Environment Study of AGNs at z = 0.3 to 3.0 using the Japanese Virtual Observatory

Y. Shirasaki, M. Ohishi, Y. Mizumoto, T. Takata, Y. Komiya (NAOJ)、
M. Tanaka (University of Tsukuba), N. Yasuda (University of Tokyo, ICRR)

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Abstrat: We present a science use case of Virtual Observatory, which is actually achieved to examine an environment of AGN upto redshift of 3.0. We used the Japanese Virtual Observatory (JVO) to obtain the Subaru Suprime-Cam images around known AGNs. According to the hierarchical galaxy formation model, AGNs are expected to be found in an environment of higher galaxy density than that of typical galaxies. The current observations, however, indicates that AGNs do not reside in a particularly high density environment. We investigated ~1000 AGNs, which is about ten times larger samples than the other studies covering the redshifts larger than 0.6. We successfully found significant excess of galaxies around AGNs at redshifts of 0.3 to 1.8.

If this work is done in a classical manner, that is, raw data are retrieved from the archive through a web interface in an interactive way and the data are reduced in a local poor machine, it may take several years to finish it. Since the Virtual Observatory system is accessible through the standard interface, it is easy to query and retrieve the data in an automatic way. We have constructed a pipeline for retrieving the data and calculating the galaxy number density around a given coordinate. This procedure was executed in parallel on ~10 quad core PCs, and it took only one day for obtaining the final result.

Our result implies that the Virtual Observatory can be a powerful tool to do an astronomical research based on large amount of data.

Subaru Data Archive (raw)

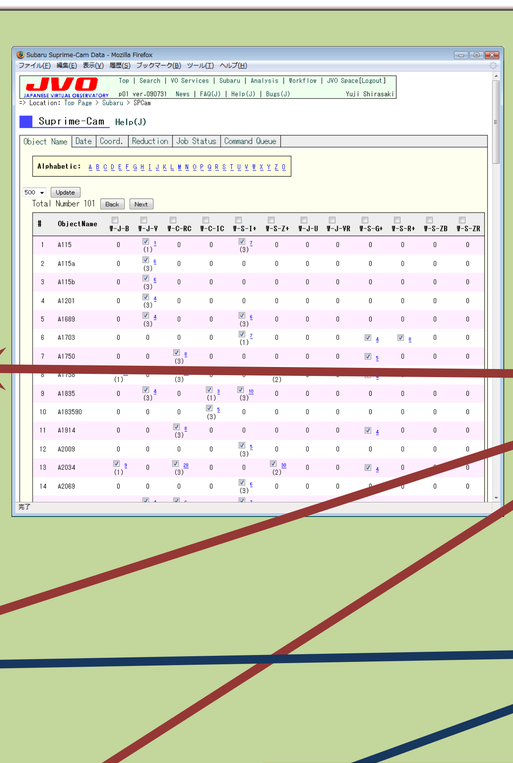
Step 0 (Admin)

Parallel processing of large amount of data

Data reduction of all the Suprime-Cam data on the JVO grid computing system (12 servers, 48 CPU cores) .

10 TB of RAW data are reduced through the JVO web interface. The processing time is ~10 days.

The metadata of the processed image are registered to the database and exposed through the VO interface.



Subaru Data Archive (processed)

