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

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Objectives

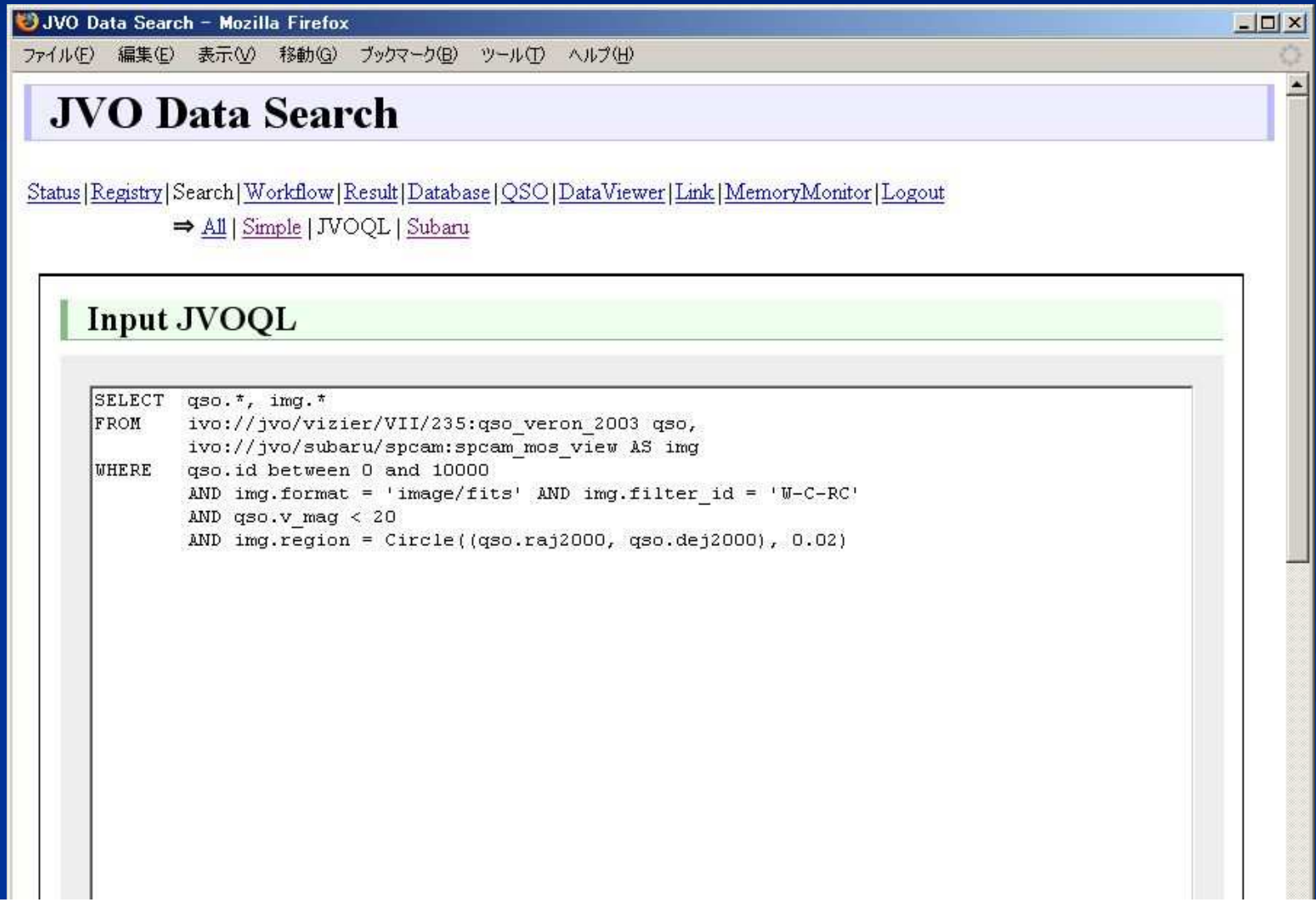
- QSO-Galaxy correlation:
  - Formation and Fuelling mechanism of QSO
  - History of the large scale structure formation
- Observations so far:
  - $z < 1.0$
  - Poor statistics (~tens of QSOs)
- Goal of our study:
  - Explore $z > 1.0$
  - High statistics (~hundreds or more)
  - QSO/AGN catalog (SDSS,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

