# CDS and the VO

# Virtual Observatory

- Framework for interoperable and efficient access to astronomical data and services
- e-Science for Astronomy
- Based on global standards
  - co-ordination via IVOA

# 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 science

# CDS involvement

- Development of VO standards
- Leadership roles in IVOA, EuroVO, VOFrance
- VO science tools and services
- VO science
- Science tutorials, outreach/education
- Assisting the Data Centre community to publish to the VO

# CDS approach to VO

- Participate fully in VO development of standards -- it helps the CDS services
- As a major content provider we need to be involved
- Careful implementation of VO in CDS services alongside other access modes
- Use VO to foster innovation and collaboration

# Projects

- European co-ordination

- **AVO** (FP5)
- **VOTech** (FP6)
- **DCA** (FP6)
- **AIDA** (FP7)
- **ICE** (FP7)

# IVOA

- Leadership roles:

  Genova - Chair 2006-7, Vice-Chair 2005-6, DCP IG Vice chair 2004-7, Comm. Standards and Processes 2007-

  Ochsenbein - VOTable Chair 2003-9

  Allen - Applications IG/WG Chair 2005-8, Comm. Science Priorities 2009-, Newsletter Editor, Secretary 2009-

  Derriere - Semantics WG Chair 2008-

  Schaaff - Grid and Web Services WG Vice Chair 2011-

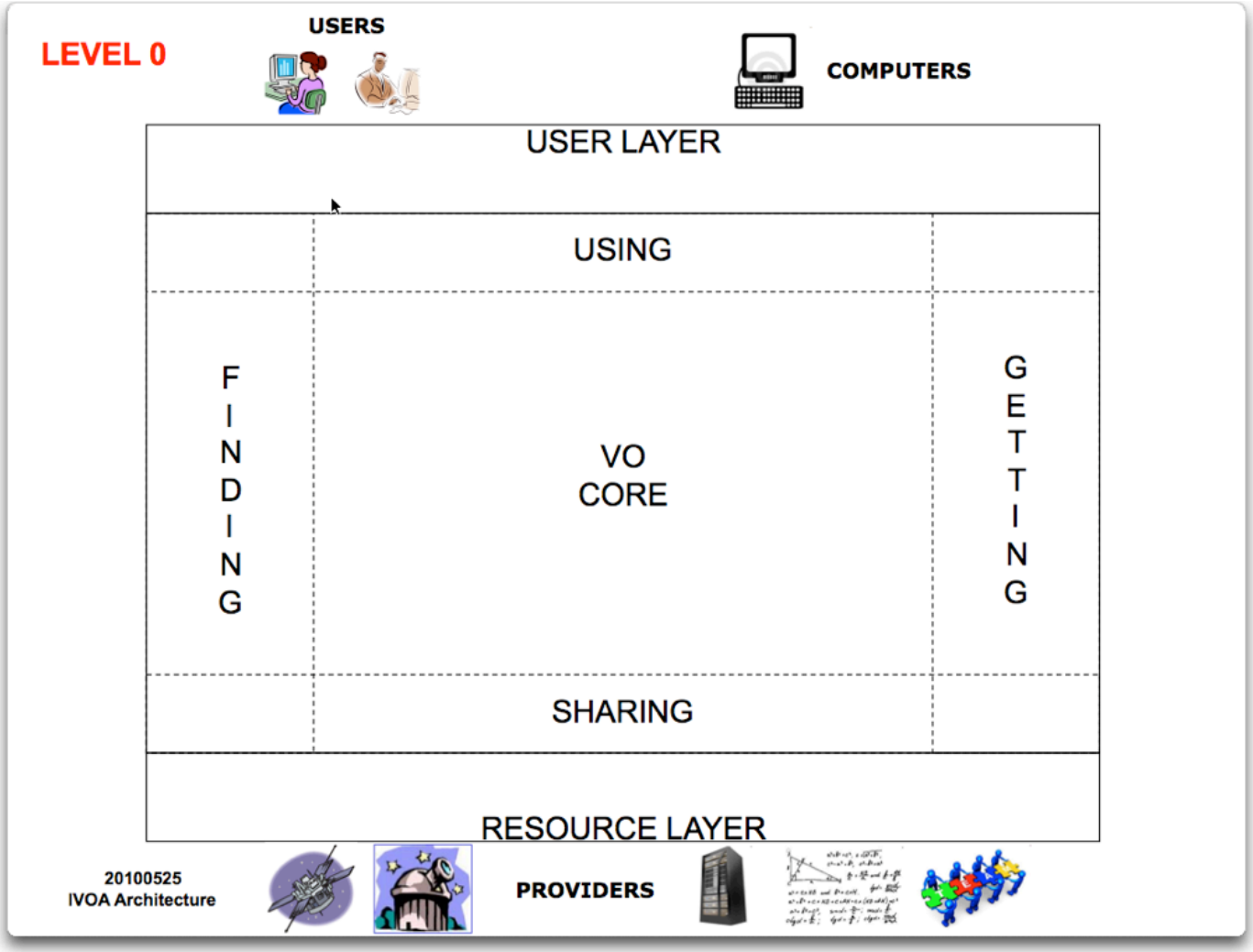
  Preite-Martinez (INAF) - Semantics WG Chair 2005-8

  Louys (LSIIT) - Data Models WG Chair 2007-11

  Wozniak (Obs. Strasbg.) - Theory WG Chair 2008-11

# IVOA - Architecture

Multi-level structure for understanding each component of the VO



**LEVEL 1**

**USERS**

**COMPUTERS**

| | | | | |
|---|---|---|---|---|
| | | USER LAYER | | |
| ***Browser Based Apps*** | | ***Desktop Apps*** | | ***Script Based Apps*** |
| | | USING | | |
| REGISTRY | ***Semantics*** | ***VO Query Languages*** | ***Data Models*** | DATA ACCESS PROTOCOLS |
| | | VO CORE | | |
| | | ***Formats*** | | |
| | | SHARING | | |
| ***Storage*** | | ***Data and Metadata Collection*** | | ***Computation*** |
| | | RESOURCE LAYER | | |

