3D visualization of astronomy data using immersive displays

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Our testbed galaxy: NGC 3198

- r.a. = 10h 19m 54.99s
- dec. = +45° 32′ 58.88″
- (constellation: Ursa Major)
- redshift = 0.00227
- distance = 31 Mly = 9.5 Mpc
- type: SB(rs)c

[Images of the galaxy in infrared (Spitzer), near IR/optical (SDSS), and ultraviolet (GALEX) bands]
Radio data cubes of galaxies

We can probe galactic motion using Doppler shift of the HI 21 cm spectral line

The resulting 3D **data cube** has 2 spatial dimensions and 1 velocity dimension
A typical radio-astronomer desktop (Karma)

NGC 3198 HI moment 0 data from the THINGS survey
Even with automated analysis systems, direct inspection of the data remains critical to ensure proper operations and to foster discovery [Hassan and Fluke 2011, PASA, 28, 150-170]

*Our brain works in 3D and we have 3D displays, why not use them to visualize our 3D data?…*

The interface between the machine and the human brain is the bottleneck in the interpretation of complex astronomical data [Norris 1994, ASPCS, 61, 51]

*Visualization tools have to be more user-friendly, is Virtual Reality the key?*

Still an active field of research – “The equivalent expertise that exists for classical interfaces such as mouse and keyboard is, however, still missing” [Punzo et al 2015, A&C, 12, 86-99]
What do we mean by 3D visualization?

The world as represented in the visual arts tradition

The world as we actually perceive it

2D
- slices/projections
- on any personal computer

flat 3D
- perspective
- and shading

stereo 3D
- stereoscopy
- (fixed viewpoint)

virtual reality
- stereoscopy + motion parallax
- on advanced displays: dual projectors, tracking cameras
3D displays for Virtual Reality

fish tanks

- a CAVE by Visbox

headsets

- the “Rift” by Oculus (Facebook)
- the “Vive” by HTC / Valve
The CAVE on U of M campus at HCI lab
# Virtual Reality with the Unity engine

<table>
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<td>Flystick wand</td>
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- Specialized software provided with the hardware
- Middleware for interfacing with VR systems

- 3D models of objects, with textures
- Camera(s)
- Lightning
- Unity, a popular cross-platform visual development environment for 3D (gaming) applications
- C# scripts defining behaviours of objects
Loading the astronomical data

standard for data storage: **FITS** = Flexible Image Transport System

- header
- (stacks of) images/tables = arrays of numbers

loaded as a 3D **texture**
= look-up table

- has to be defined in code, can be saved as an asset
- no floating-point format

property of a shader assigned to a material attached to an object
Volume rendering: ray casting in a cube of scalar data

Data cube loaded as a 3D texture and sampled along each line-of-sight (on the GPU, using custom shaders)

Multi-pass algorithm:
- XNA/Direct3D project by Kyle Hayward (posted on his blog, 2009)
- Unity project by Brian Su (posted on Unity forums and github, 2010)

Single-pass algorithm:
- “Render to 3D Texture” demo from the NVIDIA OpenGL SDK 10 Code Samples
The colour transfer function defines the colour of any data point (a voxel in 3D) as a function of parameters such as intensity, velocity, coordinates.

Colour can be given in machine space vs. perceptual space

Common examples:
- Use grayscale to show emission intensity
- Use blue-red to show blueshift/redshift

Jayanne English uses visual art techniques to clarify/support information
Example: Use 3D cursor for selection

- display coordinates and data value
- select all data of the same value (iso-contouring)
- show where a voxel falls on the histogram

Example: Overlay other data

- 2D on 3D: step an optical image through the cube, segment it and attach it to the cube’s matching features
- 3D on 3D: merge data cubes (as when making 2D image composites)
Conclusion

Aims of this exploratory project:

• Get a workbench that allows us to experiment with the aspects that we feel are important for our data (e.g. proper colouring, and overlaying other data)

Come have a look at our demo here today on the zSpace
Come visit us on U of M campus to get into the CAVE

• Raise general awareness in the astro community, and build a special interest group

We welcome any questions/comments, and new collaborators!

We are on the lookout for
- funding sources/non-academic partners
- people with the relevant interdisciplinary skills