The Need for 3D Visualization in Astronomy

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ADASS Tutorial: 3D Visualization in Astronomy
London, 2007 September 23
3D Visualization of Astronomy Data

L1448 in diverse tracers (Kauffmann et al., in prep.)
This sets the agenda for today's tutorial.

Negative Comments

- “Why not channel maps?”
- “Why not IDL?”
- “Why these pretty pictures?”

Positive Comments

- “Smashing! How can I make such plots?”
- “Can one identify objects?”
- “What data can one visualize?”

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3D Visualization of Astronomy Data

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3D Visualization of Astronomy Data

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Outline

1. Research Situations with 3D Needs
   - Spatial 3D Data & Simulations
   - Observational Data Cubes
   - Tabulated Data

2. Software: Requirements & Available Packages

3. Summary
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Research Situations with 3D Needs

Astronomical Research Pipeline

Observer's Pipeline
- take data
- reduce data

Theorist's Pipeline
- create data
- analyze data:
  - quick visualization
  - quick quantification
- publish results:
  - high quality visualization
  - high quality quantification
- popularize results

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Research Situations with 3D Needs

Astronomical Research Pipeline

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- popularize results

Theorist's Pipeline
- create data

obvious use of 3D

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Astronomical Research Pipeline

Observer's Pipeline
- take data
- reduce data
- analyze data:
  - quick visualization
  - quick quantification
- publish results:
  - high quality visualization
  - high quality quantification
- popularize results

Theorist's Pipeline
- create data
- non-obvious use of 3D (this section's focus)

obvious use of 3D
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there is a very limited number of observational datasets with three spatial dimensions

usual reasoning:
age, $\tau$, and speed, $v$, known $\Rightarrow$ 
$s = v \cdot \tau$, scale along line of sight can be calculated

simulations are further obvious merely spatial datasets
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Spectra Across an Area

L1148 in CCS (2$_1$–1$_0$) (Kauffmann et al., in prep.)

example: a cloud mapped in CCS
Research Situations with 3D Needs

Observational Data Cubes

Spectra Across an Area

example: a cloud mapped in CCS

single observation: $I(\nu)$

conversion to velocity: $\nu \rightarrow v = c \cdot (\nu_0 - \nu)/\nu_0$, for given rest frequency, $\nu_0$, i.e., uses Doppler effect
example: a cloud mapped in CCS

mapping observations: $I(\nu)$ at given $(\alpha, \delta)$

rewritten: $I(\nu, \alpha, \delta)$, i.e., 3D field

continuous cubes are called volumes
Visualization Approaches

array of spectra: i.e., plot $I[\nu]$ at given $[\alpha, \delta]$
Visualization Approaches

Research Situations with 3D Needs

Observational Data Cubes

array of spectra: i.e., plot $I[v]$ at given $[\alpha, \delta]$

channel maps: i.e., plot $I[\alpha, \delta]$ at given $v$

L1448 in $^{13}$CO (1–0)

all L1448 data: COMPLETE survey,

http://www.cfa.harvard.edu/COMPLETE/

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Visualization Approaches

array of spectra: i.e., plot $I[v]$ at given $[\alpha, \delta]$

channel maps: i.e., plot $I[\alpha, \delta]$ at given $v$

position-velocity-diagrams: e.g., plot $I[v, \alpha]$ at given $\delta$

L1448 in $^{13}\text{CO}$ (1–0)
### Visualization Approaches

**array of spectra:** i.e., plot $I_\nu$ at given $[\alpha, \delta]$

- [Image of array of spectra]

**channel maps:** i.e., plot $I_{\alpha, \delta}$ at given $\nu$

- [Image of channel maps]

**position-velocity-diagrams:** e.g., plot $I_{\nu, \alpha}$ at given $\delta$

- [Image of position-velocity-diagrams]

---

**3D visualization:** i.e., plot $I_{\nu, \alpha, \delta}$ — without further constraints

L1448 in $^{13}$CO (1–0)

- [Image of 3D visualization]