Data Discovery through JVO

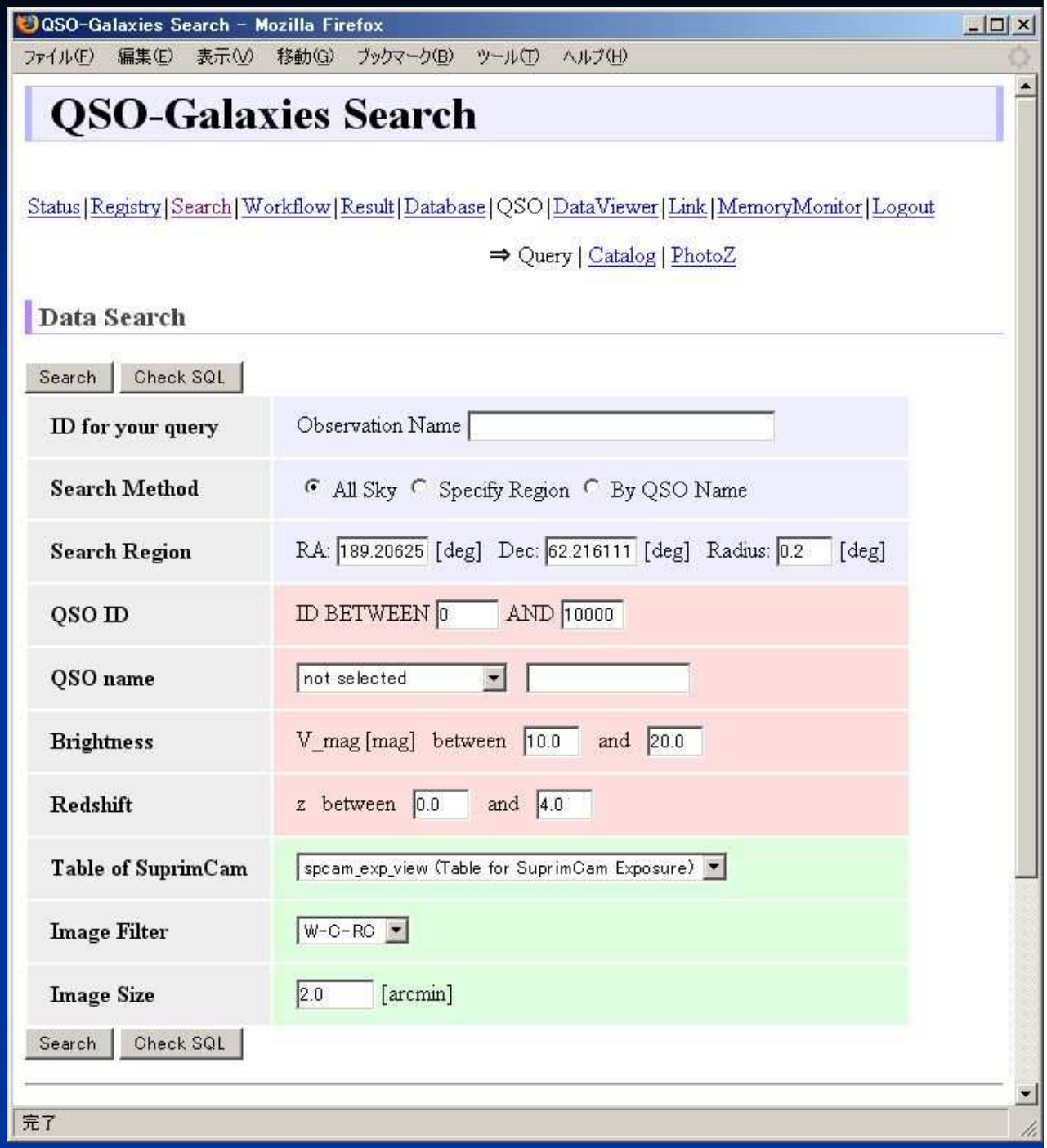
- Two VO data services are constructed:
  - QSO Catalog data service (Veron et al. 2006 from VizieR)
  - Subaru SuprimeCam image data service
  - Both services are developed by using the JVO SkyNode toolkit.
  - http://jvo.nao.ac.jp/download/skynode-toolkit
- SuprimeCam images containing cataloged QSOs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



