VO: enabling science

Mark Allen - CoSADIE Project Scientist
Vision

• Archives and databases form a ‘digital sky’
• New possibilities via data discovery, efficient data access and interoperability

Driven by:

• Exploding data rates
• Multi-λ, time-domain & survey science
• Astronomers demand/expectation of interoperability
Motivation: To enable science

via:

• Data discovery
• Efficient data access
• Interoperable analysis tools
• Interoperable data
• Scalable visualisation and computing
• Data Mining
Status - early operations

• Core standards established
• Tools and services operational
• Tool interoperability proven very useful
• Being used for science in many different ways
• Offers unique capabilities
On the hype-curve? :-)

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![Hype Cycle Diagram](image_url)

- **Time**: Plateau will be reached in:
  - 0 less than 2 years
  - 2 to 5 years
  - 5 to 10 years
  - more than 10 years
  - obsolete before plateau

- **Technology Trigger**
- **Peak of Inflated Expectations**
- **Trough of Disillusionment**
- **Slope of Enlightenment**
- **Plateau of Productivity**

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- **expectations**
  - Wireless Power
  - Hybrid Cloud Computing
  - HTML5
  - Gamification
  - Big Data
  - Crowdsourcing
  - Speech-to-Speech Translation
  - Silicon Anode Batteries
  - Natural-Language Question Answering
  - Internet of Things
  - Mobile Robots
  - Autonomous Vehicles
  - 3D Scanners
  - Automatic Content Recognition
  - Volumetric and Holographic Displays
  - 3D Bioprinting
  - Quantum Computing
  - Human Augmentation

- **3D Printing**
- **BYOD**
- **Complex-Event Processing**
- **Social Analytics**
- **Private Cloud Computing**
- **Application Stores**
- **Augmented Reality**
- **In-Memory Database Management Systems**
- **Activity Streams**
- **NFC Payment**
- **Audio Mining/Speech Analytics**
- **Cloud Computing**
- **Machine-to-Machine Communication Services**
- **Mesh Networks/Sensor**
- **Gesture Control**
- **Predictive Analytics**
- **Speech Recognition**
- **Consumer Telematics**
- **Idea Management**
- **Biometric Authentication Methods**
- **Consumeration**
- **Media Tablets**
- **Mobile OTA Payments**

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As of July 2012
VO enabled tools

• Healthy variety of approaches
• Range of VO-enabled exiting tools to VO dedicated tools
• Co-operation between tools - lets tools concentrate on strengths
• Not an ‘all in one’ package
Finding data with Aladin:

- A service can be **found** and **used** by tools that access the registry.

Metadata describes data properties e.g. FoV

Images

Catalogues

Spectra
Table Access Tools

Topcat

TAPHandle

TAP Parameters

TAP URL:
Like CasJobs ... but not just SDSS
ADQL/SQL query of tables via TOPCAT

Some services offer joins between tables and uploaded tables.
Spectral Tools
VOSA

VO SED Analyzer

- Builds an SED with photometry gathered from different VO services and compare them with different grids of models to obtain physical parameters (Teff, masses, ages, ...)

![Diagram](image.png)
Programmatic approaches

- Direct programming to access services
- Scripting languages in tools - allow transition from interactive to automated approach
- Python increasingly important
Interoperability

