

# The Astronomer's IT Toolkit and The Virtual Observatory

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1st September 2011

# Outline

- 1 Introduction
- 2 IT Toolkit
- 3 Managing data
- 4 Scripting
- 5 Virtual Observatory
- 6 Advanced VO

# We are undergoing a data *explosion*

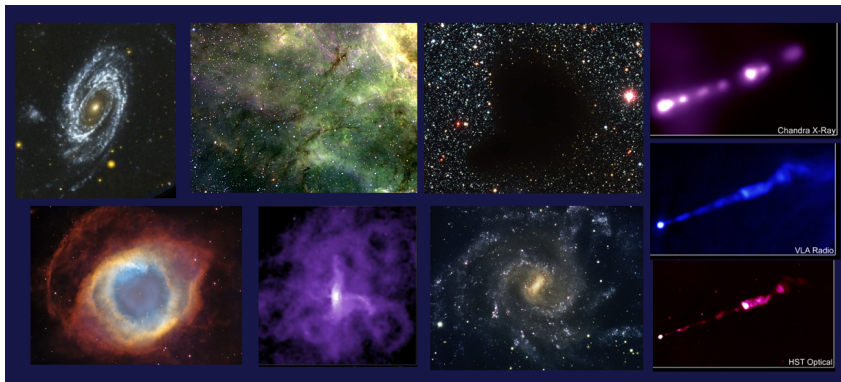
- We live in the age of the mega-survey
- Datasets are orders of magnitude larger and more complex than in the past
  - Surveys: SDSS, 2dF, 2MASS, DPOS, WMAP...
  - Digital libraries: ADS, astro-ph, NED, CDS
  - Observatory archives: HST, ATOA, MAST
  - Future examples: LSST, GALEX, SKA...

These surveys will produce **terabytes per night**

- For comparison:
  - The Library of Congress is  $\sim 20$  TB
  - SDSS has publicly released  $\sim 10$  TB
  - The Human Genome is  $< 10$  GB

# Datasets are becoming more complex

Multi-wavelength astronomy is critical



<http://www.educationgrid.org/msicii/June06Workshop/Presentations/astro-cyberinfrastructure.ppt>

# The way we do science is changing

- Massive datasets
- Multi-wavelength datasets
- New techniques
- Giant collaborations
- Use and reuse of archives
- A typical scientist will have to deal with more and more data:

You can `grep` 1 MB in a second

You can `grep` 1 GB in a minute

You can `grep` 1 TB in 2 days

You can `grep` 1 PB in 3 years

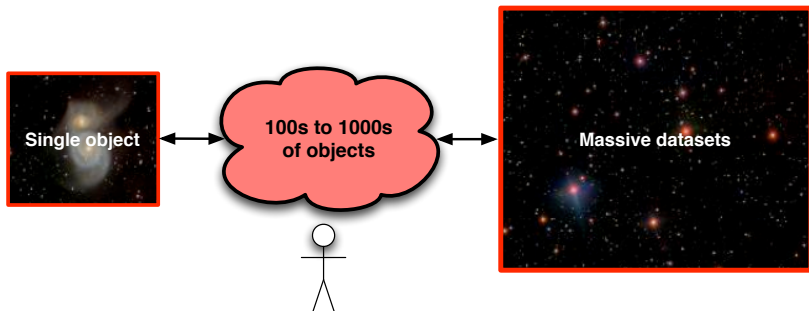


# What does this mean for astronomy?

- Software pipelines
- Massive simulations
- Distributed computing
- Supercomputing
- Robotic telescopes
- Online communication
- The Virtual Observatory
  
- Some paradigm shifts in the way we do astronomy
  - The archive is the telescope!
  - We can't store all data!



# What does this mean for you?



## Scenario: How would you solve this problem?

Your supervisor gives you a data file that they've dug out of the archives. They say that it contains Nobel prize winning data... if only you could analyse it... you take a look...

