Infrared Mg I Lines in Cool Giant and Supergiant Stars

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Abstract. We have performed multi-level Non-LTE calculations of the formation of the Mg I 7i–6h line at 12.32 μm in atmospheric models of the K giant α Boo (Arcturus) and the M supergiant α Ori (Betelgeuse). We find the calculated line profile to be in emission in both cases, whereas observations show an emission line in Arcturus and an absorption line in Betelgeuse.

1. Introduction

The 12 μm lines that occur between high-excitation Mg I Rydberg levels are potentially important diagnostics of conditions in the atmospheres of cool stars. The formation mechanism of these lines is well understood in the case of the Sun (cf. Carlsson et al. 1992) where model calculations accurately agree with observations. The emission is driven by photon losses from strong ultraviolet lines at the bottom of the Mg I term diagram leading to a collisional recombination flow from the Mg II majority stage through the closely spaced Rydberg levels. It is further enhanced by ultraviolet overionization occurring from lower-lying Mg I levels.

2. Observations, modeling and results

Observations (Noyes et al. 1995) were made with a cooled Fabry-Perot Grating Spectrometer at the NASA Infrared Telescope Facility of the strong 7i–6h transition in the spectra of the K giant α Boo, two cool M giants (R Hya, and R Leo), and three M-type supergiants (α Sco, α Ori, and α Her). Of the three giants α Boo shows an emission feature, with inferred Gaussian width about 5 km/s (comparable to the Sun); but the two M-giants and the M-type supergiants all show absorption profiles.

Our radiative transfer calculations were done with Carlsson’s (1986) plane-parallel multi-level Non-LTE code MULTI, and, for calculations in the extended atmosphere of α Orionis, the spherical symmetric version of MULTI developed by Harper (1994). We employed the 66-level, 315-line comprehensive model atom compiled by Carlsson et al. (1992) which gives excellent agreement with the solar 12 μm line profiles.

Calculated disk-integrated flux profiles for Arcturus and Betelgeuse are plotted in Fig. 1. The Arcturus model (Ayres & Linsky 1975) predicts a calculated
Figure 1. Panels show the calculated profile of the 12.32 μm line in Arcturus (left, solid line) and Betelgeuse (right) together with the observational data (dots, binned into 3 km/s bins), and the convolution of the calculated profile with the 7 km/s FWHM Lorentzian instrumental profile.

central emission of 27% above the continuum, higher than the value (18%) obtained after deconvolving the data by the 7 km/s FWHM instrumental profile. However, the equivalent line width of 0.62 km/s, is only 40% of that obtained from the best fit to the data. Either the calculated profile has overly deep absorption troughs, or we underestimated the continuum level used for the fit. (Note that the troughs are not visible in the data, nor in the instrumentally broadened calculated profile.)

The Betelgeuse model (Hartmann & Avrett 1984) produces deeper absorption troughs than Arcturus but still predicts a central emission core resulting in emission in the convolved profile, while a pure absorption profile is observed. Apparently, cool M-type stars are not well represented by the α Ori model. Thus the infrared Mg I lines are a potentially powerful diagnostic of the atmospheric structure of M-type giants and supergiants.

References

Hartmann, L., Avrett, E. H. 1984, 284, 238
Discussion Session on Infrared Spectroscopy of Cool Stars

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A Discussion Session on Infrared Spectroscopy was held in connection with the Cool Star Workshop. Panel members included: T.R. Ayres, S.C. Balachandran, J. Carr (Chair), M.S. Giampapa, T.P. Greene, H.P. Jones, E. Oliva and D.D. Sasselov. Owing to the lively nature of the informal discussions, no written report is available for inclusion in these Proceedings.
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