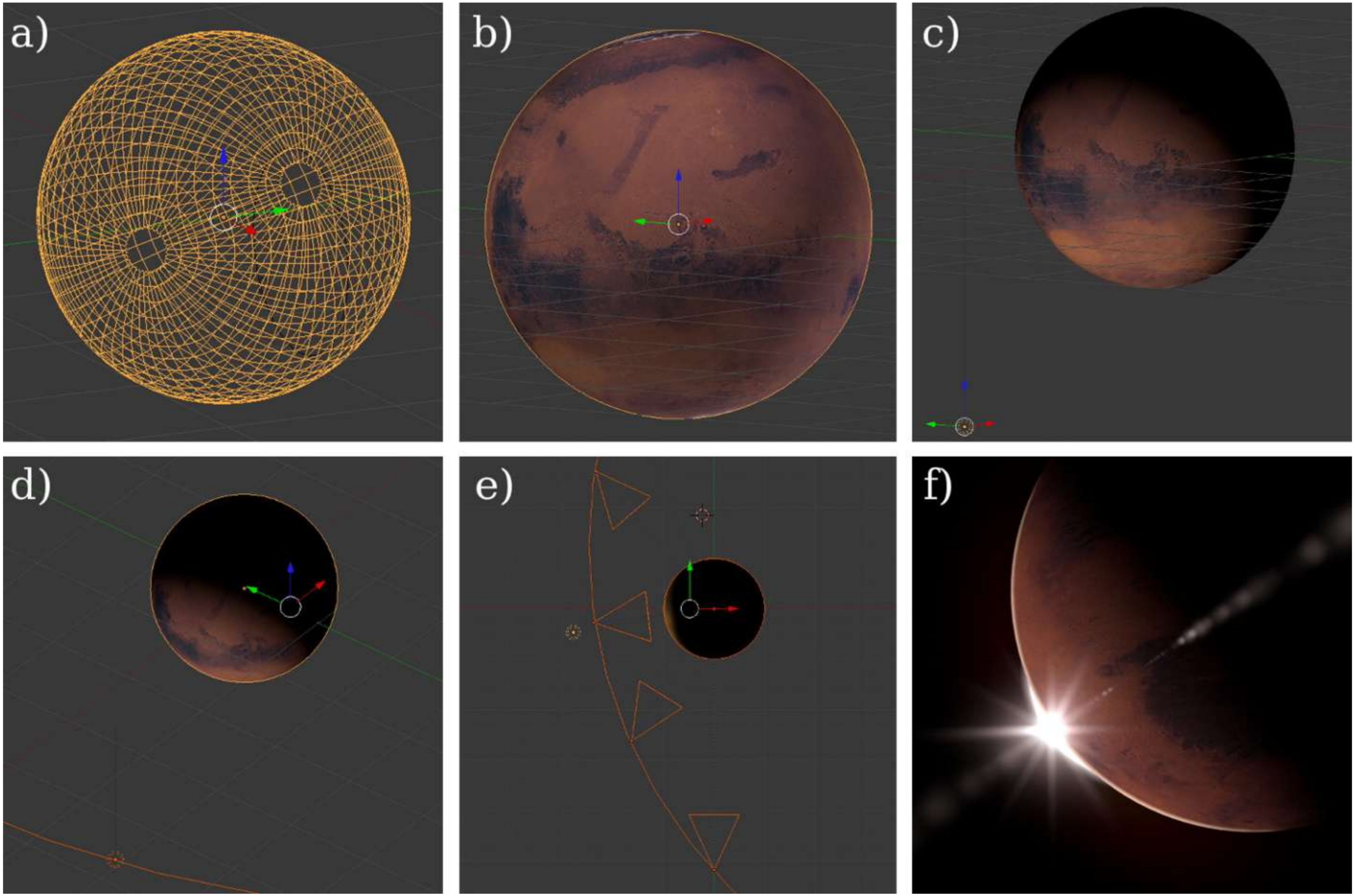
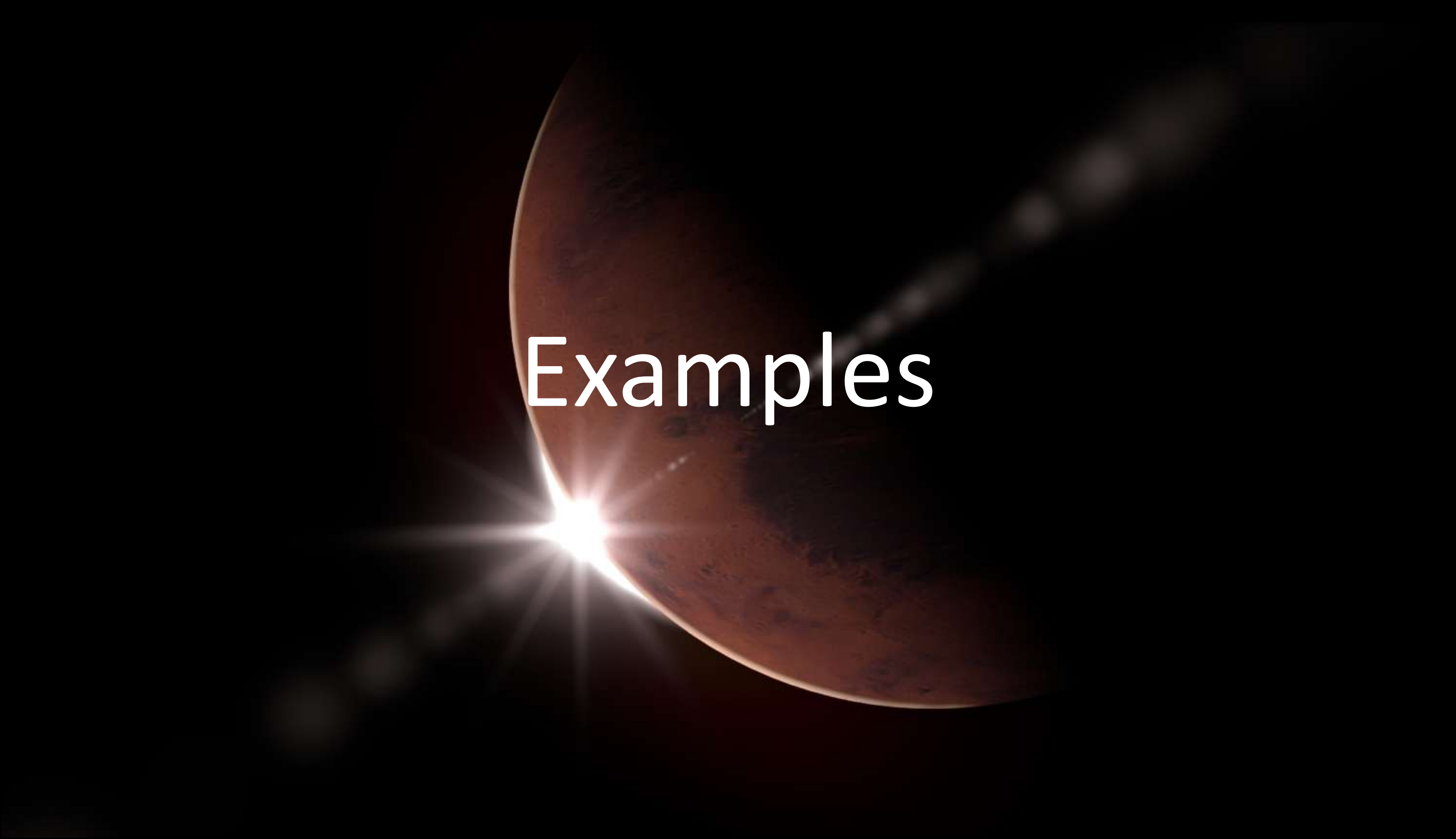
Rendering and Compositing



