PUBLICATIONS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, 111:1188–1189, 1999 September
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Conference Highlights

Photometric Redshifts and High-Redshift Galaxies[1]

The Workshop "Photometric Redshifts and High-Redshift Galaxies" was held at the Observatories of the Carnegie Institution of Washington, in Pasadena, California, on 1999 April 28–30. The 70 participants were greeted with atypically cool, overcast weather, but this did not cloud or dampen the discussions. The application of photometric redshift techniques and studies of high-redshift galaxies are evolving so rapidly that the time seemed right to gather together the active workers in these fields and determine what is the current state of the art. Ray Weymann posed several questions that were the motivating factors in convening the workshop. Although we did not expect all of them to be answered in this forum, they provide a framework in which to examine current work and focus our future efforts.

1. MOTIVATING QUESTIONS

1. What are the best techniques to use for determining only photometric redshifts: Model-free empirical fits? Empirical templates? Bruzual-Charlot model templates? What is the optimum number of templates? What weight should each flux band receive?

2. Do we have an adequate set of spectroscopic templates to use in calibrating the above photometric methods?

3. What are the best techniques to use if, in addition to the redshift, we want to determine internal extinction and the stellar population mix? For resolved galaxies, we can use pixel-by-pixel examination. For unresolved galaxies, can we determine a global star formation rate? Is it meaningful to assign global extinction and population types to these galaxies?

4. Do we have an adequate set of models/templates which can be used to calibrate photometric estimates of redshift *and* reddening *and* population type?

5. Is there a continuum of properties between optically and near-infrared selected galaxies and those detected at submillimeter wavelengths, or are the properties roughly bimodal?

6. Some techniques for finding very high redshift galaxies rely only on colors while others rely on Lyα emission. What is the true distribution of the rest equivalent width of Lyα as a function of redshift and luminosity? What determines this distribution? Dust? Velocity fields?

7. What is the luminosity function and morphological distribution of galaxies above redshift 5?

8. *How are the answers to all of the above questions to be integrated into our understanding of the formation and evolution of galaxies?*

We began the workshop with an overview by David Koo, placing the current work in the proper historical context. Using multiband photometry to estimate redshifts was used in the early 1960s (e.g., W. A. Baum, in Proc. IAU Symp. 15, ed. G. C. McVittie [New York: Macmillan, 1962], 390) although labeling the technique "photometric redshifts" did not happen until the early 1980s (e.g., D. Koo 1981, Ph.D. thesis, Univ. California, Berkeley; J. J. Puschell, F. N. Owen, & R. A. Laing, ApJ, 257, L57 [1982]; E. D. Loh & E. H. Spillar, ApJ, 303, 154 [1986]). The field lay relatively dormant until the mid-1990s when it again blossomed. This renaissance was driven by the availability of deep, multiband, photometric surveys, in particular, the Hubble Deep Field (R. E. Williams et al., AJ, 112, 1335 [1996]). Although the implementation of photometric redshifts is clearly not a mature field, it has passed the stage of having to prove that it works and has moved on to more detailed discussions of which techniques work best, how do they work, and what other information can be gained besides the redshift. The complementary topic, finding and studying high-redshift galaxies, has also exploded in the last 3 years with hundreds of galaxies now known above a redshift of $z = 3$ (e.g., C. C. Steidel et al., ApJ, in press [1999]; J. D. Lowenthal et al., ApJ, 481, 673 [1997]), a handful above a redshift of $z = 5$ (e.g., A. Dey et al., ApJ, 498, L93 [1998]; R. J. Weymann et al., ApJ, 505, L95 [1998]; H. Spinrad et al., AJ, 116, 2617 [1998]; E. M. Hu et al., ApJ, 502, L99 [1998]), and our first possible glimpses above a redshift of $z = 6$ (H.-W. Chen, K. M. Lanzetta, & S. Pascarelle, Nature, 398, 586 [1999]; Hu et al. [these Proceedings], Lanzetta et al. [these Proceedings]).

Several groups discussed their techniques and presented photometric redshift results. The methodologies range from using strictly templates to empirical fits only and combinations of both. The bottom line is they all appear to work remarkably well. Every photometric versus spectro-

[1] Workshop was held in Pasadena, California, in 1999 April. Proceedings will be edited by R. J. Weymann, L. J. Storrie-Lombardi, M. Sawicki, and R. Brunner and published in the ASP Conference Series.

scopic redshift plot displayed showed an rms error of $\sigma \leq 0.1$. Nearly everyone agrees although that we need much larger and more complete spectroscopic redshift samples to use in calibrating the photometric redshifts. Particularly at redshifts ≈ 2 and higher we only have data for objects where it is easy to obtain a spectrum and do not yet clearly understand all of the selection effects involved. We know we can get photometric redshifts, but we are just beginning to get a handle on quantifying all of the sources of error and uncertainty. A highlight of the discussion of techniques was a real-time demonstration by Tamas Budavari of the iterative process they use for creating the best spectral templates and watching the scatter in the photometric versus spectroscopic redshift diagram decrease.

The majority of the talks in the workshop covered results using photometric redshifts or discussions of high-redshift galaxies. The high-redshift galaxy topics ranged from broadband versus narrowband searches, blank field spectroscopy, and combinations of these to find galaxies at high redshift. We also discussed the role of dust and how it influences color selection, etc., and of course the new results coming from submillimeter and far-infrared wavelengths. The workshop closed with a session discussing theoretical perspectives on what we might expect to find at high redshift. Alex Szalay provided us with a superb summary. He characterized the current state of affairs with respect to photometric redshifts: "We are at an inflection point. We are at the beginning of the hard work." As a preview to the Proceedings, we close with a listing of the overview talks that opened each session:

1. David Koo, "Photometric Redshifts—A Perspective from an Old-Timer[!] on Its Past, Present, and Potential"
2. Harry Ferguson, "Color Selection and Selection Effects in the Hubble Deep Fields"
3. Chuck Steidel, "High Redshift Galaxies—What Good Are They?"
4. Esther Hu, "Searches for Very High Redshift Galaxies"
5. Andrew Blain, "Future Millimeter, Submillimeter and Far-Infrared Surveys and Their Successful Follow-up"
6. David Weinberg, "Theoretical Modeling of the High-Redshift Galaxy Population"

This brief introduction only gives a flavor of what should be a very interesting Proceedings.

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