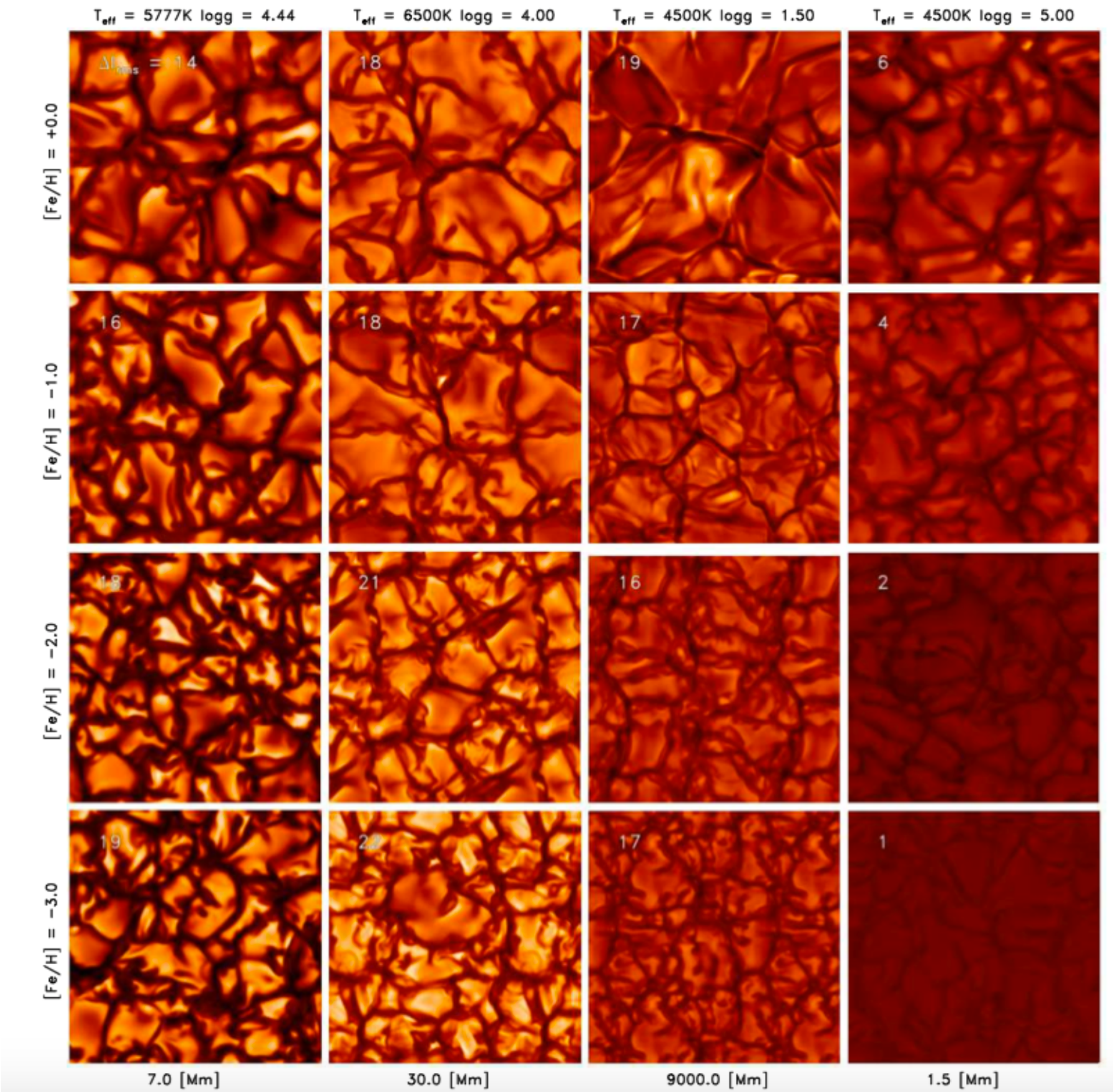
Intensité émergente

MS TO K-giant M-giant



Intensity maps for the Sun, TO, RG and dwarf star with decreasing metallicity. Note the difference in the intensity contrast for the different models with metallicity.

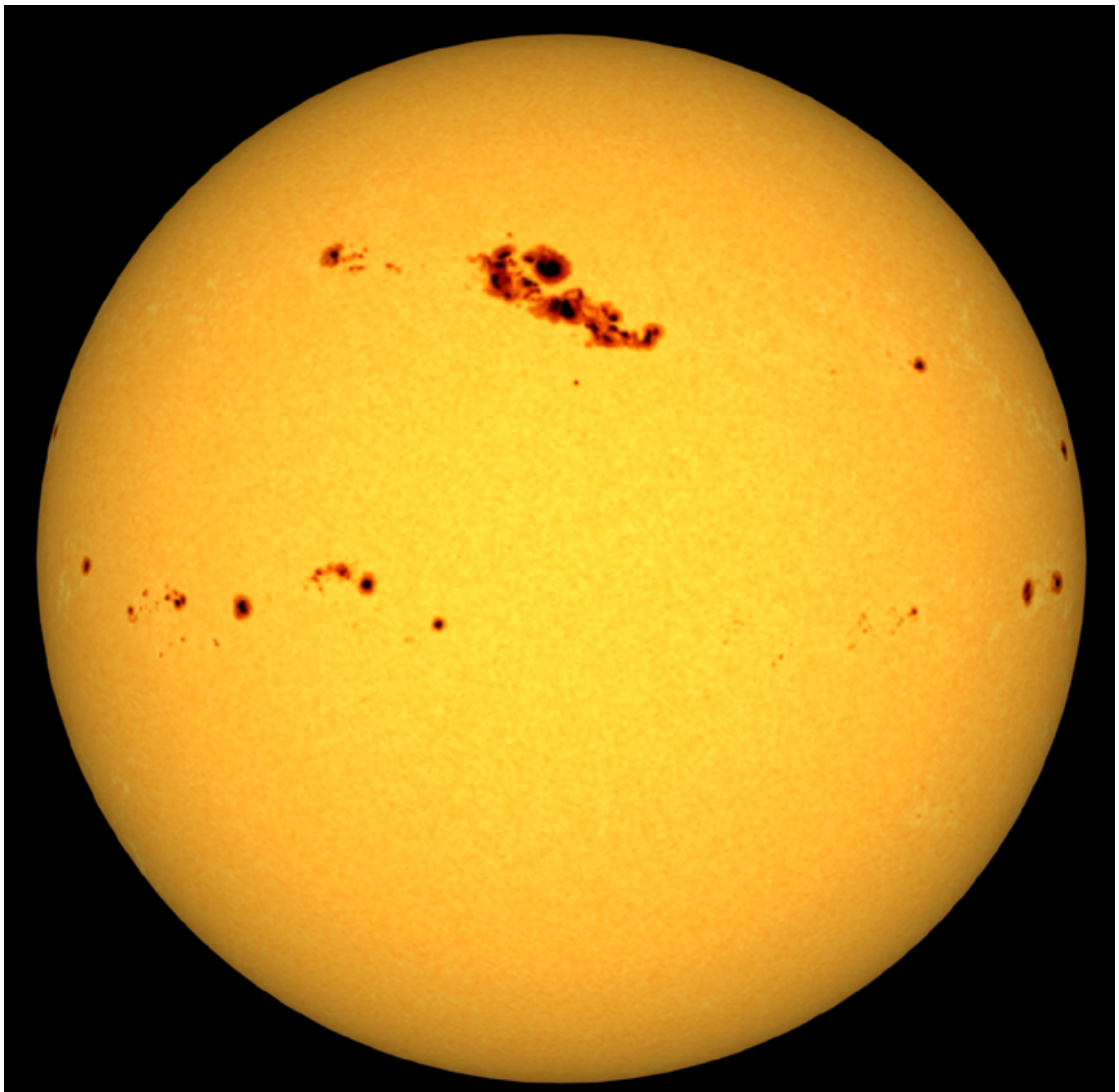
The emergent intensity increases towards higher Teff and decreases for lower surface gravities, as expected.
The granule sizes decrease with metallicity