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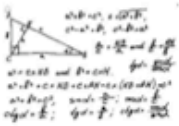
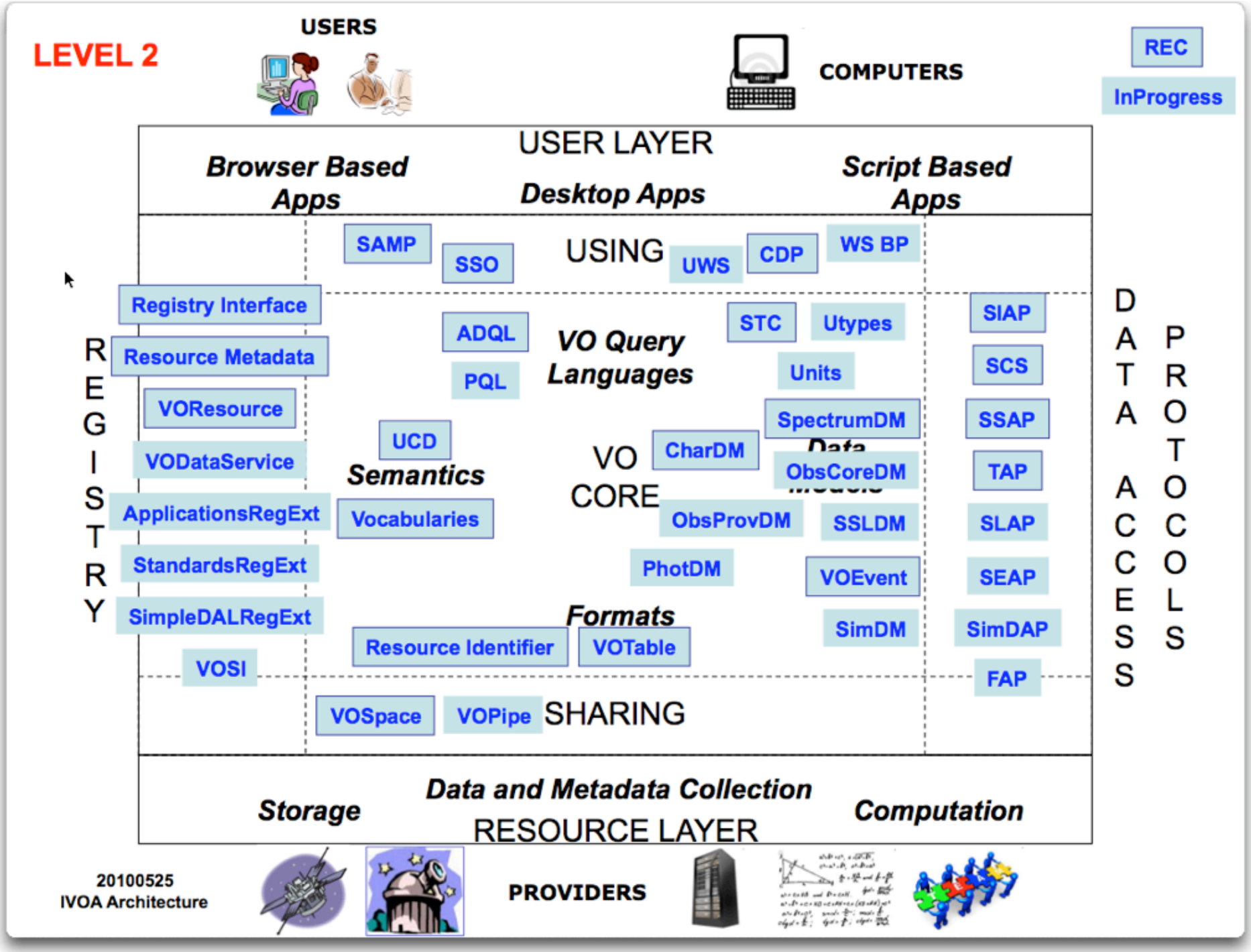
IVOA Architecture

**PROVIDERS**




LEVEL 2
USERS
COMPUTERS
REC
InProgress
USER LAYER
Browser Based Apps
Desktop Apps
Script Based Apps
SAMP
SSO
USING
UWS
CDP
WS BP
Registry Interface
Resource Metadata
VOResource
VODataService
ApplicationsRegExt
StandardsRegExt
SimpleDALRegExt
VOSI
REGISTRY
ADQL
PQL
VO Query Languages
STC
Utypes
Units
SpectrumDM
CharDM
ObsCoreDM
ObsProvDM
SSLDM
PhotDM
VOEvent
SimDM
VO CORE
UCD
Semantics
Vocabularies
Formats
Resource Identifier
VOTable
SIAP
SCS
SSAP
TAP
SLAP
SEAP
SimDAP
FAP
DATA ACCESS
PROTOCOLS
VOSpace
VOPipe
SHARING
Data and Metadata Collection
Storage
Computation
RESOURCE LAYER
PROVIDERS
20100525
IVOA Architecture

# Specific CDS contributions to IVOA standards

- VOTable
- Data Access Layer
  - Simple Spectral Access (SSA), Simple Image Access (SIA), Table Access Protocol (TAP)
- Data models: Characterisation, ObsTAP
- Applications: SAMP
- GWS: VOSpace 2.0, Basic Profiles

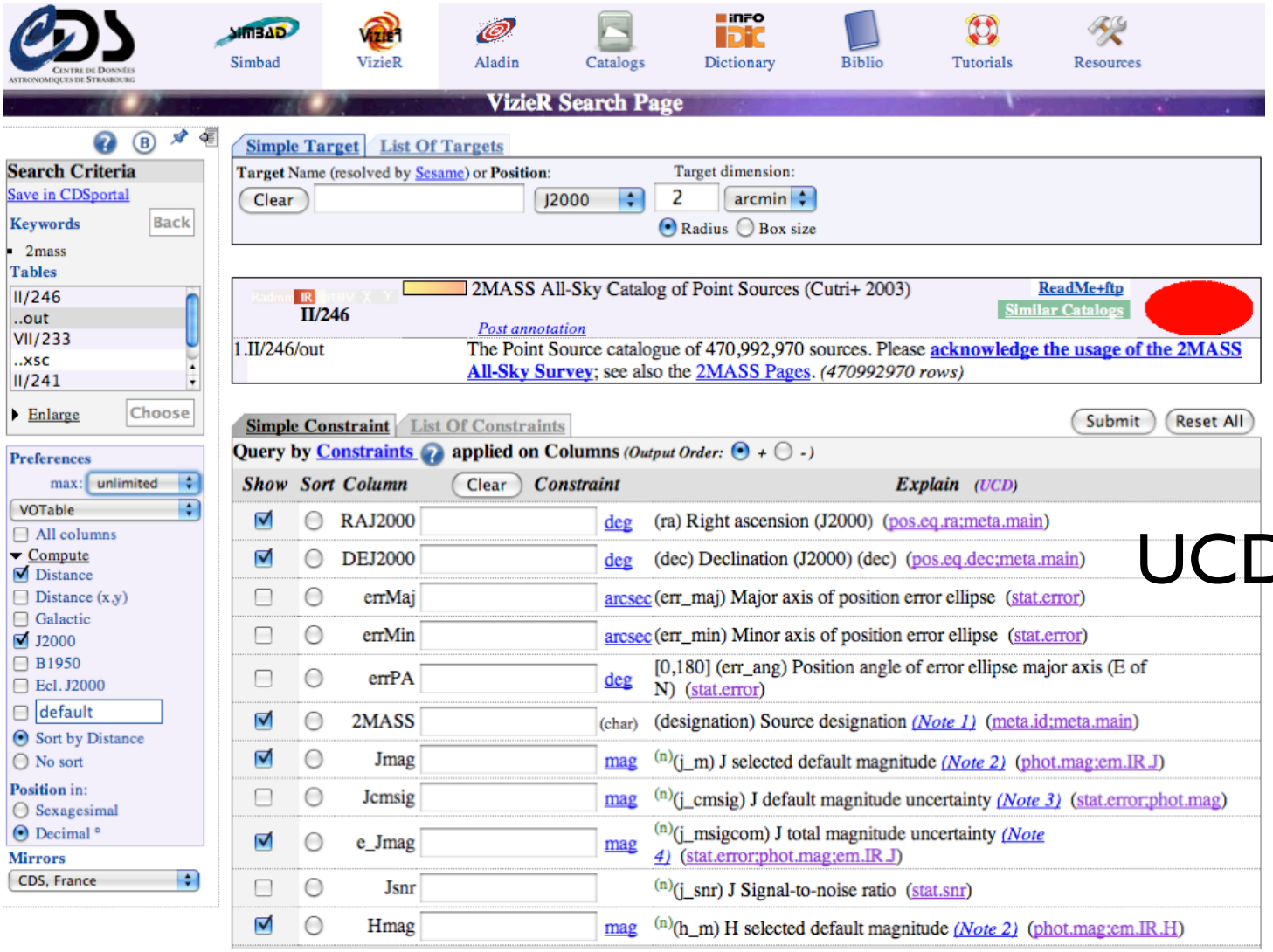
*see the list of IVOA standards 'signed' by CDS members*

- One important aspect of CDS participation: *testing implementations alongside of standards development*
  - ensures relevant and useable standards
- Examples:
  - VOSpace reference implementation and toolkit
  - UWS toolkit
  - VOTable parser
  - DMs/Characterisation in Aladin image server
  - Aladin SAMP

# VO in CDS services

- VO Compliance in services
  - VO access alongside existing modes (Vizier example to follow)
- VO interoperability of tools (SAMP)
- Innovation (e.g. CDS Portal, Healpix techniques)

