Low-Mass Stars and Brown Dwarfs

Optical/Infrared Photometry and Spectroscopy of Low-Mass Stars and Brown Dwarfs in the Field and Young Clusters

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Submitted by Robert R. King to the University of Exeter as a thesis for the degree of Doctor of Philosophy in Physics, September 2009.

I certify that all material in this thesis which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

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Abstract

In this thesis I will present optical and near-infrared photometric and spectroscopic observations of an evolved field brown dwarf binary pair and of populations of low-mass stars in high-mass young stellar clusters and will compare them to stellar and substellar theoretical model predictions.

ε Indi Ba, and Bb are the closest known brown dwarfs to the Earth, and, as such, make possible a concerted observational campaign to obtain a complete characterisation of two intermediate-age T dwarfs. Although some recent observations suggest substellar atmospheric and evolutionary models may be inconsistent with observations, there have been few conclusive tests to date. I will present high angular resolution optical, near-infrared, and thermal-infrared imaging and medium-resolution (up to R$\sim$5 000) spectroscopy of these two T dwarfs. Using these data I have derived luminosities of log L/L$_{\odot}$=$-$4.699 $\pm$ 0.017 and $-$5.232 $\pm$ 0.020 for ε Indi Ba, Bb, respectively, and I will show that the predictions of substellar evolutionary models using luminosity and mass constraints are inconsistent with the effective temperatures and surface gravities derived from fitting atmospheric models to observed spectra. Furthermore, I will show that, even where estimates of the effective temperature, surface gravity, and luminosity are available, estimates of the mass of cool brown dwarfs can be up to a factor of two lower than the measured dynamical mass. Considering the difficulty in assigning accurate ages to any system and the mass-luminosity-age degeneracy of brown dwarfs, I would caution against the over-analysis of predicted brown dwarf masses at this time.

I have also used *Chandra* X-ray observations to identify near-complete and relatively unbiased samples of pre-main-sequence stars in the young stellar clusters NGC 2244 and Trumpler 14. Using optical photometric and spectroscopic observations, I will characterise the apparent age spreads seen in the cluster pre-main-sequences. Mass estimates will then be derived for their stellar populations and used to construct the initial mass function for each cluster. It is found that NGC 2244 appears to have a Salpeter-like IMF for stars in the mass range 0.5–2.0 $M_{\odot}$ if a likely age of 2 Myr is adopted, while Tr 14 may have a top-heavy IMF at a similar age. However, I will show that because the observed slopes of the cluster pre-main-sequences are not well-matched by the predicted slope in colour-magnitude space, such determinations are heavily dependent on the assumed age of the cluster and complicated due to the large spreads in isochronal ages.

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Declaration

Chapters 2 and 3 are drawn from a paper published in Astronomy & Astrophysics by King, R. R., McCaughrean, M. J., Homeier, D., Allard, F., Scholz, R.-D., and Lodieu, N (A&A 2010, 510, A99). The grid of atmospheric models against which we compared our observations was produced by Derek Homeier. The rest of the work presented is my own.

Chapters 4 and 5 contain work which will be published in the near future in collaboration with McCaughrean, M. J., Townsley, L., and Feigelson, E., but the work presented here is my own.

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I have made use of NSO/Kitt Peak FTS data, produced by NSF/NOAO, and the SpeX Prism Spectral Libraries, maintained by Adam Burgasser[1] and I would like to thank Adam Burgasser, Mark Marley, Davy Kirkpatrick, and Sandy Leggett for useful discussion and Isabelle Baraffe for supplying the grid of brown dwarf evolutionary models.

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[1] http://www.browndwarfs.org/spexprism