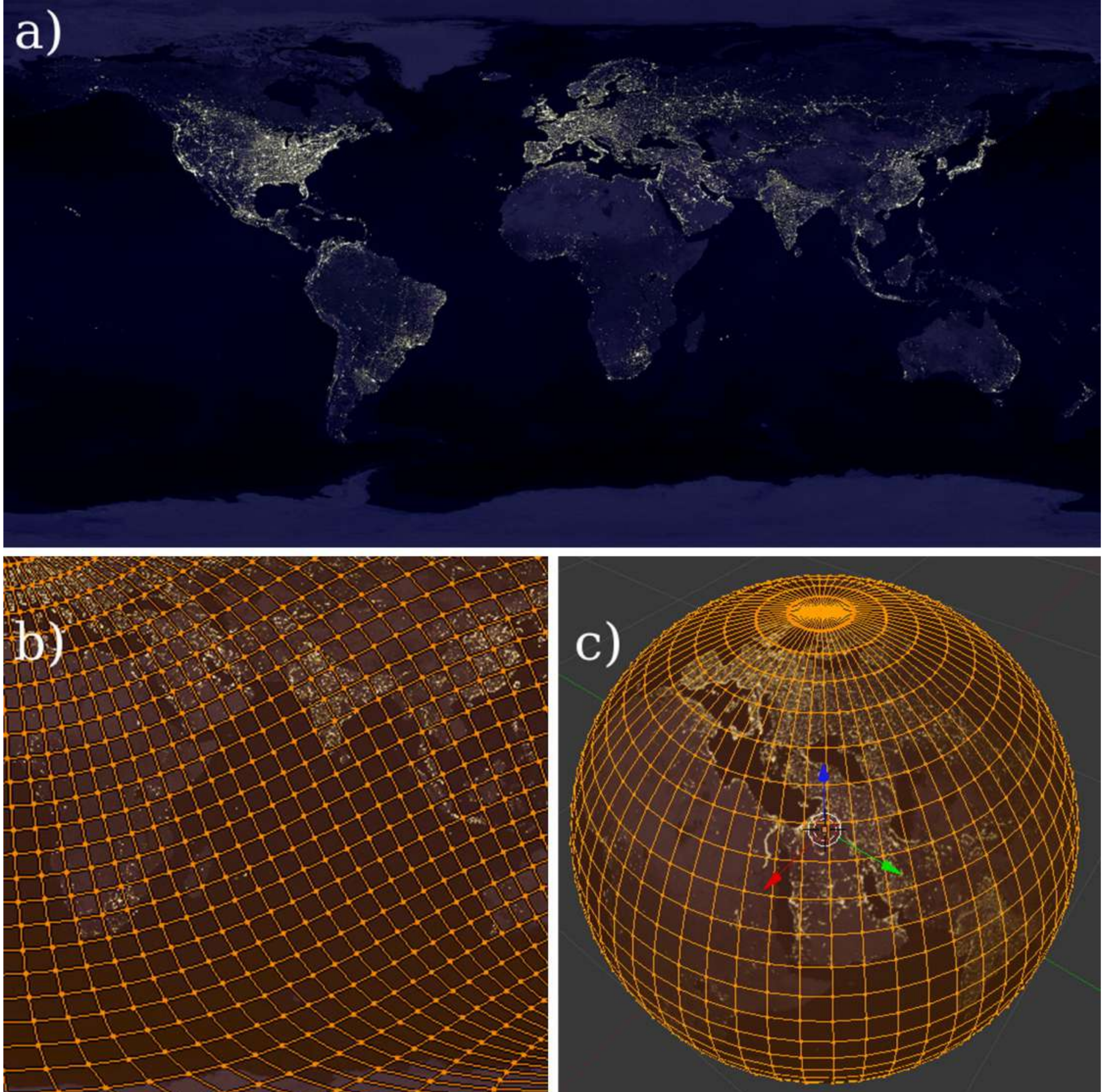
Examples



Planetary Models

- High resolution maps from orbit can be combined with atmospheres, backgrounds, and lighting elements for a realistic presentation.

See: http://www.blenderguru.com/videos/create-a-realistic-earth/



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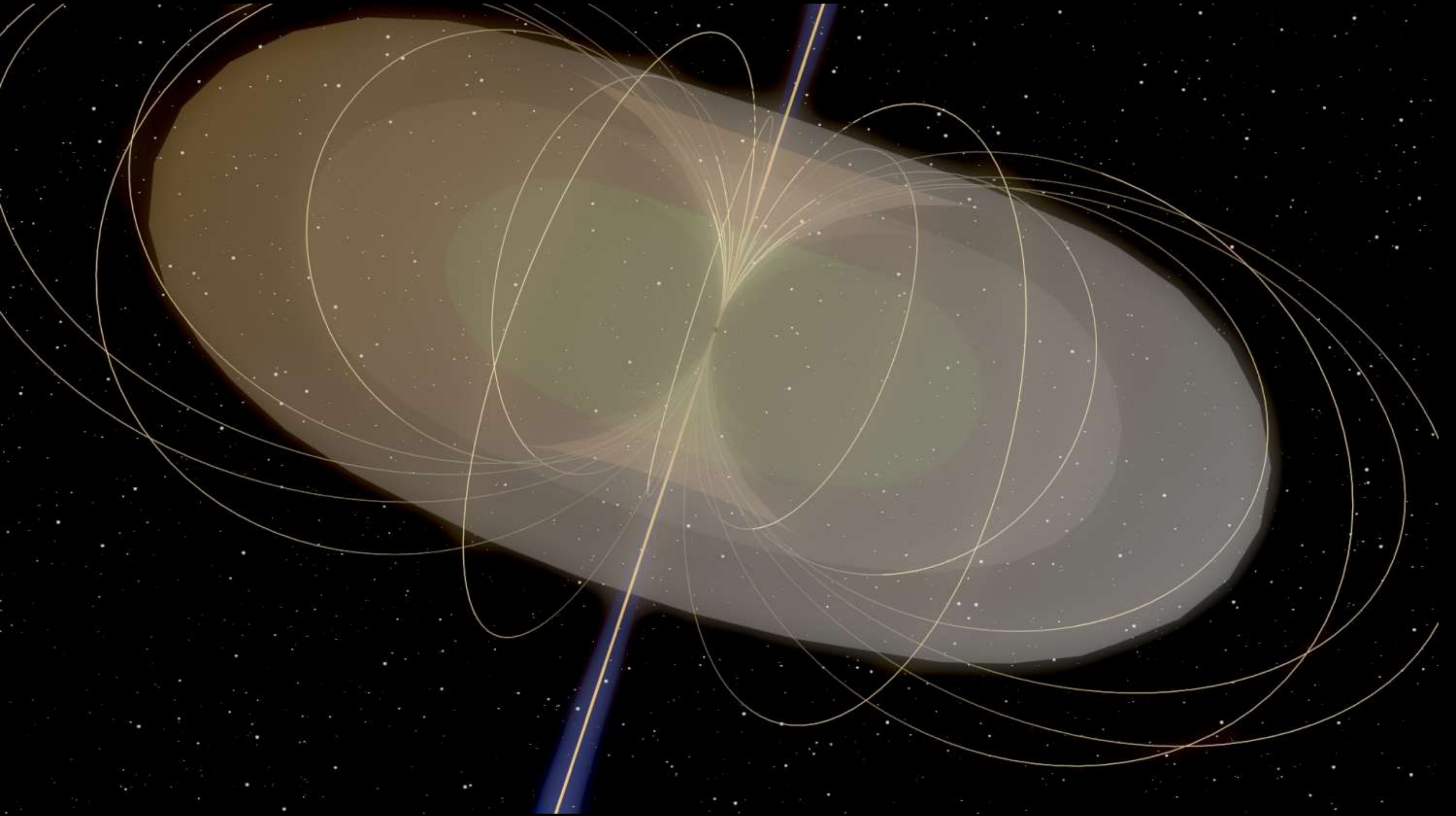
Magnetic Fields