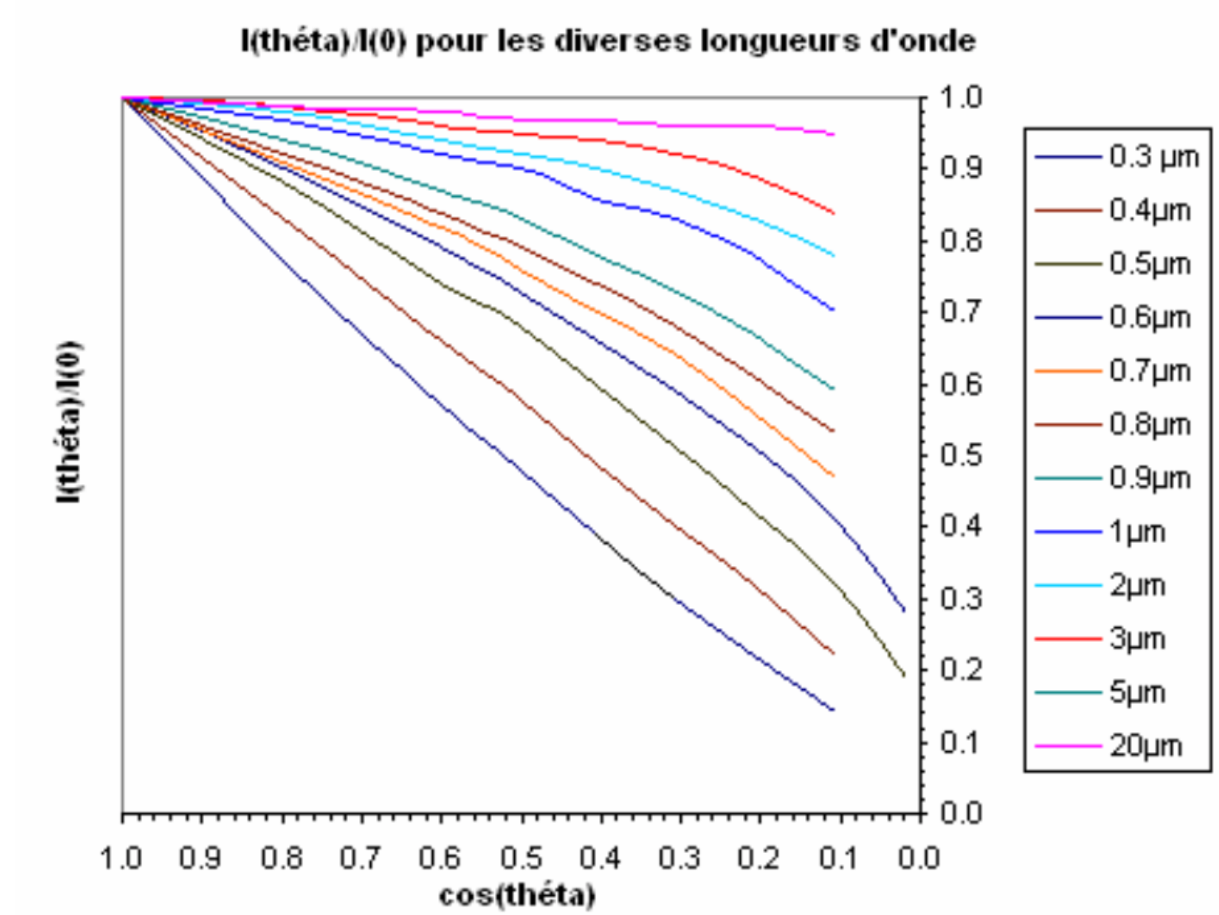
Magic et al. 2013a

Assombrissement centre bord

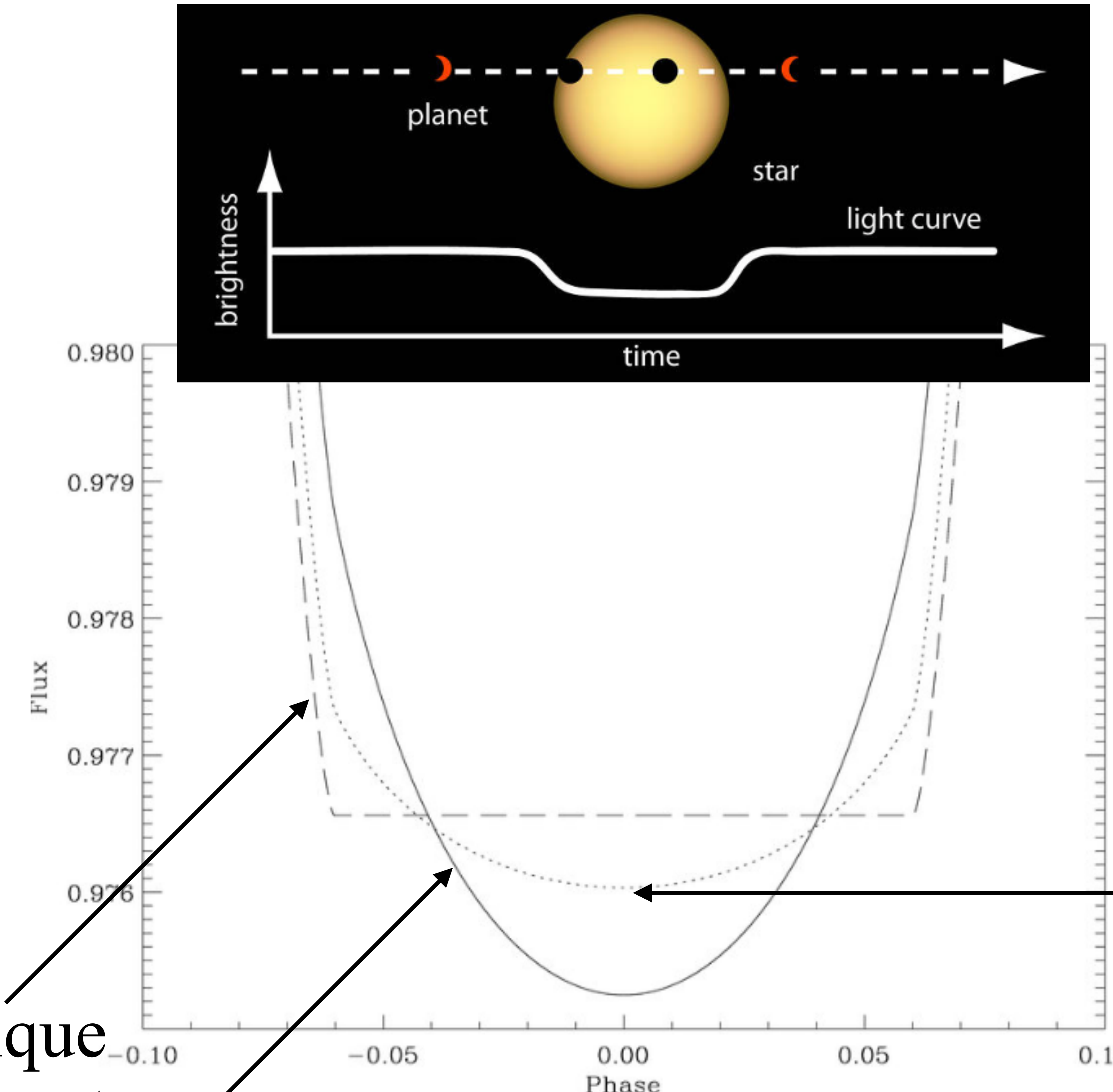
$$\frac{I(0,\mu)}{I(0,1)} = 0.6\mu + 0.4$$

$$I_\lambda = \frac{2hc^2}{\lambda^5}\frac{1}{e^{hc/kT}-1}$$





Détection de planète par transit



IR

Calcul théorique
sans assombrissement

optique

Ehrenreich 2007

Autre cas d'« anti-assombrissement » centre-bord: NP Abell 39

Energy transport

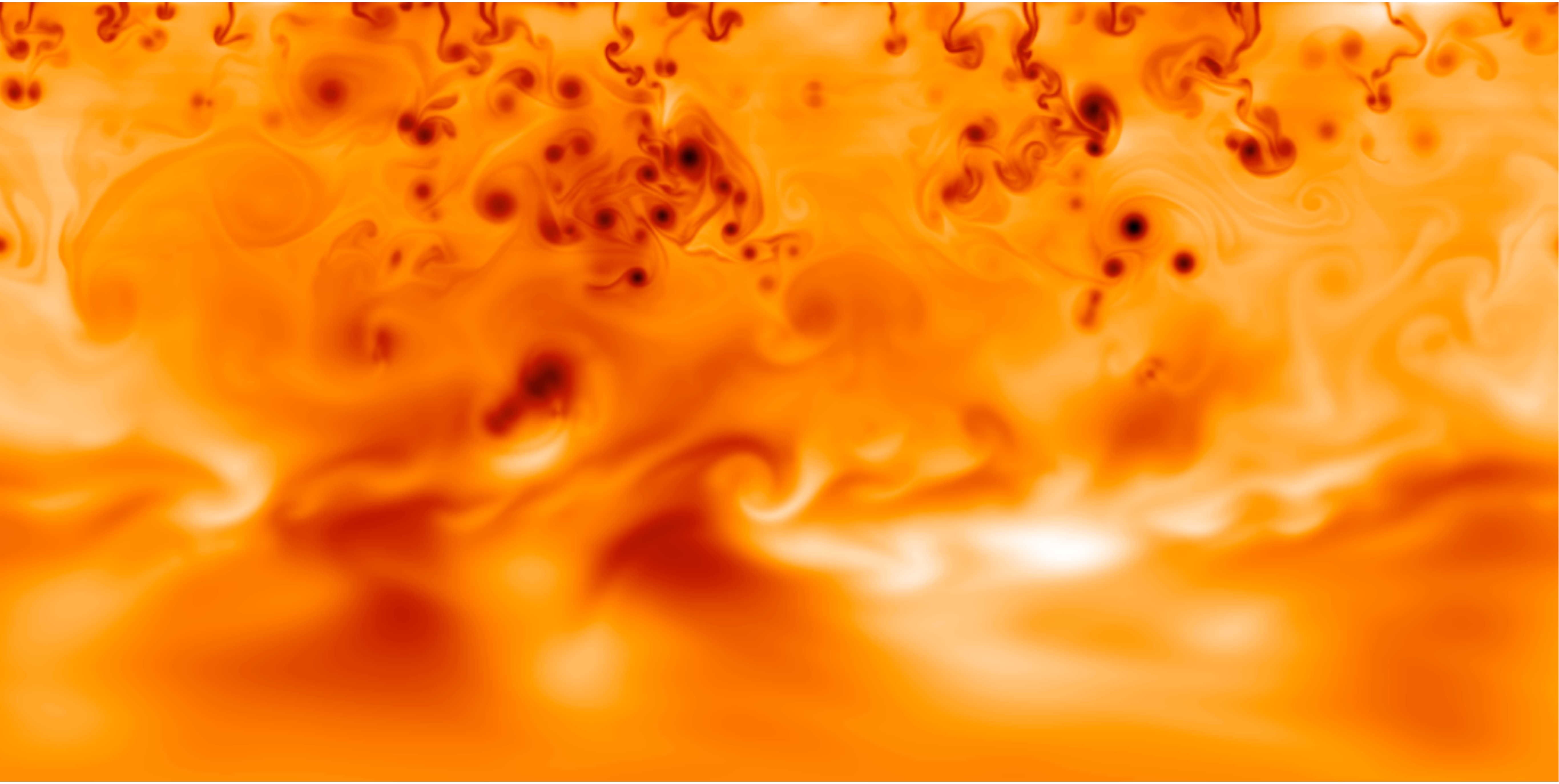
Energy transport can be understood as the result of four fundamental mechanisms:

