A Procedure to Improve Low–Quality Distance Measurements for Galaxy Group Identification

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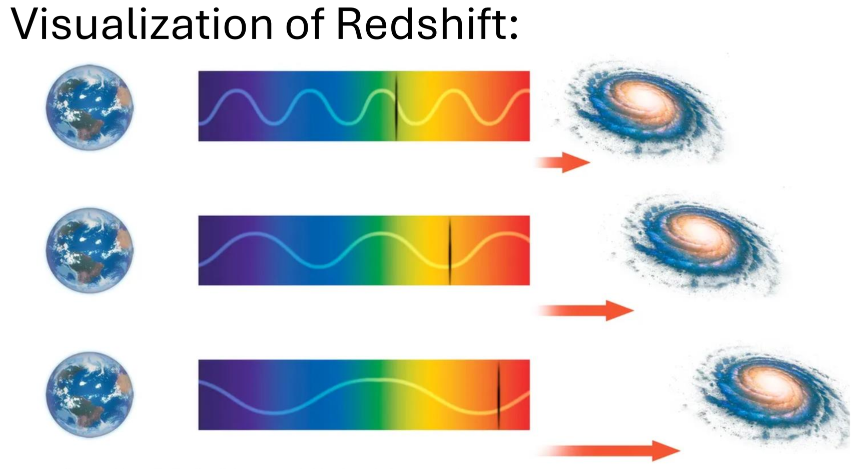
Background

In space, galaxies often exist in groups. For example, our own Milky Way galaxy exists in the Local Group, containing two giant galaxies and dozens of dwarf galaxies. Groups accelerate **galaxy evolution** as their members interact with each other and the gas and dark matter that fills the group environment. Galaxies occupy a three dimensional space yet we see them on a two dimensional sky, so we must measure their distance along the line of sight. We use the fact that as the universe expands, light is stretched on its way to us. The distance over which the light travels can be measured from this stretch, which is called a **redshift,** often referred to simply as **z**. A redshift can be measured either via spectroscopy or via imaging ("photometry"), the latter being less accurate yet easier to obtain for distant galaxies. Since the universe is expanding, we see these galaxies in the **cosmic past** as their light has traveled through space for so long, giving us a glimpse into the early stages of galaxy evolution. Group finding for distant-universe galaxies has been difficult due to the high uncertainties often associated with photometric redshifts.

By calibrating photometric redshifts using nearby-universe surveys that have high quality spectroscopic redshifts for comparison, we develop a procedure to apply to distant-universe surveys lacking high quality redshifts.

Visualization of Redshift:

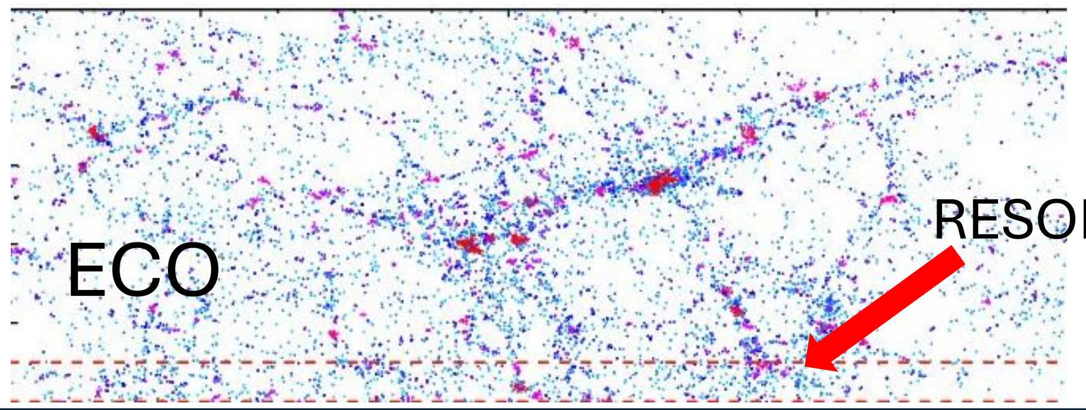


The light a galaxy emits becomes more red as it moves farther away and the wavelength stretches out. This gives a measure of how far away a galaxy is from us.

