New Cosmological Data and the Values of the Fundamental Parameters
IAU Symposium, Vol. 201, 2005
Anthony Lasenby and Althea Wilkinson, eds.

Constraining Galaxy Formation Epoch

Sukyoung Yi

Caltech, USA and CSA, Yonsei University, Korea

T. Brown, S. Heap, I. Hubeny, W. Landsman, T. Lanz and A. Sweigart

NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA

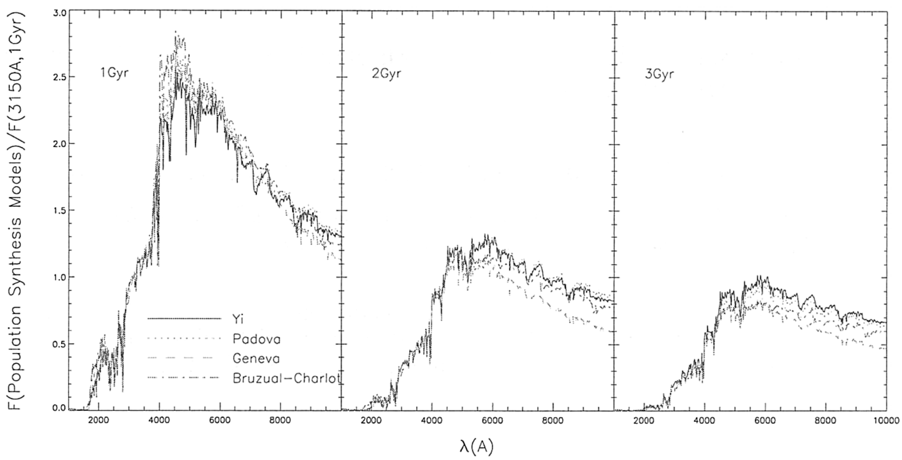
Abstract. Pinning down the ages of high redshift galaxies is the most direct way of constraining the galaxy formation epoch. There has been a debate on the age of LBDS 53W091, a red galaxy at z=1.5. The discrepancy in the age estimates of various groups is due to the difference in the population synthesis model. However, there is generally a good agreement among popular models. Polishing the models and assessing their internal uncertainties are crucial in the analysis of high redshift galaxies.

The recent spectral analysis of LBDS 53W091 by Spinrad et al. (1997) has suggested that this red galaxy at $z = 1.552$ is at least 3.5 Gyr old. This imposes an important constraint on cosmology, suggesting that it formed at $z > 6.5$, assuming recent estimates of cosmological parameters. While their analysis was heavily focused on the use of some UV spectral breaks as age indicators, we have performed χ^2 tests to the continuum of this galaxy using its UV spectrum and photometric data (R, J, H, & K: 2000 – 9000 Å in rest-frame). We have used the Yi models (Yi et al. 1997) that are based on the Yale tracks. We find it extremely difficult to reproduce such large age estimates, under the assumption of the most probable input parameters. Using the same configuration as in Spinrad et al. (solar abundance models), our analysis suggests an age of approximately 1.4 – 1.8 Gyr, which is in good agreement with those of Bruzual & Magris (1997) and of Heap et al. (1998). Yi et al. (2000) showed that it is important to adopt a realistic metallicity distribution in order to achieve accurate age estimates of galaxies. When we use Yi's chemically composite models, the data of LBDS 53W091 indicate 5 – 10% larger ages.

The large difference in age estimate between Spinrad et al. and this study is mainly due to the significant difference in the model integrated spectrum between the 1997 version Jimenez models (used by Spinrad et al.) and our models. Our Figure shows the comparison among various models (the Yi models, the Padova models, the Geneva models, the Bruzual-Charlot models). All models are normalized by their 1Gyr model at 3150Å, so the relative flux evolution is real. They are all in good agreement and would give the statistically same age estimates on the continuum of LBDS53W091.

There is no doubt that precise age estimates of high-z galaxies would be very useful for constraining cosmology. In order to fully take advantage of the power of this technique, however, we first need to understand the details of the population synthesis, which are currently creating a substantial disagreement

https://doi.org/10.1017/S0074180900217026 Published online by Cambridge University Press



in age estimate. We propose to carry out a comprehensive investigation on the various population synthesis models through a series of standard tests on the objects whose ages have been independently determined. Such objects may include the sun, M32, and Galactic globular clusters. Our models currently pass these tests reasonably (Yi et al. 2000).

Our age estimates indicate that LBDS 53W091 formed approximately at $z = 2 - 3$. However, our smaller age estimate for this *one* galaxy does not contradict work that suggests galaxies generally formed at high redshifts, regardless of the rarity of massive ellipticals at $z \approx 1.5$. Furthermore, we are just beginning to expand our observations of galaxies to high redshift, and so the existence of a few old galaxies at high redshifts does yet prove any galaxy formation scenario, although it can potentially constrain cosmological parameters (in the sense that the ages of a few objects can provide lower limits on the age of the Universe at that redshift). Finding no old galaxies at high redshift would support a low z_f for the general population. Building a larger database of observations is therefore crucial to achieve a unique and statistically significant solution.

Acknowledgments. This work was supported by the Creative Research Initiative Program of the Korean Ministry of Science & Technology grant (S.Y.).

References

Bruzual, G. A. & Magris, G. C. 1997, in The Ultraviolet Universe at Low and High Redshift, AIP vol. 408 (AIP: Woodbury), 291

Heap, S. R. et al. 1998, ApJ, 492, L131

Spinrad, H., Dey, A., Stern, D., Dunlop, J., Peacock, J., Jimenez, R. & Windhorst, R. 1997, ApJ, 484, 581

Yi, S., Demarque, P. & Oemler, A. Jr. 1997, ApJ, 486, 201

Yi, S., Brown, T. M., Heap, S., Hubeny, I., Landsman, W., Lanz, T & Sweigart, A. 2000, ApJ, 533,670