CrH AND FeH BANDS IN ATMOSPHERES OF THE ULTRACOOL OBJECTS

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Absorption CrH and FeH bands are of importance for study of atmospheres of ultracool dwarfs ($T_{\rm eff} < 2200~K$). Results from calculations of synthetic spectra of these objects using the new theoretical CrH and FeH opacities obtained by Burrows *et al.* [2] and Dulick *et al.* [3], respectively, are discussed. Comparison of the CrH and FeH spectra computed with the JOLA approximation and Burrows data is carried out. Dependencies of SEDs of ulracool dwarfs on temperature, gravity, dust opacity are discussed. We compare our synthetic SEDs with an observed spectrum of Kelu-1 (L2).

INTRODUCTION

In this paper we deal with the opacities provided by hydrides CrH and FeH in atmospheres of ultracool dwarfs. Due to low temperatures and high pressures in the atmospheres, Ti and V atoms are bonded into grains. The CrH and FeH molecular bands play more important roles in spectra of ultracool dwarfs, they are the main sources of the opacity in atmospheres of L-dwarfs near $\lambda = 1$ mkm. In particular, the 0–0 and 1–0 bands of the CrH $A^6\Sigma^+ - X^6\Sigma^+$ transition are used as primary markers for a new L-dwarf spectral class. First numerical studies of the CrH $A^6\Sigma^+ - X^6\Sigma^+$ transition were based on the raw CrH band data, but they allowed to estimate such for this transition important parameters as the oscillator strengths [4]. For the FeH molecules oscillator strengths were to be estimated too. Detailed studies of the CrH and FeH bands were impossible without an precise line list. Recently, ab initio calculations of the CrH and FeH line positions and strengths were made by Burrows *et al.* [2] and by Dulick *et al.* [3], respectively. We use them by analysis of molecular bands of these species in spectra of ultracool dwarfs.

PROCEDURE

Considering the chemical equilibrium of more than 100 species in the LTE, we compute the theoretical spectra using a version of the WITA program developed by Pavlenko [5]. We use the DUSTY and COND model atmospheres calculated by Allard [1] for two limited cases of the dust formation: an inefficient gravitational settling (dust depletes refractory elements and affects the thermal structure of the atmosphere) and an efficient settling (dust affect only the depletion of the gas). To compare our SEDs with observations we include the opacity of a dust cloud with a certain thickness which is located at a given depth in the atmosphere. Then, we assume that extended profiles of the K I and Na I resonance lines can be described by the Voight profile.

RESULTS

- Results of calculations for CrH and FeH molecules are presented in Fig. 1, which shows the SEDs computed taking into account the only molecular source of the opacity – CrH, FeH or TiO molecules in the DUSTY model 18/5.0/0.0. For comparison, a TiO spectrum is also presented here, since TiO molecules are one of the main sources of the opacity in atmospheres of M-dwarfs.

- Dependence of the density ratio of CrH and FeH molecules on the effective temperature and surface gravity of a model atmosphere is studied. In Fig. 2 the density ratio of CrH and FeH molecules versus the gas pressure is presented for a set of model atmospheres. At the left-hand panel one can see the dependence of n[CrH]/n[FeH] on the temperature, on the right-hand panel – on the surface gravity of the atmosphere. We show here differences between results obtained for the COND and DUSTY models.

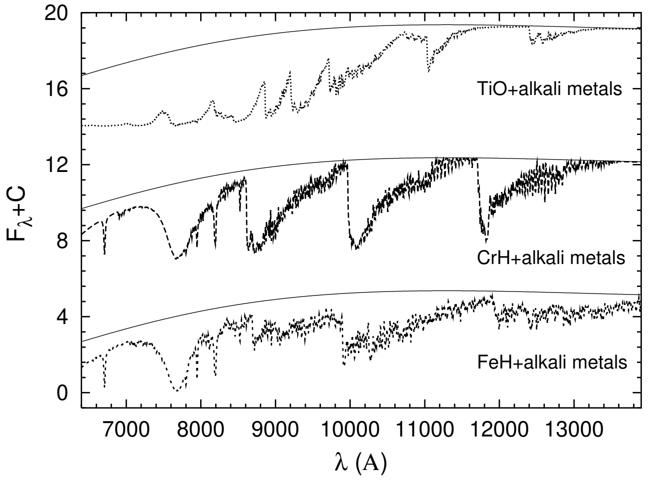

Figure 1. Synthetic spectra calculated by taking into account the TiO, CrH or FeH opacity using the DUSTY model 18/5.0/0.0. The thin solid curve shows the continuum