# VO standards used in VizieR web page interface

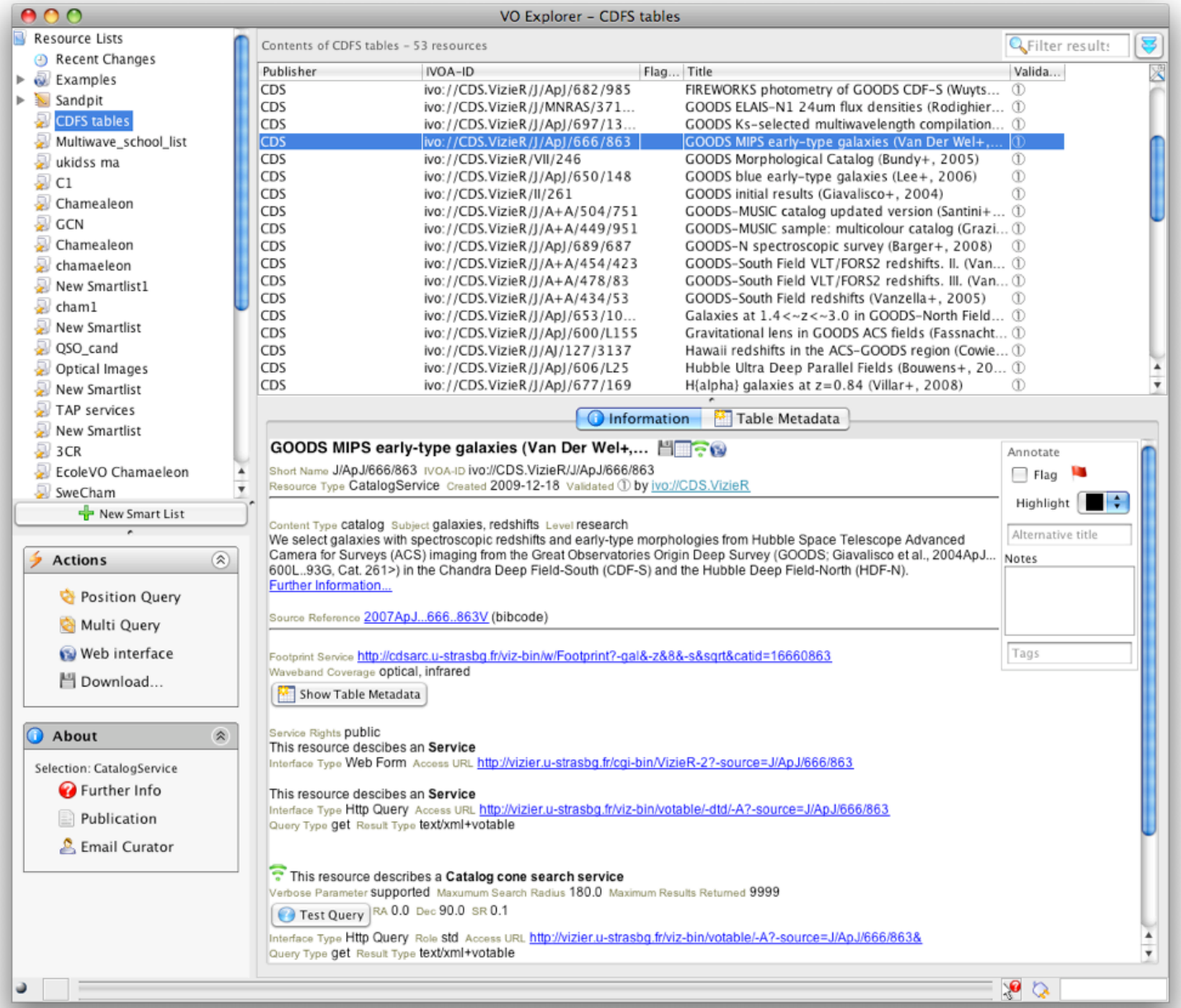


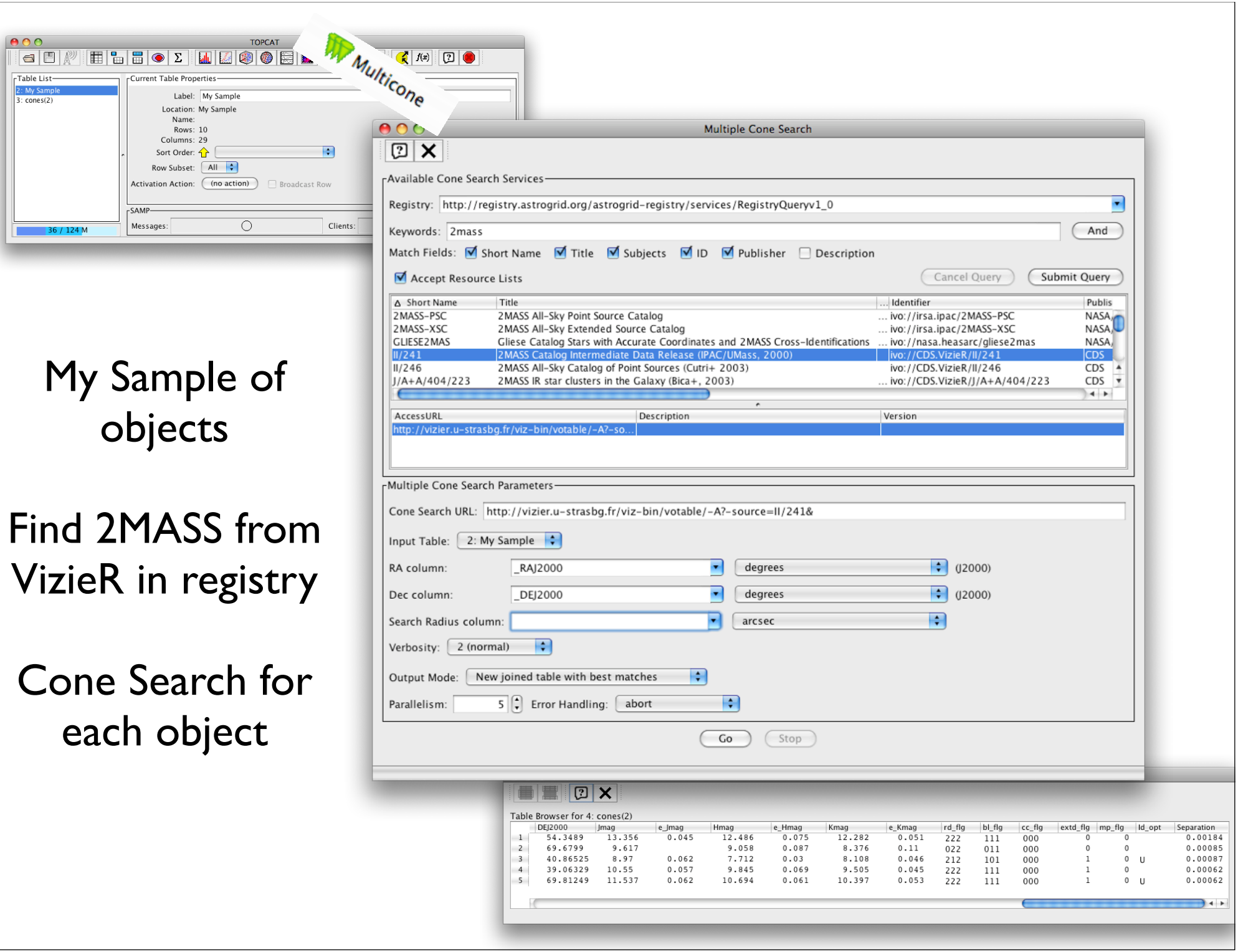

VOTable

UCDs

# VizieR catalogues described in the Registry

VizieR catalogues accessible via VOExplorer

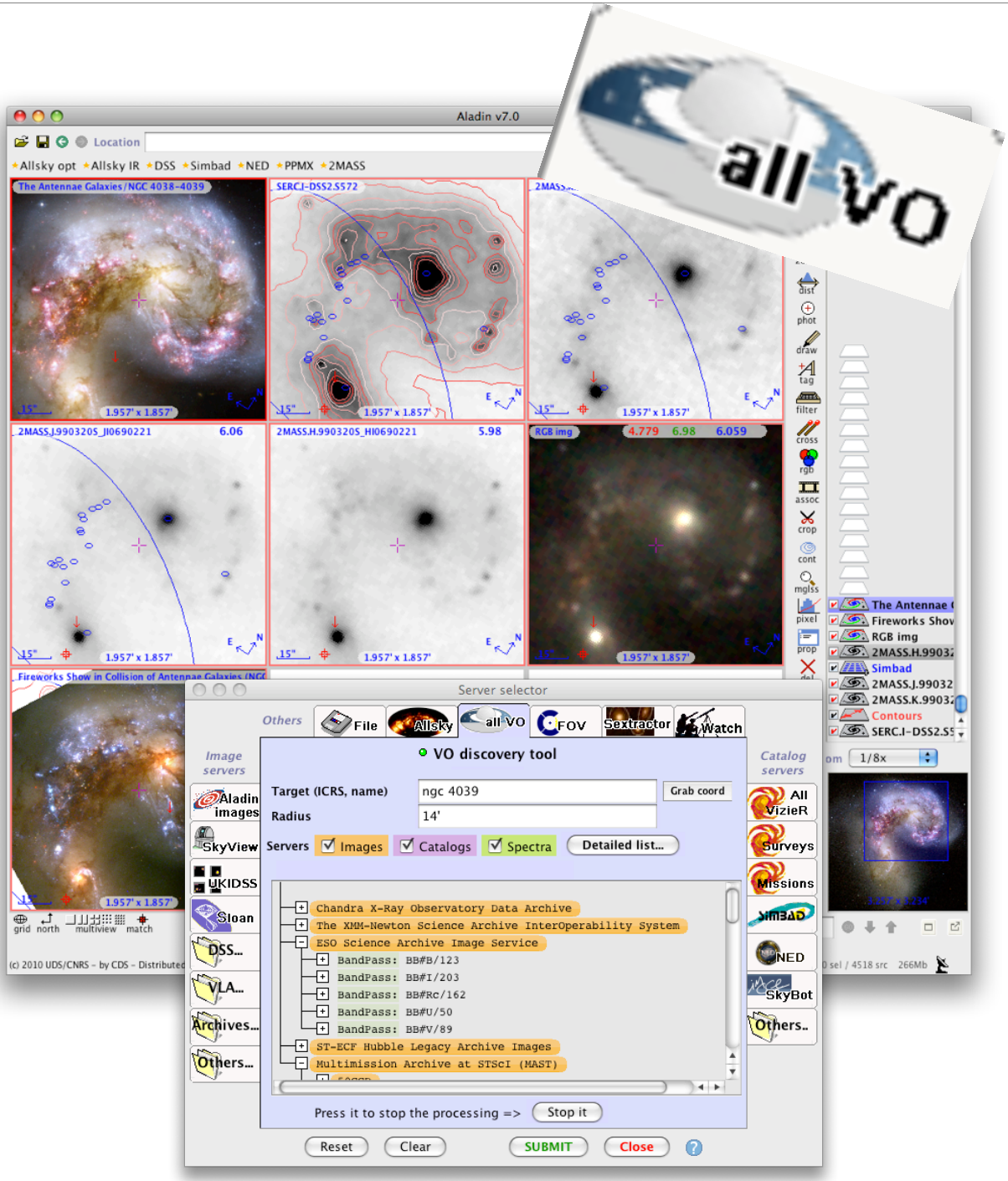





