

# Study on the Environment of QSOs with Redshift 1~3 using the JVO System

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# Objectives

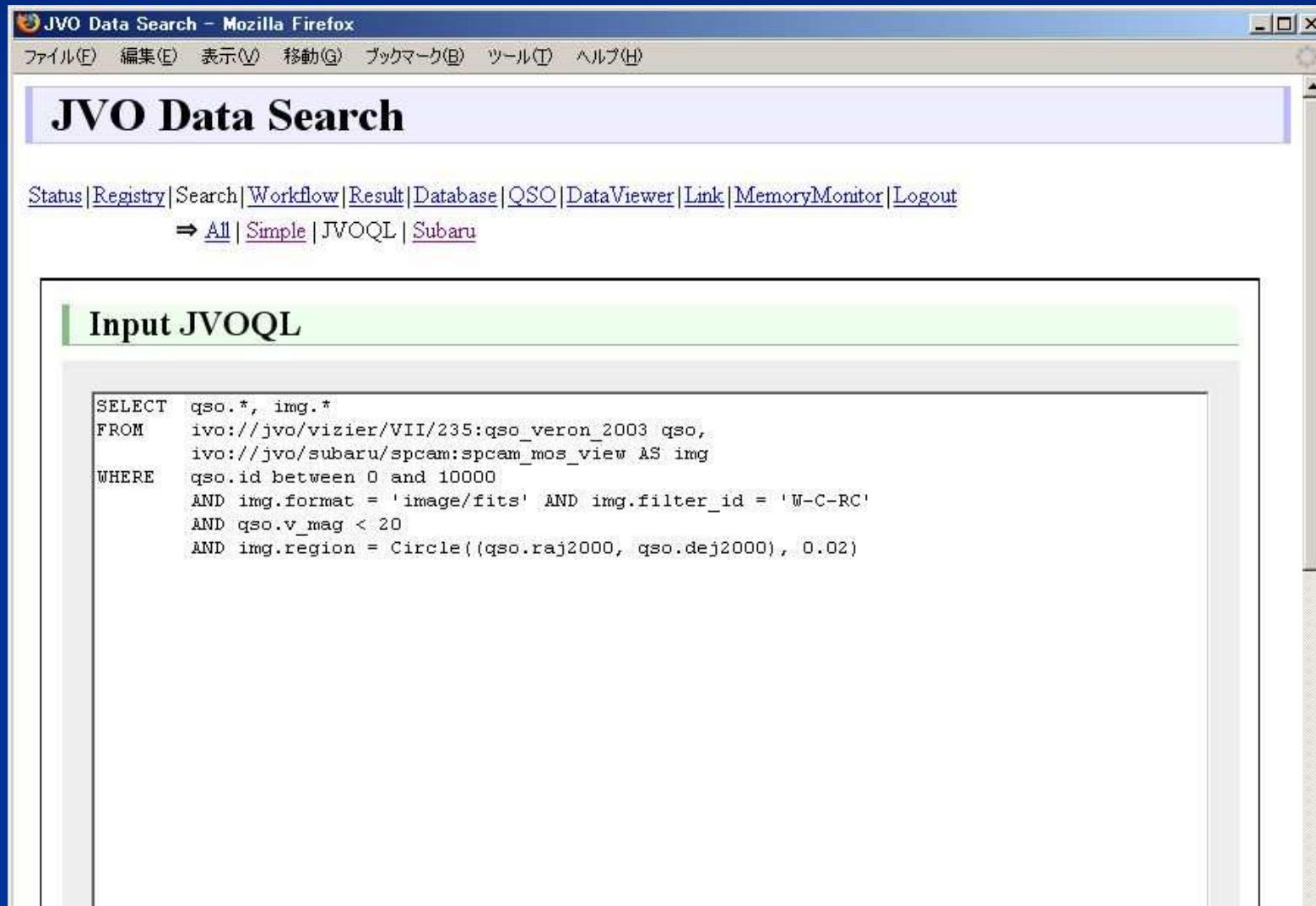
- QSO-Galaxy correlation:
  - Formation and Fuelling mechanism of QSO
  - History of the large scale structure formation
- Observations so far:
  - $z < 1.0$
  - Poor statistics ( $\sim$ tens of QSOs)
- Goal of our study:
  - Explore  $z > 1.0$
  - High statistics ( $\sim$ hundreds or more)
  - QSO/AGN catalog (SDSS, 2dF, ...) 100,000 known QSOs/AGNs
  - Archived deep images by large telescopes (Subaru).
  - Opt  $\sim$  IR (SuprimeCam, MORICS)