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```

010.1002587 -78.0749976 3.6 4.7 J0000M32 0.000 D
322.2776209 -64.6831876 3.1 3.6 J0000M52 0.108 C
328.0067189 -68.5874347 2.1 2.5 J0000M48 0.193 D
325.6616556 -67.1618942 1.8 2.0 J0000M48 2.539 B
314.1262894 -55.5638273 9.0 2.8 J0000M60 1.266 A
314.6473335 -56.3390663 3.3 3.5 J0000M60 2.522 C
334.7202054 -71.7342040 1.8 2.3 J0000M40 5.693 B
321.3525638 -63.9139186 2.0 2.1 J0000M52 2.080 B
325.7259722 -67.2143813 2.9 3.0 J0000M48 3.311 D
347.0515173 -75.2447016 2.3 3.4 J0000M36 4.345 C
325.5104290 -67.0742957 2.9 3.1 J0000M48 0.105 C
001.9296920 -77.4361767 5.9 6.9 J0000M32 1.530 B
307.3447442 -41.6675454 1.8 2.1 J0000M76 6.400 B
  
```



... and its 10 000 lines long.



## Your task:

- Find the number of galaxies of each type (A, B, C, D) that are in the declination range  $-70 < \delta < -60$ .

# What do you do next?

- 1 Run, screaming, from the room, cursing the astronomers of yesteryear. Then brew a strong coffee and prepare yourself for several days of manual adjustments.

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- 4 Write a one line Unix script in a couple of minutes, then move on to the Nobel prize winning research. You solve this kind of problem hundreds of times a day.

# A Python solution

```
1 types = {'A':0, 'B':0, 'C':0, 'D':0}
2 for line in open('catalogue.txt'):
3     cols = line.split()
4     dec = float(cols[1])
5     gtype = cols[-1]
6     if dec > -70 and dec < -60:
7         types[gtype] += 1
8
9 for gtype in types:
10    print gtype, types[gtype]
```

# A Shell solution

