# Astronomical Researches using Virtual Observatories

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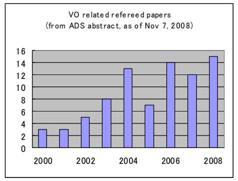
The Virtual Observatory (VO) for Astronomy is a framework that empowers astronomical researches by providing standard methods to find, access, utilize astronomical data archives distributed around the world. VO projects in the world have been strenuously developing VO software tools and portal systems. The interoperability among VO projects has been achieved with the VO standard protocols defined by the International Virtual Observatory Alliance (IVOA). As a result, VO technologies are now used in many real astronomical researches. We refer typical examples of astronomical researches enabled by VO and describe how the VO technologies are used in the researches.

## VO-related astronomical papers

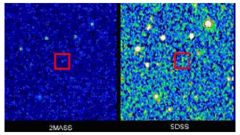



The left graph shows that the number of papers published through refereed journals is still increasing by year.
This graph is obtained from query to abstract using Astrophysics Data System (ADS). It is noted that the papers whose abstract does not include the phrase "Virtual Observatory" are not counted in this graph.

US National Virtual Observatory

# Discovery of Brown Dwarf

This research is based on an early demo project performed by NVO (National Virtual Observatory) the US VO project. (http://www.jhu.edu/news/home03/mar03/nvo.html)




The left image shows the 2MASS (left) and SDSS (right) of the newly found L-type brown dwarf, 2MASSI J0104075-005328.

Brown dwarfs are sub-stellar objects with a mass below that necessary to maintain hydrogen-burning nuclear fusion reactions. They are hard to find in the sky, since they emit almost no optical light. Only 200 brown dwarfs are discovered at that time (2003).

## Used Data

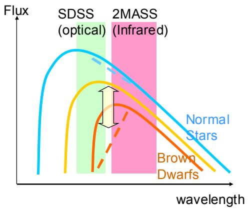
- 2MASS (Two Micron All-Sky Survey) 2nd Incremental Data Release
  - objects: 160 million
  - band : J (1.2 μm)
- SDSS (Sloan Digital Sky Survey) Early Data Release
  - objects 15 million
  - band: z (0.9 μm)

Covered area:

- about 150 square degrees (0.4% of sky)

## Selection criteria for Brown Dwarfs

The right figure is a schematic graph of Spectral Energy Distributions of Normal stars and Brown Dwarfs. Normal stars are visible in the optical range, while brown dwarfs are faint in the optical, but their strongest emissions are in the infrared range. This wavelength dependency of emission is used to identify brown dwarfs.




## VO Query Language

is based on the SQL and extended with "Region" and "XMatch" (cross match) syntax.

```
SELECT      o.id, t.id, o.ra, o.dec, o.z, t.j_m
FROM        SDSS o, TWOMASS t
WHERE       XMATCH(o,t) < 3 arcsec AND
            (o.z - t.j_m) > 1
```

... cross match condition of VOQL

... selection criteria of Brown dwarfs

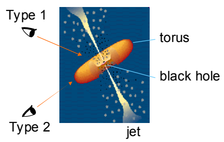
The cross-match covered an area of roughly 150 square degrees and contains 326020 matches. Further filtering through a conservative z-J color cut recovered the known brown dwarfs in that area - a T dwarf (SDSS 1346-0031) and a late-L dwarf (SDSS 1326-0038) while also uncovering three more excellent brown dwarf candidates. One of these **2MASSI J0104075-005328)** has been sprectroscopically **identified as an L5 dwarf.**

# Discovery of Obscured AGN

This research is based on the project by AVO (Astronomical Virtual Obsevatroy), current EURO VO, and was published as Astronomy&Astrophysics 424, 545–559 (2004)

While astronomers have been observed two types of quasars, now the unified model for active galactic nuclei (AGN) is largely accepted. The apparent disparate properties and nomenclature of active galaxies can be explained by the physics of black hole, accretion disk, jet, and obscuring torus convolved with the geometry of the viewing angle.
Type 1 sources are those in which we have an unimpeded view of the central regions and therefore exhibit the straight physics of AGN with no absorption. Type 2 objects arise when the view is obscured by the torus.

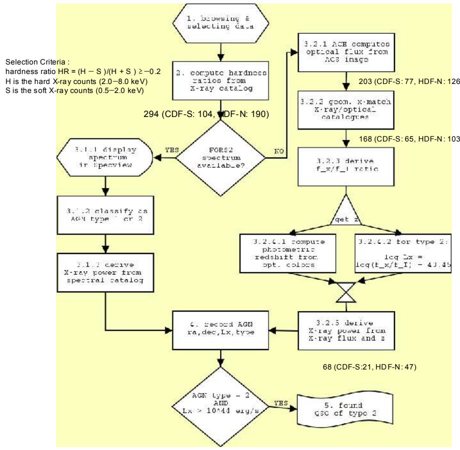
Schematic view of AGN model



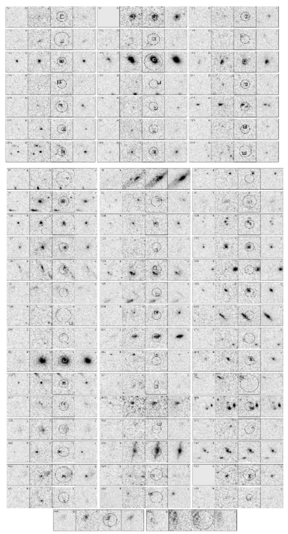

## Used data:

- Two GOODS fields:
  - Hubble Deep Field-North (HDF-N)
    - 503 objects
  - Chandra Deep Field-South (CDF-S)
    - 326 objects
    - X-ray band: 0.5-8.0keV
  - Area size of each field: 10' × 16'

Workflow to find type-2 AGN




Identified 68 type-2 AGN candidates
(Hubble ACS B,V,i,z-band images cut-outed using an AVO tool).



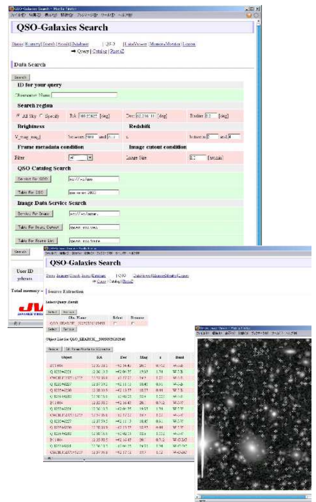
# Study on QSO environment

This is a study on the evolution of number densities around QSO (Quasi-Stellar Object) to investigate mechanism of formation and evolution of QSO, and to understand the formation history of the large-scale structure of the universe.

We applied JVO system to the study of environment of QSOs by combing the QSO catalog data service and Subaru image data service. Since we don't have a reduced data archive yet, raw data of pre-selected five fields are retrieved from the SMOKA and MASTARS service operated by NAOJ, and they are reduced with a standard analysis tool and registered as a skynode database. The fields are selected through cross-matching between QSO database and SuprimeCam frame database. A workflow for this study is as follows:

1. Select QSO coordinates from the QSO database
2. Search multi-bands imaging data which covers the QSO regions
3. Create a catalog from the imaging data by invoking a SExtractor Web service.
4. Estimate the objects' photoZ around the QSO
5. Clustering Analysis

Using this method, we investigated number density distributions of galaxies around 37 QSOs with redshift z = 0.7〜3.4. The result of ensemble average shows no significant clustering of galaxies.




Number density distributions of object around QSOs