Photometric and Spectroscopic Analysis of Cool White Dwarfs with Trigonometric Parallax Measurements

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abstract
A detailed photometric and spectroscopic analysis of cool (12,000 K) white dwarf stars is presented. The sample has been drawn from the Yale Parallax Catalog and from a proper-motion survey in the southern hemisphere. Optical $BVRI$ and infrared $JHK$ photometry, as well as spectroscopy at $\lambda$, have been secured for a sample of 152 white dwarfs. The discovery of seven new DA white dwarfs, two new DQ white dwarfs, one new magnetic white dwarf, and three weak magnetic white dwarf candidates, is reported. Our sample also identifies 19 known or suspected double degenerates.

The photometric energy distributions, the line profiles, and the trigonometric parallax measurements are combined and compared against the predictions of model atmosphere calculations to determine the effective temperature and the radius of each object in the sample, and also to constrain the atmospheric composition. New evolutionary sequences with carbon/oxygen cores with thin and thick hydrogen layers are used to derive stellar masses and ages. The results are used to improve our understanding of the chemical evolution of cool white dwarfs.

We confirm the existence of a range in effective temperature between $\sim$5000 and 6000 K where almost all white dwarfs have hydrogen-rich atmospheres. Our sample shows little evidence for mixed H/He white dwarfs, with the exception of two helium-rich DA stars, and four (possibly five) C$_2$H white dwarfs which have been interpreted as having mixed H/He/C atmospheres. The observed sequence of DQ stars is found to terminate abruptly near 6500 K, below which they are believed to turn into C$_2$H stars. True DC stars slightly above this temperature are found to exhibit hydrogen-like energy distributions despite the lack of absorption features. The mean mass of our complete sample is 0.65 with a dispersion of $\sigma \sim 0.20$.

Attempts to interpret the chemical evolution of cool white dwarfs show the problem to be complex. Convective mixing is called upon to account for the increase of the non-DA to DA ratio below 12,000 K, as well as the reappearance of helium-rich stars below $\sim$ 5000 K. The possible presence of helium in cool DA stars, the existence of the non-DA gap, and the nature of the peculiar DC stars are also explained in terms of convective mixing, although our understanding of how this mechanism works needs to be revised in order to account for these observations. Given this chemical evolution uncertainty, it is not clear whether thick or thin hydrogen layer models should be used to determine cooling ages. The oldest object in our sample is $\sim$7.9 Gyr or $\sim$9.7 Gyr old depending on whether thin or thick hydrogen layer models are used, respectively.