The Astronomer's IT Toolkit and The Virtual Observatory

Tara Murphy

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Outline

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 ~ 20 TB
  - SDSS has publicly released ~ 10 TB
  - The Human Genome is < 10 GB

Datasets are becoming more complex

Multi-wavelength astronomy is critical

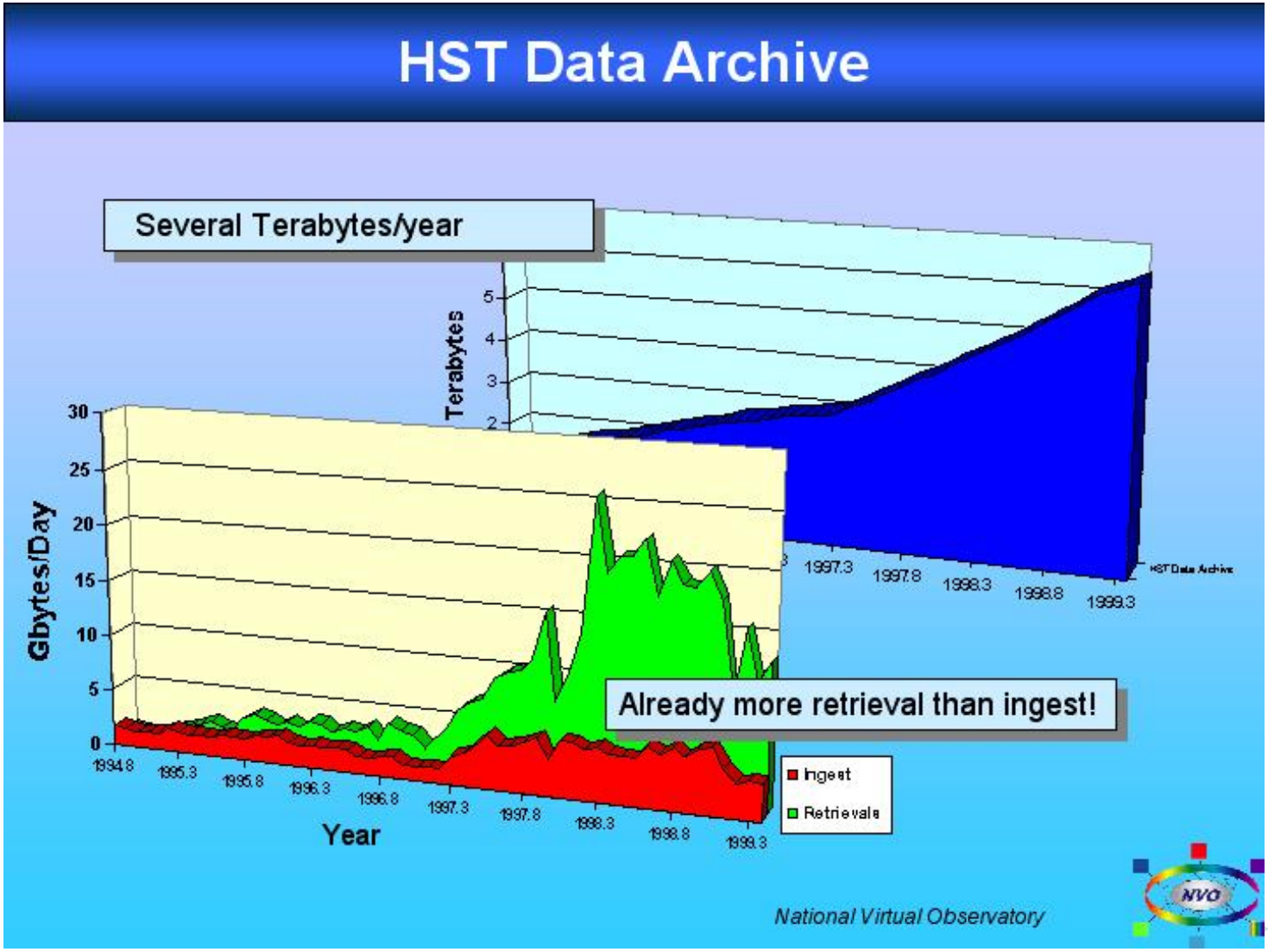
http://www.educationgrid.org/msicii/June06Workshop/Presentations/astro-cyberinfrastructure.ppt

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

The way we do science is changing



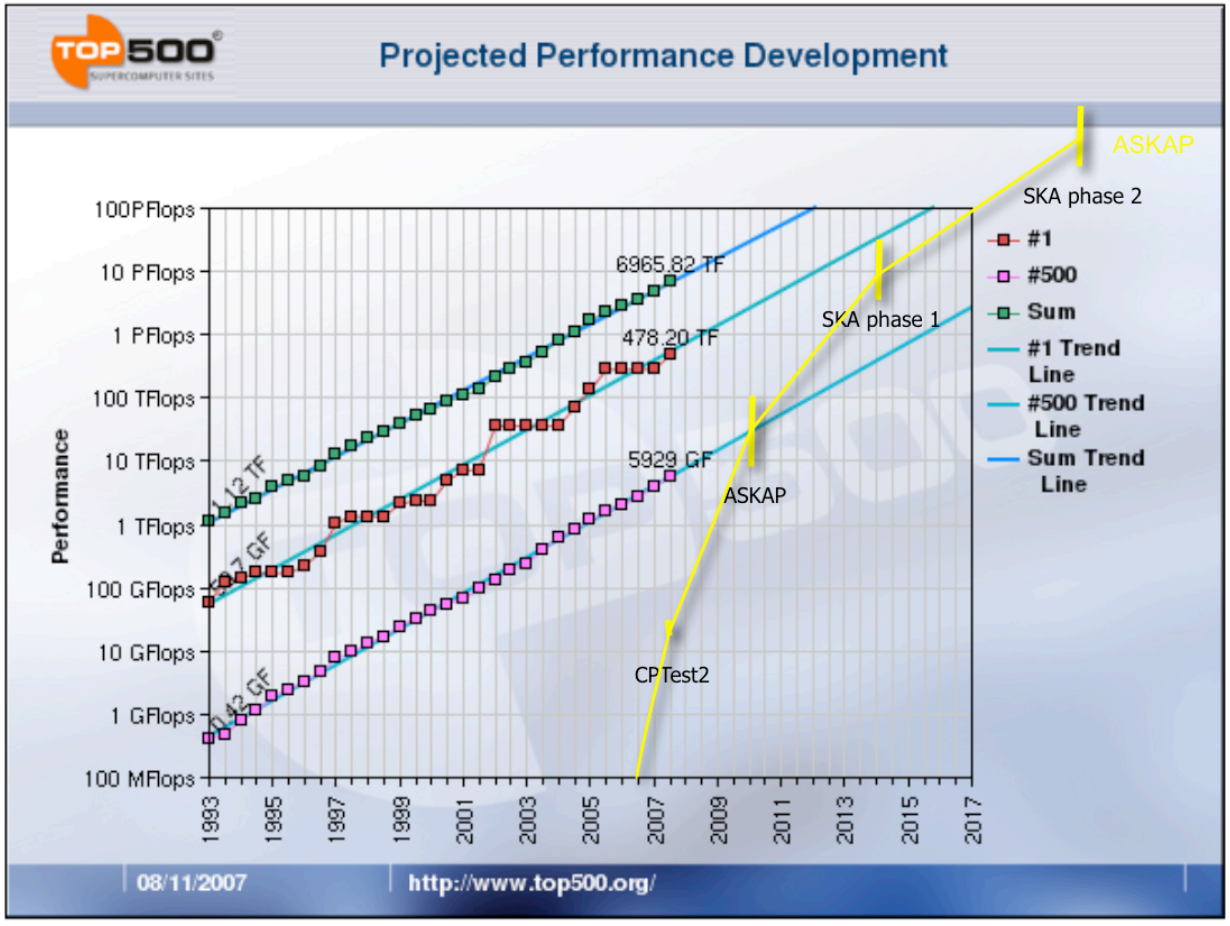
What does this mean for astronomy?

