Fundamentos de la evolución estelar

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In some sense the evolution of stars is a cyclic process. A star is born out of gas and dust that exists between the stars, known as the **interstellar medium** (ISM). During its lifetime, depending on the star's total mass, much of that material may be returned to the ISM through stellar winds and explosive events. Subsequent generations of stars can then form from this processed material.

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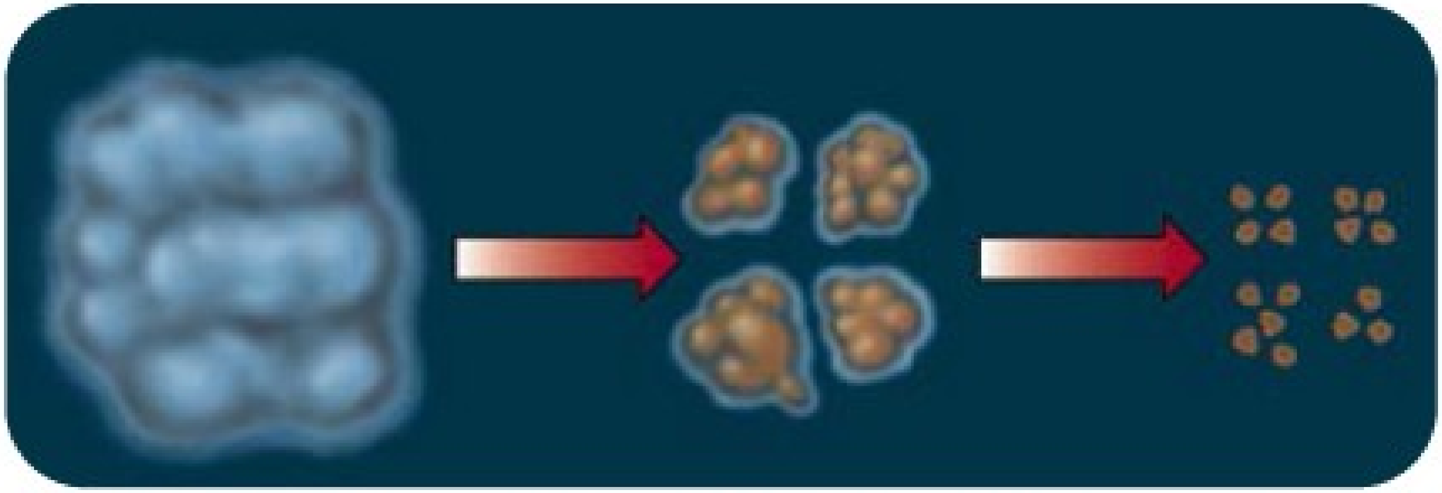

Figura 1: Colapso y fragmentación de una nube molecular. (Créditos: Pearson Prentice Hall)

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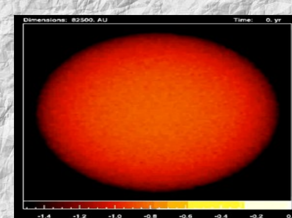

