Quasar Astrometric Redshifts with LSST

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LSST AGN Science Collaboration
Roadmap Development Meeting
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DUNLAP INSTITUTE
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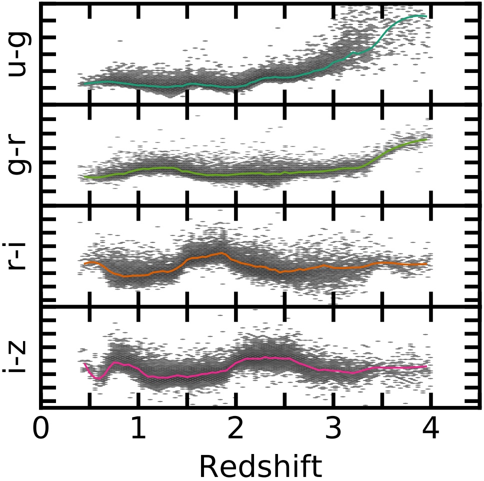
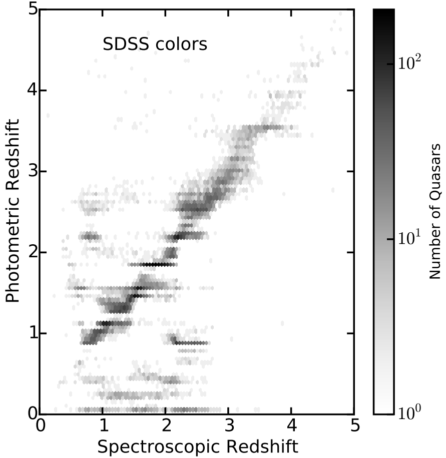
Redshift - Color Relation



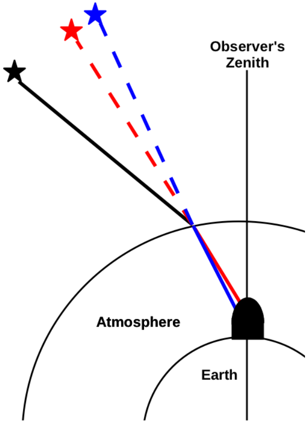
Quasar color as a function of redshift.

Redshift - Color Relation



Spectroscopic redshift vs. photometric redshift using SDSS colors.

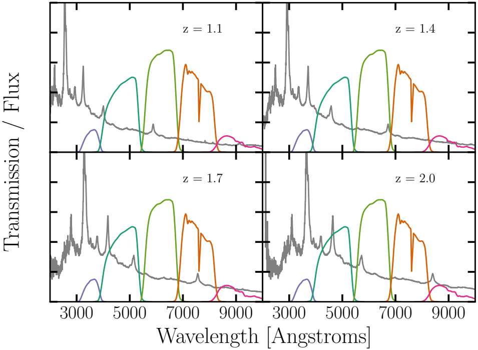
Differential Chromatic Refraction



(Kaczmarczik et al. 2009)

- Light bends entering the atmosphere, function of wavelength and airmass.

Differential Chromatic Refraction



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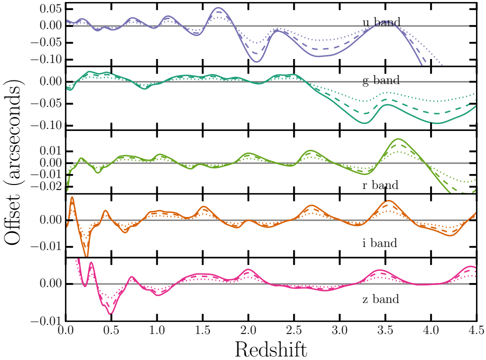
- Effective wavelength of the bandpass depends on SED. (Schneider et al. 1983)

Differential Chromatic Refraction



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- Emission lines in quasar SED change the effective wavelength as a function of redshift.