- Software pipelines
- Massive simulations
- Distributed computing
- Supercomputing
- Robotic telescopes
- Online communication
- The Virtual Observatory

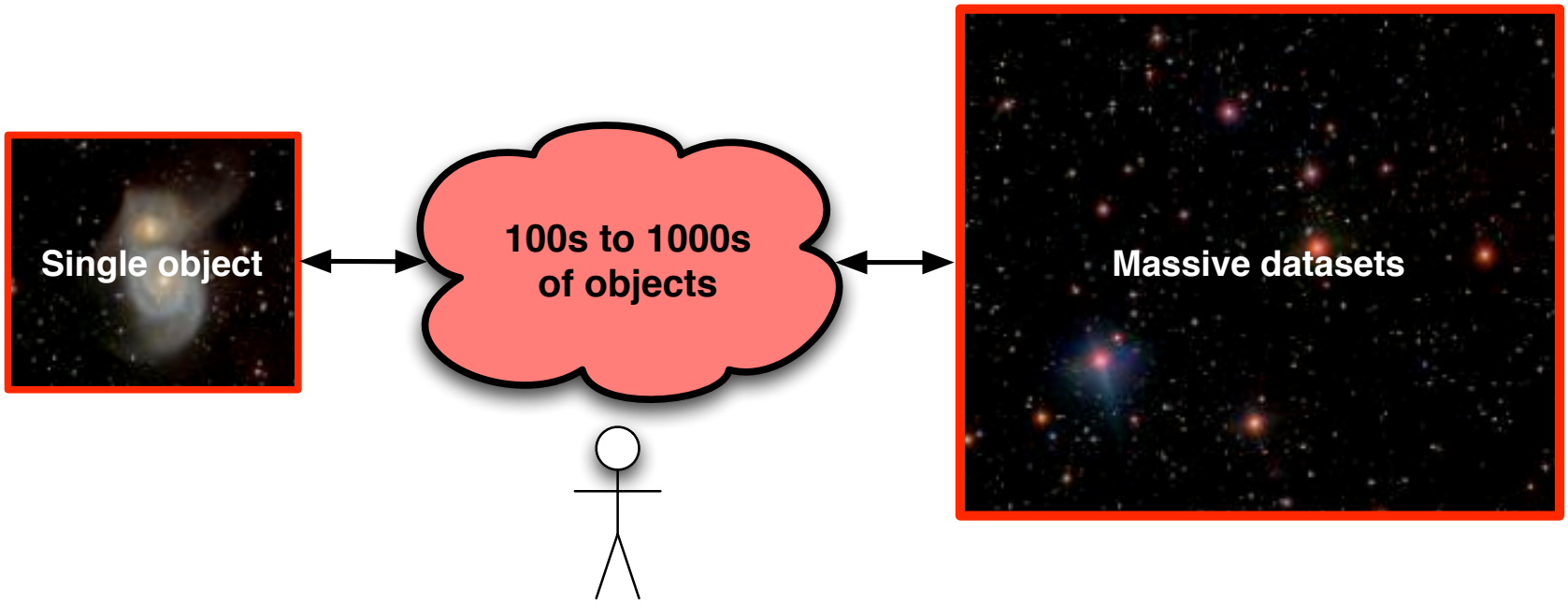
- Some paradigm shifts in the way we do astronomy
  - The archive is the telescope!
  - We can't store all data!

SKA computing requirements (Tim Cornwell)

Climbing Mount Exaflop



What does this mean for you?



Scenario: How would you solve this problem?

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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?

