THIS PDF FILE CONTAINS 3D INTERACTIVE FIGURES FOR READERS USING ADOBE READER 8.0 OR HIGHER. CLICK ON FIGURES TO ACTIVATE 3D NAVIGATION.

SWINBURNE

CENTRE FOR ASTROPHYSICS AND SUPERCOMPUTING

Visualization-directed interactive model-fitting to spectral data cubes

CRICOS provider 00111D

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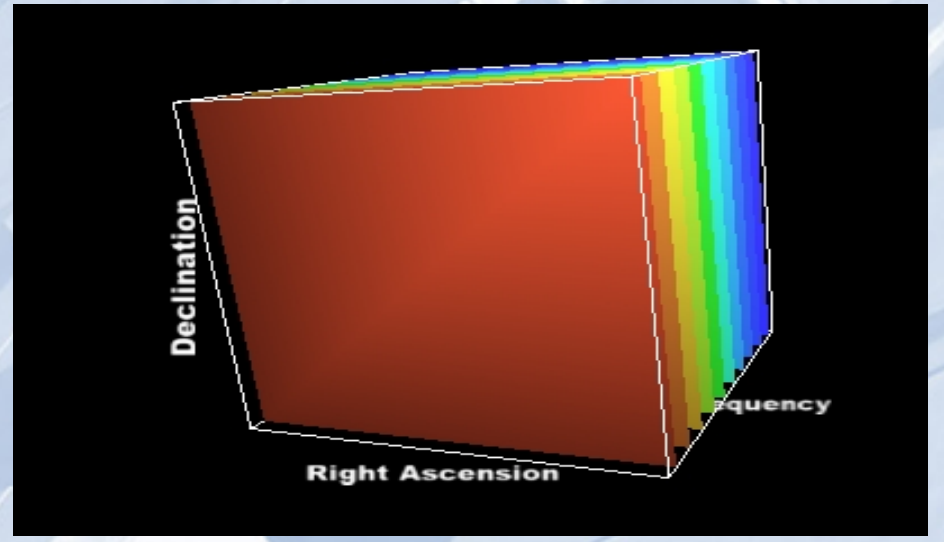
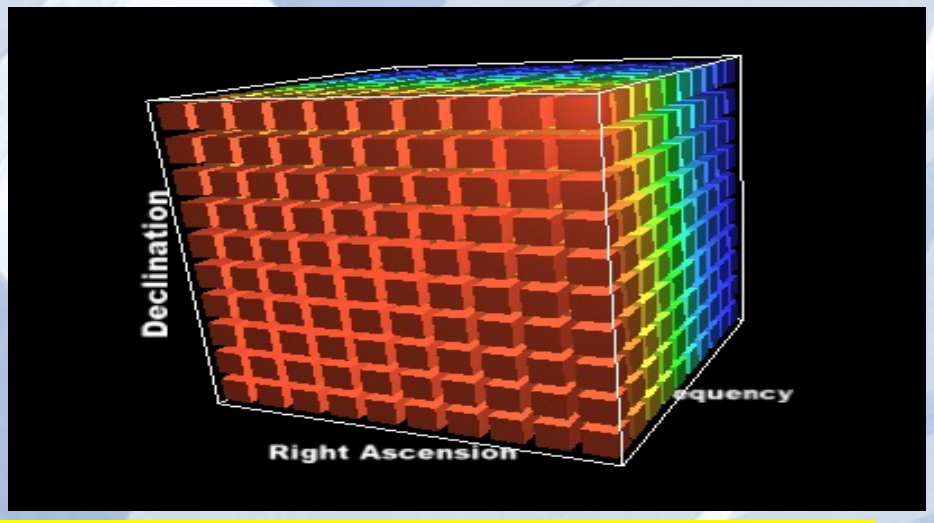
Ben Barsdell (Swin), Amr Hassan (Swin)

ADASS 2009: Sapporo, Japan

Spectral Data Cube: Definition



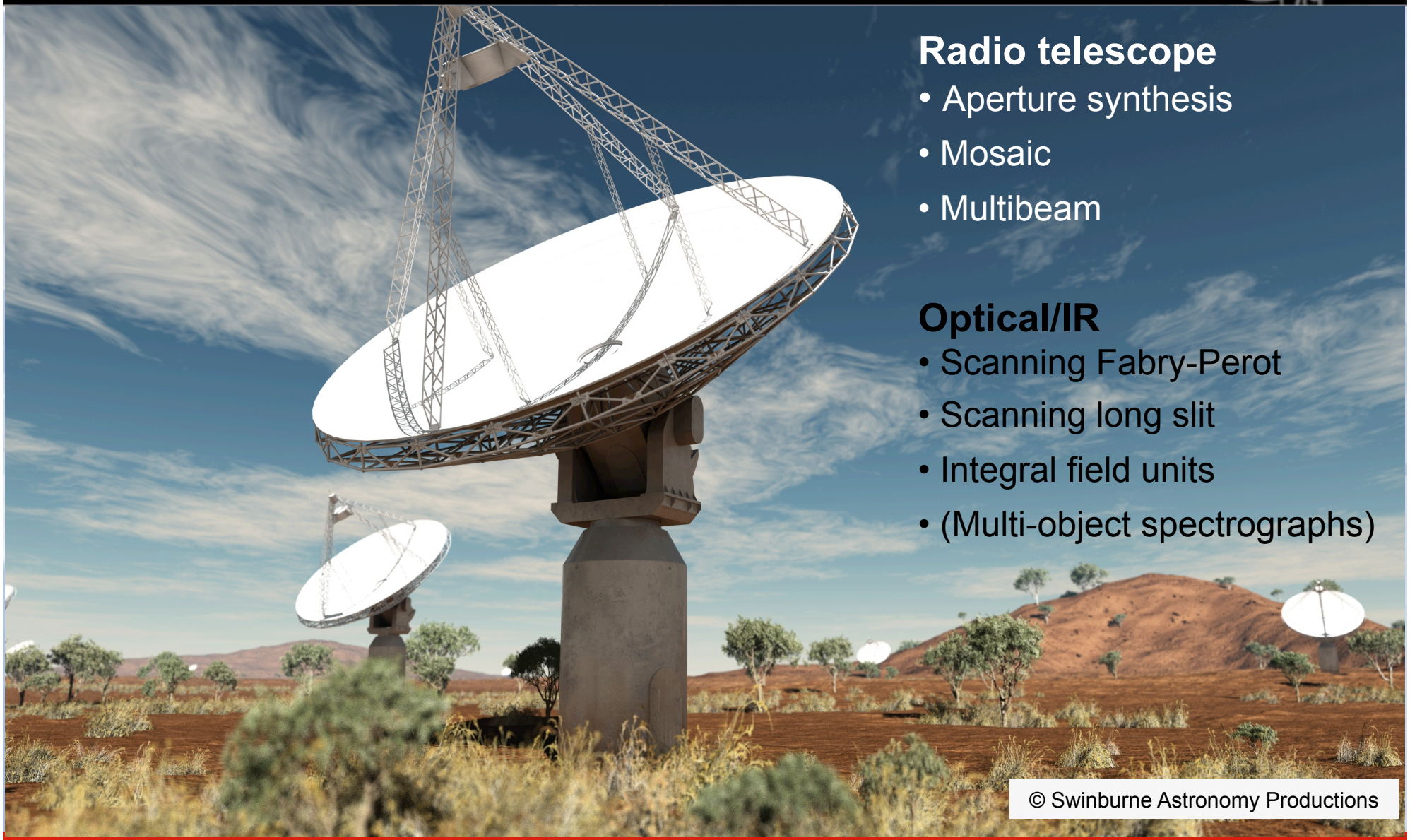


THESE ARE 3D INTERACTIVE FIGURES FOR READERS USING ADOBE READER 8.0 OR HIGHER. CLICK TO ACTIVATE.