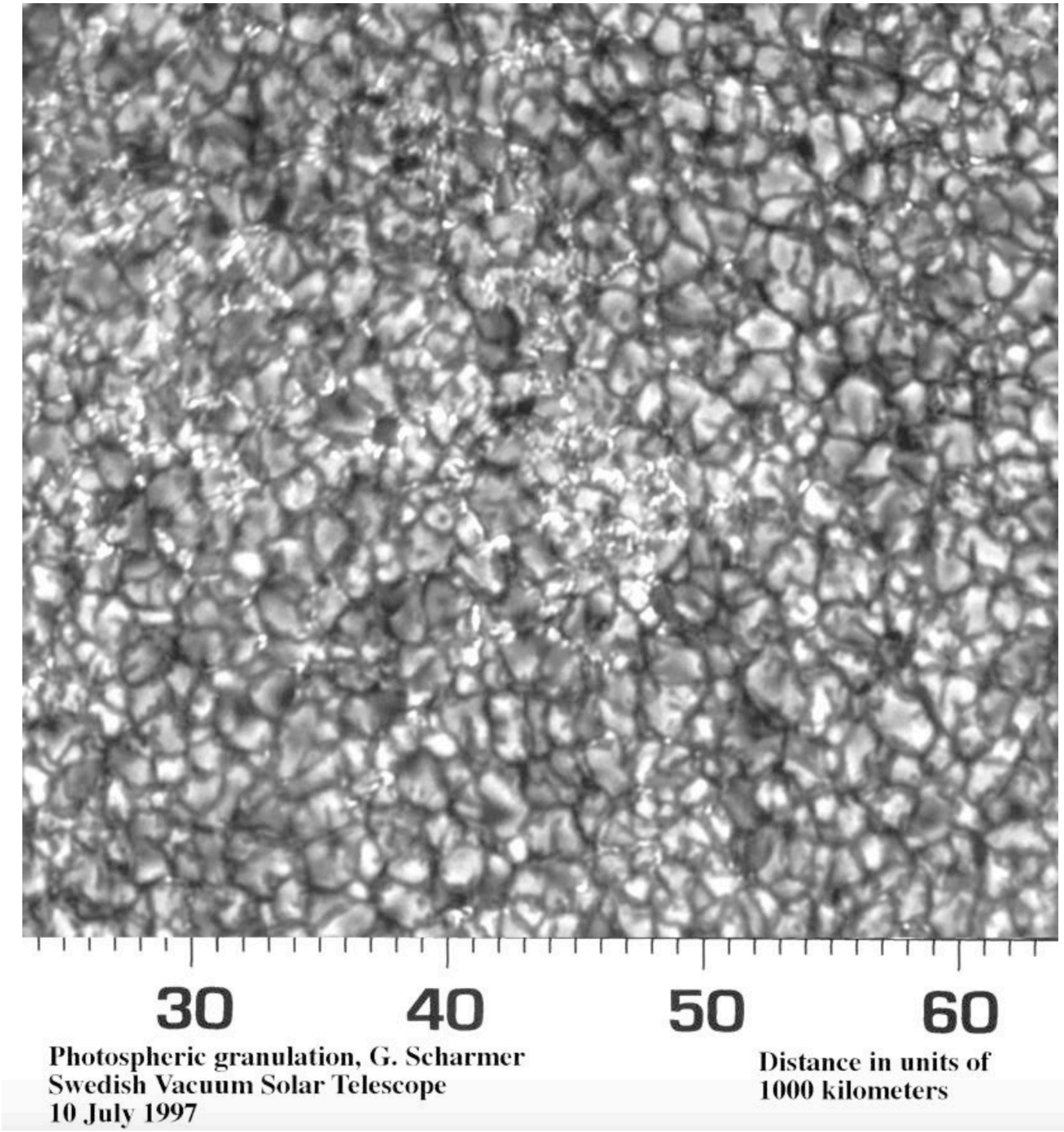
1. **Conduction**, arising from the thermal motion of electrons and ions
2. **Radiative transfer**, carried by photons
3. **Convection**, involving the movement of macroscopic gas parcels
4. **Neutrino emission** from the core

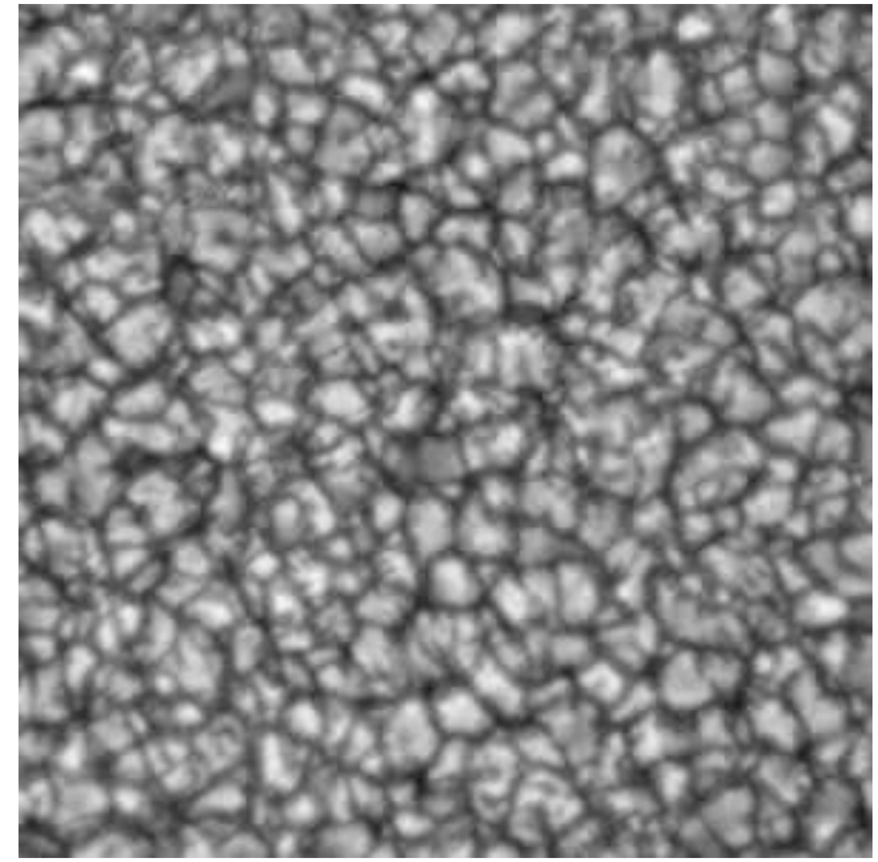
Both **conduction** and **radiative** transport may be viewed as resulting from ***random thermal motion*** of constituent **particles** (**electrons** in the first case and photons in the second)

Convection is a macroscopic or collective phenomenon.
In normal stars conduction is negligible, but it is important in stellar environments containing degenerate matter (such as white dwarfs),
Radiative transport usually dominates unless the temperature gradient in the gravitational field exceeds a critical value, in which case convection quickly becomes the most efficient means of energy transport.
Neutrino emission is important for core cooling late in the life of more massive stars.
#Neutrino emission differs from the other energy transport mechanisms in that it can operate only at extremely high temperatures and densities. The neutrinos have little interaction with the star as they carry energy out of the core at essentially light speed.

Convection







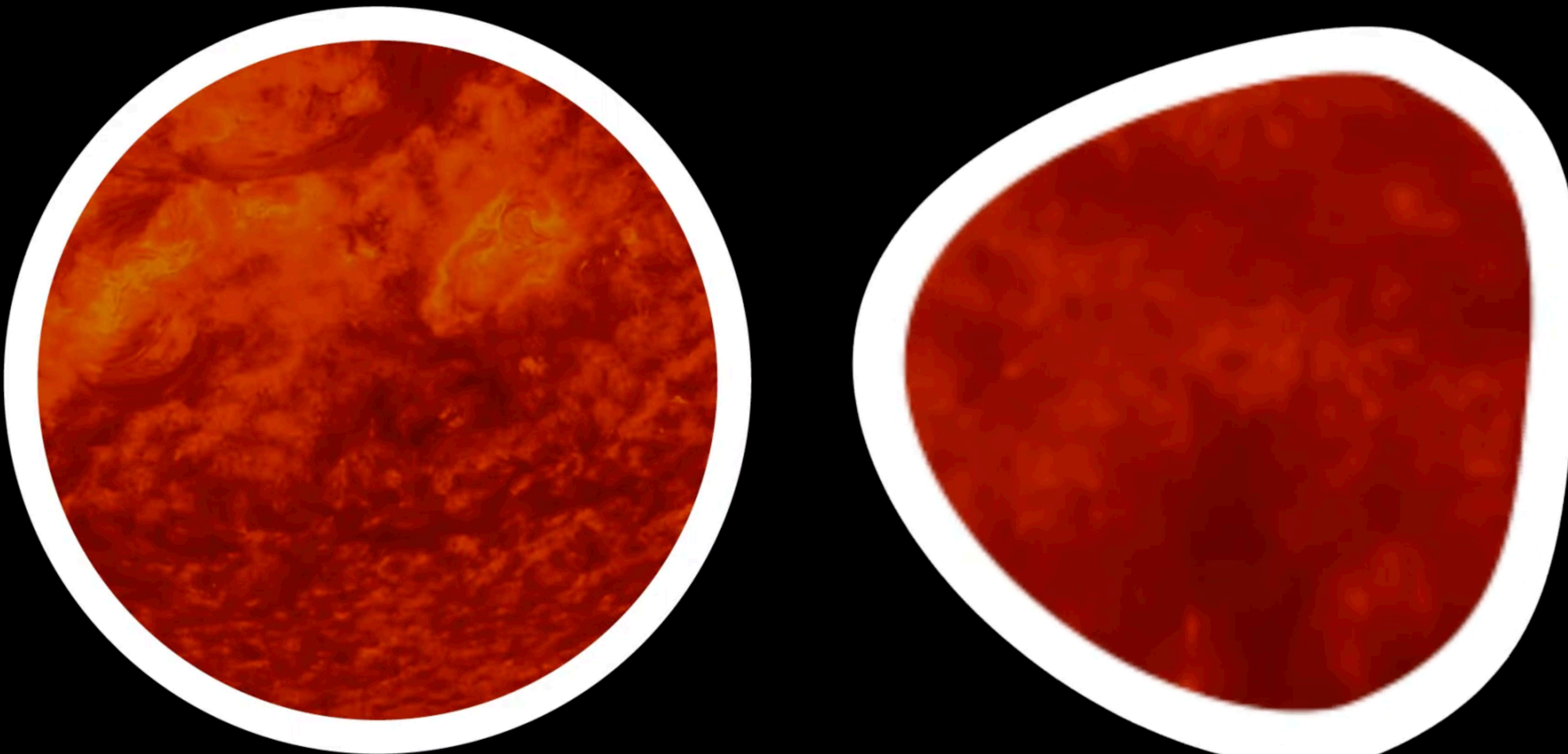
Movie: Granules are small (about 1000 km across) cellular features that cover the entire Sun except for those areas covered by sunspots. These features are the tops of convection cells where hot fluid rises up from the interior in the bright areas, spreads out across the surface, cools and then sinks inward along the dark lanes. Individual granules last for only about 20 minutes.