Aladin

Topcat

Your programs

VOSpec
<table>
<thead>
<tr>
<th>Application / Version (in alphabetical order)</th>
<th>Functionality</th>
<th>Other VO-compliant tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aladin v7.015a (March 2011)</td>
<td><strong>Search for Images:</strong> Aladin, Datascope, SkyView, VODesktop</td>
<td>DS9: Image visualisation</td>
</tr>
<tr>
<td>Datascope v3.3 (April 2010)</td>
<td><strong>Search for Spectra:</strong> Aladin, Datascope, SPLAT, Specview, VOServices, VOSpec</td>
<td>GOSSIP: SED fitting</td>
</tr>
<tr>
<td>Montage</td>
<td><strong>Search for Catalogues:</strong> Aladin, Datascope, TOPCAT, VODesktop</td>
<td>Mirage: Table visualisation</td>
</tr>
<tr>
<td>Octet</td>
<td><strong>Image visualisation:</strong> Aladin, SkyView</td>
<td>VirGO: Search for Images and Spectra</td>
</tr>
<tr>
<td>Open SkyQuery</td>
<td><strong>Spectra visualisation:</strong> SPLAT, Specview, VOServices, VOSpec</td>
<td></td>
</tr>
<tr>
<td>SkyView</td>
<td><strong>Catalogues visualisation:</strong> Aladin, TOPCAT, VOPlot</td>
<td></td>
</tr>
<tr>
<td>Specview 2.15 (August 2011)</td>
<td><strong>Cross-correlation:</strong> Aladin, Open SkyQuery, STILTS, TOPCAT</td>
<td></td>
</tr>
<tr>
<td>SPLAT 3.9.0 (May 2009)</td>
<td><strong>Scatter, 3D plots and histograms:</strong> TOPCAT, VOPlot</td>
<td></td>
</tr>
<tr>
<td>TOPCAT/STILTS 3.9/2.4 (October 2011)</td>
<td><strong>Statistics:</strong> VOSStat</td>
<td></td>
</tr>
<tr>
<td>VisIVO 1.5.7.1 (May 2009)</td>
<td><strong>Footprint Service:</strong> Aladin, VOServices</td>
<td></td>
</tr>
<tr>
<td>VOConvert 1.0 (June 2006)</td>
<td><strong>Table format conversion:</strong> TOPCAT, VOConvert</td>
<td></td>
</tr>
<tr>
<td>VODESKTOP 1.3.2 (February 2010)</td>
<td><strong>Filter curves:</strong> VOServices</td>
<td></td>
</tr>
<tr>
<td>VOEventNet</td>
<td><strong>SED building:</strong> VOSA, VOSED, VOSpec</td>
<td></td>
</tr>
<tr>
<td>VOPLOT 1.7 (September 2011)</td>
<td><strong>Fixing WCS:</strong> Aladin, WCSFixer</td>
<td></td>
</tr>
<tr>
<td>VOStat 1.1 (November 2008)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VOSA 2.2.0 (March 2011)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VOSED 2.0 (May 2011)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VOServices (Footprint, Spectrum, Filters...)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Browse the Registries**

- EURO-VO Registry
- NVO Registry
- use VODESKTOP

**Manuals, Tutorials, How-tos**

- Aladin User manual
- Datascope how to
- Montage help
- Open SkyQuery help
- SkyView documentation
- Specview examples
- SPLAT documentation
- STILTS documentation
- TOPCAT documentation
- VisIVO how to
- VODESKTOP how to
- VOSpec User manual
Published examples

Refereed Publications

The Hopkins Ultraviolet Telescope: The Final Archive
Dixon, William V.; Blair, William P.; Kruk, Jeffrey W.; Romelfanger, Mary L

Proper motions of young stars in Chamaeleon. I. A Virtual Observatory study of spectroscopically confirmed members
Lopez Martí, B.; Jimenez Esteban, F.; Bayo, A.; Barrado, D.; Solano, E.; Rodrigo, C.
A&A 2013, 551, 46L

Automated rapid follow-up of Swift gamma-ray burst alerts at 15 GHz with the AMI Large Array
Staley, T. D.; Titterington, D. J.; Fender, R. P.; Swinbank, J. D.; van der Horst, A. J.; Rowlinson, A.; Scaife, A. M. M.; Grainge, K. J. B.; Pooley, G. G.

Precovery of near-Earth asteroids by a citizen-science project of the Spanish Virtual Observatory
E. Solano, C. Rodrigo, R. Pulido, B. Carry
Accepted in Astron. Nachr

The Millennium Run Observatory: first light
Overzier, R.; Lemson, G.; Angulo, R. E.; Bertin, E.; Blaizot, J.; Henriques, B. M. B.; Marleau, G.-D.; White, S. D. M.

