

---

# **XDQSO Documentation**

***Release 0.7***

**Jo Bovy, Mike DiPompeo**

August 21, 2015



<b>1</b>	<b>Introduction</b>	<b>3</b>
<b>2</b>	<b>XDQSOz photometric quasar catalog</b>	<b>5</b>
<b>3</b>	<b>IDL code</b>	<b>7</b>
<b>4</b>	<b>Acknowledging XDQSO</b>	<b>13</b>



The XDQSO code accompanies the XDQSO/XDQSOz papers for quasar classification and photometric redshift estimation. It allows you to calculate photometric quasar probabilities to mimick [SDSS-III's BOSS](#) quasar target selection or to calculate photometric redshifts for quasars, using any combination of SDSS optical, GALEX, ultraviolet, UKIDSS near-IR, and WISE mid-IR photometry

Contents:

*[Introduction](#)*

*[XDQSOZ photometric quasar catalog](#)*

*[IDL code](#)*

*[Acknowledging XDQSO](#)*



---

## Introduction

---

To download the code use either

```
wget -qO- https://github.com/xdqso/xdqso/archive/v0.6.tar.gz | tar xvz
```

or

```
git clone https://github.com/xdqso/xdqso.git
```

Installation only requires you to set the environment variable `XDQSODATA` to the data directory of the distribution. EvilUPS setup is available.

Code is available either as `xdqso` or as `xdqsoz`. For most purposes you will want to use the `xdqsoz` functions: these allow you to calculate photometric redshifts and quasar probabilities for arbitrary redshift ranges. The `xdqsoz` routines are the functions used to create the photometric quasar catalog. If you want to mimic *SDSS-III's BOSS* quasar target selection or easily calculate probabilities in broad redshift bins you want to use the `xdqso` functions instead.

The functions `xdqso_calculate_prob` and `xdqsoz_calculate_prob` calculate photometric quasar probabilities. The former can only do this in three redshift ranges ( $z < 2.2$ ;  $2.2 \leq z \leq 3.5$ ;  $z > 3.5$ ), while the latter accommodates arbitrary redshift ranges.

Photometric redshifts can be calculated using the `xdqsoz_zpdf` and `xdqsoz_eval_zpdf` functions. The former prepares the parameters of the one-dimensional redshift PDF for individual objects, the latter then allows you to evaluate this PDF. The function `xdqsoz_calculate_prob_andz` wraps this functionality into the quasar probability calculation, including the redshift PDF sampled in increments of 0.01 in the output structure.

One can also use `xdqsoz_marginalize_colorzprob` to integrate the redshift PDF over arbitrary redshift ranges:

```
out= xdqsoz_marginalize_colorzprob(zmin,zmax,flux,flux_ivar,norm=totlike)
```

Input is dereddened `psfflux` and `psfflux_ivar` (to deredden you can use the functions `xdqso_sdss_deredden` and `xdqso_sdss_deredden_error`) and a min and max redshift; output is the marginalized likelihood (marginalized over redshift). Setting `norm=totlike` returns the total quasar likelihood. If you then multiply the 'pqso' from the photometric quasar catalog below by the ratio of out and totlike you get the desired redshift-range probability (since the prior and the denominator do not change). When calculating quasar probabilities in many bins this is much faster than calling `xdqsoz_calculate_prob` repeatedly because you do not recalculate star likelihoods and priors each time.





---

## XDQSOz photometric quasar catalog

---

The original version of the SDSS-XDQSO DR8 photometric quasar catalog that does not include WISE information is available at

[http://cosmo.nyu.edu/~jb2777/qsocat/xdqsoz\\_pqso0.5\\_imag21.5-nobadu.fits.gz](http://cosmo.nyu.edu/~jb2777/qsocat/xdqsoz_pqso0.5_imag21.5-nobadu.fits.gz)

[http://cosmo.nyu.edu/~jb2777/qsocat/README\\_pqso0.5\\_imag21.5-nobadu](http://cosmo.nyu.edu/~jb2777/qsocat/README_pqso0.5_imag21.5-nobadu)

This catalog is based on the same principle as the XDQSO method for BOSS quasar selection, but uses a slightly different algorithm (*XDQSOz*) for calculating quasar probabilities that also permits us to obtain photometric redshifts; it also allows quasar probabilities to be calculated quickly for arbitrary redshift ranges (see the accompanying code below).

The original catalog is a simple cut on  $P(\text{quasar}) > 0.5$  for all objects that pass the BOSS quasar selection flag cuts, limited further to  $i_0 < 21.5$  mag and with some bad u-columns in the SDSS imaging data masked. We have performed some first tests of the clustering of the objects in the catalog, which shows that the level of stellar contamination is small ( $< 10\%$ ), but we have yet to break this up by redshift range, etc., and perform further tests. So exercise caution when using the catalog (especially at low Galactic latitude, since the SEGUE stripes are included), and please let us know if you find any problems.