# Data Discovery through JVO

- Two VO data services are constructed:
  - QSO Catalog data service (Veron et al. 2006 from VizieR)
  - Subaru SuprimeCam image data service
  - Both services are developed by using the JVO SkyNode toolkit.
  - <http://jvo.nao.ac.jp/download/skynode-toolkit>
- SuprimeCam images containing cataloged QSOs are searched on JVO portal service.
  - Three kinds of data search methods

# SQL Search mode

General interface for data access



# User I/F Dedicated for a specific purpose

QSO-Galaxies Search - Mozilla Firefox

ファイル(F) 編集(E) 表示(V) 移動(G) ブックマーク(B) ツール(T) ヘルプ(H)

## QSO-Galaxies Search

[Status](#) | [Registry](#) | [Search](#) | [Workflow](#) | [Result](#) | [Database](#) | [QSO](#) | [DataViewer](#) | [Link](#) | [MemoryMonitor](#) | [Logout](#)

⇒ [Query](#) | [Catalog](#) | [PhotoZ](#)

### Data Search

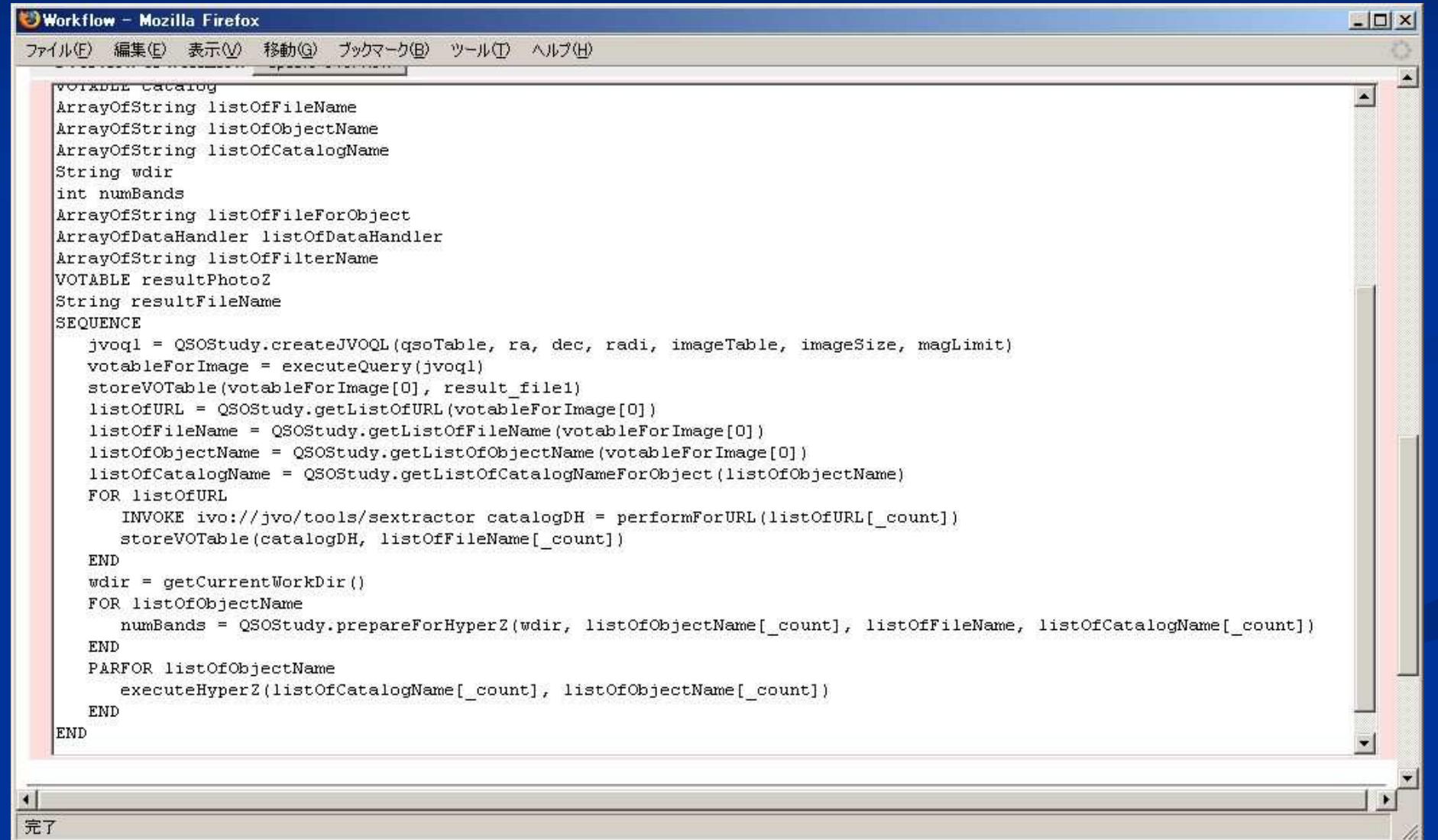
<a href="#">Search</a>	<a href="#">Check SQL</a>
ID for your query	Observation Name <input type="text"/>
Search Method	<input checked="" type="radio"/> All Sky <input type="radio"/> Specify Region <input type="radio"/> By QSO Name
Search Region	RA: <input type="text"/> [deg] Dec: <input type="text"/> [deg] Radius: <input type="text"/> [deg]
QSO ID	ID BETWEEN <input type="text"/> AND <input type="text"/>
QSO name	<input type="text"/> not selected <input type="button"/>
Brightness	V_mag [mag] between <input type="text"/> and <input type="text"/>
Redshift	z between <input type="text"/> and <input type="text"/>
Table of SuprimCam	<input type="text"/> spcam_exp_view (Table for SuprimCam Exposure) <input type="button"/>
Image Filter	<input type="text"/> W-C-RC <input type="button"/>
Image Size	<input type="text"/> 2.0 [arcmin]