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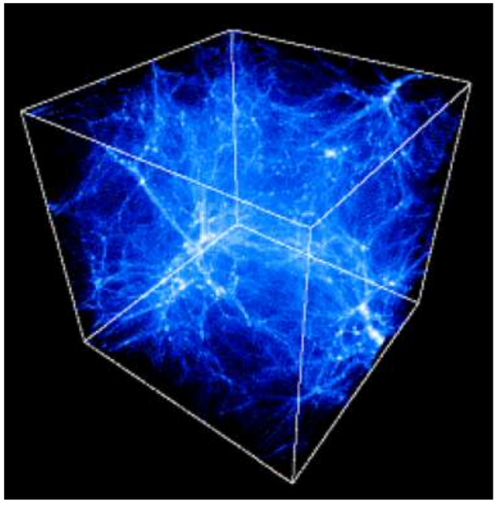
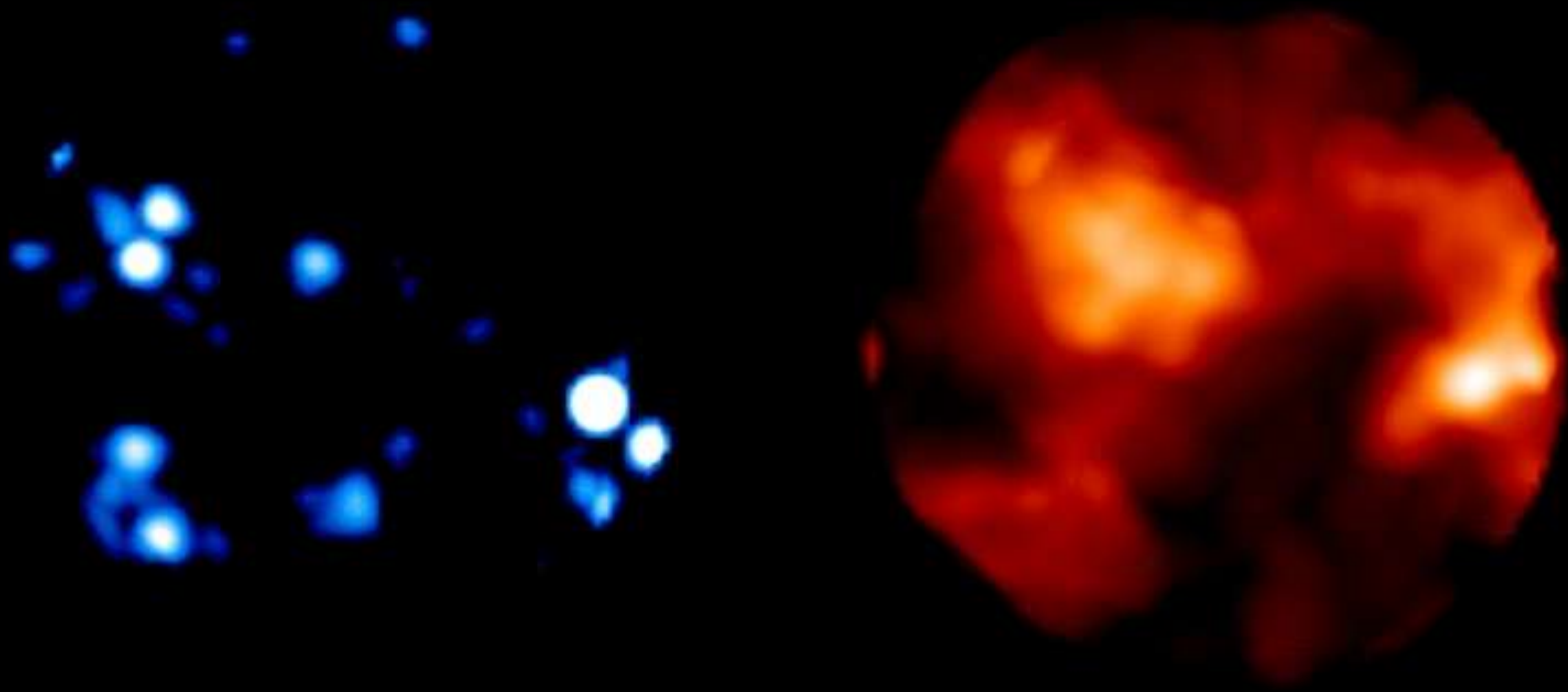
Data Cubes

- Gridded data can come from telescopes or simulations
- Radio telescopes produce grids that cover...
  - Two sky coordinates (X and Y)
  - Frequency (Z - the doppler shifted velocity)
- These cubes can show the dynamics of galaxies, planetary disks, and large scale structure formation of clusters



Data Cubes

- Density maps of the nearby Universe can be created on regularly spaced grids.
- The results of these surveys allow to study not only the density of galaxies in 3D, but also the effects of gravity in the same regions of space...