Workflow (Script) mode

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

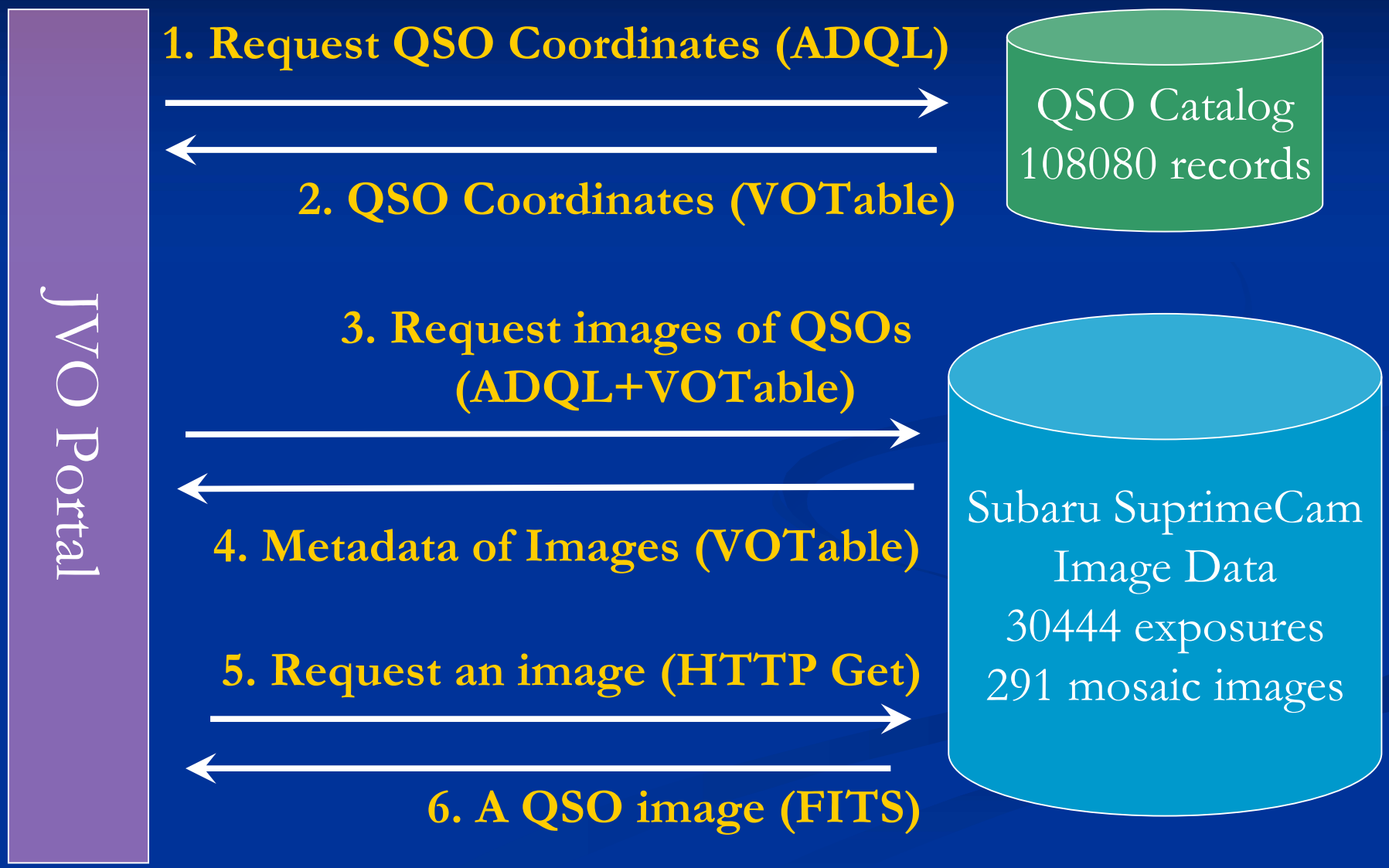
Workflow – Mozilla Firefox

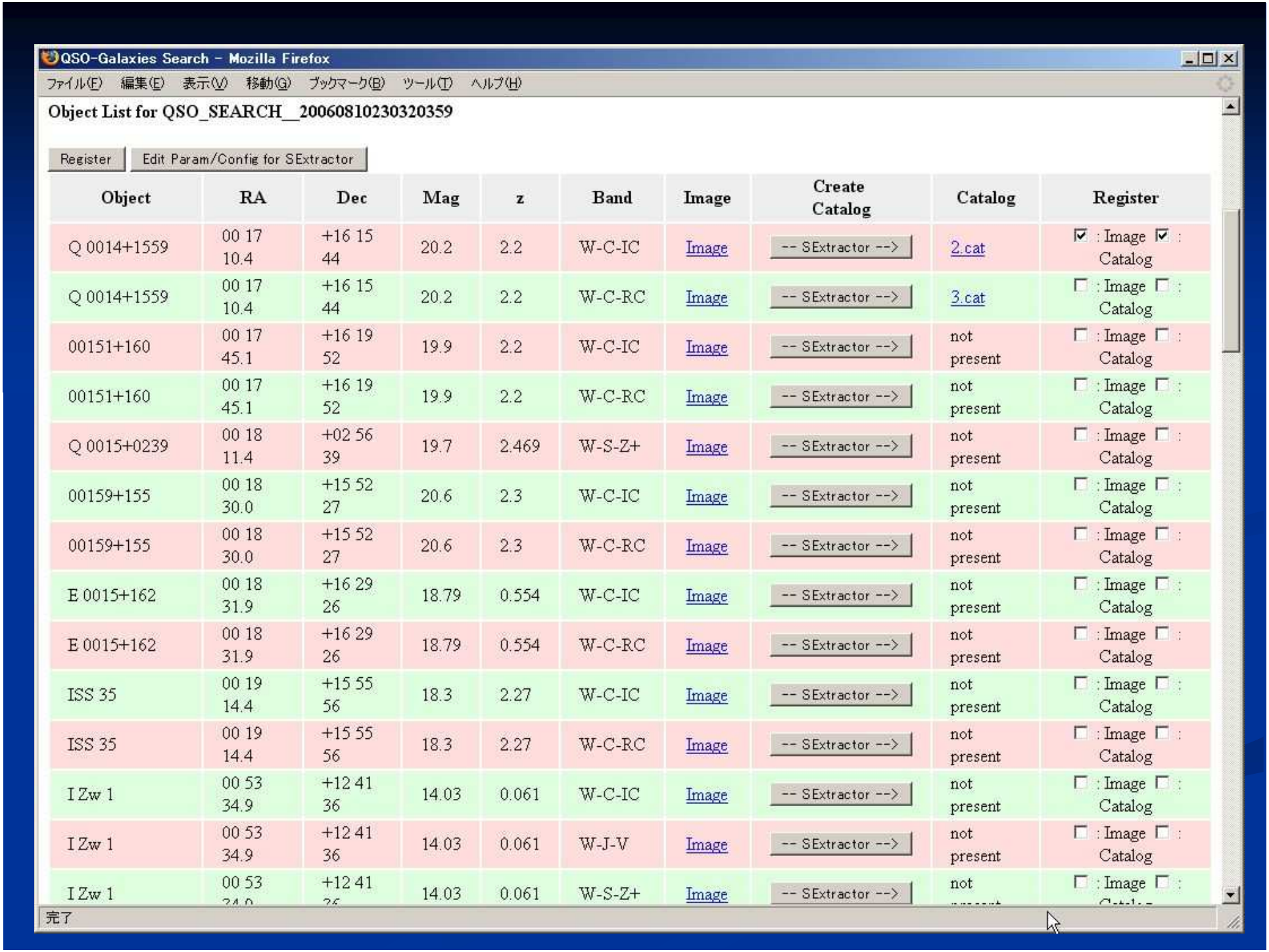
ファイル(F) 編集(E) 表示(V) 移動(G) ブックマーク(B) ツール(T) ヘルプ(H)

```
VOTABLE catalog
ArrayOfString listOfFileName
ArrayOfString listOfObjectName
ArrayOfString listOfCatalogName
String wdir
int numBands
ArrayOfString listOfFileForObject
ArrayOfDataHandler listOfDataHandler
ArrayOfString listOfFilterName
VOTABLE resultPhotoZ
String resultFileName
SEQUENCE
   jvoql = QSOStudy.createJVOQL(qsoTable, ra, dec, radi, imageTable, imageSize, magLimit)
   votableForImage = executeQuery(jvoql)
   storeVOTable(votableForImage[0], result_file1)
   listOfURL = QSOStudy.getListOfURL(votableForImage[0])
   listOfFileName = QSOStudy.getListOfFileName(votableForImage[0])
   listOfObjectName = QSOStudy.getListOfObjectName(votableForImage[0])
   listOfCatalogName = QSOStudy.getListOfCatalogNameForObject(listOfObjectName)
   FOR listOfURL
      INVOKE ivo://jvo/tools/sextractor catalogDH = performForURL(listOfURL[_count])
      storeVOTable(catalogDH, listOfFileName[_count])
   END
   wdir = getCurrentWorkDir()
   FOR listOfObjectName
      numBands = QSOStudy.prepareForHyperZ(wdir, listOfObjectName[_count], listOfFileName, listOfCatalogName[_count])
   END
   PARFOR listOfObjectName
      executeHyperZ(listOfCatalogName[_count], listOfObjectName[_count])
   END
END
```