[Search](#) | [Check SQL](#)

完了

# Workflow (Script) mode

Automate the procedure: data discovery, data retrieval, image analysis (source extraction), photo-Z estimation ...



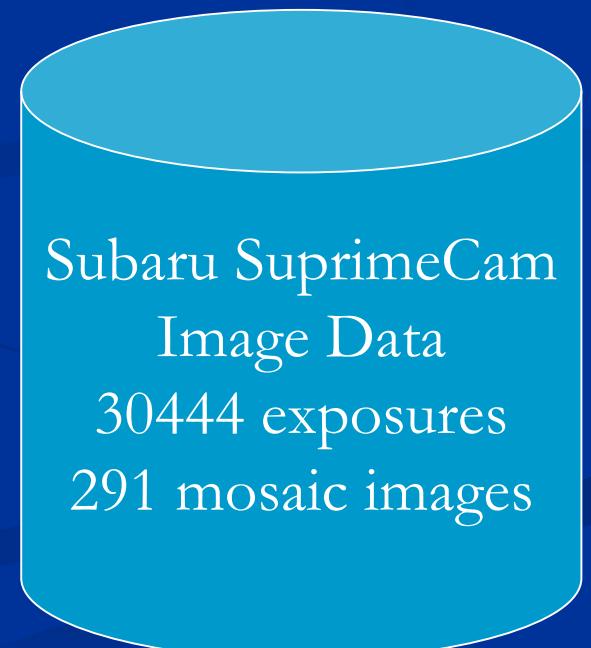
The screenshot shows a Mozilla Firefox browser window with a tab titled "Workflow - Mozilla Firefox". The main content area displays a script in a language called VOSL (VOTable-based Scripting Language). The script defines variables and performs a sequence of operations to process astronomical data. The script includes imports from the QSOStudy module, such as JVOQL and various list and catalog retrieval functions. It uses loops (FOR, PARFOR) and conditional statements (IF) to handle multiple objects and URLs.

```
VOTABLE catalog
ArrayOfString listOfFileNames
ArrayOfString list_ofObjectName
ArrayOfString list_ofCatalogName
String wdir
int numBands
ArrayOfString list_ofFileForObject
ArrayofDataHandler list_ofDataHandler
ArrayOfString list_ofFilterName
VOTABLE resultPhotoZ
String resultFileName
SEQUENCE
    jvoql = QSOStudy.createJVOQL(qsoTable, ra, dec, radi, imageTable, imageSize, magLimit)
    votableForImage = executeQuery(jvoql)
    storeVOTable(votableForImage[0], result_file1)
    list_ofURL = QSOStudy.getListOfURL(votableForImage[0])
    listOfFileNames = QSOStudy.getListOfFileNames(votableForImage[0])
    list_ofObjectName = QSOStudy.getListOfObjectName(votableForImage[0])
    list_ofCatalogName = QSOStudy.getListOfCatalogNameForObject(list_ofObjectName)
    FOR list_ofURL
        INVOKE ivo://jvo/tools/sexttractor catalogDH = performForURL(list_ofURL[_count])
        storeVOTable(catalogDH, listOfFileNames[_count])
    END
    wdir = getCurrentWorkDir()
    FOR list_ofObjectName
        numBands = QSOStudy.prepareForHyperZ(wdir, list_ofObjectName[_count], listOfFileNames, list_ofCatalogName[_count])
    END
    PARFOR list_ofObjectName
        executeHyperZ(list_ofCatalogName[_count], list_ofObjectName[_count])
    END
END
```

