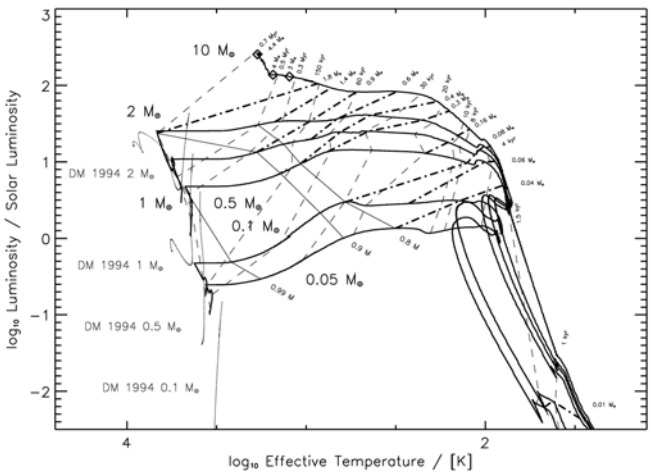
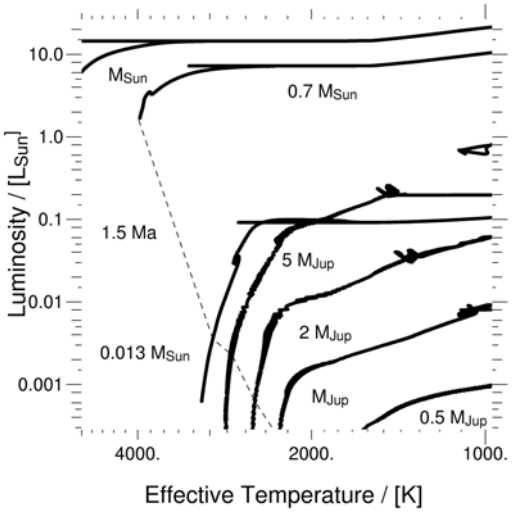
Formation-Theory across the Substellar Limit

We calculated the formation and early evolution of stars, brown dwarfs and planets. Properties and observables for objects with masses ranging from Jupiter to the Sun are evaluated from zero age to million years, directly from the respective formation theories. Thus we provide theoretical properties of very young astrophysical objects for all masses that are within reach of present instruments. While shedding light on the formation process itself, these models are also of key importance for the observational identification of young extrasolar planets by direct imaging and their characterization in terms of mass, age and type. They allow to observationally separate planets from brown dwarfs and provide quantitative links to the respective formation process.

Our fluid dynamical models with radiation, self-gravity and time-dependent convection account for detailed non-ideal equations of state, opacities and D-burning. The time-dependent convection model is calibrated to the solar radius and tested by properties of the solar convection zone. The equation system is supplemented by boundary conditions and source-terms that account for the respective formation scenarios: the collapse of gas spheres for stars and brown-dwarfs, core-accretion and envelope-capture for planets.





The left Fig. shows a large HRD for the collapse of Bonnor-Ebert spheres that reaches from quasi-isothermal collapsing cloud cores to pre-main sequence ages. The cloud masses range from 10 to 0.05 solar masses. Thick lines are *evolutionary tracks*, dashed lines are *isochrones*, dash-dotted lines are *isopleths*, i.e. lines of constant central object-mass. Thin lines show the *fraction of total cloud mass* that has been accreted with the remainder still in the envelope. Note the substantial corrections in pre-main sequence properties when compared to classical evolutionary tracks that start from an assumed initial state and ignore the formation process. D'Antona and Mazzitelli (1994), tracks, that are also calibrated to the Sun, are plotted for reference.

The right Fig. Shows an extension that reaches further into the substellar domain, down to half a Jupiter mass. The diagram shows that it is possible to separate planets (labelled in Jupiter-masses) from brown dwarfs by identifying regions in the HRD that are forbidden for objects above a given mass.

References:
• Wuchterl and Tscharnuter, 2003, A&A, 398, 1081-1090
• Wuchterl 2004, Rev. Mod. Astronomy, 17, 129-168

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