- Dimensions:
  - 2 spatial + 1 “spectral”
- (Often) Gridded data:

$$(x, y, \lambda)$$
$$(x, y, \nu)$$
$$\downarrow$$
$$(x, y, v_{los})$$

Sources of Spectral Data Cubes



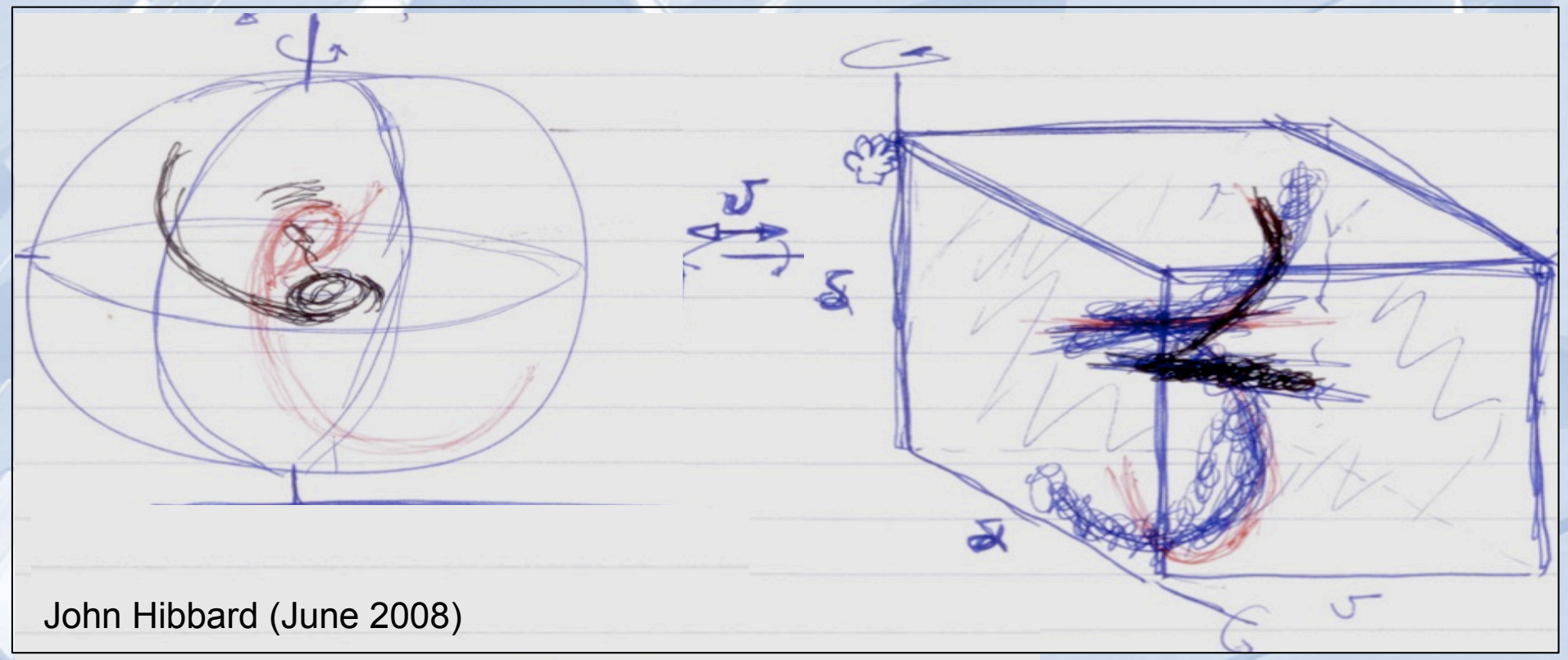
Radio telescope

- Aperture synthesis
- Mosaic
- Multibeam

Optical/IR

- Scanning Fabry-Perot
- Scanning long slit
- Integral field units
- (Multi-object spectrographs)

Simulation to Spectral Cube



6-d model space

Space: (x,y,z)

Velocity: (v_x,v_y,v_z)

3-d observation space

Space: (x, y)

Line-of-sight velocity: (v_{los})