完了

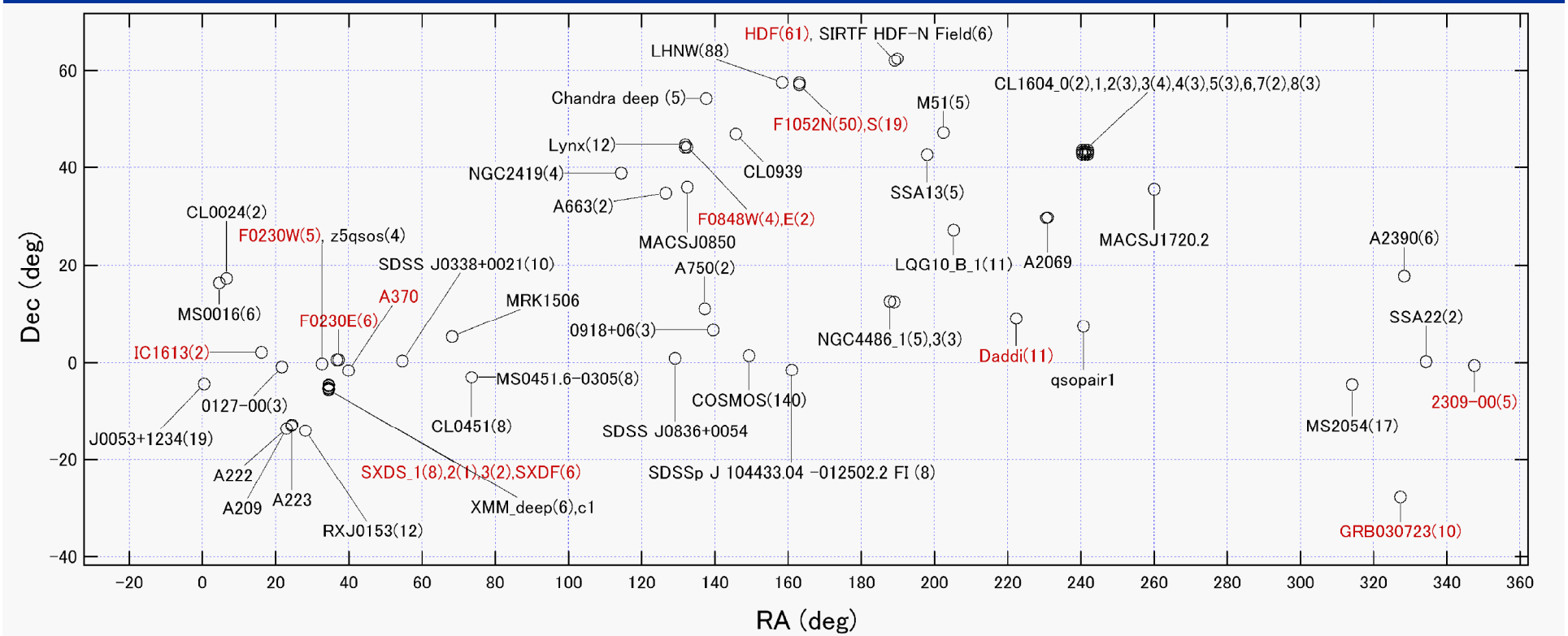
Procedure of QSO image search




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 Image -- SExtractor --> 2.cat : Image : Catalog
Q 0014+1559 00 17 10.4 +16 15 44 20.2 2.2 W-C-RC Image -- SExtractor --> 3.cat : Image : Catalog
00151+160 00 17 45.1 +16 19 52 19.9 2.2 W-C-IC Image -- SExtractor --> not present : Image : Catalog
00151+160 00 17 45.1 +16 19 52 19.9 2.2 W-C-RC Image -- SExtractor --> not present : Image : Catalog
Q 0015+0239 00 18 11.4 +02 56 39 19.7 2.469 W-S-Z+ Image -- SExtractor --> not present : Image : Catalog
00159+155 00 18 30.0 +15 52 27 20.6 2.3 W-C-IC Image -- SExtractor --> not present : Image : Catalog
00159+155 00 18 30.0 +15 52 27 20.6 2.3 W-C-RC Image -- SExtractor --> not present : Image : Catalog
E 0015+162 00 18 31.9 +16 29 26 18.79 0.554 W-C-IC Image -- SExtractor --> not present : Image : Catalog
E 0015+162 00 18 31.9 +16 29 26 18.79 0.554 W-C-RC Image -- SExtractor --> not present : Image : Catalog
ISS 35 00 19 14.4 +15 55 56 18.3 2.27 W-C-IC Image -- SExtractor --> not present : Image : Catalog
ISS 35 00 19 14.4 +15 55 56 18.3 2.27 W-C-RC Image -- SExtractor --> not present : Image : Catalog
I Zw 1 00 53 34.9 +12 41 36 14.03 0.061 W-C-IC Image -- SExtractor --> not present : Image : Catalog
I Zw 1 00 53 34.9 +12 41 36 14.03 0.061 W-J-V Image -- SExtractor --> not present : Image : Catalog
I Zw 1 00 53 +12 41 14.03 0.061 W-S-Z+ Image -- SExtractor --> not : Image :
完了