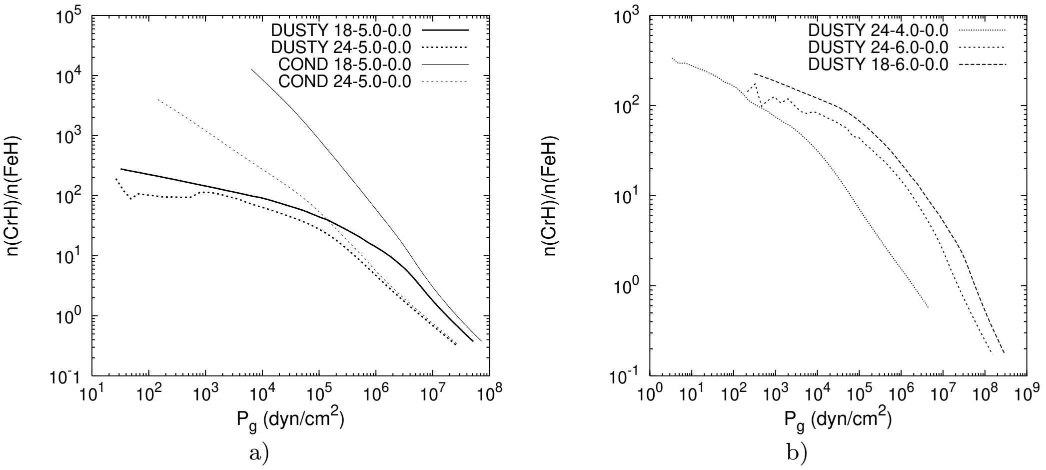

Figure 2. Dependence of the concentration ratio $n[\mathrm{CrH}]/n[\mathrm{FeH}]$ on the temperature (a) and gravity (b)

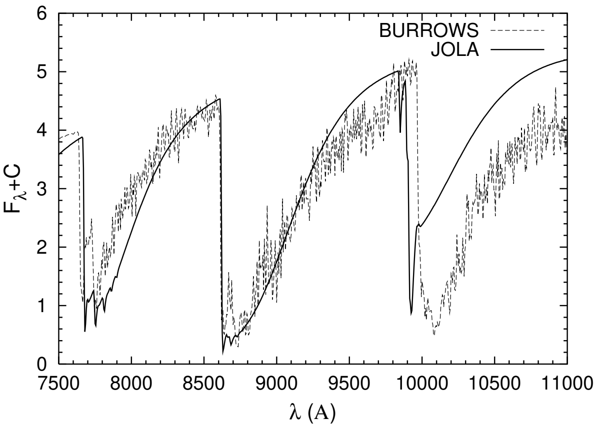

Figure 3. Comparison of a synthetic spectrum obtained with the use of the DUSTY model 18/5.0/0.0 and the JOLA approximation with the Burrows's calculations for CrH molecule

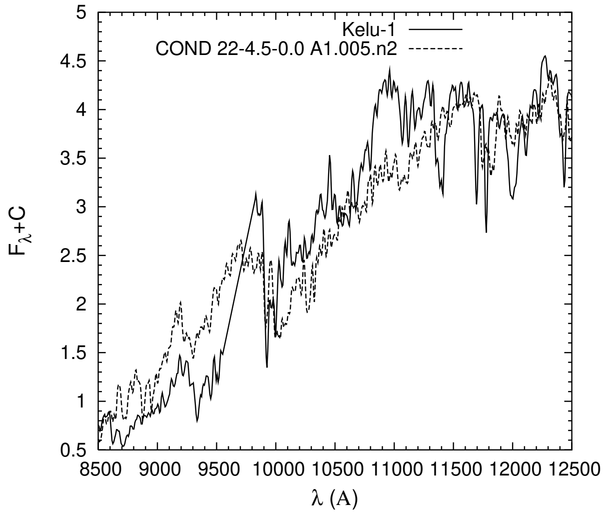

Figure 4. Comparison of a synthetic spectrum for the COND model 22–4.5–0.0 with an observed spectrum of the L-dwarf Kelu-1 [6]. For the calculations the opacity of a dust cloud with the optical thickness $\tau_{tot} = 1$ at the depth $\tau = 0.005$ is used

- We compare synthetic spectra computed with the Burrows data and with the JOLA approximation that were used in the first analysis of the CrH bands in atmospheres of L-dwarf [4]. As shown in Fig. 3 the JOLA approximation describes the main spectrum features near 760 nm and 870 nm quite well. This proves that the molecule oscillator strengths of the CrH $A^6\Sigma^+ - X^6\Sigma^+$ transition estimated by Pavlenko [4] – $gf = 0.006 \div 0.012$ – are very close to the precise ones.
- To compare our results with observed spectra we computed the SEDs taking into account the opacity of dust clouds with various parameters. In Fig. 4 we present an observed spectrum of the L-dwarf Kelu-1 and a synthetic spectrum calculated for a dust cloud with the optical thickness $\tau_{tot} = 1$ located at the depth $\tau = 0.005$; the COND model atmosphere 22–4.5–0.0 is used.

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