My Sample of objects

Find 2MASS from VizieR in registry

Cone Search for each object

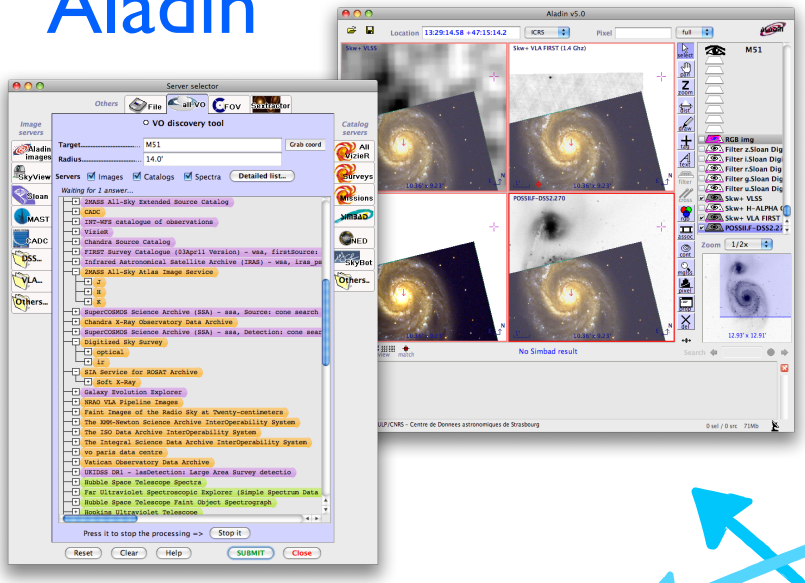



# Interactive Sky Atlas

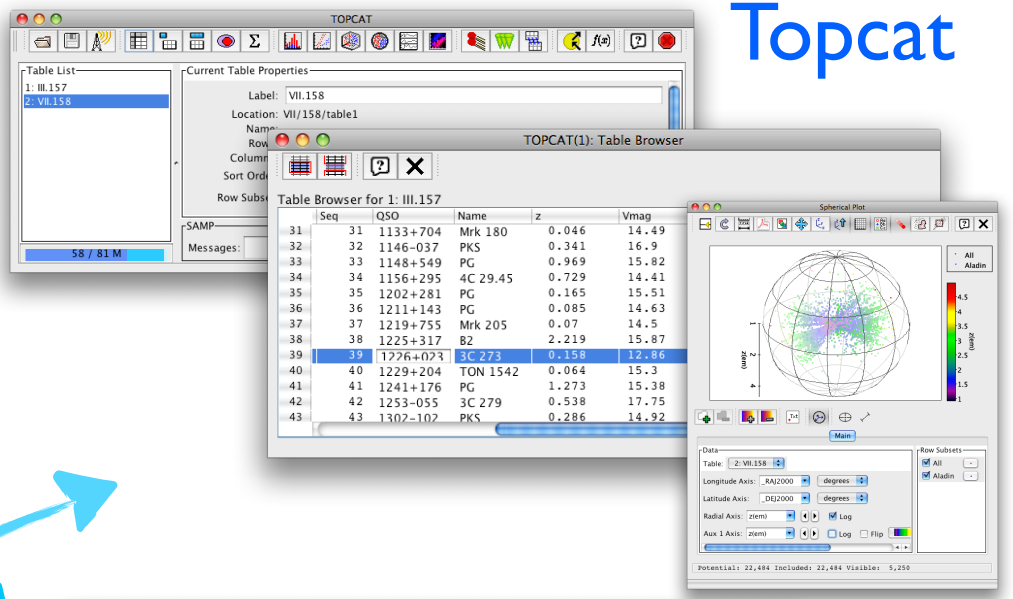
Images
Catalogues
VO Access
All Sky
Scripting
and more...