SuprimeCam QSO Fields

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



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

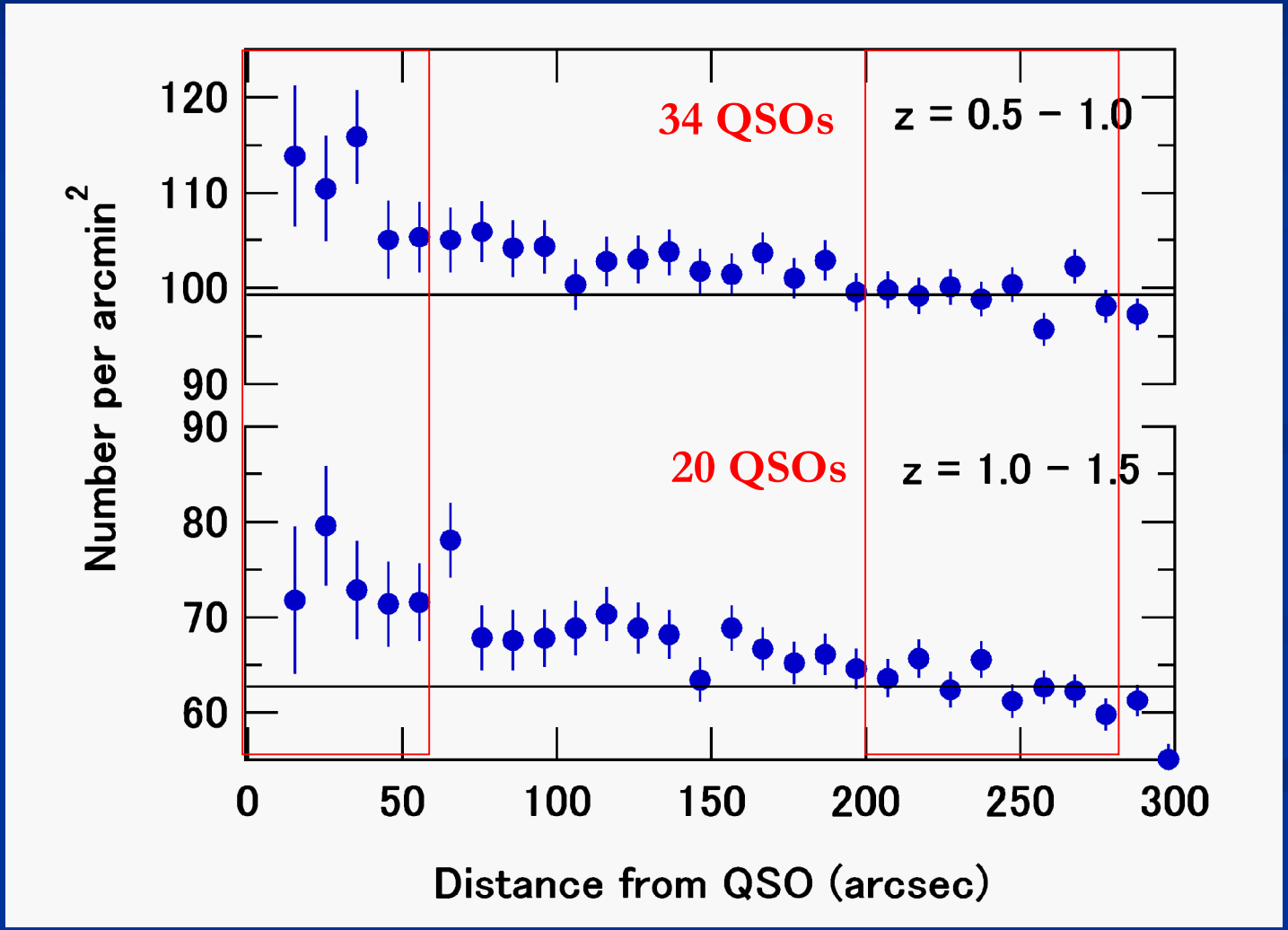
Field name	#filter	#QSO
COSMOS	4	140
LHNW	3	92
HDF	4	62
F1052N	3	50
J0053+1234	3	19
F1052S	3	19
MS2054	3	17
Lynx	3	12
RXJ0153	4	12
Daddi	3	11
GRB030723	4	10
SDSS J0338+0021	4	10
SXDS_1	5	8
SDSSp J 104433.0…	4	8
MS0451.6-0305	3	8
XMM_deep	3	6
MS0016	5	6
SIRTF HDF-N Field	4	6
F0230E	3	6