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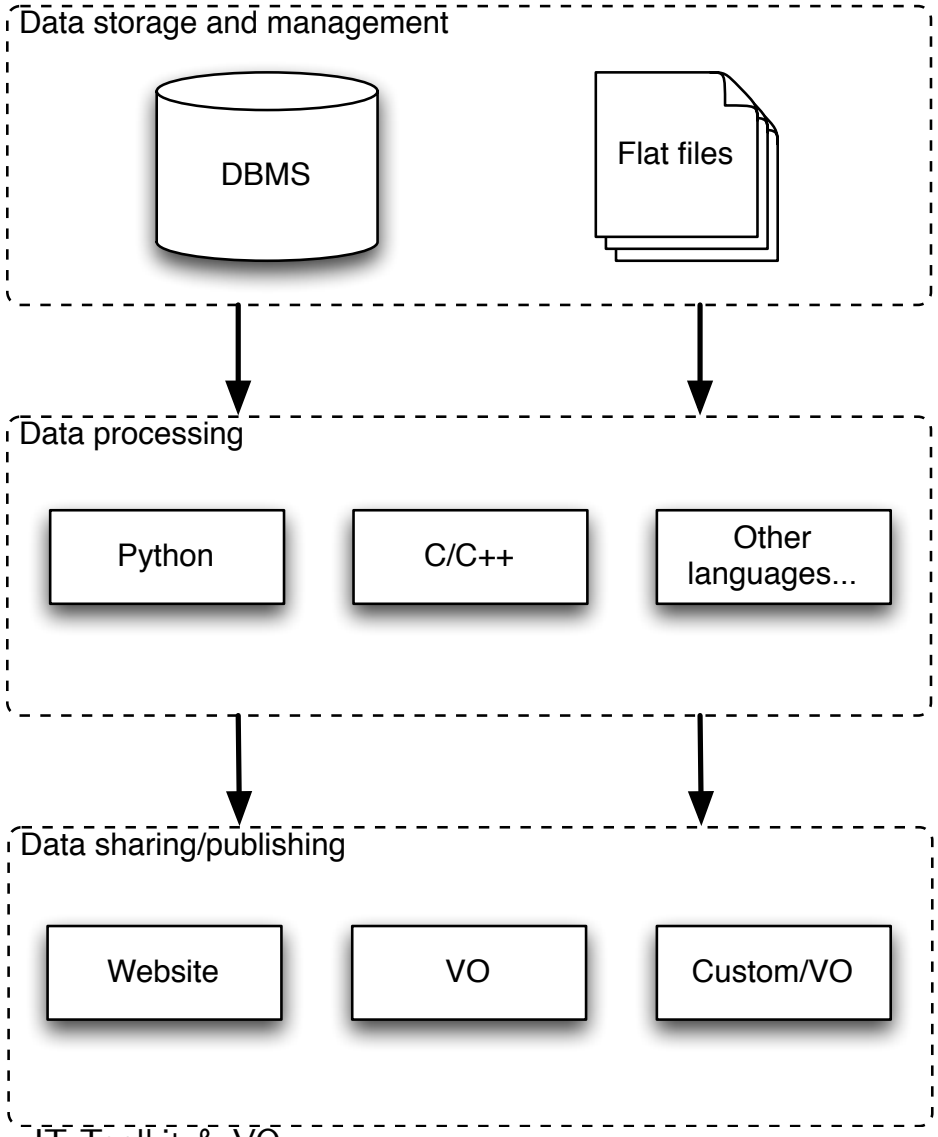
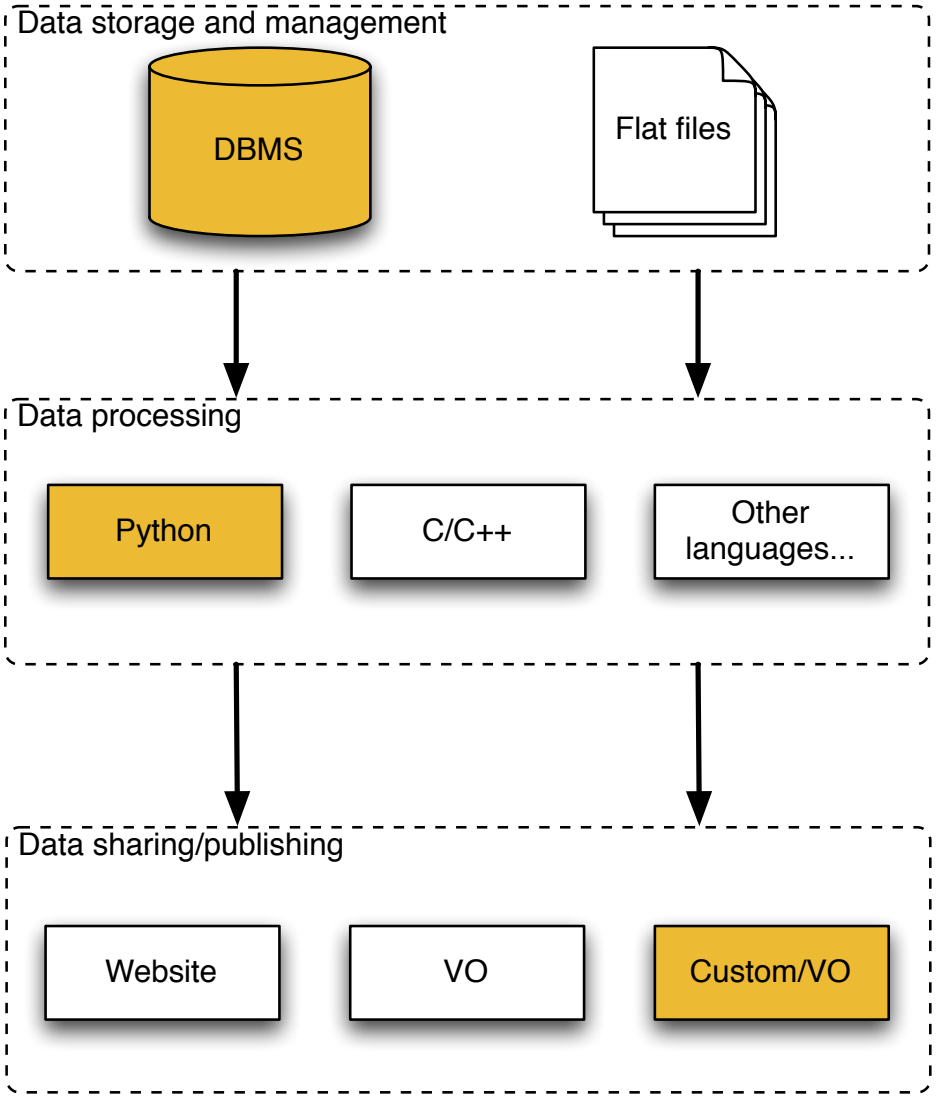
- And finally. . .
- **You have a catalogue**
  1. You want to store it
  2. You want to put it on the web
  3. You want to make it easily accessible to others

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. . .