# Procedure of QSO image search

JVO Portal

1. Request QSO Coordinates (ADQL)
2. QSO Coordinates (VOTable)
3. Request images of QSOs (ADQL+VOTable)
4. Metadata of Images (VOTable)
5. Request an image (HTTP Get)
6. A QSO image (FITS)



QSO-Galaxies Search - Mozilla Firefox

ファイル(F) 編集(E) 表示(V) 移動(G) ブックマーク(B) ツール(T) ヘルプ(H)

### Object List for QSO\_SEARCH\_20060810230320359

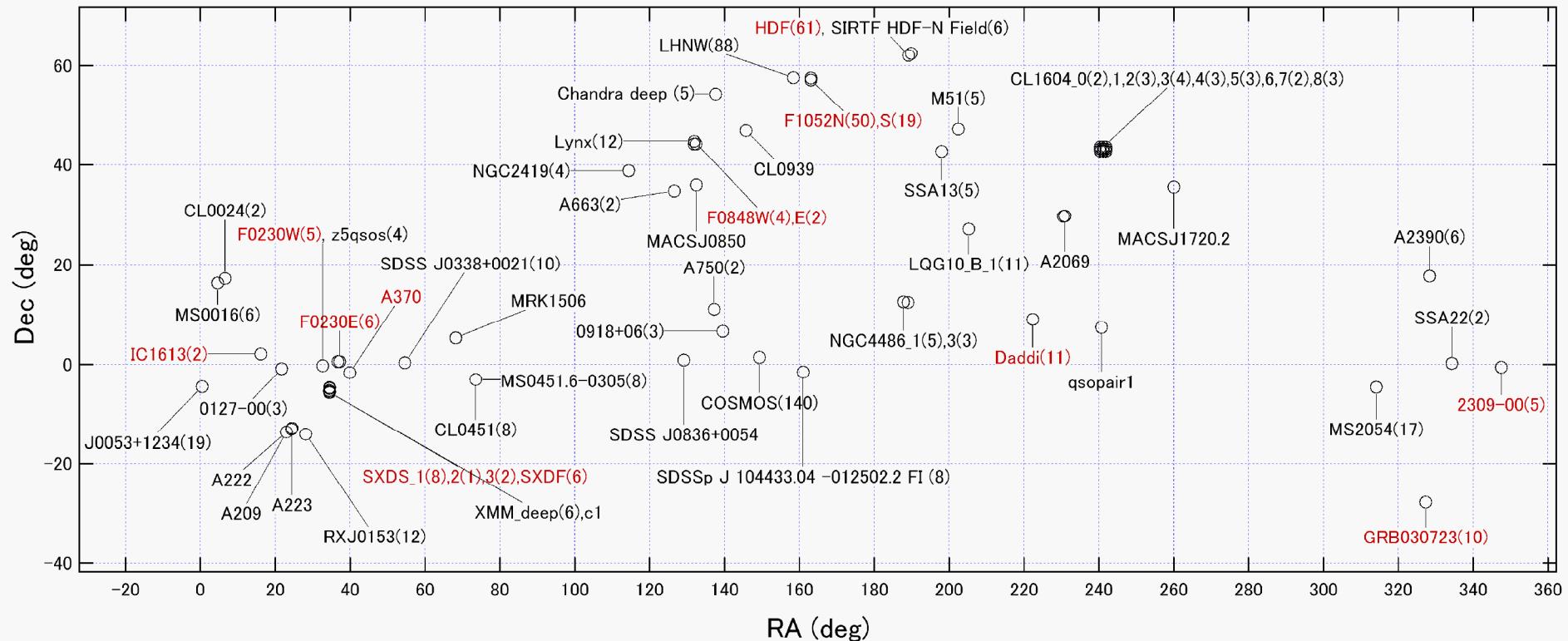
[Register](#) [Edit Param/Config for SExtractor](#)