Gravity waves

Periodically arranged bands of clouds often identify gravity waves in the atmosphere. Not all bands of clouds are related to gravity waves but such, that have a perpendicular alignment to the main wind flow.

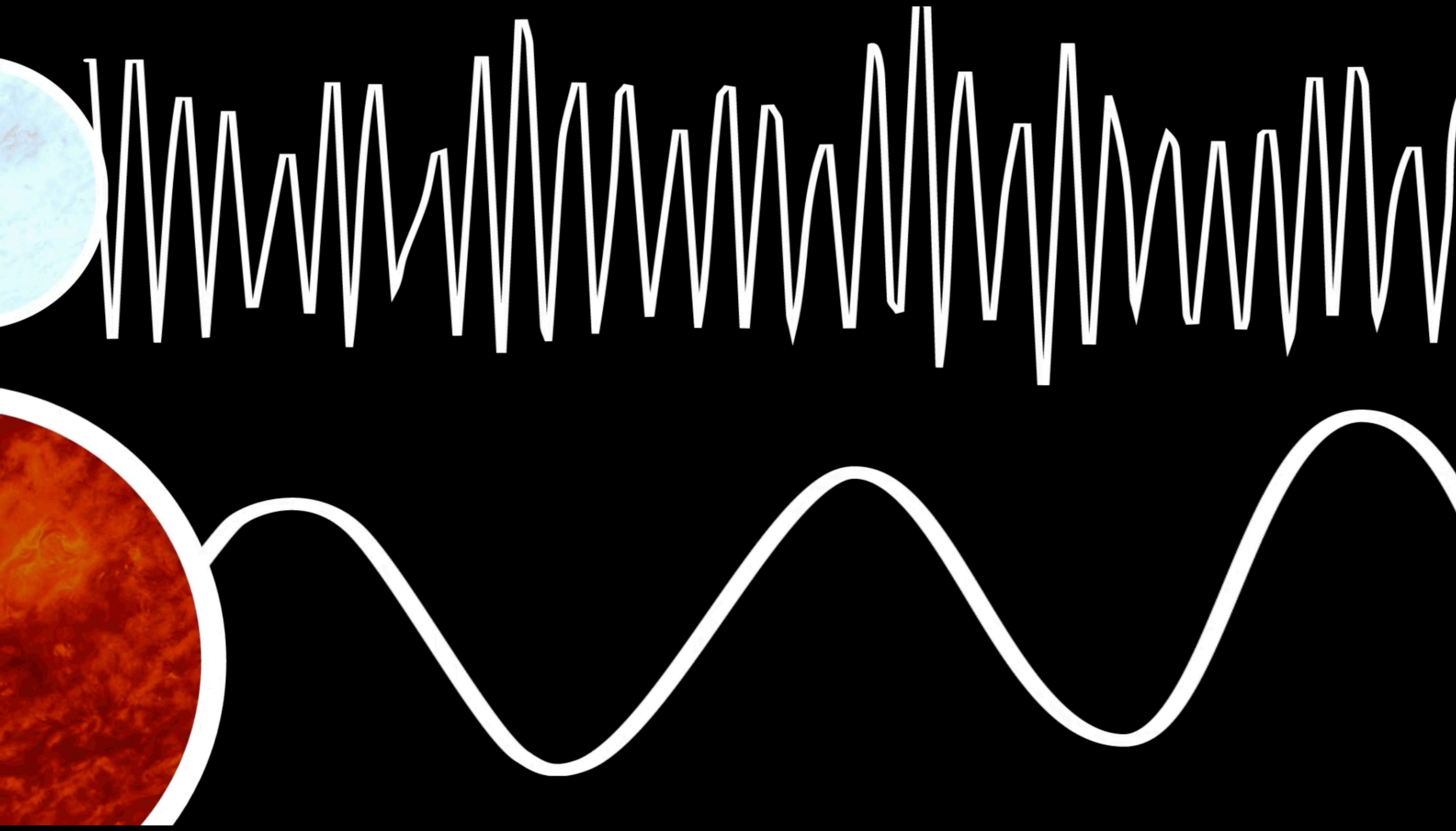
Gravity waves

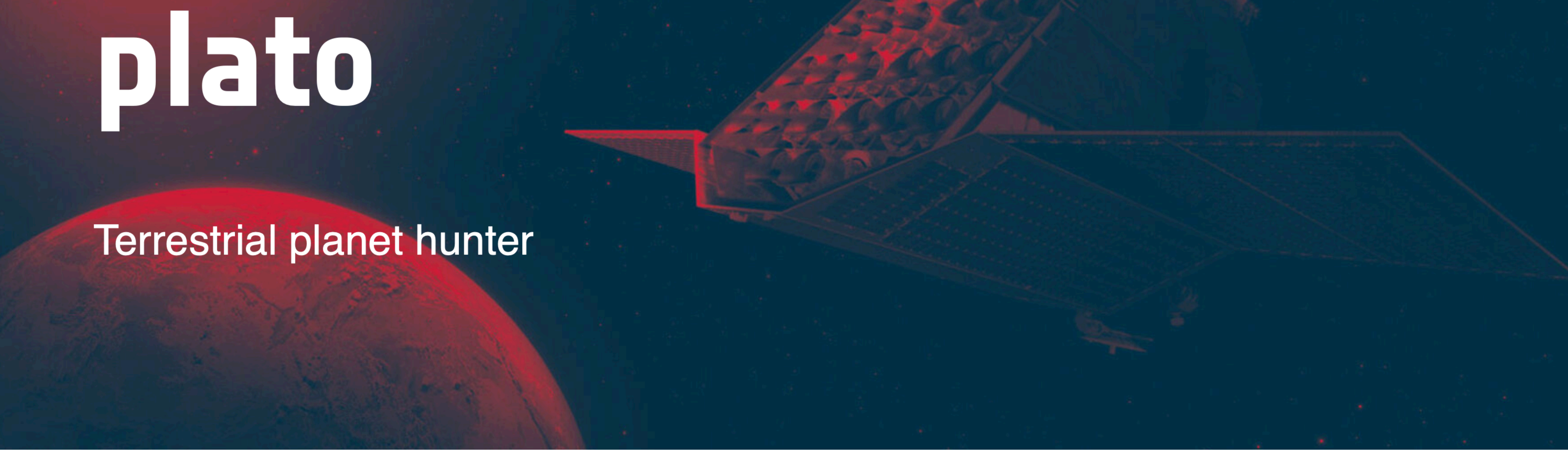
RGB star



https://www.youtube.com/watch?v=CqlVXSJNgUQ&t=8s

White dwarf





The mission

ESA's mission Plato, PLAnetary Transits and Oscillations of stars, will use its 26 cameras to study terrestrial exoplanets in orbits up to the habitable zone of Sun-like stars. The mission will measure the sizes of exoplanets and discover exomoons and rings around them. Plato will also characterise planets' host stars by studying tiny light variations in the starlight it receives.