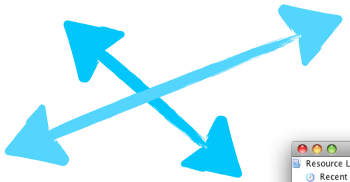
# SAMP tool interoperability

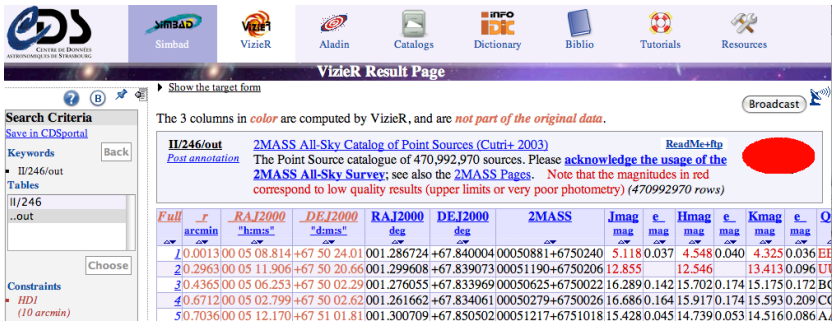
Aladin



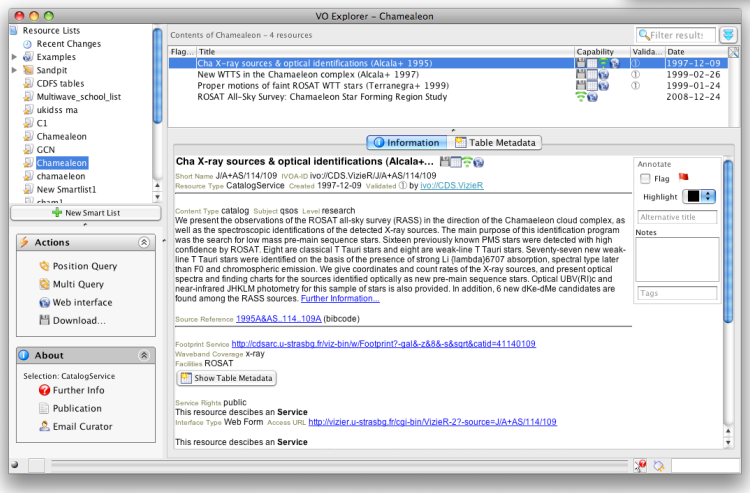
Topcat







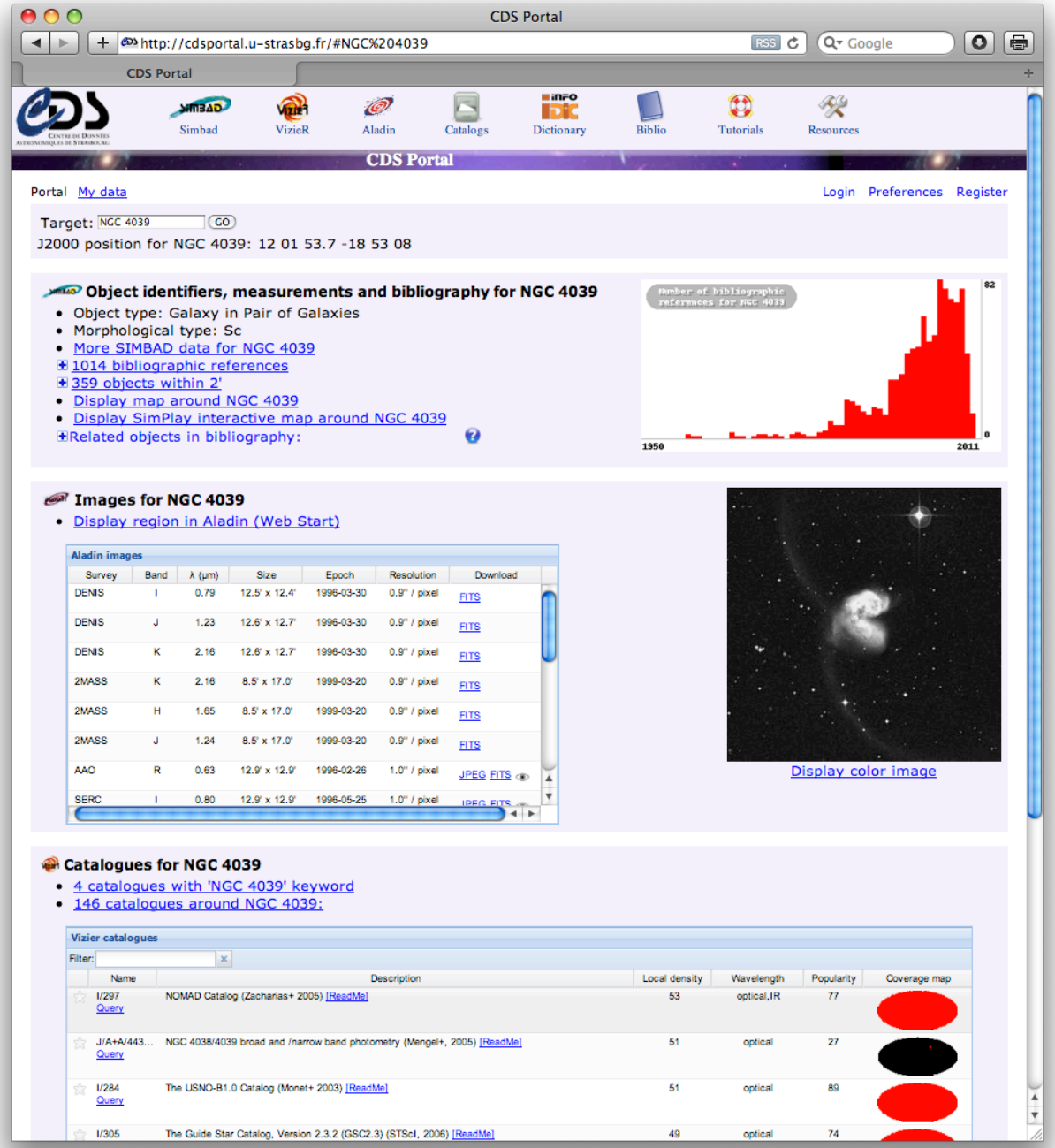

Web pages (VizieR)



