In memoriam
Yakiv Pavlenko

Our work on pre-main sequence stars and Brown dwarfs

Rafael Rebolo
Instituto de Astrofísica de Canarias

Outline

- I met Yakiv for the first time in the Symposium of the International Astronomical Union that took place in Bulgaria in 1990

IAUS 145	**Evolution of the Stars: the Photospheric Abundance Connection** Zlatni Pjasaci, Bulgaria, August 27-31, 1990 Eds. G. Michaud & A. Tutukov Kluwer Academic Publishers

Since then, we became Friends and had a
Very fruitful collaboration that extended over 34 years

Our Joint Research

- Lithium depletion in Pre-main sequence stars
  - Observations and predictions for young Very Low mass stars
- Brown dwarfs
  - General properties of brown dwarfs
  - Understanding lithium in extremely cool
- Lately, Halo brown dwarfs and the cosmological lithium problem

First work: Lithium depletion in Pre- Main sequence stars

Lithium in low-mass stars Magazzú et al. 1992
(T Tauri associations): cited 99 times

THE ASTROPHYSICAL JOURNAL, 392:159–171, 1992 June 10

LITHIUM ABUNDANCES IN CLASSICAL AND WEAK T TAURI STARS[1]

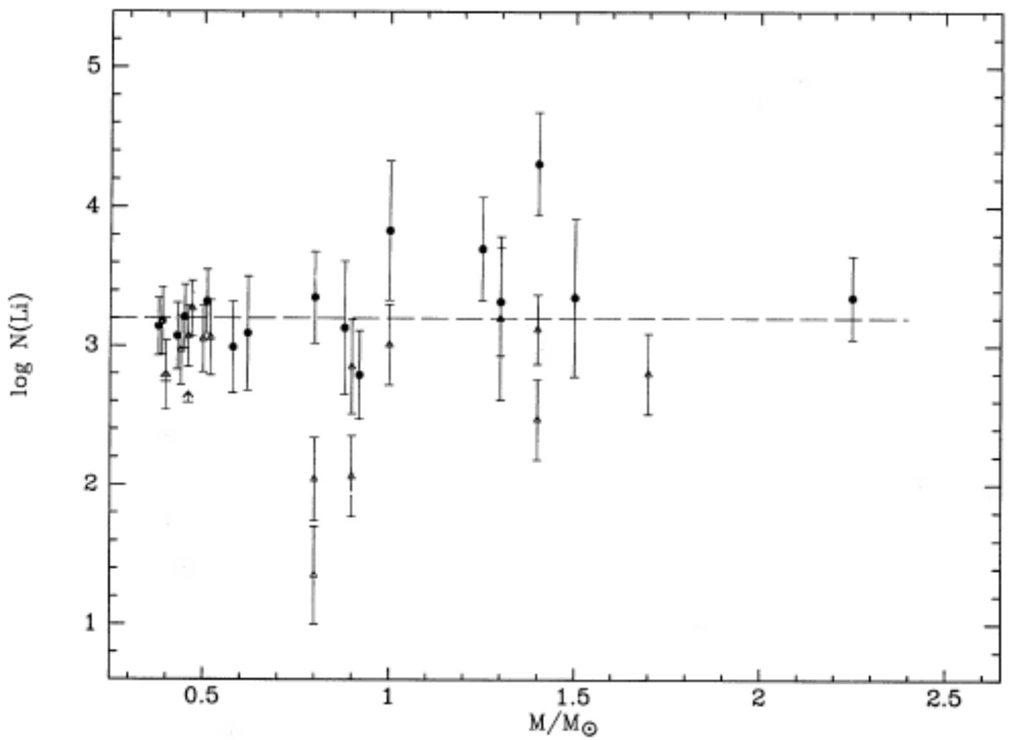
ANTONIO MAGAZZÙ,[2,3] RAFAEL REBOLO,[2] AND YAKOV V. PAVLENKO[4]
Received 1991 July 10; accepted 1991 December 10