Automated Approaches

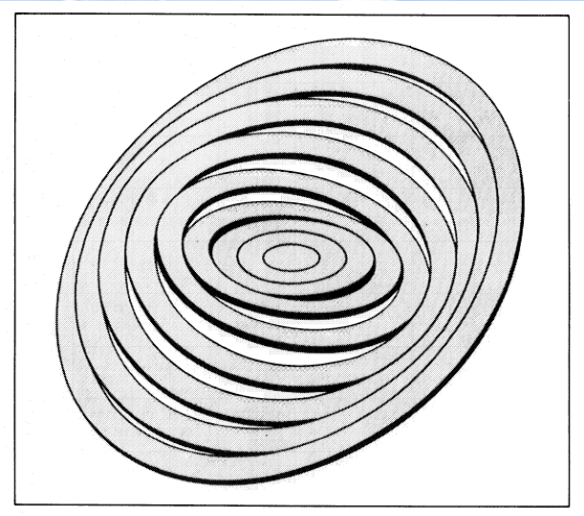


Figure 8: 3D Model

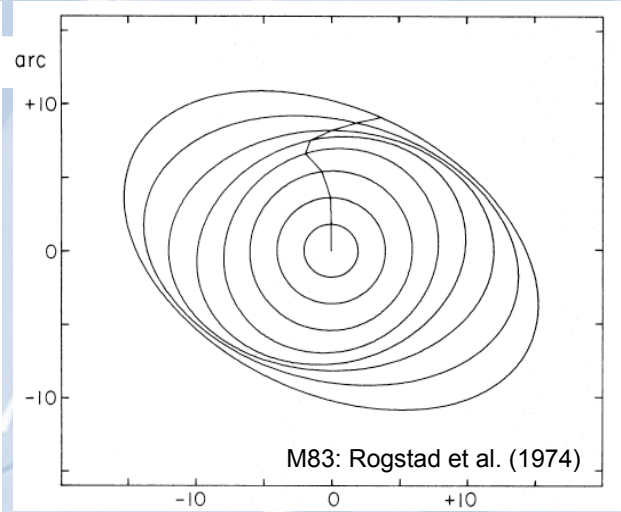


Figure 9: Projected on sky

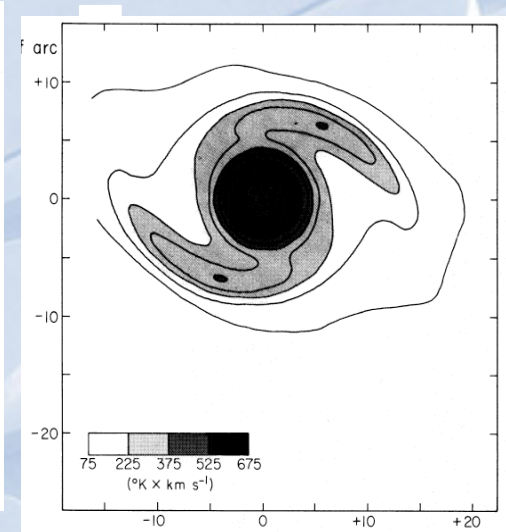


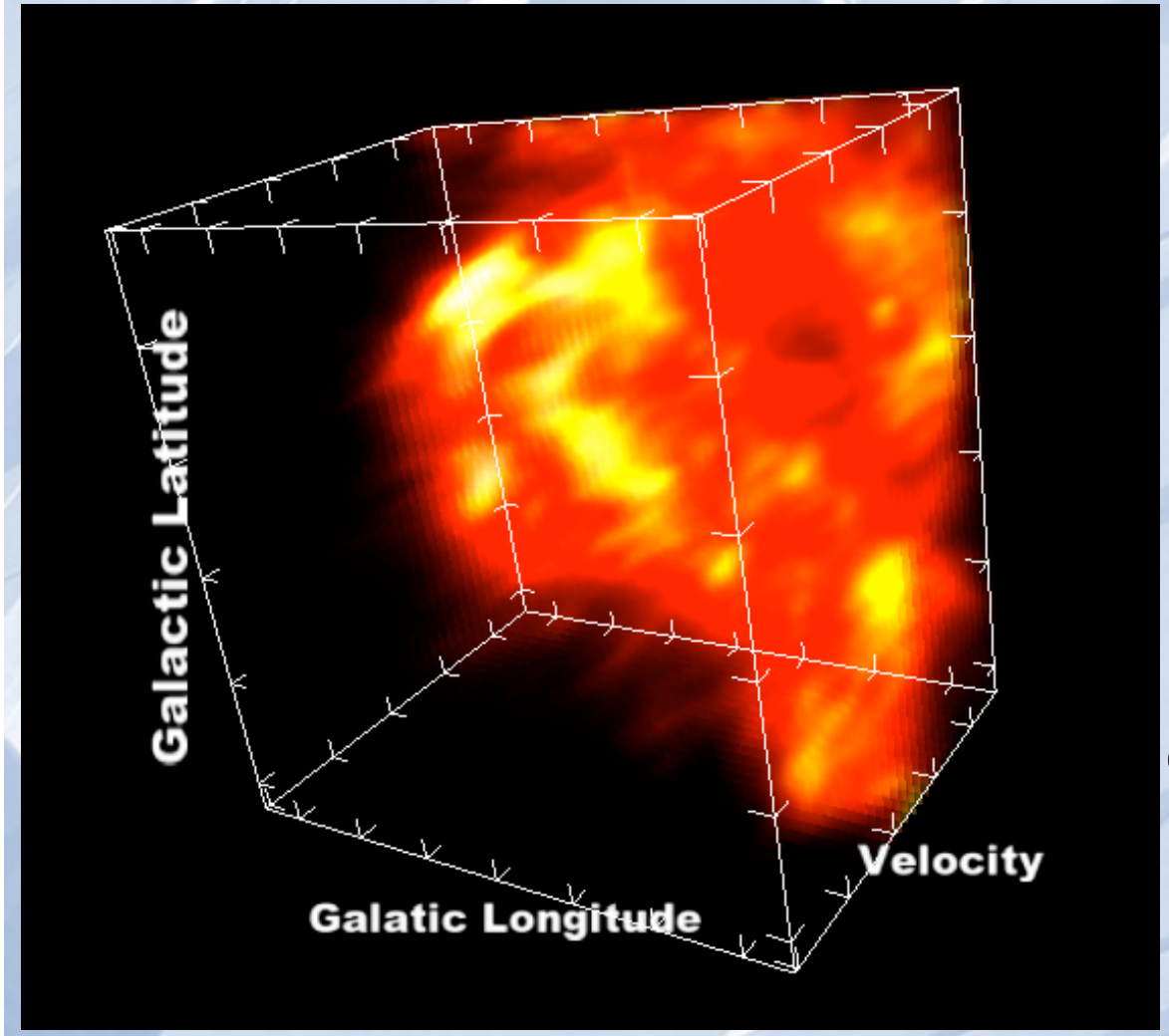
Figure 10: HI map

- Differentially rotating HI disks

  e.g. Rogstad et al. (1974); Begeman (1989)
- 4 parameters: V_{sys}, V_{circ}, i, ϕ as function of radius

- Warps? Anomalous gas? Mergers?

Visualization-directed Approach



From Canadian Galactic Plane Survey/DRAO. Courtesy J.English

Build and visualize interactive models
to
enhance intuition
and
enable fitting and analysis
of
complex kinematical structures
from
spectral data cubes

Computation

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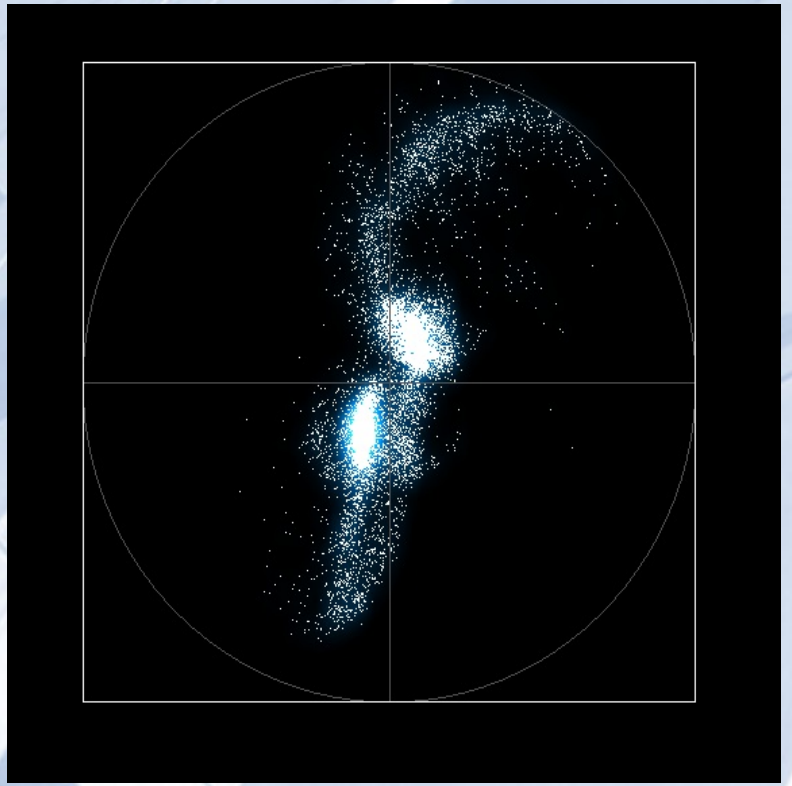
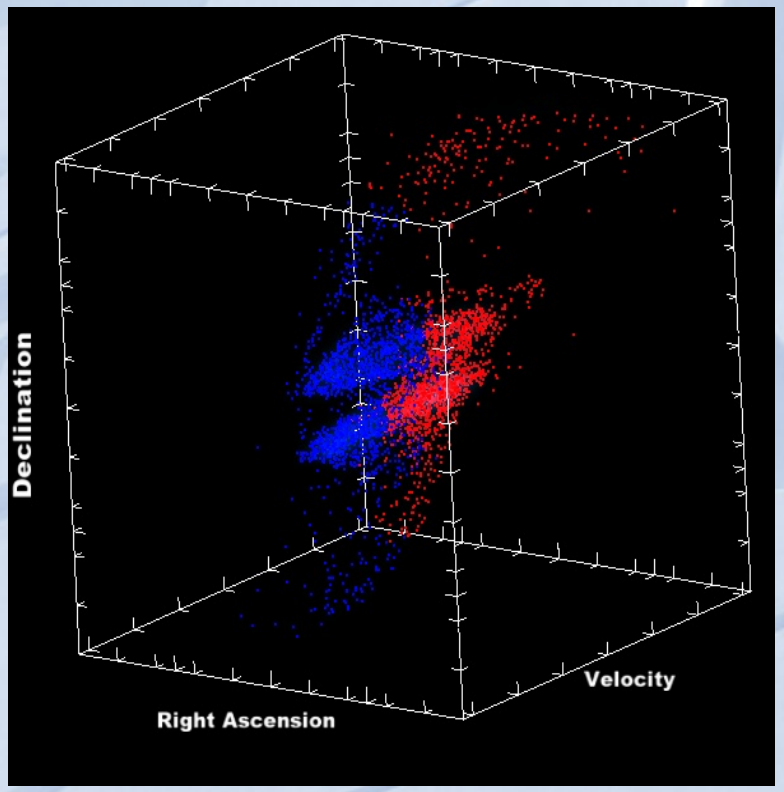