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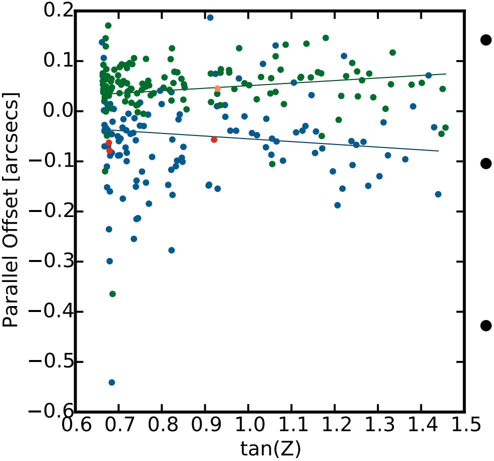
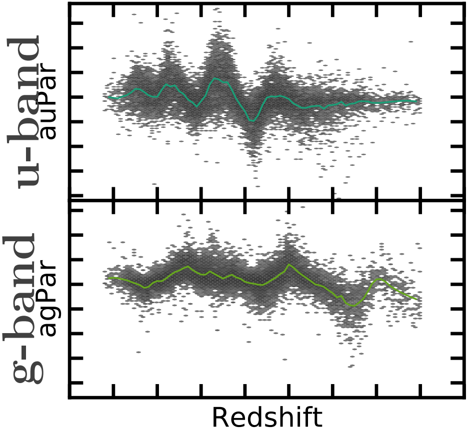


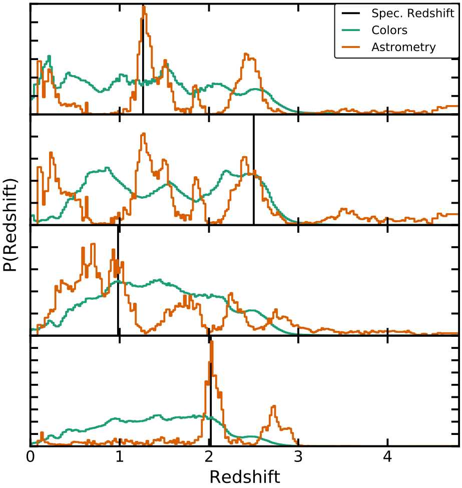
- Light bends entering the atmosphere, function of wavelength and airmass.
- Effective wavelength of the bandpass depends on SED. (Schneider et al. 1983)
- Emission lines in quasar SED change the effective wavelength as a function of redshift.
- Need observations at multiple airmasses to overcome astrometric error.

Redshift - DCR Relation



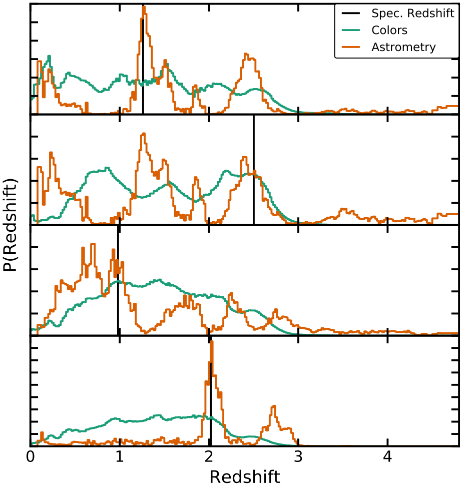
Astrometric offset as a function of redshift.

Astro-Photometric Redshifts



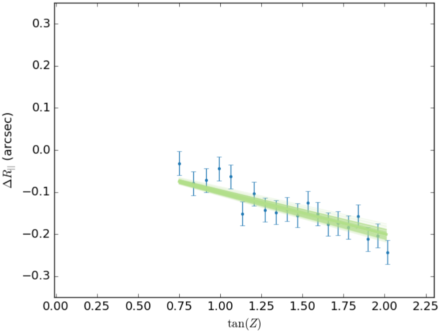
- Photometric redshift PDFs can have multiple peaks or wide plateaus.

Astro-Photometric Redshifts



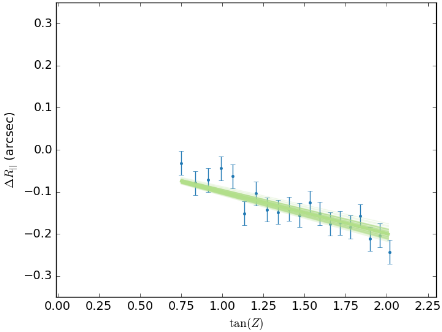
- Photometric redshift PDFs can have multiple peaks or wide plateaus.
- Incorporating astrometric PDFs can break degeneracies or isolate the correct value.

Can LSST detect the DCR effect?



- Fit the measured offsets with a straight line.

Can LSST detect the DCR effect?



- Fit the measured offsets with a straight line.
- Actually many fits, using of MCMC walkers.