Field name	#filter	#QSO
SXDF	3	6
A2390	5	6
SSA13	4	5
NGC4486_1	3	5
F0230W	3	5
Chandra deep	3	5
2309-00	3	5
M51	3	5
NGC2419	3	4
z5qsos	3	4
F0848W	3	4
CL1604_3	3	4
CL1604_2	3	3
CL1604_5	3	3
CL1604_4	4	3
0918+06	3	3
0127-00	3	3
CL1604_8	3	3
NGC4486_3	3	3

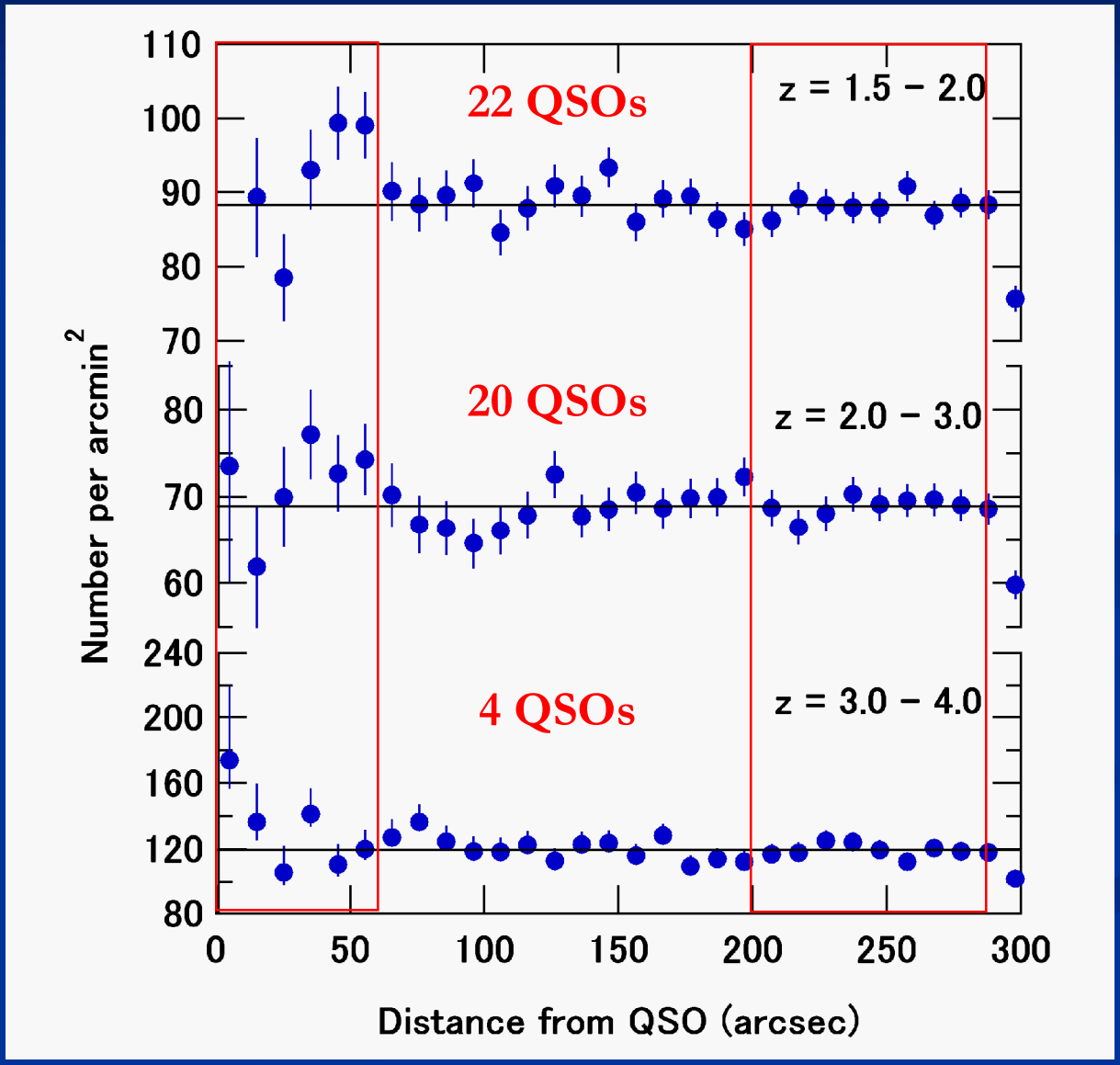
Analysis

- Reject images whose coverage is less than 50% of 10x10 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 $P(z_{QSO}) > 0.5$
- Radial distribution. (dead pix, bright objects)
- Spatial QSO-Galaxy cross-correlation amplitude B_{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