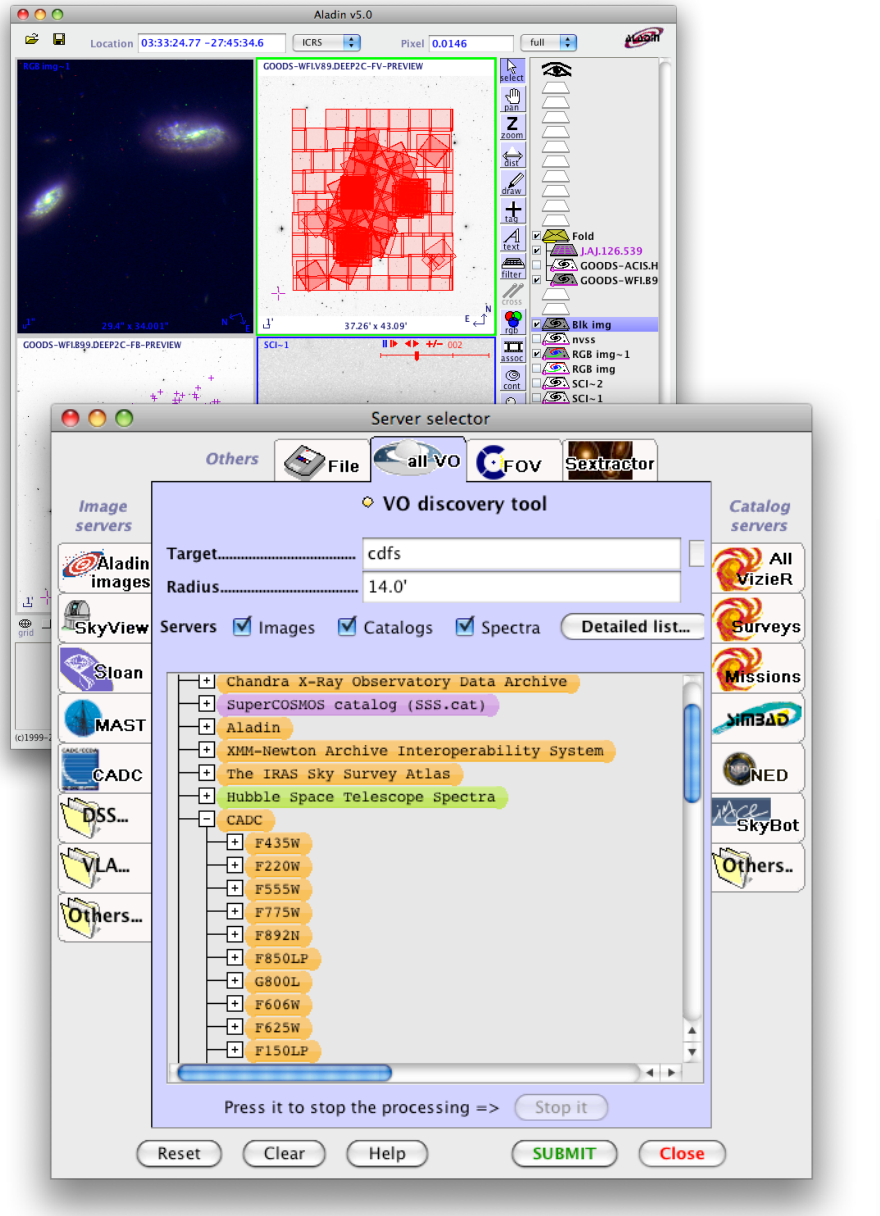

VODesktop

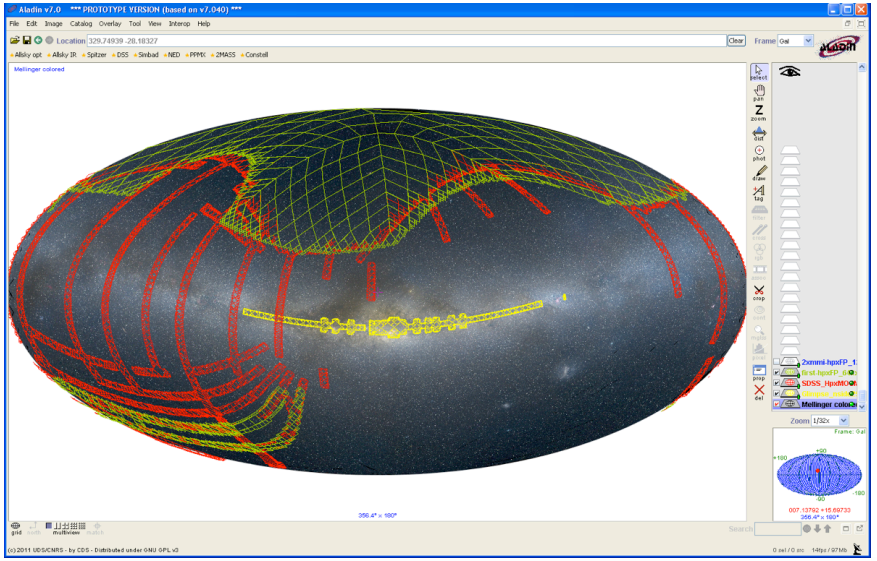
# Innovation: CDS Portal



# Innovations driving VO ideas



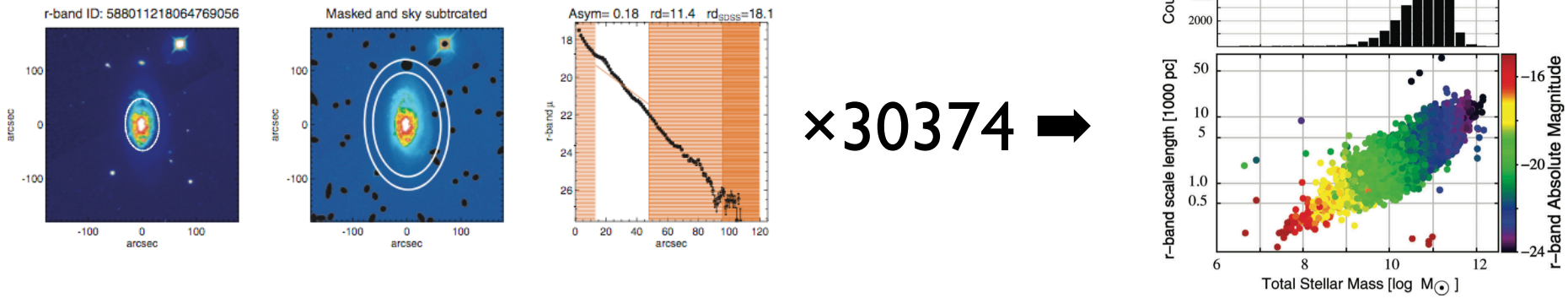
## Data Access Layer concepts

- SIA services :
  - Discovery phase ---> aladin metadata tree
  - AccessData phase : full retrieval , cutout, resampling, ----> and now :Healpix multiresolution access mode
- DataLink service :
  - relates the « discovered » obsid to data links such as
    - Access data modes
    - Provenance information
    - Etc ....

# VO Science

## e.g. Euro-VO Research Initiative

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




Freeman law of galaxy disks confirmed for large sample out to z=0.3

Supported at CDS by Allen, Boch, Schaaff

Monthly Notices
of the
ROYAL ASTRONOMICAL SOCIETY

Mon. Not. R. Astron. Soc. **406**, 1595–1608 (2010)

doi:10.1111/j.1365-2966.2010.16812.x

# Scalelength of disc galaxies

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

**ABSTRACT**

We have derived disc scalelengths for 30 374 non-interacting disc galaxies in all five Sloan Digital Sky Survey (SDSS) bands. Virtual Observatory methods and tools were used to define, retrieve and analyse the images for this unprecedentedly large sample classified as disc/spiral galaxies in the LEDA catalogue. Cross-correlation of the SDSS sample with the LEDA catalogue allowed us to investigate the variation of the scalelengths for different types of disc/spiral galaxies. We further investigate asymmetry, concentration and central velocity dispersion as indicators of morphological type, and are able to assess how the scalelength varies with respect to galaxy type. We note, however, that the concentration and asymmetry parameters have to be used with caution when investigating type dependence of structural parameters in galaxies. Here, we present the scalelength derivation method and numerous tests that we have carried out to investigate the reliability of our results. The average $r$-band disc scalelength is 3.79 kpc, with an rms dispersion of 2.05 kpc, and this is a typical value irrespective of passband and galaxy morphology, concentration and asymmetry. The derived scalelengths presented here are representative for a typical galaxy mass of $10^{10.8\pm0.5}$ M$_\odot$, and the rms dispersion is larger for more massive galaxies. Separating the derived scalelengths for different galaxy masses, the $r$-band scalelength is $1.52 \pm 0.65$ kpc for galaxies with total stellar mass between $10^{9}$–$10^{10}$ M$_\odot$ and $5.73 \pm 1.94$ kpc for galaxies with total stellar mass between $10^{11}$ and $10^{12}$ M$_\odot$. Distributions and typical trends of scalelengths have also been derived in all the other SDSS bands with linear relations that indicate the relation that connect scalelengths in one passband to another. Such transformations could be used to test the results of forthcoming cosmological simulations of galaxy formation and evolution of the Hubble sequence.