```
1 %> awk '($2>-70 && $2<-60){print $7}' catalogue.txt | sort  
| uniq -c | sort
```

# The astronomer's IT toolkit

- What IT skills do you need to do your research effectively?
  - A data reduction/processing (or simulation) package  
(e.g. Miriad, AIPS++, IRAF)
  - A FITS visualisation package  
(e.g. kvis, ds9)
  - A range of Un\*x tools  
(e.g. cut, paste, grep, sed, awk, for loops)
  - A scripting language  
(e.g. Python, Perl)
  - A plotting package  
(e.g. IDL, matplotlib, Matlab)
  - Familiarity with accessing large online resources  
(e.g. NED, SIMBAD, VizieR, ADS)
  - Version control software  
(e.g. Subversion)

# The astronomer's IT toolkit

- Plus sometimes you need to
  - Write software in C, C++, FORTRAN
  - Read other people's code. . .
  - Query databases using SQL (e.g. SDSS, 6dF)
  - Use a wiki for collaboration
  - Set up a website
  - Set up a website with forms and CGI scripts
  - Set up a database to share/organise your data
  - Use VO Tools for complex queries

{girls, guys} like {girls, guys} who have skills



# What should I do with my data?

- ... You've had an idea!
- ... You've written an observing proposal
- ... You've slaved away at the telescope for many nights
- ... You've processed your data
- ... You've analysed your images/spectra
- And finally...

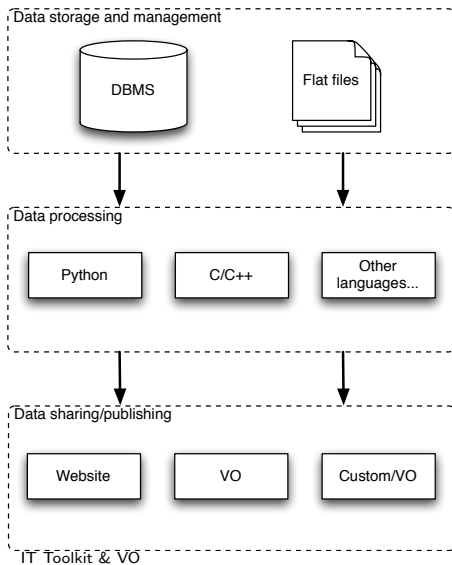
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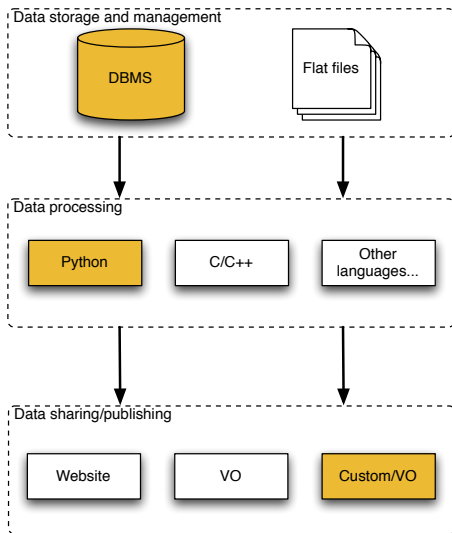
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- And finally...
- **You have a catalogue**
  - ① You want to store it
  - ② You want to put it on the web
  - ③ You want to make it easily accessible to others

# This involves (at least) 3 distinct stages



# Your technology choice at each stage is independent



# Why use databases?

- Persistence
- Access control and security
- Atomicity and concurrent access
- Standard queries
- Avoids inconsistency
- Avoids redundancy
- Avoids data isolation

However...

- Some overhead in setting up
- Need to learn new skills
- **Need to evaluate whether it is worth it for your data**

# Why use Python scripting?

- Easy to code
- Easy to read
- Supports sophisticated programming (e.g. OO)
- Many built-in functions for modern tools (e.g. databases, web)