6-d model space

Camera projection from orientation

(x,y) preserved

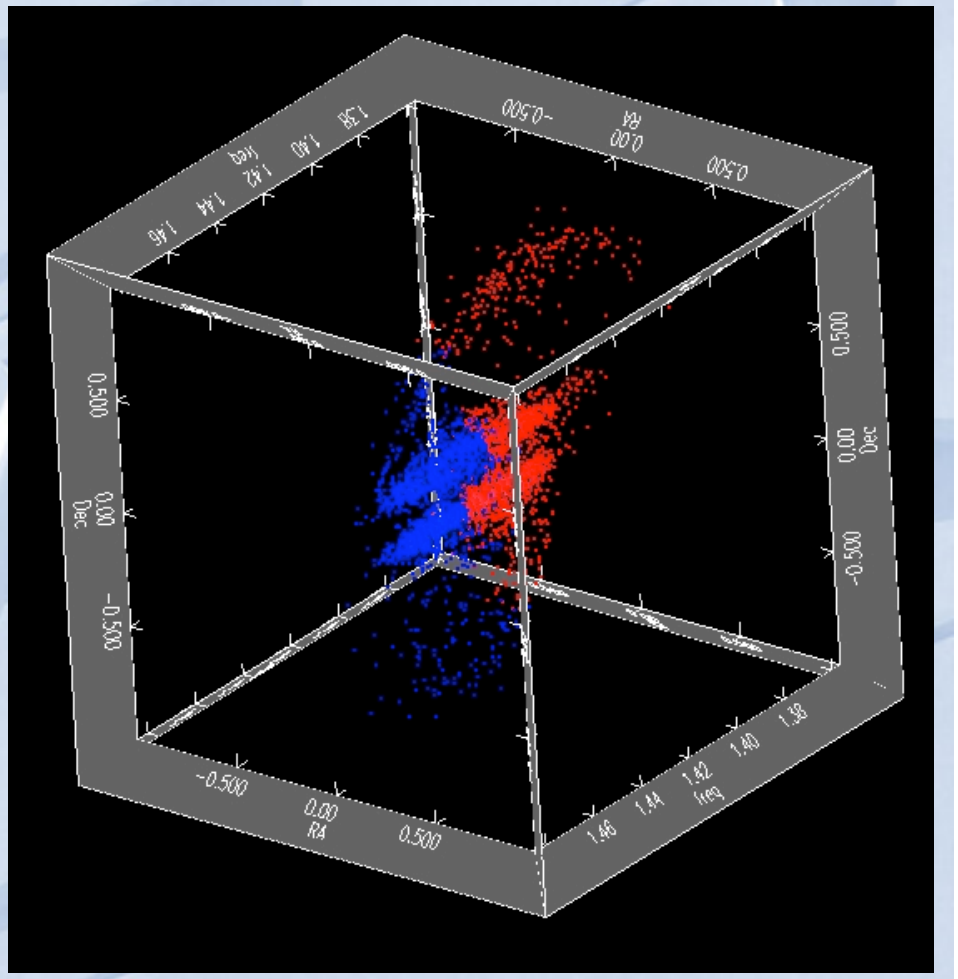
3-d observation space

Calculate v_{los} from $\mathbf{v} = (v_x, v_y, v_z)$

Add to spectral cube voxel

Technical Requirements

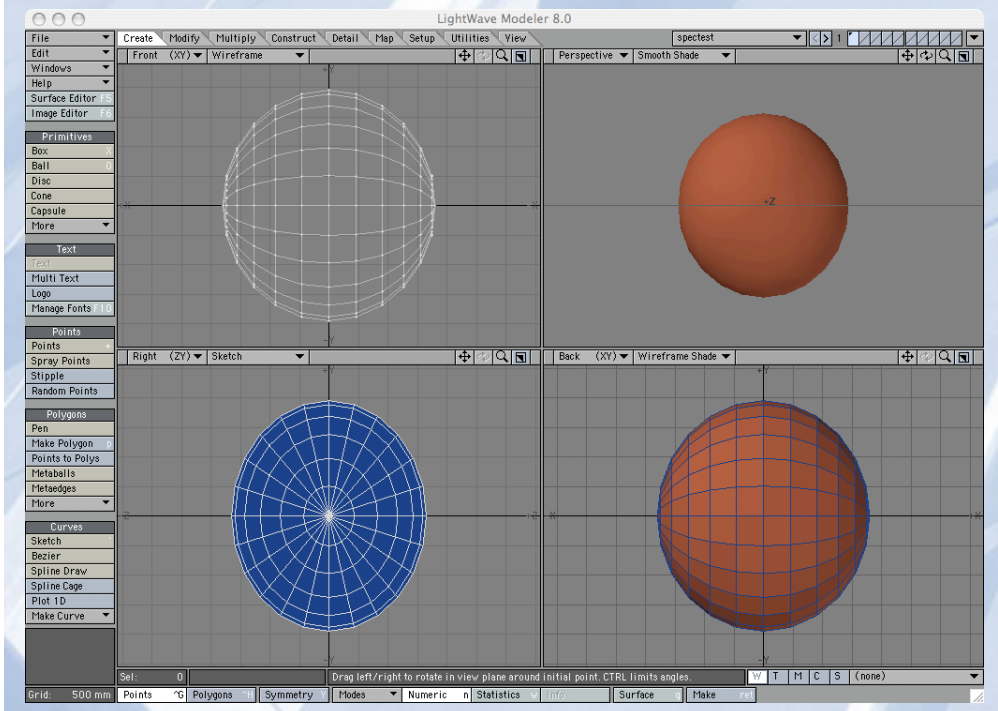
- Interactive frame-rates
- Real-time updates
- Handle simulation and data
- Volume rendering and isosurfaces
- Support stereoscopic displays
- Support 3D publication
- Simple application development



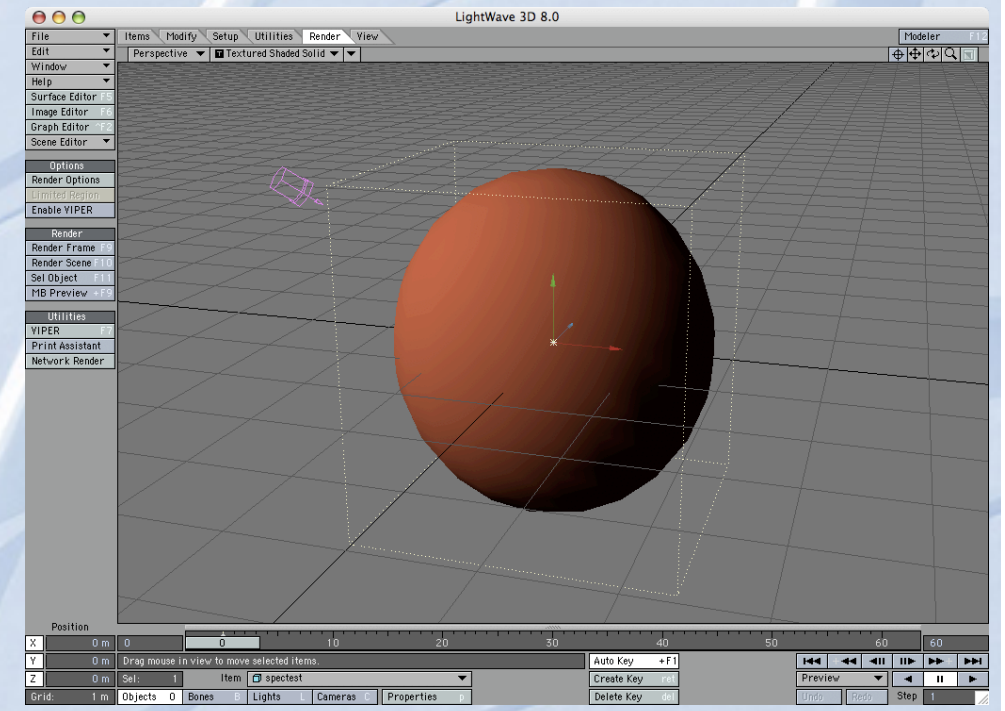
S2PLOT: Barnes et al. (2006) www.astronomy.swin.edu.au/s2plot