Subaru SkyNode

AGN SkyNode

UKIDSS SkyNode

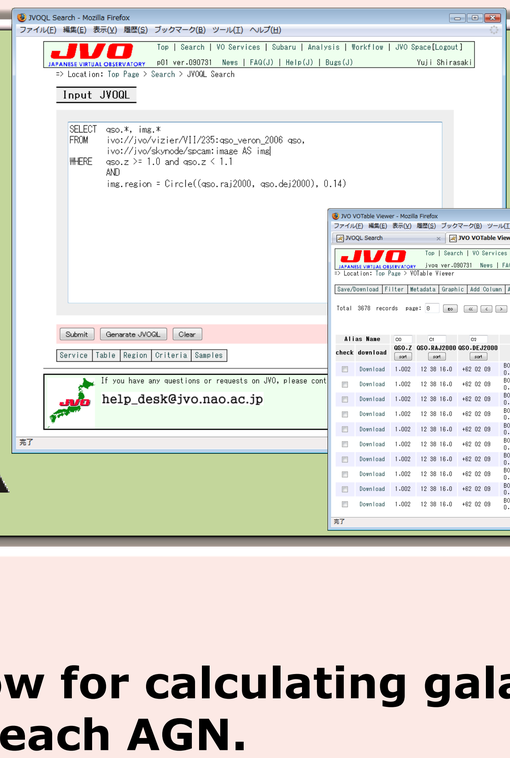
Step 1

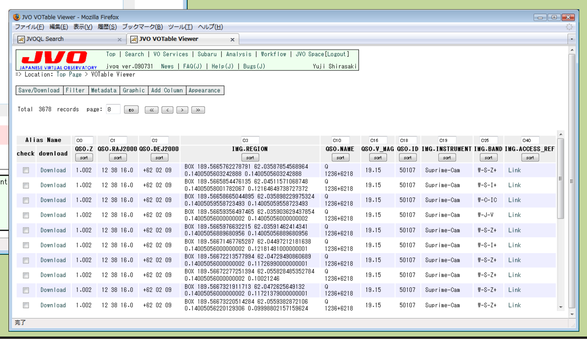
Multiple database query

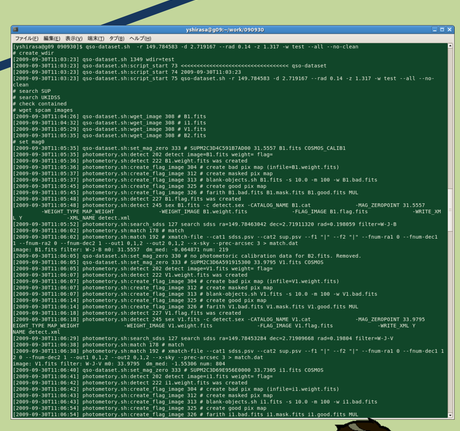
Suprime-Cam image and UKIDSS catalog data are searched around known AGNs.

The following JVO Query Language (JVOQL) is an example to do a coordinate join between AGN catalog table and Suprime-Cam metadata table:

```
SELECT  qso.*,  img.*
FROM    ivo://jvo/vizier/VII/235:qso_veron_2006 qso
        ivo://jvo/skynode/spcam:image AS img
WHERE   qso.z >= 1.0 and qso.z < 1.1
        AND
        img.region = Circle((qso.raj2000, qso.dej2000) 0.14)
```







Step 2

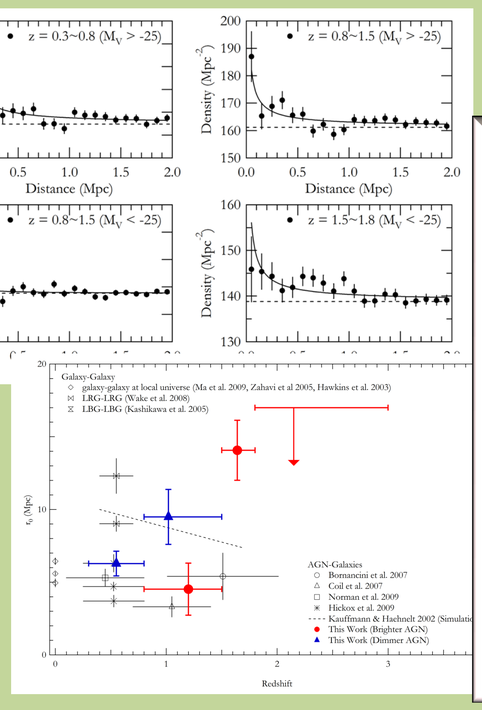
Workflow for calculating galaxy density around each AGN.

A script “qso-dataset.sh” which executes the following workflow:

1. retrieve images and catalog data around a specified coordinate of AGN. This query is directory sent to the SkyNode.
2. extract objects from the images, and cross-match to create a multi-bands catalog
3. Calculate galaxy number density around the AGN coordinate

This script is executed for every AGN found in the step 1:

```
qso-dataset.sh --ra <qso_ra> --dec <qso_dec> --rad <img_radius>
-z <qso_z>
```



Step 3

Detailed analysis on a local machine.

1. Stack the galaxy density profiles around each AGN
2. Calculate a correlation length between AGN and galaxies for each AGN’s redshift and luminosity range.
3. Write a paper…

Conclusion

Combination of all the Subaru archival data with data produced with medium-sized survey telescopes succeeded to reveal the AGN environment at intermediate redshift with higher statistic than ever achieved. The feature of the VO service that enables automated query is essential for achieving astronomical study based on huge amount of data.