An updated version of the catalog is available at

[http://www.mpia.de/homes/joe/xdqsozcat\\_galex\\_ukidss\\_wise\\_p20.fits.gz](http://www.mpia.de/homes/joe/xdqsozcat_galex_ukidss_wise_p20.fits.gz)

[http://www.mpia.de/homes/joe/README\\_pqso0.2\\_wise](http://www.mpia.de/homes/joe/README_pqso0.2_wise)

which includes updated probabilities incorporating WISE fluxes, and photometric redshift PDFs for all objects with  $P(\text{quasar}) > 0.2$ . Like the first catalog, it only includes objects that pass the BOSS quasar selection flag cuts and objects with  $i_0 < 21.5$ . There are tags to indicate if an object falls within the SDSS bright star mask, a region of bad SDSS photometry, an area with bad u-columns, or near contaminated WISE data. The same precautions as above apply to the new catalog. A catalog containing quasar/star probabilities for all point sources in SDSS DR8 is available upon request.



## Contents:

*xdqso\_calculate\_prob*  
*xdqsoz\_calculate\_prob*  
*xdqsoz\_eval\_zpdf*  
*xdqsoz\_marginalize\_colorzprob*  
*xdqsoz\_peaks*  
*xdqsoz\_qso\_track*  
*xdqsoz\_zpdf*  
*xdqsoz\_calculate\_prob\_andz*

**xdqso\_calculate\_prob** (in,/dereddened,/galex,/ukidss,/wise)

*calculate the extreme-deconvolution XDQSO QSO probability*

## Input:

in - structure containing PSFFLUX, PSFFLUX\_IVAR, EXTINCTION

## Keywords:

dereddened - psfflux, and psfflux\_ivar is already dereddened

galex - GALEX fluxes are included in input structure, with tags NUV, FUV, NUV\_ivar, and FUV\_ivar. GALEX fluxes are in nanomaggies

ukidss - UKIDSS fluxes are included in input structure, with tags APERCSIFLUX3\_Y, APERCSIFLUX3\_J, APERCSIFLUX3\_H, APERCSIFLUX3\_K, APERCSIFLUX3ERR\_Y, APERCSIFLUX3ERR\_J, APERCSIFLUX3ERR\_H, APERCSIFLUX3ERR\_K. Fluxes/errors are in SI units.

wise - WISE fluxes are included in input structure, with tags w1\_nanomaggies, w2\_nanomaggies, w1\_nanomaggies\_ivar, w2\_nanomaggies\_ivar. Fluxes are in Vega nanomaggies.

## Output:

structure containing pqso, ... (see XDQSO catalog description)

## History:

010-04-30 - Written - Bovy (NYU)

2014-04-02 - Added WISE, GALEX, UKIDSS - DiPompeo (UWyo)

**xdqsoz\_calculate\_prob** (in,zmin,zmax,/dereddened,/galex,/ukidss,wise)

*calculate the extreme-deconvolution probability ratio, marginalizing over an arbitrary redshift range*

Input:

in - structure containing PSFFLUX, PSFFLUX\_IVAR, EXTINCTION

zmin, zmax - lower, upper bound of redshift interval

Keywords:

dereddened - psfflux, and psfflux\_ivar are already dereddened

galex - GALEX fluxes are included in input structure, with tags NUV, FUV, NUV\_ivar, and FUV\_ivar. GALEX fluxes are in nanomaggies

ukidss - UKIDSS fluxes are included in input structure, with tags APERCSIFLUX3\_Y, APERCSIFLUX3\_J, APERCSIFLUX3\_H, APERCSIFLUX3\_K, APERCSIFLUX3ERR\_Y, APERCSIFLUX3ERR\_J, APERCSIFLUX3ERR\_H, APERCSIFLUX3ERR\_K. Fluxes/errors are in SI units.

wise - WISE fluxes are included in input structure, with tags w1\_nanomaggies, w2\_nanomaggies, w1\_nanomaggies\_ivar, w2\_nanomaggies\_ivar. Fluxes are in Vega nanomaggies.

Output:

out - structure containing pqso, ...

History:

2010-04-30 - Written - Bovy (NYU)

2010-05-29 - Added Galex - Bovy

2010-10-30 - Added UKIDSS - Bovy

2014-03-31 - Added WISE - DiPompeo (UWyo)

**xdqsoz\_eval\_zpdf** (z,zmean,zcovar,zamp)

*evaluate the photometric redshift PDF for a given redshift given means, covars, and amps*

Input:

z - redshift [nz]

zmean, zcovar, zamp - from [xdqsoz\\_zpdf](#)

Output:

p(z)

History:

2011-01-18 - Written - Bovy (NYU)

**xdqsoz\_marginalize\_colorzprob** (zmin,zmax,flux,flux\_ivar,/galex,/ukidss,/wise,norm=norm,/log)

*marginalize the probability of a relative flux + redshift (not a color) over redshift*