AND A LEAN, SILENT FIGURE SLOWLY FADES INTO THE GATHERING DARKNESS, AWARE AT LAST THAT IN THIS WORLD, WITH GREAT POWER THERE MUST ALSO COME -- GREAT RESPONSIBILITY!

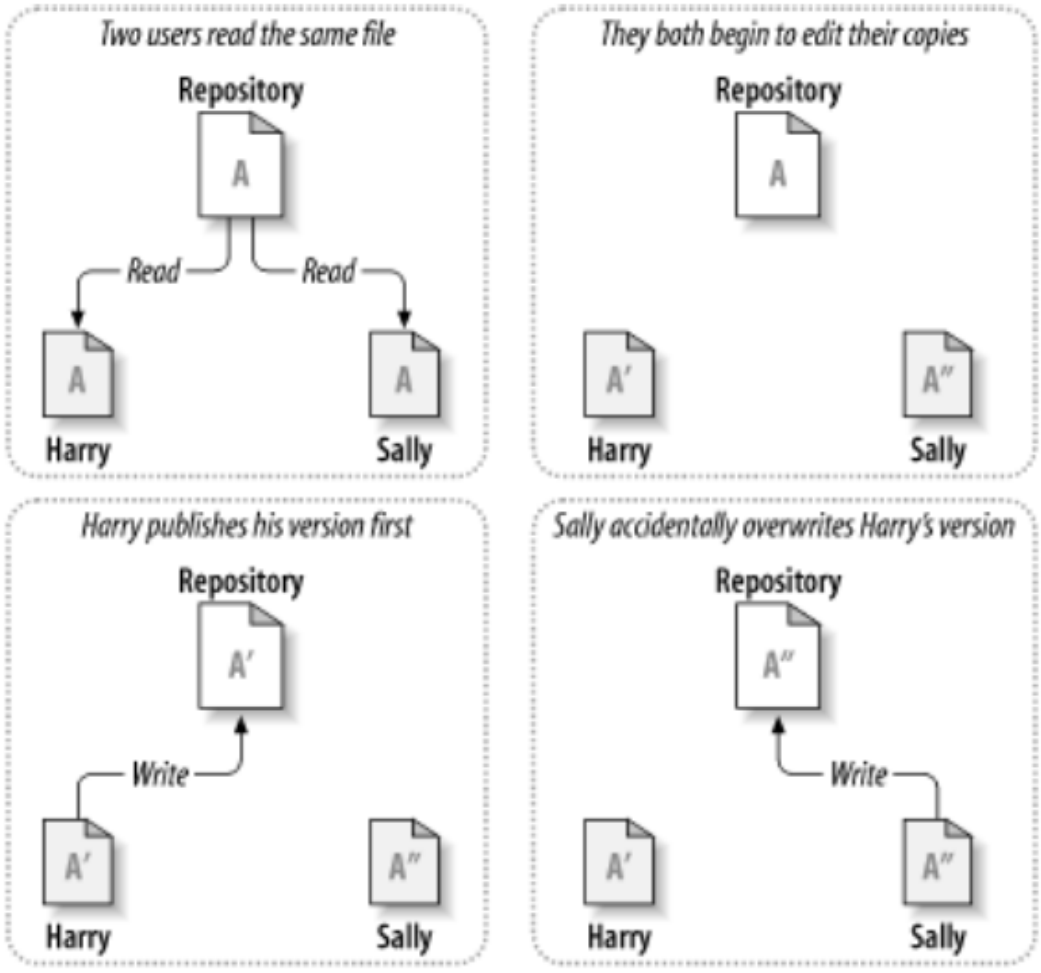
Why should I use version control?