Data from Saunders et al. 2000 and Schmoldt et al. 1999

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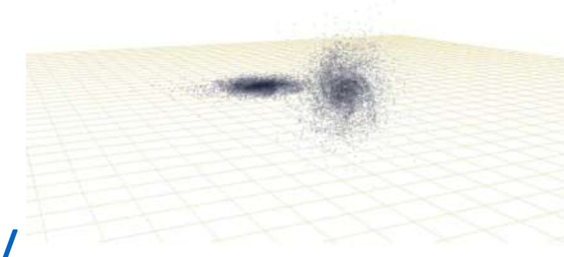
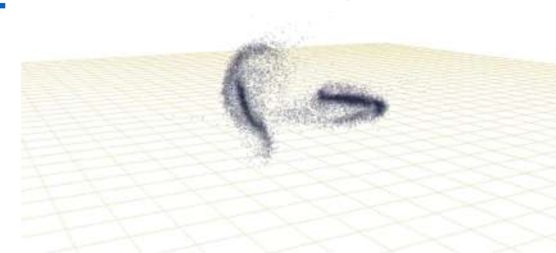
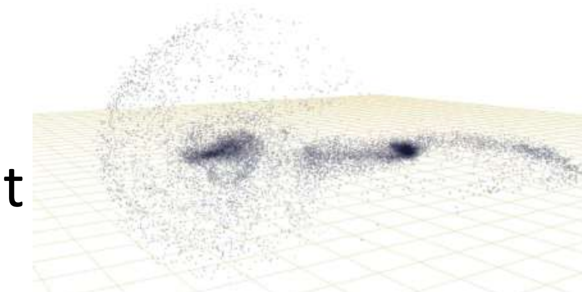
N-body Simulations

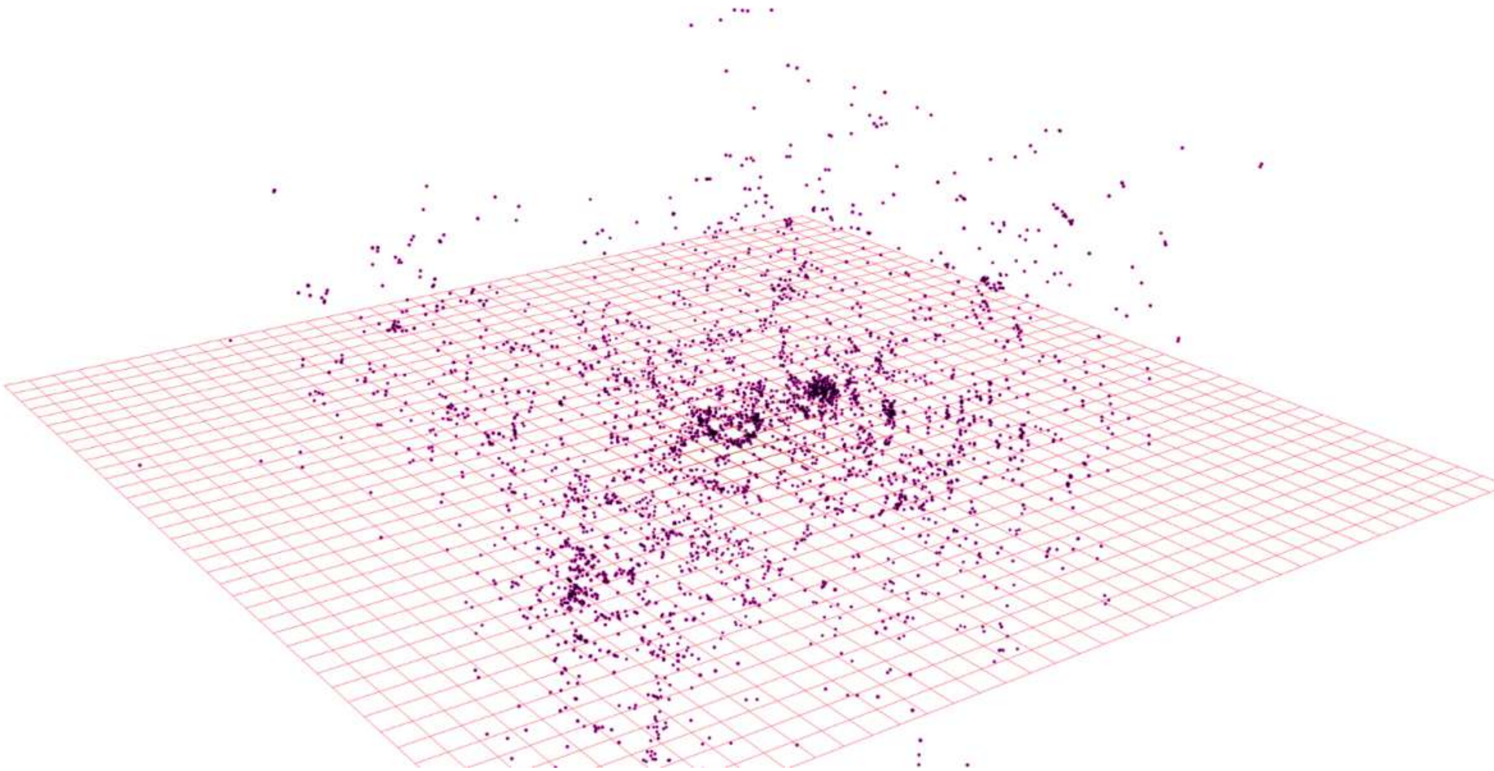
- Data generated from GADGET-2 (Galaxies and Dark Matter Interacting 2) N-body/SPH code:
  - http://www.mpa-garching.mpg.de/gadget/
- 30,000 particles, 1100 snapshots run for 2 billion years
- Blender Python interface used to bring XYZ position data into the vertices of Blender objects
- Objects are “textured” with Halos.
- Each grid square is approximately 33,000 light years







