Chromospheres in Metal-Poor Stars Revealed from the He I 10830 Å Line

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The atmospheric temperature of a star like the Sun gradually decreases with height, from $T \sim 6000$ K in the photosphere down to $T \sim 4000-5000$ K at the temperature minimum. However, as we go further upward, the temperature begins to rise again, reaching up to $T \sim 10^4$ K at a thin layer called "chromosphere". While such a temperature rise (chromospheric heating) must be caused by the transformation of some type of extra energy into thermal energy, it is generally believed that the dissipation of the magnetic energy in the magnetically active region may be responsible for this. One evidence supporting this view is the fact that the chromospheric activity tends to be lower for older stars (Skumanich law), which may be reasonably interpreted as the tendency of slower rotation for more aged stars (having suffered deceleration for a longer time), along with the above-mentioned scenario that magnetic fields created by rotation-induced dynamo are the cause of the chromospheric heating.

However, this activity–age–rotation relation has been confirmed only for comparatively young population I disk stars (with ages on the order of $\sim 10^{8-9}$ years), and little is known about the existence of chromospheres in very old metal-poor halo stars (age of $\sim 10^{10}$ years). Since rotation is likely to have almost come to rest in such old stars because of having suffered the long-lasting deceleration mechanism (magnetic braking), we may expect that chromospheres do not exist in these stars.

In order to confirm this expectation, we investigated whether the high-excitation He I line at 10830 Å (chromospheric indicator because its visibility means the existence of a high-temperature layer of $T \sim 10^4$ K) is observed in 33 disk/halo stars of various metallicities (from [Fe/H] $\sim$ +0.3 down to [Fe/H] ~ -3.7) based on the high-dispersion spectra ($R \sim 20000$) obtained on 2009 July by using IRCS+AO188 of the Subaru telescope.

We then found, rather unexpectedly, that this He I 10830 Å line is seen in absorption in almost all stars, the strength of which is nearly constant irrespective of the metallicity at [Fe/H] < -0.5 (cf. Figure 1). Actually, even BD+44 493 (the most metal-poor star among our sample, which must be very old with an extremely low metallicity of [Fe/H] $= -3.7$) clearly shows an absorption feature of this line (Figure 2). This is an evidence that chromospheric activity at a basal level persists even for very old stars, despite that their rotations are considered to be slowed down and incapable of sustaining a dynamo, suggesting that some kind of chromospheric heating mechanism independent of rotation/magnetism (e.g., acoustic heating) may take place. Accordingly, we suspect that two types of chromospheres exist:

——(1) The rotation-dependent chromospheric activity (seen in less-aged population I stars still rotating appreciably), for which organized magnetic fields generated by the dynamo mechanism is responsible.

——(2) The "basal" chromosphere of the minimum level (ubiquitously existing but detectable only in old population II stars of very slow rotation), sustained by nonmagnetic/ non-rotation mechanism (such as the dissipation of acoustic waves).

See [1] for more details of this study.

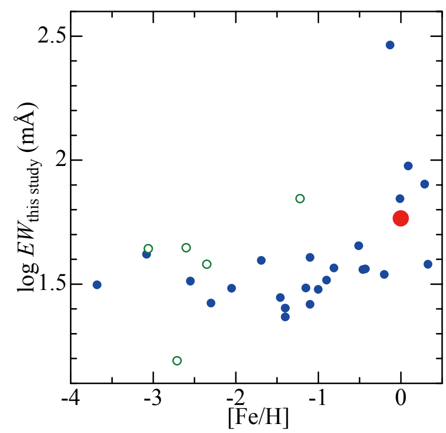

Figure 1: Logarithmic equivalent width (log *EW*) measured for the He I 10830 line, plotted against the metallicity ([Fe/H]). The results for 24 dwarfs (log $g > 3$) and 9 giants (log $g < 3$) are discriminated by filled (blue) and open (green) symbols, respectively. The Sun is indicated by the large (red) filled circle.

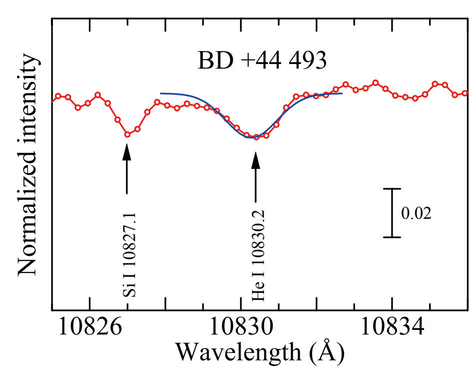

Figure 2: The spectrum of BD+44 493 ([Fe/H] = −3.7) in the neighbourhood of the He I 10830 line (red symbols). The blue solid line represents the Gaussian-fit function used for evaluation of the equivalent width.

Reference

[1] Takeda, Y., Takada-Hidai, M.: 2011, *PASJ*, **63**, S547.