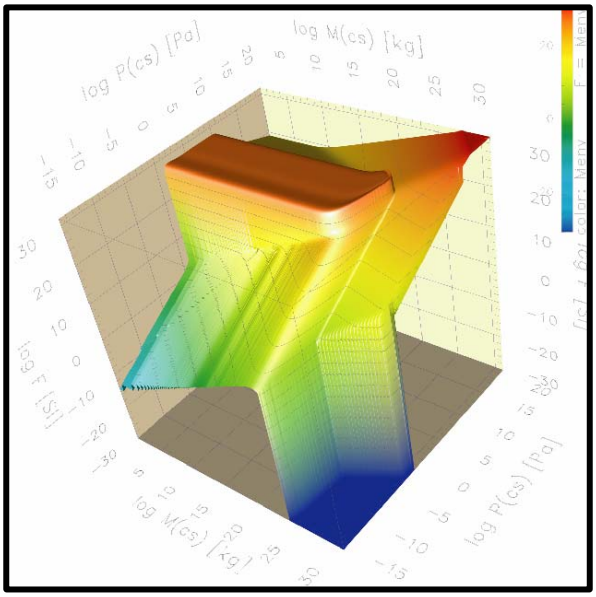
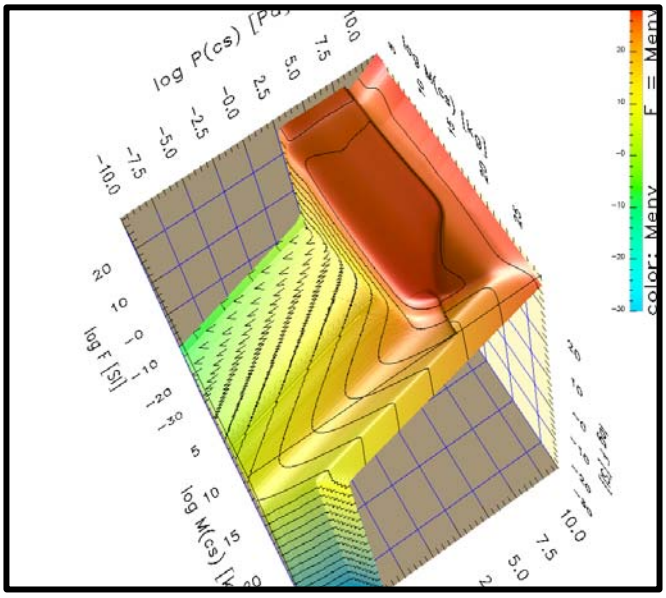
Star and Planet Formation − Theory

We have constructed the full set of solutions for hydrostatic protoplanets with fully radiative envelopes around a solid core. The envelopes have solar abundances with dust of interstellar composition added and detailed, non-ideal equations of state for H-He mixtures. The results give an overview of all possible protoplanetary equilibria in the core accretion model.

The results of our calculations are a few 10^5 protoplanetary models that allow a statistical analysis. The figures show the envelope masses of all solutions displayed as a function of core mass and inside pressure.
Great height and red colour of the surface correspond to a large envelope mass for the given combination of core mass and pressure. All axes are in logarithmic scale and SI units, 30 orders of magnitude are covered in this diagram in both mass and pressure. The left figure shows the results for an ideal gas with constant core temperature. The right side shows the same graph for a H-He mixture with an effective core temperature of a black body radiating with a fixed specific luminosity.





In the relatively flat surface in the middle (red, referred to as „island“), reside protoplanets with jovian masses. They are huge fluffy objects more than a hundred times larger than mature planets of the same mass and connect smoothly to the nebula. In contrast, the pressure of mature planets like Jupiter, drops to virtually zero on the surface, a static solution embedded inside a protoplanetary nebula does not exist. These objects sit in the top right corner of the figures, behind the „island“.
The front edge of the „island“ corresponds to the so-called critical core mass: for higher core masses no static solutions exist embedded inside a nebula. The outside pressure drops to very small values.

Our results clearly show that there is statistical evidence for a characteristic planetary mass as a consequence of fundamental principles and the properties of hydrogen and helium.

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