ABSTRACT

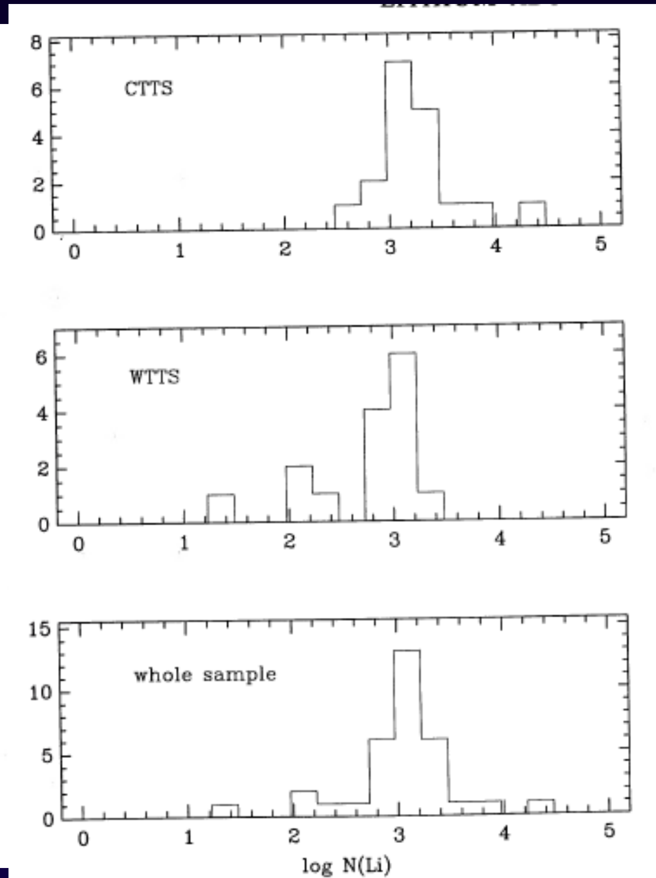
We present a study on the lithium abundance in 36 T Tauri stars (mass range 0.4–2.25 $M_\odot$), partly based on high-dispersion spectra taken with the Isaac Newton Telescope. Veiling effects have been taken into account when measuring the Li I λ670.8 nm doublet equivalent width. Non–LTE effects, studied in the range $4000 \leq T_{\rm eff} \leq 5000$ K, are significant for the coolest atmospheres, becoming smaller for $T_{\rm eff}$ close to 5000 K. Our non–LTE corrections tend to increase the derived abundance, except for high temperatures (≈5000 K) and log N(Li) $\gtrsim 3$, where an inverse trend is found.

The majority of the stars in our sample present a rather narrow distribution of abundance around log N(Li) = 3.2, the expected value of the present cosmic lithium abundance. Our results do not provide support to models of inhomogeneous big bang nucleosynthesis, that predict a very high value for the primordial lithium abundance. A remarkable lithium depletion (up to two orders of magnitude) has been found only in the most evolved T Tauri stars with $M \approx 0.8\ M_\odot$.

Subject headings: stars: abundances — stars: evolution — stars: pre-main-sequence



log N(Li)
M/M⊙



CTTS
WTTS
whole sample
log N(Li)

Astron. Astrophys. 282, 503–517 (1994)

ASTRONOMY AND ASTROPHYSICS

Pre-main sequence lithium burning

I. Weak T Tauri stars*

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Abstract. We report high-resolution spectroscopic observations for a sample of 38 T Tauri stars (TTS), complemented by UBVRI photometry of 13 TTS, and CCD VRI photometry for 2 visual binaries. Based on these observations and data taken from the literature, we derive lithium abundances in 53 TTS, concentrating on weak-line TTS (WTTS). The sample spans the range in spectral types from K0-M3, approximately corresponding to masses between 1.2 and 0.2 $M_\odot$.

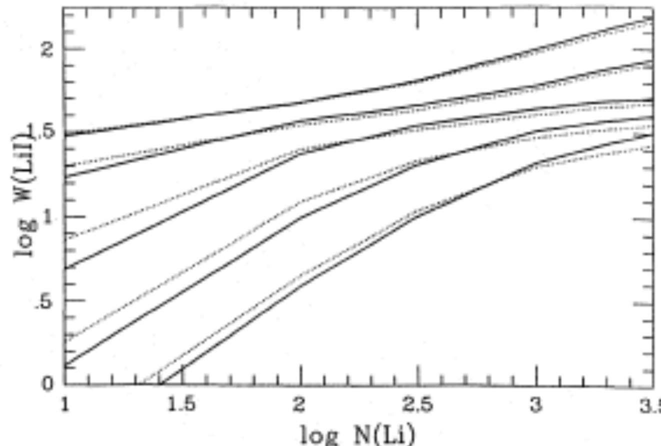
Our study of the statistical distribution of lithium abundances in WTTS gives the following results: (1) At luminosities $\geq 0.9\ L_\odot$ the Li abundances are remarkably uniform. The mean value, log N(Li)=3.1, coincides with the "cosmic" lithium abundance. (2) We find strong evidence for PMS lithium burning. Significant Li depletion appears below 0.5 $L_\odot$ in the mass range 0.9-0.2 $M_\odot$ and increases towards lower luminosities. Current theoretical evolutionary models do not seem to fit consistently the observed pattern of Li abundances in the whole mass range. In particular, at the lower mass end (0.4-0.2 $M_\odot$), the observed luminosity of the Li burning turning point is about a factor 4 higher than predicted by the models. At masses 1.2-1.0 $M_\odot$ the observations imply less PMS Li burning than theoretically expected. PMS Li burning in the mass range 0.9-0.7 $M_\odot$ is reduced in the presence of rapid rotation.