Comparison with LightWave

Modeler

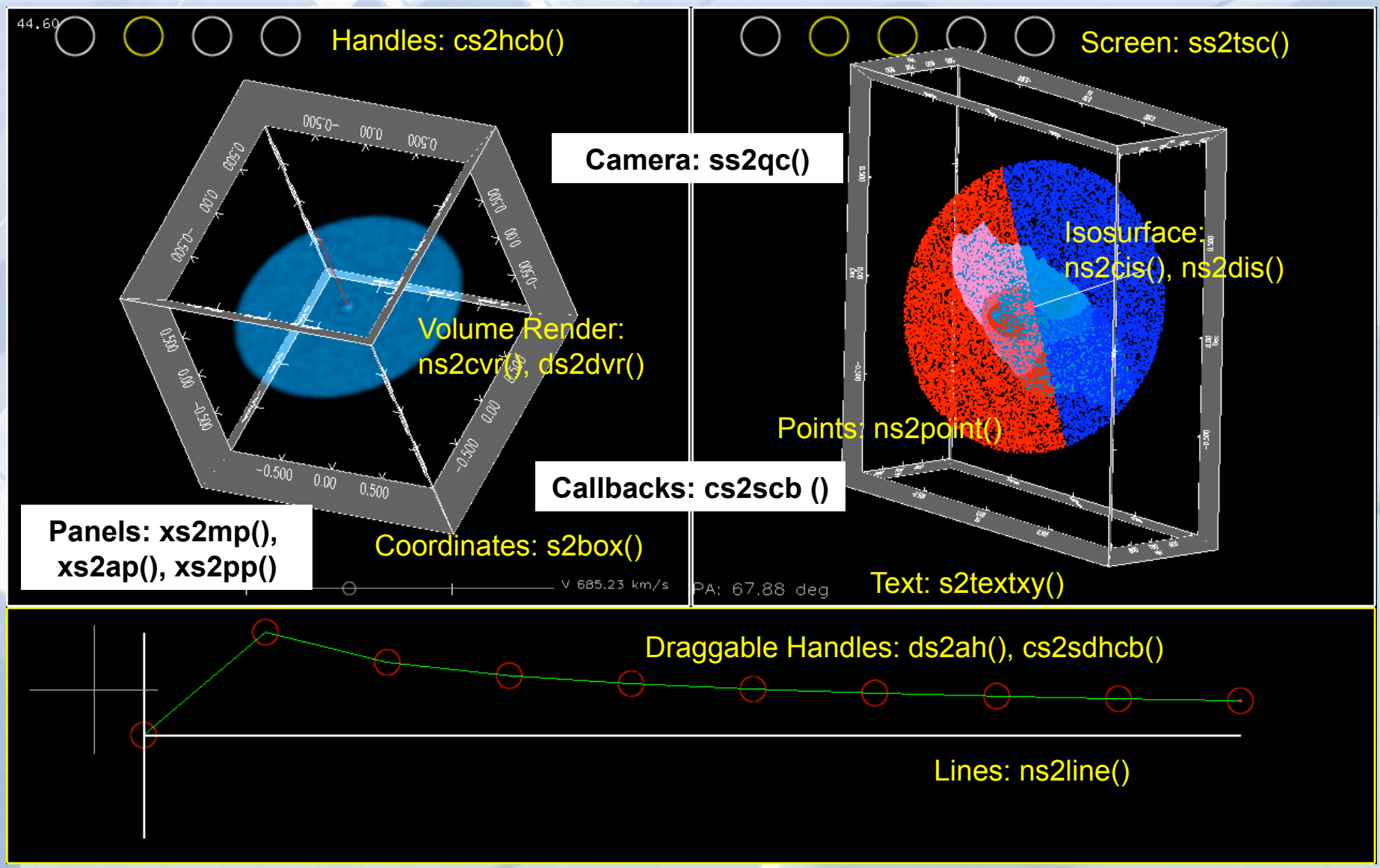


Layout: Render



Synchronization via LightWave Hub

S2PLOT Elements



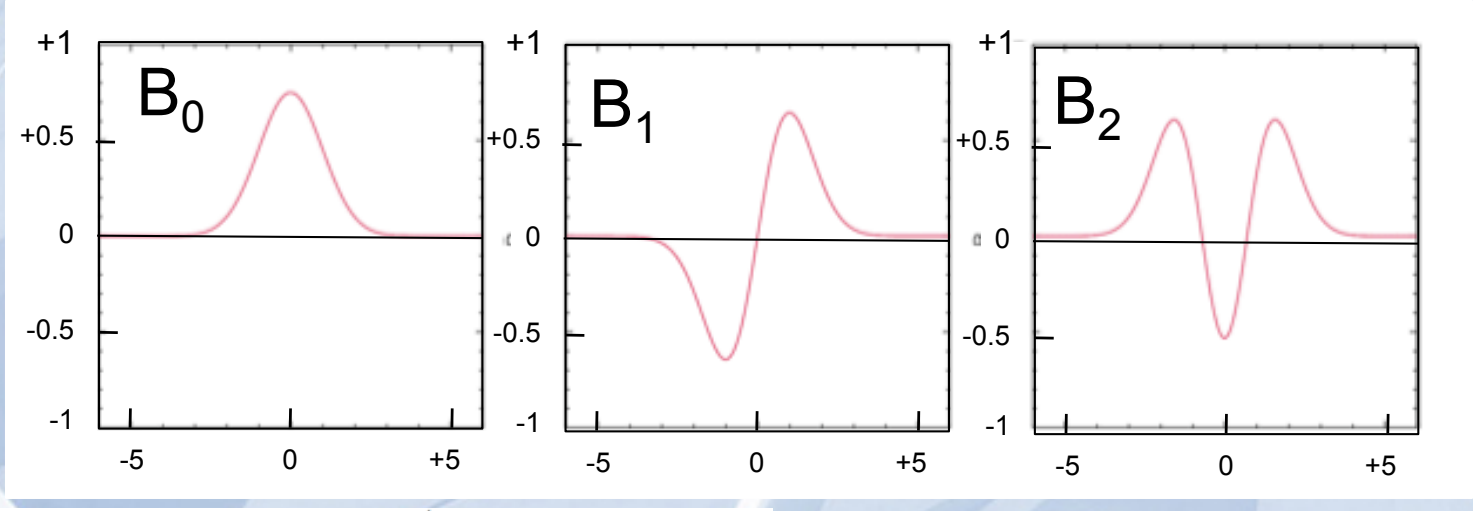
Model Elements, Controls and Tools

- V_{sys}
- Interactive Rotation curve
- Interactive Density profile
- Models:
  - Rotating disks
  - Expanding shell
  - N-body galaxies (Gadget)
- Noise!