Image Credit: BBC Sky at Night Magazine

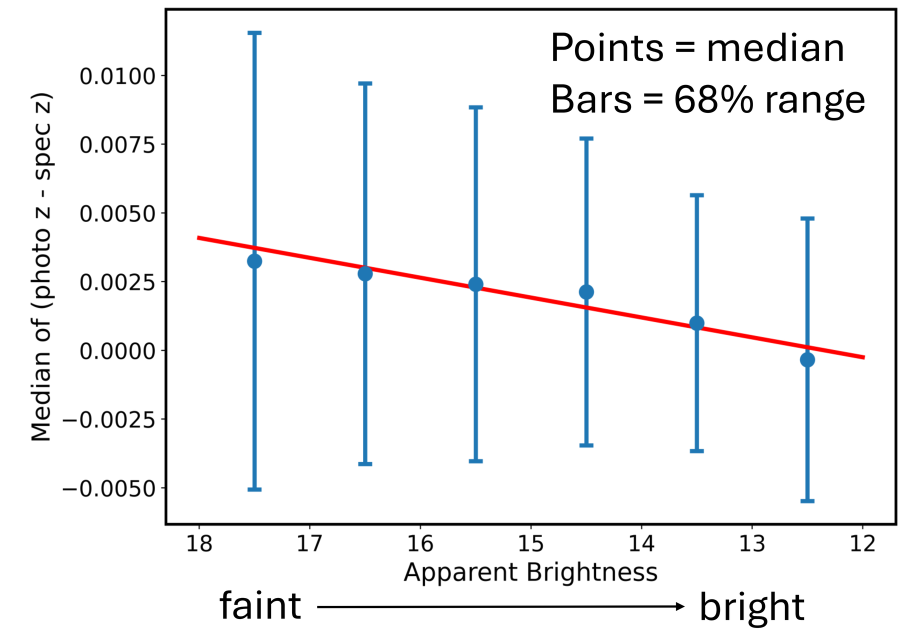
Data

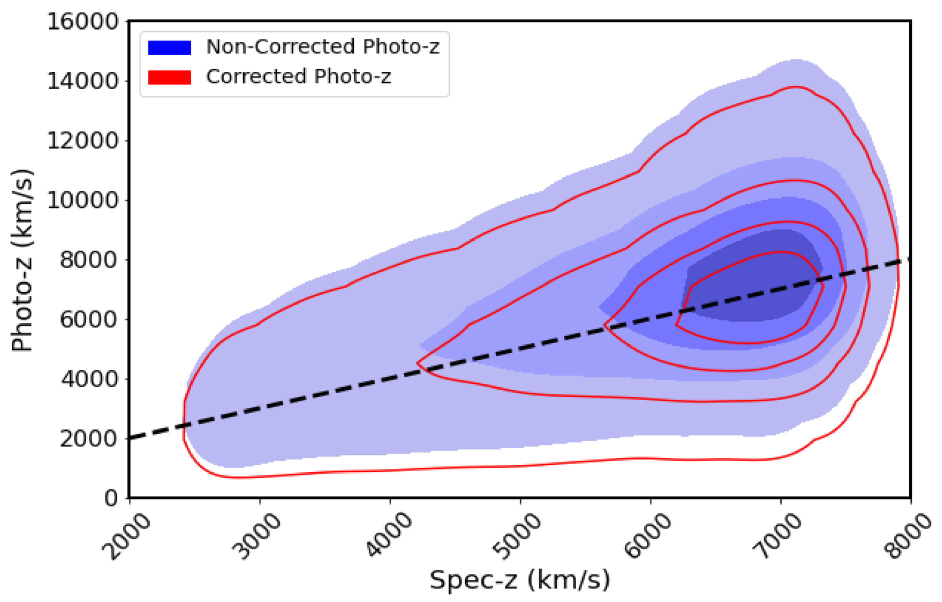
- **RESOLVE[1] and ECO[2]:** Source of spectroscopic redshifts and existing galaxy group data.
- **DESI Legacy Survey (DECaLS and BASS)[3]:** Source of photometric redshifts and reported errors. Covers a larger volume than RESOLVE & ECO, giving a full set of photo-zs



Methods

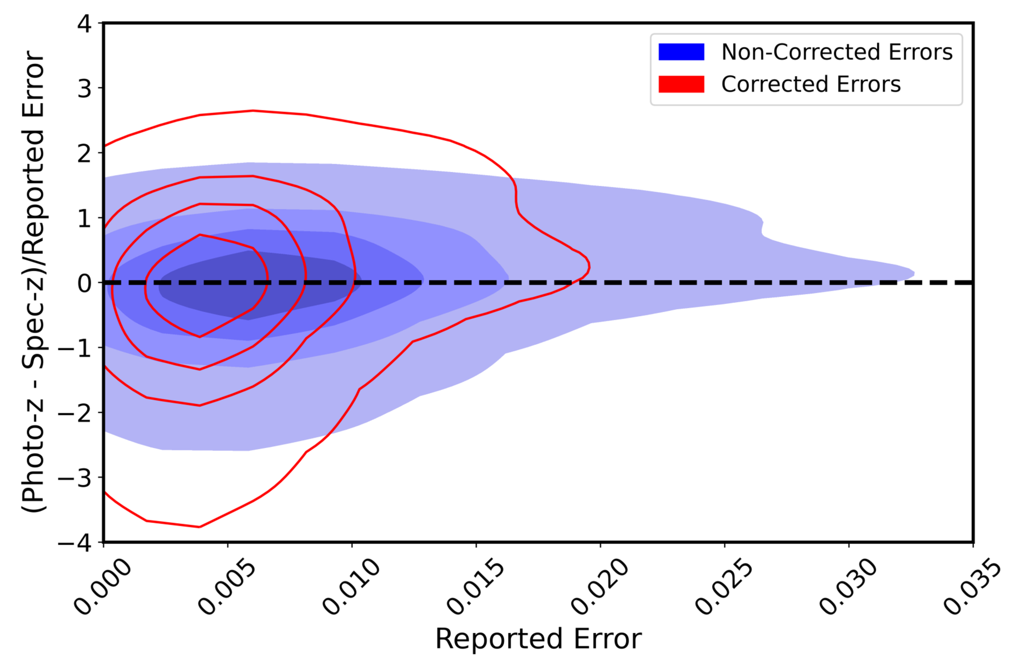
Step 1: Correcting the offset in the photometric redshift values