Galaxy Catalogs



Courtois et al. 2009 and the extragalactic distance database

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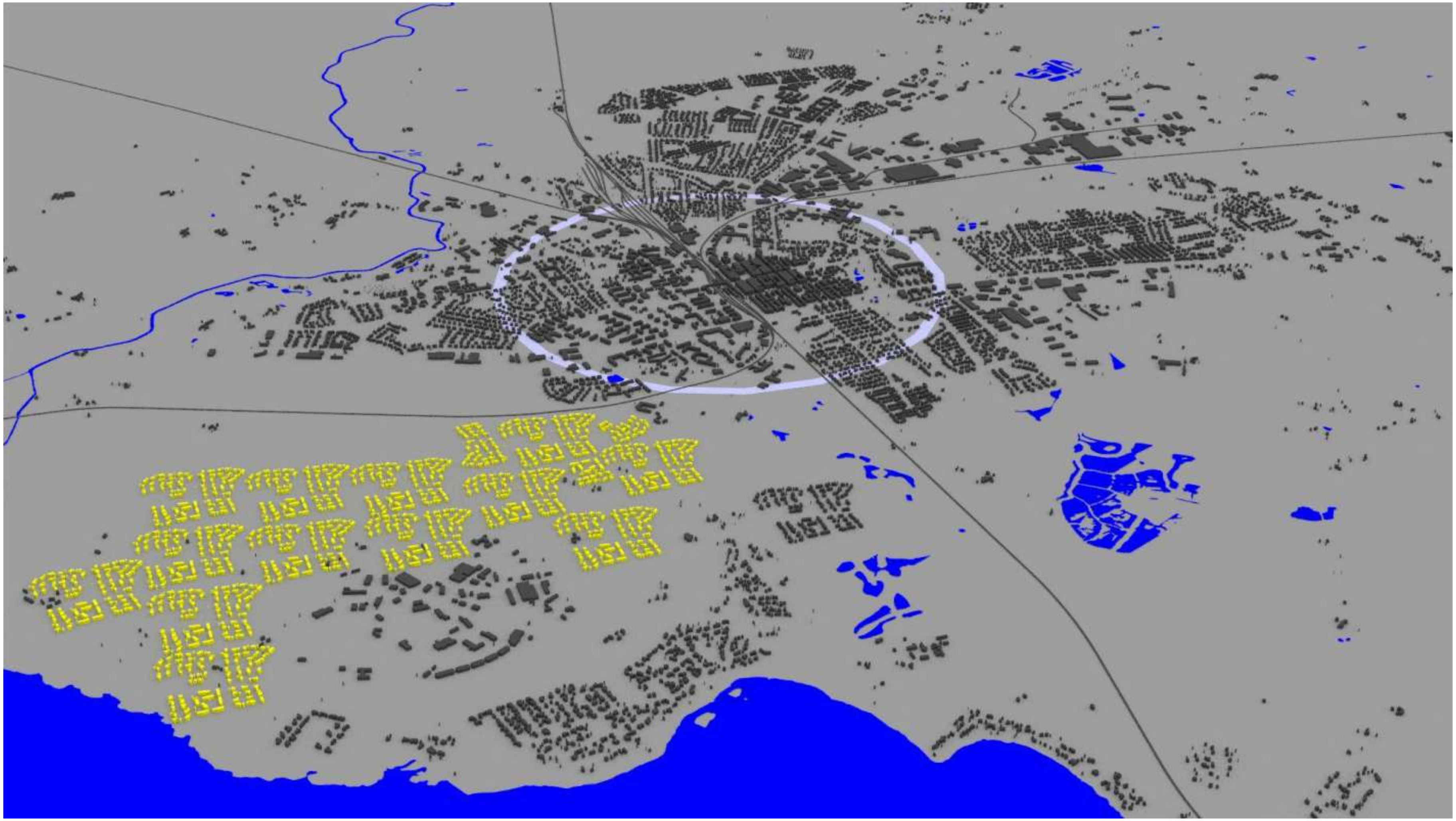
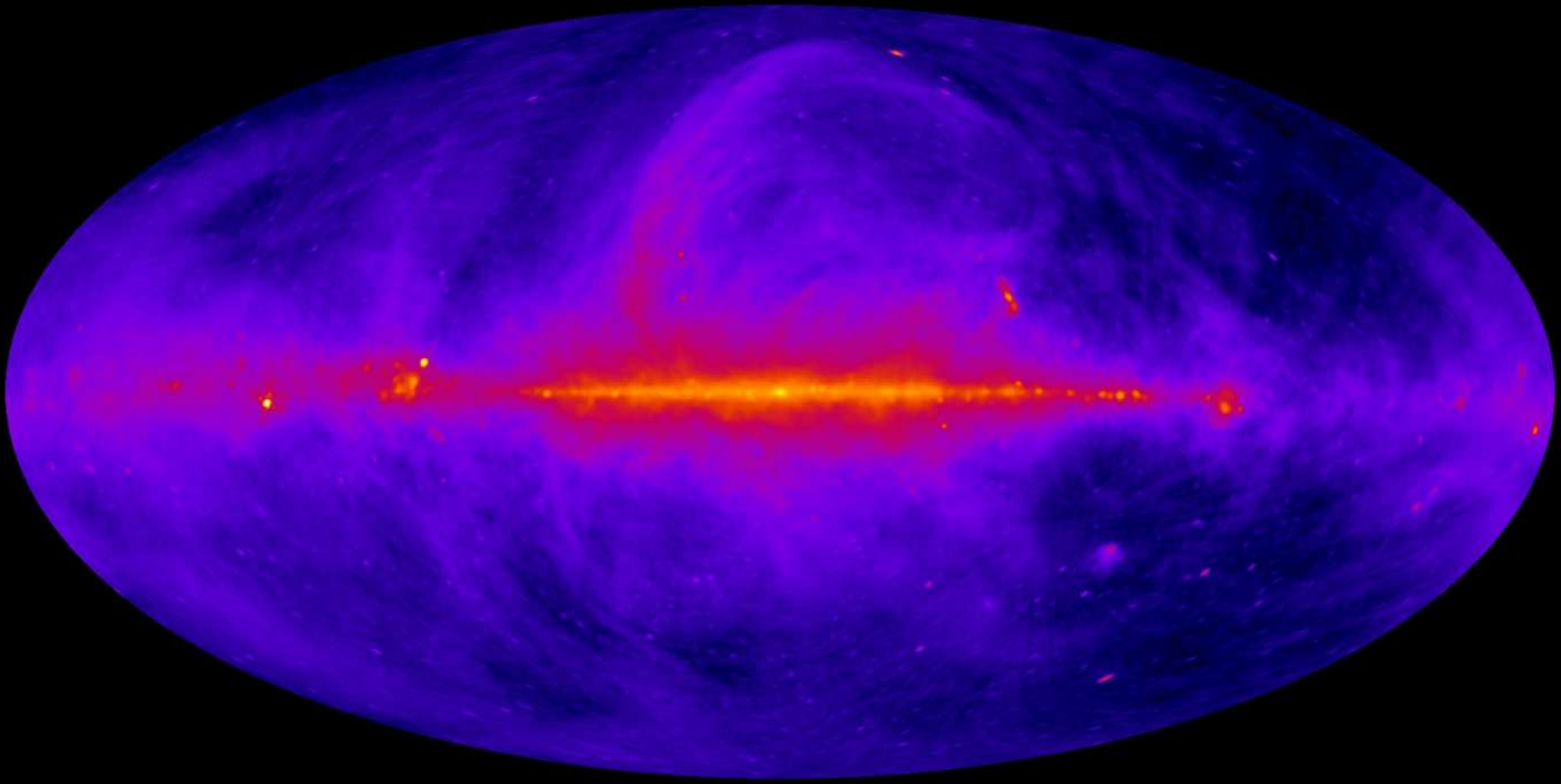
Other Sciences: Biology