Object	RA	Dec	Mag	z	Band	Image	Create Catalog	Catalog	Register
Q 0014+1559	00 17 10.4	+16 15 44	20.2	2.2	W-C-IC	<a href="#">Image</a>	<a href="#">-- SExtractor --&gt;</a>	<a href="#">2.cat</a>	<input checked="" type="checkbox"/> : Image <input checked="" type="checkbox"/> : Catalog
Q 0014+1559	00 17 10.4	+16 15 44	20.2	2.2	W-C-RC	<a href="#">Image</a>	<a href="#">-- SExtractor --&gt;</a>	<a href="#">3.cat</a>	<input type="checkbox"/> : Image <input type="checkbox"/> : Catalog
00151+160	00 17 45.1	+16 19 52	19.9	2.2	W-C-IC	<a href="#">Image</a>	<a href="#">-- SExtractor --&gt;</a>	not present	<input type="checkbox"/> : Image <input type="checkbox"/> : Catalog
00151+160	00 17 45.1	+16 19 52	19.9	2.2	W-C-RC	<a href="#">Image</a>	<a href="#">-- SExtractor --&gt;</a>	not present	<input type="checkbox"/> : Image <input type="checkbox"/> : Catalog
Q 0015+0239	00 18 11.4	+02 56 39	19.7	2.469	W-S-Z+	<a href="#">Image</a>	<a href="#">-- SExtractor --&gt;</a>	not present	<input type="checkbox"/> : Image <input type="checkbox"/> : Catalog
00159+155	00 18 30.0	+15 52 27	20.6	2.3	W-C-IC	<a href="#">Image</a>	<a href="#">-- SExtractor --&gt;</a>	not present	<input type="checkbox"/> : Image <input type="checkbox"/> : Catalog
00159+155	00 18 30.0	+15 52 27	20.6	2.3	W-C-RC	<a href="#">Image</a>	<a href="#">-- SExtractor --&gt;</a>	not present	<input type="checkbox"/> : Image <input type="checkbox"/> : Catalog
E 0015+162	00 18 31.9	+16 29 26	18.79	0.554	W-C-IC	<a href="#">Image</a>	<a href="#">-- SExtractor --&gt;</a>	not present	<input type="checkbox"/> : Image <input type="checkbox"/> : Catalog
E 0015+162	00 18 31.9	+16 29 26	18.79	0.554	W-C-RC	<a href="#">Image</a>	<a href="#">-- SExtractor --&gt;</a>	not present	<input type="checkbox"/> : Image <input type="checkbox"/> : Catalog
ISS 35	00 19 14.4	+15 55 56	18.3	2.27	W-C-IC	<a href="#">Image</a>	<a href="#">-- SExtractor --&gt;</a>	not present	<input type="checkbox"/> : Image <input type="checkbox"/> : Catalog
ISS 35	00 19 14.4	+15 55 56	18.3	2.27	W-C-RC	<a href="#">Image</a>	<a href="#">-- SExtractor --&gt;</a>	not present	<input type="checkbox"/> : Image <input type="checkbox"/> : Catalog
I Zw 1	00 53 34.9	+12 41 36	14.03	0.061	W-C-IC	<a href="#">Image</a>	<a href="#">-- SExtractor --&gt;</a>	not present	<input type="checkbox"/> : Image <input type="checkbox"/> : Catalog
I Zw 1	00 53 34.9	+12 41 36	14.03	0.061	W-J-V	<a href="#">Image</a>	<a href="#">-- SExtractor --&gt;</a>	not present	<input type="checkbox"/> : Image <input type="checkbox"/> : Catalog
I Zw 1	00 53 34.9	+12 41 36	14.03	0.061	W-S-Z+	<a href="#">Image</a>	<a href="#">-- SExtractor --&gt;</a>	not present	<input type="checkbox"/> : Image <input type="checkbox"/> : Catalog

完了

# SuprimeCam QSO Fields

- Three wide band filters, Exposure > 1000 sec
- ~60 out of 1599 fields (**17 Fields analyzed**)
- ~700 out of 108080 QSOs/AGNs (**100 QSOs/AGNs analyzed**)