- As brightness increases, photometric redshifts tend to be a better match to the highly accurate spectroscopic redshifts
- The bars on the median values represent a range/diversity, or spread, of the data
- The photo-zs match the spec-zs better after correction (red) than before correction (blue)

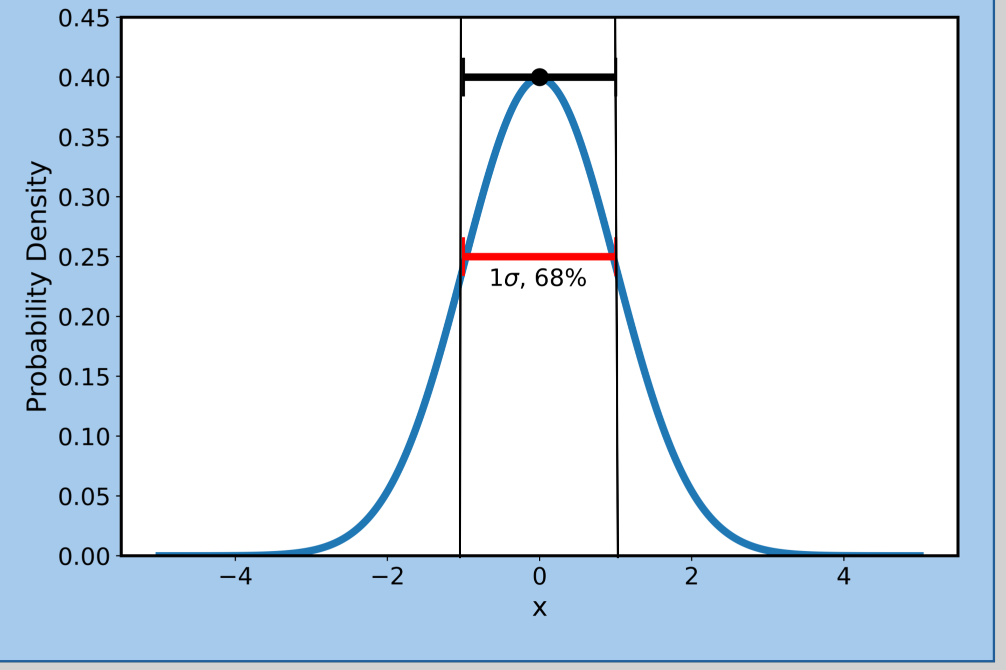
Step 2: Scaling Overestimated Errors of Photometric Redshifts



- (photo-z – spec-z) is a proxy of error as we take spec-z to be the true value of a redshift
- The reported tabulated errors from DESI were overestimated compared to the measure (photo-z – spec-z)
- Our corrections decreased the typical error bar of each photo-z measurement, shown by the correction (red) shifting left

An aside on errors

- The error bars on a data point correspond to the spread of likely measurements in repeated experiments
- The probability distribution of likely measurements is called a Gaussian
- Standard deviation σ encompasses 68% of likely measurements.



References

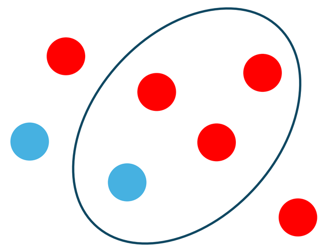
[1]Kannappan + 2008 AIP Conf. Proc 1035 (1)
[2]Moffett+2015 ApJ 812 (2)
[3]Dey+2019 AJ 157 (5)
[4]Blyth + 2016 *Proceedings of Science*

Acknowledgements

I would like to thank Dr. Sheila Kannappan and Zack Hutchens for their support in completing this project. I would also like to thank Derrick Carr for useful discussions. This project was funded under NSF grant AST-2007351. Additional support was provided by the CAP Bootcamp.