Query driven visualization of astronomical catalogs
Buddelmeijer, Hugo; Valentijn, Edwin A.
Experimental Astronomy, Volume 35, Issue 1-2, pp. 283-300

A Virtual Observatory Census to Address Dwarfs Origins, AVOCADO - I. Science goals, sample selection
Proper motions of young stars in Chamaeleon

I. A Virtual Observatory study of spectroscopically confirmed members

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ABSTRACT

• “VO based methodology to cross-match and analyse the data”
• multi-cone search + constraints on pm errors, epochs
• Compilation of multi-λ photometry

TOPCAT, Aladin, VizieR, VOSA
- Identified different moving groups
- Distinguished Chamaeleon I and II as two physical entities - not related to foreground $\varepsilon$ Cha and $\eta$ Cha
Automated rapid follow-up of *Swift* gamma-ray burst alerts at 15 GHz with the AMI Large Array


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3 Astronomical Institute Anton Pannekoek, Science Park 904, PO Box 94249, 1090 GE Amsterdam, the Netherlands
4 Kavli Institute for Cosmology Cambridge, Madingley Road, Cambridge CB3 0HA

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- 1st mJy level follow-up of GRBs
- VOEvent and automated follow-up system
- Radio afterglow detected on timescale of days
Scalelength of disc galaxies

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4European Southern Observatory, Karl-Schwarzschild-Str. 2, 85748 Garching bei München, Germany
5Kapteyn Astronomical Institute, Postbus 800, 9700 AV Groningen, the Netherlands

Accepted 2010 April 7. Received 2010 April 2; in original form 2010 February 18

- **SDSS, LEDA, Skyview, Aladin, Topcat, IDL/GDL, VOSpace + Cluster System at CDS**

- **Filtering SDSS catalogue (low extinction, available z, inclination < 70°)**

- **Cross-matching SDSS with LEDA catalogues to identify hubble classification**
Unprecedented sample - previous samples few 100s

Freeman law of galaxy disks confirmed for large sample out to $z=0.3$
All sky search for bright objects with blue colours and high proper motions

- white dwarfs, hot subdwarfs, runaway stars, or early-type stars in nearby young moving groups.

because:

- WDs are used as spectrophotometric standards
- Early-type stars in young moving groups are fundamental for understanding the evolution of star-forming regions.
- Cross-match Tycho-2 and 2MASS. Constraints $\mu > 50 \text{ mas yr}^{-1}$ and $V_T - K_S < -0.5 \text{ mas}$

- Collected multi-$\lambda$ photometry $\Rightarrow$ SED, fit models
• 32 objects identified. (27 known, 5 new)

• including hot sub-dwarf Albus 5 - confirmed with public FUSE data
VO enabling science

• part of Astronomer’s everyday tool kit
• being used in innovative ways
• ‘VO’ not well cited, but tools are!
• really is just the beginning...
Learning how

- Workshops and schools
- On-line training materials
- From your colleagues
Coming soon...
Multi-dimensional Data

Radio astronomy, Integral Field Spectroscopy, high energy, polarization, simulation, data mining datasets + ...

Time Domain Astronomy

Time Series, light curves, transient event reports, +...

• Need to ensure that these are accessible and useable within the VO
1. Load MOC-HST MOC-SDSS
2. Compute MOC inters.
3. Query Simbad by MOC

=> Realized in 5s
Observational core metadata

- Special set of parameters (columns) for uniform query across many archives/services/tables

All spectra with $\text{res} > 3000$ between 4000-5000 Å with $t_{\text{exp}} > 300s$
IVOA Newsletter

- Bi-annual
- Aimed at Astronomers
- Applications highlights
- Recent refereed journal papers with significant use of VO

http://www.ivoa.net/newsletter
Links

• IVOA - http://www.ivoa.net
• EuroVO - http://www.euro-vo.org
• EuroVO CoSADIE - http://www.cosadie.eu/twiki/bin/view/CoSADIE/WebHome
• CDS - http://cdsweb.u-strasbg.fr
• Topcat - http://www.star.bris.ac.uk/~mbt/topcat/