**Key words:** galaxies: structure.

## 1 INTRODUCTION

The exponential scalelength of a galaxy disc is one of the most fundamental parameters to determine its morphological structure as well as to model its dynamics, and the fact that the light distributions are exponential makes it possible to constrain the formation mechanisms (Freeman 1970). The scalelength determines how the stars are distributed throughout a disc, and can be used to derive this mass distribution, assuming a specific M/L ratio. Ultimately, this mass distribution is the primary constraint for determining the formation scenario (e.g. Lin & Pringle 1987; Dutton 2009, and references therein), which dictates the galaxy's evolution. As the galaxy evolves, substructures such as bulges, pseudo-bulges, bars, rings and spiral arms may build up, and this will then considerably change the morphology of the host discs (Combes & Elmegreen 1993; Elmegreen et al. 2005; Bournaud, Elmegreen & Elmegreen 2007). The scalelength value is intimately connected to the circular velocity of the galaxy halo, which in turn relates closely to the angular momentum of the halo in which the disc is formed (Dalcanton, Spergel & Summers 1997; Mo, Mao & White 1998). Up to the last few years, cosmological simulations were limited to rather low resolution, were discs and spheroids were barely resolved, and generally limited to high redshifts, so reproducing realistic disc scalelengths for modern galaxies was clearly out of reach. The current simulations reach resolutions that allow resolving the discs from high redshift down to redshift zero, and subtle mechanisms changing the disc masses and scalelengths can be studied

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The Astrophysical Journal Letters, 722:L120–L125, 2010 October 10

doi:10.1088/2041-8205/722/1/L120



# REVISITING THE SCALE LENGTH–$\mu_0$ PLANE AND THE FREEMAN LAW IN THE LOCAL UNIVERSE

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*Received 2010 May 20; accepted 2010 September 13; published 2010 September 24*

ABSTRACT

We have used Virtual Observatory technology to analyze the disk scale length $r_d$ and central surface brightness $\mu_0$ for a sample of 29,955 bright disk galaxies from the Sloan Digital Sky Survey. We use the results in the $r$ band and revisit the relation between these parameters and the galaxy morphology, and find the average value $\langle\mu_0\rangle = 20.2 \pm 0.7$ mag arcsec$^{-2}$. We confirm that late-type spirals populate the lower left corner of the $r_d$–$\mu_0$ plane and that the early and intermediate spirals are mixed in this diagram, with disky ellipticals at the top left corner. We further investigate the Freeman Law and confirm that it indeed defines an upper limit for $\mu_0$ in bright disk galaxies with $r_{\rm mag} < 17.0$, and that disks in late-type spirals ($T \geqslant 6$) have fainter central surface brightness. Our results are based on a volume-corrected sample of galaxies in the local universe ($z < 0.3$) that is two orders of magnitudes larger than any sample previously studied and deliver statistically significant implications that provide a comprehensive test bed for future theoretical studies and numerical simulations of galaxy formation and evolution.

*Key words:* galaxies: evolution – galaxies: formation – galaxies: structure

*Online-only material:* color figures

## 1. INTRODUCTION

The current mainstream galaxy formation paradigm states that galaxy disks form within dark matter halos and that there is an intimate relation between the scale length $r_d$ of the disk and that of the halo. The mass distribution of the disk is entirely set by the $r_d$ and, for example, in the exponential case, 60% of its total mass is confined within two scale lengths and 90% within four scale lengths. Moreover, the angular momentum of the disk is set by $r_d$ and the mass distribution of its host halo, and the fact that the angular momentum vectors are aligned suggests that there is a physical relation between the two. During the formation process, galaxy mergers and associated star formation and feedback processes play a crucial role in the resulting structure, however, the observed sizes of disks suggest that the combination of these physical processes indicate that galactic disks have not lost much of the original angular momentum acquired from cosmological torques (e.g., White & Rees 1978; Fall & Efstathiou 1980). The hierarchical and infall models predict comparable $r_d$, and in a cold collapse scenario (Vand 1959) since angular momentum is conserved, immediately after the collapse the gas is supported by rotation so that it quickly collects in the region where a disk forms with substantially higher rotation velocity than the halo is to form. A large $r_d$ disk forms when the disk mass is smaller than the halo mass over the mass of the disk dominates the mass of the halo in any part of the disk. The self-gravitating disk will also modify the shape of the rotation curve near the center of a galaxy (Gelato & Sommer-Larsen 1999) and the disk is then set to undergo secular evolution. The natural implication of this scenario is that the $r_d$ dictates the life of a disk, and consequently, is a prime factor which determines the position of a galaxy on the Hubble sequence.

One prominent indicator for a smooth transition from spiral toward S0 and disky ellipticals is provided by the $r_d$–$\mu_0$ diagram, where $\mu_0$ is the central surface brightness of the disk, where spirals and S0s are mixed and disky ellipticals populate the upper left corner of this diagram (Kent 1985; Scorza & Bender 1995). Another instructive relation is the Freeman Law (Freeman 1970) which relates $\mu_0$ to the galaxy morphological type. Although, some studies have found that the Freeman Law is an artifact due to selection effects (e.g., Disney 1976; Bothun 1981; Scorza & van den Bosch 1998), recent work has shown that proper consideration of selection effects can be combined with kinematic studies to explore an evolutionary sequence (e.g., van der Kruit 1987, 2002; de Jong 1996; Koda et al. 2000).

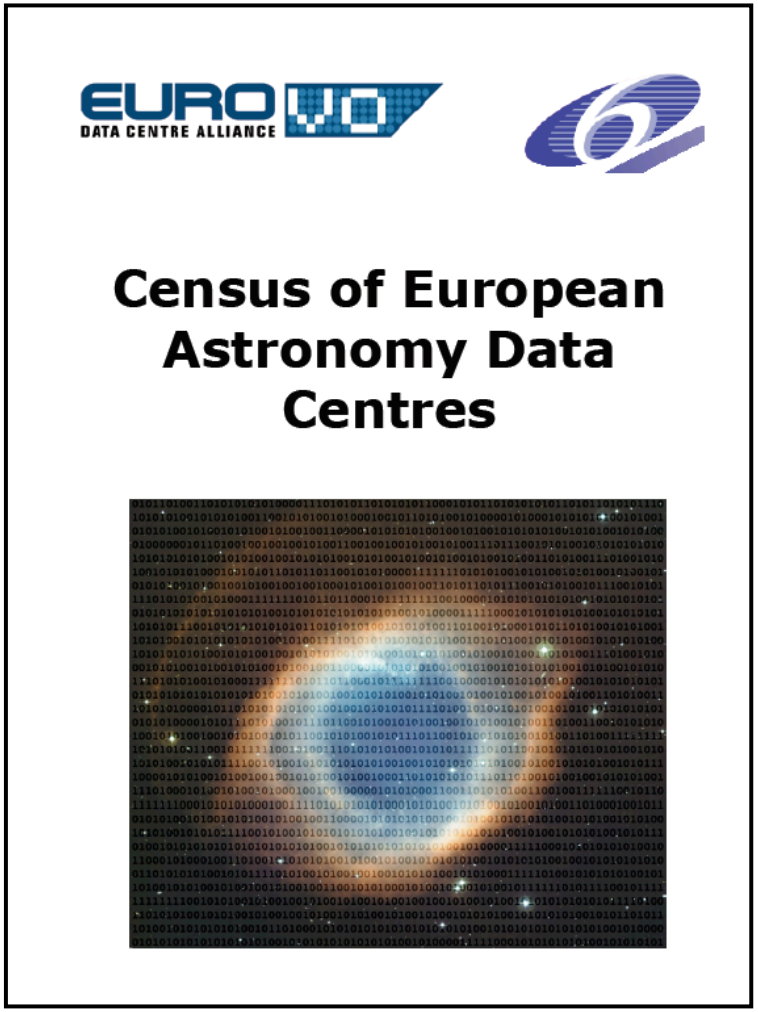
In the comparison between theory and observations, two issues complicate matters. On the theory side, mapping between initial halo angular momentum and $r_d$ is not trivial, partly due to the fact that commonly the initial specific angular momentum distribution of the visible and dark component favors disks that are more centrally concentrated than exponential (e.g., de Jong & Lacey 2000; van den Bosch 2001). Observationally, comprehensive samples have yet not been studied, and the mixture of different species such as low and high surface brightness galaxies complicate the measurements of disk parameters (McGaugh et al. 1995; Graham & de Blok 2001).