- Increasing uptake in astronomy community
- Wide community support

However...

- Takes time to learn a new language
- Language X solves all of my problems
- **Need to evaluate whether it is worth it for you**

## Why use web/VO?

- You want your data to be used as widely as possible
- Hence you want to share it in ways that are easy to access
- Writing custom solutions is intensive

However. . .

- It is easier just to put your catalogue on a website
- If you want VO-lite upload your catalogue to Vizier
- **Need to evaluate whether it is worth it for your data**

# Why should I use scripting?

- Advantages vs. manual processing
  - Speed
  - Reproducibility
  - Documentation
  - Collaboration
- Advantages vs. 'real programming'
  - Speed of development
  - Flexibility
  - Easier for a beginner to understand

# Everybody stand back, I know regular expressions!



<http://xkcd.com>



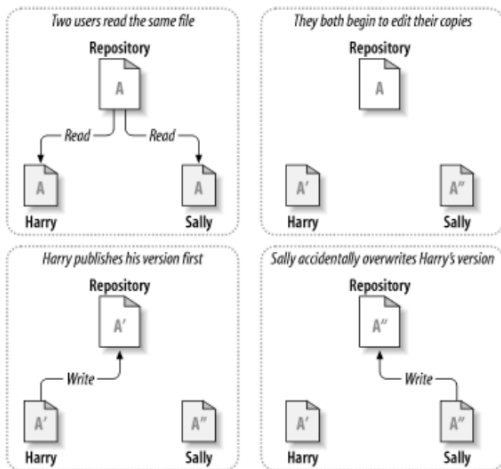
# However...



## Why should I use version control?

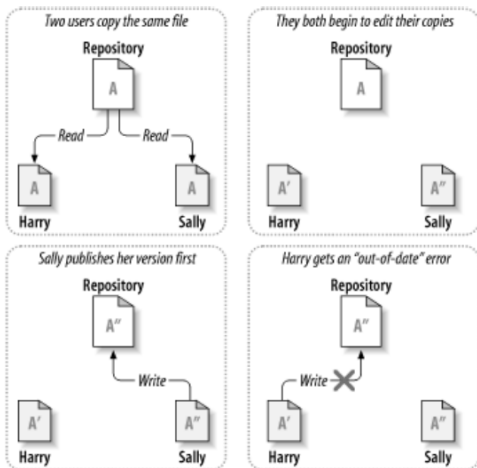
- Works as a constant backup (accessible anywhere at anytime)
- Allows syncing between laptop, work and home desktops
- Allows collaboration on source code, papers, schedule files
- Allows students and supervisors to share code/resources
- Keeps a record of who made changes and why
  
- Version control works like an e-version of a log book
  
- **It makes you a better coder!**

# The problem to avoid



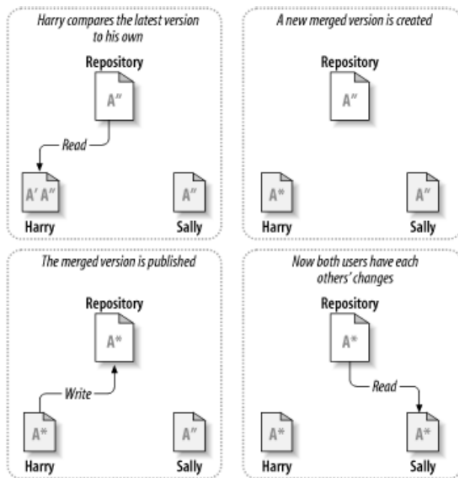
<http://svnbook.red-bean.com>

# The Copy-Modify-Merge solution



<http://svnbook.red-bean.com>

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<http://svnbook.red-bean.com>

# What is the Virtual Observatory?

- The VO addresses the data management, analysis, distribution and interoperability challenges of modern astronomy
- The main drivers are
  - Data growth: volume and richness
  - Desire to work online
  - Multi-archive science
  - Large database science

The Virtual Observatory is a distributed collection of

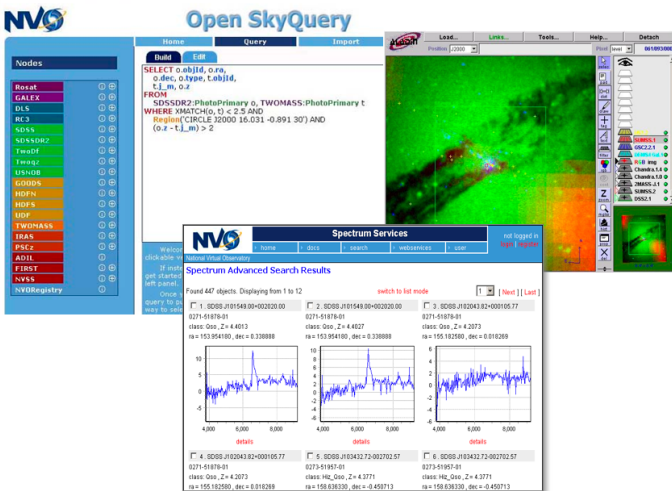
- Data resources
- Software resources
- Computing (grid) resources
- Telescopes

# The International Virtual Observatory Alliance



<http://www.ivoa.net>

# What are VO tools?



**NVO Open SkyQuery**

Home Query Import

Build Edit