Key words: stars: pre-main sequence – stars: late-type – stars evolution – stars: abundances – stars: rotation

1. Introduction

The presence of the Li I resonance line has usually been a useful criterion for identifying low-mass pre-main sequence (PMS) stars (Walter et al. 1988, Martín et al. 1992a, Pallavicini et al. 1992, Bouvier & Appenzeller 1992). Low-mass stars spend their first few million years of life as T Tauri stars (TTS), and gradually evolve into post T Tauri stars (PTTS), which represent a longer, yet scarcely observed (Jones & Herbig 1979), phase of evolution.

T Tauri stars are commonly divided in two subtypes: classical TTS (CTTS), which generally accommodate to the original criteria defining the T Tauri class (Herbig 1962), and weak TTS (WTTS), which lack most of the properties typical of the CTTS.



Cited 145 times

Lithium curves of growth
for stellar atmospheric
Effective temperatures
From 3500 K to 5500 K

Astron. Astrophys. 303, 807–818 (1995)

ASTRONOMY
AND
ASTROPHYSICS

Formation of lithium lines in very cool dwarfs

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Abstract. We present LTE and NLTE results on the formation of Li I lines (λ6103, λ6708, and λ8126) in the atmospheres of solar metallicity dwarfs with effective temperatures in the range 5500 K to 2000 K. NLTE effects are governed by overionization of Li and by the interlocking effects of energy levels. For stars with $T_{eff} \geq 4000$ K, we confirm previous findings by Magazzù et al. (1992). NLTE corrections can lower the LTE Li abundances derived from strong Li I λ6708 lines by up to 0.5 dex.

Our computations using model atmospheres with T_{eff} between 3000 K and 2000 K show that prominent Li I lines are formed. We give a set of line profiles, which support the feasability of the Li test for brown dwarfs. The ionization-dissociation equilibrium for Li species was carefully considered. NLTE effects on the Li I lines of very cool dwarfs are found to be small, implying corrections to the LTE Li abundances lower than 0.1 dex. Several numerical tests have been carried out to estimate the effects of chromosphere-like structures on the formation of LiI lines. Our preliminary results suggest that in the presence of very strong chromospheres, the line strengths are reduced.

Key words: line: formation – stars: late type; brown dwarfs – stars: abundances

ration of a large number of opacity sources; and the effects of the departure from LTE.

In the last few years several works have contributed to alleviate these problems. For instance, computations of very cool atmospheres have become available (e.g., Allard 1990). Our aim is to use these model atmospheres to study the formation of spectral lines of astrophysical interest, to interpret high resolution spectra, and in particular to derive photospheric chemical abundances.

In this paper we analyze the formation of Li I lines in the atmospheres of solar metallicity late-type stars (T_{eff} : 2000-5000 K). In former papers (Magazzù et al. 1992; Martín et al. 1992, 1994a; García López et al. 1994) we have presented results of LTE and NLTE calculations of the LiI resonance doublet in dwarfs with $T_{eff} \geq 3500$ K (G, K and early M-type stars). Here, we present a few new results on these stars and an extension to much lower effective temperatures. The computations for $T_{eff} \leq$ 3000 K are relevant to the search for brown dwarfs (BDs). A spectroscopic test able to directly confirm the substellar nature of BD candidates has been recently put forward (Rebolo et al. 1992). It consists in the detection of the Li I λ6708 feature, due to the fact that Li rapidly dissappears from the atmospheres of