The launch

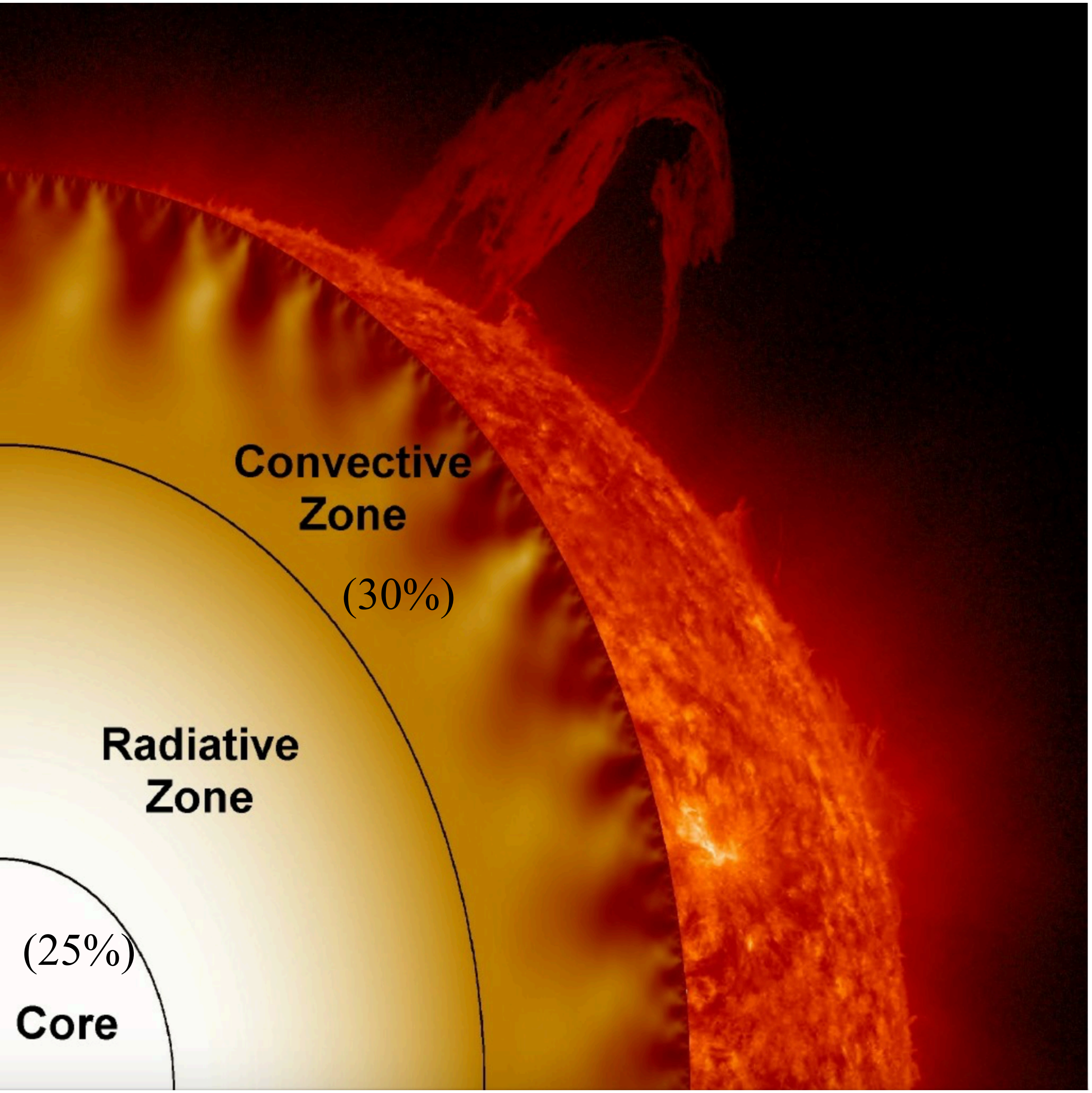
Launch: planned for December 2026

Launch location: Europe's Spaceport in French Guiana

Launch vehicle: Ariane 6

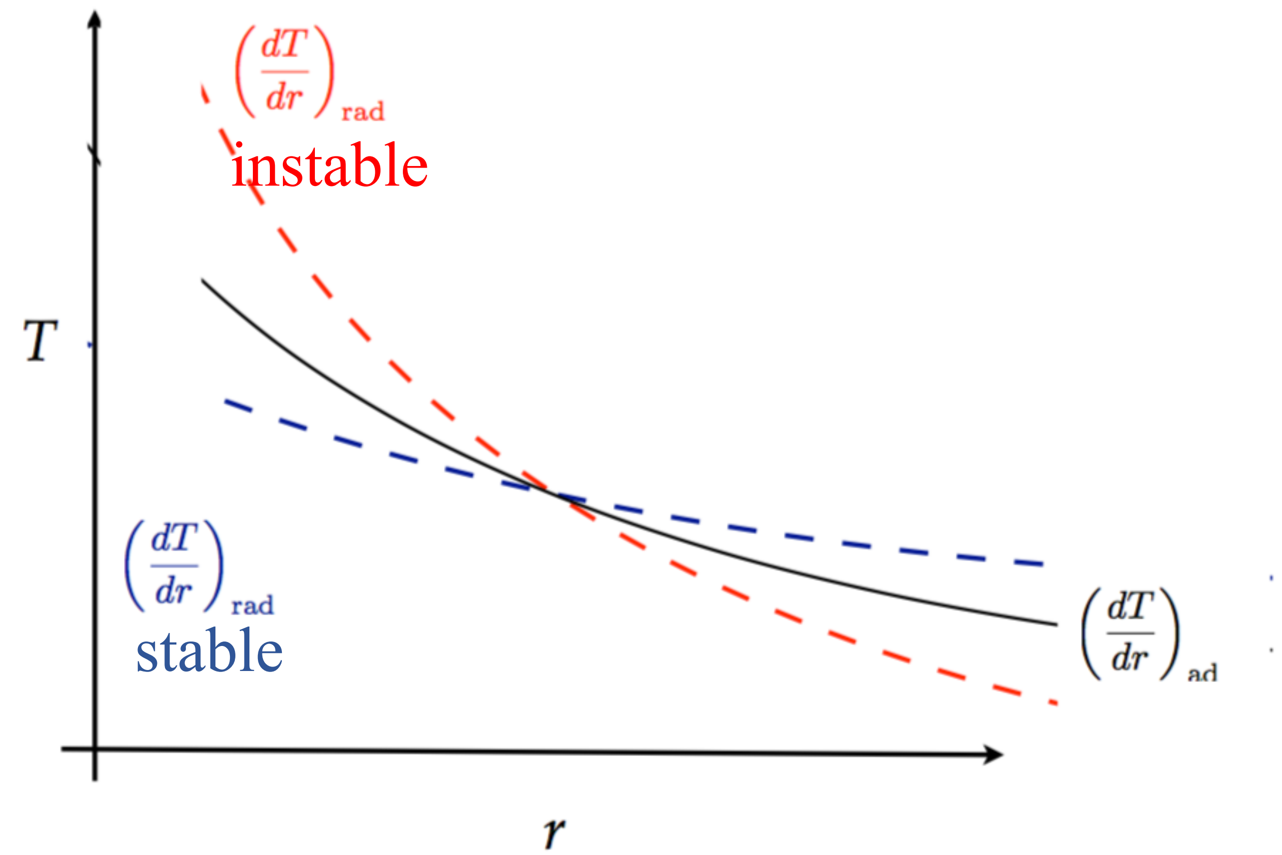
Orbit: halo orbit around Sun-Earth Lagrange point L2

https://www.esa.int/Science_Exploration/Space_Science/Plato/Asteroseismology_the_music_of_the_stars



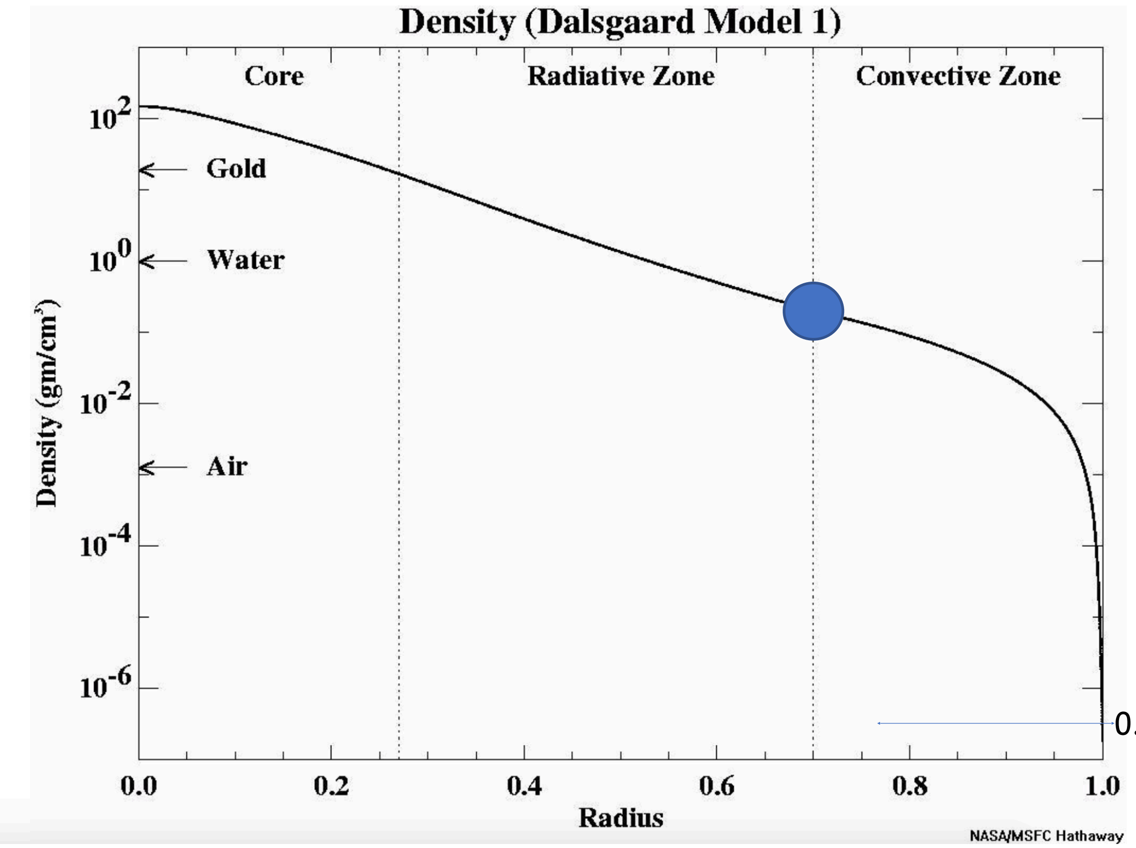
The convection zone is the outer-most layer of the solar interior. It extends from a depth of about 200,000 km right up to the visible surface. At the base of the convection zone the temperature is about 2,000,000° C. This is "cool" enough for the heavier ions (such as carbon, nitrogen, oxygen, calcium, and iron) to hold onto some of their electrons. This makes the material more opaque so that it is harder for radiation to get through. This traps heat that ultimately makes the fluid unstable and it starts to "boil" or convect.