Here, we analyze the $r_d$ and $\mu_0$ from an unprecedentedly large sample of bright disk galaxies in the nearby universe ($z < 0.3$) using the Sloan Digital Sky Survey (SDSS) Data Release 6 (York et al. 2000; Adelman-McCarthy et al. 2008). As detailed in Fathi et al. (2010, hereafter F10), both parameters were robustly determined for 30,374 galaxies in the $r$ band (only 29,955 used here as described in Section 2), whereas in other SDSS bands, the derived parameters are valid only for subsets of this sample. In the $g$, $i$, and $z$ bands (≈27,000–30,000 galaxies), the sample sizes are comparable to the one presented here. In the $u$ band, $r_d$ and $\mu_0$ were robustly derived for a few hundred objects and therefore, not considered here. Throughout this Letter, unless otherwise stated, we use disk parameters in the $r$ band and investigate the two relations mentioned above, in order to provide a comprehensive test bed for forthcoming cosmological simulations (or analytic/semi-analytic models) of galaxy formation and evolution.

# Assisting VO uptake

*CDS contributions to Data Centre Alliance project*

- Workshop tutorials
  - Scientific rationale
  - SAADA (w/L. Michel)
  - UCD tools
- Census




Allen & Depretz 2009

# Census summary

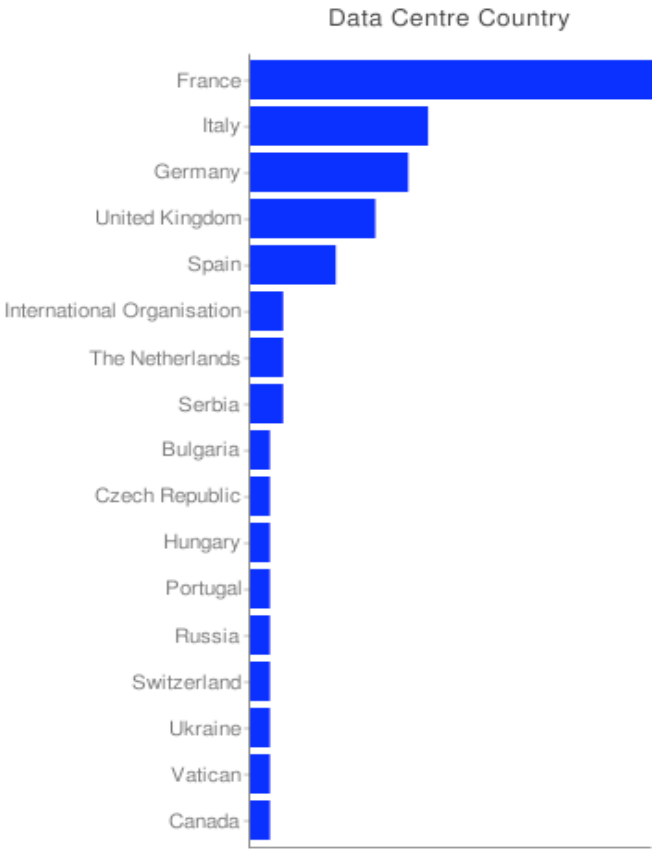
68 Data Centres

134 Observational Archives

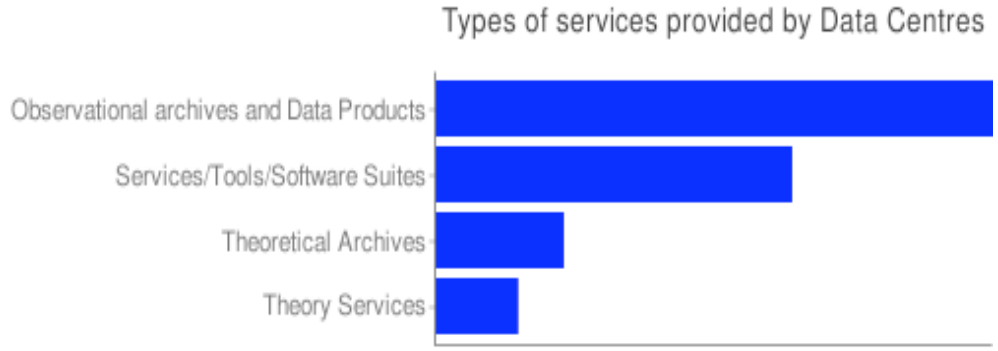
66 'Service/Tool/Software Suite'

24 Theory Archives

8 Theory Services







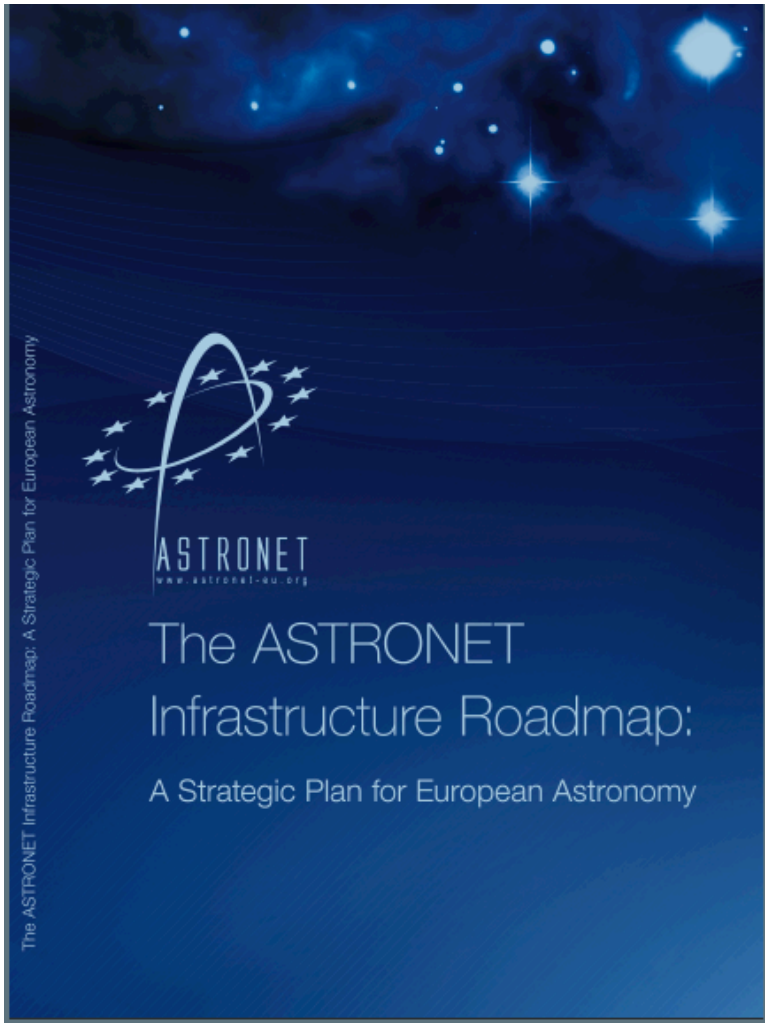

Diversity in terms of ‘scale, content and function’

# Implications for VO

- Maintain coordination of VO developments with Data Centres
- Ensure VO publishing is not significantly more difficult than web publishing
- Accommodate diversity
- Increase emphasis on 'Science ready data'
- The census identifies Data Centres who will lead up-take of VO as Euro-VO moves into operational phase

# VO as Infrastructure

- VO in the ASTRONET Infrastructure roadmap
- recommendations for VO compliance
- community validation of VO approach




Panel D members: Allen, Padovani