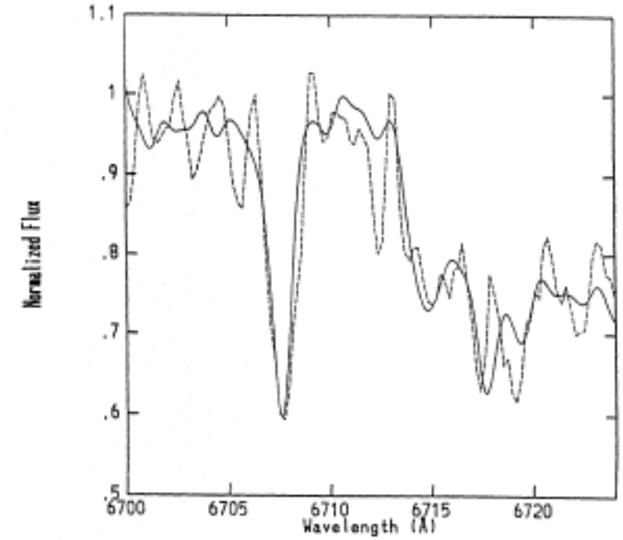


Fig. 10. LTE spectral synthesis fit to the Li I λ6708 region of the M6 T Tauri star UX Tau C. We used a model atmosphere with 3000/5.0 and log n(Li)=1.6

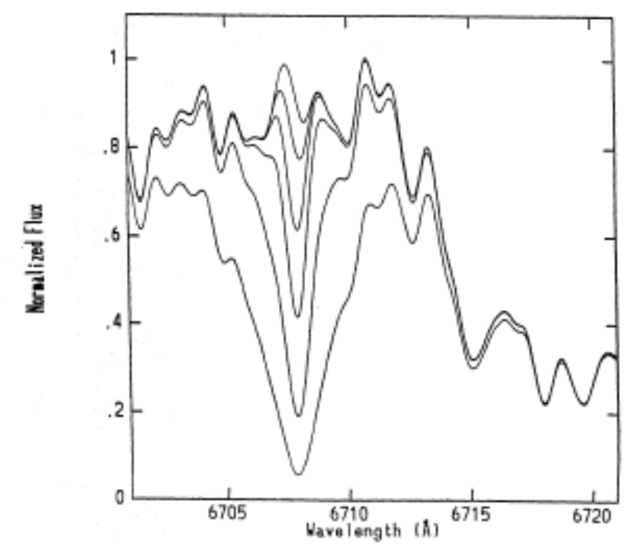
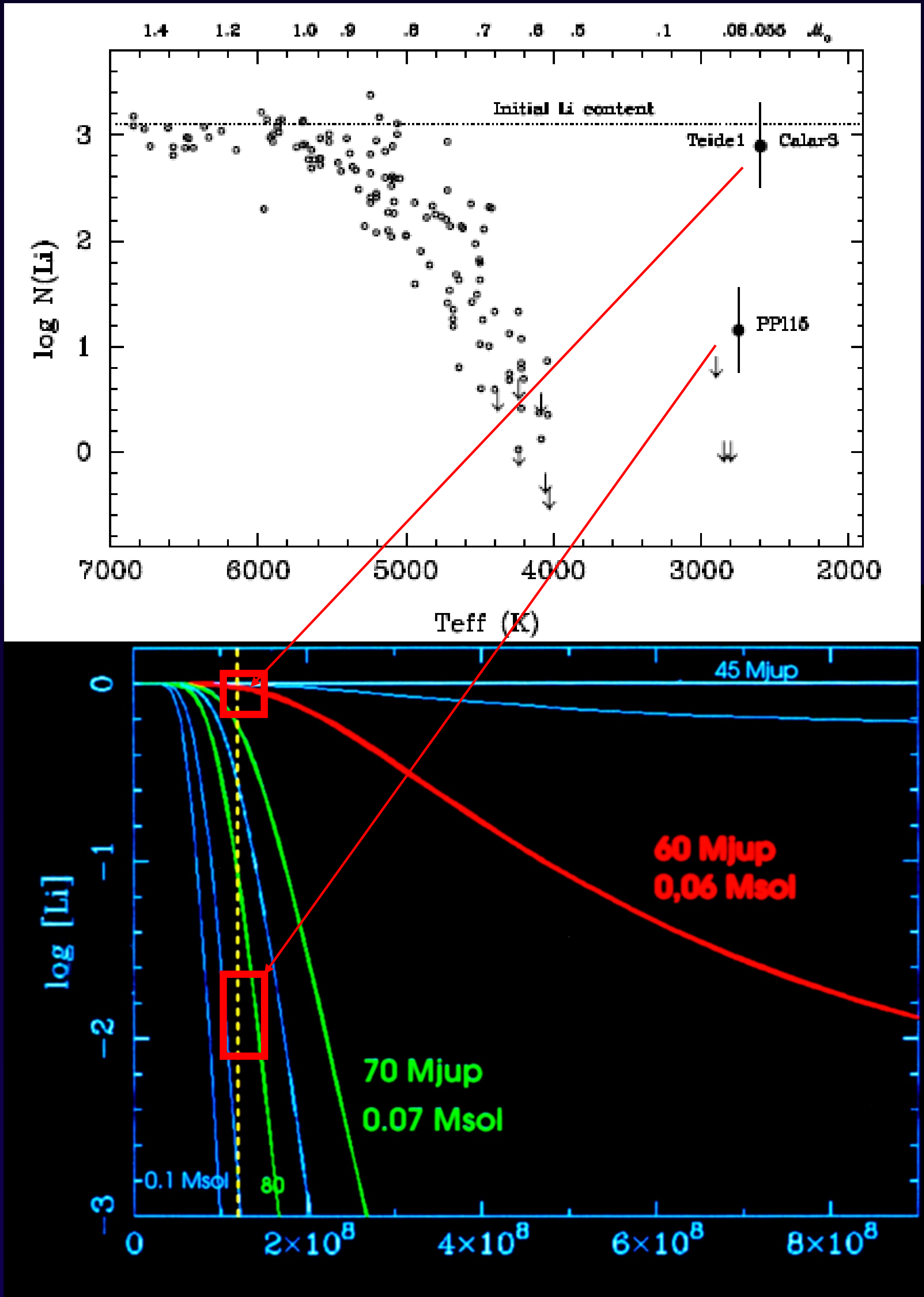