https://solarscience.msfc.nasa.gov/interior.shtml



The Schwarzschild criterion for convective instability

Although the photons travel at the speed of light, they bounce so many times through this dense material that an individual photon takes about a million years to finally reach the interface layer. The density drops from 20 g/cm³ (about the density of gold) down to only 0.2 g/cm³ (less than the density of water) from the bottom to the top of the radiative zone. The temperature falls from 7,000,000° C to about 2,000,000° C over the same distance



200 000km

gradient adiabatique: $(\gamma-1)/\gamma = 2/5$

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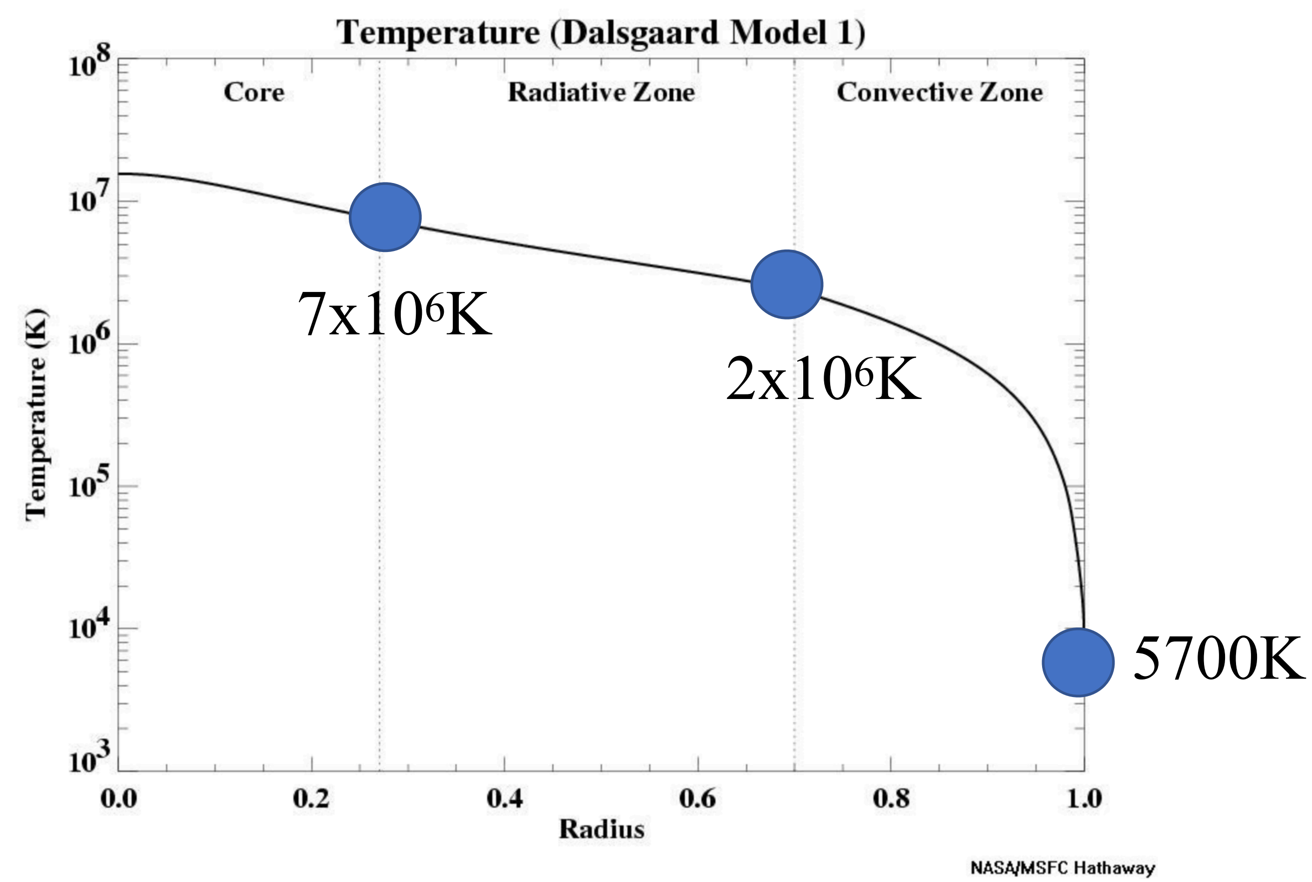

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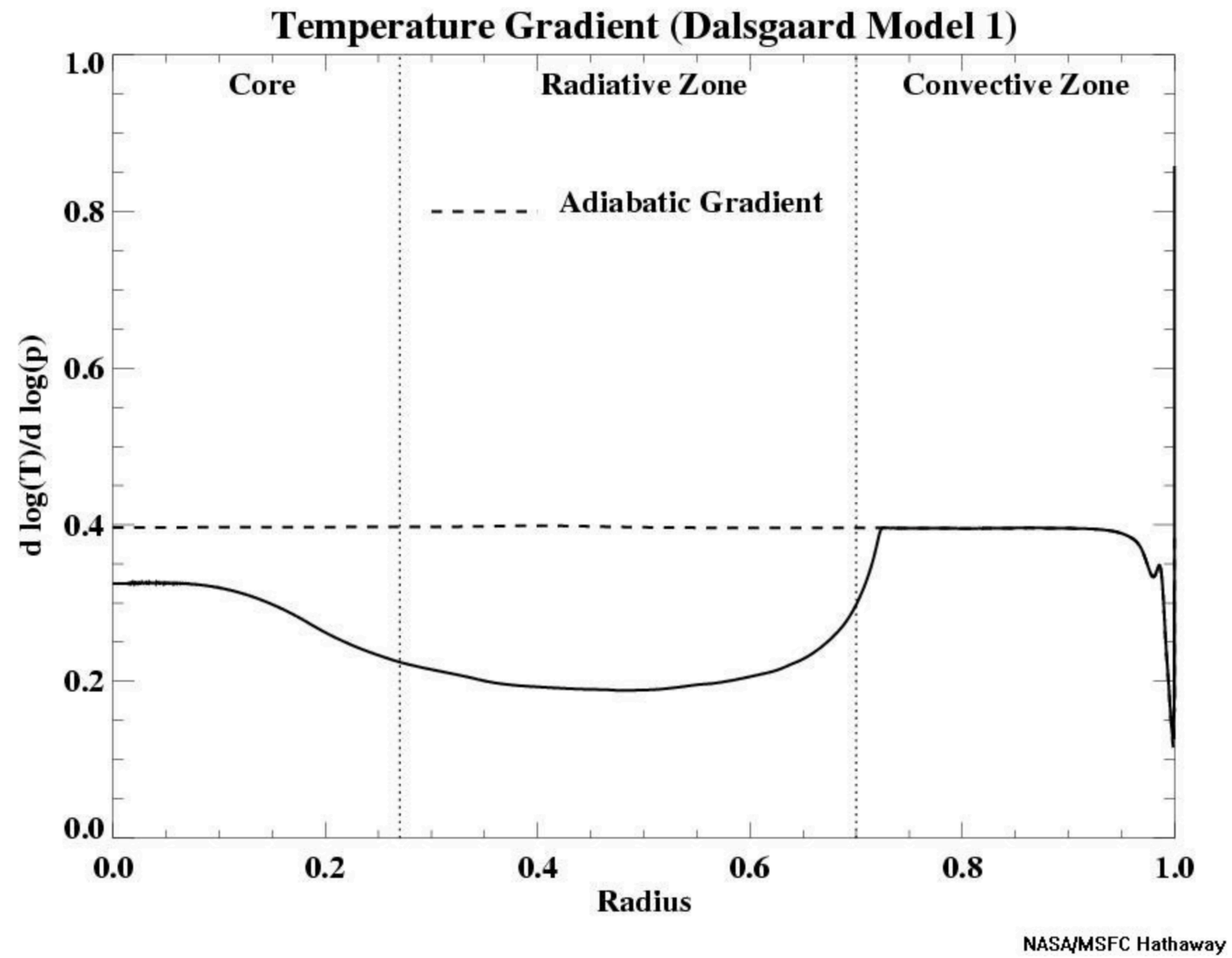
Convection occurs when the temperature gradient (the rate at which the temperature falls with height or radius) gets larger than the adiabatic gradient (the rate at which the temperature **would** fall if a volume of material were moved higher without adding heat). Where this occurs a volume of material moved upward will be warmer than its surroundings and will continue to rise further. These convective motions carry heat quite rapidly to the surface. The fluid expands and cools as it rises. At the visible surface the temperature has dropped to 5,700 K and the density is only 0.0000002 gm/cm³ (about 1/10,000th the density of air at sea level). The convective motions themselves are visible at the surface as granules and supergranules.