http://www.bioblender.org

Other Fields: Geography



http://kodex.tumblr.com/post/37038839550/visualising-qgis-data-with-blender



408 MHz NASA SkyView or Montage (Berriman et al.)
Google Spatial Media Module

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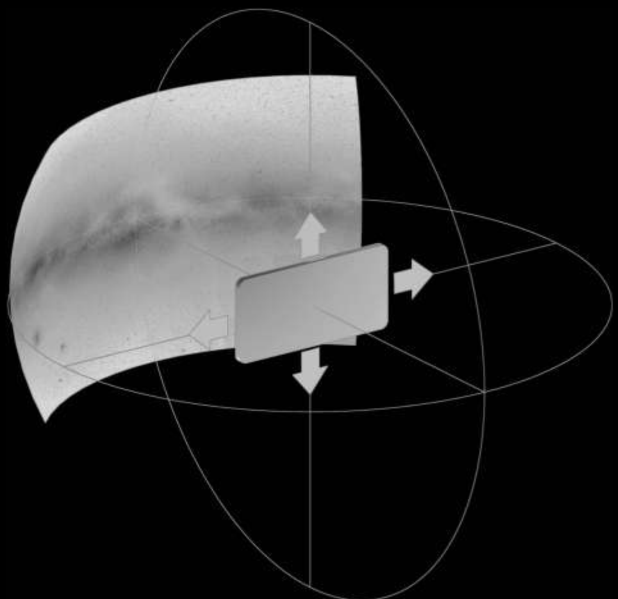
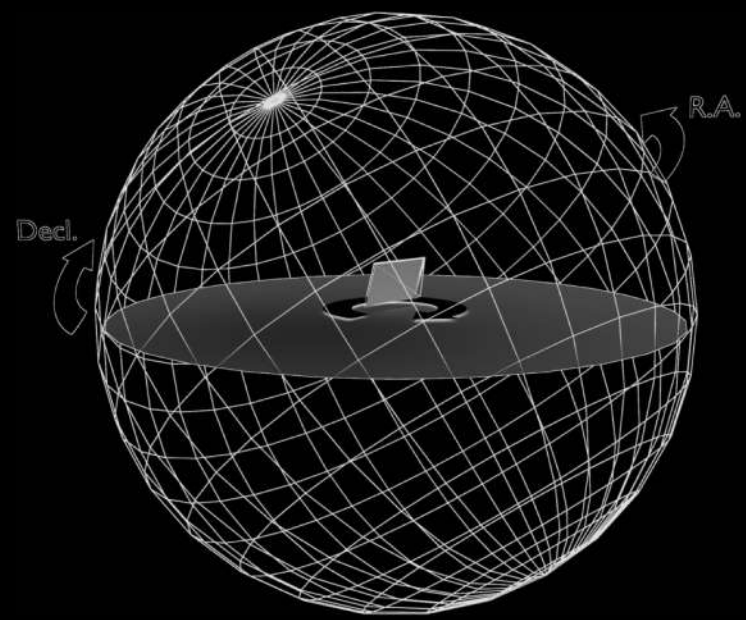
360 Panoramas (Kent 2017)

http://iopscience.iop.org/article/10.1088/1538-3873/aa5543





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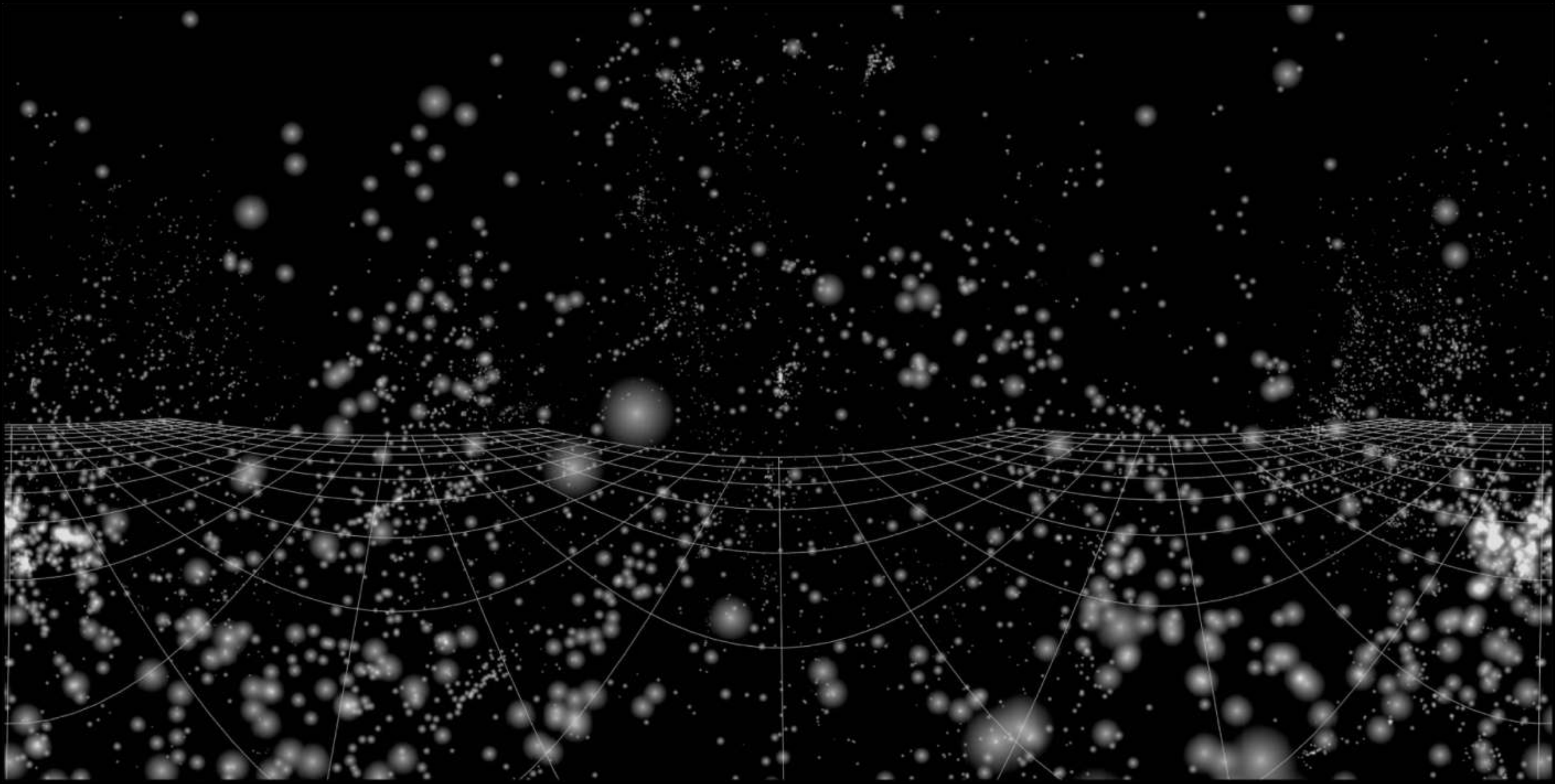
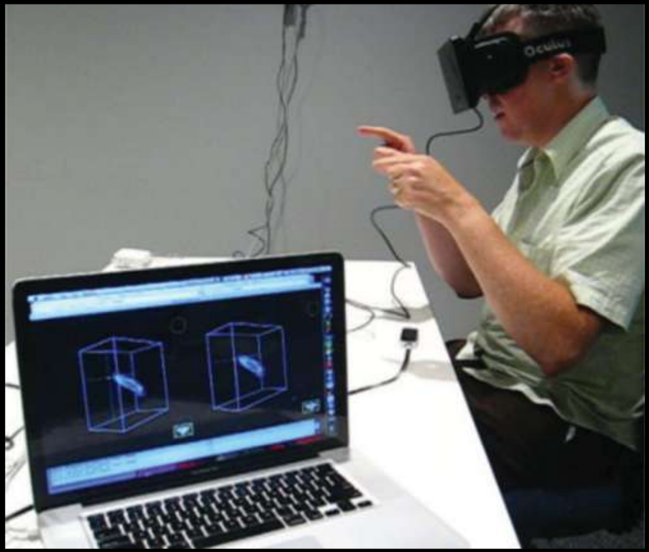