```

SELECT o.objid, o.ra,
       o.dec, o.type, t.objid,
       t.l_m, o.z
FROM
  SDSSDR2:PhotoPrimary o, TWOMASS:PhotoPrimary t
WHERE XMATCH(o, t) < 2.5 AND
       Region('CIRCLE 32000 16.031 -0.891 30') AND
       (o.z - t.l_m) > 2
  
```

**Spectrum Services** (not logged in)

National Virtual Observatory

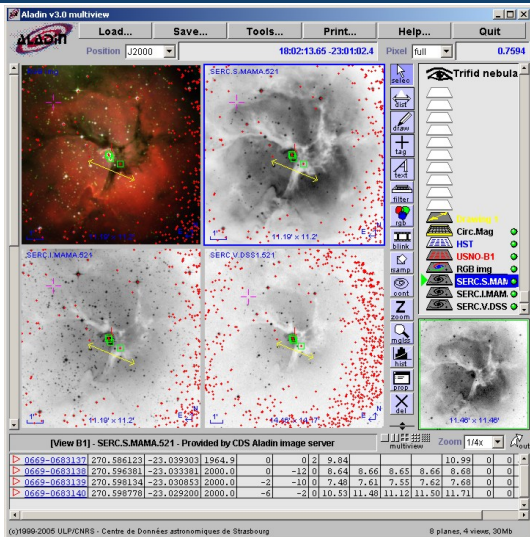
Spectrum Advanced Search Results

Found 447 objects. Displaying from 1 to 12

id	ra	dec	search	webview	user
1. SDSS.J101549.00-002620.00	101549.00	-002620.00			
2. SDSS.J101549.00-002620.00	101549.00	-002620.00			
3. SDSS.J102043.02-000105.77	102043.02	-000105.77			
4. SDSS.J102043.02-000105.77	102043.02	-000105.77			
5. SDSS.J103432.72-002702.57	103432.72	-002702.57			
6. SDSS.J103432.72-002702.57	103432.72	-002702.57			

Each result includes class Obj, class Obj\_Z, and ra/dec coordinates.

# An interactive sky atlas: Aladin



Aladin v3.0 multiview

Position: J2000 18:02:13.65 -23:01:02.4 Pixel: full 0.7594

Trifid nebula

SERC.S.MAMA.521

SERC.I.MAMA.521

SERC.V.DSS1.521

[View B1] - SERC.S.MAMA.521 - Provided by CDS Aladin image server

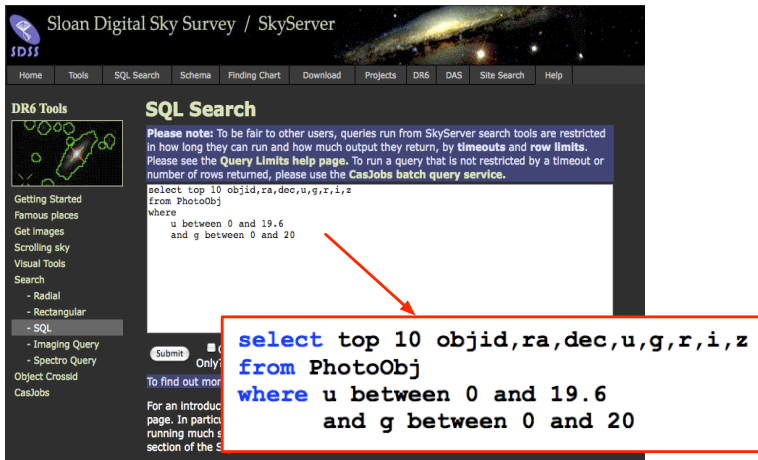
▷ 0669-0683137	270.586123	-23.039303	1964.9	0	0	2	9.84				10.99	0	0
▷ 0669-0683138	270.596381	-23.033381	2000.0	0	-12	0	8.64	8.66	8.65	8.66	8.68	0	0
▷ 0669-0683139	270.598134	-23.030853	2000.0	-2	-10	0	7.48	7.61	7.55	7.62	7.68	0	0
▷ 0669-0683140	270.598778	-23.029200	2000.0	-6	-2	0	10.53	11.48	11.12	11.50	11.71	0	0

(c)1999-2005 ULP/CNRS - Centre de Données astronomiques de Strasbourg 8 planes, 4 views, 30Mb

# An interactive sky atlas: Aladin

- Visualize digitized astronomical images
- Superimpose entries from catalogues or databases
- Interactively access online data from SIMBAD, NED, Vizier
- Fully VO aware — access other VO resources
- **See demo**
- <http://aladin.u-strasbg.fr>
  
- You can also write your own plug-ins
- The developers are very keen to get feedback from users — they are happy to make suggested changes!

# Querying online databases: SDSS



Sloan Digital Sky Survey / SkyServer

Home Tools SQL Search Schema Finding Chart Download Projects DR6 DAS Site Search Help

**DR6 Tools**

- Getting Started
- Famous places
- Get Images
- Scrolling sky
- Visual Tools
- Search
  - Radial
  - Rectangular
  - SQL
  - Imaging Query
  - Spectro Query
- Object Crossid
- CasJobs

**SQL Search**

**Please note:** To be fair to other users, queries run from SkyServer search tools are restricted in how long they can run and how much output they return, by **timeouts** and **row limits**. Please see the **Query Limits help page**. To run a query that is not restricted by a timeout or number of rows returned, please use the **CasJobs batch query service**.