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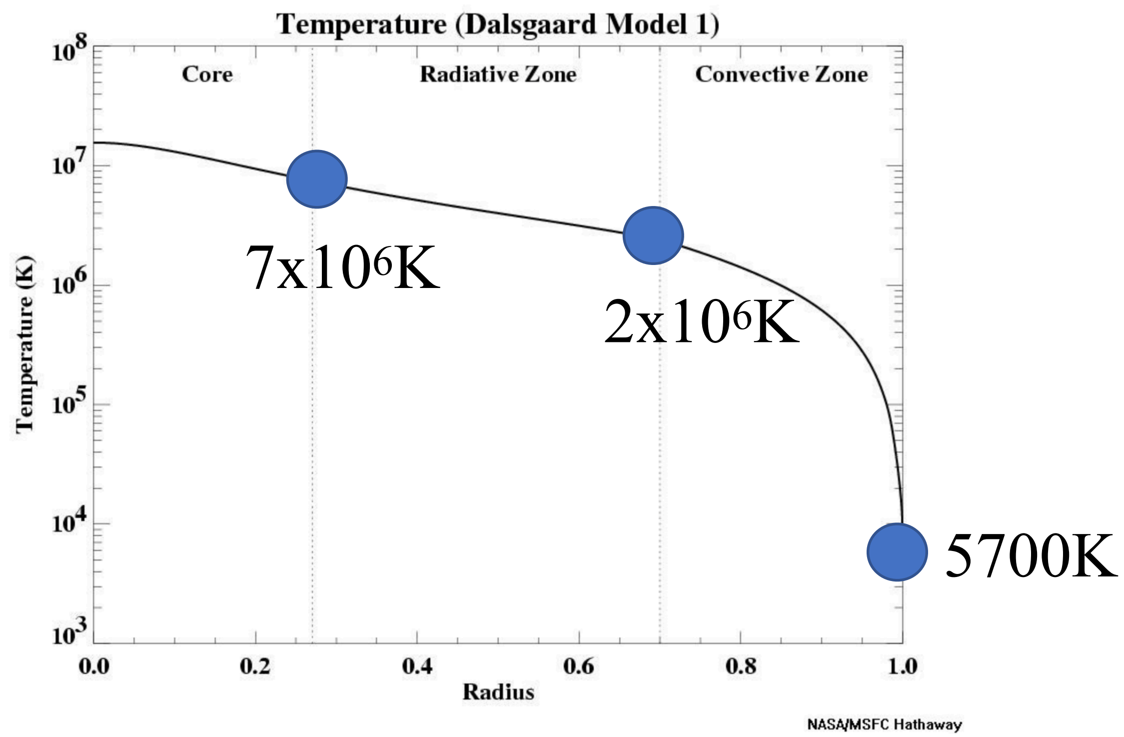
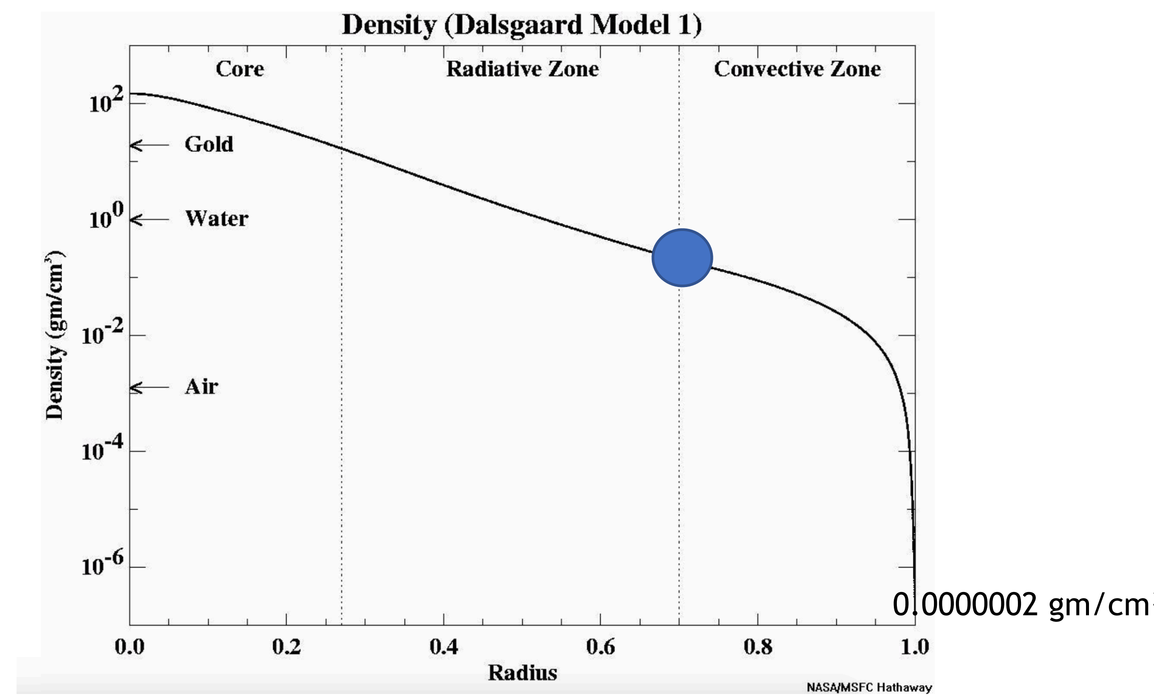
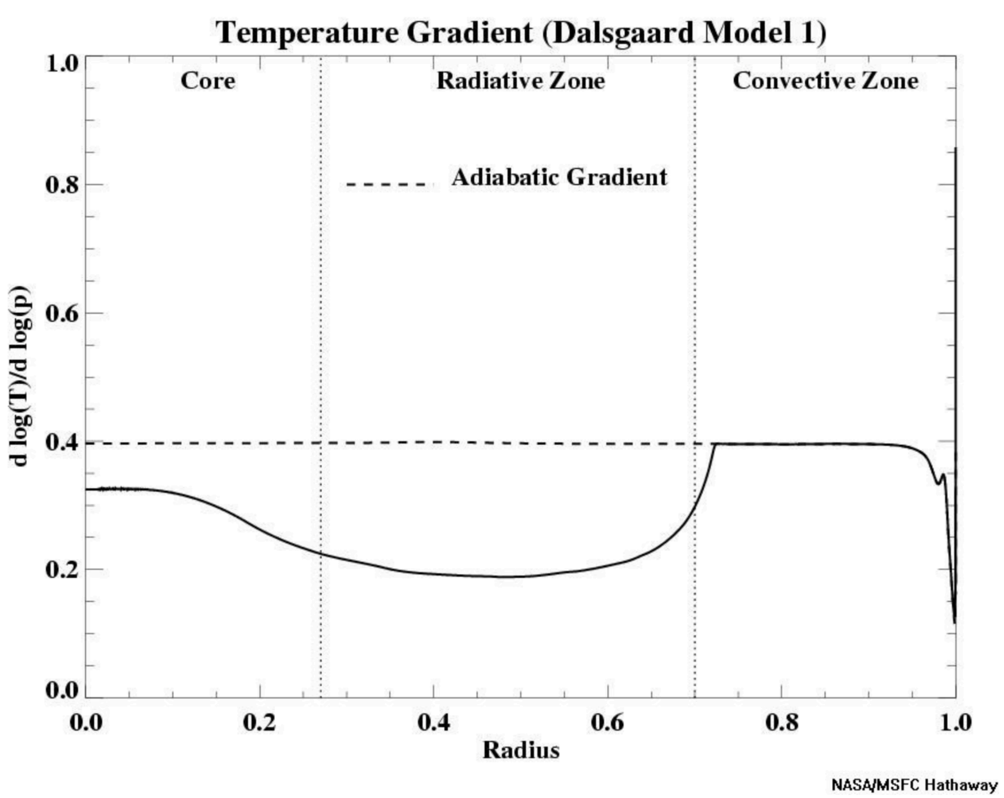