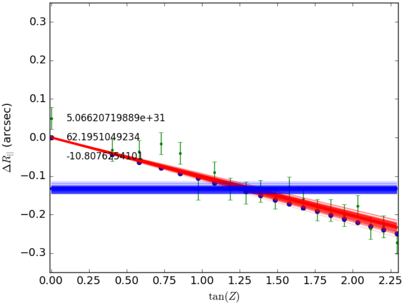
Bayes Factor

$M_1 = mx + 0.0$ - a model quasar
$M_2 = 0.0x + b$ - a "star"

$$K = \frac{Pr(D|M_1)}{Pr(D|M_2)} = \frac{e^{\ln \mathcal{L}_{M_1}}}{e^{\ln \mathcal{L}_{M_2}}} \tag{1}$$

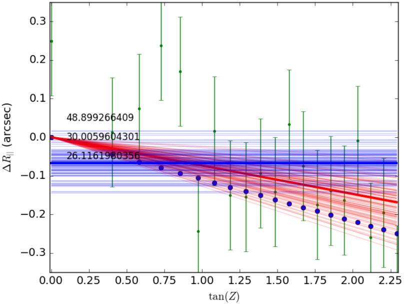
More quasar: $K > 1$.
Very strongly favoring a quasar: $K > 100$.

Bayes Factor - Examples



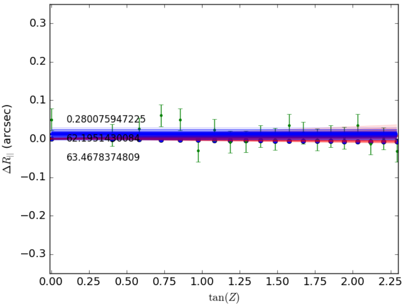
- Redshift: 2.1
- Airmass Range: 1.0 to 2.5
- Astrometric Err.: 0.020 arcsec
- Number of Observations: 20

Bayes Factor - Examples



- Redshift: 2.1
- Airmass Range: 1.0 to 2.5
- Astrometric Err.: 0.100 arcsec
- Number of Observations: 20

Bayes Factor - Examples



- Redshift: 0.6
- Airmass Range: 1.0 to 2.5
- Astrometric Err.: 0.020 arcsec
- Number of Observations: 20

Bayes Factor - Examples

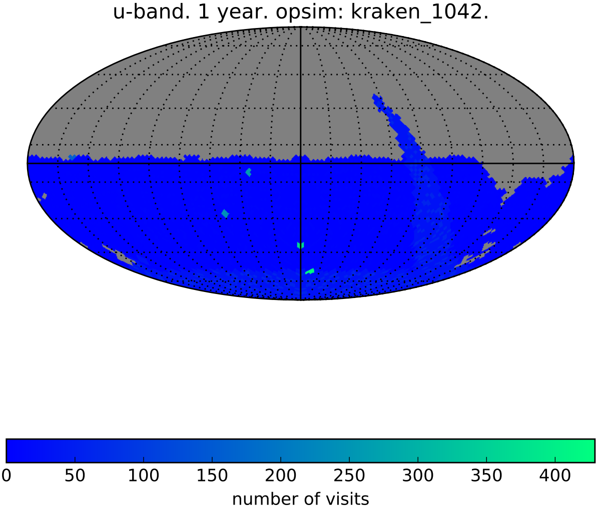
In general these increase the Bayes factor:

- Redshift: stronger emission lines in bandpass
- Airmass Range: wider range
- Astrometric Err.: smaller error
- Number of Observations: more observations

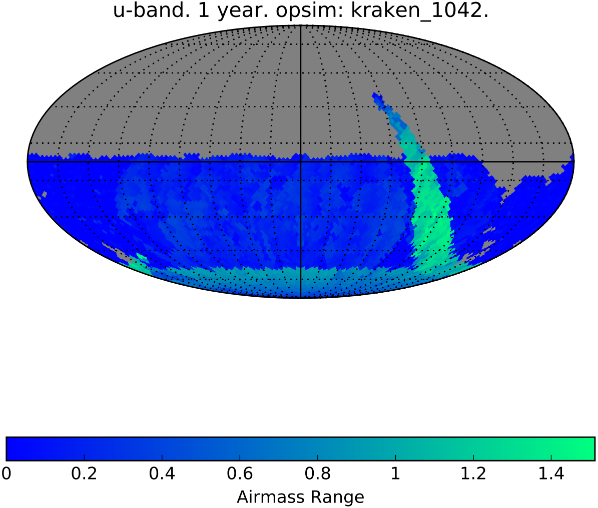
Operations Simulator and Metric Analysis Framework

- OpSims: potential survey observing schedules.
- Give airmass and filter for every pointing on the sky.
- Produce maps of the sky that summarize a given statistic.
- *kraken_1042*: the current baseline cadence.