Testing Results

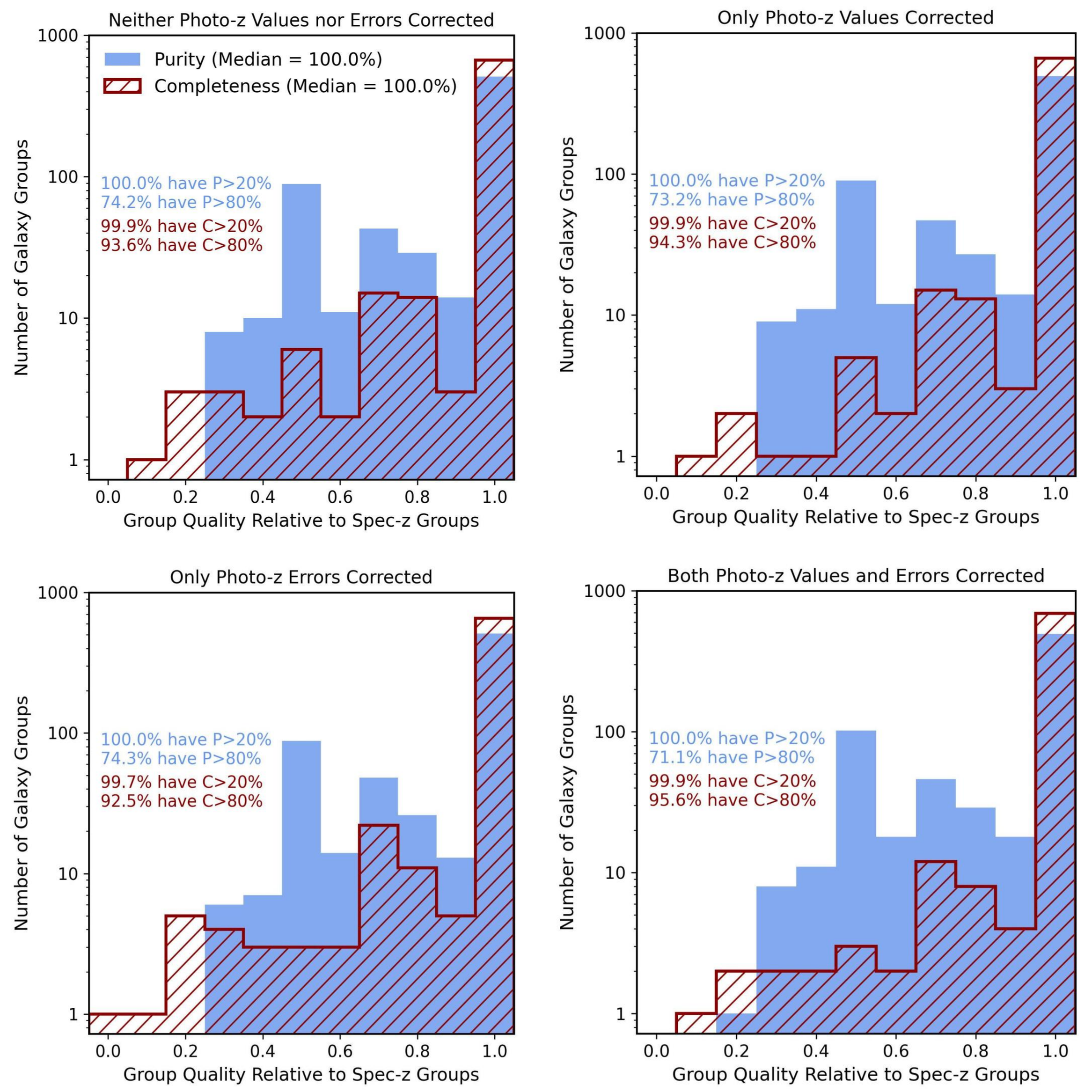
To understand how quality is measured for group finding, we analyze purity and completeness:



Red group is the high quality group
Oval is group found using photometric redshifts

- **Purity** compromised by including blue contaminant
- **Completeness** compromised by missing 2 reds

Redoing group finding with our corrections:



- Using groups found by ECO and RESOLVE spec-zs as high quality groups for comparison
- Comparisons of the top left and bottom right plot show the improvements of completeness though a slight decrease in purity

Conclusion

Key Points

- Photometric redshift and error corrections can improve data quality for group finding
- Correcting photo-z errors results in increased purity while changing the values results in increased completeness
- Follow-up work: probe how purity and completeness depend on group properties (e.g. number of galaxies)

Future Applications:

- LADUMA[4] survey simulation for distant-universe group finding
- Analysis of group environment effects on galaxy evolution in the cosmic past