Investigation of thermal processes during mass accretion and subsequent cooling of a protoplanet

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Introduction

Investigating how stars and planetary systems form is key to understanding them in their current state. Here I modeled the formation and subsequent cooling by accretion energy, solar flux, and loss of heat by blackbody emission of an Earth-like planet.

Methods

This is a very simple model, with no mass loss. The protoplanet was given an initial radius of 6.375×10^6 cm (~64 km), a constant density of 5.5 g cm^{-3}, and a specific heat of accreted material of 10^7 erg kg^{-1} K^{-1}.

During the accretion phase, both the mass and time were increased by 1000 equal increments. The temperature of each layer was increased by both accretion energy (gravitational potential energy converted into thermal energy), and solar flux energy from the protostar. There was also a temperature decrease due to blackbody emission from the top layer. As each layer was added to the protoplanet, the potential energy was calculated as such:

$$U = \frac{GMm}{R}$$

Where G is the gravitational constant, M is the total mass of the planet, m is the mass of each layer, and R is the total radius of the protoplanet. The potential energy was then converted into heat by calculating:

$$T = \frac{U}{mCp}$$

where T is temperature in Kelvin, and $Cp = 10^7 \; erg \; g^{-1} \; K^{-1}$ is the specific heat.

The model was run once with an assumed emissivity of 1 for blackbody emission. It was run a second time with an emissivity of 0.3333. This was to take into account an insulating atmosphere surrounding the planet, which would help to retain some of the heat.