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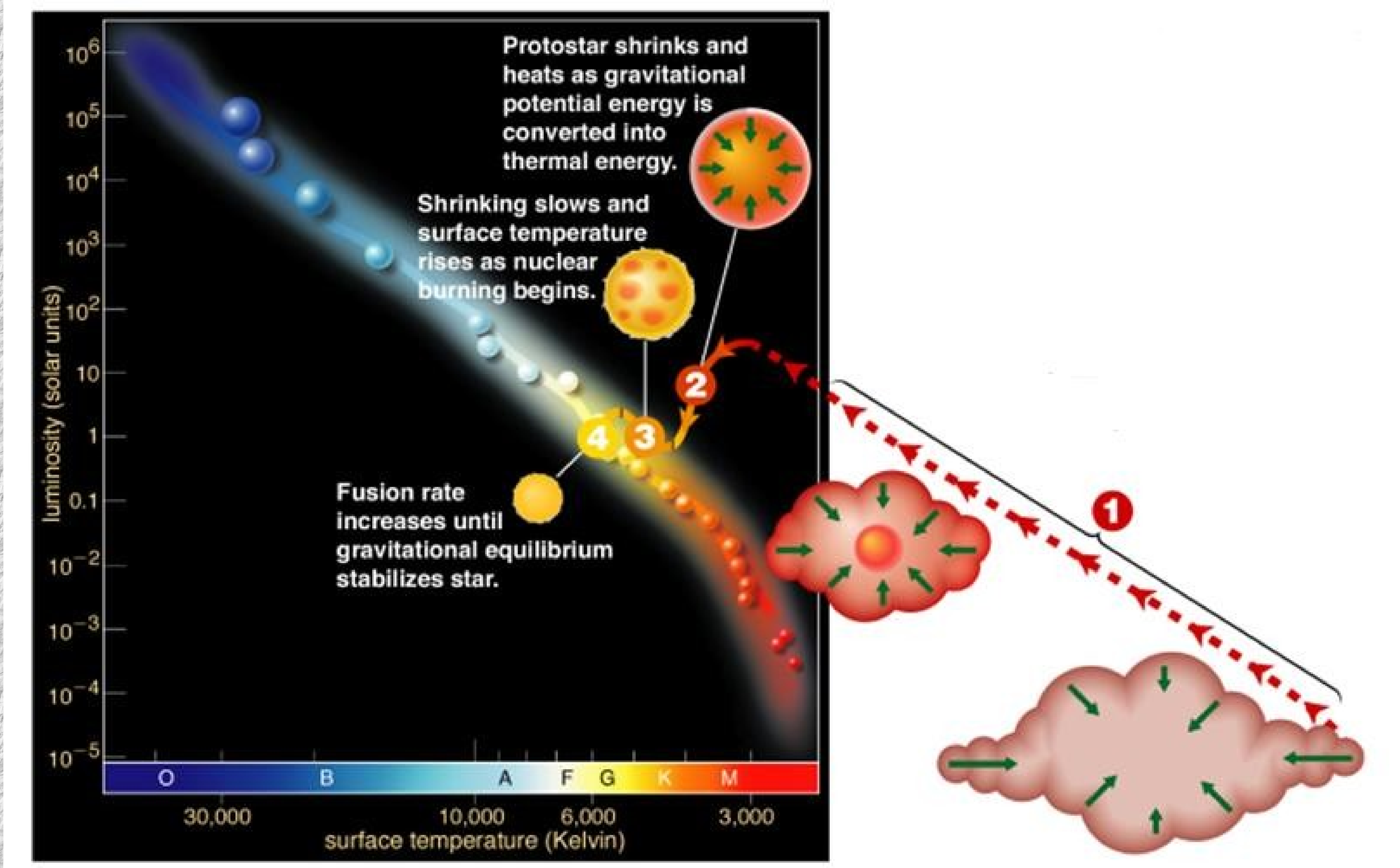

Stellar Evolution in Early Phases of Gravitational Contraction