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ADASS 3D Tutorial
### Visualization Approaches

**array of spectra:** i.e., plot $I[v]$ at given $[\alpha, \delta]$  

![Array of Spectra](image1.png)

**channel maps:** i.e., plot $I[\alpha, \delta]$ at given $v$  

![Channel Maps](image2.png)

**position-velocity-diagrams:** e.g., plot $I[v, \alpha]$ at given $\delta$  

![Position-Velocity Diagrams](image3.png)

**3D visualization:** i.e., plot $I[v, \alpha, \delta]$ — without further constraints  

![3D Visualization](image4.png)

*choice of visualization approach* is based on *scientific problem, personal preferences, and data size*

*all approaches except for 3D require memorizing during data analysis*

*3D visualization* is thus particularly interesting for the *analysis of large datasets*
Ridge et al. (2006):

a 10 pc shell of warm (29 K) dust in Perseus

probably driven by expanding HII-region

relation to molecular cloud?
Illustration: Feature-Discovery in Large Datasets

$^{13}$CO channel maps:
no obvious features
map has 250 000 pixels...

8 $\mu$m emission knots:
one out of three shows unusual $^{13}$CO velocities
Illustration: Feature-Discovery in Large Datasets

\(^{13}\)CO 3D visualization:

**clear indication** for extended emission from the shell

(Borkin & Arce, in prep.)
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non-volumetric data:
- data towards specific positions
- interesting for archival research

dense cores in Perseus seen in Topcat
Research Situations with 3D Needs

Tabulated Data

non-volumetric data:
- data towards specific positions
- interesting for archival research

interactive selection of objects crucial for archival work

generally: tools are important features of viewing software

dense cores in Perseus seen in Topcat
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obvious variations in requirements:

- data format
- availability of tools
- level of specialization
Ranges in Software Requirements

obvious variations in requirements:
- data format
- availability of tools
- level of specialization

not so obvious variations:
- interactivity & GUIs
- figure quality & complexity
Figure Quality & Complexity

L1148 in CCS (2₁⁻¹₀) (Kauffmann et al., in prep.)

Publication-quality plots have other requirements than data analysis plots.

Script-driven 3D software with high resolution output is needed here.
Ranges in Software Requirements

obvious variations in requirements:
- data format
- availability of tools
- level of specialization

not so obvious variations:
- interactivity & GUIs
- figure quality & complexity

there is no standard application that meets all requirements at the same time

different users will need different packages
Available Software: Presented at ADASS 07

3D visualization tools: also come Tuesday, 1:30 pm

<table>
<thead>
<tr>
<th>Name</th>
<th>Presentation</th>
<th>Aim</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D Slicer</td>
<td>O7.1, O7.2, D4</td>
<td>spectral data cubes (+ anything else)</td>
</tr>
<tr>
<td>OsiriX</td>
<td>this tutorial</td>
<td>spectral data cubes (+ any volume)</td>
</tr>
<tr>
<td>VisIVO</td>
<td>this tutorial</td>
<td>anything</td>
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<tr>
<td>S2PLOT</td>
<td>O7.3, P2.4</td>
<td>anything</td>
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<tr>
<td>Gaia 3D</td>
<td>P2.7</td>
<td>spectral data cubes</td>
</tr>
<tr>
<td>TopCat</td>
<td>D14</td>
<td>any tabulated data</td>
</tr>
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</table>

*colored packages* are demo’ed in this tutorial

**packages related to 3D:**

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>HEALPix</td>
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<td>MUSE tools</td>
<td>P2.9</td>
</tr>
<tr>
<td>Euro3D</td>
<td>P1.20</td>
</tr>
</tbody>
</table>

*packages are complementary because of different aims*

program list: join us at [http://am.iic.harvard.edu/RelatedProjects](http://am.iic.harvard.edu/RelatedProjects)

many of them used also in further posters and demos
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Summary

3D astronomy software:
- not only for pretty pictures
- also for non-spatial data
- different for different users

Come and try out!