- 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

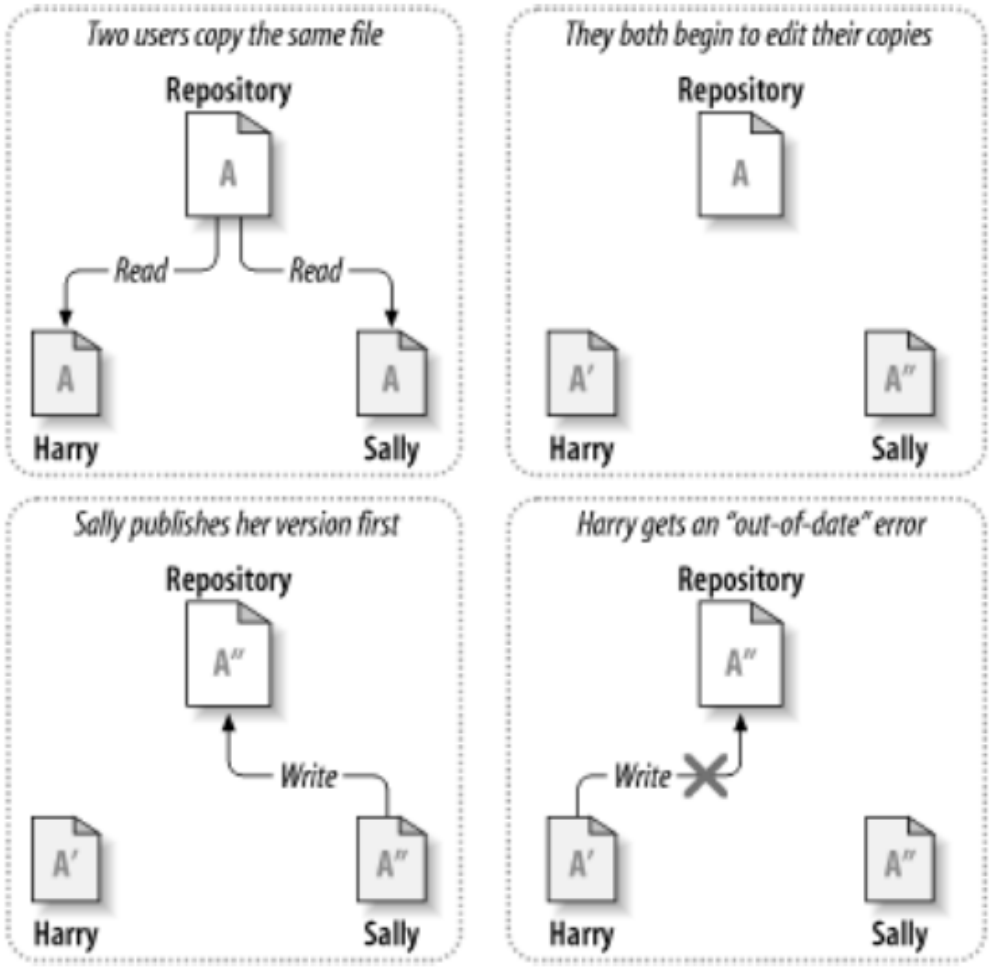
- **It makes you a better coder!**

The problem to avoid



http://svnbook.red-bean.com

The Copy-Modify-Merge solution



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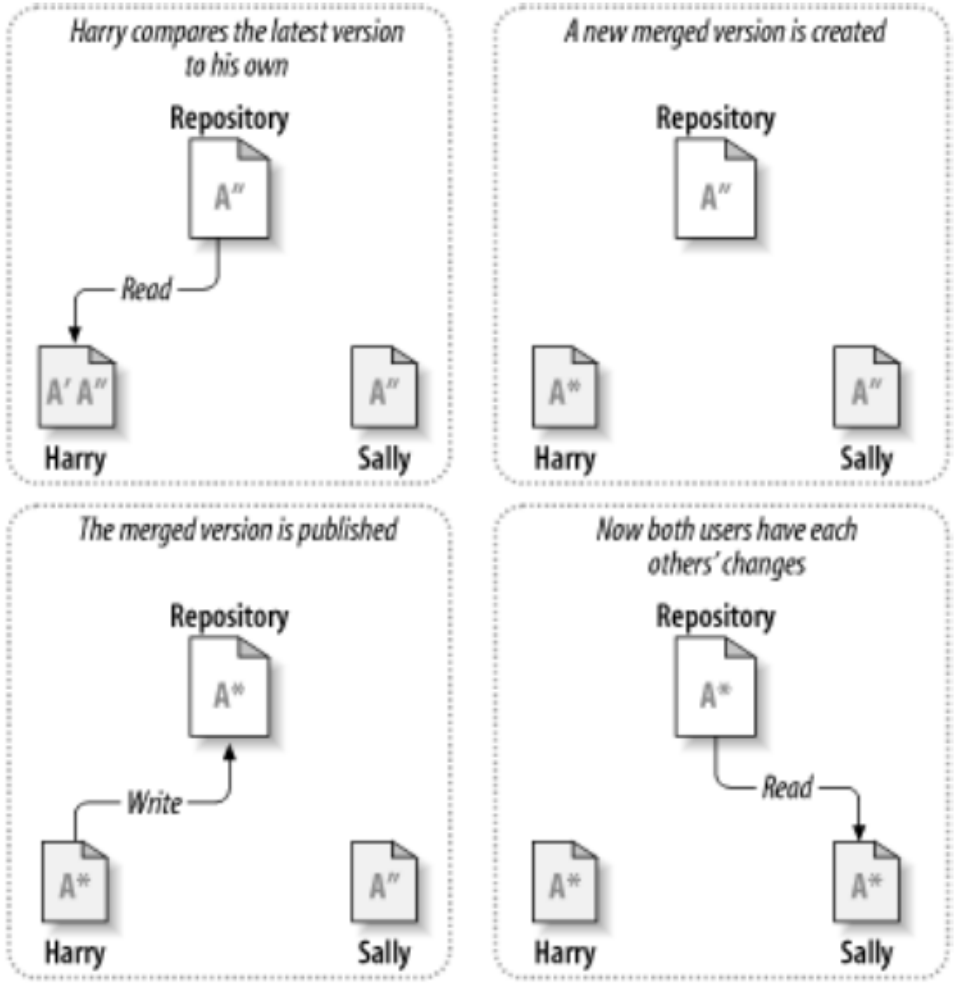

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What is the Virtual Observatory?

- 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

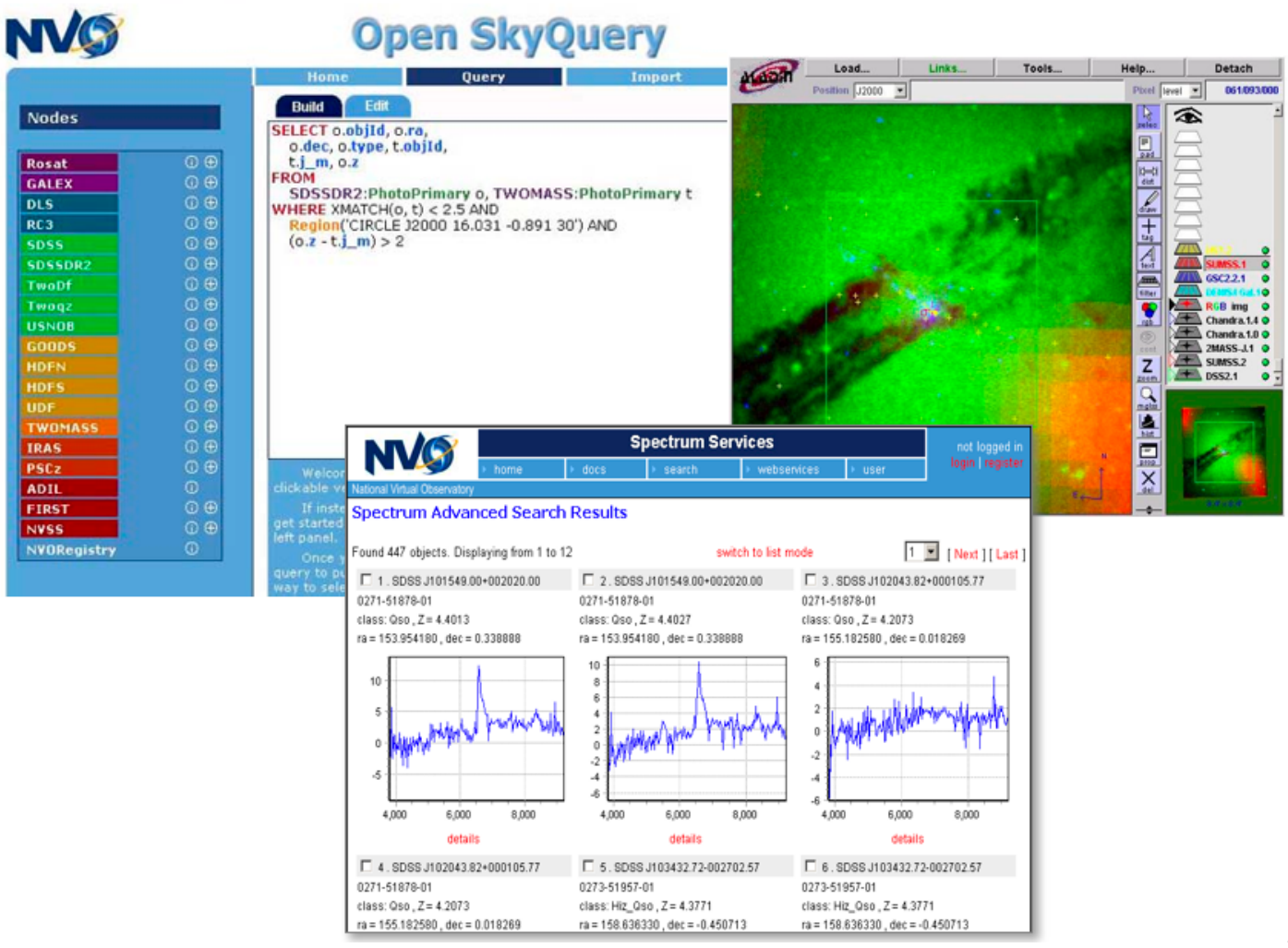
The Virtual Observatory is a distributed collection of

