Quasar clustering with SDSS

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SSGW @High-I
Quasars in ‘survey’ science

• In recent years, large surveys like SDSS and 2dF QSO redshift survey have accumulated large spectroscopic data sets of quasars.
• SDSS has surveyed optically-selected quasars over a quarter of the all-sky and wide range of redshift (0<z<6).
• Many statistical studies of quasars have been done with the survey data.
Quasars in SDSS-1/2/3

- **SDSS-1/2** (Data Release 1-7; 1999-2008)
  - Quasar catalog by Schneider et al. (2010)
  - 105,783 quasars @0<z<5 (<z>=1.49)

- **SDSS-3** (DR8-12; 2008-2014)
  - Baryonic Oscillation Spectroscopic Survey (BOSS)
  - Quasar catalog by Paris et al. (2016)
  - 297,301 quasars (184,101 @z>2.15)
Quasars in SDSS-1/2/3

SDSS-1/2

Schneider et al. (2010)

SDSS-3

Paris et al. (2016)
Quasars in SDSS-1/2/3

Paris et al. (2016)
Quasars in SDSS-4

• SDSS-4 through 2014 to 2020
• First DR (DR13) will come out on 31st July.
• Quasars in extended-BOSS (eBOSS) program
• 700,000 mid-z (1<z<2.2) quasars and 40,000 high-z (2.2<z<3.5) quasars to be targeted
Quasars in SDSS-4

Myers et al. (2015)
To do statistics

• We need to understand a quasar sample: is it reflecting the real quasar population completely and unbiasedly?
• To answer this question, we need to look into how a quasar sample is made.
Quasar candidates

• Quasars appear as point sources in photometry, but not all point sources are selected for spectroscopic follow-up observation because of efficiency issue.

• Quasar target selection (QTS) chooses quasar targets.
  – Main concern is to separate quasars from non-quasars (mostly stars) in color-color space.
  – SDSS QTS has evolved through each iteration.
QTS

• QTS of SDSS-1/2 selects outliers from stellar locus in color-color space as quasar candidates, while QTS of SDSS-3/4 calculates probability of being a quasar of a point source given flux and color with photometric error accounted more thoroughly.

Richards et al. (2002)  
Completeness of quasar sample

Completeness = fraction of simulated quasars that are selected by QTS algorithm

- SDSS-1/2
  Richards et al. (2002)
Completeness of quasar sample

- SDSS-3
  Ross et al. (2013)
Quasar clustering

- Quasar
  an efficient object to probe the early universe
- Clustering
  a way to probe large-scale structures, which sheds light on galaxy formation and evolution, and cosmology
Quasar clustering quasar groups

- Test on the cosmological principle (homogeneity)

Clowes et al. (2013)

Park, Song et al. (2015)
Quasar clustering
quasar density

- Song et al. (2016, under review)
- Quasar distribution on density map of CMASS galaxies @z~0.5

\[ \rho_{20}^{\log_{10}} \text{mean}(\rho_{20}) \]

\[ 7^\circ < \text{dec} < 9^\circ \]

\[ n_Q \]

\[ \text{slope} \approx 0.62 \]
Quasar clustering correlation functions (CFs)

- Shen et al. (2013): cross-CFs of quasars and CMASS galaxies @z~0.5
- Eftekharzadeh et al. (2015): auto-CFs of quasars @z~2.5
Conclusion

• Large survey data of quasars are available.
• To do statistics with the survey data, it is important to understand the data first.
• Quasar clustering can be studied in several ways, and be used to understand large-scale structures and cosmology.