# THE COLORS OF G AND K GIANT STARS

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The material on which this talk is based is contained in a paper submitted to Astronomy and Astrophysics. The summary of this paper is given below.

## SUMMARY

In previous papers, we have discussed the calculation of model atmospheres for metal-deficient and solar-abundance giant stars and have presented a grid of such models. We have now carried out synthetic spectrum calculations at a resolution of 0.1 Å between 3000 and 7200 Å for most of the models of this grid. We have also computed synthetic spectra at wavelengths up to 12000 Å for some of the grid models. The calculations allow for the presence of thousands of atomic and molecular lines. Examples of these spectra are shown in this paper.

We show a comparison of observed and computed spectra for short wavelength intervals for the Sun, α Boo, γ Tau and the G8 III-IV stars $\phi^2$ Ori (HD Nos. 124897, 27371 and 37160). Low dispersion synthetic spectra are used to illustrate spectral classification criteria. We have compared observed and computed spectral scans for a number of K giants with different metal abundances.

We have convolved the synthetic spectra with the sensitivity frunctions of various photometric systems in order to obtain theoretical colors as well as bolometric corrections. The zero



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points of the colors have primarily been found by adopting certain fundamental parameters for the star $\phi^2$ Ori. Some colors of Sirius, Vega, Procyon and the solar-type star HR 483 (HD Nos. 48915, 172167, 61421 and 10307) have also been used, in combination with their corresponding models, to check the zero points. The color grid is given in an accompanying paper submitted to Astronomy and Astrophysics.

We have studied the influence of terrestrial atmospheric and interstellar extinction on some of the colors. The influence of varying the abundances of particular elements, such as nitrogen, has also been studied, as have the effects of changes in the Doppler broadening velocity and in the treatment of damping.

We have compared the grid of colors with the observed colors of a sample of giant stars with relatively well-known fundamental parameters. The overall agreement was found to be good, although certain systematic discrepancies occur, especially for the ultraviolet colors and the CN indices. These discrepancies are interpreted in terms of incomplete blocking. In the first case this is probably the consequence of not including weak spectral lines in the computations or possibly of assuming LTE, and the second is probably the result of nitrogen enrichment when CNO processed material is mixed to the surface during the subgiant phase.

We have also used the theoretical colors for analysis of the properties and possibilities of the different photometric systems. Using the locations of the models and corresponding stars in certain two-color diagrams as well as a more general approach, where the effects of observational errors are transformed to effects on the fundamental parameters deduced for the stars, we find quantitative measures of the power of various color systems. This study also leads to the disclosure of certain new properties of some systems, which should be exploited in future investigations. The computed colors will be applied to the analysis of observations of globular cluster stars in forthcoming papers.

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## DISCUSSION

*KODAIRA:* You have mentioned a certain discrepancy between your model prediction for α Boo and the observations in the near IR region. Is α Boo a special case or have you the same problem for other red giants? If this is the case, what reasons do you suspect?

*BELL:* I don't think we have any troubles in the IR but we are examining this region. Our problems occur in the UV and we have examined various possible causes.

*KODAIRA:* How large is the atmospheric extent in your plane-parallel atmosphere with the lowest surface gravity log g = 0.75?

*BELL:* The temperature errors which are caused by our neglect of sphericity effects are thought to be smaller than 100K. Details are given in Gustafsson, et al. (Astr. Astrophys. **42**, 407).

*BUSCOMBE:* Have you tested your models with very luminous G supergiants? Can you discern the effects of the stellar wind which Cox believes should deplete atmospheric hydrogen?

*BELL:* We have not yet computed models for G supergiants, although we plan to do so. We will have to compute opacity distribution functions for a higher Doppler broadening velocity in order to do this. I would think that the effects suggested by Cox, at least for the most extreme depletion of hydrogen, would cause the spectra to appear super-metal-rich. The color-temperature relation would be substantially altered. I'd be surprised if this is consistent with the observations.

*COX:* The calculation of high luminosity models with high helium is exactly what is needed to check whether a large helium enrichment really exists. We must remember that helium is neutral and there still is plenty of hydrogen. Do you plan to do such models?

*BELL:* Possibly.

*PEL:* In our comparison of the Walraven photometry with the computed fluxes of Kurucz we find discrepanices in the UV similar to the ones you mentioned, but surprisingly enough the agreement improves when going from main-sequence stars to supergiants. The latter fit quite well even at 3250 Å. Do you find this also in your computations?

*BELL:* I don't think so. However our low gravity models are cooler than the Kurucz models which you refer to.

*PEL:* But at the lower temperatures of your models you do not see that the excess UV flux decreases towards lower gravity?

*BELL:* I don't think so. However, the UV flux is quite sensitive to the adopted Doppler broadening velocity. Lines of OH, as well as atomic lines, might affect the flux at the wavelengths which you mention.

*STENCEL:* Could you briefly compare your models with the grid of cool model atmospheres published by H.R. Johnson?

*BELL:* Johnson has shown that the opacity sampling method does yield a model similar to the corresponding model in our grid. I have not done detailed comparison with his models. The model used for $\alpha$ Tau by Lambert and Luck, which I think was computed by Dragon of Indiana, does have lower pressures near the surface than does our corresponding model. This does have some effect on the emergent spectrum, for example in the TiO bands.