Planets are different from rocks/gas clouds b/c their interiors have different properties than their exteriors.

1. Comparing pressure from gravity to electronic binding energy:

\[ \frac{GMm}{R^2} \sim E_{\text{bind}} \Rightarrow R \sim \begin{cases} 3000 \text{ km} & \text{for rocky bodies (} E_{\text{bind}} \sim 1 \text{ eV)} \\ 1000 \text{ km} & \text{for icy bodies (} E_{\text{bind}} \sim 0.1 \text{ eV)} \end{cases} \]

\( R@ = 6300 \text{ km, for comparison} \)

2. This is the radius at which material phase transitions start to happen b/c of gravity.

3. Assuming all heat from formation goes into internal heating:

\[ \frac{GM^2}{R} \sim MC_P \Delta T \Rightarrow \Delta T \sim \begin{cases} 40,000 \text{ K for Earth} \\ 4,000 \text{ K for ice} \\ 400 \text{ K for hydrogen @ 1 g-cm}^{-3} \end{cases} \]

This estimate is too high in part because a lot of formation energy is radiated away.

4. Let’s get at \( \Delta T \) a different way. Fourier’s law of conduction (analogous to diffusion):

\[ \frac{dT}{dr} \propto \frac{dQ}{dt} \frac{1}{4\pi r^2} \Rightarrow \frac{dQ}{dt} \propto \text{volume, since the amount of heat radiated} \]

\[ \frac{dT}{dr} \propto \frac{r^3}{r^2} \]

\[ \Rightarrow R \sim \begin{cases} 1000 \text{ km} & \text{for } \Delta T \sim 1000 \text{ K (melting point of rock)} \\ 300 \text{ km} & \text{for } \Delta T \sim 100 \text{ K (melting point of ice)} \end{cases} \]

Planets are electronically cold (i.e. not ideal gases; internal energy comes from material bonds) but ionically hot (there is enough heat to melt the material). Another way...
to say this is that for some amount of temperature change $\Delta T$, a planet's volume won't change very much (but a star's will. Stars can be described as ideal gases).