- Warps
- Hot spots
- Jets

- **Quantitative tools:** 3-d Cartesian Shapelets

Cartesian Shapelets: Refregier (2003)



$$\phi_n(x) \equiv \left(2^n \pi^{1/2} n!\right)^{-1/2} H_n(x) e^{-x^2/2}$$

$$B_n(x;\beta) \equiv \beta^{-1/2} \phi_n(\beta^{-1} x)$$

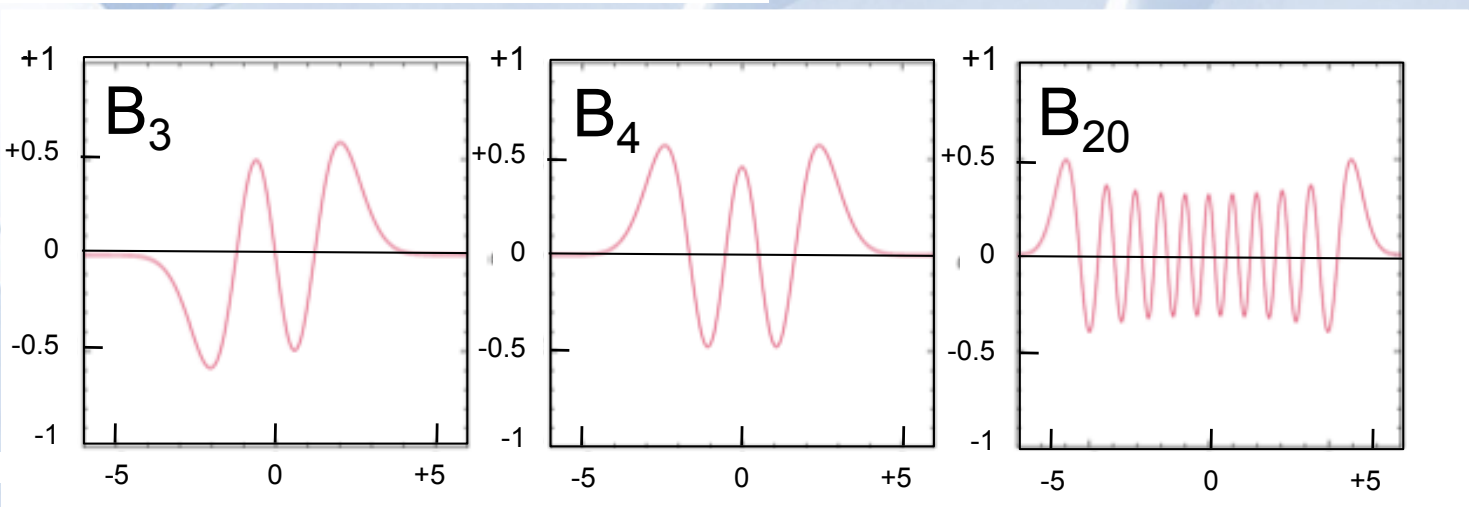


Figure courtesy: Adrian Malec (Swinburne)

2-D Shapelet Reconstruction

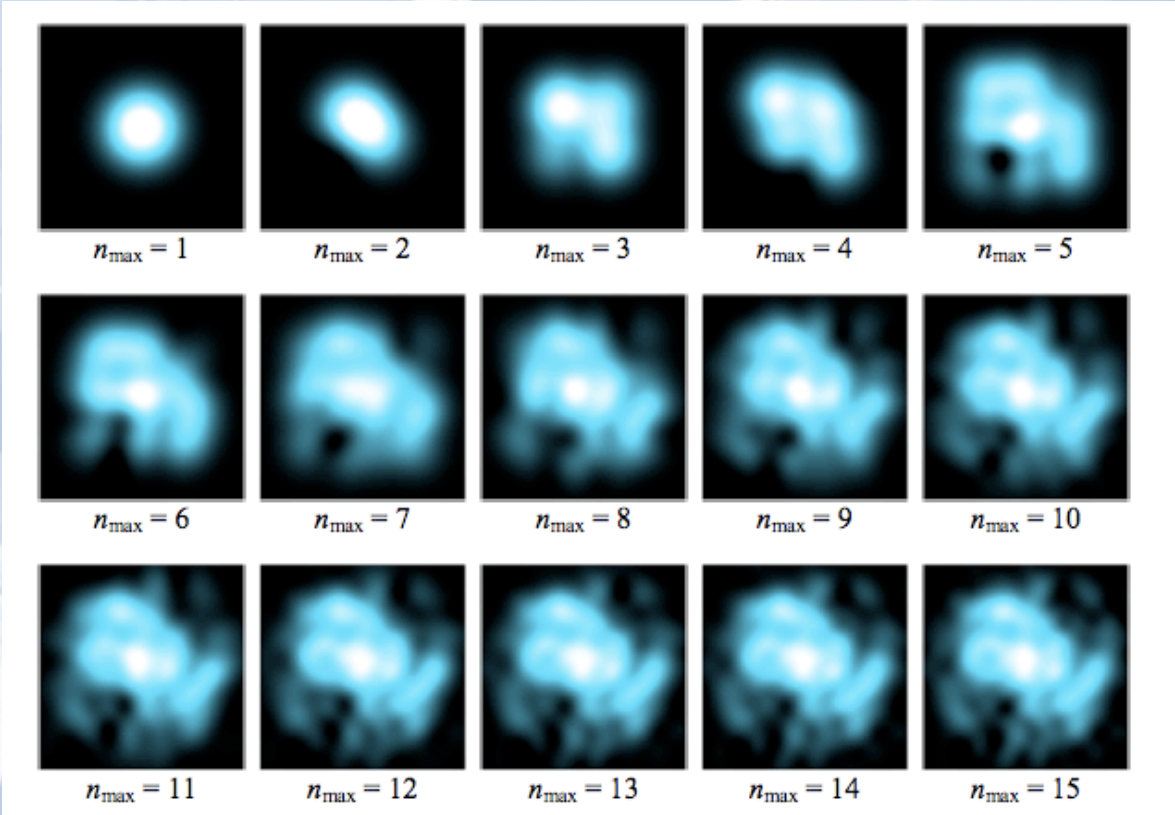
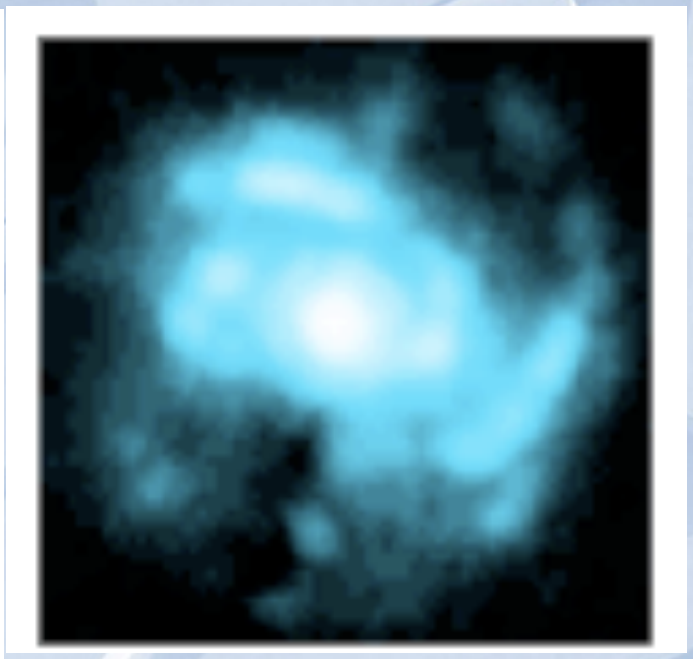


Figure courtesy: Adrian Malec (Swinburne)