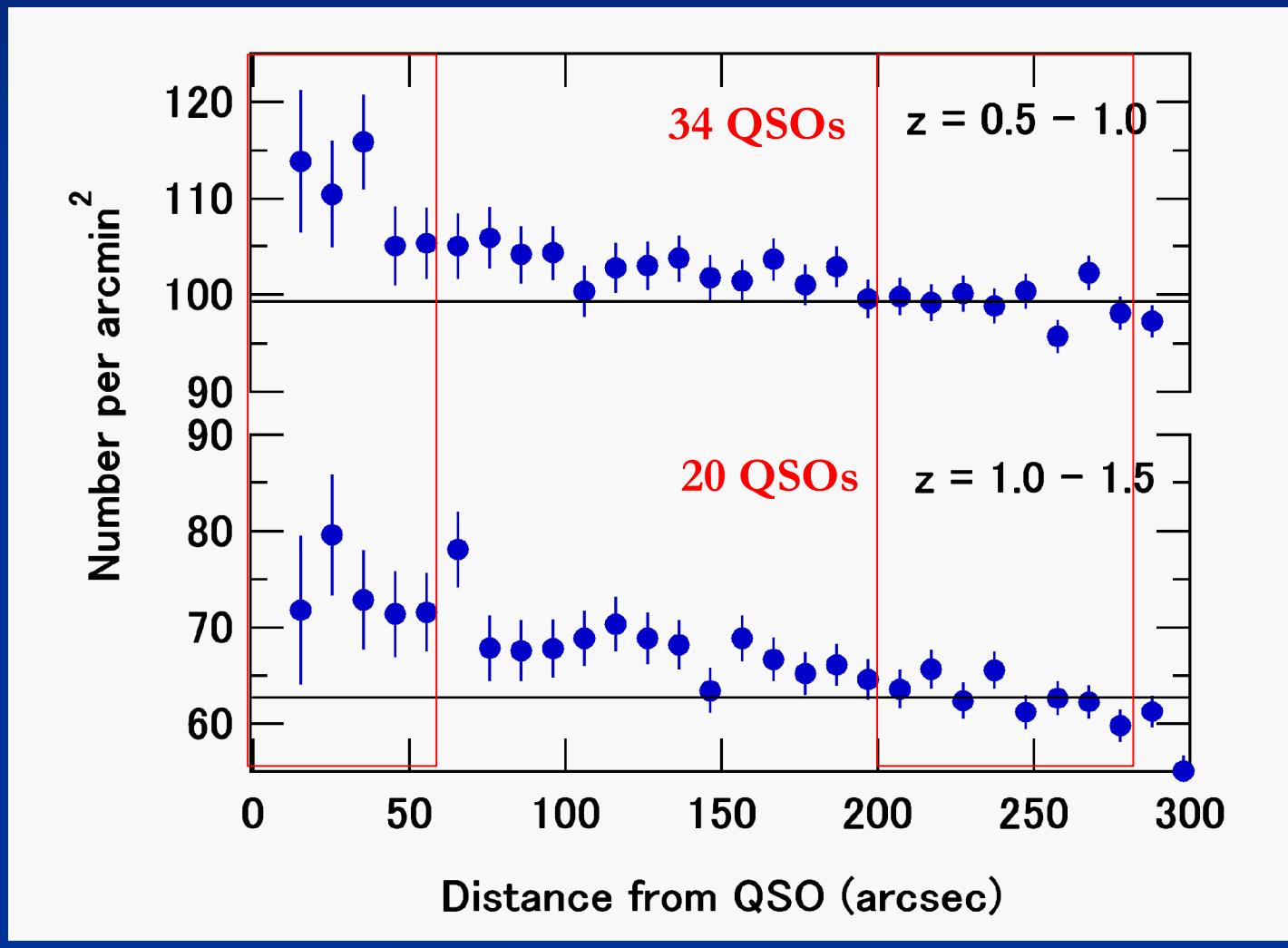
# Number of QSOs in each field ( $\#QSO >= 3$ )

Field name	#filter	#QSO	Field name	#filter	#QSO
COSMOS	4	140	SXDF	3	6
LHNW	3	92	A2390	5	6
HDF	4	62	SSA13	4	5
F1052N	3	50	NGC4486_1	3	5
J0053+1234	3	19	F0230W	3	5
F1052S	3	19	Chandra deep	3	5
MS2054	3	17	2309-00	3	5
Lynx	3	12	M51	3	5
RXJ0153	4	12	NGC2419	3	4
Daddi	3	11	z5qsos	3	4
GRB030723	4	10	F0848W	3	4
SDSS J0338+0021	4	10	CL1604_3	3	4
<u>SXDS_1</u>	5	8	CL1604_2	3	3
SDSSp J 104433.0...	4	8	CL1604_5	3	3
MS0451.6-0305	3	8	CL1604_4	4	3
XMM_deep	3	6	0918+06	3	3
MS0016	5	6	0127-00	3	3
SIRTF HDF-N Field	4	6	CL1604_8	3	3
<u>F0230E</u>	3	6	NGC4486_3	3	3

