A&A 500, 549 (2009)
DOI: 10.1051/0004-6361/200912205

Astronomy & Astrophysics
Special issue

COMMENTARY ON: BESSELL M. S., CASTELLI F., AND PLEZ B., 1998, A&A, 333, 231

Modeling stellar colors

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This very influential paper by Bessell et al. provided the community with synthetic broadband colors, bolometric corrections, and a stellar effective temperature scale based on the most up-to-date theoretical models existing at that time. This type of information is crucial from several points of view. On one hand, it allows one to test the stellar atmosphere models themselves by comparing these results with the observations. On the other hand, it is required for interpreting observed color-magnitude diagrams, for performing fine spectroscopic analyses, and for modeling stellar populations, among many other applications.

The possibility of providing these basic data in a purely experimental way (i.e. independent of models and, therefore, of their assumptions) was very limited. For instance, the works by Code et al. (1976) and Ridgway et al. (1980), which obtained fundamental effective temperature scales from direct angular diameter measurements for early type and cool giant stars, were based on just a handful of stars in the solar neighborhood. The possibility of establishing similar scales in other regions of the Hertzprung-Russell diagram and for low metallicity was out of reach with the existing technological capabilities. The so-called *empirical scales*, like those based on the infrared flux method (e.g. Alonso et al. 1996), covered larger regions of the H–R diagram and wider metallicities ranges than the fundamental scales, but still they were restricted in stellar characteristics.

The theoretically based work by Bessell, Castelli, and Plez encompassed and homogeneously sampled a very wide range of stellar parameter space. It was based on synthetic spectra computed with the latest improvements in the original ATLAS (Kurucz 1979) and MARCS (Gustafsson et al. 1975) models, which had been extensively used for more than 20 years. Thanks to the latest refinements, these codes, and in particular their computed fluxes, showed excellent agreement with the by then limited available observed spectrophotometry. Therefore, it was the appropriate time for computing synthetic colors from these grids of model atmospheres, so that one could explore a wider range of temperatures, gravities, and abundances than those covered by existing scales.

The paper was a collaborative effort led by M. S. Bessell, who in previous years had worked to define the passbands of the existing well-established broad-band $UBVRIJHKL$ system using synthetic photometry and observed spectrophotometry (e.g. Bessell & Brett 1988). Castelli had worked to refine the Kurucz model atmosphere ATLAS code and the opacity distribution functions (ODF), hydrogen lines, and treatment of convection for stars of K spectral-type and earlier (e.g. Castelli et al. 1997), while Plez had worked on including of molecular line opacity for cool oxygen-rich M stars in the MARCS model atmosphere code (e.g. Plez et al. 1992).

A key aspect of this work was the comparison with the empirical relations available at that time, including temperature scales, color-color diagrams, and color-bolometric corrections. Such a comparison revealed generally good agreement, which helped the community gain confidence in using these theoretically based colors and relations. The discrepancies were also relevant for identifying the possible limitations of the models (e.g. deficient list of H_2O lines, opacities due to grains and polyatomic molecules).

Another important part of the paper was the appendices where they provided additional tables and discussed assumptions underlying stellar standard photometry, flux calibrations, bolometric corrections, and reddening corrections. These are often neglected subjects that hinder the interpretation of observations and comparison with theory. They provided the zero-point flux calibrations for the standard $UBVRIJHKL$ photometric system and discussed the colors of Vega and the Sun. The discussion of the undefined bolometric magnitude scale clarified the issue and led to the IAU defining the bolometric correction of the Sun several years later.

At the time of writing this note, the Bessell, Castelli, and Plez work has been cited over 500 times in studies covering an ample variety of fields in astronomy. Its influence, however, is even greater than what this number suggests. The synthetic colors, bolometric corrections, and temperature scale given in that paper are coded in a variety of models (e.g., stellar population models) some of which are in turn intensively used nowadays in extragalactic and cosmological studies. In that way the results of the Bessell, Castelli, and Plez paper have contributed to nearly all fields of astronomy. Its nearly constant citation rate over the past decade suggests that this influence will continue for many years.

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