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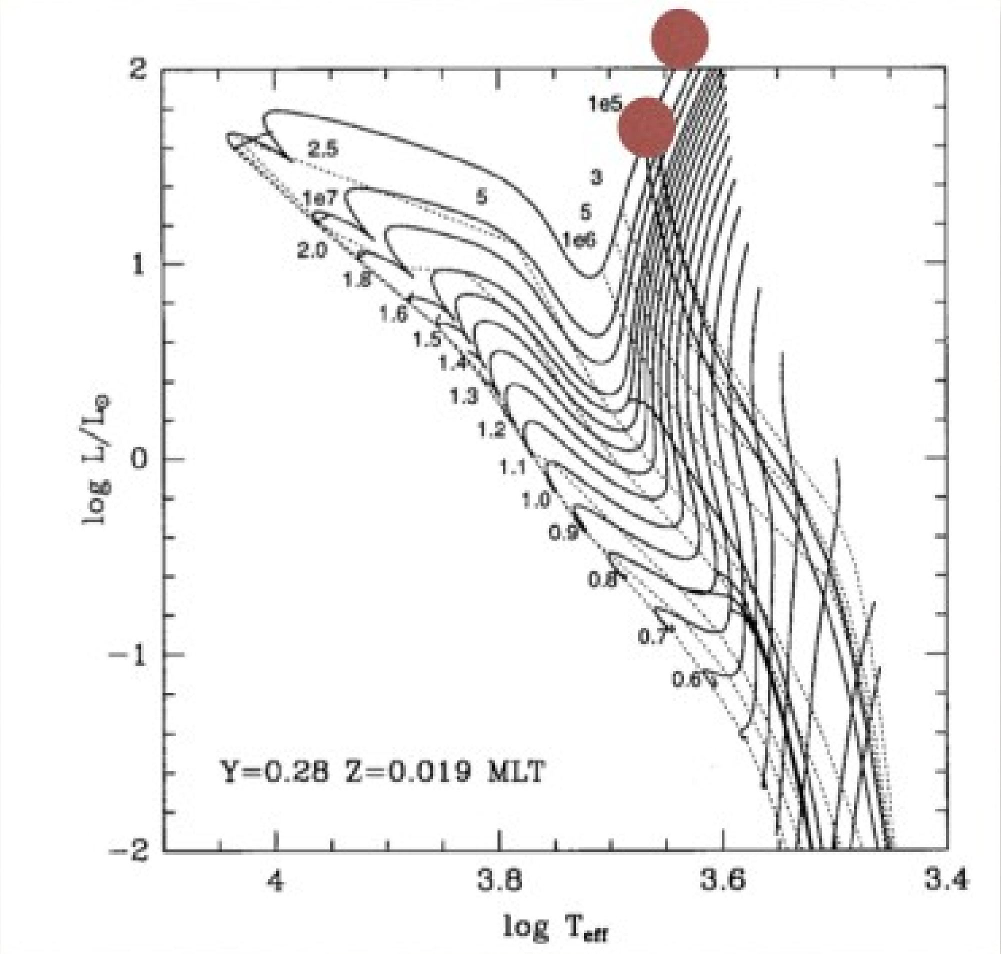
(Received August 28, 1961)