```
select top 10 objid,ra,dec,u,g,r,i,z
from PhotoObj
where
  u between 0 and 19.6
  and g between 0 and 20
```

Submit Only: To find out more For an introduc page. In particu running much s section of the S

**select top 10 objid,ra,dec,u,g,r,i,z  
from PhotoObj  
where u between 0 and 19.6  
and g between 0 and 20**

<http://cas.sdss.org/astrodr6/en/tools/search/sql.asp>

# Querying online databases: Open Sky Query



**Open SkyQuery**

Home Simple Query **Advanced Query** Import Tutorial Help

National Virtual Observatory

**Nodes**

- Rosat
- XMM
- GALEX
- GALEXR1
- DLS
- RC3
- GSC2
- NBCKDEDR1
- SDSS
- SDSSDR2
- SDSSDR3
- SDSSDR4
- TwoDf
- Twoqz
- TWOSLAQLRGEDR
- TWOSLAQQSOEDR
- USNOB
- GOODS
- HDFN
- HDFS
- UDF
- TWOMASS
- IRAS
- PSCz
- FIRST
- NVSS

**Build** **Edit** **Submit**

```

SELECT o.objId, o.ra,
       o.dec, o.r, o.type,
       t.objId, t.ra, t.dec
FROM
SDSS:PhotoPrimary o, TWOMASS:PhotoPrimary t
WHERE XMATCH(o, t) < 3.5 AND
      Region(CIRCLE J2000 181.3 -0.76 6.5) AND
      o.type = 3
  
```

Welcome to the Open SkyQuery interactive query builder. You should see a parsed, clickable version of your entered query in the pane directly above this one.

If instead you see "Query is empty", this means that builder needs a node or two to get started. You can add nodes to the builder by clicking the desired node's "+" icon in the left panel.

Once you have some sql in the above panel, you can then click on a token in that query to pull up a menu with options appropriate for that specific token. For example, one way to select an additional column from a mythical 'mytable' is to click on 'mytable' and then chose 'Add Selection', then pick the desired column from the given choices.

You can switch between 'edit' and 'build' modes at any time by using the tabs at the top of the query panel. Your changes from one will carry over to the other. Most menu options have additional mouse-over info.

**Sample Queries**

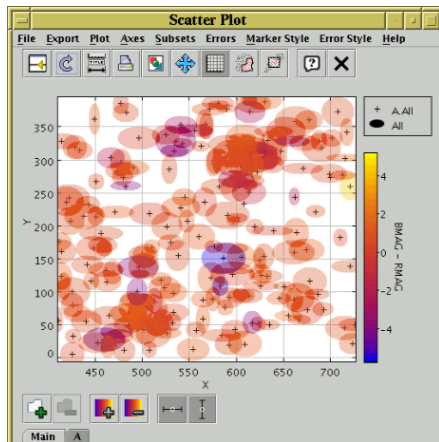
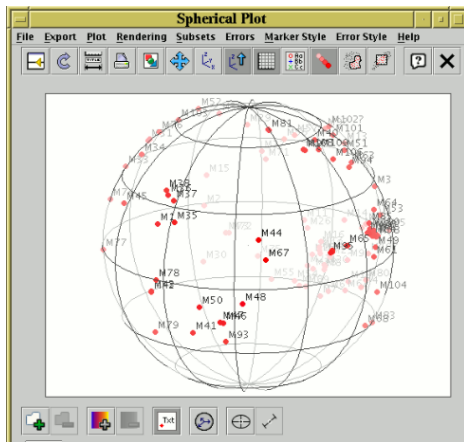
- XMatch/Region
- XMatch/Region 2
- Three Node Match
- Brown Dwarf Search
- MyData XMatch (upload)
- Xmatch t\* (upload)
- ABELL\_Xmatch (upload)
- Single Node Query
- Single Node Join

<http://openskyquery.net/Sky/SkySite>