Fig. 11. Synthetic LTE Li I λ6708 profiles for 2500/5.0 model atmosphere and log n(Li)=3.0, 2.0, 1.0, 0.0, -1.0 and -2.0

Cited 75 times

Based on Yakiv´s work we concluded that the object Teide 1 and Calar 3 we had discovered in 1995 and proposed as Brown dwarf were indeed ,

true brown dwarfs



As new very cool stars and Brown dwarfs were discovered between 1995 and 2000 Yakiv computed theoretical spectra to explain the new observations

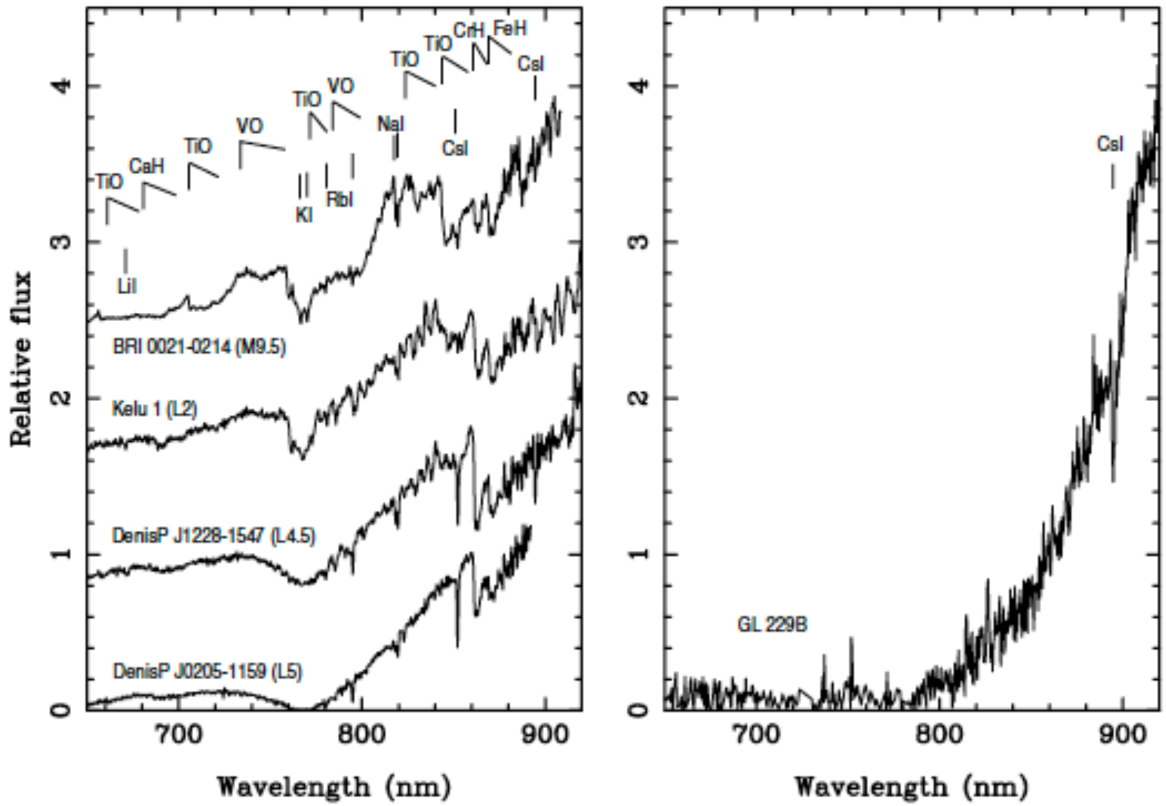


Fig. 1. Far-red optical spectra for our sample. New observations are those of Kelu 1, Denis-P J1228–1547 and Denis-P J0205–1159 (KeckII spectrum). Data for BRI 0021-0214 and Gl 229B have been collected from Martín et al. (1996) and from Schultz et al. (1998), respectively. Spectral types for the L-dwarfs are given following the classification of Martín et al. (1999). Spectra in the left panel have been shifted by 0.8 units for clarity. Identification of some atomic and molecular features is provided in the top.

Astron. Astrophys. 355, 245–255 (2000)

ASTRONOMY
AND
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On the interpretation of the optical spectra of L-type dwarfs*

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Abstract. We present synthetic optical spectra in the red and far-red (640–930 nm) of a sample of field L dwarfs suitably selected to cover this new spectral class, and the brown dwarf GL 229B. We have used the recent "dusty" atmospheres by Tsuji (2000) and by Allard (1999), and a synthesis code (Pavlenko et al. 1995) working under LTE conditions which considers the chemical equilibrium of more than 100 molecular species and the detailed opacities for the most relevant bands. Our computations show that the alkali elements Li, Na, K, Rb, and Cs govern the optical spectra of the objects in our sample, with Na and K contributing significantly to block the optical emergent radiation. Molecular absorption bands of oxides (TiO and VO) and hydrides (CrH, FeH and CaH) also dominate at these wavelengths in the early L-types showing a strength that progressively decreases for later types. We find that the densities of these molecules in the atmospheres of our objects