Abstract

The surface condition for red giant stars worked out in the previous paper indicates that stars lie in the low luminosity and low temperature region of the *H-R* diagram cannot be in equilibrium so that the evolutional path of contracting stars in this region will be different from that calculated by HENYEY et al. The age of these stars along the loci of quasi-static solutions is calculated. The result seems to explain well the *H-R* diagram of a young cluster NGC 2264.

PRE-MAIN SEQUENCE (PMS) PHASE

A DESCRIPTION



- Formation: dynamical collapse
- Hayashi track: pre-main sequence phase starts

  Along Hayashi track:
  - star contracts on t_{KH}
  - no (appreciable) nuclear reaction
  - luminosity given by gravity
  - L ~ $R^2 T_{eff}^4$ ~R^2 decreases
  - $T_c \propto \rho_c^{1/3} \propto 1/R$ increases
  - opacity decreases inside

PRE-MAIN SEQUENCE (PMS) PHASE

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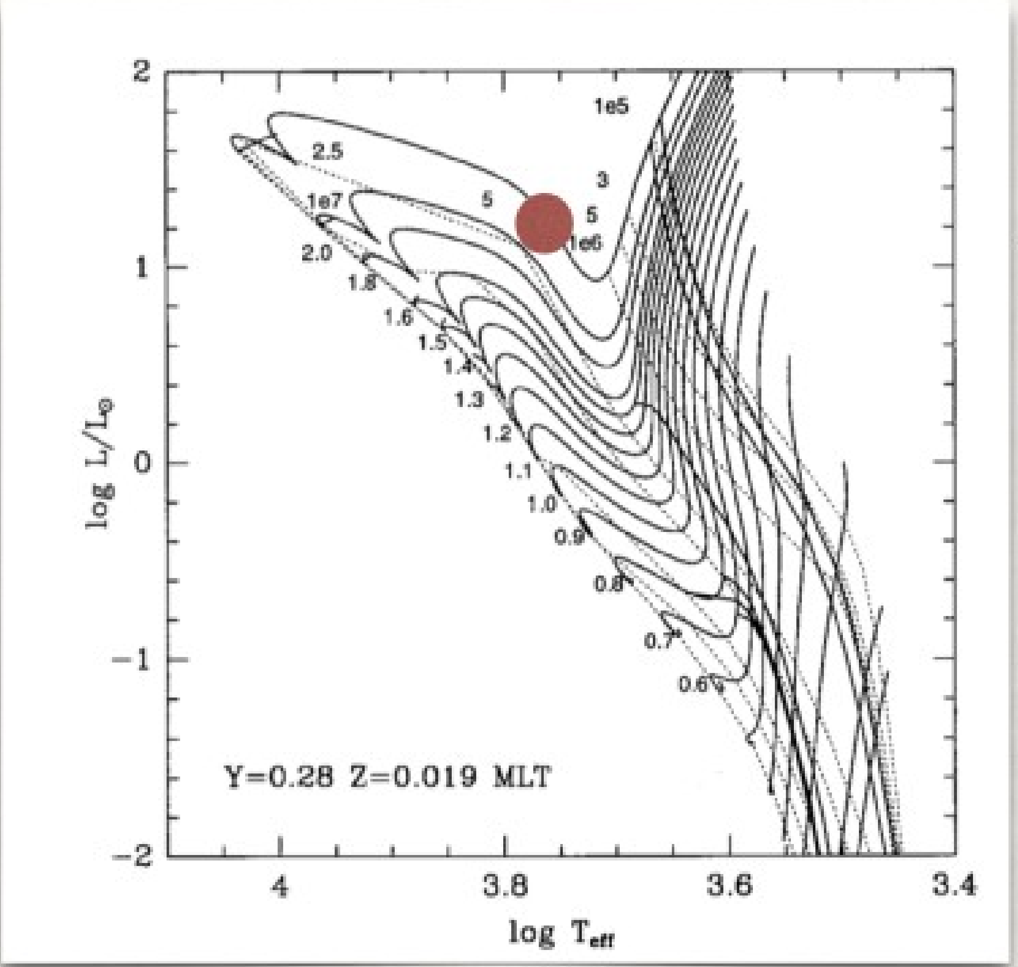