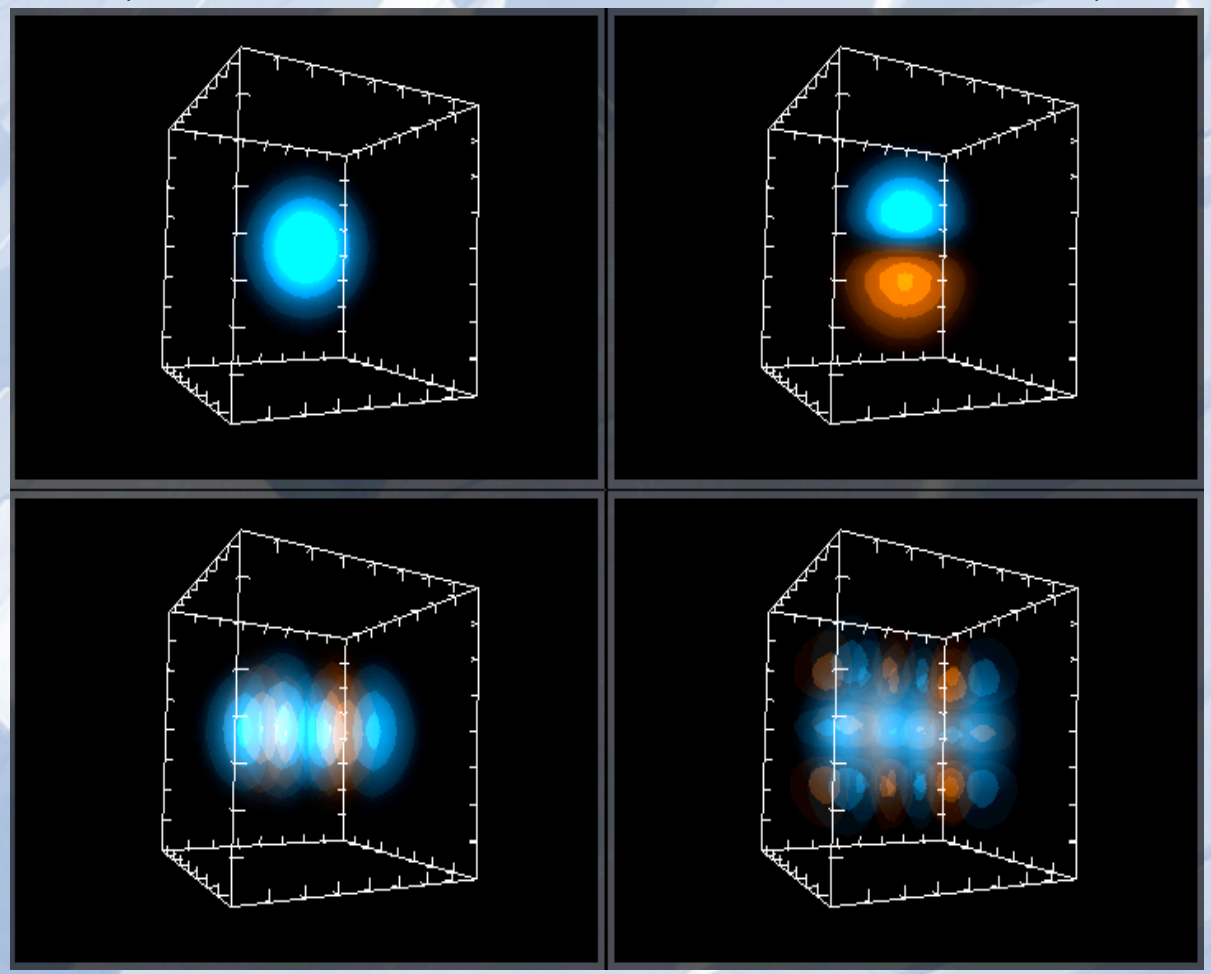


Original Image

- Image simulation (Massey et al. 2004; Ferry et al. 2008)
- Morphological classification (Kelly & McKay 2004; Young et al. 2005)
- Weak lensing (Refregier & Bacon 2003; Kuijken 2006; Massey et al. 2007)

3-d Cartesian Shapelets (Fluke, Malec, Barsdell, et al. in prep)

$\Phi_{3,(000)}$ $\Phi_{3,(010)}$



$\Phi_{3,(202)}$ $\Phi_{3,(124)}$

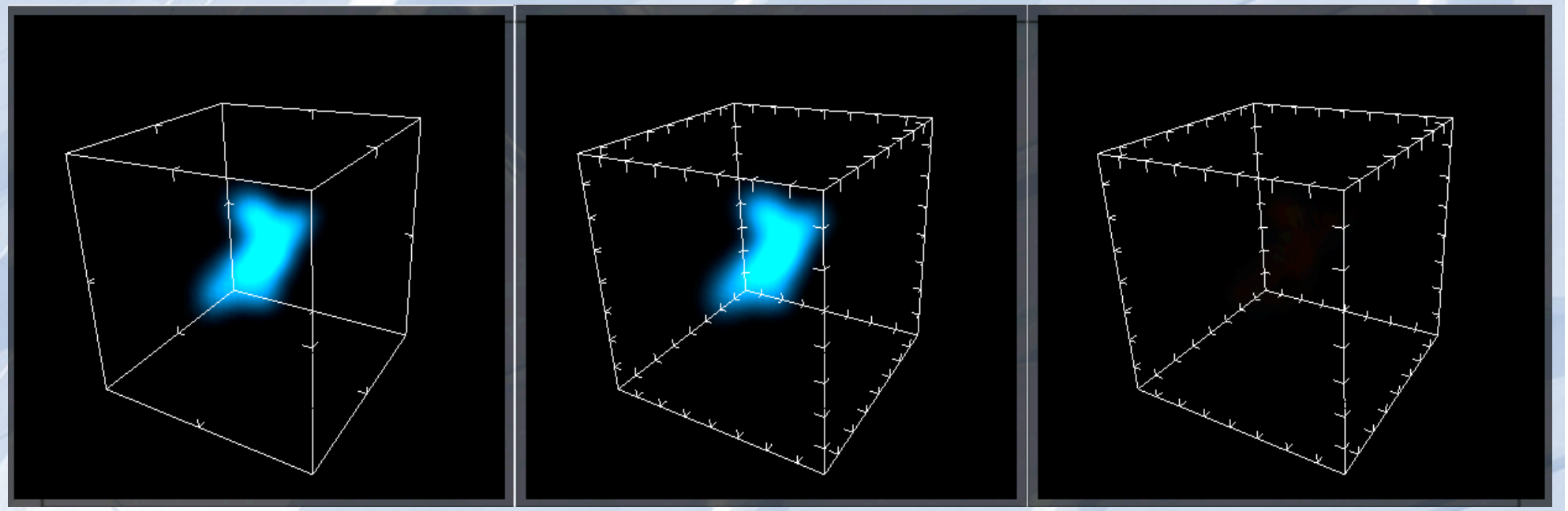
$$\phi_n(x) \equiv \left(2^n \pi^{1/2} n!\right)^{-1/2} H_n(x) e^{-x^2/2}$$

$$\phi_{3,\boldsymbol{n}}(\boldsymbol{x}) \equiv \phi_{n_1}(x_1)\phi_{n_2}(x_2)\phi_{n_3}(x_3)$$

$$f_{3,n} = \int_V f_3(\boldsymbol{x}) B_{3,n}(\boldsymbol{x};\beta) \mathrm{d}^3 x$$

$$f_3(\boldsymbol{x}) = \sum_{n_1,n_2,n_3}^{\infty} f_{3,n} B_{3,n}(\boldsymbol{x};\beta).$$

3D Cartesian Shapelets (Fluke, Malec et al. in prep)



Input Model **Reconstruction (GPU!!)** **Residual**

$$f_{3,\boldsymbol{n}} = \int_V f_3(\boldsymbol{x}) B_{3,\boldsymbol{n}}(\boldsymbol{x};\beta)\mathrm{d}^3x$$

$$f_3(\boldsymbol{x}) = \sum_{n_1,n_2,n_3}^{\infty} f_{3,\boldsymbol{n}} B_{3,\boldsymbol{n}}(\boldsymbol{x};\beta)$$