Input:

zmin, zmax - redshift

flux - [nfluxes] or [nfluxes,ndata] array of fluxes

flux\_ivar - [nfluxes] or [nfluxes,ndata] array of flux\_ivars

Keywords:

galex - use GALEX fits

ukidss - use UKIDSS fits

wise - use WISE fits

log - calculate log

Output:

number or array of probabilities

Optional Output:

norm - normalization factor (likelihood marginalized over redshift 0 to infinity)

History:

2011-01-16 - Written - Bovy (NYU)

2014-03-31 - Added WISE - DiPompeo (UWyo)

**xdqsoz\_peaks** (flux,flux\_ivar,nzs=nzs,peak\_threshold=peak\_threshold,/galex,/ukidss,/wise,/plot,peakz=peakz,xdqsoz=xdqsoz)

*calculate the number of peaks of a zpdf as well as the MAP z*

Input:

flux - dereddened flux

flux\_ivar - dereddened flux\_ivar

Optional Input:

nzs - number of points to sample the PDF at

peak\_threshold - threshold for defining a peak (contiguous region with p above peak\_threshold)

Keywords:

galex - use GALEX fits

ukidss - use UKIDSS fits

wise - use WISE fits

plot - make QS plot

Output:

number of peaks

Optional Output:

peakz - MAP z

xdqsoz - structure containing {peakz,peakprob,peakfwhm,otherz,otherprob,otherfwhm} for all peaks

History:

2011-01-18 - Written - Bovy (NYU)

2014-03-31 - Added WISE - DiPompeo (UWyo)

**xdqsoz\_qso\_track** (z,i=i,/galex,/ukidss,/wise)

*calculate the mean quasar locus*

Input:

z - redshift or array of redshifts [N]

Optional Input:

i= dereddened i-band magnitude

Keywords:

galex - use GALEX fits

ukidss - use UKIDSS fits

wise - use WISE fits

Output:

mags[ndim,N] - array of apparent magnitudes (ugriz[NUV,FUV,YJHK])

History:

2011-04-01 - Written - Bovy (NYU)

2014-04-02 - Added WISE - DiPompeo (UWyo)

**xdqsoz\_zpdf**, flux, flux\_ivar, /galex, /ukidss, /wise, zmean=zmean, zcovar=zcovar, zamp=zamp

*calculate the photometric redshift pdf using XDQSOz*

Input:

flux - [nfluxes] or [nfluxes,ndata] array of fluxes

flux\_ivar - [nfluxes] or [nfluxes,ndata] array of flux\_ivars

Keywords:

galex - use GALEX fits

ukidss - use UKIDSS fits

wise - use WISE fits

Output:

zmean - [ngauss,ndata] array of means

zcovar - [ngauss,ndata] array of covars

zamp - [ngauss,ndata] array of amplitudes

History:

2011-01-18 - Written - Bovy (NYU)

2014-04-02 - Added WISE - DiPompeo (UWyo)

**xdqsoz\_calculate\_prob\_andz** (in,zmin,zmax,/dereddened,/galex,/ukidss,/wise)

*The same as xdqsoz\_calculate\_prob, with xdqsoz\_zpdf wrapped in to simultaneously calculate z PDF*

Input:

in - structure containing PSFFLUX, PSFFLUX\_IVAR, EXTINCTION

zmin, zmax - lower, upper bound of redshift interval

**Keywords:**

dereddened - psfflux, and psfflux\_ivar are already dereddened

galex - GALEX fluxes are included in psfflux, psfflux\_ivar, and extinction; use them

ukidss - use UKIDSS (like /galex)

wise - use WISE (like /galex)

**Output:**

out - structure containing pqso, ... , z array from zmin to zmax in 0.01 increments, z PDF at each value of z.

**History:**

2014-03-31 - Written - DiPompeo (UWyo)





---

## Acknowledging XDQSO

---

Please cite the relevant papers among the following:

BOSS CORE target selection paper (also cite [Ross et al. 2011](#)): *Think outside the color box: probabilistic target selection and the SDSS-XDQSO quasar targeting catalog*, Bovy, J., et al., 2010, *ApJ*, **729**, 141 [[ApJ](#)] [[ADS](#)]

Photometric redshifts: *Photometric redshifts and quasar probabilities from a single, data-driven generative model*, Bovy, J., et al., 2011, *ApJ*, **749**, 41 [[ApJ](#)] [[ADS](#)]

Updated XDQSO with WISE: *Quasar Probabilities and Redshifts from WISE mid-IR through GALEX UV Photometry*, DiPompeo, M. A., et al., 2015, *MNRAS*, **452**, 3124 [[MNRAS](#)] [[ADS](#)]

Catalog paper: *The SDSS-XDQSO photometric quasar catalog*, Myers, A. D., et al., 2015, in preparation

XD methodology paper: *Extreme deconvolution: inferring complete distribution functions from noisy, heterogeneous and incomplete observations*, Bovy, J., Hogg, D. W., & Roweis, S. T., 2011, *AOAS*, **5**, 2B, 1657 [[AOAS](#)] [[ADS](#)]