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

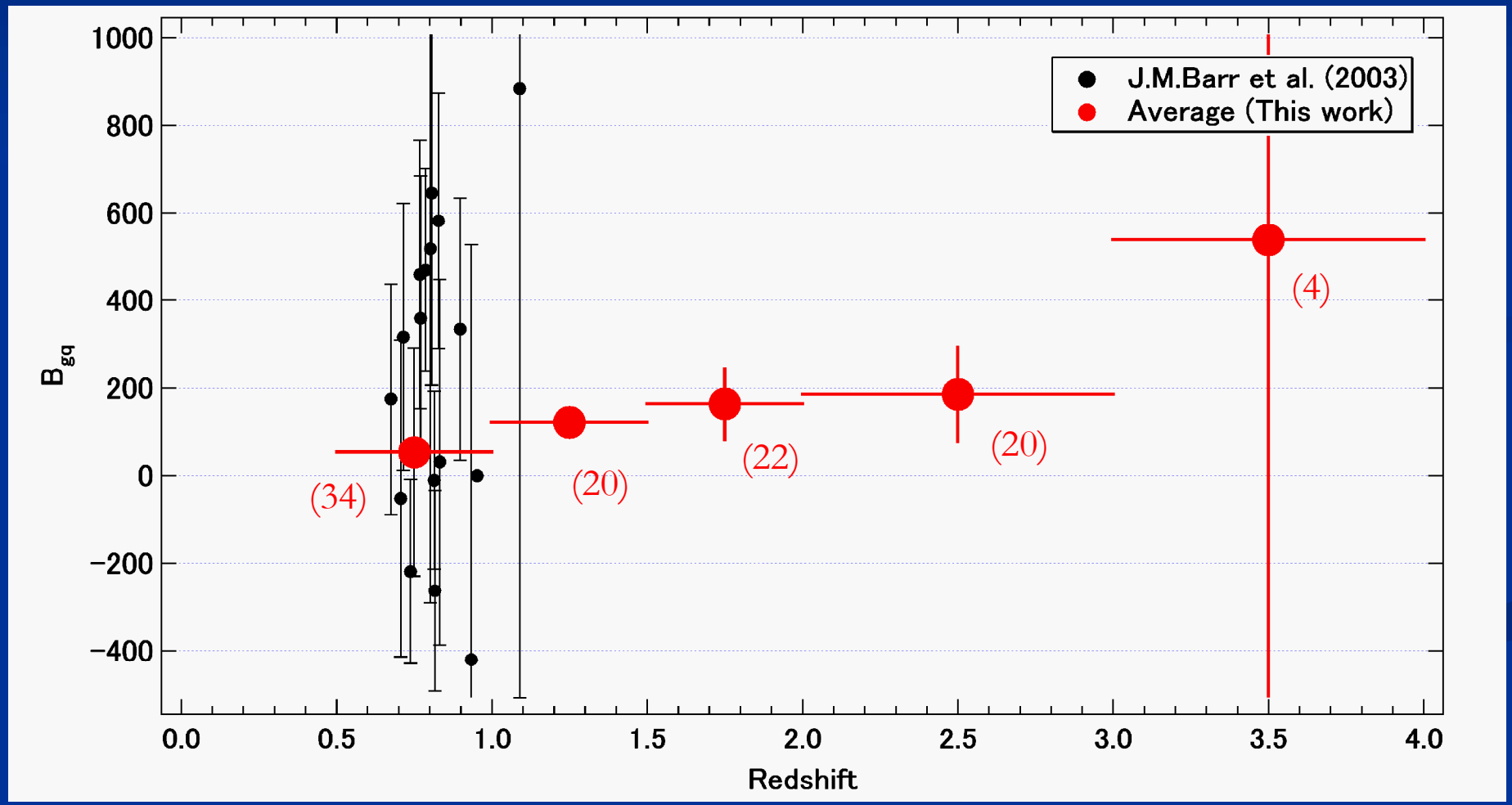
Total Number within 60 arcsec (0.5 Mpc)

Number expected from BG region (200~280 arcsec)

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

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 anlyzed)
  - Incorporate IR data (Subaru MOIRCS etc.)
    - Better Photometric redshift estimate.
    - Early type galaxies.