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# Aspects of Multi-Dimensional Modelling of Substellar Atmospheres

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**Abstract.** Theoretical arguments and observations suggest that the atmospheres of Brown Dwarfs and planets are very dynamic on chemical and on physical time scales. The modelling of such substellar atmospheres has, hence, been much more demanding than initially anticipated. This Splinter[1] has combined new developments in atmosphere modelling, with novel observational techniques, and new challenges arising from planetary and space weather observations.

## 1. Introduction

A rich molecular gas-phase chemistry coupled with cloud formation processes determines the atmosphere spectra of very low-mass, cool objects. Interferometry (E. Pedretti, Sect. 2) and polarimetry (S. Berdyugina, Sect. 3) can potentially provide more insight. However, present day interferometers are not capable of surface imaging Brown Dwarfs and planets due to financial constraints. Polarimetry, as a novel planet detection method, benefits from Rayleigh scattering on high-altitude sub-$\mu$m cloud particles. Such clouds were predicted to form by non-equilibrium processes several years ago

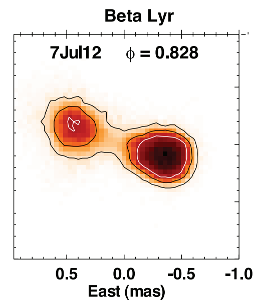
[1]http://star-www.st-and.ac.uk/~ch80/CS16/MultiDSplinter_CS16.html

(Woitke & Helling 2004). Wavelength dependent transit timing may reveal the interaction of the planetary exosphere with the stellar corona, and hence, limits may be set on planetary magnetic field strengths (A.A. Vidotto, Sect. 4). Radiative MHD simulations suggest that magnetic field driven convection significantly changes in fully convective objects compared to the Sun: M-dwarfs are suggested to exhibit darker magnetic structures (B. Beeck, Sect. 5). Studies of multi-dimensional radiative transfer emphasize that full solutions of physical problems are needed to access limits approximations (E. Baron, Sect. 6). The superrotation observed in planetary atmospheres is suggested to result from standing Rossby waves generated by the thermal forcing of the day-night temperature difference (A.P. Showman, Sect. 7). A search for transit-time variations at 8 $\mu$m reveals a difference between the transit and the secondary eclipse timing after subtracting stellar variability, and hence, confirms the superrotation on HD 189733b (E. Agol, Sect. 8). Results of multi-dimensional simulations are starting to be used as input for 1D model atmospheres for synthetic spectra production (D. Homeier, Sect. 9).

## 2. Combined Interferometry for Substellar Variability (Ettore Pedretti)

Optical and infrared long–baseline interferometry allows high–resolution imaging that is out of reach for the current large telescope facilities and for the planned 30m class telescopes. Examples of typical and future targets for long–baseline interferometry are stellar surfaces, planet–forming discs, active galactic nuclei and extrasolar planets. The main interferometric facilities in the northern hemisphere are the center for high angular resolution astronomy (CHARA) array and the Keck interferometer. CHARA is a visible and infrared interferometer composed of 6 one–metre telescopes on a 330m maximum baseline (see Pedtretti et al. 2009). The Keck interferometer is composed of two 10m telescopes on a 85m baseline and works mainly in the infrared. The main facility in the southern hemisphere is the very large telescope interferometer (VLTI), composed of four 8m telescopes and four 2m telescopes on a 200m maximum baseline. The Sidney university stellar interferometer (SUSI) in Australia has the longest available baseline in the world (640m) but so far has only used up to 80m baselines. Previous generation interferometers provided unique science by measuring the diameters of stars with two telescopes or by providing simple model dependent imaging combining up to 3 telescopes (Berger et al. 2001, Monnier et al. 2003, Pedretti et al. 2009) Model–independent imaging of complex objects was achieved quite recently at the CHARA array, that obtained the first image of a main-sequence star, Altair (Monnier et al. 2007). CHARA also imaged the most distant eclipsing system, the star $\beta$ Lirae and witnessed the spectacular eclipse from the $\epsilon$ Aur system (Kloppenborg et al. 2010; Fig. 1). The VLTI imaged the young stellar object IRAS 13481-6124 (Kraus et al. 2010).

An interesting question is whether interferometry could resolve brown dwarfs and provide the same sort of high–resolution pictures offered to its larger stellar cousins. $\epsilon$ Indi B is the nearest brown dwarf (Scholz et al 2003). The distance is 3.6 pc, corresponding to an angular diameter of 0.3 milliarcseconds, and a magnitude at H band Mh = 11.3. $\epsilon$ Indi B is in the southern hemisphere, therefore it is only accessible by the VLTI and SUSI. The VLTI does not have long enough baselines, its maximum baseline being 200m. SUSI with its 640m baselines would achieve in the infrared, at H band a resolution of 0.5 milliarcseconds, therefore it could measure the diameter and effective temperature of $\epsilon$ Indi B if its bolometric flux was known. However SUSI has never used baselines longer than 80m and it is not sensitive enough to reach Mh = 11.3, Alpha Aql



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