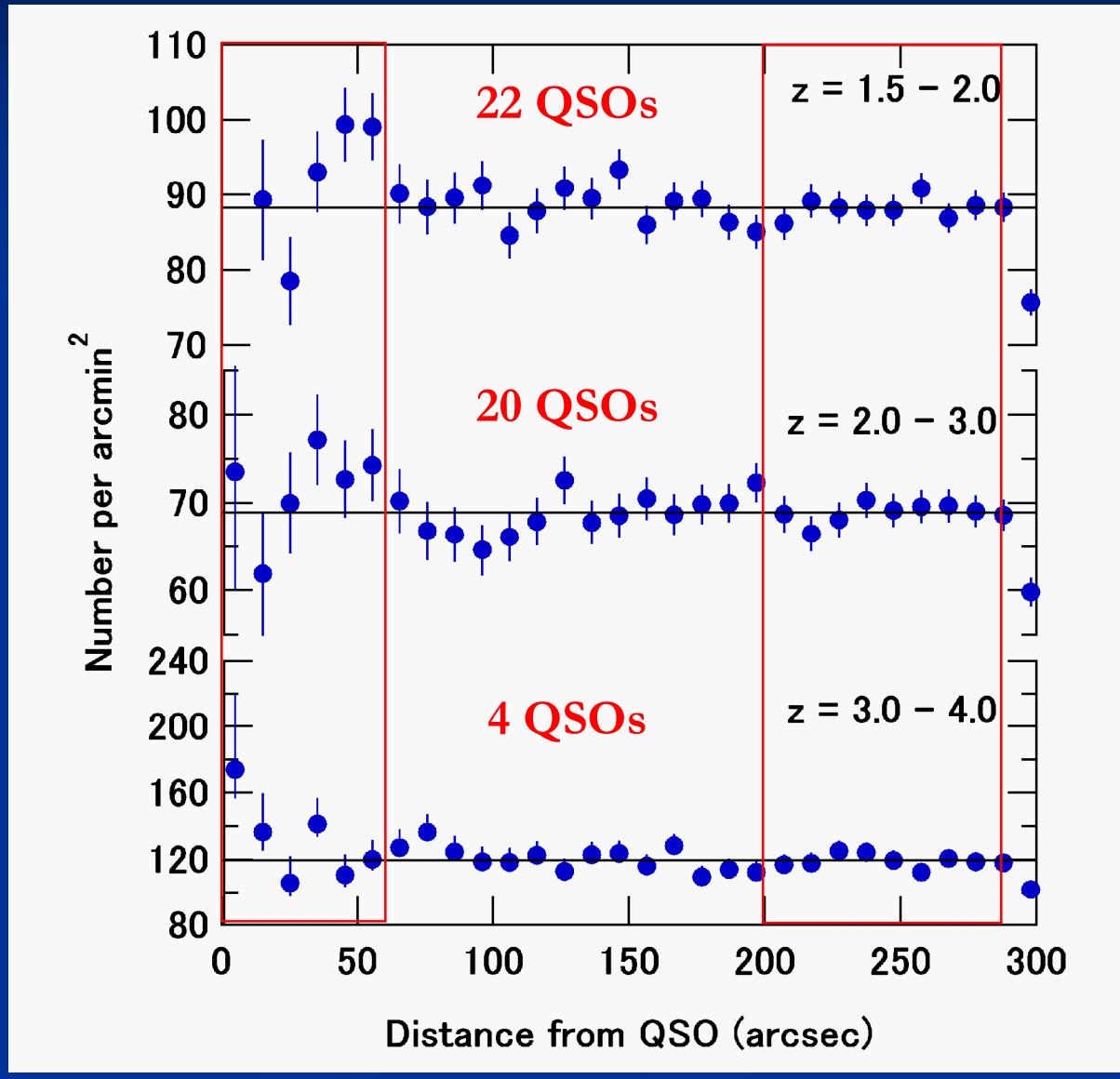
# Analysis

- Reject images whose coverage is less than 50% of  $10 \times 10 \text{ armin}^2$  area centered at QSO position.
- Check if there are at least three-bands images.
- Source Catalog around QSOs (SExtractor)
- Calculate redshift probability  $P(z)$  (HyperZ)
- Select objects with  $P(z_{\text{QSO}}) > 0.5$
- Radial distribution. (dead pix, bright objects)
- Spatial QSO-Galaxy cross-correlation amplitude  $B_{\text{gq}}$