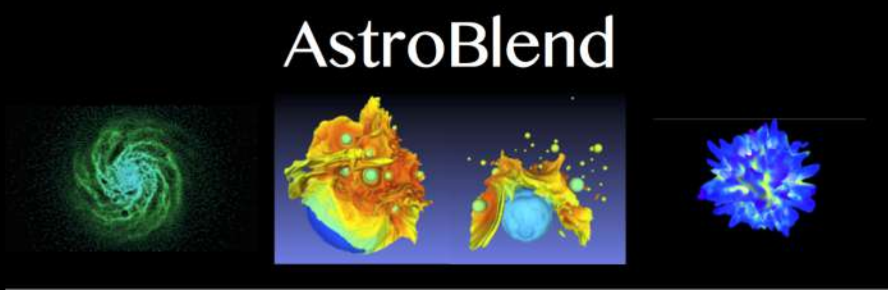
Courtois and Tully et al. Extragalactic Distance Database

https://www.youtube.com/watch?v=vW93wkDqz54

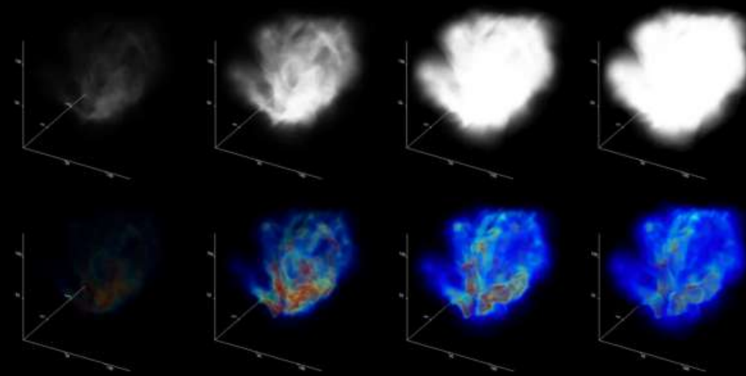


Fluke et al. 2018

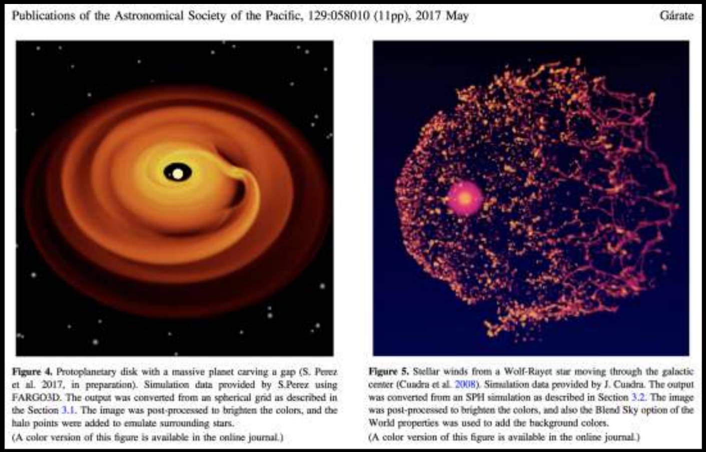
Vohl et al. 2017



Jill Naiman et al.



Rhys Taylor et al.



Publications of the Astronomical Society of the Pacific, 129:058010 (11pp), 2017 May — Gárate

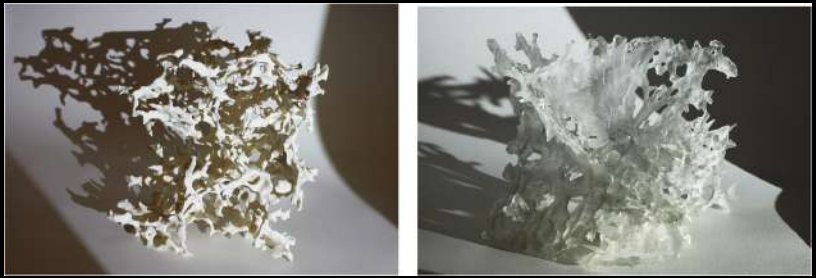
Figure 4. Protoplanetary disk with a massive planet carving a gap (S. Perez et al. 2017, in preparation). Simulation data provided by S.Perez using FARGO3D. The output was converted from an spherical grid as described in the Section 3.1. The image was post-processed to brighten the colors, and the halo points were added to emulate surrounding stars.
(A color version of this figure is available in the online journal.)

Figure 5. Stellar winds from a Wolf-Rayet star moving through the galactic center (Cuadra et al. 2008). Simulation data provided by J. Cuadra. The output was converted from an SPH simulation as described in Section 3.2. The image was post-processed to brighten the colors, and also the Blend Sky option of the World properties was used to add the background colors.
(A color version of this figure is available in the online journal.)

Matias Garate et al.

Education and public outreach

Thomas Madura



Benedikt Diemer and Isaac Facio

NRAO NINE Program

PASP Special Issue

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Edited by Brian R. Kent

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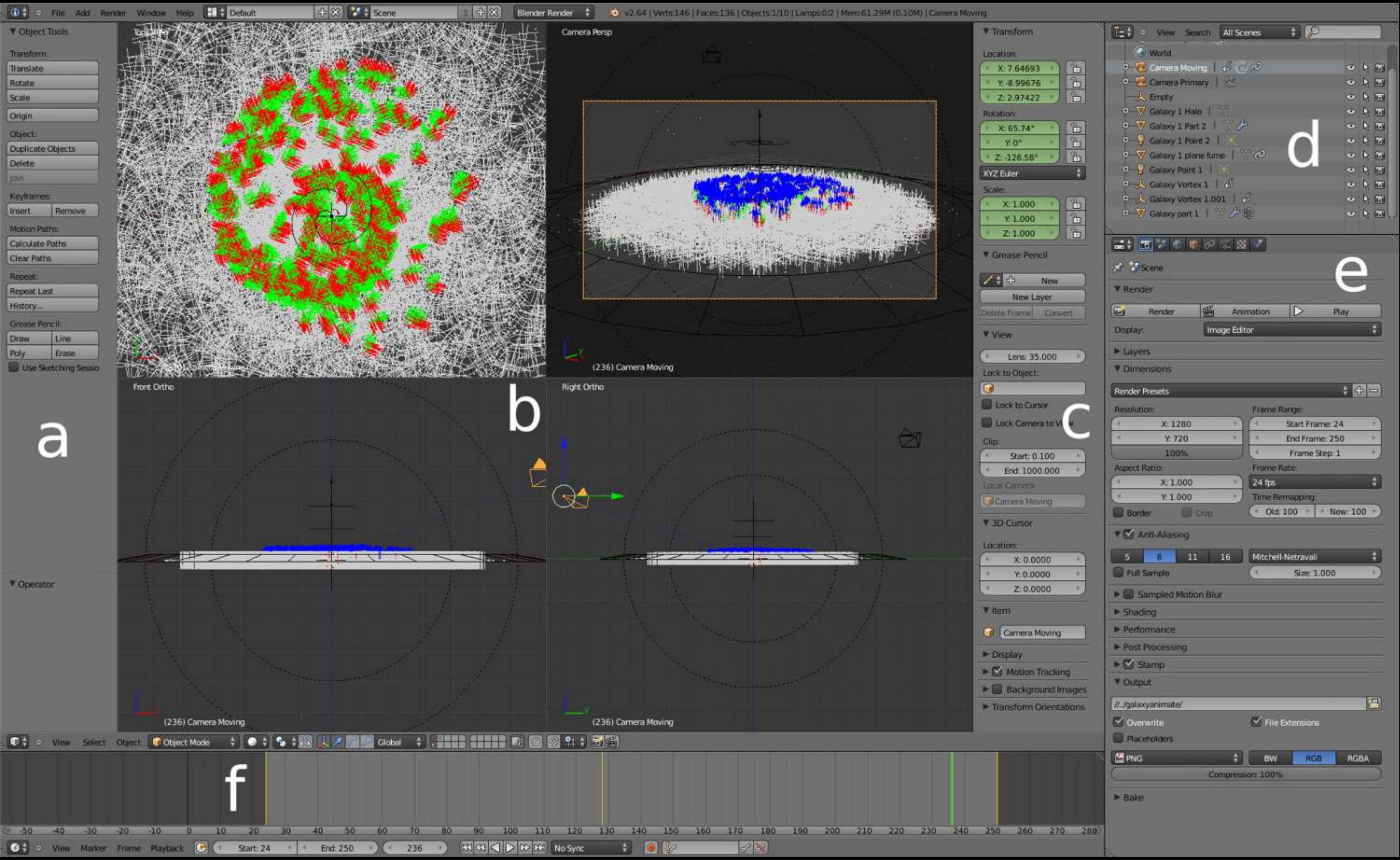
PUBLISHED FOR THE ASTRONOMICAL SOCIETY OF THE PACIFIC BY IOP PUBLISHING