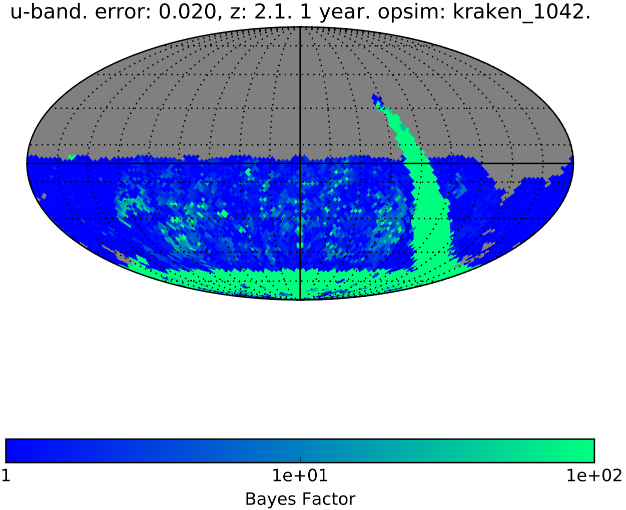
Number of Observations at Every Position



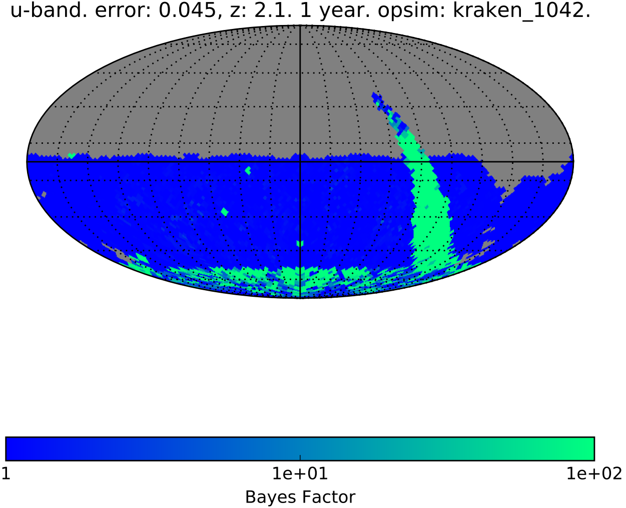
Range of Airmasses of Observations



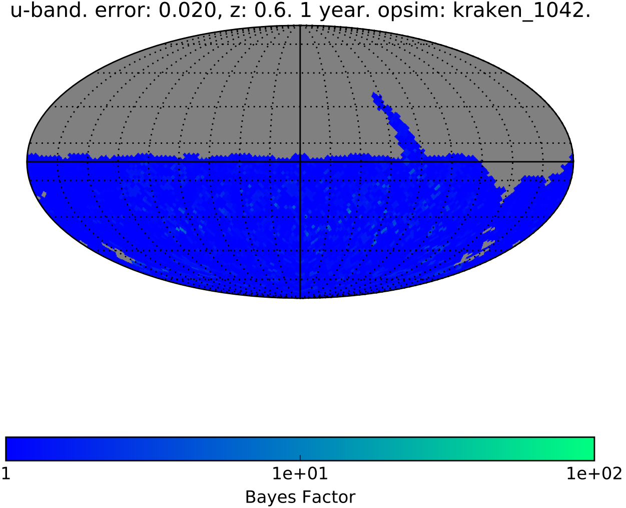
Bayes Factor for Every Position



Bayes Factor for Every Position



Bayes Factor for Every Position



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Summary

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Developing a MAF:

- Can determine if DCR effect will be detectable based on a given OpSim.
- Effected by number of observations, range of airmasses, and astrometric errors.

Next Steps

- Combine the measured slopes and errors with colors using machine learning regression algorithms to estimate redshifts.
    - How much will detection of DCR improve a redshifts?
    - What redshift ranges will have the greatest benefit?
- What constraints on the cadence / airmass limits are necessary to get a benefit?
- How can we make this more realistic?
    - Baldwin Effect.
    - Astrometric errors at the survey limit.