- Formation: dynamical collapse
- Hayashi track: pre-main sequence phase starts
- Radiative core develops : star moves to left
  - Temperature and L increase

PRE-MAIN SEQUENCE (PMS) PHASE

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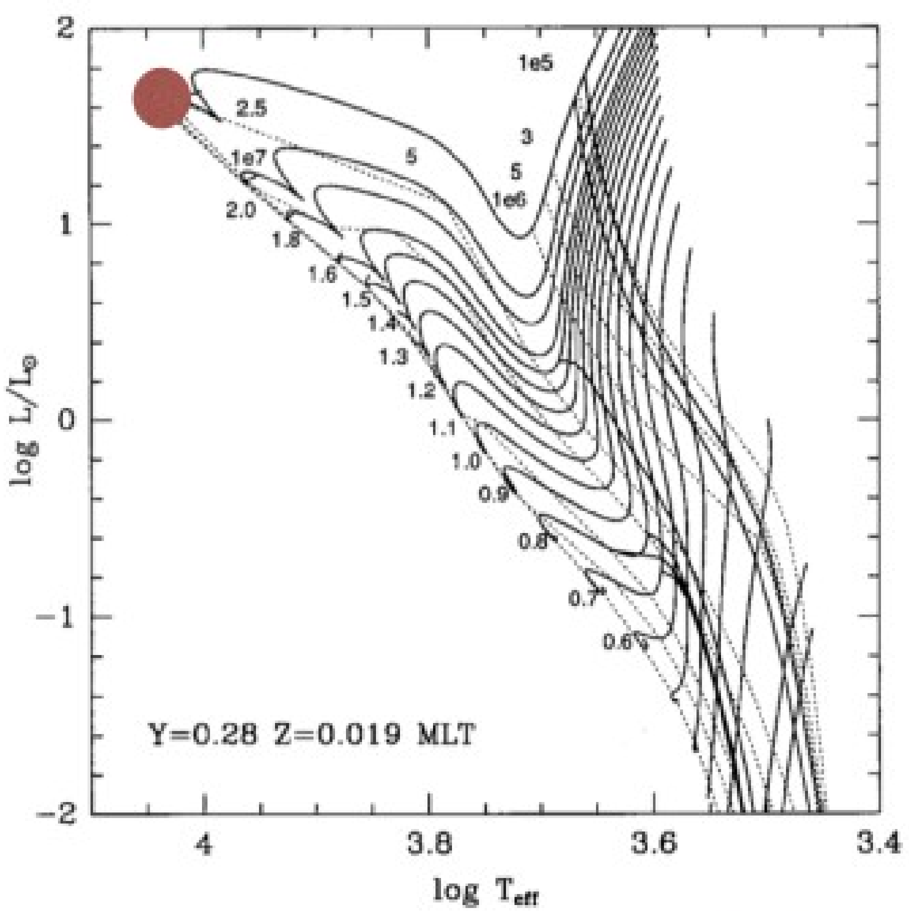
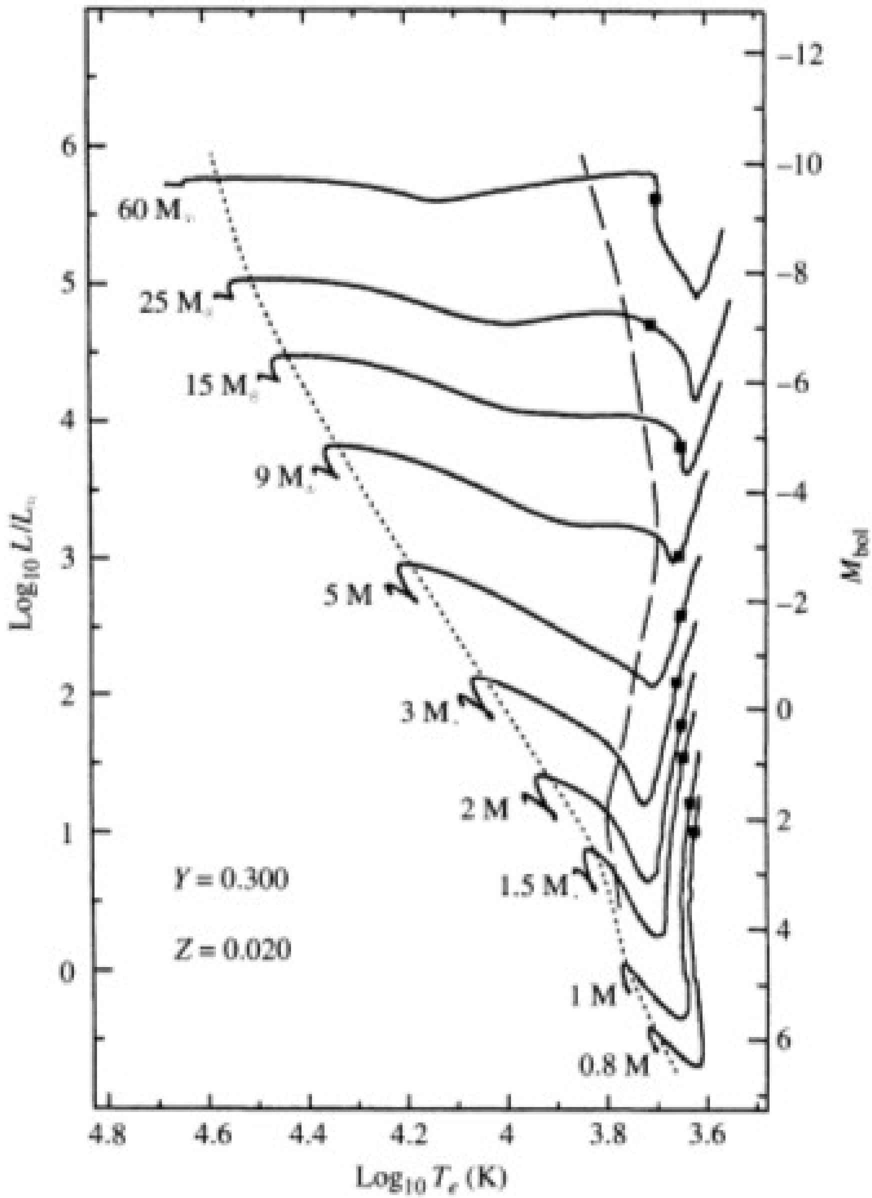


- Formation: dynamical collapse
- Hayashi track: pre-main sequence phase starts
- Radiative core develops : star moves to left
- **H burning and thermal equilibrium**: star on Zero Age Main Sequence (ZAMS)