are considerably smaller by larger factors than those predicted by chemical equilibrium considerations. This is consistent with Ti and V atoms being depleted into grains of dust. strong resonance feature even at very cool effective temperatures (~1000 K); depending on the effective temperature and on the amount of dust in the atmospheres of very cool dwarfs, it might be possible to achieve the detection of lithium even at temperatures this cool. Changes in the physical conditions governing dust formation in L-type objects will cause variability of the alkali lines, particularly of the shorter wavelength lines.

Key words: stars: atmospheres – stars: fundamental parameters – stars: low-mass, brown dwarfs

1. Introduction

The optical spectra of the recently discovered very cool dwarfs present new challenges to theoretical interpretation. Their spectral characteristics are drastically different from those of the well known M-dwarfs and this has prompted the use of a new spectral classification, the so-called L-dwarfs (Martín et al. 1997a, 1999;

Last professional correspondence October 1st, 2024

On Tue, 1 Oct 2024 at 13:33, Rafael Rebolo <rrl@iac.es> wrote:

hi Yakiv,

following our past conversation , I would appreciate if you compute a high resolution spectrum (R=100.000) of Luhman 16 A and B, adopting the parameters that we are considering most adequate in the new paper.

The spectral range I am most interested is 1 to 2.3 microns, in order to use it as a template for RV cross-correlation, but feel free to extend the range as it would be interesting to see the aspect of Rb, K and Li lines in the visible at this
super high resolution.

With the future ELT 39m. telescope and the instrument ANDES which is under construction with participation of our group this resolution will be available and we will obtain very good spectra in the visible for Luhman 16 A and B, I want to make a case for ELT observations with ANDES on this brown dwarf system.

Many thanks

Rafa

Dear Rafa,
Received, thanks...
Will do in the next few days of this week.
Today I work from home... Sorry, sleepless night...
Sometimes it happens.
C u tomorrow,
yp

Thanks Yakiv ,
you will be always with us