http://iopscience.iop.org/journal/1538-3873/page/Techniques-and-Methods-for-Astrophysical-Data-Visualization

A Tour of the Blender Interface



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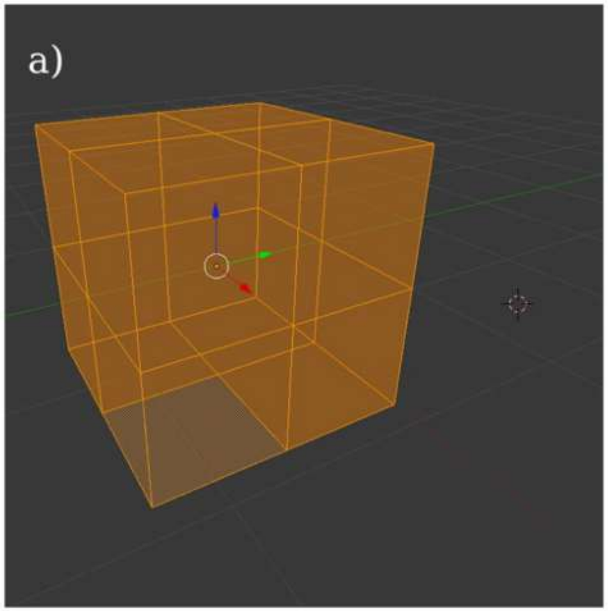
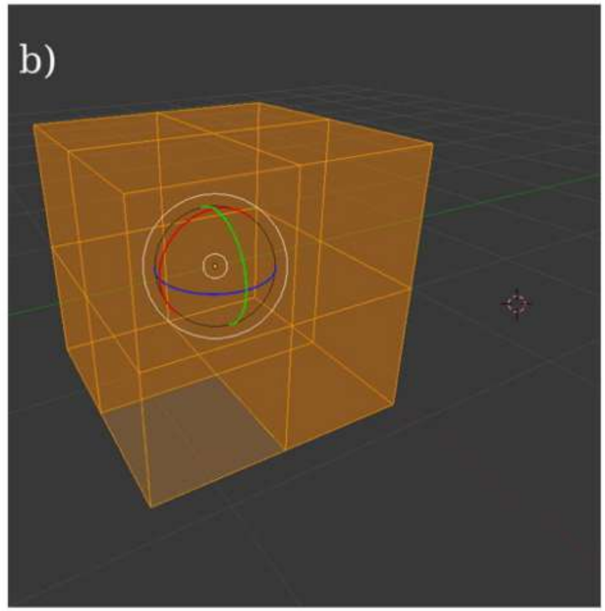
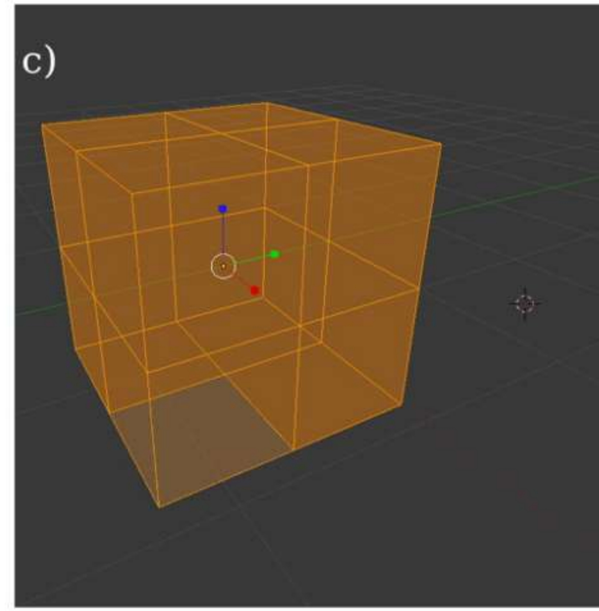
Blender interface



Translation

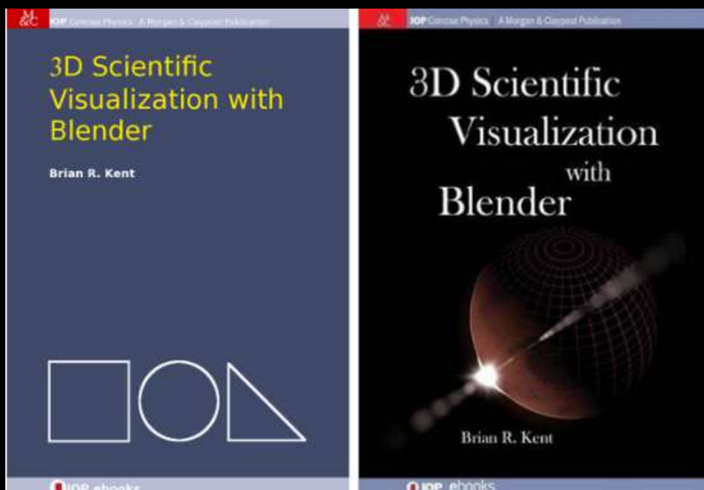


Rotation



Scaling

Interesting in learning more?



Book and tutorials available at:

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

https://www.youtube.com/VisualizeAstronomy

Twitter and Instagram: @VizAstro

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