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

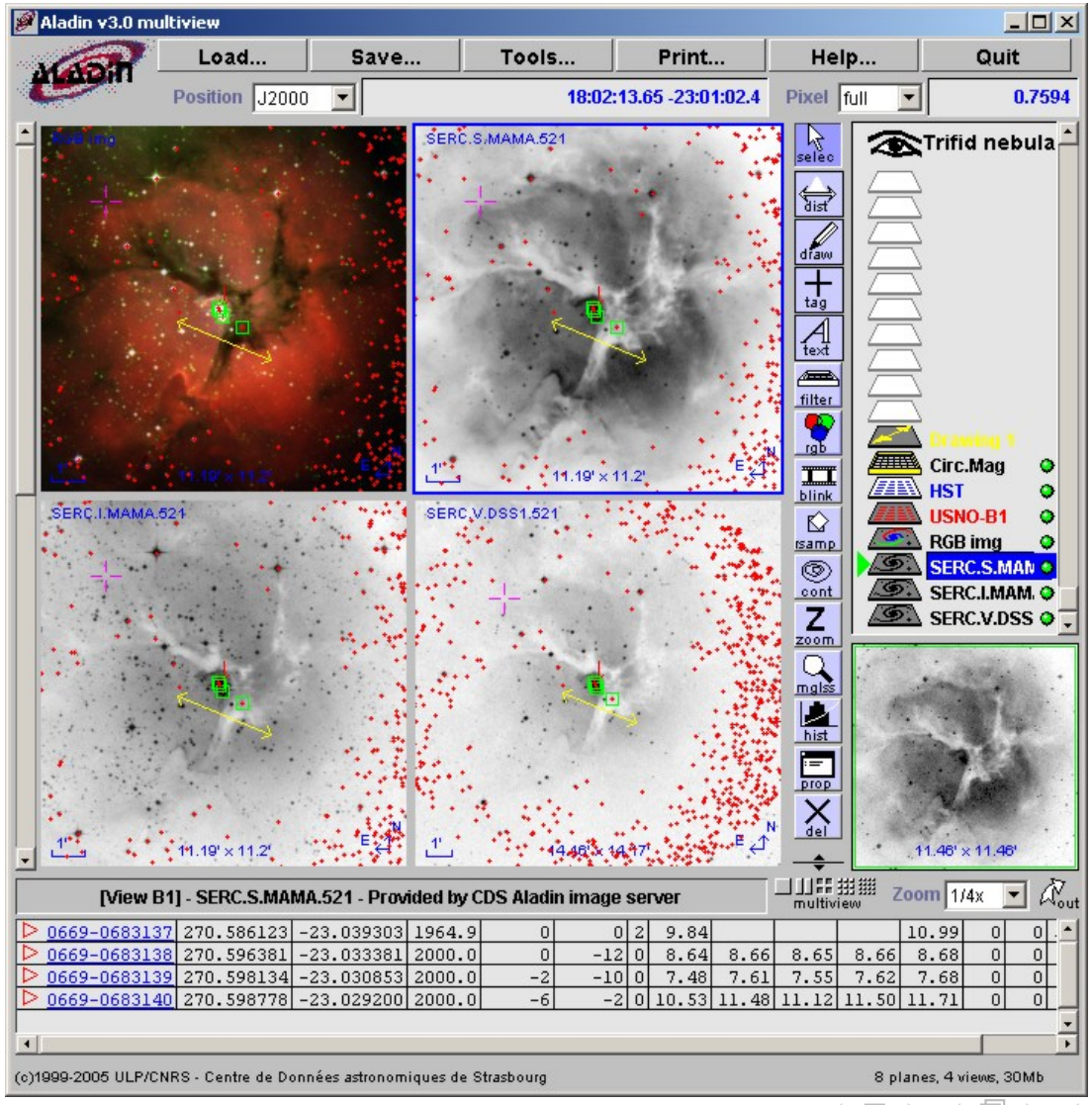
The International Virtual Observatory Alliance

http://www.ivoa.net

What are VO tools?



