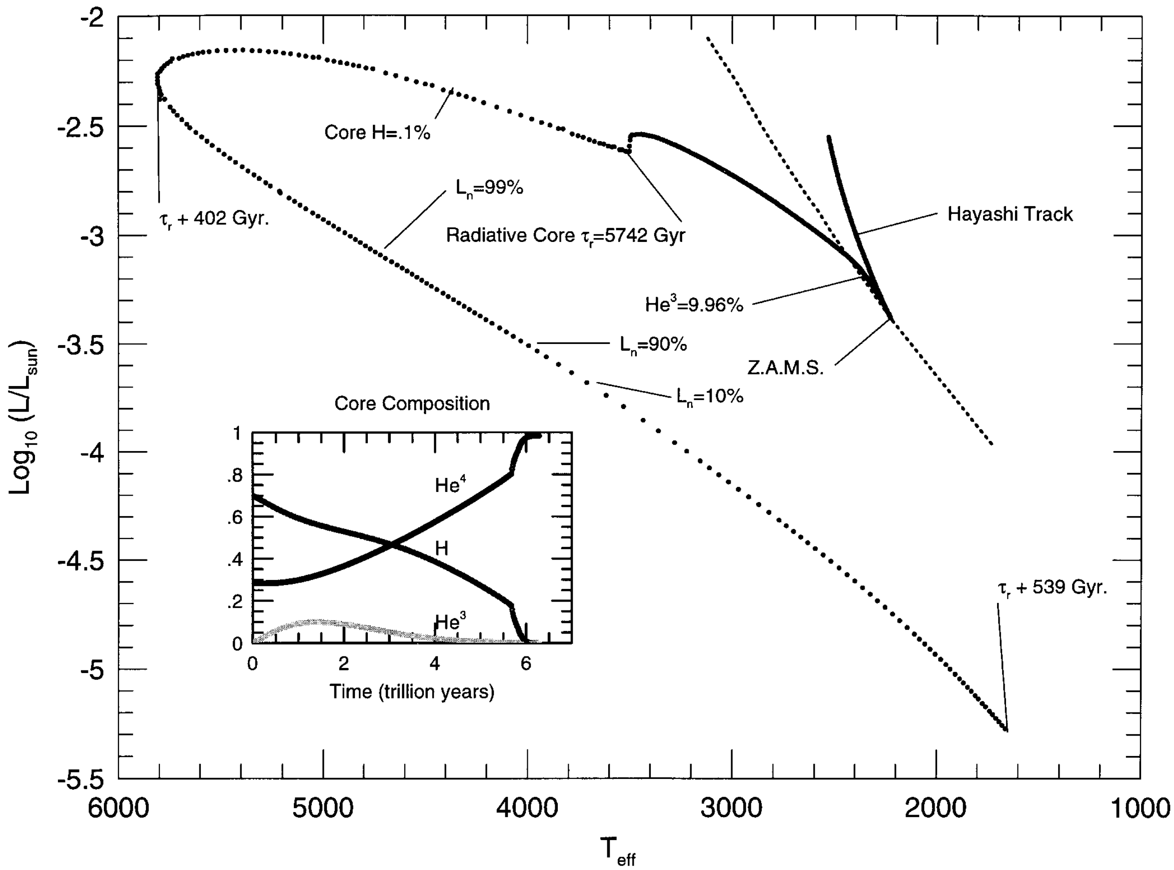

FIG. 1.—Evolution in the Hertzsprung-Russell diagram for a star of mass $M_* = 0.10\ M_\odot$. Each small filled circle delineating the evolutionary track represents a separate converged model. The star begins its evolution on a pre–main-sequence Hayashi track and ends up as a helium white dwarf, cooling into obscurity. The inset diagram shows the chemical composition of the star over the course of its evolution; the mass fractions in H, ^{3}He, and ^{4}He are plotted as functions of time.

and more luminous. After 1.38×10^{12} yr, the star has a mass fraction in ^{3}He of 9.95%, which constitutes a maximum value. At this moment, the central temperature is 4.8×10^6 K. At later times, the ^{3}He is consumed faster than it is produced and the mass fraction declines.

The buildup of ^{3}He has an interesting effect on the star. As ^{3}He accumulates, the nuclear energy generation rate at a particular temperature and density increases. The core is therefore able to expand and steadily reduce its density, even in the face of a slowly increasing total luminosity. As the hydrogen mass fraction of the star drops from its initial value of $X_H = 0.7$ to $X_H = 0.5$, the central density decreases from 309 to 204 gm cm^{-3}. The temperature in the core during this epoch rises slowly from 4.4 to 5.1 million kelvins.

Between 1.5 and 4 Gyr, the mass fraction of ^{3}He declines steadily, eventually reaching the structurally negligible values associated with equilibrium PPI burning. During this broad main-sequence phase, the star is methodically turning itself into ^{4}He. After 3.05 Gyr, ^{4}He comes to dominate the mass fraction. At this point the photosphere has heated to a temperature of $T_* = 2500$ K and the luminosity is just less than 0.1% of the current solar value.

As the amount of available hydrogen per gram diminishes, the energy generation rate at a particular temperature and density declines. The central regions are compelled to grow denser and hotter in order to satisfy the energy demands of the star. After 5.74 Gyr, the star contains only 16% hydrogen by mass, the surface temperature is $T_* = 3450$ K, and the luminosity is $\log_{10}[L_*/L_\odot] = -2.54$. This point represents a critical juncture in the evolution of the star. The increasing helium fraction lowers the opacity to the point where radiative transport is capable of transmitting the energy flux, and convection ceases in the center. This development of a radiative core, which soon spreads through the nuclear burning region, almost immediately fixes the composition of the envelope. The unchanging envelope composition in turn allows for the development of a mild composition inhomogeneity, as the remaining hydrogen in the radiative core is rapidly converted into helium. The development of the radiative core causes the entire star to contract slightly and produces a mild but sudden decline in luminosity. This behavior can be seen on the evolutionary track in the Hertzsprung-Russell diagram.

Once the radiative core has developed, the near-eternal youth of the star draws to a close, and the evolutionary timescale accelerates. The central regions become isothermal as hydrogen is exhausted, and the core steadily increases in mass as a modest nuclear shell source works its way outward through the star. The shell-burning source is located within the radiative region of the star, and so the envelope composition continues to remain fixed. The evolution of the star in the H-R diagram during this phase is toward rapidly higher temperatures. The unassuming 0.10 $M_\odot$ red dwarf stars of today will eventually grow hotter than the current Sun, although they will never be more than $\sim$1% as bright. Evolution to higher temperatures occurs