Next steps…

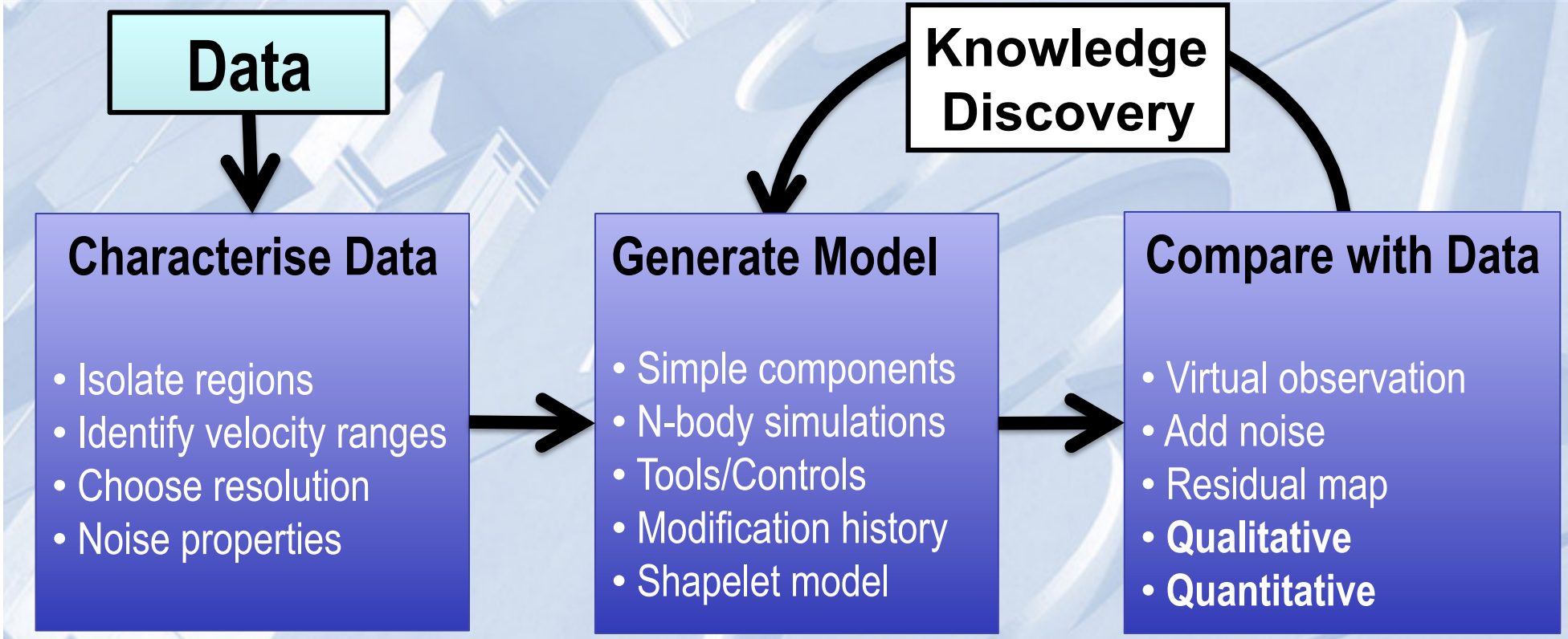
Visualization (Amr Hassan: Poster #27)

- S2PLOT prototype - only suitable for small cubes
- Integrate with GPU volume rendering framework

General-Purpose GPU Computing (Ben Barsdell: Poster #4)

- “Real-time” model fitting
- Advantages in using GPU = highly parallel computation

Summary



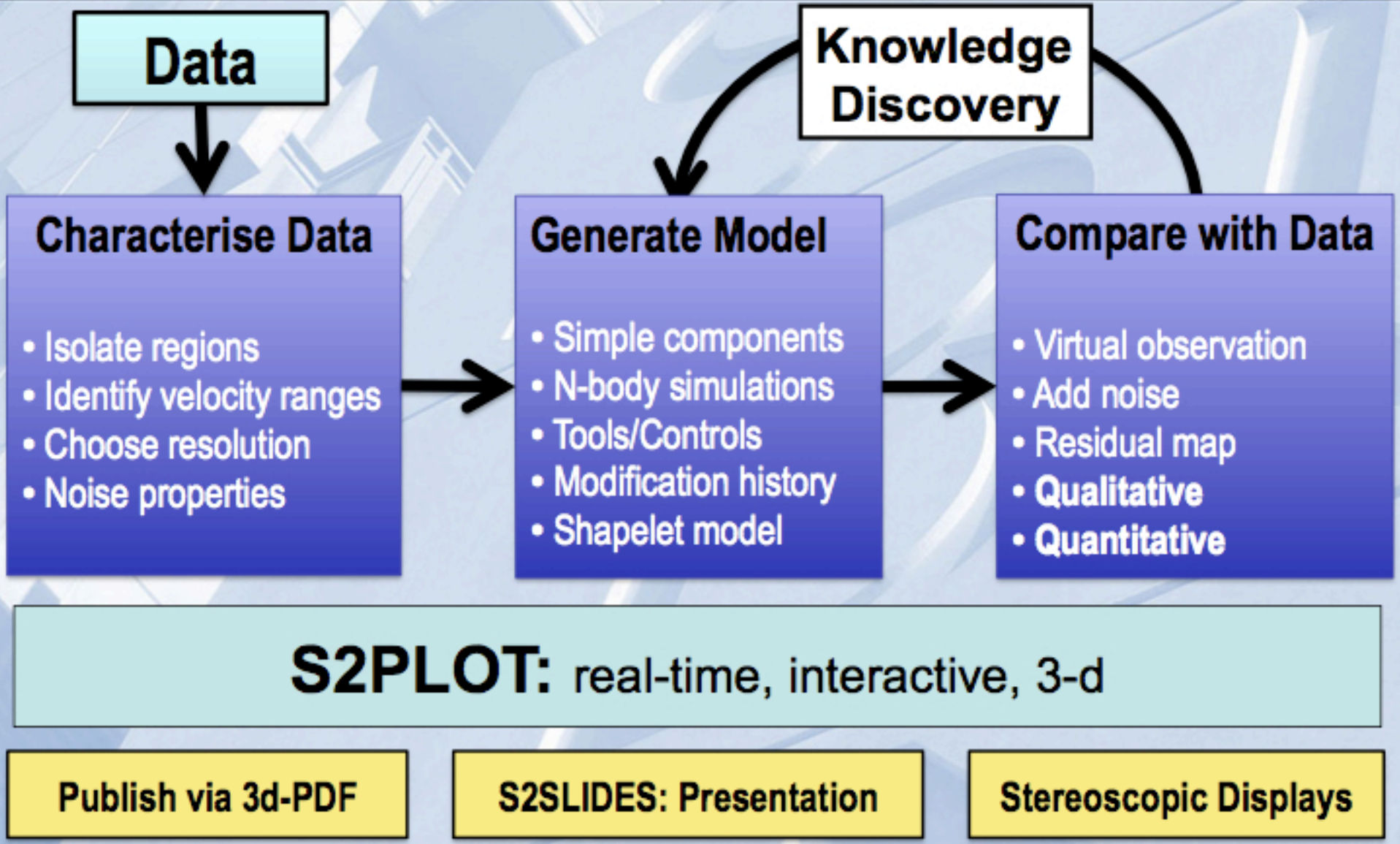
S2PLOT: real-time, interactive, 3-d

Publish via 3d-PDF

S2SLIDES: Presentation

Stereoscopic Displays

Summary


Data
Knowledge Discovery
Characterise Data
• Isolate regions
• Identify velocity ranges
• Choose resolution
• Noise properties
Generate Model
• Simple components
• N-body simulations
• Tools/Controls
• Modification history
• Shapelet model
Compare with Data
• Virtual observation
• Add noise
• Residual map
• Qualitative
• Quantitative
S2PLOT: real-time, interactive, 3-d
Publish via 3d-PDF
S2SLIDES: Presentation
Stereoscopic Displays