An interactive sky atlas: Aladin

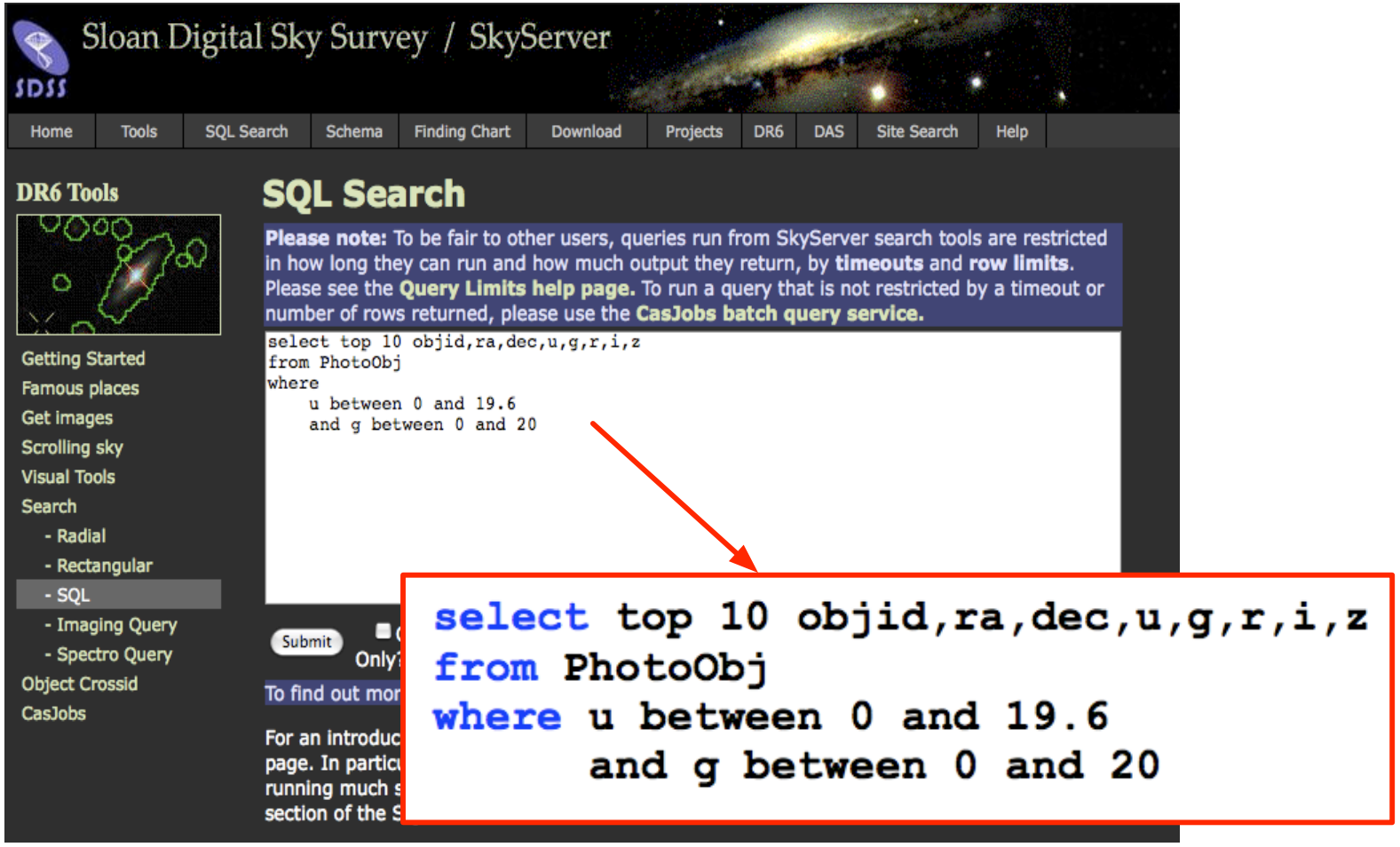


An interactive sky atlas: Aladin

- 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



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

Querying online databases: Open Sky Query

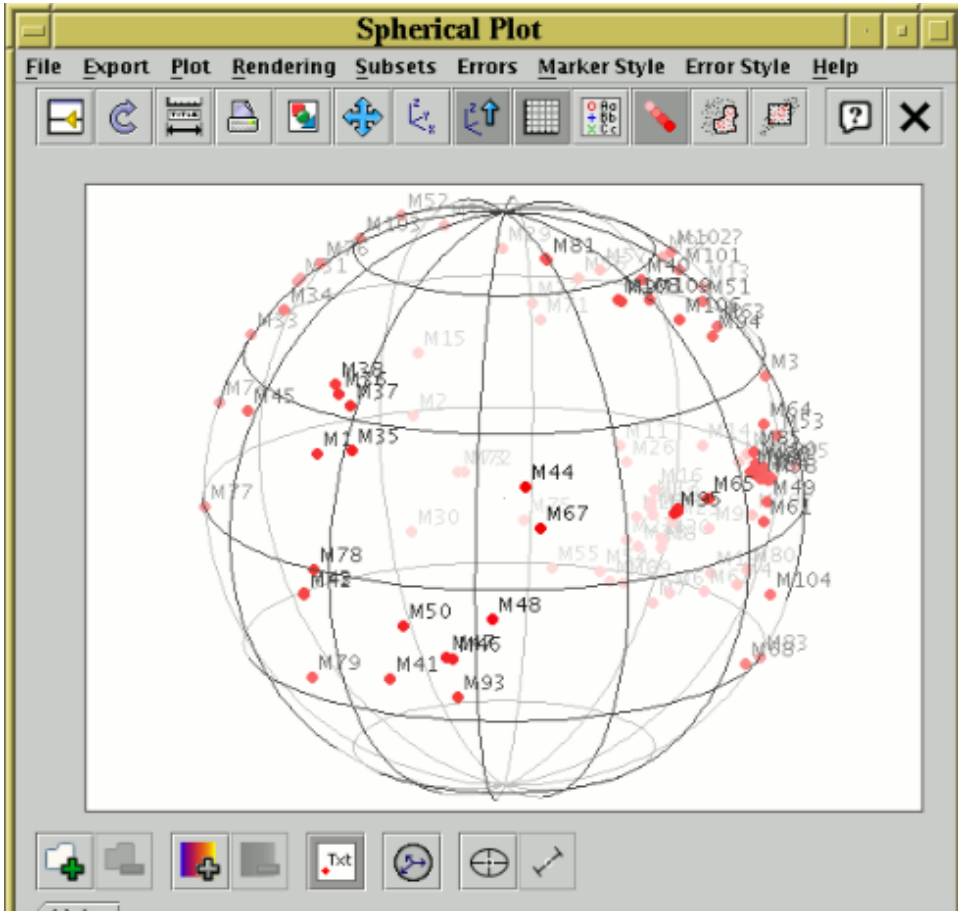
http://openskyquery.net/Sky/SkySite

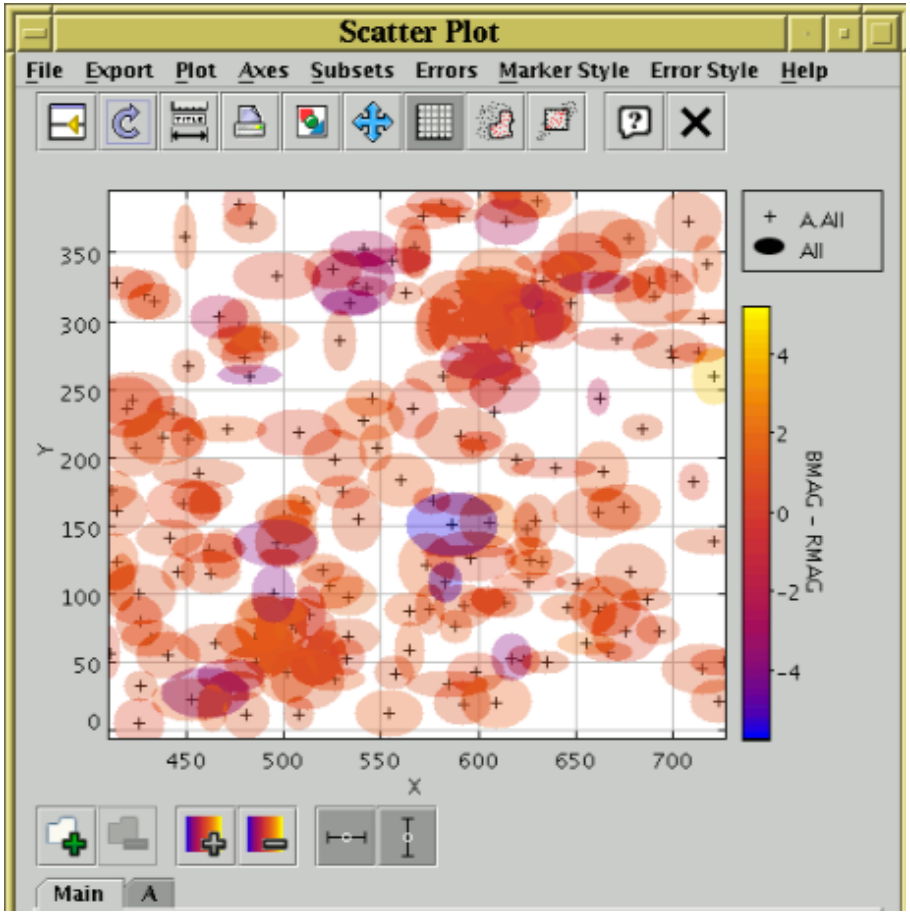
VO enabled plotting

- 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



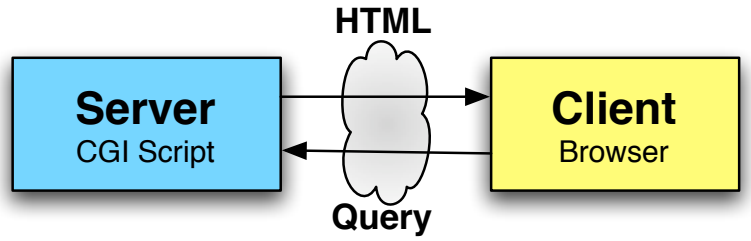


Other tools worth looking at

