VO for Astronomers:

Where Are We Now?

Disclaimer. No VO developers were harmed in the course of our studies – only bothered... a lot! Do not try repeat without proper training: severe risk of rising coffee expenses

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Instead of Introduction

- The Virtual Observatory is a realisation of the e-Science concept in astronomy.

- **Data archives and software tools** interoperating using a set of peer-reviewed standards and technologies developed by the IVOA form a powerful *virtual environment* aimed at facilitating astronomical research and increasing scientific output of data

What does that mean???

- to increase $N_{paper}/Gb$
WWW and VO: similarities

- **W3C**
  - HTML/XHTML
  - Javascript specs

- **Resources:**
  - web-sites
  - portals/directories
  - web-services

- **Tools:**
  - browsers
    - Firefox
    - IE
  - command-line
  - specialised
    - Picassa
    - Google Earth

- **IVOA**
  - VOTable
  - all other standards

- **Resources:**
  - data archives
  - CAS
  - web-services

- **Tools:**
  - data browsers
    - VODesktop
    - Aladin
    - DataScope
  - command-line
  - specialised
    - VisIVO
What is already accomplished

• On the IVOA side:
  − a comprehensive set of standards, although still a lot to work on
• On the application developers side:
  − a heterogeneous set of tools from very general to very specialised
• On the data/service providers side:
  − many data collections and archives at wavelength domains from gamma to radio, although some major players are still out of the game
  − first services providing access to models
  − online data analysis services start to appear
What about science?

- Quite a long break after the first paper by Padovani et al.
- New results appeared recently
  - Caballero et al.
  - Solano et al.
  - Richards et al.
  - ...
- At present, the VO-enabled research is mostly data mining
  - Is it already possible to go beyond???
    YES, of course!
Motivation:

_Segregation of young galaxies in cluster centres_

High \([\alpha/Fe]\) ratios, metallicities and velocity dispersions for 5 low-luminosity galaxies in the the Abell 496 core (Chilingarian+08), one of them is a newly discovered cE (M32-like) galaxy (6-th known in the Universe). Stellar populations suggest massive progenitors.
#1: What was done inside VO

VO workflow includes:

- querying Vizier to retrieve a list of Abell clusters having $z<0.05$, then NED for Galactic extinction

- querying HLA via SIAP interface to locate broadband WFPC2 data

- running SExtractor service on these images and processing its output:
  - converting everything into B band, correcting for whatever is possible
  - selecting extended objects having effective radii below 0.7 kpc and B-band mean effective surface brightness higher than 20 mag/arcsec^2;

- querying NED to check if there are published redshifts for the selected objects, looking for additional data (X-ray and optical photometry...
#1: What we got out of the VO

Data for 53 clusters analysed
- a large number of candidate galaxies found
- two were immediately confirmed from SDSS
- almost empty locus of cE got filled

What's next???
- follow-up ground spectroscopy to study stellar populations
- simulations to reproduce the properties
3 clusters with 8 cE candidates were observed (2 nights at 6-m)
- all 8 were confirmed
- all 8 have old metal-rich populations evident of more massive progenitors

Simulations of tidal stripping of lenticulars were conducted
- density increase is reproduced
- stellar mass loss is reproduced
- 2-component brightness profiles are reproduced
#1: Main result

- The class of cE galaxies was converted from “unique” into “common under certain environmental conditions”
- Evidences are given for an importance of tidal stripping of stellar discs of lenticular galaxies as a way to form “compactish” ellipticals
- Now we can explain freaks like VCC1199 having supersolar metallicity with $M_B = -15$
- The first study made with VO, then followed-up with a large telescope and reproduced by simulations
#1 Issues

- No VO access to NED
- SIAP in HLA is not public, i.e. undocumented
- Had to setup customised SExtractor service and spend a lot of time playing with its (undocumented) features
- It took 3 semesters to convince TAC to get telescope time (social engineering)
- During observations it turned out that I was the first to use that particular mode of the instrument, so no data reduction software was available
- Modellers + observers + VO developers in the same team = possibly explosive!
#2: optical/NIR galaxy colours

• Just an example of what can be done with the VO from scratch in 1 week by 2 people
• Goal: studying optical/NIR colours of nearby galaxies and connecting them to the stellar populations
  - NIR magnitudes are much less sensitive to the stellar population age compared to the optical, therefore they are good stellar mass indicators (although not perfect)
  - extinction effects are smaller in NIR
  - spectroscopic ages and metallicities are important additional bricks of information
• Challenge: ONLY 1 WEEK TO COMPLETE

Collaboration with Ivan Zolotukhin (SAI MSU)
#2: optical/NIR galaxy colours

**Resources used:**
- SDSS DR7 catalogues
- SDSS DR7 spectra
- UKIDSS DR4 Large Area Survey catalogue

**Techniques:**
- cross-match (VO-possible)
- stellar population modelling using PEGASE2/PEGASE.HR (VO-possible)
- *NBursts* spectral fitting (non-VO)

**Tools:**
- Topcat/STILTS to join and merge the tables (just to simplify the life)
- script-based access to SDSS
- *possible* to use VO Desktop for UKIDSS
#2: What was done (1)

- SDSS CASJobs to select all galaxies with 0.03<z<0.3 in stripes 9 to 16 (spectroscopic sample): 170k objects
- WFCAM Archive to cross-match against UKIDSS DR4 LAS (possible with Astrogrid VO Desktop since Monday)
- Fitting optical/NIR SED against PEGASE2 models to get rest-frame magnitudes (K-corrections)
- Fitting SDSS spectra to get velocity dispersions, ages and metallicities
#2: What was done (2)

- SDSS: 170k galaxies (black)
- UKIDSS: 77k (blue)
- spectral fitting post-processing: 50k, including 23k having z<0.15 (red)
#2: Issues

- **Aperture effects**: Petrosian radii in SDSS and UKIDSS are sometimes very different
  - Solution: using aperture magnitudes for colours + SDSS r' to renormalize the SED
- **K-corrections**: controversial information is given in literature
  - Solution: compute them ourselves
#2: Issues (technical)

- SDSS DR7 is not inside the VO, one has to proceed through CASJobs
- Problems accessing UKIDSS DR4 through VO (proprietary access with authorisation) simply because nobody has tried it so far – *now solved*
- Downloading/uploading/converting tables – quite annoying
- No way to cross-match against uploaded tables using ADQL
- In addition I had to compete with the job-queue and finally ran out disk quota while fitting 170k spectra
There is a 4-mag high-luminosity tail of the red sequence in $H$ band with a slightly different slope. These galaxies can form only by merging red sequence galaxies.
There is a significant age gradient in the "blue cloud"; most of the red sequence objects are old.
In the optical-NIR colours (e.g. g-H) the blue cloud starts to overlap the red sequence – probably extinction effects, since galaxies show intermediate stellar population younger than of red sequence objects.
#2: Still a lot to do

• All this was just a simple example, but it should not take too long to “polish” it, think a little bit about the interpretation and convert into a refereed Letter

• Still we foresee to add GALEX data and fit spectra together with photometry with more realistic galaxy model than a simple SSP: 2 bursts of star formation, dust attenuation)
  – Difficulty: GALEX is accessible via its own CASJobs even different from Sloan

• Another important point will be to understand the nature of outliers
Summary

• The VO is already at the production level. Scientists (not associated to VO projects) are feeling the way
• First scientific results obtained are important and impressive. The advantages of the approach are clear.
• However, the major problem for a scientist in the VO now is a large number of very little but very annoying infrastructural faults: all the individual bricks exist, but putting them together is tricky