200 000km



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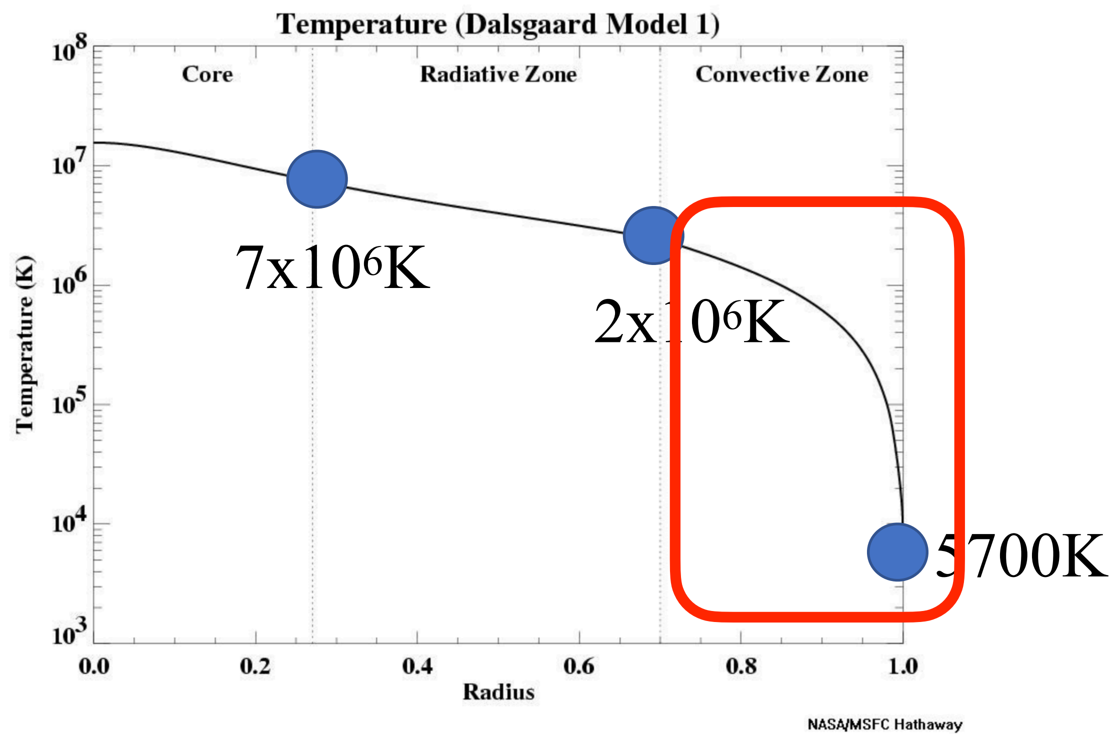
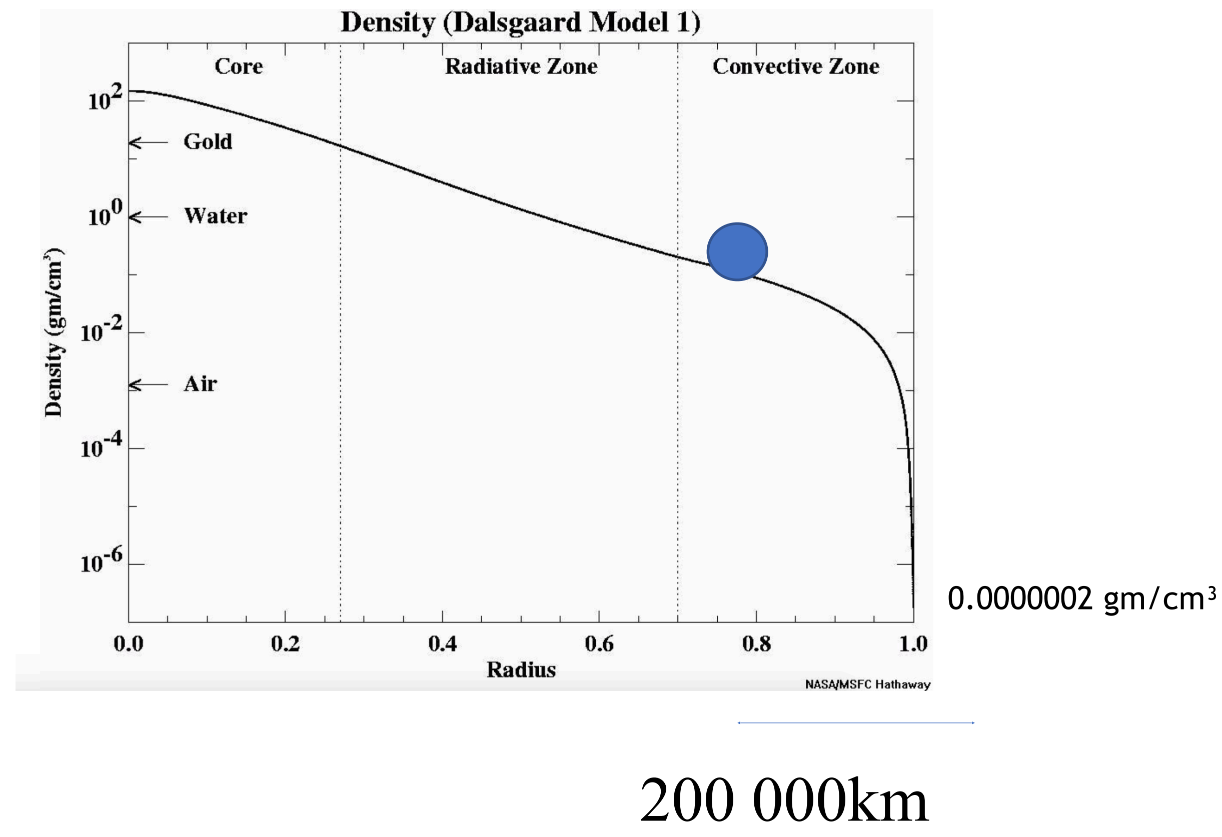
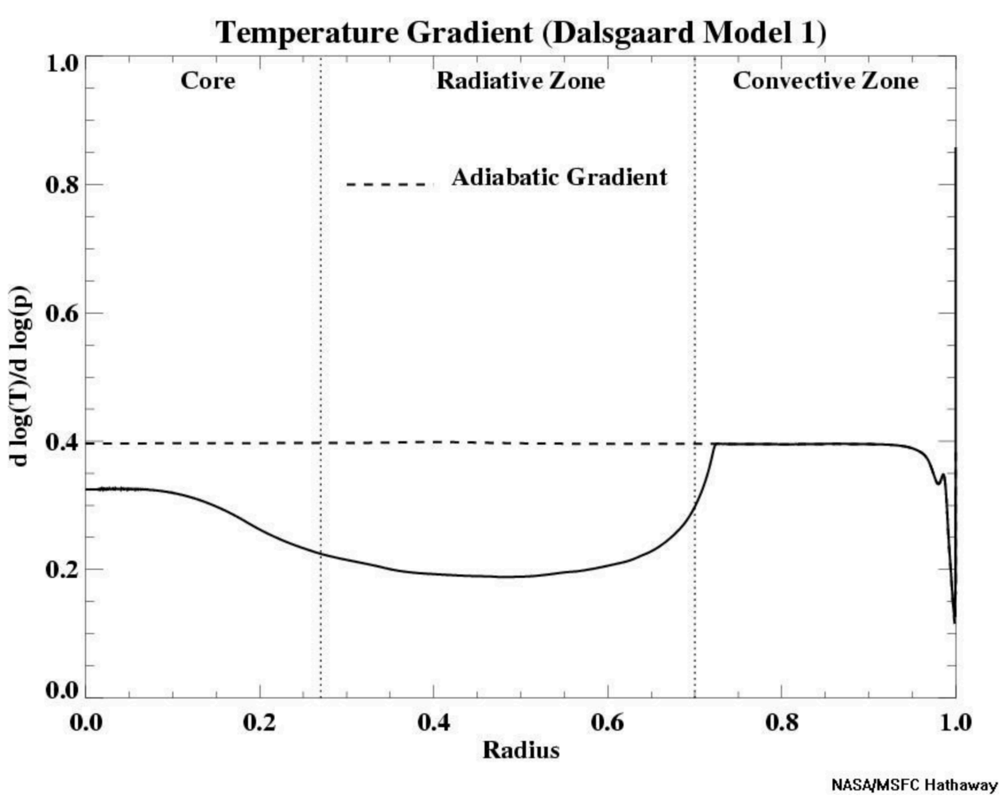
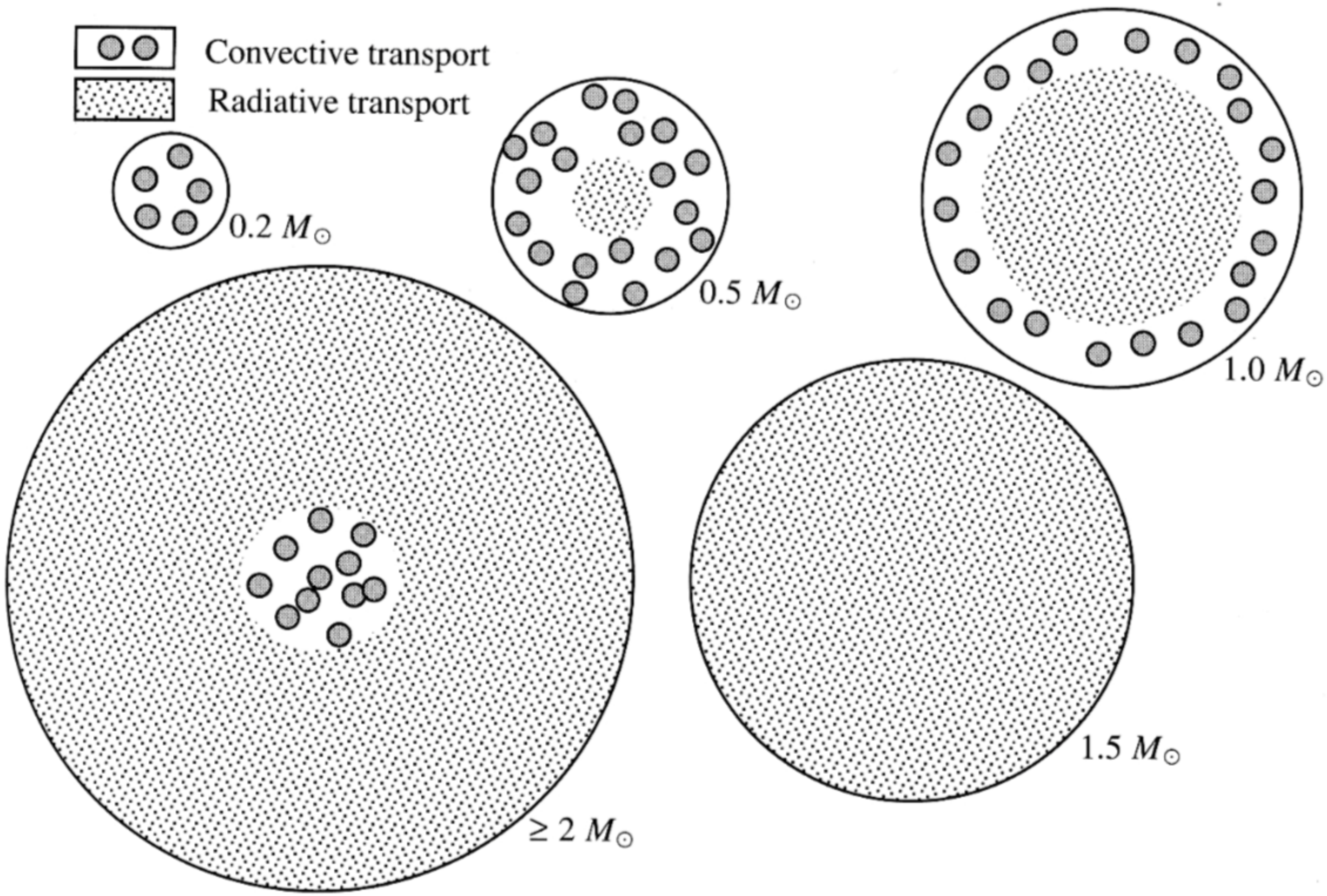






Les mouvements convectifs transportent la chaleur rapidement vers la surface. Le fluide se dilate et refroidit en montant.

https://solarscience.msfc.nasa.gov/interior.shtml



Zones of convection and radiation in main-sequence stars of various masses. The lowest mass stars are completely convective. A radiative core develops at $M \simeq 0.4 M_\odot$, and a star is fully radiative at $M \simeq 1.5 M_\odot$. The core region is again convective for masses $M \gtrsim 2 M_\odot$. The relative sizes of the stars shown here are approximately correct, while on the main sequence. (Figure reproduced from Bradt, H., Astrophysics Processes, CUP).