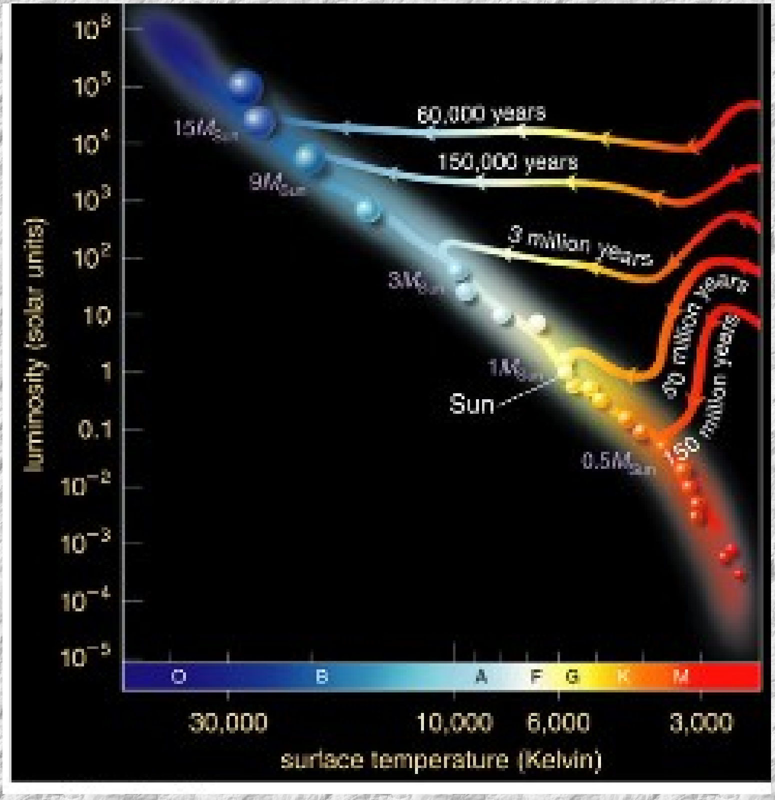


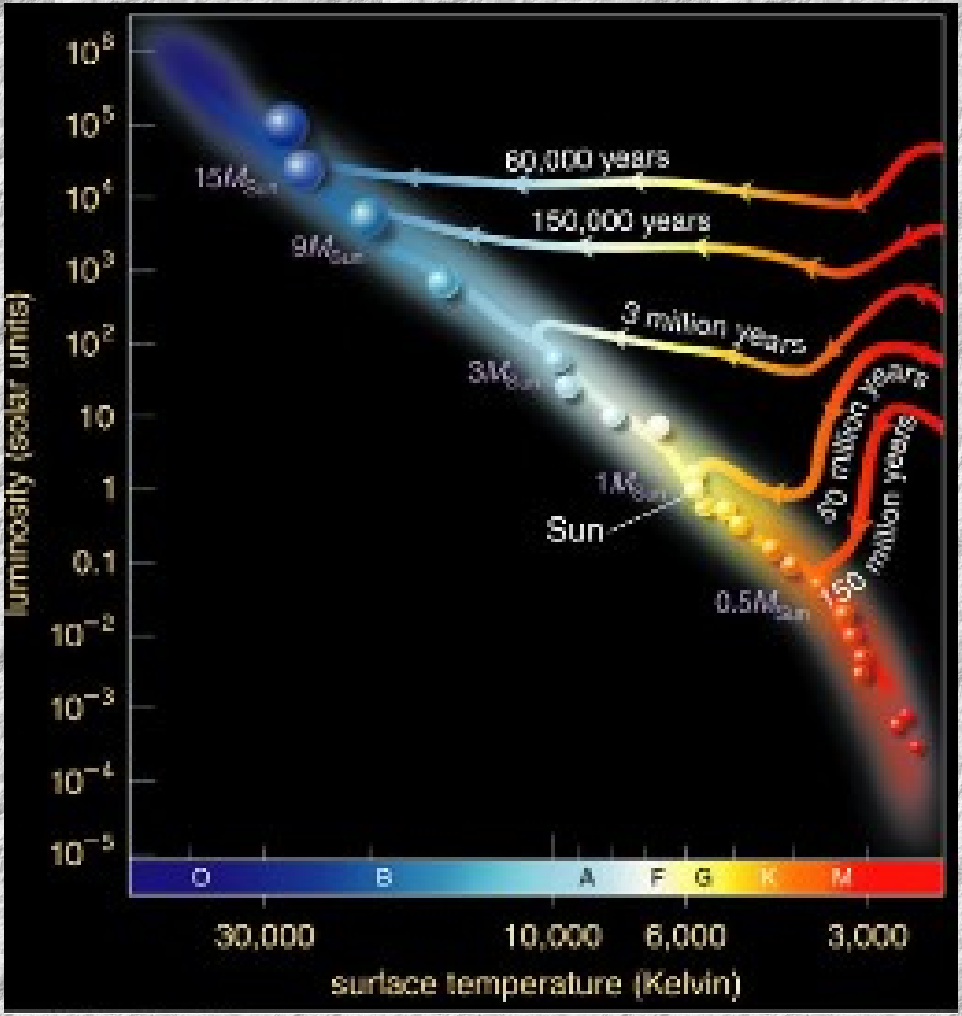
Initial Mass ($M_\odot$)	Contraction Time (Myr)
60	0.0282
25	0.0708
15	0.117
9	0.288
5	1.15
3	7.24
2	23.4
1.5	35.4
1	38.9
0.8	68.4