# Average Radial Profile for $z = 0.5 \sim 1.5$



# Average Radial Profile for $z = 1.5 \sim 4.0$



# Spatial QSO-Galaxy cross-correlation amplitude $B_{gq}$

Number density of Galaxy at a distance  $r$  from a QSO

$$n(r)\delta V = \rho_g [1 + \xi_{qg}(r)]\delta V$$

Average Number density of Galaxy at QSO redshift

$$\xi_{qg}(r) = B_{gq} r^{-\gamma}$$

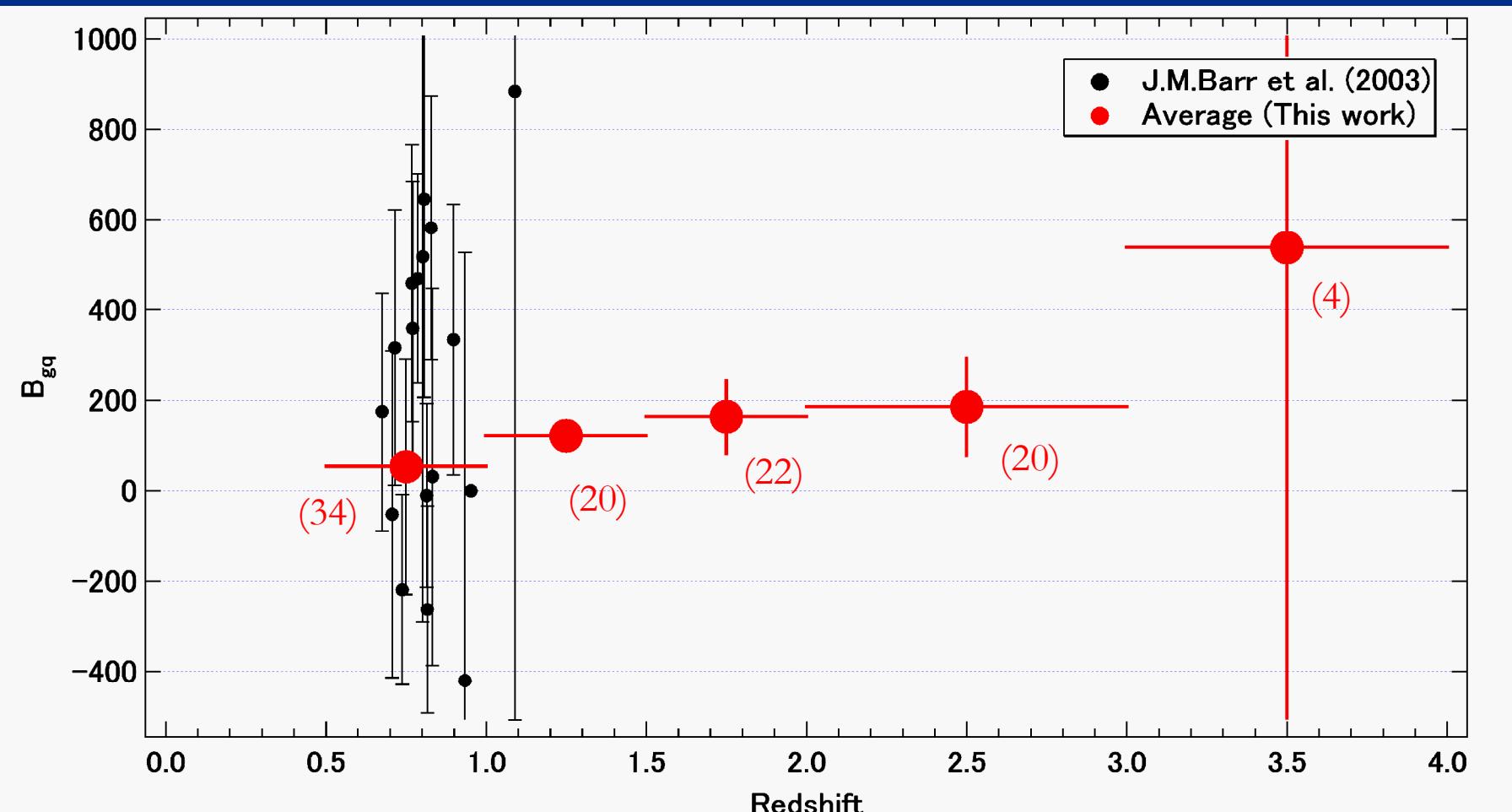
Total Number within 60 arcsec (0.5 Mpc)

Number expected from BG region  
(200~280 arcsec)

$$B_{gq} = \frac{3 - \gamma}{2\pi} \frac{N_{tot} - N_{bg}}{\phi(m_{lim}, z) I_\gamma} (0.5 \text{Mpc})^{\gamma - 3}$$

Number density brighter than limiting magnitude at QSO redshift

# $B_{gq}$ vs Redshift



# Summary

- Data discovery of deep images around known QSOs is easily achieved.
  - 700 QSOs are imaged by Subaru SuprimeCam
  - 100 QSOs are analyzed.
- $B_{gq}$  is derived for  $z = 0.5 \sim 4.0$ 
  - Tendency of increase of  $B_{gq}$  at higher redshifts
  - Clustering seems to be significant for  $M < -25$
- Future Work
  - Analyze more data (only 20% of data is analyzed )
  - Incorporate IR data (Subaru MOIRCS etc.)
    - Better Photometric redshift estimate.
    - Early type galaxies.