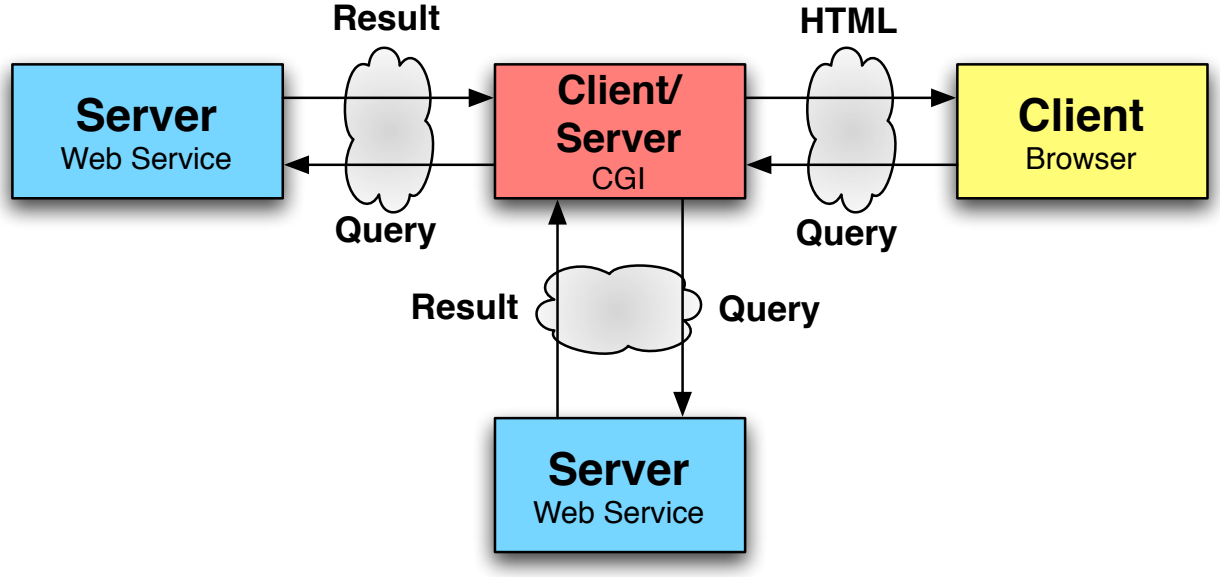
- DataScope
  heasarc.gsfc.nasa.gov/vo
- SkyView
  http://skyview.gsfc.nasa.gov
- MyADS
  http://myads.harvard.edu
- AstroGrid
  http://www2.astrogrid.org/science
- Google Sky
  http://www.google.com/sky

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 Astroinformatics School website
  http://www.icrar.org/news/pastevents/astroinformatics
- Resources available from the NVO Summer School website
  http://www.us-vo.org/summer-school

- Look out for the Astroinformatics School in 2012