FIGURE 12.11 Classical pre-main-sequence evolutionary tracks computed for stars of various masses with the composition $X = 0.68$, $Y = 0.30$, and $Z = 0.02$. The direction of evolution on each track is generally from low effective temperature to high effective temperature (right to left). The mass of each model is indicated beside its evolutionary track. The square on each track indicates the onset of deuterium burning in these calculations. The long-dash line represents the point on each track where convection in the envelope stops and the envelope becomes purely radiative. The short-dash line marks the onset of convection in the core of the star. Contraction times for each track are given in Table 12.1. (Figure adapted from Bernasconi and Maeder, *Astron. Astrophys.*, *307*, 829, 1996.)

ZAMS
(the zero-age main sequence)

The diagonal line in the H–R diagram where stars of various masses first reach the main sequence and begin equilibrium hydrogen burning is known as the **zero-age main sequence** (ZAMS). Inspection of the classical results given in Table 12.1 shows that the amount of time required for stars to collapse onto the ZAMS is inversely related to mass; a 0.8 $M_\odot$ star takes over 68 Myr to reach the ZAMS, whereas a 60 $M_\odot$ star makes it to the ZAMS in only 28,000 years!





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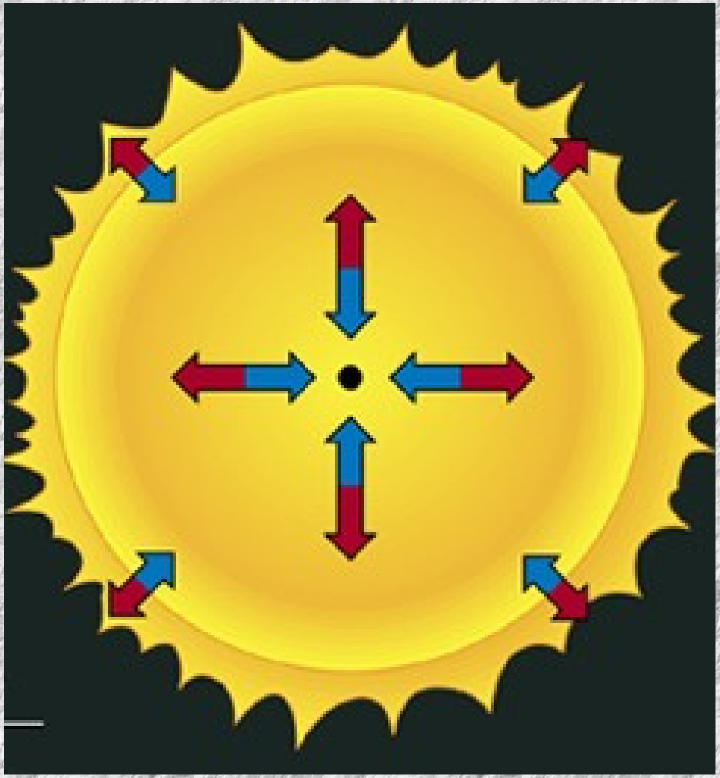
Contraction toward the main sequence takes only ~1% of star lif

Stars spend ~80% of star life on the Main Sequence

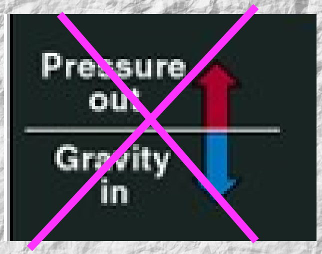
La secuencia principal (Main Sequence - MS)

- Balance: la fuerza de gravedad y la presión (fusión).
- En la MS: H → He
- MS es la fase más larga.



Y después … ?

