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THE NON-LTE FORMATION OF LI I LINES FROM COOL STARS

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ABSTRACT We summarize an extensive study of departures from LTE in the formation of Li I lines from cool stars. Their neglect produces appreciable errors in lithium abundance determinations, which vary in sign as well as size between stars of different effective temperature, gravity or metallicity. As an illustration we display corrections to a scatter plot published by Rebolo, Molaro, and Beckman (1988).

INTRODUCTION

Lithium is important far in excess of its lightness, fragility and scarcity. There are many ongoing debates in which differences between observed stellar lithium abundances are employed to gauge scenarios for the evolution of young stars, main-sequence stars, old stars, the Galaxy, and the universe. Lithium abundance determination lies at the root of all such debates (cf. proceedings edited by D'Antona 1991). We calibrate one of its standard assumptions, LTE line formation.

ANALYSIS

We have performed a detailed non-LTE analysis of Li I line formation across a cool-star grid of radiative-equilibrium model atmospheres with variation in effective temperature (4500–7500K), gravity (log g=0–4.5), metallicity ([Fe/H]=-3–0) and lithium abundance (0.6–4.2), using an elaborate 21-level, 70-line lithium model atom. Version 2.0 of the program MULTI by Carlsson (1986) was employed to identify and analyze the non-LTE mechanisms that control stellar Li I

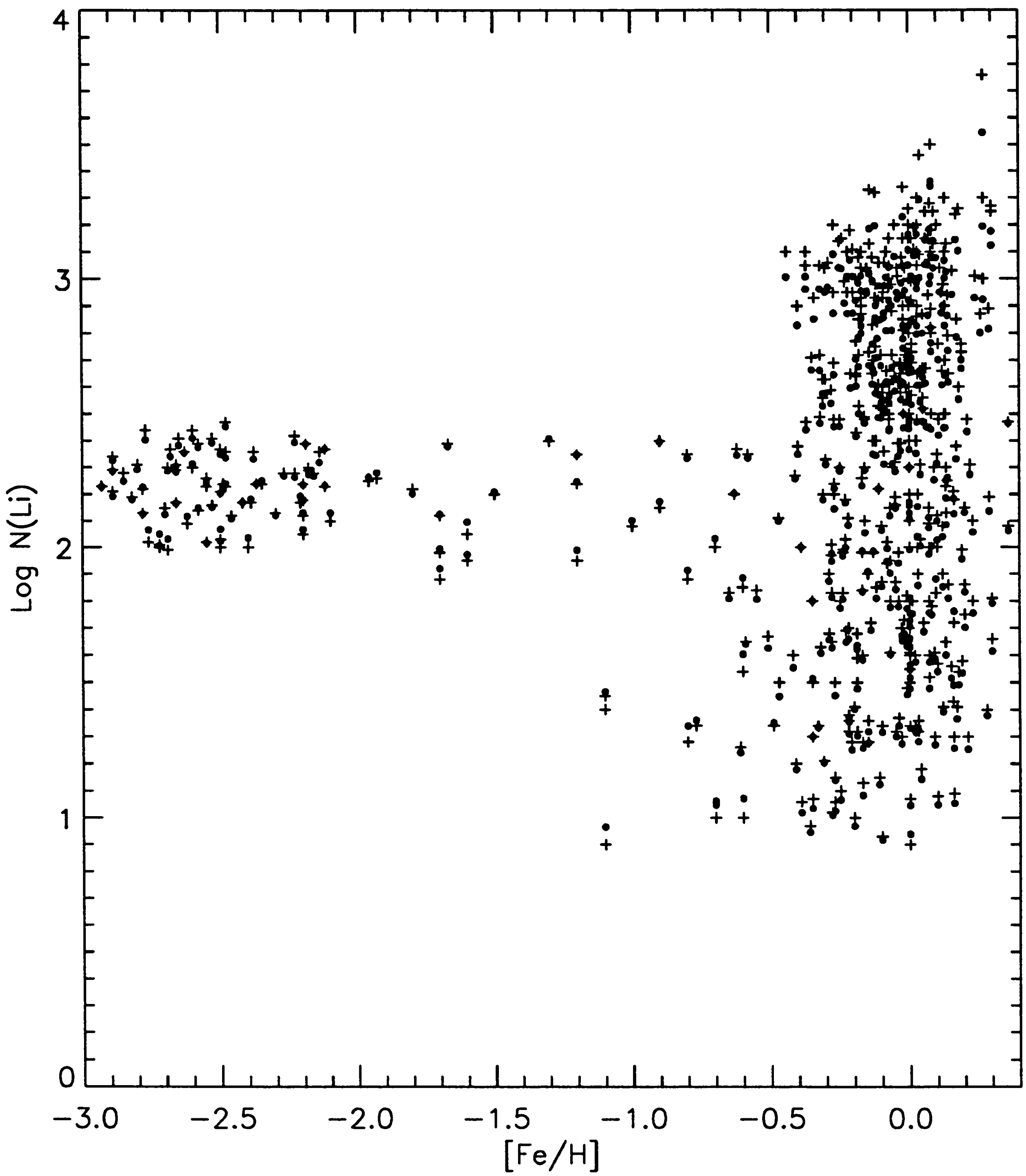

FIGURE I Lithium abundances $\log N(\text{Li})$ on the $\log N(\text{H}) = 12$ scale, determined from the Li I 670.8 nm line against metallicity [Fe/H], after Fig. 3 of Rebolo, Molaro, and Beckman (1988) and compiled from the same sources. Filled circles are non-LTE estimates, plus symbols are LTE estimates for the same stars. The vertical separation between adjacent symbols represents the non-LTE correction.

lines in great depth. Details will be published elsewhere (Carlsson et al. 1994).

There are various mechanisms which compete in their effects on emergent Li I line strengths. The most important ones are resonance-line photon losses, continuum absorption, ultraviolet overionization, and replenishment recombination. Their neglect produces errors in lithium abundance determinations that vary in sign as well as size, both across the stellar grid and between the two easiest observable Li I lines (λ 670.8 nm and λ 610.4 nm).

The errors are appreciable for all cooler stars and largest for cool lithium-rich metal-poor giants for which LTE theory overestimates the lithium abundance by up to 1.0 dex. The errors reverse sign between lithium-rich stars and lithium-poor stars for the 670.8 nm resonance line, but not for the 610.4 nm subordinate line. Polynomial fits to the derived non-LTE corrections are given in Carlsson et al. (1994).

APPLICATION

We illustrate the effect of the resulting non-LTE corrections in Fig. I. It shows that non-LTE corrections are not doing away with the patterns which make diagrams such as these well-studied, in particular the small spread for metal-poor stars at left and the large spread for metal-rich stars at right (cf. Spite 1990, 1991). Nevertheless, the LTE-to-non-LTE shifts are large enough that they must be taken into account. This is the case in particular when the slope of relationships such as (N(Li) – [Fe/H]) are taken as evidence to prove or disprove theoretical scenarios. The dependencies that the corrections have on effective temperature, metallicity and surface gravity affect such slopes in systematic fashion.

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