## VO enabled plotting

- Many VO tools let you select sources and plot them
- All VO tools allow you to retrieve data as an XML VO table
- TOPCAT is an interactive graphical tool for analysis and manipulation of tabular data
- TOPCAT manifesto: *Does what you want with tables*
- <http://www.star.bris.ac.uk/~mbt/topcat>

# VO enabled plotting: TOPCAT

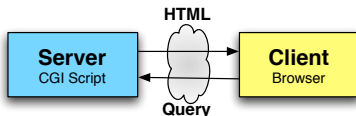


## Other tools worth looking at

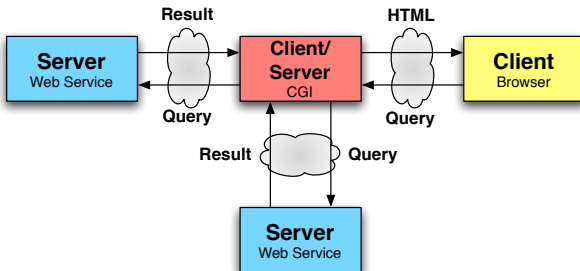
- DataScope  
[heasarc.gsfc.nasa.gov/vo](http://heasarc.gsfc.nasa.gov/vo)
- SkyView  
<http://skyview.gsfc.nasa.gov>
- MyADS  
<http://myads.harvard.edu>
- AstroGrid  
<http://www2.astrogrid.org/science>
- Google Sky  
<http://www.google.com/sky>

# Under the bonnet of the VO

- Many dynamic websites use the CGI client-server interaction



- The Web Service-client interaction



## Accessing the VO using scripts

- VO protocols make it possible to access the VO automatically
- You can integrate online database queries into your programs
- Libraries available for most major languages
- Java and Python probably best supported at the moment
- <http://www.us-vo.org/summer-school/2008/index.html>

# Getting your data into the VO

- 1 Upload to existing service (e.g. Vizier)  
`http://vizier.u-strasbg.fr/cgi-bin/VizieR`
- 2 Set up your own VO compliant server  
Implement VO protocols such as Cone Search  
`http://www.ivoa.net/Documents/latest/ConeSearch.html`
- 3 Off the shelf setup (e.g. Astrogrid DSA)  
`http://www.astrogrid.org/maven/docs/HEAD/pal/index.html`

## Interesting things I didn't cover

- Machine learning  
<http://www.cs.waikato.ac.nz/ml/weka>
- High performance computing
- Object oriented programming
- Web services

# IT is critical in future astronomy

- IT is becoming increasingly important in 'everyday' science
- It is important to learn/improve these skills now!
- Your PhD is the best opportunity you'll ever get
- (Your first postdoc is the second best opportunity ;)
- Resources available from the Astrominformatics School website  
<http://www.icrar.org/news/pastevents/astrominformatics>
- Resources available from the NVO Summer School website  
<http://www.us-vo.org/summer-school>
- Look out for the Astrominformatics School in 2012