- Cuando el H en el núcleo esté casi consumido, el balance se pierde → la estructura y apariencia de la estrella cambiará …



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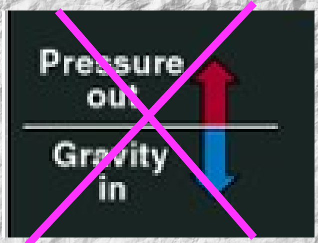

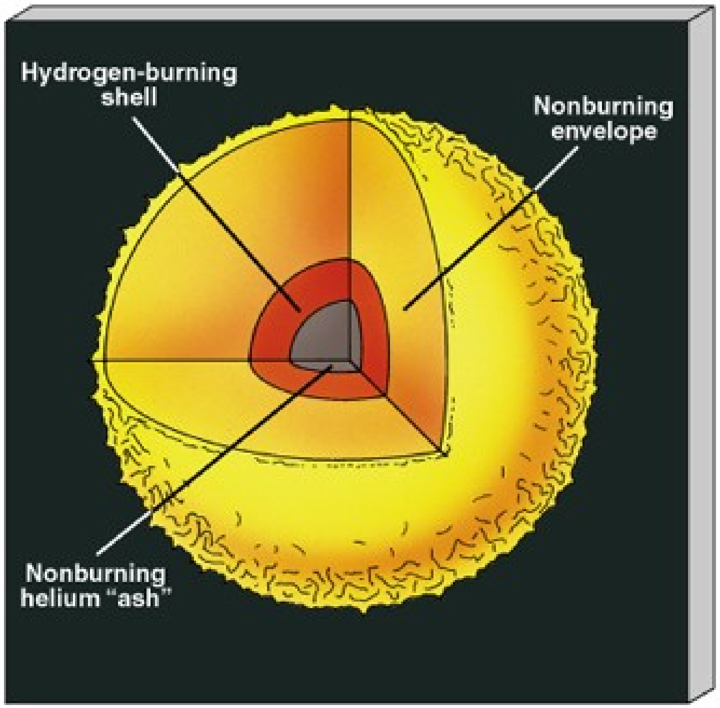

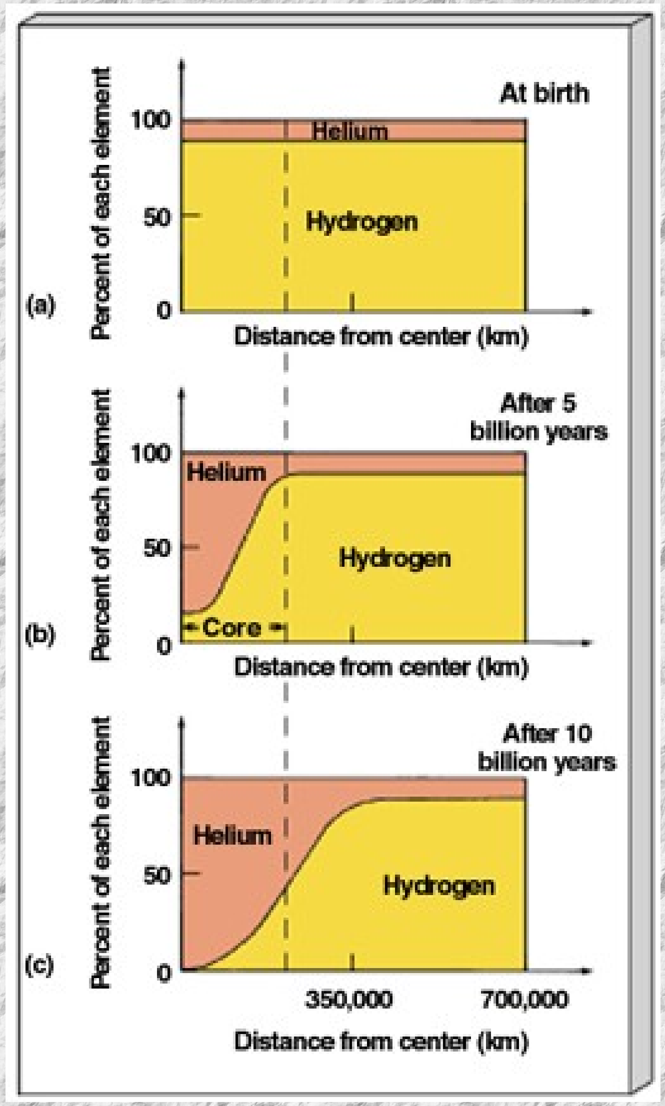

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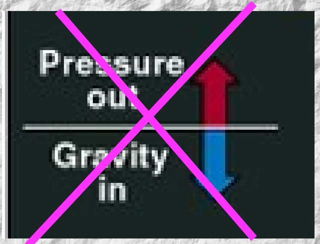

→ MASA!!!